

# TESS

## Science Mission Status

**George Ricker (MIT)**

**TESS PI**

**APAC Meeting**

**NASA Headquarters**

**12 April 2018**

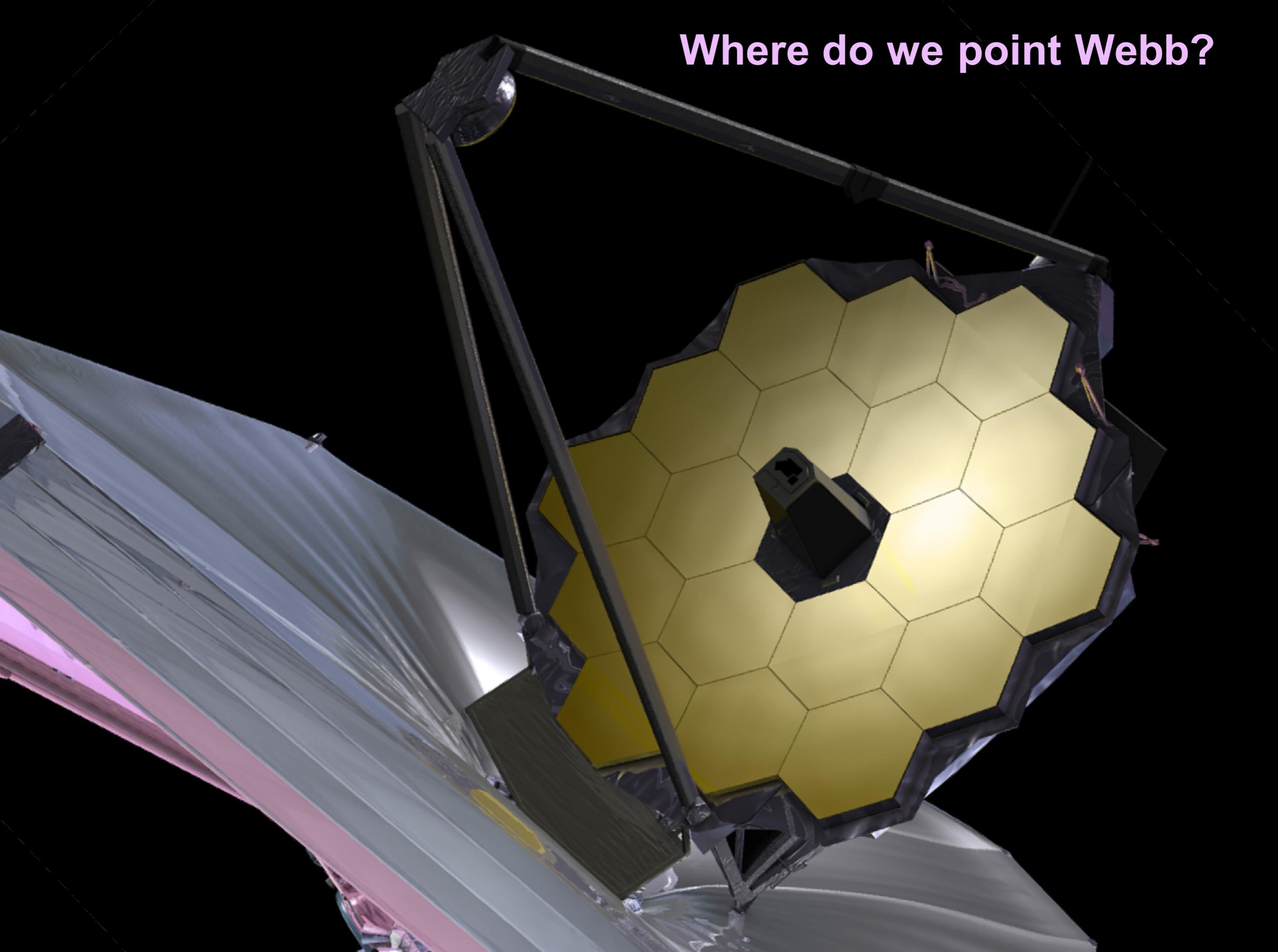
**collaboration including:**

MIT/MKI, MIT/LL, NASA Goddard, NASA Ames, Orbital ATK, STScI, SAO, MPIA-Germany, Las Cumbres Observatory, Geneva Observatory, OHP-France, University of California, University of Florida, Aarhus University-Denmark, Harvard College Observatory, Princeton University, Vanderbilt University...

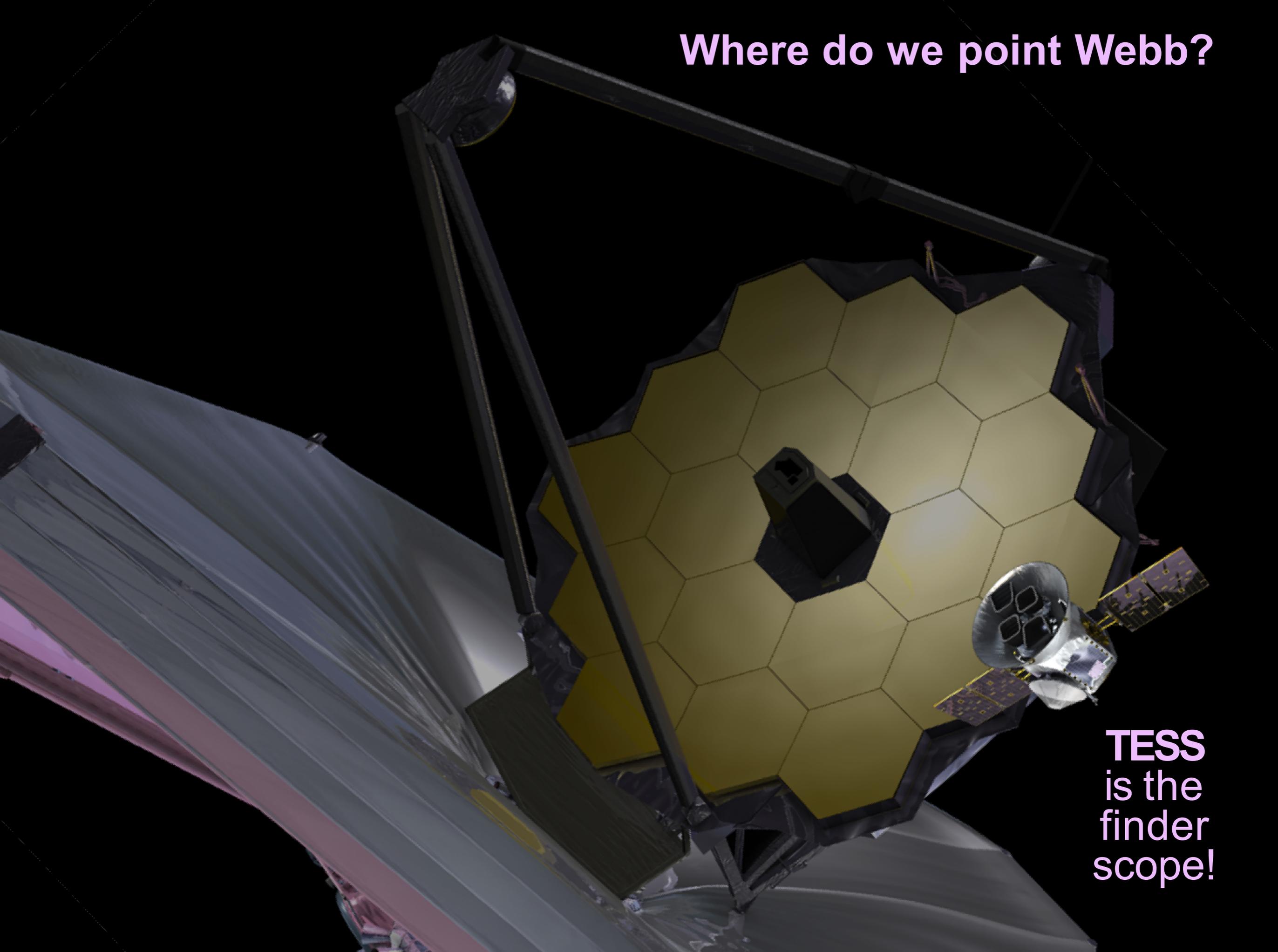
# NASA's Exoplanet Missions



Where do we point Webb?

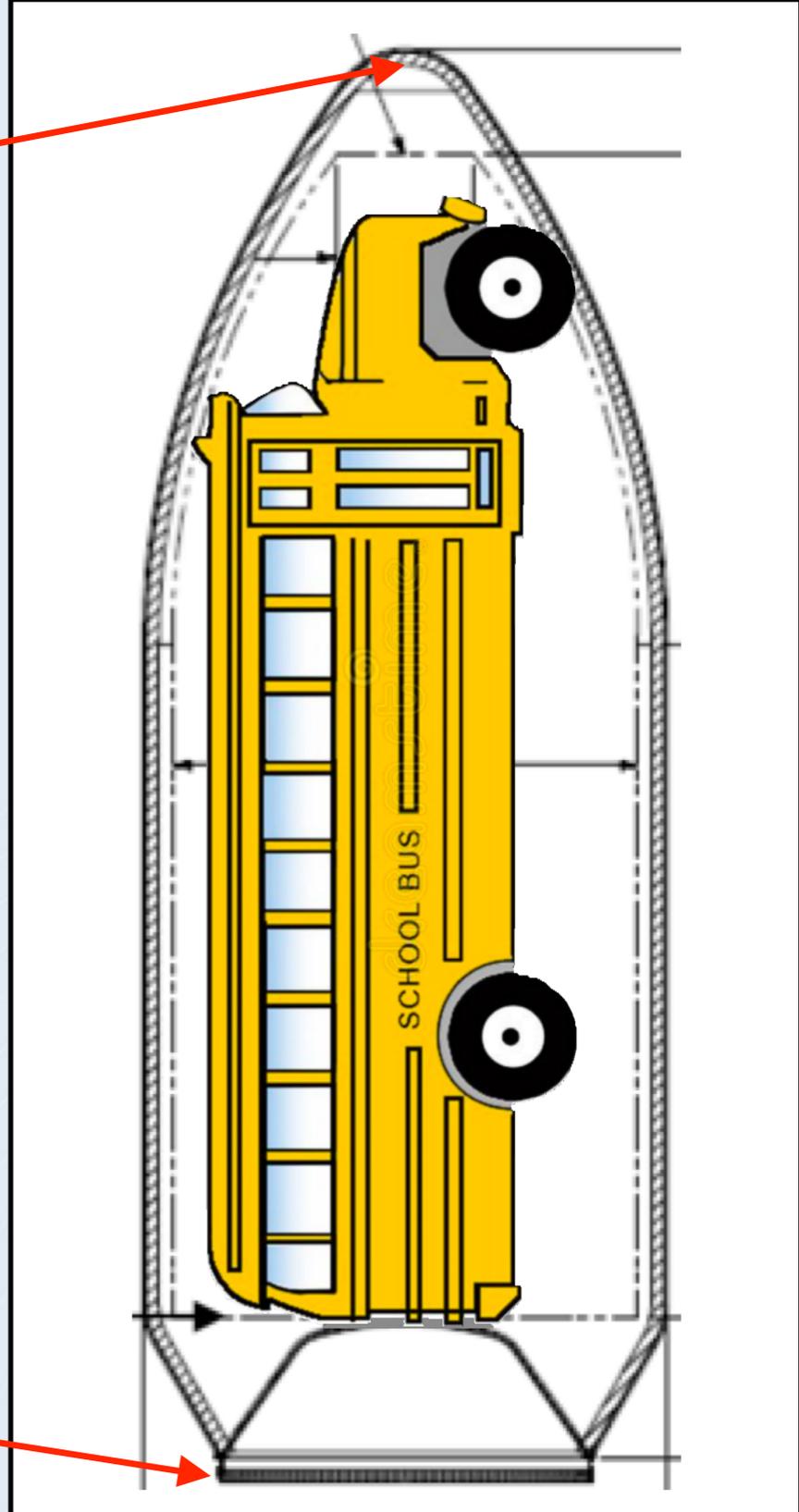
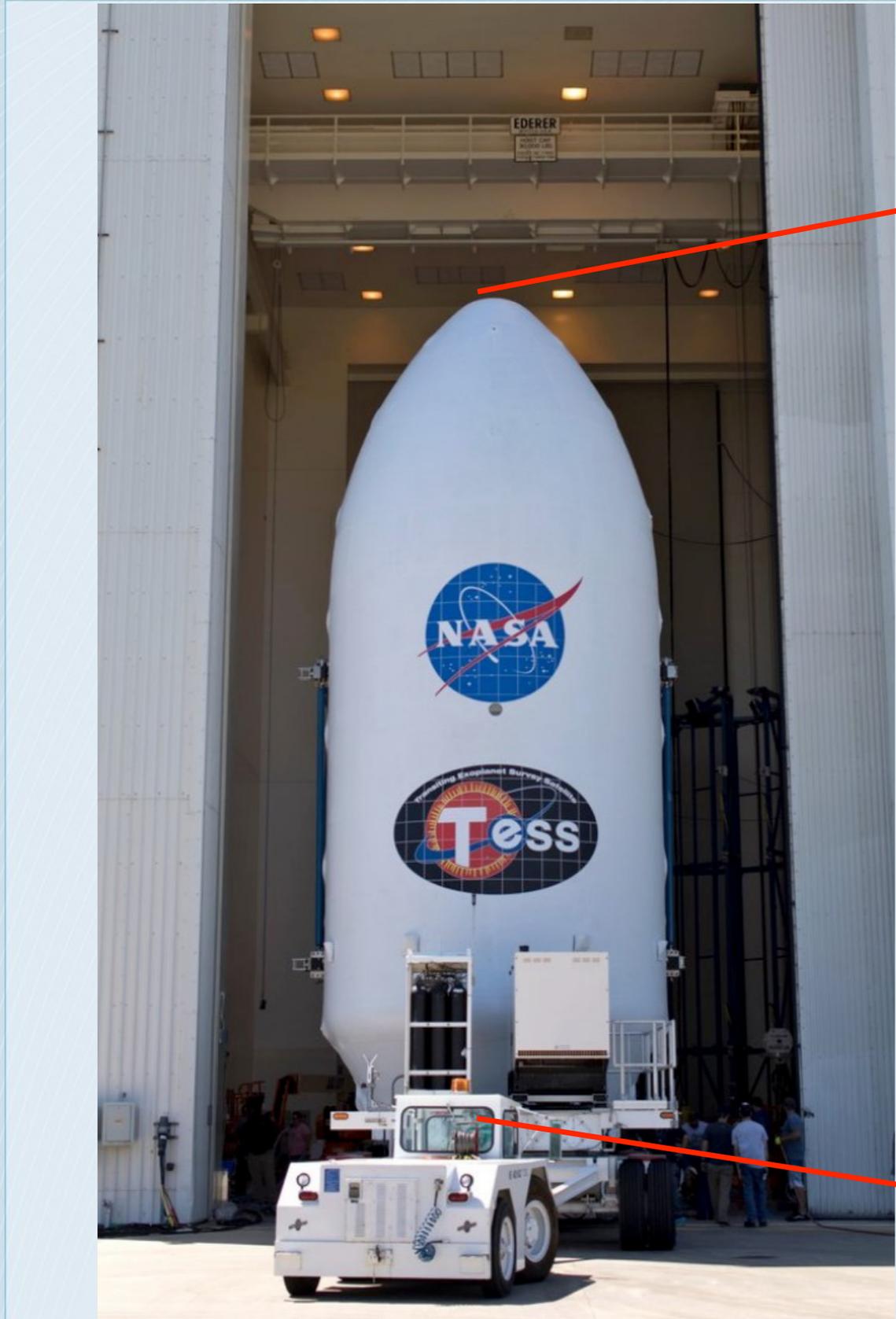


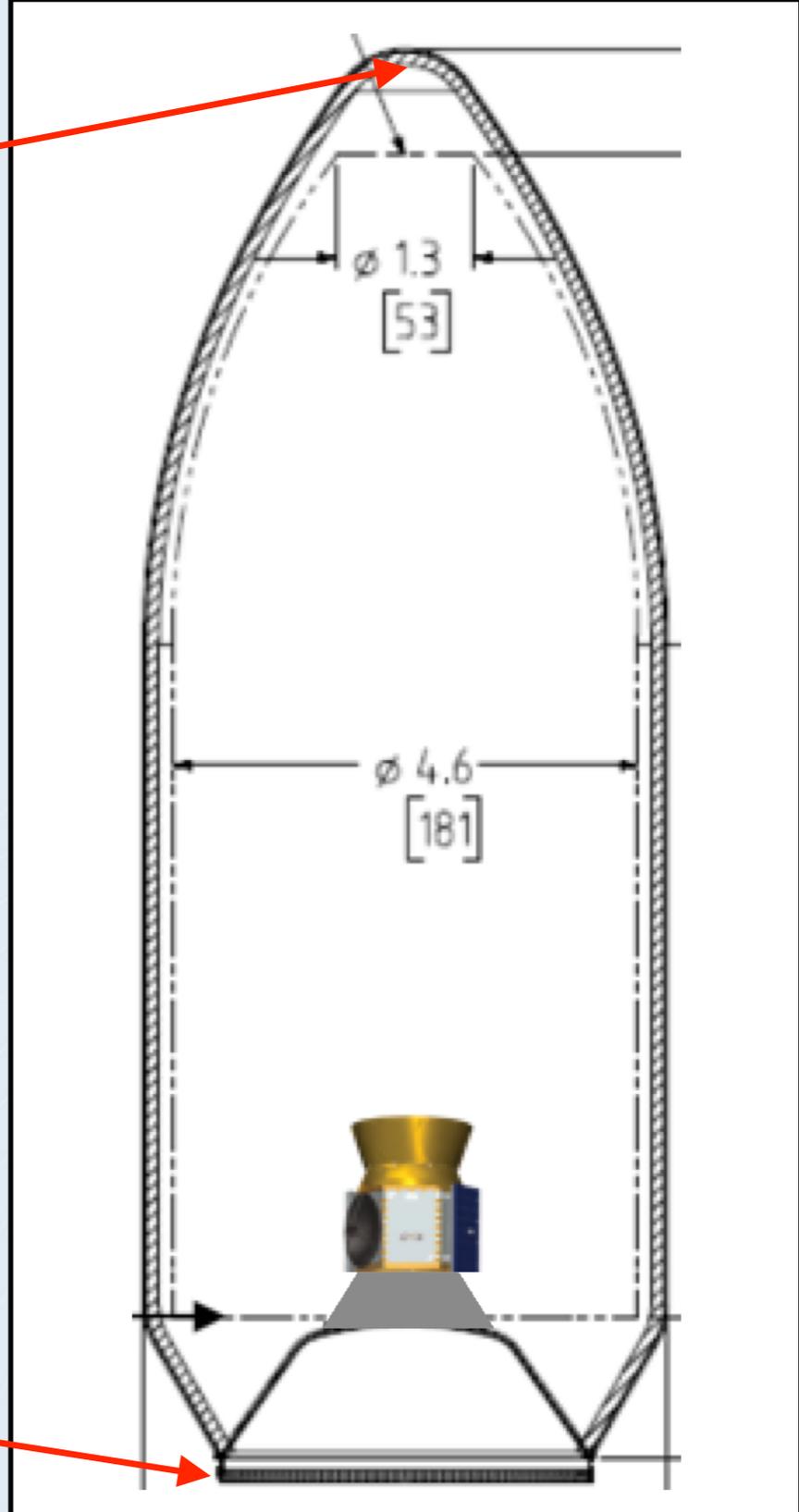
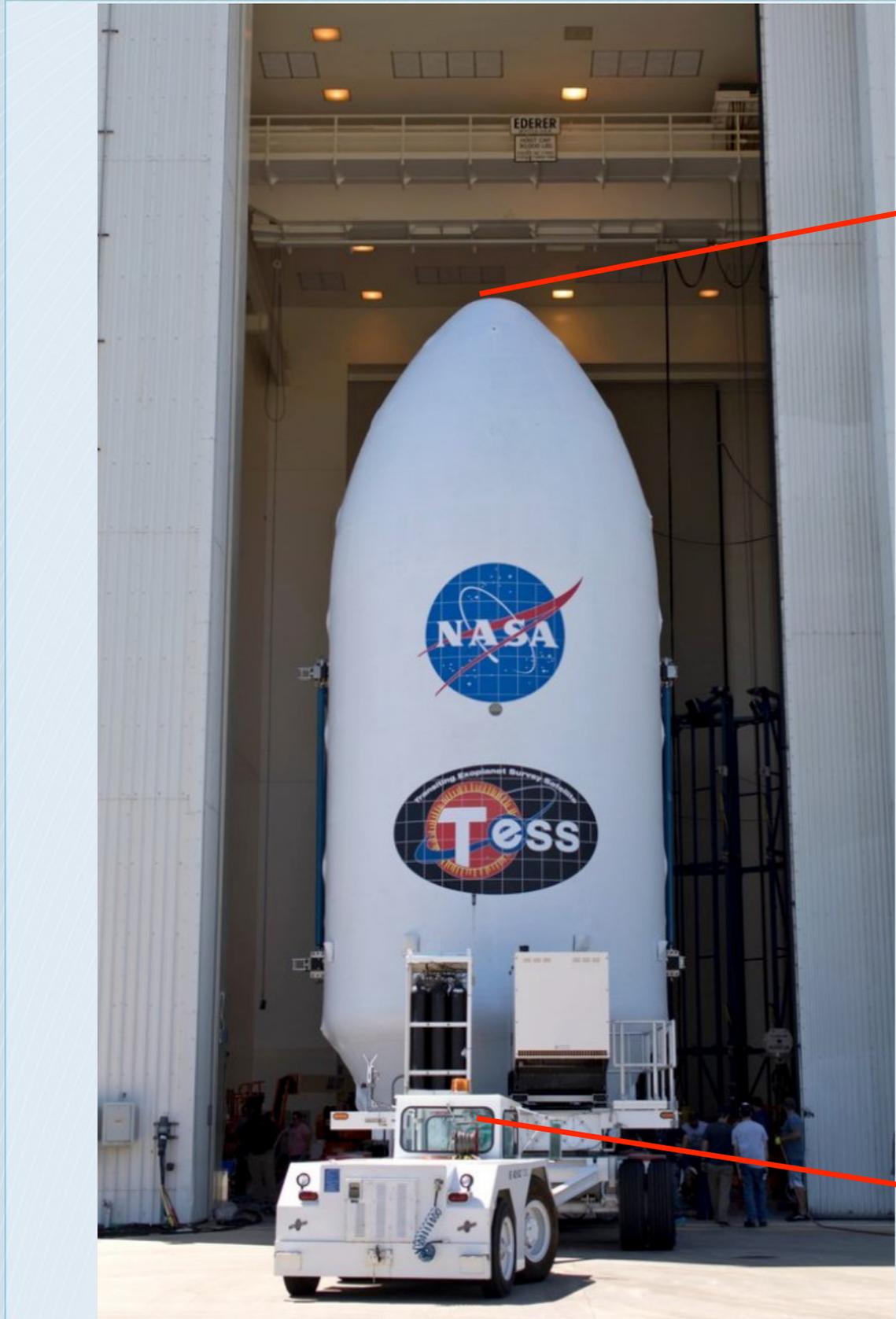
Where do we point Webb?



**TESS**  
is the  
finder  
scope!









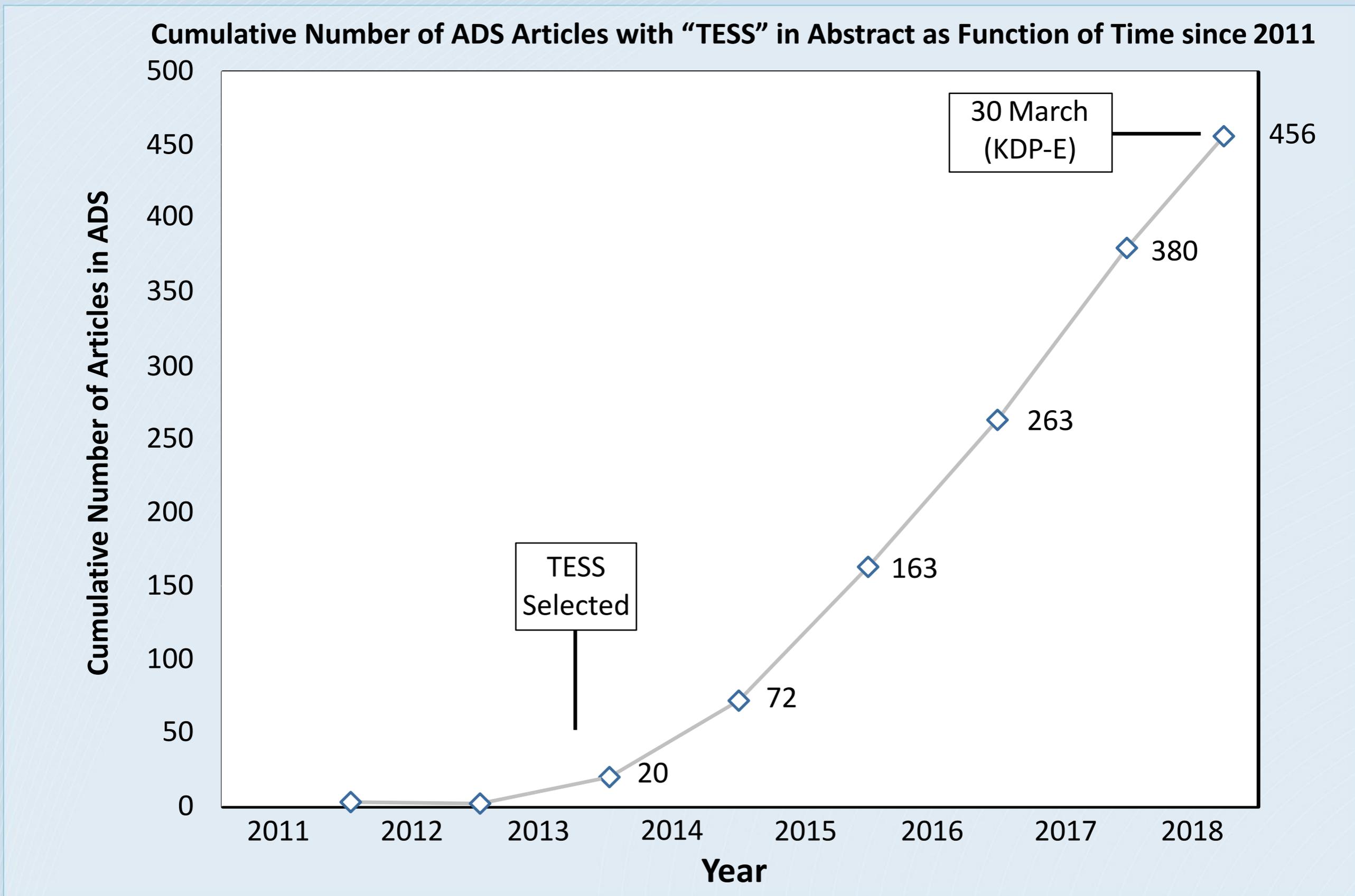
## *Meet TESS, Seeker of Alien Worlds*

NASA's new spacecraft, to be launched next month, will give scientists a much clearer view of the planets orbiting stars near to us.

By DENNIS OVERBYE MARCH 26, 2018



# NASA Astrophysics Data System ArCcles with "TESS" in Abstract



\* Definition of Etendue [ $m^2 \cdot \text{deg}^2$ ]:

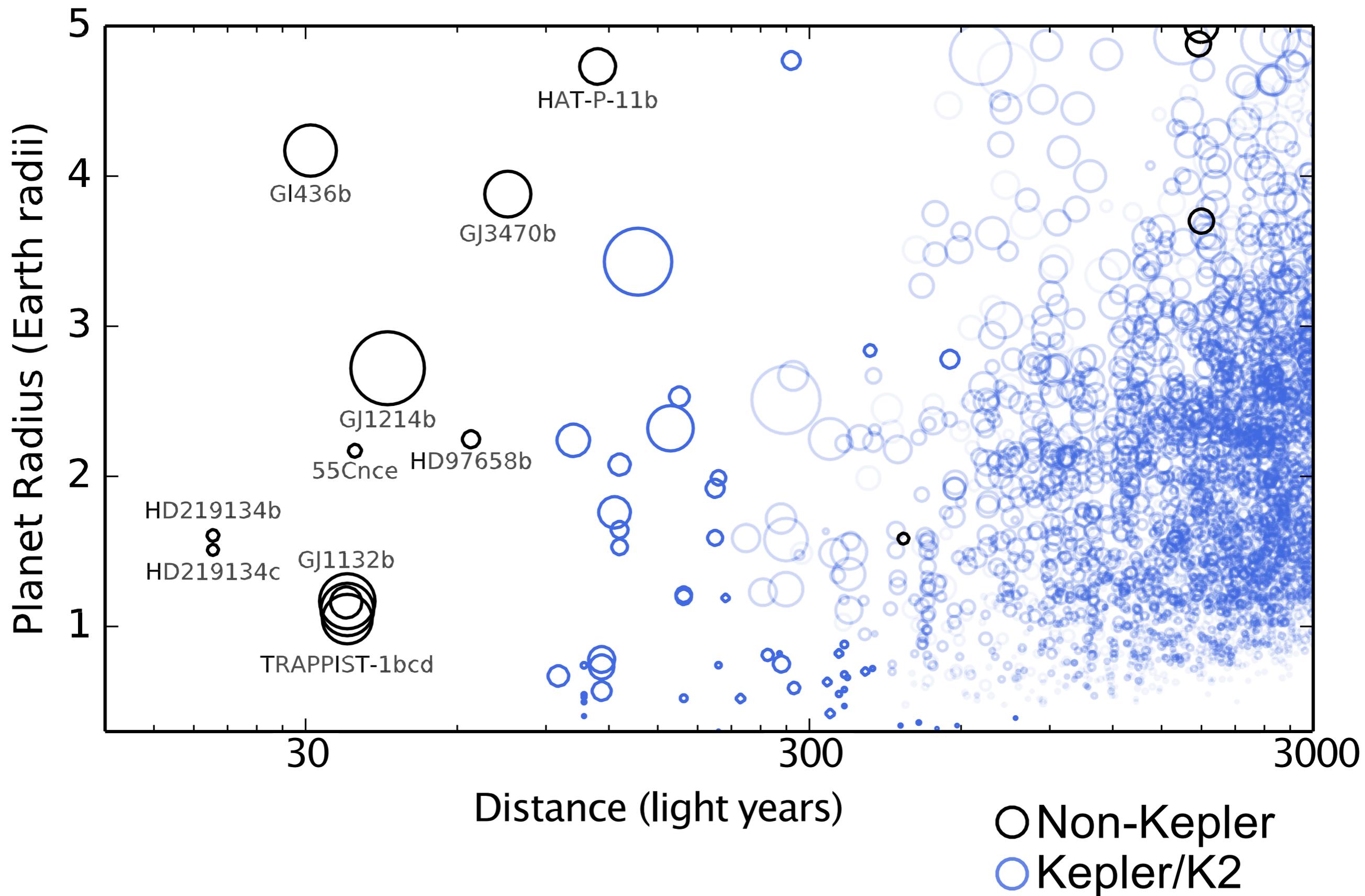
$$E = A_{\text{optics}} * \Omega_{\text{net}}$$

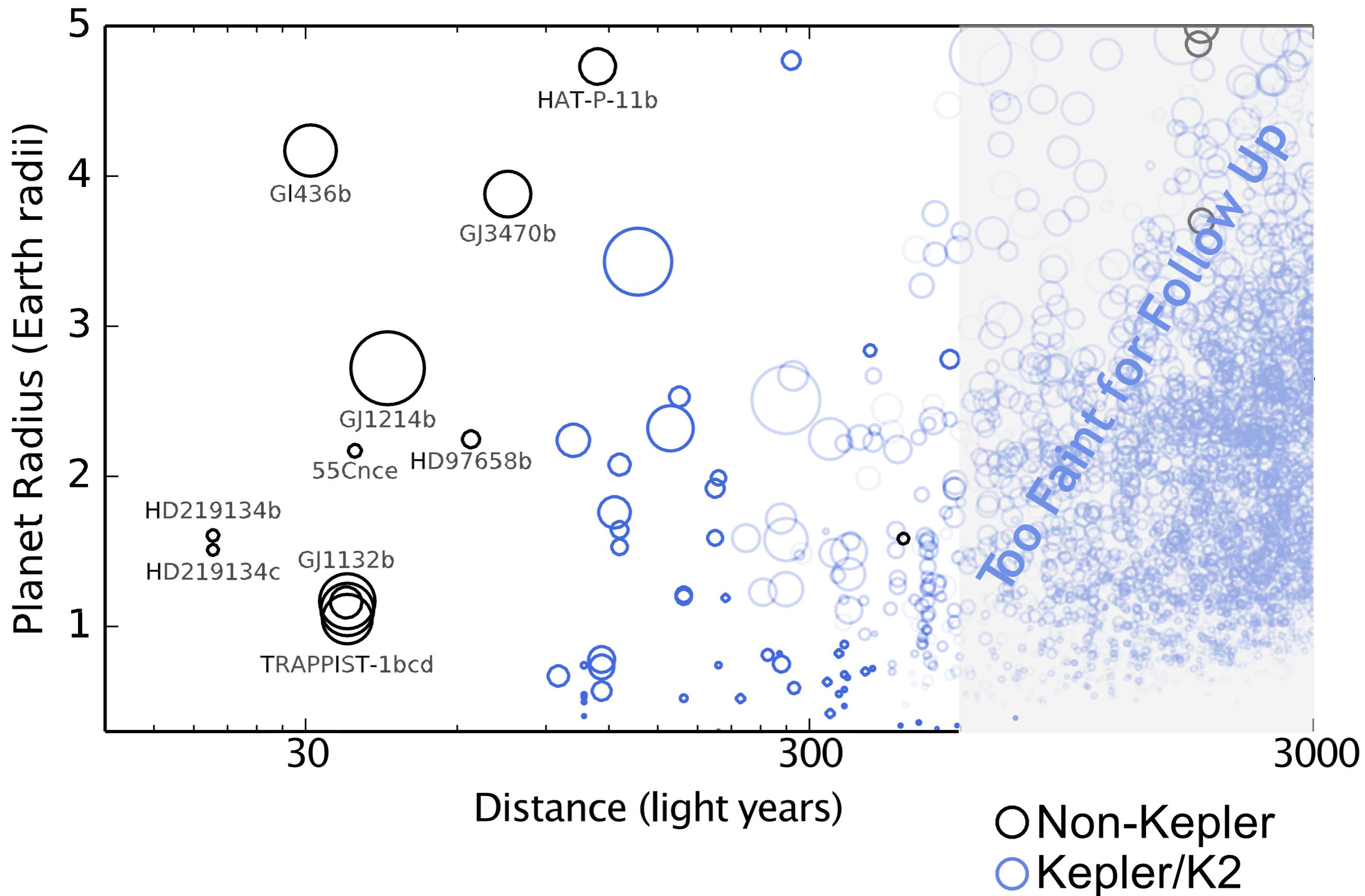
$$\text{where } \Omega_{\text{net}} = \Omega_{\text{gross}} * \left( \frac{\# \text{ pixels telemetered}}{\# \text{ pixels in focal plane}} \right)$$

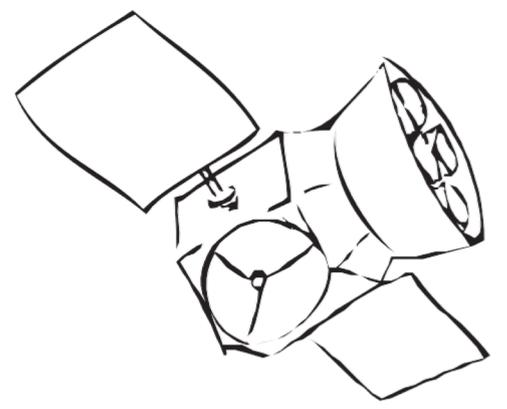
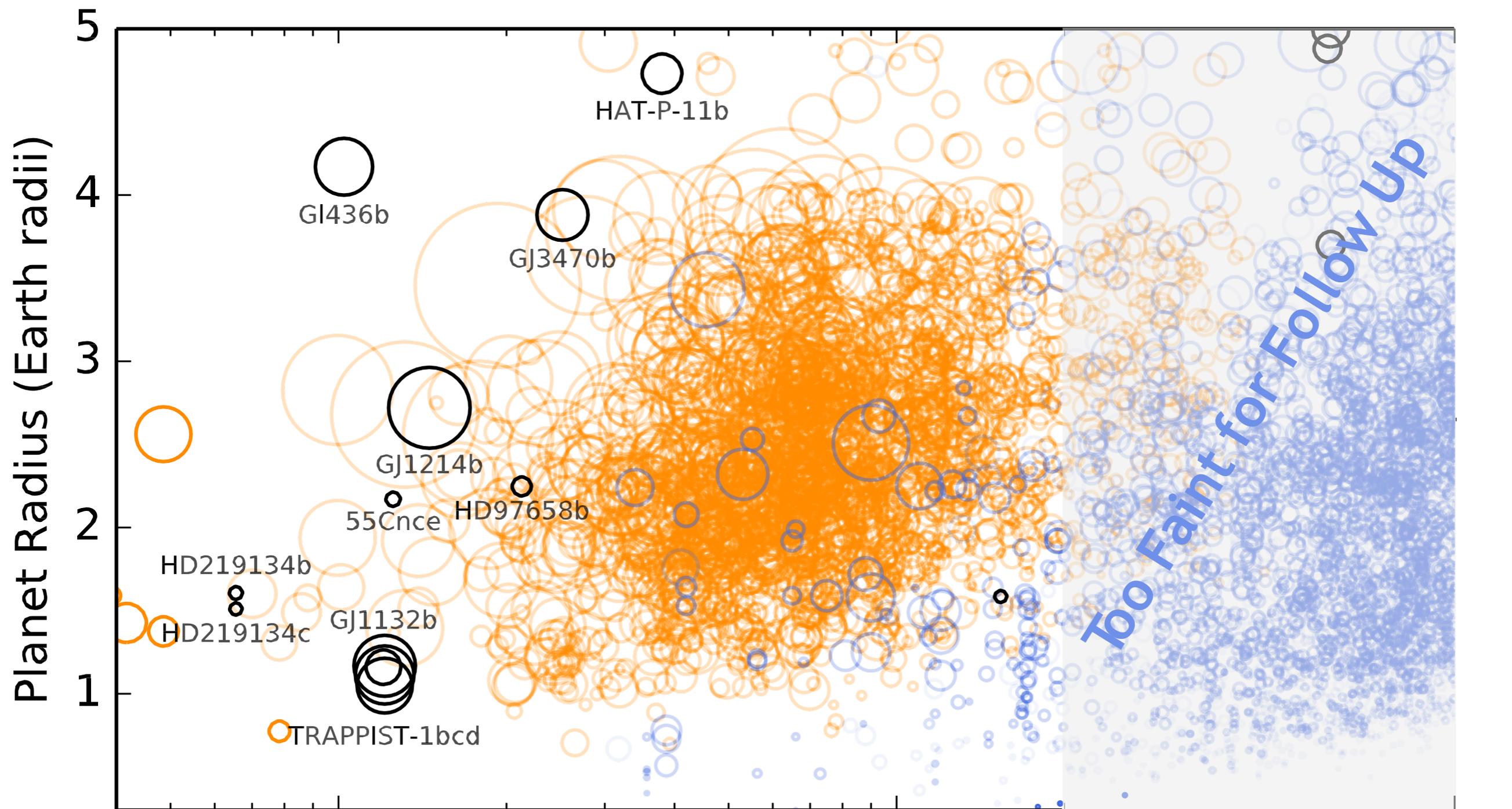
	$A_{\text{optics}}$ [ $m^2$ ]	$\Omega_{\text{gross}}$ [ $\text{deg}^2$ ]	$\frac{\# \text{ pixels telemetered}}{\# \text{ pixels in focal plane}}$	E [ $m^2 \text{ deg}^2$ ]
<b>TESS</b>	0.0095	2304	1	21.9
<b>Kepler</b>	0.71	105	0.06	4.20

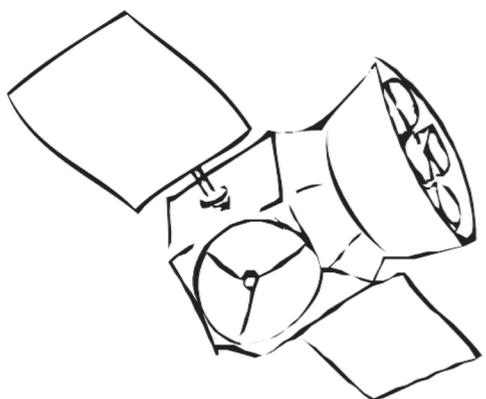
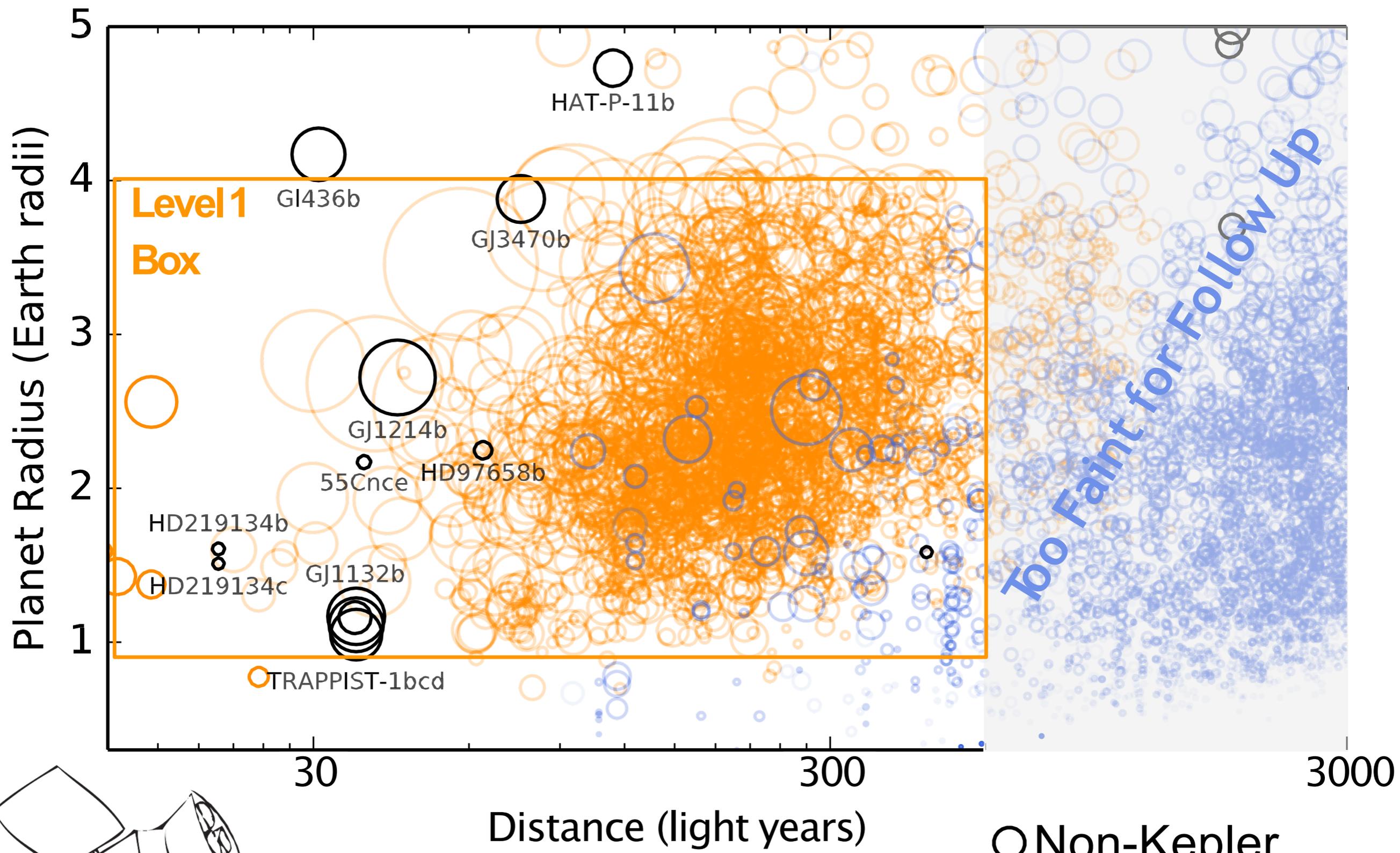
**TESS is the highest etendue optical space mission yet flown:  
~5 times greater than Kepler**

Bryson et al. 2010  
Ricker et al. 2016





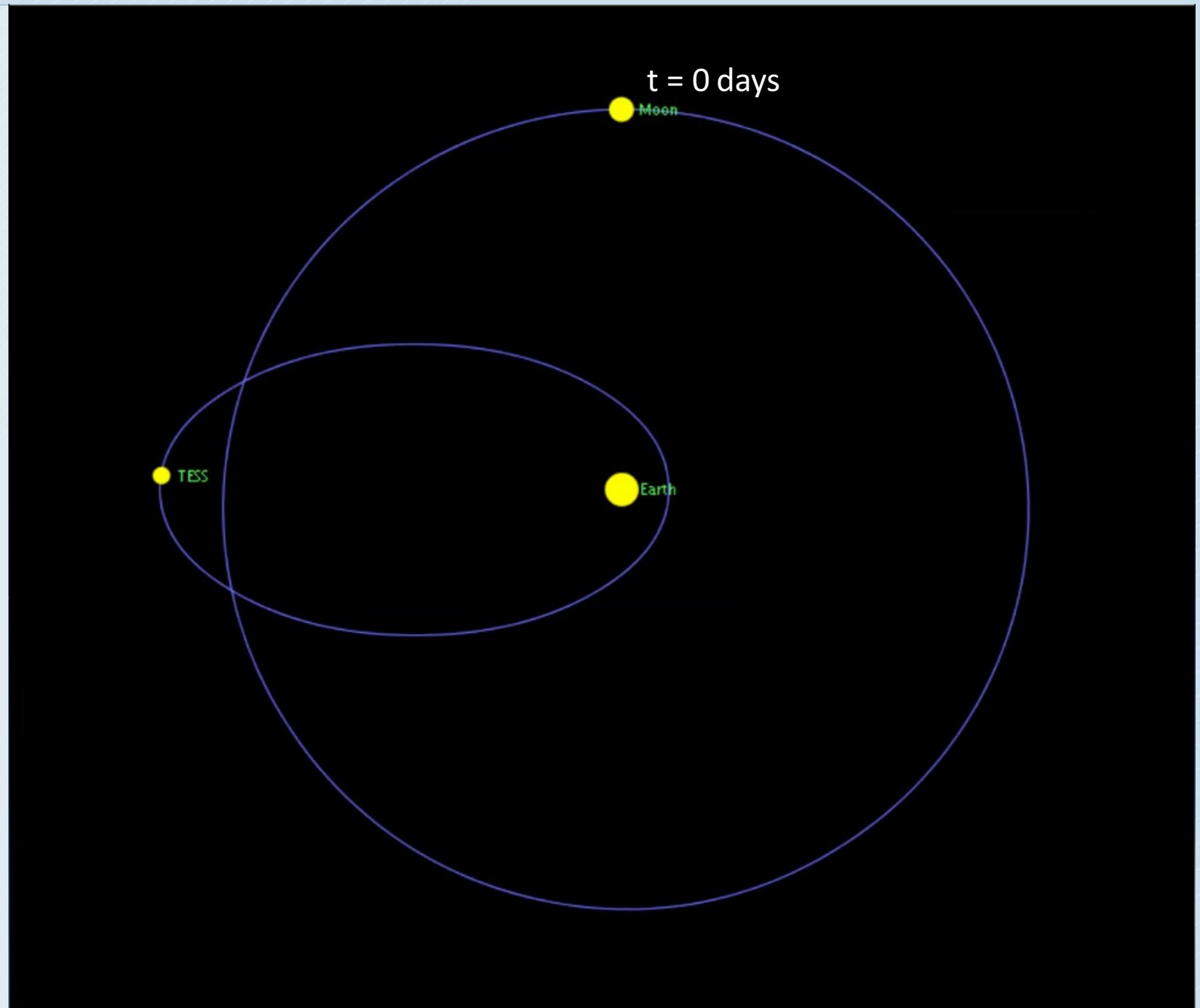




- TESS will monitor the brightness of 200,000 stars for ~26 days to search for transiting exoplanets
  - *Target: Earths, super-Earths, and sub-Neptunes*
- TESS will provide images of every object in every observed field at a 30 minute cadence
  - *Anticipated result: Photometric data for ~20 million stars and ~10 million galaxies*
- Ground analyses of TESS data will reveal transiting planets by looking for regular dips in the brightness of each star
- Ground follow-up observations will:
  - *Confirm the presence of a transiting planet*
  - *Determine the mass of the planet*

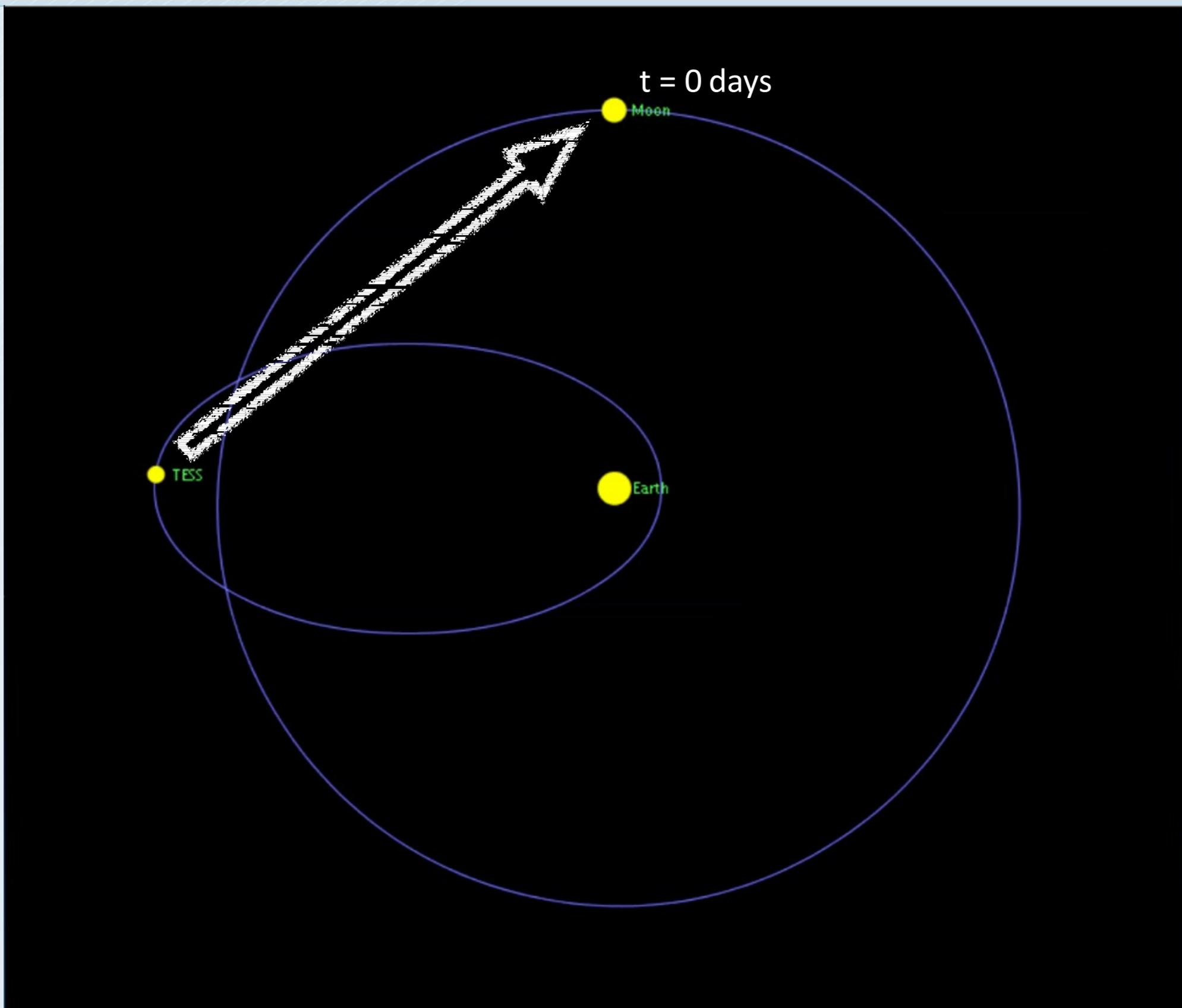
Uninterrupted  
viewing for >95% of  
time

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



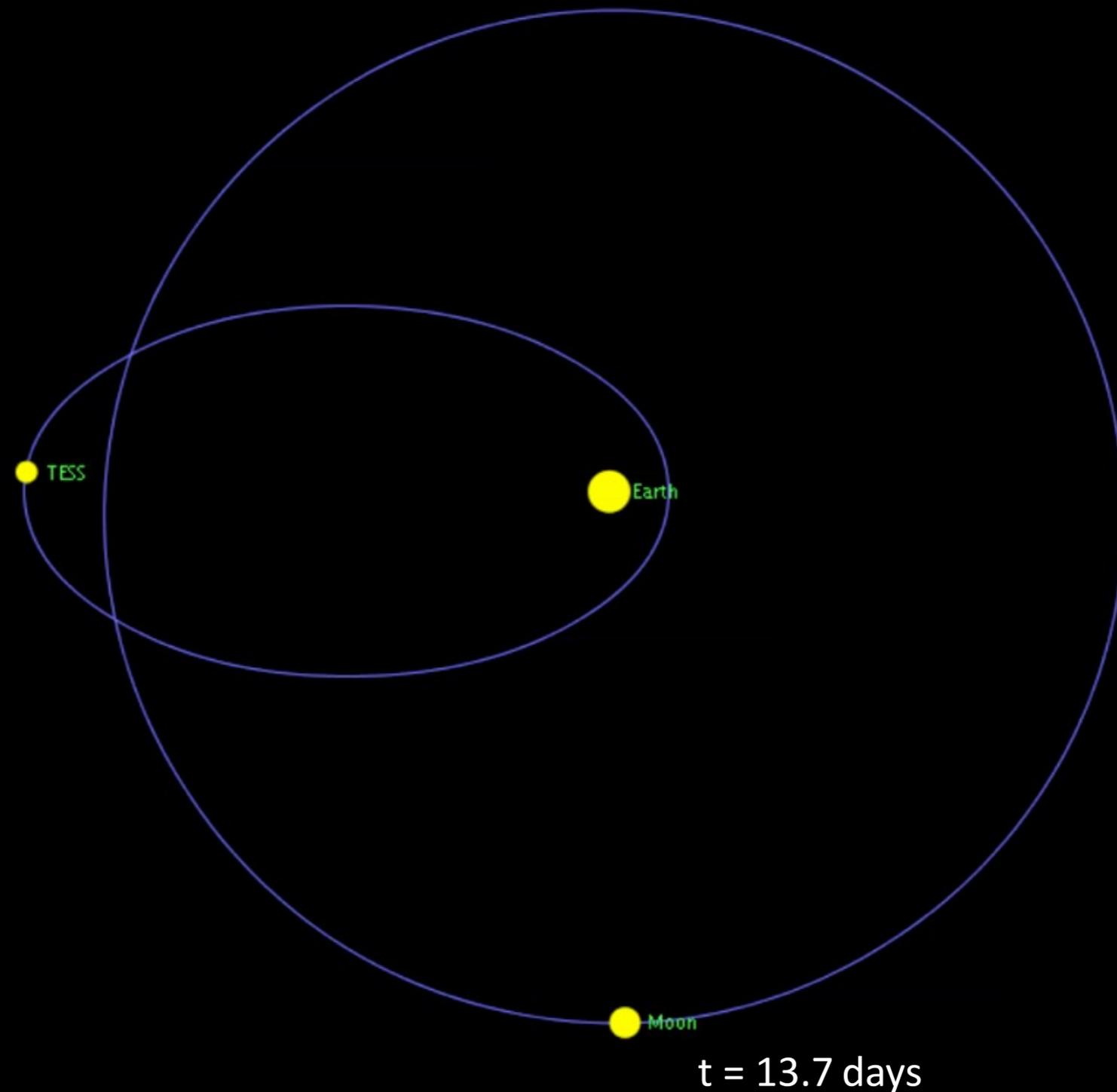
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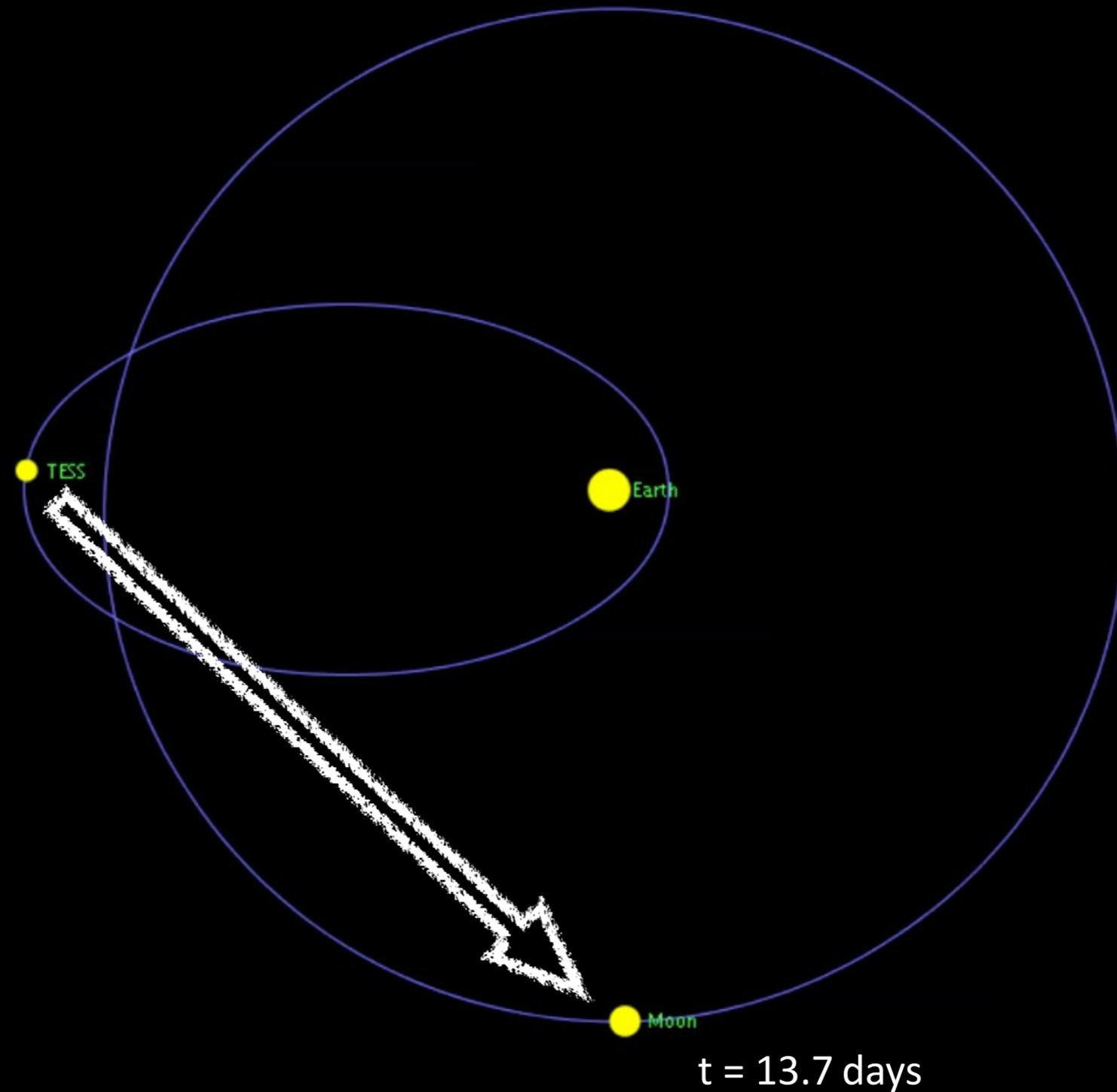
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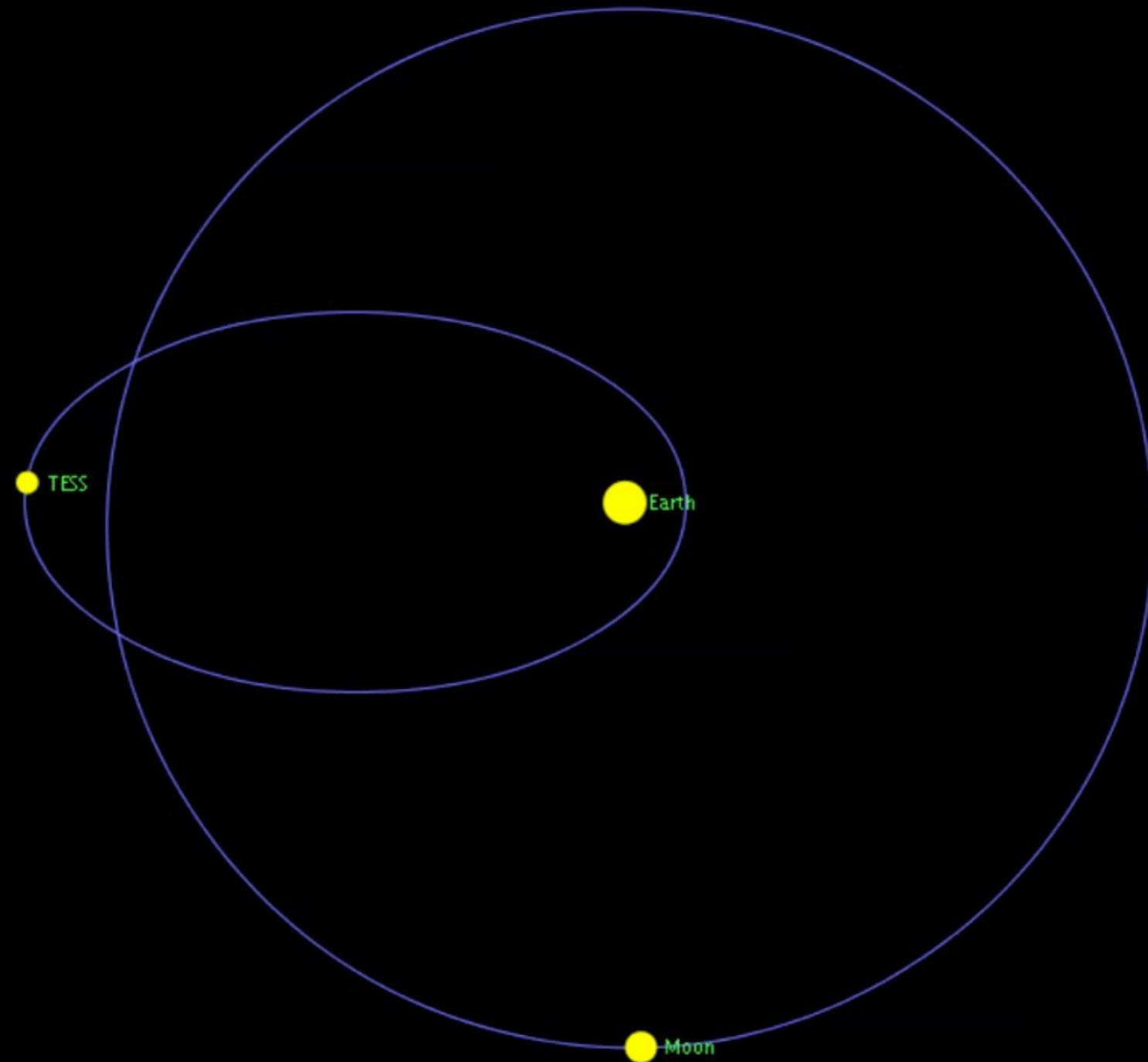
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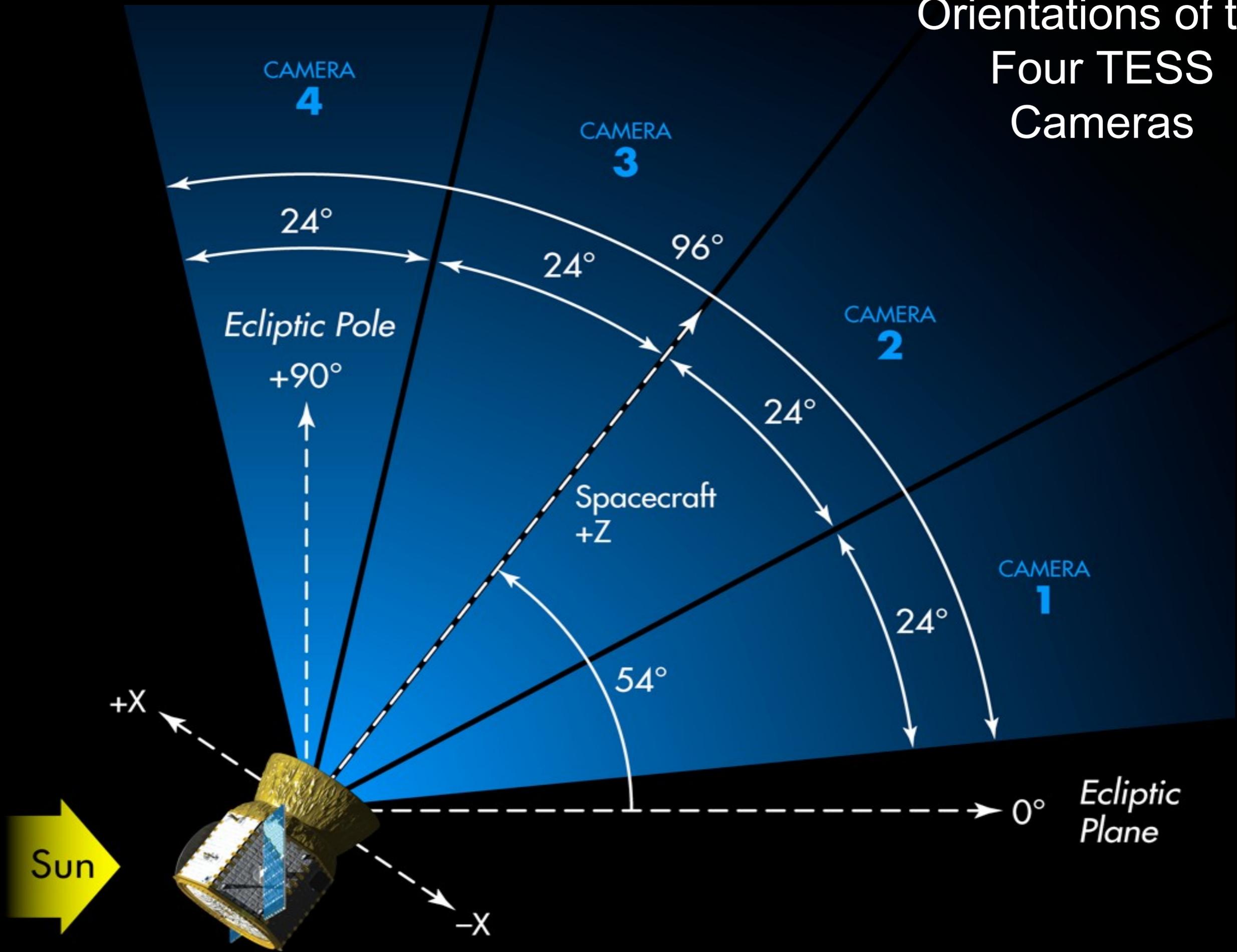
TESS Orbit is *Stable* for Decades (*no station keeping fuel req'd*)

## Provides eight major advantages:

- Extended & Unbroken Observations: *>300 hrs per orbit*
  - Long Orbit Life: *~ Decades (no station keeping fuel req'd)*
  - Thermal Stability: *<40 mK/hr (passive control only)*
  - Earth/Moon Stray Light Reduction: *10<sup>6</sup> times less than LEO*
  - Low Radiation Levels: *Outside of Earth's Radiation Belts*
  - Frequent Launch Windows: *Several days per lunar month*
  - Excellent Pointing Stability: *No Drag, No Gravity Gradient*
  - **High Data Rates:** *100 Mbit/s (185 GB in 4.5hr at Perigee)*
- ➔ *1/R<sup>2</sup> advantage: ~ 23 dB improvement over an L2 orbit  
(>50 dB improvement over Earth-trailing orbit e.g. Kepler/Spitzer)*

Gangestad et al. 2013 (astro-ph 1306.5333)

# Orientations of the Four TESS Cameras



# One TESS Camera: 24 degrees

**30-minute exposure**  
**full frame images (FFI)**  
(>30 million stars and galaxies in survey...)

**1300 successive FFI's for**  
**each sky segment**  
**(27 days)**

● Moon  $\sim 0.2 \text{ deg}^2$   
 $\Rightarrow$  10,000  
moons would  
fit inside the  
TESS FOV

Kepler FOV  
 $\sim 100 \text{ deg}^2$

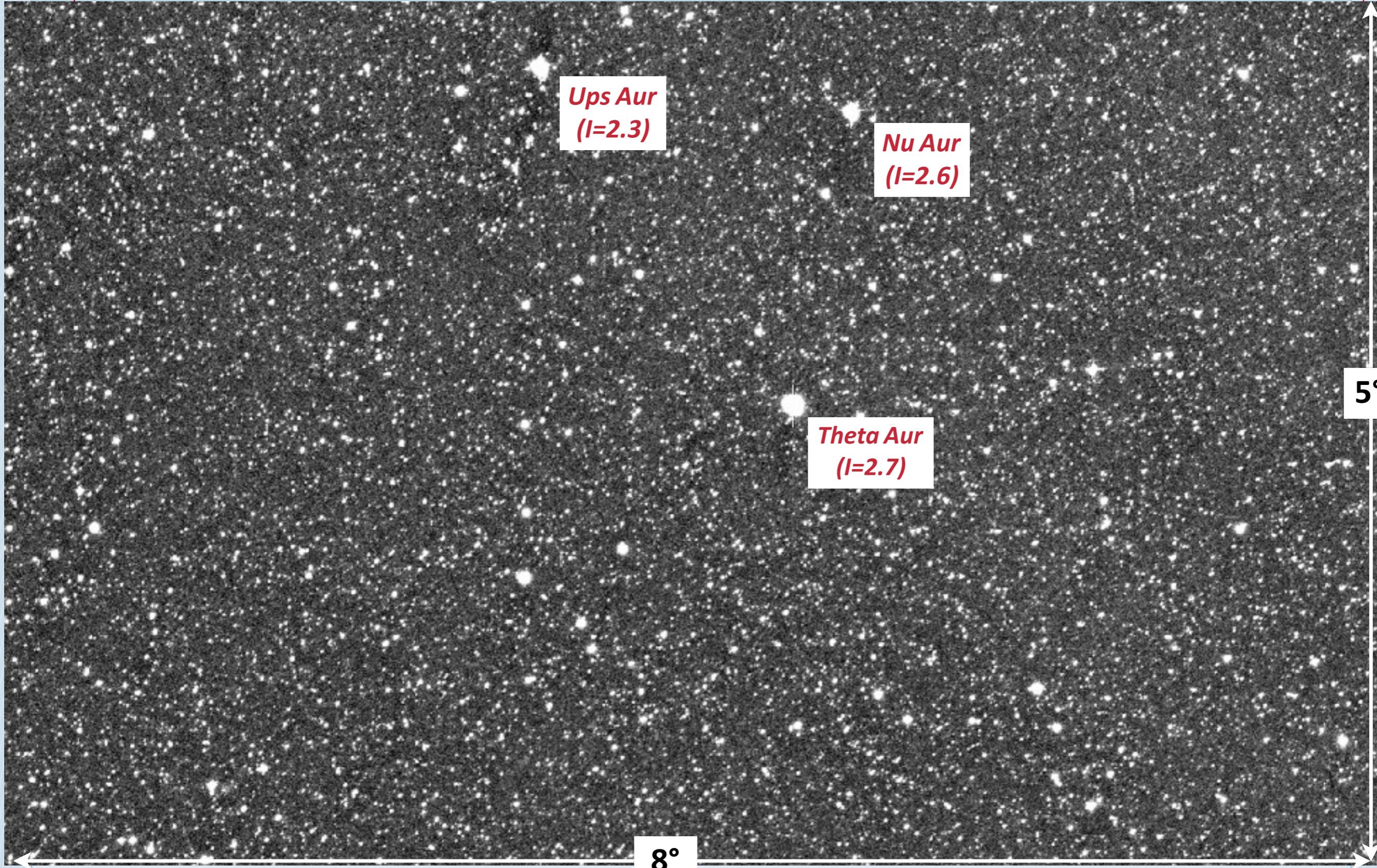


# *TESS 2 sec Image--Auriga/Perseus Field--MIT RooVop*

**IMAGE TAKEN WITH AN ENGINEERING MODEL TESS CAMERA--NOT A SIMULATION !!**



IMAGE TAKEN WITH AN ENGINEERING MODEL TESS CAMERA--NOT A SIMULATION !!



Follow-up Program required for confirmation of exoplanet candidates

False positive:

- Identification
- Contamination
- Light curves

Stellar properties

Radial velocity (mass) measurements

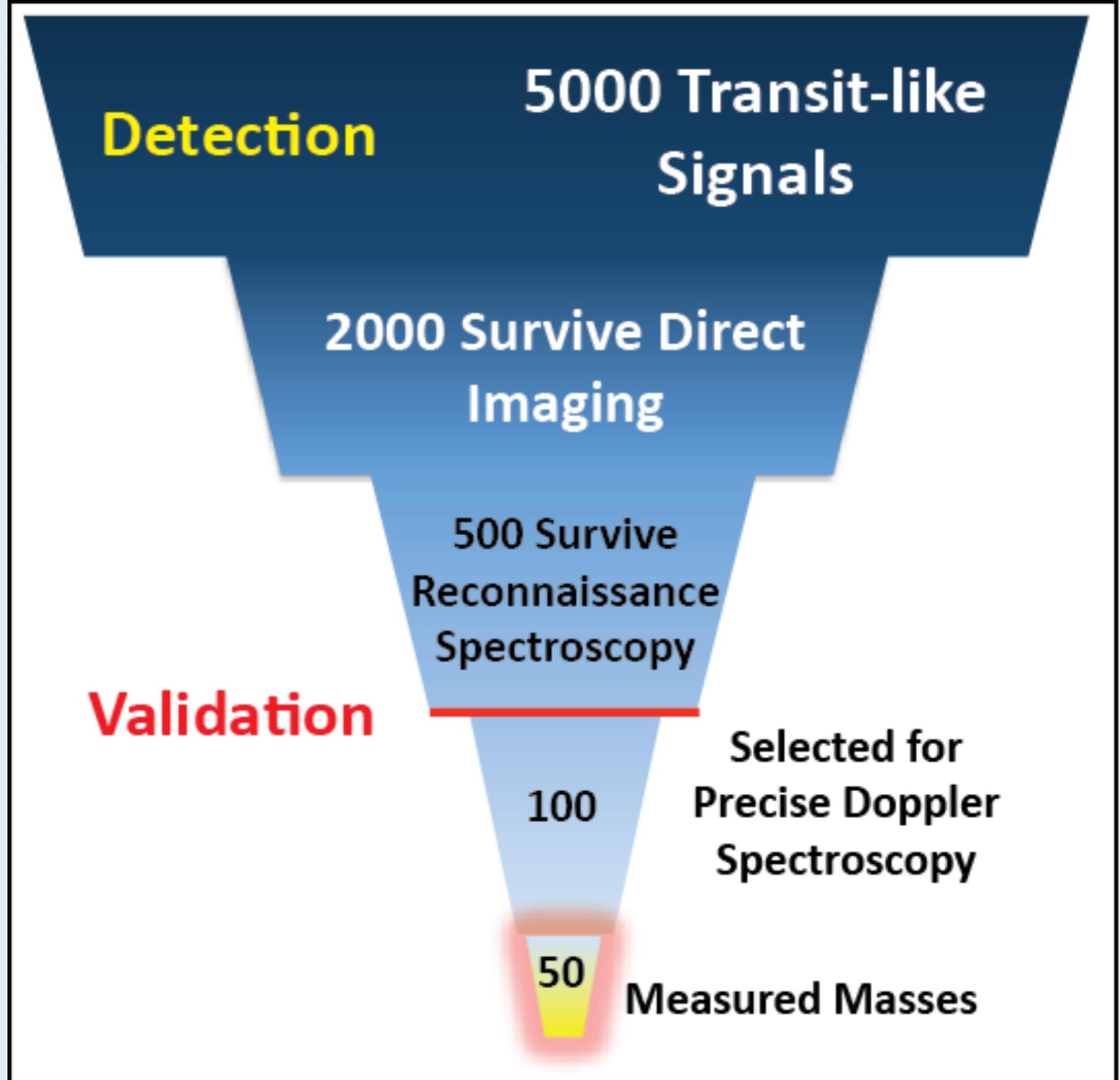
Partner

Institutions:

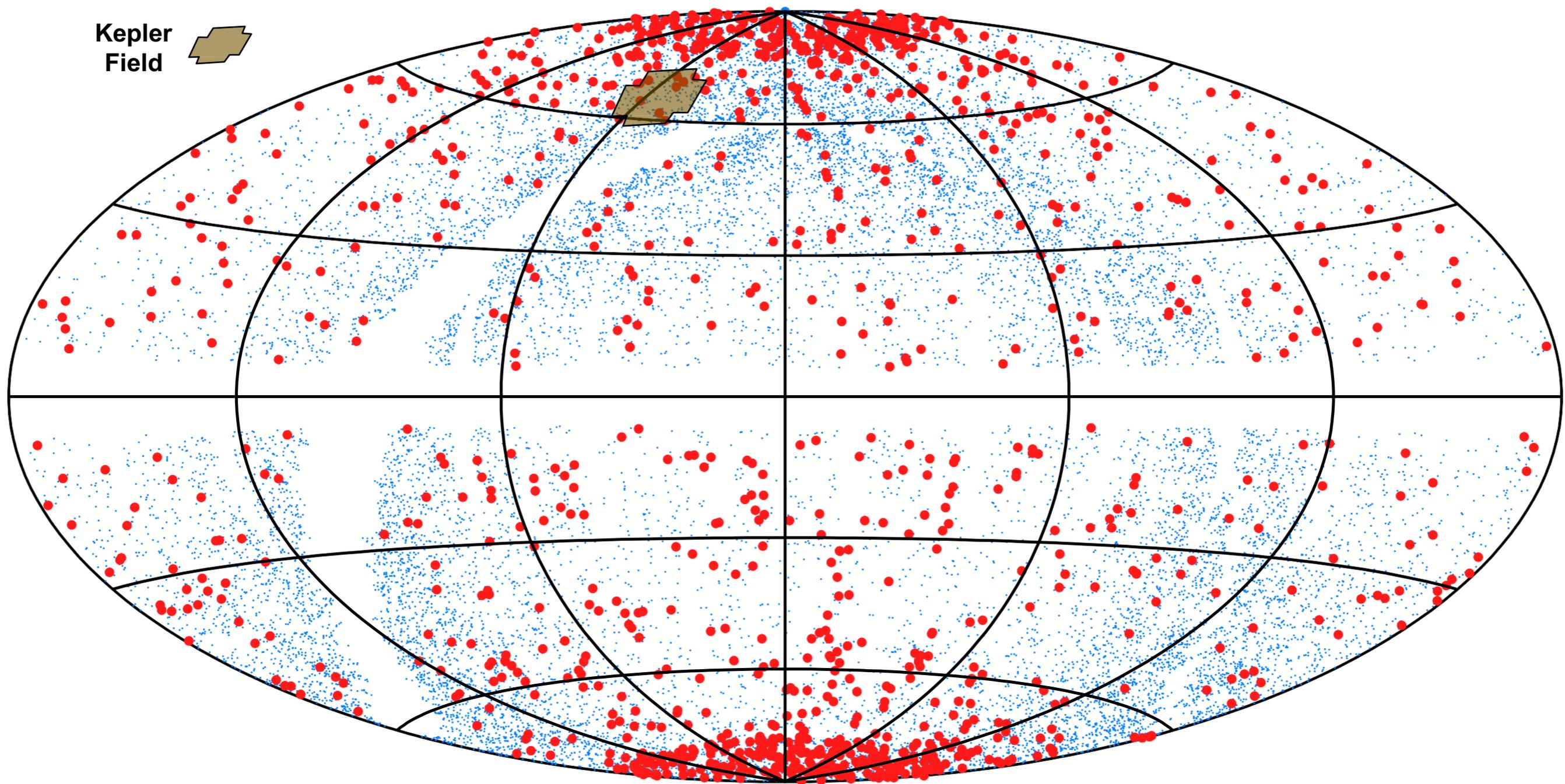
SAO (funded)

Co-I Follow Up

Contributions



# Simulated TESS Planet Detections



Kepler  
Field

Ecliptic  
Coordinates

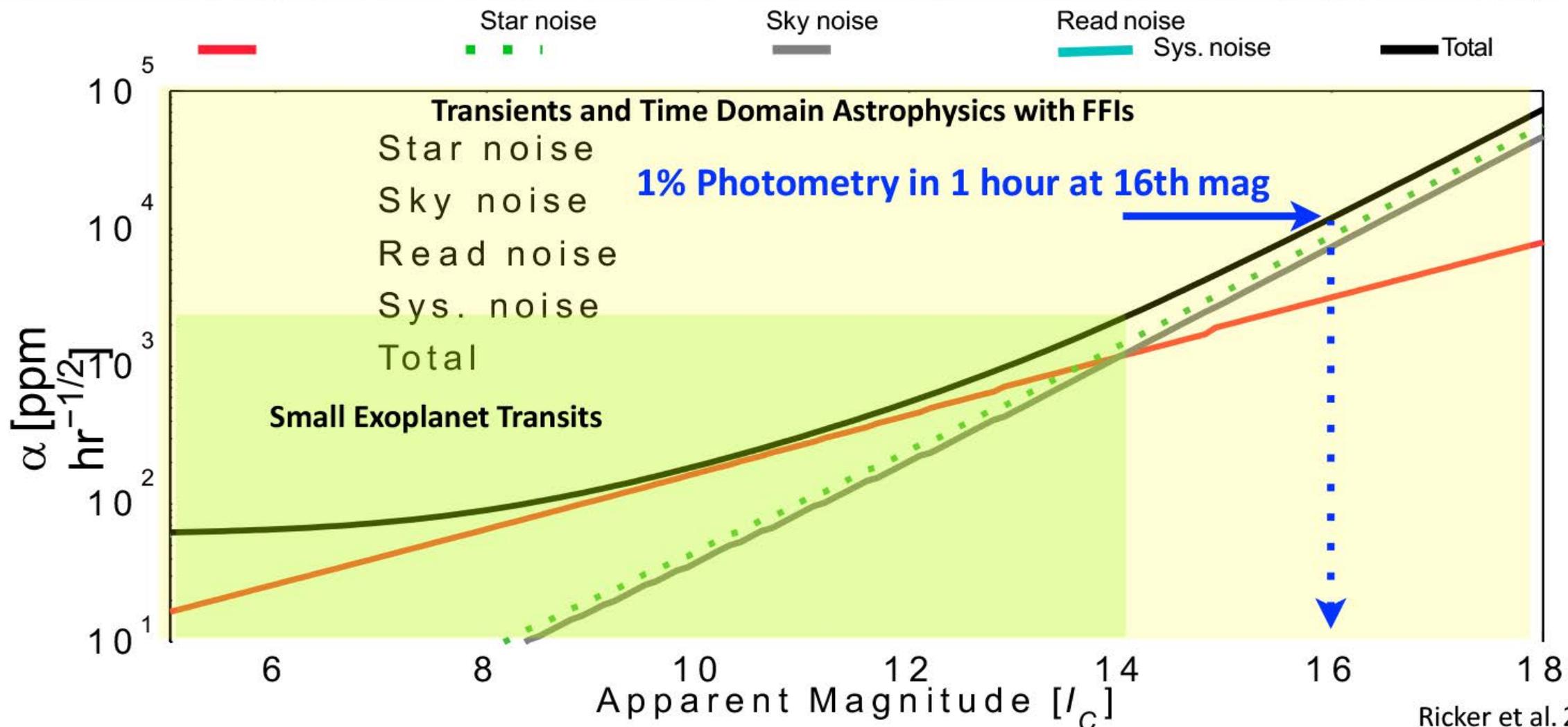
Sullivan et al. (arXiv:1506.08845)

- Detectable planets around **200,000 pre-selected stars**
- Detectable planets around **20,000,000 stars in full frame images**

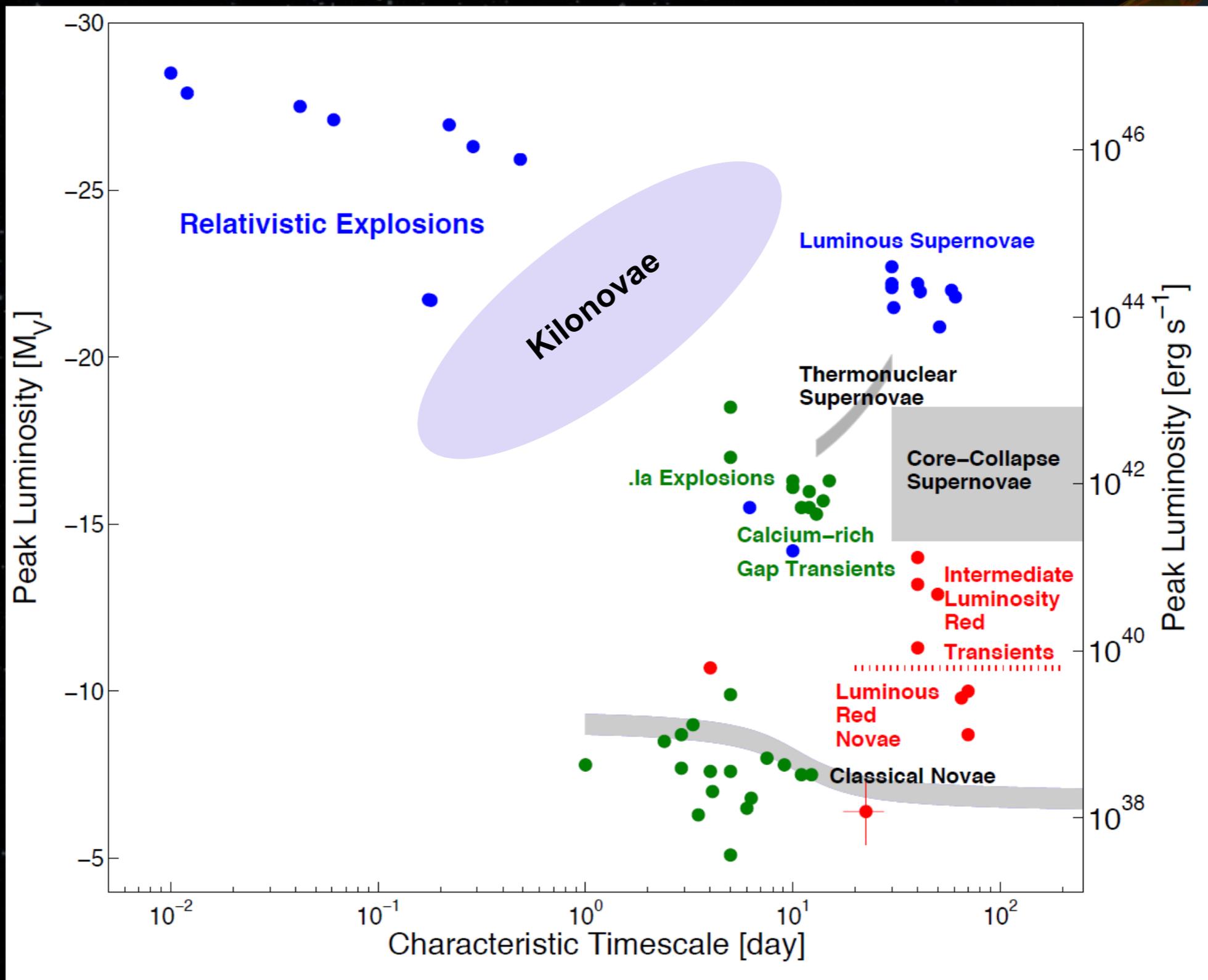
# TESS can also go deep...

- In one hour:
  - 1% photometry at 16<sup>th</sup> mag
  - <10% photometry at 18<sup>th</sup> mag
- In 12 hours:
  - Approximately 10% photometry at 19.5 mag

~1 Billion  
Stars + Galaxies

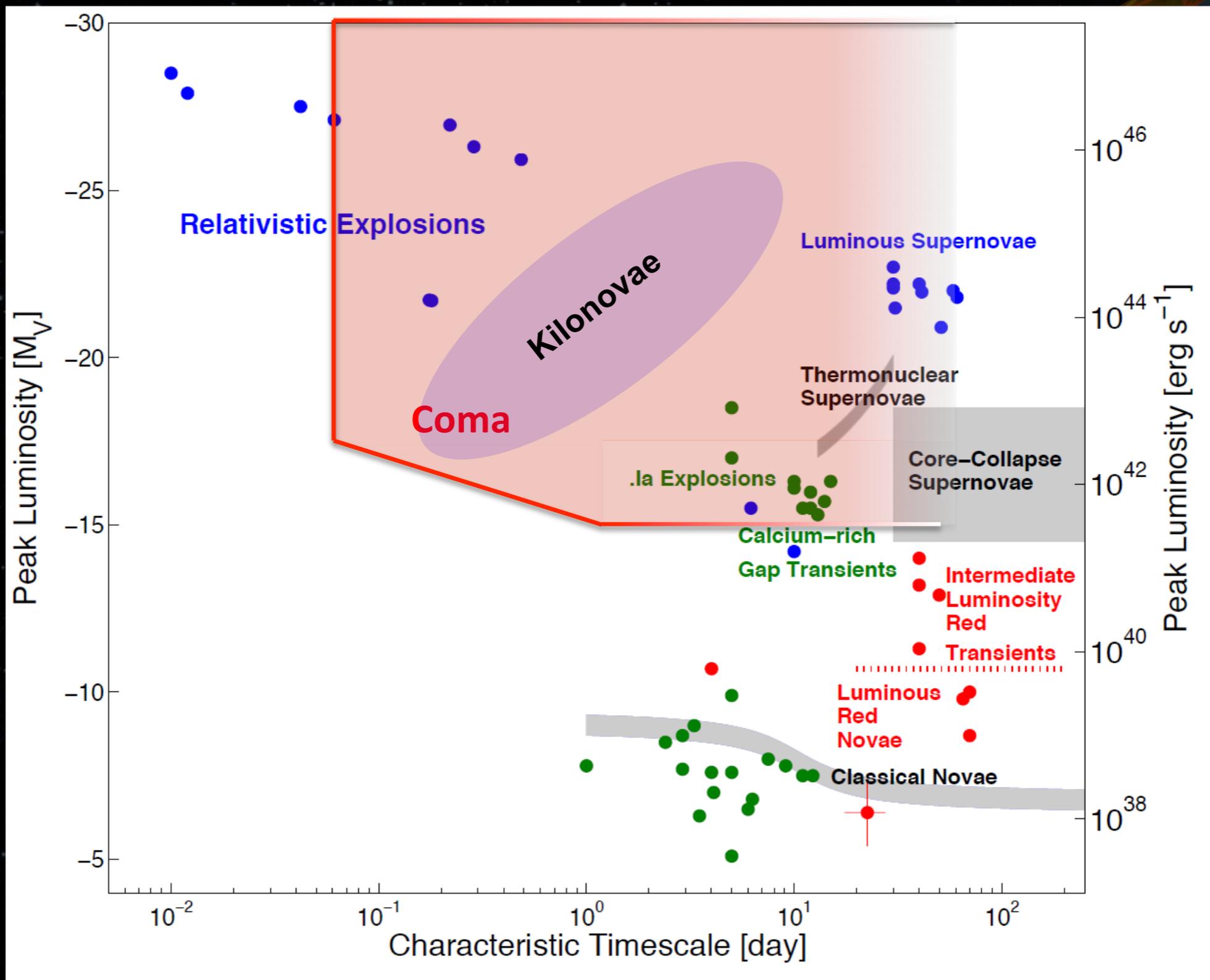


# TESS and Depth

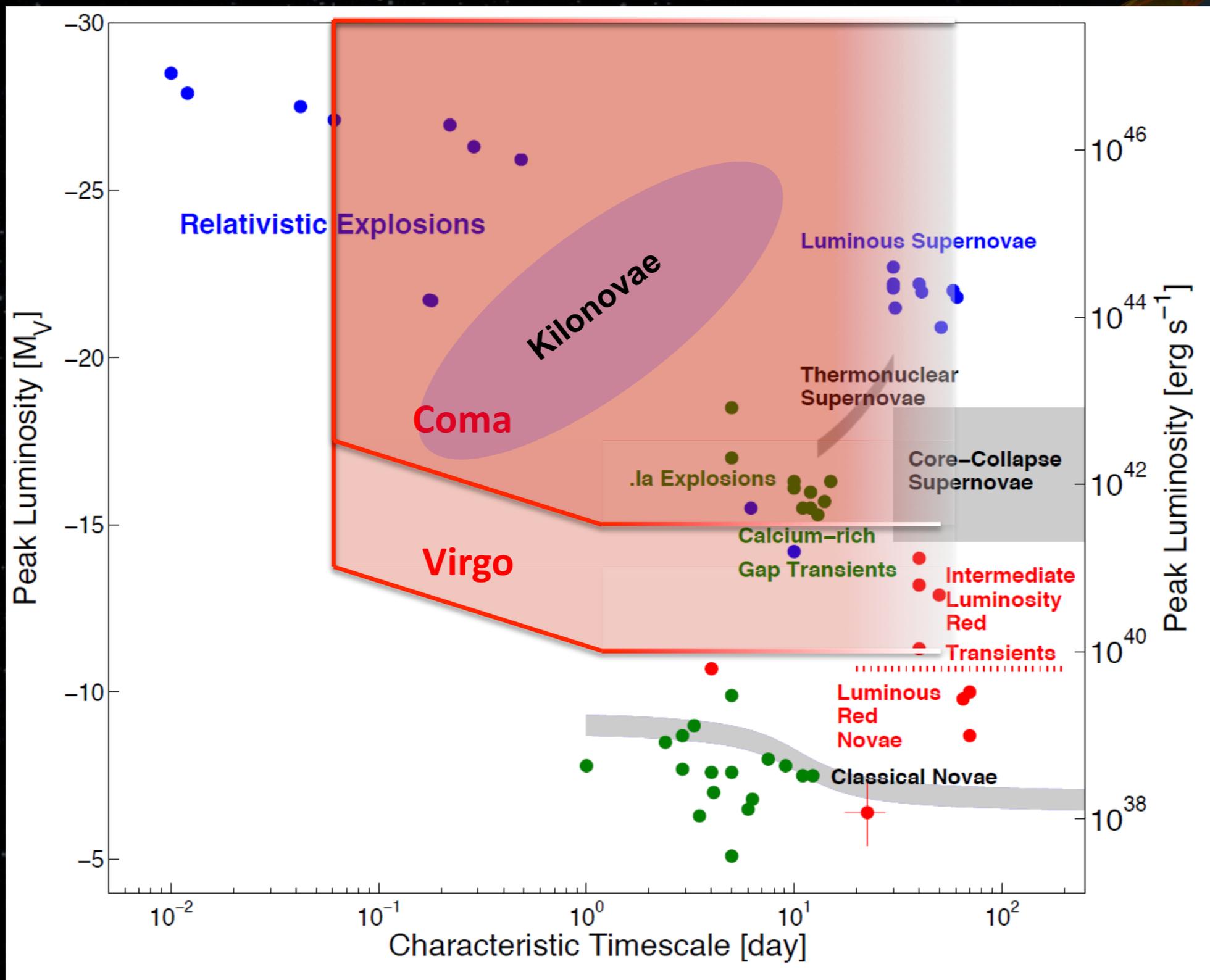


Plot Credit: Mansi Kasliwal

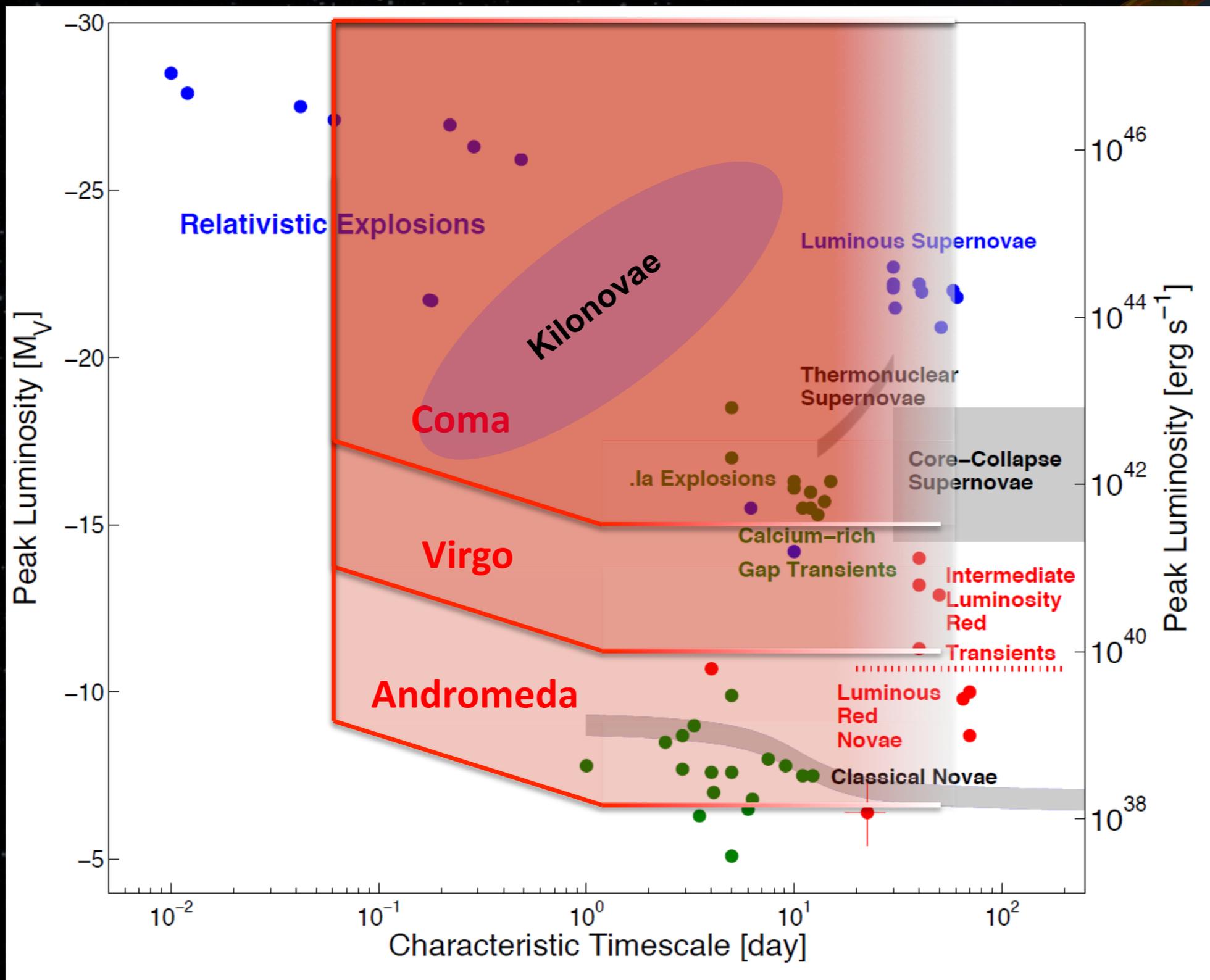
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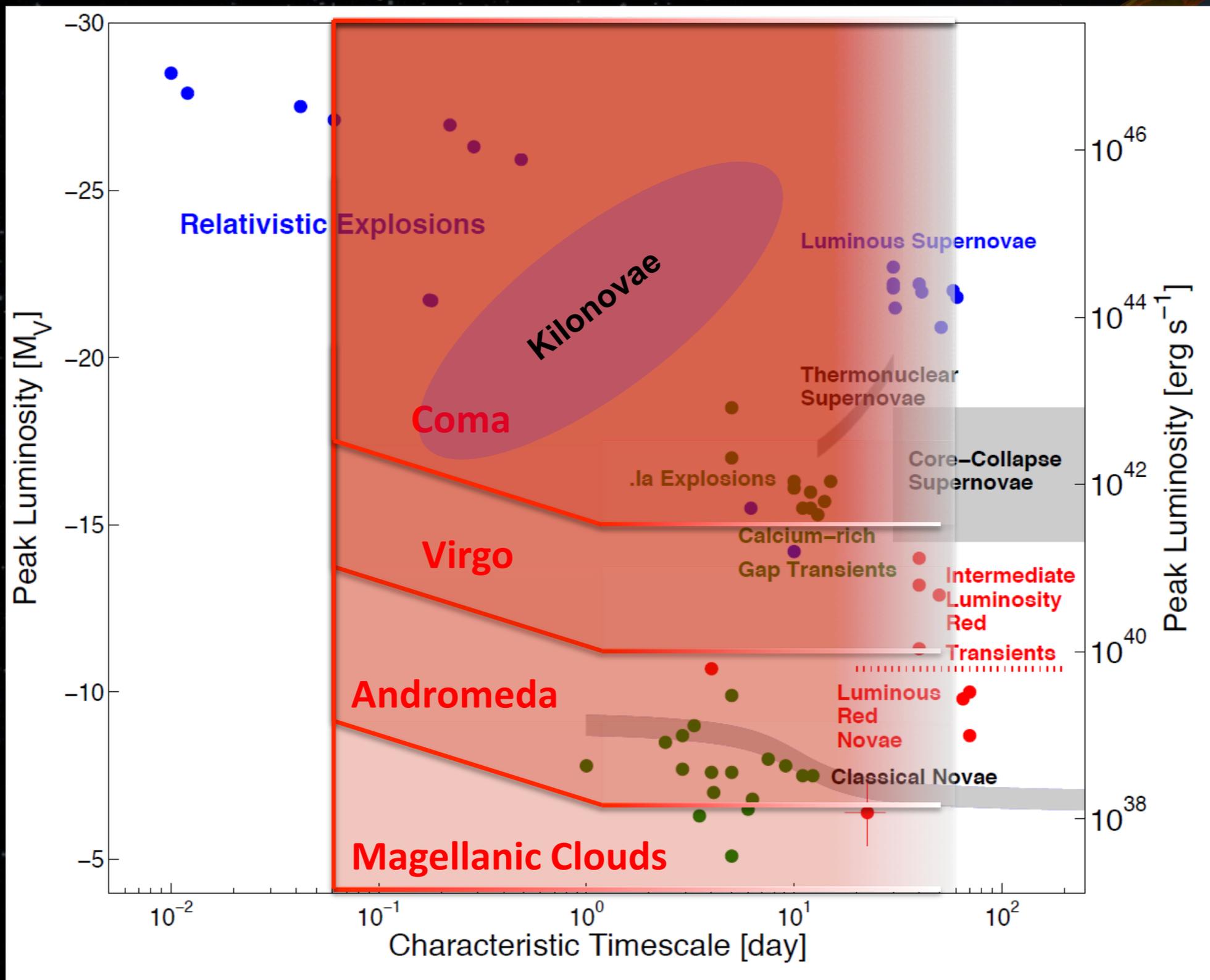
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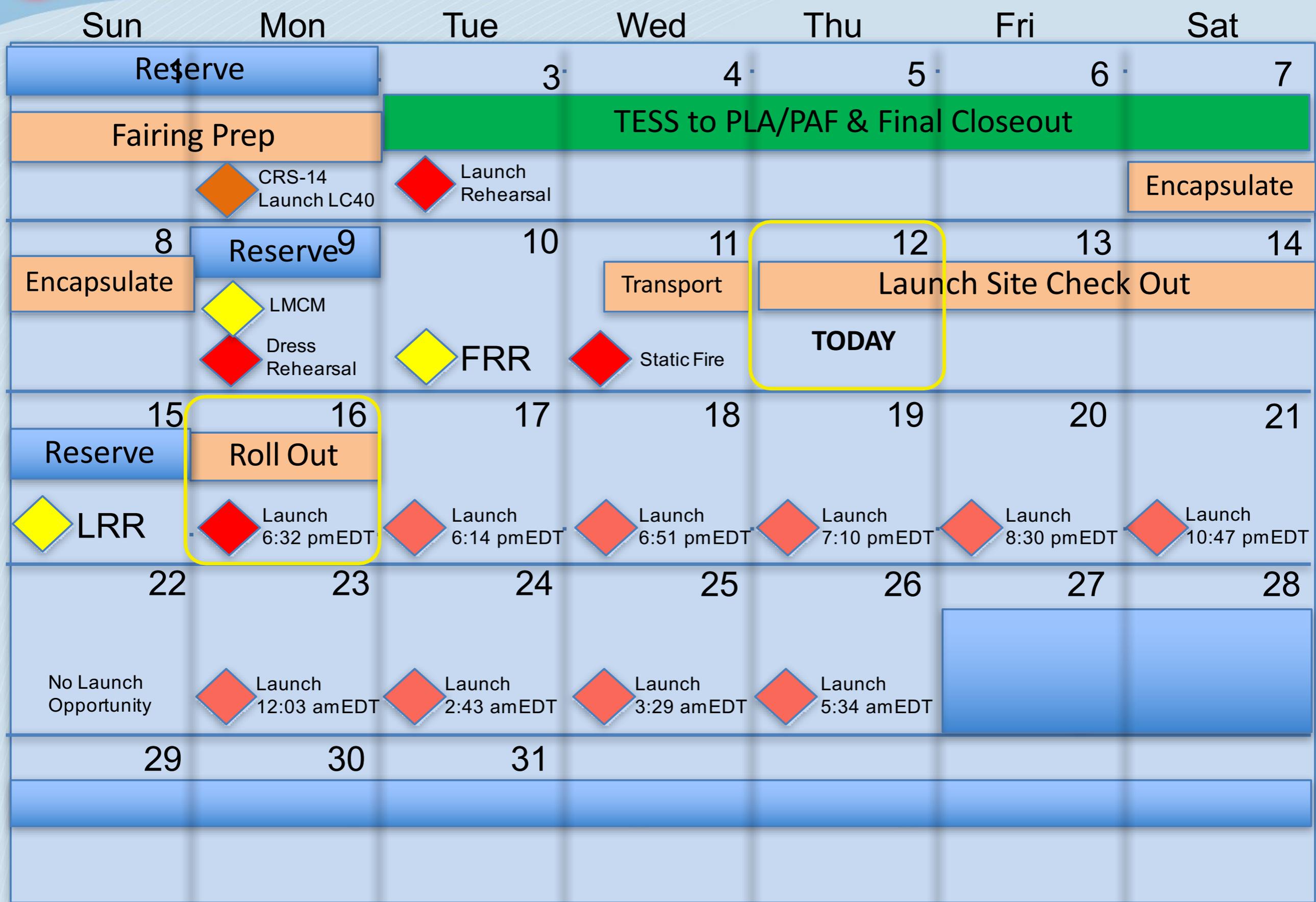


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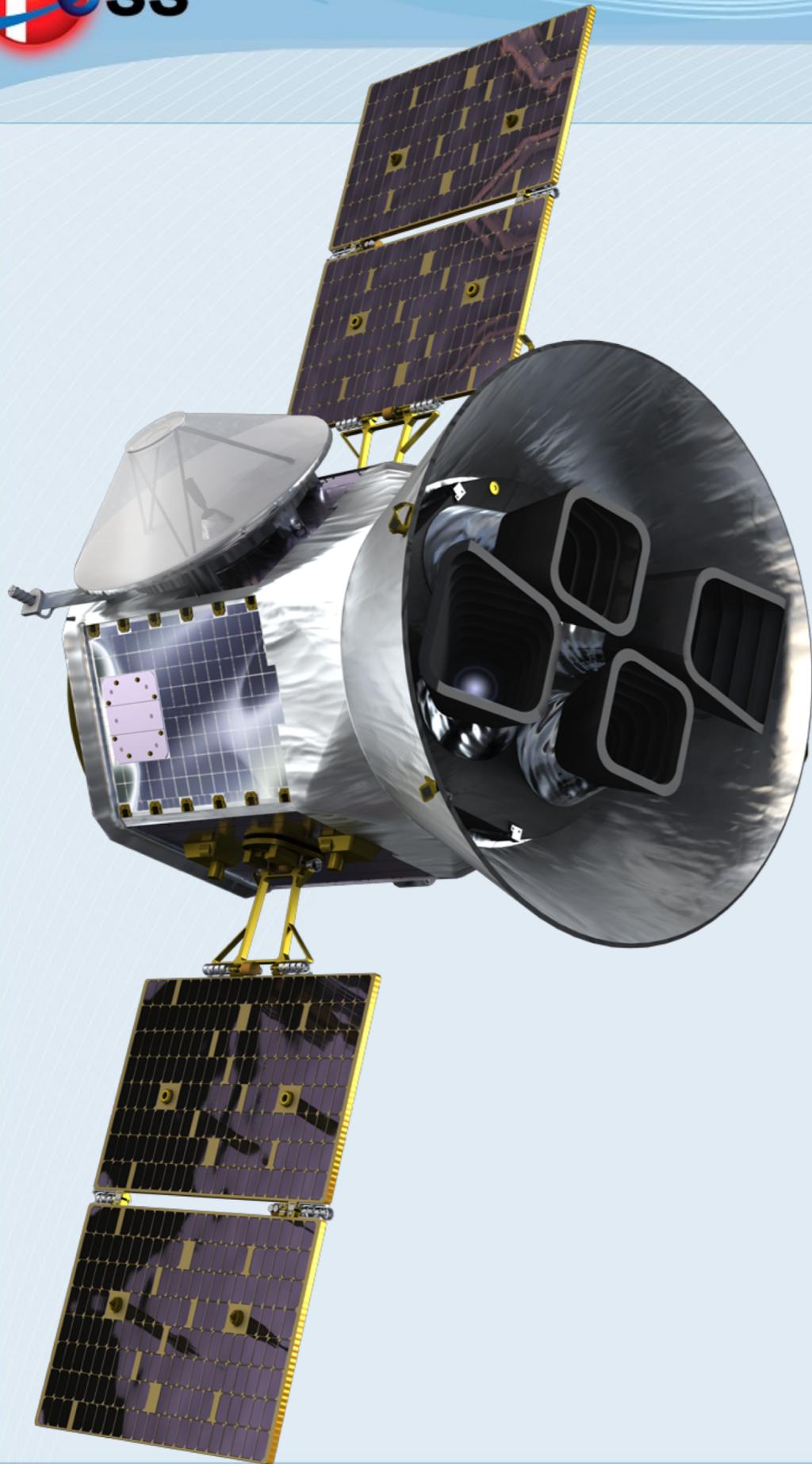




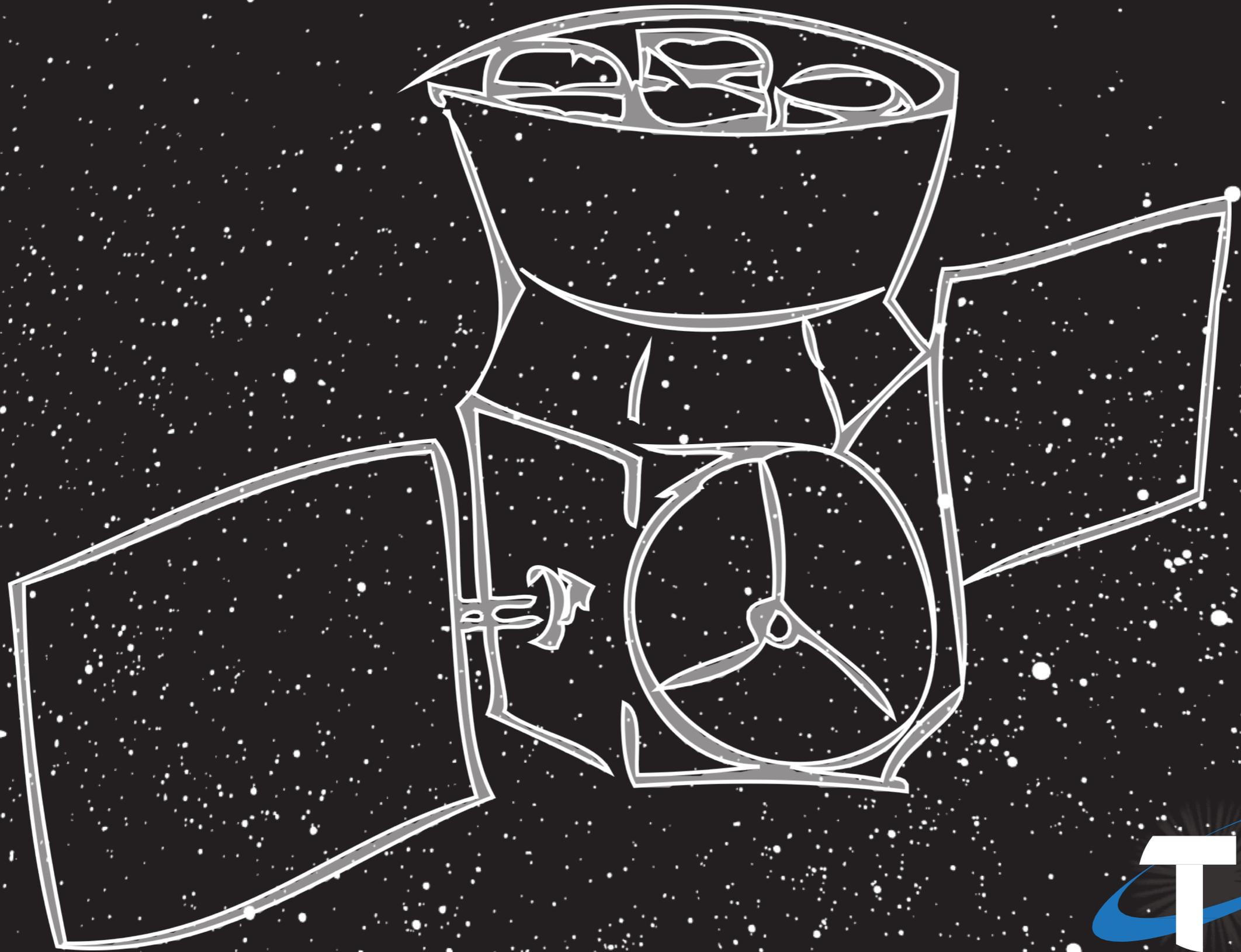
# Current TESS Schedule Flow - April 2018



# Takeaways



- TESS will find nearby bright small transiting planets ideal for atmospheric composition measurements by **JWST** and upcoming giant 20-, 30-, and 40-meter ground-based telescopes.
- TESS can operate in its lunar-resonant, high earth orbit for more than two decades.
- TESS planets will endure as the best small planet targets for radial velocity mass measurements and atmospheric characterization.
- TESS will fly a highly adaptable data handling unit, enabling support of a broad range of time domain astrophysics, well beyond exoplanet studies.



**T**ess