High Dispersion Investigation of CP Stars around the Hα Line

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What New Group of Stars are the CP Stars?

Nothing really new, only a terminology – Chemically Peculiar stars – which reflects the progress made both in the observational and theoretical fields of the study of stars from late B to early F type. The spectra of CP stars have in common anomalous intensities of the lines of several elements which can be interpreted as an anomalous chemical composition of their atmosphere due to surface phenomena. This terminology was first introduced by G.W. Preston in 1974 (*Ann. Review Astron. Astrophys.* **12,** 257).

CP stars are found among the whole upper main sequence and several subclasses have to be considered. From their spectra, they are generally grouped into the following classes: Helium-strong, Helium-weak, mercury-manganese, Bp including the Si λ-4200, Ap and metallic line stars. It is possible that the CNO stars represent a hotter class of these objects.

Why are Some Stars Chemically Peculiar?

The observations have shown that the atmospheres of the CP stars are more stable than those of the normal stars because of the slow rotation and/or because of the presence of a magnetic field. In such a frame, diffusion mechanism can occur and enable the production of anomalous atmospheric abundance (see for example the review presented at the IAU General Assembly in Montreal and published in the *Astronomical Journal:* S. Vauclair, *Astr. J.* **86,** 513, 1981).

This theory offers a coherent picture, and comparison between theoretical results and observations are consistent but there are still a number of remaining problems. The real situation is very complicated as diffusion mechanisms are affected by many parameters unknown or badly known, as rotation, turbulence, winds, magnetic fields. How all these parameters act together to produce the abundance observed is not yet well understood in spite of the large amount of results obtained up to now (see the last colloquium on this subject held in Liège in June 1981). Obviously more observations are needed.

To handle the problems in the best way, European astronomers have decided to unite their efforts (Mrs, Mr, Catalano, Derrider, Faraggiana, Floquet, Hensberge, Maitzen, Manfroid, Mathys, Morguleff, North, Renson, Schneider, van Santwoort, Weiss).

New instrumentation developed by ESO gives us the opportunity to extend our field of investigation. In 1982, the announcement of the availability of the Coudé Echelle Spectrometer (CES) fed by the 1.4 m Coudé Auxiliary Telescope (CAT) (D. Enard, *The Messenger* No. 26, p. 22, 1981) encouraged us to submit a programme centred on the observations of the Hα line of CP stars at high dispersion.

Why Shall We Observe the Hα Line at High Dispersion?

High-precision measurements of hydrogen line profiles are an important tool in understanding the structure of the atmosphere of early-type stars. The core of the Hα line is formed at a great height in the photosphere and therefore is very sensitive to deviation from local thermodynamic equilibrium and accelerated gas flows. The existence of hot outer regions can be detected by excess emission which occurs in the core of the Hα line. (For developments on that subject, see for example "Activity and outer atmospheres of the stars", F. Praderie, 11th advanced course, Swiss Society of Astronomy and Astrophysics, Saas Fee, 1981.)

Up to now, few observations suggest that some CP stars have outer regions at higher temperature than the one indicated by the continuum energy distribution. For example ultraviolet observations of α And (C. Aydin and M. Hack, *Astron. Astrophys. Suppl.* **33,** 27, 1978) indicated the presence of resonance lines of Si IV and probably of NV which are the signature of hot outer layers not usually observed in stars of such gravity and effective temperature.

But, with IUE observations, E. Böhm-Vitense and T. Dettmann (*Astrophysical Journal* **236,** 560, 1981) have reached a negative conclusion for 3 other Ap stars. Infrared excesses have been observed in some CP stars (Groote, D., Kaufmann, J.P., 1981, *Astron. Astrophys.* **94,** L23). O. Havnes (1981, 23rd Liège Astrophys. Coll. p. 403) analyses 3 different mechanisms for producing such infrared excesses in some CP stars, and his most likely explanation was that this infrared excess is produced by free-free emission from a gas shell around the star or from a polar stellar wind.

Those observations show the need of measurements of the Hα line profile in order to detect gas flow and/or hotter outer regions. CP stars being slow rotators, the core of the line can be precisely observed; this is not the case for normal stars where higher rotation obliterates moderate emission.

The Hα Line Profile with the CES

When you are among the first observers with a new instrument, you have in mind the obvious question, which is not necessarily trivial: how shall I reduce my observations? Don't worry if you observe with the CES system. F. Middelburg of ESO has developed a powerful system, called "IHAP", to handle it. Nevertheless, to reduce data, you have to feed the computer with some more data than only those obtained by observations: for example a wavelength table for the wavelength calibration. This is not a trivial job when you have observed in the 6550 Å spectral region with a resolving power of 100,000. Of course, there is a calibration source – a thorium

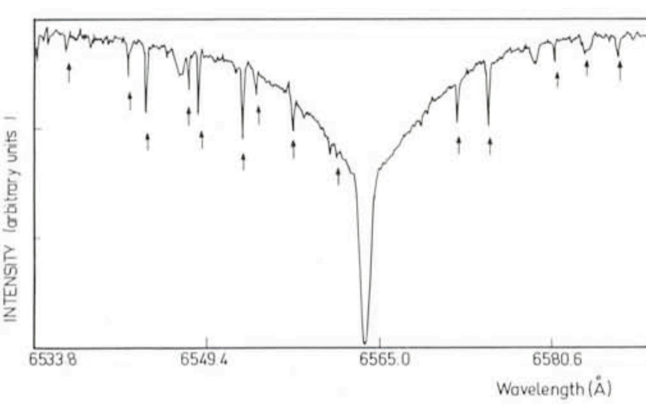


Fig. 1: *High-dispersion spectra of the star HD 17081 around the Hα line. Telluric lines shown with an arrow.*

lamp – but in the spectral range of interest there are too few lines, so it is more or less useless.

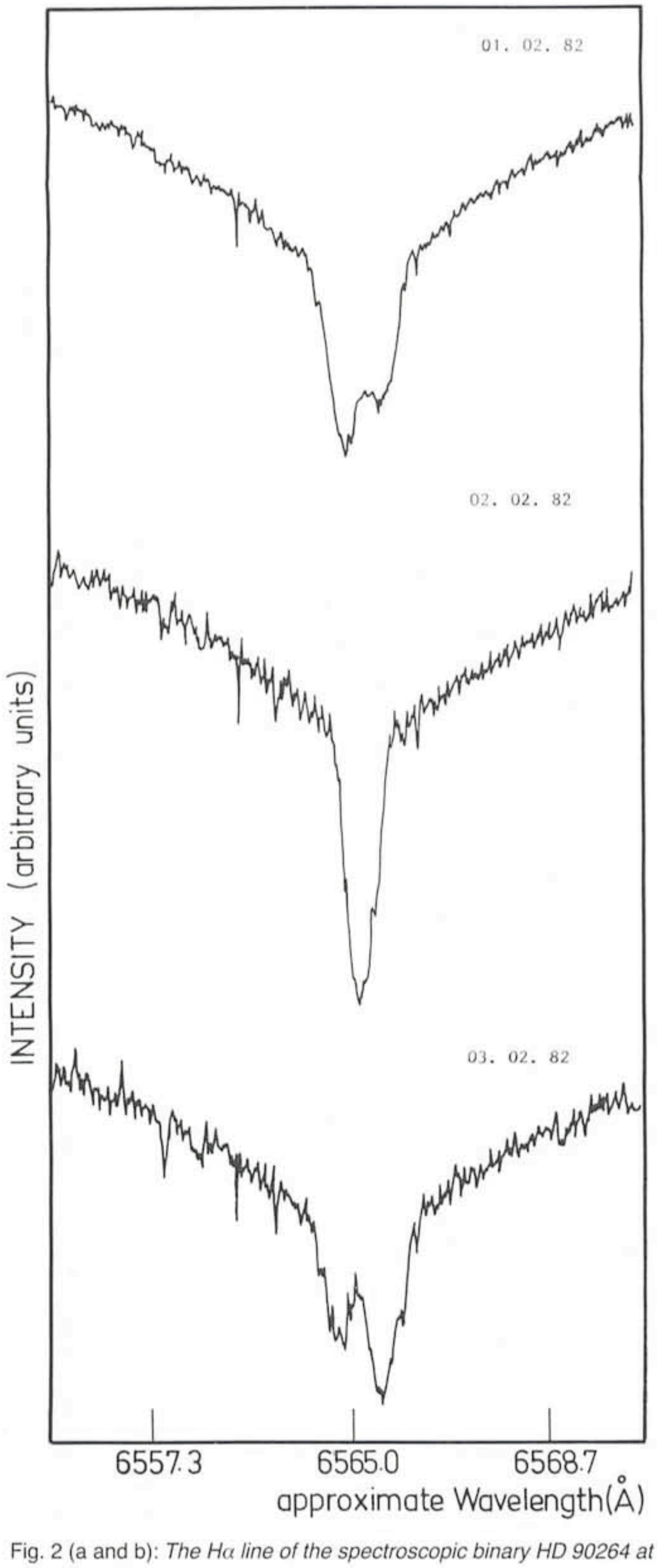
Happily nature is there! With such a resolution, telluric lines can be observed and they offer a free calibration spectrum with numerous well-spaced lines as can be seen in Fig. 1. But nothing is perfect! Some of them fall exactly in the Hα line. So, when for the first time of your life you see a high-dispersion profile of Hα of a CP star you are looking at it with a pounding heart: can you find in any little bump in the core a proof of the emission which would indicate the presence of a hotter outer region? Throughout the first night you are a bit anxious; something or nothing? If something is present in the core of the line: what is it? But, very soon, you have the answer during the observation of a star whith a large radial velocity which changes strongly the position of the Hα line: this small bump is only due to some telluric line. So we can say that none of the CP stars we observed present radical differences in their Hα profile, whatever their infrared excess.

We have observed with the CES 21 He-weak, BP and Ap stars. The He-weak stars are considered as being the extension of Bp Si stars to hotter temperatures. A quick look at the Hα line profile shows that there is no strong exotic feature. But our colleague Juan Zorec comments that some of those profiles are similar to those observed for some Be stars at certain phases of their variability. This aspect will be studied in detail with theoretical profiles of the Hα line.

The Hα Profile of the He-weak Star HD 90264

He-weak stars are defined as having abnormally weak helium lines. For more information on this subject see, for example, the introductory lecture given by Jaschek, C. and Jaschek, M. at the Colloquium on CP stars (23rd Liège Colloquium Coll. p. 417, 1981).

Among our programme stars, we observed HD 90264 which is also a double-line spectroscopic binary. Binaries are very common among Am stars and it seems that the tidal interaction is the braking agent which induces slow rotation for those stars. This scenario cannot act for the other CP stars, because their percentage of binary systems is more or less the same as that



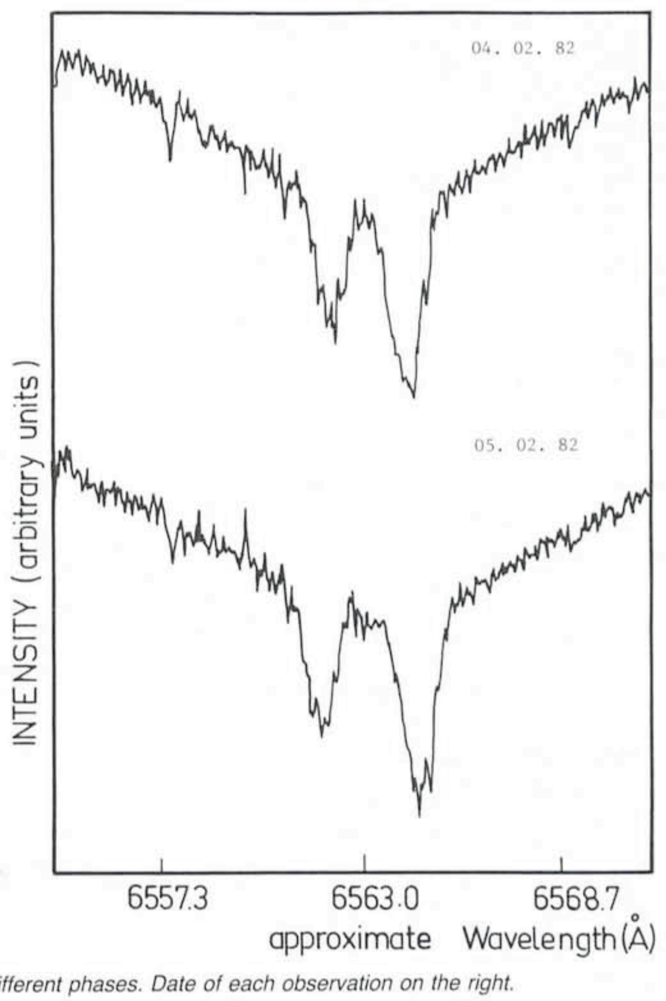


Fig. 2 (a and b): *The Hα line of the spectroscopic binary HD 90264 at different phases. Date of each observation on the right.*

of normal stars; some other mechanism must act in order to produce slow rotation: magnetic braking for instance.

Many metallic line stars have a companion which is also Am. This can easily be understood: very often the two components have nearly identical mass and luminosity so, due to their slow rotation, the diffusion process produces the same effect in each star. However, some cases are difficult to understand: for example the system 66 Eri has two stars similar in mass and luminosity but one of them is normal and the other is a Bp star.

But rather few CP stars—excluding Am stars—which are double line spectroscopic binaries have been analysed. To observe more such systems is important because it could help us to establish limits for the development of the CP phenomena either in physical condition of the atmosphere or in time scale. This is why we focussed our attention on the star HD 90264.

In spite of its magnitude ($m_v = 4.96$), the star HD 90264 is very poorly known. First quoted as being a spectroscopic binary in the radial velocity catalogue of the Lick Observatory (1912), it appears in the Wilson's radial velocity catalogue (1953) as a double-line spectroscopic binary. M. Jaschek, C. Jaschek and M. Arnal in 1969 classified it as a helium-weak star — (*P.A.S.P.* **81,** 650), of spectral type B9V. N. Houck classified it as a B8V star in the Michigan spectral catalogue.

The spectral type can also be obtained from colour indices. We estimated it from the values given by the Centre de Données stellaires. With uvby-photometry we found a spectral type B5 or B6V; using UBV photometry, M. Jaschek, C. Jaschek and M. Arnal also found a B6 type. This disagreement is the source of the definition of those stars: B-type stars for which the intensity of the helium line does not correspond either to the colour of the star or to the hydrogen line intensity.

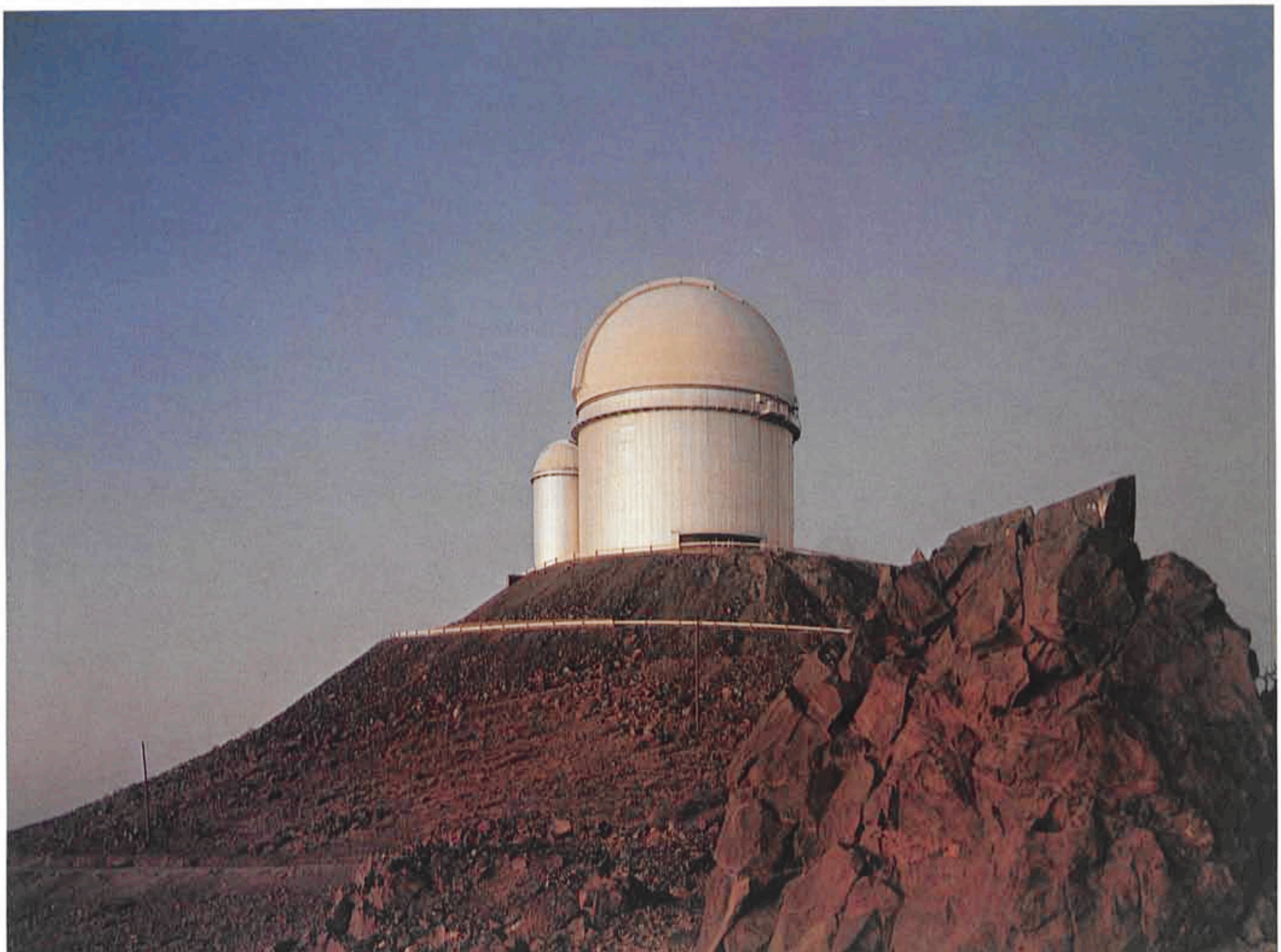
H. Pedersen and B. Thomsen (*Astron. Astrophys. Suppl.* **30,** 11, 1977) photometrically observed the behaviour of the He I λ 4026 Å line and suspected variability but could not find any definite period. F. Rufener informs us that, in the Geneva photometric system, this star shows no variability. The Hα profiles shown in Fig. 2 present different aspects due to the binarity. Apparently one quarter of the binary period is covered.

On 2 February the two components had the same radial velocity: one line is observed; on 5 February the Hα line of each component is clearly separated. From those profiles we have estimated an effective temperature of roughly 17,000 K for each star. The two components are certainly similar in mass and luminosity according to their Hα lines.

But now it is necessary to determine if both stars are—or not—CP stars. For such a purpose coudé spectra taken with the 1.5 m telescope will be the best. With spectra taken at different phases, it is possible to determine the nature of each component and to determine the parameters of the orbit. But an important question mark: How to have those spectra taken in spite of a too heavy demand of time at the 1.5 m telescope?

This question is not trivial and opens the door to a more general point: how to obtain very occasional observations of one object without applying for several telescope nights which would be ridiculous?

Last but not least, I want to express my thanks to all staff members and night assistants, and especially to Dr. E. Maurice and C. Aguirre.



The dome of the ESO 3.6 m telescope (photo C. Madsen).