The Helium Variable HD 64740—an X-ray Binary?

K. Hunger

Professor Kurt Hunger is a frequent user of the coudé spectrograph at the 1.5 m telescope on La Silla. His work has mainly concentrated on high-dispersion spectral investigations of stars with the aim of determining their physical parameters and chemical abundances. However, as is sometimes the case in fundamental research, unexpected discoveries may result from other (unrelated) programmes. The following article is a beautiful example of such an event. Professor Hunger recently left the Technical University in Berlin to succeed Prof. A. Unsöld as director of the Kiel Institute.

In the course of the spectroscopic investigation of helium-rich stars, carried out at the Institut für Astrophysik of the Technische Universität Berlin and also at the Institut für Theoretische Physik und Sternwarte of the University of Kiel, two of the stars were found to be variable in the strength of the helium lines: σ Ori E as found by K. Hunger, and HD 37776, by S. Clas-Offick. The latter was discovered independently by P.E. Nissen of the University of Aarhus, from narrow-band photometry centered at the line He I λ 4026 Å. This powerful method was later employed by H. Pedersen and B. Thomsen, also from Aarhus, who added a number of new helium variables (cf. *Messenger* No. 11, p. 15). Among these, a total of 5 helium-rich are known at present.

Despite much effort spent to unravel the nature of the prototype of the helium variables, σ Ori E, no satisfactory solution has been found so far. Is it a spotty rotating field star (oblique rotator), or is it a close binary with an accretion disc? An argument in favour of the first hypothesis is the recent discovery of a (variable) magnetic field. The binary hypothesis, on the other hand, is made plausible by the discovery of a (variable) shell. Whatever final model will emerge, the coming and going of the helium lines must be accompanied by radial velocity shifts that amount to sizeable fractions of the observed rotational velocity, v sin = 150 km/s.

No Line Shifts

However, no shifts are readily detectable, D. Groote, Berlin, and K. Hunger, Kiel, employed a rather sophisticated method to detect radial velocity variations of amplitudes as low as 1 km/s, from 20 Å/mm spectrograms, taken at La Silla. The principle of this method is as follows: two spectrograms taken at different phases are traced on the PDS-Microdensitometer of the Institute in Kiel and the output is stored on magnetic tape. The next step is to bring the two *stellar* spectrograms to optimum coincidence by shifting in wavelength one spectrogram with respect to the other.

This is done in the computer by means of a correlation function that correlates the two spectrograms for the various shifts. The maximum of this function yields the optimum coincidence. The final step then is to find out by how much the *laboratory* lines are displaced in that given relative position. The result for σ Ori E was that no radial velocity variations with amplitudes larger than 2 km/s occur, a fact that poses a serious problem to any model.

Spectra of HD 64740

An interesting by-product of the above outlined method was obtained as follows. In order to test the accuracy, the method had to be applied to a star having no radial velocity variations, and resembling as closely as possible the spectrum of σ Ori E. These conditions are hardly met by any known stable star. Therefore, the brightest helium star that itself is a helium variable, was chosen, HD 64740, with $m_V = 4^m.6$, and several spectrograms were taken in rapid succession (exposure time ≈ 6 min) to ensure that no velocity shifts occurred between the first and the last plate. This test indeed proved the above claimed accuracy.

To make further use of these test plates, D. Groote and J.P. Kaufmann, Berlin, started a detailed spectral analysis of HD 64740, based on a computer averaged spectrum that is composed of a total of 8 spectrograms, each belonging to the phase of helium minimum, and each widened to 0.5 mm. The emulsion is Kodak IIa-O, baked in nitrogen. Figure 1 demonstrates how smooth the averaged (intensity) tracing comes out, the quality almost approaching solar standards! The observed profile of H_δ and He I 4121 is given by the full

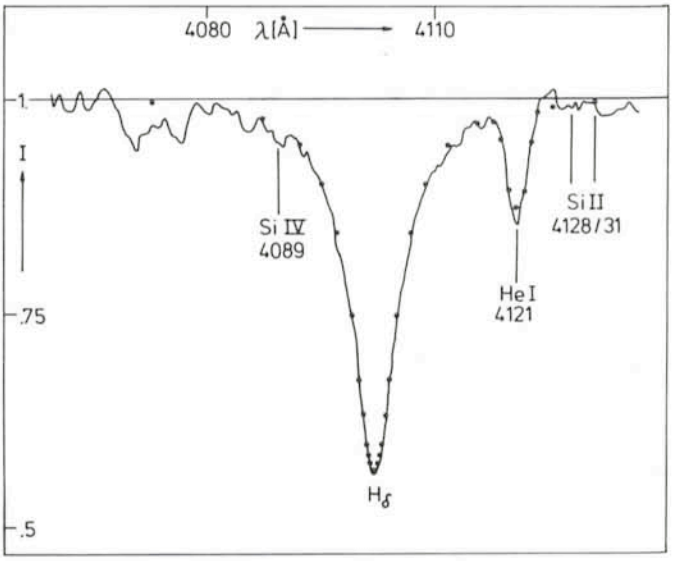

Fig. 1. — *Computer averaged spectrum of HD 64740 near 4100 Å.*

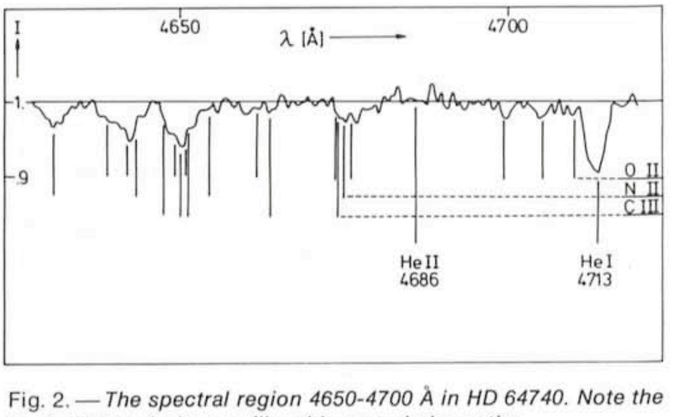

Fig. 2. — *The spectral region 4650-4700 Å in HD 64740. Note the He II 4686 emission profile with central absorption.*

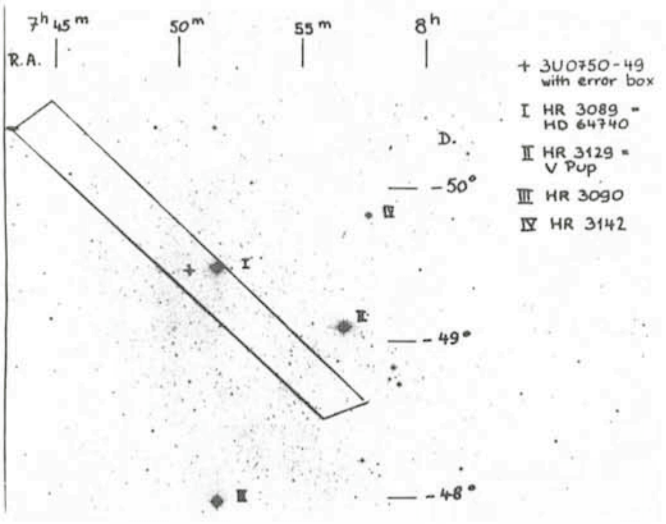

Fig. 3. — *The sky area near the X-ray source 3U 0750-49.*

line. Dots represent the theoretical profile obtained from an adapted model atmosphere. The effective temperature turns out to be exceptionally high (27,000 K), for the class of helium variables. At this temperature, the line of He II λ 4686 Å should appear in absorption with an equivalent width of 50 mÅ. Figure 2 shows a portion of the spectrum from λ 4650 to 4700 Å. No absorption line is readily detectable at λ 4686, although the weak lines of O II, N II and C III can be identified down to 20 mÅ (for identification see the right-hand scale).

Instead, a broad emission feature is indicated, with a central absorption of the anticipated strength. The emission exceeds the (well-defined) continuum by 2 per cent.

A New Class of X-ray Sources?

In X-ray binary systems, He II λ 4686 sometimes appears in emission. HD 64740 indeed is located inside the error box of the weak source 3U 0750-49 (see Fig. 3) as was noted already by Pedersen and Thomsen, whereas the contact binary V Pup, so far suspected to be the candidate, lies 3 arc min outside the error box. Better X-ray positions are needed to confirm the identification. However, if confirmed, it would mean that a new class of X-ray sources has been found. It would also solve the mystery of the helium variables, which would then be binaries containing a compact object, i.e. either white dwarf or neutron star.

The N 119 Complex in the Large Magellanic Cloud

J. Melnick

One of the most striking objects seen in blue photographs of the Large Magellanic Cloud (LMC) is a spiral-shaped H II region situated almost at the very centre of the so-called "bar" of the LMC. This H II region is generally referred to as N 119, since it is the one hundred and nineteenth entry in a catalogue of emission nebulae in the LMC prepared in 1956 by the American astronomer Karl Henize.

Figure 1 shows a negative enlargement of N 119 made from an excellent ultraviolet plate of the central region of the LMC obtained with the ESO Schmidt telescope on La Silla. On this plate, the peculiar structure of N 119 can be very clearly appreciated. It mainly consists of a bright condensation with a bright star cluster at its centre and two prominent, spiral-shaped filaments extending several arc-minutes on either side of the nuclear region. The overall diameter of the "spiral" filaments is about 8 arc-minutes or more than 100 pc, i.e. more than twenty times larger than the Orion nebula; indeed, even the central part of N 119 is already much larger than Orion!

It can also be seen in figure 1 that the area around N 119 appears to be a region of relatively recent and vigorous star formation. Several open clusters may be discerned on the photograph as well as a large number of individual stars which are significantly brighter than the field stars in the LMC bar. In addition, the whole region is covered with faint, diffuse gaseous filaments.

What is the nature of this peculiar object? Are the spiral-shaped filaments only the densest parts of a gigantic spherical shell of gas seen projected against the plane of the sky? If so, is this shell expanding? Or are the filaments really thin wisps of gas in the interstellar space? With these questions in mind, and as part of a more general programme, investigating the internal kinematics of giant emission nebulae in external galaxies, I have obtained accurate velocity profiles at the positions along the "arms" of N 119 as indicated in figure 1.

The Fabry-Pérot Spectrometer

The instrument used for this work was a photoelectric Pressure-Scanned Fabry-Pérot Spectrometer at the 1.5 m telescope of the Cerro-Tololo Interamerican Observatory. The principle of operation of the Fabry-Pérot interferometer is illustrated in figure 2.

It basically consists of two parallel, semi-transparent mirrors. Parallel light entering the cavity formed by the two mirrors undergoes multiple reflections inside the cavity, producing the interference pattern shown in figure 3. When perfectly monochromatic light is fed into the cavity, it is then concentrated by the interferometer in very narrow rings, each corresponding to the same wavelength, but to a different interference order. Assuming that the mirrors are perfectly parallel, the resolution of the interferometer is given by the width of the rings which in turn depends on the number of reflections inside the mirrors and on their separation. With the advent of low-absorption dialectric multilayer coatings, very narrow rings can be produced.

In typical astronomical use the wavelength of the line to be studied is first preselected, usually by means of interference filters. However, the observed light is still not monochromatic and the width of the rings depends also on the intrinsic width of the observed line. Since the "instrumental" width of the rings is very small, very accurate information about the shape of the observed lines can be obtained.

Typically, Fabry-Pérot interferometers are used in two modes: In the first, more classical mode, a Fabry-Pérot is placed in front of a photographic camera, for instance to