An investigation on close binaries in the Sco-Cen Complex

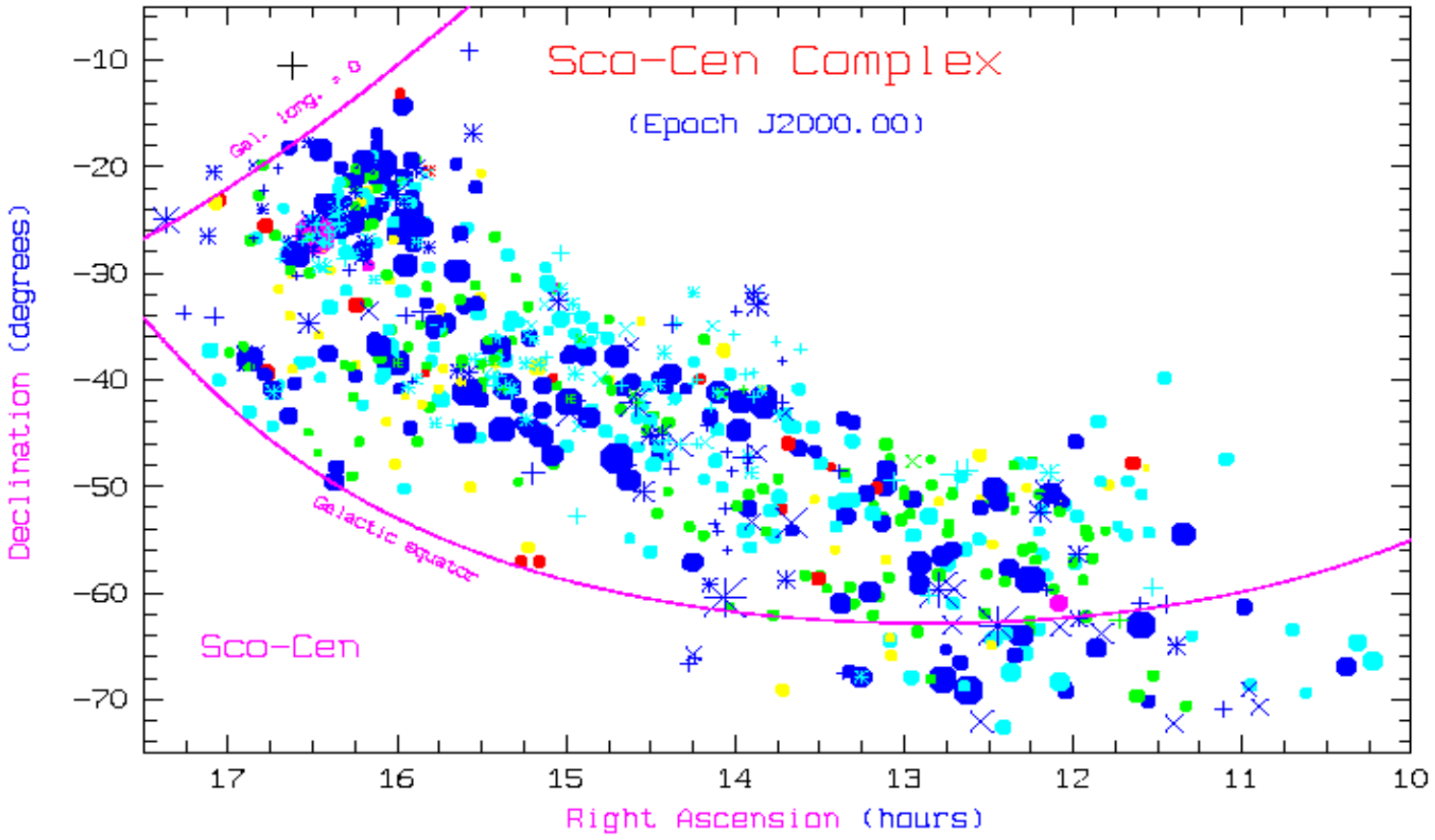
Christian Nitschelm

Instituto de Astronomía
Universidad Católica del Norte
Antofagasta
Chile

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. In this talk, we present results we derived about duplicity and multiplicity throughout the Sco-Cen Complex, and especially on yet unknown or poorly studied close binaries (eclipsing and spectroscopic binaries).

The Sco-Cen Complex in the sky

(equatorial coordinates J2000.0)



The Sco-Cen Complex is composed by three nearby Southern OB associations:

Lower Centaurus Crux (LCC)

Upper Centaurus Lupus (UCL)

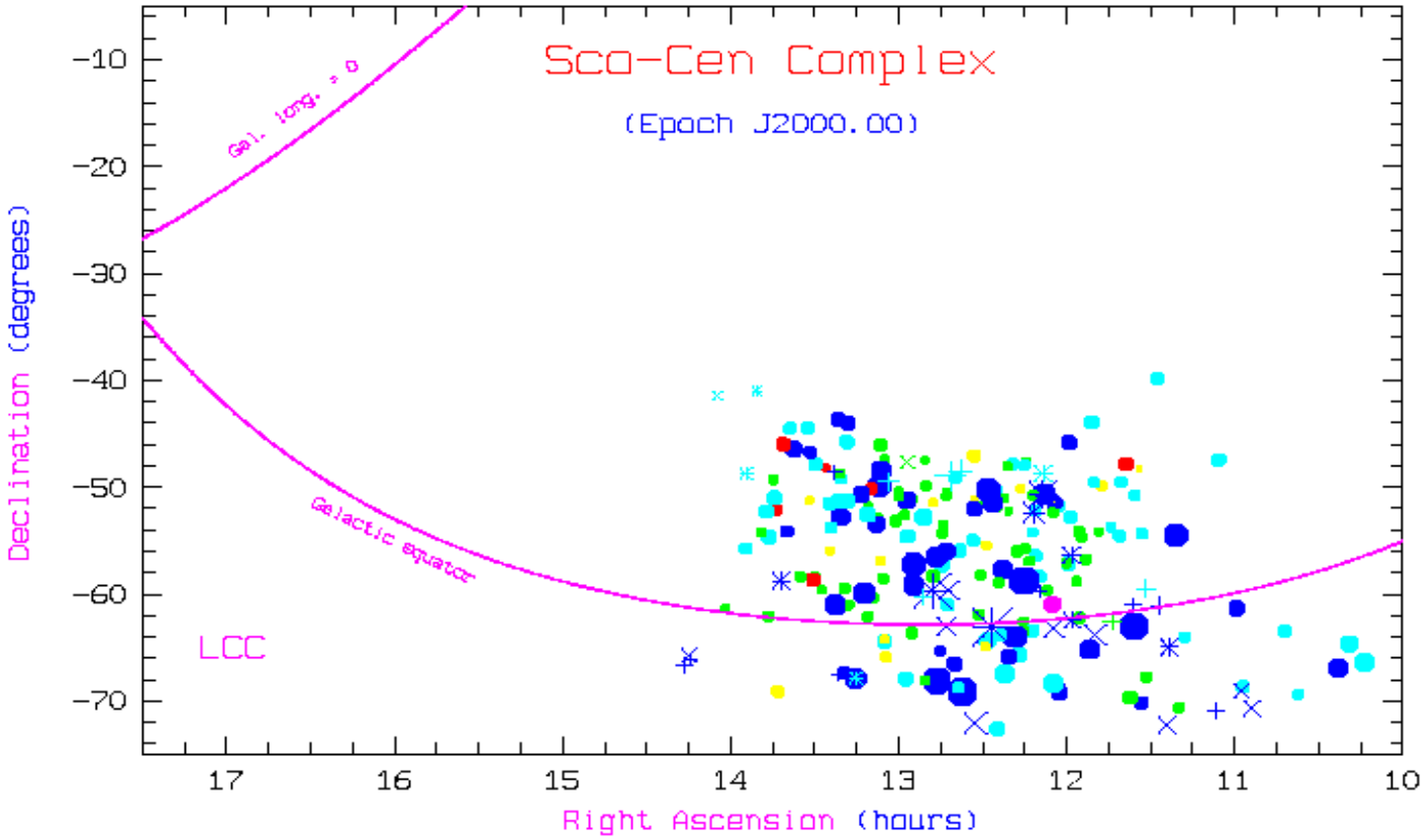
Upper Scorpius (US)

These three OB associations are actually very young:

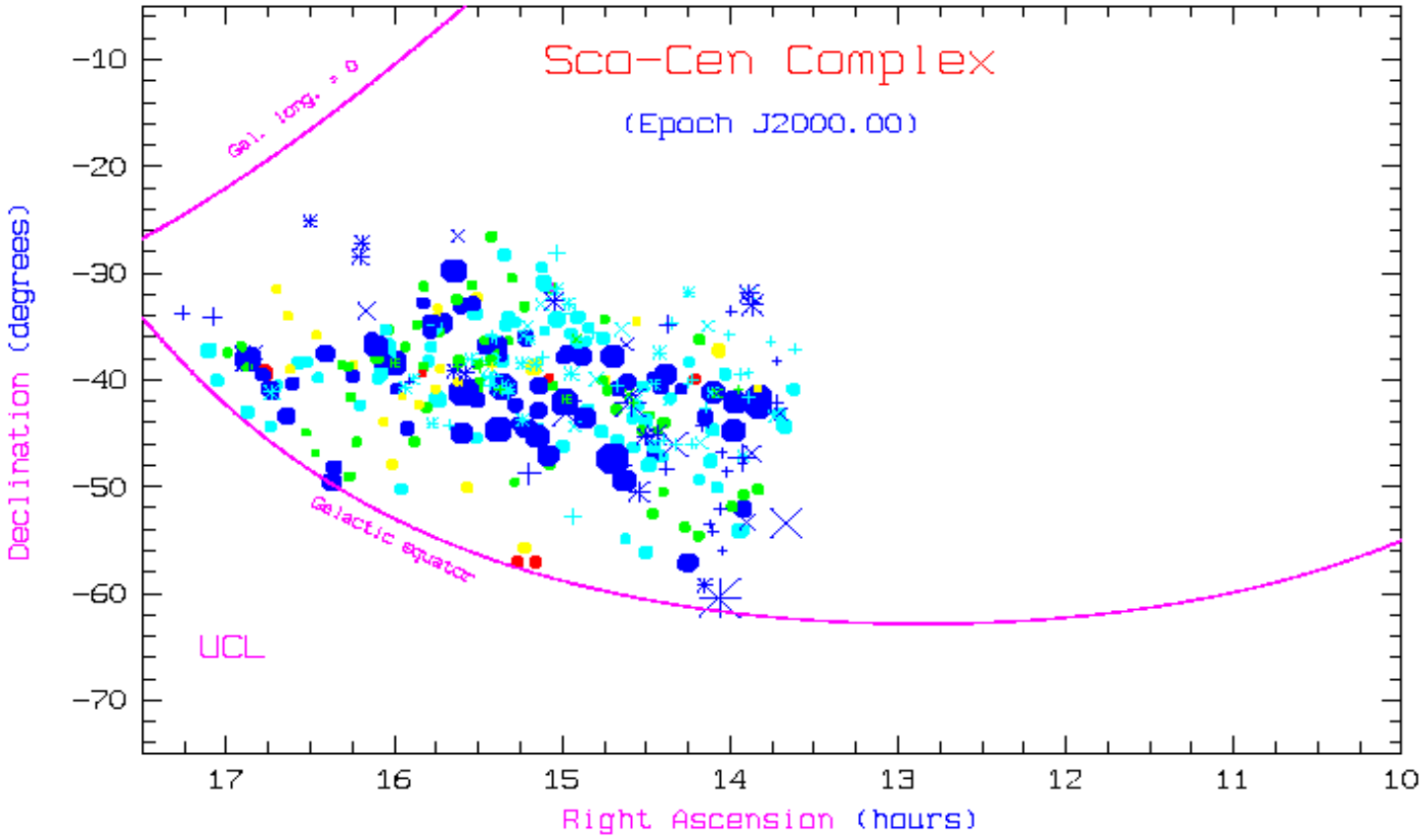
LCC and UCL: between 10 and 15 Myr

US: only 5 Myr *(from various authors)*

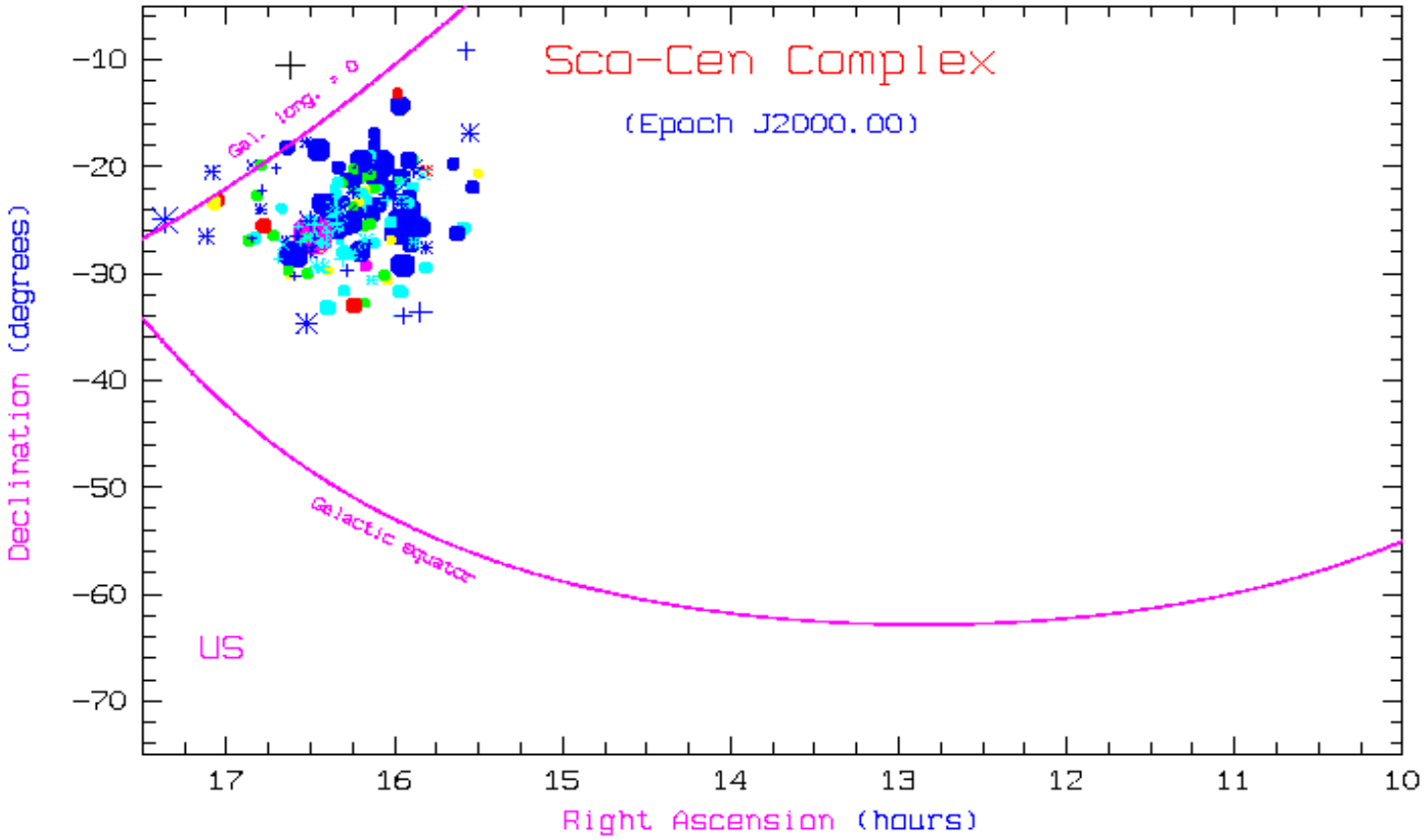
Lower Centaurus Crux (LCC)



Upper Centaurus Lupus (UCL)



Upper Scorpius (US)



Mean distances of LCC, UCL and US and Hipparcos-based selection of the members

- LCC: 118 ± 2 pc (180 secure members)
- UCL: 140 ± 2 pc (221 secure members)
- US: 145 ± 2 pc (120 secure members)

(de Zeeuw et al., 1999, AJ vol. 117 (I), 354)

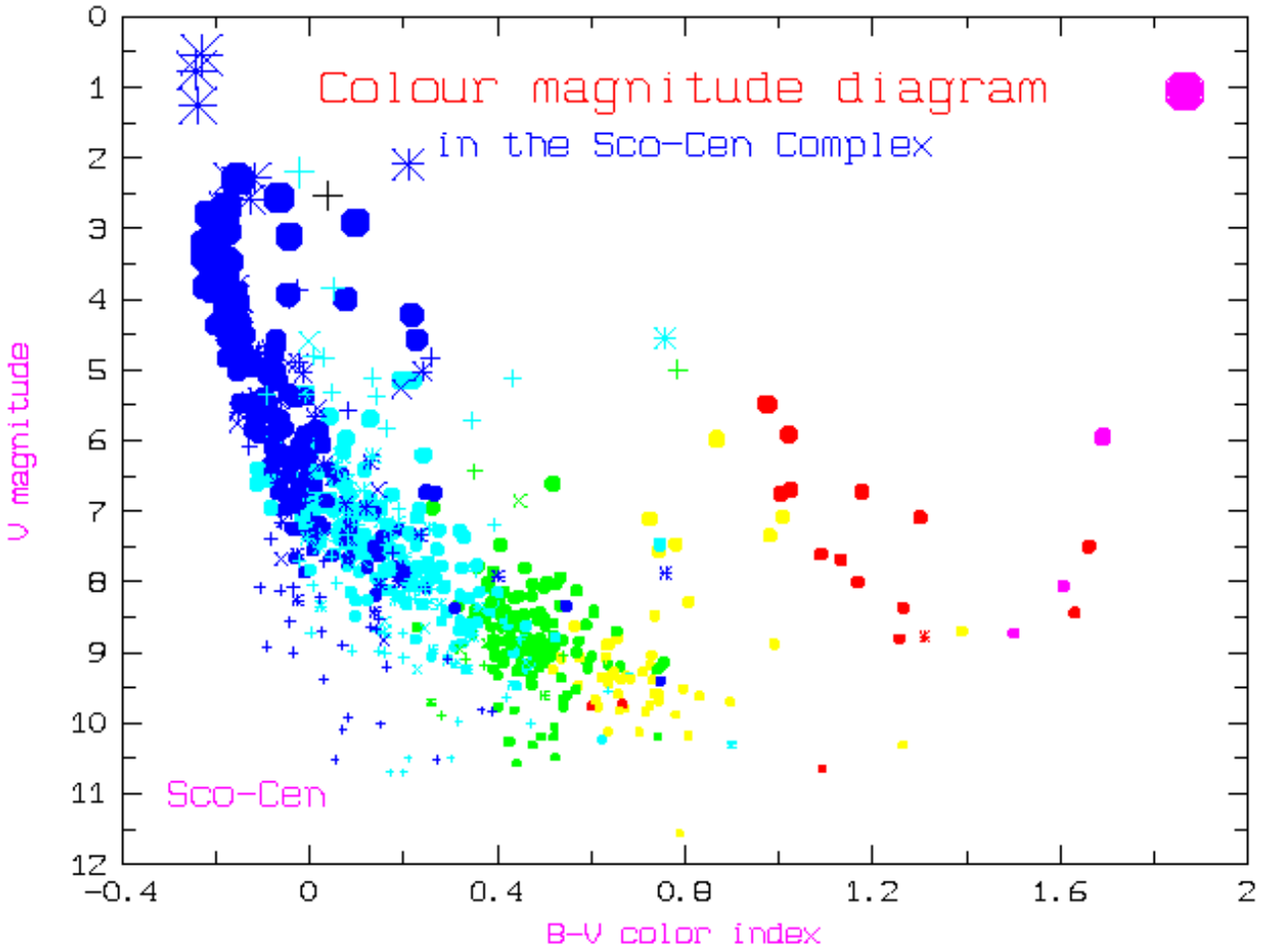
The secure membership is based on astrometric criteria applied in a consistent way to all objects in this region of the sky.
But apart from a number of cases with known duplicity it ignores The possibility that these criteria are violated *as a consequence of* duplicity. Therefore we were compelled to reconsider 141 objects from two earlier membership studies:

de Geus, 1988, PhD Thesis, Leiden Observatory

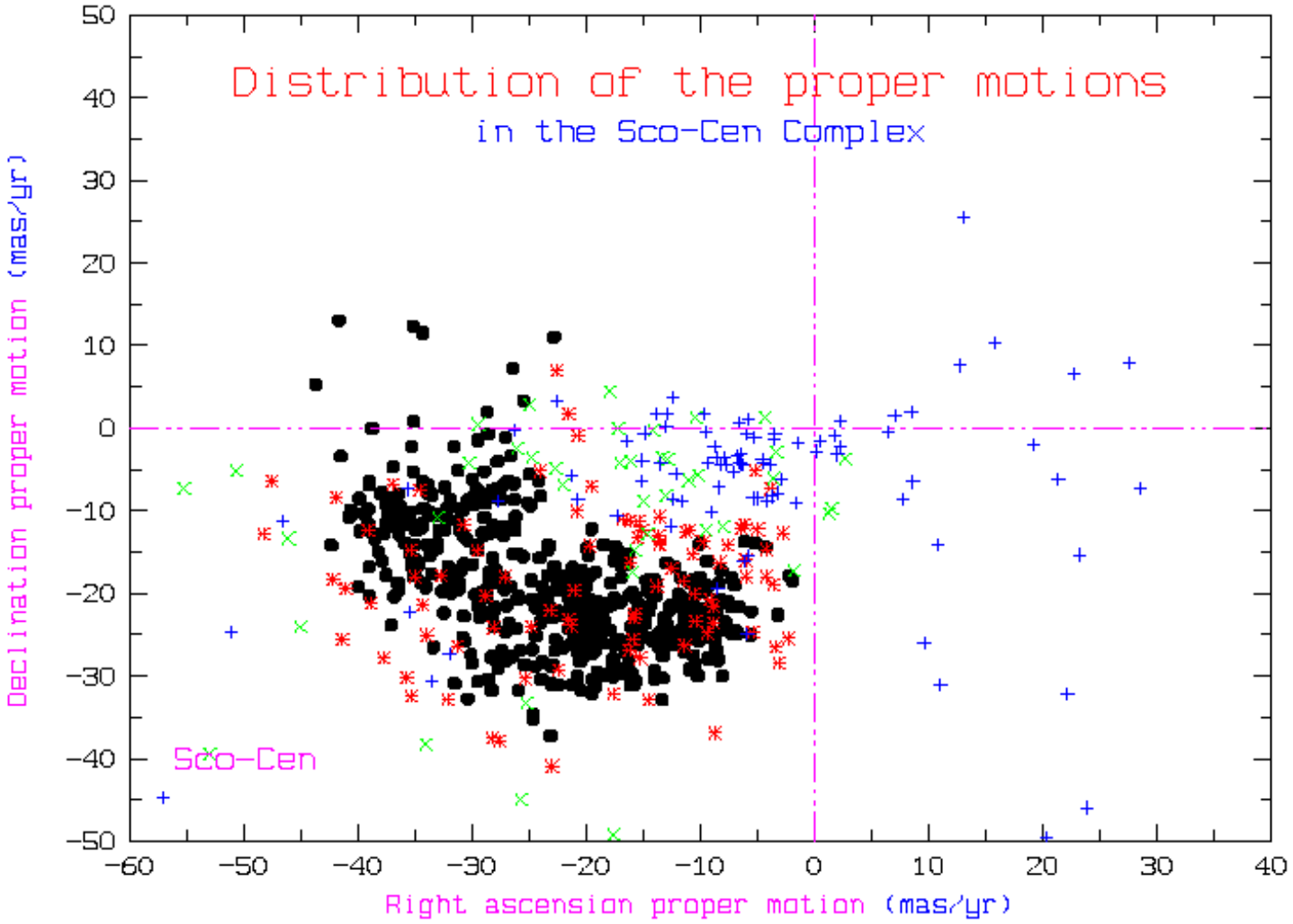
Brown & Verschueren, 1997, A&A vol. 319, 811

which were rejected by de Zeeuw et al. (1999), as possible (95) or doubtful (46) members.

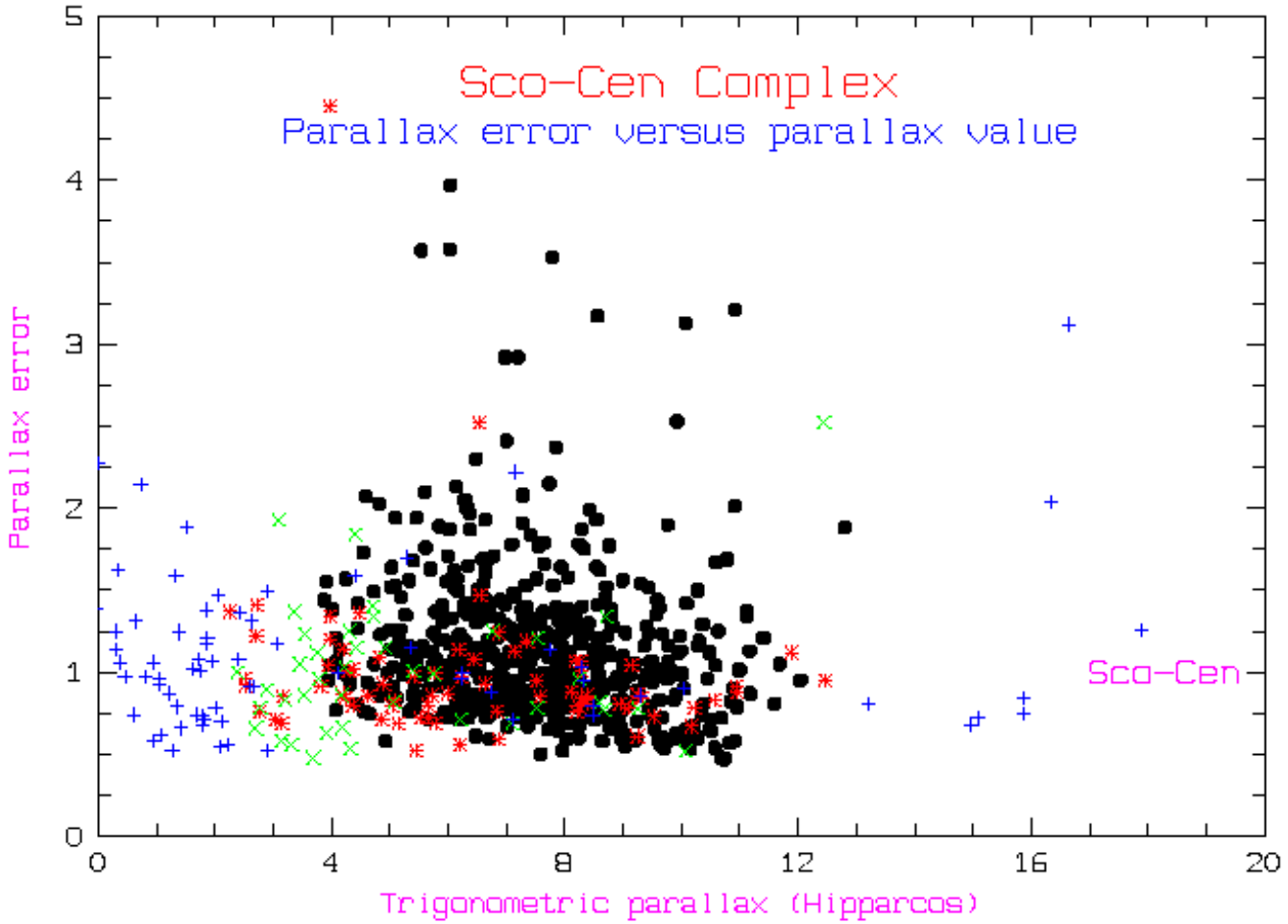
Selection of the possible members: The Hertzsprung Russell Diagram



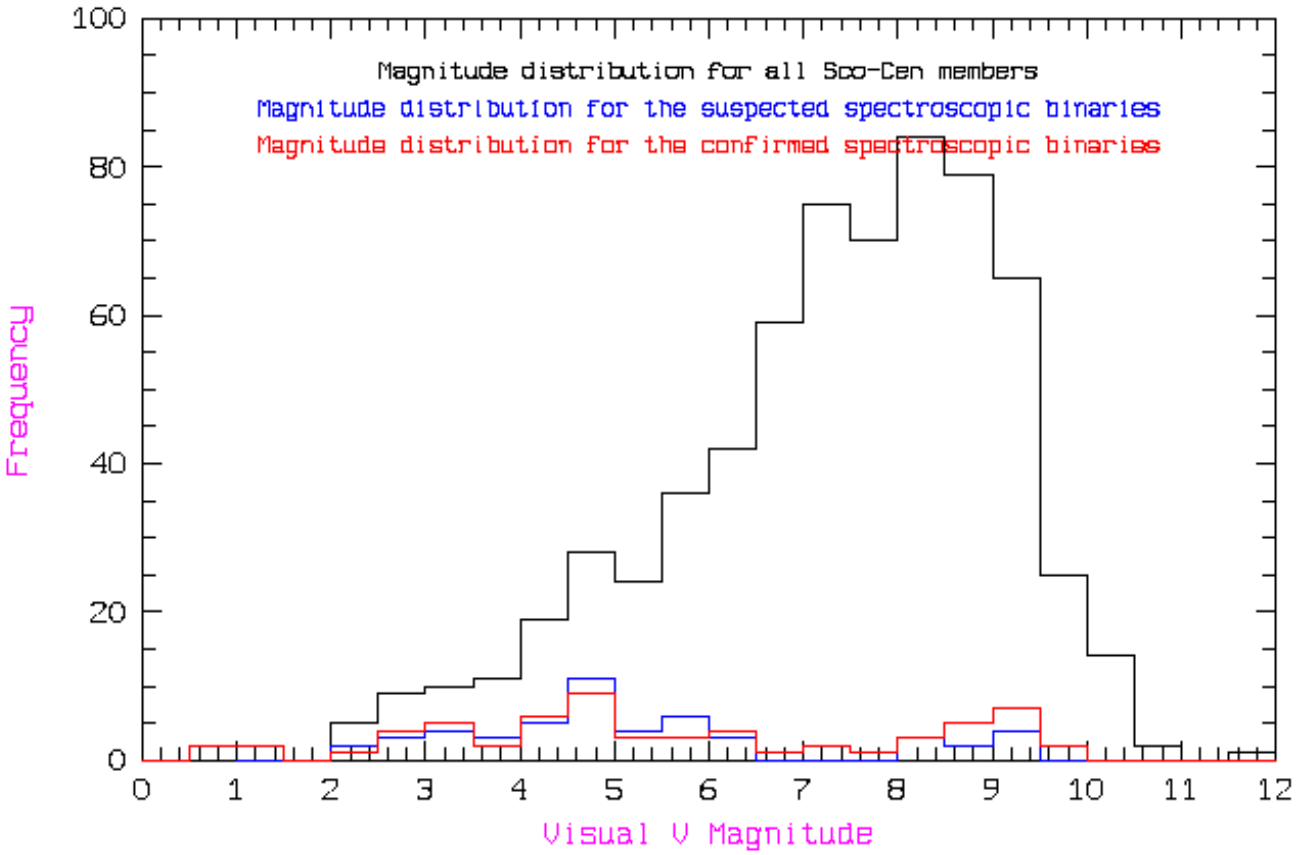
Selection of the possible members: The Hipparcos proper motions



Selection of the possible members: The Hipparcos parallax values



First conclusion: lack of spectroscopic binaries among the fainter stars (V > 5)



Second conclusion: lack of knowledge on binaries having period values between 3 months and several years

- Many close binaries (eclipsing binaries and SB) known with short periods (< 3 months)
- Only 3 binaries known with a “middle” period between 3 months and 9 years
- Many wide (visual) binaries known with a long period (greater than 9 years)

=> An investigation is now needed for finding yet unknown spectroscopic binaries among the fainter stars (mainly for V > 5) and for finding several yet unknown binaries having “middle” period values (3 months < P < 10 years)

Our recent high resolution spectroscopic observations

At least 3, better 4 or more, good observations (S/N ~ 200), taken at different dates for each target are needed.

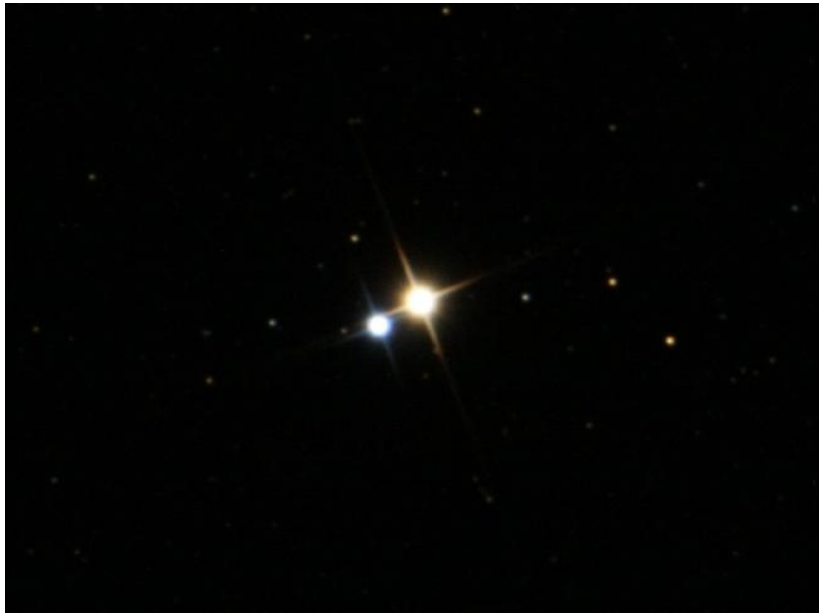
We were already getting many observations during several runs with:

- Echelec (La Silla, CL), during the nineties (138 *)
- Caspec (La Silla, CL), during the nineties (157 *)
- FEROS (La Silla, CL), from 2000 to 2016? (117 *)
- Giraffe (Sutherland, ZA), from 2003 to 2008 (76 *)
- Hercules (Mount John, NZ), July 2003 (50 *)

=> 306 stars observed at least one time

- BESO (Cerro Amazones, CL), since 2011?

Some results concerning close binaries



Recent publications

Mon. Not. R. Astron. Soc. **379**, 349–356 (2007) doi:10.1111/j.1365-2966.2007.11955.x

The eclipsing double-lined binaries V883 Cen and η Mus*

H. Hensberge,[1]† C. Nitschelm,[1,2] E. H. Olsen,[3] C. Sterken,[4]‡ M. David,[2] L. M. Freyhammer,[1,5] N. R. Landin,[6] M. Y. Bouzid,[4] C. Papadaki,[1,4,7] J. D. Pritchard,[7] J. V. Clausen[3] and L. P. R. Vaz[6]

[1]*Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussel, Belgium*
[2]*University of Antwerp, Middelheimlaan 1, B-2020 Antwerpen, Belgium*
[3]*Niels Bohr Institute, Copenhagen University, Juliane Maries Vej 30, DK-2100 Copenhagen Ø, Denmark*
[4]*Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussel, Belgium*
[5]*Centre for Astrophysics, University of Central Lancashire, Preston PR1 2HE*
[6]*Departamento de Fisica, Universidade Federal de Minas Gerais, C.P. 702, Belo Horizonte 30123-970 MG, Brazil*
[7]*European Southern Observatory, Casilla 1901, Santiago, Chile*

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ABSTRACT

We derive the orbital period and monitor in detail the eclipses of two deep-southern double-lined eclipsing binaries of considerable interest. We present new *uvby* photometry over more than 100 nights for V883 Cen, scan for the first time the eclipses of η Mus and analyse the data for these two systems together with earlier published photometry. We also add information from high-dispersion spectra.

V883 Cen consists of two sharp-lined, mid-B-type stars in an orbit of 35.44733 d. The slower rotating component, $P_{\rm rot} = 55.215$ d, is a chemically peculiar star of the type He-weak SrTi that is partially eclipsed by its slightly more massive companion. Owing to the high eccentricity of the orbit and its orientation, only one eclipse occurs. The orbital period of η Mus is 57.5 h, rather than the 20 d quoted up to the present in the literature. That close binary, consisting of two late-B-type stars, shows identical partial eclipses. Interest in the close binary is triggered by the pre-main-sequence companion at 2.7 arcsec. HD 118978, one of the comparison stars used for V883 Cen, is identified as a new variable. This fast-rotating B9 (sub)giant belongs presumably to the class of slowly pulsating B-type stars.

Key words: binaries: eclipsing – binaries: spectroscopic – stars: chemically peculiar – stars: individual: V883 Cen – stars: individual: η Mus – stars: individual: HD 118978.

1 INTRODUCTION

As a by-product of searching for and cataloguing binaries in the stellar associations in Scorpius–Centaurus, attention was drawn to bright double-lined eclipsing binaries that did not yet receive much interest. Their light curves were never monitored, and even their orbital periods were unknown or doubtful. Nevertheless, information in the literature and in our collection of high-dispersion spectra indicated that they are interesting candidates for deriving very precise fundamental stellar parameters.

V883 Cen (HD 123335, HR 5292) consists of two well-detached components, both sharp-lined, one of which is a chemically peculiar star. This Bp star is partially eclipsed by its slightly more massive, mid-B companion. The rotation is not synchronized with the orbital motion. As a consequence, different parts of the surface of the Bp star can be scanned during different eclipses, giving a unique opportunity to study inhomogeneities on the stellar surface or/and stratification by diffusion processes in the atmosphere in a more direct way. Moreover, we anticipate that the application of a spectra-disentangling algorithm to a set of high-dispersion spectra suitably spread over the orbital period will reveal weak spectral lines with depths as small as 0.1 per cent, which is of considerable interest to abundance studies and spectral line identification in normal and chemically peculiar mid-B stars.

The interest of η Mus (HD 114911, HR 4993) lies in the combination of the massive close binary (late-B components) with a pre-main-sequence star (PMS) at a few arcsec separation. A late-A chemically peculiar star, exhibiting common proper motion, may also be loosely connected to the system. Precise fundamental stellar parameters and the determination of its distance from the Sun should clarify its relationship with the young stellar association in Lower

*Based on observations obtained at the European Southern Observatory (ESO), La Silla, Chile, and at the South African Astronomical Observatory (SAAO), Sutherland, South Africa.

†E-mail: herman@oma.be
‡Research Director, Belgian Fund for Scientific Research (FWO).

Duplicity and multiplicity in the Sco-Cen Complex. The η-Muscae multiple system

C. Nitschelm[1,2], M. David[2], N. Rezende Landin[3], V. Bakış[4], H. Hensberge[5]

[1]Instituto de Astronomia, Universidad Católica del Norte, Avenida Angamos 0610, Antofagasta, Chile
[2]Astrophysics Research Group, Antwerp University, Middelheimlaan 1, B-2020 Antwerpen, Belgium
[3]Departamento de Física, Universidade Federal de Minas Gerais, C.P. 702, Belo Horizonte 30123-970 MG, Brazil
[4]Canakkale Onsekiz Mart Univ. Physics Dept. and Ulupınar Astrophysical Observatory, Terzioğlu Campus, TR-17040, Canakkale, Turkey
[5]Royal Observatory of Belgium, Ringlaan 3, 1180 Brussels, Belgium

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.

In this poster, we present results we derived about duplicity and multiplicity throughout the Sco-Cen Complex, with emphasis on one particular multiple system, η Muscae, containing a light pre-main sequence component as well as massive stars.

Keywords

OB associations; Sco OB2; binaries: spectroscopic, eclipsing, visual; massive stars; star: individual: η Muscae

The young Sco-Cen Complex (Sco OB2)

The Sco-Cen Complex (or Sco OB2) is composed by three nearby Southern OB associations: Lower Centaurus Crux (LCC), Upper Centaurus Lupus (UCL) and Upper Scorpius (US) (figure 1).

Three three OB associations are actually very young:

+ LCC: 16 ± 1 Myr (Mamajek et al. 2002) viz 118 ± 2 pc (180 secure members)
+ UCL: 17 ± 1 Myr (Mamajek et al. 2002) at 140 ± 2 pc (221 secure members)
+ US: about 5 Myr (Preibisch et al. 2002, various authors) at 145 ± 2 pc (120 secure members)

The secure membership is based on astrometric criteria applied in a consistent way to all objects in this region of the sky.

Apart from a number of cases with known duplicity it ignores that astrometric criteria may be violated in case of unrecognized duplicity. Therefore we were compelled to include information on 141 objects from two earlier membership studies (de Geus, 1988; Brown & Verschueren, 1997) which were rejected by de Zeeuw et al. (1999), as possible (95) or doubtful (46) members.

Selection of the Sco-Cen Complex members using Hipparcos data for the secure members already selected by de Zeeuw et al. (1999), i.e. with the Hertzsprung-Russell diagram (figure 2), the proper motion distribution, the transverse velocity distribution and the parallax distribution:

Creation of the Sco-Cen Complex Catalogue (Nitschelm 2003):

+ Information on 754 stars secure (LCC:180+UCL:221+US:120), suspected (141) or rejected (92) members
+ Synthesis of the literature, Simbad, etc., inclusive classification, spectrum and light variability, multiplicity
+ Membership probability (from de Zeeuw et al. 1999)

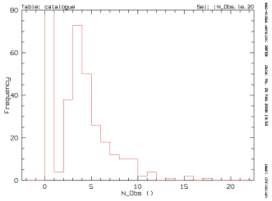


Figure 5: Number of high-resolution echelle spectra available per object (502 targets are presently without any observation and one very specific target, the double-lined spectroscopic binary HD 123335, was observed 134 times).

η Muscae: a multiple system with massive and light stars

η Muscae ($V = 4.8$ mag) consists of at least three components: a massive close binary with almost identical components of 3.3 $M_\odot$ separated by 14 $R_\odot$ in a 2.4-day circular orbit (figure 6), and a much less massive pre-main sequence component (η Mus C), at 300 AU, first seen by Meilicz & Hubrig (2000) and not contributing to the visual spectra. At 6202 au, there is a Ap star, η Mus B, which may not be bound to the system, in view of its radial velocity differing by 13 km/s from the centre-of-mass radial velocity of the close binary. Its kinematics suggests strongly that it belongs to the Lower Centaurus-Crux OB association (LCC).

The close binary η Mus A produces (partial) eclipses due to the orbital inclination of 77° (figure 13). Orbital and stellar parameters for the close binary have recently been determined (Bakış *et al.* 2007) combining their high-resolution spectroscopy with photometry from Hensberge et al. (2007). The distance found from the close-binary analysis (103 pc) is slightly small, compared to the trigonometric distance of 118 pc derived from the *hipparcos* astrometry. Both papers agree on the age of 20 Myr for the system. Hensberge et al. (2007) use the non-gray non-rotation evolutionary tracks of Landin et al. (2006) to estimate the mass of the PMS star near 0.8 $M_\odot$ (figure 7).

Transformation from theoretical to colour-magnitude HR diagram was done by means of ATLAS 9 models (Bessel, Castelli & Plez, 1998) and the interstellar reddening correction was estimated from colour excesses of Cutrali, Franco & Knade (1997) and the extinction law of Rieke & Lebofsky (1985).

Neither the age of the stars, the distance or its kinematics exclude that η Muscae is potentially a member of LCC, but the conclusion on its membership remains uncertain.

There are some indirect indications for the presence of a fourth, relatively massive (early-A?), component:

- independent of the Doppler separation between the Mg II lines of the close-binary components, in between them the continuum is never reached (suggesting a possible underlying, broad component);
- the trigonometric distance of η Muscae would be reproduced by the close-binary analysis if an additional component is responsible for 20 per cent of the visual light;
- one of the close-binary stars rotates faster than the other one. Lack of orbit-spin synchronization is not expected, and possibly a consequence of the presence of an additional body.

It is our intention to check in the near future the existence or absence of a third component contributing to the visual spectrum based on the application of three-component spectra disentangling to selected spectral intervals in the data listed in Table 1 (figures 8 and 9).

This will help to clarify the relation of η Muscae with LCC. If the system belongs to LCC it sets useful limits on the age of the PMS star and therefore on PMS tracks. It may also clarify whether the difference between the systemic velocity of the close binary and η Mus-C could be a consequence of a wide orbit of the close binary around the yet unidentified component.

Table 1: Number of spectra available for η Muscae

observing run	epochs	number of observations	spetrograph	$\frac{\lambda}{\Delta\lambda}$	range (nm)
2003	02/09 – 02/15	9	*ESO FEROS*	48,000	370 – 900
2003	06/10 – 06/16	6	*SAAO GIRAFFE*	39,000	377 – 556
2006	05/17 – 05/20	43	*MJUO HERCULES*	41,000	450 – 720
2006	08/19 – 09/15	7	*MJUO HERCULES*	41,000	365 – 940

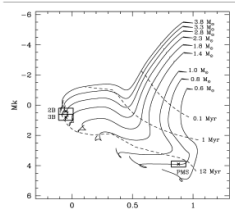


Figure 7: Position of the components of η Mus in the (M_v,B-K) diagram with a set of evolutionary tracks (solid lines) and isochrones (dashed lines). The presence of a third late-B-type component would change the position of the close-binary components from '2B' to '3B'.

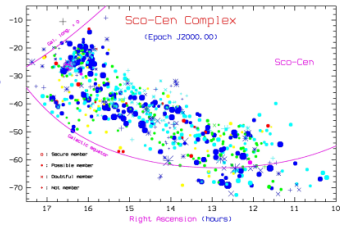


Figure 1: The Sco-Cen Complex (Sco OB2) in the Southern sky, using 2000 equatorial coordinates (the diameter of each spot is a function of the V magnitude of the corresponding star, whereas its colour is connected with the stellar spectral type: black for O; blue for B; cyan for A; green for F; yellow for G; red for K; magenta for M).

Review of the duplicity and multiplicity in the Sco-Cen Complex

For each selected object:

+ Thorough literature, Simbad and Catalogue (CCDM, Washington Double Star Catalogue, CHARA, SB8 and SB9) investigation
+ In case of physical binarity or multiplicity, known orbital period, if any
+ Recent observations (Echelec, Canpec, FEROS, Giraffe (SAAO), Hercules (Mount John))

Creation of the auxiliary duplicity / multiplicity catalogues (Nitschelm 2003):

+ Catalogue of optical pairs (false binaries)
+ Catalogue of visual binaries => orbits
+ Catalogue of eclipsing binaries and ellipsoidal stars
+ Catalogue of confirmed spectroscopic binaries
+ Catalogue of suspected spectroscopic binaries
+ Catalogue of Hipparcos selected suspected binaries in Sco OB2 (Pourbaix & Boffin 2003)
+ Catalogue of objects of special interest, mainly the double-lined spectroscopic binaries and the eclipsing binaries, for future spectra disentangling projects
+ Discrepancies coming from the literature.
+ High-resolution spectroscopic observations already available

First conclusion (figure 3): lack of detected spectroscopic binaries among the fainter stars ($V > 5$)

Second conclusion: lack of knowledge on stars having period values between three months and several years: Only 3 binaries known with period between 3 months and 9 years

+ Many bright close binaries (eclipsing binaries and SB) known with short periods (< 3 months) (see, for instance, Levato et al. 1987)
+ Many wide (visual) binaries known (period longer than 9 years)

=> Gap between the short-period spectroscopic binaries and the visual binaries should be closed by long-term spectroscopy and interferometry

Third conclusion: Lack of recent observations for visual binaries

+ Many old observations for visual double or multiple stars from W. Herschel to the seventies
+ Too few recent observations (but the Hipparcos catalogue, Mason et al. 2001, Hartkopf et al. 2001, Shatsky & Tokovinin 2002, Kouwenhoven et al. 2005, Kouwenhoven et al. 2007, etc.).
+ New binaries with fast motion discovered by Hipparcos, without a satisfactory orbit

Kinds of observations needed:

+ A blind spectroscopic survey of the whole Sco-Cen Complex for the discovery of yet unknown spectroscopic binaries
+ Observations of suspected and confirmed spectroscopic binaries arising from the literature, possibly including photometry to detect yet unknown eclipses

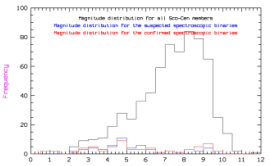


Figure 3: Magnitude histogram of all objects of our sample, the confirmed spectroscopic binaries and the suspected ones.

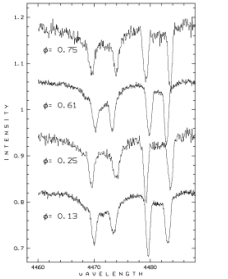


Figure 8: Extracts of spectra of η Muscae (with He I and Mg II lines) obtained in 2003 at SAAO ($\phi = 0.25$ and 0.75) and ESO ($\phi = 0.13$ and 0.61).

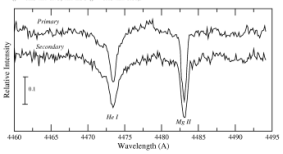


Figure 9: Disentangled spectra of the components of η Muscae (from Bakış et al. 2007), obtained from the Mt. John spectra. They give, independent from fig. 14, evidence for a broad component underlying the Mg II lines of the components.

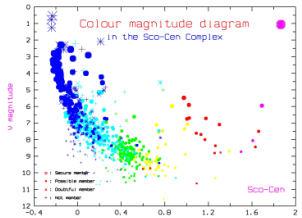


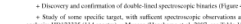
Figure 2: The Hertzsprung-Russell diagram of the Sco-Cen Complex (the diameter of each spot is a function of the V magnitude of the corresponding star, whereas its colour is connected with the stellar spectral type: black for O; blue for B; cyan for A; green for F; yellow for G; red for K; magenta for M).

Our recent high resolution spectroscopic observations:

+ At least 3, better 4 or more, good observations (S/N ≥ 200) for each target are needed
+ We already have observations from several runs with:
=> Echelec (La Silla) during the nineties
=> Canpec (La Silla) during the nineties
=> FEROS (La Silla) from 2000 on
=> Giraffe (Sutherland, ZA) from 2003 on
=> Hercules (Mount John, NZ) in 2003 and 2006
252 stars already observed at least one time
=> BESO (FEROS II, 1.5-m Hexapod Telescope Cerro Amazones) from 2008 (?)

First results:

+ Discovery and confirmation of double-lined spectroscopic binaries (Figure 4)
+ Study of some specific target, with sufficient spectroscopic observations available for detailed analysis: HD123335 (114 spectra), η Muscae (Hensberge et al. 2007, see Table 1), V831 Centauri (32 spectra), V964 Centauri (44 spectra), γ Lupi (40 old observations and 2 recent spectra), δ Librae (48 old observations and 4 recent spectra)
+ Several targets having presently only one, two or three observations are waiting new observations (figure 5)
+ Necessity to separate observations by different time-intervals:



to increase the probability of detecting SB character and to get a better constraint on the number of possible periods

+ Photometric and spectroscopic observations either for the surveys in blind or for some very specific objects on peculiar interest
+ Astrometric observations for visual binaries

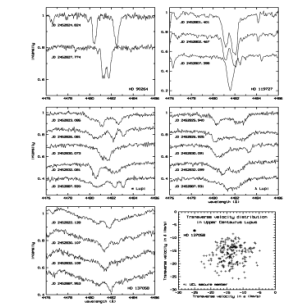


Figure 4: Discovery and confirmation of double-lined spectroscopic binaries (Nitschelm 2004).

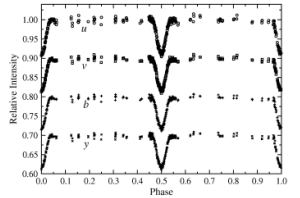


Figure 6: *u*, *v*, *b* and *y* light curves of η Muscae.

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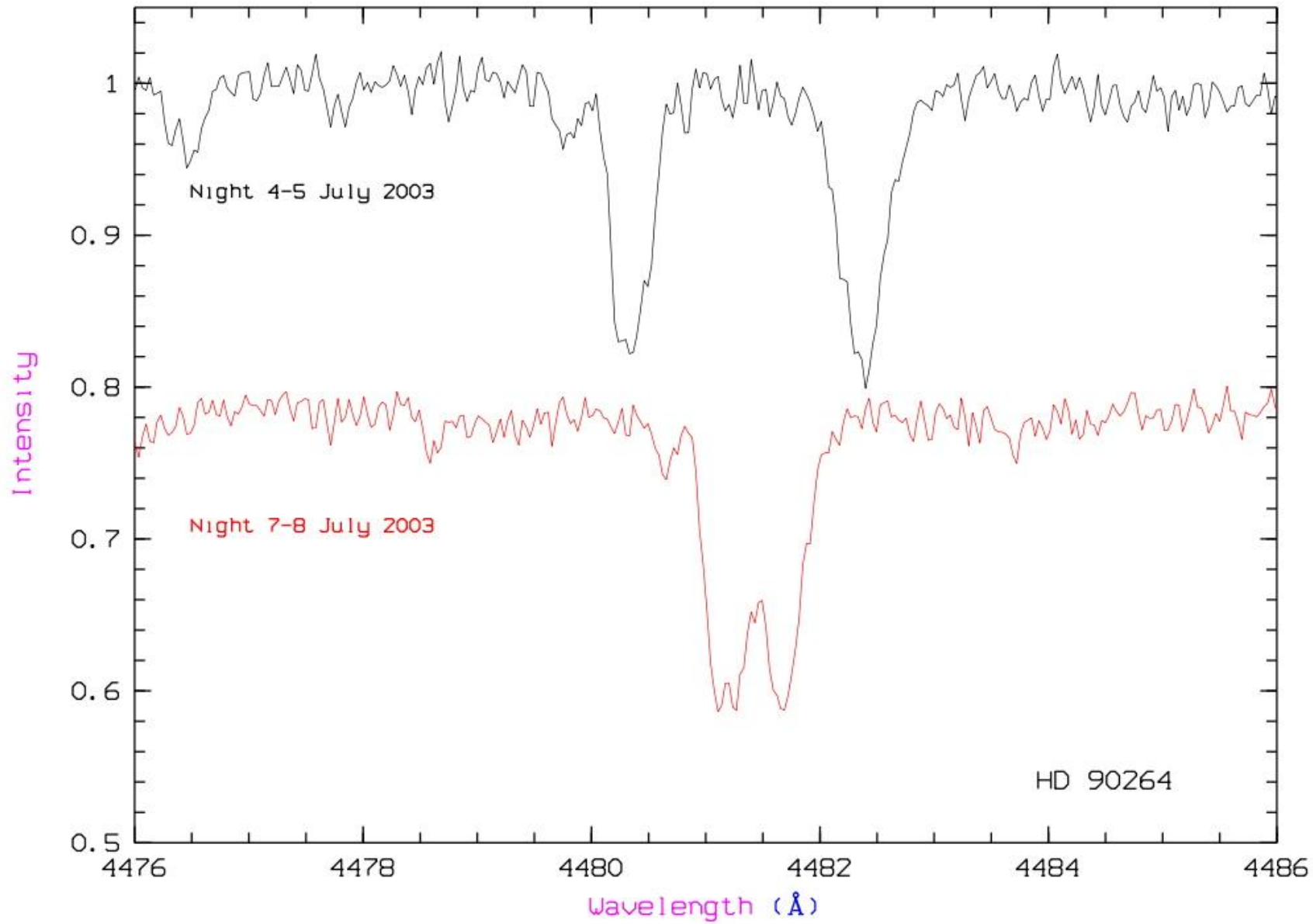

Night 4-5 July 2003
Night 7-8 July 2003
HD 90264
Intensity
Wavelength (Å)
1
0.9
0.8
0.7
0.6
0.5
4476
4478
4480
4482
4484
4486

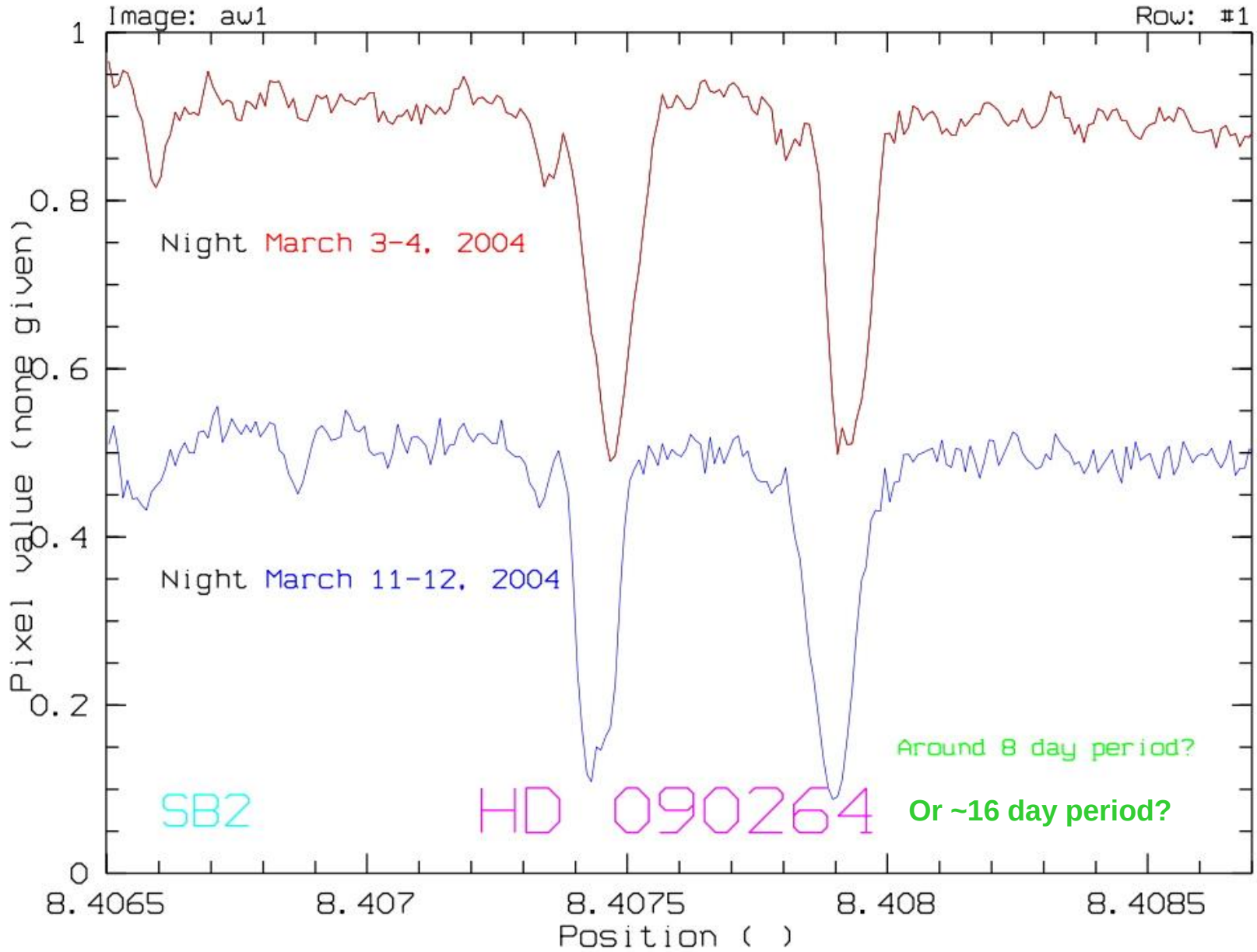
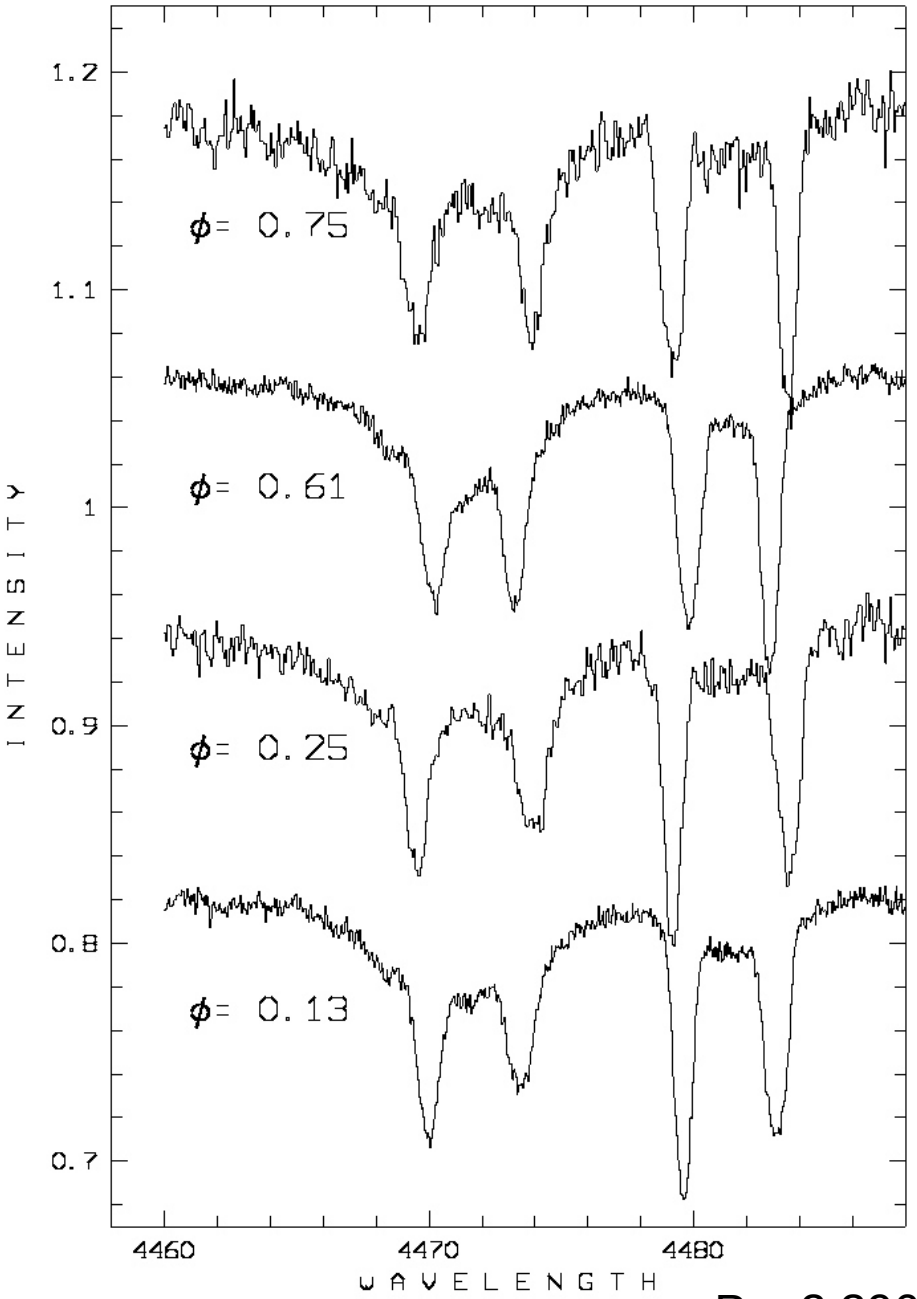
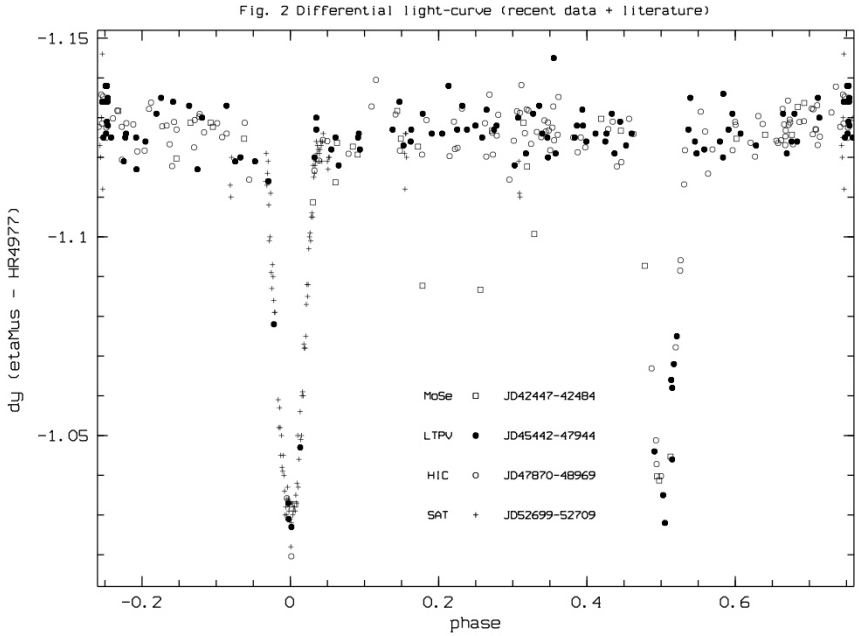


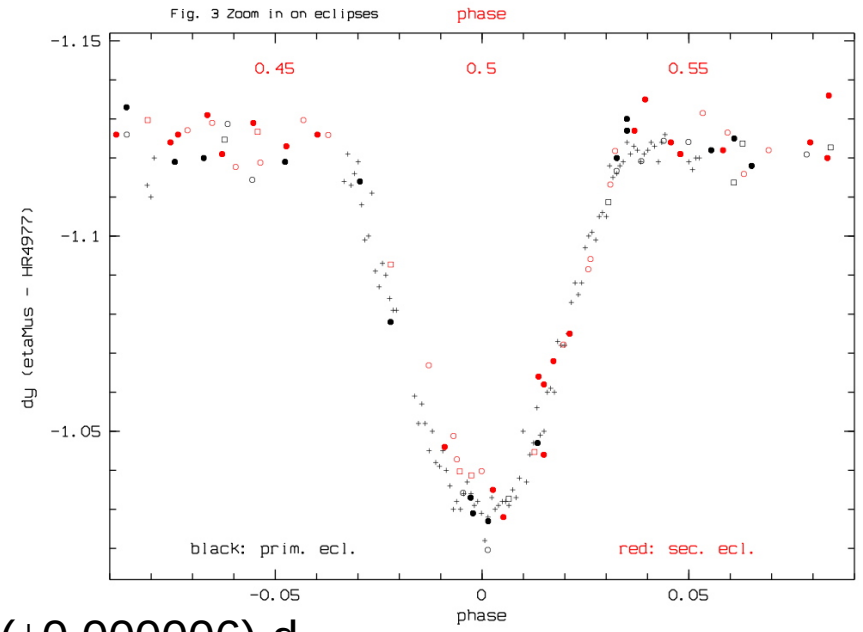
Image: aw1
Row: #1
Pixel value (none given)
1
0.8
0.6
0.4
0.2
0
Night March 3-4, 2004
Night March 11-12, 2004
Around 8 day period?
SB2
HD 090264
Or ~16 day period?
8.4065
8.407
8.4075
8.408
8.4085
Position ( )

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 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 confirmed (this star is a very stable object, according to the Hipparcos catalogue). The two spectra obtained with three days in-between clearly confirm the double-lined nature of this star, without ambiguity. 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. Our 2004 FEROS observations are suggesting a period around 8 days or around 16 days. More observations are needed for this object.





η Muscae (SB2 + EB)



P = 2.396321(±0.000006) d

η Muscae: A very well studied multiple system

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The eclipsing double-lined binaries V883 Cen and η Mus★

H. Hensberge,[1]† C. Nitschelm,[1,2] E. H. Olsen,[3] C. Sterken,[4]‡ M. David,[2] L. M. Freyhammer,[1,5] N. R. Landin,[6] M. Y. Bouzid,[4] C. Papadaki,[1,4,7] J. D. Pritchard,[7] J. V. Clausen[3] and L. P. R. Vaz[6]

[1]*Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussel, Belgium*
[2]*University of Antwerp, Middelheimlaan 1, B-2020 Antwerpen, Belgium*
[3]*Niels Bohr Institute, Copenhagen University, Juliane Maries Vej 30, DK-2100 Copenhagen Ø, Denmark*
[4]*Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussel, Belgium*
[5]*Centre for Astrophysics, University of Central Lancashire, Preston PR1 2HE*
[6]*Departamento de Fisica, Universidade Federal de Minas Gerais, C.P. 702, Belo Horizonte 30123-970 MG, Brazil*
[7]*European Southern Observatory, Casilla 1901, Santiago, Chile*

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ABSTRACT

We derive the orbital period and monitor in detail the eclipses of two deep-sou lined eclipsing binaries of considerable interest. We present new *uvby* photome than 100 nights for V883 Cen, scan for the first time the eclipses of η Mus and a for these two systems together with earlier published photometry. We also ad from high-dispersion spectra.

V883 Cen consists of two sharp-lined, mid-B-type stars in an orbit of 35.44733 rotating component, $P_{\rm rot} = 55.215$ d, is a chemically peculiar star of the type He- is partially eclipsed by its slightly more massive companion. Owing to the hig of the orbit and its orientation, only one eclipse occurs. The orbital period of η rather than the 20 d quoted up to the present in the literature. That close binary two late-B-type stars, shows identical partial eclipses. Interest in the close bina by the pre-main-sequence companion at 2.7 arcsec. HD 118978, one of the co used for V883 Cen, is identified as a new variable. This fast-rotating B9 (sub) presumably to the class of slowly pulsating B-type stars.

Key words: binaries: eclipsing – binaries: spectroscopic – stars: chemically pe individual: V883 Cen – stars: individual: η Mus – stars: individual: HD 118978

1 INTRODUCTION

As a by-product of searching for and cataloguing binaries in the stellar associations in Scorpius–Centaurus, attention was drawn to bright double-lined eclipsing binaries that did not yet receive much interest. Their light curves were never monitored, and even their orbital periods were unknown or doubtful. Nevertheless, information in the literature and in our collection of high-dispersion spectra indicated that they are interesting candidates for deriving very precise fundamental stellar parameters.

V883 Cen (HD 123335, HR 5292) consists of two well-detached components, both sharp-lined, one of which is a chemically peculiar star. This Bp star is partially eclipsed by it massive, mid-B companion. The rotation is not syn the orbital motion. As a consequence, different par of the Bp star can be scanned during different ec unique opportunity to study inhomogeneities on th or/and stratification by diffusion processes in the a more direct way. Moreover, we anticipate that the spectra-disentangling algorithm to a set of high-di suitably spread over the orbital period will reveal we with depths as small as 0.1 per cent, which is of cons to abundance studies and spectral line identificatio chemically peculiar mid-B stars.

The interest of η Mus (HD 114911, HR 4993) l bination of the massive close binary (late-B comp pre-main-sequence star (PMS) at a few arcsec sepa chemically peculiar star, exhibiting common prop also be loosely connected to the system. Precise fun parameters and the determination of its distance fron clarify its relationship with the young stellar assoc

★Based on observations obtained at the European Southern Observatory (ESO), La Silla, Chile, and at the South African Astronomical Observatory (SAAO), Sutherland, South Africa.

†E-mail: herman@oma.be
‡Research Director, Belgian Fund for Scientific Research (FWO).

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η Muscae: a young detached binary with two identical components

V. Bakış,[1]★ H. Bakış, Z. Eker and O. Demircan

Çanakkale Onsekiz Mart University Observatory, Terzioğlu Campus, TR-17040, Çanakkale, Turkey

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ABSTRACT

High-resolution ($\lambda/{\rm d}\lambda \sim 41\,000$) echelle spectra of the multiple system η Muscae were analysed. Precise spectroscopic orbital elements of the close pair η Muscae-A were obtained by means of two techniques; cross-correlation and spectral disentangling. The updated light elements of the close pair were derived using new photometric and spectroscopic data together with *Hipparcos* ephemerides. According to simultaneous studies of radial velocities with *Hipparcos* light curve and recent and historic light curves in Strömgren bands, η Mus-A consists of two quasi-identical components: $M_1 = 3.30\,{\rm M}_\odot$, $M_2 = 3.29\,{\rm M}_\odot$, $R_1 = 2.14\,{\rm R}_\odot$, $R_2 = 2.13\,{\rm R}_\odot$, $T_1 = 12\,700$ K and $T_2 = 12\,550$ K separated from each other by $a = 14.11\,{\rm R}_\odot$ in an orbit inclined 77°.4. The membership of η Mus-A to the Lower Centaurus–Crux OB association is discussed. The rotational velocity of the primary component was found to be smaller than that of the secondary component. The asynchronous slow rotation of the primary and the synchronous rotation of the secondary imply a recent decrease in the orbital period, either due to orbital angular momentum being transferred to the visual companion η Mus-C or due to relatively frequent stellar encounters in this crowded region. The visual companion η Mus-B is found to be gravitationally unbound to the close pair η Mus-A. The radial velocity measurements of the visual companion η Mus-B, when combined with its positional information, support its membership to the Lower Centaurus–Crux OB association, but the evidence for membership of η Mus-A is weaker.

Key words: binaries: general – stars: kinematics – stars: individual: η Muscae – techniques: photometric – techniques: radial velocities – techniques: spectroscopic.

1 INTRODUCTION

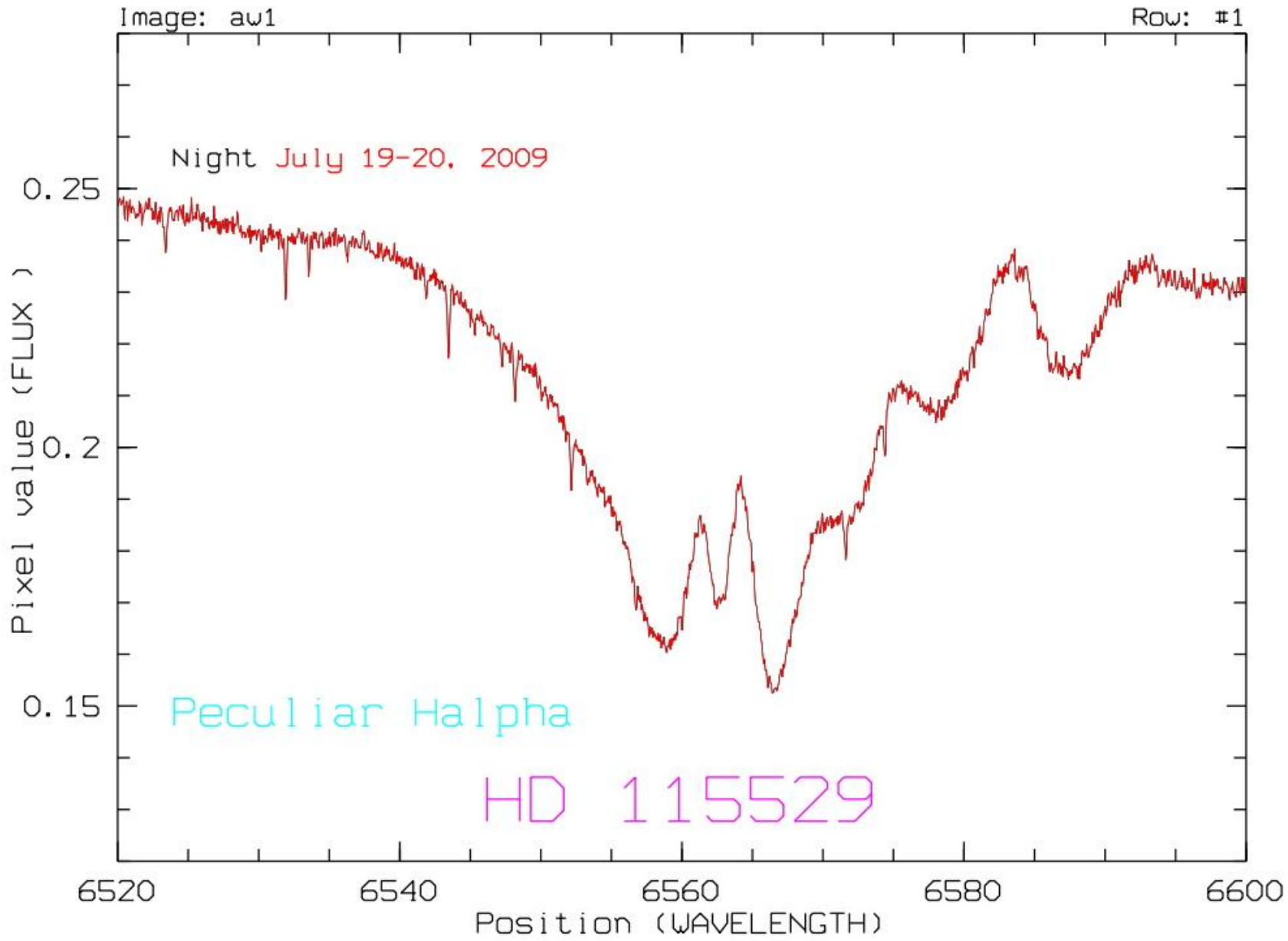
The bright southern binary system η Muscae (HD 114911, Hip64661, $V \sim 4.78$ mag, $P \sim 2.40$ d) is one of the eclipsing binary stars discovered during the *Hipparcos* survey (ESA 1997). The trigonometric parallax of the system, as obtained by *Hipparcos*, is 8.04 mas. There were several studies (e.g. Schilt & Jackson 1949; Eggen & Lyngå 1968; Crawford, Barnes & Golson 1970; Lindroos 1983; van Paradijs et al. 1986; Slawson, Hill & Landstreet 1992) which discussed the brightness and colours of η Mus. Moffat & Seggewiss (1977) noted the photometric variations of η Mus-A during their narrow-band photometric observations of the Wolf–Rayet binary θ Mus. The small number of observations did not allow them to derive a unique period; instead, they suggested a number of possible periods including the true one.

In the catalogue of multiple stars (Tokovinin 1997), η Mus is listed with a common proper motion visual companion, η Mus-B, at 60 arcsec from η Mus-A at a position angle of 332°. η Mus-B is 3.4 mag fainter than η Mus-A. Later, Medici & Hubrig (2000) reported that the triple system η Mus is actually a quadruple system. Details of the quadruple system were later given by Hubrig et al. (2001). The fourth component, η Mus-C, which is separated by 2.71 arcsec at a position angle of 125°, was announced to be 5.25, 4.54 and 3.32 mag dimmer than η Mus-A in *J*, *H* and *K* bands, respectively, and claimed to be a pre-main sequence (PMS) object with a mass of $0.88\,{\rm M}_\odot$ and effective temperature of $T_{\rm eff} = 4900$ K.

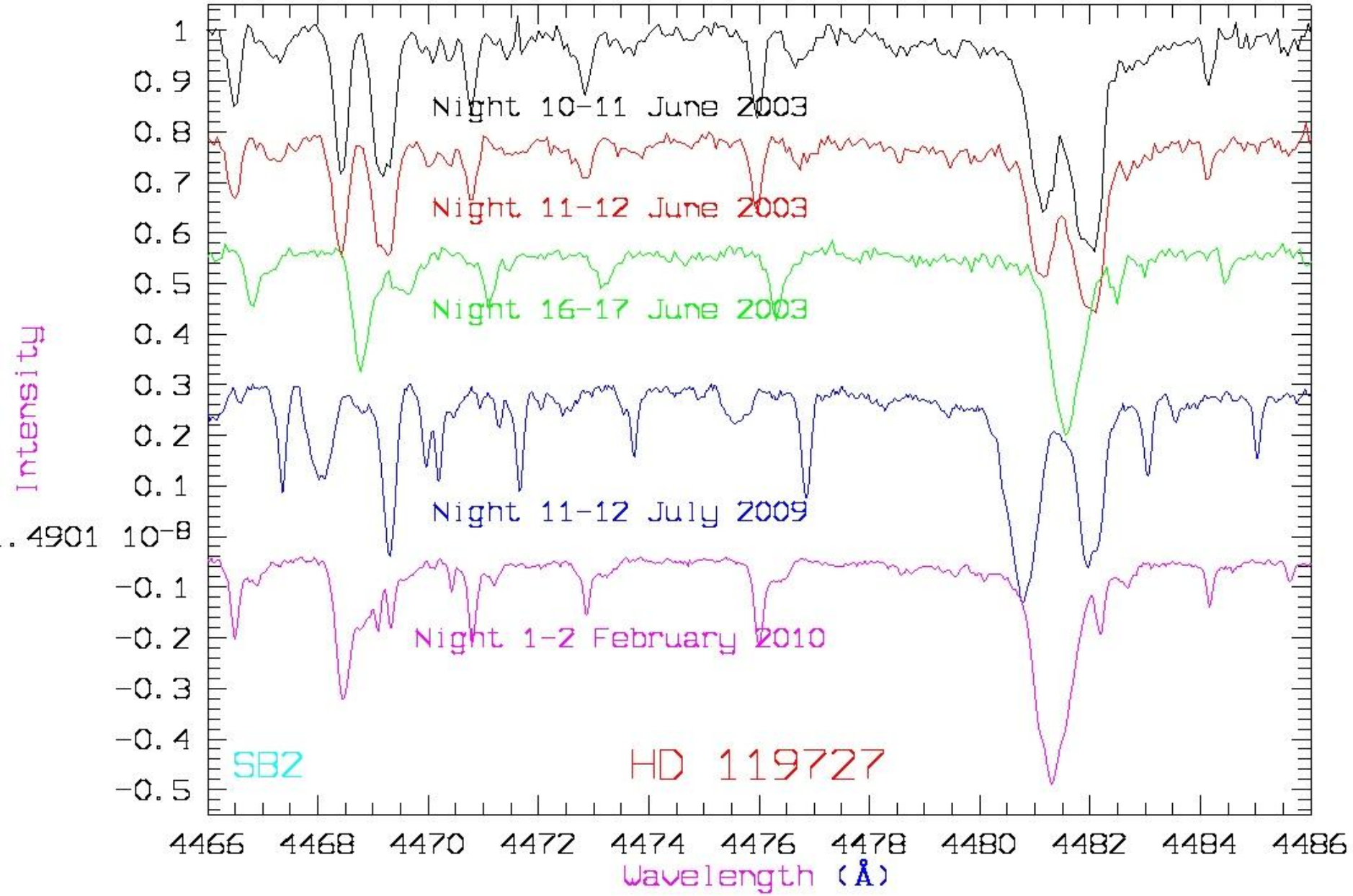
Slawson et al. (1992) compiled *UBV* photometric measurements of a large number of B- and A-type stars, including η Mus-A, in a sky region containing Sco–Cen. $U - B$ and $B - V$ colours of η Mus-A in this list (−0.36, −0.09) imply a colour temperature of 12 700 K, which is consistent with the effective temperature of 12 760 K determined by Hubrig et al. (2001) using Geneva photometry. However, using spectrophotometric data and referring to the drop between the Balmer and the Paschen continuums (Balmer jump), Sokolov (1995) gave a rather different effective temperature of $16\,130 \pm 960$ K.

According to de Zeeuw et al. (1999), η Mus-A is given ∼60 per cent probability of being a member of Scorpio–Centaurus (or Sco OB). Sco OB is the OB association nearest to the Sun, which is believed to be ∼16–20 Myr old (Sartori, Lepine & Dias 2003).

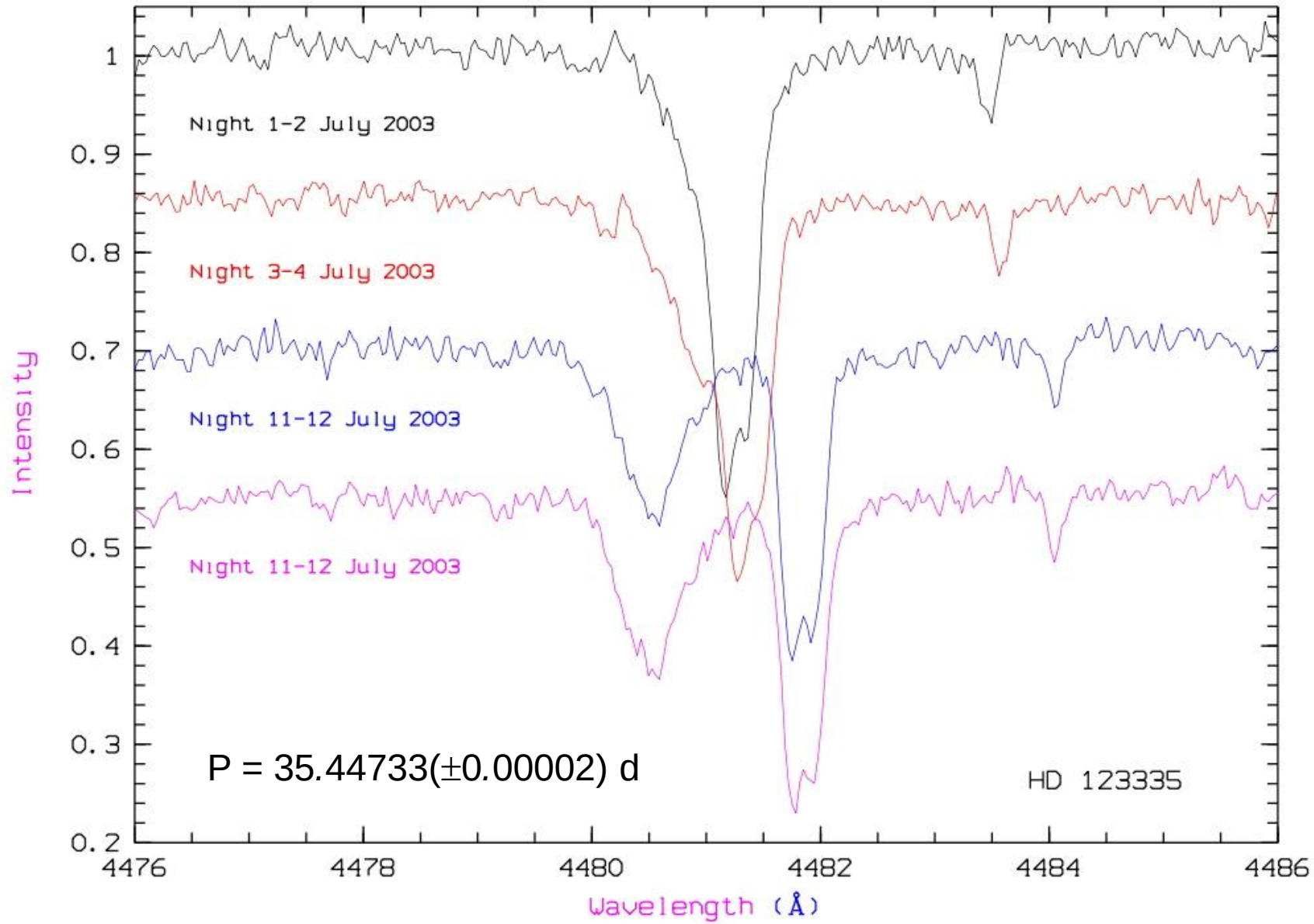
★E-mail: bakisv@comu.edu.tr



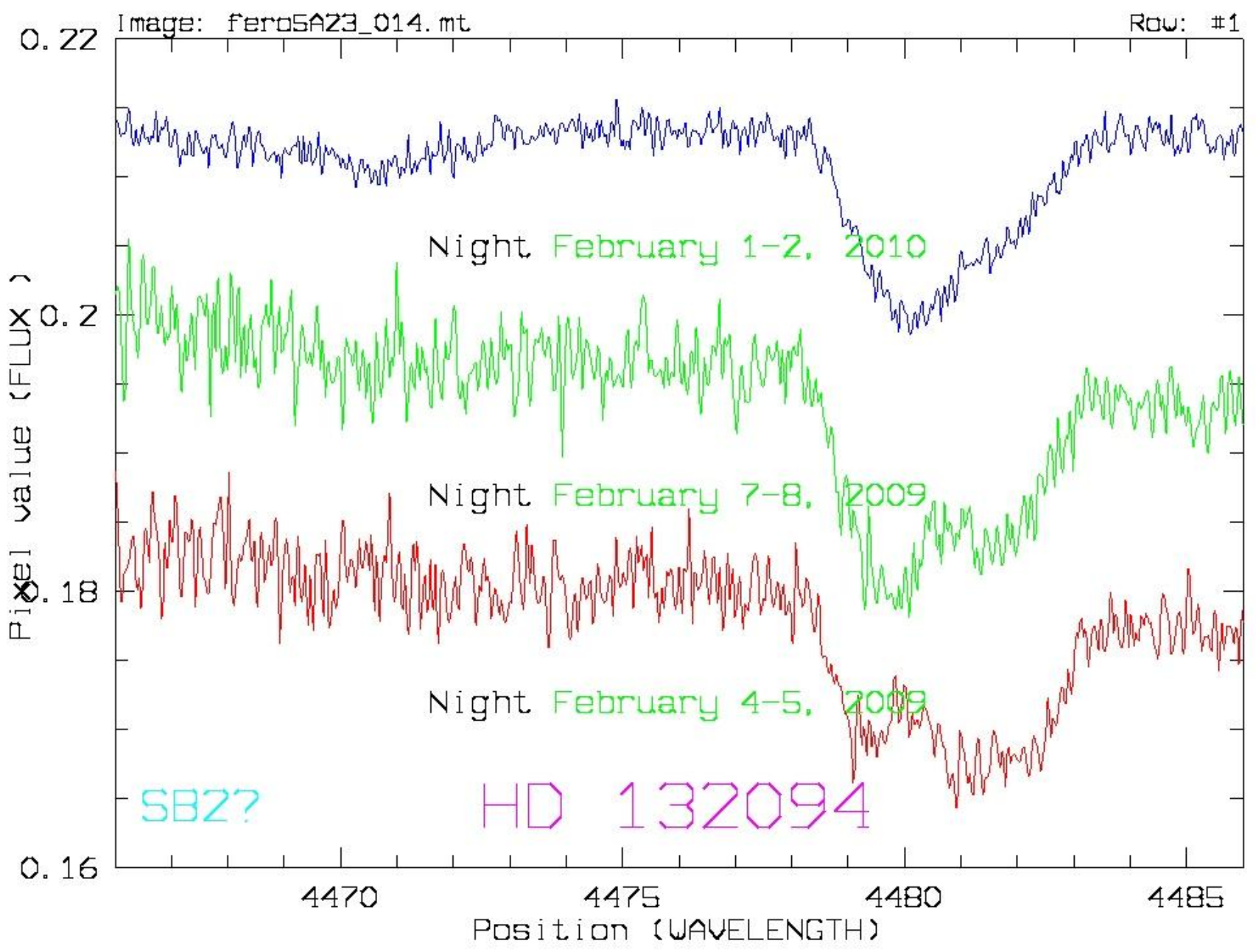
HD 115529 is unknown as close or visual binary; Hα is peculiar.


Night 10-11 June 2003
Night 11-12 June 2003
Night 16-17 June 2003
Night 11-12 July 2009
Night 1-2 February 2010
SB2
HD 119727
Intensity
1.4901 10-8
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.1
-0.2
-0.3
-0.4
-0.5
4466
4468
4470
4472
4474
4476
4478
4480
4482
4484
4486
Wavelength (Å)

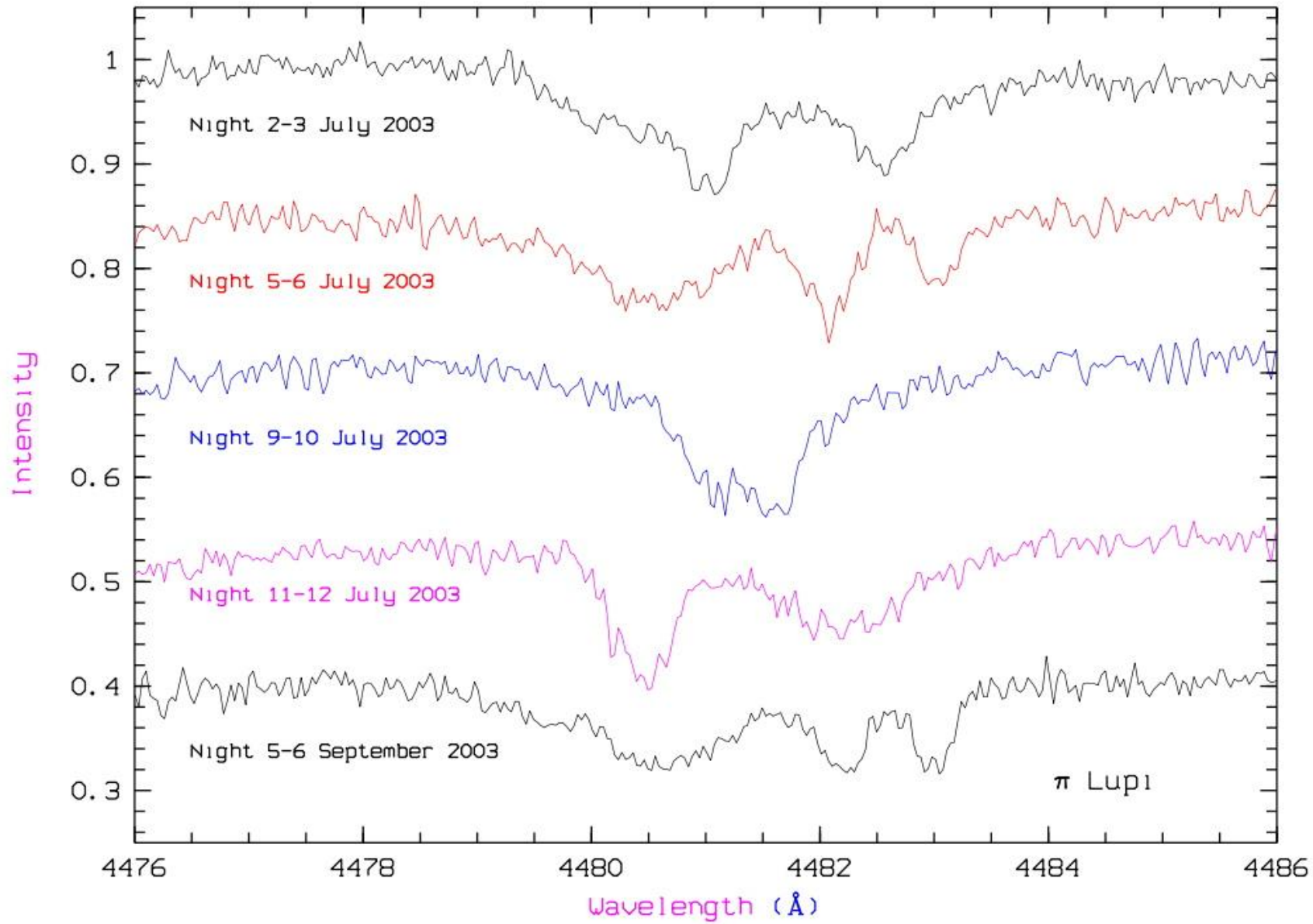
HD 119727 (V = 6.42, A1V) is an obvious, previously unknown SB2. The separation of the lines changed considerably in one week, but not in two consecutive days. The two components of the SB2 are slow rotators. **HD 119727** is a secure member of LCC. More observations of this object, both spectroscopic and photometric, are needed, especially for finding a correct value for the period and to initiate a disentangling process of the spectra.



HD 123335: Very nice case of SB2 + EB (Hensberge et al. 2007)



Our observations are showing that **HD 132094** is possibly a SB2


Night 2-3 July 2003
Night 5-6 July 2003
Night 9-10 July 2003
Night 11-12 July 2003
Night 5-6 September 2003
π Lupi
Intensity
Wavelength (Å)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
4476
4478
4480
4482
4484
4486

The double star **π Lupi** = **HD 133242 + HD 133243**, 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 (Hoeit & 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. Indeed, three components can easily be recognized, of which two are sharp-lined.

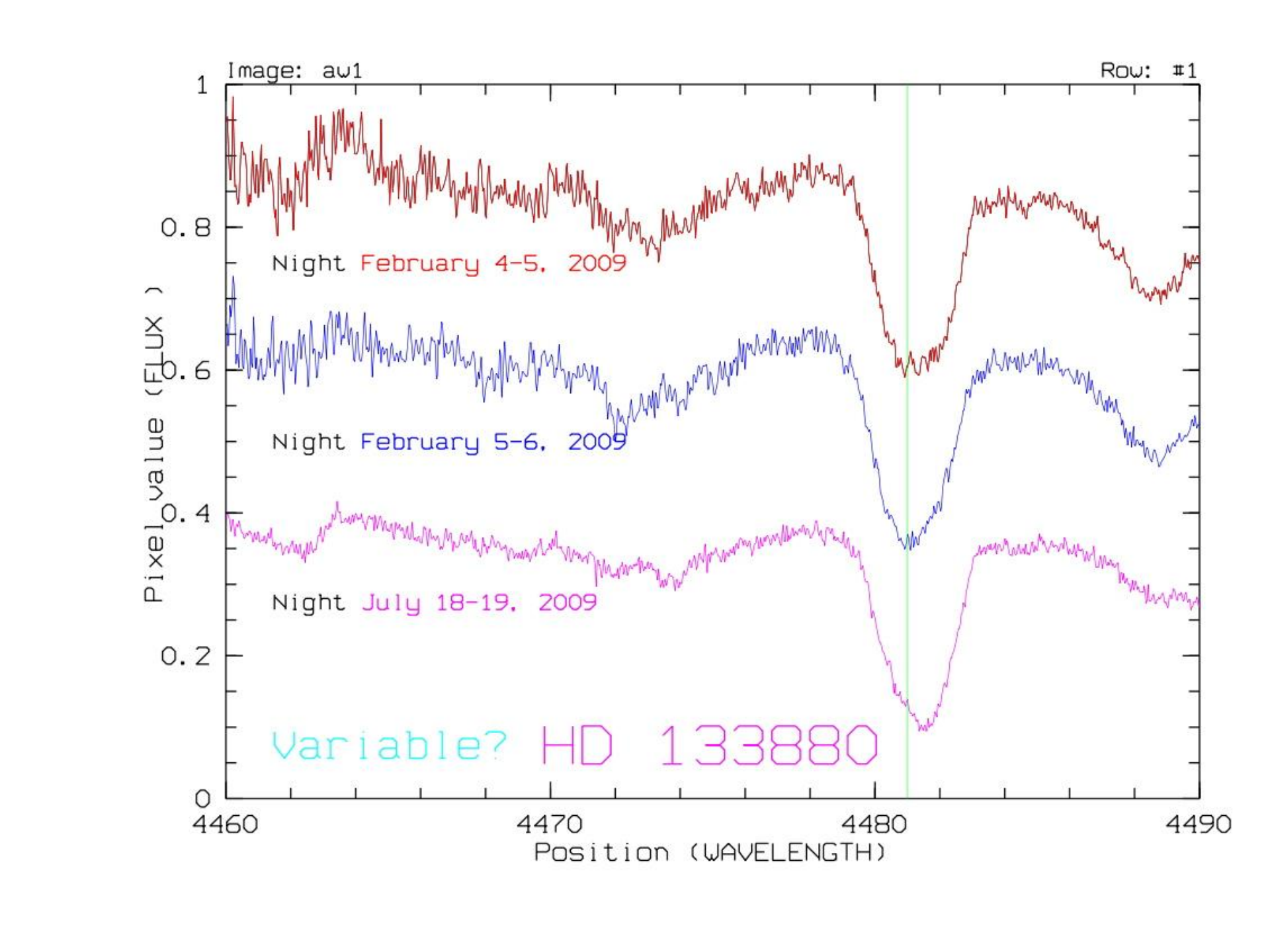
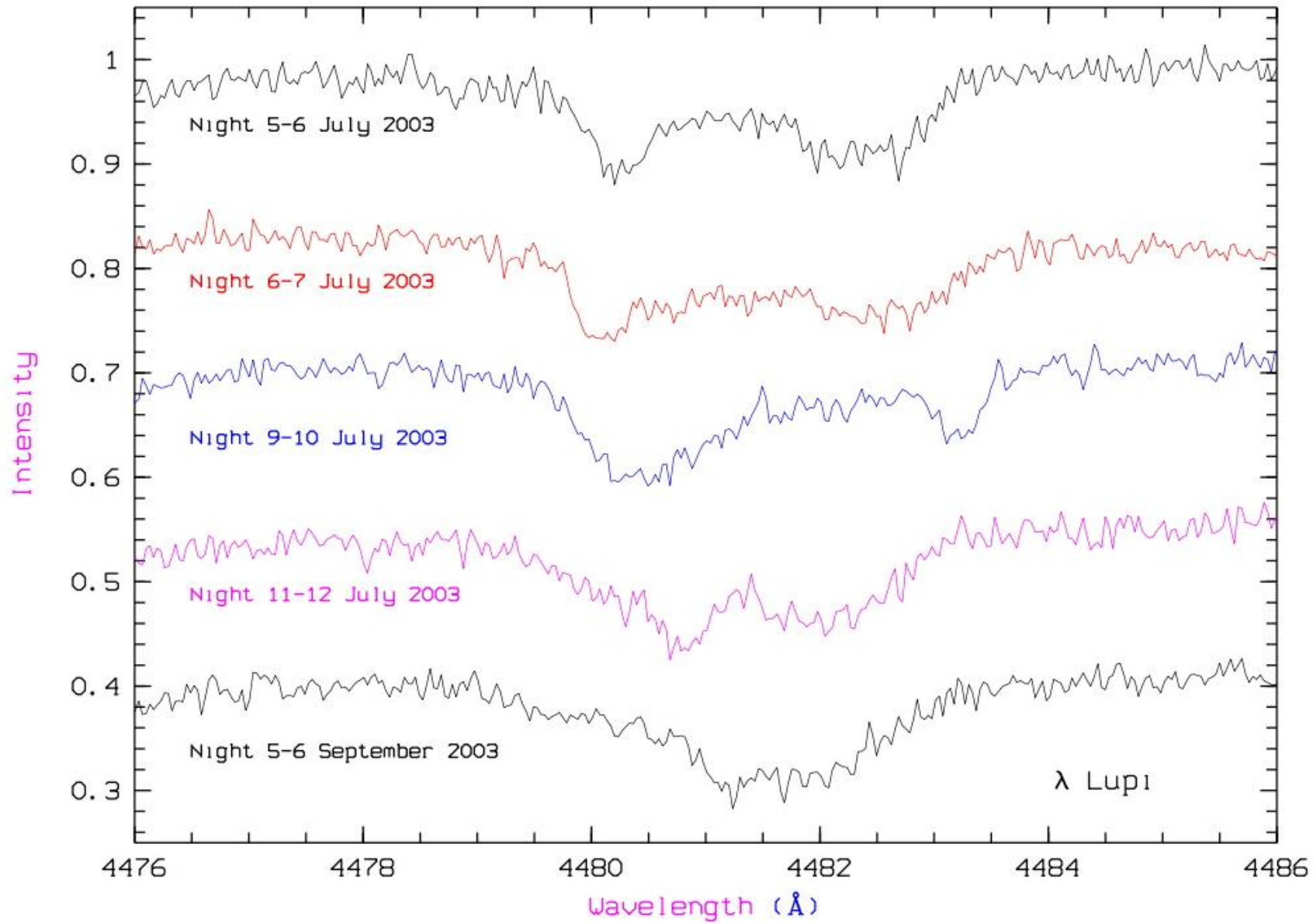


Image: aw1
Row: #1
Night February 4-5, 2009
Night February 5-6, 2009
Night July 18-19, 2009
Variable? HD 133880
Pixel value (FLUX)
Position (WAVELENGTH)
0
0.2
0.4
0.6
0.8
1
4460
4470
4480
4490

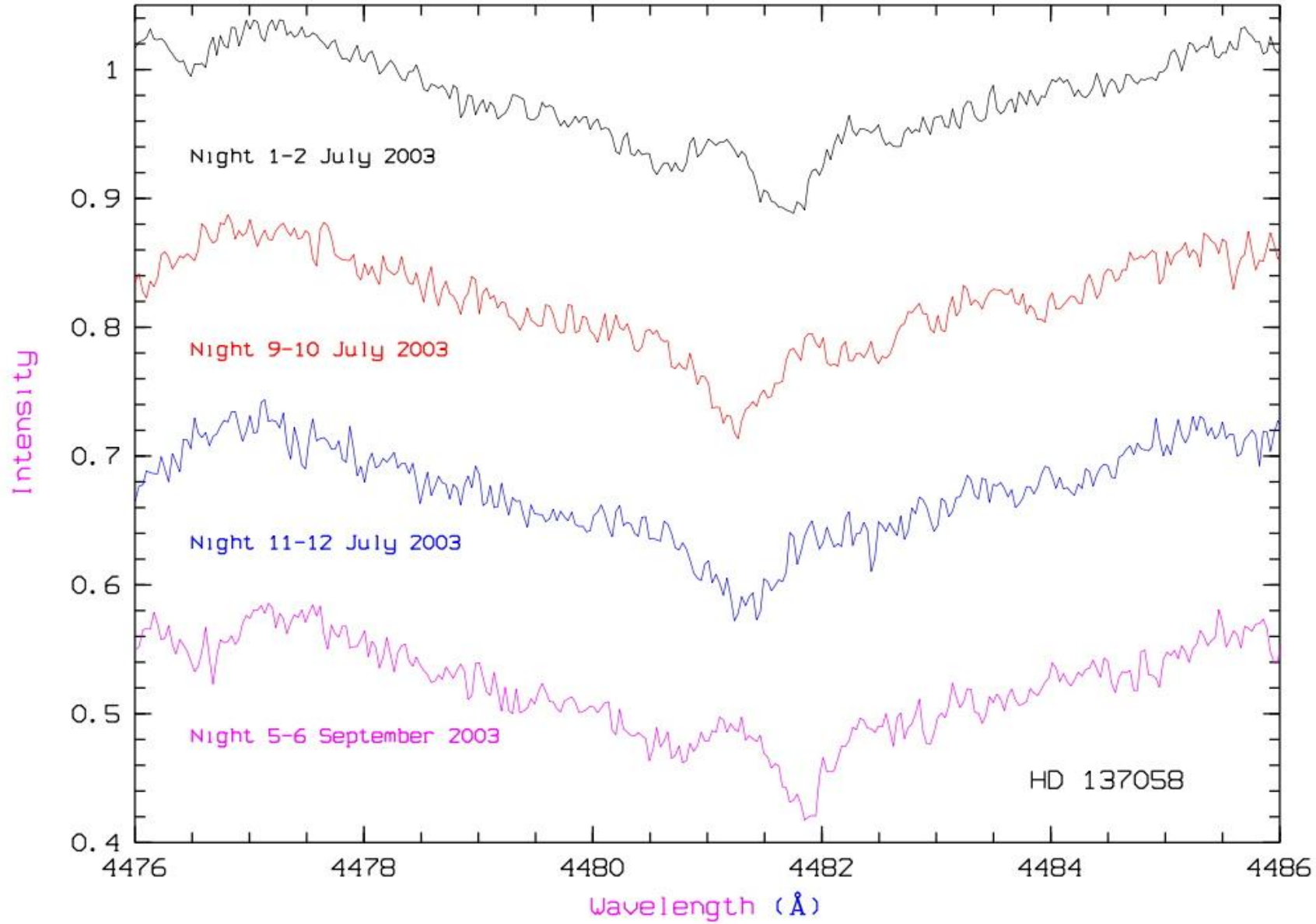
HD 133880: Binary system
A: V = 5.75 at 3.29”, B8IV Si
B: V = 9.0 at 1.22” Physical system (H2001, KW2005)
(H2001 = Hubrig et al. 2001,
KW2005 = Kouwenhoven at al. 2005)
Our FEROS observations are showing a variability in the spectrum of the A component, possibly a spectroscopic binary nature. Obviously, more observations are needed for having a better understanding of this specific object.


Night 5-6 July 2003
Night 6-7 July 2003
Night 9-10 July 2003
Night 11-12 July 2003
Night 5-6 September 2003
λ Lupi
Intensity
Wavelength (Å)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
4476
4478
4480
4482
4484
4486

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”. 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.

λ Lupi = HD 133955:

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. 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.


Night 1-2 July 2003
Night 9-10 July 2003
Night 11-12 July 2003
Night 5-6 September 2003
HD 137058
Intensity
Wavelength (Å)
1
0.9
0.8
0.7
0.6
0.5
0.4
4476
4478
4480
4482
4484
4486

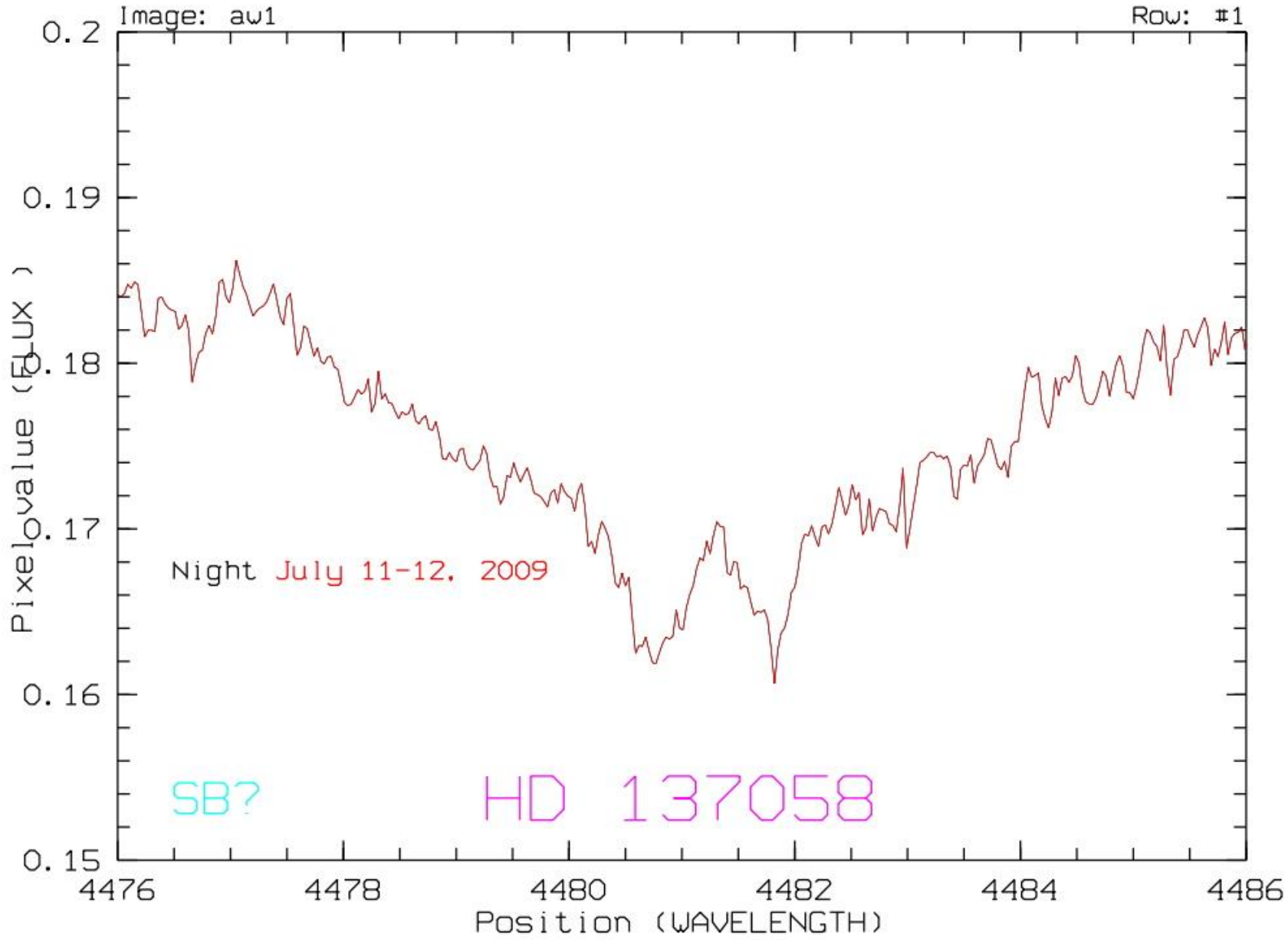


Image: aw1
Row: #1
0.2
0.19
0.18
0.17
0.16
0.15
Pixelvalue (FLUX)
Night July 11-12, 2009
SB?
HD 137058
4476
4478
4480
4482
4484
4486
Position (WAVELENGTH)

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. 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.

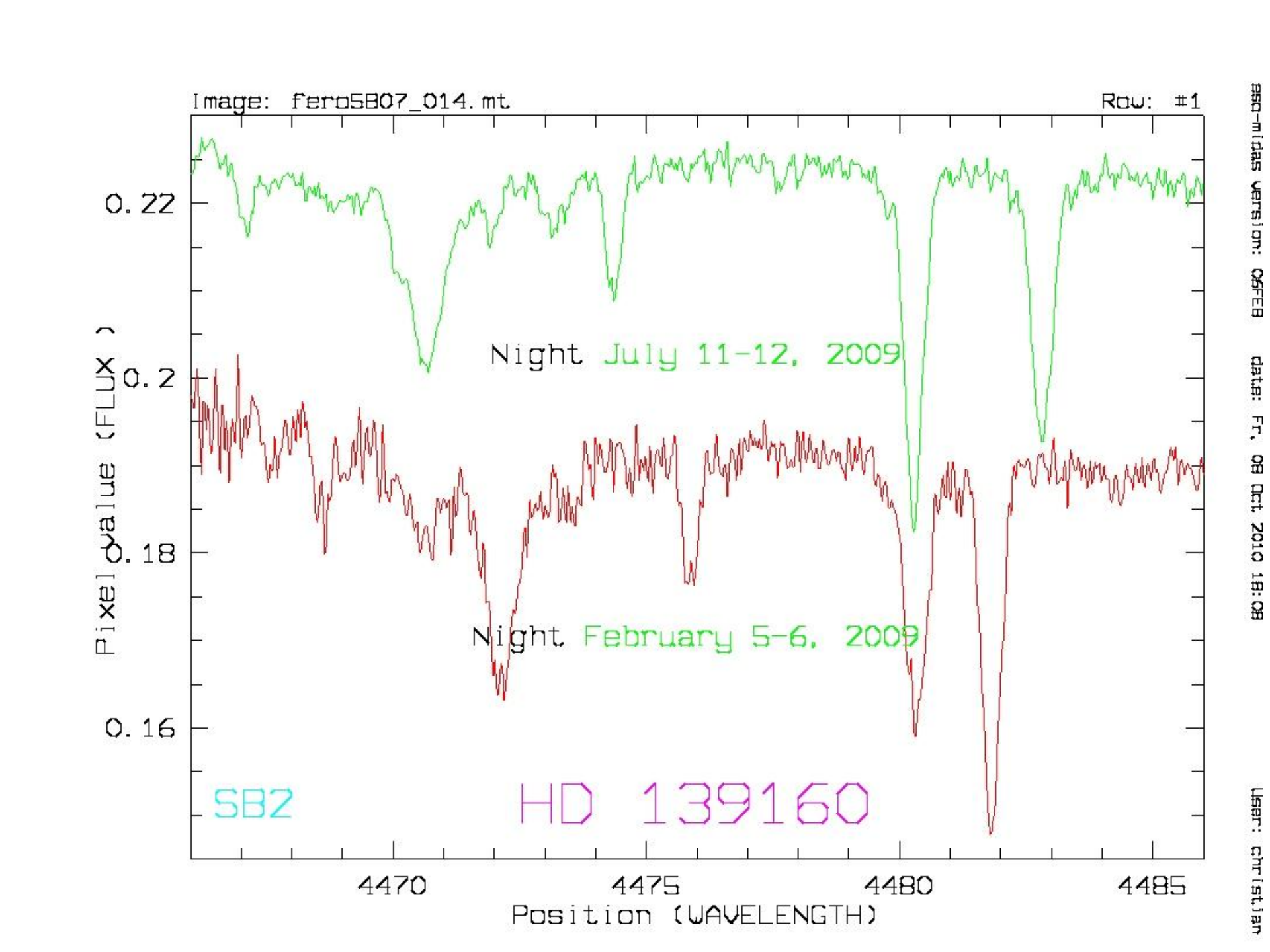


Image: fero5807_014.mt
Row: #1
0.22
0.2
0.18
0.16
Pixel value (FLUX)
Night July 11-12, 2009
Night February 5-6, 2009
SB2
HD 139160
4470
4475
4480
4485
Position (WAVELENGTH)
esо-midas version: 06FEB
date: Fr, 08 Oct 2010 18:08
User: christian

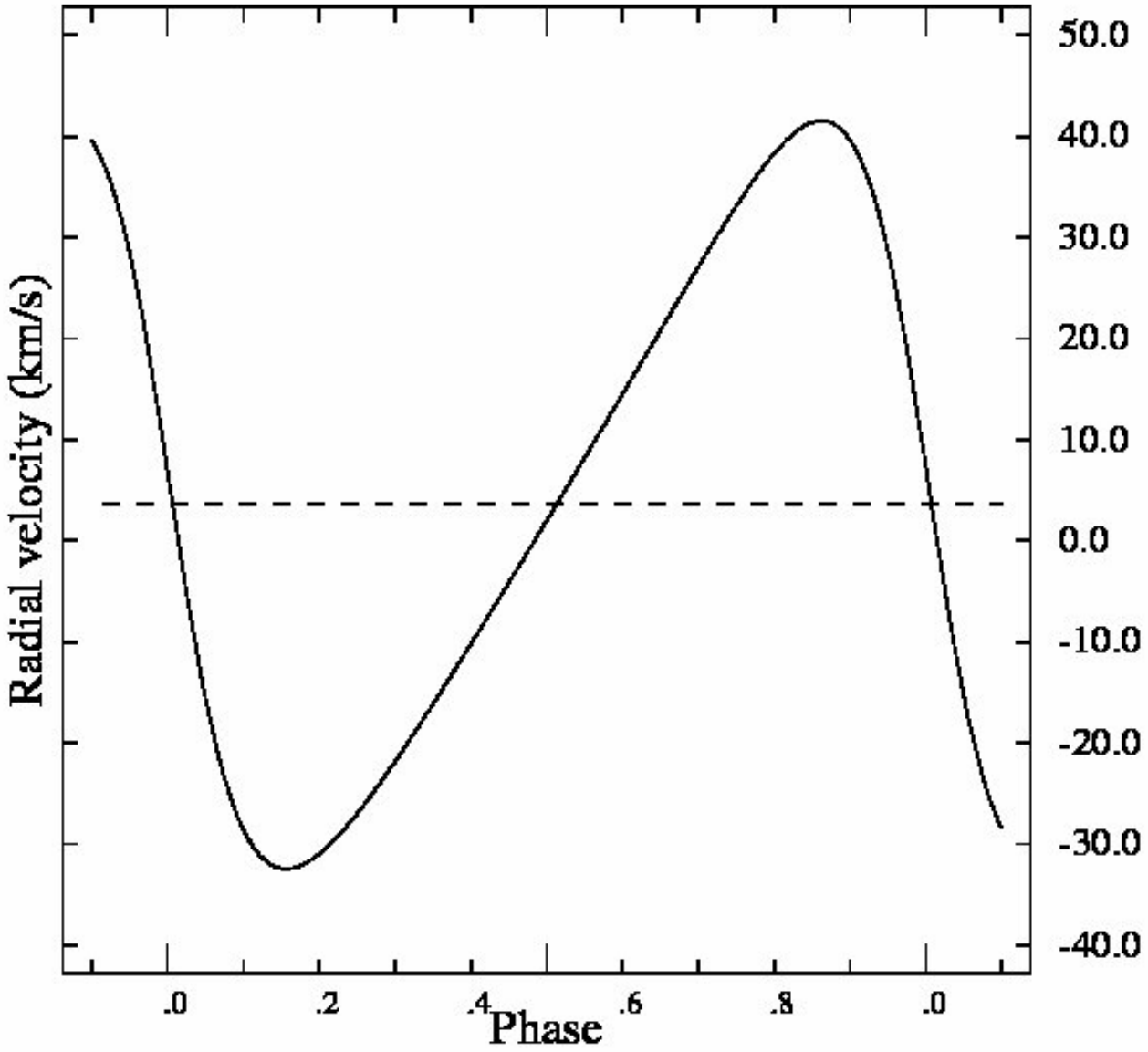
HD 139160: Known SB2

SB9 catalogue:
V = 6.19, B7IV
Orbit
Period (d.) : 5.2766
Eccentricity : 0.33
K1 (km/s) : 37.0
V0 (km/s) : +3.7
Author: Levato et al. (1987)
Note SB9: Although the velocity-curve published by Levato et al. (1987) does not look convincing, A.D. Thackeray (Mem. Roy. Astron. Soc., 70, 33, 1966) measured double lines on two plates.

For this object, we confirm the SB2 nature, whereas its Sco-Cen Complex membership is given as 98 by de Zeeuw et al. (1999). Nevertheless, the orbit remains suspicious and new observations are needed during new runs for a confirmation of the period.

Radial velocity versus phase, according to Levato at al. (1987)

HD 139160



Many more observations needed

- Observations made during the nineties with CASPEC are not yet available, except for one run
- Many targets having presently only one or two observations are waiting new observations
- Necessity to separate observations by different time-intervals:

  a-----b----------c----------d

  to increase the probability of detecting SB character and to get a better constraint on the number of possible periods
- Photometric and spectroscopic observations either for the surveys in blind or for some very specific objects on peculiar interest

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Many thanks for your attention