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An Investigation on Close Binaries in the Sco-Cen Complex

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Abstract. The Sco-Cen Complex is composed of three nearby southern OB associations: Lower Centaurus Crux, Upper Centaurus Lupus and Upper Scorpius. Using the literature, the Simbad database, the results from the HIPPARCOS astrometry satellite and our own high-resolution spectroscopy research programme, we compiled a catalogue of data on secure and possible members of the Sco-Cen Complex. We present results we derived about duplicity and multiplicity throughout the Sco-Cen Complex, and especially on yet unknown or poorly studied eclipsing and spectroscopic close binaries.

1. The Sco-Cen Complex (Sco OB2)

The work we report here is part of a long-term project to study multiplicity in young associations where it is likely to be still primordial (Brown 2001). The Sco-Cen Complex consists of three nearby Southern OB associations: Lower Centaurus Crux (LCC), Upper Centaurus Lupus (UCL) and Upper Scorpius (US). They were first identified by Blaauw (1964) within the system formerly known as the Sco OB2 association but, according to more recent results, they extend far beyond the latter.

These groups are very young:

- LCC: 16 ± 1 Myr (Mamajek et al. 2002) at 118 ± 2 pc (180 secure members)
- UCL: 17 ± 1 Myr (Mamajek et al. 2002) at 140 ± 2 pc (222 secure members)
- US: about 5 Myr (Preibisch et al. 2002, various authors) at 145 ± 2 pc (120 s.m.)

The "secure membership" and the distances cited above, were established by de Zeeuw et al. (1999) who applied strictly astrometric criteria (de Bruijne 1999; Hoogerwerf & Aguilar 1999) in a consistent way to all objects which were observed by HIPPARCOS in this region of the sky. Most of the 522 members thus identified are main sequence stars. In the post-HIPPARCOS era numerous pre-main sequence objects have been identified as additional members (see for instance Reipurth & Zinnecker 1993; Mamajek et al. 2002; Preibisch et al. 2002) albeit without an actual quantified membership probability.

The secure membership can be considered as complete for the single stars in the HIPPARCOS database. However, in the case of multiple objects, the astrometric criteria may be violated due to a difference between the systemic velocity and the observed one. De Zeeuw et al. (1999) discussed this problem and (in order to safeguard the homogeneity of the information used) chose not to include such objects in the membership lists, even where it was clear that orbital motion could explain a deviation as e.g. with HIP 78401 in US. So there is a certain bias against multiplicity in the membership selection, the major problem arising not from the known cases such as HIP 67786 or HIP 71121 in UCL, but from those with unrecognised duplicity.

Obviously this should be avoided as far as possible in an investigation of this very property among the members. Therefore we were compelled to reconsider 141 objects from two earlier membership studies (de Geus 1988; Brown & Verschueren 1997) which were rejected by de Zeeuw et al. (1999), as possible members until evidence to the contrary becomes available. On the other hand we did not include the pre-main sequence objects mentioned above, limiting our study to the magnitude limit set by HIPPARCOS. So the sample we finally selected for our study contains 657 stars.

2. Duplicity and multiplicity in the Sco-Cen Complex

2.1. Methodology

The first part of our work was devoted to the creation of the Sco-Cen Complex Catalogue (Nitschelm 2003), where we collect existing information on our objects from the literature (among many others, Levato et al. 1987, Hartkopf et al. 2001, Shatsky & Tokovinin 2002, Kouwenhoven et al. 2005, Kouwenhoven et al. 2007) and from several catalogues (Simbad, Bright Star Catalogue, CCDM, Washington Double Star Catalogue, CHARA, SB8 and SB9). The structure of the catalogue allows easy selection of subcatalogues focusing on e.g. visual binaries, eclipsing binaries, systems with known orbital period, systems suitable for spectral disentangling, etc.

In the course of this literature study, we discovered a few (unacceptable) discrepancies in period values for some known (bright) spectroscopic binaries (among others, η Muscae, γ Lupi, λ Librae), mainly comparing the literature or the SB8/SB9 catalogue versus HIPPARCOS data. The particular case of η Muscae is already solved in favour of the photometric value (Hensberge et al. 2007; Bakış et al. 2007), but, for the other cases, we must conclude that the published orbital periods are not yet uniquely defined by the data. In their online catalogue, Eggleton & Tokovinin (2008) mention γ Lupi and λ Librae as probable hierarchical triple systems, with respective periods of $2.808\,d$ and $12.46\,d$ for the close binaries, values coming from the SB9 catalogue, but our study on old measurements is clearly showing that they are not unique, whilst, for γ Lupi, the $2.808\,d$ value is not in agreement with the photometric period coming from HIPPARCOS.

It is important to notice that information on newly detected interferometric binaries provided by McAlister & Hartkopf (1988) was partly erroneously interpreted in the Bright Star Catalogue, producing fictitious binary stars with a magnitude difference of 2.0 magnitudes (this is the case for λ Librae and σ Scorpii, for instance). If needed, this ambiguity can be solved with high-resolution spectroscopic observations.

The second part is a blind spectroscopic survey to detect spectrum variability in our objects. We aim to obtain at least three (but preferably more) high-resolution, high-S/N (> 200) spectra with a varying time-baseline. This work is on-going; so far we have completely covered 164 of our targets in this way; 89 others have been observed at least one time (Fig. 1). Some preliminary results are given further on.

Since time-resolved high-resolution spectroscopy, blindly applied to a large sample of stars, is time-consuming, we also tried alternative ways to identify candidate

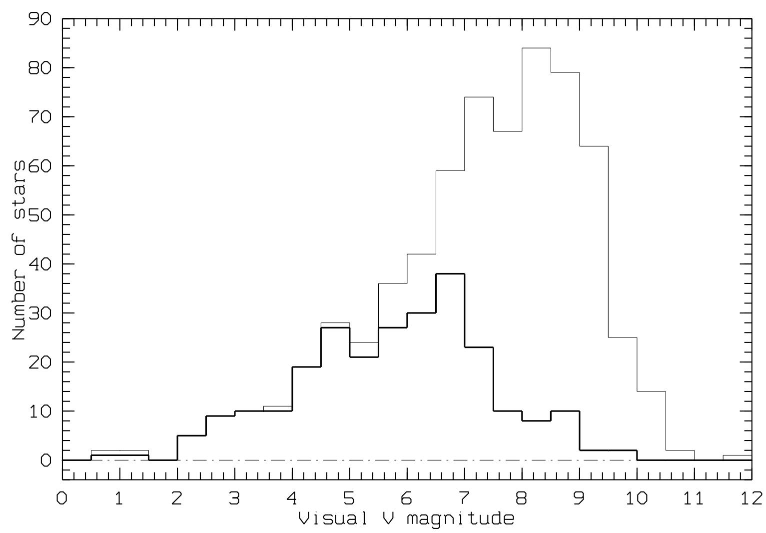

Figure 1. Magnitude histogram (bold) of the 253 targets observed so far, compared with the whole sample (657 stars). The spectra were obtained with Echelec, FEROS, Giraffe, Hercules and HERMES.

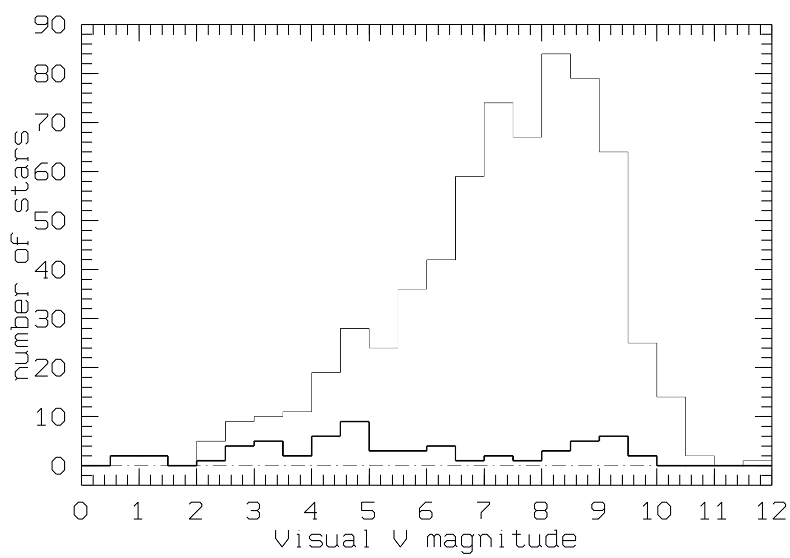

Figure 2. Magnitude histogram of all Sco-Cen members of our sample and of the confirmed spectroscopic binaries (bold). The lack of spectroscopic binary knowledge for fainter stars ($V > 5.0$) is obvious.

binaries for spectroscopic follow-up. For wider systems, Pourbaix (2002) provided a list of 49 suspected wide binaries (expected orbital periods in the range 0.1 to 3 years, which is providing some help for filling the observed period "gap" between three months and nine years), based on an analysis of HIPPARCOS astrometry. The objects in this list were targeted with higher priority than the rest and have by now almost all been observed at least three times.

For close binaries we turned to the publicly available photometric surveys produced by HIPPARCOS and ASAS (Pojmanski 2001). Both projects have led to the establishment of lists of variable stars (Koen & Eyer 2002; Pojmanski 2002). There is only little overlap between these two catalogues, which is partly explained by the fact that ASAS photometry may be unreliable for stars brighter than $V = 8.5$ (Pojmanski 2002).

In the ASAS Catalog of Variable Stars (Pojmanski 2002, ACVS) we found only two of our targets, notably HIP 70919 (also detected by Koen & Eyer 2002) and HIP 77157 (= HT Lup), identified as a triple system (Sz 68) by Ghez et al. (1997).

In Koen & Eyer (2002) we found 16 of them. With the exception of HIP 71121 (= σ Lup, a known ellipsoidal variable), there is no indication that their light variations are due to eclipses or ellipsoidality. The automated detection algorithm used by Koen & Eyer (2002) was tuned to minimise false detections so it is likely that a number of low-amplitude variables $\Delta m < 0.05$ were missed. Therefore we devised a more sensitive non-automated procedure to detect light variability (and hence possible targets for dedicated spectroscopic observations). This work is nearing completion and is expected to yield a few tens of hitherto undetected variables.

2.2. Discovery or confirmation of double-lined spectroscopic binaries (Fig. 3)

HD 90264 ($V = 4.97$, B8V, member of LCC). It was termed SB2 by Pedersen & Thomsen (1977) and by Hubrig & Mathys (1996). For Dolk et al. (2003), it is a SB1. Curiously the latter two papers quote very different values for $v \sin i$ (80 km/s and 7 km/s resp.) neither of which is confirmed by our observations. Anyway, the two spectra obtained with three days in–between clearly confirm the SB2 nature of this star, without ambiguity. The two components are very sharp–lined stars with similar spectral type and mass. The blue–shifted component in both spectra is the HgMn component.

HD 119727 ($V = 6.42$, A1V, LCC member). This is a *newly detected* SB2 with sharp-lined components and considerable changes of RVs in one week. A few new observations were made between 02/2009 and 03/2011, but the period remains unknown.

HD 132094 ($V = 7.26$, B9V, member of UCL). According to Kouwenhoven et al. (2005), who were using the near infrared ADONIS/SHARPII+ system, then on the ESO 3.6 meter telescope at La Silla, Chile, HD 132094 has no visual companion. We got 3 FEROS observations, between 02/2009 and 02/2010, and then 5 in 03/2011, which clearly indicate spectral variability but (based on the data we have so far) not binarity.

π Lupi = HD 133242 ($V = 4.57$, B5V) **+ HD 133243** ($V = 4.65$, B5IV), member of UCL. A visual binary with $P_{\rm orb} = 517$ yr, semi-major axis $a = 1\overset{''}{.}59$ (Nitschelm 2003). π Lupi was found to be a RV variable by Buscombe & Morris (1960). Since the spectra exhibit three distinct sets of lines, we find that π Lupi as a whole is at least quadruple.

λ Lupi = HD 133955 ($V = 4.43 + 5.23$, B3V, member of UCL). λ Lupi was identified as a RV variable by Buscombe & Morris (1960). One of the components of the visual binary ($P_{\rm orb} = 72.36$ yr, $a = 0\overset{''}{.}265$, (Nitschelm 2003) is a slowly rotating SB2. The other visual component is probably fast rotating (underlying broad Mg II component). The SB2 period must be shorter than 1 week, the mass ratio roughly 0.7.

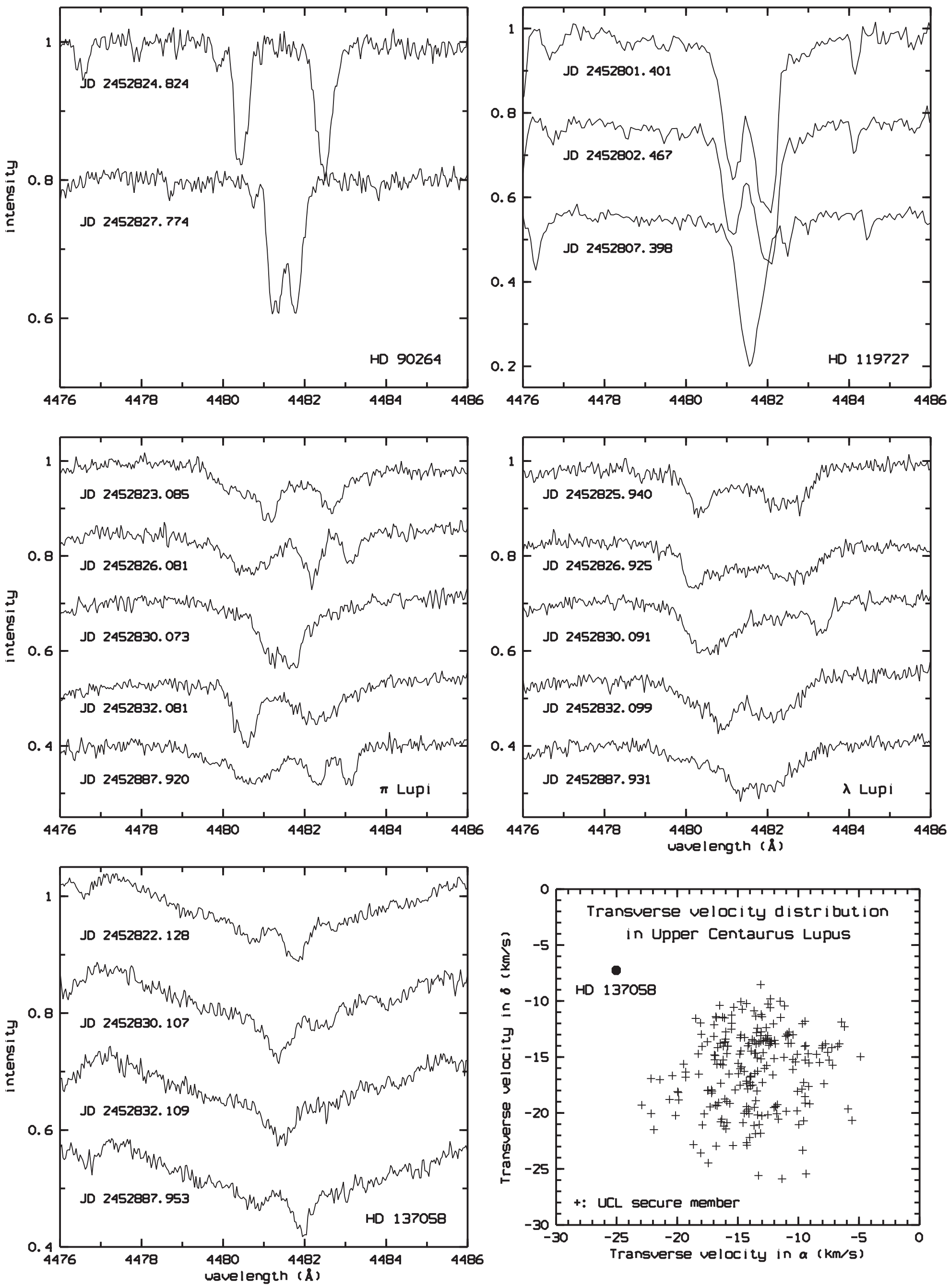

Figure 3. Discovery and confirmation of double-lined spectroscopic (mainly non-eclipsing) binaries (Nitschelm 2004).

k Lupi = HD 137058 (V = 4.70, A0IVn): Fast rotator ($v \sin i$ = 268 km/s, Brown & Verschueren 1997) and possibly a SB2, as suggested by a moving sharp component superposed on a very broad Mg II line. If so, then the very different line strength suggests a mass ratio far from unity. HD 137058 is one of the objects we added to our sample as a "possible" member.

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