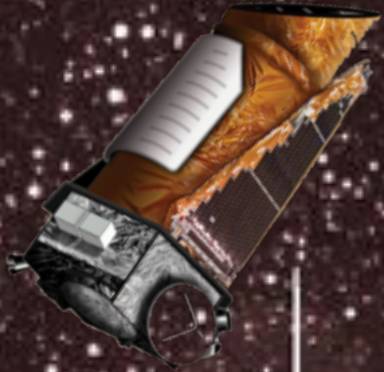
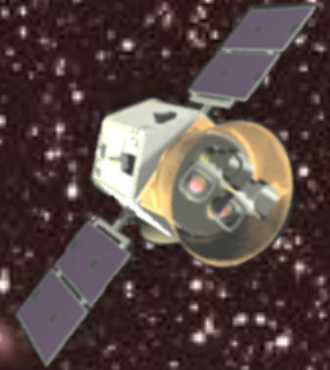


NASA's Search for Habitable Worlds



Jon M. Jenkins
NASA Ames Research Center



Monday February 10, 2020

2nd Grade, Orchard School, San Jose CA



Solar Eclipse 2017



Eclipse

EXPERIENCE
THE 2017 ECLIPSE ACROSS AMERICA
AUGUST 21, 2017
<http://eclipse2017.nasa.gov>

We find planets by looking for micro-eclipses





Solar Eclipse 2017



Credits: M. Druckmüller



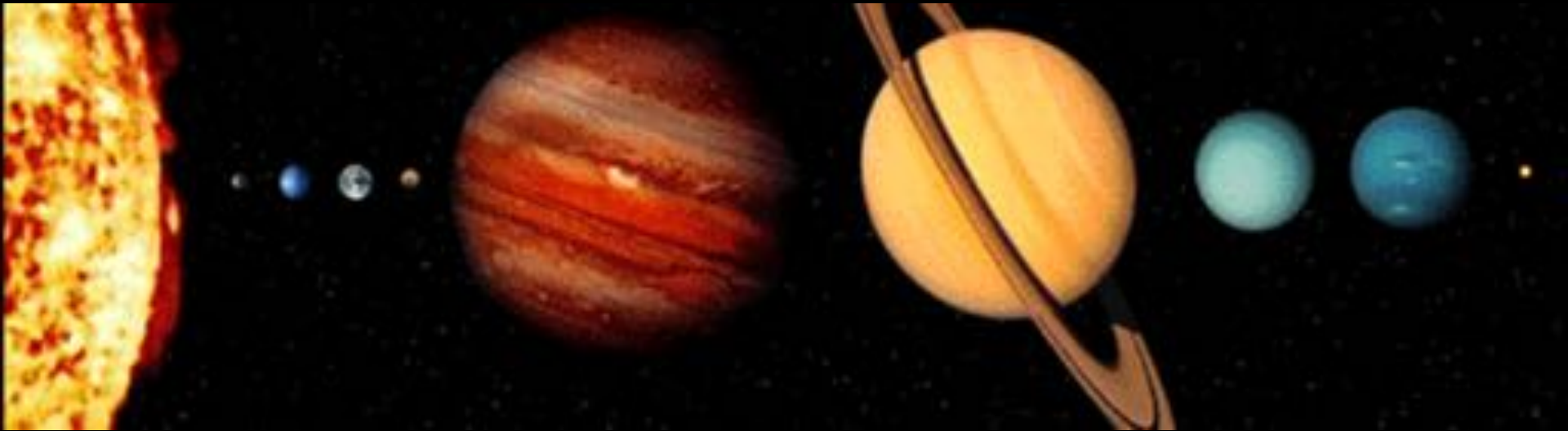
NASA/Rami Daud, Alcyon Technical Services

We find planets by looking
for micro-eclipses



All the Known Planets In 1994

Kepler
A Search for Earth-size
Planets





A More Recent Pictures of Planets





ALL 786 KNOWN
PLANETS

(AS OF JUNE 2012)

TO SCALE

(SOME PLANET SIZES ESTIMATED BASED ON PROBS)



THIS IS OUR SOLAR SYSTEM.

THE REST OF THESE ORBIT OTHER STARS
AND WERE ONLY DISCOVERED RECENTLY.

MOST OF THEM ARE HUGE BECAUSE
THOSE ARE THE KIND WE LEARNED TO
DETECT FIRST, BUT NOW WE'RE FINDING THAT
SMALL ONES ARE ACTUALLY MORE COMMON.

WE KNOW NOTHING ABOUT WHAT'S ON ANY OF THEM



What Does Habitable Mean To You?





What Does Habitable Mean To You?

- Right temperature
- Air
- Liquid water
- Light
- Radiation shield
- Asteroid protection

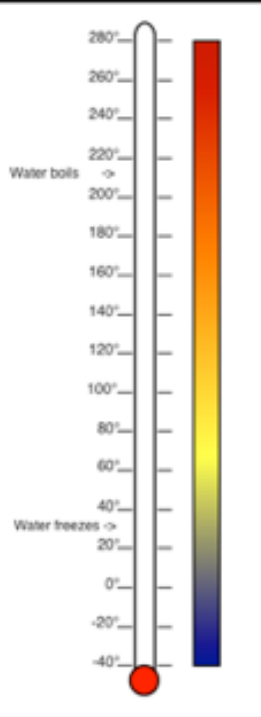




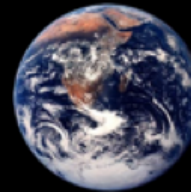
The Goldilocks Zone



Venus: Way too hot!



Mars: Way too cold, and small!

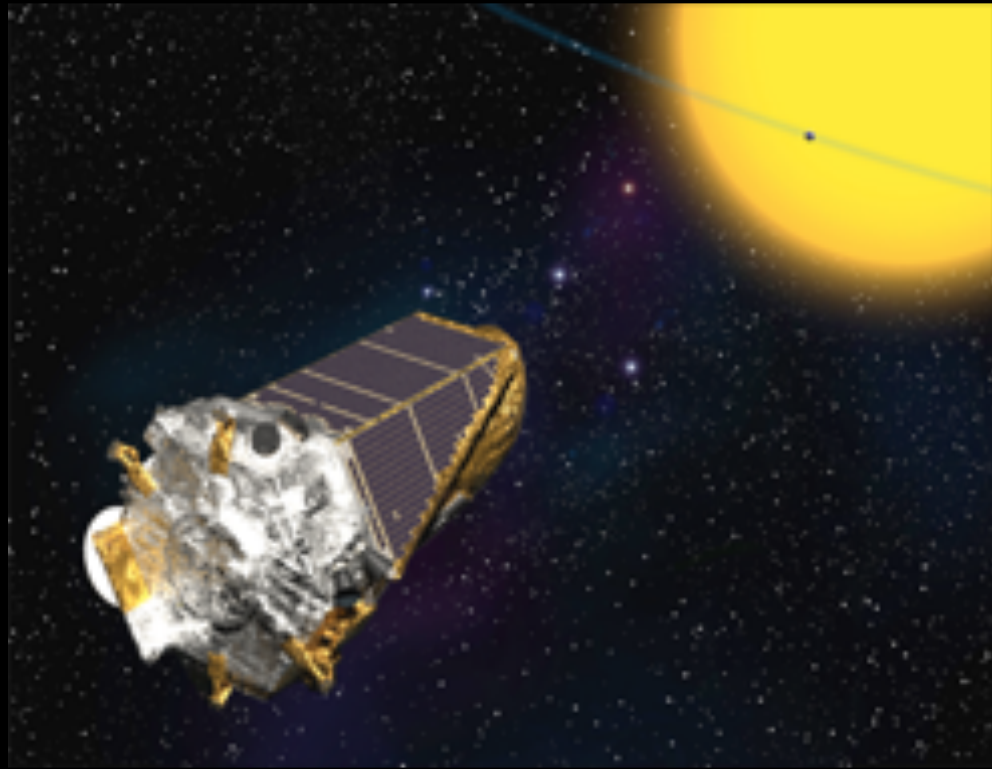


Earth: Just right!

The *Kepler* Mission

How many stars like the Sun have
Earth-like planets orbiting them?

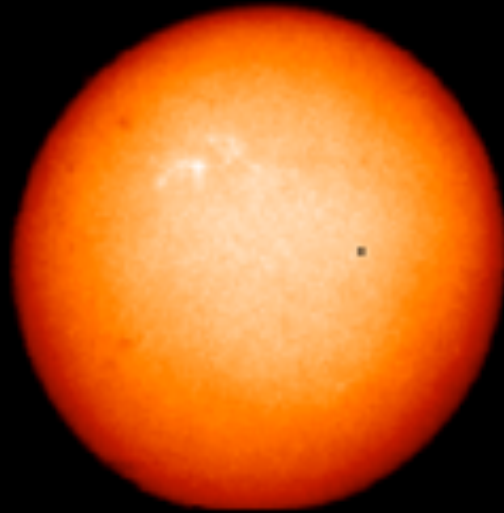
Kepler searches for transiting
planets





Stars are far away ...

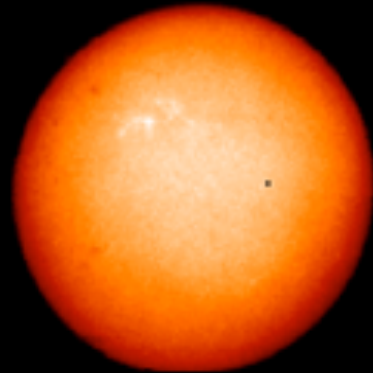
Kepler
A Search for Earth-size
Planets

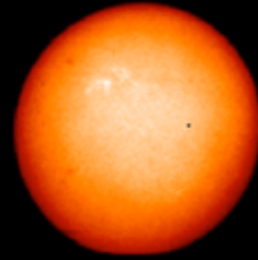


Let's move this star away . . .



Kepler
A Search for Earth-size
Planets

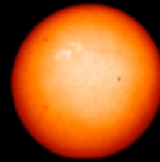




. . .and farther . . .



Kepler
A Search for Earth-size
Planets





Kepler
A Search for Earth-size
Planets





. . .and farther



Kepler
A Search for Earth-size
Planets





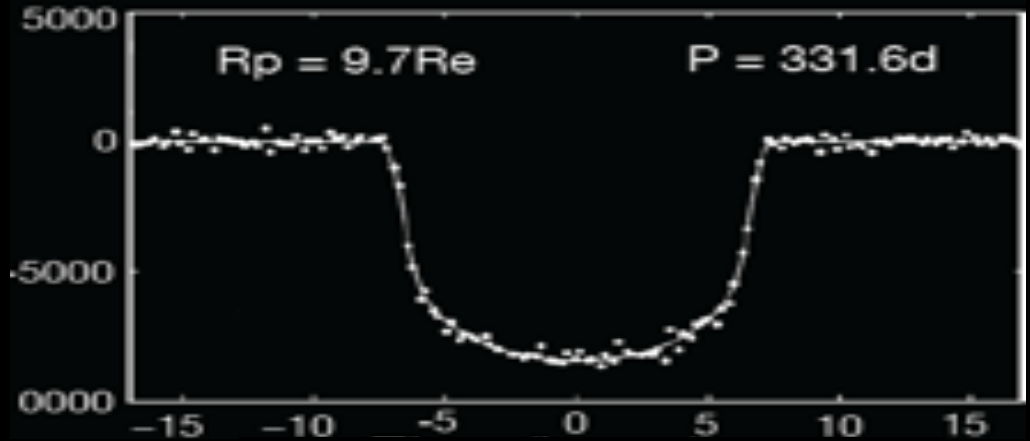
Stars are very far away.
We cannot see the planet cross in front of the star.



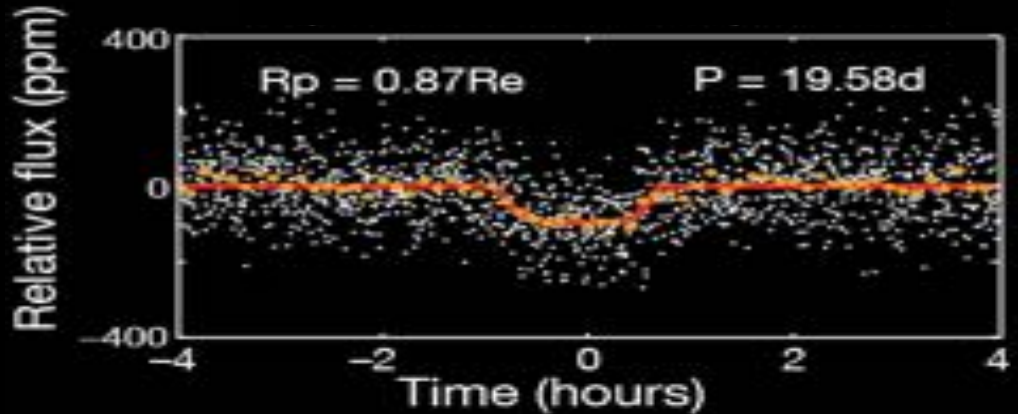
How Hard is it to Find Good Planets?



Jupiter (~1%)



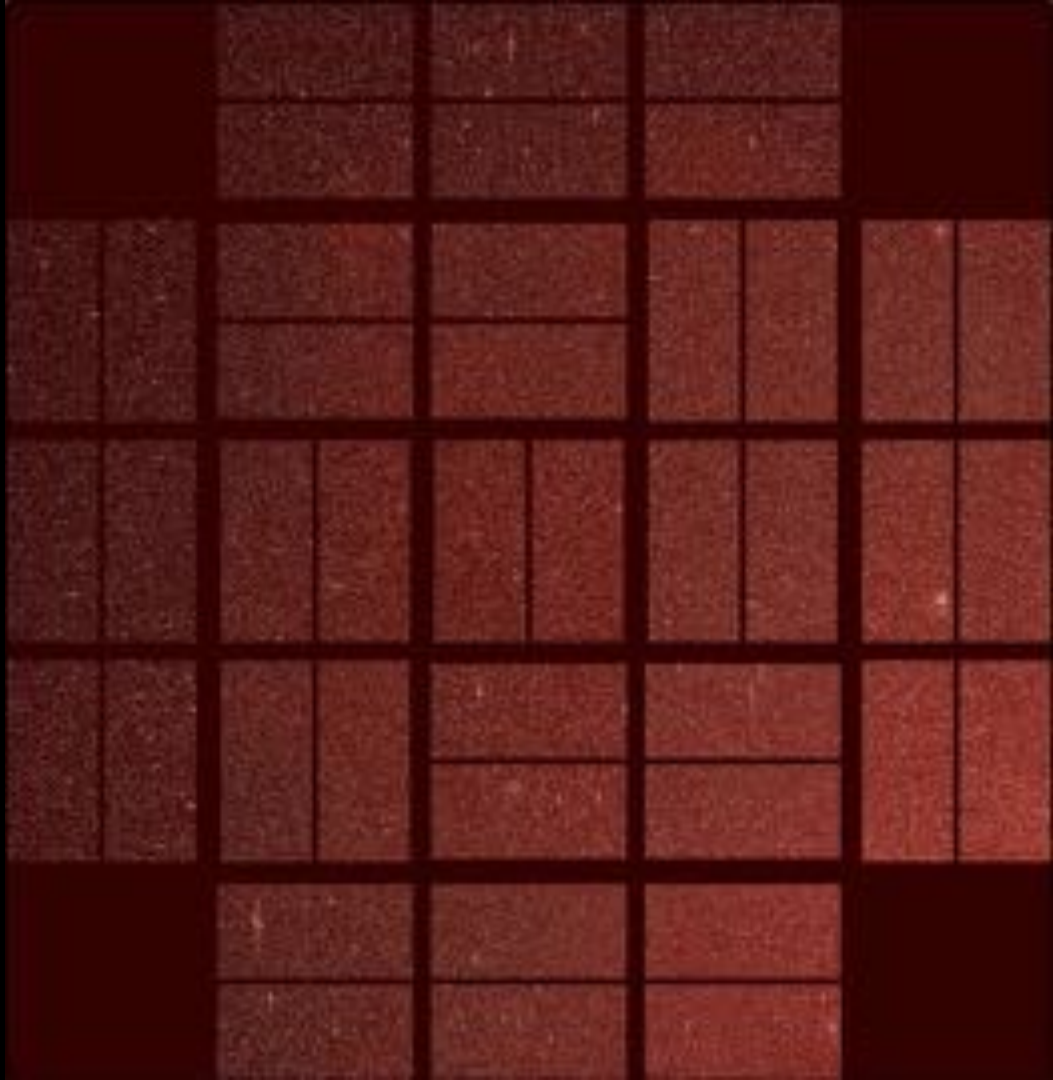
Earth (~0.01%)



First Light Image



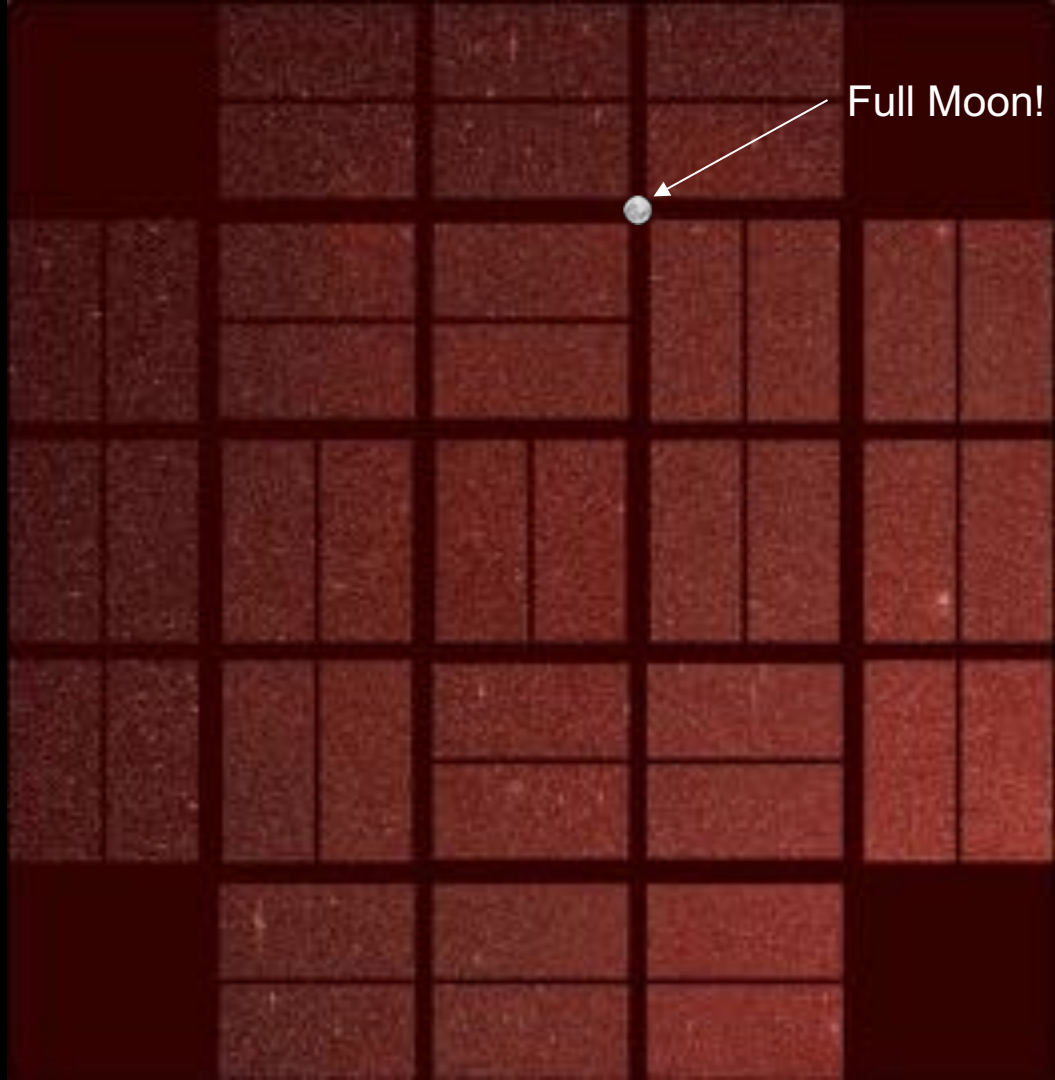
Launched
March 7 2009



First Light Image



Launched
March 7 2009



Full Moon!



Small Rocky Planets



Kepler-20e

Venus

Earth

Kepler-20f



Kepler discovers two Earth-size planets, which scientists believe are rocky, Kepler-20e and Kepler-20f. These two planets are in the Milky Way galaxy, but not in our solar system. Their solar system also contains larger gas giant planets (like Jupiter) in larger orbits.



Circumbinary Planets:

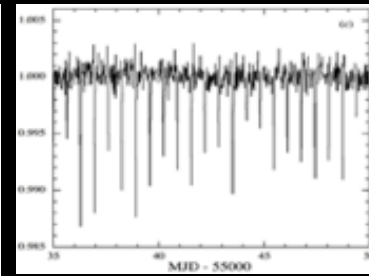
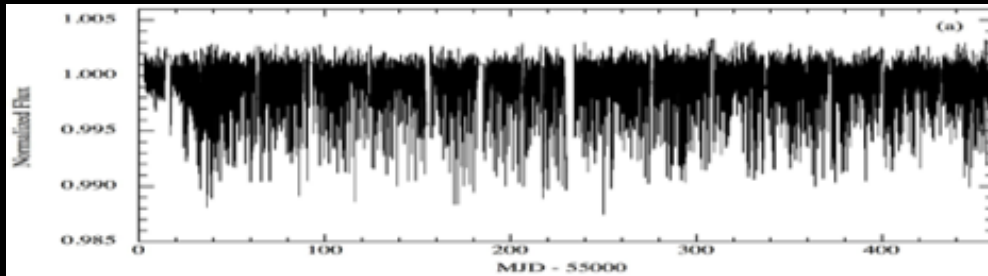
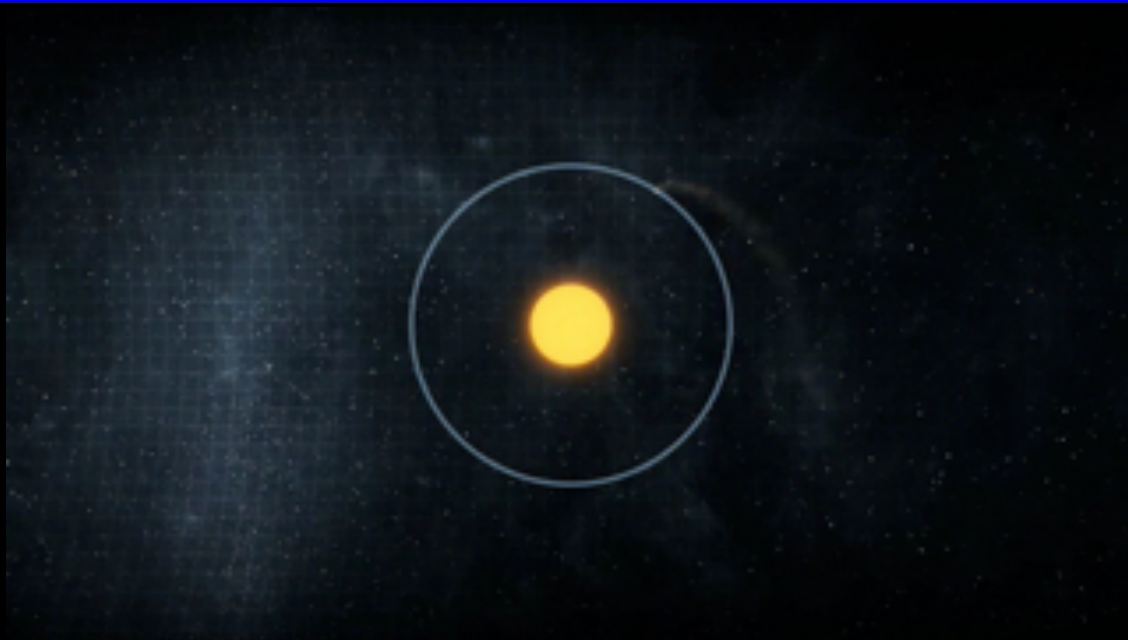


Kepler 35



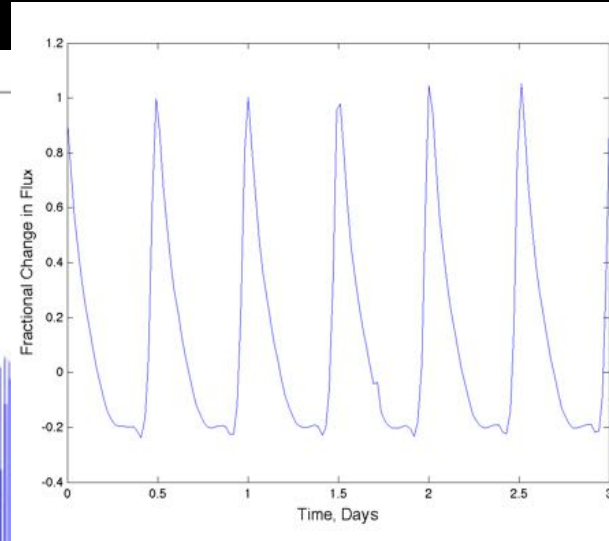
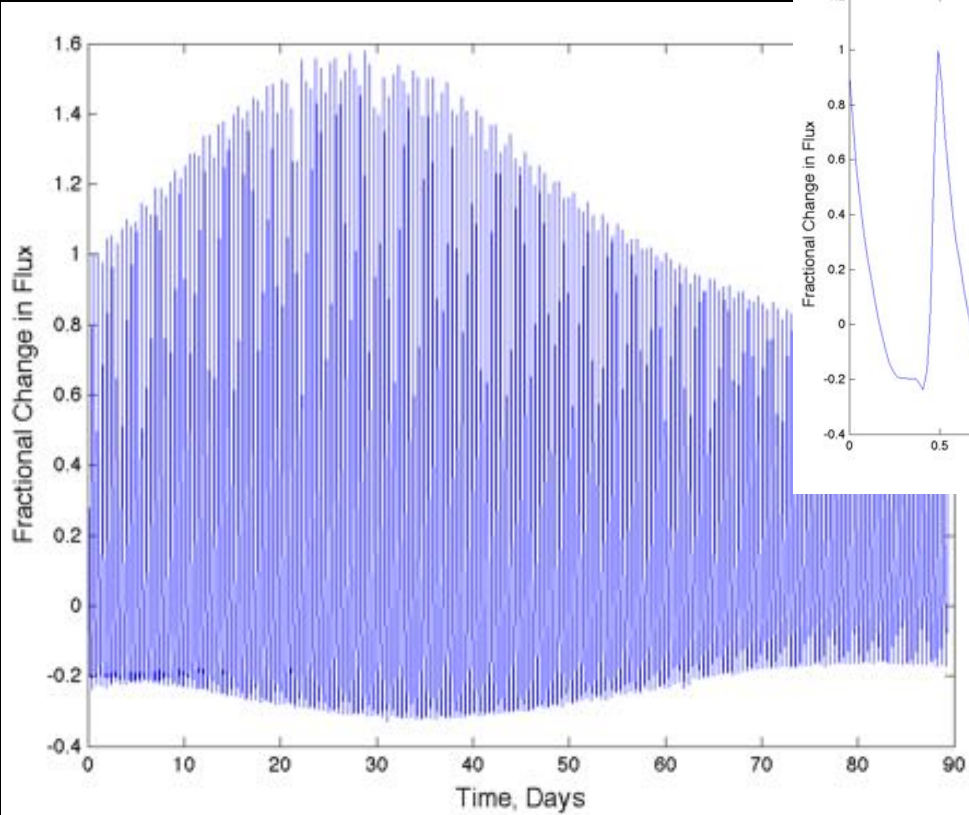


A Disintegrating Sub-Mercury-Size Planet



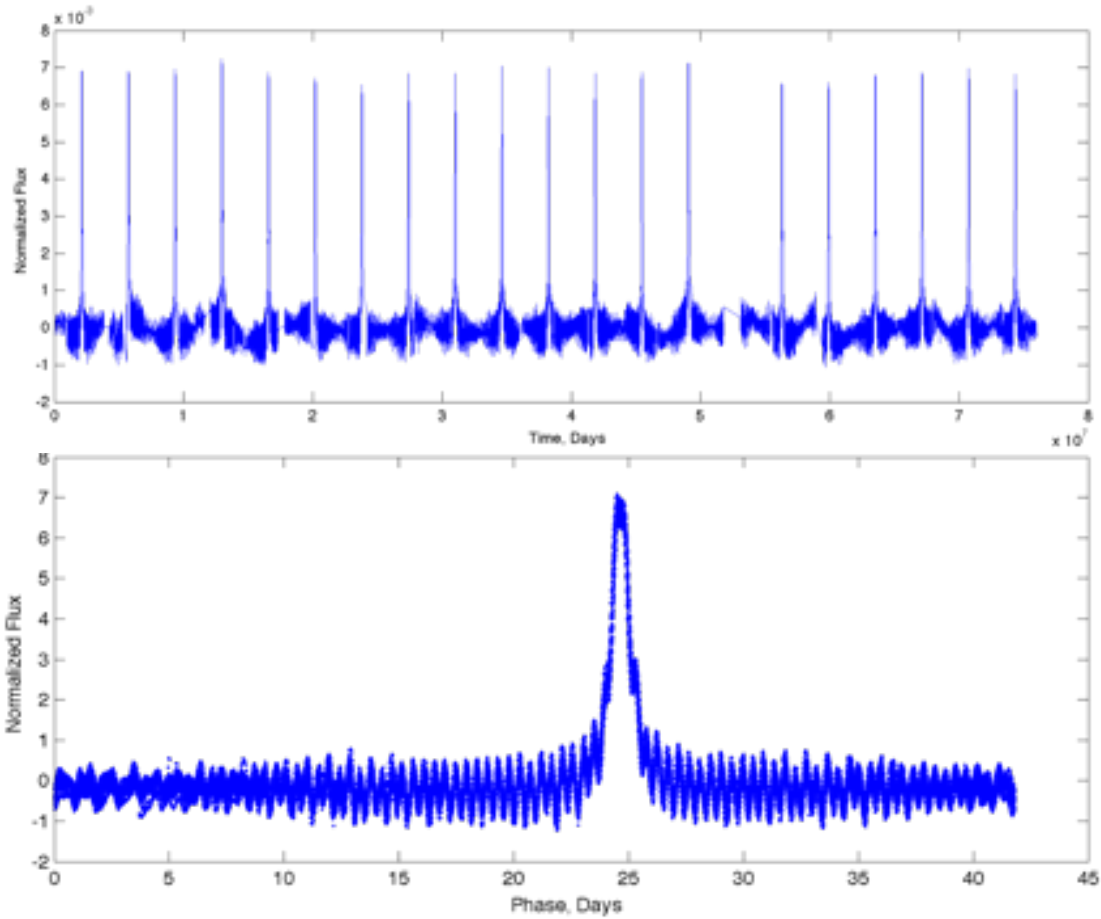


An RR Lyra Star





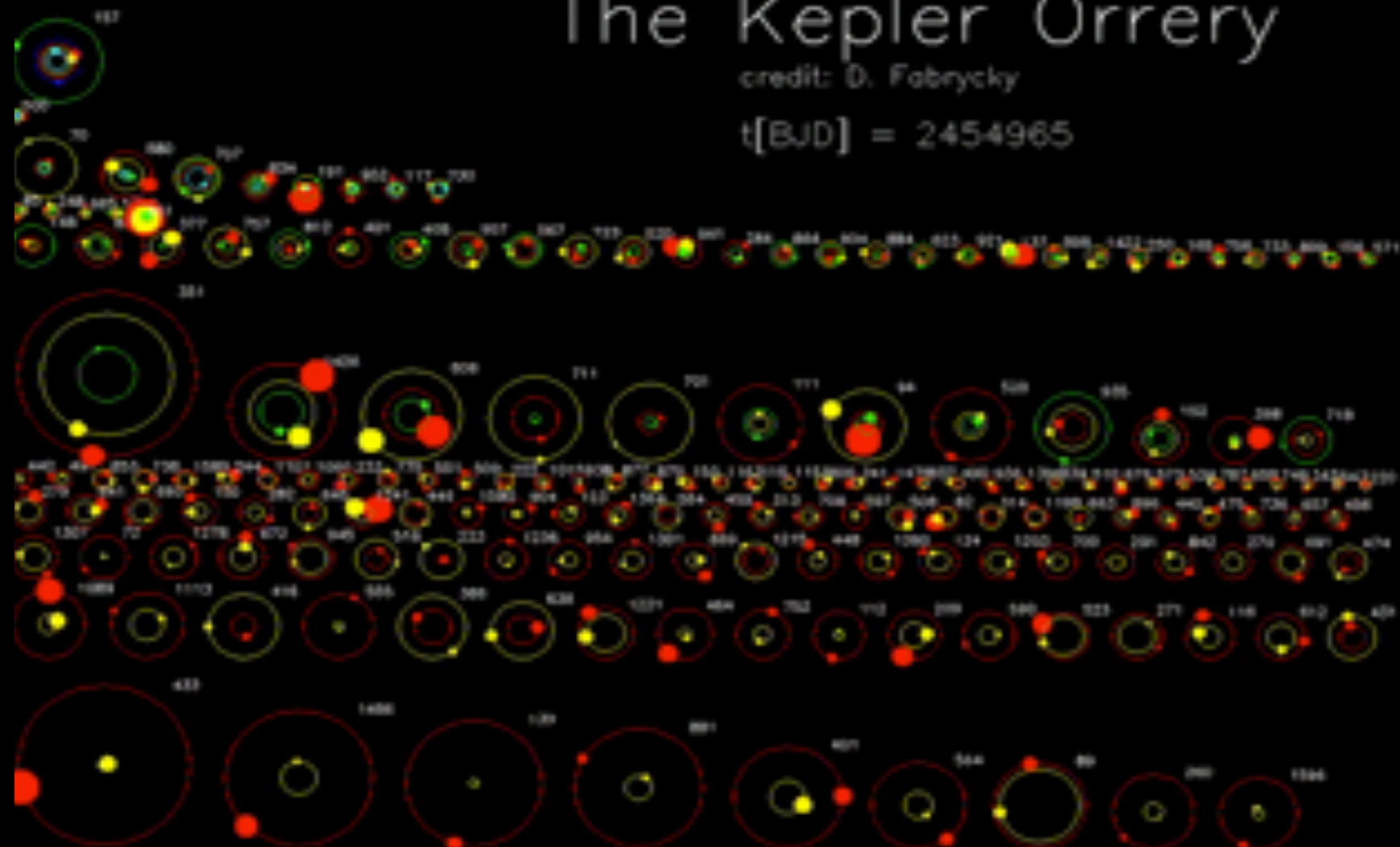
Heartbeat Stars: KOI-54



The Kepler Orrery

credit: D. Fabrycky

$t[\text{BJD}] = 2454965$



Kepler taught us that planets are everywhere!

What Next?

The image features a large, overlapping cluster of small, identical replicas of the Transiting Exoplanet Survey Satellite (TESS). Each satellite is shown from a perspective that highlights its white cylindrical body, gold-colored sunshields, and two large, dark purple solar panel arrays. The satellites are arranged in a roughly circular pattern, filling most of the frame against a solid black background. Overlaid in the center of this cluster is the text "TESS Elation!" in a bold, red, sans-serif font. The overall effect is one of abundance and excitement, suggesting a large-scale mission or a significant discovery related to the TESS project.

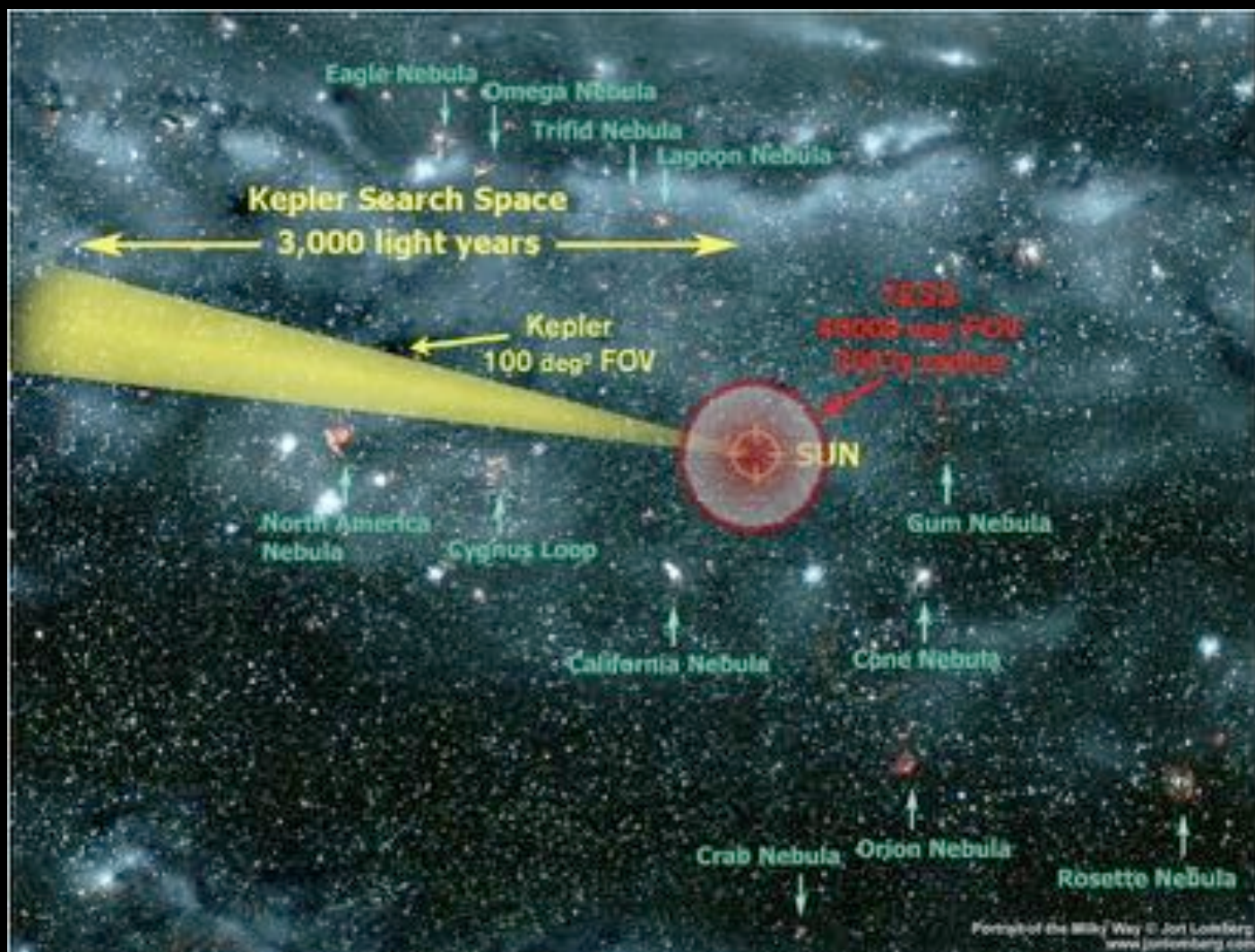
TESS Elation!



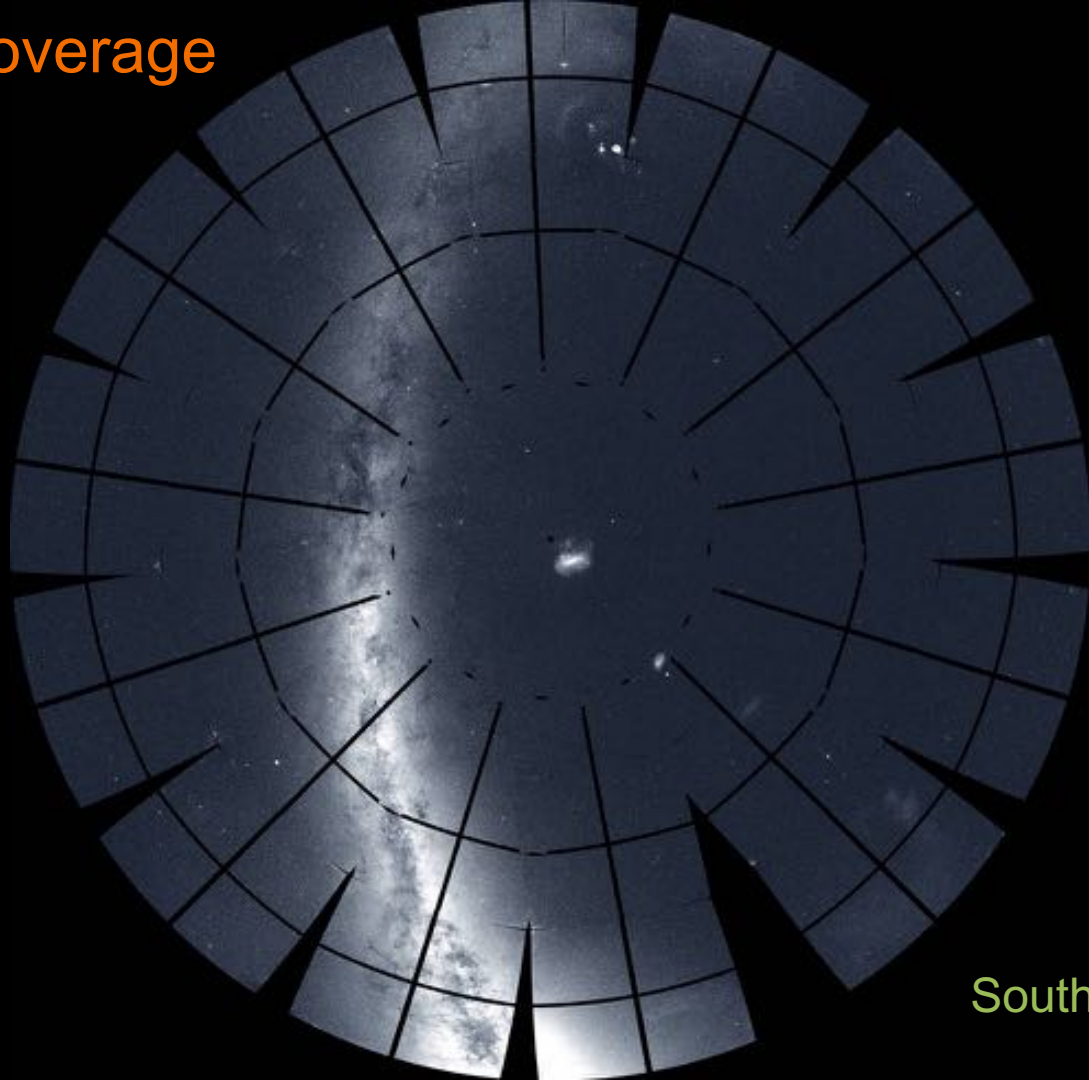
TRANSITING EXOPLANET SURVEY SATELLITE

*DISCOVERING NEW EARTHS AND SUPER-EARTHS
IN THE SOLAR NEIGHBORHOOD*



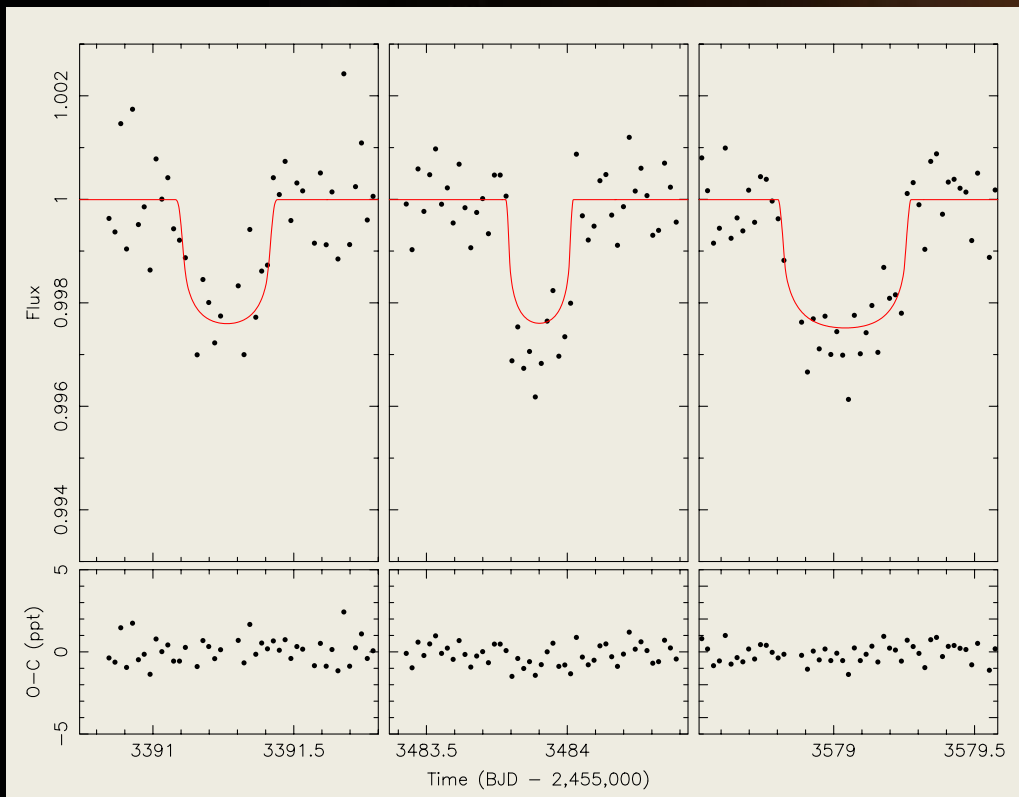


TESS Sky Coverage

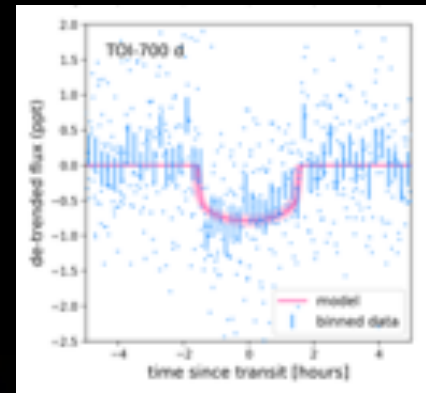
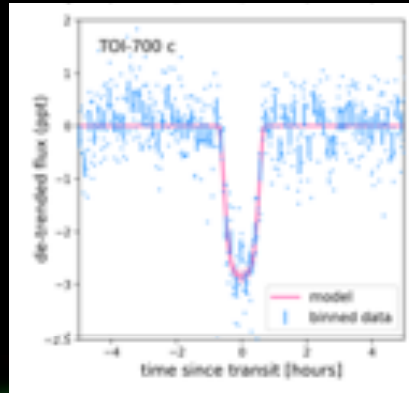
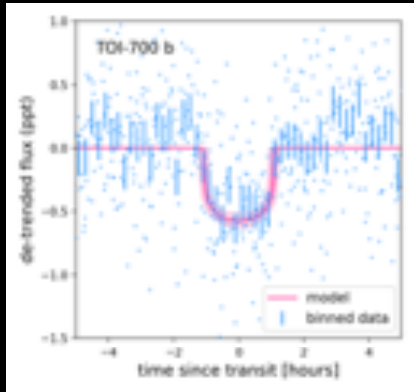


Southern Hemisphere

First Circumbinary Planet: TOI-1338b



TESS's First Earth-Sized Habitable Zone Planet: TOI-700d



Detecting Biomarkers through Transit Spectroscopy

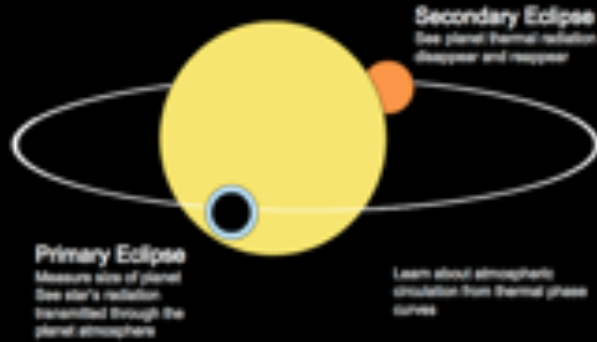
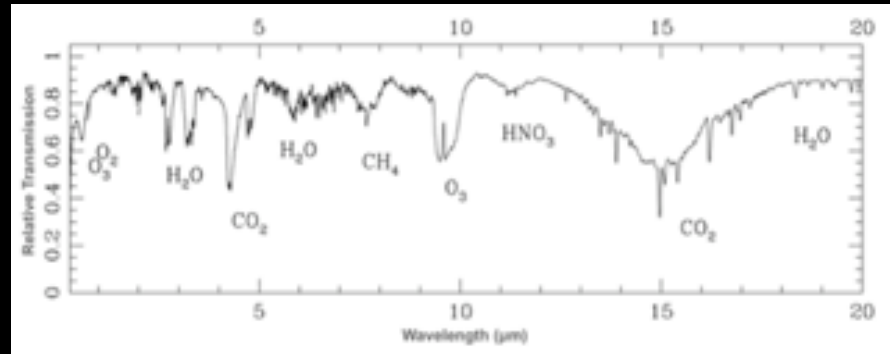


Figure by S. Seager



Kaltenegger, L. and Traub, W. (2009) Transits of Earth-Like Planets, ApJ

Exoplanet Missions



What can you do to help study exoplanets?

Do you like Science?

Do you like Math?

Do you like Art?

We need:

- Scientists
- Astronomers
- Engineers
- Data Scientists
- Mathematicians
- Software Engineers
- Artists



Do you have questions?