11-2014

NASA's search for life beyond the Earth

John W. Delano Prof
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SOMEWHERE

by Ray Goodwin

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

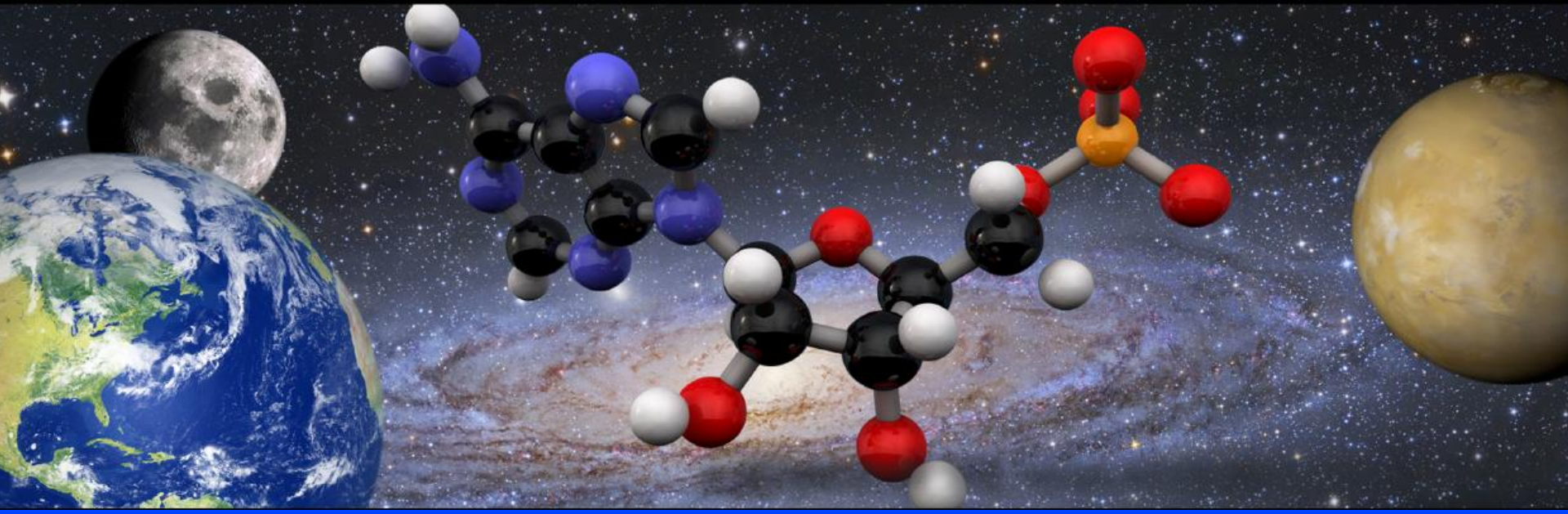
Somewhere there are rivers
Flowing fast and free
Somewhere there are rivers
That we can never see

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



NASA's Search for Life on Worlds beyond our Solar System

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University at Albany (SUNY)
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Education is not the filling of a pail, but the lighting of a fire.

William Butler Yeats

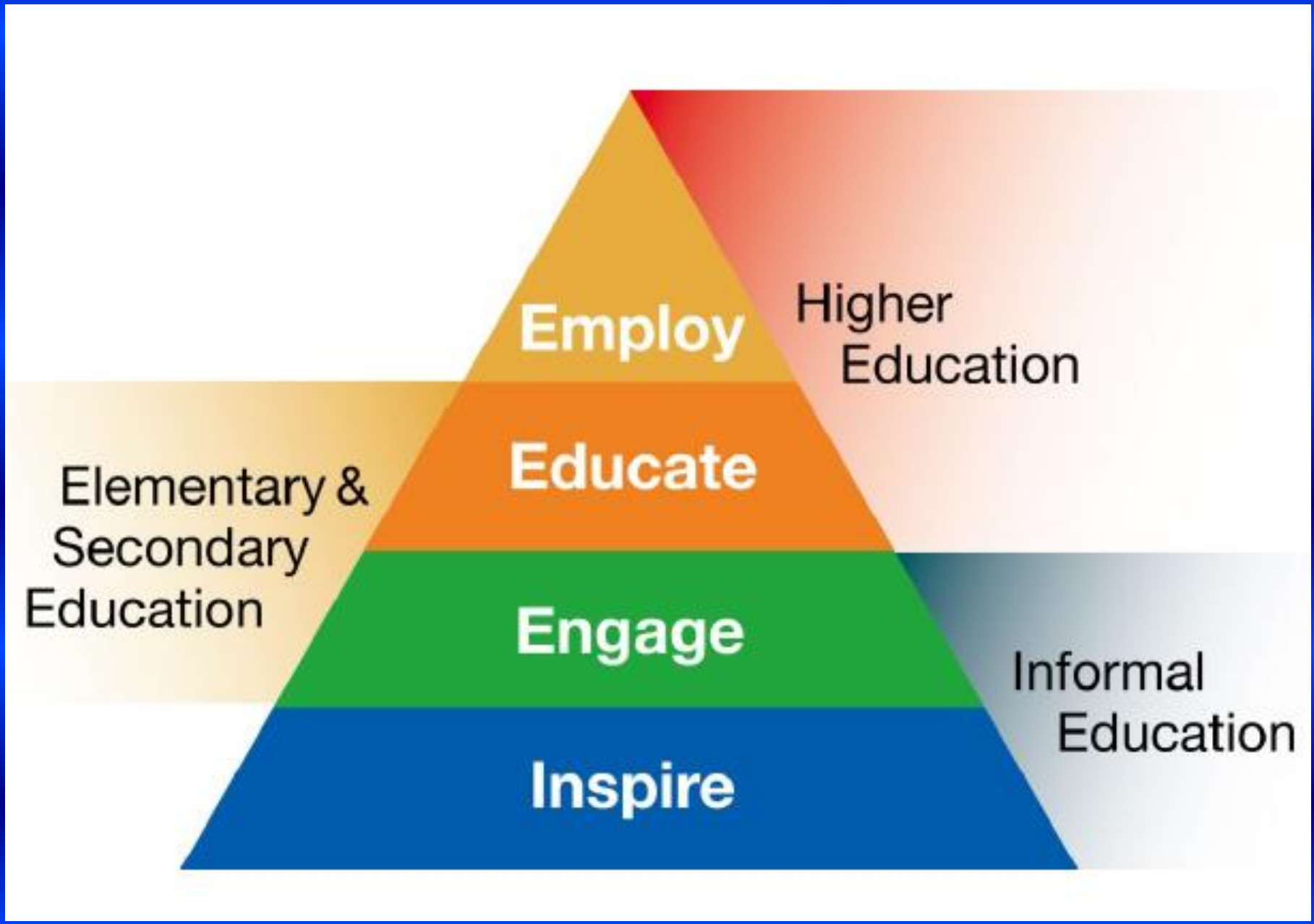
It is the supreme art of inspired teaching that awakens the joy of learning.

Albert Einstein

Hope is the thing with feathers that perches in the soul and sings the tune without the words and never stops at all.

Emily Dickinson

NASA's Educational Strategic Framework



NASA's next generation space launch system (SLS)

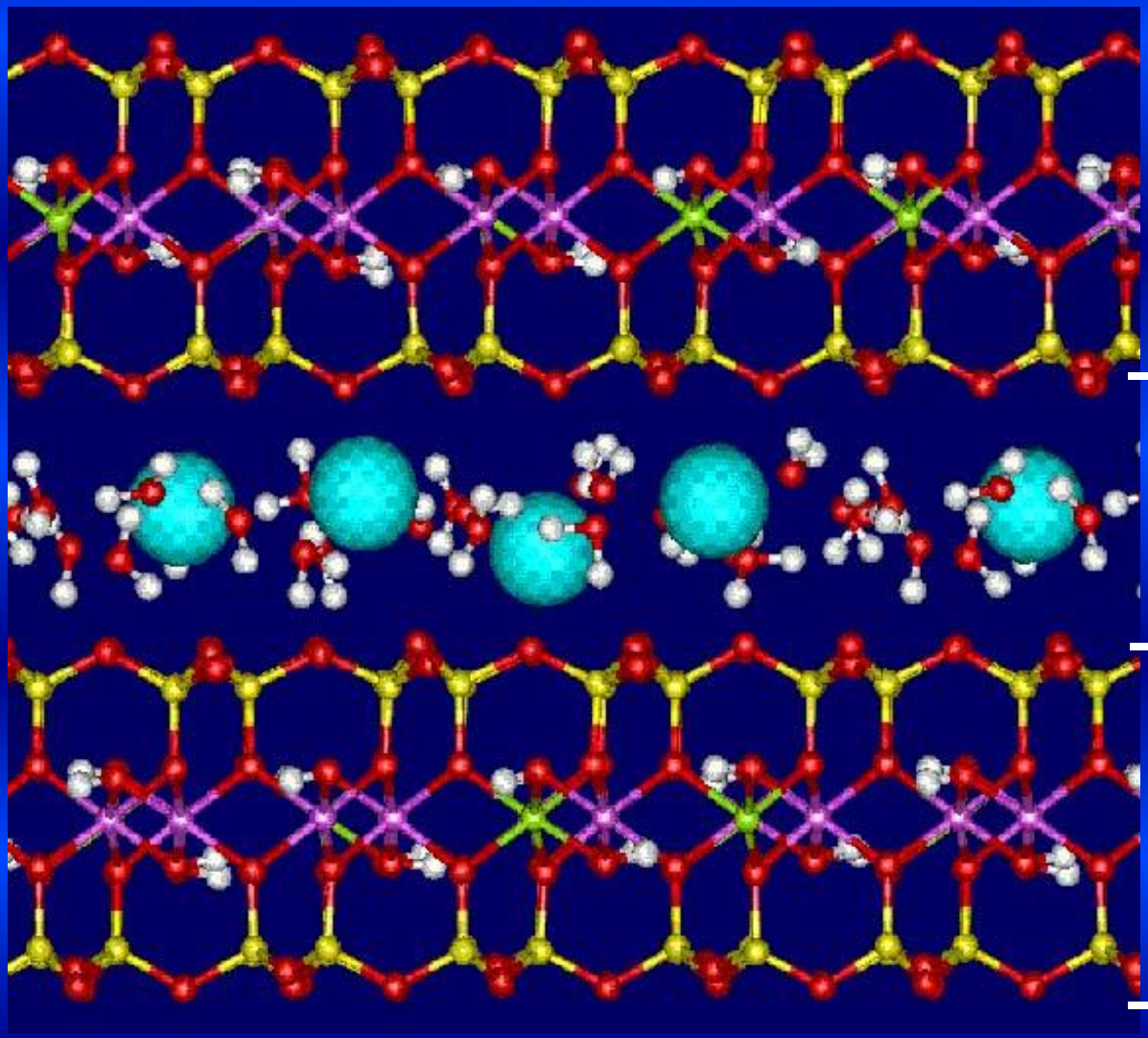
http://www.youtube.com/watch?v=mLQL2TfPHQA

Carbonaceous chondrite (meteorite)

Montmorillonite

O
Si
Al

Na, Ca
H
Mg, Fe



~1.4 nm

Interlayer with cation and H_2O

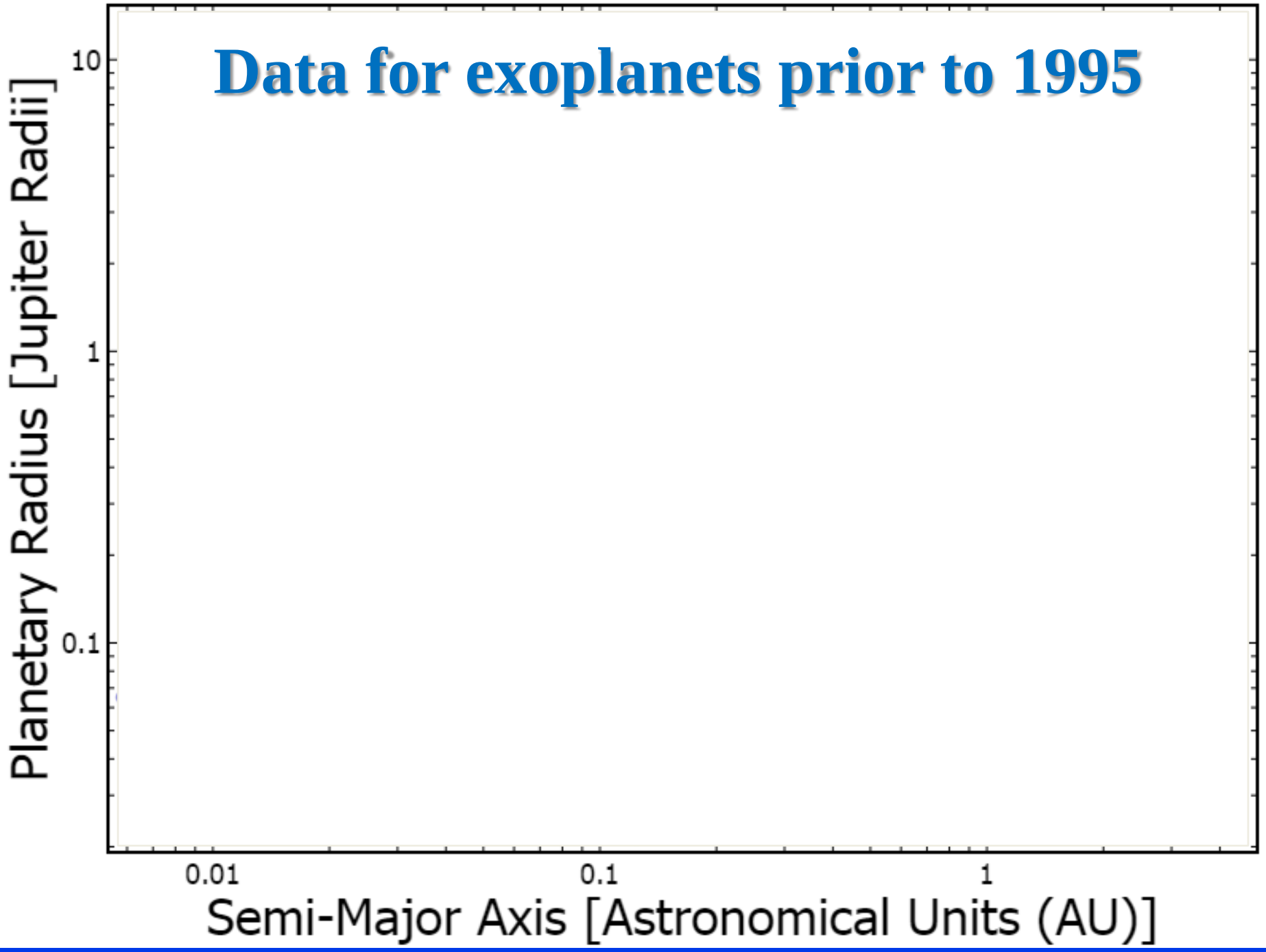
~0.9 nm

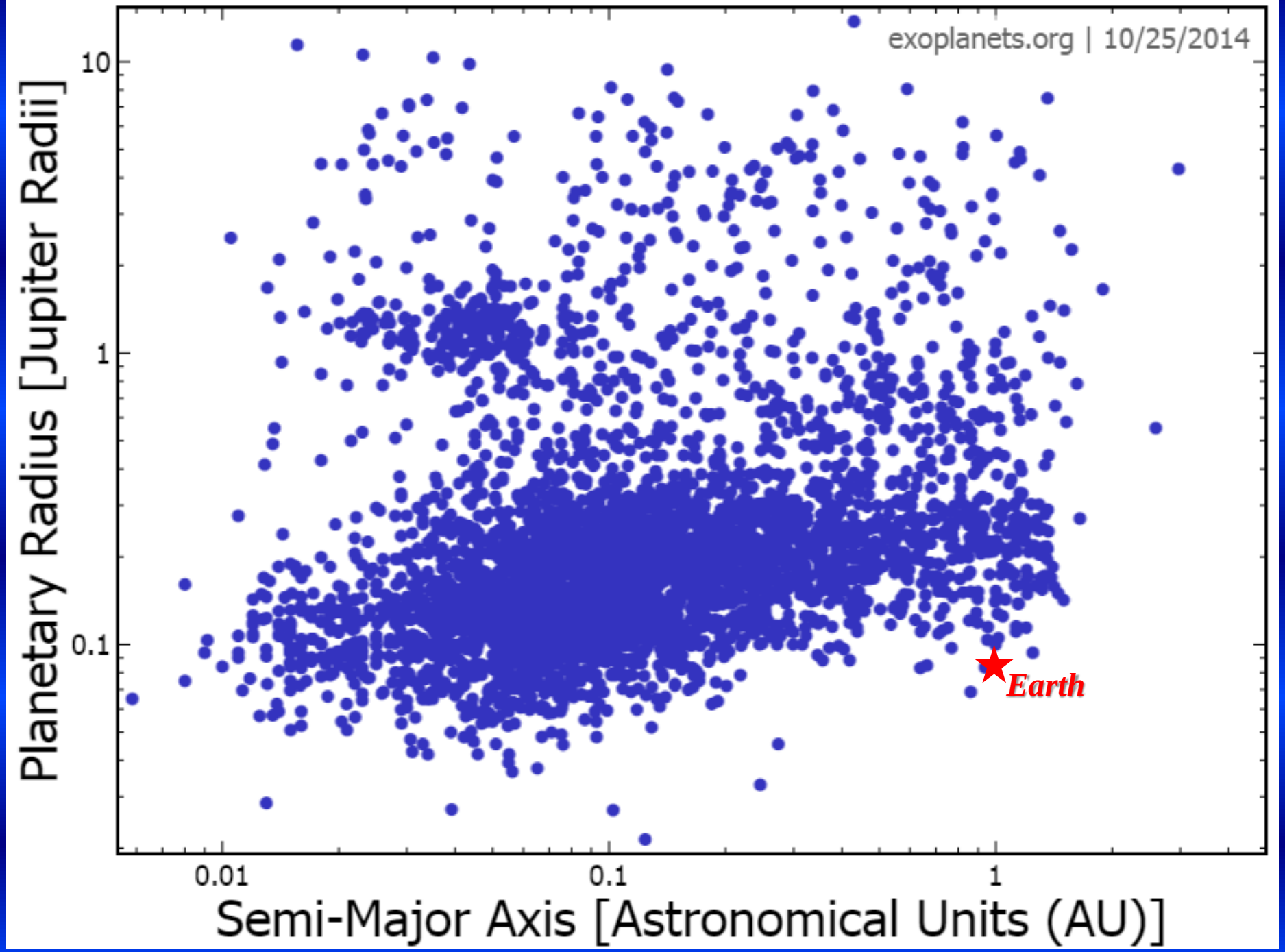
$(Na_{0.2}Ca_{0.1})(Al_{1.5}Mg_{0.3}Fe_{0.2})(Si_{3.9}Al_{0.1})O_{10}(OH)_2 \cdot nH_2O$

interlayer *octahedral* *tetrahedral*

The search for habitable worlds: Environments, Materials, and Processes

Data for exoplanets prior to 1995




exoplanets.org | 10/25/2014
Planetary Radius [Jupiter Radii]
10
1
0.1
0.01
0.1
1
Semi-Major Axis [Astronomical Units (AU)]
Earth

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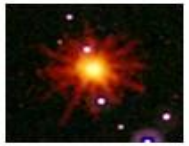

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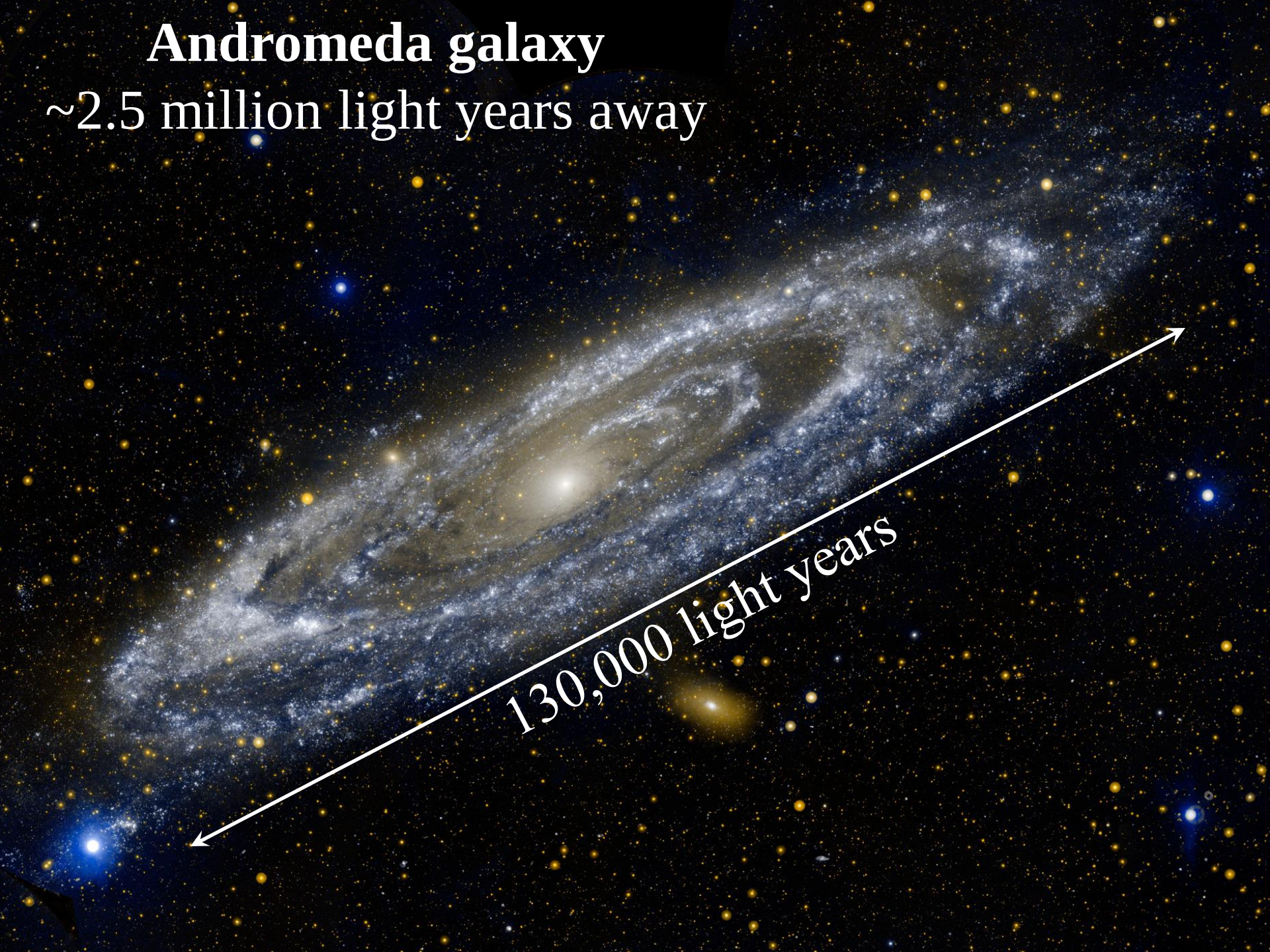
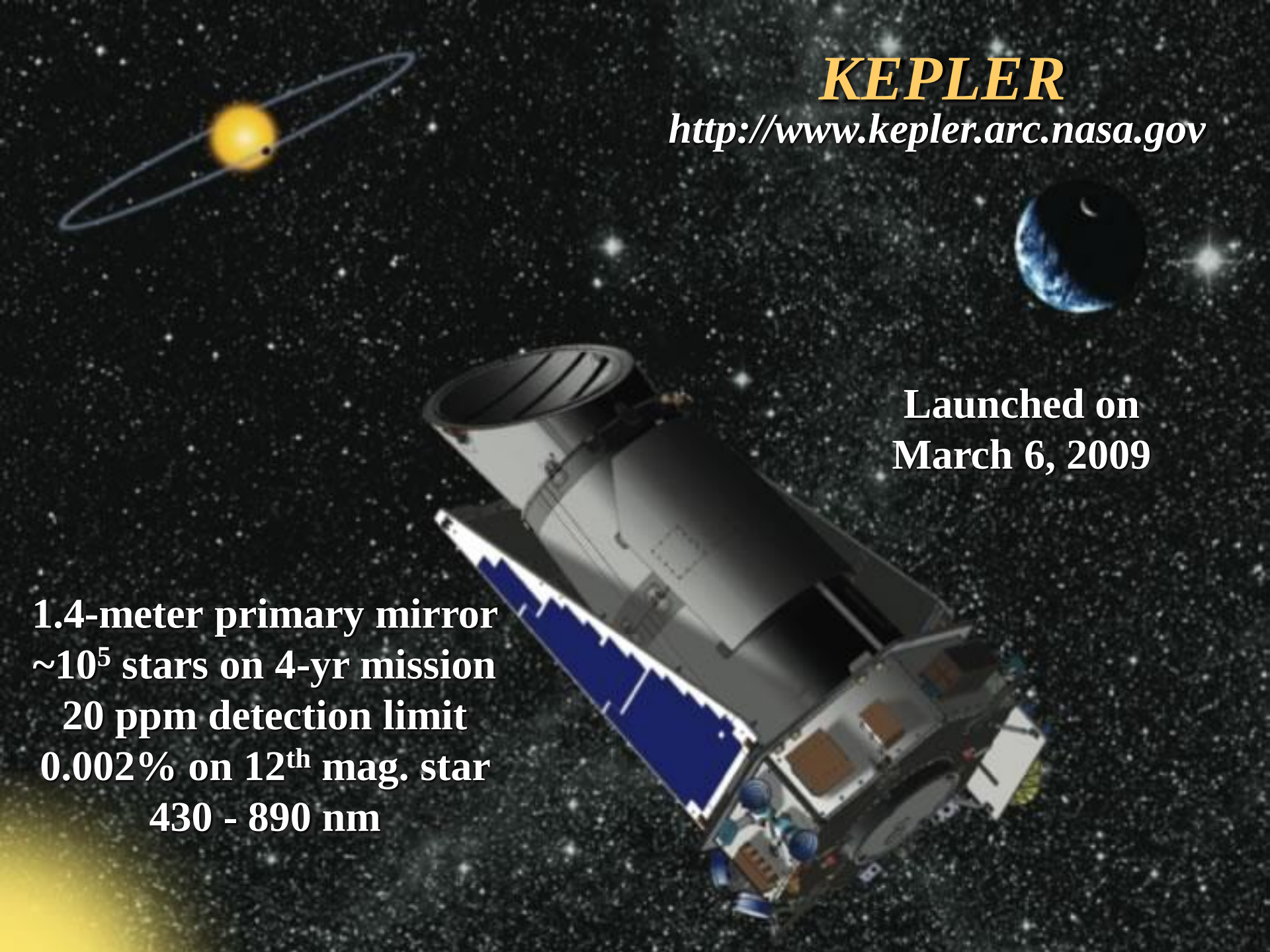
http://spacemath.gsfc.nasa.gov

Hubble Ultra Deep Field image showing ~10,000 galaxies

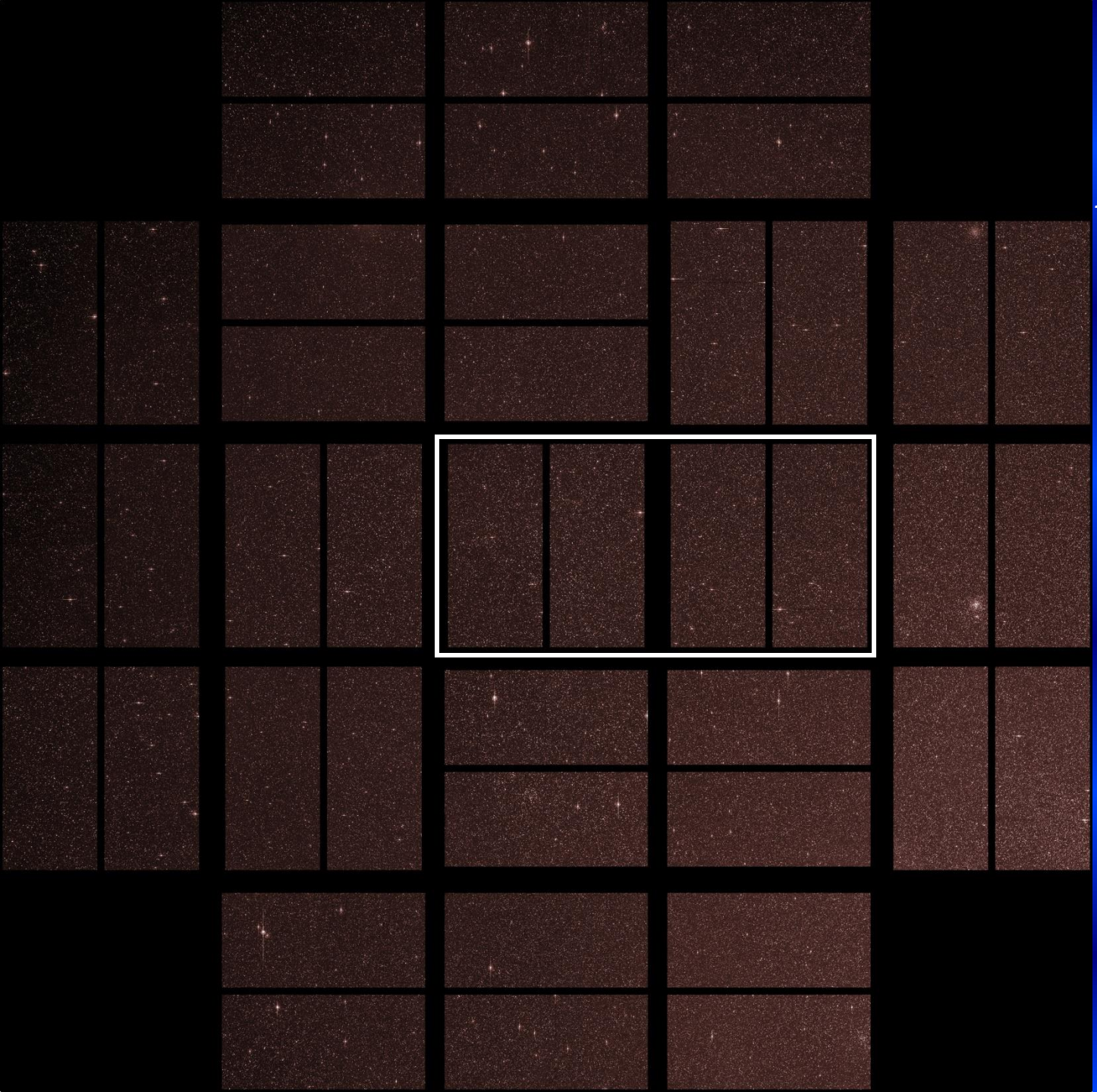

NGC 7331
~50 million light-years away


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

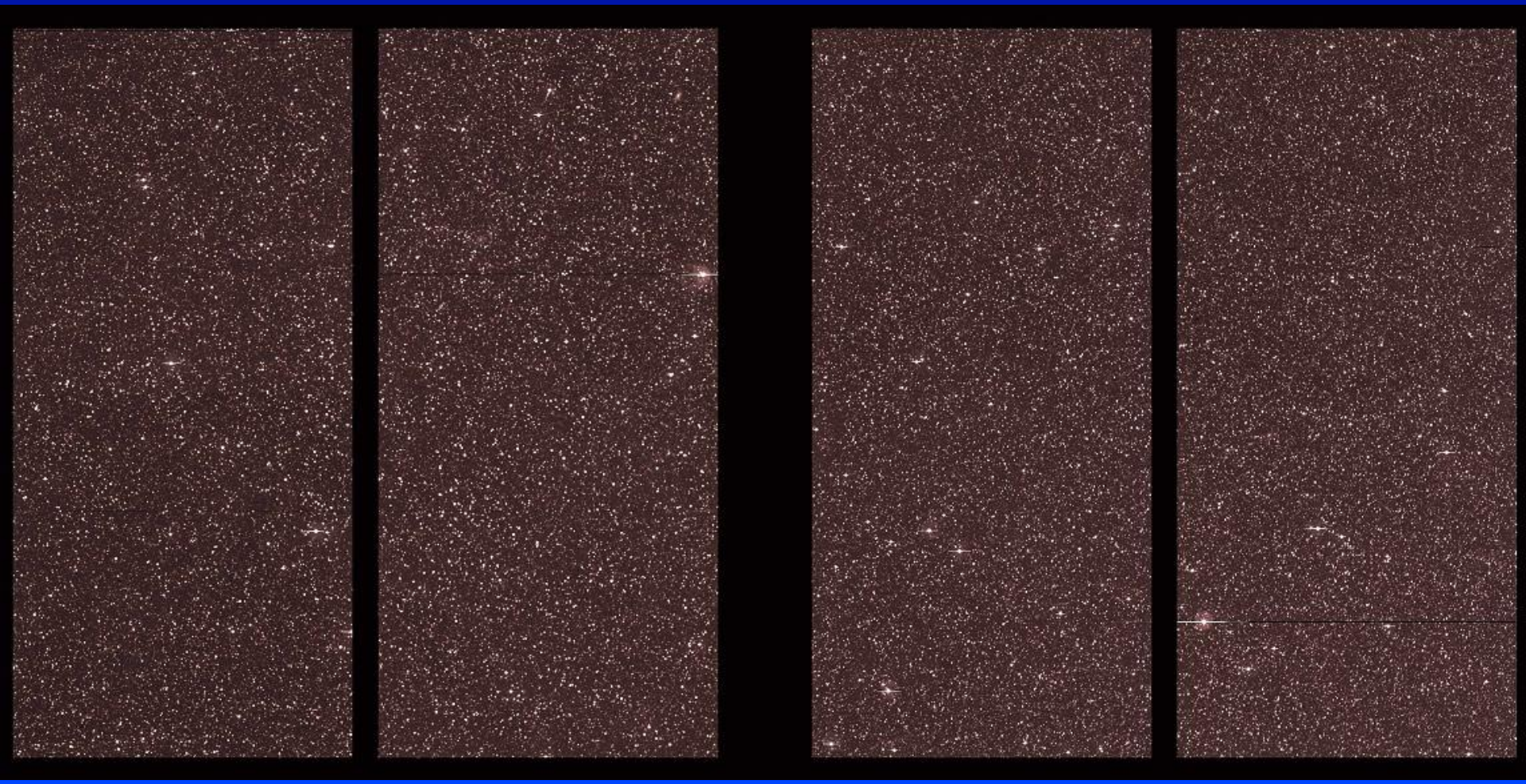

KEPLER
http://www.kepler.arc.nasa.gov
Launched on
March 6, 2009
1.4-meter primary mirror
~10^5 stars on 4-yr mission
20 ppm detection limit
0.002% on 12th mag. star
430 - 890 nm

Animation of NASA's *Kepler* spacecraft in orbit

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



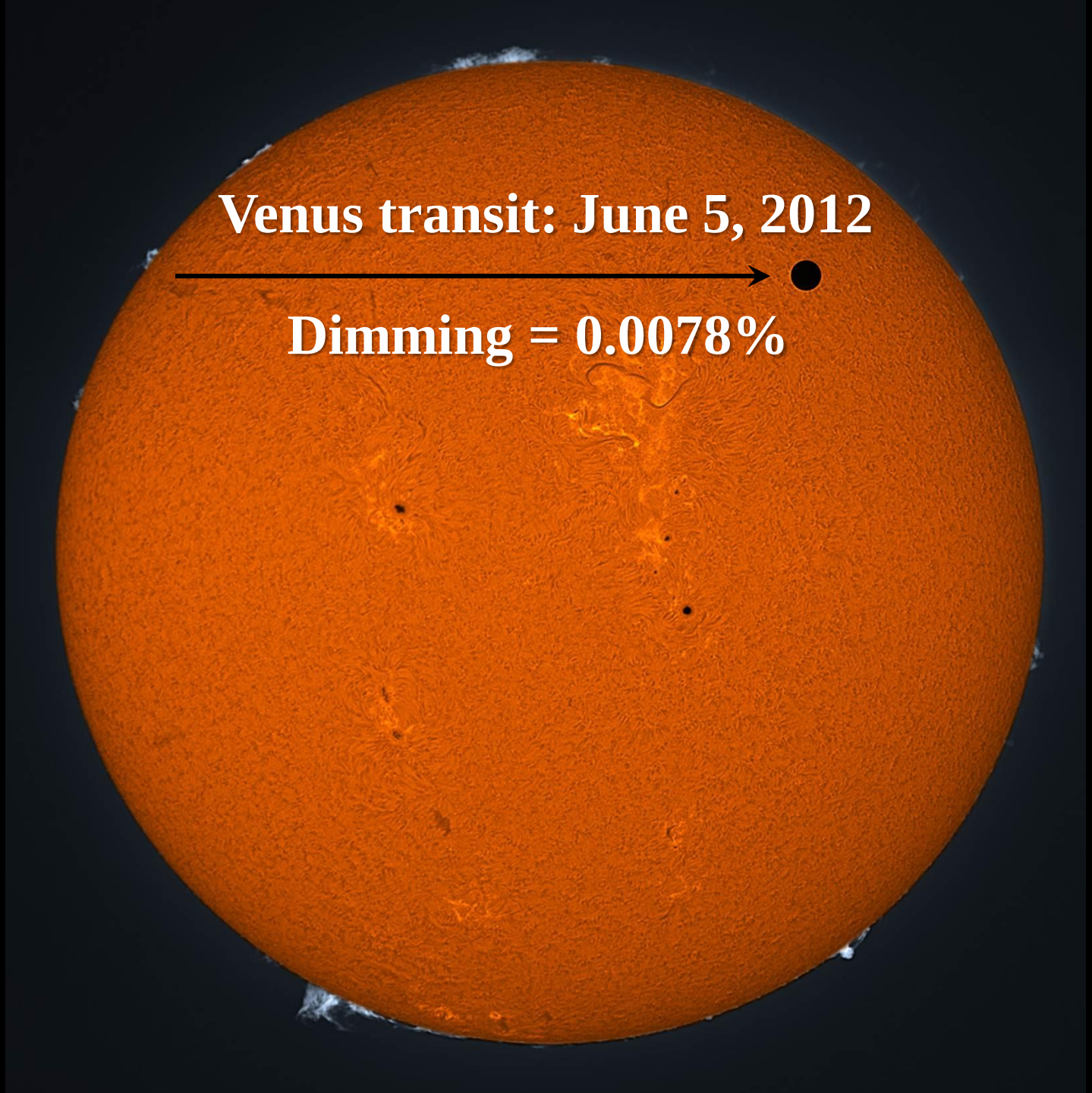
Kepler **images of stars being continuously monitored for variations in brightness**



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

Illustration of dimming caused by a transit

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


Venus transit: June 5, 2012
Dimming = 0.0078%

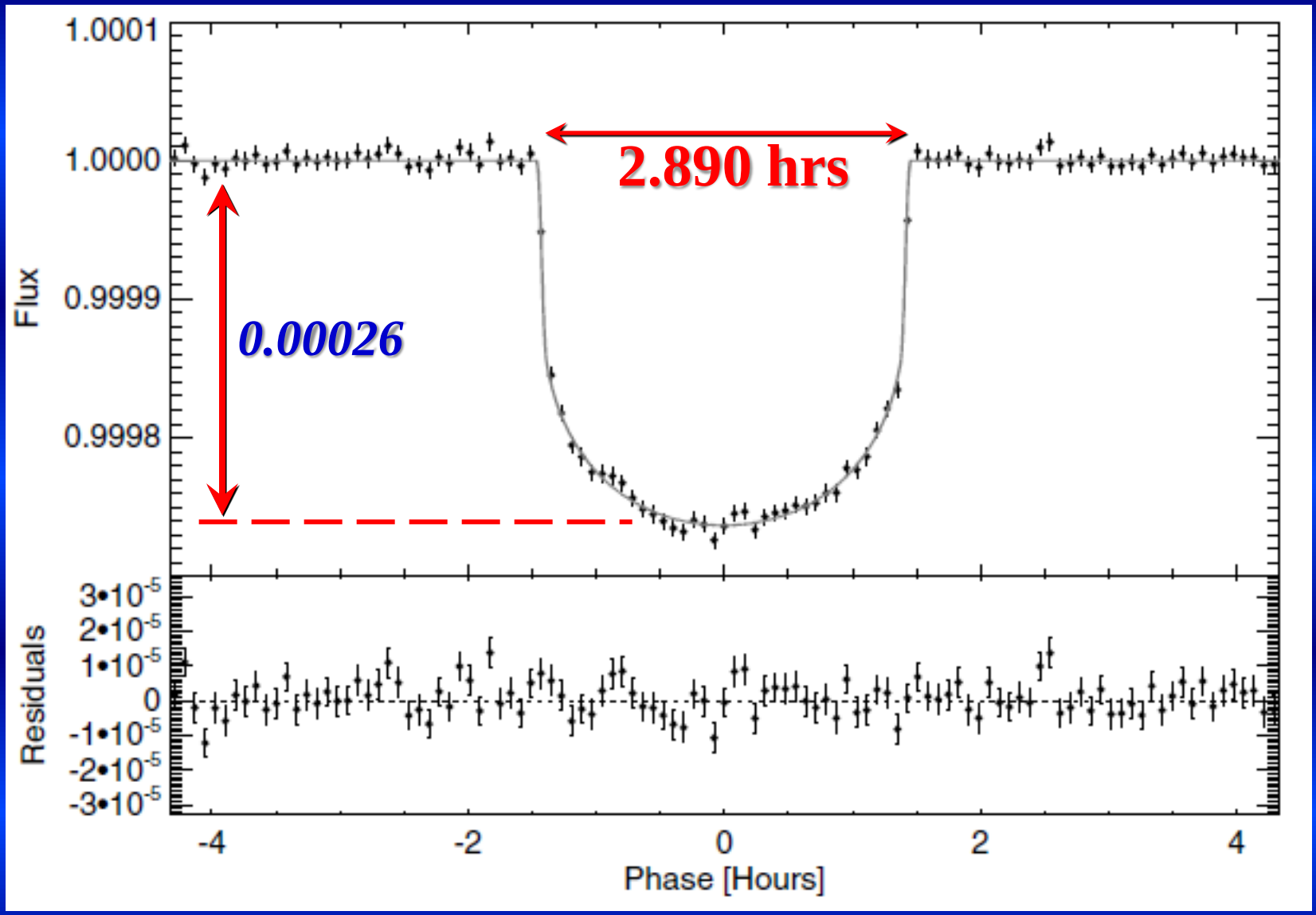
Exoplanets are (usually) not directly visible since they are lost in the glare of the host star

http://www.youtube.com/watch?v=88l2re9xW_4&feature=BFa&list=PL19C72465C51B6BE0

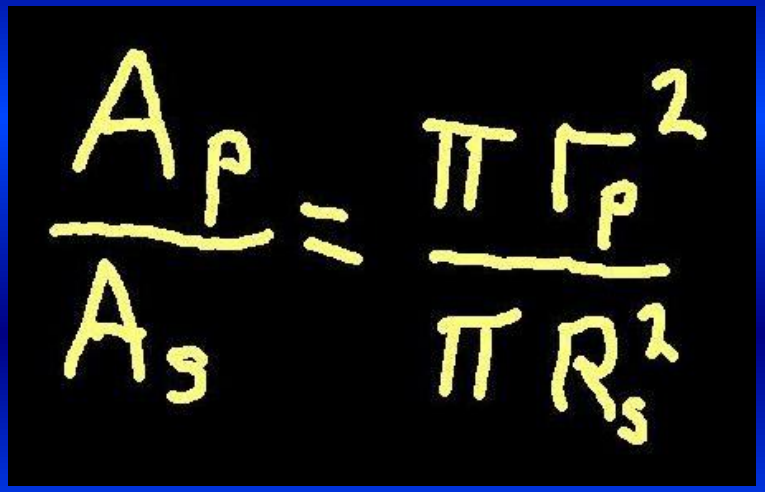
From Earth, the transiting planet dims the starlight during its transit.

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

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



S. Ballard, et al. (2014) *Kepler-93b: A terrestrial world measured to within 120 km, and test case for a new Spitzer observing mode.* Astrophysical Journal, 790, 16pp.



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

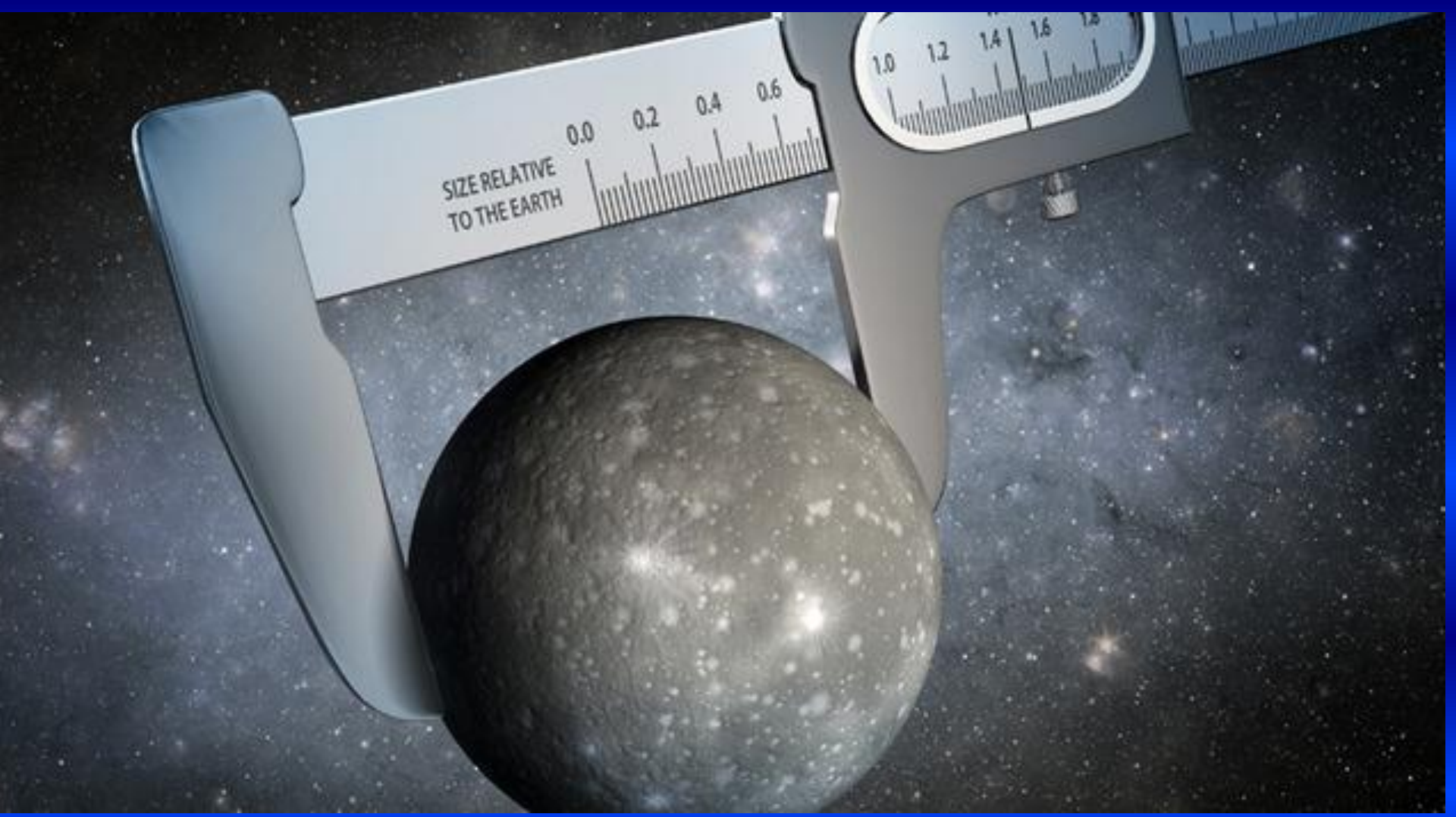
Initial brightness = 1.00000
Final brightness = 0.99974

Dimming = 0.00026
R_s = 639,000 km

$$0.00026 = \frac{(\text{Radius}_{\text{planet}})^2}{(639{,}000\ \text{km})^2}$$

$$(\text{Radius}_{\text{planet}})^2 = 0.00026 * (639{,}000\ \text{km})^2$$

$(\text{Radius}_{\text{planet}})$ = 10,300 km = 1.6x $\text{Radius}_{\text{Earth}}$



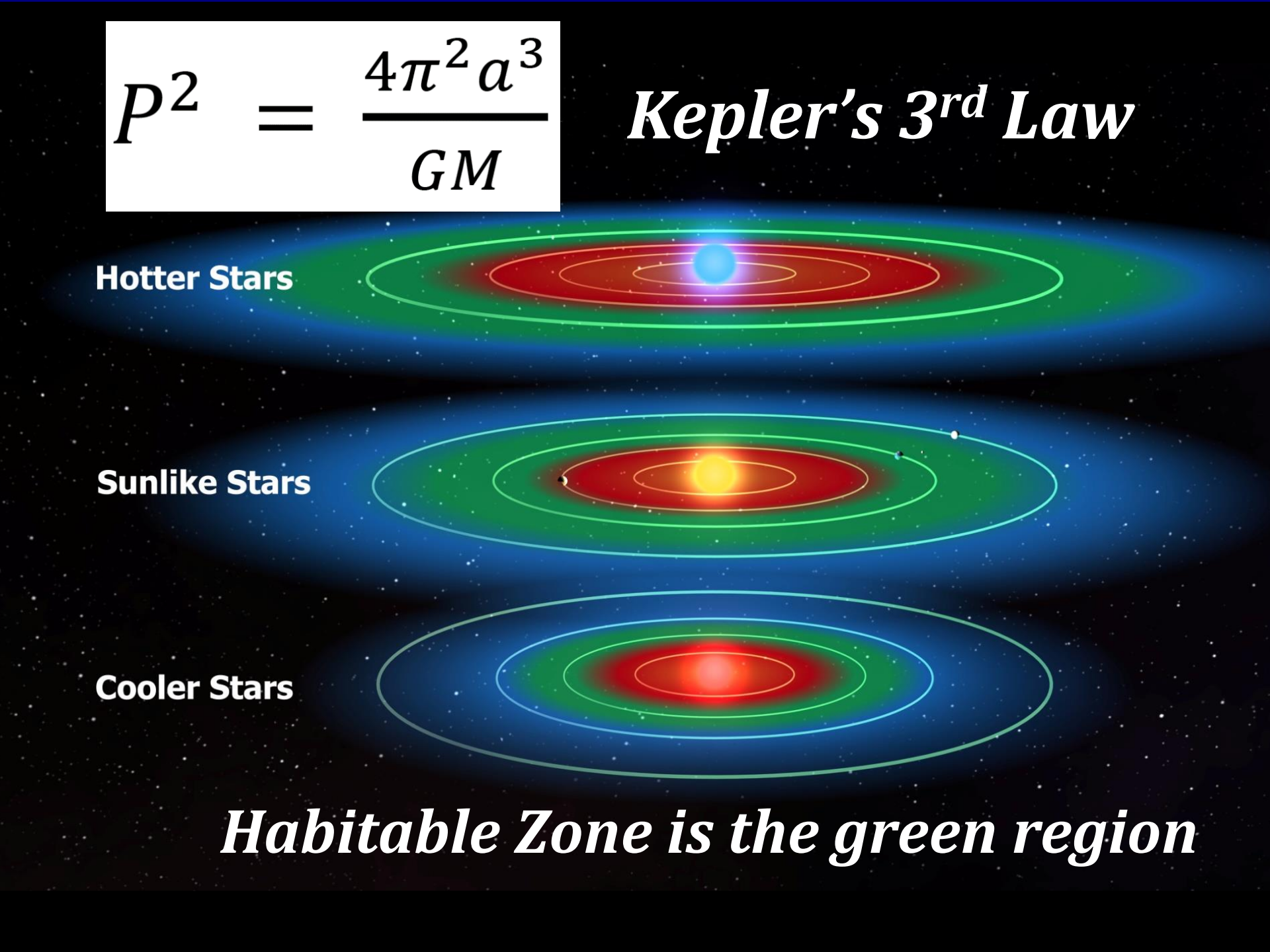
Kepler-93b **1.481 ± 0.019 R_{earth}** **~300 ly**

Density = 6.3 ± 2.6 g/cm^3 **4.7267398 Earth-days**

T ~ 1400°F **6.6 ± 0.9 Gy** **3.8 ± 1.5 M_{earth}**

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

Kepler's 3rd Law

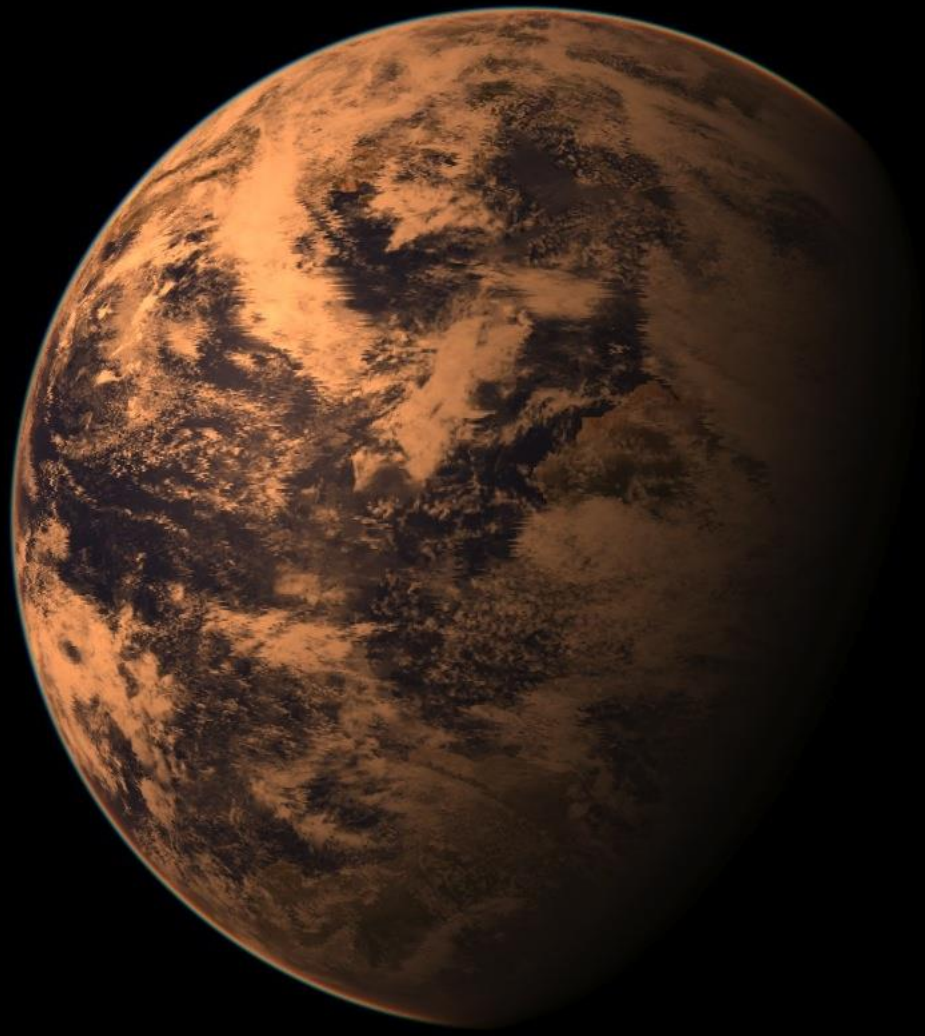


Habitable Zone is the green region

Gliese 667C c ($4.54\ M_{\oplus}$)

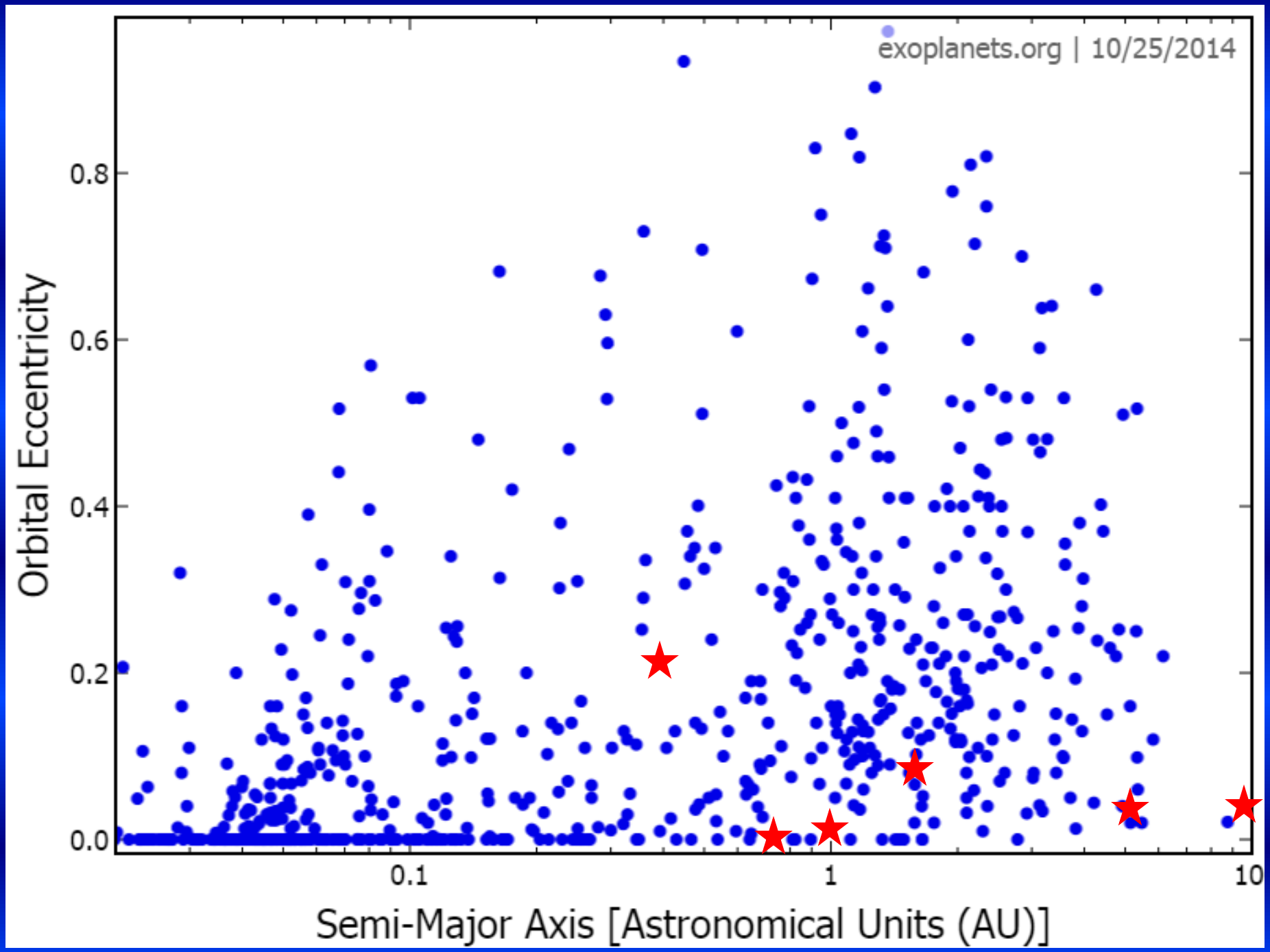
Earth

Mars

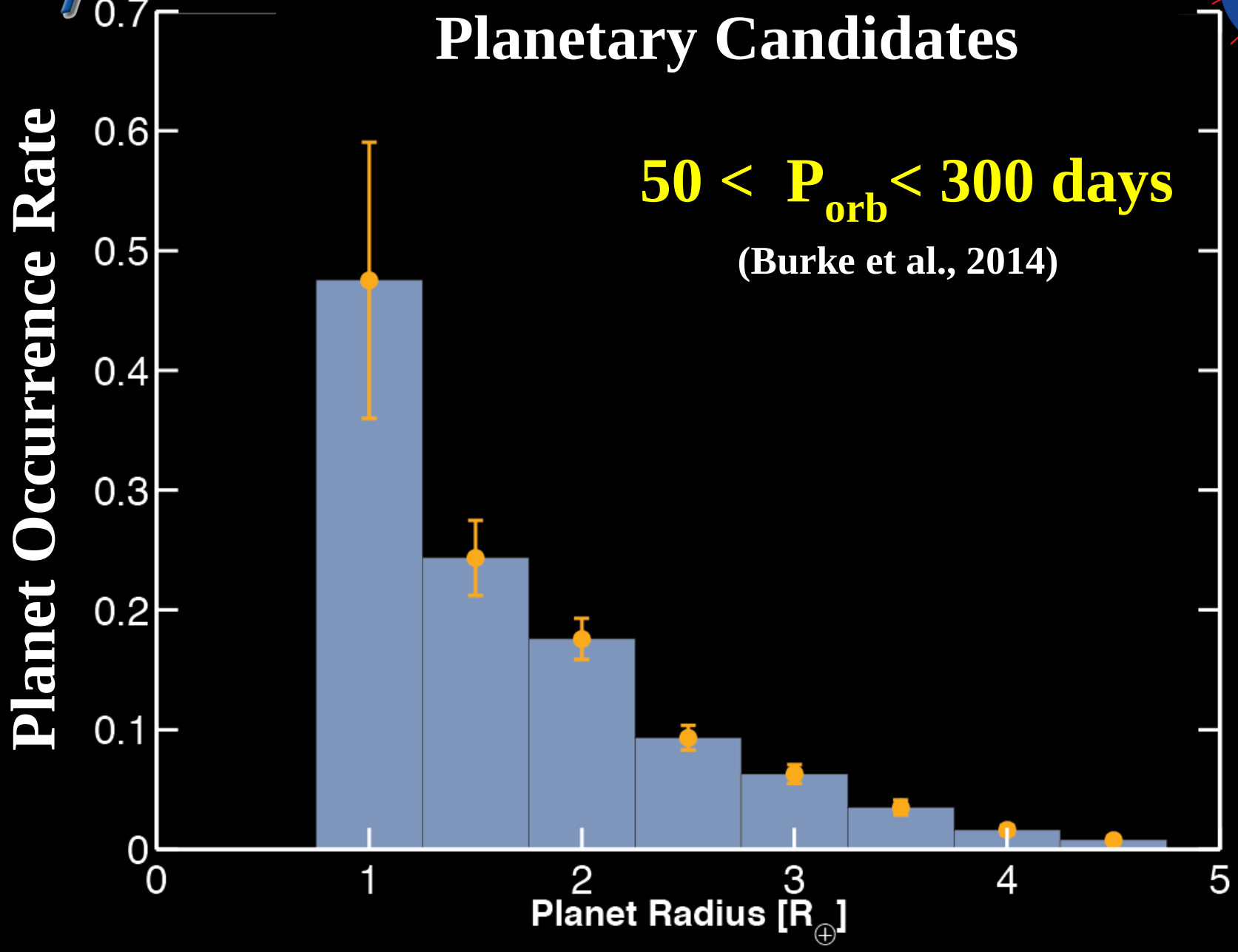


CREDIT: PHL @ UPR Arecibo (phl.upr.edu)


Gliese 667Cc at 22.1 light years

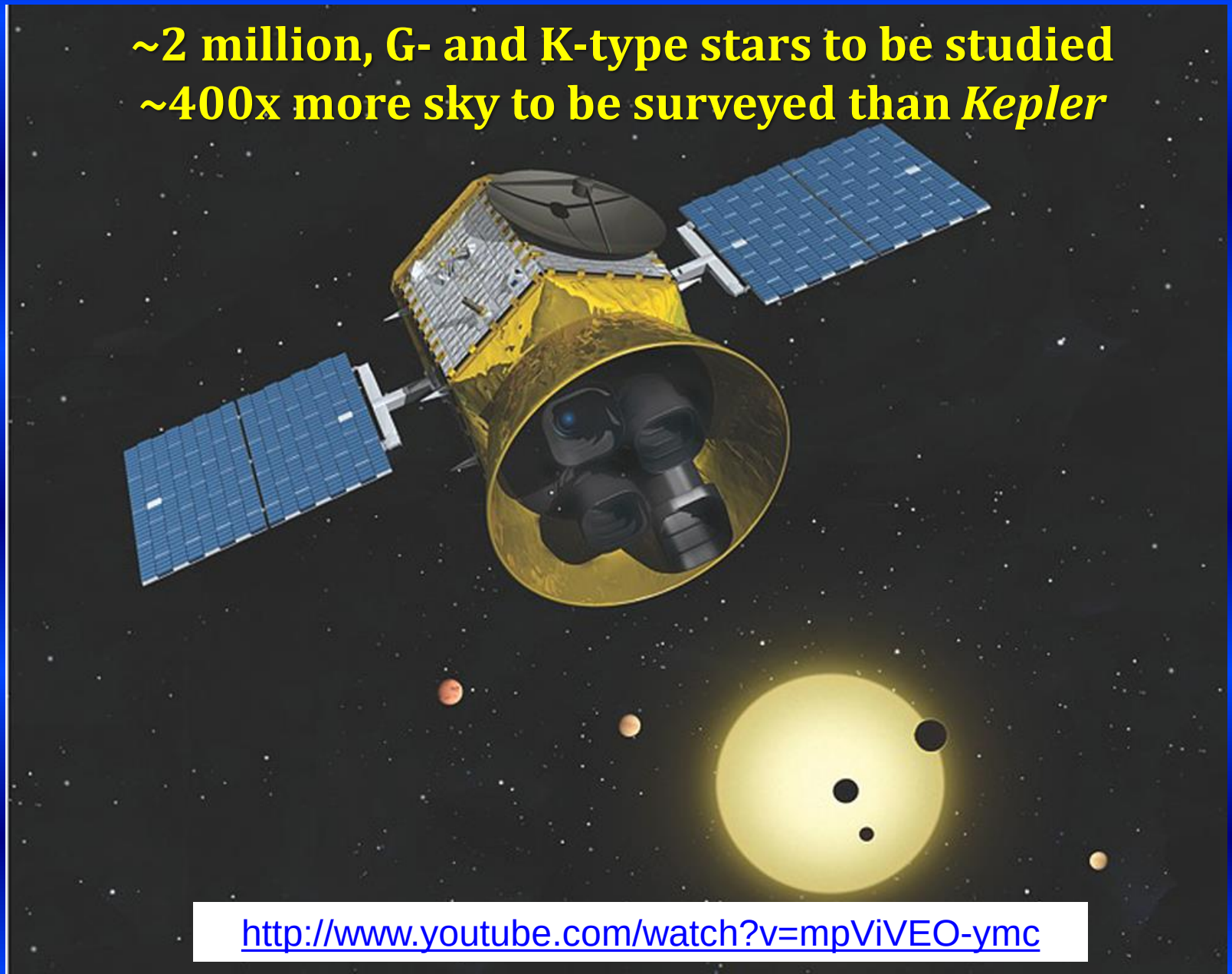

exoplanets.org | 10/25/2014
Orbital Eccentricity
0.0
0.2
0.4
0.6
0.8
0.1
1
10
Semi-Major Axis [Astronomical Units (AU)]

Estimated Occurrence Rate of Planetary Candidates



Habitable exomoon by Dan Durda

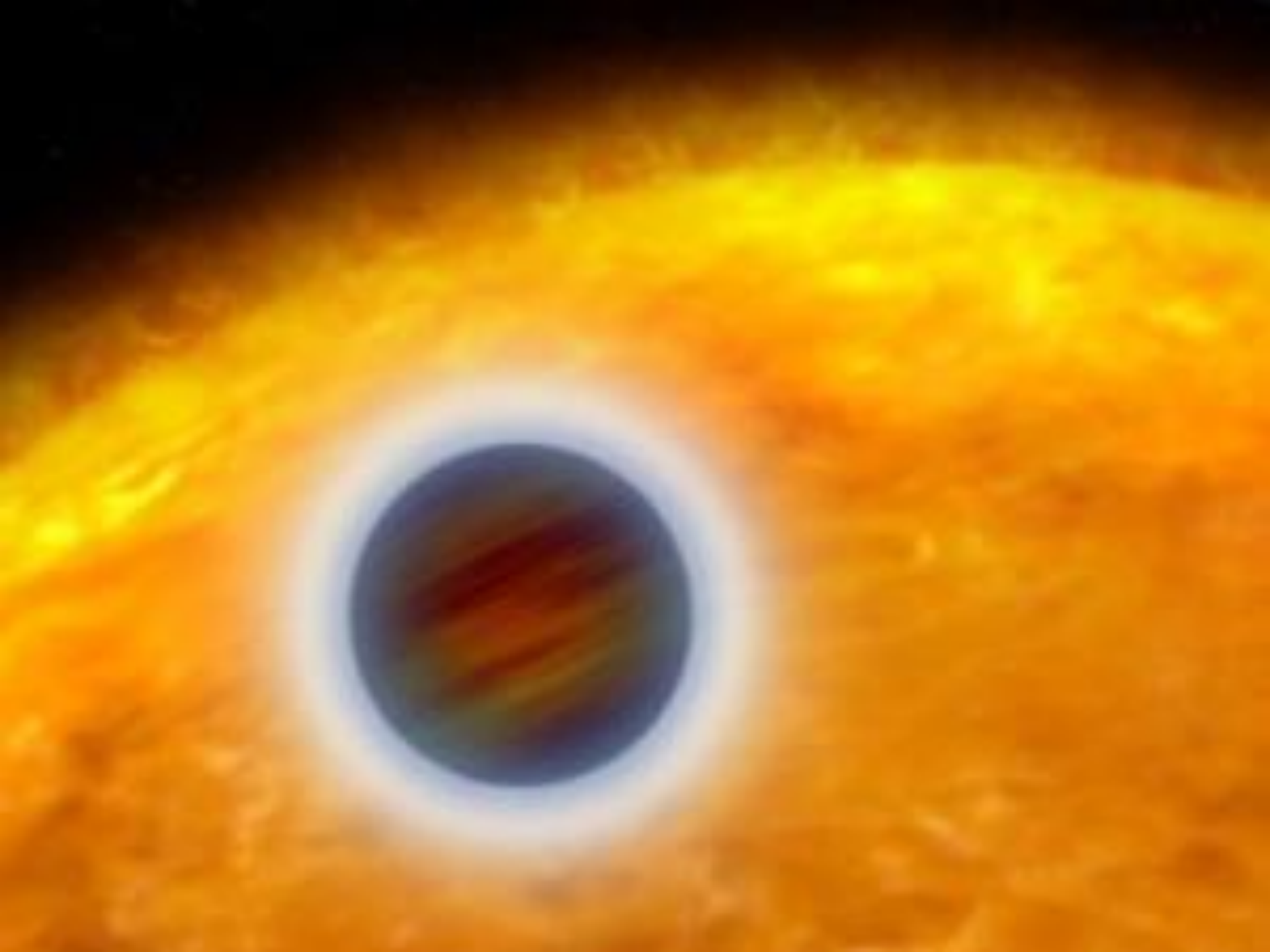
TESS = Transiting Exoplanet Survey Satellite (launch in 2017)



Starshade Concept

- Contrast and inner working angle are decoupled from the telescope aperture size
  - A simple space telescope can be used
  - No wavefront correction is needed
- No outer working angle

http://www.jpl.nasa.gov/video/?id=1284



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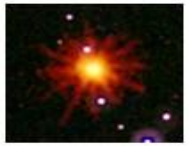

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Important points

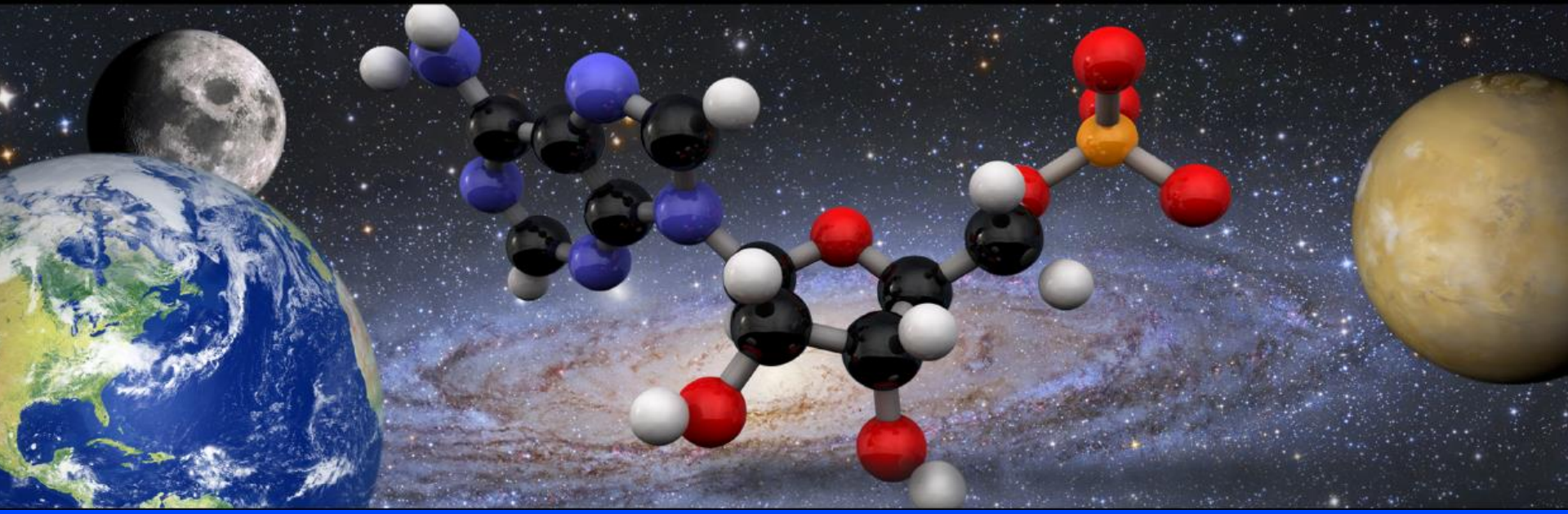
- **Planets are common and diverse in the galaxy**
- **Planets (≤10x Earth-mass) are common**
- **Estimate of 10^9-10^{10} habitable planets in our galaxy**
- **Low eccentricity orbits are *not* common**
- **Characteristics that define 'habitability' include …**

semi-major axis of orbit within *Goldilock's* zone
stable, long-lived stars (F, G, and maybe K, M)
absence of tidal lock (?)
size of planet (~0.5 - 5x Earth-mass)
age of planetary system
environmental cycling of elements (e.g., tectonics)
presence of magnetic field (?)
planetary albedo and atmospheric composition
tilt of planet's axis of rotation (obliquity)

Image from Chang'e 5 T1

We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know that place for the first time.

T. S. Eliot in *"Four Quartets"*



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