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Direct mass determination of low-mass PMS stars from long-period spectroscopic systems

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Abstract. The determination of accurate masses from the study of binary orbits requires a combination of complementary observing techniques. In this respect, of particular interest is the solution of astrometric orbits for long-period spectroscopic binaries by applying interferometric techniques.
Results of a high-resolution spectroscopic monitoring of low-mass Pre-Main Sequence (PMS) spectroscopic binary (SB) systems in nearby star formation regions (SFR) of the Southern Hemisphere, conducted at ESO with FEROS, aiming to identify SB systems with long-period orbits, suitable for follow-up observations with the VLTI are presented. The ultimate aim is the determination of dynamical masses for a representative sample of young low-mass stars of different masses and ages to provide strong observational constraints for current PMS theoretical models.

Key words. Stars: binaries: spectroscopic – Stars: pre-main sequence – low-mass – fundamental parameters

1. Introduction

An accurate determination of fundamental stellar physical quantities is crucial in order to improve our knowledge of the evolution of stellar structures from the pre-main sequence (PMS) to the main sequence (MS) phase. In particular, the determination of accurate masses from binary orbits critically depends on precise determination of the orbital inclination, which requires a combination of complementary observing techniques. Direct mass determinations with errors lower than 5% is possible in the case of double-lined spectroscopic binaries (SB2) whose components are either eclipsing (EB) (see Covino et al. 2004, and references therein), or have astrometrically measurable orbits (see for example Woitas et al. 2001). The astrometric orbits yield the sum of the component masses via the Kepler's third law, while spectroscopic ones provide the orbital period and the minimum masses of the com-

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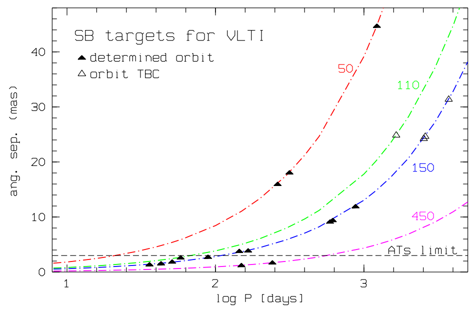

Fig. 1. Maximum angular separation for the sample of PMS SB systems. The dashed lines indicate the corresponding separations at distances of 45, 110, 140 and 450 pc, assuming a total mass of 1 $M_{\odot}$. The horizontal line marks the angular resolution limit for the VLTI Auxiliary Telescopes.

ponents, or the mass function in case of SB1 systems (for which the parallax is needed).

2. Spectroscopy and sample selection

Radial velocity measurements are based on high resolution spectra obtained mainly with FEROS (Fiber-fed Extended Range Optical Spectrograph), at the 1.5m and 2.2m telescopes of the ESO-La Silla Observatory. The selection of the main spectroscopic targets was carried out through a preliminary study of a wider sample of young SB candidates, most of which already classified as weak-T Tauri stars (WTTS) and located closer than about 150 pc, in the major nearby SFRs (e.g. Chamaeleon, Lupus, Ophiucus, Corona Australis, Scorpio-Centaurus) and the nearest young stellar associations (namely, TW Hydra, Crux, and Tucana) (Sterzik et al. 1999; Melo et al. 2001; Alcalá et al. 2002; Guenther et al. 2004). The result has been the identification of a still growing number of young short- and long-period SB systems with determined spectroscopic orbits.

3. First test cases for astrometry

The sample of PMS SB targets with spectroscopic orbits solved up to now that are suitable for astrometric measurement with VLTI sums up to nearly forty stars belonging to binary and multiple systems located in different nearby SFRs and young stellar associations. At the distance of the nearest young star associations (≈50 pc), the astrometric orbits of SB2 systems with orbital period longer than a few hundred days can be solved by means of near-IR interferometry at the VLT, allowing the determination of absolute masses and other fundamental parameters for the components. In particular, the current VLTI capabilities should enable us to resolve with the necessary precision binary orbits with angular projected semi-major axes of the order of ten mas, corresponding to orbital periods around 600–1000 days for a 1 $M_{\odot}$ system at about 150 pc distance. Fig. 1 shows the maximum angular separation for our current sample of PMS SB systems with solved spectroscopic orbits. Particularly interesting test cases are represented by SB systems in the period interval from a few hundreds to a few thousand days located closer than about 150 pc. Among these, some spectroscopic hierarchical triple systems have also been revealed, for which combined orbital solutions will allow us to determine the masses of all components. One of the triples, in the Crux SFR (≈ 110 pc), is made up of a sixty-days orbital-period inner SB2 system with a third lower-mass component orbiting around the mass-center of the system in a four-year period (Alcalá et al. 2002). Other interesting cases are represented by the long-period SB1 system BS Ind, located at about 50 pc in the Tucana-Horologium association, whose cooler component appears to be a short-period eclipsing binary (Guenther et al. 2004), and by the very young spectroscopic hierarchical triple system in Lupus, RX J1524-3209, in which a low-mass short-period SB2 is gravitationally perturbed by a less massive tertiary component on a long-period orbit shown in Fig. 2 (Esposito et al. 2005).

4. Conclusions

In cases like the ones considered here, the combination of spectroscopic and astrometric orbital solutions should enable us to derive the

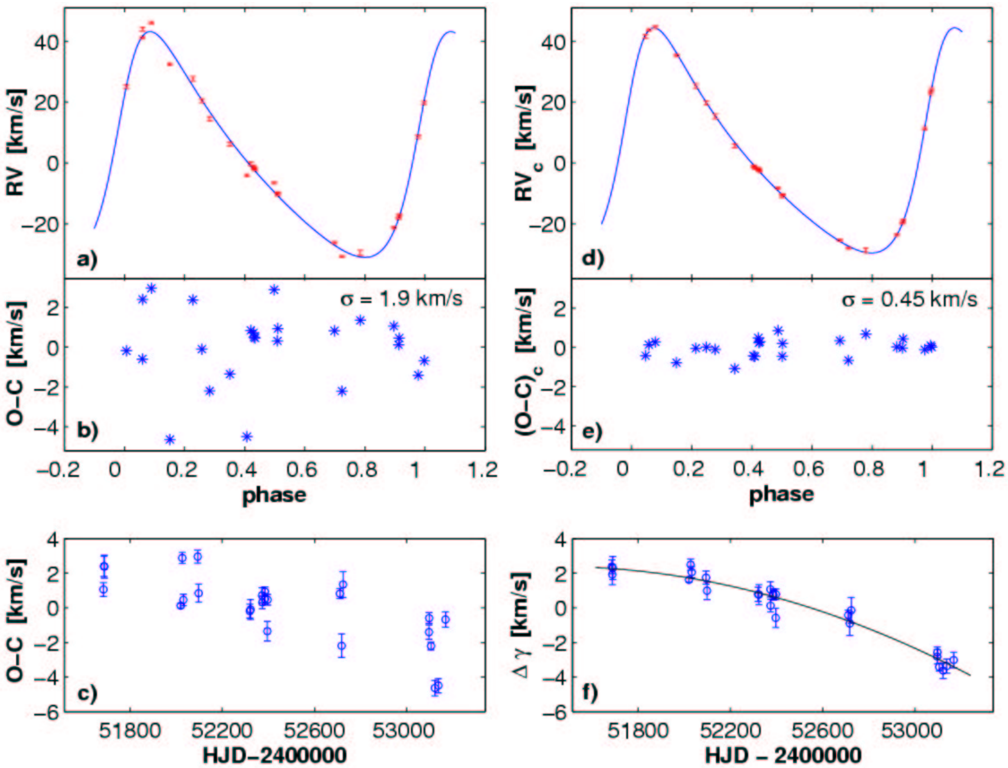

Fig. 2. Iterative solution of the primary radial velocity curve of the SB2 system RX J1524-3209. The left panels show the initial orbital solution and the corresponding residuals; the right panels show the best-fit orbital solution after correction for systematic trend in the gamma radial velocity revealing the presence of a tertiary component on a long-period orbit (Esposito et al. 2005).

mass of the individual components, thus providing us with an extremely valuable test for PMS evolution models. Hovewer, in order to achieve a reliable determination of the orbital parameters, in particular of the orbital inclination, high precision astrometric measurements and an adequate temporal sampling are mandatory. Last but not least, as the distances to the main nearby SFRs are still not well determined, obtaining precise orbital parallaxes by means of VLTI astrometry will be another sensible goal of the programme.

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