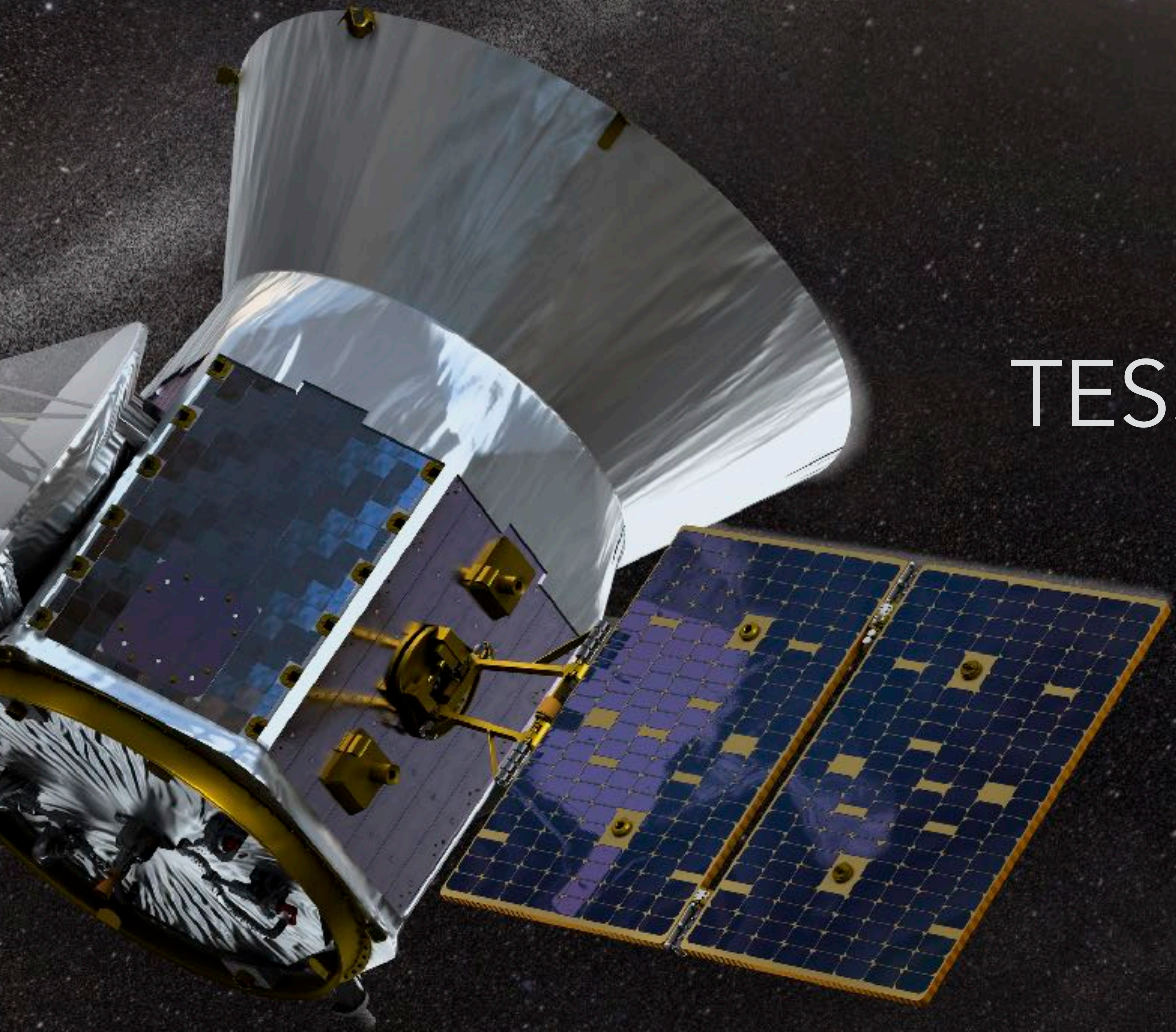


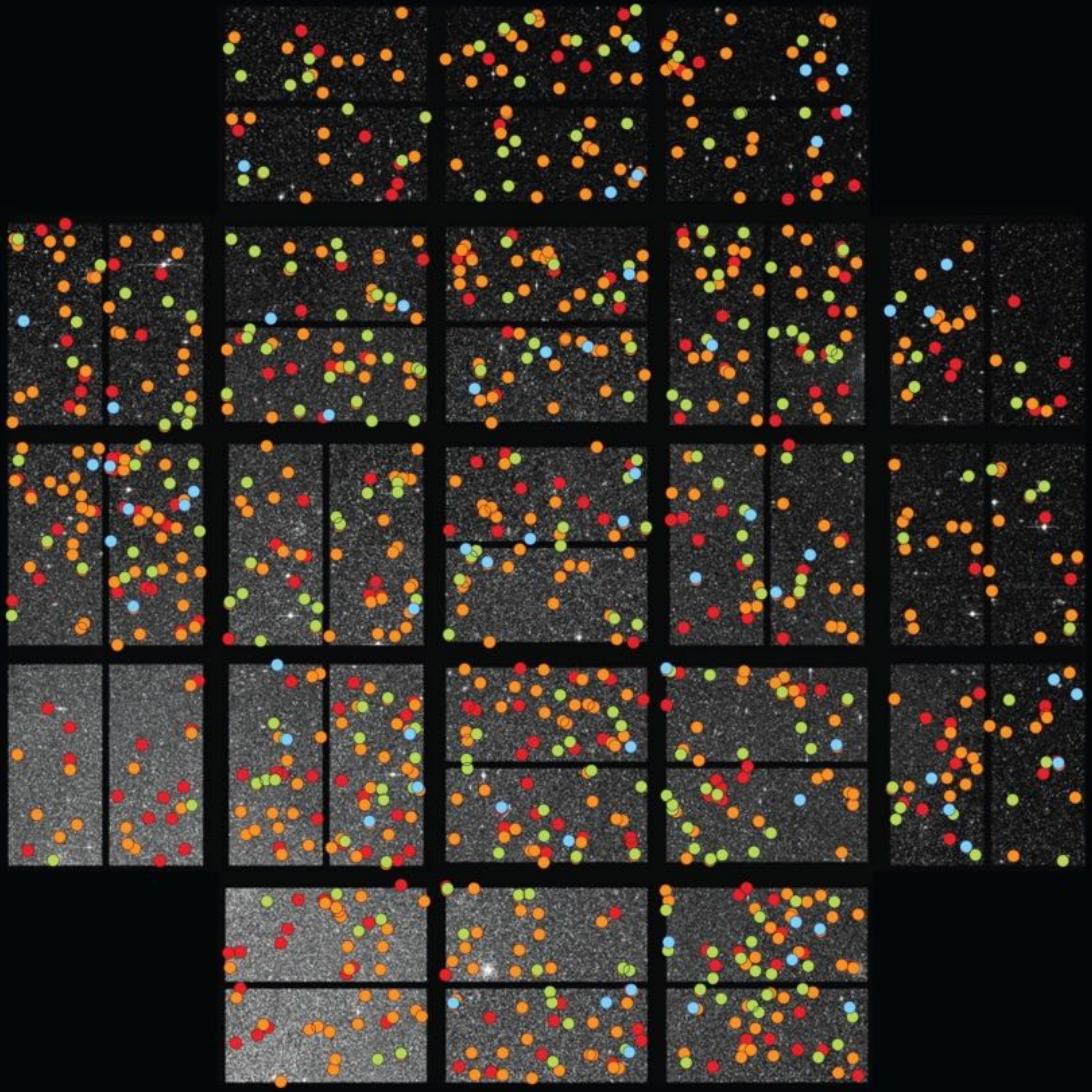
TESS: Transiting Exoplanet Survey Satellite

Elisa Quintana
NASA Goddard Space Flight Center
Sagan Workshop July 23, 2018


George Ricker (P.I.)
TESS Science Office
MIT + Harvard/Smithsonian CfA
TESS Project Management
TESS Science Support Center (GI Office)
NASA Goddard
Data Archive
STScI MAST
NASA

Kepler Mission (2009-2013)

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



Earth-size

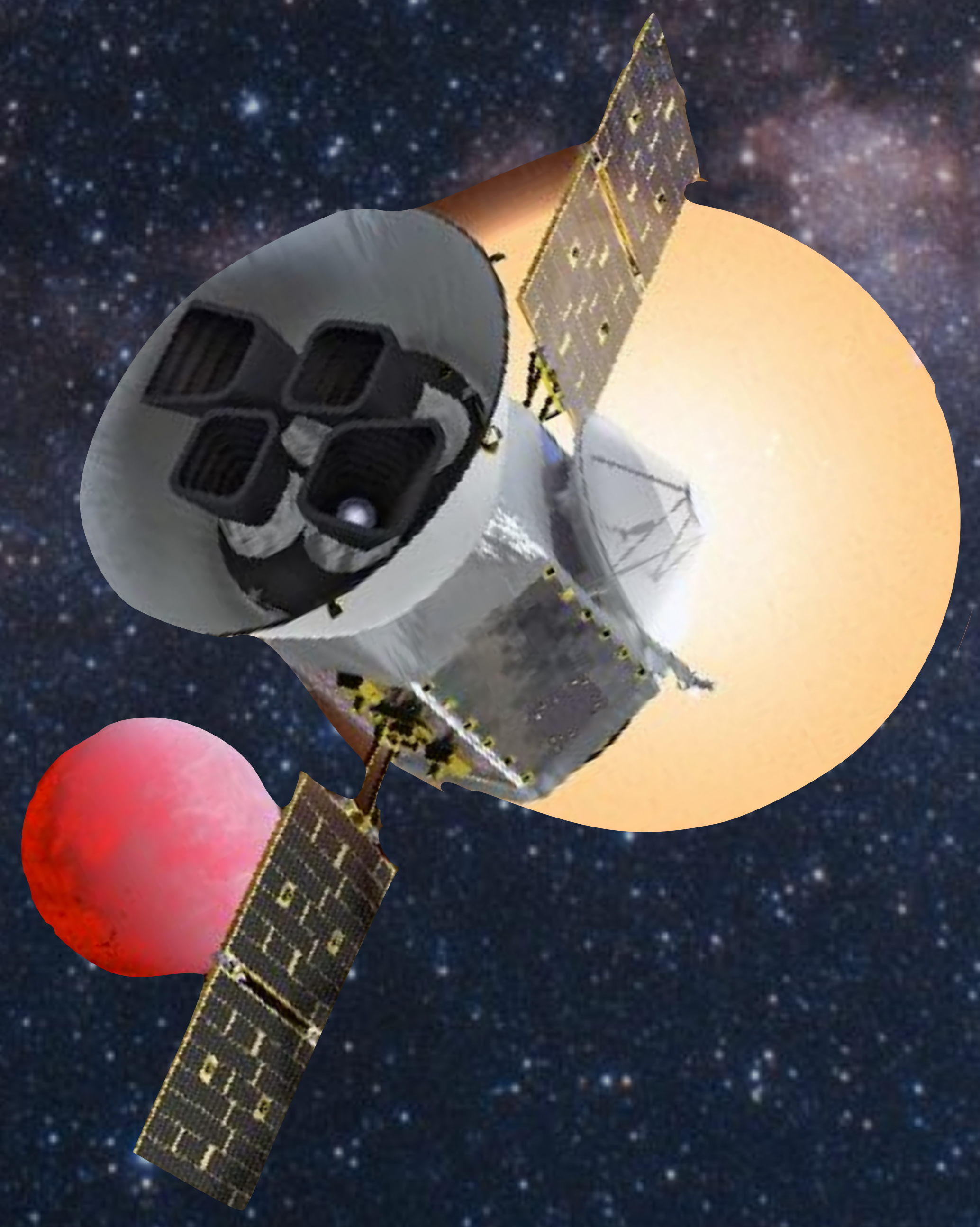
Super-Earth size
1.25 - 2.0 Earth-size

Neptune-size
2.0 - 6.0 Earth-size

Giant-planet size
6.0 - 22 Earth-size

TESS Mission (2018+)

Search for small planets around nearby stars that are easier to study

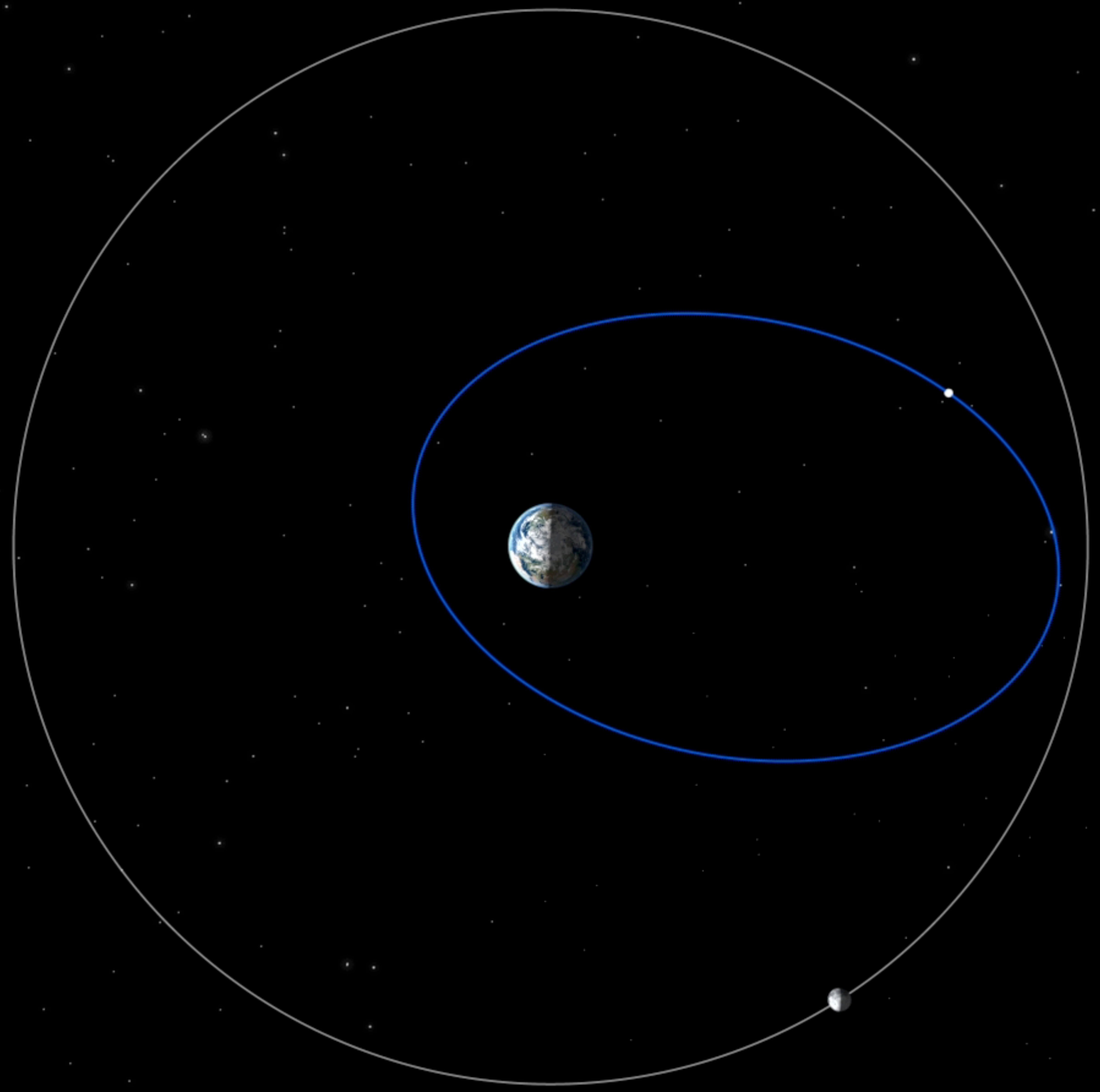


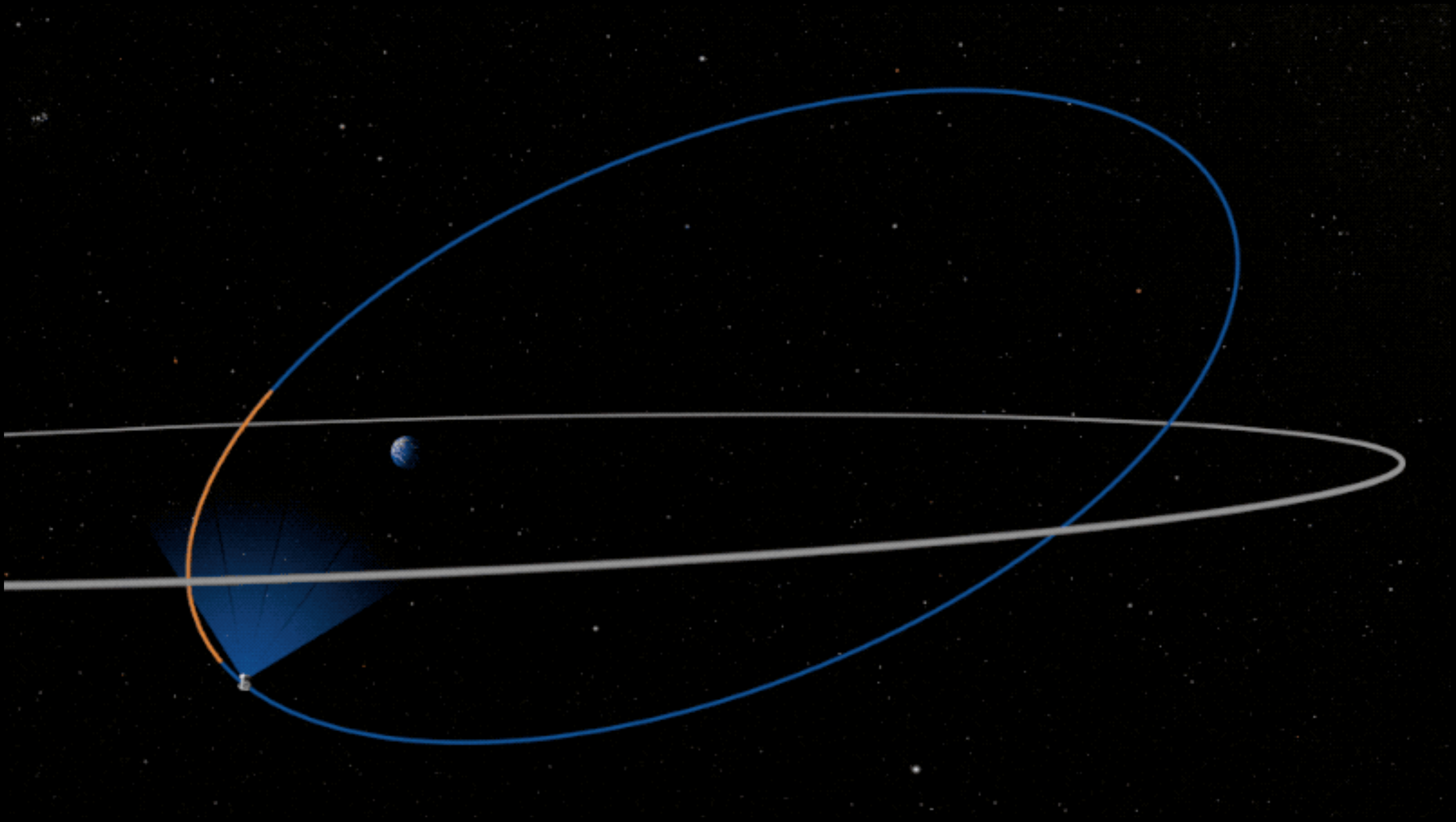
TESS launched on

April 18!

on a SpaceX Falcon 9.

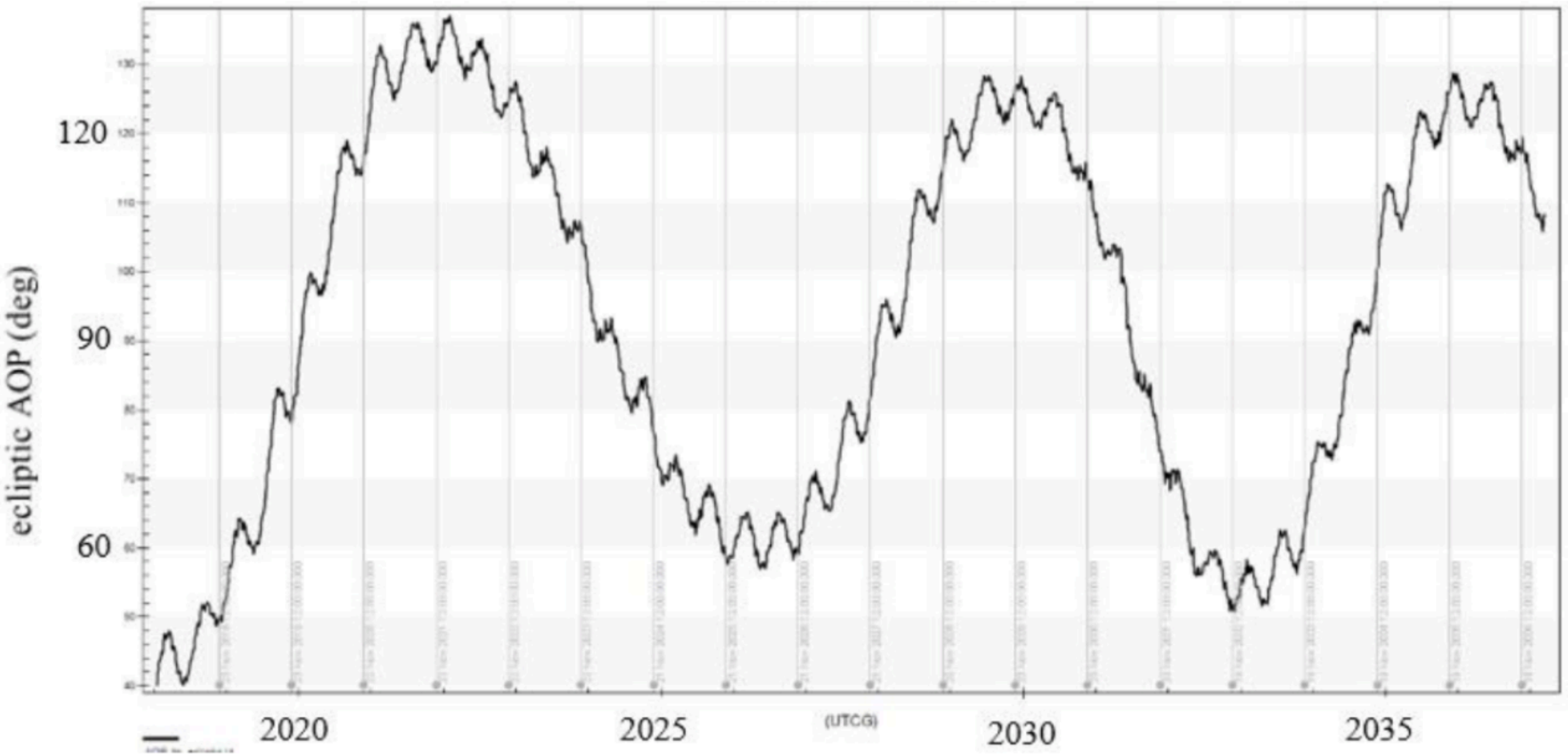
2 to 1 RESONANCE WITH THE MOON





TESS Science Orbit Dynamics

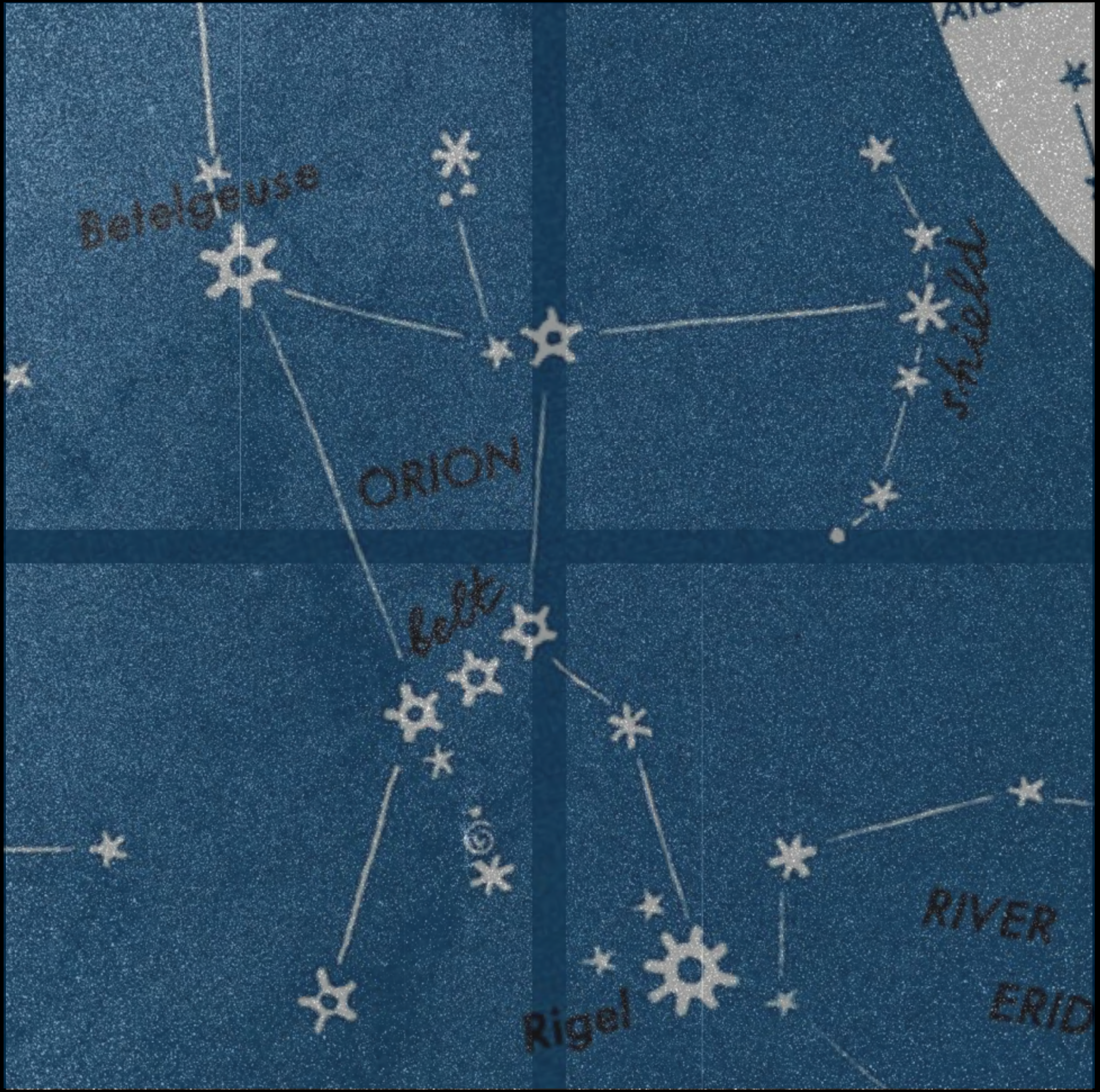
For highly eccentric orbit it is known that eccentricity and inclination oscillate together, as described by the Kozai mechanism



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

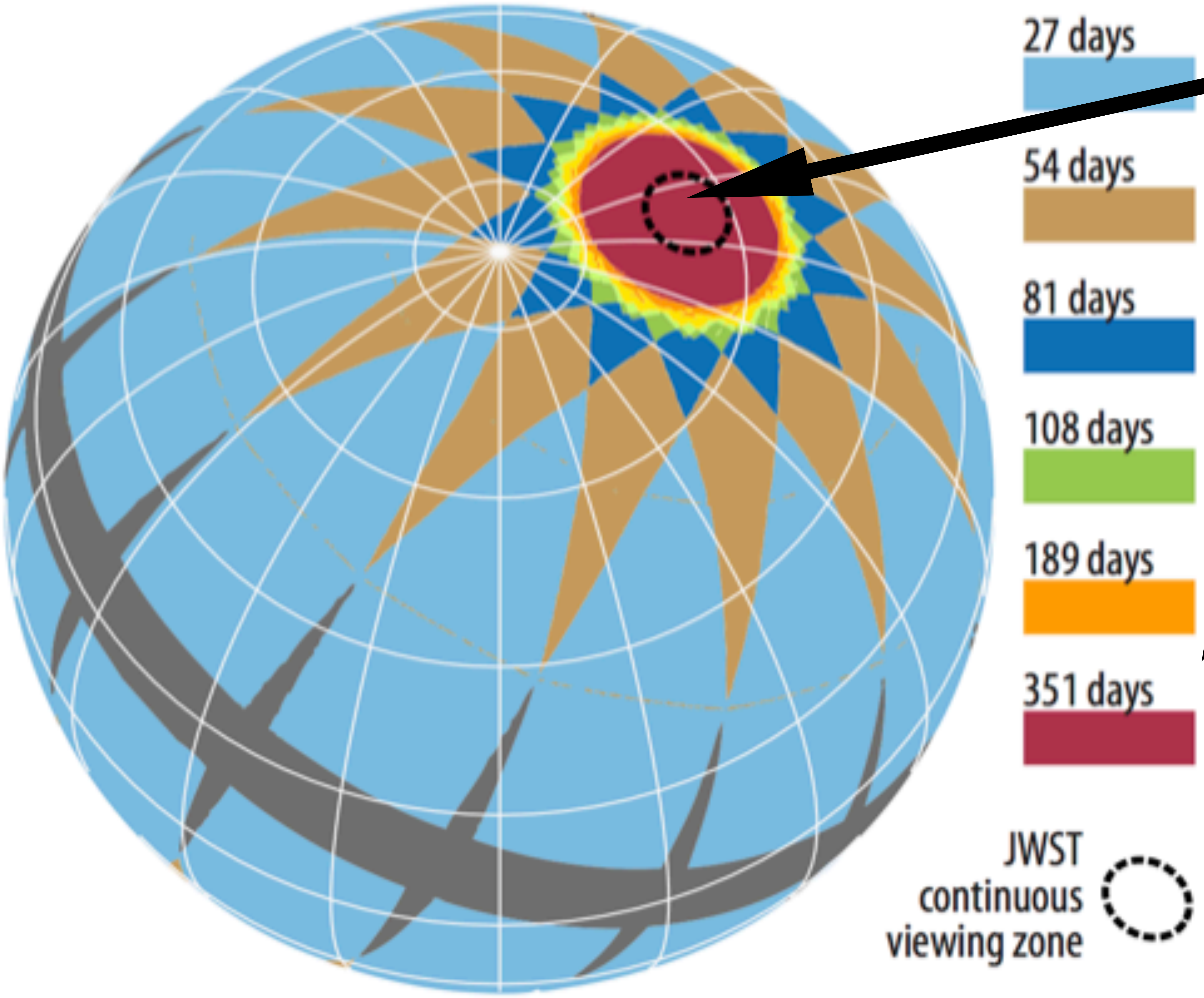
FOV from one TESS camera:

24°



constellations by H. A. Rey


CAMERA 1

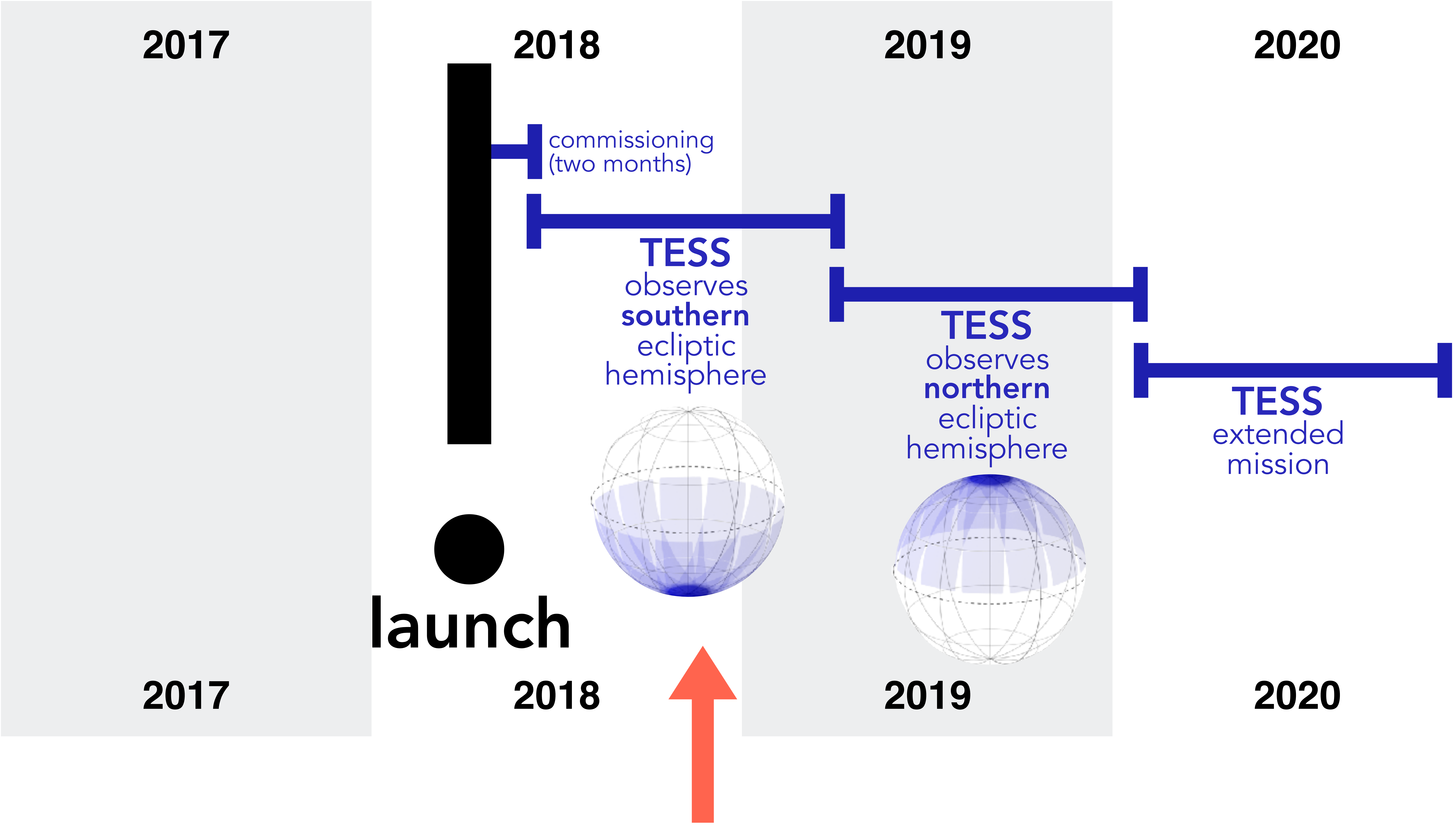


High Value Planets

Long baseline

Overlap with Webb

TESS timeline:



Sectors 1-4 released L+6 mo

slide courtesy Zach Berta-Thompson

Kepler vs TESS

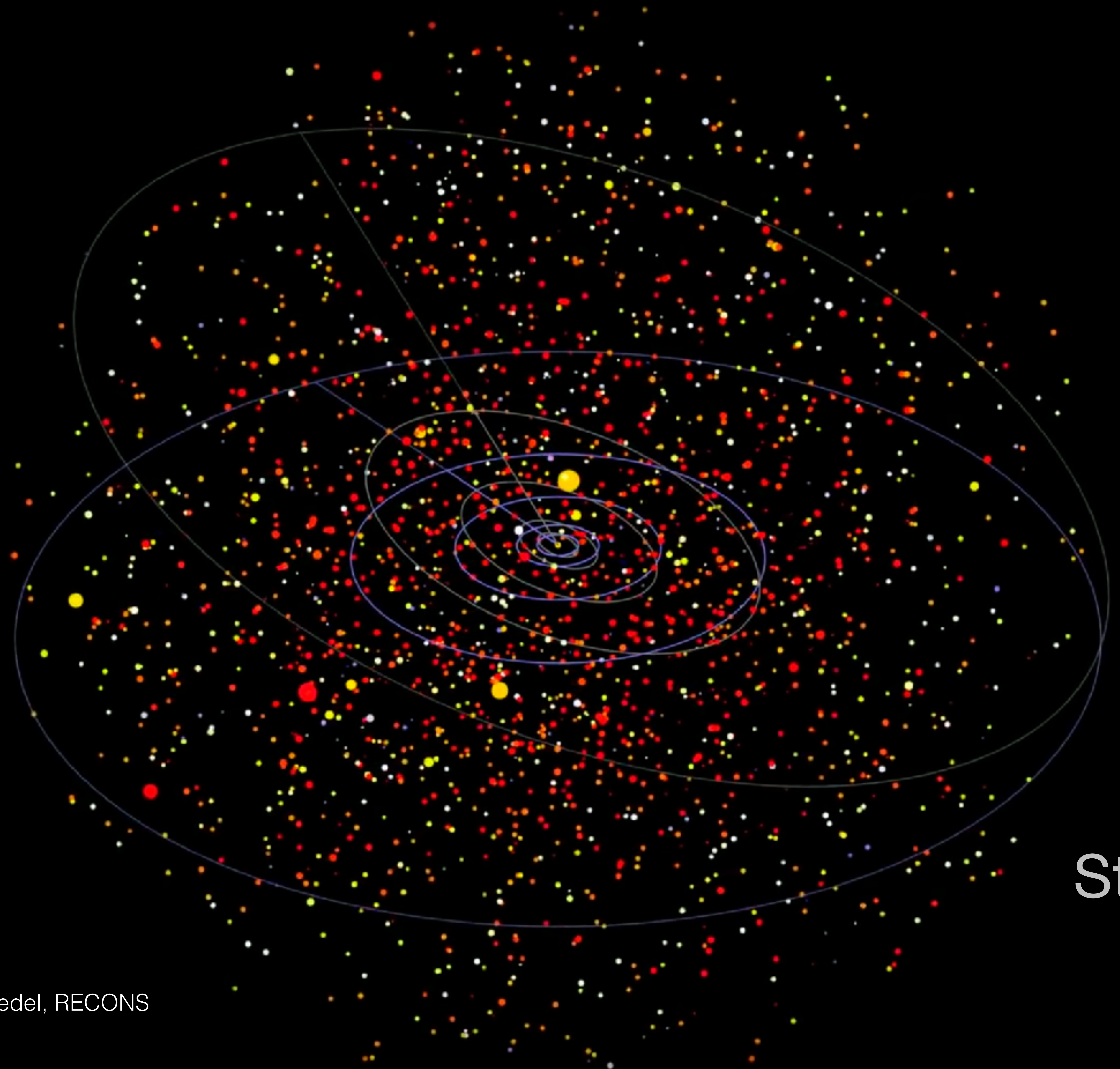
Kepler vs TESS

	TESS	Kepler
Pixel Size	21 arcsec	4 arcsec
Baseline	27 - 351 days	4 yrs, 80 d for K2
Single CCD	2048 x 2048	Two 2200 x 1024
Num CCDs	16	21 CCDs
Wavelength	600-1100 nm	400-900 nm

These are the Stars in the Neighborhood

Legend:

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

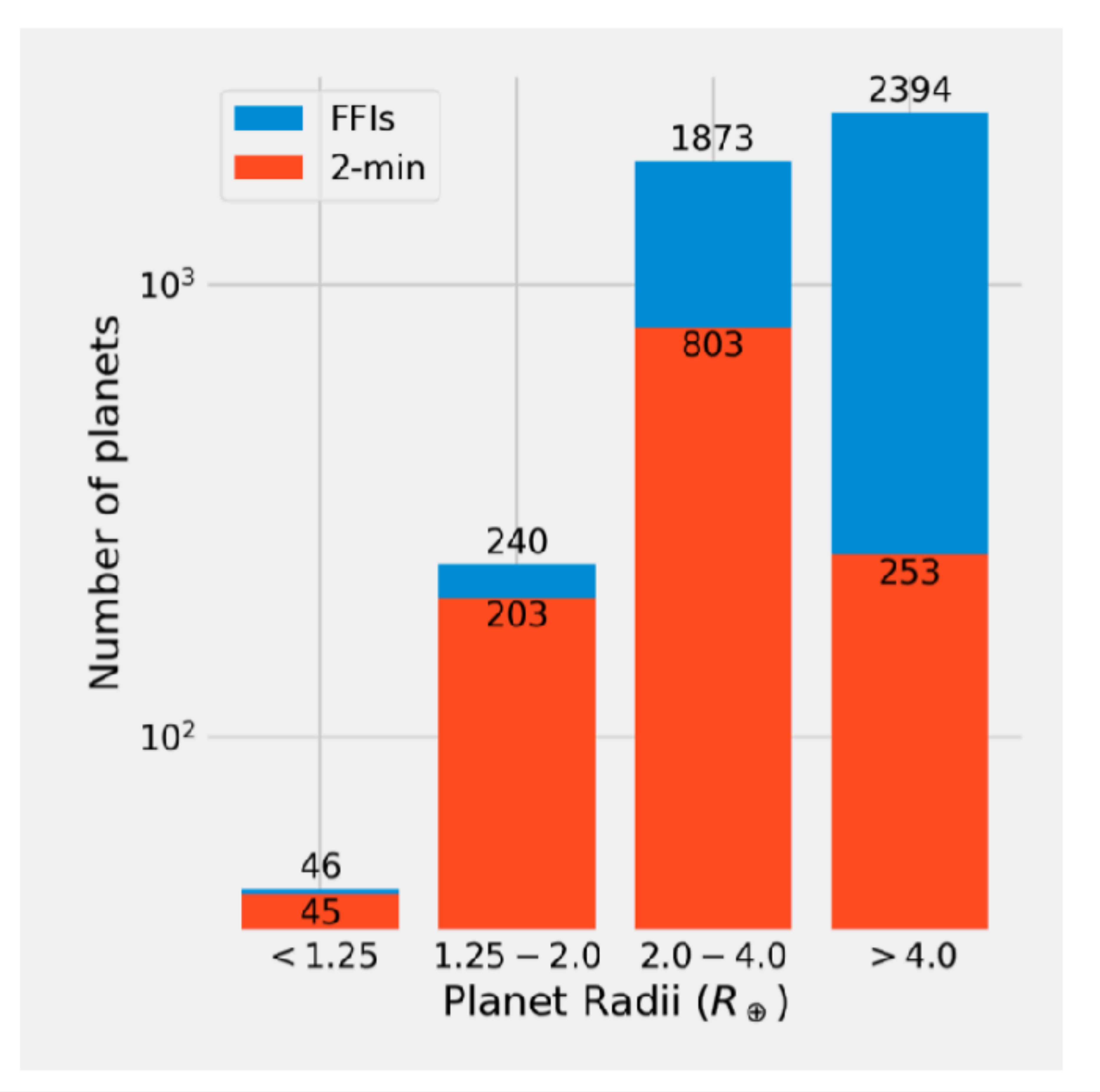


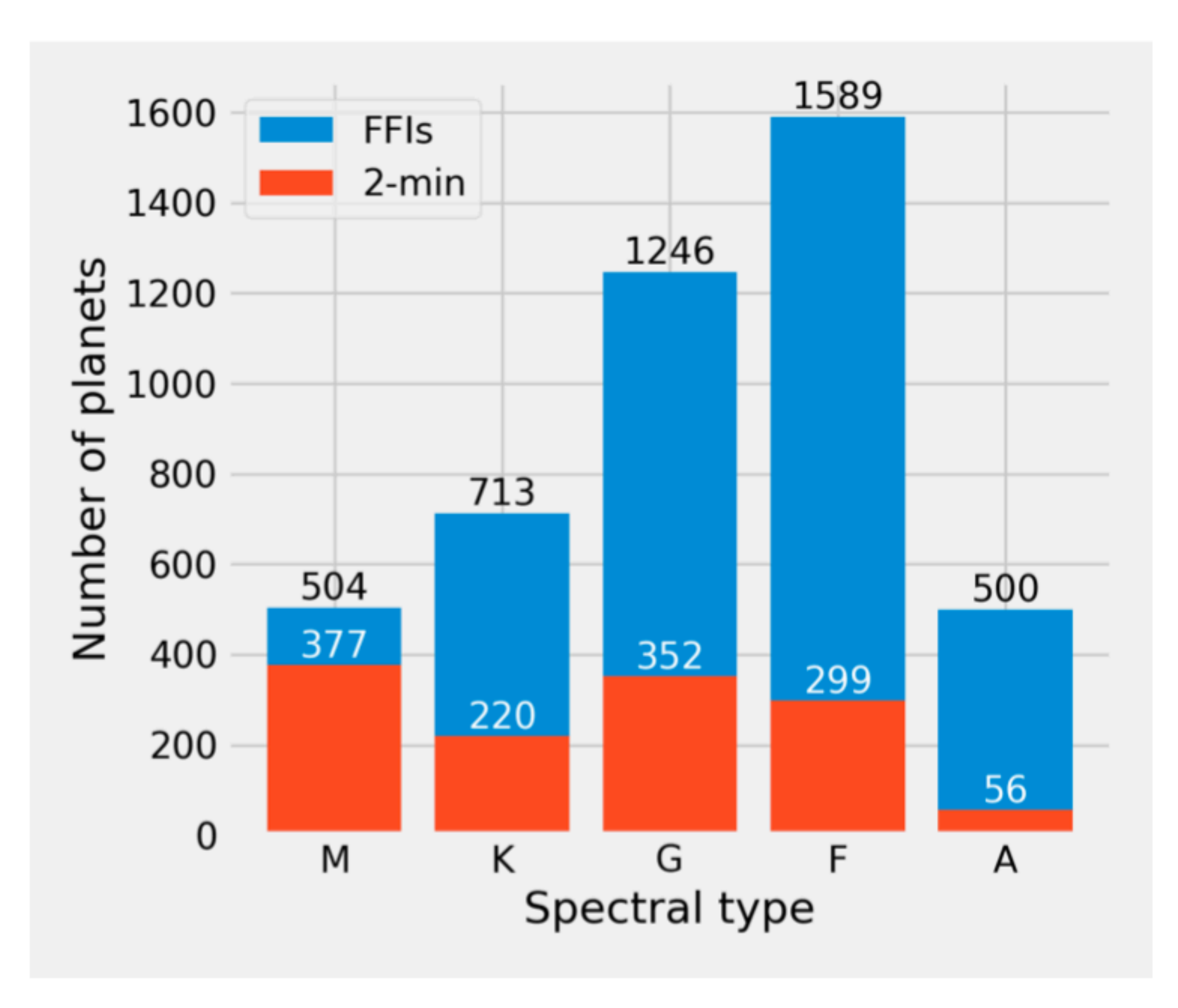
Stars within 80 light years of Sun

image credit: A. Riedel, RECONS

First Test Image!

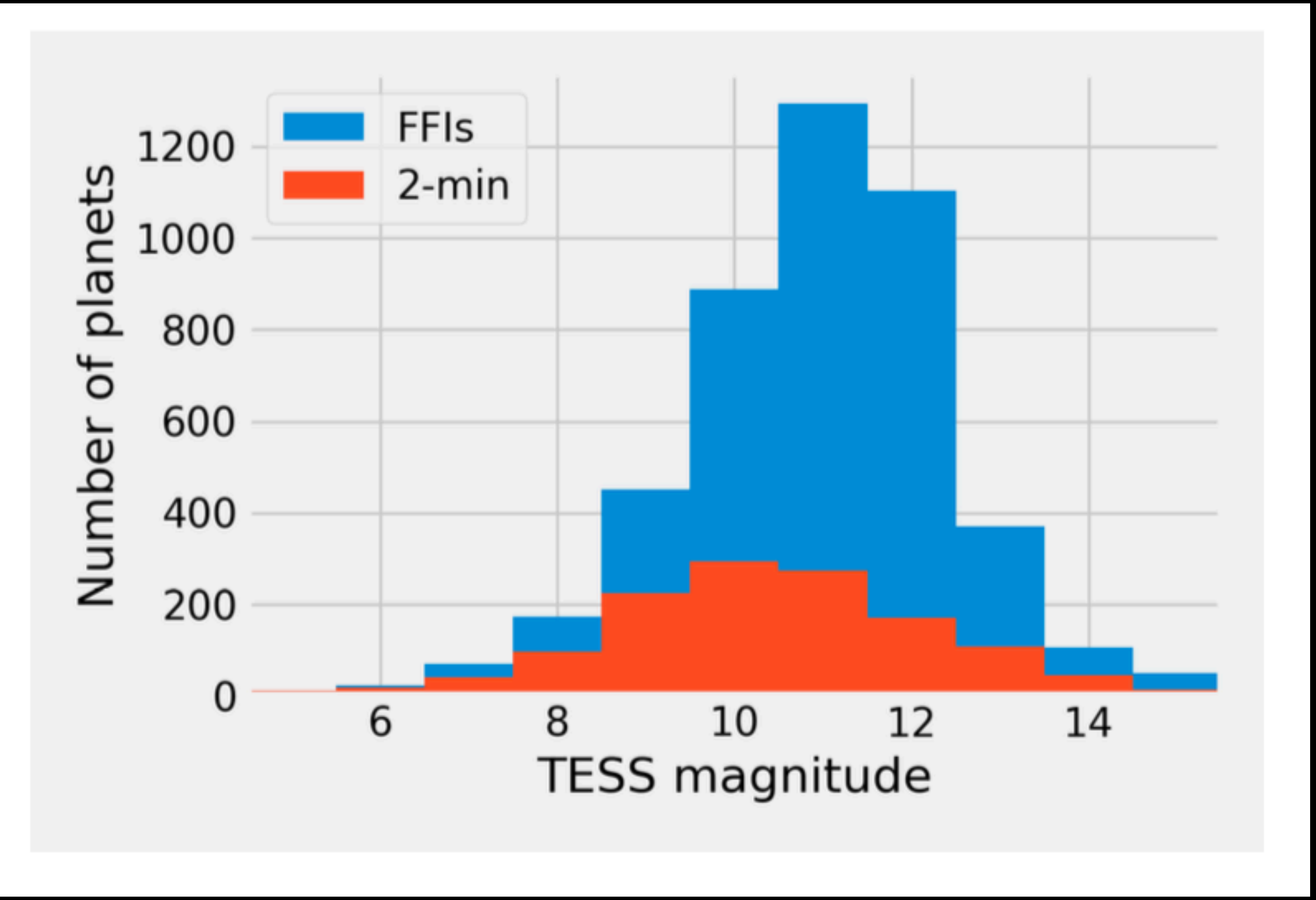
What will TESS find?

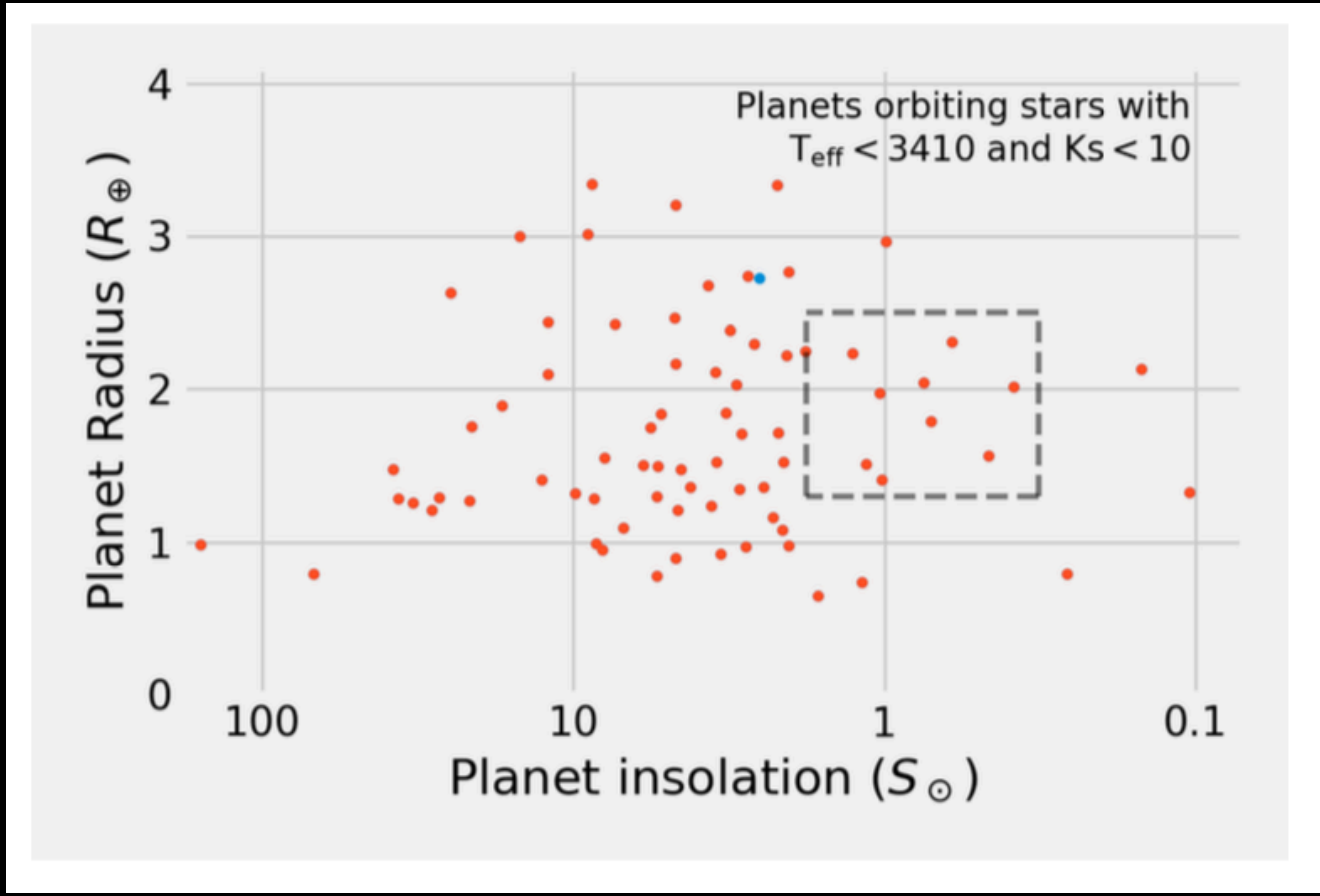




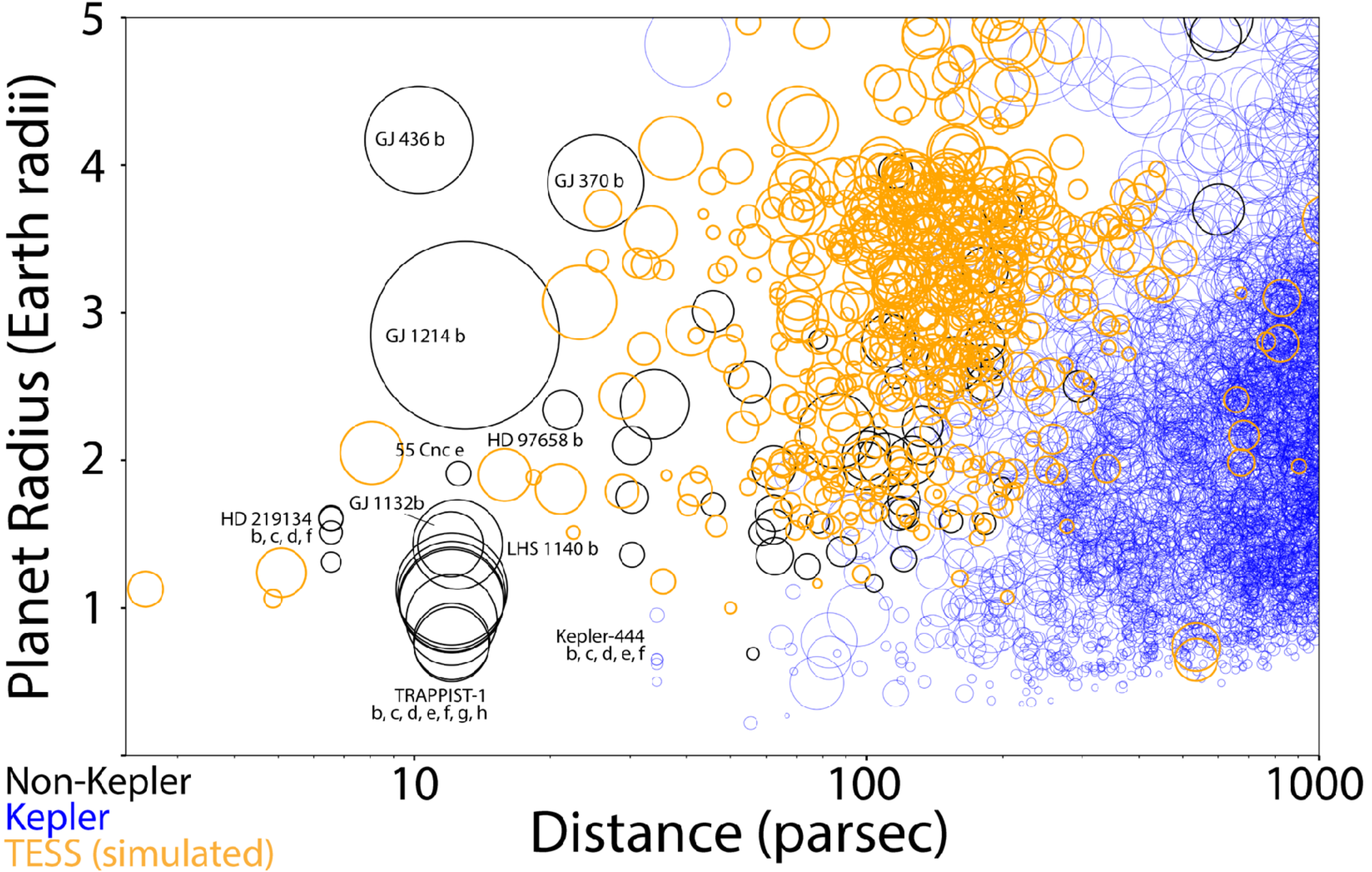
Barclay et al. in prep

What will TESS find?



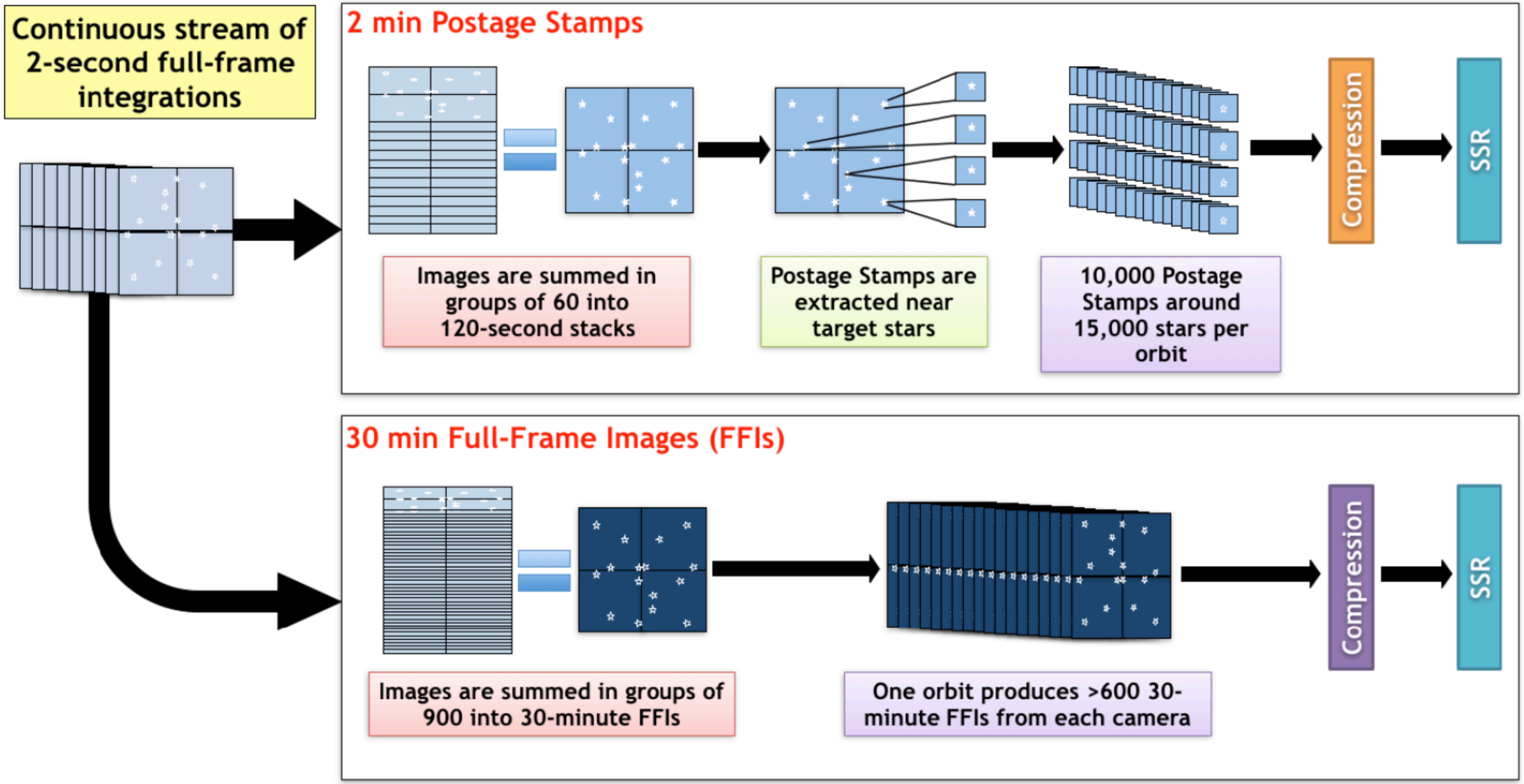


Barclay et al. in prep



5
4
3
2
1
Planet Radius (Earth radii)
GJ 436 b
GJ 370 b
GJ 1214 b
HD 97658 b
55 Cnc e
GJ 1132b
HD 219134
b, c, d, f
LHS 1140 b
Kepler-444
b, c, d, e, f
TRAPPIST-1
b, c, d, e, f, g, h
10
100
1000
Distance (parsec)
Non-Kepler
Kepler
TESS (simulated)

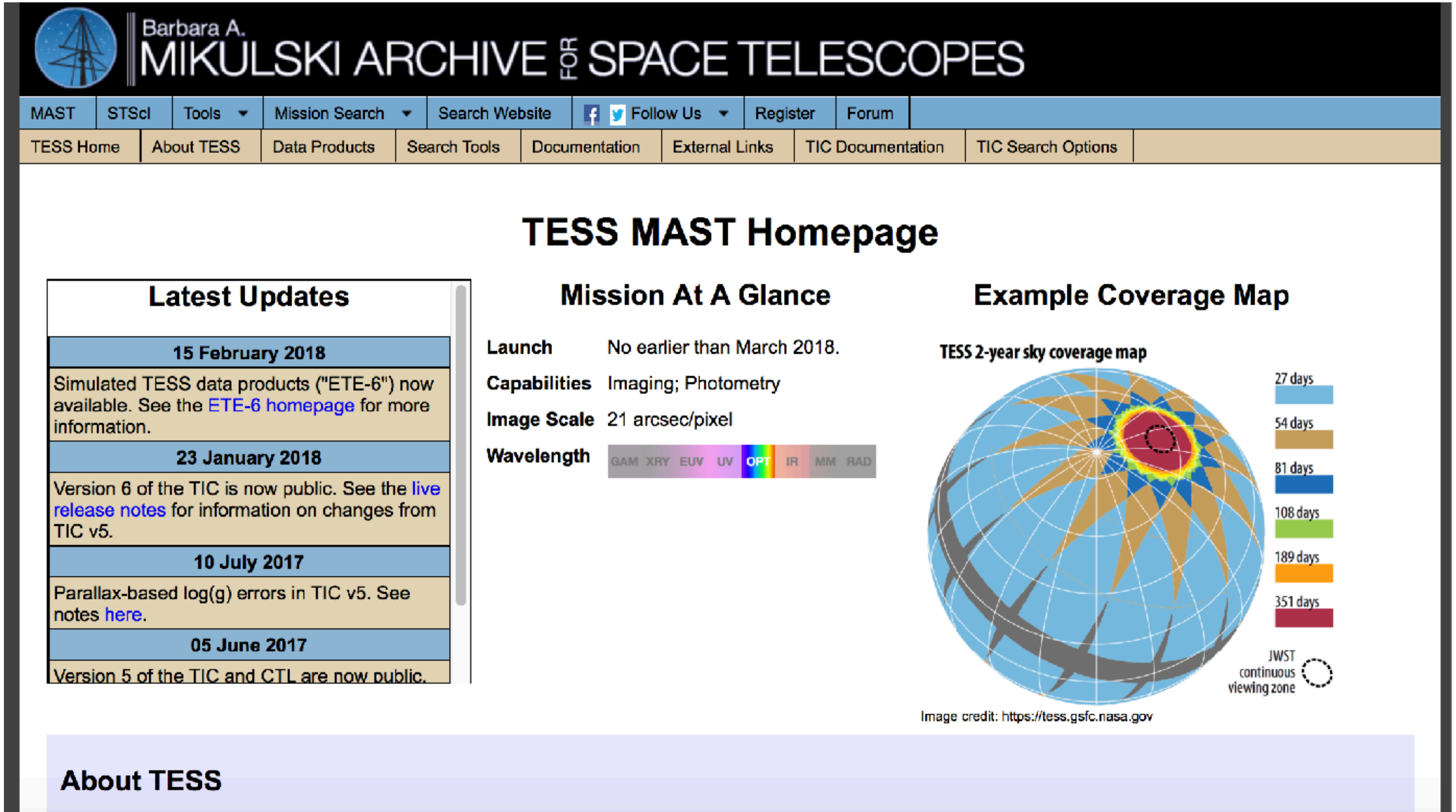
Lots of Data!



Continuous stream of 2-second full-frame integrations
2 min Postage Stamps
Images are summed in groups of 60 into 120-second stacks
Postage Stamps are extracted near target stars
10,000 Postage Stamps around 15,000 stars per orbit
Compression
SSR
30 min Full-Frame Images (FFIs)
Images are summed in groups of 900 into 30-minute FFIs
One orbit produces >600 30-minute FFIs from each camera
Compression
SSR

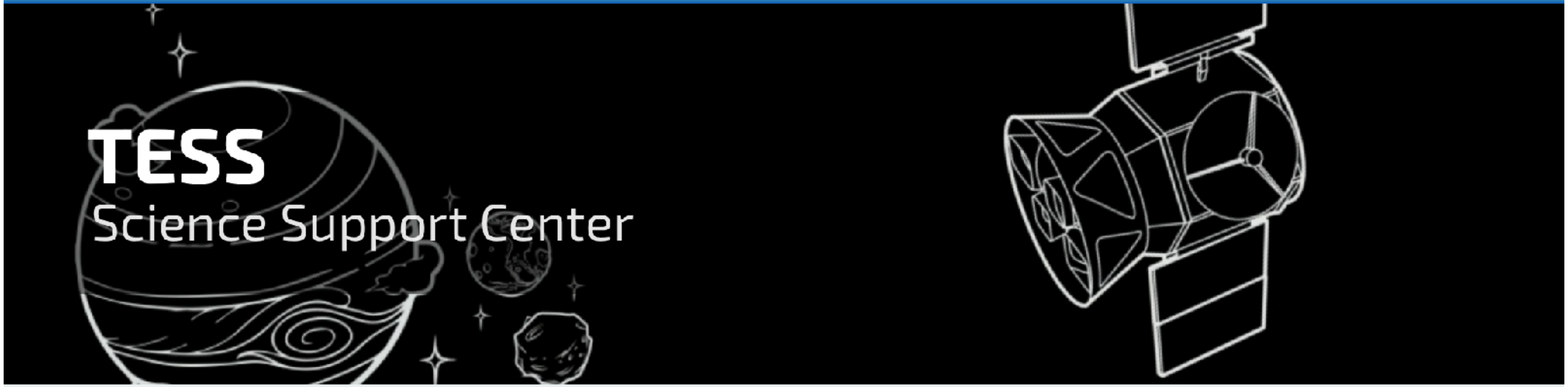
MAST (archive.stsci.edu/tess)

The official archive for TESS mission data products is the Mikulski Archive for Space Telescopes (MAST) which is hosted at the Space Telescope Science Institute (STScI).



TESS GI Office (bit.ly/tessgi)

TESS News Mission Using TESS Data analysis Education & Outreach HEASARC Helpdesk



TESS mission

The Transiting Exoplanet Survey Satellite (TESS) is a two-year survey that will discover exoplanets in orbit around bright stars.

More »

Proposing science

The TESS Guest Investigator Program is an annual call where scientists can propose new observations and receive funding and support.

More »

Data access

Access simulated data, documentation, data analysis software, and find information on the follow-up observing program.

More »

News for scientists

TESS successfully completes lunar flyby

21 May 2018

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K2 GO Office (lightkurve.keplerscience.org)

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1.0b7

Search docs

GETTING STARTED

- Quickstart
- Installation
- API documentation

TUTORIALS

- Introduction to lightkurve
- Science with lightkurve
- Systematics correction using lightkurve

ABOUT LIGHTKURVE

- Contributing and reporting issues
- Citing and acknowledging lightkurve
- Other software

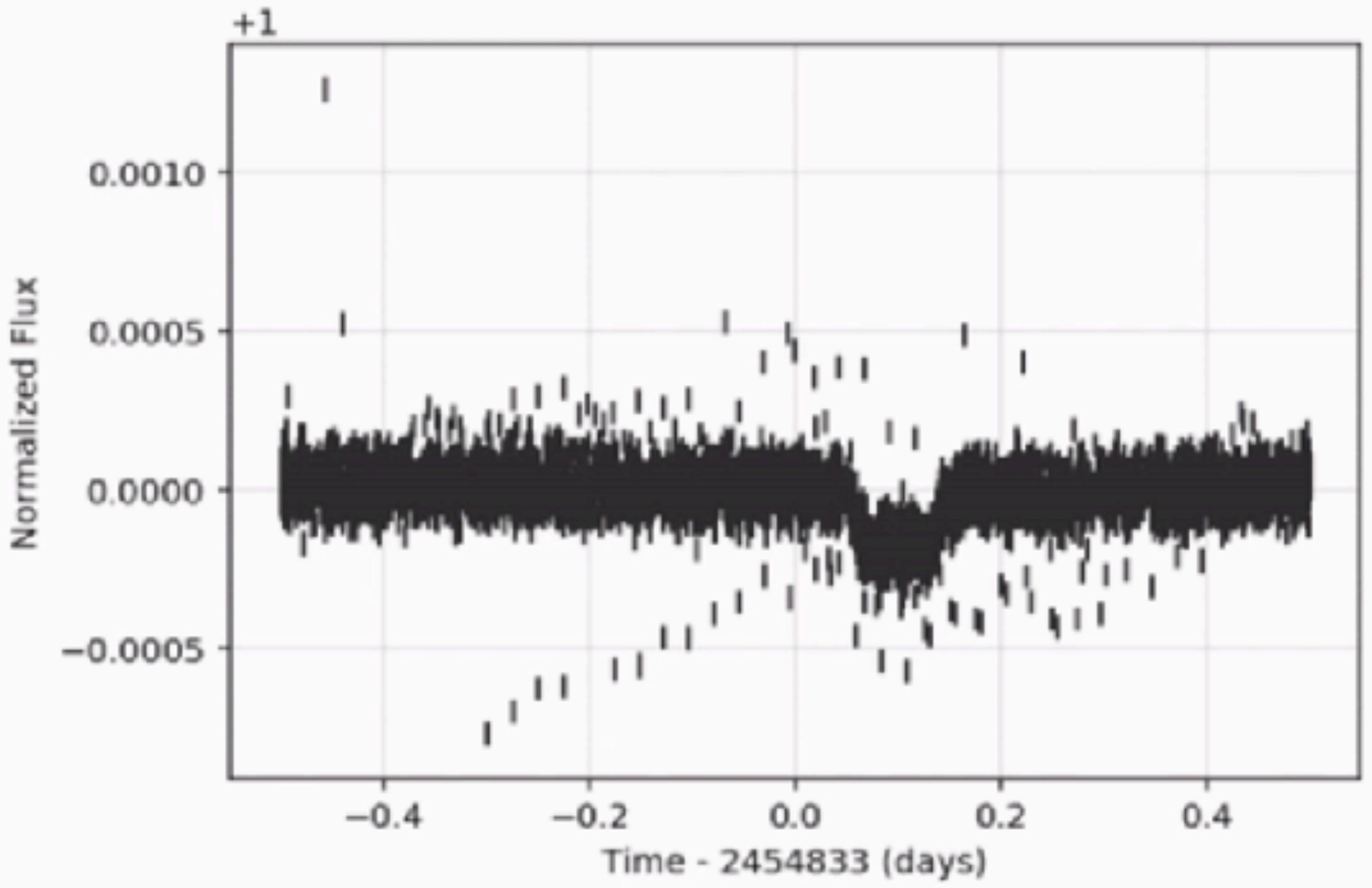
Docs » Welcome to lightkurve! View page source

Welcome to lightkurve!

The **lightkurve** Python package offers a beautiful and user-friendly way to analyze astronomical flux time series data, in particular the pixels and lightcurves obtained by **NASA's Kepler, K2, and TESS missions.**

```
%%capture
tpf = KeplerTargetPixelFile.from_archive('kepler-10', quarter=5)
```

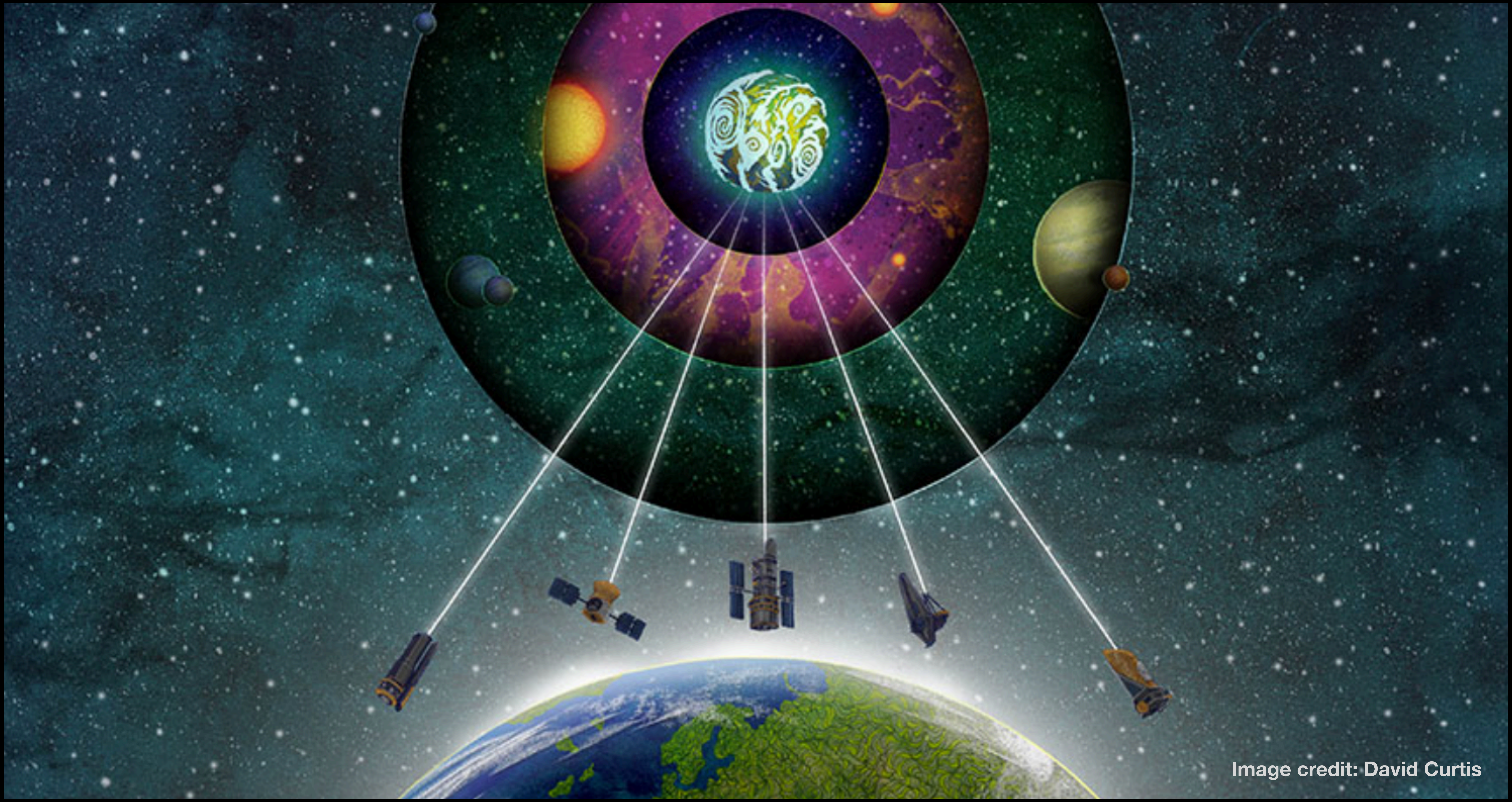
```
tpf.to_lightcurve().flatten().fold(period=0.837501).plot();
```



This package aims to lower the barrier for both students, astronomers, and citizen scientists interested in analyzing Kepler and TESS space telescope data. It does this by providing high-

Backup

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



DAVE

Discovery and Vetting of Exoplanets

1 Planet search

Target selection
Light curve creation

2 Robotic Vetting Tools

Centroiding
Odd/Even Depth
Significant Secondary
Transit Consistency/Shape
Ephemeris Matching

3 Catalog of False Positives

(including other team's K2 light curves)

K2 GO Cycle 3: P.I. Thompson
K2 GO Cycle 4: P.I. Mullally
K2 GO Cycle 5: P.I. Quintana

DAVE Team: Geert Barentsen, Knicole Colon, Jeff Coughlin, Fergal Mullally, Susan Mullally, Veselin Kostov, Tom Barclay, Chris Burke

Welcome to DAVE:
Discovery and Vetting of K2 Exoplanets

Below are our latest K2 planet candidate dispositions.

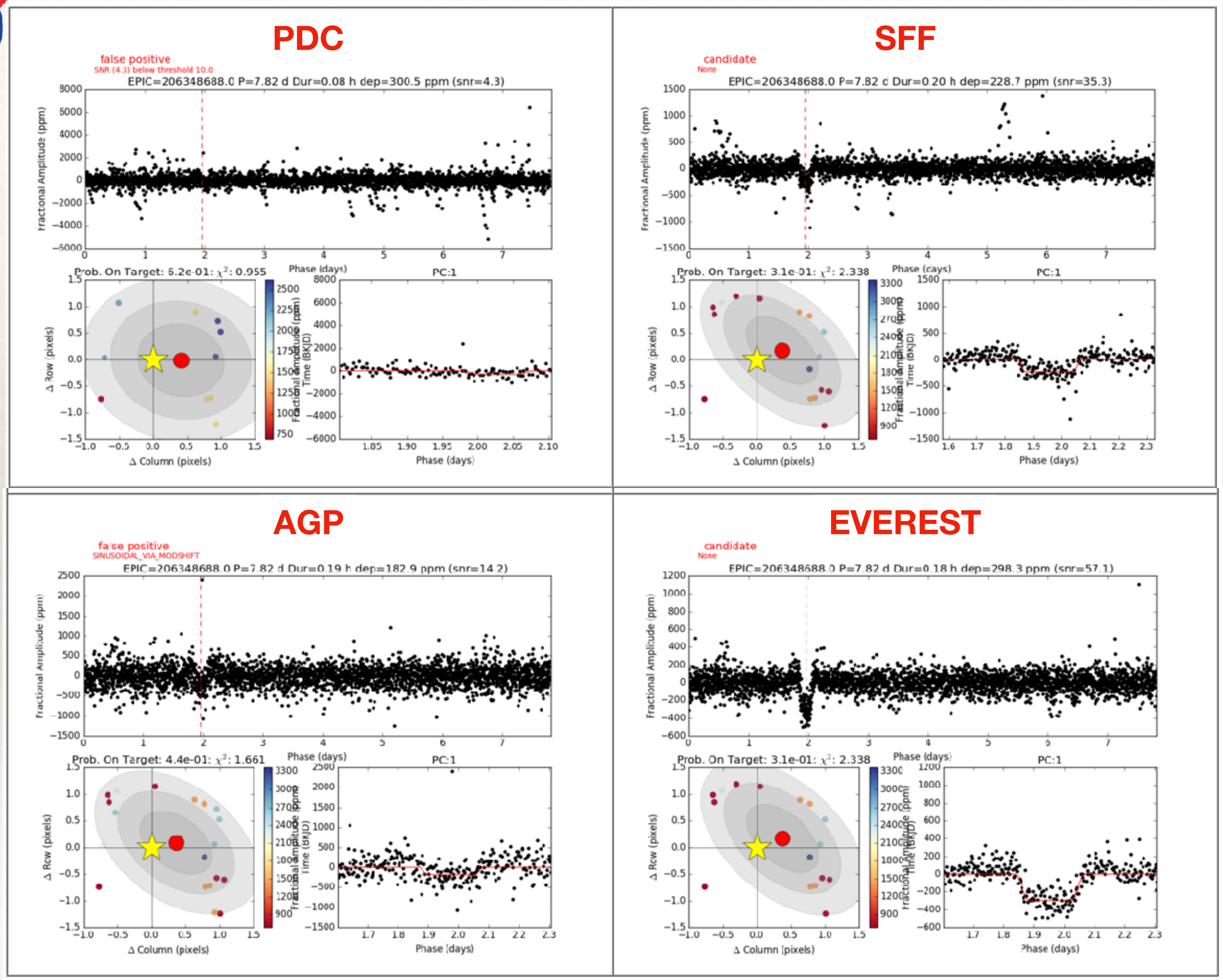
CANDIDATE DISPOSITIONS

MEET THE TEAM

DAVE Disposition Table

EPIC ID	Period (Days)	Epoch (BKJD)	Disp	Notes	Link to Vetting Plots
206162305	7.066	2178.04496	FP	Centroid offset and plausible odd/even	http://keplertcert.seti.org/DAVE/AllK2/Output/206162305
210389383	14.085	2264.948453	FP	Everest shows significant secondary	http://keplertcert.seti.org/DAVE/AllK2/Output/210389383
210401157	1.316	2264.5424	FP	Likely an EB, looks ellipsoidal	http://keplertcert.seti.org/DAVE/AllK2/Output/210401157
210754505	0.871	2264.106617	FP	Fails Odd/Even	http://keplertcert.seti.org/DAVE/AllK2/Output/210754505
210954046	0.95	2263.966371	FP	Shows Significant Secondary	http://keplertcert.seti.org/DAVE/AllK2/Output/210954046

DAVE Compares Community Light Curves



Where do we point JWST?

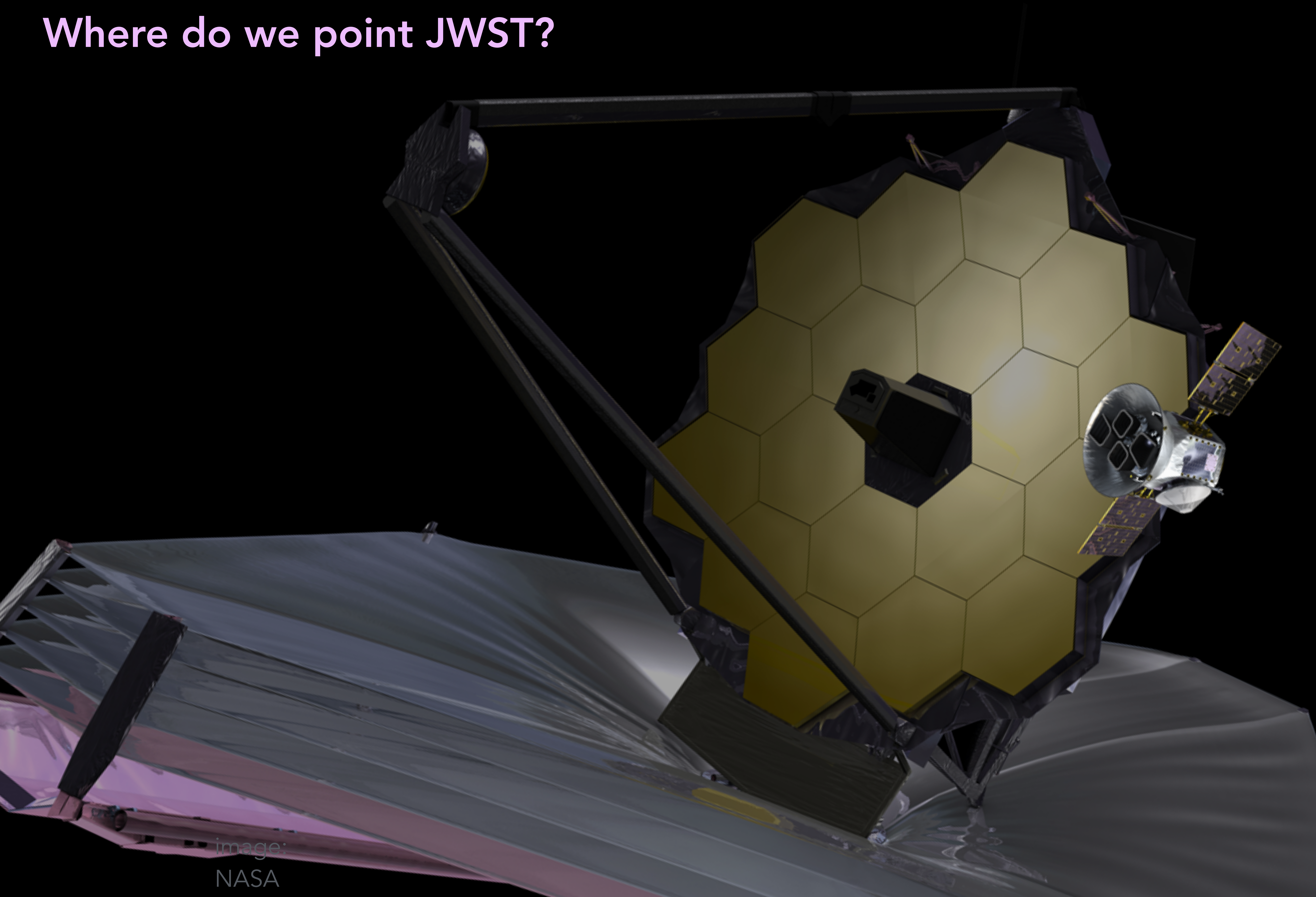
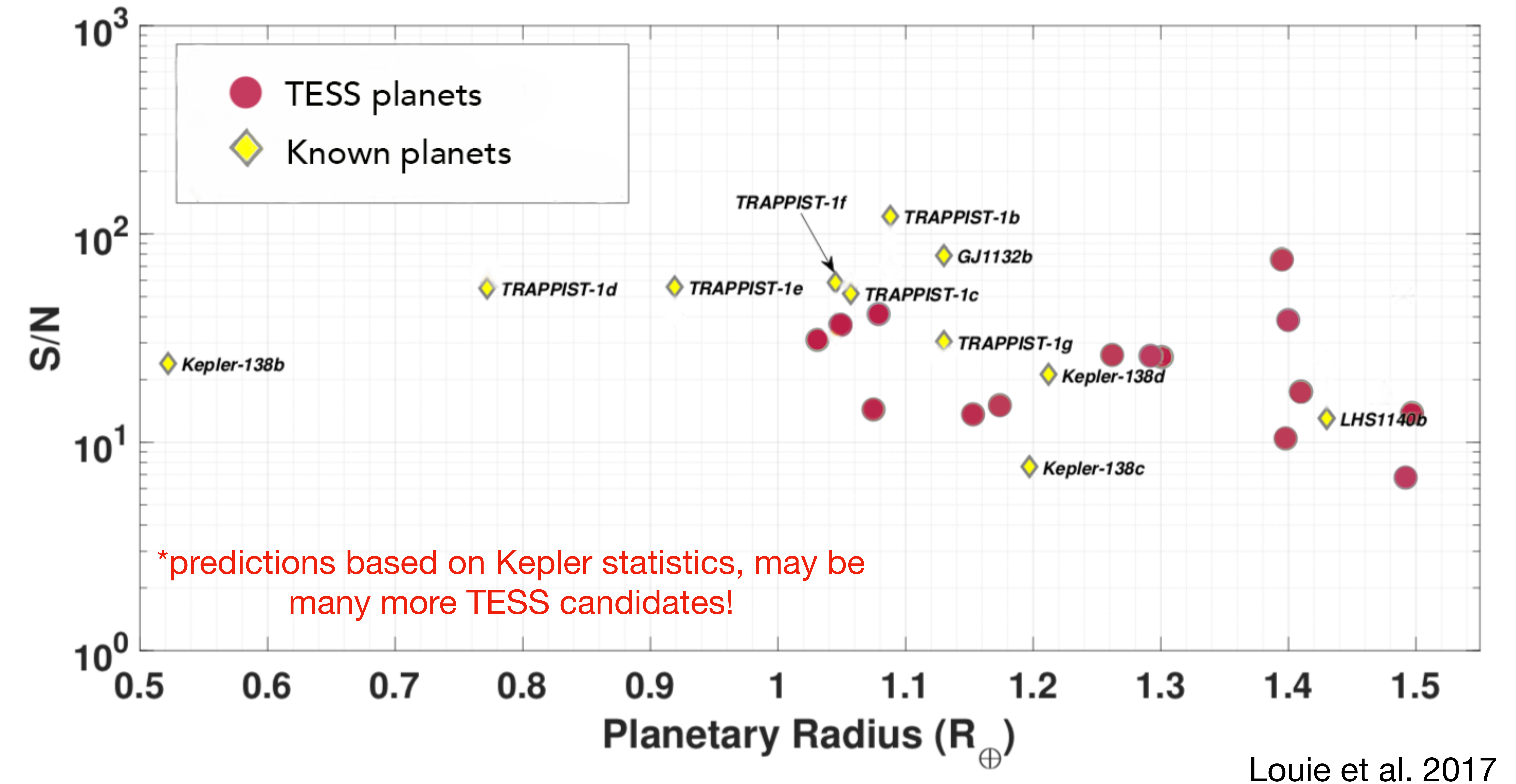


image: NASA

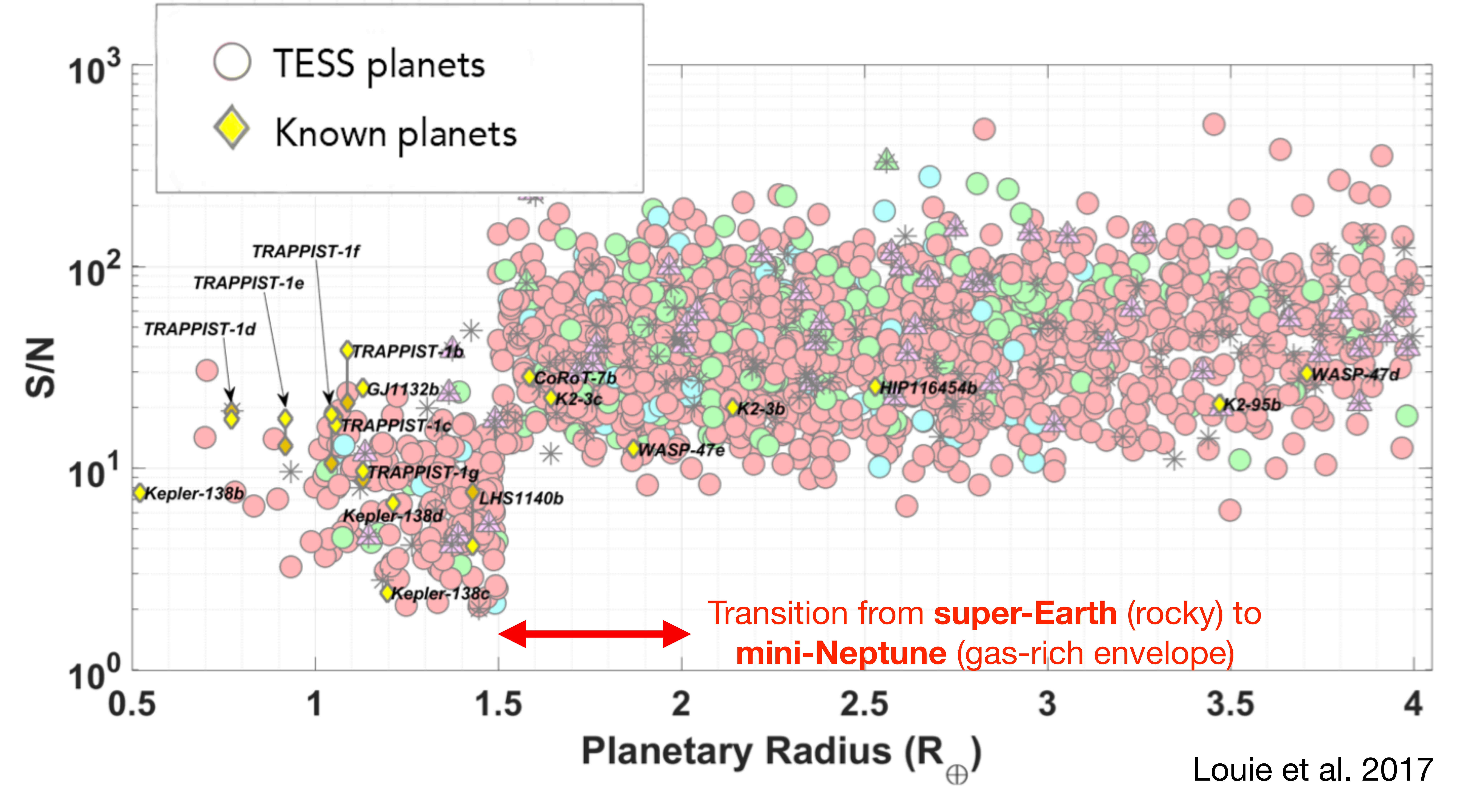
TESS
is our
finder
scope!

Best candidates for probing potentially habitable atmospheres with JWST



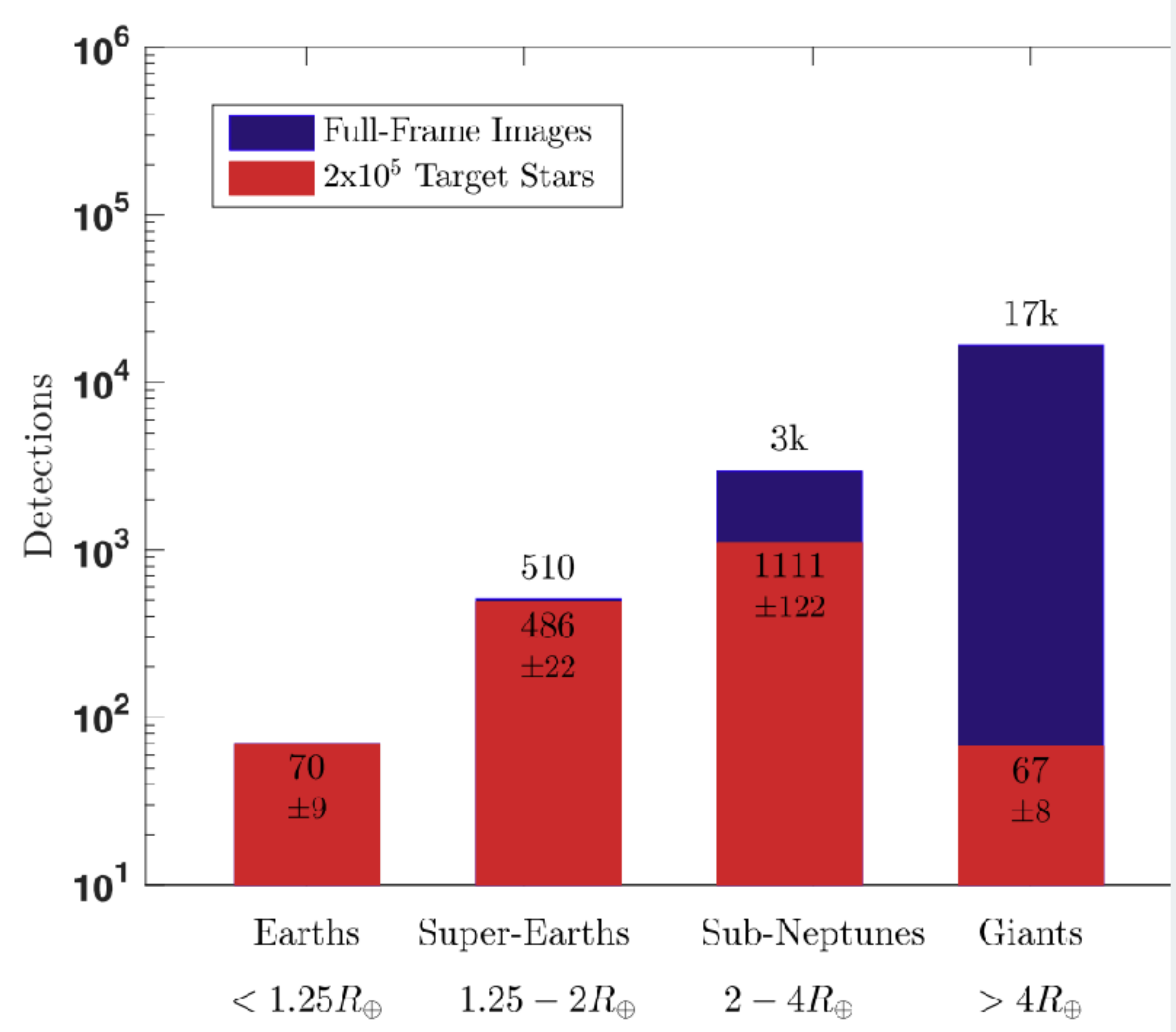
Louie et al. 2017

TESS will find LOTS of planets smaller than Neptune for atmosphere characterization



Louie et al. 2017

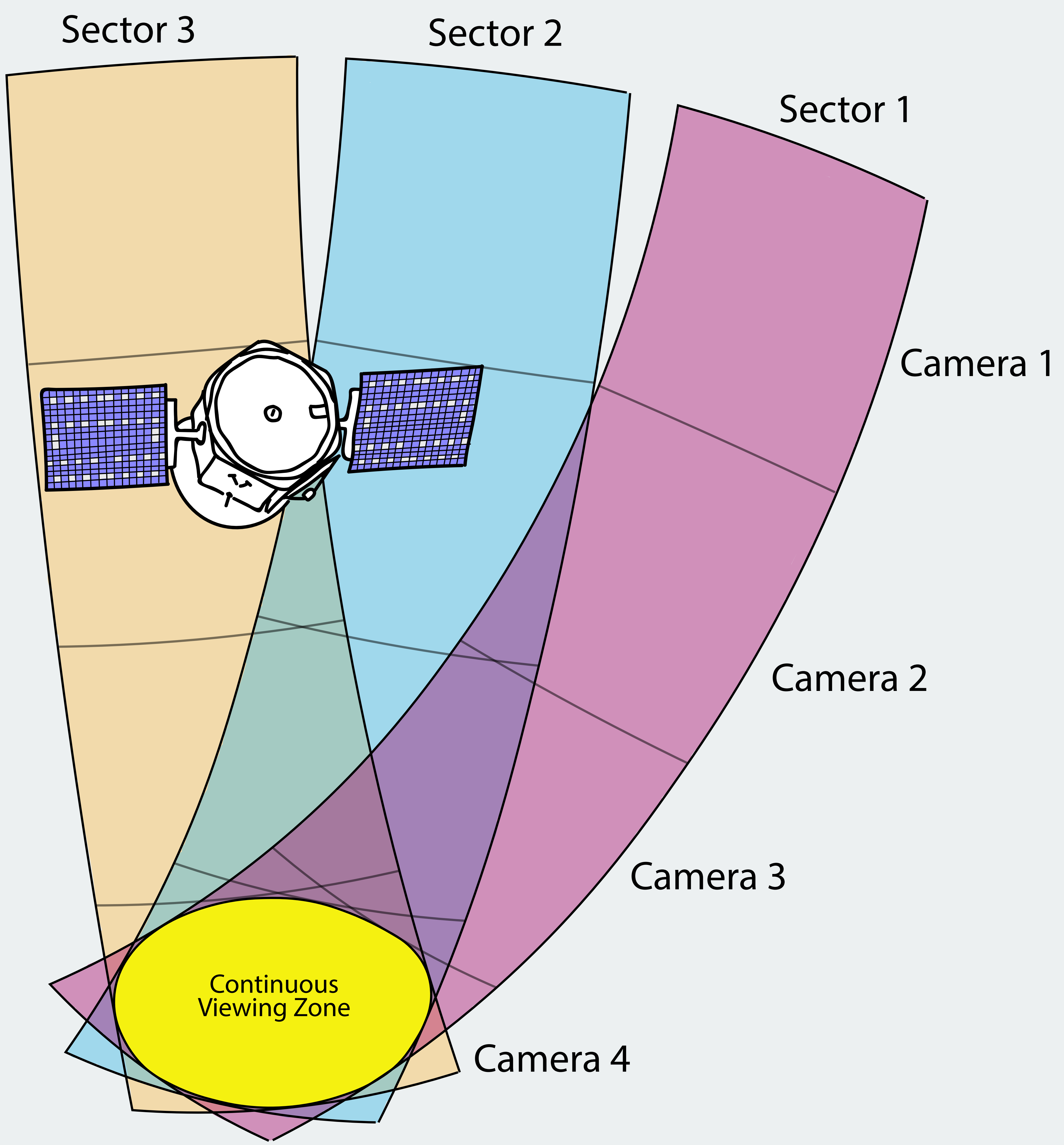
Why do we need a new yield estimate



- Planet yields estimates are useful because
  - We can plan follow-up observations
  - We can perform trade studies on our prioritization algorithms
  - We can manage expectations
- Sullivan published a wonderful paper with yield estimates for the TESS mission.
- However, we revised this analysis because we now know the stars TESS will observe and the strategy

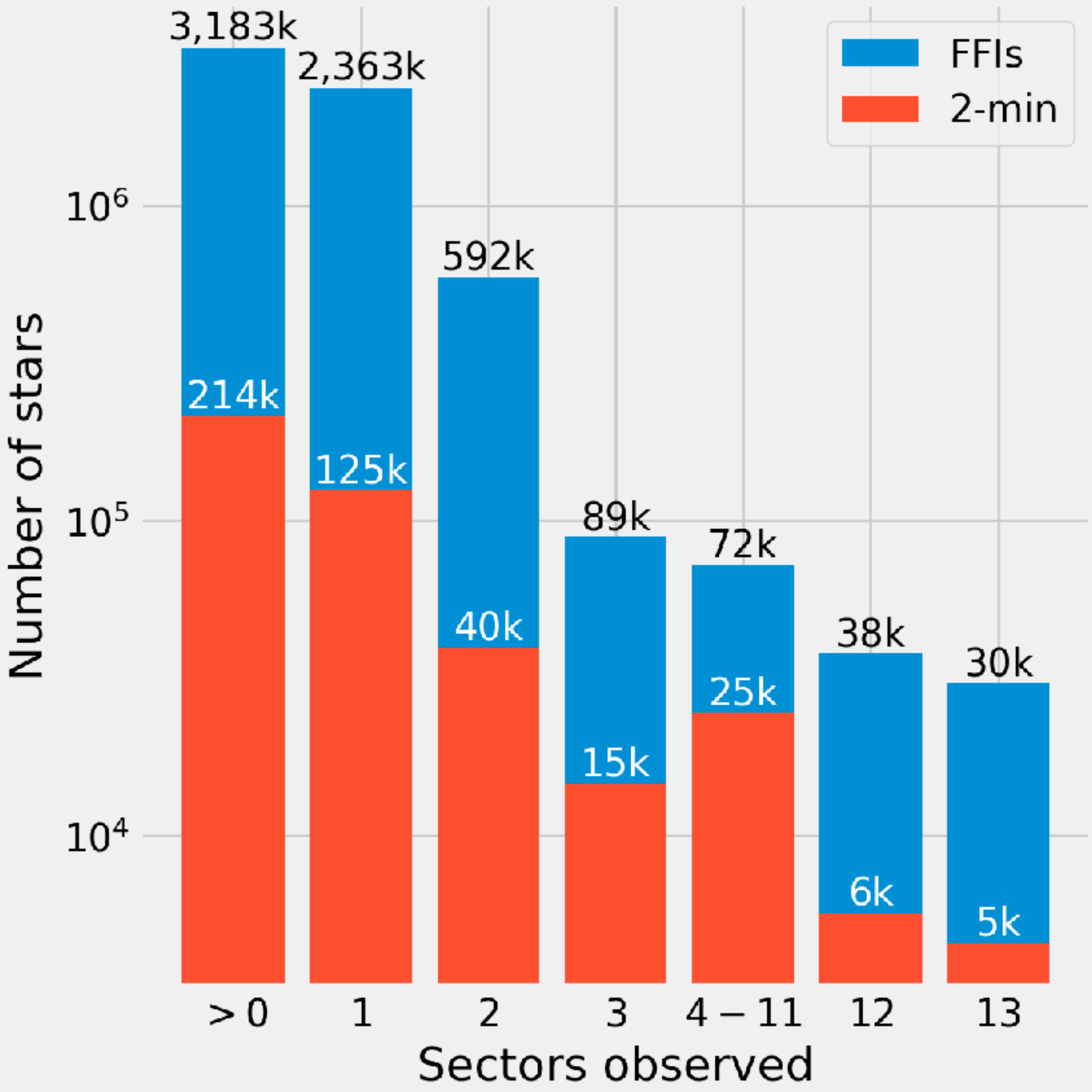
Sullivan et al. 2015, Bouma et al. 2017

Selection of stars



- The TESS Input Catalog + the Candidate Target List provide stellar properties for millions of stars
- We aimed to mimic realistic star selection - two observing modes
- We used the CTL prioritization
- At each pointing
  - 6000 stars are selected from the CVZ
  - 8200 from lower ecliptic latitudes
- 214,000 unique stars at 2-min cadence
- 3.1M in FFI data

Selection of stars



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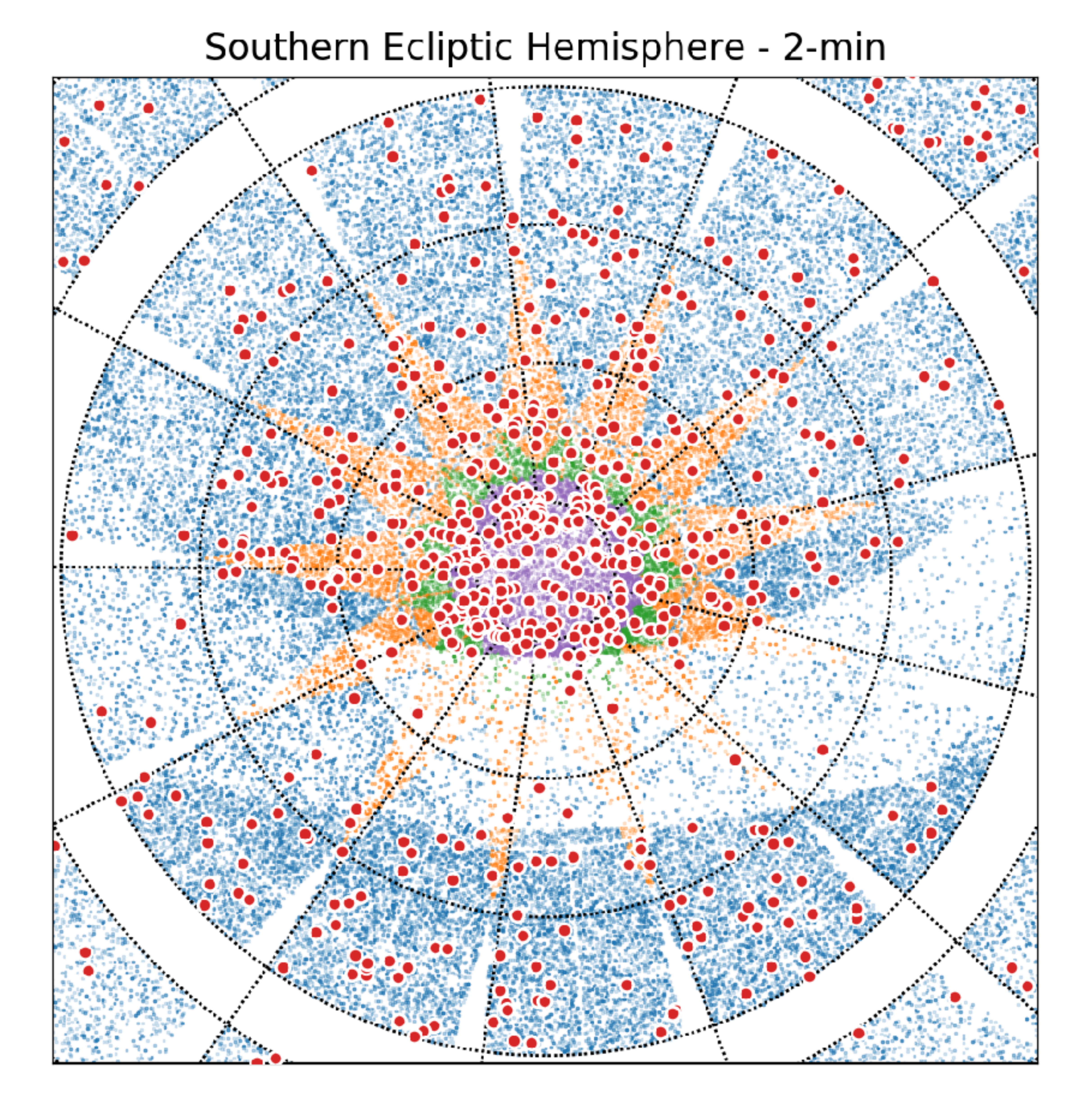
Injecting and detecting planets



Each star gets zero or more planets, drawn from a Poisson distribution

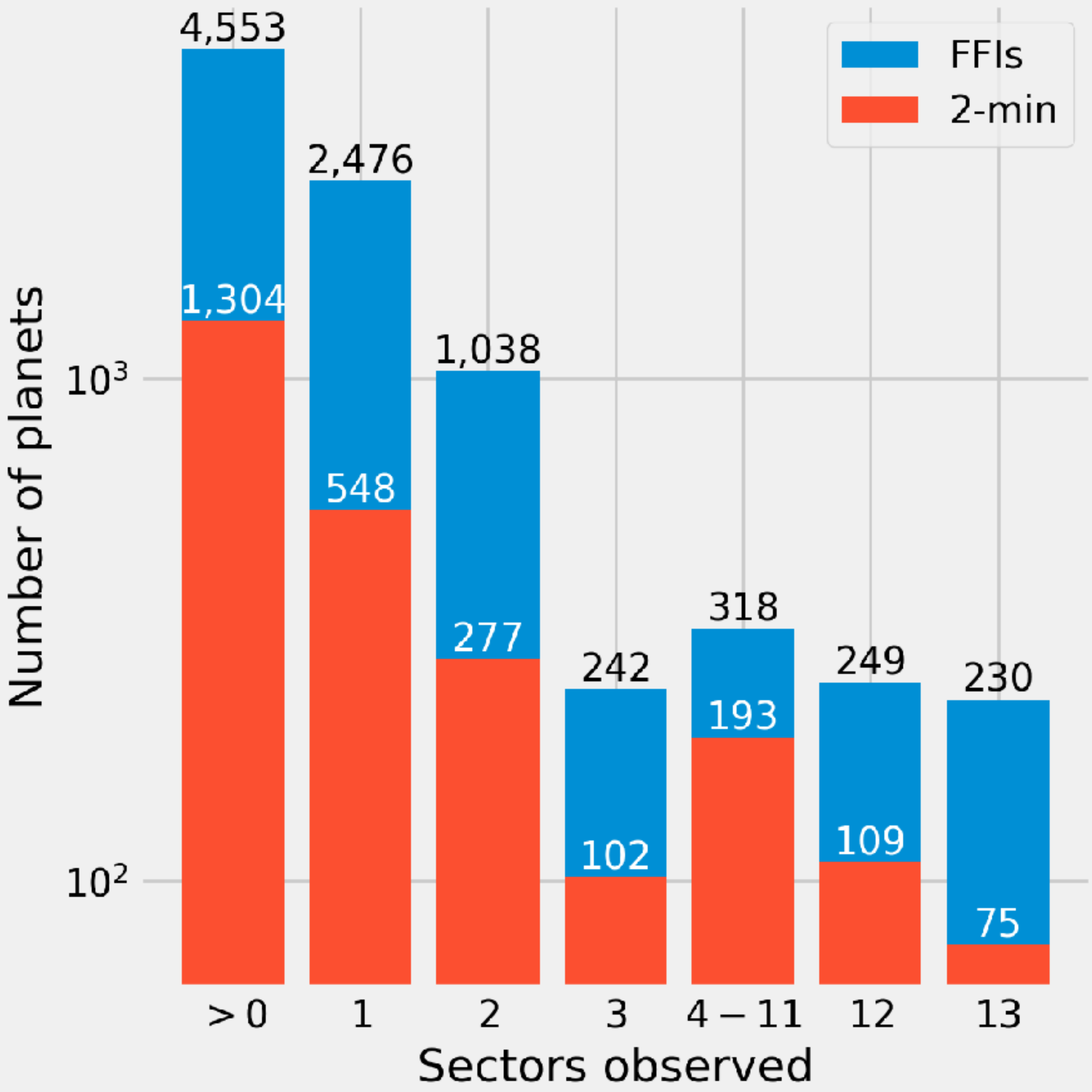
Planets are drawn with periods, radii, and eccentricities

- M-dwarfs use periods/radii/multiplicity from Dressing et al. 2015
- Hotter stars use Fressin et al. 2013

We picked a fiducial observations start date of June 28, 2018. This then yields an observation duration -> # of transits

We then test if a planet transits, and whether the combined SNR is above the TESS noise level from Ricker et al./Sullivan et al./Bouma et al.

Injecting and detecting planets



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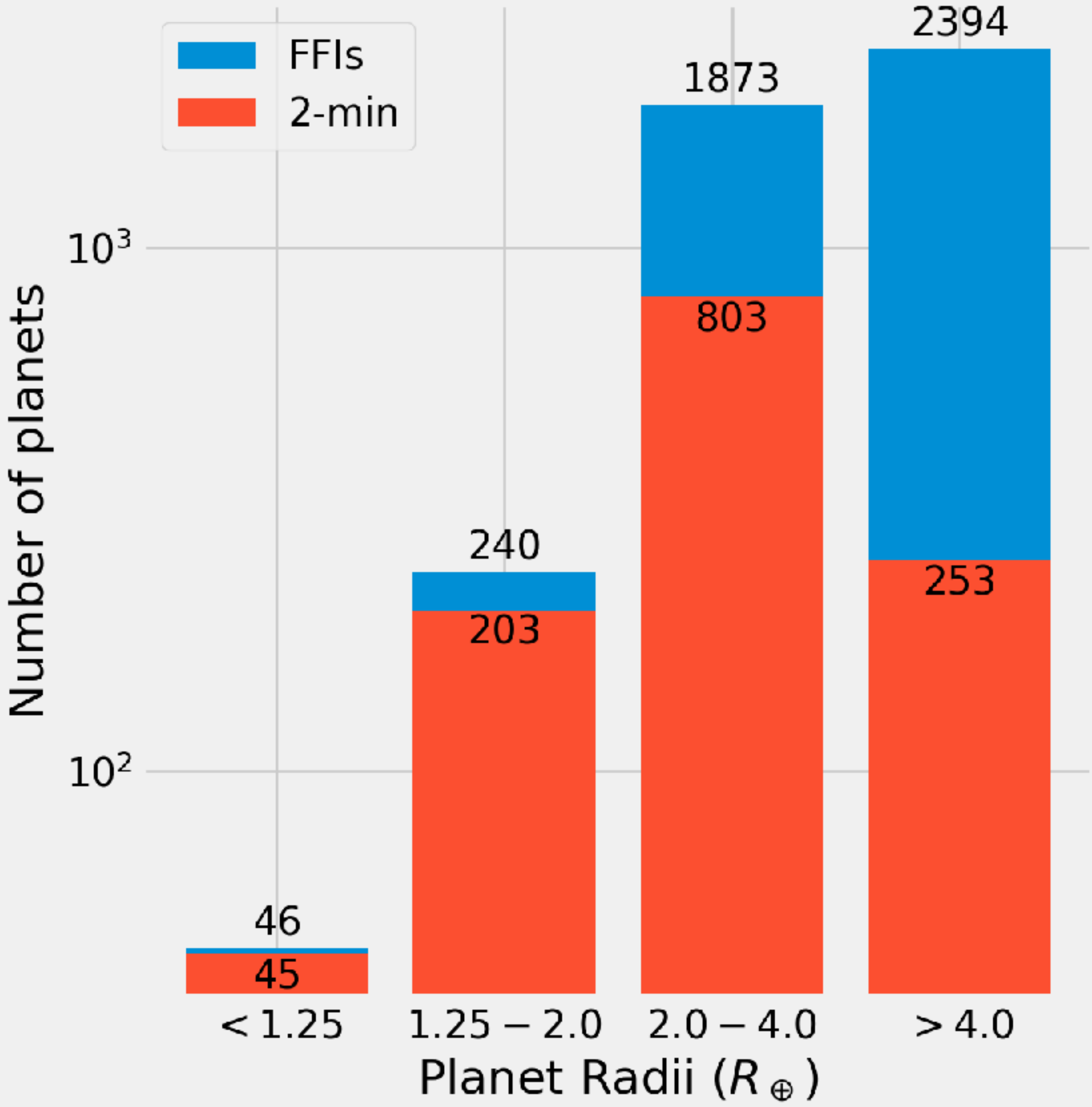
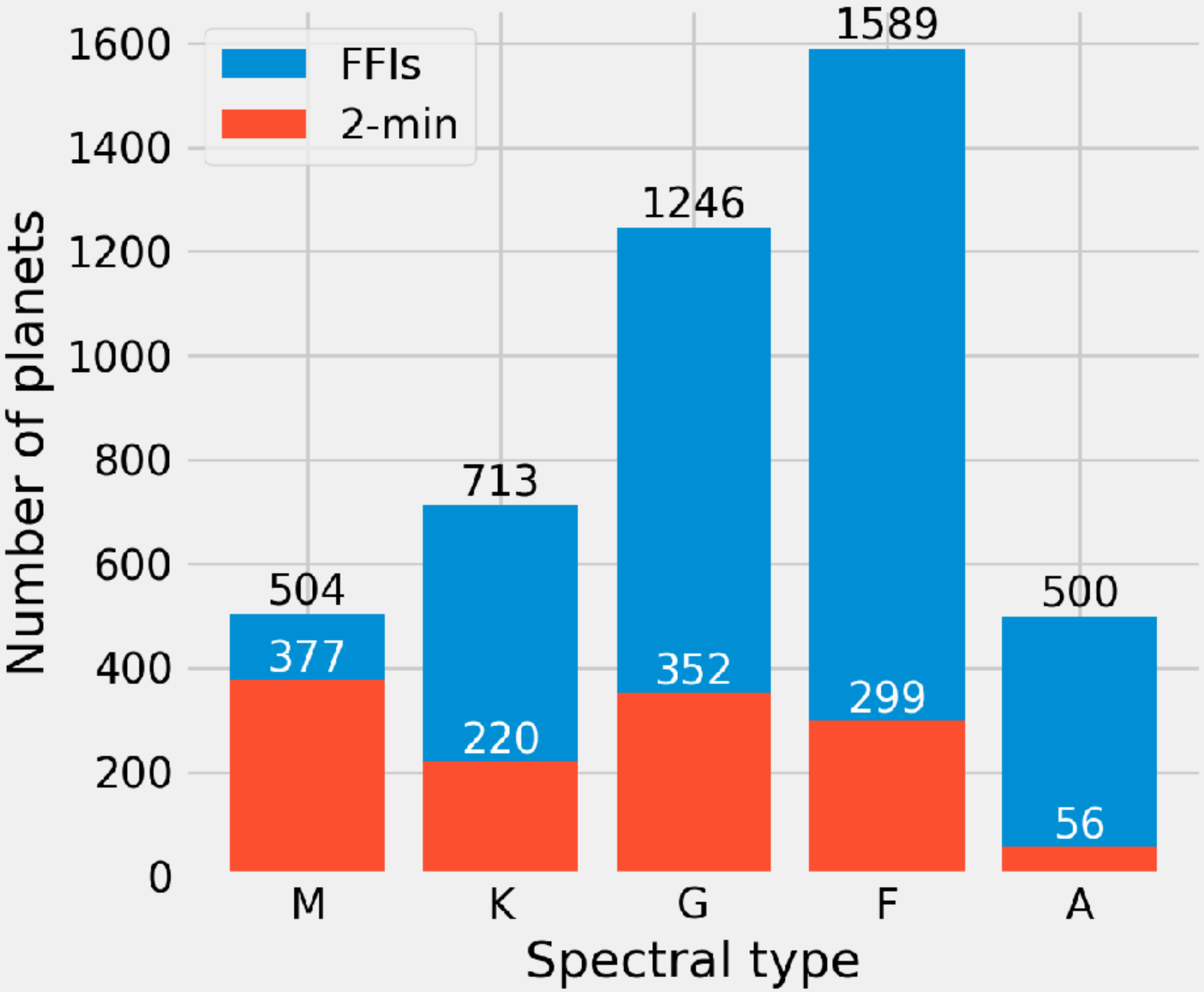
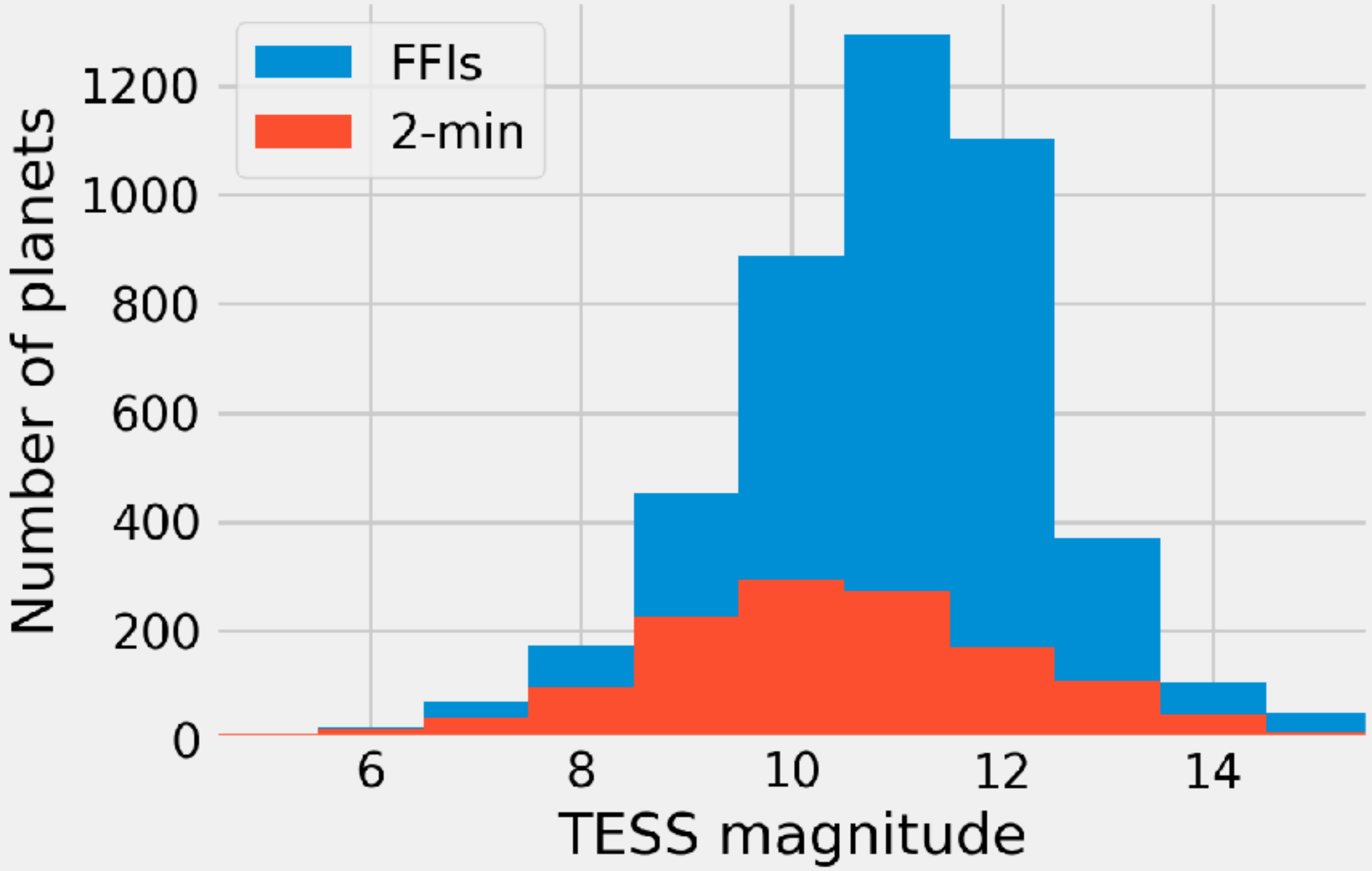
The planet radius distribution



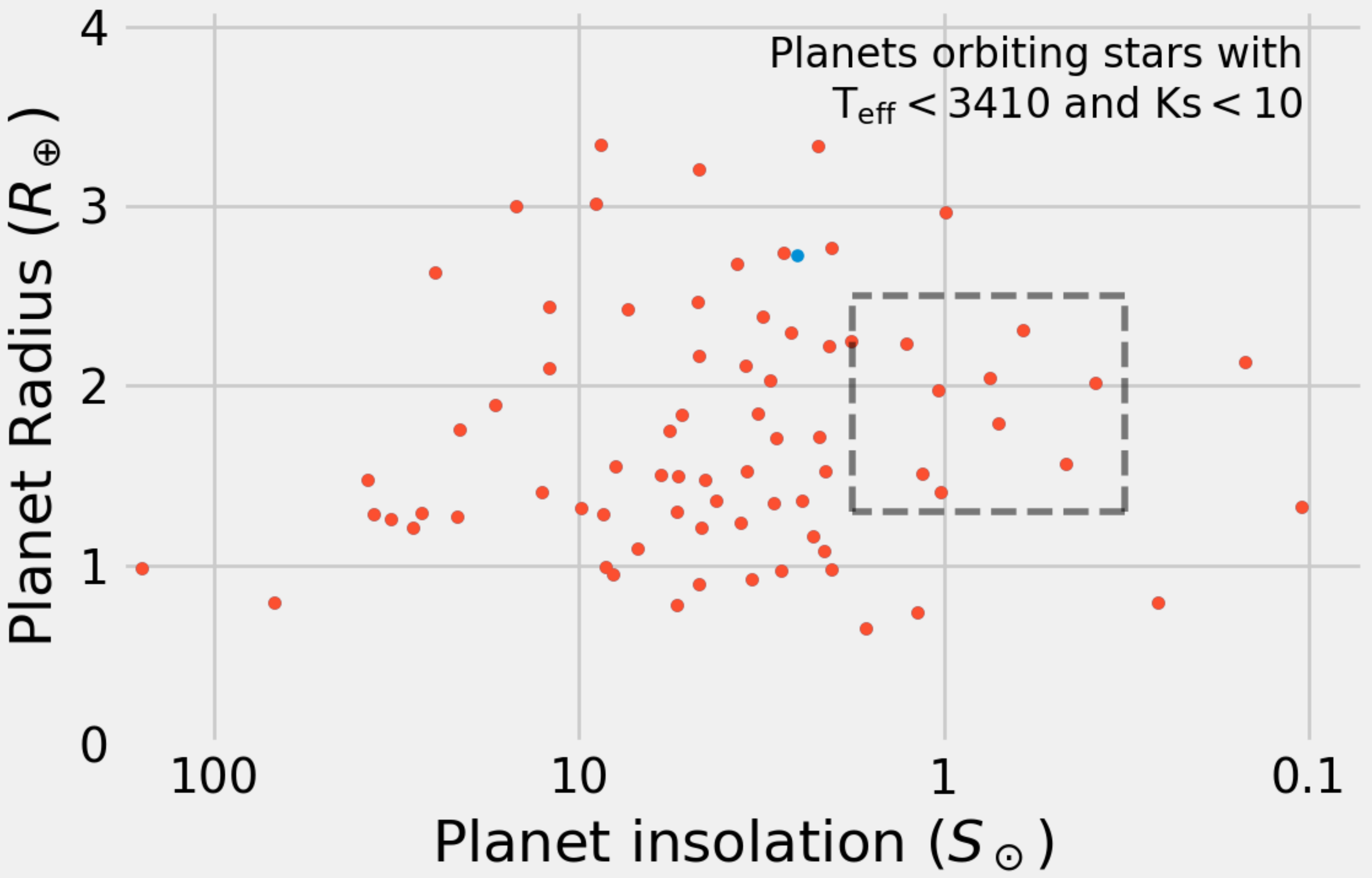


Planets amenable to RV follow-up



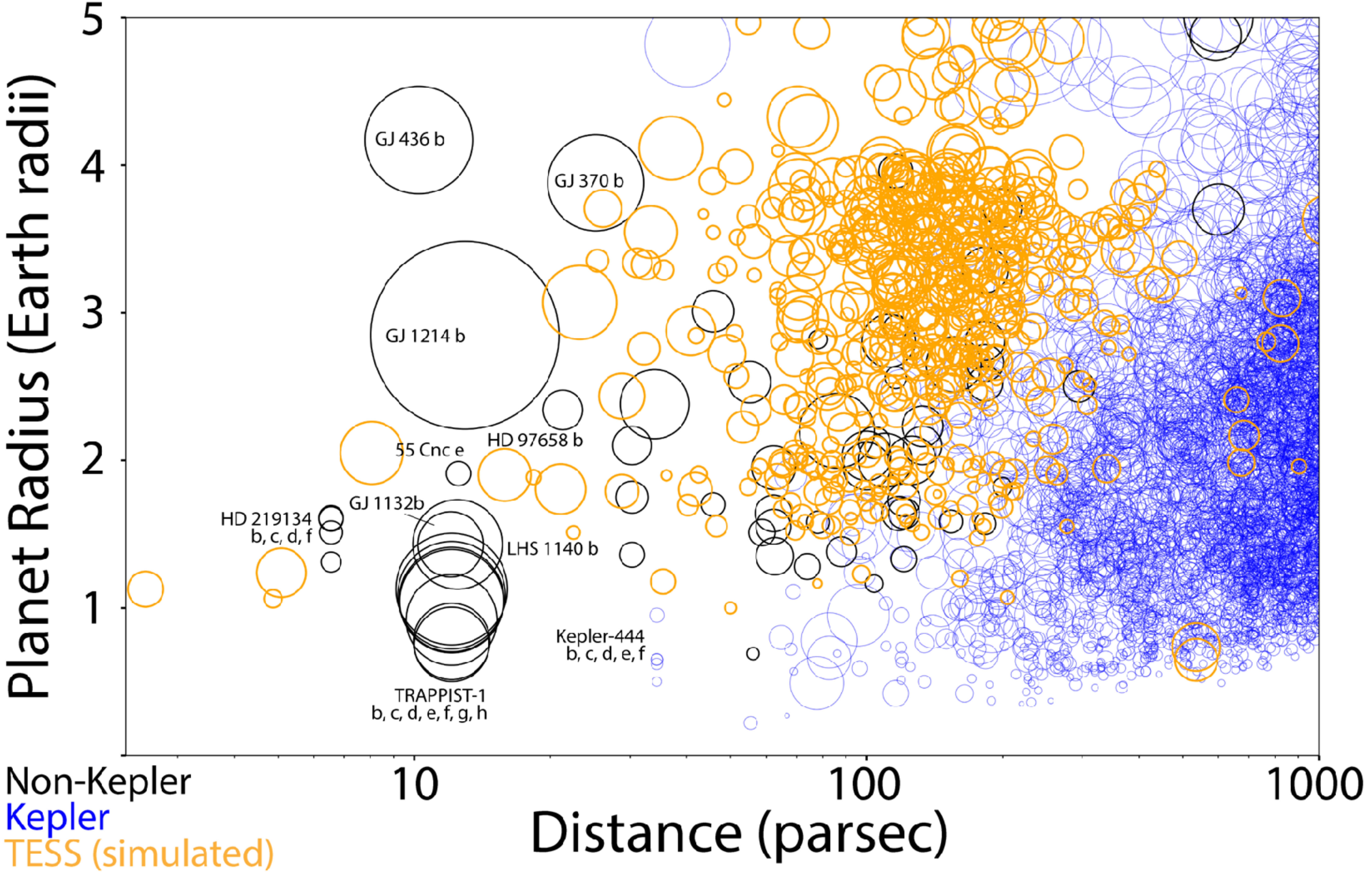
- On average, TESS planets orbit stars 3 magnitudes brighter than Kepler.
- We predict that TESS will find 1300 planets smaller than four Earth-radii around stars brighter than V=12.
  - We will triple the number of planets smaller than 4 Earth-radii with measurable masses
- 10 planets in our simulation orbit stars brighter than 55 Cnc
- The closest planets in the simulation orbits Lalande 21185, a star 2.5 pc away
  - 47 planets within 50 pc, and 236 within 100 pc, which doubles and quadruples the number of transiting planets known within 50 and 100 pc
- Our simulation contains 71 planets in the optimistic zone, of which 11 are smaller than 2 Earth-radii. All the habitable zone planets orbit Mdwarfs.

Small planets for atmospheric characterization



Planets orbiting bright, cool stars

- Teff < 3410 K
- Stars brighter than Kmag=10
- 76 total planets
- About a dozen in the HZ



Planet Radius (Earth radii)
5
4
3
2
1
GJ 436 b
GJ 370 b
GJ 1214 b
HD 97658 b
55 Cnc e
GJ 1132b
HD 219134
b, c, d, f
LHS 1140 b
Kepler-444
b, c, d, e, f
TRAPPIST-1
b, c, d, e, f, g, h
10
100
1000
Distance (parsec)
Non-Kepler
Kepler
TESS (simulated)