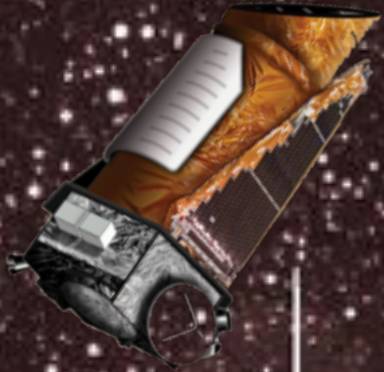
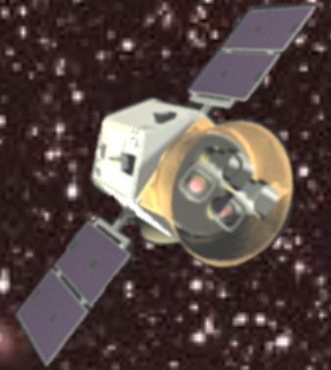


A NASA Space Scientist/Astronomer Searching for Habitable Worlds



**Jon M. Jenkins
NASA Ames Research Center**



Tuesday March 3, 2020

Saratoga High School, Saratoga CA

An Introduction to Dr. Jon Jenkins

I've conducted research for NASA since 1987 as an undergraduate student

- Guest Investigator on Pioneer Venus
- Co-Investigator on several Discovery class mission concepts to explore Venus and find exoplanets
- Co-investigator for Data Processing for NASA's Kepler/K2 and TESS Missions

How did I get here?



I Grew Up Near NASA's Kennedy Space Center

- My parents worked at KSC
- Dad was an aeronautical engineer and one of the first software engineers. He worked on the Mercury, Gemini, Apollo and Shuttle programs
- We watched many launches of rockets and spacecraft from our back yard
- I often lay in the summer grass looking up at the stars wondering if there were planets with beings looking up into their night sky at us asking the same question



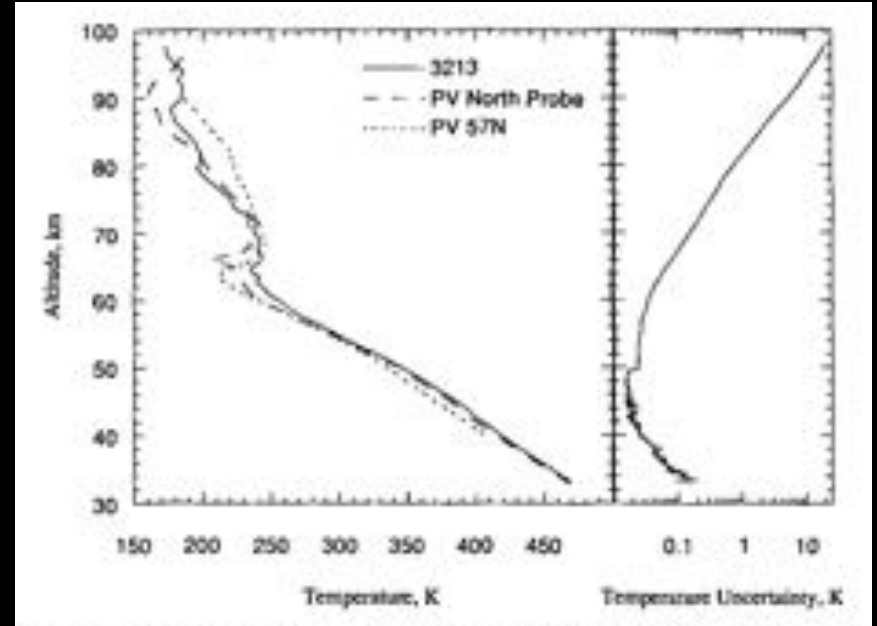
I Grew Up on Merritt Island, Florida

- I enjoyed math and science in school
- I took two years of calculus in HS
- I was on the wrestling team, played trombone in HS and in college, played judo
- I read a lot of science fiction
- I went to Georgia Institute of Technology and studied Electrical Engineering



What Does Electrical Engineering Have to do with Astronomy and Exoplanets?

- I was short on rent
- I met Dr. Paul Steffes, who did research for NASA
- Electromagnetic properties of various gases
- Pizza oven to simulate Venus
- We had a biological freezer (-120° C) to simulate conditions on Jupiter and Saturn
- Pioneer Venus Orbiter and the Magellan Spacecraft
- Meeting Bill Borucki, PI for the Kepler Mission



Jenkins+ (1994)

What Was Life Like Before Exoplanets (1994)?





All the Known Planets In 1994

Kepler
A Search for Earth-size
Planets





A More Recent Pictures of Planets (2012)





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?

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

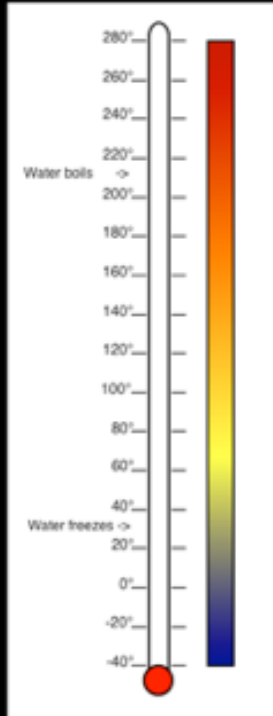




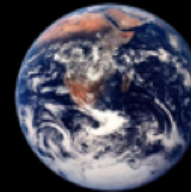
The Goldilocks Zone



Venus: Way too hot!



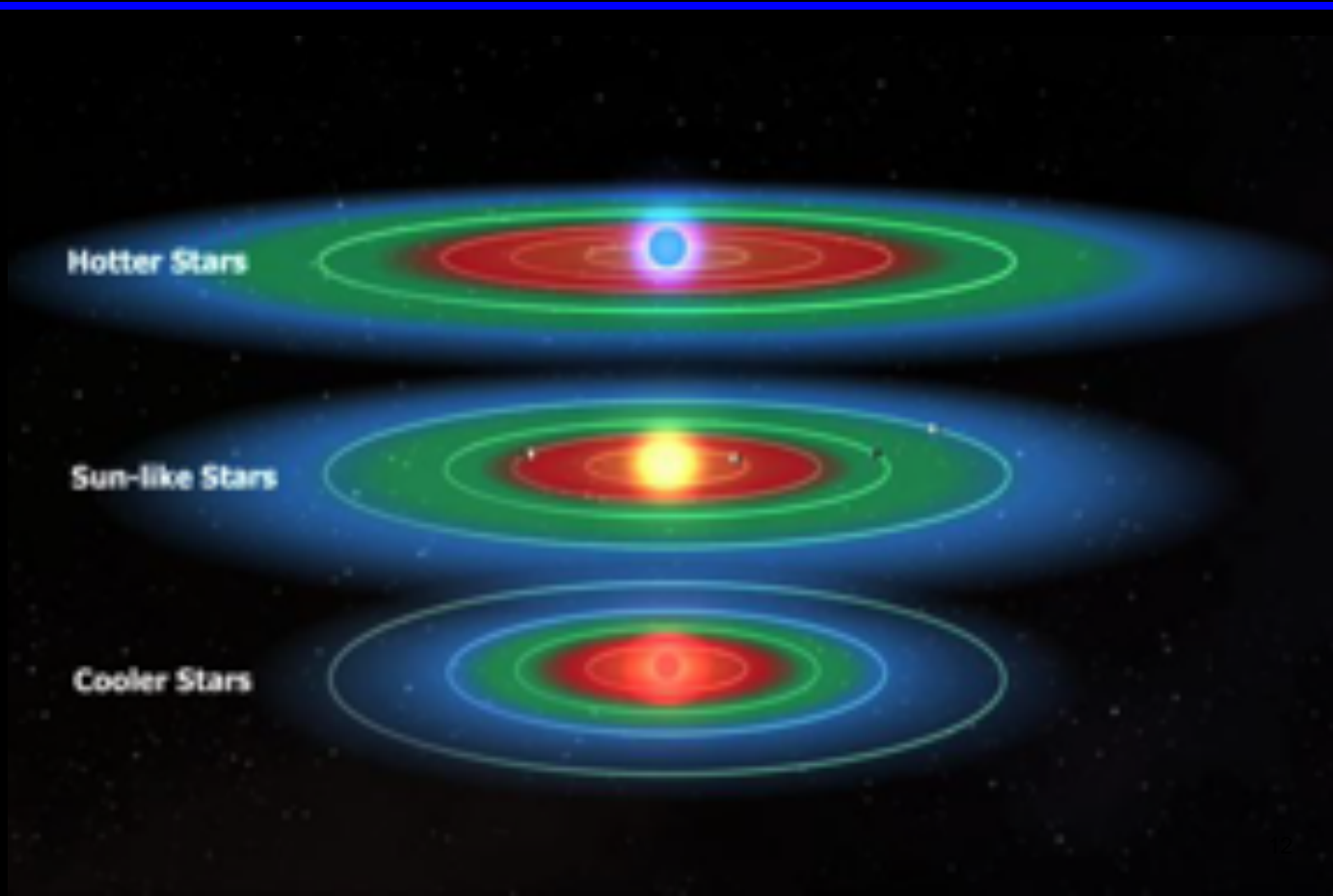
Mars: Way too cold, and small!



Earth: Just right!



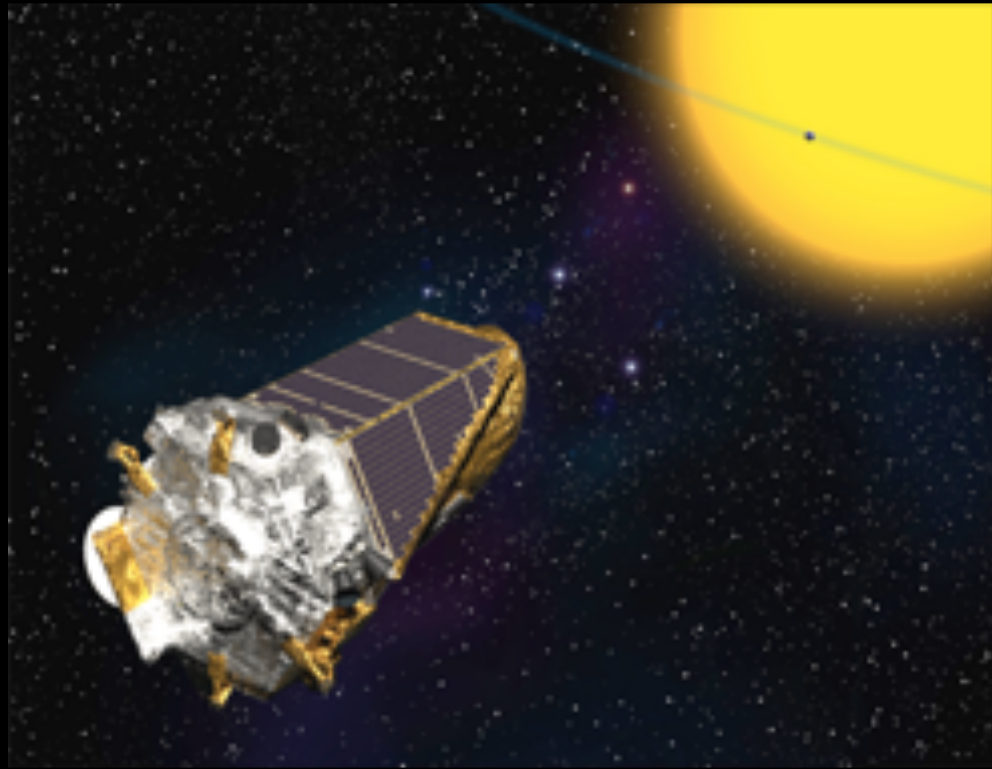
Habitable Zones



The *Kepler* Mission

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

Kepler searches for transiting
planets



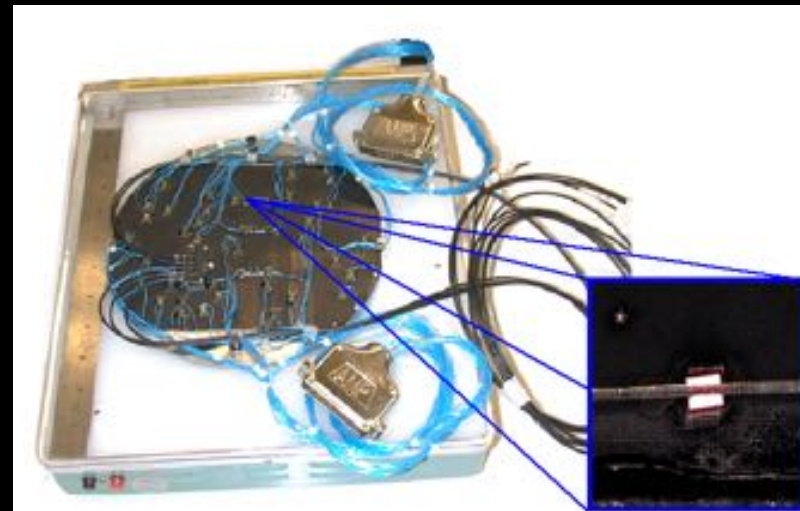
Kepler Tech Demo 1998

The precision needed to find Earth-size planets is daunting:

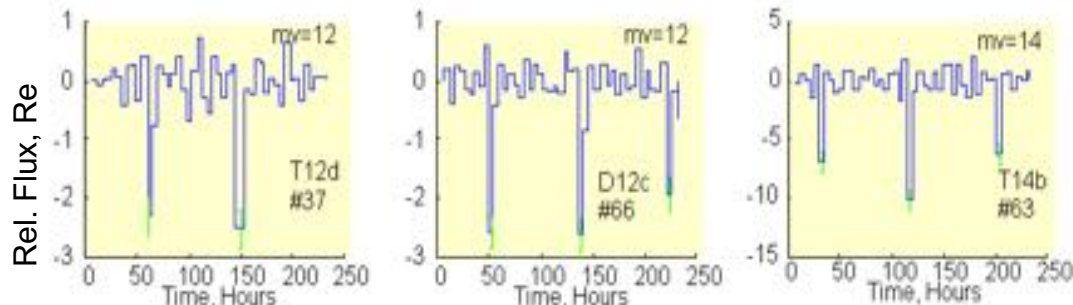
20 parts per million

That's like being able to tell when a gnat flies across a headlight of a car coming over a hill a mile away at night

We had to invent technology to prove we could do it



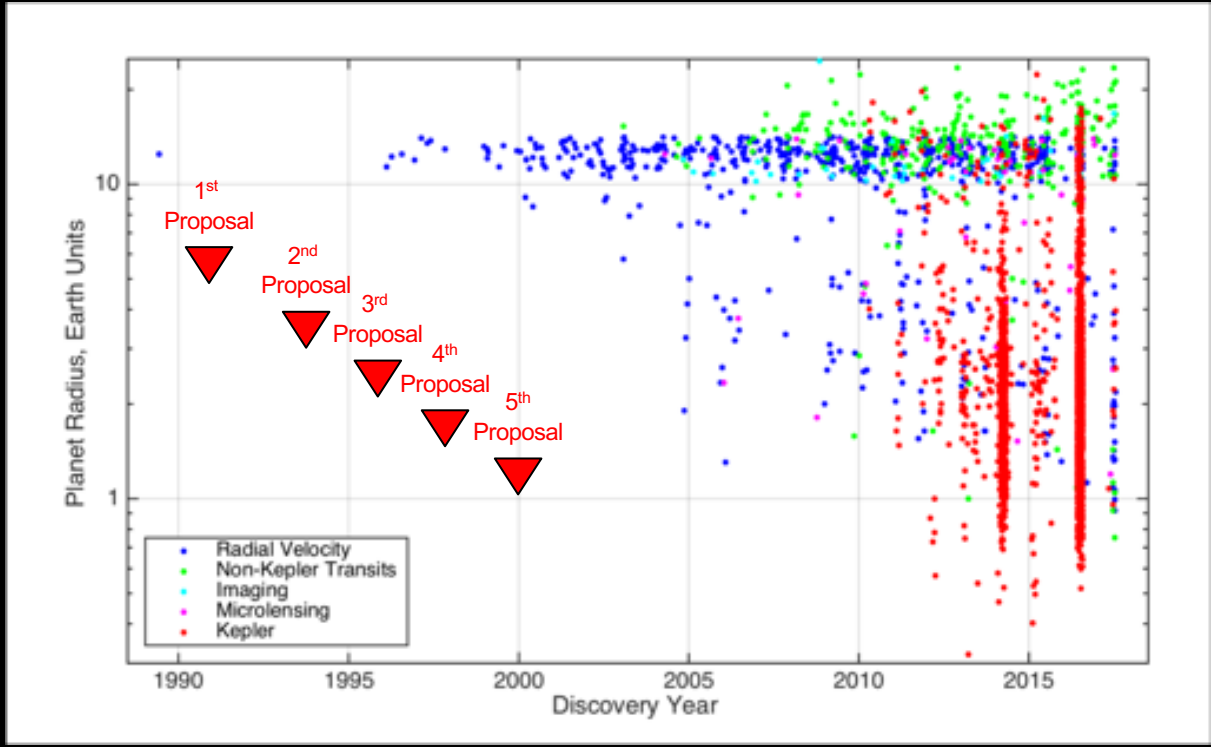
David Koch, DPI



Data set test145f flux145foptap decorr2 7 dat



Persistence Pays Off: Exoplanet Discoveries Over Time*

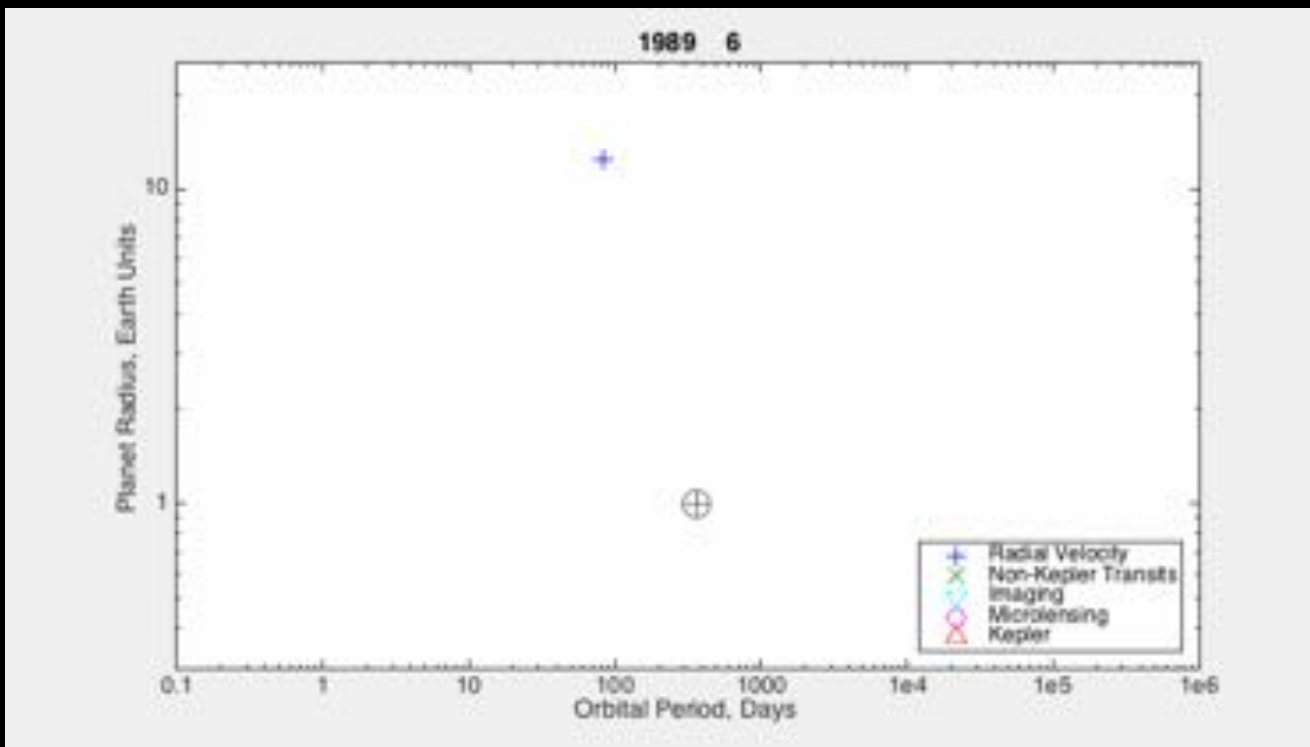


Radii estimated for non-transiting exoplanets
Discovery data dithered slightly

*According to <https://exoplanetarchive.ipac.caltech.edu> as of 8/29/17



Exoplanet Discoveries



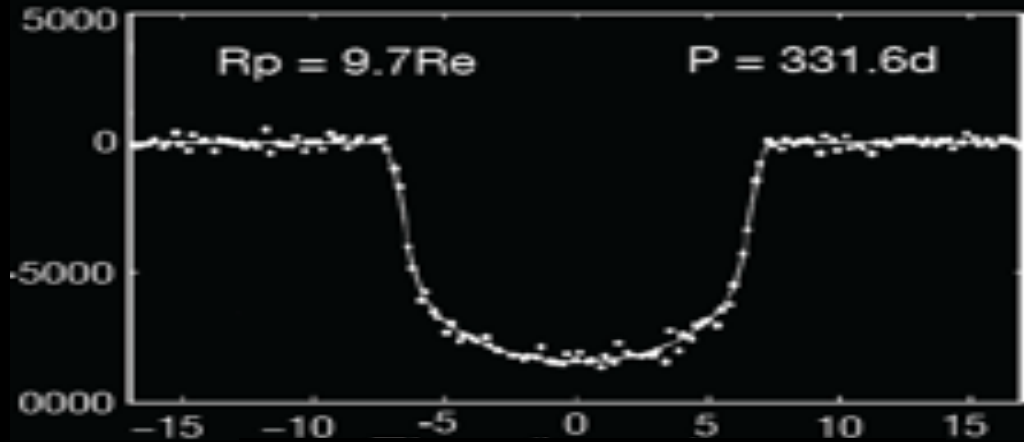
*According to <https://exoplanetarchive.ipac.caltech.edu> as of 8/29/17



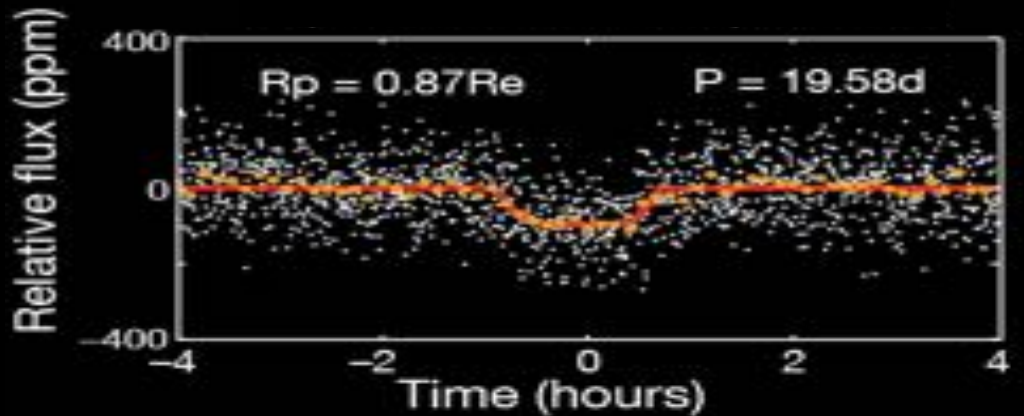
How Hard is it to Find Good Planets?



Jupiter (~1%)



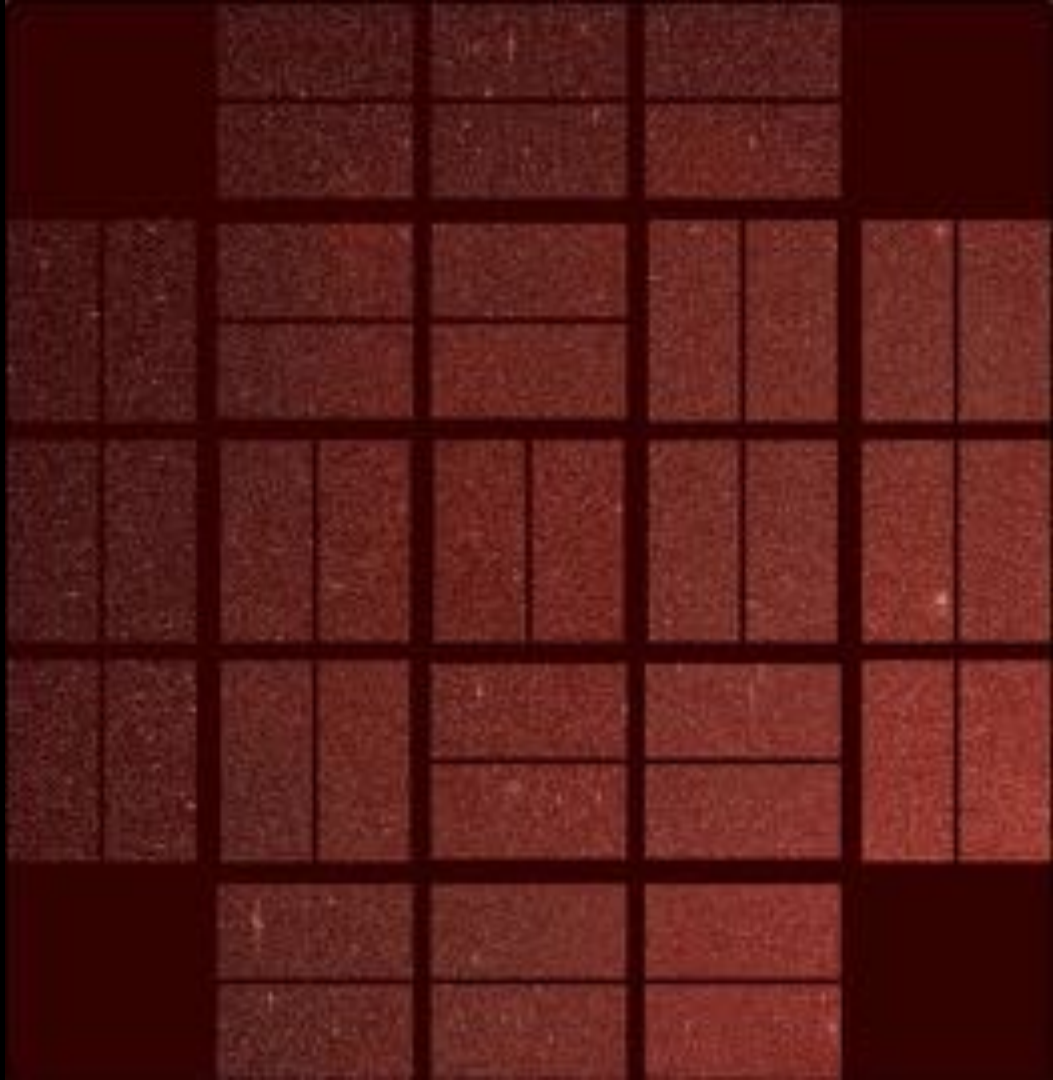
Earth (~0.01%)



First Light Image



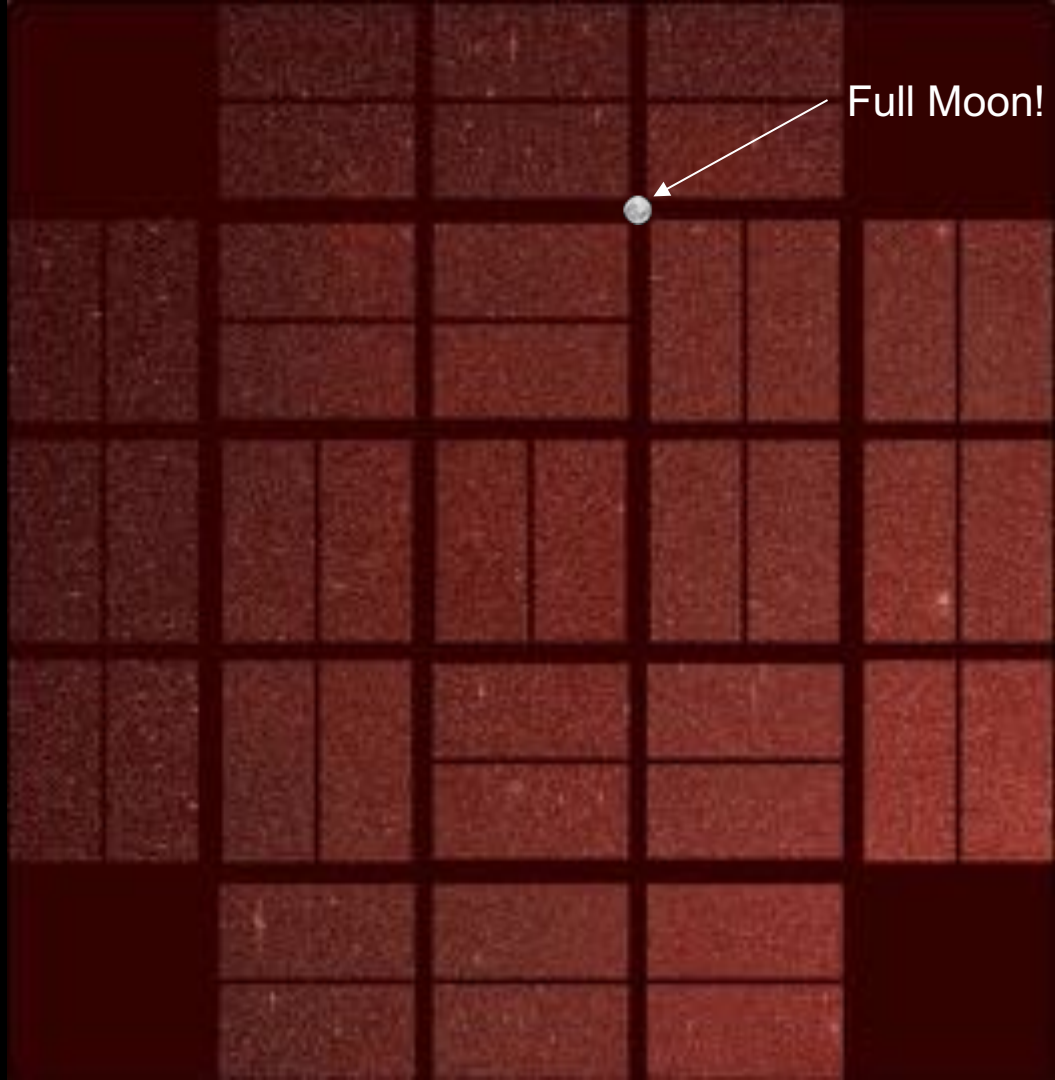
Launched
March 7 2009



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:

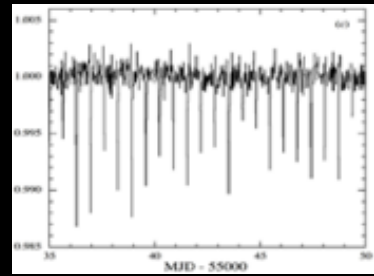
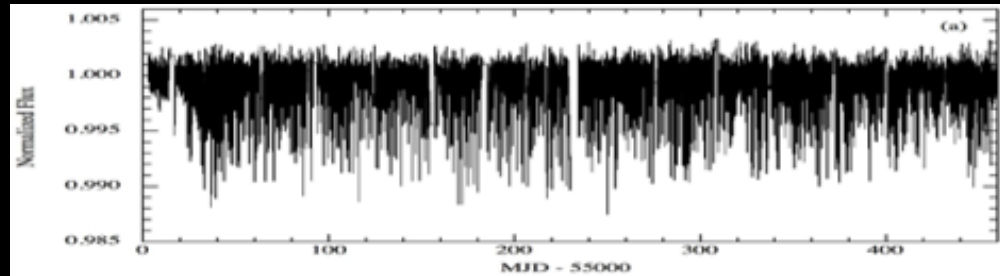
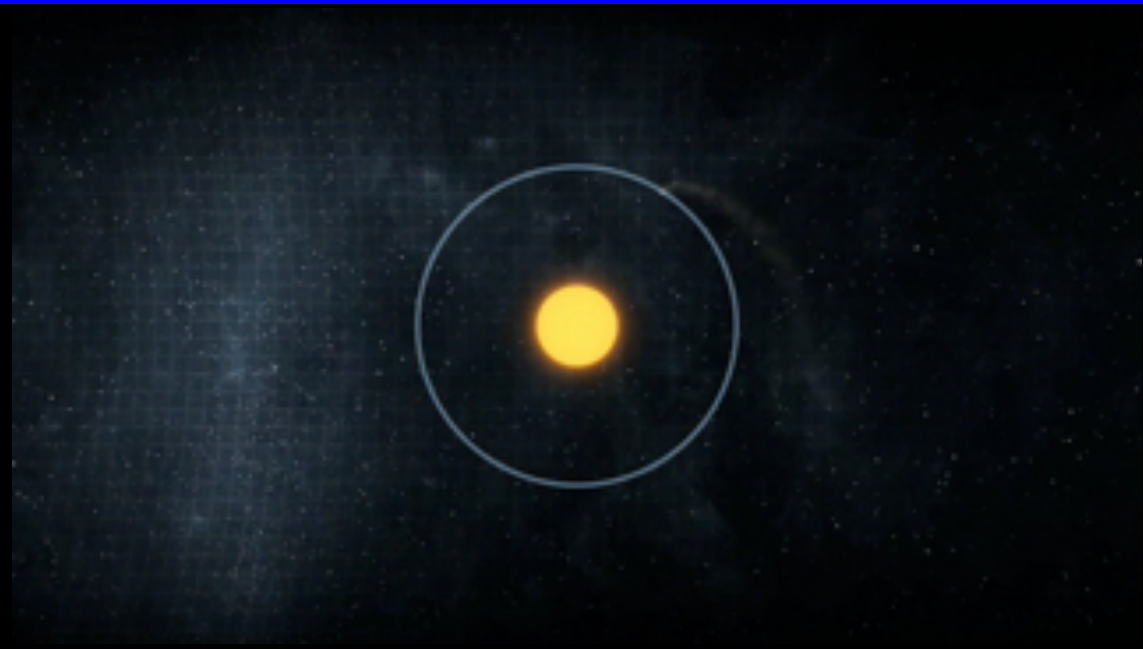


Kepler 35



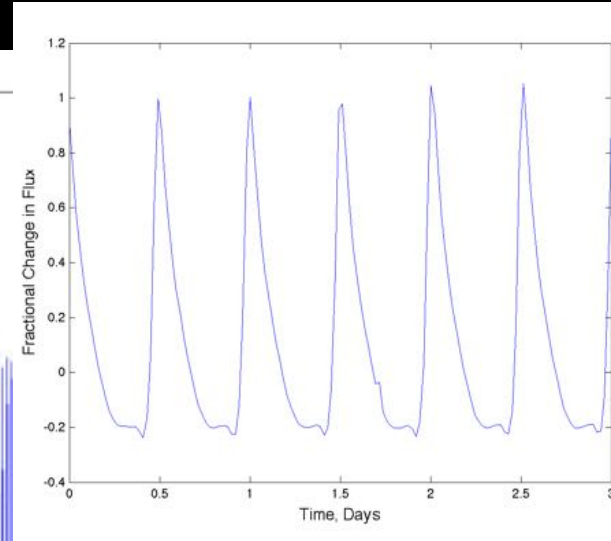
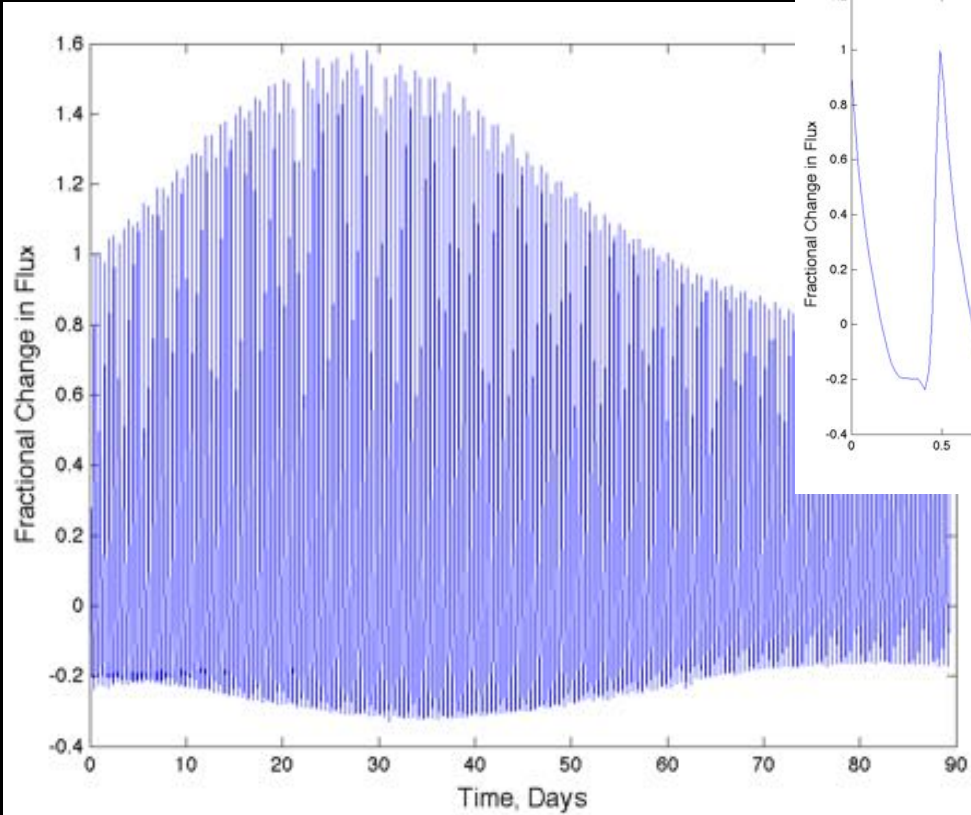


A Disintegrating Sub-Mercury-Size Planet



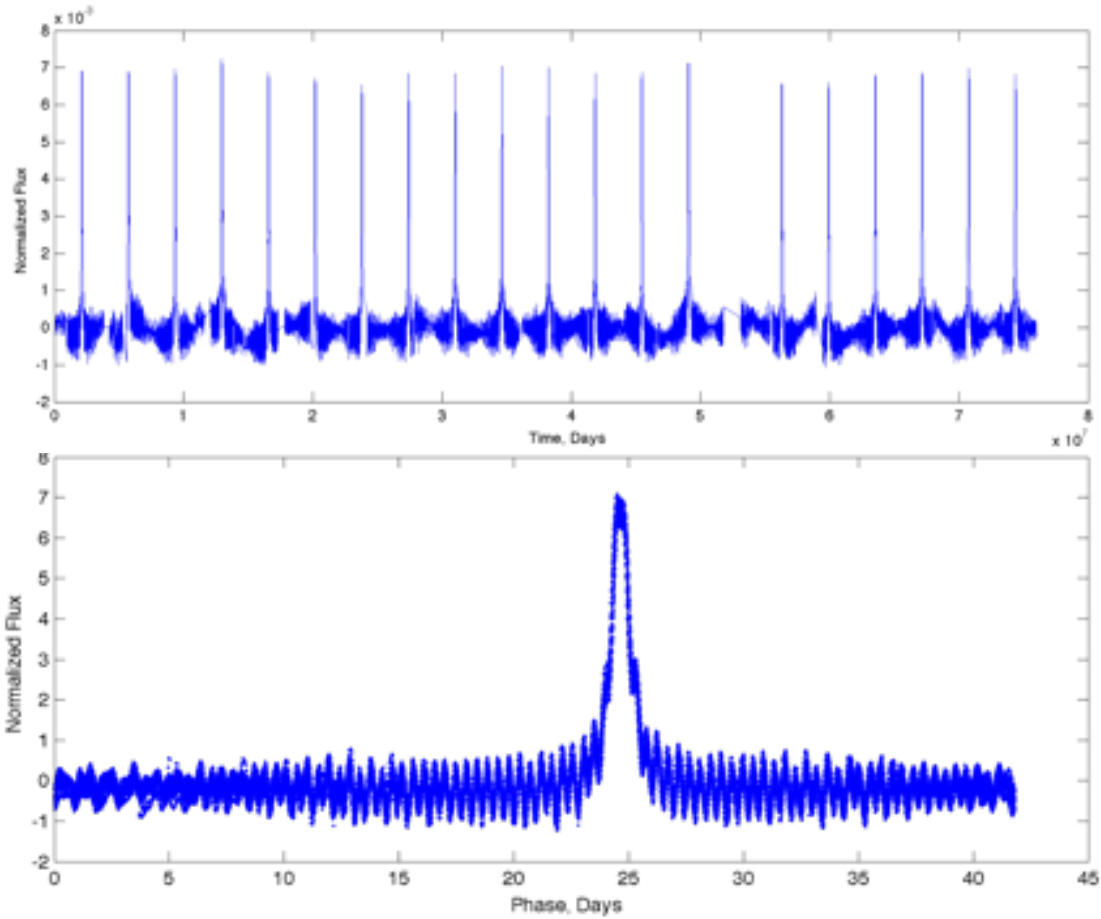


An RR Lyra Star





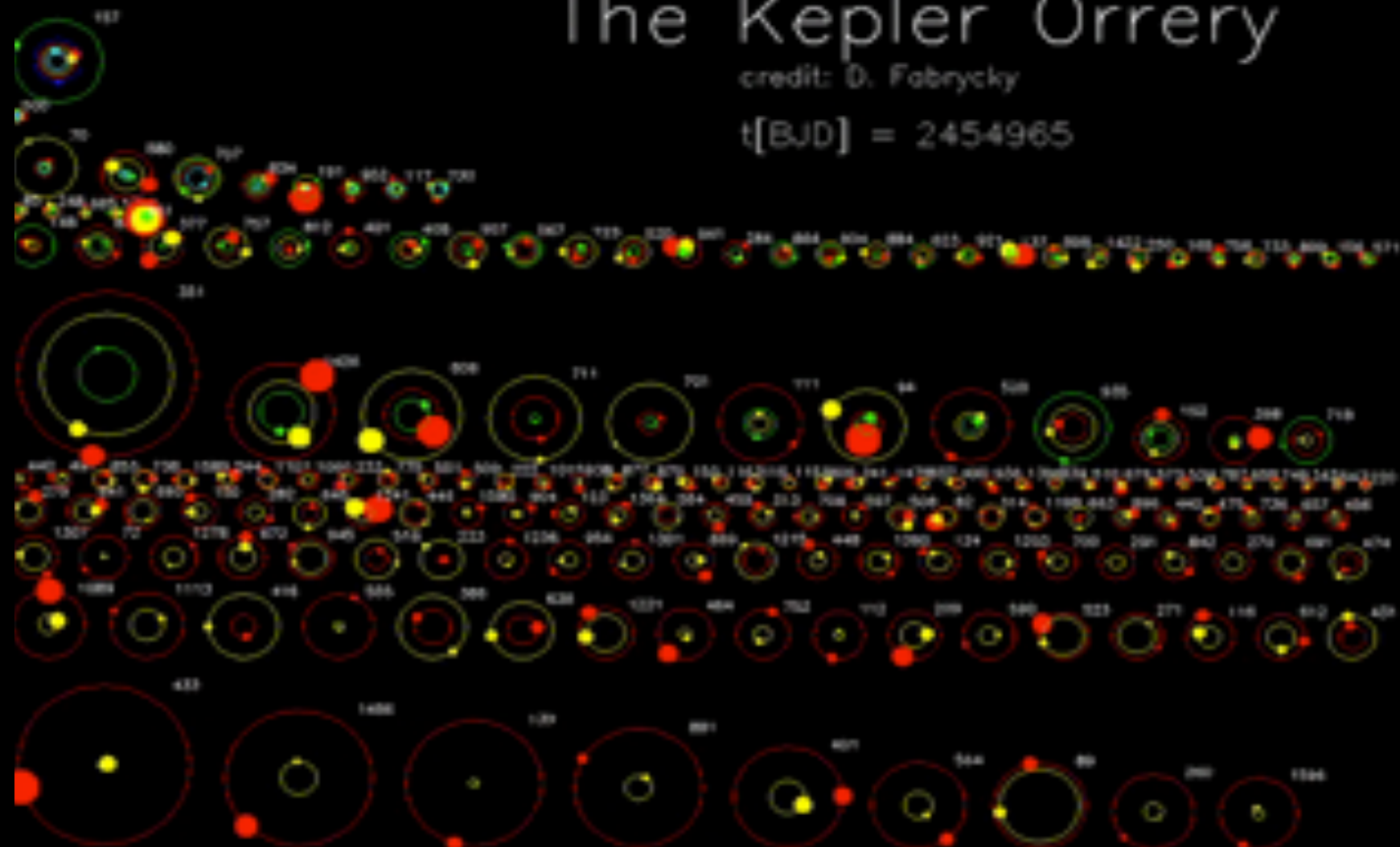
Heartbeat Stars: KOI-54



The Kepler Orrery

credit: D. Fabrycky

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



Kepler taught us that planets are everywhere!

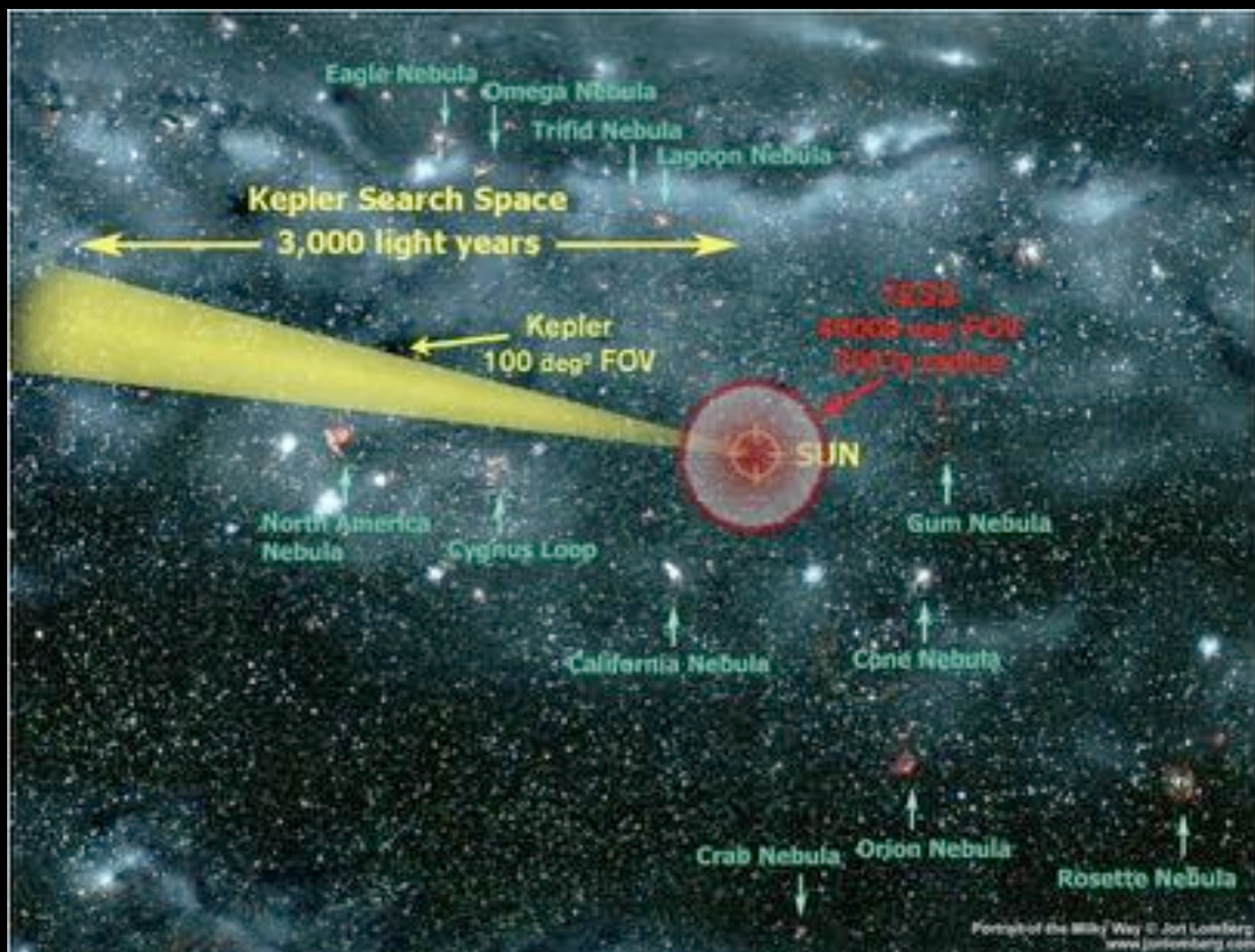
What Next?



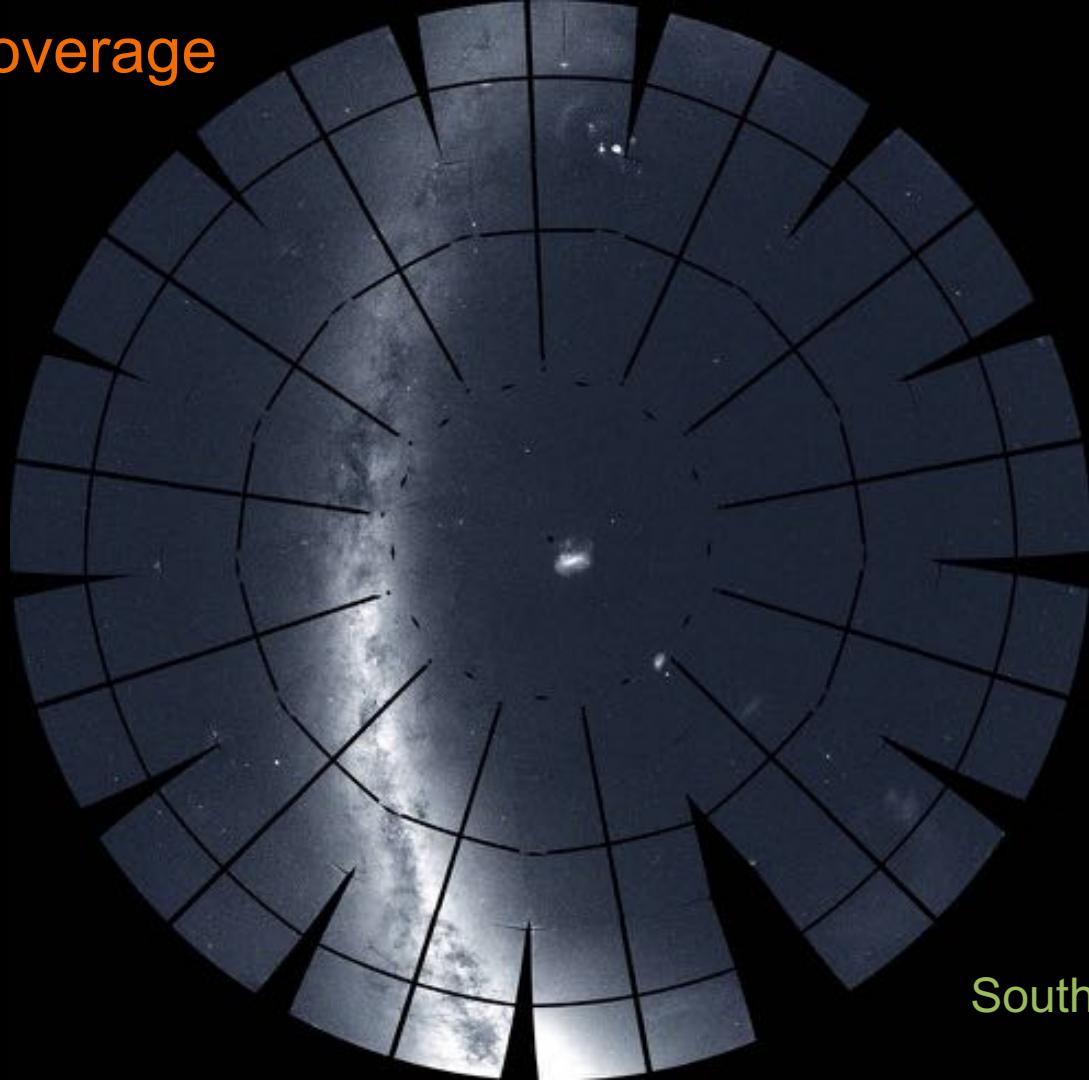
TRANSITING EXOPLANET SURVEY SATELLITE

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



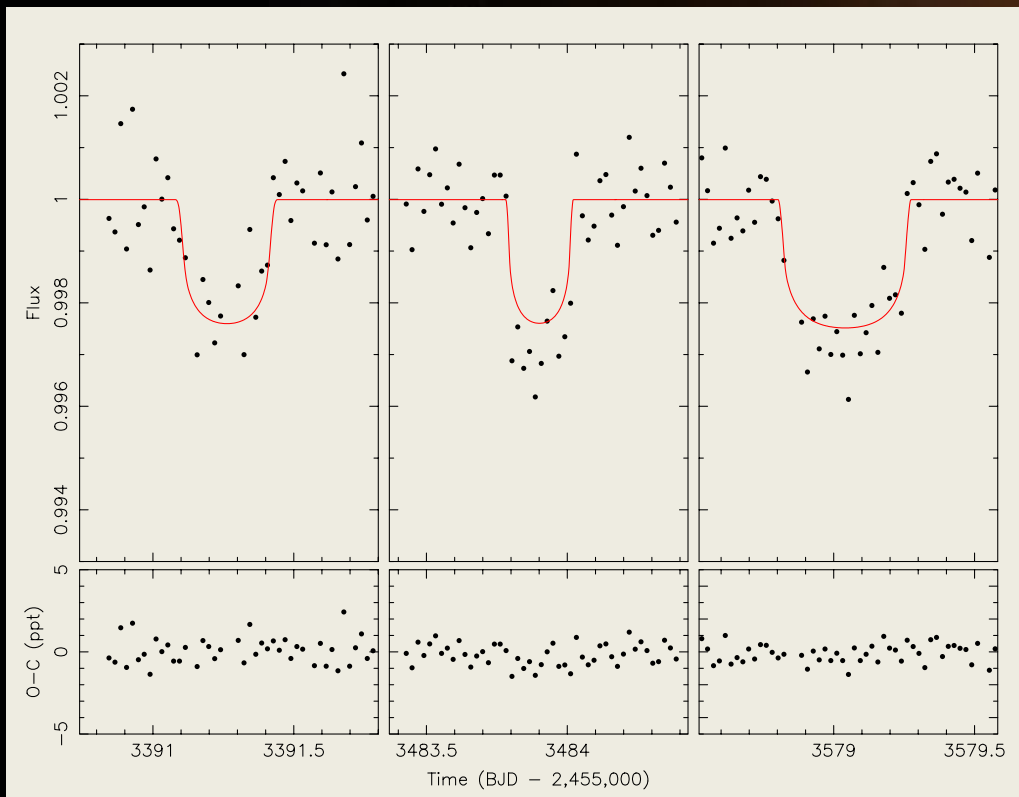


TESS Sky Coverage

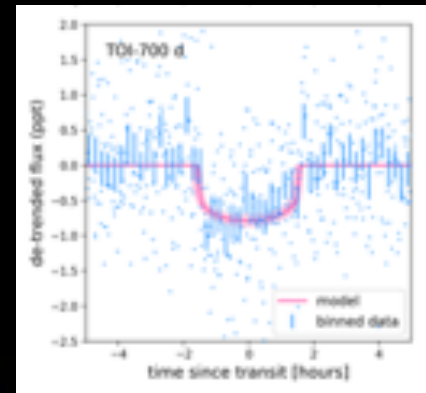
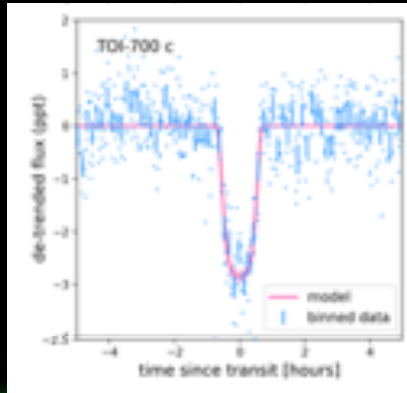
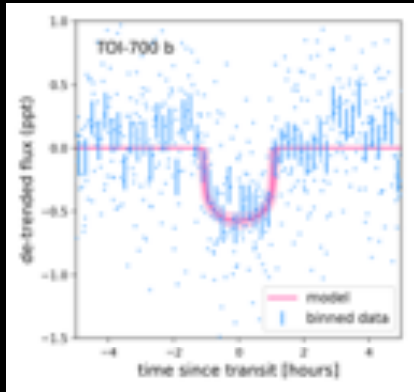


Southern Hemisphere

First Circumbinary Planet: TOI-1338b



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



Detecting Biomarkers through Transit Spectroscopy

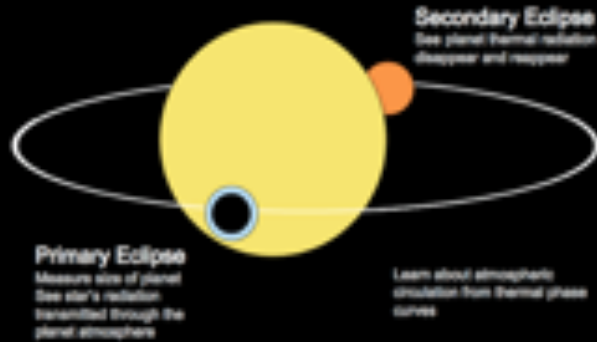
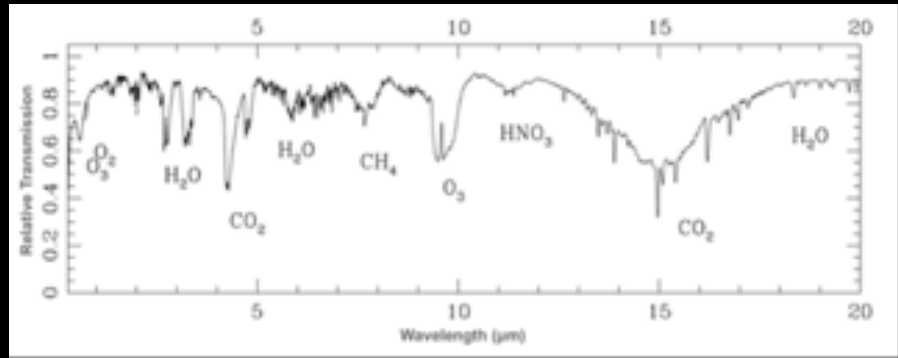


Figure by S. Seager



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

Exoplanet Missions



W. M. Keck Observatory



Large Binocular Telescope Interferometer



NN-EXPLORE

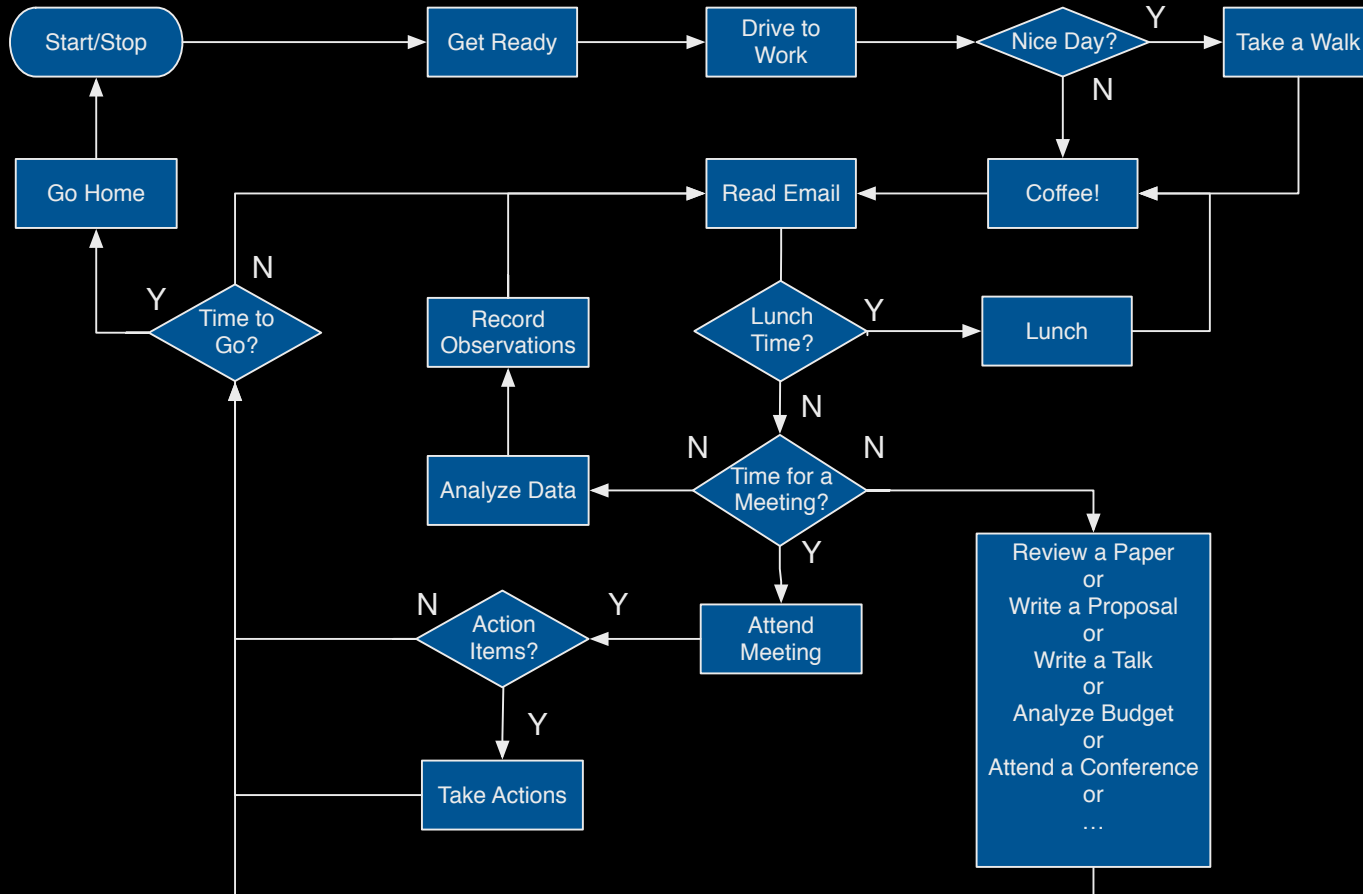
Ground Telescopes with NASA participation

¹ NASA/ESA Partnership

² NASA/ESA/CSA Partnership

³ CNES/ESA

A Typical Day



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



Earning Potential

Aerospace Engineer: \$64K-148K

Mechanical Engineer: \$55K-\$122K

Software Engineer: \$60K-\$125K

Electrical Engineer: \$57K-\$127K

Astrophysicist: \$46K-\$119K

Research Scientist: \$46K-\$106K

Project Manager: \$78K-\$173K

Benefits:

Vacation/Sick Leave

Medical/Dental/Vision

Disability Insurance

Pension Plan

401K Plan

Do you have questions?