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Coming shell phase of the Be star 4 Herculis*

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Abstract. After a relatively short period of quiescence (1989 – 1991), the B7V star 4 Her entered a new Be and shell phase. The most interesting feature which accompanies the beginning of the new shell episode is an apparent doubling of several different metallic *shell* lines seen consistently in our high-S/N electronic spectra. We suggest that this doubling is a consequence of a central emission feature rather than of a two-component shell.

Key words: stars: emission-line, Be – binaries: spectroscopic

4 Her (HD 142926, HR 5938; V=$5^m.75$, v.sini=300 km s^{-1}) is a well known and rather frequently observed Be and shell star. The estimates of its spectral type by different authors vary between B7 IV-V and B9e. The available UBV observations (Harmanec et al. 1980) clearly indicate that the spectral type is close to B7V, in agreement with more recent spectroscopic determinations (c.f., e.g., Slettebak 1982). The spectral type based on the BCD classification is B8V (Zorec & Briot 1991). Hubert (1971) reported remarkable spectral changes of the star which occurred between 1953 and 1970. No emission components of the Balmer lines were visible until 1963. Since 1965, a shell core in the Hα emission had been visible together with unusually broad metallic shell lines. Compiling all published remarks on the appearance of 4 Her spectrum, Hubert concluded that the Balmer emission might appear and disappear periodically, with a period between 28 and 43 years.

Harmanec et al. (1973) discovered periodic radial-velocity variations of the hydrogen shell lines with a period 46.023 days and suggested the object is a single-line spectroscopic binary. The system elements were later refined by Heard et al. (1975) to P=46.194 days, K=12 km s^{-1} and e=0.3. In a subsequent paper, Harmanec et al. (1976) studied the variations of emission and absorption components of the hydrogen lines and concluded that 4 Her is an interacting binary and that the observed eccentricity of the orbit is spurious, caused by the effects of circumstellar matter.

The long-term spectral variations of 4 Her have been monitored at Ondřejov since 1969 and at Haute Provence since 1953 at low, and since 1960 at high dispersion. We are thus in the position to document the decline of the shell phase which started in 1962-63 (Hubert 1971) and the subsequent development of a new shell episode. The recent period when the emission in Hα was not detectable was relatively short (1989-1991), whereas the previous cycle of a normal B7 absorption spectrum lasted 10 years.

In Fig. 1 we present a sequence of Hα spectra taken from 1976 to 1993. It clearly documents the disappearance and subsequent re-appearance of the Hα emission. The first four profiles were extracted from photographic spectra taken at Ondřejov, while the other two were obtained with a 1872-pixel reticon in the coudé spectrograph of the Ondřejov 2-m telescope (JD 2448841.432) and with the Aurélie spectrograph in the coudé focus of the 1.52 m telescope at the Haute Provence Observatory (JD 2449007.698). Figure 2 illustrates a part of blue spectra where the weak metallic shell lines are observable. These spectra were taken on JD 2448811.410 (296B) and JD 2449006.670 (F202) with the Aurélie spectrograph. Each frame from Aurélie covered 200 Å, the resolving power being about 20 000, while the S/N ratio varied between 600 to 700. The reduction of raw spectra obtained with solid state detectors was basically the same as that described by Horn et al. (1992).

A synthetic spectrum (T_{eff} = 14000 K, log g = 3.0, v sini = 300 km s^{-1}) plotted in each figure should give an upper limit for the photospheric lines in 4 Her .

The most interesting feature visible in both blue spectra is the apparent doubling of some shell lines. This doubling is probably caused by the presence of weak emission in line cores. Seven lines with clearly defined central reversals were detected in the interval of wavelengths 4400 - 4600 Å: 4395.031 Å - Ti II 19, 4416.817 Å - Fe II 27, 4443.802 Å - Ti II 19, 4481.228 Å - Mg II 4 (1), 4501.270 Å - Ti II 31 (2), 4508.383 Å - Fe II 38 (3), and 4515.337 Å - Fe II 37 (4). Numbers in parentheses correspond to numbers in Fig. 2. There are three well defined lines without any obvious central emission: $\lambda\lambda$ 4470Å, 4549Å, and 4583 Å. While in the first group it was relatively easy to identify the lines and achieve consistent radial velocities for their identifications, the lines in the latter group are obviously close

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* This research is based on observations from the Haute Provence and Ondřejov observatories

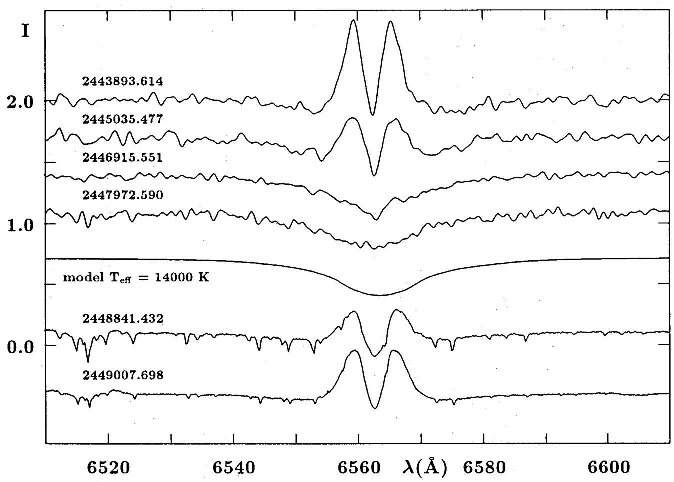

Fig. 1. Hα spectra of 4 Her taken from 1976 to 1993. The profiles are arranged in order of increasing time (JD-240000 is given to the left of each spectrum). The profiles are plotted in heliocentric wavelength scale. The basic parameters for the synthetic spectrum (which is shown only to illustrate the influence of the envelope) are also given

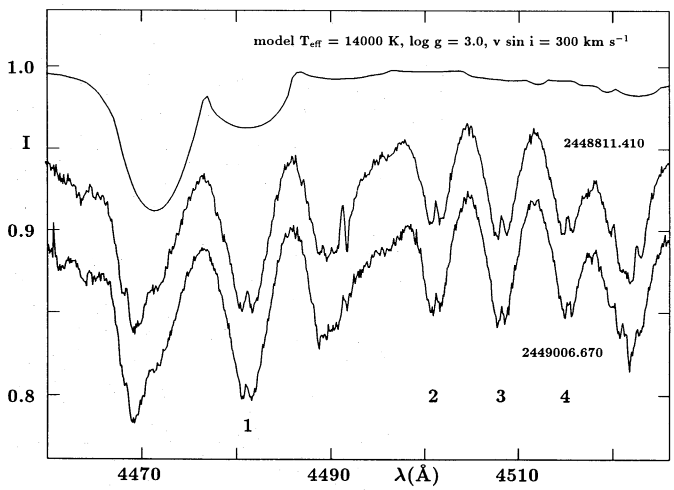

Fig. 2. Shell spectra of 4 Her in the same format as Fig. 1. See the text for the identification of the strongest (numbered) lines

blends of several contributing lines. The line blending is readily seen for the features near λ 4490 Å and λ 4524 Å. We suspect that the line blending is the cause of the apparent absence of central reversals in the spectral lines in question.

The radial velocities of the "double" absorption lines differ for some 50 km s^{-1}. While the velocity of neither of the apparent double metallic shell absorptions corresponds to the expected orbital velocity of the primary or secondary star, the centres of shell lines seem to follow the primary's motion quite well. At present time we cannot discriminate between a central emission feature and a real doubling of the shell lines conclusively. However, the stability of these features seems to speak against a two-component shell. Doazan (1976) has observed a similar feature in the broad Balmer absorptions of *o* And before the onset of a new shell episode. Later Baade (1983, 1989) and Porri & Stalio (1988) detected roughly central quasi-emission bumps in the rotationally broadened absorption lines of several stars (ν Pup – B8III, ω Car – B8IIIe, ϵ Cap – B3IIIe and η Cen – B1.5Vne). However, to the best of our knowledge, never before was such a sharp central emission observed in the cores of *the metallic shell lines*. Baade (1989) found no major variations in the shape, strength or radial velocity of these features on a timescale up to a few years. In 4 Her, we can only document the stability of the emission peaks over the period of a few months.

Baade (1990) argued that the emission bumps may be produced by smooth equator-to-pole variations of any scalar atmospheric quantity, but only for stars with $i < 40°$. Jeffery (1991) succeeded to reproduce the observed profiles by a model with cooler polar caps. This hypothesis still needs further confirmation through the comparison of observed and theoretical profiles for the Balmer and diffuse helium line profiles. A similar modelling for the Be envelopes could answer the question whether there is a physical connection between the quasi-emission bumps observed in photospheric lines of B/Be stars and similar features which we detected in the shell lines of 4 Her. Interestingly enough, in ϵ Cap the emission peaks were observed shortly *after* the disappearance of shell, while Doazan (1976) made the observations more than one year *before* the start of a new shell episode of *o* And. However, one must keep in mind that the existing observations of the phenomenon are still very scanty. In 4 Her we have not observed any "photospheric" lines (He I 4471 and Mg II 4481 are blended with the shell lines) while the other authors have not studied shell lines. Note also that our interpretation implies that Baade's observations of ν Pup actually identified this star as a previously unknown bright Be star. Its further observations not only in the He I and Mg II lines but also in Hα would be very desirable.

Our observations of the weak and roughly central emission in the shell spectrum of 4 Her were obtained at two different orbital phases ($0^P.86$ and $1^P.09$). Their radial velocities are in agreement with the radial velocity curve. Unfortunately – since both observed phases are close to phases of systemic-velocity crossings – additional observations near both conjunctions are needed before a firm conclusion about the association of the emission with the Be primary in orbit will be possible.

For the moment, we conclude that the faint central emission is a real feature, probably associated with the primary star of the binary system, and causally related to the development of a new shell. Needless to say, further systematic high-S/N spectral observations are very desirable since such phases are rare and do not last too long. Moreover, in the particular case of 4 Her, systematic RV observations of the central emission peak could help to obtain more accurate orbital elements of the binary, possibly free from the effects of spurious eccentricity seen in the velocity curve of the hydrogen shell lines.

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References

Baade D. 1983, A&A 124, 283

Baade D. 1989, A&A 222, 200

Baade D. 1990, in *Angular Momentum and Mass Loss for Hot Stars*, NATO Advanced Research Workshop, (Ed. by L.A. Willson and R. Stalio), Kluwer, p. 177

Doazan V. 1976, in *Be and Shell Stars*, IAU Symp. No. 70, (Ed. by A. Slettebak), Reidel, p. 37

Harmanec P., Koubský P., Krpata J. 1973, A&A 22, 337

Harmanec P., Koubský P., Krpata J., Žďárský F. 1976, Bull. Astron.Inst.Czechosl. 27, 47

Harmanec P., Horn J., Koubský P., Žďárský F., Kříž S., Pavlovski K. 1980, Bull. Astron.Inst.Czechosl. 31, 144

Heard J.F., Hurkens R., Harmanec P., Koubský P., Krpata J. 1975, A&A 42, 47

Horn J., Hubert A.-M., Hubert H., Koubský P., Bailloux N. 1992, A&A 259, L5

Hubert H. 1971, A&A 11, 100

Jeffery C.S. 1991, MNRAS 249, 327

Porri A., Stalio R. 1988, A&AS 75, 371

Slettebak A. 1982, ApJS 50, 55

Zorec J., Briot D. 1991, A&A 245, 150

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