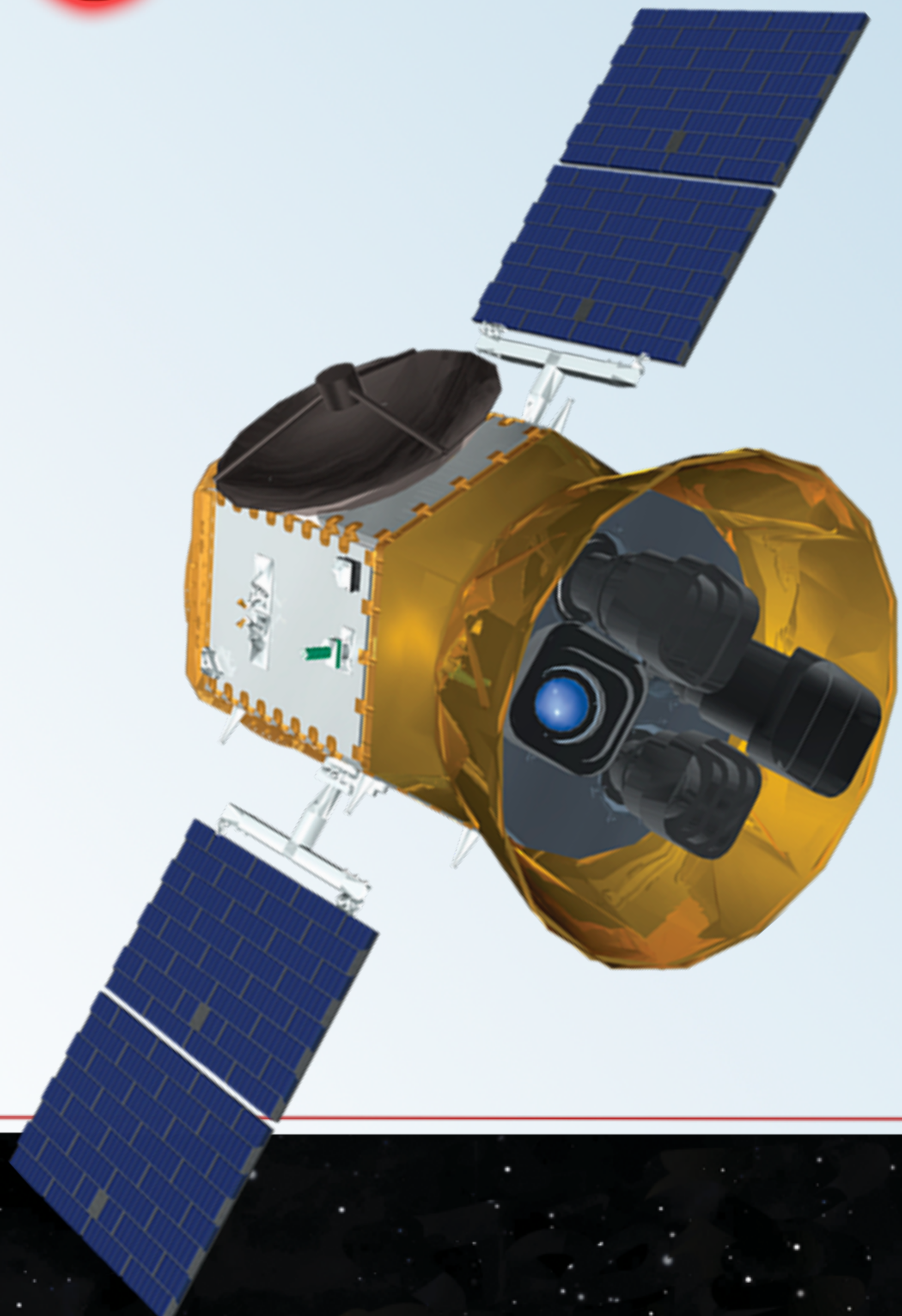
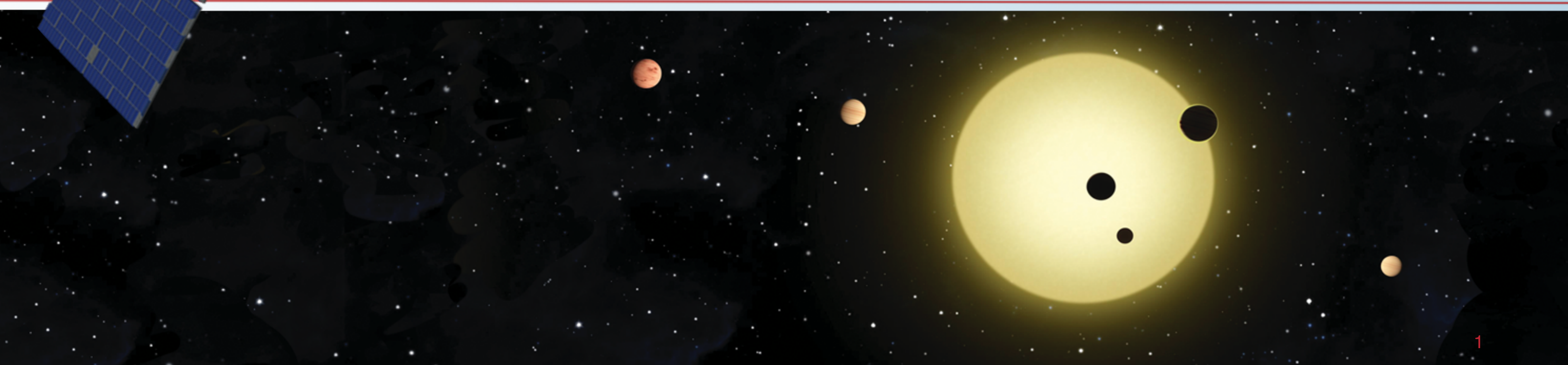
TESS and Galactic Science



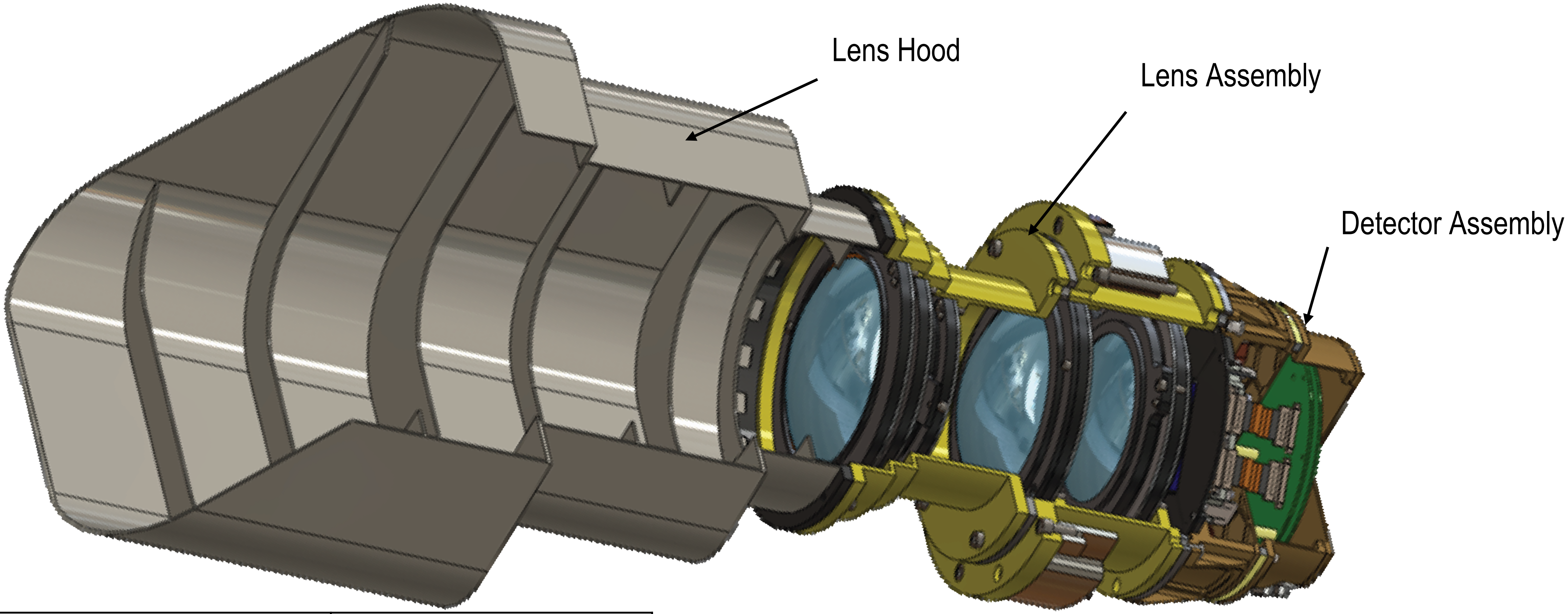
Keivan Stassun

WFIRST Meeting
18 November 2014

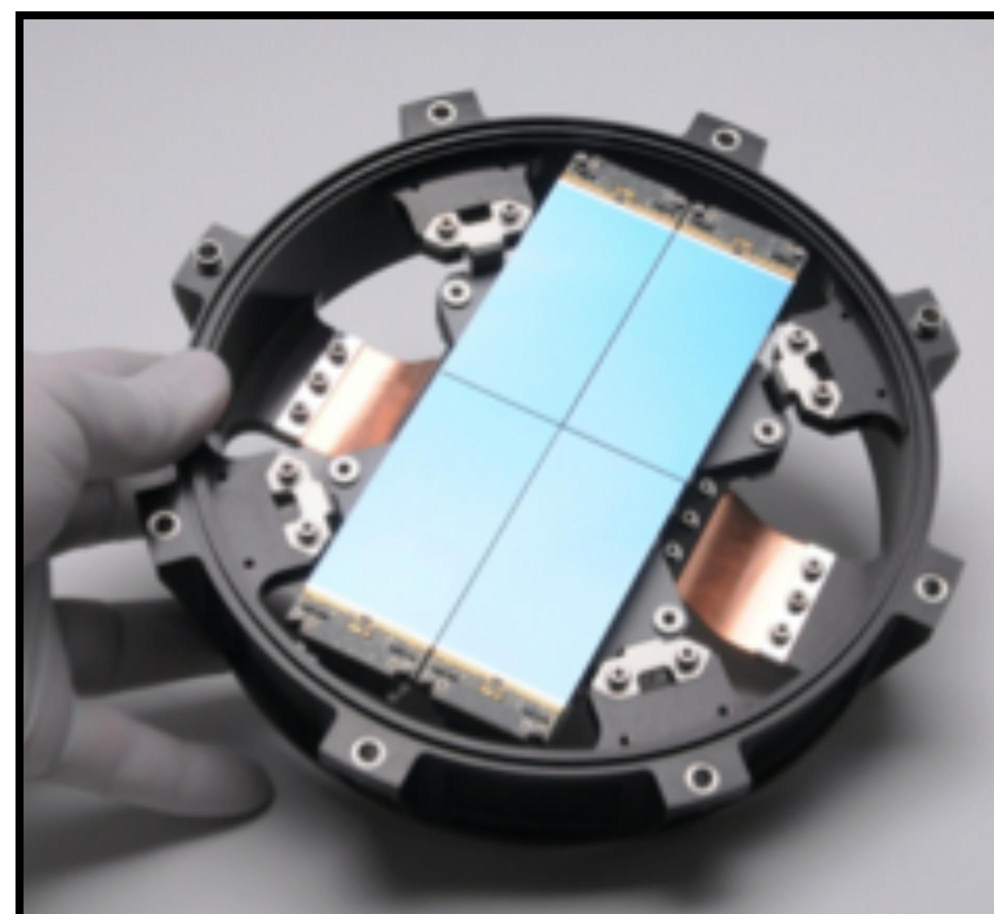


Preliminary TESS Mission Schedule

Activity	Date	Status
Systems Requirement Review	12-13 Feb 2014	✓ Completed
Preliminary Design Review	8-11 Sep 2014	✓ Completed
Mission Confirmation	31 Oct 2014	✓ Completed
Launch Vehicle Selection	mid-December 2015	Upcoming
Critical Design Review	18-21 May 2015	Upcoming
Systems Integration Review	4 Oct 2016	Planned
Launch Readiness Review	2 Aug 2017	Planned
Science Mission Complete	8 Oct 2020	Planned



Entrance pupil diameter	10.5 cm
Bandpass	600-1000 nm
Field of view	24° x 24°
Cadence for target stars	2 min
Cadence for full frame images	30 min
Nominal mag. Range	I = 4-16

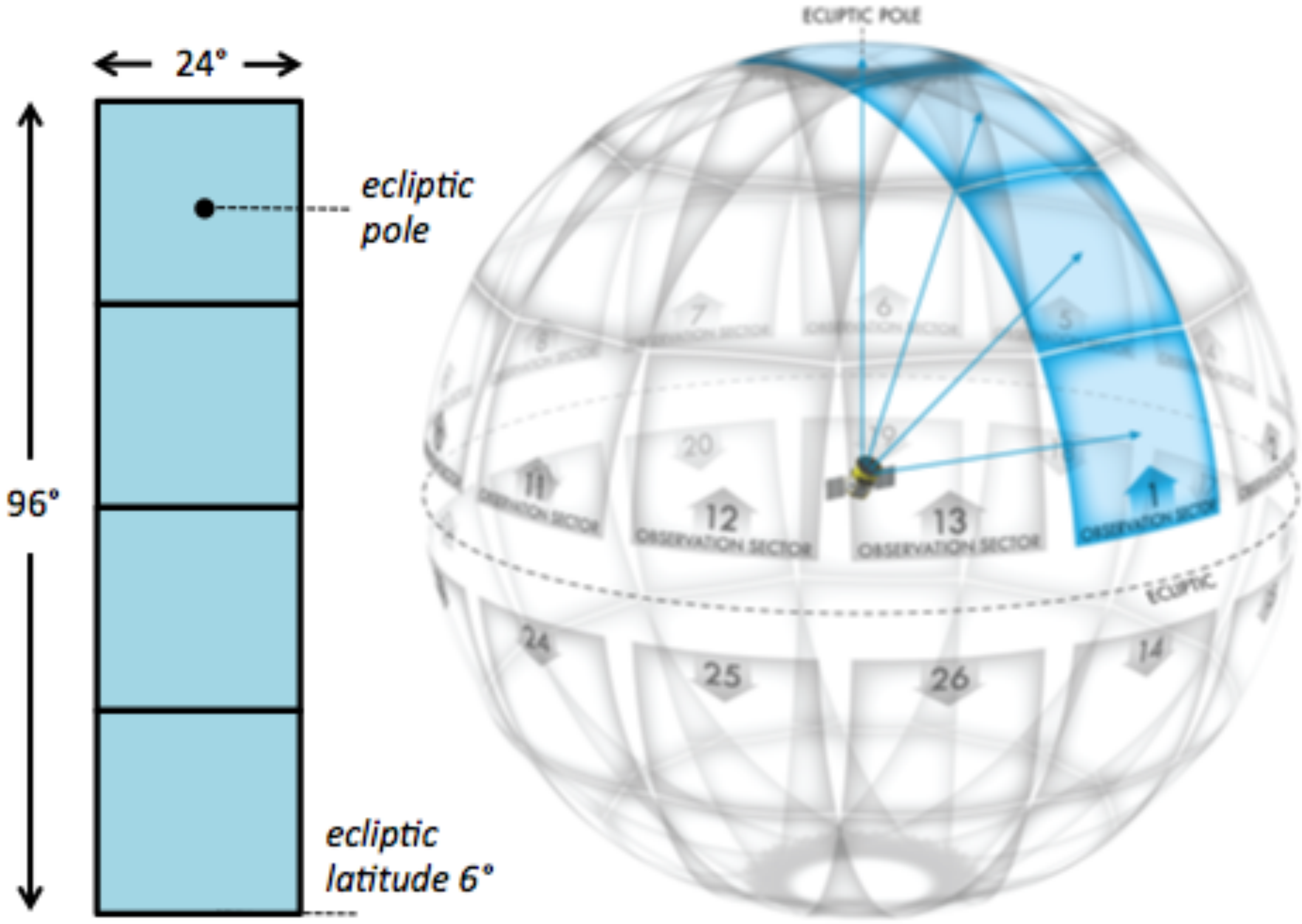


TESS Baseline Science Requirements

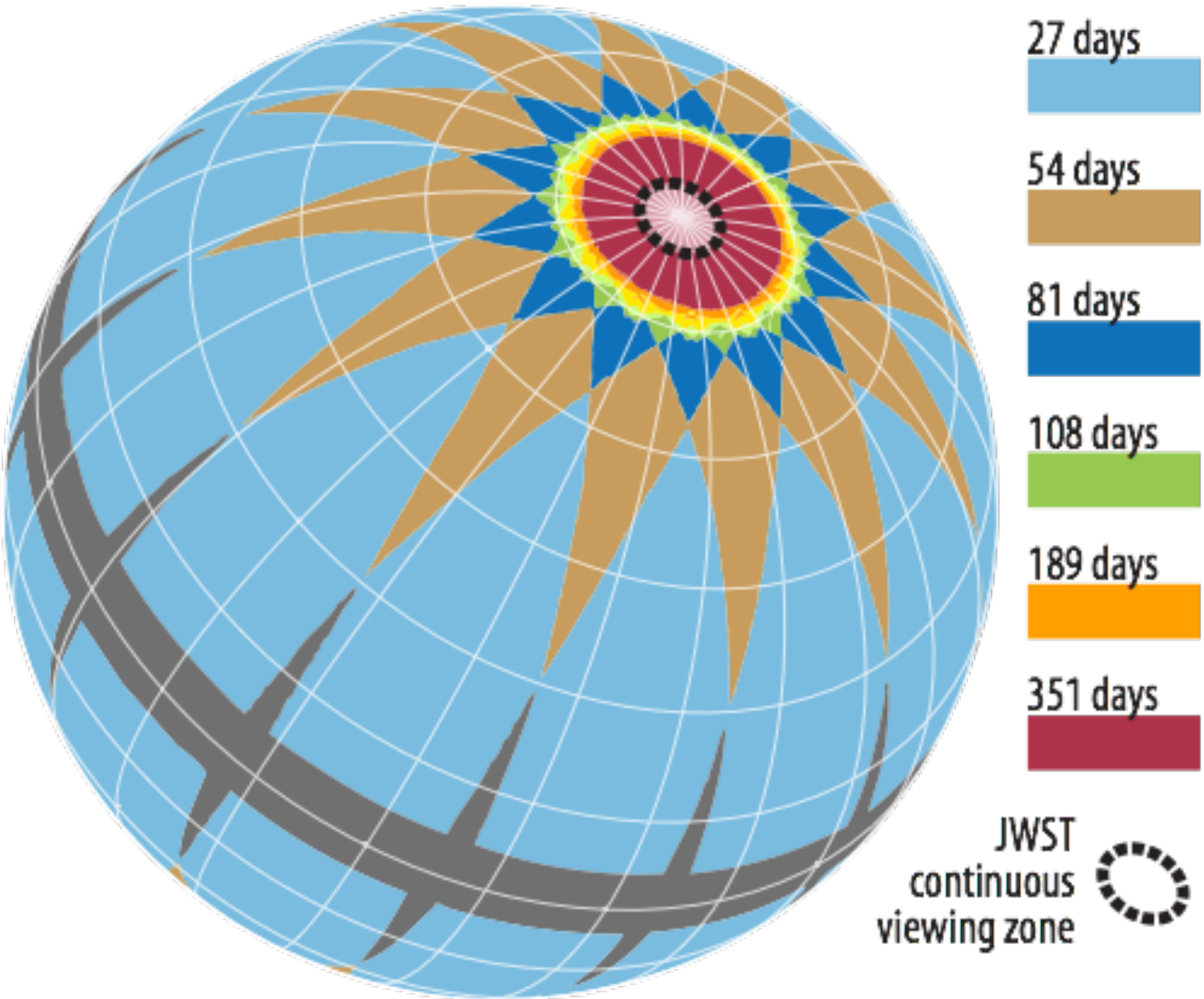
- BSR1: TESS shall perform a **wide-field sky survey** sensitive to transiting planets with orbital periods of less than 10 days. In this survey, TESS shall monitor >200,000 stars spread over the celestial sphere with a photometric sensitivity sufficient to permit detection of transiting *planets with a radius ≥ 2.5 R_{Earth}*.

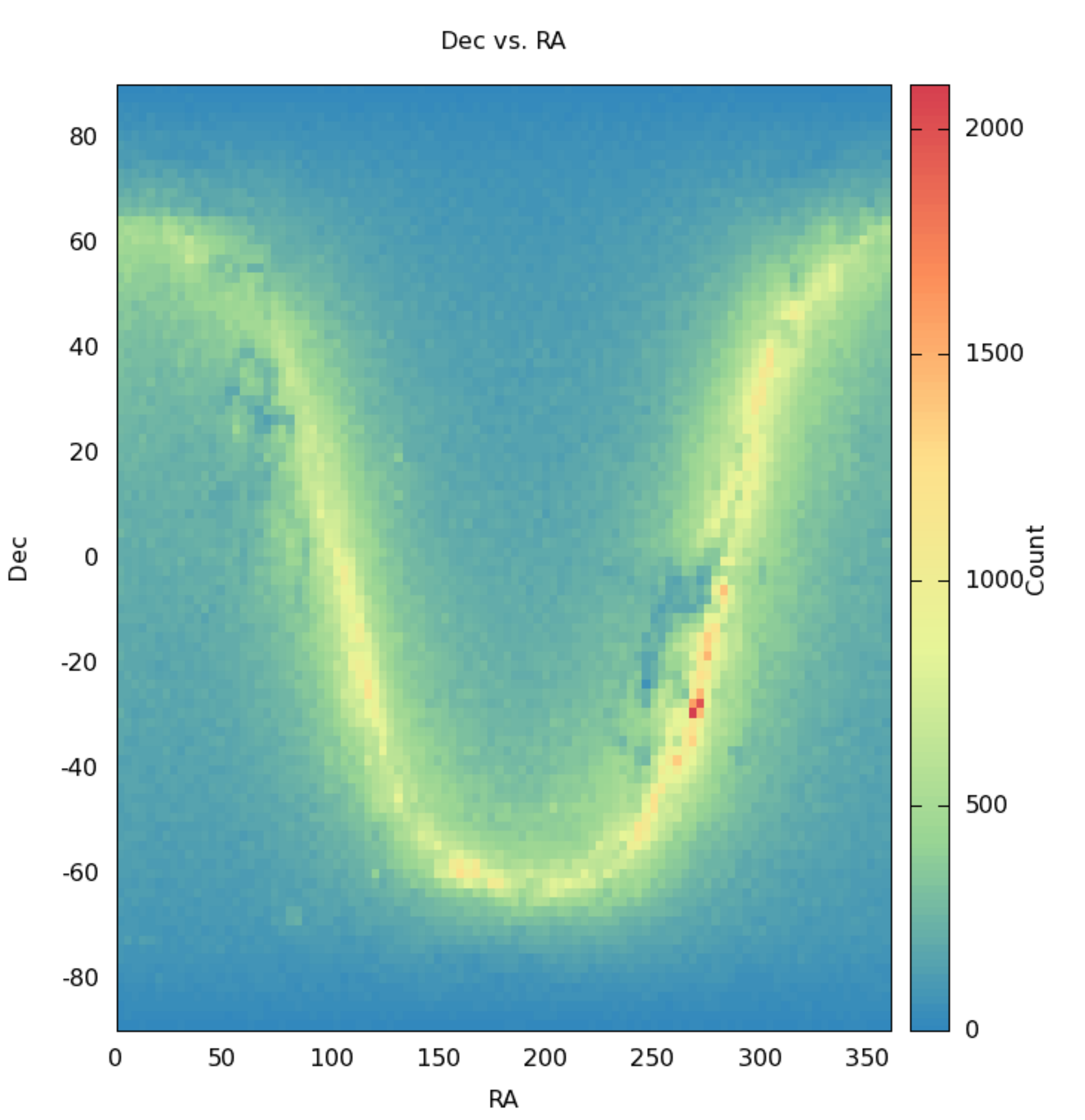
- BSR2: TESS shall perform a **concurrent [narrow field] sky survey** sensitive to transiting planets with *periods of 120 days or more.* In this survey, TESS shall *monitor >10,000 stars in regions centered on the ecliptic poles* with a photometric sensitivity sufficient to permit detection of transiting *planets with a radius ≥ 2.5 R_{Earth}.*

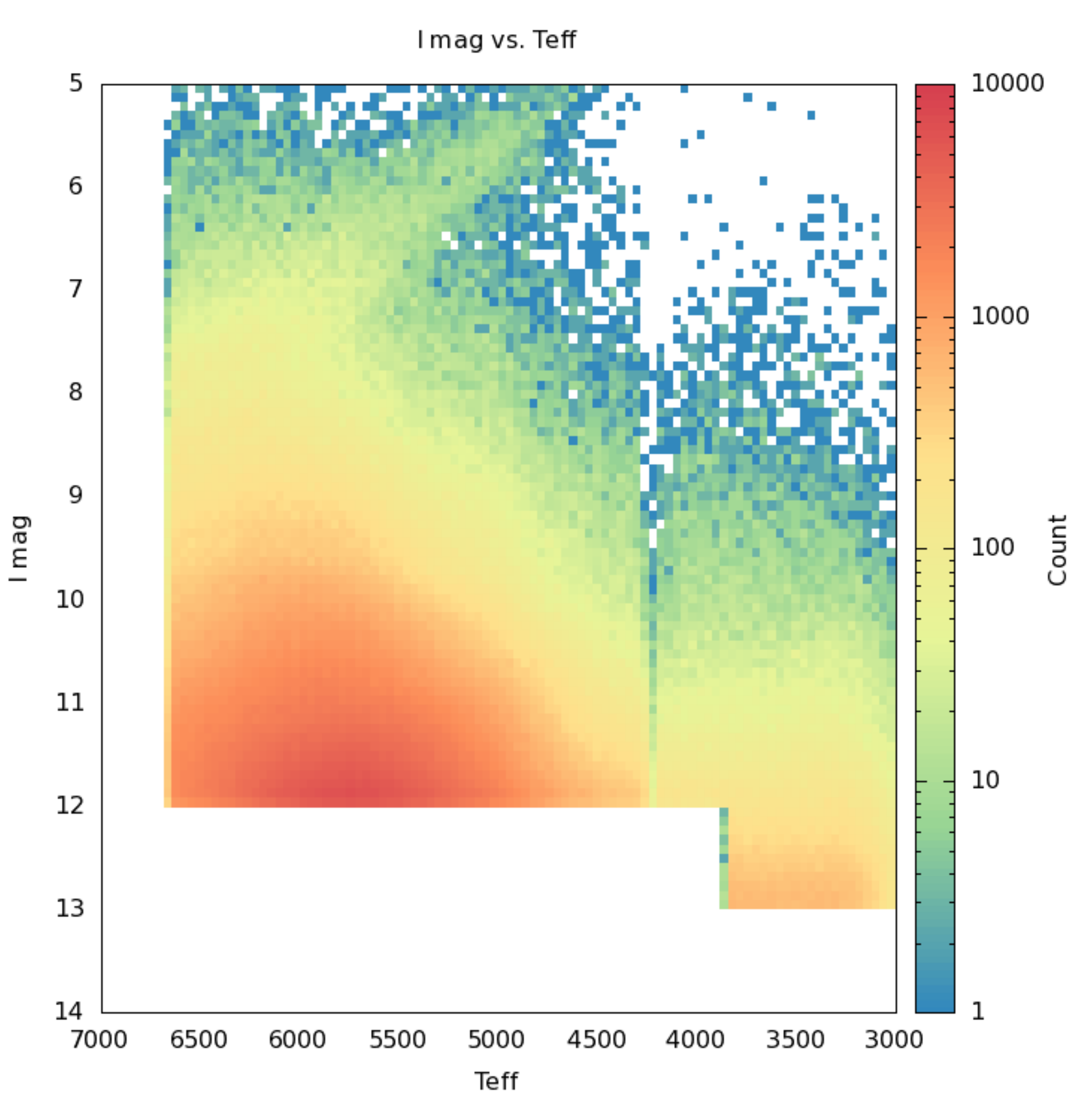
- BSR3: The TESS team shall assure that **masses of fifty (50) planets** *with radii less than 4 R_{Earth} are determined.*



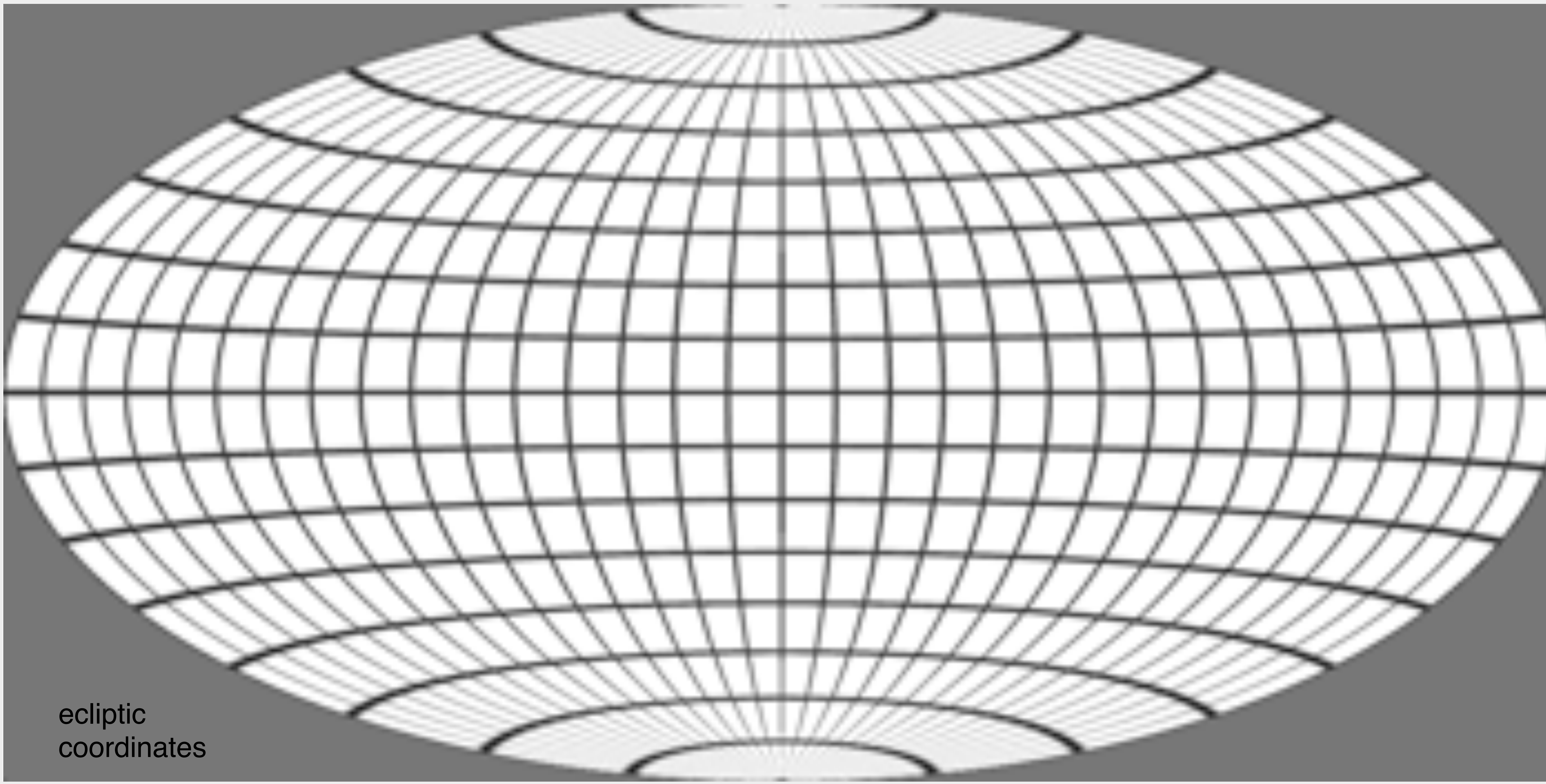
24°
96°
ecliptic
pole
ecliptic
latitude 6°
ECLIPTIC POLE
7
6
5
11
OBSERVATION SECTOR
20
12
OBSERVATION SECTOR
13
OBSERVATION SECTOR
1
OBSERVATION SECTOR
ECLIPTIC
24
25
26
14


27 days
54 days
81 days
108 days
189 days
351 days
JWST continuous viewing zone


Dec vs. RA
Dec
RA
Count
80
60
40
20
0
-20
-40
-60
-80
0
50
100
150
200
250
300
350
2000
1500
1000
500
0


I mag vs. Teff
I mag
Teff
Count
5
6
7
8
9
10
11
12
13
14
7000
6500
6000
5500
5000
4500
4000
3500
3000
10000
1000
100
10
1

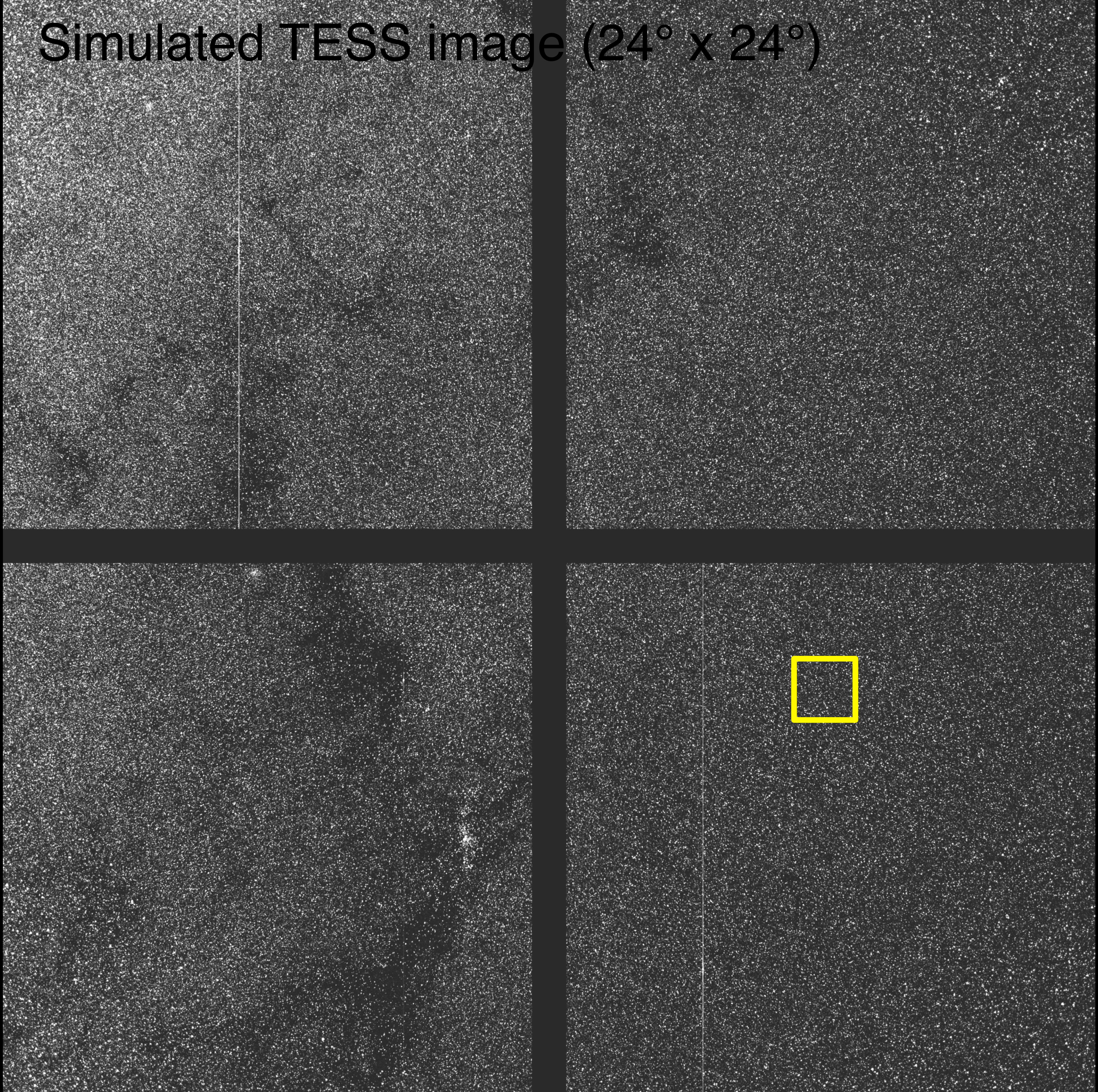
Simulated TESS detections

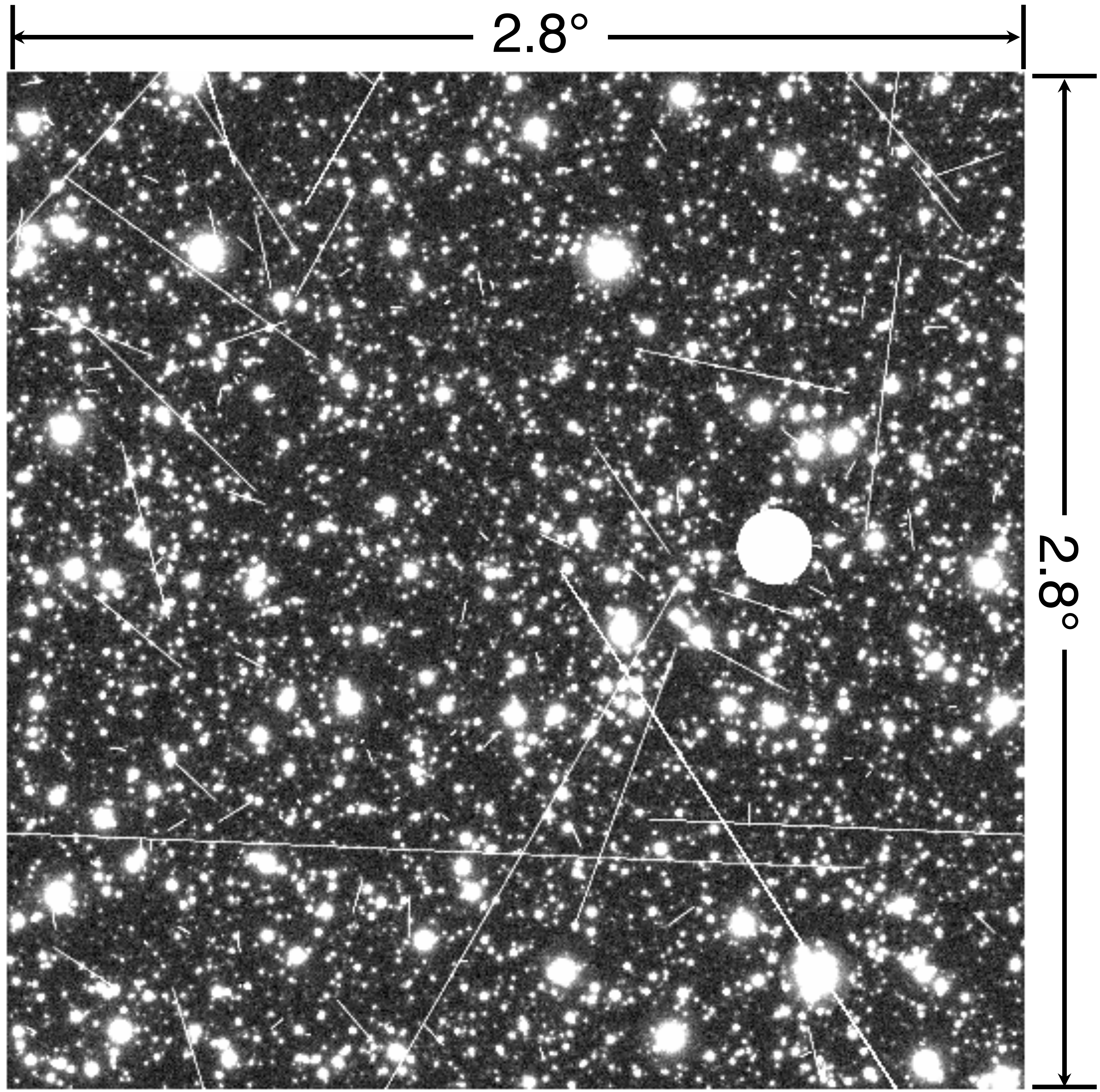


- detectable planets around pre-selected target stars
- detectable planets around other stars in full-frame images

Sullivan et al., in prep.

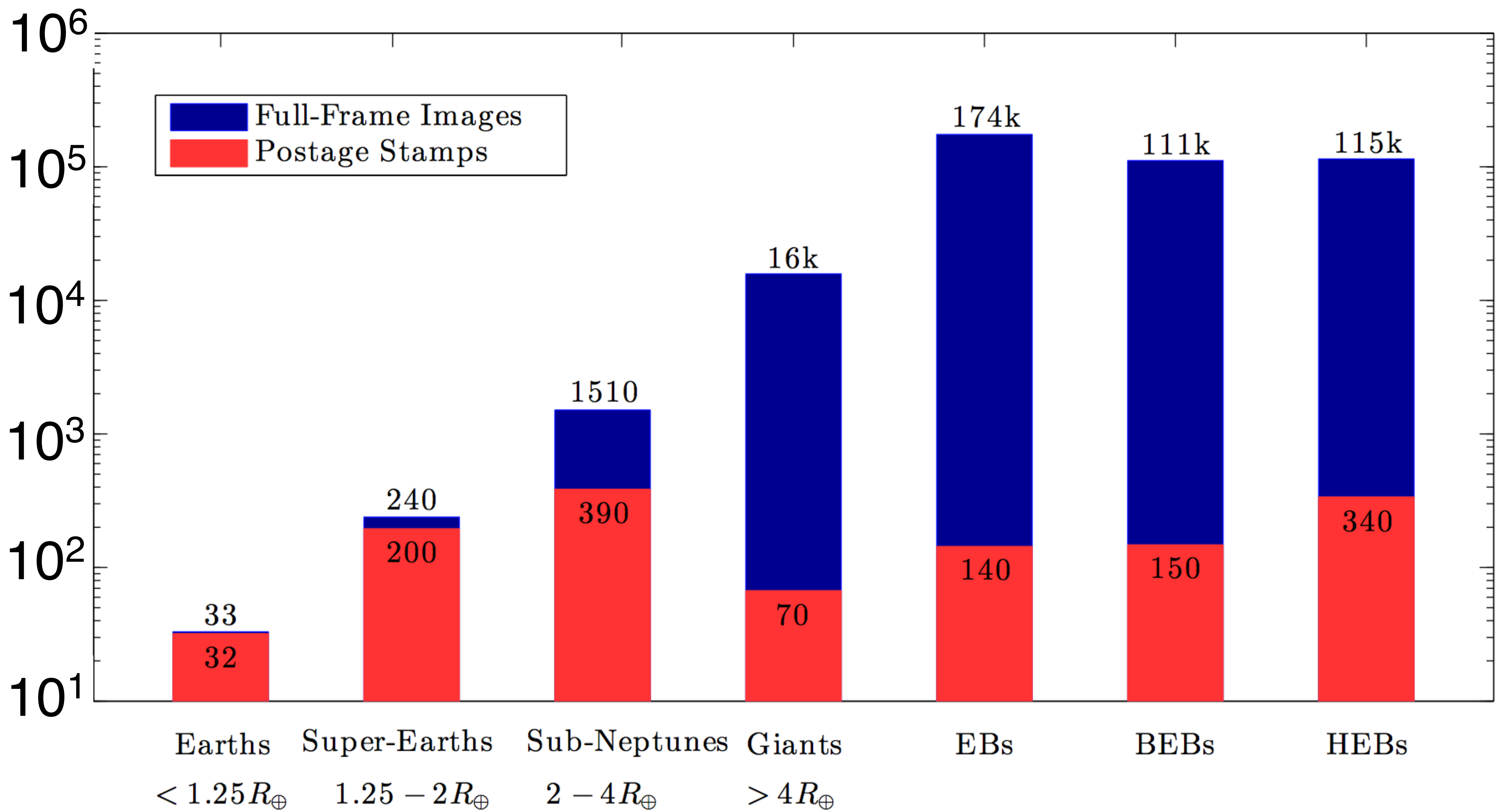
Simulated TESS image (24° x 24°)



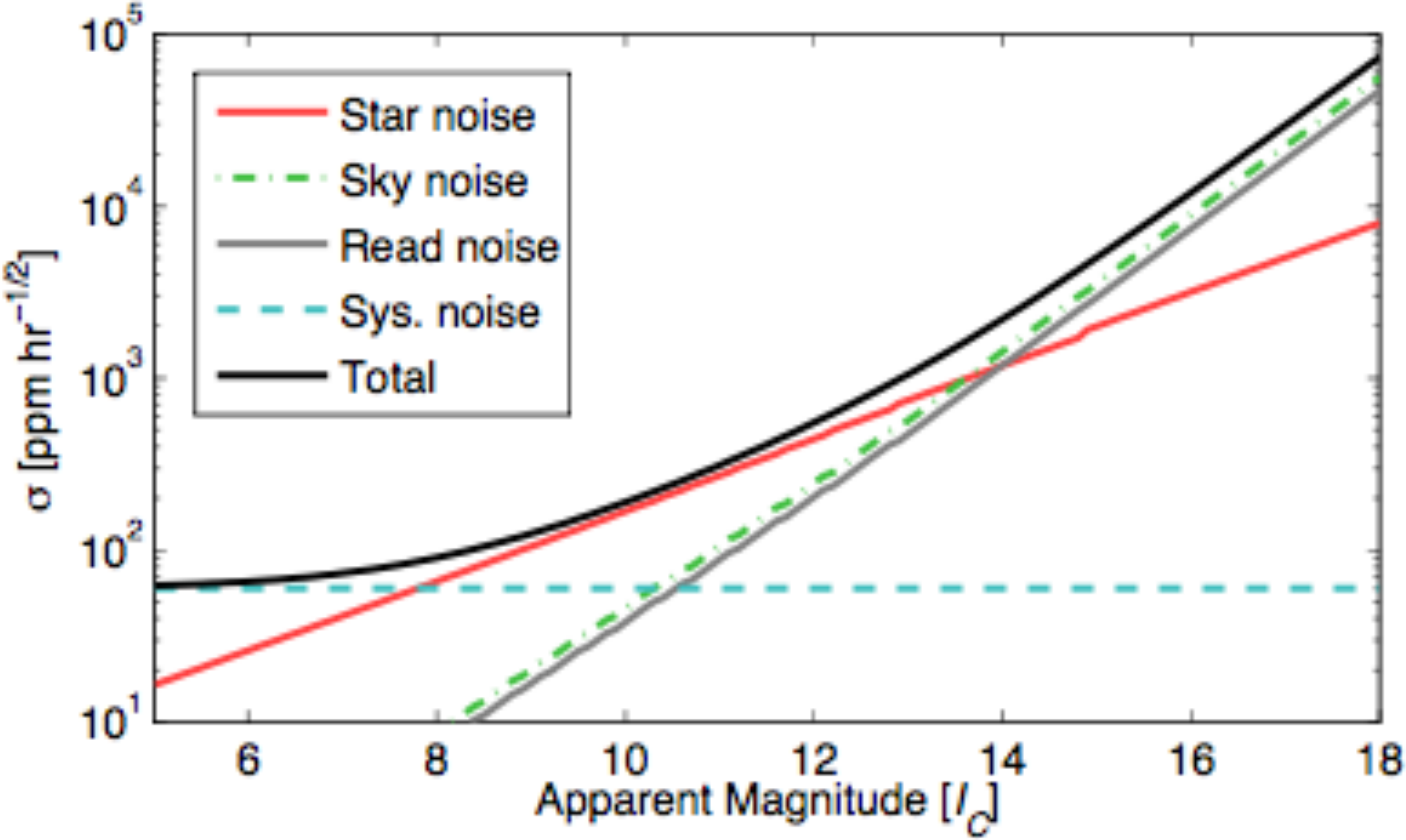


2.8°
2.8°

Simulated TESS detections



Sullivan et al., in prep.



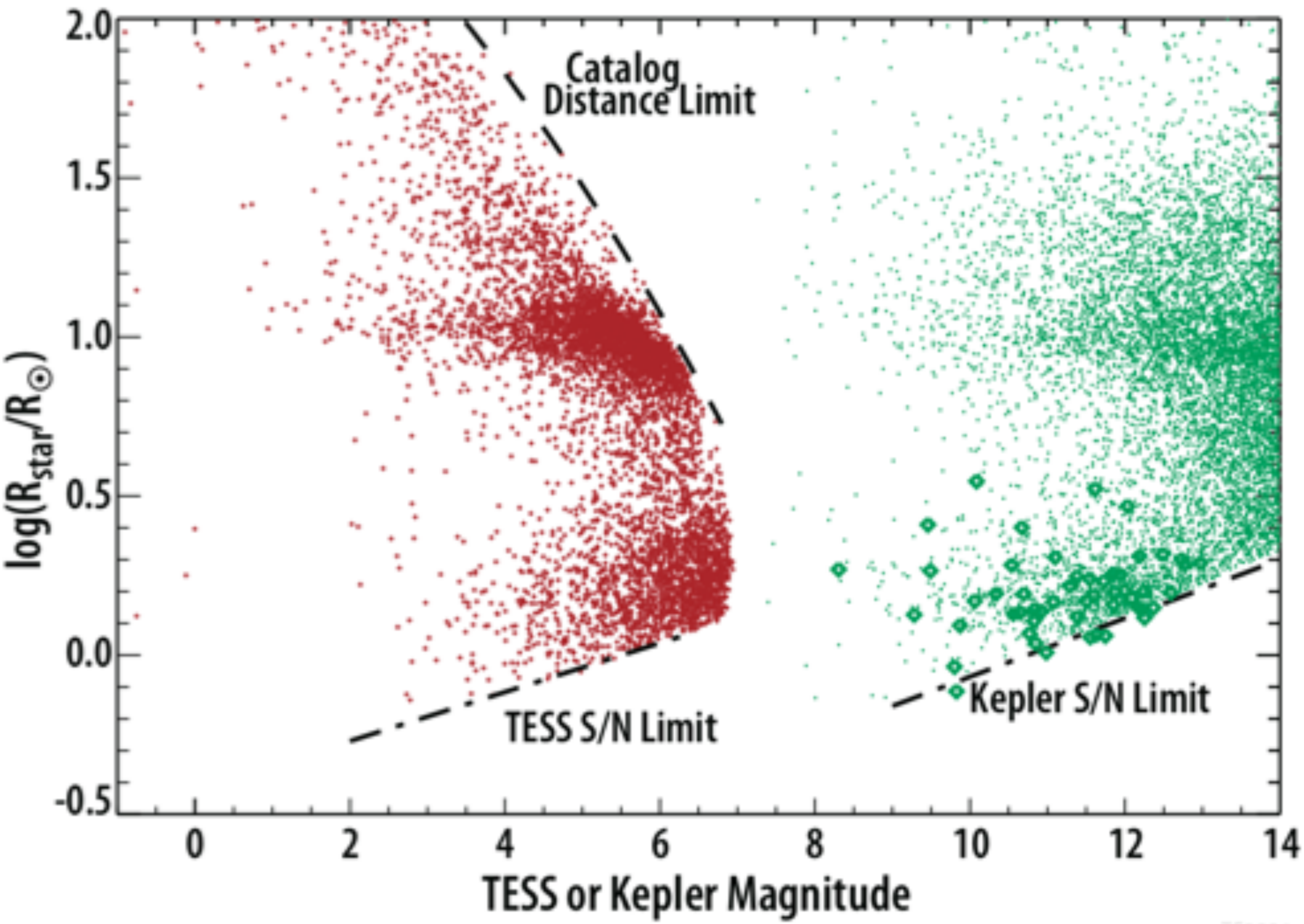
Ricker et al. (2014)

Opportunities for Galactic Science

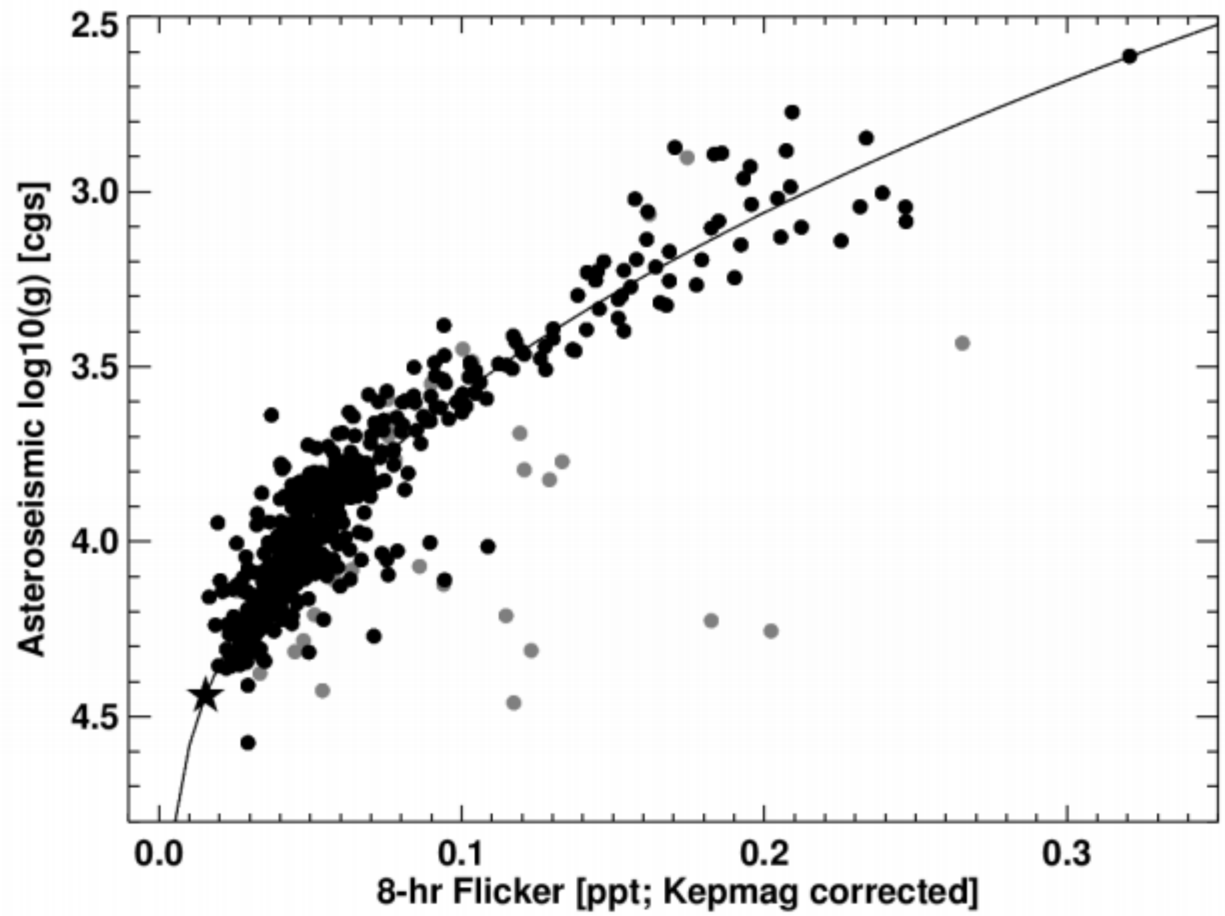
30-360 days, 60-600 ppm lightcurves for stars over all sky with I<12 and better than ~0.01 mag for 12<I<16

- Using 2-min cadence
  - eclipsing binaries for fundamental parameters
  - asteroseismology, mainly for red giants (TESS for nearby stars, WFIRST for distant stars… compare stellar properties in different environments?)
  - stellar granulation "flicker"… accurate gravities (ages) for many many stars (extend this to IR for WFIRST?)

Prospects for *p*-mode detection

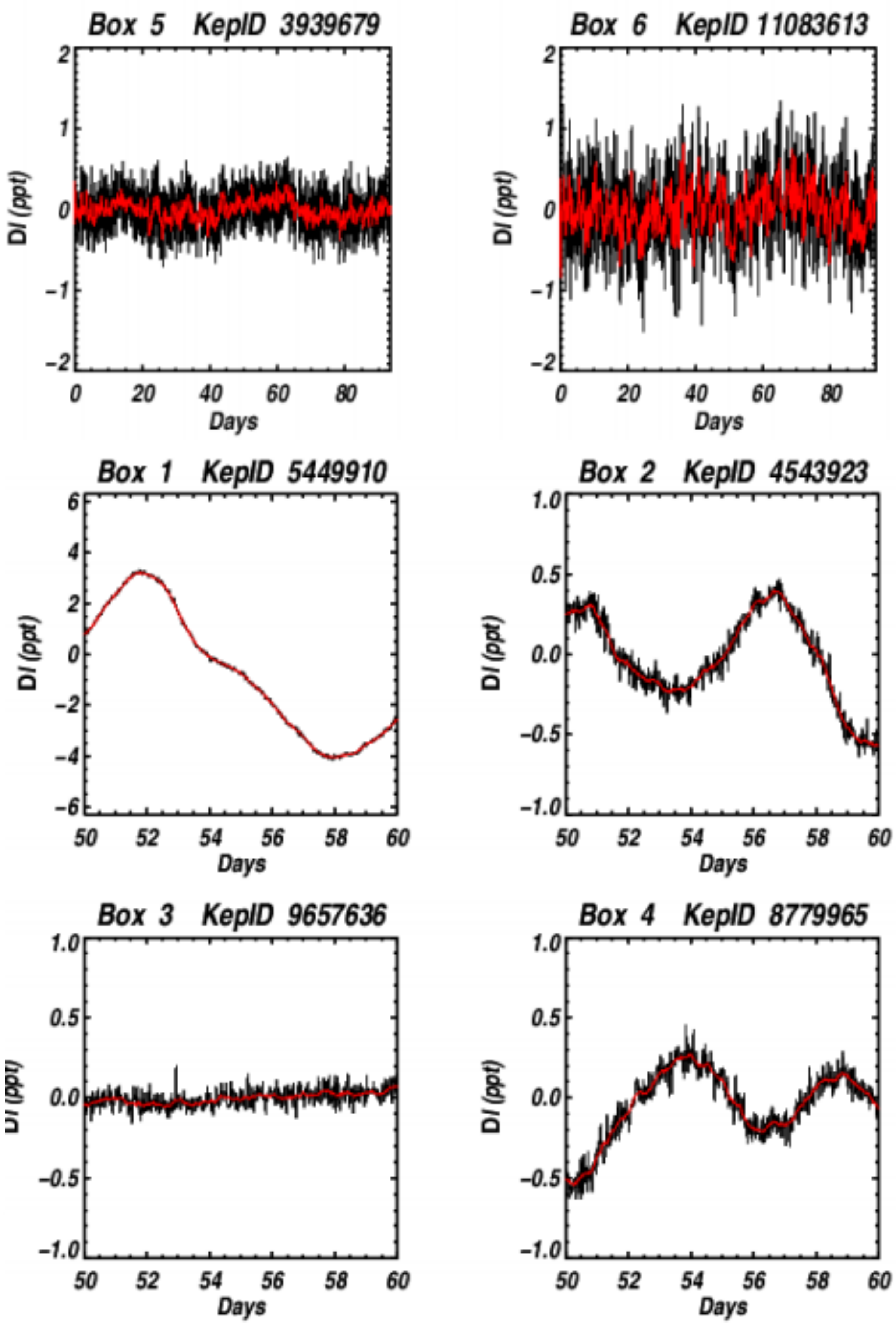


Stellar gravities (ages) from granulation "flicker"



- Stellar log *g* accurate to ~0.15 dex
- For dwarfs: ~30 ppm (visible light)
- For giants: ~500 ppm (visible light)
- Flicker detectable down to ~20% of shot noise… as long as shot noise is well behaved and characterized!
- Granulation amplitudes probably much lower in the IR…

(Bastien et al., Nature, 2013)



Opportunities for Galactic Science

30-350 days, 60-600 ppm lightcurves for stars over all sky with I<12 and better than ~0.01 mag for 12<I<16

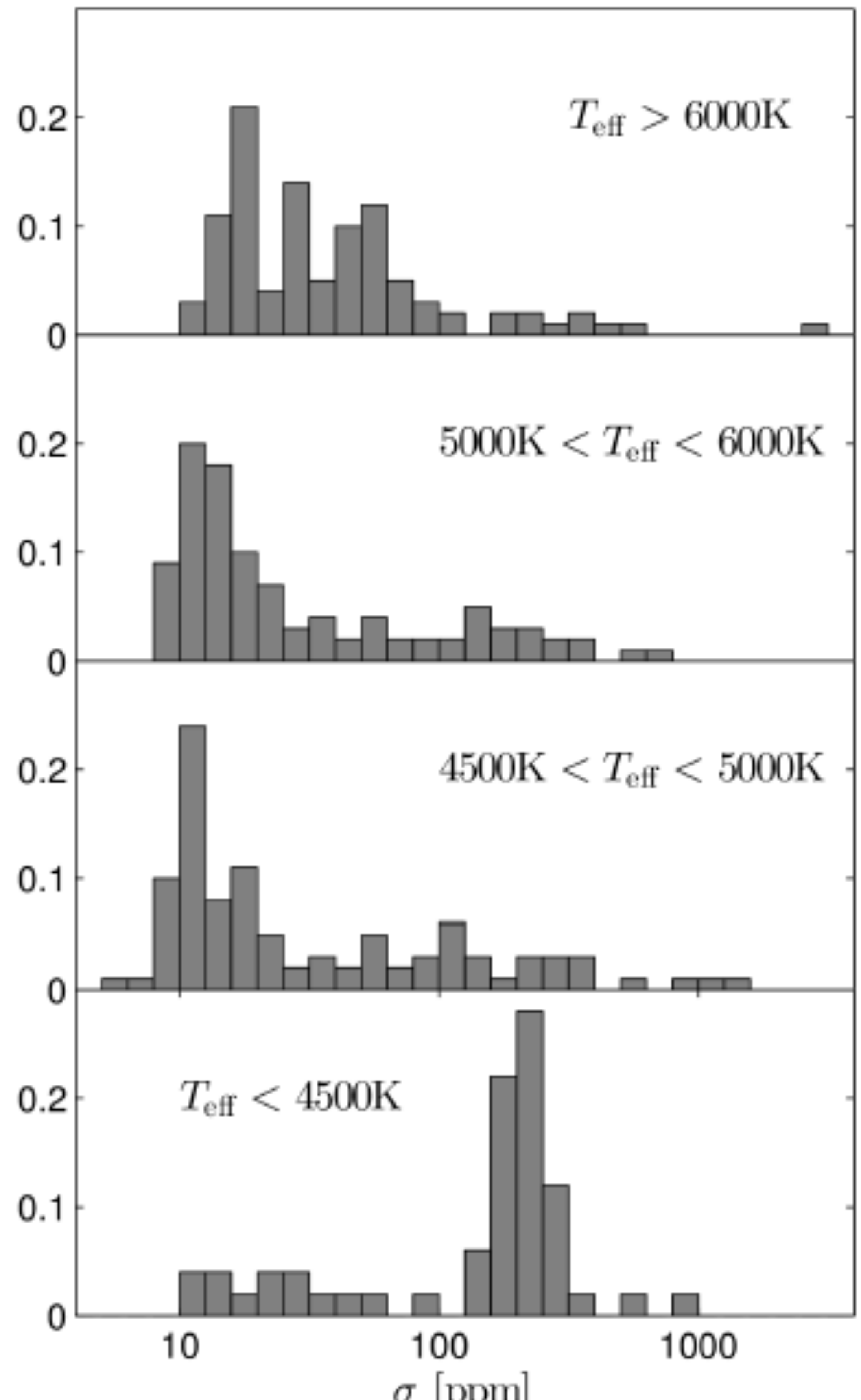
- Using Full Frame Images:
  - lightcurves of late type stars - weather and rotation of late M dwarfs and a few L/T dwarfs
  - rotation for ~all stars in nearby open clusters
  - Better lightcurves for all known variable stars in the sky than ever before, by a lot
  - Kepler-level lightcurves for all known EBs except those found by OGLE, et al

Opportunities for Galactic Science

A WFIRST coronograph could be a great tool for studying TESS-detected systems. The TESS planets themselves would be too short-period for even a coronograph, but one could:

- look for long-period planets in the TESS systems
- look at the circumstellar environments for dust or debris disks
- eclipsing disks?

Stellar variability from Basri et al. (2013)

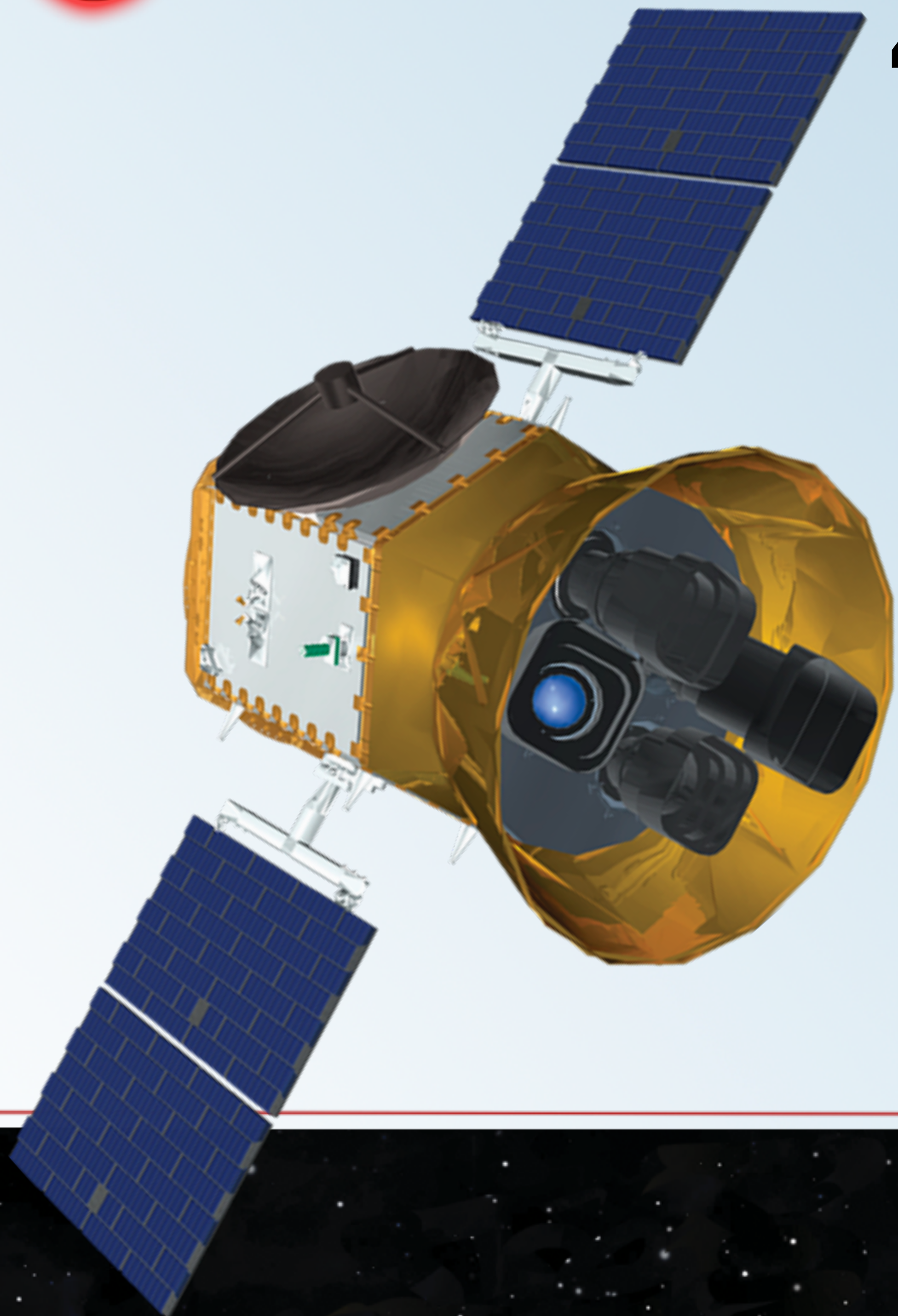


Overall TESS Science Status

- Emerging Science Case for Full-Frame Images (FFI)
  - *Resource for Broader Astronomical Community*
  - *Strongly Complements **Large Synoptic Survey Telescope** (LSST)*
    - *LSST: Stars fainter than 16th magnitude*
    - *TESS: Stars brighter than 16th magnitude*

TESS Working Groups

Working group	Chairs
Planet simulations	Josh Winn
Target star selection	Keivan Stassun, Josh Pepper
Follow-up observations	Dave Latham
Asteroseismology	Jørgen Christensen-Dalsgaard, Hans Kjeldsen
“Serendipitous” science	Peter McCullough, Garrett Jernigan
Atmospheric characterization	Jacob Bean
Habitability	Lisa Kaltenegger
Eclipsing binaries	Bill Welsh, Nader Haghighipour



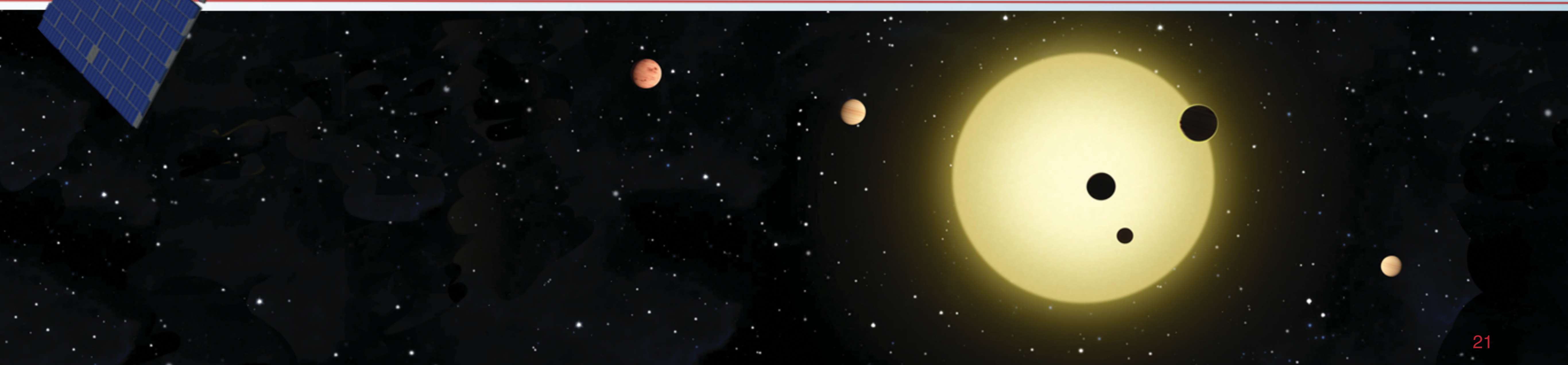
Conference at MIT:

“Science with TESS”

30 Sep–2 Oct 2015

SOC Chair: Sara Seager
LOC Chair: Zach Berta

Heighten General Astronomical Interest in TESS
Especially for non-exoplanet community



TESS Science Objectives

- OBJECTIVE 1: Identify a diverse sample of transiting exoplanets with *radii less than 2.5 R_{Earth} and orbital periods of up to 10 days* orbiting the brightest stars in the solar neighborhood.

- OBJECTIVE 2: Identify a sample of transiting exoplanets with *radii less than 2.5 R_{Earth} and orbital periods 120 days or more* orbiting bright stars situated near the ecliptic poles, locations that are optimal for JWST followup.

- OBJECTIVE 3: Establish the masses of a sample of TESS-located transiting planets with *radii less than 4 R_{Earth} by means of analytical techniques* and/or precise radial velocity (PRV)** measurements*.

** PRV measurements require TESS-committed ground-based assets.

* Analytical techniques include asteroseismology, transit time variations,...

TESS Level One Baseline Requirements

Objectives	Baseline Science Requirements	Baseline Technical Requirements	Baseline Data Requirements
Objective 1: Find planets with radius $R<2.5R_E$ and periods $P<10$ days	**BSR 1:** Monitor 200,000 stars over celestial sphere with sensitivity to find exoplanets with $R=2.5R_E$ and $P\leq10$ days	**BTR 1:** Two-year mission after two-month checkout	**BDR 1:** ≥95% of data collected delivered to the SOC
Objective 2: Find planets with $R<2.5R_E$ and $P<120$ days in JWST CVZ	**BSR 2:** Monitor 10,000 stars near ecliptic poles with sensitivity to find exoplanets with $R=2.5R_E$ and $P\geq120$ days	**BTR 2:** Collect data from each star for ≥20 days	**BDR 2:** Deliver processed data to MAST every 4 months
Objective 3: Measure the masses of a sample of exoplanets with $R<4R_E$	**BSR 3:** Measure the masses of 50 planets with $R<4R_E$	**BTR 3:** Instrument effective area $A_{eff}\geq50$ cm^2 in 600-1000 nm bandpass	**BDR 3:** Final delivery of processed data to MAST at end of Phase F
		BTR 4: Systematic error floor of 60 ppm for I=8 in one hour	**BDR 4:** No proprietary period for data at archive
		BTR 5: Temporal resolution ≤2 minutes	
		BTR 6: Data processing and ground follow-up sufficient to measure masses of 50 planets with $R<4R_E$	

TESS Level One Threshold Requirements

Objectives	Threshold Science Requirements	Threshold Technical Requirements	Threshold Data Requirements
Objective 1: Find planets with radius $R<2.5R_E$ and periods $P<10$ days	**TSR 1:** Monitor 100,000 stars over celestial sphere with sensitivity to find exoplanets with $R=2.5R_E$ and $P\leq10$ days	**TTR 1:** Mission designed to execute survey of 100,000 stars	**TDR 1:** ≥95% of data collected delivered to the SOC
Objective 2: Find planets with $R<2.5R_E$ and $P<120$ days in JWST CVZ	**TSR 2:** Monitor 5,000 stars near ecliptic poles with sensitivity to find exoplanets with $R=2.5R_E$ and $P\geq120$ days	**TTR 2:** Collect data from each star for ≥20 days	**TDR 2:** Deliver processed data to MAST every 4 months
Objective 3: Measure the masses of a sample of exoplanets with $R<4R_E$	**TSR 3:** Measure the masses of 35 planets with $R<4R_E$	**TTR 3:** Instrument effective area $A_{eff}\geq40$ cm^2 in 600-1000 nm bandpass	**TDR 3:** Final delivery of processed data to MAST at end of Phase F
		TTR 4: Systematic error floor of 80 ppm for I=8 in one hour	**TDR 4:** No proprietary period for data at archive
		TTR 5: Temporal resolution ≤5 minutes	
		TTR 6: Data processing and ground follow-up sufficient to measure masses of 35 planets with $R<4R_E$	