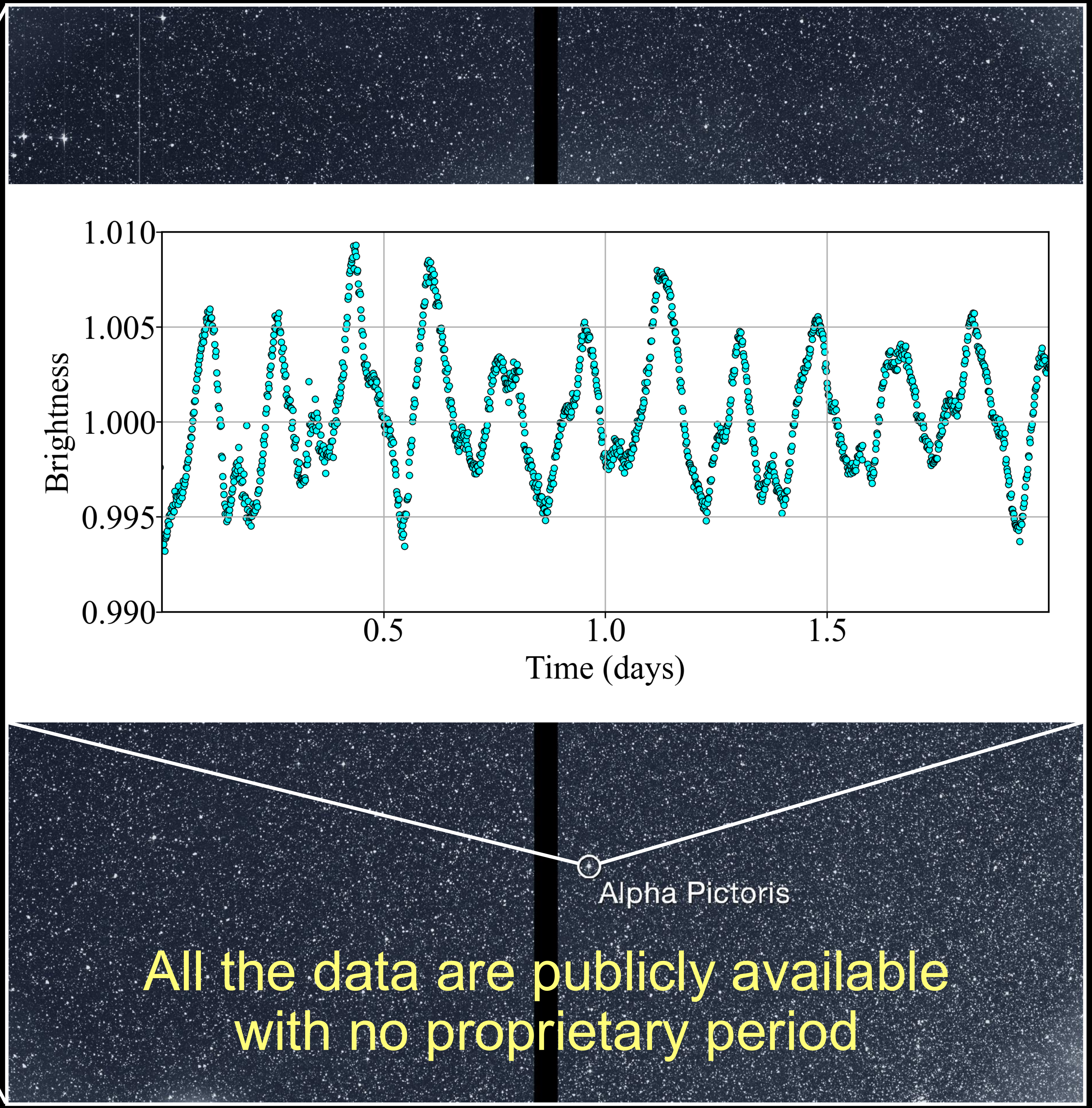
TESS Mission Update

Allison Youngblood
TESS Project Scientist
NASA Goddard Space Flight Center

Special thanks to the entire TESS mission team, especially:
George Ricker (MIT), Roland Vanderspek (MIT), Josh Winn (Princeton), Christina Hedges (UMBC), Susan Neff (GSFC), Susan Mullally (STScI), Jon Jenkins (ARC), Dave Latham (SAO), David Ciardi (Caltech), and the TESS Users Committee

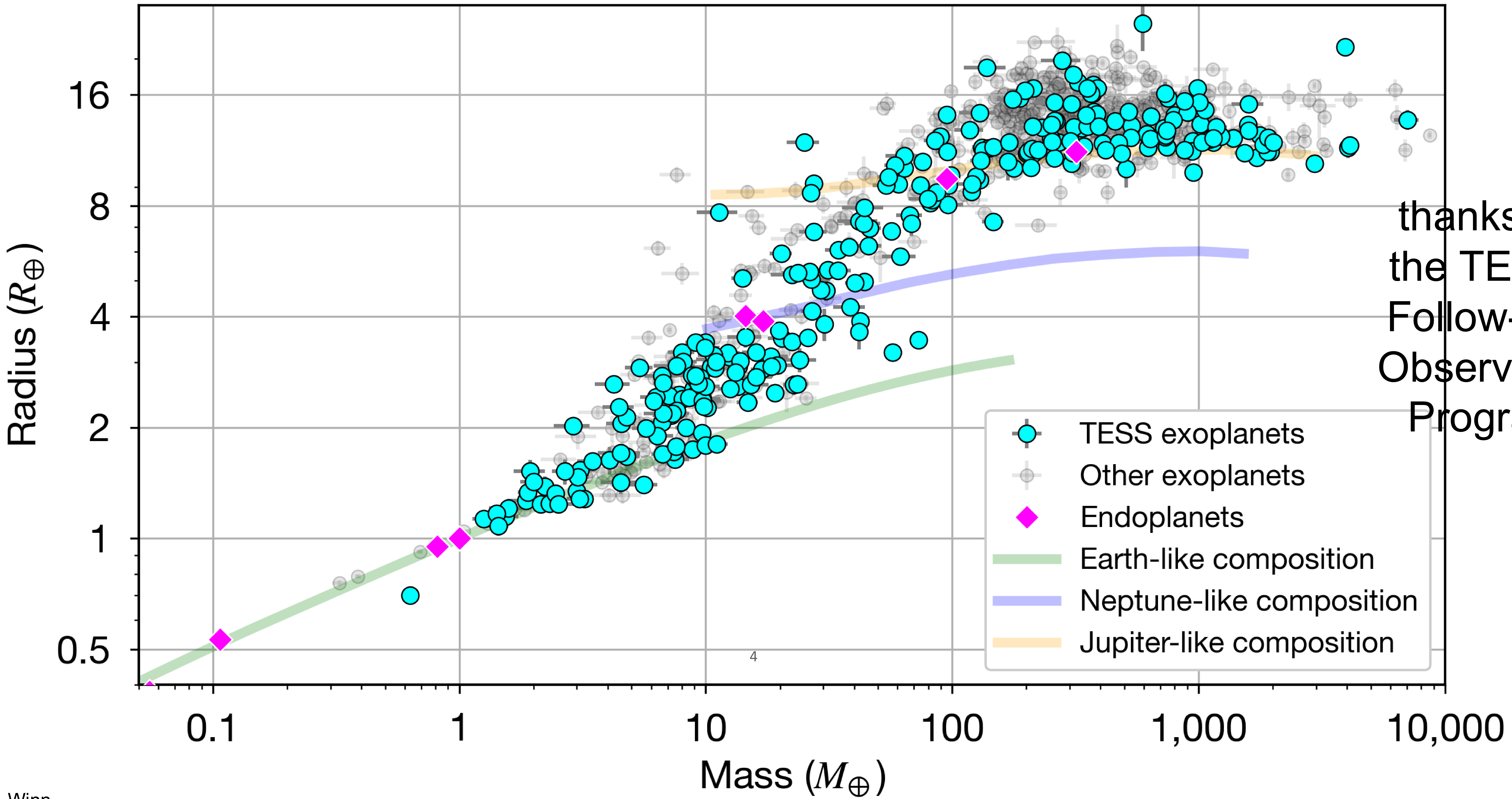


4 x 10.5 cm telescopes
24° x 96° field of view
1' angular resolution
600 – 1050 nm bandpass
200 s cadence (FFIs)
20 s and 120 s cadence (postage stamps)
27 day sectors

Figure: E. Kruse

Confirmed & Candidate Transiting Planets of Any Size in 2024

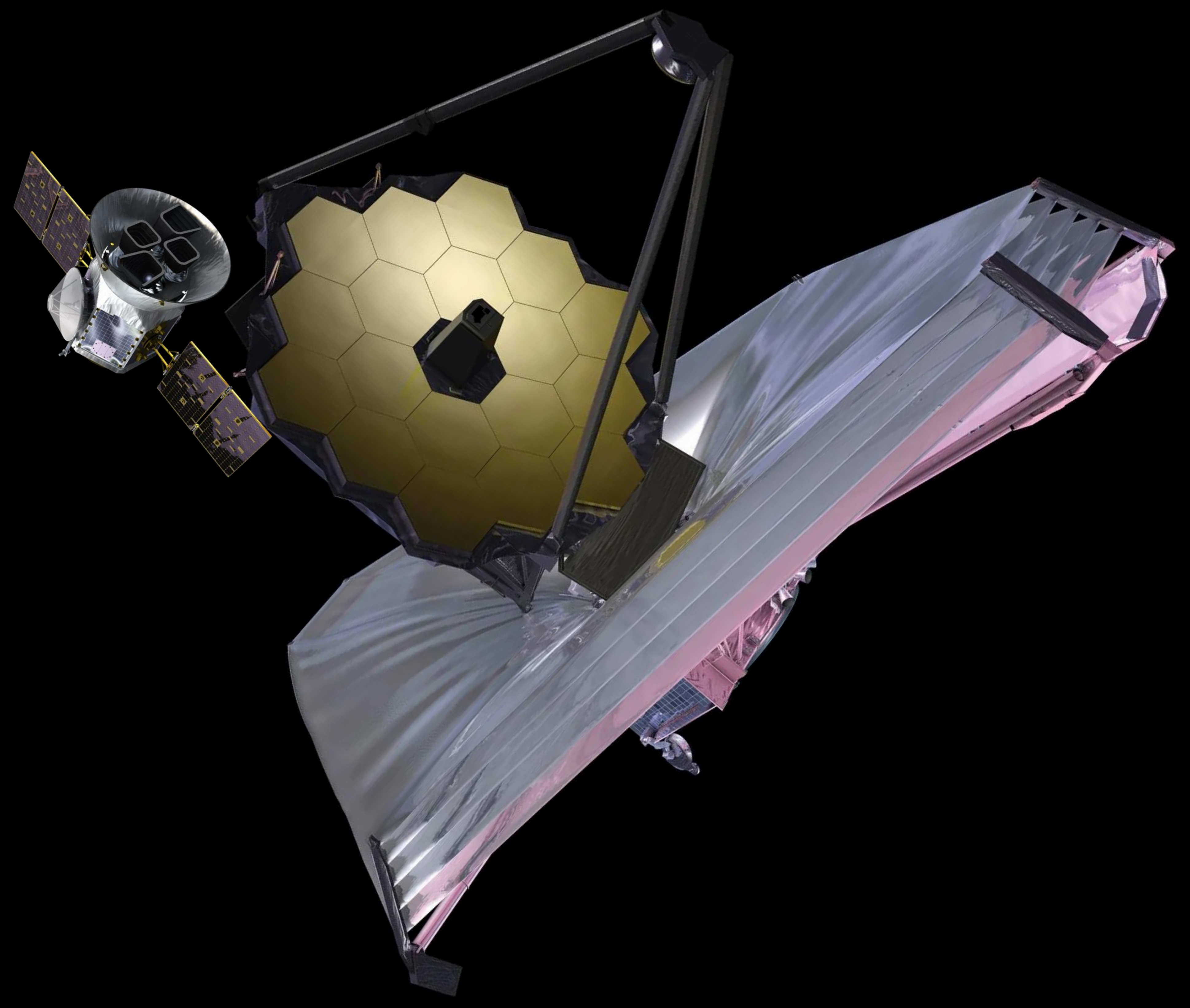
TESS finds planets with measurable masses



thanks to the TESS Follow-up Observing Program

Figure: J. Winn

TESS locates prime targets for HST and JWST



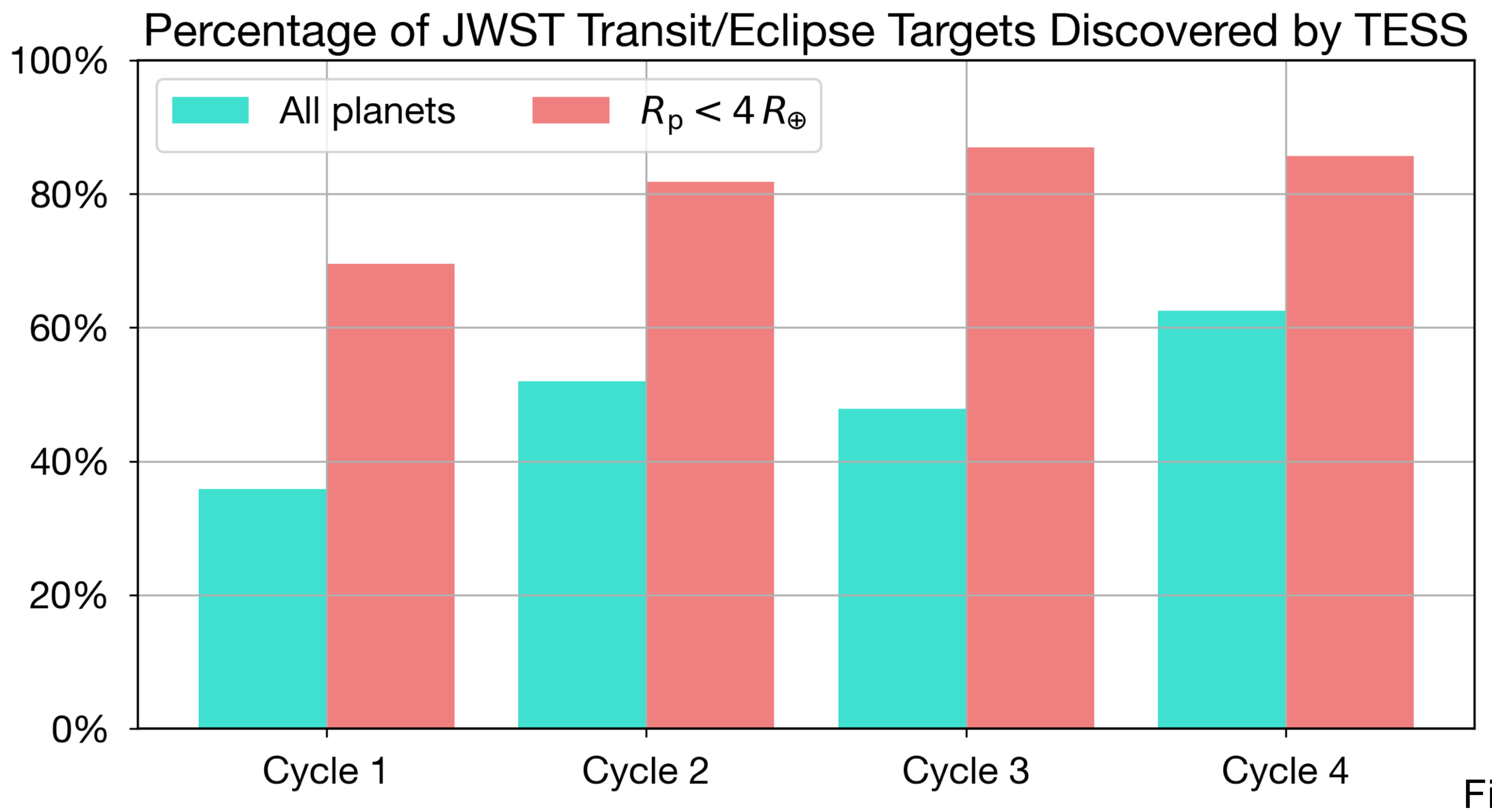


Figure: J. Winn

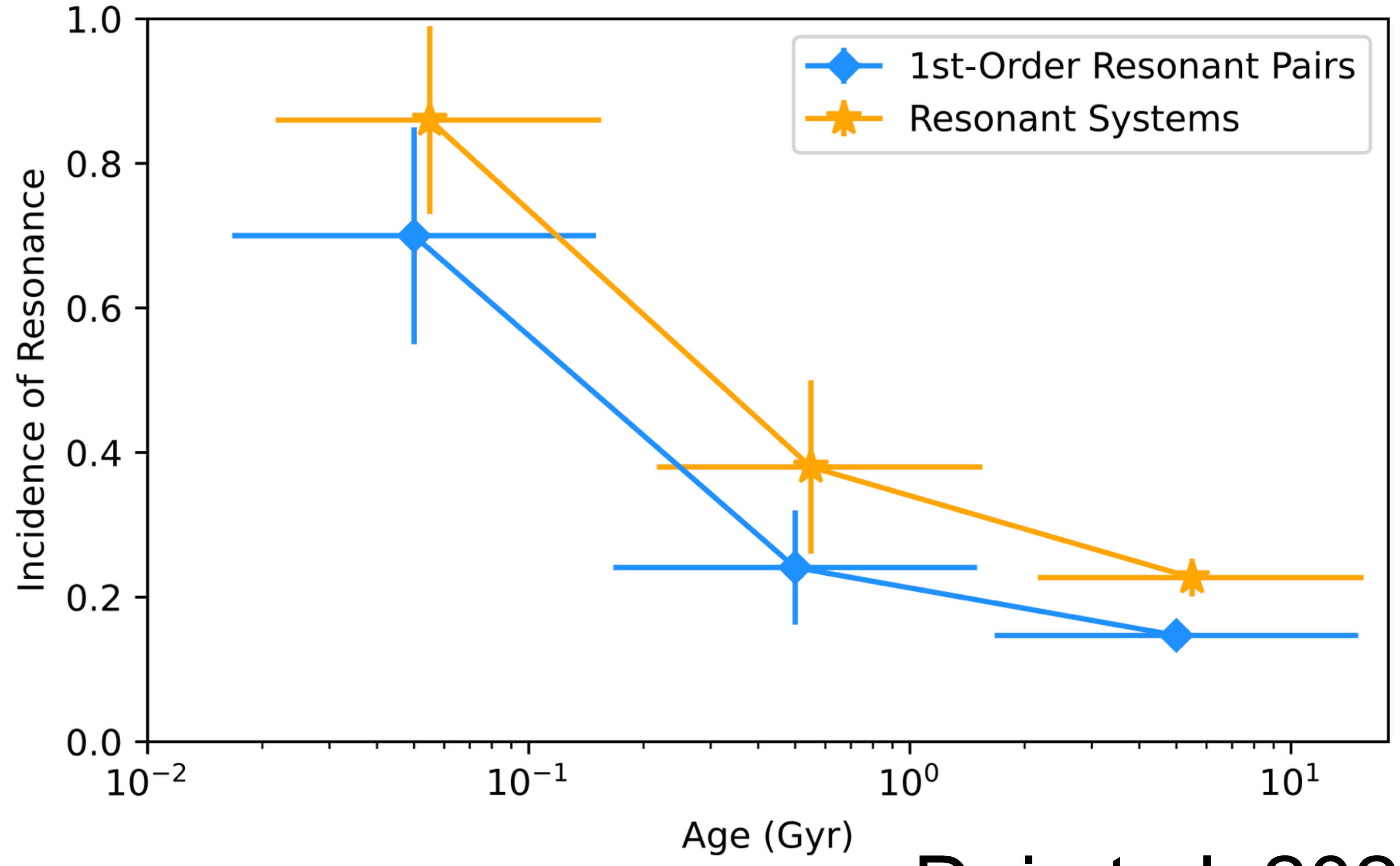
Plus

Rocky Worlds DDT
(500 JWST hr +
250 HST orbits

Survey of Transiting Exoplanets in Lyman-alpha

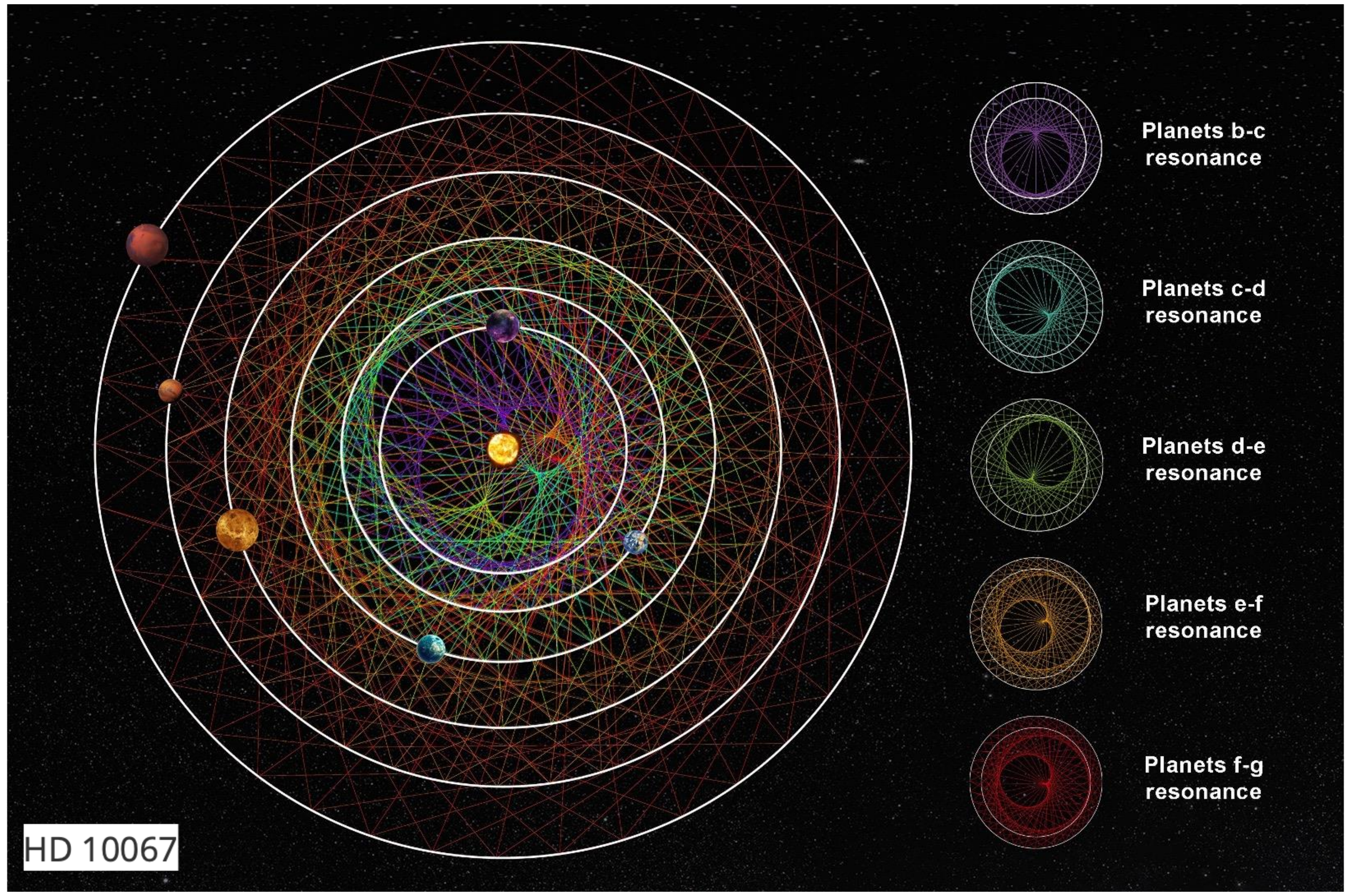
(625 HST orbits)

TESS powers surveys

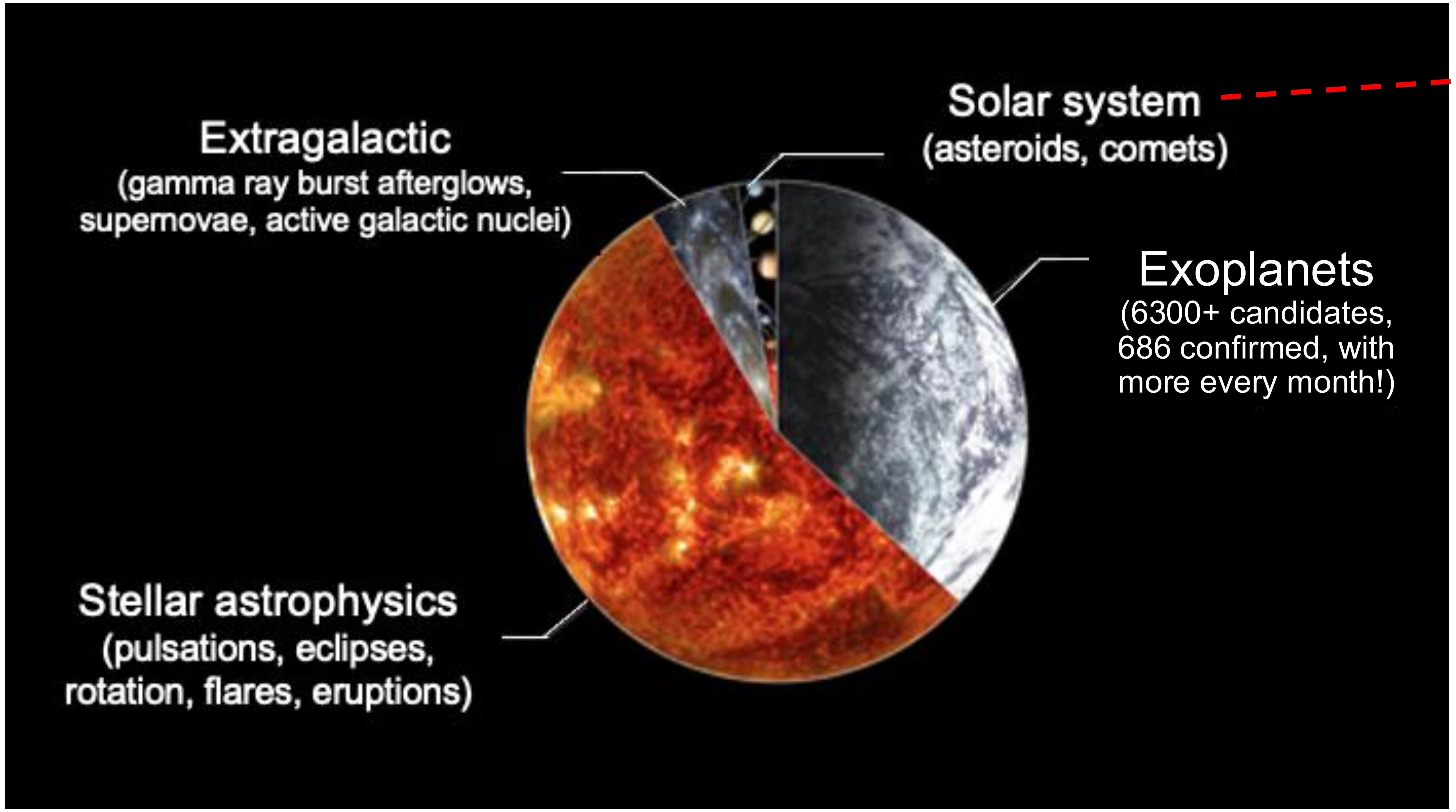


Dai et al. 2024

- Young mini-Neptunes are common (Vach+ 2024)
- Small planets are rare around low-metallicity stars (Boley+ 2024)
- Hot Jupiters are most common around Sun-like stars (Yee+ 2023; Schulte+ 2024; Beleznay+ 2022; Kanodia+ 2024)
- Hot Jupiters occasionally have close companions (Hord+ 2022; Maciejewskie+ 2023; Korth+ 2024; Hord+ 2021)
- Resonant chains of planets are common at early ages (Dai+ 2023, 2024; Luque+ 2023)



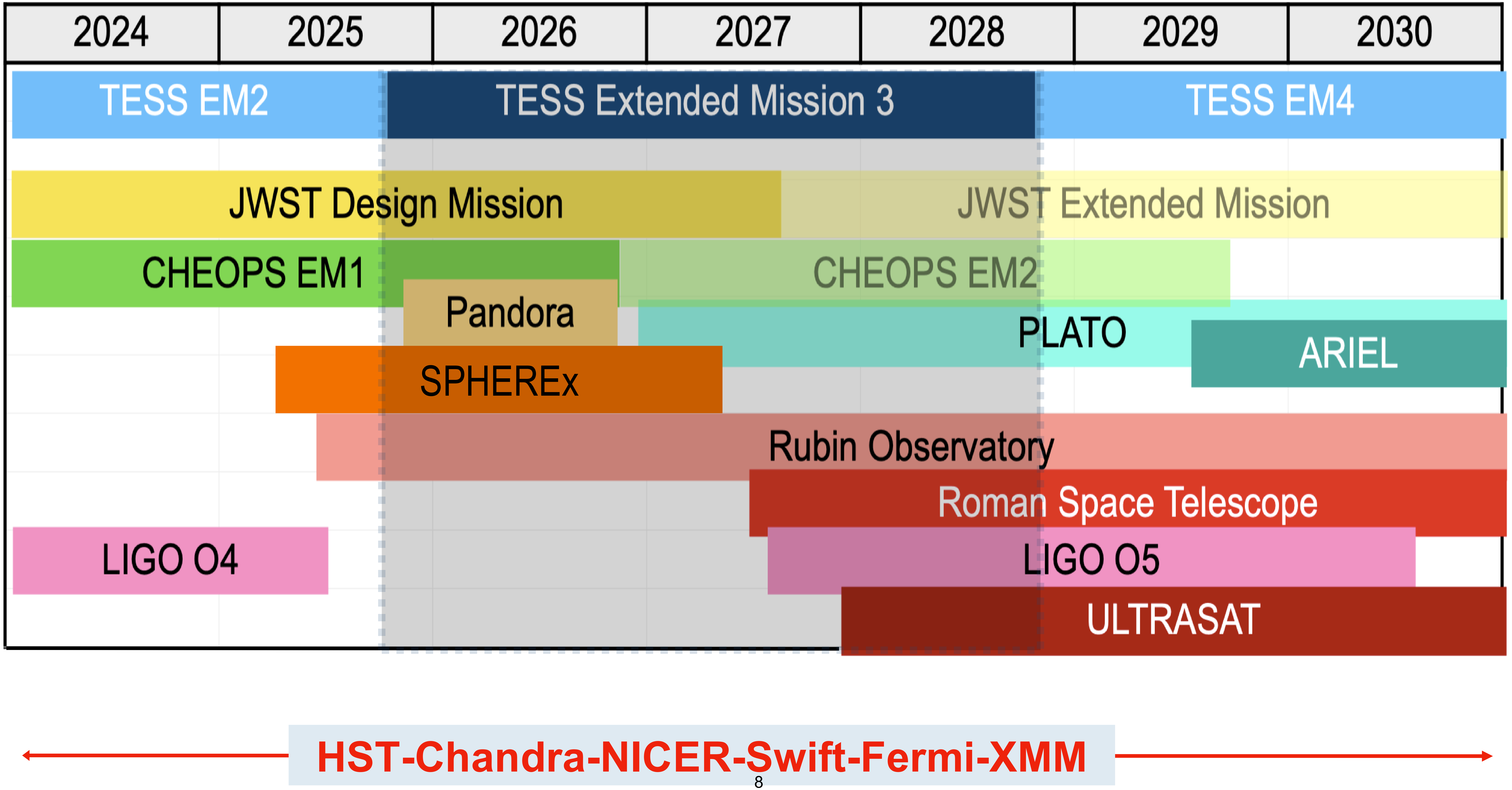
And TESS does so much more than just exoplanets!



Pre-discovery observations of comet 3I/ATLAS

(Feinstein et al. 2025; Martínez-Palomera et al. 2025)

What's next for TESS?



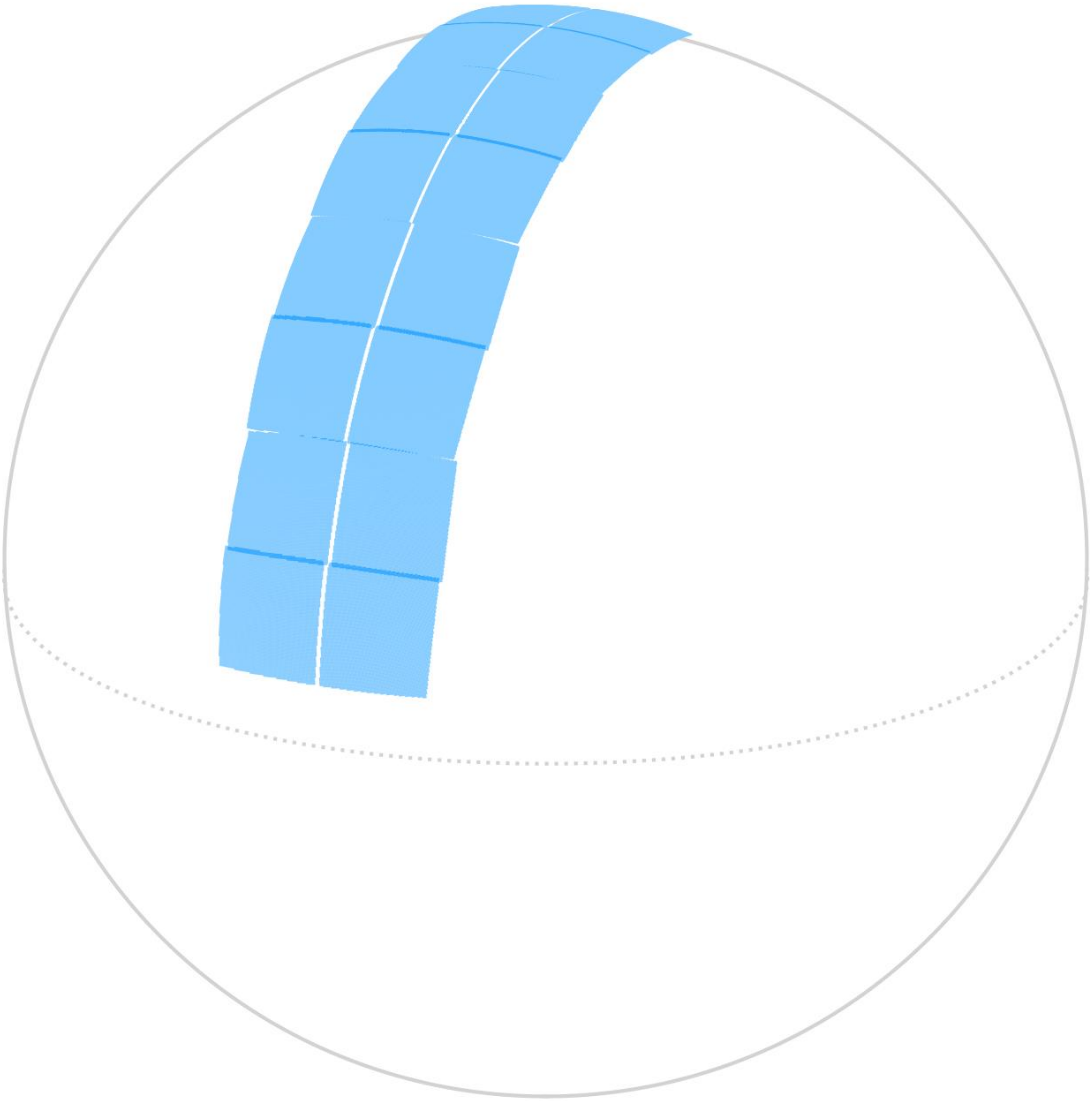
The TESS instrument and spacecraft are healthy

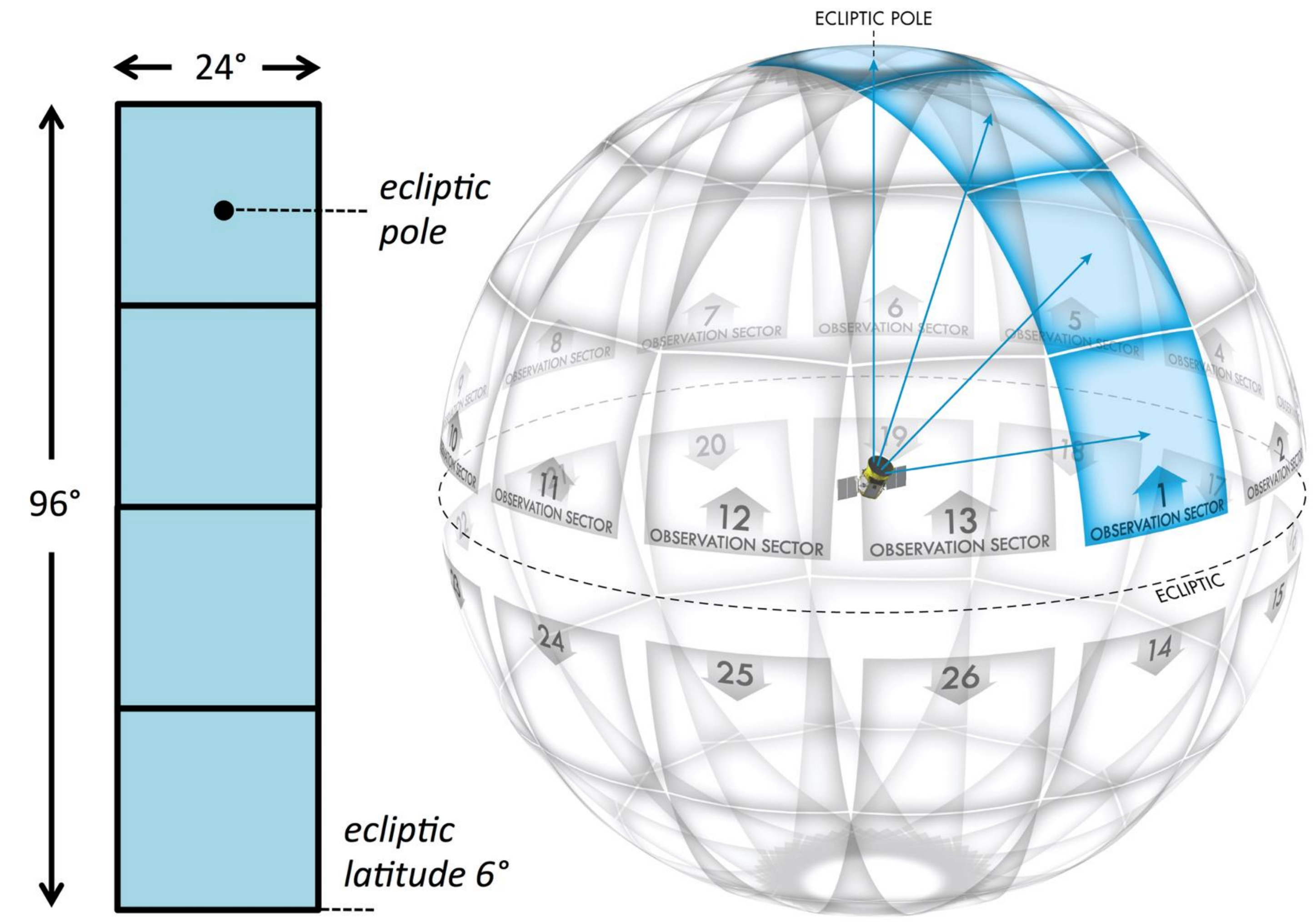
- TESS is in a high-altitude, stable orbit with plenty of propellant
- Solar panel and battery capacity can support operations through at least the 2030s
- Spacecraft fine pointing and instrument photometric performance remain excellent
- In anticipation of the expected eventual decline of the gyroscope, the mission is developing a gyro-less fine pointing mode

Cycle 7
(Oct 2024 – Sep 2025)

TESS Senior Review update

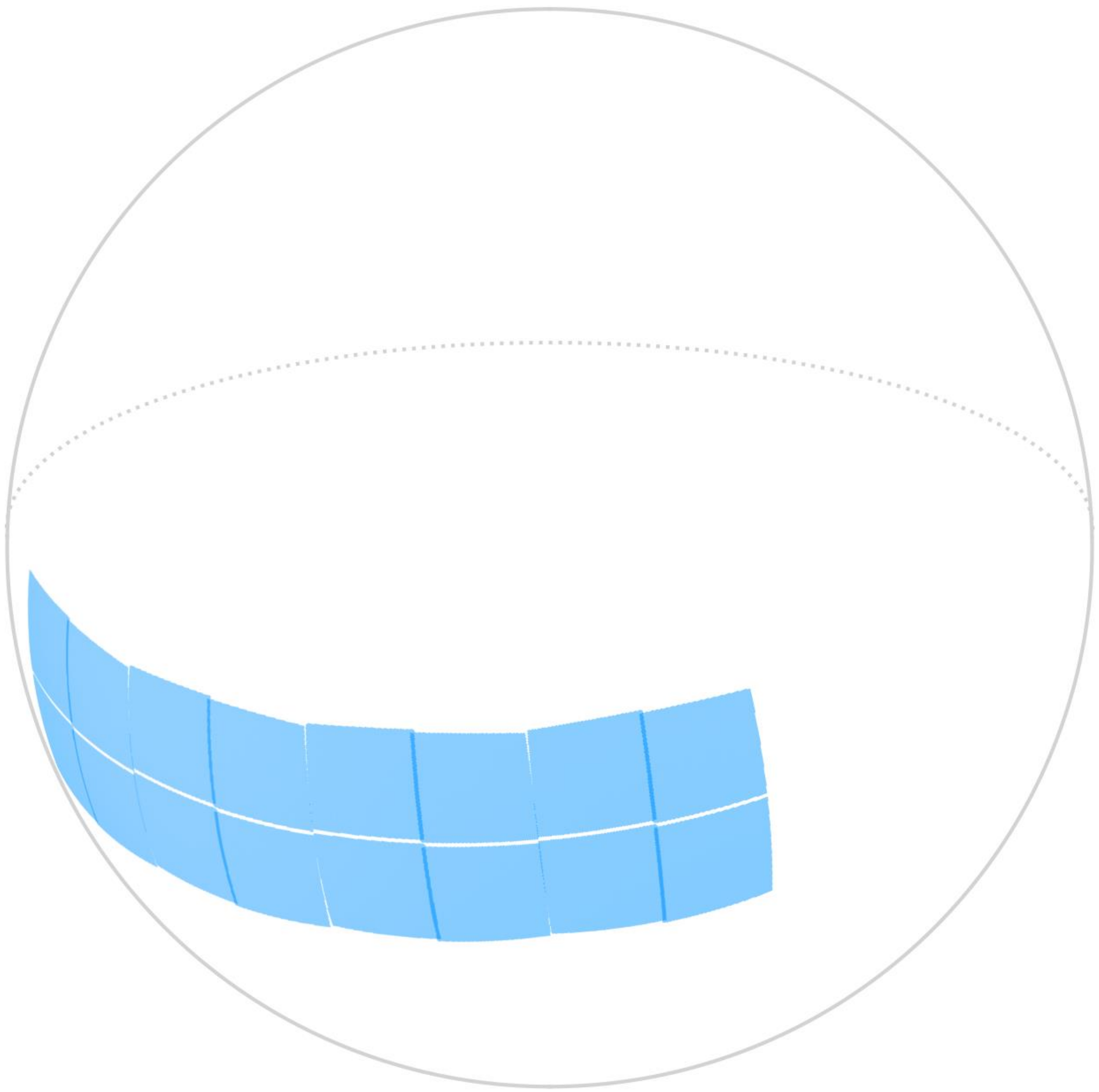
- TESS was rated “Excellent” by the Senior Review panel and will be continuing for a third extended mission (EM3)
- In formulating TESS EM3, we had two major constraints:
  - ~30% budget reduction (beginning Oct 2025)
  - Community input on our observation strategy and programmatic priorities



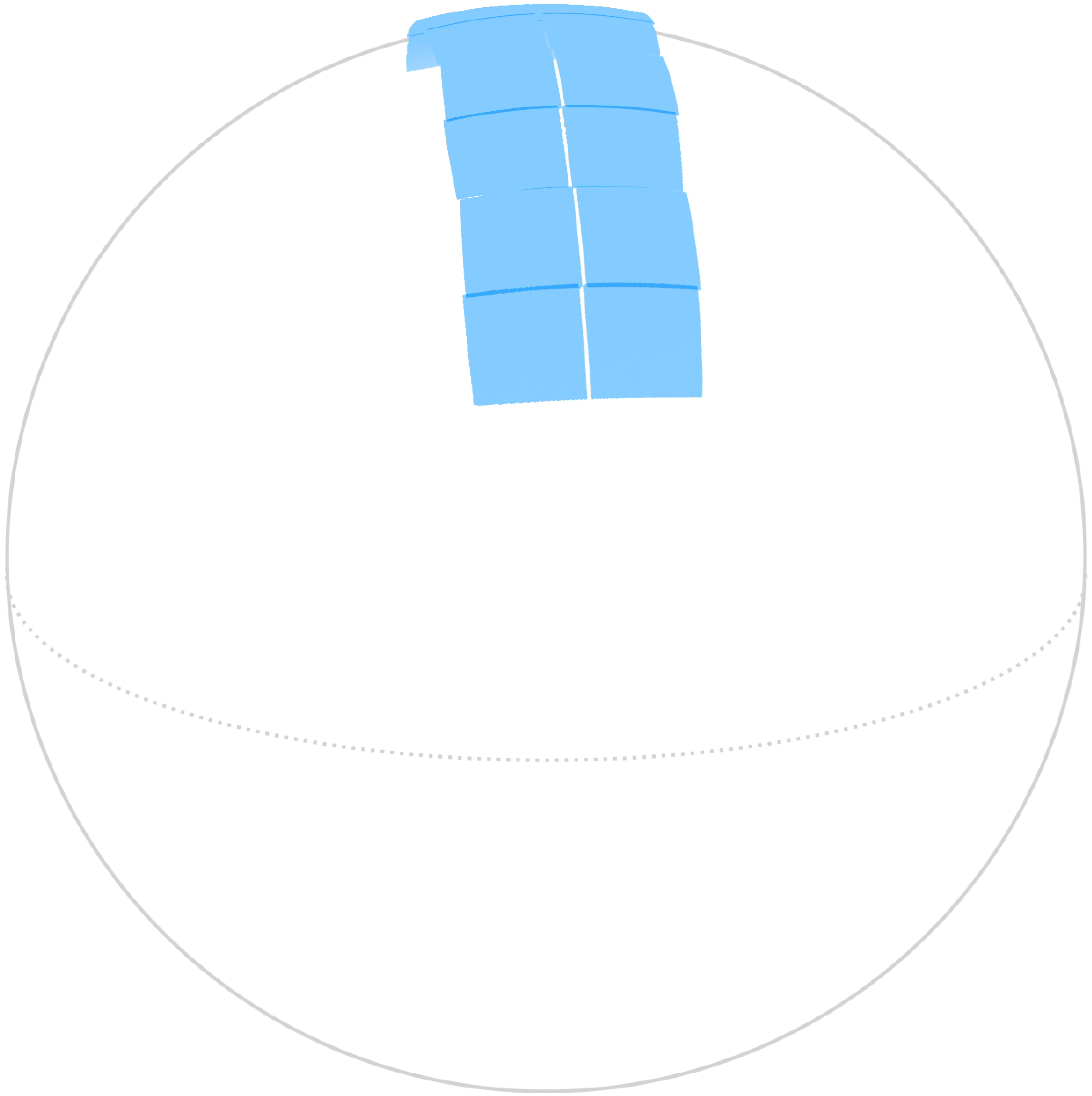


	Prime Mission	EM1	EM2
FFI cadence	30 min	10 min	200 s
Postage stamp cadence	120 s	120 s 20 s	120 s 20 s

Standard TESS Observing Pattern

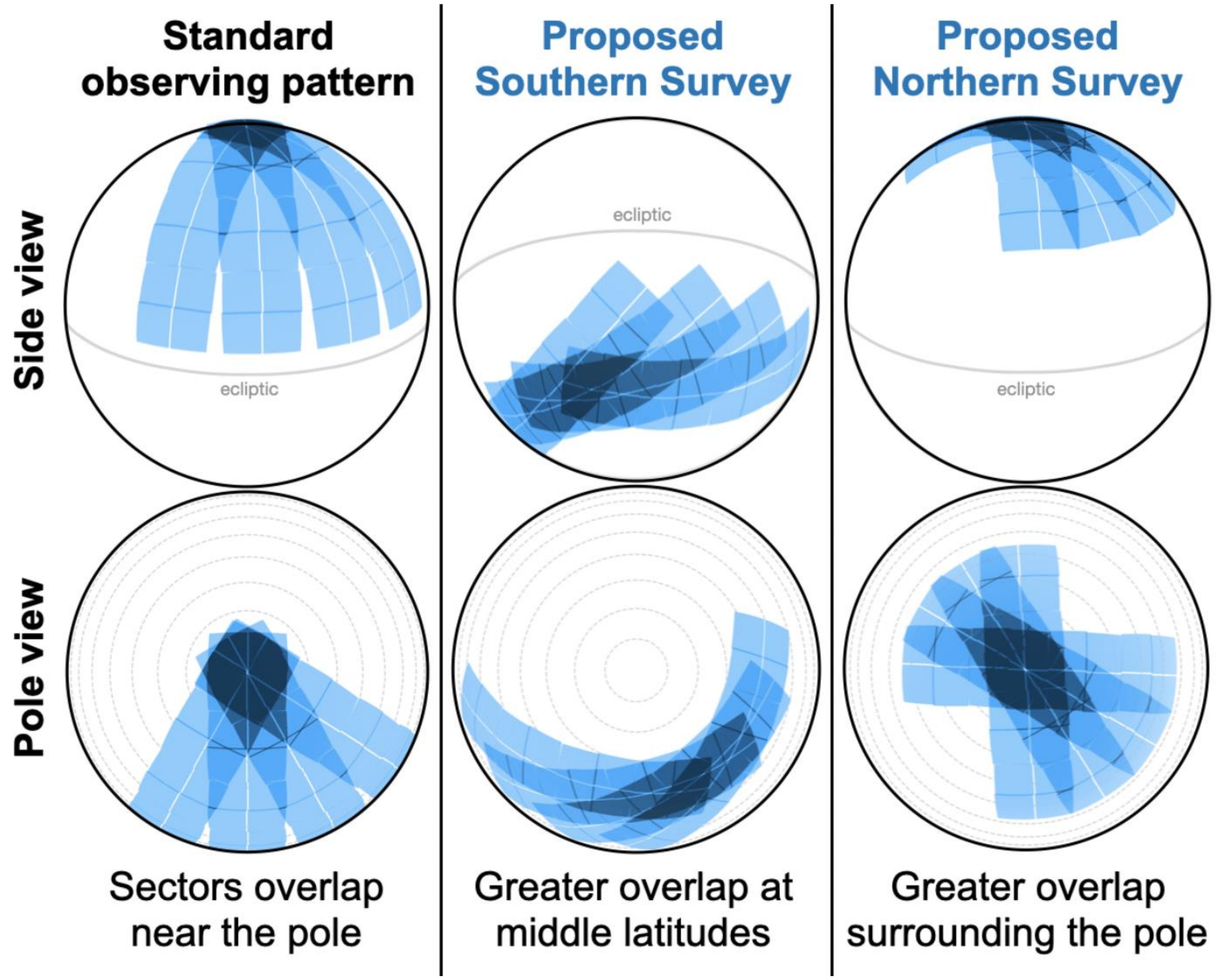


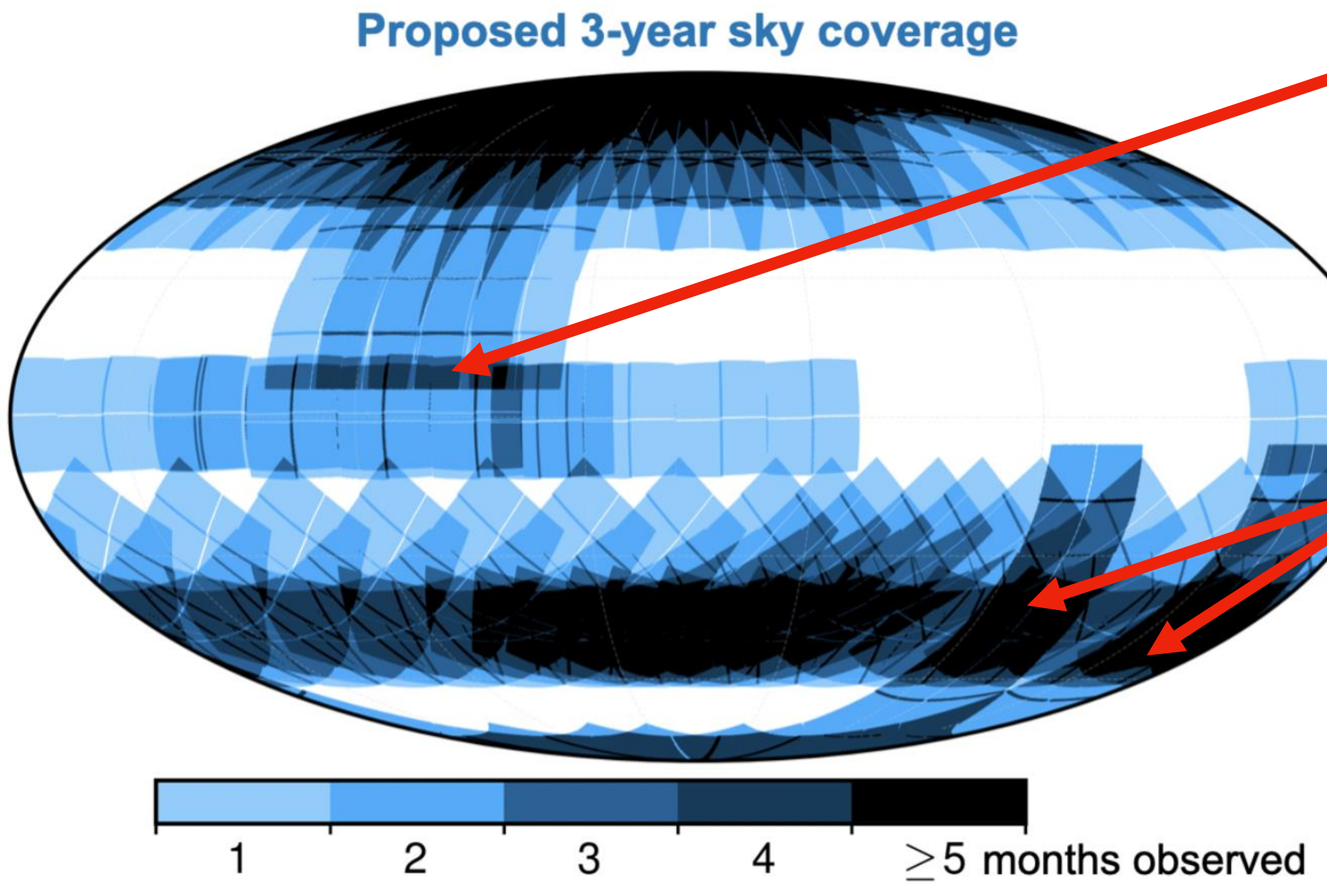
EM3 Southern Survey



EM3 Northern Survey

EM3: Observing strategy





Filling in the gaps to complete the survey

Extended sector duration test (2 x 54-day sectors in the south)

	Prime Mission	EM1	EM2	EM3 (proposed)
FFI cadence	30 min	10 min	200 s	200 s
Postage stamp cadence	120 s	120 s 20 s	120 s 20 s	120 s 20 s

Number of consecutive sectors	Area of sky in EM3
≥ 1	70%
≥ 2	37%
≥ 3	15%
≥ 4	9%

Figures: J. Winn

EM3: Light curves with longer continuous timespans will benefit many scientific areas

- Longer-period planets, including habitable zone planets orbiting M dwarfs
- Rotation periods of older stars
- Better coverage of supernovae, gamma-ray burst afterglows, and other optical transients

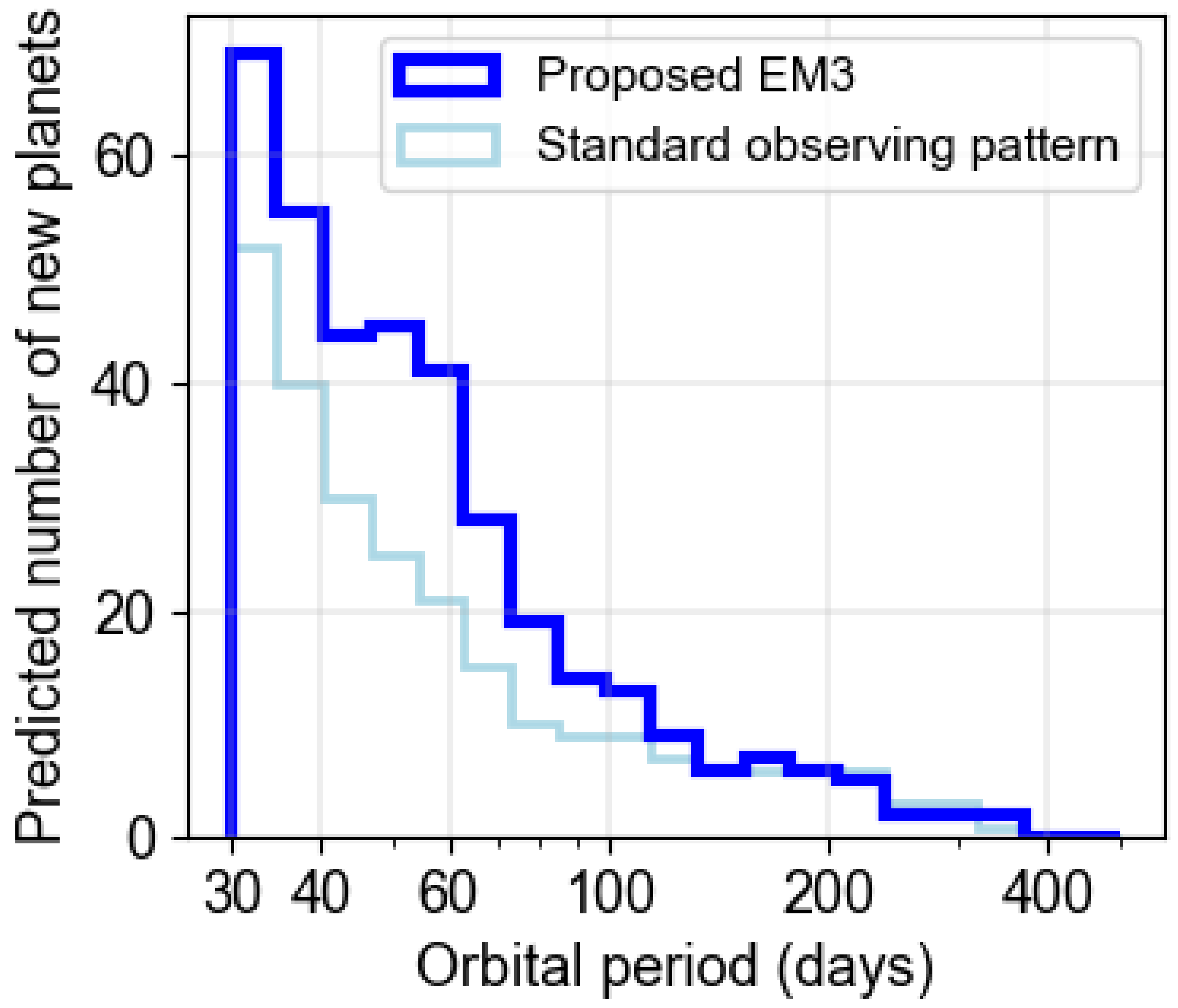
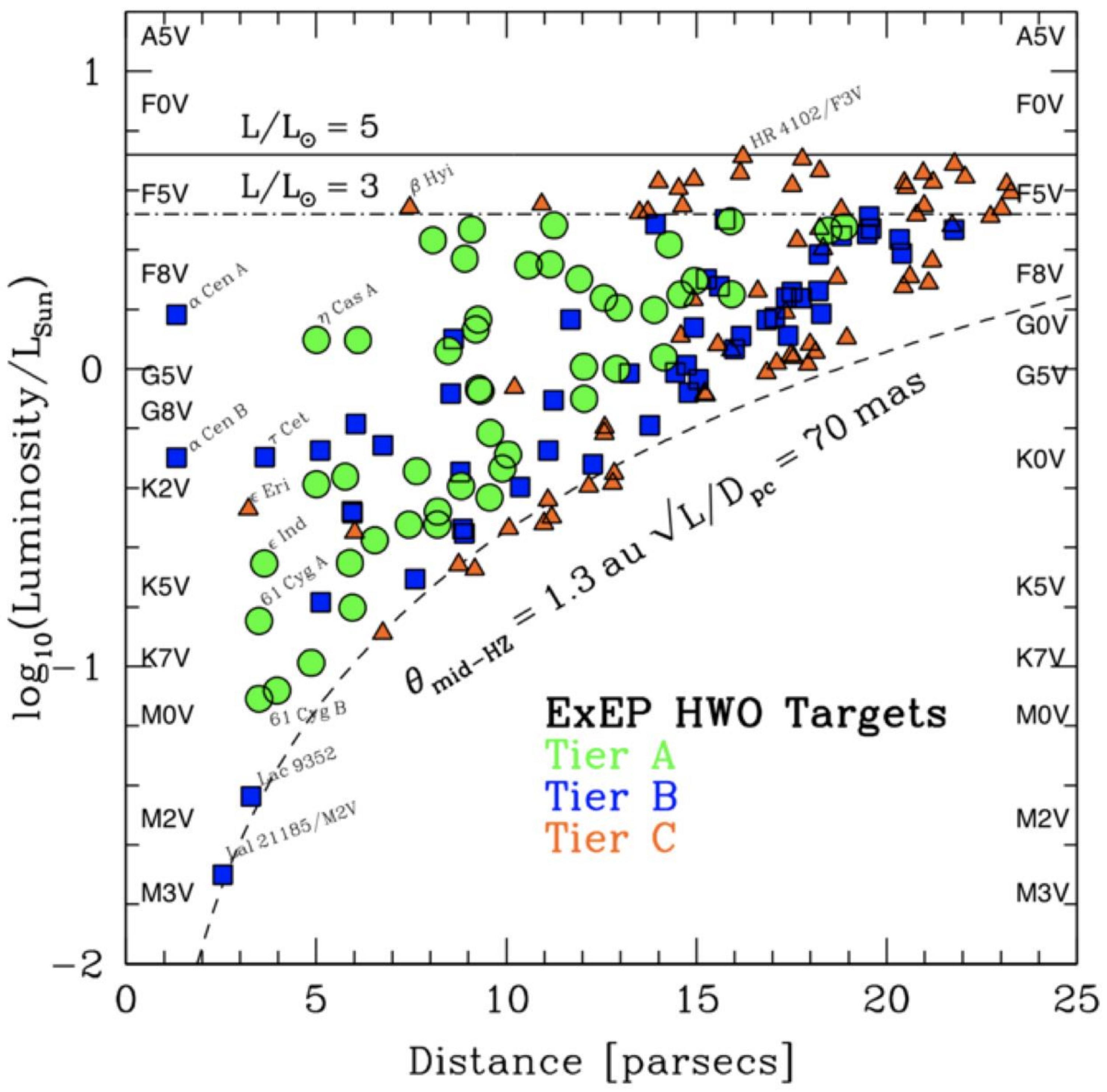


Figure credit: J. Winn & M. Kunimoto

EM3: Characterization of Habitable Worlds Observatory (HWO) stars

- HWO will search bright, nearby FGK stars for Earth-sized habitable zone planets in reflected light.
- Knowledge of host star parameters like mass, radius, age, and inclination are highly desirable.
- TESS has begun observing HWO stars in the field with our highest quality observation mode (20-s cadence) to enable detection of rotation periods, solar-like oscillations, and flares.



Mamajek & Stapelfeldt 2024

EM3: Data and analysis tools

- Continue to provide FFIs, and 20-s, 120-s, and FFI-based 200-s light curves to MAST, maintain community HLSP archive at MAST
  - SPOC FFI light curves expanding to >640,000 targets/sector
  - QLP FFI light curves have improved precision
- MAST provides many ways to interact with and download TESS data: bulk downloads, MAST portal, astroquery.mast, lcviz (online light curve viewer), TESSCut cutout service, and TIKE cloud computing platform
- TESS Science Support Center staffs the Help Desk, maintains the Lightkurve python package and other analysis and proposal tools, and hosts AAS data workshops

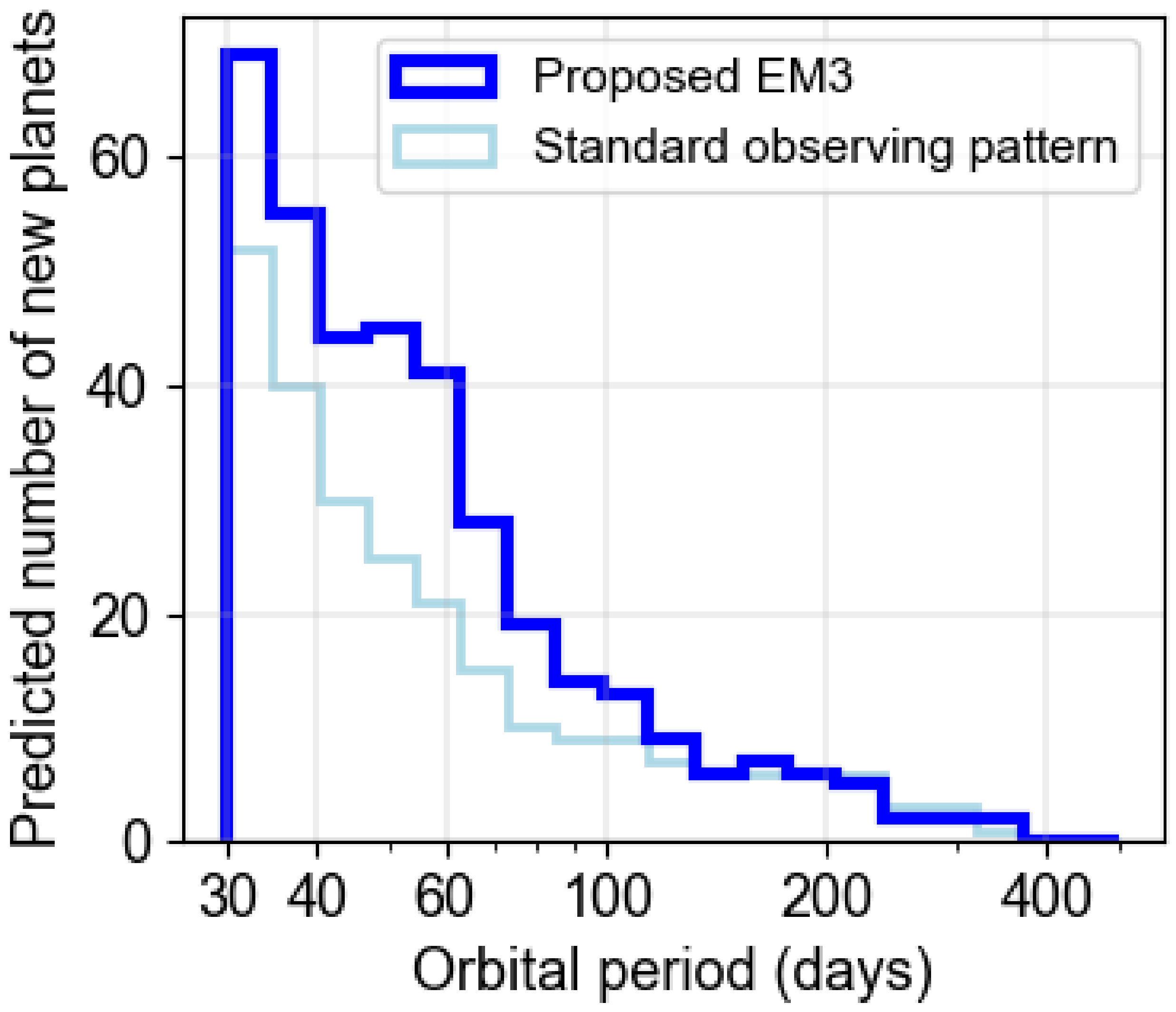
	Prime Mission	EM1	EM2	EM3
FFI cadence	30 min	10 min	200 s	200 s
Postage stamp cadence	120 s	120 s 20 s	120 s 20 s	120 s 20 s

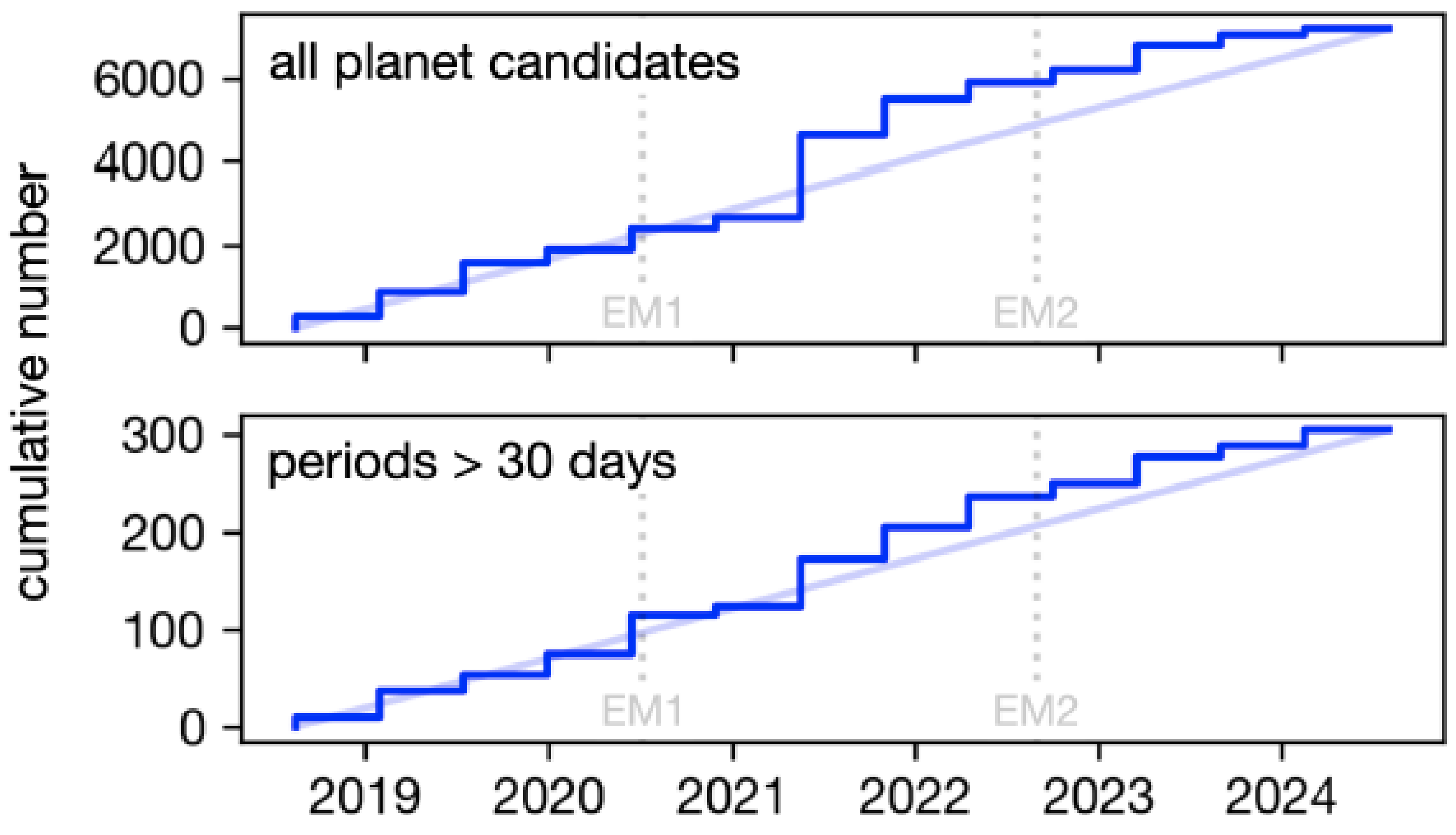
Visit the TESS Science Support Center website

Email the Help Desk:
tesshelp@bigbang.gsfc.nasa.gov

EM3: Planet candidates

- Continue generating TOIs, transitioning to automated vetting next year
- Ground-based follow-up program (TFOP) has >700 members worldwide who help confirm TOIs

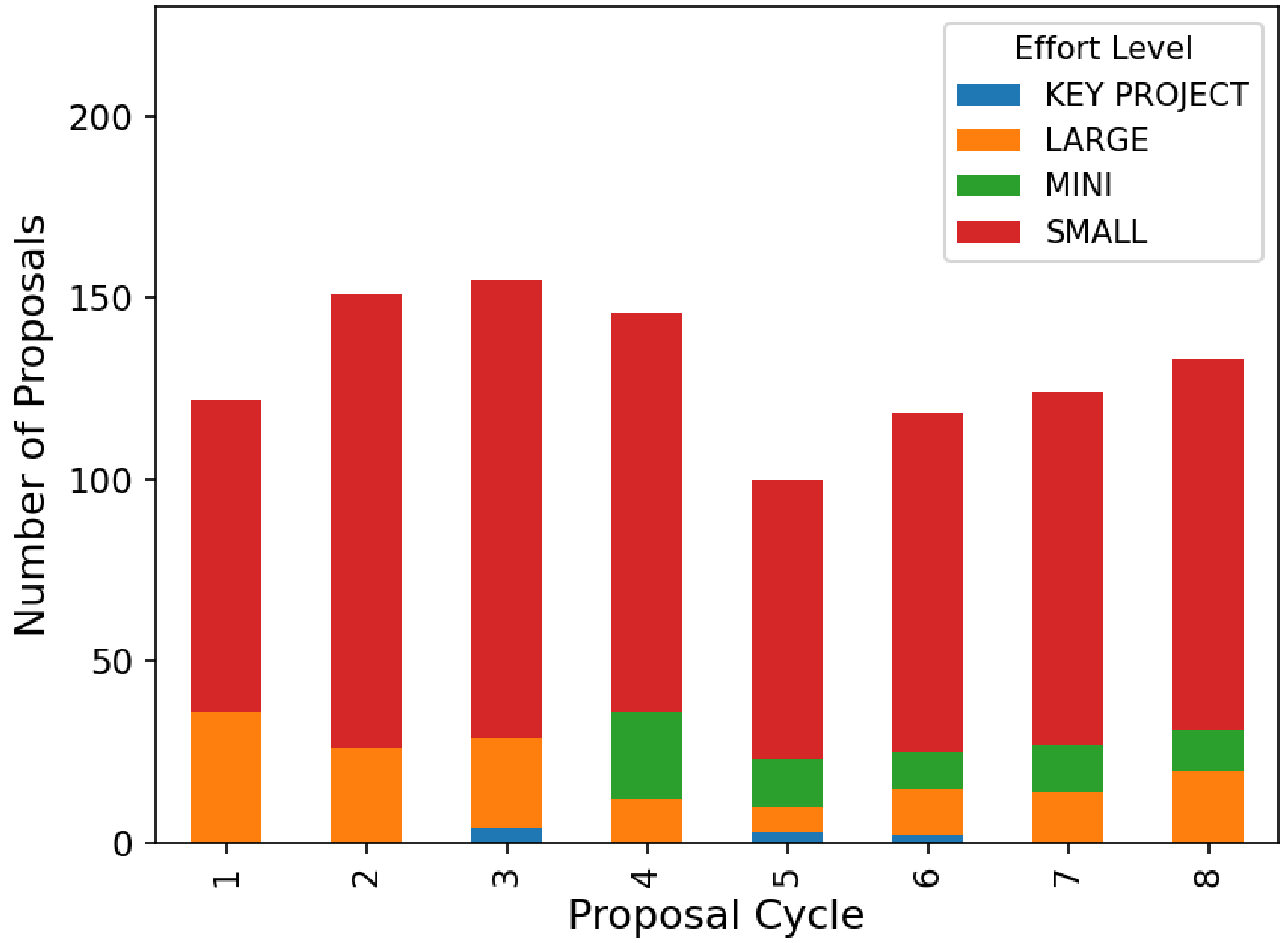




Figures: J. Winn

EM3: General Investigator grants

- Grant funding available via General Investigator program ($2M/yr).
  - Mini (targets only), Small (up to $90k), and Large (up to $250k) solicited
  - Cycle 8 begins Sep 15
    - 132 proposals received; 22 Large and Small proposals “selectable”, 11 Mini proposals selected
  - Cycle 9 deadline expected next spring



TESS Users Committee (TUC)

Provides broad-based input to the TESS Project about the needs and priorities of the TESS user community.

Four new TUC members to be announced soon!

Daniel Huber (Chair)
Institute for Astronomy, University of Hawaii at Manoa

Marcel Agüeros
Columbia University

Luke Bouma
Caltech

Adina Feinstein
Michigan State University

Teruyuki Hirano
NAOJ, The Graduate University for Advanced Studies (SOKENDAI)

Savita Mathur
Instituto de Astrofísica de Canarias

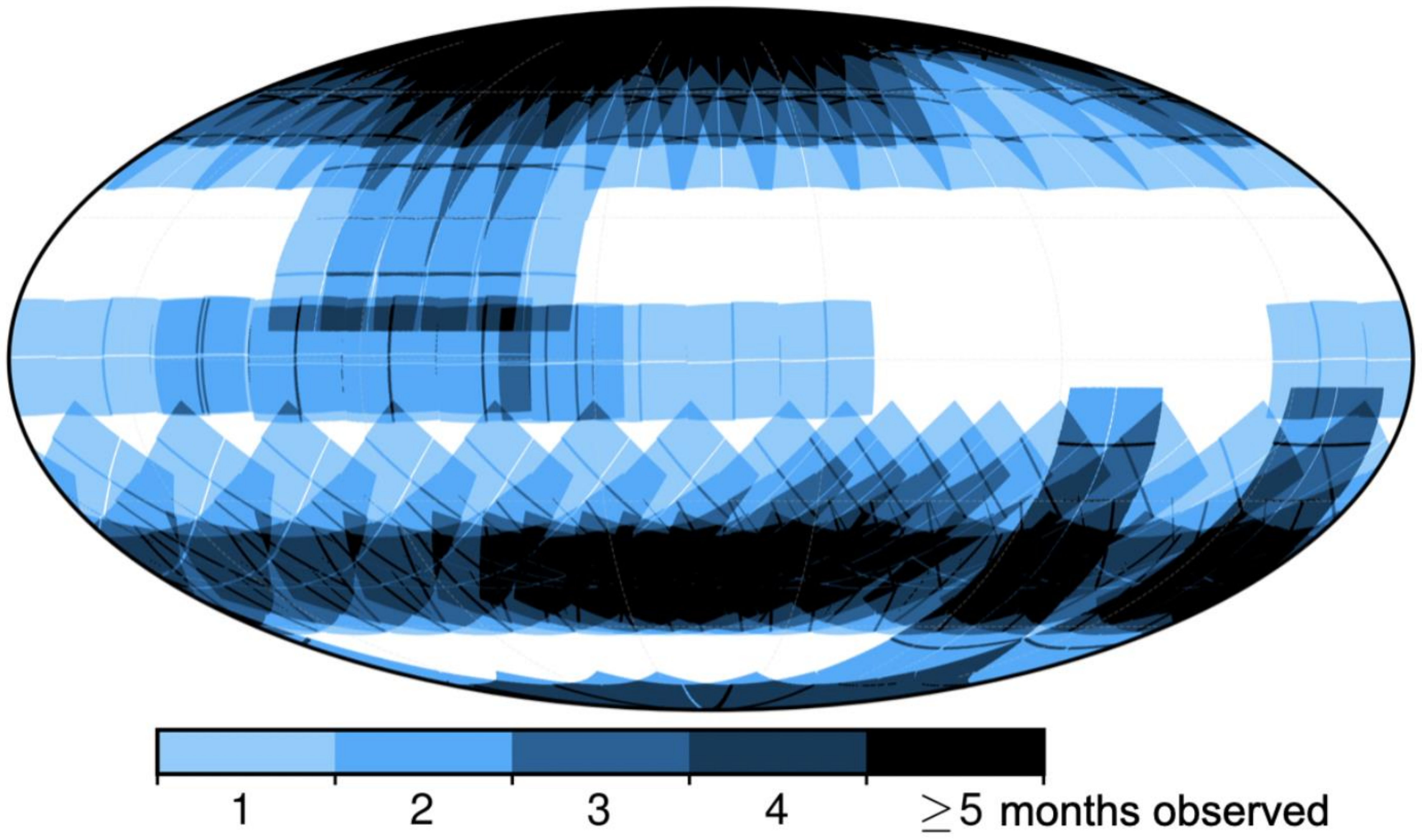
Armin Rest
Space Telescope Science Institute

Malena Rice
Yale University

Krista Lynne Smith
Texas A&M University

Summary

Sky coverage (Cycles 8-10)



- The next three years of the TESS survey will bring longer light curves in new areas of the sky.
- Expect new advances in:
  - Longer-period planets
  - Rotation periods of older stars
  - Tracking evolution of supernovae, gamma-ray burst afterglows, and other optical transients
- Cycle 8 contains two 54-day sectors and a concentration of observations at southern middle latitudes.

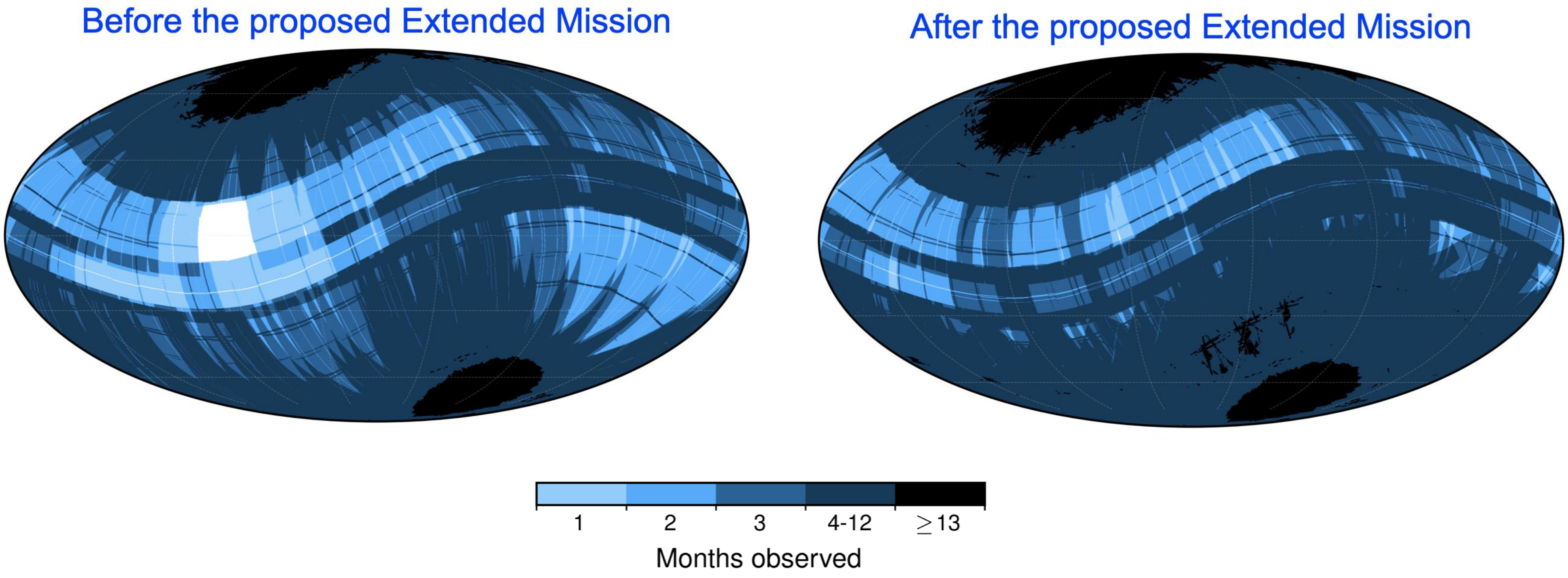
Backup

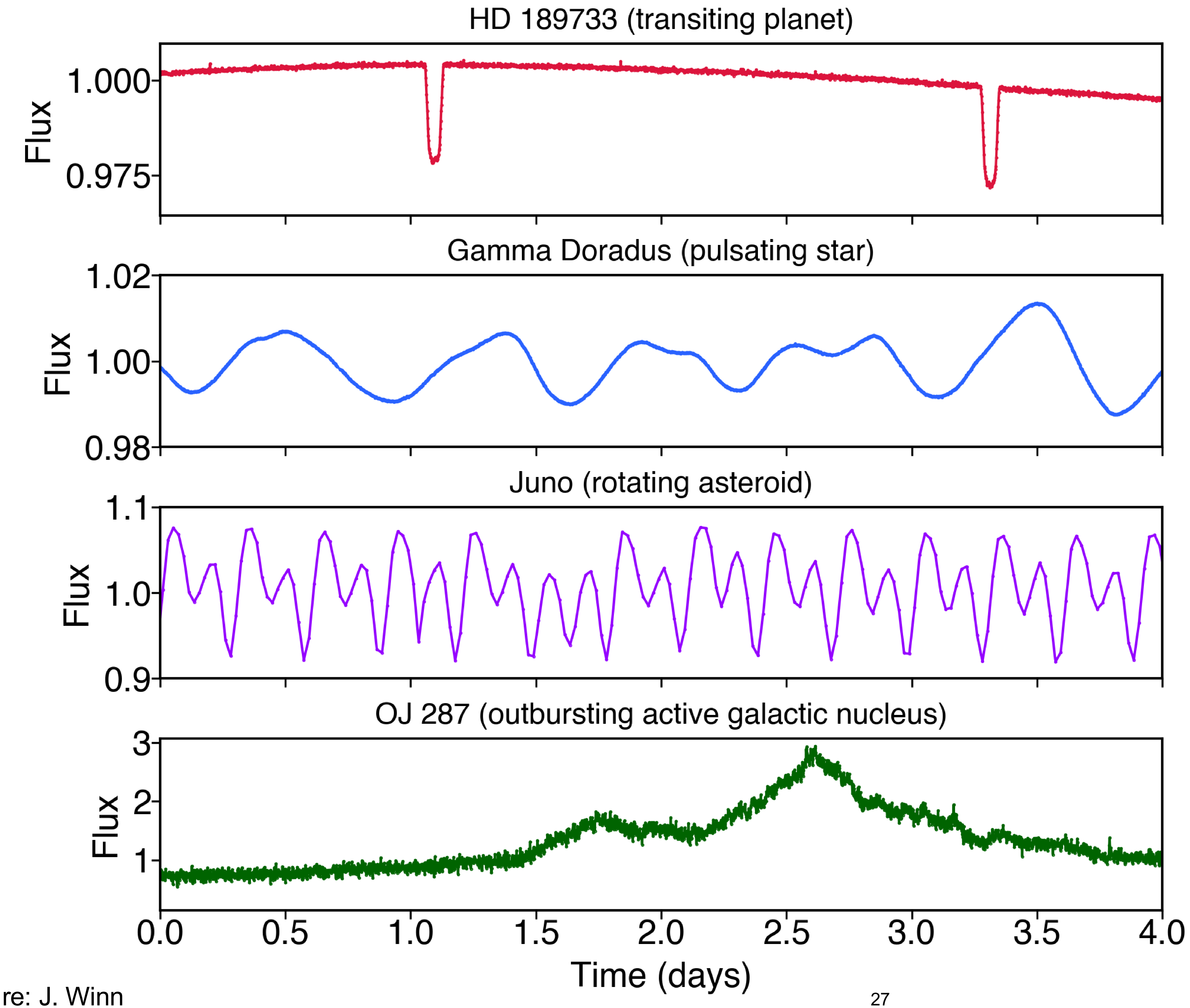
Confirmed Transiting Planets Smaller than Neptune in 2018

Confirmed Transiting Planets Smaller than Neptune in 2024

Confirmed & Candidate Transiting Planets Smaller than Neptune in 2024

Proposed observing strategy for EM3





Transiting planets
≈6300 candidates
≈600 confirmed

Stellar astrophysics
pulsations, eclipses, rotation, flares, eruptions
HWO candidate targets

Asteroids & comets
rotation, outbursts

Active galactic nuclei
variability, flares

Figure: J. Winn

TESS Stands at the Nexus of NASA's Primary Science Goals

Two Parallel Threads for TESS

NASA SMD Science Plan

- Are we alone? How did we get here?
- How does the universe work?

Astro2020 Science Priority Areas

- **Pathways to Habitable Worlds,** with the goal of trying to discover worlds that could resemble Earth and answer the fundamental question: "Are we alone?"
- **New Windows on the Dynamic Universe,** including a suite of small and medium-scale ground and space-based observational facilities across the EM spectrum to discover and characterize the brightness and spectra of transient sources as they appear and fade away.

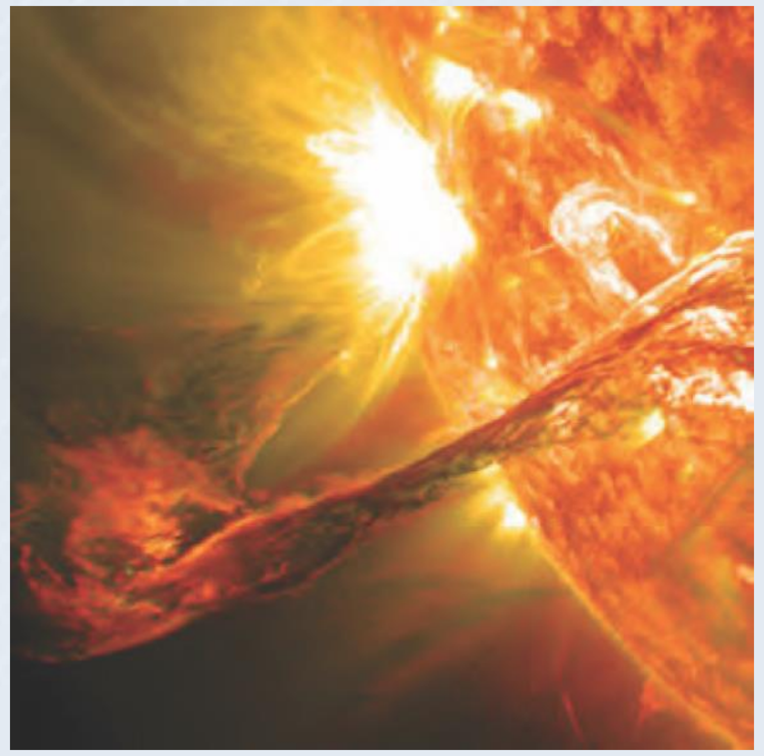
Some specific applications of TESS data

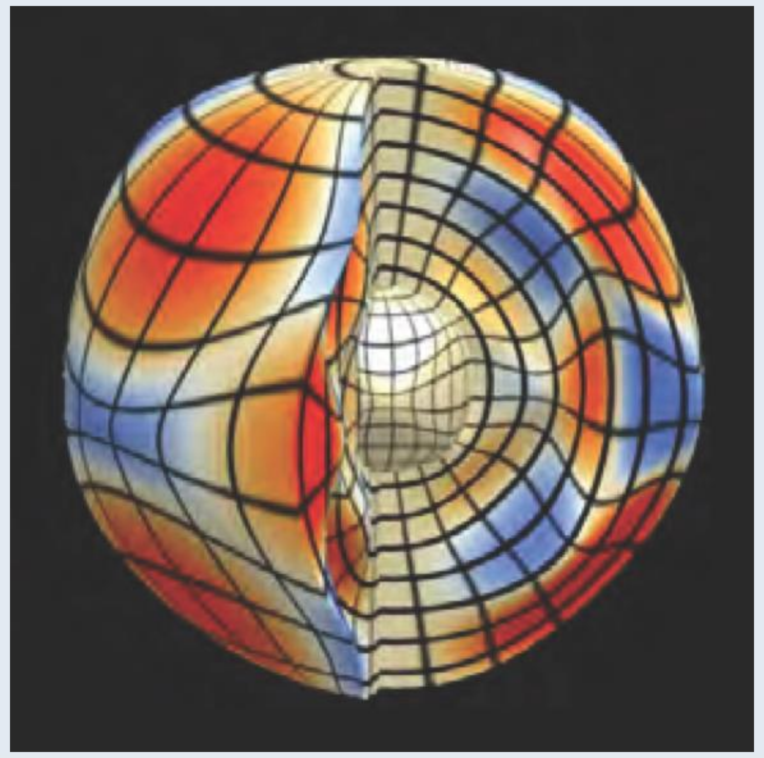
- HWO Preparations
  Also:
  PLATO, ARIEL, Roman…
- Contemporaneous EM3 Observations:
  JWST Rubin Roman
  LIGO ULTRASAT

TESS's general capabilities

- Precise short-cadence optical photometry
- Continuous observations for weeks at a time
- Nearly complete coverage of the entire sky
- Full-frame image data enabling blind surveys & serendipitous discovery

TESS is Enabling a Broad Range of Astrophysical Discovery Areas





Solar System Objects:

Thousands in 6 years…

- ✓ Comets
- ✓ Asteroids
- ✓ Trans-Neptunian Objects
- ✓ SDOs/Centaurs

Explosive & Variable Extragalactic Sources:

Thousands in 6 years…

- ✓ Supernovae
- ✓ AGNs
- ✓ Blazars
- ✓ Quasars
- ✓ Tidal Disruption Events
- ✓ Gamma-ray Bursts
- ✦ Kilonovae (NS-NS Gravitational Wave Counterparts)
- ✦ **EBOT/FBOT** [searches underway…]

✓ TESS Results in Years 1-6

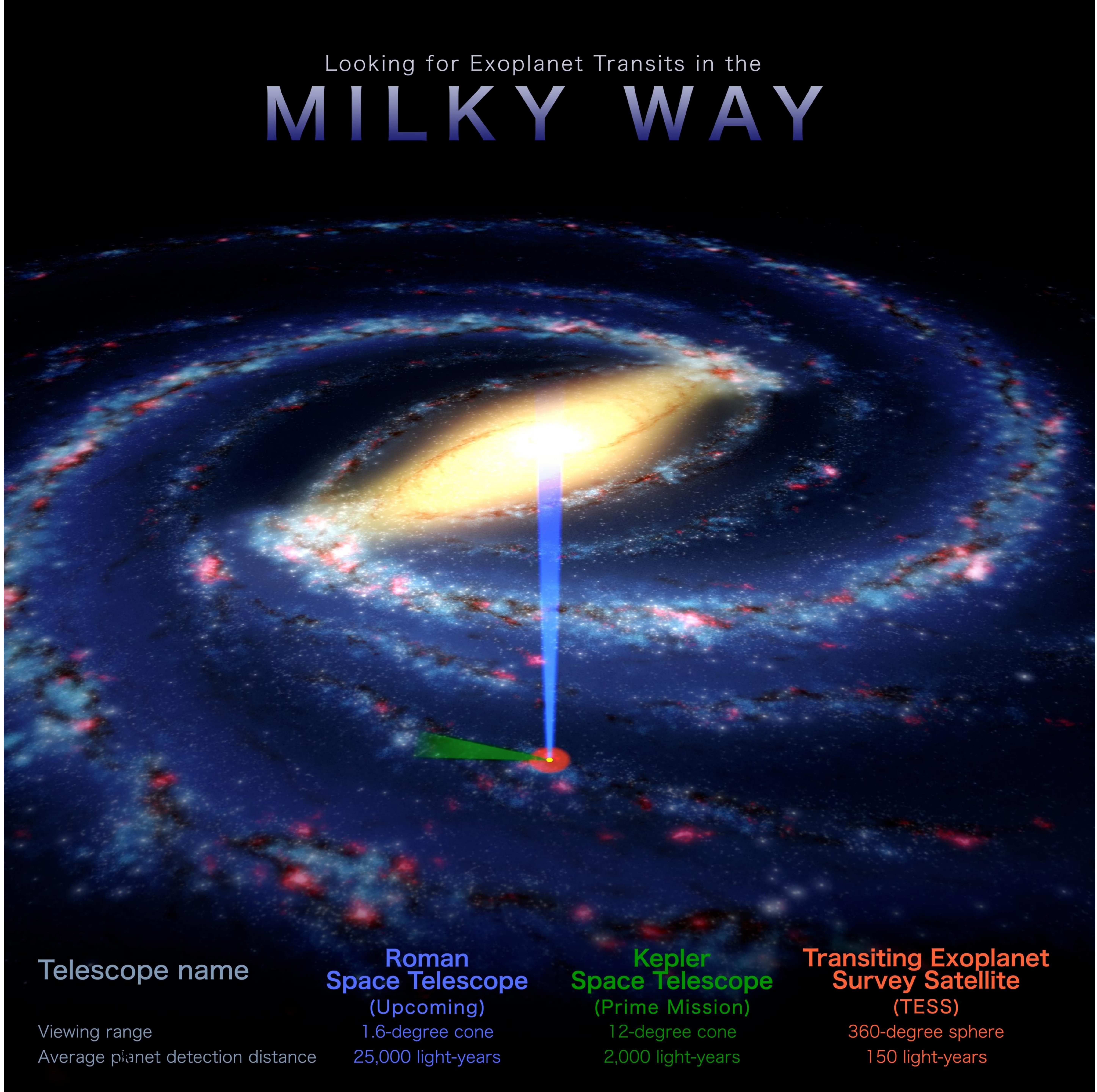
Variable Stars:

Millions in 6 years…

- ✓ Asterioseismology
- ✓ Brown Dwarfs
- ✓ Eclipsing Binaries
- ✓ Flare Stars
- ✓ Cepheids
- ✓ T Tauri Stars
- ✓ Cluster Gyrochronology
- ✓ White Dwarfs
- ✓ Neutron Stars
- ✓ Emission line stars (Be stars)
- ✓ RR Lyrae Stars
- ✓ WD Oscillations
- ✓ Novae
- ✓ Young Stellar Objects

TESS's original goal:
Discover 50 small exoplanets and measure their masses

- When TESS launched in 2018, Kepler/K2 was wrapping up and JWST was on the horizon
- By surveying nearby bright stars spread over the sky for two years, TESS could find the best small planets for JWST follow-up



What is the expected distribution of *planet equilibrium temperature*?

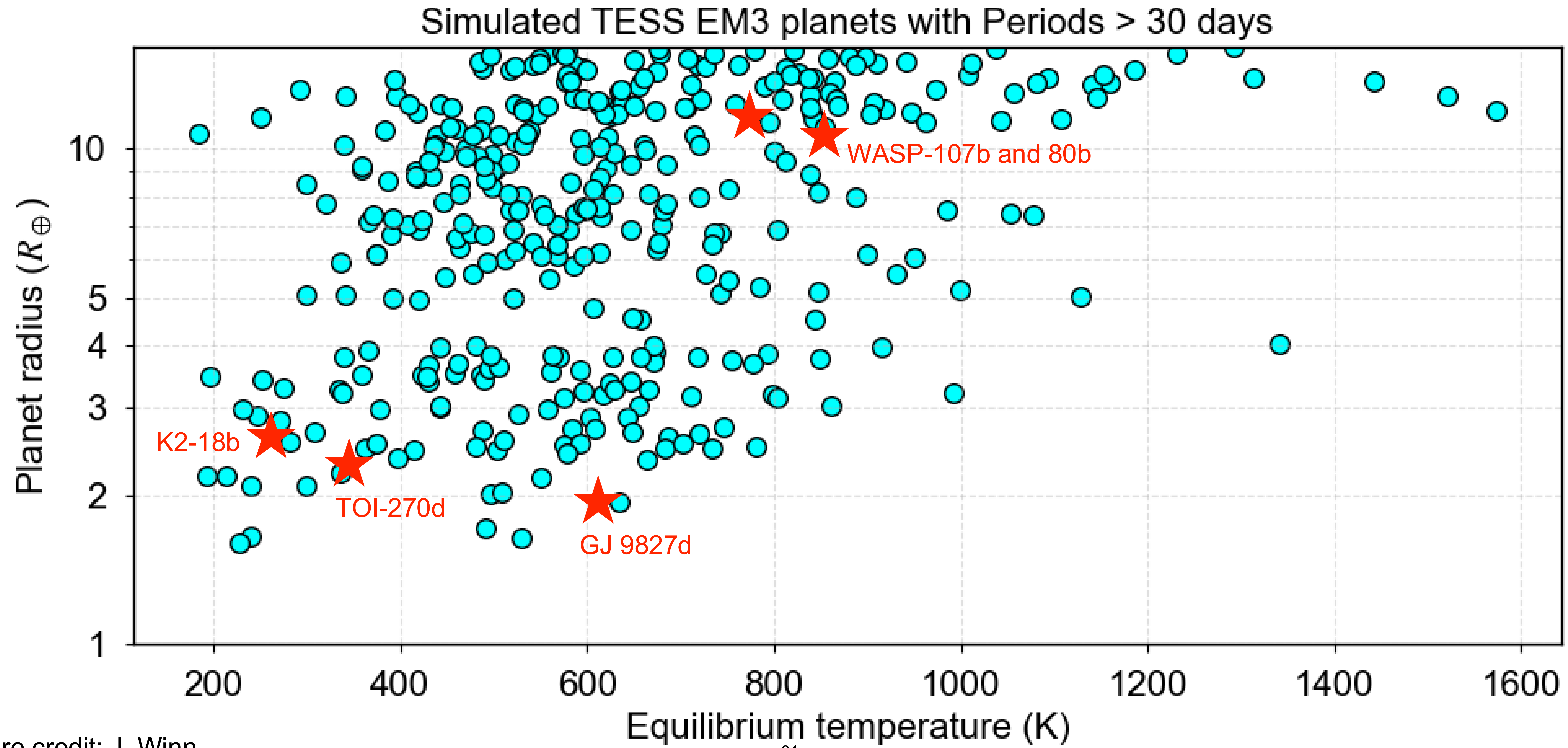
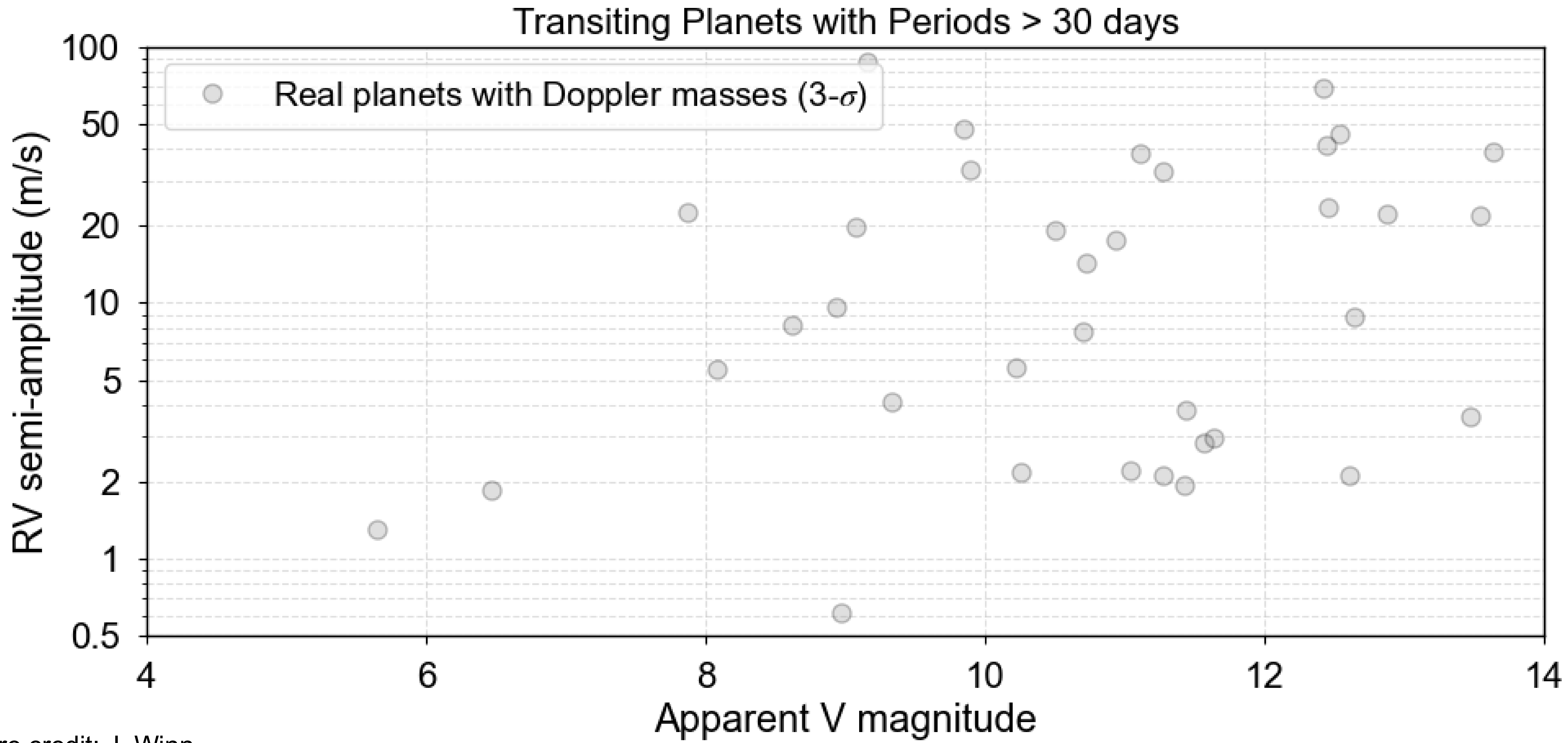


Figure credit: J. Winn

What fraction should be characterizable via ***Doppler measurements*** from the ground?



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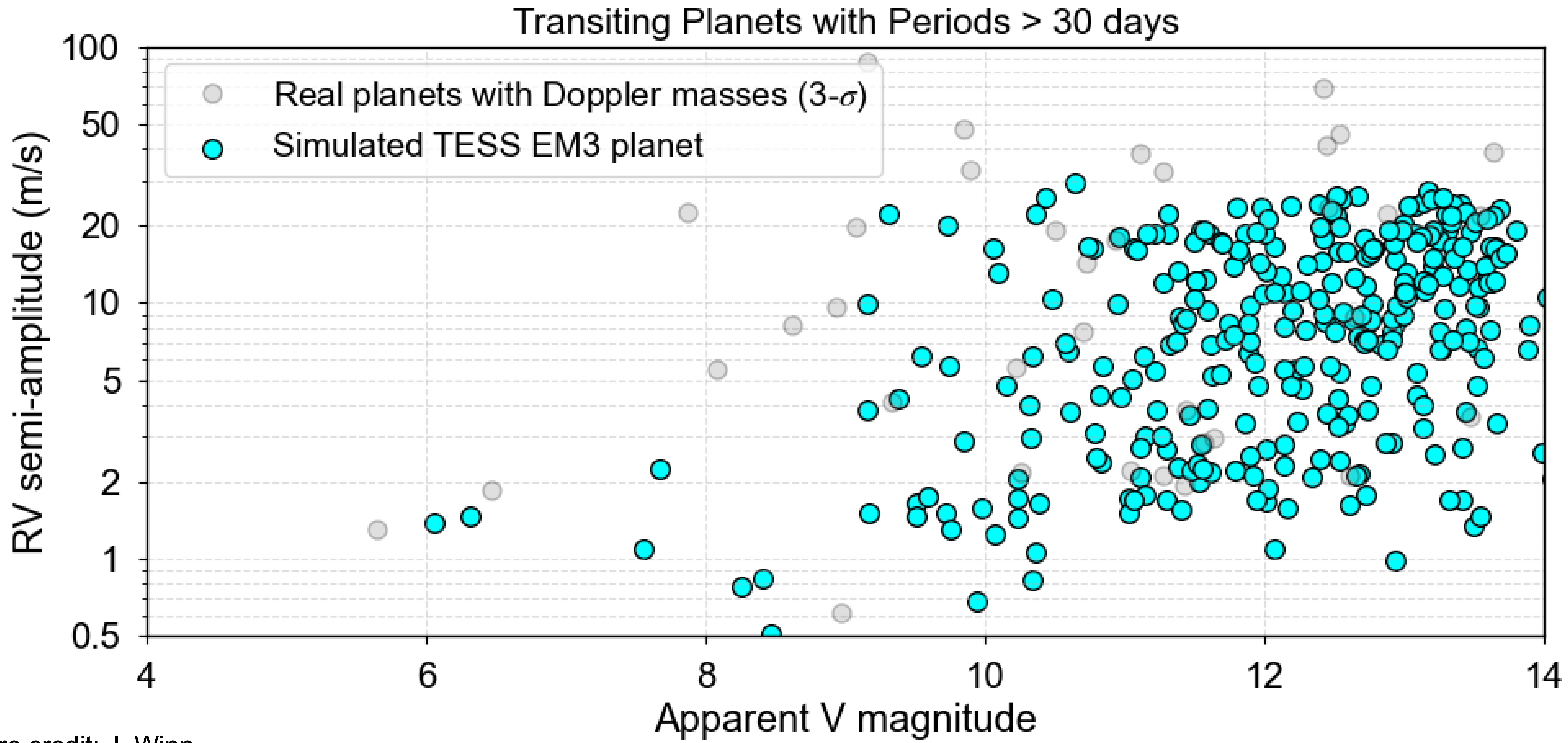

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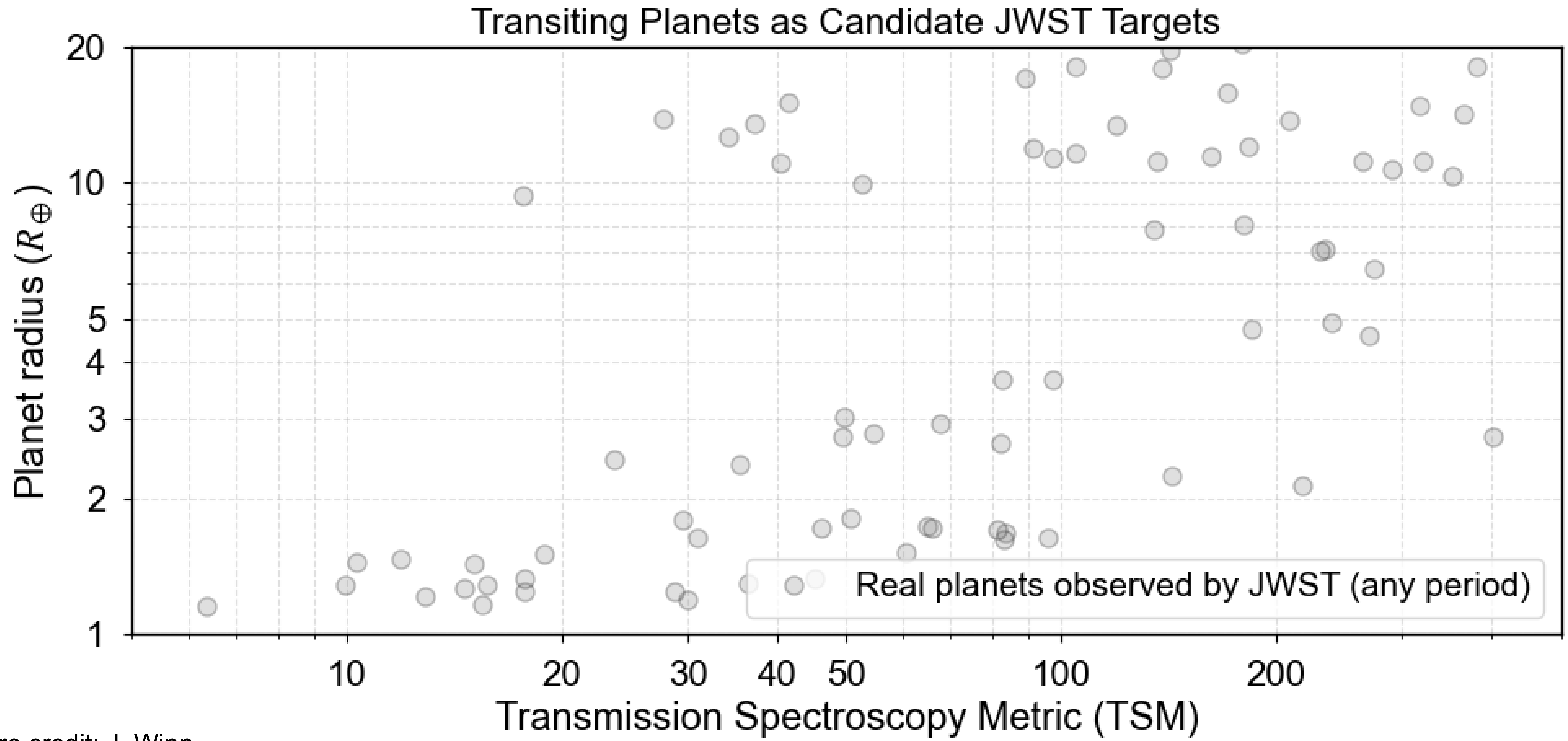

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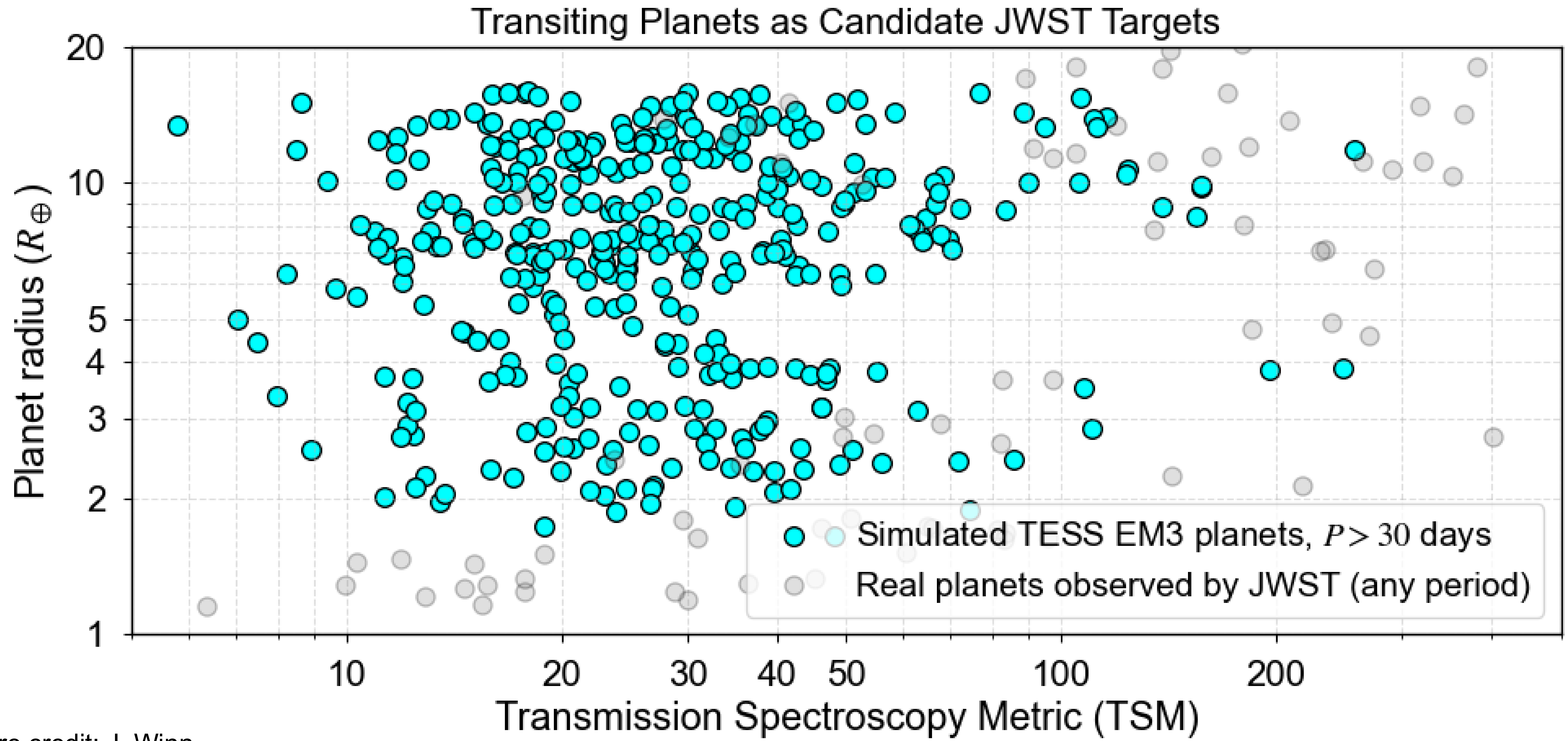
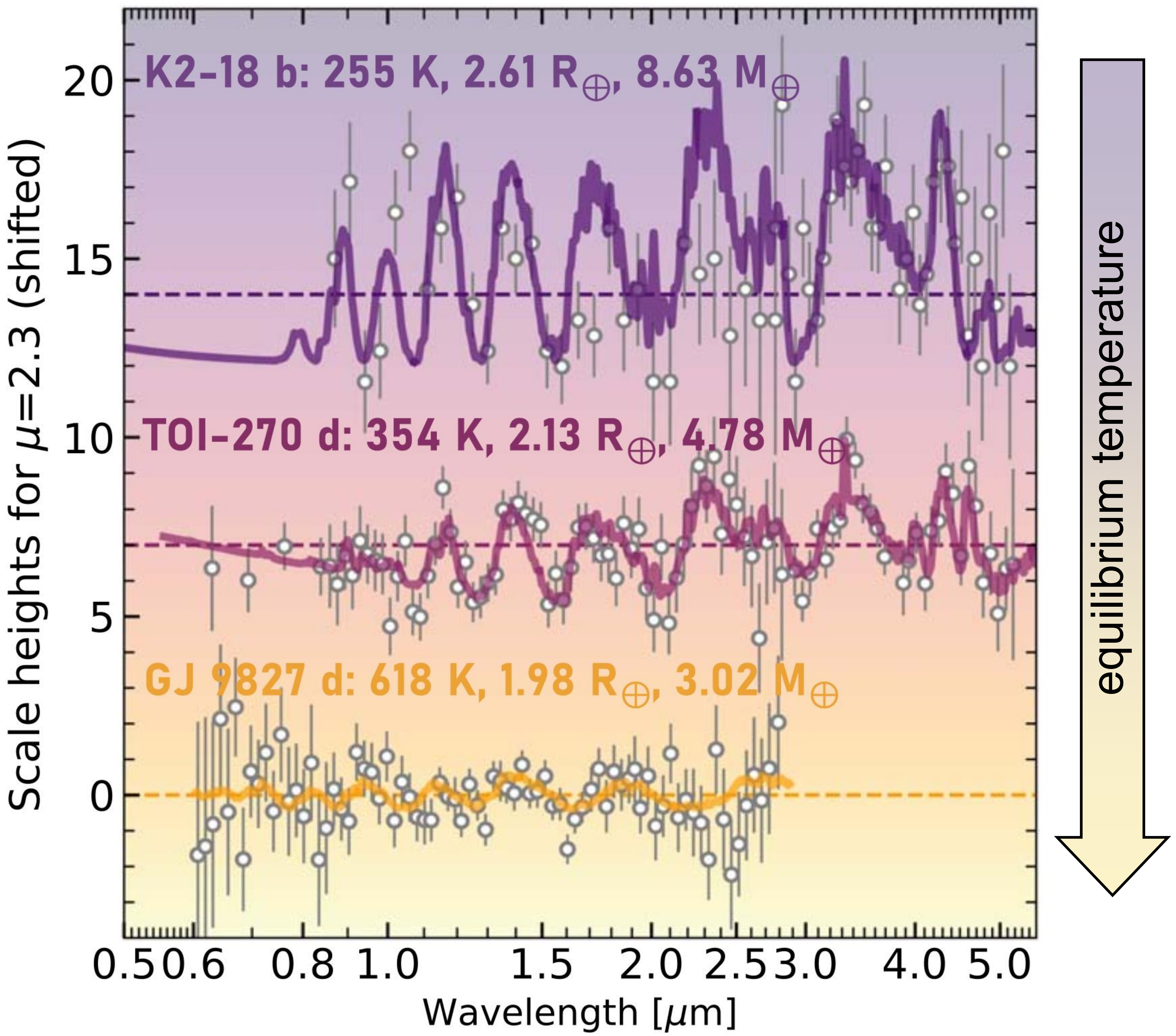


Figure credit: J. Winn

Scientific advances with long-period planets

Atmospheres

Broaden the range of chemical compositions and clouds that can be studied with **JWST**, **ARIEL**, and other telescopes



Exploration of sub-Neptunes

Are they gas dwarfs?

Hycean planets?

Something else?

Steam worlds?

JWST has only observed a few examples and they all seem different.

"We're running out of good targets."
— B. Benneke

Figure: Piaulet-G. et al. (2024)

Scientific advances with long-period planets

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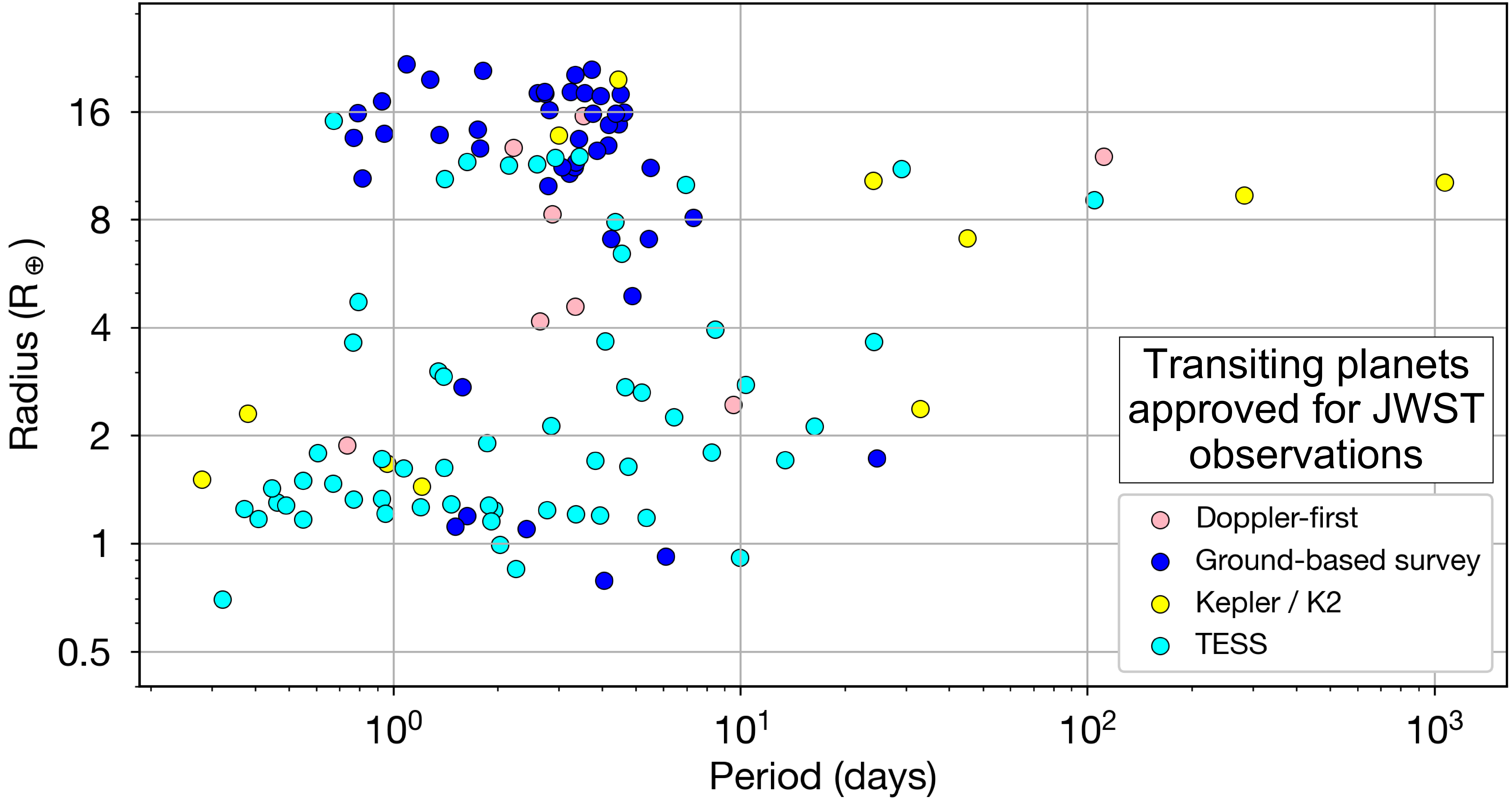
Broaden the range of chemical compositions and clouds that can be studied with **JWST**, **ARIEL**, and other telescopes



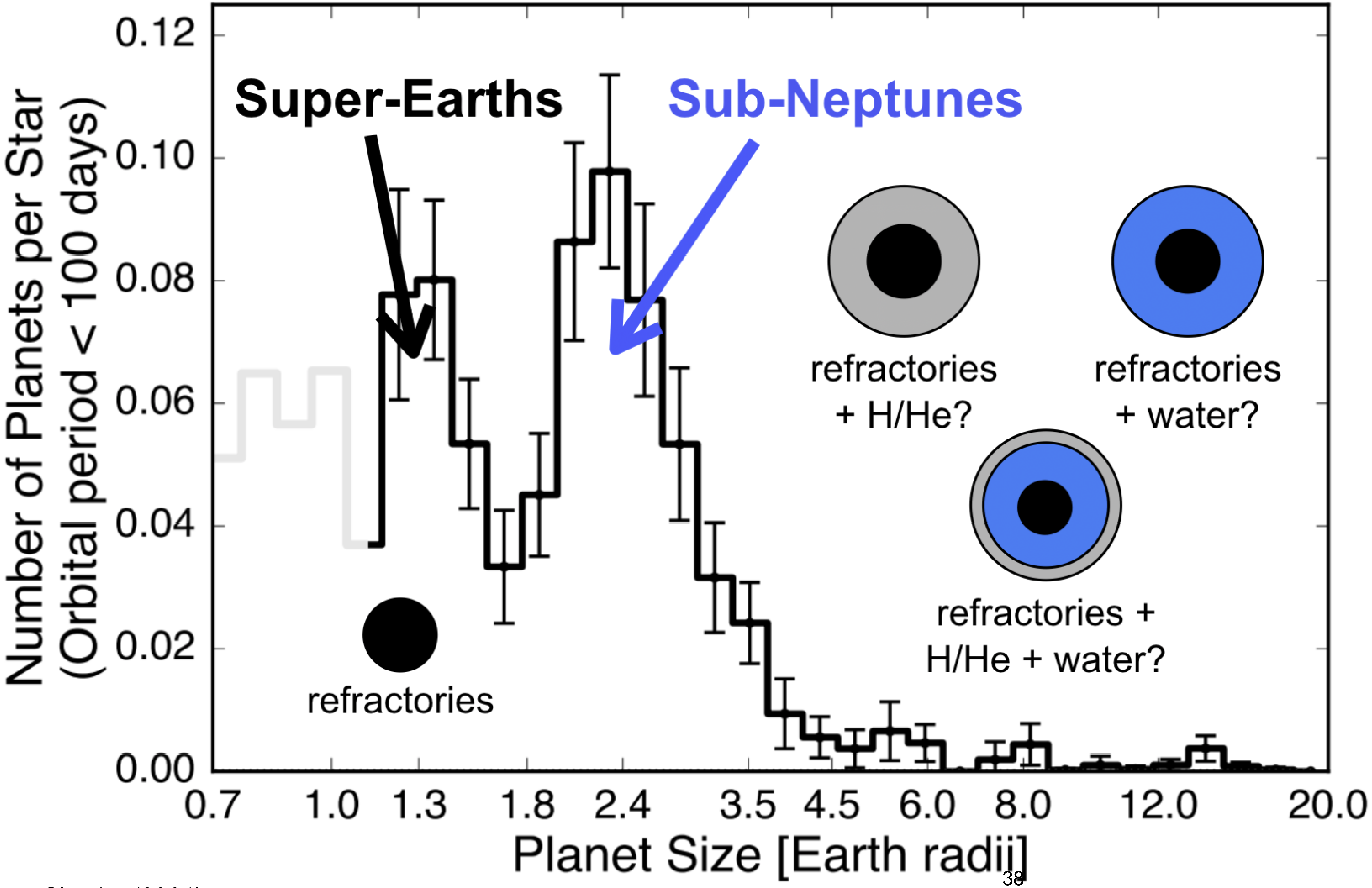
Kepler/K2 observed ≈1/20th of the sky

For every Kepler/K2 system, we expect ~19 similar systems are waiting to be found elsewhere on the sky...

...including some systems with much brighter stars!

Scientific advances with long-period planets

Demographics



Why is there a dip in the radius distribution?

Atmospheric loss due to photo-evaporation?

Core-powered mass loss?

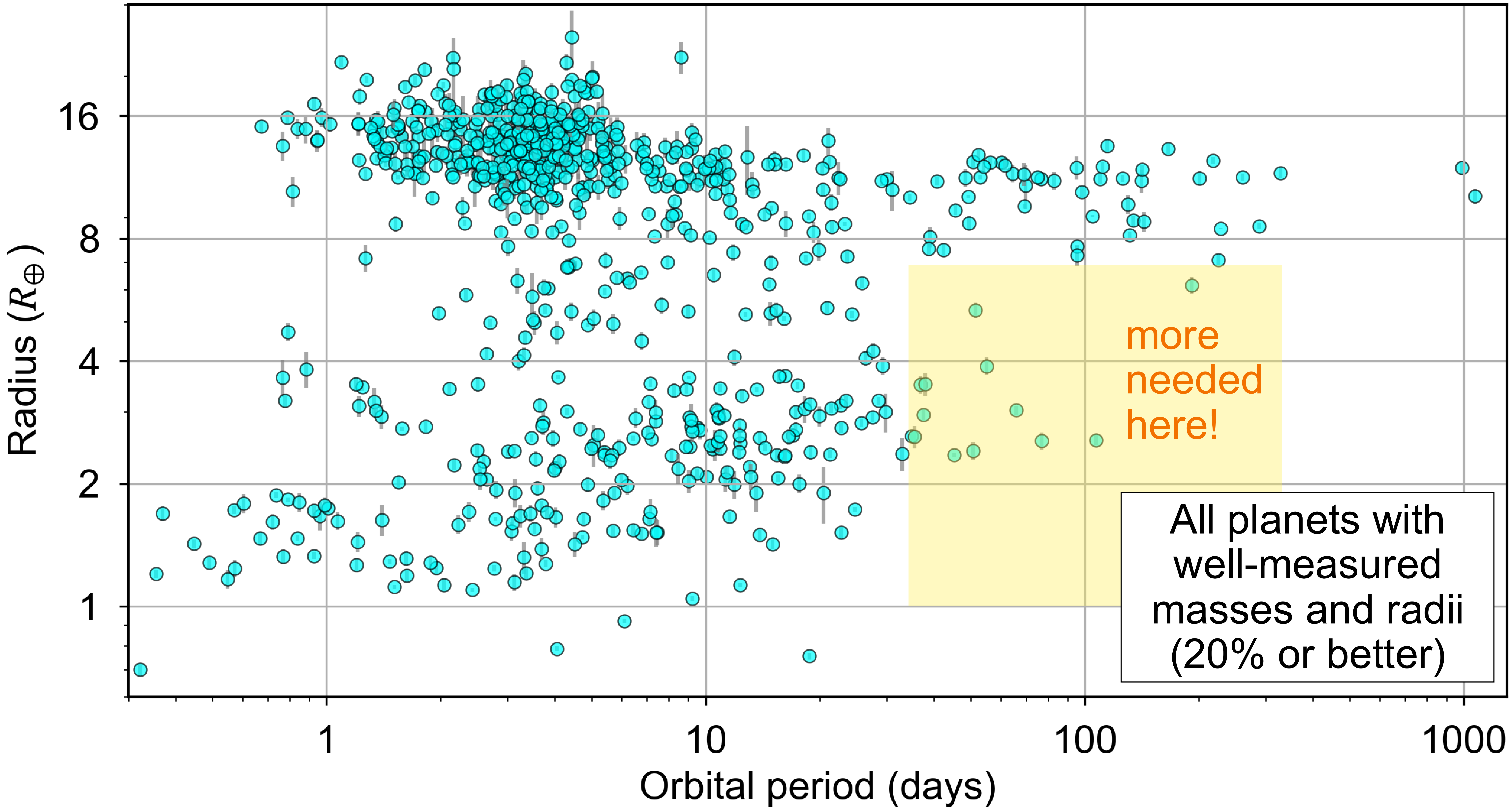
Or some other reason?

Needed: masses & atmospheric spectroscopy of planets spanning a range of sizes & periods

Figure: Cloutier (2024)

Scientific advances with long-period planets

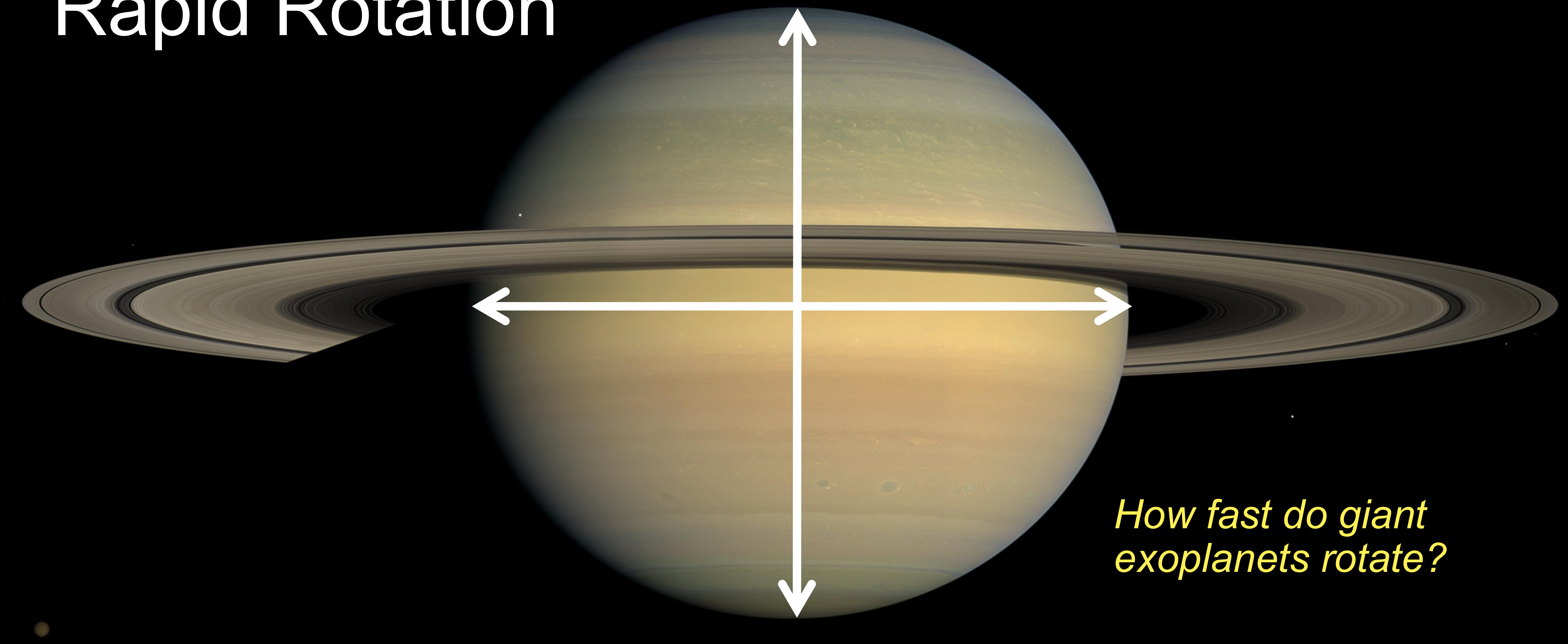
Demographics



See also: Armstrong et al. (2025) on the NCORES survey

Scientific advances with long-period planets

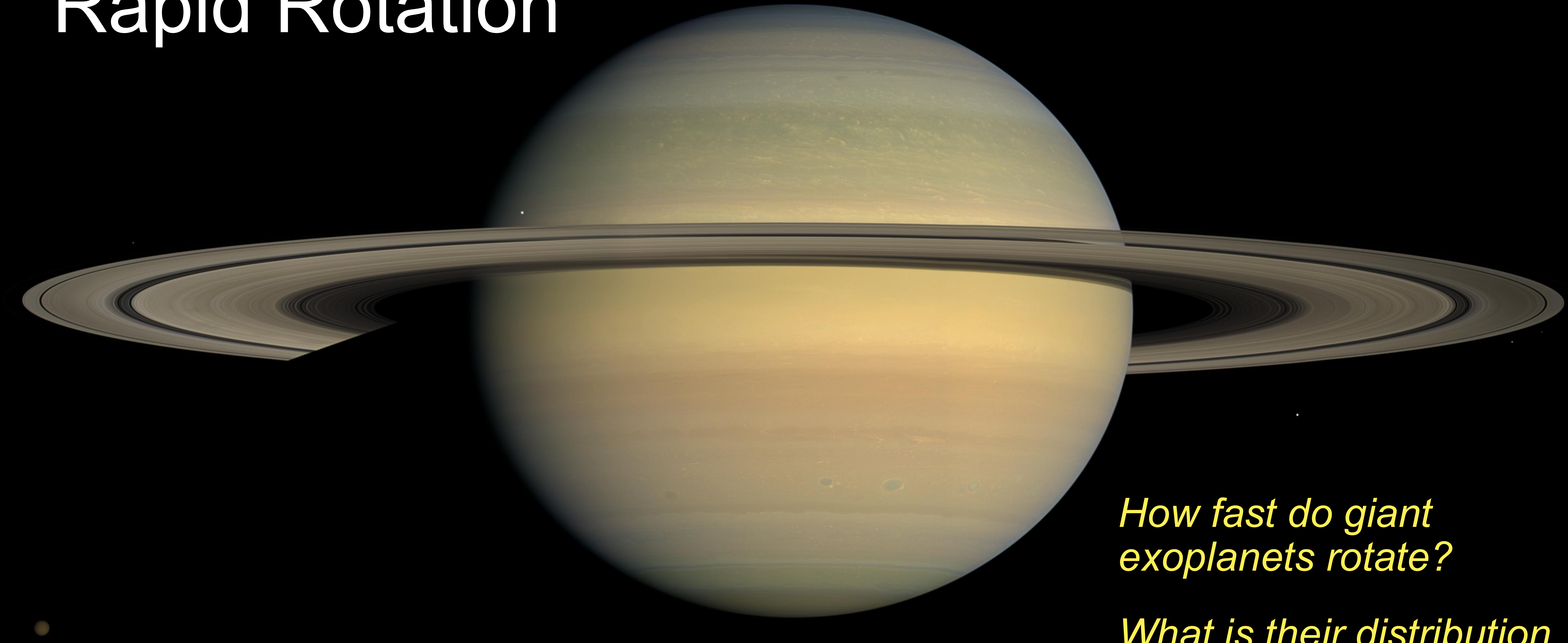
Rapid Rotation



How fast do giant exoplanets rotate?

Scientific advances with long-period planets

Rapid Rotation



How fast do giant exoplanets rotate?

What is their distribution of obliquities?

Lammers & Winn (2024)

See also: Seager & Hui (2002), Barnes & Fortney (2003)

Requirements:

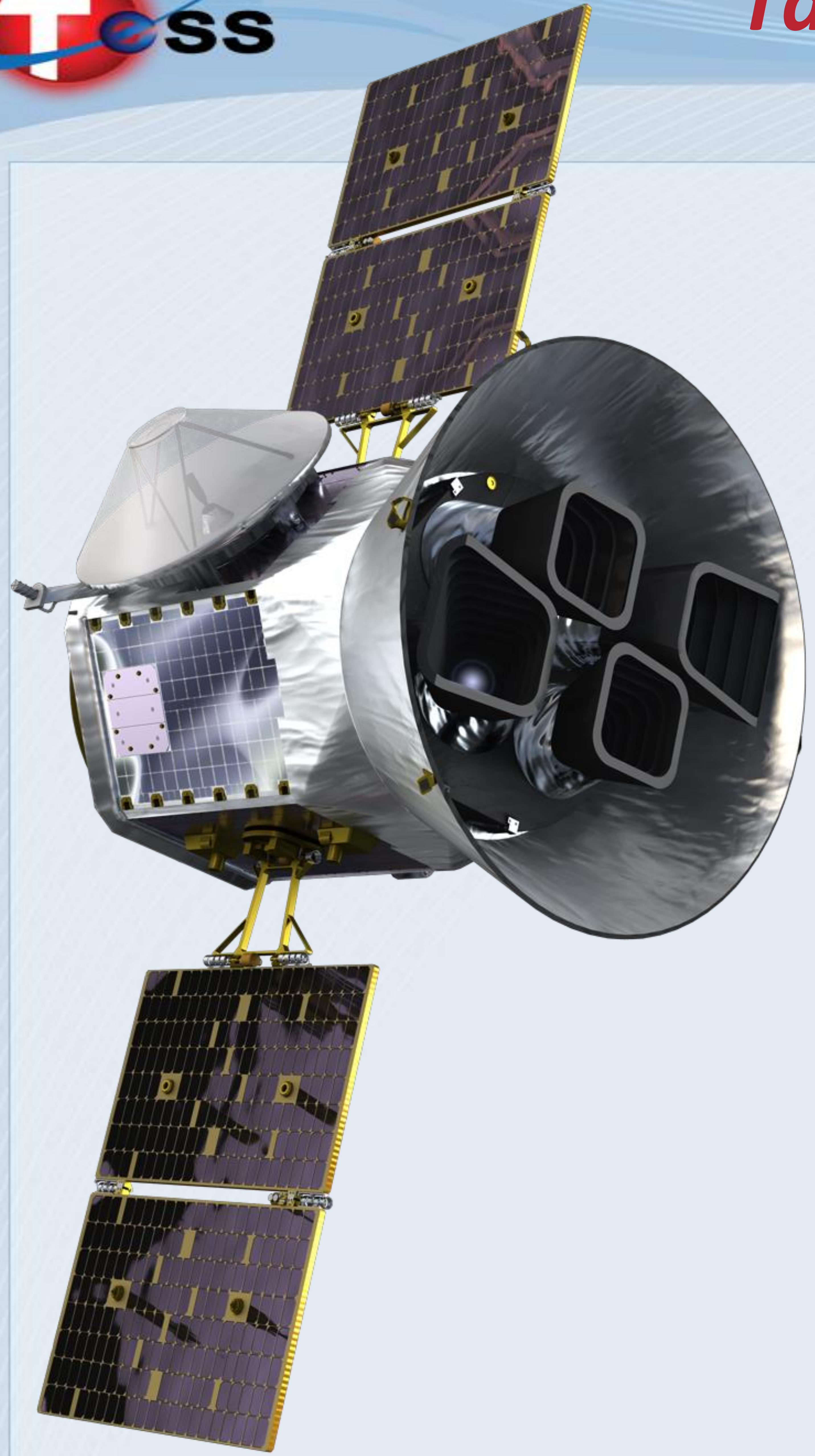
- Precision of ~100 ppm in 1 min ✔ JWST
- Transiting giant planet with $P \gtrsim 60$ days ✔ TESS

Lammers & Winn (2024)

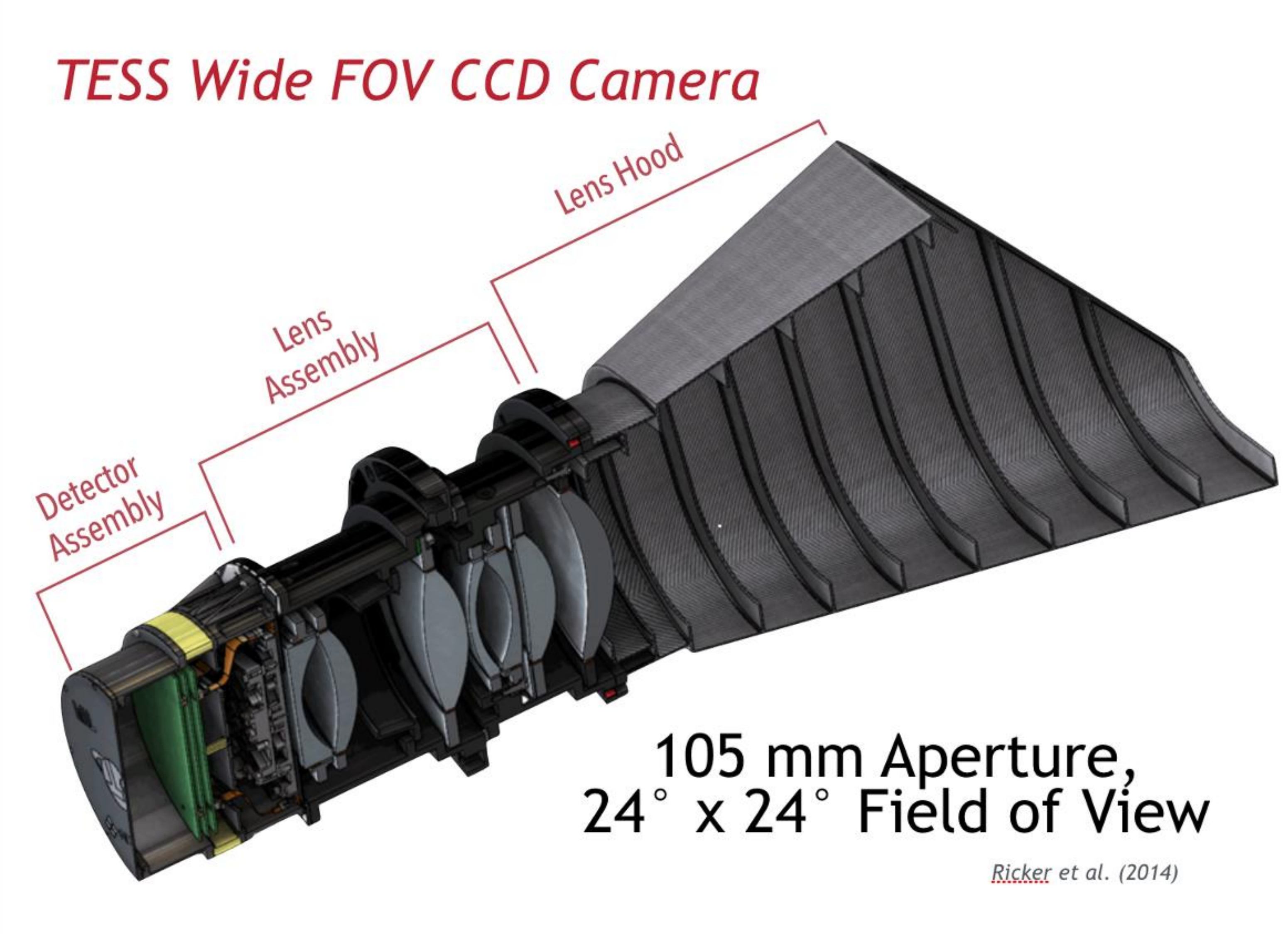
See also: Seager & Hui (2002), Barnes & Fortney (2003)

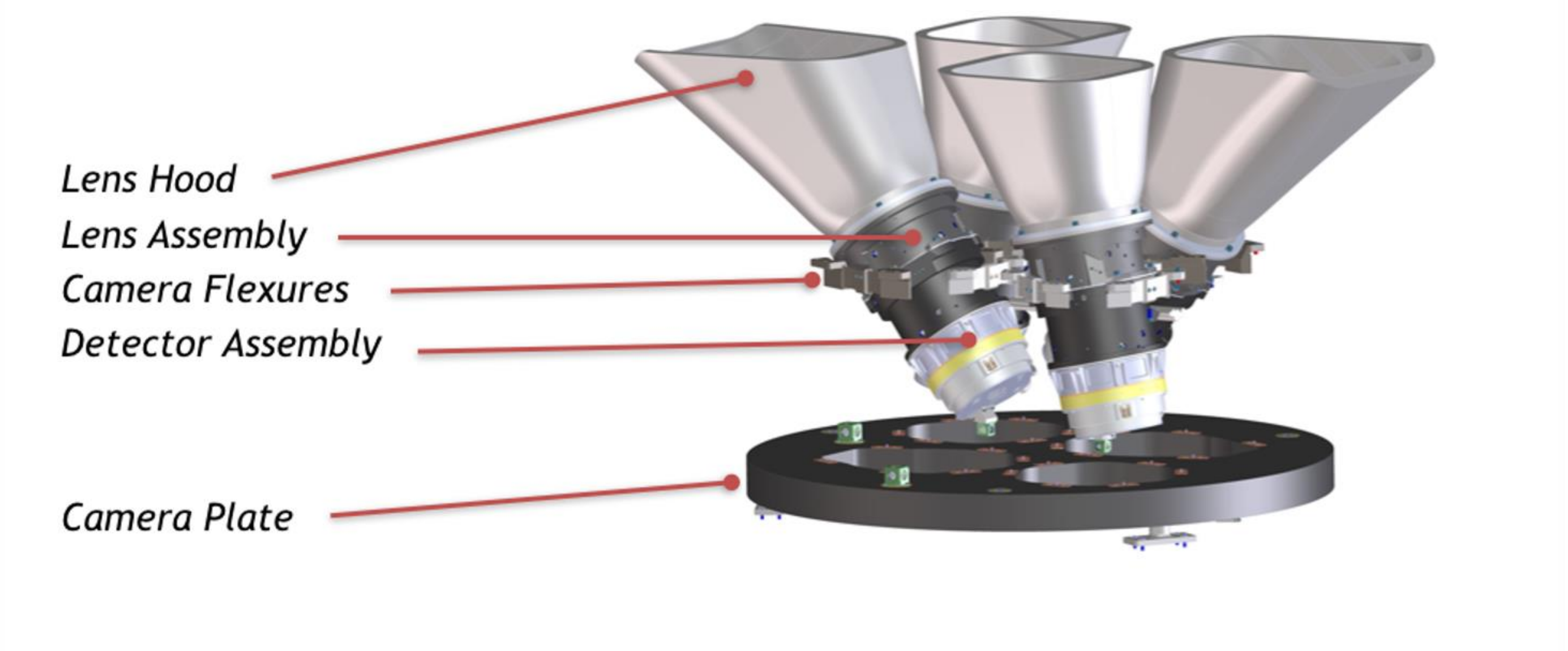

simulated JWST-NIRISS/SOSS
observation of TOI-199 b
Δ flux [ppm]
100
50
0
−50
−100
−150
0
2
4
6
8
10
Time [hours]

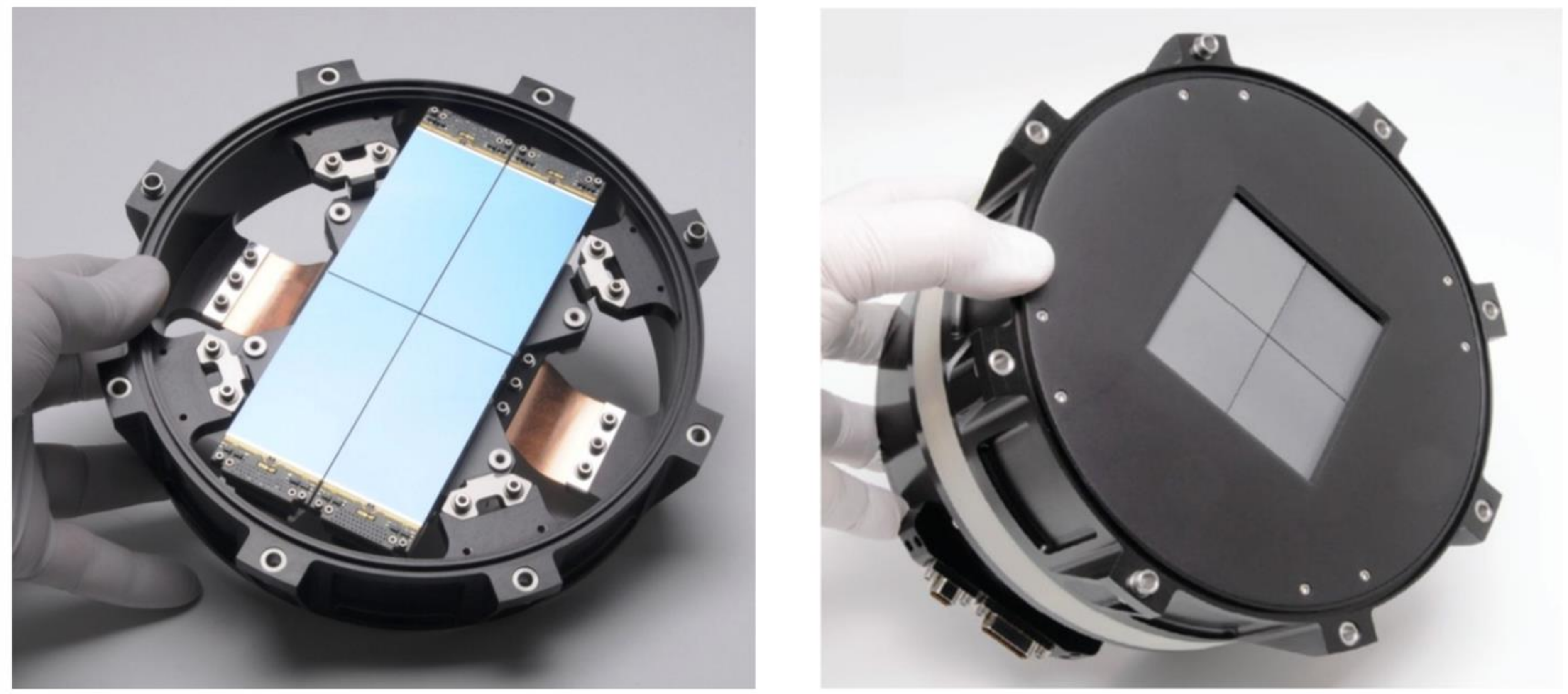
Takeaways: TESS's Science Mission Accomplishments

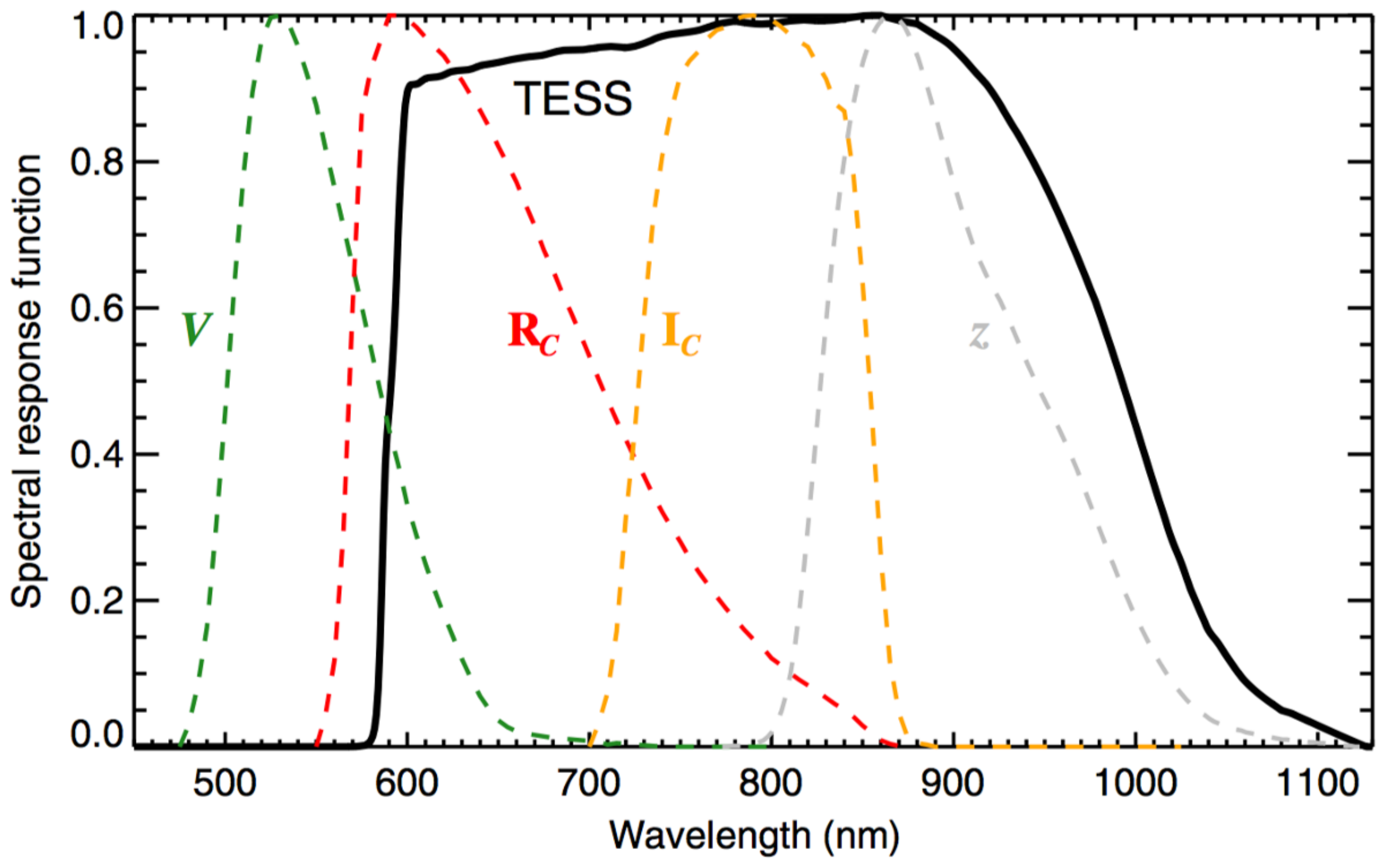


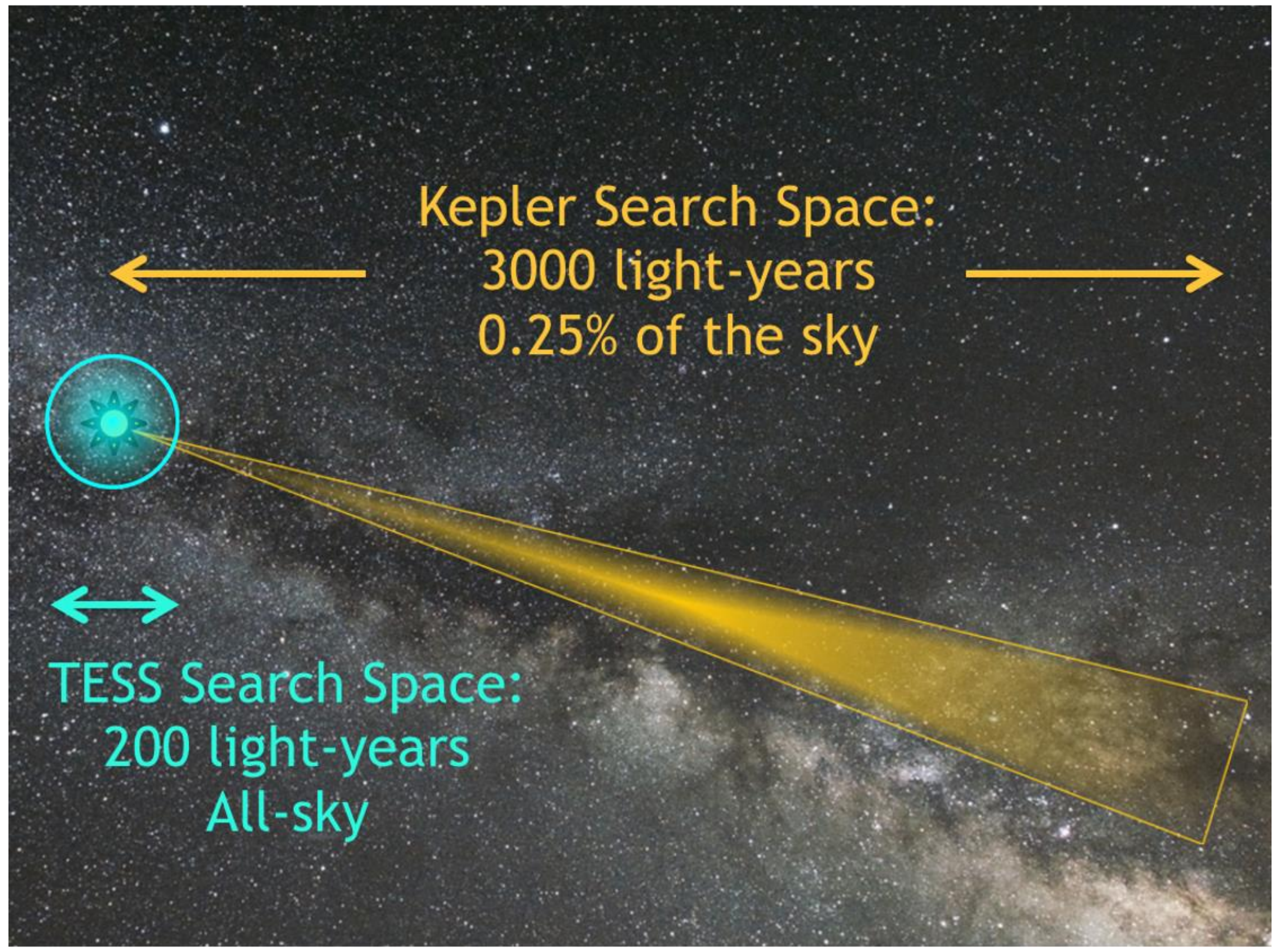
- TESS's unique lunar resonant orbit greatly simplifies the mission
  - *Stable operations in principle could last until 2038 or later*
- TESS's spacecraft long-term pointing precision is unique
  - *~ 20 milli-arcseconds (**1/1000th pixel**) on 1 hour time scales*
- TESS's camera performance continues to be superb
  - *Focus is stable to ~1µm on 1 hour time scales*
  - *Photometric precision is ~10-15 ppm (**~5x better than planned**) for bright stars*
  - *Achieves stacked FFI limiting magnitudes I_{mag} ~ +20*
- TESS's full frame images and 20s "postage stamps" continue to enable a wide range of astrophysics discoveries
  - ***Rich trove of high-value exoplanet targets for future missions, including PLATO, Ariel, and HWO***
  - ***Transient Science: Stellar Astrophysics, "TDAMM"***
  - ***"Precovery" galactic/extragalactic transient observations are routine***


TESS Wide FOV CCD Camera
Lens Hood
Lens Assembly
Detector Assembly
105 mm Aperture,
24° x 24° Field of View
Ricker et al. (2014)


Lens Hood
Lens Assembly
Camera Flexures
Detector Assembly
Camera Plate




TESS
V
R_C
I_C
z
Spectral response function
Wavelength (nm)
0.0
0.2
0.4
0.6
0.8
1.0
500
600
700
800
900
1000
1100


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

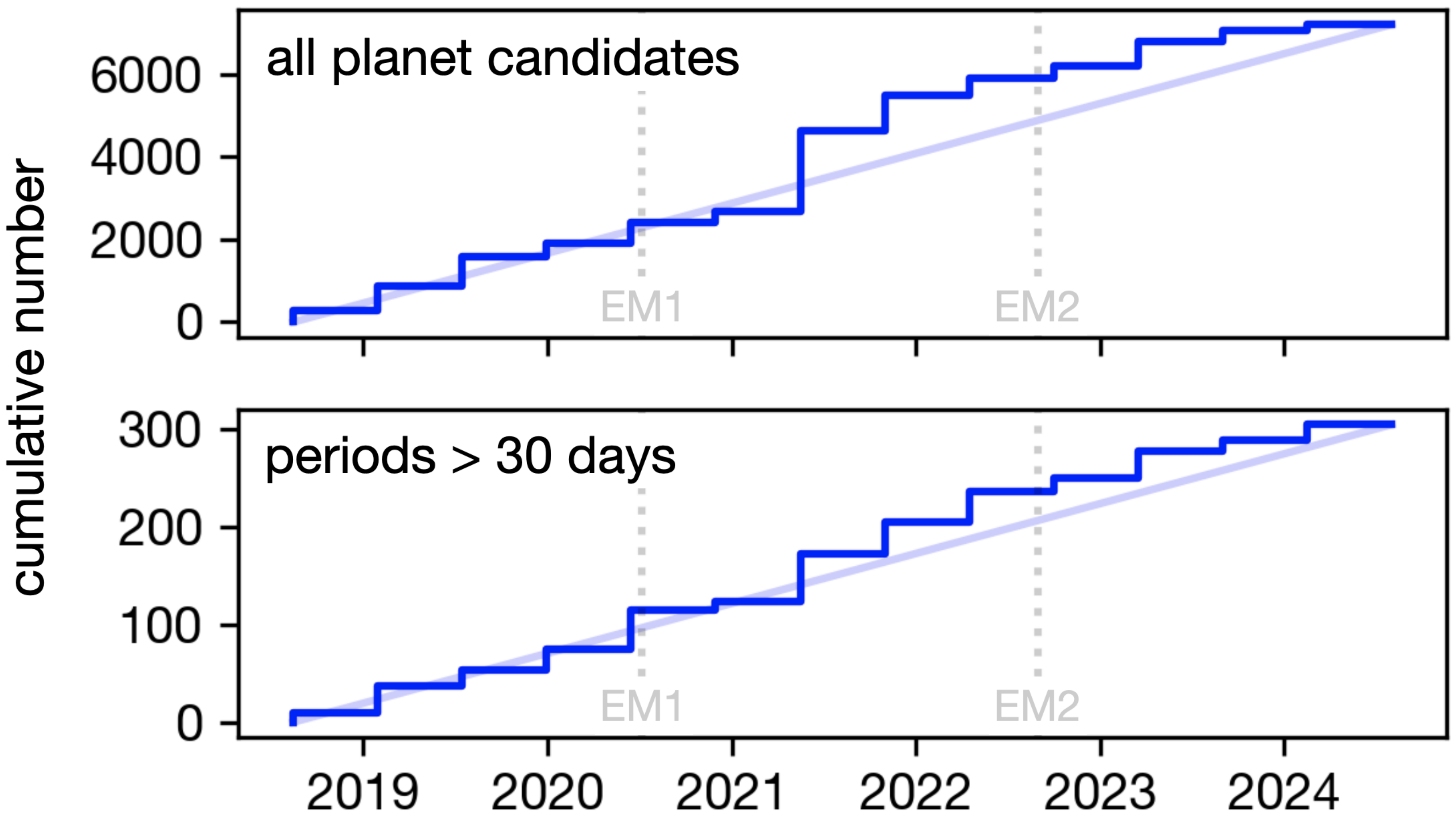
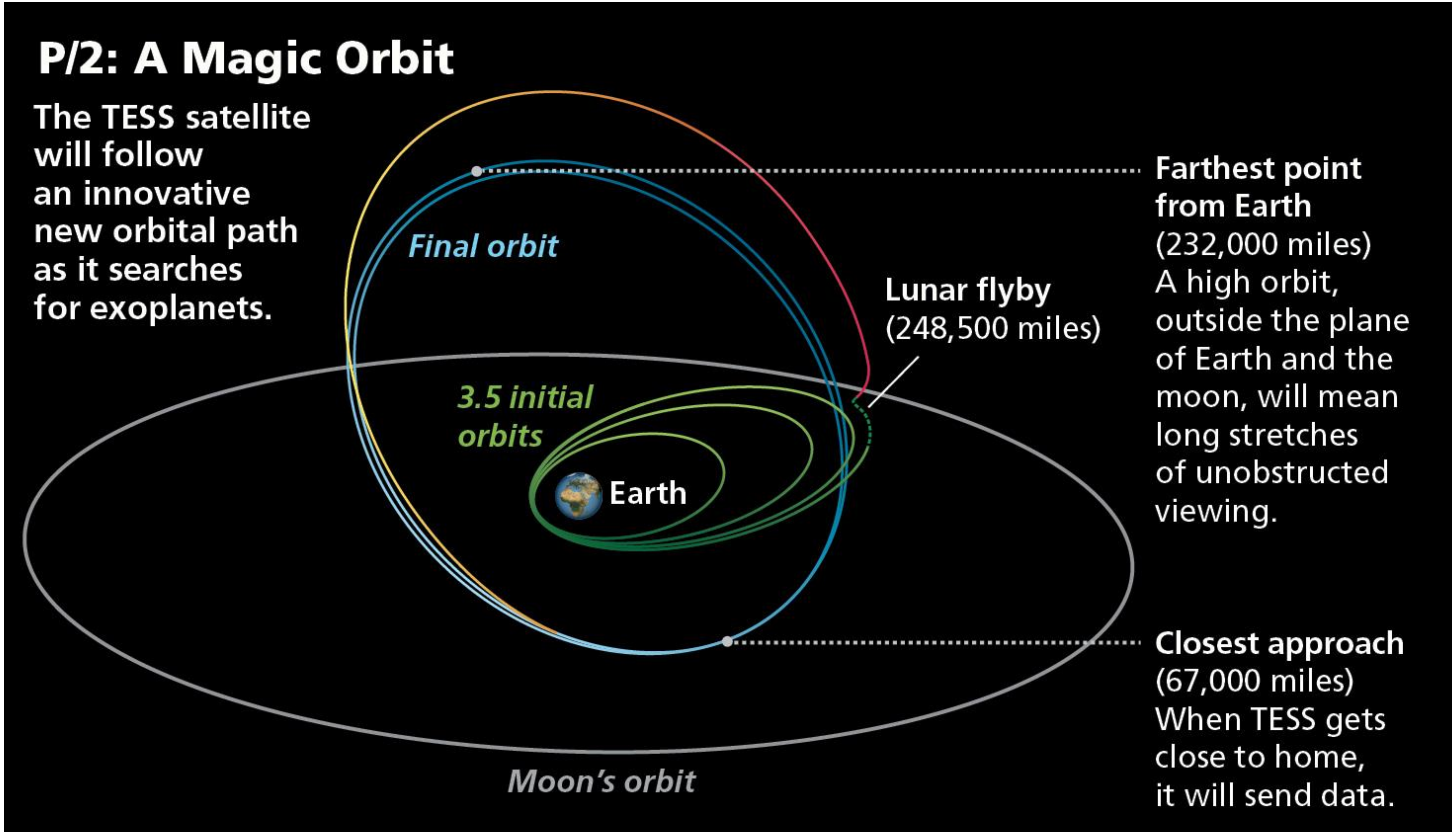
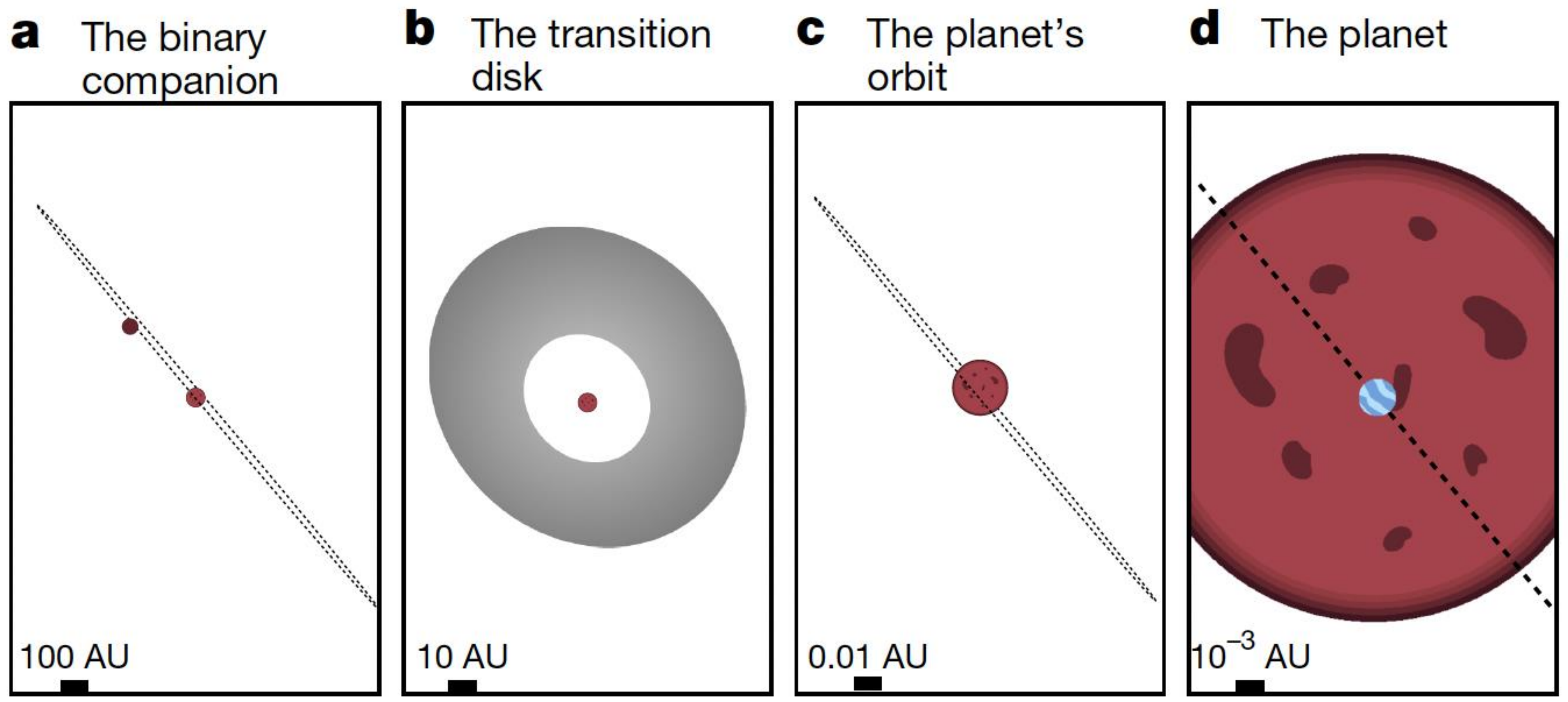


Figure credit: J. Winn


P/2: A Magic Orbit
The TESS satellite will follow an innovative new orbital path as it searches for exoplanets.
Final orbit
3.5 initial orbits
Earth
Moon's orbit
Lunar flyby (248,500 miles)
Farthest point from Earth (232,000 miles) A high orbit, outside the plane of Earth and the moon, will mean long stretches of unobstructed viewing.
Closest approach (67,000 miles) When TESS gets close to home, it will send data.

TESS finds unusual and interesting planets

- The youngest known transiting planet (Barber+ 2024)
- A young system of 6 resonant sub-Neptunes (Luque+ 2023)
- A giant planet that has somehow avoided stellar engulfment (8 UMi; Hon+ 2023)



Barber et al. 2024