Spectrophotometric Signature of Circumstellar Matter around 89 Her

L.L. Kiss[1], **K. Szatmáry**[1], **J. Vinkó**[2]
[1]Astron. Obs. and Dept. of Experimental Physics, University of Szeged
[2]Dept. of Optics and Quantumelectronics, University of Szeged
H-6720 Szeged, Dóm tér 9, Hungary
E-mail: l.kiss, k.szatmary, vinko@physx.u-szeged.hu

Abstract

The bright supergiant and suspected binary star 89 Herculis is studied with help of infrared and optical spectroscopy. The high-resolution sodium D profiles suggest multiple velocity structure of circumstellar clouds. Astrophysical parameters are derived by fitting model spectra in the infrared region. Our results are in agreement with the recently emerged view of the system based on radio and infrared observations. We also discuss photometric and radial velocity variations concluding that pulsations are barely detectable in velocity data. This behaviour is likely to be caused by the spectral line profile distorsions due to circumstellar envelope.
Keywords: *stars: semiregular stars – stars: individual: 89 Her*

1. Introduction

89 Her = V441 Her = HD 163506 = IRAS 17534+2603 is a bright (V = 5.43 mag) supergiant star of spectral type F2 Ibe. This star shows a light change due to semiregular pulsation (SRd type) with P = 65 d and A $\leq$ 0.1 mag. Both the period and the amplitude of the light curve are unstable. So far there is no widely accepted explanation of the mechanism that drives this variability. As many other supergiant stars, 89 Her has circumstellar dust shells due to episodic mass loss. Changes in these shells with time can presumably be revealed by the average brightness of the star. The photoelectric V light curve was analysed with Fourier and wavelet methods earlier (Szatmáry and Kiss 1997).

The radial velocity practically does not vary with the photometric period, although Percy et al. (2000) found a broad peak in the frequency spectrum at 60-70 days. 89 Her is a spectroscopic binary with P_{orb}=288 d.

According to the commonly accepted view of 89 Her, it is a post-AGB star which evolves to a central star of a planetary nebula. The observed circumstellar envelope proves this scenario. This envelope was ejected a few thousand years ago, although there are some signs (mainly spectroscopic pieces of evidence) that sudden mass-losses occured in the last few decades too. On the other hand, the physical properties of the star are very uncertain. Neither its mass nor luminosity are known with acceptable accuracy. We obtained near-infrared spectra in the Ca-triplet regime. Fitting the hidrogen Paschen-lines with ATLAS9 models, we have obtained $T_{\rm eff} = 6000$ K and $\log g = 0.5$, as a preliminary result. This may confirm the supergiant status of the star.

The period study has revealed a 288 day variation in the light curve which is probably caused by the orbital motion: the varying distance means varying optical path in the circumstellar cloud. This periodicity cannot be detected in the color curve, hence the cloud in the line-of-sight is very homogeneous. The orbital parameters of the 89 Her system (Waters et al. 1993) are: $P_{\rm orb} = 288.36$ d, $e = 0.189$, $K=3.09\,{\rm km\,s^{-1}}$, $a_1 \sin i = 12\times10^6$ km, $f(M_2) = 0.0008\,M_\odot$. If we assume a mass of $0.6\,M_\odot$ for the primary, the most probable mass of the secondary is between 0.08 and $0.15\,M_\odot$. Adopting a luminosity for the primary of $3000\,L_\odot$, the radius is about $43\,R_\odot$ for an effective temperature of 6500 K.

2. Spectroscopic observations

High resolution optical spectroscopy was carried out on eight nights in 1996 and three nights in 1997 at the David Dunlap Observatory. We used the 1.88 m telescope equipped with the echelle spectrograph. The studied wavelength region was between 6200–6600 Å in 1996 and 5860–6660 Å in 1997. The resolution ($\lambda/\Delta\lambda$) is about 30000, while the typical S/N ratio is around 150-200.

A sample spectrum is shown in Fig. 1. The studied wavelength range covers the strong sodium D doublet and the Hα line. The latter shows very characteristic P Cygni-profile, usually attributed to a strong stellar wind. Other P Cygni-profiles are present, too, while the spectrum is fairly rich in very narrow emission lines. Several absorption lines make the spectrum partially similar to that of the "normal" stars. The general appearance suggests that even in the optical ranges the star is barely visible through the circumstellar nebula.

A question arises: how can we derive stellar radial velocities from such spectra? There are very few pure absorption lines originating in the stellar photosphere, the majority of spectral lines is disturbed by one or more emission components. It looks almost impossible to separate stellar and circumstellar contributions. Therefore, we conclude that earlier radial velocity data from medium-resolution spectra should be carefully re-analysed.

Some interesting conclusions are based on simple comparisons of different spectral lines. First, we compare the strongest sodium doublet and the Hα line

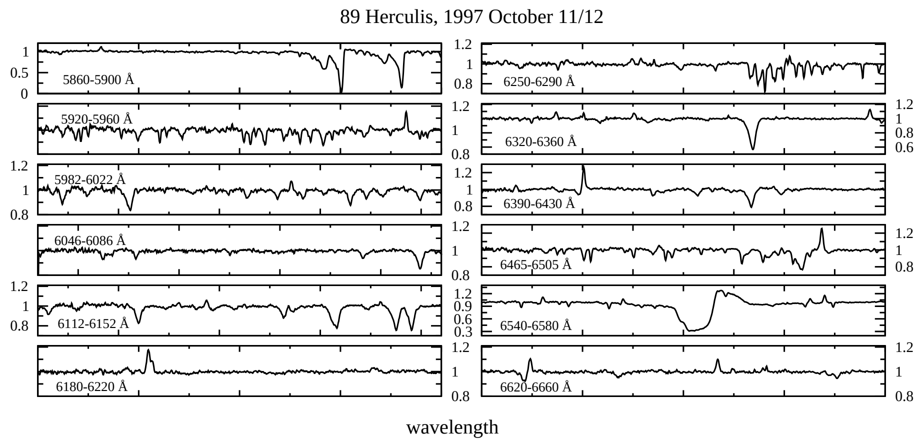

Figure 1: A sample spectrum of 89 Herculis taken in 1997. Note the different scaling of the vertical axes in different subpanels.

(Fig. 2). The two components of the doublet have very similar substructures. They are likely to originate in discrete circumstellar shells with different expansion velocities. The close similarity to the velocity structure of the Hα line strengthens the idea that the weaker components of the doublet originate at 89 Her indeed, not in the intervening interstellar matter. One can identify a shell with $v_{exp} \approx 85$ km s^{-1}, while a weaker feature is unambiguously present with $v_{exp} \approx 140$ km s^{-1}.

Second, two metallic P Cygni-profiles were compared with a pure Si II absorption line and sodium D1 line. It is interesting, that the emission components of the P Cygni-profiles coincide with the minimum of the absorption line, while the sodium D is displaced relative to all lines by more than $+10\,\mathrm{km\,s^{-1}}$.

Finally, three narrow emission lines are compared (Fig. 2). The radial velocities of the emission peaks are in very good agreement, however, the seemingly pure emission lines have companion absorption components at $\sim\!-120\,\mathrm{km\,s^{-1}}$. Our conclusion is that the optical spectrum of 89 Her is extremely complex due to the presence of circumstellar matter. A future investigation should address the various components of the whole system (a pulsating post-AGB star, a secondary companion of unknown nature, a thick circumstellar nebula with discrete velocity structures) and their contributions to the observed spectrum.

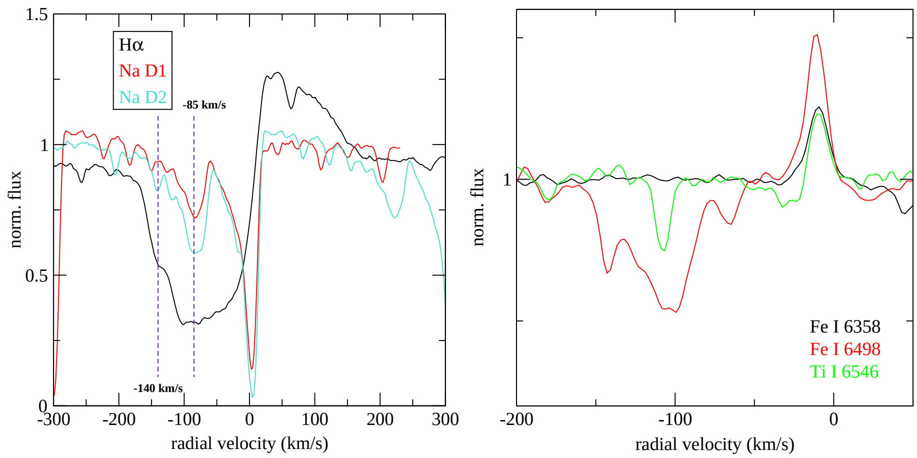

Figure 2: Left: A comparison of the strongest spectral lines. A main expansion velocity of 85 $\mathrm{km\,s^{-1}}$ is suggested by the absorption minimum of the hydrogen P Cygni-profile and the secondary components of the sodium doublet. A weaker feature is also present at $-140\,\mathrm{km\,s^{-1}}$. Right: A comparison of three seemingly pure emission lines. Although the absorption features look similar, the Fe I 6498 and Ti I 6546 lines are in that spectral region which is strongly affected by the atmospheric telluric lines.

Acknowledgements

This work was supported by the Hungarian OTKA grants No. T032258 and T034615, the "Bolyai János" Research Scholarship of LLK from the Hungarian Academy of Sciences and FKFP Grant 0010/2001.

References

Percy, J.R., Bakos, A.G., Henry, G.W., 2000, PASP 112, 840
Szatmáry, K., Kiss, L.L., 1997, IAPPP Comm. No. 67, 66
Waters, L.B., Waelkens, C., Mayor, M., Trams, N.R., 1993, A&A 269, 242