A SEARCH FOR PLANETARY ECLIPSES OF WHITE DWARFS IN THE PAN-STARRS1 MEDIUM-DEEP FIELDS

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Abstract

We present a search for eclipses of ∼1700 white dwarfs in the Pan-STARRS1 medium-deep fields. Candidate eclipse events are selected by identifying low outliers in over 4,300,000 light curve measurements. We find no short-duration eclipses consistent with being caused by a planetary size companion. This large dataset enables us to place strong constraints on the close-in planet occurrence rates around white dwarfs for planets as small as 2 $R_\oplus$. Our results indicate that gas giant planets orbiting just outside the Roche limit are rare, occurring around less than 0.2% of white dwarfs. Habitable-zone super-Earths and hot super-Earths are less abundant than similar classes of planets around main-sequence stars. These constraints give important insight into the ultimate fate of the large population of exoplanets orbiting main sequence stars.

Method

- Select 661 WDs via reduced proper motion and $\sim$ 1100 via color-color diagrams and similar control sample.
- Custom-built photometry pipeline to ensure non-detections are recorded
- Search for eclipses by identifying low outliers in the light curves (dropouts).
- We employ a series of automated photometry and image-based filters to eliminate 99.9% of candidate dropouts. Remaining candidates are visually inspected.
- Calculate expected eclipse rates as a function of $R_p/R_\star$, $a/R_\star$ and observed eclipse depth (ΔF).
- Place upper limits on the planet occurrence rates using the expected eclipse rates and Poisson statistics.

Results

- We find no short-duration eclipse events.
- Short-period planets orbiting WDs are rare or non-existent.

Manuscript

This work has been submitted to ApJ and is currently under review. A pre-print manuscript is currently available at:

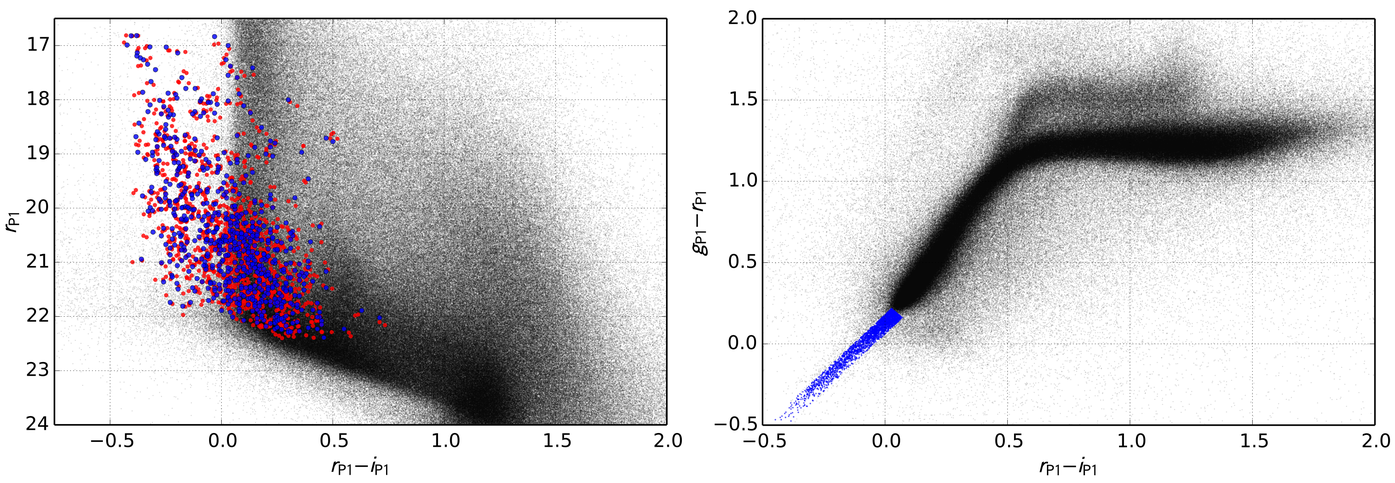
`http://www.ifa.hawaii.edu/users/bfulton/WDeclipse.html`

References

1. Queloz, D., Bouchy, F., Moutou, C., et al. The CoRoT-7 planetary system: two orbiting super-Earths. *A&A* **506**, 303–319, October (2009).

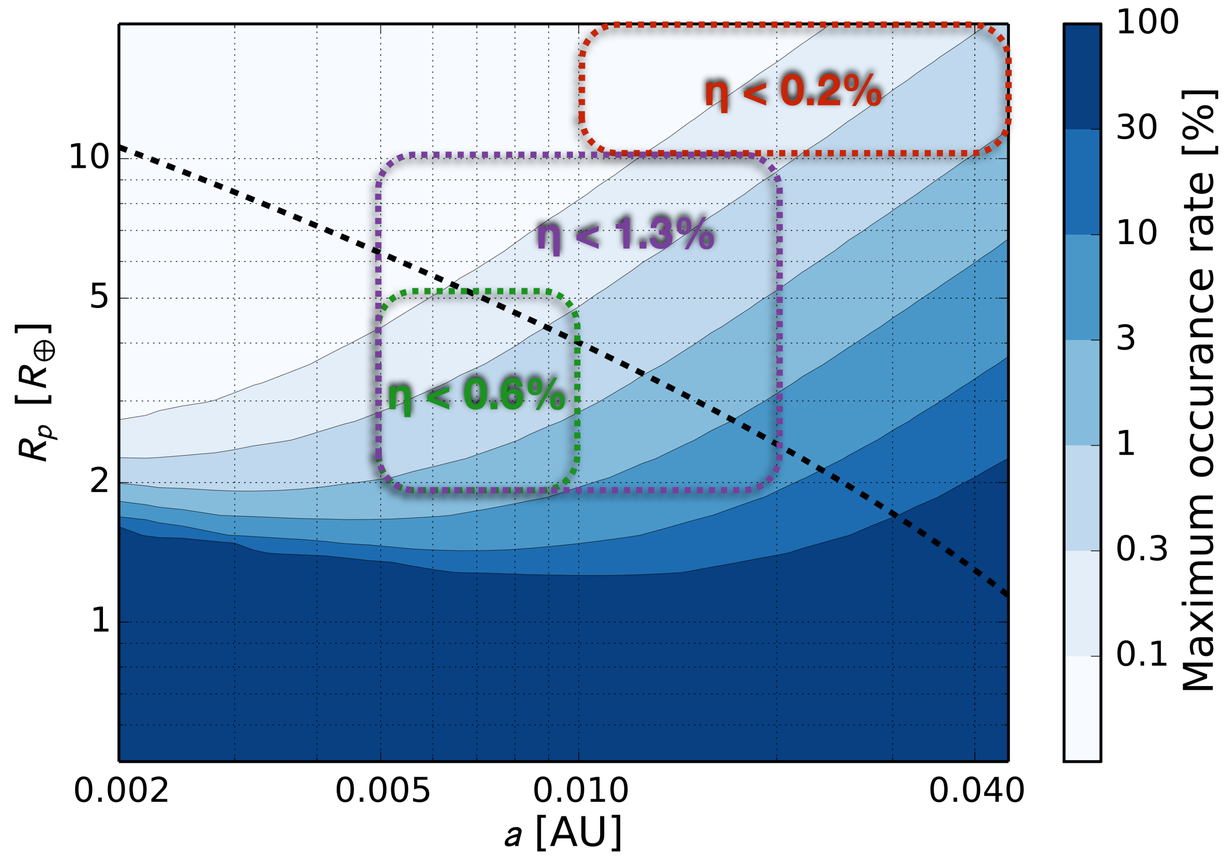
2. Agol, E. Transit Surveys for Earths in the Habitable Zones of White Dwarfs. *ApJL* **731**, L31, April (2011).

WD Sample



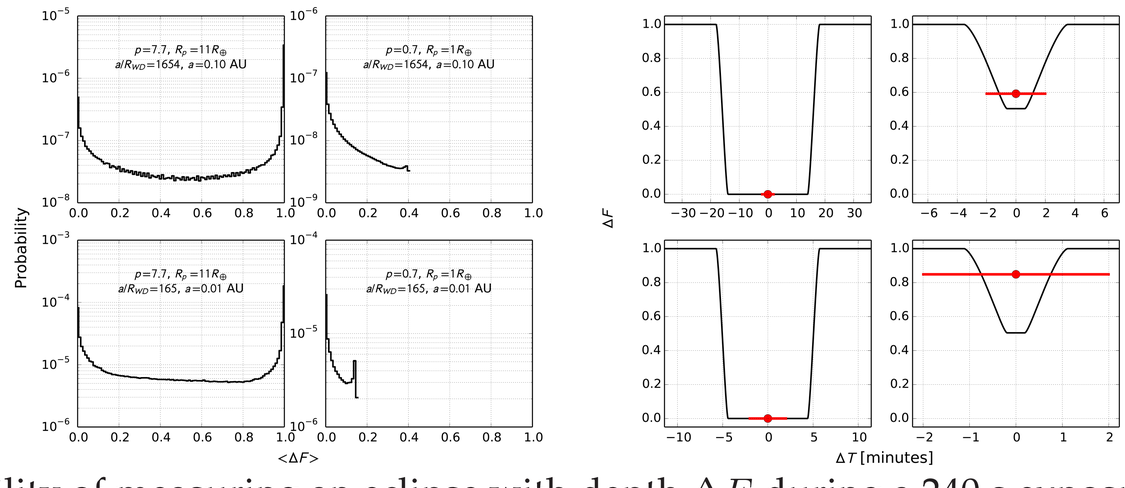
Left: Astrometrically-selected WDs (blue) and control sample stars (red). *Right:* The color-selected WDs (blue points) are identified by the narrow tail of extremely blue stars in the ($g_{\rm P1}$-$r_{\rm P1}$) vs. ($r_{\rm P1}$-$i_{\rm P1}$) color plane. The small black points are all detections from deep stacks of the medium-deep fields that were not selected for either the control or WD samples.

Occurrence constraints



Maximum planet occurrence rate at 68% confidence. The dashed line marks the point where the eclipse duration is equal to the integration time. The maximum occurrence rates will be slightly underestimated in the region to the upper right of this dashed line. The region marked in red corresponds to Jupiter-sized planets orbiting just outside the Roche limit much like hot Jupiters around main sequence stars. The region in green corresponds to hot super-Earth-sized planets much like CoRoT-7b[1]. The region in purple corresponds to super-Earth to Jupiter-sized planets in the continuously habitable zone (CHZ[2]).

Transit probabilities and shapes



Left: probability of measuring an eclipse with depth ΔF during a 240 s exposure of a random WD that hosts a companion with the orbital parameters shown. p is the planet to star radius ratio, R_p is the planet radius in Earth radii, a/R_{WD} is the semi-major axis normalized by the WD radius, and a is the semi-major axis in AU. *Right:* Model eclipse light curves for the planet parameters shown on the left and an impact parameter 1.0. The red circle is the mean flux for an exposure centered on the mid-eclipse time. The bar extending from the red circle shows the length of the exposure time.