Possible Subaru-TESS Synergy Campaign

Norio Narita (ABC/NAOJ)

on behalf of Japanese TESS consortium

Outline

- Introduction of TESS
  - Schedule, current status, extended mission
  - Orbit, survey plan, and expected sensitivity
- TESS Science Cases
  - Exoplanets: Targets, planet yield
  - Asteroseismology, supernovae, superflare, variable stars
  - Guest Investigator Program
- Possible Synergies of Subaru with TESS
  - Introduction of Japanese TESS Consortium

TESS Overview

- TESS is the next flagship space mission for exoplanet studies after Kepler mission, expected to launch in 2017 August
- Almost-all-sky survey of "transiting" planets around nearby 500,000 stars
- 2 year observation with 4 cameras (10cm diameter) each having 24^{o} x 24^{o} FoV

- Providing ~20 Earth-like transiting planets around HZ for further follow-up observations with ELTs and JWST

TESS Timeline

2013: selected as Medium-Class Explores mission

2014: passed PDR, and Vehicle was selected as SpaceX Falcon 9

2015: Critical Design Review, lab test ongoing

2017: planned to be launched in August

-about two months to reach the High Earth Orbit

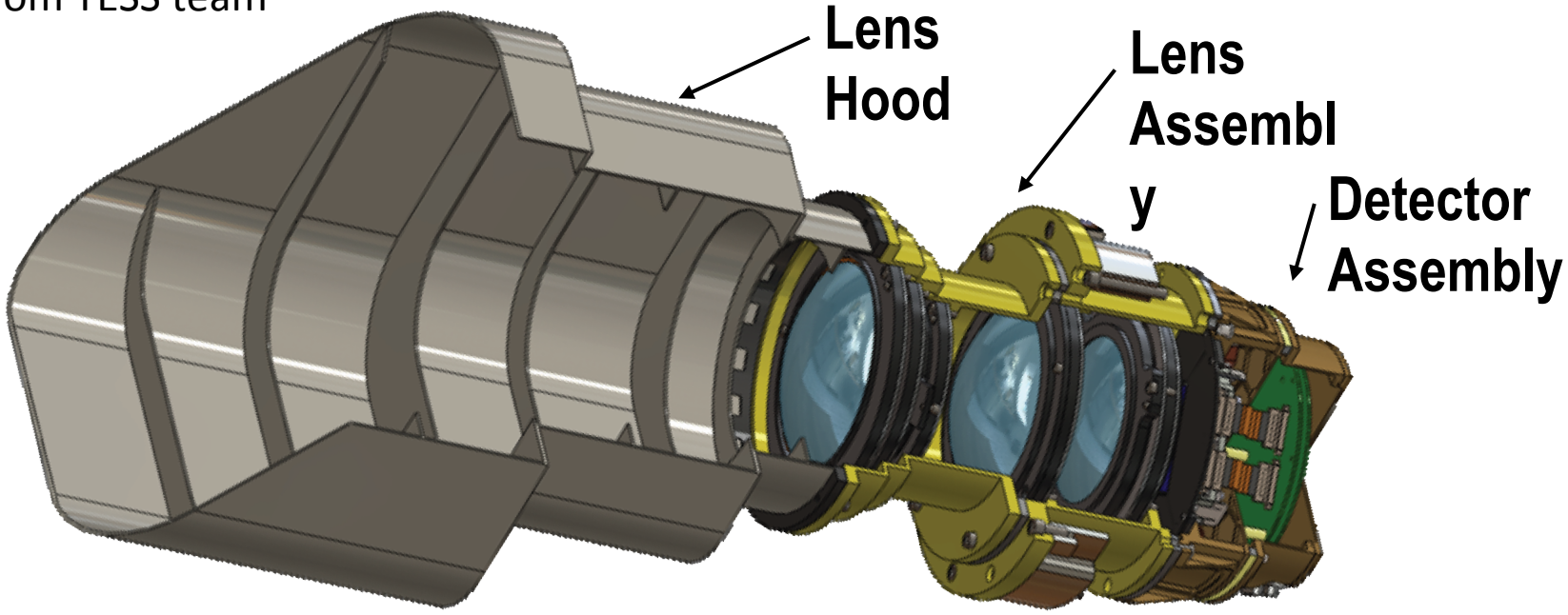
-first science data will be released in 18A semester

2018: observing the first hemisphere

2019: observing the other hemisphere

2020: possible extension (discussions ongoing)

slide from TESS team

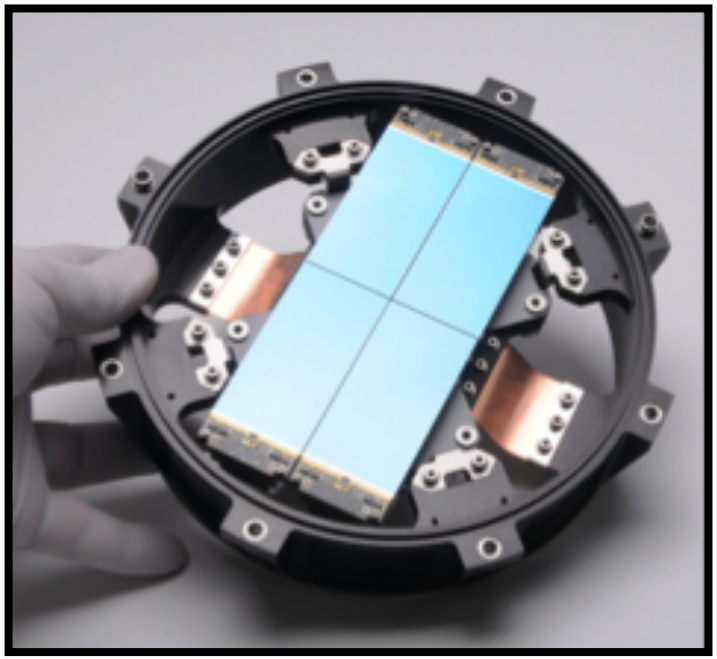


Entrance pupil diameter	10.5 cm
Bandpass	600-1000 nm
Field of view	24° x 24°
Cadence for target stars	2 min
Cadence for full frame images	30 min

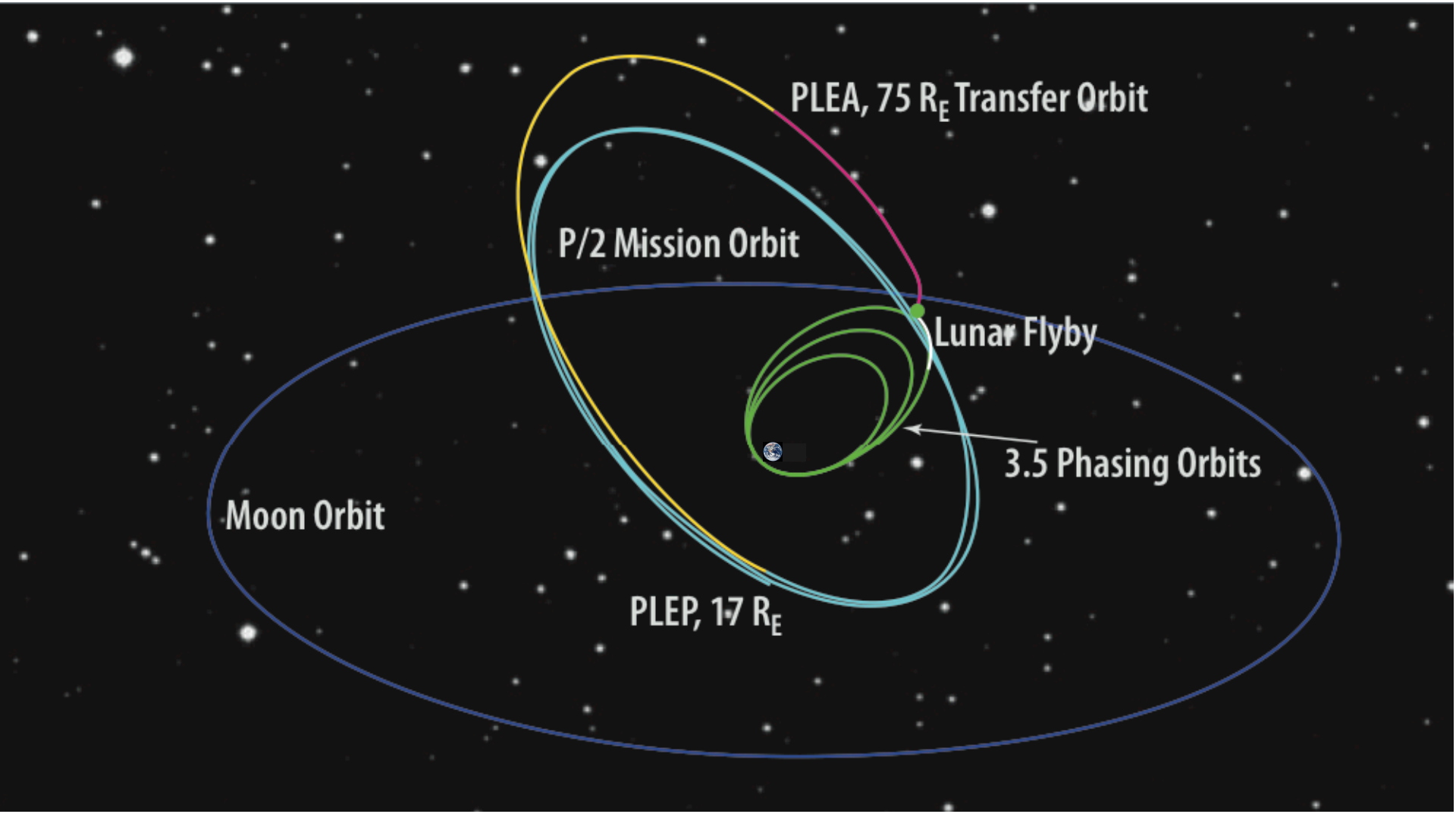
four 2048 x 4096 CCDs

each CCD
= 2048 x 2048 imaging
+ 2048 x 2048 storing

in total
4096 x 4096 imaging



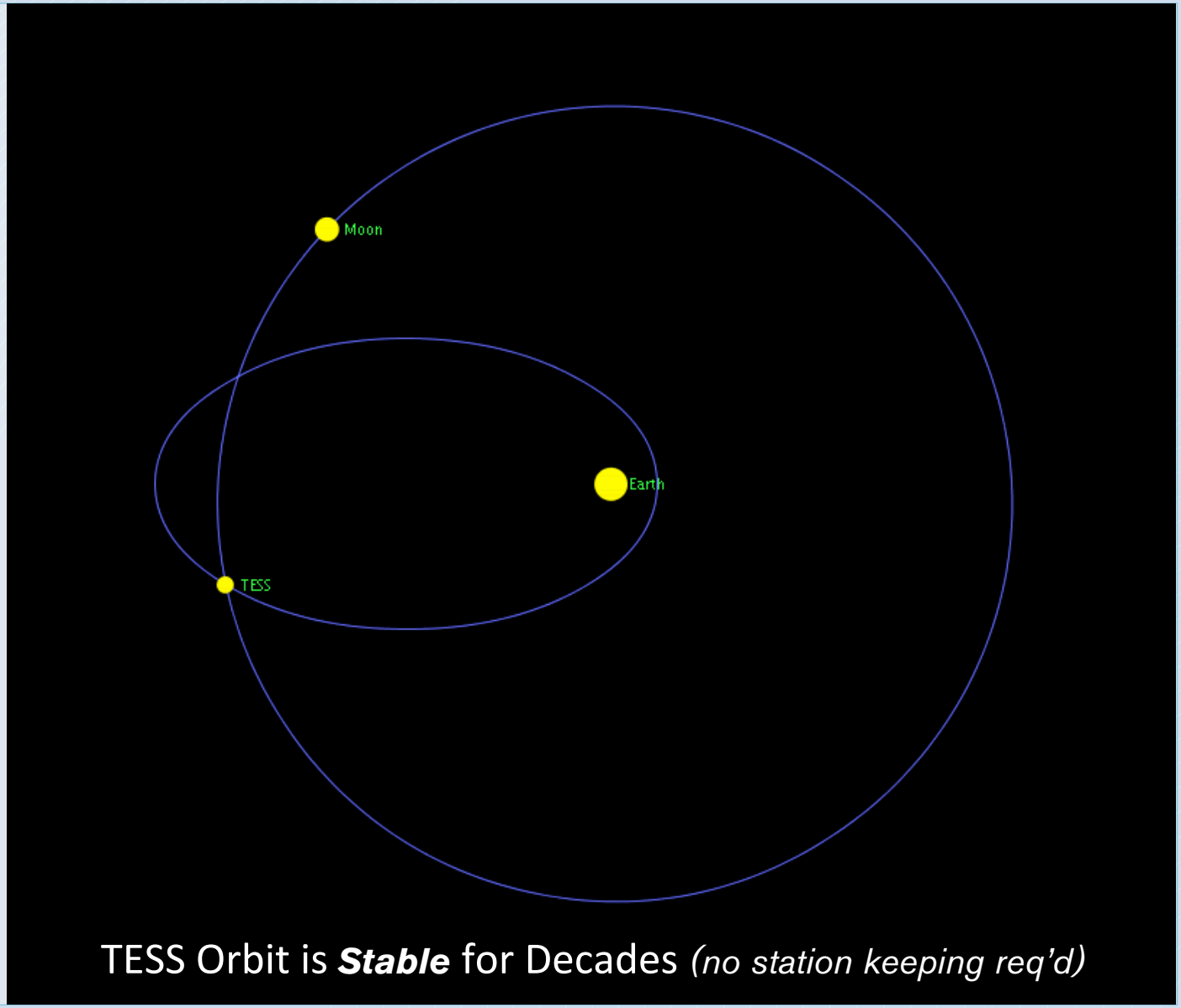
TESS High Earth Orbit and Downlink



TESS's Novel High Orbit

Uninterrupted viewing for >95% of time

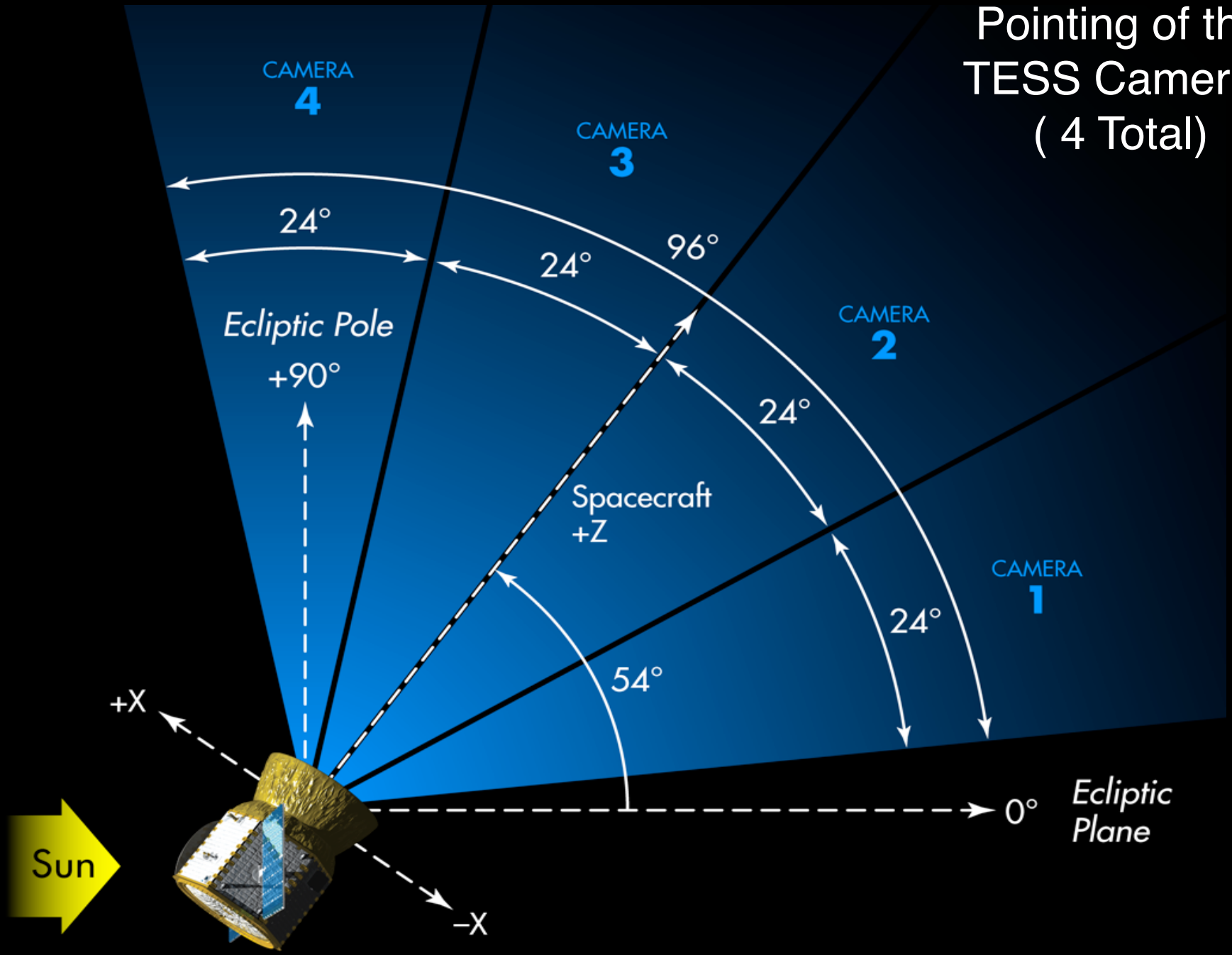
Orbital Periods:
TESS = 13.7 days
Moon = 27.4 days
➡ 2:1 Resonance
➡ 90° Phasing



TESS Orbit is ***Stable*** for Decades *(no station keeping req'd)*

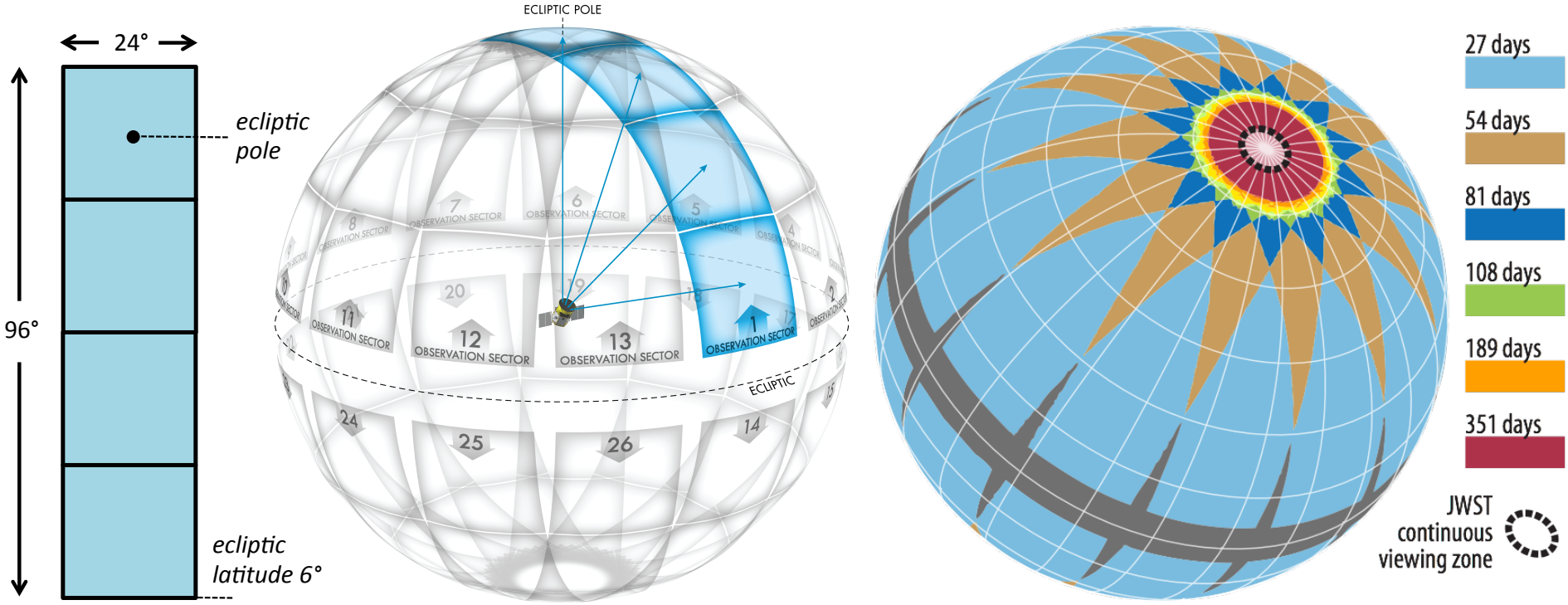
slide from TESS team

Pointing of the TESS Cameras (4 Total)



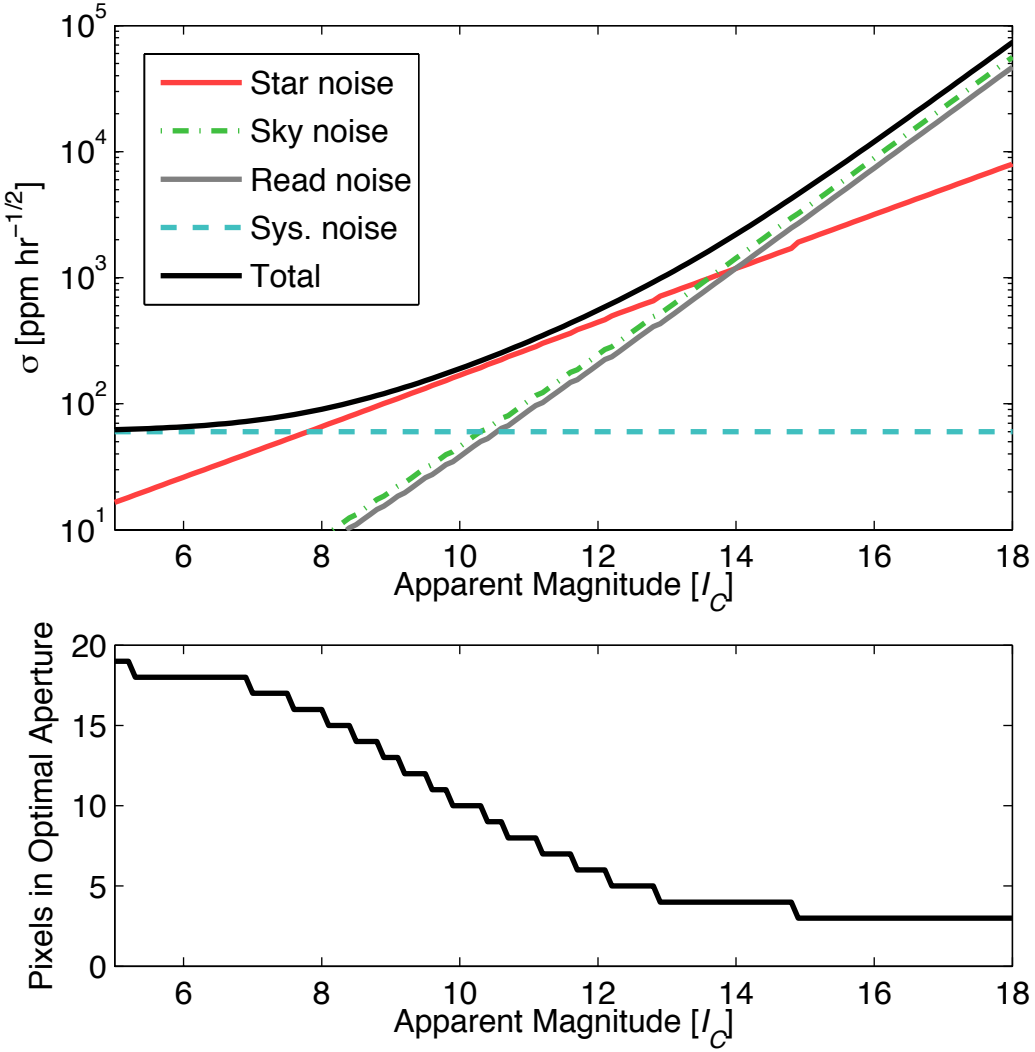
slide from TESS team

TESS Field of View and Strategy



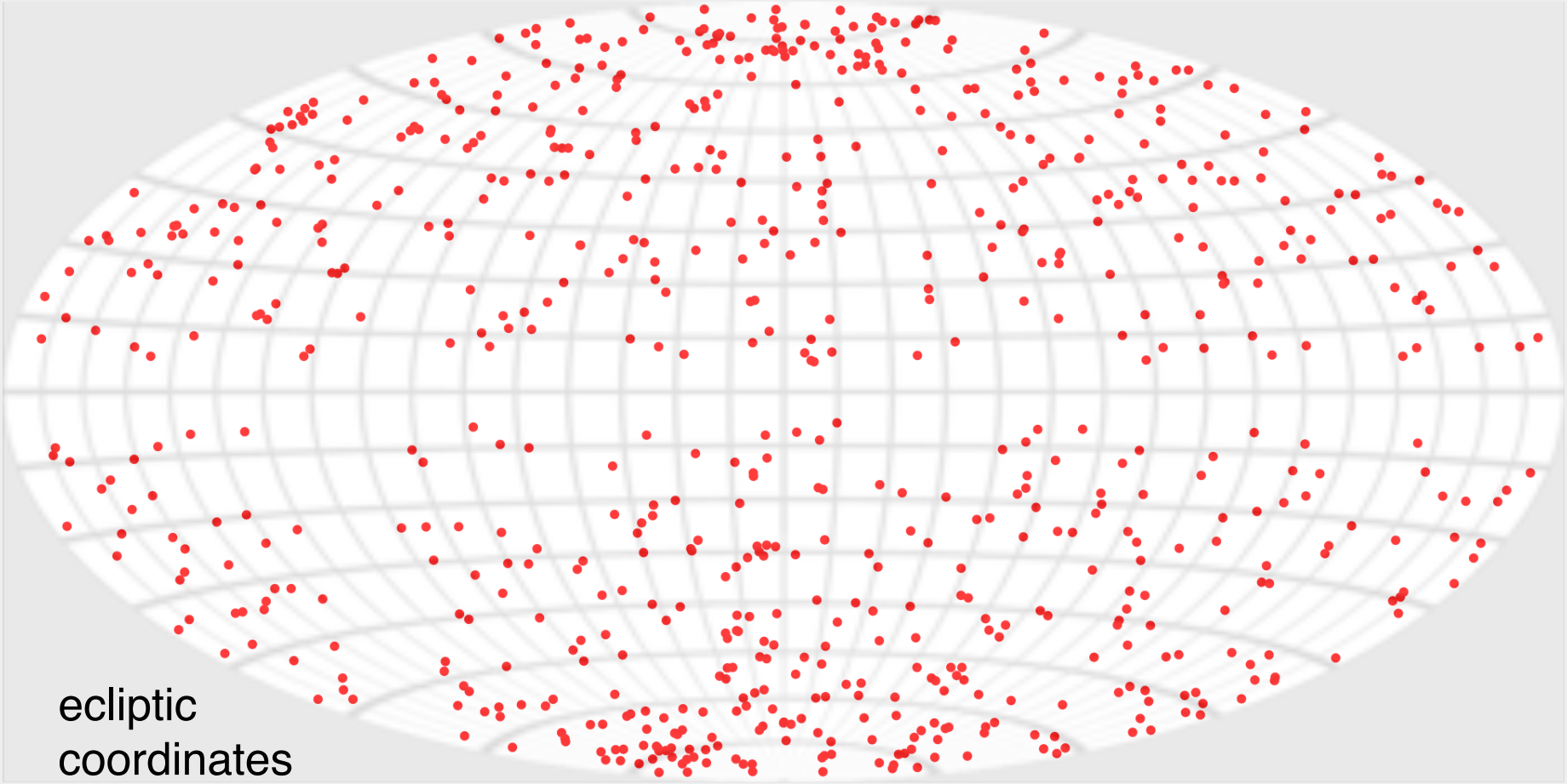
- TESS observes 27 days for each rectangle sector (24^o x 96^o)
- Start with one of hemispheres (1 year) and then the other hemisphere (1 year), and possible extension.

TESS Expected Sensitivity



- Better than 0.1% (per hr) photometric precision for I mag < 12
- Sufficient to detect (sub)Earth-size planets around M dwarfs
- 1% precision for I~16
- It may be also useful for other science cases

Simulated TESS detections

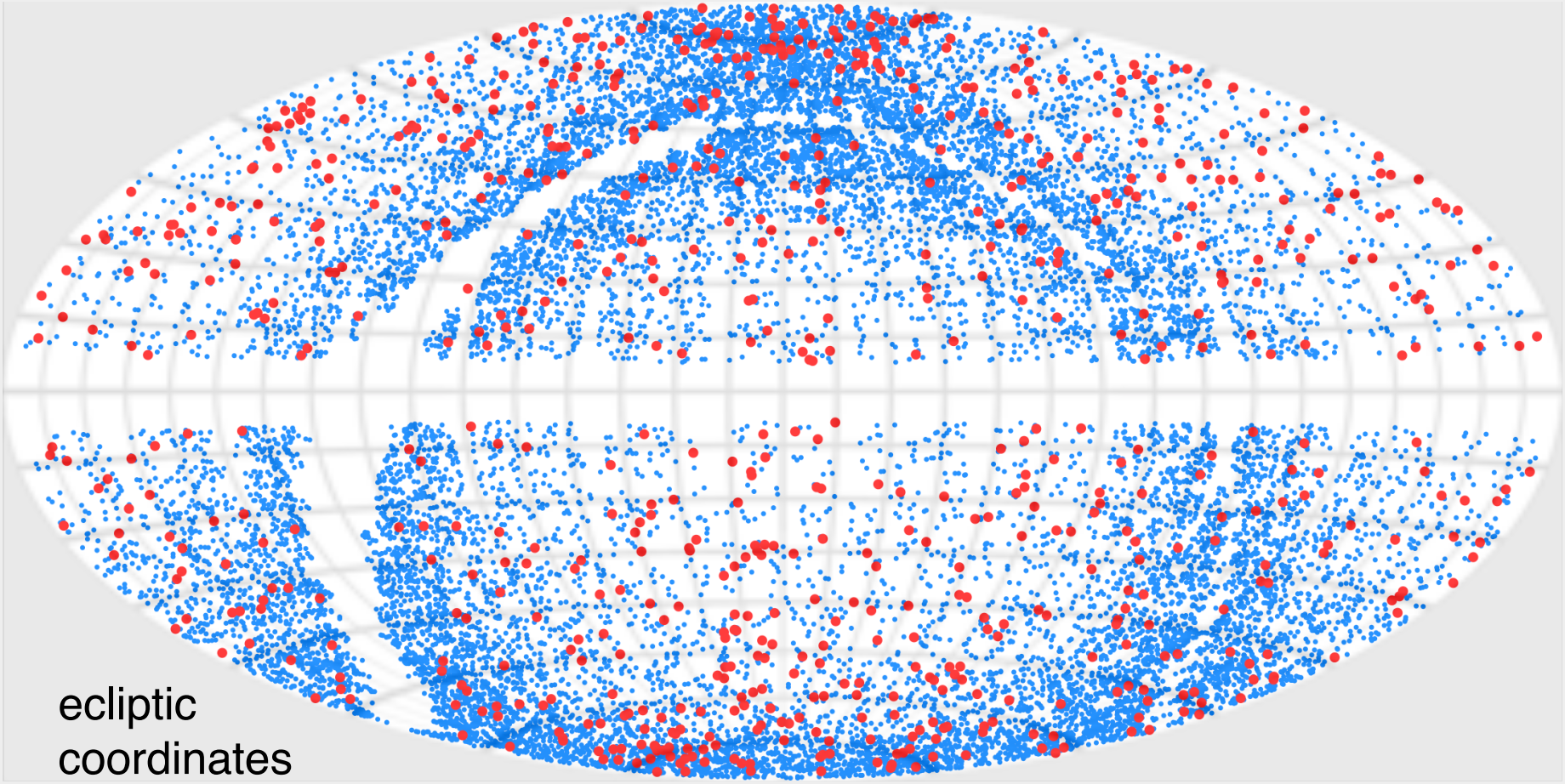


Sullivan et al. (2015)

detectable planets around
pre-selected target stars

slide from TESS team

Simulated TESS detections

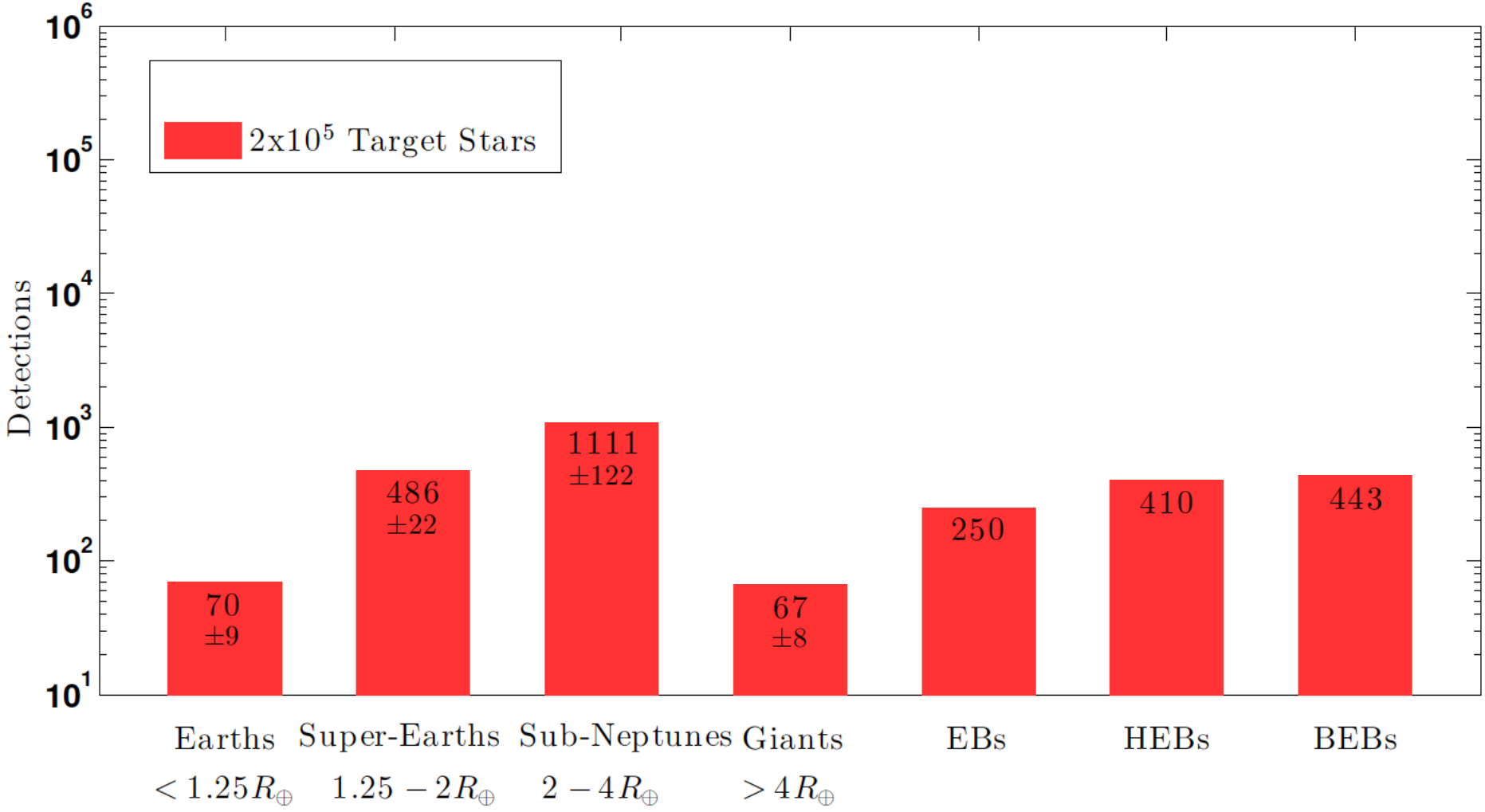


Sullivan et al. (2015)

detectable planets around pre-selected target stars

detectable planets around other stars in full-frame images

slide from TESS team

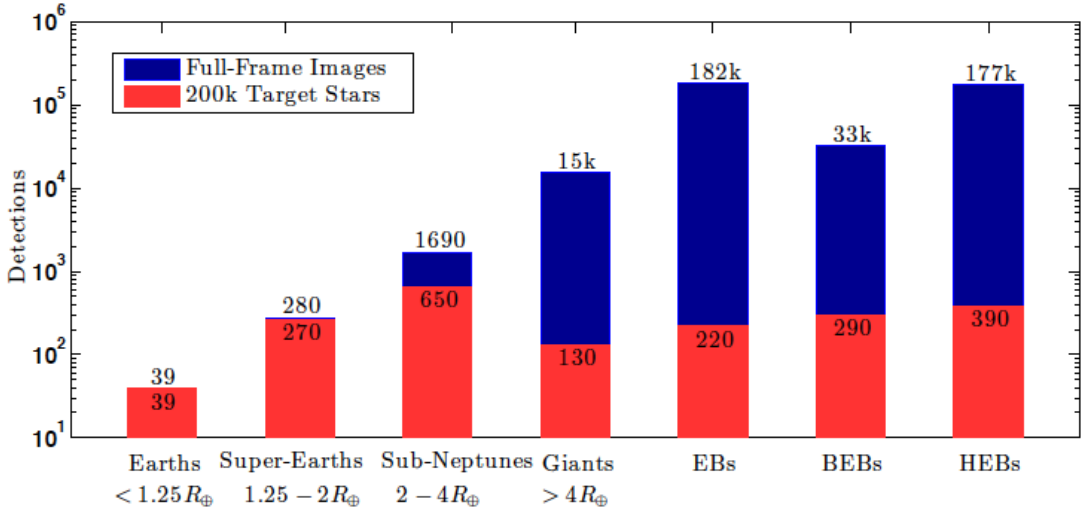


slide from TESS team

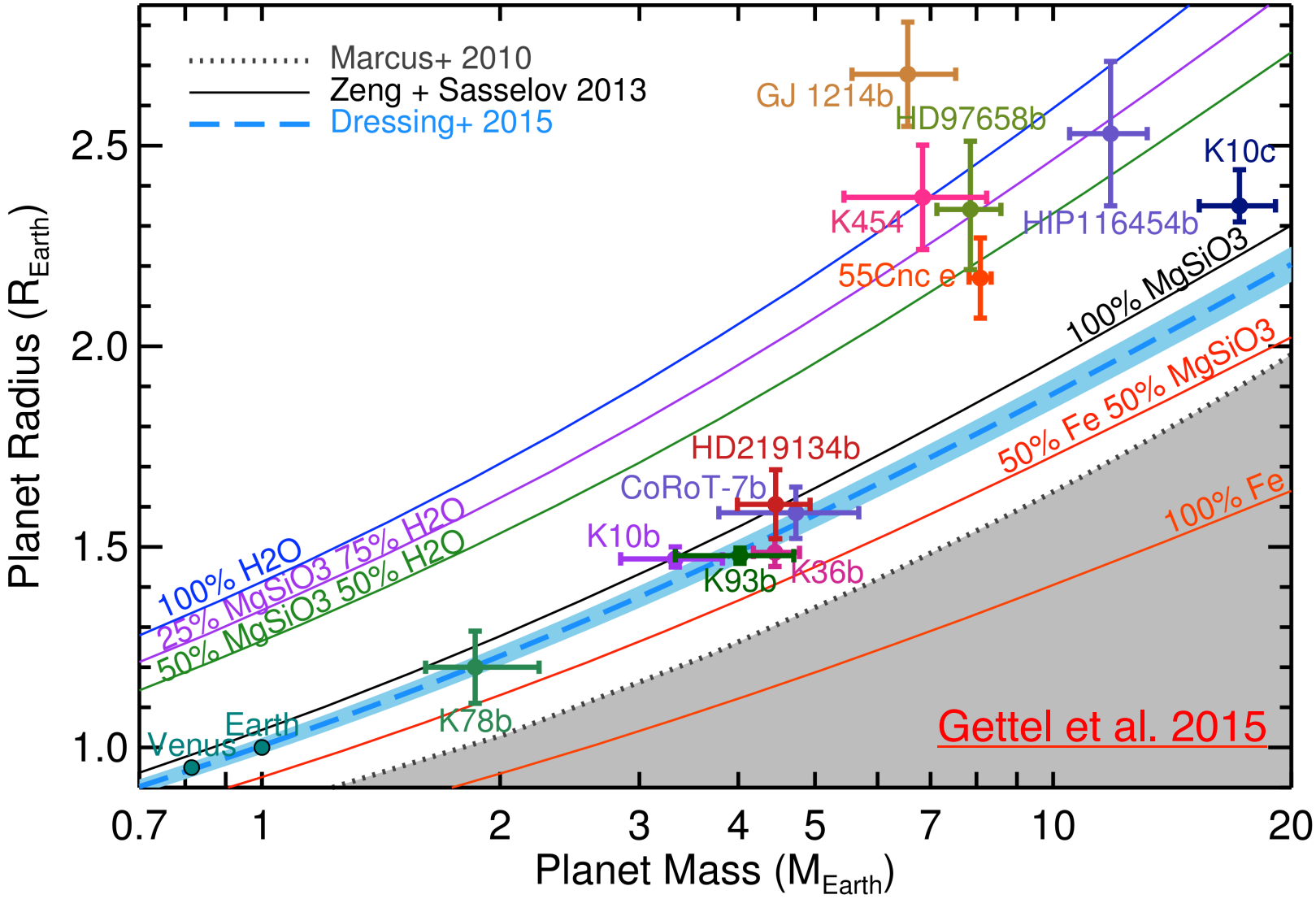
Sullivan et al. (2015)

TESS Planet Yield Simulation (Sullivan+2015)

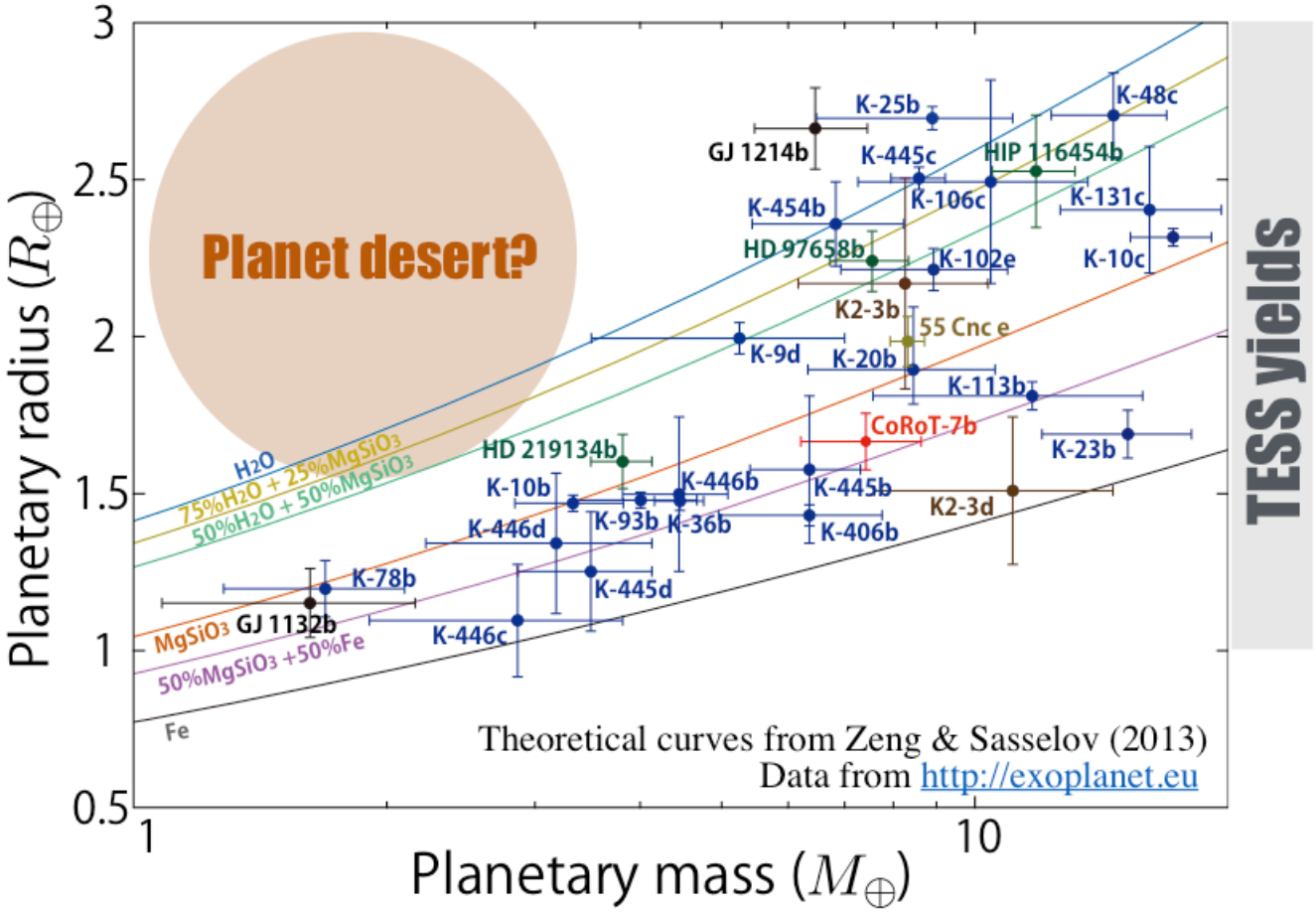
- about 300 planets: smaller than 2 R_{earth}
  - among those, ~165 planets are orbiting M dwarfs
  - ~100 planets are orbiting I<10 host stars
  - about 20 planets are orbiting within or near habitable zone
- about 650 planets: between 2 R_{earth} and 4 R_{earth}
  - boundary of “super-Earth” and “mini-Neptune”
  - also important targets for planetary science



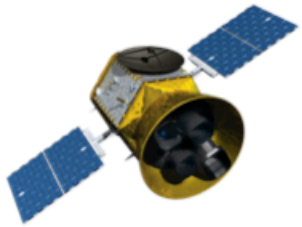
TESS and Subaru/IRD can reveal mass-radius relationship of small planets



To Be, or Not to Be Rocky Planets ?



TESS yields



- The paucity of planets with $\lesssim 3\,M_\oplus$ and $\sim 1.5 - 3\,R_\oplus$?
  , which corresponds to transition from rocky planets to gas dwarfs?
  (Weiss & Marcy,2014;Rogers,2014; Marcy+14; Buchhave+14;Wolfgang & Lopez,2014)

- **Earth-sized planets** are "**Earth-like**" planets?
  — Small planets are dry, wet, or waterlogged?

Courtesy of Y. Hori

Other Science Cases: Not Only Exoplanet!

- Asteroseismology
  - Stellar physics, Galactic archaeology
- Transient
  - Supernovae, GRBs, Gravitational wave counterparts
- Variable stars
  - Cepheid, Mira, Eclipsing binaries (young and dying)
- Stellar flares
- Solar system small bodies
- Variability of AGN/Blazers/Quasars
- Unknown fast transient (new time domain science)

What Subaru can do with TESS?

- TESS plans to release TESS object of interest (TOI) data and Full Frame Image (FFL) data every 4 months

- Subaru can follow-up TOI targets (i.e. exoplanets) and other interesting objects (asteroseismology target, transient, etc) soon after the data releases

- Very high scientific productivity is expected

Subaru-TESS Synergies in Exoplanet Studies

- Validation of very interesting planets
  - within 1 year after data release
  - AO imaging to eliminate false positives: AO188/SCExAO
- Characterization (mass, orbit, atmospheres)
  - within 2-4 years
  - IRD is especially useful to measure RVs of M dwarfs
  - FOCAS/MOIRCS (SWIMS?) are useful for studies of atmos.

- Providing the most interesting ~20 transiting planets for TMT's FL from Subaru -> toward TMT key program

Subaru-TESS Synergies in Other Studies

- Asteroseismology:
  - spectroscopic (high resolution) follow-up
- Galactic archeology:
  - spectroscopic (high resolution) follow-up
- Transient:
  - spectroscopic (low, medium resolution) follow-up
- Super-flare stars:
  - spectroscopic (high resolution) follow-up

FOCAS/HDS/IRD will be useful for those studies

Establishment of Japanese TESS Consortium

Aims:

1. Detailed considerations of Subaru-TESS synergetic campaign
   - What kind of science?
   - How many nights?
   - Which instruments?
2. Providing latest information of TESS to Japanese community
   - preparing Guest Investigator Proposal
   - 4 Japanese researchers are joining the TESS team as collaborators and can access to latest information

Establishment of Japanese TESS Consortium

Previous activities:

- 2015 Nov. 26-27: Japanese TESS Science Workshop
  - about 60 attendees
  - 19 talks for not only exoplanets, but also asteroseismology, galactic archeology, supernovae, transient, variable stars, Wolf-Rayet stars, super-flare stars
  - Following the discussions, we established Japanese-TESS consortium here
- 2015 Dec. 17: First regular meeting
- 2015 Dec. 18: Web-ex meeting with TESS board members

Upcoming Activities

- 2016 Jan. 21: Subaru UM FY 2015
  - Introduction of TESS mission and Japanese TESS consortium to the Subaru community

- 2016 Jan or Feb: Subaru Advisory Committee
  - introduction of Japanese TESS consortium and ask to start discussions for Subaru-TESS synergetic campaign

- 2016 Jan: Call for more members to the consortium

Considering Subaru-TESS Synergetic Campaign

- Exoplanets
  - We have estimated the number of necessary Subaru IRD nights to determine mass/orbit of interesting TESS planet candidates

- Other Science Cases
  - We will start discussions with consortium members of other fields after call for members
  - tennet, gopira ML

Summary

- TESS is the next flagship exoplanet mission to search for interesting exoplanets in the solar neighborhood

- Not only exoplanets, but also other fields (such as stars, transient, and galactic archeology) can receive benefits from TESS data

- Subaru-TESS synergetic campaign would benefit Japanese astronomical community