Underlying planetary parameter distribution from WASP data

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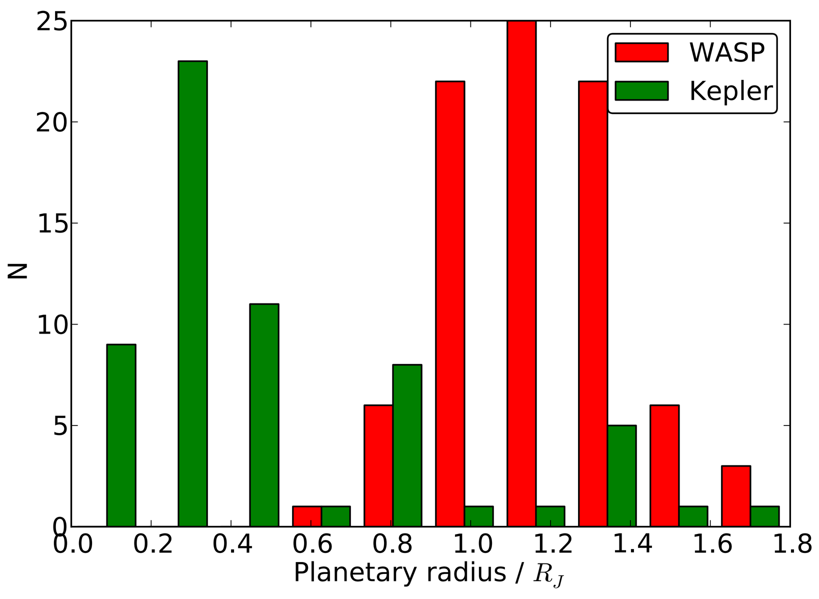
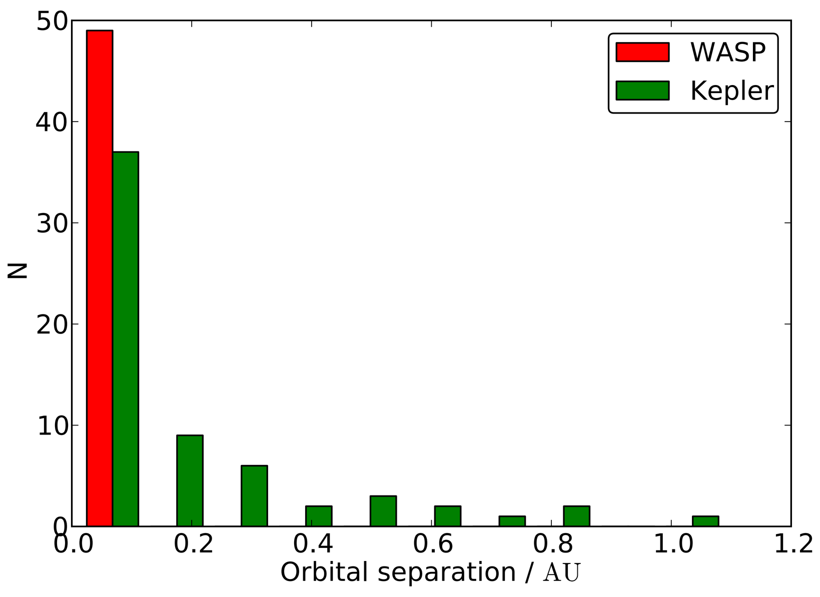
Introduction

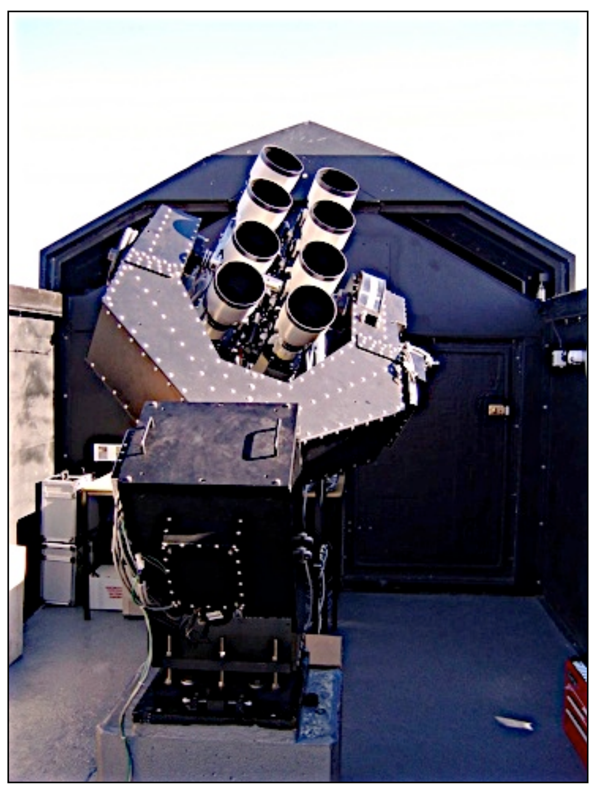
How can we use detected planetary populations to estimate the underlying true population?





Calculating the population of extrasolar planets in our galaxy is a difficult task, due to observational selection effects and low sample size.

WASP (Pollacco et al., 2006, below) is the most successful transiting exoplanet survey to date, with more than 60 planets announced. Over 30 million objects have been observed during the 8 year lifetime of the project.

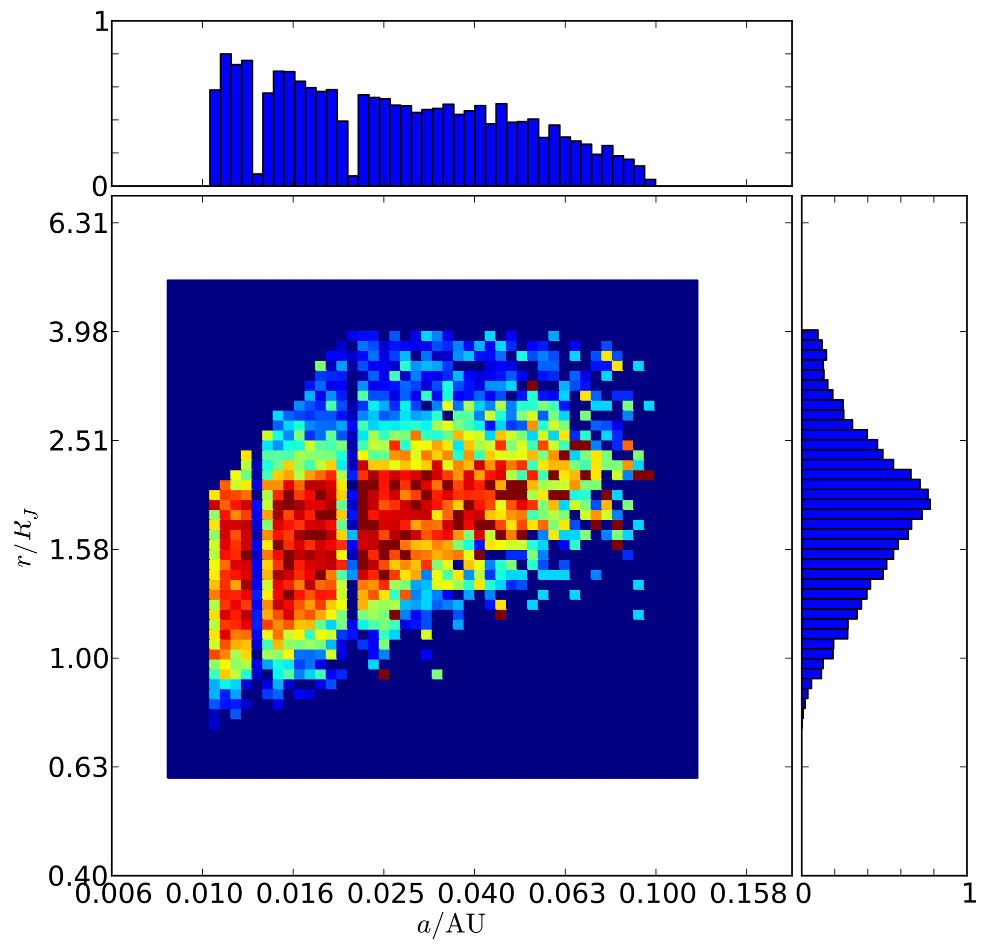


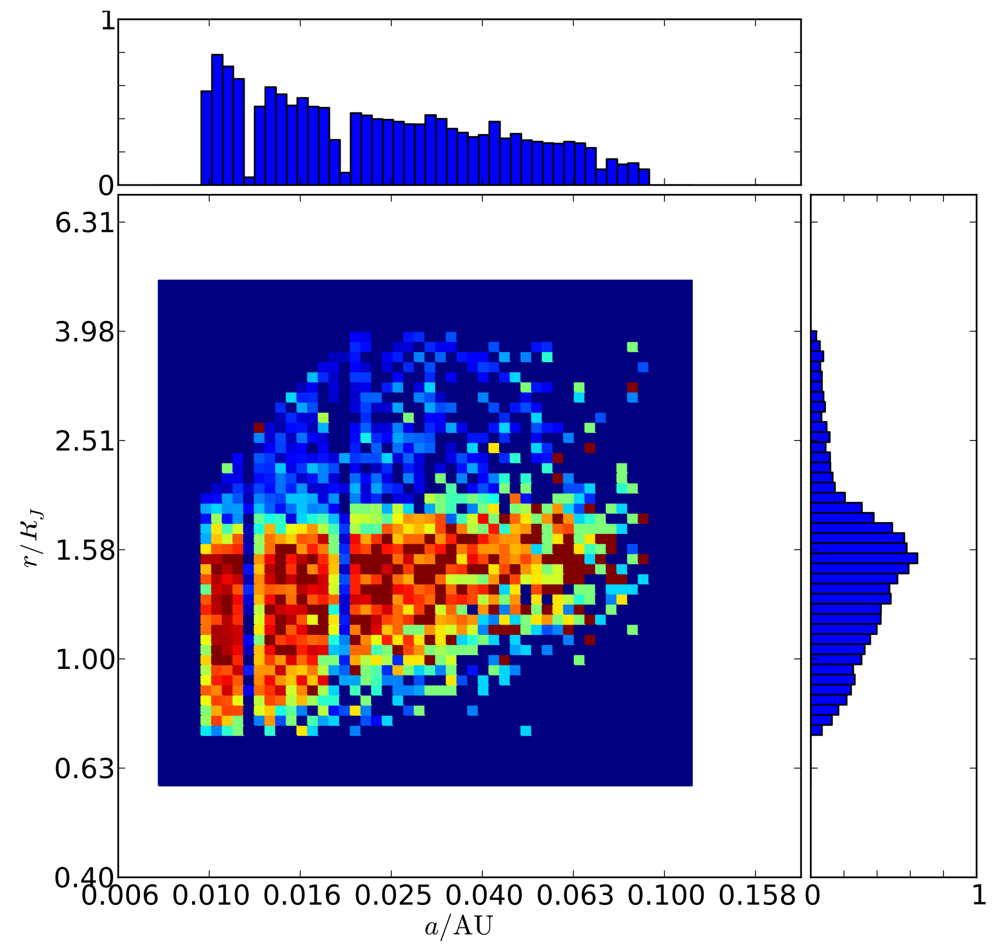
Kepler can make much more precise photometric measurements, and is therefore fantastic for analysing Earth type planets, but its sensitivity is much lower to planets with larger radii.

Kepler's comparatively low number of target stars means that WASP has detected many more Jupiter sized objects. We can make a more precise calculation to determine the hot Jupiter population, but the selection effects must be understood. This can be achieved by inserting synthetic transit signals into WASP data, and calculating the fraction that are detected.

Results

After simulating synthetic transits and passing them through the WASP analysis pipeline, the fraction of detected models to total input models gives the sensitivity map to that planet. To the right is the sensitivity map to WASP-12b whereas below is the map for WASP-5b. Given that they have different structure and mean radius levels suggests that there is quite a range over which WASP is sensitive, but many data sets must be combined to calculate it.

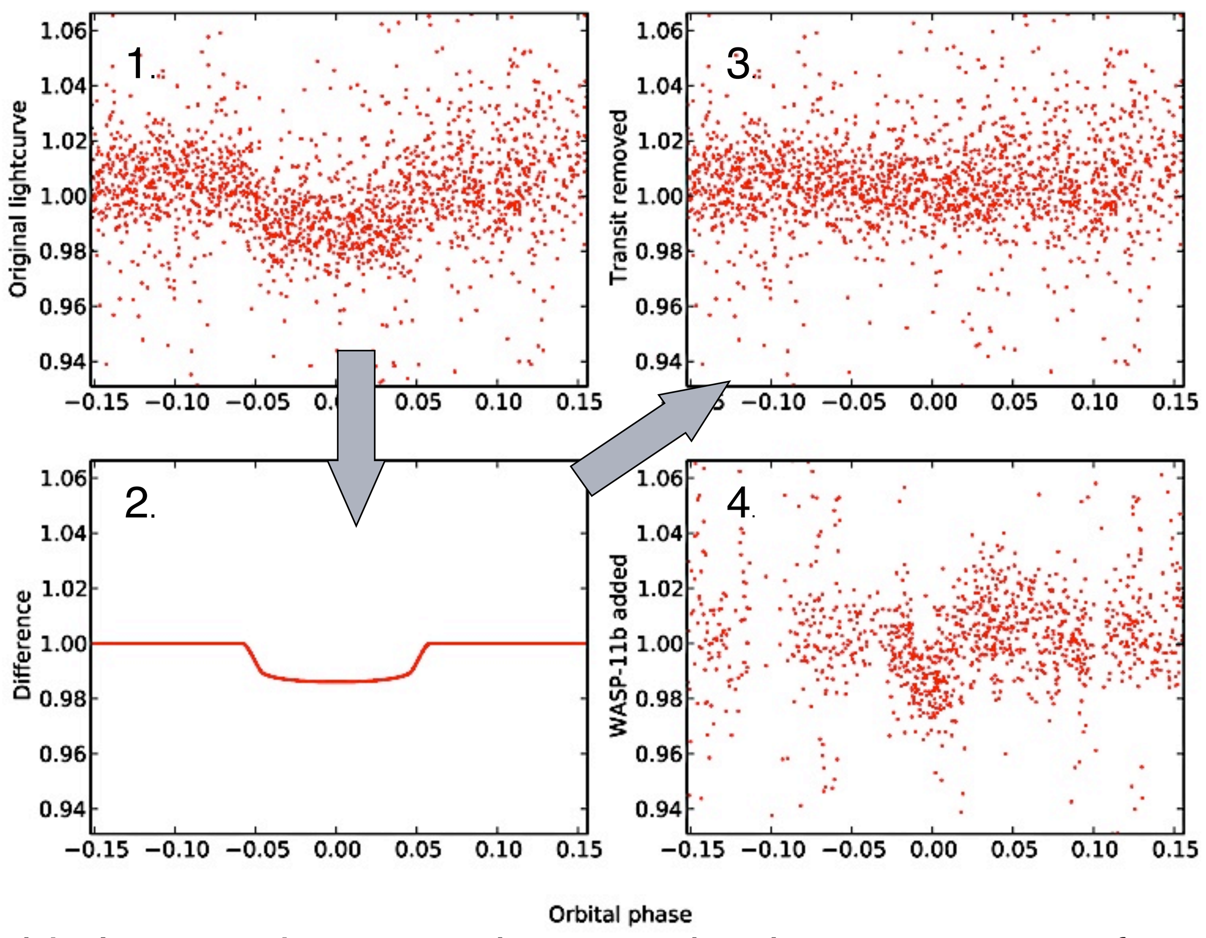




Each proposed simulated transit is either accepted, or rejected at one of two stages: either the BLS does not detect it, or it is rejected based on parameters calculated during the transit search to reduce the false positive rate. For example these parameters include how statistically likely the detected object is to be a planet, or the amount of ellipsoidal modulation, which would indicate an eclipsing binary. These maps can be combined with the probability of transit to give the probability of detection for any system.

Method

To constrain the stellar parameters, lightcurves with known planets were chosen. The true transits were then removed from the lightcurves, and fake transits inserted using the Mandel & Agol (2002) transit model, with limb darkening coefficients from Claret (2000).



Planetary radius and orbital separation were chosen to be the parameters of interest as these are physical characteristics of a system, and translate directly to selection effects in transit surveys. All other parameters are randomised to reduce the bias towards these parameters.

The figure above shows WASP-12b data containing (1) the true WASP-12-b transit, (2) the model used to remove the transit, (3) the transit removed and (4) the transit of WASP-11b inserted. All data have been folded on the orbital phase of the respective contained transit.

Systems where the planet would have been tidally disrupted by its host star, and systems where the planet is not transiting were not analysed, but grazing transits are included. The included models are analysed with the WASP transit search pipeline, consisting of a box least squares (BLS) search, with parameter refinement and error estimation using an MCMC algorithm (Collier Cameron et al., 2006).

Discussion

The next step is to apply the selection effects calculated to a proposed synthetic planetary population, and compare the results to WASP's observed distribution. The input population can be iteratively adjusted so it matches the observed population, and allowed distributions of planets can be identified.

Using systems where the known planets were discovered allows the relative sensitivity to planets to be calculated: given that we found *something* around this object, we can ascertain what else could have been detected.

By using any input lightcurve with or without a known planet, the absolute frequency of detections can be calculated, and used to determine the underlying population of hot Jupiters.

References

Claret, A., 2000, A&A, 363, 1081

Mandel, K., Agol, E., 2002, ApJ, 580, L171

Pollacco, D. L., et al., 2006, PASP, 118, 1407

Collier Cameron, A., et al., 2006, MNRAS, 373, 799

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