Transiting Planet Simulations from the All Sky Extrasolar Planets Survey

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**Abstract.** Many of the planets discovered via the radial velocity technique are hot Jupiters in 3–5 day orbits with $\sim 10\%$ chance of transiting their parent star. However, radial velocity surveys for extra-solar planets generally require substantial amounts of large telescope time in order to monitor a sufficient number of stars due to the single-object capabilities of the spectrograph. A multi-object Doppler survey instrument has been developed which is based on the dispersed fixed-delay interferometer design. We present simulations of the expected results from the Sloan Doppler survey based on calculated noise models and sensitivity for the instrument and the known distribution of exoplanetary system parameters. We have developed code for automatically sifting and fitting the planet candidates produced by the survey to allow for fast follow-up observations to be conducted. A transit ephemeris is automatically calculated by the code for each candidate and updated when new data becomes available. The techniques presented here may be applied to a wide range of multi-object planet surveys.

1. Introduction

Of the transiting planets known thus far, three were discovered via the radial velocity technique and subsequently followed up photometrically. These are HD 209458b (Charbonneau et al. 2006), HD 149026b (Sato et al. 2005), and HD 189733b (Bouchy et al. 2005). A multi-object Doppler survey instrument, the W.M. Keck Exoplanet Tracker, has been developed which builds upon the success (Ge et al. 2006) of the prototype instrument, Exoplanet Tracker (ET), which is based on the dispersed fixed-delay interferometer design. This new instrument is being used to conduct an All Sky Extrasolar Planets Survey (ASEPS) with the Sloan 2.5m wide-field telescope, expected to dramatically increase the detection rate using the Doppler method. Since the initial survey is optimised towards the discovery of hot Jupiters orbiting stars in the magnitude range $8 < V < 12$, the planet discoveries will be ideal candidates for the possible detection of a transit signature in the corresponding lightcurve. We have conducted survey simulations (Kane, Schneider, & Ge 2006) to estimate how many transiting planets can be expected.

2. Simulated Data

To estimate how many planets we expect to detect in a given radial velocity observing program, we performed a series of Monte-Carlo simulations which inject
planets into a realistic sample of target stars based on the known distribution and characteristics of exoplanets. For this simulation, a stellar population model was generated using the Besançon Galactic model (Robin et al. 2003) for a magnitude limited survey in the Kepler field. The Kepler field is an ideal location for a multi-object radial velocity survey since the results would not only compliment the transit survey to be undertaken by the Kepler mission, but also aid in target selection. In total, 23708 main sequence stars were used in the simulation from which 751 were concluded to harbour planets based on the planet-metallicity correlation (Fischer & Valenti 2005). The cumulative histogram of the planet-harbouring probability for the sample, shown in Figure 1 (left), demonstrates the substantial reduction in probability beyond $\sim 5\%$.

The distribution of planet parameters was used to calculate the expected distribution of radial velocity amplitudes. Figure 1 (right) shows the number of planets detectable from the simulated data at the $3\sigma$ level as a function of the rms radial velocity precision of the experiment. In this example, doubling the precision of the instrument increases the planet yield by $\sim 17\%$, whereas doubling the number of survey stars will increase the planet yield by 100%.

3. Radial Velocity Fitting Code

The FORTRAN code written for the purpose of sifting planet candidates from the dataset uses a weighted Lomb-Scargle (L-S) periodogram to detect a periodic signal in the data. If a significant periodic signal is detected, the data are subjected to an iterated grid-search fitting routine to determine the best fit planetary parameters for that target. Figure 2 (left) shows a typical periodogram where the dotted lines indicate various falsealarm probabilities.

The number of false detections resulting from this technique depends upon the periodic false-alarm probability threshold one adopts as the selection criteria. Figure 2 (right) shows that by adopting a relatively conservative threshold, one can eliminate false detections with minimal loss to planet yield.

Those planetary signatures failing to be recovered are generally at the photon noise-limit of the instrument or have a period considerably more than the
survey duration. This sifting and fitting method has proven to be remarkably robust and is able to operate in an automated fashion.

4. Number of Transiting Planets and Photometric Follow-up

The total planet yield expected from the simulated data for the Kepler field survey is \( \sim 275 \) planets for an instrument such as the ASEPS instrument assuming a 30 day observing window. To approximate the number of transiting planets, the geometric transit probability was calculated for each star/planet system as part of the Monte-Carlo simulation. Once all the detection limitations are taken into account, the total expected number is \( \sim 10 \) transiting planets.

Considering the high number of expected hot Jupiters expected from the survey, the radial velocity fitting code automatically calculates a transit ephemeris for each candidate and is updated when new data becomes available. Since the transit duration is brief compared with the fitted period, the maximum window for obtaining photometric transit observations after the radial velocity data has been obtained is also calculated. Through this process, we hope to provide a quick and efficient method for maximising the number of transit discoveries (Kane 2006).

Acknowledgments. We acknowledge support from the W.M. Keck Foundation, NSF, NASA, and the University of Florida.

References

Bouchy, F., et al., 2005, A&A, 444, L15
Charbonneau, D., Brown, T.M., Latham, D.W., Mayor, M., 2000, ApJ, 529, L45
Fischer, D.A., Valenti, J., 2005, ApJ, 622, 1102
Ge, J., et al., 2006, ApJ, 648, 683
Kane, S.R., 2006, MNRAS, submitted
Kane, S.R., Schneider, D.P., Ge, J., 2006, MNRAS, submitted
Robin, A.C., Reylé, C., Derrière, S., Picaud, S., 2003, A&A, 409, 523
Sato, B., et al., 2005, ApJ, 633, 465