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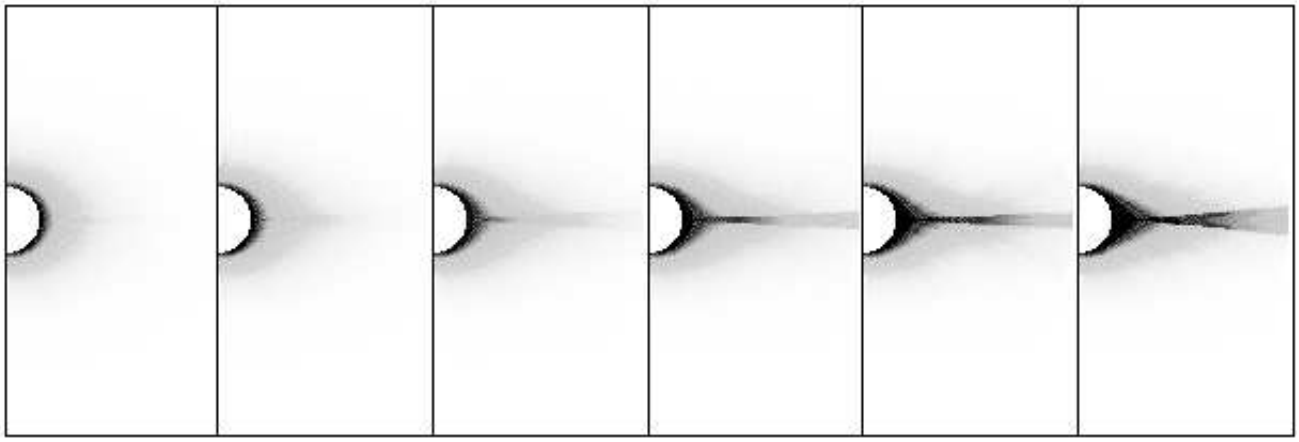

Be STAR NEWSLETTER

NUMBER 32

July 1997

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The electronic version is available on the World Wide Web (`http://www.chara.gsu.edu/BeNews/intro.html`) *or by anonymous ftp* (`ftp chara.gsu.edu, cd BeNews`).

1. EDITORIAL

There is always keen interest in the first data from a new spacecraft. In this 32nd issue of the *Be Star Newsletter* we include a report on some initial results on the nature of photometric variability in B and Be stars from the *HIPPARCOS* satellite. Especially interesting is a rather spectacular photometric outburst in υ Cyg. Now γ Cas was not only the first Be star to be discovered, but more researchers have studied this star in the past 150 years than any other Be star (it is said that if one works on Be stars long enough she/he will eventually write one or more papers on γ Cas!). Well, new data from the *ASCA, RXTE*, and *HST* spacecraft have revealed a modulation in its X-ray & FUV flux on a time scale consistent with its rotation period. Some implications of this are discussed in *WHAT'S HAPPENING?*. There are also new results from ground-based telescopes reported in this issue: apparent quasi-periodic behavior for the emission line outbursts in μ Cen, complex H & He emission line variations in the disk of the Be star in the X-ray binary V635 Cas/4U 0115+634, and the recent discovery of five new speckle binary Be stars. In another contribution, the promise of amateur equipment for detecting cyclic and transient Hα emission line variability in Be stars is clearly demonstrated. We also call attention to the recent impressive progress on modeling NRP and the geometries of Be star disks and include our newly expanded bibliography of recent papers on active B stars and related objects of possible interest to the community.

Traditionally the *Newsletter* has been published at irregular intervals with a frequency governed by the number of contributions. Usually two issues a year are produced. Starting with Issue No. 33 we would like to adopt a more firm schedule for publication. We propose continuing a semiannual publication frequency with issues finalized in June and December. The cutoff date for contributions/abstracts for Issue 33 will be:

November 30, 1997.

Contributions should be sent by electronic mail to

`gjpeters@mucen.usc.edu` and `gies@chara.gsu.edu`

As mentioned in the last *Newsletter*, we are now **requiring** that abstracts be submitted as LaTeX files. A template for their preparation is provided in this issue and can also be downloaded from our web site. Illustrations should be sent by E-mail as a PostScript file. If it is not possible to transmit your contribution electronically, please send or fax (213-740-6342) a dark camera-ready copy.

Again we wish you a happy & productive summer and encourage you to announce your discoveries and express new ideas in Issue No. 33 of the *Be Star Newsletter*.

Gerrie Peters, Editor-in-Chief

2. WORKING GROUP MATTERS

2.1. Working Group News

Hello Fellow Members of IAU WG On Active B Stars–

IAU Meeting

This is the year of the triennial IAU GA meeting which will be held in August in Kyoto, Japan. Thanks to the work of Mike Jerzykiewicz, we have "Room H" reserved at 9:00-10:30 am on August 27th. My term as your WG Chairman will come to an end at that time. Unfortunately, I will not be able attend the GA myself, but John Percy has kindly agreed to preside over the meeting. Please send me agenda items that might occur to you and I will forward them to John.

A New International Meeting on B/Be Stars

It has already been $3\frac{1}{2}$ years since the last international Symposium on B/Be stars at Juan-les-Pins, France, and it is certainly time to take stock of the many advances in our field since that convocation with a new meeting. This winter the Universities of Valencia and Alicante, Spain have issued an invitation for a meeting to be held there in the next year or two in Alicante. The OC has accepted this invitation with thanks and appreciation to the hosts for their patience in awaiting our acceptance: The next meeting will be held in Alicante, Spain, on or about June, 1999. We will seek IAU sponsorship of a colloquium or symposium. Our tentative date will give us nearly a year to prepare a proposal to the IAU. I have asked Juan Fabregat who advanced this invitation to chair and form the LOC.

Our B star OC has voted on five members of the SOC, in addition to Fabregat, and the SOC elected a Chair. The elected members of the SOC for the Spain meeting are:

J. Fabregat (Spain) – Chair, LOC
M. Smith (USA) – Chair, SOC
E. Kambe (Japan)
S. Stefl (Czech Republic)
J. Bjorkman (USA)
A. Fullerton (Germany)

It is likely that additional members of the SOC will be appointed as the theme and title for the meeting become more defined. I will be putting out a call to the WG membership very soon requesting ideas for a title. I hope by the time of the Kyoto meeting to have a title for our Kyoto conclave to confirm.

Elections

On a related matter I now open "the electronic floor" for three nominations of WG members who, with me, will be retiring from these posts this summer. These are Rens Waters, Catharine Garmany, Petr Harmanec, and Myron Smith. (IAU Commission No. 40 will appoint a replacement for Katy's position.) Any other member of our

WG who also belongs to the IAU is eligible. We will follow the example set three years ago by Luis Balona in having an election by electronic ballot. (Please indicate "Nomination" in the subject header and send nominations to the BEIAU account listed below.) Following the reconstitution of the WG, we will elect a new Chair from this group. I hope to have all electoral matters settled before our meeting.

Cooperative Search for Light Transients with Amateurs

My final item is to inform you of an initiative started in North America between professional and amateur astronomers that we hope can spread to many other countries. The idea is to put the search for optical photometric transients of classical Be stars on the less than the accidental footing that they have had up until now. Many of you will recall Luis Balona's publishing of the "flickering" behavior in the light curve of κ CMa during an outburst in 1991. In a new paper in A&A Suppl., the Hvar Observatory group (Pavlovski *et al.*) have shown that even bright Be stars can undergo sudden bright or faint excursions in their light curves. Smith *et al.* now have a paper in press (see Abstracts in this issue) in which FUV spectrophotometry shows a "ringing" with a period of 3 hrs. There is a general feeling that if a pattern could be discerned from a population of such (so far) accidentally discovered events, it could lead to a better understanding of the instabilities responsible for the outbursts in classical Be stars.

Toward this end, I have formed a liaison committee (Smith, Balona, Percy) to oversee activity between amateur and professional astronomers. The basic idea is to combine the discovery of such events by a few professional "scouts" with follow up work hours or a night later by a rapid-response force. Thus far we have had a candidate for scout step forward, Dr. Elaine Halbedel of Corralitos Observatory in Las Cruces, NM). In addition, we have placed a call to the AAVSO asking for help. This has netted three part-time volunteers (R. Fried, R. Wasatonic, R. Zissell), as well as an amateur spectroscopist in Germany, Ernst Pollmann (see Pollmann's article later in this issue). If you are interested in joining this effort or if you know of amateur astronomers in your area with PEP equipment and capability of observing with < 0.01 mag please errors, please let me know.

Best wishes/Clear Skies –

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Chair of IAU WG on Active B Stars
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3. CONTRIBUTIONS

3.1. Preliminary results on photometric variability of B and Be stars with HIPPARCOS

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Rapid and mid-term variability has been searched in a sample of 26 B and 23 Be bright stars (V$\leq$ 5) with photometric measurements by HIPPARCOS. This astrometric satellite of the European Space Agency, was launched in August 1989, and operated up to August 1993.

The HIPPARCOS magnitude, designated as Hp, is defined by a broad pass-band which ranges from 340 to 850 nm (Turon et al. 1992). This broad-band system yields magnitudes close to the visual magnitude V. The advantage of HIPPARCOS photometry is the high accuracy of measurements of the Hp magnitude of bright stars (for Hp$\leq$ 5 mag, σ(Hp) = 0.001 mag), the number of measurements per star, about 200, and the duration of the monitoring. It has allowed us to detect new variables and to estimate their timescales.

One Be star of our sample, HD 78764 (HR 3642, V sini = 120 km/s) has been discovered with a non-sinusoidal light curve of period P = 138 days, and of a total amplitude 0.1 mag. We searched for an hypothetic low-mass companion (X-ray compact object or cool giant). However HD 78764 was not found among optically bright OB stars detected in the ROSAT all-sky survey (Berghöfer et al. 1996). On the other hand, Baade (1992) did not succeed in finding spectral lines of a cool companion in bright southern Be stars including HD 78764. Due to the lack of RV photospheric line data, we cannot clearly assign the photometric variability of HD 78764 to orbital motion of a secondary or to apsidal motion of the circumstellar disk. Finally it should be stressed that recently Sterken et al. (1996) detected two additional cases of Be stars with such long periods and no direct evidence of companions.

Among 26 B stars, quoted in the literature as NSV (New Suspected Variable) stars, 14 of them have been confirmed by Hipparcos data as microvariable stars. Short periodicities (P$\leq$ 3.5 days) have been suspected or confirmed in a few B stars of the sample. Among them, the 53 Per type variable ι Her (HR 6588) has been detected with a periodic light curve (P = 3.487 days) of a total amplitude 0.025 mag.

Almost all the Be stars of the sample have shown a rapid variability superimposed on long-time scale changes. The total amplitude of the long-term variability ranges between 0.05 and 0.3 mag. depending on the star considered. It has been noted that the total amplitude of the rapid variations is higher for Be stars than for B stars. Furthermore some Be stars such as λ Eri, ω CMa, HD 57150, 66 Oph and υ Cyg have shown during the HIPPARCOS mission, one or several outbursts with a variable strength. Other stars such as ϵ Cap and χ Oph have shown one or several fading events. In the case of the Be variable shell star ζ Tau, the behaviour of the magnitude Hp follows the V/R curve provided by Guo et al. (1995) with a minimum

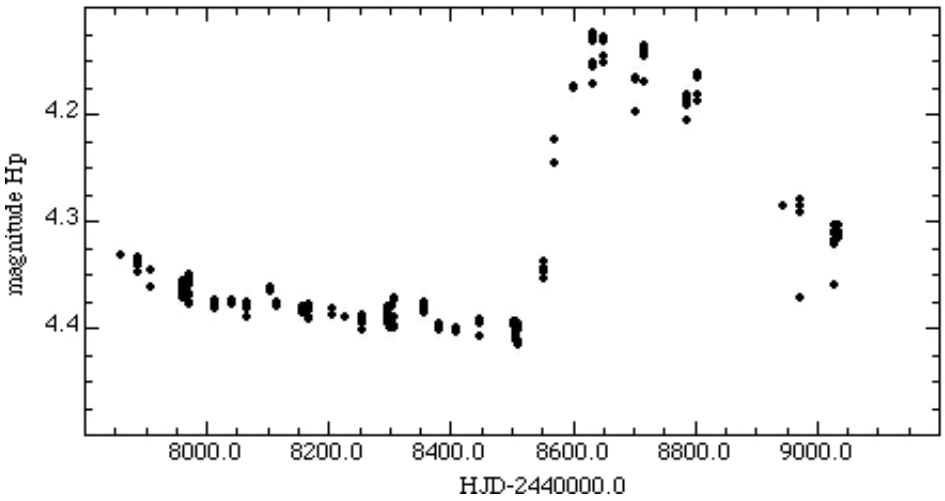

FIGURE 1. Light variations of υ Cyg in the Hp filter.

of brightness at maximum of the V/R ratio. Finally short periodicities (P$\leq$ 3.5 days) have been suspected or confirmed in about one third of the Be stars.

An illustration of the presence of rapid as well as long-term variations is given in Fig. 1 for the Be star υ Cyg (HD 202904, V sin i = 180 km/s). An outburst occured in less than 100 days.

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3.2. V635 Cas, the optical component of the Be/X-ray transient 4U 0115+634

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Astronomy Centre, MAPS, University of Sussex, Brighton, U.K.

We have monitored the optical component of the Be/X-ray binary 4U 0115+634 since 1991, using a variety of telescopes to obtain intermediate-resolution optical spectroscopy and optical and infrared photometry. 4U 0115+634 contains a fast-rotating neutron star ($P_{\rm s}$ = 3.61 s) in a relatively close ($P_{\rm orb}$ = 24.3 d) and eccentric (e = 0.34)

orbit around a Be star. Occasionally the neutron star accretes material from the envelope of the Be star and then it is observed as a high-luminosity ($L_{\rm x} \approx 10^{36} - 10^{38}$ erg s^{-1}) X-ray pulsar. Unlike other Be/X-ray transients, 4U 0115+634 does not display modulation of its X-ray lightcurve at the orbital period. A complete description of the X-ray behaviour of the system has been presented in Negueruela et al. (1997).

We have used blue-end spectroscopy and photometric data to classify the central star as a late Oe star. Due to contamination of the photospheric lines by circumstellar emission, the exact spectral class is difficult to estimate, but we believe O9.5Ve is most likely (Unger et al., submitted to A&A).

The temporal evolution of V635 Cas is very different from that of any other Be star. It displays large variations in all its optical and infrared magnitudes (typically showing brightenings of up to $\sim$ 1.3 mag over 2 – 3 months) with no significant changes in the associated colours. In October 1991, the source underwent a violent optical and infrared outburst, showing strong unidentified emission lines in the red and infrared emission. The equivalent width of Hα reached a maximum of EW =$-$18 Å, while it is typically $-$4 Å during quiescence.

Previously, it had been assumed that these changes were due to the formation of an accretion disc around the neutron star that contributed to the overall optical and infrared brightness and the strength of Hα (Kriss et al. 1983; Mendelson & Mazeh 1991). Our observations, however, show that the observed correlations between the X-ray/optical/infrared lightcurves are not compatible with this explanation. Moreover, there are no indications of transient Hα emitting sources. All the variability seems to be associated with the envelope of the Be star.

The shape of the spectral lines can change dramatically on a time-scale of a few weeks. The correlation between the shape of Hα, the brightness of the source and its X-ray activity is difficult to assess. When it is faint, Hα and the He I $\lambda\lambda$ 6678, 7065 Å lines normally show shell profiles. When the source is brighter, Hα is single-peaked and the He I lines are in emission. X-ray outbursts have generally coincided with the bright phases. After the October 1991 outburst, Hα was briefly observed in absorption and then was double-peaked for at least eighteen months.

In November 1995 there was a major disruption of the circumstellar envelope. A large X-ray outburst took place while the source displayed strongly asymmetric double-peaked emission lines. During 1996, the line profiles slowly evolved and the source seems to have started a cycle of V/R variability (Negueruela et al., submitted to A&A).

The presence of the neutron star companion in a close orbit is a likely cause for the anomalous behaviour of the Be star. The orbit is not so close as that of the X-ray binary A 0538$-$66, in which the neutron star is believed to cause localised Roche-lobe overflow from the primary (Charles et al. 1983), but close enough for the gravitational pull of the neutron star to be a significant factor in the evolution of the circumstellar envelope. However, this is not the only possible explanation. The Be star in the Be/X-ray binary X Persei also displays unusually strong variability, even though in this case the neutron star is believed to be in a very wide orbit and cannot have a strong influence on the disc. Given its peculiar characteristics, the study of 4U 0115+634 can provide vital clues about the dynamical processes in the

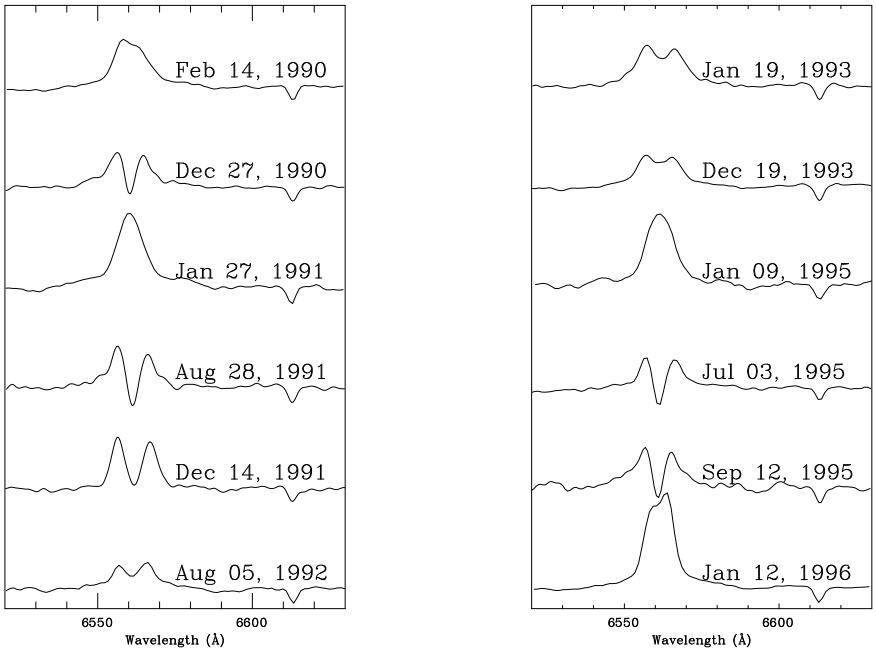

FIGURE 1. Evolution of the Hα line profile in V635 Cas. The spectra have been normalised and smoothed with a Gaussian function of σ = 1 Å. X-ray outbursts from 4U 0115+634 have been detected during February 1990, February and April 1991, May 1994 and November – December 1995. There was a minor flare in January 1995. See Negueruela et al. (1997) for references.

discs surrounding Be stars.

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3.3. A Speckle Survey of Southern Be Stars

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In early 1996, a speckle observing run at the Cerro Tololo 4.0-m Blanco telescope was well-timed for a survey of 48 bright Be stars. These stars were selected via a blind sample of stars classified as "Be" in the Bright Star Catalogue (Hoffleit & Warren 1992). All observations were made with the GSU speckle camera (McAlister et al. 1987b; Mason et al. 1993a) and reduced using the "Directed Vector Autocorrelation" (DVA) algorithm (Bagnuolo et al. 1992). All observations were made between 1996 March 4—7 using the Strömgren y filter ($\lambda/\Delta\lambda = 549/22$ nm).

Any binary system with a projected separation $0\farcs035 < \rho < 1\farcs5$ and a magnitude difference $\Delta m < 3.0$ should be detected with our system. Stars whose speckle transform showed a double-star pattern were cross-checked against the Washington Double Star Catalog (maintained at the U.S. Naval Observatory by C.E. Worley; see WWW site `http://aries.usno.navy.mil/ad/wds/wds.html`) to identify previously known binaries. Four of the detected binaries are known astrometric binaries (HD 56014, HD 72067, HD 131492, and HD 135734), and one is a new binary system (HD 54309), which we designate CHARA 246.

Of the 48 objects surveyed, 5 are binary within the limits of speckle detection, yielding a multiplicity fraction of $10\pm4\%$ (based on counting statistics). This is comparable to the multiplicity fraction of 13.9% found for a larger sample of 211 B-type dwarf stars and 12.8% for all dwarf-type stars (McAlister et al. 1993). Our results confirm those of Abt (1987) who finds that Be and normal B stars have similar binary frequencies and period distributions for orbital periods greater than one month. Abt also claims that binaries are rare among Be stars for periods shorter than one month (with the exception of the class of Be plus neutron star binaries); this will be an important issue to explore with the next generation of optical interferometers (such as the CHARA Array; see our WWW site at `http://www.chara.gsu.edu/CHARA/chara_array.html`).

Table 1 lists all known speckle binaries containing Be stars from various CHARA speckle observing programs (the list does not include binaries with separations wider than $1\farcs5$; see the WDS for these). The columns list WDS designation, name, HD number, and a publication reference code (the first three letters of the first author's last name followed by the year of publication). A full description of our work (including lists of null detections) has been submitted to the *Astronomical Journal* (Mason et al. 1997 = Mas97b in Table 1).

TABLE 1 – Be Star Speckle Binaries

WDS Designation	Discoverer	HD	Ref.
01093+4715	Stt 515	6811	Mas97b
03492+2408	CHARA 125	23862	Mas93b
05244−0224	Da 5 Aa,B	35411	McA76, Mas97b
	McA 18 Aab,c	35411	McA76, Mas97b
06288−0702	StF 919 BC	45726	Mas97b
06290+2013	Btz Aa	45542	Mas97a
07003−2207	Fin 334	52437	Har96
07074−2350	CHARA 246	54309	Mas97b
07143−2621	Fin 323	56014	Mas97b
08291−4410	B 1101	72067	Mas97b
13031−7129	CHARA 228	113120	Har96
14567−6247	Fin 372	131492	Mas97b
15185−4753	HJ 4753	135734	Mas97b
15329+3121	Cou 610	138749	Har97
18352+3427	CHARA 75	171780	Mas97b
19503+0754	CHARA 89	187567	McA87a,McA87b
20295+5604	Kui 97	195554	Mas97b
20474+3629	Stt 413 Aa,B	198183	Har94, Mas97b
20598+4732	McA 65 Aa	200120	Mas97b
22359+3938	CHARA 112 Aa	214168	Mas97b
22504+4157	CHARA 115	216200	Mas97b
23019+4219	McA 77 AB	217675	Har96, Mas97b

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McAlister, H.A., Hartkopf. W.I., Hutter, D.J., & Franz, O.G. 1987b, AJ, 93, 688

McAlister, H.A., Mason, B.D., Hartkopf, W.I., & Shara, M.M. 1993, AJ, 106, 1639

3.4. Observations of Hα Emissions of Be Stars with an Objective Prism and CCD Camera

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The appearance of Be stars is characterized by hydrogen emission lines whose strength decreases as the terms of the Balmer series increase. In this connection, Hα always exhibits by far the strongest emission. Even if short-term periodic variations have been observed, with many stars their long-term behavior is in most cases irregular. Stars exemplifying this kind of behavior are γ Cas, ζ Tau, 48 Lib and BU Tau, to name but a few.

This star class presents particularly fascinating objects not only to professional astronomy, but also to the amateur astronomer. The most popular stars observable in the northern hemisphere are γ Cas, ζ Tau, P Cyg, β Lyr, o And, κ Dra, BU Tau, and ϕ Per.

The use of CCD cameras (and objective prism spectrographs for instance) opens up a field of activity where - assuming the work is meticulous - results may be achieved which may even be presented to the representatives of professional astronomy who take an interest in them. The equipment used for achieving the results presented in this article is a configuration consisting of a Maksutov reflecting telescope (f = 1,000 mm, aperture = 100 mm), the so-called Russian ton, and an objective prism made of F_2 flint glass of the same aperture or edge length with a refracting angle of 30°. This instrument's medium linear dispersion is 6.0 Å/pixel for Hα. It is connected to a CCD camera with a Philips Co. FT800P chip of 386 x 290 pixels, a 6.4 x 4.8 mm field size and a spectral resolution at Hα of $\lambda/\Delta\lambda \sim 2000$.

The equivalent width, W_λ, was calculated using the standard formula. When performing the integration for W_λ, the intensity within the spectrum is thus always referred to the local continuum intensity. For a continuum adjustment of the overall spectrum, polynomial or spline functions are more appropriate.

In general, it is not possible to determine the equivalent width W_λ using amateur instruments with a measurement accuracy of more than 5%. For the observations reported here, the standard deviations were approximately 3% and even 1.7% for the ζ Tau observations.

The equivalent widths of the Hα emission of some of the stars mentioned in the introductory lines have been observed with the aim of monitoring their behavior in the course of time. Results are shown in the accompanying figures.

β Lyr: As per discussion with Dr. Hanuschik the Hα variability can presumable be explained by the fact that the secondary component (B-star with thick disc) is being covered by the B6 star and that only the continuum intensity is varying due to the eclipsing process.

P Cyg: During the relevant period there is a moderate reduction of intensity of approximately 20-30%. There are continuing investigations of the results regarding periodic variations (period = 100-150 days?) in Heidelberg (Germany).

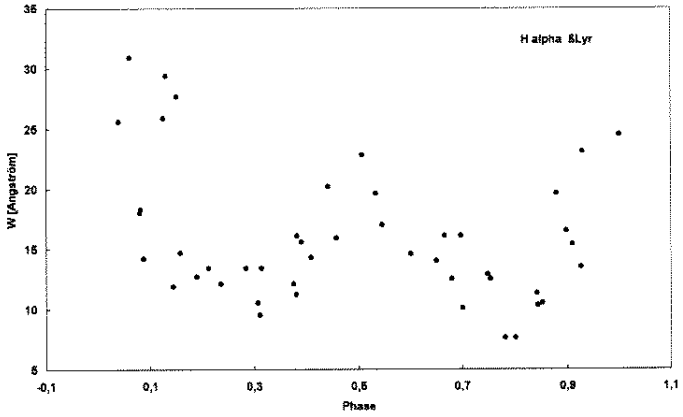

FIGURE 1. Hα equivalent width variations in β Lyr as a function of orbital phase.

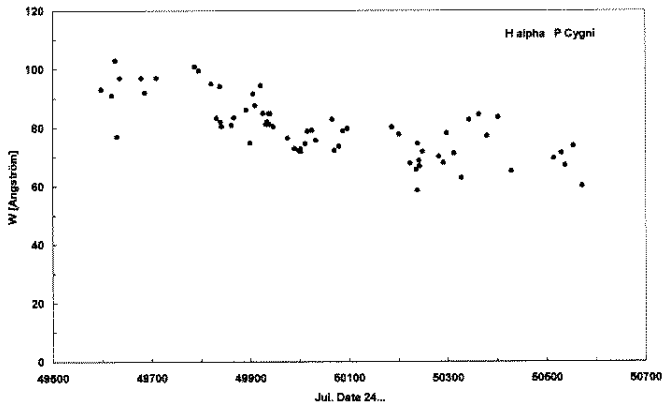

FIGURE 2. Hα equivalent width variations of P Cyg.

γ Cas: Results have already been submitted to Myron Smith.

ζ Tau: Short-time variability is seen (average = 1.12 Å/hr) over a period of several hours during 3 nights. During 2 nights, control measurements were made of Hα in β Tau. My work on ζ Tau continues.

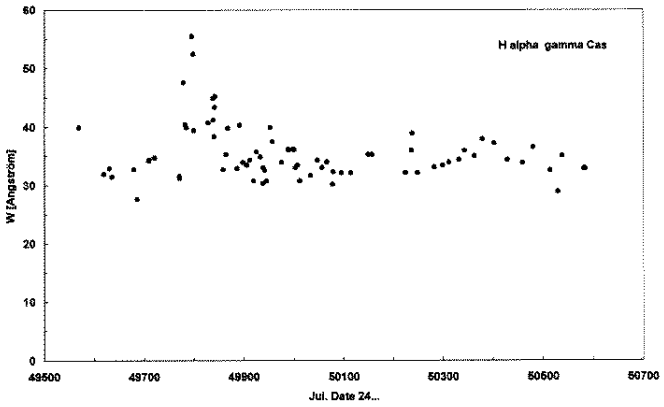

FIGURE 3. Hα equivalent width variations of γ Cas.

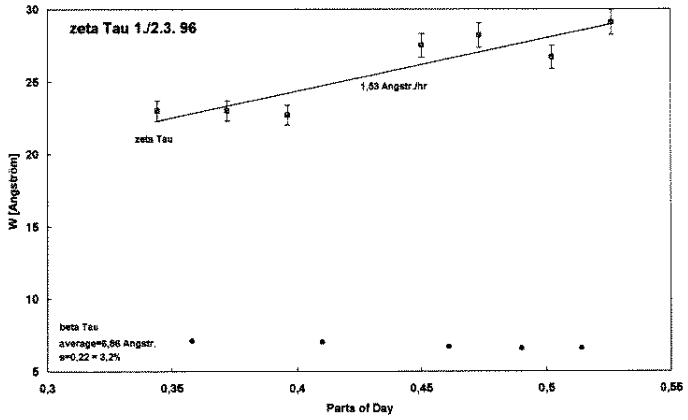

FIGURE 4. Rapid Hα equivalent width variations of ζ Tau.

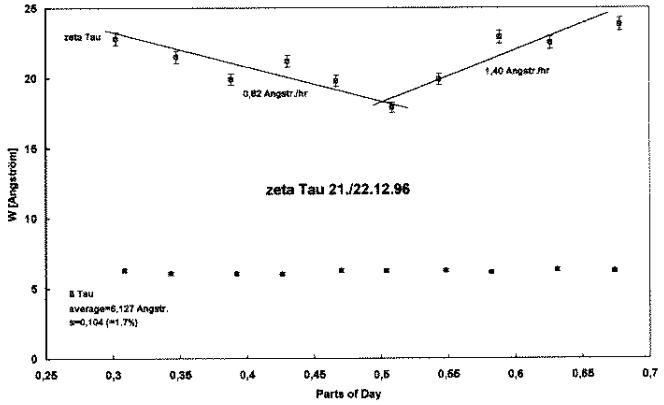

FIGURE 5. Rapid Hα equivalent width variations of ζ Tau.

4. WHAT'S HAPPENING?

4.1. An experimental ephemeris of the emission outbursts of μ Centauri: observational verification requested

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The purpose of this note is not to announce a result but to seek help in the accumulation of observational evidence in support of or against a preliminary scheme for the prediction of the emission outbursts of the bright Be star μ Cen (for earlier observations see Baade D., Dachs J., van de Weygaert R, Steeman F., 1988, A&A 198, 211 and Hanuschik R.W., Dachs J., Baudzus M., Thimm G., 1993, A&A 274, 356).

Our analysis of long series of spectra tentatively suggests that outbursts do not occur at random but follow a coherent temporal pattern. Some 300 echelle spectra obtained in 1995-1997 and another two dozens from 1992 cover more than a dozen minor and major outbursts. Our current best 'model' reproduces more than 80% of them. With one and the same set of parameters also the outbursts reported by Hanuschik et al. (1993, op. cit.) are quite satisfactorily accounted for.

Extrapolating our findings into the future, we now expect that

1. the equivalent widths of emission lines (e.g., Balmer and Paschen series, Si II 634.7) will reach maxima on (JD-2,450,000) 535, 547, 570, 606, 628, 665 and 686 with an estimated uncertainty of $\leq$7 days;

2. the change in equivalent width of the P15 emission will on (JD-2,450,000) 570, 628, and 686 be about 0.15-0.3 nm (with the middle outburst being at the low end of this range) whereas for the other events it will only reach 0.05-0.15 nm (with the first two reaching a slightly smaller amplitude than the last two each of which is a blend of two minor events);

3. in the Paschen lines, the rise time is roughly proportional to the amplitude and for the larger outbursts typically amounts to 10-15 days (valley to peak);

4. the onset of the emission increase in the Balmer lines will be later by up to 10 days in the stronger (by less in the weaker) outbursts, the increase may even be preceded by a temporary decrease, and the rise to the maxima is steeper;

5. at the time of an outburst, the V/R ratio especially of the He I 587.6, 667.8, and 706.5 emission lines varies cyclically on a time scale of 0.6±0.05 days which seems to be different for each emission event. At lower spectral resolution and/or S/N, the overall radial velocity of especially the higher Balmer lines may appear to vary instead.

A crude schematic picture of our current guess of the behavior of the emission in the higher Paschen lines is given in Fig. 1. Note that the predictive power of our model is much less pronounced for the strength of the outbursts than for their time.

Between March 6 and April 27, we hope to obtain new series of spectra with the Heidelberg Extended Range Optical Spectrograph (HEROS, Rivinius et al. 1997, A&A, 318, 819) attached to the ESO 0.5 and 1.5-m telescopes at La Silla. During this period, dense observational sequences at high spectral resolving power (≥15,000) and S/N (≥100) of any of the emission lines mentioned above would be of great value. Outside our own monitoring interval, even scattered observations, preferrably of the higher Paschen or lower Balmer lines, could provide tests of the expected variability. Photometry that may document the light and particularly the color variations associated with outbursts could be profitably attempted at any time. If you can help, kindly contact any of the authors. However, we caution once again that at this stage our conjectures have a significant speculative component.

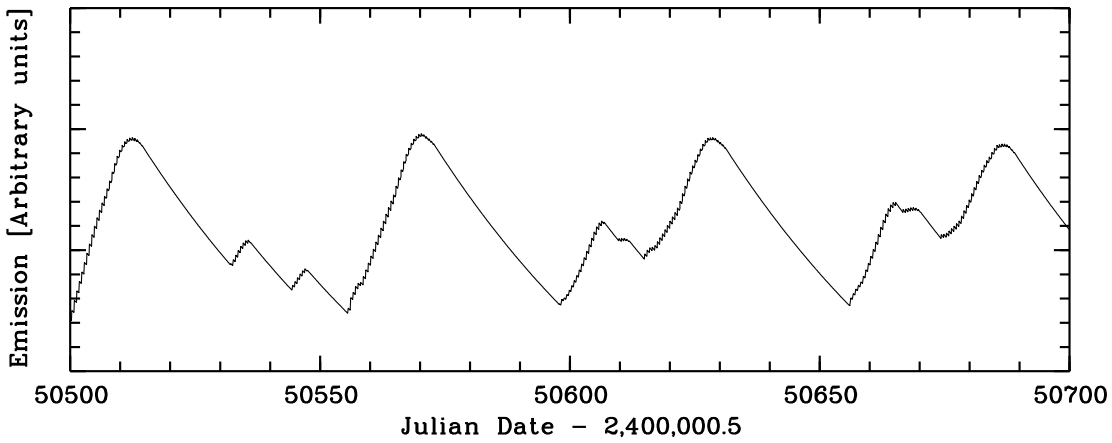

FIGURE 1. A tentative forecast for the variability between March and August, 1997 of the P15 emission in μ Centauri.

4.2. Report 2 on the 1996 Multi-Site and Multi-Satellite Campaign on γ Cas

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In the previous NL edition, I indicated the presence of two probable temperature spots on the surface of γ Cas. Doppler imaging work also shows a few patches of enhanced Si. The temperature spots are related to the X-ray variations, as detailed in the following. A subsequent report will detail investigations into the Si IV line Discrete Absorption Components (DACs) and migrating subfeatures, probably neither of which arises in the photosphere of this star. This work was done by Richard Robinson (CSC/GHRS), Robin Corbet (USRA/RXTE), and myself.

We have obtained simultaneous *RXTE*/PCA and HST/GHRS light curves for the B0.5e star γ Cas in order to compare its X-ray and ultraviolet continuum flux behaviors. The GHRS dataset consisted of a nearly continuous time sequence of UV spectra covering an interval 21+ hours. Each 40Å spectrum was centered on the Si IV $\lambda\lambda$1394-1403 lines, was exposed for 1s, and had a S/N ratio per pixel near 90. Combining spectra and integrating over >100 continuum pixels allowed us to define a UV continuum light curve binned to 1 minute with an S/N ratio of several hundred pix^{-1}. The light curve in Figure 1 exhibits variations over a time comparable to the rotation period of the star, with two broad minima 10 hours apart and having depths of 0.8% and 1.9%. The long term trends in the UV are anti-correlated with the X-ray fluxes, with the X-rays exhibiting increases of $\sim$10% and $\sim$40% during times of UV flux minima. The stability of the long-term X-ray variations on γ Cas has been confirmed by contemporaneous *ASCA* observations, by additional *RXTE* data we obtained in September, and from published data in 1985. We are able to phase the data to a tentative X-ray period of 1.12499$\pm$0.00001 days. This value is consistent with the star's expected rotational period.

The X-ray emission from γ Cas appears to consist of two primary components. The first is a slowly varying "basal" flux representing the minimum level seen during any given phase. Superimposed on this are rapid fluctuations, "shots", which have lifetimes ranging from $<$ 10 s to $\geq$10 minutes. The character of these components varies from orbit to orbit, indicating that the emissions are not produced in a "stationary," truly chaotic environment. Moreover, both the number and amplitude of the shots increase as the UV flux decreases. The shot profiles are symmetric and can have extremely rapid decay rates. Whether one assumes plasma cooling by hydrodynamic expansion or radiation, the decay rate leads to densities for the X-ray emission sites which are roughly photospheric ($\geq 10^{14}$ cm^{-3}). The shots have a slightly harder flux distribution than the basal component, suggesting that the two emission regions are not cospatial. The softening of X-ray color at the UV flux maxima supports this conclusion. The X-ray spectrum indicates a quasi-temperature of $\sim 10^8$K, in agreement with earlier studies.

We present a picture in which the observed UV continuum variations result from the presence of magnetically generated "spots" on the surface of the star. These features

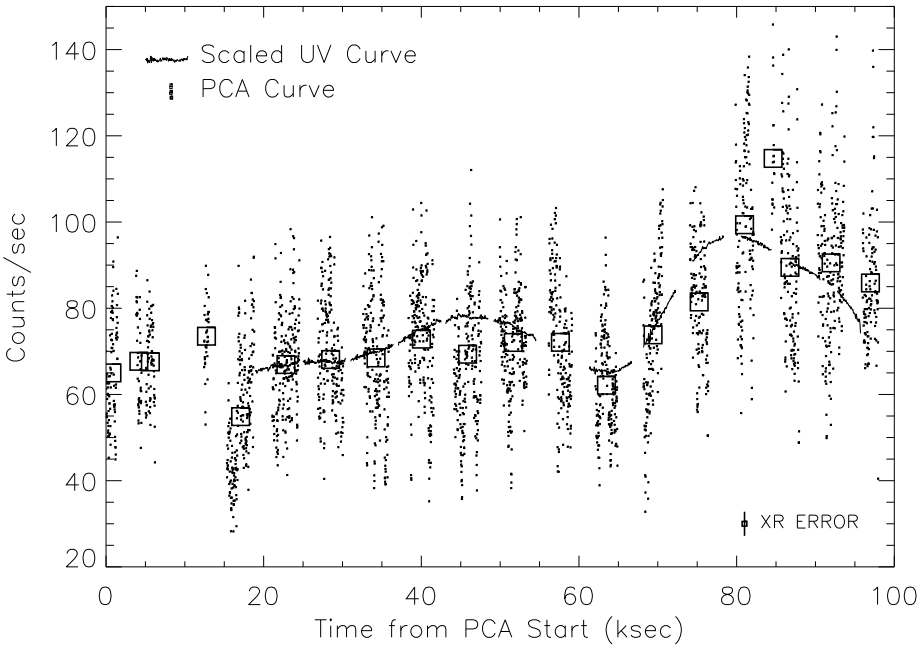

FIGURE 1. Simultaneous X-ray and UV (λ1400) light curves for γ Cas on 1996 March 14-15. Open boxes denote X-ray orbital averages. The UV light has been rescaled by $-30\times$ such that the UV flux minima appear as quasi maxima.

are probably associated with both the basal component formed in a magnetosphere and the shots, which are flare-like events arising within the photosphere. The energies and luminosities of the flares are very strong by comparison with other classes of flare stars. For example, the peak luminosity, 3×10^{32} ergs s^{-1}, of even the weakest events in our sample is several higher than the most luminous flares found on cool active stars. Our interpretation raises several critical theoretical questions, such as: how can chaotic fields be maintained on a star which does not have a convective envelope, and how can flares occur in a plasma with T $\sim10^8$ K and $N_e \geq 10^{14}$ cm^{-3}?

These results suggest that γ Cas is a member of an arguably new group of hot stars which flare continuously. This group represents an extension of the Si- and He-anomalous Bp stars to high values of T_{eff} and rotation.

4.3. Progress on Modeling NRP-related Profile Variations

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Readers will find several new papers in the bibliography section that mark significant progress in modeling and understanding the line profile variations related to nonradial pulsations (NRP).

Telting and Schrijvers and collaborators (Schrijvers et al. 1997; Telting & Schrijvers 1997a, 1997b; plus Telting's Ph.D. dissertation from the University of Amsterdam) have performed a huge exploration of the kinds of variability expected for diverse mode types, projected rotational velocity, inclination angle, ratio of horizontal to vertical velocity, and pulsation amplitude. They include a first order correction for rotational effects in their models, and they show that time series methods applied across the line profile offer significant diagnostics for probing the mode type. Through a vast number of numerical experiments they show that the variation across the line profile of complex phase at the signal frequency in the periodogram is more closely related to the degree l than the azimuthal order m, and they show that signals at harmonic periods of the fundamental may be used to help estimate m.

Townsend (1997; plus his Ph.D. dissertation from University College London) presents a new modeling code, BRUCE, that attempts to model the pulsational eigenfunctions for rotating stars in as realistic a way as possible. He includes rotational deformation, limb and gravity darkening, and a full representation of NRP modes for a given rotational velocity (following the methods of Lee and Saio). His code uses as a starting point non-LTE model line profiles calculated as functions of the local angle to the surface normal, local temperature, and gravity. The code will have direct application to high signal-to-noise spectra of rapidly rotating stars (like the Be stars).

Investigators interested in NRP will find a feast of new ideas and results in these remarkable papers. The application of these new methods will help extend the field of asteroseismology to the hot stars.

4.4. SONGNews

SONG, the Stellar Oscillations Network Group, is a broad, community based project with the goals of obtaining coordinated seismic observations of astrophysically important stars and, if necessary, of developing and deploying any specialized instrumentation that might be needed. While the focus is on solar type stars, we hope to draw on the experience and expertise of groups working on other classes of non-radially oscillating stars. Ultimately, the data produced through this program should return to the community.

The SONG Newsletter, SONGNews is distributed from the National Optical Astronomy Observatories. Send articles to be included to `song@noao.edu`. To add your name to the SONGNews distribution list send e-mail to the same address. Issues are also available via the World Wide Web at
`http://www.noao.edu/noao/song/`.

4.5. Be Disks Resolved!

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Readers will not want to miss an exciting recent paper by Quirrenbach et al. (1997, ApJ, 479, 477) which reports in full on high resolution observations of several famous Be stars with the U.S. Naval Research Laboratory's MkIII interferometer. Quirrenbach et al. show that while the stars were not resolved in continuum wavelengths, they were resolved in narrow band Hα filters *and* most showed significant asymmetries in the Hα emission flux. The elongation position angles are fully consistent with the expected orientations of circumstellar disks from polarimetric observations. In cases like ζ Tau, the asymmetry is sufficient to restrict the disk opening angle to less than 20°. These important new results appear to vindicate the flattened disk model for Be star circumstellar envelopes that originated with Struve, and they offer a wonderful glimpse of the future in high angular resolution astronomy.

5. PREPRINTS RECEIVED

Dynamical Models of Winds from Rotating Hot Stars

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The hottest and most massive stars (spectral types O, B, Wolf-Rayet) have strong stellar winds that are believed to be driven by line scattering of the star's continuum radiation field. The atmospheres and winds of many hot stars exhibit the effects of rapid rotation, pulsation, and possibly surface magnetic fields, inferred from observations of ultraviolet spectral lines and polarization. The complex time variability in these observations is not yet well understood. The purpose of this dissertation is to model the dynamics of winds around rotating hot stars and synthesize theoretical observational diagnostics to compare with actual data.

Before dealing with rotation, however, we derive the theory of radiative driving of stellar winds, and uncover several new useful aspects of the theory for spherical, nonrotating stars. The presence of *limb darkening* of the stellar radiation is found to be able to increase the mass flux $\dot{M}$ by 10–15% over standard models assuming a uniformly-bright star, and the wind's asymptotic terminal velocity v_∞ should decrease by the same amount. We also introduce a new approximation method for estimating the terminal velocity, which is both conceptually simpler and more physically transparent than existing approximation algorithms. Finally, from theoretical line profile modeling we find that observational determinations of v_∞ may be underestimated by several hundred km s^{-1} if *unsaturated* P Cygni lines are used.

Rotation affects a star by introducing centrifugal and Coriolis forces, decreasing the effective gravity and making the star oblate. This in turn redistributes the emerging radiative flux to preferentially heat the stellar poles, an effect known as *gravity darkening.* Although previous models have computed the increase in equatorial mass flux due to the lower effective gravity there, none have incorporated gravity darkening. We find that the brighter (darker) flux from the poles (equator) has a much stronger impact on the mass flux, increasing (decreasing) the mass loss and local wind density. This, in addition to the existence of *nonradial* radiation forces from a rotating star, which tend to point latitudinally away from the equator and azimuthally opposite the rotation, produces a net *poleward* deflection of wind streamlines. This is contrary to the "wind compressed disk" model of Bjorkman and Cassinelli, and also seems incompatible with observational inferences of equatorial density enhancements in some systems. This work is ongoing, and we are endeavoring to include all the relevant physics in hydrodynamical simulations.

We also dynamically model spectral-line *time variability* by inducing corotating nonaxisymmetric structure in the equatorial plane of a hot-star wind. By varying the radiation force over localized "star spots," the wind develops fast and slow streams which collide to form corotating interaction regions (CIRs) similar to those in the solar wind. We synthesize P Cygni type line profiles for a stationary observer, and find

that "discrete absorption components" (DACs) accelerate slowly through the profiles as complex nonlinear structures rotate in front of the star. We also examine the photospheric origin of such variability, in a preliminary manner, by deriving the theory of stellar pulsations, waves, and discontinuities. Although most observed low-order pulsation modes are evanescently damped in the photosphere, we find that the presence of an accelerating wind can allow waves of *all* frequencies to propagate radially. We thus make a first attempt at outlining the possible "photospheric connection" between interior and wind variability that observations are beginning to confirm.

Ph.D. Dissertation completed at the University of Delaware, 2 August 1996, under the direction of Dr. Stanley Owocki.
For copies, contact `cranmer@bartol.udel.edu`, *or download individual chapters as postscript from:* `http://www.bartol.udel.edu/~cranmer/cranmer_thesis.html`

New Perspectives on AX Monocerotis

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AX Monocerotis is a 232^d, non-eclipsing, interacting binary star which consists of a K giant, a Be-like giant, and large amounts of circumstellar material. The K star is probably a synchronous rotator and in contact with its critical lobe. The Be star was believed to be a rapid rotator based on extremely wide absorption lines, but new spectra show that these lines arise from the circumstellar environment. Hydrogen emission, also circumstellar, is many times stronger than the continuum. Near-ultraviolet light curves exhibit a $0.^m5$ dip near phase 0.75 , but there is no such variability at longer wavelengths. Gas flow trajectories from the cusp of the K star toward the Be star provide a simple explanation for the photometric and spectroscopic behavior. Evidence for a decreasing orbital period suggests that AX Mon may be a precursor of common envelope evolution. We present several possible models for AX Mon based

on 1) new and archival visible photometry, 2) archival ultraviolet spectroscopy, 3) new and archival visible spectroscopy, 4) new visible polarimetry, and 5) new radio photometry. Future observations, including optical interferometry, are proposed and justified.

1997, ApJ, 484, 394 *For reprints, contact* N. Elias, nme@fornax.usno.navy.mil.

Multi-site continuous spectroscopy V. Rapid photospheric variability in the Be star 48 Per from the MUSICOS 1989 campaign

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Rapid variability in the photospheric He I 6678 line of the Be star 48 Per (HD 25940, HR 1273) has been detected from 258 high S/N CCD spectra taken with four 1.5–2.0 meter telescopes over three consecutive nights during the multi–site spectroscopic MUSICOS 1989 campaign. 48 Per is a rather moderate–V sin i star, known to have presented slight long–term variations in the intensity of Balmer emission lines and in the V/R ratio. It is shown that the MUSICOS 1989 observations preceded a new activity phase. Search for line–profile variations, hereafter *lpv*, was performed with time–series analysis using two methods (TF+CLEAN and Least–Squares) and with analysis of residuals. Weak blue–to–red and red–to–blue moving subfeatures with the same acceleration have been detected in the residuals. Their presence confirms that this star is seen under a moderate angle of inclination, $i \sim 40°$, in agreement with estimates based on fundamental stellar parameters. A 6.04 c/d frequency, associated with the moving subfeatures mentioned above, has been firmly established from time–series analysis and corresponds more closely, in the frame of non–radial pulsations

(NRP), to a tesseral mode ($|m| = l - 1 = 9 \pm 2$). Two other possible frequencies (0.85 and 2.77 c/d) have been detected but need to be confirmed with new observations obtained over a longer time span. Despite additional spectra obtained at Haute Provence Observatory, we could not confirm the previous value of the orbital period or the amplitude of the radial velocity curve of 48 Per, and therefore it was premature to search for tidally–forced oscillations.

† Henri Hubert died on February 10, 1996

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Be star surveys with CCD photometry. II. NGC 1818 and its neighbouring cluster in the LMC

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As part of an ongoing photometric survey of young Magellanic Cloud clusters we identified Be stars in NGC 1818 and a nearby smaller cluster in the Large Magellanic Cloud. The neighbouring cluster does not appear to contain any evolved stars, and its sparsely populated main sequence does not extend to stars as massive as in NGC 1818. Both clusters are younger than the surrounding field population, but the current data do not allow to conclude whether NGC 1818 is a binary cluster or not. The small cluster is more heavily reddened than NGC 1818 indicating the presence of differential reddening, leftover gas and dust from the star formation process, or a larger distance. NGC 1818 does not seem to be significantly affected by differential reddening.

We find both clusters to be rich in Be stars. The field only contains very few Be stars as one would expect for a predominantly older population. NGC 1818 contains almost as many Be stars as the slightly younger SMC cluster NGC 330, while NGC 2004, a young LMC cluster, has a lower Be star content.

We discuss problems in comparing Be star fractions in Magellanic Cloud clusters and Galactic open clusters and possible constraints on Be star theories.

1997, A&A, 317, 448 *For reprints, contact* grebel@astro.uni-wuerzburg.de
Abstract, full text, and data tables can be retrieved from
`http://www.astro.uni-wuerzburg.de/~grebel/publications.html`

Line formation in Be star envelopes II. Disk oscillations

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We present numerical model calculations for an especially interesting class of Hα emission line profiles from Be star disks, those with asymmetric shape and long-term variability (so-called class 2 profiles). As an underlying model for the disk we investigate the hypothesis of Okazaki (1992) that these profiles are caused by a distortion of a quasi-Keplerian disk. The distortion has the form of a one-armed global disk oscillation (density and velocity wave).

The radiation transfer in the disk is calculated with an improved version of the spatially implicit 3D radiative transfer code of Hummel (1994).

The resulting sets of Hα emission line profiles reproduce well the observed structures of fully-resolved class 2 Hα emission lines, like double peaks and winebottle-type shoulders. For high inclinations, shell-type profiles result. It is shown that the full variety of observed profile shapes is caused by the interaction of kinematical and non-coherent scattering broadening. While this result has already been found by Hummel (1994) for the symmetric (class 1) Hα profiles, it is proven here for the second major profile class as well.

The comparison between observed and theoretical emission shows that the model of global disk oscillations is in full agreement with the observed shapes and the cyclic long-term variability of class 2 profiles.

1997, A&A, 320, 852 *For reprints, contact,* `hummel@usm.uni-muenchen.de`

MULTI-PERIODICITY OF ζ OPHIUCHI FROM MULTI-SITE OBSERVATIONS

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We present results from simultaneous multi-site high-resolution spectroscopic and photometric observations of ζ Ophiuchi (HD149757) taken in 1993 May. Our spectroscopic data include about 100 hours of continuous monitoring of the star.

The line-profile variations of He I λ6678, which are characterized by features traveling from blue to red, are well reproduced by two large amplitude sinusoids and other sinusoids with smaller amplitudes. The period of the sinusoid with the largest amplitude is 2.018 hr (f_1) which differs from the 2.43 hr of previous publications, although it is possible that 2.43 hr is an alias of 2.018 hr. The period of the second largest amplitude is, in agreement with previous studies, 3.337 hr (f_2). Periods of smaller amplitude sinusoids are 2.432 hr (f_3), 1.257 hr ($f_1 + f_2$), 1.008 hr ($2f_1$), 2.107 hr (f_4), 1.293 hr ($f_2 + f_4$), 1.668 hr ($2f_2$), all of which have some relation to the two main periods. The two principal periods have close superperiods of about 10.05 hr. We discuss the commensurability and other features of the periodicity.

Our photometric observations, though limited, confirm again the very small amplitude of the light variations which are close to their detection limit. No counterpart of the 2.018 hr and 3.337 hr periods can be detected.

1997, ApJ, 481, 406

Inhibition of Wind Compressed Disk Formation by Nonradial Line-Forces in Rotating Hot-Star Winds

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We investigate the effects of nonradial line-forces on the formation of a "Wind Compressed Disk" (WCD) around a rapidly rotating B-star. Such nonradial forces can arise both from asymmetries in the line resonances in the rotating wind, and from rotational distortion of the stellar surface. They characteristically include a latitudinal force component directed *away* from the equator, and an azimuthal force component acting *against* the sense of rotation. Here we present results from radiation-hydrodynamical simulations showing that these nonradial forces can lead to an effective *suppression* of the equatorward flow needed to form a WCD, as well as a modest ($\sim 20\%$) *spin-down* of the wind rotation. Furthermore, contrary to previous expectations that the wind mass flux should be enhanced by the reduced effective gravity near the equator, we show here that gravity darkening effects can actually lead to a *reduced* mass loss, and thus lower density, in the wind from the equatorial region.

Overall, the results here thus imply a flow configuration that is markedly different from that derived in previous models of winds from rotating early-type stars. In particular, a major conclusion is that equatorial wind compression effects should be effectively suppressed in any radiatively driven stellar wind for which, as in the usual CAK formalism, the driving includes a significant component from optically thick lines. This presents a serious challenge to the WCD paradigm as an explanation

for disk formation around Be and other rapidly rotating hot stars thought to have CAK-type, line-driven winds.

1996, ApJ, 472, L115

Dynamic Processes in Be Star Atmospheres. VI. Simultaneous X-ray, Ultraviolet, and Optical Variations in λ Eridani

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We document the results of a simultaneous wavelength monitoring on the B2e star λ Eri. This campaign was carried out from ground stations and with the ROSAT, ASCA, IUE, and Voyager 2 space platforms during a week in February-March 1995; a smaller follow-up was conducted in September 1995. During the first of these intervals λ Eri exhibited extraordinary wind and disk-ejection activity. The ROSAT/HRI X-ray light curves showed no large flares such as the one the ROSAT/PSCA observed in 1991. However, possible low level fluctuations in the February-March ROSAT data occurred at the same time as unusual activity in Hα, He I λ6678, He II λ1640, and the C IV doublet. For example, the hydrogen and helium lines exhibited an emission in the blue half of their profiles, probably lasting several hours. The C IV lines showed a strong high-velocity Discrete Absorption Component (DAC) accompanied by unusually strong absorption at lower velocities. The helium line activity suggests that a mass ejection occurred at the base of the wind while the strong C III (Voyager) and C IV (IUE) lines implies that shock interactions occurred in the wind flow. It is not clear that the X-ray elevations are directly related to the strong C IV absorptions because the former changed on a much more rapid timescale than absorptions in the C IV lines.

Within hours of the mild X-ray flux variations found by ROSAT on February 28, the Voyager UVS observed a "ringing" that decayed over three 3-hr. cycles. The amplitude of these fluctuations was strong (50%) at $\lambda\lambda$950-1100, decreased rapidly with wavelength, and faded to nondetection longward of λ1300. Various considerations indicate that these continuum variations were not due to an instrumental pathology in the UVS. Rather, they appear to be due to a time-dependent flux deficit in the $\lambda\lambda$950-1250 region. We outline a scenario in which a dense plasma structure over the star's surface is heated and cooled quasi-periodically to produce such flux changes. Observations of new examples of this phenomenon are badly needed. Amateur as-

tronomers can make a significant contribution to its understanding by searching for ringing in light curves of Be stars during their outburst phases.

Finally we draw attention to an increase in the emission of the Hα line that occurred at about the time the FUV ringing started. This increased emission hints that $\sim$50,000K plasma near the star's surface can influence the circumstellar disc at $\sim$12R$_*$ by its increased Lyman continuum flux.

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PG 1002+506: a Be Star Apparently at Z > +10 kpc

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PG 1002+506 is found to be a Be star, one of two so far found by the Palomar-Green survey. Its spectrum is classified as a B5 $\pm$ 1 Ve, with $T_{\rm eff} = 14,900 \pm 1200$, $\log g = 4.2 \pm 0.2$, and $v \sin i = 340 \pm 50$ km s^{-1}. At $b = +51°$, its height above the Galactic plane would therefore be $Z = +10.8$ kpc, putting this apparently young, rapidly rotating star well into the Galactic halo. Its heliocentric radial velocity is found to be -2 ± 15 km s^{-1}, consistent with either having been formed in the Galactic disk and subsequently ejected, or having been formed in the halo.

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Spectroscopic Observations of Some Be/B Stars at High Galactic Latitudes

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Spectral types, rotational velocities, and radial velocities were estimated for eight Be and two non-emission B stars at high galactic latitudes from CCD spectra, and

their distances from the galactic plane calculated. All of the objects appear to be spectroscopically normal; for the Be stars, at least, there is no reason to invoke an unusual origin for this sample of stars.

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7. MEETINGS

- 14 – 17 October 1997
  ESO WORKSHOP ON CYCLICAL VARIABILITY IN STELLAR WINDS: RECENT DEVELOPMENTS AND FUTURE APPLICATIONS
  ESO Headquarters, Garching be Muenchen, Germany
  WWW: http://www.eso.org/windvar

- 11 – 14 November 1997
  ULTRAVIOLET ASTROPHYSICS BEYOND THE IUE FINAL ARCHIVE
  Sevilla, Spain
  WWW: http://www.vilspa.esa.es/iue/iue.html

- 1 – 5 December 1997
  WORKSHOP ON HOT STARS IN OPEN CLUSTERS OF THE GALAXY AND THE MAGELLANIC CLOUDS
  La Plata, Argentina
  Contact: hoc97@fcaglp.fcaglp.unlp.edu.ar

- 15 – 19 June 1998
  Proposed IAU Colloquium: Variable and Non-spherical Stellar Winds in Luminous Hot Stars
  Heidelberg, Germany
  WWW: http://www.lsw.uni-heidelberg.de/iaucoll/

- June 1999
  International Meeting on B/Be Stars
  Alicante, Spain (see Working Group Matters)

See WWW site `http://cadcwww.dao.nrc.ca/meetings/meetings.html` for more.

8. LATEX TEMPLATE FOR ABSTRACTS

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}\end{center}
\centerline{\bf           A. Author$^1$ and B. Author$^2$
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             \\    $^2$   Institute Two and Address
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