A High Mass and Low Obliquity for the Young Neptune K2-25b

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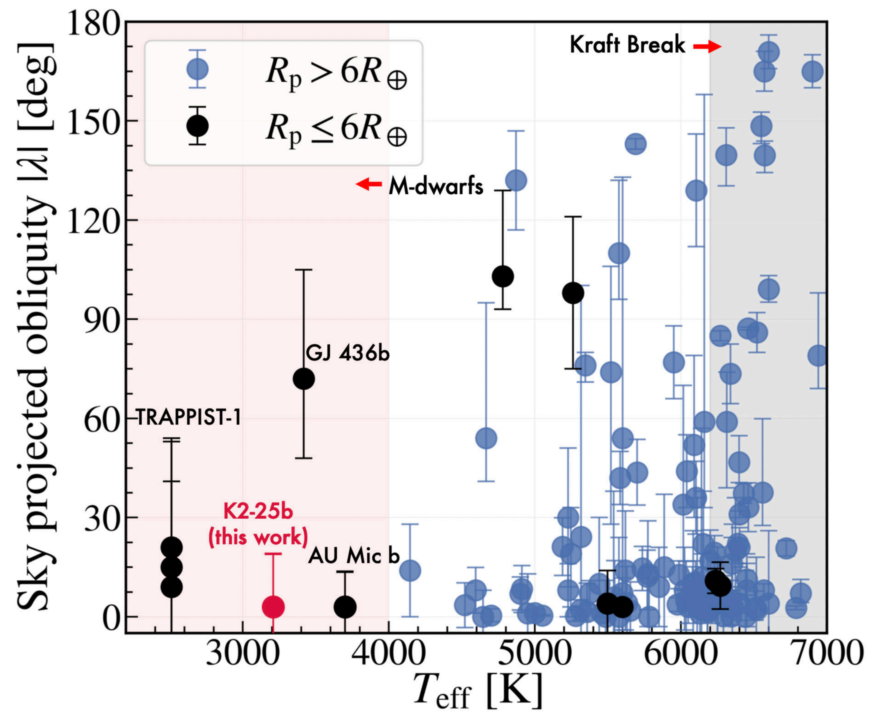
Young planets allow us study how planets form and evolve

Young systems have had less time to evolve from their formation state than older planets, and thus are useful probes of planet formation and subsequent evolution.

Orbital eccentricity and **stellar obliquity**—the angle between the stellar rotation axis and the planet orbit normal—are powerful probes of planet formation and dynamical interactions.

We present the detailed characterization of **the K2-25b system, which is one of very few M-dwarf planets that has its mass, eccentricity, and obliquity constrained.**

Only **4 M-dwarf planetary systems have measured obliquities** via the Rossiter-McLaughlin (RM) effect.



K2-25b is a **Neptune-sized** planet orbiting an M4.5 dwarf in the ~700MYr Hyades cluster discovered in K2-data (see Mann et al. 2016).

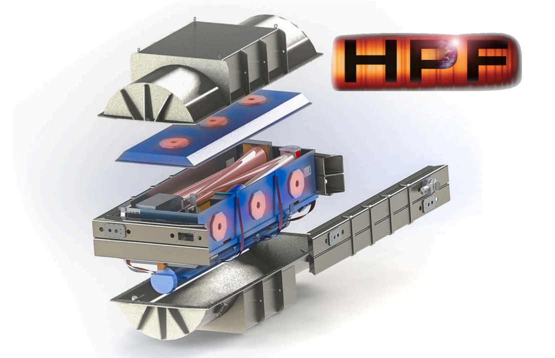
Orbiting a young, rapidly rotating M-dwarf, K2-25b is amenable for **Rossiter-McLaughlin observations** to constrain its obliquity.

Stellar Parameters	
P_{rot}	1.88days
Spt. Type	M4.5
Age	~700MYr
Jmag	11.3

Planet Parameters	
P_{orb}	3.5days
R	3.4REarth
M	25±5MEarth
e	0.43±0.05

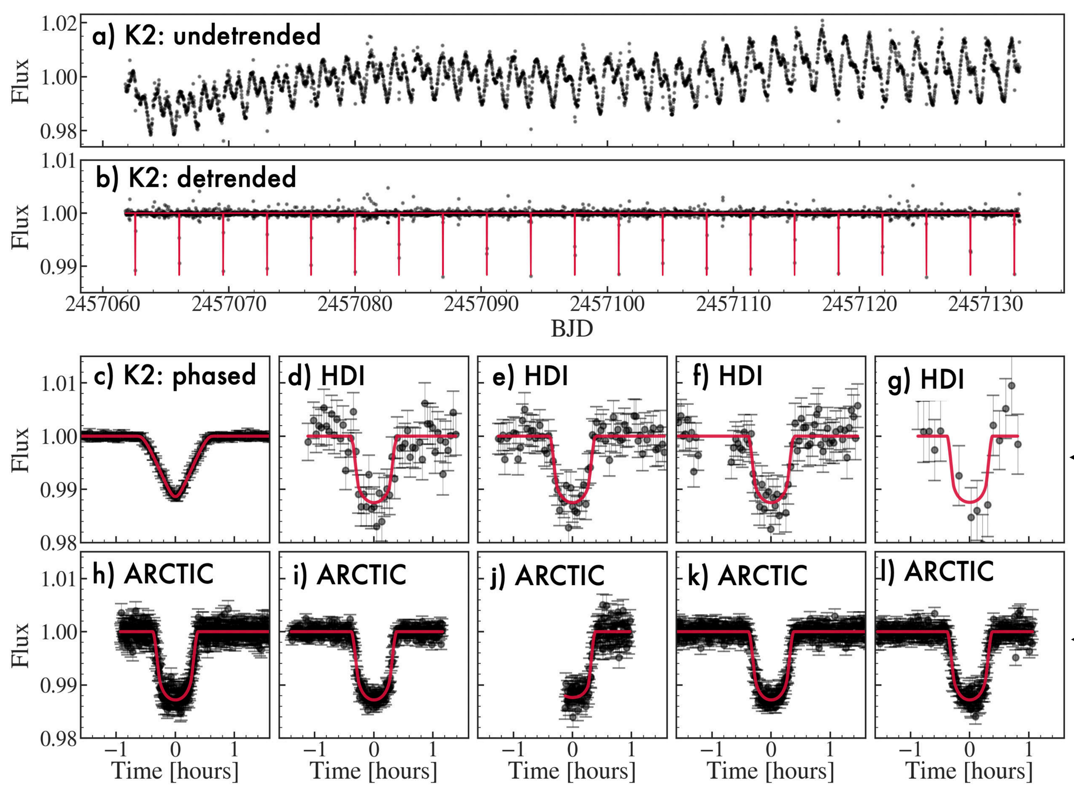
The Habitable-zone Planet Finder (HPF) is a near-infrared spectrograph on the 10m Hobby-Eberly Telescope at McDonald Observatory.

Wavelength range: 810-1280nm
Resolution: 55,000
Temp. stability: 1mK (Stefansson et al. 2016)
Calibrator: Laser-Frequency Comb (LFC)
Precision: ~1.5m/s (Metcalf et al. 2019)



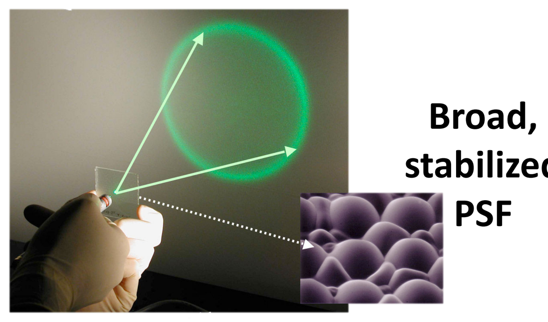
We characterized the properties of K2-25b using diffuser-assisted observations and precision RV observations in and out of transit

We used precision **diffuser-assisted photometry** to constrain the orbital parameters of K2-25b.



We use the **Photoeccentric Effect** to help constrain eccentricity from the transits.

Engineered Diffusers deliver precision photometry (Stefansson et al. 2017).



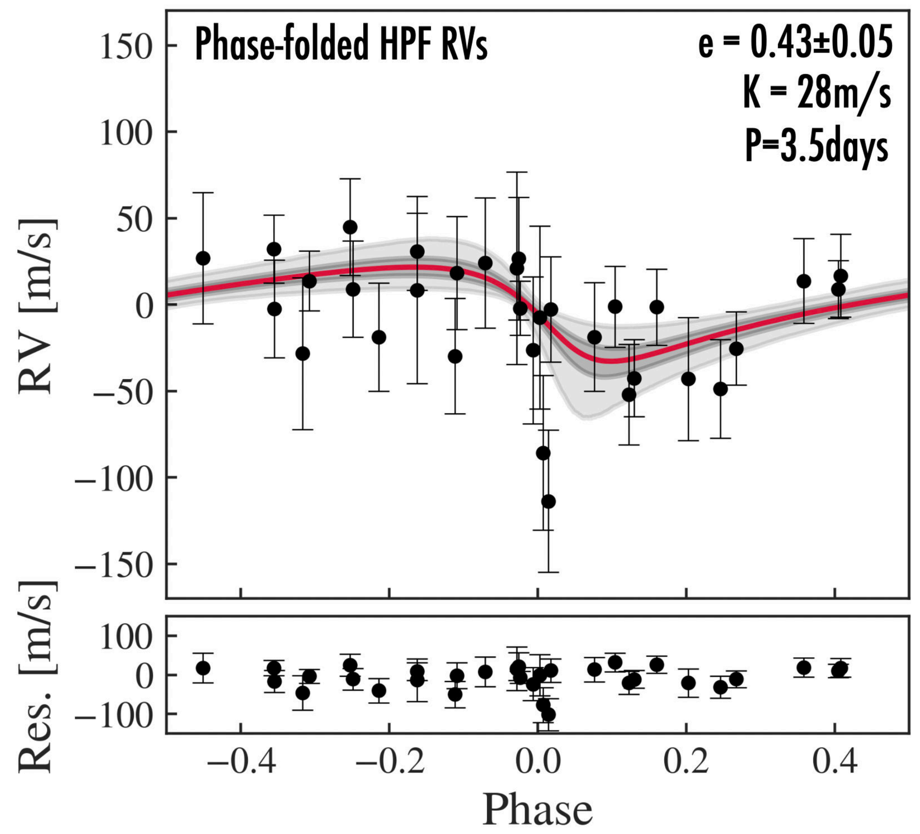
3.5m@APO

ARCTIC imager

0.9m WIYN

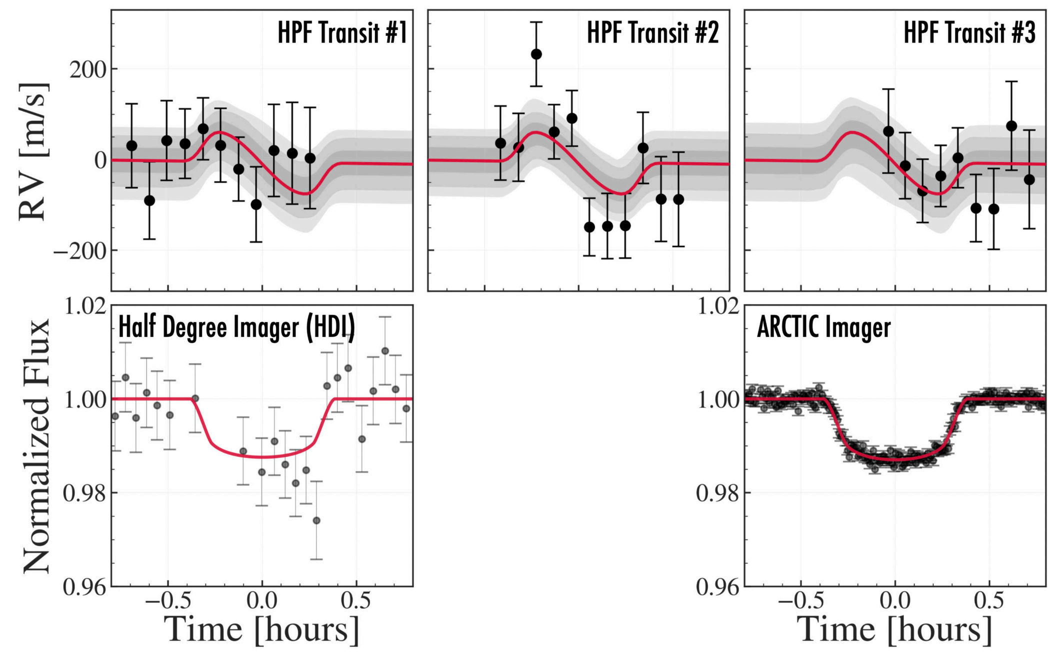
Half-Degree Imager (HDI)

We constrain the mass to be **M=25±5MEarth**



We use a quasi-periodic **Gaussian Process** used to model the stellar activity.

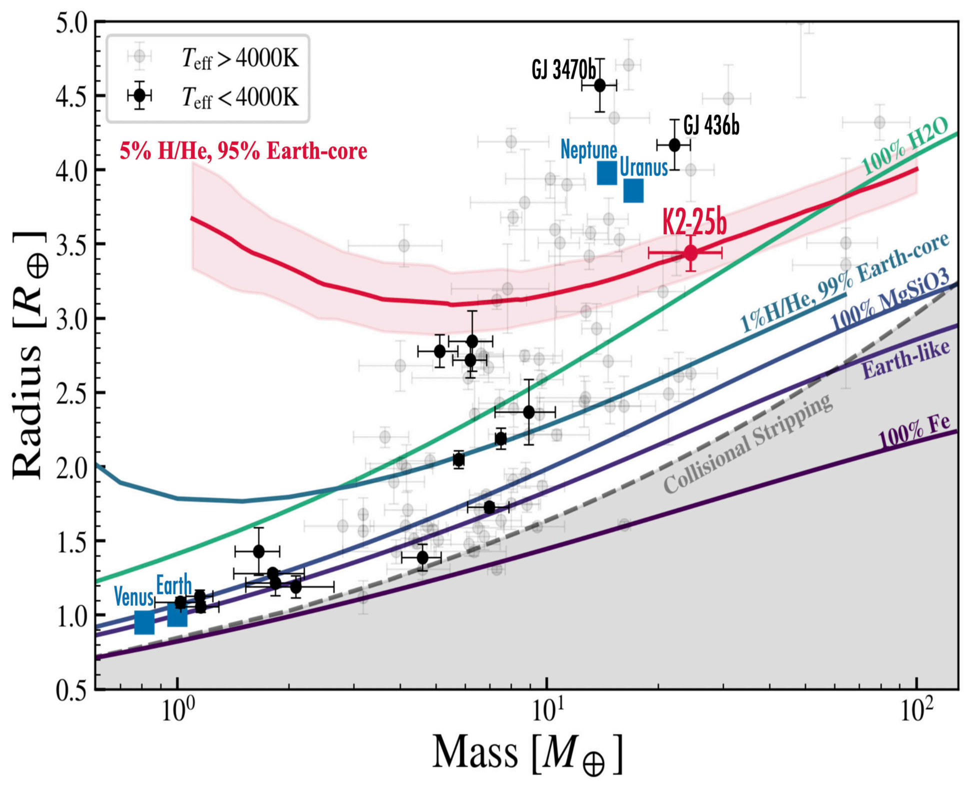
Three HPF Rossiter-McLaughlin effect observations of K2-25b favor a pro-grade **well-aligned orbit** (**λ**=3±16°).



We obtain a **true obliquity** of: $\psi = 17^{+11}_{-8}{}^\circ$

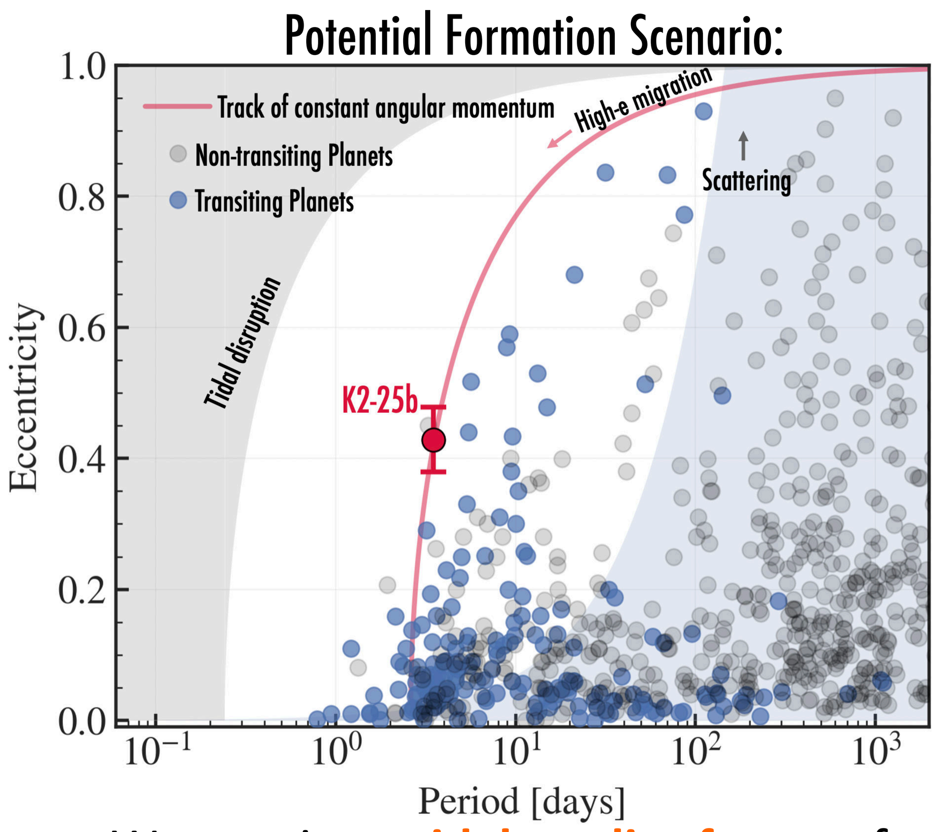
K2-25b is a dense sub-Neptune with a well-aligned, but eccentric short-period orbit

K2-25b is dense for its size, and likely has ~5% H/He atmosphere, assuming a H/He atmosphere enveloped by a rocky core.



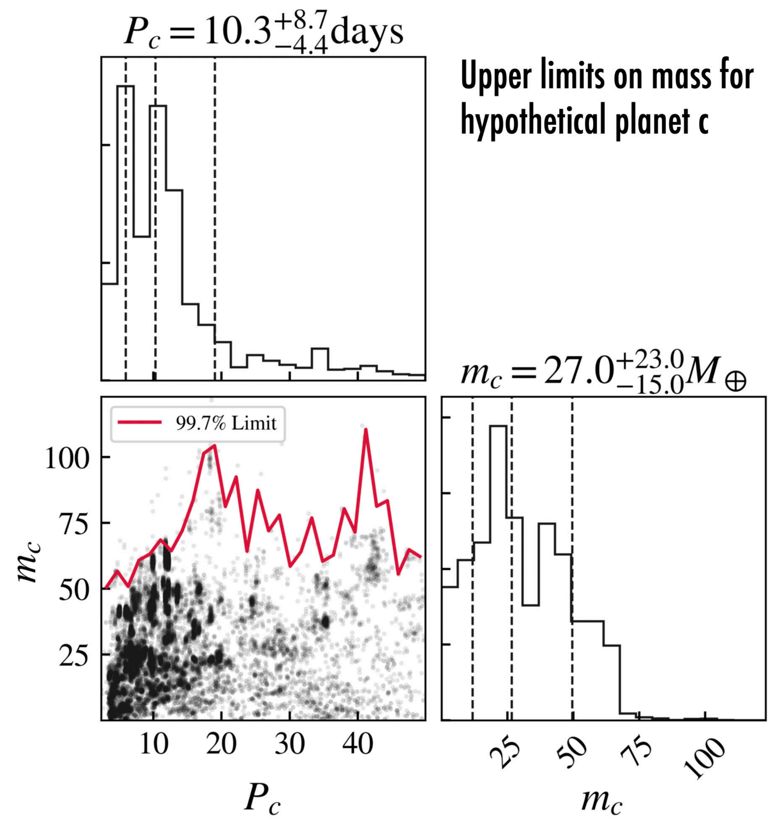
K2-25b is **similar to GJ 436b** (similar R, P, M), both eccentric. However, GJ 436b is misaligned, while K2-25b is well-aligned.

K2-25b could have formed via high **eccentricity-migration** to explain its moderate eccentricity but low obliquity.



We require a **tidal quality factor** of Q’>10[5] to get a circularization timescale >700MYr

A 2nd planet could help explain the moderate eccentricity. We place upper mass limits **<82MEarth** at 99.7% confidence.



We see **no clear evidence for a second planet** from RVs or photometry

Future Work

Future Hubble/JWST observations could constrain the **atmospheric properties** of K2-25b, which could have a high mean-molecular weight atmosphere.

Measuring the obliquities of **more M-dwarf systems** will give further insights into their formation and evolution.

M-dwarf planet radius ratios are large which enables obliquity studies of smaller planets, and of planets in **multi-planet** systems.

Occurrence of Hot Jupiters is lower around M-dwarfs. Does this result in **different orbital architectures** in M-dwarf systems than those seen in for earlier-type systems?

Paper submitted — on arXiv soon !

Sagan Exoplanet Summer Workshop 2020
Extreme Precision Radial Velocities

References:
Dawson & Johnson 2012)
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