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Variations of The Transit Timing of Planets in Binary Star Systems

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Abstract

We have carried out numerical calculations of the variations of the transit timing of a close-in giant planet in a binary star system. To determine whether the TTV method is capable of detecting transiting extrasolar planets in binary systems, we calculated TTV signals for different values of the mass-ratio and orbital elements of a binary and its transiting circumprimary planet. Results suggest that TTV signals in the currently known close planet-hosting binaries are small. However, there are regions of the parameter-space where the perturbation of the secondary star may become large enough to create measurable variations in the transit timing of a close-in planet. We present the result of our study and discuss their applicability to the detection of planets in binary stars systems using CoRoT and Kepler space telescopes.

1. Introduction

Approximately 70 percent of all stars in the solar neighborhood are members of binary or multiple star systems. It is therefore not surprising that among the currently known 450 extrasolar planets, ~40 orbit stars that are members of binaries. This fact has led to the conclusion that many more planets may exist in and around binary stars, and the knowledge of the dynamics of planets in binary systems is crucial.

In general, one can distinguish three types of stable orbits for planets in binary systems (Figure 1):

(i) **S-Type**, where planet orbits one of the two stars,

(ii) **P-Type**, where planet orbits the entire binary,

(iii) **L-Type**, where planet orbits close to one of the two equilibrium points L4 and L5 (Trojan planets).

All currently known planets in binary systems are of the S-type.

There are several methods of detecting extrasolar planets. The two most common ones are the radial velocity and transit photometry. While radial velocity has been successful in detecting the majority of the currently known extrasolar planets, transit photometry has detect more than 70 extrasolar planets.

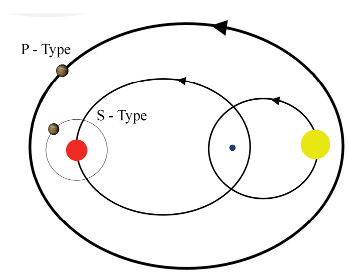

Figure 1: Schemata of the S and P-type configuration.

Among the currently known planet-hosting binaries, there are three with separations smaller than 20 AU. These systems present unique cases for the study of planet formation and dynamics in binaries as the perturbation of the of their secondary stars will have significant effects on the dynamics of their circumprimary planets. Among these systems, the binary of GL86 is of particular interest. The primary of this binary is host to a giant planet with a mass of 4 M_J in a 15-day orbit. The close-in orbit of this planet suggests that many giant planets may exist in short-period orbits around stars of a binary implying that many of them may also transit their host stars. In moderately close binary systems, the stellar companion may affect the timing of these transits and create variations that can be used to detect planets.

2. Models and Methods

Transits of a planet on a Keplerian orbit occur at time intervals which are equal to the orbital period. If a second star orbits this system (star-planet), its perturbation will disturb the Keplerian orbit and the transits are no longer periodic. A measurement of the variations of transit timing will enable us to make a better estimate of the mass and orbital elements of the binary companion. We have carried out N-body simulations of a binary-planetary system using the Lie-integration method where the planet transits the primary star and its orbit is perturbed by the stellar companion. We calculated TTVs for the transiting planet by subtracting the time of the eclipse of the unperturbed case (T_1) from the perturbed case (T_2), $dT = T_1 - T_2$. We subtracted the rate of apsidal precession from the TTV signals: 2.8sec/period for Gliese 86b and 12.249 hr/period.

3. Conclusions

Figure 2 shows the TTV signals for the 30-day planet of Gliese 876. This system contains two Jupiter-mass planets on moderate eccentric orbits and near the 2:1 mean-motion resonance (P_1=30.1d and P_2=61.0 d) [4]. As shown here, the transit timing of the 30-day planet varies due to the perturtbation of the second body. Figure 3 shows the TTV signals for the planets in the binary Gliese 86. This binary is about 11 pc away from the Sun in the constellation Eridanus and consists of a K1 main sequence star with a mass of 0.7 solar-masses. The secondary star of this system, in all probability, is a white dwarf with a minimum mass of 0.55 solar-masses. The binary separation is ~18.75 AU and its eccentricity is unconstraint with a maximum value of ~0.7 [5]. We calculated TTVs for this system for 10 years, equivalent to the double observation time of the space mission CoRoT. As shown in Figure 3, the curve of the TTV is changing very slowly, because of the long period of the secondary star (~100 years).

We have carried our similar simulations for variety of binaries with different mass-rations and orbital elements. We will present the results of our study and discuss their applicability to the detection of planets in binary star systems using the CoRoT and Kepler space telescopes.

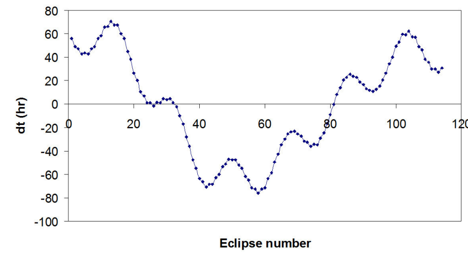

Figure 2: TTV for the planet Gliese 876c. The period of the planet is p=30.1d.

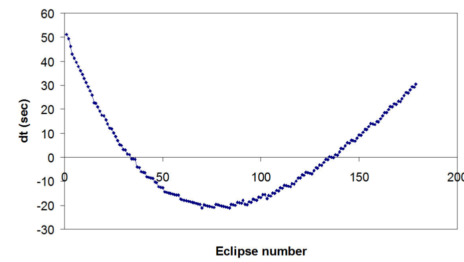

Figure 2: TTV for the planet Gliese 86b. The period of the planet is p=15.8d.

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References

[1] Agol, E., Steffen, J., Sari, R. and Clarkson, W.: On detecting terrestrial planets with timing of giant planet transits, MNRAS, Vol. 359, pp. 567-579, 2005. [2] Schneider, J. and Chevreton, M.: The photometric search for Earth-sized extrasolar planets by occulation in binary systems, Vol. 232, pp.251-257, 1990. [3] Pilat-Lohinger, E., Dvorak, R.: Stability of S-type Orbits in Binaries, CeMDA, Vol. 82, pp. 143-153, 2002. [4] Marcy, G. W., Butler R. P., Fischer, D. Vogt S. S., LissauerJ.J., Rivera E.J.,: A pair of resonant planets orbiting GJ 876, APJ, Vol. 556, pp. 296-301, 2001. [5] Mugrauer, M., Neuhäuser, R.: Gl86B: a white dwarf orbits an exoplanet host star, MNRAS. 361, pp. L15-L19, 2005 497.