New triple systems in the RasTyc sample of stellar X-ray sources **,***,****

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ABSTRACT

Context. During the study of a large set of late-type stellar X-ray sources, we discovered a large fraction of multiple systems. Aims. In this paper we investigate the orbital elements and kinematic properties of three new spectroscopic triple systems as well as spectral types and astrophysical parameters (Teff, log g, vsin i, log N(Li)) of their components. Methods. We conducted follow-up optical observations, both photometric and spectroscopic at high resolution, of these systems. We used a synthetic approach and the cross-correlation method to derive most of the stellar parameters. Results. We estimated reliable radial velocities and deduced the orbital elements of the inner binaries. The comparison of the observed spectra with synthetic composite ones, obtained as the weighted sum of three spectra of non-active reference stars, allowed us to determine the stellar parameters for each component of these systems. We found all are only composed of main sequence stars. Conclusions. These three systems are certainly stable hierarchical triples composed of short-period inner binaries plus a tertiary component in a long-period orbit. From their kinematics and/or Lithium content, these systems result to be fairly young.

Key words. stars: binaries (including multiple): close – stars: binaries: spectroscopic – X-rays: stars: stars: late-type – stars: fundamental parameters – techniques: radial velocities

1. Introduction

Binary and multiple stars are very important astrophysical laboratories. In particular, spectro-photometric and spectro-astrometric binaries offer the unique opportunity to determine, with a high level of accuracy, the basic stellar parameters (mass, radius, and effective temperature) to study stellar structure and evolution. However, the formation and evolution of binary stars are still debated subjects (e.g., Zinnecker & Mathieu, 2001). Especially, a still unsolved problem is the formation of close binaries with main sequence components separated by few solar radii that in the proto-stellar phase should have been in contact.

In the last years, to answer many of these open questions, relevant observational and theoretical efforts are being done to improve continuously the statistics of binary systems with different periods, mass ratios, etc. (e.g., Tokovinin et al. 2006).

Close binaries containing at least one late-type component, such as RS CVn and BY Dra systems, are objects with the strongest magnetic activity (starspots, plages, flares) induced by a dynamo action in the sub-photospheric convection zone. Their strong activity is mainly due to their very fast rotation (spin-orbit synchronization by tidal forces) and to proximity effects.

X-ray sky surveys performed in recent years have allowed to identify thousands of active late-type stars in the field and in open clusters. Follow-up observations of the optical counterparts of X-ray sources have led to discover very young stars far from the typical birth sites, i.e. open clusters and stars forming regions (e.g., Wichmann et al., 2003a; Zickgraf et al., 2005; Torres et al., 2006; Guillout et al., 2008), as well as to detect several spectroscopic binaries (e.g., Wichmann et al., 2003b; Frasca et al., 2006). The knowledge of the incidence of binaries and multiple systems in X-ray selected samples of active stars is extremely important to study the recent local star formation history.

One of the largest (~ 14 000 active stars) and most comprehensive set of stellar X-ray sources in the field is the so-called RasTyc sample, which is the result of the cross-correlation of the ROSAT All-Sky Survey (RASS) with the TYCHO catalog (Guillout et al., 1999). We began to analyze a representative sub-sample of the RasTyc population in the northern hemisphere (Guillout et al., 2008) to obtain some reliable statistics about the RasTyc stellar characteristics. For this purpose, we led campaigns of high-resolution spectroscopic observations, with the ÉLODIE échelle spectrograph at the 193-cm telescope and the AURELIE spectrograph at the 152-cm telescope of the Observatoire de Haute Provence (OHP). For all the sources, we performed a detailed analysis of the cross-correlation function (CCF) and found that single-lined (SB1), double-lined (SB2), and triple-lined (SB3) spectroscopic systems altogether account
Table 1. Main data of the three RasTyc sources from the literature.

| RasTyc Name   | Name  | $\alpha$ (2000) (h m s) | $\delta$ (2000) (° ′ ″) | $V_\pi$ | $\pi$ | $\mu_\alpha$ | $\mu_\delta$ | X-ray source | Counts |
|---------------|-------|-------------------------|-------------------------|---------|-------|-------------|-------------|--------------|--------|
| RasTyc 0524+6739 | BD+67 381 | 05 24 53.2 | +67 39 39 | 9.065 | 7.8+9.3 | −0.5 | 26.7 | J052450.9+673939 | 4.21x10^{-1} |
| RasTyc 1828+3506 | BD+35 3261 | 18 28 50.3 | +35 06 34 | 9.049 | 12.2+8.2 | 12.3 | −3.5 | J182849.7+350637 | 6.24x10^{-2} |
| RasTyc 2034+8253 | BD+82 622 | 20 34 27.5 | +82 53 35 | 9.730 | — | 61.5 | 35.5 | J203426.2+825334 | 3.75x10^{-1} |

$^a$ V magnitude and proper motions from the TYCHO-2 catalog (Høg et al., 2000);
$^b$ Parallax from the TYCHO-1 catalog (ESA, 1997).
Table 5. Orbital parameters of the three systems. The errors on the last significant digit are enclosed in parenthesis. $P = \text{Primary}$ and $S = \text{Secondary}$.

| Name           | HJD0 (2 450 000+) | $P_{\text{orb}}$ (days) | $e$ | $\omega$ (°) | $\gamma$ (km s$^{-1}$) | $k$ (km s$^{-1}$) | $M S \sin i$ ($M_\odot$) | $M P / M S$ |
|----------------|-------------------|--------------------------|-----|--------------|-------------------------|-----------------|----------------------------|------------|
| RasTyc 0524+6739 | 2212.02(5)$^a$    | 3.6588(2)                | 0.042(3) | 294(5) | $-13.4(2)$     | 82.2(3)/84.5(3) | 0.889(6)/0.865(6)   | 1.028(4)   |
| RasTyc 1828+3506 | 3565.95(4)$^b$    | 7.595(5)                 | 0              |         | $-21.5(4)$     | 72.4(5)/73.7(5) | 1.24(2)/1.22(2)     | 1.018(9)   |
| RasTyc 2034+8253 | 2471.3(3)$^b$     | 4.9543(2)                | 0              |         | $-11.2(3)$     | 38.8(3)/39.5(3) | 0.124(2)/0.122(2)   | 1.02(1)    |

$^a$ Heliocentric Julian Date (HJD) of the periastron passage; $^b$ HJD of the inferior conjunction of the primary (more massive) component.

Fig. 5. Radial velocity curves of the new three RasTyc triple systems. Large symbols refers to AURELIE data while smaller symbols are used for Frasca spectrograph data. Filled and open circles for the primary (more massive) and secondary component of the inner binaries have been used, respectively. In each panel, the solid and dashed lines represents the orbital solutions for the primary and secondary component, respectively, whereas the dotted line represents the barycenter of the inner binary. The asterisks are used for the tertiary component and plus symbols refer to blended RV values. The RV errors are always smaller than, or comparable to, the symbol size. The $V$ photometry is displayed, as a function of the orbital phase, on the top panel of each box.

For the two RasTyc systems with the shortest orbital periods, the RV value of the tertiary component is very close to the barycentric velocity ($\gamma$) of the inner binary during different observing seasons. Thus, we could not try any evaluation of the orbital period of the tertiary component. As the vast majority of the already known triple systems, each of our sources consists of a short-period inner binary with a third component orbiting around the close pair in a long-period orbit. These systems display a typical “hierarchical” configuration (Evans 1968). In particular, RasTyc 2034+8253 was already known as a visual binary (Muller 1976). From the observations of Muller (1976, 1978, 1990) and Fabricius et al. (2002), this component seems to have a regular evolution because the position angle and the separation are constantly growing. Thus, its orbital period must be significantly greater than the period of observations (about 20 years) implying a degree of hierarchy $X \gg 1500$, where $X$ is defined as the ratio of the “external” period (orbit of tertiary component around the center of mass to the inner binary) to the “internal” period (that of the inner binary).

On the contrary, in 2005, the tertiary component of RasTyc 1828+3506 displays a RV systematically higher (3.3 km s$^{-1}$) than that of the barycenter of the inner binary (see Fig. 5 middle panel). Moreover, we found a highly significant RV increase (more than 15 km s$^{-1}$) for the tertiary component.
configuration. We found that the weight for the components of all inner binaries due both to fast rotation and nearness. Moreover, tidal interaction in these binaries leads to synchronization between orbital and rotational periods of both components. It is worth noticing that the periods of all these three systems are smaller than, or very close to, the cut-off value of 7.56 days found by [Melo et al., 2001] for orbital circularization in Pre-Main Sequence (PMS) binaries. According to Zahn & Bouchet (1989), for close late-type binaries with masses ranging from 0.5 to 1.25 M⊙, the cut-off period may be as long as 7.2 to 8.5 days, depending on the masses and on the assumptions of the initial conditions. So, being all these systems older than PMS stars, they should be already circularized, in substantial agreement with the results from the solution of their RV curves. The non-detection of photometric variation in RasTyc 1828+3506 could be related both to the fairly long orbital/rotational period (7.595 days) and to the relatively early spectral types of the system components with shallower convective envelopes and, consequently, with a reduced dynamo action compared to cooler stars with the same rotation rate.

3.3. Astrophysical parameters and other properties

The use of ROTFIT and COMPO2 codes allowed us to derive the spectral type and the APs for the components of each system (Table 7). We used spectra of stars of the same spectral types retrieved from the ELODIE Archive (Prugniel & Soubiran, 2001) to build up the reference spectra displayed in Fig. 1. Moreover, the relative continuum contributions of the tertiary components are in agreement with their spectral types found by us, taking into account the errors derived from the distribution of the best spectral combinations. This uncertainty is about 1.5 spectral subclasses, except for the tertiary component of RasTyc 0524+6739, the coolest star, for which the uncertainty is more than 2 spectral subclasses. Regarding log g and [Fe/H], despite the rather large errors, we can state that the three systems are composed of MS stars with a nearly solar metallicity.

We found that the weight for the components of all inner binaries is nearly equal (Table 7), i.e., their luminosity ratio is ≃ 1. This is compatible with the mass ratio (M_p/M_s) ≃ 1 (Table 5) derived from the solution of the RV curves, if the two twin stars are both on the MS. Our results, although not statistically significant, are in favor of an excess of twins in spectroscopic binaries containing a third body as suggested by Tokovin et al. (2006). Moreover, the CCF dips of RasTyc 1828+3505 and RasTyc 2034+8253 would suggest a tertiary component brighter than each star of the inner binary. However, the weights quoted in Table 7 for RasTyc 1828+3505 are in conflict with the depth

| Name     | V (mag) | B – V (mag) | U – B (mag) | Dist. (pc) |
|----------|---------|-------------|-------------|------------|
| RasTyc 0524+6739 | 8.892(7) | 0.773(7) | 0.235(9) | 75 ± 20 |
| RasTyc 1828+3506 | 8.951(8) | 0.578(6) | 0.015(8) | 115 ± 25 |
| RasTyc 2034+8253 | 9.49(2) | 0.96(1) | 0.70(3) | 80 ± 20 |

a V magnitude at maximum brightness.
Table 7. Physical parameters for each component of the three systems.

| Component       | Primary (P) | Secondary (S) | Tertiary (T) |
|-----------------|-------------|---------------|-------------|
| RasTyc 0524+6739: |             |               |             |
| $T_{\text{eff}}$ (K) | 5350 ± 280  | 5270 ± 279    | 4700 ± 459  |
| log $g$         | 4.2 ± 0.3   | 4.2 ± 0.4     | 4.2 ± 0.4   |
| [Fe/H]         | −0.21 ± 0.18| −0.24 ± 0.21  | −0.12 ± 0.11|
| $v\sin i$ (km s$^{-1}$) | 12 ± 2     | 12 ± 3        | < 5         |
| Weight         | 0.45 ± 0.05 | 0.43 ± 0.05   | 0.12 ± 0.02 |
| Sp. Type       | G9V         | G9V           | K5V         |
| RasTyc 1828+3506: |             |               |             |
| $T_{\text{eff}}$ (K) | 5800 ± 400  | 5800 ± 350    | 5480 ± 300  |
| log $g$         | 4.2 ± 0.2   | 4.2 ± 0.2     | 4.3 ± 0.2   |
| [Fe/H]         | −0.27 ± 0.17| −0.24 ± 0.18  | −0.21 ± 0.12|
| $v\sin i$ (km s$^{-1}$) | 12 ± 1     | 11 ± 2        | < 5         |
| Weight         | 0.38 ± 0.08 | 0.33 ± 0.08   | 0.29 ± 0.03 |
| Sp. Type       | G1V         | G1V           | G4V         |
| RasTyc 2034+8253: |             |               |             |
| $T_{\text{eff}}$ (K) | 4960 ± 260  | 4920 ± 300    | 5090 ± 200  |
| log $g$         | 4.3 ± 0.2   | 4.4 ± 0.2     | 4.4 ± 0.2   |
| [Fe/H]         | −0.23 ± 0.24| −0.23 ± 0.23  | −0.05 ± 0.17|
| $v\sin i$ (km s$^{-1}$) | < 5        | < 5           | < 5         |
| Weight         | 0.31 ± 0.04 | 0.30 ± 0.04   | 0.39 ± 0.04 |
| Sp. Type       | K3V         | K3V           | K1V         |
| $EW$(Li) (mA)  | —           | —             | 49 ± 15     |
| log $N$(Li)    | —           | —             | 1.8 ± 2.0   |

of the CCF dips. The inconsistency is removed if we take into account the earlier spectral type and the faster rotation of the components of the inner binary of this system compared to the tertiary star.

We used the nomenclature proposed by Lafrenière et al. (2008) assigning the letter A to the brightest (more massive for MS stars) component and enclosing in parentheses the components forming the inner binary. We found one system (RasTyc 2034+8253) and two systems (RasTyc 0524+6739 and RasTyc 1828+3506) in the A,(B,C) and (A,B),C configurations, respectively. Although our sources appear to be older than PMS stage (Sect. 3.4), the configurations found are similar to those typically encountered in PMS stars (Lafrenière et al., 2008; Correia et al., 2006). Moreover, Mayor & Mazeh (1987) and Tokovinin et al. (2006) found that the most massive component in the multiple stellar systems is preferentially in the close binaries. In particular, Tokovinin et al. (2006) found a small fraction of systems (17 ± 4 %) where the spectroscopic primary is not the most massive star.

Our results seem to be consistent with those of these authors and need to be confirmed with a larger statistical sample of multiple systems. The analysis of all the triple systems found by us in the RasTyc sample, for which we are still collecting RV data, will help us to confirm these findings.

3.4. Age estimation and kinematics

It is well established, for stars later than about mid-G spectral type, that the strength of the Li ι $\lambda$6707.8 line can be used as an age estimator, a high log $N$(Li) being a youth indicator. Although the Lithium abundance can not be simply converted into age, we can give a rough evaluation of the age by comparing the log $N$(Li) value of our systems (Table 7) to that of Pleiades and Hyades stars having the same temperature (see, e.g., Soderblom et al., 1993; Jeffries, 2000). We report the estimated age in Table 8.

The parallax ($\pi$) from TYCHO-1 catalog (ESA, 1997) are not enough accurate. Thus, we estimated photometric distances (Table 5) from the “integrated” $V$ magnitude measured by us and the mean $V$ absolute magnitude for each triple system. The precision of proper motions for these systems is 1.5 mas yr$^{-1}$ in TYCHO-2 catalog (Heg et al., 2000). From these two parameters and barycentric RVs of the inner binary, we computed the space-velocity components ($U,V,W$) of these SB3s in the left-handed coordinate system. Their space velocities are con-
consistent with those of the young-disk (YD) population (Fig. 5). Based on two kinematics methods (Klutsch et al. 2008), we determined the membership probability (Table 8) to five young Stellar Kinematic Groups (SKGs; Montes et al. 2001).

For RasTyc 0524+6739, we did not observe any Li absorption lines in the spectra (Fig. 7 top panel), notwithstanding the spectral types of its components that would permit the detection of the Li line also with a moderate abundance. Thus, this system should be older than the Hyades. Therefore, even though its position in the $UVW$ diagrams points to a marginal association with the young Ursa Major (UMa) group ($Age \sim 300\text{ Myr}$), we do not consider this star as a new member of this SKG.

For RasTyc 1828+3506, except for the tertiary component (Fig. 7 middle panel), the log $N$(Li) value we deduce for it is only slightly higher than that of Hyades stars. Therefore, the age of the system could be in the range 400–600 Myr, ruling out its membership to the Pleiades moving group.

Finally, even though the RasTyc 2034+8253 kinematics is marginally consistent with that of the already known members of IC 2391 supercluster, we can clearly distinguish the Lithium lines for the three components (Fig. 2 lower panels). The log $N$(Li) value found for its three components is very similar and reinforce the idea of a common origin for all the components. This value is only slightly lower than that of Pleiades stars. Therefore, we estimate an age between 100 and 300 Myr which is compatible with that of two stellar populations in IC 2391 supercluster (Eggen 1991). The agreement between the kinematic age and that inferred from the Lithium suggests that this system can be a possible new member of this SKG.

### 4. Conclusions

This paper is devoted to the analysis of three new triple systems discovered in the RasTyc sample of stellar X-ray sources. Their spectroscopic and photometric data allow us to conclude that they are almost certainly stable hierarchical triple systems composed of short-period inner binaries plus a tertiary component in a long-period orbit. The orbital periods of the inner binaries range from 3.5 to 7.6 days and the orbits are practically circular. From the high-resolution spectra we also found the spectral composition and the astrophysical parameters of the components that turn out to be all G-K main sequence stars. In all cases, the components of the inner binaries have nearly the same masses, spectral types, and luminosities. From their kinematics and/or Lithium content, these systems result to be fairly young. RasTyc 2034+8253 is the only system in which the Li i $\lambda$6707.8 line is strong enough to be clearly visible in the spectra of all the three components and suggests an age in the range 100–300 Myr. It is a possible new member of the IC 2391 supercluster. For the remaining systems, the membership to young moving groups is rather uncertain.

Our spectroscopic survey has revealed that multiple systems represent a large fraction of the RasTyc sources. However, a detailed analysis is absolutely necessary for drawing statistically significant conclusions. Since RasTyc objects are relatively nearby, the discovery and the study of new triple systems, such as those presented in the present paper, can contribute to a better understanding of the formation and the evolution of close binaries and multiple systems in the solar neighborhood.

### References

Bevington, P. R. 1969, “Data Reduction and Error Analysis for the Physical Sciences”, McGraw-Hill Book Company, 237

Correia, S., Zinnecker, H., Ratzka, T., & Sterzik, M. F. 2006, A&A, 459, 909

Eggen, O. J. 1991, AJ, 102, 2028

Eggen, O. J. 1996, AJ, 112, 1595

ESA, 1997, The Hipparcos and Tycho Catalogues, ESA SP-1200

Evans, D. S. 1968, QJRAS, 9, 388

Fabricius, C., Hög, E., Makarov, V. V., et al. 2002, A&A, 384, 180

Frasca, A., & Catalano, S. 1994, A&A, 284, 883

Frasca, A., Alcalá, J. M., Covino, E., et al. 2003, A&A, 405, 149

Guillout, P., Klutsch, A., Frasca, A., et al. 2008, A&A, to be submitted

Jeffries, R. D. 2000, in Stellar Clusters and Associations: Convection, Rotation, and Dynamos, ed. R. Pallavicini, G. Micela, & S. Sciortino, ASP Conf. Series, 198, 245

Montes, D., Fernández-Figueroa, M. J., de Castro, E., & Cornide, M. 1995, A&AS, 109, 135

Montes, D., López-Santiago, J., Gálvez, M. C., et al. 2001, MNRAS, 328, 45

Prugniel, P., Souihar, C. 2001, A&A, 369, 1048

Soderblom, D. R., Jones, B. F., Balachandran, S., et al. 1993, AJ, 106, 1059

Table 8. Kinematic parameters of the new triple systems.

| Name          | Age (Myr) | $U$ (km s$^{-1}$) | $V$ (km s$^{-1}$) | $W$ (km s$^{-1}$) | Moving Group | Probability (%) |
|---------------|-----------|-------------------|-------------------|-------------------|--------------|----------------|
| RasTyc 0524+6739 | > 600     | $-16.1 \pm 1.9$   | $-1.1 \pm 1.9$    | $0.6 \pm 1.5$     | UMa          | 5 – 35         |
| RasTyc 1828+3506 | 400 – 600 | $8.5 \pm 1.0$     | $-15.6 \pm 1.0$   | $-13.7 \pm 1.9$   | Pleiades     | 25 – 55        |
| RasTyc 2034+8253 | 100 – 300 | $19.1 \pm 4.1$    | $-14.0 \pm 2.0$   | $-17.3 \pm 4.8$   | IC 2391      | 5 – 15         |
Tokovinin, A., Thomas, S., Sterzik, M., & Udry, S. 2006, A&A, 450, 681
Torres, C. A. O., Quast, G. R., da Silva, L., et al. 2006, A&A, 460, 695
Wichmann, R., Schmitt, J. H. M. M., & Hubrig, S. 2003a, A&A, 399, 983
Wichmann, R., Schmitt, J. H. M. M., & Hubrig, S. 2003b, A&A, 400, 293
Zahn, J.-P., & Bouchet, L. 1989, A&A, 223, 112
Zickgraf, F.-J., Krautter, J., Reffert, S., et al. 2005, A&A, 433, 151
Zinnecker, H. & Mathieu, R. D. (eds.) 2001, The formation of binary stars, Proc.
IAU Symp. 200, ASP Conf. Series
Fig. 2. The CCFs of RasTyc 0524+6739 permit to emphasize the change of configuration from a one-peak shape at a conjunction (left top panel) to a three-peak shape (right lower panel), passing through phases of partial blending in which only two peaks are easily distinguishable (left lower panel and right top panel). The RV uncertainty is about 1 km s$^{-1}$ at our spectral resolution. On each panel, the multiple Gaussian fits of the CCFs are overplotted with full lines (top box) and the residuals of the fits are plotted in the lower box.

Fig. 3. The CCFs of RasTyc 1828+3506 clearly show three peaks with different widths. The two components of the inner binary appear to rotate faster than the third star, probably due to spin-orbit synchronization.

Fig. 4. The CCFs of RasTyc 2034+8253 at two orbital phases. The triple system nature appears from the CCF (left panel), while it is completely hidden at another phase of observation (right panel).
Fig. 1. High resolution spectra of RasTyc 0524+6739 (top panels), RasTyc 1828+3506 (middle panels) and RasTyc 2034+8253 (lower panels) acquired with the AURELII spectrograph at the 152-cm telescope of the OHP both in the H$\alpha$ (left panels) and the Lithium spectral regions (right panels). The laboratory wavelengths of the Fe$\textsc{i}$ $\lambda$6546.2 and the H$\alpha$ lines as well as those of the Li$\textsc{i}$ $\lambda$6707.8, and the Ca$\textsc{i}$ $\lambda$6717.7 are marked with vertical dashed lines in the H$\alpha$ and Lithium spectral regions, respectively.
Table 2. Radial velocity of the primary (more massive, $v_P$), secondary ($v_S$), and tertiary ($v_T$) components of RasTyc 0524+6739 from Aurelie (OHP) and FRESCO (OAC) spectra. The orbital phase has been computed according to the ephemeris $HJD_{\text{inf. conj.}} = 2451997.7654 + 3.6587 \times E$, with zero phase corresponding to the inferior conjunction for the primary component.

| H.J.D. (2450000+) | Phase | $v_P$ (km s$^{-1}$) | $\Delta v_P$ (km s$^{-1}$) | $v_S$ (km s$^{-1}$) | $\Delta v_S$ (km s$^{-1}$) | $v_T$ (km s$^{-1}$) | $\Delta v_T$ (km s$^{-1}$) | Obs$^c$ |
|-------------------|-------|---------------------|----------------------------|-------------------|--------------------------|-------------------|----------------------------|--------|
| 2216.45508        | 0.773 | 67.22               | 1.47                       | -96.83            | 1.51                     | -14.69            | 1.50                       | OHP    |
| 2217.51416        | 0.062 | -47.21              | 0.96                       | 19.18             | 0.76                     | -12.33            | 0.77                       | OHP    |
| 3570.57544        | 0.882 | 33.45               | 1.35                       | -71.51            | 1.58                     | -14.50            | 1.30                       | OHP    |
| 3571.60986        | 0.165 | -82.68              | 1.18                       | 54.48             | 1.17                     | -12.72            | 1.37                       | OHP    |
| 3572.51733        | 0.413 | -59.27              | 1.30                       | 33.95             | 1.30                     | -14.78            | 1.40                       | OHP    |
| 3579.60791        | 0.351 | -81.26              | 1.12                       | 57.18             | 1.11                     | -12.64            | 1.12                       | OHP    |
| 3580.57983        | 0.617 | 41.87               | 1.47                       | -73.43            | 1.46                     | -13.26            | 1.20                       | OHP    |
| 3581.57056        | 0.161 | -78.56              | 1.52                       | 55.35             | 1.52                     | -12.17            | 1.70                       | OHP    |
| 3583.60596        | 0.444 | -42.14              | 1.46                       | 17.90             | 1.47                     | -14.14            | 1.40                       | OHP    |
| 3585.61300        | 0.992 | —                   | —                          | —                 | —                        | —                 | —                          | —      |
| 3586.60889        | 0.264 | -95.28              | 1.31                       | 68.24             | 1.42                     | -12.29            | 1.30                       | OHP    |
| 3587.61035        | 0.538 | 7.17                | 1.50                       | -32.99            | 1.53                     | —                 | —                          | OHP    |
| 3588.58545        | 0.805 | 56.72               | 1.52                       | -91.28            | 1.51                     | -14.80            | 1.60                       | OHP    |
| 3589.60693        | 0.084 | -53.96              | 1.42                       | 27.28             | 1.51                     | -13.05            | 0.90                       | OHP    |
| 3590.61060        | 0.358 | -78.68              | 1.47                       | 52.60             | 1.52                     | -14.00            | 1.70                       | OHP    |
| 3782.34390        | 0.763 | 67.87               | 0.96                       | -99.81            | 0.98                     | -15.74            | 2.28                       | OAC    |
| 3791.33690        | 0.221 | -90.43              | 0.82                       | 69.26             | 0.90                     | -13.63            | 1.53                       | OAC    |
| 3792.44580        | 0.524 | —                   | —                          | —                 | —                        | —                 | —                          | —      |
| 3798.41420        | 0.155 | -78.78              | 0.84                       | 52.93             | 0.85                     | -14.10            | 1.85                       | OAC    |
| 3799.38410        | 0.420 | -56.04              | 0.88                       | 29.01             | 0.89                     | -13.11            | 1.77                       | OAC    |
| 3800.33420        | 0.680 | 69.56               | 2.89                       | -90.69            | 2.64                     | -13.54            | 4.16                       | OAC    |
| 3809.33300        | 0.140 | -72.26              | 1.01                       | 49.68             | 0.96                     | -13.97            | 1.58                       | OAC    |
| 3811.39950        | 0.705 | 68.02               | 1.02                       | -99.04            | 0.98                     | -16.24            | 2.47                       | OAC    |
| 3812.38150        | 0.973 | —                   | —                          | —                 | —                        | —                 | —                          | —      |
| 3826.29570        | 0.776 | 67.96               | 0.60                       | -95.73            | 0.64                     | -14.50            | 0.92                       | OAC    |
| 3828.30120        | 0.324 | -86.83              | 0.89                       | 64.96             | 0.87                     | -13.16            | 1.87                       | OAC    |
| 3833.30580        | 0.692 | 70.25               | 0.77                       | -92.96            | 0.88                     | -12.26            | 1.75                       | OAC    |
| 3835.30440        | 0.238 | -94.74              | 0.96                       | 68.45             | 0.89                     | -16.45            | 1.91                       | OAC    |

$^a$ Heliocentric Julian date at mid exposure.
$^b$ Blended CCF peaks.
$^c$ OHP = Observatoire de Haute Provence; OAC = Osservatorio Astrofisico di Catania.
Table 3. Radial velocity of the primary (more massive, $v_P$), secondary ($v_S$), and tertiary ($v_T$) components of RasTyc 1828+3506 from Aurelie (OHP) and FRESCO (OAC) spectra. The orbital phase has been computed only for the data of 2005 according to the ephemeris $HJD_{inf, conj} = 2452001.408 + 7.595 \times E$, with zero phase corresponding to the inferior conjunction for the primary component.

| H.J.D.$^a$ (2450000+) | Phase | $v_P$ (km s$^{-1}$) | $\Delta v_P$ (km s$^{-1}$) | $v_S$ (km s$^{-1}$) | $\Delta v_S$ (km s$^{-1}$) | $v_T$ (km s$^{-1}$) | $\Delta v_T$ (km s$^{-1}$) | Obs$^c$ |
|------------------------|-------|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|-------|
| 3261.35425 | — | -75.11 | 1.17 | 37.34 | 1.27 | -24.06 | 1.26 | OHP |
| 3571.41016 | 0.715 | 47.23 | 1.33 | -95.86 | 1.36 | -19.98 | 1.25 | OHP |
| 3572.36621 | 0.841 | 42.22 | 1.35 | -79.96 | 1.16 | -18.02 | 1.34 | OHP |
| 3573.37378 | 0.974 | — $^b$ | — | — | — | -19.56 | 1.39 | OHP |
| 3574.40454 | 0.109 | -59.63 | 1.34 | 21.01 | 1.83 | -19.32 | 1.20 | OHP |
| 3575.42236 | 0.244 | -93.37 | 1.15 | 53.36 | 1.15 | -18.03 | 1.30 | OHP |
| 3576.43481 | 0.377 | -70.82 | 1.71 | 34.91 | 1.34 | -17.80 | 1.27 | OHP |
| 3577.36768 | 0.500 | — $^b$ | — | — | — | -19.55 | 1.40 | OHP |
| 3578.36035 | 0.630 | 30.30 | 1.70 | -67.73 | 2.82 | -17.81 | 1.27 | OHP |
| 3579.36890 | 0.763 | 51.28 | 1.33 | -99.08 | 1.18 | -17.38 | 1.26 | OHP |
| 3580.35083 | 0.892 | 21.90 | 1.28 | -65.14 | 1.34 | -17.90 | 1.26 | OHP |
| 3581.38745 | 0.029 | — $^b$ | — | — | — | -18.81 | 1.39 | OHP |
| 3582.36328 | 0.157 | -83.31 | 1.60 | 32.82 | 1.22 | -17.96 | 1.20 | OHP |
| 3583.37573 | 0.291 | -92.79 | 1.34 | 51.14 | 1.36 | -17.43 | 1.26 | OHP |
| 3648.39840 | 0.852 | 40.56 | 1.23 | -82.21 | 1.04 | -15.66 | 0.69 | OAC |
| 3657.36380 | 0.032 | -43.51 | 1.24 | — | — | -13.00 | 0.71 | OAC |
| 3927.49000 | — | -66.97 | 1.64 | — $^b$ | — | — | — | OAC |
| 3931.45260 | — | 30.57 | 5.23 | -82.14 | 2.13 | -8.81 | 2.32 | OAC |
| 3932.46490 | — | 44.26 | 2.37 | -96.87 | 2.68 | -7.45 | 2.22 | OAC |
| 3940.42350 | — | 38.43 | 1.62 | -98.48 | 1.11 | -8.97 | 1.07 | OAC |

$^a$ Heliocentric Julian date at mid exposure.

$^b$ Blended CCF peaks.

$^c$ OHP = Observatoire de Haute Provence; OAC = Osservatorio Astrofisico di Catania.
Table 4. Radial velocity of the primary (more massive, \(v_P\)), secondary (\(v_S\)), and tertiary (\(v_T\)) components of RasTyc 2034+8253 from Aurelie (OHP) and FRESCO (OAC) spectra. The orbital phase has been computed according to the ephemeris \(HJD_{\text{inf.conj.}} = 2452010.7086 + 4.9538 \times E\), with zero phase corresponding to the inferior conjunction for the primary component.

| H.J.D.\(^a\) \((2450000+)\) | Phase | \(v_P\) \((\text{km s}^{-1})\) | \(\Delta v_P\) \((\text{km s}^{-1})\) | \(v_S\) \((\text{km s}^{-1})\) | \(\Delta v_S\) \((\text{km s}^{-1})\) | \(v_T\) \((\text{km s}^{-1})\) | \(\Delta v_T\) \((\text{km s}^{-1})\) | Obs\(^c\) |
|-------------------------|-------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-------|
| 2475.51587              | 0.828 | 20.57 1.27     | -43.24 1.41     | -10.96 1.26     | OHP             |
| 2482.39160              | 0.216 | -50.12 1.42    | 29.29 1.28      | -9.99 1.39      | OHP             |
| 3213.54565              | 0.811 | 25.34 1.28     | -47.15 1.36     | -10.75 1.27     | OHP             |
| 3214.55176              | 0.014 | -50.62 1.28    | 27.43 1.41      | -11.96 1.26     | OHP             |
| 3215.54883              | 0.215 | -31.46 1.28    | 5.58 1.44       | -13.23 1.41     | OHP             |
| 3261.42578              | 0.476 | -10.36 1.26    | -10.35 1.31     | OHP             |
| 3261.59082              | 0.510 |                    |                   | -10.71 1.37     | OHP             |
| 3262.40967              | 0.675 | 23.25 1.42     | -45.85 1.42     | -10.79 1.27     | OHP             |
| 3264.55518              | 0.108 | -35.53 1.36    | 13.24 1.43      | -10.83 1.28     | OHP             |
| 3265.35815              | 0.270 | -49.28 1.28    | 29.36 1.28      | -9.46 1.26      | OHP             |
| 3265.60254              | 0.319 | -45.91 1.42    | 24.57 1.42      | -10.71 1.27     | OHP             |
| 3266.34009              | 0.468 |                    |                   | -10.02 1.31     | OHP             |
| 3267.31812              | 0.666 | 23.25 1.27     | -45.01 1.48     | -9.68 1.26      | OHP             |
| 3268.33228              | 0.870 | 17.08 1.34     | -39.55 1.43     | -9.69 1.26      | OHP             |
| 3570.51855              | 0.871 | 17.60 1.27     | -39.72 1.27     | -10.00 1.28     | OHP             |
| 3571.46240              | 0.062 |                    |                   | -10.33 1.29     | OHP             |
| 3572.46777              | 0.265 | -50.64 1.28    | 28.86 1.40      | -10.66 1.27     | OHP             |
| 3218.52790              | 0.817 | 24.88 1.38     | -46.29 1.57     | -9.65 0.79      | OAC             |
| 3219.52590              | 0.018 |                    |                   | -10.71 0.24     | OAC             |
| 3220.53390              | 0.222 | -49.63 1.07    | 27.41 1.07      | -11.17 0.61     | OAC             |
| 3224.54270              | 0.031 |                    |                   | -11.53 0.36     | OAC             |
| 3225.52580              | 0.229 | -50.25 1.82    | 28.06 1.62      | -11.20 0.59     | OAC             |
| 3256.57340              | 0.497 |                    |                   | -9.25 0.36      | OAC             |
| 3273.38010              | 0.889 | 11.83 1.12     | -38.13 1.32     | -13.28 0.78     | OAC             |
| 3275.41070              | 0.299 | -48.73 1.04    | 26.07 1.14      | -11.70 0.61     | OAC             |
| 3279.34730              | 0.094 | -30.29 1.27    | 13.36 1.44      | -10.36 0.60     | OAC             |
| 3281.39960              | 0.508 |                    |                   | -9.19 0.33      | OAC             |
| 3285.45010              | 0.326 | -46.27 1.07    | 23.98 1.14      | -11.57 0.62     | OAC             |
| 3354.34210              | 0.233 | -48.64 1.05    | 28.44 1.13      | -10.19 0.40     | OAC             |

\(^a\) Heliocentric Julian date at mid exposure.

\(^b\) Blended CCF peaks.

\(^c\) OHP = Observatoire de Haute-Provence; OAC = Osservatorio Astrofisico di Catania.
Fig. 8. The $U-V$ (Left top panel), $V-W$ (Right top panel), and $U-W$ (Lower panel) diagrams of the RasTyc triple systems. The average velocity components (dots) of some young SKGs and those of some late-type stars members of these young SKGs (Montes et al., 2001) are also plotted (square, triangle, circle, upside down triangle, and U symbols for the IC 2391 supercluster, Pleiades, Castor, UMa moving groups, and Hyades supercluster, respectively). The locus of the young-disk (YD) and the old-disk (OD) populations (Eggen, 1996) are also marked on the $U-V$ diagram.