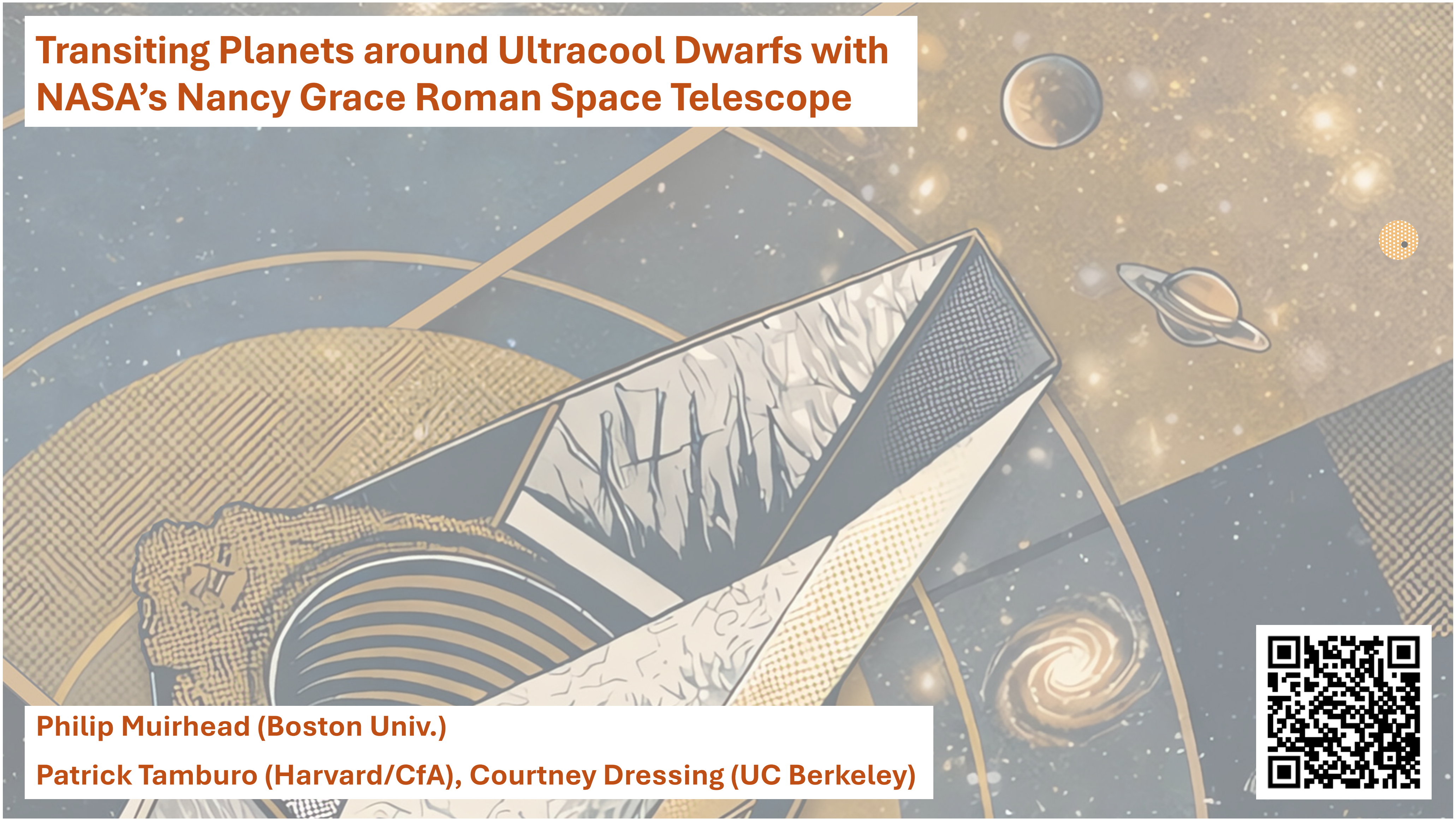
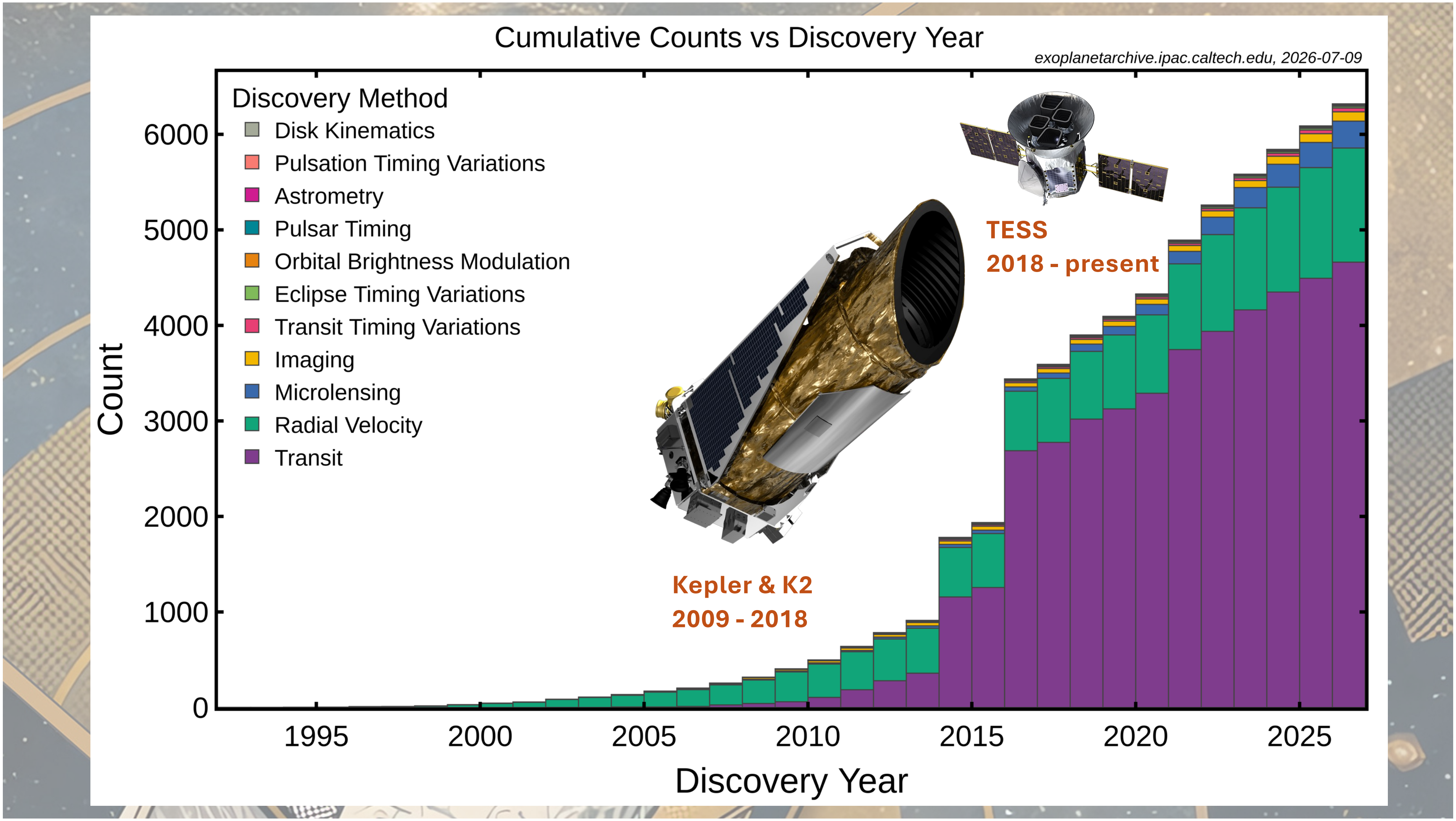
Transiting Planets around Ultracool Dwarfs with NASA's Nancy Grace Roman Space Telescope

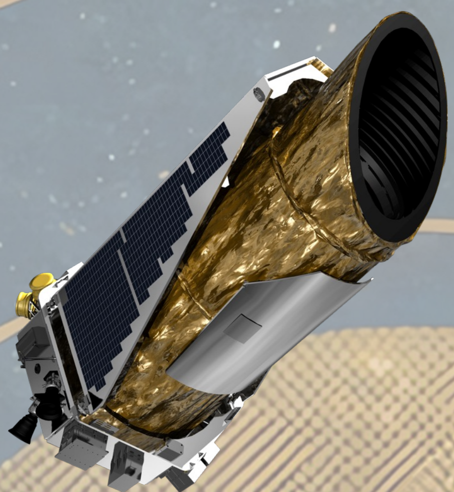


Philip Muirhead (Boston Univ.)

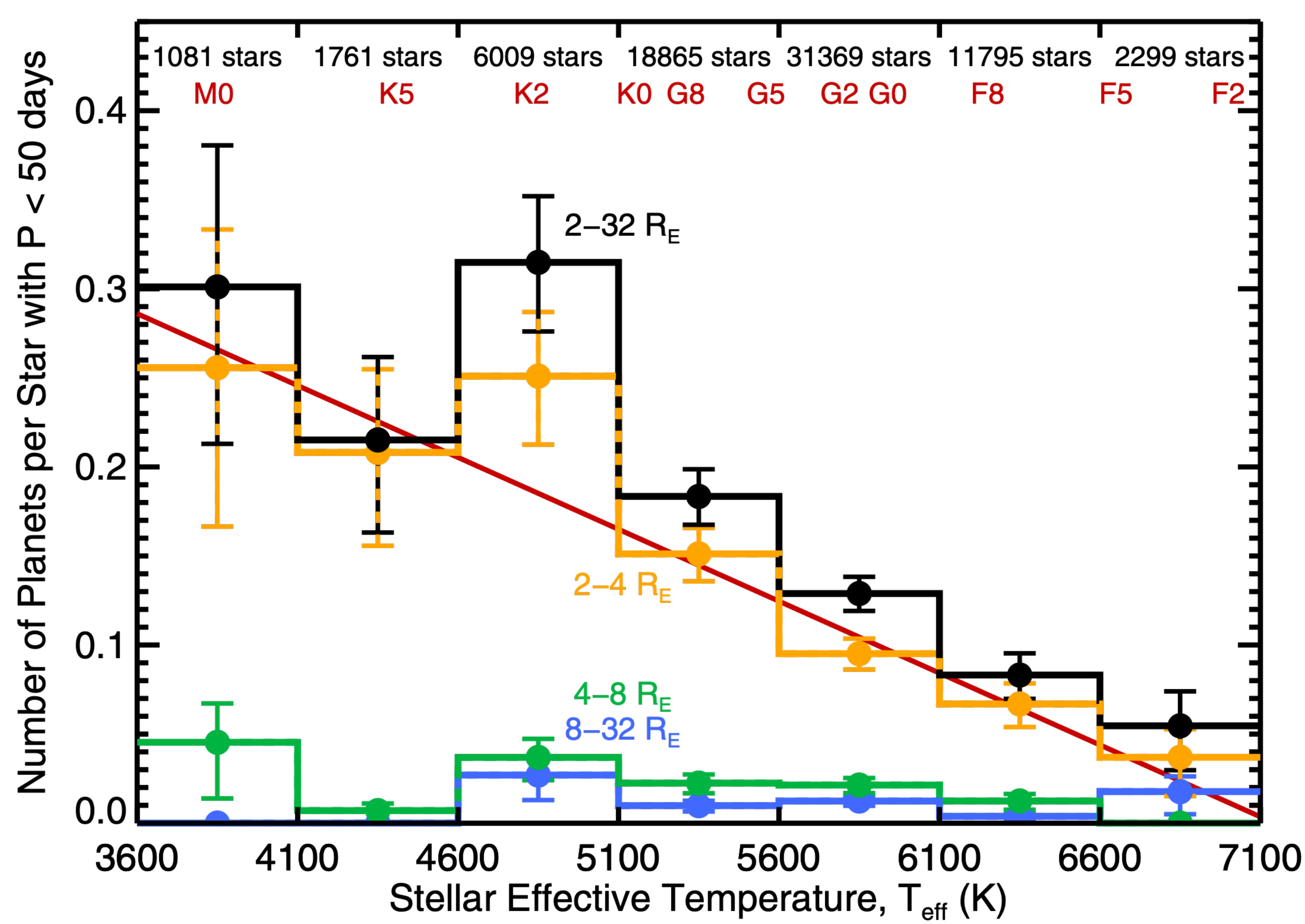
Patrick Tamburo (Harvard/CfA), Courtney Dressing (UC Berkeley)



Cumulative Counts vs Discovery Year
exoplanetarchive.ipac.caltech.edu, 2026-07-09
Discovery Method
Disk Kinematics
Pulsation Timing Variations
Astrometry
Pulsar Timing
Orbital Brightness Modulation
Eclipse Timing Variations
Transit Timing Variations
Imaging
Microlensing
Radial Velocity
Transit
TESS
2018 - present
Kepler & K2
2009 - 2018
Count
0
1000
2000
3000
4000
5000
6000
1995
2000
2005
2010
2015
2020
2025
Discovery Year



$$f_{\text{cell}} = \sum_{j=1}^{n_{\text{pl,cell}}} \frac{1/p_j}{n_{\star,j}},$$

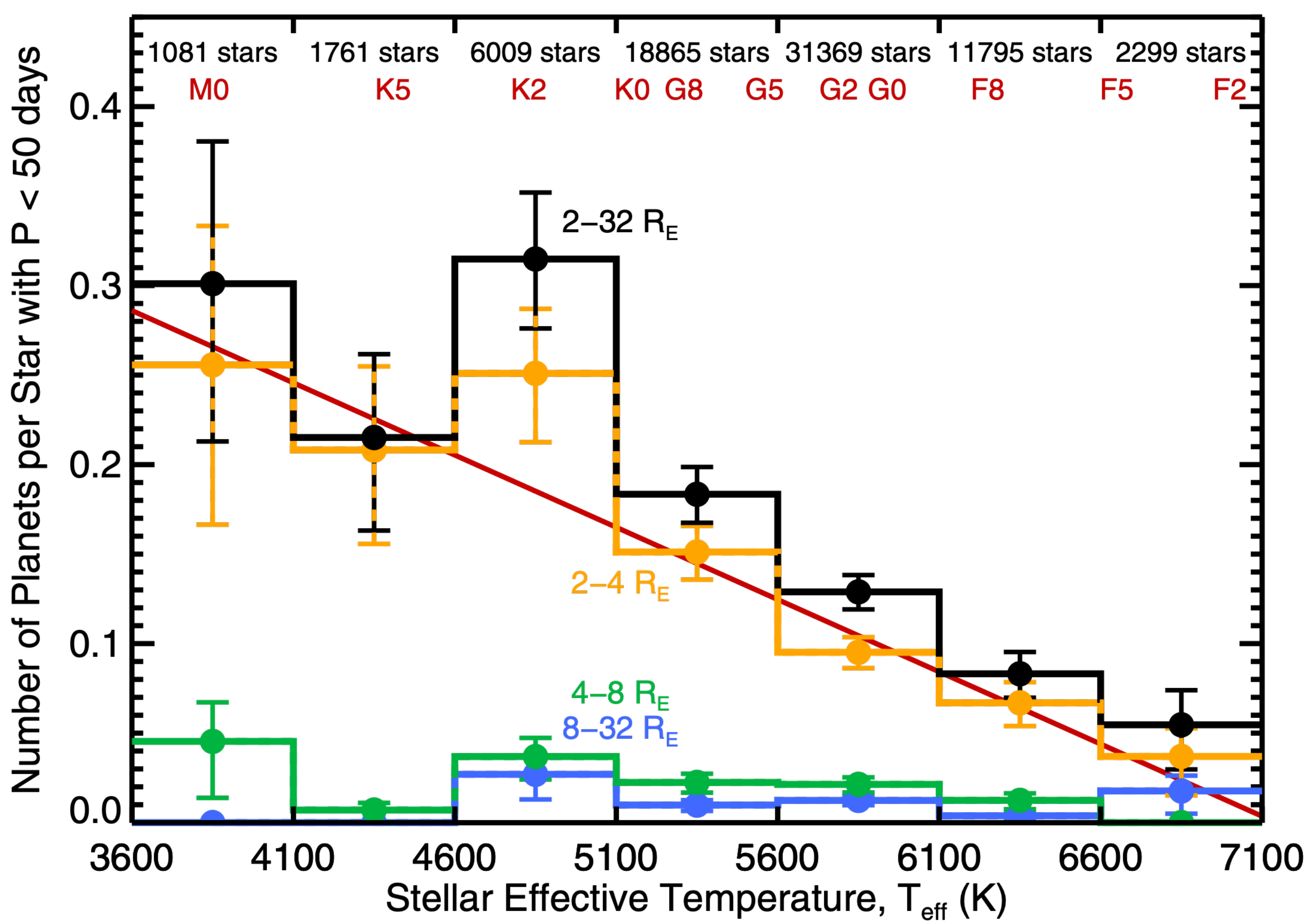


Howard et al. (2012)

Hard Part I:
Find the transiting planets

$$f_{\rm cell} = \sum_{j=1}^{n_{\rm pl,cell}} \frac{1/p_j}{n_{\star,j}},$$

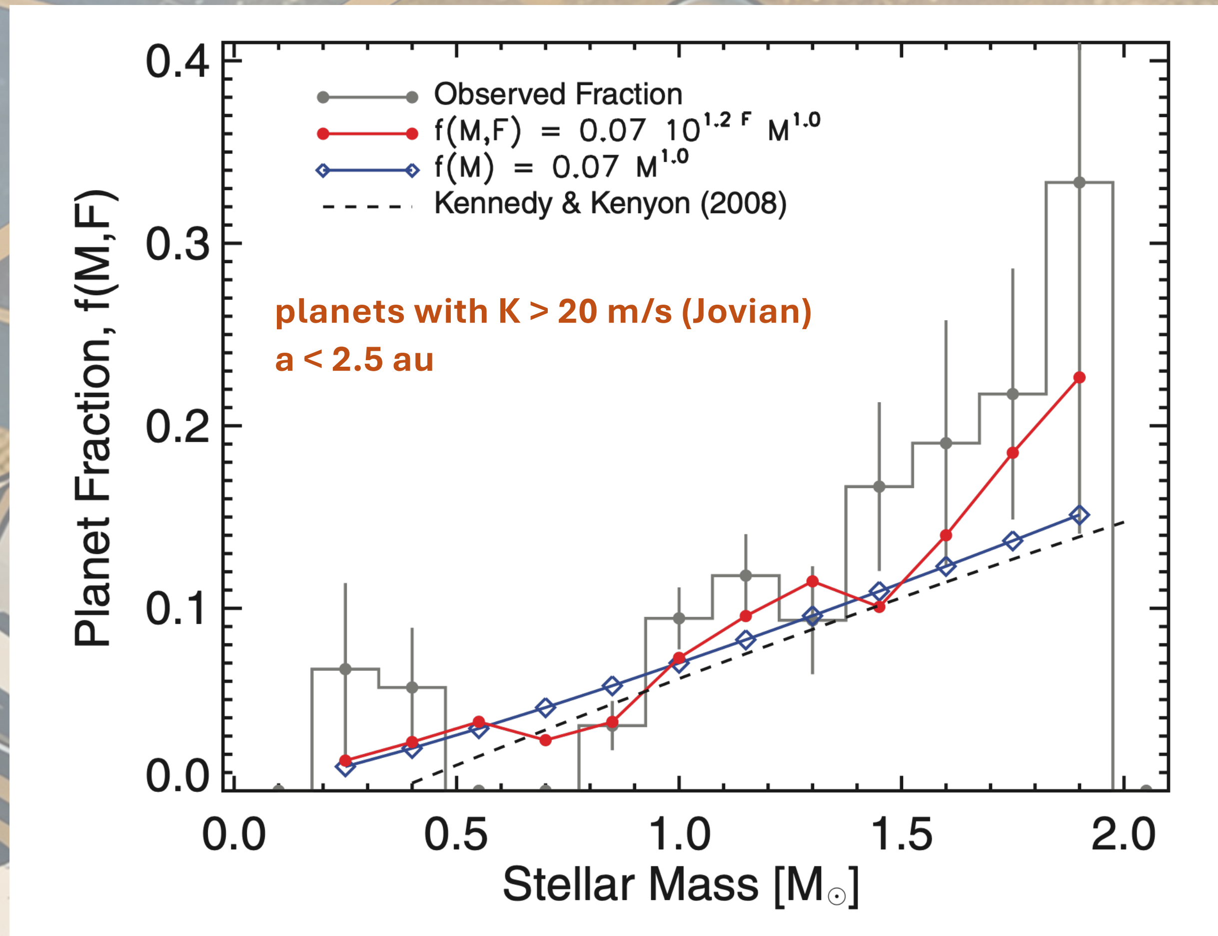
Hard Part II:
Knowing thy stars
(this was pre-Gaia!)

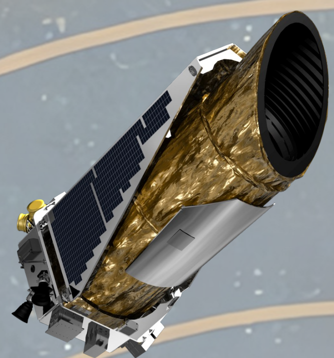


Howard et al. (2012)

In contrast to *giant* planets, which are rare around low-mass/M-type stars.

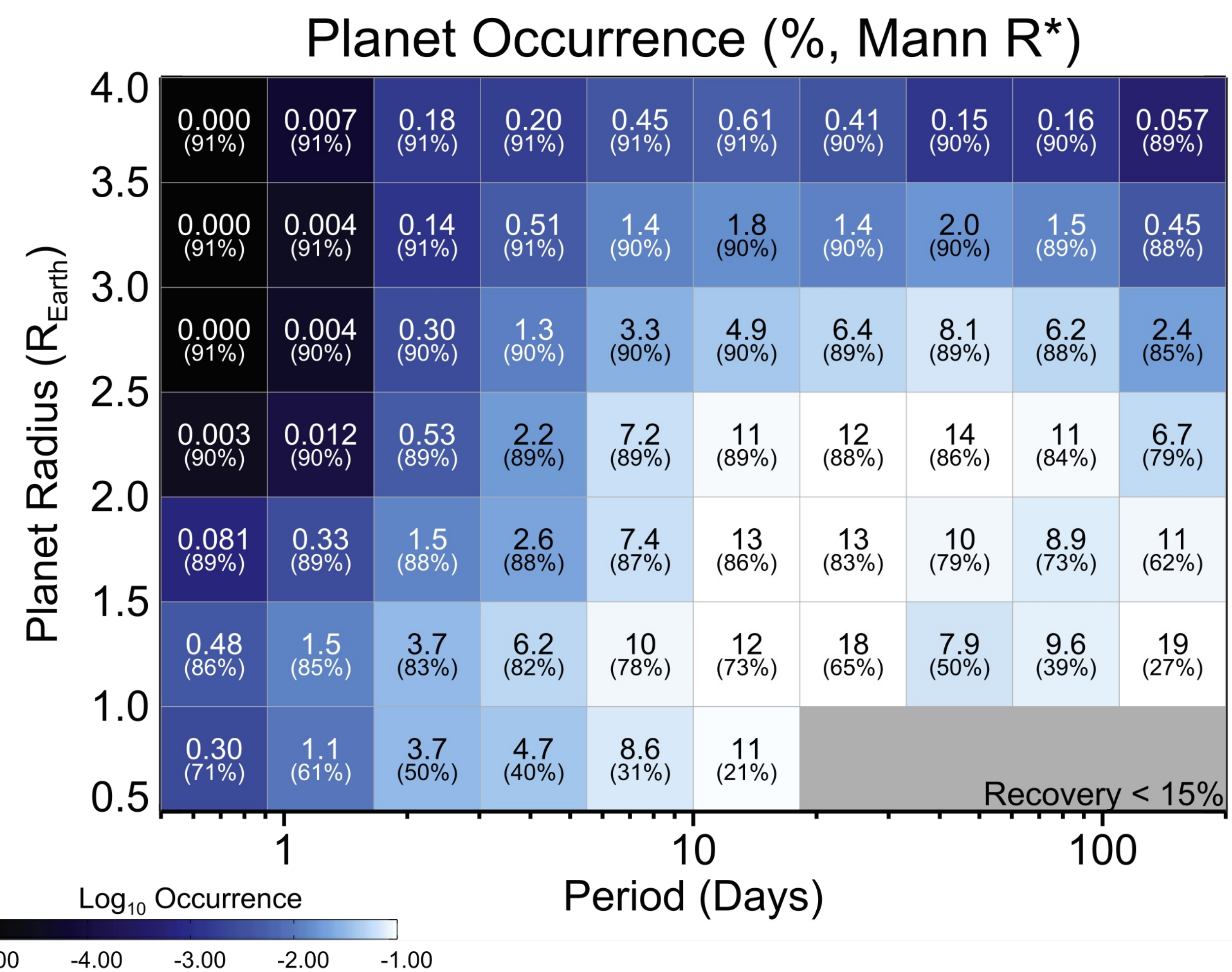
Johnson & Apps (2010)



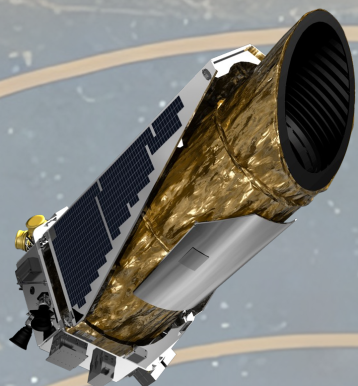


Detailed analysis of early Ms in Kepler (M1-M4):

2.5 planets per Early M
P<50 days
1-4 Re

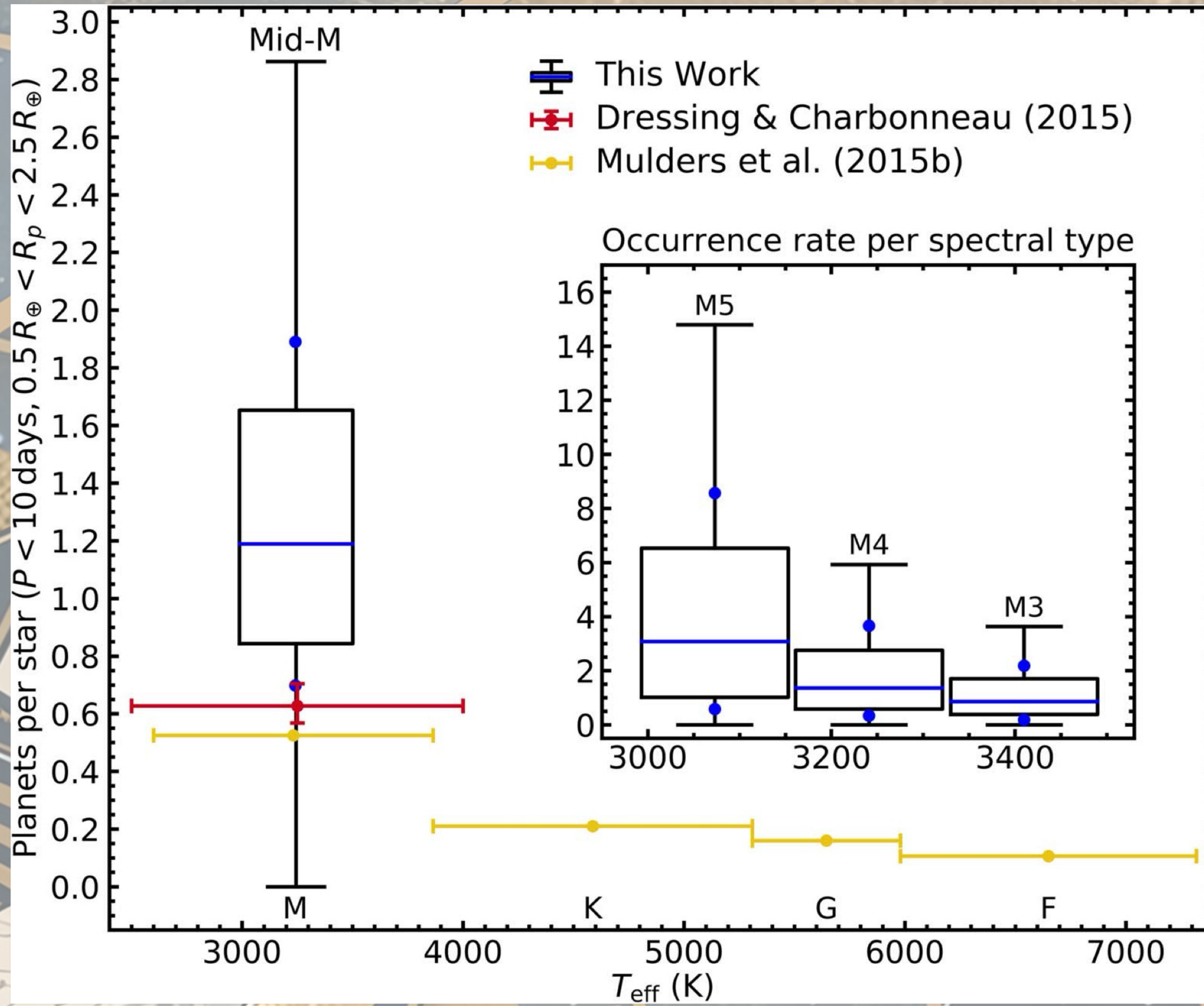


Dressing & Charbonneau (2015)

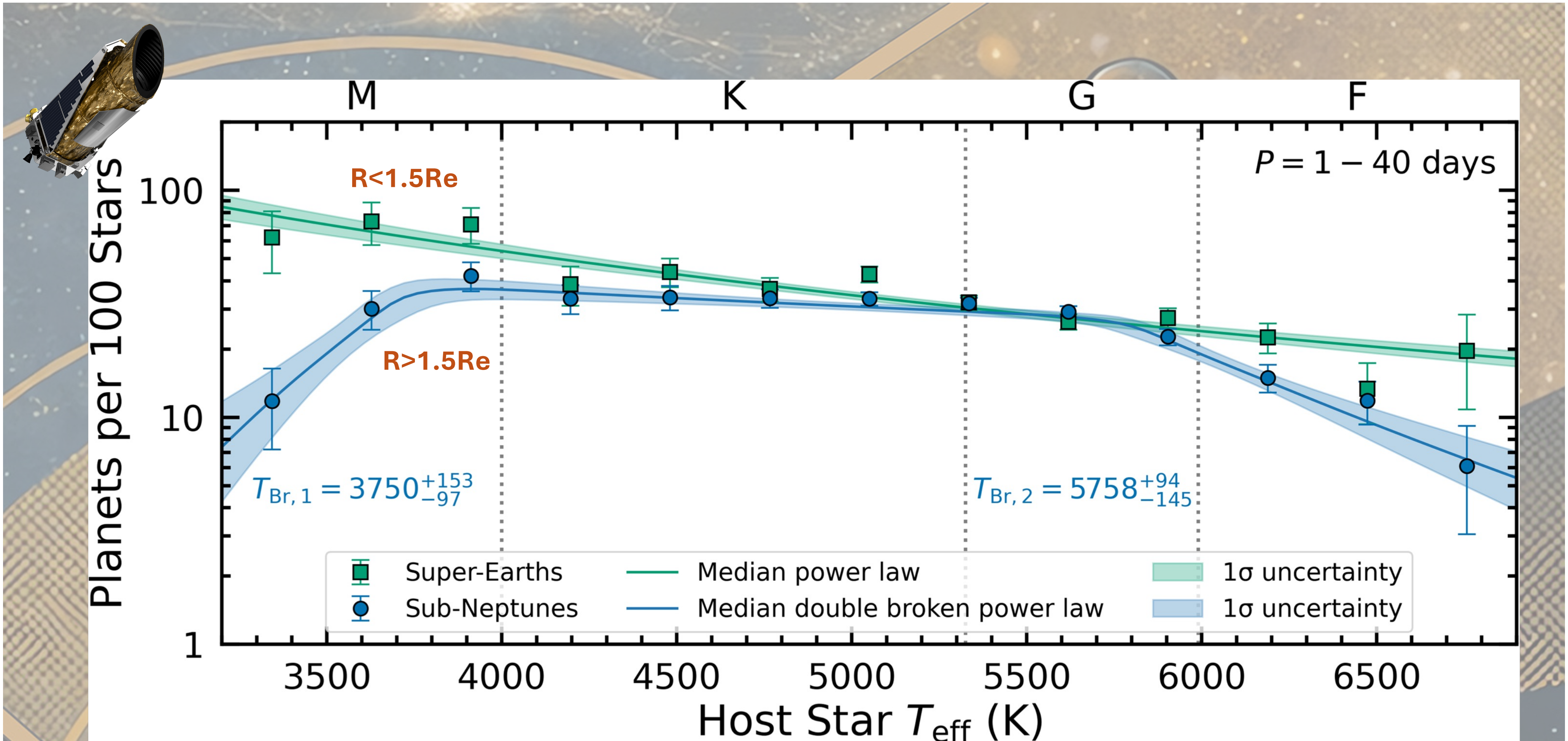


Not many *mid*-Ms in Kepler, but several compact multis around them (K-42, K-445, K-446)

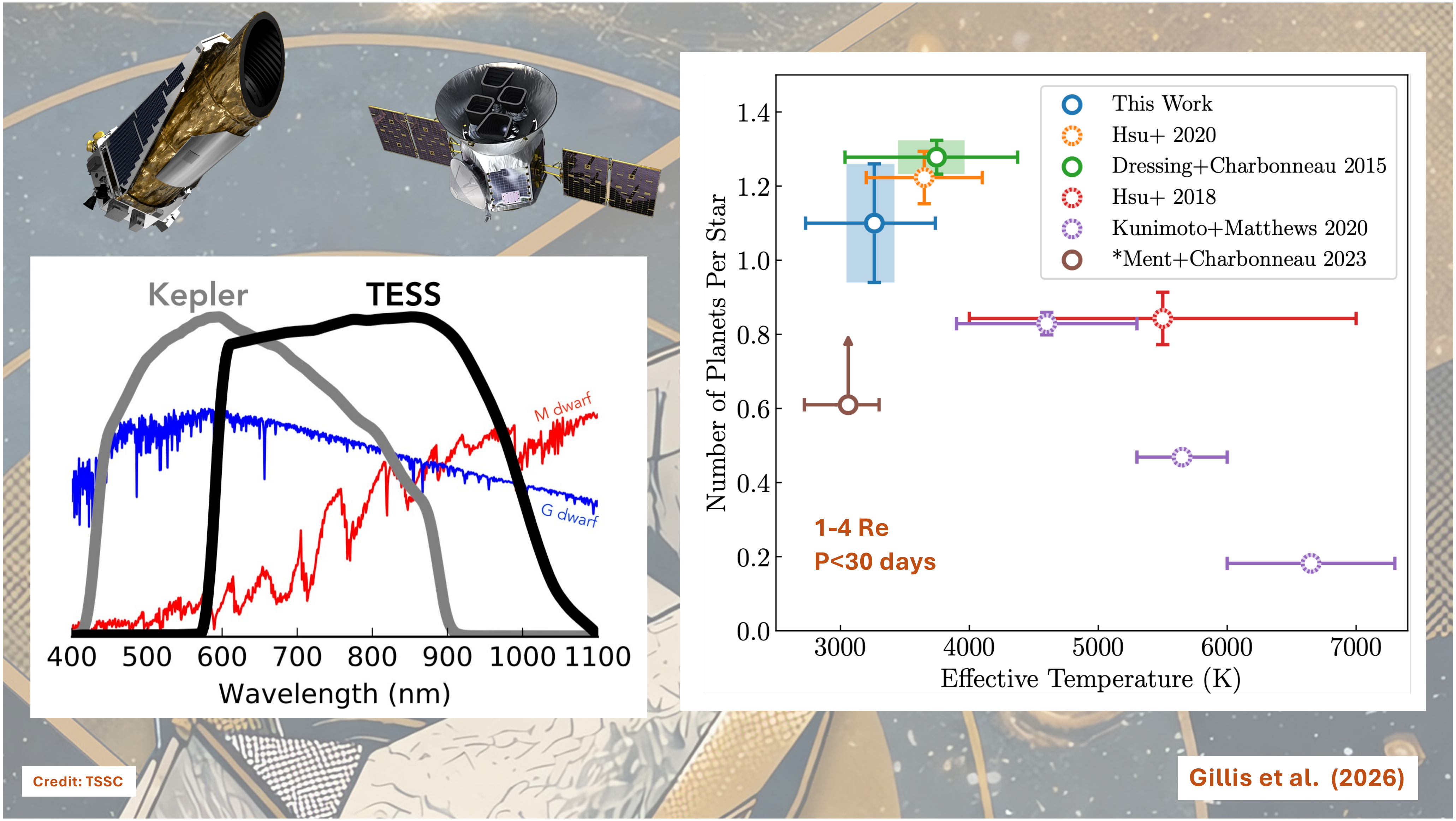
Suggested planet occurrence continues to rise to late Ms! But with large uncertainty.



Hardegree-Ullman et al. (2019) with Gaia DR2 for sample properties



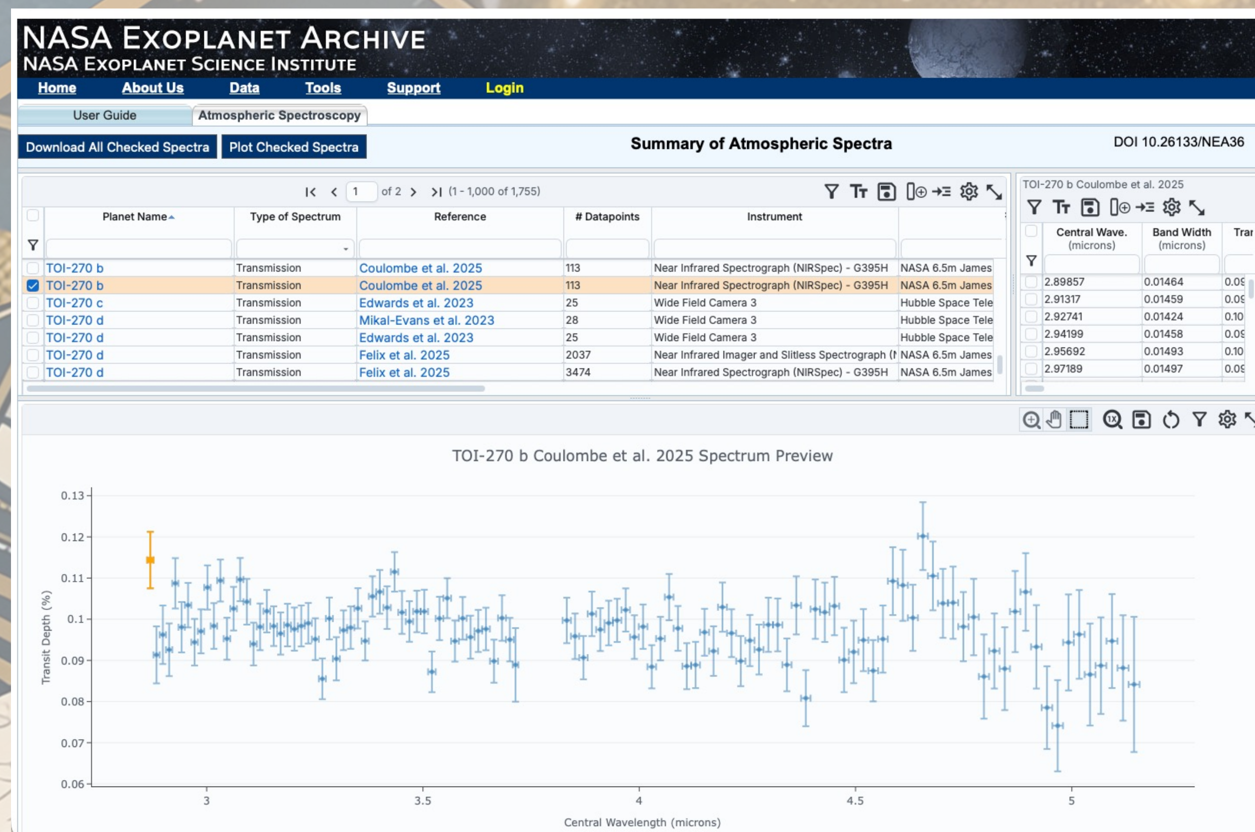
Hardegree-Ullman et al. (2025): Kepler+K2 show super-earths continue to rise with decreasing stellar mass, while sub-Neptunes decrease.


Kepler
TESS
M dwarf
G dwarf
400 500 600 700 800 900 1000 1100
Wavelength (nm)
Credit: TSSC
This Work
Hsu+ 2020
Dressing+Charbonneau 2015
Hsu+ 2018
Kunimoto+Matthews 2020
*Ment+Charbonneau 2023
Number of Planets Per Star
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4
1-4 Re
P<30 days
3000 4000 5000 6000 7000
Effective Temperature (K)
Gillis et al. (2026)

Implications for *transmission spectroscopy*
Easier for short-period planets around Ms

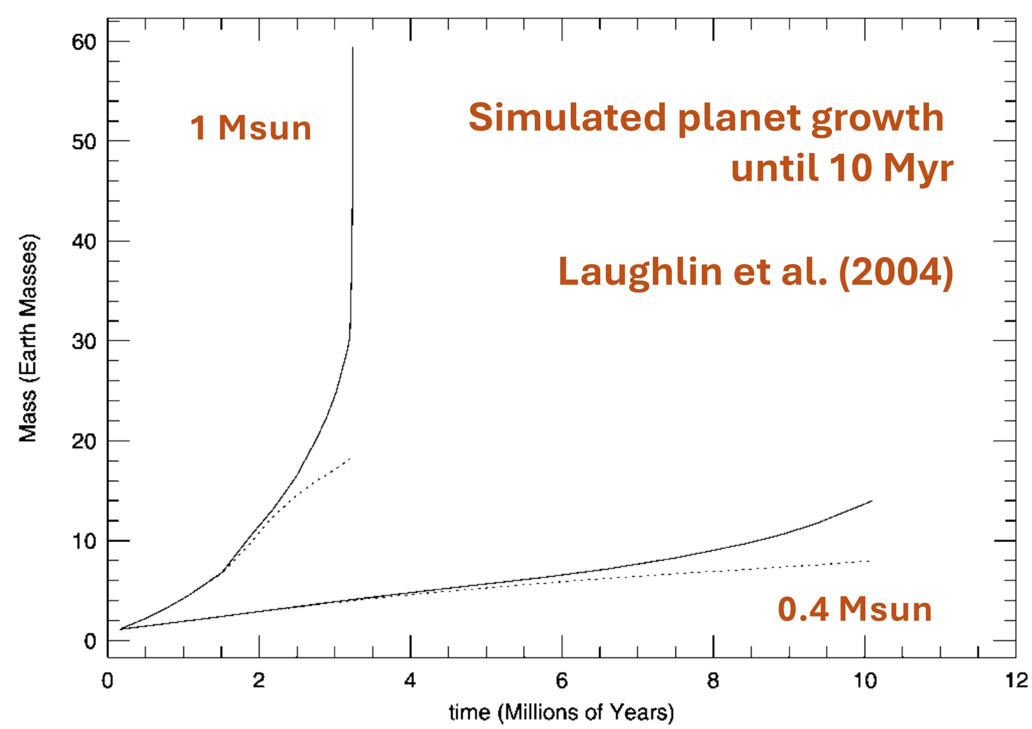
Of the 83 R<4Re planets with spectra, 52 orbit M dwarfs!

Moderate evidence for steam atmosphere in TOI-270b (1.3Re, Coulombe et al. 2025)



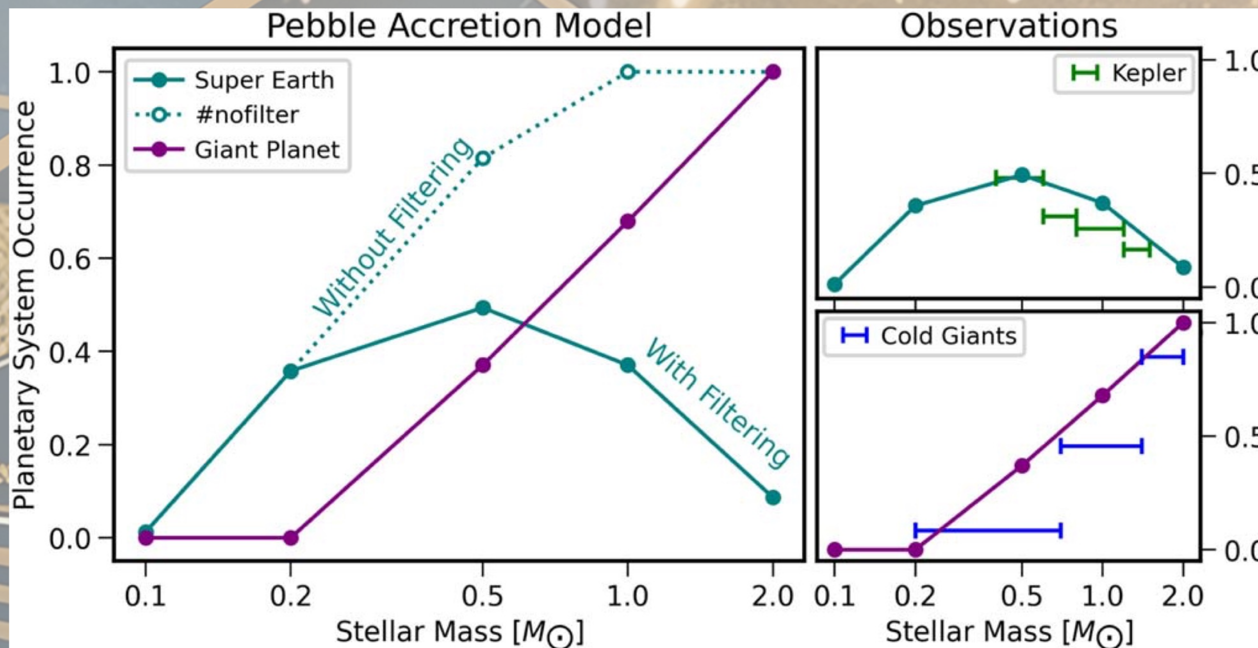
What does this mean for planet formation?

- Lack of gas giants is reasonably well explained by core accretion.
- Prevalence of Earths and Super Earths is less understood.
    - Suggests nearly <u>100% efficiency</u> of solid material accretion (Lu et al. 2020)



What does this mean for planet formation?

Mulders et al. 2021: Gas giants suppress pebble flows and super Earths

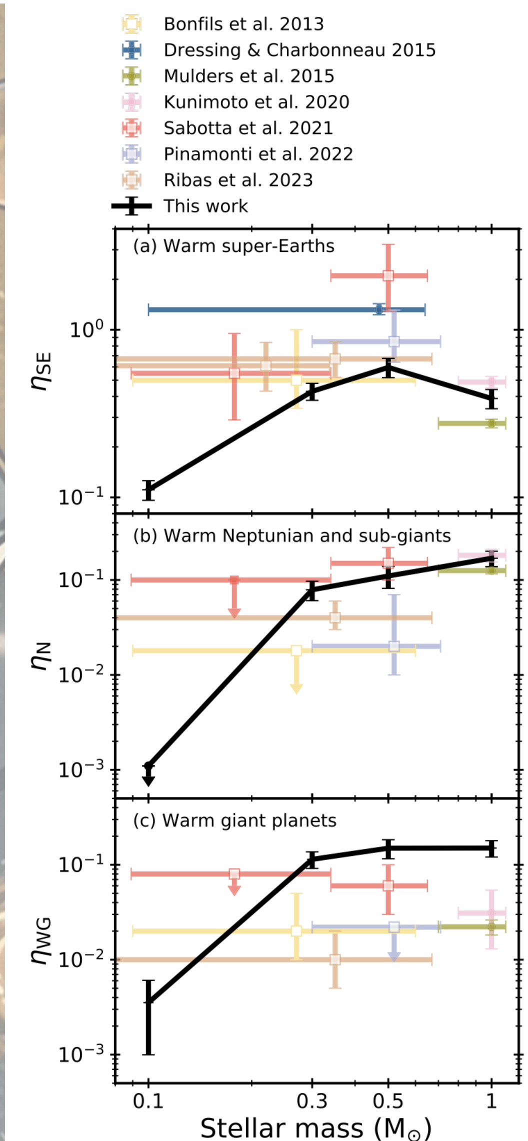


HOWEVER, Bryan & Lee (2025) see a positive correlation between inner super Earths and outer gas giants for most FGK stars, and never an anticorrelation.

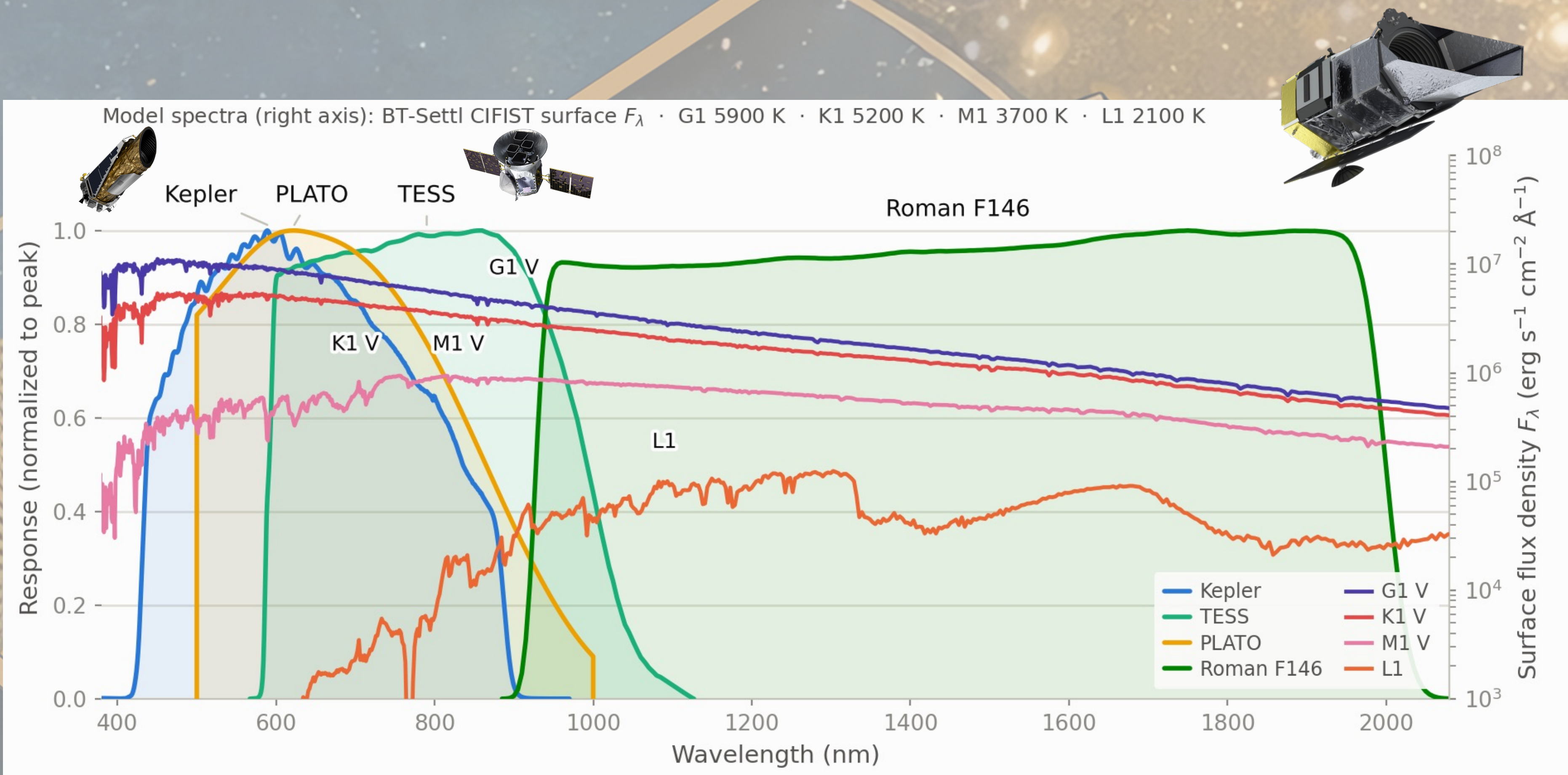
What does this mean for planet formation

Pan et al. (2025) also propose an inverted V-shaped curve for super-Earths, but for different reasons.

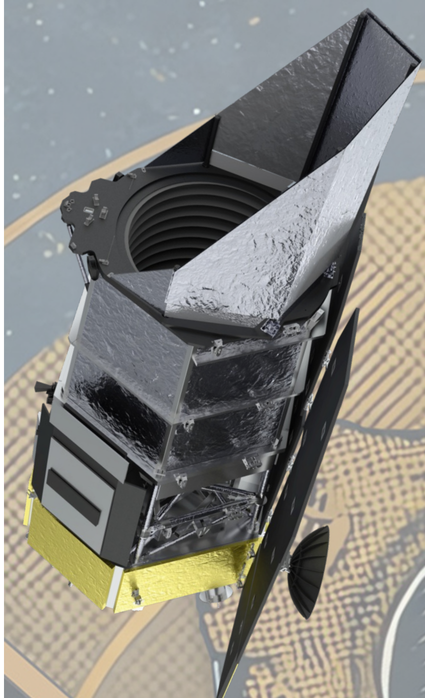
More solid disk mass close to M dwarfs and easier migration inward for outer SEs.

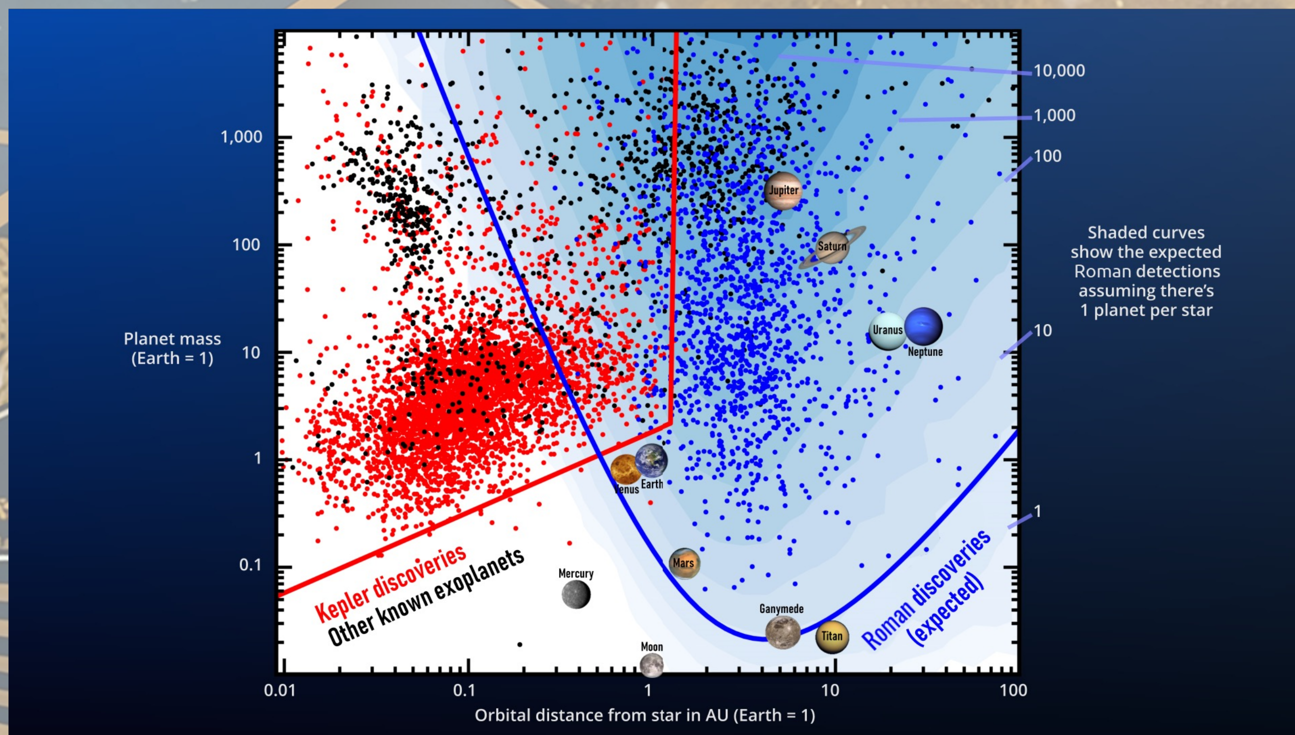


Is there a V-shaped curve? Need more planets around late Ms and ultra-cool dwarfs!



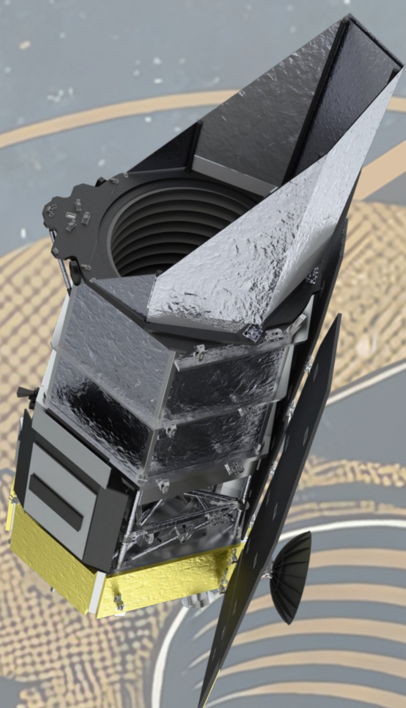
Microlensing will tell us a lot about planet formation around M dwarfs





But will struggle with short-period planets

But Roman is also a transit mission (now)!



1 2026AJ....171..282N 2026/05
Twinkle Twinkle Little Star, Roman Sees Where You Are: Predicting Exoplanet Transit Yields in the Rosette Nebula with the Nancy Grace Roman Space Telescope
Narayan, Ritvik Sai; Soares-Furtado, Melinda; Limbach, Mary Anne *and 3 more*

2 2026MNRAS.546ag088E 2026/02
A planet—host ratio relation to synthesize microlensing and transiting exoplanet demography from Roman
Edmondson, Kathryn; Kerins, Eamonn

3 2023ApJS..269....5W 2023/11 cited: 54
Transiting Exoplanet Yields for the Roman Galactic Bulge Time Domain Survey Predicted from Pixel-level Simulations
Wilson, Robert F.; Barclay, Thomas; Powell, Brian P. *and 8 more*

4 2023AJ....165..251T 2023/06 cited: 20
Predicting the Yield of Small Transiting Exoplanets around Mid-M and Ultracool Dwarfs in the Nancy Grace Roman Space Telescope Galactic Bulge Time Domain Survey
Tamburo, Patrick; Muirhead, Philip S.; Dressing, Courtney D.

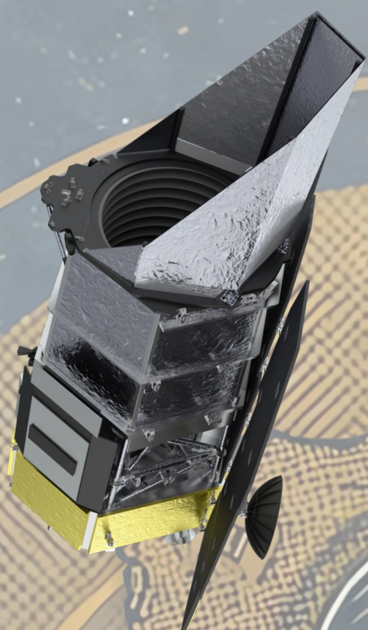
5 2023PASP..135a4401L 2023/01 cited: 17
The TEMPO Survey. I. Predicting Yields of Transiting Exosatellites, Moons, and Planets from a 30 days Survey of Orion with the Roman Space Telescope
Limbach, Mary Anne; Soares-Furtado, Melinda; Vanderburg, Andrew *and 12 more*

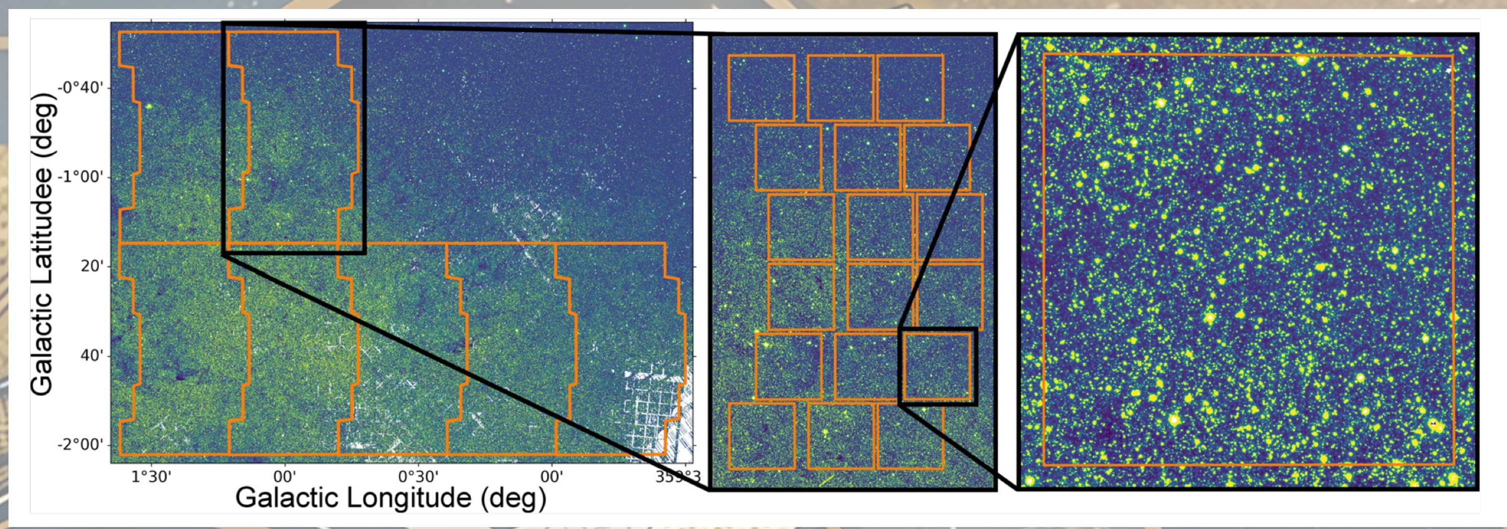
6 2017PASP..129d4401M 2017/04 cited: 43
Measuring the Galactic Distribution of Transiting Planets with WFIRST
Montet, Benjamin T.; Yee, Jennifer C.; Penny, Matthew T.

ADS: property:refereed and (title:"roman" or title:"wfirst" or title:”wide field infrared survey telescope") and title:"transit" and (title:"planet" or title:"exoplanet")

Predicting the Yield of Small Transiting Exoplanets around Mid-M and Ultracool Dwarfs in the Nancy Grace Roman Space Telescope Galactic Bulge Time Domain Survey

Patrick Tamburo[1], Philip S. Muirhead[1], and Courtney D. Dressing[2]

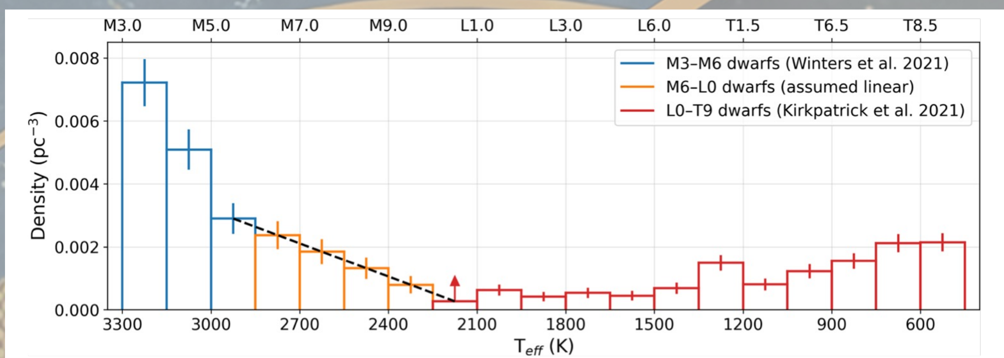


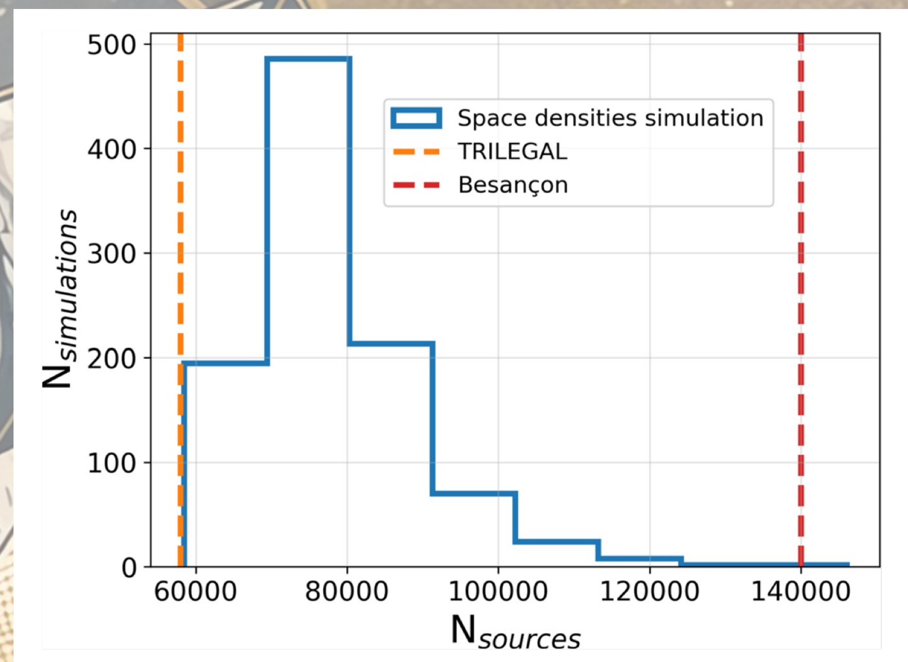


GBTDS is the natural option for large numbers of transiting planets (Montet et al. 2017, Wilson et al. 2023)

We used the “Cycle 7” survey design, since superseded! 15 min cadence, 7 fields.

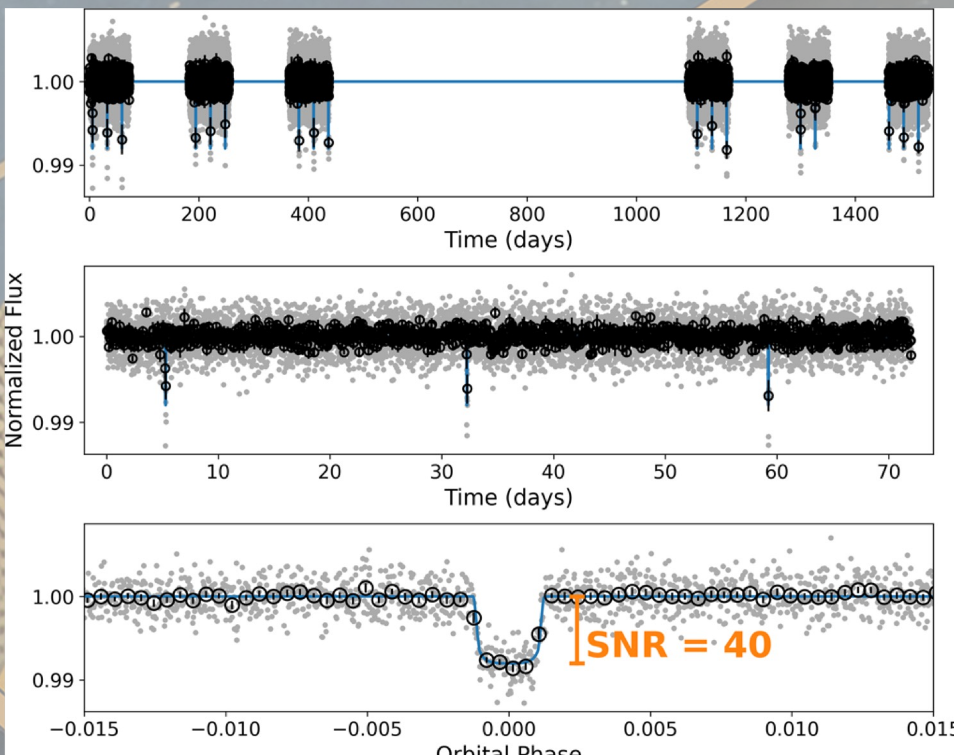
Scaled local space densities into the GBTD survey fields. (Teff < 3300 K, M3+)

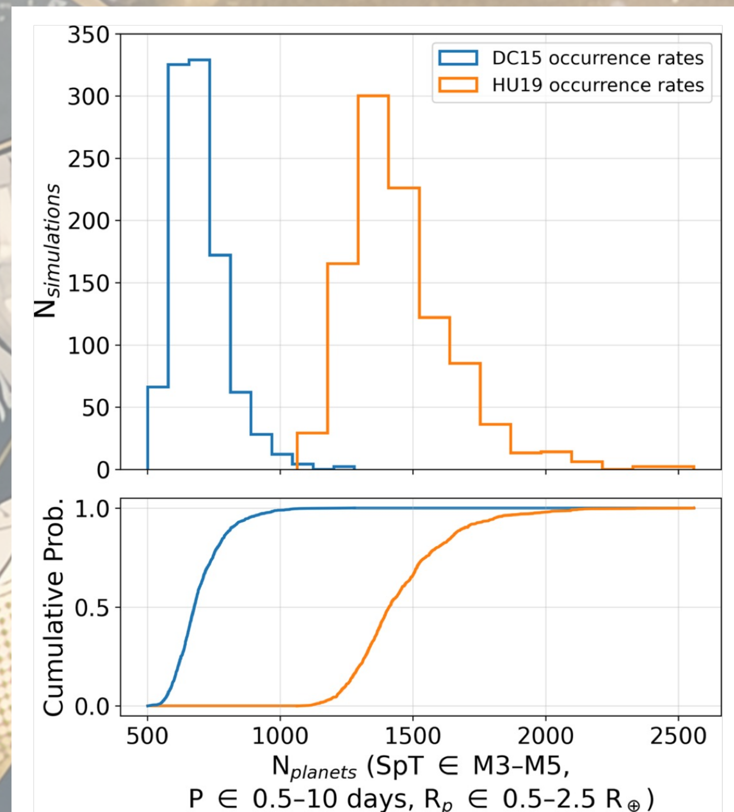




F146 < 21
All < 3.5 kpc away
Assumed field statistics

Populated hypothetical stars with hypothetical planets. (Ignored Fe/H effects and crowding.)





Large numbers of UCD planets will test predictions of the inverted V-shape.

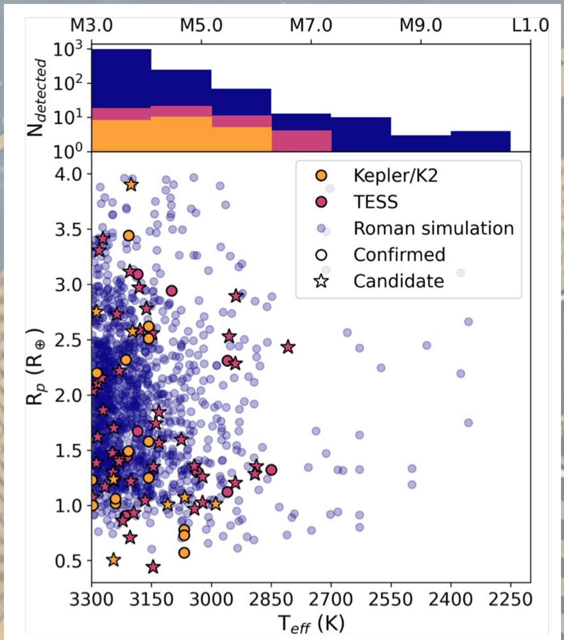


Table 3
Planets Detected in Our Injection and Recovery Simulation as a Function of $T_{\rm eff}$/SpT under the Assumption of the DC15 Occurrence Rates

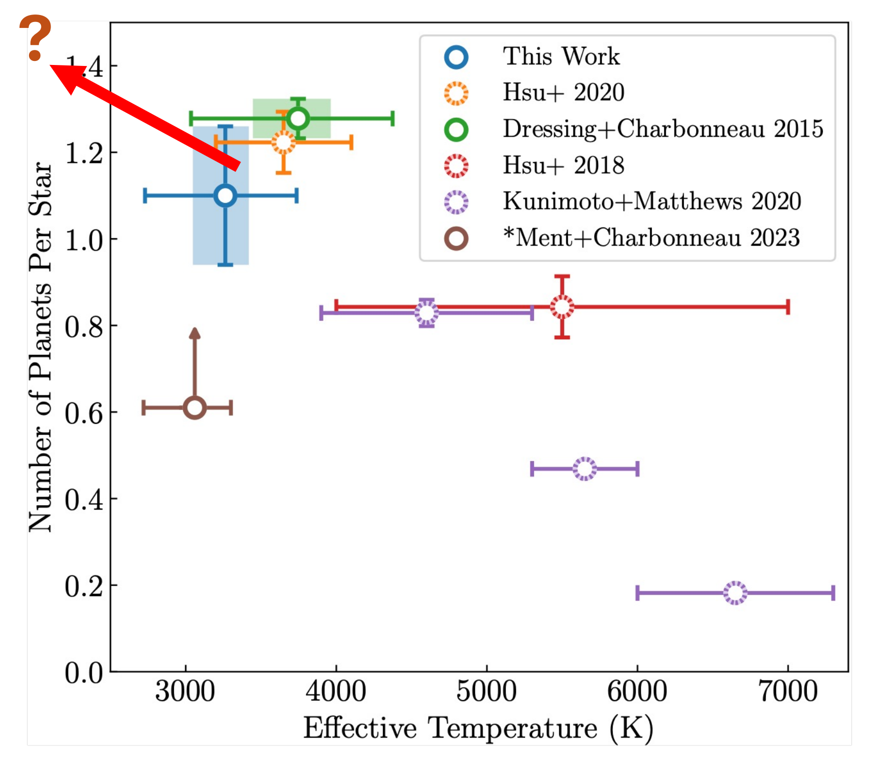
$T_{\rm eff}$ (K)	SpT	Roman	Kepler	TESS
3300–3150	M3.0–M4.0	488^{+114}_{-80}	8	18
3150–3000	M4.0–M5.0	631^{+104}_{-92}	10	21
3000–2850	M5.0–M6.0	163^{+33}_{-27}	5	11
2850–2700	M6.0–M7.0	47 ± 11	0	4
2700–2550	M7.0–M8.0	18^{+7}_{-6}	0	0
2550–2400	M8.0–M9.0	7 ± 4	0	0
2400–2250	M9.0–L0.0	2^{+3}_{-1}	0	0
2250–450	L0.0–T9.0	1^{+1}_{-1}	0	0

Note that Wilson et al. (2023) predicted nearly identical numbers of UCDs with F146<21, but ½ as many planet detections owing to higher SNR requirement (8σ vs 7.1σ) and crowding effects.

Suppose there is no V-shape?

Would suggest a major revision in our understanding of planet formation.

SEs form earlier when disk masses are higher?



Hard Part I:
Build \$$10^9$ telescope capable of finding transiting planets

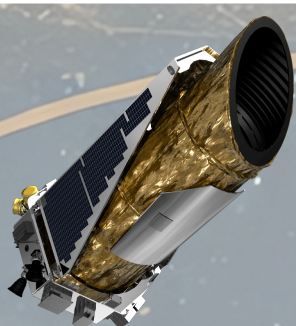
$$f_{\mathrm{cell}} = \sum_{j=1}^{n_{\mathrm{pl,cell}}} \frac{1/p_j}{n_{\star,j}},$$

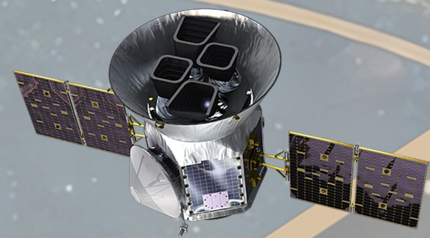
Hard Part II:
Knowing thy stars

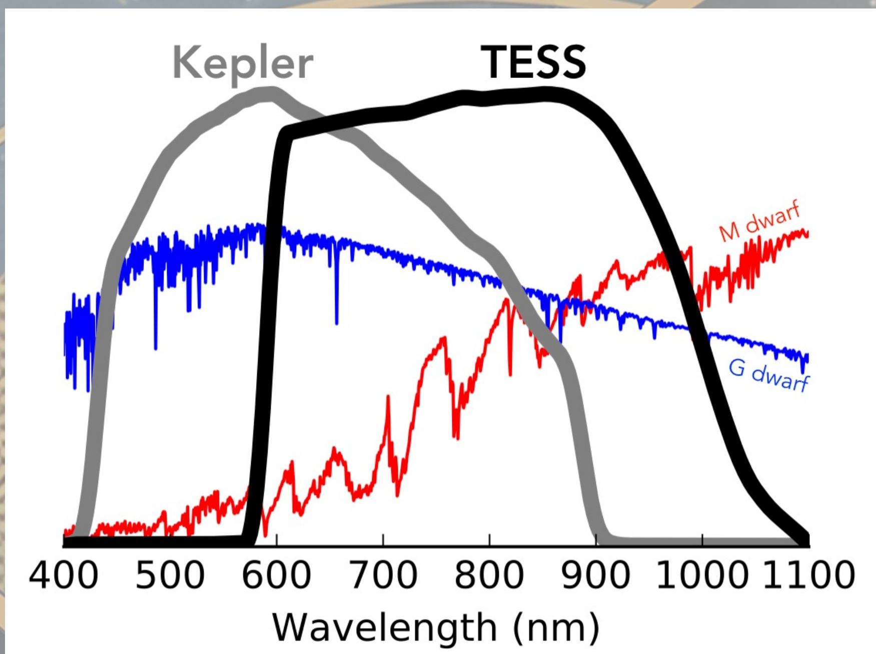
Most have Gaia G>23, so we won't have many luminosities.

Mining the Roman GBTDS for Ultracool Dwarfs: Evolving Variability and Transiting Companions

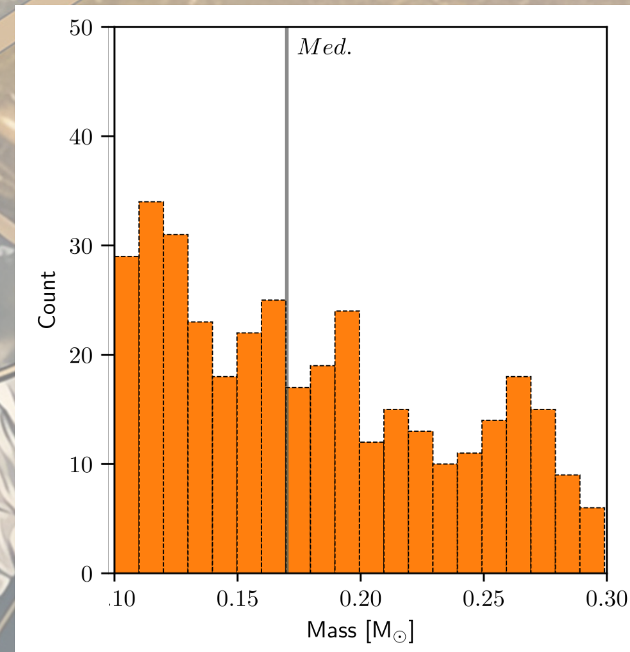
Principal Investigator	Mary Anne Limbach
PI Institution	University of Michigan
Co-Investigators	Brooke Kotten (University of Michigan) Rohan Gupta (University of Michigan)







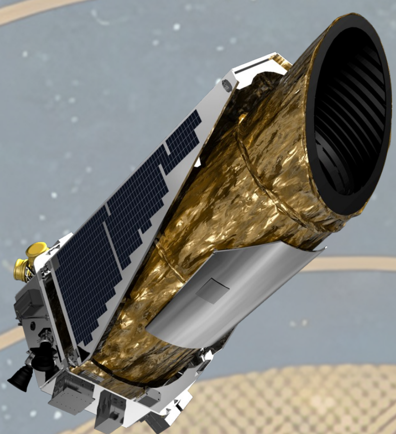
Credit: TSSC



Ment & Charbonneau (2023)

Redder bandpass of TESS enabled observations of many more mid-to-late Ms

Though cadence limited stats to P<7 days



Comparison to FGK stars
Mulders et al. (2015)