

Earth 2.0 : NASA's Search for Earth-size Planets



Image credit: NASA

Outline

The Kepler mission

Target

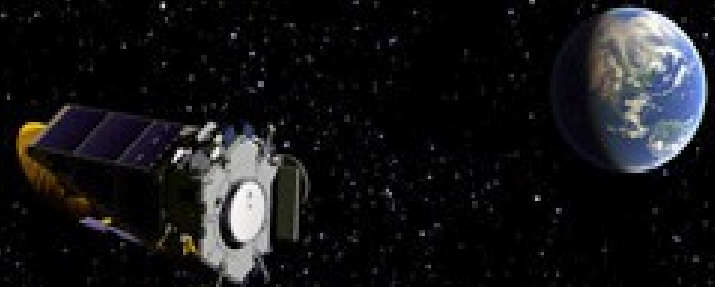
Technique

Results

Kepler



A Search for Habitable Planets



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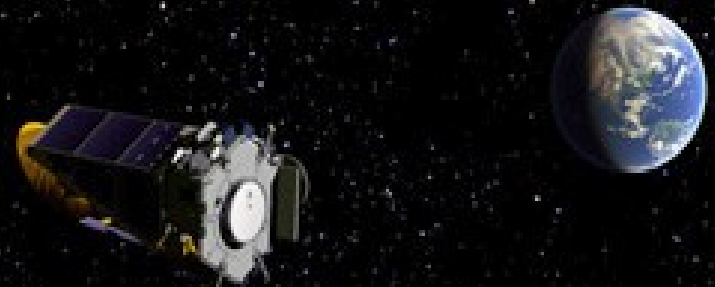


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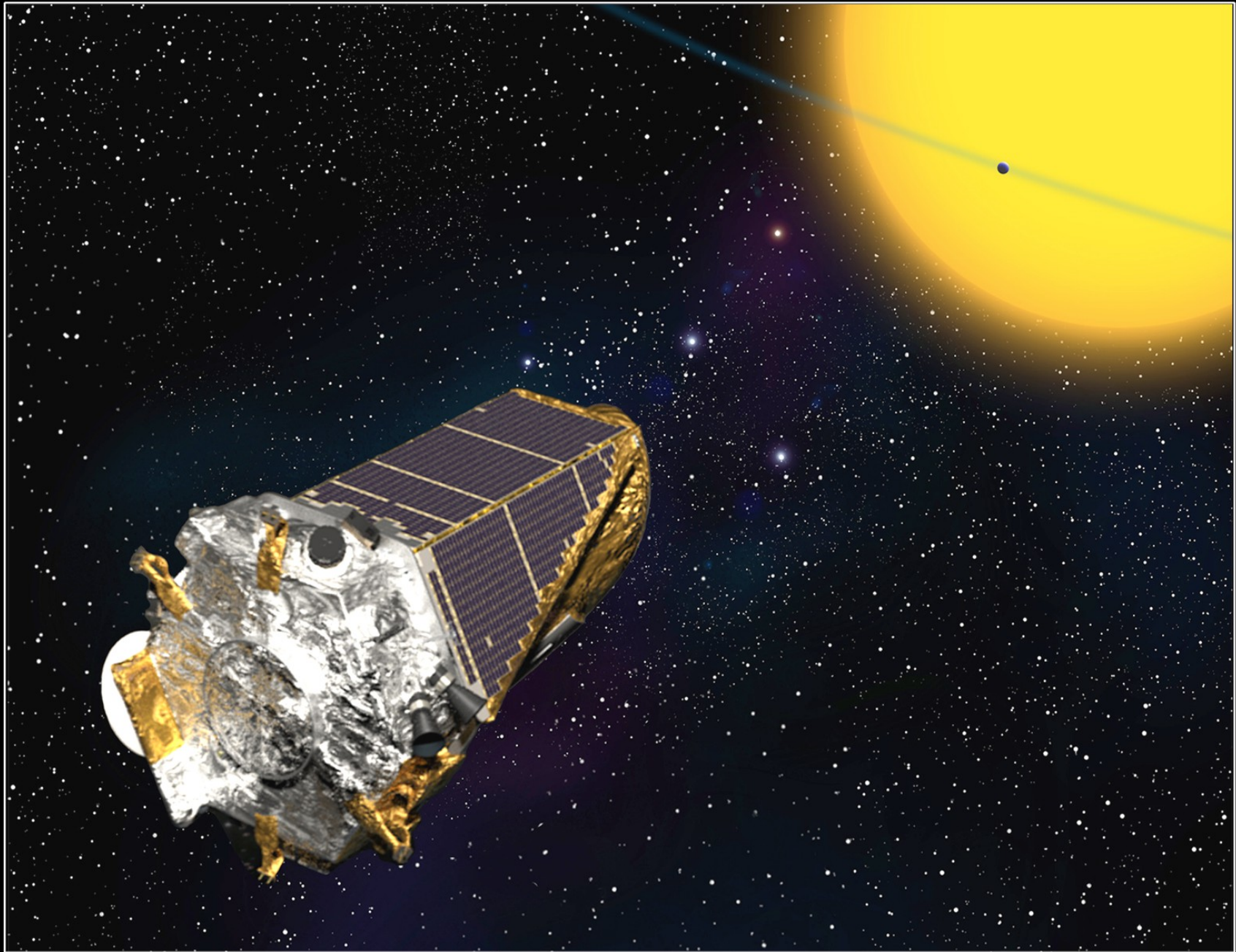
Kepler



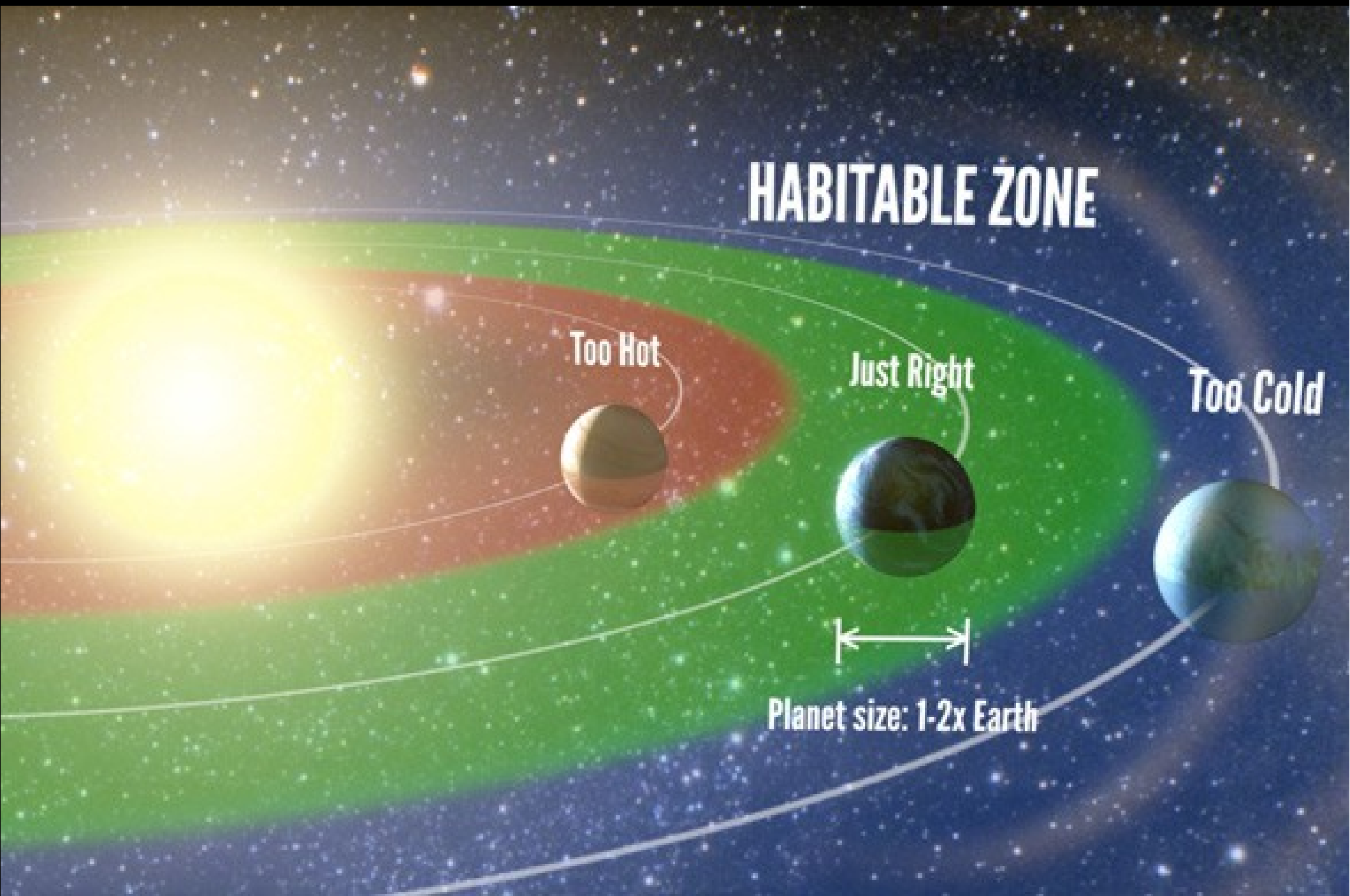
A Search for Habitable Planets



What fraction of stars in our galaxy harbor potentially habitable, Earth-size planets?

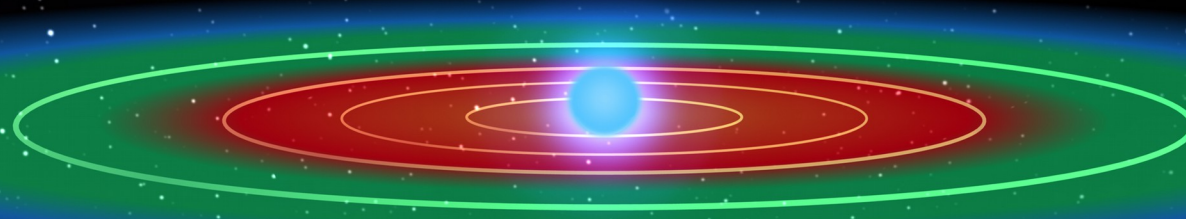


The “habitable zone”

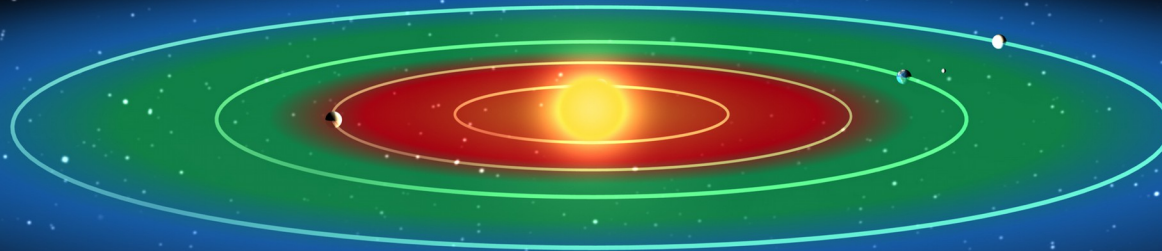


The “habitable zone”

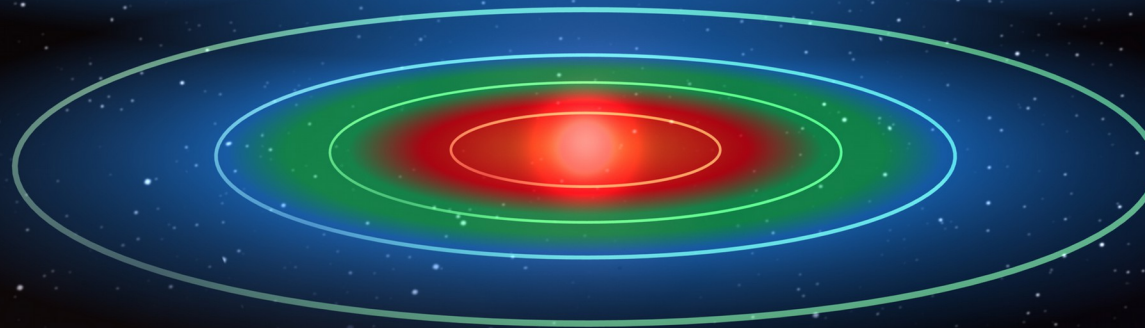
Hotter Stars



Sunlike Stars



Cooler Stars



Estimating the # of advanced civilizations in the Milky Way

Which factors do you think are important?





The Drake Equation

$$N = R^* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$



Where:

- N = # civilizations in Galaxy w/detectable electromagnetic emissions
- R^* = Rate of star formation suitable for the development of intelligent life
- f_p = Fraction of those stars with planetary systems
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- L = Length of time such civilizations release detectable signals into space

Kepler launch 06 March 2009

Cape Canaveral
Delta II rocket
0.95 m mirror



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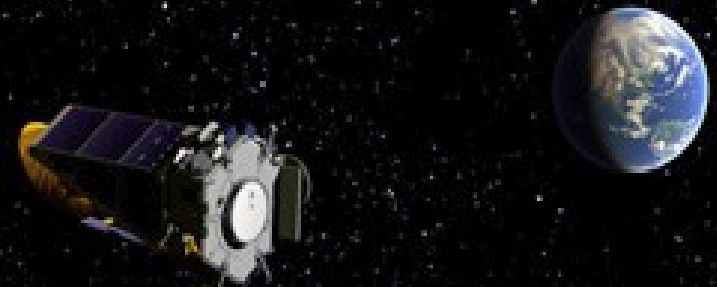
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Kepler



A Search for Habitable Planets



Where does Kepler search?





The primary Kepler mission



Outline

The Kepler mission

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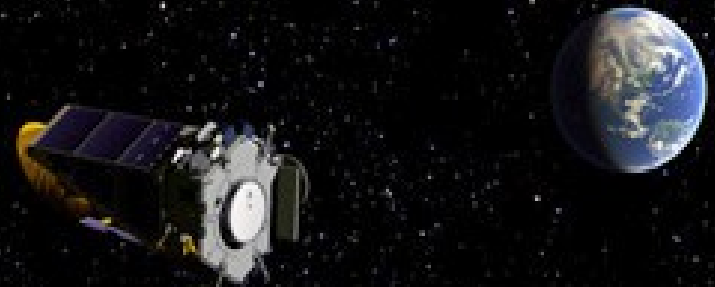
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A Search for Habitable Planets



Exoplanet Detection Methods

Radial velocity

Pulsar timing

Direct imaging

Gravitational microlensing

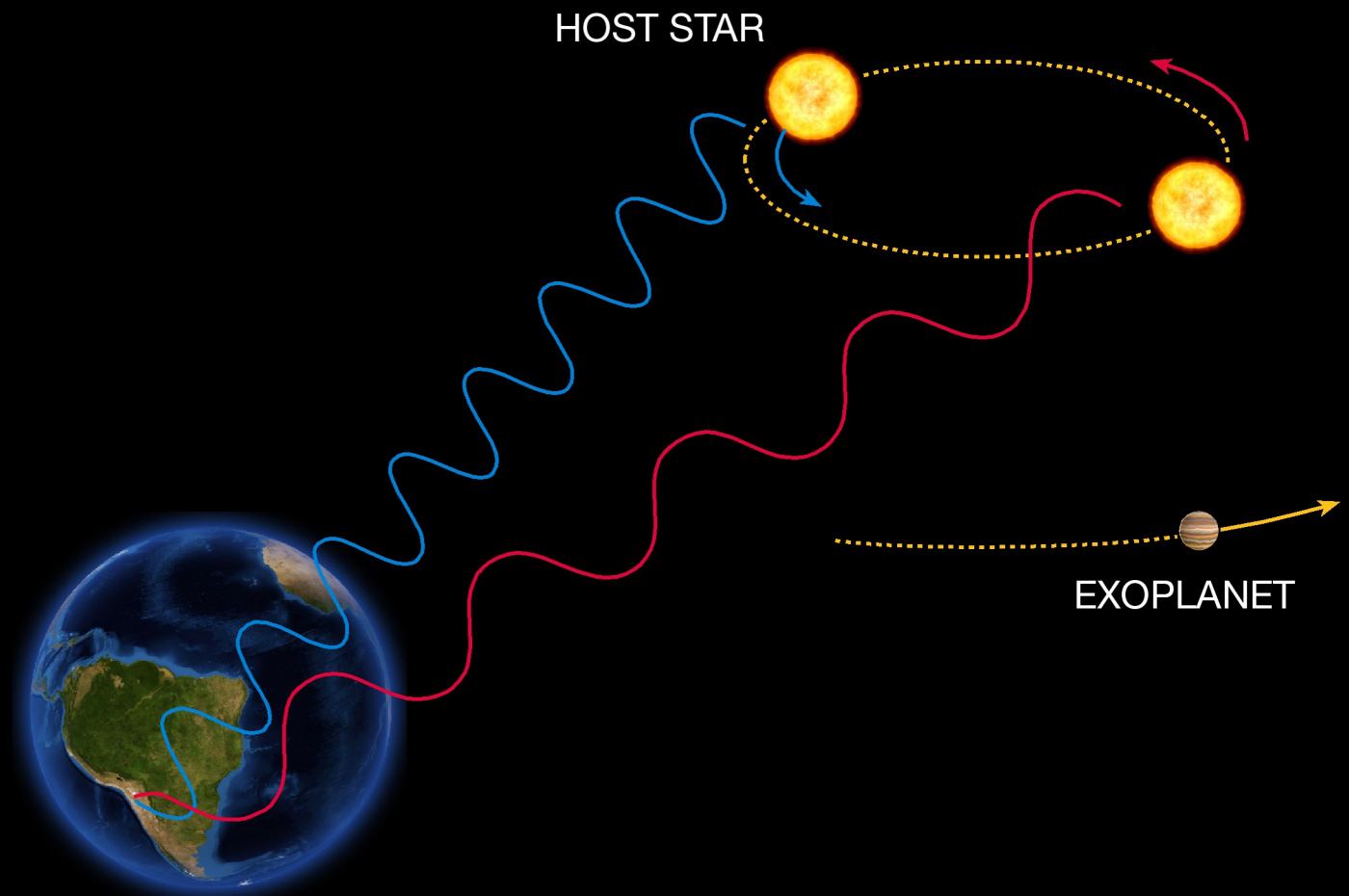
Transit

Polarimetry

Astrometry

Exoplanet Detection Methods

Radial velocity

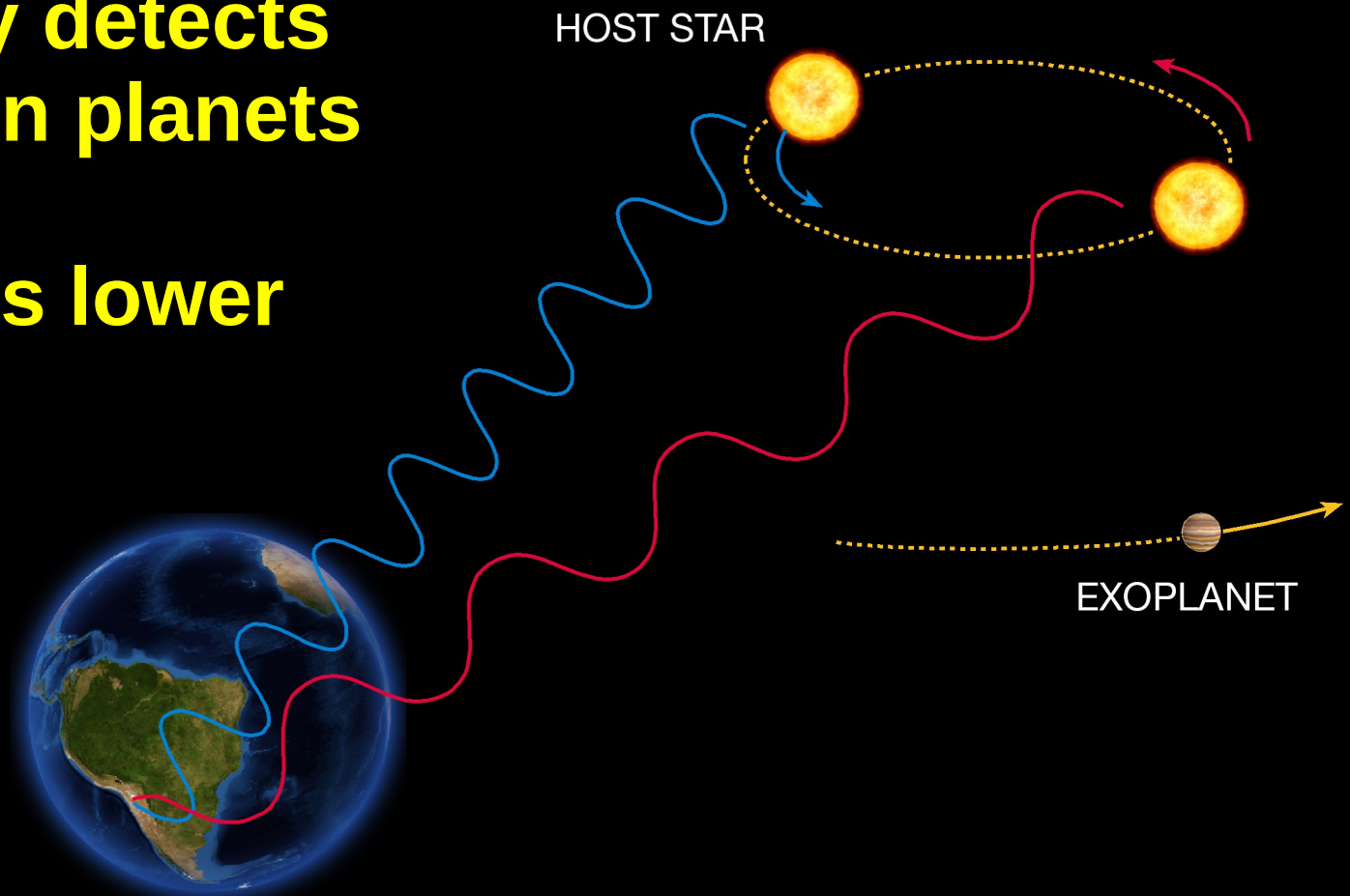


Exoplanet Detection Methods

Radial velocity

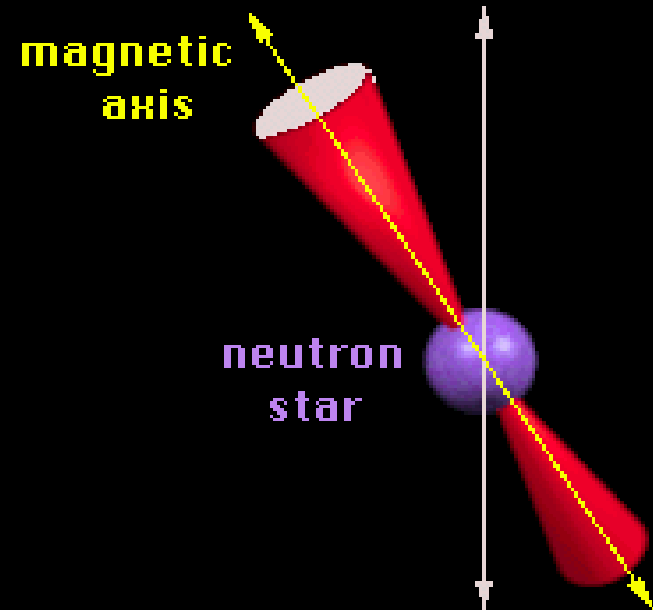
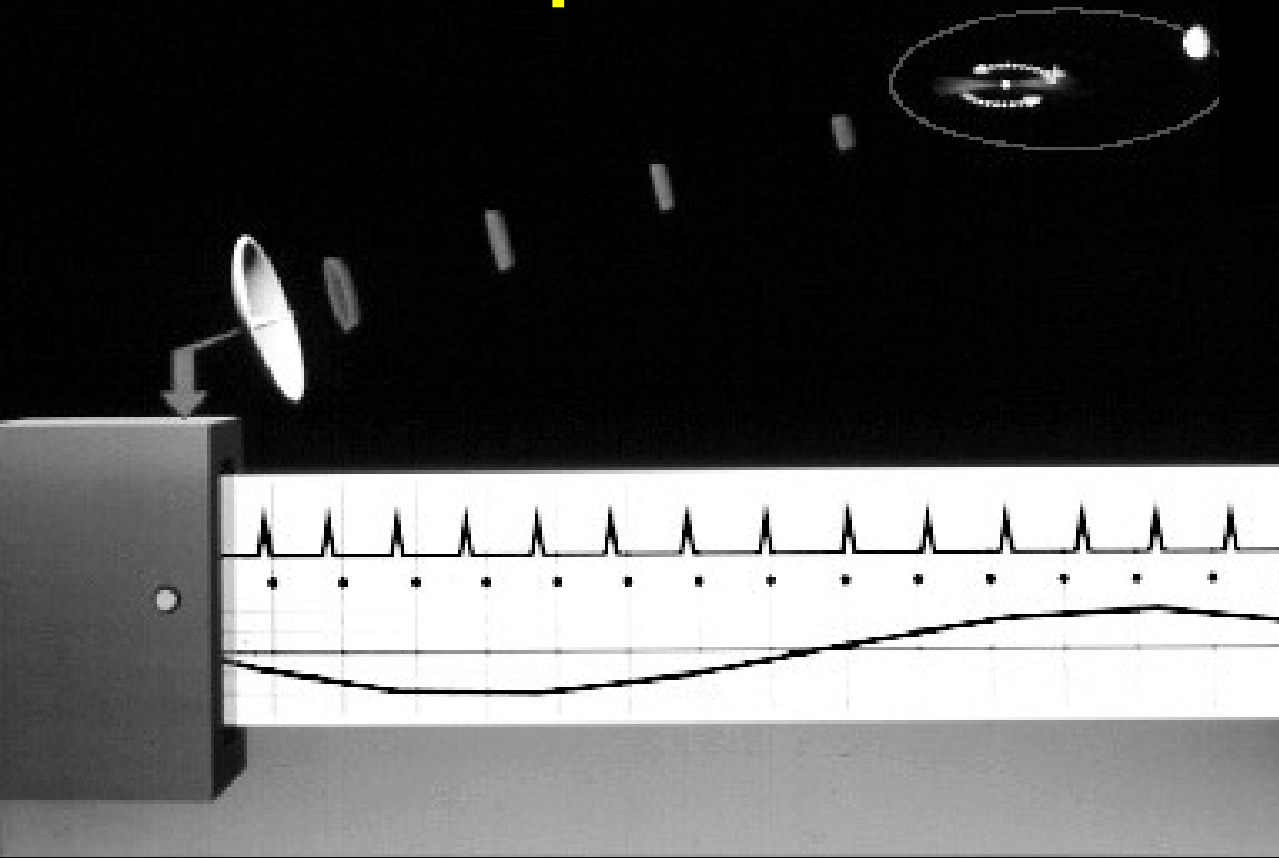
Preferentially detects large, close-in planets

Only provides lower limit to mass



Exoplanet Detection Methods

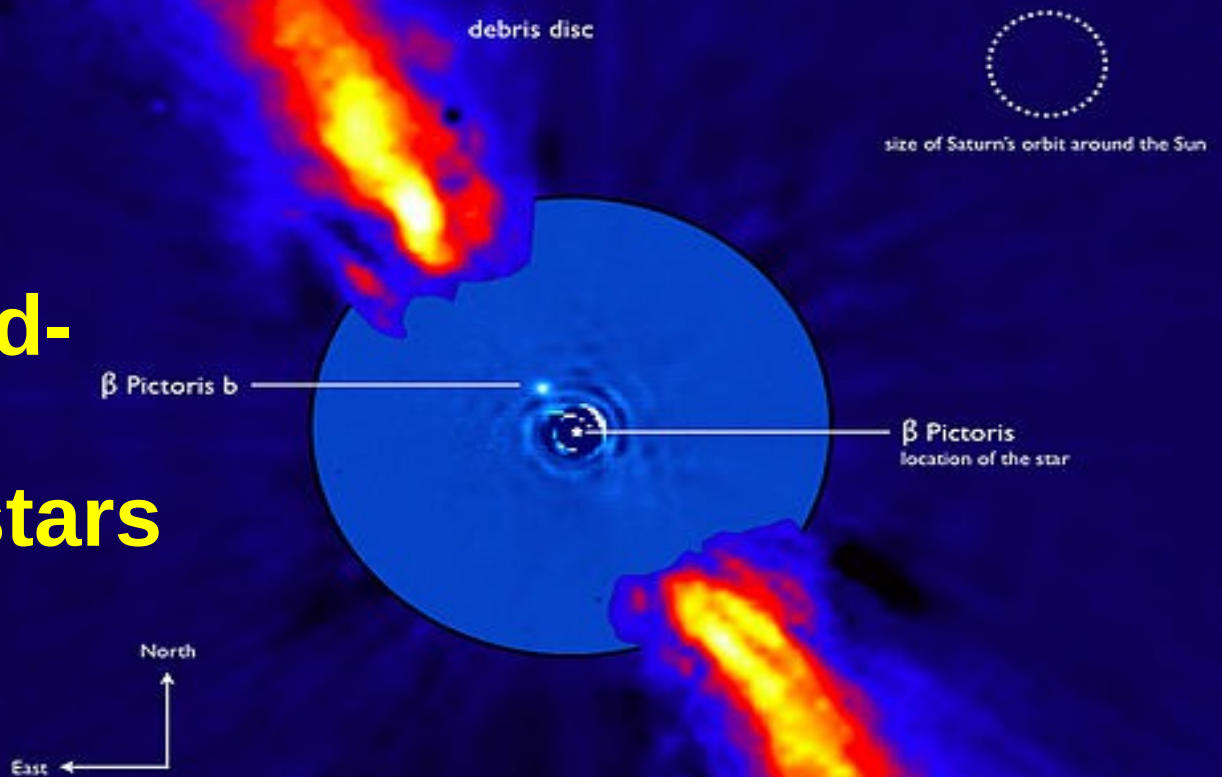
Pulsar timing
quite rare & inhospitable
1991 blooper



Exoplanet Detection Methods

Direct imaging

Prefers infrared-bright planets far from faint stars



How does Kepler search? Transit photometry

150,000 stars observed

Planets may occult their parent star



The first recorded transit of Venus

❖ CRABTREE WATCHING THE TRANSIT OF VENUS · A · D · 1639 ❖

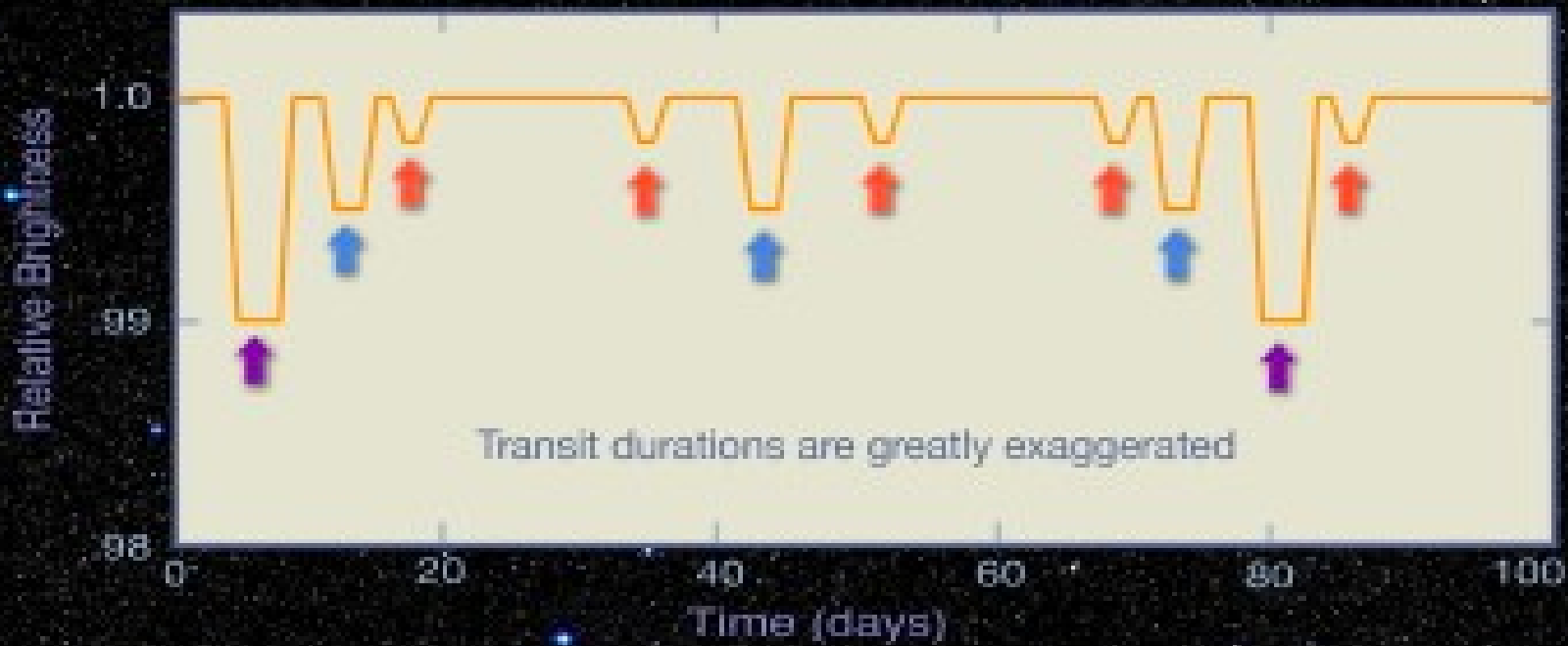




Transit Signature of a Multiple-Planet System



- Planets can be distinguished by:
- Different periods
 - Different depths
 - Different durations





How does Kepler search?

Transit photometry

**Kepler provides planetary “candidates”
Ideally confirmed by another technique**

10% false positives:

Tightly bound or dim binary star companion

Stellar pulsations

Periodic instrumental glitches

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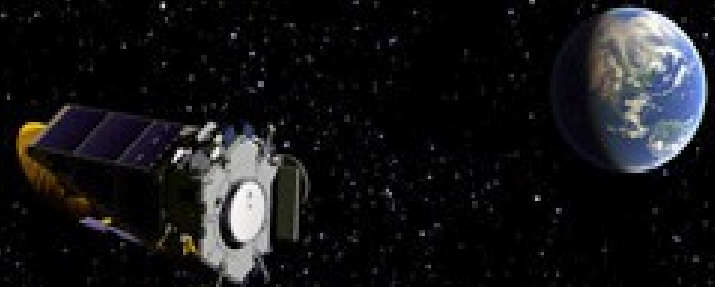
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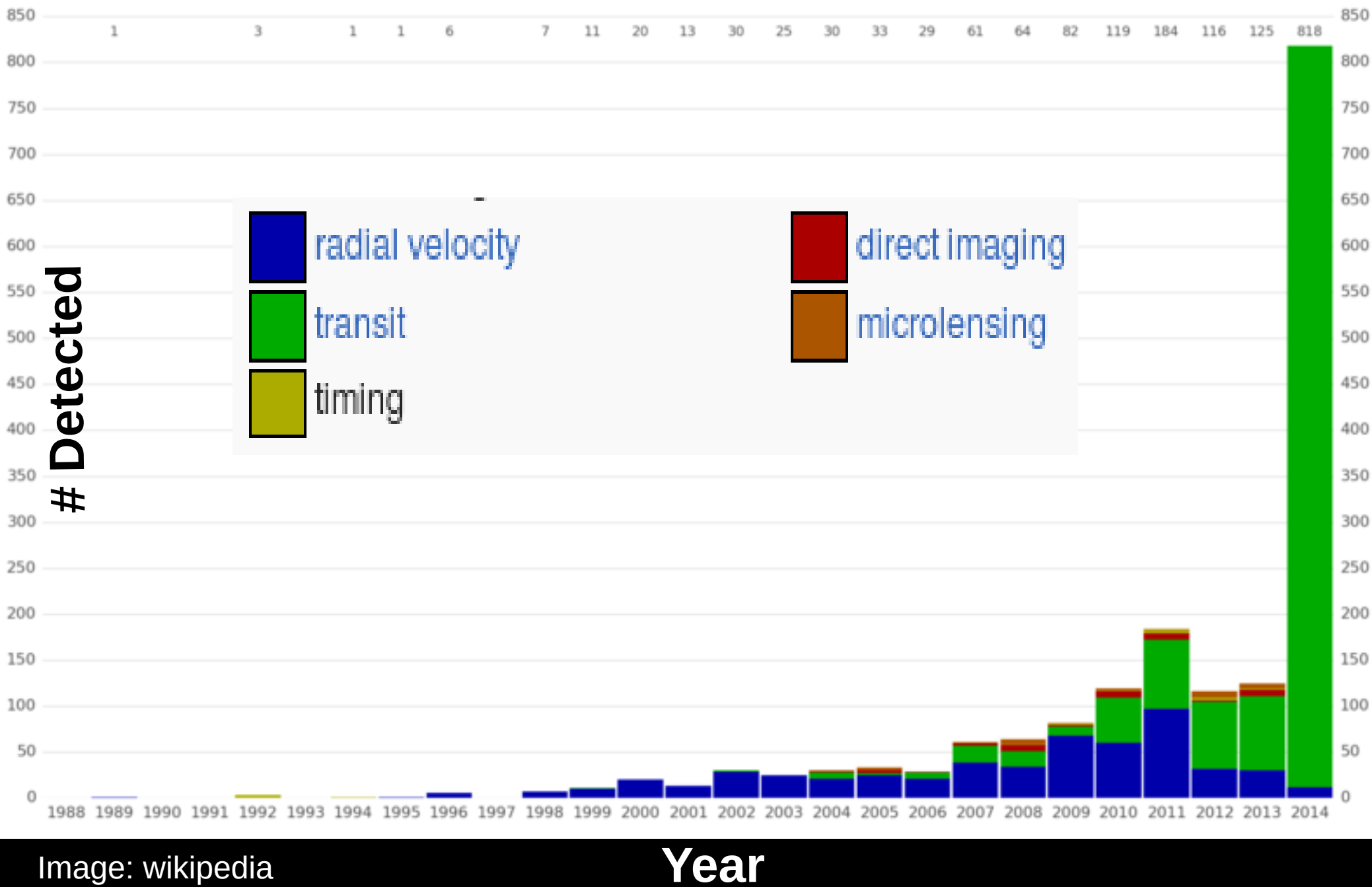
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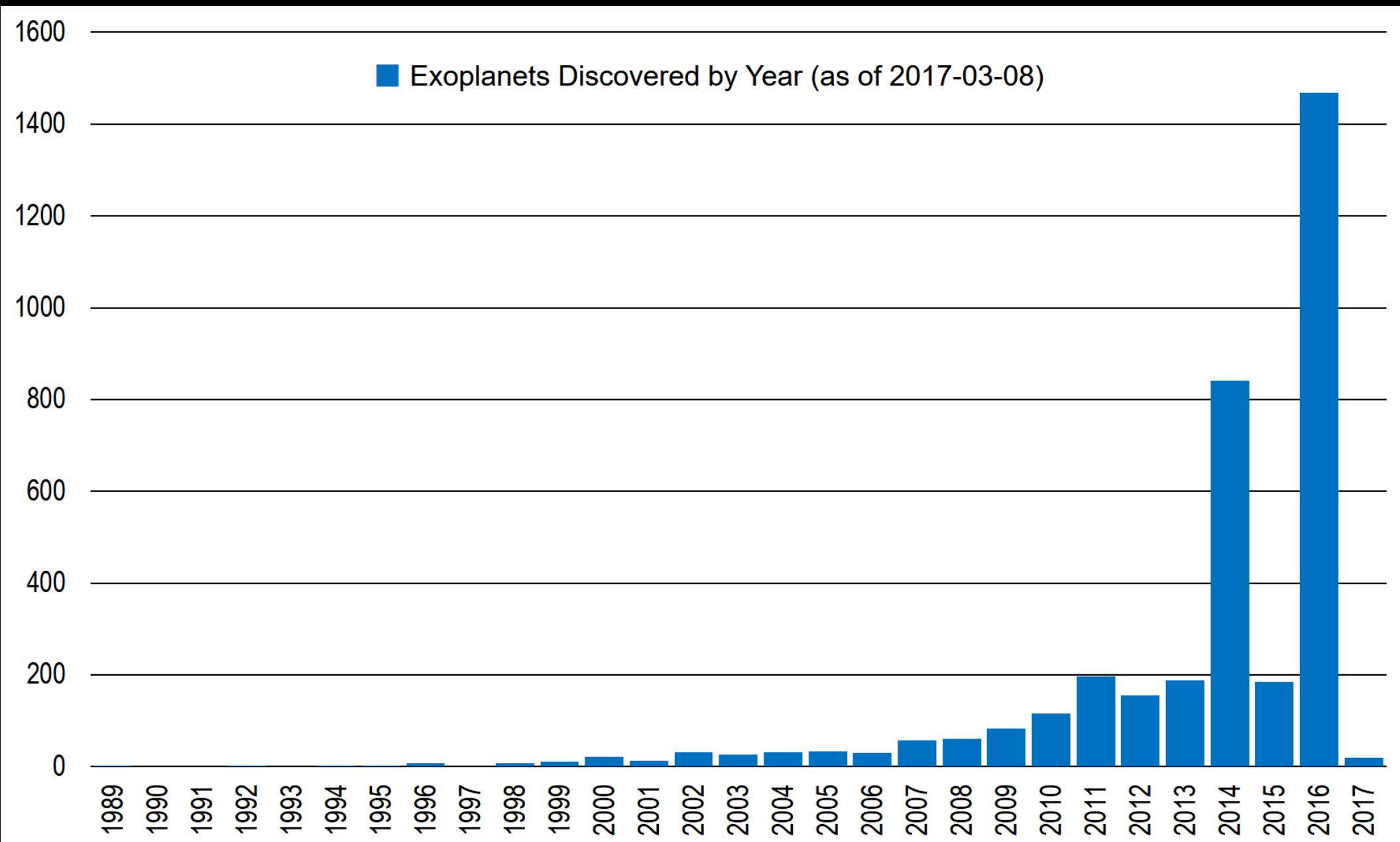


A Search for Habitable Planets



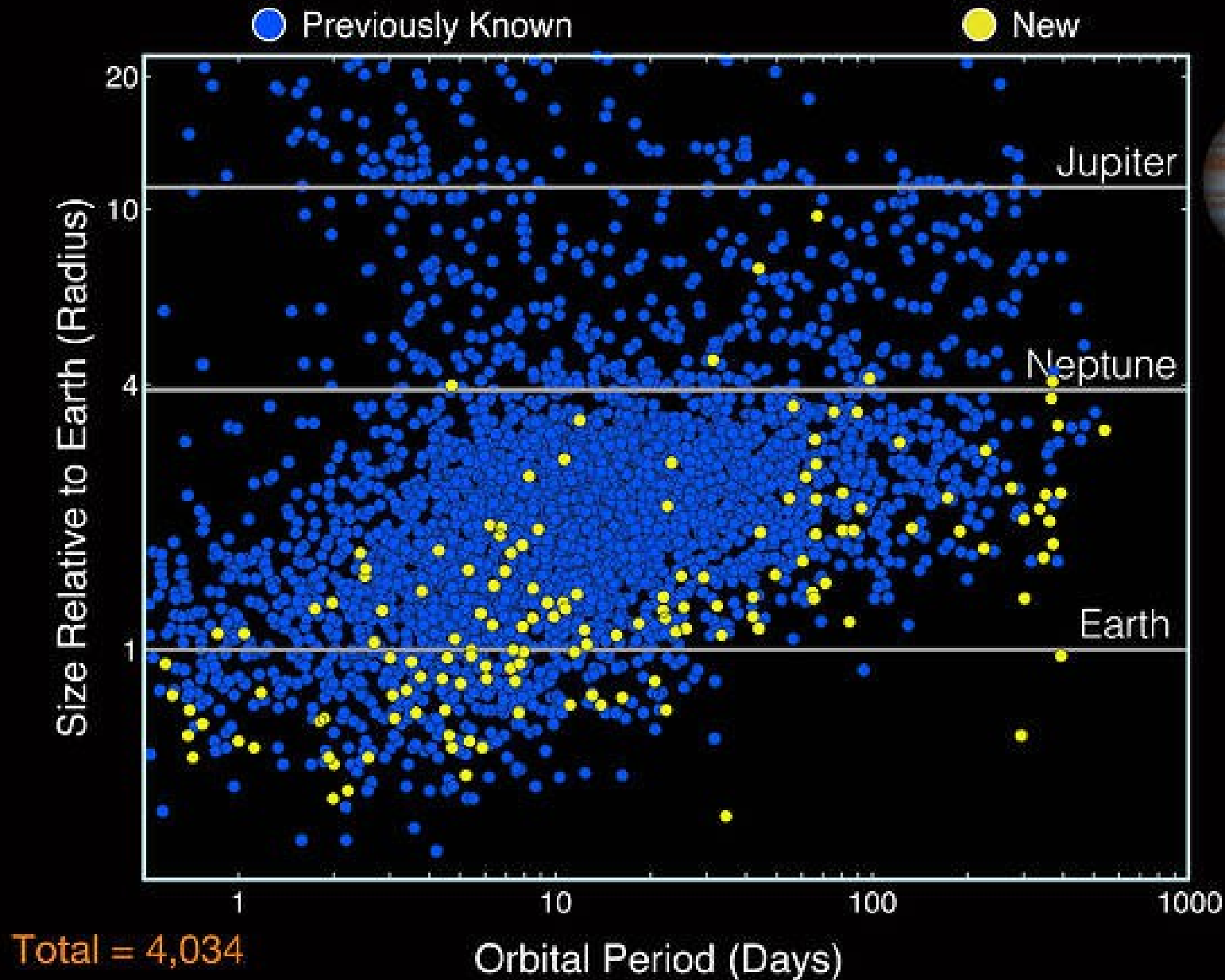
Exoplanet Detection Methods





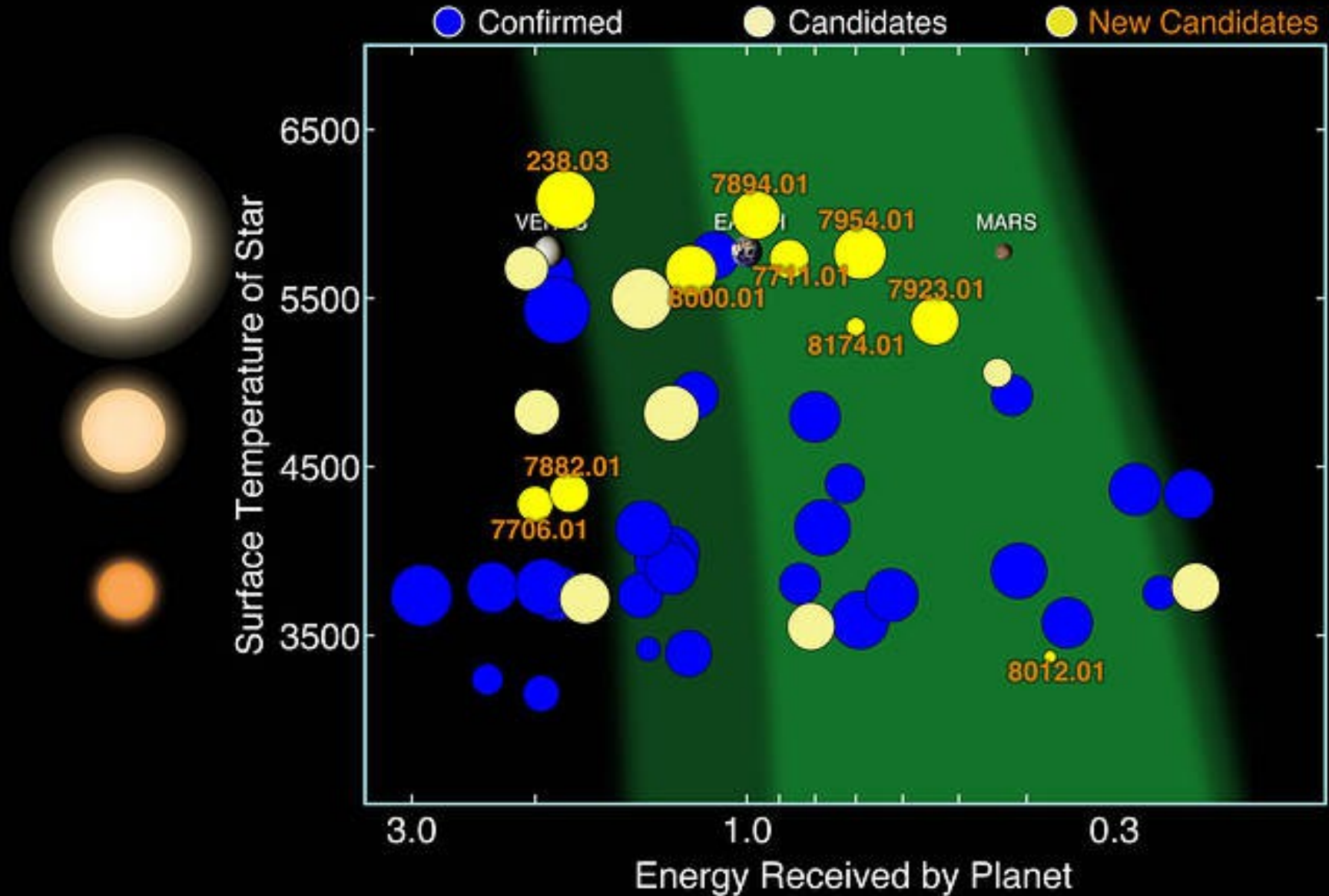
New Kepler Planet Candidates

As of June 2017

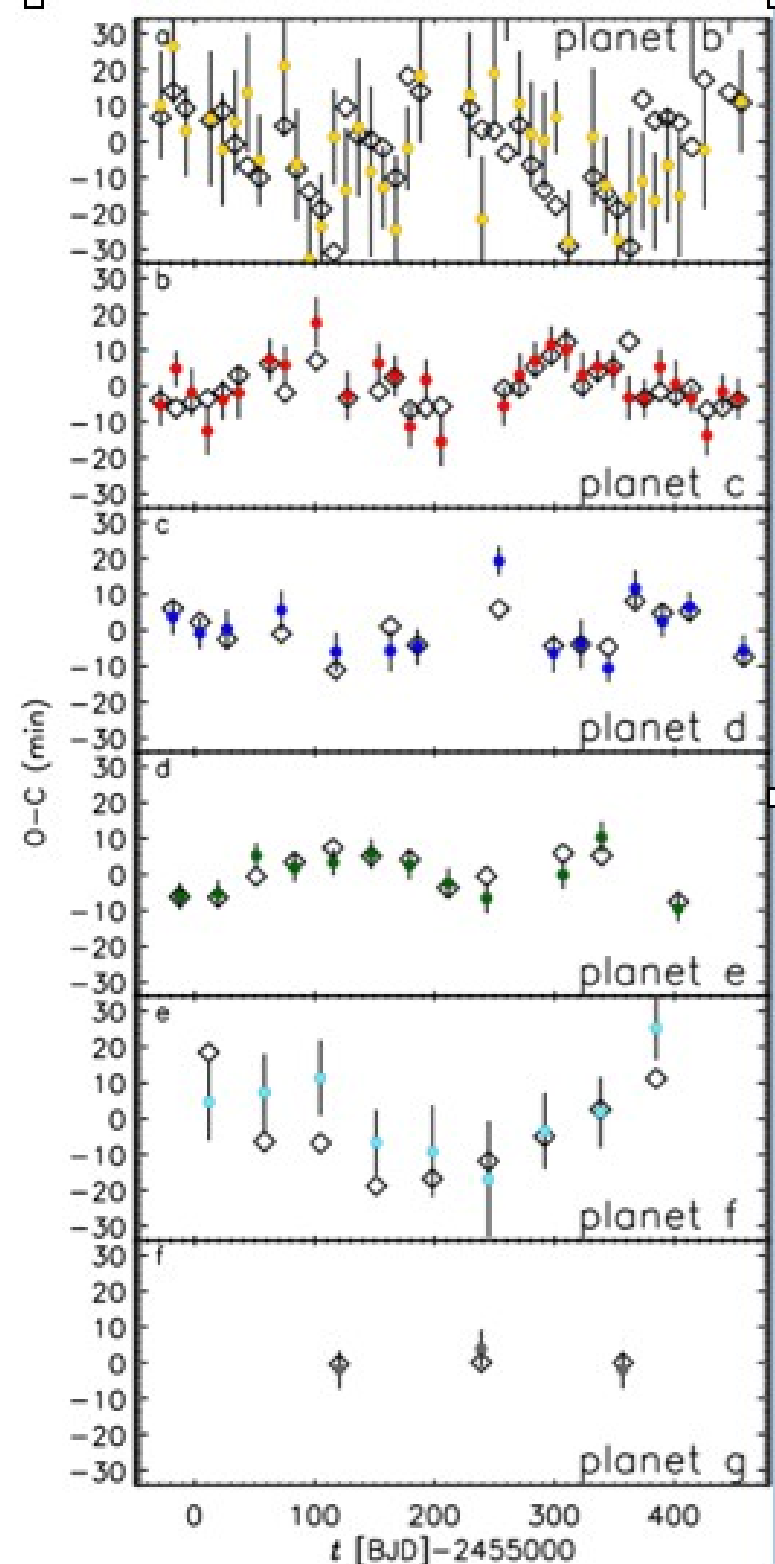
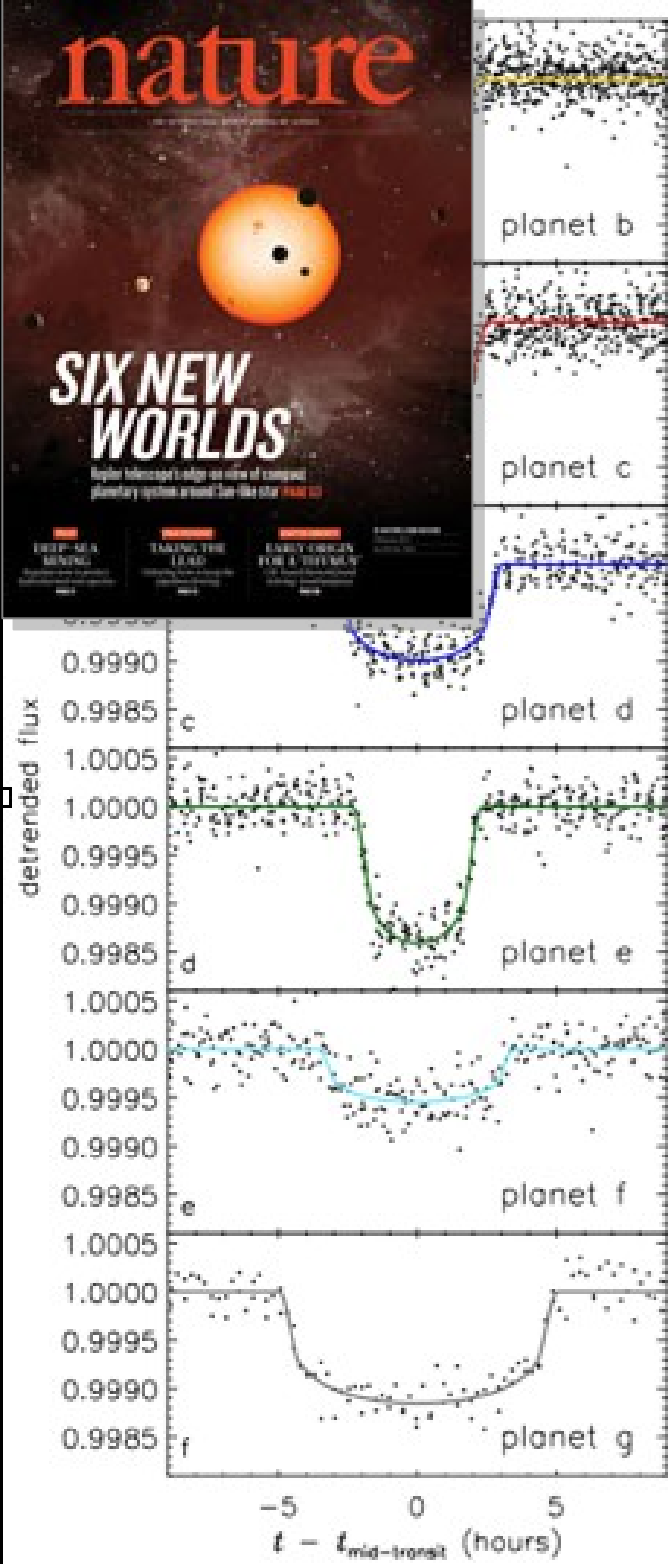


Kepler Habitable Zone Planets

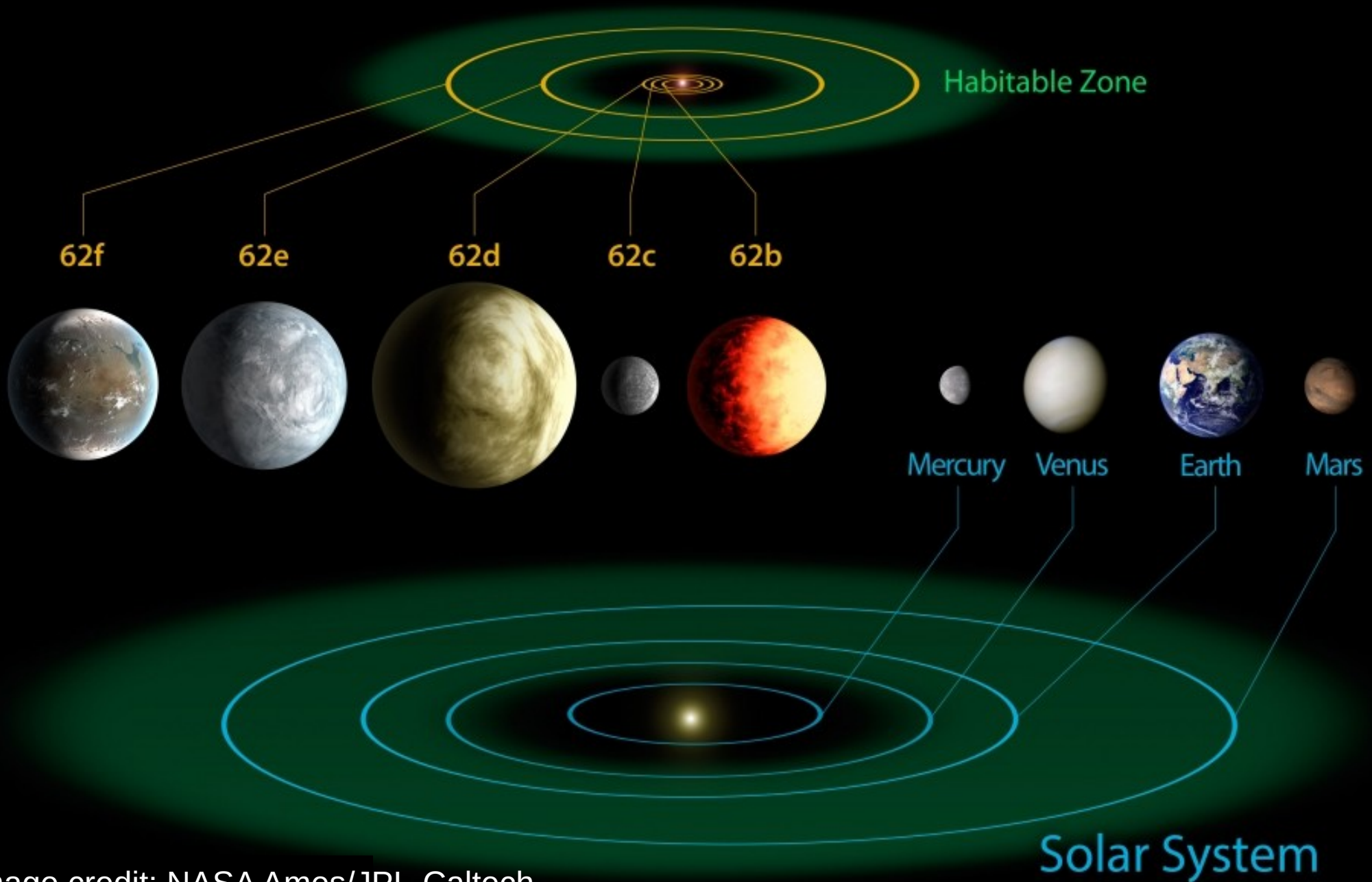
As of June 2017



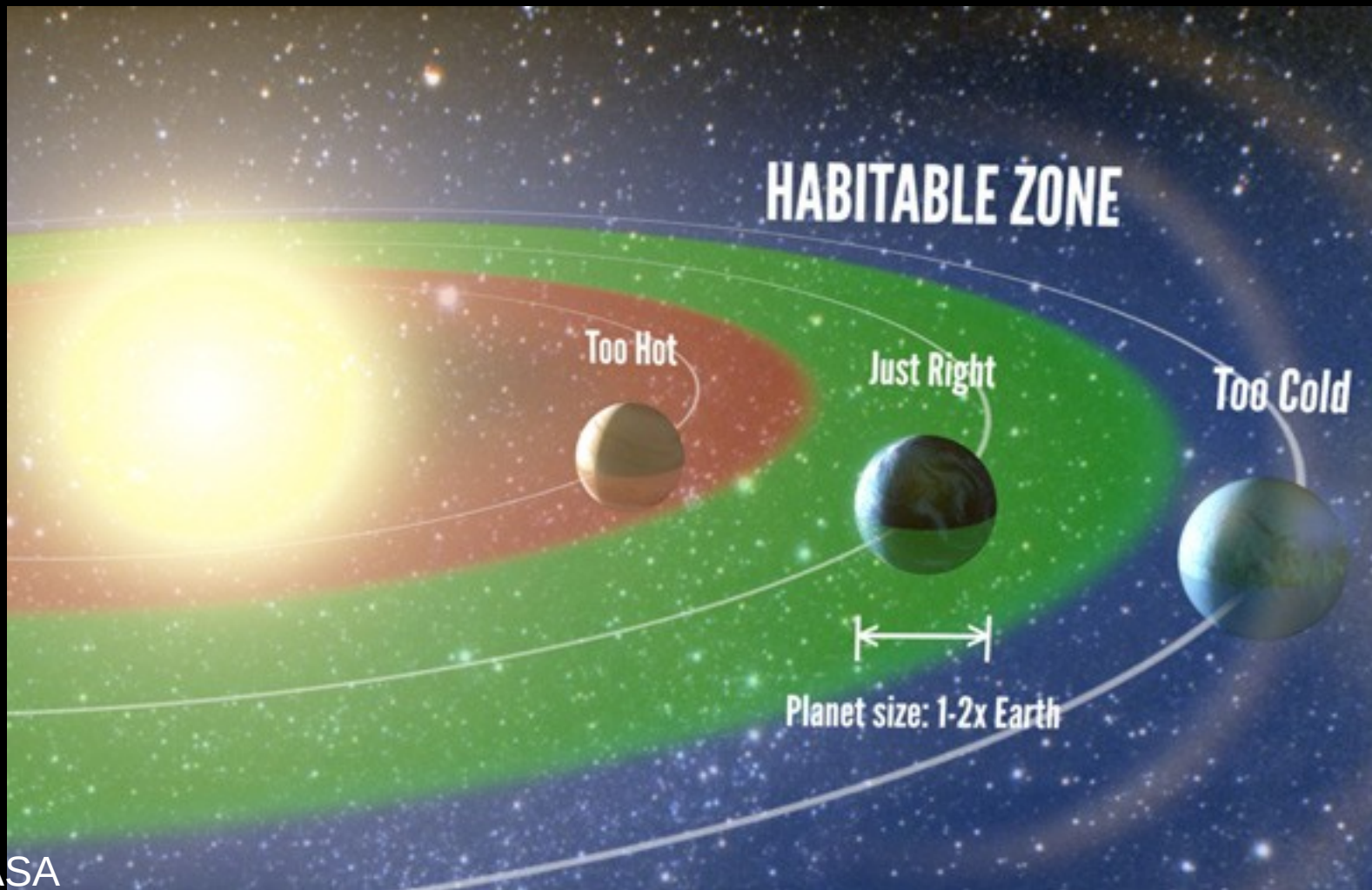
Kepler 62 system



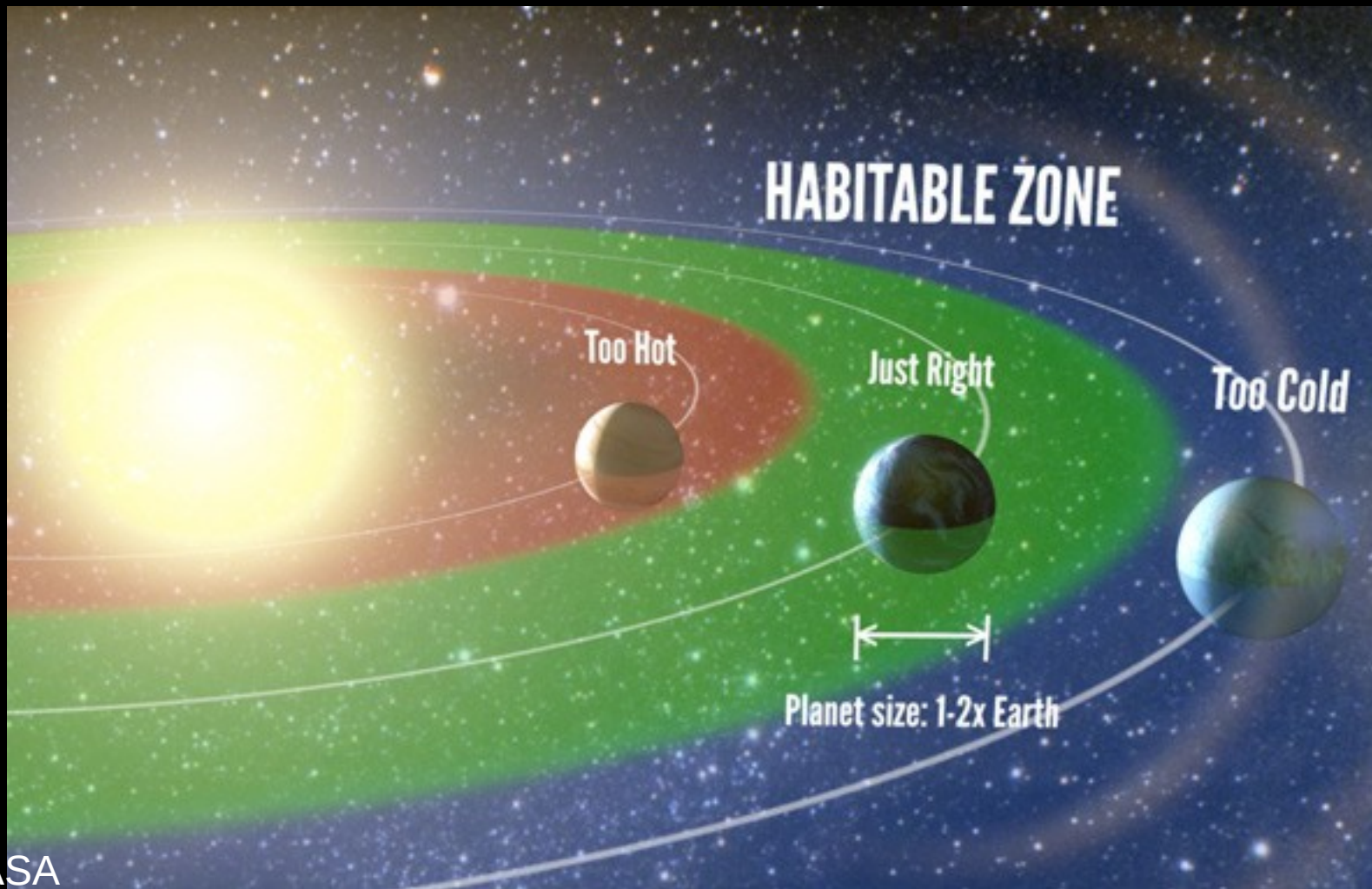
Kepler-62 System



22% of Sun-like stars harbor Earth-size planets orbiting in their habitable zones (Petigura et al. 2013)



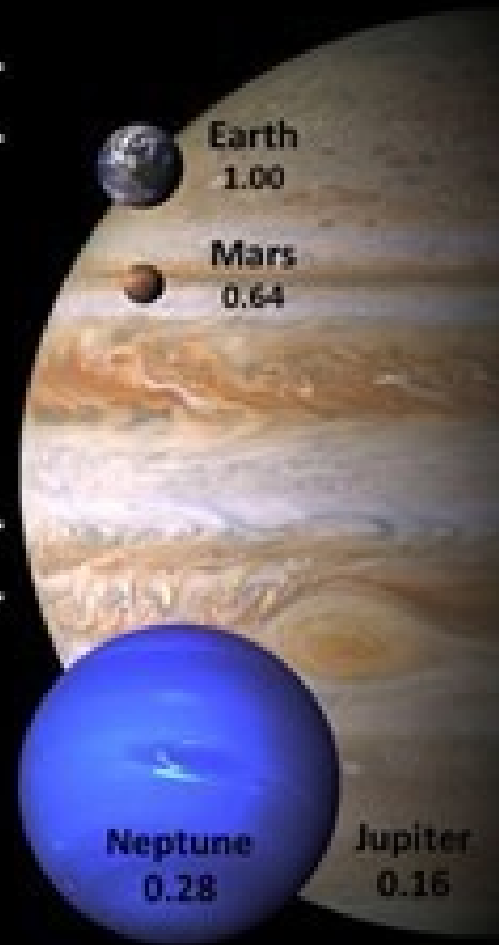
Extrapolate the result to the entire Milky Way: 40 billion habitable Earth-size planets (Petigura et al. 2013)



Current Potentially Habitable Exoplanets

Ranked in Order of Similarity to Earth

#1	#2	#3	#4	#5	#6
				 NEW	
Kepler-62 e 0.83	Gliese 667C c 0.82	Gliese 581 g* 0.82	Tau Ceti e* 0.77	Gliese 667C f 0.76	Kepler-22 b 0.75
#7	#8	#9	#10	#11	#12
				 NEW	
Gliese 163 c 0.74	HD 40307 g* 0.72	Kepler-61 b 0.72	Kepler-62 f 0.67	Gliese 667C e 0.60	Gliese 581 d 0.53



*planet candidates

Number below the names is the Earth Similarity Index (ESI)

CREDIT: PHL @ UPR Arecibo (phl.upr.edu) June 26, 2013



The Drake Equation



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The Drake Equation



$$N \sim 10 \cdot 1 \cdot 0.2 \cdot ? \cdot ? \cdot ? \cdot ?$$

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The Drake Equation

Progressing from left to right, the equation is increasingly uncertain.

The equation is conceptual, something to start a conversation on how to approach a search for life.

Fermi Paradox: *Where are they?*

Exoplanets By the Numbers

As of April 2018: 4496 candidates; 3717 confirmed; 927 terrestrial

Galaxy Total: ~40 billion

22% of Sun-like stars harbor Earth-size, habitable planets

Nearest: Proxima b at 4 lyr

Mass range: a few lunar masses to 30 Jupiter masses

Orbital periods: a few hours to thousands of years

Kepler



A Search for Habitable Planets

