A&A 366, 965–971 (2001)
DOI: 10.1051/0004-6361:20000355

Astronomy & Astrophysics

RX J1603.8-3938 – a surprising pre-main sequence spectroscopic binary*

E. W. Guenther[1], G. Torres[2], N. Batalha[3,4], V. Joergens[5], R. Neuhäuser[5,6], J. Vijapurkar[7], and R. Mundt[8]

[1] Thüringer Landessternwarte Tautenburg, Karl-Schwarzschild-Observatorium, Sternwarte 5, 07778 Tautenburg, Germany
[2] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
[3] currently at the Planetary Systems Branch NASA Ames Research Center Mailstop 245-3 Moffett Field, CA 94035-1000, USA
[4] Departamento de Astrofísica, Observatório Nacional, Rua General José Cristino 77, São Cristovão, Rio de Janeiro, RJ 20921, Brazil
[5] Max-Planck-Institut für extraterrestrische Physik, Giessenbachstr. 1, 85741 Garching, Germany
[6] University of Hawaii, Institute for Astronomy, 2680 Woodlawn Dr., Honolulu, HI 96822, USA
[7] Homi Bhabha Centre for Science Education (Tata Inst. of Fundamental Research), V. N. Purav Marg Mankhurd, Mumbai 400088, India
[8] Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg, Germany

Received 21 August 2000 / Accepted 27 November 2000

Abstract. We have determined the orbit of the double-lined spectroscopic binary RX J1603.8-3938. The binary consists of two weak-line T Tauri stars, both of which have a spectral type between K3 and K4. The period of the circular orbit is 7.55626 ± 0.00021 days and the mass ratio 0.9266 ± 0.0063. To our knowledge RX J1603.8-3938 is thus the pre-main sequence binary with the longest period that has a circular orbit. Despite the fact that the masses and spectral types of the two components are almost identical, the photospheric lines are much stronger in one component than in the other. In the wavelength region between 5500 and 7800 Å we find that the ratio of the equivalent widths of the primary to the secondary is 0.60 ± 0.03. This ratio is constant in time, and is the same for all photospheric lines. Since the components are weak-line T Tauri stars, the effect cannot be explained by any kind of veiling. We are led to the conclusion that the secondary is 0.55 ± 0.05 mag fainter than the primary. It thus turns out that evolutionary tracks of pre-main sequence single stars are unable to explain the position of this system in the HR diagram.

Key words. stars: binaries: spectroscopic – stars: formation — stars: late-type – stars: pre-main sequence

1. Introduction

The most fundamental parameter of a star is its mass, which determines almost everything about its birth, life, and death. For low mass pre-main sequence stars this parameter is practically always derived by comparing the location of the star in the Hertzsprung-Russell (HR) diagram with theoretically calculated evolutionary tracks, i.e. it has not been determined directly. Since the evolutionary tracks published by different groups differ a lot, it is necessary to test them thoroughly. A good way to do this is by comparing the masses derived from the evolutionary tracks with dynamically determined masses. Direct determinations of the mass are possible if the object is a double-lined spectroscopic binary, and if additionally the inclination is known.

The inclination can be determined either if the system is eclipsing, or if it is spatially resolved, or if the motion of the photo-centre is measured astrometrically. In some special cases the inclination might also be estimated indirectly. For example, in the case of a circumbinary disk, it is reasonable to assume that the inclination of the orbit is roughly the same as the disk. In the near future the determination of the masses of many pre-main sequence stars will be possible when the VLTI becomes available. Additionally, upcoming space astrometry missions (FAME, DIVA, SIM, GAIA) will allow us to measure the motion of the photo-centre for many spectroscopic binaries. In order to prepare for these projects, we

Send offprint requests to: E. W. Guenther

* Based on observations obtained at the European Southern Observatory at La Silla, Chile in program 62.I-0418, 63.I-0096, 64.I-0294, 65.I-0012, and also under the bilateral ESO – Observatório Nacional agreement.

have thus initiated a survey for pre-main sequence spectroscopic binaries located in nearby star-forming regions. Additionally, we also derive the orbits of recently discovered double-lined spectroscopic binaries.

However, even if the inclination of the system is not known, in double-lined spectroscopic binary systems the mass ratios of the components can still be used to constrain evolutionary tracks. Thus, these objects are also of interest. We present here the orbital solution of the double-lined spectroscopic binary RX J1603.8-3938. Although RX J1603.8-3938 is a short period binary, and it is neither eclipsing nor a suitable target for the VLTI, it turns out to be quite interesting for our understanding of early stellar evolution.

Apart from being useful for deriving the masses, the pre-main sequence binaries are also interesting as such. First of all, the mass ratios of binaries of different orbital periods may hold important clues for the formation of these systems. Secondly, the evolution of the orbital elements gives important clues on the tidal interaction of the binary. Duquennoy & Mayor (1991) find for stars in the solar neighbourhood that binaries with periods of 11d or less have circular orbits, and binaries with longer periods have a mean eccentricity of 0.31 ± 0.04. Zahn & Bouchet (1989) studied the tidal interaction theoretically, and found that almost all of the orbital circularisation of low-mass stars occurs during the pre-main sequence phase of evolution. Mathieu (1992) in fact found that the transition period between circular and eccentric orbits is apparently between 4 and 5 d for pre-main sequence stars, and thus significantly shorter than for main-sequence stars. However, the number of pre-main sequence binary systems with solved orbits is still quite low, and surprises can be expected when more orbits are solved. By studying pre-main sequence binaries we can thus learn more about tidal interaction, especially on the timescales on which this process works. Since pre-main sequence stars are quite frequently covered with spots, they are often suitable for investigating whether short-period systems have their rotation synchronised with the orbital motion. The only pre-main sequence spectroscopic binary where the synchronization of the rotational periods of the components have been studied up to now is V773 Tau (Rydgren & Vrba 1993; Welty 1995).

For this system it was found that the rotational period of the stars is about three days, whereas the orbital period of the system is about 51 days. Last but not least, short-period pre-main sequence stars often show significant amounts of stellar activity. They are often strong X-ray sources, and very large flares have been reported. Non-thermal radio emission has been detected in some cases. Thus, short period pre-main sequence binaries are very suitable, in order to learn more about the generation of magnetic fields, and the stellar activity in pre-main sequence stars. The best studied case in this respect is again V773 Tau (Guenther et al. 2000).

2. General properties of the object

RX J1603.8-3938 was first detected as a strong X-ray source by ROSAT (Krautter et al. 1997). Optical follow up observations by Wichmann et al. (1997) then demonstrated that the object is a pre-main sequence star. The binary nature was first recognised on a single high resolution spectrum taken with CASPEC on the ESO 3.6 m telescope (Wichmann et al. 1999). Based on $U\ B\ V\ R\ I$-photometry, and the fact that the equivalent width of Hα is less than 10 Å, RX J1603.8-3938 is classified as weak-line T Tauri star. This classification is in agreement with the equivalent width of the Li I 6708-line of the two components of 0.41 ± 0.04 Å, and 0.43 ± 0.07 Å (see Sect. 4.2).

RX J1603.8-3938 was also observed by the HIPPARCOS satellite, and is included in the TYCHO-2 catalogue (TYC 7855-01106-1). Using the formula given in the TYCHO catalogue we converted the $B_{\rm T}$ and $V_{\rm T}$ magnitudes to the Johnson system. We find that the V-magnitude of 11.01 ± 0.17 and the $B-V$ colour index of 0.97 ± 0.16 are fully consistent with the V-magnitude of 11.02 and $B-V$ colour index 1.05 obtained by Wichmann et al. (1997). The object is located in the Lupus 3 star forming region.

The proper motion of -16.4 ± 2.4 mas yr^{-1} in RA, and -28.4 ± 2.3 mas yr^{-1} in DEC as listed in the TYCHO-2 Catalogue is also consistent with membership in the Lupus star-forming region. The generally accepted distance to the Lupus 3 star-forming region is about 140 pc (Hughes et al. 1997). However, this value has recently been questioned, as Knude & Hog (1997) derived a distance of only 100 pc.

3. Observations and data-reduction

Using the Echelle spectrograph FEROS (Fiber fed Extended Range Spectrograph) on the 1.5 m telescope at La Silla, we have obtained 17 spectra of RX J1603.8-3938 over a time span of about one and a half years. The spectra cover the wavelength region between about 3600 Å and 9200 Å, and have a resolution of $\lambda/\Delta\lambda = 48\,000$. FEROS is optimised for high precision measurements of the radial velocities. The standard MIDAS pipeline for FEROS was used to subtract bias, flat-field, remove the scattered light, subtract the sky background, and extract and wavelength calibrate the spectra. Precise measurements of the radial-velocity have then been carried out by cross-correlating the spectra with spectra of the radial-velocity standard HR 5777 which was observed with FEROS too. The radial velocity of HR 5777 is known to be stable, and has been determined with an accuracy of 55 ms^{-1} (Murdoch 1993). We have observed HR 5777 in every observing run and find that the accuracy of our measurements is better than 80 ms^{-1}. However, because the signal to noise ratio is less in RX J1603.8-3938, the errors are of the order of 250 ms^{-1} for the primary component, and somewhat larger for the secondary component.

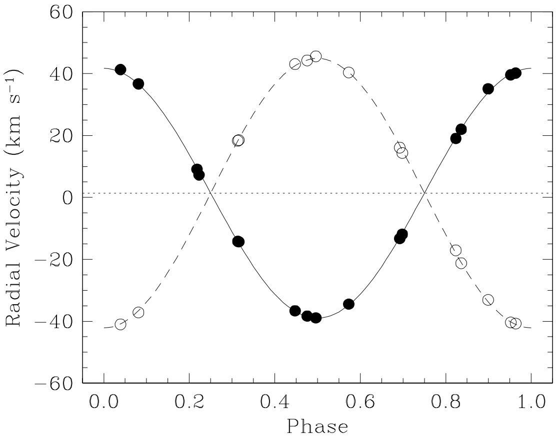

Fig. 1. Orbital solution for RX J1603.8-3938 from the elements given in Table 2. The scatter around the fit is 0.54 and 0.57 km^{-1} for the primary (filled symbols) and secondary (open symbols)

Table 1. Radial-velocity measurements of RX J1603.8-3938

HJD	RV(A) [$km\,s^{-1}$]	RV(B) [$km\,s^{-1}$]
2451263.7482	−14.18	18.30
2451290.8430	35.10	−33.10
2451331.7718	−14.33	18.50
2451332.7660	−36.63	43.06
2451333.7155	−34.46	40.38
2451335.7024	21.99	−21.24
2451355.8031	−38.90	45.60
2451621.7546	−13.26	16.09
2451621.7991	−11.89	14.36
2451622.7472	19.05	−17.07
2451623.7174	39.59	−40.36
2451623.8056	40.16	−40.72
2451624.6924	36.70	−37.15
2451625.7288	9.11	
2451625.7636	7.28	
2451733.4630	−38.33	44.26
2451737.7188	41.29	−40.99

4. Results

4.1. The orbit

The radial velocity measurements (given in Table 1) of the two components are well fitted by a circular orbit (Table 2). The scatter of the data points around the orbit is 0.54 and 0.57 $km\,s^{-1}$ for the primary and secondary, respectively (Fig. 1). The fact that the scatter of the data is slightly larger than the accuracy of our measurement is possibly due to stellar activity. The upper limit of the eccentricity is 0.005. We also find a heliocentric systemic velocity of $+1.380 \pm 0.099$ $km\,s^{-1}$, which is fully consistent with the value $+2.7 \pm 1.2$ $km\,s^{-1}$ of the known members of the Lupus star-forming region (Wichmann et al. 1999).

Table 2. Orbital elements of RX J1603.8-3938

period	7.55626 ± 0.00021 days
systemic velocity	$+1.380 \pm 0.099$ $km\,s^{-1}$
K_A	40.33 ± 0.19 $km\,s^{-1}$
K_B	43.53 ± 0.20 $km\,s^{-1}$
T_{max} [HJD]	2451525.8484 ± 0.0044
$a_A \sin i$	4.191 ± 0.021 Gm
$a_B \sin i$	4.523 ± 0.022 Gm
$M_A \sin^3 i$	0.2396 ± 0.0027 $M_\odot$
$M_B \sin^3 i$	0.2220 ± 0.0025 $M_\odot$
Mass-ratio q	0.9265 ± 0.0063
eccentricity	0.0

4.2. Spectral types and brightness of the components

Figure 2 shows a small part of the spectra taken in five consecutive nights. Very prominent is the Li I 6708-line which is characteristic for pre-main sequence stars. We measured an apparent equivalent width for the Li I 6708-line of 0.251 ± 0.018 and 0.163 ± 0.026 Å, for the primary and secondary component, respectively.

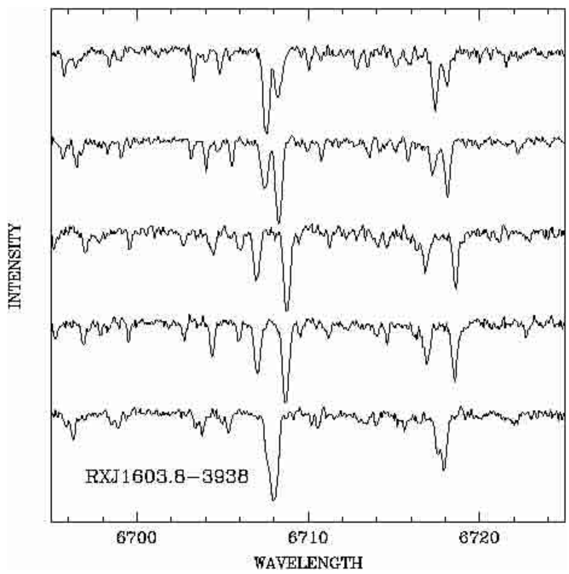

Fig. 2. Small part of the spectra taken of RX J1603.8-3938 in five consecutive nights. Clearly visible are the two sets lines of the two companions. The equivalent widths of the photospheric lines are clearly smaller in one component compared to the other

The most striking feature of this binary system is that although the masses of the two stars differ by only 7%, the line strength of the two components is clearly different (see Fig. 2). We determined an average ratio of the equivalent widths of EW_B/EW_A is 0.60 ± 0.03 for unblended photospheric lines in the spectral range between 5800 to 7800 Å. This value is the same for all spectra taken where the two components are well separated. This number does not directly reflect the brightness difference of the two stars at these wavelength bands as the equivalent width of spectral lines depends on temperature. Thus, the spectral types of the two components have to be determined first. In order to do this we compared the spectrum of RX J1603.8-3938 with template spectra of K2V, K3V, and K5V stars.

From these spectra, we conclude that both stars have to have a spectral type earlier than K5, and later than K2. In the next step we selected a number of unblended spectral lines with different sensitivity to temperature. That is, lines where the equivalent width increases when going from a K3 to a K5-star, and lines where the equivalent width remains almost constant in this regime. For lines where the equivalent width remains constant within 20%, we find a ratio of $EW_{\rm B}/EW_{\rm A} = 0.62 \pm 0.05$. For the lines that are relatively sensitive to the temperature in this regime, we derive $EW_{\rm B}/EW_{\rm A} = 0.59 \pm 0.04$. Thus, within the errors, there is no difference between the two sets of lines, despite the fact that the equivalent width of some features such as FeI 6750.164, and TiI 6743.127 changes by a factor of three when going from a K3 to a K5 star. This is shown in Fig. 3, where we display the equivalent width ratios for our binary versus those between the K3 and K5 templates, for a number of spectral lines. The relatively small change in the ratios for the components of our binary stands in contrast to the broad range seen between the K3 and K5 templates. This is effectively a very sensitive test of the temperature *difference* between the stars in RX J1603.8-3938, and it indicates that there cannot be a large difference in their spectral types. Both must be between K3 and K5. However, we can narrow this range down even further. Since the sum of the equivalent width of the two components is slightly larger than the equivalent width of the K3V-template ($EW_{\rm K3}/EW_{\rm A+B} = 0.83 \pm 0.03$), a K3V-template is actually not possible and the spectral types of the stars have to be very slightly later than K3. If the two stars had a spectral type of K5, a small amount of veiling would in principle be possible since the sum of the equivalent width of the two stars is smaller than that of the K5V-template ($EW_{\rm K5}/EW_{\rm A+B} = 1.37 \pm 0.12$). However, even in this case the veiling would be too small to explain the large difference in the equivalent width of the two components. A substantial amount of veiling would also be highly unusual for weak-line T Tauri stars, and we thus conclude that the veiling is unable to explain the difference in strength of the lines.

The fact that the photospheric lines of the secondary are considerably weaker than those of the primary can be explained by a difference in the brightness of the stars. The precise difference in brightness of course depends on the accuracy with which the spectral types where determined. The brightness difference obviously becomes larger when the primary has an earlier spectral type than the secondary, and smaller, when the secondary has an earlier spectral type than the primary. In order to estimate the maximum amplitude of this effect let us take the K5 template as the secondary, and the K3 template as the primary. If the secondary were a K5 star, the brightness difference would be as large as 1.1 mag. In the hypothetical case that the secondary where a K2 star, the difference

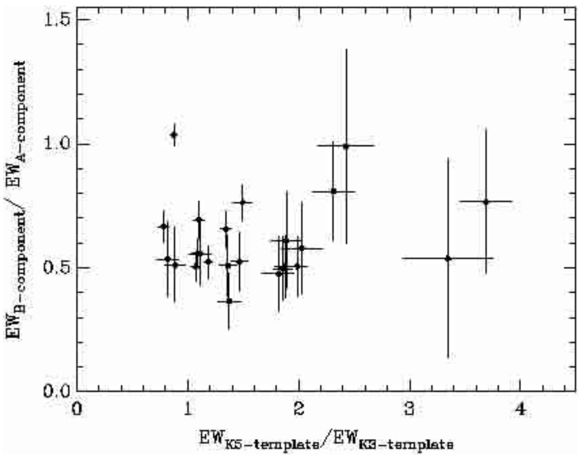

Fig. 3. This figure shows the ratio of the equivalent width of the K3-template to the K5-template versus the ratio of the equivalent width of the two components of the object. Please note that the equivalent width of some lines changes by a factor of up to three when going from the K3-template to the K5-template. In contrast to this, there is no obvious difference of the ratio of the equivalent width between the two components for lines that are sensitive to the spectral type, and lines that are insensitive. Thus, the difference in spectral types between the two components has to be much smaller than the difference between the K3-template K5-template

would be 0.4 mag. However, it is quite unreasonable to assume that the fainter component has the earlier spectral type. That the primary is a K2 star also is not possible, since the observed equivalent width of some lines in RX J1603.8-3938 are already larger than those of a K2 star, leaving no room for a secondary. We thus conclude that both stars have about the same spectral type (K3 to K4), and that the secondary is about 0.6 mag fainter than the primary.

If the difference between the equivalent width of the two components is interpreted as a difference in brightness than the values of the equivalent width for the Li I 6708-line has to be corrected correspondingly. Instead of 0.251±0.018 and 0.163±0.026 Å, the true equivalent width of the Li I 6708-line are 0.41±0.04 Å, and 0.43±0.07 Å, respectively. Since the upper limit of the equivalent width of the Li I 6708-line for stars in IC 2602, IC 2391, and IC 4665 which have an age of 36 Myrs is 0.35 Å at the spectral type K3, RX J1603.8-3938 is correspondingly younger the stars in these clusters (Martín 1997).

4.3. Rotational periods and stellar activity

As mentioned before, both stars are weak-line T Tauri stars. In all spectra, Hα is seen in emission, all higher Balmer lines are in absorption. The average equivalent width (sum of both components) of Hα is 0.21 ± 0.07 Å. The first interesting thing to find out about the components is, whether their axial rotation is synchronised with the orbital motion (synchronised rotation). Answering this question is in principle easy. One simply has to compare the rotational period of the stars, which is determined by monitoring some tracers on the stellar surface, with the orbital period. For example, if the stellar surface is covered with large spots, the photometric period can easily be compared with the orbital period. In a similar way, this can also be done by monitoring the variations of the equivalent width of photospheric lines.

Unfortunately, the variations of the equivalent width for the primary and secondary are too small to determine any period (0.006 to 0.008 Å for Li I 6708 line). The photometric variation of 0.167 magnitudes rms given in the TYCHO-2 catalog is too close to the photometric accuracy of this experiment. Thus, it would not be possible to derive any photometric period from these data either. Another possibility would be to use the emission components of the Ca II lines. Since these features originate in plage regions, they can also be used as a tracer. However, although this feature is present, it is very small, and the equivalent width of the emission feature of the Ca II IR triplet lines varies only by 12% and 21% in the primary and secondary. This feature also does not allow us to draw any conclusions on the rotational periods of the stars. Thus, the low level of stellar activity prevents us from determining the rotational periods of the stars.

5. Discussion

We have determined the orbit of the pre-main sequence double-lined spectroscopic binary RX J1603.8-3938. Although RX J1603.8-3938 is a young binary system, the orbit is circular, despite the fact that the period is 7.5 d. This is quite surprising, because pre-main sequence binaries with periods longer than 5 d usually have eccentric orbits (Mathieu 1992). Only for main-sequence stars, this boundary shifts to about 11 days (Duquennoy & Mayor 1991). With values of 0.41 and 0.43 Å for the equivalent width of the Li I 6708 line, the strength of this feature in both components is substantially larger than is typical for stars of the same spectral type in the Pleiades (Soderblom et al. 1993). This and other evidence clearly establishes the system as a pre-main sequence object. The results for RX J1603.8-3938 imply that circularization certainly operates during the pre-main sequence phase of evolution. To our knowledge RX J1603.8-3938 is the binary with the longest period that has a circular orbit which is known for sure to be pre-main sequence. During the refereeing process we learned that an independent orbit for this system was derived by other authors (Melo et al. 2000), giving very similar elements[1].

From the orbit, we also conclude that the masses of the two companions are almost identical. In contrast to this, we find that the equivalent width of the photospheric lines are a factor of 1.7 smaller in the secondary than in the primary. As already outlined above, the small equivalent width of the secondary cannot be explained by the presence of a veiling continuum, as the two components are weak-line T Tauri stars. For a binary with orbital period of 7.5 d, extinction in front of one component is also not an option. Another possibility would be the presence of very large spots. For example, the long-term changes in the apparent magnitude of the young star P1724 of 0.2 mag are presumably caused by large spots. The spots also produce a short-term photometric modulation with an amplitude of 0.4 mag, and their shape and location were reconstructed by Doppler tomography (Neuhäuser et al. 1998). If spots play an important role in the case of RX J1603.8-3938, we would also expect periodic variations in its photometry and radial velocity. For example, Saar & Donahue (1997) find for late-type dwarfs a RV variation (semi-amplitude) of $A_{\rm s} = 0.0065\, f_{\rm s}^{0.9}\, v \sin i$ km s^{-1}, where $f_{\rm s}$ is the filling factor in percent. If the same holds for young stars, and most of the 0.5 km s^{-1} scatter in our RV curves were caused by spots, we would estimate the filling factor to be of the order of 5 to 10%. As mentioned before, the brightness in the V-band given in the TYCHO-2 catalogue of 11.01 ± 0.17 is the same, within the errors, as the value 11.02 given by Wichmann et al. (1997), making large amplitude variations unlikely. While this does not rule out the presence of spots completely, it seems somewhat unlikely that the difference in the equivalent width between the A and the B component is caused by spots. Since the spectral types are essentially identical, we are led to the conclusion that the secondary is intrinsically fainter than the primary by 0.55 ± 0.05 mag. Using the photometry by Wichmann et al. (1997) and the TYCHO-2 catalogue we can place the two stars into the HR diagram. From our measurements we thus conclude that the A and B components have bolometric luminosities of 5.32 ± 0.05, and 5.87 ± 0.05 mag assuming a distance of 140 pc, or 6.05 ± 0.05 and 6.60 ± 0.05 assuming a distance of 100 pc.

Figure 4 shows the position of the two components in the HR digram, together with the evolutionary tracks by D'Antona & Mazzitelli (1994). From the position of the objects in the HR diagram, one would conclude that the two stars have different ages, and different masses. For example, if we assume a distance of 140 pc, we would estimate the mass of the primary to be slightly larger than 1.0 $M_{\odot}$, and that of the secondary as $\sim$0.85 $M_{\odot}$. However, the true mass ratio is 0.9266 ± 0.0063. Even more worrying is that the ages of the two components come out different. From the Fig. 4 we would estimate the age of the primary as 1 to $2\,10^7$ yrs, and the age of the secondary as $\sim 3\,10^7$ yrs. Such a large difference in age is also in contradiction to the fact that the equivalent widths of the Li I 6708 lines of the two stars are the same. Even if the determination of the spectral-types were grossly wrong, we are unable to shift the secondary far enough to be in agreement with the true mass-ratio. In order to demonstrate this, we also marked the position of the B component if the secondary were a K5 star (B3), and if the secondary were a K2 star (B1). However, as pointed out before, the B1-case is highly hypothetical. If the secondary were a K5 star, the mass derived from the evolutionary tracks would

[1] The name is not given in this article but the object denoted as S5 seems to be RX J1603.8-3938 (Covino 2000).

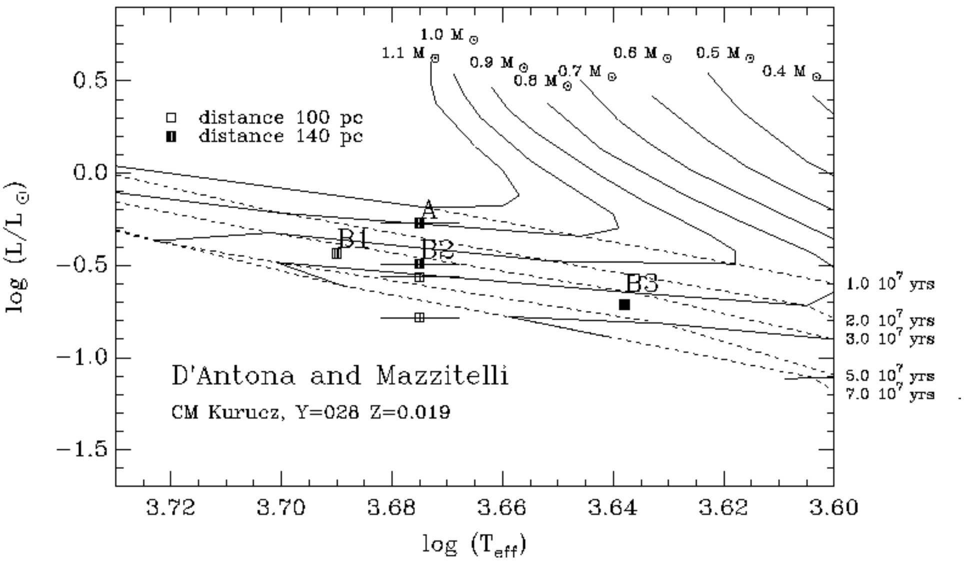

Fig. 4. Shown is the position of the two companions of RX J1603.8-3938 in the HR diagram. The filled symbols are for distance of 140 pc. Marked with A is the position of primary component. With B1, B2, B3 we denote the positions of the secondary component, where B1 is the position if the spectral type of the secondary is K2. B2 is for a spectral-type of K3, and B3 for a spectral type K5. Since the total luminosity of the system has to be kept constant, the point A would also move. For example, if the secondary gets fainter, the primary would get brighter. However, we decided not to show the A1, A2, A3 because all these points would be close to A, and the figure would become confusing. The open symbols are for a distance of the system of 100 pc. In this case, we assume that both companions have a spectral type of K3. Also shown are the evolutionary tracks calculated by D'Antona & Mazzitelli (1994). According to these tracks the two components would have different ages, and different masses, in contradiction to the mass ratio derived from the orbit. As can clearly be seen, even if the determination of the spectral-types were grossly wrong, we are unable to shift the secondary far enough to be in agreement with the true mass-ratio

be ∼0.75 $M_{\odot}$. Thus, the conflict with the true mass-ratio would be even larger.

We can also turn round this argument: let us assume that the primary has a mass of one solar mass and a spectral type of K3. Then the secondary would have a mass of 0.93 $M_{\odot}$ according to the mass-ratio derived from the orbit. In this case we would derive from the evolutionary tracks that its effective temperature would have to be 4470 K, corresponding to a spectral type of about K4, and the secondary would be about 0.2 mag fainter than the primary. However, if the secondary had this effective temperature, the brightness difference derived from the measurements of the equivalent width would be almost one magnitude. So, there is again the same discrepancy between the evolutionary tracks and the measured large difference in equivalent width of the lines.

Figure 5 shows the position of the two components of RX J1603.8-3938 in the colour-magnitude diagram (using the brightness and $V - I_c$-colour published by Wichmann et al. 1997). Also shown is the average position of the stars in the clusters IC 2391 and IC 2602 taken from Stauffer et al. (1997). These two clusters have an estimated age of 25 Myr. For a distance of 100 pc, the primary falls slightly above and the secondary slightly below the average position of stars in IC 2391 and IC 2602 in the colour-magnitude diagram. For a distance of 140 pc, both components are above the average position of stars in the two clusters.

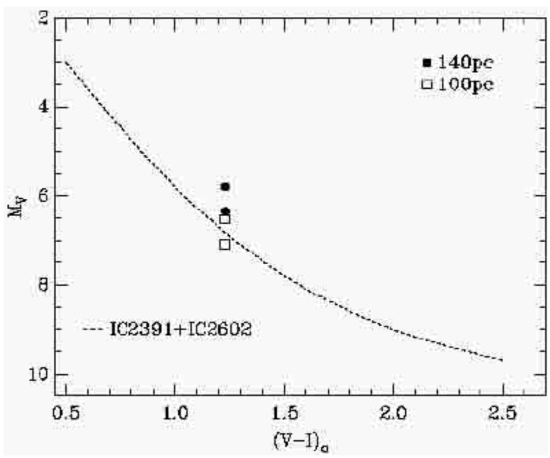

Fig. 5. The position of RX J1603.8-3938 in the colour-magnitude diagram of IC 2391 and IC 2602. The two clusters have an age of 25 Myr. For a distance of 100 pc, RX J1603.8-3938 fits in to the colour-magnitude diagram of these two clusters. For 140 pc, both stars are above the curve

In fact, due to the limited photometric accuracy, intrinsic variability, slight difference in distance, and possible differences in age and chemical composition between the two clusters, the scatter of the members of these two clusters is comparable to the distance of the two components of RX J1603.8-3938. From an observational point of view, the positions of the two components of RX J1603.8-3938 are by no means special. The problem in placing RX J1603.8-3938 onto the HR diagram is not so much the specific evolutionary tracks used but the fact that two pre-main sequence stars of almost identical mass have such a differences in brightness. If a cluster of stars is observed, this difference in brightness would not be recognised because of the large scatter in the colour-magnitude diagram. One possible explanation for the problem in comparing RX J1603.8-3938 with the tracks is that the evolutionary tracks that are computed for isolated stars, are not valid for very close binaries that may have interacted during the formation. Another problem of course is that the observed colour, and magnitudes have to be converted in to $T_{\rm eff}$ and $L/L_\odot$ before they can be compared with the evolutionary tracks.

Acknowledgements. We are grateful to the support group of the ESO 1.5 m telescope at La Silla, especially Fernando Selman, Emanuela Pompei, and Rolando Vega, for helping us with the observations. N.B. acknowledges the support of the Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ). RN wishes to acknowledge financial support from the Bundesministerium für Bildung und Forschung through the Deutsche Zentrum für Luft- und Raumfahrt e.V. (DLR) under grant number 50 OR 0003. VJ thanks the Deutsche Forschungsgemeinschaft for their financial support through the Schwerpunktprogramm Sternentstehung. We acknowledge the use of IRAF, MIDAS, IDL and STARLINK software for preparing the observations and for analysing the data.

References

Alcalá, J. M., Covino, E., Franchini, M., et al. 1993, A&A, 272, 225
Appenzeller, I., & Mundt, R. 1989, A&AR, 1, 291
Covino, E., private communication
D'Antona, F., & Mazzitelli, I. 1994 ApJS, 90, 467
Duquennoy, A., & Mayor, M. 1991, A&A, 248, 485
Guenther, E. W., Stelzer, B., Neuhäuser, R., et al. 2000, A&A, 357, 206
Hughes, J., Hartigan, P., & Clampitt, L. 1993, AJ, 105, 571
Knude, J., & Hog, E. 1998, A&A, 338, 897
Krautter, J., Wichmann, R., Schmitt, J. H. M. M., et al. 1997, A&AS, 123, 329
Martín, E. L. 1997, A&A, 321, 492
Mathieu, R. D. 1992, in Binaries as Tracers of Stellar Formation, ed. A. Duquennoy, & M. Mayor (Cambridge University Press, Cambridge), 155
Melo, C. H. F., Covino, E., Alcalá, J. M., & Torres, G. 2000, in Poster Proceedings of IAU Symposium 200, ed. B. Repurth, & H. Zinnecker
Murdoch, K. A., Hearnshaw, J. B., & Clark, M. 1993, ApJ, 413, 349
Neuhäuser, R., Wolk, S. J., Torres, G., et al. 1998, A&A, 334, 873
Rydgren A. E., & Vrba, F. J. 1983, ApJ, 267, 191
Saar, S. H., & Donahue, R. A. 1997, ApJ, 485, 319
Soderblom, D. R., Jones, B. F., Balachandran, S., et al. 1993, AJ, 106, 1059
Stauffer, J. R., Hartmann, L. W., Prosser, Ch. F., et al. 1997, ApJ, 479, 776
Welty, A. D. 1995, AJ, 110, 776
Wichmann, R., Krautter, J., Covino E., et al. 1997, A&A, 320, 185
Wichmann, R., Covino, E., Alcaá, J. M., et al. 1999, MNRAS, 307, 909
Zahn, J.-P., & Bouchet, L. 1989, A&A, 223, 112