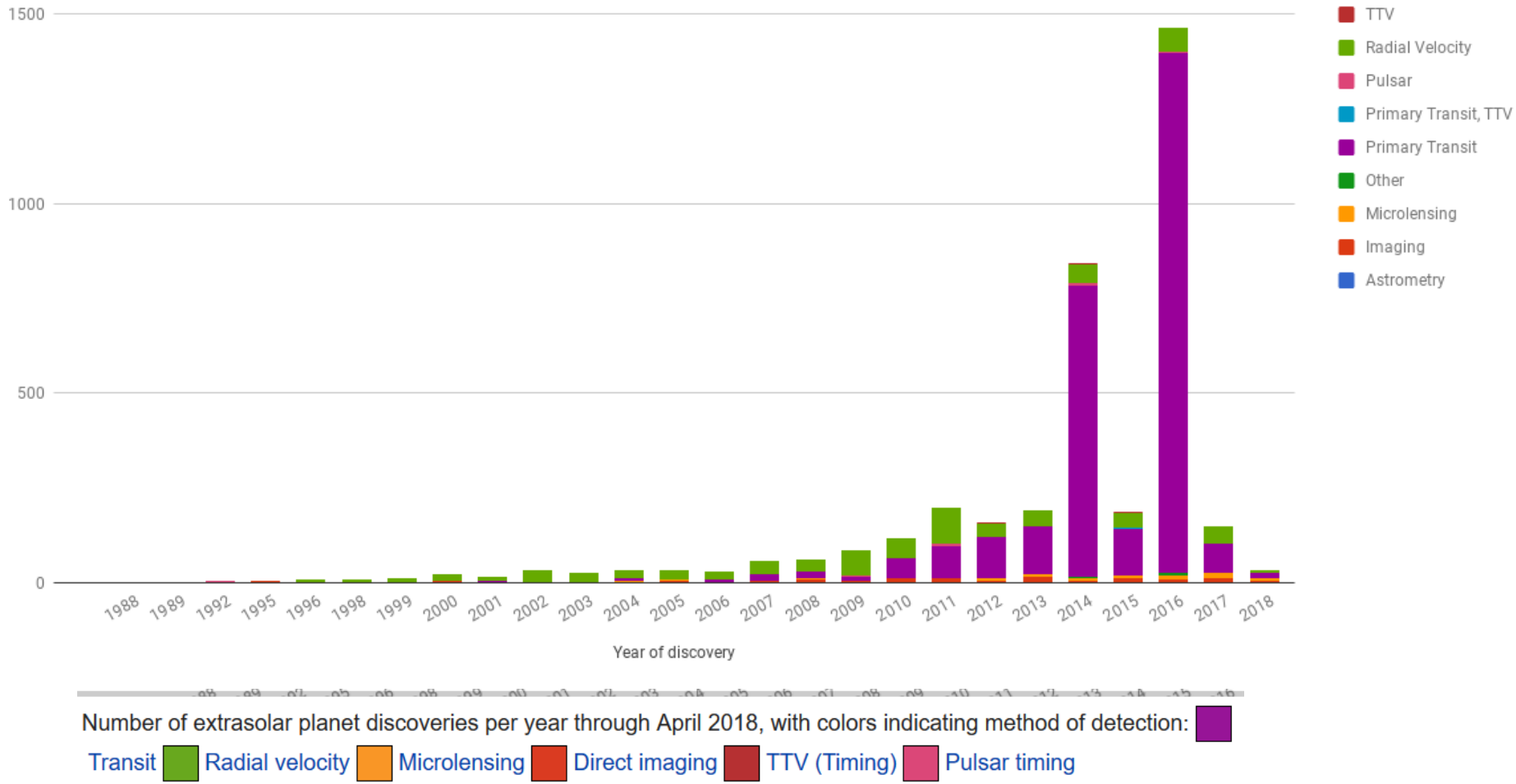
Planets in other Star Systems

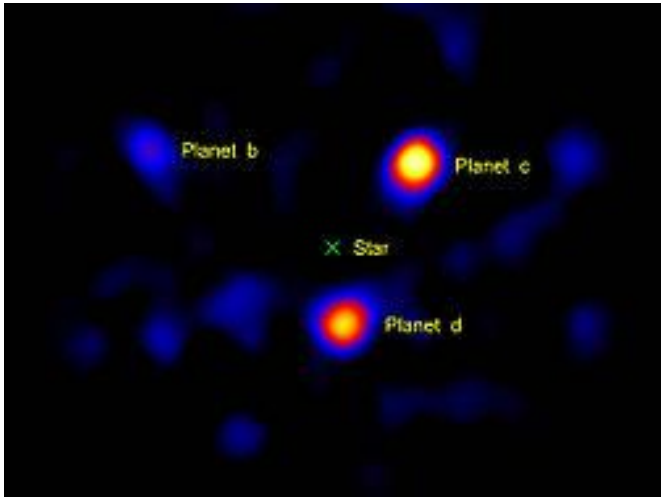
- test out how planets are formed with more examples
- first extrasolar planet observed in 1995 Nobel Prize, 2019, Michel Mayer, Didier Queloz). In Jan 2000, 28 observed and now >4118 confirmed (10/2019). Many systems with 2 or more observed planets
- difficult to observe directly
- mostly look for impact on Star: wobbles due to gravity of planets OR reduction of light due to “eclipse”
- Planet orbits obey Kepler’s laws. If multiple planets, will have to add effects of planets (our solar system, have Jupiter with 12 year orbit, Earth with 1 year, etc). It would take time (>30 years) to understand a system similar to our own Solar System

Planets in other Star Systems



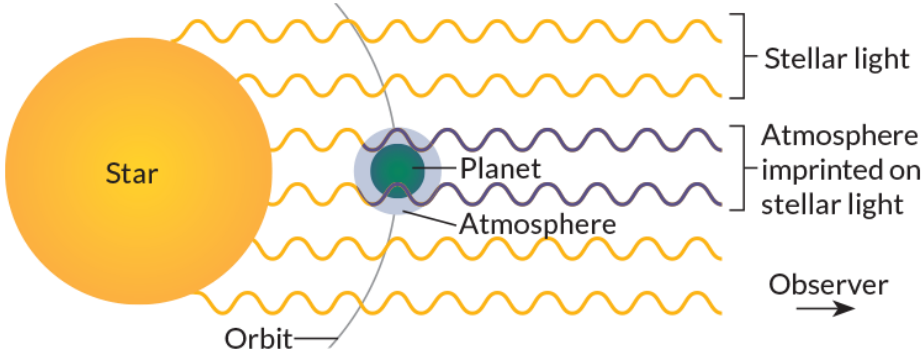
From Wikipedia – shows how discovered. Transit (purple)=eclipsing

Observe Directly – very hard to discover

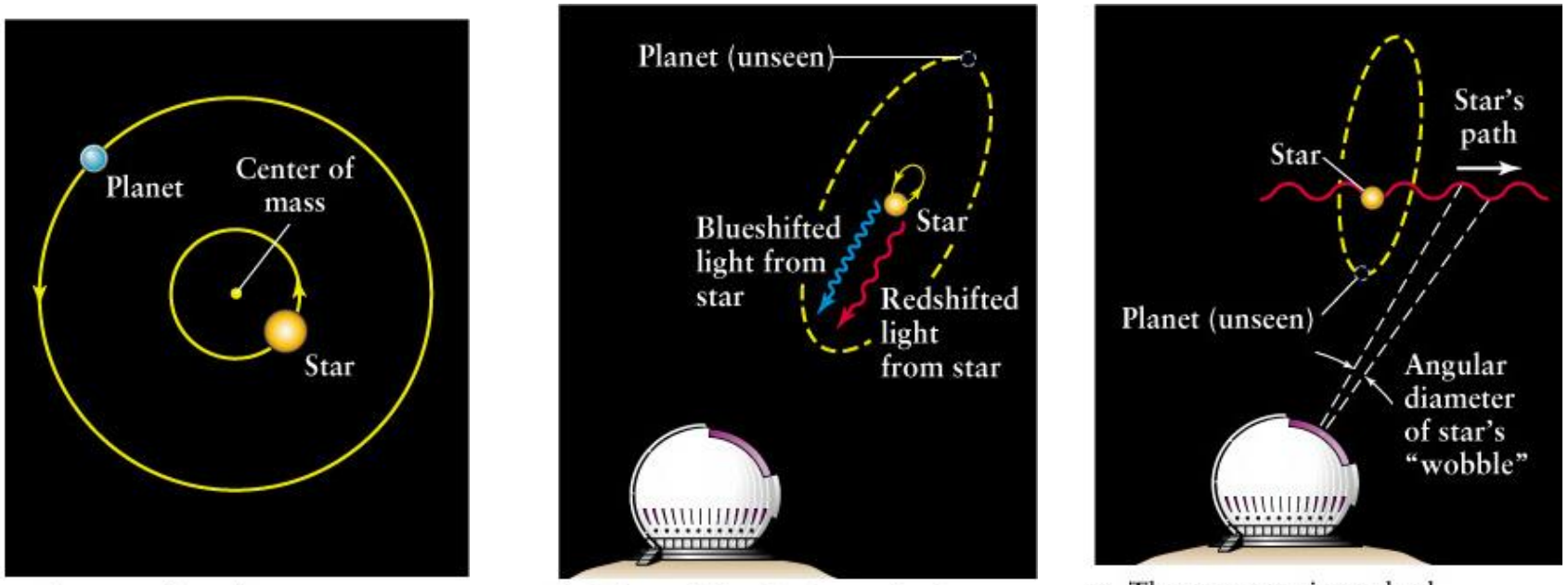


← block out star in telescope optics

Use if found exoplanet by other means. Can study atmosphere. Have detected atmospheres in Gas Giants (like Jupiter) found in other systems. Hubble, Spitzer and Kepler Telescopes have seen evidence of water, carbon dioxide, methane. Planet K2 18b significant water, super Earth-size, and in habitable zone (2019)



Observe by Star's Wobble: Doppler Shift or Proper Motion



a. A star and its planet

b. The radial velocity method

c. The astrometric method

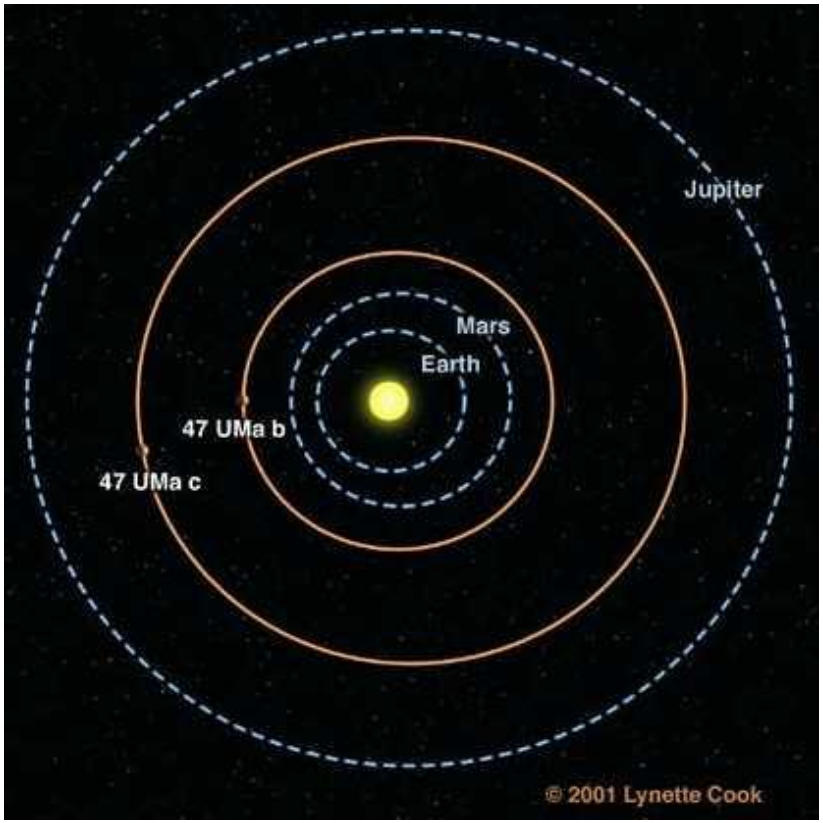
the larger the planet the larger the gravitational pull on star

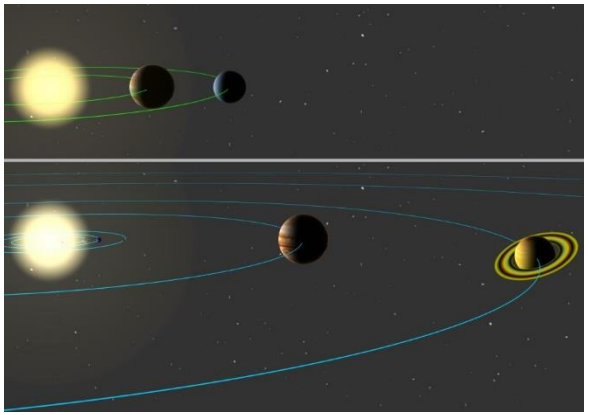
the smaller the orbit the larger the gravitational pull on star

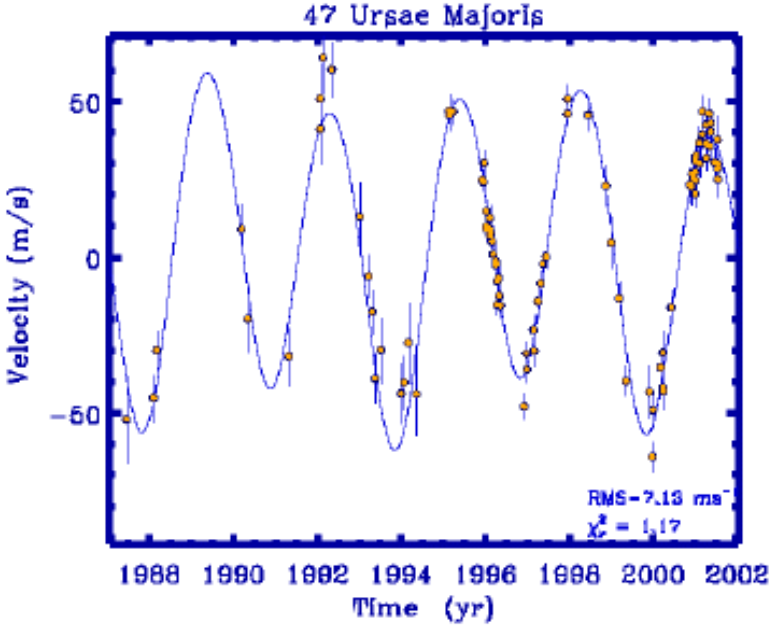
the smaller the orbit the more rapid is the wobble of star

→ easiest to see large planets which are close to their stars by Doppler shift "radial velocity" in slide 2

47 Ursae Majoris (one of first discovered)



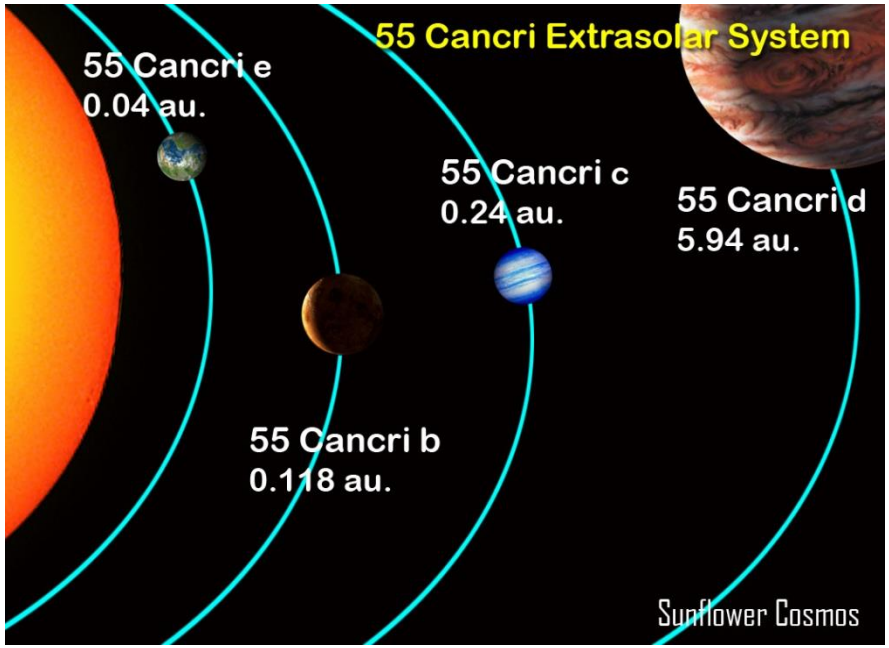




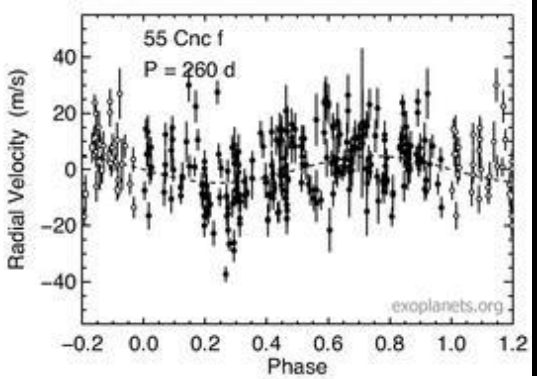
Doppler shift shows at least 2 very large planets. Note Doppler shift accurate to about 5 m/s. speed of a human jogging

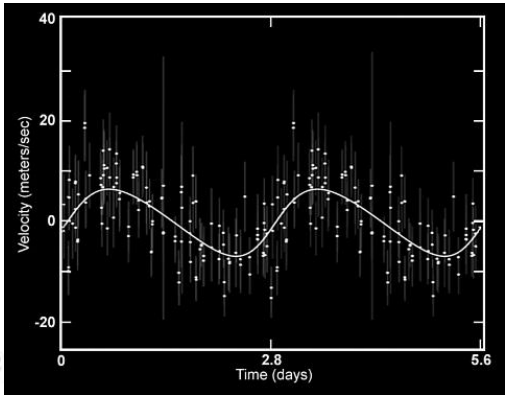
Saw change in Doppler shift during 1986-1992. Then collected much more data to observe periodic motion, discover exoplanet

55 Cancri (one of first discovered)

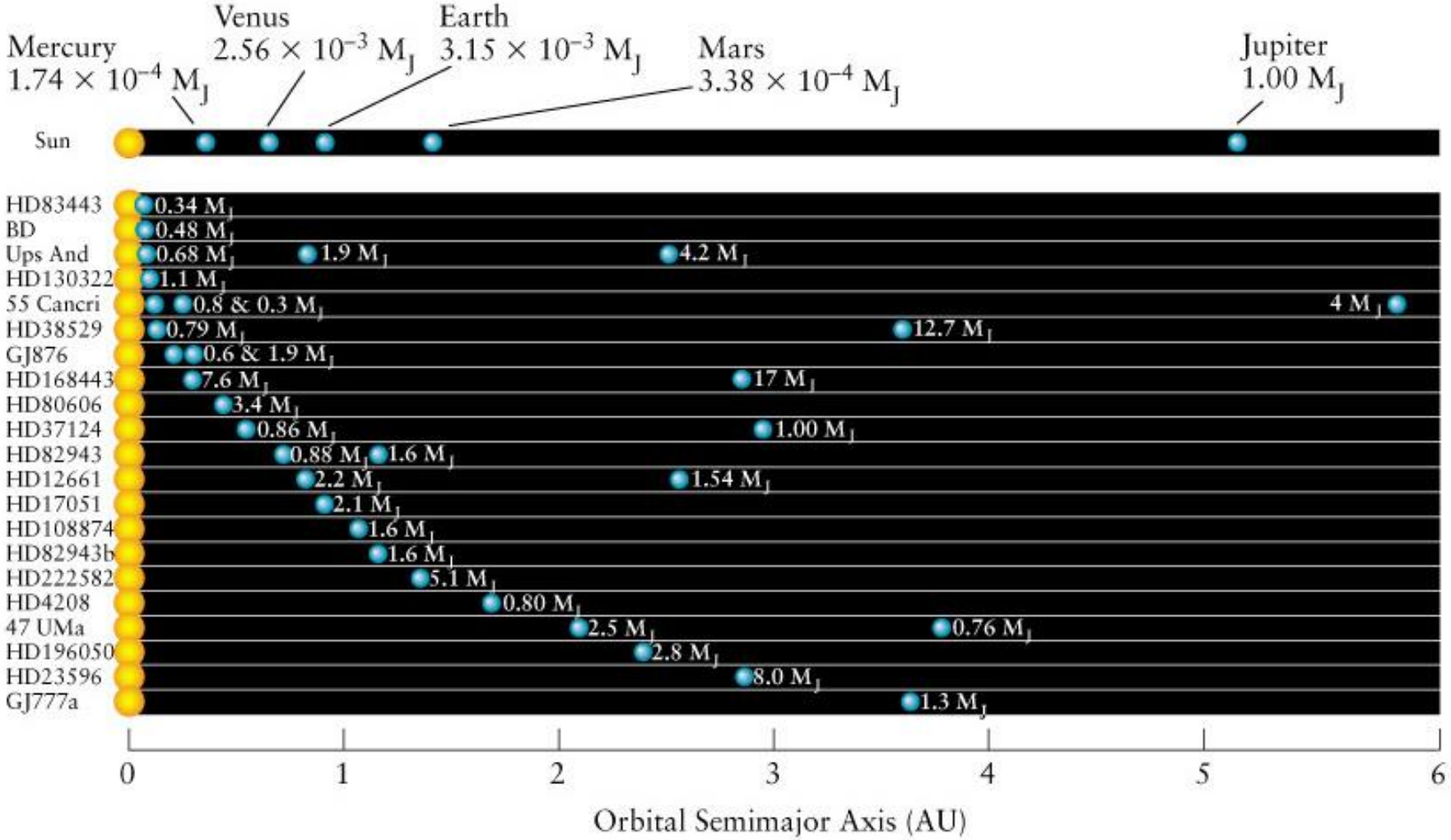


Doppler shift very complicated. One close large planet plus 3-4 more?



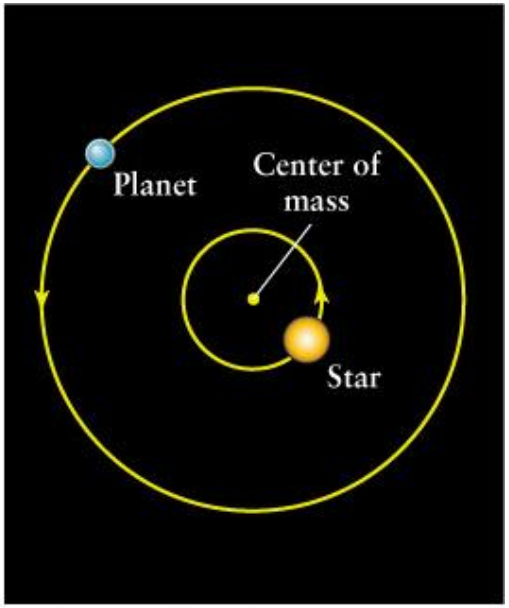


Summary: subset of exoplanets found by Doppler shift -- easiest to find big planets close to a star

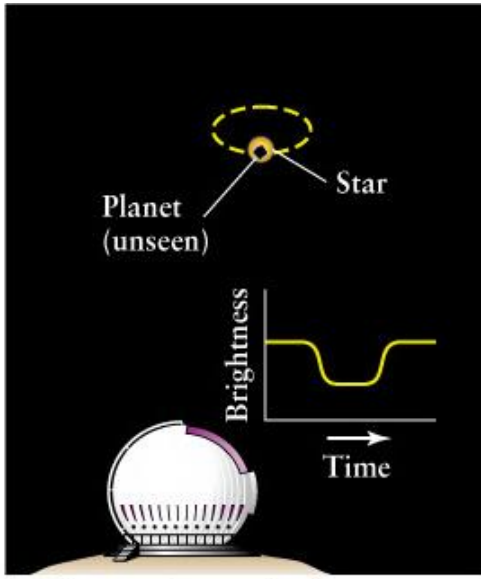


M_J= mass of Jupiter

Observe by planet eclipsing star = transit in slide 2

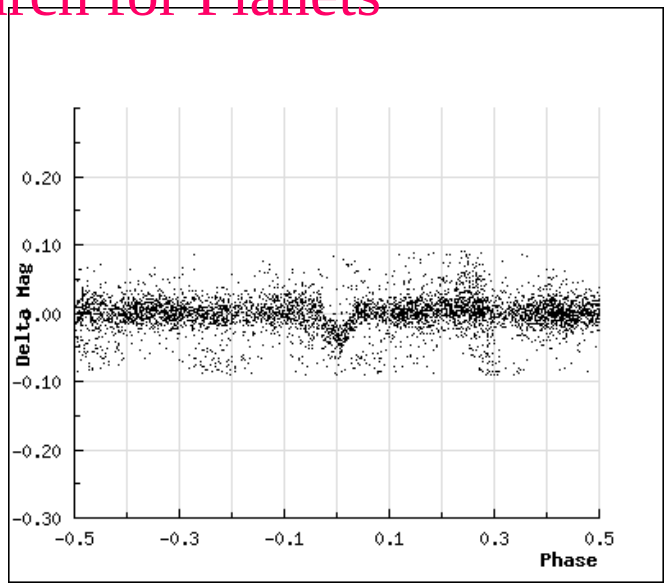


a. A star and its planet



d. The transient method

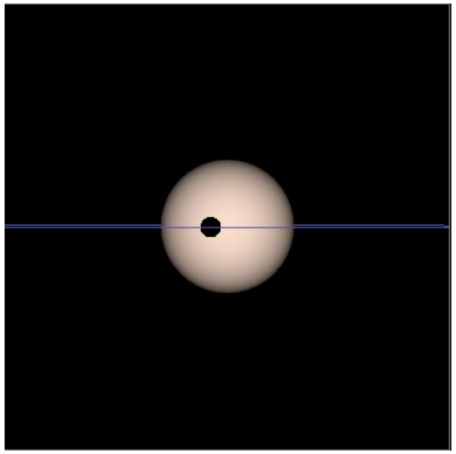
WASP-4 Wide Angle Search for Planets



Jupiter would reduce Sun's light by 1%; Earth reduces by .01%

"easy" (done by 7th grader at NIU Science Fair knowing what star to look at)

once spotted can confirm by Doppler shift and try to observe atmosphere. Need planet to be aligned with Earth-star so it passes in front of star



Kepler telescope

- launched in 2009, designed to detect Earth-sized (or smaller) planets by observing them eclipsing their stars
- In orbit around the Sun….away from the Earth, points away from the Sun
- Looked at 150,000 main sequence stars (every 20 minutes) measures luminosity to 20 parts per million (0.000002). 95 megapixel camera
- Database at www.planethunters.org
- 2013: two motors fail, can no longer “point”. After this mostly just points away from Sun. End operations October 2018.

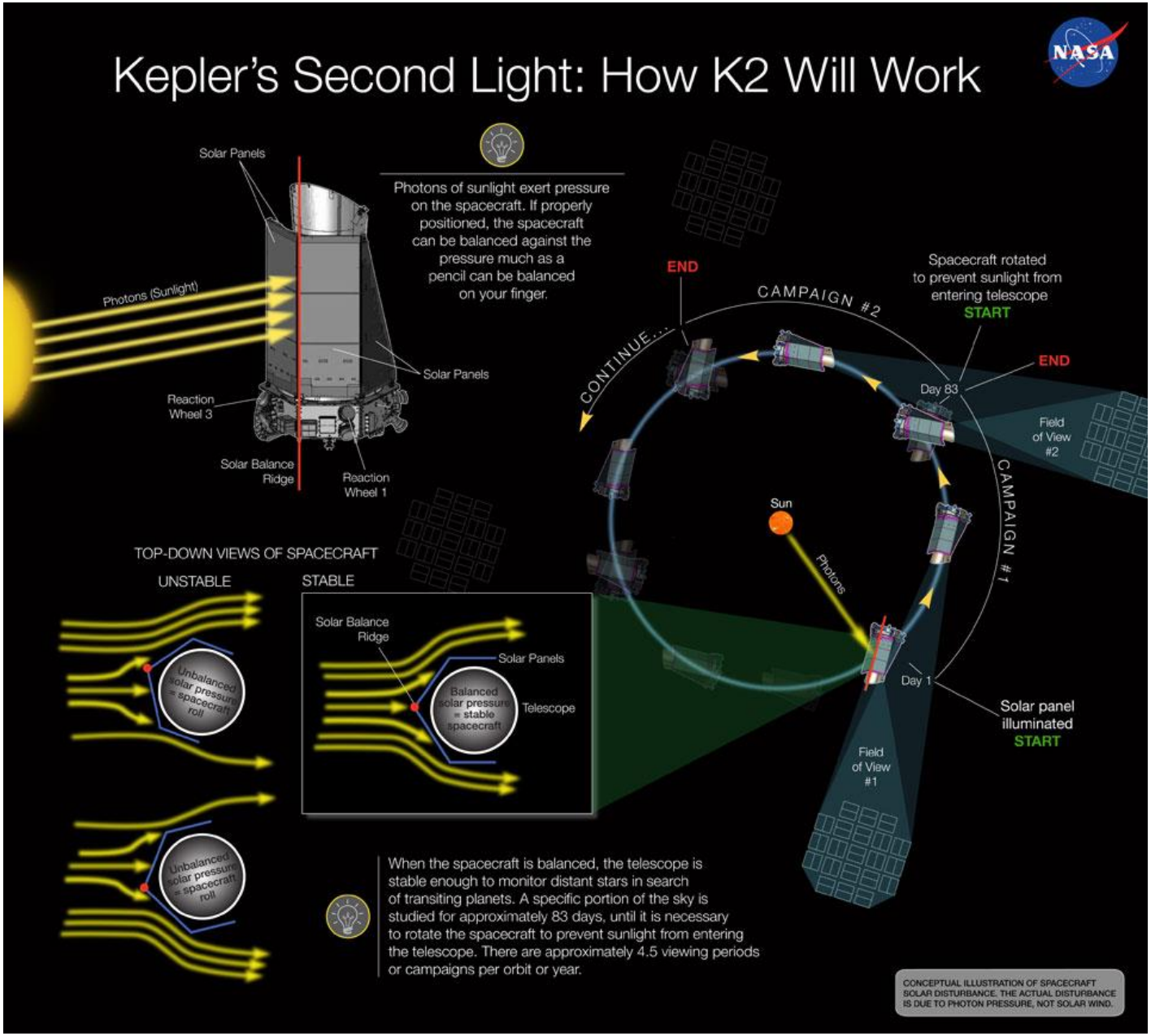
Kepler telescope

- orbit
- Around Sun

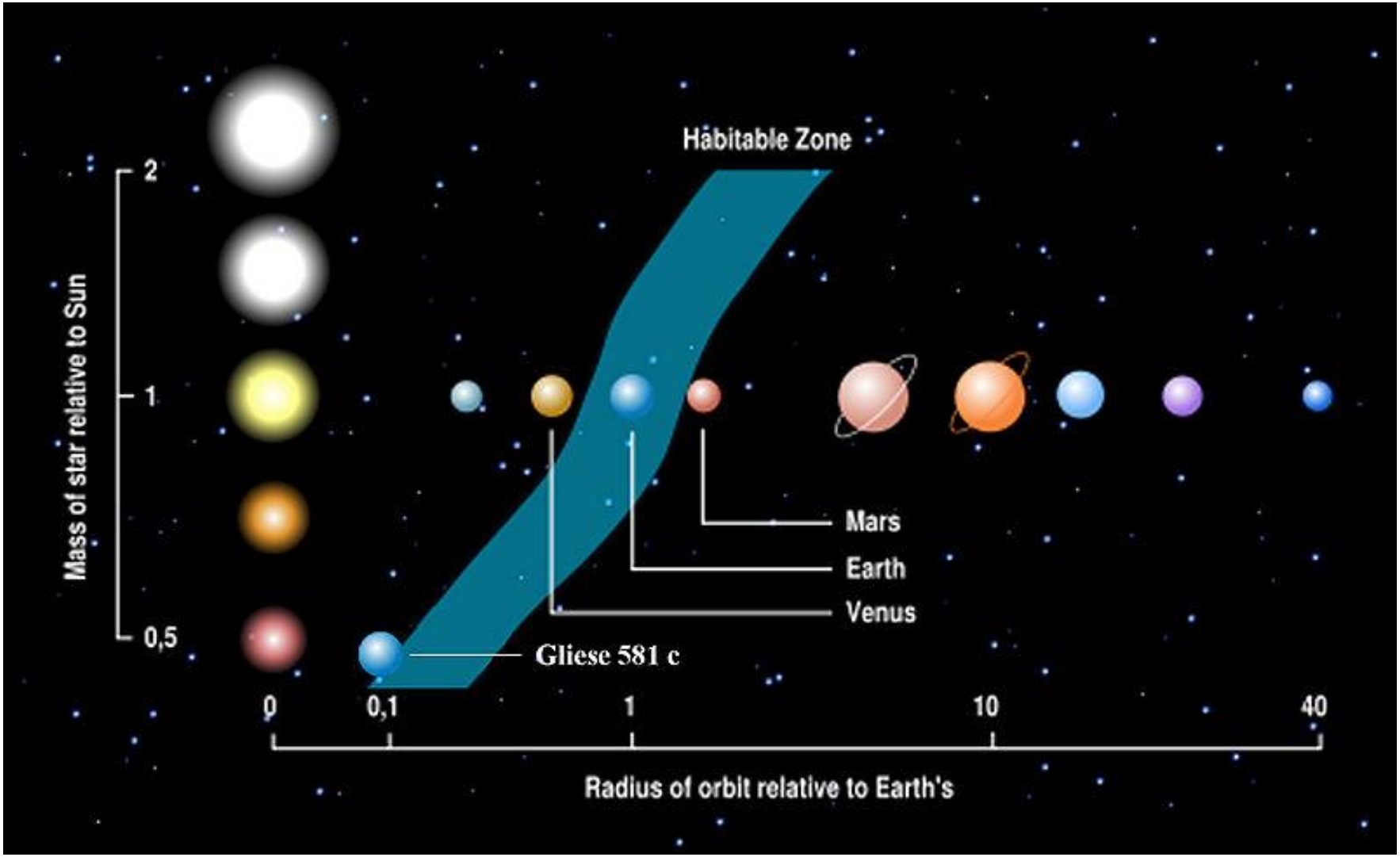
original field of view (Cygnus + Lyra)

chosen by star density and #pixels

Kepler telescope after motor failure

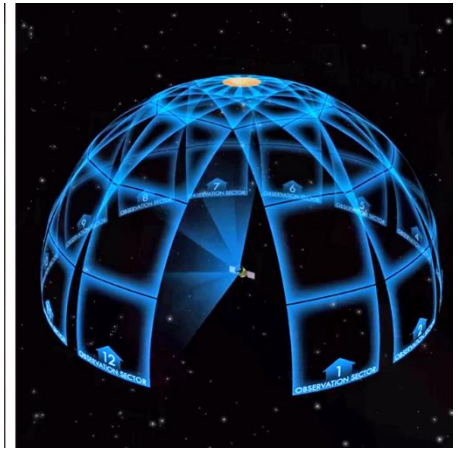


habitable zones = where possibly liquid water in 1 star systems



Depends on star's luminosity. Dimmer stars have habitable zone closer to star. Earth in habitable zone; Mars and Venus just outside of it.

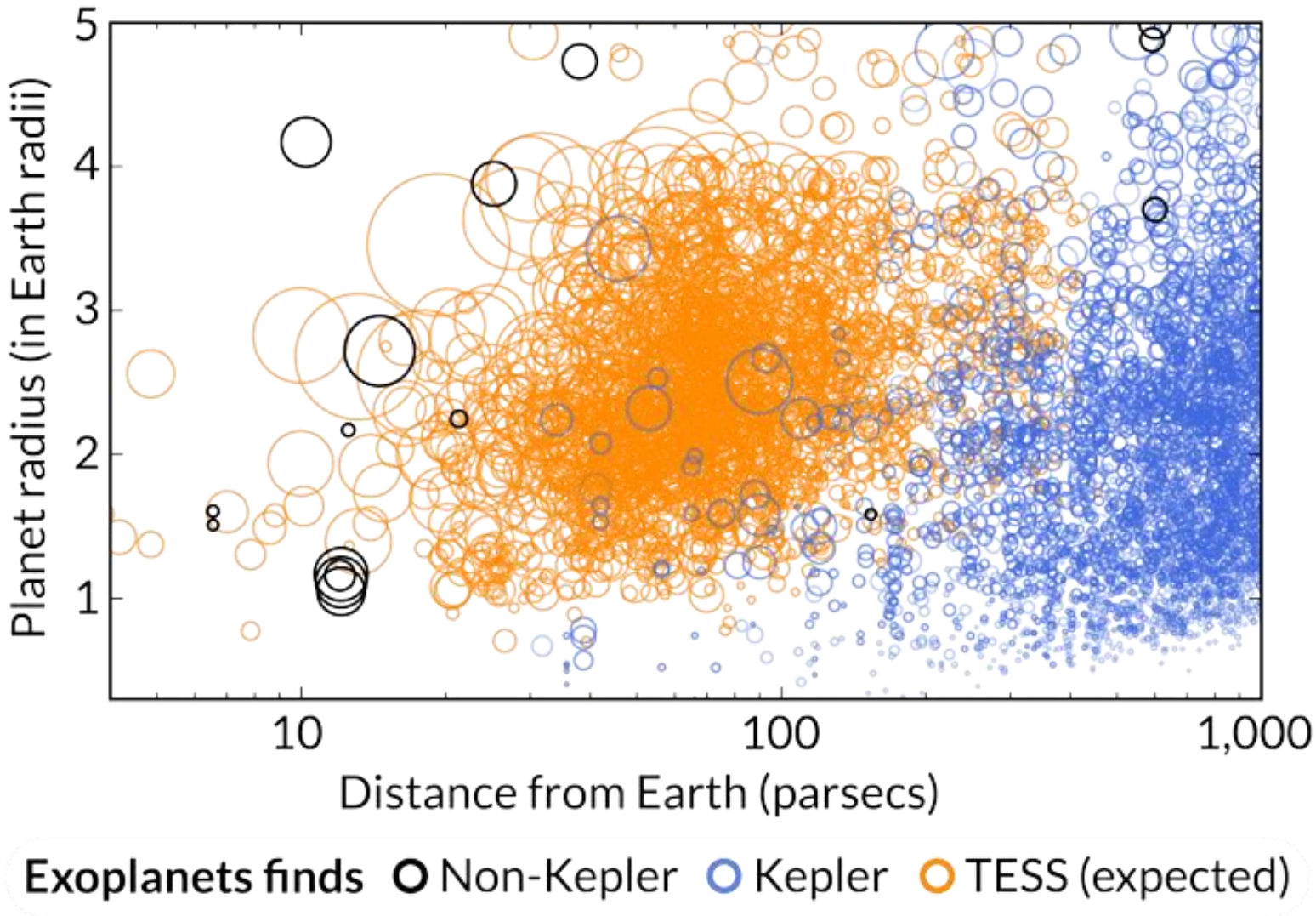
TESS telescope



Point to different regions

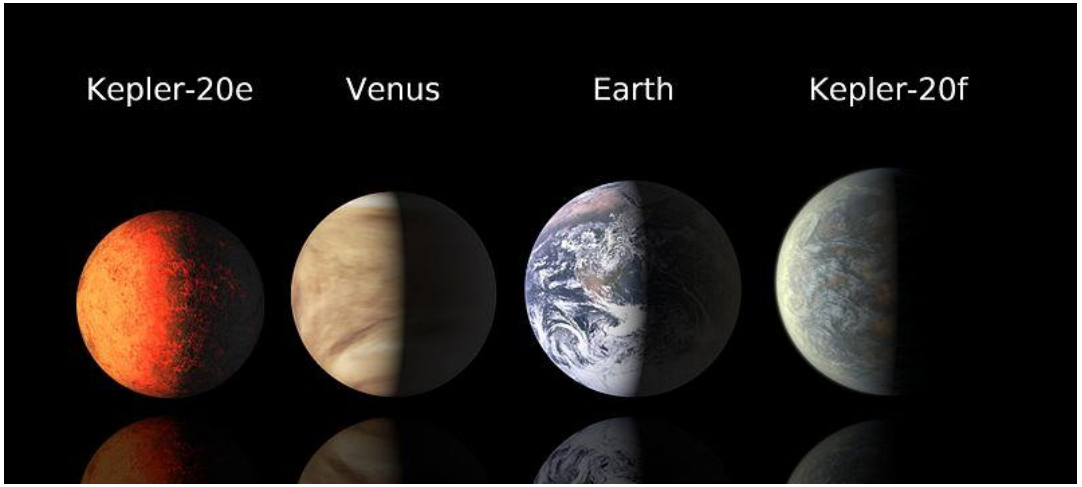
- Transiting Exoplanet Survey Satellite launched April 18, 2018. Like Kepler, look for change in star intensity due to planet eclipsing the star
- Perform all-sky survey of ALL stars close to us. In “high” orbit about Earth but always away from the Moon
- Primary scans G, K, M class stars, about 500,000 stars in total. One minute exposures for selected stars and 30 minute exposures over full field-of-view. Will point to different regions of the sky
- Expected to discover > 3000 exoplanets many of which should be Earth-like. Maybe 20 could be Earth or super-Earths located in the habitable zone

Expected results from Tess telescope. Larger circles represent planets easier to find. TESS will find planets closer to Earth.

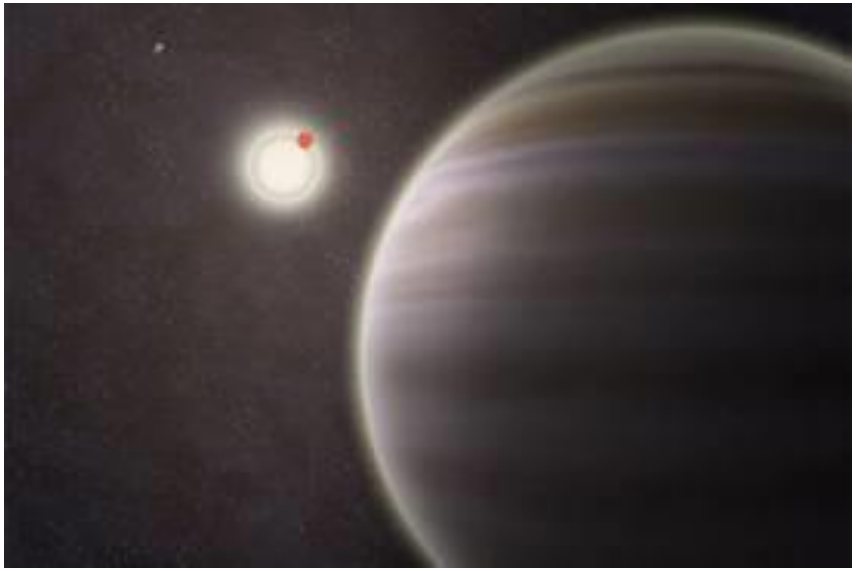


Science News April 28, 2018. Zach Berta-Thompson

Kepler Results: many Earth-like planets some in habitable zones (liquid water)



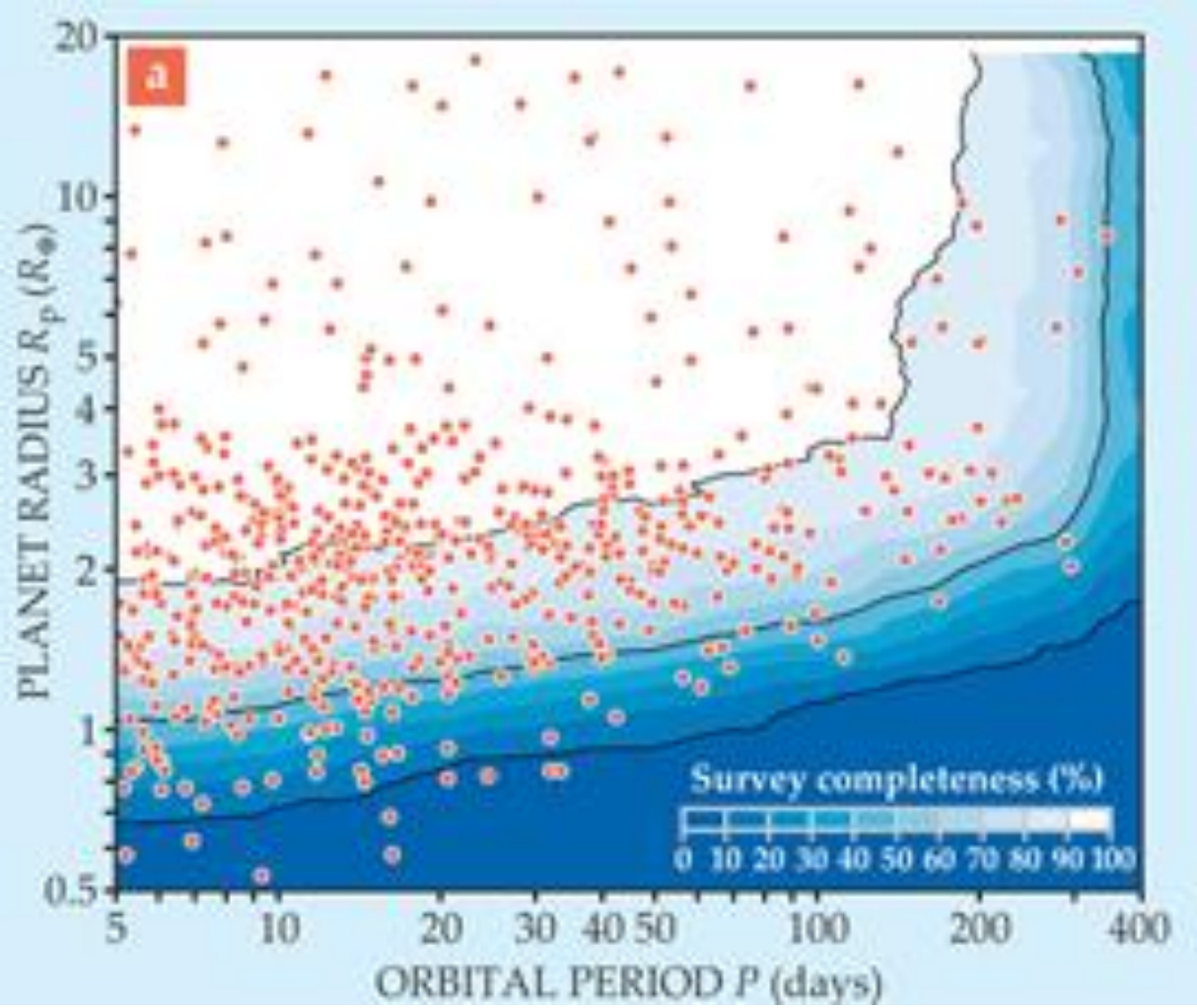
Kepler 35 – binary star



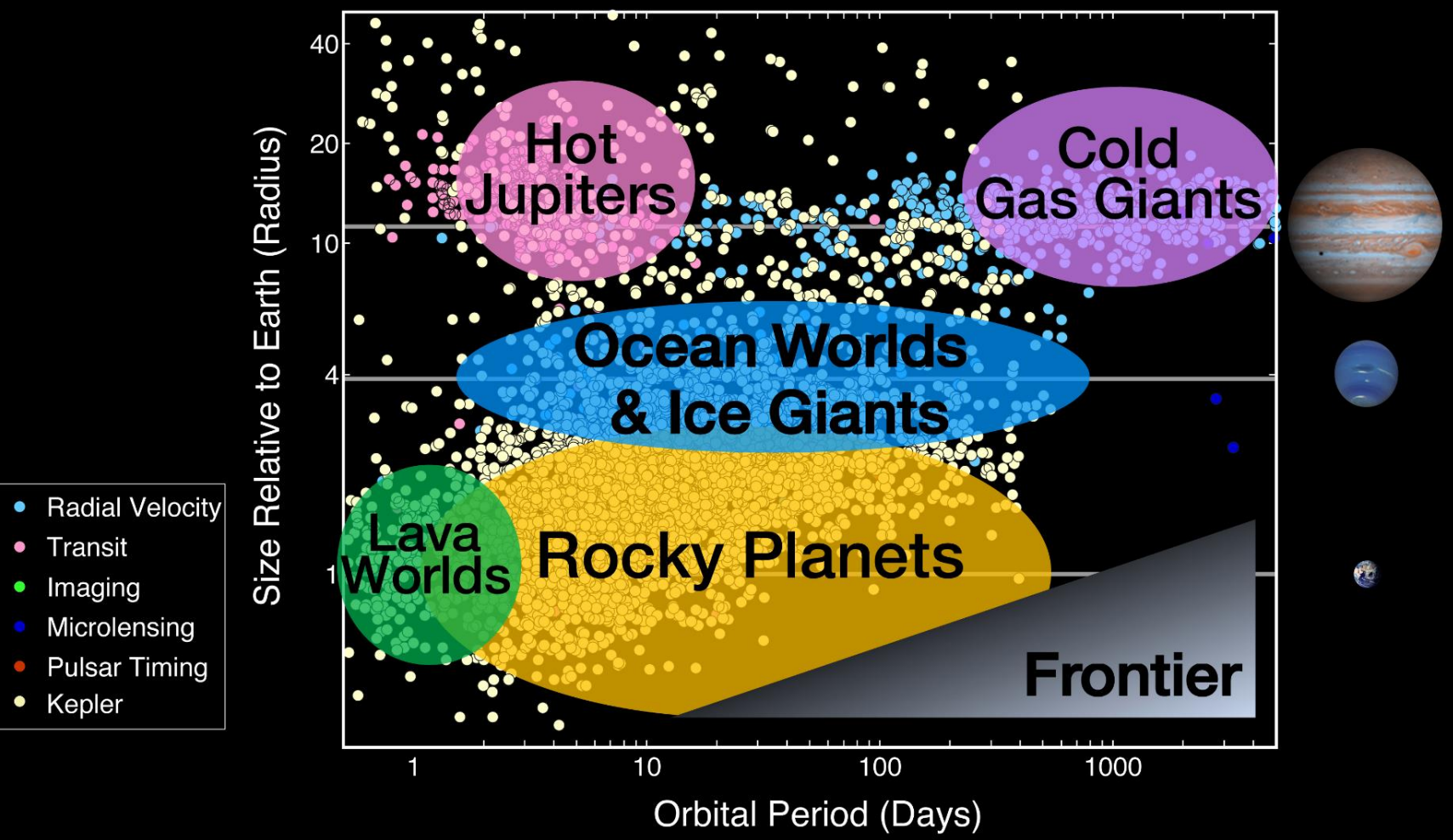
Planet orbiting 4-star system (2 close binaries)

Kepler telescope

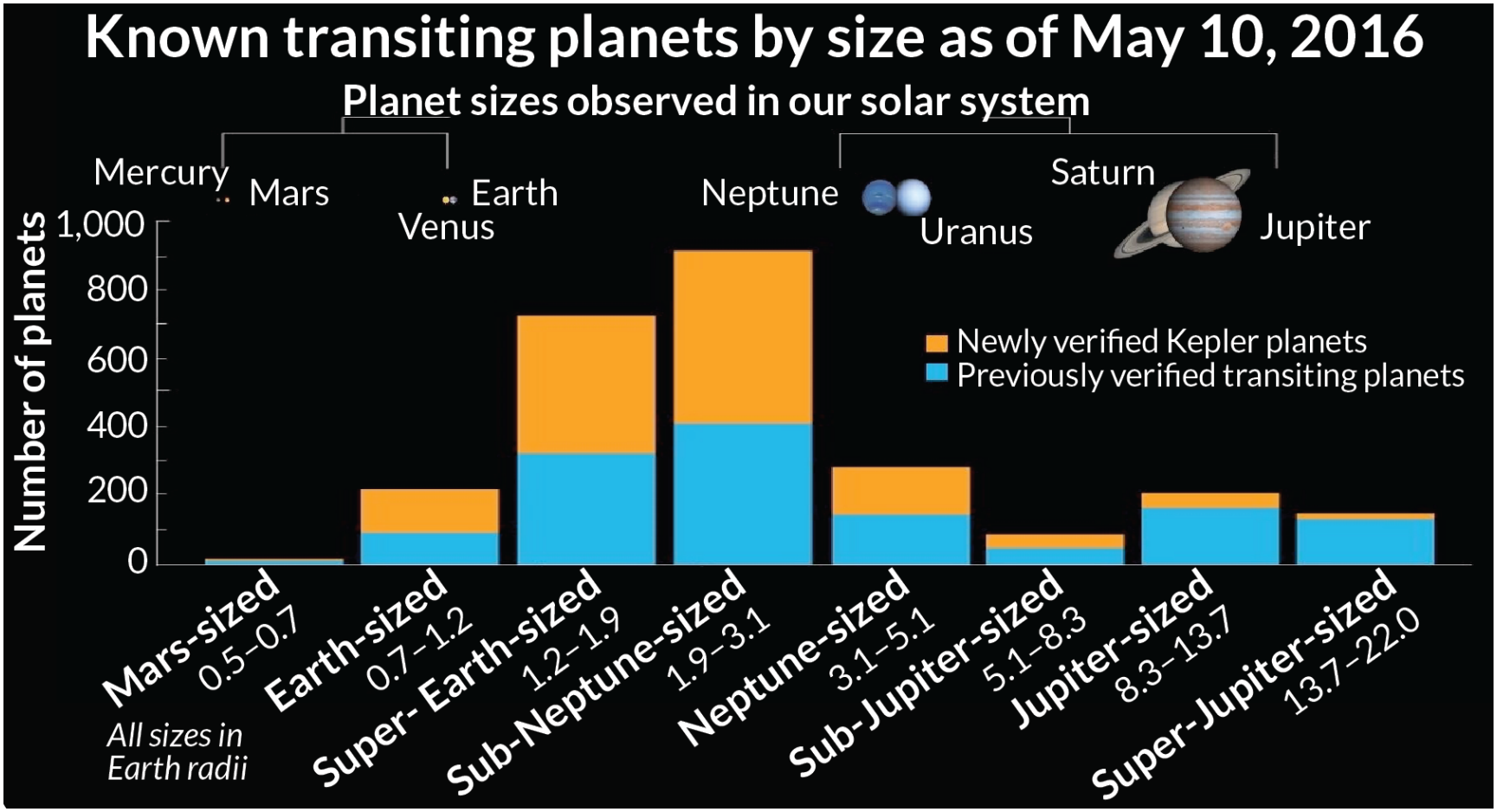
- collect data from 2009-2013. Not sensitive to long periods like Jupiter's 12 years. Barely sensitive to 1-year orbits as ideally see many eclipses
- Sees a lot of planets between Earth and Neptune size. 603 in plot (1/14)

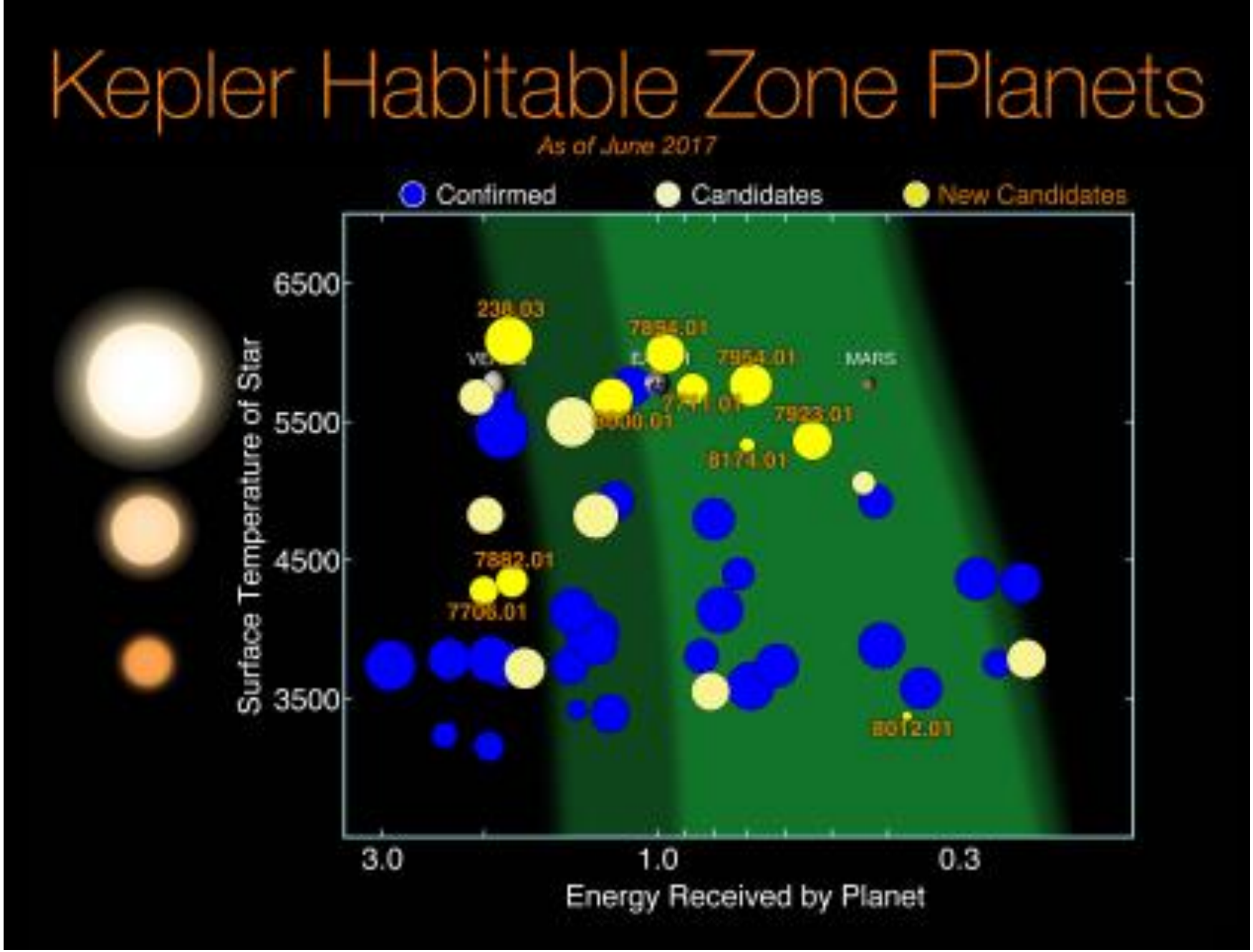


Exoplanet Populations



2681 found by Kepler 10/2018
3851 found by everyone 10/2018

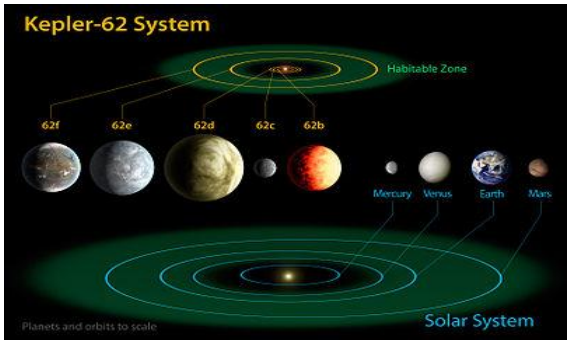



Kepler Habitable Zone Planets
As of June 2017
Confirmed
Candidates
New Candidates
Surface Temperature of Star
6500
5500
4500
3500
3.0
1.0
0.3
Energy Received by Planet
MARS
7954.01
7923.01
8174.01
7882.01
7706.01
8012.01

Complicated process to confirm. For example, may end up being small star and not planet.

Exoplanet Highlights 2014-2016

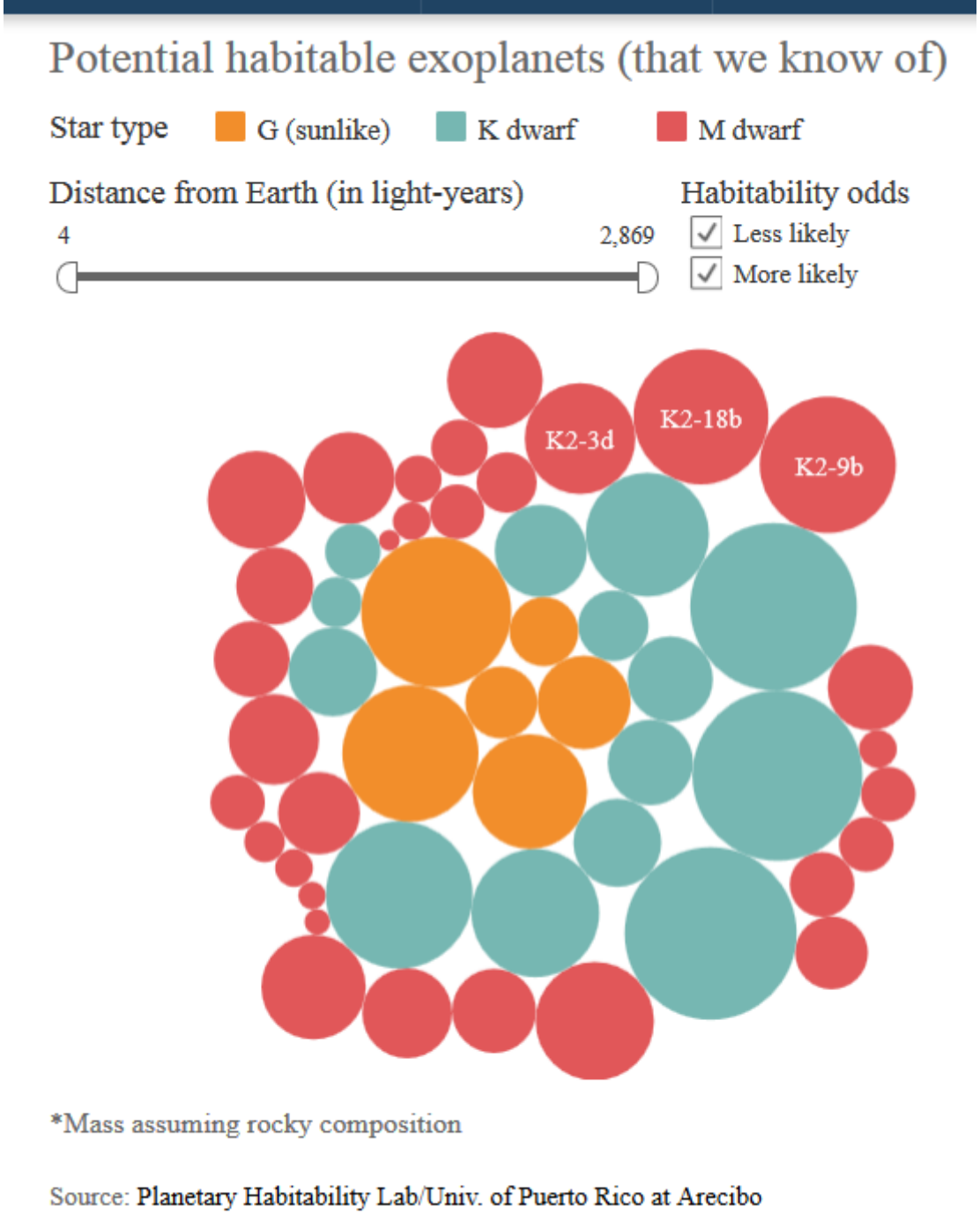
- Smallest: Kepler-37b. About the size of our Moon
- Closest Proxima Centauri B has Earth-sized but very close to star 0.05 AU with 11 day period. Strong tidal forces and solar flares
- Earthiest: Kepler-78b has earthlike mass and diameter but 8.5 hour orbit and temp>2000 degrees C
- Intriguing 1: Kepler-62e and 62f are 2 Earthlike planets in habitable zone. Both ~twice Earth size at .4 and .7 AU from star ~0.2 Sun's luminosity



- Intriguing 2: star Gliese667C has three planets in habitable zone. But 3 star system with "C" being a M1 class with 1% of Sun's luminosity → poor for "intelligent" life

Exoplanets 2017 : nearby stars

Science News article June 24, 2017

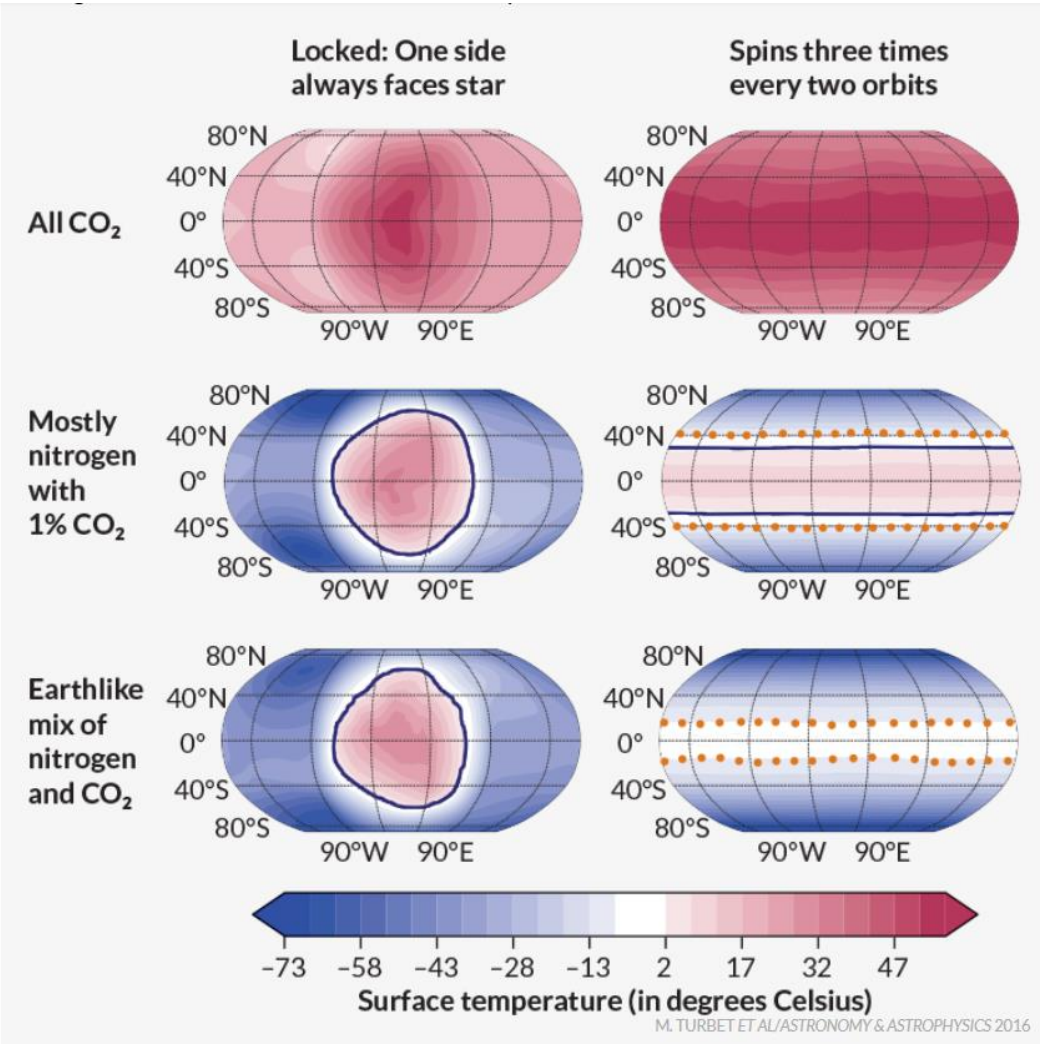


Science News article June 24, 2017

Strong tidal forces as close to star cause impact on planet's spin.

Note: Mercury orbits Sun with 3:2 spin vs orbital period "resonance"

Large solar flares problematic as so close



Surface temperatures Proxima b, small planet orbiting red star nearest to Earth. depend on: planet's spin, makeup of atmosphere. Many scenarios: solid lines mark areas where liquid water could endure year-round. Orange dots mark zones with seasonal water potential.