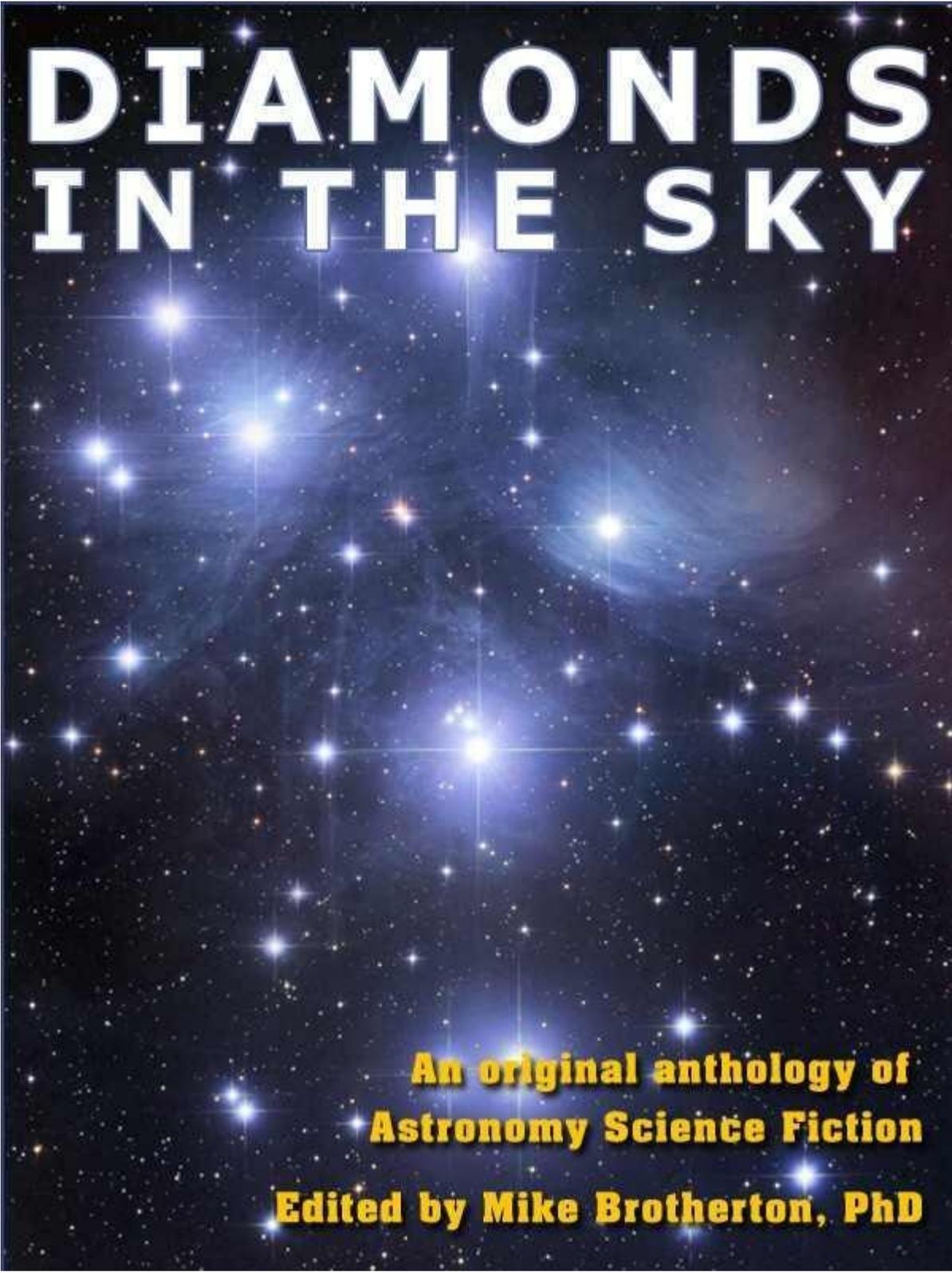


# DIAMONDS IN THE SKY



**An original anthology of  
Astronomy Science Fiction**

**Edited by Mike Brotherton, PhD**

# **Diamonds in the Sky**

**Edited by**

***Mike Brotherton.PhD.***

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## **How I Saved the World (Valentin Ivanov)**

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It permeates space and has a subtle but important effect on our existence. What if the effect were not so subtle? Keywords: Dark Energy.

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Life in the Milky Way can be harsh depending the neighborhood you live in. You should hope you have helpful neighbors when the times are harsh. This story originally appeared in *The Age of Reason*, edited by Kurt Roth, at SFF.net in 1999. Keywords: Supernova (type 1a.)

## **Planet Killer (Kevin Grazier and Ges Seger)**

And sometimes the times are harsh but you have to depend on yourselves. It helps if you have a little unlikely but useful faster-than-light starships as in *Star Trek*. Keywords: That would be telling!

## **The Listening-Glass (Alexis Glynn Latner)**

What's the future hold for astronomy and astronomers? What would it be like to work on the moon? An earlier version of the story was first published in the February, 1991 issue of Analog Science Fiction/Science Fact. Keywords: Radio astronomy, the Moon.

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A sophisticated tale about the ultimate journey. Previously published in Asimov's Science Fiction, Jan. 1998. Keywords: Black holes.

## **Contributors**

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## ***In The Autumn of the Empire***

by [Jerry Oltion](#)

This story also appears in *Analog* magazine.

The emperor of Earth didn't like to be wrong. Many of his acolytes had learned that the hard way, though this was merely rumor, since no surviving member of the inner court had actually caught Hadron the Perfect in a mistake, nor even witnessed one.

So when the little common girl, who had been brought to the palace garden to provide a photo op for His Excellency amid the falling leaves, asked him, "Why is there autumn?" two of his attendants faked sudden allergy attacks and ran coughing for the infirmary while another quickly said, "It's because of the tilt of the Earth's—"

Too late. The emperor laughed and said in his reedy voice, "Ah, my little darling, that's an easy one. We get autumn because the Earth is moving away from the Sun. Soon we'll be millions of miles away from it, and it'll be winter. But don't you worry, because that's as far away as we'll go, and then we'll swing around in our orbit and head closer to the Sun again, and it will be spring, and when we get as close as we're going to go, it'll be summer and the whole cycle will start all over again." He smiled for the video cameras in a sickly attempt to look caring and avuncular.

Curiously, only one of the camera crew wet himself. The others looked at him in puzzlement as he stammered an apology and rushed after the two fake allergy sufferers.

The others continued filming the emperor and the little girl amid the multicolored leaves, and the videocast streamed out into the datasphere, where the emperor's billions of subjects heard his explanation. Most of them hardly paused in their labors. A small fraction said, "Hmm, I didn't know that." And a smaller fraction yet said, "Wait a minute, it's the tilt of the Earth's axis that causes seasons."

Those people were never heard from again.

An astute businessman heard the emperor's pronouncement and immediately bought every cubic foot of refrigerated warehouse space he could find, funding it by selling everything he owned in the tourism industry. Then he bought every perishable fruit and vegetable he could lay his hands on, packing them away in his warehouses for a future he hoped would never come.

For the next few weeks the world buzzed with speculation, and even a few jokes about the emperor's knowledge of the planet he ruled with absolute authority, but the continual disappearance of jokesters and people with astronomical training slowed the innuendo until it seemed that the whole incident would blow over by winter. Or summer, if you lived in the southern hemisphere.

Yet one universal truth that had proved true for millennia kept raising its ugly head: it's nearly impossible to purge bad data from the system. The emperor's explanation to the little girl kept resurfacing to blossom

across the datasphere yet again. Overzealous teachers even used it in classrooms to curry favor with the censors so they could slip in more controversial lessons about evolution or human sexuality.

People were by now quite used to "coming out of the water dry" — kowtowing to the official truth while privately knowing it was hogwash — but this particular one led to too many logical inconsistencies. How could Aunt Ortencia be watching her crocuses bloom in Argentina while the leaves fell in Canada if the whole world experienced the same seasons at once? How could Antarctica be dipping into six months of sunlight and the Arctic into six months of darkness if it was autumn everywhere? More to the point, how could people in the Northern hemisphere buy fresh fruit in February if February was winter in the southern hemisphere, too?

Something had to give, and it wouldn't be the emperor. So nobody was really surprised to find vast engines springing up all over the planet, engines that tapped into the very fabric of space for their power and pushed against that fabric with all their might. Earthquakes rocked the world, but the emperor assured everyone that they would soon subside, and in that he was correct. When the stress in every major fault was finally released, the continents relaxed and went along for the ride.

The few surviving astronomers noted a curious thing: Polaris was no longer the north star. Night after night it slipped farther to the south, until the sky whirled around the Cat's Eye nebula in Draco instead.

Thereafter, the Sun rose directly in the east for everyone on Earth, took exactly twelve hours to cross the sky, and set directly in the west. It did that week after week, with no variation whatsoever. The Earth's axis no longer tilted with respect to the Sun.

A careful observer would note that the Sun was also somewhat smaller in the sky than before. The Earth had been moved farther away from it.

Winter arrived in the northern hemisphere as always. People in the southern hemisphere were rudely surprised to discover themselves drifting from spring right back into winter again, but since saying that something was amiss would mean contradicting the emperor's stated view of how things worked — not to mention reality itself now that the planet's orbit had been changed to match his description of it — they prudently remained silent and buckled down for a cold and hungry season. An enterprising businessman's foresight in storing perishables saved people from scurvy and rickets, but it was not a happy time.

The Earth moved on in its orbit, just as the emperor had promised the little girl in his garden. It moved slowly at aphelion, extending winter several weeks longer than usual, but eventually snow banks thawed the world over. Farmers planted their crops. The growing season was shorter than usual, owing to the Earth's faster orbital speed when nearer the Sun, but there was just enough time for most fruits and vegetables to mature before the weather turned cold again. And the owner of a vast network of refrigerated warehouse space became even wealthier as it dawned on people that an entire planet's worth of perishables would have to be stored at once if they were to avoid a repeat of last winter's famine.

Life went on. People adjusted to the curiously regular days and the oddly irregular seasons, although most secretly longed for the days when they could buy a fresh orange from Brazil in January or take a sunny vacation to Australia when the clouds in Seattle became too much to bear.

The emperor aged, and eventually died. His son ascended to the throne, and a momentary hush fell across the Earth as his new subjects dared to wonder if he might defy his father as children often do once they come into their inheritance.

To improve the odds, a small group of surviving astronomers presented him with a coronation gift of a globe, ostensibly as a symbol of his dominion, but tilted at a rakish angle of 23.5 degrees. It was, in fact, an ancient and valuable artifact from one of the observatory museums. The astronomers had bribed a courtier to install a

bright light to the side of the throne that would shine on the globe when they presented it to the new emperor, so that he might see how the northern hemisphere tilted toward the light in its summer, and how it tilted away in winter while the southern hemisphere experienced the opposite season.

Solemnly, they presented the globe to their absolute ruler. Smiling for the cameras that captured this moment for posterity, he accepted it and spun it a couple times around. Then he leaned close and examined the figure-eight printed in the Pacific Ocean. "An... a... lemma," he read slowly. "Did I pronounce that right?"

"Yes, your Excellency," one of the astronomers said, and the fact that he wasn't lying to save his skin cheered the others immensely.

The emperor examined the small print next to it. "Showing the Sun's declination throughout the year. And this is a historic artifact?"

"Yes, your Excellency," said the astronomer.

"Ah, then my father *was* wrong."

A collective sigh arose across the entire world, until the new emperor said, "This is clearly a diagram of the Earth's orbit before he changed it to match his mistaken notion. A figure eight. That would explain why everything seemed so timeless during the dead of winter, and again in the middle of summer, when I was a child. The Earth actually did pause there at the extremes of its orbit before reversing course."

He handed the globe to one of his advisors. "Make it do that again." He turned to the cameras and spoke to the world at large. "Your benevolent and merciful emperor now makes his first decree: I will make the world follow its proper orbit, a figure eight."

## **Afterword:**

Amateur astronomers love to put on star parties where people can look through a telescope at the amazing things in the night sky. When I started doing that, I was amazed at how many misconceptions people have about the way things work on an astronomical scale. People get the terms "solar system," "galaxy," and "universe" mixed up all the time. They often think light-years and parsecs are units of time. And they nearly all think that seasons are the result of the Earth moving toward and away from the Sun in its orbit.

These are perfectly understandable misconceptions. We're familiar with our own neighborhoods, our towns and maybe our home states. Our experiences teach us how things work on that scale. But the farther afield we go, the less we can rely on experience. The notion that light takes time to cross great distances isn't intuitively obvious because you have to get out to the Moon or beyond before the delay is noticeable. Solar systems and galaxies are both mind-bogglingly bigger than the Earth, not to mention how big the entire universe is, so it's understandable that people would confuse the terms. And we're used to getting warmer when we're near a heat source, so it's not surprising that people think that's why the weather is warmer in summer.

Then they look at a globe and see the analemma printed out there in the middle of the Pacific Ocean. What the heck is that thing, anyway? No explanation on most globes, and a totally useless explanation when there is one. Small wonder if people think it's the shape of the Earth's orbit.

But when you start adding all these misconceptions together, things start falling apart. If distance from the Sun causes seasons, then why is it winter in the southern hemisphere when it's summer in the north? If we orbit in a figure-eight, what are we orbiting around during that second loop? And so on.

Misconceptions have a nasty habit of biting you when you most need the real knowledge they're masking. Writers are always looking for situations like that to tell stories about. This one was too perfect to resist.

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## ***End of the World***

by [Alma Alexander](#)

It was one of the cheap trips.

Plasmaform expeditions could not by definition be 'crowded', not literally, because no physical body was actually present — but although space was vast and empty and all around them, Ter felt surrounded by others, asphyxiated by them, overwhelmed by the weight of their presence. If they had been corporeal it might have translated into an overpowering odor of morning breath and unwashed bodies or the sickening smell of sweet snacks from the school group on the far end of the Plasmaform cloud. Instead, it was the suffocating sense of the presence of uncomfortable numbers of people sharing what should have been an intimate personal space.

In theory there were anywhere between three to seven levels of communication within the cloud, and it should have been possible to filter out all but the innermost one, the one most directly related to one's own concerns, and the emergency channel. But it was a cheap trip. Second and even third communication tiers kept on intruding into Ter's consciousness. The babble of other people's voices inside her head made her feel giddy and confused and irrationally angry — particularly as one of the intrusive presences was the painstakingly pedantic teacher of the school group, whose constant input of facts and figures about the spectacle unfolding before the group implied that there was to be a test on the subject matter afterwards (and dire consequences threatened if the facts and figures were not regurgitated properly). Another irritation came from a chatty, chirpy tour guide of a large group of gawking tourists, the kind who conceived it his bounden duty to fill every moment of silence with a mindless patter designed to keep his charges' limited attention span focused on the matter at hand and preventing anyone from falling asleep and then suing the company for having missed the main event.

:::So — when this star was still supporting life, who can tell me how it was classified?:::

That was the schoolteacher. Thankfully the field was too weak to transmit the individual answers from every student, but then the teacher was given to repeating every answer anyway, just to make sure everyone got it.

:::That's right. Very good. It was a G2 star. Who can tell me more about it? Yes, that's correct. We are about 26,000 light years from the center of the galaxy. Yes, the star is currently believed to be about 10 billion years old. Very good, it originally fused hydrogen into helium in its core, nicely done, about 4 million tonnes a second of matter would have been converted into energy at its core about halfway through its life. And what is happening in its core right now?:::

<<Unfortunately, ladies and gentlemen, this star lacks sufficient mass to provide us with some real fireworks. We will not be witnessing a supernova — it would, of course, be much more spectacular — it looks something like this...>>

The tour guide, apparently had had access to some sort of visual crutch because every so often he would pause dramatically to allow his group to gaze upon something that Ter could not see.

<<Instead, we are here to witness the expansion of what is really a perfectly ordinary run-of-the-mill average

star, on the small side mass-wise, into its red giant phase. This is not an uncommon event around the galaxy, of course. You might well ask why our particular company, with our reputation for taking you to be witness to far more unique and exciting events in the cosmos, chose to lay on this particular tour — the answer, ladies and gentlemen, is the third planet away from the star in this particular solar system. Many years ago, this planet was called Terra. Earth.>>

Ter — whose own name was drawn from the name of that legendary planet, the cradle of humanity, from whose doomed surface people had fled four and a half billion years before — tried to shut her mind to the intrusions, and stared out at the spectacle before her. They hung just a little way beyond Terra itself, a darkened orb showing as just a dramatic crescent from their position. Ter had had the digital memory implants — she called them to mind now, images of Earth as it once was, the luminous blue and white globe hanging in the dark of interstellar space — the glitter of lights that had once been human cities, limning the edges of continents on the shores of oceans. The water oceans were long gone by now, of course, and the cities were not even a memory of ruins, the continents themselves just melted outlines on a lifeless globe from which the last life had fled almost too long ago for the world to remember it had ever existed.

Ter recalled her own school days, and the lessons that had been passed down by her great-grandfather, long before she had entered school. He had learned the stories he told her from his own great-grandfather in his turn, stories passed down through the generations, to go with the memory implants of long-vanished history from a distant planet, of the Earth that had once been. Ter's own world, the planet on which she had been born, on which generations of her ancestors had been born, had a certain kind of savage beauty of its own — but it was a harsh place, and it had molded Ter's people into its own image. In her physical form, she did not resemble much the gracile humans who had once walked Terra, the planet on which the human race had been born. A different gravity and a different sun had made her short, stocky, long-armed, her powerful shoulder muscles fusing with the neck to support a large head with a strong, robust jawline and eyes that saw deeper into the infra-red than her ancestors' eyes had done. But she had been a child with a vivid imagination, born with a gift to internalize and assimilate the memories that had been implanted in her, memories that were not her own — things seen with eyes different from hers but still human, more human than hers, the original human vision. She 'remembered' palm trees. It had been billions of years since the last palm tree had withered on the Earth as it slowly turned into a global desert, its atmosphere changing and eventually leaching away into space, the carbon dioxide levels in the air dropping until finally there was not enough to support photosynthesis and most of the green plants had died — and had taken the biosphere with them.

And the Sun was no longer the pleasantly warm yellow orb from which it was possible to shelter in the shadow of a friendly tree. Because there were no more trees, and the Sun was a hot orange disk in the sky. And growing bigger.

As though triggered by that memory, the schoolteacher was back in her mind.

:::And is there an atmosphere there now? Very good. No. Can someone tell me what the Sun would look like from the surface of the planet a billion years ago? A hundred years ago? In the immediate aftermath of what we are about to witness...? Oh *very* good question. Of course, there would not necessarily *be* a planet in the aftermath...:::

And the guide had the pictures.

<<You can see what the star would have looked like from the surface of the Earth — if anyone had been left to look — over the last couple of billion years. We started off with the yellow G-type star under which our ancestors evolved on the planet — but watch what happens as the star gets hotter, and redder — the planet's atmosphere eventually changes, and then gradually boils away into space — and the friendly star, look, now about 100 times larger than it had been during the phase during which it supported life on the surface of the Earth, and from the surface of the planet, now molten and with lava lakes instead of the liquid water oceans of its antiquity, the star our ancestors once called the Sun now takes up almost half the sky...>>

"Oh, just do it," Ter whispered to herself, tears in her eyes, watching the cinder that had once been a planet called Earth drifting helplessly just outside the huge red ball of fire which took up most of her field of vision. "Just do it..."

That was what they had come here to see, this motley group of the descendants of the human race which had scattered into the far reaches of the Milky Way when it had become obvious that they had to leave, or die with their world. They had come to see the end of the Earth. They had come to the funeral of the mother world.

And the teacher would not stop talking. And the tour guide would not stop yapping.

If she could have afforded it, she would have paid the exorbitant sum that the Vixhor, the alien race who had sold them the Plasmaform technology, usually demanded for specialized solo trips — but Vixhor prices were steep, and this was the best she could do, this package deal with the school (maybe twenty schools, for all she knew, thankfully she was only picking up the mental chatter of the one group) and the thrill-seekers who cruised around the galaxy to observe the birth and death of stars and skirt the rims of black holes while giggling mindlessly at their own daring. It was in the company of gawky, ignorant schoolchildren and inane tourists that she had to come and witness this, and gather it up in her memory banks for her own folks to see, and know, and remember. The great-grandfather who had told her the stories of Earth was long dead — but her grandfather was still alive, and he remembered hearing his stories too. It was for him that Ter was here. For him, and for all the ones that had gone before him who could not be here to see this, and for those who would come after, who would also need to know, to remember.

She was here to mourn — to cast a metaphorical flower into a grave of fire, as a world died.

She had believed those private thoughts to be her own, but apparently there were more levels to Plasmaform than even she knew, because the response that bloomed in her mind was not her own words — a presence foreign, alien... *Vixhor*.

*It is good. It is good that you are here. That you are one who is here who mourns.*

"Get out of my head!" Ter said, rubbing the metaphorical hands of her Plasmaform body against her metaphorical Plasmaform temples.

Apologies. Private thought exchange. No need to involve others. We are grateful you are here. Watch. Remember.

Ter did remember. As the disk of the red star grew infinitesimally, and then a little more, her great-grandfather's words swam back into her mind — "The Earth will be incinerated, one day," he had told her. "Cremated. Just like we do with our own dead. And then? Can you tell me what will happen, after?"

:::And what will happen afterwards? Yes, that's right. At some point, when the red giant phase is over, the remnants of the Sun will lose the shell of its outer gases to space, leaving behind the dead core, a white dwarf, sitting in the middle of a planetary nebula....:::

Ter opened her mind to the schoolteacher and let a blistering response return along the pathway.

:::Oh, show some respect! The Earth is being incinerated. Cremated. And in those clouds of solar gas that will escape into the planetary nebula, the ashes of the Earth will be, sent out into space....:::

:::Who is that? Vixhor Main, we have an intrusion....:::

She left the teacher to a panicked exchange with the control matrix of the expedition, in time to catch the tour guide finally stop talking as the Sun reached out with fiery tentacles and the crescent of the Earth vanished into the maw of the red star.

<<Ladies and gentlemen, I give you ... the end of the world.>>

*Watch*, said the Vixhor in Ter's head.

And then there was silence as everything turned to fire and ashes, and then nothing was there except the huge red star hanging in empty space, as though nothing had ever been there at all.

But something had been.

Something that had, in its turn, given birth to Ter herself — the human DNA that had taken itself to another star, itself and its memories of the world that had once turned blue and white and perfect around its perfect yellow star.

"Farewell, Terra," whispered the girl who bore the vanished world's name. The end of the world. The first world. For a long time, the only world that the human race had ever known — the only place in the whole wondrous universe filled with amazing things which they could call home.

And now, in the place where it had been, there was nothing but fire.

Ter did not speak her next words out loud, but somehow she wound up saying them in her mind almost together with the Vixhor presence that still lingered within her.

We will remember. We will remember you.

## **Afterword**

Alma's story "End of the World" was inspired by the death of our Sun and the eventual fate of the planet which was the birthplace of the human race — more about the events that will transpire at that time can be found here:

[http://en.wikipedia.org/wiki/Formation\\_and\\_evolution\\_of\\_the\\_solar\\_system](http://en.wikipedia.org/wiki/Formation_and_evolution_of_the_solar_system)

[http://en.wikipedia.org/wiki/Hertzsprung-Russell\\_diagram](http://en.wikipedia.org/wiki/Hertzsprung-Russell_diagram)

[http://en.wikipedia.org/wiki/Image:Sun\\_Life.png](http://en.wikipedia.org/wiki/Image:Sun_Life.png)

[http://www.valdosta.edu/phy/astro/pl\\_shows/bh\\_2001/bh/page10.html](http://www.valdosta.edu/phy/astro/pl_shows/bh_2001/bh/page10.html)

<http://www.astronomy.ohio-state.edu/~pogge/Lectures/vistas97.html>

<http://www.nineplanets.org/sol.html>

## ***The Freshmen Hook Up***

by [Wil McCarthy](#)

Living the entirety of their lives in puddles of water, the Bitomites of Kosm are creatures of abiding simplicity, with an immune system best described as "reluctantly promiscuous", and with few of the refined attributes we expect from Standard Model signatories. Nevertheless, their lifetimes are among the longest known, limited only by their mating habits, which are themselves so complex and so singular as to merit a treatise of their own, which you currently hold in your attentive hands.

Therefore. . .

We begin with the puddle itself, which has a distinctly muddy appearance, being amply stocked with the even simpler raw materials from which the Bitomites self-assemble. Initially this body of water is too cramped to support Bitomite life, but as this is the rainy season in Kosm, the puddle undergoes a period of rapid expansion followed by a much longer period of filling that swells its borders in a slower, statelier manner.

Will this rainy season ever end? What preceded it, and what will come after? These questions will someday provide great consternation for the Bitomites, as well as limitless employment for their philosophers, puddleographers and puddleologists. For that matter, why should there be a puddle at all, and why so conveniently supplied with pieces of Bitomite, and with the exact conditions necessary for their assembly? But for our purposes here, we shall regard these questions as unanswerable, or at least unlikely to be answered during the span of your reading.

So. There comes a point in the puddle's expansion when a large number of Bitomites appear, suddenly and spontaneously, and while not all the raw materials are consumed in the process, the great majority of them are. Consequently, the water is greatly clarified, and as the Bitomites open their little eyes and blink in bewilderment at the world around them, they obey their most basic instinct and begin swimming toward one another to spawn.

But the pond is expanding, yes? Filling with rain? Their speed of travel is inherently limited by the friction of the surrounding medium, and so on the whole they find themselves drawing farther apart rather than closer. Poor Bitomites! The best they can do is form little clouds, dwarfed by the empty waters surrounding, and slowly fight their way inward, toward a center they can feel but not see.

Finally a few of them manage to stick together, and then a few more, until the waters are speckled with little black dots floating loose among the clouds. And then, as their collective body heat finds fewer and fewer avenues of escape, the communal balls one by one exceed the threshold temperature above which the Bitomites are induced — indeed, compelled! — to mate.

*Fiat lux*: bioluminescence begins, and the puddle flares with orgy lights. And as the Bitomites find one another, they come together in a strange way — their promiscuous immunity drawing no distinction between "self" and "other", and thus presenting no barrier to the absolute merger of bodies. Two Bitomites become one, and the resulting flash of light and hormones raises the ardor of the ones who haven't yet found a partner. Lust begets lust — as lust will do! — and so the process accelerates.

Now, members of this second generation of Bitomites — whom we will call Sophomores — are heavier than the members of the first generation — the Freshmen — each Sophomore being made up of the remnants of its two parents, along with other materials collected randomly from the water. Slower moving, the Sophomores tend to cluster in the center of the swarm while their smaller peers (or elders, if you prefer) continue to mate on the periphery. This goes on for quite some time, but as the population of Sophomores rises and its members come into increasingly heated and intimate contact, eventually their little subcolony within the swarm is ready to mate as well.

Hey, baby! Hey, baby!

Are the Sophomores more adventurous than their forebears? More lecherous? More emotionally needy? They may bump and grind in pairs, but it takes three of them to do the deed for real, and the Junior offspring they produce weigh many times more than the original Bitomites did (and do, for there are large numbers of Freshmen hanging around the periphery of the swarm, still looking for a date). And here's where it starts to get really complex, because when two Juniors combine, they can not only produce four different kinds of Senior offspring, each with its own distinctive mass and major and lifestyle choice, but they sometimes also regurgitate one of their perfectly intact parents or grandparents in the process!

Welcome back, Mom.

Moreover, these Seniors are more than capable of mating with Freshmen and Sophomores in complex ways, and they do so with great vigor, producing such a variety of Masters within the swarm that we must wonder how compatible partners manage to find one another at all. Indeed, while the process of mating is more energetic at this stage, it happens less and less frequently.

Such is the fate of aging societies, alas.

Within this kaleidoscopic fifth generation, only one possible pairing produces offspring heavier than its parents. These are the Doctors, and while *their* offspring are even more varied — call them Lawyers, Accountants, Engineers, etc. — the most numerous among them are the Professors. These are sessile, contemplative creatures who, even when fully surrounded by swarming and amorous students, are quite incapable of mating.

"We consider ourselves above such squelchiness", one Professor Magnus Ironicus famously quipped. "Let the students have their heat and fun; sooner or later they'll wear themselves out. We're the end of their line, and we shall welcome each of them among us in due course."

However kindly these words may seem, there's an undeniable menace behind them — the languid arrogance of an immovable object in the path of an ultimately resistible force. And yet, just when things seem to be settling down within the swarm, instabilities have begun which will, in due course, not only scatter the gathered bodies back into their parent cloud, but touch off a mosh pit of sweaty collision — one hesitates to call it mating — in which the press of bodies can force even the Professors together with one another, or with smaller Bitomites, to form a bewildering variety of heavy, sterile offspring — the Graduates — who go on to form cold but exquisitely complex societies of their own.

(Whole libraries have been composed on *that* subject, so we'll say nothing further about it here, except that you likely owe your own existence to it.)

According to the more prophetic branches of Bitomite philosophy, however, the Professors will nevertheless rule the puddle some day, for the Graduates have limited lifespans. Some of these are quite long — indeed, some Graduates can only be destroyed by mating with a student in the heat of an orgy swarm, or in the innards or outards of some other pond dweller who cares little for the Bitomial consequences of its own activity. (A nuclear reactor, say, or a particle accelerator, or a pondic ray from elsewhere in the puddle.)

But in any case, the "death" of a Graduate means the birth or rebirth of smaller Bitomites, who if they are sterile must themselves die someday, and if they are vital must someday take part in the complex mating ritual, of which Professors are the logical endpoint.

Check and mate, or so it would seem. *Herr Professor über alles.*

But in nearly every puddle of Kosm there are creatures so vastly much larger than the Bitomites that mere philosophy can scarcely be aware of them. In fact, these creatures *are* Bitomites in the strictest sense, having been created in the final paroxysms of the mating swarm. But the similarity ends there, for these entities — call them Corporations and, in the most extreme cases, Political Parties — are capable of swallowing student and professor and graduate alike, smooshing them permanently into collectives which no known force can break apart and from which, in the case of Political Parties, no information can escape.

But on a final note, there are peculiar things that can happen in a rain puddle when it gets old and big and thin enough, when the seasons change, when the surface of the water is disturbed. The Bitomites may presume to know their future, but unless all the contents of the puddle are known, along with all the myriad forces acting within and upon it, who among them can so prognosticate, without sooner or later playing the fool? Indeed, who can say that the Professors might not someday learn to dance, and thus give birth to miracles yet undreamed?

Meanwhile, as long as the Freshmen continue to frolic with one another, and with the Seniors, the puddle remains a realm of ever-expanding possibility, within which an infinity of stories can be told in each passing moment — including this one. Enjoy.

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## **Galactic Stress**

by [David Levine](#)

Dana sat at her vanity table, looking up at the reflection in the mirror of the plain white ceiling above, and sighed. She could discern no improvement in her vision. The vague, shadowy dimness still loitered at the edges of her view like a lurking thief. Casing the joint. Biding its time.

She chastised herself for impatience. She'd had her first injection less than twenty-four hours ago. She shouldn't expect immediate results.

Or maybe she was in the placebo group.

Fear clutched at the back of her throat. This clinical trial was her last hope. All the standard treatments had failed to stem the gradual increase in intraocular pressure that was slowly, steadily stealing her sight. Her mother had been forced to give up driving at age 35, and today needed an image amplifier even to read her email. That kind of impairment would destroy Dana's career.

Dana's adviser had tried to reassure her that she could always change tracks to theoretical astronomy. But observational astronomy was her passion. If she couldn't see clearly. . .

She leaned in closer to the mirror, looking into her own eyes. Observing. Studying. It was what she always did with a problem. She'd spent a lot of time looking at her own eyes since her diagnosis. The fine brown, amber, and gold structures of her hazel irises always reminded her of the delicate, glowing filaments of the Crab Nebula, or the Helix Nebula as seen in infrared.

Were they . . . different? They seemed . . . deeper, somehow. More convoluted? More colorful?

Dana shook her head. Wishful thinking, that was all. There shouldn't be any changes in the irises at all. She closed her eyes, took a deep breath, and dug through her jewelry box for a pair of caps. After only a moment's thought she selected the cloisonné pair that Jeremy had given her when she'd successfully defended her Ph.D. thesis. She snapped the grinning sun onto the socket in her left temple, then the devilishly winking crescent moon on the right.

They always made her smile. Especially when, as now, she needed a reminder that someone out there loved her. She couldn't deny she was jealous of Jeremy's trip to the Sagan space telescope at L2, but he'd be back home in just twenty more days.

She leaned back and blew a kiss toward the ceiling, then headed downstairs for breakfast. It wouldn't do to be late, not on the day of her long-awaited time slot at the Morgenstern Haptic Visualization Facility.

\* \* \*

During her commute, Dana normally read the latest *Astrophys. J.* on her handheld datappliance, but today she looked out the ziptrain window. For some reason the same aspens and spruces she'd zipped past every day for the past three years seemed especially beautiful today. The flicker of sunlight in their branches was

fascinating. . . mesmerizing, even.

She was so distracted she nearly missed her stop. And then, as she hurried through the closing door, she lost her balance and stumbled. She barely kept herself from sprawling across the concrete platform.

By the time she reached her lab she was beginning to realize that something strange was happening. She felt funny — giddy, lightheaded, maybe even a little woozy — and everything seemed brighter, bolder, more dynamic, more colorful.

She spent a few minutes watching the cream swirl in her coffee — it reminded her of the Whirlpool Galaxy — before she thought that maybe she should call the clinic. She had been warned that there could be perceptual side effects, and they might want to know about this. Mind you, this wasn't so bad. A little trippy, but not unpleasant. But still. . .

She was just pulling out her dataplance to make the call when it chimed, reminding her that she was due at the Morgenstern HVF in fifteen minutes.

Dana double-checked that all the work files on her dataplance were up to date, then slipped on her coat and headed for the door. The facility was ten minutes' walk across campus and she didn't want to chance being even a minute late. She'd call right after her session.

Waiting for the elevator, she realized that she felt a little wobbly on her feet, and the lights overhead seemed to thrum, unnaturally vibrant. Was she being foolish? Should she call in sick, try to reschedule? But as she hurried across campus, the imposing tower of the HVF looming over the Physics building, she realized that she didn't have any choice but to proceed. She was just a lowly post-doc . . . she'd had to pull every string she had to get even four hours of that multi-billion-dollar facility's time to herself. If she bailed out at the last minute, the administrators would have to scramble to fill her slot and she'd be on their shit list for sure. It might be months before she'd get another time slot, if ever.

She quickened her pace.

\* \* \*

The HVF technician's shirt was a colorful collage of moving images, and Dana had to close her eyes as he leaned over her to buckle the strap across her chest. The interface drugs would help prevent her body from moving during her session, among other things, but just as when dreaming, a certain amount of motion did occur and nobody wanted the IV to pull out.

"Comfy?" the tech said, patting the buckle.

Dana's mouth was dry. She just nodded and tried to smile.

"All right. You can put your caps here."

She snapped the cloisonné caps off of her temple sockets and dropped them clattering onto the proffered tray, which the tech set down on a small table beside Dana's couch. He then handed her a pair of neural cables, which she snapped into place, white on the left and red on the right as usual.

"Now, you might feel a little pinch. . ."

"I'd prefer the right arm, please."

"Got it."

The tech was good; the IV needle slid into Dana's vein with little more than a tweak of pain. After he'd secured the needle with a dab of sterile adhesive, he helped her to slip her wrists under the elastic on the couch's arms. So far it was just like every other HVF session she'd had, with no sign that for the next four hours she'd have the computer on the other end of the cables — the third-most-powerful scientific data visualization facility in the world — entirely to herself. She couldn't wait.

Finally, the tech bent down to where she could see her. Already it was getting hard for her to keep her eyes open. "Okay, you're good to go. Lights on or off?"

"Off, please."

"Productive dreams!"

The tech moved away, and a moment later darkness descended. Dana thought she could hear the HVF thrumming all around her, but that was absurd — the room was thoroughly soundproofed. For the next four hours the only information going in or out of this room would be through her neural cables.

Dana keyed her access code into the numeric pad under her right hand. It was awkward, but she'd learned to cope with a right-handed world. Then she took a breath, closed her eyes, and pressed ENTER.

\* \* \*

When she opened her eyes, or seemed to, Dana saw what appeared to be a loose, fuzzy ball of stars. It floated ahead of her in the darkness at chest level; if she wanted to, she could lean forward and put her arms about half-way around it. A thin, tepid warmth came from the ball, like the heat of a single match at arm's length, gently warming her chest and the underside of her chin.

This was her dataset. This was the accumulated result of decades of observations, some of them her own, from telescopes and dishes all over the Earth, above it, and around it. And the HVF was her gateway to truly understanding it.

The fuzzy ball of "stars" was actually a representation of the entire visible universe — a ball of galaxy clusters fourteen billion light-years in radius, with the Earth at the center. Since the universe began fourteen billion years ago, the farthest anyone could see in any direction was fourteen billion light-years. There might be more universe beyond that limit — in fact, there almost certainly was — but there was no way for anyone on Earth to know anything about it.

This view was not really possible in the physical universe, of course. If Dana had really stood at this point in space, only the nearest galaxies to her would look like this. The galaxies farther away would appear younger, because their light was coming from billions of light-years away and was thus billions of years old, and the light would also be redshifted because they were moving away from her. The view beyond that would fade into the chaos of the Big Bang. But in this simulation, she saw the entire visible universe in its "current" state, all at the same time, with no redshift.

Dana moved the control panel from its default position on the right to within easy reach of her left hand, then zoomed in a bit, enlarging the ball to about three times her own height. Or alternatively, she thought, shrinking herself to a mere ten billion light-years tall. The rapid apparent motion made her dizzy; she had to stand still, blinking her simulated eyes, for a long moment until the sensation went away. At this scale the warmth of the ball was more apparent, like a bonfire some distance away, and Dana could easily see the structure of the universe — rather than an even distribution across space, the galaxy clusters were grouped

into walls and filaments, like the walls of bubbles in foam, with mostly empty space between. One of her professors liked to say that it looked like the inside of a pumpkin.

She reached out her hand and took one of the filaments between her thumb and forefinger. The strand of galaxy clusters felt like a warm, grainy string between her fingertips, and as she tugged gently it resisted weakly. It felt a bit like pumpkin guts, actually, though stretchier and slimier . . . almost like gritty mucus.

This was the "haptic" part of the Haptic Visualization Facility — the simulation of the sense of touch. Haptic feedback gave Dana information on gravitic attraction, density and composition of the interstellar medium, average stellar population and temperature of the galaxy clusters, and much more, in a way that she could appreciate both consciously and intuitively. But because the sense of touch was so ancient, located in the brain's most primitive areas and integrated most closely with the autonomic nervous system, it was surprisingly difficult to fool — an effective touch simulation required massive amounts of computing capacity. And to simulate this enormous dataset, hundreds of exabytes, she needed every bit of the HVF's considerable power.

Which was why she had to make the most effective use of her time. She'd experienced HVF simulations before, though never one this large; she shouldn't be wasting precious minutes marveling at the technology. Honestly, what had gotten into her?

Dana turned to the control panel to zoom in a little closer. But as she turned, another wave of vertigo overtook her, and the galaxies seemed to flare in intensity. She closed her eyes against the sudden bright colors. . .

. . . and the view didn't change.

Again she closed her eyes. Nothing. The galaxies in her view continued to shine vibrantly, almost overwhelming in their brightness and variety of colors. She squeezed her eyes tight shut, feeling the muscles tense, but they didn't shut out the view.

Instinctually she put her hands to her eyes, but that didn't help either. She felt her closed eyes beneath her fingers, but her hands didn't block the view.

Now she was getting a little frightened. She pulled her hands away from her eyes and held them in front of herself.

She couldn't see her hands.

She couldn't see herself at all.

She felt herself. Her body was there. Her hands could touch it, and she felt her hands on her body. Her simulated hands on her simulated body. If she were actually running her real hands over her real body, she'd feel the straps and the tug of the IV. Was her body writhing on the couch, straining against its straps, or lying passively? She couldn't tell. Her own body might as well be fourteen billion light-years away, it was so far beyond her perceptions. . .

No. Stop it. Don't panic. There was just some kind of glitch in the system. The HVF software was one-of-a-kind, constantly under development — largely by Computer Science graduate students — and it did have more than its share of bugs. She'd work around this bug the way she'd learned to work around so many others.

But it was still unnerving not to be able to shut out the view of the universe. Especially since it seemed to be

getting more vibrant and dynamic by the minute. In fact, it was becoming overwhelming. The light of a hundred billion galaxies pierced her vision with an almost physical force.

Unthinkingly, she put up her hands to block the light . . . and felt them tangle in the threads and membranes of the universe. Trapped like a bug in a spider's web. Her heart pounded and she thrashed in helpless, irrational panic.

One of her flailing, invisible hands smacked into the control panel, sending it sailing off into the darkness to her left. She tried to grab it before it got away, but succeeded only in pressing several buttons . . . including the Hide button in the upper right. The panel vanished, still moving quickly away.

And she began to fall.

Dana shrieked as the structure of the universe expanded, or she shrank. Filaments and webs of galaxies whipped past her, stroking and clinging and tickling her hands, her face, her legs . . . some particularly dense knots of young galaxies burned her skin like hot sparks.

She must have triggered a continuous zoom toward the center of the simulation; it felt like a factor of ten every ten seconds. She groped for the hidden control panel, but the onrushing galaxies were so bright . . . and she couldn't even see her own hands . . . and her head spun, and she had trouble keeping focus. No matter how far she reached, the control panel was nowhere to be found.

And if she couldn't find the control panel, she couldn't hit the panic switch that would shut the simulation down.

This shouldn't be happening, she told herself. As amazing as the universe was, and as impressive as the haptic interface was, she shouldn't be so overwhelmed by it. It had to be some kind of interaction between the glaucoma drugs and the interface drugs.

Knowing this didn't help. She was still *falling*! Plummeting uncontrollably through the universe a quintillion times faster than light. And her heart and guts wouldn't listen to her brain.

She was now a hundred million light-years tall, and shrinking rapidly. The bubble-like structure of the universe quickly grew so large that it became invisible, replaced by clusters of galaxies . . . the forest vanishing, the trees becoming individual. Each galaxy cluster was a loose ball, basketball-sized or so. She collided with one as she fell, sending tiny galaxies scattering in every direction; the sensation on her skin was like sand grains in a sandstorm. Intellectually she knew it was only a simulation, but she still felt guilty for the destruction she'd caused.

Dana fell through the dense wall of galaxy clusters into the empty space between. Ahead of her another strand of clusters grew and grew, visibly separating into individual galaxies as she watched. They didn't twinkle like stars seen from Earth — the interstellar medium was hard vacuum, compared to Earth's atmosphere — but they seemed to vibrate with drug-induced intensity, their light reaching out to claw at her eyes.

She searched frantically for the control panel, feeling all around the place it had vanished, reaching as far as she could . . . but again and again her invisible fingers found nothing. Her heart pounded in her throat and she fought down panic. It was getting harder and harder to remember that this was a simulation. Her primitive monkey brain insisted she was plummeting to her death.

She fell into the strand of clusters, galaxies flashing by on either side. Each galaxy was now hubcap-sized . . . she must have shrunk to only a million light-years tall. The galaxies were beautiful and terrible, shimmering

glowing confections, spirals and disks and strange elongated comas. Most had a thick bulge in the center, a dense conglomeration of stars . . . the heat of the nearby ones felt like a burning road flare, and their gravity tugged at her stomach as she fell past. A barred spiral galaxy smashed itself to bits against her invisible leg as she passed, feeling like a hot buzz-saw of stars on her calf. She cried out from the pain. Another galaxy, this one an irregular elliptical giant almost half as big as she was, came rushing up at her and she curled up in terror, but it just missed her.

What if the galactic core, with its super-massive black hole, had hit her? Could she die in the simulation? There were supposed to be safeguards . . . but the HVF was no ordinary sim, and between software bugs and experimental drugs she might be beyond its parameters.

She looked around, fighting down nausea as her invisible, simulated head spun. After that last near-miss she seemed to have fallen into another empty area, this time a space between galaxies within a galaxy cluster. Based on how large that last galaxy had been, she must be about a hundred thousand light-years tall now, and the average distance between galaxies in a cluster was a few million light-years. She might be safe.

But as she looked down, she realized she was not safe. She was falling toward the center of the simulation, and that center was Earth. The spiraling disk of the Milky Way, Earth's home galaxy, grew and grew before her, looming with broad flat inevitability. It was like driving at full speed into a solid wall of headlights.

Dana's headlong rush seemed to slow as the Milky Way expanded to fill her view and more, spiral arms resolving themselves into broad rivers of individual stars, but she was still going to hit it hard. She angled herself forward, held her arms ahead of her like a diver, and held her breath.

The galaxy had grown to about a hundred times as wide as her height, so she was perhaps a thousand light-years tall, when she smacked into one spiral arm. Stars and nebulae and interstellar gas battered her extended arms and face, but by now she was moving slowly enough that the blow was more like a sudden hailstorm than slamming into a wall. She gasped from the rough, scouring impact, but she didn't think she'd broken anything.

Stunned, she fell into the galaxy as though it were a mighty ocean. The shock of her body passing through the interstellar medium made new stars spring into life, crackling like popcorn on her leading edges.

She was still shrinking. The hail of stars rapidly thinned to a hot drizzle. Soon she was mostly falling between them, with only the occasional searing impact. She must be about ten light-years tall now; the stars were about as far apart as the length of her leg. Each individual star was too small to be anything other than a blazing-hot bright point.

She fell through near-emptiness for a long time before one star began to distinguish itself from the rest, directly ahead, as she knew it must. The Earth's sun.

How much longer could this game go on? Would she slam into the Earth, her body breaking open from the impact? Or would she keep going, deeper and deeper, vanishing into subatomic space?

No. She knew that her dataset didn't include anything smaller than a satellite.

Unless her drug-addled brain kept going without data, making up smaller and smaller particles while her body gibbered in some mental hospital. . .

A stiff, gritty breeze began to push at her, chilling her skin and making her blink. She was falling through the Oort cloud, the thin sphere of cold gas and chunks of ice that surrounded the sun out to a distance of two light-years . . . twice her own current height.

The Oort surrounded her for a long time, as she shrank from a light-year to a light-month in height, her progress continuing to slow. Even at only one light-month tall she was still a hundred times bigger than the orbit of Neptune, the outermost of the true planets. There was an awful lot of mostly empty space in the solar system.

She was a comet now, falling inward from the Oort. Would she leave a tail behind herself as she approached the sun?

The solar system itself began to come into view before her now, the orbit of Neptune a skinny blue ellipse no longer than the palm of her hand. The ellipse only existed in the simulation, of course; the planet itself was far, far too small to be seen. Smaller ellipses just visible within Neptune's orbit were the orbits of Uranus, Saturn, and Jupiter; Earth's orbit was indistinguishable from the sun at this scale. She continued to decelerate, though still moving at an apparent speed that would certainly kill her if she slammed into a solid object with her physical body. And she was heading right for Earth.

She had to do something before then. But what?

Dana was now about the same size as the orbit of Neptune . . . about eight light-hours tall. Still falling at a speed impossible for any physical object. Still slowing. The chill wind of the Oort cloud had faded away to nothing; she was now near enough to the sun that the spaces between the planets were blown clear by the solar wind. The solar wind itself, nothing more than charged particles, was too tenuous to be felt even by her drug-heightened and computer-stimulated senses.

The ellipses of the solar system continued to swell before her, the orbits of the inner solar system planets now becoming distinct from the sun. The planets themselves were still invisible, not even specks . . . she was perhaps one light-hour tall now, a bit bigger than the diameter of Mars's orbit, and even mighty Jupiter was less than a hundredth of one percent of that.

As the inner solar system expanded, she realized that the sun had begun to shift to one side. She was no longer falling directly toward it; she was now falling toward the Earth. She always had been, of course, though the distinction had not been apparent until now. The planet itself, far too small to see, was indicated by a blinking point on the ellipse of its orbit. Dead ahead.

Time passed, as she drifted down through the vast emptiness of the solar system. She seemed to be merely hanging in space now, the stars through which she had plummeted so rapidly now standing completely still, the orbits of the inner planets expanding slowly ahead of her. But she knew she was still moving at a physically impossible speed. She'd shrunk from one light-hour to ten light-minutes tall in less than ten seconds . . . that meant that she was approaching the Earth at more than three hundred times the speed of light. It still felt like a crawl, with no nearby objects to compare herself to.

Dana could no longer see all of Earth's orbit at once, and the other inner planets' orbits were too far to the sides now for her to see without turning her head. Ahead, the blinking point that represented the Earth began to expand into a visible circle, but soon she realized it was not the planet itself but the orbit of the Moon.

Although Dana's fall was still slowing, the appearance of a visible feature made it seem terribly fast again. The Moon's orbit grew from invisibility to an ellipse the size of her head in a matter of seconds, rushing toward her like the mouth of an oncoming tunnel as seen from a speeding train. In and around that tunnel mouth she saw many flickering green curves — circles, ellipses, and parabolas representing the orbits of artificial satellites.

One of those was the Sagan space telescope, poised at the L2 point on the far side of the Earth from the Sun, well beyond the Moon. And that was where Jeremy was.

Dana's heart beat harder at the thought.

Her brain knew this was only a simulation, that Jeremy wasn't really there. But her heart ached for him.

They'd been apart for so many months, and now . . . now she was about to die. Her simulated body was going to slam into the solid simulated Earth, far denser and proportionally much bigger than the galaxy that had grazed her leg so painfully. She didn't know what would happen to her then, but her terrified screaming monkey mind insisted that she would go *splat*, and between the bugs and the drugs she couldn't be sure she wouldn't.

The Moon's orbit was now a skinny ellipse as long as her arm. She must be about five light-seconds tall, and coming in just above the plane of the ecliptic. The Sun was to her left, so Jeremy would be off to her right, on the far side of the Sun from the Earth and about four times farther from Earth than the Moon . . . just *there*.

And there he was. A tiny, tiny green ellipse, no bigger than her fingertip, represented the Sagan telescope's station-keeping orbit around the L2 point. She had already nearly passed it.

Desperately she reached out to the speeding ellipse. *I love you, Jeremy*, she thought. . .

. . .and her hand struck something hard and cool.

The control panel. When it had flown out of her reach, it must have automatically returned to its default position by her right hand. But it was still invisible, and she hadn't thought to look for it there.

Heart pounding, Dana ran her clumsy right hand around the panel's smooth rounded edge, fumbling for the Hide button in the upper right. She found it and pressed it.

The control panel appeared.

Beyond it, the Earth was already the size of a basketball, and growing rapidly. The simulation was cloudless, a photorealistic globe surrounded by the green circles of artificial satellites. She fell toward it, slowing but still moving at killing speed.

The Earth shimmered in her drug-addled vision, huge and bold and powerful. The home of all humankind. So small in the immensity of the universe, yet so immense to her.

As terrified as she was, she was overcome with awe.

She couldn't wait to tell Jeremy about this. . .

Jeremy!

Dana slammed the Stop button with her thumb. Immediately she halted her downward plunge.

She hung, gasping, in space. She must be no more than five percent of a light-second tall; the Earth was now a sphere bigger in diameter than her height, its surface just an arm's length away.

She reached out and touched it. It was cool and smooth and very hard.

Dana leaned against the Earth and sobbed with relief.

\* \* \*

Dana peered anxiously at the people coming off the flight from Florida. There he was! Moving slowly, still unaccustomed to gravity, but she'd never mistake Jeremy's face.

And she could see it so clearly! Even only twenty days into the experimental treatment, she was already detecting an improvement in her vision.

She ran to Jeremy and embraced him with a shriek of joy. "Did you bring me anything?" she teased.

"Just a head full of stars," he said, and kissed her. "How about you?"

"Well. . ." Her headlong plummet through space had, amazingly, taken only five minutes of her HVF time. Once she'd recovered her composure, she'd gone on to complete her researches as planned . . . in fact, her unexpected side trip had given her some very interesting insights. "Actually, I have some important results to share. But first, I want to share something else. . ."

Jeremy squawked as she picked him up and spun him around. Then she set him down, and they headed for the exit.

### **Afterword:**

This story follows in the footsteps of the book "Cosmic View" by Kees Boeke (1957) and the films *Cosmic Zoom* by Eva Szasz (1968), *Powers of Ten* by Ray and Charles Eames (1977), and *Cosmic Voyage* by Bayley Silleck (1996).

Like those earlier works, it attempts to give an understanding of the scale of the universe by giving a high-speed guided tour from the largest scale to the smallest. Because this is a short story rather than an art book or a movie, it lacks stunning visuals, but I hope that it offers instead the full range of senses and emotions provided by the reader's imagination.

If you'd like to take an interactive online version of Dana's voyage, you can do so here:

<http://www.wordwizz.com/pwrsof10.htm>

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## ***The Moon is a Harsh Pig***

by [Gerald M. Weinberg](#)

*Follow your inner moonlight; don't hide the madness.*

— Allen Ginsberg

"That's the most disgusting thing I ever saw."

"It's just a pig, Zeke. The biggest one on the planet, according to the sign. 527 kilos."

"Is that with or without the mud? Yuk."

"Mud is a perfectly natural environment for a pig," said Astrid, studying the Planetary Fair sign as it scrolled past. "—or a sow. She's a female."

"All the more disgusting."

*How did I wind up with this bozo on my thesis trip? she thought. He's cute and he's smart, but he knows it and he's trying too hard to convince me. Why can't he just relax?*

He attempted to put his arm around her waist and steer her away from the pigpen, but she moved his hand away and stayed put. *Too bad you couldn't afford this trip on your own money. You linked up with him to qualify for a companion fare.*

*In other words, you sold yourself for money. Now he thinks he's entitled to collect. Well, deal with it, girl! He can be charming. Maybe I can get him to loosen up. Get his mind off my body.*

"Come on," she said. "I'll show you the rest of the fair, so you'll see why Parma is so interesting."

He made a sour face, but allowed himself to be led outside the pig building into the open air. He took a deep breath, as if to remove the odor from his nose, then gazed up at the open sky. "I'd rather be sitting on the beach with you, smooching by the light of that fabulous moon."

"Stop acting as if I were one of those twenty-first century floozies. I've only known you for two days, and I have no intention of smooching with you. Besides, I came here to study the history and culture of this planet, not to make out with some oversexed rich, spoiled, know-it-all."

He checked the sleeves of his body suit for invisible lint. "What's your major, anyway?"

*He sure dresses well, but doesn't even seem to know that his fancy suit repels lint. Maybe that's because his father's tailor made it for him. "Exodus anthropology."*

They approached a booth with distorting mirrors. He stopped to check his image, then changed his suit color to a pale gold. "What the heck is ... whatever you said?"

"Better I show you." They were now passing the protein pavilion, so she invited him to take a seat at one of the outdoor tables. A waitress stopped at their table, and while Zeke was busy peering down her low-cut peasant blouse, Astrid ordered a sample plate along with a bottle of *Cave de Rivesaltes*.

"All of the farmers of Parma came here to escape the Pollution. As an exodus anthropologist, my job is to study how their cultures have changed since they left Earth, and for what reasons."

"Who cares about that?" He cast his gaze around the crowd of other patrons, adjusting his suit to a brilliant crimson. "Looks just like any other backward planet. Look what they're wearing."

The waitress arrived with a giant platter holding a loaf of crusty bread surrounded by artfully arranged slices and wedges of cheese. She set down a bottle of deep golden wine, pulled the cork, and offered him a small sample to taste.

Astrid could see Zeke had no idea what he was tasting, but allowed him to accept the wine with a great pretense of sophistication.

Once the waitress was gone and Zeke had stopped watching the sway of her departing hips, Astrid held up a wedge of cheese with a hard, dark brown rind.

"Take this cheese, for example. *Idiazabal* is made from unpasteurized milk that can only come from the *latxa* breed of sheep. On Earth, it could only come from the Basque region of Spain, but when the Pollution destroyed conditions there, the Basque herders sold their land to speculators and took their flocks here, to Parma."

She held the cheese wedge up to his nose. He sniffed it suspiciously. "Why here?"

"This was the most earthlike planet available. Their cheese has such high market value they can export it and earn enough to maintain their traditional way of life. It's the same for the specialty products of all the agricultural people who came here."

She nibbled on the *Idiazabal*, then gave it to him and picked up a chunk of whitish cheese laced with irregular blue veins. "The producers of Stilton, for example, came from England."

He wrinkled his nose. "It stinks. I can smell it from here. Who would want it?"

"Oh, just millions. They're willing to pay top prices, because they can't get real Stilton anywhere else." She swept her hand over the tray. "It's the same with all these cheeses. And olives. And onions. And meats. Just about any delicacy that can no longer be produced on Earth."

He pushed the tray to her side of the table. "But Earth can produce all these things."

"No, only cheap, inferior, imitations. Here, taste some of this." She handed him a strip of pink dried meat. He looked at it dubiously, sniffed it, then worried off a small bite.

"Mmm, not bad. What kind of cheese is this?"

"It's not cheese. It's *prosciutto*, or Parma ham. Dry-cured, from a pig like Greta."

He gagged and spit out the half-chewed ham. "From an *animal*?" He rinsed his mouth with a swig of wine, then spit the mouthful on the packed earth floor.

"Of course an animal. Where else would it come from?"

"From a vat, of course." His face was turning pale green, contrasting with the crimson of his suit.

"This is real *prosciutto*. Originally from central and northern Italy. It brings forty or fifty times the price of that vat imitation—Vam, isn't it called? That premium allows these farmers to thrive."

He stood. "Let's get out of here. I can't—" He put his hand over his mouth and bolted for the entrance.

She could see he was about to vomit, but knew he could never admit it. She gave him time to answer nature's call, paid the bill, and followed him out onto the moon-lit concourse. *He's got potential, but I've got to break through his defenses.*

He appeared five minutes later, looking a bit better and acting as if nothing had happened. "I was studying the moon," he alibied. "I didn't tell you, but my field is astrophysics—a lot more scientific than—what was it?—exodus archaeology."

"Anthropology," she corrected, smiling to herself because she knew he'd made the mistake intentionally. He was about to do some serious ego-building, at her expense, if possible. *Well, maybe I can break it down, and reach him that way.*

"Yeah, whatever." He pointed to the sky. "Let me teach you something that you probably don't know. See that moon? Do you know why you only see a crescent?"

She stared up at the glowing half-disk. "It's because different parts of the moon light up at different times."

He clasped his forehead in mock dismay. "My god, that's dumb."

"What's dumb about it? That's the way it works."

"Wanna bet?"

*Here it comes.* "What would we bet? You have everything you could ever want." *Or your father does.*

"Except a kiss from you."

"Oh, not that again, Zeke. Don't be so boring." She held up her palm as if ready to push him away.

"Why not? If my explanation is correct, and you lose, then you'll kiss me."

She threw him a coquettish glance. "Hmm. I don't know about that. What if *you* lose?"

"I won't lose."

She shrugged. "But it's no bet if you have nothing to lose."

"So, what do you propose?"

She paused as if considering possibilities, though she already knew where this was going. "For starters, if you lose, you pay for my return trip, full fare."

"Sure," he said, cocky as ever.

She realized her mistake immediately. *That didn't work. It's his father's money. It wouldn't bother him to pay.*

She offered her hand to shake on the deal, but he held up one finger, signaling another condition. "If you lose, I'll pay your fare anyway, but we have to take the long way back. And you'll share a cabin with me."

She knew the long way back was at least two weeks. "I think you just raised the stakes." She thought fast. "Under the circumstances, we need to throw in one more thing, to balance the odds."

"What did you have in mind?" Apparently he still didn't have a hint that he might lose.

"Hmm. Remember that pig we saw?"

"You mean that ... Greta, the champion sow?"

"That's the one."

"What about her?"

"If you lose, you have to climb into the pigpen and kiss her. On the lips."

He rocked his head back and forth, tossing his golden curls from side to side.

"Very funny. Okay, why not? I'm not going to lose."

He extended his hand. She shook it, sealing the bet. He didn't release her hand until she led him up in front of a uniformed policeman and asked for directions to the live animal pens.

On their way to the pens, they passed a small girl, perhaps five years old, bouncing a large multi-colored ball—probably a prize from one of the gaming booths. Zeke moved quickly and snatched the ball on a bounce. When the girl started to cry, he seized her hand and pressed his own palm sensor on hers. "Here's money for the ball. Enough for ten new ones. Now get lost!"

Astrid wanted to hug the child and wipe away her tears, but the five-year-old was already running back to her friends, wailing. Zeke tugged Astrid's elbow.

"Let's get out of here before she complains to her parents. Her Mama is probably a hundred-kilo farm wife who wrings chicken's necks and eats them alive, feathers and all."

Astrid pried his fingers off her arm, but couldn't see much alternative to following him as he searched for a spot adequately dark for his demonstration.

Eventually, he found a barn-like structure filled from wall to wall with animal pens, though the stalls on their end of the building were all vacant. "This should be dark enough," he said, setting his data pod on the railing of the nearest stall and turning on its light beam. "This will be the sun, shining its light on both the planet and the moon. Now you stand here." He swept away some straw on the dirt floor.

"You'll be the planet."

"I'm supposed to be a *planet*?"

"Well, okay, think of yourself as *you*, *standing* on the planet. You're looking up at the moon." He held up the ball in both hands. "This will be the moon."

"And what am I supposed to do?"

"Just stand there and look at the moon while I carry it around you. You do know that the moon rotates around the planet, don't you?"

"That doesn't sound right, but if you say so, okay. It's your demonstration."

"Good. Now, face away from the sun—my pod—and watch the shadow on the ball." He stood in front of her so that she and the ball and the "sun" were in a straight line. "Tell me about the shadow you see."

She was distracted for a moment as two young boys led a noisy flock of white and black sheep into a pen about thirty meters away. Once the sheep were safely penned, they stopped bleating. She looked at the ball. "There isn't any shadow. Not that I can see from here with the sun behind me. It's illuminating the whole moon."

"Right. That's what we call the full moon. No shadow. Now, watch what happens when I move over to your left side."

"I'm supposed to watch you?" *He's actually very good at explaining this. He'd make a good teacher if he wasn't so full of himself. If I give him a hard time, that might help.*

"Well, not me. The moon." He wiggled the ball. "Where's the shadow now."

"That's easy. The right side of the ball is dark. Half the ball."

"Exactly. That's the half moon. And now what happens when I move the moon between you and the pod—between you and the sun."

She didn't even look. "It's all shadow, of course. Because the sun's shining on the other side."

"So there you are. The new moon. And that's how phases of the moon work."

He puckered up his lips and made a smacking sound. "Time to pay up."

She shook her head and wagged her finger at him. "Not so fast, lover boy. You haven't heard my explanation yet."

"Sure, I did. You said that there are lights on the moon that go on and off in phases. That's pretty much the most stupid thing I've ever heard. Bad science. Very bad science. In fact, it's not science at all. It's pure fantasy."

"And what makes it bad science, Mr. Smarty?" She held her arm extended stiffly in front of her, to fend him off.

"Because there's no evidence, no data, whatsoever. Science is based on facts. Observable facts."

"And what observable facts did you give me in your so-called proof?"

"I *showed* you, with this ball. You could see it with your own eyes."

She lifted an eyebrow. "Ah, so the moon is a child's ball?"

"Now you're being silly. Of course the moon isn't a ball. I was using an analogy."

"Oh, so now science is based on analogy, not facts?"

He wrinkled his face in frustration. "Of course not. Stop acting like a girl."

*I ought to smack him, but this is going to be better.* "I'm not acting. So your ball demonstration wasn't a proof after all, right?"

He dropped the ball into the straw and raised his hands in a gesture of mock surrender. "Maybe. But it's as good a proof as you can get without actually going to the moon itself."

*Finally.* "So, let's go to the moon and get some observable facts for ourselves."

He crossed his arms over his chest, showing resistance but obviously intended to impress her with his artificially enhanced biceps. "Now you're *really* being silly. That would take five or six hours."

"I don't think it would take that long. It didn't take much longer than that to get to this planet from Earth."

Zeke slapped his forehead. His expression said, *How dumb can a broad be?* What he said out loud was, "If you knew anything about astrophysics, you'd know it's faster from planet to planet," he explained impatiently, "We came through hyper-space. To get to the moon, we'd have to take an ordinary taxi through real-space, which means we can only go at real speeds. I don't know exactly how far this moon is, but I'd say it's at least 300,000 kilometers, which means about five hours each way."

"It looks like it's a lot closer than that."

"Sure. And it lights up in phases. Archaeologists know all about it, don't they?"

"More than you do," she pouted. "I've studied it for my thesis. Anyway, even if I'm wrong, I won't concede our bet unless we have a real proof."

She studied his face as he considered her proposal. *He must think I'm dumber than a hammer. I hope he thinks he can make whoopee on the five-hour trip.*

"Okay," he said at last. "I'll call a taxi."

The taxi arrived two minutes after they reached the cab stand. It was a rather ordinary rocket car of such an old model that Astrid had never seen one quite like it. She made a mental note in her data files—a nice bit of detail for her thesis. Inside, however, it did have conventional privacy controls. Zeke blocked off the driver and proceeded to continue his smooch campaign on Astrid.

He'd been pawing at her for about ten minutes, and seemed to think he was making progress, when she turned on the view window and gave a little squeak.

"There it is. Isn't it lovely?"

He didn't turn his face away from its position about a hand's breadth away from her lips. "There's *what?*"

"The moon, of course." She slid away from his face and pointed at the screen.

"See, I was right."

He didn't look, but inched closer, narrowing the gap again between their faces.

"It can't be the moon. We're no more than a few thousand clicks up."

"So? I *told* you how close the moon was."

They circled the moon for another twenty minutes, examining what turned out to be a huge curved disc in a geo-stationary orbit. The back of the disc consisted of a criss-cross of slim metal structural members, while the front was a black background covered with millions of tiny lights. Tonight, half the lights were on, projecting an image of a half moon to the residents of Parma below.

Zeke remained silent until they returned to the fairgrounds. He paid for her ticket without complaint, and she wondered if his ego was going to allow him to ask her about the moon. She led him from the cab stand along the concourse until they were alongside Greta's pigpen, at which point he stopped and said, "How did you know?"

"I'm an exodus anthropologist. It's my business to know these things. Of course I know about the phases of Earth's moon, or of any natural moon, but Parma has no natural moon. The first immigrants didn't realize that was a problem until they noticed that their animals weren't breeding properly. That would have made their migration hopes hash, but a scientist—an anthropologist, actually—showed that the cause was the missing moon, so there were no biological phases. The pigs and sheep and other animals were genetically adapted to the Earth's moon cycles."

She edge him closer to the pigpen. "The animals, like Greta here, were absolutely essential to maintaining the immigrants' way of life, but buying and moving a moon was way too expensive. Instead, they hired an engineering firm to build them that artificial one, with lights that simulated the phases of Earth's moon."

They were now looking down over the railing at Greta, grunting and wallowing in her mud. He stared, wide-eyed, into the pen. "You took unfair advantage of me," he said. "How could I know the moon was artificial?"

"Oh, if you were a real astrophysicist, you could have known by your own principles."

"Huh?"

"Observable facts, remember? Ever since we landed here, the moon has been in the same position in the sky. It's in a geosynchronous orbit. It shows phases, because that's what it was designed to do, but it doesn't rise and set like Earth's moon. In fact, I *told* you it didn't rotate around Parma."

"So, you set me up."

"No, Zeke, you set yourself up by being an arrogant fool."

"I may be a fool, but I'm bigger and stronger than you." He flexed the muscles in his artificially enhanced chest to show his defiance. "I say you cheated me, so I'm not going to pay the second part of the bet. And, I'm going to collect the kiss you cheated me out of."

He grabbed her shoulder and started to pull her towards him.

She took hold of his wrist, placed her other hand under his elbow, and pivoted around on her right foot. He wouldn't let go, so she spun him around faster until his legs hit the railing. Over he tumbled, splashing on his rump into the mud right in front of Greta. Without hesitation, the giant sow moved forward and immediately pressed her snout into his face.

"That's the only kiss you're going to get," she called in after him. "And one more thing you didn't know. I didn't buy my muscles. I *earned* them, by working out. Unlike the muscles you bought, they're not just for show."

Greta's huge tongue bathed his face. He wiped off some of the pig slobber with the back of his hand, then began to laugh. "I guess she recognizes me as real pig because that's the way I've been acting."

She broke into a smile and reached down to offer a hand for pulling him out.

"You finally got that right."

"I guess I was trying too hard to impress you. Can you forgive me? Can we start over from square one?"

She yanked him out of the pen. "We'll see. You can start by—"

"—cleaning up?" he asked, watching his suit shed mud.

"You can do that later. I was thinking you could find that little girl and give her ball back. With an apology."

### **Afterword:**

In this story, I was aiming at a number of lessons:

1. "Know-it-all" scientists aren't scientists.
2. Astronomical events (like phases of the moon) have a lot more influence on things than we are aware of.
3. How easily we can fool ourselves with simulations.
4. And, of course, how lunar phenomena actually work.

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## ***The Point***

by [Mike Brotherton](#)

"Do you remember the day we met?"

Her question filled his mind, ever so slowly, as his mind spanned several light seconds and their spatial overlap was not perfect. There was also an echo that indicated his photonic synapses were losing coherence faster than he had anticipated.

The end was coming.

"I remember," he thought so she could hear it.

In a universe that had been nothing but thought for eons, his consciousness floated amidst the microwave pulses that were his memories, and he restored them to his awareness.

He did remember. He remembered everything now with perfect clarity, although it was an early memory and heavily reconstructed numerous times on his 71 million year maintenance schedule.

Eighteen-year-old Cody Justin Taylor, as he had been known then, first met nineteen-year-old Vanessa Amber London, as she had been known then, on Wednesday, November 19, 2008, in their introductory astronomy class.

The professor was wrapping up her lecture. "To summarize our modern understanding of cosmology, the universe began 13.7 billion years ago in an infinitely hot cauldron of creation we call the Big Bang. That initial fireball expanded, cooled, with dark matter and normal matter collapsing under gravity into galaxies, each full of stars and planets, where life like butterflies and bacteria, people and puppy dogs, could arise."

Students in the lecture hall began fidgeting as they did when the prof grew poetic toward the end of class, as she often did. Unperturbed, she pressed on. "The universe will continue expanding, forever, and now we know that the expansion is accelerating. The future we face could be described as the big empty, when the Milky Way and all galaxies become totally isolated, but it's also possible that this repulsive, expansive force we refer to as dark energy will increase its power and eventually rip even individual atoms apart. It will be an utterly complete destruction."

The professor stood there in the ensuing silence, seemingly trying to get the shifting and restless students to consider the philosophical import of these grand pronouncements about the future of everything. "Any questions or comments?"

That was when he spoke up. He hadn't been fidgeting, shifting, or restless, but uncharacteristically contemplative. "If the universe is just going to keep expanding into nothingness, even destroying itself, then, well, what's the point?"

"What do you mean, exactly?" the professor asked, frowning but leaning forward.

Turmoil brewed within him, and he suppressed his shyness at speaking out in front of such a large class. "What's the point of doing anything? My homework, for starters?"

That raised a few chuckles.

The professor stepped back, smiling and appearing to relax. "Your grade, for starters. But this is a question we all have to face. Nothing is forever. We all die, sooner or later. Some turn to religion. Others to, I don't know, their work, family, partying, something. Myself, I consider how lucky I am to even be alive. Out of all the people that could have existed, and that number exceeds the grains of sand on every beach on Earth, here I am. Me. Getting to be, to live. I'm going to take advantage of that by spending my time doing things I love, and I suggest all of you do as well. And do your homework, too."

She dismissed them then amidst mild laughter, and as he grabbed his backpack and stood to leave, he found a tall raven-haired girl glaring at him.

"You stole that from Woody Allen," she said.

"What?" he answered.

"In the face of an expanding universe, what's the point?" she persisted. "Annie Hall. I'm surprised the prof didn't call you out on it."

"I don't know what you're talking about," he said, truthfully.

She looked at him hard for a long moment, then tilted her head and smiled at him. "You're a liar or a little neurotic then. Either way, we're going to get to know each other."

"We are?"

"We are. And you're going to watch Annie Hall with me tomorrow night."

She was cute, so they did.

And they did more than just that, too. They did the things that young humans do together. They dated, loved, married, and raised children, more or less in that order.

There were good times, and bad times. But more good than bad.

In 2031, they vacationed in a space hotel, and discovered that making love in zero gravity wasn't all that wonderful. Still, it was an experience that they cherished. It was hard to believe from that unique perspective that the Energy Wars were devastating so much of the world. Earth was a calm, blue swirl as seen from space, and the suffering distant, even invisible.

In 2041, the first in a series of significant life-extension drugs was released to the general public. The fifty-something American couple remained looking and feeling fifty-something, and celebrated the births of several grandchildren.

In 2061, they vacationed on the Moon.

Cody realized that the times, they were a changin', in a qualitatively profound manner. A lot of the promises of the futurists were coming true, although he still didn't have a flying car or a jet pack like his retired dad ranted about on occasion. But a man could delay aging, vacation on the Moon, and access all the knowledge

of the world in seconds via brain implant.

In 2071, when global temperatures had skyrocketed and the fight to preserve Florida's coastline was given up as lost, Cody and Vanessa received medical nanotechnology into their bloodstream that restored their youth. Smooth skin, dark hair, with muscle tones and metabolisms to match. It was a tremendous excuse to dance.

Then things got weird.

In the decades and centuries that followed, technology allowed them to change appearance, change sex, even change species to a certain extent. The population alternatively fought and rejoiced over such things.

Intelligent computers thought for people. Intelligent robots worked for people. People lived and loved.

In the 23rd century, Cody and Vanessa moved to Mars and rarely regretted it. The sunsets on Mars were lovely then.

They decided not to homestead an asteroid, and skipped the first several interstellar colonizations. Finally in 2554, they accepted the challenge of taming Tau Ceti III, named Georgia by popular vote.

Those were a few good centuries, and he barely fought with Vanessa at all.

They did separate, however, eventually. Who could stay together for so long with so many opportunities? Cody visited the Orion star-forming region, while Vanessa remained on Georgia for a time before taking the plunge into the Galactic center to study the supermassive black hole there, weighing some three million times the sun, and its exotic environment.

When Cody and Vanessa met again, it was the second age of Cytannus, a regional empire in the Sagittarius arm, in the year 4432, as reckoned by their calendar. They fell together again like no time had passed, even though one was an android and the other was a space mermaid. Sometimes life is like that.

They compromised and settled together as sea leviathans on a water world and sang symphonies to each other for several centuries. Post-human existence had its possibilities.

Together they traveled to watch dwarf novas, novas, supernovas, and hypernovas, all from appropriately safe distances. Explosions were always good entertainment.

They made the trip to Andromeda and met the alien species that had colonized that galaxy from rim to core. The aliens smelled bad, but were very nice people.

Three point seven million years after the astronomy class in which Cody and Vanessa had first met, they shed their corporeal bodies entirely in favor of distributed pan-dimensional intelligences and entered a different realm of existence where even more was possible.

Over the following billions of years, time moved on, and the universe expanded in an accelerating fashion.

They would have cried, if they could have, when some five billion years after their astronomy class, just as their professor had predicted, the sun expanded into a red giant. All life on Earth died in a slow, intense roast.

Billions of years further along, after the Milky Way and Andromeda had merged and galaxies beyond the Local Group had vanished from sight, Cody knew that the game was winding down and it was only a matter of time. But what a grand time!

Cody loved Vanessa in a mental, physical, and emotional way that was incomprehensible in the century that they had met. What is it really like when you can know someone in every way possible, and accept them as you do yourself? Someone you had spent billions of years knowing? No one in the 21st century could have articulated the nature of their relationship. He knew it now, at the end.

"I remember," he thought, back in the end times of the present.

Vanessa sent him another thought to echo through his extended mind. "Did you get the point?"

"Yes," he thought, "I got the point," appreciating what he was and where he had gone, where they had gone.

The universe continued to rip itself apart in its death throes, and together they shared the unique experience.

## **Afterword:**

No one I solicited for the anthology came through with a cosmology story, and I really wanted something in the tradition of Asimov's ["The Last Question,"](#) that tackled the big picture. As fun as Asimov's story is, it is 50 years out of date, a bit clunky, and our understanding of cosmology has changed significantly, even in just the last decade (thank NASA's Wilkinson Microwave Anisotropy Probe, also known as WMAP). Reprints were probably out, then. I also didn't want to write a long story. As a professor I know how reluctant I am to assign anything much over 5000 words as supplemental reading, so ideally I wanted to come in with a punchy short short. One of my favorite very short stories of all time, coincidentally about the far future, is Frederick Pohl's much anthologized ["Day Million,"](#) which is in some ways one of the first post-human stories and is still effective today.

There was campus event in the fall of 2007 about the science in the arts and humanities, and vice versa, and I was asked to do a reading on short notice. A very short reading, maybe 10 to 15 minutes. Ouch. That's barely enough time to read a scene from a novel, let alone put it in context, and picking one scene from a novel to represent the whole book, full of an audience of people who weren't necessarily science fiction fans...well, it was going to be awkward. So I sat down the night before and wrote this Day Million inspired cosmology story I had been thinking about.

One of the things about cosmology that is so hard for people to grasp, and there are a number of conceptual difficulties, is how to have a human perspective about the nature and ultimate fate of the universe. It's hard enough to envision how big the universe is, and how small the Earth, let alone a single person on its surface. Even harder is to also envision the time spans involved. I wanted to give readers some idea about our best understanding of these things, and some ideas about how to think about them that wasn't depressing.

After I gave the reading and the event was over for the evening, a student came up to shake my hand and thank me, telling me that the story really moved him. He said he'd been trying to make sense of some big questions, and I had given him some new perspectives to think about.

We as a species are accelerating into the future just as is all of space-time, and this is only the beginning.

## **Squish**

by [Daniel M. Hoyt](#)

Meyer felt his brain *squish* into being in his new biobod.

A struggling investigator, he never could have afforded the exotic light-speed transport himself, but his client, Benton Reege — *Time and Space* magazine's Entrepreneur of the Year for 36 years running since the mag named him Architect of the Milky Way in 2100 — dropped as many solcreds on his weekly haircut.

"First time, huh?" A high male voice boomed directly in front of him, but Meyer only saw a too-bright yellow haze and closed his eyes.

"It takes a few minutes for your mind to adjust to your new biobod," the man recited. "You've just had your brain mapped, flung through space on an encoded light wave, and rewired from scratch into this brand-spanking-new brain matter; you can't expect to see clearly right off the bat. Your mind needs to learn the physical connections first."

After several failed trials, Meyer was able to open his eyes long enough to get a clear look at the medtech, a stumpy blond casually inspecting his fingernails. He wore a simple white lab coat, with the Reege company emblem embossed on the chest.

"Ready?"

Meyer nodded. His neck felt thicker than he'd expected; in fact, *everything* felt too large. "I'm big," he said, raising his right arm. Surprisingly, it didn't *feel* heavy — more like what he was used to on Earth.

The medtech chuckled. "That's how we make biobods for Mercury. The gravity here is about a third of Earth's; if we grew bodies with the same mass as your Earth body *was*, you'd feel like you were a third the weight, too. Your biobod's three times the mass of your Earth body — not volume, thankfully, since your skin, flesh and organs are much heavier! By adapting your biobod for the gravity, instead of forcing your mind to retrain to a low-g environment, we eliminate the need for extensive physical training like the old-time astronauts had to do."

Meyer didn't like the emphasis on the word *was*. "My Earth body?"

"Didn't Mr. Reege tell you? Your old body was destroyed at the other end. It's a side *benefit* of squisher travel — you get new bodies wherever you go, gravity-adapted and maintenance-free. The only downside is you don't know who's looking back at you in the mirror." The medtech laughed. "Want to see?"

He thrust a mirror in front of Meyer.

The face looking back at him was big and strange, with a wide nose and mouth below tiny black eyes. Meyer had gotten used to seeing a deep, jagged scar near his left ear — he'd hoped one day to scratch together enough solcreds for the medbots to fix it. That wouldn't be needed now.

"When can I see Mr. Reege?"

"Now; the transition is pretty quick. Stand up."

Despite the medtech's explanation, Meyer was surprised to find that climbing out of the chair felt remarkably as he'd remembered on Earth. Walking was similar as well.

Meyer glanced out a passing window. "Are we going outside?"

"No. Your biobod's adapted for gravity, but not Mercury's incredible temperature swings — starts close to 200 below, Celsius, up here on the 85th parallel, and goes over 100 above — more than boiling water on Earth."

Meyer whistled.

"Down at the equator, where most of Mr. Reege's high-temperature experiments are, it gets up well over 400 — enough to incinerate your Earth body without protection."

As they passed a window, Meyer remarked on a worker outside, wearing full-body space suits.

The medtech paused. "Mercury's atmo is flaky — not enough gravity to keep it here, so parts keep floating off. Supply tanks create a breathable atmo in the buildings, but you need a suit outside. It's like the Moon, only *much* hotter."

Meyer stared out the window. It was gray everywhere. "Is that steam?"

"Water comes out of nowhere; it vaporizes or freezes, depending on the temp. They tell me there's hydrogen and oxygen in both the vaporized Mercury rocks and the solar wind, and sometimes they combine."

The medtech nudged Meyer and led him down a hallway to Reege's office. Inside, he found Mr. Reege at his desk, working. He looked remarkably like a larger Reege — same face and body structure, same pencil mustache, just bigger.

Reege grinned, stood and offered a meaty hand. "I've been expecting you. How was your trip?"

Meyer shrugged. "Different. You do this squisher thing often yourself?"

Laughing, Reege said, "Rarely any more. I did, of course, in the early days of each colony, but it got tiring after a while. Believe it or not, all those colonies were set up the old-fashioned way, with materials transported on laser fusion drives developed over a hundred years ago. I spent more decades than you can imagine making those colonies fly, which also meant creating an economy from nothing for hundreds or thousands." He leaned back in his chair and rocked. "The medbots developed mid-21st are the only reason I'm still alive and kicking today at 160." Reege smiled. "I don't think I've squished in ten, fifteen years now."

"You didn't come out with me?" Meyer was confused. "I saw you back on Earth a few hours ago."

Reege nodded, leaned far over his desk and said conspiratorially, "You saw my *Earth* presence. After squishing a few too many times for my tastes, I came up with an idea." He sat back and rocked his chair. "You've heard of full-body repairers?"

"Replicators?" The best Meyer could hope for one day were medbots, tiny repairers injected directly into your bloodstream that navigated your body to repair things at a cellular level. "I thought they were just

rumor."

"They exist. But you have to plan ahead. You can't just grow a biobod overnight, you know — it takes *years*, even with rapigrow medbots. Did you know they're grown from common DNA elements until puberty, when they introduce the DNA variants? That's when you can make a custom biobod for yourself, rather than walking around in a generic one like yours."

"I think I follow you. You squish into a biobod that's right there, physically, instead of beaming your brain to another planet?"

Reege jabbed a finger toward Meyer. "Exactly. Five years planning, and you can have a much younger replica of yourself, through the magic of the squisher. Plus, the direct-access squisher isn't as expensive, since you don't need to go off-planet to use a gravitational waveguide."

"You could essentially use a high-volume optical cable, right? Combined with the brain mapping completed half a century ago, it's a simple process of deconstructing, transmitting and reconstructing — like Bell's telephone?"

Reege laughed. "Not so simple, but close enough for the layman. The biggest problem is the brain mapping — the process itself damages the brain beyond repair, rendering the body useless. Remapping doesn't do this. The data stream is decrypted at the other end real-time and rehosted to the new biobod, which can be grown to be perfect."

"I have to say, I'm not feeling very perfect."

"You'll get used to it," Reege said drily. "Back to the point: What if I could squish to *two* places at the same time?"

Meyer stared blankly.

"You don't need to know the details; all that really matters is that I put a team on it, and they managed to find a way of manipulating the waveguide to split the beam."

Stunned, Meyer opened his mouth and shut it, like a dying fish.

"And then I thought, what if I could squish to *ten* places at the same time?" Reege paused. "Turns out I could. So I squished to all nine of my colonies at once, and replicated locally as well. We all keep in touch, and collectively we get ten times the work done in the same amount of time."

"Impressive," Meyer said after the revelation had sunk in. "But you still haven't told me why I'm here."

"Ah. Yes." Reege pressed a button on his desk and stood up. "I'd like to show you our facilities."

Puzzled, Meyer stood up. Something sharp poked his thick neck, and everything went black.

\* \* \*

Meyer's brain *squished* again. He felt dizzy, as if he were swaying.

After a few minutes, Meyer's eyes focused. He was alone with a petite female Reege medtech — trim and redheaded, she looked northern European. "Earth?"

The woman shook her head. "Venus Sky City 4, 50 clicks above the surface," she said in a raspy alto. "Up here, it's similar to Earth's temperature and pressure."

The room shifted unexpectedly as Meyer tried to stand, throwing him to the floor. "I don't feel well."

"Welcome to living in the air. It's usually pretty stable, but every four or five days, the traveling winds come around at the cloud layer and remind us we're not on solid ground." The medtech shrugged. "Then again, the ground's no picnic, either. That's why we're floating up here. Feels like Earth, doesn't it?"

"Except for the swaying."

"That could be solved if we could grow Venusian bodies that don't crush halfway to the surface — it's 92 times Earth's pressure. We can lick the temperature problem. It's over 460 *everywhere* on the Venusian surface, like a planet-sized greenhouse, close enough to Mercury's max, 420, to benefit from their high temp research. But we're still struggling with the pressure."

Meyer sighed. "I suppose I'm to see Reege?"

Meyer followed the medtech down a long hallway with several glass doors. Through one of them, green bodies hung lifeless. They resembled humans only in basic form; they looked more like foliage. "What are those?" Meyer asked, jabbing a finger at a door in passing.

The medtech glanced back at Meyer, but didn't slow down. "We call those the Martians. They're experimental photosynthetic biobods, modeled after Earth plants, green from the chlorophyll, an attempt to grow a *fully* environment-adapted biobod, capable of breathing the Venusian atmo and withstanding the environment. The surface atmo is almost all carbon dioxide — add a little water, and you get photosynthesis. The problem is that there's none on the surface, and it *never* rains." She glanced back again and scowled. "They wouldn't last very long down there without a healthy supply of water — *if* they could take the pressure, which they can't."

Arriving at the end of the hallway, the medtech swung open a hand-carved wooden door — in stark contrast to the glass and steel everywhere else — and escorted Meyer inside. There at his desk, identical to the one on Mercury and Earth, sat a twin to Earth's Reege.

"Good to meet you, Meyer. Sit down, please. I have some questions for you." Reege smiled pleasantly and indicated a chair opposite his desk.

Meyer hesitated; he remained standing, ready to run if needed. "Before we get comfortable and someone jabs me in the neck with a hypo, let me ask *you* a question. Why am I here?"

Venusian Reege's smile faded. "An excellent question, Meyer. Why do you think you're here?"

Meyer relaxed and sat down. "First, I'm here to establish that you're the real Benton Reege, using a simple question that you would answer in a specific way — which you've done. The rest I'm a little hazy on, now. When I left for Mercury — this morning, was it? — I thought there was an imposter Reege on one of the colonies, undermining the Reege empire from within, and I was supposed to find him. When I saw Reege on Mercury, I figured he was the imposter, and my job was done."

"But you're no longer sure of this?" Reege steepled his fingers and looked gravely over them.

Meyer hesitated and fiddled with a pen lying on the desk. "Mercurian Reege told me an interesting — and plausible — story about there *already* being bona fide Reeges on *all* of the colonies."

Fidgeting in his chair, Reege stared at his desk for a minute before looking up to answer. "That's correct; there are ten of us."

Meyer cocked his head to one side. "Thus, my dilemma. If he's not the imposter, why'd he drug me and send me here? If he *is* the imposter, why'd he send me here instead of just killing me or something?"

"Let me be clear. That Reege should *not* have confided this information to you; but the fact that he did establishes his authenticity. The imposter would not have known this fact; the particular team involved in that one-time experiment are all fiercely loyal — and closely monitored." Reege looked up and smiled, but he looked *past* Meyer. "Isn't that right, Dolores?"

Meyer realized too late that he hadn't seen the redheaded medtech leave. Twisting violently, he tried to spin around and stand simultaneously, but she was quicker, and the hypo found its mark.

"Fiercely loyal, Mr. Reege," she said, smiling, as Meyer lost consciousness for the second time that day.

\* \* \*

*Squish.*

Meyer groggily opened his eyes after a few minutes. Even with the haze, he knew he was alone. Struggling to his feet, he lurched toward a door.

*A sumo wrestler biobod? Am I back on Mercury?*

The door swung open. A husky, dark-skinned man in a Reege lab coat paused in the doorway, frowning. "See what happens when you don't wait long enough? Sit down."

Shaking his head, Meyer refused. "I'm okay now," he wheezed. "Where am I?"

The medtech pointed to the window. "Look."

Stumbling over, Meyer looked outside at the reddish-orange desert landscape. Mars, probably the Victoria Crater, judging by the view. Every schoolchild had memorized that crater, since it was near the site of Earth's first off-world colony.

That explained the plus-sized biobod. The Mars gravity and pressure were similar to Mercury's, but without the temperature extremes — merely 140 below on the South Pole's winter ice cap to a pleasant 20 above in summer up north. Because of the planet's tilt and lopsided orbit, the seasons got milder the farther north you went. Near equatorial Victoria Crater was practically idyllic for Mars — bearable temperatures and interesting views.

"Mr. Reege is waiting," the medtech said drily, and led the way out the door and around the perimeter of a large round room where several other medtechs busied themselves. "It's mostly carbon dioxide here, like Venus — didn't you come from there just now? — but here we can get oxygen and small amounts of nitrogen from the atmo, too, so we can recycle our air."

"What? No green Martian bodies here?"

The medtech's face contorted, confused. "Why would there be — oh! You saw the Martians, didn't you?"

Meyer grinned.

"Those are actually based on a *working* design we use here. Oh, don't you raise an eyebrow at me! They're up at the North Pole, where there's plenty of ice we can melt." The medtech headed down a hallway nearly opposite the squisher recovery room.

"So, there really *are* little green men on Mars?"

Laughing, the medtech corrected, "*Big* green men." He turned a corner and knocked on a plain metal door, then opened it.

Reege stood by a window. He turned as Meyer entered.

Meyer sighed, and quizzed him as he had the other two. "If you're going to stick me like the others, just do it now," he said tiredly after a swallow of water the medtech had offered him before leaving. Meyer sat down.

"No, we drug the water instead," Reege said with a straight face, then chuckled. "Just kidding; it's safe." He turned his head and stared out the window.

"Is there *really* an imposter, Mr. Reege?"

Reege walked to the door. "No tricks, Meyer. Come with me." He left abruptly.

Meyer followed quickly, but struggled to catch up to Reege through frequent twists and turns down labyrinthine hallways. At last, Meyer found Reege waiting by an open door.

"In here," Reege said and slipped inside. "Close the door behind you. This is just between us."

Once closed in, Meyer eyed Reege suspiciously. "I don't trust you."

"That's okay; *I* trust *you* — that's why you were hired for this task." Reege sighed. "Could you take a seat over there, please? This . . . procedure will only take a moment."

Meyer hesitated.

"I assure you, you'll be out of here in no time at all. Put on that headset by the chair."

Still suspicious, Meyer settled into the seat and donned the headset.

\* \* \*

*Squish.*

Meyer fought the urge to escape this time; he waited for the inevitable arrival of a medtech to escort him to Reege.

"Jupiter, I presume," he croaked.

"No," giggled a statuesque blonde woman, looking straight off Malibu beach. "We can't make biobods for the gas giants! You're on one of a few dozen observation stations in the asteroid belt between Mars and Jupiter. Reege squished in earlier to meet you." She huffed and glanced at the door.

Meyer stood. "Shall we go?"

Navigating the curved hallways in the wagon-wheel space station to a transport tube that would take them across the spokes to the other side, Meyer chatted with the blonde medtech. Spinning at one-gee and atmoed with Earth air, his space station biobod was identical to his now-destroyed Earth body — except for the scar.

"We do more than just monitoring out here, you know," she said defensively when Meyer challenged the usefulness of observation stations. "We also have raw mineral mining operations all over these asteroids, especially the M-types — metallic, that is. Like Mars, these are *working* colonies here, not just research colonies. That's how we've been able to multiply the number of observation stations out here so quickly, not to mention that the waveguides here established the original departure points for the outer system colonies. This station orbits our mining HQ on Ceres — also considered a dwarf planet for the last century, by the way; look out that window there — which has about a third of the total mass in the main belt, comprised of some two million asteroids. Of course, we're tracking the other three main asteroids, Vesta — that's the only one you can see with the naked eye from Earth — Pallas and Hygiea. Together, they make up another half the mass of Ceres."

"So, if those four are half the material out here, the other two million asteroids are pretty small?"

"In comparison, yes. But the one that hit Earth 65 million years ago was still big enough to make the dinosaurs extinct!"

Meyer laughed. "Point taken. By the way, with all those asteroids and comets out here, how do you keep from hitting them? This space station is *huge!*"

The medtech grinned. "First off, comets are different; asteroids don't have a coma, a fuzzy atmo formed from frozen gases released as a comet nears the Sun. The gases grab dust, which makes the comet's tail. With the exception of a few main-belt comets orbiting here, most comets only come *through* the asteroid belt; even the short-period comets — recurring in less than 200 years — originate farther out. The closest is near Jupiter's orbit; most travel well past the Kuiper belt, where Pluto orbits, some may even go to the edge of the Solar System. We still don't know for sure, but we think the long-period comets come from the Oort cloud."

The medtech paused outside Reege's office. "As for the asteroids in the main belt here, they look bunched together on star maps, but there's an incredible amount of space for all of them, so don't worry. You can go on in; maybe we'll get to talk later." The blonde smiled affectionately and retreated around the hallway.

*Unlikely, considering my previous receptions.* Furious, Meyer twisted the doorknob and barged in unannounced. "Why am I here?" he asked without preamble. Once verified, before Reege could distract him Meyer blurted out angrily, "Why bother with the formalities, Reege? Why not just drug me and get on with it?"

Reege shrugged. "Okay," he said simply and went back to his work.

Rustling behind Meyer was quickly followed by a sharp pain in his neck. *Me and my big—*

\* \* \*

*Squish.*

*I'm getting tired of this routine.*

A few minutes later, Meyer followed a medtech to Reege's office on the largest of Jupiter's 63 named moons, Ganymede.

"Believe it or not," Reege said, staring out a window overlooking Jupiter, soon after the introductory formalities established him as the genuine Jovian Reege, "I don't own the *entire* Solar System, as some maintain. I gave the colonies on Io, Europa and Callisto — the other Galilean moons — to friends years ago." Chuckling, he turned to Meyer. "I kept Ganymede because it's more *interesting*. Unlike the other satellites in the Solar System, Ganymede has its own magnetosphere, *and* it's permanently embedded in Jupiter's, which is 14 times larger than Earth's — enough to protect all four Galilean moons from solar wind. There's nothing else like it."

Meyer found his biobod agile and graceful, considering Ganymede's one-sixth-gee made for a huge biobod, even by Mercurian standards. Joining Reege at the window, he said, casually, "Your medtech claimed your office always faces Jupiter?"

Reege smiled and turned back to the window. "Ganymede is tidally locked, with this face always inward. You're fortunate today to see the Great Red Spot — over there, just on the edge of the horizon. It fluctuates, sometimes disappears for a while, but it always comes back, spinning counter-clockwise, moving within an atmospheric band one way, while other bands around it move the other way. The time-lapse vids are spectacular."

"I saw one in the squisher recovery room," Meyer said. "I found it unsettling."

"You probably get seasick on Earth, don't you?" Reege headed for his desk without waiting for an answer. "That planet is *fascinating*, Meyer, worth every solcred it takes to study it. It has rings, you know, mostly dust and not even noticed until the late 20th century. It generates *more* heat than it gets from the Sun. It's a giant gravity well, big enough to have helped shape the entire Solar System. Comets routinely collide with it, often enough that they used to call it the Solar System's vacuum cleaner back in the 20th — they erroneously thought that passing cosmic bodies that weren't pulled in were swept to the outer system and kept away from the inner system planets."

Meyer was skeptical. "I know Jupiter's big, but surely it's not *that* big!" He took a seat facing Reege's desk.

"It *is*, actually," said Reege. "The gravitational field acts on a couple *thousand* asteroids, most of them as far away from here as Mars, some more like the distance to the Sun. They're clustered in two so-called camps, the 'Greeks' leading Jupiter's orbit and the 'Trojans' following it."

The medtech spouted a lot of information Meyer wasn't interested in — like that Ganymede was between negative 120 and 200, with an oxygen-rich atmo — but there was one thing Meyer didn't quite believe. "Is it true that Europa orbits *exactly* twice for every orbit of Ganymede? And Io orbits *exactly* four times? That seems awfully convenient to be a coincidence."

"It's true; it's called orbital resonance. And you're stalling."

Smiling, Meyer said, "Can we dispense with drugging me this time? Just take me to your lab and I'll do whatever you want."

"Fair enough," Reege said, standing. "Let's go."

\* \* \*

*Squish.*

Meyer started to remember. He talked to Jovian Reege, an unexpectedly civil conversation; he followed Reege to a lab, where he was asked to sit down; they talked some more, and then . . . he was squished to

Titan, the largest of Saturn's 60 known moons.

With a one-seventh-gee biobod, Meyer thought at first that he was still on Ganymede and had just fallen asleep. The medtech in the squisher recovery room corrected him, and took him to Reege for their usual conversation.

Like Jovian Reege, Saturnal Reege's office took advantage of Titan's tidally-locked orbit for a magnificent permanent view of Saturn, with its unique ice ring system. Unlike Ganymede, Titan's opaque atmosphere prevented a direct view; the image came from an observer craft Reege had put in geosynchronous orbit.

"It's very similar to Jupiter in some respects," Reege reflected, glancing toward the view window from his desk. "It has atmospheric banding, although the winds are much faster, reaching 1800 clicks per hour. The most striking difference, of course, is from the planetary rings; they're actually an uncountable number of individual particles, mostly ice, anywhere from dust to the size of a small ground transport vehicle. They even have their own atmosphere."

Meyer soon tired of Reege's dissertation, finding him somewhat dry and far less congenial than Jovian Reege. "I thought there were several colonies on Titan? This facility seems smaller than the one on Ganymede."

"It is," Reege said, with an annoyed twang. "There's several dozen colonies, in fact. They're very popular; once you clear the dense, nitrogen-rich atmosphere haze around a colony, you find that the ground features resemble Earth's. But this particular colony is strictly research. We're trying to replicate the kinds of conditions that spawned life on Earth."

Stunned, Meyer stared. "You're trying to create *life*?"

Reege offered a half-smile as an answer and rose. "I think you know the drill at this point. Let's go."

\* \* \*

*Squish.*

Meyer sat up and swung his legs over the chair. They seemed very much like his Earth legs. Rubbing his temples, memories flooded his mind.

He'd observed Uranus from Reege's orbiter, noted its 27 moons named for characters from Shakespeare and Pope, and marveled at its 13 distinct ring systems — mostly ice, like Saturn's, but up and down instead of across, due to Uranus' odd axial tilt, almost perpendicular to its orbit. It made for some odd weather, which Reege was studying for some experiments in the asteroid belt. Reege was reluctant to give specific details, but Meyer got the impression he was attempting to terraform one of the oddly-spinning asteroids in the main belt.

Meyer had orbited Neptune, often called an "ice giant" like Uranus, because of the higher levels of atmospheric ice. He'd found Neptune's ring system less disturbing; while not as substantial as Saturn's, at least the rings were parallel to orbit. He'd been amused to learn that its 13 moons were all named, like Neptune, after mythological sea gods; he'd been amazed to learn that the winds could be *faster* than Saturn's — 2100 kilometers per hour, the fastest in the Solar System. Meyer wasn't surprised to find Reege's principle interest in Neptune was research, but he hadn't expected Reege's unbridled enthusiasm. Evidently, Neptune's gravitational influence on the icy worlds of the deep-space Kuiper belt beyond the planet was as profound as Jupiter's influence on the asteroid belt, completely dominating the belt and giving it shape.

"You're on Earth now," said a dark-haired male medtech flatly.

"Not Pluto?" asked Meyer, getting up.

The medtech started toward the door, motioning for Meyer to follow. "Pluto? Why would we be on Pluto? We abandoned that research station decades ago. It was only in operation for a few years, anyway, and it was a political struggle the whole time."

"Because of its planetary status?"

"Yes. It started in the early 21st, when they reclassified it as a dwarf planet. A couple years later, it changed it to a plutoid — along with Haumea, Makemake and Eris, out in the scattered disc beyond the Kuiper belt. Some astronomers did not take kindly to this, and got it reclassified as a planet years later — that lasted for a decade, maybe. It's changed so many times since then, I don't even know what it is now. When Mr. Reege established the station, it was a planet; when it was reclassified again, he abandoned it. There's nothing of interest on that desolate baked potato, anyway; nothing on any of its three moons, either. The only thing it has going for it is being the largest rock in the Kuiper belt."

"I spoke to Mr. Reege orbiting Neptune," Meyer offered. "He was very enthusiastic about exploring the Kuiper belt."

The medtech chuckled. "It'll be his great-great-grandchildren doing that; there's just too much to explore, even at light speed. Until we figure out how to go faster than light, honestly, there's nothing there that we can't get from Neptune's orbiter."

The medtech admitted Meyer to Reege's office and left.

"Mirror?" Reege pulled a hand mirror from his desk and offered it.

Shocked at seeing his Earth face — less the scar — Meyer stuttered, "M-my face?"

Grinning, Reege said, "A bonus for a job well done."

"I didn't *do* anything!"

"I believe another me mentioned that we were retrieving some of your memories? That's not the complete truth. You were also carrying confidential communications, encoded into your brain scans."

Meyer felt a lump in his throat. "I was a carrier pigeon?"

Reege scowled. "That's unpleasant. You were a trusted courier."

"There never was an imposter, was there?"

"No."

Enraged, Meyer stood with fists clenched, fingernails biting into his palms.

"Sit down."

"Why? So you can manipulate me some more?"

"Sit down, please," Reege said calmly. "Don't force me to be impolite."

Shaking, Meyer sat stiffly. "Do I at least get an explanation?"

"I devised this system decades ago. Certain . . . informational aspects of keeping my colonies running smoothly requires the utmost discretion. Waveguide communications are secure, but the medtechs can't always be trusted. All ten of us need to be kept up to date in a timely manner — thus, the trusted courier system via squisher."

Meyer counted in his head. "Including you, there were only nine."

Reege smiled apologetically. "We chose not to bring you out of recovery on Pluto."

"Pluto? Isn't that abandoned?"

"The Sol Council *thinks* it is, but I couldn't abandon it — not with what's at stake there."

Meyer thought for a moment. "FTL?"

Reege's smile faded; he punched a few buttons on his desk console, stood and offered a hand. "It's been a pleasure doing business with you, Meyer. I trust quadrupling your agreed-upon fee would ensure your discretion?"

Meyer considered this, stood and shook Reege's hand. "Done."

"Excellent," Reege said, smiling. "You'll find your account credited already. If you'll please follow the medtech for debriefing. . . ."

\* \* \*

*Squish.*

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## ***Jaiden's Weaver***

by [Mary Robinette Kowal](#)

I was never one of those girls who fell in love with horses. For one thing, on our part of New Oregon they were largely impractical animals. Most of the countryside consisted of forests attached to sheer hills and you wanted to ride something with a little more clinging ability. So from the time I was, well, from the time I can remember I wanted a teddy bear spider more than I wanted to breathe.

The problem is that teddy bear spiders were not cheap, especially not for a pioneer family trying to make a go of it.

Mom and Dad had moved us out of Landington in the first wave of expansion, to take advantage of the homesteading act. Our new place was way out on the eastern side of the Olson mountains where Dad had found this natural level patch about halfway up a forested ridge, so we got sunshine all year round, except for the weeks in spring and autumn when the shadow of our planet's rings passed over us. Our simple extruded concrete house had nothing going for it except a view of the valley, which faced due south to where the rings were like a giant arch in the sky. Even as a twelve-year-old, angry at being taken away from our livewalls in town to this dead structure, I fell in love with the wild beauty of the trees clinging to the sheer faces of the valley walls.

The only thing that would have made it better was a teddy bear spider so I could go exploring on my own. I felt trapped by the walls of the house and the valley. I had this dream that, if I had a spider, I'd be able to sell its weavings for enough to install livewalls in my room. That's not as crazy as it sounds; teddy-bear spider weavings are collected all over the colonies and sell for insane amounts of money.

I had a search setup so anytime there was news of a teddy bear spider or a new tube surfaced, I'd be right there, watching those adorable long-legged beasts. I loved their plump furry faces and wanted to run my fingers through their silky russet fur.

I wonder what goes through a survey team's mind when they name things. I mean a teddy bear spider isn't a bear and it isn't a spider, but it looks like both those things. On the other hand, a fartycat looks nothing like a cat. They do stink, though.

Not quite a year after we'd moved, one of my city friends had forwarded an ad from a local board which set my heart to racing.

*Teddy bear spider eggs: 75NOD shipped direct.*

See, I'd been looking at adult or adolescent teddies which cost more than my folks had set aside for me to go to university. It hadn't even occurred to me that I could raise one up myself. My mindless yearning changed into purpose.

I slapped that ad onto a piece of epaper and ran into the kitchen. "Dad! Mom! Look at this."

Dad glanced up from the eggs he was cracking into a bowl and pursed his lips the way he always did right

before saying *no*. "Jaiden, that's a lot of money."

I waved the ad again as if it were a token to get me on a ride at the fair. "We'd make back the money when the teddy started to weave. Please? I've seen their weavings in stores for hundreds of NOD."

Mom ganged up on me. "That's how much the store sells a weaving for, it's not how much they pay for them. Even if it were, you're not just talking the cost of the eggs. It's the cost of feeding it, housing it, vet bills..."

I knew better than to keep arguing. Sometimes if I waited and tried again later, I could get them to change their minds. Still holding the ad, I went outside and plopped on the log bench Dad had made for the front of the house. The broad silver band of the ring spanned the sky, blocked by only a few clouds. In school I'd read about Earth and how it didn't have a ring at all, but it's hard to imagine life without that constant band of silver in the sky.

As the days shortened, the sun was starting to skirt the edge of the ring and I could see the band of its shadow laying across the land to the south of us. It wouldn't be long until we hit the Dark Days which signaled the end of autumn.

I know some people like the diffuse light when the sun is behind the ring, but I can't stand the way the land feels perpetually overcast, particularly when you can see blue sky, which means that to the south or north of you, it's a pretty day. It's funny how solid the rings look from the ground the rest of the year. You have to wait until the Dark Days to see the sun filtered through the ring to remember that the ring is made up of rocks and dust. When I was little, my grandma used to tell me that the ring was a teddy bear spider's weaving hung up in the sky to dry. Which, if I'd thought about it I'd have known was foolishness since a teddy's weaving was golden and not silver.

The only good thing about the Dark Days, to my eye, was that it meant we'd exchange presents on Bottom Day, when the sun passed under the ring and we returned to full light again. It occurred to me that maybe, if I kept hinting, my folks might give me a teddy egg for Bottom Day. It seemed like that would be fitting and all.

\* \* \*

The Dark Days fell on us about a week later and it hit me harder than it had ever done in the city. The artificial street lights and the hustle bustle of the city kept you from feeling the gloom so much. Not that it got full dark, even out where we were, but it was gray and dreary. The cold front that followed the shadow of the rings across the surface of the planet brought rain with it, which left me trapped in the house with my family.

Really, the rains only lasted a few days but when they passed, we were into the cold spell. It wasn't as cold as full winter would be, but Mom made me bundle up anyway. My jacket was smart enough to regulate the temperature, but she also wanted me to wear the hat and scarf she'd knitted. They were clunky things of red wool that always needed adjusting. As soon as I was out of sight, I took them off and hung them on a tree branch, making a note to pass back the same way when I came home. Mom was so proud of having made something herself, that I'd hate to lose them.

I needed thin saplings so I could weave them into the sort of basketry nesting house that teddies liked. I'd downloaded the DIY instructions onto my handy and the multitool which Dad had given me last Bottom Day had a small handsaw on it. If Mom and Dad gave me an egg for Bottom Day I needed to make sure it had a home. Besides, showing them that I could build the nesting house would prove I could take care of a teddy.

I staggered into the house close to dinner time, leaves sticking in my hair and mud coating my rump where I'd slid down the hill, hauling saplings.

Mom picked a leaf out of my hair. "Where's your hat and scarf?"

I winced. "I was hot so I hung them on a branch while I was cutting saplings for a nesting house."

She rubbed her forehead like I'd pained her somehow. "If you can't keep track of your things, I don't know how you think you can take care of a pet."

The air and everything tightened in my throat and my eyes burned, but I refused to cry. "I'll go get them."

I ran out the door before she could say anything else. Mom hollered my name, but I didn't stop until I was at the tree where I'd left them.

The scarf was there, but not my hat.

I finally saw the bright red wool, way up in a tree. A fuzzywurm had snagged it and was building a nest for the winter. With no way to get the hat, I took the scarf and trudged home. The pile of saplings looked like garbage.

\* \* \*

That sense of despair lasted, oh, I'd say overnight. The moment I'd finished schoolwork the next day I was outside, putting the nesting house together. My folks said not a word about it the whole time I worked.

By the time New Oregon's orbit brought our axial tilt around far enough for the sun to peek under the ring, I was well-nigh unto frantic. See, Mom and Dad went into town right before the end of the Dark Days. If they were going to get an egg for me, that was the time to do it.

Bottom Day morning dawned, and I do mean dawned, bright and clear. You don't know how much you miss the sun until you've gone weeks without seeing more than a filtered spot in the sky. I bounded out of bed and stood in the sunbeam that angled in my window. It heated me through until sheer excitement sent me running to the kitchen. No one else was up, but the disc with our Bottom Day gifts was already laid out.

The piece of paper that held the clue about where to find my gift was the same pale gold as a teddy-bear spider's egg. I was supposed to wait until my folks got up, but that was totally impossible, so I peeked.

"A bower of sticks you have made,  
There you'll find the gift we gave."

I squealed when I read it. Down the hall, I heard one of them stirring, but I was halfway out the door by then. The morning dew soaked through my socks as I ran to the nesting house.

The hut of twisted saplings leaned to one side but it was the most beautiful thing I had ever seen. Dew coated it and each droplet shone like LEDs had been embedded in the wood. I ducked under the low doorway and there, tucked in the corner, was my gift, wrapped in the same pale gold as my clue. It was about three times larger than I'd expected and for a minute I thought they'd gotten me more than one egg, before realizing it was protective padding. As carefully as I could, I peeled off the paper.

Inside was a teddy bear spider toy, a plush confection, complete with its own "egg" for playing at hatching. It was a glorious toy and I hated it.

If you ever have children, don't do this to them.

I had been so sure they were going to give me an egg that I felt as if I'd had one and lost it. I couldn't even touch the thing.

Mom came out about then. "Jaiden?"

I screamed something, probably that I hated her, and took off running. Branches caught me in the face and snarled in my hair. I went down the mountain because it was faster than going up and all I wanted was to get away. If I had fallen, I wouldn't have cared. I think some part of me wanted to fall, wanted my parents to understand how much they had hurt me.

Dad found me sitting on a little level spot. I don't remember stopping.

He crouched beside me. "Honey, I'm sorry. I thought you'd like the toy."

"Yeah. If I was six." I wouldn't look at him.

"I know how much you wanted a teddy, but we can't afford one." He sighed and inched closer. "You don't think I'd disappoint my little girl if I had a choice, do you?"

Of course I did. And I didn't, at the same time. I'd pretty much run myself out so I just shrugged.

We didn't say much else, but I let him fly me home with the jetpack.

I don't know if this makes sense to you. How you can want something so much, you make yourself sick. And when it looks like you're going to get it, then to have it yanked away — no, not yanked away, for it to have never existed... Do you understand that?

\* \* \*

The same way I tried to tear down the nesting house, I canceled all my searches for teddy bear spider news and tubes. But the yearning came back. If anything, stronger than before. And it occurred to me that I could earn the money and buy the teddy bear spider egg myself.

So at night after my folks had gone to bed, I pretended I was an adult — which is not as hard as you think — and did small Mechanical Turk jobs for people. Nothing shocking, just sorting data for a few cents at a time. The whole time I kept thinking about how much money we could sell its weavings for and how I'd make all this money back just from those. I pictured riding my teddy down the cliffs and how we'd cling to the side like it was nothing.

At the tail end of winter, the planet's tilt made the sun pass behind the rings on its journey to the top edge. For some reason, this transit never seems as bad as when it drops under. I suppose it's because you know spring is coming.

Now, I'll tell you, I didn't have much hope when Top Day came. My parents seemed to opt for a neutral gift rather than risking another outburst. They gave me a whole NOD, which, considering my allowance was 5 pence was an amazing display of largess. I thanked them and immediately tucked it away with my other savings.

But we were well into summer before my account hit the magical 75 NOD.

My hands started shaking and sweat greased them so I could hardly hold anything. It took three tries to remember where I'd saved that old ad. I called it up and fired a message off to the breeder, suddenly sure the

address was no good, or he'd stopped selling them or the price had risen or any number of things.

Fellow didn't write to me until the next day. Another one of those neo-Luddites that limited their online time. His message was terse, as most of them are.

"Eggs available. Sex not guaranteed. Send delivery address with payment." And then his bank number for the deposit.

I almost squeed myself, filling all that in and counting the days before the egg would get here.

\* \* \*

I was out tidying the nesting house when Dad bellowed my name — my whole name too — so I knew I'd done something wrong. I ran to the house but stopped before I was all the way in the door.

Sitting on the small wood coffee table was a white parcel. Even from the door, I could see my name on it.

I'd never seen my dad angry before. Irritated, maybe. Disappointed, yes. But not angry. Not furious. His face was red and blotchy. There was a vein in the middle of his forehead I'd never seen before. It was a little purple snake of rage living under his skin.

"Jaiden. What is this?"

I wasn't even all the way in the house but I stopped moving. I opened my mouth but no sound came out. Trying again, my voice squeaked into being. "It's my teddy egg."

Dad pointed at the box. "Didn't your mother and I say you couldn't have a teddy bear spider?"

"You said we couldn't afford to buy one. I bought it on my own."

Dad's jaw tightened. "Did you? And how exactly could you afford that?"

"I've been saving all year. I worked odd jobs being a Mechanical Turk. I did web design for neo-Luddites. I worked in the field." As I said that, it was like strength came back into my body. "I earned it."

Dad worked his jaw for a moment and that vein in his forehead died away. He hung his head, then picked the box up. "Okay. Let's tell your mother."

\* \* \*

How Dad explained it to Mom, I'll never know.

It seemed as if, once the egg arrived my folks joined me in the anticipation of its hatching. I'd sit in the nesting house, my school work in my lap during the last weeks, and Mom would sit with me, knitting. I don't know if she was there to make sure I did my homework, or because she found the bower of woven branches peaceful.

"Jaiden?" Her voice was almost reverent.

When I looked up, she was staring at my egg. A sound I had taken for a branch scratching the side of our house came again. At the same time, the egg rocked slightly.

I dumped my work without any care and scrambled across the dirt floor on my knees, scarcely daring to breathe.

What's the longest you've ever wanted something for? It felt like every day I had ever wanted that teddy bear spider all piled in my body at once, ready to split my skin down all the seams. I couldn't breathe for the pressure of my wish finally coming true.

Oh, how I wanted to help it out of the egg, but I knew it had to come out on its own. I wouldn't have a role until it was free and then — then I wasn't ready. I didn't have the fruit paste its mother would have given it or the towel to help wipe the moisture from its limbs so it would imprint on me.

I must have made some sound of despair because Mom said, "What is it?"

I told her what I'd forgotten and then, bless her, she said, "You stay. I'll get them."

I stayed. Oh, how I stayed. I don't remember Mom coming back but I know she did because I had the towel and fruit paste when I needed it. But everything else, I remember as if I were still living it. Each tiny rock of the egg. The barely audible scritch from inside.

The moment when the first triangular piece of egg broke away from the end, a strange, almost acrid smell came from the interior. I strained to see in that opening for the first glimpse of my teddy, but it was still too soon to touch the egg.

The process of hatching took most of an hour. When my teddy pushed its head out of the egg, damp, with the fur matted against its head, it seemed almost entirely helpless. It chirruped, like a cricket, and tumbled free.

Using the towel, I wiped its face, the way its mother would lick it dry and the teddy pushed against my hand.

I don't know if you've ever seen a newly hatched teddy bear spider. When they first come out, they look like nothing so much as a drowned house cat. By the time they are dry, their downy baby fur has sprung out to give them the plumpness you associate with them. Their ears are outsized to their heads yet and their eyes are closed for the first several hours after hatching. The combination makes them seem adorable and helpless.

"Well," Mom said, "is it a boy or a girl?"

I pulled the towel away to look for ovipositors and noticed — I don't understand how I didn't notice until then — but I finally noticed my teddy was missing a leg.

"Jaiden?"

I remembered to look for the ovipositors. "A girl."

Then I counted again, touching each long leg. My teddy squirmed with pleasure as I fondled her toes. She cooed. Oh, my heart melted even as I was dying inside. All I could think about was that I had somehow caused the leg to be missing. That I had mishandled the egg or the nesting house hadn't been the right temperature.

"What are you going to call her?" Mom knelt beside me to look into the bundle.

"Kallisto. Kali for short." I'd thought that was terribly clever. Two goddesses from ancient religions, referenced with a single name. Except my poor teddy didn't have eight arms like Kali the destroyer, she only had seven.

"What's the matter?" Mom stroked my head.

I pulled the towel back to show her the place on Kali's side where her eighth leg should have been. It was one of her hind limbs, designed for weaving. Mom didn't say anything. She kissed me on the forehead and went inside.

I leaned against the wall of the nesting house and rocked my baby teddy. They really do look like teddy bears, you know. Especially when they are young and about the right size. The illusion vanishes when they open their mouths, of course, and the three lobes of flesh part, right along the lines of the threads of a stuffed bear's mouth. But even that was a source of utter fascination to me. Her long coiled tongue looked like a pink seashell or party favor and it quested out of her mouth for the fruit paste as if it were an extra arm. If only she had come with a spare.

\* \* \*

Mom and Dad came out later and crowded into the nesting house with us. I had spent the intervening time memorizing the features of my teddy. Kali was asleep in my arms, and her whole body pulsed with her breath. I was imagining it, of course, but it seemed as if she were already bigger than when she had come out of the egg. Teddies grow at a monstrous rate, nearly reaching their full size in their first year. I wouldn't try to ride her until she was two, of course, but she'd be nearly large enough for me to by next Top Day.

Dad cleared his throat. "Jaiden, we need to talk to you about the teddy."

Without even looking at him, I knew something bad was coming, the way his voice was careful and neutral.

"I earned her." At the time, the only thing I could figure was they were going to complain again about having the teddy at all. "I earned money to buy her egg and I'll earn money to pay for her keep."

Dad tried again. "Your mother said the teddy is deformed."

I didn't say anything to that. Sure she was missing a leg, but one look at her perfect face would tell you that deformed was the wrong word to use.

Into my silence, Mom said, "We spoke to the man who sold the egg to you. He said he'd replace the egg."

Now two thoughts went through my head at the same time. One was that they couldn't have spoken to him, because he was a neo-Luddite and didn't give out his number. The second and more pressing thing was that Mom had said, "replace."

"She's mine." I clutched her tighter. I'd fallen in love, you see? It didn't matter one whit that she was missing a leg. She had seven more and wasn't she the most beautiful thing I'd ever seen? If you look at a picture of her face, I'd defy you to find a teddy bear spider with a more perfect set of features.

Mom and Dad looked at each other like they were trying to double their strength. "She needs to be put down."

I don't remember which of them said that. It might as well have been both of them.

"No!"

Dad held out his hands. "I'll take care of it honey. She won't feel a thing. The man will send you another."

"No. Kali is mine and I love her." Now you might argue about what a thirteen-year-old could know about love or whether it was possible to learn to love something in the span of time I'd held Kali, but what you can't argue about is how deeply I felt it. I'd loved Kali since before I saw her, since the first moment I held that egg in my hands. She represented all of my hopes and efforts for the last year, and she might be flawed, but no other egg would be as thoroughly mine.

Mom opened her mouth to try again but I cut her off. "I earned her and I can choose what to do with her, can't I?"

"But she'll never weave and won't be able to carry you up the cliffs. What good is she?" Dad gestured at the leftover fruit paste. "She's going to be a burden. An expensive pet."

"She's mine." I glared at them.

To my amazement, Mom put her hand on Dad's arm. "Ken, let her keep it."

You've never met my parents but all my experience with them told me that Dad was the softie and Mom was the rule maker. Later I asked her why she let me keep Kali. She said, "You were looking at her like she was your firstborn. I knew you'd never forgive us if we took her away."

And she would have been right.

\* \* \*

The funny thing was, Kali had no idea she was missing a leg. She scrambled up hills as if she were meant to be seven-legged. When she got old enough, I'd ride her and we'd ramble through the mountains for hours, exploring all the places I wanted to go but couldn't on my own. She loved nothing better than to climb to the top of the mountain and look out at everything around us. I'd lean between her legs and she'd rest her head on my shoulder, chirruping with contentment.

She even helped around the farm. We spent one summer helping Dad string irrigation lines between the terraces of the farm. It would have been tricky work with the jetpack, or just climbing by human power, but Kali could cling to the cliffs like they were level ground.

And then, when she was three, and the sun entered the ring heading toward winter, Kali started to weave, as they do. I guess the weaving is something that's genetically encoded in them, because all teddies follow the same pattern and I don't know how else they'd learn it.

Kali's now, Kali's was different. The missing leg, you see? It's the first time I think she knew something was wrong with her, because she had that pattern in her head, but she didn't have the equipment to make it go right. My beautiful girl tore out three weaves and snapped at me when I tried to help. I wished we spoke a common language, but there was no way I could explain to her that she was deformed. In fact, it was the first time I'd thought it since she hatched. My heart broke all over again, watching her try to weave and fail.

\* \* \*

On Bottom Day, I went outside before my parents were up, to take Kali her present. She met me at the front door the way she did every morning, her whole body vibrating and dancing with delight. If I'd had my way, she would have slept inside with me, but even I had to admit a full-grown teddy bear spider was just too big for a house.

She had this funny little hop she'd do when she was excited where she'd bounce about a foot off the ground. I

had wanted to get out to her nesting house with the gift before she woke, but that was clearly a vain hope. I gave her the honeyed fruitroll and let her wrap her long tongue around it.

Chirruping, she took it and bounded toward her nesting house. Evidently I didn't follow fast enough because Kali came back and nudged me from behind.

"Hey!" I laughed. "Cut it out. I haven't got any more."

She pushed me again and I started to get the sense she had something to show me. Now, you've probably already guessed it, but I'll tell you I hadn't an inkling.

Kali had figured out how to weave.

The sun hadn't risen high enough to get into the nesting house, but the weaving seemed to make its own light. Normally, a teddy will just make one per season, but it was like Kali had gotten so excited to finally sort out how, she had made two. Each of them had the thousands of dense strands of golden silk you think about when you think about a teddy's weaving, but instead of being in the traditional pattern, Kali had made a spiral galaxy of her own invention. The arms rotated out in a pinwheel with thinner, gossamer sections in between. She'd incorporated bits of the landscape into the weavings, like they always do, but one of them took my breath away so fast I had to sit.

Embroidered into the fabric was a weathered strand of red wool. She'd found that old hat Mom had made me, out in the fuzzywurm's tree, and built it into her weaving. I started to cry, until I realized Kali didn't understand how happy she'd made me. Jumping up, I rubbed her soft ears and told her over and over what a good girl she was, until she shimmered with happiness.

We sold one of the weavings online at auction for a ridiculous sum on account of it being unique.

The other one? The one with my hat woven in.

That one's got my past and my future woven in it. I'd sooner stop breathing than sell either.

## **Afterword:**

In the summer of 2008 I was fortunate enough to attend the [Launchpad Writer's workshop](#), run by Mike Brotherton. While there, Jerry Oltion gave us a tour of the solar system and I learned that besides Saturn, Jupiter, Uranus and Neptune also have rings. It's quite possible that Pluto has them as well. I innocently asked the question, "Could a habitable planet have rings, too?" The answer was "yes" and this story was born. One of the things that you notice when looking at pictures of Saturn is the strong shadow cast by the rings across the planet's surface. What would it be like to live on a world where that was part of your daily life? So many of our holidays and rituals are based on the stars or the moon that it seems likely that having an arch in the sky would have an enormous impact on the culture of a ringed planet. You might miss the solstice if you aren't paying attention, but there's no way you could fail to notice Bottom Day.

## ***How I Saved the World***

by [Valentin D. Ivanov](#)

Saving the world is expensive and time-consuming. To say nothing of the sweat and toil. The troubles began with the doctors who drained a few liters of your blood every day, not to mention the other types of body fluids. God forbid you showed the faintest sign of weakness or illness. Sneezing in front of the wrong people would reduce your chances to fly by orders of magnitude.

Then, you had to undergo the weightlessness training — just a fancy name for the *vomit comet* flights. They put you on a jet transport, and mind you, this was a Russian banger long past its retirement age. I wouldn't be surprised if Gagarin himself trained on the same aircraft. This thing chattered more than my wife and her sister over the phone on a Sunday afternoon. Oh, just forget it. So, one morning they loaded you and the other wannabe supermen, and took off. It was scary, I know. The worst came after the plane started diving to the ground. Even then the pilots had to squeeze every last horse power from the engines because the air resistance slowed the bird down. Your free fall exercise was nothing *but* free.

All the trainees rolled to the front end after every dive when the pilots leveled the machine — thanks God the bowels of the cargo bay were covered with thick layers of rubber and plastic. You could swear that the wings were falling off. We all could. This was when the real fear hit. Each session lasted for an hour, and there were way too many of them. After the first climb I asked myself why I was doing this. Three flights later I was having fun, actually.

You are about to save the world, remember? And on your own nickel too, so I hope you enjoyed the weightlessness training, because the afternoons after the flights were much worse. And I mean, *much* worse. The Russians locked you up in a classroom to study the *matchast*, or the material part, as they call the equipment. You listened to tedious lectures about the ship systems, sitting at a wooden desk covered with carvings: names, dates and cartoons worthy of a certain well-known gentleman's magazine. Who said Russian art was dead?

Professor Kuznetsov, that was the name of the torturer, walked among the desks. He was fat, short and bald. It was hard to decide which of the three had made him hate the world and you in particular. The professor carried a long stick to poke the students who couldn't answer the questions he shouted at them as if they were criminals. Or stupid, which in his opinion was infinitely worse.

"You pity supermen!" Kuznetsov liked to yell. Apparently, the concept of gender equality had bypassed him because he just ignored the last two remaining women in the class. The other six had left after the first week of his schooling. "You think you know everything!" His accent thickened. "You know nothing! You kill your comrades in space because you no reading manual."

At least you knew which era this dinosaur came from — the era of the comrades.

Just like the guys who had created the hardware we would be using. True, only part of it (albeit the largest) originated in the Soviet times. For example, the paint sprayers were new, but the zero-g lavatory looked like it had been put together by the grandfather of Dr. Kuznetsov. And the spacesuits... They were knock-offs from the Soviet Moon Program that had failed around the time my father was born.

It was small wonder the passing of the *matchast* qualification exams felt like a successful revolution. I don't know much about your class, but in mine nobody dropped out. Perhaps it had to do with the Russian general who came on a tour of inspection in the middle of that horrible month. He looked genuinely surprised to hear we had complaints. The Russians never whine, they go straight to a full-scale revolution, if they are unhappy. Before leaving, he wished us luck and mentioned that we might be forced to retake the class if our grades were lower than eighty percent. I am sure this remark accounted for our success more than the efforts of Dr. Kuznetsov. To our surprise, the old prof made it a point to shake hands with each and every one of his former students after the exam. We let him; we were feeling generous that day.

We might have actually considered sitting in that class for another term should we have known more about the survival training. It must have been based on requirements undoubtedly predating the Gagarin flight. What do you mean? No, I didn't know for sure, it was just a gut feeling.

They airdropped us — same as you, I guess — in Northern Canada, which was a better option than Siberia, only logistics-wise. In terms of cold, it was the same. Then, they airdropped us in Saudi Arabia, because this was the only desert country that kept a semi-resemblance to a government after the Big Bad News. Finally, they airdropped us in the Black Sea off the Crimean coast. Unlike the American astronauts who trained off the Hawaiian coast, we didn't have to face any sharks. A week at each of these wonderful places bleaches your skin, strengthens your spirit and makes you hate extreme tourism until the end of your days, which may be quite close anyway. Right?

They woke you up at five in the morning on the launch day. You ate your breakfast of choice. Nine out of ten Americans who take the Russian flights to The Hammer have bacon and eggs. I don't know about the others, perhaps it made them feel more like Glenn or Armstrong, but I ordered it because it was low on residue. Which probably was the reason why the Apollo astronauts had been fed bacon and eggs in the first place.

Then you found yourself on the same old bus that used to take the Soviet cosmonauts to the launch pad. You took the lift up. The engineers smiled, the doctors patted you on the shoulder and your personal chauffeur — also known as the Soyuz pilot — shook hands with you and sent you to hell. It was not an offense but an idiomatic Russian good luck wish. According to tradition, he had pissed on the first stage of the launcher just a few moments before, and you wondered if he had had time to wash his hands. Then, they put you and your crew-mates in the capsule, another relic from the glorious past of the Soviet Space Program.

Three quarters of the launch attempts are scrubbed nowadays. Far more than in the old times but since the Big Bad News came, the Russians had to quadruple their rocket production, and quality control hasn't been what it used to be. I hope you didn't have to go through it more than once. I was among the lucky twenty-five percent. Six minutes later, we were in orbit. It took twice as much to convince myself that all my bones were still in their place. I feel I should be grateful to the space suit for that, because the vibrations during the launch were teeth-shattering.

The Earth is wonderful to look at from space! I have trouble finding words to describe it. It is like a beautiful woman, pregnant with life. It is like a blue eye looking at you. It is like a magic orb. I know, it is getting worse, so I will stop here. Parting with half of my money to see the world from above was worth it, and the mission had just begun. It was some consolation that I had made my fortune, or at least the biggest part of it, preparing missions like this one. And if we fail to save the world, it wouldn't matter how much money one has got, right?

You spent in low Earth orbit about two hours. A lengthy check-list kept you busy, while all you wanted to do was to sit by the window and look at the Earth. The docking with the space tug module provided some additional excitement, but it was automated and the days when unmanned transports used to ram the stations were long gone. This was also the last chance to bail out in case of technical trouble. There was no abort option once you were on your way to The Hammer. We were flying a high-risk, high-gain mission. And an expensive one, too.

"Look," the pilot pointed at the window facing away from the Earth. "See bright star?"

"Yes," nodded the three of us, all supermen of the purest breed.

"That the International Space Station. See?"

I wish they had higher requirements for the linguistic skills of the pilots. What if an emergency happened and we misunderstood each other because of his poor English?

The ISS was flying outside, distracting me from my concerns. This is where NASA sends the astronauts from, to the American operation on The Hammer. They launch from the Cape in an *Orion*, dock with the station and board the LRTV, the Long Range Transfer Vehicle, the Agency's pride and joy. They have individual rooms in there, even if little larger than a big suitcase. In contrast, the Russians fly their construction crews, a.k.a. space tourists, on a direct trajectory to The Hammer. We embarked on it a few minutes after seeing the ISS.

The following two weeks were the most boring time you ever had in your life. The ship was moving at an astonishing speed, nearly fifteen kilometers per second with respect to the Earth. But the distances were so huge, you could never notice it, right? Well, no. You could see the disk of the Earth growing smaller during the first few days, if you were careful to look at it only once every few hours. Later the variations became too small to notice with a naked eye. With a rare orbital configuration, your mission could fly by the Moon, and you could see her getting bigger and then disappearing in the distance. No such luck? No, me neither. I have been told that the controllers try to avoid those launch windows, because the lunar [mascons](#) can affect the trajectories in unpredictable ways, and nobody wants an extra course correction.

The odds you will feel miserable during the first few days in space are one to four. Vomiting, headache, loss of orientation and coordination, all come in the package. Never mind how rigorous the selection is and how much the candidates train; weightlessness has the final say. Of course, I didn't.

The Russians had come up with a plan for fighting the boredom. It was simple and paid off in more than one way. On each mission they flew a package of scientific instruments. Usually, it included a small telescope, sometimes a magnetometer or gamma ray detector. Anyone could file a request to use them, for a modest fee. You would be surprised how many people, and not necessarily scientists, were willing to do that. I guess the impending end of the world made people more inclined to spend their money. This also gave the wannabe heroes like me and you a chance to do something useful while waiting to save the Earth. Considering that our two-month training didn't qualify us to operate the spacecraft systems, and there was not much housekeeping to do on board, this was a plus.

In our case, it was an optical telescope, a little more than a good digital camera. Every eight hours, new tasks arrived. The observer on duty picked up the top one and executed it. Then the next one, and so on. We were good kids for ten days, until we first pointed the telescope to The Hammer. That was the end of our scientific program. The flight controllers didn't make a big fuss over it. I guess the previous missions had taught them what to expect.

\* \* \*

"The Hammer is a triaxial ellipsoid, seven hundred meters along the major axis and four hundred and fifty along the other two. In other words, about two thousand and twelve hundred feet. It weighs two hundred million tons, or four hundred and forty billion pounds which qualifies the encounter of The Hammer with the Earth as an extinction level event. Luckily for humanity, it was spotted thirty years before the impact, which had given us plenty of time." This is how the Russian foremen will start your orientation tomorrow. You have to be sober in the morning but you can have another glass now. This one is on me.

They will hand you the brushes after the orientation. I mean, the sprayers.

Because this is the reason why you are here — to paint. Most asteroids are loose piles of rubble, and The Hammer is not an exception. If you detonate a big dumb bomb in front of it, as they usually did in the old movies, part of the rocks will evaporate, but most of them will shatter, and your one Big Bad News will become many Big Bad ... err ... Problems. Of course, the tiniest pieces will burn out in the atmosphere, but with anything as massive as The Hammer as high as it was, this is not enough.

Luckily, the bodies in the Solar System have a natural propulsion of their own, as long as they rotate. Don't worry, I didn't get it at first either. Let's begin with temperature. The asteroid heats up by the Sun and cools down by emitting radiation into the space. The surface pointing towards the Sun is the warmest, right? But the thing turns around! And the warmest part soon moves into the shadow where it begins to cool down. The longer it stays in the shadow, the cooler it becomes. Every idiot who has ever fallen asleep on the beach knows that it gets coldest at the end of the night, just before sunrise.

The important point is... You must know it because they have told you about momentum conservation all the way back in high school. Anyway, the asteroid gets a little kick with every emitted photon, in the direction opposite to that of the photon. The surface with higher temperature emits more and gets more kicks than the one with lower temperature, so it looks as if somebody pushes the asteroid towards its coolest part.

Still with me? I pity humankind, with saviors like this... The overall force is directed either along or opposite the orbital motion, depending on the direction of the diurnal rotation. I think you've drunk too much... Diurnal rotation is ... like the rotation of the Earth that causes day and night to alternate. Yes, the kicks can either increase or reduce the orbital velocity of the asteroid. Hm, maybe you didn't drink enough. The asteroid can move to the outskirts of the Solar System, or fall towards the Sun ... over millennia... I bet they told you this is the Yarkovsky effect.

Left to its own devices, The Hammer falls toward the Sun by about a kilometer per year. In thirty years, this "natural propulsion" can not deflect it from hitting the Earth unless it gets help. This is why the French are building a large battery of microwave guns near The Hammer, and the Chinese, an enormous free-floating field of solar batteries to feed them with power, while we and the Russians share the painting job, making sure that The Hammer absorbs as much microwave energy as possible, heating it up well above what the Sun would have done alone. Our efforts will help this heap of rocks fall towards the Sun almost a hundred times faster. Enough to streak through the upper atmosphere, instead of hitting the American West coast. To us, the saviors of the world! Cheers!

\* \* \*

If we are lucky and the eggheads are correct, thirty years down the road, The Hammer will swing by the Earth on its way to the Sun, and everybody who has worked here will proudly hang on their walls certificates that say, "Thanks for saving the World, from the grateful Earth", or something like that. Signed by the President, of course.

Meanwhile, you will spend the next three months here at the *Yarkovsky Base*. You will be outside for the best part of them, in a bright orange spacesuit, painting the rocks black. Here is a piece of advice for you. Whatever you do, don't ever call your foreman Tom Sawyer. Even behind his back. Even with the radio off. He has ways of hearing you and he gets very upset. The man just thinks that painting fences is the best job ever.

This bar is the only sane place on The Hammer, but you ain't going to enjoy it often from now on. Oh, I must have missed to mention — we just used up your alcohol allowance for the next six weeks. Cheers!

## Afterword:

Translation Valentin D. Ivanov and Kalin Nenov  
Valentin D. Ivanov  
March 11-14/April 3, 2007, La Silla  
Oct 18-19, 2008, Santiago

This story is mainly about asteroids, extinction level impacts, and forgotten civil engineers.

Asteroids are a constant threat to life on Earth. Recent craters on the face of our planet testify that the danger is real. Governments gradually come to realize that. The US Congress requested from NASA in 2007 a report for the current and near-future capabilities of humanity to detect and deflect dangerous bodies larger than 200 meters in diameter. The limit was set by the effect of the impact — larger, and presumably heavier, bodies will change the climate globally and will affect life on the entire planet. While the detection requirements are almost within reach of present-day technology, deflection is another matter. The "Hollywood approach" — to drill holes into the asteroids, and to blow nuclear bombs inside, can only break them into pieces. The same amount of mass will fall on the Earth. A better solution is to set the explosions on the asteroid's surface because the evaporated material flying away from the asteroid and the momentum conservation will give the asteroid a kick in the opposite direction. Perhaps, this is the best short-notice anti-asteroid defense we have. Given an earlier warning before the impact, we can attempt to deviate the path of an asteroid with mass drivers. These devices throw material away from the surface, and again, the conservation of momentum law moves the asteroid away. Or, we can resort to accelerating the natural Yarkovsky effect, described in the story. Unlike the other solutions, the infrastructure that we will have to build — the solar farms and the microwave guns — will remain in place, to be re-used as power plants beaming cheap energy back to us, or even for defense against other asteroids, if the orbital configuration allows it.

Ivan Osipovich Yarkovsky (1844-1902) was a Polish civil engineer who worked for a Russian railroad company for the most part of his life. He was born in the small military station of Osveya, near Vitebsck, in the family of a doctor. Over the centuries, this territory has been part of the Polish empire, the Russian Empire, and it's now in Belarus. Science was Yarkovsky's hobby, and he described what is now known as the "classical Yarkovsky effect" some time around 1900s. The further history of this discovery resembles a mystery novel with a particularly convoluted plot. His contribution was forgotten until 1951, when the Estonian astrophysicist Ernst Öpik, working in Northern Ireland at the time, remembered reading four decades earlier an old pamphlet by Yarkovsky, describing the orbital evolution of asteroids due to heating/cooling and rotation.

Wikipedia contains a nice article about the Yarkovsky effect, complete with illustrations:

[http://en.wikipedia.org/wiki/Yarkovsky\\_effect](http://en.wikipedia.org/wiki/Yarkovsky_effect)

The effect is an observational fact, being measured with radar ranging, by the JPL astronomer Steven Chesley and his team on the asteroid *6489 Golevka*. A report about this study was published in the prestigious *Science* magazine in 2003: or <http://www.sciencemag.org/cgi/content/abstract/302/5651/1739> or <http://adsabs.harvard.edu/abs/2003Sci...302.1739C>

A comprehensive article about the life and work of Ivan Yarkovsky, written by George Beekman, can be found in the *Journal for the History of Astronomy*: <http://adsabs.harvard.edu/abs/2006JHA....37...71B>

*Mascon* — a region of a planet or a moon that contains a positive gravitational anomaly, due to excessive distribution of mass on or under the surface. An example of a mascon is Mauna Kea. The lunar mascons are sufficient to affect the orbit of artificial lunar orbiters. [back](#)



## ***Dog Star***

by [Jeffrey A. Carver](#)

"Don't you think we're coming in just a little fast?" asked a husky voice behind Jake in the tiny spaceboat.

"There's a critic on every ship," Jake muttered, without breaking his concentration.

"Just doing my job, I'm just — whooo, that asteroid's really coming at us!" Jake didn't argue. The gray, potato-shaped object was indeed getting large quickly — which was exactly according to his plan. Its orbit was less than ideal, and he had only one day to make a survey before it caromed off another asteroid. He wanted to find out: Was it a candidate for mining? Was it worth chasing if it got knocked out of the cluster?

"Like I said, we want to get in fast and get out, before it bounces off NEA-238," Jake said. If he was right and this rock turned out to have mining potential, his tagging it could be just what he needed to break out of the ranks of the junior surveyors. A lot of Earth-approaching asteroids had been nudged by robot boosters together into this Near-Earth cluster, but not many of them had been studied in detail yet. He had a feeling about this one. "Look — haven't I logged, like two hundred asteroid landings? What are you worried about — oh crap, what's that?"

An alarm honked, the spaceboat jerked, and there was suddenly a much-too-bright flare of rocket exhaust in his peripheral vision. Jake glanced at the control board, then outside — and was horrified to see a bright jet of flame shooting sideways out of the boat. Sideways! He slapped the cutoff, checked for signs of fire — there were none — then hastily rechecked his approach speed. He'd been okay before, but not any longer. He'd just lost his main engine. Without that for braking, he was definitely approaching too fast.

"Rrrr, you just shut off our rocket," Sam said, squirming around behind him. "Why'd you do that?"

"Had to," Jake said with a gulp, trying not to betray the fear that was rising in his throat. Think fast now!  
"Looks like we've got to use the attitude thrusters for braking."

"But they're — isn't that just for emerg—"

"This is an emergency!" Jake disengaged the computer from the thrusters. He needed them all firing in the same direction to brake. "Okay — almost — hold on now!" The thrusters sputtered, and he felt a push, slowing them. But not nearly enough.

"You aren't doing this to impress me, are you?" cried Sam.

"No!" He shut up and focused on the asteroid swelling before them. Oh jeez, too fast! Trying not to panic, he kicked in thrust to the right. The asteroid mushroomed before them, and they glanced in with a bone-jarring crack. They bounced in a flat arc, sending a cloud of dust spraying from the surface — and for a moment, he thought they'd skip off entirely. But no ... they bounced twice again, before skidding and shuddering to a stop. The dust they'd kicked up arced slowly back down in the feeble gravity.

Jake gasped and slumped in relief. Then he put out a spacesuit-gloved hand to check the readouts on the

console — and got a jolt of electricity through his spacesuit glove. "Yow!" He rocked back as sparks shot from the console. "What the—?" He punched the master cutoff — but too late, his console was smoking. It must have been the dust, carrying an electrostatic charge — powerful enough to short out his instruments. "I need to vent! Are you sealed in?" he yelled. As soon as he heard Sam's yes, he popped the canopy and pushed it open. The cockpit atmosphere puffed out, taking the smoke with it.

"Rrr, I'm okay. Are you okay?" came a muffled voice behind him.

He blinked. "Yeah, I'm all right. Dunno about the boat, though." He poked tentatively at the console and switched the master back on. Nothing. At all. No power, no comm, no nav, no thrusters. Air in his suit was still flowing, at least. Looking out the cockpit window at the surface of the asteroid, he was grateful that the dust had cushioned their impact. But they needed help — and soon. He keyed his spacesuit comm. "Mayday, Mayday, Mayday. This is scout EX-71, can anyone hear me?" He repeated the call half a dozen times. But there was no answer, and he knew perfectly well there wasn't going to be one. His suit comm didn't have the range.

Turning his head, he squinted through his helmet visor. Earth was about the size of a tennis ball, white and blue against the black of space. It was about ten days away by direct flight, if they had a ship designed and fueled for such a trip, which they didn't. He turned his head the other way to pick out the Big Dipper and Cassiopeia. A bit of directional calculation confirmed that their sightline to the mining survey base was presently blocked by the asteroid. Well, it was sixteen hours away under normal thrust, with a working rocket — which they didn't have, anymore.

And just under two days from here — without any rocket power at all — was asteroid NEA-238, on a collision course. "I wish I'd listened to you," he muttered to Sam. Sam had wanted him to stick to his filed flight plan, instead of detouring to follow his *instinct* on this new rock.

"Me, too. Am I being a bad dog if I suggest we get out and check for damage?" Sam said, nudging him in the back of the helmet.

Releasing his harness, he floated out onto the step-down ledge. He bounced a little to gauge the gravity — not much — then turned to help Sam with his harness. The smartmutt's black-and-white face was just visible through the helmet faceplate. When Jake released the buckle, the border collie launched himself up and out of the cockpit, gliding in a graceful arc to the asteroid surface. In his spacesuit with the air and power pack on his back, he looked less like a dog than a small cargo pod with legs. Nonetheless, he managed well in microgravity, and he swung his head around now, assessing the local conditions. He reared up momentarily on his hind legs. "Not much to hold us here. We should move carefully." He started nosing around the outside of the broken spaceship.

Jake followed.

\* \* \*

It didn't take long to tally up the bad news. The main rocket had burned through the side of its combustion chamber and was useless. It was a miracle it hadn't blown up. The thrusters were dead. So there was no way they could fly back to base under their own power. Also, the hard landing had cracked the hull casing under the electronics, and the short caused by the electrically charged dust had indeed taken out all communications, as well as computer and nav.

"Bones," Sam said, sitting disconsolately by Jake.

"Well," Jake said, "at least we know the transmitter's beyond repair, so we won't waste time with it."

Sam cocked his head inside the helmet. "Ooff. Are you saying that to reassure me?"

"Not really. Just saying ... we need to think of another approach. And we don't have much time. What — two days? No, eighteen hours."

"But — rrrffff — people will come looking?" Sam's encased tail slapped once, hopefully, in the silence.

Jake's face burned. "When we don't report in, yeah. But they'll look in the wrong place. I feel really dumb now, not calling in the course change."

"Why didn't you?"

"I just wanted to get this first look, without anyone yelling at me, before it was too late. I know it was stupid, but you have no idea how much I want to—"

"Get promoted, so they don't treat you like a kid. I know." Sam swung his head around, pointing with his nose at the flank of the survey boat. "What else have we got in there? Anything that can make a signal?"

"Let's look." Jake started opening the side compartments. "We need to pull the sled out first. Stand back." He yanked a couple of levers to free the cradle arms holding the large sample sled, then slid the unit out until the flat sled stuck out from the hull, a foot off the ground, like a wide gangplank. "I wonder if this thing still has power."

"Thought all the power was dead," Sam said.

"This is separate. It's got a small zEEP converter, for its levitator."

"You mean one of those quantum vacuum thingies?"

"Zero point energy. Yeah." Jake switched the unit on and released it from its cradle. The sled — a flat, rectangular pallet with an opening and some gear in the center — sank until it floated, bobbing slightly, about six inches off the ground. A flat plate on the underside provided the levitation, drawing energy for its repulsive force from the virtual particles that flickered continuously in and out of existence in the apparently empty vacuum of space.

"If that thing can float like that, can't we use it somehow to get off this rock?" The border collie lifted his elongated faceplate-covered nose, as though to sniff the thing.

"Thing is," Jake explained, "this is the only thing it's good for — floating just off the ground. It's great for that, because it doesn't need batteries or fuel. But it's strictly a local effect — close to that levitator plate. As soon it gets more than a few inches off the ground, the effect disappears."

"So if we tried to ride it—"

"It'd be a really short flight. We can jump higher than this thing can float." Jake turned the unit off and it settled to the ground.

"Rrmmf. Squirrels and bones." Sam started to raise his spacesuited leg to the sled, then apparently thought better of it.

"Anyway, we're wasting time." Jake stuck his head into the compartment. "There must be something in here we could signal home with." There wasn't. He opened the next compartment. "A laser of some kind would be

nice, like a torch laser. But I don't see anything. This prospecting scanner has a laser inside it, but we'd have to tear it apart to get at it. There ought to be some flares or something."

"Any spare communicators?" the dog asked.

"I wish. You know how in the old days, there used to be redundancy?"

"I wasn't there."

"Well, that was the old days. Wait! Here are some flares!" With a rush of hope, he pulled the box out and examined the contents. His heart sank. "For marking landing areas. Probably not bright enough for anyone to see back at base. We can try, though." He set the box aside and pulled out everything that looked as though it could possibly be useful. "We'd better take stock..."

\* \* \*

The shadows were already long; soon, the sun set and they paused to rest. The inventory was bleak. The little boat was meant for short-range surveys, close to the base-station. Jake had taken them a little further afield than the boat really was equipped for — which would have been all right if the crash landing hadn't taken out so many of the onboard systems. They not only had to worry about a collision in fifteen hours with asteroid NEA-238, they also had dwindling power. Oxygen and water weren't immediate worries, but their power was limited mostly to the packs that recharged their suits. The boat's fuel cell was producing only a trickle, which put the last nail in the coffin of any hope of getting away on the boat.

"We're going to have to tap whatever power we can get from the sled," Jake muttered, "and see if we can cannibalize that laser." The asteroid had a slow rotation rate, and they had some time yet before the base-station would come up over the horizon. At that point they would try to signal with the flares, with a makeshift laser, or with anything else they could manage.

While Jake worked by the light of a small lantern, Sam, with his border-collie can-do spirit, determinedly kept at his job; he was going to keep Jake's morale up by pummeling him with questions. At first he quizzed Jake on what he was doing, but Jake growled at that, and the dog switched tactics. "So, is that nice girl in Analysis ever going to notice that you like her? She treats me real nice. Wufff."

Jake looked up from a tangle of wire and glared. "If we get back alive, you can introduce us." He cursed at the useless hardware in his hands. "Sometimes I think you dogs were more useful before we gave you speech."

The dog bobbed his head away and looked out at the stars. He coughed as if he'd gotten something stuck in his throat. "Okay, no talk about girls. And you don't want me to ask what you're going to do with that wire, even if you do get it hooked up..."

"I'm trying to feed power to the batteries, and hope it keeps us from freezing, and maybe lets us fire up a laser."

"Oh." Sam didn't sound convinced.

"Talk about something else. Distract me."

"Hoo — hmmm. You want to talk about the elections coming up back home?"

"No!"

"Okay, then." Sam turned his head, as if searching the dark of space around them for ideas. "All right, I got it. I got it. This thing's been on my mind ever since I heard about it."

"Oh yeah, what's that?"

The dog made a whuffing noise. "Well ... it's about space. You know how space is big? Really, really big?"

"Ya-a-ah."

"Listen, you asked to be distracted ... and there's something that's always bothered me. About the universe."

"The universe!" Jake looked up. "What about the universe?"

The dog sighed. "It's such a mind-boggling concept, you know? The universe. It's so huge. We sit here and look out at it, and I can't even wrap my mind around it."

"Maybe dogs weren't meant to think of such lofty things."

Sam snorted in derision. "Like you understand it so well. I may just be a gene-spliced mutt with a chip in my head, but that doesn't mean I can't wonder about the awesome grandeur of space."

"I—"

"Don't even start. Like this crazy business about the universe expanding—"

"It is expanding."

"I know that. And it's expanding faster all the time. What's that all about, anyway? Even though gravity's sucking on the universe, trying to make it crunch back down?"

Jake glanced up again, frowning. "Well, yeah. That's because there's a force—"

"I know, I know. I read about it. Dark something. Dark emissary? Dark—"

"Energy. Dark energy," Jake said.

"No, that's not it. Wouldn't make any sense. Dark enigma?"

"No. I mean, yes — it's an enigma. That's not what it's called, though."

"Dark matter," the dog guessed.

"Dark matter doesn't push the universe apart. In fact, dark matter helps hold the galaxies together."

"Grrrr. I thought that was strings."

Jake squinted in the dim light at the lengthening line of half-untangled wire in his hand. *I really don't know what I'm doing*, he thought. Finally he reacted to what the dog had said. "No, string theory's different."

"Grrrrrr. Maybe dark superglue holds the galaxies together, then."

Jake laughed. "Okay, I'll buy that."

"So what is it that's pushing everything apart?"

"I told you. Dark energy."

"Wulllll ... what kind of name is that? Isn't energy supposed to be light? Like glowing stuff? And fire?"

"Yeah, usually. But—"

"Bombs. They make a lot of light. And noise. Ka-boom!" The dog sneezed. "So how can this other energy be dark?"

Jake finally had the wire untangled. He began stretching it from the sled to the battery bay. "I guess that's the point. They called it dark because nobody can see it. They can't even measure it directly. It's too subtle, I guess." Should he connect this wire straight to the battery?

Sam was shaking his head, his ears flapping inside his helmet. "If I say black is white, is that subtle?"

"Um—"

"Subtle as a screen door on a submarine."

"Whoa, boy. Did you just learn that?" The regulator. He should attach the wire to the regulator.

"Never mind. You're trying to get energy out of that wire. If we see a spark, we'll know it's real. But how do we know this *dark energy* is real, for Pete's sake? I'll bet even Pete doesn't believe it."

"Pete wouldn't believe it if I told him the sun rose in the east."

"It doesn't, on the station. Okay, bad example. But if you're going to give something a crazy name like dark energy, don't you at least have to know it's there? Know something about it?"

"We do know something about it. Can you shove those pliers towards me? We know something's pushing the universe to expand."

"But how?" The dog nudged the pliers. "How do we know?"

"Because of supernovas, I think."

"Supernovas are pushing the universe apart? I love supernovas! They're so bright!" The dog's face widened in a toothy grin inside his helmet.

"Supernovas aren't causing it. Supernovas are how we know." He paused; Sam looked crestfallen. "They're like measuring sticks."

"Okay. Next fable, please."

"Really — astronomers use this special kind of supernova as what they call standard candles. By observing them carefully, they can tell how bright they are."

"Well, ruff. What's so hard about that?"

"Nothing, if the supernova were right next door. Of course, then we'd be toast. But they're not, they're off in

distant galaxies. Thing is, there's this special kind of supernova that astronomers know are all pretty much the same brightness really — not just how bright they look in our telescopes — and that lets them figure out how far away the galaxy is."

"Woofee! They know how far away the galaxy is. I'm so excited I can hardly breathe. Can you see me fogging up my faceplate?" Sam was breathing fast, and actually was fogging his faceplate a little.

"It's not that easy to measure, you know. They can't just, like, shine a laser-finder on it."

"Speaking of lasers, how's that thing coming? I've been watching our rotation, and I think the base will be over the horizon soon."

Jake flexed his gloved fists, which were starting to cramp up. He wasn't just wishing he hadn't taken the detour; he was wishing he'd paid more attention in his electrical classes. He had the laser awkwardly hanging out of the survey scanner. It needed juice from the boat's batteries, and right now it wasn't strong enough. "I'm doing my best here. I'm just hoping we can pull enough extra power from that sled to make this laser work."

The border collie leaned in and licked at him — catching only the inside of his faceplate. "You can do it. Anyway, you're not fooling me."

Disconcerted, Jake said, "I'm not trying to fool you."

"About the galaxy distances, I mean. They could figure it out from the red shift, right? So these astronomers have learned zip, the way I see it."

Jake sighed, reaching to loosen a connector. "Dummy. Why'd we ever give you dogs voices, anyway? How can you say they've learned zip. They've learned a lot—"

"Don't call me a dummy. Or I'll call you worse."

"I doubt you even know anything worse."

"Oh yeah? You pink and pukle son of a Jack Russell—"

"All right. You're not a dummy. But the thing is, they get a different answer from the red shift. Different from the one they get from the brightness, I mean." Jake gestured, making a stirring motion. "They put the two numbers in a big equation pot—"

"What equations? You know I don't like equations."

"Equations for how fast space expands — from the Big Bang and stuff. They stir these numbers all around, and what they come up with is—" He paused, and squinted at the terminal on the battery regulator. Did he have the right one?

"I'm waiting. Earth to Jake. Please continue."

"Huh?" The wire slipped out of his hand, and he swore. "Well, it turns out the galaxies are farther apart than they should be, based on how fast space was expanding a zillion years ago, according to the red-shift." He caught the wire again, and started twisting it around the terminal.

"So?" the dog prompted.

"Soooo ... after looking at all this, which at first made no sense, they concluded that the universe isn't just expanding, it's expanding faster now than it was before! That's why the galaxies are farther away than they should be." He tightened the terminal nut and looked at the spacesuited dog. "So how could that be? How could the universe be speeding up, when gravity is trying to slow it down?"

"Arrr, that's what I'm trying to ask you — how could it be?" asked the dog.

Jake shook his head. "It's been half a century now, and they still don't know for sure. They call it dark energy, but they don't understand it."

"Who is this *they* person, anyway?" Sam asked, with a little yip in his voice. "It could be aliens behind it all, making us think this stuff is true. Are aliens the *they*?"

"I don't think so. Not unless aliens have taken over all the astronomy departments on Earth and the Moon and Mars."

"Could happen."

"I suppose it could, yes. But I don't think it has. Are you keeping track of our rotation for me?"

The dog snapped to attention and peered at the constellations. He hopped up on top of the cockpit. The inertia of his oxygen pack nearly carried him right on over to the other side. "Yes. My friend, if you have laser light, I think we may have a sightline to base." The dog's tail wagged slowly in its encasement.

"All right. I need a little more time. Tell me when it's coming near to overhead." Jake worked in earnest now, testing the connections with gentle tugs. He took a deep breath and turned on the zEEP generator on the mining sled. A meter on the battery indicated a slight charge coming in. Good. Jake turned his attention to the laser dangling out of the scanner housing. It was going to be really hard to aim...

"Shine your light now," Sam said.

Jake gripped the unit and aimed the laser up. The base should be one of those points of light just south of Altair. He squeezed the switch. A faint sparkle of green laser light shone through floating dust. When the dust cleared from the path, he couldn't see the beam at all. Determinedly, he swept it around the patch of sky the best he could. "I don't know if this is—" he began. The power light on the unit went out. He swore.

"Aww," Sam said. "Grrr. Can you fix it?"

Jake pursed his lips and sighed. "Not enough juice. I guess this quantum-energy thing isn't really made to be an electrical generator. It makes enough for its own controls, but mostly it just levitates." He looked up into the black sky, with its sprinkling of stars. "I wonder if anyone saw the laser." He shook his head and picked up the flares. "We'd better light a couple of these." Taking two flares, he hiked far enough to place them on a mound for maximum visibility. He lit the flares and then, unimpressed by their red sparkle, trudged back to the boat.

"We'd better keep thinking," he said, mulling the approaching NEA-238.

\* \* \*

While they were pondering, Jake swapped fresh oxygen and power packs into their suits. He thought briefly of trying to tap power from one of the suit packs. But he was too afraid of draining or blowing the packs. It wouldn't do any good for them to be seen if they couldn't last long enough for rescue. They had a quiet meal,

of the pasty stuff you ate right inside your helmet. It tasted incredibly good to him right now.

"I've been thinking," Sam said, hopping down from the boat in a graceful arc. He swung his space-helmeted snout toward Jake. "Finish telling me about dark energy, please."

"Look, I don't really think right now is—"

"Please. It won't hurt."

Jake rolled his eyes. "What do you want to know?"

"Tell me what dark energy is," said the dog.

"Nobody knows — except that it's an energy field that's pushing against gravity."

"Okay, so it's a sort of antigravity, right?"

"I guess."

"And this energy is coming from...?"

"Well, it seems to come from space itself."

"Like that zero-point stuff you were talking about? Like the levitator uses?"

"I guess. Maybe."

"Uh-huh." The border collie cocked his head and grinned. "Rrrrrfff! You know something? I think we'll get to see the sun rise in the west tomorrow, after all."

"What's that supposed to mean?"

The dog padded over to the sled and put a paw on it. "Zeep — zero — energy. The levitator pushes things apart — just like dark energy. Right?"

"R-r-right. I guess."

"Are you thinking what I'm thinking?"

Jake stared at the dog open-mouthed for a moment. "Well, we've been through that. It can't levitate against space. It needs something to repel. And as soon as it gets a few inches off the ground, its power falls way off." He shook his head at the dog. "It just doesn't work at a distance."

"Rrrr. It pushes real hard up close, though, doesn't it?" The dog was gazing at him intently.

"Yeah, I guess so."

"Can we try something?" the border collie asked.

Jake shrugged. "All right."

"Raise that sled up as far as it will go, then throw some sand or something up under it. Right up against the

levitator plates."

"Um — okay." Frowning, Jake adjusted the sled controls until it was floating six or eight inches off the surface of the asteroid.

"Good. Let's test Newton's laws. Got a shovel?"

He looked around and found a small, flat spade. "All right. Let me get some dirt here." He scooped up some loose dust, then maneuvered close to the sled. "Here goes." Feeling very awkward, he flung the dirt under the sled, trying to angle it up.

The dirt never touched the levitator plates. Instead, it ricocheted down with a force that made Jake hop back in alarm, and sent a cloud of dust out the sides. The sled bounced up a few feet from the reaction force, then sank slowly back down, bobbing as though on a sudden wave.

"Holy freakin'—" Jake began.

"That's it! Rruffff! That's what we have to do! It's just like a rocket!"

"That's amazing! But—"

"There's plenty of dust and loose stuff here."

"True. But we can't just stand beside it shoveling sand under, can we?" Jake whispered.

"Maybe we can. Now bear with me on this..."

\* \* \*

Loading the sled with loose dirt was a time-consuming and extremely messy business. But the sled was built for carrying dirt samples, and it came equipped with side panels to hold the loose stuff, and even a transparent tarp to go over it to keep samples from floating away in the microgravity. It had a pulverizing auger aimed down through the square hole in the center of the sled, but the boat's dying fuel cells didn't have enough power to drive it.

In the end, Jake shoveled. Fortunately, there was plenty of loose stuff on the surface. The dirt had almost no weight, but it did have mass and inertia, and when he got it moving upward, it tended to keep moving upward. He lost quite a few shovelfuls before he got the hang of lifting and then redirecting it down into the sled. After a while, he clanged onto rock and metal. *Metal! He was right about this asteroid!* he thought. He moved the sled to a fresh patch of loose dirt. Gradually, the sled began to fill up with asteroid dust.

"I couldn't dig better myself," Sam said with a woof.

"You'll get your chance," Jake muttered, panting from the exertion. He eyed the slowly growing pile inside the sled. They had a long way to go.

\* \* \*

By the time the sled was piled high with asteroid dirt, Jake needed a rest and some food. The sled looked like a loaded cart without wheels, and with a funny-looking post at one end, holding the controls. "Spare supplies next," Jake said, sucking food paste and water from his helmet dispensers.

"And a name," said Sam. "It needs a name."

"You think about that, while I do this." Jake got busy bringing spacesuit recharge-packs from the boat. He used vacuum-grade duct tape to hold everything to the control post, including the remaining flares. Then he levitated the sled again and used a lot of duct tape to secure a couple of clipboards and his shovel at an angle to the unused auger, where it extended downward through the square hole. Jake stood with his hands on his hips, studying his handiwork. The shovel and clipboards were pretty crude; but they only had to withstand comparatively minor forces, deflecting the dirt sideways under the levitator.

"All we really need to do, right, is get off this rock and get headed in the right direction toward base. When we get closer to home, they'll be able to pick up our suit-comms and flares. Right?"

"Right," answered the dog. "And you found iron and nickel here, so maybe they'll forgive you for being so boneheaded." He paused. "Get it? Boneheaded?"

"Yah," Jake said wearily.

"Wouldn't it be funny," Sam said, "if, after all this, they came right here and rescued us?"

"I wouldn't mind a bit," Jake said, yawning. He needed some sleep. They only had about eight hours until asteroid NEA-238 would loom very fast. But they couldn't try anything until this asteroid had rotated to the proper launch position, with the base-station above the horizon. So in their urgency to get off this rock, they had four hours to kill.

"I don't know about you," Jake said, "but I'm bone tired. Let's get some sleep, okay?"

"Bone-tired, rrrff," said Sam. "All right, let's rest." That said, he turned around a few times before settling down. A minute or two later, he was sound asleep.

It took Jake a little longer.

\* \* \*

In the morning, they woke to the stars circling overhead, and the sun disappearing behind the asteroid horizon. They ate a brief breakfast of spacesuit-grade paste. "You look like you've been through a mud-bath," Sam said.

"We're not going to be a pretty ship," Jake said, wiping them both down as well as he could. He didn't care so much if the suits looked dirty, but they needed to see clearly through their faceplates. They were depending on the stars for navigation.

"Beauty is in the eye of the beholder, right?" Sam said.

"True. Have you thought of a name yet?"

"Yep."

\* \* \*

Sam grew nervous, when the time came to be strapped into place. The dog's tail twitched, as Jake tested the straps, then clipped the tarp down, and finally tightened the cords securing himself to the control post. "It'll work," Jake assured him. "It was your idea, remember?"

The dog was looking around through the clear tarp. "I don't want to go flying off into space."

"You'll be fine. Just do what comes naturally." He surveyed the sled and shook his head. Sam was strapped onto the top of the dirt pile, under the tarp containment. Behind the dog was the opening in the sled.

Jake looked up. The correct star groups were almost overhead. Their trajectory was going to be, to say the least, approximate. But they just needed to get close enough to the base-station for somebody to triangulate on their signals. "Ready?"

"Woof."

"Ready to launch space-sled Dog Star. Zero!" He switched full power to the levitators. "Dig, Sam — dig!"

The sled lurched up from the surface of the asteroid on the levitator's repulsion field. Sam dug ferociously, spraying pebbles and dust down through the opening — where it deflected off the clipboards and flew directly under the levitator. The instant it entered the levitator-field, the dust shot downward with a silent whoosh, creating a crude rocket blast that billowed out as it hit the surface. The thrust came in gentle bumps and lurches, as the dog shoveled with his feet. The sled wobbled alarmingly and threatened to careen to one side. Jake shifted his weight like a windsurfer. It was precarious, and he nearly overbalanced, but finally he managed to steady it.

"Keep digging!"

Sam didn't answer, but kept digging. The sled continued wobbling upward — inch by inch, it seemed. "It's working!" They were climbing, really climbing, up over and away from the wrecked spaceboat. It couldn't possibly work — and wouldn't have, in stronger gravity. But it did work. As the border collie dug, panting audibly, spraying dirt into the repulsion field, they continued their slow, bobbing climb away from the asteroid. Beneath them was a rocket contrail of asteroid dirt.

"We're away!" Jake cried. "We're away, Sam!" Peering past his feet, he could see the spaceboat shrinking. The rounded shape of the asteroid was becoming visible. The sun blazed around the edge, then came into view, forcing him to look away. He craned his neck to focus on the star-patterns above them, and the few recognizable glints of light that were other asteroids in the Near-Earth cluster. "A little more to your left, Sam!"

"Woof!" the dog said, panting happily.

There was a lot of space to cross between here and the base station. But if Sam kept digging, and they didn't run out of dirt, and they managed to steer this thing, and their suit-comms worked, and nothing else went wrong — why, they could be in radio range of rescue by dinner time. Jake felt a rush of confidence. "Good dog!" he crowed.

"Hree-haw!" Sam barked, digging as he'd never dug before. And why not? The fate of the Dog Star was riding on him.

## **Afterword to "Dog Star"**

I'd been pondering for some time how to tell a story about dark energy, a concept so cosmic — its effects felt only over billions of years — as to seem impossible to tell in human terms. Somewhere in my unpredictable subconscious, this urge dovetailed with my fond recollection of a joke circulating on the internet: "How many dogs [name your breed] does it take to change a light bulb?" For the border collie, the answer is: "Just me. And while I'm up there, I'll bring that wiring up to code for you." (I once had a border-collie mix, the

smartest dog I've ever known. And yeah, his name was Sam. Jeez, I miss that dog.)

The central conversation about dark energy was the first piece of the story that I wrote, though I didn't know yet that it was a dog asking the questions. I had to get that right, and clear, and conversational — and that was hard enough in itself. The next hard thing was figuring out how to wrap a story around it in which that conversation, and really knowing something about dark energy, would make a difference in the lives of the characters. I hope I succeeded. I realize the story is, in many ways, a throwback to the can-do, just give me a wrench and a place to stand, science-fiction stories of the 1950's. But that's okay — I loved those stories, and I don't see why they can't be updated to the Twenty-first Century.

But I confess, I wonder — along with Sam — what were those astronomers thinking, when they named an invisible something that holds the galaxies together *dark matter*, and a few years later, named another invisible something that pushes the universe apart *dark energy*? What were they thinking?

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## ***The Touch***

by [G. David Nordley](#)

Sani moaned in a high pitch airy whistle and Modani rushed back to the screened-off alcove in the mud brick hut after showing a comforting fluff of featherfur to the children. That was the way Sani wanted it; the young ones would have to deal with her final crisis soon enough.

"Apologies, my love," Sani whispered. "For a moment the pain was too much, and I lost control."

Modani made no sound, but with a fluff and a lay showed his deep concern. Softly, with all three fingers of the left hand, he groomed his dying mate, a gesture that at one time might have led to ovulation, but now only recalled fond memories. Though she had become thin, Sani looked no worse for the immobilizing cancer. The small lump on her neck was hardly noticeable, but their local crest-pruner said it went down into her spine, and to cut it out would likely kill her immediately.

"I will get more painkiller from the chemist, my love." Modani whistled and they touched beaks in a gentle reminder of their mating dance so many years ago.

\* \* \*

A hundred thousand years before Sani's cancer took hold, the great blue disk and ultraviolet arms of the majestic Whirlpool galaxy filled David Martin's field of view. He scanned for polarizations by strong, extensive, magnetic fields. There! An evolved neutron star ... not a lopsided pulsar with a bumpy field whipping around, but a near-classic dipole with an ion wind streaming out of its poles. The field should, he determined, be well organized, with hundreds of Tesla out to megameters from the relatively tiny thirty-kilometer sphere at its center; a featherbed entry.

Orienting the superconducting loops in every nanocell of his body, he tacked against the faint plasma breeze of the galaxy's central black hole, gradually bending his path toward his chosen decelerator.

His pattern recognition codes latched onto a memory of air pillow diving with Ellen from a hundred million years ago, and he reexperienced the undiminished thrill of defying his youthful fear of heights. Ten thousand light-years out from the star he woke his wife, and suggested a reprise.

She gleefully concurred, so they willed their nanocells to take human form again, for the first time in ten million years. Trillions of submicroscopic hexagonal toroids arranged themselves to emulate skin, hair, flesh and bone; optical data links carefully arranged themselves to simulate nerves and glands. Most of a billion years of experience was set carefully aside from conscious thought so that they could enjoy real-universe sensation again.

Ellen laughed joyfully, surrounding him with legs and arms, devouring him with kisses as they tumbled through the void, delighting to join one another as if they had not been one undifferentiated physical being just a few moments before.

\* \* \*

For Modani, the trip to the village would not be the simple thing it had been as a youngster. There were too many angry people out there, would-be tribal leaders whose superstitions and egos had been bypassed by the new, Ixoran-style civil service. The desperate and the lazy had been known to waylay travelers. *I should not go alone*, he thought. *If anything happens to me, it will be a far worse tragedy for the children than Sani's pain.*

He stuck his head out of the door, smelled the freshly mown reeds he kept around the border of his land and listened. They lay on top of older dry reeds because this allowed air circulation which hastened drying. But this also let the unwary think they could place a silent foot on the soft new reeds - and then the snap when the dry, brittle, reeds below broke would betray their approach.

He thought he heard such a snap, then silence.

The silence continued. An animal?

He almost turned back, but then thought of his poor mate's agony. Convincing himself that he would probably get away with it, he donned a leather greatcape and bid his oldest to care for Sani. He resolved to buy as much medicine as he could to reduce the number of such trips alone. Half their family's savings were in his purse; he would have taken it all except for the threat of robbery.

Then Modani headed across his fields toward Omphan Village at several body lengths in a heartbeat, his four sleek thin legs still whipcord strong, galloping at the pace of urgency. He felt guilty about his own good health.

\* \* \*

The neutron star lay in a medium-age open cluster, still brilliant with new blue-white stars and set off by a garnet-tinted supergiant here and there, but already penetrated by the older stars of the arm and of the halo. David and Ellen hit its magnetic pillow holding hands in a flat spin like a pair of skydivers, and bounced away at half of lightspeed, having raised the general temperature of the plasma around their impact point a femtokelvin or so. They tingled as their nanocells repaired radiation damage as fast as it happened.

As they left the region, they reformed themselves into a thousand telescopes, which they spread into a globular constellation a hundred million kilometers across; a giant's eye to examine their surroundings in detail, sending everything to the small remaining central coordinating sphere. Their conscious time sense slowed; thoughts that used to take microseconds now took hours as their data links stretched over light minutes, but to them it was as if the galaxy around them had contracted and accelerated its motion.

The view exhilarated them; indeed, David reflected, by their self-chosen logical structure, it was one of those fuzzy patterns that *defined* exhilaration; the feeling of speed.

There! A white and a yellow giant were distended into nearly touching eggs of light, spinning madly around each other, almost ready to coalesce.

There! Orbiting a brand new white dwarf, they found a brown dwarf with glowing bands under a magnificent multihued ring system, all still encased in the nebula of the white dwarf's final mass expulsion. A secondary planetary system was forming.

There! An old ruddy, overinflated windbag of a star circled a white dwarf grown heavy from the giant's effluvia. If it grew heavy enough, it would collapse and explode as a supernova. Though such things were always hard to predict, they might be in time for the show.

And there! Not a thousand astronomical units from the red and white pair was an older interloper, its spectrum tinged with orange. Its passage was distant and gentle enough that its planetary system was undisturbed - and this planetary system included a rare, tiny blue and white marble not so different from far away Earth.

Ellen turned all their thousand eyes in that direction. It was her initiative, but there was no conflict - such design problems had been well worked out even before they had moved out of the Mind of Mars to seek adventure in the real cosmos with nanocell bodies. This blue green world they saw was teeming with life by virtue of the oxygen in its spectrum, but had it evolved intelligence?

Close enough to the orange star for heavy tides, it had a large moon locked in synchronous orbit of about a day and a half. The star's gravity tried to stretch the system, adding orbital energy which the tides in the planet's ocean tried to take away, pounding on its continents - neither, David thought, would win their argument in the lifetime of the orange-tinted star.

*Remarkable, Ellen, to chance upon such a world so soon in our exploration of the Whirlpool.*

*But, David, what a dangerous place indeed for it to be!*

David agreed. That incipient supernova should soon reset any biological evolutionary clocks in the area. The white dwarf had already grown to an almost unstable 1.44 solar masses, and the giant's atmosphere continued to slosh out of its Roche lobe, adding more and more mass.

Collapse was inevitable, but when? The model was too sensitive to a myriad of conditions and the supernova might have already happened, or it might not happen for another hundred thousand years.

\* \* \*

In one of her earliest memories, the ones you never throw away or store elsewhere, Ellen had been a ranger at Mt. Hood and rescued an orphaned bear cub. Despite geological warnings that an eruption was about to occur, she had been told to return it to its environment. After the eruption, she found its charred body with the beacon still operating. What choice would it have made if it could have understood? "Let nature take its course" was the rule then and wisdom now; but sadness still held her.

David, not snooping, but aware of her as always, prodded her to reduce the output multiplier of her emotive subroutines. *Silly*, she thought, she had left it on high from the lovemaking. She imagined a strong cup of coffee, and that chased the blues away. Contentment returned.

Long ago, unable to resolve the problem logically, they had simply decided that their place in things was to let the universe unfold *its* will and watch. But since it was their rule, and they were a hundred million years away from any human critics, they could make exceptions.

Curious, David and Ellen reconfigured themselves into a great conducting loop and soared in the plasma currents of the cluster, gently bending their path in an arc many billions of kilometers in radius toward the golden sun of the little blue world.

The data they gathered confirmed early hopes and fears; the world was inhabited. A race of gracile, vaguely avian centauroids lived in a metastable system of low-technology tribal cultures which, from the ruins they could see, had lasted for thousands of years. Cycles of conquest, decay, and rebirth would allow little progress toward the technology those beings would need to survive.

Reaching the star, they parachuted through its ionic wind, slowed to a planetary pace, and drank in the light

of the star, giving trillions of trillions of tiny flywheels their fill. They felt powerful.

Then they sailed to a chance comet and devoured it as it bulled its way through the starwind back to its cryogenic lair. A year later, the comet was a shining sphere, composed almost entirely of their nanocell doppelgangers, and went off to convert some of its fellow comets to their purposes.

Thus, they built a great telescope system at the edge of the planetary system, to observe everything from gamma rays to quasistatic currents. Soon, the vast storehouse of memory which had followed them as photons would be collected again, augmented by news of home and beyond. And thirty million years from now, the great eyes and ears of the Milky Way would learn of their adventures and spread the word to the minds of a hundred billion worlds.

But that would have to wait. The nuclear weather inside the nearby massive star was as chaotic and unpredictable as rainy days in the Minnesota Augusts of David's childhood. If there was to be any data from the blue green world, they'd best get it with what they had while it was still alive.

With a fountain of ions, their machine pushed them toward the golden sun, and they curved through its solar wind to reach the life-world.

\* \* \*

Modani saw the ruffians before they saw him, and had a bolt on his bow in the flick of a crest. Nonetheless, they continued to shadow him, racing along in the brush parallel to the road. *They could not keep that up and remain quiet*, he thought, and he broke into a light trot.

An arrow whistled by him, with the black and red feather's of Drua's cult. Superstitious mystics! Fear tugged at him. That group preached the strong should rule the weak, and resented the increasing influence of technicians. Which meant they would resent Modani, if they knew him.

*No*, he thought, *it was not so romantic when one who ground glass well stood equal with powerful warriors*. But most people were not warriors, and bit by bit, through the central council, the guilds had a crest-standing strength of their own.

Another arrow brought him back to reality; no guild help today! Enough of philosophy; more likely these hoodlums merely thought they had a right to his purse if they could take it. He'd been a racer in his youth and had kept up with it after a fashion on the odd rest day. The young ruffians would be surprised to see an oldster pick up the pace so!

As he did, they broke cover and scrambled after him. Indeed, they were mottle-crested young - but heavy with the indulgence of the undisciplined strong. He increased his distance, gauging his own endurance carefully. He could not, nor would he run forever, so he looked for opportunities.

After a bend in the road, he spotted a large Athota plant circle - one of the trunks was down, making a door, and there were gaps between the trunks for shooting arrows. Excited by danger and angry with the degenerates, he dove into this natural blind before they rounded the bend and plotted his ambush.

They galloped along in clouds of dust, puffing with fatigue. They wheeled and reared, confused at his absence. Then they saw the Athota circle, but too late. He put a bolt into the flank of one of them and the neck of the other. *Maybe they would respect that!* he thought. At least they fled squawking, in pain.

Still nervous, but urgent in his errand, Modani left the Athota plant circle and continued down the road for Omphan in the fastest cursorial trot that he could sustain.

\* \* \*

"Look," Ellen exclaimed. In the form of a flock of local avian life, their eyes turned to a fertile valley just north of the south polar glaciers, between two dramatic mountain ranges, one folded, the other volcanic, and they wheeled in the sky as one, descending to spy on its villages and farms. They drank in the smells and sights, the culture and language, the sounds and music. David dipped into his memory and relived the wonder of one who had seen thousands of crystal blue lakes ringed by great white pine trees in his youth, and could spend hours in contemplation of yet another.

While their conscious minds wondered, their myriads of subroutines were busy with the data coming in. Flying insects gave them the key to the biology of the land below, and samples of the blood of its dominant vertebrates. They saw a great stone temple with handwritten scrolls, and learned the world was called Li and the people, Tha-Li. They perched for days in the marketplace and the temple to learn its brand of wisdom. Then the flock that was David and Ellen flew out along an uncrowded path to the countryside, took the form of the visitors from a different part of Li and began walking back to the village.

\* \* \*

Preoccupied with Sani and his burden of painkilling medicine - which some of Drua's cult might mistake for wealth to be plundered by the right of might - Modani had trotted well past a finely dressed Ixoran couple before he realized something was wrong. After a moment of indecision, he quickly retraced a few strides back to them: a silvercrest and a gold, decked out in folly. He would not have their blood on his conscience.

"Forgive me, Gentles, but you should not be seen out here like that. There are those around who would kill you for it!"

The couple clicked their beaks in surprise.

"Our apologies for whatever offense we have given, Gentleone," the silvercrest intoned. "We are new in this land, so please educate us to our danger, whoever you are."

It was Modani's turn to click in surprise at hearing such a natural Thocan accent from Ixorans. "I am called Modani, Gentles. But, the eastern cape you wear, with its high collar and cuts at each hip! And you are weaponless! Do not think your people's conquests have been forgiven by the followers of Drua's cult in these parts."

"We heard little of this in the town," the silvercrest said. "We came to study your people and thought we would most easily fit in as eastern visitors, whose questions would not seem too ignorant. This Drua is news to us. Do you credit his views yourself, Gentleone?"

"No," Modani replied softly, "I put my faith in chemists and in the school of experience. I think the change you easterners brought was healthy, but I am quiet about such views in the Thocan countryside! The livelihood of priests is threatened and their ambitions are not kept in check by fear of their own lies." He snorted in contempt. "But take no greater comfort in the fanatics who actually believe their cant; for, if anything, they are even more dangerous. Even I was pursued today, by bandits associated with Drua. Please disguise yourselves or you, and I, may be killed!"

Their crests rose in mild surprise. He blinked hard at such ignorance and flipped his own in condescension. Despite the cold, the couple shed their cloaks immediately, revealing fine linen shifts and rich woven back blankets with elegantly restrained silver embroidery, still a rich attractive nuisance, but not so obviously foreign. Something seemed to go between them as they momentarily touched hands, and this made Modani think poignantly of Sani.

He flicked his crest in an approving farewell and said, "Now Gentles, you must excuse me. I would talk, but my mate is deathly ill and I am bringing medicine," then turned to resume his journey.

\* \* \*

Though David and Ellen, with the wisdom of ages at their disposal, discussed billions of options through parallel optical channels at near lightspeed, the question was simple:

*Would it bother the dance of the cosmos if we help?* Ellen asked. *Modani has befriended us, with no interference on our part, for a perfectly moral and sentient reason. That makes it different; a friend is not a specimen. This matters to me!*

*But the supernova!* David replied. *Why save someone now, only to have them die even more painfully of radiation poisoning? Or do we try to stop a supernova, too and alter the evolution of an entire galaxy?*

*David, this galaxy will evolve anyway. Maybe not the same way, but so what? Anyway, by the laws of chaos, even the littlest conscious thing we do might eventually change things more than a supernova. Besides, delaying a supernova would be an interesting project. I'm not sure even we could do that!*

*There might be another way to handle the Supernova,* David replied, *but Modani and his people would have to be mentally strong enough to learn, very quickly, that the universe is much different than it has always been to them. We may have to destroy their culture to save their lives.*

*Perhaps not. The first step is Sani's illness. Let the new patterns form from there.*

\* \* \*

"Pardon us, Gentle Modani. I am Daiffidi and my mate, Ellani," the silvercrest gestured to his companion, "is a physician of some ability, and I know a thing or two as well. Perhaps we could help you, who have been generous with your advice for us."

The gold moved her hands and produced a seaflyer by some conjuror's trick. Modani thought momentarily that these people were just the type of charlatans that should be avoided at all costs. But then the seaflyer quietly and purposefully flew on toward the hut. What conjuror could make it do that? Despite his rational philosophy, he did not dismiss the gods entirely; he had only a lack of evidence. But here might be evidence! He pranced nervously.

The one called Ellani read this tension and sang the song of jest. "Forgive my theatrics, Gentleone, but that bird was, well, part of me. It will look in on Sani to see if we need to make haste. Please don't worry; it only looks like magic. We have much to tell you, friend."

They claimed no magic, but what art could do that! "Much indeed!" he stammered, "But we should hurry."

Ellani only fluffed comfortingly. "Sani is asleep and does not suffer now."

*How could she know?* Modani wondered. But he led them at a normal pace.

\* \* \*

Once at the hut, Daiffidi took up immediately with the young ones. Modani and Ellani went behind the rude curtain, where the gull perched on the rim of the sleep basket in which Sani curled. Ellani held out a hand. "Your lessons begin now, Gentleone."

Ellani displayed a posture of simplicity to him, and the bird flew to her hand.

It dissolved into a sphere of white and melted into her hand, which became empty as if the bird had never existed. It was too much.

Modani fell upon the floor and wailed in the minor key of abjection, his mental universe crashing down around him as he uttered the formulas he had learned as a youth. "Forgive my unbelief, I pray. Forgive my lack of sacrifices. It is my fault, not Sani's; curse me, not the one who is faultless."

But the presumed god, Ellani, fluffed in disappointment and frustration, crest down in despair at his obeisance.

"No, no," she protested. "We are just very ancient people who have learned a few wonderful tricks through the ages."

Modani looked up, crest splayed in embarrassment.

Ellani smoothed it as a parent would a nestling's.

\* \* \*

A thousand astronomical units away in the heart of the distended red star, nuclei roared from collision to collision like lions caged in desperately little space. The worst of these rattlings made their torturous way through dense stagnant plasma to the outer layers of the star. Free of the compressed core, the eruption burst forth and roiled the great distended atmosphere. Gas slopped gas over its gravitational border and spiraled onto its dying white dwarf companion.

A lesser star might have gone nova and blown off the excess in a self-extinguishing spasm, but this white dwarf was heavy and drank deep from its companion; the infalling hydrogen and helium sustained a stellar atmosphere thick enough for a gently pulsing fusion reaction. A few kilometers deeper, the helium ash of this fusion, fused into carbon, nitrogen, oxygen, and neon. Below that, the core of the white dwarf, already dangerously massive and degenerate, grew even heavier.

David and Ellen's telescopes noted the flickering, and updated their model. It could not be too long now - a billion seconds, perhaps.

\* \* \*

Ellen saw Sani stir from her fog of pain. A brief ripple of uncertainty went through Sani's crest and Ellen took her hand from Modani's crest. "I'm afraid I've disturbed your mate."

The Tha-Li woman made a gesture of unconcern. "My pardon, Gentleone, but what did you do?"

Crest and featherfur rising in hopeful anticipation, Ellani produced and absorbed the seaflyer.

"Marvelous!" Sani even managed a chirp of delight. "How did you do it?"

A volume of infrared communication passed between Ellen and David in a millisecond; it was review - they had already made their decision.

"First," Ellen said, "we must be the greatest secret of your lives, because what we are and what we have would change the pattern of your race. So please hold all this down the gut. Understood?"

Modani nodded, but Sani's crest rose a bit.

"Would that be so awful? I knit, but while I dream of many patterns, only a few get finished. The children need to eat," she clicked apologetically. "I think what our culture might become on its own is like some big pattern in the future, which we may or may not finish. Is so abstract a thing worth the hunger of even one child?"

"It is a hard choice, Sani," Ellani agreed. "Yes, some pattern will develop regardless. But think of the millions of lives that have been spent through your history to get you this far. And look at your priests and kings; some are good men, no doubt, but would you trust most of their lot with the abilities we have? Or would you have us reign like gods, picking, choosing, disciplining and inevitably remaking you into our image?"

Sani's crest fell back. After a long silence, she said. "I understand. But I ask you, whatever you are, to pity the children who may die."

Ellani nodded gravely. "We promised we would save Sani, and that means save your world as well. It's a somewhat bigger project than you can now understand, but, Modani, if you and your family will keep our secret, we will do it."

Modani held still for several heartbeats to show contemplation, then flicked his crest in agreement.

Ellani's featherfur suggested motherly understanding. "And yes, Sani, we pity all those who suffer and die. We were once flesh and blood, just as you are..."

\* \* \*

Everyone watched the operation, magnified and displayed on a large flat screen grown by David, who narrated for the wide-eyed tall-crested young ones.

Ellen laid a finger on Sani's tumor, and sent some of her nanocells in through the pores under Sani's featherfur. Using ultrasound, she found the nerves and blood vessels that served the tumor. At incredible speeds, her nanocell constructs severed and cauterized the vessels, starving the tumor. She found where the tumor was pressing Sani's spine, and busily ate it away, sending the debris into a limbic vein system. Normal cells began dividing immediately to replace the tumor.

*Something in their past evolution prepared the Tha-Li for massive cell replacement.* David noted.

*Li is passing through a spiral arm and has drifted through young star clusters for millions of years,* she replied. *More than one supernova may have helped select survivors.*

Ellen made a special nanocell that included a diamond stylus to serve as her tool, and then, atom by atom, she charted the proteins of a cancer cell and found out how it was fooling Sani's immune system. She sent nanocells to the organ which ran Sani's immunological defenses and made a few slight improvements. With their chemical blindfolds removed, Sani's own scavenger cells attacked the cancer cells with impressive efficiency.

Job done, Ellen's nanocells rushed back to her finger, and her host's beaks clicked with surprise and happiness.

"What," Sani inquired following all the congratulations, "is it like to have such powers?"

"It is," David answered, "like having an almost infinite set of choices and trying to decide what to do, or not do with them. You worry about the non-choices forever."

Sani's crest fell a bit. "You don't sound entirely happy," she clucked.

Ellen gently stroked the featherfur on Sani's forehead, and cooed. "Don't worry. We can tell ourselves to be happy, or even tell ourselves to just not think about it. Then everything is fine."

\* \* \*

A thousand astronomical units away, another David and Ellen reformed themselves in the cells of their communications base. They shared anticipation. The best part of splitting themselves this way would be the thrill of discovery when they rejoined the selves still on Li. Being two places at once was nothing particularly new to them, but this would be a significant separation in distance.

They expanded the communications base's thermonuclear powerplant and diverted work to an ultra-efficient microwave transmitter with the capacity of thousands of terawatts. When it was done, David and Ellen formed themselves into netlike fabric, spread themselves in front of the beam and were thrown toward the incipient supernova by a blast of microwaves too big to pass through the tiny holes of their net.

The universe contracted all around, and the great angry red star, now blue-shifted into the x-ray spectrum, rushed toward them as their own tiny microscopic lasers twinkled, acting in unison to urge the odd atom or dust mote out of their way.

Even a hundred astronomical units out, David and Ellen saw that the space around the red giant was rich in matter. Approaching from the white dwarf side, the accretion disk looked like a dark line against the surface of the reddish giant star, except where it was closest to the white dwarf and hottest. To sensors shielded from the direct light of the stars, space was filled with the reddish glow of discarded atoms.

Many of these atoms were already ionized by the ultraviolet part of the white dwarf's spectrum, so, to their magnetic field, it was like falling into another pillow, or diving into molasses.

*It's going to be very, very close, David.*

*Yes; there is perhaps already enough mass in the accretion disk.*

*But not on the star itself. It's still below Chandrasekhar's limit. If we were to ignite it now, in a nova, it would blow the disk and some of the companion's atmosphere away.*

*And there'd be a little time even after it passes the limit?*

*Maybe, Ellen. But the timing depends on things inside the white dwarf we cannot possibly know. We'll have to control things in real time.*

*Leave a relay?*

*Maybe...*

*I am not afraid, they told each other.*

The fall through the giant's hot sticky plasma breath toward their ticking cosmic time bomb would take years, but there was no help for that. It was, in fact, enough time for even their long lives to pass before them in

detail.

\* \* \*

Modani's crest stayed rigidly poised between up and down as Daiffidi explained the danger from the tiny red disk in the sky that did not move. The telescope made it easier, but still, it was a stretch of comprehension. What he grasped was that stars could explode in big ways and small ways, and that the tiny white speck next to the disk that did not move could explode in either way. It was particularly hard to understand that that tiny point was heavier than the huge red egg.

But he had no basis for questioning his benefactors as Daiffidi told them how to build shelters that would protect them if the star exploded in the small way. They would need to live underground as a separate sun scorched the land for a few weeks.

"We should survive that," Sani remarked, full of the confidence of restored health. "Especially if we take seed stock into the shelters with us."

Modani touched her bill with his. "I think there is more. Daiffidi, there is no guarantee, is there, that such preparations will be sufficient? In the worst case, if the star explodes the large way, what will it be like?"

For one of the few times in the year Modani had known him, Daiffidi hesitated. "There will be burning," he finally said. "The neutrinos themselves won't quite kill you this far away, but some of the atoms throughout your world will become radioactive. A gravitational wave will flex the planet. The temperature of your planet's mantle will increase a degree or so. Magma will start moving.

"A few days later, a blast will reach you. X-rays and Gamma rays will cascade into your upper atmosphere and it will appear to burn. A blast of photons will scorch your planet's surface. But no one will be here. In the far reaches of your planetary system, we are preparing a fleet to take you to a new world before that happens. You'll have a badly shocked culture, but better than none at all."

But Modani resisted that thought. "What would happen if we stay with our ancestors?"

Daiffidi showed discomfort. "Things will seem to back off for a bit, but silent invisible and lethal particles will sweep through as the star dims to merely the brightness of another sun in your sky. Within a week of that the star will become a visible hairy globe that will increase in brightness again until, for several weeks, it floods you with a million times your own sun's brilliance. The deep sea shelters will last the longest, but we think the oceans may boil away, eventually. It will take years to dim; the planet's surface will be cleansed of everything."

So they would all become Daiffidi and Ellani's foundlings, shorn of their world, their history rendered quaint and meaningless. A great emptiness came over Modani.

"Don't give up hope yet," Ellani said.

\* \* \*

David and Ellen fell on the moon of a subgiant planet in a delicate resonance orbit that skirted the edge of the red hot vacuum disk around the two stars. They began immediately to devour the moon. In an hour, their two hundred kilograms of nanocells became four hundred. In three days, they became as massive as a small moon themselves. They spread themselves out in a great sheet of matter, balancing between gravity and photons, shielding the planet from the glare of the star, drinking in the wind from the disk and channeled it down to the planet, using the energy of its fall to the surface to run a vast refrigerator, pumping heat out the other side.

In a month, the planet had gained enough mass to affect its orbit. In two months, the resonance was broken and it was on a trajectory which would take it first through the outer layers of the red giant and then onward toward the white dwarf.

\* \* \*

On a crisp clear night, Modani watched the star and tried to imagine what was happening. He felt a confusion of feelings. Yes, he felt pride in the telescopes he had built which had shown exploding stars and discredited the cult of Drua, but that had been Daiffidi and Ellani's knowledge. And he felt pride in the shelters built in caves and in great tubes on the sea floor. But he and Sani were too healthy and active for their age, something which had begun to attract notice as their friends passed on. Little by little, they had withdrawn and now kept to themselves and their small fields. Thus it was a surprise to have folk approach from out of the night. But caution turned to happiness when Daiffidi, Ellani, and Dosni identified themselves.

"The years treat you well, Gentleones," he greeted them, touching beaks with all.

"Ah, years ignore us, but you have fought them well. And Sani?"

"Still in the race, thanks to you. But we both see the finish line."

He brought them in, and helped Sani up off her blanket to let her touch beaks with neck unbent.

"We understand. That is what we've come to talk to you about. We think Dosni is well prepared to take over your duties. And we have a promise to keep."

"Ah, elders," Dosni said, "To speak of promises reminds me of my mate at home. But before I go, I have a request. You have told us you were once flesh and blood, like us. What did you look like?" Dosni's eyes reflected the sunset from the hut's single window, and so seemed to glow with curiosity. Modani flicked his crest in amusement at his son's insatiable thirst for the new.

"Do you promise not to be afraid?" Ellani replied - part in jest, Modani thought.

The young one's featherfur ruffled down in embarrassed assent.

"You too, Modani?" Ellani asked. He nodded. *What had he to fear?*

But, before his eyes, their perfect Li bodies melted into a hairless, fleshy lipped, biped half again his size, with a bulging skull and odd flesh protuberances. He was prepared, intellectually, for the difference, the alienness. But he had been thoroughly imprinted with the old fears of devils, monsters and jealous gods as a young Li, and his featherfur fluffed out involuntarily, embarrassing him. In spite of himself, he backed away.

Dosni's crest was relaxed, however, and his eyes were bright and curious. He asked Daiffidi and Ellani many questions, which they answered without embarrassment, which Modani had always been too deferential to pose. But Modani made no effort to stay his son. His own reluctance to ask personal questions was the imprint of a more cautious time and a more stern upbringing.

"Father, I need to go back to my own house, now," Dosni said at last, long toward midnight. Modani nodded in assent. Dosni lived with his young mate a short trot down the trail, not a dangerous journey even in these times, and there was work to be done tomorrow.

So, to Modani's relief, Daiffidi and Ellani resumed their Li form and they all made farewells to Dosni. Afterwards, the four remaining friends went into Modani's house and settled down and pushed sucking

needles through the skins of fermented tholfruit.

"What promise did you mean," Modani finally asked, slightly less inhibited and still unclear as to what Daiffidi's greeting statement had meant.

"We promised to save Sani's life," he answered, simply.

"But you did!" Sani chirped.

"For the tissue-thin slice of a world line. We can do much better than that, but there is a cost to an indefinite life span which is very hard to explain. You must imagine yourselves going on without end, and ask yourselves if that is what you really want."

"I think I understand," Sani chirped in low, thoughtful tones, "that to live in such a manner is both its own blessing and its own curse. I know the blessing, but what is the curse?"

"There is," Ellen added softly, "some wisdom in your myth of a musician who wished for wings, and, having her wish granted, loved flying so much that she never used her hands again..."

"...and so became the mother of all flying things," Modani added. "I think I understand the dilemma. In fact, by just making the offer you have put us in it, have you not? For if we refuse now, our end becomes not simply an inevitability, but a form of suicide."

"My mate!" Sani interjected. "That's not fair to our friends. Daiffidi, we have suspected for some time that you could do this for us," her crest made an ironic half rise and settled, "or to us. And we have not asked. Someone could call that a form of suicide - being too polite to ask for our lives. Well, I am curious and want to know more than I have life in which to learn. How is it with you? What is the problem?"

"We all exist," Daiffidi said, "as patterns of data and logic, systems of input and output which can include biological parts or not. It doesn't matter as long as the same sensory input leads to the same conscious image. We can exist in any calculating machine that is large enough, and for Ellani and me, these assemblages of nanocells give us the greatest independent physical capability.

"We worry about why we keep going, whether our existence serves any significant purpose. Can anything in an infinite cosmos claim to be significant? We accumulate knowledge, but it all falls within known bounds - it is like numbering all the points on a line. But however pointless existence is, there never seems sufficient reason to *stop* existing." He flipped his crest in a yes-and-no gesture. "So we go on."

"It's a logical trap, really, but I doubt it is possible to appreciate the full complexity of it without having the logical resources we have."

"We shouldn't be too discouraging," Ellani added. "We don't worry when we don't want to worry, we don't feel sad if it isn't convenient, and we've had an awful lot of fun. This living forever isn't bad at all, but it is a decision you need to make, and, in our experience, it's a decision that doesn't get unmade."

Sani closed her eyes completely, then opened them again. "I'm not sure."

Modani's featherfur bristled again with memories of village stories about immortal ghouls that sucked life fluids from the living like juice from a tholfruit. "Gentleones," he said, "I am overcome. Forgive me if I absent myself a moment for nature and to find the rightful place for my featherfur."

Everyone nodded at him and he left the group to be alone in his garden for a few moments, fertilizing this

and that. He told himself over and over that this strange offer was from his dearest friends. Sani and he could live forever. But at a price - a price that would clearly mean giving up much of what he thought he knew about life. Could he do that? Could he embrace such a strange future?

The larger moon hung low in the east, a bright crescent the size of a child's kicking ball held at arm's length; they had stayed up late and the sun would soon rise. Modani had no trouble in seeing the craters and mountains on the back side, nor the minuscule disks of the nearer wanderers; it was as if there was more light. His hindquarters shifted involuntarily and his crest rose.

Slowly he looked up. The tiny red disk which did not move was now a brilliant beacon, a searing point of light in the west that cast its own shadow.

Keeping himself as calm as he could, he turned toward the house and called out.

"Sani. Gentleones, it has started..."

\* \* \*

A white dwarf is a small target. Tides stretched the planet one way and squeezed in another. Great magnetic fields formed and whipped up an uncontrollable magnetic storm. Radiation from both sides lanced through David and Ellen faster than they could repair themselves. Still they fought to keep it on course.

The dwarf flared and the planet broke, disrupted as billions of atmospheres of pressure blasted through its ends. All became plasma, trapped in fields beyond any control. There would be no escape. To preserve themselves for a few more moments, they contracted to an essential core and used the mass and energy of their dying outer layers to cool the inner layers.

*Have we succeeded, David?*

*I think so, but it all depends on how advanced the dwarf's core is, and how much matter we will blow away from it. Thoughts were harder now, as cells struggled to contain damage and redundant pathways were lost.*

*We are evaporating, Ellen observed. It seems strange. I wish we could send this experience to the other David and Ellen.*

*If we could, we would send ourselves. Since we can't, the logic is that we accept what must happen, and enjoy it. I think they will understand and be happy for us. Since we are them, we would understand in their place. That is all they need to know; that it can be done. They will know that... that last logical barrier to will can be broken.*

*David, I'm losing memories. I'll hold onto you until the last.*

*And I will hold onto you. So, after a hundred million years, to end. I am at peace. And free. Free... Farewell.*

*Farewell.*

\* \* \*

Photons ran rampant inside the white dwarf, chipping off pieces of nuclei here and there, which were gobbled up by larger, more stable nuclei. Here, a neon nucleus collided with a helium nucleus head on, and before they could disentangle themselves, a neutron stole away with their excess energy, and a magnesium nucleus was born.

An iron core started to form, the harbinger of catastrophe imminent. Iron had no excess energy to give in support of the hungry masses pressing upon it. The star began to shrink, compress, and burn hotter. Soon the remaining nuclear fuel would detonate. Immediately. Devastatingly.

But on the surface, triggered by the disintegrating planet with far more hydrogen and helium than the white dwarf could digest in its usual incremental manner, another explosion was already in progress, throwing matter out and away. A glowing cloud, bright as a million suns, fled out from the white dwarf. The influx stopped. The star stopped growing poised on the brink of disaster.

On Tha-Li, four beings watched the sky.

\* \* \*

"You should go to the shelters," Daiffidi said.

Modani's beak dipped to him in negation. "We have agreed to leave the space for younger Tha-Li. I feel, one way or another, we are done with this world. Now, tell me. The travels we have made with you, the gardens we have grown together, the troubles we have taken to fend off robbers without killing them," Sani asked. "If we became like you, would we remember all of this?"

"Yes, you will," said Ellen, "and more, much more."

They were silent for a long time, watching the new sun burn. Then Sani's crest raised slowly in a coy humor. "Will I be able to mate again with my Modani?"

Ellen smiled. "For eternity, if you want."

Her crest rose high, her eyes went open and bright. "Then, yes, take us with you."

### **Afterword:**

This story was first published in an anthology, *The Age of Reason*, edited by Kurt Roth, at SFF.net in 1999. In addition to making supernova astrophysics an experimental science it touches on some of the "big issues," like "what does it all mean?" and "where are we going?"

I was asked to briefly elaborate on some of the science in the story. Hopefully the following will prove useful, or at least point people in the right direction.

*A hundred thousand years before Sani's cancer took hold, the great blue disk and ultraviolet arms of the majestic Whirlpool galaxy filled David Martin's field of view.*

The Whirlpool galaxy is about 23 million light years away, south of the tip of the Big Dipper's handle. It is about half the mass of the Milky Way and 70% of its diameter. Assuming David is traveling near the speed of light, he is only a little more distant from the galaxy than the visible spiral is wide. Google "Whirlpool Galaxy."

*Orienting the superconducting loops in every nanocell of his body...*

David and Ellen's personalities reside in a swarm of trillions of "nanocells." These are conceived to be roughly the size of biological cells, but made of much sturdier stuff, and not permanently specialized. Linked as a data processing system, they form a supercomputer. As a physical system, the cells can join each other in almost any imaginable configuration. Read Kurzweil's *The Singularity is Near*, and project.

*...he tacked against the faint plasma breeze of the galaxy's central black hole, gradually bending his path toward his chosen decelerator.*

*Curious, David and Ellen reconfigured themselves into a great conducting loop and soared in the plasma currents of the cluster...*

When a charged particle (the "plasma breeze") encounters a magnetic field, it is deflected one way, and, action equaling reaction, the object generating the field is pushed in the other. A current loop creates a magnetic field with a north and south pole, much like a bar magnet's.

*Most of a billion years of experience was set carefully aside from conscious thought so that they could enjoy real-universe sensation again.*

Emulated emotions, such as boredom, can be turned off, when inconvenient. In this case, the fun of experiencing something anew can be lived over and over.

*As they left the region, they reformed themselves into a thousand telescopes, which they spread into a globular constellation a hundred million kilometers across; a giant's eye...*

David and Ellen can see Sani's world by forming a large optical synthetic aperture telescope. The wider the telescope, the smaller the objects it can see. For the mathematically inclined,  $R \approx 1.22 \lambda / A$  where R is the resolution in radians.  $\lambda$  is the wavelength of light and A is the telescope aperture. To get actual size, rather than the angular size, multiply by the distance to the object. In visible light (a wavelength of 500 nm, or  $5 \times 10^{-7}$  m), a one-meter-wide telescope would be able to resolve objects  $5 \times 10^{-7}$  radians apart. A 100 million kilometer-wide telescope ( $1 \times 10^{11}$  m) might resolve 5 km sources at 100,000 light years. That's ideally - the source must provide enough photons for all the elements of the array to combine, which limits this trick to bright objects.

*There! An old ruddy, overinflated windbag of a star circled a white dwarf grown heavy from the giant's effluvia. If it grew heavy enough, it would explode as a supernov...*

The white dwarf would become a "Type Ia" supernova. Wikipedia has a good article.

More massive stars form ultra dense iron cores by fusion reactions of lighter elements. The cores collapse when they become more massive than Chandrasekhar's limit (Google "Chandrasekhar"), about 1.4 solar masses, starting a process that leads to the explosion we see and a neutron star remnant.

A Type Ia may not go that way. A Type Ia supernova starts out as a white dwarf a little less than Chandrasekhar's limit which then gains mass - generally hydrogen and helium from a nearby companion star that is losing mass in its red giant stage. This forms a layer on top of the carbon and oxygen "ash" from previous fusion reactions. As the white dwarf gets close to Chandrasekhar's limit, the picture gets unclear. But the fusion reactions that create heavier elements may happen all at once in a thermonuclear explosion that "deflagrates" the star before it can collapse into a neutron star. Since this always happens at about the same mass, and produces supernovae of about the same brightness (about 5 billion times solar luminosity at peak), Type Ia supernovae can be used as "standard candles" to gauge the size of the universe. Google "standard candles."

*...before they had moved out of the Mind of Mars to seek adventure in the real cosmos with nanocell bodies.*

In this future history, the *Mind of Mars* is a supercomputer on the moon Phobos in which billions of human-descended Martians live as computer programs in virtual worlds of their own choosing. They can go back and forth from biological, or other technological bodies, at will. It's mentioned in *After the Vikings*

(ScorpiusDigital.com).

*Close enough to the orange star for heavy tides, it had a large moon locked in synchronous orbit of about a day and a half. The star's gravity tried to stretch the system, adding orbital energy which the tides in the planet's ocean tried to take away, pounding on its continents - neither, David thought, would win their argument in the lifetime of the orange-tinted star.*

Imagine our moon in a geosynchronous orbit like communications satellites! We wouldn't have the twice daily lunar tides, but we would still have solar tides, which are about half as strong. Modani's world is closer to its dimmer, but not that much less massive, sun. Its solar tides are about as strong as our combined lunar and solar tides.

*Reaching the star, they parachuted through its ionic wind, slowed to a planetary pace, and drank in the light of the star, giving trillions of trillions of tiny flywheels their fill.*

A nanoscale flywheel composed of a single molecule is very strong per unit weight and can store much more energy than any conceivable chemical battery.

*We may have to destroy their culture to save their lives.*

When nuclear scientist Enrico Fermi realized that both alien civilizations and interstellar travel were at least physically possible, if not easy, with sufficiently advanced technology, he asked "Where are they?" One possible answer is that they are or have been here, but are very careful to avoid disturbing our culture - the way a human scientist might not interfere with a colony of chimpanzees. In "Star Trek" lore, this is called "the Prime Directive."

*Daiffidi told them how to build shelters that would protect them if the star exploded. They would need to live underground as a separate sun scorched the land for a few weeks.*

To prevent the supernova, David and Ellen must trigger an "ordinary" nova, burning away the hydrogen and helium accumulating on the surface of the white dwarf. The result will be in the top range of ordinary nova luminosity, around a million Suns.

*"...In the worst case, if the star explodes the large way, what will it be like? ...the first radiation to escape the star will be neutrinos... The temperature of your planet's mantle will increase a degree or so, almost instantly. Magma will start moving.*

Maybe.

The nuclear reactions in the current model of a Type Ia supernova would still produce a lot of neutrinos, though maybe not as much as a core collapse. I've gone a bit beyond what I can show quantitatively here, though we have to allow some new astronomical discoveries to the hundred million years or so between our time and the story's!

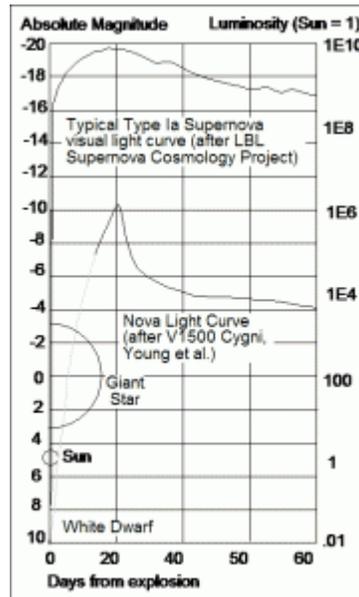
*"...seconds later, a blast of photons will scorch your planet's surface..."*

There should be a gamma ray burst as the shock wave reaches the white dwarf's surface. The "star" rapidly expands and, over the next few weeks, a huge ball of vaporized and highly radioactive nickel and iron will provide most of the energy. Big explosions take time.

*But no one will be here. In the far reaches of your planetary system, we are preparing a fleet to take you to a new world before that happens. You'll have a badly shocked culture, but better than none at all."*

Moving an entire planet's population to somewhere in space is not an exercise for those afraid of big numbers. But, when one does the math instead of arguing from personal incredulity, it isn't impossible at all. At this point, I'd like to recommend a couple of Arthur C. Clarke stories on this theme: *Rescue Party* and *The Star*.

I'll end with a graph of the luminosity of a supernova versus an ordinary nova versus days since the explosion. The left scale is in absolute magnitude - Google "absolute magnitude" for the Wikipedia article. The right scale is a log scale of luminosity with the sun equal to one.



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## ***Planet Killer***

by [Ges Seger and Kevin Grazier](#)

*Characters and situations originally appeared in The Once and Future War by Ges Seger*

**10 OCTOBER 2191**

**MSV PROCYON**

**250 LIGHT-YEARS FROM THE COALSACK**

"XO, we're not doing anything for a day or two anyway," Lieutenant-Commodore Bob Keith said as he and Executive Officer Kevin O'Byrne strode into the Officer's Wardroom, "Why should it matter how Science is mapping this star system?"

"Because they could be doing it a whole lot better," Kevin snapped.

Bob ignored Kevin's complaint temporarily in order to attend to a more immediately urgent matter. "Coffee?"

"Please. Leaded and black." Kevin snagged a table next to the forward window and stared at the (filtered) G0V star two astronomical units off *Procyon's* bow while Bob went to the coffee machines. On paper, *Procyon* could have traveled the 650 light-years from Mars to the Coalsack in a little over 100 days. Actual practice was another matter, especially when this was the first time anyone had ever attempted sustained faster than light travel across the Galaxy without benefit of a wormhole network. The Chief Engineer wanted complete, periodic, and frequent inspections of the stardrives — a sensible precaution, with the closest drydock nearly 400 light-years behind them and only enough spares onboard to rebuild both drives twice. The Astrogation team required complete, periodic, and frequent calibration checks of the nav platform — also a sensible precaution, since everyone onboard wished to return home at some point. The mission rules for both the outbound and return transits, therefore, required *Procyon* to stop in a star system roughly every ten parsecs to accomplish both tasks.

*And that, Kevin thought morosely, is why we're sitting around a star in the middle of nowhere twiddling our thumbs. Why can't people just live a little...*

"Here you go," Bob said, then he sat down himself.

"Thanks."

"So, XO, enlighten me on your proposal for planetary detection." Bob sipped his mocha before continuing dryly, "I expect this will be good."

"It is. Rerig a detonation laser for broadband EMP, then set it off. Three hours, four tops, you have position and doppler on everything in system. At least everything important."

Bob took another sip from his mocha and stared at Kevin over the top rims of his glasses. "You think every problem can be solved by the indiscriminate use of nuclear weapons, don't you?"

"Well, it's better than what Science is doing right now." Kevin O'Byrne, *Procyon's* second in command, was both aggressive and creative, sometimes at the same time. An excess of patience, however, was not one of his virtues.

"Faster you mean, not better," Bob corrected.

"A full-spectrum eight octant scan is rough enough without having the ship's computer tied up recalibrating the nav platforms."

"Could be worse, XO."

Kevin took the bait. "How so?"

"Somebody could be shooting at us while we're doing this."

Kevin smiled. "Point taken."

"Which brings us to my biggest problem with your plan." Another sip of mocha, and Bob continued, "With only 100 warshots per tube, we can't be popping off detonation lasers like cheap fireworks. Especially since we don't know if we'll run into Malzurkians."

However enthusiastic Kevin had been with his innovative proposal for using *Procyon's* armament to advance science, he couldn't argue with Bob's logic. To date, Mankind's only encounter with an alien race had taken place in 2178 when the Malzurkians had opened a wormhole near Jupiter and then attempted to destroy all human civilization in the Solar System. Humanity had been too busy fighting for its survival to bother finding out where the other end had opened.

Kevin sighed and slumped back in his chair. "You're right."

Bob took a long pull off his mocha and asked, "You know what your problem is, XO? You're bored."

"And what, exactly, was your first clue, sir?"

Bob snorted in humor at Kevin's dig and answered, "We're farther away from home than anyone's ever BEEN before, and instead of enjoying Creation, you want to do performance art with our main weaponry..."

JEDI, *Procyon's* artificial intelligence, interrupted the conversation at that moment. "Captain, Dr. Davies wishes to speak to you."

"Put her through."

The table repeater stopped being an electronic menu and displayed Dr. Pamela Davies down in the main science lab. "Captain, you can tell Mr. O'Byrne where he can stick his nukes. We've found planets."

"He's right here with me. Tell him yourself."

Kevin attempted to steer the conversation back on topic. "How many planets?"

"Two so far. A jovian at roughly 3 AU, and a terrestrial at 1.2."

"That's the outer edge of the Goldilocks Zone for this star, isn't it?"

"It is within its habitable zone, yes." Pamela subtly emphasized the words "habitable zone" to indicate exactly how she felt about O'Byrne's cavalier astrobiology nomenclature. "Captain, we've taken spectra from both planets, and something's not right in this system."

"Elaborate on 'not right'."

Pamela took a deep breath. "Okay. Starting with the gas giant, it's got a fairly standard atmosphere to a first approximation. When you look at it closer, there's a very strong helium-3 line."

"Your point? All gas giants have helium-3. Mars used to mine tons of the stuff from Jupiter when the Cislunars shut down all the regolith processors..."

"No, captain, you don't understand. The amount of helium-3 required to generate this spectral response is orders of magnitude beyond anything Jupiter has. It's not ... natural."

Bob and Kevin looked at each other, then back at the repeater. "Helium-3 is a decay product of tritium," Bob speculated out loud.

"That just shoves the problem back one level," Kevin offered. "How did that much tritium get in its atmosphere to begin with?"

"Much as it pains me, Captain, I have to agree with Mr. O'Byrne. We may want to wait on that problem because of the inner planet. Its spectrum looks an oxygen-nitrogen atmosphere, diagnostic that this was an inhabited planet — plant life at the very least. Still there are anomalies that we can't resolve from our current position."

"If you're asking to move closer, consider the request approved. Download the planetary state vectors to Lt. DeMarco so she can start on a system ephemeris. We'll let you know when we're in range."

"Thank you, sir," and Pamela killed the connection.

"Battle stations before we approach?" Kevin asked as he and Bob stood up.

Bob nodded. "Still bored, XO?"

Kevin smiled as he turned for the hatch. "Maybe next time I'll be careful what I wish for. Maybe."

\* \* \*

"Minus three gradient in five, four, three, downwarping ... NOW," Carmen Sanchez called out from Helm as she smoothly brought *Procyon* sublight 200,000 kilometers trailing and sunward of the inner planet.

Kevin swept a practiced eye across the threat board in Combat Information. "No targets, no active tracking," he announced.

Bob relaxed at his station. "Stand down from general quarters, maintain yellow alert. Science Center, your ship."

"Thank you captain," Pamela acknowledged. Orders now flew rapidly between Science and Helm as Carmen had to position *Procyon* to unmask various sensors during their approach. Drones shot out of *Procyon's*

missile tubes, and the ship's tactical crew in CIC directed them into appropriate orbits around the approaching planet.

"CIC to Bridge. I've got a good visual off the forward cameras."

"Pipe it up, XO," Bob ordered.

The main viewscreen jumped, and the expanding image of the inner planet began to fill it. Bob's stomach turned as he saw not the expected white and blue of an Earth-like planet, but a sickly brown shroud of clouds.

After a long moment, Carmen offered, "Doesn't it sort of look like Mars before terraformation?"

"No, Ms. Sanchez," Bob said, "Mars looked cleaner. Bridge to Science."

"Can we get back to you, Captain? We're a little busy right now."

*At the start of the mission, she would have told me to make it quick. I've made progress...* "Any better luck on atmospheric composition from here?"

"Much better. We're getting lots of NOX species ... nitric acid... No ozone, which is surprising for the amount of oxygen in the atmosphere. Plenty of ionizing radiation present, consistent with radioisotopes of carbon, nitrogen, and oxygen still in suspension."

Many more questions crowded into Bob's mind, but he squelched them all ruthlessly. *They're busy. Let them do their jobs...* "Thanks, Ms. Davies. Keep me posted, Bridge out."

\* \* \*

"The quick way of describing the inner planet's atmosphere," Pamela started in Main Briefing hours later, "would be 'radioactive smog.'"

"Like twentieth century California?" Kevin offered helpfully.

Before Pamela could follow up her withering stare with a supporting comment, Bob interjected absently, "No, that was just plain smog."

"Captain?"

Bob started as if from a daydream. *When did the cloud layer become radioactive?*

Pamela looked to her left and nodded to Dr. Mathews, who answered, "Our drones have taken *in situ* samples, and we've already run 'em through the mass spec. What we've gleaned from the isotope fractions suggests the event took place sometime between 500 and 1,000 years ago. Without a good handle on the intensity of the initial exposure, we can't pin it down any closer."

"There was also an awful lot of UV-induced chemical reactions going on either simultaneous with, or just prior to, the radiation event. We have no idea what the starting atmospheric mix was before things started happening."

"So what was the event," Carmen asked. "Global nuclear war?"

Dr. Mathews shook his head. "The isotope ratios are all wrong. We'd be seeing residuals for fission products,

fusion products, silicon, and other lithophile elements in the atmosphere as well."

"And in orbit," Chief Engineer Alex Duncan added. "If you can launch a ballistic missile, it's not a big leap to putting a payload into orbit. Where are the derelict satellites?"

"You're assuming our hypothetical culture developed in the same manner that ours did," Bob interrupted. "Until we get some more data points, that's not an assumption I'm comfortable making."

"What if they didn't do it to themselves?" Kevin asked.

There was a pregnant pause before Carmen voiced the subject which had already sprung to minds of all the military in the briefing room. "Malzurkians?"

"People. Time out," Bob said forcefully. Looking at Pamela, he continued, "Unless the Science Team has something else to report, we have yet to see any evidence there was sentient life on this planet, advanced or otherwise. It is useless to speculate who did what to whom when we don't even know if there was a victim."

"Hypothetically speaking, sir," Kevin argued. "During the war the Malzurkians used enhanced radiation weapons to clear the Mangala Valley beachhead."

"Then there's a quick way to settle this," Bob said, "Dr. Mathews. Assume a planet-wide bombardment using enhanced radiation weapons. Is the measured radiation spectrum from the atmosphere consistent with this hypothesis?"

"No."

"Is it consistent with any lesser usage of enhanced radiation weaponry?"

"No."

"What would be consistent with our measurements?"

"I'll take this one," Pamela said. "A supernova within ten parsecs could in theory account for all the observed damage in this system."

"Like Nova Orionis?" Kevin asked. The death of the star formerly known as Betelgeuse had been a spectacular learning experience for two generations of human astronomers, and the radiation pulse was still fifteen light-years from the Solar System.

"It came to a lot of our minds when we looked at the inner planet," Dr. Mathews said.

Carmen looked over at Pamela, a quizzical expression on his face. "Permission to ask a potentially embarrassing question."

"I'm not military, Ms. Sanchez, you need not ask permission."

"Which star exploded?"

There was a long silence as the scientists looked at each other helplessly.

"Good question," Bob mused. "From what I recall of my astronomy history, none have ever been recorded in this particular area."

"Exactly," Carmen said. "Any star going supernova within 400 light years of home should have been one of the brightest stars in our sky before exploding. Alpha and Gamma Crucis were still there when we passed them, and we still see Beta Crucis and Beta Centauri. That's all the known candidate stars between Sol and the Coalsack."

Kevin chimed in, "All that is predicated upon the idea that it was a Type II supernova, of course."

Carmen looked at Kevin quizzically, then over at Pamela. "There's more than one type of supernova?"

Dr. Mathews explained, "Indeed. Type I supernovae, for instance, occur in binary pairs — when a white dwarf is in a close orbit around a larger star. If the stars are close enough, the dwarf can accrete material from the companion star, until the pressure of the added matter overcomes the electron degeneracy pressure supporting it. The resulting implosion initiates a violent runaway fusion reaction and subsequent explosion. It usually blows the white dwarf apart, but in some cases can actually recur cyclically."

"But regardless, we still should have seen something. Right?" Carmen asked persistently.

Pamela turned to Bob and asked, "Do you need an answer right now?"

"No."

"Well, we need to mine what data we have and build computer models to tell you what happened here."

"Do you have all the data you need?"

"Are we operating under a time limit?"

"That's what I'm about to find out, Doctor. Ms. Sanchez, nav platform status?"

"Calibration's done. We're ready for the next leg."

"Mr. Duncan?"

"Starboard drive is secured and charging. We'll be ready to answer bells in three hours."

"I see no further reason we need to remain in system, then."

Pamela was now visibly annoyed. "Captain, I don't like unanswered questions. This whole system is an unanswered question."

"And perhaps someday, someone else will be out this way and take a year or two to nose around some more to solve it." Unintentionally, Bob's normally placid bass voice became tinged with iron as he continued, "The Coalsack is still 250 light-years ahead of us. Let's not be so excited that we lose focus on our primary mission."

Pamela looked down at the table. "Sorry, captain."

"Then let's get buttoned up and ready to go. Dismissed."

**14 OCTOBER 2191**

**239 LIGHT-YEARS FROM THE COALSACK**

The blast shield was down over the panoramic window in the officer's wardroom, as it usually was while *Procyon* was traveling faster than light. Lieutenant Kendra "Heater" Jackson contemplated this as she looked for an open table and said sarcastically, "Another day flying blind into the unknown."

Lieutenant Nathan "Cato" Perry rolled his eyes as he caught up with her. "You know what looking at FTL-induced aberration does to some people, or have you forgotten what happened to Ensign Varanov two days out of Alpha Centauri?"

"It was the only chess game I've ever seen him lose. This one?"

"Yeah." They both sat down at a table next to the window and Cato continued, "He lost because he was too busy reversing the polarity of his nutrient flow all over his queenside pawns."

"You didn't have to make him sit down so he was facing the window."

"Yes, I did. I wanted to win."

Heater frowned judgmentally at Cato, causing him to add defensively, "It's called 'situational awareness'."

There was a snort of humor from the next table over. Heater wheeled around to vent her sarcasm on a more personal target, only to end up face to face with a thoroughly-amused Bob Keith.

"Uh, sir!"

"I'll have to remember that trick. I'm not a very good chess player."

"Care to join us, sir?" Cato blurted.

Bob shrugged his shoulders, put his Bible on the table next to him, and stood up enough to turn his chair around. "Sure."

Heater stood up. "Lieutenant Jackson. I pilot Remora 3."

Cato joined her. "Lieutenant Perry. I'm the WESO for Remora 3."

"Ah," Bob said, pointing at Cato. "You find it, classify it, and jam it. Then Lieutenant Jackson kills it."

"It's a symbiotic relationship, sir," Heater acknowledged.

Bob laughed as he shook their hands. With nearly four hundred military and civilian personnel on board, he hadn't come close to greeting everyone currently assigned to *Procyon* personally. After sitting back down, he asked, "You've got face time with the ship's CO. Anything on your minds?"

"As a matter of fact..." Cato blurted. "Why did the Martian Space Force send a top-of-the-line battleship on its maiden voyage to the Coalsack?"

Heater rolled her eyes. Cato was very good at his job, but in most social settings he had difficulty suppressing his inner geek.

"Easy," Bob answered, "Because it was there."

Heater couldn't help herself. "Oh, you're kidding me. You're what Cato here is going to turn into in twenty

years."

Bob's eyebrow raised.

"Sir."

It was now Cato's turn to be annoyed. "Hey!"

Bob raised a hand and halted both of them. "Early in *Procyon's* design process, I specced out two separate designs. One was a fast battleship, and the other was optimized for long-range galactic exploration. You have no idea how surprised I was when both specs turned out to be nearly identical. As for our destination, a scientific advisory panel was given a choice between the Pleiades and the Coalsack as potential destinations for this mission. The panel, almost unanimously, chose the Coalsack."

"But the Coalsack is 200 light years farther away," Cato said plaintively.

"Distance was not a mission selection criterion. Scientific merit was, and the Coalsack was simply ... more interesting ... than the Pleiades."

Heater considered a comment concerning the military merit of either destination but wisely left it unsaid. It didn't matter anyway, as something on Bob's wrist started beeping. He looked at it, made a face, and said, "Physical Training time. So that, boys and girls, concludes today's history lesson."

Cato stood up with Bob. "A pleasure, sir."

Heater also stood. "Sir."

After Bob had strode out of the wardroom, Cato said, "So that's why we're going to the Coalsack."

Heater looked at the blast shield over the forward window. "Yeah, but we still can't see where we're going."

**17 OCTOBER 2191**

**230 LIGHT-YEARS FROM THE COALSACK**

The planets were much easier to find at the next stop. *Procyon* dropped sublight half a second ahead of schedule when it hit the superjovian's minus three gradient just before the K0 subgiant's minus three gradient. After that excitement, it was a simple matter of scanning the plane described by both gravitation vectors to find the planet responsible.

"Beautiful system," Carmen said as *Procyon* leisurely approached the gas giant. The planet itself had just enough methane in its atmosphere to add a bluish tinge to its white- and rust-colored cloud belts. The space around it was lit with multiple rings, two terrestrial-planet-sized moons, several smaller icy satellites, and dozens of icy "rocks".

Bob looked at the main viewscreen, then did a double-take. "JEDI, zoom on the second moon to the left."

The screen blurred, then stabilized. Ugly brown clouds roiled across the surface of the moon.

Kevin caught the significance immediately. "Woah. Deja vu."

"Exactly, XO. Bridge to Science."

"If it's about the gas giant, we've noticed it and we're already on it," Pamela snapped. The uproar down in the main science lab could clearly be heard on the bridge end of the connection.

The entire bridge crew turned to face Bob. *Uh-oh...*

It was Kevin that broke the 'Oh, Crap' moment. "Let me guess. The gas giant has the same whopping huge helium-3 line in its spectrum that the one in the last system had, right?"

Pamela flinched almost imperceptibly, relaxed, squared her shoulders, and started, "The commander is right about the presence of helium-3 in the jovian's atmosphere, even if his use of scientific nomenclature leaves much to be desired. The gas giant also has a strong radiation spectrum consistent with carbon-14 decay as well. That would be similarly consistent with the methane we detected on our way in." There was a slight pause before she continued, "Did you have something you wanted to report?"

"Um, yes. You might want your crew to take a look at the large moons when you get a chance. Their atmospheres may look familiar. Bridge out." After the connection died, he turned to Kevin and with a raised eyebrow asked simply, "Whopping huge?"

"I panicked."

"Given the situation, XO, you're allowed. I want this ship on yellow alert two minutes ago. Equip all Remoras with deep recon packages, I want two in space at all times on a six-hour rotation. Nothing moves in this system without us knowing about it first, understood?"

"Yes, sir." After Kevin relayed orders to the appropriate people, he turned back to Bob and said, "I thought you didn't believe what we saw in the previous system was caused by enemy action."

"I wasn't convinced that it was caused by Malzurkians, XO. To be honest, I'm still not convinced it's Malzurkians, even after seeing this system."

"Well, if it wasn't Malzurkians, then..." Carmen trailed off.

Bob finished the thought grimly, "Then who? Someone who could crush the Malzurkians like a bug."

**18 OCTOBER 2191**

**230 LIGHT-YEARS FROM THE COALSACK**

"Remora Three, DSO. Docking clamps cleared and retracted. Confirm independent. Good hunting..." The Docking Signal Officer gave final instructions, and an editorial comment, to the departing Remora, "...and when I say 'good hunting', I mean I hope you find *nothing*."

"Roger that, DSO," Heater chuckled, "*Tom Servo*, departing." She pulsed the Remora's underside RCS thrusters to separate from *Procyon*, then spun the ship around to its assigned patrol heading and smoothly brought the main engines online.

When they were docked, *Procyon's* four Remoras appeared to be mere streamlined extensions of her hull. Unlike their oceanic counterparts, these Remoras had much sharper teeth. They had an impressive assortment of weapons and, given the current situation, Heater was not afraid to use any of them. Something about this star system had their command staff rattled, and it was their job to find out what it was.

"Gotta agree with the DSO today," Cato chimed in from the right-hand seat. Cato was the Remora's WESO,

the Weapons/Electronics Systems Officer. After his initial scan of the threat board, he continued, "Yo Heater, we got scads of moons here. Why do the planets and moons with air get all the attention?"

Cato got on Heater's nerves at times. *Great, it's gonna be one of those patrols today...* "If you want to scan the ice moons, there are plenty of 'em. Knock yourself out."

Cato turned the visible light camera towards a moon just entering into eclipse. "Aye sir. If nothing else, this one'll be worthy of blowing up, framing, and hanging on the wardroom..." His words trailed off as the image appeared on his screen.

"What?" Heater asked impatiently.

"Wait one." Cato tended to chatter while he worked. "I can't believe what I think I see. The detector on this camera is sensitive to light a lot fainter than what the eye can see, but if I stretch the image..."

On Cato's monitor, the computer-processed image clearly revealed a faint haze surrounding the moon. "Heater, about face! This moon has an atmosphere. It's tenuous, but it's there."

"Thought you had a bug up your behind about things with atmospheres," Heater chided as she brought *Tom Servo* about.

"You don't understand," Cato said, no longer in his normal "playful banter" mode. "Moons like this aren't massive enough to have atmospheres, and when they do they don't have 'em for long. This means that something heated the snot out of this moon, and recently. Could have been a meteoroid strike, a stellar flare...."

"...weapons fire," interrupted Heater.

"...weapons fire," Cato confirmed. "I want to get multispectral images of the moon, I bet I know what that gas is. Mapping IR bands to RGB, and..."

"And?"

"Frak me!" blurted Lt. Perry.

"Frak? You've been hanging around O'Byrne too much," Heater said. "Whatcha got?"

"See for yourself. I'm sending the scan to your monitor."

Heater saw the image of the moon on her viewscreen. Exactly half of the moon appeared gray-white in the false color image, the other half a brilliant blue — as if somebody had sawed both a pool cue ball and 2 ball in half, and glued one half of each ball together.

"What do you say now, Heater?"

"Frak me!"

\* \* \*

"Even today," Dr. Davies lectured in Main Briefing hours later, "scientists disagree on the 'correct' material state of glass. At room temperature it has no crystalline structure and will flow over time. On the other hand it's brittle, will support shear, and is certainly very hard. Amorphous ice is similar in this respect: it's hard,

but lacks a crystalline structure. What we have here," she said gesturing to the viewscreen, "is a moon where one hemisphere is amorphous ice, the other is ordinary crystalline ice."

Bob didn't like where this was heading. "So how do you turn one form to the other?"

"I'm getting to that," offered Davies, "but bear with me a bit longer. The Remora crew first noticed a rarified atmosphere around the fifth moon. The WESO speculated, correctly I might add, that the atmosphere was atomic oxygen. A large pulse of energy, like gamma rays for instance, would vaporize some of the ice, and melt much of the rest..." Davies searched for a word, then just made one up, "... of the 'pulseward' side. The vaporized ice would be photodissociated into hydrogen and oxygen by the UV radiation of this planet's star. The lighter hydrogen escapes the system rapidly; the oxygen hangs around a bit longer. That explains the tenuous atmosphere. We're far from this planet's star; it's cold out here. The ice that melted to liquid refroze almost instantaneously, yielding the amorphous ice hemisphere."

"Talk about being two-faced," Kevin quipped.

Bob, on the same page, added, "Too bad the name Janus is already taken at Saturn. But why this ice moon?"

"Oh it wasn't just one ice moon," Davies said as she changed the display on the viewscreen, "*all* of the icy moons in this system are altered in this fashion." On the holoviewer now was a computer-generated graphic of the planet and its system of moons, each moon displayed as a fusion of two very different halves.

"*Madre Dios*," Carmen murmured.

"In fact, it gets even better," Davies continued, "JEDI, bring up simulation Davies 13-bravo." The onscreen image was replaced by a similar image, but with only 8 moons. "We determined the state vectors — positions and velocities — for each of the moons, as well as their spin orientations. We then eliminated moons with chaotic orbits or spin states, and then JEDI integrated their trajectories backwards. JEDI, run simulation 20 years per second."

The simulated two-faced moons orbited backwards on the holoviewer. After half a minute, Kevin asked impatiently, "And we're looking for...?"

Dr. Davies, in her best military impersonation, said, "Wait for it.... There! JEDI, pause."

The simulation stopped. The amorphous ice hemispheres of all the moons were facing the same direction.

"Okay, that's interesting," Kevin replied with only a hint of nervousness in his voice.

Bob leaned forward and adjusted his glasses to try to read the frame index of the simulation. "How long ago was this, doctor?"

"About one thousand years ago."

"Wasn't that when the damage happened in the previous star system?" Carmen asked.

"Roughly, yes," Pamela answered.

There was a long, silent pause. Bob finally said, "Two systems twenty light years apart receive the same types of damage at about the same time. Dr. Davies, please tell me it's a coincidence. Lie to me if you have to."

Pamela shrugged her shoulders helplessly. "A supernova or hypernova would explain the evidence perfectly, but we're right back to the question Commander Sanchez posed the last time we discussed this. Which star exploded?"

"There's always the 'invincible alien armada' theory," Kevin offered none too helpfully.

"Show me how damage on this scale can be done to an entire star system by an invincible alien armada and I'll consider it," Bob shot back waspishly.

Bob and Kevin glared at each other across the table for a moment before Bob continued, "Ms. Sanchez, nav platform status?"

"Nominal. Recalibration should be done in six hours."

"Good. Mr. Duncan, drive status?"

"Port drive check should be complete in twenty-four hours, barring the unforeseeable."

"So we're here at least another day. XO, can we keep the Remoras on deep recon deployment for that long?"

"Yes. I'll need to borrow all our relief helmsmen so I can rotate my dedicated crews into rest breaks — with Ms. Sanchez's permission?"

Carmen nodded, and Kevin continued, "If I have to, I'll take one out myself and stand patrol."

"Do what it takes, Mr. O'Byrne. Dismissed."

## **2 NOVEMBER 2191**

### **185 LIGHT-YEARS FROM THE COALSACK**

"We really have to stop meeting like this," Pamela said as both senior scientists and *Procyon's* senior officers filed into Main Briefing. "Even my crew is getting jumpy."

"At least it wasn't radioactive planetesimals in chaotic orbits this time," Kevin replied. Their previous maintenance stop had been particularly harrowing.

"Yes, did the science staff ever figure out what happened?" Bob asked, "They've had JEDI running some pretty extensive sims all week."

"Staff agrees that the belt was not the result of a planetary breakup. What happened, happened to a previously-stable planetesimal belt. Even twentieth century planetary scientists could have understood the theory, if not the sheer scale, of application we witnessed."

"That's a relief," Bob said as he sat down. Almost as an afterthought, he added, "Sort of."

"How's that, sir?" Carmen asked, "You've still got something out there capable of kicking very large rocks around like soccer balls."

"Anything that could convert a planet into a planetesimal belt has to deal with its gravitational binding energy. For the Earth, the amount of energy works out to about a week's worth of energy from the entire Sun..."

"How do you KNOW stuff like that off the top of your head?" Pamela interrupted with disbelief, "Some government program you can't talk about?"

Bob allowed a slight smile to cross his lips. "Actually, it was a rather memorable homework problem in undergraduate physics. Fortunately, it looks like we won't have to worry about that particular scenario."

"But we still have a very persistent unanswered question to deal with," Kevin said darkly.

"Unfortunately, true. JEDI, display current system ephemeris."

The holoviewer engaged and a simulation of the current star system hovered over the table. Pamela took over from there. "Three gas giants in the outer system, all with the same anomalous helium-3 line in their atmospheric spectrum. There are four inner planets, numbers 2 and 3 have atmospheres. Number 2 has the same radioactive smog we've been observing in other planets with large nitrogen concentrations. Number 3 resembles Mars after phase one terraformation — carbon dioxide and water vapor — and also shows radioactivity consistent with the presence of carbon-14."

After Bob finished his sip of mocha, he asked, "Any ideas?"

Pamela looked nervous before answering, "I really want this to be due to natural causes, but the evidence just doesn't add up that way. We've got four systems over a distance of sixty parsecs showing the exact same pattern of damage, and no obvious mechanism that we can find."

Dr. Mathews speculated, "What if a star pulled an Eta Carinae on us — well what we're expecting from Eta Carinae anyway — and went hypernova? A big enough hypernova doesn't even leave behind a black hole." He then added, "No smoking gun."

Pamela corrected, "While you're absolutely correct about a hypernova's potential to destroy even its own core, I'm not sure that helps us here. Let's use your example, Eta Carinae, as our poster child. It underwent a giant eruption that was witnessed on Earth in 1843, and which was nearly as bright as a supernova itself."

Dr. Mathews agreed, "Right, it's called a false supernova."

"In a few years," Pamela continued for the non-astronomers in the room, "Eta Carinae produced almost as much visible light as a supernova explosion, but it *survived* — leaving behind two huge lobes of expanding matter. Since then we've observed several false supernova. They are considered precursors, and are often followed shortly after by a full-blown stellar explosion. In every case something resembling a nebula has been left behind: 'smoke', from the hypernova's gun."

As everybody in the room digested that information, Pamela finished, "Finally, before anybody says it, the internal structure and mass of all the candidate stars in the vicinity — the Crucis supergiants and Beta Centauri — have been known for centuries. None of them come close to matching Eta Carinae and we see no evidence of eruptions of any kind."

"Further, let's add that we've also clearly established that, there is no historical evidence from Earth records, right?" Bob asked. After an awkward pause, he continued the thought, "As I said last month, I don't remember any supernova — Type I, Type II, hyper, or false — taking place in this particular area of the galaxy in the past millennium."

There was a long, awkward pause. Finally, Bob squared his shoulders and said, "Okay, I think we all need to be thinking in terms of someone rather than something. What are we up against?"

Dr. Mathews looked at Pamela, who nodded for him to go ahead. "First off, captain, you'll need to look at what damage has been caused. The 'radioactive smog' we've been observing is the result of ultraviolet — or even higher energy — radiation bombarding atmospheric nitrogen and inducing various chemical reactions. If we assume gamma rays, that would also account for the lack of ozone we've been seeing in planets with significant oxygen concentrations."

"What about the radiation?"

"Electrons, protons, high-velocity atomic nuclei, and a whole zoo of other sub-atomic particles." Mathews paused for a second, then continued slowly, "I've just described a nasty solar flare. If it's big enough, the tritium it would generate in a gas giant's atmosphere would explain the helium-3 lines we've been observing."

"So our nasty boys can trigger really big stellar flares," Kevin mused. "Is that possible?"

"Not with our technology base. If the Malzurkians had it, they would have used it on us in the war."

Bob drummed his fingers nervously on the table, looking absently at the system ephemeris as he pondered everything he had just heard. Finally, he said, "We will proceed with our mission as ordered. However, we all need to be prepared to abort and get this information back home."

"Abort our mission to the Coalsack?" Pamela asked.

"Mission orders allow the ship commander to abort the primary mission in the event humanity is in jeopardy. That particular section was written with Malzurkians in mind, but the Space Force gave me some latitude in how I choose to interpret, or exercise, it." Looking across the room, he added, "We're not there yet, people, but we're getting awfully close."

## **5 NOVEMBER 2191**

### **170 LIGHT-YEARS FROM THE COALSACK**

Bob was working over a particularly difficult section of Rachmaninoff's Second Concerto on his piano when he felt a tremor in his sustainer pedal — the same tremor he always felt when *Procyon* dropped sublight. Knocking the piano bench over in his haste, he was on his feet and out the door of his cabin at a dead run before the first battle station klaxons sounded throughout the ship. Seconds later, he had sprinted up the steps to the command deck and was running into the bridge.

"Watch officer, Captain has the conn," Carmen snapped while working controls at Helm.

"Bridge aye."

"This is the Captain I have the conn, status?" Bob gasped as he fell into his station and rapidly scanned his repeaters.

"We dropped across a minus four gradient one minute ago. I'm generating a vector tangential to the gravity well."

"What minus four gradient? We're five light-years from the nearest star!"

"Good question. I wanted to set EMCON Bravo as well, but we've got a radiation problem and I had to rig plasma screens instead."

*When you don't know what you're up against, try not to be seen. Never thought she was paying attention in combat sims...* Bob thought. "Good, fast work, Ms. Sanchez. Bridge to CIC."

"CIC, O'Byrne," Kevin looked as rattled as Bob felt.

"How long can the screens hold this load?"

"We're in no immediate danger, but I wouldn't want to stay in this position too long. The radiation is also partially blinding our sensors, and we can't get a good look around us until we do something about that."

"Thank you, XO, bridge out. Ms. Sanchez, maintain course, ahead full."

"Ahead full, aye sir."

Between the minus four and minus three gradients of a gravity well, *Procyon's* drive performance was significantly degraded. Given that this was the difference between 2,000 times lightspeed and twice lightspeed, the difference was currently meaningless. In just over a minute, the aurora that was shimmering across the plasma screens faded into nothingness.

"Okay, that's a lot better," Kevin reported from CIC. "You can stop while we take a look around."

"Ms. Sanchez, all stop."

"Aye, sir."

"Okay," Kevin reported, "We've got a gravity well source at zero-two negative by zero nine one, range six point one five AU. Appears to be several solar masses, with no obvious visual source. You might want Commander Duncan to take a look at some of these potential space readings, because I can't believe the strength of this magnetic field. Before you ask, systems passed a quick diagnostic."

"Feed it to Engineering. Bridge to Engineering."

"Engineering, Commander Duncan."

"I need you to take a look at the telemetry CIC is forwarding you."

Alex looked off camera for a moment, suppressed a curse, then said, "You're running a sim up there, right?"

"Negative. The source is currently six AU off our starboard beam."

"You're not thinking about getting any closer, I hope. A magnetic field this strong could pull water molecules apart from several hundred kilometers away."

*That's a visual I didn't need right now...* "Unless we've got a real compelling reason, I was planning on keeping us right where we are now. Bridge out."

"I heard that, and it sounds like good advice," Kevin added from the CIC repeater. "We're relaying everything to Main Science."

"Do we need to remain at battle stations?"

"No, but Yellow Alert goes without speaking."

Bob smiled. "Understood. Set condition yellow, XO. Bridge out."

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Six hours later, a swirling disk hovered over the table in Main Briefing. Ghostly lobes shot out of the top and bottom along the disk's rotation axis. Irrationally, Bob wanted to duck out of the way of the hologram as he looked at it.

"The object 6 AU away is confirmed to be a black hole," Pamela started, "We've been able to refine Commander O'Byrne's quick measurement of several solar masses to approximately 6.115 solar masses."

"If it's a black hole, what about that magnetic field? I thought black holes weren't supposed to have them," Kevin said.

"Think, commander. You've got very rapidly-moving plasma around the event horizon, which is the next best thing to an electric current loop. Of course you're going to have a magnetic field." Pamela turned to address the rest of the briefing. "The density and composition of the accretion disk does give us an important clue as to this system's age. After analysis, we conclude that this system can't be much over..." she paused for effect, "...one thousand years old."

"Now there's a suspiciously familiar number..." Bob murmured.

"That thought occurred to a lot of us, too."

"But doesn't it take a supernova to form a black hole?" Carmen asked.

"So did that thought."

"Great. So our nasties have now graduated from sterilizing planets to generating black holes?" Kevin said.

"Hold on. I had my staff do some data mining through our archives over the past several hours, and we may have found how to generate this system without blowing up a star. This is a mechanism first proposed in the late twentieth/early twenty-first century to explain some of the intense gamma ray events being detected by the Vela satellites. The Velas were launched to detect gamma ray signatures from space-based nuclear weapons test ban violations."

"It's a gamma burster?" Kevin said incredulously.

"It's a gamma burster," Pamela confirmed. "It's something we've observed for hundreds of years, but always in distant galaxies. It never really occurred to anyone that they could happen in ours."

"So does a gamma burster explain what we've been seeing the past month?" Bob asked.

She manipulated some controls, and the hologram above the table changed to show two neutron stars slowly spiraling toward each other. "It does. We start with neutron stars in mutual orbit."

"Why aren't their orbits stable?" Carmen asked, noting the decaying orbits.

"Two reasons." Almost unconsciously, Pamela got up and slowly paced around the table as she spoke, almost as if lecturing a class. "First, gravitational wave emissions. Mostly because the progenitor neutron stars are so fast and close to each other. Now watch what happens when they approach each other's tidal limits... Their accretion disks interact, creating an intermittent drag..."

In the simulation, the approaching neutron stars suddenly shredded apart along their mutual orbits. The debris rapidly spiraled into the system's center of gravity, then two intense beams of radiation shot out along the system's rotational axis. "In the process of forming the final black hole, the excess energy is funneled out along their orbital angular momentum vector ... which becomes the black hole's spin axis," Pamela explained matter-of-factly. "The leading edge of the jet will consist of an intense burst of gamma rays, followed very shortly by highly-relativistic particle radiation. With sufficient plasma densities, it is possible the beams may be self-focusing over interstellar distances. You're basically cramming the energy of an entire supernova into two very narrow opposing jets."

Bob's mouth slowly opened. "Where would the beams have been aimed?"

"When we originally dropped sublight, we were very nearly looking down the rotational axis of the accretion disk," Carmen trailed off, then looked up and said. "JEDI, display current astrogation plot. Include this location plus the location of our last four maintenance stops."

The display swam and projected the requested data. Bob now took over. "JEDI, assume a gamma-ray generating event of the type previously modeled by Dr. Davies has taken place. Given the current alignment of this system's rotation axis relative to the galaxy, plot where the radiation jet would fall on this chart."

The radiation beam shot out from the newly-formed black hole and speared through the galaxy. One by one, the lobe approached each of the previous four systems *Procyon* had visited over the past month.

One by one, it missed each one.

Carmen muttered an inarticulate and vaguely Spanish-sounding curse under her breath. "Reminds me of my Masters' thesis research," Bob said, clearly disappointed by the outcome of the simulation.

Kevin's face, however, showed he didn't share everyone else's mood. Bob noticed this and said, "Yes, XO?"

Kevin finally found the words he was looking for. Looking at the ceiling, he asked, "JEDI, are we using current positions for the highlighted stars?"

"Yes."

"Bingo," Kevin said with overly-savage triumph.

"Oh, my," Bob breathed. He understood what Kevin was getting at immediately.

"What? What's wrong?" Pamela asked. She was uncharacteristically slow on the uptake.

"We never corrected the sim for one thousand years of proper motion. We're looking at the stars where they were when we visited them, not where they were when the event happened." Kevin leaned back in his chair and finished smugly, "Never send an AI to do a man's work."

A wave of recognition slowly broke over the briefing room. "Mr. O'Byrne, would you mind doing the honors?" Bob asked.

"With pleasure. JEDI, edit sim. For the four stars highlighted, change their galactic positions to where they were at the time of the gamma ray event and allow the stars to move based on their recorded proper motion and galactic orbit."

"Done," JEDI said almost immediately. Only those with astronomy backgrounds knew the amount of

calculation hidden in the slight gap between command and response.

"Reset simulation to starting positions and go," Kevin commanded.

Again, the radiation lobe shot out from the newly-formed black hole and speared through the galaxy. One by one, each of the four systems *Procyon* had visited was tagged by the jet.

Everyone stared at the holo before Bob said with a deliberately-exaggerated Tharsis backcountry drawl, "Yup. There's your problem..."

After the laughter died down, Pamela continued, "Let's not relax just yet," Dr. Mathews interjected. "Is that thing pointed anywhere toward Sol?"

Carmen eyeballed the holo and replied, "Not a problem. It's in plane but fifteen degrees antispinward. The only reason we came across the aftereffects was that we were cutting across the direct bearing between Sol and the Coalsack to head for Beta Crucis."

"Which would explain why we never saw anything from home space," Kevin added.

Bob turned to Pamela and asked, "Do we need to stay around here any more?"

"No. Case closed."

"Good. Ms. Sanchez, have Lt. DeMarco plot a minimum-time course to the minus four gradient and resume our previous course from there..." As people stood up to leave Bob added, "...but before you go.... I need to say something. You all have no idea how relieved I am right now. As a man of both science and faith, I will also admit to being ... embarrassed. We've all been guilty of tunnel vision, ignoring an obvious answer for what we've witnessed, instead seeing Malzurkians, or worse, laying in wait behind every moon and planet. Perhaps it's understandable, given our recent history, that we're still a little shell-shocked. The irony in this case is that, consciously or otherwise, we were overlooking a force far more frightening than any alien race could ever be. This was never the action of any alien race — it was an act of God."

Bob paused to let that thought sink in, then continued, "A wise man once noted that WE are all made of stardust. Every atom in your body was once in a star, and many of those were created in the cataclysm of supernova billions of years ago. But as we venture out into space, surrounding ourselves with increasingly more sophisticated technology, we've tended to forget how fragile our bodies, our race, and our planets truly are. The Universe is a very inhospitable place; and as we continue on our mission we would be wise to reflect upon that, and how rare and blessed is our existence. Dismissed."

**6 NOVEMBER 2191**

**35 LIGHT-YEARS FROM BETA CRUCIS**

Kevin entered the bridge to stand evening watch and found Bob absently fiddling with one of his station's repeaters. "What are you doing, sir?"

"Evening, XO. Just playing with Dr. Davies' gamma ray burster sim."

"Still? It's six light-years behind us. Let go of the past."

"You deal with it in your way, XO. I'll deal with it in mine." Bob levered himself up from his usual slouch and sat up straighter. "The ship is normal in all aspects. The watch was completely boring. We're holding

course and speed for system entry during midwatch tomorrow."

"Boring," Kevin mused. "Haven't been able to say that for a while."

"I know. I got so bored I seriously considered bending mission rules, foregoing the next stop, and ordering a course change to Beta Crucis from here."

"I wouldn't, sir. Our crew needs the downtime after the past month."

"Hence why I didn't do it."

"So, still being bored, you then resorted to randomly sterilizing thousands of star systems throughout the galaxy by playing with Science's GRB sim."

"Somebody's having issues about letting go," Bob teased. He swiveled the repeater toward Kevin and continued, "I was actually playing with the initial conditions of the neutron star collision to see what would happen with the beams."

"Anything interesting?"

"As a matter of fact, yes. Did you know that a difference of two kilometers in lateral separation during initial orbital capture yanks the beam fifteen degrees to spinward?"

"So?"

"On a direct heading to the Solar System?" Bob prompted further.

After a long pause, Kevin simply said, "Ah."

"There but for two kilometers and the grace of God goes Humanity. With that humbling thought, I bid you good night." Bob stood, stretched, and yawned before continuing, "This is the Captain, the Executive Officer has the conn."

"Bridge aye," the crew chorused.

"This is the Executive Officer, I have the conn," and Kevin sat down at the captain's station.

"Bridge aye."

Kevin ran some quick status checks across the station repeaters as he got himself settled in the captain's chair. He then looked at the simulation Bob had been running for a long moment. Curiosity fought with "letting go" and the more practical impulse to clear the repeater.

Curiosity won.

## **Afterword:**

**Comments from Kevin Grazier:** When I was asked to consider writing a science fiction story that also served as an astronomy lesson, my thoughts instantly bifurcated with both paths eventually re-converging to create "Planet Killer". I had recently had lunch with Phil Plait, author of *Death from the Skies: These are the Ways the World Will End*. One of the topics we discussed, because wholesale death and carnage always makes a Denny's lunch more palatable, was what would happen to planet Earth were we in one of the polar

"beams" of a nearby gamma ray burster. "Nearby", in this case, means "anywhere within the Milky Way Galaxy". In short, life on Earth would be largely exterminated in less time than it took us to finish our lunch: a mass extinction that would put to shame anything that has happened in Earth's history to date. As we discussed the gory details, I couldn't help but think that the scenario was so dramatic that Hollywood has overlooked the ultimate in disaster flicks.

At the same time, my mind also raced to "I have got to include Ges!" Ges Seger and I met as undergraduates at Purdue University, and had written several things together over the years. Most notably, we wrote a script for the series *Star Trek: Voyager* that resulted in an invitation for us to pitch story lines at the Hart Building — the *Star Trek* offices at Paramount Studios. We work very synergistically and often come up with ideas and scenarios together that are better than what either of us come up with independently. I also really quite enjoyed the characters from his novel, *The Once and Future War*, and thought that it would be a whole lot of fun to let the crew of Procyon tell us the tale of a murder mystery of planetary proportions.

**Comments from Ges Seger:** Kevin and I have been friends since we were in the same residence hall at Purdue University, and writing partners for almost as long. This generally means I sometimes have access to writing opportunities of which I would not normally be aware. *Planet Killer* was one of those opportunities.

About the same time Kevin approached me for contributing to the book *The Science of Dune*, he mentioned he had been invited to contribute to an anthology that would consist of science fiction stories based on specific concepts in modern astronomy and astrophysics. We kicked some ideas around for a couple of emails before he made the inspired simultaneous choice of both concept and story seed — an astronomical "murder mystery" which would serve as either a prequel or sequel to *The Once and Future War*.

As I read that email I realized that of the two possibilities (prequel or sequel), the prequel made far more sense. The backstory of the Martian starship Procyon, her first crew, and her first mission were very well-developed in my fictional universe thanks to an aborted attempt to write a novel on it in the early 1990's. As I realized this, I got this vivid mental image of Bob Keith looking at a holotank showing the path of the gamma ray burster's beam and saying, "Yep, there's your problem."

That's when the Muse hit. Hard.

The first draft of *Planet Killer* literally wrote itself in three hours, spread over seven nights hammering away at a laptop between shuttling children back and forth to dance class. I was a bit afraid I hadn't left Kevin much to do, but those fears proved groundless as we co-wrote/co-edited the second draft together and added a lot more material. Kevin and I just seem to mesh as a writing team in ways that I can't explain easily, and that came through in spades as the final version of the story got hammered into the form you see now.

And truth to tell? It was kind of fun having him play in my universe with my characters and ships. No pressure, Kevin, but I hope we can do it again.

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## ***The Listening Glass***

by [Alexis Glynn Latner](#)

Acrophobia. It always hit him here, midway on the catwalk. He let his gloves slide along the guidewires. Within the bulky gloves his palms sweated profusely. Ahead of him and even higher up, the catwalk ended at the antenna suspended on the convergence of three sets of immensely long cables. There was nothing under the antenna. Nothing. Hard vacuum, underlined with a thin, curved shell of material that gleamed coldly in the downward periphery of his vision. He dared not look down. If he did he would freeze.

The antenna's present position left too much slack in the catwalk for his liking. Every step caused a ripple to propagate up the catwalk ahead of his boots. In the confines of his suit helmet, his breathing sounded too quick and ragged. He tore his eyes away from the alarming frailty of the catwalk and fixed them on the motionless horizon, the tangle of crater rims on the dark gray edge of the world. The horizon reminded him that this was the Moon. It had only one-sixth of the gravity of Earth. Fact: the catwalk was rated to carry twice the mass represented by himself plus spacesuit. Doggedly he kept going.

The antenna resembled a large leggy spider, hanging upside down on flimsy strands of web. Appearances were deceiving on the Moon. The cables could easily support the antenna plus a work crew in spacesuits. Had done so during the construction phase. Making the structure sturdy enough for Earth gravity would have been over-designing to a ludicrous extent. Nevertheless, he was acutely aware of the vertical vacuum under the antenna, exceeding the height of the towering rocket that brought the first men to the Moon five decades ago. He made a quick and rather morbid mental calculation. You could stack one and a half Saturn Fives under the antenna.

His mouth felt very dry. And he detested the scratchy inorganic tang on his tongue. He could taste the gray indifference of this world. The acrophobia had never been this bad before. But then he'd never gone up to the antenna alone. At night. Stars, unsympathetic, icily burning, filled the black sky. Starlight thousands of years old rained down, and it pooled far below his feet. He resisted the urge to look down into the vast, cold, mesmerizing shimmer of it. People could freeze up here, in such a paralytic state of fright that somebody had to come up and retrieve them. He could, and probably should, turn around, go back to the habitat, and not mention this abortive excursion. No. Take another step, another, another: he was not going to let the acrophobia get to him.

This trip up to the antenna seemed to be taking a lifetime, as if the catwalk were as long as his life span. In a way, it was.

The catwalk began in the fifth grade, to be exact, with a report card that included a glaring D in Science. Bright and bored in classes taught by mediocre teachers to pupils of average intelligence, he had been indifferent to grades. But the D stung. The class started an astronomy unit. Reports were assigned, prepared, presented. The others read silly little pages about The Moon or The Planet Jupiter — childish, inept transcriptions from the encyclopedia. But he really researched his topic, at the public library. In front of the class, he drew a line down the whole length of the chalkboard to represent the electromagnetic spectrum; he showed them the small fraction of the spectrum taken up by visible light, and the far greater span of radio. He explained how radio telescopes revealed the invisible mysteries of the universe. He showed them. The next report card featured an A-plus in Science. And he had done astronomy ever since, from the backyard

telescope to the vast machine on which he treaded now.

He checked his position. Fifty feet from where the catwalk ended at the antenna. The antenna was mobile within a volume of space of some hundreds of cubic meters. And when it moved, the end of the catwalk moved with it. Of course he had put the safety switch on. Hadn't he? He should not have thought about that. He froze. The moonsuit had a radio. Maybe he should tell someone what he was up to. His throat constricted. He felt his motor muscles congealing too.

With an angry act of will, he started going again. He reached the antenna platform.

Then he let it happen, impulsively looked down, through the grate of the platform floor, and past the wide wheel with the azimuth arm hanging on it; down, into the crater full of radio telescope. The edge of it marked an immense circle like an inverse horizon. Triumphant and vertiginous, he clung to the platform's guard rail. The last steps were the hardest. It was just that simple.

There had been dreary years of delay, constipation of funds, and design compromise. And then the last and hardest part. Construction. The fact that the site was on the far side of the Moon had amplified every difficulty, every mistake, by at least an order of magnitude. But now it was finished, real, and ready to be tested, first thing tomorrow. He had come up here tonight to make sure that one last detail was put right before the big day. As a manager, people said, he was too detail-oriented.

In the center of the platform stood a dog-house sized metal box which housed the equipment, which contained the detail that he was after. Making himself let go of the rail, he strode toward the housing. There was nothing to hold onto between the guardrail and the equipment housing.

Then he noticed the lights on the corners of the platform. They flashed a red warning strobe. *The antenna was being repositioned.* Shocked, he stared. It wasn't supposed to happen with someone up here! But the structure slewed under his feet. He made a panic lunge, launched himself toward the equipment housing.

Colliding with the housing, he failed to secure a handhold on the slick box, and ricocheted off. The platform dropped underneath him. He could not find stopping traction as he skidded toward the far edge of the platform. Desperately he grabbed at the guardrail, with the full force of his Earth-powered muscles, misdirected. He reached too high and jackknifed over the rail. He flailed. Then he started falling.

The azimuth arm wheeled around. It went by at the limits of his desperate reach; his glove brushed the metal frame. The arm moved away. He tumbled. Across his sight swung the azimuth arm's wheel, stars, the silver chasm of dish.

He fell slowly and realized it. A hammer and a feather have the same acceleration on the Moon and so does a man falling to his death. He had time to think. Not necessarily death. If the dish stopped him cold, it would definitely kill him. If the dish broke instantly, it would barely slow him down, and hitting the crater floor would kill him. But if the dish broke slowly it might actually break his fall.

The sides of the dish rose up with the ominous leisure of a mounting tidal wave. Just before the wave broke, he tried to fold the bulky spacesuit, cannonball, as though he were falling into a net.

His swaddled shoulder took the impact. The shocked dish gave way, slowly. Then it tore, letting him drop to the crater floor. He hit the floor bone-bruisingly hard, bounced, and finally sprawled on his back.

To his surprise, he was not dead. But he had the wind knocked out of him. He gasped for air. From the jagged hole in the dish above him, fragments drifted down, tumbling. He couldn't breathe. Darkness with red veins closed in on him. Faintly he heard a clamor in his suit radio. "John! John!" Somebody sounded

hysterical. He tried to answer. All he could get out was a broken wheeze.

\* \* \*

The ongoing clamor in his ears bothered John. Garbled words. Verbal static. Finally, something intelligible. "ETA twenty minutes. Keep the victim immobile."

"Roger, Yuegong Base, hurry!"

He took inventory of his body. Dull pain here and there. He rolled over with a pained grunt.

A young man jumped in front of John and he recognized Edward. The computer engineer. Edward waved his hands. "Don't move!"

There was a woman whirling away from the radio station where she had been standing. He knew her too. Jennifer said, "Good Lord!"

"Good morning," he said thickly. "Tell 'em to turn back. I'm all right." With an effort, John sat up.

Edward pleaded, "Please don't move!"

John tried an exaggerated shrug, then rolled his head. Didn't feel too bad, considering. If this had been Earth and Earth's weighty gravity, he would have been dead.

Jennifer hurried over. "Lie back down! You're hurt even if you don't have enough sense to know it!"

"I want to know who moved the antenna," he said.

"I'm terribly sorry!" Edward blurted. "Your colleague sent a message saying that it was very important to look at the supernova right away without even waiting for tomorrow morning, so I entered the coordinates, I didn't know you were up there!"

"What colleague?"

"Baltazar," said Jennifer. "Just what were you doing up there?"

"What supernova?" John asked.

"You forgot to put the safety on."

John frowned. "I put it on."

"The antenna won't move with the safety on."

"I put it on! Edward, check the safety switch!"

"Yes sir." Edward scuttled to the control panel. He called back, "It's on!" A very young, very honest man, he went on to say, "This is my fault too — I never once thought to test the safety switch circuit!"

"Not your job," John said.

"Oh, but I should have—"

"No, not you." Jennifer shook her head. "So it's faulty. What a way to find out."

Vindicated, John swung his feet around. They had deposited him on the overnight cot here in the control room. His moonsuit lay in the corner, sadly dirty and disassembled. Jennifer's Chinese colleague, Zheng, crouched there, staring at the suit. The drift of his thoughts was easy to guess. Scuffs and scrapes marred the moonsuit's outer fabric. The cranium of the helmet had a terrible dent in it. John felt a strange internal quiver that must have been a shudder. Anxiously he inventoried his body once more. All dull pains, except one tiny sharp one needling the base of his head. "I'm OK," he said shakily. "You can all go to bed or whatever."

"Not after having the living daylight's scared out of us like this!" Jen retorted, and she added, "This isn't some hotel to go sauntering around alone at night, you old fool!"

That wasn't fair. He hadn't been sauntering. And she had as many gray hairs as he did.

She refused to tell the medical rescue team from Yuegong Base to turn back.

The team, two men, thundered in through the airlock with a medivac cocoon, ready to stuff an unconscious victim into it and bundle him away. John pointed out that he could move all of his limbs and digits and felt basically intact.

The doctor, with the red cross on the arm of his coverall, frowned. "Internal injuries are very deceptive under conditions of low gravity. You need to be examined in the hospital."

"Take him!" Jennifer said emphatically.

\* \* \*

At least they let him sit up, belted into a cramped seat behind the pilot. Moondust sprayed past the porthole at his shoulder as the moonhopper took off. The dust cleared as the hopper gained altitude. Then he could see Sand Lake with its rim wall around a wide pale plain. There lay a patch of silver threads, an incongruous cross-stitch on the hoop of lunar plain: the Lunar Far-Side Very Low Frequency Array, LFSVLFA, Jennifer's project.

The hopper looped around to its intended course. John glimpsed the radio dish, filling the crater Bolton on the edge of Sand Lake. He ought to have been inspecting the damage instead of going to the hospital at Yuegong Base.

Sure he was sick. Sick of Sand Lake, sick of the hardscrabble living conditions here. Sick of the Bolton dish. It had been a mistake on his part to move up into management. A big mistake to take over the project manager's job when Phil Taylor was disqualified by a heart condition. If it had been Phil today, taking that heart-stopping fall, the hopper would be ferrying a corpse back to Yuegong Base.

Less busy now, the pilot called back, hospitably, "Anybody want a Lifesaver?"

"Bad for your teeth," the doctor disapproved.

"Good for the dustmouth," the pilot rejoined, amiably.

"Thanks." Carefully John extracted one piece from the battered roll. Cherry. He welcomed it to mask the bitter tang of failure in his mouth.

The giant crater Schrödinger rolled under the moonhopper. Sand Lake was a detail in the rough rim of

Schrödinger, just as Bolton poked the edge of Sand Lake. The far side of the Moon: big holes have little ones cratered in to blight them, little ones have lesser ones, and so ad infinitum. A short while later, the hopper passed the unmistakable ringed plain Humboldt. Something flashed in Humboldt like pale green heat lightning. A moonflash, lunar rock that sparked as it cooled off after the long hot day.

Below and ahead of the hopper, the terminator, the edge of the day, threw the moonscape into vivid relief, craters dark, rims bright. The crawling terminator would take four weeks to make it around the Moon back to this place. The hopper easily overtook and left it behind. The sun glared in John's porthole. He pulled down the sun filter. In the hopper's wide cockpit window, the airless sky was black as ever over the sunlit horizon. The arc of horizon featured a wide shallow depression, the profile of the Sea of Crises.

"There she blows!" the pilot sang out. And then the Earth rose out of Crisium. The edge of night bowed from pole to pole; day was a crescent of brilliant, glazed blue. The home planet hung on the Moon's stars as lightly as a Christmas ornament in a tree. John started to cry.

The other two men had fallen silent. Fingers pressed to the corners of his eyes, John squelched the tears. He heard a pen scratching on paper. The doctor. Making notes.

The pilot took it upon himself to dispel the awkward silence. "Ever read the book *Voyager*? About the first plane to fly around the world?"

"As a matter of fact, yes," John managed to answer in an even tone.

"That's my all-time favorite book," said the pilot. They were traversing the Sea of Crises now, with the beautiful blue globe of Earth ascendant in the cockpit window. "I always think about that when I see the Earth up there. They flew around the world — around that!" The pilot waved a hand at the Earth. "Nine days, one tank of gas, no stopping, right by one typhoon and over the mountains of Africa, and everything — I see a typhoon up there now."

The hopper skirted Serenity, and then began the final approach to its destination. Skillfully the pilot swooped over the rill and the mountain both named Hadley. A glint of sunlight marked the Apollo 15 Memorial. It was a very long way down. Fear of falling clenched John's stomach with a vengeance.

The radio crackled on with the information that a squad of paramedics would meet the hopper at the port. What was the status of the victim?

"Not to worry," the pilot replied. "There's nothing really wrong with him that a few days of Earthshine won't cure."

"They want my opinion, not yours," said the doctor, icily.

"Hey, I know what I'm talking about. I been on the Moon for two years and you just got here!" said the pilot, and nodded to John. "See ya around."

The doctor ordered a complete physical examination. John felt tired. He just wanted to rest. Instead he was stripped and prodded and sampled, while his examiners talked in grave undertones about multiple contusions. Meaning bruises.

John had to argue for permission to make a call out. This is like jail, he thought grimly, one phone call if you insist. Finally they let him use the hospital uplink. He got a connection to Washington, DC, USA, Earth, with the bill for it to be sent to the Space Radio Astronomy Consortium. SPARAC's budget was tight, and the call would have to be held to a few minutes, no more. No problem. What he had to tell the Consortium's

executive director was short and not sweet.

\* \* \*

"I don't believe this!" was Schropfer's initial reaction. "There's only one manmade structure on the Moon more than three hundred feet high, and you fall off it?!"

"I didn't expect the antenna to move under me!"

"Why didn't you just hang on?"

"I panicked," John grated. "What's this crap about a supernova, anyway?"

"There's a brand new one in the Magellanic clouds. Baltazar was beside himself with curiosity, and it occurred to him to try the Bolton dish on it."

John swore.

"He had my approval," Schropfer said mildly. "Would have been good PR, a nice headline. NEW LUNAR RADIO TELESCOPE STUDIES SUPERNOVA."

"What for?" John asked coldly.

"Good question. Baltazar prevailed upon VLBA America to take a look. But at a declination of minus 73 degrees, only the dishes in Hawaii and the Virgin Islands could pick it up at all, just over their southern horizon. The data was noisy.

"The Australia Telescope happens to be committed to a configuration incompatible with investigating the supernova. And VLBA Pacifica is all buttoned up because of a typhoon bearing down on Easter Island. That leaves Bolton. Which is in just the right place and ready for its first trial run."

"I'd like a full report on all this."

"I take it you haven't checked your email," said Schropfer.

"They won't let me out of the hospital tonight! They're wasting my time and theirs, because I feel fine—"

"A 591-foot fall is not trivial, my friend. Not even on the Moon."

"The dish absorbed most of the impact."

With a delay of two and a half seconds, the signal traveled to Earth and Schropfer's reply came back. Schropfer seemed to pause longer than that, though, before John finally heard him say, "That's too bad."

\* \* \*

Being in the hospital offered one single advantage: hot showers. John rubbed a clear spot in the fogged bathroom mirror and inspected his contusions. Dark bruises blotched his back, with smaller and more painful yellow spots.

It was well past midnight, Moon Mean Time. That left just enough night for it to be a very bad one. He dozed off, felt himself falling, and jerked awake in a sweat, his heart fluttering. With a loud scuff of shoe soles on a

floor with a high coefficient of friction, the nurse walked in to check on him. Finally, in the last hour or two, he slept. He dreamed about moon-gray dust spattered with the vivid red of blood.

In the morning they let him go. Still wearing the despicable plastic bracelet on his wrist, he left the hospital building. The skylight over Dave Scott Plaza framed the crescent Earth. He paused to admire Earth, and another pedestrian, presumably late and rushing to work, promptly ran into him. Suddenly John wondered whether his idiotic fall had been publicized. Did people here in Yuegong Base know all about it? The prospect mortified him. Breaking into a hot sweat, he hurried toward his office.

The office was an out-of-the-way cube of space shared with the staff of the Yuegong Sino-American Observatory. None of them had arrived for the day yet. He checked the clock. 8:13 a.m. Typical, he thought: astronomers tend not to exist at that hour of the morning. He found the report from Schropfer in his email inbox, and a video file from Ramona. Remembering one last roll of wintergreen candy, somewhere in his desk, he rummaged to find it. Then he viewed the video. He sat down and sucked on a piece of candy as he watched his wife's image.

Her backdrop was recognizable girderwork, the bolted-together but unfinished interior of the big space station under construction at Earth-Moon Lagrange Point Five. "Hi. I'm in the center of L-5 Station." She placed a pen in the air in front of her. It hovered with a slight slow drift. "No gravity. So I'm not going to be saying anything too serious!" She smiled, not with her lips but rather with her brown eyes. She had secured her long brown hair in Apache braids. Very much his Ramona. She retrieved the pen before it drifted away. "I have a friend I want to introduce you to. He's very nice."

Instantly, John felt a pang of jealousy.

Ramona whistled softly, "C'mere, sweetie!" Something fluttered into the picture. A bunch of highly active feathers. It attached itself to Ramona's proffered finger, and resolved into a parakeet, perched upside down relative to her. "This is my little friend Admiral. Admiral Bird!" Ramona declared. So much for jealousy. The bird wasn't even green, it was blue. Ramona gently turned her hand and the parakeet upright. "People thought birds would freak out in zero gravity. Not Admiral! He's learned how to fly here." The bird preened the feathers of one wing. "Humans can fly in zero g too...." She finished with a shy glance and a curl of a smile.

He understood, and he longed for her. The last time he visited Ramona in L-5, she had taken him to a special corridor of the space station. Not finished or furnished, the management intended it to be a weightless art gallery at a future date. It had a picture window full of stars and Moon and shining Earth. Quite unofficially, it served the inhabitants of L-5 as Lover's Lane in zero g. Where, as Ramona put it, you could make love like the birds called white-throated swifts, which mate in the air, tumbling together as they fly in the canyons of the West.

She ended the video by saying, "I wish it wasn't three more weeks before you come to L-5 again. I love you and honor what you're doing. Make it work."

\* \* \*

It was very quiet in the office. The resident astronomers had yet to appear. Odd. Enjoying the privacy, he read the report on the supernova.

Right ascension one hour, six minutes; declination minus seventy-three degrees. That put the supernova in the Small Magellanic Cloud and closer than any supernova since the 1987 event in the Large Magellanic Cloud. OK. An interesting object. But supernovas weren't great radio sources, not until well after the catastrophic fact.

In the case of SN 1987A (appended) the neutrino blast came first, then ultraviolet. Then the balefire blaze of

visible light. Satellite observatories picked up x-radiation six months later and gamma rays right after that. Eleven years later came the first whisper of synchrotron radio emission, and the first radiograph of the supernova remnant was produced by the VLA, a blurry image of the clotted shell of matter thrown into space when the giant blue star exploded.

The detection of a pulsar had been announced in 1989. And retracted in 1990. The "pulsar" turned out to have been a fluke in the observing equipment at Cerro Tololo. The real thing had yet to be confirmed: thirty years and still no pulsar, though theory predicted that the supernova should have left one to mark its place.

Baltazar knew all of this, yet hadn't been able to wait even a day to have a look at this newest supernova!

The VLBA data was interesting in a Rorschach way — the human brain could imagine something significant in it. Much less imaginative, the VLBA supercomputer had not managed to massage the data into anything recognizable. Schropfer had been in management, fund-raising, begging for bucks, so long that he couldn't even make a sound scientific judgment anymore, John thought disgustedly. He rubbed his neck. There was a nagging twinge, a crick in his neck. It bothered him more than the soreness and stiffness of the remainder of his body.

Dec -73. Solidly in the Bolton reflector's observing swath on the celestial sphere. And RA 0106. The supernova had appeared near Bolton's zenith. Ironic: right now Bolton was in a great position to register the radio data that might take months and years to show up.

John called Schropfer again. "For what it's worth to look at the supernova, we can repair the dish," he said, without preamble. "Some segments fell out. But we have spares in case of micrometeorite hits."

Schropfer shook his head grimly. "Jen did a damage assessment, which I just got. It's worse than a hole. Two of the support pylons are buckled and the whole dish is sagging. As in, out of round. As in, inoperable!"

"Oh, no!"

"What did you expect? You're two hundred pounds on Earth, the suit's just about that much more, and I'm too upset right now to convert to newtons of force that hit the dish! How in the name of perdition am I going to meet the cost of replacing pylons?"

In shock, John shook his head. The Space Radio Consortium subsisted on whatever money its member universities could spare. Plus funding that Schropfer elicited from government and the private sector. Building the Bolton dish had blown the seams of SPARAC's budget and, furthermore, had put SPARAC embarrassingly in debt to the SETI Society. Schropfer continued, "Yuegong Hospital sent me a report on you, too. I conclude that the worst damage to you is your ego. Too bad. It would have been cheaper to fix your bones than the bones of the dish!"

Thanks for the sympathy, John thought, you little son-of-a-bitch! He signed off curtly. The pain in the neck had a name now. Schropfer.

John's workstation chimed. There was Jen's report, just in. Twelve lines long. She didn't specify what did the damage. As if God or the impersonal universe had flicked something into the dish. She was very specific, though, about the extent of the damage. And the result. To function, the reflector had to have a perfect spherical curve. And now it didn't. It sagged. He felt sick.

John left the office. Rapidly he walked through the service tunnel toward Yuegong's moonport. Residual moon dust rasped underfoot. Half-formed in his mind was the idea of quitting. Just like that. Give up and walk away. And let Schropfer have the whole mess.

First he had to find out when the next shuttle to L-5 would be leaving Yuegong Base.

\* \* \*

He happened to see the Port Director's administrative assistant before she saw him. He disliked her: brightly blonde and polished, she always smiled too much, insincerely and in the context of explaining why it would not be possible for the Port to meet some need on the part of the Sand Lake project immediately, or according to the original schedule, or at all. He ducked into a hangar. Watching the woman walk by, he compared her to Ramona, very unfavorably.

A casually uniformed man approached, wiping his hands with a towel. "May we help you?"

"I'm — looking for one of the pilots." John remembered the name stenciled on the blue jumpsuit. "Cantu."

"Over there in the moonhopper. Bang on the side."

John went that way, vaguely framing his inquiry about transportation to L-5. It ought to sound casual, he thought. A sharp smell of hot glue permeated the hangar. As he walked on the floor he felt traces of something underfoot, not gray moon grit, but slick plastic powder. The moonhopper had every service hatch and access panel wide open, and parts were lined up on the floor. When John banged as directed, Cantu popped out of a hatch. "Hi! Doin' better? Did you know you almost had tons of company back at Sand Lake?"

"We did?"

"The observatory astronomers here. They went nuts. They would have gone right over to Sand Lake. Except it seems you don't have room for them yet, or the power supply, or the connections for their instruments."

"Not until Phase II," John murmured.

"So they hauled out to L-5."

Mired in Earth's tidal forces, always facing Earth, rotating on its own axis only once a month, it would take the Moon days to turn far enough for the supernova to be seen from Yuegong Base. That accounted for the lack of life in the observatory office.

Cantu asked, "Ready to go back to study the supernova?"

Going to L-5 meant running away from his work and bumping into other astronomers who had rushed to L-5 to follow theirs. So going to L-5 was not an option. Dislocated from the idea that brought him to the port, his thoughts tumbled.

"In case you're wondering, this vehicle isn't deceased, just having preventative maintenance!" Cantu affectionately whacked the hull of the hopper.

John registered the hollow thump. "That's not metal," he said. "Come to think of it, metal doesn't predominate in any of your spacecraft and vehicles. Composite materials do."

"Huh? Oh, heck yeah. Fiber, resin, glass and glue is where it's at. The Rutan *Voyager* was the first aircraft," Cantu enthused, "to really exploit composite construction — otherwise no way they could have done it. Now everything in aerospace is like that."

Thinking hard, John spoke slowly. "I've got a problem. My radio telescope was damaged yesterday. It's not made of metal — here, that was neither necessary nor desirable. The understructure is a species of L-glass/thermoplastic composite."

"Sounds familiar."

"I've got to get it fixed right away, and I have an idea, involving glue, but I need a professional opinion."

"In that case, you were talking to the right guy in the first place!" Cantu whistled loudly. "Hey, Rod! That's Sylvester Rodriguez. A master mechanic. Don't call him grease monkey, more like glue monkey! Come into the break room and I'll put on some coffee for us."

\* \* \*

Later that afternoon, he made a call to Ramona. She was unavailable, at work in the white room where she was a senior technician. So he left a message. He felt awkward. The accident had left a bruise on his chin, somehow banged against the helmet. "Hi, love," he began. "I'm looking forward to meeting Admiral Bird. I'm in Yuegong Base right now because we had a problem with the dish yesterday. Right now — it's Friday 3 p.m. — I'm on my way back to Sand Lake. I will make the dish work." The last sentence came out with a vehemence that surprised him. Lamely he added, "I took a bit of a fall yesterday and — well, never mind, just a bruise or two. Have a good weekend up there. Bye." He wanted to say more. But not to the L-5 Technical Support Division's message machine.

\* \* \*

Heavily laden this time, the moonhopper pitched up on the blast of its altitude jets. This time John rode shotgun, beside Cantu. He had a vertiginously good view of the lunar Apennine Mountains: a mosaic of intensely bright and dark shapes, geological chiaroscuro. Cantu flicked the jet controls. The hopper zoomed away toward the far side of the Moon.

Since yesterday, the terminator had moved further west, further from Sand Lake. Good. Temperatures would have settled down now, all cooled off, improving the chances of fixing the dish. "I really appreciate this," he said aloud. "I'm sure you guys could find a more entertaining way to spend your weekend, even in Yuegong Base."

Cantu laughed. "Supernovas don't happen all the time, and everybody in Yuegong's got the itch to see it. No way I'd pass up the chance to hear it." These men weren't European, Castilian, like Baltazar. Indian blood darkened their skin — reminding John of Ramona — and they had the kind of practical outlook that he had met in Mexican-American men before. "This job goes on my resume," said Rodriguez, from the back seat.

The hopper made the transit from sunlight to night. Glaring gray moonscape turned to silver, a soft bluish silver: Earthlight graced the maria and the crater rims. Magnificent desolation, Aldrin had said. That was true, but only in the light of Earth. And the Earth was sinking into the horizon behind the hopper.

John thought about the *Voyager* and its long thin wings that flexed in flight. The two pilots had used biological metaphors to describe the experience. The plane porpoised. It felt like riding on the back of a pterodactyl. It flew like a great flapping seagull — around the Earth. Dick Rutan and Jeanna Yeager endured danger and discomfort, breaking-point emotional strain, nightmarish problems. He was no pilot, no derring-doer like those two. Like them, though, he had a machine made out of exotic materials, a dream, a dream machine that could frame a nightmare. Rutan and Yeager never gave up. He wasn't going to either. And if the attempt to fix the dish failed, damaged it worse than ever, if everything hit the fan ... he was not going to quit even then. Schropfer would have to fire him. His neck hurt. He ignored it.

Below the hopper was the far side of the Moon, alien land lit only by the cold white stars. "I gather that you radio astronomers prefer a quiet neighborhood," Cantu commented. "But what do you do for fun?"

"The habitat is pretty basic. Most of it tucked into a lava tube, inhabited outbuildings radiation-shielded with bagged lunar regolith. No amenities. We read a lot. I work with an old hen who reads murder mysteries, and when I ran out of my own books I started on hers." Did her penchant for mysteries point to a dark psychological angle — something about suppressed hostility in Jen's character? Maybe it was just that too many hard weeks of being cooped up in the habitat, too closely with too few people, promoted homicidal fantasies. He had enjoyed the murder mysteries.

"That's the only way I came to read *War and Peace*," Cantu answered breezily. "Cause this guy in my bunkroom had it."

Rodriguez was a different type, a slight and quiet man, all business. "That it down there?"

John replied, "That's the Lunar Far-Side Very Low Frequency Array in the Sanduleak walled plain. Which was named for a twentieth-century astronomer and promptly if disrespectfully corrupted to Sand Lake. Look on the far edge of Sanduleak. See the bright dimple? That's Bolton. And the reflector."

"How does it work?"

"It sits there. It's a photon bucket. The bucket reflects incident radiation to the center, where the antenna is. The antenna is what moves. There's an older dish of this kind in Arecibo, Puerto Rico — a real workhorse in my field." Reflectively, he added, "Bolton is to Arecibo as Voyager is to, oh, maybe a Cessna. Principles the same, materials radically new and different. Composite construction makes Bolton flexible — and fragile. Arecibo stood up to a major hurricane once, in 1989. Earth gravity alone would flatten Bolton."

The reflector was eggshell-thin but not rigid, the pylons stiff yet resilient, the whole structure nonmetal-like, quirky to the extent that it was hard to know what to expect of the exotic materials. John did know. He had parsed the quirks of the machine for all of the months of its construction. A kibitzer like Schropfer could have Bolton's specs strewn all over his desk, and still not know what to expect of the structure.

The hopper swerved over the shore of Sand Lake, braked and began a slow hovering descent toward Bolton. The habitat was tucked into crater Bell, right on the edge of Bolton. Little craters have lesser ones.... John radioed. "Anybody home?" Home sweet home, he thought. Cold showers and gritty floors. Close quarters in which your colleagues' harmless traits got on your nerves. Jen's chocolates, shedding oily brown particles on the pages of technical reports as well as murder mysteries. Zheng's bad breath. And Edward's mild-mannered, rational, relentless pessimism.

Jen's voice replied. "Welcome back. Whatever is that load on top of the hopper?"

"Popsicle sticks," said John. "And duct tape." Rodriguez grinned briefly.

"Cantu, set us down close to the crater edge. Don't worry, it's reinforced, and will not crumble. There's a crane down there that can handle the cargo under the dish. X marks the ideal spot."

"Can do," said the pilot, winking at the pun on his name. He put the hopper down neatly on the landing field's X by the brink of Bolton.

John invited them into the control room. Jennifer seemed as shocked as a hausfrau that he had brought guests home unannounced.

The guests seemed genuinely interested in the instruments and computers, and the radio contour map tacked up on the wall. "I thought your instrument wasn't working," said Rodriguez.

"We have two radio telescopes at this facility," Jen explained. "The Very Low Frequency Array has been operational for three months now." Clicking into professor mode, she explained how her VLF Array was mapping the magnetosphere of Jupiter.

\* \* \*

"Most stars are not single," she was saying. "Binary systems are the norm. Our Sun was very nearly a double star, the other one being Jupiter, if Jupiter had been somewhat bigger. Jupiter is nearly a star, and it generates its own heat and an immense magnetic field..."

John glanced at his workstation's inbox. There was a message for him, from Ramona, datelined Friday 5:14 p.m. YOU'RE IN PAIN AND I AM WORRIED! He stared at the message, unconsciously rubbing his neck.

"She's right," said Jennifer, behind him.

"None of your business," he said brusquely.

Rodriguez had disappeared into the restroom, and Cantu was being introduced to the observatory's main computer by Edward. Jennifer asked, "Why did you bring these people here?"

"They're going to help us fix the dish."

Her eyebrows shot up. "As easy as that?"

"Maybe not. It's a long shot. An idea."

"When?"

He shrugged past the crick in his neck. "No time like the present."

\* \* \*

From this side, the dish was the dim convex canopy of a forest of pylons. Anchored in the crater floor, the slim pylons rose up to branch at the top. The branches terminated in twigs, each attached to one segment of the dish. The position of each dish segment could be adjusted by the control computer. Sensors told the computer the precise position of every segment. Adding everything up, the computer had found the dish sagging. The human eye could not detect the sag, at least not now, with artificial lights shredding the lunar night under the dish.

It was the Moon's slow midnight. But human affairs adhered to the twenty-four-hour artifice of Moon Mean Time. They had spent Friday night unloading the cargo from the hopper and getting ready. John had, again, slept badly. This time his neck hurt all night. And he was troubled by the kind of garish bad dreams that he had been having in recent weeks, the color-pandemonium with which his brain attempted to compensate for the monochromatic tedium of waking life on the Moon. Now it was Saturday morning, still early, 9 a.m. John circled around the site with an impatient mixture of gliding and skipping steps. He wanted to get this over with.

Floodlights illuminated one of the pylons. Twenty feet above the crater floor, it bent at an angle of some fifteen degrees. The hollow-cored pylon had buckled like a soda straw. Now a long cable descended from the

crown of the pylon. The cable ended at a winch anchored on the crater floor, as far away from the pylon as possible.

Two ropes, shorter than the winch cable, dangled from the top of the pylon. John called, "Jennifer, you and Zheng on this one. You'll back off and hold it taut. Out that way — right angles to the cable. Don't actively pull unless you get the word." Jen rapidly translated that into Chinese for Zheng. John continued, "You all know how hard it is to get good traction. So use the anchor posts. Cantu, you and me on the other rope. Edward operates the winch, and Rodriguez spots. He'll tell us if the pylon sways one way or another."

Rodriguez signaled assent.

The bulky moonsuited form of Edward fussed over the winch. Edward said, "This procedure still strikes me as illogical. The basic notion is to *lift*. Right?"

"Ever been to Easter Island?" John asked, "That's how they got the stone heads up. A bunch of people on the ground, pulling on the longest ropes they had."

"I hardly think that qualifies as a reliable precedent. And what about the stress on the points of attachment?"

"For the record," said John, "I'm not 100 percent sure that this will work. I *am* sure it's the thing to try. Ready, everybody? Let's do it."

Moonsuited forms shuffled to their places. At a signal from Rodriguez, Edward turned on the winch. It whirred soundlessly in the airlessness here. The cable oscillated, went taut.

Fifteen hundred feet across, the dim down side of the dish stretched away to the ends of the crater. John felt a sudden conviction of futility. Edward was right. They might as well have been insects, busy but ridiculous ants, trying to reshape this vast thing.

Rodriguez said rapidly, "Pylon's starting to straighten out. Going true. Still true. It's trying to lean to the right!" he waved an arm. "Left rope, pull!" Jennifer and Zheng pulled. The Chinese man had a foot propped on an anchor post, and pulled mightily.

"Let up! Left, let up! Right side pull!"

John pulled. His feet slipped and he skidded. Cantu stumbled. They got anchored again, then, and with their combined mass under the rope, pulled. John felt the rope come to them. Over their heads, the pylon and with it the filmy acres of dish had actually responded to their puny effort.

"That's it! That's it! Ropes, stop pulling! Just hold steady there. Slow the winch — that's about right — Left! Pull, but not too hard! Good! Ease off that winch — anchor the side ropes — put the winch brake on. Not like that!" Rodriguez headed toward the winch with loping strides of a moon veteran making haste. "That's not how the brake works!"

"Oh," said Edward.

Now the pylon looked straight. Only, like a bent soda straw, it had one terribly weak point. Without the winch cable holding it, the pylon would keel back over.

Climbing into the driver's seat, Rodriguez started the crane. It was a light, long-necked, mobile piece of machinery on treads. Using the crane, Rodriguez hoisted one end of a moonglass beam. The inside of the beam was reamed out to match the curvature of the pylon and coated with glue. With some help from the

ground he placed the beam up against the pylon. Glued, it stuck. Then he positioned another beam on the other side of the pylon. "Popsicle sticks in place," Rodriguez commented. With adroit operation of the crane and helpers scrambling on the crater floor, he wrapped the splinted pylon with a ninety-yard length of plastic fabric, stretching and wrapping it.

The glue had to cure. It was time for lunch anyway, though not as simple as knocking off and grabbing a sandwich on the spot: taking off the moonsuits was a chore in itself. After lunch, Rodriguez took a nap. Cantu helped himself to a murder mystery.

\* \* \*

According to the computer, the dish sagged less now. So far, so good. John rubbed his neck, inflamed by the morning's exertion in the spacesuit. The more damaged pylon was yet to come.

Jennifer came into the control room to check the accumulating data from her LFSVLFA. She asked, "How did you get that material? I didn't know we had that much credit with the Yuegong warehouse."

"We don't. I faked an appropriation authorization that said something about a state of scientific emergency. And a facsimile of a fund transfer writ. The check'll bounce Monday morning."

She rolled her eyes. "Oh, Lord! This had better work!"

He shrugged around the pain in his neck. "My responsibility alone. I didn't tell our two friends that I was fleecing the Port. Cantu probably has an idea, but he can plead innocence. If this fails, it's my funeral."

"Don't say that! We didn't tell you Thursday night— but one of the air valves in your suit jammed when you fell. If we hadn't found you and taken the risk of moving you right away—!" She left the outcome unspoken. "It was the sound of your breathing. I was sure you couldn't get enough air. I was right. When we took off the helmet you were turning purple!"

Not knowing quite what to say, John said, "Thank you."

"I was overjoyed when you sat up and talked." Jennifer added, quietly, "It haunts me. I could have lost a good colleague and a good friend."

It went both ways, he thought, with or without chocolate crumbs. "You're that for me too, and you have been for years," he said. "I'm not handling everything so well. I'm sorry."

"It's half fixed," she said briskly. "You brought good help. If we had the facilities, I'd bake cookies for those guys. Very handy people. Unlike somebody else we know of Spanish ancestry!"

John nodded ruefully. "Murphy's Law and Baltazar's Rule."

She spelled out that old joke of theirs. "The better the theoretician, the more things go wrong when he lays his hands on the instruments. Lord, if he'd been here this morning the dish probably would have fallen down around our ears."

They grinned at each other.

\* \* \*

Rodriguez announced that the glue was 97 percent as hard as it was going to get. Cantu stretched and

groaned. "Is this gonna be worth it?" He levered his feet into his spacesuit.

Struggling to squeeze into her own suit, Jennifer puffed, "Good question." She used to be skinny as a rail. But since moving to the Moon and being form-fitted with a moonsuit, she had put on weight — enough to make it hard for her to don the suit. She decided to pause for a lecture. "Normally, radio astronomers don't scramble to observe a supernova. Optical astronomers do."

"Especially when they find themselves on the wrong side of the Moon." Like an eel, Cantu wriggled into the top half of his own suit.

"It's a truly cataclysmic event, a giant star dying, blowing most of its mass out in gusts of ionized matter. I would expect radio thermal emission, though not quite this soon. Heat noise. In science," she continued, "it's also important to check for that which one does not expect to detect, or not yet."

"What's that?" Cantu asked, carefully sealing his waist seam.

John said, "The corpse, spinning in its grave."

"Doin' *what*?"

Jennifer chuckled. "He means a neutron star. The core of the supernova radically collapses into a mass of neutrons, a neutron star, with all of the angular momentum — the rotating force — of the original star compressed into a much smaller package. So the neutron star spins rapidly. Several revolutions per second."

"How do you know?" All suited up, Rodriguez waited, leaning against the airlock with his helmet tucked under one arm.

"It also has a strong magnetic field inherited from the original star. This generates powerful beams of radiation which rotate as fast as the neutron star spins. Like the beam of a lighthouse. Our Solar System may or may not be in the path of the beam. If it is, we identify the source as a pulsar, and it can be quite a lovely radio object," said Jen. "The pulsar takes time to crystallize, though." John pushed down on the shoulders of her suit. The suit settled and her head emerged from the neckhole. "Thanks. No, right now — unless all of our theories are wrong — the neutron star at the core of that supernova is buried in fire and fury. It isn't a pulsar yet."

John checked his air supply. Zheng had fixed the jammed valve, Jen said. It seemed to function perfectly. He took a deep breath. They had in-suit air for six to eight hours. Enough time for the rest of the repair job to make it or break it.

This pylon was more bent than the first one because John had hit the dish closer to it. Rodriguez made a close inspection. Everybody else stood there and watched passively. They were all tired.

Pieces of dish lay on the crater floor. John picked one up. He turned the shard over in his glove. Thin, light glass manufactured from the lunar regolith, it had a shiny metallic coating on one side. With a chill, he remembered falling toward the shiny dish, expecting to die. He would have died, had not the flexing pylons absorbed the impact; had not the matrix of glass segments sagged like a safety net before breaking under him. Looking up, he saw stars through the jagged hole in the dish.

"I'm concerned," said Edward, "that our efforts will damage the dish. It would be very unfortunate if we overstressed the points of attachment of the pylon to the dish. Look, the angle of the bent portion is more extreme than the other one was. The branches are sharply counter-bent. Can they take the strain?"

"I think so," John said shortly.

"The pylon might even break there where it's bent," Edward persisted. "Of course, the opportunity to study the supernova may be worth taking considerable risk, scientifically speaking. I don't know about that."

Jennifer put her helmet against John's, using sound conduction to speak privately. "I do know."

"I want to fix it," he said.

"You're doing this just because you're a stubborn coot who's got his back up. And the rest of us like you enough to work our tails off for you."

Like winter rain, Edward did not let up. "Shouldn't you run this by the project engineers, or possibly Mr. Schropfer, before attempting—"

On the in-suit radio, Jennifer snapped, "Edward, your point is valid but your timing stinks. Go to that winch and get ready."

Rodriguez had an announcement to make. At least five-sixths of the pylon's branches were still securely attached to the dish. "Good enough for government work!" The bent section of pylon was unlikely to break and fall off. If it did, he'd holler. And everybody should run like hell.

The winch pulled. The kink in the pylon straightened out by degrees. John imagined what he would have heard if there had been air to carry the sounds: the groan of the pylon material and squeaks from the mosaic of glass segments. Maybe reports of glass breaking. Not that, he hoped to God.

With one alarm when it keeled to the left, and those on the right side had to scrape and haul, the pylon was jacked upright, the winch cable braked. Then Rodriguez and his helpers swarmed around the pylon to put on the glue, the splints and the cloth. Edward vanished into the control room.

John piled up the broken dish segments, then swept the crater floor clean of glass fragments. You make a mess, you clean it up. He probably cut a funny figure, a spacesuit pushing a broom.

Edward radioed from the control room. "It's better, but not quite better enough. However, with some reprogramming the computer may be able to compensate for that by adjusting individual segments. I can't promise anything, of course, but I'll do my best."

"How about breaks in the dish?" John asked quickly. He had sweat that needed wiping off his brow. Not possible with a spacesuit on. "Stress fractures—?"

"Not indicated, though the computer isn't really programmed to detect stress fractures of the kind that might have been caused by today's activities. It's geared to analyze micrometeorite impact damage."

"Never mind. It sounds good enough to go with."

Within an hour, exhausted snores could be heard in the habitat. It was Sunday now. 12:17 a.m.

Past mere exhaustion, John felt morbidly sleepless. Sitting in bed, he read the supernova report again. Then somebody knocked on the door. "Come in," he said peevishly.

Without preamble, Jennifer told him, "It looked to me like you had a sore neck all day,"

"Yeah. A crick or something."

"How is the crick tonight?"

"It's in fine fettle," he said sourly. "A really great crick."

She probed his neck with her fingers.

"Ouch!"

"Let's try this on it. It's my arthritis liniment."

"I didn't know you had arthritis."

"That is my darkest little secret," she replied.

The liniment went on cool with a wintergreen reek. Then it started to feel warm. Jennifer massaged the neck. To his gratification, the knot of muscles loosened up under her fingertips. Satisfied, Jennifer told him to call it a night, and she departed. He intended to read for a while longer. But he fell asleep with the pages of the report scattered over his bunk.

And dreamed about falling toward the dish.

This time he did not jerk awake. He crashed through the dish, with bright glass panes of it spinning away. Then the dreamer lightly landed in a forest — a tropical forest, improbably situated below the Bolton dish. Color surrounded him, but not the lurid colors of his bad dreams. Lush greens, blossoming bold reds, wild purples and pinks, colors of Puerto Rico. In Technicolor. The dreamer was pleased with himself.

A glossy black toucan perched on a branch, bobbing its head with the great yellow bill. Then he saw the hummingbird. Green as a June bug, it hovered near him. The tiny bird hummed. A beam of golden light illuminated the humming bird. The dreamer looked up. The sky was a convex blue dome with a hole in it. Golden light spilled in through the hole.

The reading light was shining into his upturned face. 7:03 a.m. Sunday morning, by the clock, and he had slept, not long, but well.

Out of force of habit, John checked his email. The doctor in Yuegong Hospital crisply pointed out that he had NOT given John Clay permission to return to work. Two news services and an internet tabloid wanted to interview Dr. Clay about his death-defying fall from a telescope on the Moon. Finally, Schropfer had messaged, RECEIVED CONFIRMATION OF APPROPRIATION REQUEST FILLED. **\*\*WHAT\*\*** REQUEST?

John erased all of the messages.

Another habit, instilled over almost a year of being project manager here, was that of counting noses. Could everybody be accounted for — was anybody missing, out in the lunar environment, in trouble? So he immediately noticed the absence of Rodriguez from the group.

"Checking the repair job," Cantu informed him.

"The shape of the dish is just inside the acceptable parameters," said Edward, proudly, "now that the computer has made more than six hundred coordinated adjustments to the segments." Disheveled, Edward

appeared to have fussed over the computer most of the night, maybe sacked out on the control room cot for a bare hour or two.

"We're ready," said Jennifer, significantly.

John shook his head. "I just remembered something," he said. "A problem up in the equipment house. That's why I went up in the first place."

Instantly Edward volunteered to go up the catwalk and attend to whatever it was. But Jennifer said, "No. He needs to get back up on the horse."

This time he was trembling inside the spacesuit, probably pale as a piece of chalk, glad that the suit concealed those facts so well. "You're three-fourths of the way up!" Jennifer encouraged over the radio. He glanced back toward the gaggle of spacesuits at the base of the catwalk. Jen and Edward and Cantu and Zheng — the last all encouraging waves in the absence of knowing what to say in English. John waved back. Without looking down, he registered the gleam of the dish, photons reflected toward where he was going now.

When he stepped onto the antenna platform, his knees buckled. He sat down with an undignified little bounce.

"That's it!" Jen cheered. "Take a breather! Look up," she suggested.

"Where is it?" asked Cantu.

"There, in the Small Magellanic Cloud, but the supernova is still too faint to see with the naked eye," Jennifer answered. "Bear in mind that the Cloud is a galaxy of stars. A few weeks from now the supernova will be outshining the rest of that galaxy."

Incalescent — one hundred and sixty thousand years ago and away — SN 2019C was the signal flare of a vast cataclysm, in which a giant star blew up hot as hell. No: it was hot, all right, but not infernal. Hot as heaven, hot as the forges of heaven. Heavy elements were being created in the supernova, iron and gold, carbon and oxygen, the atoms of which Moons and moonsuits, future Earths and living things were made.

He picked his own personal collection of atoms up and walked to the equipment housing. Carefully he lifted the broad aluminum lid and locked it into an open position.

Jennifer asked, "What *is* the problem?"

Thumb to forefinger, he plucked sheets of clear plastic off the circuitry. "The contractors left the protective sheathing on."

Jennifer transmitted an unladylike curse having to do with the contractors, and what else they might have been capable of forgetting to do.

"Oh, my," said Edward, "I don't think those gentlemen would forget *that*."

John had removed all of the plastic, and the equipment looked sharp and clean, solid-state of the art. He glanced at the gleam beneath the grated floor. "Rodriguez?" he radioed. "You down there?"

"I take it you won't be dropping in."

"Not today. How's it look?"

"The job'll hold for a few years, minimum."

"By that time, it'll be time for the Phase II enhancements," John said, with satisfaction. He closed the lid and, returning to the catwalk, hurried down to *Luna firma*. When he reached the bottom, the other spacesuits clapped for him. "It's ready now," John said.

\* \* \*

"But is your photon bucket going to work with a hole in it?" asked Cantu.

"Sure. Remember *Voyager's* takeoff? The plane flew OK anyway. Something like that." Cantu might not have been born yet then, but John remembered watching it on TV, in December of 1986, the end of the year that began, disastrously, with *Challenger*. The experimental plane rolled down the California runway, loaded to the gills with fuel, and its long, fuel-laden wings flexed down, scraping the ground. The *Voyager* took off with wires hanging out of ragged wingtips where winglets had been scraped off. And the plane did not touch Earth again before it had circled the planet. It had not really needed the winglets.

Bolton did not really need the few segments that had been knocked out of it. John felt a stirring of euphoria, the old anticipation of having a dream machine to work with. It had been a long time since he last felt that way: for months, he had stared at the diggings in the crater, thinking how little it all resembled the first grand idea. Now, Bolton was ready to meet the ancient voyage of radio waves from the universe.

Edward said, "I haven't finished checking out the computer and its interactivity with the rest of the system." Edward had a fresh contribution of rain for the parade. "I can't guarantee that there aren't any bugs lurking, and in fact by departing from the trial timetable—"

"Forget it!" John said shortly. "The time to try is now." And he started down the path to the control room, stirring up puffs of moondust.

\* \* \*

"A radio interferometer — a chain of dishes strung across a continent, or an ocean, or even from Earth across space — can resolve finer detail. None have this aperture." He opened the window shutters. The control room was perched on the rim of Bolton, below one of the cable towers. He let his eyes follow the cables out over the expanse of the dish. Fifty acres. The antenna hung over the dish like a spider on a tricornered web fifteen hundred feet across. Behind the other two cable towers, the Sanduleak plain stretched away for gray miles. Starlight faintly reflected from LFSVLFA like a metallic hint of waves in Sand Lake.

"Human activities on Earth generate an incredible amount of radio noise, swamping the faint signals from the universe. Located here, the dish and the Very Low Frequency Array are shielded from the radio noise of Earth, by the bulk of the Moon. I might add that the Moon itself is dead quiet apart from very rare rock electric discharges. No weather — no lightning, no seismic activity. For radio astronomy, there is no better place than this. Here goes." Displacing Edward from the controls, John entered a right ascension and declination.

The red lights flashed at the corners of the distant antenna platform. John flashed back to being there, to the panicked realization that the platform was slewing out from under him. Arms crossed, John watched the antenna move. Unlike Arecibo, there was no whirl and vibration from the machine. This one repositioned silently.

"First off, not the supernova," John explained. "Instead we'll scan something called Centaurus A. It's a radio galaxy, a blazing strong source in the radio sky. This is to verify that the receiver's working. Like making sure your new home stereo can pick up the local pop-around-the-clock music station before you go for the university radio station, the one with a weak and unreliable transmitter located ten miles away." He had an afterthought. "Edward, can you convert the signal to sound?"

"Whatever for?" Jen said.

"Show and tell for our company." John explained, "Radio astronomers never listen to the stars. It's not informative for scientific purposes."

Methodically, Edward made the arrangements, hitching this circuit to that.

The antenna slid slowly now, smooth as silk on glass, gliding past the point where the radio waves from Centarus A were focused by the reflector, for a drift scan. On the display screen, the signal came in with what looked like the lift of a bell curve. Converted by Edward's arrangements to sound waves, the signal hissed.

"Static," Cantu remarked.

"Sweetest static I've ever heard!" John replied fervently. The hiss crescendoed as the bell curve tipped over on the display screen. "Jen, just look at that curve! It's classic." The computer brain of the observatory, buried deep under the lunar ground, analyzed the signal. Data windows lined the top and bottom of the display screen. He tapped a window, opened it to read out the red shift of the radio galaxy. "This is great. This is instant gratification. The machine works! Jen, let's break out the champagne!"

"Coming!" She opened the locker with a cheerful rattle.

Then John entered the coordinates of SN 2019C and changed the control settings. "This time, no drifting. The signal, if any, will be too faint to catch unless we sit on it. We'll be looking for thermal radio emissions at a likely wavelength, six centimeters. Don't be surprised if we register, and hear, nothing."

"Cannot be much yet!" Zheng said. "But is good this working!"

"Absolutely, and we're going to celebrate. Champagne, anyone?"

Outside, the antenna slewed to its new position. Sitting in the master chair, John ran a hand lightly over the controls. User-friendly, he thought with approval, lucid, thanks in part to design changes that he had insisted on. "We're in position. We'll give it some settle-down time."

Poured into plastic glasses, the champagne fizzed. The sound conversion hissed just as faintly, pale noise that originated in the circuitry.

"Nada," remarked Cantu, not too worried. Champagne in one hand, he accepted a piece of the chocolate that Jen was offering around in the other.

John thumbed through the supernova report. Thirty hours old, SN 2013C should be brightening rapidly as it began to expand, on the verge of blowing its outer layers off, but still, in fact, intact. Realistically, there was no radio signal to be expected yet. At least not from 2013C.

\* \* \*

"This machine has state-of-the art timing," John said. "Routinely, the receiver averages out any fluctuations

in the signal. But a signal can be too faint to detect when it's averaged like that. So I'm going to delete the averaging, in order to search for a coherent, pulsed signal with a period of one to ten milliseconds between pulses."

Jennifer raised an eyebrow.

"Do you still want it converted to sound?" Edward asked.

"Yes. If we get anything."

"What's going on?" asked Cantu. "Making sure the corpse isn't spinning in its grave yet?"

"Actually, we don't have the resolution to distinguish a pulsar at the exact location of SN 2013C from one in the vicinity." John watched the bubbles in his glass. They rose slowly, just as things on the Moon fell slowly, giving you time to think. "Most stars aren't solitary. There's no reason for the supernova not to be in a binary star system — with a pulsar left over from a supernova ages ago, maybe even a millisecond pulsar."

"Unlikely," Jennifer commented.

"But very desirable," he countered. "Millisecond pulsars are the most accurate clocks in all creation. If we had one in the vicinity of a supernova in progress, we could observe what happened to the timing as the pulsar got hit by gravity waves, radiation, maybe plasma from the supernova. Also, the amount of mass lost in the supernova — and whether or not it breaks up into more than one body — that would register in the signal from a pulsar in the right location. And Bolton is better equipped to read such a signal than any other facility on the Earth or off it. Right, Jen?"

"Yes, but a pulsar is still darn unlikely to be there," said Jennifer. "Has the champagne gone to your head already?"

"Serendipity happens," John pointed out.

\* \* \*

Under the rim of the crater, the big dish gleamed in the faint rain of photons. The receiving instruments caught a unique radio thread; the computer teased it out of the background circuit noise. Edward promptly converted and amplified the signal. It came out as a conversation-stopping loud hum. Echoing from the bare walls, the hum sounded startlingly pure, and made Jennifer leap up, spilling some champagne. "Edward! Make sure that's not our equipment!" she gasped.

"High C!" Cantu guessed. "Are you sure that's not little green men?"

John said rapidly, "It's consistent with a millisecond pulsar." With a glance, he verified that the display screen was representing the signal as a series of spikes. Data windows lined up under the running spikes. John opened one window and read the period of the signal: two point one thousandths of a second. "I think we've made a very timely discovery, thanks to you guys helping us fix the dish."

"Hot damn!" Grinning from ear to ear, Cantu pumped Rodriguez's hand, then Zheng's.

Jennifer was too surprised to be jubilant. She asked, "Whatever made you look for it right away?"

"I read over the previous data last night, and slept on it." John smiled. "And then I dreamed about a hummingbird. It was humming, just like this." He turned both palms up in the bright flurry of sound echoing

around the room.

"I'll be darned!"

John laughed.

Edward solemnly announced, "I can't be *absolutely* sure it's not the equipment, but it seems unlikely," whereupon Jennifer bounded over and kissed Edward. Then she said, "Let's let Schropfer know!"

John nodded. "And Ramona."

"Of course."

Ramona would want to hear about the hummingbird dream — she would be delighted. But that was a gift to save until he saw her in person again. "She knows enough astronomical nomenclature to understand this." He sent the same brief message on its way to the L-5 space station as well as to Washington, DC, Earth. The photons of his message traveled to L-5 and to Earth at the same speed of light with which the pulsar's signal had crossed intergalactic space to meet the radio telescope on the Moon.

PSR 0106-73

IT WORKS

## **AFTERWORD**

This story was first published in the February, 1991 issue of *Analog Science Fiction/Science Fact*. Because I'm not an astronomer myself, I did a great deal of research. Even more important, I posed questions to scientist friends. These included Marc R. Hairston and Sedge L. Simons, both of whom have Ph.D.s in Space Physics from Rice University. And both of whom have great imaginations.

My most invaluable consultant was Dr. Linda Dressel. At the time she was on the faculty at Rice University; she's now with the Space Telescope Science Institute. She is a radio astronomer who has worked at the big radio dish in Arecibo Puerto Rico. She helped me move Arecibo to the Moon.

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## ***Approaching Perimelasma***

by [Geoffrey A. Landis](#)

There is a sudden frisson of adrenaline, a surge of something approaching terror (if I could still feel terror), and I realize that this is it, this time I am the one who is doing it.

I'm the one who is going to drop into a black hole.

Oh, my god. This time I'm not you.

This is real.

Of course, I have experienced this exact feeling before. We both know exactly what it feels like.

\* \* \*

My body seems weird, too big and at once too small. The feel of my muscles, my vision, my kinesthetic sense, everything is wrong. Everything is strange. My vision is fuzzy, and colors are oddly distorted. When I move, my body moves unexpectedly fast. But there seems to be nothing wrong with it. Already I am getting used to it. "It will do," I say.

There is too much to know, too much to be all at once. I slowly coalesce the fragments of your personality. None of them are you. All of them are you.

A pilot, of course, you must have, you must be, a pilot. I integrate your pilot persona, and he is me. I will fly to the heart of a darkness far darker than any mere unexplored continent. A scientist, somebody to understand your experience, yes. I synthesize a persona. You are him, too, and I understand.

And someone to simply experience it, to tell the tale (if any of me will survive to tell the tale) of how you dropped into a black hole, and how you survived. If you survive. Me. I will call myself Wolf, naming myself after a nearby star, for no reason whatsoever, except maybe to claim, if only to myself, that I am not you.

All of we are me are you. But, in a real sense, you're not here at all. None of me are you. You are far away. Safe.

\* \* \*

Some black holes, my scientist persona whispers, are decorated with an accretion disk, shining like a gaudy signal in the sky. Dust and gas from the interstellar medium fall toward the hungry singularity, accelerating to nearly the speed of light in their descent, swirling madly as they fall. It collides; compresses; ionizes. Friction heats the plasma millions of degrees, to emit a brilliant glow of hard x-rays. Such black holes are anything but black; the incandescence of the infalling gas may be the most brilliantly glowing thing in a galaxy. Nobody and nothing would be able to get near it; nothing would be able to survive the radiation.

The Virgo hole is not one of these. It is ancient, dating from the very first burst of star-formation when the

universe was new, and has long ago swallowed or ejected all the interstellar gas in its region, carving an emptiness far into the interstellar medium around it.

The black hole is 57 light years from Earth. Ten billion years ago, it had been a supermassive star, and exploded in a supernova that for a brief moment had shone brighter than the galaxy, in the process tossing away half its mass. Now there is nothing left of the star. The burned-out remnant, some thirty times the mass of the sun, has pulled in space itself around it, leaving nothing behind but gravity.

\* \* \*

Before the download, the psychologist investigated my—your — mental soundness. We must have passed the test, obviously, since I'm here. What type of man would allow himself to fall into a black hole? That is my question. Maybe if I can answer that, I would understand myself.

But this did not seem to interest the psychologist. She did not, in fact, even look directly at me. Her face had the focusless abstract gaze characteristic of somebody hotlinked by the optic nerve to a computer system. Her talk was perfunctory. To be fair, the object her study was not the flesh me, but my computed reflection, the digital maps of my soul. I remember the last thing she said.

"We are fascinated with black holes because of their depth of metaphor," she said, looking nowhere. "A black hole is, literally, the place of no return. We see it as a metaphor for how we, ourselves, are hurled blindly into a place from which no information ever reaches us, the place from which no one ever returns. We live our lives falling into the future, and we will all inevitably meet the singularity." She paused, expecting no doubt some comment. But I remained silent.

"Just remember this," she said, and for the first time her eyes returned to the outside world and focused on me. "This is a real black hole, not a metaphor. Don't treat it like a metaphor. Expect reality." She paused, and finally added, "Trust the math. It's all we really know, and all that we have to trust."

Little help.

\* \* \*

Wolf versus the black hole! One might think that such a contest is an unequal one, that the black hole has an overwhelming advantage.

Not quite so unequal, though.

On my side, I have technology. To start with, the wormhole, the technological sleight-of-space which got you 57 light years from Earth in the first place.

The wormhole is a monster of relativity no less than the black hole, a trick of curved space allowed by the theory of general relativity. After the Virgo black hole was discovered, a wormhole mouth was laborously dragged to it, slower than light, a project that took over a century. Once the wormhole was here, though, the trip is only a short one, barely a meter of travel. Anybody could come here and drop into it.

A wormhole — a far too cute name, but one we seem to be stuck with — is a shortcut from one place to another. Physically, it is nothing more than a loop of exotic matter. If you move through the hoop on this side of the wormhole, you emerge out the hoop on that side. Topologically, the two sides of the wormhole are pasted together, a piece cut out of space glued together elsewhere.

Exhibiting an excessive sense of caution, the proctors of Earthspace refused to allow the other end of the

Virgo wormhole to exit at the usual transportation nexus, the wormhole swarm at Neptune-Trojan 4. The far end of the wormhole opens instead to an orbit around Wolf-562, an undistinguished red dwarf sun circled by two airless planets that are little more than frozen rocks, 21 light years from Earthspace. To get here we had to take a double wormhole hop: Wolf, Virgo.

The black hole is a hundred kilometers across. The wormhole is only a few meters across. I would think that they were overly cautious.

The first lesson of relativity is that time and space are one. For a long time after the theoretical prediction that such a thing as a traversable wormhole ought to be possible, it was believed that a wormhole could also be made to traverse time as well. It was only much later, when wormhole travel was tested, that it was found that the Cauchy instability makes it impossible to make a wormhole lead backward in time. The theory was correct — space and time are indeed just aspects of the same reality, spacetime — but any attempt to move a wormhole in such a way that it becomes a timehole produces a vacuum polarization to cancel out the time effect.

After we — the spaceship I am to pilot, and myself/yourself — come through the wormhole, the wormhole engineers go to work. I have never seen this process close up, so I stay nearby to watch. This is going to be interesting.

A wormhole looks like nothing more than a circular loop of string. It is, in fact, a loop of exotic material, negative-mass cosmic string. The engineers, working telerobotically via vacuum manipulator pods, spray charge onto the string. They charge it until it literally glows with Paschen discharge, like a neon light in the dirty vacuum, and then use the electric charge to manipulate the shape. With the application of invisible electromagnetic fields, the string starts to twist. This is a slow process. Only a few meters across, the wormhole loop has a mass roughly equal to that of Jupiter. Negative to that of Jupiter, to be precise, my scientist persona reminds me, but either way, it is a slow thing to move.

Ponderously, then, it twists further and further, until at last it becomes a lemniscate, a figure of eight. The instant the string touches itself, it shimmers for a moment, and then suddenly there are two glowing circles before us, twisting and oscillating in shape like jellyfish.

The engineers spray more charge onto the two wormholes, and the two wormholes, arcing lightning into space, slowly repel each other. The vibrations of the cosmic string are spraying out gravitational radiation like a dog shaking off water — even where I am, floating ten kilometers distant, I can feel it, like the swaying of invisible tides — and as they radiate energy the loops enlarge. The radiation represents a serious danger. If the engineers lose control of the string for even a brief instant, it might enter the instability known as "squiggle mode," and catastrophically enlarge. The engineers damp out the radiation before it gets critical, though — they are, after all, well practiced at this — and the loops stabilize into two perfect circles. On the other side, at Wolf, precisely the same scene has played out, and two loops of exotic string now circle Wolf-562 as well. The wormhole has been cloned.

All wormholes are daughters of the original wormhole, found floating in the depths of interstellar space eleven hundred years ago, a natural loop of negative cosmic string ancient as the Big Bang, invisible to the eyes save for the distortion of spacetime. That first one led from nowhere interesting to nowhere exciting, but from that one we bred hundreds, and now we casually move wormhole mouths from star to star, breeding new wormholes as it suits us, to form an ever-expanding network of connections.

I should not have been so close. Angry red lights have been flashing in my peripheral vision, warning blinkers that I have been ignoring. The energy radiated in the form of gravitational waves had been prodigious, and would have, to a lesser person, been dangerous. But in my new body I am nearly invulnerable, and if I can't stand a mere wormhole cloning, there is no way I would be able to stand a black hole. So I ignore the warnings, wave briefly to the engineers, though I doubt that they can even see me,

floating kilometers away, and use my reaction jets to scoot over to my ship.

\* \* \*

The ship I will pilot is docked to the research station, where the scientists have their instruments and the biological humans have their living quarters. The wormhole station is huge compared to my ship, which is a tiny ovoid occupying a berth almost invisible against the hull. There is no hurry for me to get to it.

I'm surprised that any of the technicians even see me, tiny as I am in the void, but a few of them apparently do, because in my radio I hear casual greetings called out: how's it, *ohayo gozaimasu*, hey glad you made it, how's the bod? It's hard to tell from the radio voices which ones are people I know, and which are only casual acquaintances. I answer back: how's it, *ohayo*, yo, surpassing spec. None of them seem inclined to chat, but then, they're busy with their own work.

They are dropping things into the black hole.

Throwing things in, more to say. The wormhole station orbits a tenth of an astronomical unit from the Virgo black hole, closer to the black hole than Mercury is to the sun. This is an orbit with a period of a little over two days, but, even so close to the black hole, there is nothing to see. A rock, released to fall straight downward, takes almost a day to reach the horizon.

One of the scientists supervising, a biological human named Sue, takes the time to talk with me a bit, explaining what they are measuring. What interests me most is that they are measuring whether the fall deviates from a straight line. This measures whether the black hole is rotating. Even a slight rotation would mess up the intricate dance of the trajectory required for my ship. However, the best current theories predict that an old black hole will have shed its angular momentum long ago, and, so far as the technicians can determine, their results show that the conjecture holds.

The black hole, or the absence in space where it is located, is utterly invisible from here. I follow the pointing finger of the scientist, but there is nothing to see. Even if I had a telescope, it is unlikely that I would be able to pick out the tiny region of utter blackness against the irregular darkness of an unfamiliar sky.

My ship is not so different from the drop probes. The main difference is that I will be on it.

Before boarding the station, I jet over in close to inspect my ship, a miniature egg of perfectly reflective material. The hull is made of a single crystal of a synthetic material so strong that no earthly force could even dent it.

A black hole, though, is no earthly force.

\* \* \*

Wolf versus the black hole! The second technological trick I have in my duel against the black hole is my body.

I am no longer a fragile, fluid-filled biological human. The tidal forces approaching the horizon of a black hole would rip a true human apart in mere instants; the accelerations required to hover would squash one into liquid. To make this journey, I have downloaded your fragile biological mind into a body of more robust material. As important as the strength of my new body is the fact that it is tiny. The force produced by the curvature of gravity is proportional to the size of the object. My new body, a millimeter tall, is millions of times more resistant to being stretched to spaghetti.

The new body has another advantage as well. With my mind operating as software on a computer the size of a pinpoint, my thinking and my reflexes are thousands of times faster than biological. In fact, I have already chosen to slow my thinking down, so that I can still interact with the biologicals. At full speed, my microsecond reactions are lightning compared to the molasses of neuron speeds in biological humans. I see far in the ultraviolet now, a necessary compensation for the fact that my vision would consist of nothing but a blur if I tried to see by visible light.

You could have made my body any shape, of course, a tiny cube or even a featureless sphere. But you followed the dictates of social convention. A right human should be recognizably a human, even if I am to be smaller than an ant, and so my body mimics a human body, although no part of it is organic, and my brain faithfully executes your own human brain software. From what I see and feel, externally and internally, I am completely, perfectly human.

As is right and proper. What is the value of experience to a machine?

Later, after I return — if I return — I can upload back. I can become you.

But the return is, as they say, still somewhat problematical.

You, my original, what do you feel? Why did I think I would do it? I imagine you laughing hysterically about the trick you played, sending me to drop into the black hole while you sit back in perfect comfort, in no danger. Imagining your laughter comforts me, for all that I know that it is false. I've been in the other place before, and never laughed.

I remember the first time I fell into a star.

\* \* \*

We were hotlinked together, that time, united in online-realttime, our separate brains reacting as one brain. I remember what I thought, the incredible electric feel: ohmigod, am I really going to do this? Is it too late to back out?

The idea had been nothing more than a whim, a crazy idea, at first. We had been dropping probes into a star, Groombridge 1830B, studying the dynamics of a flare star. We were done, just about, and the last-day-of-project party was just getting in swing. We were all fuzzed with neurotransmitter randomizers, creativity spinning wild and critical thinking nearly zeroed. Somebody, I think it had been Jenna, said, we could ride one down, you know. Wait for a flare, and then plunge through the middle of it. Helluva ride.

Helluva splash at the end, too, somebody said, and laughed.

Sure, somebody said. It might have been me. What do you figure? Download yourself to temp storage and then uplink frames from yourself as you drop?

That works, Jenna said. Better: we copy our bodies first, then link the two brains. One body drops; the other copy hotlinks to it.

Somehow, I don't remember when, the word "we" had grown to include me.

"Sure," I said. "And the copy on top is in null-input suspension; experiences the whole thing real-time."

In the morning, when we were focused again, I might have dismissed the idea as a whim of the fuzz, but for Jenna the decision was already immovable as a droplet of neutronium. Sure we're dropping, let's start now.

We made a few changes. It takes a long time to fall into a star, even a small one like Bee, so the copy was reengineered to a slower thought rate, and the original body in null-input was frame-synched to the drop copy with impulse-echoers. Since the two brains were molecule by molecule identical, the uplink bandwidth required was minimal.

The probes were reworked to take a biological, which meant mostly that a cooling system had to be added to hold the interior temperature within the liquidus range of water. We did that by the simplest method possible: we surrounded the probes with a huge block of cometary ice. As it sublimated, the ionized gas would carry away heat. A secondary advantage of that was that our friends, watching from orbit, would have a blazing cometary trail to cheer on. When the ice was used up, of course, the body would slowly vaporize. None of us would actually survive to hit the star.

But that was no particular concern. If the experience turned out to be too undesirable, we could always edit the pain part of it out of the memory later.

It would have made more sense, perhaps, to have simply recorded the brain-uplink from the copy onto a local high-temp buffer, squirted it back, and linked to it as a memory upload. But Jenna would have none of that. She wanted to experience it in realtime, or at least in as close to realtime as speed-of-light delays allow.

Three of us, Jenna, Martha, and me, dropped. Something seems to be missing from my memory here; I can't remember the reason I decided to do it. It must have been something about a biological body, some a-rational consideration that seemed normal to my then-body that I could never back down from a crazy whim of Jenna's.

And I had the same experience, the same feeling then, as I, you, did, always do, the feeling that my god I am the copy and I am going to die. But that time, of course, thinking every thought in synchrony, there was no way at all to tell the copy from the original, to split the me from you.

It is, in its way, a glorious feeling.

I dropped.

You felt it, you remember it. Boring at first, the long drop with nothing but freefall and the chatter of friends over the radio-link. Then the ice shell slowly flaking away, ionizing and beginning to glow, a diaphanous cocoon of pale violet, and below the red star getting larger and larger, the surface mottled and wrinkled, and then suddenly we fell into and through the flare, a huge luminous vault above us, dwarfing our bodies in the immensity of creation.

An unguessable distance beneath me, the curvature of the star vanished, and, still falling at three hundred kilometers per second, I was hanging motionless over an infinite plane stretching from horizon to horizon.

And then the last of the ice vaporized, and I was suddenly suspended in nothing, hanging nailed to the burning sky over endless crimson horizons of infinity, and pain came like the inevitability of mountains — I didn't edit it — pain like infinite oceans, like continents, like a vast, airless world.

Jenna, now I remember. The odd thing is, I never did really connect in any significant way with Jenna. She was already in a quadrad of her own, a quadrad she was fiercely loyal to, one that was solid and accepting to her chameleon character, neither needing nor wanting a fifth for completion.

Long after, maybe a century or two later, I found out that Jenna had disassembled herself. After her quadrad split apart, she downloaded her character to a mainframe, and then painstakingly cataloged everything that made her Jenna: all her various skills and insights, everything she had experienced, no matter how minor,

each facet of her character, every memory and dream and longing: the myriad subroutines of personality. She indexed her soul, and she put the ten thousand pieces of it into the public domain for download. A thousand people, maybe a million people, maybe even more, have pieces of Jenna, her cleverness, her insight, her skill at playing antique instruments.

But nobody has her sense of self. After she copied her subroutines, she deleted herself.

\* \* \*

And who am I?

\* \* \*

Two of the technicians who fit me into my spaceship and who assist in the ten thousand elements of the preflight check are the same friends from that drop, long ago; one of them even still in the same biological body as he had then, although eight hundred years older, his vigor undiminished by biological reconstruction. My survival, if I am to survive, will be dependent on microsecond timing, and I'm embarrassed not to be able to remember his name.

He was, I recall, rather stodgy and conservative even back then.

We joke and trade small talk as the checkout proceeds. I'm still distracted by my self-questioning, the implications of my growing realization that I have no understanding of why I'm doing this.

Exploring a black hole would be no adventure if only we had faster than light travel, but of the thousand technological miracles of the third and fourth millennia, this one miracle was never realized. If I had the mythical FTL motor, I could simply drive out of the black hole. At the event horizon, space falls into the black hole at the speed of light; the mythical motor would make that no barrier.

But such a motor we do not have. One of the reasons I'm taking the plunge — not the only one, not the main one, but one — is in the hope that scientific measurements of the warped space inside the black hole will elucidate the nature of space and time, and so I myself will make one of the innumerable small steps to bring us closer to a FTL drive.

The spaceship I am to pilot has a drive nearly — but not quite — as good. It contains a microscopic twist of spacetime inside an impervious housing, a twist that will parity-reverse ordinary matter into mirror-matter. This total conversion engine gives my ship truly ferocious levels of thrust. The gentlest nudge of my steering rockets will give me thousands of gravities of acceleration. Unthinkable acceleration for a biological body, no matter how well cushioned. The engine will allow the rocket to dare the unthinkable, to hover at the very edge of the event horizon, to maneuver where space itself is accelerating at nearly lightspeed. This vehicle, no larger than a peanut, contains the engines of an interstellar probe.

Even with such an engine, most of the ship is reaction mass.

The preflight checks are all green. I am ready to go. I power up my instruments, check everything out for myself, verify what has already been checked three times, and then check once again. My pilot persona is very thorough. Green.

"You still haven't named your ship," comes a voice to me. It is the technician, the one whose name I have forgotten. "What is your call sign?"

One way journey, I think. Maybe something from Dante? No, Sartre said it better: no exit. "*Huis Clos*," I say,

and drop free.

Let them look it up.

\* \* \*

Alone.

The laws of orbital mechanics have not been suspended, and I do not drop into the black hole. Not yet. With the slightest touch of my steering engines — I do not dare use the main engine this close to the station — I drop into an elliptical orbit, one with a perimelasma closer to, but still well outside the dangerous zone of the black hole. The black hole is still invisible, but inside my tiny kingdom I have enhanced senses of exquisite sensitivity, spreading across the entire spectrum from radio to gamma radiation. I look with my new eyes to see if I can detect an x-ray glow of interstellar hydrogen being ripped apart, but if there is any such, it is too faint to be visible with even my sensitive instruments. The interstellar medium is so thin here as to be essentially nonexistent. The black hole is invisible.

I smile. This makes it better, somehow. The black hole is pure, unsullied by any outside matter. It consists of gravity and nothing else, as close to a pure mathematical abstraction as anything in the universe can ever be.

It is not too late to back away. If I were to choose to accelerate at a million gravities, I would reach relativistic velocities in about thirty seconds. No wormholes would be needed for me to run away; I would barely even need to slow down my brain to cruise at nearly the speed of light to anywhere in the colonized galaxy.

But I know I won't. The psychologist knew it too, damn her, or she would never have approved me for the mission. Why? What is it about me?

As I worry about this with part of my attention, while the pilot persona flies the ship, I flash onto a realization, and at this realization another memory hits. It is the psychologist, and in the memory I'm attracted to her sexually, so much so that you are distracted from what she is saying.

I feel no sexual attraction now, of course. I can barely remember what it is. That part of the memory is odd, alien.

"We can't copy the whole brain to the simulation, but we can copy enough that, to yourself, you will still feel like yourself," she said. She is talking to the air, not to you. "You won't notice any gaps."

I'm brain damaged. This is the explanation.

You frowned. "How could I not notice that some of my memories are missing?"

"The brain makes adjustments. Remember, at any given time, you never even use one percent of one percent of your memories. What we'll be leaving out will be stuff that you will never have any reason to think about. The memory of the taste of strawberries, for example; the floor-plan of the house you lived in as a teenager. Your first kiss."

This bothered you somewhat — you want to remain yourself. I concentrate, hard. What do strawberries taste like? I can't remember. I'm not even certain what color they are. Round fruits, like apples, I think, only smaller. And the same color as apples, or something similar, I'm sure, except I don't remember what color that is.

You decided that you can live with the editing, as long as it doesn't change the essential you. You smiled. "Leave in the first kiss."

So I can never possibly solve the riddle, what kind of a man is it that would deliberately allow himself to drop into a black hole. I cannot, because I don't have the memories of you. In a real sense, I am not you at all.

But I do remember the kiss. The walk in the darkness, the grass wet with dew, the moon a silver sliver on the horizon, turning to her and her face already turned up to meet my lips. The taste indescribable, more feeling than taste (not like strawberries at all), the small hardness of her teeth behind the lips — all there. Except the one critical detail: I don't have any idea at all who she was.

What else am I missing? Do I even know what I don't know?

I was a child, maybe nine, and there was no tree in the neighborhood that you could not climb. I was a careful, meticulous, methodical climber. On the tallest of the trees, when you reached toward the top, you were above the forest canopy (did I live in a forest?) and, out of the dimness of the forest floor, emerged into brilliant sunshine. Nobody else could climb like you; nobody ever suspected how high I climbed. It was your private hiding place, so high that the world was nothing but a sea of green waves in the valley between the mountains.

It was my own stupidity, really. At the very limit of the altitude needed to emerge into sunlight, the branches were skinny, narrow as your little finger. They bent alarmingly with your weight, but I knew exactly how much they would take. The bending was a thrill, but I was cautious, and knew exactly what I was doing.

It was further down, where the branches were thick and safe, that I got careless. Three points of support, that was the rule of safety, but I was reaching for one branch, not paying attention, when one in my other hand broke, and I was off balance. I slipped. For a prolonged instant I was suspended in space, branches all about me, but I reached out and grasped only leaves, and I fell and fell and fell, and all I could think as leaves and branches fell upward past me was, oh my, I made a miscalculation; I was really stupid.

The flash memory ends with no conclusion. I must have hit the ground, but I cannot remember it. Somebody must have found me, or else I wandered or crawled back, perhaps in a daze, and found somebody, but I cannot remember it.

\* \* \*

Half a million kilometers from the hole. If my elliptical orbit were around the sun instead of a black hole, I would already have penetrated the surface. I now hold the record for the closest human approach. There is still nothing to see with unmagnified senses. It seems surreal that I'm in the grip of something so powerful that is utterly invisible. With my augmented eyes used as a telescope, I can detect the black hole by what isn't there, a tiny place of blackness nearly indistinguishable from any other patch of darkness except for an odd motion of the stars near it.

My ship is sending a continuous stream of telemetry back to the station. I have an urge to add a verbal commentary — there is plenty of bandwidth, but I have nothing to say. There is only one person I have any interest in talking to, and you are cocooned at absolute zero, waiting for me to upload myself and become you.

My ellipse takes me inward, moving faster and faster. I am still in Newton's grip, far from the sphere where Einstein takes hold.

A tenth of a solar radius. The blackness I orbit is now large enough to see without a telescope, as large as the

sun seen from Earth, and swells as I watch with time-distorted senses. Due to its gravity, the blackness in front of the star pattern is a bit larger than the disk of the black hole itself. Square root of 27 over two — about two and a half times larger, the physicist persona notes. I watch in fascination.

What I see is a bubble of pure blackness. The bubble pushes the distant stars away from it as it swells. My orbital motion makes the background stars appear to sweep across the sky, and I watch them approach the black hole and then, smoothly pushed by the gravity, move off to the side, a river of stars flowing past an invisible obstacle. It is a gravitational lensing effect, I know, but the view of flowing stars is so spectacular that I cannot help but watch it. The gravity pushes each star to one side or the other. If a star were to pass directly behind the hole, it would appear to split and for an instant become a perfect circle of light, an Einstein ring. But this precise alignment is too rare to see by accident.

Closer, I notice an even odder effect. The sweeping stars detour smoothly around the bubble of blackness, but very close to the bubble, there are other stars, stars which actually move in the opposite direction, a counterflowing river of stars. It takes me a long time (microseconds perhaps) before my physicist persona tells me that I am seeing the image of the stars in the Einstein mirror. The entire external universe is mirrored in a narrow ring outside the black hole, and the mirror image flows along with a mirror of my own motion.

In the center of the ring there is nothing at all.

Five thousand kilometers, and I am moving fast. The gravitational acceleration here is over ten million gees, and I am still fifty times the Schwarzschild radius from the black hole. Einstein's correction is still tiny, though, and if I were to do nothing, my orbit will whip around the black hole and still escape into the outside world.

One thousand kilometers. Perimelasma, the closest point of my elliptical orbit. Ten times the Schwarzschild radius, close enough that Einstein's correction to Newton now makes a small difference to the geometry of space. I fire my engines. My speed is so tremendous that it takes over a second of my engine firing at a million gravities to circularize my orbit.

My time sense has long since speeded up back to normal, and then faster than normal. I orbit the black hole about ten times per second.

My god, this is why I exist, this is why I'm here.

All my doubts are gone in the rush of naked power. No biological could have survived this far; no biological could have even survived the million-gee circularization burn, and I am only at the very beginning. I grin like a maniac, throb with a most unscientific excitement that must be the electronic equivalent of an adrenaline high.

Oh, this ship is good. This ship is sweet. A million-gee burn, smooth as magnetic levitation and I barely cracked the throttle. I should have taken it for a spin before dropping in, should have hot-rodged *Huis Clos* around the stellar neighborhood. But it had been absolutely out of the question to fire the main engine close to the wormhole station. Even with the incredible efficiency of the engine, that million-gee perimelasma burn must have lit up the research station like an unexpected sun.

I can't wait to take *Huis Clos* in and see what it will *really* do.

My orbital velocity is a quarter of the speed of light.

The orbit at nine hundred kilometers is only a parking orbit, a chance for me to configure my equipment, make final measurements and, in principle, a last chance for me to change my mind. There is nothing to

reconnoiter that the probes have not already measured, though, and there is no chance that I will change my mind, however sensible that may seem.

The river of stars swirls in a dance of counterflow around the blackness below me. The horizon awaits.

The horizon below is invisible, but real. There is no barrier at the horizon, nothing to see, nothing to feel. I will be even unable to detect it, except for my calculations.

An event horizon is a one-way membrane, a place you can pass into but neither you nor your radio signals can pass out of. According to the mathematics, as I pass through the event horizon, the directions of space and time change identity. Space rotates into time; time rotates into space. What this means is that the direction to the center of the black hole, after I pass the event horizon, will be the future. The direction out of the black hole will be the past. This is the reason that no one and nothing can ever leave a black hole; the way inward is the one direction we always must go, whether we will it or not: into the future.

Or so the mathematics says.

The future, inside a black hole, is a very short one.

So far the mathematics have been right on. But nevertheless, I go on. With infinitesimal blasts from my engine, I inch my orbit lower.

The bubble of blackness gets larger, and the counterflow of stars around it becomes more complex. As I approach three times the Schwarzschild radius, 180 km, I check all my systems. This is the point of no rescue: inside three Schwarzschild radii, no orbits are stable, and my automatic systems will be constantly thrusting to adjust my orbital parameters to keep me from falling into the black hole or being flung away to infinity. My systems are all functional, in perfect form for the dangerous drop. My orbital velocity is already half the speed of light. Below this point centrifugal force will decrease toward zero as I lower my orbit, and I must use my thrusters to increase my velocity as I descend, or else plunge into the hole.

When I grew up, in the last years of the second millennium, nobody thought that they would live forever. Nobody would have believed me if I told them that, by my thousandth birthday, I would have no concept of truly dying.

Even if all our clever tricks fail, even if I plunge through the event horizon and am stretched into spaghetti and crushed by the singularity, I will not die. You, my original, will live on, and if you were to die, we have made dozens of back-ups and spin-off copies of ourselves in the past, some versions of which must surely still be living on. My individual life has little importance. I can, if I chose, uplink my brain-state to the orbiting station right at this instant, and reawake, whole, continuing this exact thought, unaware (except on an abstract intellectual level) that I and you are not the same.

But we are not the same, you and I. I am an edited down version of you, and the memories that have been edited out, even if I never happen to think them, make me different, a new individual. Not you.

On a metaphorical level, a black hole stands for death, the blackness that is sucking us all in. But what meaning does death have in a world of matrix back-ups and modular personality? Is my plunge a death wish? Is it thumbing my nose at death? Because I intend to survive. Not you. Me.

I orbit the black hole over a hundred times a second now, but I have revved my brain processing speed accordingly, so that my orbit seems to me leisurely enough. The view here is odd. The black hole has swollen to the size of a small world below me, a world of perfect velvet darkness, surrounded by a belt of madly rotating stars.

No engine, no matter how energetic, can put a ship into an orbit at 1.5 times the Schwarzschild radius; at this distance, the orbital velocity is the speed of light, and not even my total-conversion engine can accelerate me to that speed. Below that there are no orbits at all. I stop my descent at an orbit just sixty kilometers from the event horizon, when my orbital velocity reaches 85% of the speed of light. Here I can coast, ignoring the constant small adjustments of the thrusters that keep my orbit from sliding off the knife-edge. The velvet blackness of the black hole is almost half of the universe now, and if I were to trust the outside view, I am diving at a slant downward into the black hole. I ignore my pilot's urge to override the automated navigation and manually even out the trajectory. The downward slant is only relativistic aberration, nothing more, an illusion of my velocity.

85% of the speed of light is as fast as I dare orbit; I must conserve my fuel for the difficult part of the plunge to come.

In my unsteady orbit 60 kilometers above the black hole, I let my ship's computer chat with the computer of the wormhole station, updating and downloading my sensor's observations.

At this point, according to the mission plan, I am supposed to uplink my brain state, so that should anything go wrong further down the well, you, my original, will be able to download my state and experiences to this point. To hell with that, I think, a tiny bit of rebellion. I am not you. If you awaken with my memories, I will be no less dead.

Nobody at the wormhole station questions my decision not to upload.

I remember one other thing now. "You're a type N personality," the psychologist had said, twitching her thumb to leaf through invisible pages of test results. The gesture marked her era; only a person who had grown up before computer hotlinks would move a physical muscle in commanding a virtual. She was twenty-first century, possibly even twentieth. "But I suppose you already know that."

"Type N?" you asked.

"Novelty-seeking," she said. "Most particularly, one not prone to panic at new situations."

"Oh," you said. You did already know that. "Speaking of novelty seeking, how do you feel about going to bed with a type N personality?"

"That would be unprofessional." She frowned. "I think."

"Not even one who is about to jump down a black hole?"

She terminated the computer link with a flick of her wrist, and turned to look at you. "Well—"

\* \* \*

From this point onward, microsecond timing is necessary for the dance we have planned to succeed. My computer and the station computer meticulously compare clocks, measuring Doppler shifts to exquisite precision. My clocks are running slow, as expected, but half of the slowness is relativistic time dilation due to my velocity. The gravitational redshift is still modest. After some milliseconds — a long wait for me, in my hyped-up state — they declare that they agree. The station has already done their part, and I begin the next phase of my descent.

The first thing I do is fire my engine to stop my orbit. I crack the throttle to fifty million gees of acceleration, and the burn takes nearly a second, a veritable eternity, to slow my flight.

For a moment I hover, and start to drop. I dare not drop too fast, and I ramp my throttle up, to a hundred megagee, five hundred, a billion gravities. At forty billion gravities of acceleration my engine thrust equals the gravity of the black hole and I hover.

The blackness has now swallowed half of the universe. Everything beneath me is black. Between the black below and the starry sky above, a spectacularly bright line exactly bisects the sky. I have reached the altitude at which orbital velocity is just equal to the speed of light, and the light from my rocket exhaust is in orbit around the black hole. The line I see around the sky is my view of my own rocket, seen by light that has traveled all the way around the black hole. All I can see is the exhaust, far brighter than anything else in the sky.

The second brightest thing is the laser beacon from the wormhole station above me, shifted from the original red laser color to a greenish blue. The laser marks the exact line between the station and the black hole, and I maneuver carefully until I am directly beneath the orbiting station.

At forty billion gravities, even my ultrastrong body is at its limits. I cannot move, and even my smallest finger is pressed against the form-fitting acceleration couch. But the controls, hardware interfaced to my brain, do not require me to lift a finger to command the spacecraft. The command I give *Huis Clos* is: down.

Inward from the photon sphere, the bright line of my exhaust vanishes. Every stray photon from my drive is now sucked downward.

Now my view of the universe has changed. The black hole has become the universe around me, and the universe itself, all the galaxies and stars and the wormhole station, is a shrinking sphere of sparkling dust above me.

Sixty billion gravities. Seventy. Eighty.

Eighty billion gravities is full throttle. I am burning fuel at an incredible rate, and only barely hold steady. I am still twenty kilometers above the horizon.

There is an unbreakable law of physics: incredible accelerations require incredible fuel consumption. Even though my spaceship is, by mass, comprised mostly of fuel, I can maintain less than a millisecond worth of thrust at this acceleration. I cut my engine and drop.

It will not be long now. This is my last chance to uplink a copy of my mind back to the wormhole station to wake in your body, with my last memory the decision to upload my mind.

I do not.

The stars are blueshifted by a factor of two, which does not make them noticeably bluer. Now that I have stopped accelerating, the starlight is falling into the hole along with me, and the stars do not blueshift any further. My instruments probe the vacuum around me. The theorists tell that the vacuum close to the horizon of a black hole is an exotic vacuum, abristle with secret energy. Only a ship plunging through the event horizon would be able to measure this. I do, recording the results carefully on my ship's on-board recorders, since it is now far too late to send anything back by radio.

There is no sign to mark the event horizon, and there is no indication at all when I cross it. If it were not for my computer, there would be no way for me to tell that I have passed the point of no return.

Nothing is different. I look around the tiny cabin, and can see no change. The blackness below me continues to grow, but is otherwise not changed. The outside universe continues to shrink above me; the brightness

beginning to concentrate into a belt around the edge of the glowing sphere of stars, but this is only an effect of my motion. The only difference is that I have only a few hundred microseconds left.

From the viewpoint of the outside world, the light from my spacecraft has slowed down and stopped at the horizon. But I have far outstripped my lagging image, and am falling toward the center at incredible speed. At the exact center is the singularity, far smaller than an atom, a mathematical point of infinite gravity and infinite mystery.

Whoever I am, whether or not I survive, I am now the first person to penetrate the event horizon of a black hole. That's worth a cheer, even with nobody to hear. Now I have to count on the hope that the microsecond timing of the technicians above me had been perfect for the second part of my intricate dance that might, if all goes well, allow me to survive this feat.

Above me, according to theory, the stars have already burned out, and even the most miserly red dwarf has sputtered the last of its hydrogen fuel and grown cold. The universe has already ended, and the stars have gone out. I still see a steady glow of starlight from the universe above me, but this is fossil light, light that has been falling down into the black hole with me for eons, trapped in the infinitely stretched time of the black hole.

For me, time has rotated into space, and space into time. Nothing feels different to me, but I cannot avoid the singularity at the center of the black hole any more than I can avoid the future. Unless, that is, I have a trick.

Of course I have a trick.

At the center of the spherical universe above me is a dot of bright blue-violet; the fossil light of the laser beacon from the orbiting station. My reaction jets have kept on adjusting my trajectory to keep me centered in the guidance beam, so I am directly below the station. Anything dropped from the station will, if everything works right, drop directly on the path I follow.

I am approaching close to the center now, and the tidal forces stretching my body are creeping swiftly toward a billion gees per millimeter. Much higher and even my tremendously strong body will be ripped to spaghetti. There are only microseconds left for me. It is time.

I hammer my engine, full throttle. Far away, and long ago, my friends at the wormhole station above dropped a wormhole into the event horizon. If their timing was perfect—

From a universe that has already died, the wormhole cometh.

Even with my enhanced time sense, things happen fast. The laser beacon blinks out, and the wormhole sweeps down around me like the vengeance of God, far faster than I can react. The sparkle-filled sphere of the universe blinks out like a light, and the black hole — and the tidal forces stretching my body — abruptly disappears. For a single instant I see a black disk below me, and then the wormhole rotates, twists, stretches, and then silently vanishes.

Ripped apart by the black hole.

My ship is vibrating like a bell from the abrupt release of tidal stretching. "I did it," I shout. "It worked! God damn it, it really worked!"

This was what was predicted by the theorists, that I would be able to pass through the wormhole before it was shredded by the singularity at the center. The other possibility, that the singularity itself, infinitesimally small and infinitely powerful, might follow me through the wormhole, was laughed at by everyone who had any

claim to understand wormhole physics. This time, the theorists were right.

But where am I?

There should be congratulations pouring in to my radio by now, teams of friends and technicians swarming over to greet me, cheering and shouting.

"*Huis Clos*," I say, over the radio. "I made it! *Huis Clos* here. Is anybody there?"

In theory, I should have reemerged at Wolf-562. But I do not see it. In fact, what I see is not recognizably the universe at all.

There are no stars.

Instead of stars, the sky is filled with lines, parallel lines of white light by the uncountable thousands. Dominating the sky, where the star Wolf-562 should have been, is a glowing red cylinder, perfectly straight, stretching to infinity in both directions.

Have I been transported into some other universe? Could the black hole's gravity sever the wormhole, cutting it loose from our universe entirely and connect it into this strange new one?

If so, it has doomed me. The wormhole behind me, my only exit from this strange universe, is already destroyed. Not that escaping through it could have done me any good — it would only have brought me back to the place I escaped, to be crushed by the singularity of the black hole.

I could just turn my brain off, and I will have lost nothing, in a sense. They will bring you out of your suspended state, tell you that the edition of you that dropped into the black hole failed to upload, and they lost contact after it passed the event horizon. The experiment failed, but you had never been in danger.

But, however much you think we are the same, I am not you. I am a unique individual. When they revive you, without your expected new memories, I will still be gone.

I want to survive. I want to return.

A universe of tubes of light! Brilliant bars of an infinite cage. The bright lines in the sky have slight variations in color, from pale red to plasma-arc blue. They must be similar to the red cylinder near me, I figure, but light-years away. How could a universe have lines of light instead of stars?

I am amazingly well equipped to investigate that question, with senses that range from radio through X-ray, and I have nothing else to do for the next thousand years or so. So I take a spectrum of the light from the glowing red cylinder.

I have no expectation that the spectrum will reveal anything I can interpret, but oddly, it looks normal. Impossibly, it looks like the spectrum of a star.

The computer can even identify, from its data of millions of spectra, precisely which star. The light from the cylinder has the spectral signature of Wolf-562.

Coincidence? It cannot possibly be coincidence, out of billions of possible spectra, that this glowing sword in the sky has exactly the spectrum of the star that should have been there. There can be no other conclusion but that the cylinder *is* Wolf-562.

I take a few more spectra, this time picking at random three of the lines of light in the sky, and the computer analyzes them for me. A bright one: the spectrum of 61 Virginis. A dimmer one: a match to Wolf-1061. A blue-white streak: Vega.

The lines in the sky are stars.

What does this mean?

I'm not in another universe. I am in our universe, but the universe has been transformed. Could the collision of a wormhole with a black hole destroy our entire universe, stretching suns like taffy into infinite straight lines? Impossible. Even if it had, I would still see far-away stars as dots, since the light from them has been traveling for hundreds of years.

The universe cannot have changed. Therefore, by logic, it must be me who has been transformed.

Having figured out this much, the only possible answer is obvious.

When the mathematicians describe the passage across the event horizon of a black hole, they say that the space and time directions switch identity. I had always thought this only a mathematical oddity, but if it were true, if I had rotated when I passed the event horizon, and was now perceiving time as a direction in space, and one of the space axes as time — this would explain everything. Stars extend from billions of years into the past to long into the future; perceiving time as space, I see lines of light. If I were to come closer and find one of the rocky planets of Wolf 562, it would look like a braid around the star, a helix of solid rock. Could I land on it? How would I interact with a world where what I perceive as time is a direction in space?

My physicist persona doesn't like this explanation, but is at a loss to find a better one. In this strange sideways existence, I must be violating the conservation laws of physics like mad, but the persona could find no other hypothesis and must reluctantly agree: time is rotated into space.

To anybody outside, I must look like a string, a knobby long rope with one end at the wormhole and the other at my death, wherever that might be. But nobody could see me fast enough, since with no extension in time I must only be a transient event that bursts everywhere into existence and vanishes at the same instant. There is no way I could signal, no way I can communicate—

Or? Time, to me, is now a direction I can travel in as simply as using my rocket. I could find a planet, travel parallel to the direction of the surface—

But, no, all I could do would be only to appear to the inhabitants briefly as a disk, a cross-section of myself, infinitely thin. There is no way I could communicate.

But I can travel in time, if I want. Is there any way I can use this?

Wait. If I have rotated from space into time, then there is one direction in space which I cannot travel. Which direction is that? The direction that used to be away from the black hole.

Interesting thoughts, but not ones which help me much. To return, I need to once again flip space and time. I could dive into a black hole. This would again rotate space and time, but it wouldn't do me any good: once I left the black hole — if I could leave the black hole — nothing would change.

Unless there were a wormhole inside the black hole, falling inward to destruction just at the same instant I was there? But the only wormhole that has fallen into a black hole was already destroyed. Unless, could I travel forward in time? Surely some day the research team would drop a new wormhole into the black hole—

Idiot. Of course there's a solution. I can travel either direction in time now, forward *or* back. I need only to move back to an instant just after the wormhole passed through the event horizon, and, applying full thrust, shoot through. The very moment that my original self shoots through the wormhole to escape the singularity, I can pass through the opposite direction, and rotate myself back into the real universe.

The station at Virgo black hole is 40 light years away, and I don't dare use the original wormhole to reach it. My spacetime-rotated body must be an elongated snake in this version of space-time, and I do not wish to find out what a wormhole passage will do to it until I have no other choice. Still, that is no problem for me. Even with barely enough fuel to thrust for a few microseconds, I can reach an appreciable fraction of lightspeed, and I can slow down my brain to make the trip appear only an instant.

To an outside observer, it takes literally no time at all.

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"No," says the psych tech, when I ask her. "There's no law that compels you to uplink back into your original. You're a free human being. Your original can't force you."

"Great," I say. Soon I'm going to have to arrange to get a biological body built for myself. This one is superb, but it's a disadvantage in social intercourse to being only a millimeter tall.

The transition back to real space worked perfectly. Once I figured out how to navigate in time-rotated space, it had been easy enough to find the wormhole and the exact instant it had penetrated the event horizon.

"Are you going to link your experiences to the public domain?" the tech asks. "I think he would like to see what you experienced. Musta been pretty incredible."

"Maybe," I said.

"For that matter," the psych tech added, "I'd like to link it, too."

"I'll think about it."

So I am a real human being now, independent of you, my original.

There had been cheers and celebrations when I had emerged from the wormhole, but nobody had an inkling quite how strange my trip had been until I told them. Even then, I doubt that I was quite believed until the sensor readings and computer logs of *Huis Clos* confirmed my story with hard data.

The physicists had been ecstatic. A new tool to probe time and space. The ability to rotate space into time will open up incredible capabilities. They were already planning new expeditions, not the least of which was a trip to probe right to the singularity itself.

They had been duly impressed with my solution to the problem, although, after an hour of thinking it over, they all agreed it had been quite obvious. "It was lucky," one of them remarked, "that you decided to go through the wormhole from the opposite side, that second time."

"Why?" I asked.

"If you'd gone through the same direction, you'd have rotated an additional ninety degrees, instead of going back."

"So?"

"Reversed the time vector. Turns you into antimatter. First touch of the interstellar medium — Poof."

"Oh," I said. I hadn't thought of that. It made me feel a little less clever.

Now that the mission is over, I have no purpose, no direction for my existence. The future is empty, the black hole that we all must travel into. I will get a biological body, yes, and embark on the process of finding out who I am. Maybe, I think, this is a task that everybody has to do.

And then I will meet you. With luck, perhaps I'll even like you.

And maybe, if I should like you enough, and I feel confident, I'll decide to upload you into myself, and once more, we will again be one.

### **Afterword:**

I was thinking about what you would see if you dropped down toward the event horizon of a black hole. Black holes are icons of science fiction, but it is surprising to notice how few science fiction stories really describe, in any realistic way, what a black hole would be like. The problem with describing a black hole, of course, is that you can't actually see it. Still, there are some fascinating things about the way light bends around a black hole. So I had this idea of a spaceship that would fly right up to the edge of the event horizon, and that, of course, immediately led me to the problem of how that could possibly happen, since the intense tidal forces near any stellar-mass black hole would rip any spaceship to spaghetti long before you could ever get near the regions where general relativity made any difference. But tidal forces are proportional to how big you are — they're all about the difference in gravity between your head and your feet, so if you were small enough, tidal forces would not be a problem. So this became another thread of the story.

At the same time, I'd been giving some thought to the concept of "downloading," which is the idea that, as technology advances, some day one might be able to actually copy a person's brain into a computer, and — from the point of view of the person — you would be exactly the same, but now a person living in software, instead of a body made out of meat. But would you be the same person? It's a knotty question. And what if you edited yourself, when you made the copy?

And then, once you're dropping into a black hole, there's the question of what happens next. A couple of years earlier I'd done some thinking about wormholes, along with Matt Visser and several other scientists and science fiction writers (the work eventually was published as a scientific paper in the journal *Physical Review*). I added some of that thinking to the story, too, as a way to get out once you've gotten in. There is, in the mathematics, a very odd thing that happens as you pass the event horizon of a black hole. From the point of view of an outside observer, time and space switch coordinates. To you, the radial direction — that is, the direction to the center of the black hole — becomes the time direction, and the center of the black hole is the future, which is the one direction in which we are all constrained to travel. The idea of a rotation of the coordinate system, so that time becomes distance, and distance time, was just too weird for me not to try to visualize. What if you really could switch to these rotated coordinates? What would it look like to you?

And, finally, when I wrote this story there wasn't a word for the closest approach in an orbit around a black hole. We have "perigee" for the closest approach in an orbit around the Earth, "perihelion" for an orbit around the sun, and even "perijove" for an orbit around Jupiter. I chose the word "perimelasma" for the closest approach to a black hole, using the suffix melasma, Greek for a black object. After I wrote this, other people have proposed the word "perinegricon" (Latin "negri-," the adjective black), but I like my word better (and I also like to keep to the use of a Greek suffix, since the prefix "peri" is from the Greek).

So the story gave me a bit of room to play around with these ideas, and set my imagination freewheeling a bit. I can't guarantee that any of this is what it "really" would be like, but as much as I could, I tried to stay with the real laws of physics without cheating. Hope you like it!

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## **Contributors**

### **Jeffrey A. Carver**

#### **Dog Star**

Jeffrey A. Carver is the author of numerous science fiction novels, including *Battlestar Galactica: the Miniseries* and *Eternity's End*, a finalist for the Nebula Award. His stories are character driven, ranging from hard SF (The Chaos Chronicles) to the "sense of wonder" stories of the Star Rigger universe (*Star Rigger's Way*, *Dragons in the Stars*, and others). His favorite themes include star travel, alien contact, and transcendent realities—and their moral, ethical, and spiritual implications. His new novel, *Sunborn*, was published in 2008. A native of Huron, Ohio, Carver now lives in the Boston area. His interests include his family, science, space, and aviation. He has created a web site for aspiring young authors at [writesf.com](http://writesf.com), and teaches writing at workshops such as the New England Young Writers Conference at Bread Loaf, Vermont. Learn more online at [starrigger.net](http://starrigger.net) where you will also find a variety of ebooks available for download, and on his blog, Pushing a Snake Up a Hill ([starrigger.blogspot.com](http://starrigger.blogspot.com)).

### **Valentin D. Ivanov**

#### **How I Saved the World**

Valentin D. Ivanov was born in Bulgaria in 1967. He received an M.S. in Physics with specialization in Astronomy from the University of Sofia in 1992, a Ph.D. in Astronomy from the University of Arizona in 2001, and he has been working for the European Southern Observatory ever since. Valentin has a broad area of research interests — from extrasolar planets to obscured Milky Way clusters and active galaxies. He is married, with two children. Valentin began to write science fiction and fantasy in high school. He has published in his native country a collection of fantasy stories based on Bulgarian folklore, written in collaboration with Kiril Dobrev. His personal home-page can be found at: <http://www.sc.eso.org/~vivanov/> and his blog (written in both Bulgarian and English) at: <http://valio98.blog.bg/>

### **Geoffrey A. Landis**

#### **Approaching Perimelasma**

To learn more about this author, visit the following website: <http://www.geoffreylandis.com>.

### **Daniel M. Hoyt**

#### **Squish**

Daniel M. Hoyt is a math and computer geek who also writes Science Fiction, Fantasy and Horror. He

currently has a full time job supporting, updating and re-architecting a 40-something Fortran program working with the computational physics of rockets and their trajectories. Fun stuff, really. Under his tutelage, it's been completely ported to C++ and has an Eclipse-base Java UI, as well, so it's not exactly trivial. In fact, it's rocket science!

As for his writing career, he has about a dozen genre short story credits, two anthologies edited with Martin H. Greenberg at Tekno, and he's currently shopping his first novel. You can find his work in leading magazines and anthologies (many available on Amazon.com). You can learn more about him at <http://www.danielmhoyt.com>.

## Alexis Glynn Latner

### The Listening Glass

According to an analysis done in 2005, Alexis Glynn Latner was the seventh most published woman fiction author in the 75-year history of *Analog Science Fiction* magazine, originally called *Astounding Stories*. Besides novelettes and short stories in *Analog*, her stories have appeared in *Amazing Stories* and *Sorcerous Signals* and the anthologies *Bending the Landscape: Horror* and *Horrors Beyond 2 — Stories of Strange Creations*, and two mystery anthologies. Her science fiction novel *Hurricane Moon* was published by Pyr in July 2007.

"Science fiction has been called the literature with a sense of wonder," she says, "and that was because scientists found wonder in the universe. They still do, and my science fiction reflects that."

She holds a B. A. in linguistics from Rice University and an M. A. in systematic theology from the Graduate Theological Union in Berkeley, California. From 2004 until 2007 she was the South-Central Regional Director of the Science Fiction and Fantasy Writers of America. In 2008, she was the vice president of the Houston, Texas writers' group The Final Twist. Besides speculative fiction, she does editing, writes magazine articles about science, technology, and aviation, and teaches creative writing through the Glasscock School of Continuing Studies at Rice University. She works in Rice University's Fondren Library. For fun and real-life adventure, she pilots sailplanes and rides with friends in their single-engine power planes.

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## Ges Seger and Kevin Grazier

### Planet Killer

#### **Kevin R. Grazier, Ph.D.**

Dr. Kevin Grazier holds the dual titles of Investigation Scientist and Science Planning Engineer for the Cassini/Huygens Mission to Saturn and Titan at NASA's Jet Propulsion Laboratory in Pasadena, CA. He earned B.S. degrees in computer science and geology from Purdue University, and a B.S. in physics from Oakland University. He earned his M.S. in physics from Purdue, and then went to UCLA for his doctoral research in planetary physics. At JPL he has written mission planning and analysis software that won numerous JPL- and NASA-wide awards. Dr. Grazier still continues research involving computer simulations of Solar System dynamics, evolution, and chaos.

Dr. Grazier is also currently the Science Advisor for the animated educational TV series *The Zula Patrol*, and for the SciFi Channel series *Eureka* and *Battlestar Galactica*. He recently served as editor and contributing author for the books *The Science of Dune* and the *Science of Michael Crichton* for the BenBella Publishing Science of Popular Culture series.

## **Ges Seger**

Ges Seger was born in Quincy, Illinois in 1962. Raised in Danville, Indiana, he graduated from Purdue University in 1984 with a BS in Physics and the Air Force Institute of Technology in 1989 with a MS in Engineering Physics. He is currently employed at Wright-Patterson AFB, Ohio as a webmaster and Perl hacker.

He is the author of the novel *The Once and Future War*, and was a contributing author for *The Science of Dune*.

His after-work duties as family soccer mom, combined with the discovery of a latent talent for Irish Step Dancing basically leaves him no time for anything in the way of meaningful hobbies.

## **Mary Robinette Kowal**

### **Jaiden's Weaver**

Mary Robinette Kowal is the 2008 recipient of the Campbell Award for Best New Writer. Her short fiction has appeared in *Strange Horizons*, *Cosmos* and *Subterranean*. Mary, a professional puppeteer and voice actor, lives in NYC with her husband Rob and nine manual typewriters. Her first novel, *Shades of Milk and Honey*, will be published by Tor in 2010. To learn more about the author, visit: <http://www.maryrobinettekowal.com>

## **G. David Nordley**

### **The Touch**

Gerald was born in Minneapolis MN in 1947 and was raised in suburban Golden Valley, MN attending Golden Valley High School. He originally intended to be an astronomer and majored in physics at Macalester College, in St. Paul, MN with that in mind. But, faced with the reality of the draft after graduation, he joined the US Air Force as an airman basic in 1969. He gained a reserve commission as a second lieutenant in 1970, and surprised himself by staying for a career.

He spent some time in radar intercept control and battle management, including tours in Alaska and Korea, but worked mainly as an astronautical engineer, managing satellite operations, engineering, and advanced propulsion research. In the latter capacity, he met and became inspired to write by physicist and author Dr. Robert L. Forward. He retired as a major at the end of 1989 and began submitting stories in 1990, using the "G. David" form of his name for fiction (though lately it has migrated to articles as well) and Gerald D. for technical papers, the intent being to separate the work in computer author searches.

As a writer, his main interest is the future of human exploration and settlement of space, and his stories typically focus on the dramatic aspects of individual lives within the broad sweep of a plausible human future. Trying to keep up with just what is plausible is a challenge, but he recycles his research for occasional nonfiction articles. He continues to write a few pieces of short fiction each year, but is currently

concentrating on novels, with three complete books looking for publishers and two more in serious production efforts. *After the Vikings*, a collection of linked Mars-related stories was published as an electronic book by Scorpius Digital in September 2001, with a print version appearing in 2003 (which is currently sold out). *The Black Hole Project*, a novel in five parts written with C. Sanford Lowe, was published as a series in Analog in 2006-2007. He is a four-time winner of the AnLab, the Analog reader's award for best story or article of the year, and has also been a Hugo and Nebula award nominee.

Besides writing, he consults in aeronautical engineering, dabbles in real estate, and among other volunteer activities is the treasurer of CONTACT, Cultures of the Imagination, an interdisciplinary educational group concerned with issues related to the development of intelligent life — from raw planets to expansion into space. He is a fellow of the British Interplanetary Society; senior member of the American Institute of Aeronautics and Astronautics, a signatory of the Invitation to ETI, and a life member of the Science Fiction Writers of America. He lives in Sunnyvale CA with his wife, Gayle Wiesner, a retired Apple Computer programmer.

You can learn more about him, his fiction and nonfiction by visiting his website at: [www.gdnordley.com](http://www.gdnordley.com)

## **Gerald M. Weinberg**

### **The Moon is a Harsh Pig**

Gerald M. Weinberg (Jerry) writes "nerd novels," such as *The Aremac Project*, about how brilliant people produce quality work. Before taking up his science fiction career, he published books on human behavior, including *Weinberg on Writing: The Fieldstone Method*, *The Psychology of Computer Programming* and an *Introduction to General Systems Thinking*. He also wrote books on leadership including *Becoming a Technical Leader*, *The Secrets of Consulting* (Foreword by Virginia Satir), *More Secrets of Consulting*, and the four-volume *Quality Software Management* series. He incorporates his knowledge of science, engineering, and human behavior into all of his writing and consulting work (with writers, hi-tech researchers, and software engineers).

Early in his career, he was the architect for the Mercury Project's space tracking network and designer of the world's first multiprogrammed operating system. Winner of the Warnier Prize and the Stevens Award for his writing on software quality, he is also a charter member of the Computing Hall of Fame in San Diego and the University of Nebraska Hall of Fame. His website and blogs may be found at: <http://www.geraldmweinberg.com>.

## **David Levine**

### **Galactic Stress**

David D. Levine is a lifelong science fiction reader whose midlife crisis was to take a sabbatical from his high-tech job to attend Clarion West in 2000. It seems to have worked. He made his first professional sale in 2001, won the Writers of the Future Contest in 2002, was nominated for the John W. Campbell award in 2003, was nominated for the Hugo Award and the Campbell again in 2004, and won a Hugo in 2006 (Best Short Story, for "Tk'Tk'Tk"). His "Titanium Mike Saves the Day" was nominated for a Nebula Award in 2008, and a collection of his short stories, "Space Magic", is available from Wheatland Press (<http://www.wheatlandpress.com>). He lives in Portland, Oregon with his wife, Kate Yule, with whom he edits the fanzine *Bento*, and their website is at <http://www.BentoPress.com>.

## **Wil McCarthy**

### **The Freshmen Hook Up**

Wil McCarthy has served as a consultant in a variety of areas. Creative consulting includes: personal and professional editing, continuity and fact checking, web content creation, graphic novel and dramatic scripts, science advice, and the writing of creative fiction and nonfiction. Technical consulting includes proposal writing, software engineering, LAN setup and security, robotics, Artificial Intelligence/Artificial Life, guidance/navigation/control, systems engineering/troubleshooting, and space science/spacecraft design. You can learn more about him and his novels by visiting his website: <http://www.wilmccarthy.com/>

## **Alma Alexander**

### **End of the World**

Alma Alexander is a Pacific Northwest writer known primarily for her longer, novel-length works ("The Secrets of Jin Shei", "The Hidden Queen", "Changer of Days", the YA Worldweavers trilogy) — and has hitherto been leaning more towards the fantasy side of the speculative fiction spectrum — however, as an alumna of the 2008 LaunchPad astronomy workshop for writers she has been energized and inspired to write both shorter fiction and more cutting-edge SF.

Alma's website can be found at [www.almaalexander.com](http://www.almaalexander.com)

## **Jerry Oltion**

### **In The Autumn of the Empire**

Jerry Oltion is the author of over 100 short stories and 15 novels in the science fiction and fantasy genres. He is also an avid amateur astronomer and telescope builder, designing a new type of telescope mount that he calls the "trackball." Details can be found on his website: [www.sff.net/people/j.oltion](http://www.sff.net/people/j.oltion)

## **Mike Brotherton**

### **The Point**

When Mike was six, he wanted to be an astronomer or a paleontologist. When he was twelve he wanted to be a science fiction writer. He went to college at Rice University intending to get a degree in electrical engineering and work for JPL or NASA. He ended up double majoring in EE and space physics and went on to the University of Texas at Austin to study astronomy. After getting his PhD in 1996, he worked at Lawrence Livermore National Laboratory and Kitt Peak National Observatory. He's now an associate professor in the department of Physics and Astronomy at the University of Wyoming; his specialty is quasars. He's actually used the Hubble Space Telescope, the Chandra X-ray Observatory, the Keck Telescope and the Very Large Array in New Mexico. He has two hard science fiction novels out from Tor. Star Dragon was a finalist for the John W. Campbell Award. Spider Star features a dark matter planet. You can learn more about Mike at <http://www.mikebrotherton.com>

## ***About the Project***

Diamonds in the Sky is a collection of astronomy-based science fiction stories edited by [Mike Brotherton](#) and funded under his [National Science Foundation](#) grant AST 05-07781. The purpose of the anthology is to provide stories with ample and accurate astronomy spanning a range of topics covered in introductory courses. Instructors in high school and college may find these stories useful, as some students may learn concepts more easily through story than from lecture. Fans of science fiction with good science should also enjoy these stories. Contributions include both original stories and reprints from some of the top science fiction writers working today. Special thanks to Jeremy Tolbert, Scott Humphries, and Nicole Wade for their efforts.