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Search for Life

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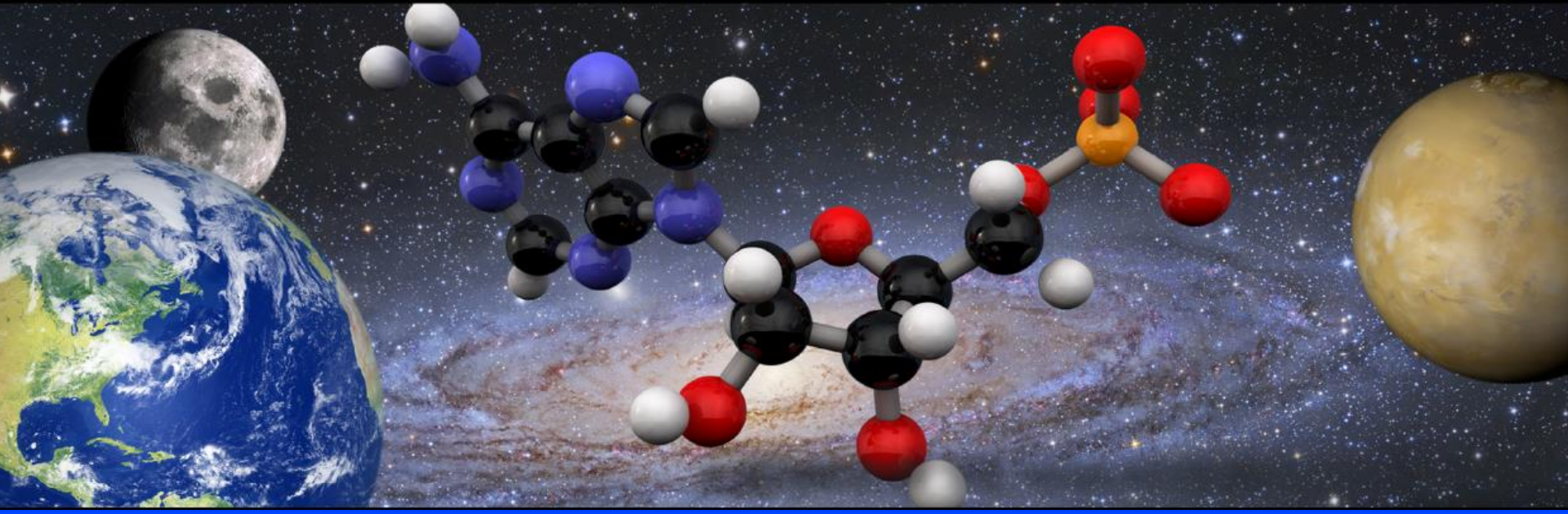

NASA's Search for Life beyond the Earth

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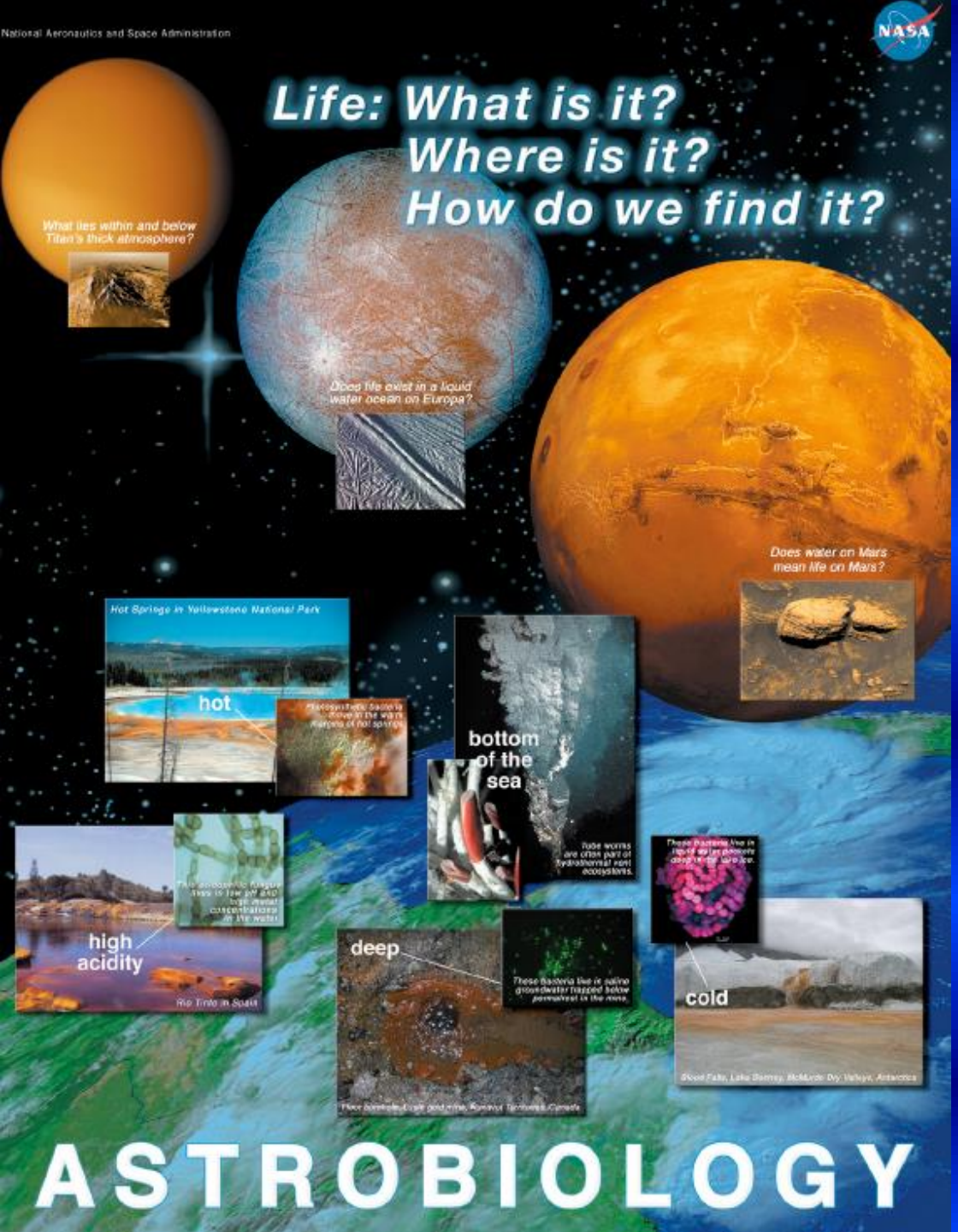
NASA's Space Launch System (SLS)

http://www.youtube.com/watch?v=mLQL2TfPHQA



What is Astrobiology?

It is a multidisciplinary science with the goal of understanding the origin, evolution, and distribution of life in the Universe.

Chemistry, microbiology, biochemistry, geochemistry, planetary science, astrophysics, geophysics, paleontology

* * QUESTIONS * *

- What is life?
- Are planets common in the Universe?
- *Is our solar system typical?*
- In what ways is planet Earth unusual?
- *Is most life likely to be carbon-based?*
- Is complex life common in the Universe?
- *Does life elsewhere follow similar evolutionary trends and evolutionary rates?*
- Is intelligence inevitable during evolution?
- *What was the Earth like when life formed?*

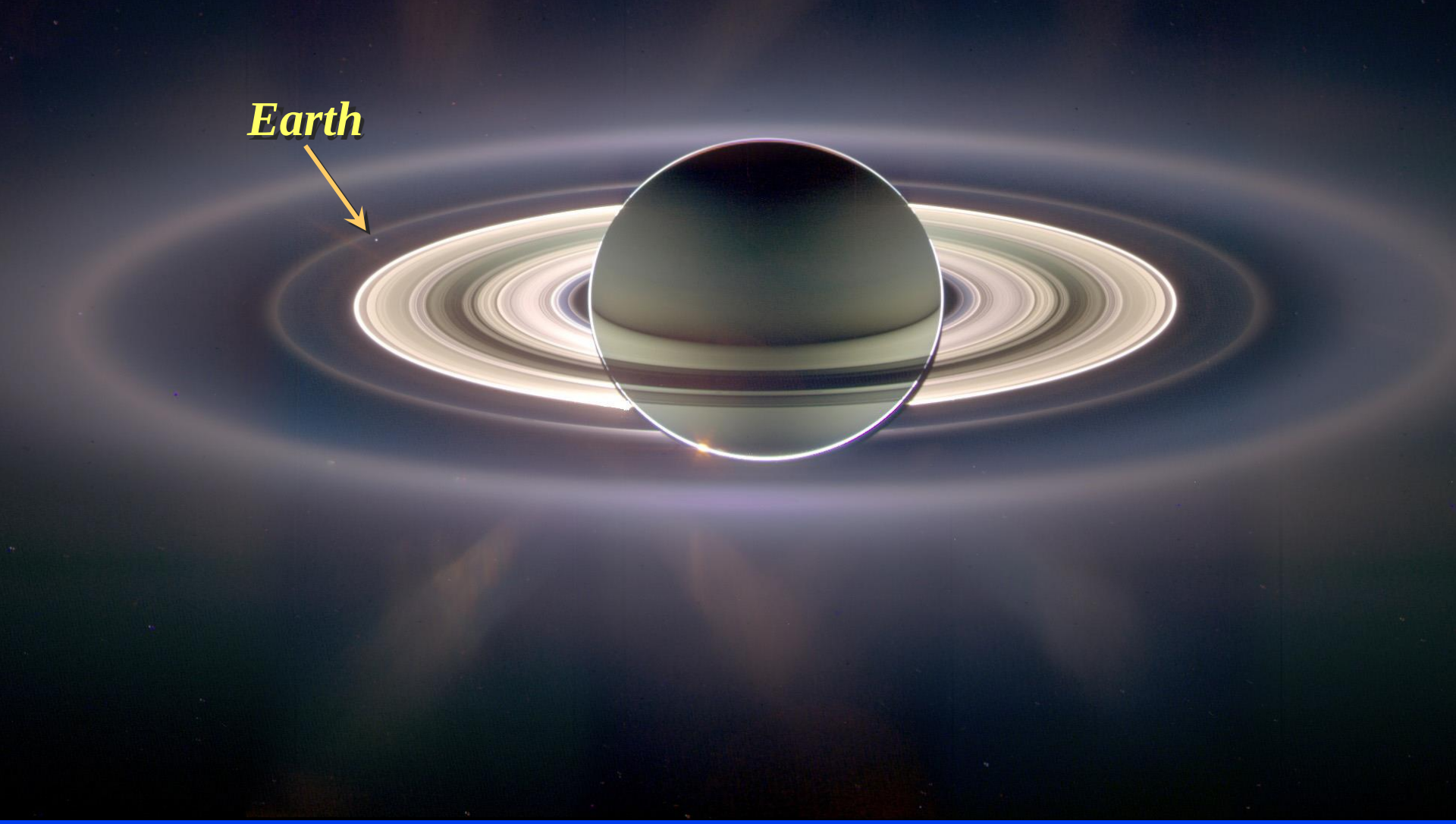


How diverse is life on Earth?

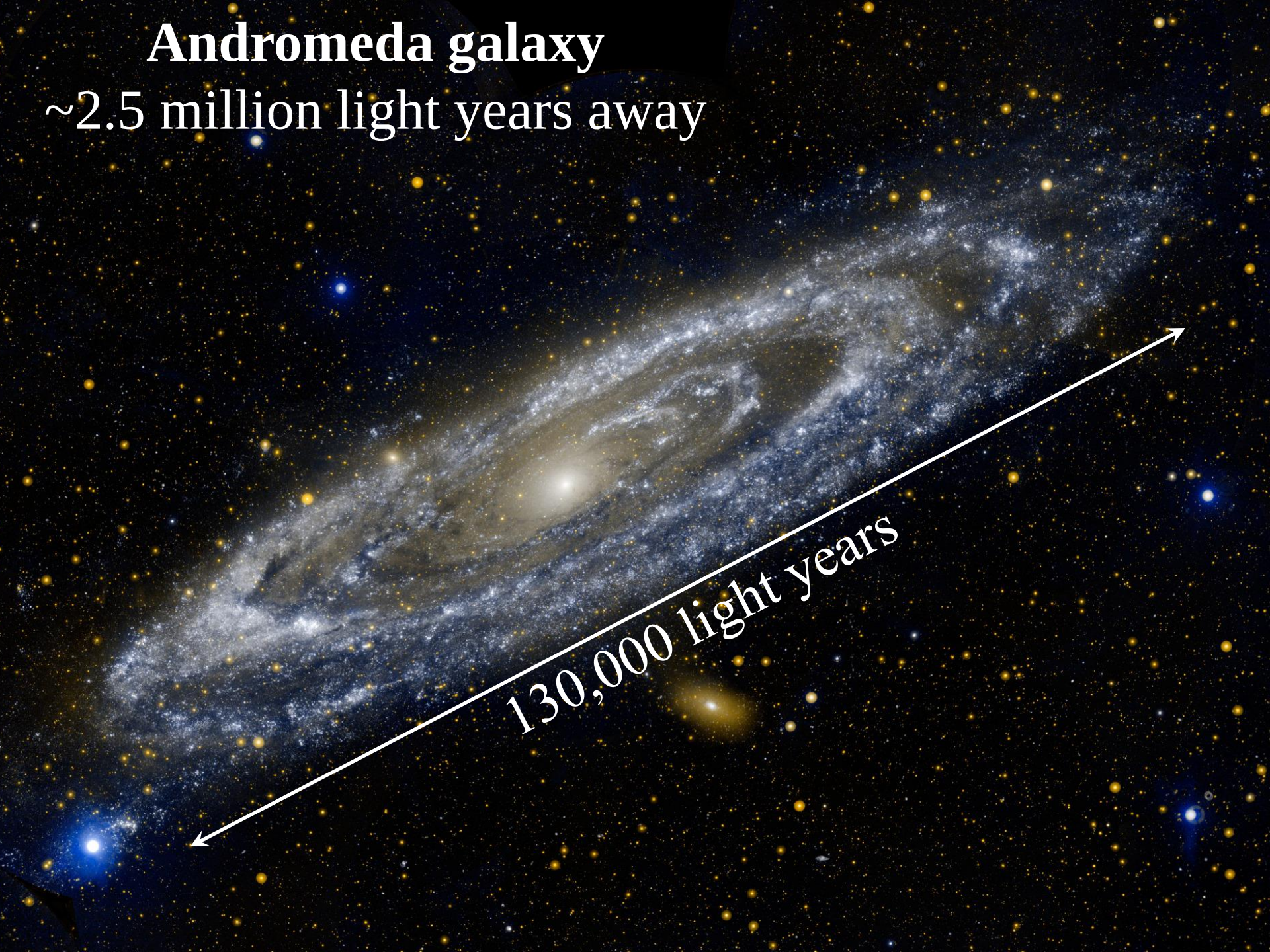
- **Green plants:** $>10^5$ ***species***
- **Animals:** $>10^6$ ***species***
- **Bacteria:** $>6 \times 10^3$ ***species***
- **Fungus:** $>10^6$ ***species***
- **Viruses:** $>3.6 \times 10^3$




Is there anyone else out there?

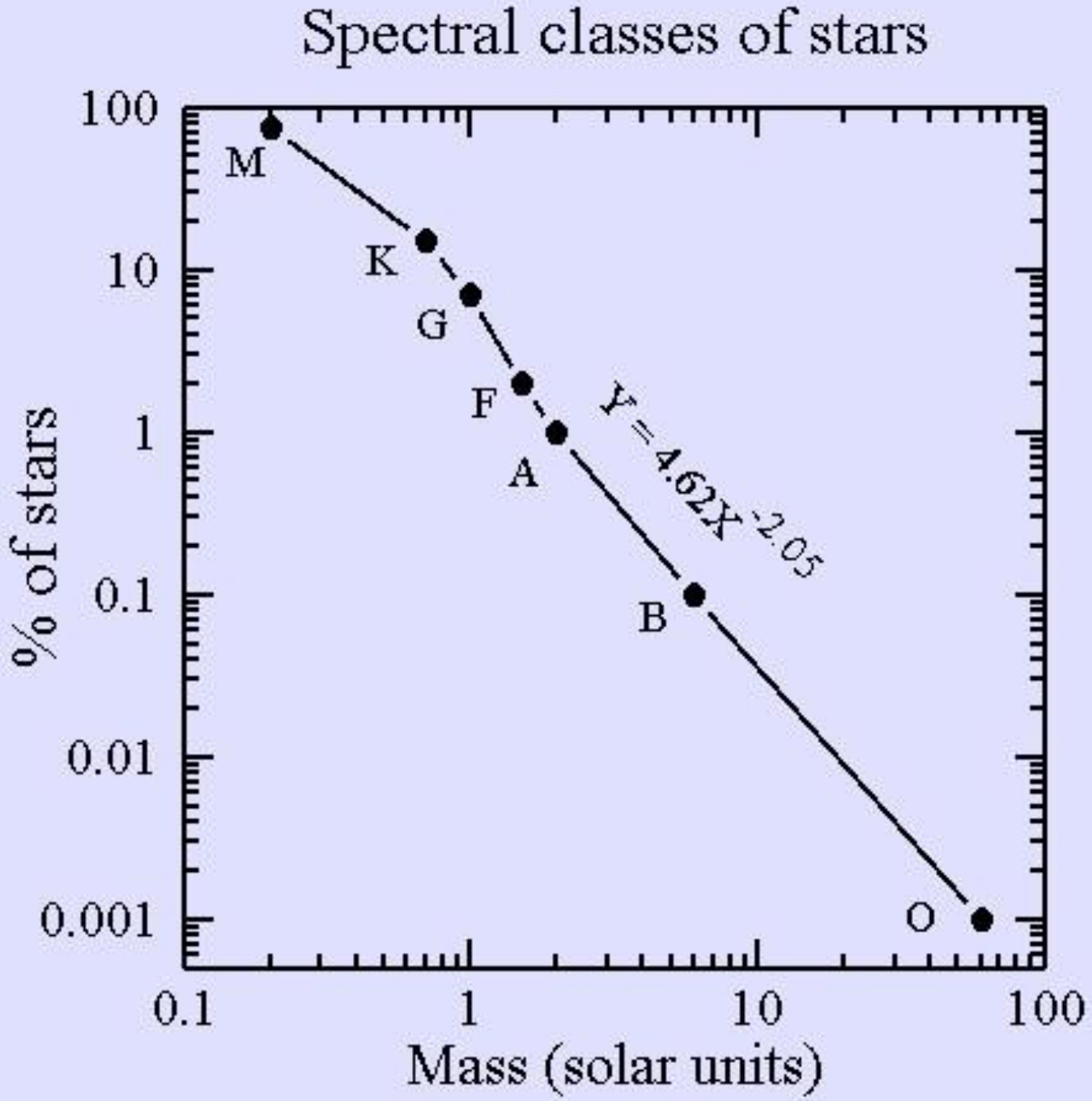


The pale blue dot of Earth as seen from NASA's *Cassini* orbiter at Saturn


Andromeda galaxy
~2.5 million light years away
130,000 light years

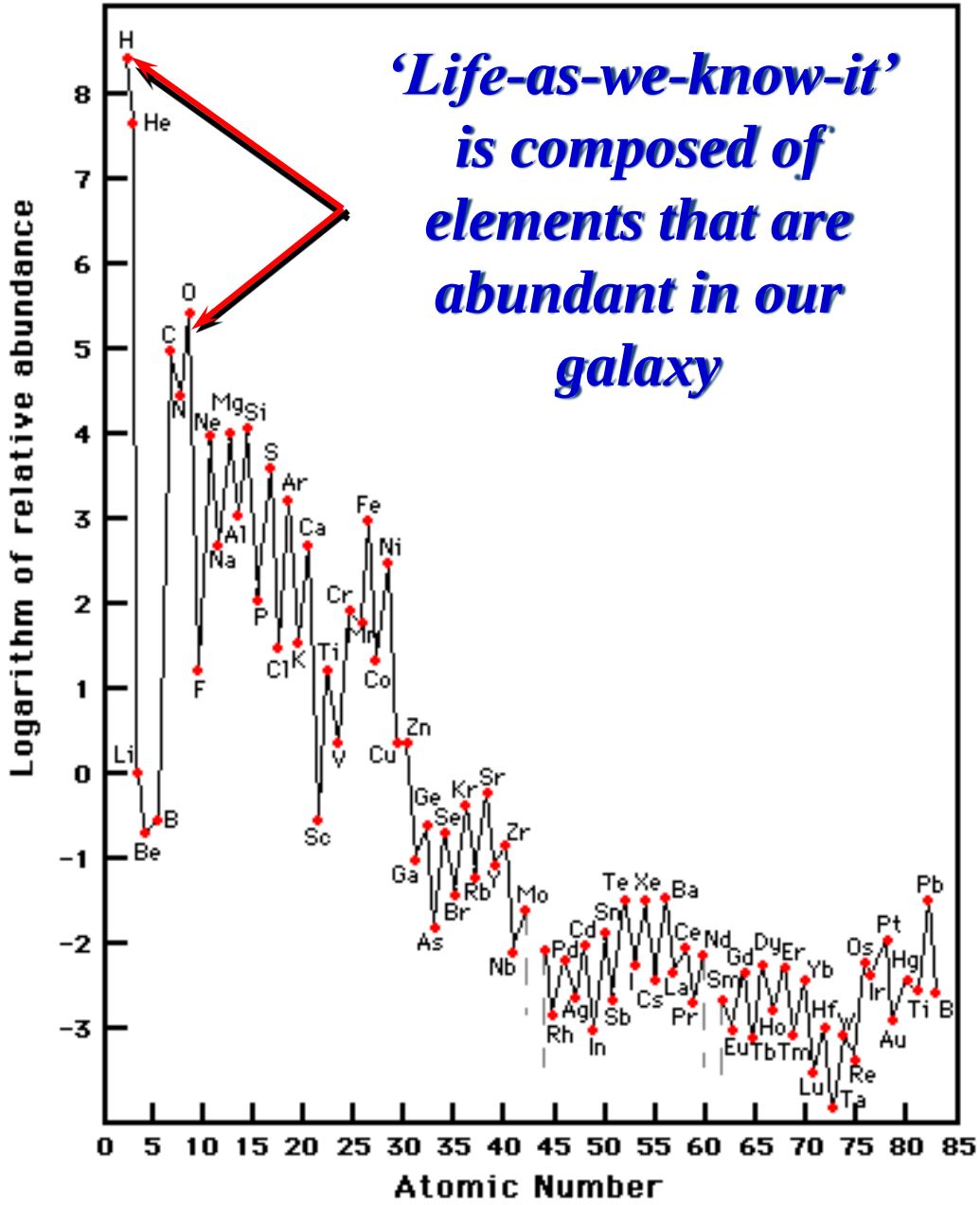

NGC 7331
~50 million light-years away

Hubble Ultra Deep Field image showing ~10,000 galaxies


Spectral classes of stars
100
10
1
0.1
0.01
0.001
% of stars
M
K
G
F
A
B
O
Y = 4.62X -2.05
0.1
1
10
100
Mass (solar units)

Is most life elsewhere likely to be carbon-based?

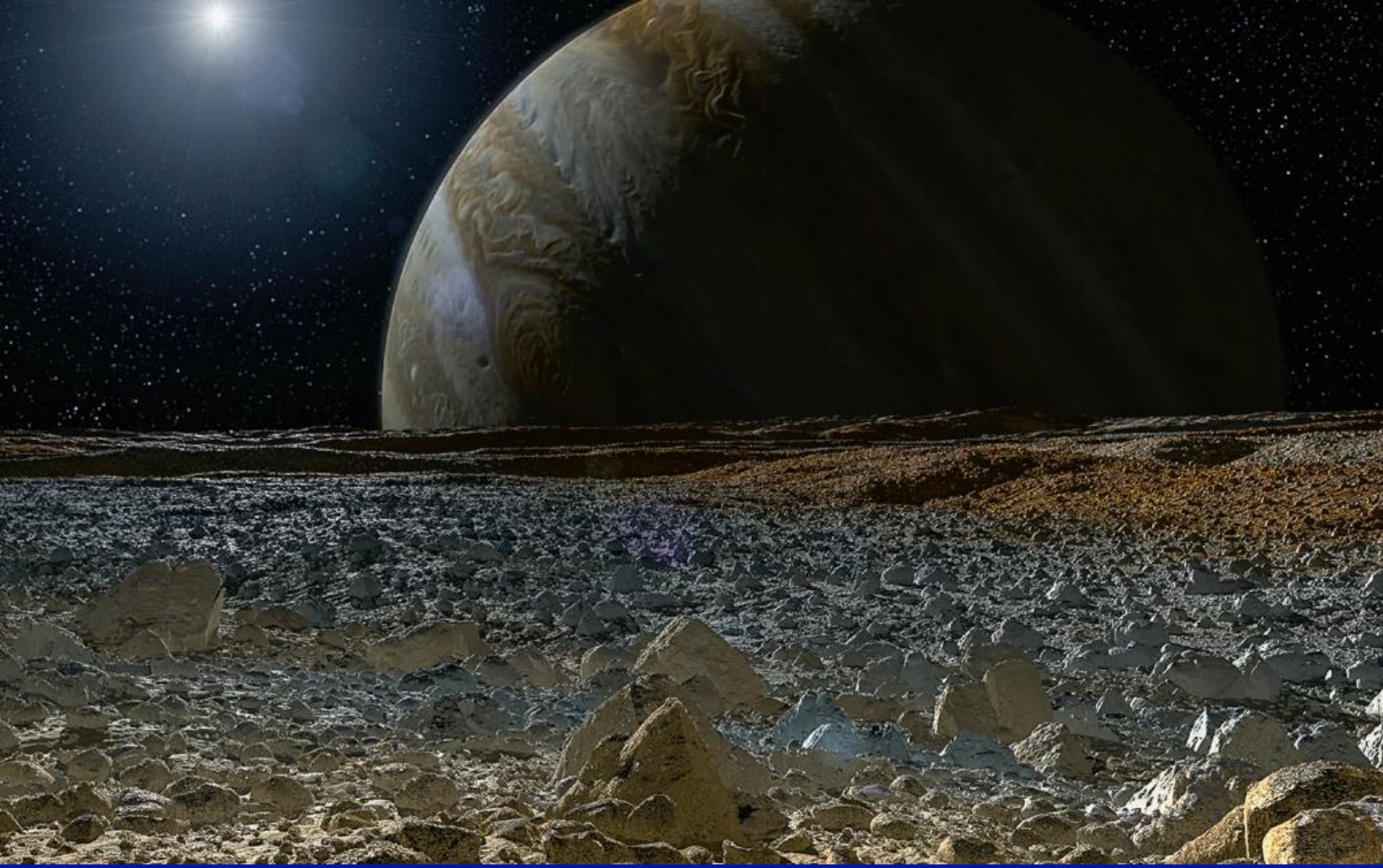
'Life-as-we-know-it' is composed of elements that are abundant in our galaxy



Relative abundance of the elements in the Universe. Abundances are scaled so that silicon (Si) = 10000. From Mason (1968).

Carbonaceous chondrite (meteorite)

Mt. Sharp as viewed by NASA's *Curiosity* rover in Gale Crater on Mars



E. Hand (2015) *Plumes on Europa tease NASA mission planners*. Science, 347, 932-933.

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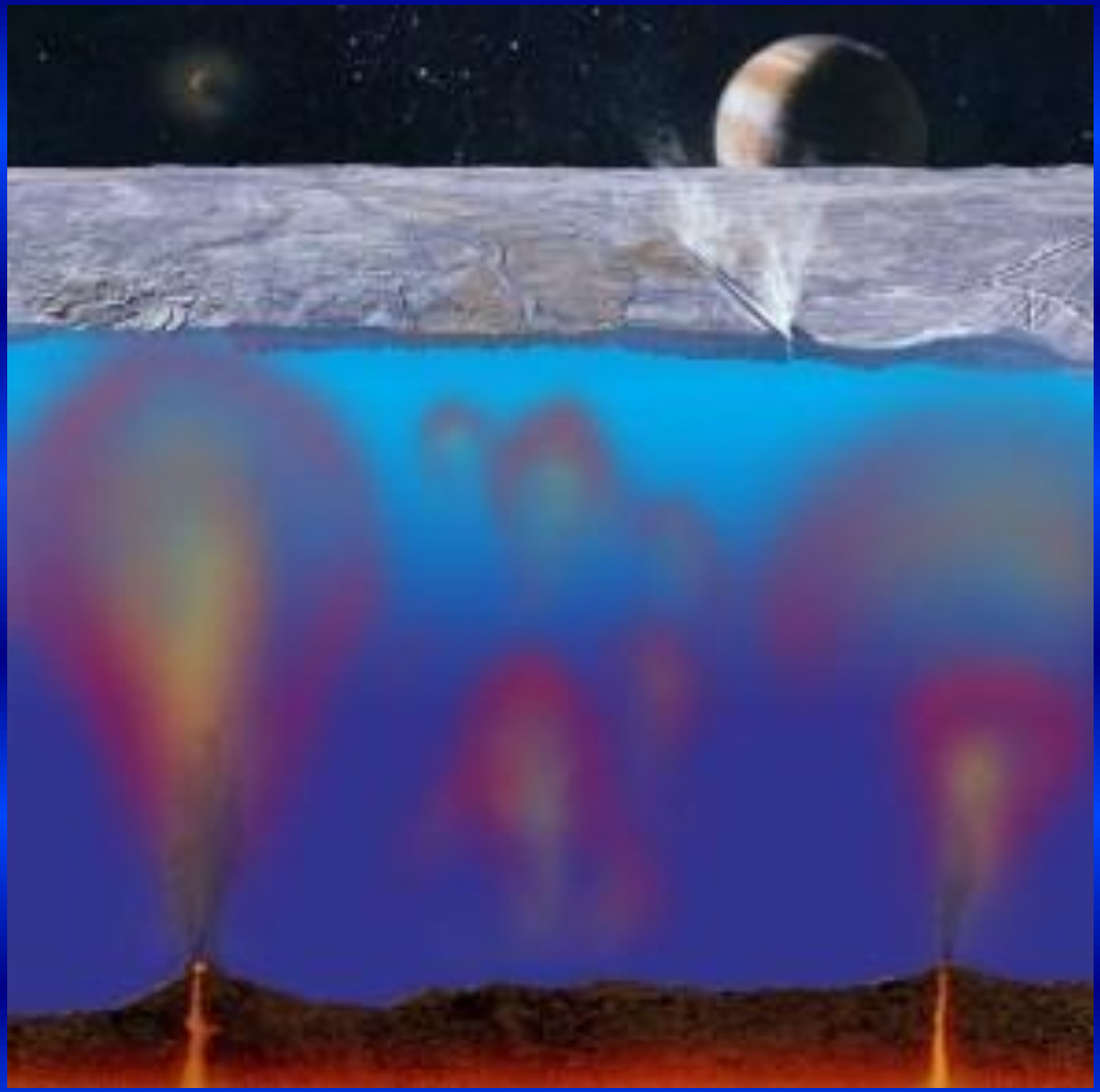
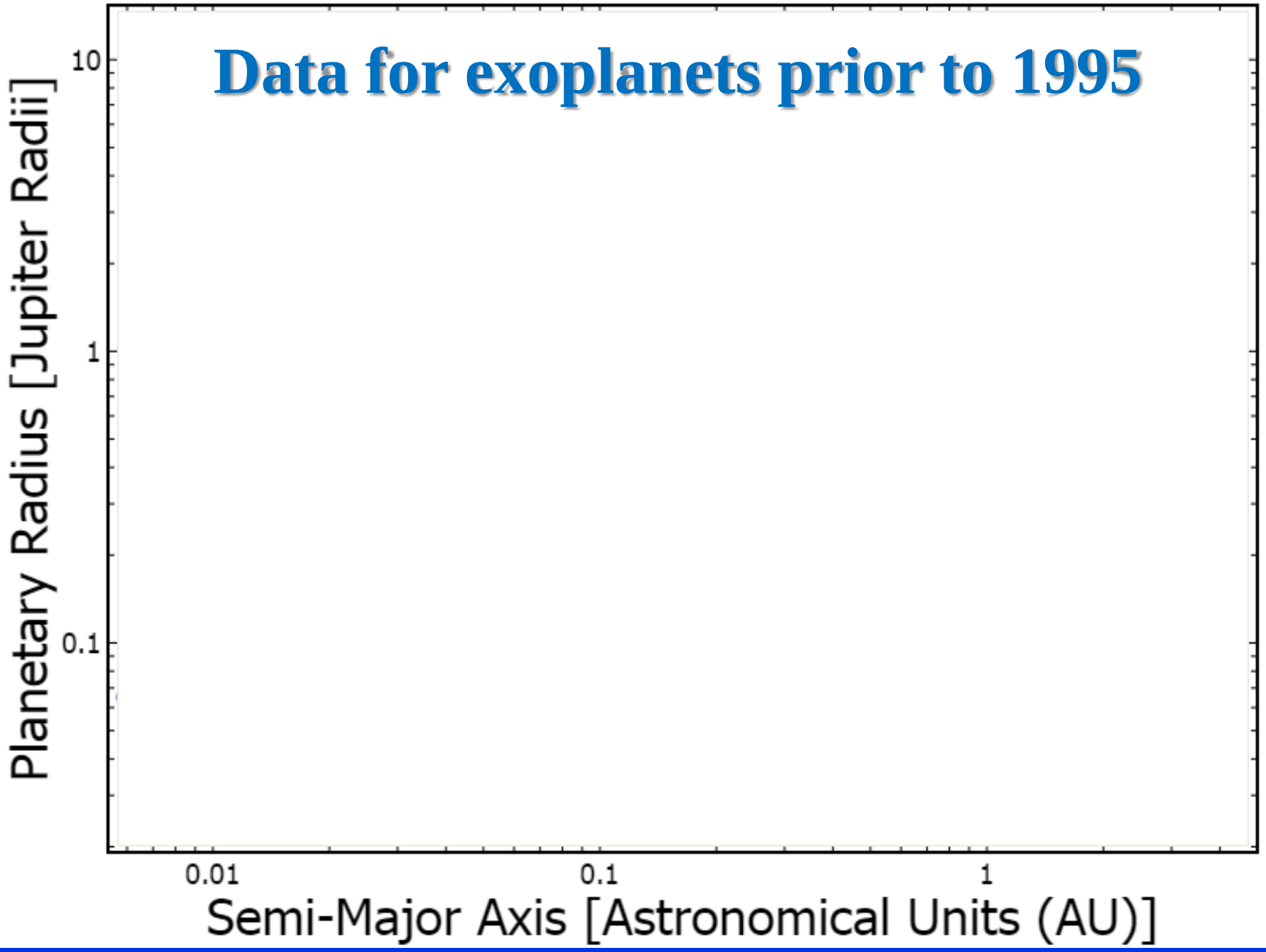
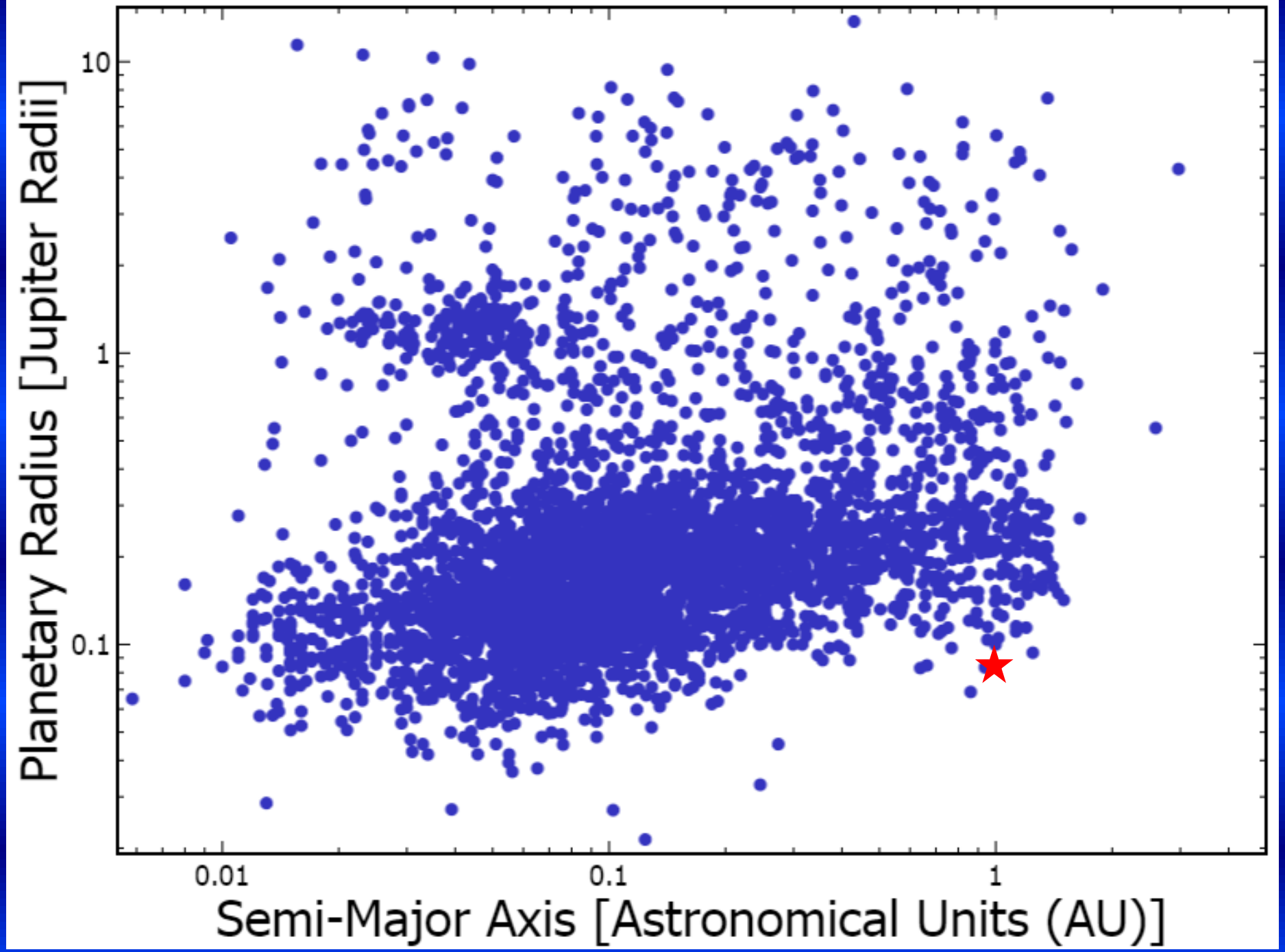


Data for exoplanets prior to 1995




Planetary Radius [Jupiter Radii]
10
1
0.1
0.01
0.1
1
Semi-Major Axis [Astronomical Units (AU)]

KEPLER

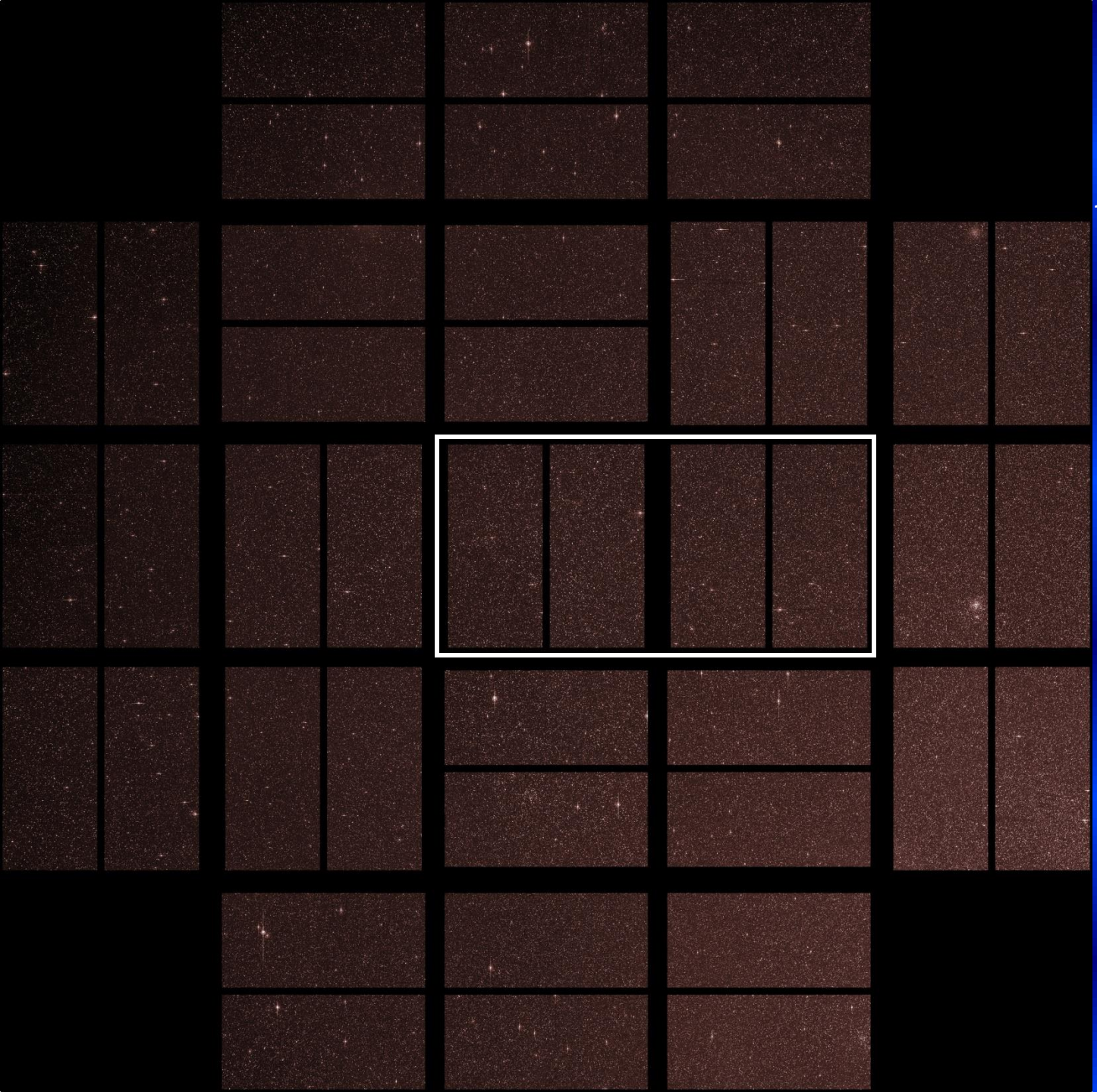
http://www.kepler.arc.nasa.gov

Launched on
March 6, 2009

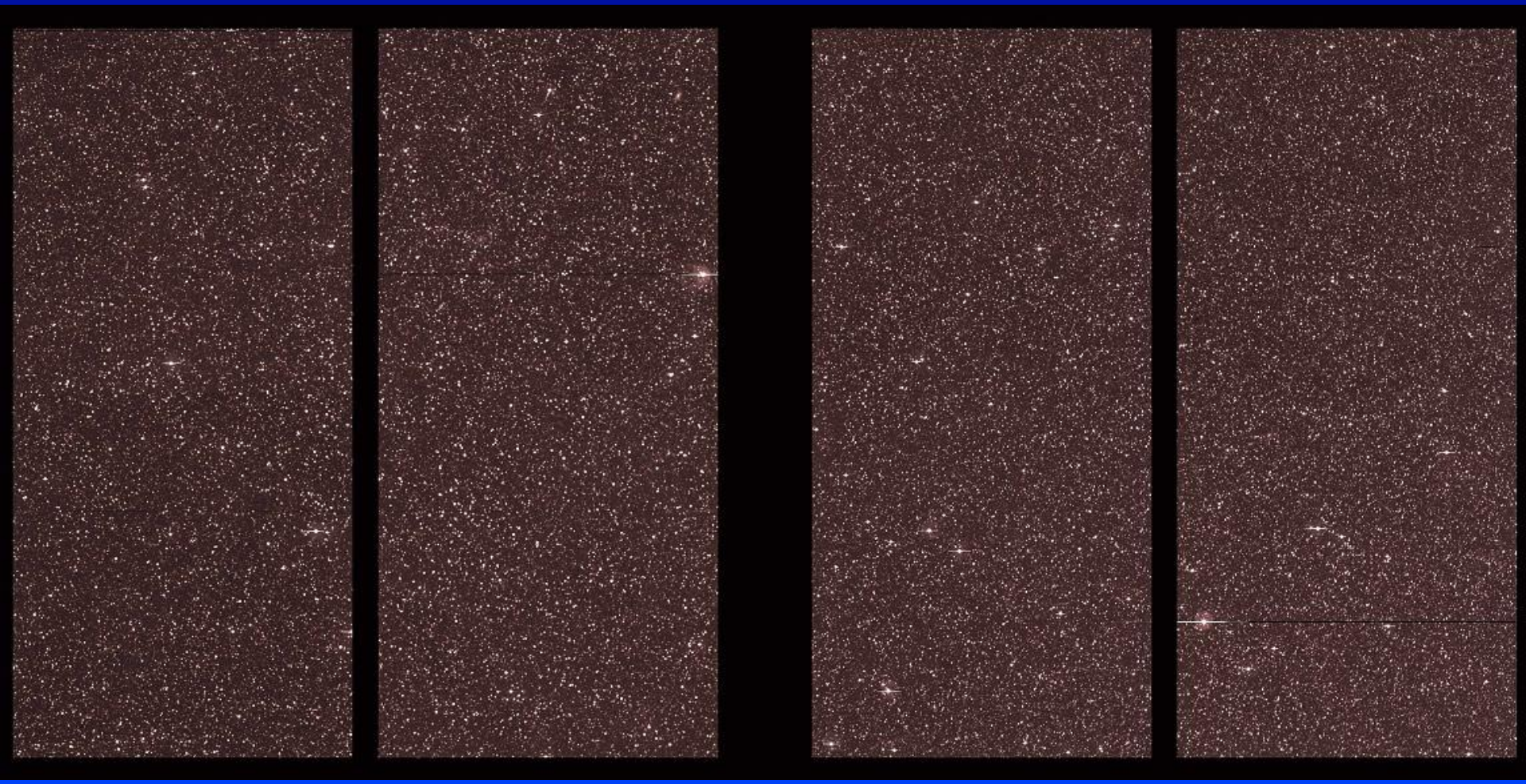
1.4-meter primary mirror
~10^5 stars on 4-yr mission
20 ppm detection limit
0.002% on 12^{th} mag. star
430 - 890 nm

Animation of NASA's *Kepler* spacecraft in orbit

http://www.youtube.com/watch?v=54fnbJ1hZik



Kepler **images of stars being continuously monitored for variations in brightness**



Kepler **images of stars being continuously monitored for variations in brightness**

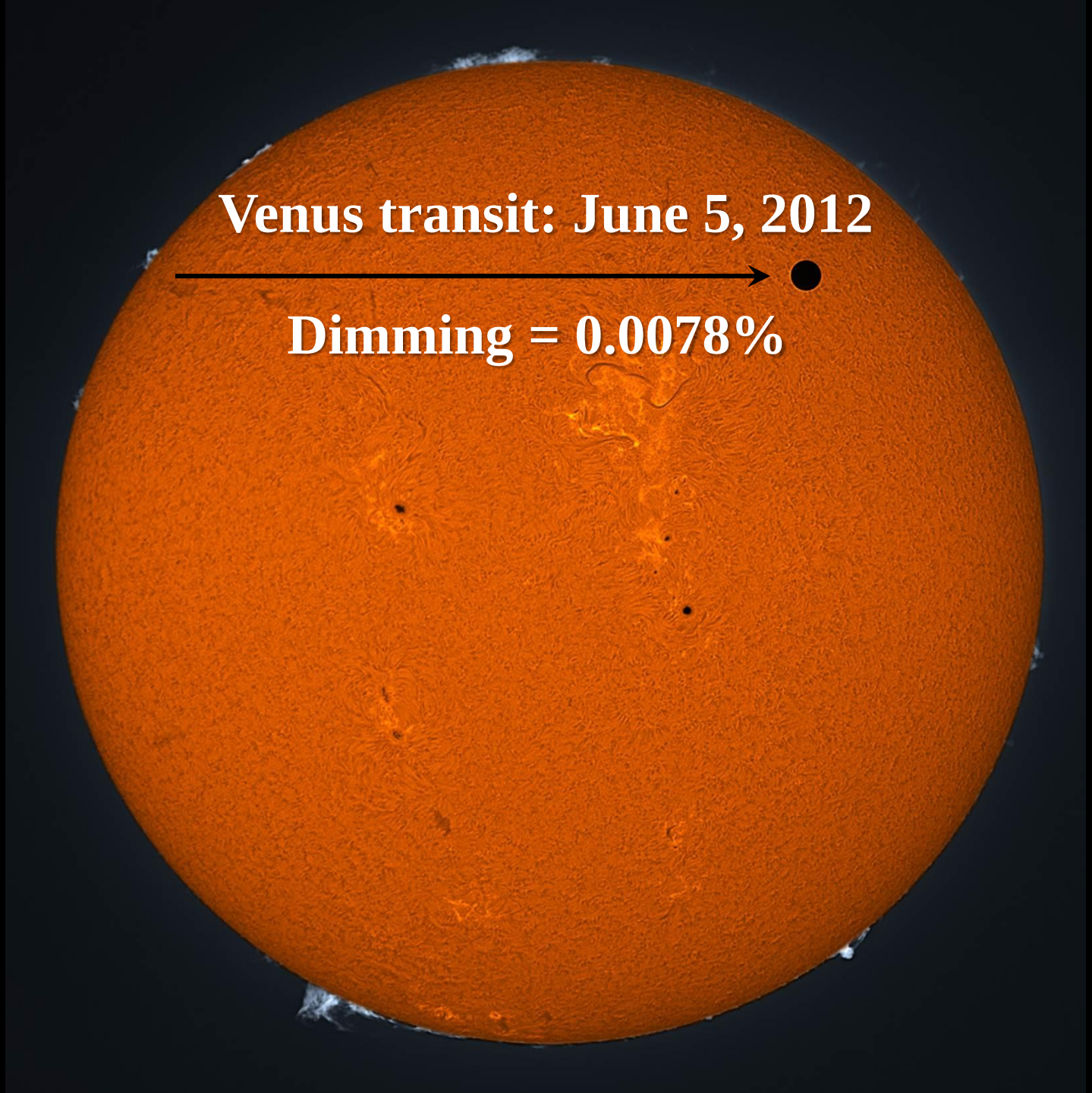

Venus transit: June 5, 2012
Dimming = 0.0078%

Illustration of dimming caused by a transit

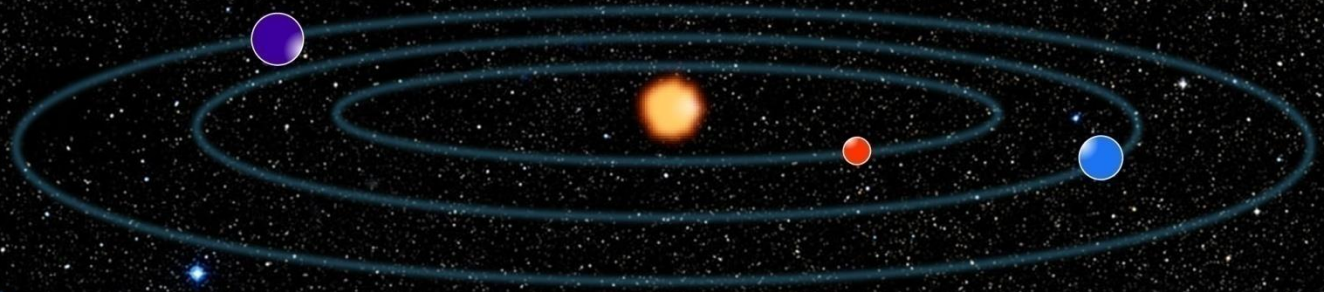
http://www.youtube.com/watch?v=vjdxJQj4QHY&feature=autoplay&list=PL19C72465C51B6BE0&playnext=2

From Earth, the transiting planet dims the starlight during its transit.

$$\frac{A_p}{A_s} = \frac{\pi r_p^2}{\pi R_s^2}$$

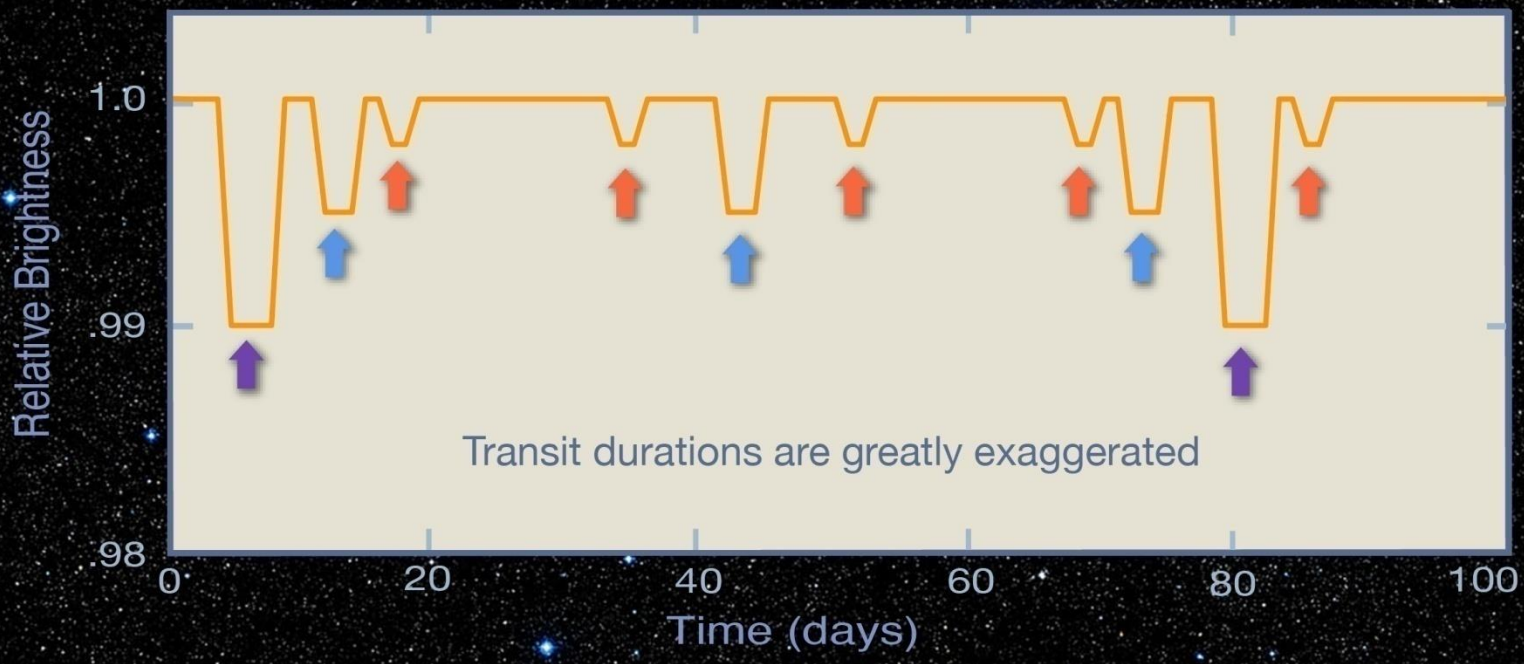
The fraction of dimming is the ratio of their projected cross-sections.

Transit Signature of a Multiple-Planet System



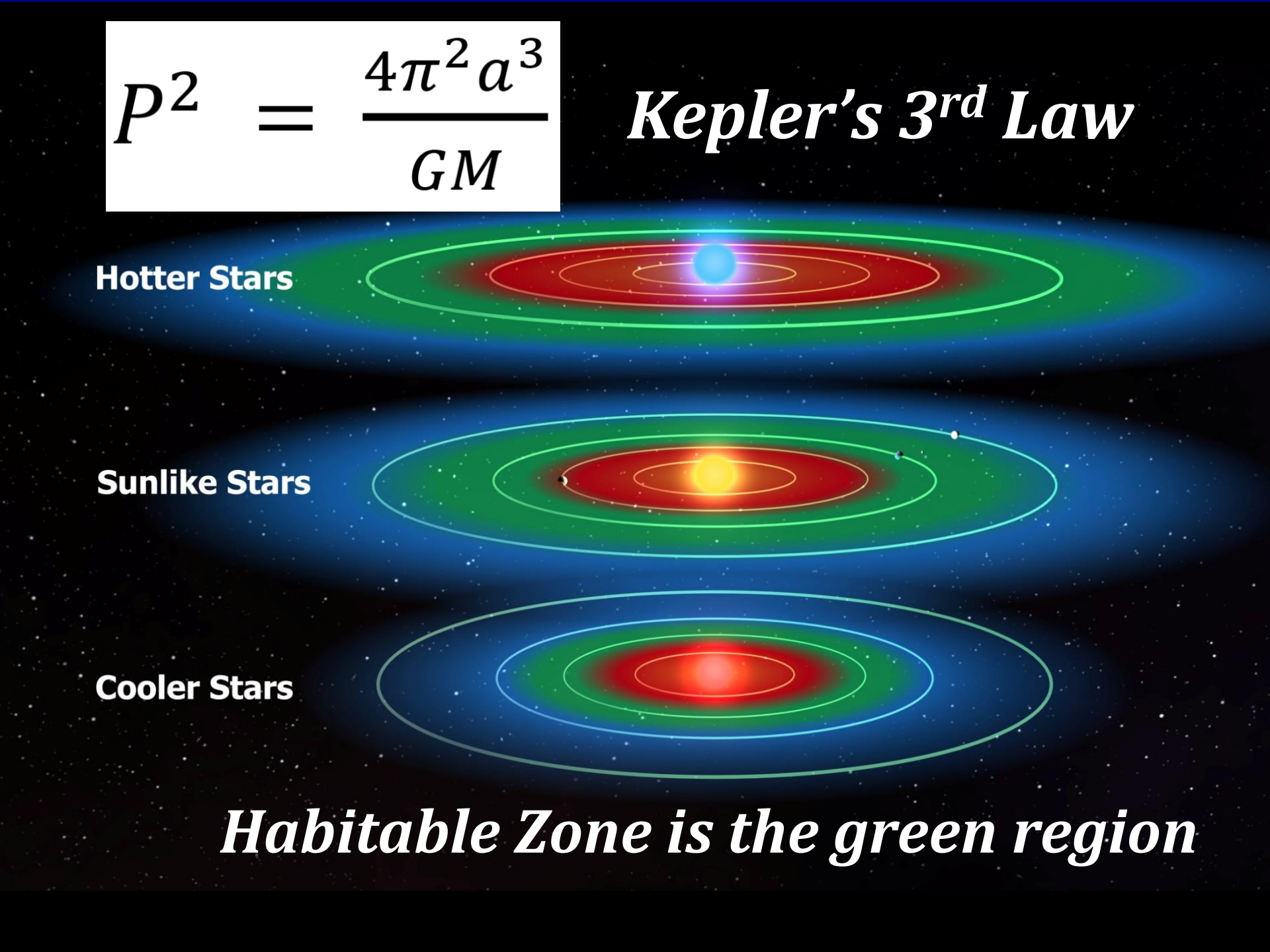
Planets can be distinguished by:

- Different periods
- Different depths
- Different durations

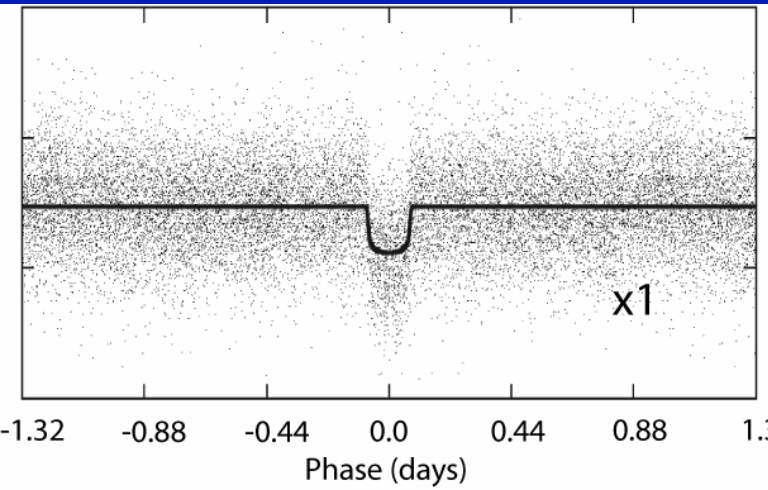


$$P^2 = \frac{4\pi^2 a^3}{GM}$$

Kepler's 3rd Law



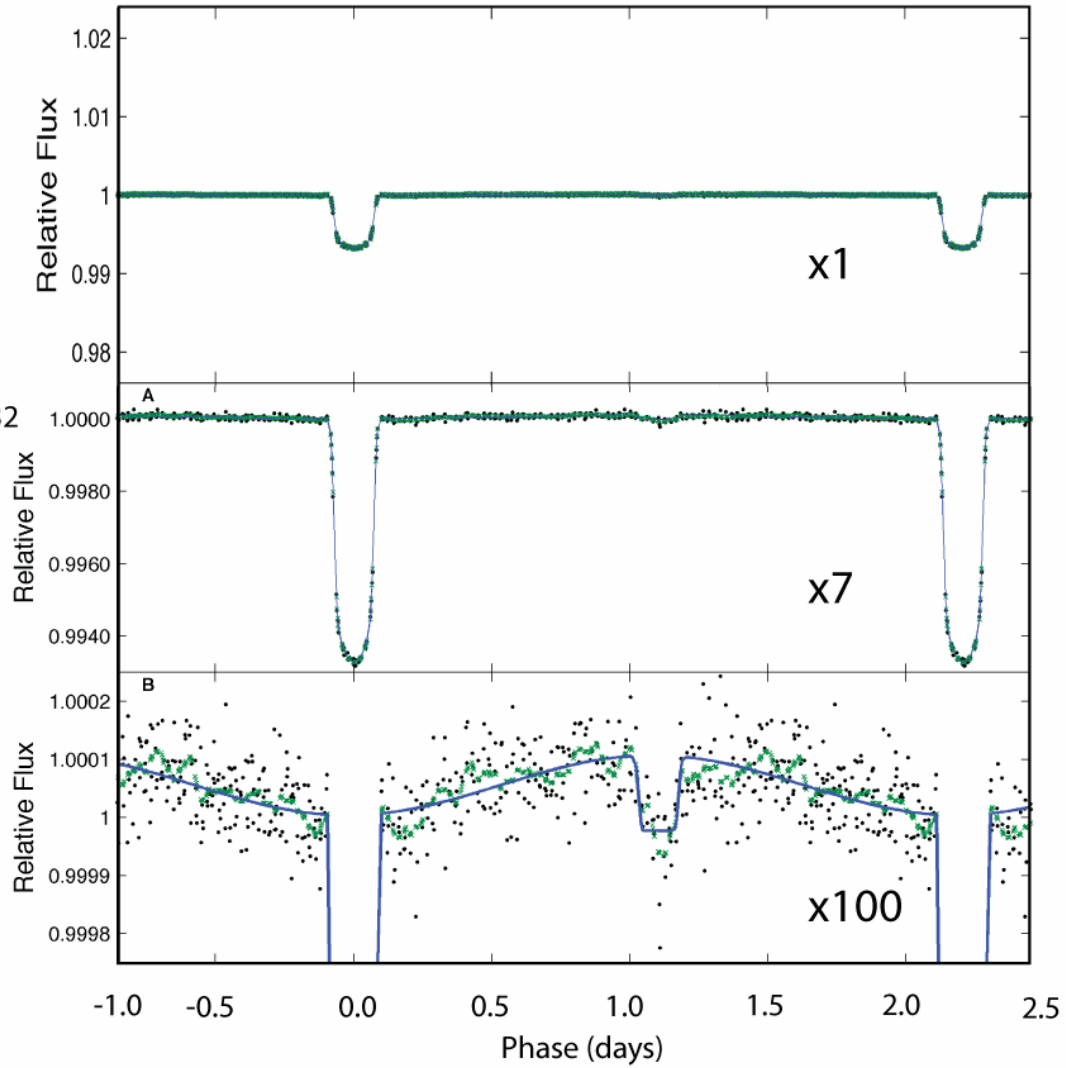
Habitable Zone is the green region



16,620 HATNet data points (57.7 days of data)

HAT-P-7b data from the ground
A. Pal et al., 2008

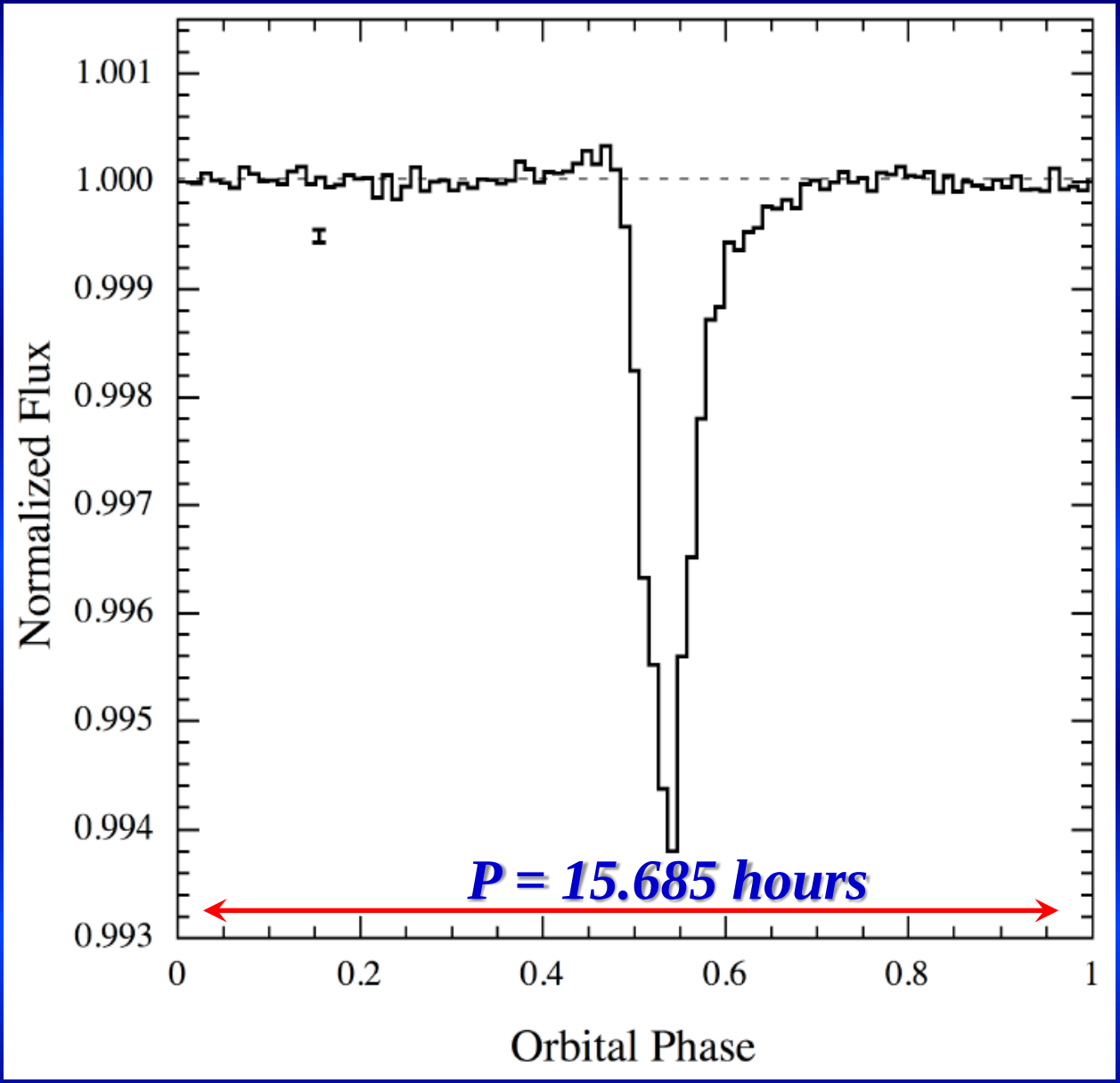
Comparison of data from ground-based instrument and the *Kepler* spacecraft



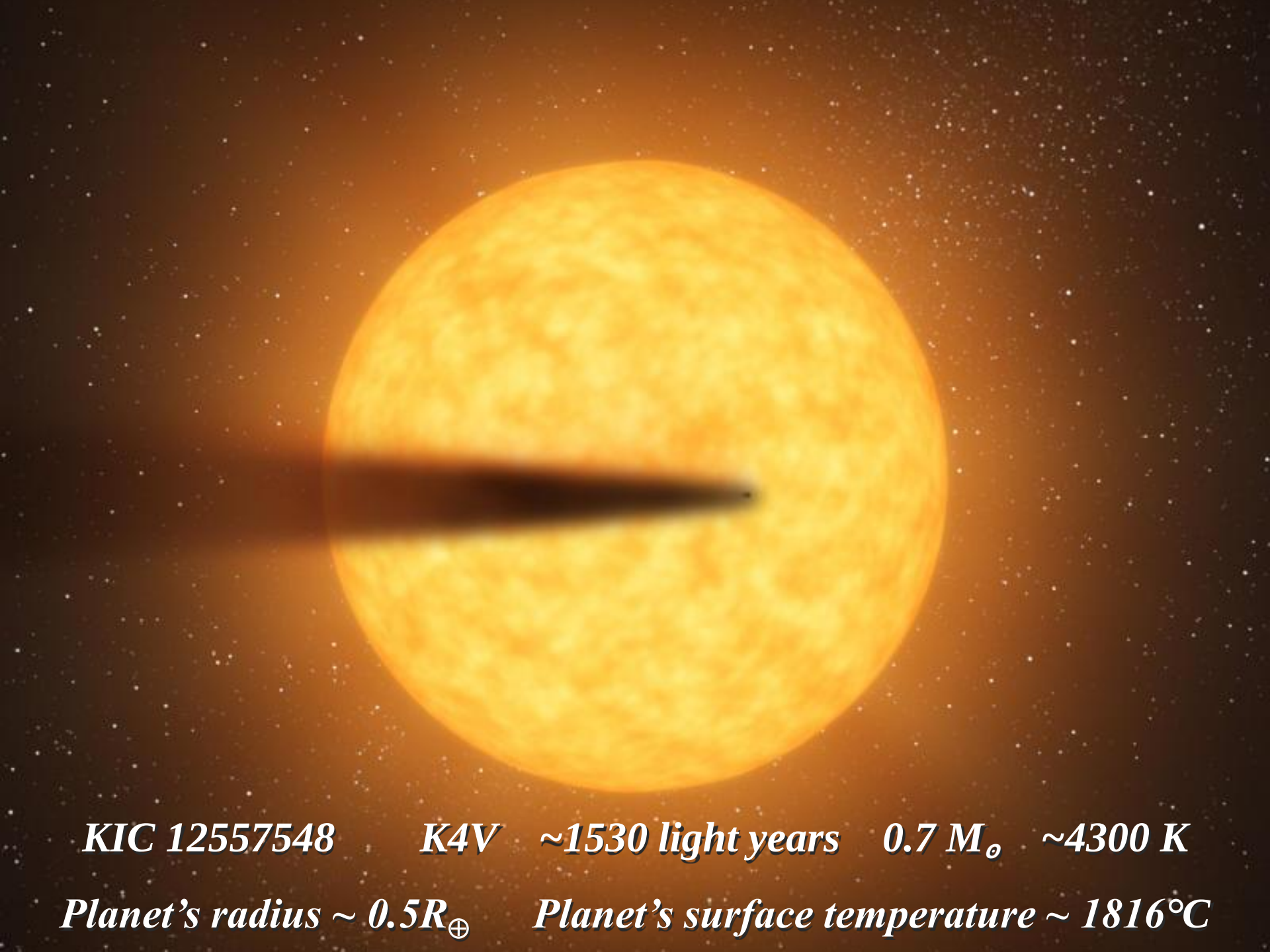
Kepler Commissioning data (10 days)
W. Borucki et al., 2009

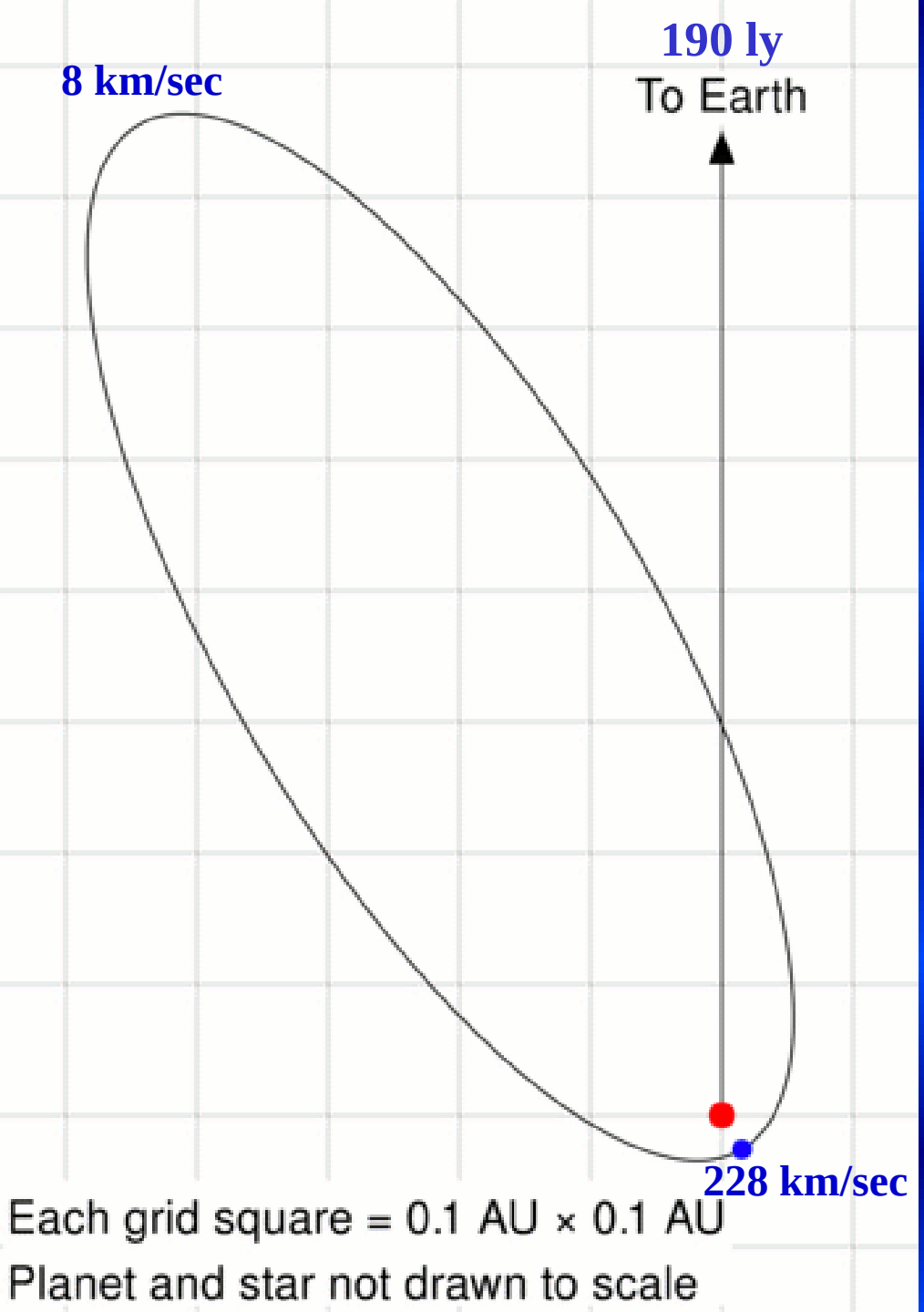
Simulation of the HAT-P-7 light curve measured by NASA's *Kepler* spacecraft

http://www.youtube.com/watch?v=-U5xbO5OUUo



Rappaport et al. (2012) *Possible disintegrating short-period super-Mercury orbiting KIC 12557548*. Astrophysical J., 752 (1), 13p.
doi: 10.1088/0004-637X/752/1/1


KIC 12557548 K4V ~1530 light years 0.7 $M_\odot$ ~4300 K
Planet's radius ~ 0.5$R_\oplus$ Planet's surface temperature ~ 1816°C



HD 80606 (binary star system: 1200 AU)

G5V star; 190 light years

5370 K

[Fe/H] = 0.34

~7.6 Gyr

0.782 L_{Sun}

0.850 M_{Sun}

HD 80606b

a = 0.453 AU

e = 0.9336

t = 111.436 days

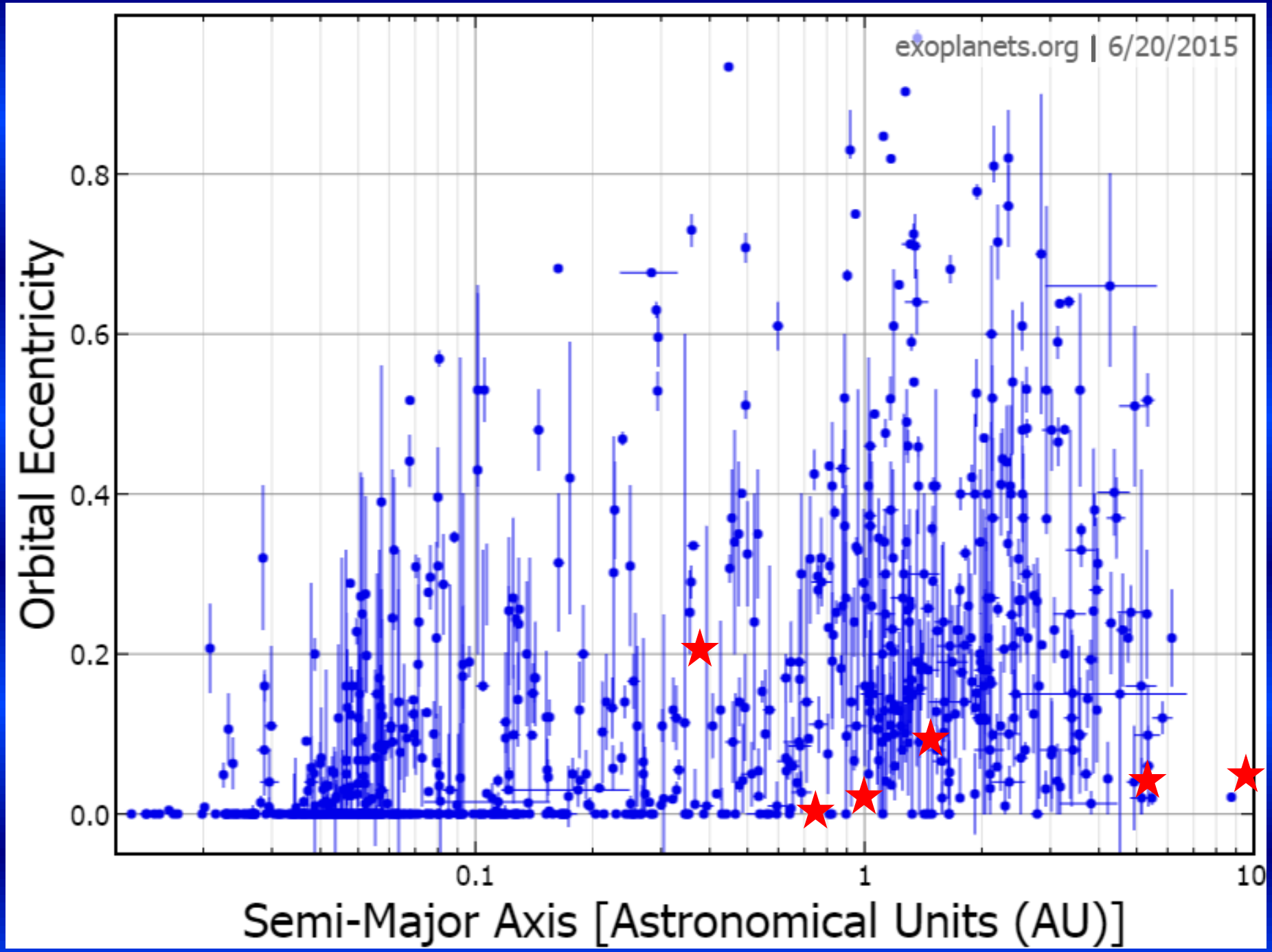
$\rho \sim 4440$ kg/m^3 ; 9.6 g

0.921 $R_{Jupiter}$

3.94 $M_{Jupiter}$

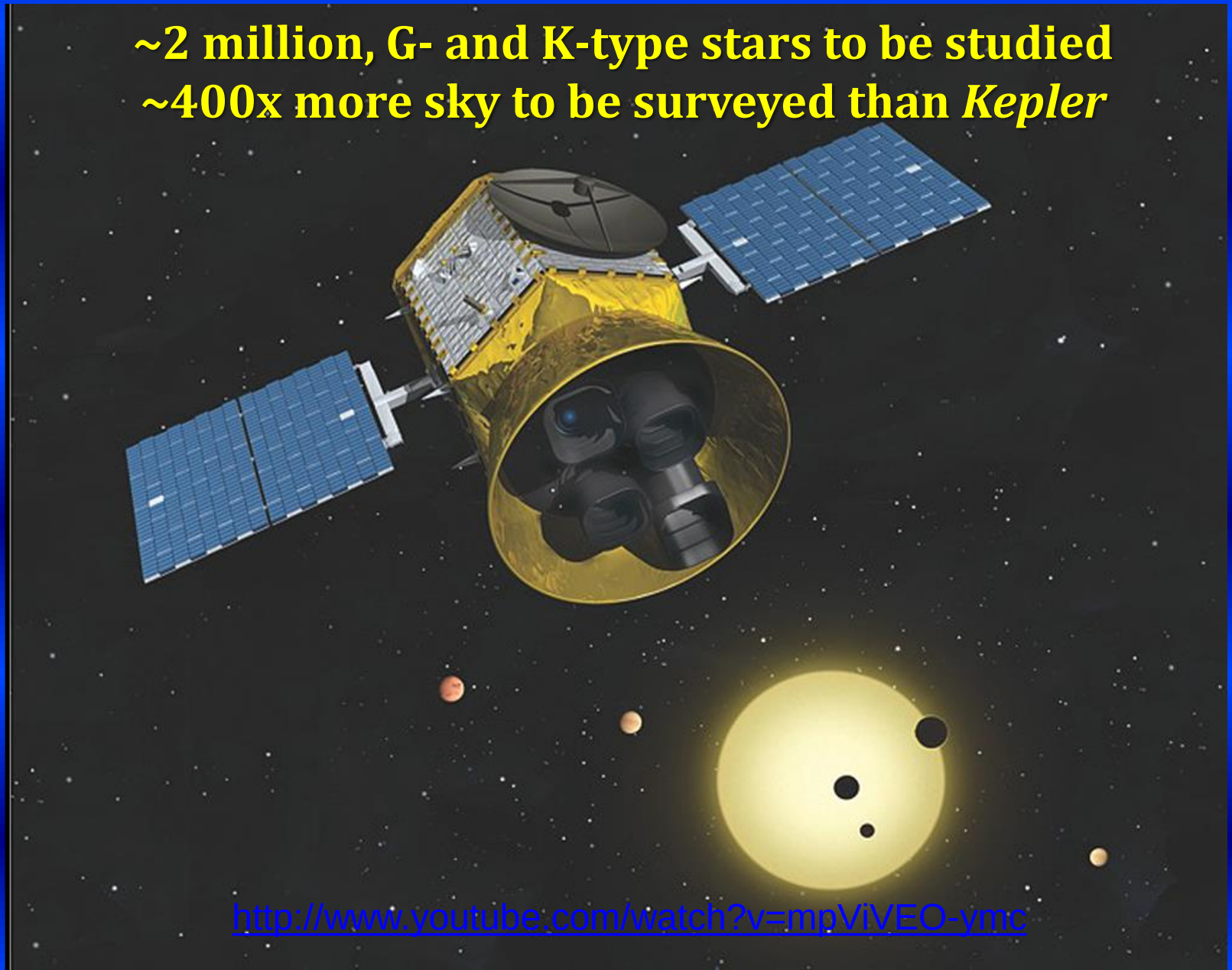
transit = 12.1 hours

~10,000 ppm dimming


exoplanets.org | 6/20/2015
Orbital Eccentricity
0.0
0.2
0.4
0.6
0.8
0.1
1
10
Semi-Major Axis [Astronomical Units (AU)]

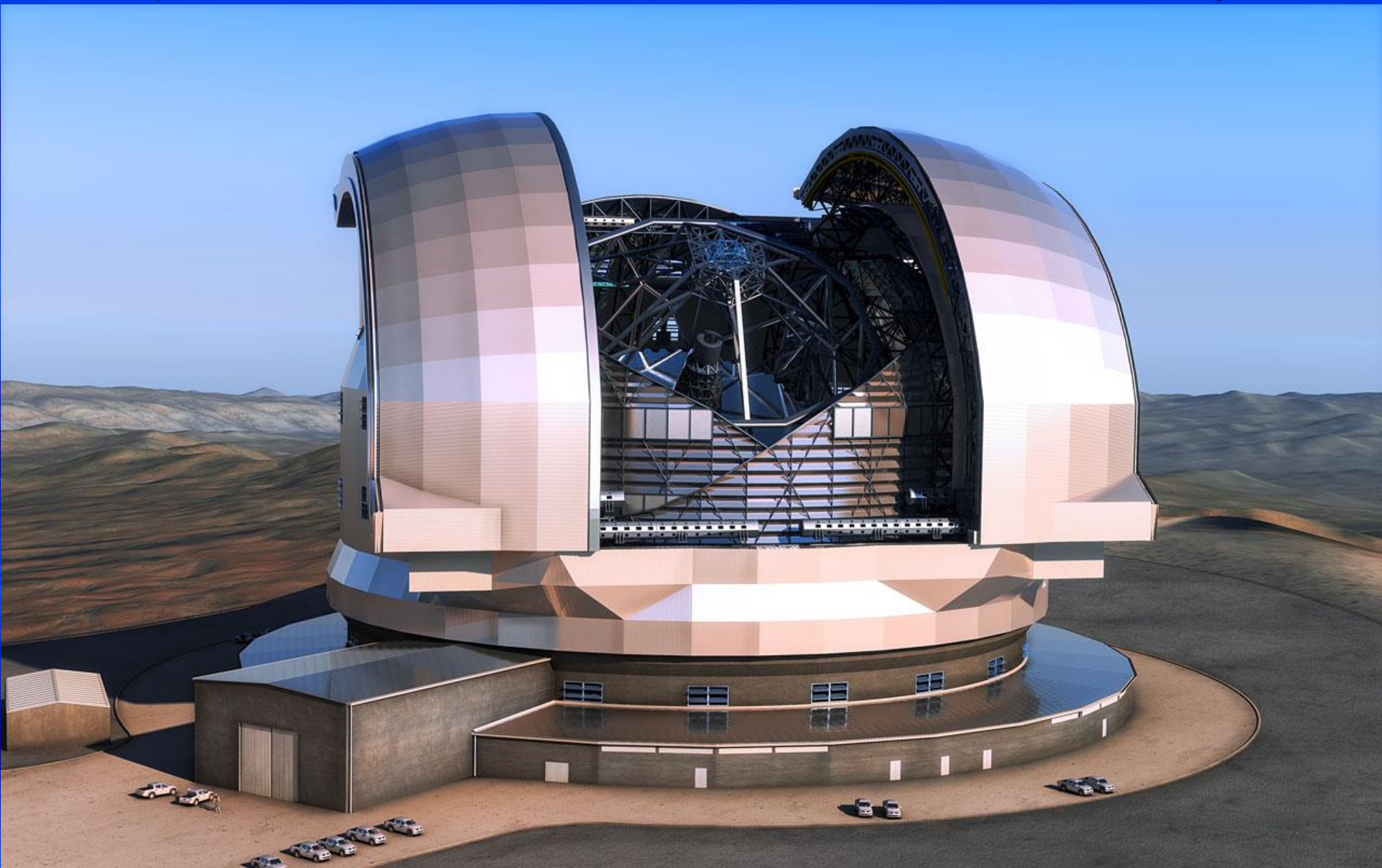

Gliese 667Cc at 22.1 light years

TESS = Transiting Exoplanet Survey Satellite (launch in 2017)



European Extremely Large Telescope (E-ELT)

(39-meters in diameter; Atacama Desert in Chile)



SOMEWHERE

by Ray Goodwin

Somewhere there are mountains
Glistening in the snow
Somewhere there are mountains
That we shall never know

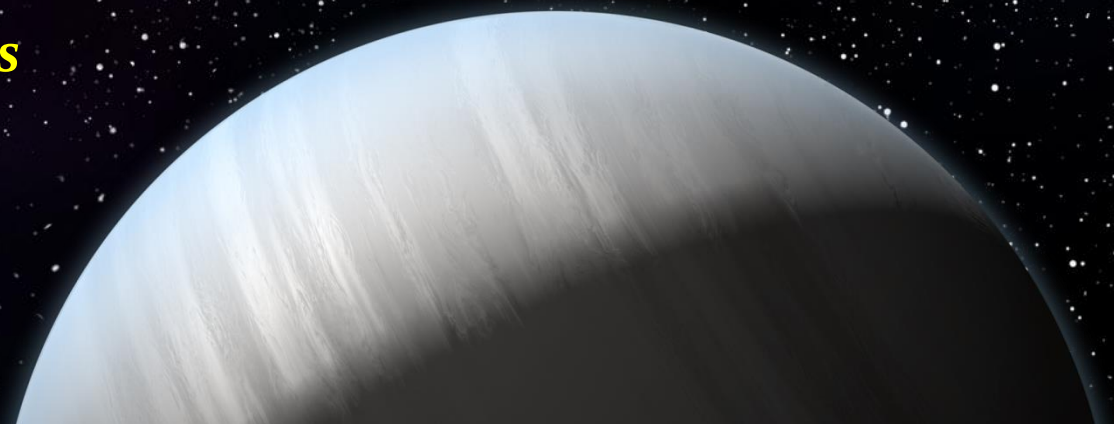
Somewhere there are rivers
Flowing fast and free
Somewhere there are rivers
That we can never see

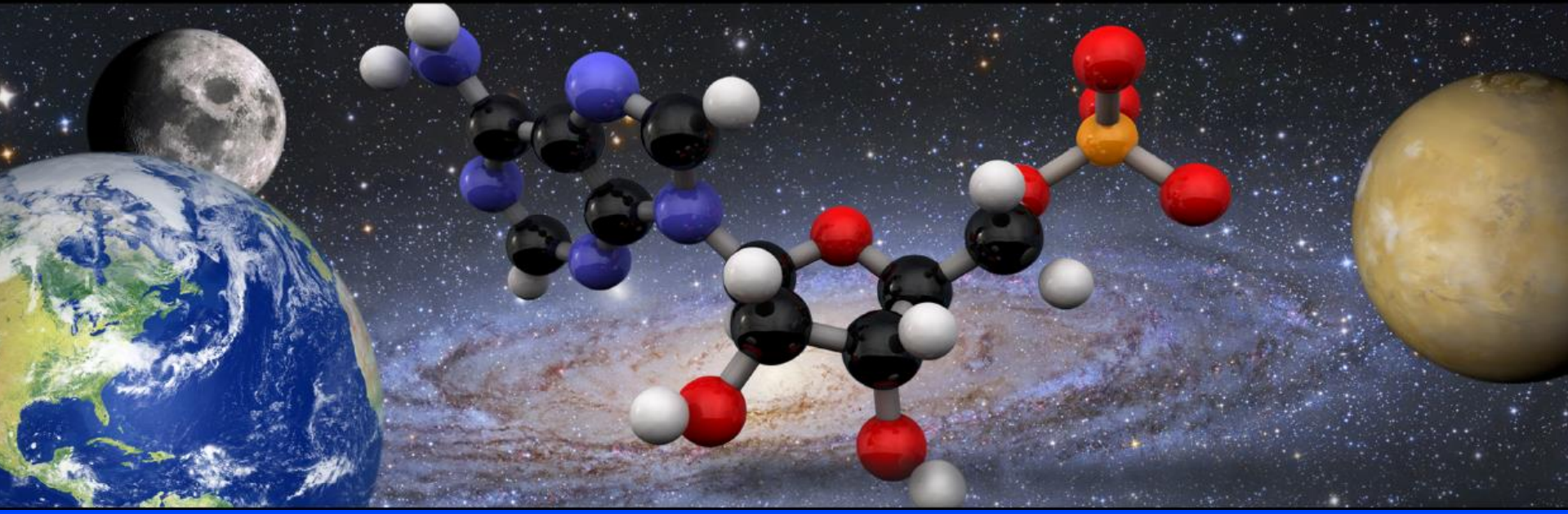
Somewhere there are oceans
And sun drenched island sands
Forests full of creatures
In vastly distant lands

Somewhere there's a planet
Beneath an alien star
The people watch our tiny sun
And wonder where we are

One day perhaps we'll find them
Across the void of space
Perhaps through ways as yet not known
We'll meet them face to face

Slide from William Borucki NASA
Ames Research Center
Principal Investigator, *Kepler* mission





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