Planet occurrence rates in K2’s ultracool dwarfs

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Planets around ultracool stars

TRAPPIST-1 System

Inner Solar System

Enlarged 25x

Illustration

Artist's rendering - NASA/JPL-Caltech
Example(s) of ultracool star systems

- Catalogue of all discovered planets
- Large gap between TRAPPIST-1 and other M-Dwarf planet candidates
- How many more planets in that gap?
K2’s observations of ultracool stars

- 611 ultracool dwarfs observed by K2
- 445 spectroscopically confirmed (J. Gagne)
- TRAPPIST-1 is an unbiased member of the sample!
Occurrence rate model: Poisson process

Statistical model:
Planet detections drawn from inhomogeneous **Poisson process**, with rate parameter $\lambda(R,P) = \eta \times \eta_t \times \eta_d$

Catalogue of planets within a sample of observed stars
Automatic transit search pipeline

- Injection recovery modelling to find detection sensitivity
- Pipeline finds 6 of the TRAPPIST-1 planets
- No other strong detections
Determine completeness with injection-recovery modelling

- **Detection sensitivity:** probability of finding a transit \((R, P)\) if it’s in the lightcurve.

- Fraction of injected signals found

- Integrated over sample of targets

M. Sestovic, B.-O. Demory, *in prep*
Determine completeness with injection-recovery modelling

- **Completeness**
  chance of finding a planet with a random inclination

M. Sestovic, B.-O. Demory, *in prep*
Dependence of occurrence rate on radius

- **Occurrence rate per star**, integrated over period
- 0.5 – 40 days
- Upper limits on super earths and above
- Suggests finding TRAPPIST-1 in the sample is lucky

Shading: 1σ width

M. Sestovic, B.-O. Demory, *in prep*
Was TRAPPIST-1 a lucky find?

- If 100% of ultracool stars have a TRAPPIST-1-like planetary system, **we would have a 73% chance of finding at least one**
- If 20% of stars have a system, we would have a 23% chance
- If 5% of stars have a system, we would have a 6.2% chance
- If 1% of stars have a system, we would have a 1.3% chance

- Chances are lower if we “shuffle” the periods
TRAPPIST-1 is a lucky find, and still unique

- Detecting TRAPPIST-1 in the K2 sample implies that either we were lucky, or that such systems are **not rare**
- We can place constraints on the occurrence rates of super-Earths and above, fewer than 1.0 – 0.1 per star.
- More accurate statistical model for occurrence rates; including system architecture and multiplicity would be useful.

**Additional work**

- As a side-effect of the Gaussian process detrending, we obtain periodicities for stellar variability in ultracool dwarfs, can study rotation patterns as a population.

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