Astronomy & Astrophysics manuscript no. Dubrovnik˙poster May 13, 2004
(DOI: will be inserted by hand later)

The binary population in the Sco-Cen Complex

Discovery and confirmation of double-lined spectroscopic binaries ⋆

Christian Nitschelm

Astrophysics Research Group, RUCA, University of Antwerp, Middelheimlaan 1, 2020 Antwerp, Belgium
e-mail: christian.nitschelm@ua.ac.be

20-24 October 2003

Abstract. In the framework of "a Hipparcos based study of the binary population in nearby OB associations", the population of binaries in the Sco-Cen Complex (composed by three nearby southern OB associations: Lower Centaurus Crux, Upper Centaurus Lupus and Upper Scorpius) is studied.

Almost no faint spectroscopic binaries (V fainter than 6.5) are identified at present, such that within the 664 secure and possible members of the Sco-Cen Complex, at least 90 new SB1 and SB2 are waiting detection.

Two recent high-resolution spectroscopic runs at Sutherland Observatory (South Africa) and at Mount John Observatory (New Zealand) allow the detection and confirmation of SB2s from preliminary reduced spectra.

1. The Sco-Cen Complex

The Sco-Cen Complex, also named Sco OB2 in the literature, is composed of three nearby southern OB associations, Lower Centaurus Crux (LCC), Upper Centaurus Lupus (UCL) and Upper Scorpius (US), first identified by Blaauw (1964). During the pre-Hipparcos era, many of the bright members of the Sco-Cen Complex were observed frequently, whereas the fainter objects were largely ignored.

Using Hipparcos data (Perryman 1997) and two selection methods (see Hoogerwerf & Aguilar 1999 and de Bruijne 1999), de Zeeuw et al. (1999) made a thorough study of membership of the three OB associations LCC, UCL and US. For the whole Sco-Cen Complex, they found a total of 521 secure members: 120 in US, 221 in UCL and 180 in LCC. The mean distances of the three associations were found to be 145 ± 2 pc for US, 140 ± 2 pc for UCL and 118 ± 2 pc for LCC. No systematic studies of the duplicity were made, except two partial ones (Levato et al. 1987, Verschueren et al. 1996) and recent specific studies on pre-main-sequence objects (Jayawardhana et al. 2002, Mamajek et al. 2002, Preibisch et al. 2002).

We compiled a list of 664 objects which should be screened for multiplicity. In this list, 521 objects are the secure members (see de Zeeuw et al. 1999) and 143 are possible members, according to pre-Hipparcos studies (de Geus 1988, Brown 1996) and considering the moderate discrepancy in transverse velocity, but not selected by de Zeeuw *et al.* who preferred to publish a selection based solely on the Hipparcos data, rather than use additional information of very inhomogeneous quality. This is at the expense of some members, especially in the case of binarity (see Nitschelm 2003).

In 2003, high-dispersion spectroscopy with the purpose to detect binarity was obtained in observing runs at Sutherland Observatory (SAAO), South Africa (June 10-17), and at Mount John University Observatory, New Zealand (July 1-12).

2. The June 2003 observations in South Africa

2.1. General description

At Sutherland Observatory, the fibre-fed echelle spectrograph GIRAFFE available at the 1.9-m telescope was used, with the blue prism giving a wavelength range 3770 Å - 5560 Å in 36 spectral orders with a resolution of 39000.

Pointing overhead and instrument sensitivity set the time required to obtain a spectrum with signal-to-noice ratio 200 at λ 4500 Å to 15 minutes for a 6^{th} magnitude blue star. Including regular wavelength calibration checks (detection of low amplitude binaries) with arc spectra and late-type radial velocity standards, 48 spectra of 13 main programme stars with $6.4 < V < 7.0$ were obtained in 6.5 useful nights. None of the targets was a known binary.

⋆ Based on observations made at Sutherland Observatory, South Africa, and at Mount John University Observatory, New Zealand

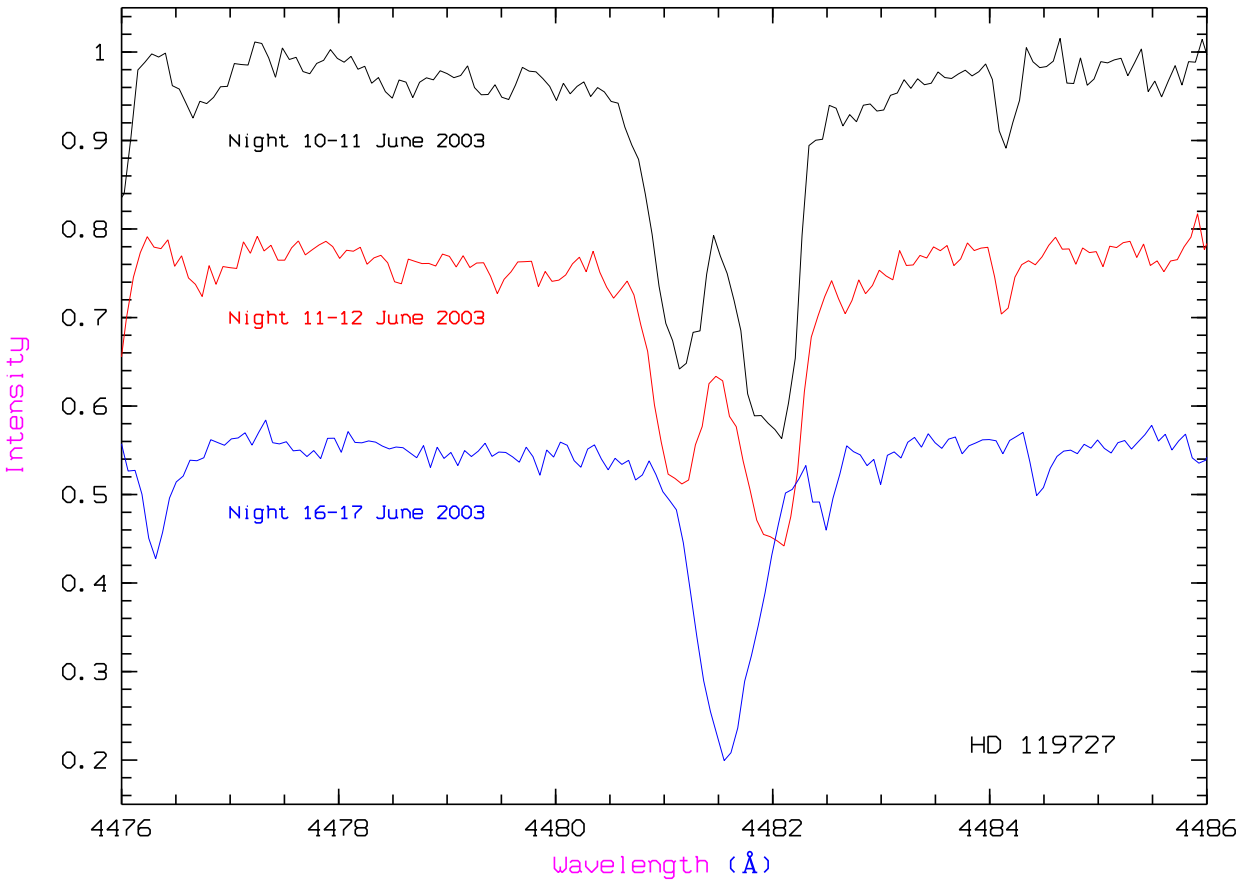

Fig. 1. The Mg II 4481.2 Å line in the spectra of HD 119727 with GIRAFFE

2.2. HD 119727

Most of the targets turn out to be fast rotators which need a detailed analysis, but HD 119727 (V = 6.42, A1V) is an obvious, previously unknown SB2 (see Fig. 1). The separation of the lines changed considerably in one week, but not in two consecutive days. The two components of the SB2 are slow rotators. HD 119727 is a secure member of LCC.

3. The July 2003 observations in New Zealand

3.1. General description

At Mount John University Observatory, the fi bre-fed echelle spectrograph HERCULES, available at the 1.0-m telescope, was used in position 4 of the grating, giving an useful spectral range 3760 Å - 4560 Å in 34 spectral orders, with a resolution of 35000. Faster pointing and a higher instrument sensitivity more than compensate for the smaller telescope size, when compared to GIRAFFE, at least up to 6.7 in V magnitude.

Hence, the site was judged efficient to observe bright suspected spectroscopic binaries and the brighter end of the main programme stars. With about 50% of time lost due to bad weather, data were collected for 29 suspected spectroscopic binaries and 9 presumed single stars. A few bright suspected spectroscopic binaries are obvious SB2.

3.2. HD 90264

The star HD 90264 (V = 4.97, B8V) is a secure member of LCC. This star was termed as a double-lined spectroscopic binary by Pedersen & Thomsen (1977), then by Hubrig & Mathys (1996). For Dolk et al. (2003), who were using a short piece of a high dispersion spectrum from the CES instrument at ESO, around the Hg λ 3984 line, it is a SB1 with $v \sin i$ = 7 km/s (and not 80 km/s as Hubrig & Mathys (1996) quote). On the other hand, the variability of HD 90264, suspected by various authors, was never confi rmed (this star is a very stable object, according to the Hipparcos catalogue).

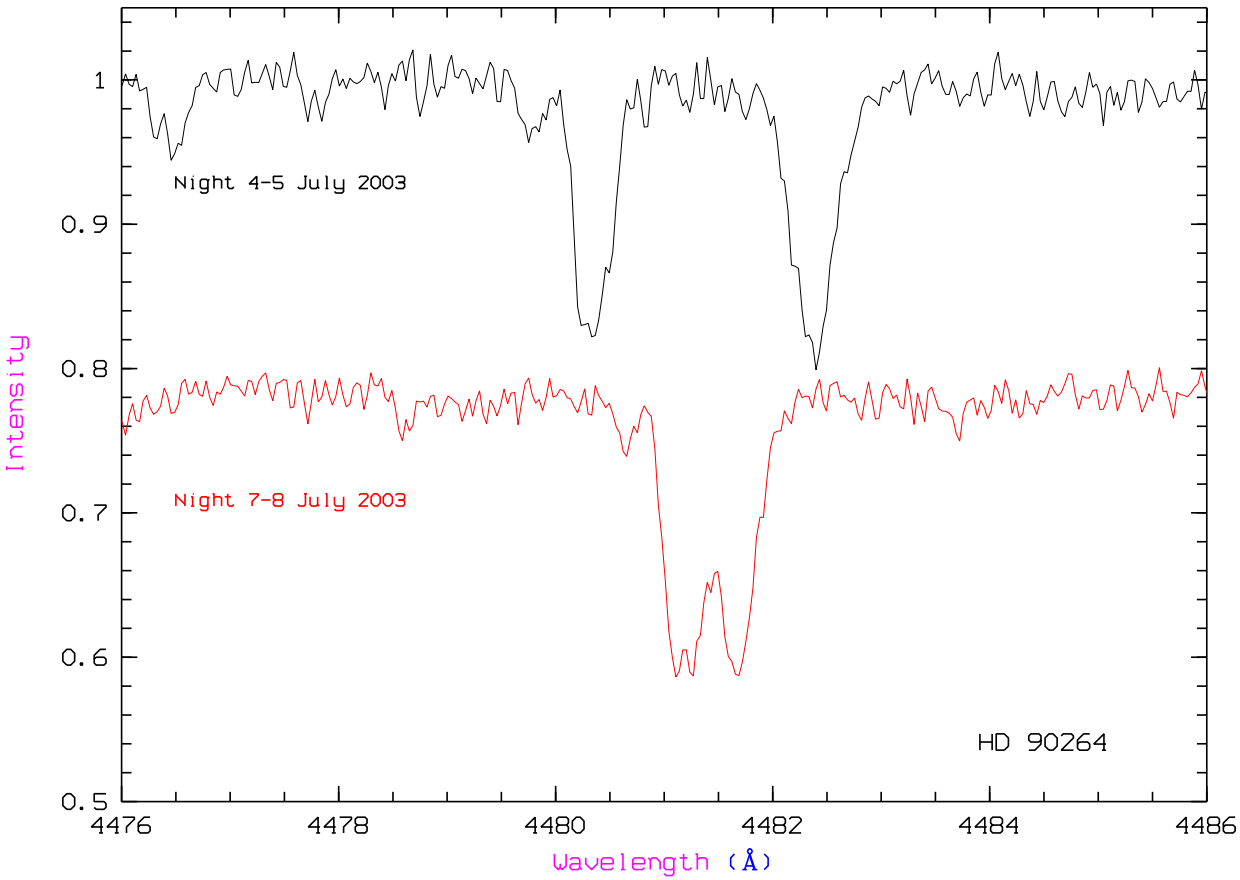

Fig. 2. The Mg II 4481.2 Å line in the spectra of HD 90264 with HERCULES

The two spectra obtained with three days in-between clearly confirm the double-lined nature of this star, without ambiguity (see Fig. 2). The two components are very sharp-lined stars and have similar spectral type and mass. The blue-shifted component in both spectra is a HgMn component.

3.3. π Lupi = HD 133242 + HD 133243

The double star π Lupi, which is a secure member of UCL, is composed of HD 133242, the A component (V = 4.57, B5V), and HD 133243, the B component (V = 4.65, B5IV). This is a physical pair and the orbit is known, with a period of 517 years and a mean separation of 1.59 arcsec (Nitschelm 2003). Buscombe & Morris (1960) noted that at least one of the components is a radial velocity variable, using observations made in June 1955 and April 1956. The short time baseline (less than one year) was then giving evidence for a third body. Later, π Lupi was found to be a spectroscopic binary by Buscombe & Stoeckley (1975). On the other hand, the Bright Star Catalogue (Hoffleit & Jaschek 1982) describes both components, A and B, as known spectroscopic binaries (SB), but the sources used in the BSC are not mentioned.

π Lupi was observed four times in ten days and, then, one time two months later. We did not resolve the visual binary. At first sight, the system consist of a complex multiple system, at least a SB2+SB1 system (see Fig. 3). Indeed, three components can easily be recognized, of which two are sharped-lined.

3.4. λ Lupi = HD 133955

The star λ Lupi (HD 133955, B3V), a secure member of UCL, is a known physical pair, with a brighter A component (V = 4.43) and a fainter B component (V = 5.23). The period of the orbit is 72.36 years and the mean separation is 0.265 arcsec (Nitschelm 2003). HD 133955 was clearly identified as a radial velocity variable by Buscombe & Morris (1960), using observations made in June 1955 and April 1956. In the Sixth Catalog of Orbits of Visual Binary Stars (Hartkopf et al. 2001), the star λ Lupi is described as A or B being ”probably a spectroscopic subsystem, as the RV of the combined light shows a range of 50 km/s”.

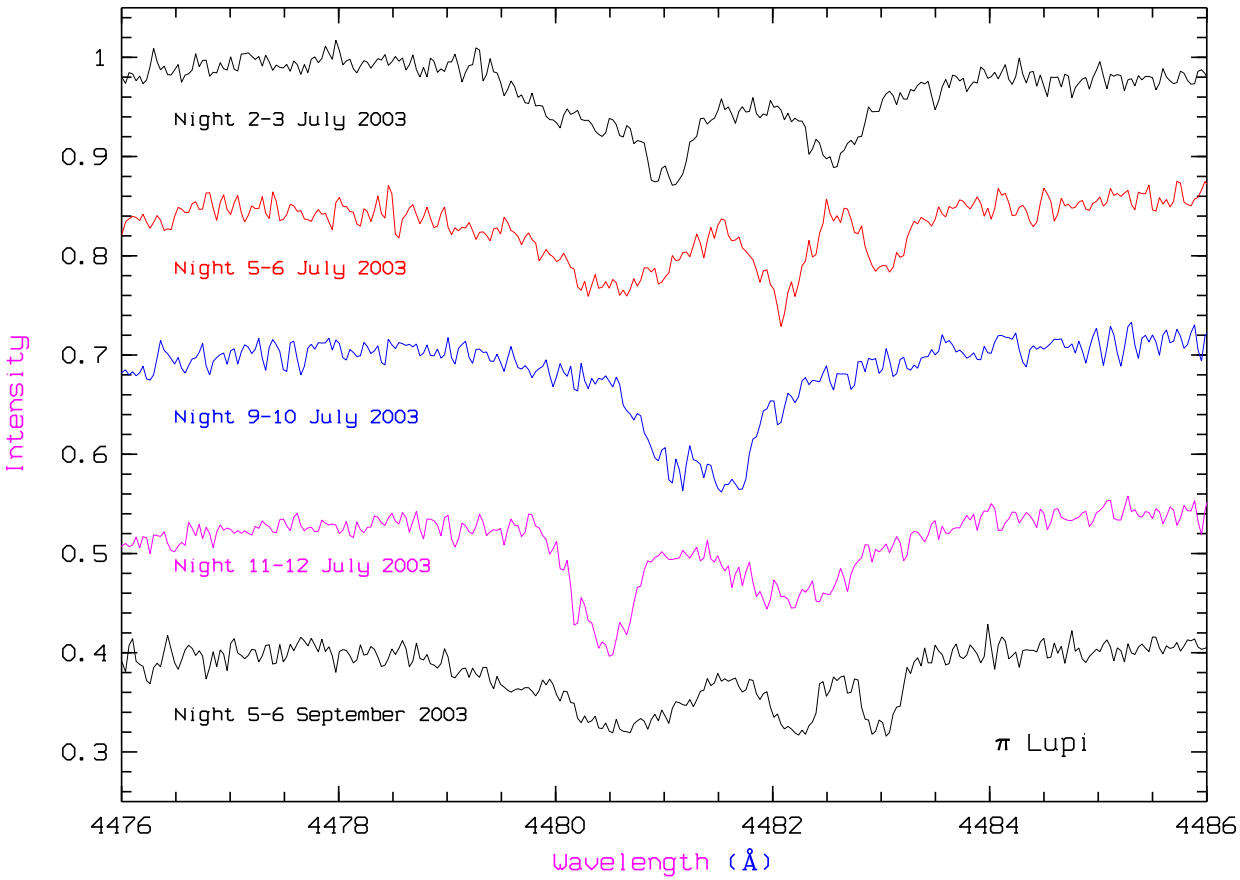

Fig. 3. The Mg II 4481.2 Å line in the spectra of π Lupi with HERCULES

Brown & Verschueren (1997), using two ECHELEC spectra (resolving power 21500) derived $v \sin i$ = 135 km/s. No indication of line-doubling is seen in these spectra, but a difference of 14.5 km/s in line position was measured.

Our observations, made four times during a period of six days, then one more two month after, detect the double-lined nature of one of the components of the system (see Fig. 4). The relatively fast switching of the line components indicates an orbital period shorter than one week. The mass ratio can be roughly estimated to 0.7 for this SB2. The two components of the SB2 are slow rotators. The subsisting depression between the lines when they are well-separated suggests the presence of a third, much broader Mg II line. This could be the Mg II line of the spectrum of the other component of the visible pair, which is also an early-type star. In this case, this component would be a fast rotator.

3.5. k Lupi = HD 137058

The star k Lupi (HD 137058, V = 4.70, A0IVn) is the A component of a very wide optical multiple system, where all other components are very faint and clearly background stars. A suspicion of physical multiplicity is coming from Hipparcos Double and Multiple Systems Annex (DMSA, see Perryman 1997), with a stochastic solution. HD 137058 is a fast rotator, with $v \sin i$ = 268 km/s, according to Brown & Verschueren (1997).

The star k Lupi was observed three times in July and one time two months after. The Mg II line at 4481.2 Å shows a variable feature (one narrow component inside a very broad line) which is possibly due to a SB2 character (see Fig. 5). If the primary component of this possible double-lined spectroscopic binary is the fast rotator, then the contrast in line strength suggests a mass ratio very different from unity.

It was rejected by de Zeeuw et al. (1999) as a possible member of UCL, due to its quite important discrepancy in transverse velocity (see Fig. 6). Even with a higher level of multiplicity and its parallax value which put it directly inside UCL, it seems to be difficult to assert it could really be a member.

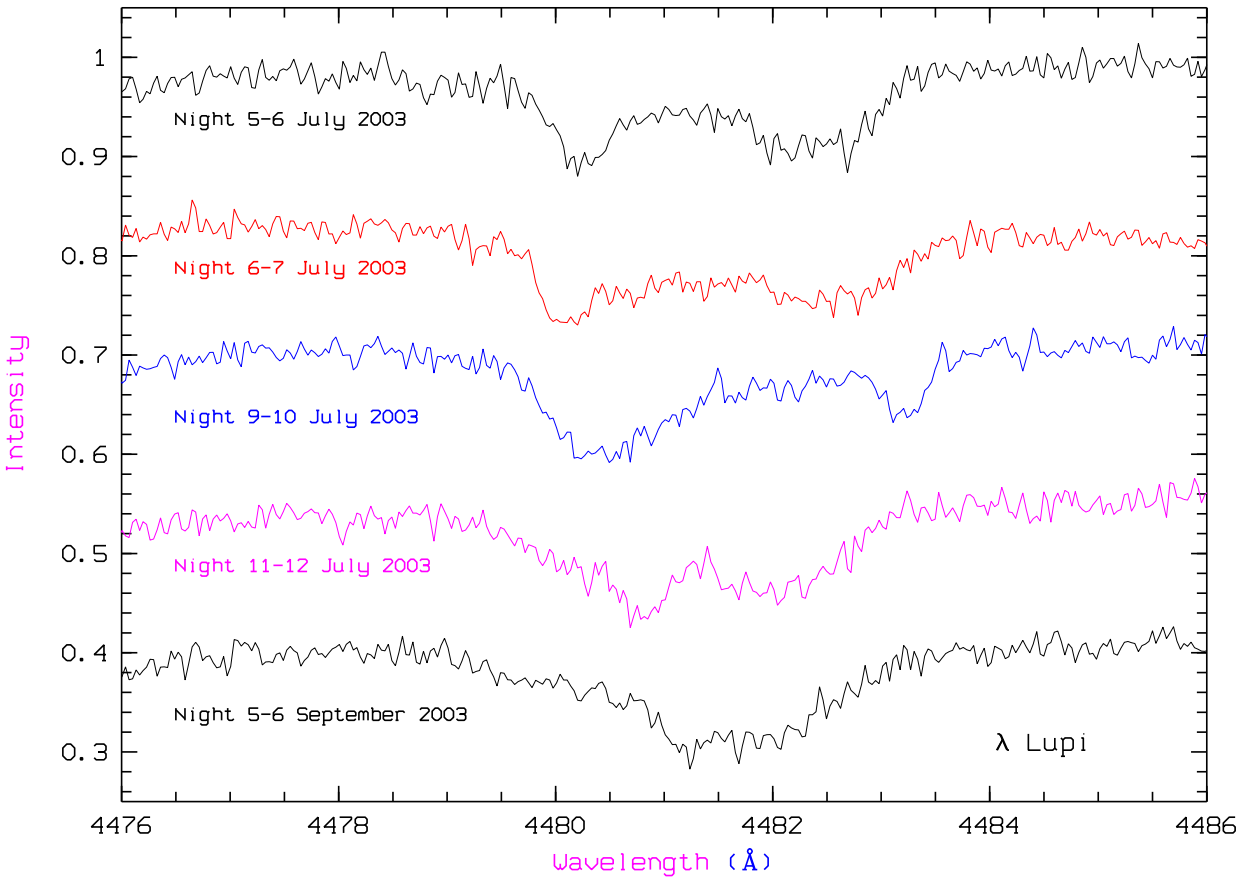

Fig. 4. The Mg II 4481.2 Å line in the spectra of λ Lupi with HERCULES

4. Conclusion

The results presented here are a first contribution of a deep study of the duplicity in the Sco-Cen Complex, which is far from complete. A realistic statistical study of the binary parameters, especially on faint members, will need an extensive effort. In the near future, we will complete the reduction of all spectra obtained in 2003 and obtain new data during our next run at La Silla Observatory, with FEROS at the 2.2-m telescope (four nights in March 2004).

Two systems, known as double-lined spectroscopic binaries as well as eclipsing binaries, are already being studied in more detail, η Muscae = HD 114911 (Hensberge et al. 2003a) and V883 Cen = HD 123335 (Hensberge et al. 2003b).

Nevertheless, an effort is now needed on the study of the five systems described in this poster. More high-resolution spectroscopic observations are essential for the determination of mass ratios, periods and orbital parameters of the secure SB2 HD 90264, HD 119727 and λ Lupi. The complex system of π Lupi appears to need spectral disentangling first. HD 137058 would also need a more detailed study on a search of a period, if any.

Acknowledgements. This work was supported by the European ESA/PRODEX project number 14732/00NL/SFe(IC).

The author especially acknowledges Marc David, Herman Hensberge, Dimitri Pourbaix and René Mante for their support in this project.

He also acknowledges the staff of the South African Astronomical Observatory (SAAO) and of the Department of Physics and Astrophysics of the University of Canterbury, Christchurch, for the opportunity to use their facilities and for their support.

In SAAO, he especially acknowledges David Laney (Cape Town Observatory), who gave him the introduction to the GIRAFFE spectrograph, and François van Wyk (Sutherland Observatory), who was the observing assistant at the 1.9-m telescope.

Last, but not least, a special thank is given to David Ramm (PhD student at University of Canterbury), who gave the introduction to the HERCULES spectrograph to the author and who observed six of our programme stars (including π Lupi, λ Lupi and HD 137058) the night 5-6 September 2003.

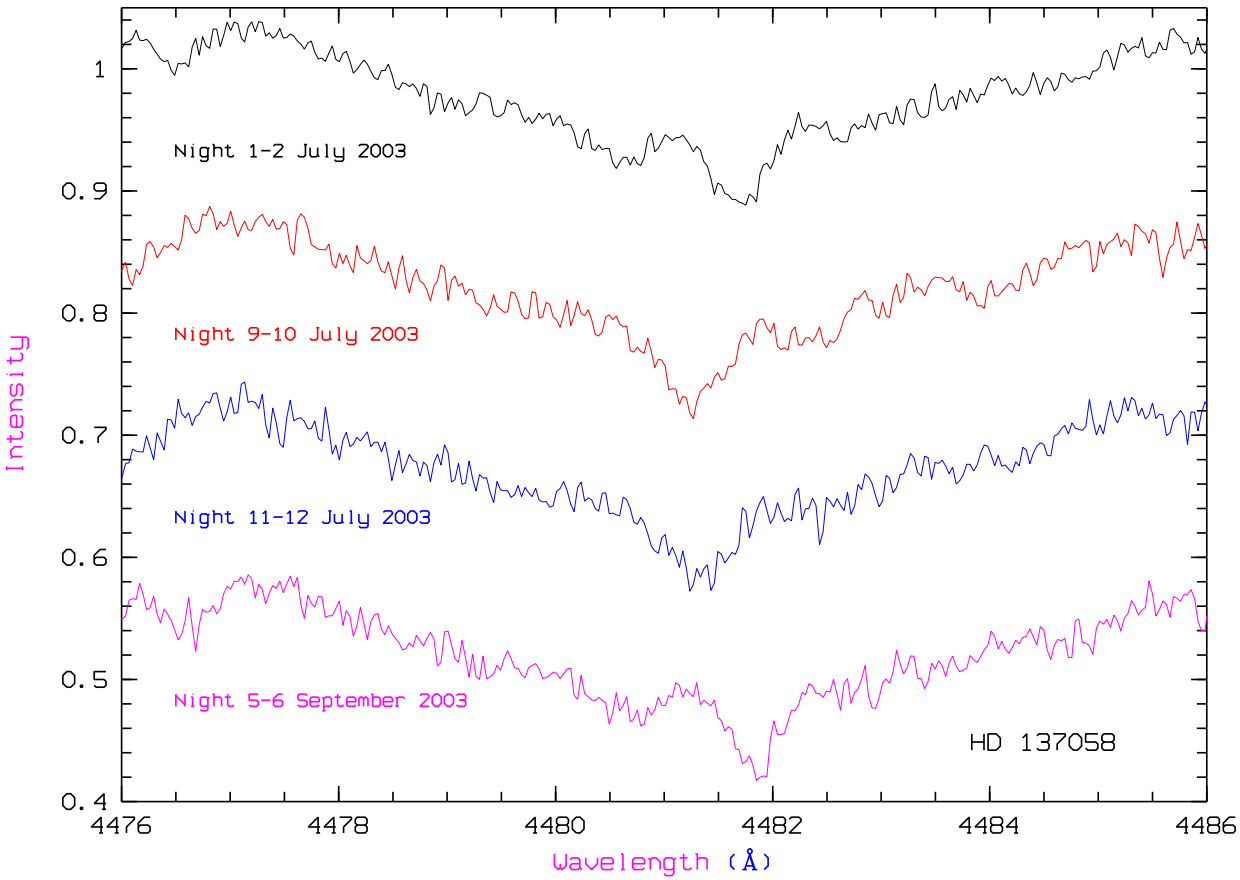

Fig. 5. The Mg II 4481.2 Å line in the spectra of k Lupi with HERCULES

References

Blaauw, A. 1964, in The Galaxy and the Magellanic Clouds (International Astronomical Union; Symposium no. 20, held in Canberra, March 18-28, 1963), ed. F. J. Kerr, Vol. 20 (Australian Academy of Science, Canberra: International Astronomical Union), 50–56
Brown, A. G. A. 1996, PhD thesis, Sterrewacht Leiden, Leiden, The Netherlands
Brown, A. G. A. & Verschueren, W. 1997, A&A, 319, 811
Buscombe, W. & Morris, P. M. 1960, MNRAS, 121, 263
Buscombe, W. & Stoeckley, T. R. 1975, ASpS, 37, 197
de Bruijne, J. H. J. 1999, MNRAS, 306, 381
de Geus, E. J. 1988, PhD thesis, Sterrewacht Leiden, Leiden, The Netherlands
de Zeeuw, P. T., Hoogerwerf, R., de Bruijne, J. H. J., Brown, A. G. A., & Blaauw, A. 1999, AJ, 117, 354
Dolk, L., Wahlgren, G. M., & Hubrig, S. 2003, A&A, 402, 299
Hartkopf, W. I., Mason, B. D., & Worley, C. E. 2001, AJ, 122, 3472
Hensberge, H., Nitschelm, C., Bouzid, M. Y., et al. 2003a, in Open Issues in Local Star Formation and Early Stellar Evolution, ed. J. Gregorio-Hetem & J. Lépine, Vol. 299 (Ouro Preto, Minas Gerais, Brazil, April 5-10, 2003: Kluwer Academic Publishers (Astrophysics and Space Science Library)), in press
Hensberge, H., Nitschelm, C., Freyhammer, L. M., et al. 2003b, in Spectroscopically and Spatially Resolving the Components of Close Binary Stars, ed. R. Hilditch, H. Hensberge, & K. Pavlovski (San Francisco, California, USA: Astronomical Society of the Pacifi c Conference Series), in press
Hoffleit, D. & Jaschek, C. 1982, The Bright Star Catalogue (New Haven, Connecticut, USA: Yale University Observatory)
Hoogerwerf, R. & Aguilar, L. A. 1999, MNRAS, 306, 394
Hubrig, S. & Mathys, G. 1996, A&AS, 120, 457
Jayawardhana, R., Mohanty, S., & Basri, G. 2002, ApJ, 578, L141
Levato, H., Malaroda, S., Morrell, N., & Solivella, G. 1987, ApJS, 64, 487

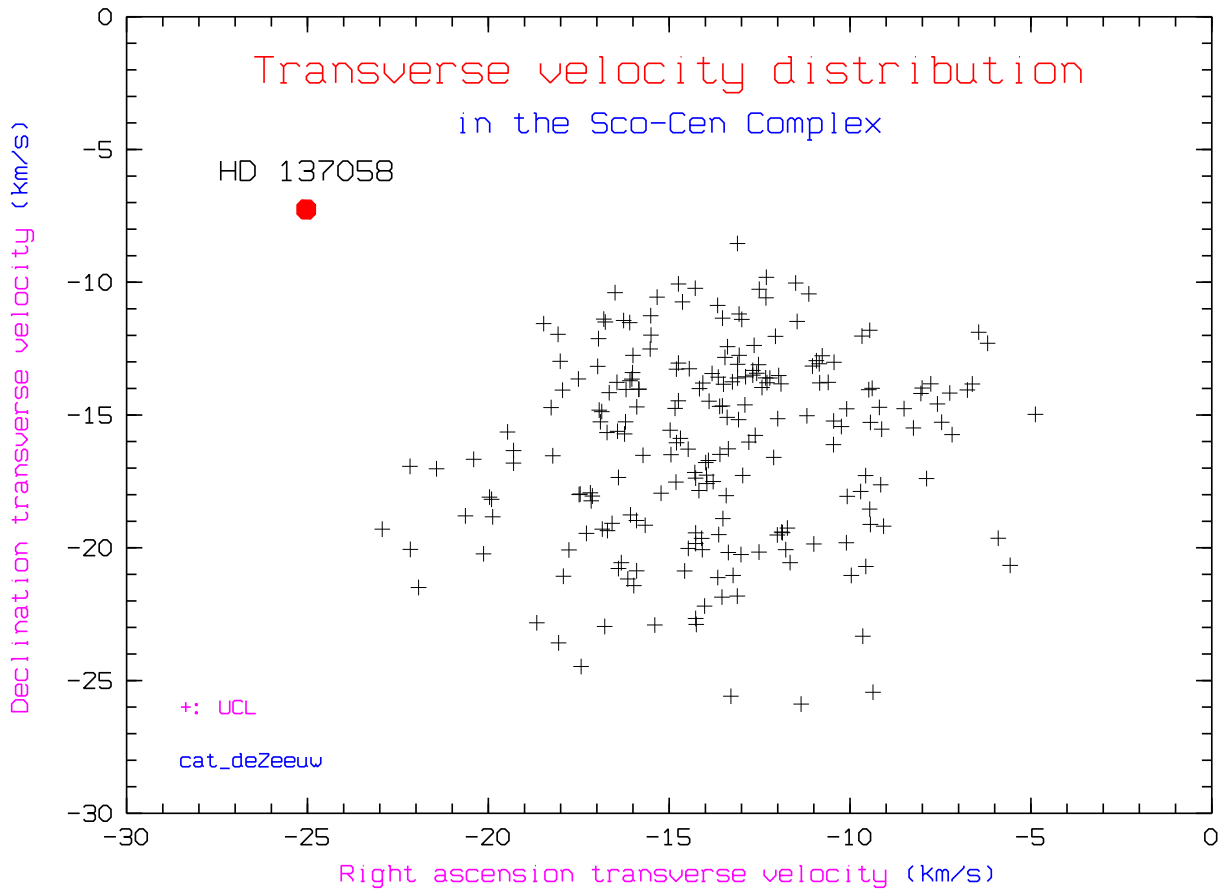

Fig. 6. Discrepancy in transverse velocity for the star k Lupi

Mamajek, E. E., Meyer, M. R., & Liebert, J. 2002, AJ, 124, 1670

Nitschelm, C. 2003, in Open Issues in Local Star Formation and Early Stellar Evolution, ed. J. Gregorio-Hetem & J. Lépine, Vol. 299 (Ouro Preto, Minas Gerais, Brazil, April 5-10, 2003: Kluwer Academic Publishers (Astrophysics and Space Science Library)), in press

Pedersen, H. & Thomsen, B. 1977, A&AS, 30, 11

Perryman, M. A. C. 1997, The Hipparcos and Tycho Catalogues (ESA SP-1200), ed. E. S. Agency, Vol. 1 (ESTEC, Noordwijk, The Netherlands: ESA Publication Division)

Preibisch, T., Brown, A. G. A., Bridges, T., Guenther, E., & Zinnecker, H. 2002, AJ, 124, 404

Verschueren, W., David, M., & Brown, A. G. A. 1996, in The origins, evolution, and destinies of binary stars in clusters, ed. E. F. Milone & J.-C. Mermilliod, Vol. 90 (San Francisco, California, USA: Astronomical Society of the Pacifi c Conference Series), 131–132