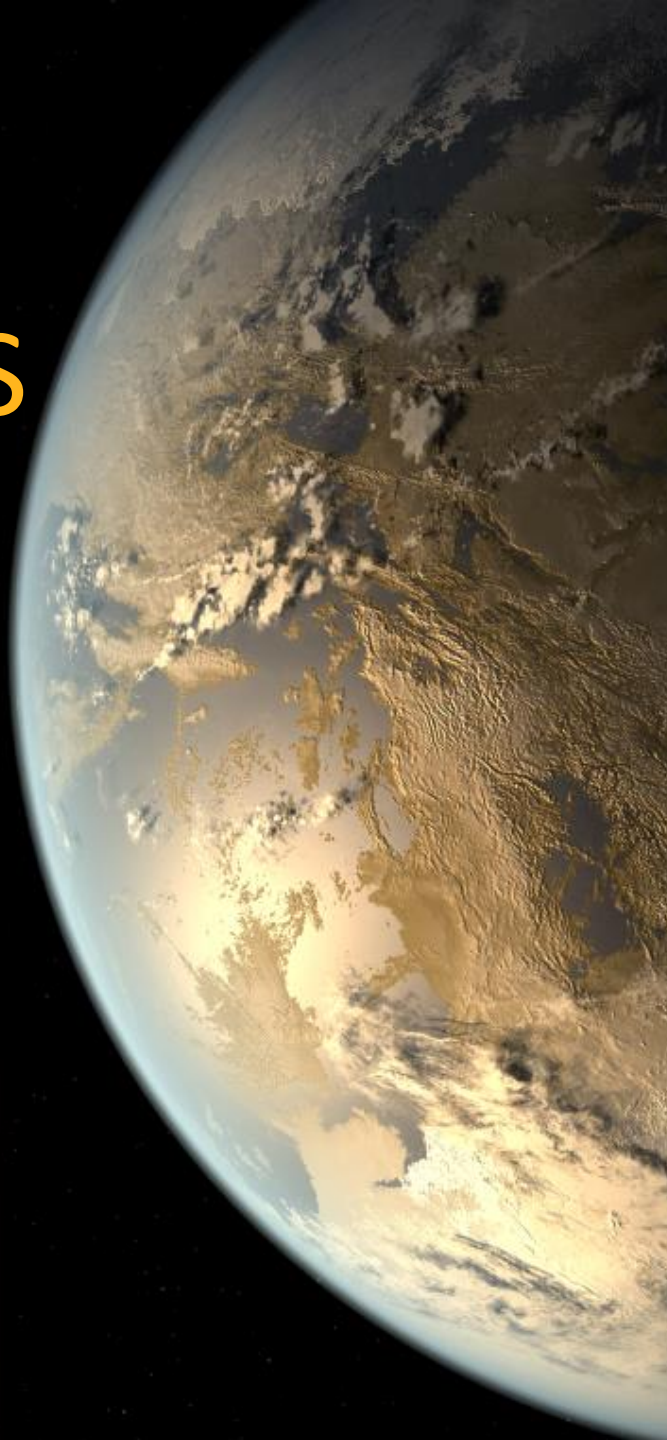
Transiting Exoplanet Survey Satellite---TESS



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Outline

- Mission Background
- Basic Introduction
- Science Objectives
- Current Status & News
- Summary

TESS Mission Background

- Concept of worlds beyond Earth: back to 2000 years, Epicurus (ca. 300 BCE).

- Contemporary search for exoplanets: Mid-19th Century -- A dark companion, orbit a binary star system (Jacob, 1855; See, 1896), soon discredited (Moulton, 1899).

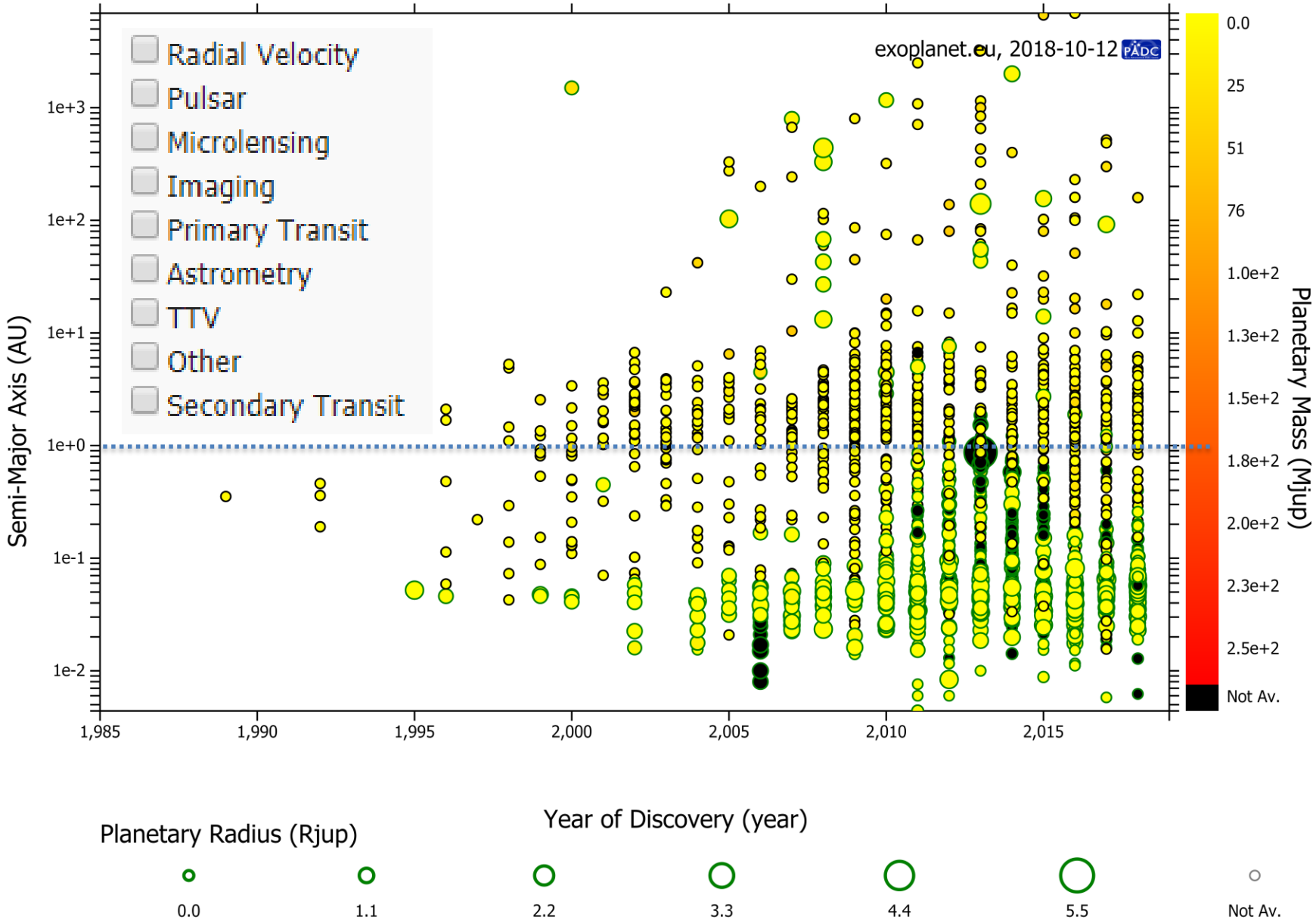
- The discovery of Exoplanets emerged in past few decades.

- 1989. Latham, et al. HD 114762 b (brown dwarf), by Radial Velocity method.

- Many Satellites; 8+ Techniques; 3793 confirmed Exoplanets.(NASA Exoplanet Archive Oct 13. 2018)

Sara Seager, et al. Exoplanets, ISBN-13: 978-0816529452
Latham, David W., et al. "The unseen companion of HD114762: a probable brown dwarf." Nature 339.6219(1989):38-40.
Data from: https://exoplanetarchive.ipac.caltech.edu/cgi-bin/TblView/nph-tblView?app=ExoTbls&config=planets

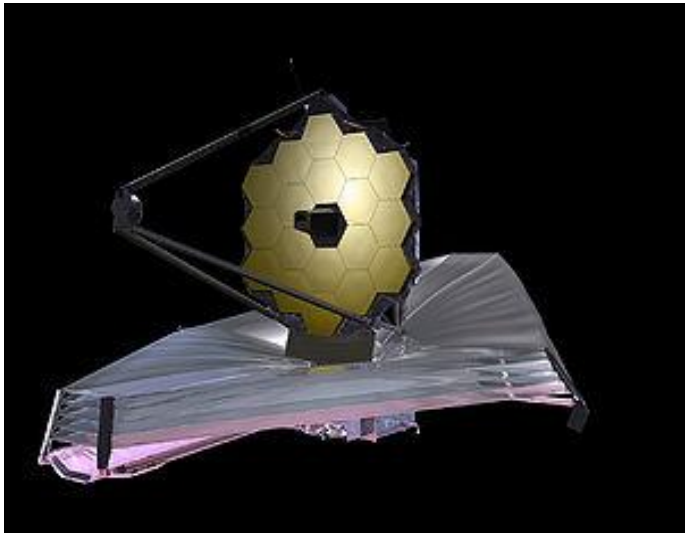
TESS Mission Background



Data from http://exoplanet.eu/

TESS Mission Background

Kepler, 2009.03



JWST, 2020s

- Challenge for Kepler: many planet candidate host stars may simply be too faint (for e.g. JWST) to analyze.
- → Here comes TESS!
- TESS focus on stars that are much brighter than Kepler's → radial velocity follow-up observations → planet confirmation and mass measurements.

TESS Basic Introduction

Transiting Exoplanet Survey Satellite

MIT-led NASA mission

2ys all-sky survey

transiting exoplanets

Launch date: April 18, 2018

Costs:

Kepler: US$640 million at launch,

TESS: only ~US$200 million (+ US$87 million for launch).

TESS Mission Background

What is the goal?

All-sky, two year photometric Exoplanet discovery.

New Earths and Super-Earths in the Solar Neighborhood.

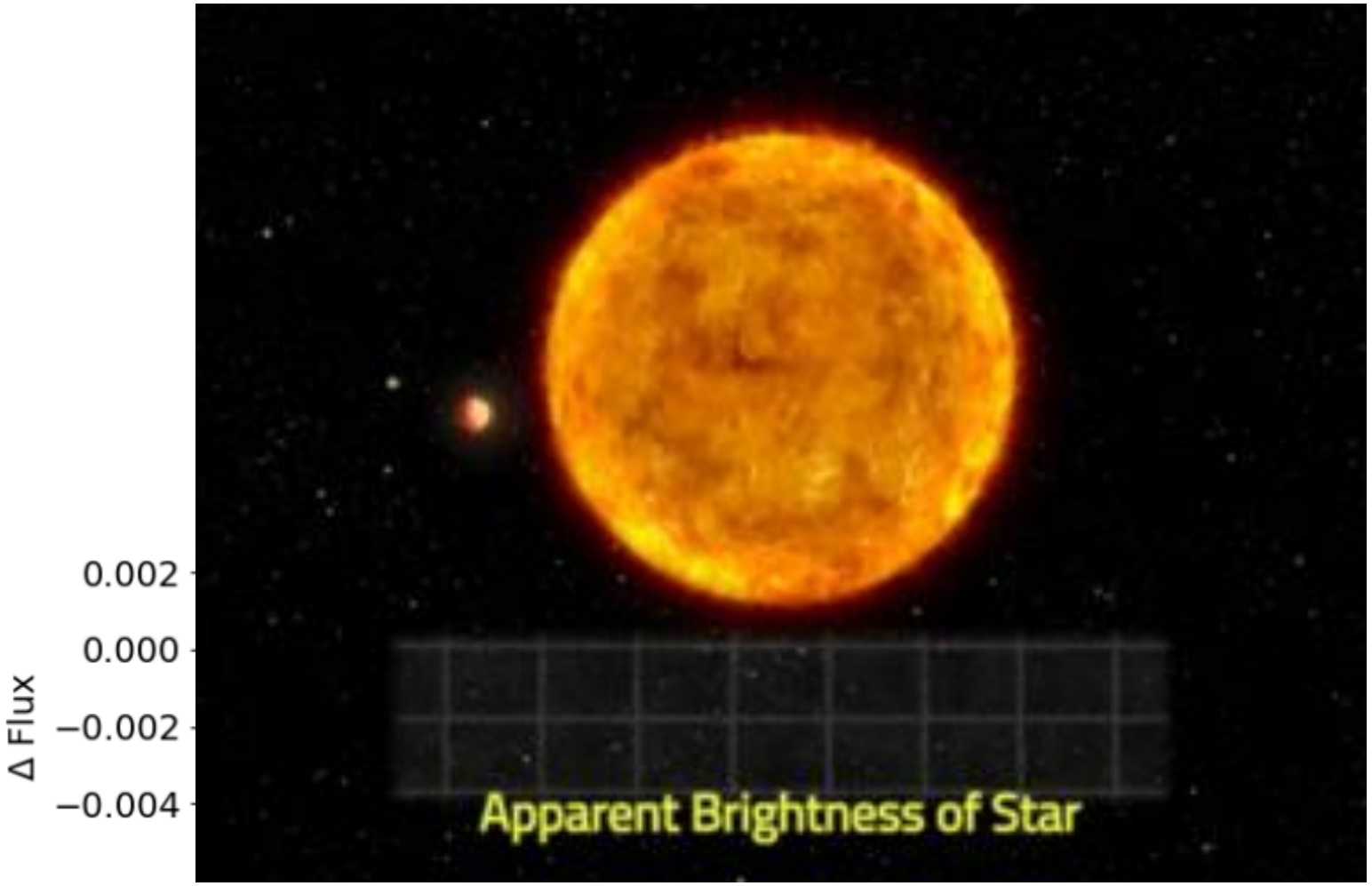
Around stars bright enough for spectroscopic investigations of planetary masses and atmospheres.

Monitoring > 200,000 stars' brightness
Cataloging > 1,500 transiting exoplanet candidates

TESS Mission Background

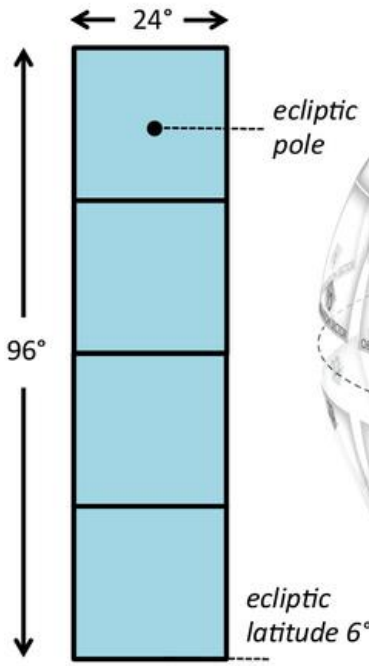
How TESS finds exoplanets?

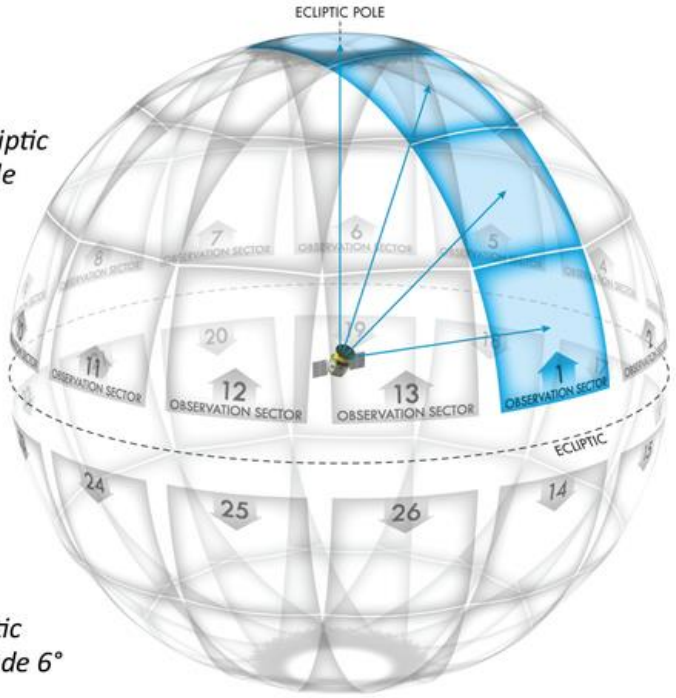
→ Transits



TESS Science Objectives

By what instruments?





+ Optical images.
+ 4 identical cameras.
+ Each 24×24 degree FOV.
+ Aligned → cover 90×24 degree strips of the sky: 'sectors.'
+ Each camera: four 2k x 2k CCDs; Pixel scale: 21 arcsec/pixel.
+ Detectors sensitive 600~1000nm (blue to the near-IR).

  Redder observing band pass → more M dwarfs

+ Aims for 50 ppm photometric precision on stars Mag 9-15

TESS Science Objectives

By what instruments?

→ 1. Lens Assembly

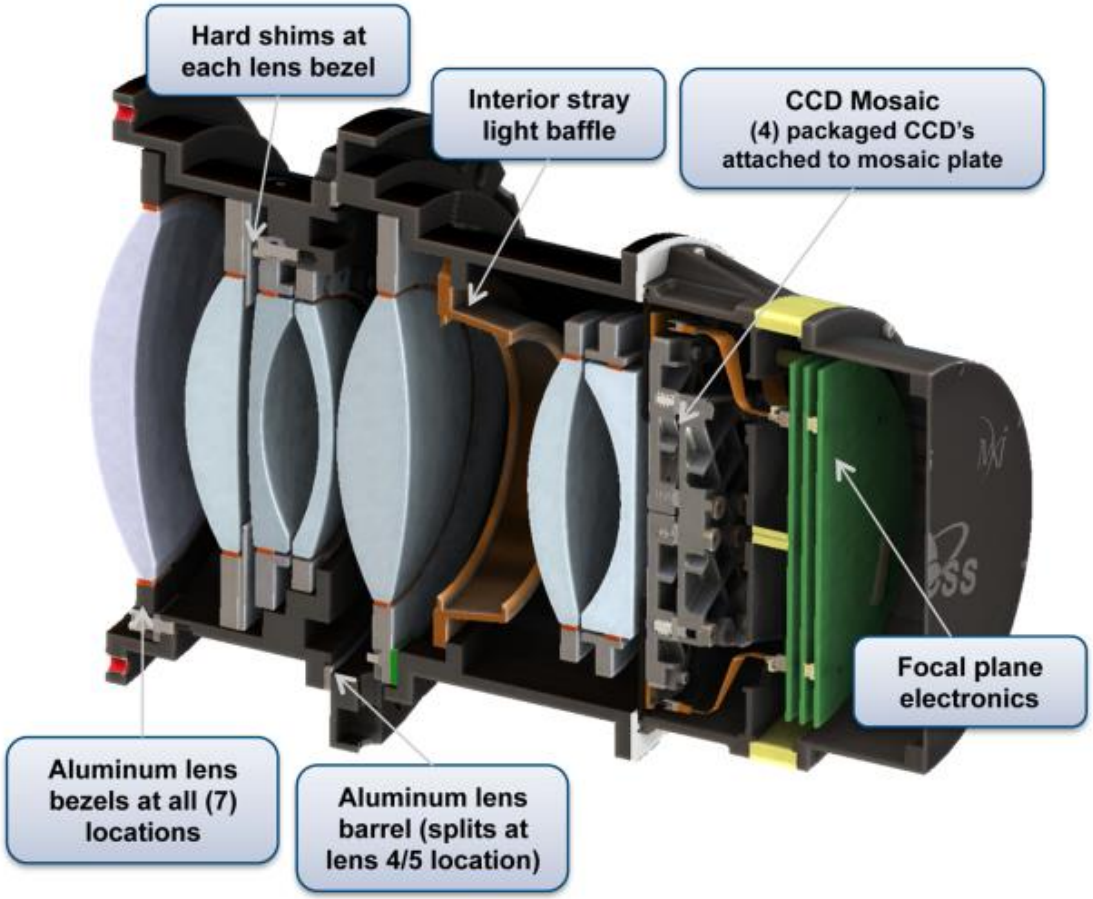


Fig. 2 Diagram of the lens assembly, charge-coupled device (CCD) focal plane, and detector electronics for one of the four TESS cameras.

Ricker et al.: Transiting Exoplanet Survey Satellite

TESS Science Objectives

By what instruments?

→ 2. Detector Assembly

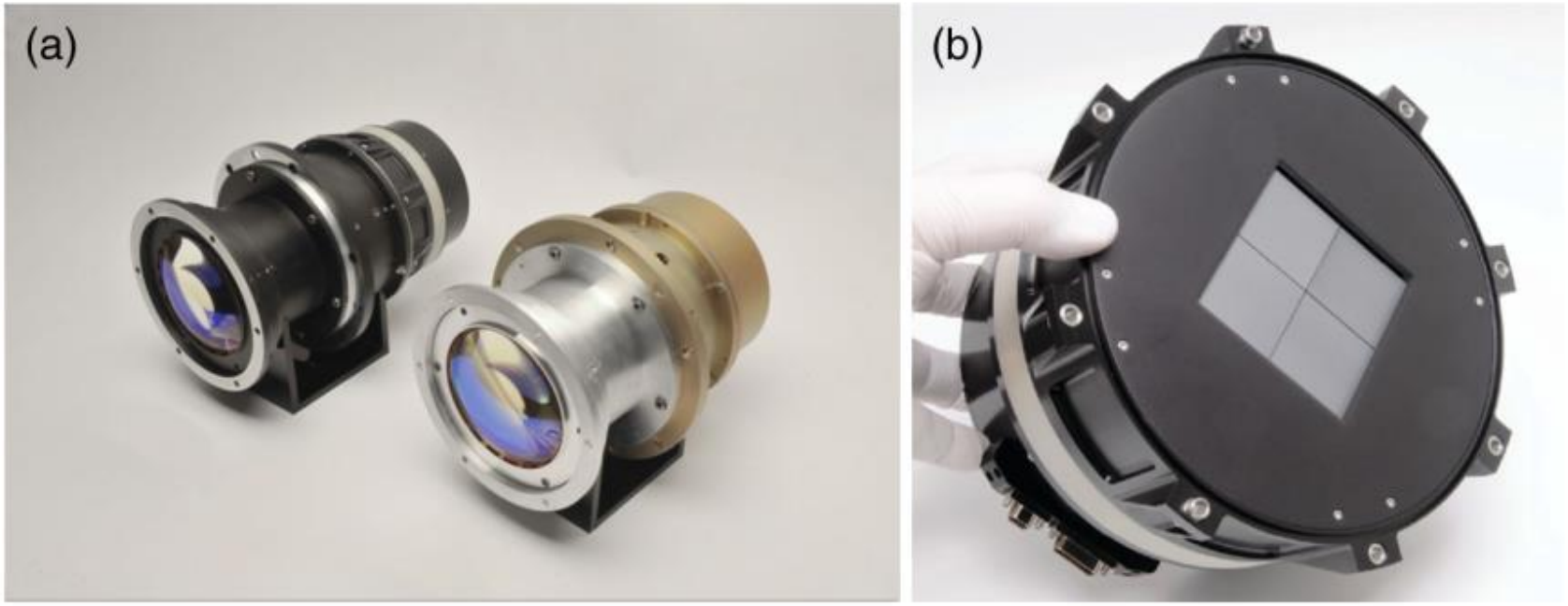


Fig. 3 (a) Two lens prototypes were constructed during phase A. One was subjected to thermal vacuum testing at the operational temperature; the other was subjected to vibration testing. (b) The detector assembly of one of the prototype lenses. The frame-store regions of the CCDs are covered.

Ricker et al.: Transiting Exoplanet Survey Satellite

TESS Science Objectives

How TESS scanning the sky?

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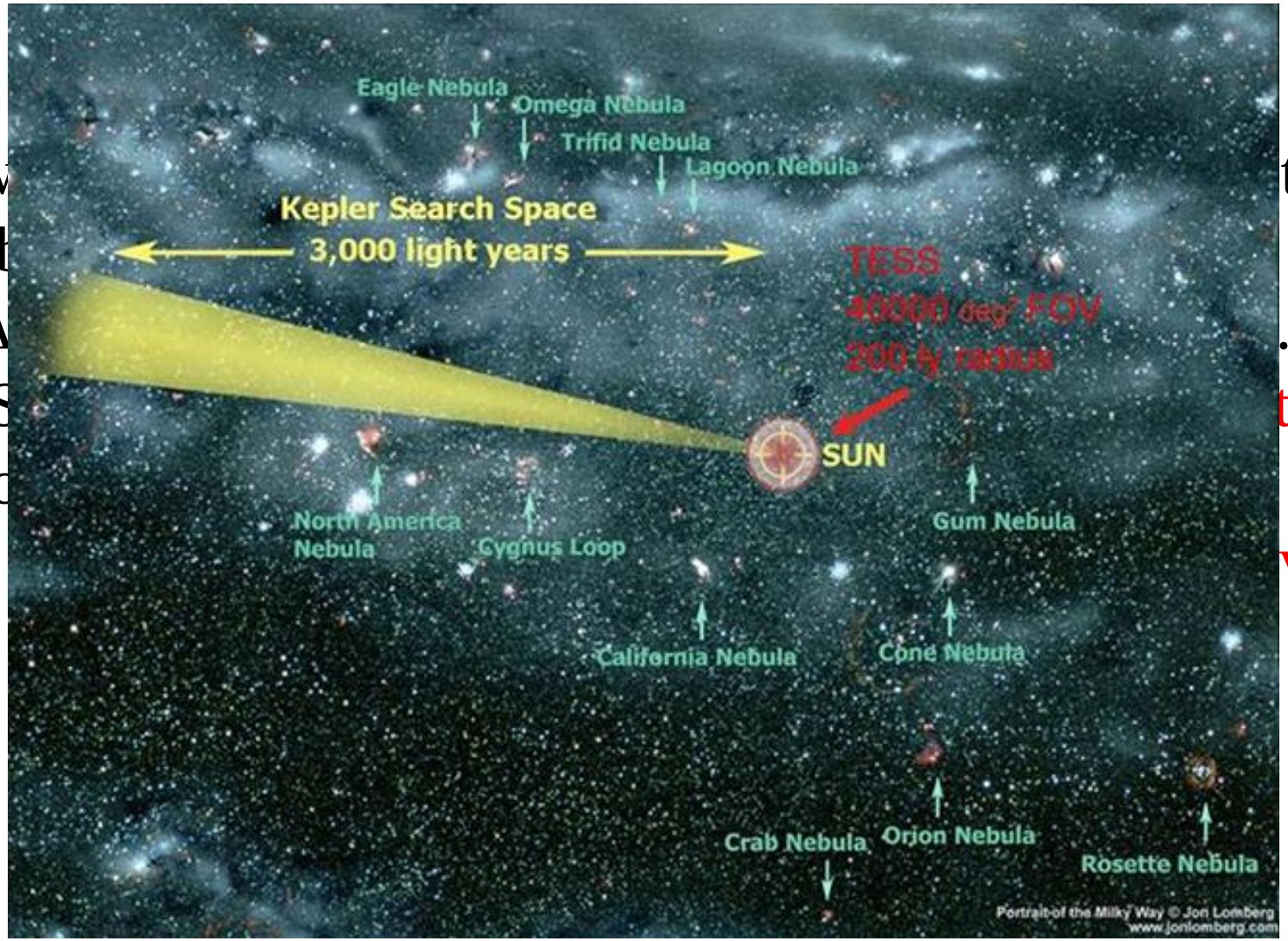

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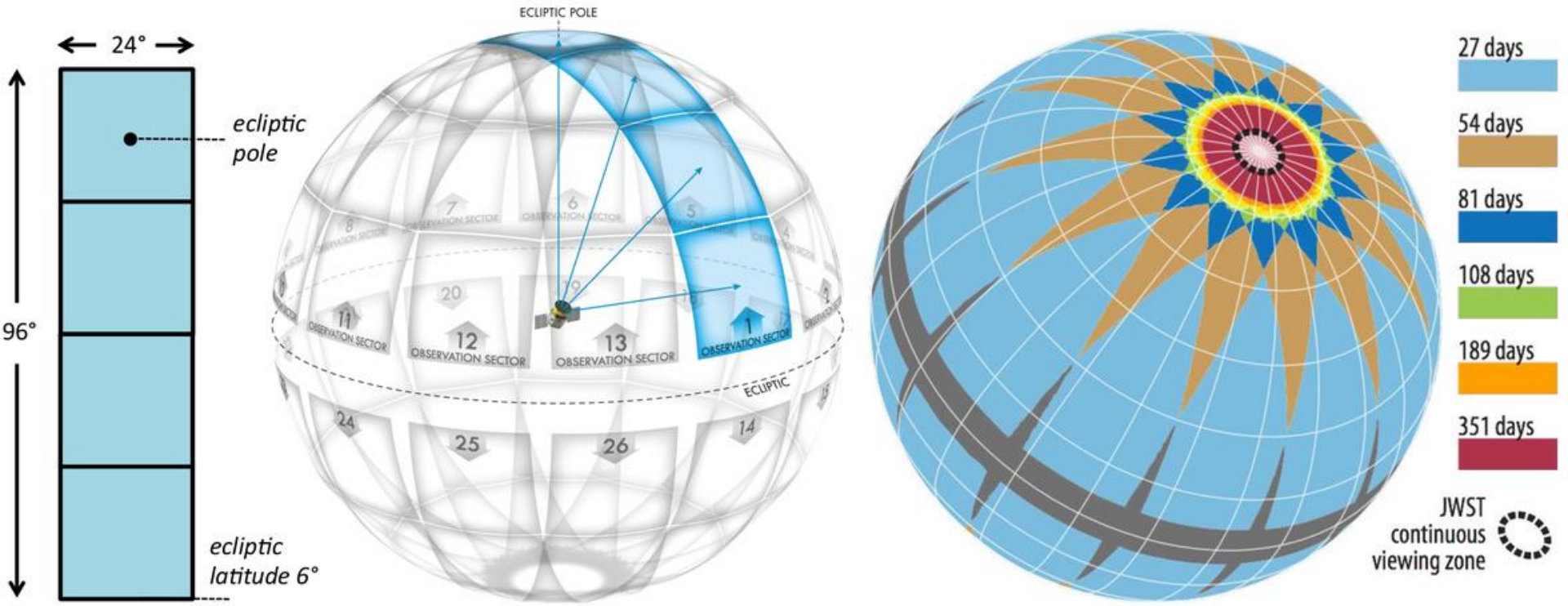
Ricker et al.: Transiting Exoplanet Survey Satellite

TESS Science Objectives

How TESS scanning the sky?



Left: the instantaneous combined field of view of the four TESS cameras. Middle: suddivision of the celestial sphere into 26 observation sectors (13 per hemisphere). Right: Duration of observations on the celestial sphere, taking into account the overlap between sectors. The dashed black circle enclosing the ecliptic pole shows the region which JWST will be able to observe at any time.

TESS Science Objectives

How TESS scanning the sky?

Semi-major axis	240,000 km (150,000 mi)
Eccentricity	0.55
Perigee	108,000 km (67,000 mi)
Apogee	375,000 km (233,000 mi)
Inclination	37°
Period	13.7 days

TESS observes from unique High Earth Orbit (HEO):

+ Unobstructed view for continuous light curves

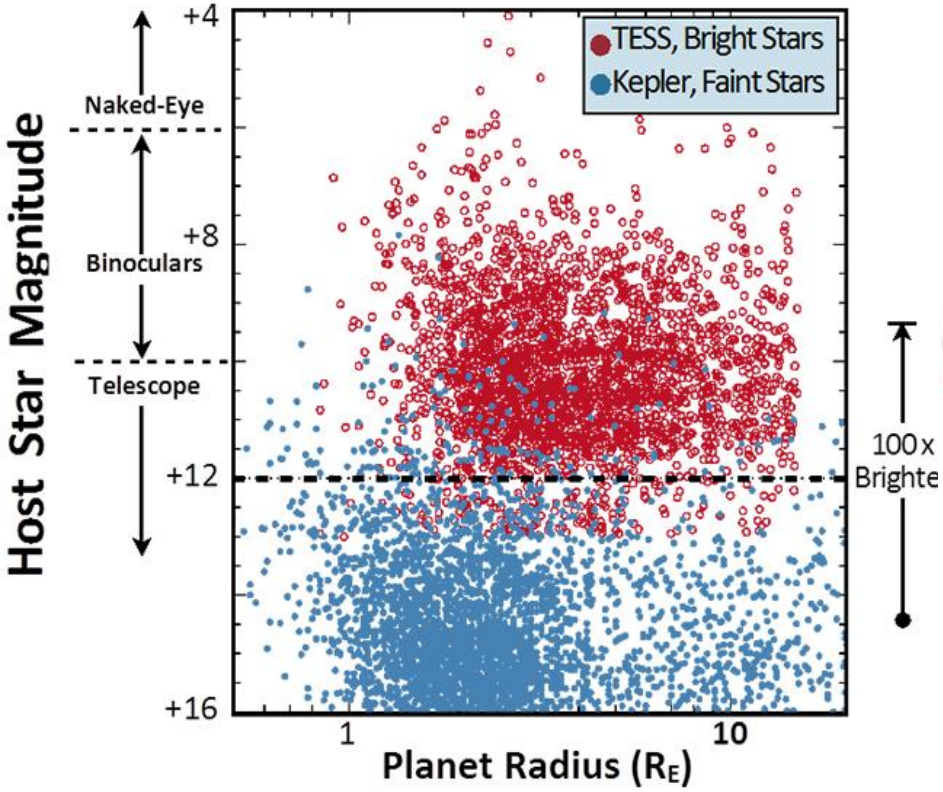
+ Two 13.7 day orbits per observation sector

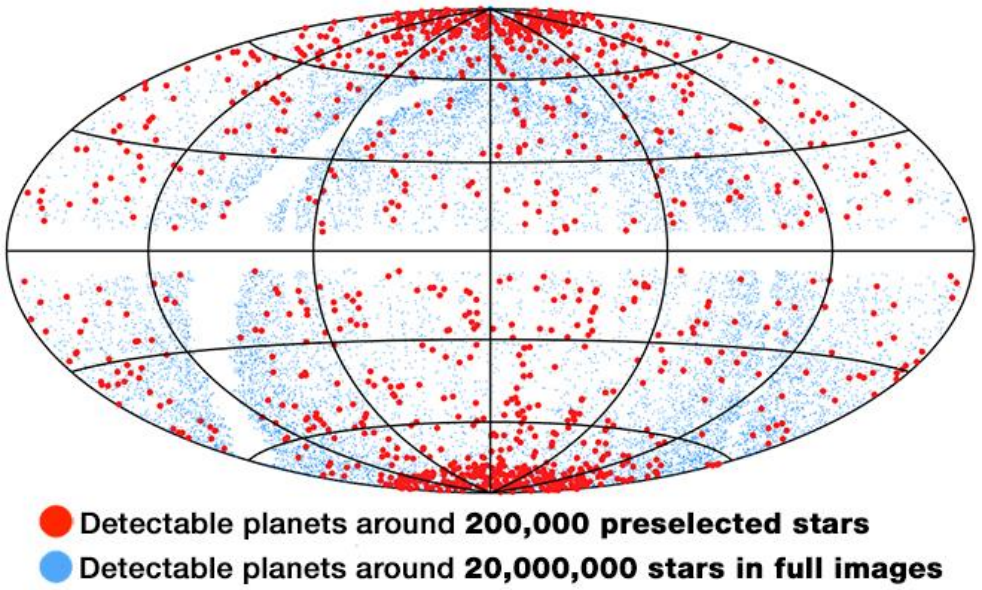
Animation of Transiting Exoplanet Survey Satellite's trajectory from 18 April 2018 to 18 December 2019

Transiting Exoplanet Survey Satellite • Earth • Moon

TESS Science Objectives

Predicted TESS outcome





Simulation of Expected TESS Exoplanet discoveries; Sullivan, et al 2015.

TESS Current Status & News

TESS Current Status & News

Recent News --- LHS 3844b

Simulations → TESS could detects hundreds of planets around nearby M dwarfs (Sullivan et al. 2015; etc.).

On Sep 19, Roland K. et al. reported the first such detection, based on data from the first month of the survey.

TESS Current Status & News

Recent News --- LHS 3844b

LHS 3844:

- M dwarf
- Located 15 pc (49 ly) away
- Mass/Radius 15%/19% of the Sun's

LHS 3844b:

- 1.32 ± 0.02 times larger than the Earth
- Orbits/ 11h

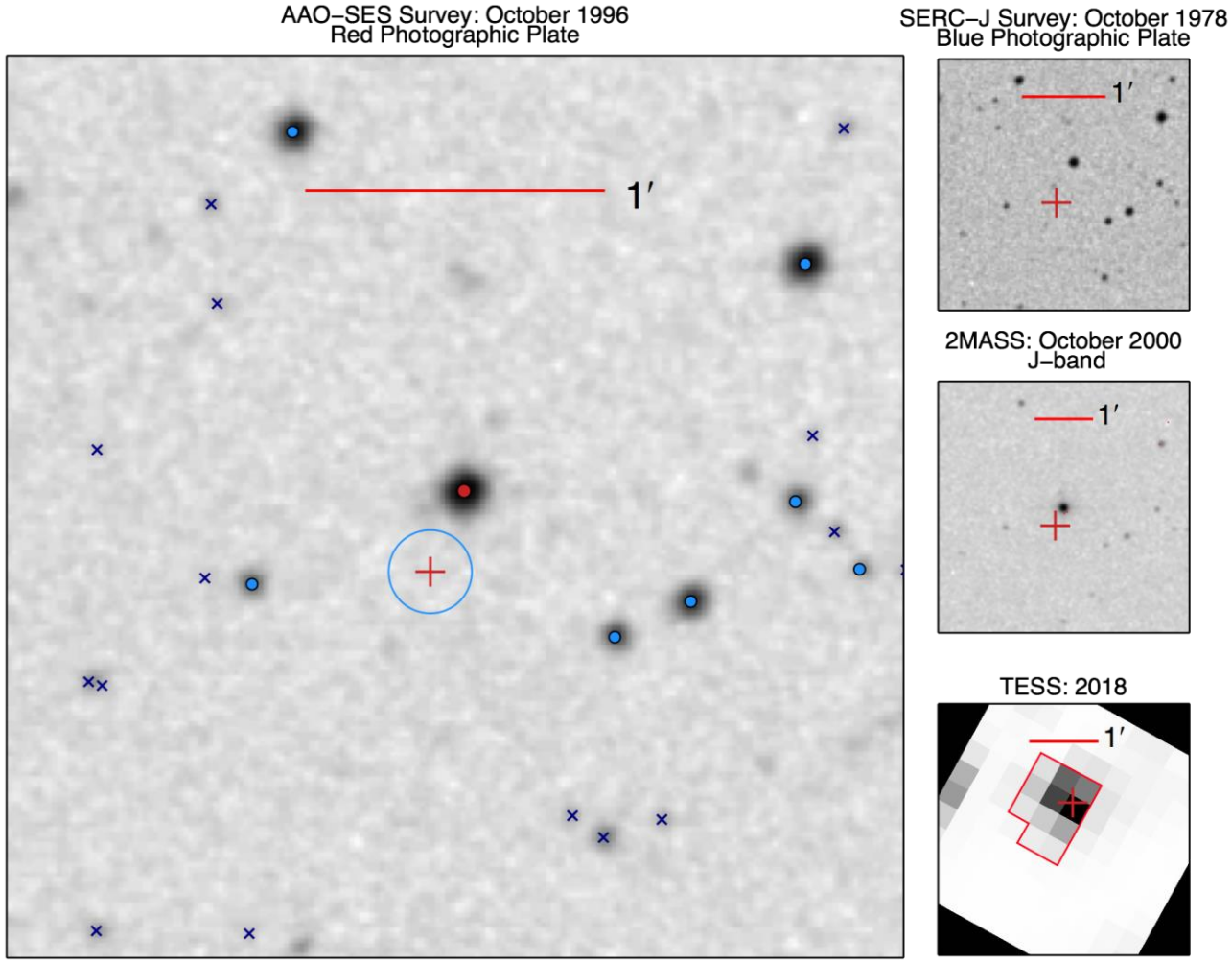
Close-orbiting planets are very common around M dwarfs, based on results from the Kepler survey (Dressing & Charbonneau 2015; Muirhead et al. 2015).

arXiv:1809.07242 [astro-ph.EP]

TESS Current Status & News

Recent News --- LHS 3844b

Images of the field surrounding LHS 3844



Blue circle:
10σ upper limit on the motion of the center of light during transits
→ rules out transit signal is from other stars.

arXiv:1809.07242 [astro-ph.EP]

TESS Current Status & News

Recent News --- LHS 3844b

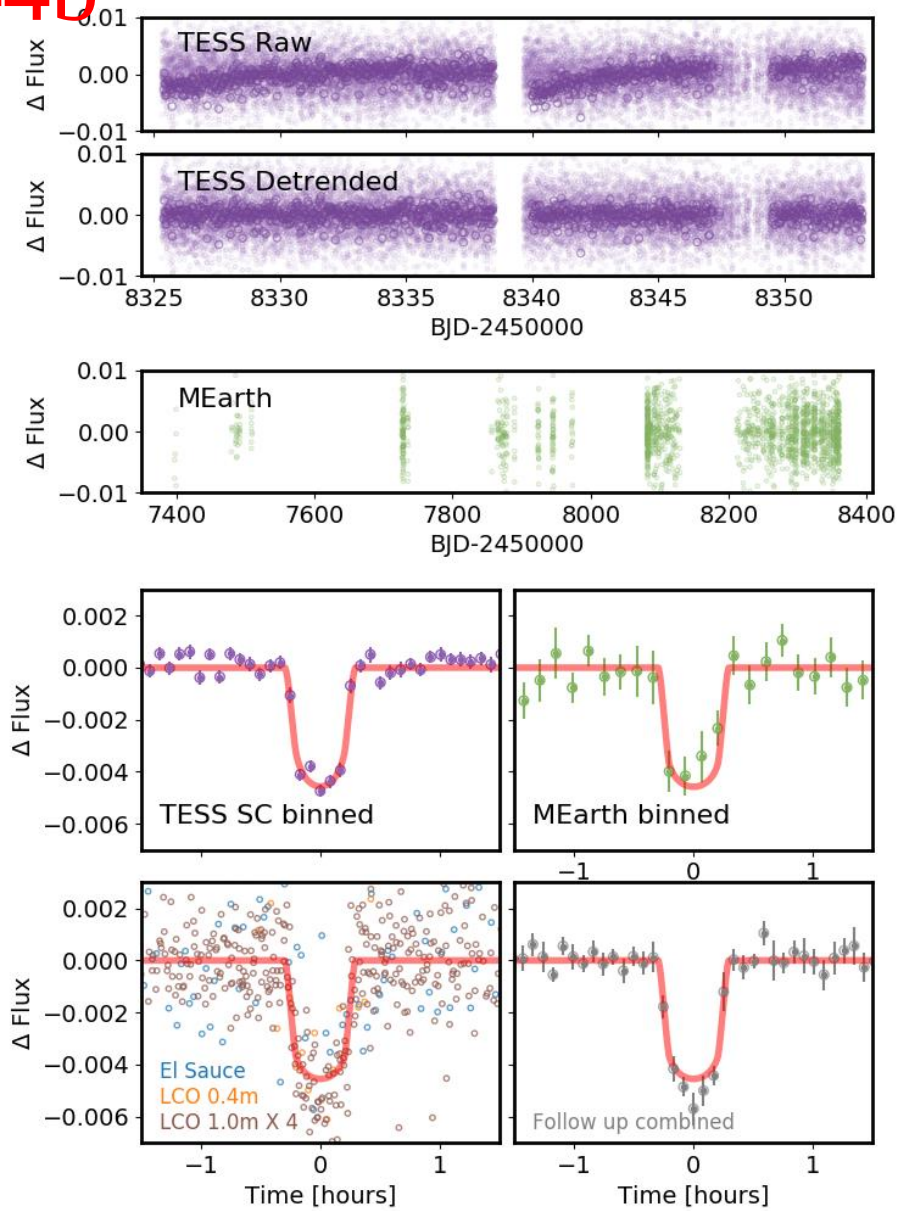
Light Curves of LHS 3844:

The Top two: TESS data, before and after high-pass filtering

The Middle one: MEarth Observatory, after correcting for systematics, 8 min averages

The bottom four: Additional ground-based transit observations; Together conform fading events within 2″ of LHS 3844.

Then They rules out Possible False Positives.

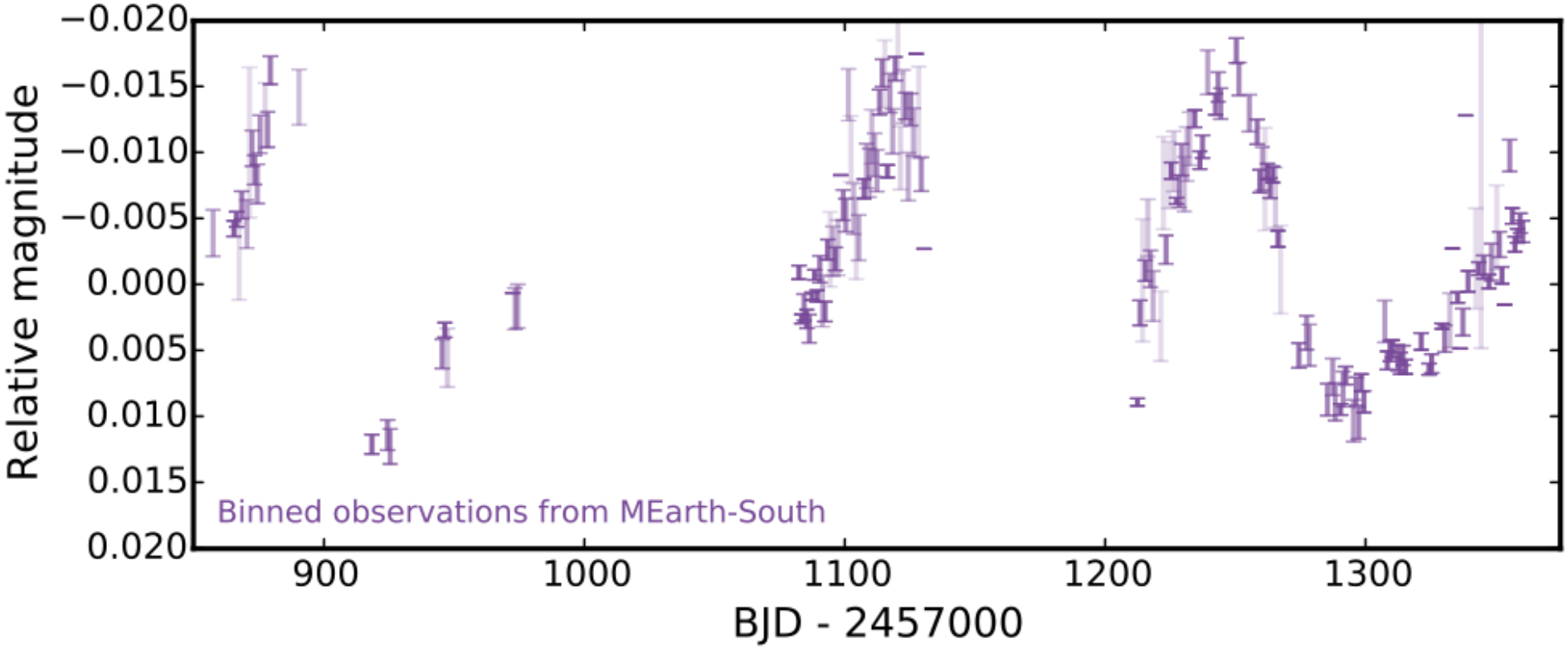


arXiv:1809.07242 [astro-ph.EP]

TESS Current Status & News

Recent News --- LHS 3844b

Light Curves of LHS 3844:



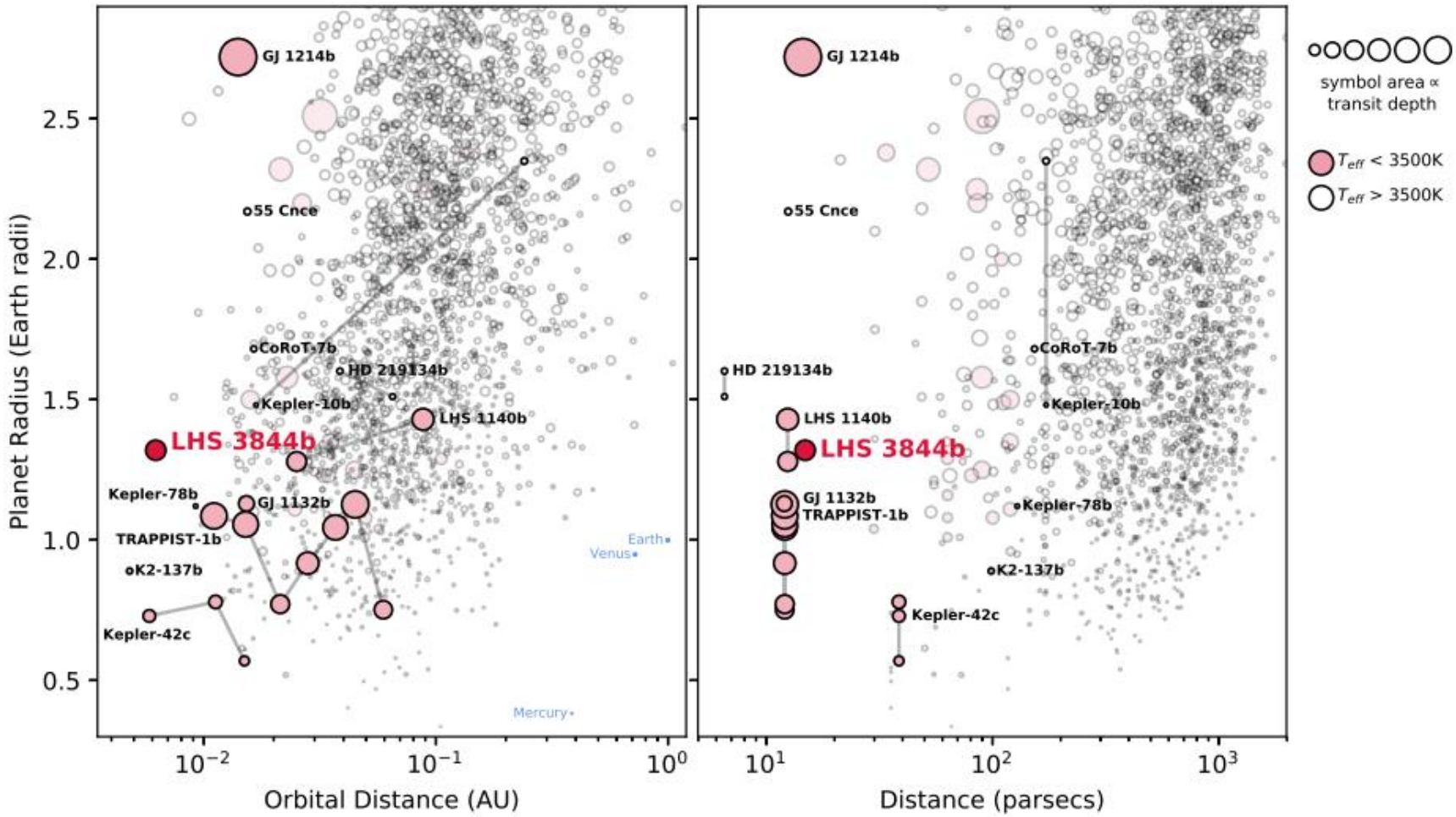
MEarth Observatory: Long-term photometric monitoring of LHS 3844, 1 day avg.

arXiv:1809.07242 [astro-ph.EP]

TESS Current Status & News

Recent News --- LHS 3844b

LHS 3844 b in the context of other known exoplanets



arXiv:1809.07242 [astro-ph.EP]

TESS Current Status & News

Recent News --- LHS 3844b

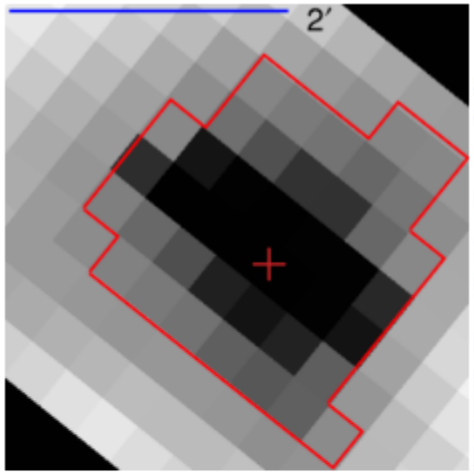
Discussion

- One of the closet known planets (2 perspectives).
- Good for atmospheric characterization through transit and occultation (secondary eclipse) spectroscopy.
  ← ranking 2nd among the 907 planets (< 2 R_{Earth}) in the NASA Exoplanet Archive by a crude signal-to-noise metric.
- The ultra-short period will also facilitate the measurement of the planet's mass through Doppler spectroscopy.

arXiv:1809.07242 [astro-ph.EP]

TESS Current Status & News

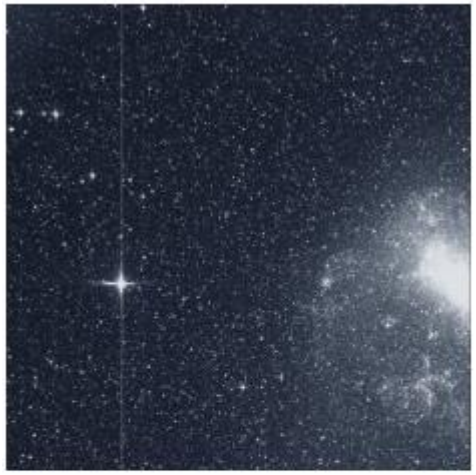
Other News



Preliminary Target Pixel Files from TESS Object of Interest Alerts Now Public at MAST

access_time 2018-10-04

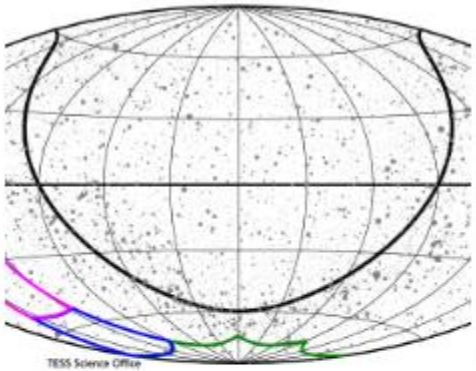
folder_open TSO



NASA’ s TESS Shares First Science Image in Hunt to Find New Worlds

access_time 2018-09-17

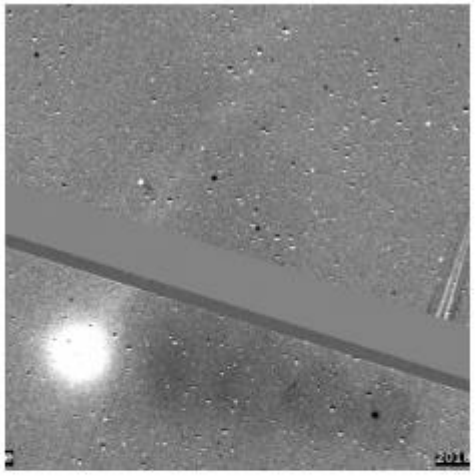
folder_open Science News



NASA’ s TESS Mission Completes First Science Observation Sector

access_time 2018-09-05

folder_open Science News



Catching a Comet: How the TESS Science Office found C/2018 N1

access_time 2018-08-10

folder_open Science News

https://tess.mit.edu/news/

TESS Current Status & News

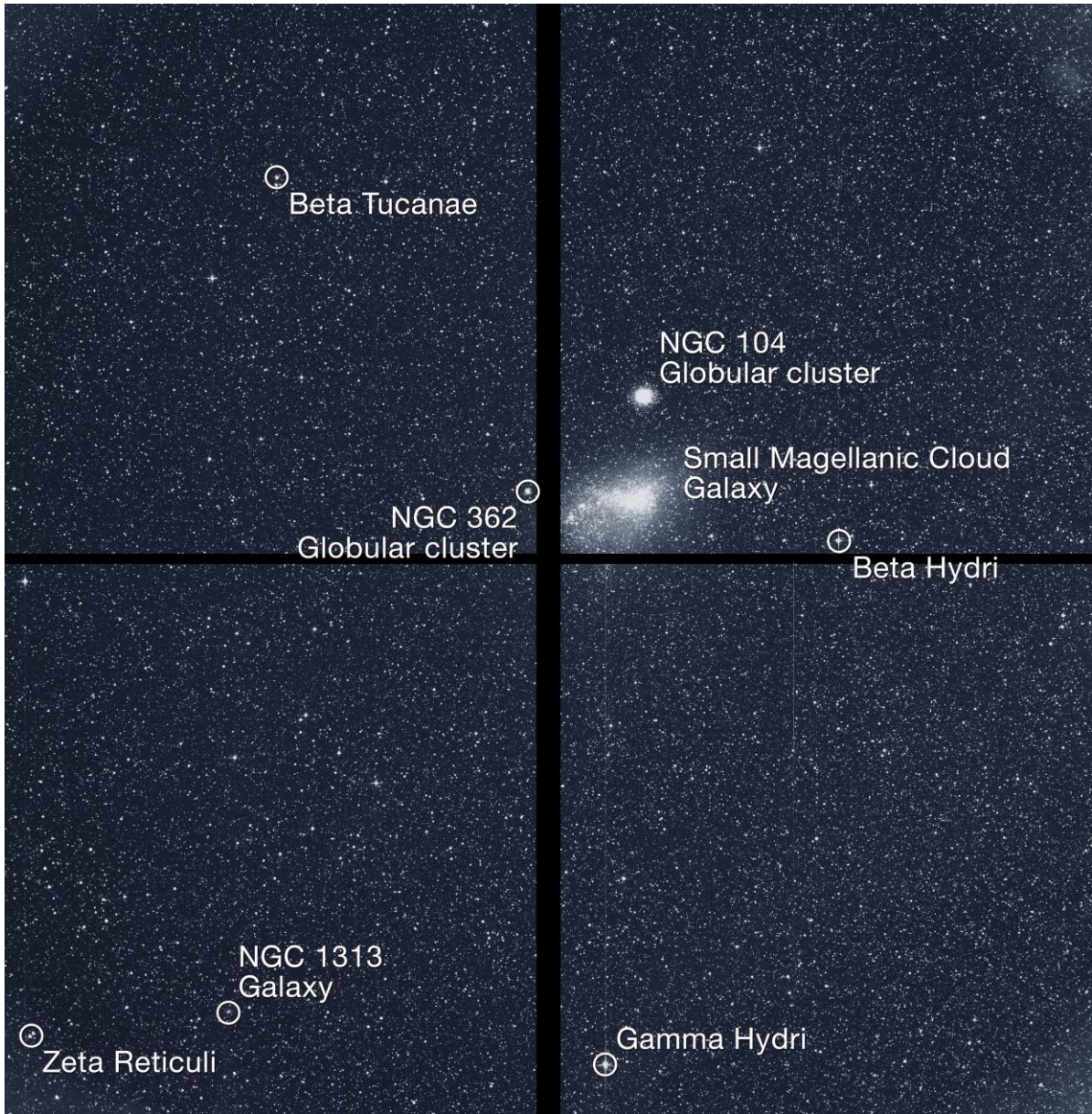
Other News

https://tess.mit.edu/news/

TESS Current Status & News

Other News

Southern sky
third camera
30-minute imaging period
Aug. 7.
Bright objects are labeled.



https://tess.mit.edu/news/

TESS Current Status & News

Data Access

https://archive.stsci.edu/prepds/tess-data-alerts/#dataaccess

Data Access

The data products are available for download through the table below. A bundle of all data products for all targets is available for download at the top of the table. Note that the exoplanet parameters are from the Sector 1 information when an exoplanet candidate is present in both Sector 1 and Sector 2.

TOI Target Information (Download .csv File) | Bundle Of All Files (Download .tar.gz File)										
TIC ID	TOI ID	Sector	RA (deg.)	Dec. (deg.)	Period (days)	Epoch (TJD)	TP File	LC File	DV File	Comment
25155310	114.01	1	63.373890	-69.226789	3.288671	1327.520891	tp.fits	lc.fits	dvs.pdf | dvr.pdf	
25375553	143.01	1	328.767654	-22.612566	2.310894	1325.58249	tp.fits	lc.fits	dvs.pdf | dvr.pdf	
29344935	109.01	1	313.215480	-25.687338	2.766737	1326.127529	tp.fits	lc.fits	dvs.pdf | dvr.pdf	
29831208	124.01	1	66.582618	-67.806508	1.842906	1326.54449	tp.fits	lc.fits	dvs.pdf | dvr.pdf	
38846515	106.01	1	68.959732	-64.027040	2.849493	1326.744466	tp.fits	lc.fits	dvs.pdf | dvr.pdf	
52368076	125.01	1	23.594697	-66.675830	4.6539	1327.432505	tp.fits	lc.fits	dvs.pdf | dvr.pdf	Planet #1
52368076	125.01	2	23.594697	-66.675830	4.6539	1327.432505	tp.fits	lc.fits	dvs.pdf | dvr.pdf	Planet #1
52368076	125.02	1	23.594697	-66.675830	9.151371	1334.456322	tp.fits	lc.fits	dvs.pdf | dvr.pdf	Planet #2
52368076	125.02	2	23.594697	-66.675830	9.151371	1334.456322	tp.fits	lc.fits	dvs.pdf | dvr.pdf	Planet #2
62483237	139.01	1	336.402307	-34.909623	11.058421	1334.896388	tp.fits	lc.fits	dvs.pdf | dvr.pdf	
70440470	126.01	1	339.489337	-35.153982	3.035381	1326.731043	tp.fits	lc.fits	dvs.pdf | dvr.pdf	
89020549	132.01	1	338.399420	-43.436628	2.109307	1326.903983	tp.fits	lc.fits	dvs.pdf | dvr.pdf	
92352620	107.01	1	313.783108	-34.135572	3.950054	1328.29934	tp.fits	lc.fits	dvs.pdf | dvr.pdf	
97409519	113.01	1	332.714323	-30.749674	3.372877	1327.053085	tp.fits	lc.fits	dvs.pdf | dvr.pdf	
140068425	140.01	1	330.301574	-49.060026	2.28139	1327.399305	tp.fits	lc.fits	dvs.pdf | dvr.pdf	
144065872	105.01	1	337.457199	-48.003087	2.184659	1326.50599	tp.fits	lc.fits	dvs.pdf | dvr.pdf	

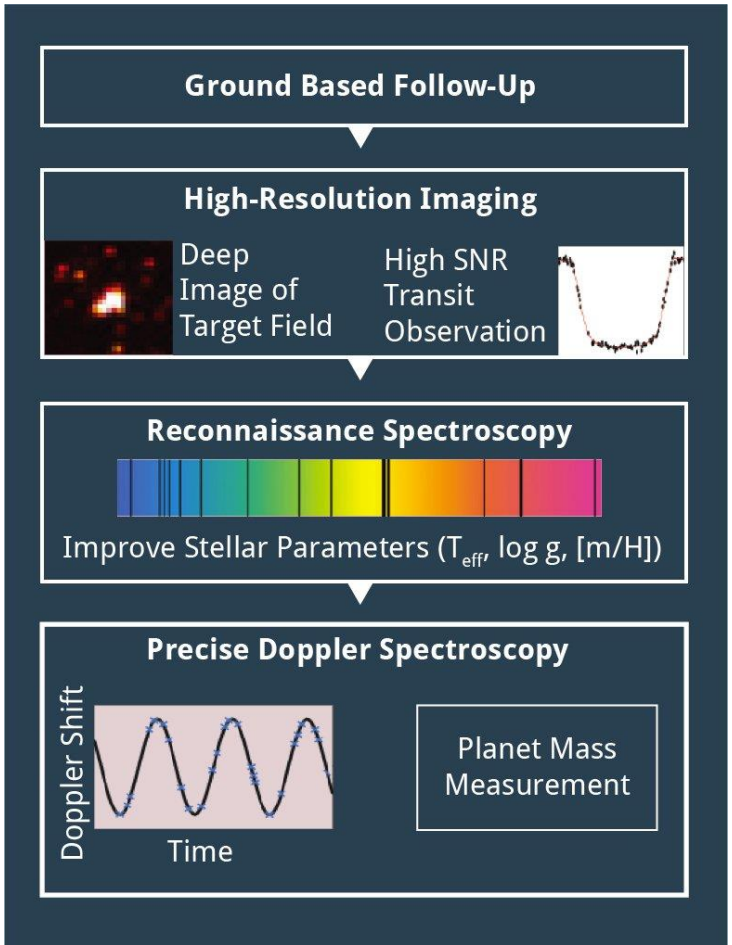
https://tess.mit.edu/news/

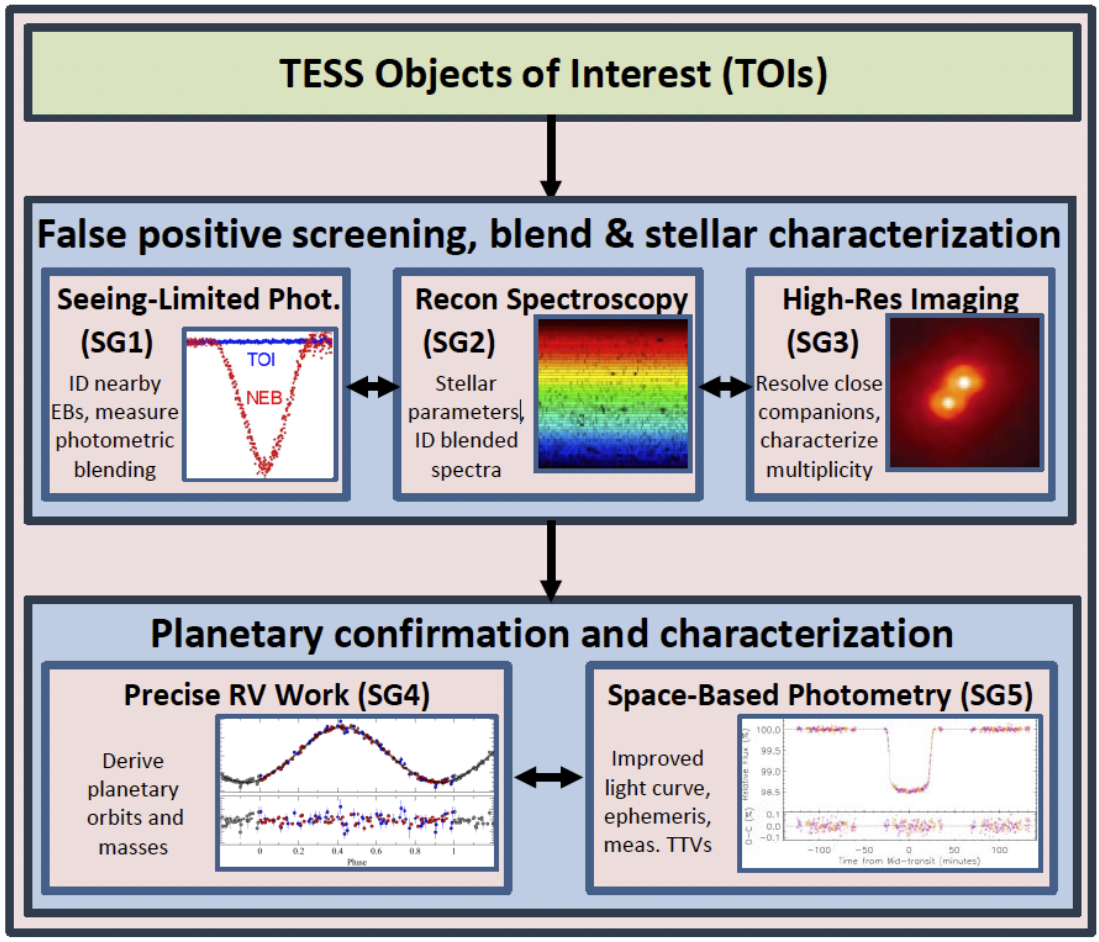
TESS Current Status & News

TFOP Overview

TESS Follow-up Observing Program

+ Measuring masses for 50 transiting planets smaller than 4 Earth radii.

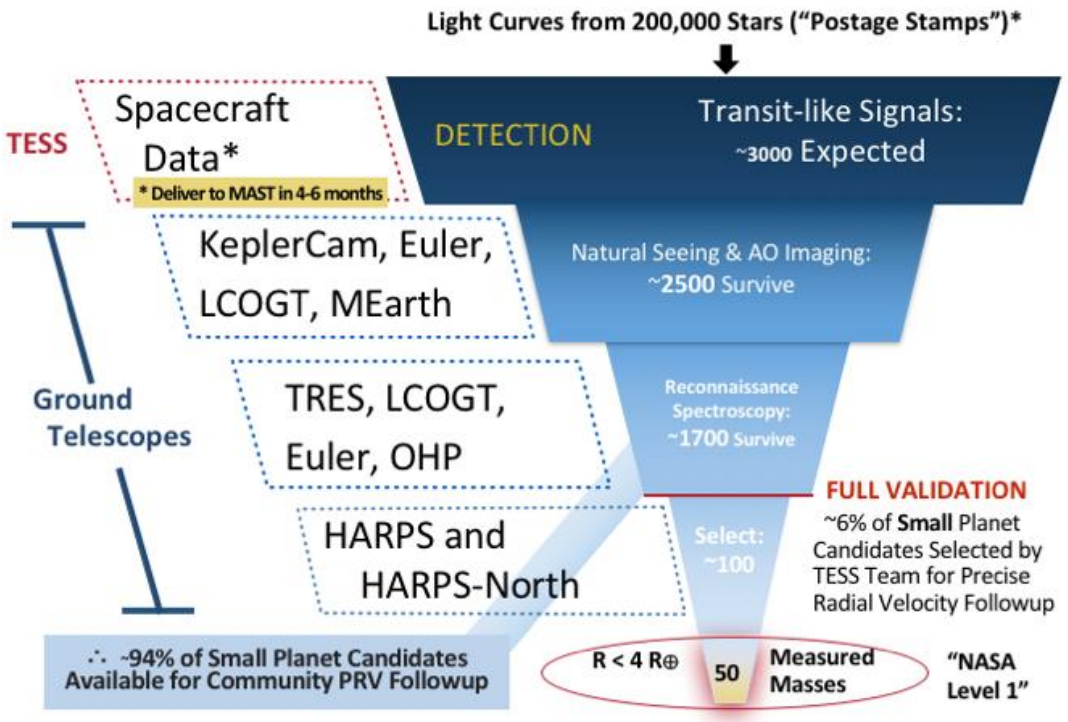




TESS Current Status & News

TFOP Overview

TESS Follow-up Observing Program



Small Planet Validation and Mass Measurements Process: Achieving a Baseline Science Requirement of measuring the masses of fifty planets with radii less than 4 R_{EARTH}.

Summary

- Transiting is one of the most successful exoplanets discovery technique.
- TESS: MIT-led NASA mission; 2ys photometric, target for bright nearby Solar neighborhoods, redder observing band pass .
- Discovery LHS 3844b around a nearby M dwarf during the first TESS observing sector → prospects of future discoveries are bright. 90% of the sky has not yet been surveyed by either TESS or Kepler.
- TESS follow-up observations will open the door for a host of new discoveries about exoplanets, and perhaps of the processes behind the formation and evolution of planetary systems.

References

- https://arxiv.org/pdf/1406.0151.pdf
- https://arxiv.org/abs/1809.07242
- https://en.wikipedia.org/wiki/Transiting_Exoplanet_Survey_Satellite
- https://tess.mit.edu/
- https://tess.gsfc.nasa.gov/index.html
- http://web.ipac.caltech.edu/staff/christia/slides/christiansen_k2tessspecialsession_aas2017.pptx
- …