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Planets in Binaries

A. Eggenberger, S. Udry, M. Mayor

Geneva Observatory, CH-1290 Sauverny, Switzerland

Abstract. Various scenarios have been proposed to explain planet formation and the diversity of properties observed for extrasolar planets. In particular, the influence of stellar duplicity on planet formation is still unclear and observations are needed to constrain the models. In this presentation, we discuss the preliminary results of an ongoing program aiming to detect extrasolar planets in spectroscopic binaries.

1. Introduction

To date, several planets have been discovered in known multiple star systems (Table 1) and searches for wide companions to stars harboring planets have revealed a few new cases. Moreover, a fraction of stars known to host planets exhibit a drift in the systemic velocity indicating the presence of an additional distant companion (Fischer et al. 2001). These observations show that planets form and survive in certain types of multiple systems.

The mass-period distribution seems to be different for planets in binaries and for planets orbiting around single stars (Zucker & Mazeh 2002). Though this observation has to be confirmed, the effect of stellar duplicity on planet formation and evolution is an important issue (e.g., Udry, Mayor & Santos 2002; Eggenberger, Udry & Mayor 2002). Two major models have been proposed to explain giant planet formation: the standard core accretion model (e.g., Pollack et al. 1996) and the disk instability scenario (Boss 1997). The effect of stellar duplicity on planet formation in the context of these two scenarios has only been studied for a few specific cases (Boss 1998; Nelson 2000; see Kley 2000 for a more detailed review). Conclusions are however still unclear and observations would help to constrain the different models.

2. Our Program

We have started a program to search for short-period circumprimary giant planets in single-lined spectroscopic binaries. Our sample of binaries has been selected on the basis of different CORAVEL surveys for G and K dwarfs of the solar neighborhood (Duquennoy & Mayor 1991; Halbwachs et al. 2003). Single-lined spectroscopic binaries with a period longer than approximately 2 years have been retained and the total sample is composed of about 100 binaries covering both hemispheres. For each binary, 10 to 15 high-precision radial velocity measurements are taken over two observational seasons with the CORALIE or the ELODIE spectrograph. Residual velocities around the Keplerian orbit (when the

Table 1. Planets orbiting a star member of a multiple system with confirmed orbital or common proper motion.

Star	a_{bin} (AU)	a_{pl} (AU)	$M_p \sin i$ (M_J)	Bin. Ref.
HD 40979	~ 6400	0.811	3.32	1
Gl 777 A	~ 3000	3.65	1.15	4
HD 80606	~ 1200	0.469	3.90	8
55 Cnc B	~ 1065	0.115/0.241/5.9	0.84/0.21/4.05	2,10
16 Cyg B	~ 850	1.66	1.64	11
Ups And	~ 750	0.059/0.828/2.56	0.69/1.96/3.98	9,11
HD 178911 B	~ 640	0.32	6.292	6
Tau Boo	~ 240	0.05	4.09	3,11
HD 195019	~ 150	0.136	3.55	4,11
HD 114762	~ 130	0.351	10.96	11
HD 19994	~ 100	1.3	2.0	3
Gl 86	~ 19 / > 20	0.11	4	7,5

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orbit is closed) or around a drift (for longer period systems) are then analyzed and short-period radial velocity variations are searched for.

Currently, the program is midcourse. Figure 1 shows the dispersion of residual velocities for the southern binaries with more than 5 measurements. A fraction of these binaries have a small residual velocity dispersion, which shows that the precision required to search for giant planets in single-lined spectroscopic binaries is achieved. The other binaries are marginally or strongly variable. Residual velocity variations can be due to different effects:

• The star is an unrecognized double-lined spectroscopic binary revealed by the higher precision of the ELODIE/CORALIE spectrographs. In such a case, the secondary spectrum introduces an additional source of noise on the measurement of the radial velocity and the binary is rejected from the sample.

• The primary is an active star.

• The spectroscopic binary is also a visual pair. When the binary separation is close to the diameter of the spectrograph fiber (projected onto the sky), the fraction of light coming from the secondary that enters the fiber is variable and depends on the seeing and on the guiding. This produces radial velocity variations of the cross-correlation function (Pepe et al. 2000).

• The binary is in fact a triple system whose secondary component, bright enough to perturb the spectrum, is itself a double system (Santos et al. 2002).

• There is a planet orbiting the primary.

To differentiate between these effects, diagnostics such as the analysis of the cross-correlation function shape (bisector inverse slope, hereafter BIS) and photometry are used. In particular, the velocity variations of a star that also

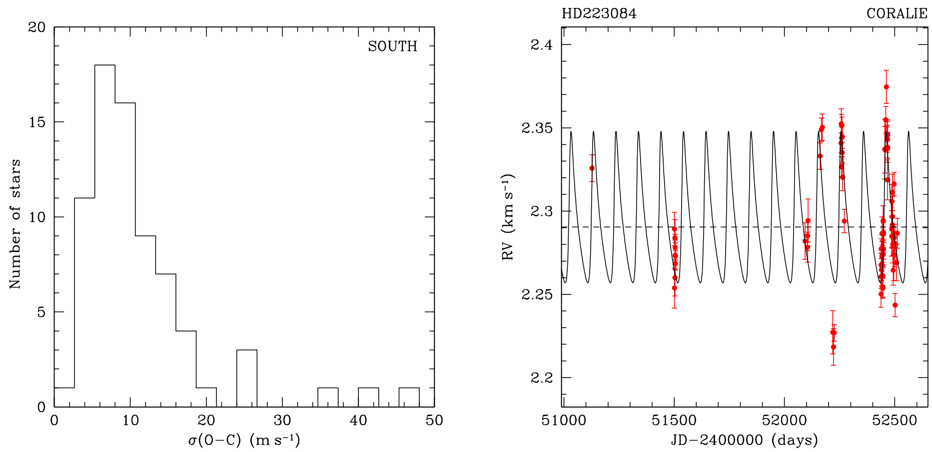

Figure 1. Left: Distribution of residual velocities dispersion for the southern binaries with more than 5 measurements. Right: Periodic radial velocity signal for HD 223084 (linear drift subtracted).

shows a correlation between the BIS and the radial velocity and/or photometric variations are not caused by a planet (Queloz et al. 2001; Santos et al. 2002).

3. HD 223084: Not a Planet but a Triple System

HD 223084 is a long-period spectroscopic binary showing a linear drift of -0.31 $\mathrm{km\,s^{-1}\,yr^{-1}}$. High-precision radial velocity measurements have revealed residual velocity variations that can be fitted with a 102-day Keplerian orbit (Figure 1). Even though this star is marginally active ($\log R'_{HK} = -4.64$, Santos et al. 2000), stellar activity is unlikely to be responsible for the observed radial velocity variations. The rotational period is 8 days (using the calibration of Noyes et al. 1984) and the projected rotational velocity derived from the cross-correlation function (Santos et al. 2002) is 4.6 $\mathrm{km\,s^{-1}}$. According to the Hipparcos catalogue (ESA 1997), HD 223084 is photometrically stable with a magnitude scatter of 0.010 mag.

A first analysis of the cross-correlation function bisector inverse slope as a function of residual velocity showed no correlation, favoring the planetary explanation. However, new data have revealed a positive correlation (Figure 2). Figure 2 also shows residual velocities obtained for HD 223084 using two different correlation templates, i.e. two different sets of spectral lines. The orbit obtained with a template optimized for M4 dwarfs is consistent with the one deduced with our traditional template for K0 dwarfs, except that the amplitude of the residual velocity variation is more than 10 times larger.

The presence of a planet orbiting HD 223084 is then ruled out by our new observations. HD 223084 is a triple system with a bright primary and a faint 102-day period spectroscopic binary. Residual velocity variations are due to the orbital motion of the short-period faint binary whose spectrum moves with respect to the fixed primary one (see Zucker et al. 2002 for more details).

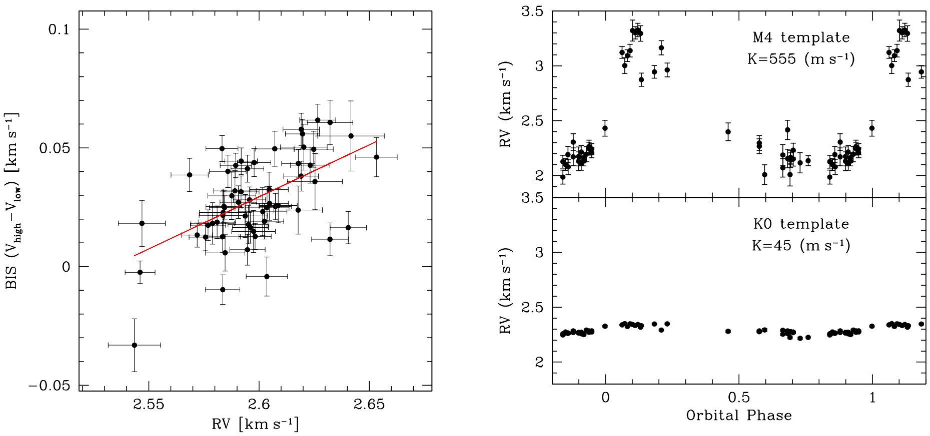

Figure 2. Left: Bisector inverse slope vs. residual velocity. The linear fit has a slope of 0.44. Right: Phase-folded radial velocity data obtained with two different correlation templates.

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