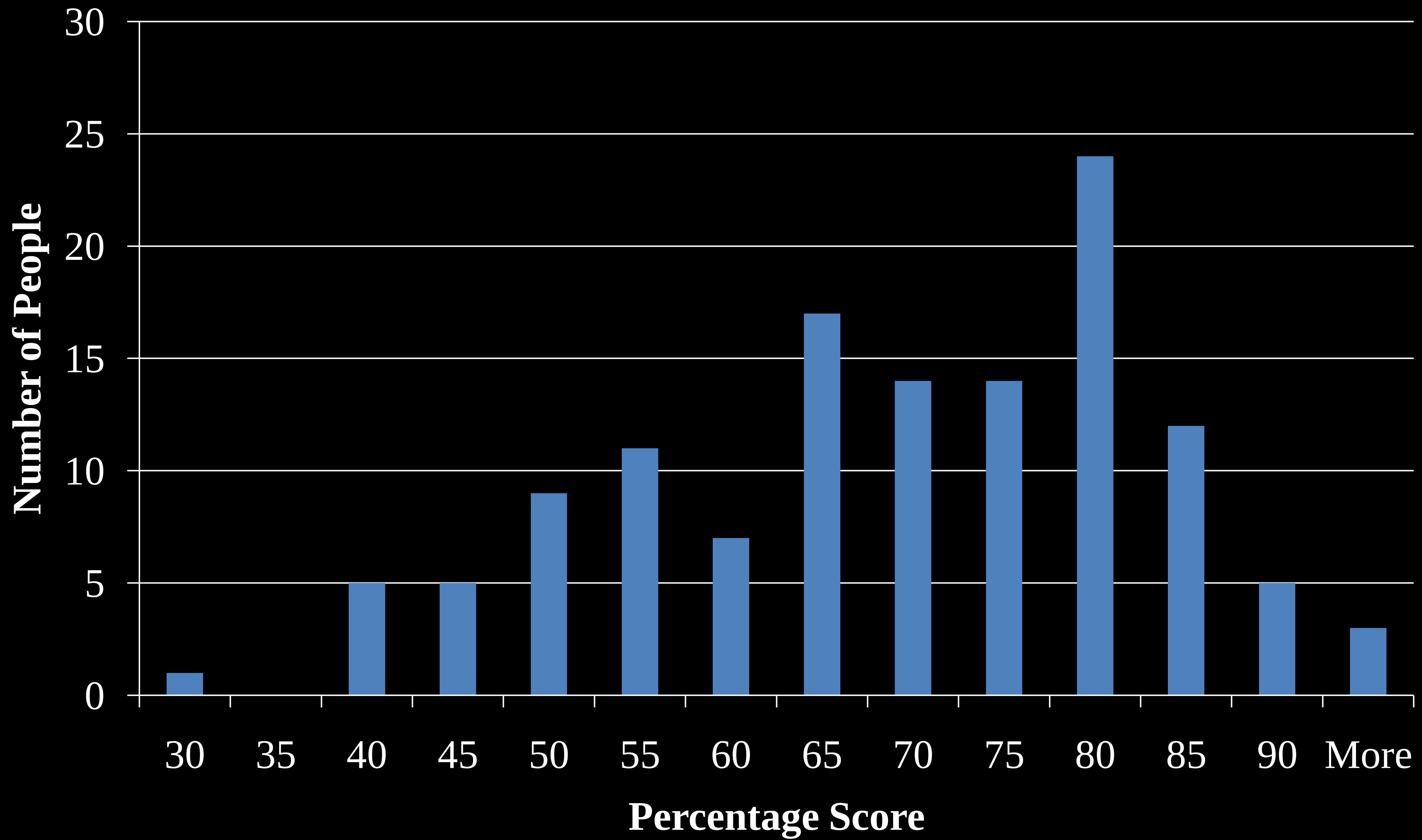
Midterm Exam Results

- Grades are posted, in the same fashion as before.
- If you want to talk about which questions were missed, please come talk to any of us (we all have copies of the exam).
- Class average: 67.2%
- 70% of people improved (average 14%)
- Mode answer correct 38/40 (95%) of time.
  - Compare to 83% on the first exam

Exam 2 Score Distribution



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  - Compare to 83% on the first exam

Star A and Star B are identical in every way except that Star B is ten times farther away from you. How do their apparent magnitudes differ?

- The relationship between flux (F) and luminosity (L):

$$F = \frac{L}{4\pi r^2}$$

- 10 times farther = 10^2 times fainter
- 2 factors of 10 in brightness = difference of 2 times 2.5 in magnitudes = 5 magnitudes

Consider the dark line absorption spectra shown below for Star X and Star Z. What can you determine about the color of the two stars?

- How does color relate to temperature?
  - Hotter things appear bluer, colder things appear redder
  - 95% of you remembered this!
- How does temperature relate to the number or position of absorption lines in a spectrum?
  - There’s no relationship whatsoever.

Stars

10/31 – Classification of Stars
11/3 – Star formation and lifetimes
11/4-11 – Luminosity, Temperature & Size in Lab
11/5 – Stellar Evolution
11/7 – Binary Stars
11/10-17 – Galaxies and the Universe
11/19 – Review for Midterm Exam 3
11/21 – Midterm Exam 3

Astronomy Notes Readings/Review

- For today, Chapter 11, sections 12-15
- For Monday & Wednesday, Chapter 13, all sections
- DO NOT READ CHAPTER 12 (unless you want to)
- For next Friday, Chapter 11, sections 10-11

- Rajib’s weekend homework: Put together a collection of review questions from those sections that you will be responsible for.

Classification of Stars

- Why classify stars (or other objects)?
  - Classification provides a means at organizing things by similar property. By grouping things together, we can learn more about them. What features happen stochastically (randomly), and what things happen for some physical reason?
  - Example 1: Humans have two arms, two legs, hair, etc. But no two humans have the same finger print.
  - Example 2: Jovian planets have similar structures, compositions, rings, many moons. But Jupiter doesn’t look like Saturn or Uranus or Neptune.
- What measureable/identifiable properties can we use to classify stars?
  - Temperature, luminosity (or absolute magnitude), composition, speed(?), size

Classification of Stars

- Historically, the first classification of stars was done by composition.
- (Ok, there are older ones, but they are not important…)
- Astronomers at Harvard sorted the stars according to the strength of hydrogen absorption lines in the visible part of the spectrum.
  - A-Q (17 classes! Yikes!)
  - Two men supervised: Edward Pickering, Henry Draper
  - An army of women did the work: Williamina, Fleming, Antonia Maury, others

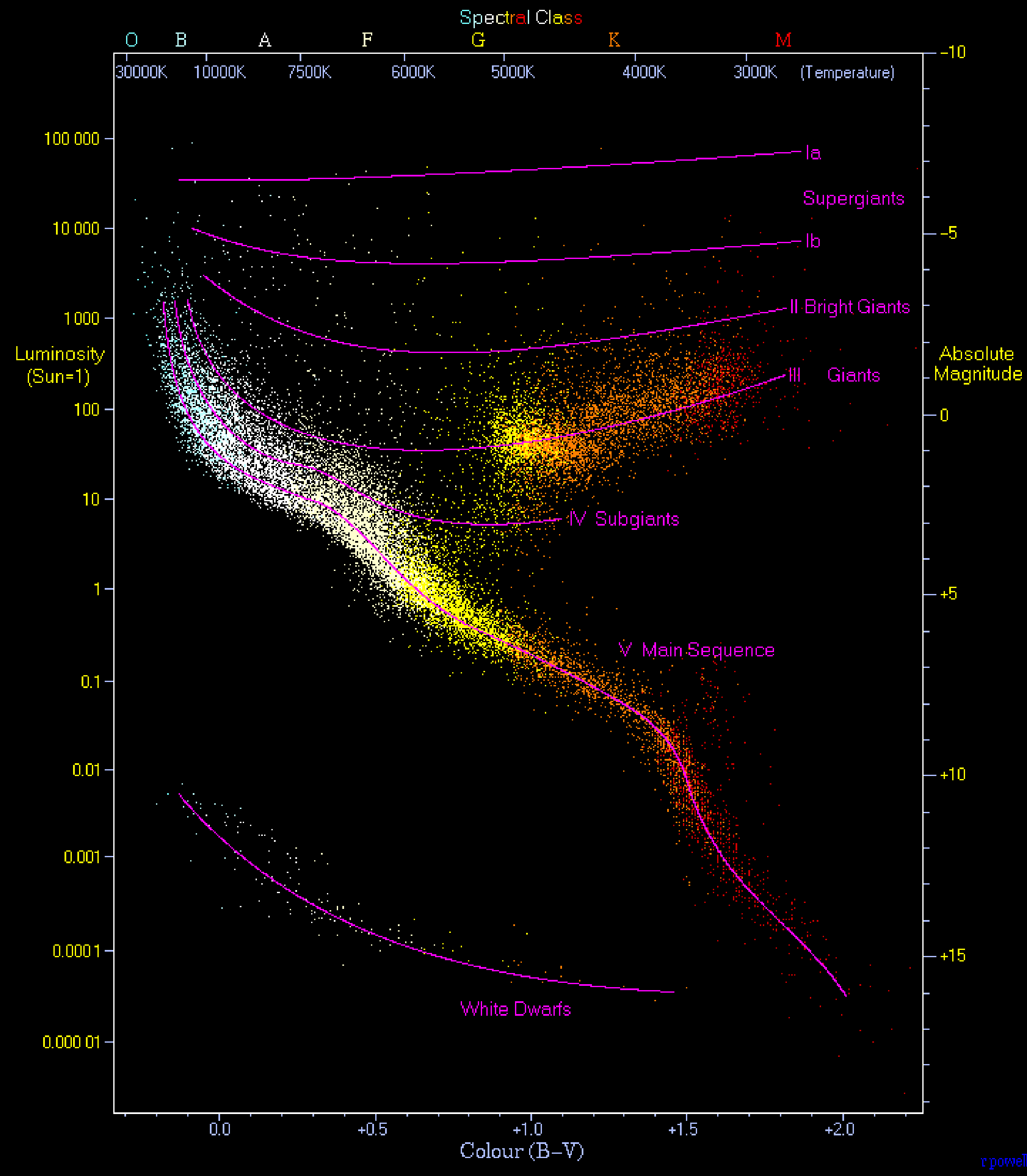
Classification of Stars

- Eventually, this scheme was found to be rather limiting in understanding stars…
- Two wonderful female astronomers, Annie Jump Cannon and Cecilia Payne-Gaposchkin, stepped in and cleaned this up.
  - Annie got rid of all but A, B, F, G, K, M, and O
  - Cecilia rearranged this into a more useful sequence according the temperature: O B A F G K M
  - (OMG WTF?)
  - http://astro2.byu.edu/~sdb/Mnemonic.html
  - These are *spectral types*.
- Since then, we have added a few more (R, N, S, L, and T)

Classification of Stars

- Another way to classify stars was thought up by William Wilson Morgan, Phillip C. Keenan and Edith Kellman from Yerkes Observatory according to gravity/luminosity (I for the brightest, VII for the faintest). This was limiting in other respects.
- Ejnar Hertzsprung and Henry Norris Russell independently came up with the idea of combining the two schemes.

The Hertzsprung - Russell Diagram



Lecture Tutorials

- Break up into groups of 2-3
  - NO MORE THAN THREE, NO SINGLES
- In your group, work through the following:
  - H-R Diagram (pages 109-110)
  - Discuss the answers – don't be silent!
- MarkDan, Jacquelyn, and I will be roaming around if you need help…
- If your group finishes, check your answers with another group.
- If you are confident that your answers are correct, help another group that is struggling to find their own answers.

Think
Pair
Share!

Star A has an absolute magnitude of -8.1 and belongs to spectral class B8. Star B has absolute an magnitude of 11.2 and also belongs to spectral class B8. Which star has the higher temperature?

A. Star A
B. Star B
C. They have the same temperature.
D. There is not enough information to determine which star is hotter.

A red giant of spectral type K9 and a red main sequence star of the same spectral type have the same

A. Luminosity
B. Temperature
C. Absolute Magnitude

The two axes on the Hertzsprung-Russell (H-R) diagram can be

A. luminosity and temperature.
B. apparent magnitude and absolute magnitude.
C. radius and main sequence.
D. radius and luminosity.
E. spectral type and temperature.

On an H-R diagram, stars at the same temperature are found

A. aligned horizontally (i.e., next to each another).
B. aligned vertically (i.e., one above the other).
C. along the main sequence.

On an H-R diagram, stars with the same luminosity are found

A. aligned horizontally (i.e., next to each another).
B. aligned vertically (i.e., one above the other).
C. along the main sequence.

Which of the following sequences of spectral classes represent the *coolest to hottest stars?*

A. OBAFGKM
B. ABFGKMO
C. OMKGFBA
D. MKGFABO
E. MFKGABO

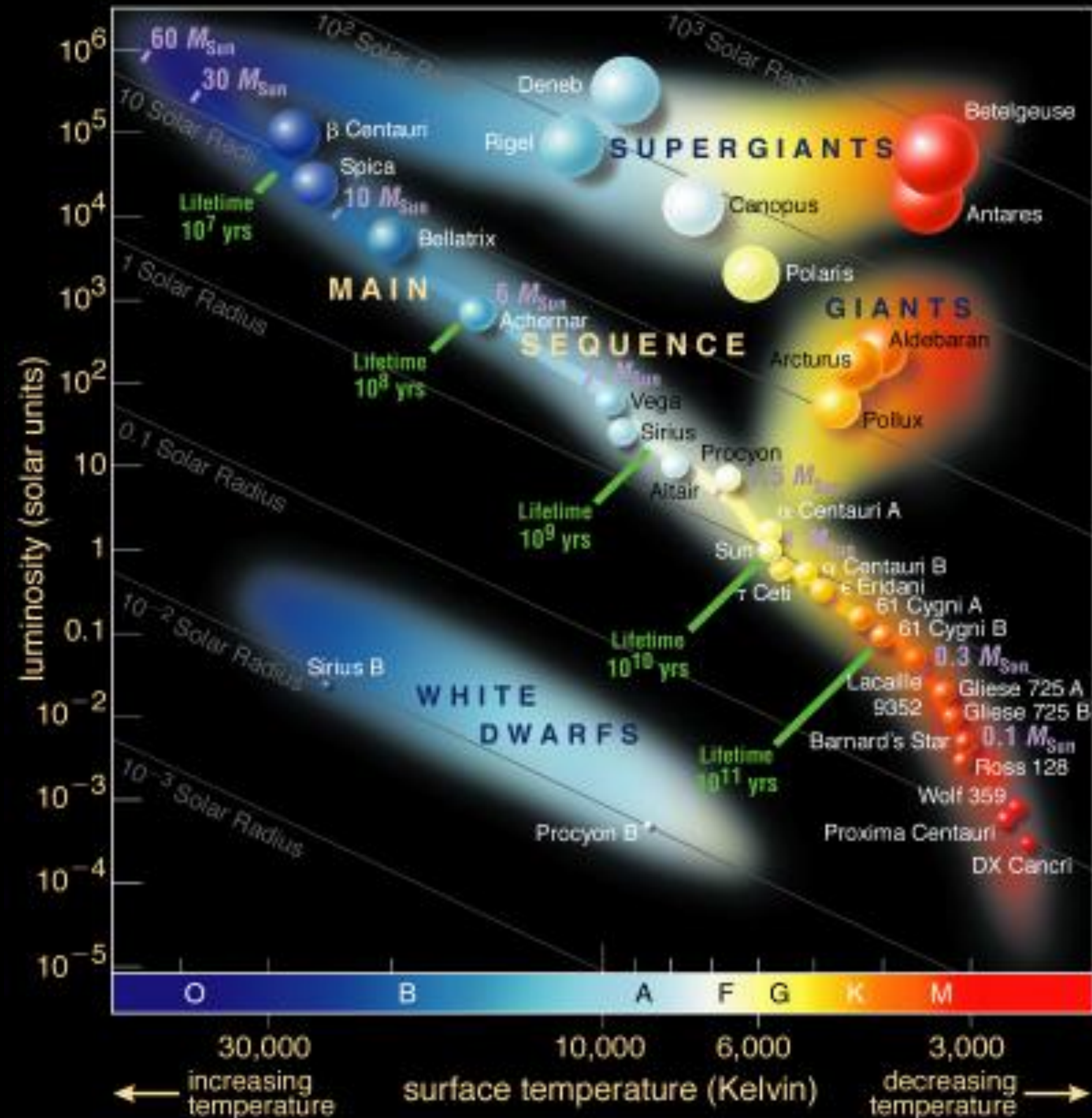
Which of the following statements is always true of two stars that have the same absolute magnitude?

A. They have the same temperature.
B. They have the same luminosity.
C. They have the same spectral class.
D. They have the same surface area.
E. None the above.

Quiz #9

Use the HR diagram on the right, and any information you remember from the reading to draw conclusions about the relationships between stars in terms of luminosity, temperature, mass, size, and class.

You may start now.
You have until 12:05.



Message from MarkDan

The last window for doing the Moon phases observations for the Semester Project starts tonight:

NOVEMBER 3 - 19

Star Formation & Lifetimes

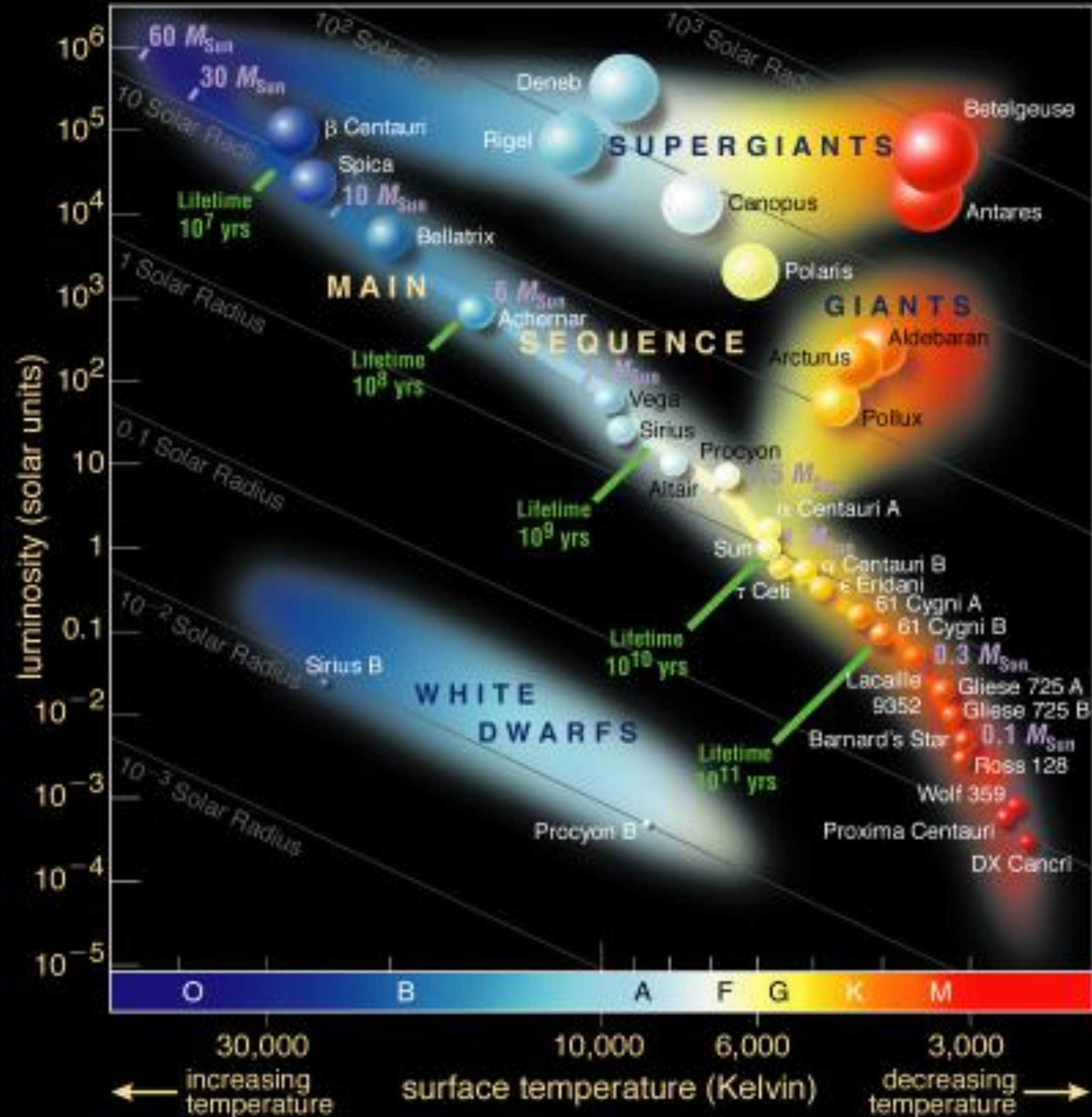
11/5 – Stellar Evolution

11/7 – Binary Stars

11/10-17 – Galaxies and the Universe

11/19 – Review for Midterm Exam 3

11/21 – Midterm Exam 3

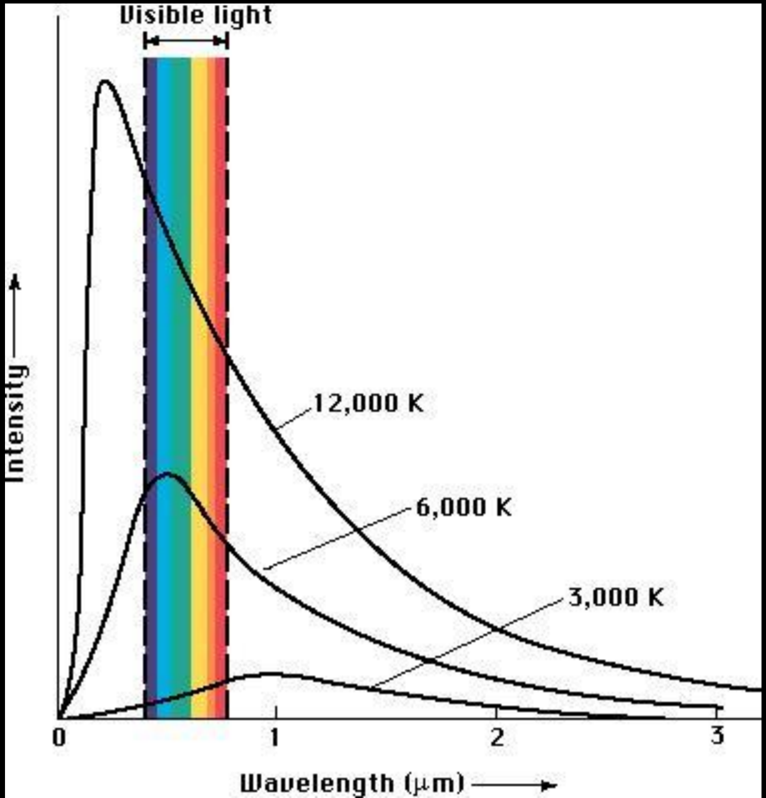


60 M_{Sun}
30 M_{Sun}
10 M_{Sun}
6 M_{Sun}
1 M_{Sun}
0.3 M_{Sun}
0.1 M_{Sun}
10^2 Solar Radii
10^3 Solar Radii
10 Solar Radii
1 Solar Radius
0.1 Solar Radius
10^{-2} Solar Radius
10^{-3} Solar Radius
Deneb
Rigel
Betelgeuse
Antares
Canopus
Polaris
SUPERGIANTS
GIANTS
Aldebaran
Arcturus
Pollux
β Centauri
Spica
Bellatrix
Achernar
MAIN
SEQUENCE
Vega
Sirius
Procyon
Altair
α Centauri A
Sun
α Centauri B
ε Eridani
τ Ceti
61 Cygni A
61 Cygni B
Lacaille 9352
Gliese 725 A
Gliese 725 B
Barnard's Star
Ross 128
Wolf 359
Proxima Centauri
DX Cancri
Sirius B
Procyon B
WHITE DWARFS
Lifetime 10^7 yrs
Lifetime 10^8 yrs
Lifetime 10^9 yrs
Lifetime 10^{10} yrs
Lifetime 10^{11} yrs
luminosity (solar units)
10^6
10^5
10^4
10^3
10^2
10
1
0.1
10^{-2}
10^{-3}
10^{-4}
10^{-5}
O
B
A
F
G
K
M
30,000
10,000
6,000
3,000
increasing temperature
surface temperature (Kelvin)
decreasing temperature

Aside: Why is temperature plotted backwards?

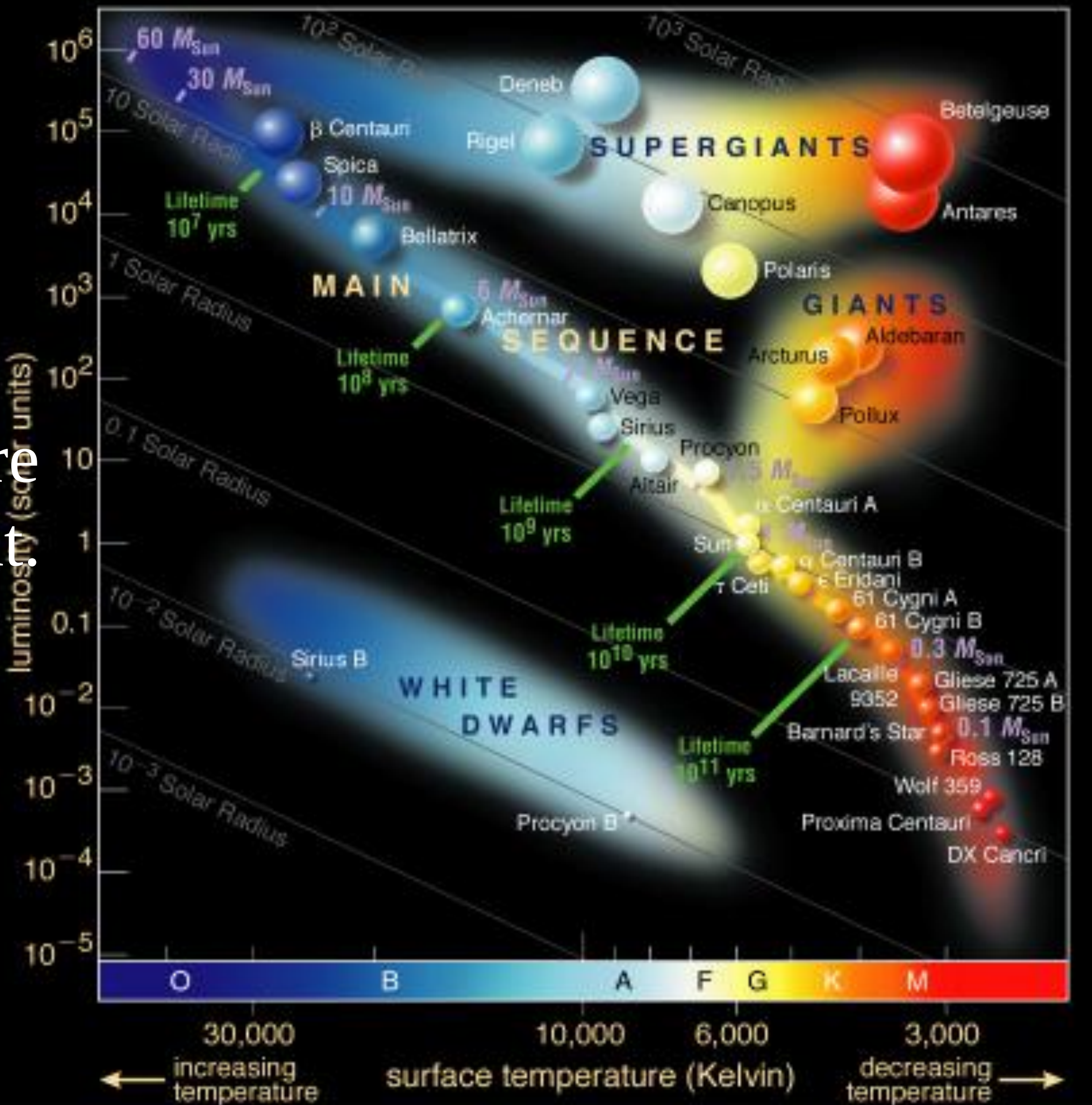
- Because magnitudes are backwards….
- Huh? What do magnitudes have to do with temperature????

• B = apparent magnitude of blue light
• V = apparent magnitude of greenish/yellowish light
• B-V measures how much more green light than blue light = a measure of color or temperature
• Smaller B-V = hotter
• HR Diagram also called a Color-Magnitude Diagram



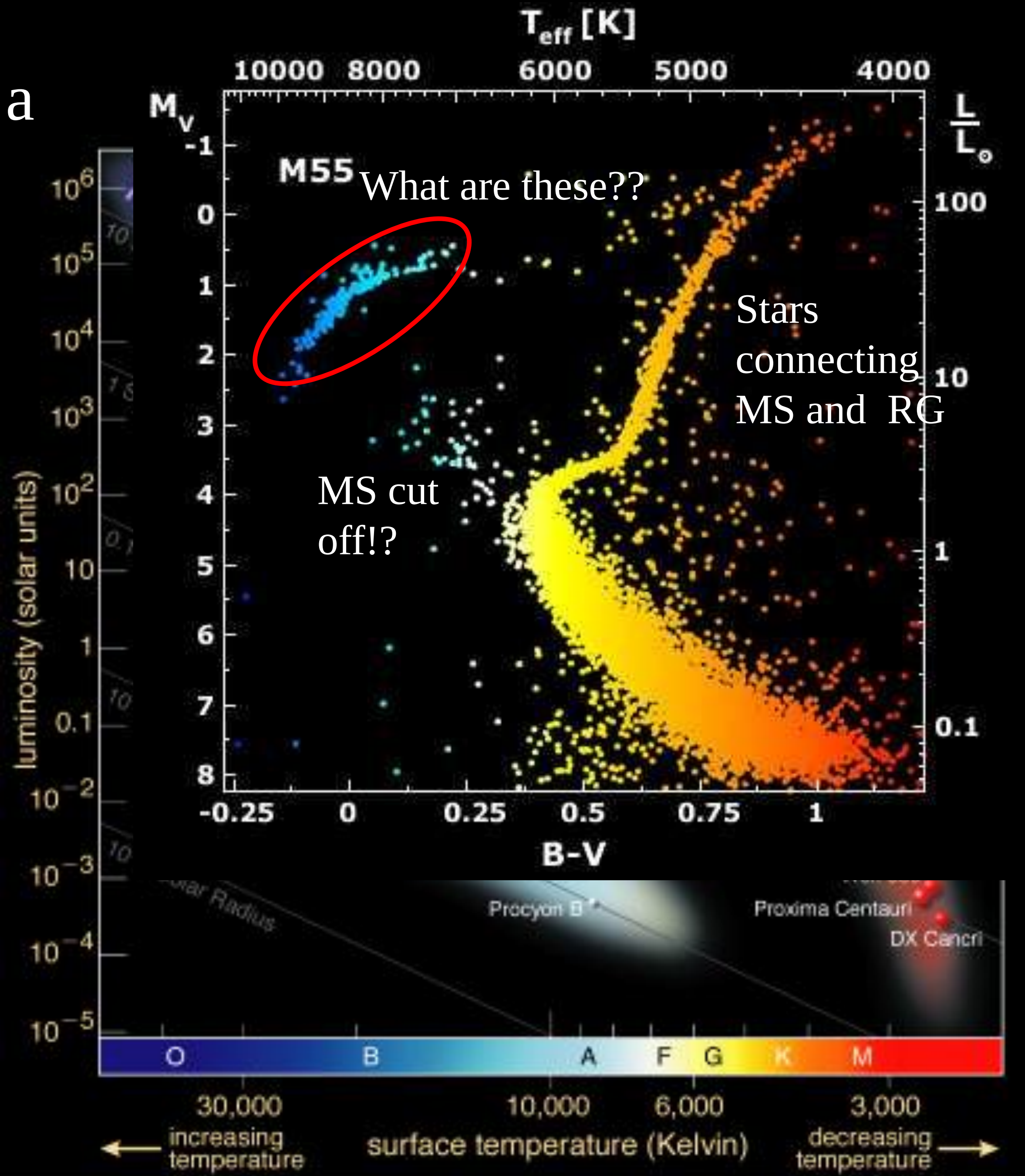
How can we understand this?

By building models that employ the laws of nature that we think are relevant. If they don't explain the observations, then we haven't applied the right laws (or we haven't applied them correctly).



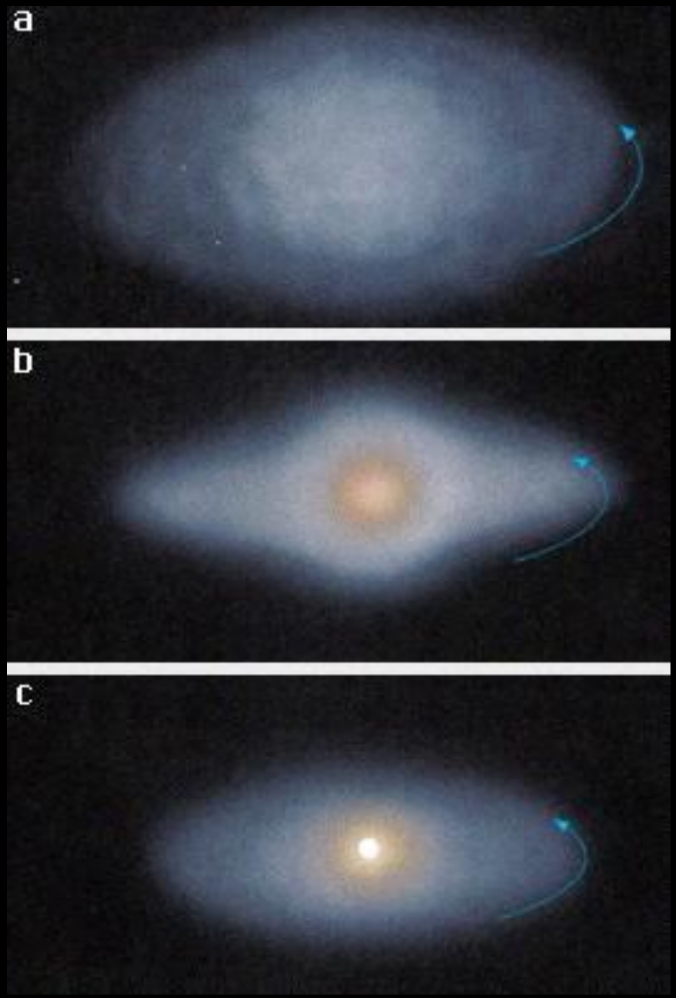
What observations does a model of stars need to explain?

- In the main sequence, hotter stars have to be more luminous ,bigger, and more massive.
- Other classes exist also – cold, luminous stars (red giants), and hot, dim stars (white dwarfs).
- A model should explain the relative numbers in each class (e.g., 90% in the main sequence).



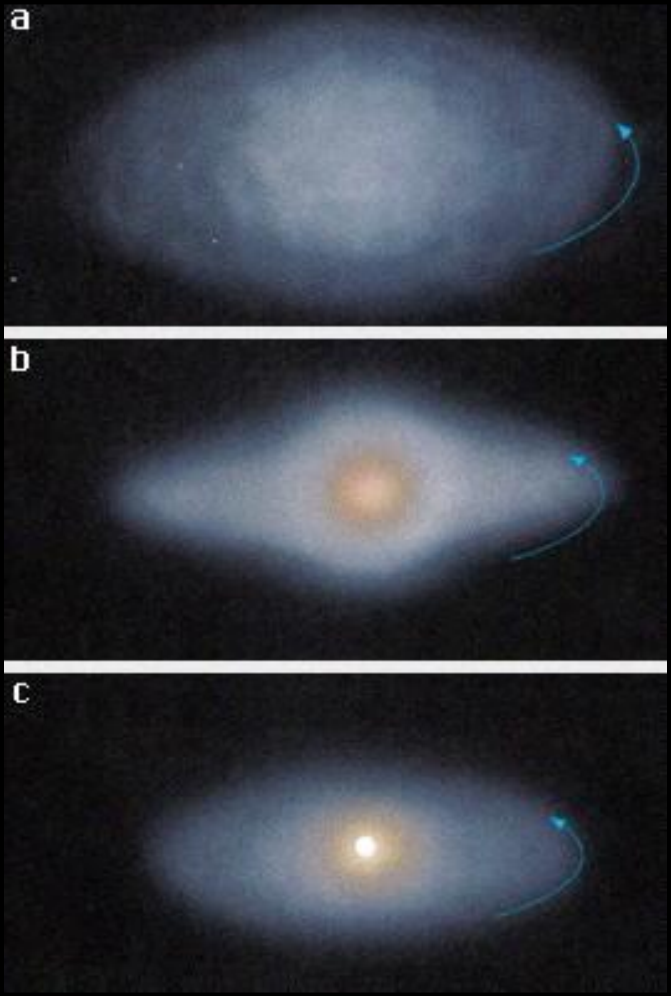
A model for forming stars…

- Just like the rest of the Solar System – collapse of a giant nebula by its own gravity…
- As atoms fall toward the center, they move faster = higher temperature
- (Temperature is a measure of the average speed of atoms in a gas.)



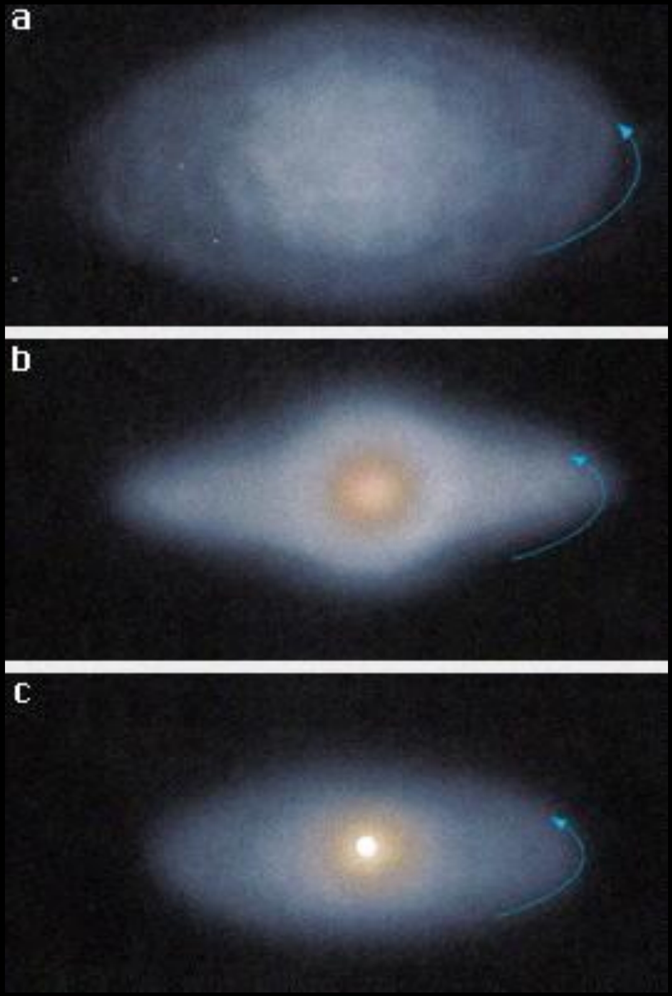
A model for forming stars…

- Most of the mass of the collapsing cloud goes to the center (the Sun contains ~99.8% of the mass of the Solar System).
- The center of the cloud is the hottest and densest.
- Can this heating-by-gravity model explain the HR diagram?



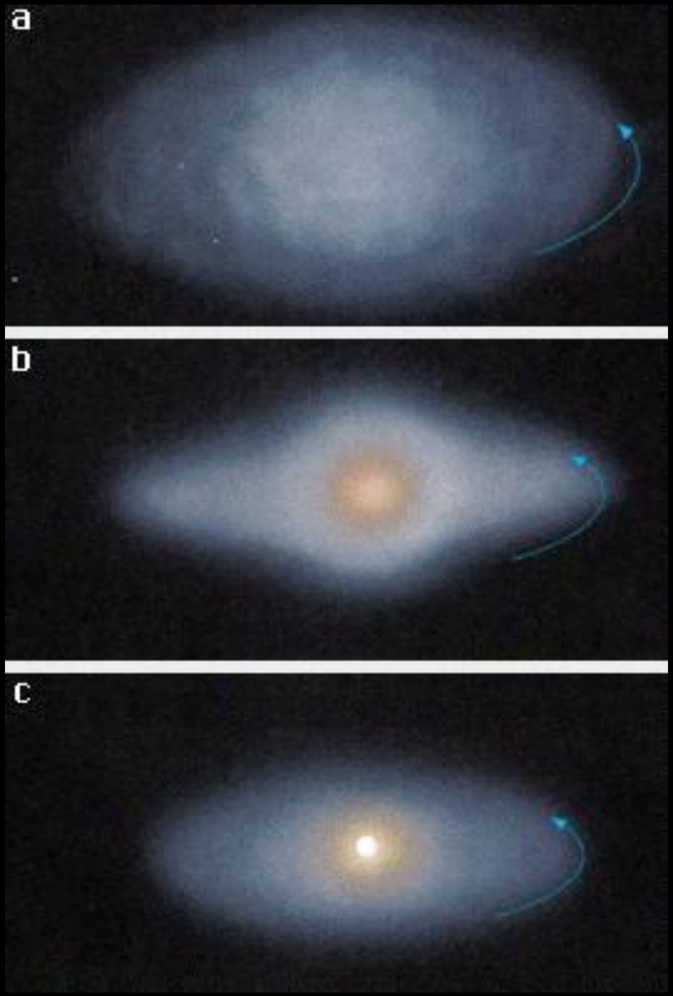
A model for forming stars…

- This model predicts that more massive stars would start out hotter than less massive stars. Stars of the Sun's mass should last 30 million years before they cool down.



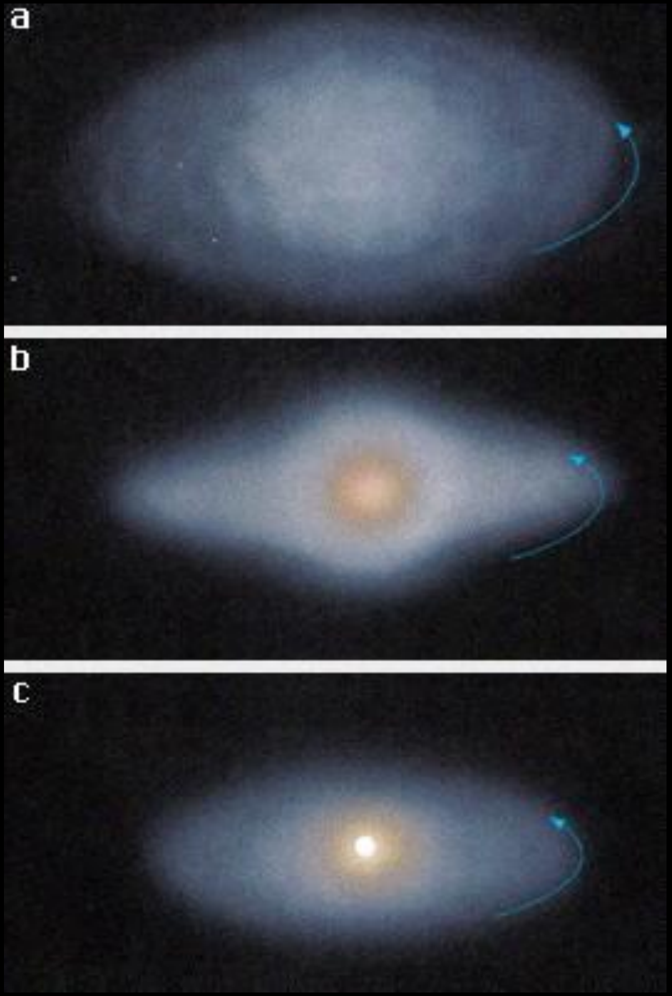
A model for forming stars…

- Does this mesh with observations?
- No.
- Can’t explain red giants or white dwarfs.
- Age is too young compared to what geology tells us about the age of the Earth.
- Doesn’t explain trend in sizes – we should a variety of sizes/masses that “pile up” at the cool end as stars cool down



A model for forming stars…

- The model does explain the other objects in the Solar System, so it is probably not far off.
- We can actually see other systems in the process of forming, which gives us confidence. So perhaps that part about the central star is just incomplete
- Something else (other than gravity) is required to power the Sun and other stars.
  - Chemical reactions? Doesn't work.
  - Radioactive decay? Nope.
  - Nuclear reactions?



Nuclear fusion

- The simplest fusion reaction: take the light element in the universe, hydrogen, and make the second lightest element, helium.
- Hydrogen mass = 1.00795 AMU
- Helium mass = 4.0026 AMU
- Need 4 hydrogen atoms to make a helium atom, but that combined mass is 4.0318 AMU
- What happens to the extra 0.029 AMU (0.7% of the mass)?
- $E = mc^2$!

Nuclear fusion

- The Sun has a mass of about 2×10^{30} kilograms
- Of this, about 75% is hydrogen.
- How much energy could the Sun produce by fusing hydrogen into helium?
  - Mass converted = $0.007 \times 0.75 \times (2 \times 10^{30}\ \text{kg}) = 10^{28}$ kg
  - $E = mc^2 = (10^{28}\ \text{kg}) \times (3 \times 10^{8}\ \text{m/s})^2 = 2.1 \times 10^{38}$ kiloWatt-hours
- The Sun is a 3.8×10^{23} kiloWatt lightbulb, so it could last about 7×10^{14} hours = 80 billion years.
- Models actually predict that only the inner 1/8th of the mass will actually be involved in converting hydrogen to helium, so that phase will last 10 billion years.

Nuclear fusion

- The problem with fusion is that we have to get the nuclei of atoms close enough so that they bind together.
  - Analogy: Try putting like-poles of two magnets together. Not easy. Even harder if they are stronger magnets (or, in the case of atoms, they have more protons).
  - Possible solution: swing the magnets together at high speed.
- Making atoms strike each other with high speed means having high temperatures (and sufficiently high densities to get interactions)…
  - Sound familiar? We get exactly this in the gravitational collapse model of the Solar System formation.

Nuclear Fusion vs. Gravity

- Gravity is always an attractive force, so it will always pull things toward the center of a star.
- Nuclear fusion causes an explosion (think atom bomb, but not quite – it's not f*u*sion) will causes an outward, repulsive force.
- In (most) stars, these two forces balance each other → *hydrostatic equilibrium* (traxoline…)
- More massive stars need to fuse atoms at a higher rate to balance their own gravity. (Higher rate = Higher temperature!) As a result, they "burn through" their fuel more quickly, and shine more brightly.

Nuclear Fusion vs. Gravity

- Analogy:
  - Massive stars = SUVs of astronomy - they hold more fuel, but use it up more quickly.
  - Low-mass stars = light, economy cars - they less fuel, but don't "burn" their fuel as quickly so they get better mileage.
- Prediction 1: More massive star should be hotter and more luminous…
  - Yes! That's what the main sequence says!

Nuclear Fusion vs. Gravity

- Prediction 2: What happens when the fuel runs out?
  - Evolution and death → red giants, supernovae, white dwarfs, neutron stars, black holes
  - Get to this next time…
- Another side note of classification: The primary feature that separates planets (whatever they are) from stars is whether or not they are (or had been) fusing elements in their cores.
- The LT goes over how the rate of fuel consumption changes with the mass of the star… (Hint: The rate of fuel consumption is the amount of fuel divided by the time it takes to use that fuel.)

Lecture Tutorials

- Break up into groups of 2-3
  - NO MORE THAN THREE, NO SINGLES
- In your group, work through the following:
  - Star Formation and Lifetimes (pages 111-112)
  - Discuss the answers – don't be silent!
- MarkDan, Jacquelyn, and I will be roaming around if you need help…
- If your group finishes, check your answers with another group.
- If you are confident that your answers are correct, help another group that is struggling to find their own answers.

OMG that was a lot of info for a Monday…

- While gravity is important to initially forming stars, it cannot be what powers stars.
- Nuclear fusion is the other viable alternative.
- The balance (“*hydrostatic equilibrium*”) between gravity and explosions from nuclear reactions has important consequences for the temperatures, luminosities, and lifetimes of stars.
- The mass of a star and its struggle against gravity is of crucial importance to determining its life.

Think

Pair

Share!

Consider the information given below about the lifetime of three main sequence stars A, B, and C.

Star A will be a main sequence star for 45,000 million years.

Star B will be a main sequence star for 70 million years.

Star C will be a main sequence star for 2 million years

Which of the following is a true statement about these stars?

A. Star A has the greatest mass.
B. Star C has the greatest mass.
C. Stars A, B and C all have approximately the same mass.
D. There is not enough information to determine the answer.

Which of the following statements best describes how the lifetimes compare between Star A that has a mass equal to the Sun and Star B containing three times more mass than the Sun?

A. Star A will live more than three times longer than Star B.
B. Star A will live three times longer than Star B.
C. The two stars will have the same lifetime.
D. Star A will live three times shorter than Star B.
E. Star A will live less than three times as long as Star B.

Stellar Evolution

11/7 – Binary Stars

11/10-17 – Galaxies and the Universe

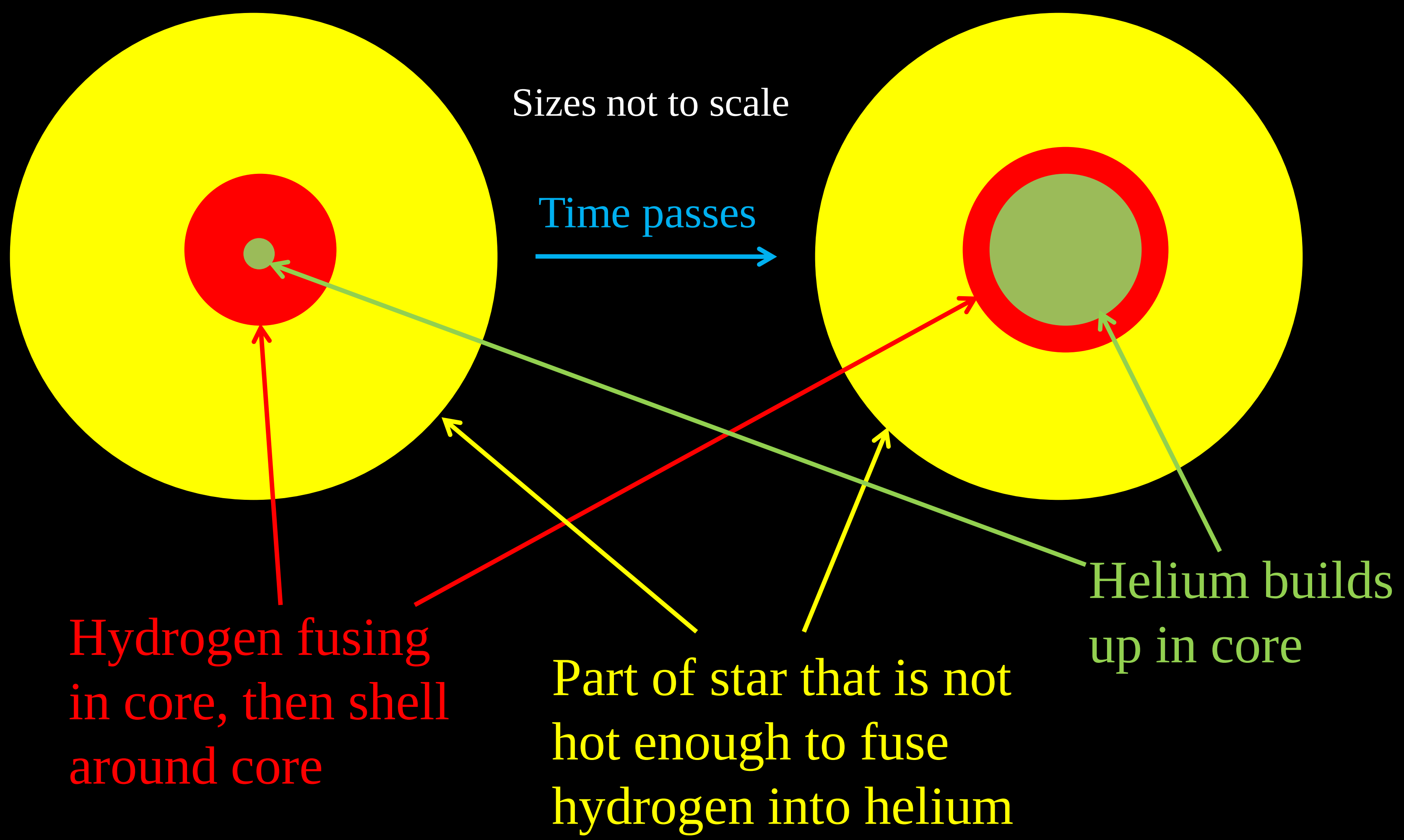
11/19 – Review for Midterm Exam 3

11/21 – Midterm Exam 3

So, what happens when a star “runs out of fuel?”

- A better phrasing of that question: What happens when a star can no longer convert hydrogen to helium in its core?
- As hydrogen is fused into helium, helium builds up in the core of the star. There is less and less hydrogen in the core to fuse.
- The core starts to contract, since it is not being held up as well against gravity, and it gets hotter.
- A shell of gas surrounding the core can then get hot enough to also fuse hydrogen into helium.

So, what happens when a star "runs out of fuel?"



So, what happens when a star "runs out of fuel?"

- The portions of the star that were not involved in fusing hydrogen (the envelope), start expanding due to the increased heat in the core. The size of the star can easily increase 100-fold or more.
- The outer portions of the star (that we see) are so far from the hot core, that they get much cooler. → red giant/supergiant
- Gravity is so weak at that distance, the gas in that envelope can slowly leave the star. Over time, we'll start seeing the hotter and hotter layers → The star will get bluer…

So, what happens when a star "runs out of fuel?"

- There are two avenues a star can take ***<u>depending on its mass</u>***…
  - Higher mass stars (>0.5 x Sun): It is hot enough to make the helium atoms start fusing into heavier elements like carbon and oxygen.
  - Lower mass stars (<0.5 x Sun): *Degeneracy pressure* holds up the star's core against gravity and it slowly cools down → a white dwarf with a planetary nebula around it (the gas that had left the outer portions of the star).

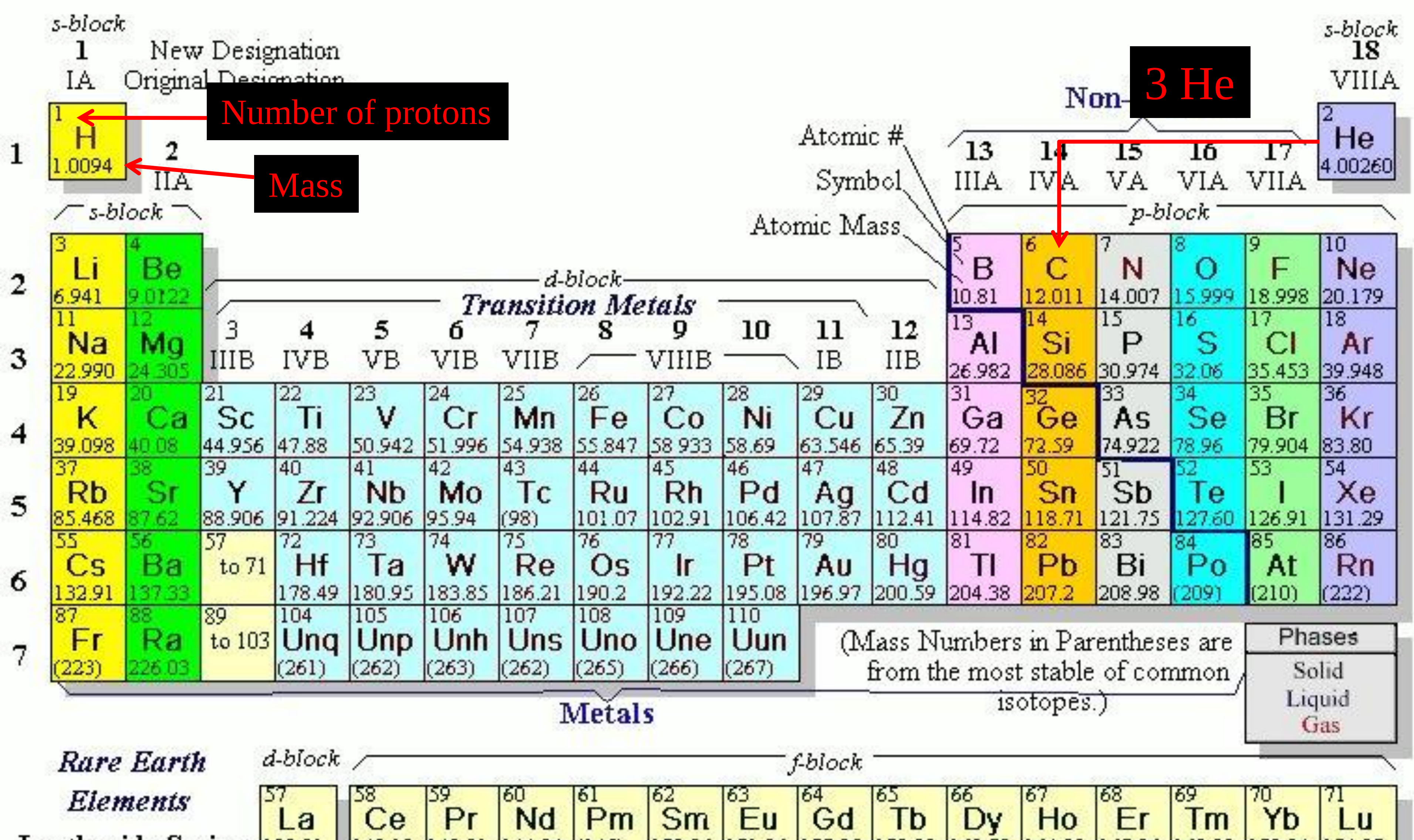
What is this “degeneracy pressure” thing?

- Fancy traxoline for the kind of pressure that keeps you from falling through your seat.
- If the temperature does not get high enough for atoms to fuse (they can never travel fast enough), they will limit how closely you can pack them together.
- This kind of pressure does not depend on temperature.

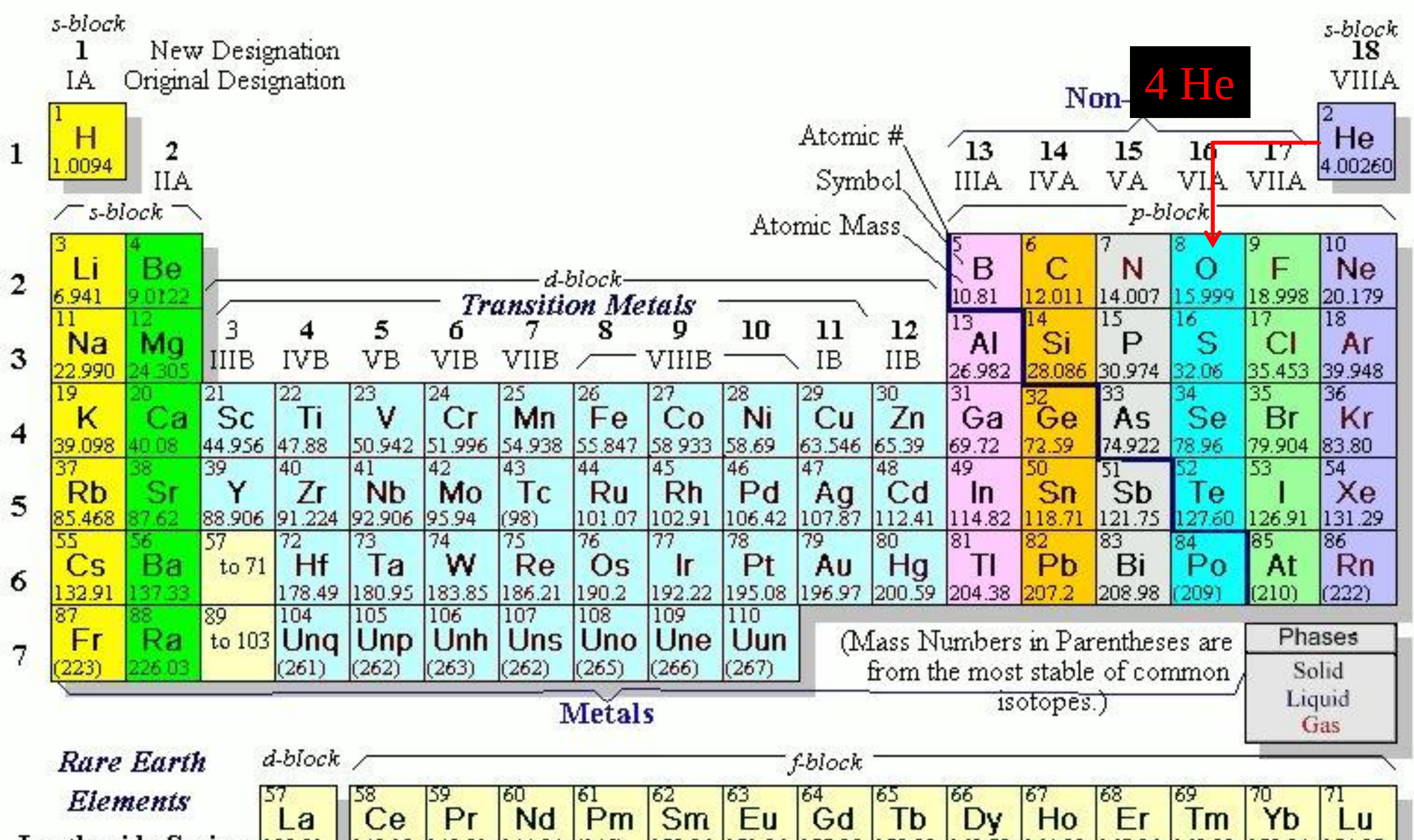
What is this "degeneracy pressure" thing?

- In a star, this pressure can only happen through a slow, gentle build-up, and can only provide support up to a given mass/weight – up to 1.4 times the mass of the Sun. (Think: What time is it when an elephant sits on a table?)
- Fancier traxoline: This is called *electron degeneracy pressure*. There is another kind called *neutron degeneracy pressure*, which we'll get to in a bit…

4H → He… then what?



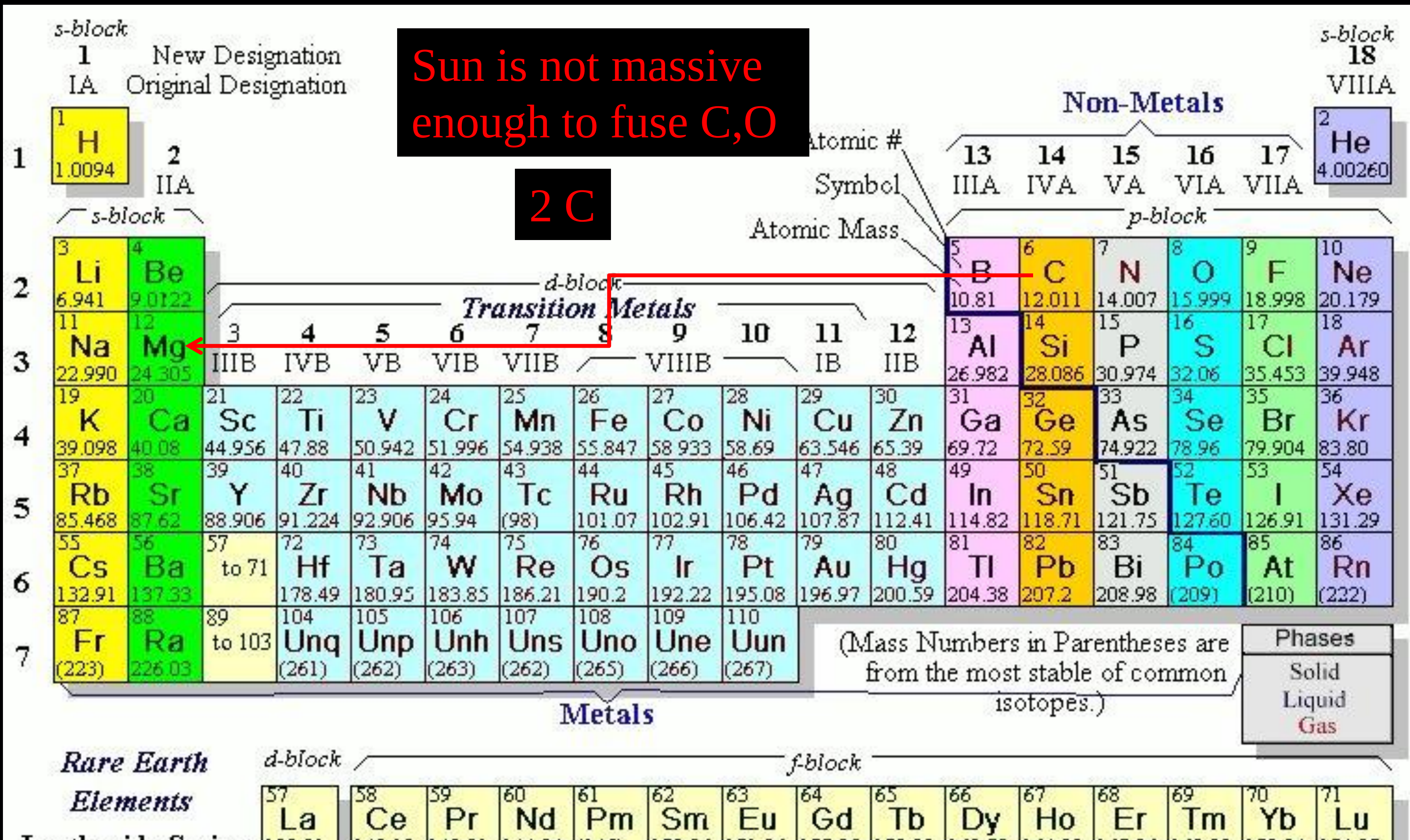
4H → He… then what?



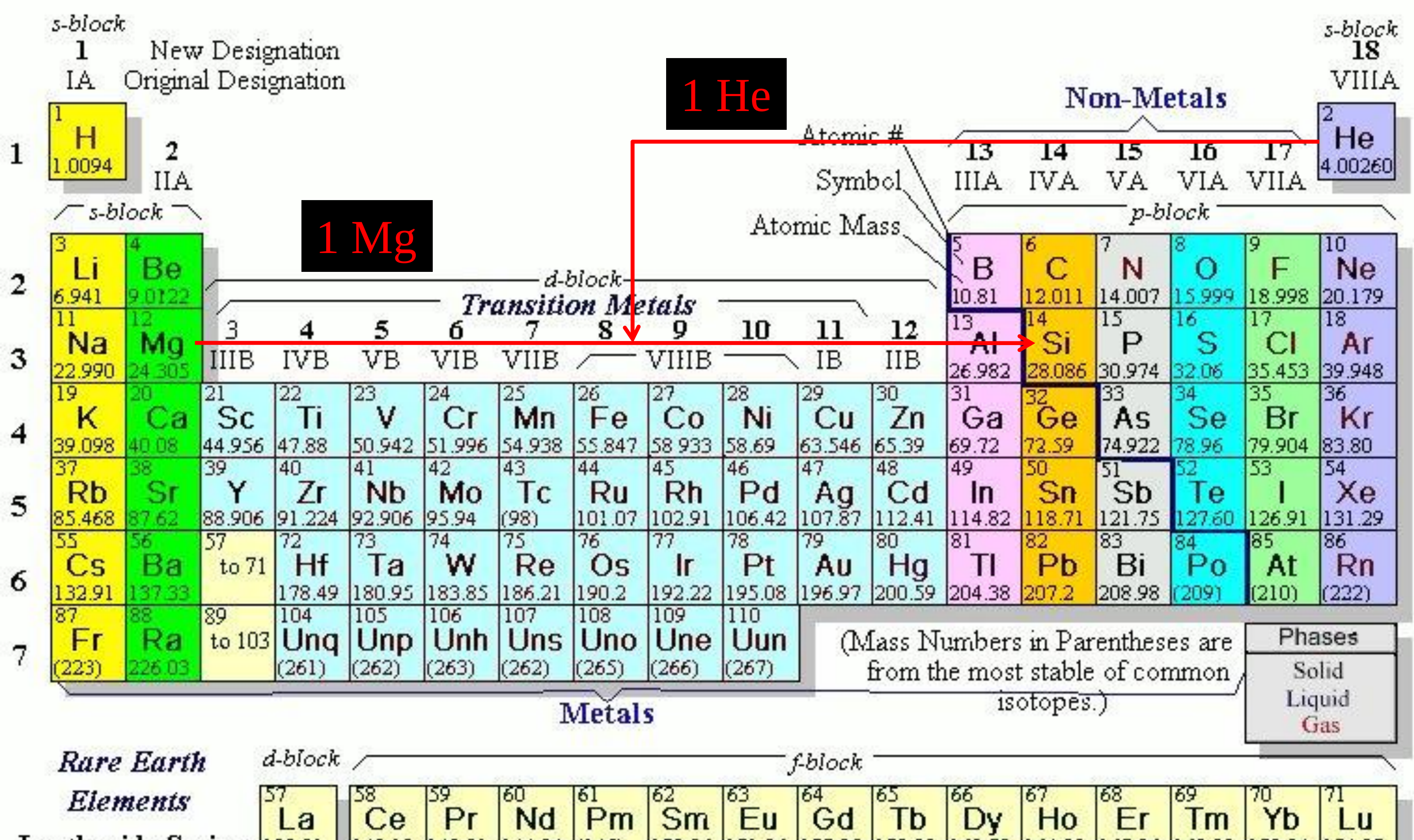
Aside: Nuclear Reaction Rates

- Is the core temperature larger or smaller for helium fusion compared to hydrogen fusion?
  – Larger, hotter
- So, is the rate of nuclear reactions larger or smaller for helium fusion compared to hydrogen fusion?
  – Larger, faster
- Then is the helium-fusing life of a star shorter or longer than the hydrogen-fusing life?
  – Much shorter

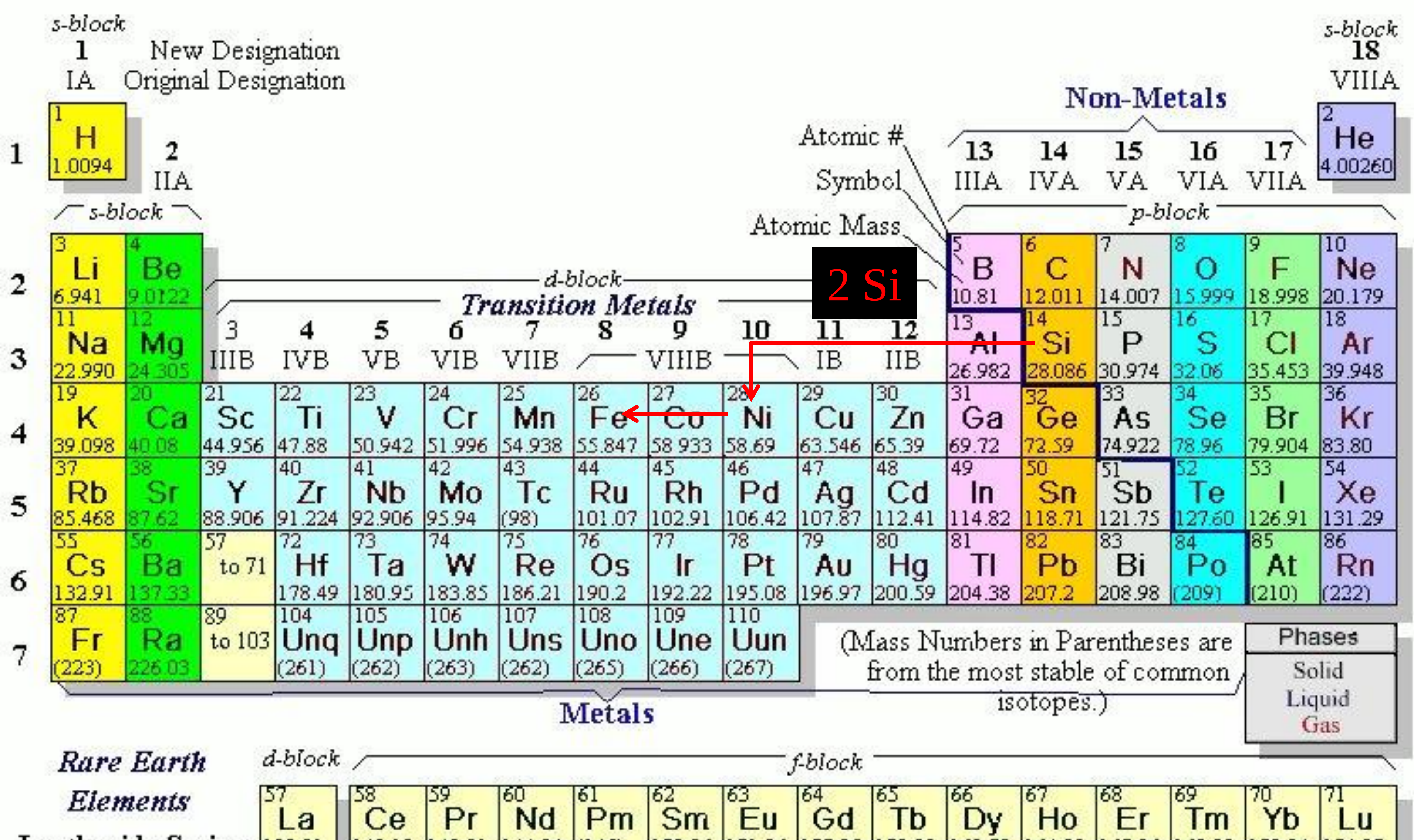
4H → He… then what?



4H → He… then what?



4H → He… then what?



So, what happens when a star "runs out of fuel?"

- Ok, ok. So then iron fuses into the next heavier thing, right? Nope.
- Iron presents a problem, because it has the most stable nucleus of all the elements. To get iron to fuse, you have to add energy…
- Stars initially more than ~8 times the mass of the Sun futilely try to fuse iron. For their efforts, they lose energy and there is no longer any support against gravity… uh-oh

So, what happens when a star "runs out of fuel?"

- Then the star goes supernova, literally.
- Within seconds…
  - The star's core collapses under its own gravity.
  - The collapse causes a bounce when one side of the core collides with the opposite side of the core, like a ball hitting the ground.
  - The outer, lighter layers of the star feel the bounce, which causes them to explode into space.
- This is a "core-collapse" or "Type 2" supernova.
- Type 1 is when a white dwarf in a binary system gets leaked on by its companion and that leakage pushes it over the edge of what electron degeneracy can support.

What's left after a supernova?

- The collapsed core endures so much pressure that the electron and protons in atoms combine to form neutrons.
- If the mass of what's left is not too high, degeneracy pressure from these neutrons can balance gravity → neutron star (<2 times Sun)
- If not, there's nothing we know of to stop it from collapsing completely into an infinitely small, infinitely dense singularity. What we "see" is a black hole.

Lecture Tutorials

- Break up into groups of 2-3
  - NO MORE THAN THREE, NO SINGLES
- In your group, work through the following:
  - Stellar Evolution (pages 121-122)
  - Discuss the answers – don't be silent!
- MarkDan, Jacquelyn, and I will be roaming around if you need help…
- If your group finishes, check your answers with another group.
- If you are confident that your answers are correct, help another group that is struggling to find their own answers.

New Schedule for Galaxies and the Universe Unit (already posted)

- Monday , 11/10– Finding distances
  - LT: Parallax and Distances, Spectroscopic Parallax
  - AN: Chapter 11, sections 2 and 3
- Wednesday, 11/12 – Types of Galaxies
  - LT: Galaxy Classification
  - AN: Chapter 15, sections 1-11
- Friday, 11/14 – The Universe as a Time Machine
  - LT: Looking at Distant Objects
  - AN: Chapter 15, section 16
- Monday, 11/17 – Expansion of the Universe
  - LT: Expansion of the Universe
  - AN: Chapter 16, sections 1-4

Think
Pair
Share!

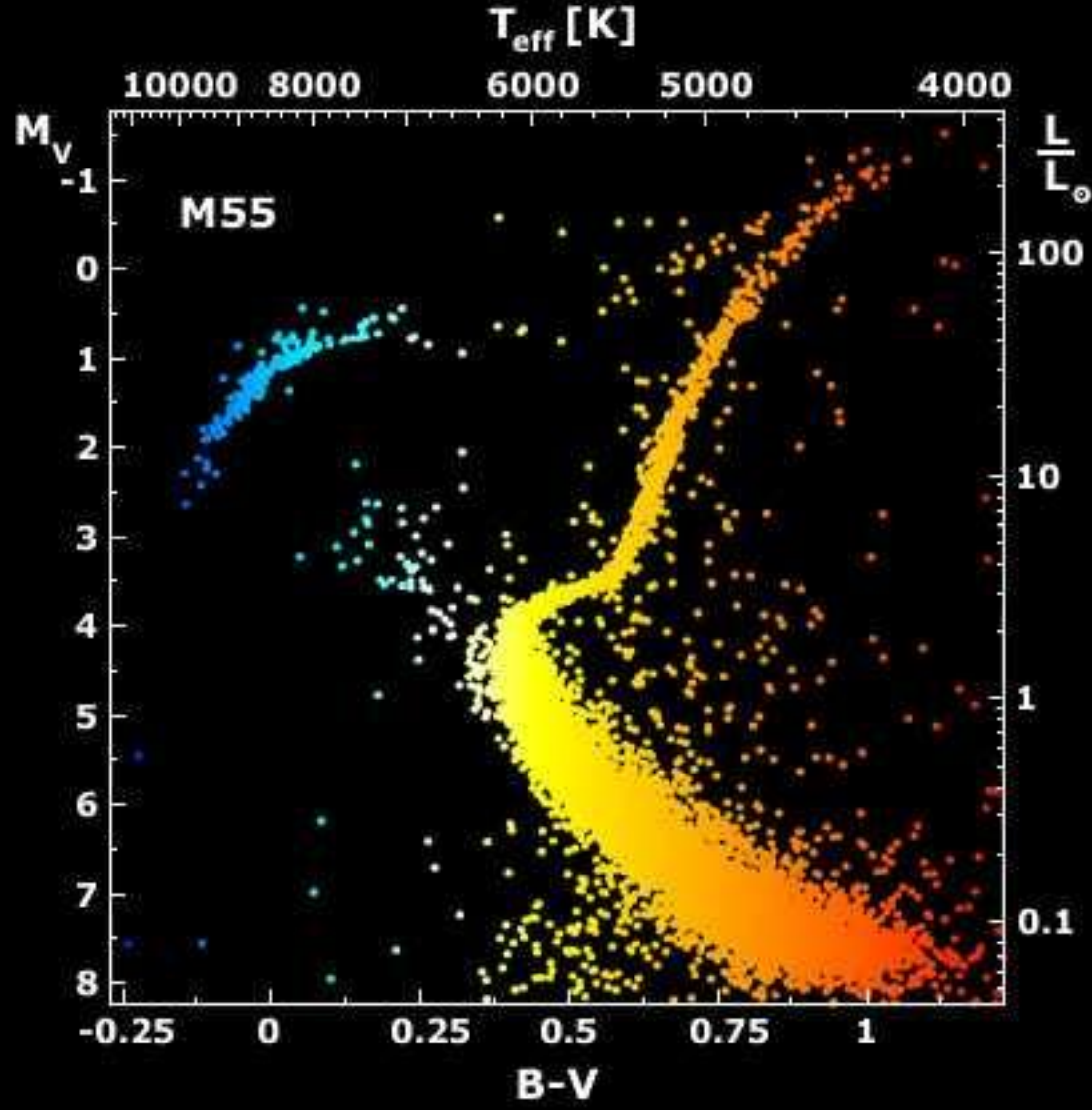
The eventual fate of our Sun is to

A. collapse into a black hole.
B. form a neutron star.
C. become a steadily cooling white dwarf.
D. explode as a Type I supernova leaving no remnant.

Which of the following lists, in the correct order, a possible evolutionary path for a star?

A. Red Giant, Neutron Star, White Dwarf, Nothing
B. Red Giant, Type II Supernova, Black Hole, Nothing
C. Red Giant, Type II Supernova, Planetary Nebula, Neutron Star
D. Red Giant, Planetary Nebula, White Dwarf
E. Red Giant, Planetary Nebula, Black Hole

Test the Theory: How does stellar evolution explain this?



Black holes don't suck.

- Remember that gravitational acceleration from an object depends on its *mass* and the *distance* to it (multiply by your mass to get the force between you and it).
- The escape velocity is the velocity that you initially have to have from where you are to escape an object's gravity. The closer you are to something, the large the force of gravity, and the larger the escape velocity.
- Black holes are just objects where it is possible to get so close to them, that the escape velocity exceeds the speed of light.

Black holes don't suck.

- The *event horizon* is the mathematical/imaginary surface where the escape velocity is equal to the speed of light. This depends solely on the mass of the object.
- The Sun's event horizon is about 3 km.
- The Earth's event horizon is about 9 mm.
- Rajib's event horizon is smaller than a proton.
- One can't get within 3km of the center of the Sun, or within 9mm of the center of the Earth, or within a proton-size of the center of Rajib, so there's no worries.

Black holes don’t suck.

- The event horizon is what we (meaning Hollywood) usually think of when we say BLACK HOLE.
- These are tiny, so it is actually pretty hard to feed a black hole. Think about trying to toss food into the mouth of a baby from across a football field…

Binary Stars

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11/10-17 – Galaxies and the Universe

11/19 – Review for Midterm Exam 3

11/21 – Midterm Exam 3

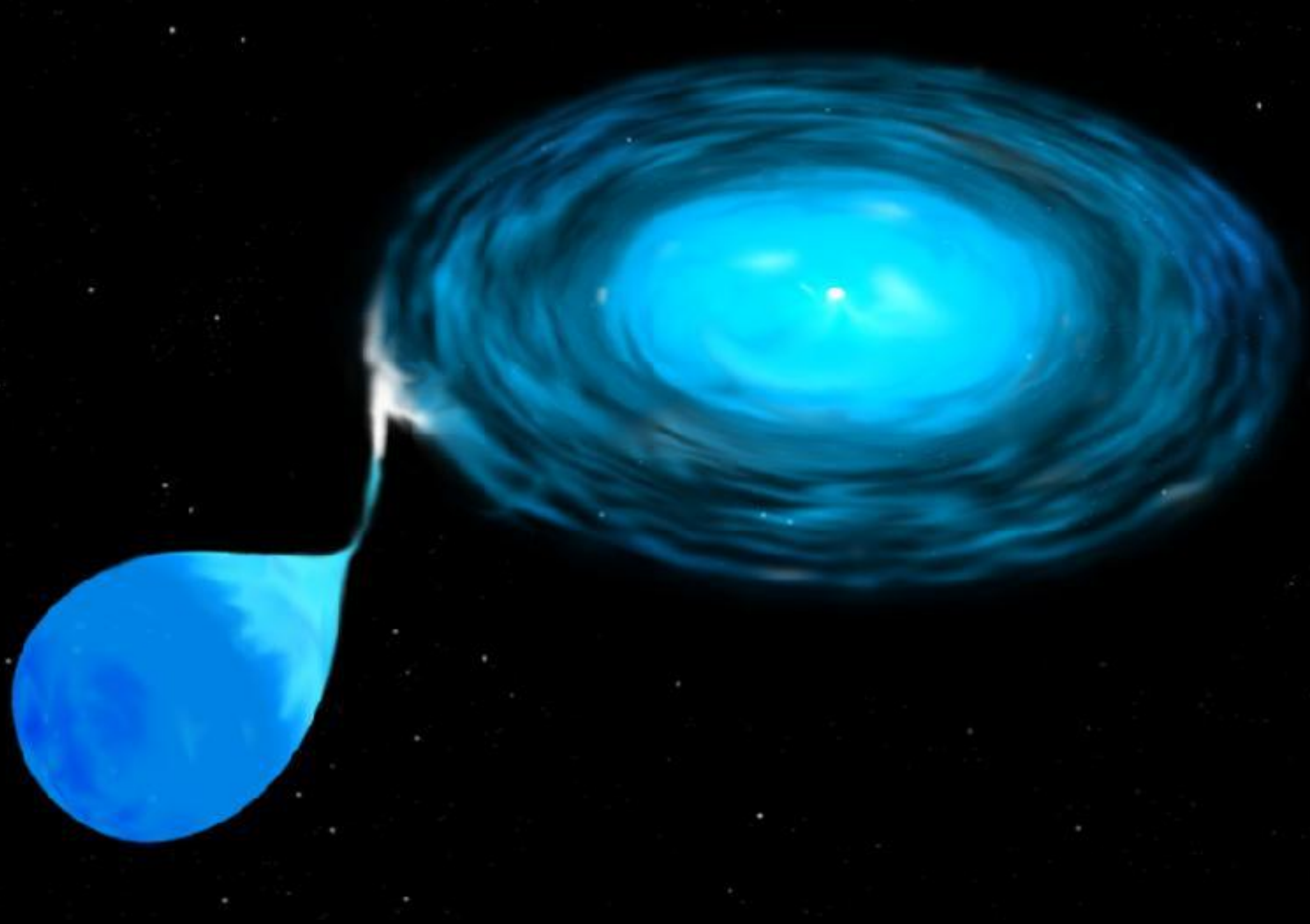
Binary Stars

- A pair of stars that are gravitationally bound and orbit each other.
- [“Double star” is not the same thing. → two stars that happen to be close together in projection on the sky.]
- Roughly 2/3 of stars are in binaries.
- Typically, it appears that stars in binaries are the same age. → probably formed as a binary.

Evolution of Binary stars

- As the two stars age together, the more massive one will evolve off the MS first…
- Quite often, one observes a lower-mass MS star with a *compact object* (white dwarf or neutron star or black hole).
- White dwarfs with MS companions offer two interesting phenomena when the WD pulls gas off the MS…
  - Nova: periodic fusion of hydrogen on the surface
  - Type 1 Supernova: pushing the white dwarf above 1.4 Msun where degeneracy pressure can no longer balance gravity. → complete annihilation (no NS, BH)

Artist’s Rendition

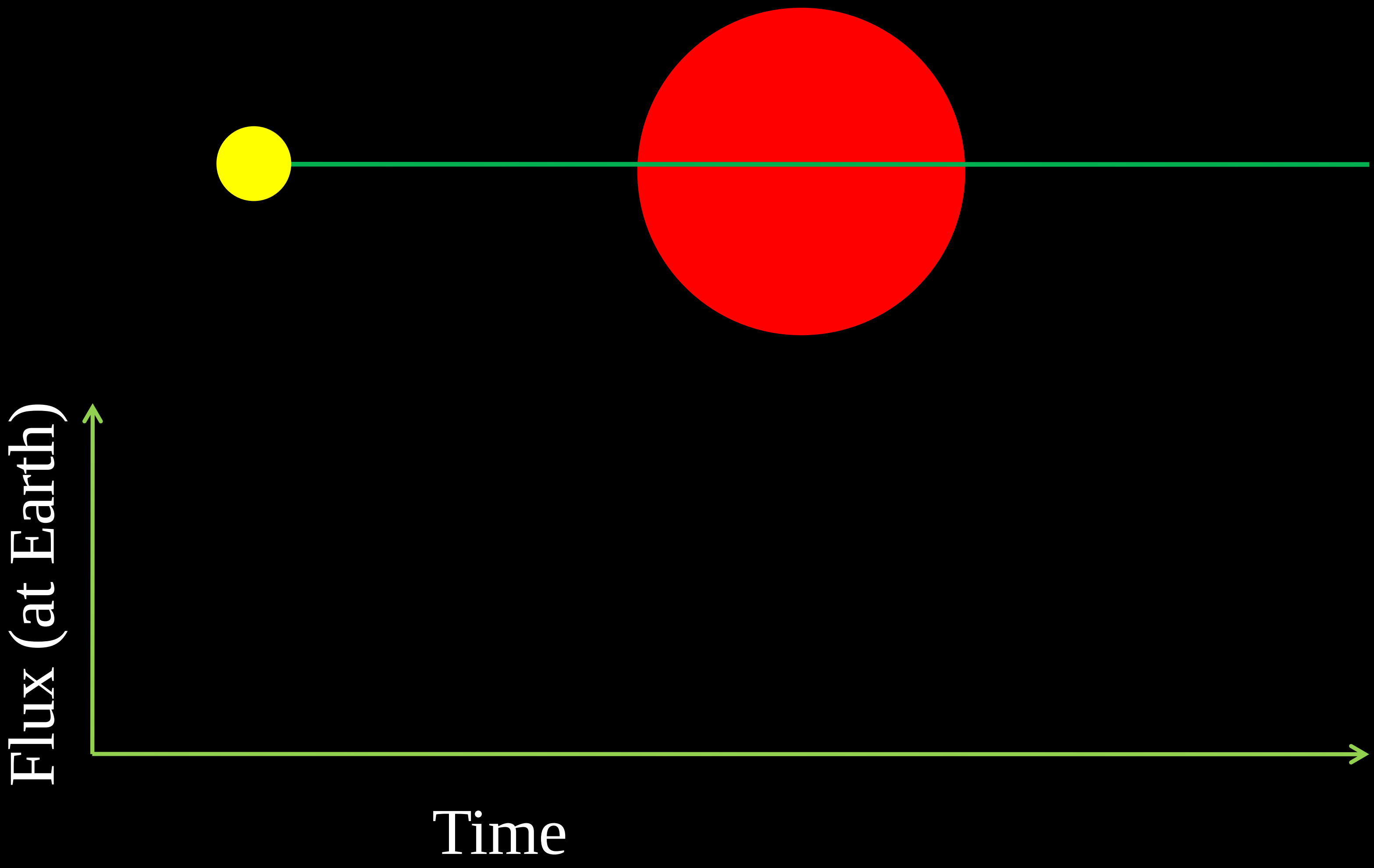


Binary Stars

- Recall :
  - For a fixed size, a hotter object gives off more light (the “height of the peak” of the blackbody is taller).
  - Two objects orbiting each other will do so with the same average speed (Kepler’s Third Law)
  - We can measure the “radial velocity” of stars using the Doppler Shift.
- These three concepts can help us use the combined light from stars to infer the sizes and relative temperatures of the stars.

Binary Star Light Curves

Edge-on Binary System



Binary Star Light Curves

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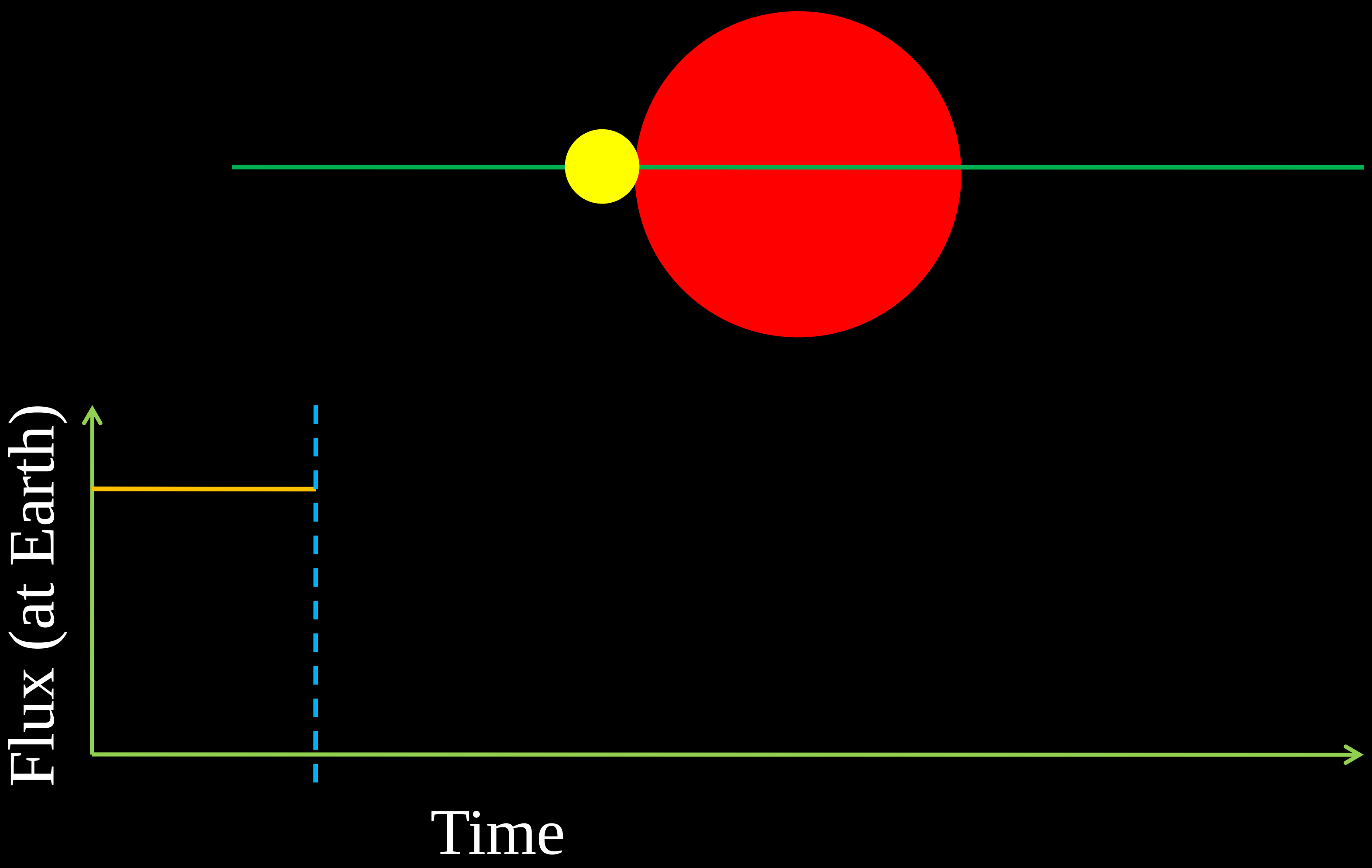

Binary Star Light Curves

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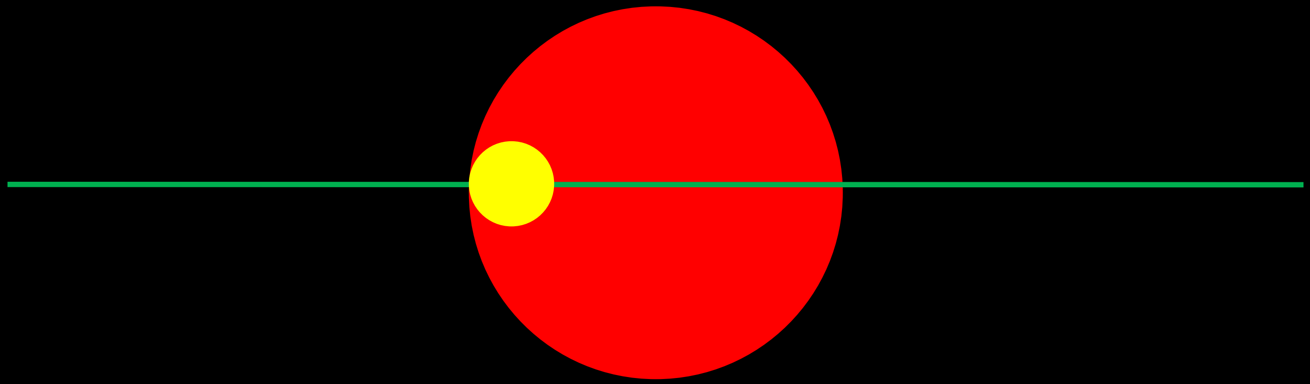

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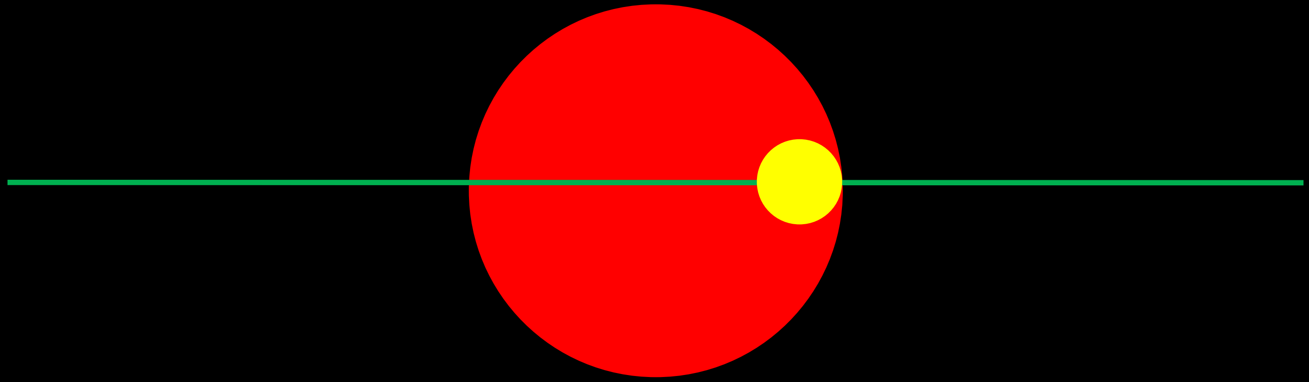

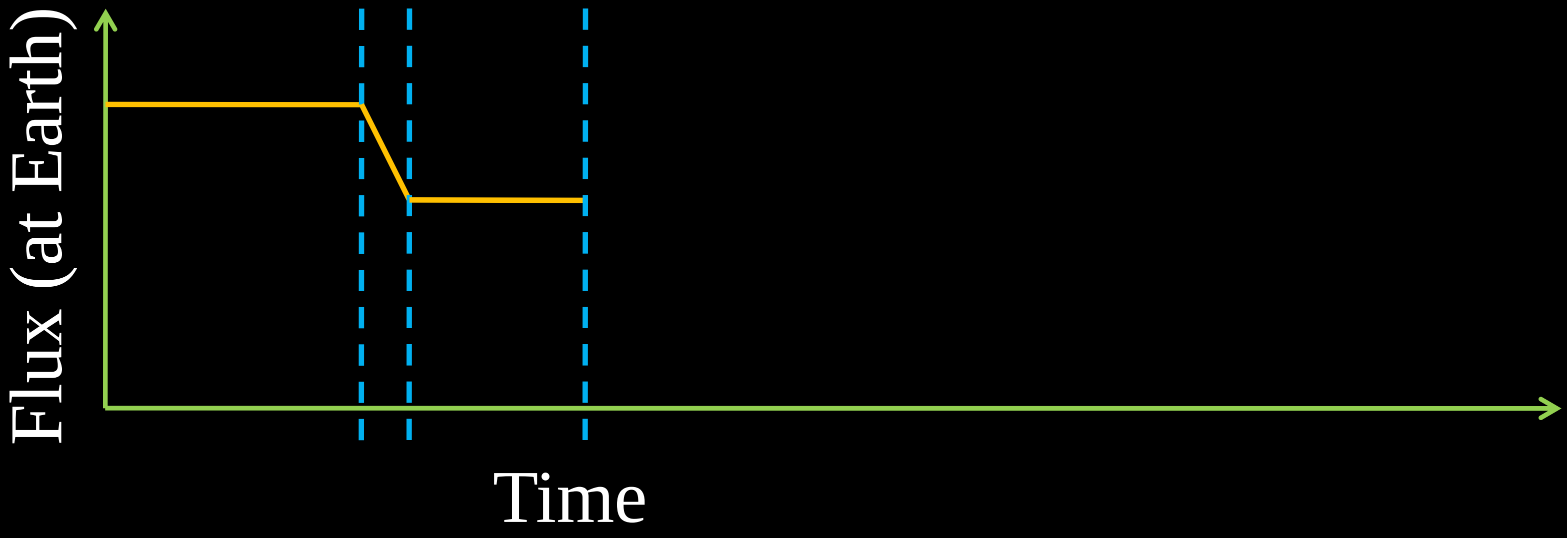

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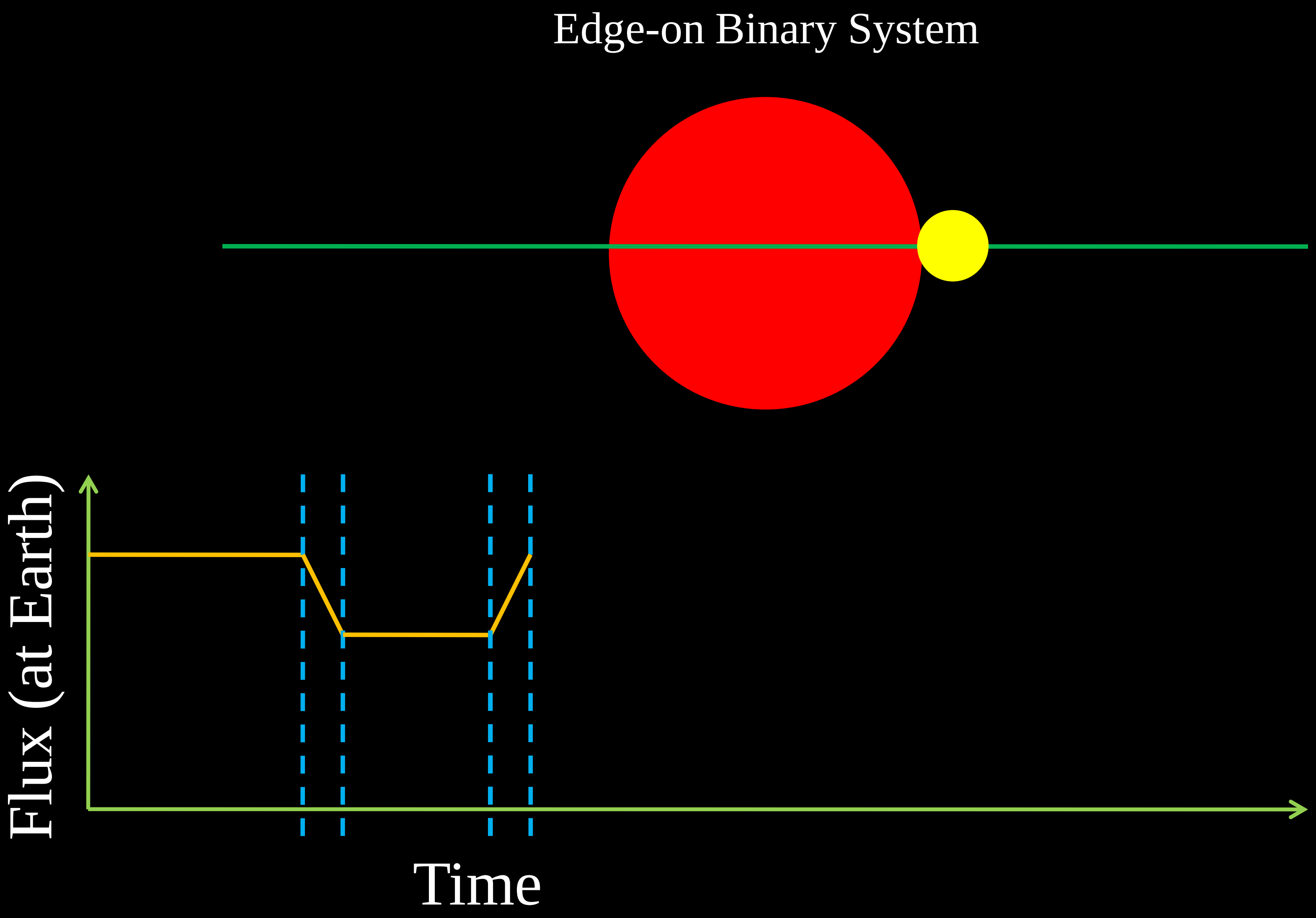

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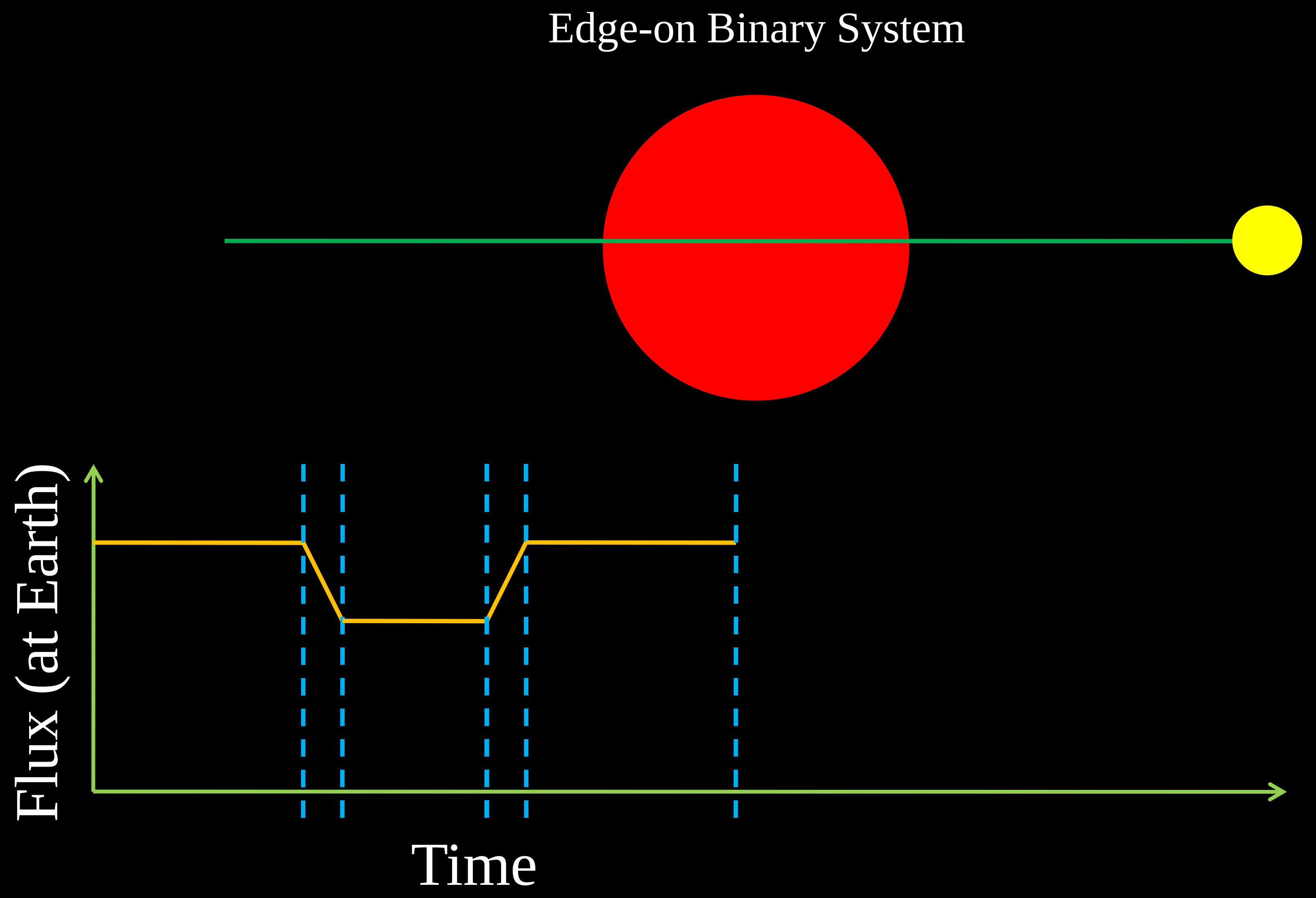

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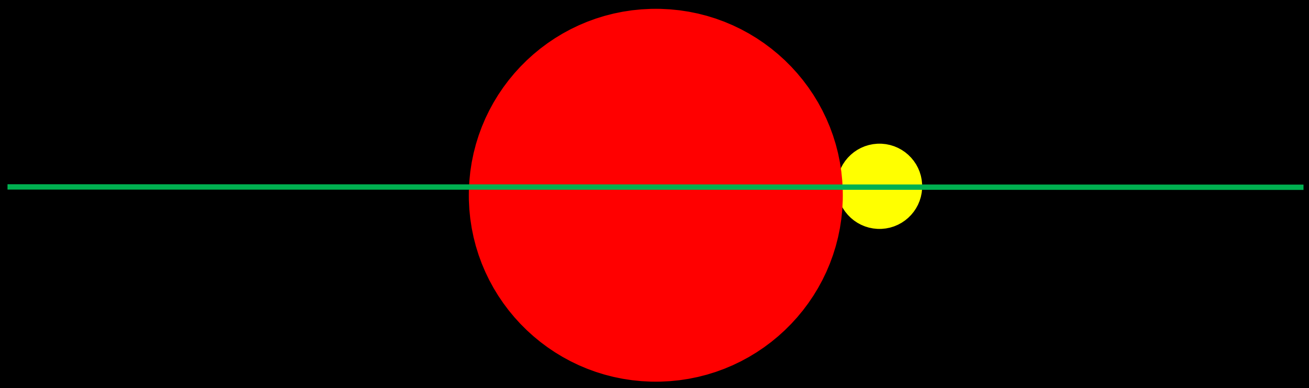

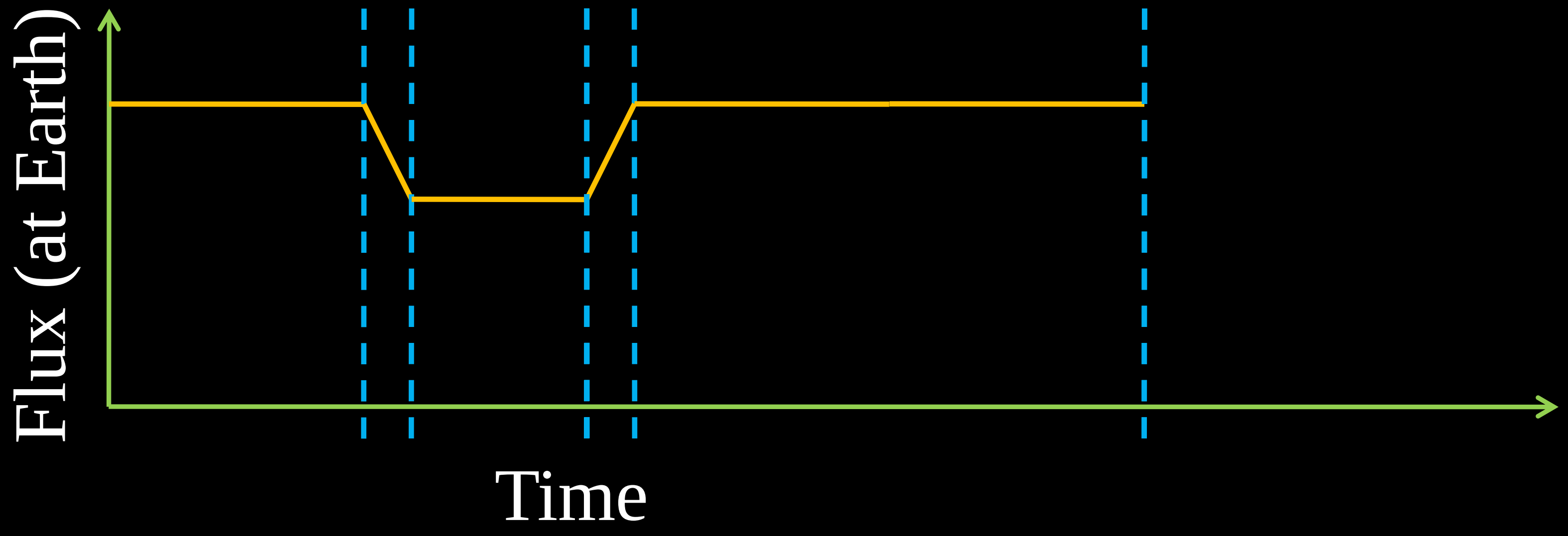

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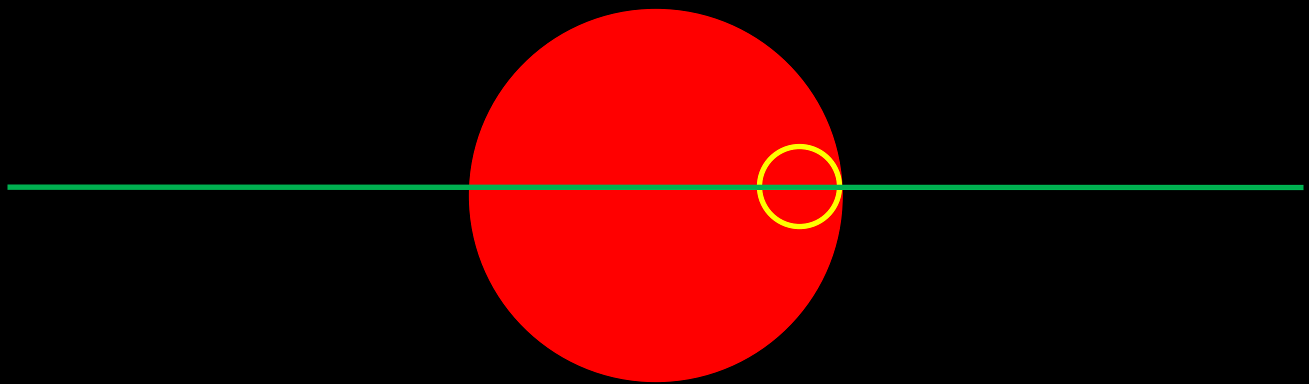

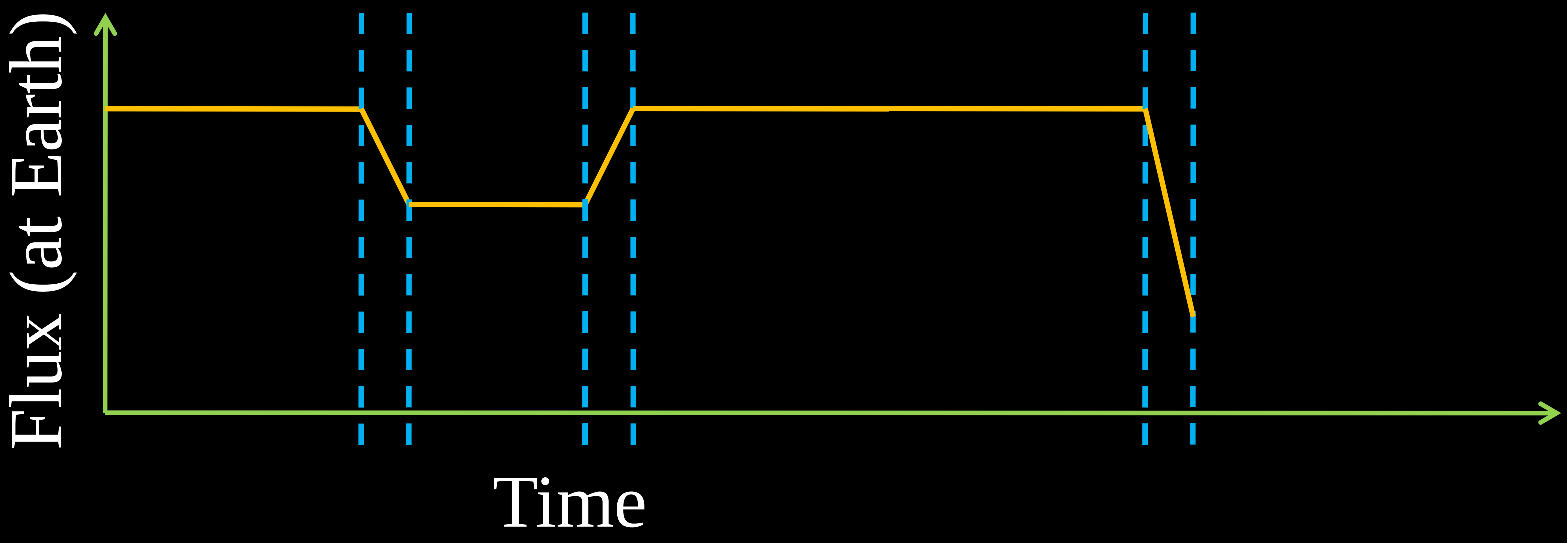

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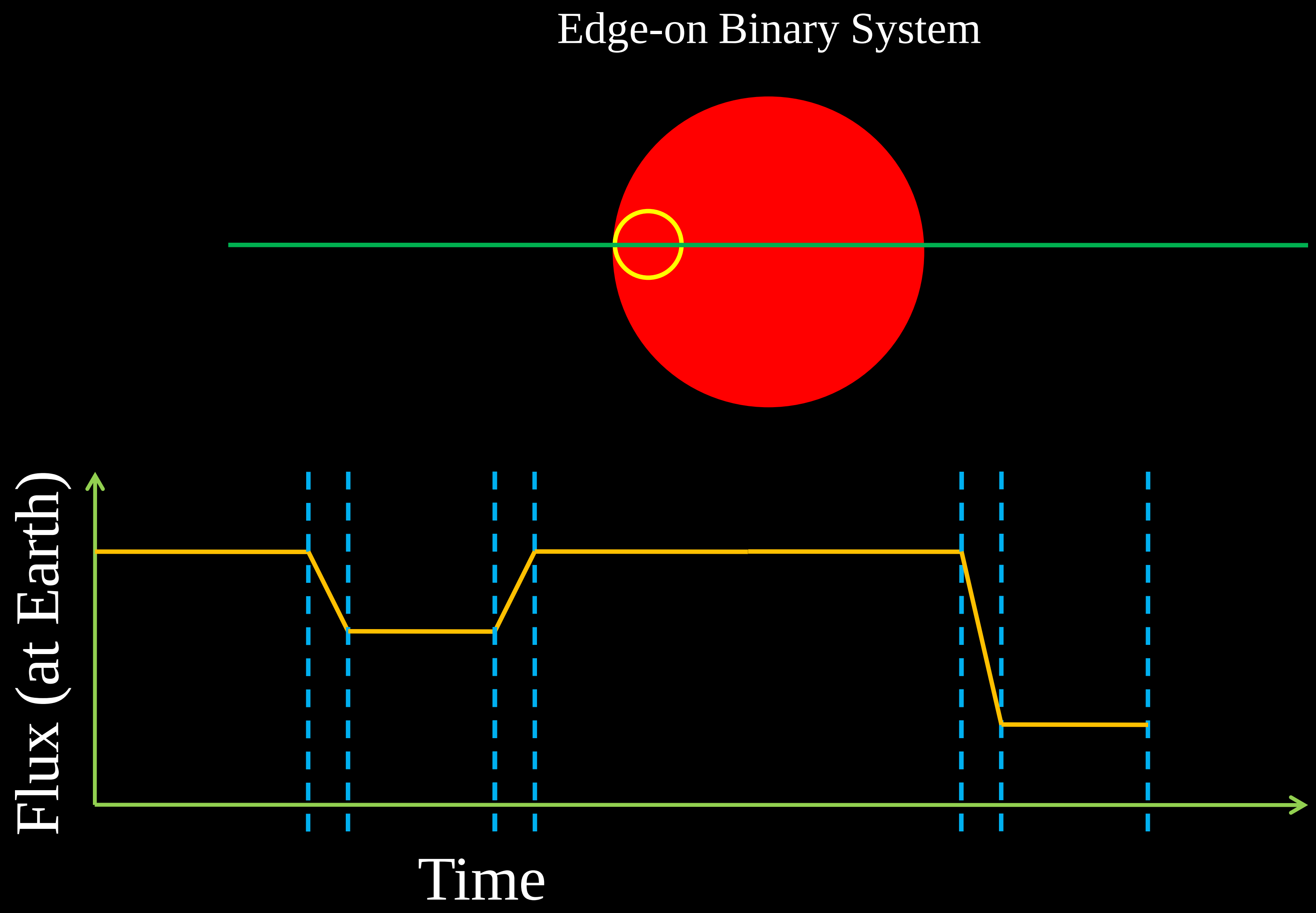

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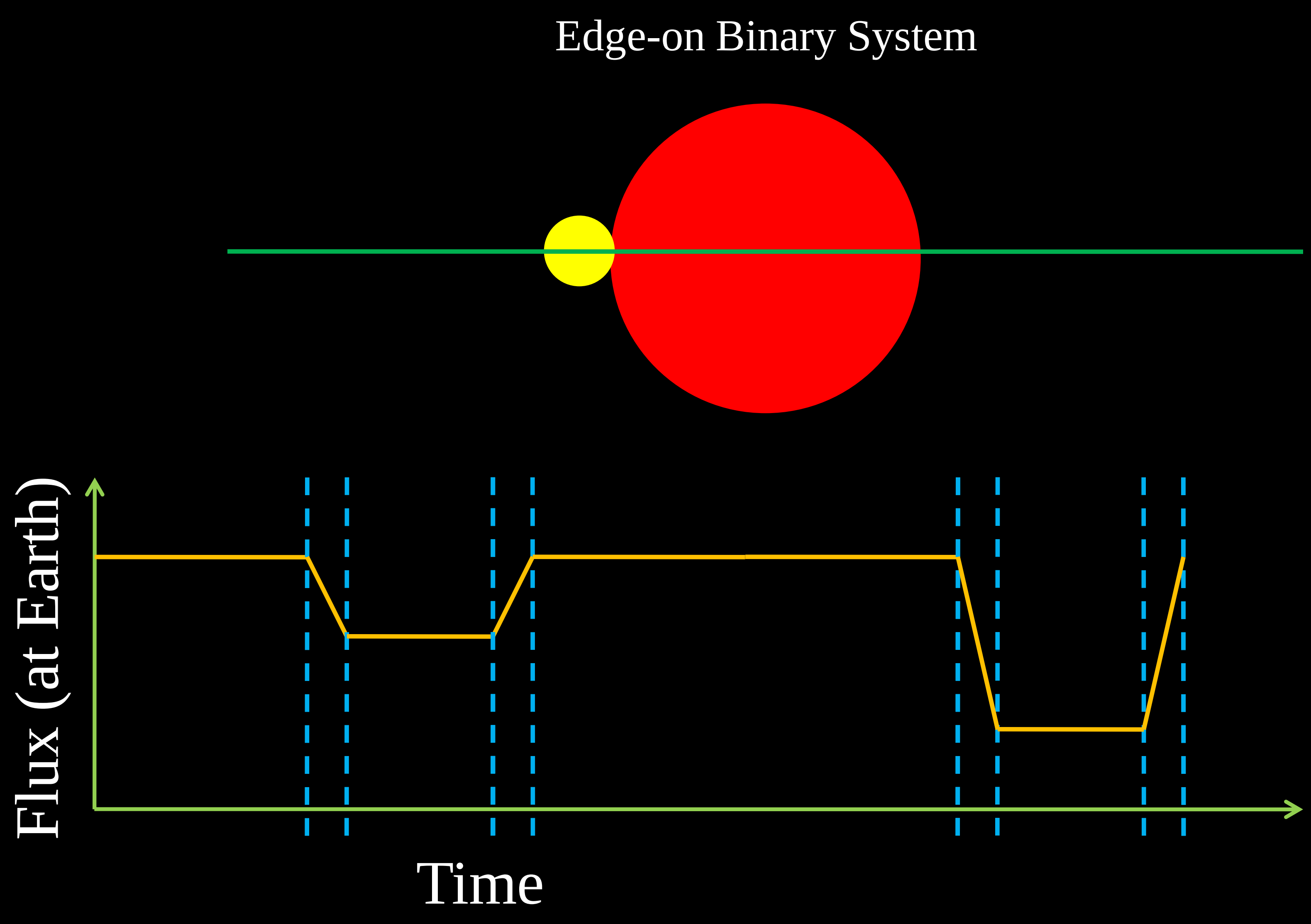

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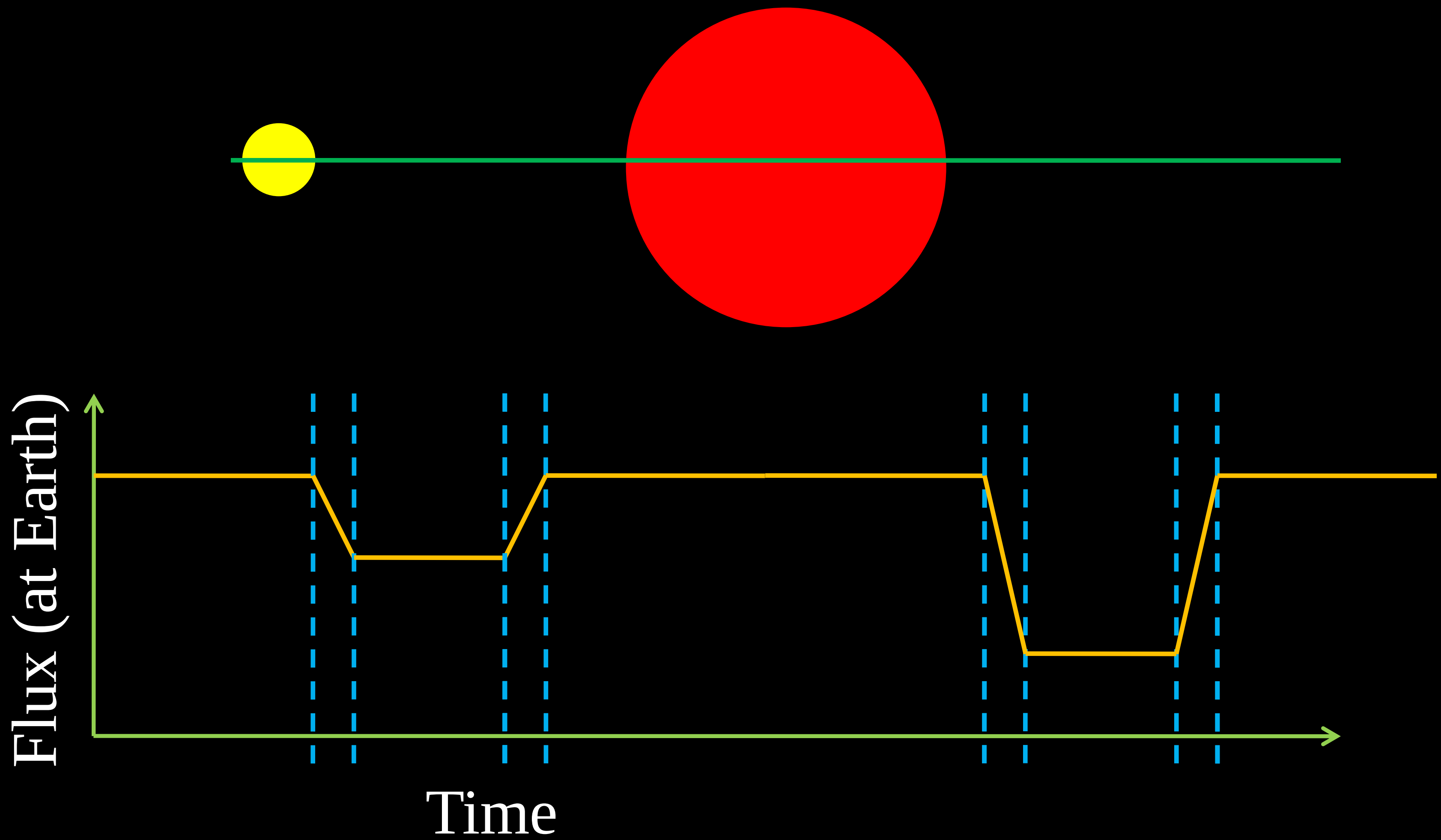

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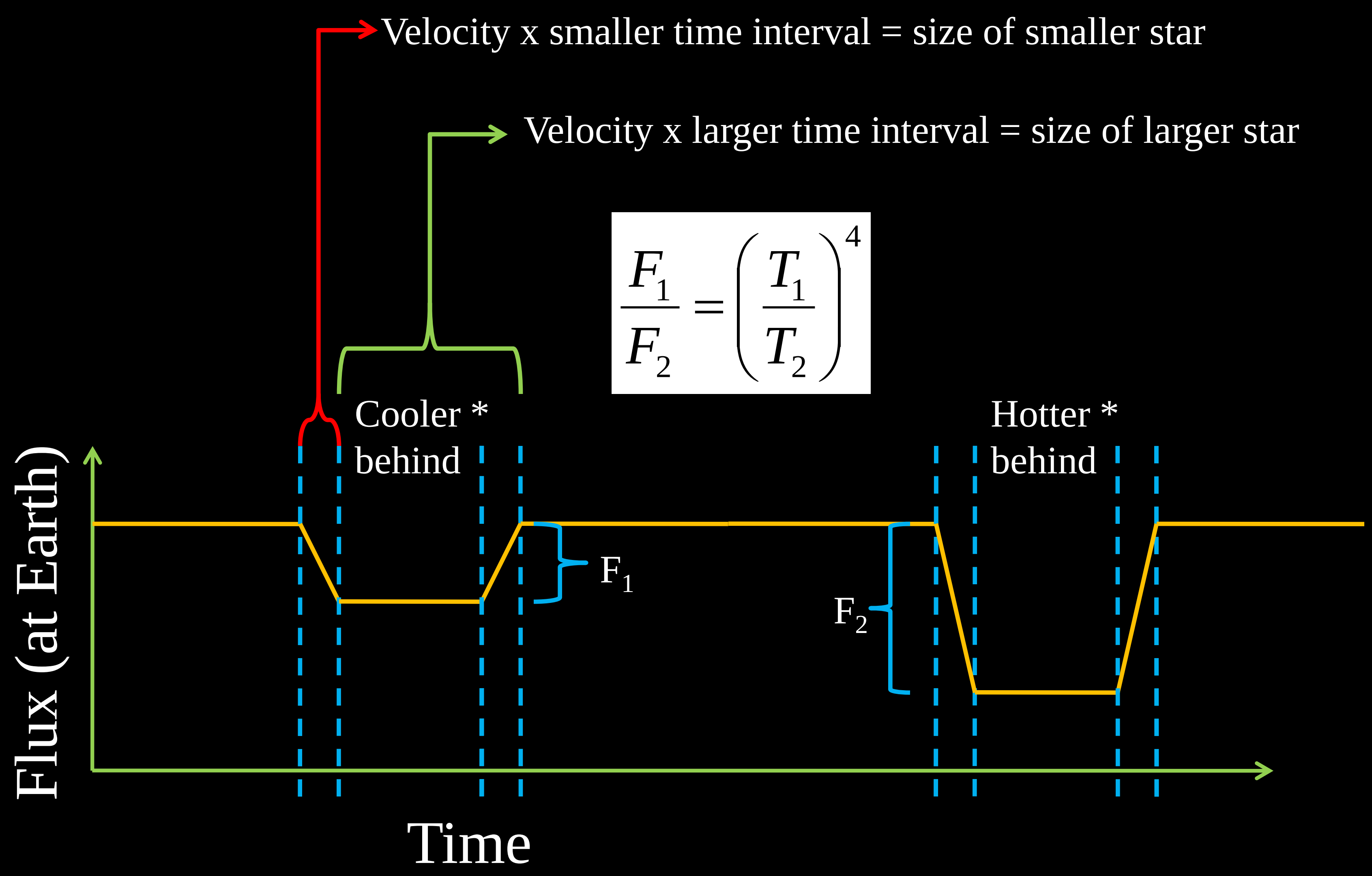
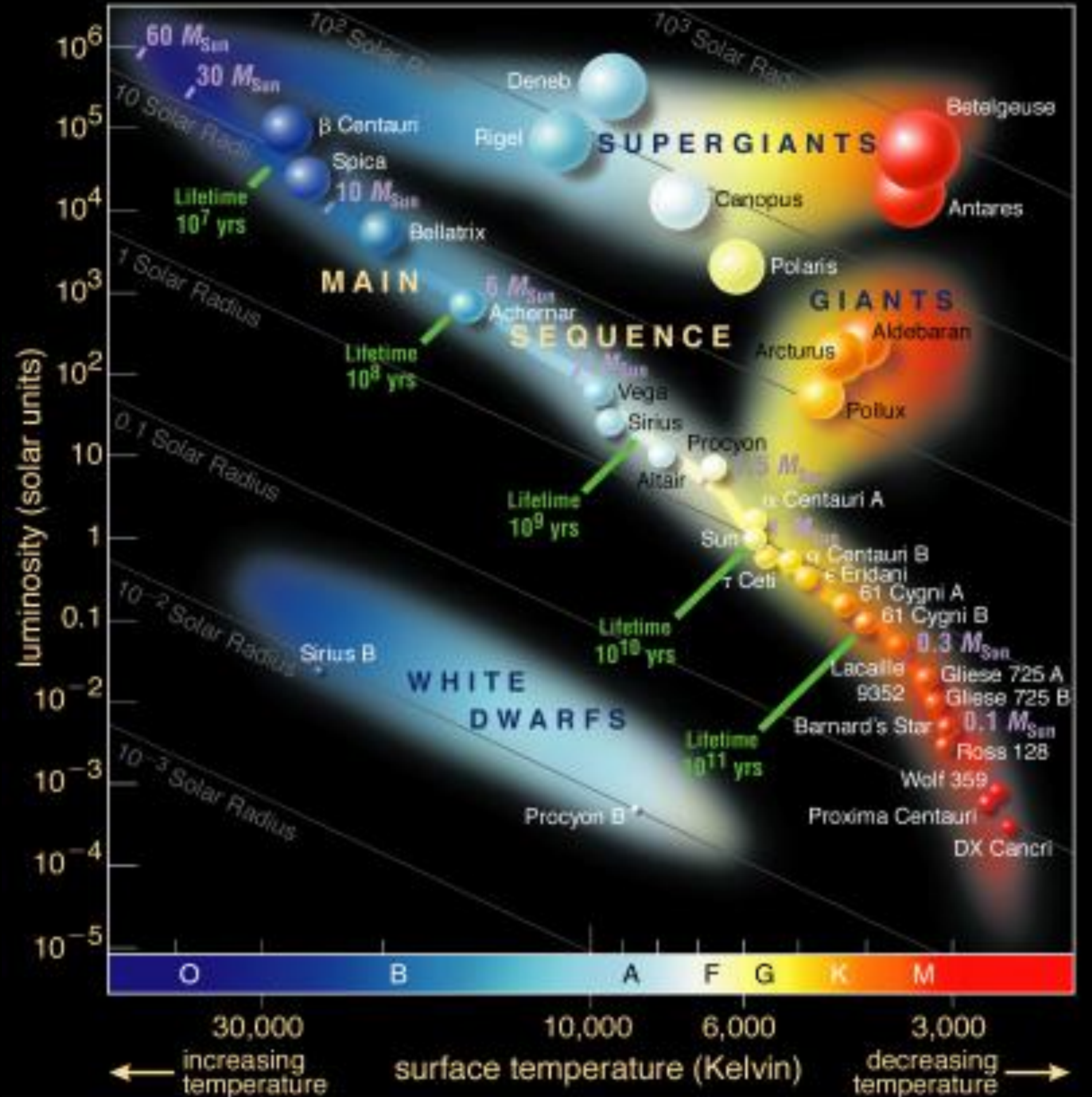




luminosity (solar units)
surface temperature (Kelvin)
increasing temperature
decreasing temperature
30,000
10,000
6,000
3,000
O
B
A
F
G
K
M
SUPERGIANTS
GIANTS
MAIN SEQUENCE
WHITE DWARFS
60 M_Sun
30 M_Sun
10 M_Sun
6 M_Sun
1.5 M_Sun
0.3 M_Sun
0.1 M_Sun
10 Solar Radii
10² Solar Radii
10³ Solar Radii
1 Solar Radius
0.1 Solar Radius
10⁻² Solar Radius
10⁻³ Solar Radius
Lifetime 10⁷ yrs
Lifetime 10⁸ yrs
Lifetime 10⁹ yrs
Lifetime 10¹⁰ yrs
Lifetime 10¹¹ yrs
Deneb
Rigel
Betelgeuse
Antares
Canopus
Polaris
Aldebaran
Arcturus
Pollux
β Centauri
Spica
Bellatrix
Achernar
Vega
Sirius
Procyon
Altair
α Centauri A
Sun
τ Ceti
α Centauri B
ε Eridani
61 Cygni A
61 Cygni B
Lacaille 9352
Gliese 725 A
Gliese 725 B
Barnard's Star
Ross 128
Wolf 359
Proxima Centauri
DX Cancri
Sirius B
Procyon B

Lecture Tutorials

- Break up into groups of 2-3
  - NO MORE THAN THREE, NO SINGLES
- In your group, work through the following:
  - Binary Stars (pages 113-116)
  - Discuss the answers – don't be silent!
- MarkDan, Jacquelyn, and I will be roaming around if you need help…
- If your group finishes, check your answers with another group.
- If you are confident that your answers are correct, help another group that is struggling to find their own answers.

Think
Pair
Share!

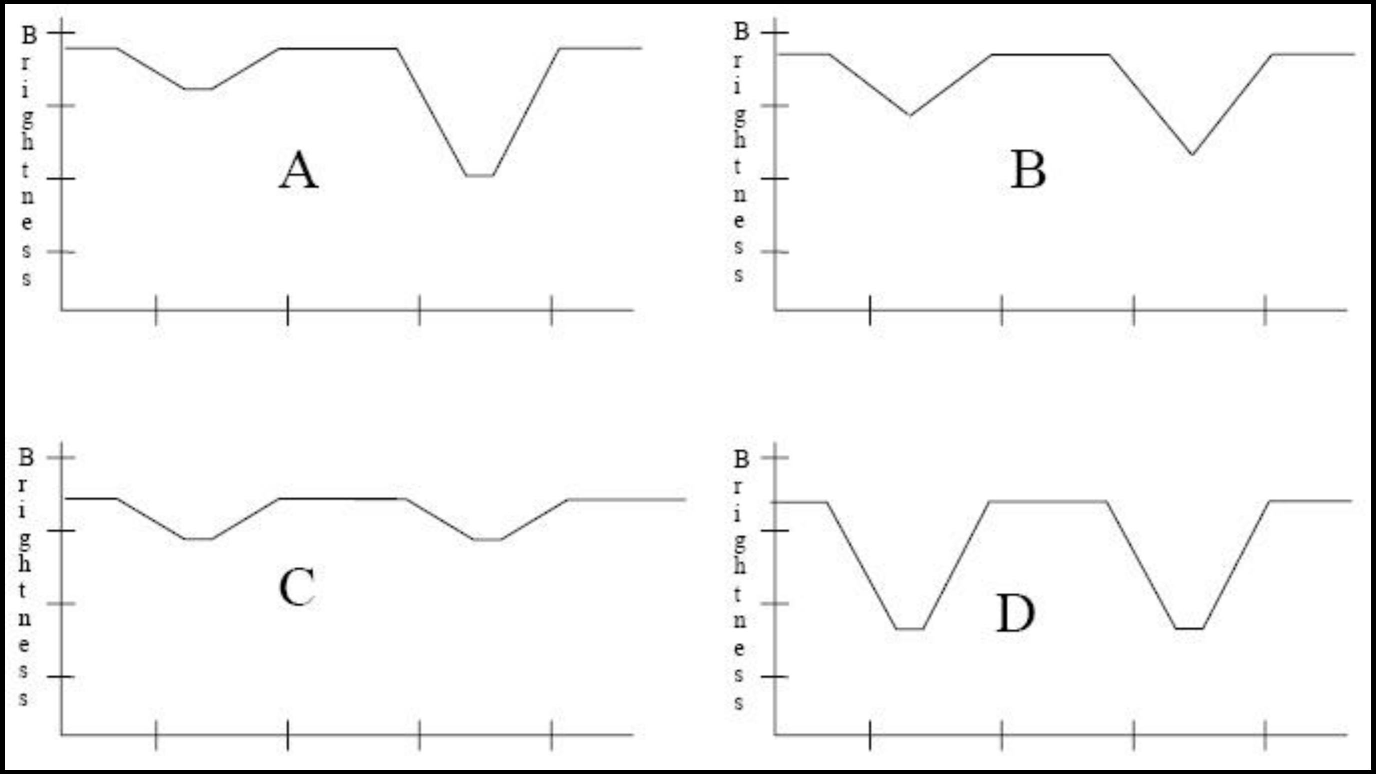
From which binary star system (made up of two main sequence stars) described below would an Earth observer detect the least amount of total light?

A. When a star with an absolute magnitude of 5.0 is in front of a star with an absolute magnitude of -2.0.
B. When a star with an absolute magnitude of 1.0 is behind a star with an absolute magnitude of -2.0.
C. When a star with an absolute magnitude of 5.0 is behind a star with an absolute magnitude of 1.0.
D. When a star with an absolute magnitude of 5.0 is in front of a star with an absolute magnitude of 1.0.
E. When a star with an absolute magnitude of 5.0 is behind a star with an absolute magnitude of -2.0.

When would you receive the greatest amount of light from a binary star system consisting of a M5 Red Giant and an M5 main sequence star?

A. When the Red Giant is in front of the main sequence star.
B. When the main sequence star is in front of the Red Giant.
C. You would receive the same amount of light for both situations described in choices A and B.
D. None of the above.

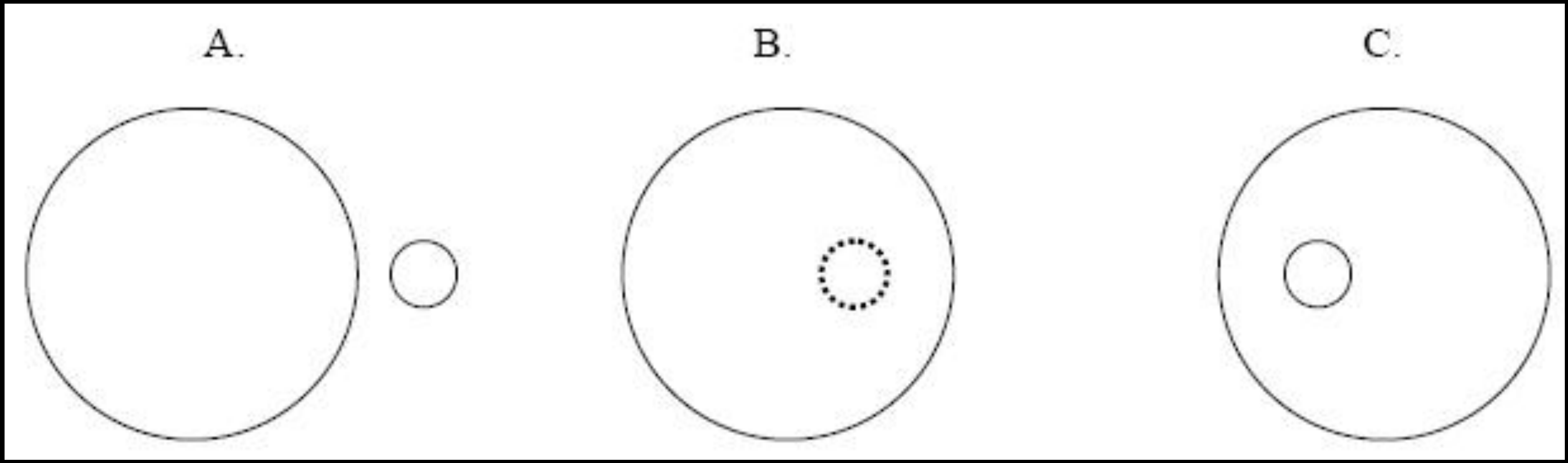
Which of the graphs (A-D) would correspond with an A spectral type main sequence star orbiting a Red Giant star in a binary star system? If none of the graphs seems to be possible, answer with an “E”.



Which of the following is true of a binary star system consisting of a Red Giant and a White Dwarf?

A. You will receive more energy when the dwarf is behind the giant than when the giant is behind the dwarf.
B. The time it takes for the dwarf to pass behind the giant is shorter than the time for the giant to pass behind the dwarf.
C. The force of gravity exerted on the dwarf by giant is stronger than the force of gravity exerted of the giant on the dwarf.
D. The orbital period of the dwarf is shorter than the orbital period of the giant.
E. None of the above.

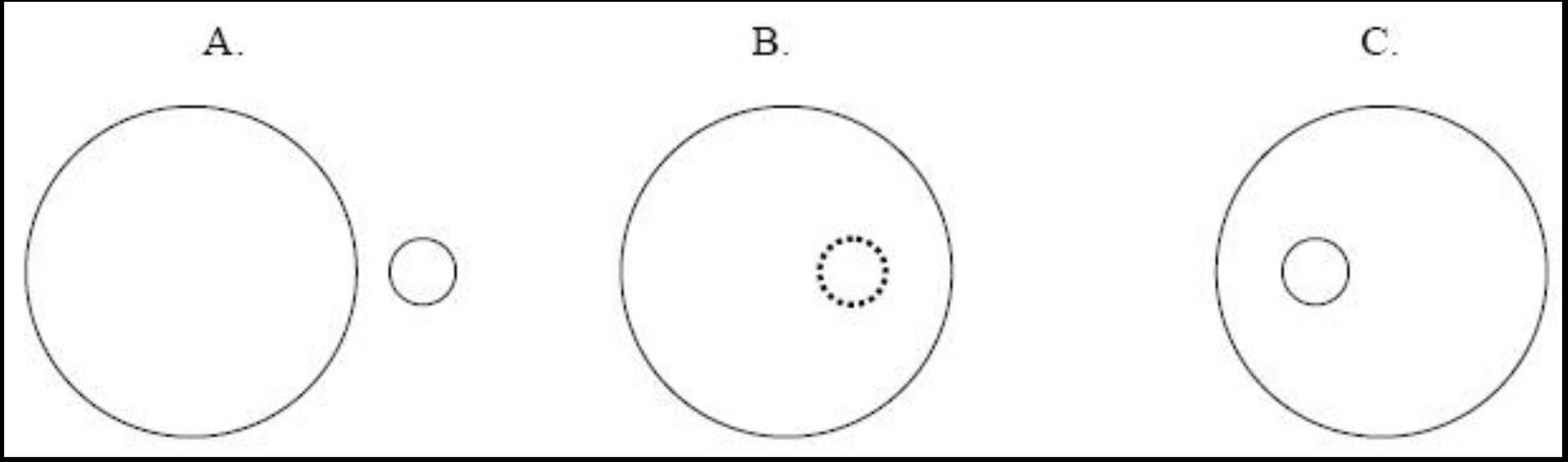
The sketches below illustrates how two main sequence stars might look at three different times. *Note: The sketch with the small circle shown with dashed lines illustrates the time when the smaller star was located behind the larger star.*



In which case shown would the amount of light we would observe from Earth be the least?

A. at time A
B. at time B
C. at time C
D. At more than one of the times.
E. There is not enough information to determine this.

The sketches below illustrates how two main sequence stars might look at three different times. *Note: The sketch with the small circle shown with dashed lines illustrates the time when the smaller star was located behind the larger star.*



In which case shown would the amount of light we would observe from Earth be the greatest?

A. at time A
B. at time B
C. at time C
D. At more than one of the times.
E. There is not enough information to determine this.

Black holes are formed by

A. a lack of any light in a region of space.
B. supernovae from the most massive stars.
C. supernovae from binary stars.
D. collapsed dark nebulae.

How does the Sun produce the energy that heats our planet?

A. The gases inside the Sun are on fire; they are burning like a giant bonfire.
B. Hydrogen atoms are combined into helium atoms inside the Sun’s core. Small amounts of mass are converted into huge amounts of energy in this process.
C. When you compress the gas in the Sun, it heats up. This heat radiates outward through the star.
D. Magnetic energy gets trapped in sunspots and active regions. When this energy is released, it explodes off the Sun as flares that give off tremendous amounts of energy.
E. The core of the Sun has radioactive materials that give off energy as they decay into other elements.

Main sequence stars begin life as

A. a very large planet.
B. a cloud of gas and dust.
C. a very hot planet.
D. an explosion at the center of a newly forming solar system.