K2-149: A HIGHLY PACKED SYSTEM WITH FOUR NEW SUB-NEPTUNES

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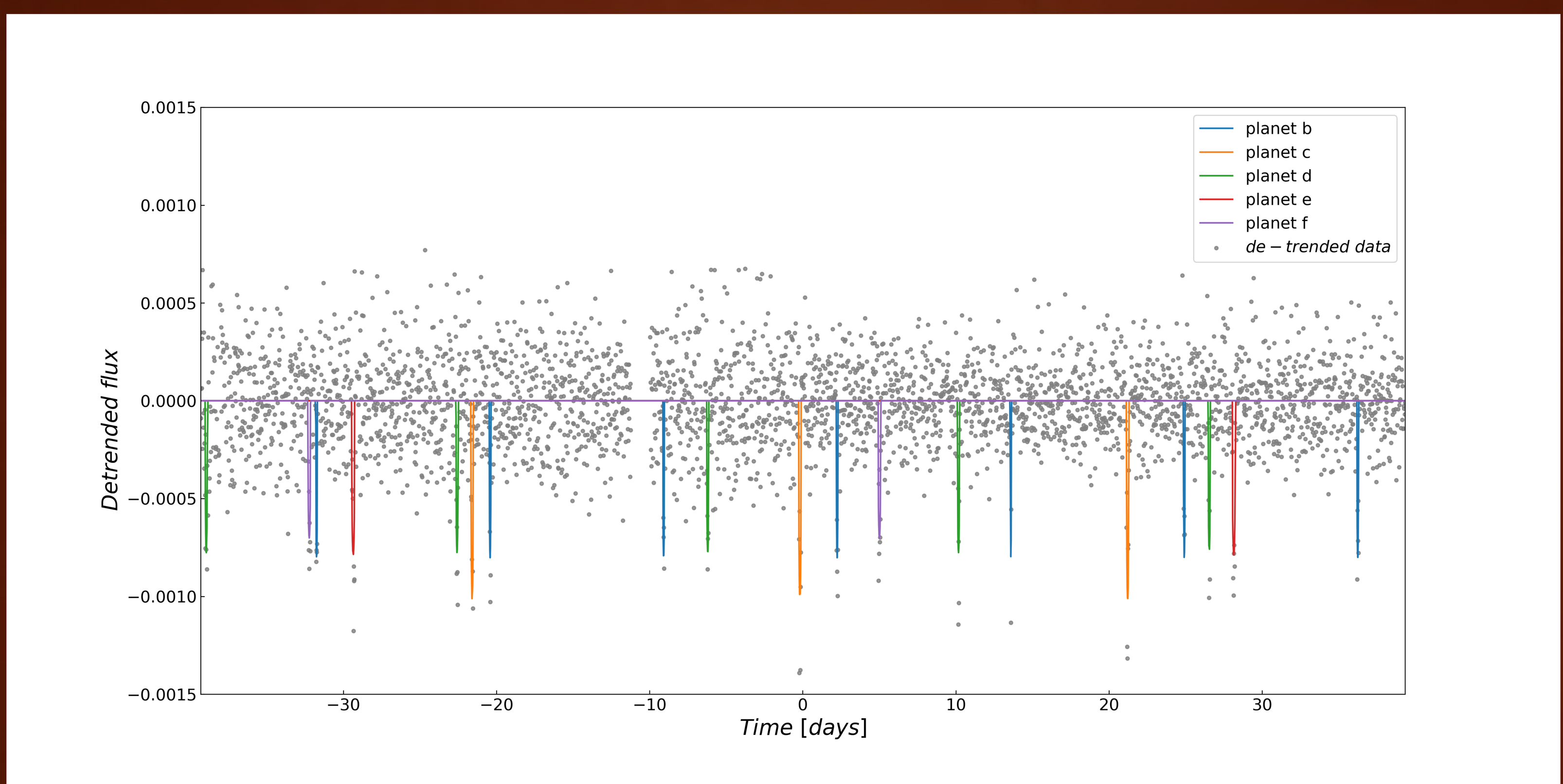
OVERVIEW

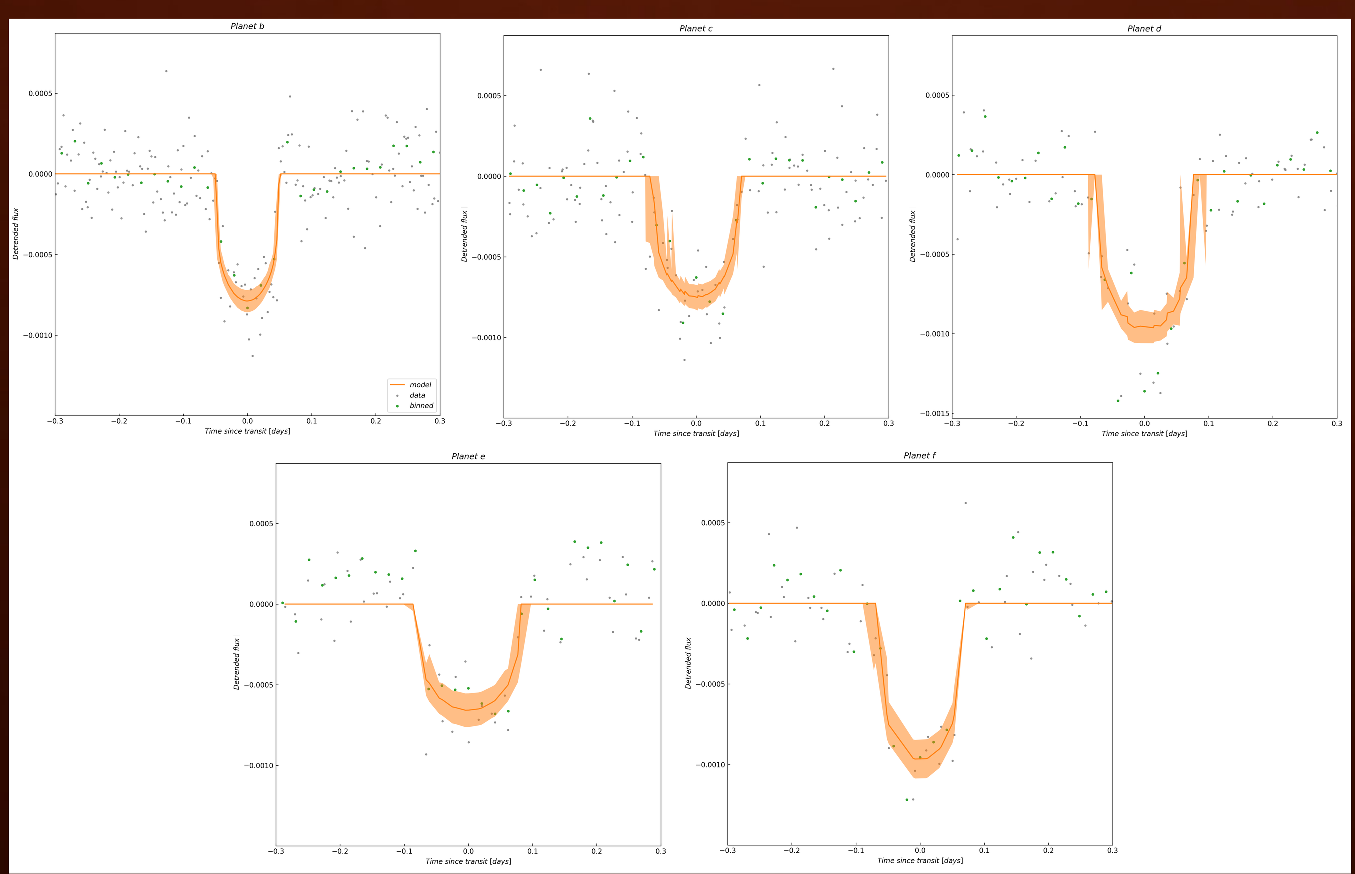
- We report the discovery of four new transiting sub-Neptunes orbiting **K2-149** (EPIC 220522664), an M1 (Kp=13.79, J=11.45) star.
- Aside the previously confirmed K2-149 b, we announce four new transiting planets, K2-149 c, d, e and f, whose measured orbital periods and radii were 16.37, 21.38, 37.23 and 57.47 days, and 1.61, 1.82, 1.53 and 2.08 $R_\oplus$, respectively.
- K2-149 f has an irradiation $S/S_\oplus$=1.04 that places it within the optimistic habitable zone of an M1 star, close to the inner edge of the conservative HZ.
- K2-149 is the second most packed multi-planetary system of transiting sub-Neptunes. This could result in strong planetary interactions, probably detectable via transit-timing variations (TTVs).
- We plan to propose CHEOPS observations of the K2-149 system to further investigate the possible planets interactions and, to a lesser extent, to update and increase the precision of the K2 computed ephemeris and to detect new transiting planets.

TRANSIT SEARCH AND MCMC ANALYSIS



K2-149 Gaussian process flattened `EVEREST 2.0` light curve with planet fits.

- K2-149 b was already discovered by [4].
- The new planets were found as part of the `TFAW` survey [1].
- `EVEREST 2.0` light curve and `TLS` transit detection [3] were used.
- We only consider **significant periods** (SDE≥9.0, i.e FAP $<10^{-4}$) that have passed our multi-layer vetting procedure [1].



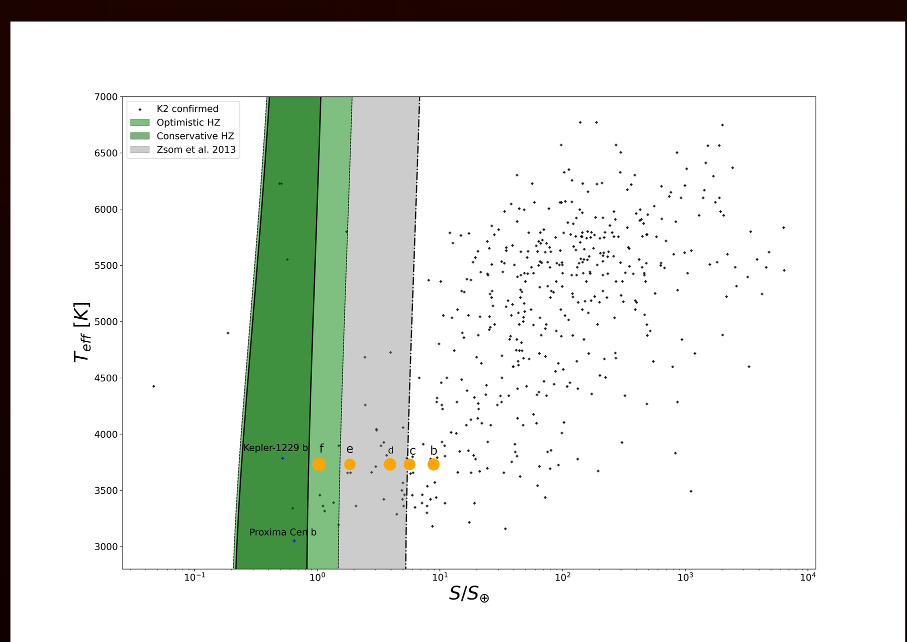
Phase-folded K2-149 light curves for the five transiting planets with best-fit transit models overlaid. Orange-shaded areas comprise the 16% and 84% percentiles.

Table 2. MCMC posterior transit parameters values and their uncertainties (25% and 75% quantiles) for the K2-149 planetary system.

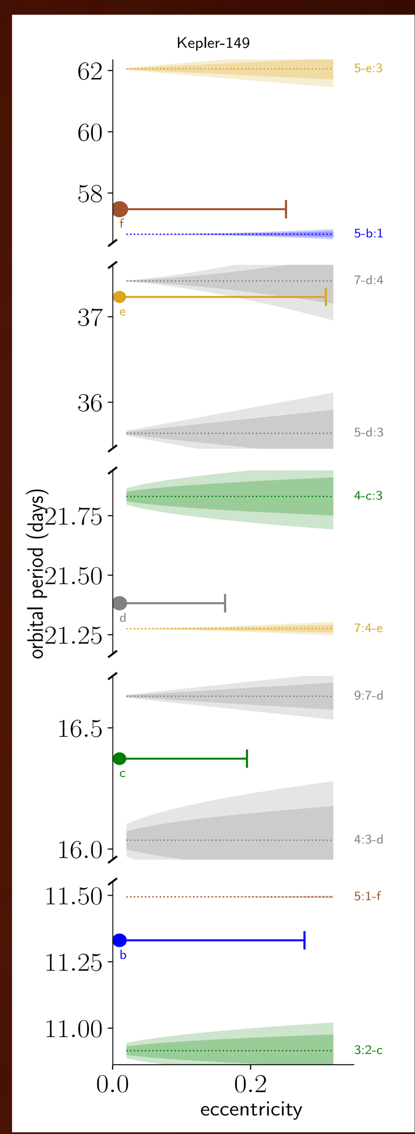
Planet	T_0(BJD-2454833)	P(days)	$a(AU)$	$R_p(R_\oplus)$	$i(^\circ)$
b	$2566.6756^{+0.0033}_{-0.0047}$	$11.3308^{+0.0011}_{-0.0009}$	$0.0834^{+0.0028}_{-0.0028}$	$1.7326^{+0.0962}_{-0.1000}$	$90.5973^{+0.6533}_{-1.8384}$
c	$2559.4740^{+0.0190}_{-0.0133}$	$16.3729^{+0.0037}_{-0.0058}$	$0.1045^{+0.0027}_{-0.0026}$	$1.6065^{+0.1081}_{-0.0951}$	$90.0011^{+0.5700}_{-0.5718}$
d	$2576.8494^{+0.0131}_{-0.0207}$	$21.3822^{+0.0252}_{-0.0104}$	$0.1256^{+0.0025}_{-0.0025}$	$1.8220^{+0.0986}_{-0.0990}$	$89.9996^{+0.3770}_{-0.3787}$
e	$2566.1986^{+0.0106}_{-0.0097}$	$37.2316^{+0.0144}_{-0.0145}$	$0.1829^{+0.0027}_{-0.0027}$	$1.5315^{+0.1437}_{-0.1434}$	$90.0063^{+0.4540}_{-0.4640}$
f	$2569.0908^{+0.0060}_{-0.0069}$	$57.4714^{+0.0078}_{-0.0068}$	$0.2440^{+0.0028}_{-0.0028}$	$2.0808^{+0.1650}_{-0.1602}$	$89.4812^{+0.0368}_{-0.0311}$

K2-149 f WITHIN THE OPTIMISTIC HZ

- K2-149 f has an irradiation of $S/S_\oplus$=1.04.
- This places it **within the optimistic HZ of an M1 star, close to the inner edge of the conservative HZ.**
- K2-149 e and d are within the HZ for hot desert worlds [7].

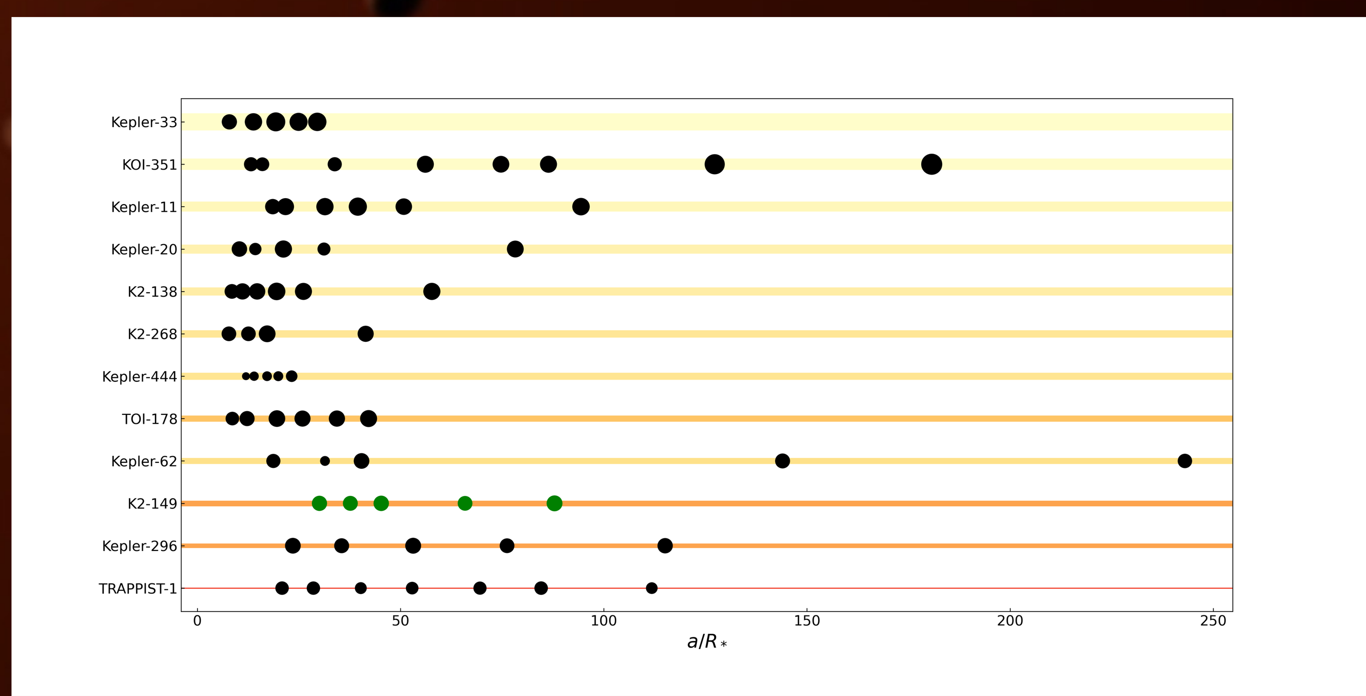


MEAN-MOTION RESONANCES AND PLANET GAPS



- Ratio of orbital periods between successive K2-149 planets are: c:b = 1.445, d:c = 1.306, e:d = 1.741, f:e = 1.544.
- Estimated planet masses from mass–radius relationships in [5].
- Mean-motion resonance widths are analytically estimated as in [6] to know how close the planets are from possible resonances.
- K2-149 e is sufficiently near its mutual 7-d:4 resonance at low eccentricity for its dynamics to be affected, likely inducing TTVs.
- The rest of planet pairs are not near any low-order resonances.
- Study of additional planets in inner/exterior orbital gaps is underway.

COMPARISON TO OTHER PACKED SYSTEMS



Orbital spacing of systems with ≥4 transiting planets. Systems are from largest (top) to smallest (bottom) stellar host. Regions are colored according to the host temperatures. Colored regions widths are scaled to the stellar radii. Planets sizes are in $R_\oplus$ but logarithmicaly enlarged.

- K2-149 is the most packed system composed only of sub-Neptune type planets after Kepler-444.
- For example, K2-138, Kepler-11, Kepler-20 show gaps between outermost planets [2]. Further population studies and CHEOPS observations could confirm/rule out this gap for K2-149.

K2-149 CHEOPS OBSERVATIONS

- CHEOPS could unveil possible interactions between K2-149 e and K2-149 d via TTVs and/or the presence of non-transiting planets in the system.
- K2-based ephemeris could be updated, and its precision increased with CHEOPS observations.
- CHEOPS might detect new K2-149 transiting planets.

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