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### NASA's search for life beyond the Earth

John W. Delano Prof  
*UAlbany*, [jdelano@albany.edu](mailto:jdelano@albany.edu)

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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*

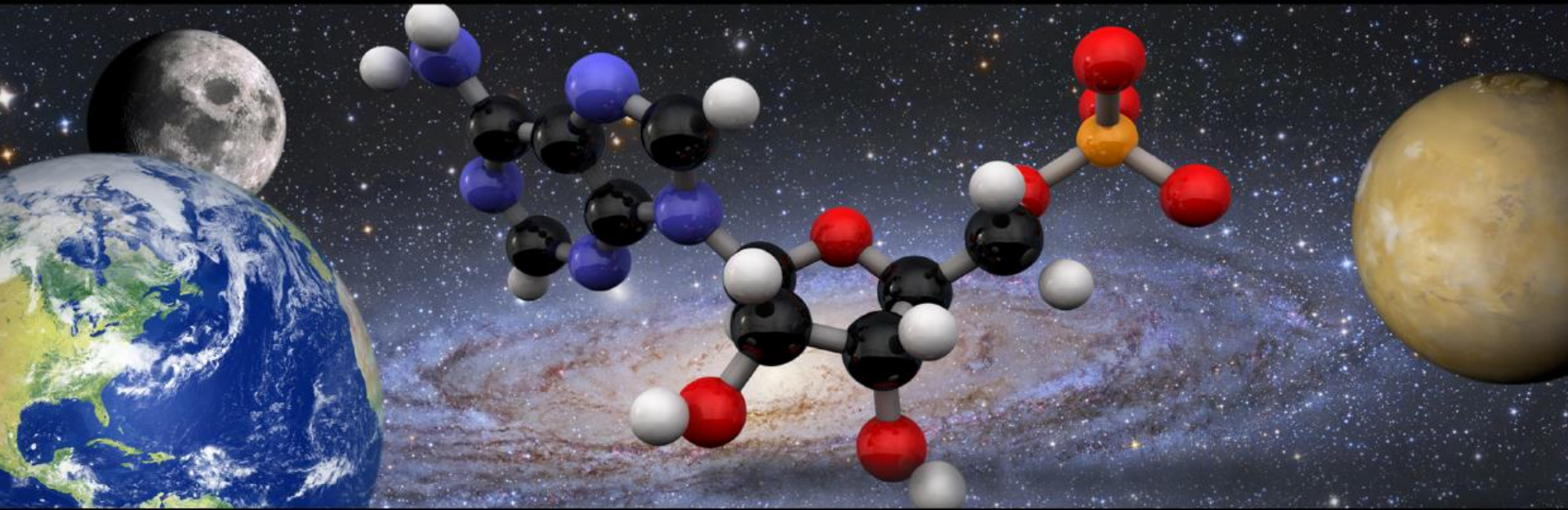
*Somewhere there's a planet  
Beneath an alien star  
The people watch our tiny sun  
And wonder where we are*

*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***

***John W. Delano, Ph.D.***

***Distinguished Teaching Professor Emeritus  
Associate Dean, College of Arts and Sciences  
University at Albany (SUNY)***

***[jdelano@albany.edu](mailto:jdelano@albany.edu)***

*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)

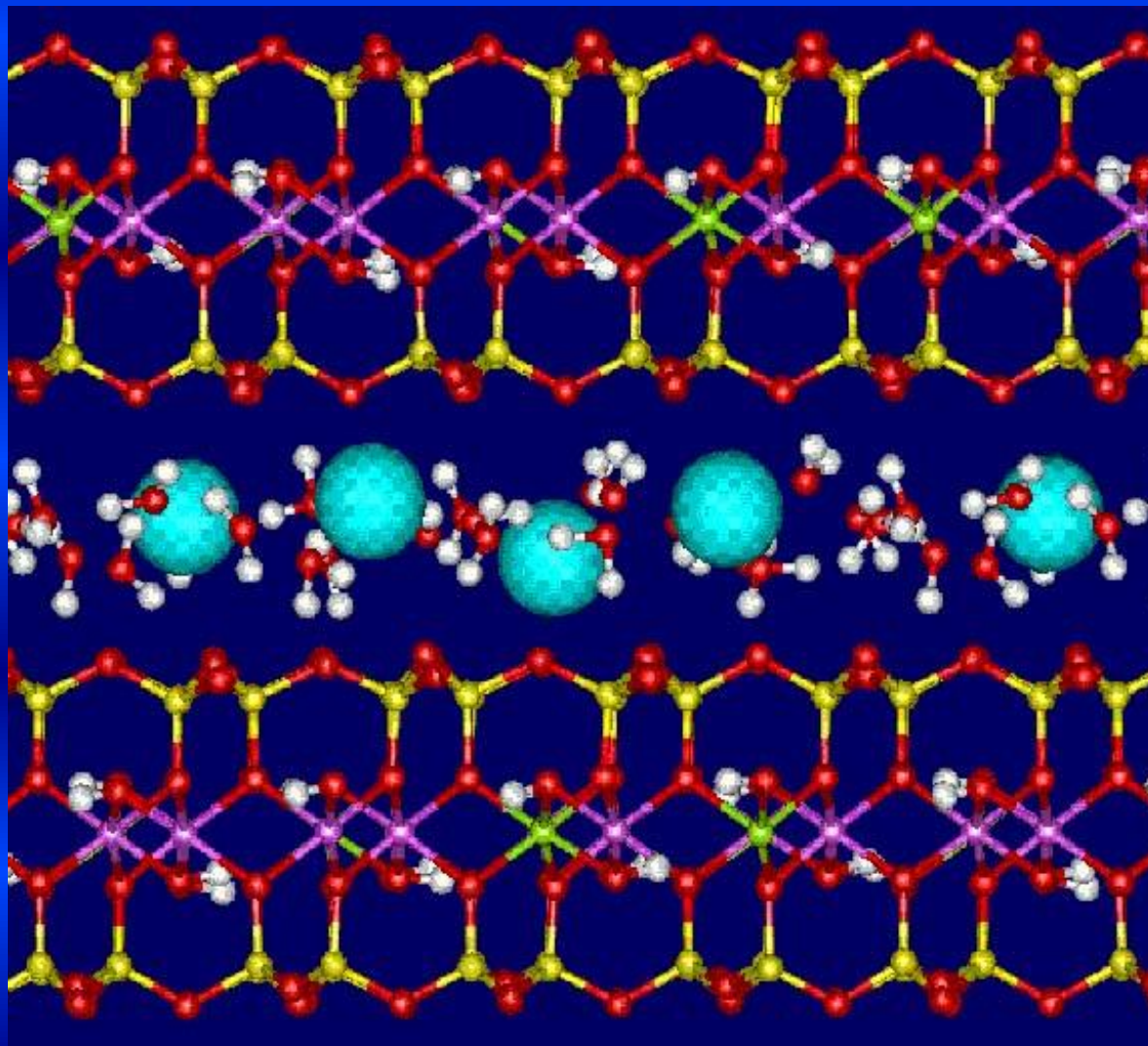




# Montmorillonite

- O
- Si
- Al

- Na, Ca
- H
- Mg, Fe



~1.4 nm

Interlayer  
with cation  
and H<sub>2</sub>O

~0.9 nm





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

# Data for exoplanets prior to 1995

Planetary Radius [Jupiter Radii]

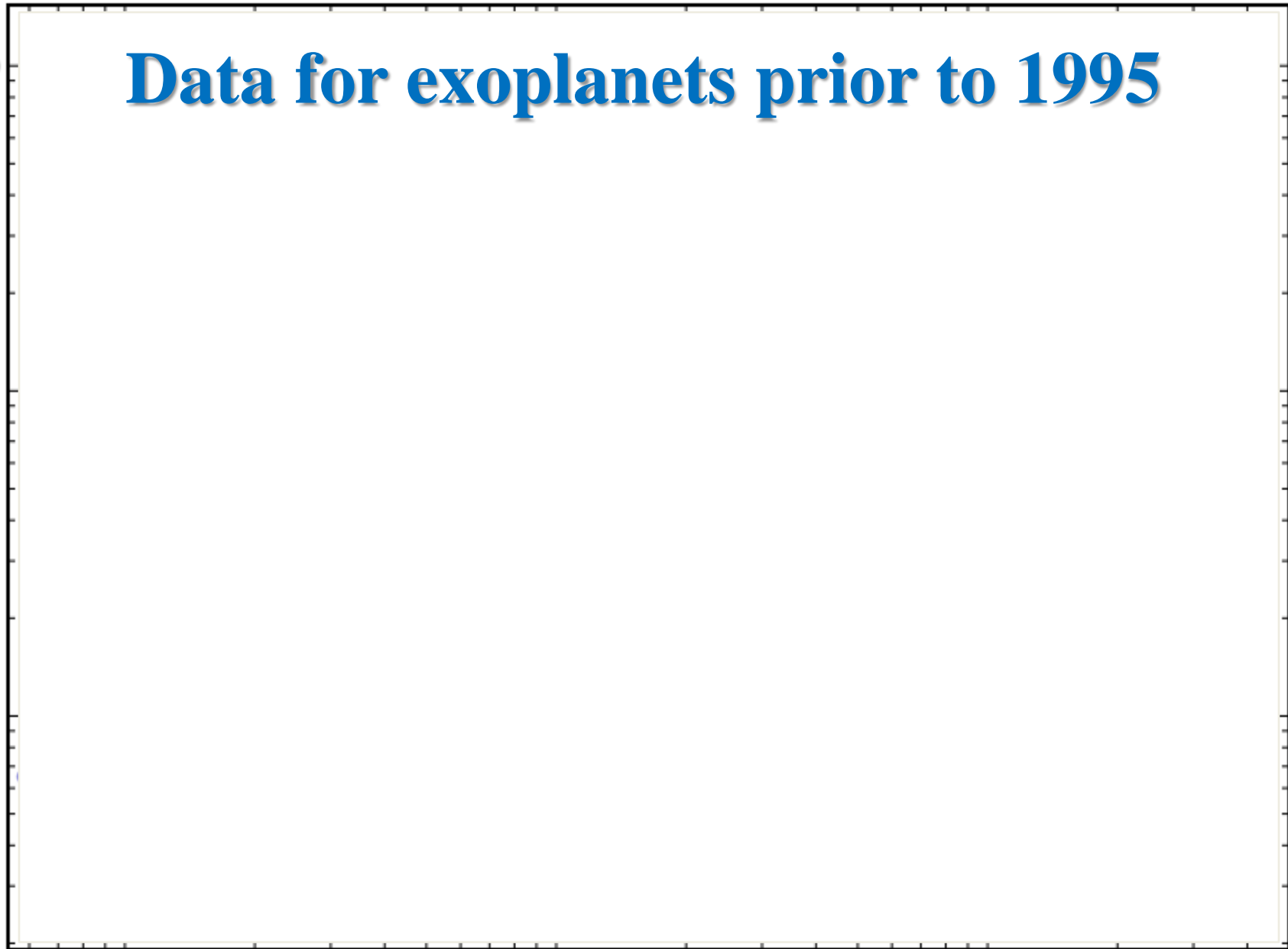
10  
1  
0.1

0.01

0.1

1

Semi-Major Axis [Astronomical Units (AU)]





Planetary Radius [Jupiter Radii]

10  
1  
0.1

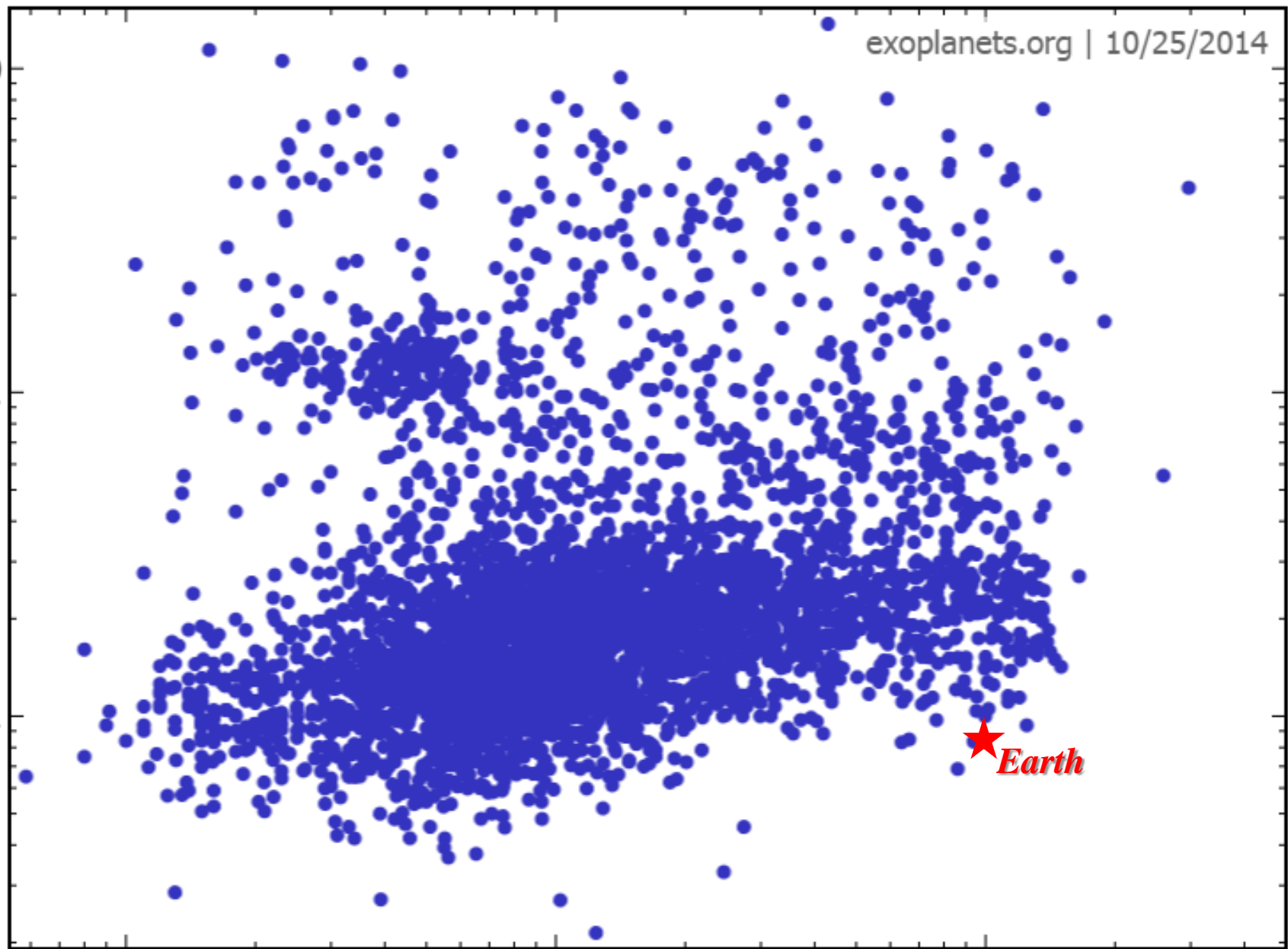
0.01

0.1

1

Semi-Major Axis [Astronomical Units (AU)]

★ *Earth*





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# Space Math @ NASA

Math

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## Space Math @ NASA

SpaceMath@NASA introduces students to the use of mathematics in today's scientific discoveries. Through press releases and other articles, we explore how many kinds of mathematics skills come together in exploring the universe.

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## Math in the News

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## Math Videos



NASA 4-minute videos featuring math resources [\[click here\]](#)

## Problem Archives

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- [Problems 343 to Current](#)

## Partnerships

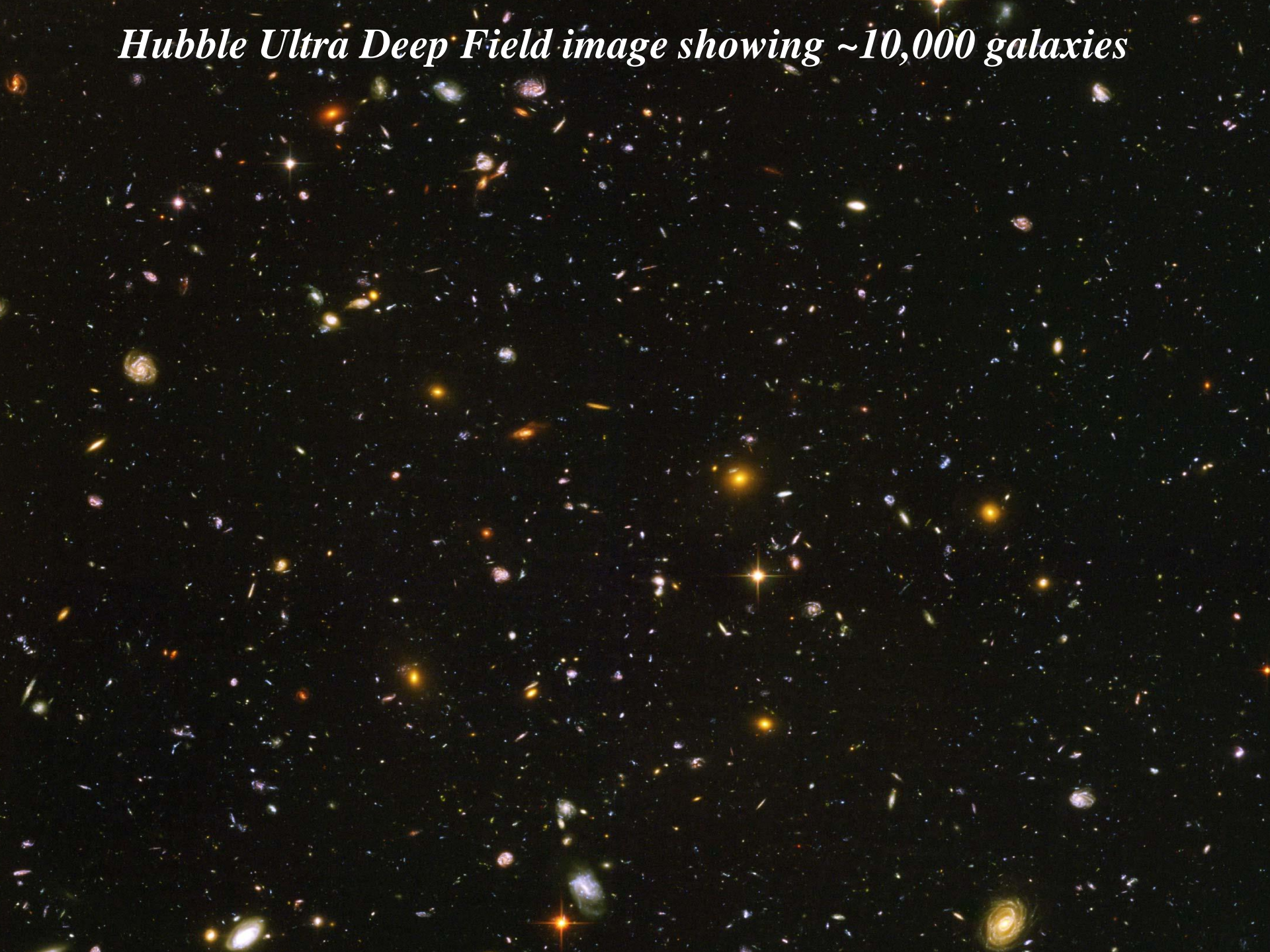


Sun-Earth Day  
Featuring  
Technology  
Through Time  
Essays

<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 12<sup>th</sup> mag. star  
430 - 890 nm**

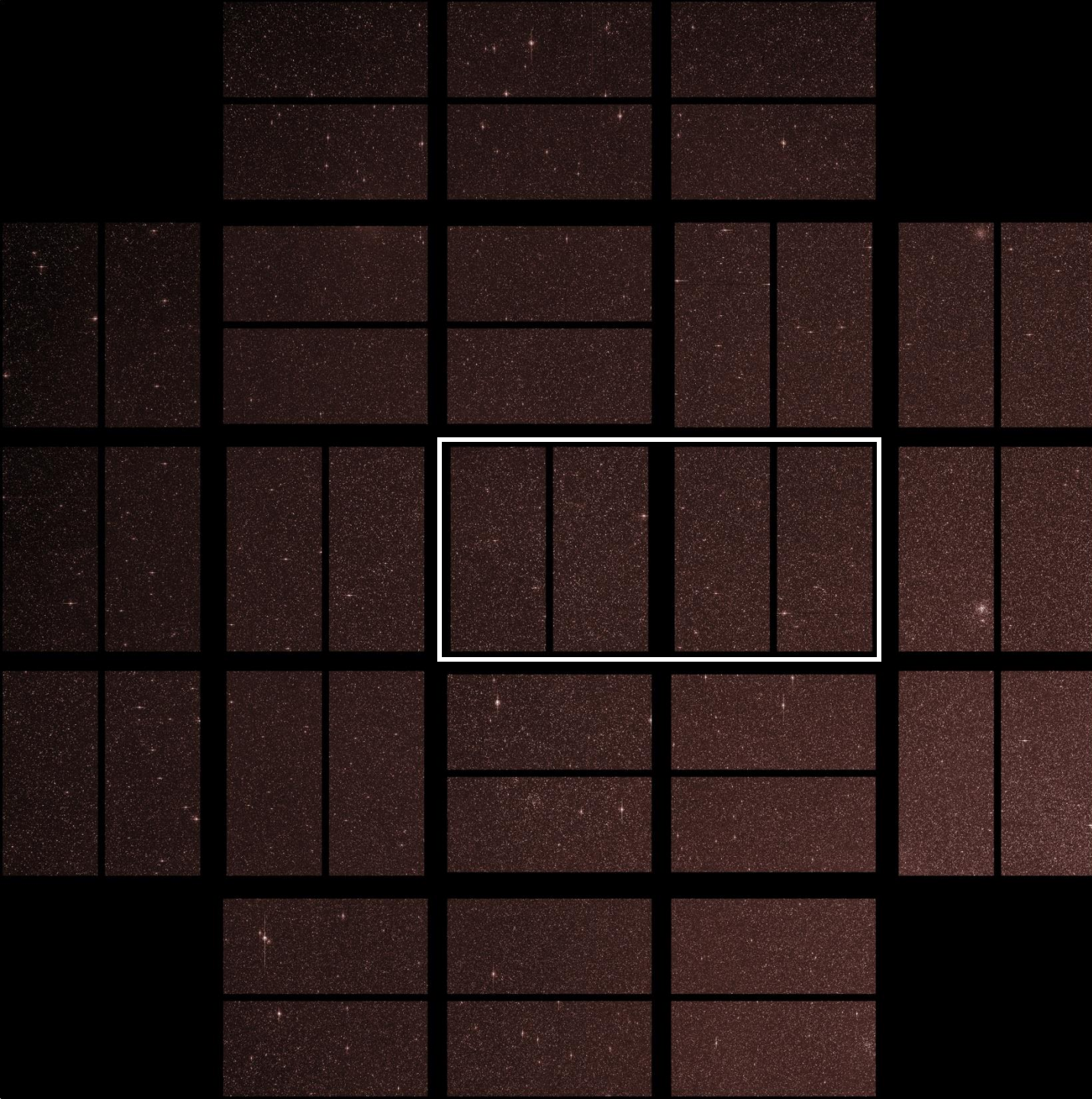




# Animation of NASA's *Kepler* spacecraft in orbit

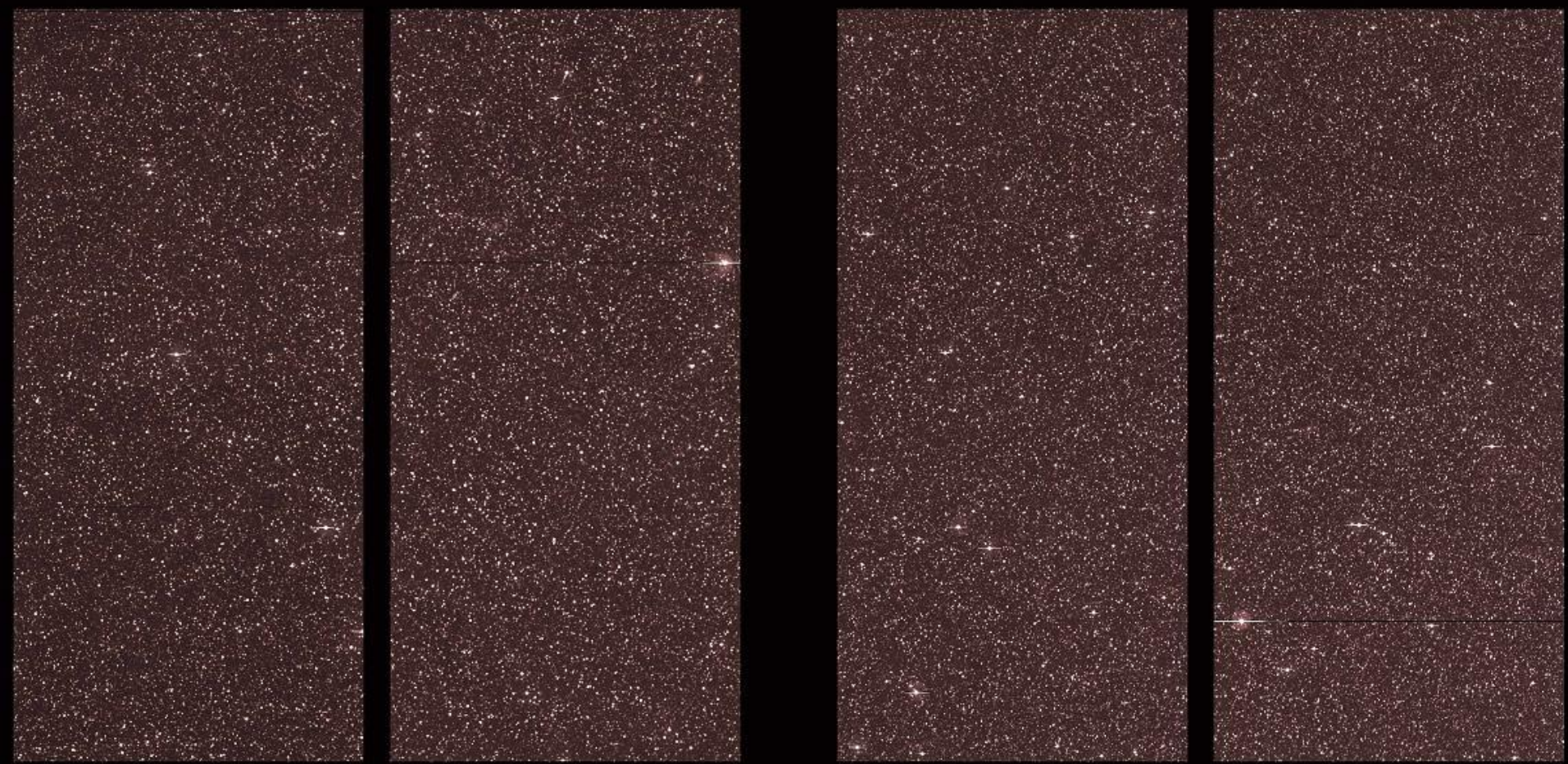
<http://www.youtube.com/watch?v=54fnbJ1hZik>





*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>

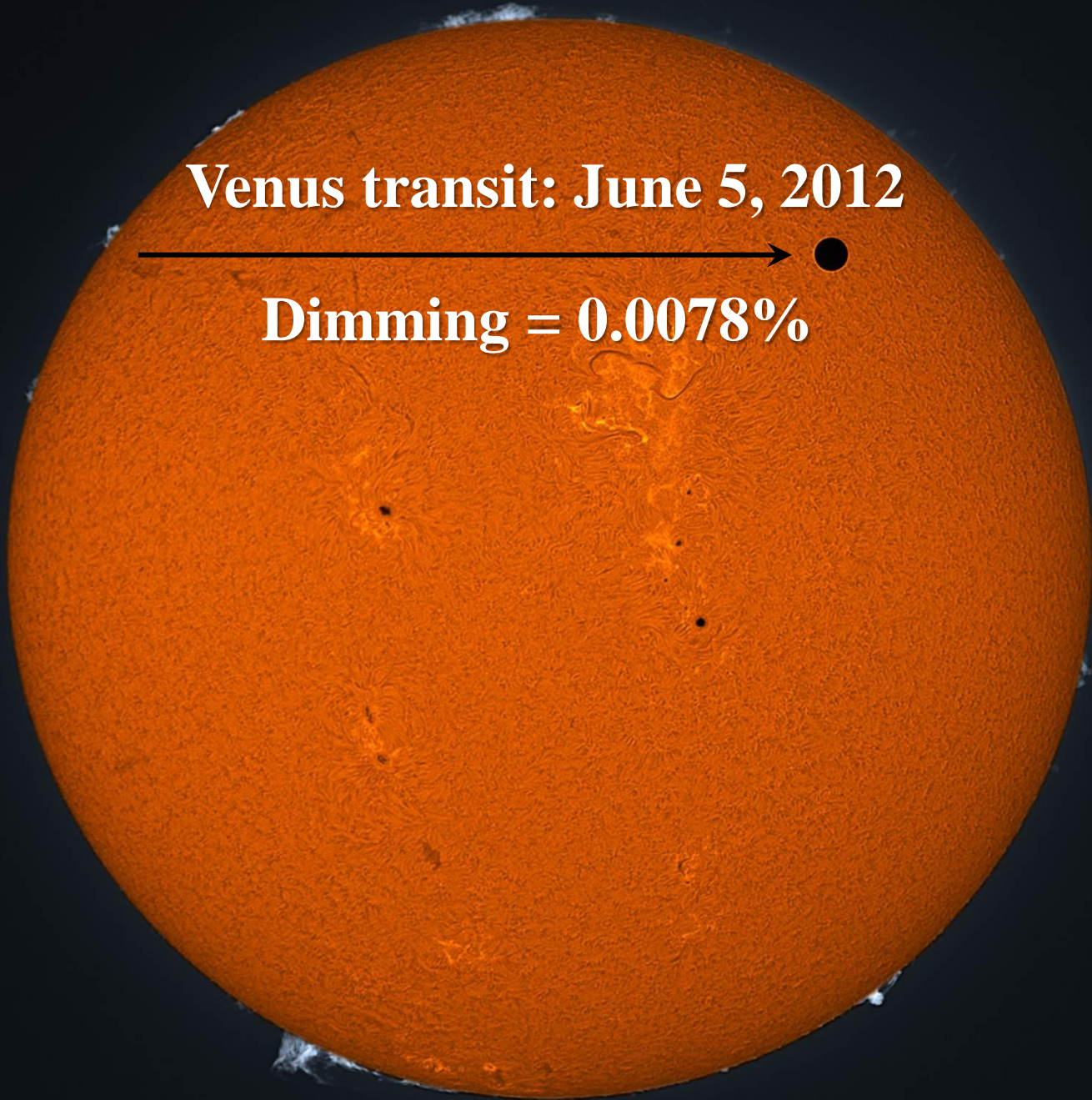




Venus transit: June 5, 2012

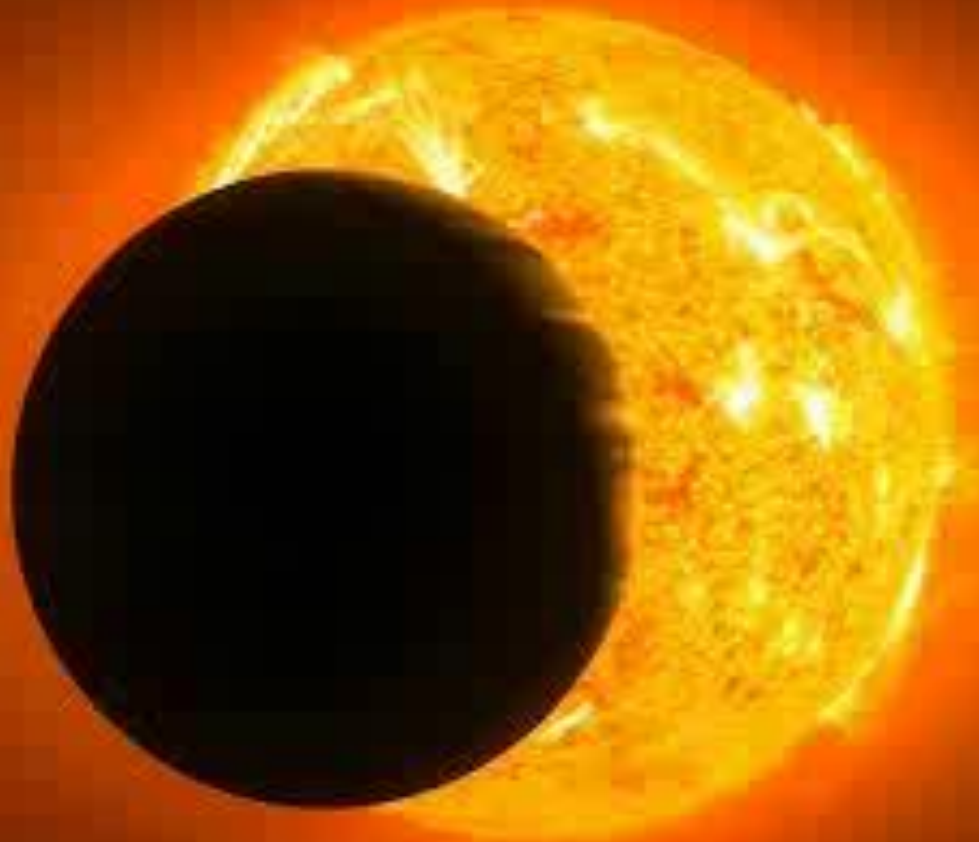


Dimming = 0.0078%



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



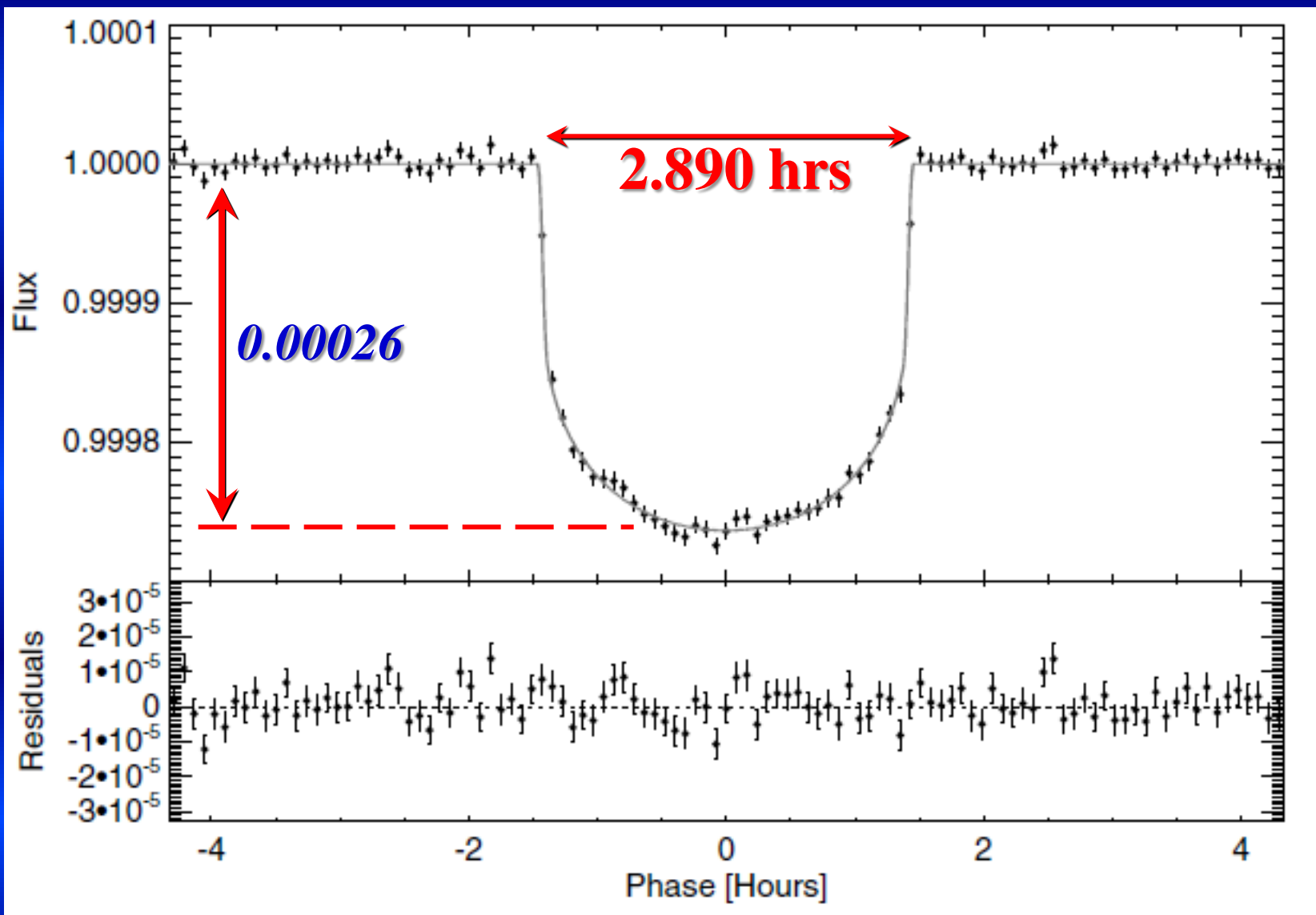




**From Earth, the transiting planet dims the starlight during its transit.**

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

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



**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

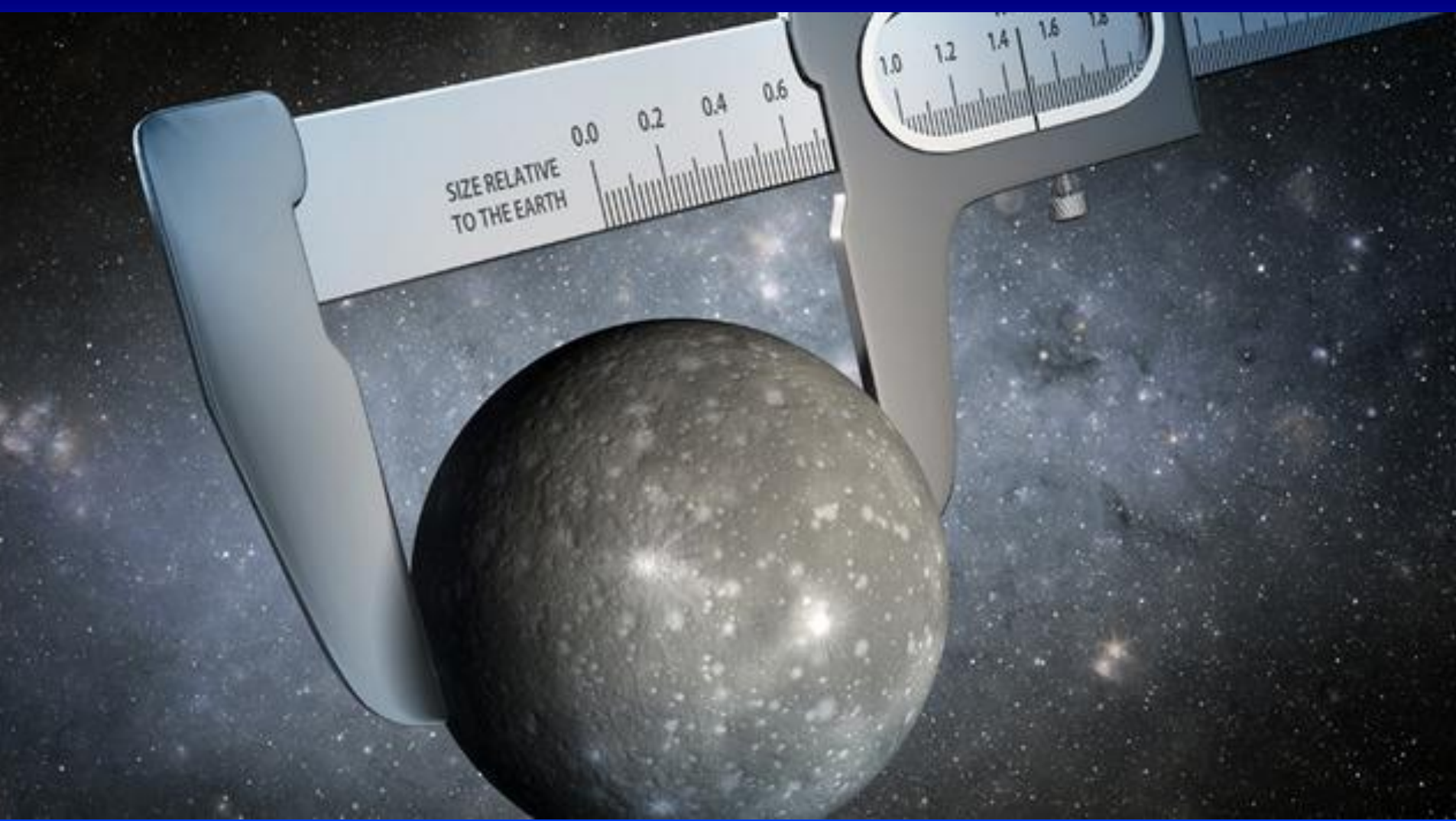
Dimming = 0.00026

$R_s = 639,000$  km

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

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

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



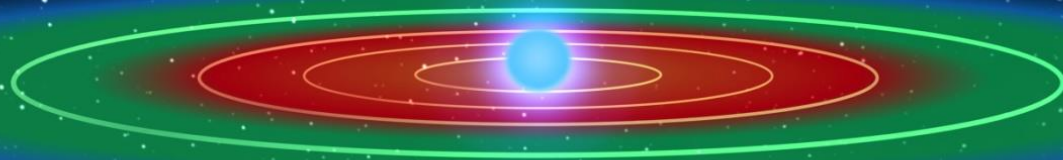
**Kepler-93b**       $1.481 \pm 0.019 R_{\text{earth}}$        $\sim 300 \text{ ly}$   
**Density =  $6.3 \pm 2.6 \text{ g/cm}^3$**       **4.7267398 Earth-days**  
**T  $\sim 1400^\circ\text{F}$**        **$6.6 \pm 0.9 \text{ Gy}$**        **$3.8 \pm 1.5 M_{\text{earth}}$**



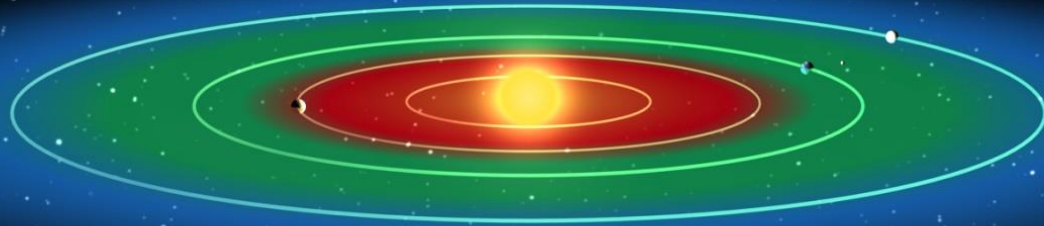
$$P^2 = \frac{4\pi^2 a^3}{GM}$$

## *Kepler's 3<sup>rd</sup> Law*

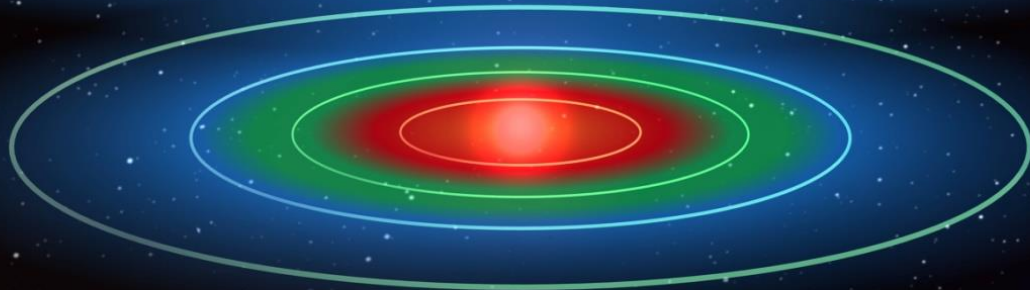
**Hotter Stars**



**Sunlike Stars**



**Cooler Stars**



*Habitable Zone is the green region*

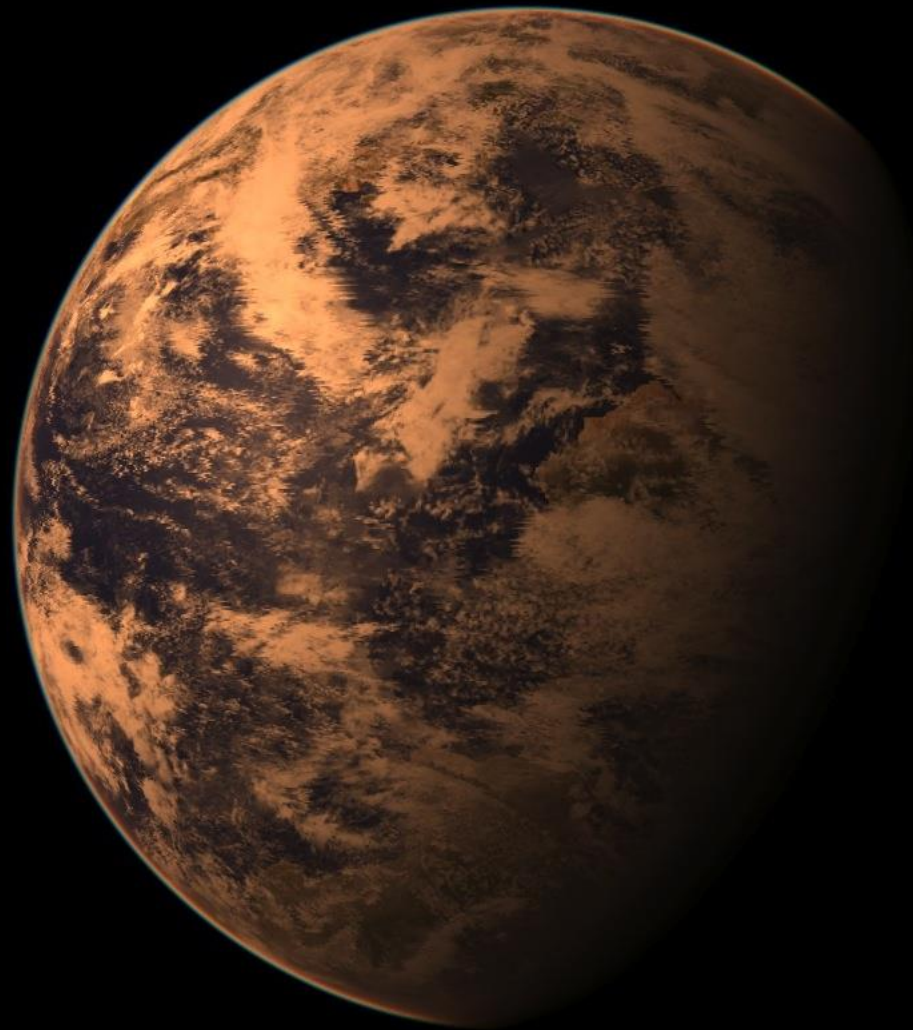
# Gliese 667C c (4.54 $M_{\oplus}$ )



Earth



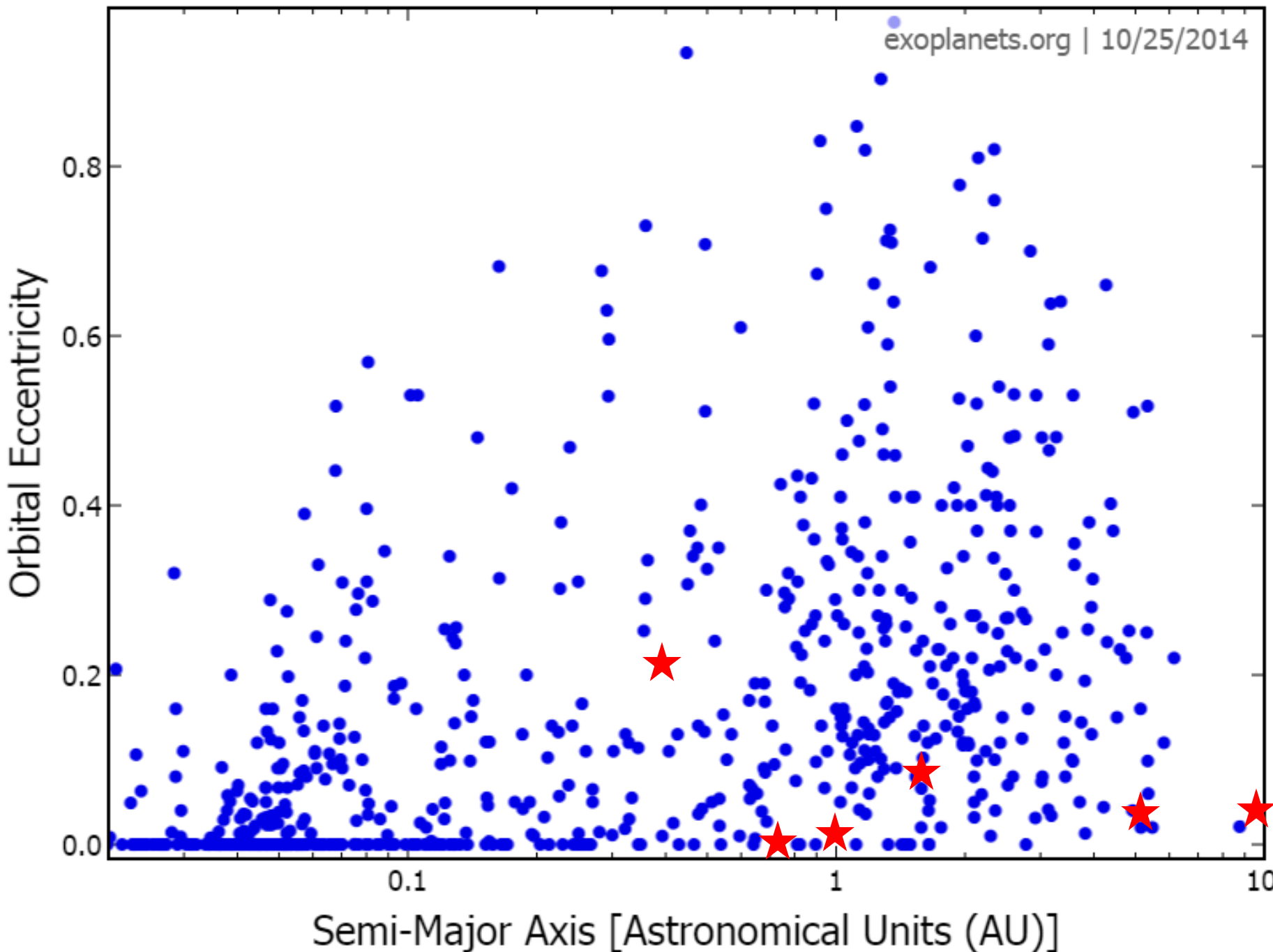
Mars







*Gliese 667Cc at 22.1 light years*



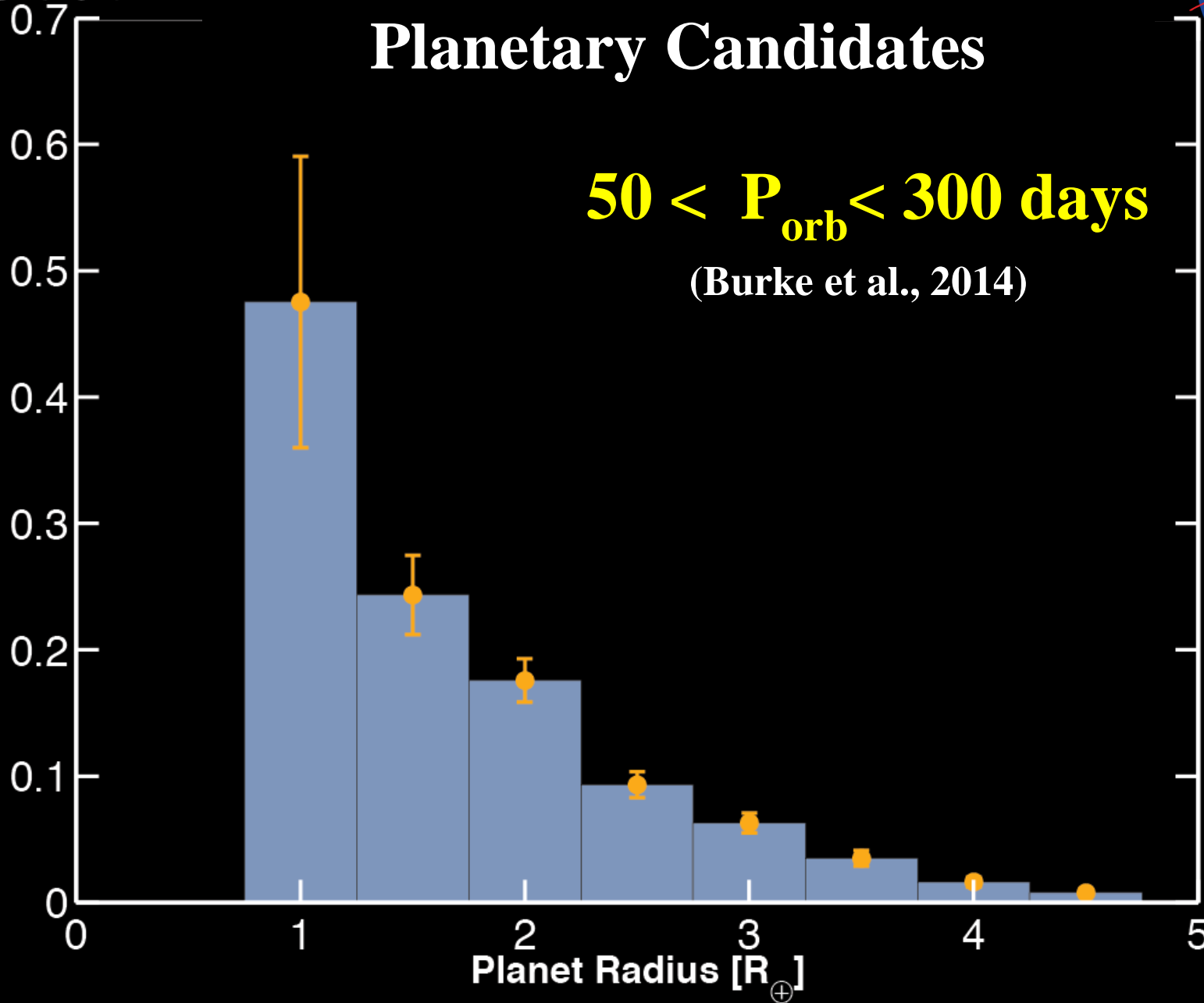


# Estimated Occurrence Rate of Planetary Candidates

Planet Occurrence Rate

**$50 < P_{\text{orb}} < 300$  days**

(Burke et al., 2014)



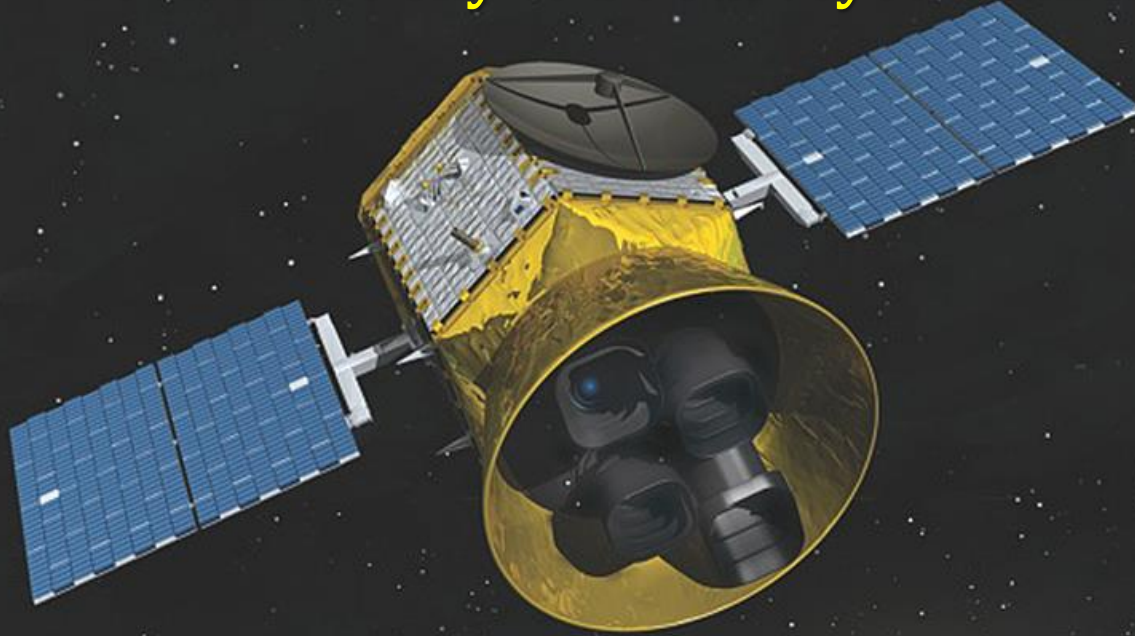
# *Habitable exomoon by Dan Durda*





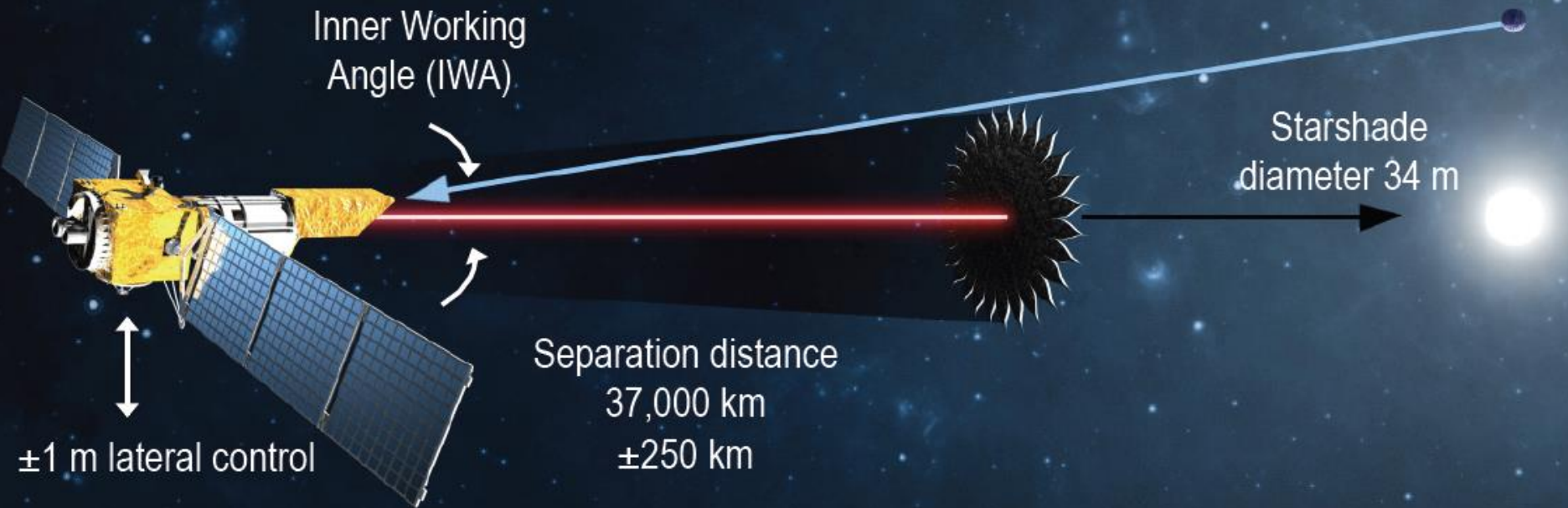
# TESS = Transiting Exoplanet Survey Satellite (launch in 2017)

**~2 million, G- and K-type stars to be studied**  
**~400x more sky to be surveyed than *Kepler***



<http://www.youtube.com/watch?v=mpViVEO-ymc>

# Starshade Concept

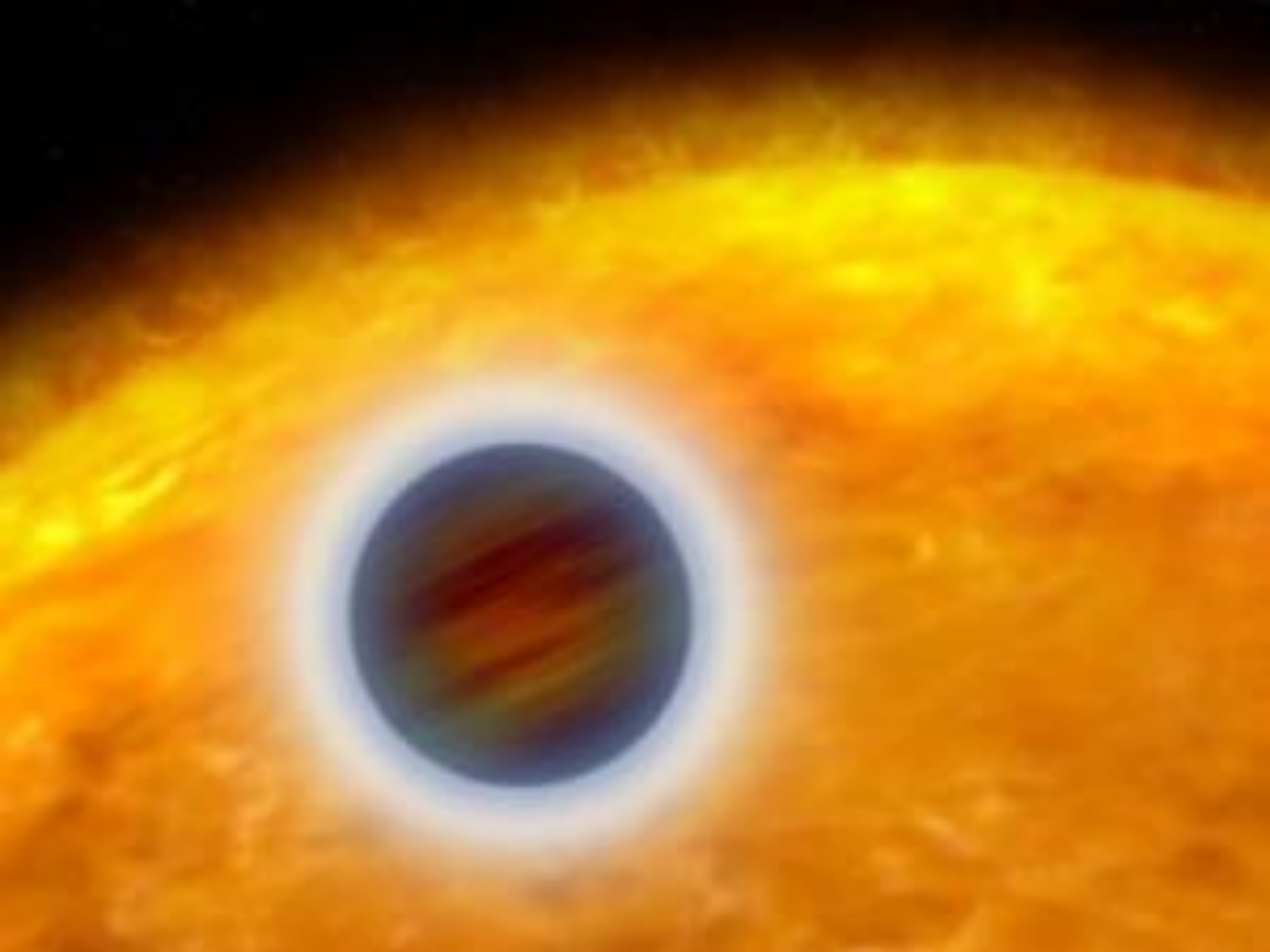


Telescope diameter 1.1 m

- 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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Sun-Earth Day  
Featuring  
Technology  
Through Time  
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<http://spacemath.gsfc.nasa.gov>



## *Important points*

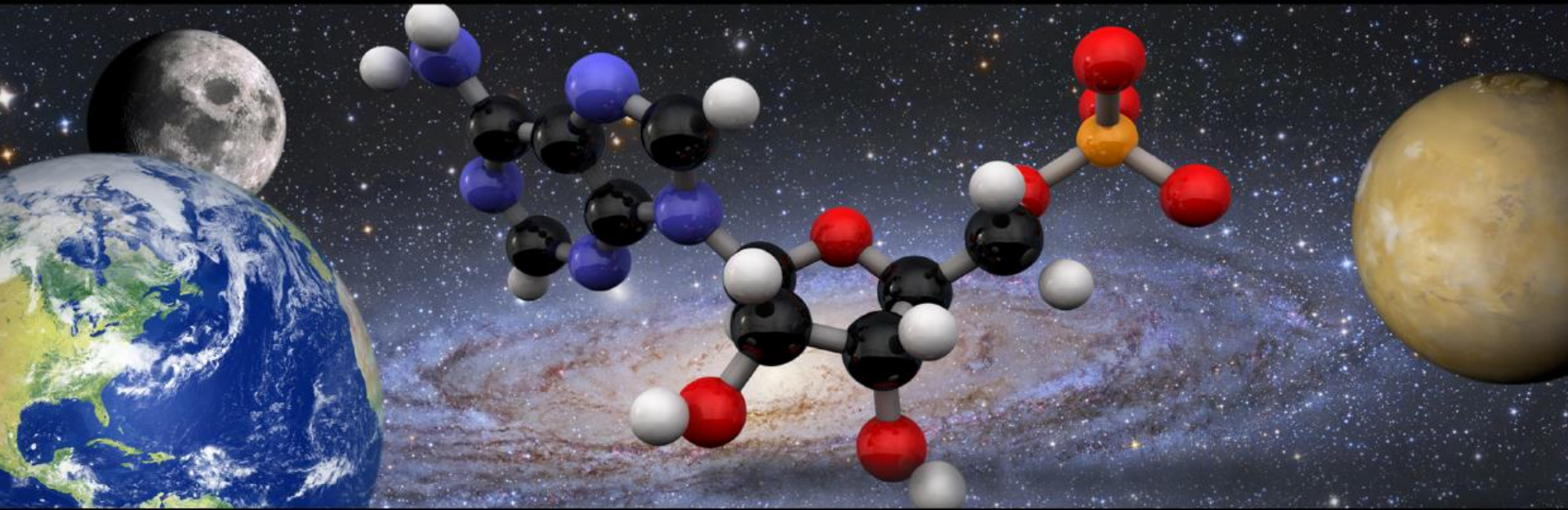
- **Planets are common and diverse in the galaxy**
- **Planets ( $\leq 10x$  Earth-mass) are common**
- **Estimate of  $10^9$ - $10^{10}$  habitable planets in our galaxy**
- **Low eccentricity orbits are not common**
- **Characteristics that define ‘habitability’ include ...**
  - semi-major axis of orbit within *Goldilock’s* zone
  - stable, long-lived stars (F, G, and maybe K, M)
  - absence of tidal lock (?)
  - size of planet ( $\sim 0.5$  -  $5x$  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)



*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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