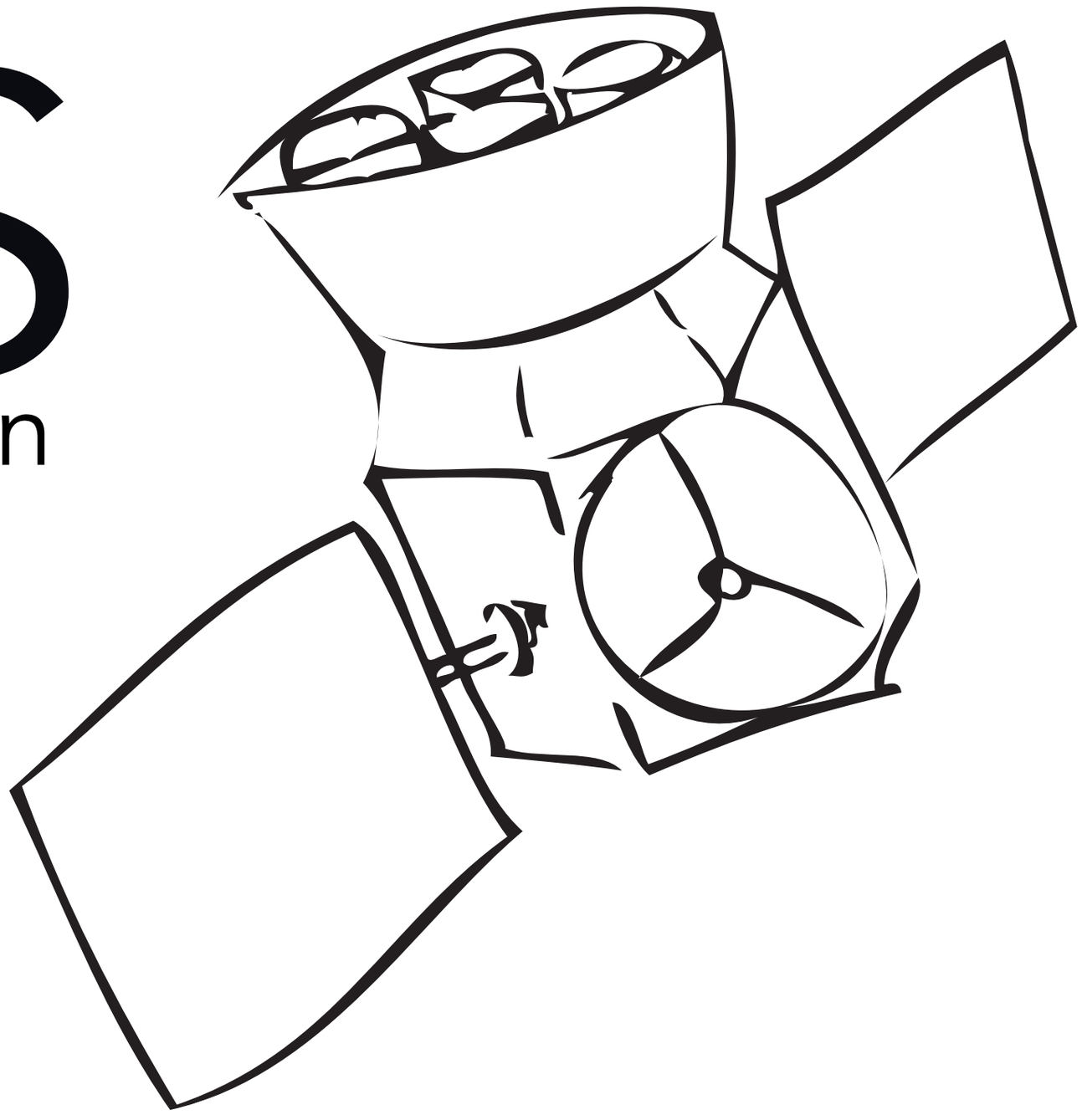
the TESS mission

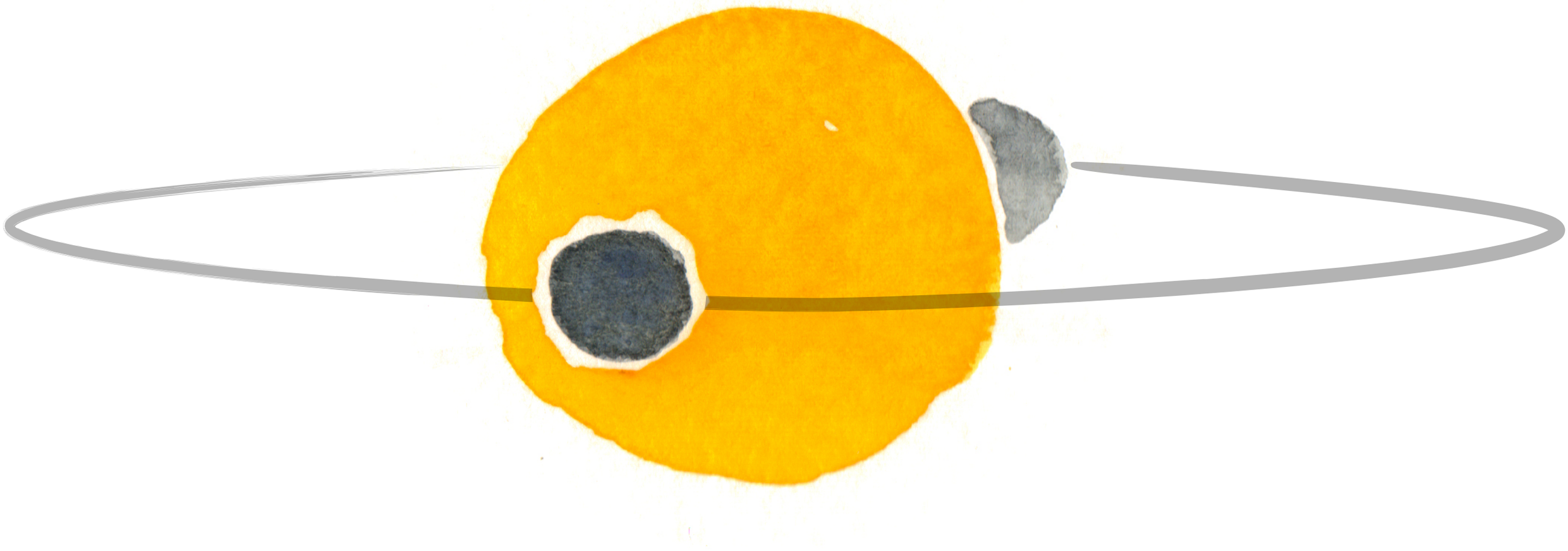


Zach Berta-Thompson

Torres Exoplanet Fellow, MIT

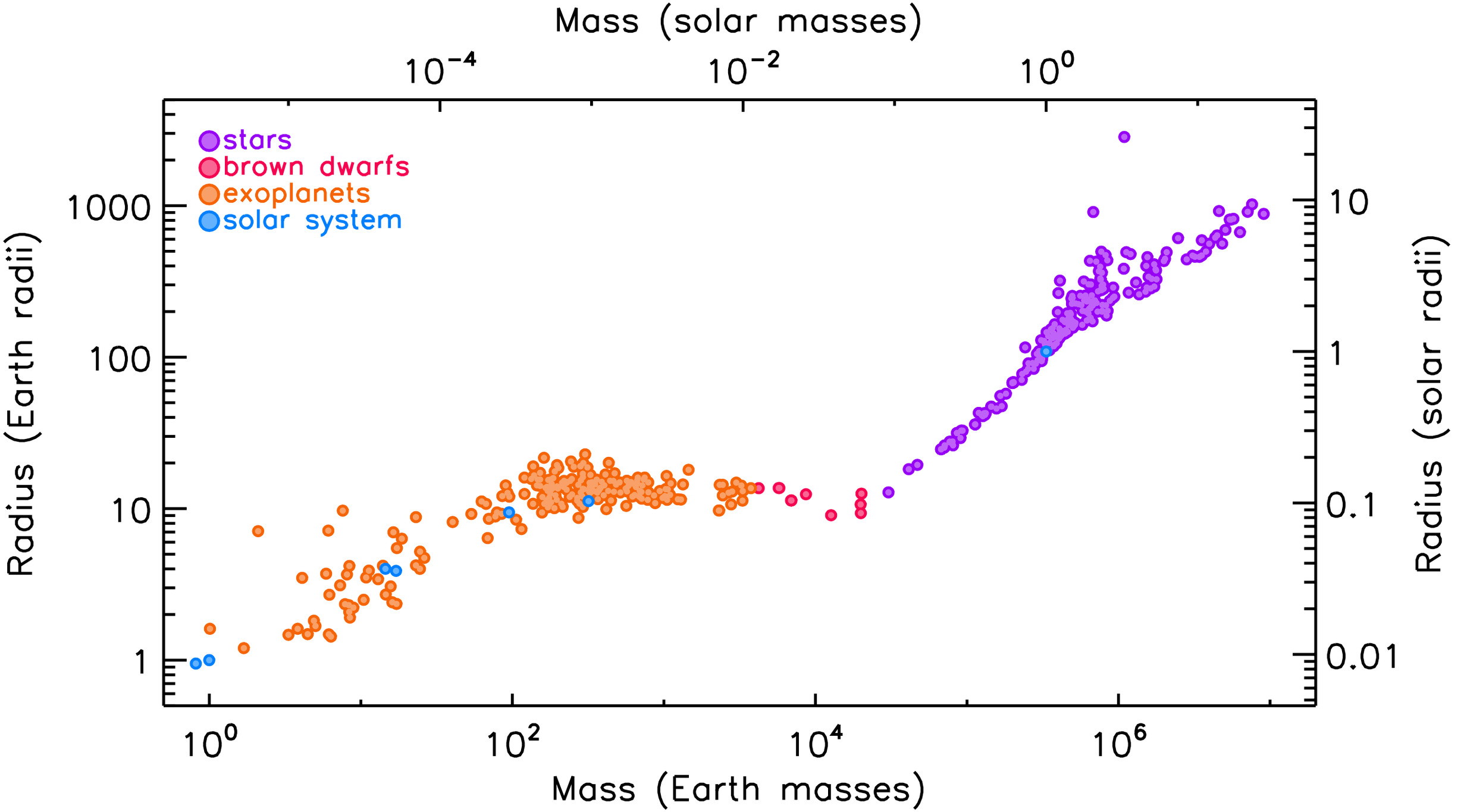
Cambridge, MA, USA

Transiting exoplanets
are useful laboratories.

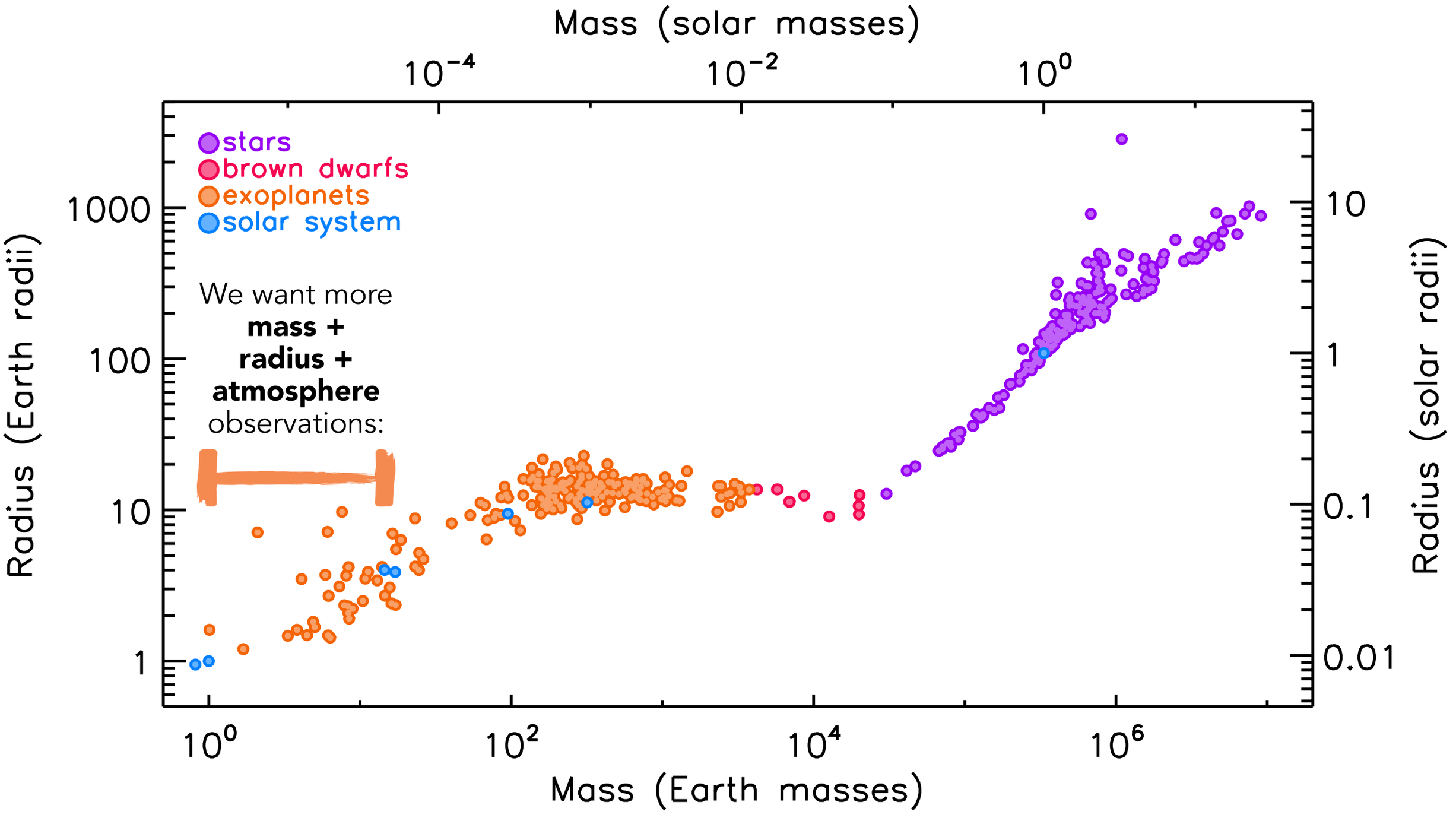


For a transiting exoplanet, we can directly observe
planet size + orbit + mass + atmosphere.

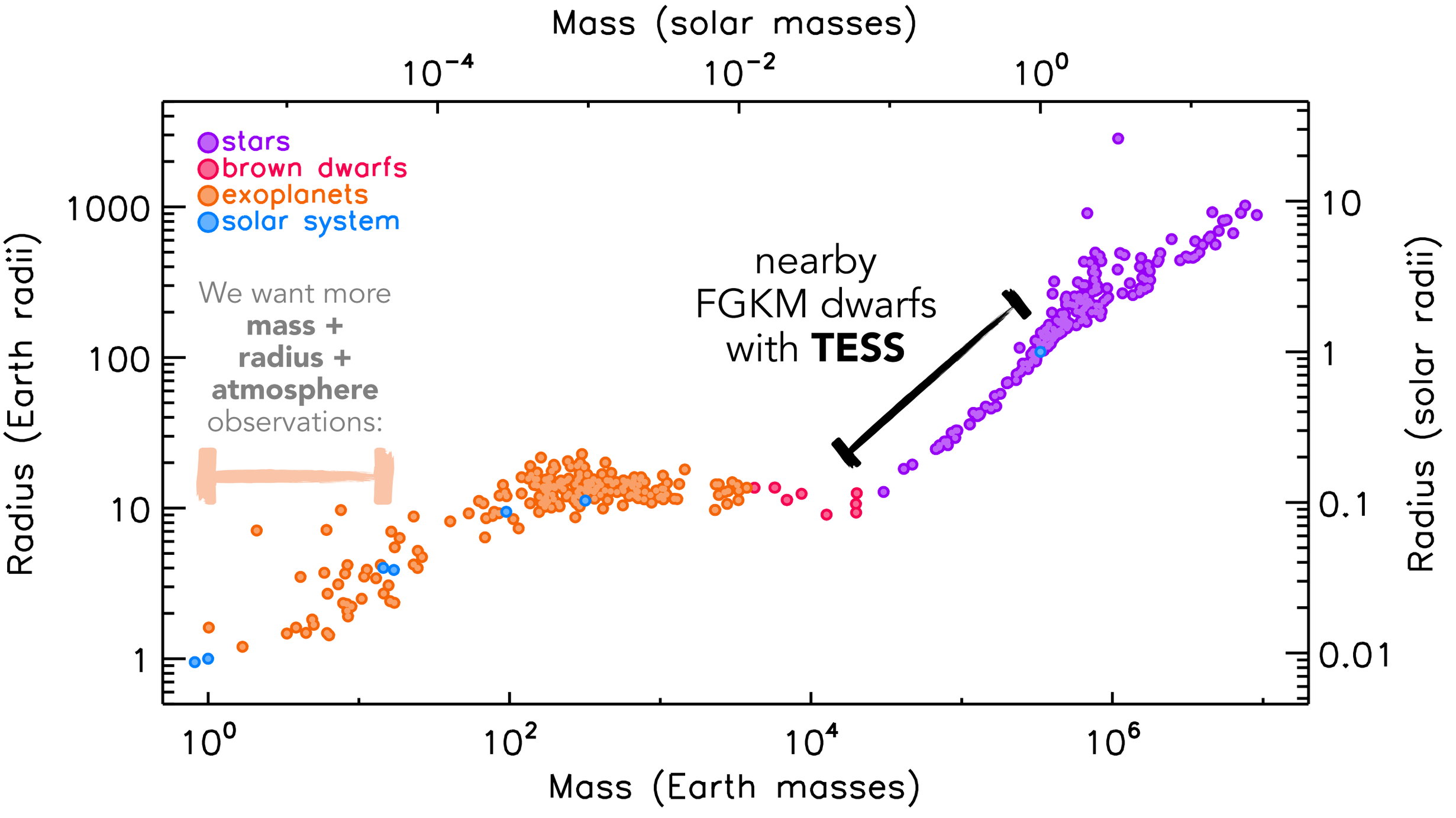
painted by Zach Berta-Thompson, adapted from original by Tim Brown, circa 2000



curated exoplanet data from _____



curated exoplanet data from _____



curated exoplanet data from _____

(1) the present limitations

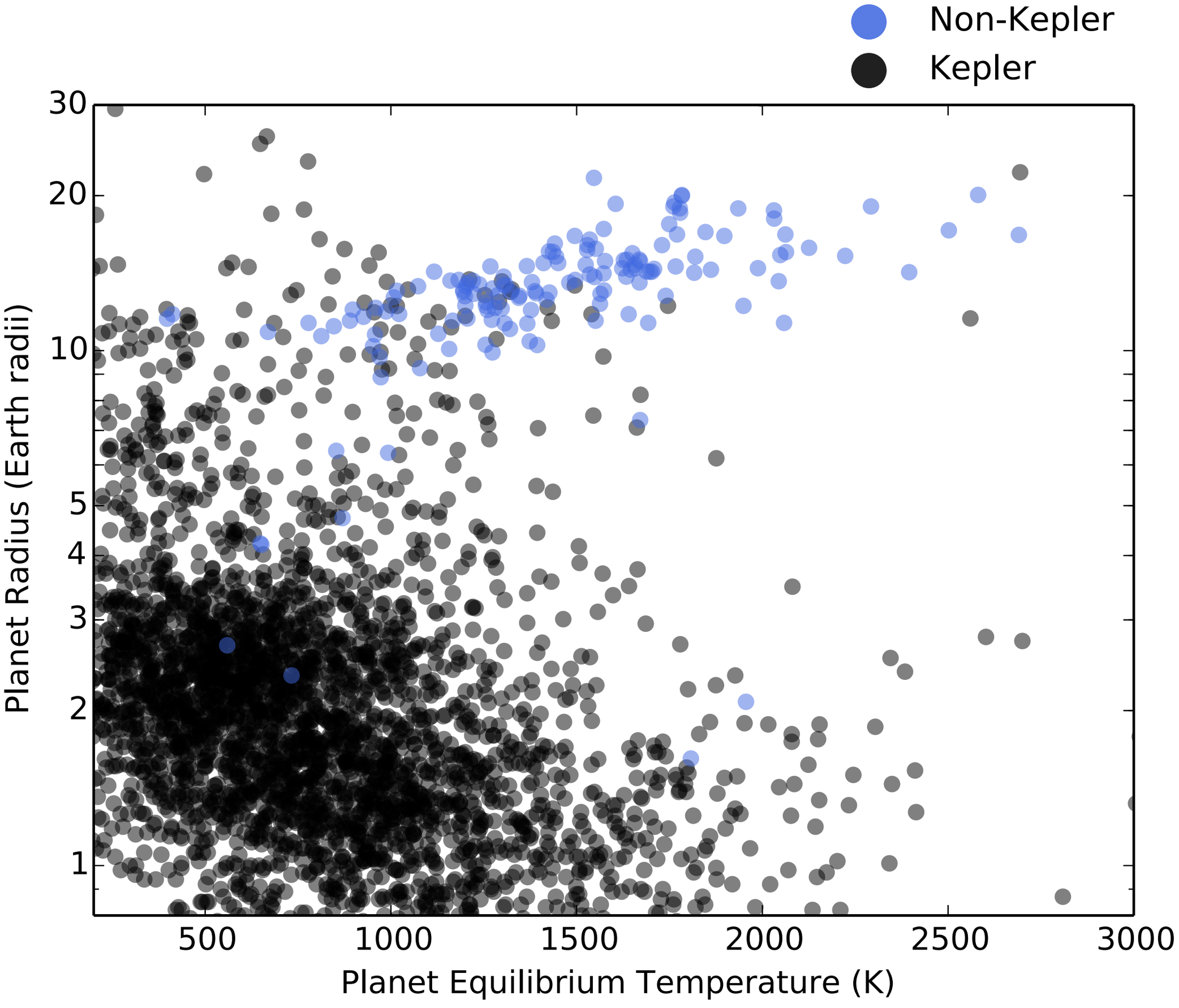
(2) the TESS mission

(3) the future

(1) the present limitations

(2) the TESS mission

(3) the future


Non-Kepler
Kepler
30
20
10
5
4
3
2
1
Planet Radius (Earth radii)
500
1000
1500
2000
2500
3000
Planet Equilibrium Temperature (K)

zoom by Zach Berta-Thompson, early 2015

Transiting Exoplanets

Kepler

Non-Kepler

0h
September

3h

6h
December

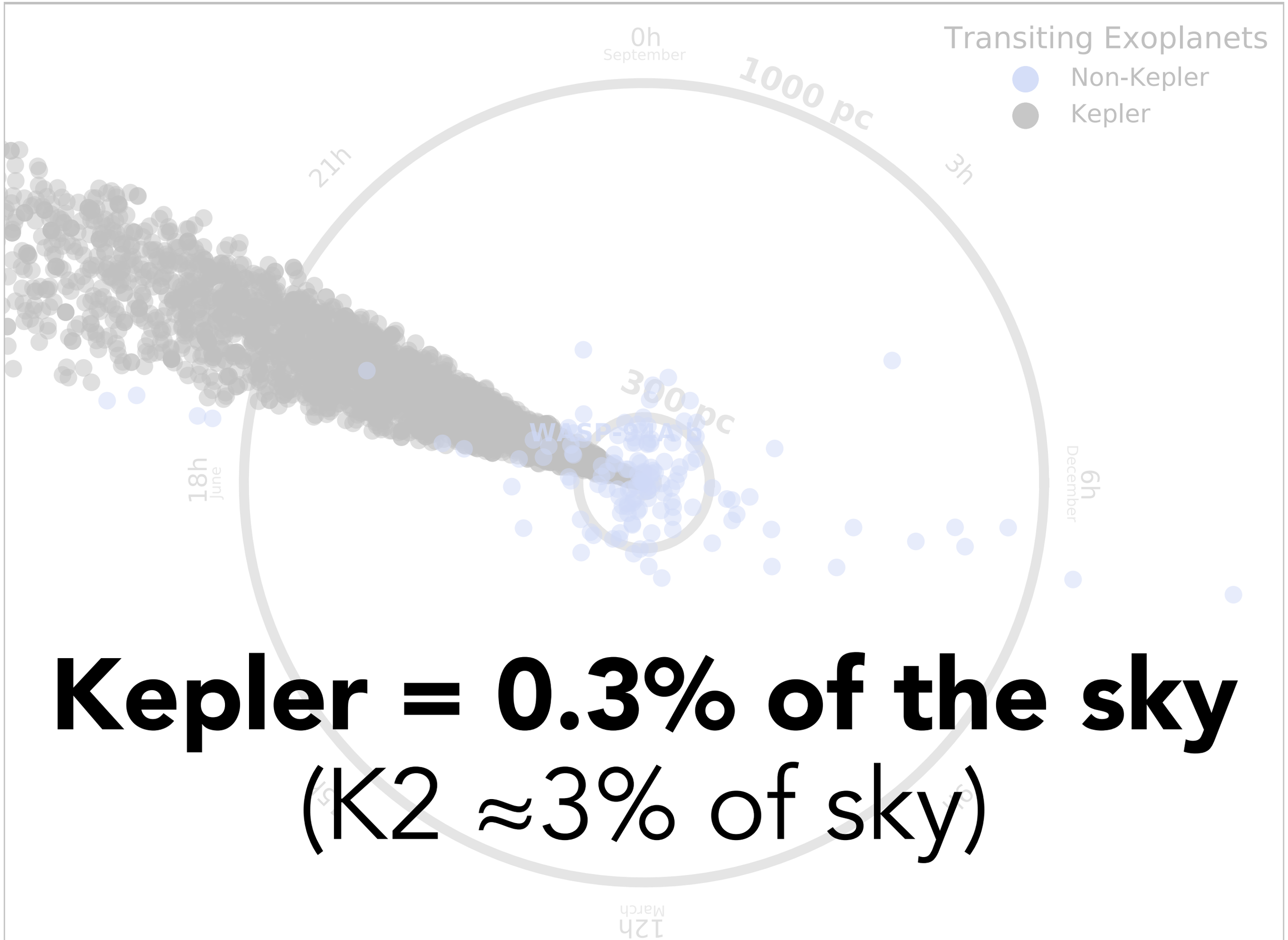
9h

12h
March

15h

18h
June

21h



Kepler = 0.3% of the sky

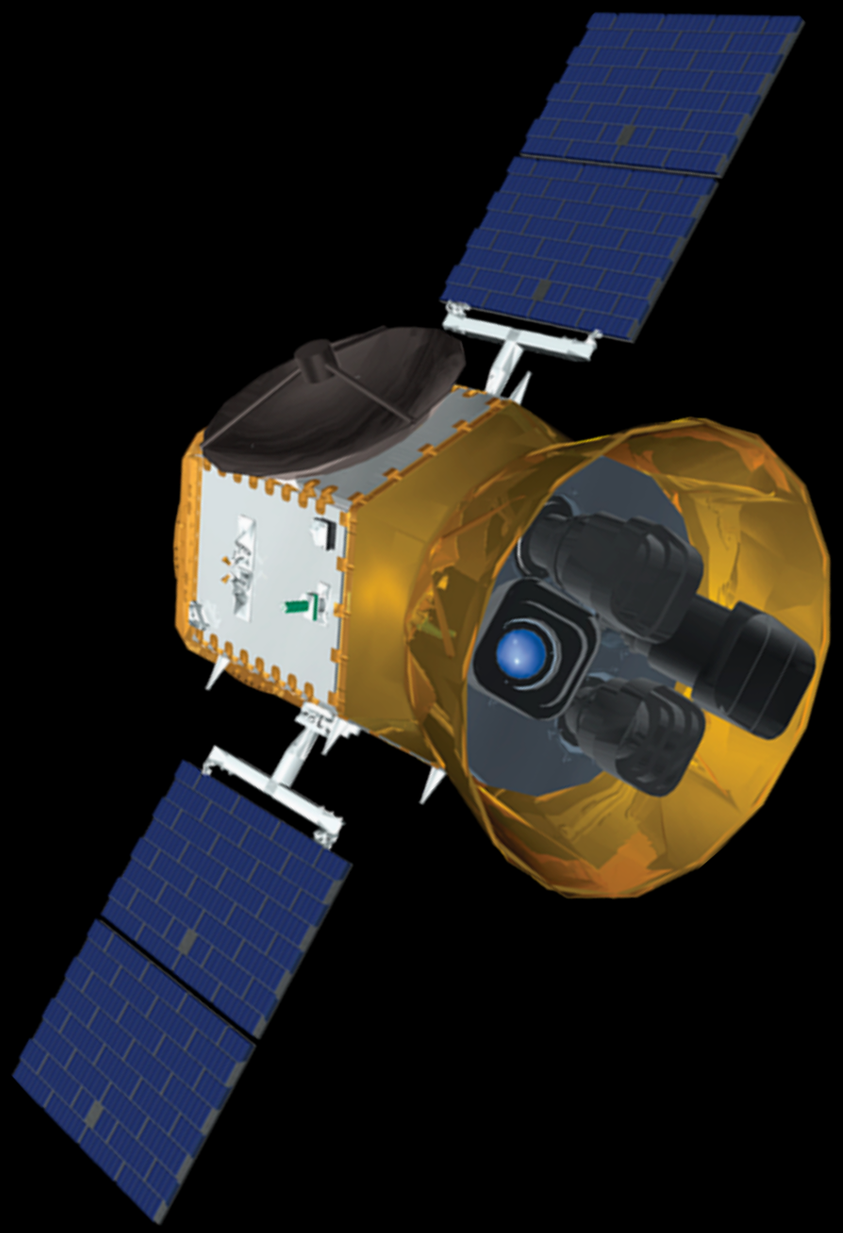
(K2 ≈3% of sky)

(1) the present limitations

(2) the TESS mission

(3) the future

TESS Transiting Exoplanet Survey Satellite

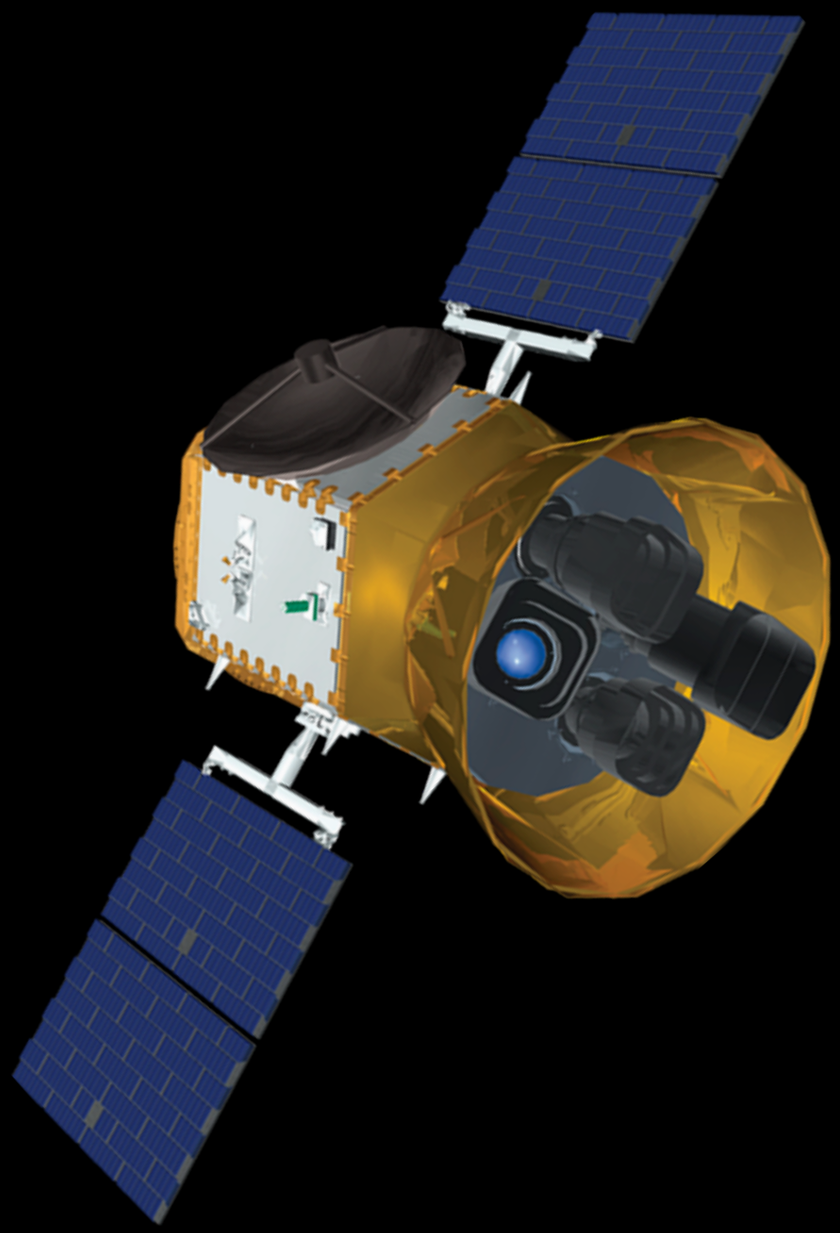


NASA Explorer Mission

searching the whole sky to find hundreds of small exoplanets amenable to detailed characterization

Ricker et al., *JATIS*, (2014)

TESS Transiting Exoplanet Survey Satellite



PI = George Ricker

Massachusetts Institute of Technology

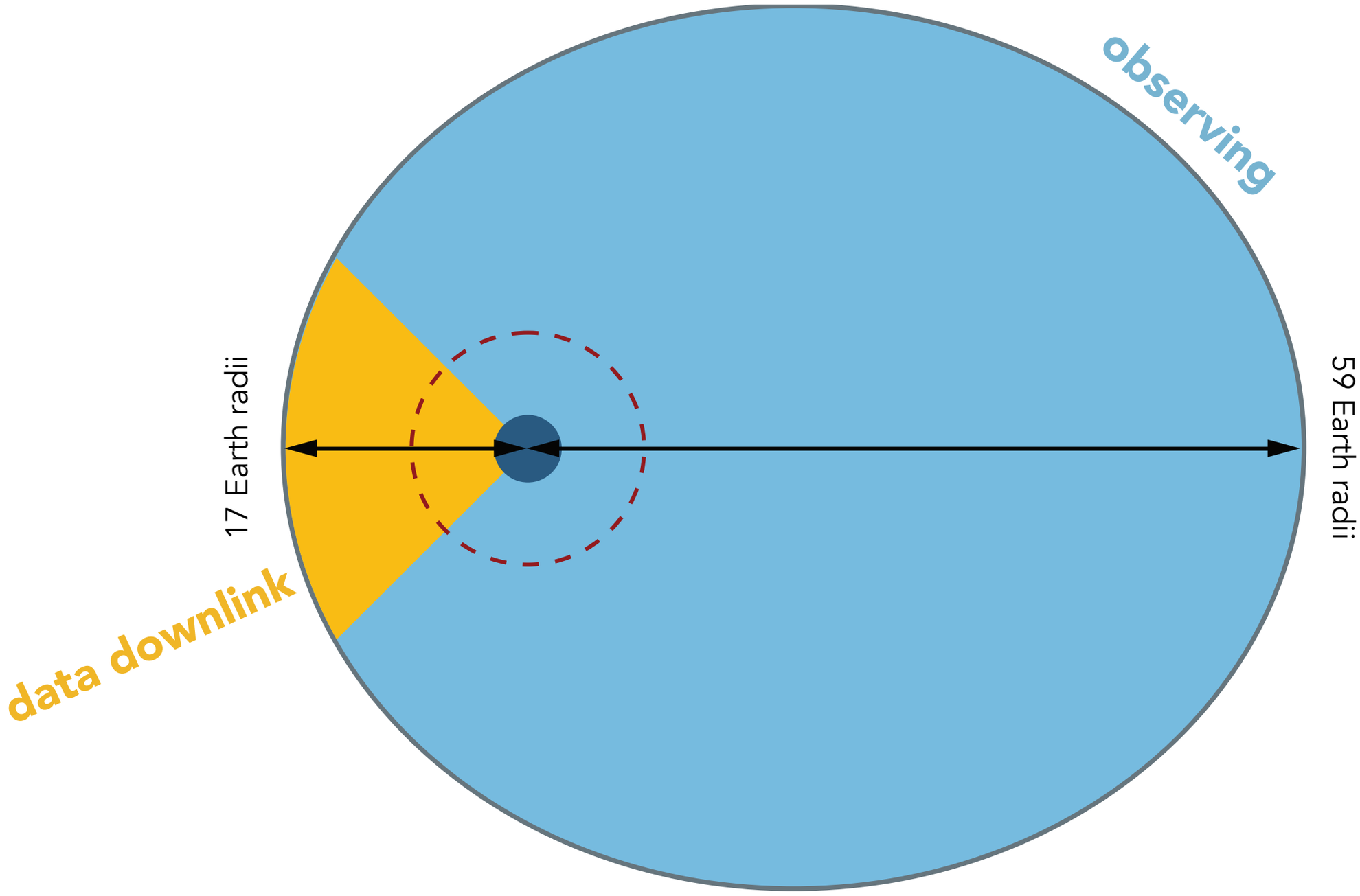
Science Center

MIT + Harvard/Smithsonian CfA

collaboration including:

NASA Goddard, NASA Ames, Orbital Sciences, STScI, SAO, MPIA-Germany, Las Cumbres Observatory, Geneva Observatory, OHP-France, University of Florida, Aarhus University-Denmark, Harvard College Observatory, Vanderbilt University

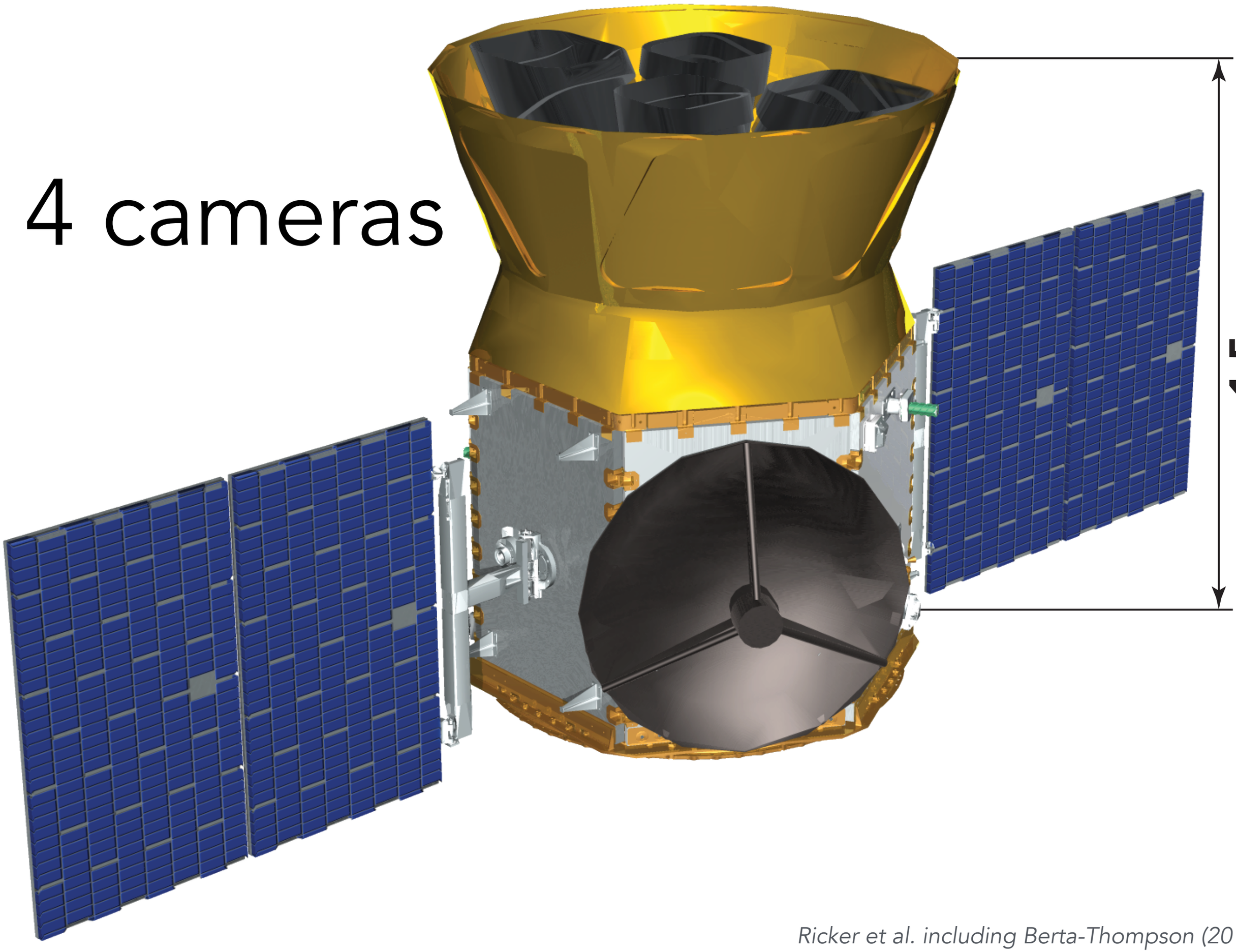
Ricker et al., *JATIS*, (2014)



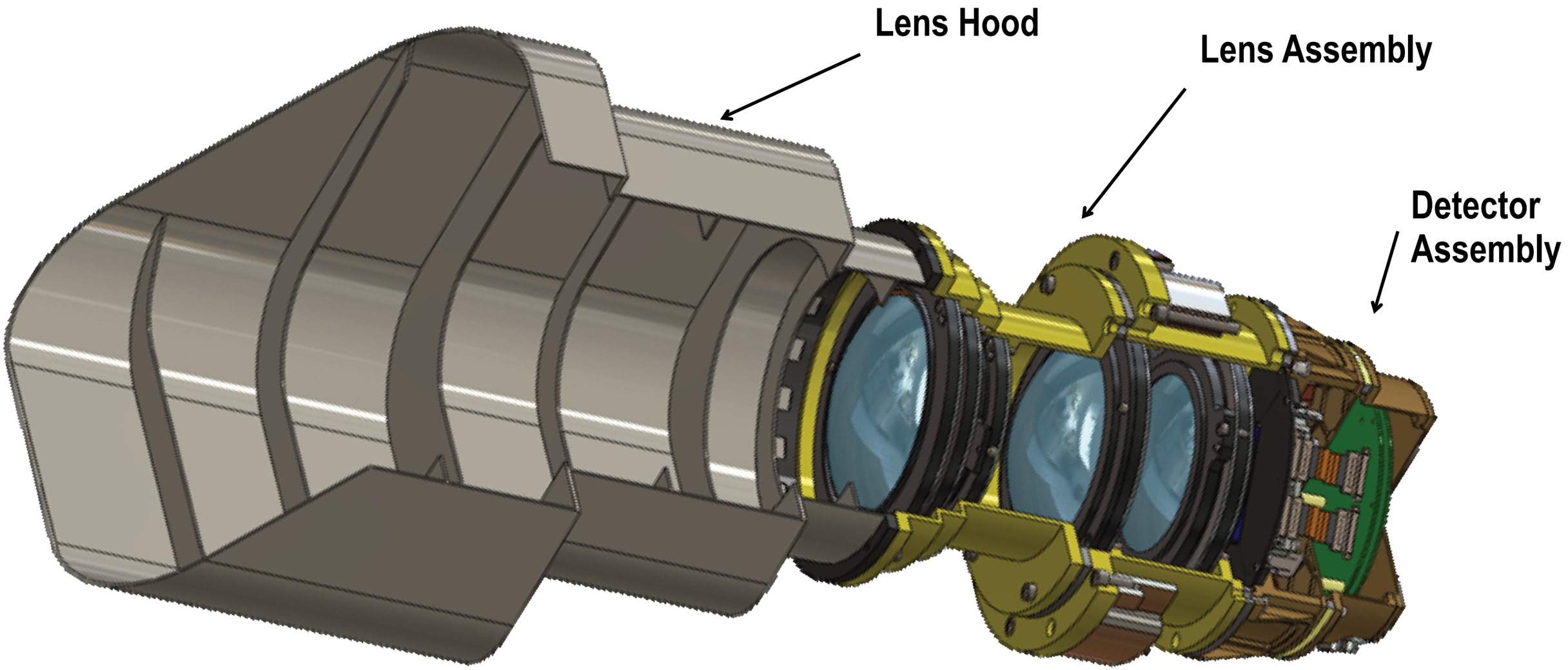
13.7 day High Earth Orbit
(2:1 lunar resonance)

Ricker et al. including Berta-Thompson (2014)

4 cameras



Ricker et al. including Berta-Thompson (2014)



10.5 cm diameter, 24°x24° field of view

Ricker et al. including Berta-Thompson (2014)

CAMERA
4

CAMERA
3

CAMERA
2

CAMERA
1

24°

24°

96°

24°

24°

54°

Ecliptic Pole

+90°

Spacecraft
+Z

+X

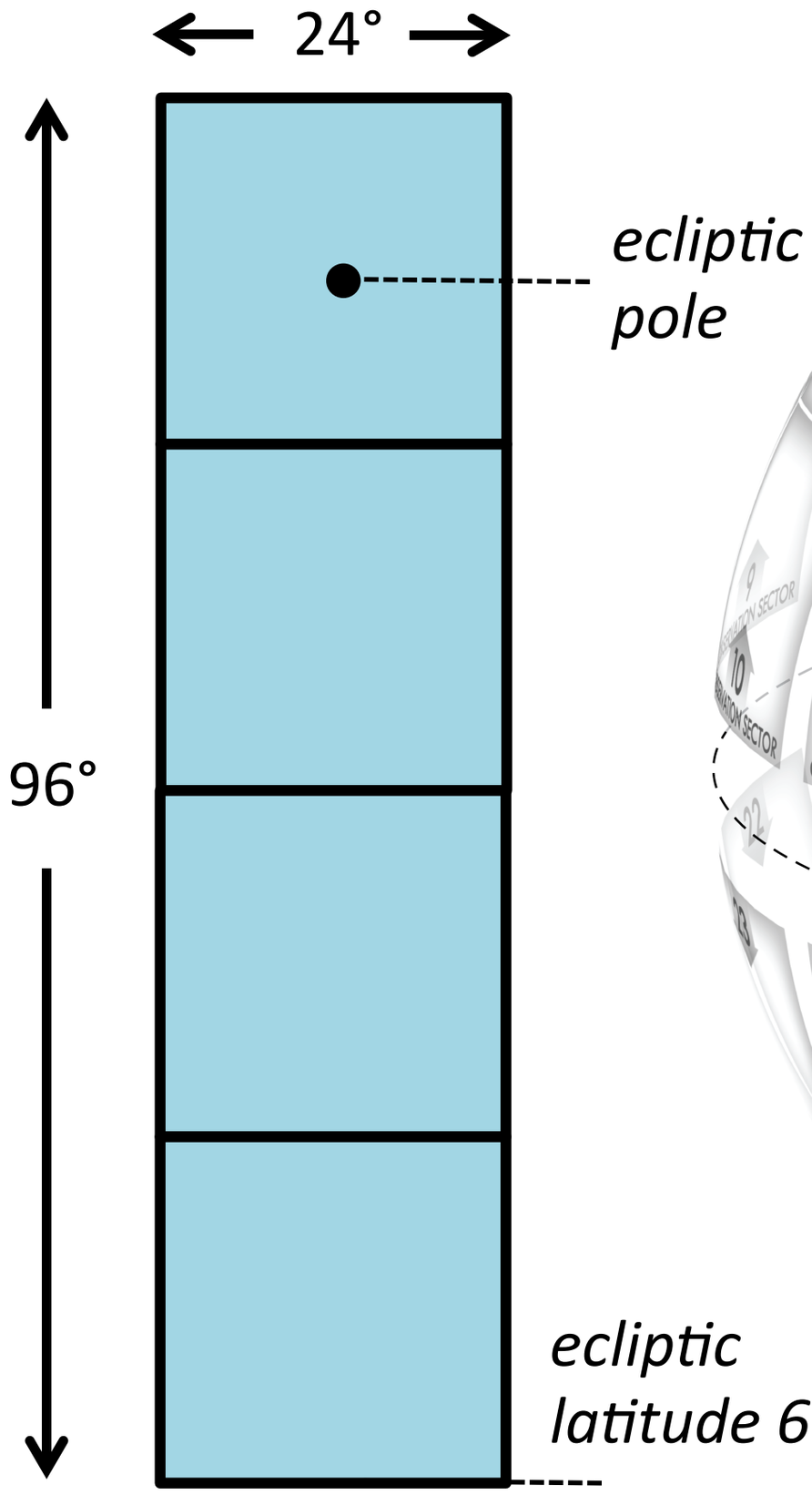
Sun

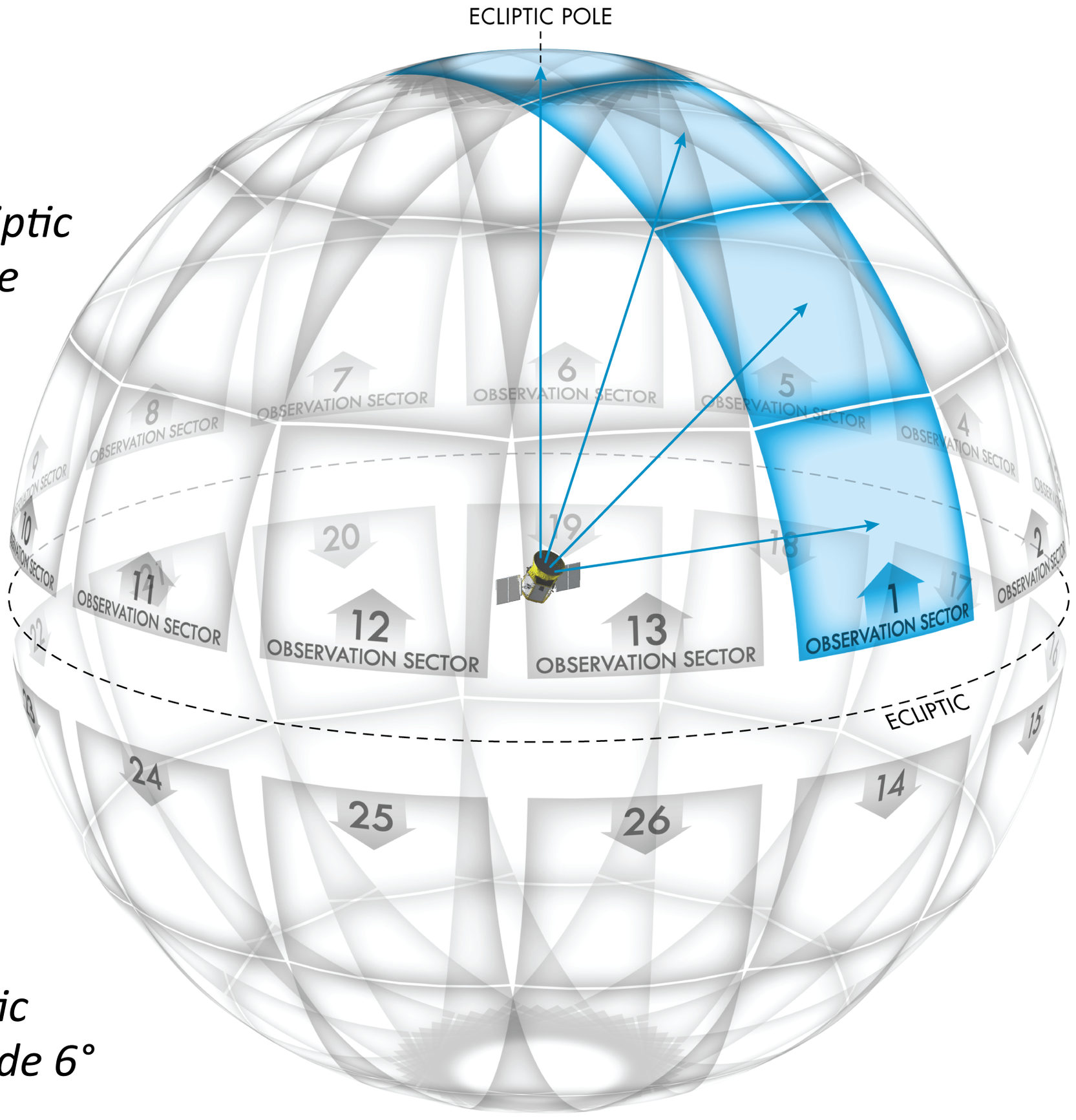
–X

0°

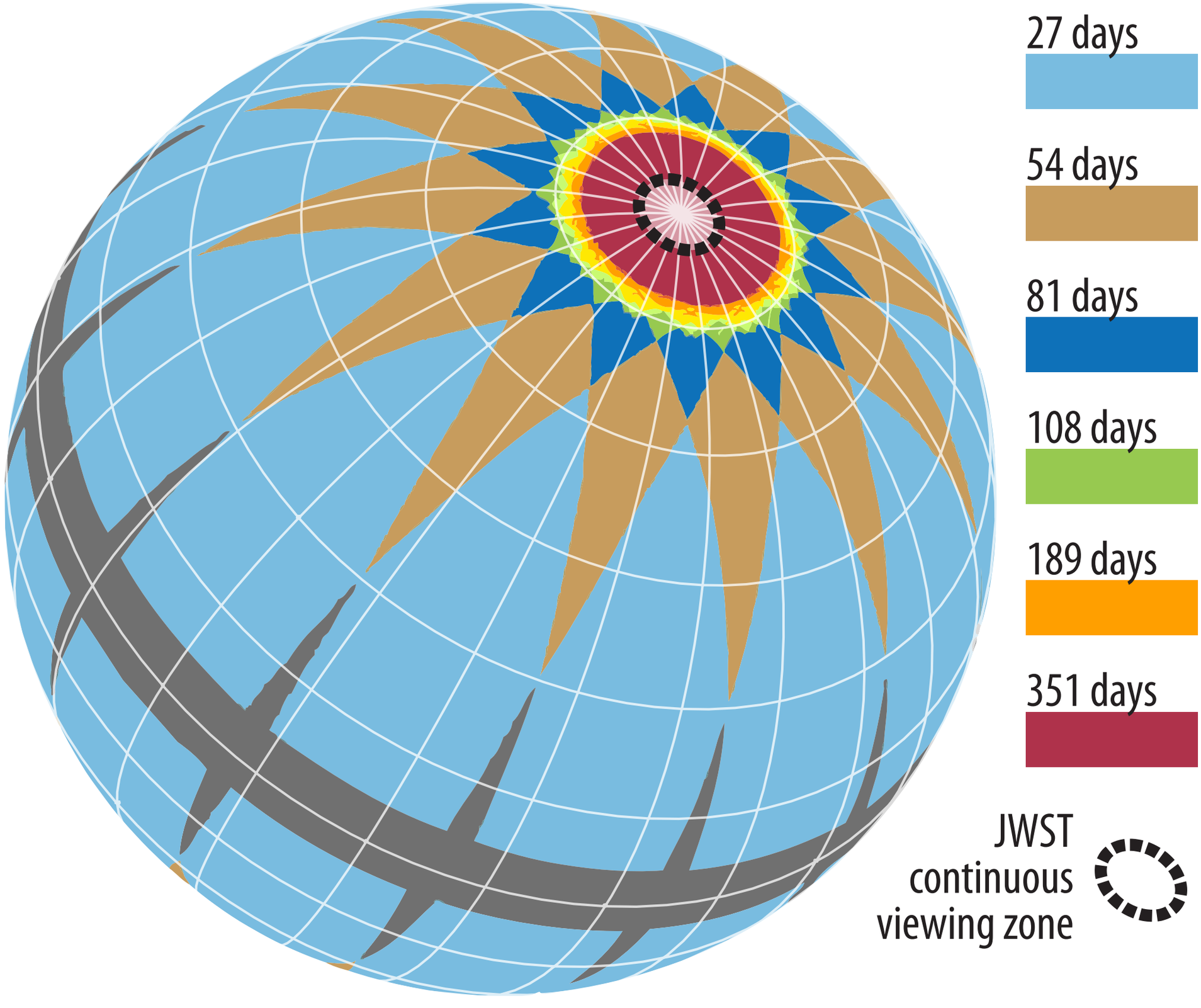
Ecliptic Plane

Ricker et al. including Berta-Thompson (2014)

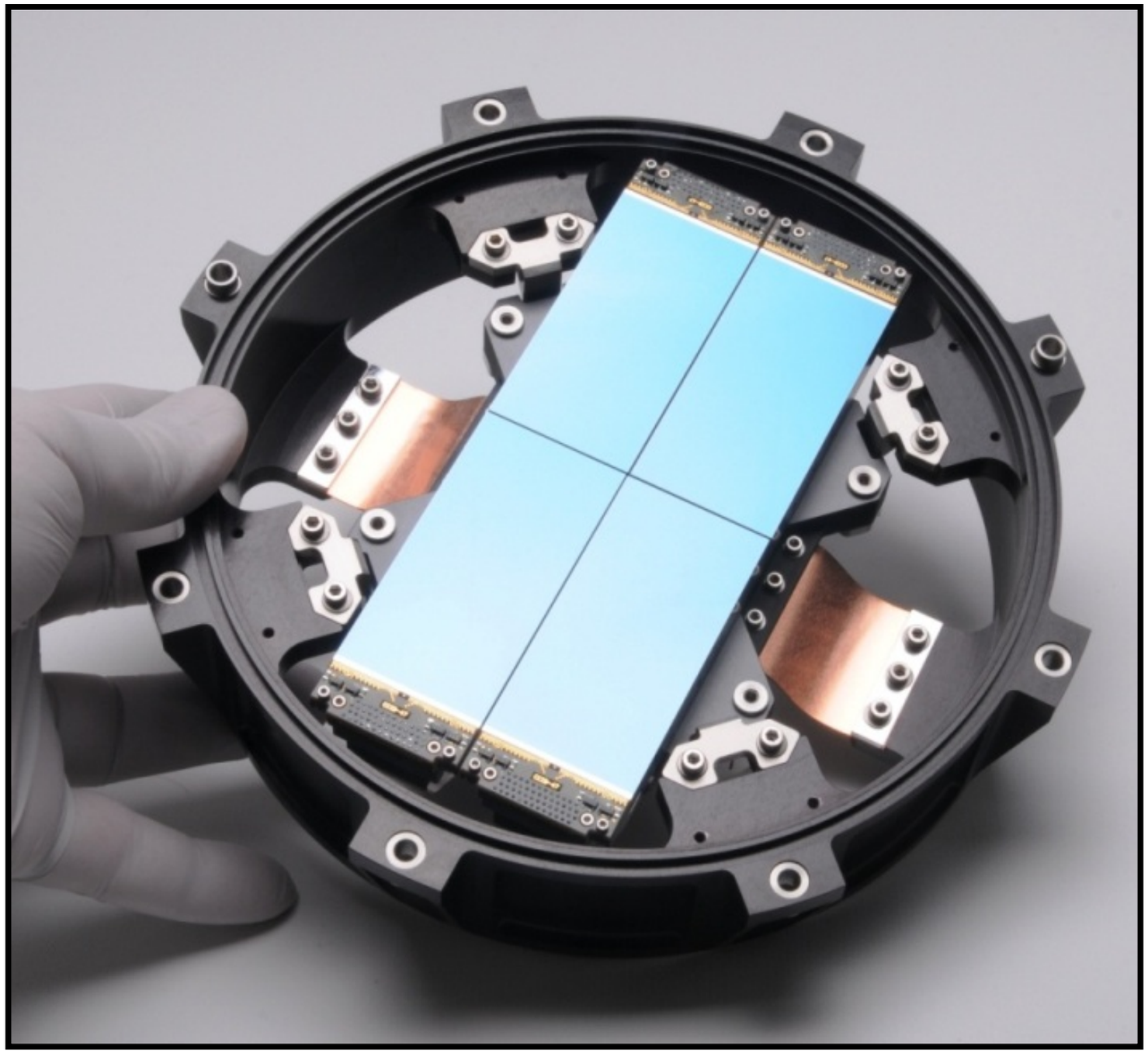




Ricker et al. including Berta-Thompson (2014)



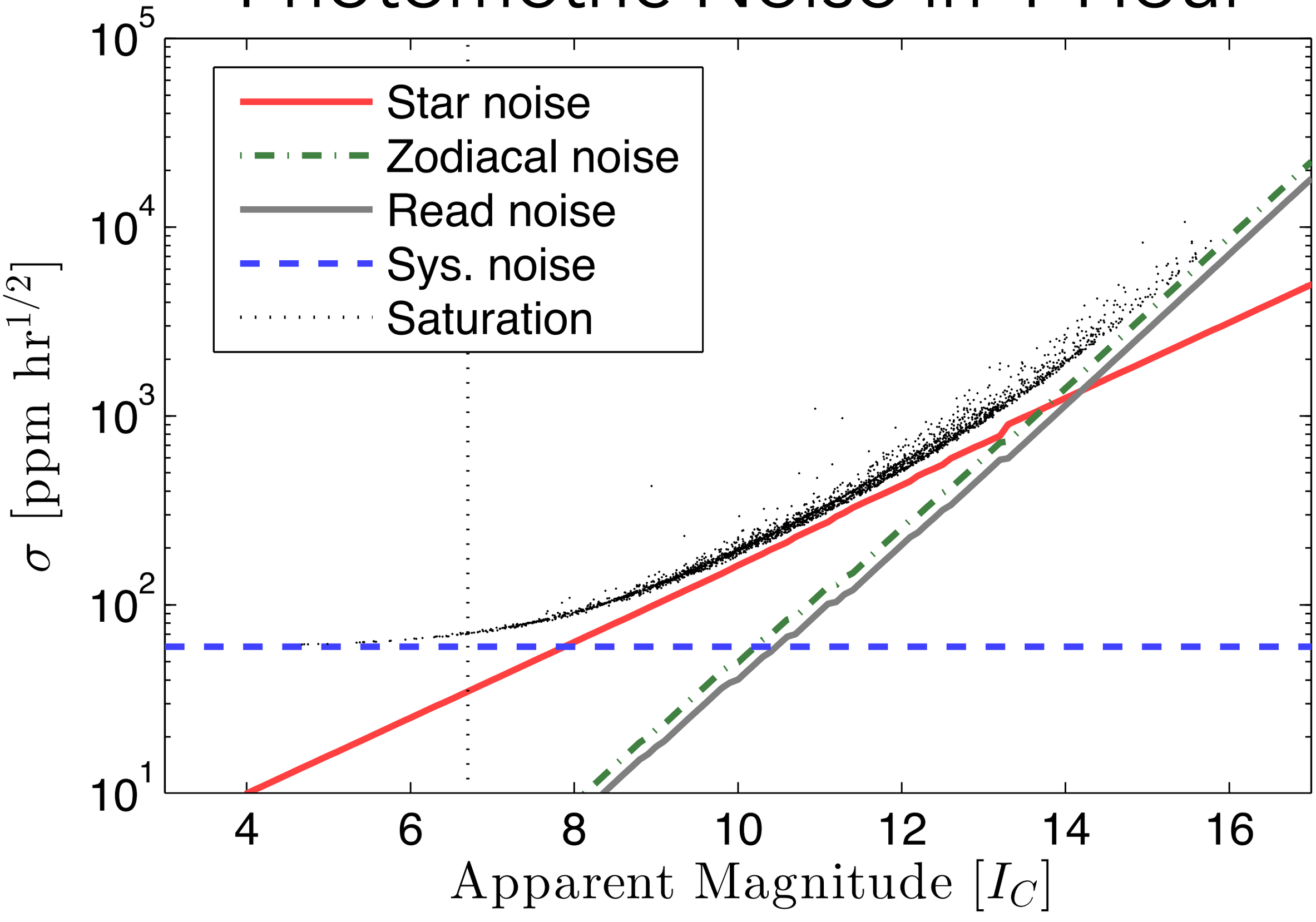
Ricker et al. including Berta-Thompson (2014)



deep depletion CCDs
600-1000nm bandpass

Ricker et al. including Berta-Thompson (2014)

Photometric Noise in 1 Hour

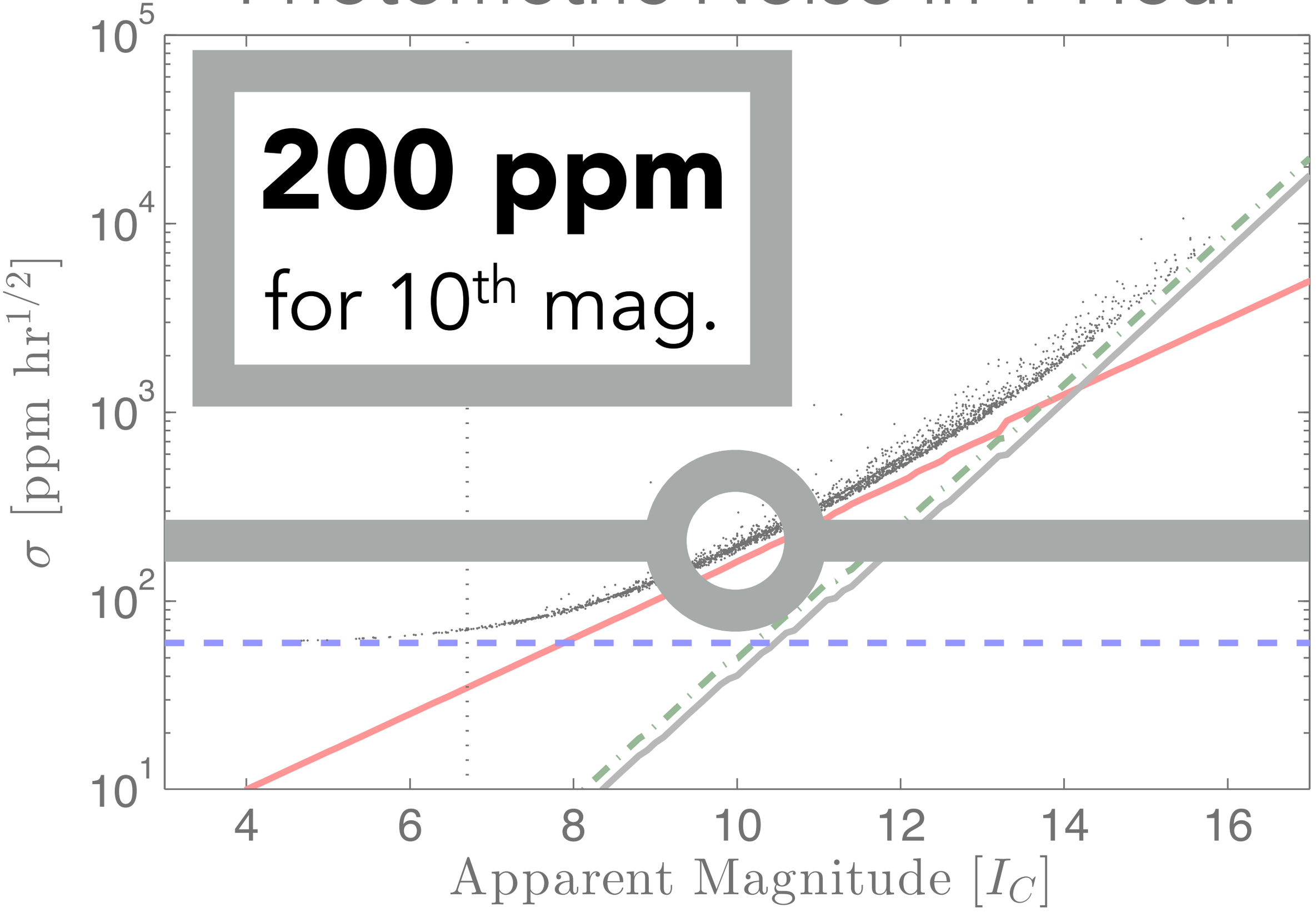


Ricker et al. (2014); Sullivan et al. (accepted & on arxiv), both including Berta-Thompson

Photometric Noise in 1 Hour

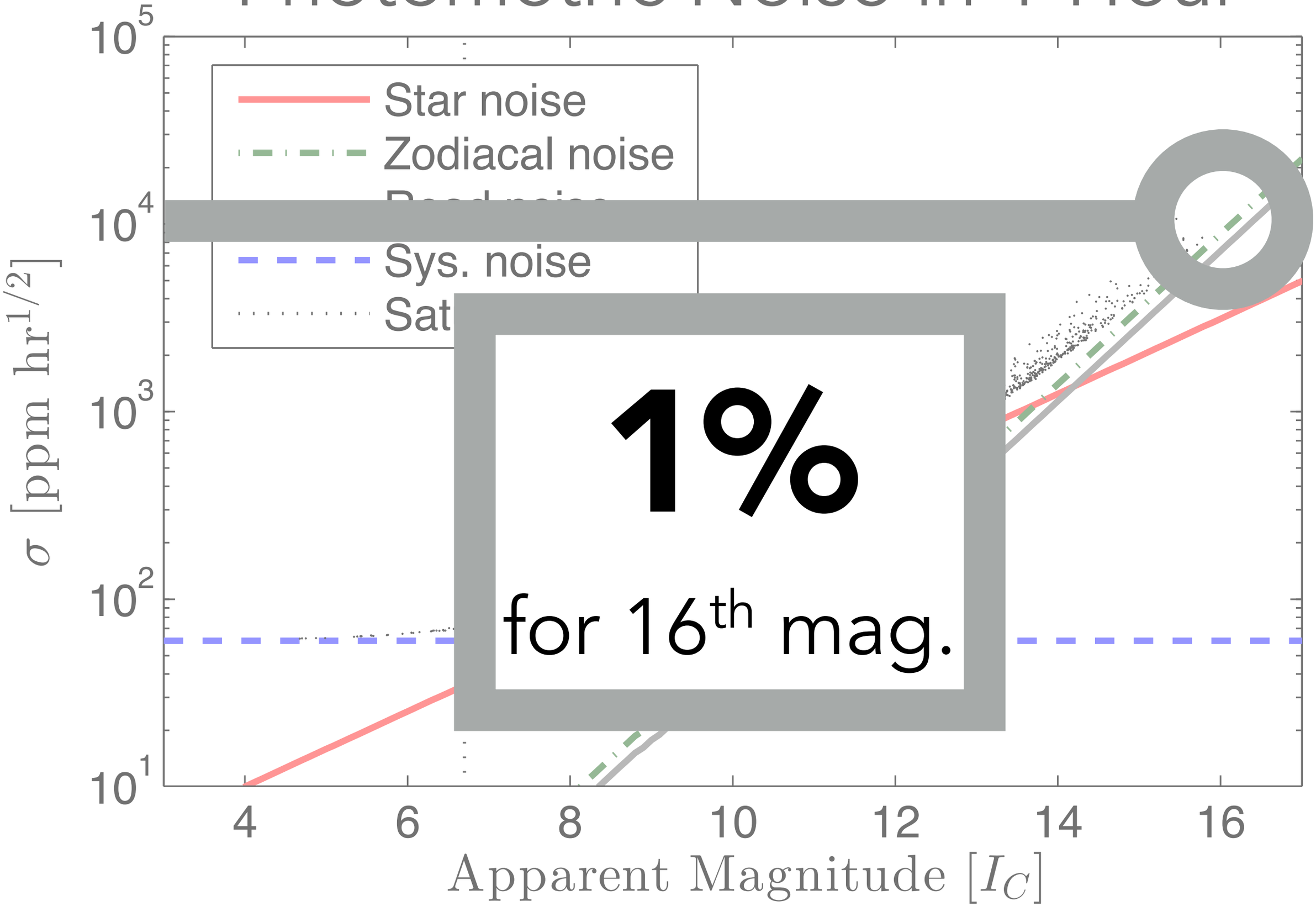
200 ppm

for 10th mag.



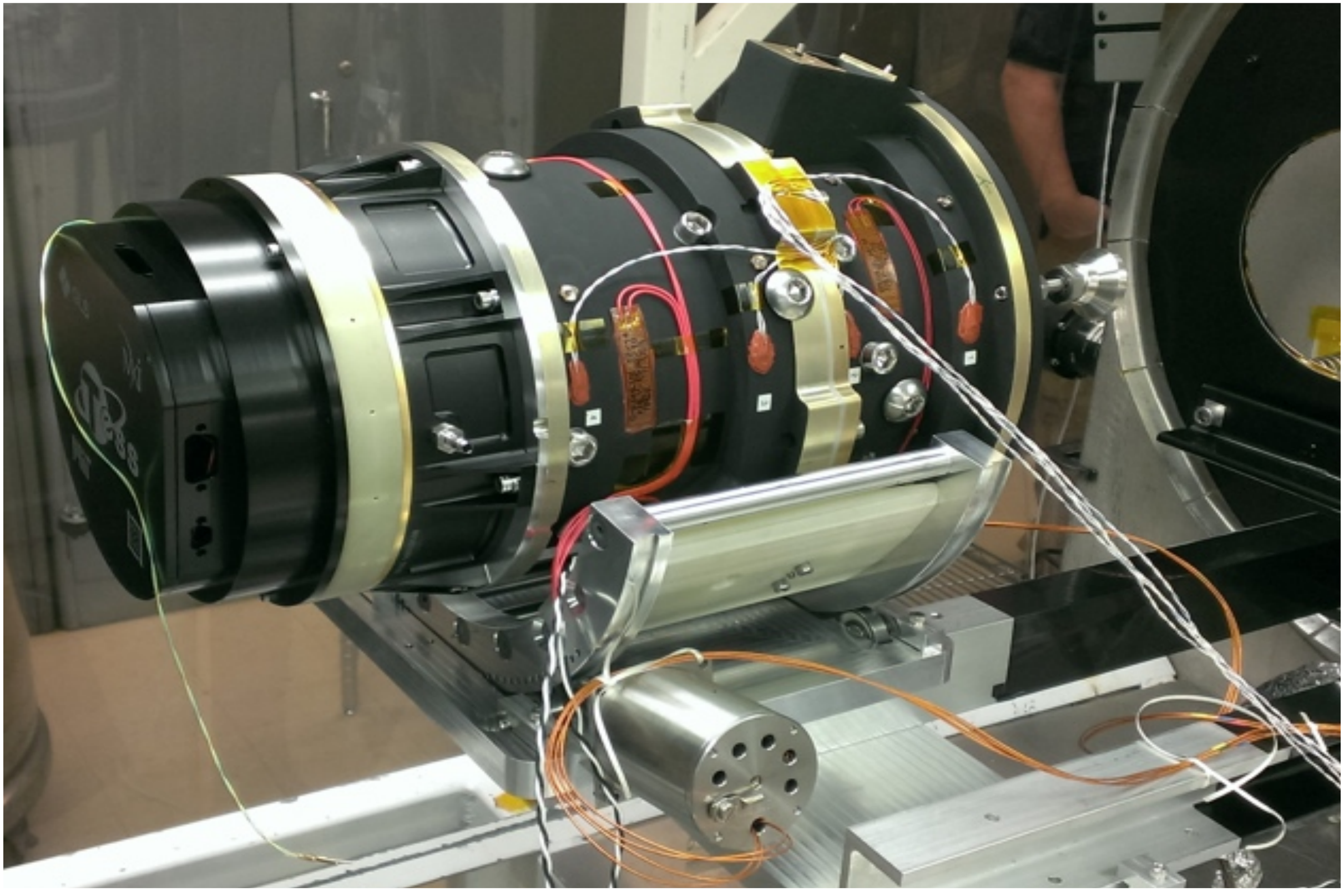
Ricker et al. (2014); Sullivan et al. (accepted & on arxiv), both including Berta-Thompson

Photometric Noise in 1 Hour

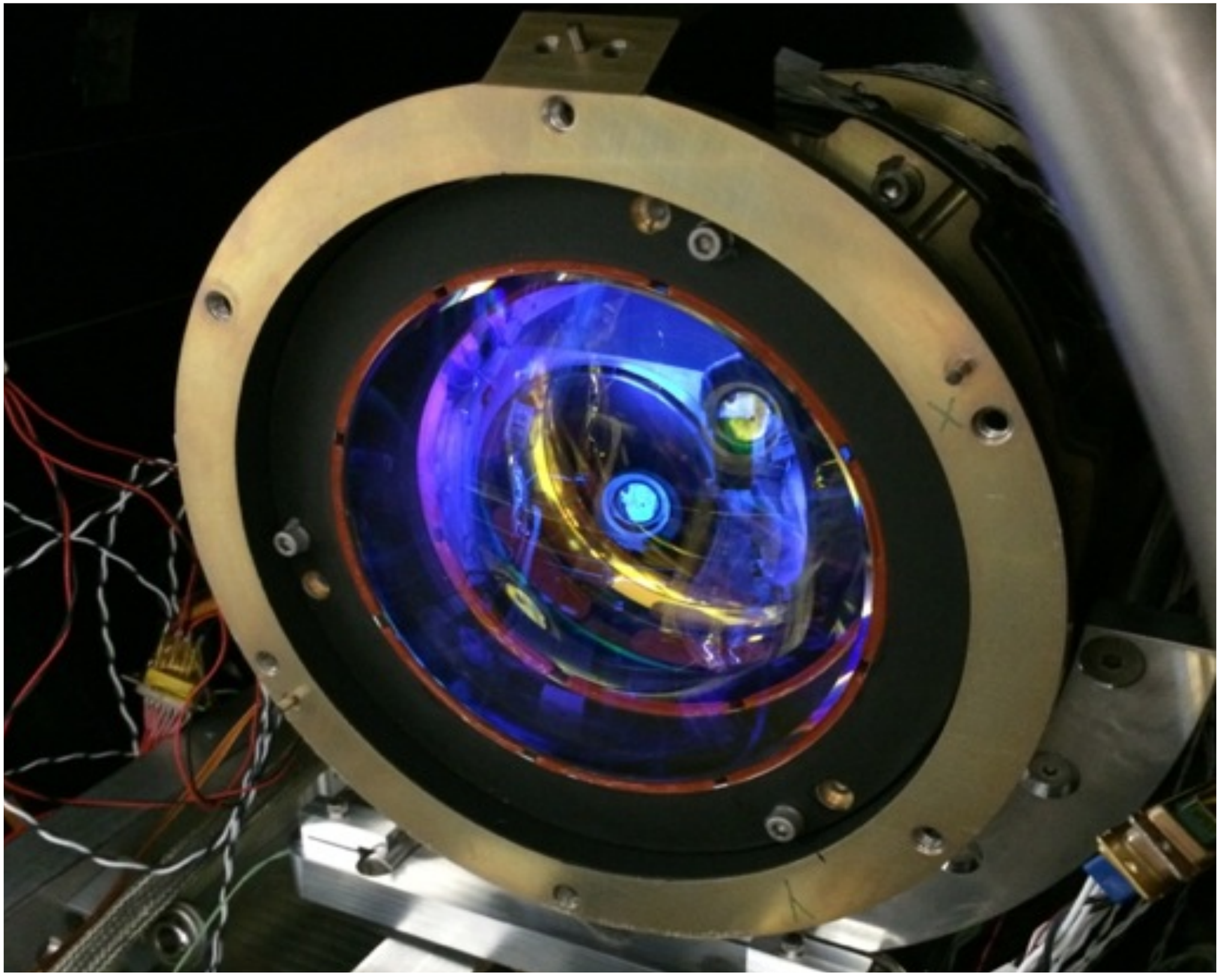


Ricker et al. (2014); Sullivan et al. (accepted & on arxiv), both including Berta-Thompson

TESS camera testing at MIT (risk-reduction unit)



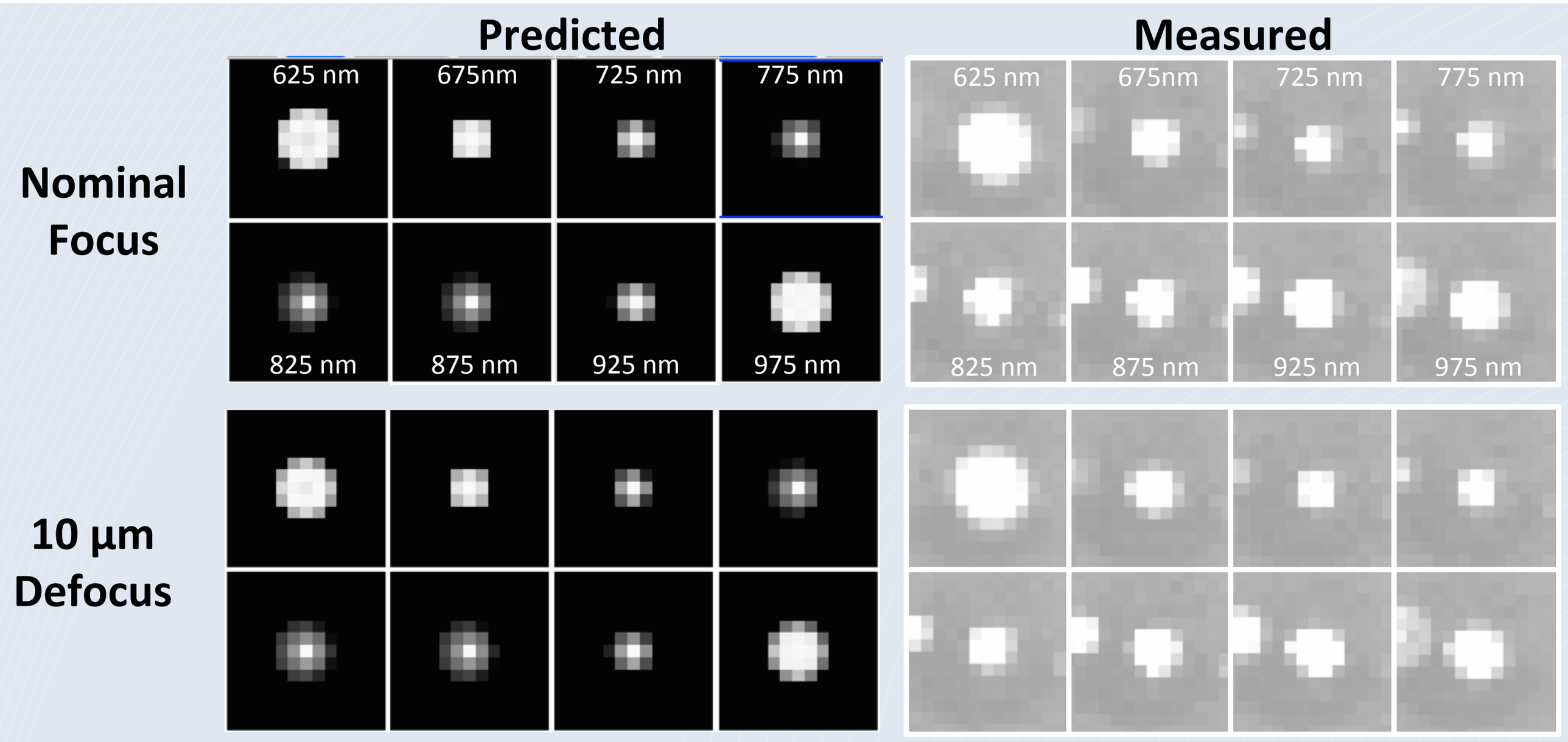
TESS camera testing at MIT (risk-reduction unit)



Joel Villasenor, Carolyn Thayer, Tim Sauerwine

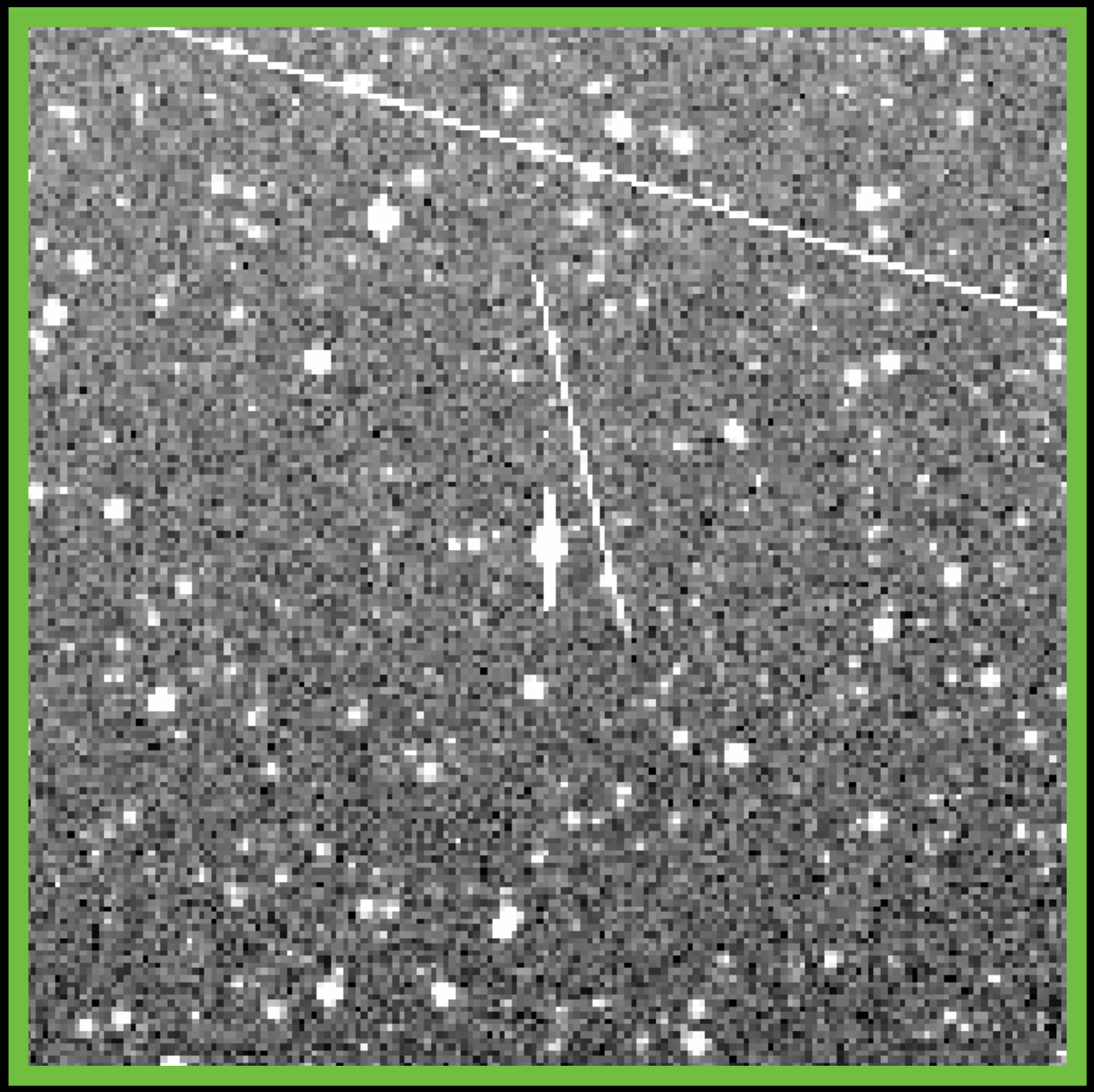
2s frames from TESS camera (at room temperature)

for example:
starting to measure the PSF, to verify optics



also: characterizing detector, flat-fielding, QE…
…we need a light stable light source!

TESS takes a new exposure once every **2 seconds**

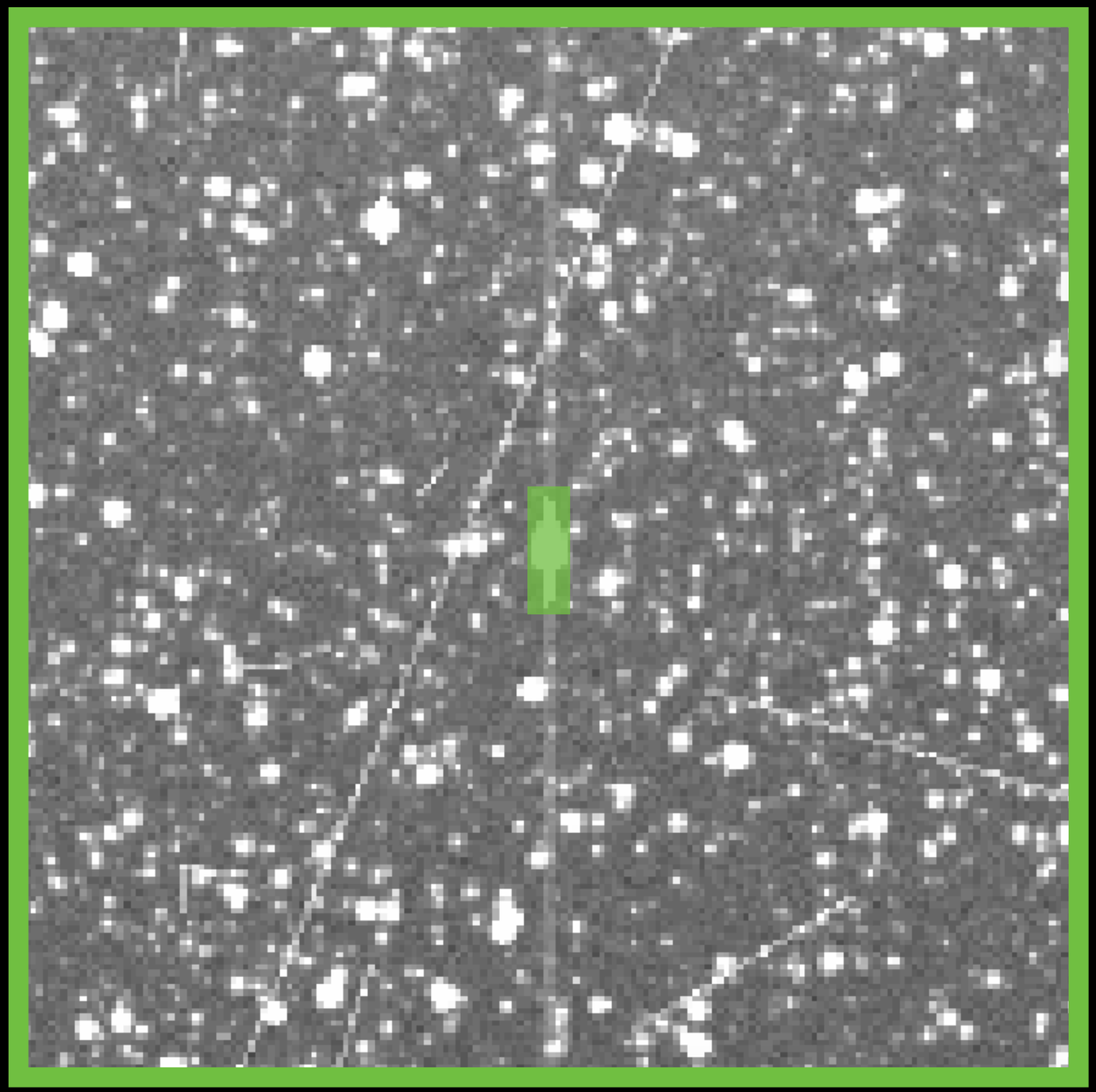


1 degree

simulated images by Zach Berta-Thompson

DOWNLINK:
20-second
asteroseismic
cadence for
1500 stars

for the brightest seismology targets

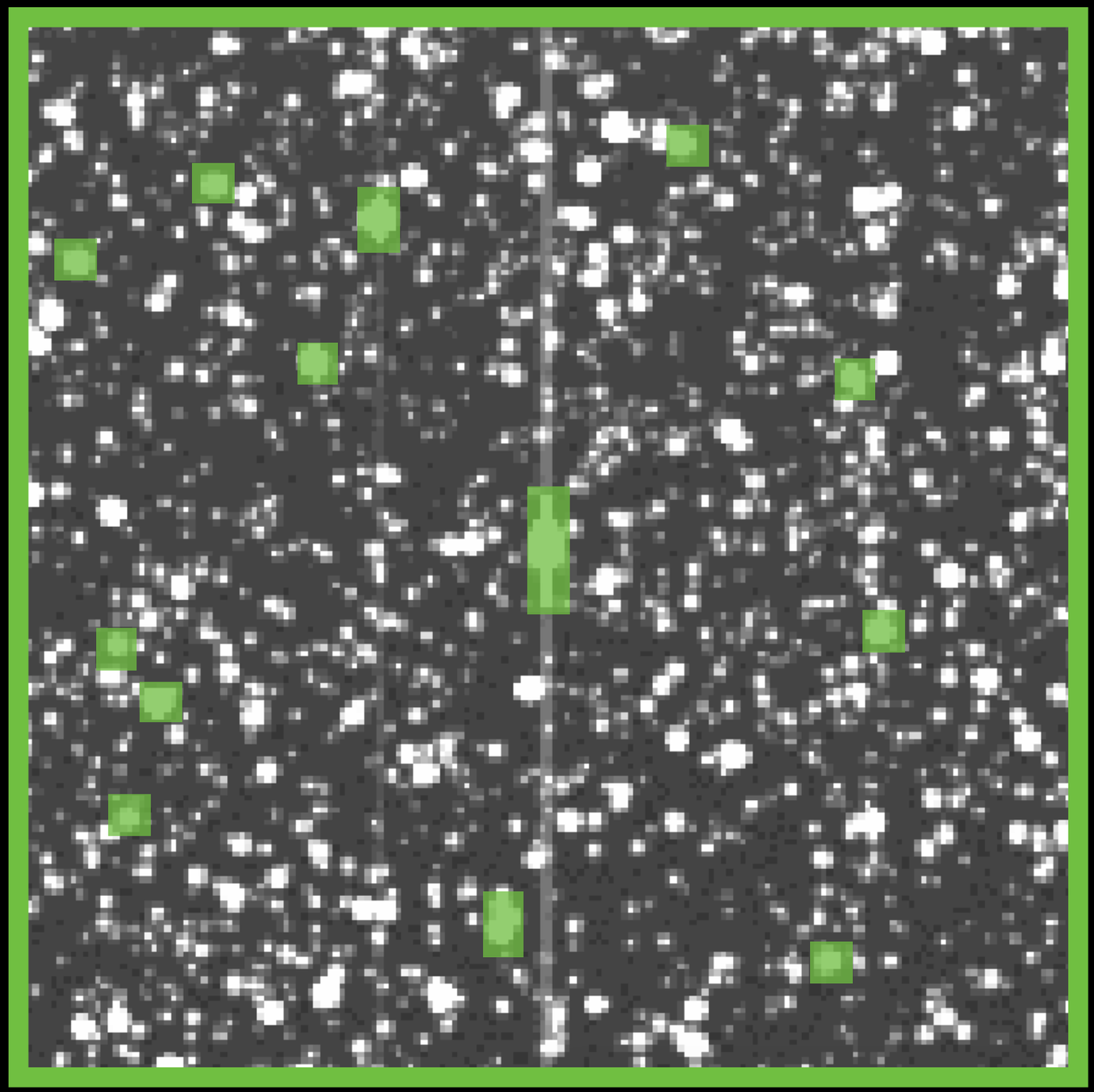


1 degree

simulated images by Zach Berta-Thompson

DOWNLINK:
2-minute cadence
for 200,000 stars

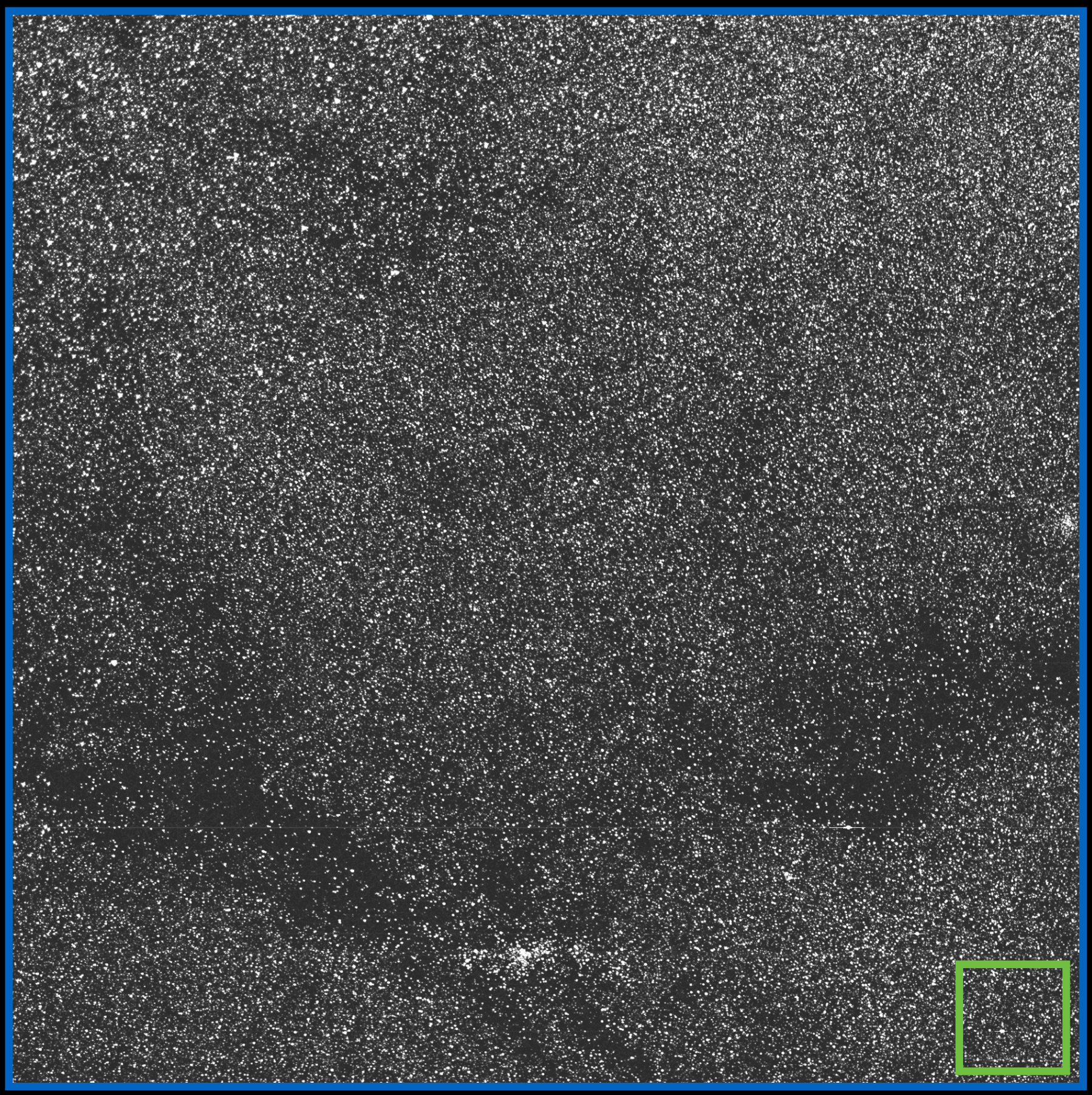
prioritizing
detectability of
small planets



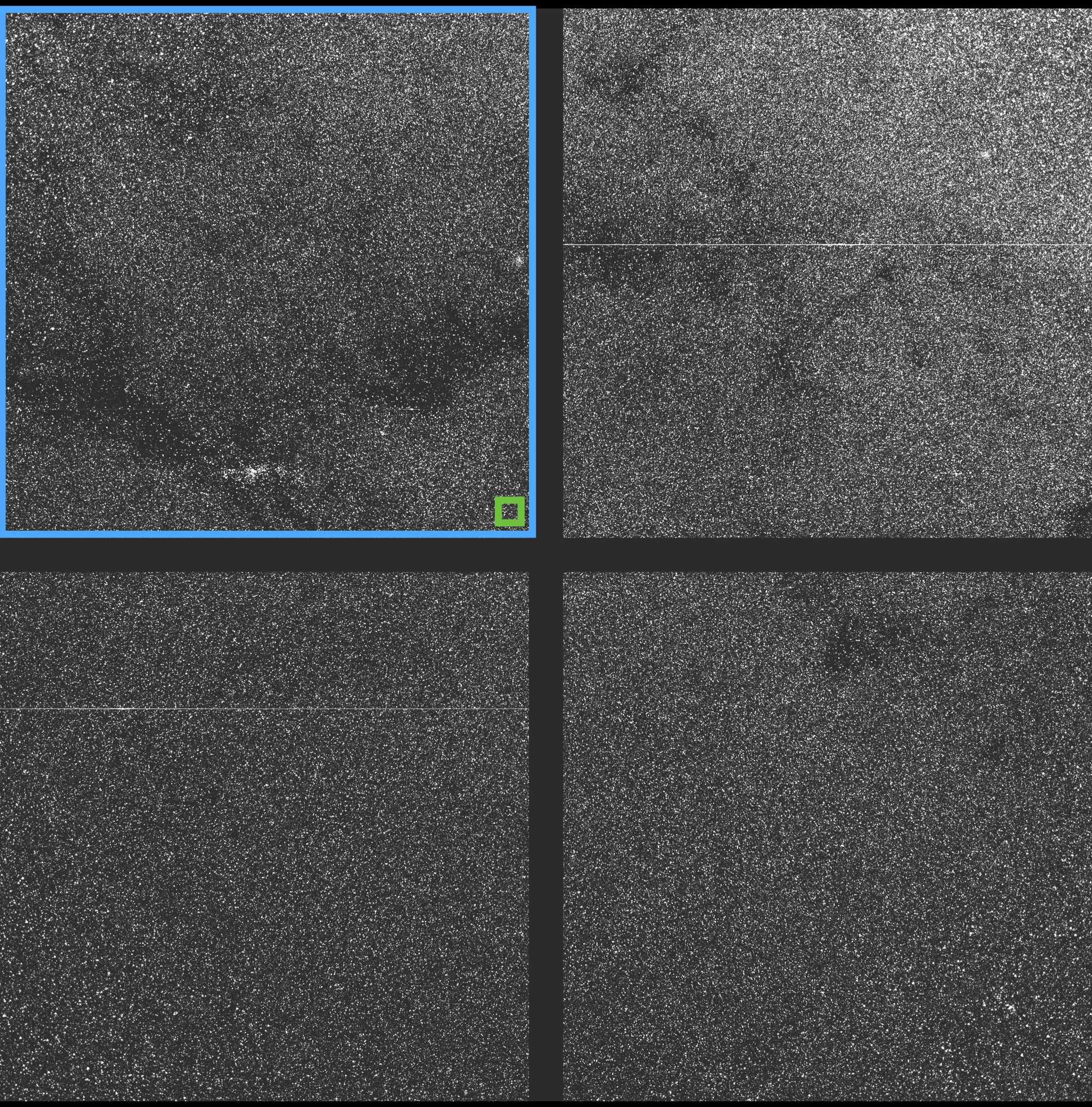
1 degree

simulated images by Zach Berta-Thompson

one CCD:
12 degrees



one camera:



one camera:

Betelgeuse

ORION

BULL
7

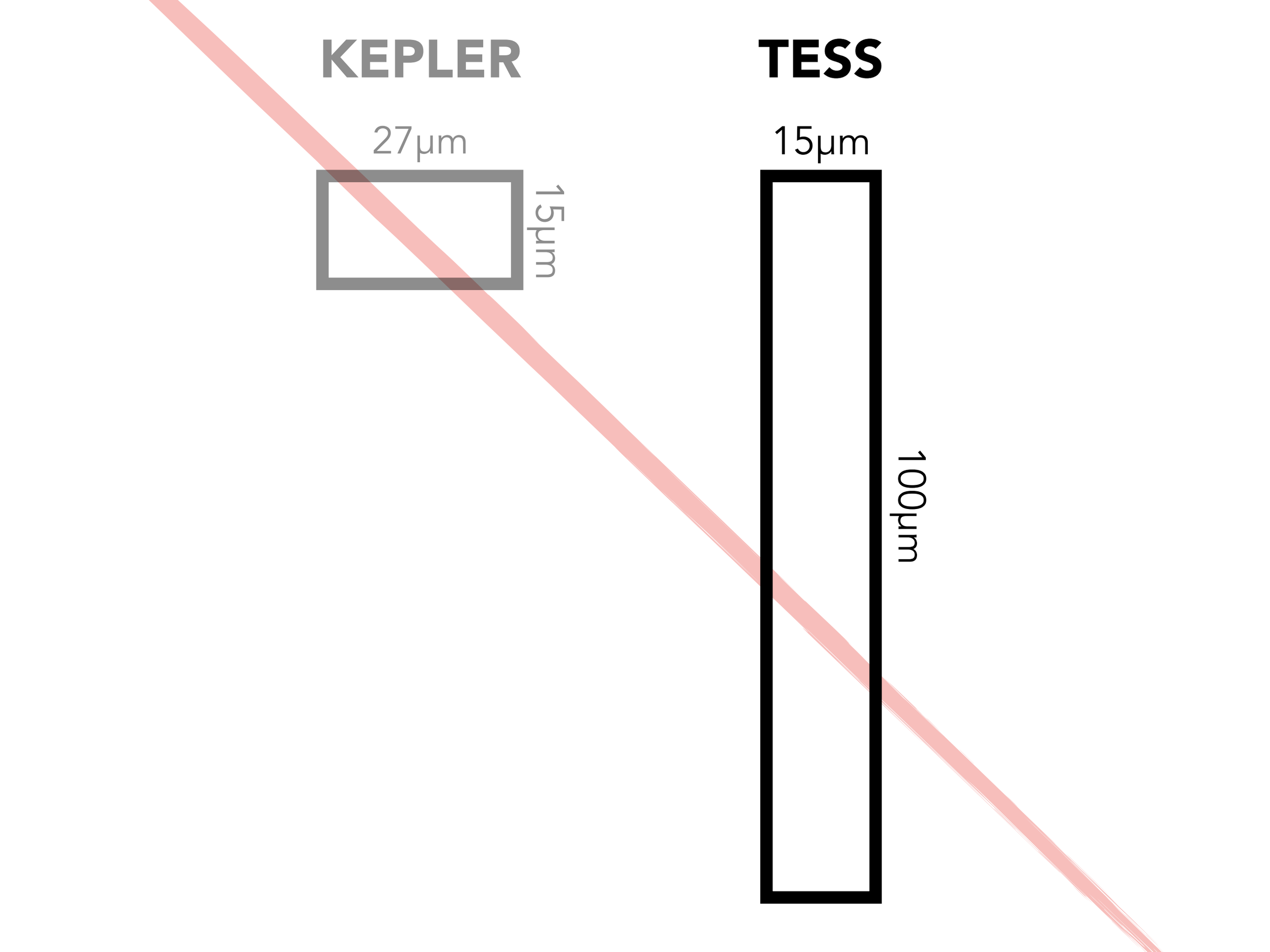
Rigel

RIVER
ERIDANUS

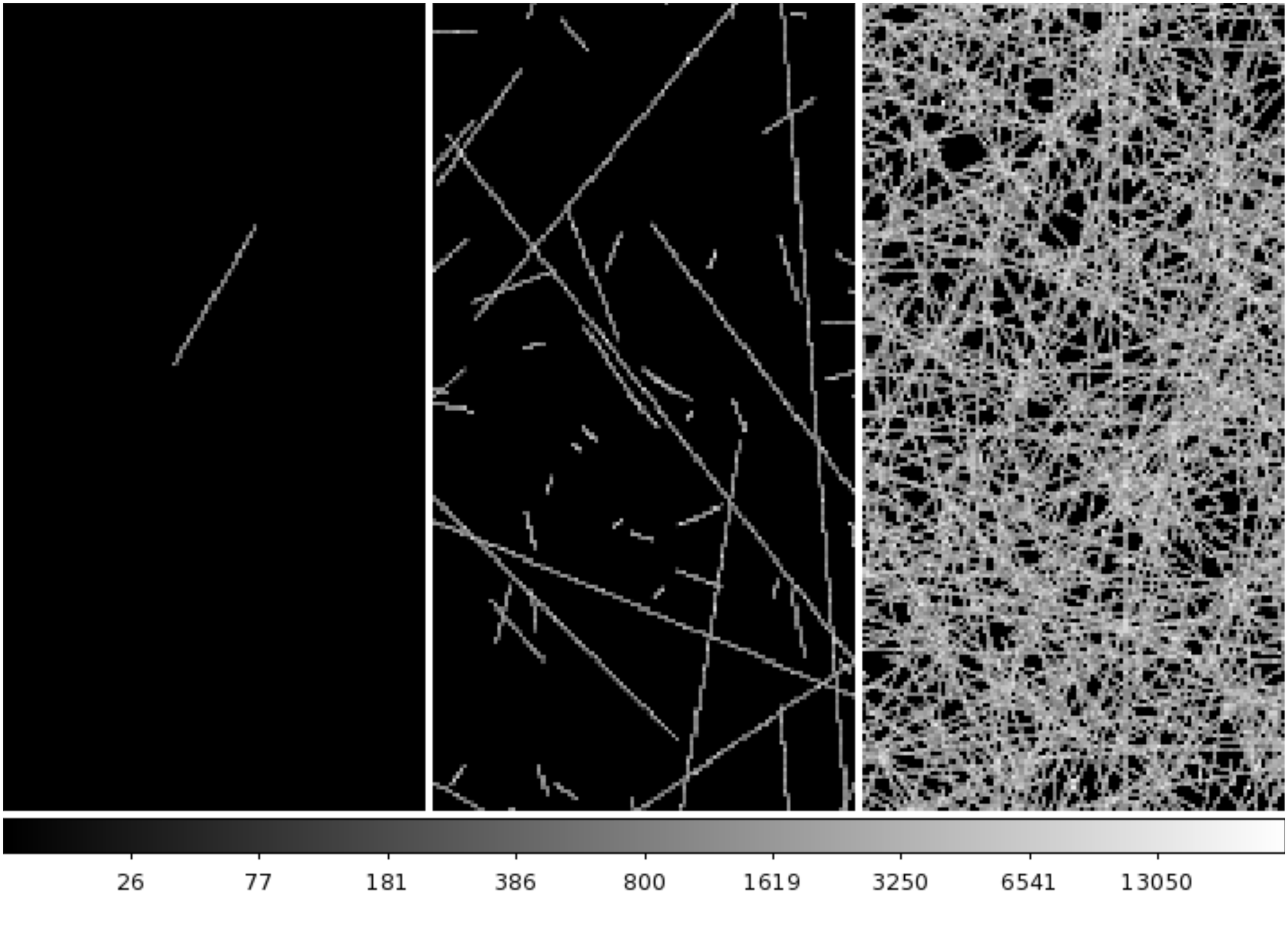
constellations by H. A. Rey

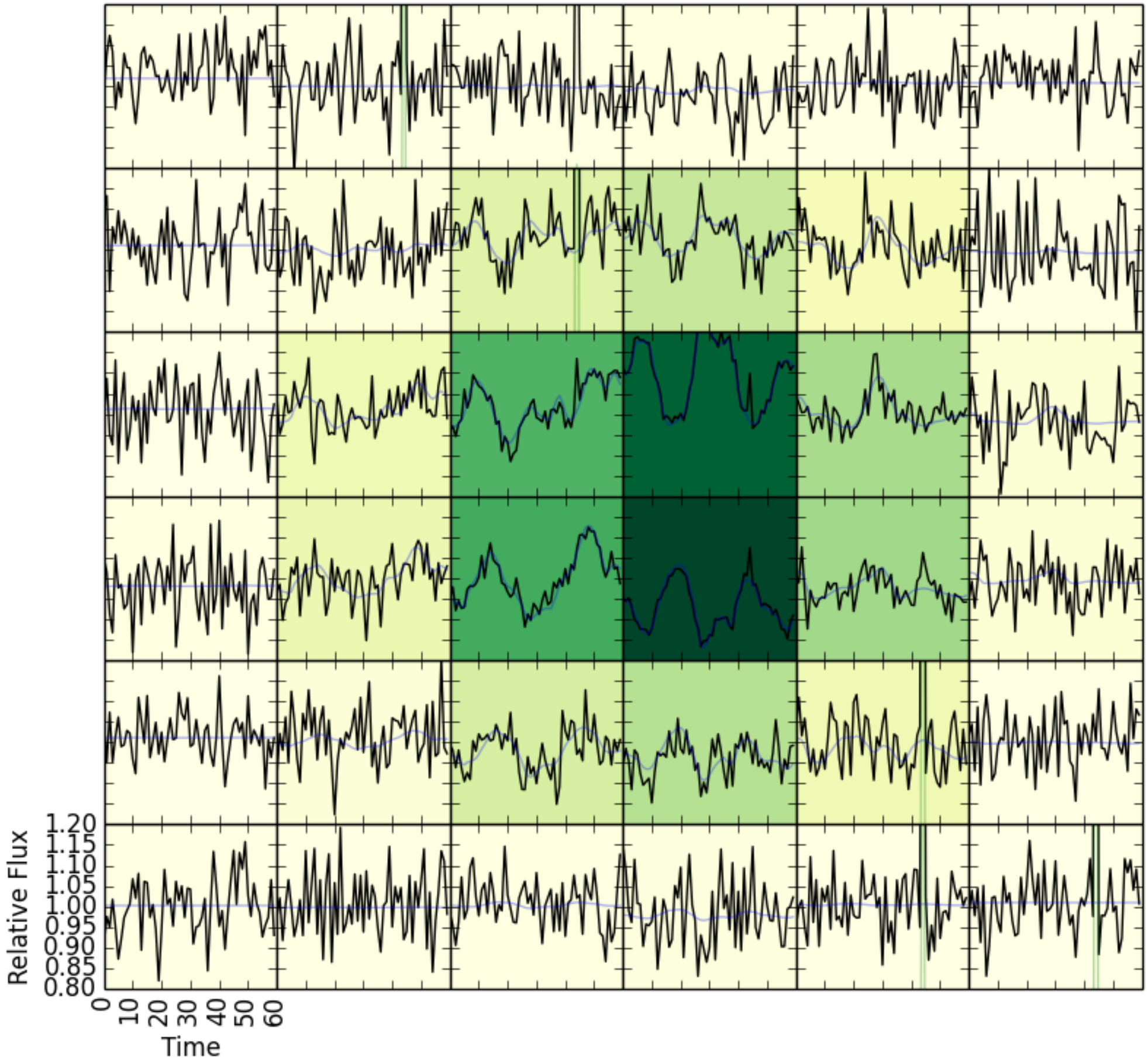
DOWNLINK:
30-minute cadence
for full frame images

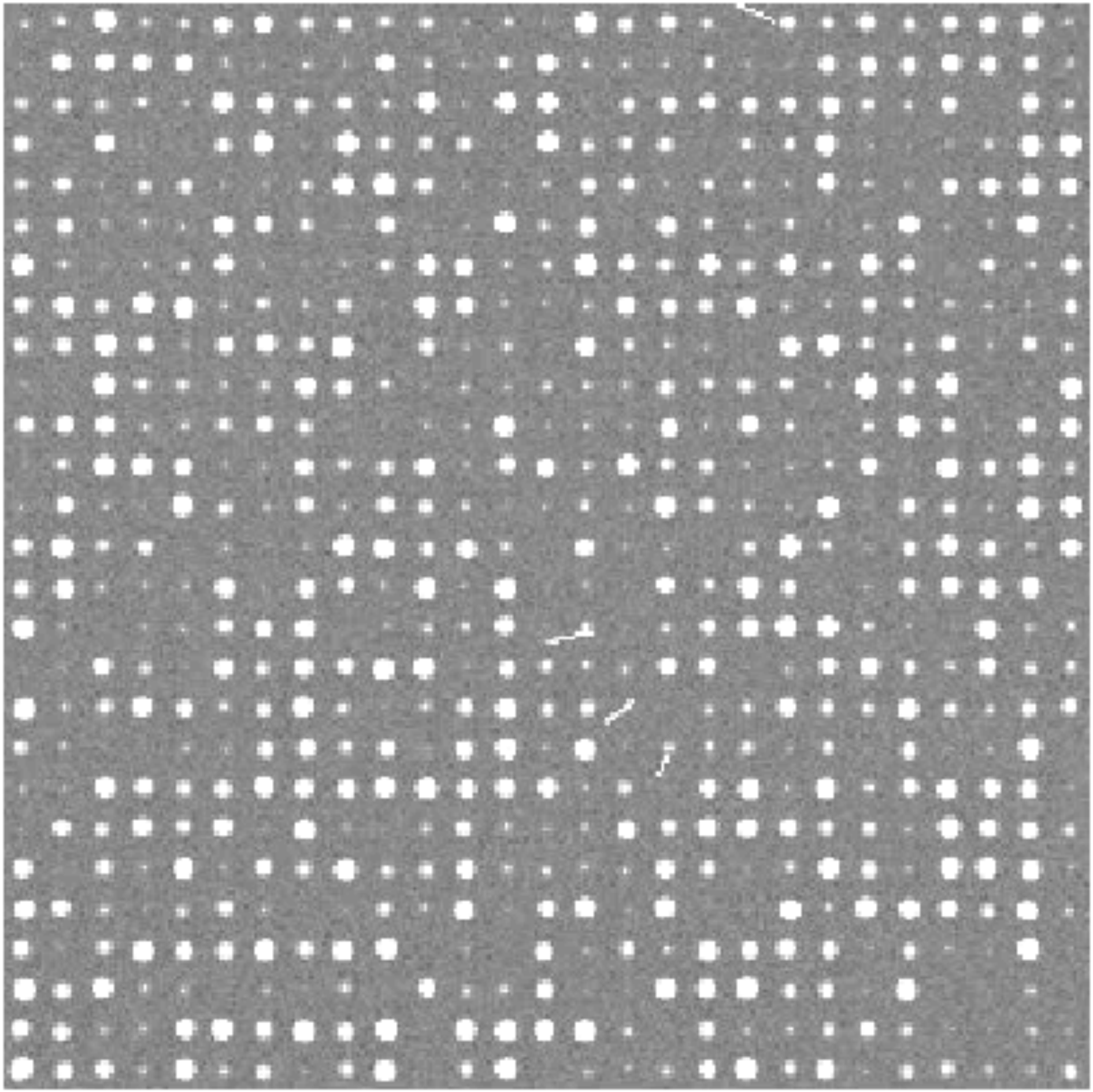
one camera:


KEPLER
27μm
15μm
TESS
15μm
100μm

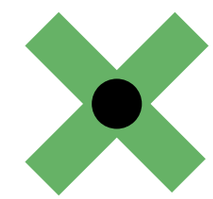
2s 120s 1800s

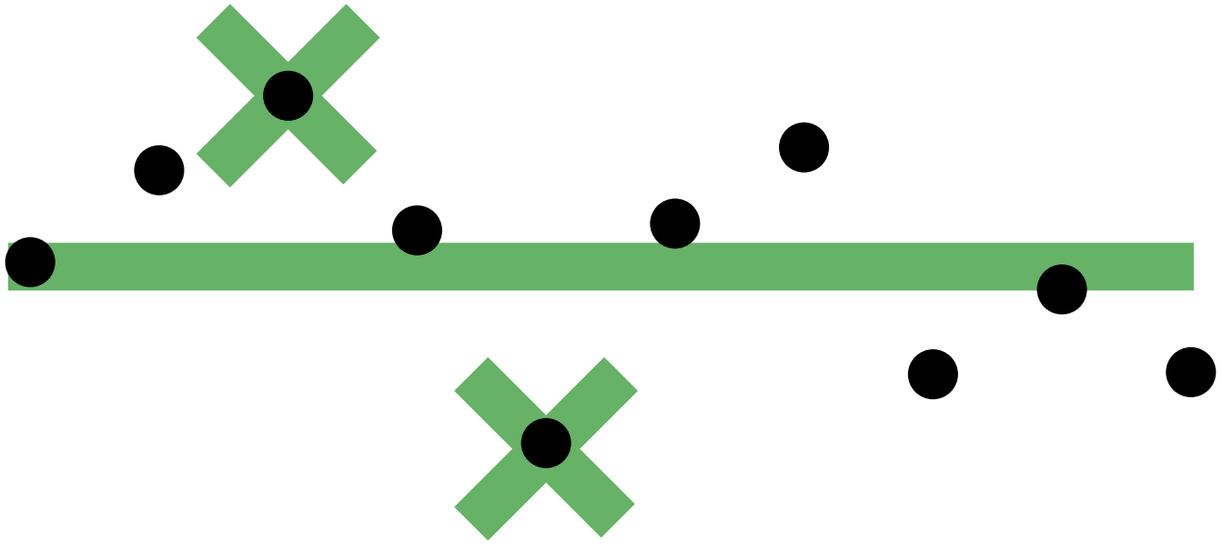


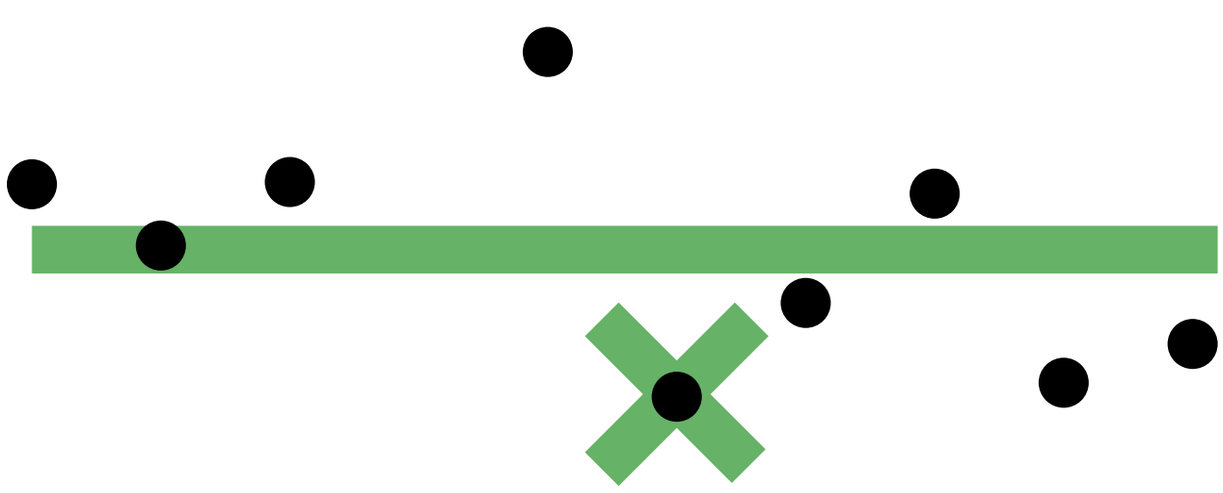

Relative Flux
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
0
10
20
30
40
50
60
Time



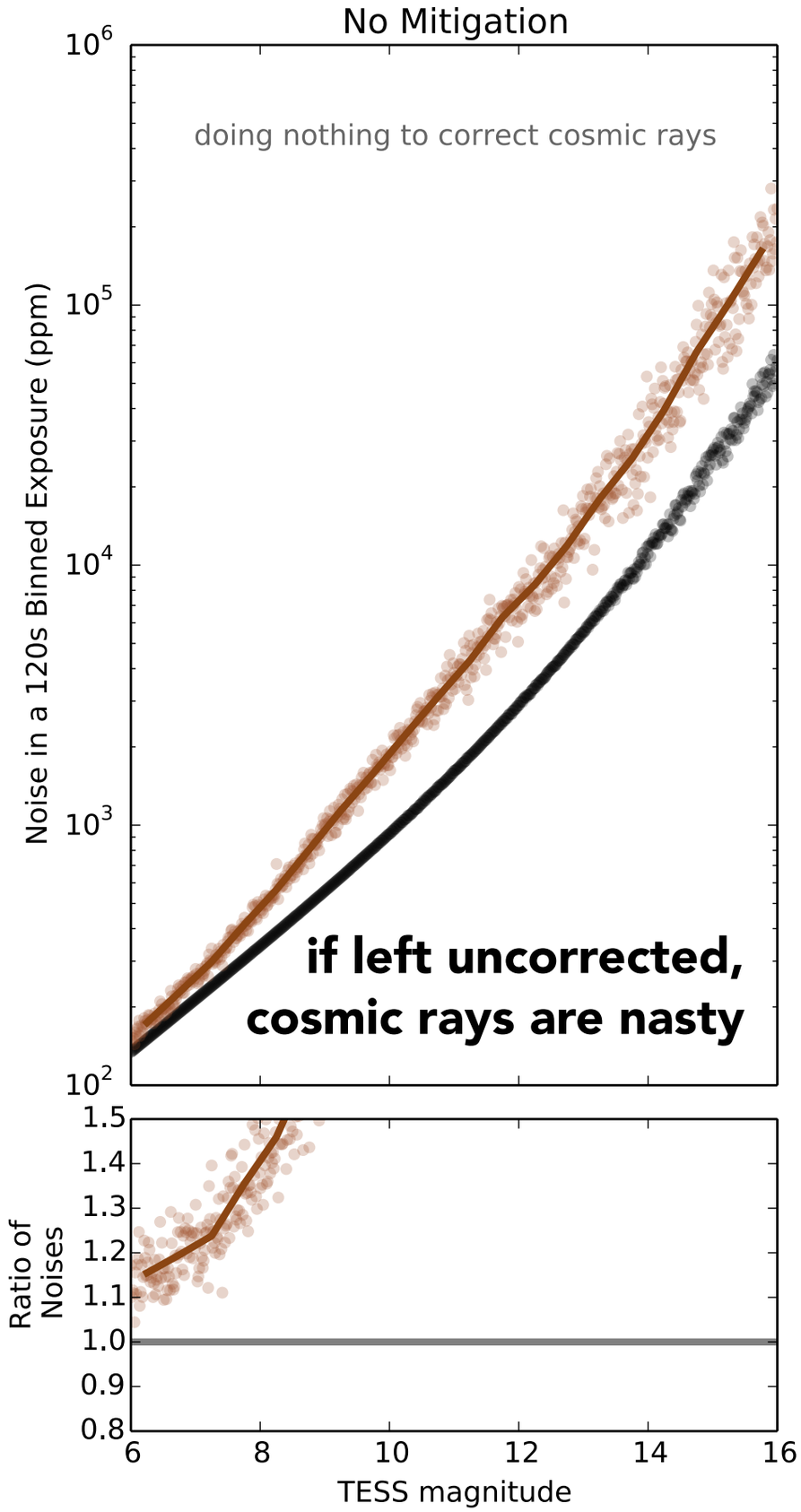
Central 8/10



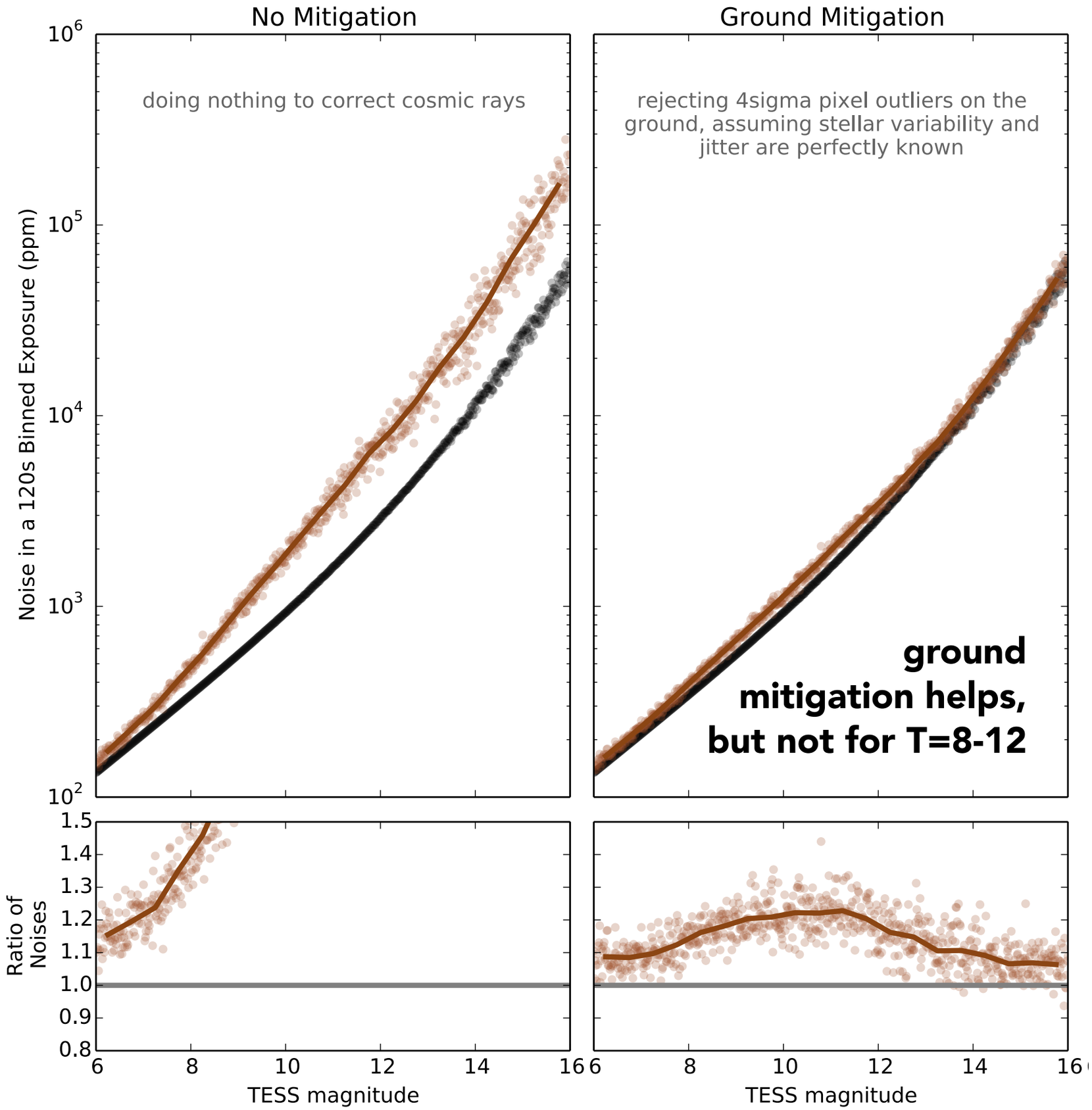




Cosmic Ray Impact for 120s Exposures



Cosmic Ray Impact for 120s Exposures



Cosmic Ray Impact for 120s Exposures

No Mitigation

doing nothing to correct cosmic rays

Ground Mitigation

rejecting 4sigma pixel outliers on the ground, assuming stellar variability and jitter are perfectly known

Space Mitigation

mitigating cosmic rays onboard, using a [Central 8 out of 10] strategy, including jitter (and uniform intrapixel sensitivity) but not stellar variability

space mitigation is best for T>8.5, although not perfect

Noise in a 120s Binned Exposure (ppm)

10^6
10^5
10^4
10^3
10^2

Ratio of Noises

1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8

6 8 10 12 14 16

TESS magnitude

(1) the present limitations

(2) the TESS mission

(3) the future

simulate Galaxy filled stars

+ planets orbiting those stars

+ instrumental noise sources

+ survey sky coverage

+ astrophysical false positives

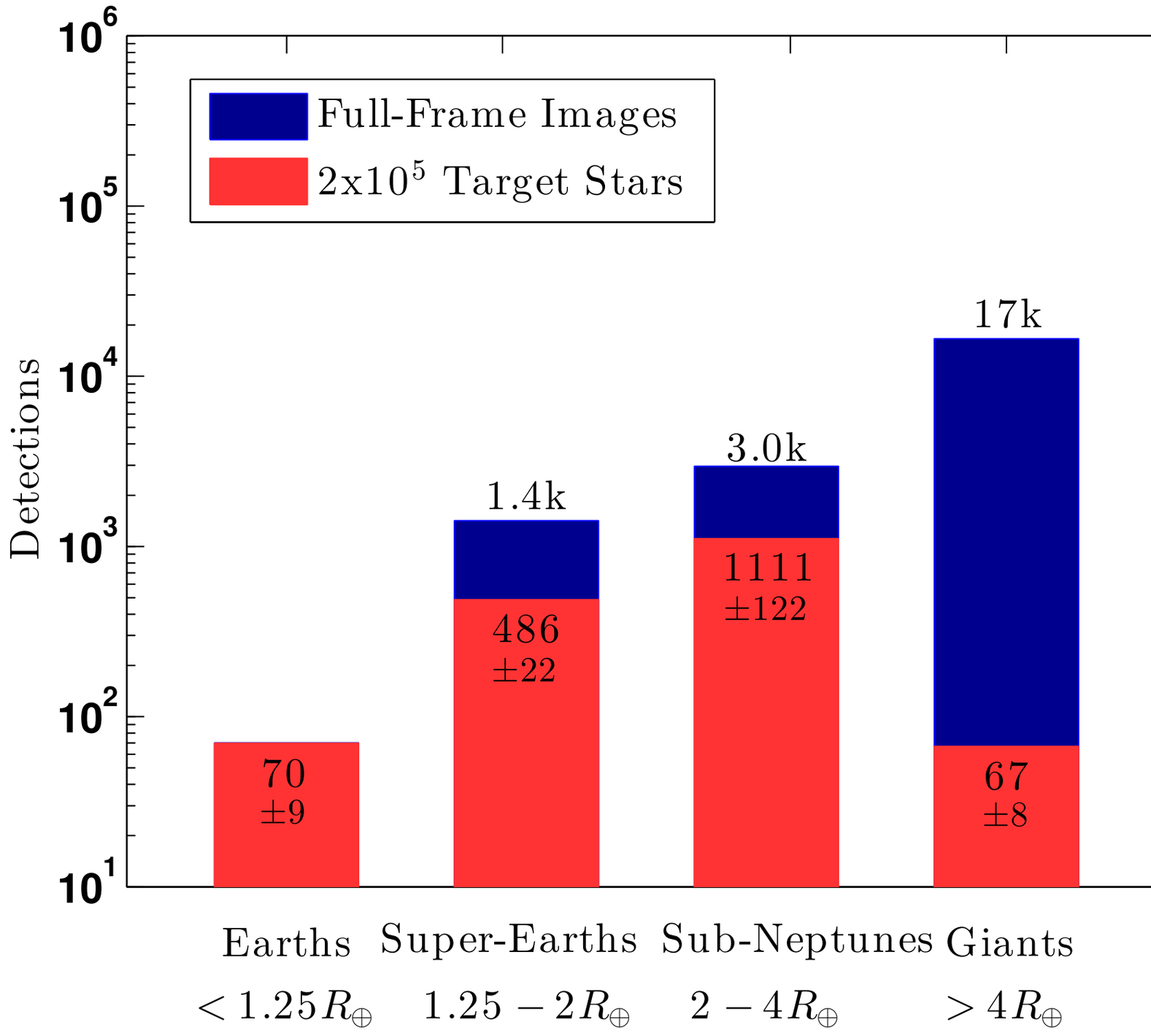
+ transiting planet detections

---

a predicted catalog of TESS planets

Peter Sullivan et al. (accepted to ApJ & on arxiv)

The Predicted TESS Yield

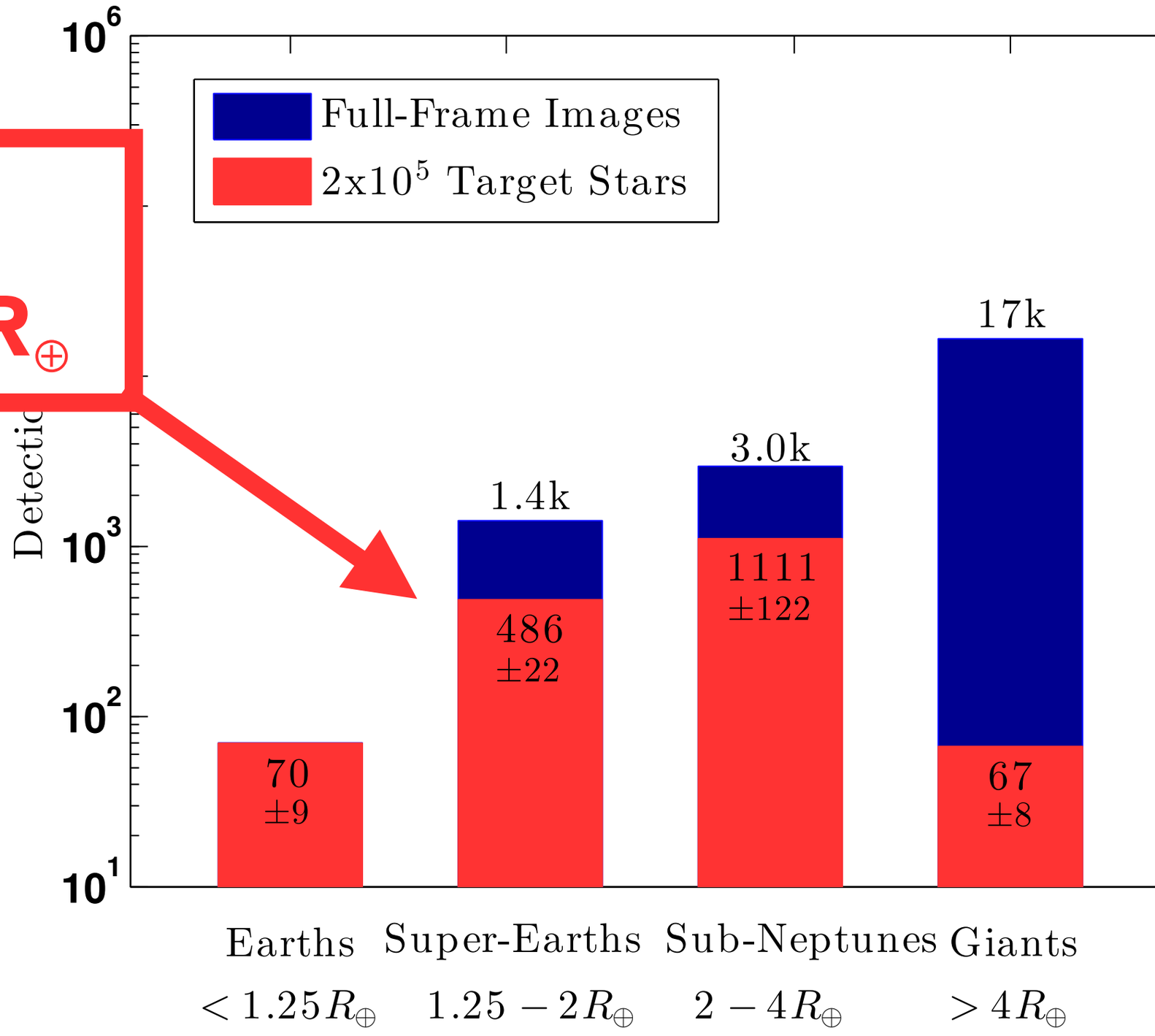


Sullivan et al. including Berta-Thompson (accepted)

The Predicted TESS Yield

500 planets smaller than $2R_\oplus$

mass measurements could resolve the rocky planet transition

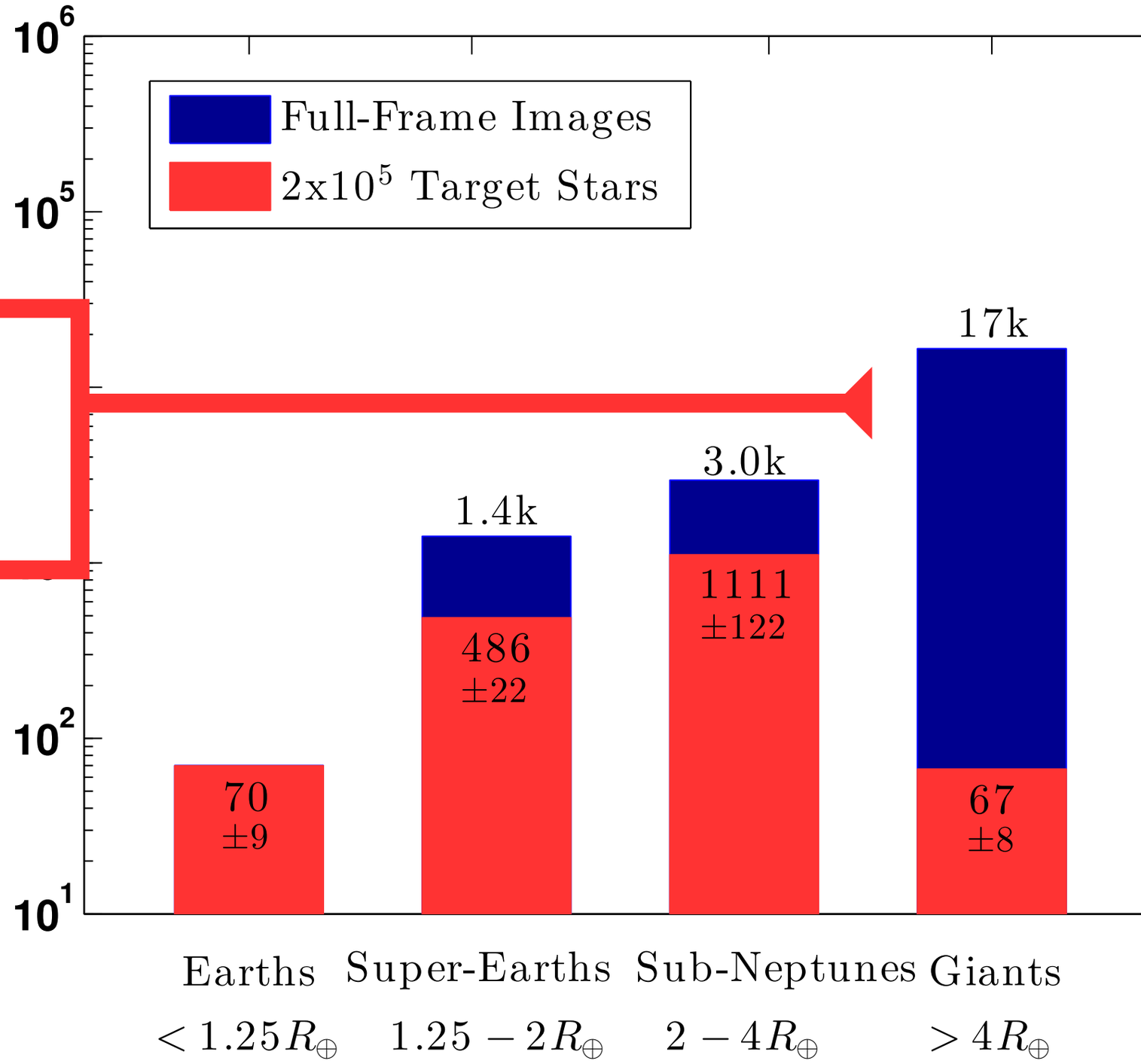


Sullivan et al. including Berta-Thompson (accepted)

The Predicted TESS Yield

1500 planets smaller than $4R_\oplus$

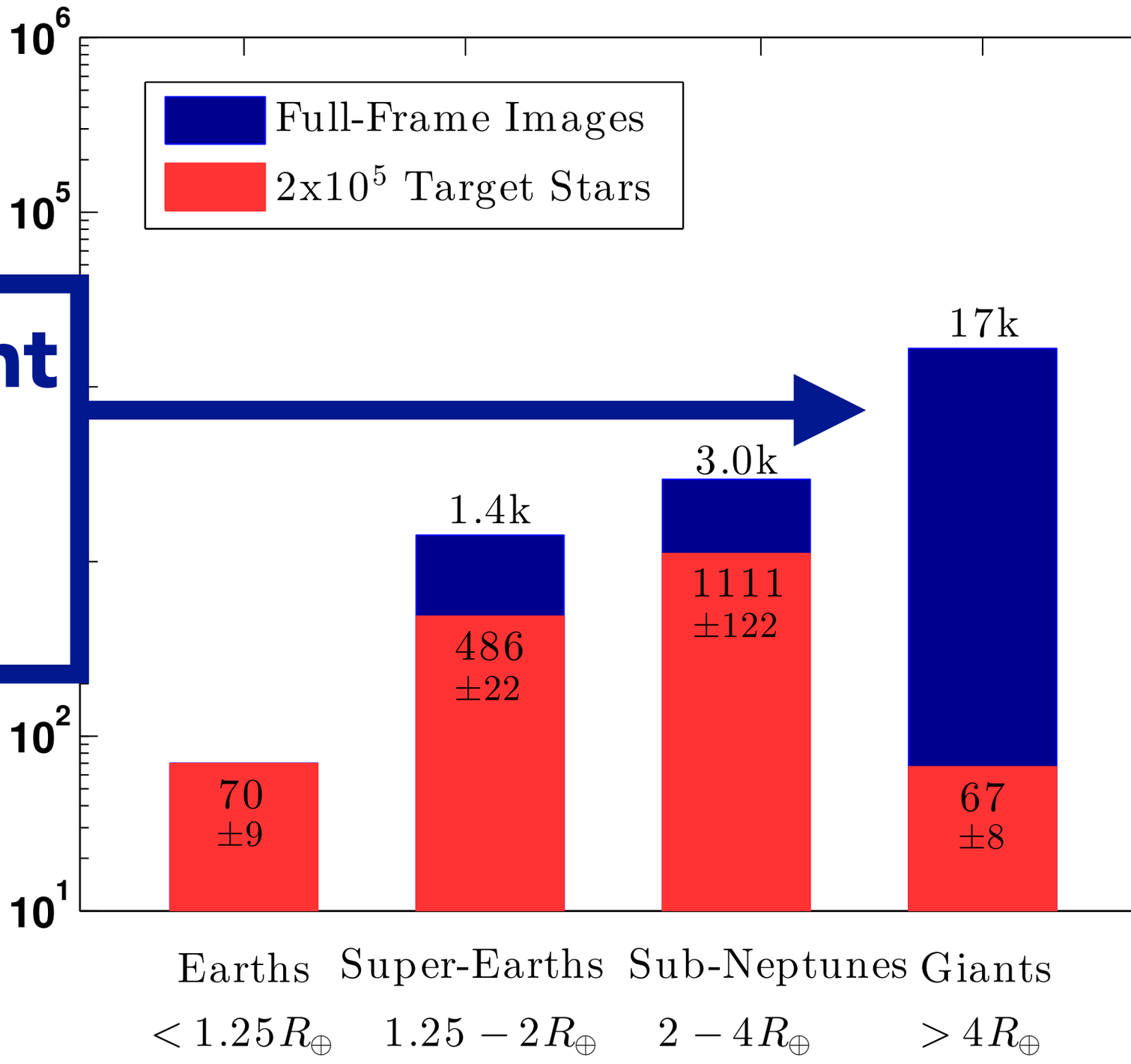
atmospheric studies will be possible for many of these



Sullivan et al. including Berta-Thompson (accepted)

The Predicted TESS Yield

rare, distant, giant planets found with FFI's



Sullivan et al. including Berta-Thompson (accepted)

zoom by Zach Berta-Thompson, early 2015

Transiting Exoplanets

Non-Kepler
Kepler
Predicted TESS

0h
September

3h

6h
December

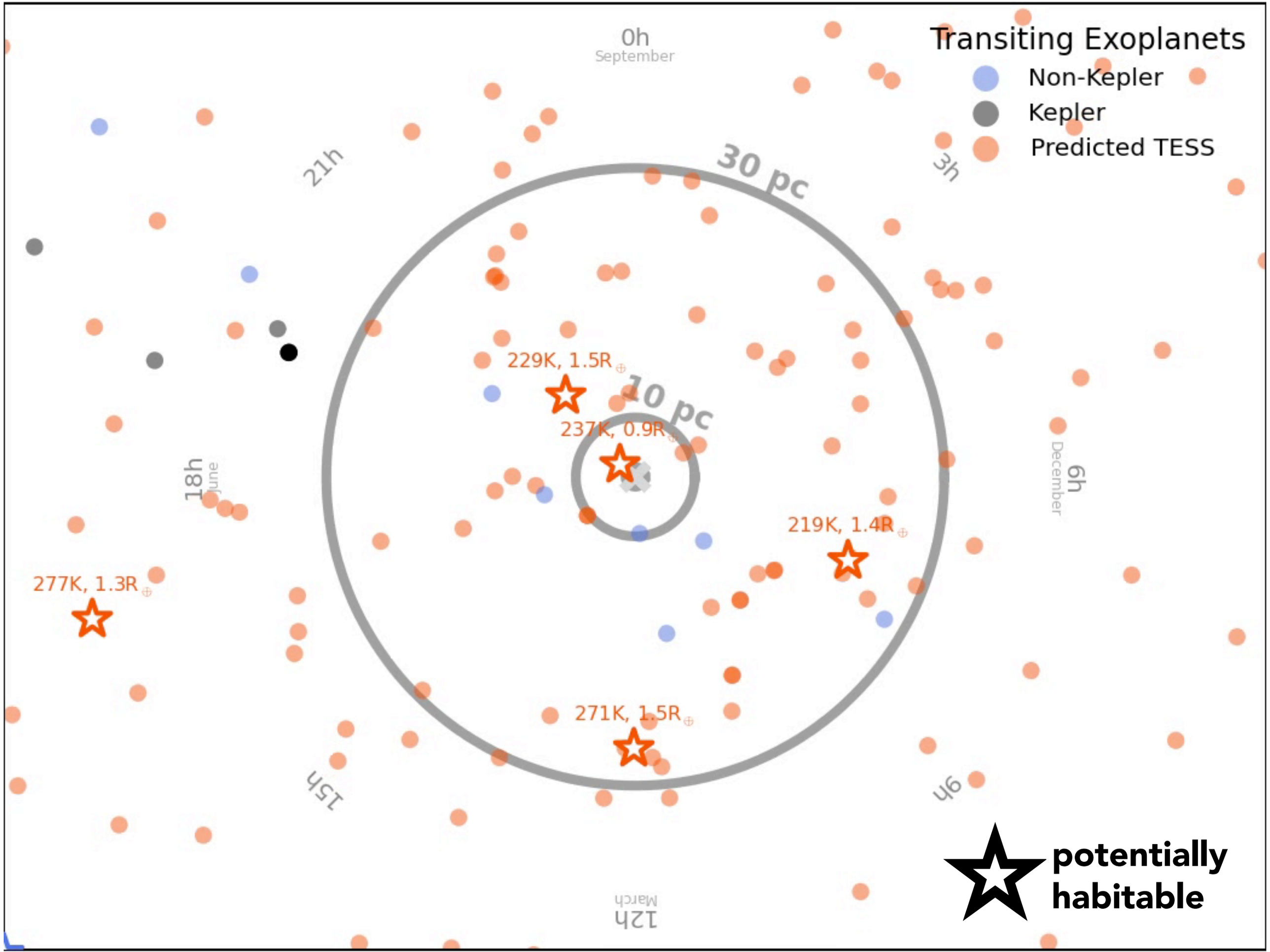
9h

12h
March

15h

18h
June

21h


Transiting Exoplanets
Non-Kepler
Kepler
Predicted TESS
0h
September
21h
3h
30 pc
10 pc
229K, 1.5R⊕
237K, 0.9R⊕
219K, 1.4R⊕
277K, 1.3R⊕
271K, 1.5R⊕
18h
June
6h
December
15h
9h
12h
March
potentially habitable

TESS is on schedule for launch

August 2017.

After ~two months of commissioning, the TESS sky survey will begin about

November 2017.

Data will be released publicly

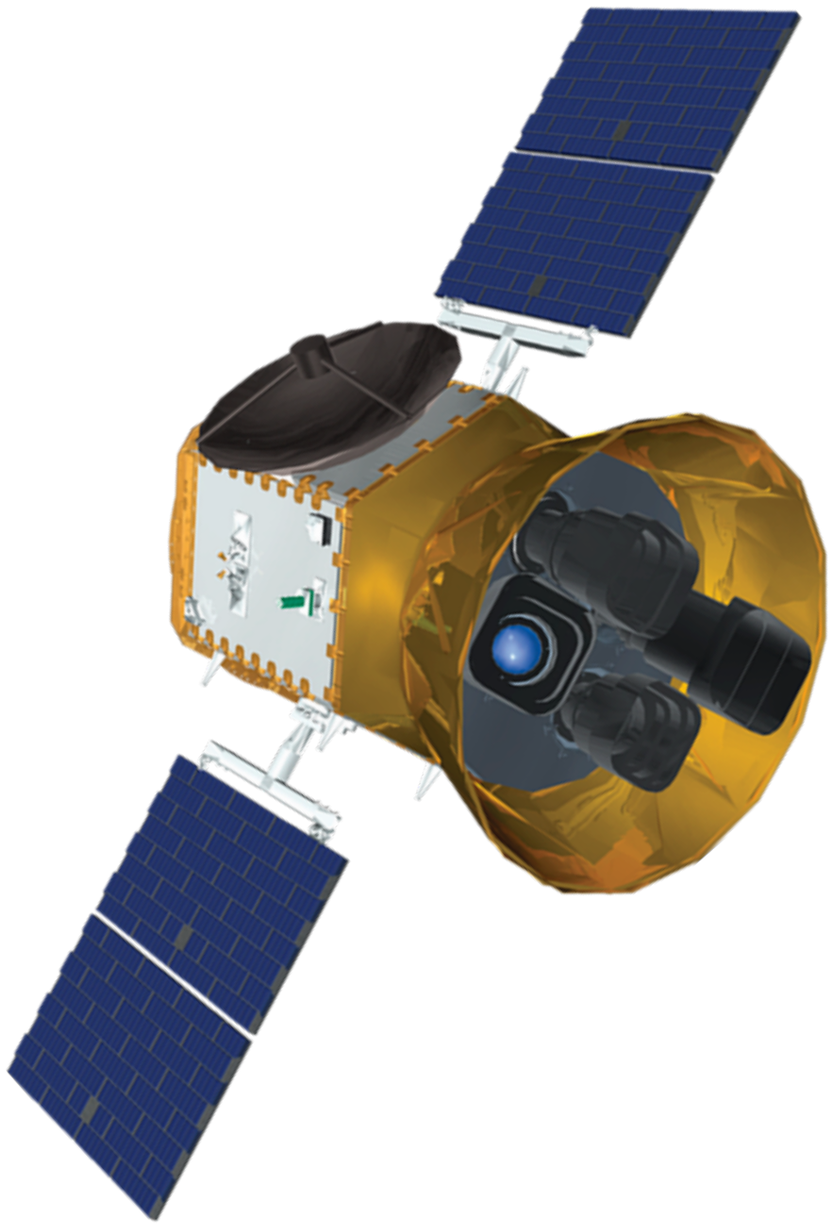
<four months*

from when it is collected.

*hopefully faster!

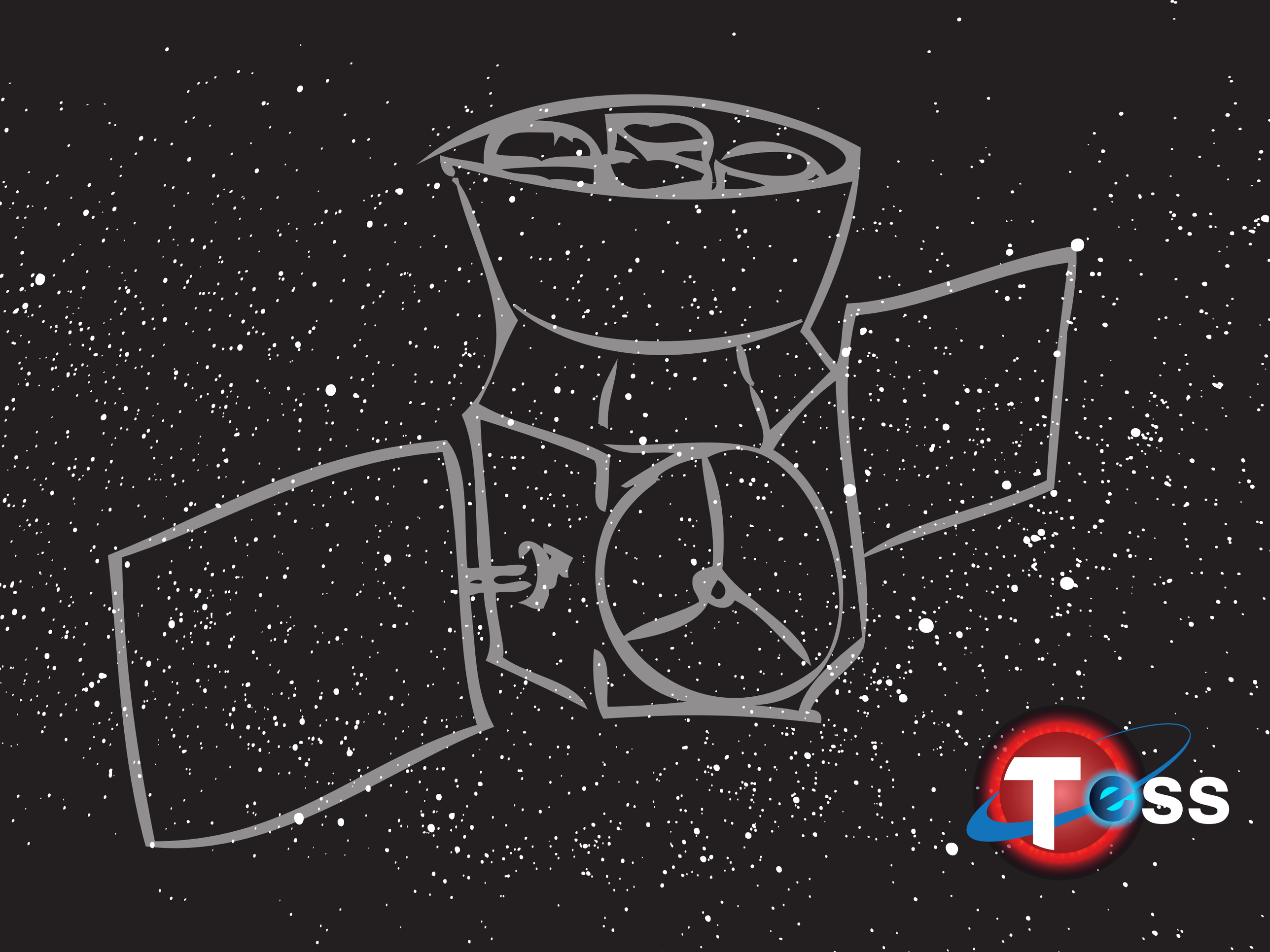
TESS CHEOPS

- CHEOPS has 9X the collecting area of TESS.
- TESS observes 60% of the sky for only 27 days.
- For orbital periods >3 days, one CHEOPS transit could surpass TESS' phased precision.



Conclusions

- TESS will launch in 2017.
- TESS will observe…
  1500 stars at 20s cadence,
  200,000 stars at 2m,
  most of the sky at 30m.
- TESS will find hundreds of new easy-to-observe small planets transiting nearby stars.


TESS