Extrasolar Planets in Multi-Body Systems: Theory and Observations
K. Goździewski, A. Niedzielski and J. Schneider (eds)
EAS Publications Series, **42** *(2010) 137-141*
www.eas.org

LINE BISECTOR ANALYSIS OF STARS WITH COMPANIONS IN THE SARG SURVEY AT THE TNG

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Abstract. We present an analysis of how bisectors of spectral lines vary, for a few stars observed during the high-accuracy radial-velocity planet survey ongoing at the Telescopio Nazionale Galileo (TNG) using the Galileo High Resolution Spectrograph (Spettrografo Alta Risoluzione Galileo, SARG), and discuss their relation with differential radial velocities. The iodine cell lines employed in the radial velocity measurements were used to improve the wavelength calibration and then removed before bisector analysis. The line bisectors were then computed from average absorption profiles obtained by cross-correlation of the stellar spectra with a mask made from suitable lines of a solar catalog. Bisector velocity spans were determined and the run of bisector velocity span against radial velocity was studied to search for correlations between line asymmetries and radial velocity variations. We present an analysis of spectra of HD 216122B that show a slight contamination likely to be due to a stellar companion, and an analysis of spectra of HD 76036A, a case where the line bisectors are useful for improving the RV measurements. These systems are part of a survey sample being observed with adaptive optics (AdOpt at the TNG since 2006) in an attempt to visually resolve stellar companions.

1 Introduction

Stellar spectra in the range 4580–6170 Å were obtained with the high resolution spectrograph SARG at the TNG. Every spectral order was divided into 7 chunks

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DOI: 10.1051/eas/1042013

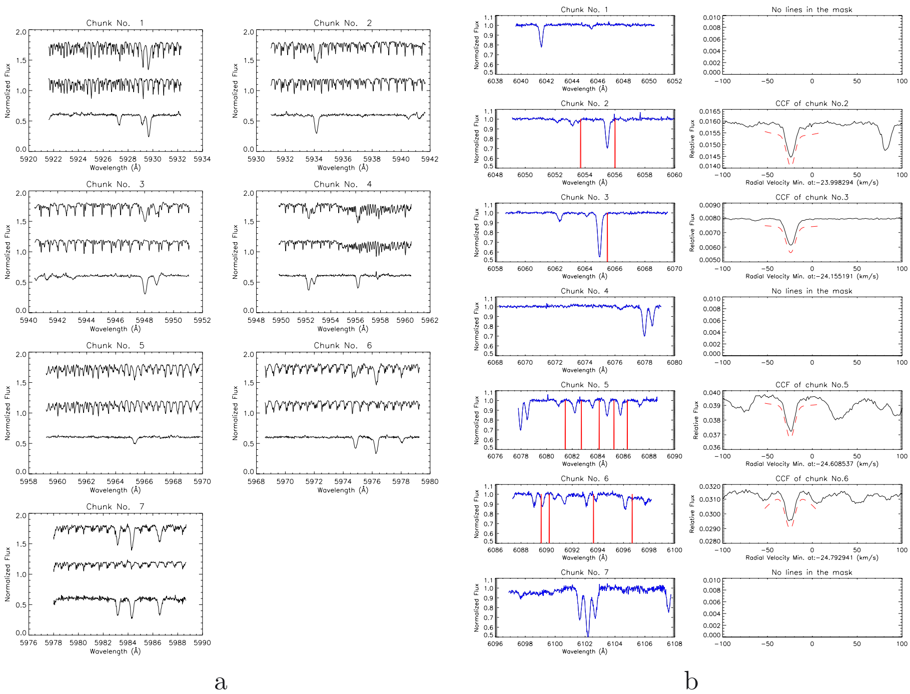

Fig. 1. a) Stellar spectrum, divided into 7 chunks. The spectra have been shifted arbitrarily in flux. *Upper panel:* the stellar spectrum with iodine lines, *middle panel*: the B-star spectrum with the iodine lines, *lower panel:* the clean stellar spectrum after dividing the star by the B-star spectrum. b) An order of the stellar spectrum. The left column shows individual chunks of the spectrum (in blue), after removal of the iodine lines. The mask used for the determination of the CCF (only suitable lines) is shown in red. It is made of δ-functions centered on the rest wavelengths of the selected lines. There are wavelength shifts between the stellar lines and the mask peaks due to the non-zero radial velocity of the star. The CCF for individual chunks computed by cross-correlating the spectra with the masks are shown in the right panels. The red dashed line, shifted slightly below the profiles for clarity, represents the Gaussian fit computed to determine the local minimum of the CCF for each chunk.

of ∼10 Å and the spectrum of a B-star, used in the radial velocity (RV) determination, was employed to remove the iodine lines superposed on the stellar spectrum for wavelength calibration (see Fig. 1). To compute the cross-correlation function (CCF) a mask is constructed from the solar catalog of Moore *et al.* (1966), selecting those lines separated from their neighbors by $\geq$0.1 Å, intensity in the range 3–30 Fraunhofer and well-defined, unblended shapes, avoiding telluric features. The mask is a sum of δ-functions: 1 for the selected wavelengths and 0 elsewhere. The CCF is computed for every chunk, multiplied by a weight, added and finally normalized. Some profiles are shown in Figure 1.

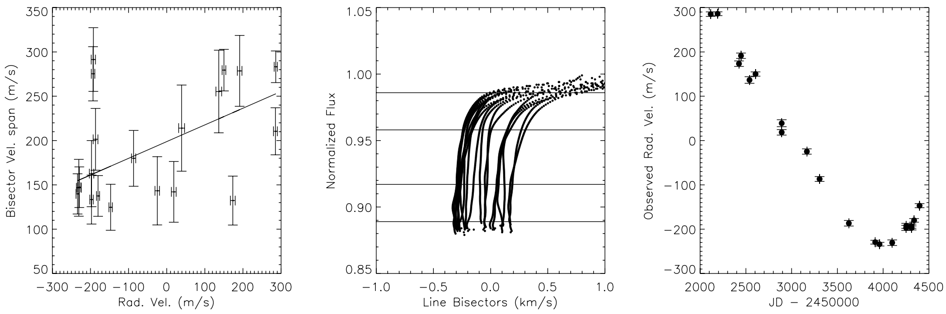

Fig. 2. *Left panel*: plot of BVS *vs.* RV and their linear correlation, which has a significance of 88.5%. *Central panel*: LB for 20 different spectra. Horizontal lines enclose the "top" and "bottom" zones considered for the analysis. The BVS error (rms) is 32.4 m/s. *Right panel*: RV *vs.* time. The trend is linear until 2006, then the RV points smoothly turn up.

The line bisector (LB) is the mid point of the profile, computed from the core toward the wings. The bisector velocity span (BVS) is the velocity difference ($V_T - V_B$) between two zones of the profile: one near the wings ("top" zone) and the other near the core ("bottom" zone). See Martínez Fiorenzano, A.F. *et al.* (2005) for details of the analysis and error determination.

2 Analysis

The RVs are computed using the AUSTRAL code (Endl *et al.* 2000 and Desidera *et al.* 2003). The LBs are computed from the same spectra with an IDL code (Martínez Fiorenzano, A.F. 2005). HD 216122B is an F8 star showing RV variation with a long term trend, which has highly significant curvature in the last year (see Fig. 2). The LBs show high curvature in the red wing and there is also a marginal correlation of the BVS with RV (see Fig. 2). This is consistent with a small amount of contamination by a close stellar companion. The observed trend in RV, which is likely to be caused by the gravitational pull of a stellar companion, motivated observations with adaptive optics (AdOpt at the TNG). We are quite confident that the companion candidate has been identified (see Fig. 3), even though further tests should be done. HD 76037A is an F8 star with the signature of a stellar companion in its spectrum, clearly seen from the curved shape of its LB. The BVS-RV correlation, due to light contamination, was highly significant (99.7%) in spectra taken until 2005 (Martínez Fiorenzano, A.F. 2005), but vanished after data from 2006 (see Fig. 4), probably because the RV variations became dominated by the orbital motion. The residuals from a quadratic fit of the RVs are highly correlated with BVS (see Fig. 4). The correlation allows the computation of RVs from the LB, to improve the RV curve. There is an rms of 304.4 m/s for observed RVs and an rms of 262.8 m/s for computed RVs. This is a high priority target being observed with AdOpt at the TNG.

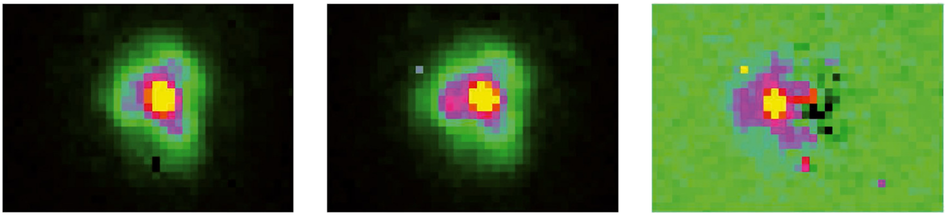

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Fig. 3. Adaptive optics identification of a close companion candidate around HD 216122B. a) Image of the wide companion HD 216122A. b) Image of HD 216122B, the star with an RV trend. c) Difference between the two images (B–A). The PSF artifacts were removed fairly well, allowing the identification of a close companion candidate at 0.2 arcsec from the star. This is probably responsible for the observed RV trend.

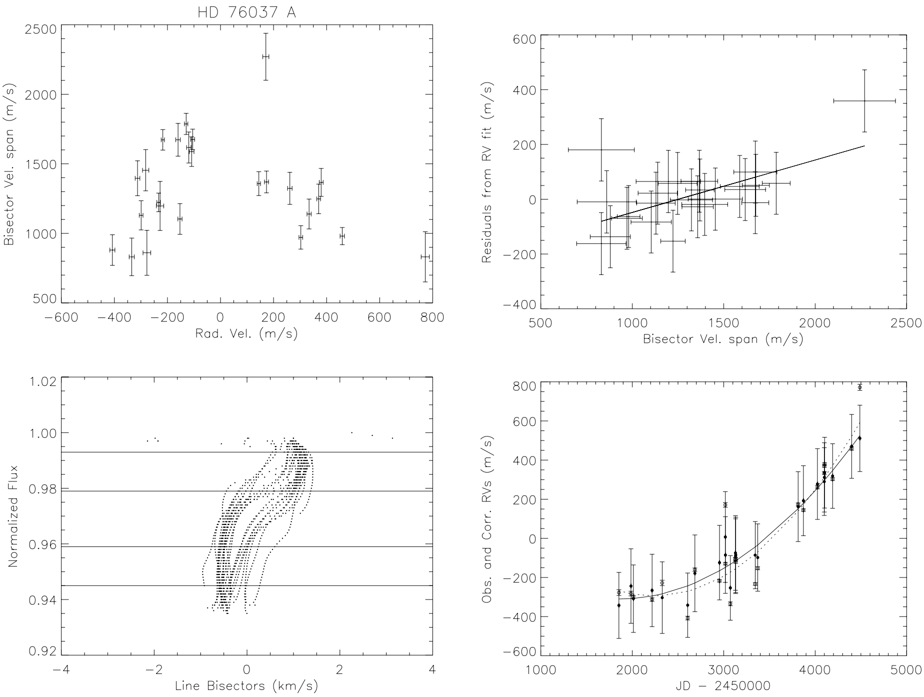

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Fig. 4. HD 76037A. a) *Upper panel*: BVS *vs.* RV. A highly significant correlation was observed in the data until 2005. *Lower panel*: LB for 25 different spectra. The horizontal lines enclose the "top" and "bottom" zones considered in the analysis. The BVS error (rms) is 116.4 m/s. b) *Upper panel*: BVS *vs.* residuals of the RV quadratic fit. There is a correlation at a significance of 99.3%. *Lower panel*: RV curve for the observed spectra (empty circles) and its quadratic fit (dotted line). The RVs computed from the BVS (filled circles) and their quadratic fit (solid line) are also shown.

3 Discussion

We studied the variation of the LB in the same spectra acquired through the iodine cell that were used for high-accuracy RV measurements. We found that the variation measured by the BVS shows spreads fully consistent with internal errors, as determined from photon statistics, spectral resolution and intrinsic line profiles. The weak correlation found for BVS-RV in the HD 216122B spectrum is consistent with slight contamination from a stellar companion. Observations with AdOpt at the TNG are being carried out in order to check this. The correlation found for the BVS and the residuals of the quadratic fit to the RV curve of HD 76037A were useful for improving the RV curve itself, reducing the rms from 304.4 m/s to 262.8 m/s. Beside these special cases of triple systems, the LB technique is being applied to the targets (wide binary systems) of the planet search survey with SARG at the TNG, to disentangle the RV variations induced by planets from those due to stellar activity and contamination from binary companions. These are complex systems that are primarily being observed spectroscopically. In addition, photometry using adaptive optics has now been shown to be useful in characterizing at least one of these systems.

References

Desidera, S., *et al.*, 2003, A&A, 405, 207

Endl, M., *et al.*, 2000, A&A, 362, 585

Gray, D.F., 1983, Pub. A.S.P., 95, 252

Martínez Fiorenzano, A.F., *et al.*, 2005, A&A, 442, 775

Martínez Fiorenzano, A.F., 2005, PhD. Thesis [astro-ph/0603788]

Moore, C.E., *et al.*, 1966, The solar spectrum 2935 Å to 8770 Å (National Bureau of Standards Monograph, Washington: US Government Printing Office (USGPO))