Tenth anniversary of 51 Peg-b : Status of and prospects for hot Jupiter studies
Proceedings of Haute Provence Observatory Colloquium (22-25 August 2005)
Edited by L. Arnold, F. Bouchy, and C. Moutou

Searching for planets around stars in wide binaries

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Abstract. We present the status of the radial velocity planet search on going at TNG using the high resolution spectrograph SARG. We are observing about 50 wide binaries with similar components, searching for planets and abundance anomalies caused by the ingestion of metal-rich planetary material. No clear planet detection emerged up to now. Evaluation of the statistical significance in terms of frequency of planets in binaries is in progress. The abundance analysis of half of the sample revealed no pair with large difference, allowing to place rather severe clues on the ingestion of metal-rich material during the main sequence lifetime of the stars.

1. Scientific motivations

The search for planets in multiple systems allows to improve our knowledge on planet formation and evolution. On one hand, the frequency of planets in binary systems has a strong effect on the global frequency of planets, more than half of solar type stars being in binary or multiple systems (Duquennoy & Mayor 1991). On the other hand, the properties of planets in binaries, and any difference with those of the planets orbiting single stars would shed light on the effects caused by the presence of the companions. The occurrence of some difference on the period-mass relation was indeed suggested (Zucker & Mazeh 2002). It is also possible that the binary companion of a planet host forces the planet to reach high eccentricities through the Kozai mechanism (Wu & Murray 2003).

Moreover, binarity can be used also to study the origin of the planet-metallicity connection (Fischer & Valenti 2005): if the ingestion of planetary material occurs, increasing the metallicity of the outer layer of the star, a chemical abundance difference between the components should be detectable. This is much easier to indentify than a chemical anomaly in a normal field star, for which no proper reference is available.

With these two science goals, we started a radial velocity (RV) survey of the components of wide binaries. We are using SARG, the high resolution spectrograph of the TNG (Gratton et al. 2001), equipped with an iodine cell to derive high precision RVs.

2. The sample

The sample was selected from the Hipparcos Multiple Star Catalog, considering binaries in the magnitude range $7.0 < V < 10.0$, with magnitude difference between the components of $\Delta V < 1.0$, projected separation larger than 2 arcsec (to avoid contamination of the spectra), parallax larger than 10 mas and error smaller than 5 mas, with $B-V > 0.45$ and spectral type later than F7. About 50 pairs (100 stars) were selected.

The sample is then formed by wide binaries with mass ratio close to 1. Considering systems with similar components is crucial for the accuracy of the differential chemical abundance analysis. Fig. 1 shows the distribution of the projected separation in AU. For most of the pairs, it results between 50 and 600 AU.

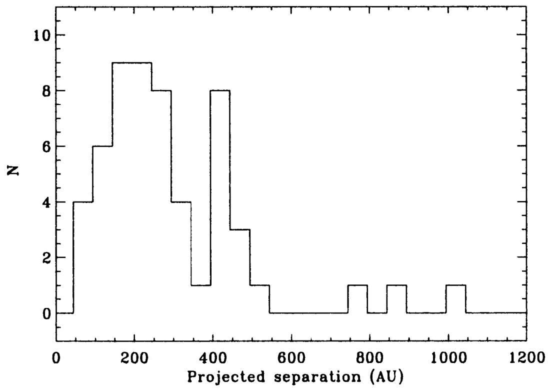

Figure 1. *Distribution of the projected separation in AU of the binaries in the sample.*

3. Abundance analysis

Differential abundance analysis was performed as described in Desidera et al. (2004a), reaching errors of about 0.02 dex in the iron content difference. We fully exploit the physical link between the components (same distance from the Sun), deriving effective temperatures difference from ionization equilibrium and gravity difference from the magnitude difference.

The analysis of 23 pairs, about half of the sample, shows that most of the pairs have abundance differences smaller than 0.02 dex and there are no pairs with differences larger than 0.07 dex. The four cases of differences larger than 0.02 dex may be spurious because of the larger error bars affecting pairs with large temperature difference ($\Delta T_{eff} \geq 400$ K), cold stars ($T_{eff} \leq 5500$ K) and stars with rotational velocity larger than 5 km/s.

Fig. 2 shows the amount of iron accreted by the nominally metal richer component to explain the observed abundance difference. For most of the slow-rotating stars warmer than 5500 K, characterized by a thinner convective envelope and for which our analyis appears to be of higher accuracy, this is similar to the estimates of rocky material accreted by the Sun during its main sequence lifetime (about 0.4 Earth masses of iron, Murray et al. 2001).

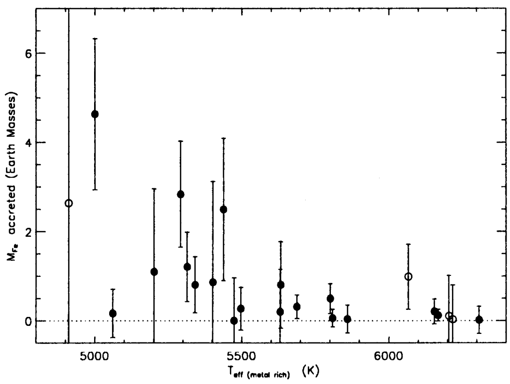

Figure 2. *Estimate of iron accreted by the metal-rich component of each pair as a function of its effective temperature, taking into account the mass of the mixing zone as in Murray et al. (2001). Empty circles: stars with significant rotation broadening, for which our analysis is less accurate. Filled circles: other stars. The less severe limits at lower effective temperatures are mostly due to the more massive convective zone of cool stars. The mass of meteoritic material is about 5.5 times the mass of iron.*

4. Radial velocities

RVs were determined using the AUSTRAL code (Endl et al. 2000) as described in Desidera et al. (2003). Typical errors are 2-3 m/s for bright stars observed as standards to monitor instrument performances and 5-10 m/s for the $V \sim 8 - 9$ program stars. 51 Peg was observed several times during the instrument commissioning and occasionally during the survey. The results are shown in Fig 3.

5. New triple systems

A by–product of our project is the detection of new spectroscopic binaries among the components of the wide binaries. These systems are then composed by at least three components. Some of these sytsems are presented in Desidera et al. (2005).

6. Stars with long term trends

About 10% of the stars in the sample show long term linear or nearly linear trends. In one case the trend is due to the known companion, as

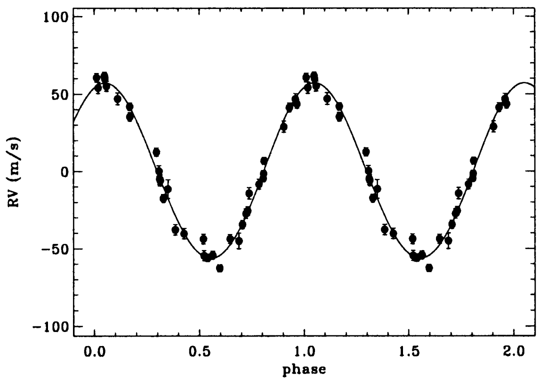

Figure 3. *Radial velocities of 51 Peg obtained with SARG phased to the orbital period.*

trends with opposite sign and nearly the same magnitude are observed for the two components. In the other cases the trends are due to low mass, possibly substellar companions. Direct imaging to search for such systems is planned. The direct identification of substellar objects as companions of stars for which age and chemical composition can be derived would play a relevant role in the calibration of models of substellar objects.

7. Low amplitude variables and planet candidates

Some further stars show RV variability above internal errors. One case we investigated in detail is that of HD 219542B. The 2000-2002 data indicated a possible periodicity of 111 days with a significance of about 97% (Desidera et al. 2003). However, the continuation of the observations revealed that the RV variations are likely due to stellar activity (Desidera et al. 2004b). Other candidates, mostly of fairly low amplitude, are emerging from our sample. Further observations are in progress.

8. Line bisectors: a tool to study stellar activity and contamination

The relevance of activity jitter for the interpretation of the RV data promped us to develop a tool to measure the profile of the spectral lines. The existence of a correlation between the variations of the RV

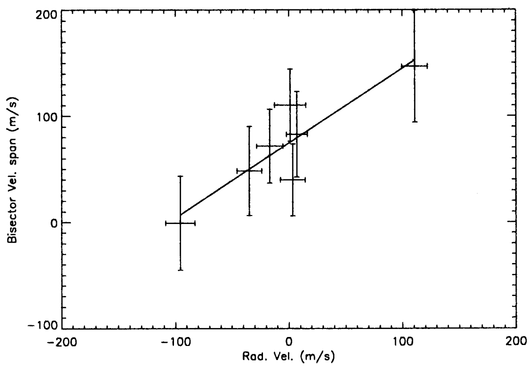

Figure 4. *Radial velocity - line bisector correlation for HD 8071B. This is likely due to the comtamination by the companion HD 8071A*

and those of the line profile might indicate a non-Keplerian origin for the observed RV variations. Our approach allows to use the same spectra acquired for the derivation of RVs, removing the iodine lines by means of a suitable spectrum of a fast rotating early type star with the iodine cell in the optical path. The procedure is described in detail in Martinez Fiorenzano et al. 2005a (see also Martinez Fiorenzano et al. 2005b).

The study of line shape is relevant for our program also as a diagnostic for the contamination of the spectra by the wide companion. In the case of HD 8071B, we indeed observe a correlation likely due to the contamination of HD 8071A. We are confident that this is the worst case, as this pair is one of the closest in our sample (separation 2.1 arcsec) and the large amplitude RV variations of HD 8071A (Desidera et al. 2005) should increase the effect of a variable contamination of the observed RVs of HD 8071B.

9. Upper limits on planetary companions

While no confirmed planet detection emerged up to now from our survey, a detailed analysis of the negative results would allow to constrain the frequency of planets in binary systems. Since we are focusing on a specific type of binaries, wide binaries with similar components, such a study is complementary to other studies of planets in binaries (Eggenberger et al. 2005).

To this aim, we are deriving upper limits on the planetary companions still compatible with the observations. For period longer than

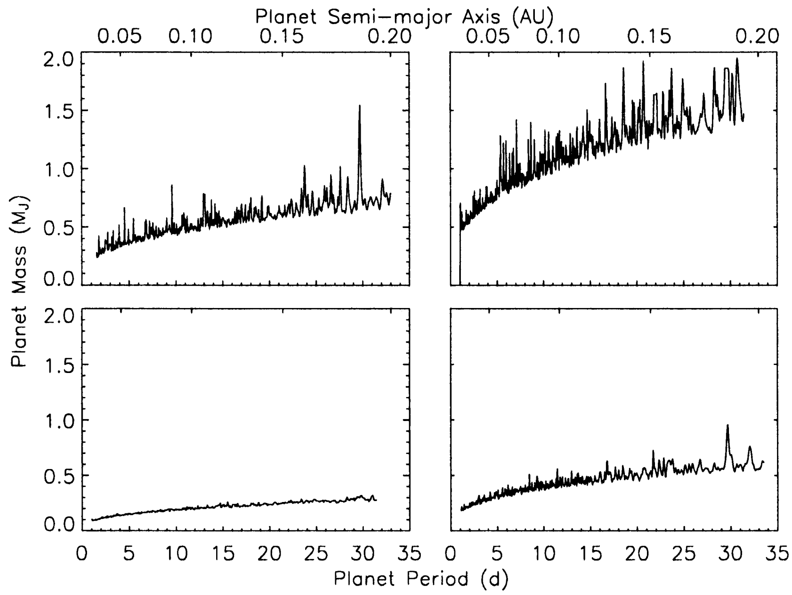

Figure 5. *Upper limits on planetary companion on short-period circular orbit for four stars representative of our sample. For the star on the upper-right corner planet detectability is strongly limited by stellar activity. The star in the lower-left corner is the one with the best limits, thanks to the low dispersion of RVs and the large number of measurements. The behaviour of the other two stars is more typical for our survey.*

a few days, we consider eccentric orbits in our estimation, as described in Desidera et al. (2003).

Fig. 5 shows the upper limits on planetary companion on short-period circular orbit for four stars representative of our sample. The results of the upper limit for period in the range 3-4 days (the typical period of 51 Peg planets) is summarized in Fig. 6. We are able to exclude 0.3 M_J, 0.5 M_J and 1.0 M_J planets in 3-4 days orbit for 34%, 62% and 96% of the 71 stars with at least 10 observations. For such short period we consider only circular orbits, as observed for the most of the close-in planets detected up to now. A full statistical evaluation of the upper limits is in progress. This will allow to place constrain on the frequency of planets around the components of wide binaries with similar components.

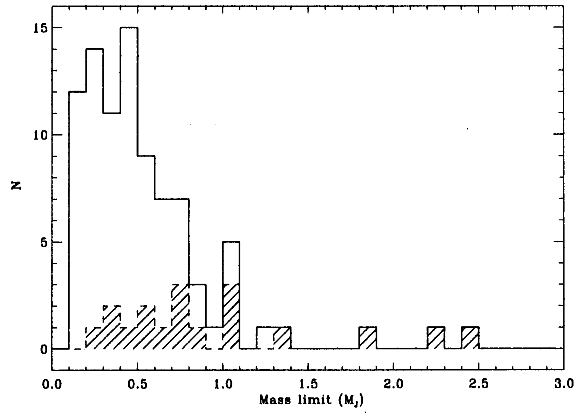

Figure 6. *Distribution of the mean upper limits between 3 to 4 days for the stars in our sample. The dashed region refers to stars with less than 10 measurements, the emtpy region to the other stars.*

Acknowledgements. This work was partially funded by COFIN 2004 'From stars to planets: accretion, disk evolution and planet formation' by Ministero Università e Ricerca Scientifica, Italy.

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