# The young planetary system K2-25: constraints on spots and companions

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## CONTEXT

Exoplanets with short orbital periods (<10 days) may have experienced complex dynamical histories, and shed light on the processes that shape planetary systems. ***Young transiting planets in open stellar clusters make probing these planets' dynamical evolution more accessible:*** young planets are in their most dynamically active period, and the well-constrained ages of stellar clusters make the ages of these planets easily identifiable.

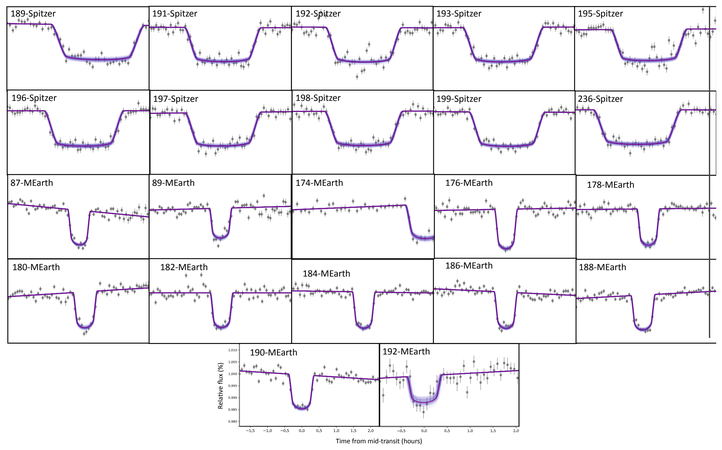


**Fig. 1:** Light curves from all 22 transits analyzed in this project.

## ABSTRACT

K2-25b is a short-period, close-in, Neptune-sized planet orbiting an M4.5 dwarf star in the Hyades open cluster.[1] It is the most accessible transiting planet of its kind, and provides insight into dynamics of Hot Neptunes. ***We explore the possibility of a non-transiting companion as a source of eccentricity, using transit timing variations (TTVs) to probe dynamics of K2-25 system.***

| K2-25b parameters | |
|---|---|
| $P$ *(days)* | 3.49 |
| $R_p/R_*$ | 0.108 |
| $a/R_*$ | 25.3 |
| $e$ | 0.227 |
| $w$ | 98.0° |
| $i$ | 88.1° |

## METHODS

We obtained photometric data of 22 non-consecutive from the Spitzer and MEarth telescopes. We fit light curves individually, using the *BATMAN*[2] and *emcee*[3] tools. *Thao et al. 2019* then fit all transits jointly, from which we derived parameters. ***We confirm a high eccentricity of e=0.227.***

One possibility is that starspots could be causing us to falsely measure a high eccentricity. We see only one obvious spot crossing in our data, and most data was obtained during a low stellar activity phase. We further investigate by looking at whether our measurements change as the star rotates, bringing new spot patterns into view. We find no correlation of measured planet radius with stellar rotation phase, indicating that ***stellar surface inhomogeneities do not significantly impact our data.***

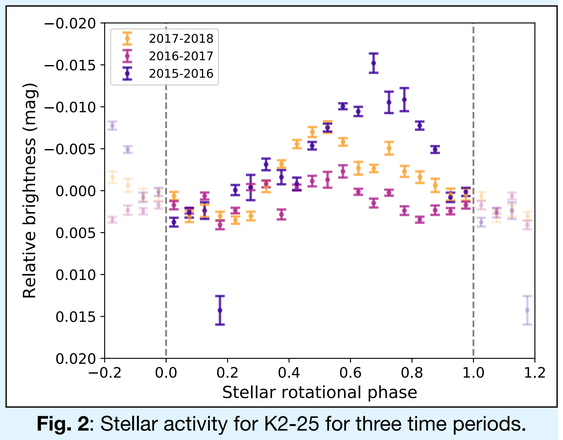


**Fig. 2**: Stellar activity for K2-25 for three time periods.

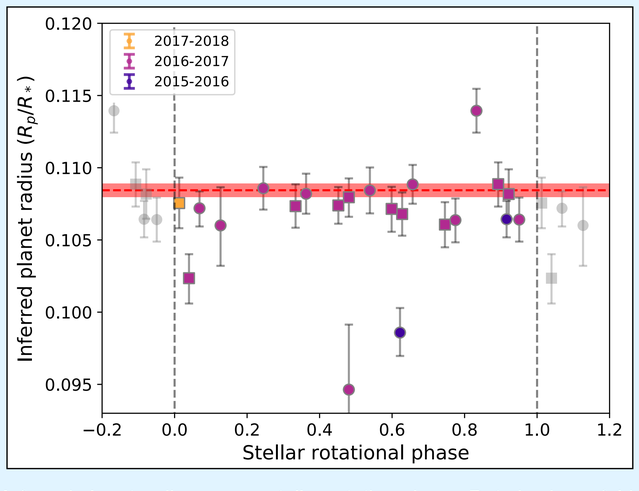


**Fig. 3:** Inferred planet radius versus stellar rotation phase. Data is phase-folded, with repeat points in grey. Red band is average planet radius across transits/instruments.

## RESULTS

Ruling out spot interference, we investigate the possible causes of this eccentricity. We calculate that due to tidal forces, K2-25b should circularize in *~35 Myr.*[4] Since this is much shorter than the age of the system (*~650 Myr)*, we conclude ***eccentricity was not imparted by a single event, but is being actively excited.*** We explore the possibility that this excitation is due to a non-transiting companion.

We look for evidence of a companion by analyzing transit timing variations (TTVs). Results of MCMC analysis reveal no obvious variations. Further analysis **rules out companions >1 M⊕ up to periods of 7 days, and companions >5 M⊕ up to a period of 15 days.** This analysis is not informative at greater periods, except at strong resonances.

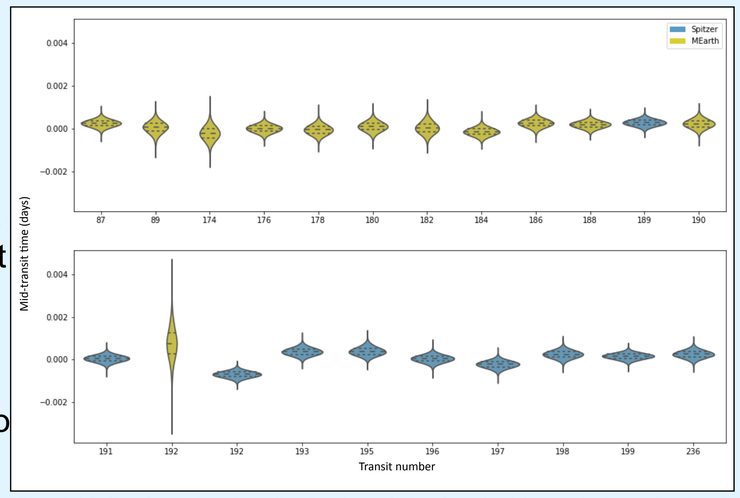


**Fig. 4:** Violin plots showing distribution of simulated mid-transit times (in days) for each transit, obtained using emcee[3] MCMC simulation. The dashed line marks the 50th percentile, and the dotted lines show the 16th and 84th percentile.

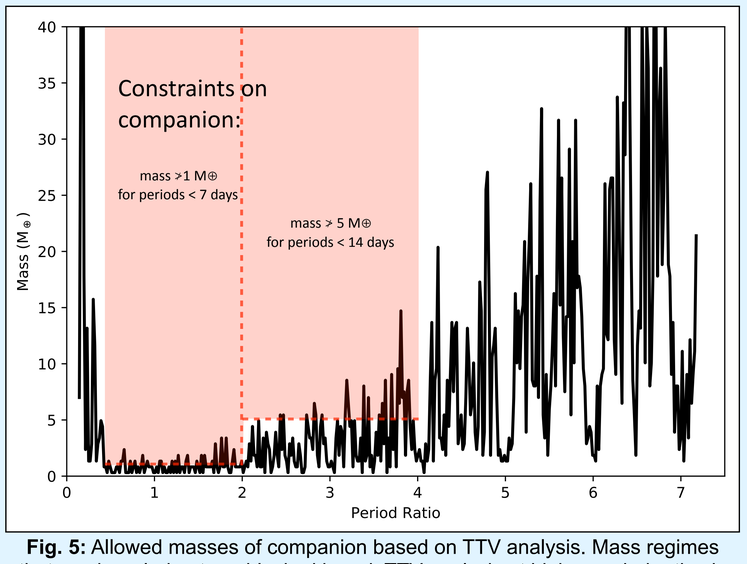


**Fig. 5:** Allowed masses of companion based on TTV analysis. Mass regimes that can be ruled out are blocked in red. TTV analysis at higher period ratios is not very informative, except at integer resonances.

## CONCLUSION

- High measured eccentricity of *e=0.227* is likely not due to spot interference, but is characteristic of the system.
- Since circularization timescale is much shorter than the age of the system (35 Myr < 650 Myr), eccentricity is being actively excited.
- Theoretical companion constrained by observation.
  ***TTV analysis rules out:***
  - ***>1 M⊕ at <7 days***
  - ***>5 M⊕ at <15 days***
- Follow-up with high-precision radial velocity measurements may reveal companion at higher periods, where TTV analysis is less illuminating.

## LITERATURE CITED

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## NEXT STEPS

- High-precision RV follow-up will further constrain mass of planet and theoretical mass of companion.
- Systems in same-age clusters with different stellar rotation could be used to probe eccentricity damping.
- Further observations of young planets could elucidate dynamical histories.