

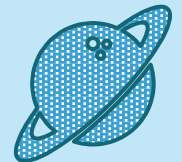
EXOPLANETS:

Worlds Around Other Stars

Megan Bedell



University of Chicago



POP QUIZ:

How many planets can you name?



**Mercury,
Venus, Earth,
Mars, Saturn,
& Jupiter**

Johannes Kepler, 1609

Uranus

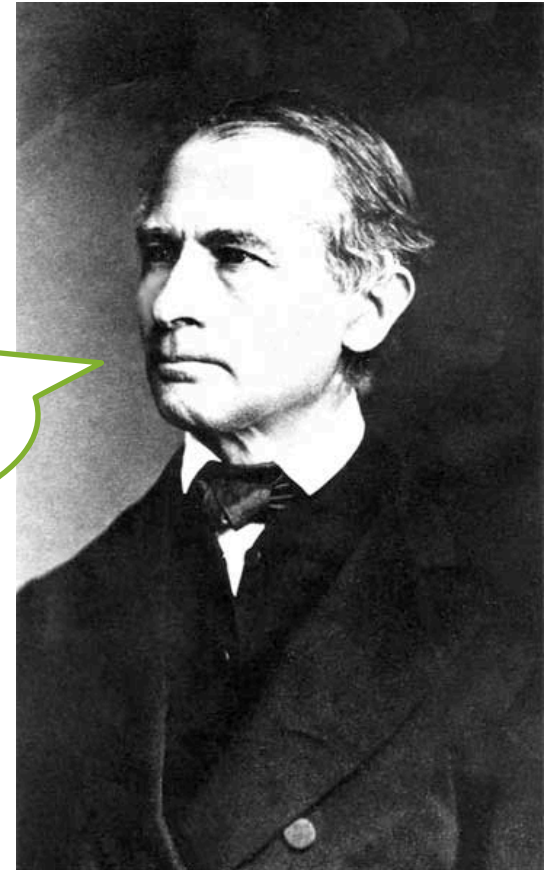
William &
Caroline
Herschel, 1781





and
another
one...

Neptune!



Urbain Le Verrier & Johann Gottfried Galle,
1846



don't forget
Pluto!

Clyde Tombough,
1930

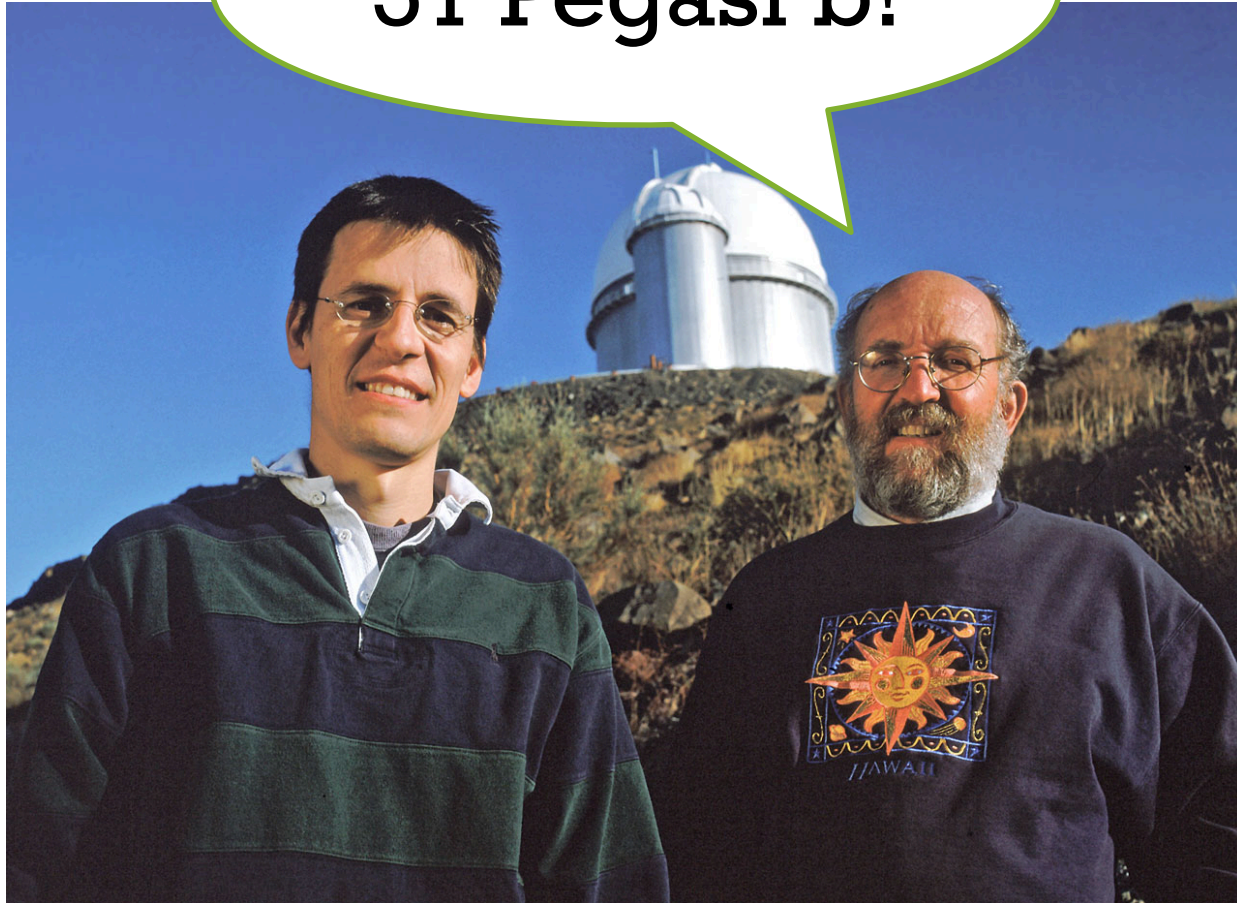


don't forget
Pluto!

not so fast...

Mike Brown, 2005

51 Pegasi b!



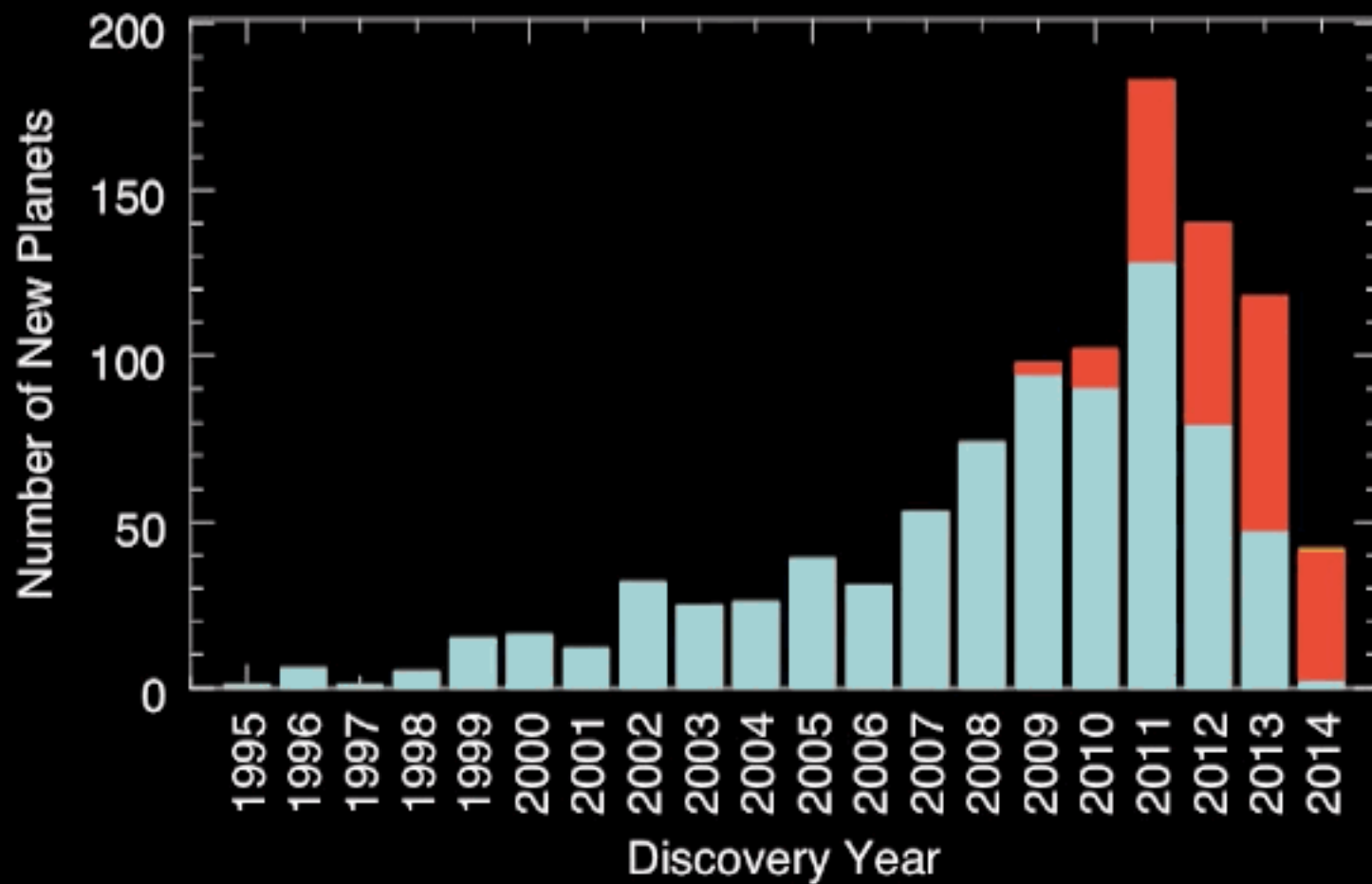
Michel Mayor & Didier Queloz, 1995

NASA Kepler team, 2009



Kepler-1 b
Kepler-2 b
Kepler-3 b
Kepler-4 b

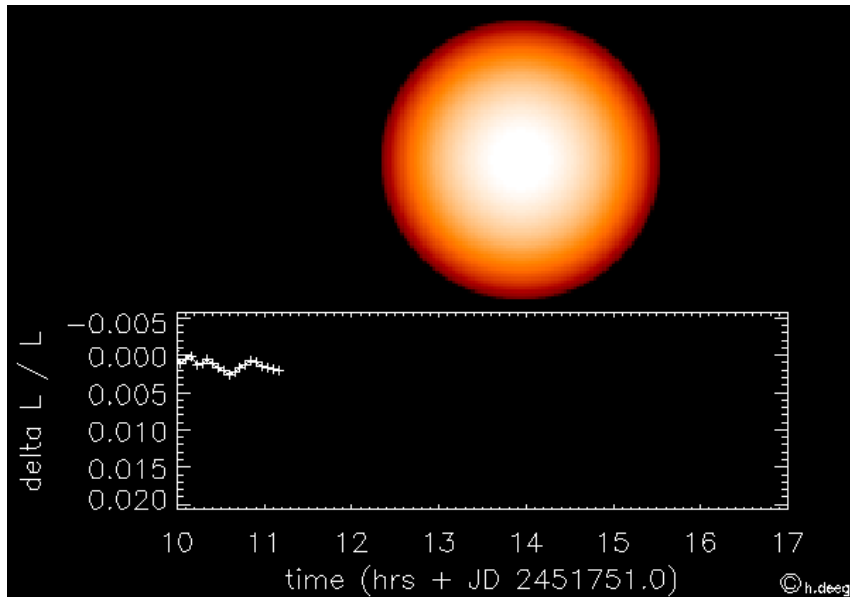
...

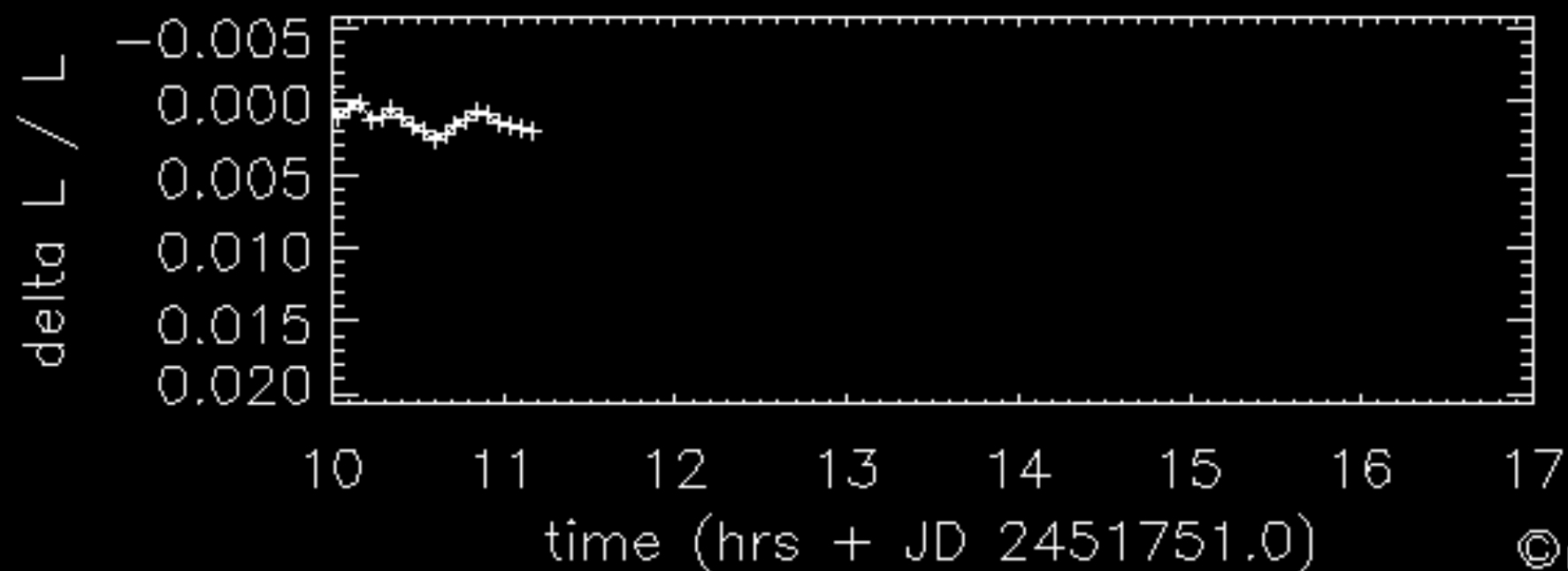
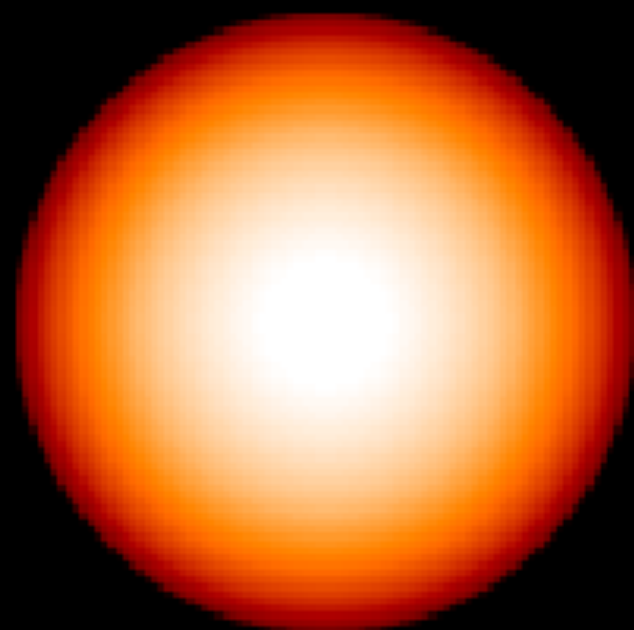


1642 Total Confirmed Planets

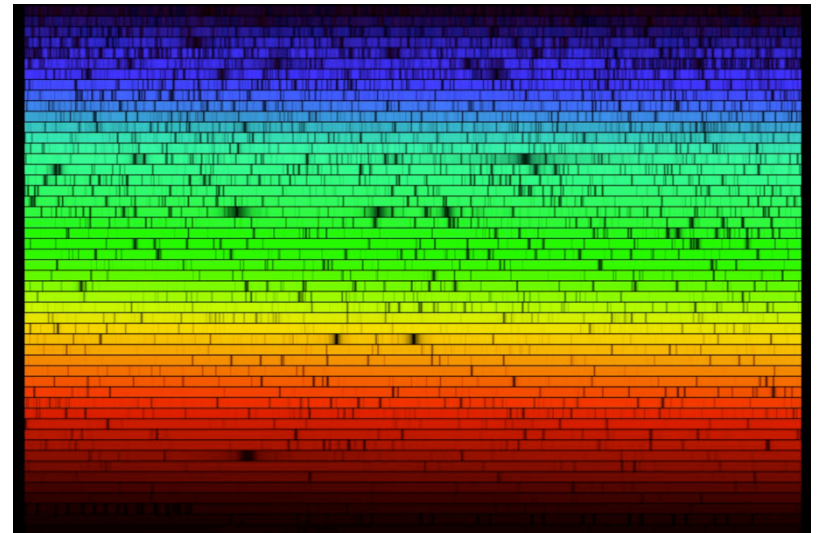
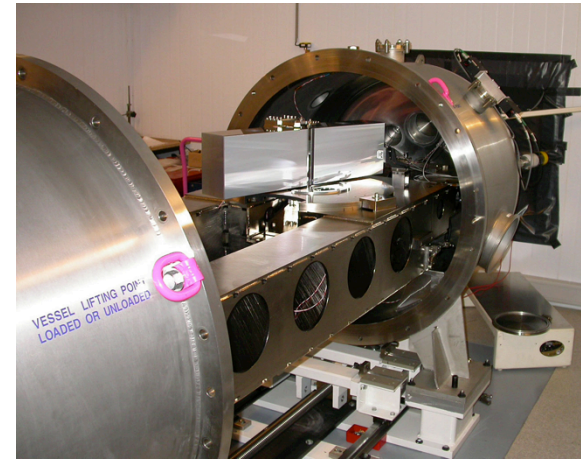
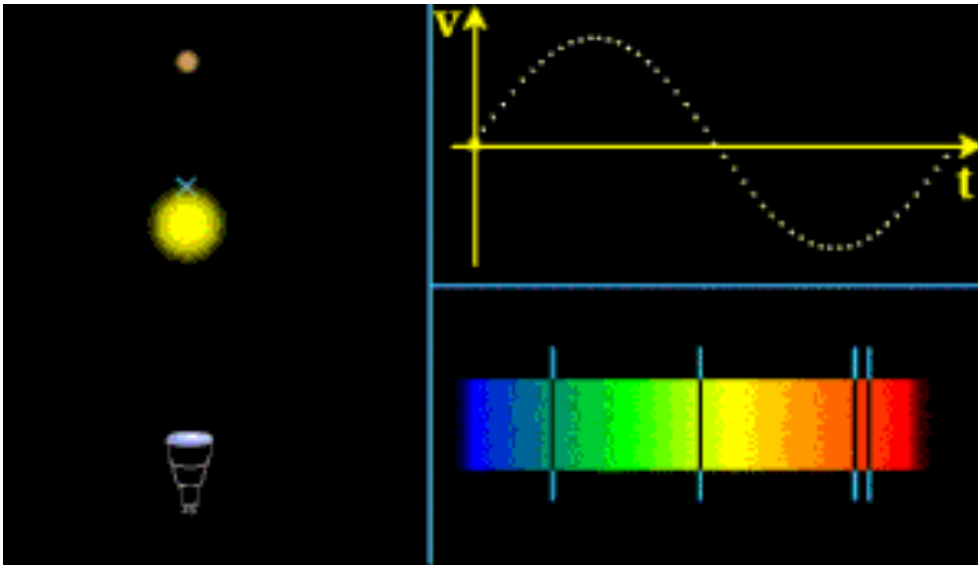
HOW DO WE FIND EXOPLANETS?

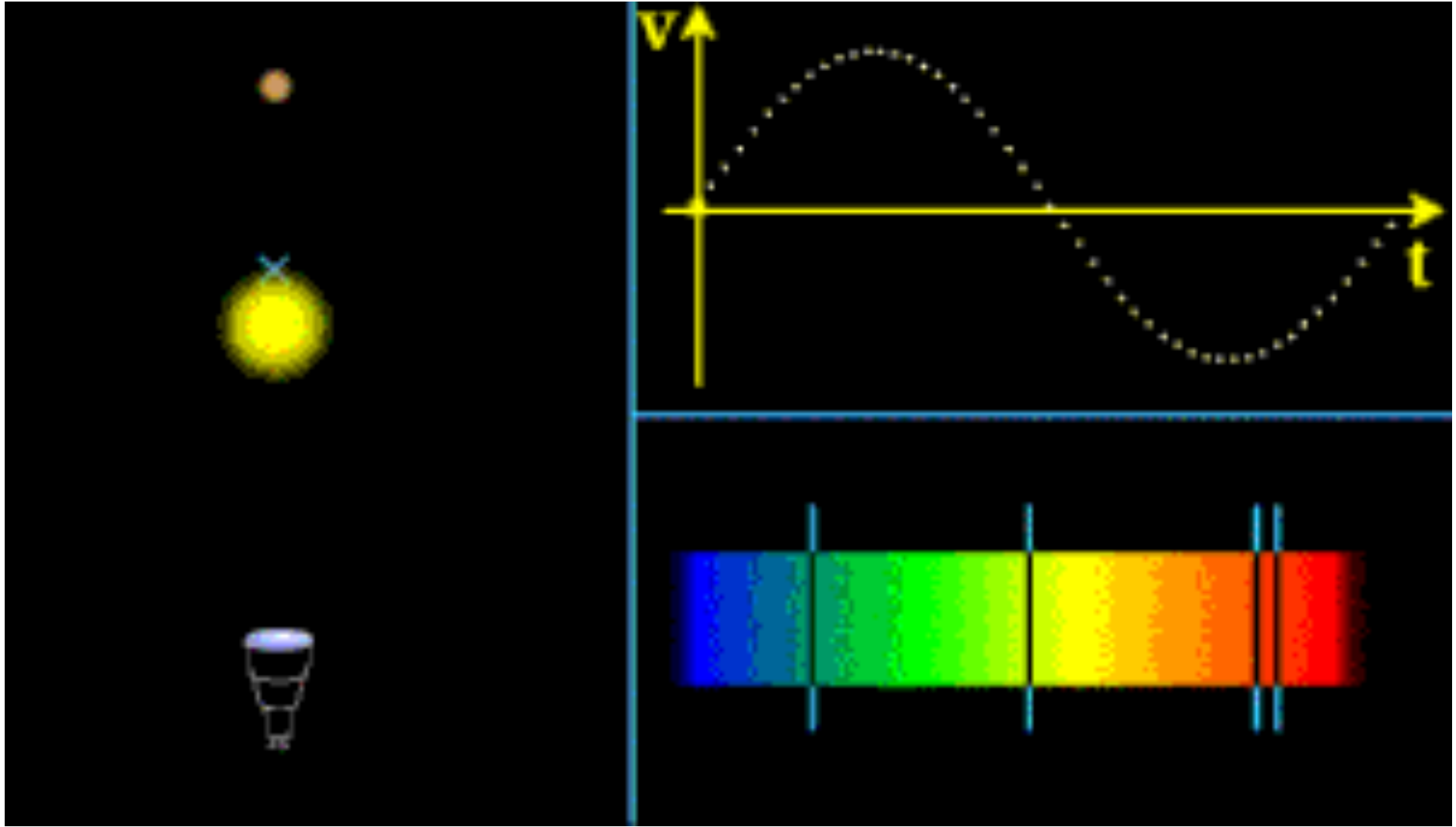
THE TRANSIT TECHNIQUE





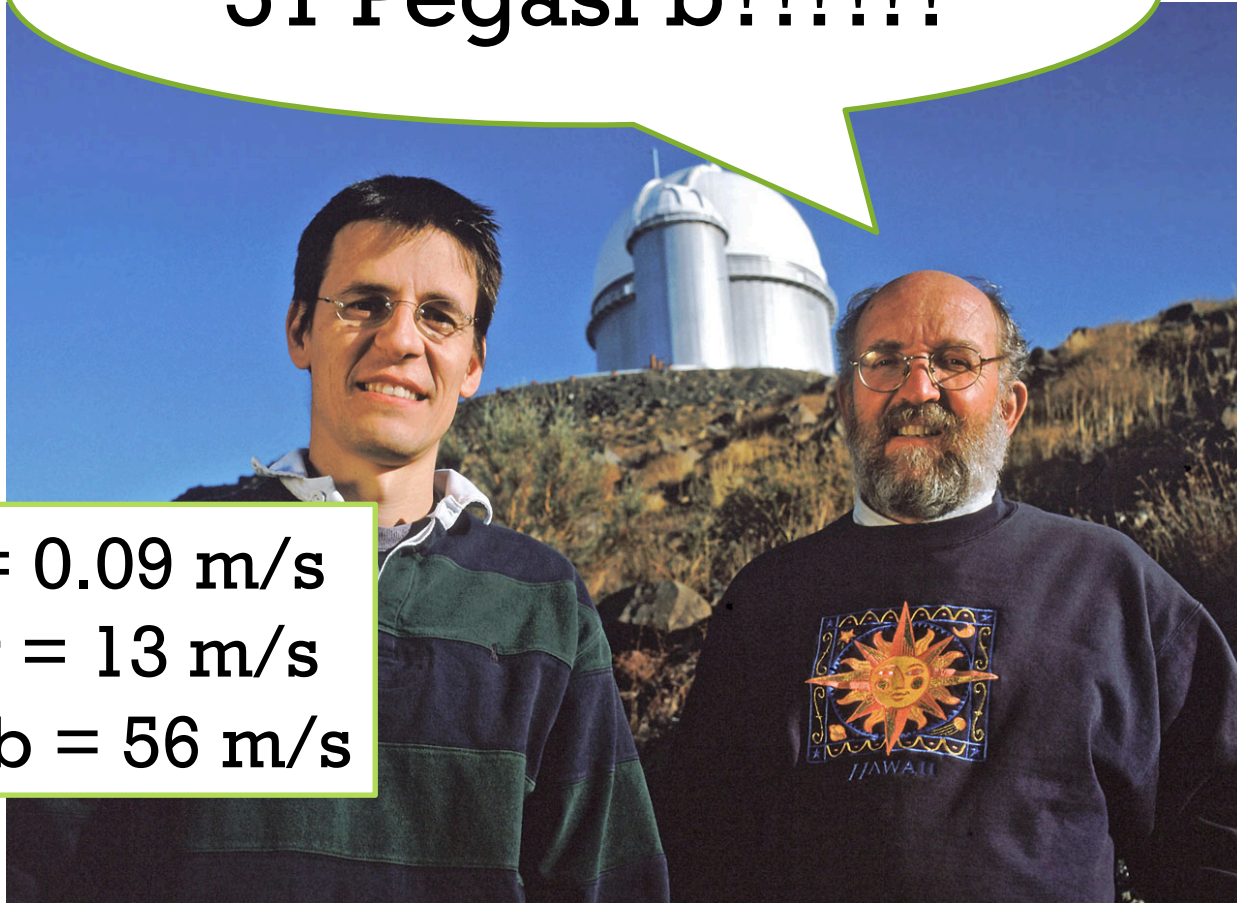
THE DOPPLER TECHNIQUE





51 Pegasi b?!?!?!?

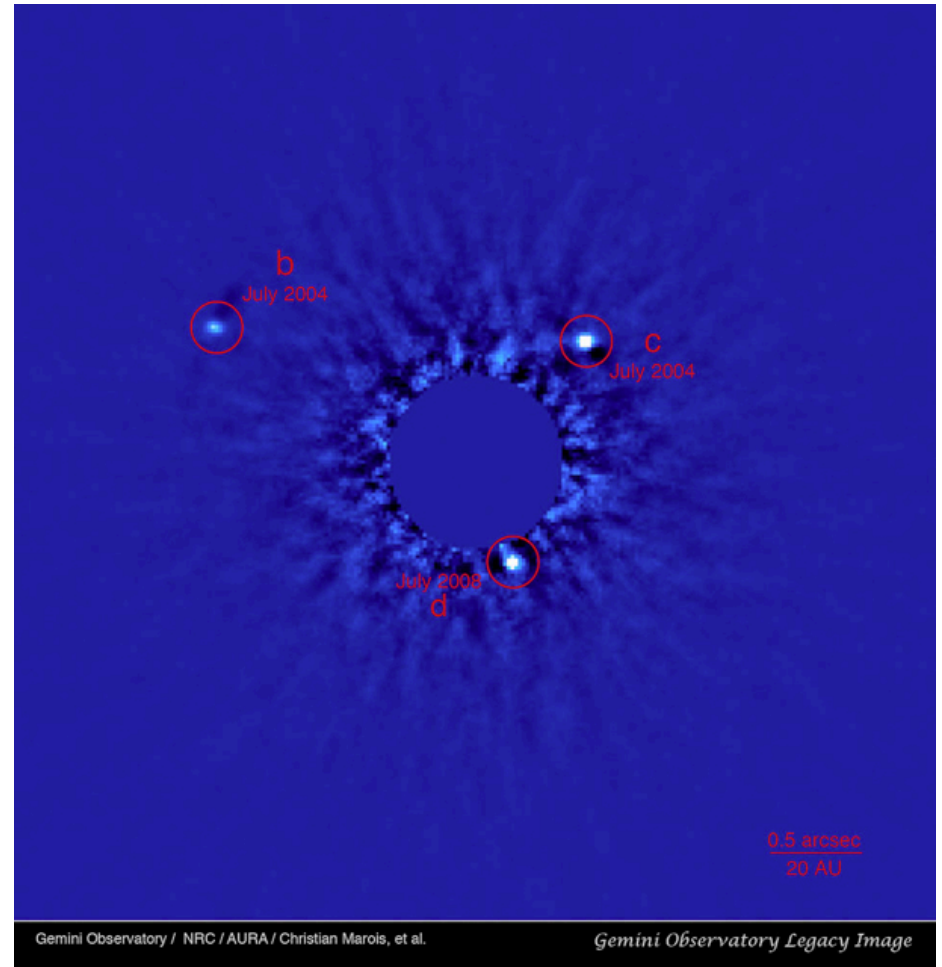
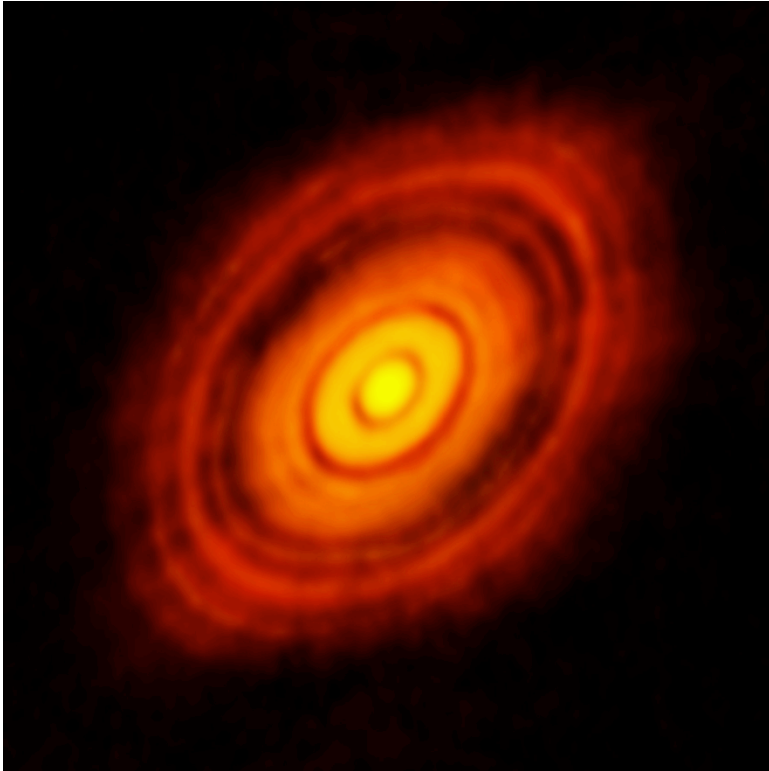
Earth = 0.09 m/s
Jupiter = 13 m/s
51 Peg b = 56 m/s



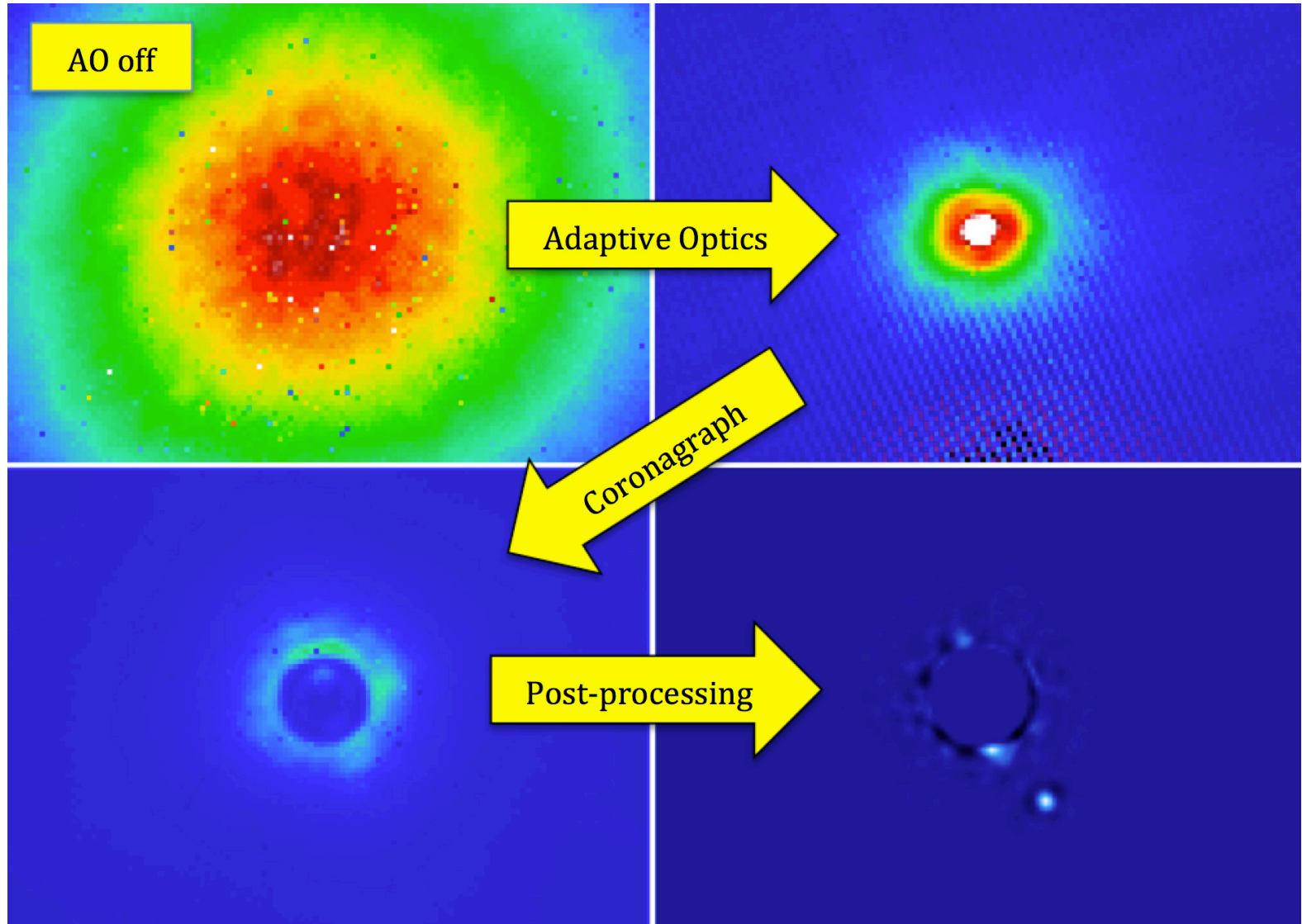
Michel Mayor & Didier Queloz, 1995



DIRECT IMAGING



DIRECT IMAGING



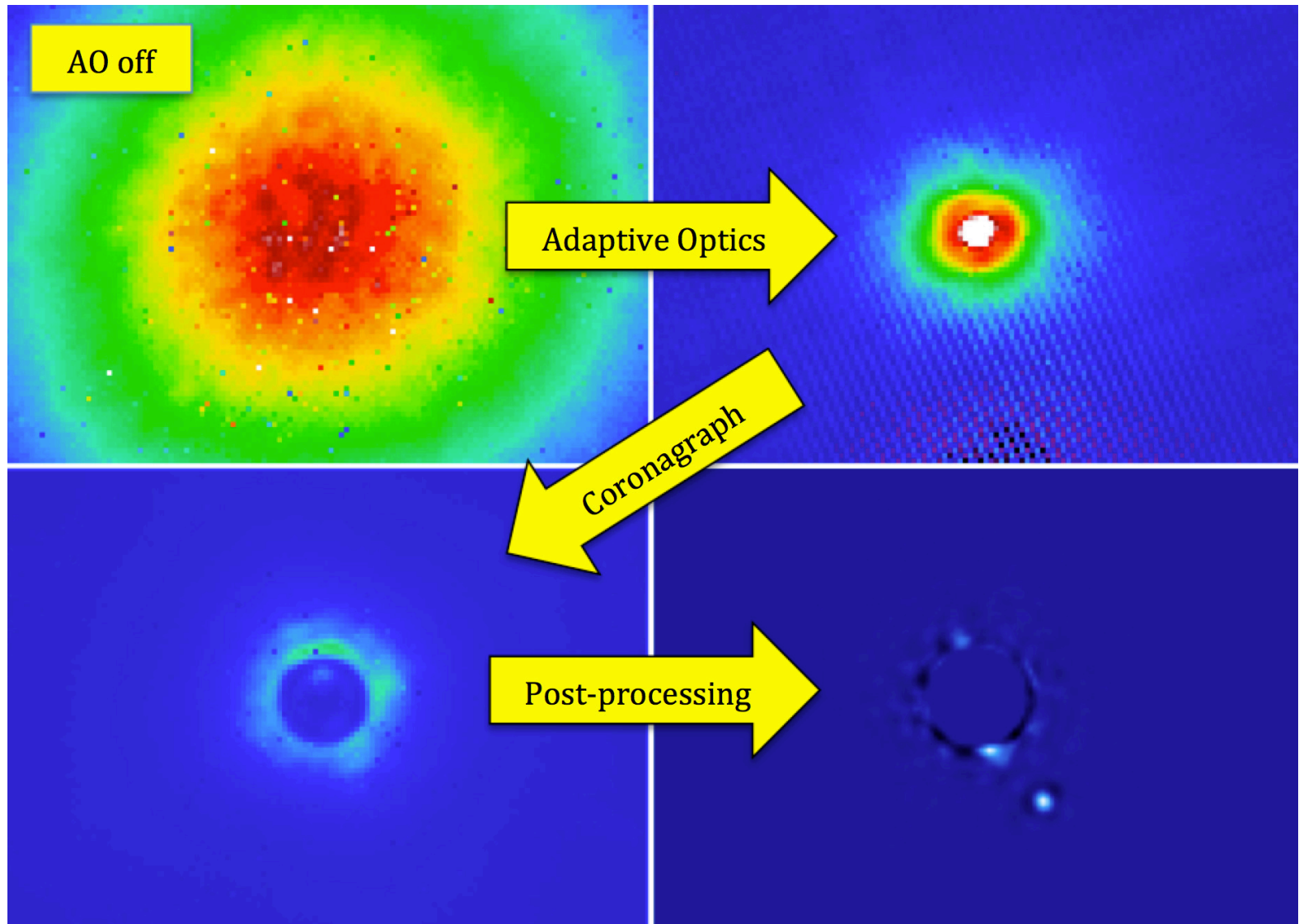
DIRECT IMAGING

AO off

adaptive optics



DIRECT IMAGING

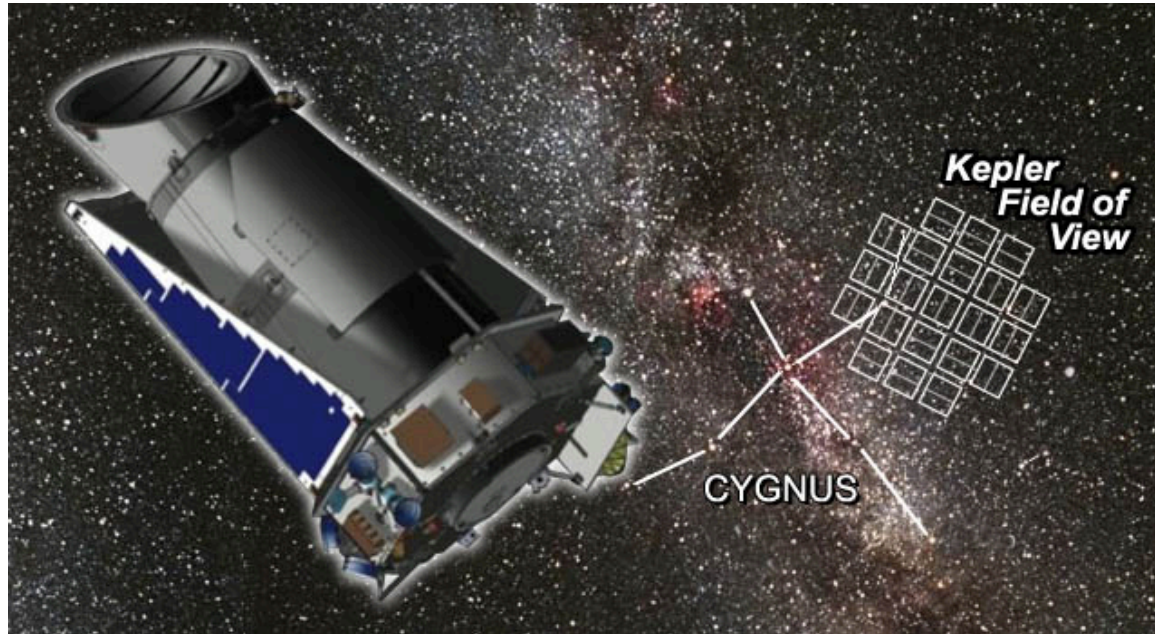


SURVEYING THE GALAXY

Where do we start?!

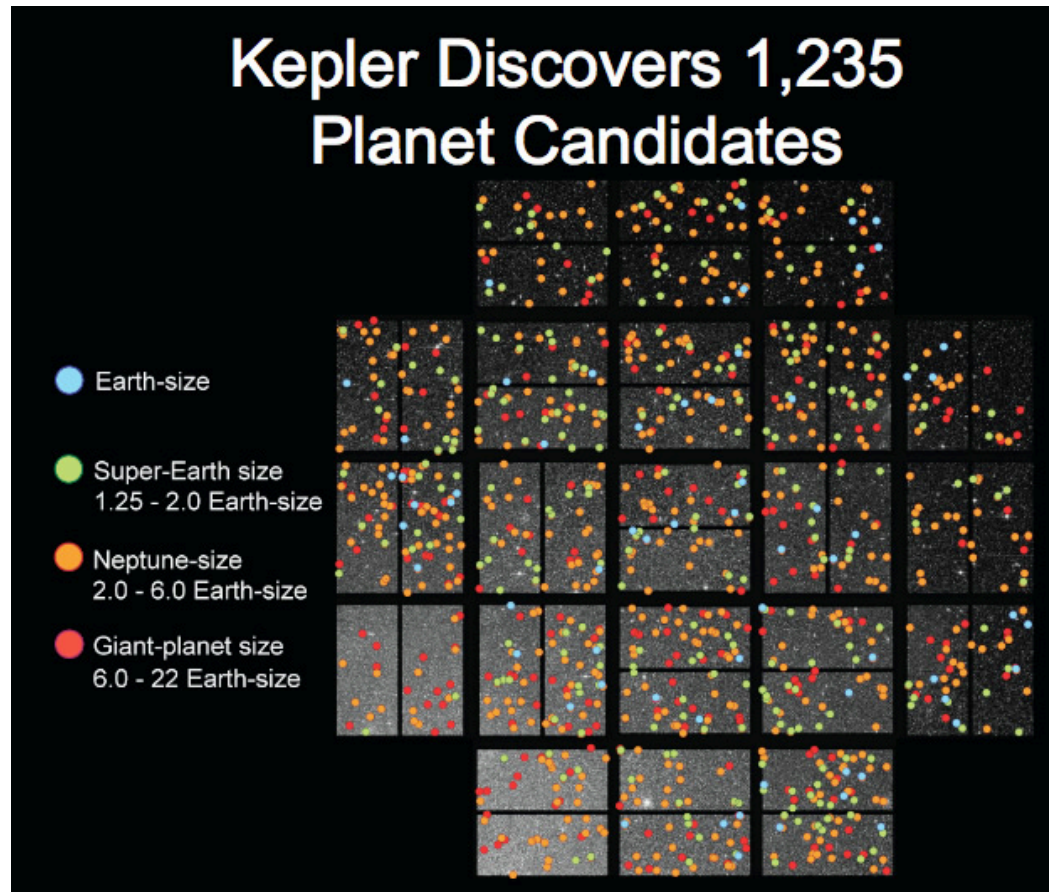


Start small, aim high



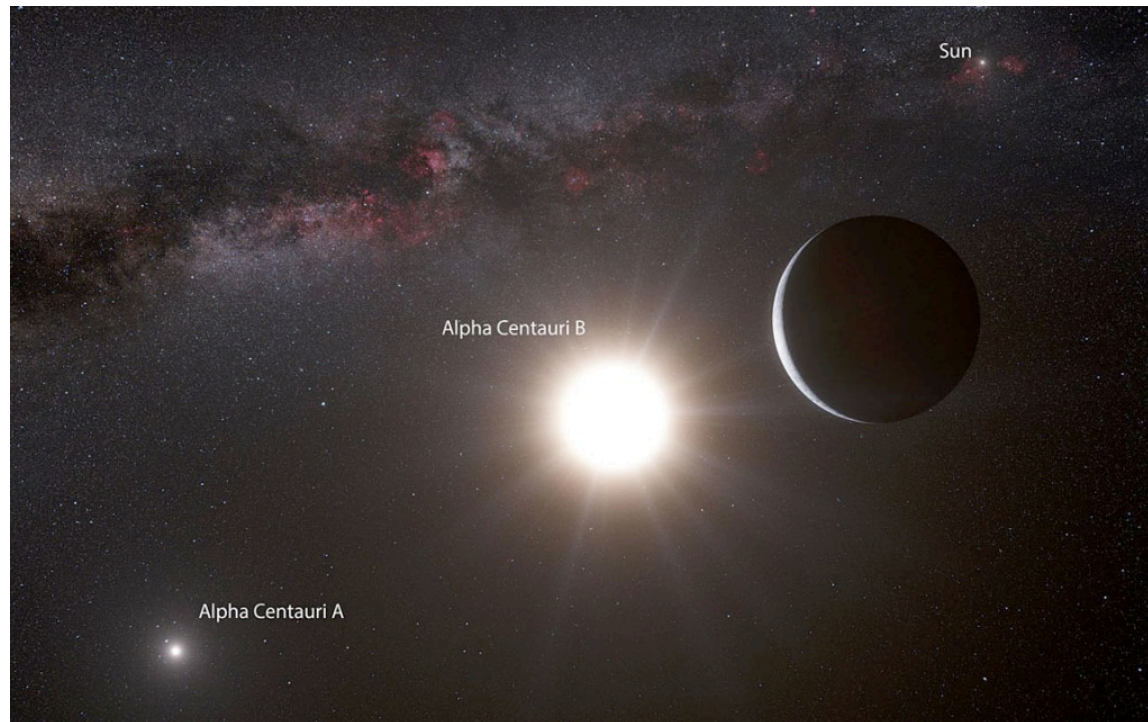
Kepler spacecraft, 2009-2013
150,000 stars surveyed in 100
square degrees on sky

Start small, aim high



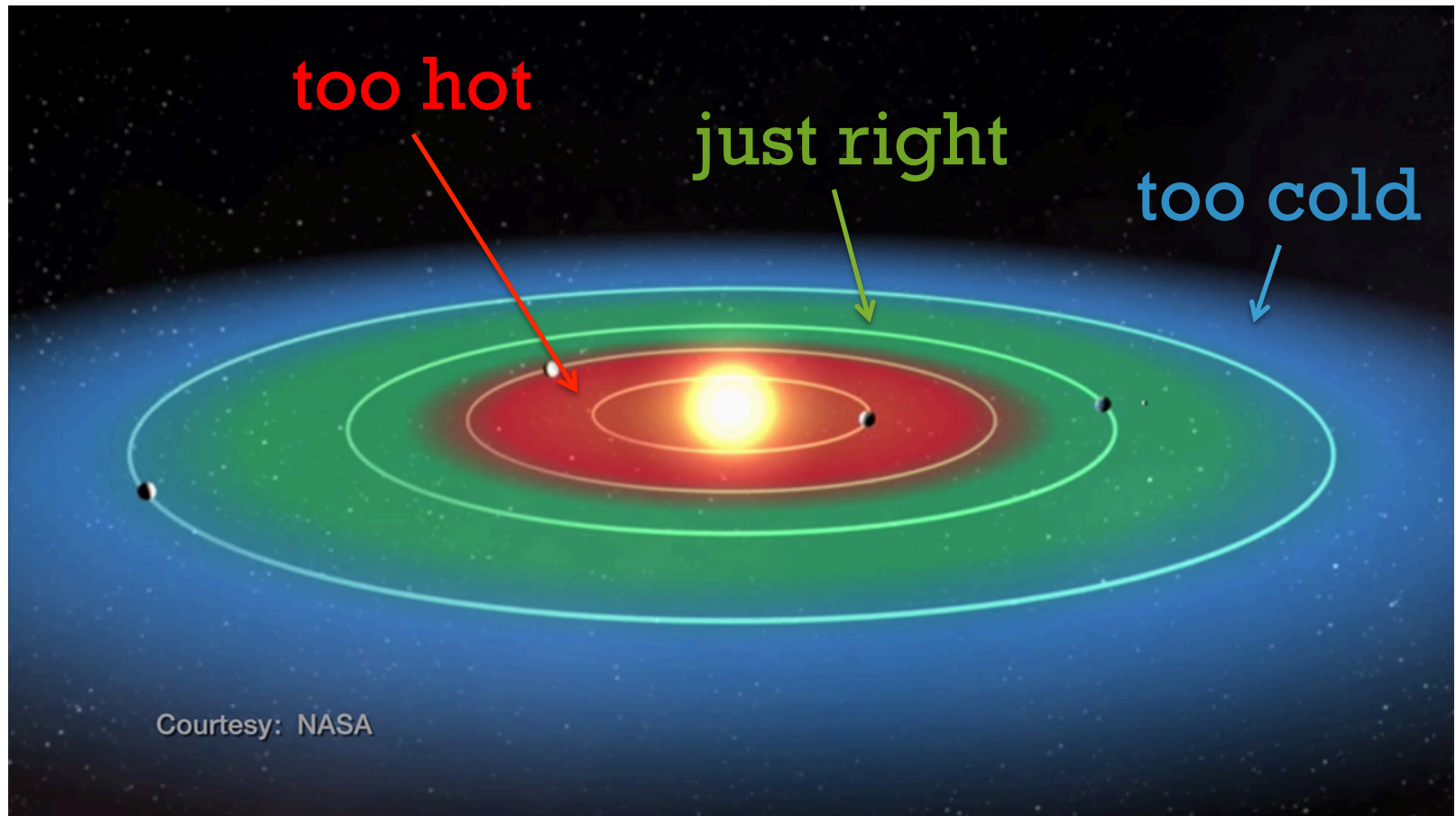
Our Nearest Neighbors

Nearby stars are the brightest & especially good for the Doppler method.

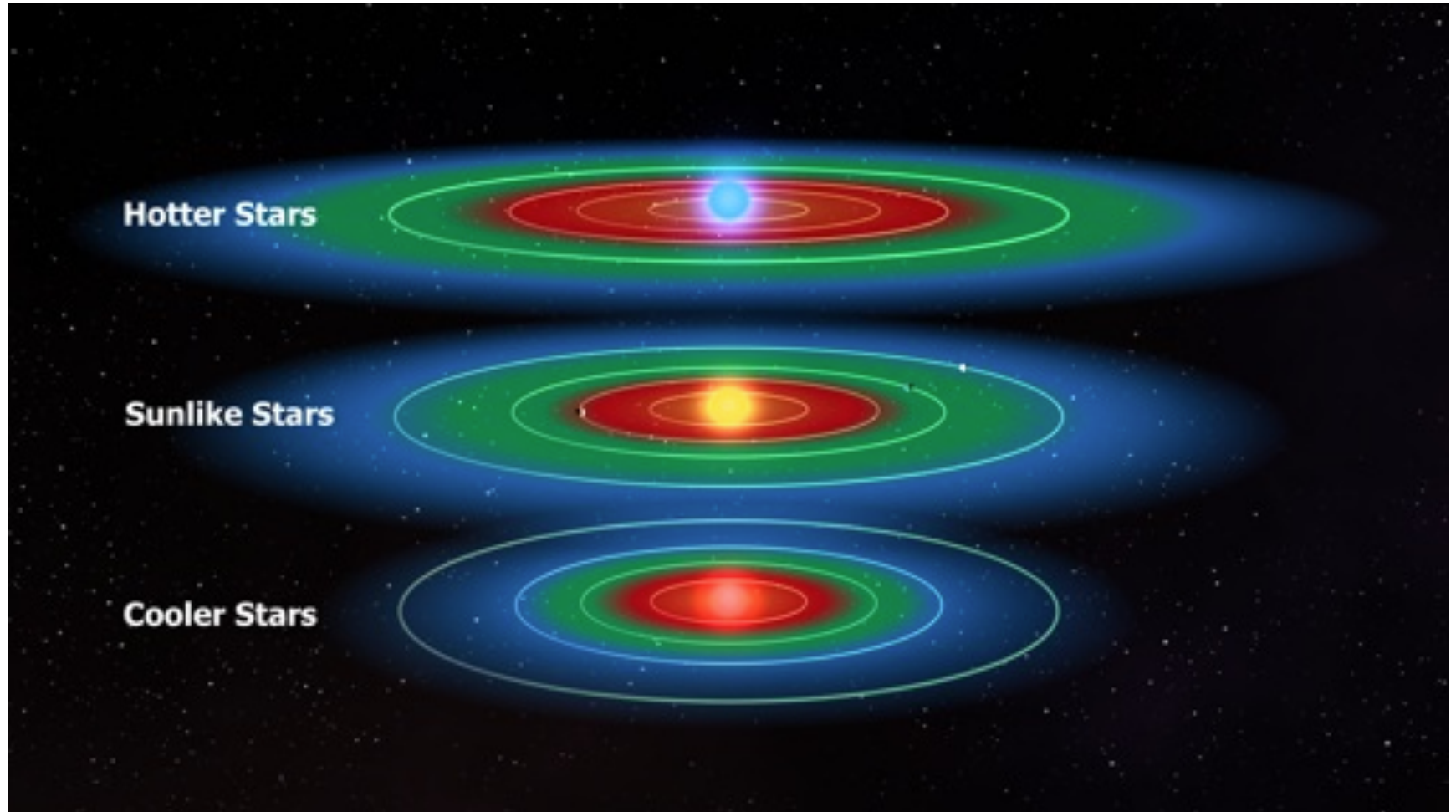


α Centauri Bb: 459 measurements needed for detection!

Target The Habitable Zone



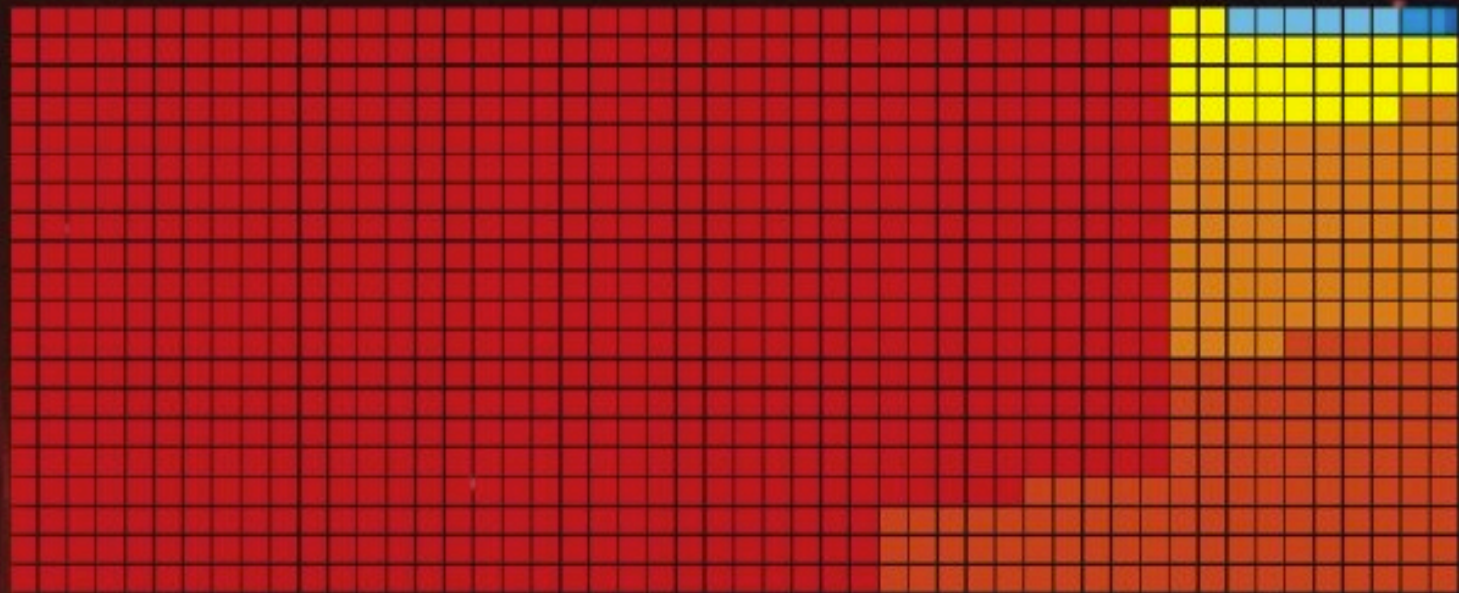
Target The Habitable Zone



The Promise of Small Stars

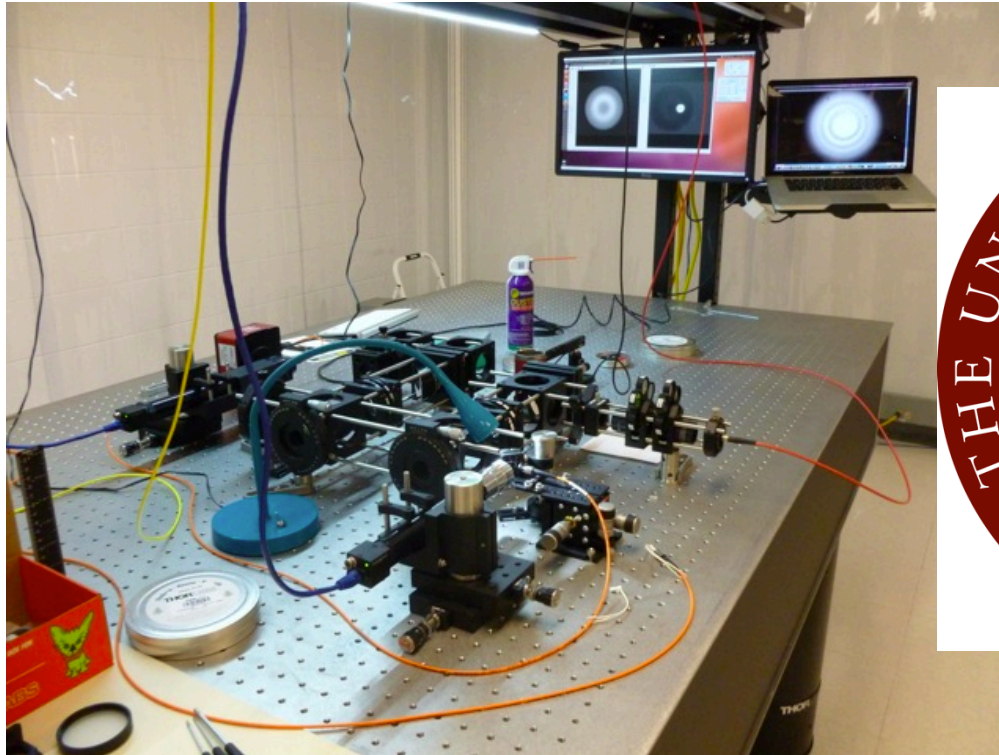
How many red dwarfs are there?

Percentage of main sequence stars in the universe



■ M (red dwarf) 76.45%	■ K 12.1%	■ G (the Sun) 7.6%	■ F 3%
■ A 0.6%	■ B 0.13%	■ O 0.00003%	

The Promise of Small Stars



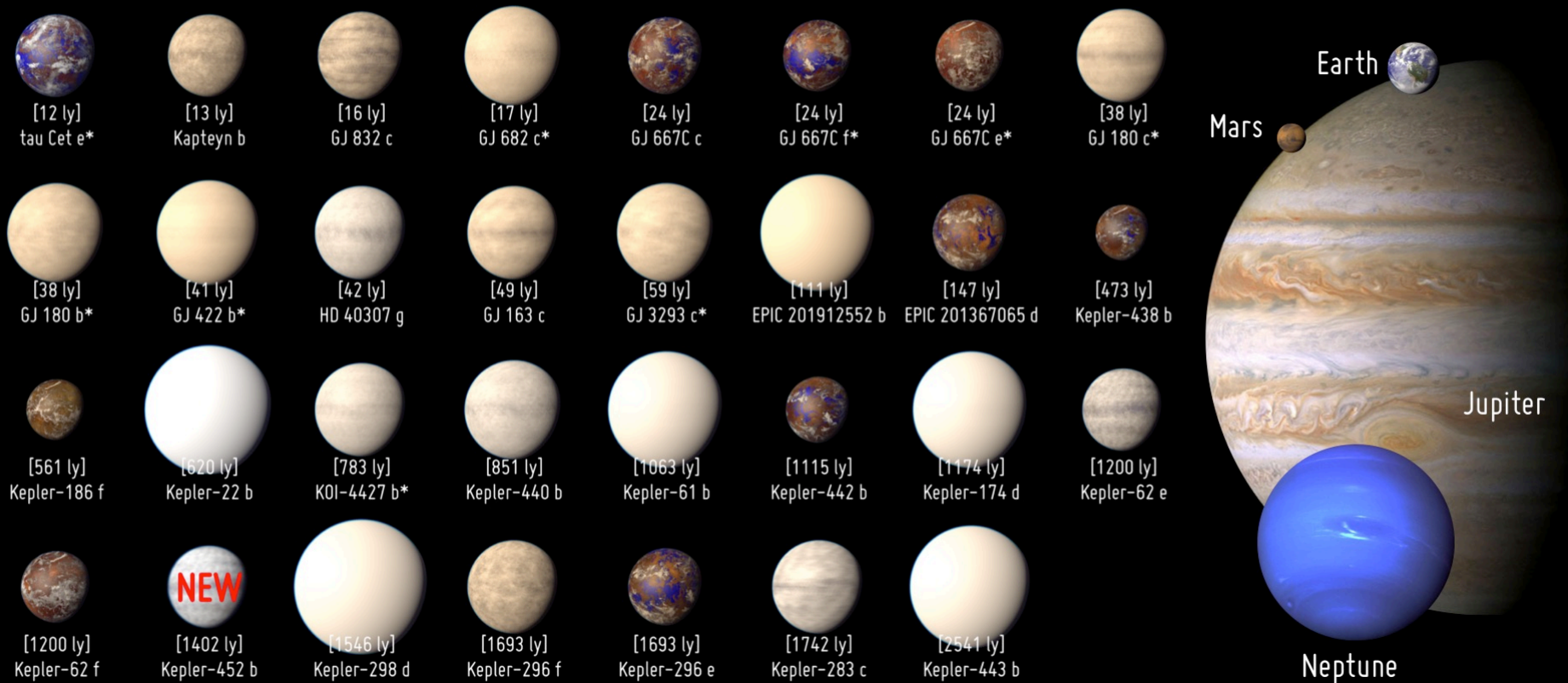
MAR^{ON}-X

**WHAT HAVE WE
FOUND?**

Habitable Worlds

Potentially Habitable Exoplanets

Ranked by Distance from Earth (light years)



Artistic representations. Earth, Mars, Jupiter, and Neptune for scale. Distance is between brackets. Planet candidates indicated with asterisks.

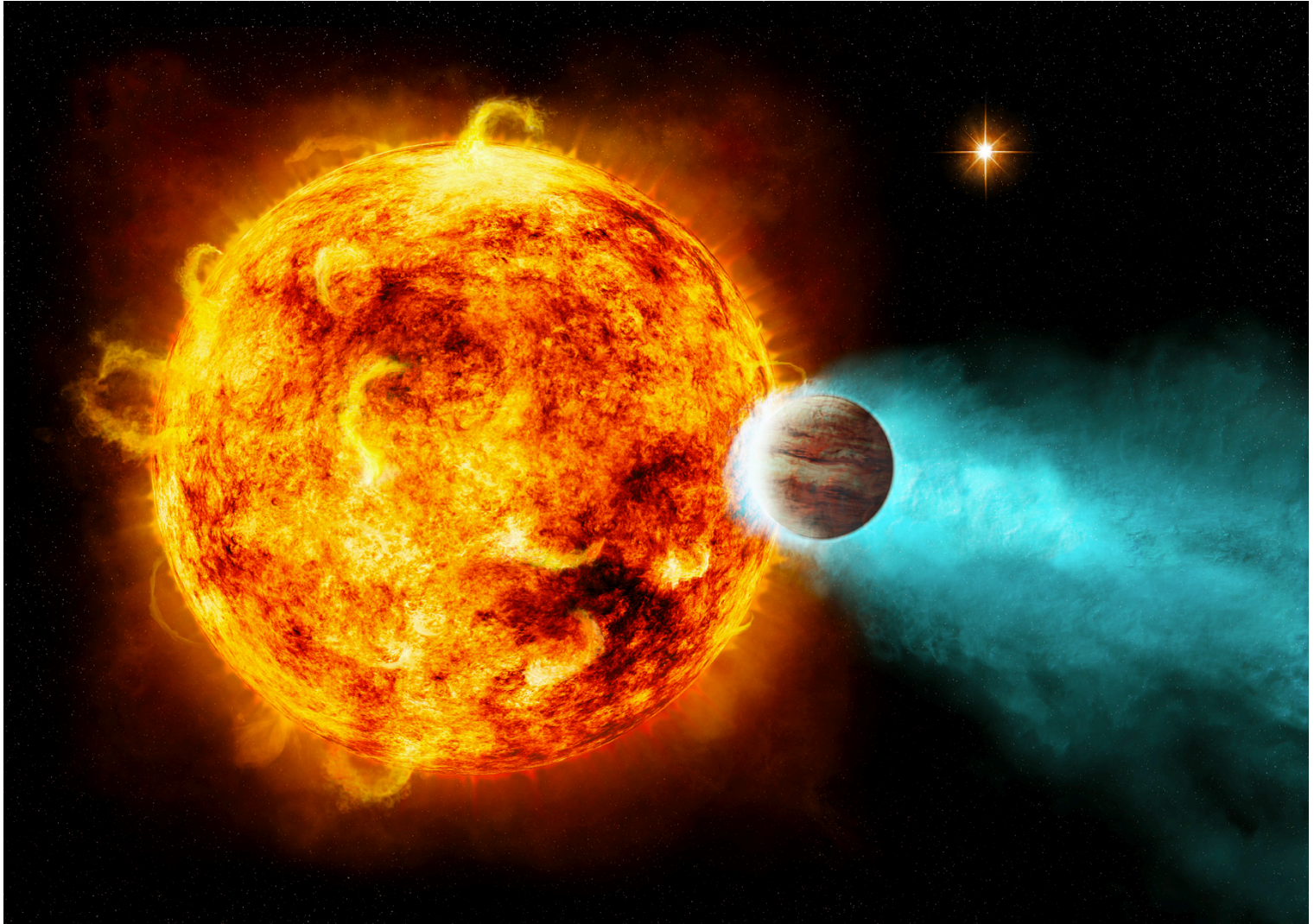
CREDIT: PHL @ UPR Arecibo (phl.upr.edu) July 23, 2015

Other Solar Systems?

Jupiter Twin Discovered Around Solar Twin



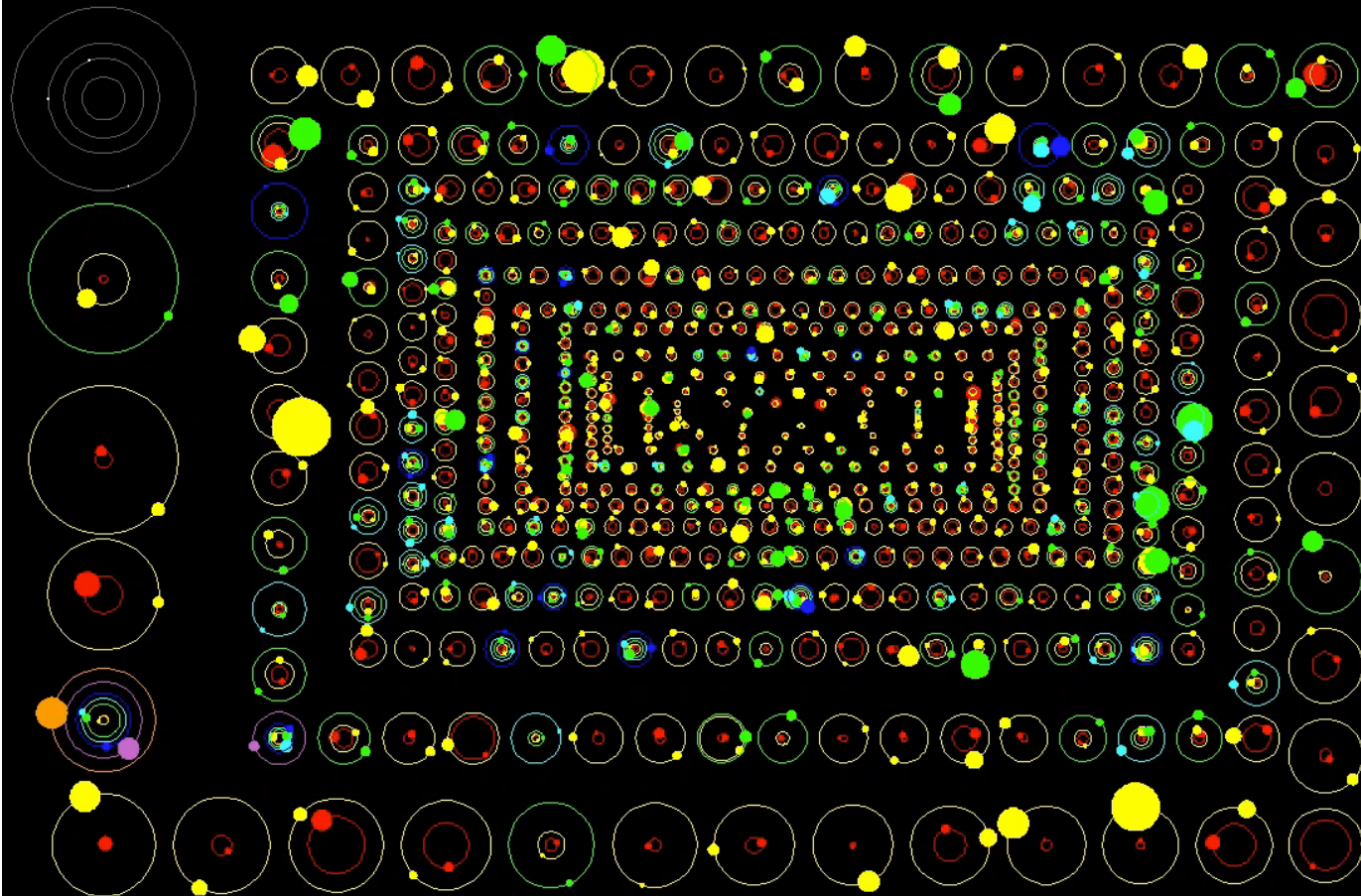
Hot Jupiters



Multi-planet Systems

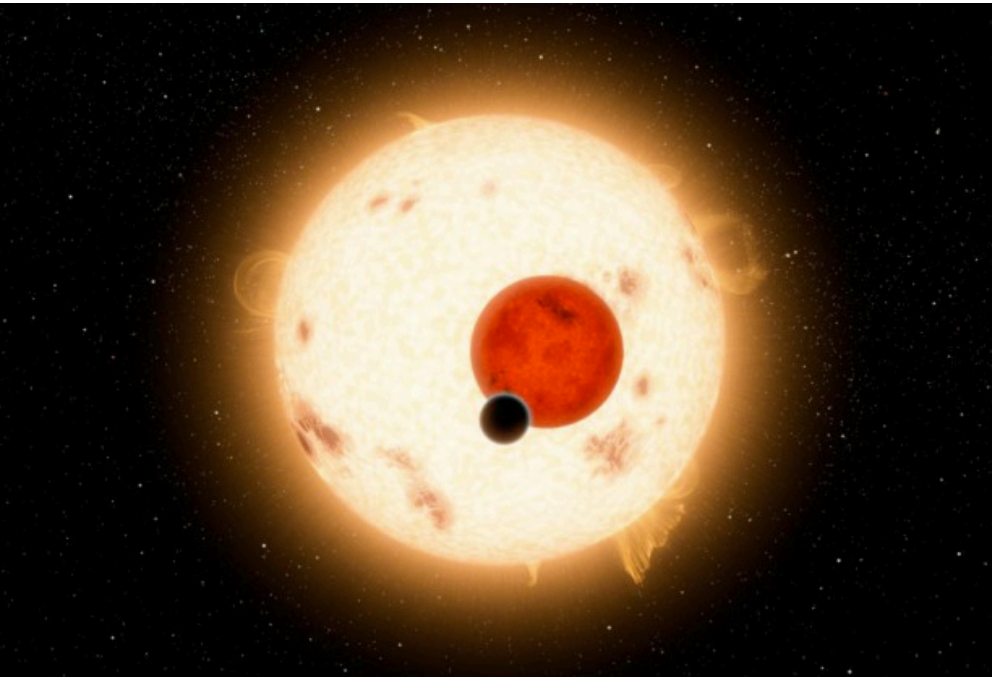
The Kepler Orrery III

$t[\text{BJD}] = 2455215$



Circumbinary Planets

(aka “Tatooines”)



ALIENS?!?!?

SETI

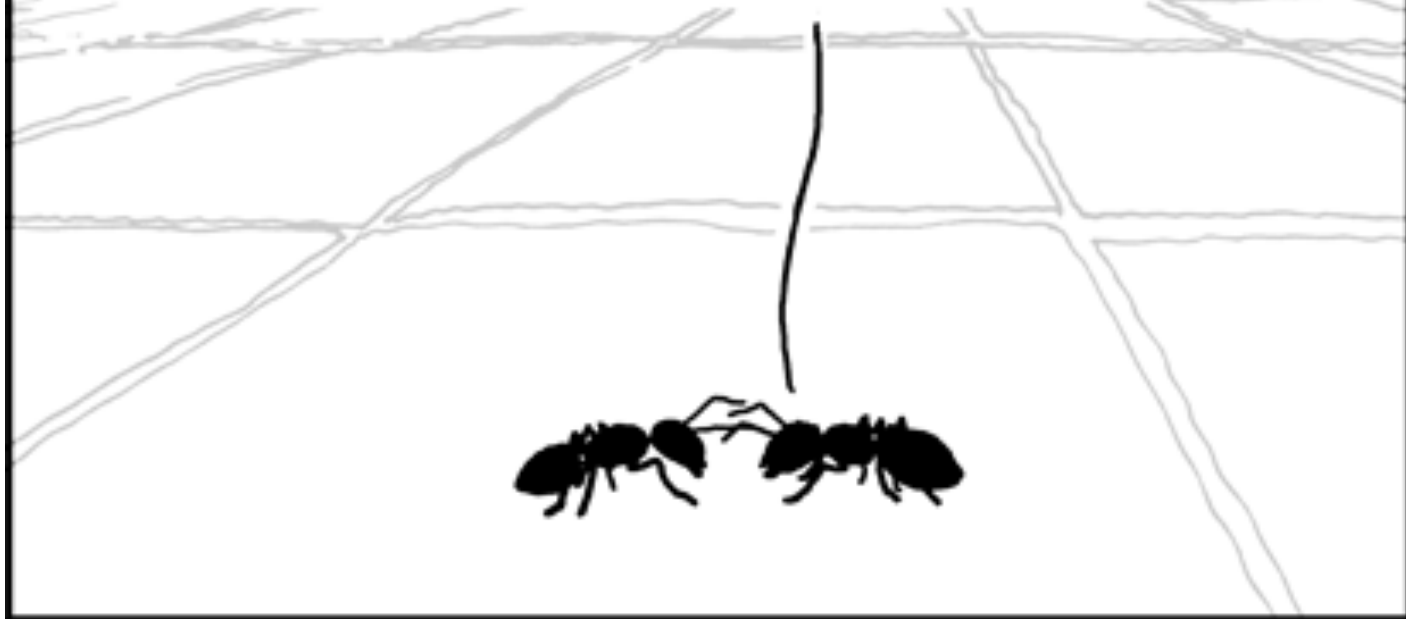
searching for **radio signals** from other civilizations



SETI

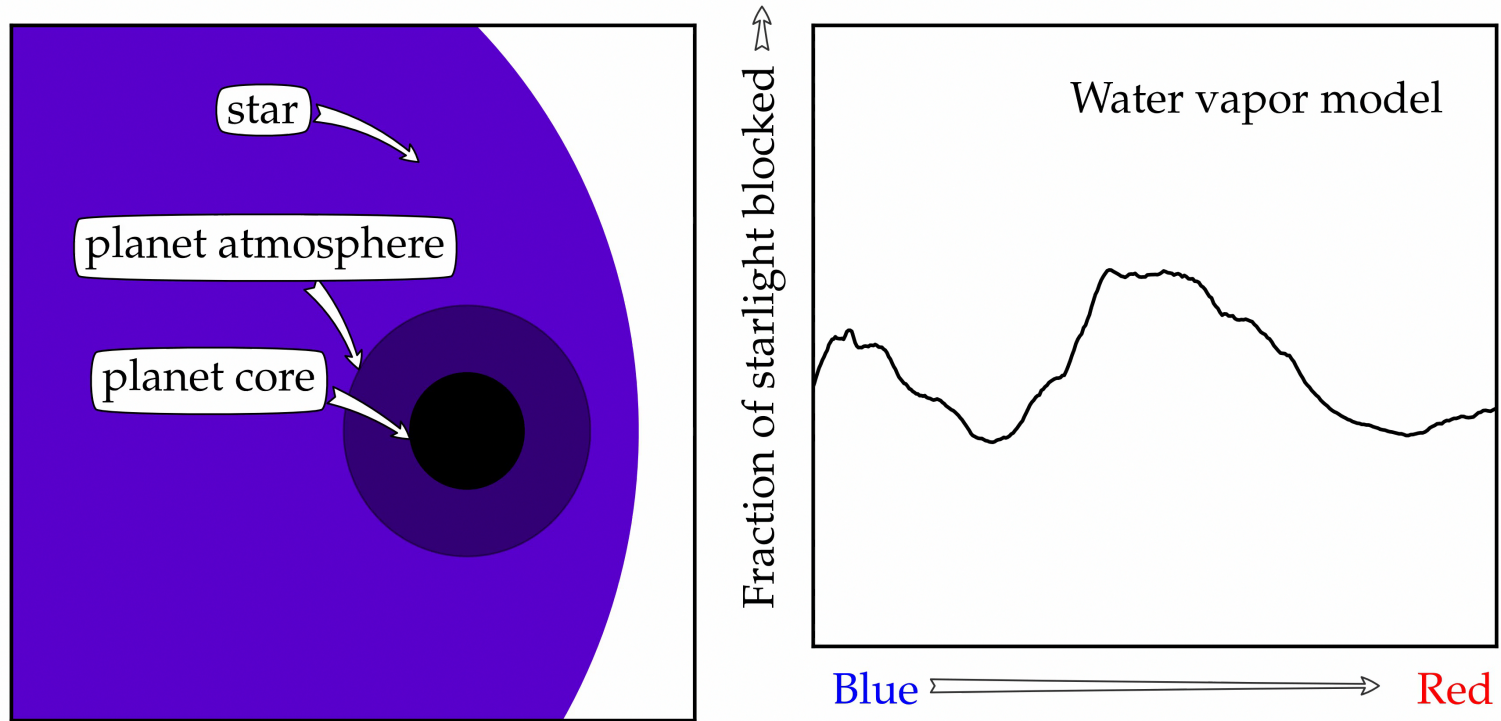
WE'VE SEARCHED DOZENS OF THESE FLOOR TILES FOR SEVERAL COMMON TYPES OF PHEROMONE TRAILS.

IF THERE WERE INTELLIGENT LIFE UP THERE, WE WOULD HAVE SEEN ITS MESSAGES BY NOW.



THE WORLD'S FIRST ANT COLONY TO ACHIEVE SENTIENCE CALLS OFF THE SEARCH FOR US.

Biological Signatures



looking into the **atmospheres** of other planets
could reveal life (intelligent or not!)

Other Wacky Ideas



ALIEN LIFE & EXOPLANETS

Has Kepler Discovered an Alien Megastructure?

OCT 14, 2015 02:23 PM ET // BY IAN O'NEILL

(Probably not.)

In Summary...

- Since 1995, we have rapidly discovered a lot of new planets!
- Exoplanets cover a wide range of properties
- Future missions will aim to find more Earth-like planets (and maybe even life!)