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New insights into the dynamics of planets in P-Type motion around binaries

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Abstract

Up to now more than 500 extra-solar planets have been discovered. Many of these extrasolar systems consist of one star and only one massive, near-by giant planet. However, recently more and more different types of systems become known, including also extrasolar planets in binaries. In our study we will concentrate on planetary systems in binaries, since a large percentage of all G-M stars are expected to be part of binary or multiple stellar systems. Therefore, these kinds of systems are worth to be investigated in detail. In particular we will concentrate on planets in P-Type motion. During the last years four such systems (NN Ser, HW Vir, HU Aqr and DP Leo) have been discovered. In our study we perform dynamical studies, where we compare simulated eclipse timing variations (ETV) to current observational data and found out, that the proposed system configurations are highly unlikely.

1. Introduction

In our study we concentrated on multiplanetary systems in binaries, since up to 70 % of all G-M stars are expected to be part of binary or multiple stellar systems. Therefore such constellations are worth to be investigated in detail. In principle, there are three possible motions for a planet in a double star system:

1. **S-Type Orbits:** In this configuration the planet moves in an orbit around one of the stars. Up to now most of the known extrasolar planets in binaries move in an S-Type orbit.

2. **P-Type Orbits:** In the P-Type configuration the planet moves around both stars, assuming the separation between the components not to be too large. Lee et al. [3] detected two extrasolar planets around the eclipsing binary system HW Virginis with the help of eclipse timing variations, Beuermann et al. [1] found two planets orbiting the recently formed post-common envelope binary NN Serpentis, and Qian et al. [4] found two planets orbiting the eclipsing polar HU Aqr.

3. **L-Type Orbits:** A further possibility is L-Type motion, where the planet moves in the Lagrangian points of the binary systems, comparable to Jupiter's Trojans. No extrasolar planets in L-Type motion have been found up to now.

Table 1: Initial conditions for the three investigated systems

Name	Mass	a [AU]	e
HU Aqr A	0.88 $M_\odot$	-	-
HU Aqr B	0.2 $M_\odot$	0.0039	?
HU Aqr AB b	5.9 M_{Jup}	3.6	0.0
HU Aqr AB c	4.5 M_{Jup}	5.4	0.51
NN Ser A	0.535 $M_\odot$	-	-
NN Ser B	0.111 $M_\odot$	0.0043	?
NN Ser AB b (1)	6.91 M_{Jup}	5.38	0.0
NN Ser AB c (1)	2.28 M_{Jup}	3.39	0.2
NN Ser AB b (2)	5.92 M_{Jup}	5.66	0.0
NN Ser AB c (2)	1.6 M_{Jup}	3.07	0.23
HW Vir A	0.485 $M_\odot$	-	-
HW Vir B	0.142 $M_\odot$	0.004	?
HW Vir AB b	19.2 M_{Jup}	5.3	0.46
HW Vir AB c	8.5 M_{Jup}	3.62	0.31

This work will be dedicated to planets and planetary systems in P-Type motion. On the one hand we investigated the dynamical stability of the three P-Type multiplanetary systems and on the other hand the eclipse timing variations (ETV) caused by the assumed planets. In this study we concentrated on the eclipse timing variations (perturbations of the stellar eclipse timing, caused by an unseen planet), since all three planetary systems were discovered via ETV measurements. In Table 1 the initial conditions for the three P-type systems are shown.

2. Results

2.1. Dynamical study

In all cases, the motion of the planets were considered in the framework of pure Newtonian forces and all the celestial bodies involved were regarded as point masses. As dynamical model for all investigations we used the full n-body problem, consisting of the two stars and the two planets. In order to study the dynamical evolution of the different systems we applied the Lie-Series Integration Method and checked these results with a Gauss-Radau integration method - both were in good agreement.

The two systems HW Vir and HU Aqr turned out to be unstable after quite a short timespan. Hence we integrated best case scenarios, with the most favorable initial conditions, that were also compatible with the given error bars. These best cases also lead to unstable motion quite fast.

For the binary system NN Ser the authors give two possible configurations for the planets. In the first case (marked with (1) in Table 1) the system turned out to be unstable and also the best case scenario leads to unstable motion. The second configuration (marked with (2) in Table 1) turned out to be stable for an integration time of 500000 years.

2.2. Eclipse timing variations

Since most of the proposed planetary systems seemed to be unstable we investigated whether a detection with the ETV method is possible at all. Thus we integrated the given binary with a fictitious planet on a P-Type orbit in different distances to the binaries barycenter. Again, in order to gain best case estimates we combined the mass of both assumed planets.

In our investigations we found that even distant planets could generate a measurable ETV signal, due to different light-travel times depending on the position of the binary with respect to the systems barycenter.

3. Conclusions

By plotting the ETV signals of some test-systems we found, that the proposed configurations are in principle detectable via ETV measurements. Yet our dynamical investigation of all three systems showed, that almost all given configurations lead to unstable motion. Thus in a next step we will investigate if any change of the initial conditions (especially of the inclination) will stabilize the systems. A detailed description of the whole work including all results can be found in Eggl et al. [2].

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