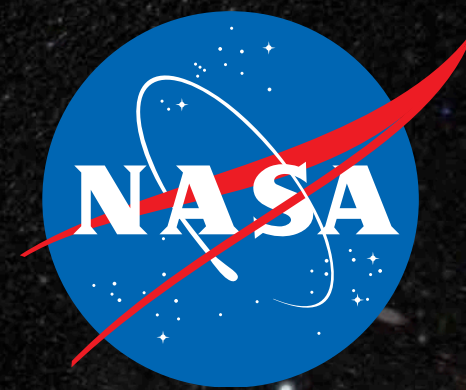




# Finding new worlds with Kepler and TESS



**Thomas Barclay**

Mid-Atlantic Senior Physicists Group

Nov 20, 2019





**Small, rocky inner planets without thick atmospheres**



**Large, massive planets with thick gaseous envelopes**



A futuristic space scene featuring a bright star in the upper left, glowing nebulae in shades of blue and purple, and several planets. One planet in the foreground shows a greenish atmosphere with swirling patterns. The background is filled with numerous small stars.

The exoplanet revolution began 25 years ago



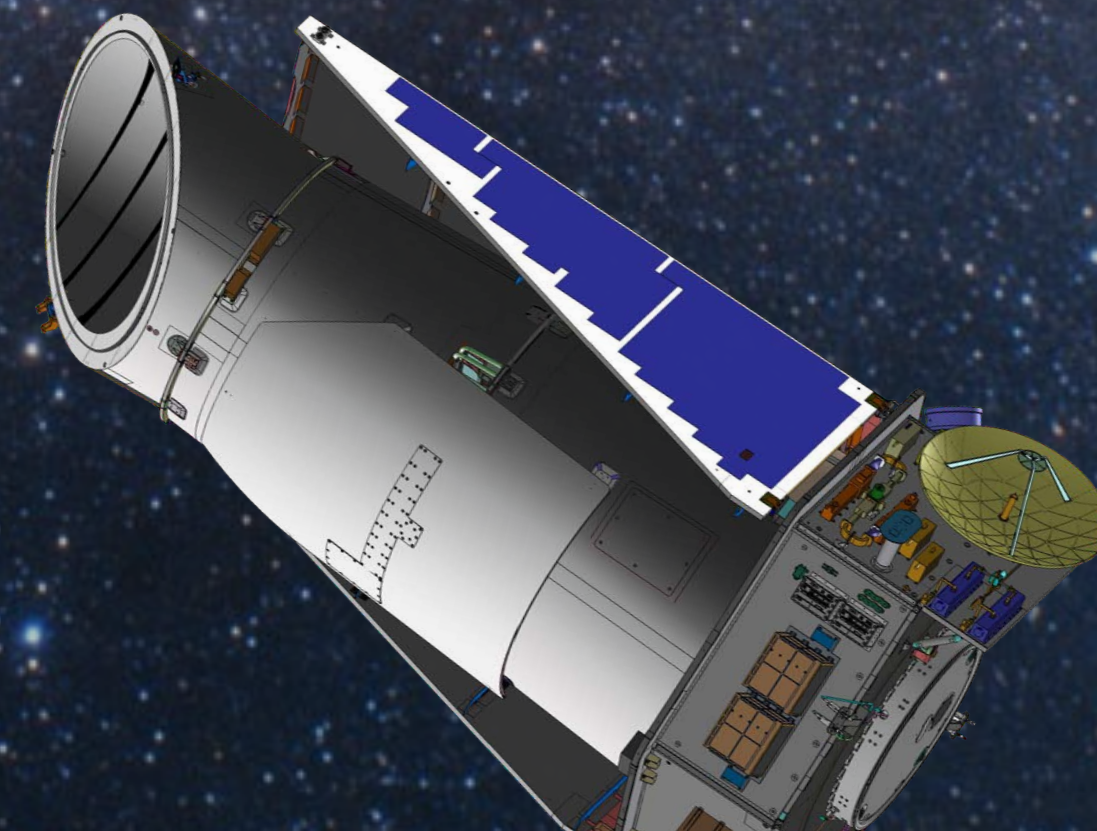


The discovery that changed the way we see our Universe



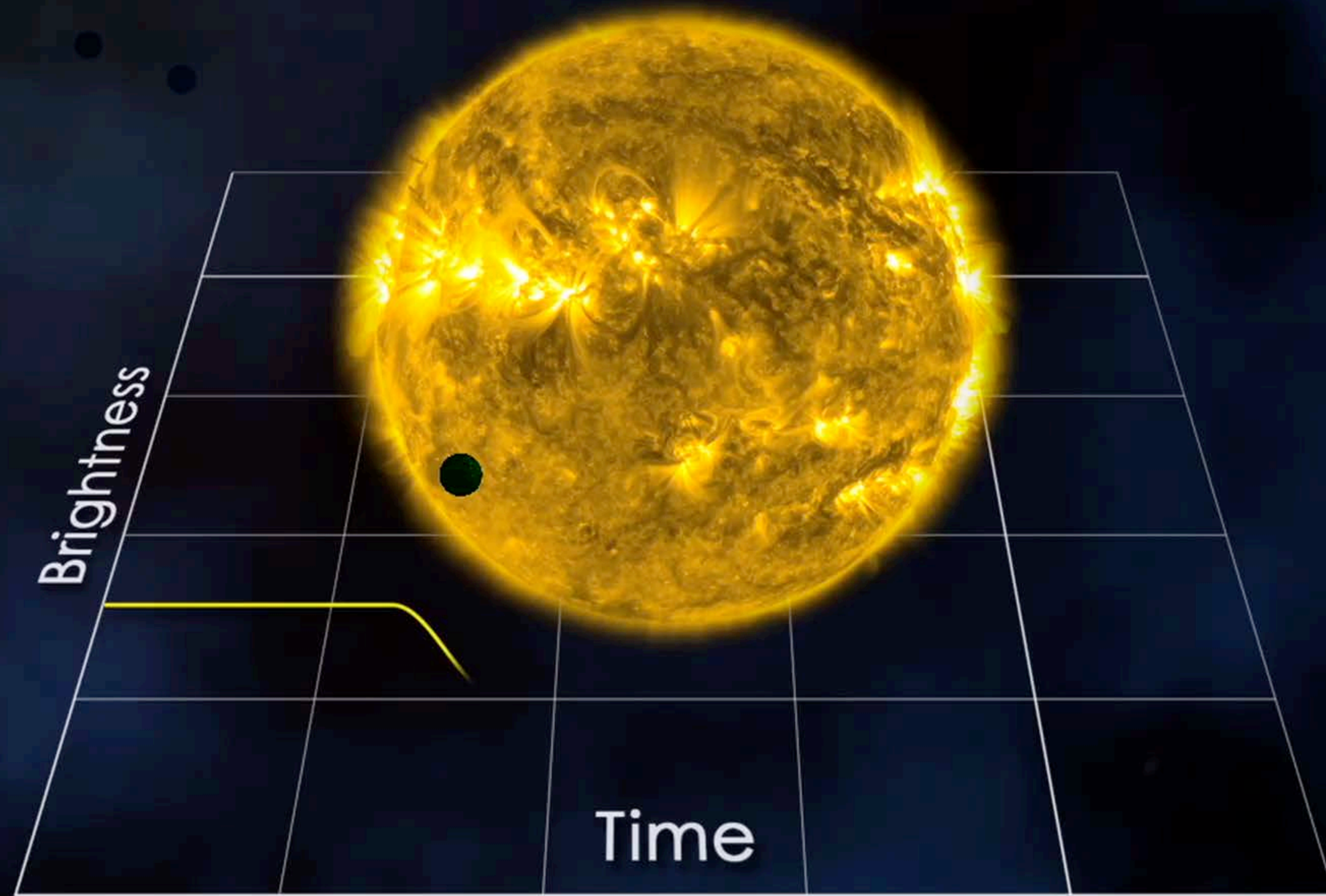
# Kepler Mission (2009-2013)

What fraction of stars in our galaxy harbor  
Earth-sized planets?



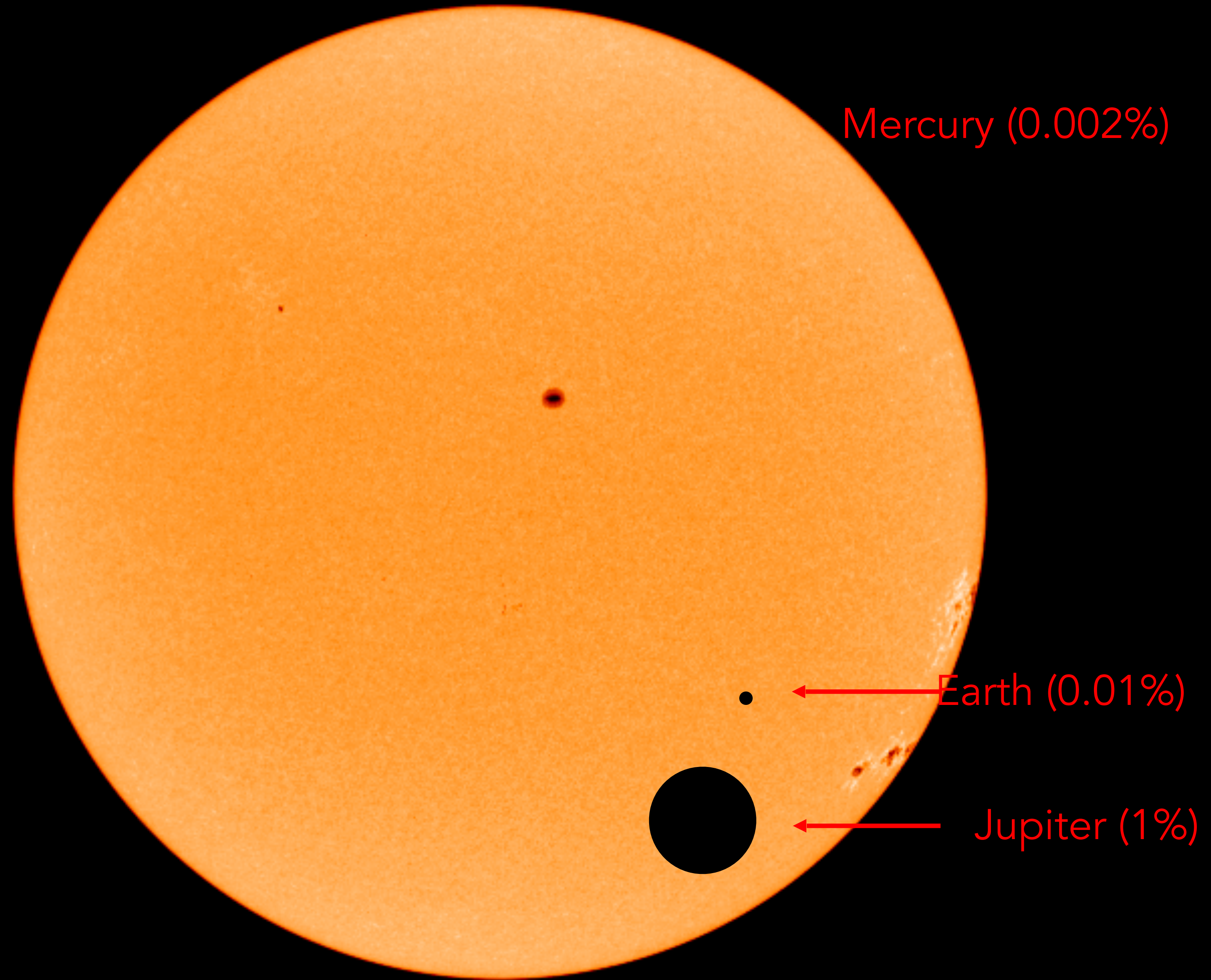


# Transit Method





# The Transit Method



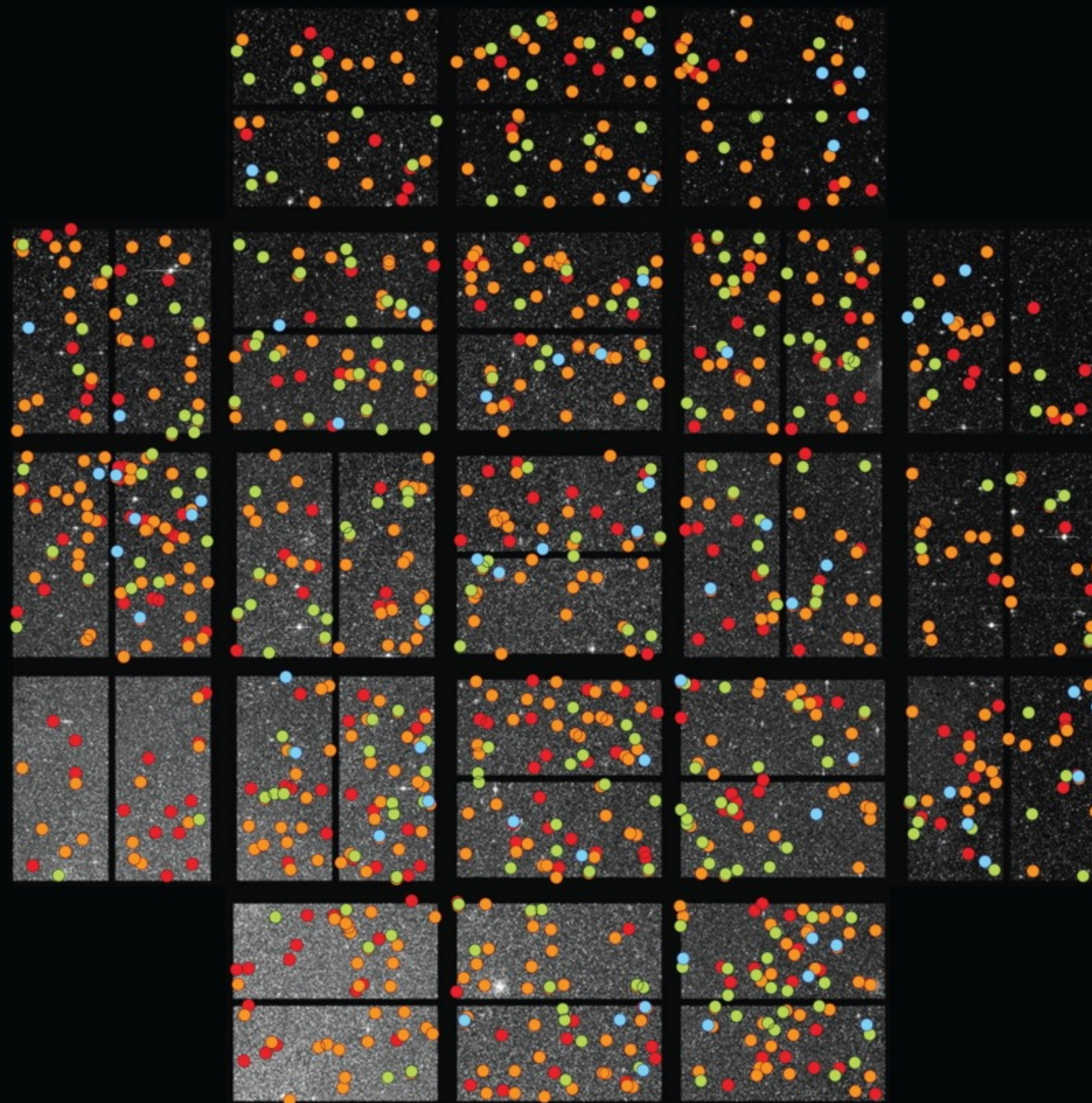


● Earth-size

● Super-Earth size  
1.25 - 2.0 Earth-size

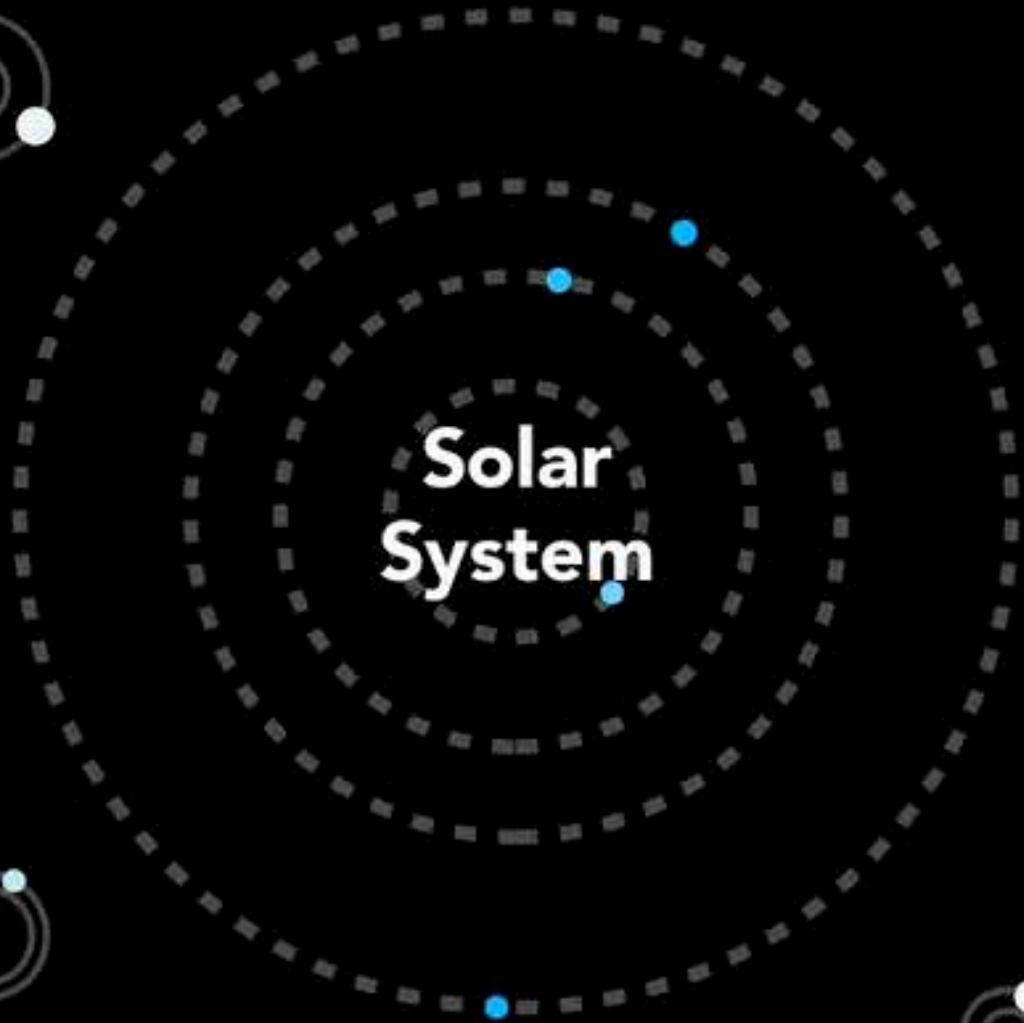
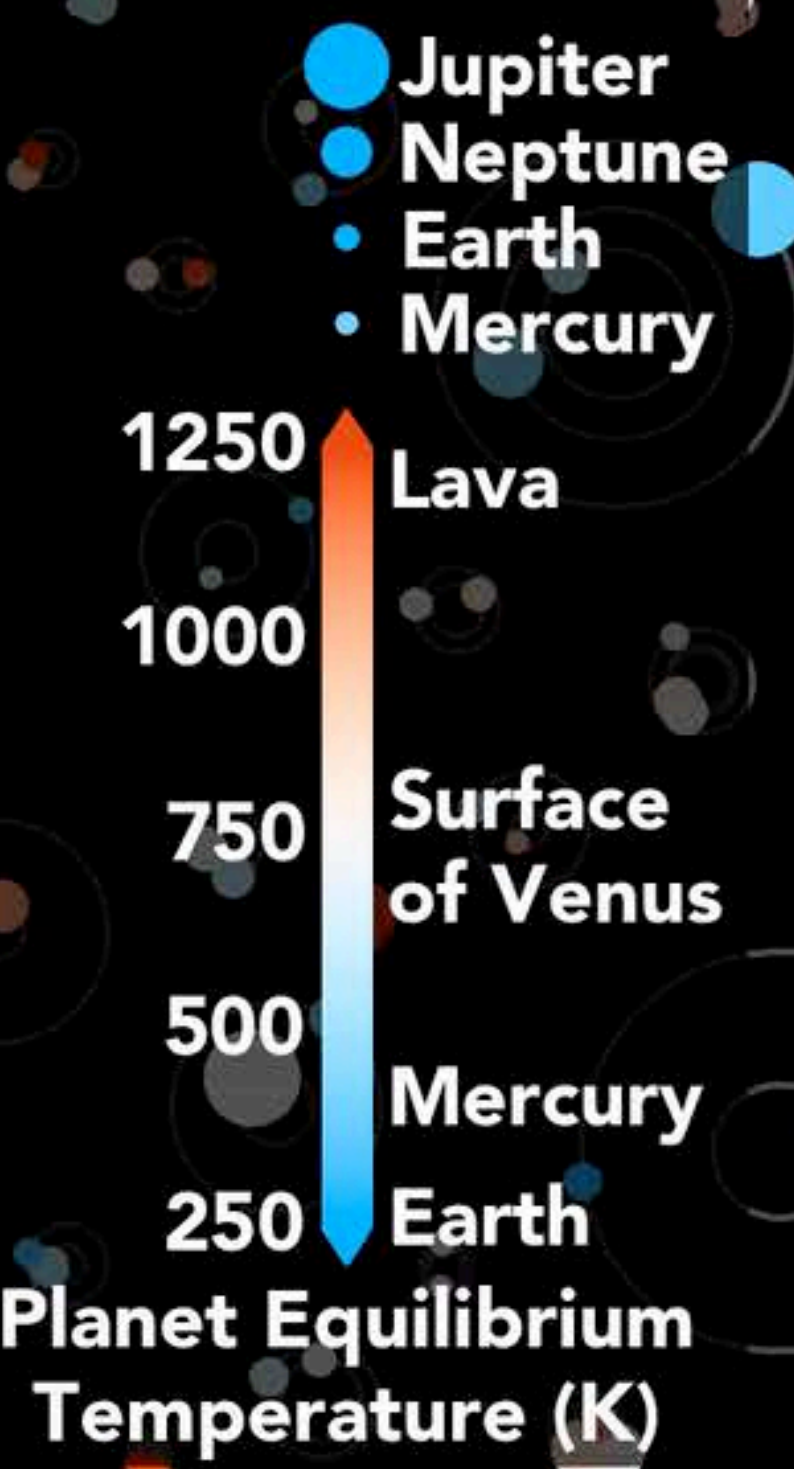
● Neptune-size  
2.0 - 6.0 Earth-size

● Giant-planet size  
6.0 - 22 Earth-size





Kepler Orrery IV  
23 Nov 2010  
By Ethan Kruse  
@ethan\_kruse



3,706 Confirmed Planets 03/08/2018 →

612 Multi-Planet Systems 03/08/2018 →

4,496 Kepler Candidates 08/31/2017 →



Star temperature  
↓



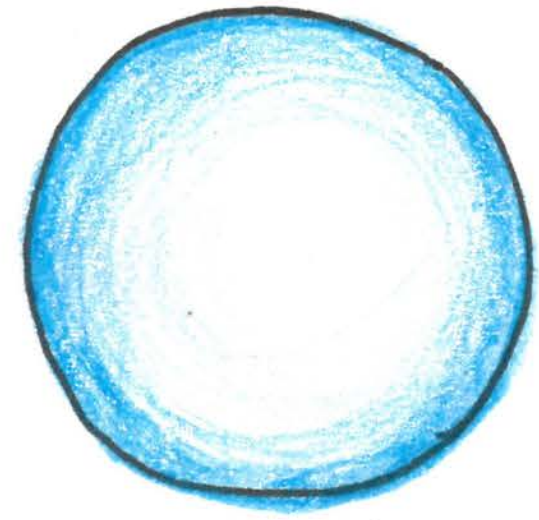
Red dwarfs



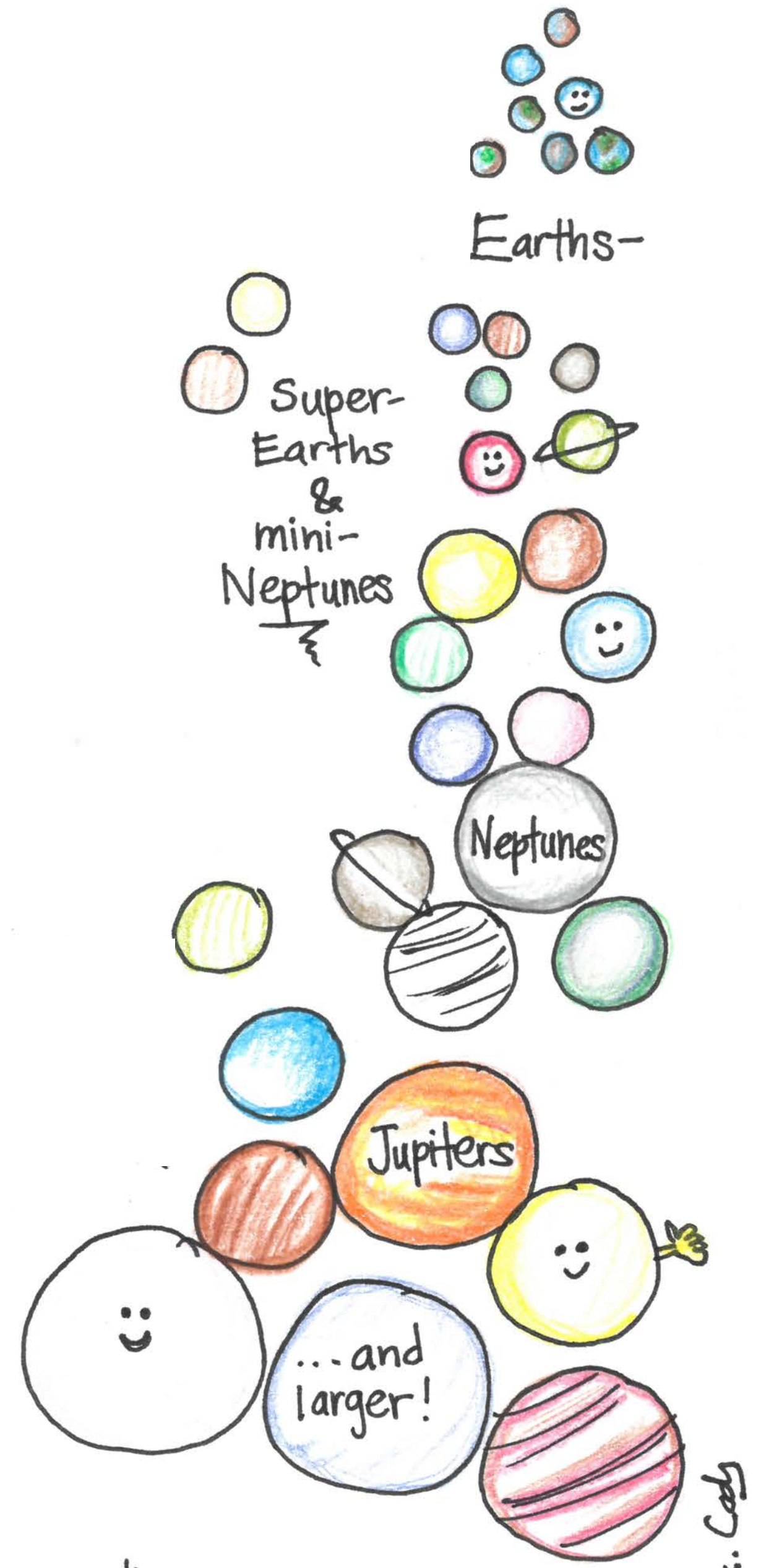
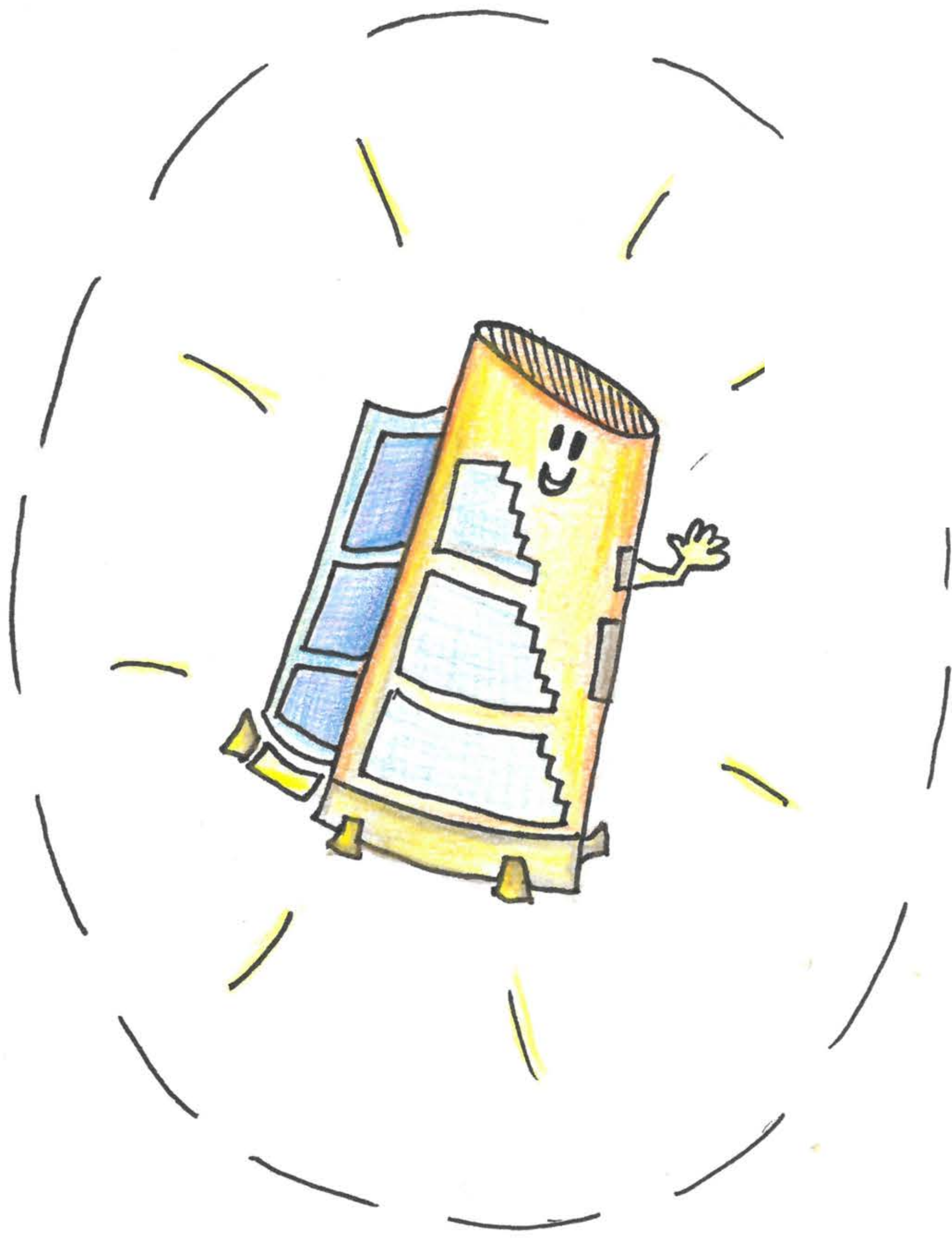
K stars



Sun-like stars



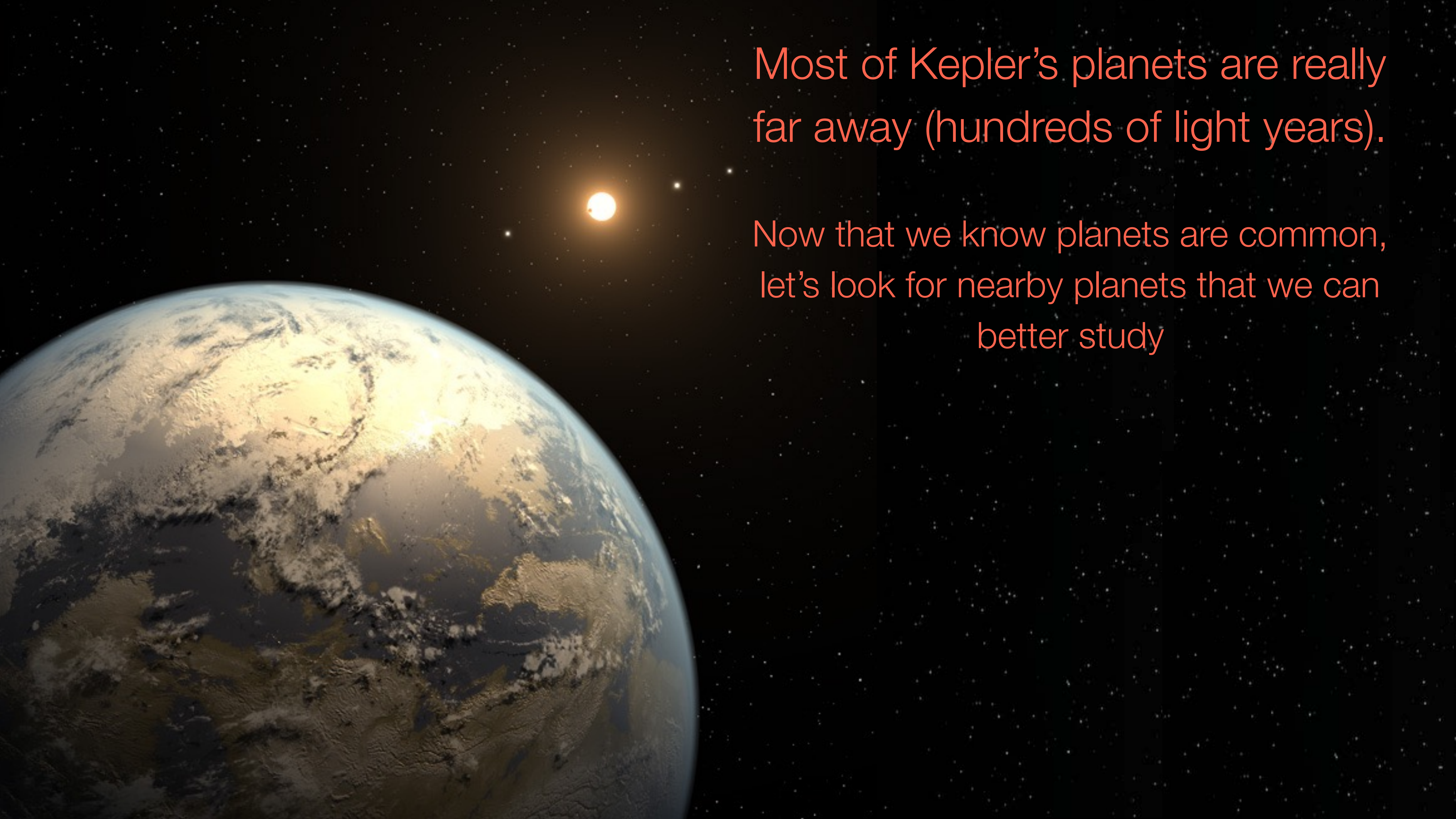
Hotter stars



\*Nothing is to scale.

A. Cooby





Most of Kepler's planets are really far away (hundreds of light years).

Now that we know planets are common, let's look for nearby planets that we can better study



# The *TESS* Mission: finding planets around our nearest and brightest neighbors





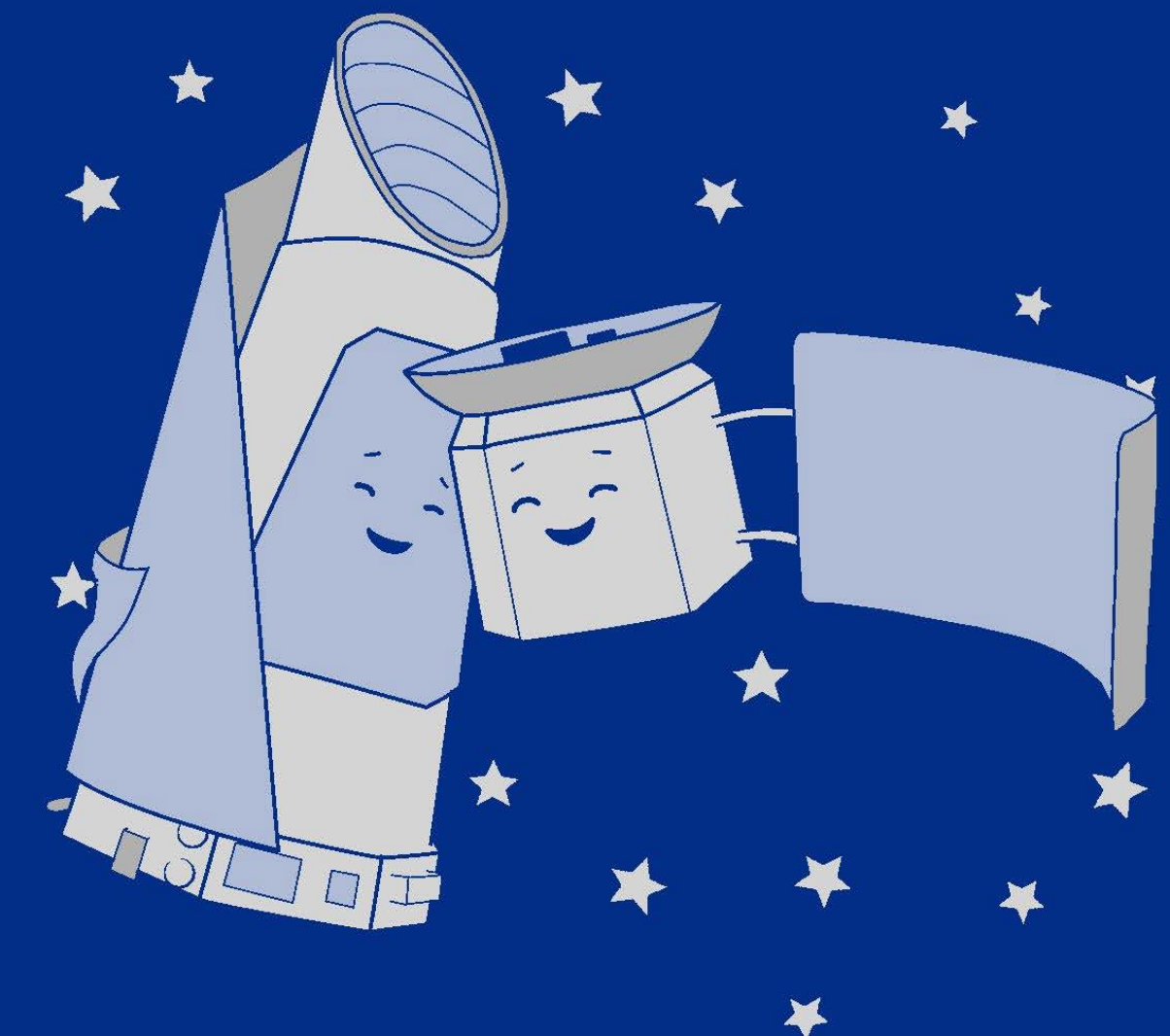
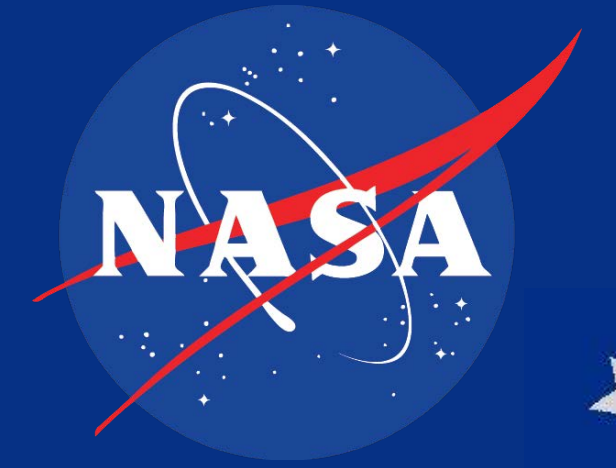








TESS launched on  
**April 18!**  
on a SpaceX Falcon 9.



Cartoon by Christina Hedges





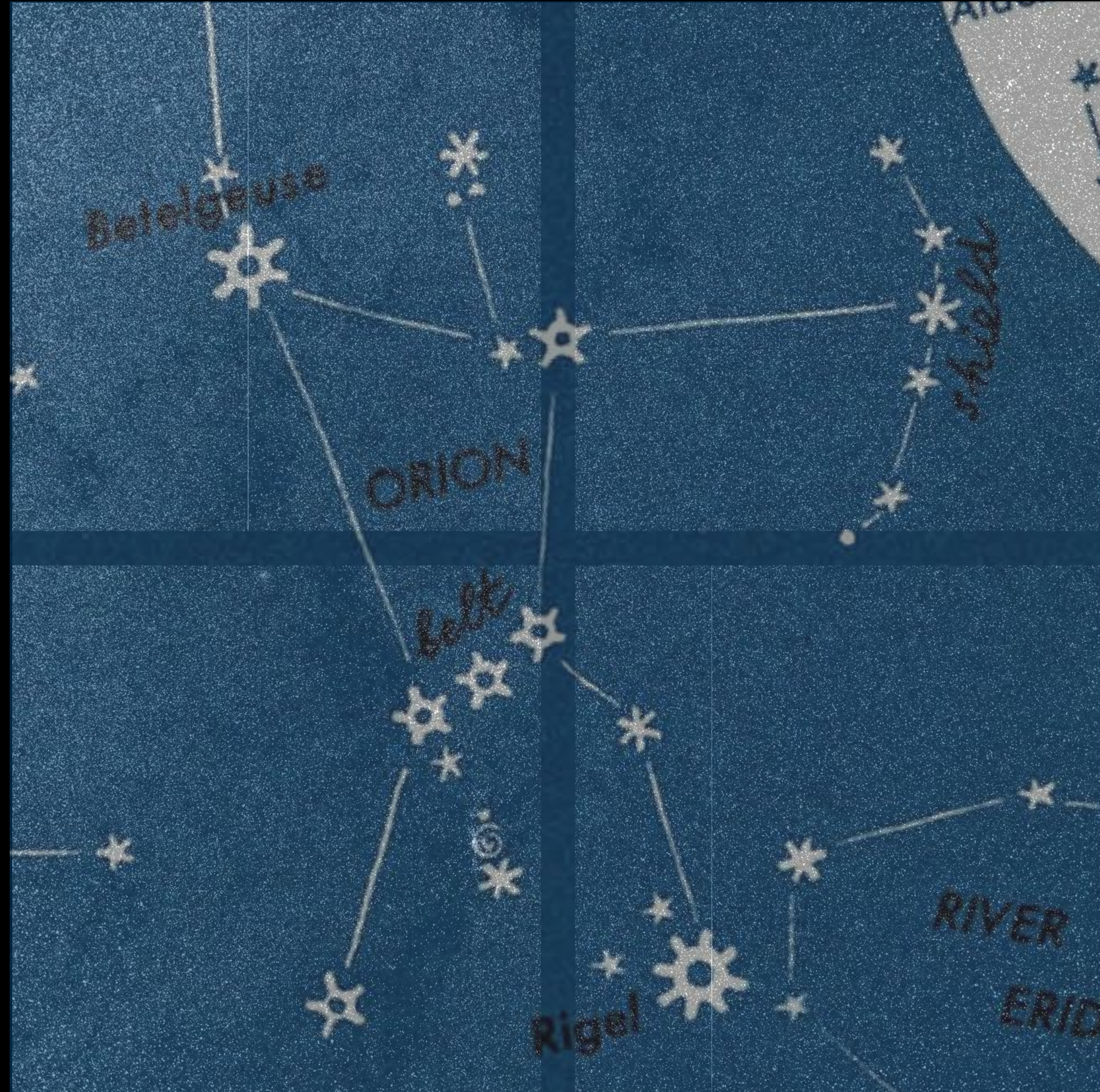






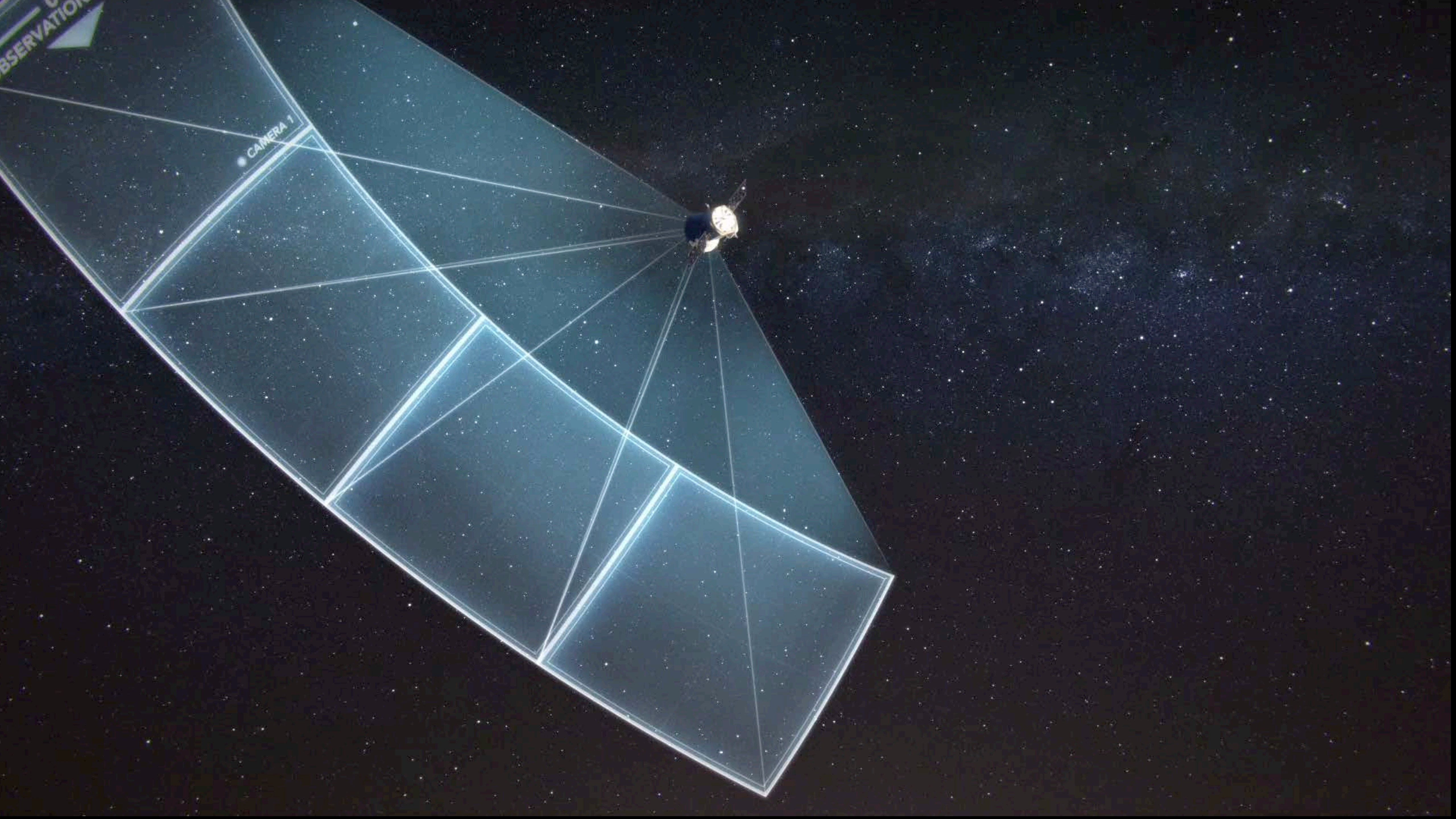
# FOV from one TESS camera:

24°



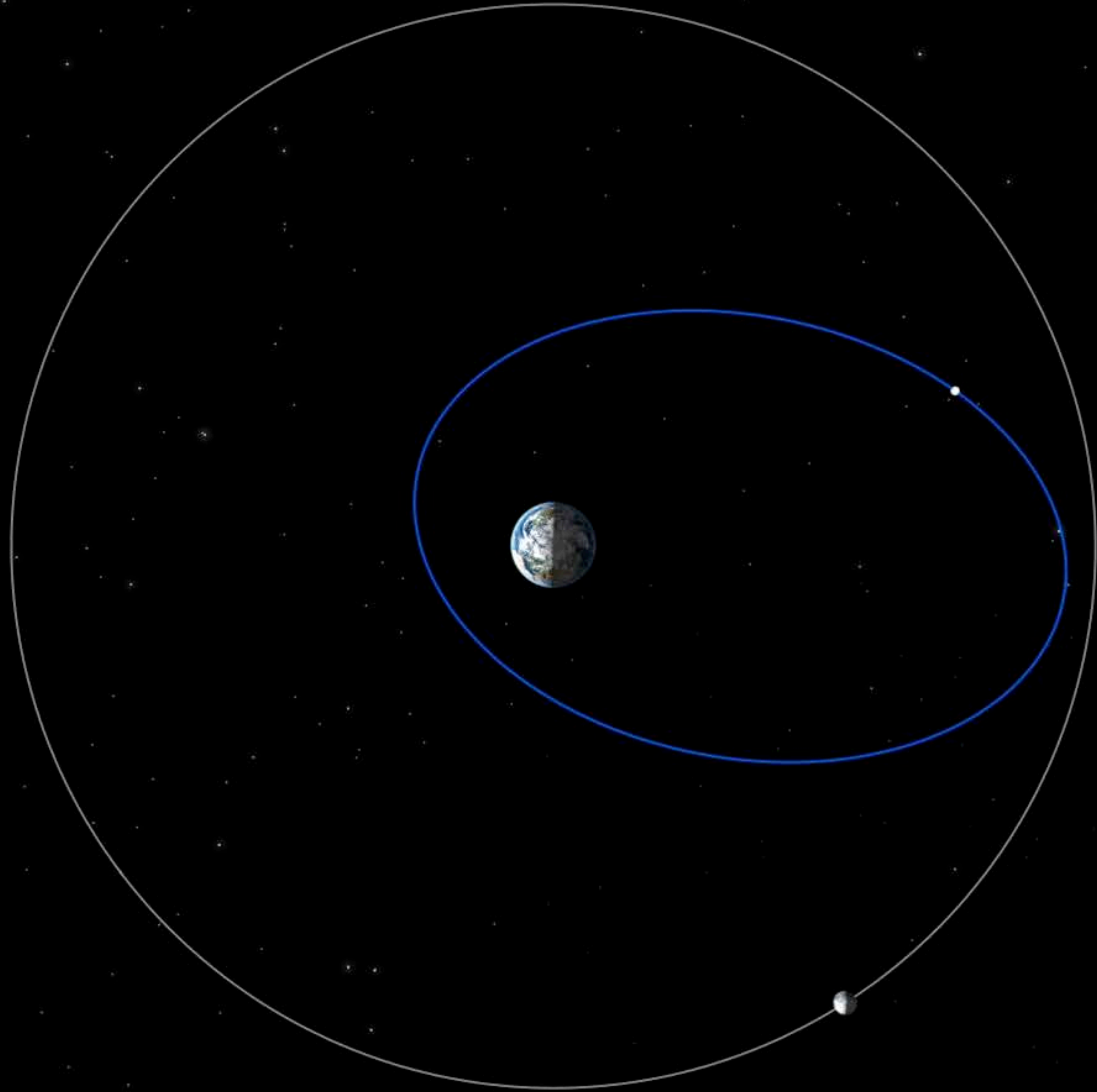
constellations by H. A. Rey



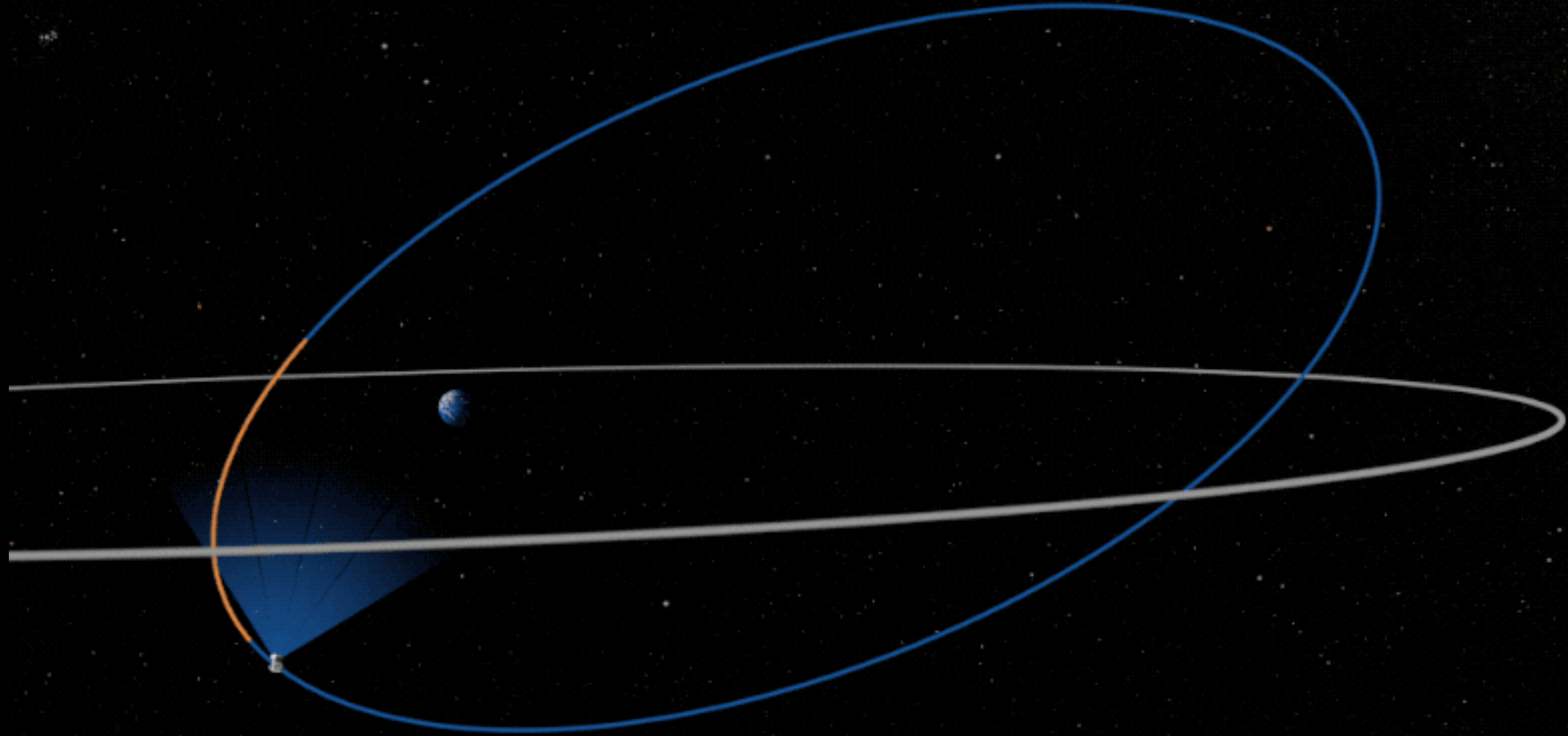




2 to 1 RESONANCE WITH THE MOON



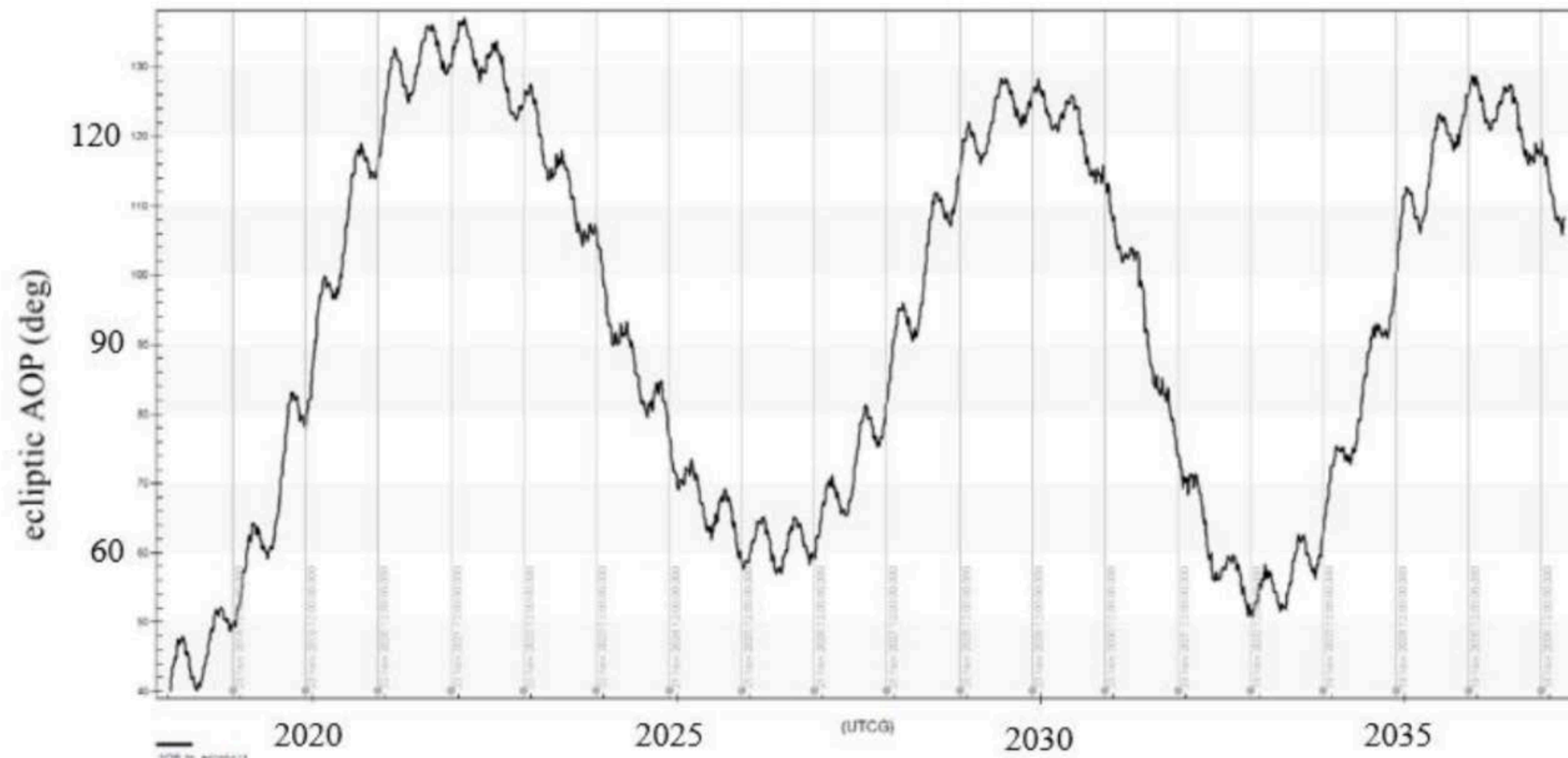






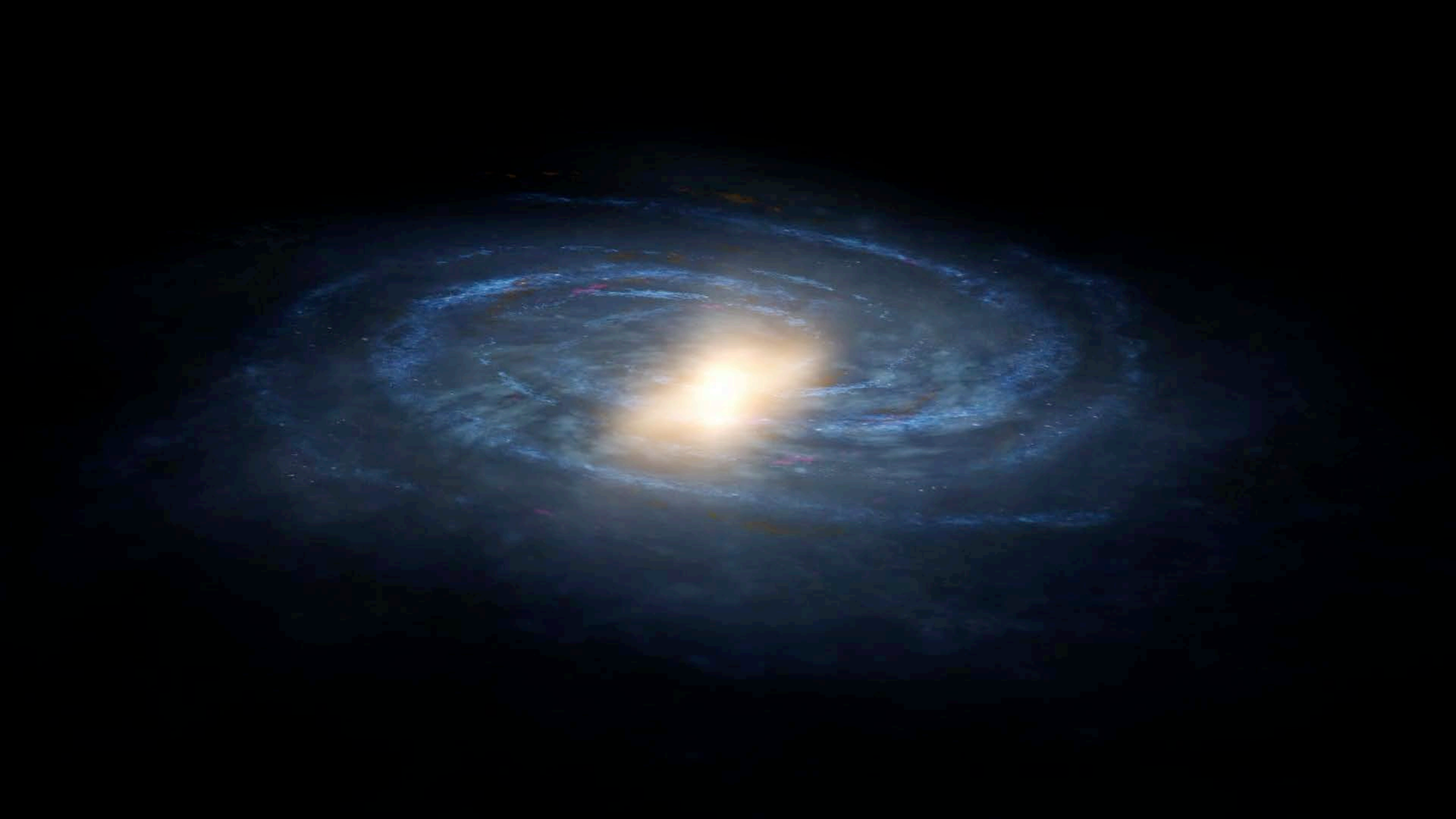
# TESS Science Orbit Dynamics

For highly eccentric orbit it is known that eccentricity and inclination oscillate together, as described by the Kozai mechanism



TESS will undergo periodic oscillations on a 10 month and a 10 year cycle. Its orbit will range from 12.8 to 14.6 days, with an average of 13.7 days



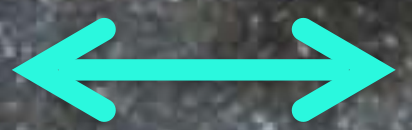
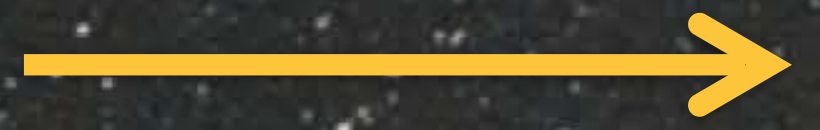
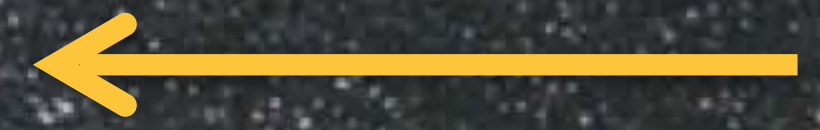
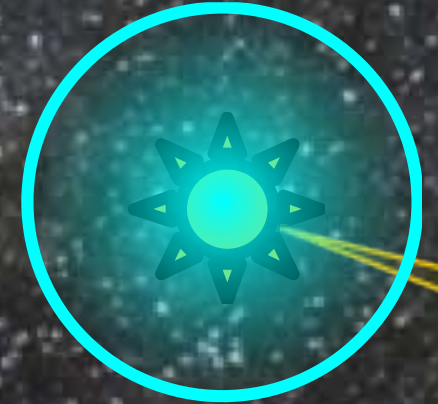




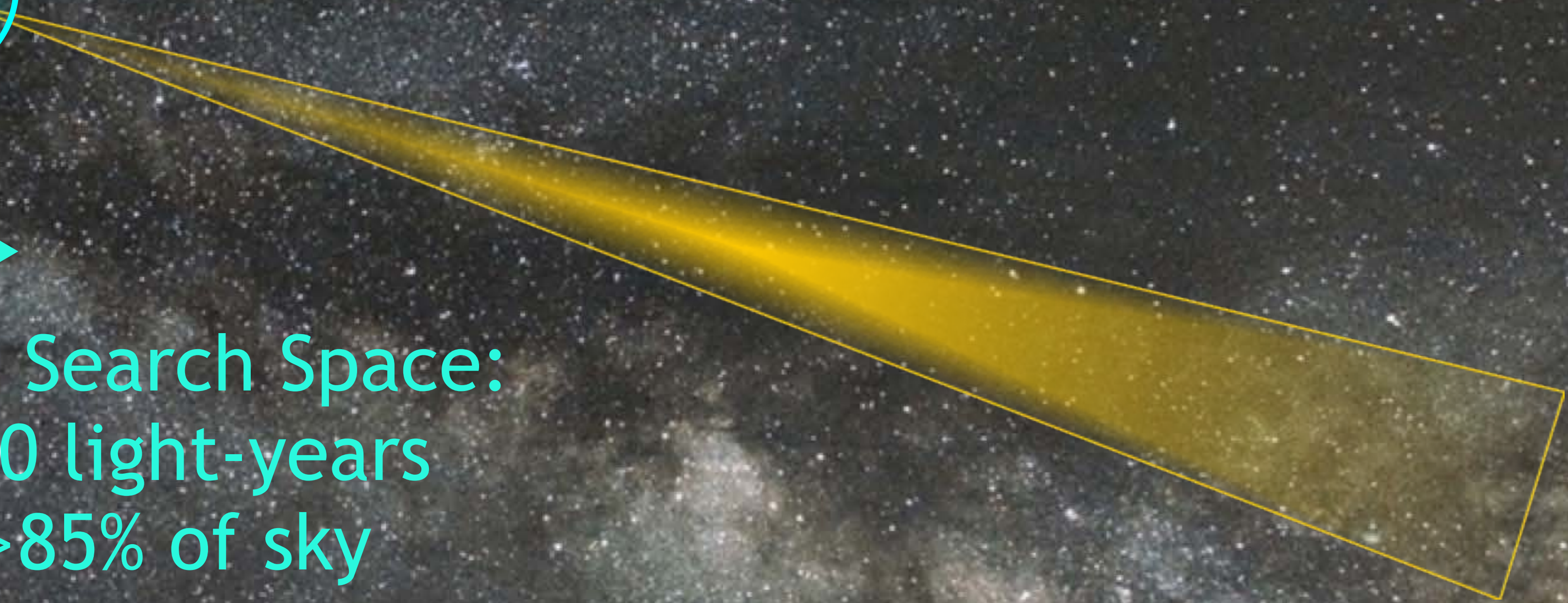




Kepler Search Space:  
3000 light-years  
0.25% of the sky



TESS Search Space:  
300 light-years  
>85% of sky





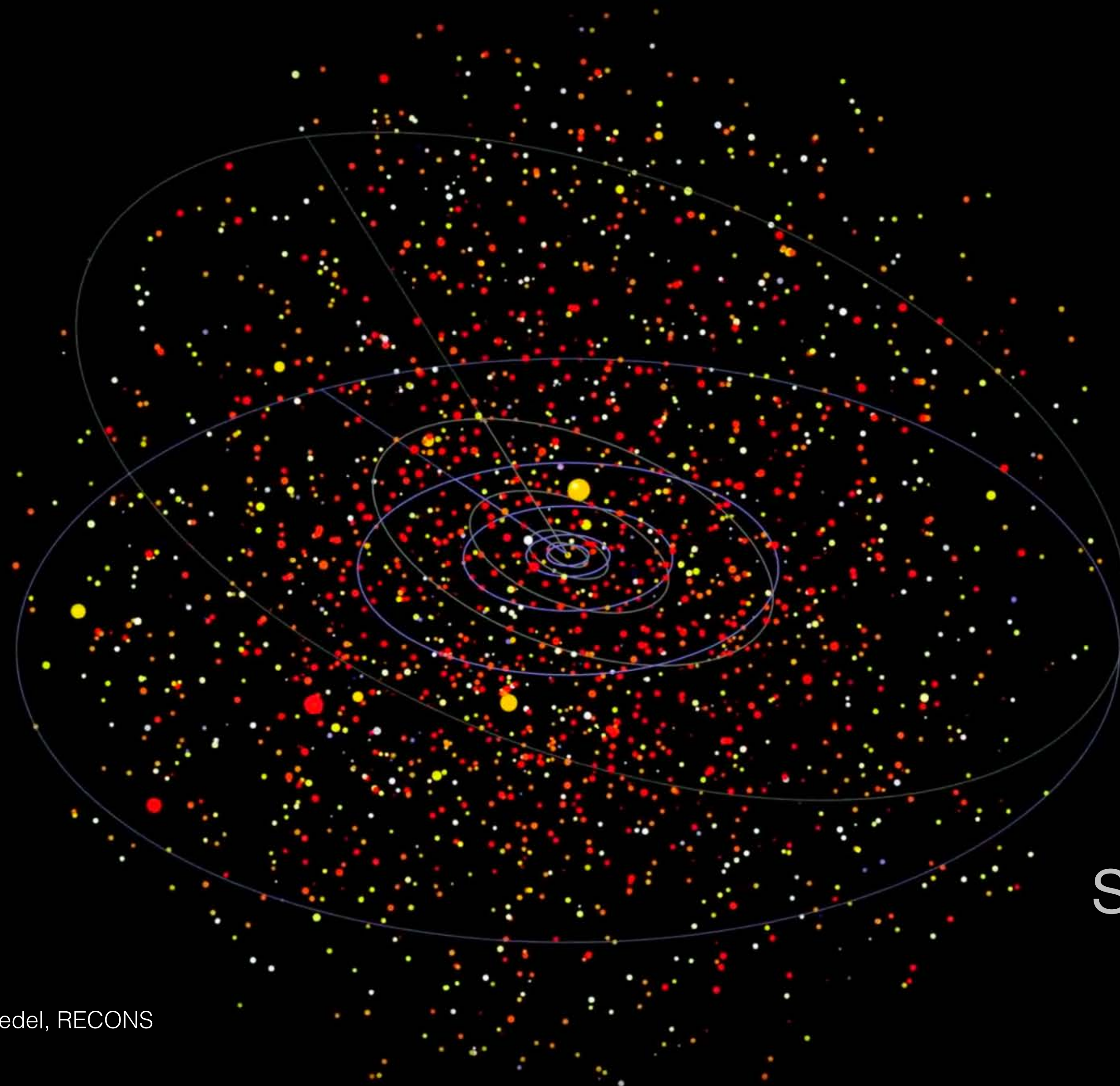




# These are the Stars in the Neighborhood

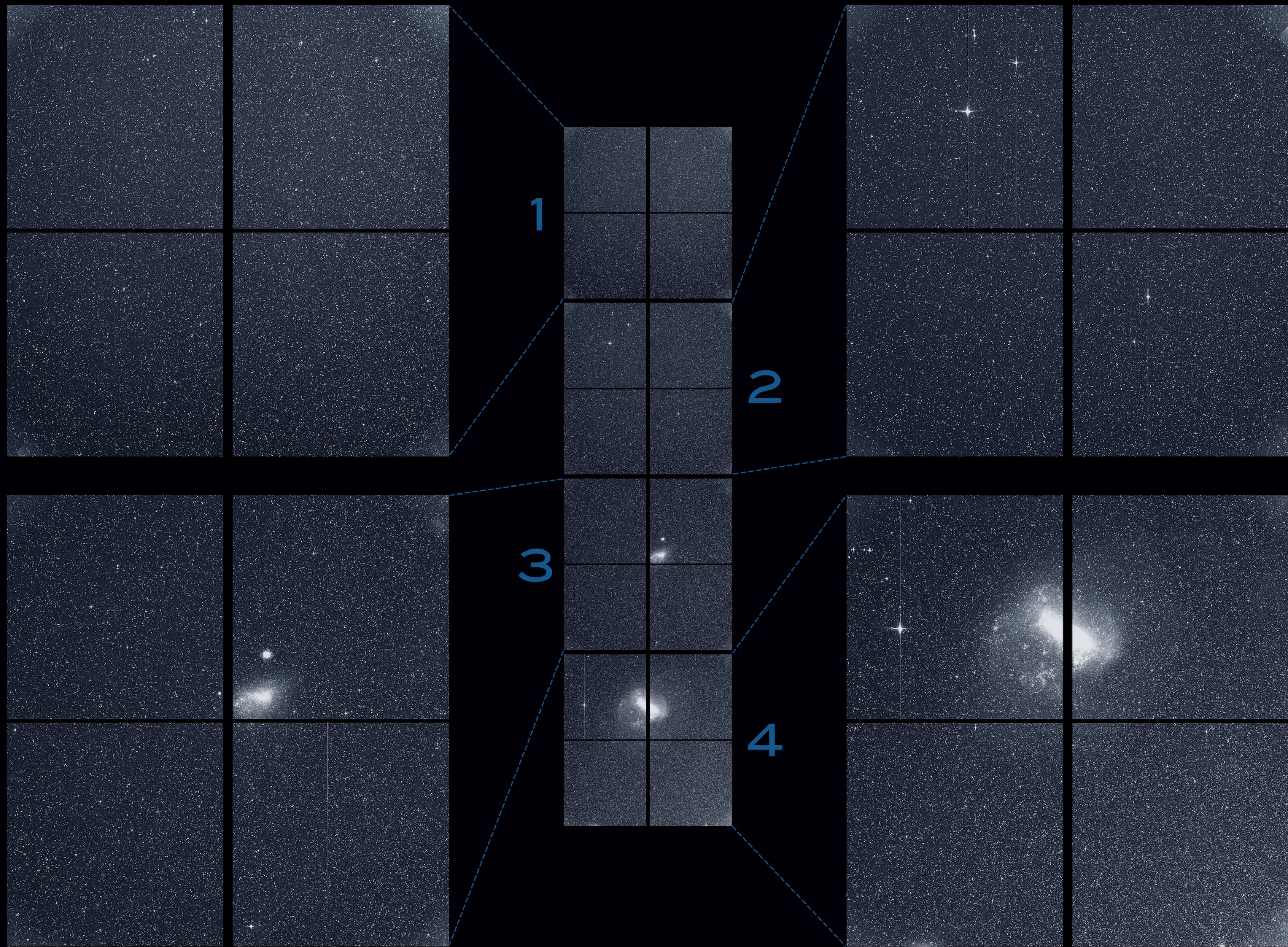
Legend:

B  
A  
F  
G  
K  
M (hot)  
M (cold)

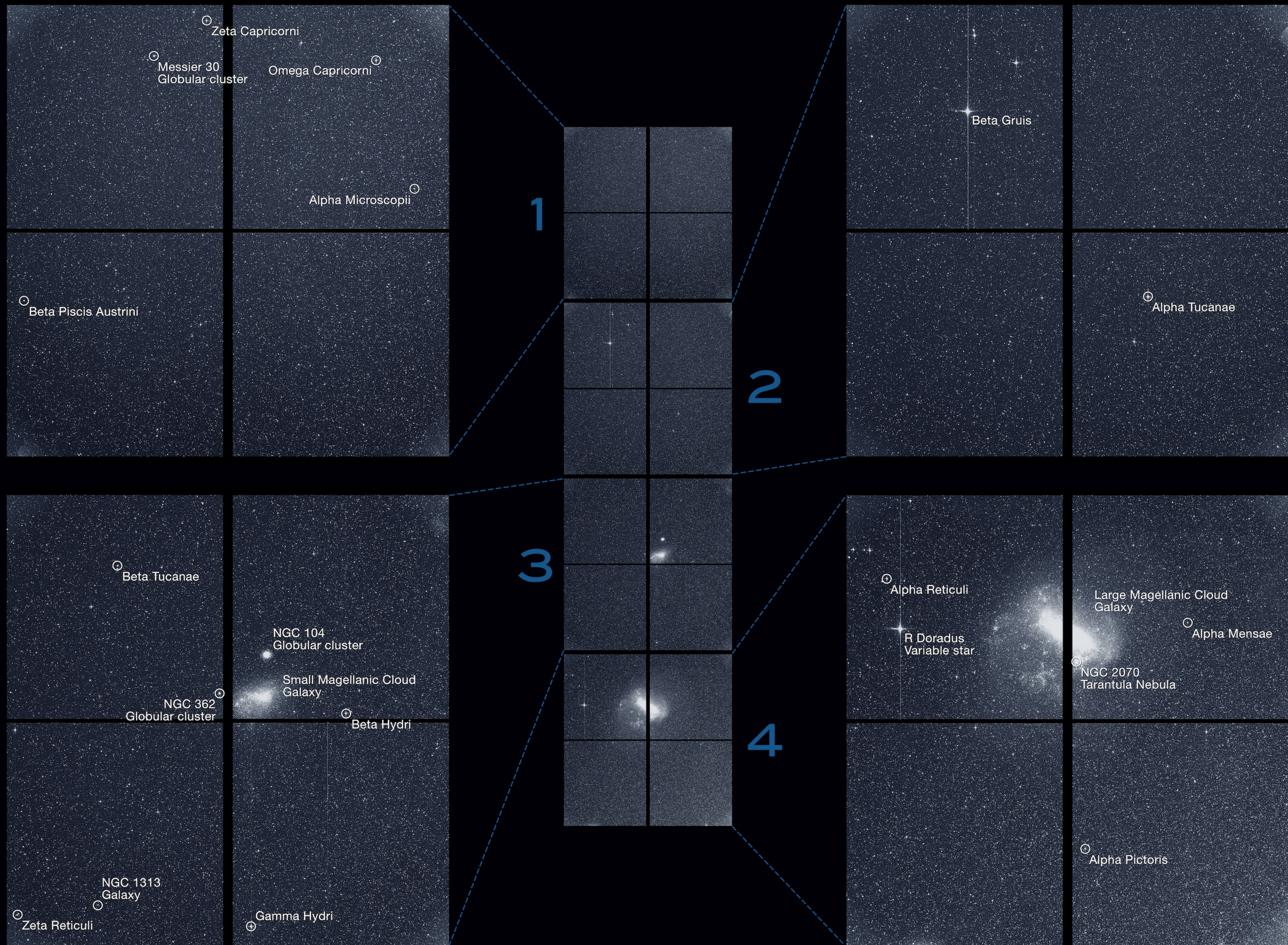


Stars within 80 light  
years of Sun













The background of the slide is a dark space filled with numerous small white stars. On the left side, there is a large, bright yellow star with a soft, glowing aura. On the right side, there is a large, grey, cratered planet, likely representing Pi Mensae c. The text is overlaid on this scene.

TESS is already starting to find its  
first planets!

This is Pi Mensae c  
a super-Earth around a  
Sun-like star 60 ly away

The planet orbits its star  
every 6.3 days

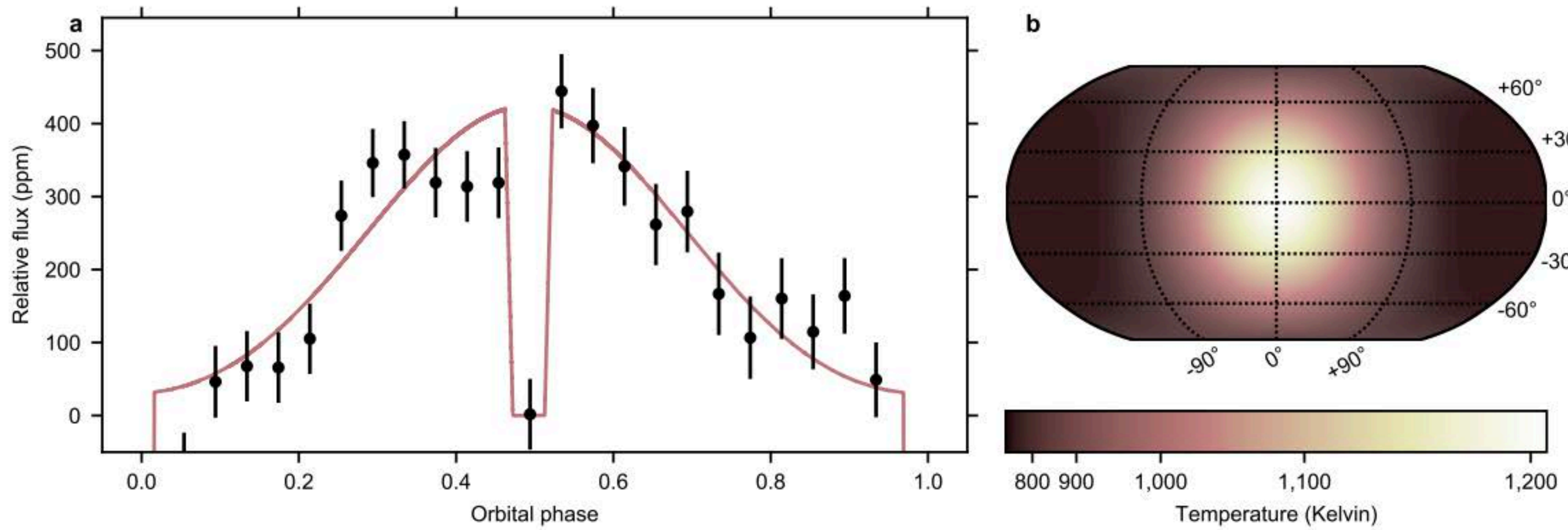




This planet orbits LHS 3844, an M  
dwarf star located 49 light years away

The planet orbits every 11 hours and is  
slightly larger than the Earth.



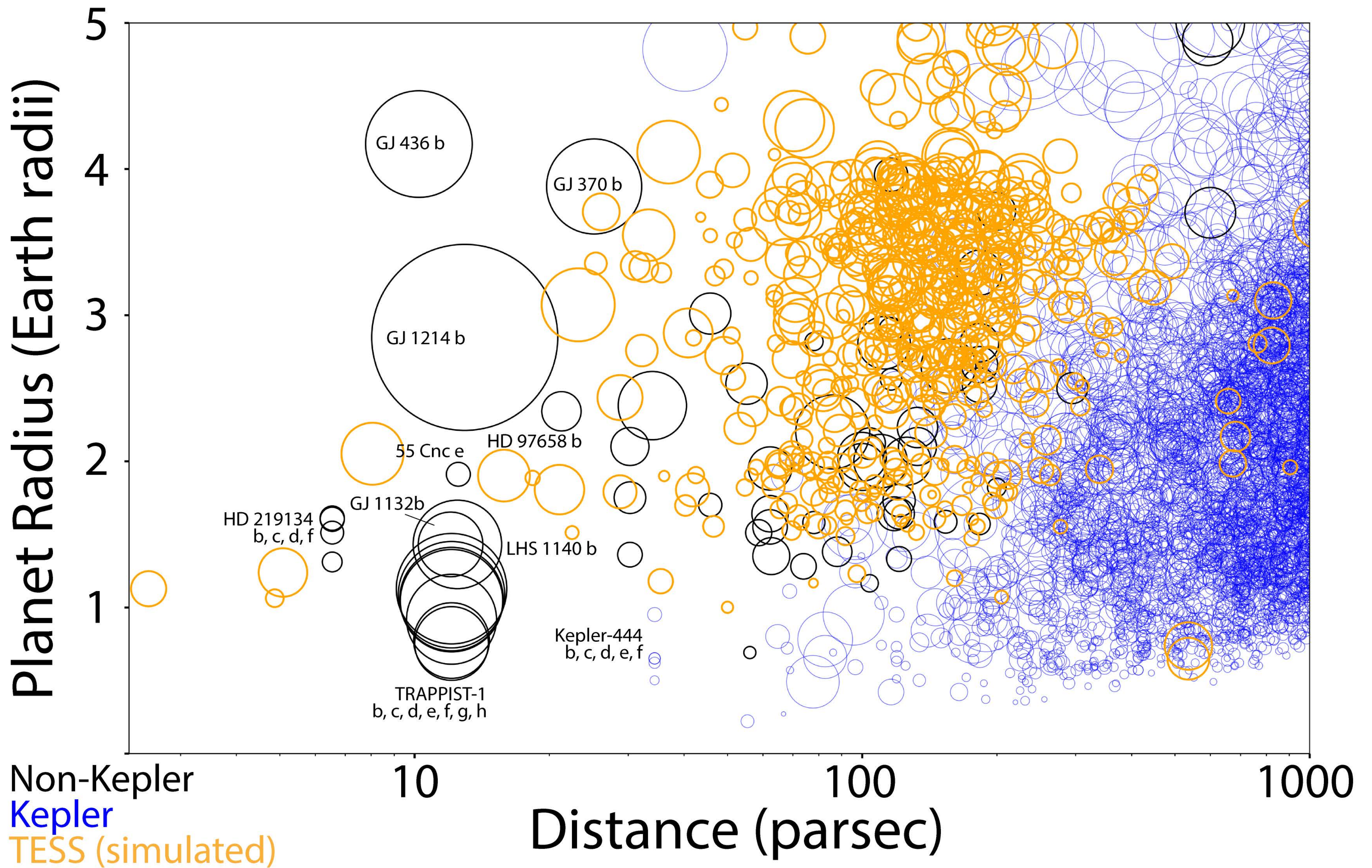


Data from the Spitzer Telescope show LHS 3844 is a synchronously rotating bare rock planet

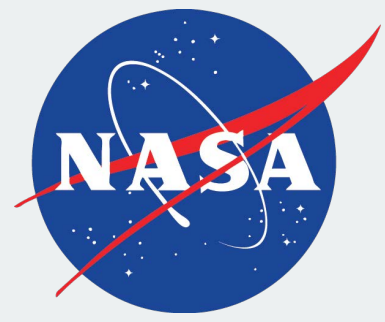




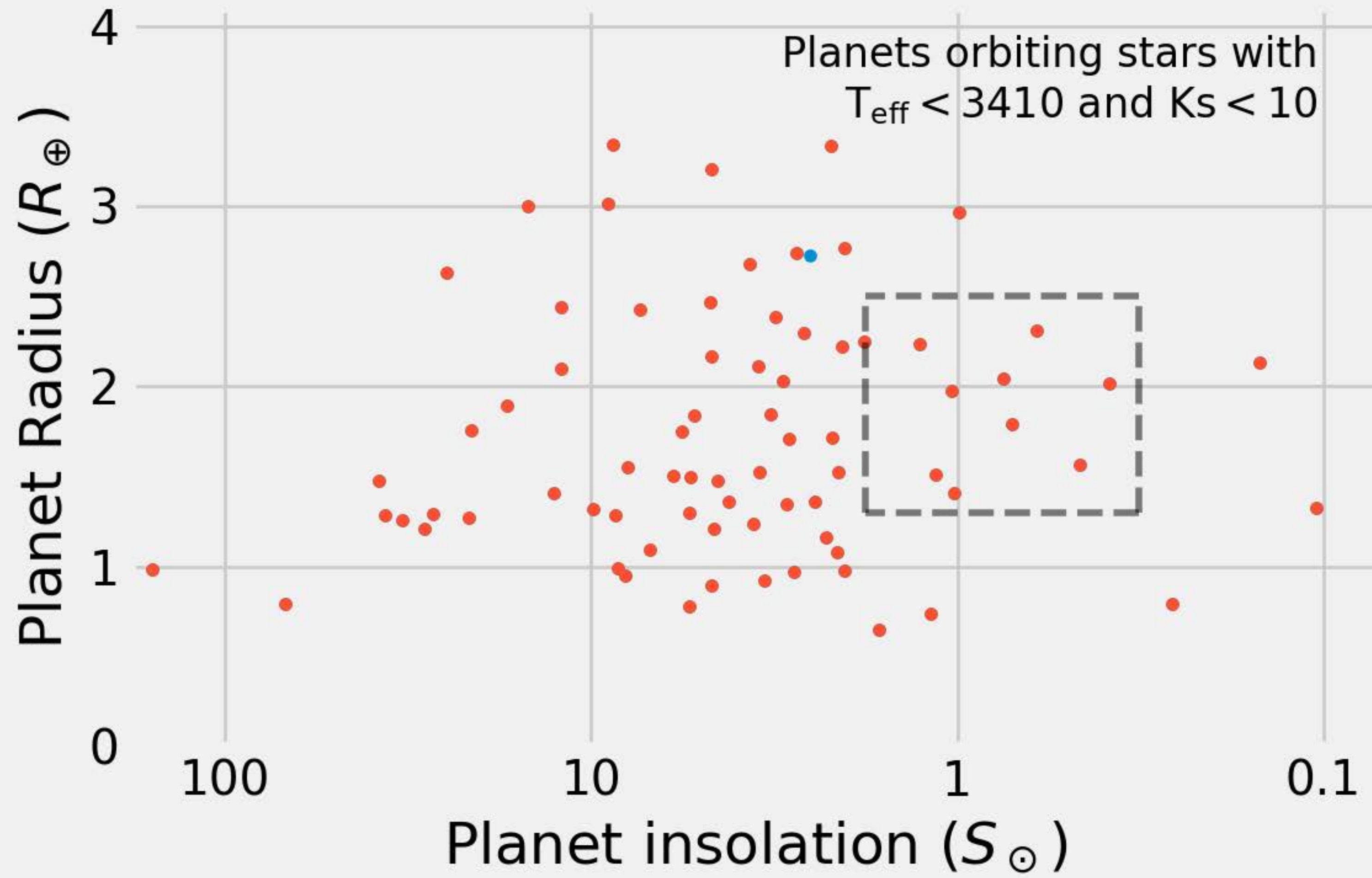








# Small planets for atmospheric characterization



Planets orbiting bright, cool stars

- $T_{\text{eff}} < 3410$  K
- Stars brighter than  $K_{\text{mag}}=10$
- 76 total planets
- About a dozen in the HZ



# Transiting Exoplanet Survey Satellite (TESS)

Planet counts



Status

Last update: October 4, 2019

29

CONFIRMED

1,183

TESS CANDIDATES

1:168:18:34:02

TIME IN ORBIT

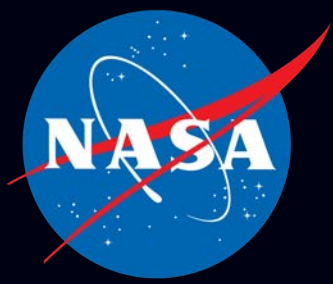


TESS will find the touchstone planets that  
will be studied for decades

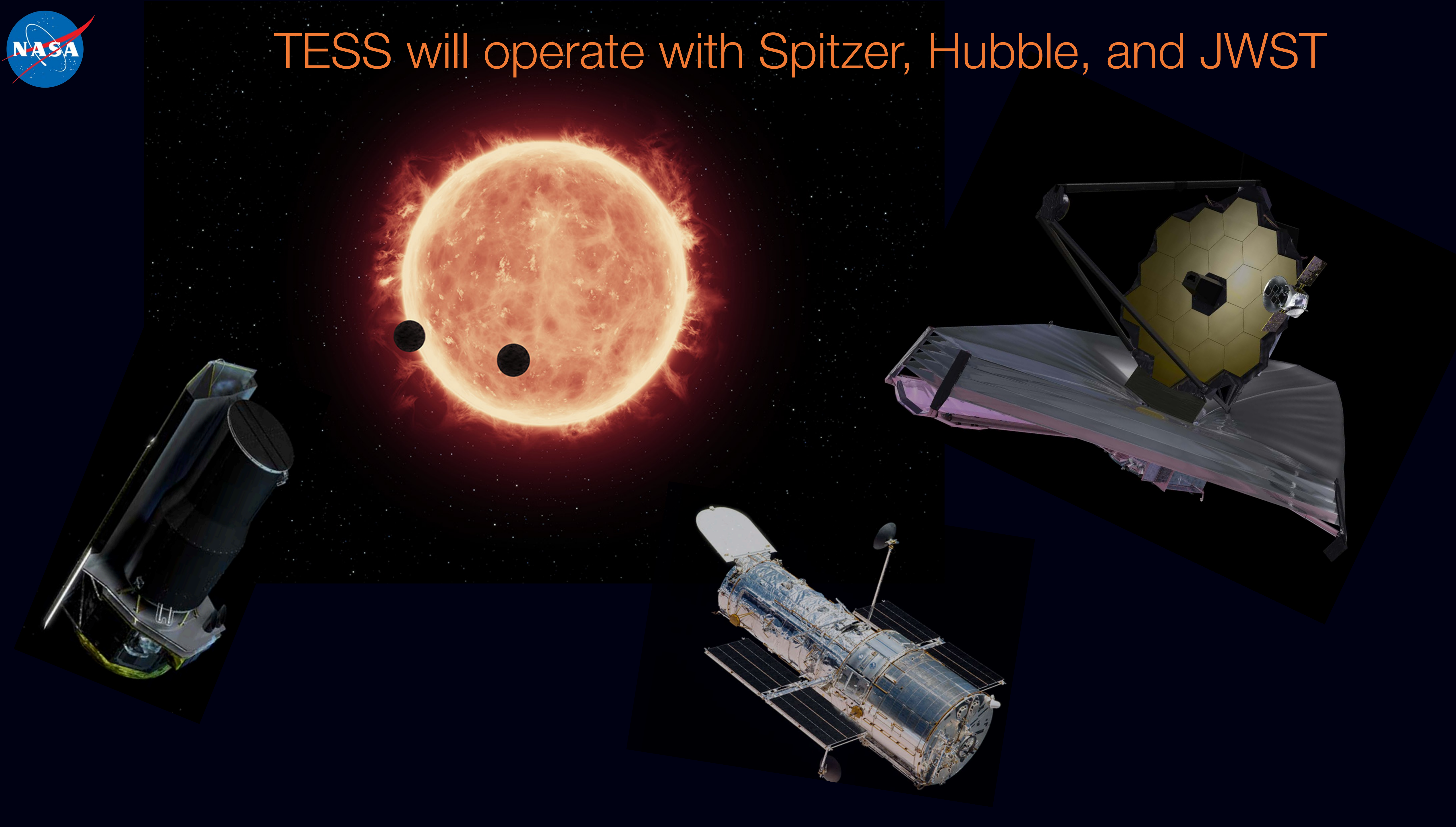


Image credit: David Curtis

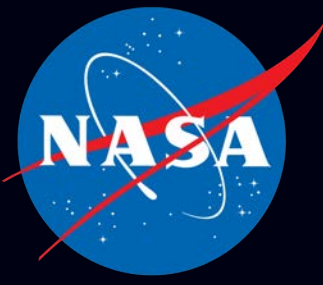




TESS will operate with Spitzer, Hubble, and JWST





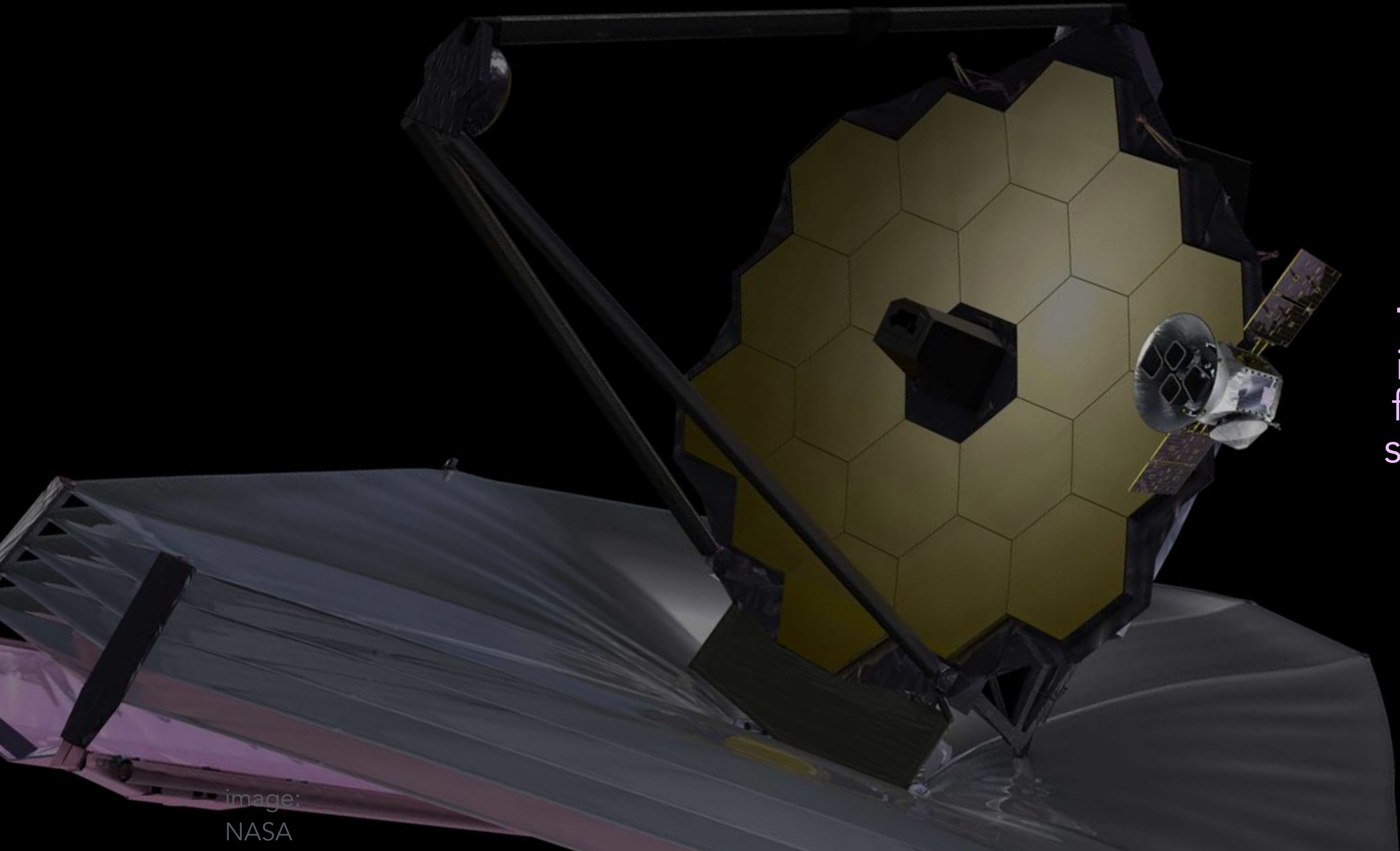


# James Webb Space Telescope (launch 2021)





# Where do we point JWST?



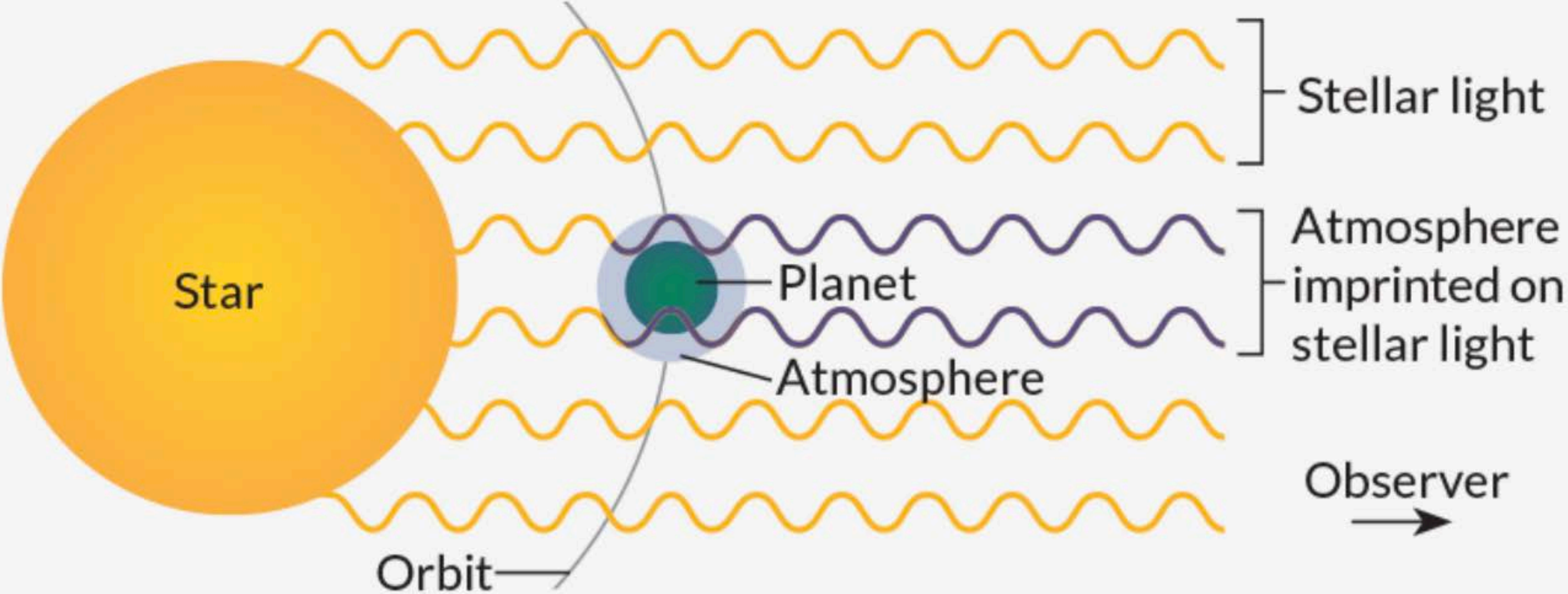
**TESS**  
is our  
finder  
scope!

image:  
NASA

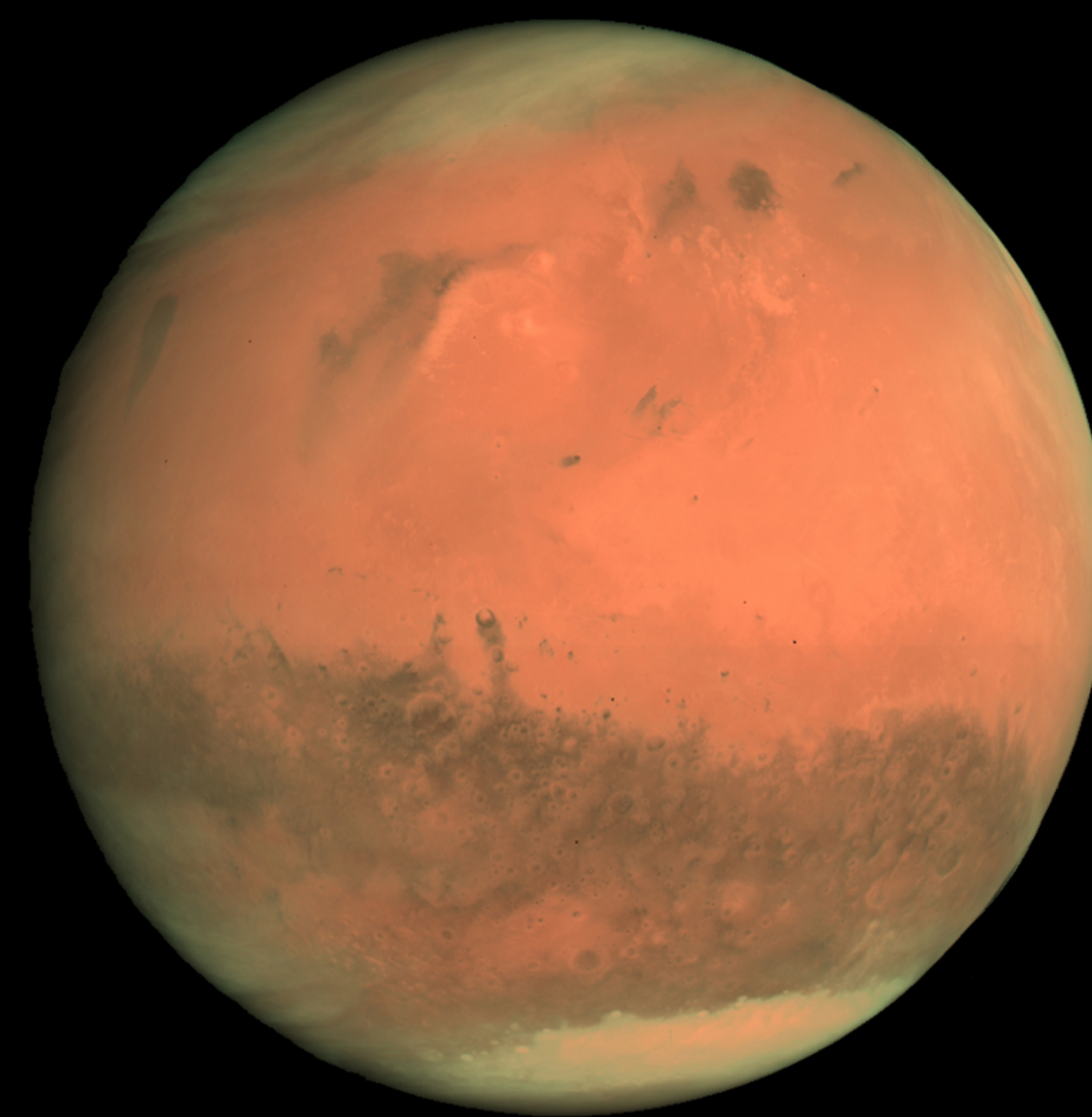
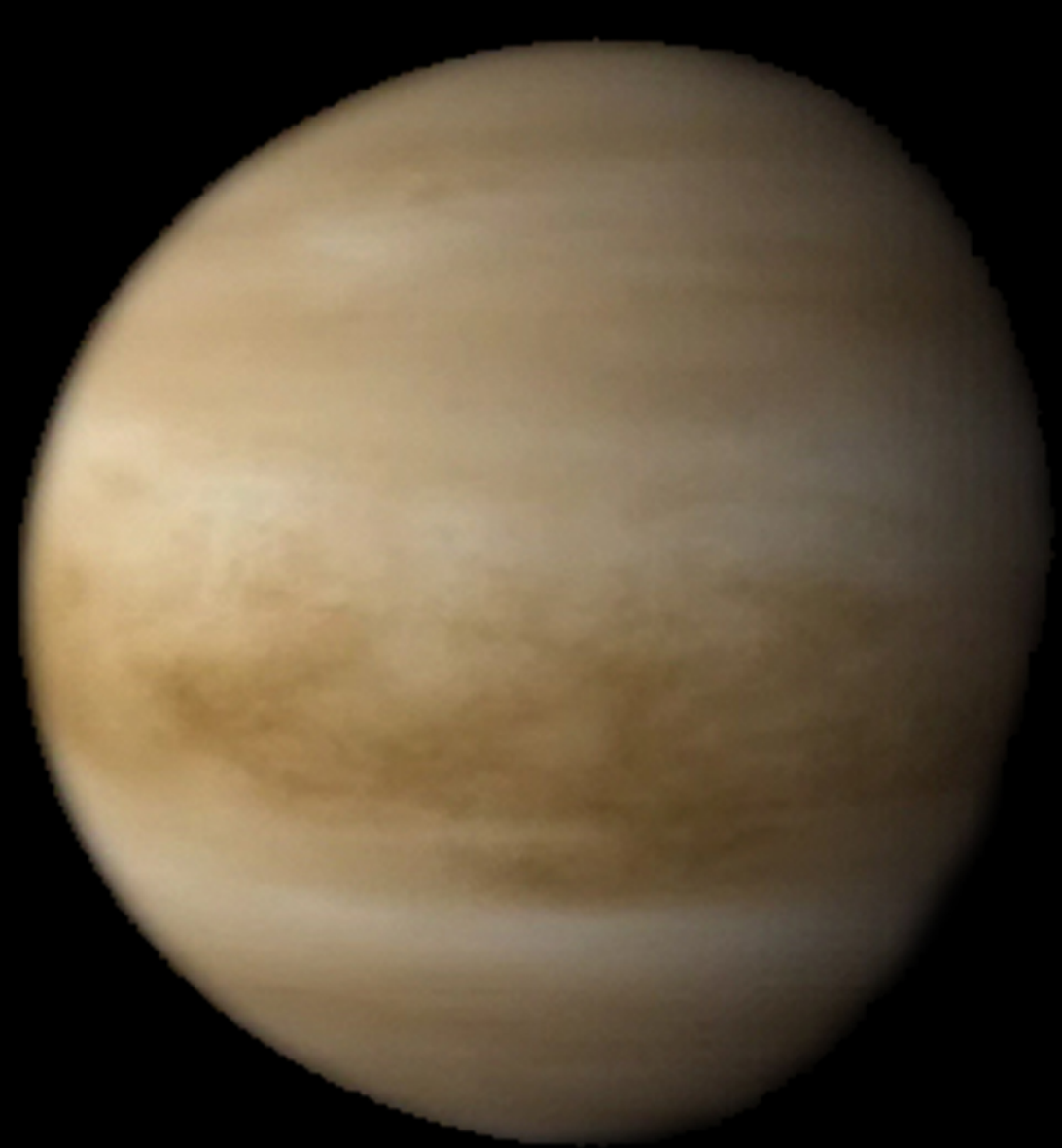


# Searching in starlight

The atmosphere of a planet in another solar system can leave a chemical fingerprint on the light from its sun, which might reveal hints of alien biological activity.

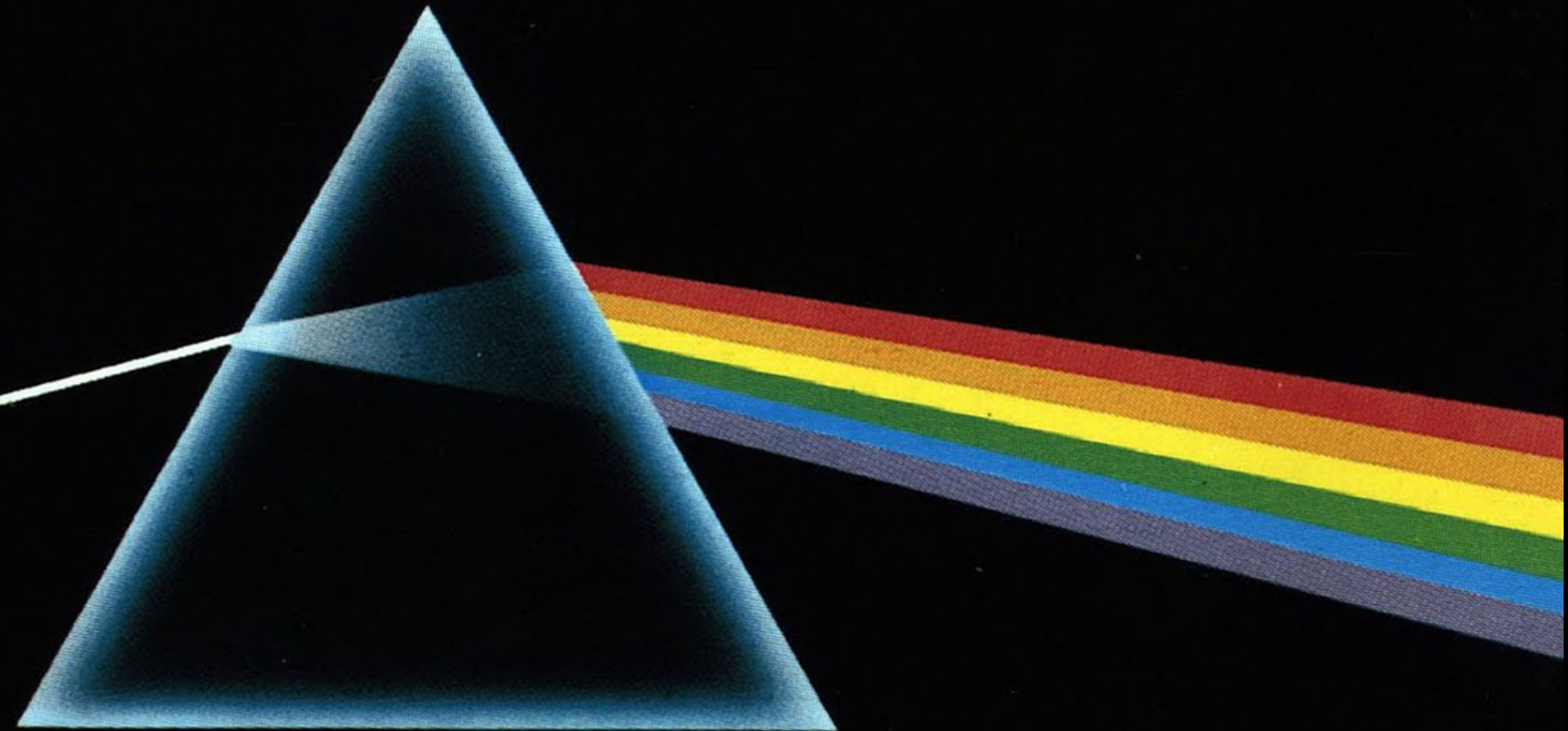






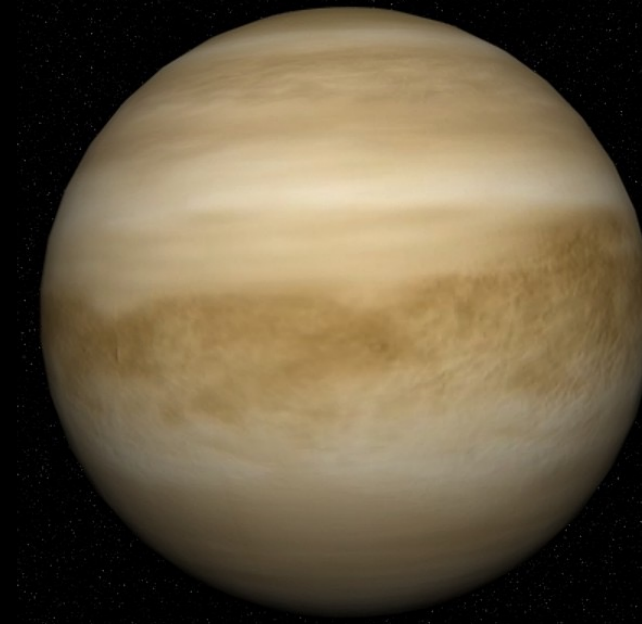
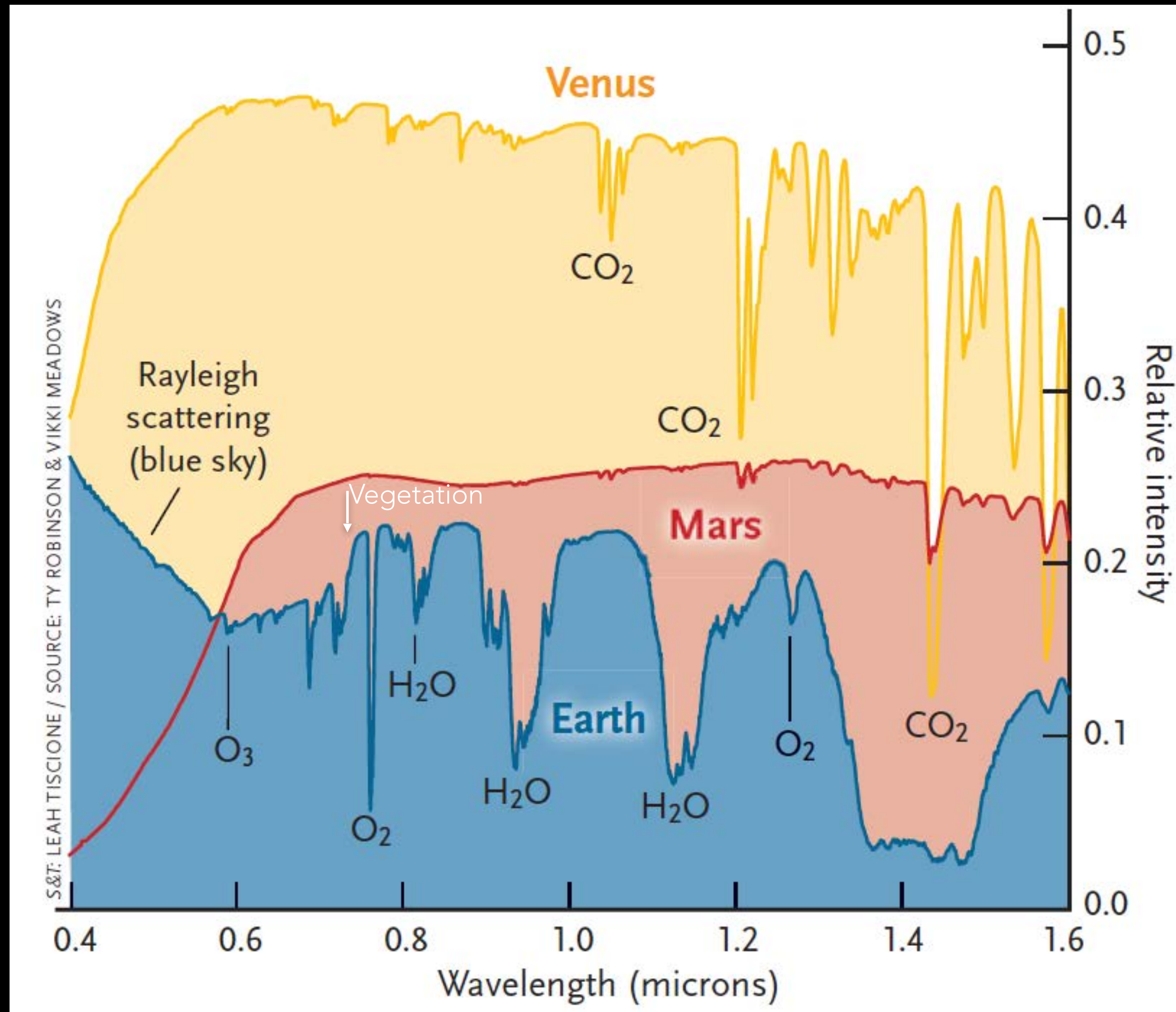


Light from Star





# Earth's Spectral Fingerprints are Unique



Credit: Sky & Telescope 10/2015; reproduced from Robinson & Meadows



