Neptunes in the Noise:
Improved Precision in Exoplanet Transit Detection

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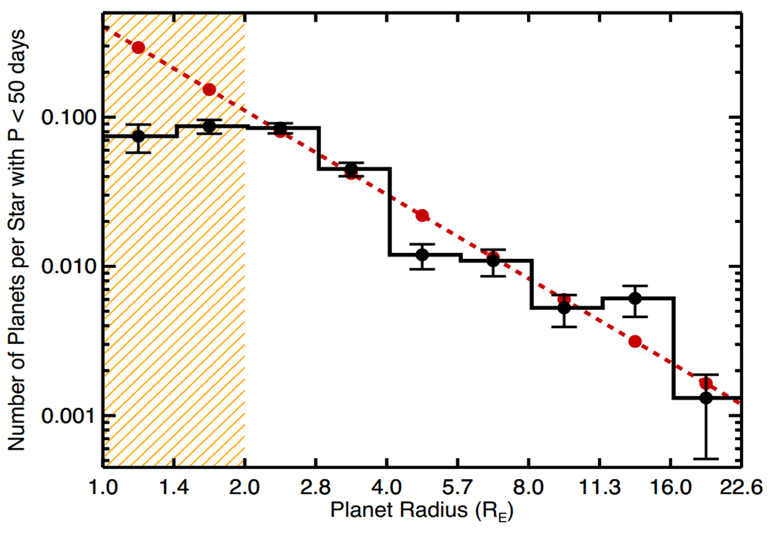


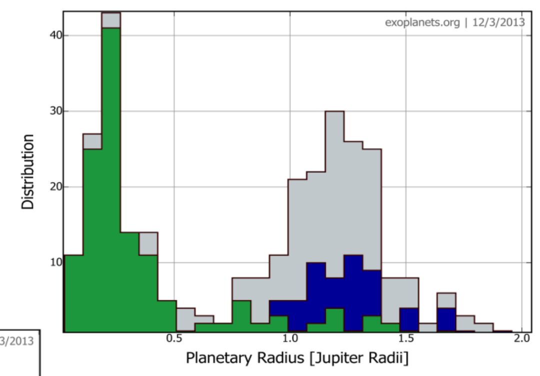
Figure 1: Distribution of Kepler planet radii, showing that small radius planets are more common than larger ones.

We present early results from a new analysis of raw data taken with the SuperWASP telescope[1]. This is shown to reduce the noise in the resulting lightcurves by up to a factor of 2 for the brightest stars compared to the existing pipeline. These new data are relatively free from systematics, and approach the millimagnitude level on transit duration timescales. Thus, we are able to detect smaller planets that pass in front of (transit) a star than those so far discovered by SuperWASP.

Kepler analysis suggests that small radius planets are more common than large ones, as seen in Figure 1 [2]. Figures 2 and 3 show that current SuperWASP exoplanets predominantly have large radii and are around stars dimmer than 11th magnitude. By reducing noise, our method can potentially find smaller planets around brighter stars which will be more valuable for follow-up.

Figure 2 (right):

Distribution of radii of all known exoplanets (grey), with those from Kepler (green) and SuperWASP (blue) also shown.



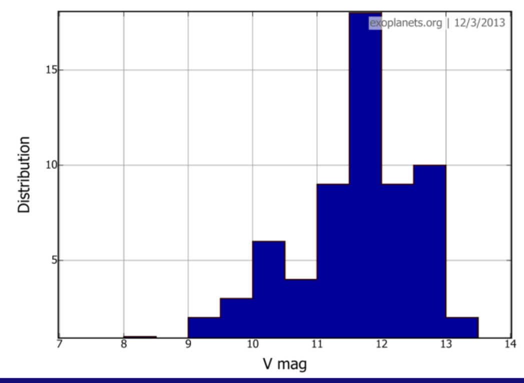


Figure 3 (left):

Distribution of magnitudes for stars found by SuperWASP to host transiting exoplanets.

Techniques used in reprocessing SuperWASP data

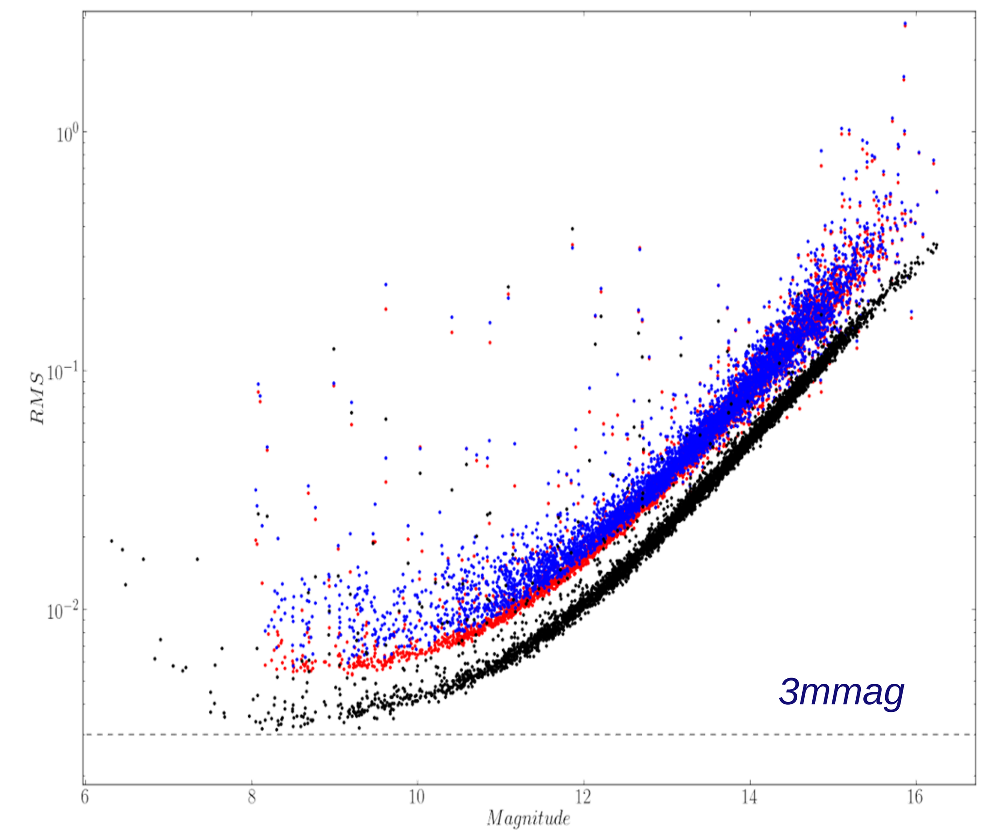
- Combining more flat field frames to reduce the photon noise contribution
- Ensuring chosen flat fields were not cloud-contaminated or saturated
- Co-located list driven photometry using soft-edged apertures
- Frame-to-frame photometric calibration using spatially dependent second order polynomial [3]

Figure 4 shows our clear improvements made in lowering the rms noise when compared to the post-systematics correction results from the previous pipeline [4].

With pure white noise statistics, the rms error in flux measurements will decrease with binning, and any deviation potentially implies residual correlated noise. Figure 5 shows a field's flux rms error decreasing with binning. Deviations from white noise statistics are 1mmag or less for bins of up to 2 hours.

We used 7 SuperWASP fields that were observed on 30 nights between Nov - Dec 2011, with only good quality frames used in lightcurve generation. These have low average astrometric errors, source ellipticity and sky brightness. We also use the zero-point magnitudes to filter out frames suffering high extinction. On average, 70% of frames (4000-8000) are kept per field to create stellar lightcurves for stars with V magnitude > 12. One field was further analysed with data from Jan-Feb and Nov-Dec 2012 to increase the baseline for observations.

Figure 4: RMS-magnitude diagram for our SuperWASP analysis (black), the original pipeline (blue) and their pipeline's results after removing systematics (red).



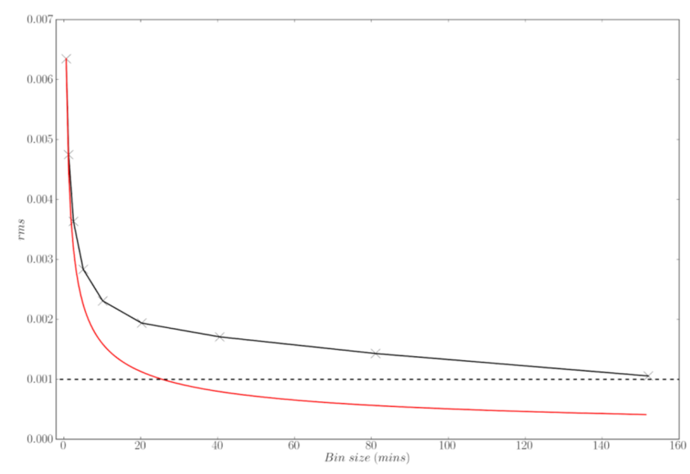


Figure 5: RMS improvements with binning for bright stars (8 < V < 11 , black) and the predicted binned rms for pure white noise (red). The dotted line highlights the 1mmag level.

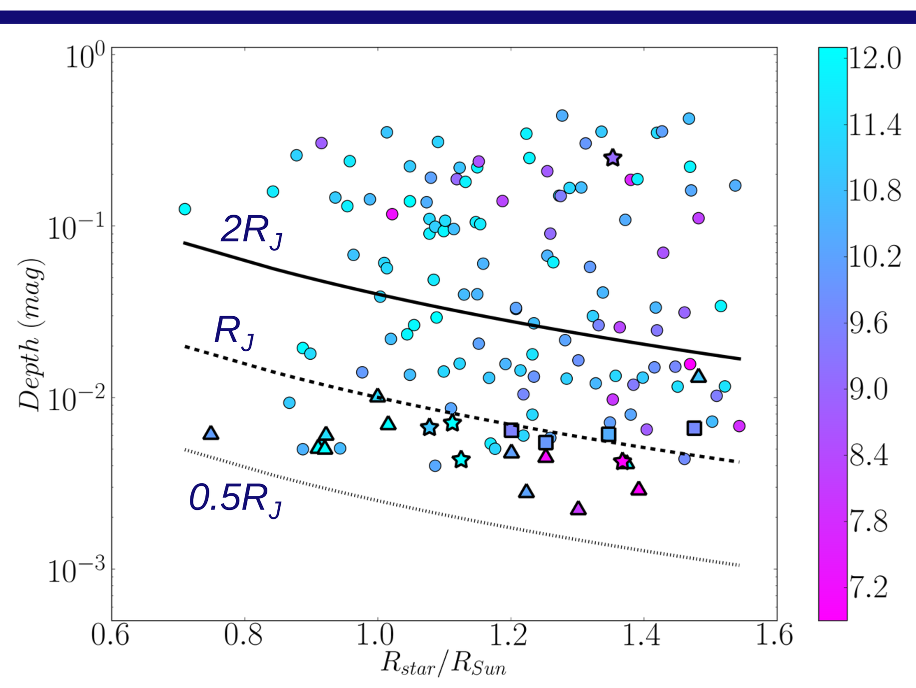


Figure 6: Detected transit depths as a function of stellar radius for the 30 night 2011 data across 7 fields (circles), the 2011-2012 extended baseline field (stars) and the extended field with a lower SNR limit of 6 (triangles), coloured by stellar magnitude. Lines denote the transit depth for planet of the radius stated.

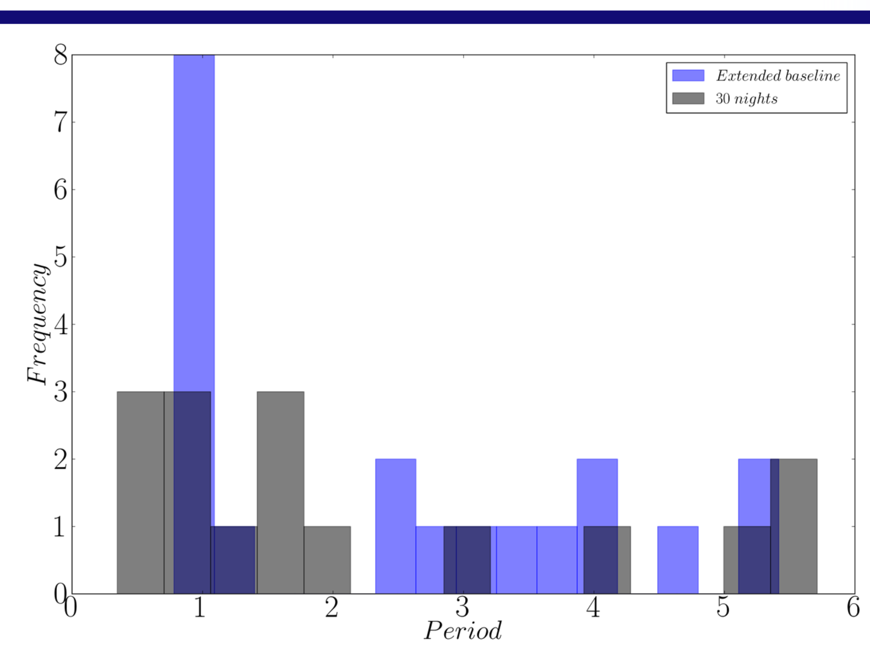


Figure 7: Period distributions for a field with 30 nights' coverage and the same field with the extended 2011-2012 baseline. More longer period candidates are detected with increasing baseline.

Candidate selection – towards longer baselines

After reprocessing, the Box-Least-Squares algorithm (BLS) [5] determines the best-fit period and depth of any variation by fitting trapezium transit models to the data. Where the BLS detection has a signal to pink noise SNR > 8, the results are analysed to remove candidates with periods close to 0.5,1 and 2 days, those with more than 80% of the in-transit data from a single night, or any with less than 3 transits.

For the remaining candidates, we determined the stellar radius of those likely to be dwarfs via their reduced proper motion [6] and inspected the lightcurves of these visually to select the best candidates which are represented in Figure 6. For the extended baseline field, we see that more, small candidates are detected and Figure 7 shows how many of these are at longer periods than in the smaller baseline data.

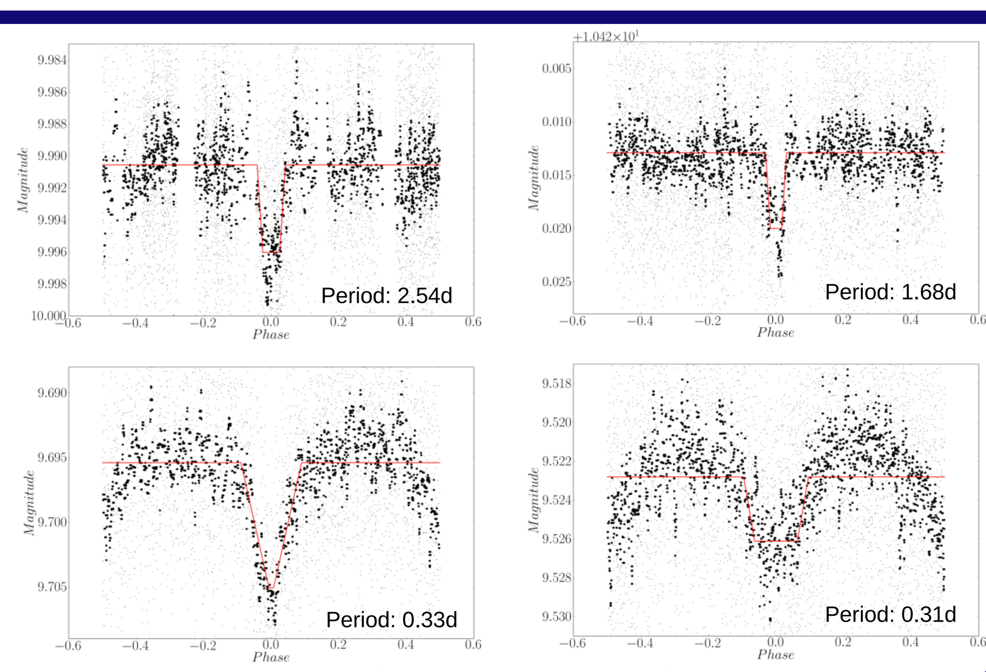


Figure 8: Phase-folded candidate lightcurves (black) and BLS model (red).

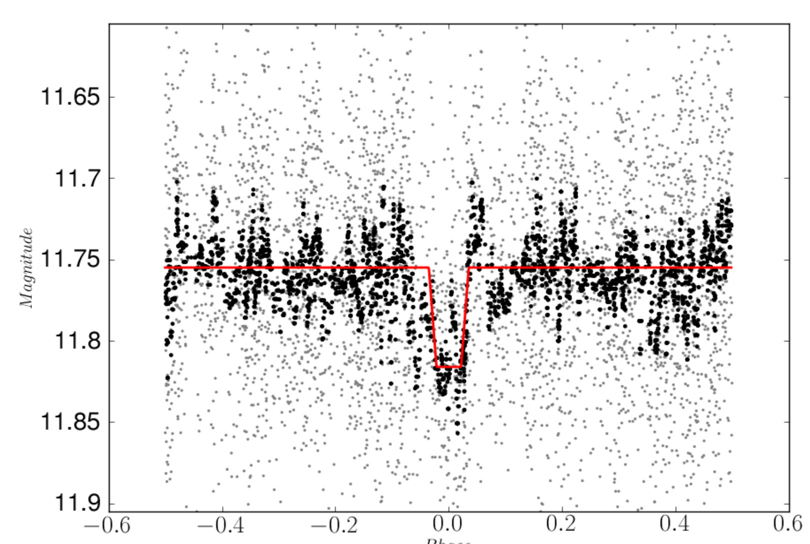


Figure 9: XO-5b phase-folded lightcurve (black) and BLS model (red) for a single transit

Example Candidates

Figure 8 shows phase-folded lightcurves for four candidates (seen as squares in Figure 6) with 3-10mmag depths around bright stars (V <10.5). The upper two plots show planet candidates compared to the two below which are likely to be binaries. The quality of these new lightcurves will enable us to easily distinguish between binary and planet candidates, and significantly reduce resource requirement for follow-up.

XO-5b Single Transit Detection

Figure 9 shows a phase curve of a single XO-5b transit detected in this analysis (SNR = 8.8), though it does not pass our selection tests as there were not 3 or more transits. The BLS model has a mid-transit JD that differs from the literature by less than 6 minutes: just 3% of the duration.

References

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