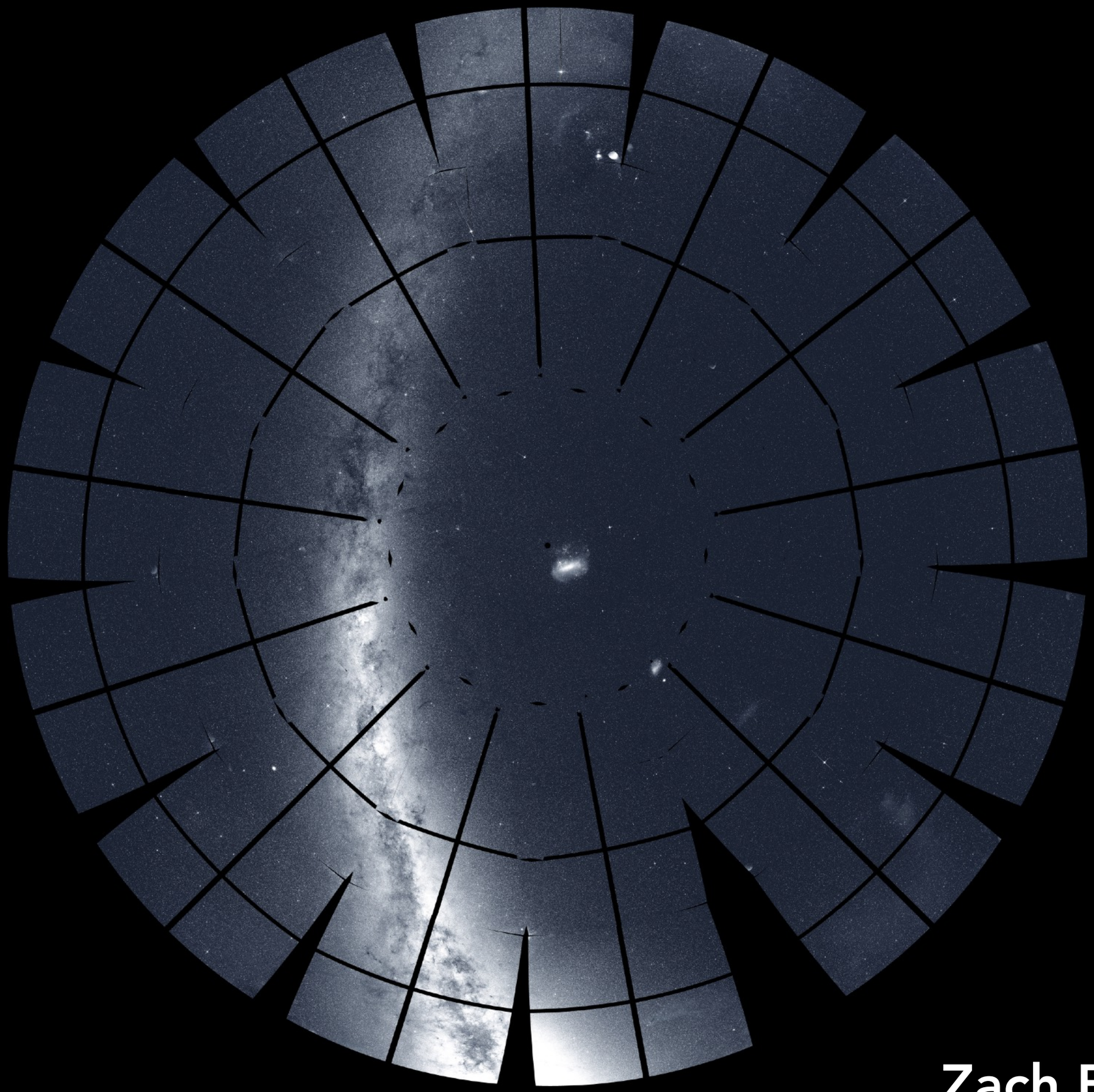


The Transiting Exoplanet Survey Satellite (TESS)

presented by

Zach Berta-Thompson

Discuss with your neighbors:

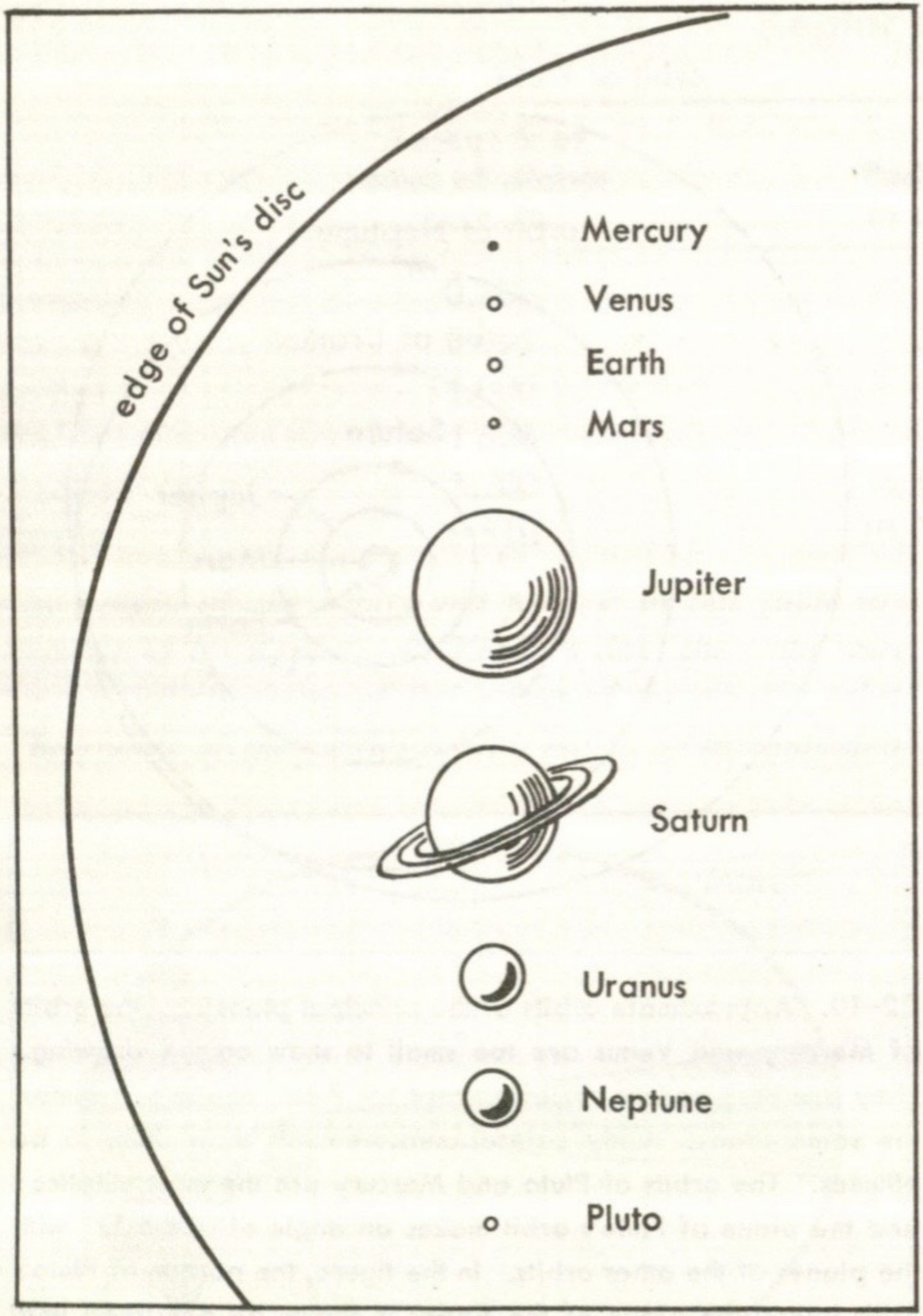
Why should we look for planets around other stars?

Learning Goals

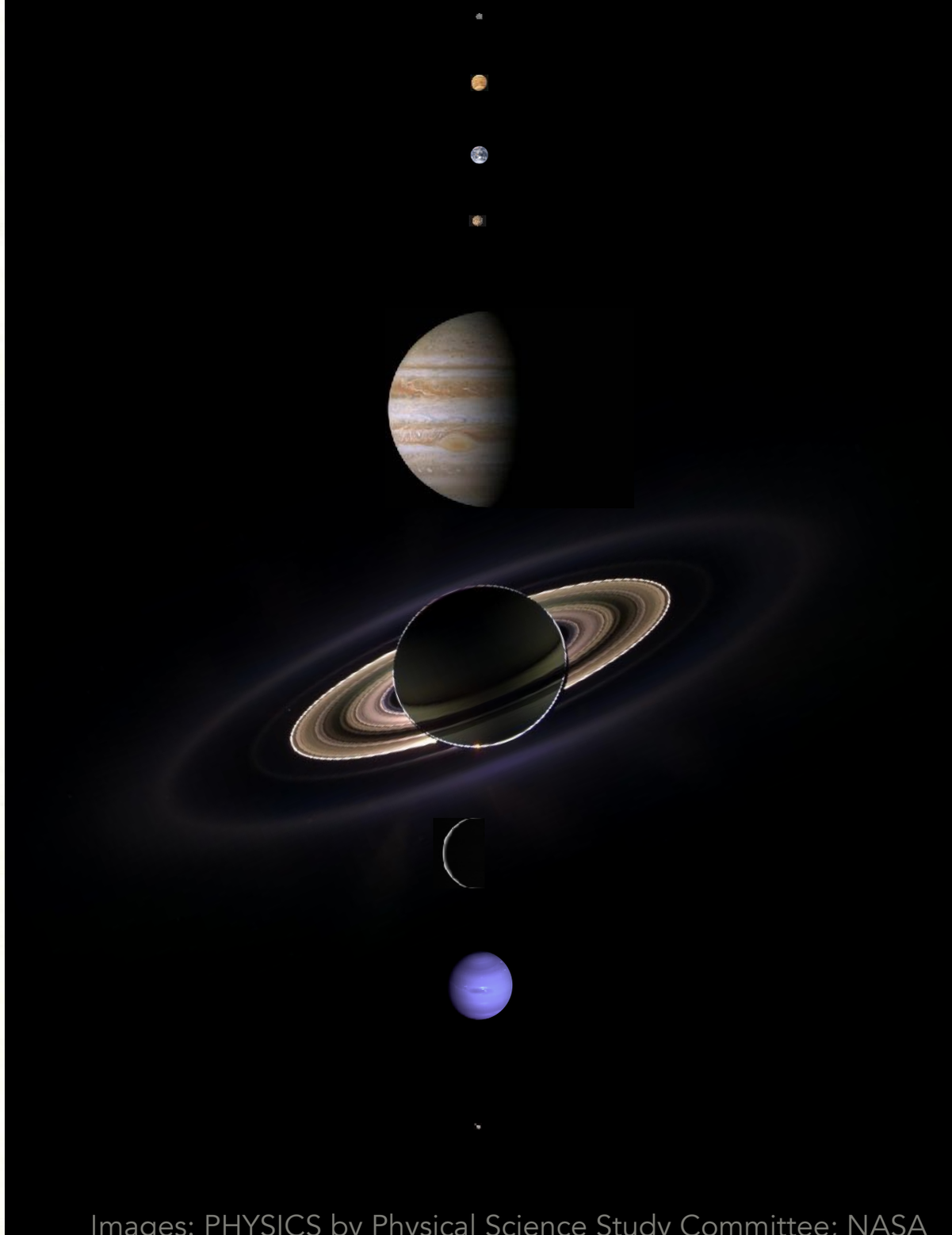
Let's try to leave here today…

- convinced that there is a need for *another* NASA exoplanet mission after Kepler
- knowing how TESS will find the closest transiting exoplanets
- with a sense of the process by which TESS was proposed, selected, built, and launched
- having (tried) to answer your questions about TESS!

What are a few things we know about exoplanets?



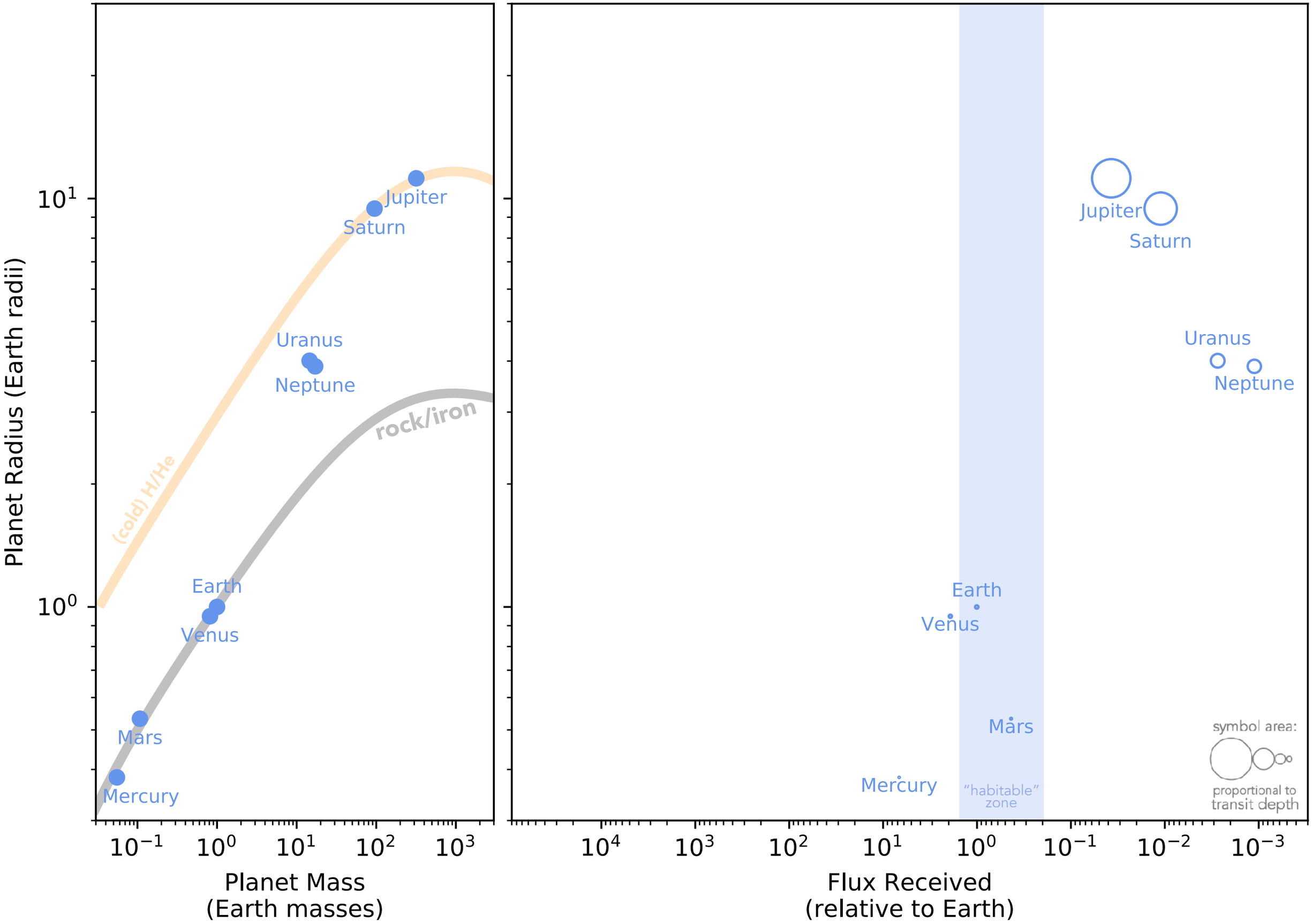
Let's meet the planets.



Images: PHYSICS by Physical Science Study Committee; NASA

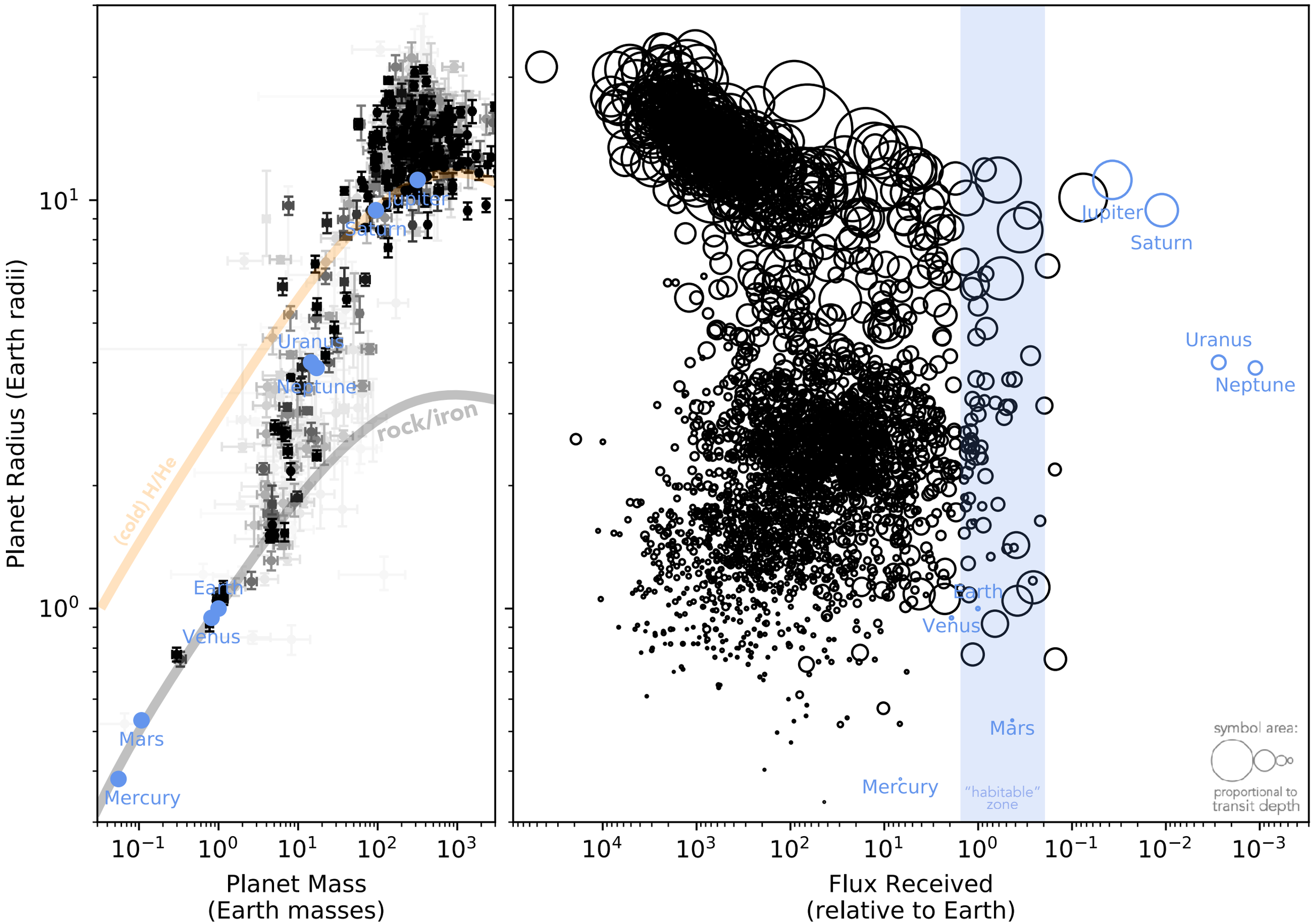

flux
time

Planetary scientists have beautiful data on eight Solar System planets.



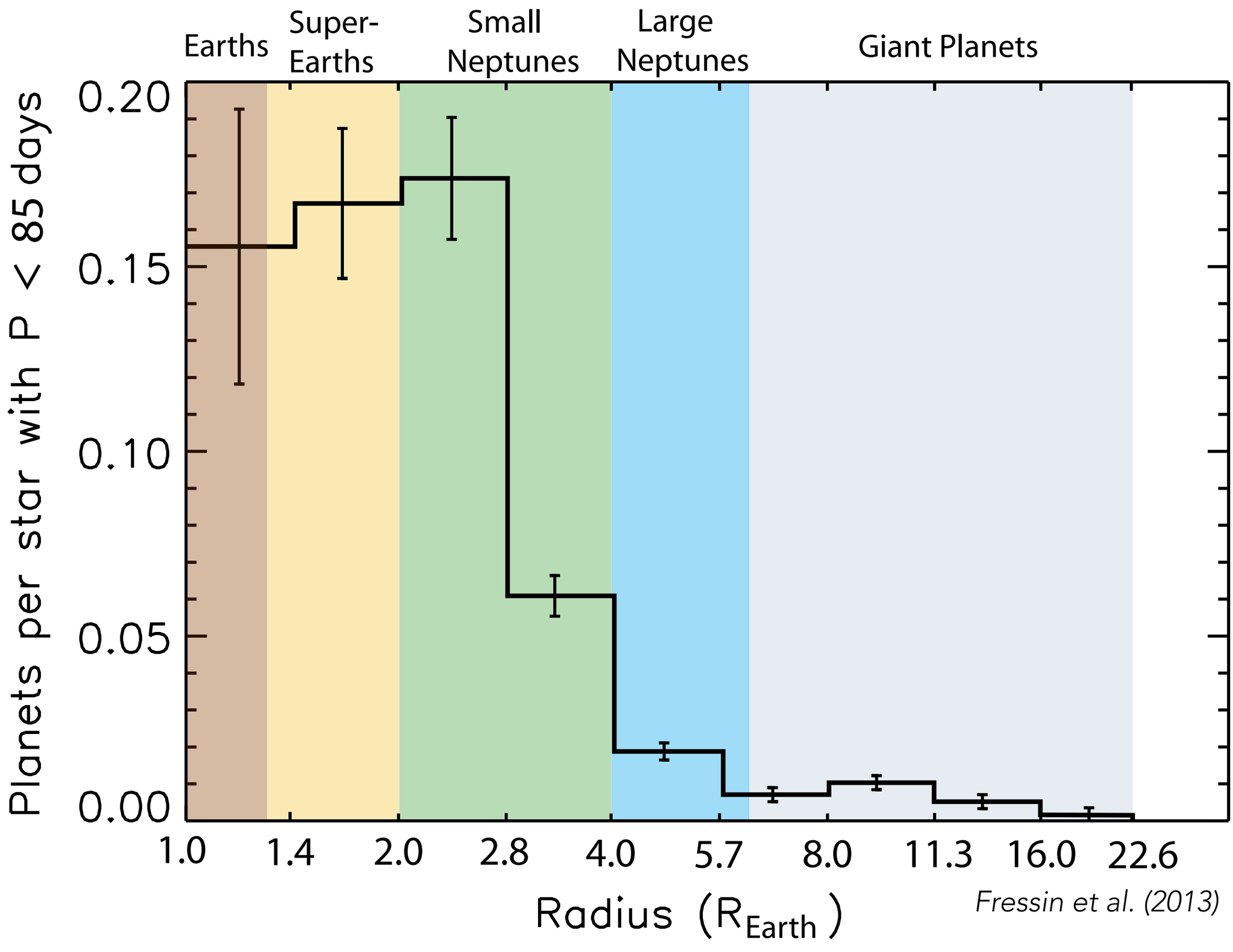
exoplanet properties from NASA Exoplanet Archive, with some curation; mass-radius models from Seager et al. (2007); HZ from Kopparapu et al. (2013)

We know thousands of transiting exoplanets, spanning diverse environments.



exoplanet properties from NASA Exoplanet Archive, with some curation; mass-radius models from Seager et al. (2007); HZ from Kopparapu et al. (2013)

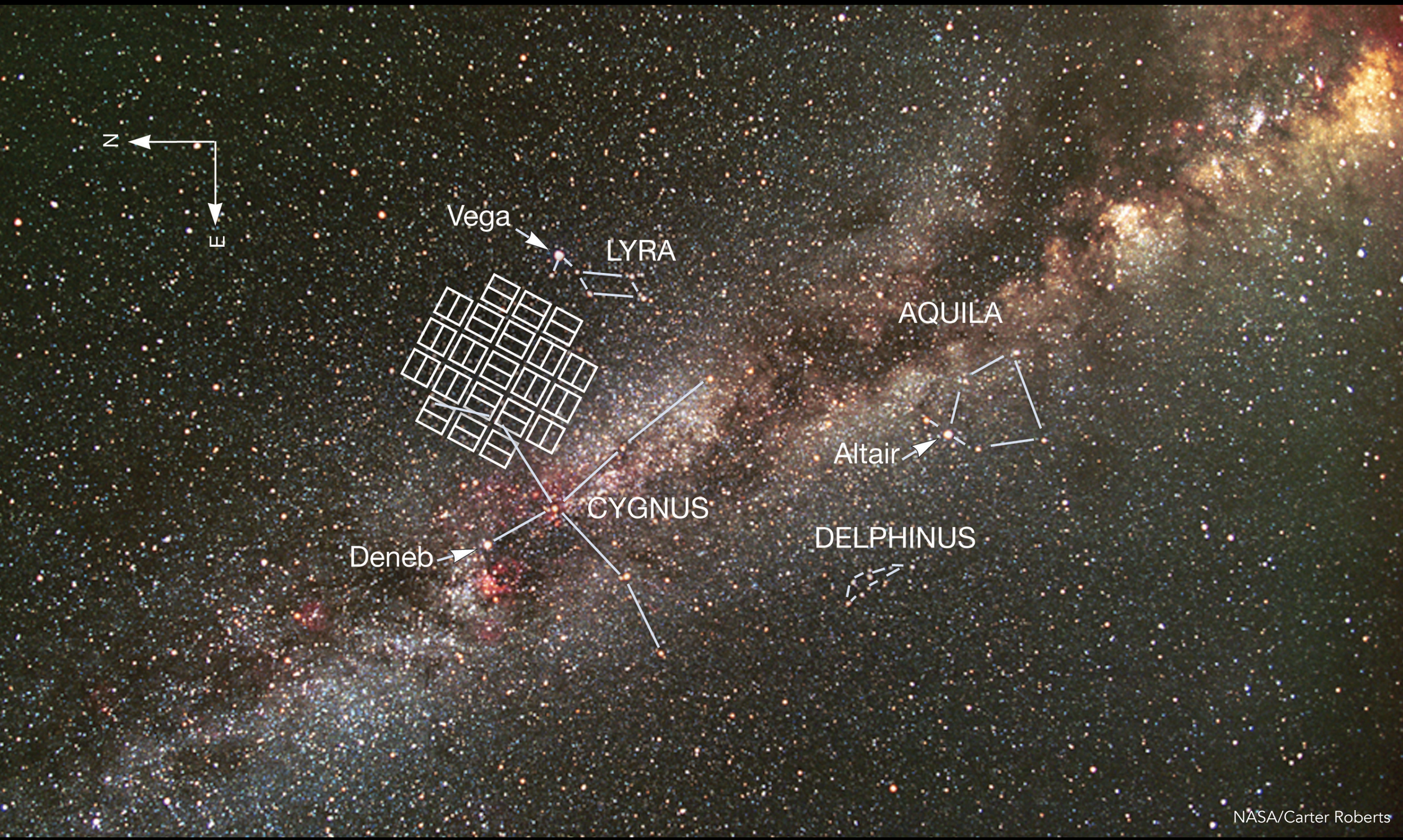
(For close-in orbits), big planets are rare and small planets are common!



Fressin et al. (2013)

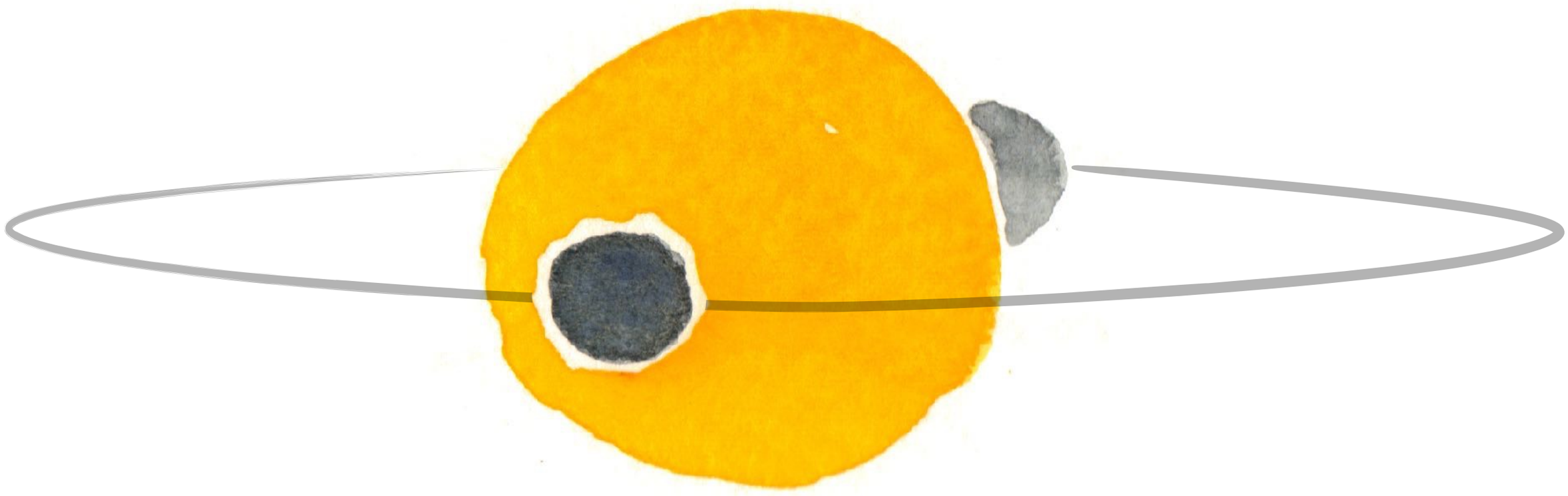
Most planets we know of were discovered by the 0.95m NASA **Kepler Space Telescope**.

Kepler spent four years staring at a tiny (0.3%) patch of the sky.



Why was NASA Kepler not enough?

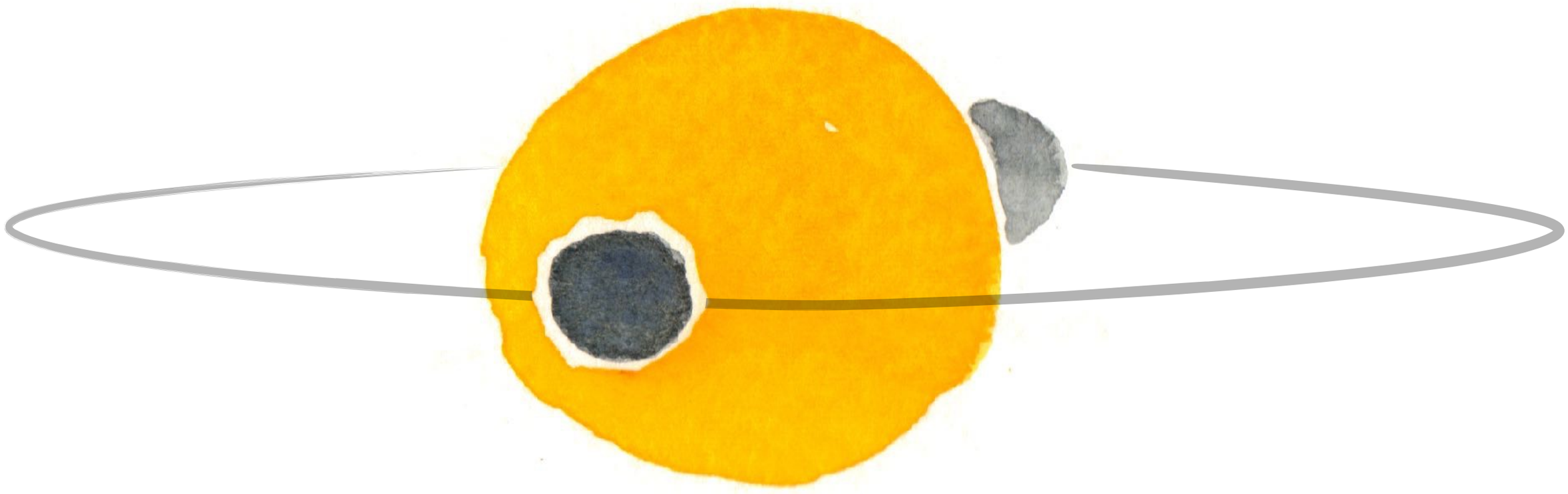
Transiting exoplanets
are useful laboratories.



For a transiting exoplanet, we can directly observe
planet size + orbit + mass + atmosphere.

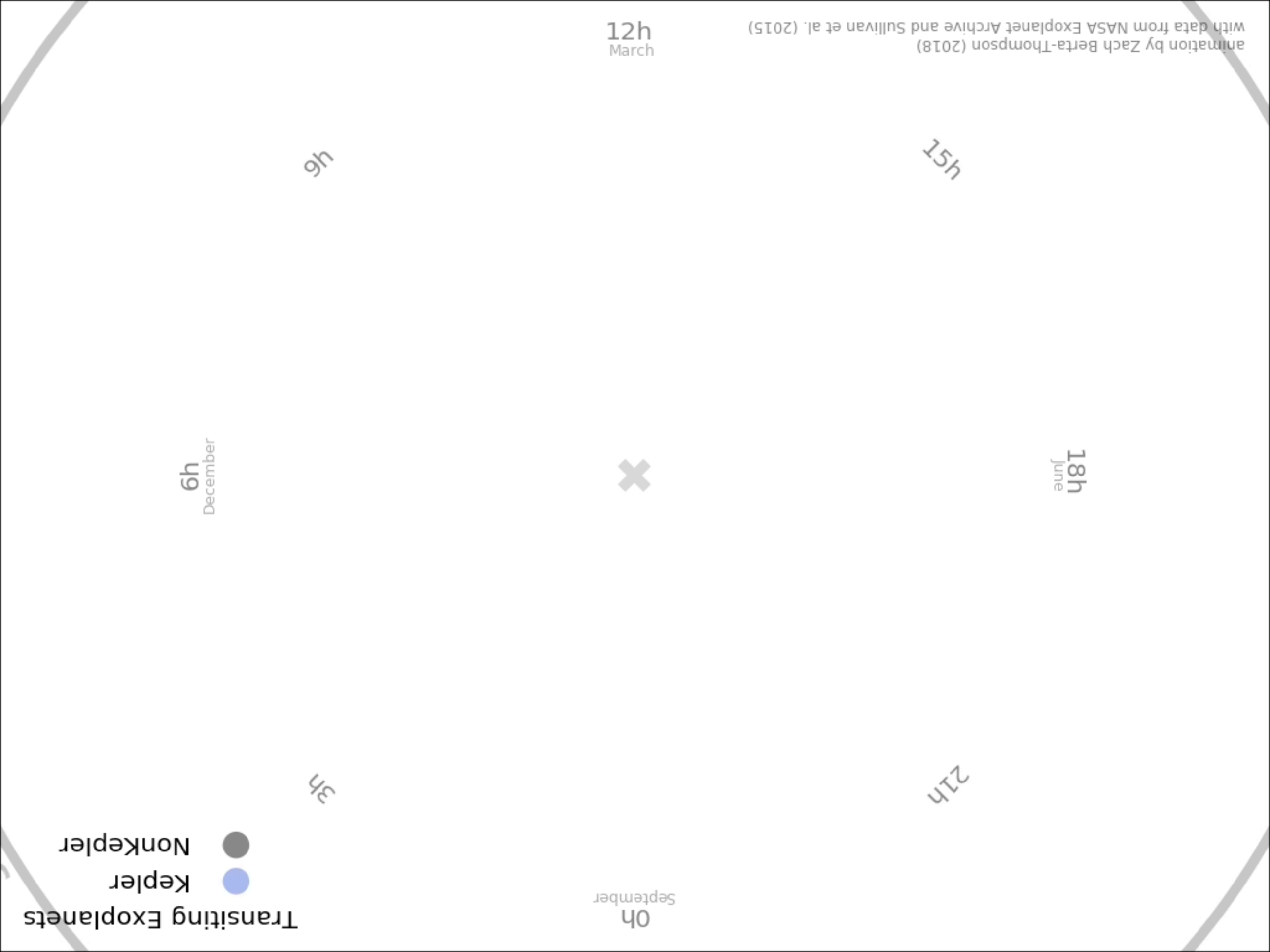
cartoon adapted from original by Tim Brown, circa 2000

Exoplanet characterization requires precise measurements. Therefore, telescopes need to collect **lots** of photons from these exoplanet systems.



For a transiting exoplanet, we can directly observe **planet size + orbit + mass + atmosphere.**

cartoon adapted from original by Tim Brown, circa 2000



animation by Zach Berta-Thompson (2018)
with data from NASA Exoplanet Archive and Sullivan et al. (2015)

Exoplanet observations are limited by the number of photons we can detect from a system.

If we need a **6.5m** telescope to observe the atmosphere of an exoplanet at **30pc**....

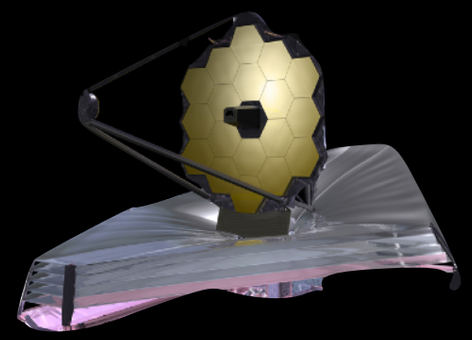


image:
NASA

Exoplanet observations are limited by the number of photons we can detect from a system.

If we need a **6.5m** telescope to observe the atmosphere of an exoplanet at **30pc**....

…then we would need a **65m** telescope to observe a similar exoplanet at **300pc**.

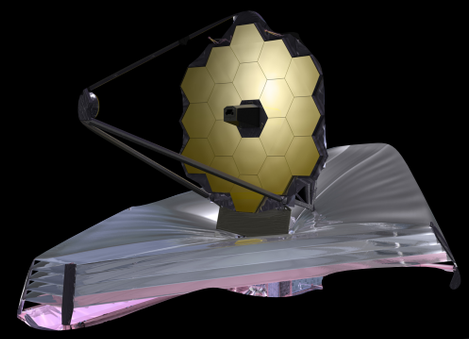
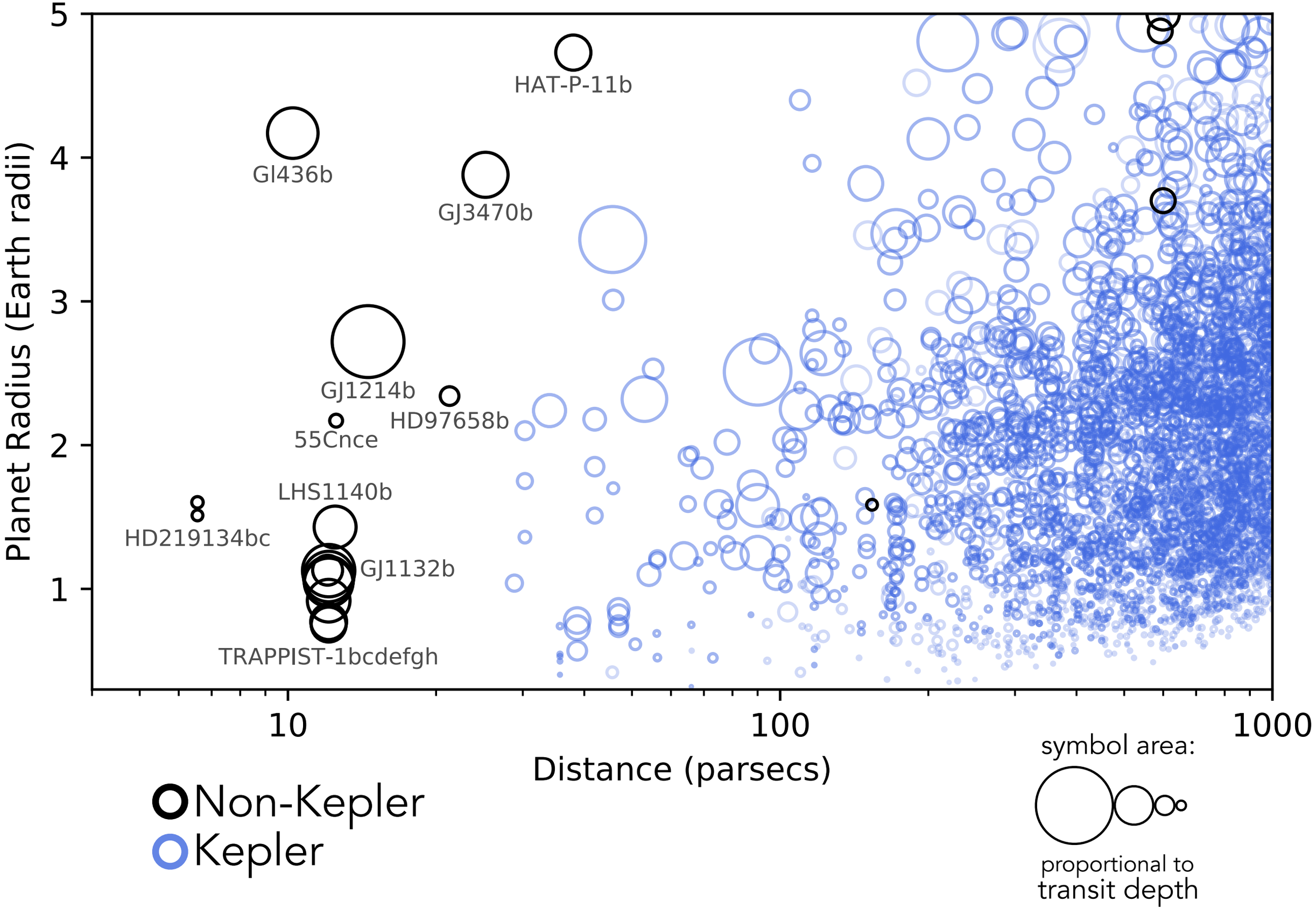


image:
NASA


Planet Radius (Earth radii)
5
4
3
2
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HAT-P-11b
Gl436b
GJ3470b
GJ1214b
HD97658b
55Cnce
LHS1140b
HD219134bc
GJ1132b
TRAPPIST-1bcdefgh
10
100
1000
Distance (parsecs)
Non-Kepler
Kepler
symbol area:
proportional to
transit depth

What is TESS?

Exoplanet Missions

WFIRST

JWST[2]

TESS

PLATO

Kepler

CHEOPS

New Worlds Telescope

Spitzer

Gaia

Hubble[1]

Habitable Exoplanet Imager

LUVOIR

CoRoT[3]

NASA Missions

ESA/European Missions

W. M. Keck Observatory

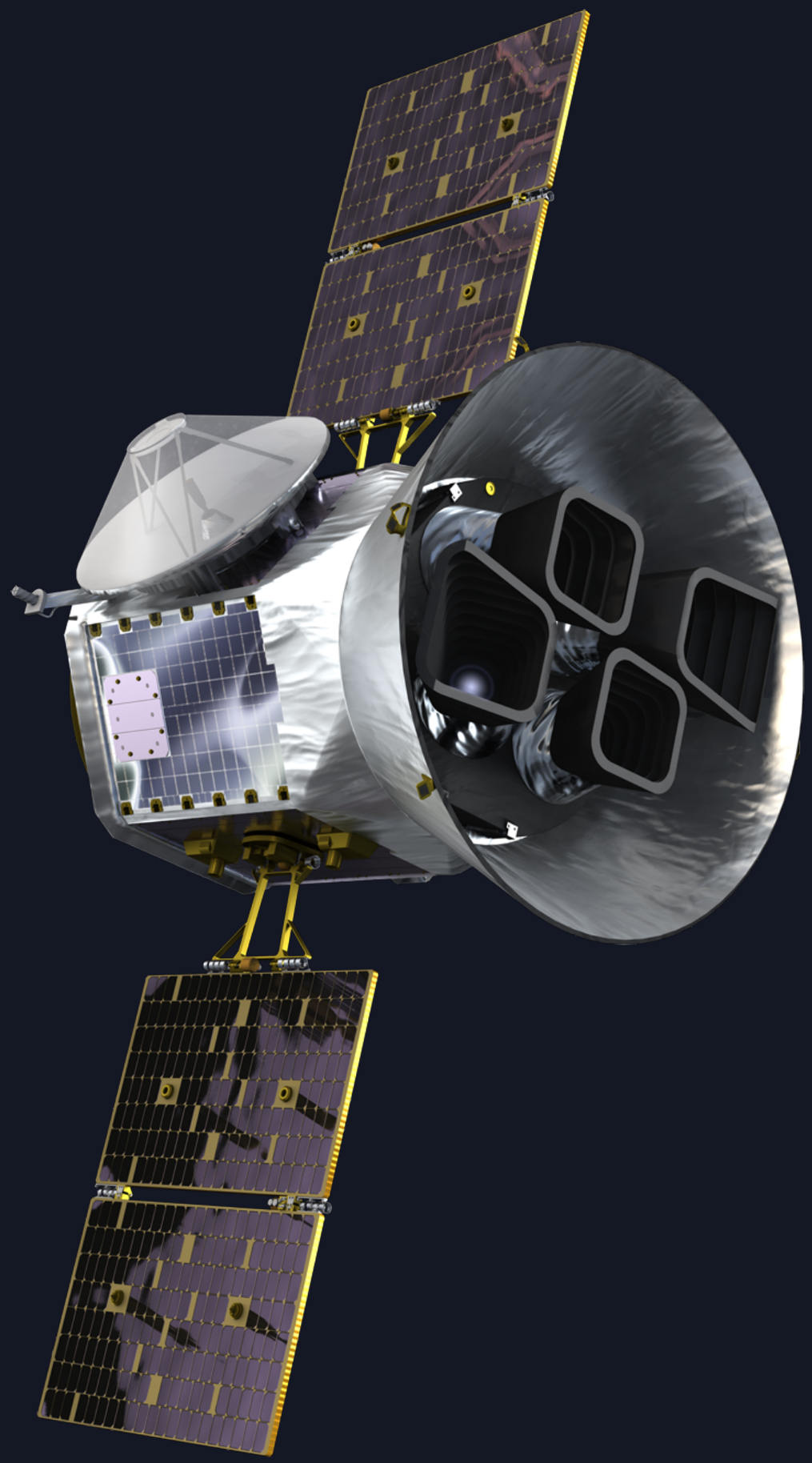
Large Binocular Telescope Interferometer

NN-EXPLORE

[1] NASA/ESA Partnership
[2] NASA/ESA/CSA Partnership
[3] CNES/ESA

Ground Telescopes with NASA participation

Image: NASA



TESS

NASA Explorer Mission

launched at
6:51pm ET, 18 April 2018
to find hundreds of nearby small exoplanets amenable to detailed characterization

Ricker et al., JATIS, (2014)

world now look into space,
nd to the planets beyond,
ave vowed that we shall not see
a hostile flag of conquest,
anner of freedom and peace.
- John F. Kennedy

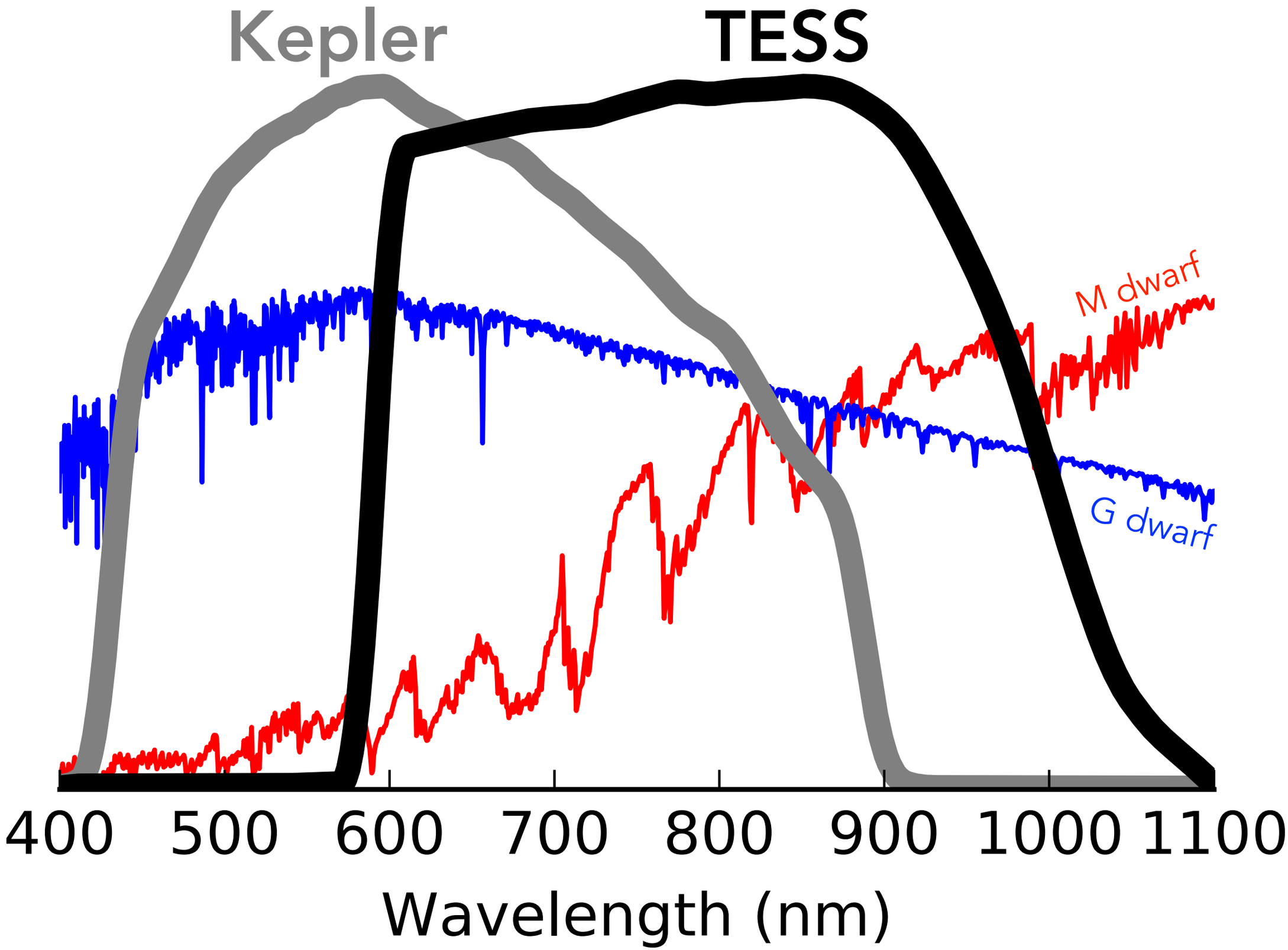

36 HOLES
MINI GOLF
Golf N Gator
6355

TESS

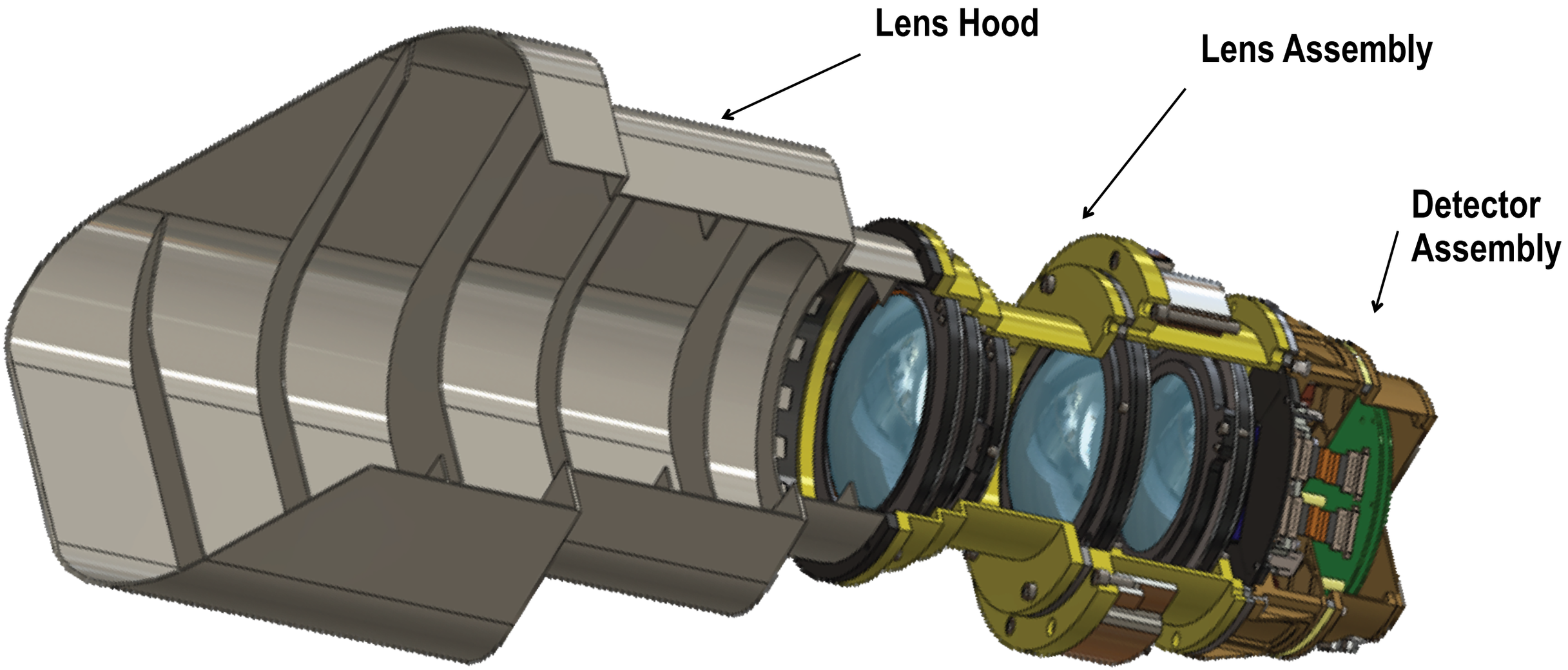
Explorer Mission

launched at
6:51pm ET, April 16
to find hundreds of nearby small exoplanets amenable to detailed characterization

Ricker et al., *JATIS*, (2014)



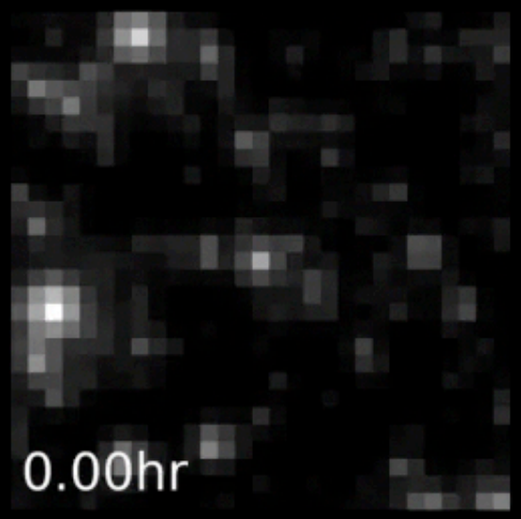
Ricker et al. (2014), Sullivan et al. (2015)

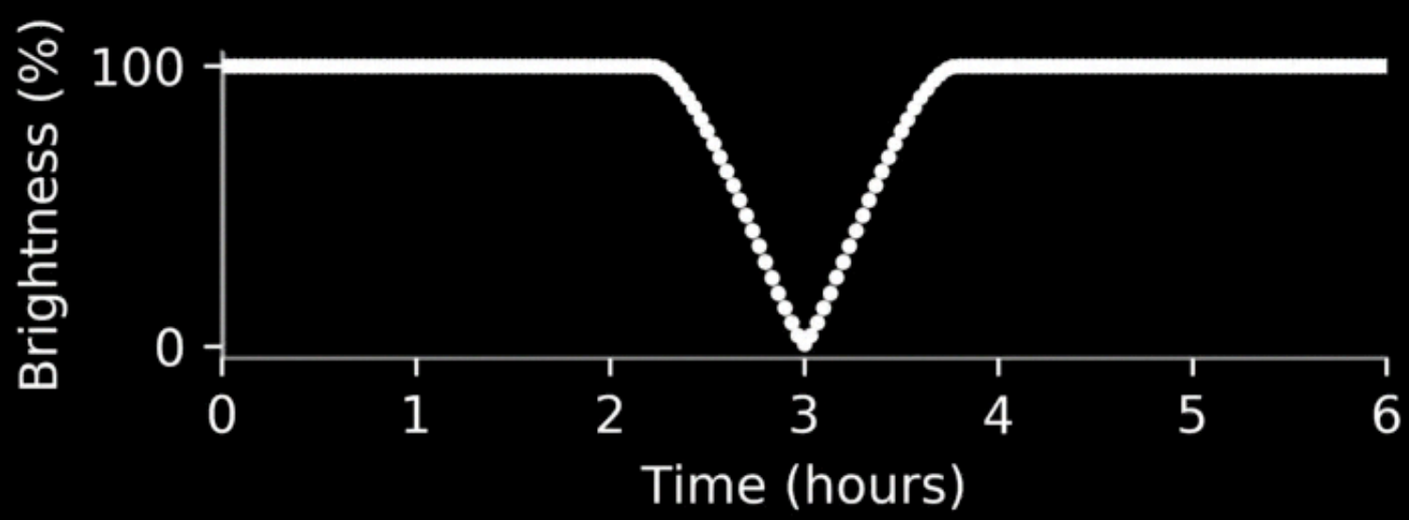


10.5 cm diameter, 24°x24° field of view

Ricker et al. (2014), Sullivan et al. (2015)

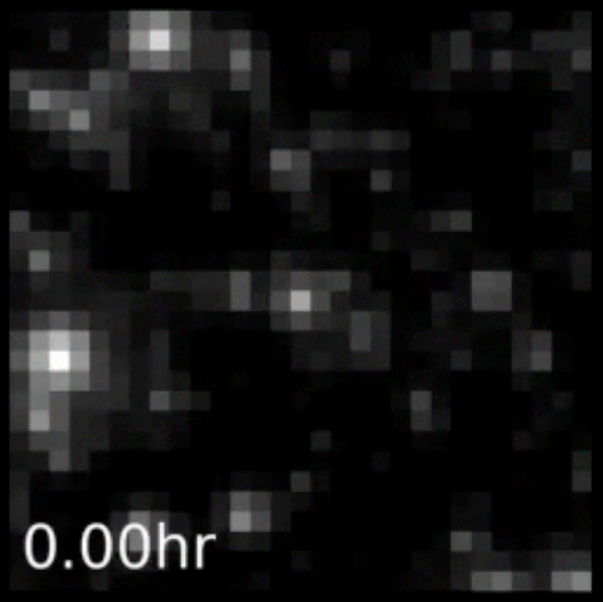
Our light curves come from time-series telescope images.

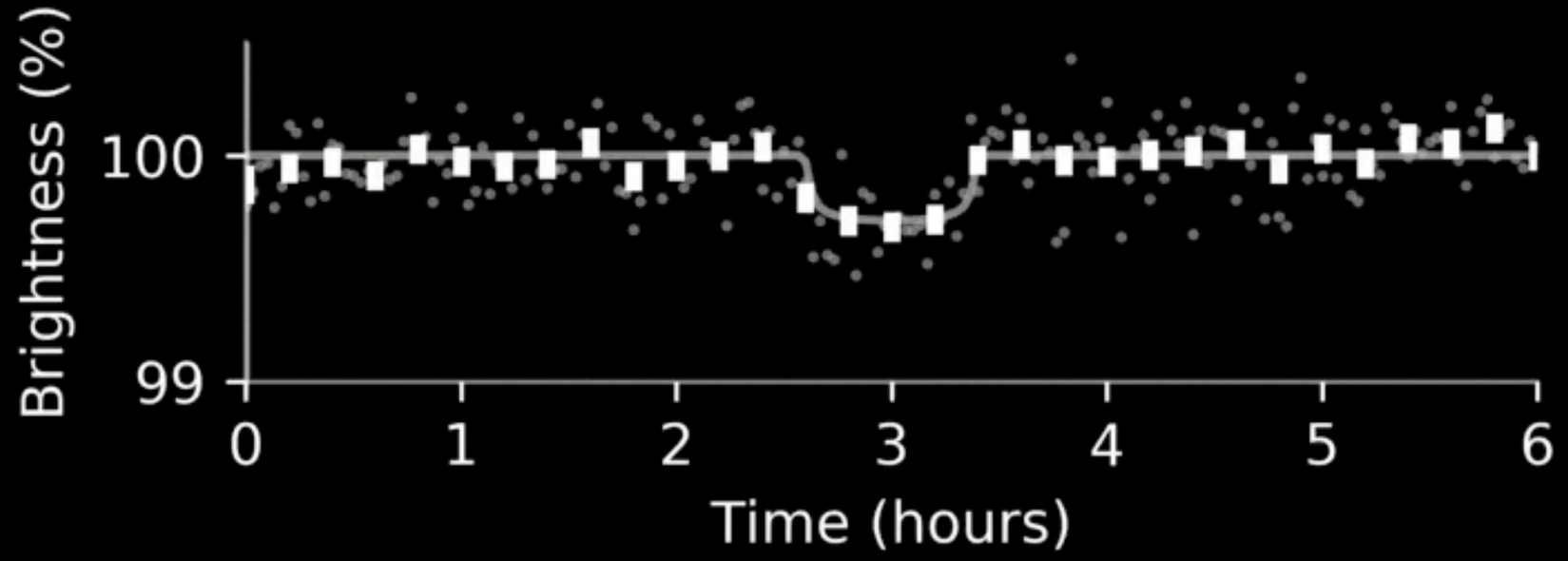




a single TESS transit of GJ1132b

$1.1R_{\oplus}$, $0.21R_{\odot}$, 12.1pc, I_C=10.7





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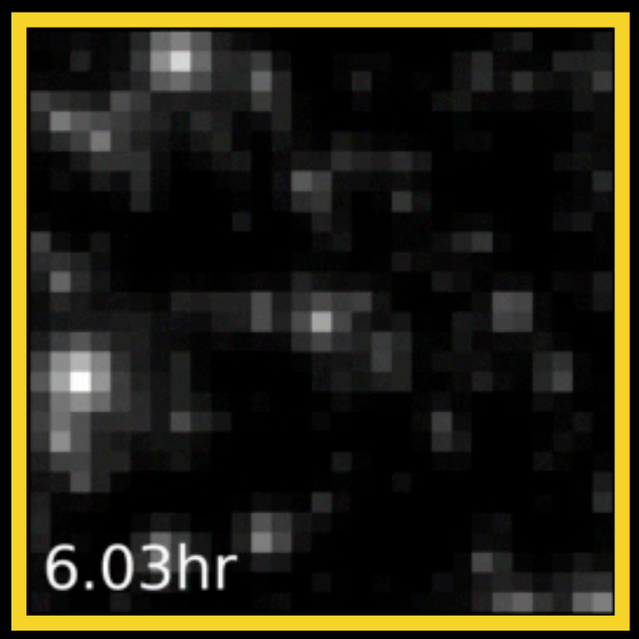
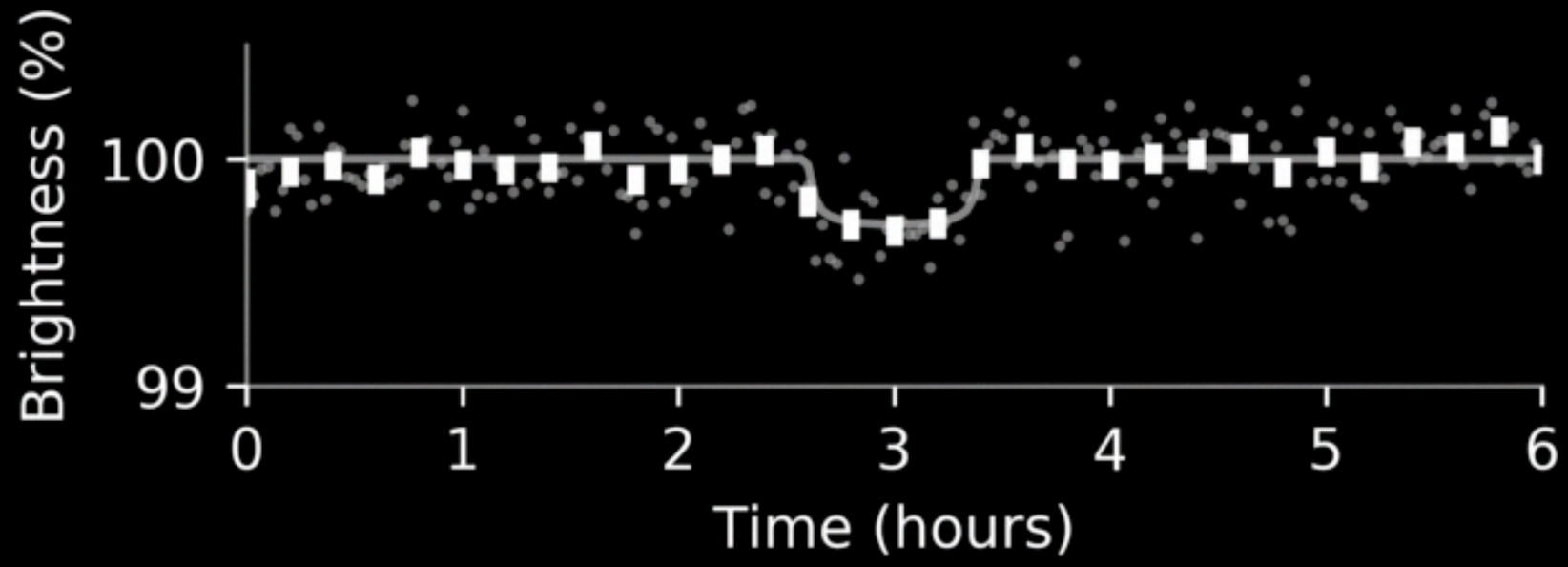
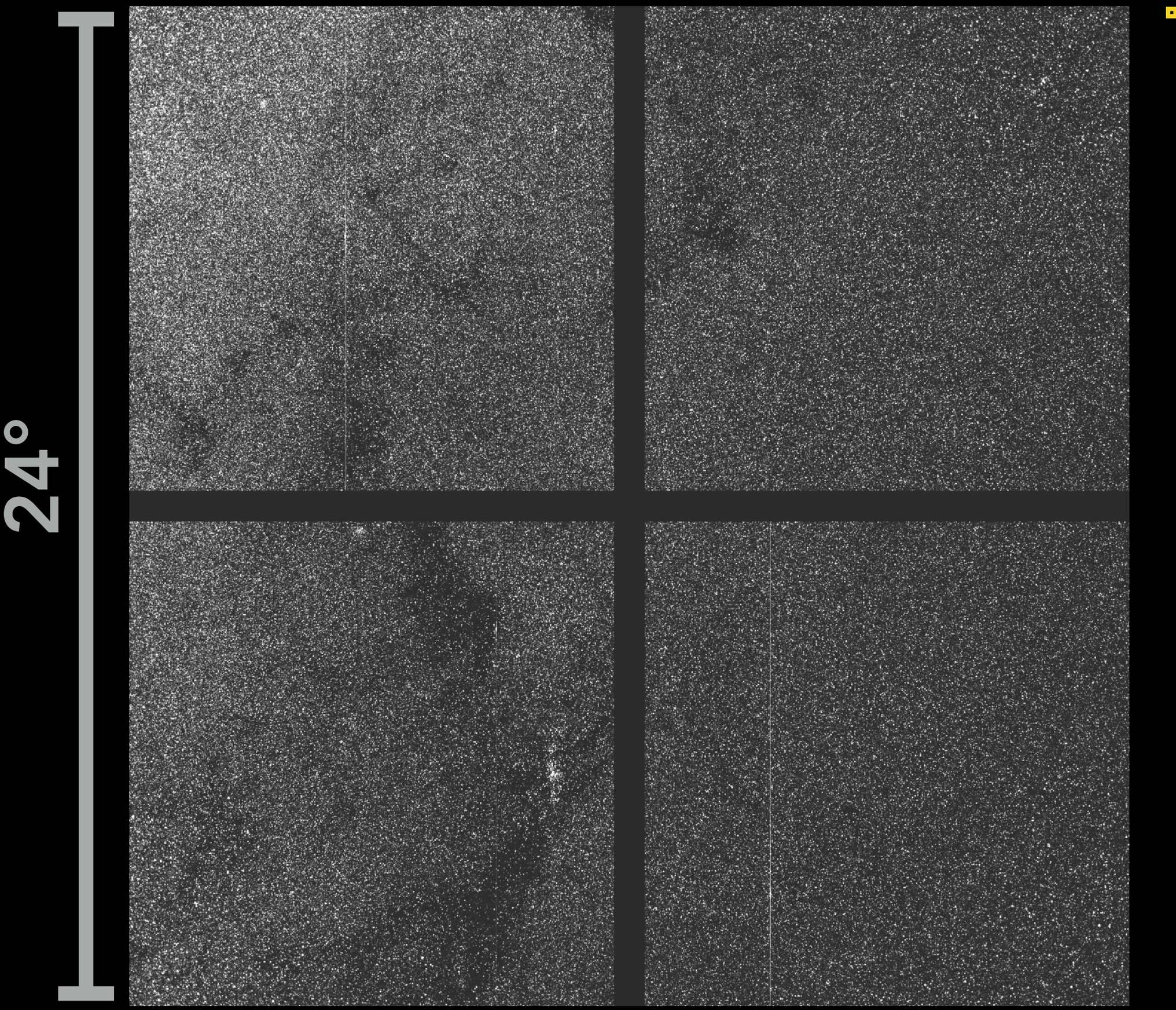
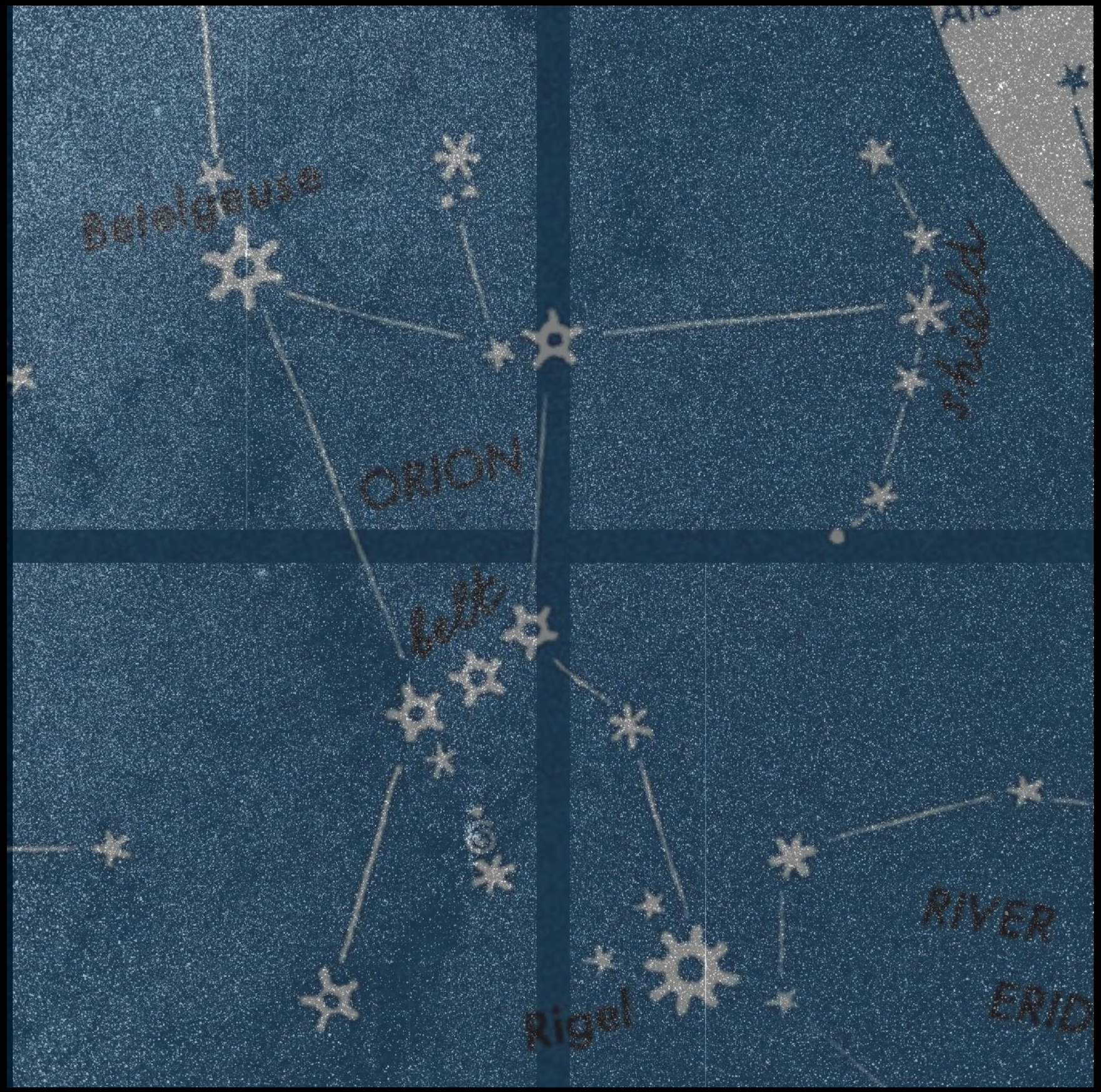




FOV from one TESS camera:



FOV from one TESS camera:



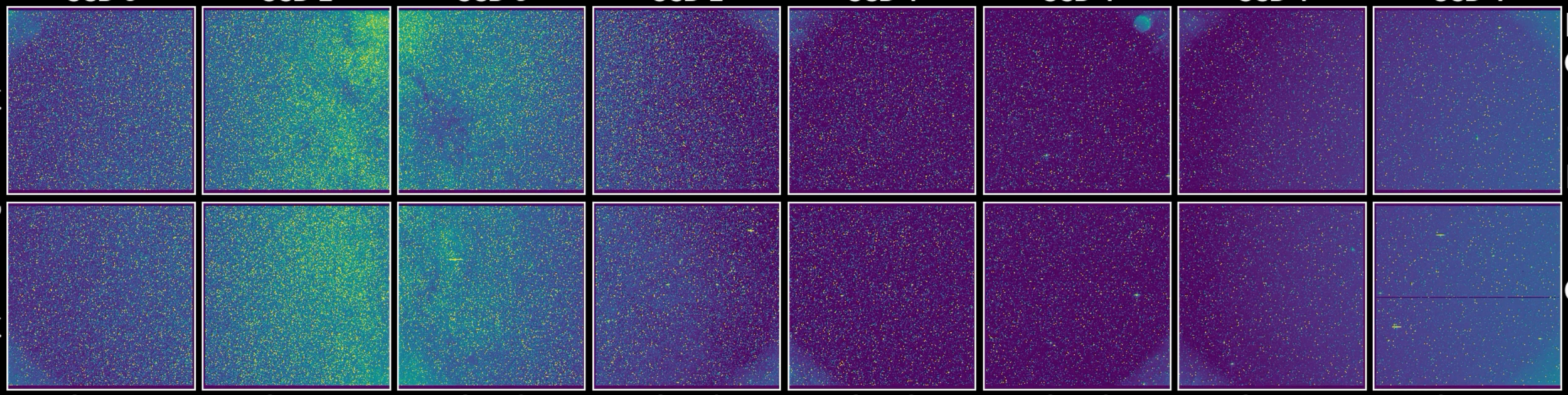
24°

constellations by H. A. Rey

TESS: The Movie
Sector 16
12 Sep 2019 03:44

Cam 1 CCD 3 | Cam 1 CCD 2 | Cam 2 CCD 3 | Cam 2 CCD 2 | Cam 3 CCD 1 | Cam 3 CCD 4 | Cam 4 CCD 1 | Cam 4 CCD 4

ECLIPTIC

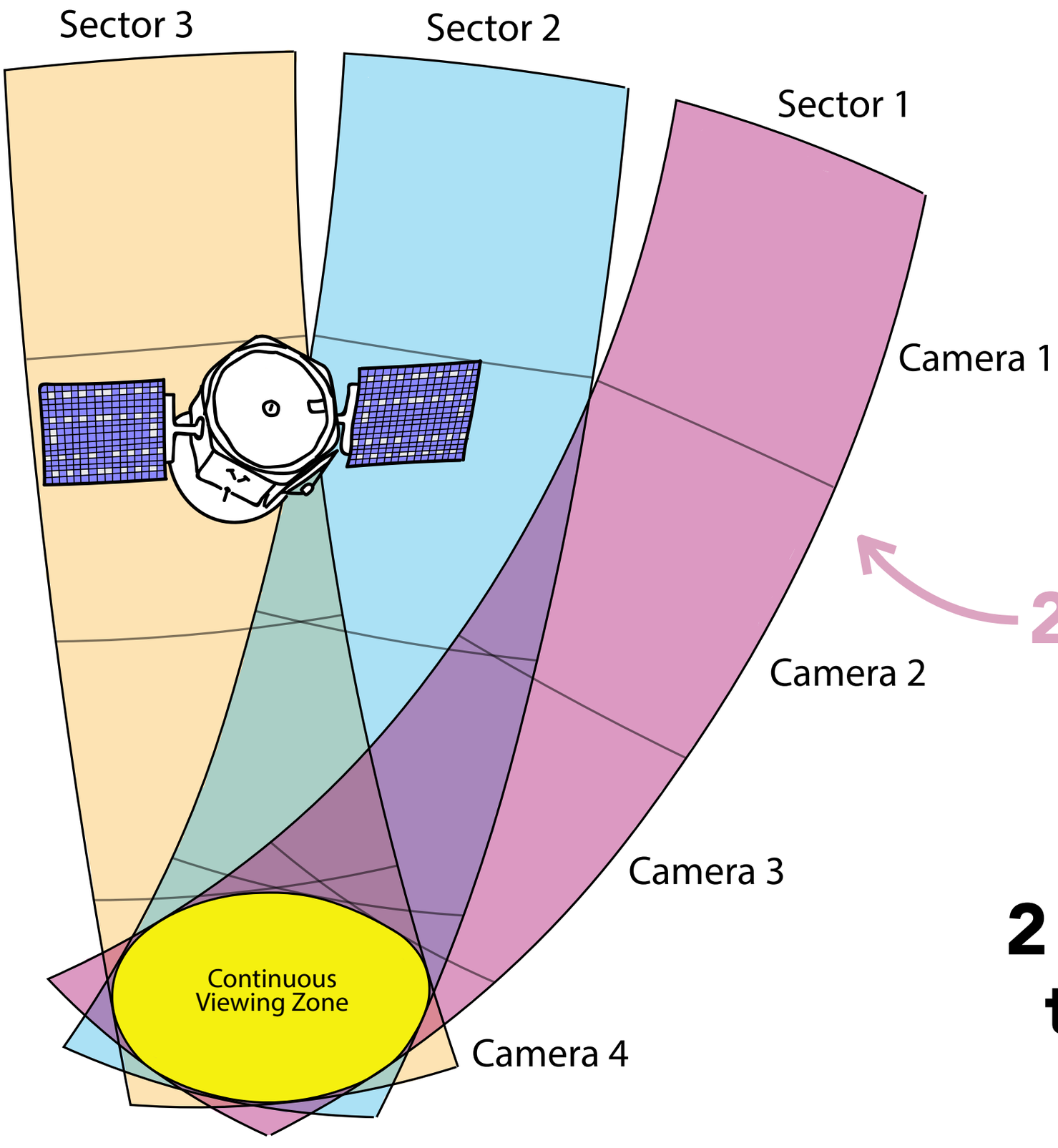


NORTH POLE

Cam 1 CCD 4 | Cam 1 CCD 1 | Cam 2 CCD 4 | Cam 2 CCD 1 | Cam 3 CCD 2 | Cam 3 CCD 3 | Cam 4 CCD 2 | Cam 4 CCD 3

By Ethan Kruse
@ethan_kruse

Cadence 24537

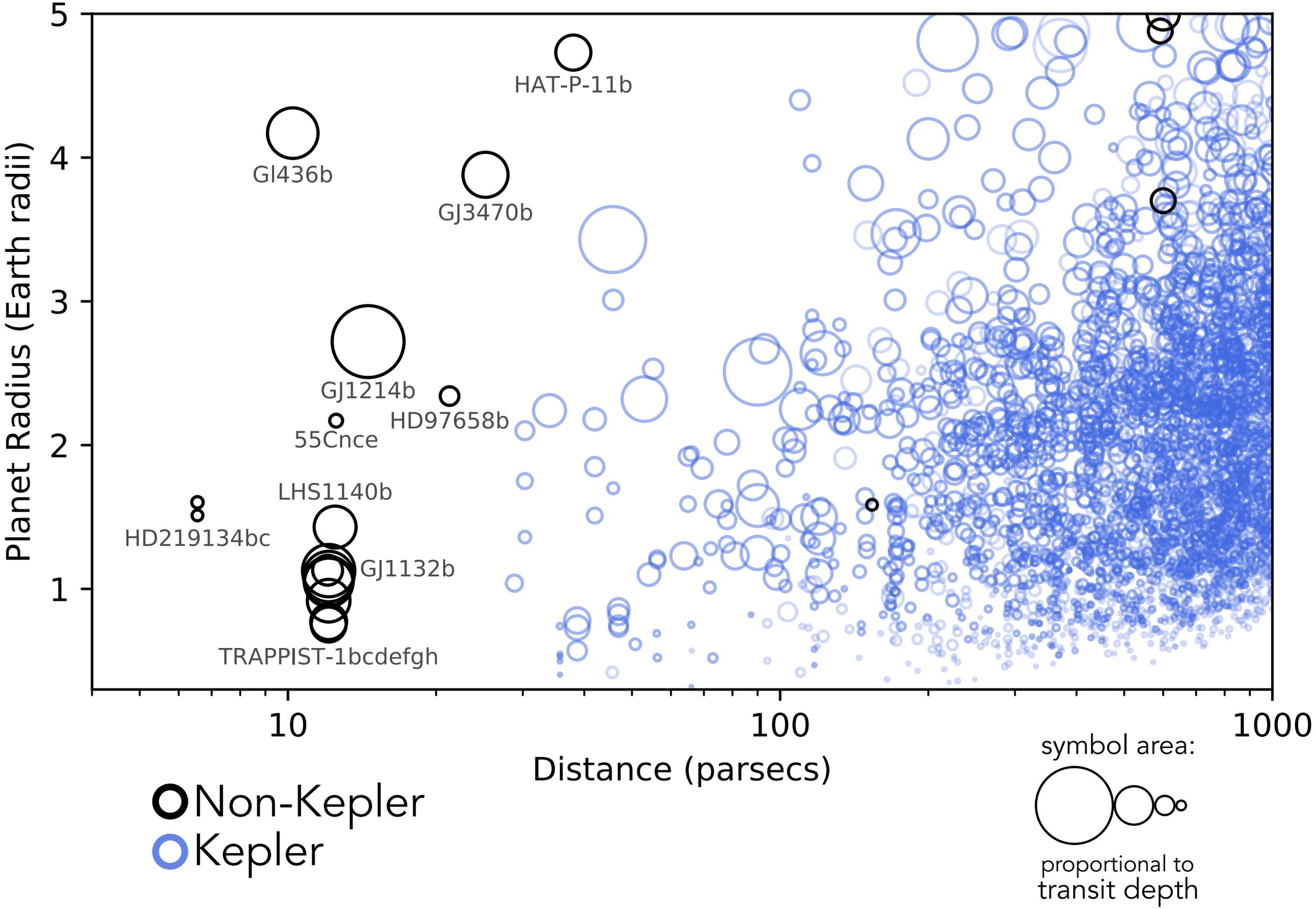


27 days/sector

2 years to cover the whole sky

(except ecliptic)

illustration from Barclay, Pepper, and Quintana (2018)


Planet Radius (Earth radii)
5
4
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2
1
HAT-P-11b
Gl436b
GJ3470b
GJ1214b
HD97658b
55Cnce
LHS1140b
HD219134bc
GJ1132b
TRAPPIST-1bcdefgh
10
100
1000
Distance (parsecs)
Non-Kepler
Kepler
symbol area:
proportional to
transit depth

TESS will find closest, brightest, easiest-to-observe transiting exoplanets!

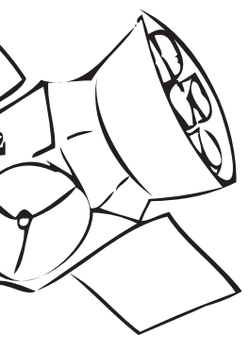
Planet Radius (Earth radii)

5
4
3
2
1

HAT-P-11b
Gl436b
GJ3470b
GJ1214b
HD97658b
55Cnce
LHS1140b
HD219134bc
GJ1132b
TRAPPIST-1bcdefgh

10
100
1000

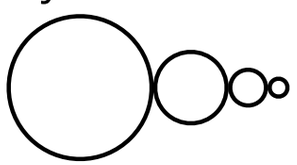
Distance (parsecs)



Non-Kepler
Kepler
TESS

TESS simulated yield from Sullivan et al. (2015), see also Ballard (2018), Bouma et al. (2017↓), Barclay et al. (2018↓)

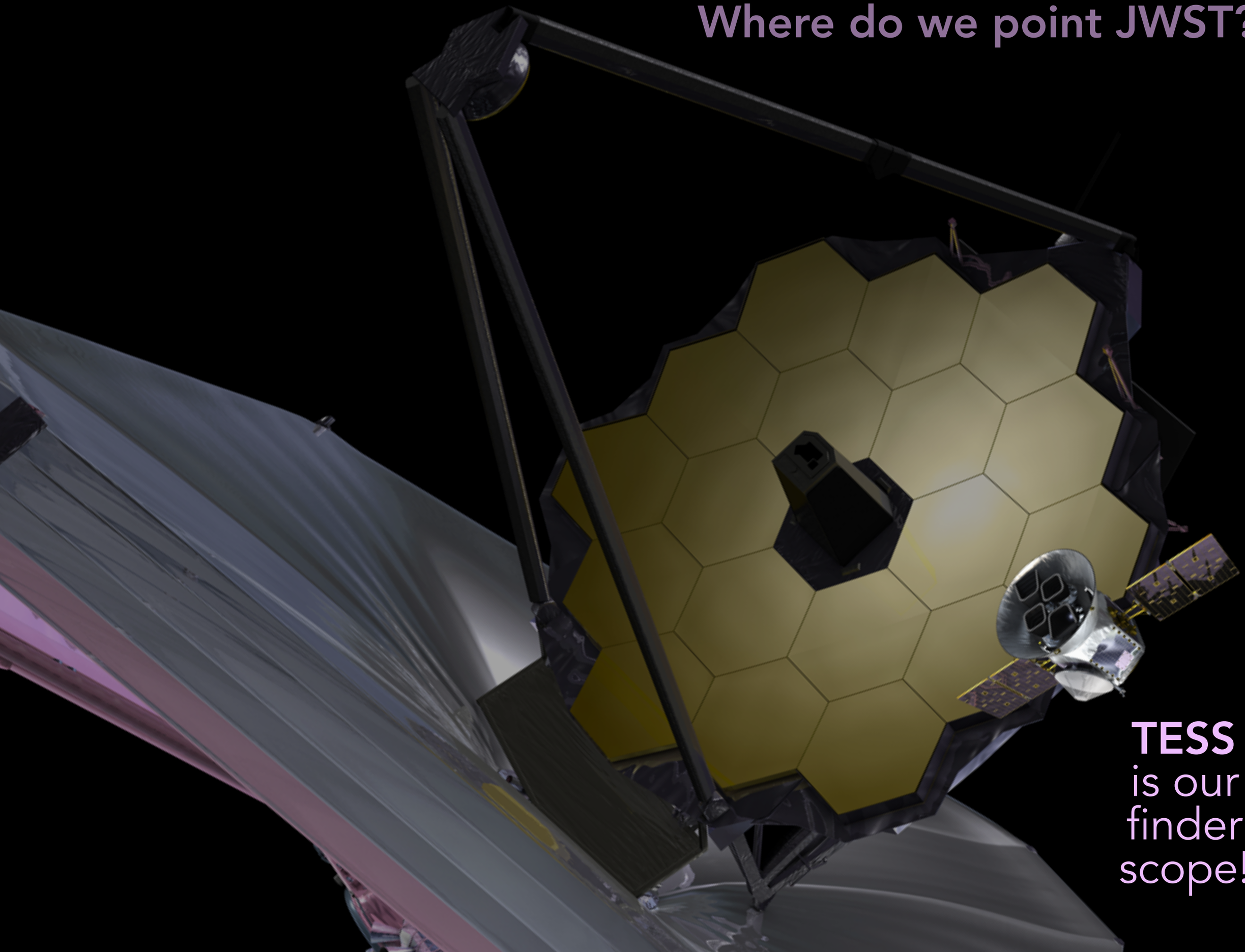
symbol area:



proportional to transit depth

Where do we point JWST?

Where do we point JWST?



TESS is our finder scope!

How was TESS built?

(looking back at the Concept Study Report)

Short History of TESS

2006 = MIT + Smithsonian Astrophysical Observatory propose TESS as a Mission of Opportunity to NASA. It failed.

2007 = TESS reformulated as a standalone small mission, with seed funding from private donors, Kavli Foundation, Google, MIT, SAO, NASA Ames. Not enough funds raised.

2008 = TESS proposed as NASA Small Explorer Mission (<$100M). Funded for Phase A, but not selected for Phase B.

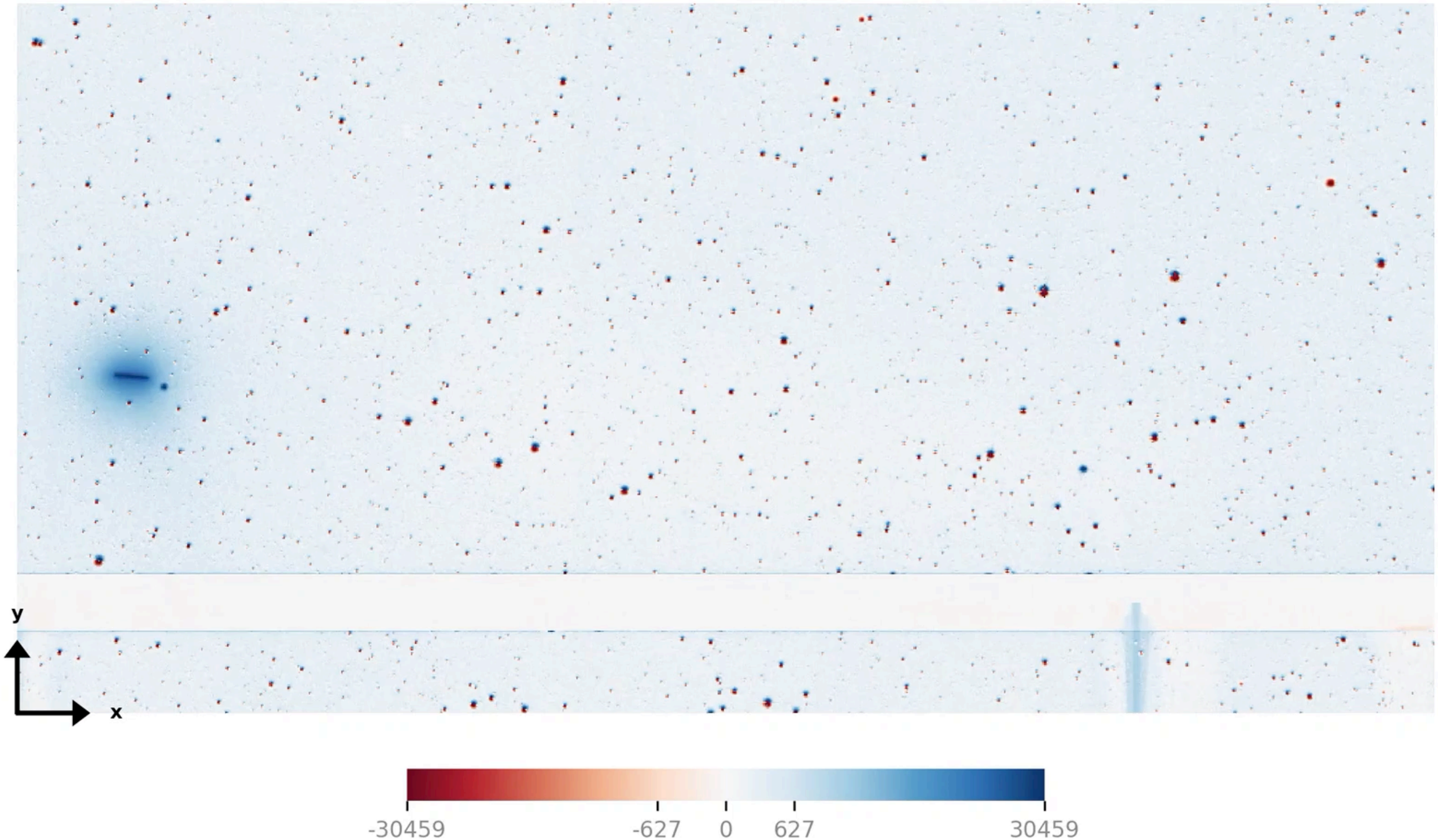
2011 = TESS submitted as NASA Explorer (<$200M), with better High Earth Orbit. Selected for a Phase A study.

2013 = TESS Explorer Mission proceeds to phase B and beyond.

TESS was built by people (like you!)

Joel Villasenor, Carolyn Thayer, Tim Sauerwein

Early **TESS** data are beautiful!



Kepler has passed the exoplanet torch to **TESS**.