COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS

Number 5193

Konkoly Observatory
Budapest
6 November 2001

HU ISSN 0374 – 0676

EMISSION ACTIVITY OF THE Be STAR 28 CMa: ENTERING A NEW CYCLE?

ŠTEFL, STANISLAV[1]; BAADE, DIETRICH[2]; RIVINIUS, THOMAS[2]; OTERO, SEBASTIAN[3]; SETIAWAN, JOHNY[4]

[1] Astronomical Institute, Academy of Sciences of the Czech Republic, CZ-25165 Ondřejov, Czech Republic, e-mail: sstefl@sunstel.asu.cas.cz

[2] European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748 Garching bei München, Germany, e-mail: dbaade@eso.org, triviniu@eso.org

[3] Liga Iberoamericana de Astronomia, Buenos Aires, Argentina, e-mail: varsao@fullzero.com.ar

[4] Kiepenheuer-Institut für Sonnenphysik, Schöneckstr. 6-7, D-79104 Freiburg, Germany, e-mail: setiawan@uni-freiburg.de

The bright southern Be star 28 CMa (HR 2740, HD 56139) is proto-typical of the spectroscopic and photometric variability of Be stars. New modeling techniques have been tested on it. Very conspicuous line profile variations (*lpv*) with a period of 1.37 d were discovered by Baade (1982a). A detailed description of the *lpv* of He I 6678 was presented by Štefl et al. (1999), and advanced non-radial pulsation models for different spectral lines were computed by Maintz et al. (2000). Although rapid light variations have been known almost equally early (Baade, 1982b), the derived periods were questionable and inconsistent with the spectroscopic one. Štefl et al. (1999) analysed the Strömgren and Geneva photometry obtained during 16 years and isolated the 1.37 d periodic component of the light variations, whose amplitude is variable from season to season and reaches only a few mmag. These rapid periodic variations are combined with much larger variations on time scales of weeks to years. The latter are probably connected with the photospheric activity of the star as well as with restructuring in the circumstellar disk. A large brightening by about $0^{m}_{.}4$ was observed by Hipparcos in 1992. New observations show that an emission outburst of a comparable intensity started in 2001.

Visual observations since 1997 April and the 1990-1993 Hipparcos database reveal that the photometric ground state of 28 CMa corresponds to a magnitude of $\sim 4^{m}_{.}05$ visually or $\sim 3^{m}_{.}98$ in the Hipparcos broad photometric band. Superimposed on this plateau are fluctuations, mainly in the form of brightenings by up to 0.1 mag. The most recent brightening, which started in 2001 March and reached about $3^{m}_{.}8$ in June, has a significantly larger amplitude. First visual observations revealing the strength of this new outburst were obtained by E. De Bernardini (Buenos Aires) on Oct. 13, 2001 and confirmed by SO on Oct. 19. The star reached $V_{vis} = 3^{m}_{.}67$. The rising branch of the 2001 light curve resembles the one during the 1992 Hipparcos outburst (see Fig. 1). The most recent observations from the end of October 2001 seem to indicate that the outburst has already reached the descending branch.

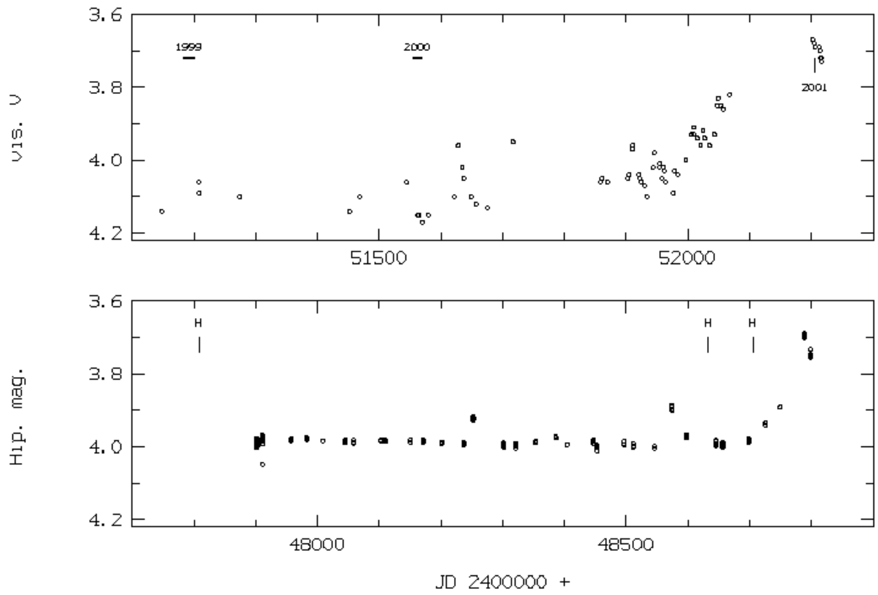

Figure 1. The strongest emission outbursts of 28 CMa observed during the past decade: the 1992 event covered by Hipparcos (lower panel, Perryman 1997) and the 2001 outburst documented by visual observations by SO (upper panel). The uncertainty of the visual magnitudes is 0.05-0.10 mag before HJD 2451900 and 0.03-0.05 mag thereafter. The times of Hα observations by Hanuschik et al. (1996) are indicated in the upper part of the lower panel. Intervals of the spectroscopic observing runs used in Fig. 2 are marked in a similar way in the upper panel.

Three high-resolution spectra obtained on October 23 and 24, 2001 with the FEROS echelle spectrograph and fiber link to the ESO 1.5-m telescope on La Silla confirm a strong outburst event. The total equivalent width of the Balmer emission lines dropped significantly (which is partly due to the strong increase in the continuum flux). But the strength of the wings increased with respect to previous years. The Hα peak height, E/C, of ≈ 3.0 is among the lowest values ever observed (see Fig. 2 and Harmanec, 1998). The shoulders in the emission profile have disappeared and the previous typical wine-bottle shape is no longer there. The other Balmer lines, particularly Hβ and Hδ, show an asymmetric structure in their cores. By contrast, intensity of metal emission lines increased only little and their peak separation did not change compared to January 2000 spectra (see Rivinius et al., 2001; Fig. 1). No emission is detectable in the wings of He I lines.

The two panels of Fig. 1 indicate that emission outbursts appear on a time scale of 200-350 days, in agreement with Hubert and Floquet (1998). Nevertheless, the outbursts around JD2448800 (1992) and 2452000 (2001) differ substantially in their dimensions. Both photometry and spectroscopy show that the recent outburst lasts several times longer and has a larger amplitude. There is intriguing evidence that another strong outburst took place on JD2445200-300. It is indicated by a $0\overset{m}{.}4$ brightening in the Strömgren b-band (see, e.g., Fig. 7 of Harmanec, 1998) and an accompanying state of low Hα emission (Hanuschik et al., 1996). Considering also the Hipparcos outburst, it appears that such

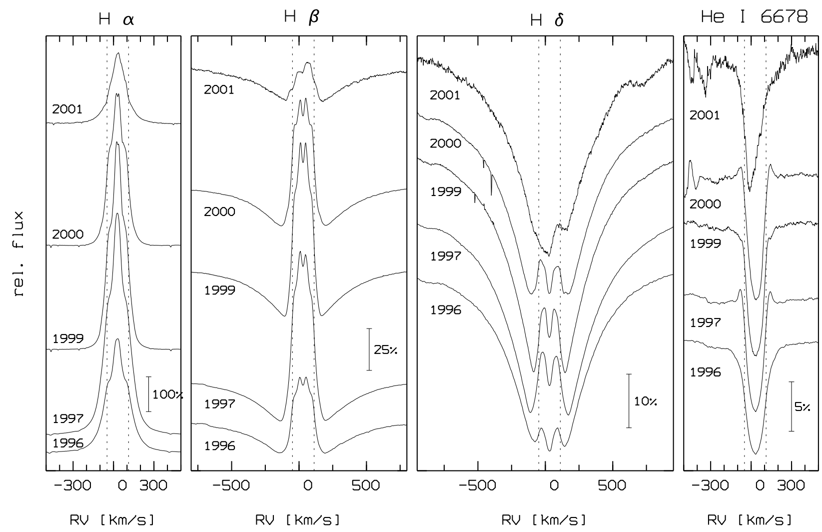

Figure 2. Comparison of mean emission profiles of selected spectral lines in the 1996, 1997, 1999, 2000 and 2001 (from Štefl et al., in preparation). A more careful inspection shows a higher emission in the wings of Hβ and Hδ lines in 1996 and 2001, when outbursts took place. Due to the large number of spectra, the strong 1.37-d *lpv*, which causes the asymmetry in the 2001 H I lines, is averaged out in the 1996 - 2000 mean spectra. The sharp features to the left of the He I line in the 2000 and 2001 spectra are due to a detector blemish. Dotted lines indicate the values of the systemic velocity $\pm\ v \sin i$. The bars to the right provide the flux scales in units of the local continuum; note the differences between individual panels.

major events take place once in 10 years; possibly they are even repetitive on a time scale of 3400-3600 days.

Analysis of the 1996 outburst (Štefl et al., in preparation) shows that 28 CMa follows the general scheme derived from line emission outbursts of μ Cen (Rivinius et al., 1998; Baade et al., 2001) but on a time scale, which is longer by at least one order of magnitude. This scheme consists of four phases: relative quiescence, precursor, outburst proper and relaxation, which are so far defined only spectroscopically. Because no spectra of 28 CMa are available for the time between February, 2000 and October, 2001, it is difficult to determine the present phase of the 2001 outburst. Based on the line emission being close to a minimum, on the missing emission in He I lines, and on the relatively high separation of emission peaks in metal lines, one may crudely guess that the outburst is in the late precursor or early outburst phase. Provided that it started in 2001 May or earlier, it develops very slowly in comparison with smaller outbursts in 28 CMa itself but also in other Be stars such as μ Cen.

If this large outburst does indeed fit the same scheme, the spectral evolution over the next weeks to months might be as follows: In the Balmer emission lines, the peak height will steadily increase while the wings will fade. At the same time, the emission will increase in the wings of He I and metal lines. The separation of emission peaks of metal lines will decrease. A double structure of the blue and red peaks may develop for a limited time until the inner part of the disk is formed. The coexistence of two pairs of emission peaks may reflect a double-ring structure of the disk as suggested recently by Rivinius et al. (2001). One may also expect the appearance of transient periods (Štefl et al. 1998, 2000), which were already observed after the weaker 1996 outburst. They may be echos of the photospheric oscillations in the inner disk. Finally, the visual magnitude will asymptotically approach its base value near $4.^m0$.

28 CMa is a pole-on star (e.g., Maintz et al., 2000) and therefore provides a nice illustration of the rule (e.g., Harmanec, 1983; Hubert & Floquet, 1998) that during outbursts such stars brighten whereas equator-on Be stars get fainter.

The present strong outburst of this bright star offers considerable opportunities: (a) If it can be confirmed that such major and the more frequent minor outbursts mainly differ in their dimensions, this might place important constraints on the unknown physics of outbursts. (b) The slow evolution permits the outburst to be studied in much detail. (c) The most exciting aspect of the latter would be to see whether during the course of an outburst the nonradial pulsation exhibits any changes. (d) Contemporaneous photometry and spectroscopy can be arranged for, which could be important to elucidate the photometric aspects of Be star outbursts.

Acknowledgements. We thank Dr. Luca Pasquini, for the kind permission to take the October, 2001 spectra within the framework of his ESO project No. 68.D-0334. S. Š appreciates the support of the Grant Agency of the Academy of Sciences of the Czech Republic (grant no. AA3003001).

References:

Baade, D.; 1982a, *A&A*, **105**, 65

Baade, D.; 1982b, *A&A*, **110**, L15

Baade, D.; Rivinius, Th.; Štefl, S.; 2001, *IAU Circular* **No. 7658**

Harmanec, P.; 1983, *Hvar Obs.Bull.* **7**, 55

Harmanec, P.; 1998, *A&A*, **334**, 558

Hanuschik, R. W.; Hummel, W.; Satorius, E.; Dietle, O.; Thimm, G.; 1996, *A&AS*, **116**, 309

Hubert, A. M.; & Floquet, M.; 1998, *A&A*, **335**, 565

Maintz, M.; Rivinius, Th.; Tubbesing, S.; Wolf B.; Štefl; Baade, D.; 2000, *IAU Coll.* **175**, p. 244

Perryman, M. A. C.; and the Hipparcos Science Team, 1997, *The Hipparcos and Tycho Catalogues*, ESA SP 1200

Rivinius, Th.; Baade, D.; Štefl, S.; Stahl, O.; Wolf, B.; Kaufer, A.; 1998, *A&A*, **333**, 125

Rivinius, Th.; Baade, D.; Štefl, S.; Maintz, M.; 2001, *A&A*, **379**, 257

Štefl, S.; Baade, D.; Rivinius, Th.; Kaufer, A.; Stahl, O.; Wolf, B.; 1998, in: *A Half Century of Stellar Pulsation Interpretation: A Tribute to Arthur N. Cox*, eds. P.A. Bradley and J.A. Guzik, *Astr. Soc. Pacific Conf. Series*, **135**, 348

Štefl, S.; Aerts, C.; Balona, L. A.; 1999, *MNRAS*, **305**, 505

Štefl, S.; Budovičová, A.; Baade, D.; Kaufer, A.; Rivinius, Th.; Stahl, O.; Wolf, B.; 2000, in *IAU Coll.* **175**, p. 240