BD Pavonis: Nova, Dwarf Nova, or . . . ?

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Among all kinds of stars probably the most spectacular ones are novae, which suddenly increase their brightness up to more than a million times and then fade again in timescales of months or years to their original faintness. In spite of this outstanding, dramatic behaviour these objects have many properties in common with other so-called cataclysmic variables (CV).

From numerous observational and theoretical work we have learned that these particular stars are very close binaries, some with orbital dimensions of the order of our sun's diameter. The systems consist of a late-type secondary filling its Roche lobe, and a very compact hot primary, which is supposed to be a white dwarf or even a neutron star. Matter flowing from the expanding cooler companion towards the primary normally cannot reach its surface directly due to its excess angular momentum. It is therefore stored first in a rotating accretion disk. An important subgroup of the CVs are the dwarf novae which in contrary to novae show quasiperiodic outbursts on a timescale of days with much smaller amplitudes.

R. Schoembs and I learned in the course of an observing programme started three years ago that a nova can attract attention not only during its discovery but even fifty years later. Part of our observations aimed at the investigation of relatively unknown old novae in the southern hemisphere. About 85 such objects, for which only fragmentary data exist, had been reported by Payne-Gaposchkin ("The Galactic Novae", 1957). Twenty-two of them were selected according to the indicated brightness and the reliability of finding charts that could be found in the literature.

In order to use the allotted observing time most efficiently, we started with taking image-tube spectra at the 1.5 m ESO telescope in June, 1980, to decide which candidates should be observed in more detail and which were even no longer detectable. For a rough brightness estimation the density of each 20-min. exposure was taken. Every two hours a plate containing the spectra of 6 different objects was developed. Probably only a spectroscopist can imagine our tension whenever the exposures were ready for a quick, first inspection in the darkroom.

One of the spectra, that of BD Pav, attracted our particular interest. It showed broad, strong, double emission lines on a well-exposed continuum (Fig. 1) suggesting a visual brightness around 15th magnitude. We were looking for just such spectra, since the doubling of lines, originating from the accretion disk, normally indicates binaries with high orbital inclination which favours the occurrence of eclipse phenomena and considerable radial velocity variations which could provide important information about the binary system.

Payne-Gaposchkin gives a brief note about BD Pav: The star has been discovered by C. D. Boyd (*Harv. Ann.* **90**, 248, 1939) on two plates taken in 1934. Within a time interval of less than 4 days the star has brightened from invisibility to 12^{m}.4. 20^{d} later it had become invisible again, i.e. fainter than 16^{m}.5. Due to the short timescale of its disappearance and the unknown minimum brightness the star has been classified as a faint, fast nova.

Had BD Pav now brightened again? Is the classification as a nova correct at all? – The possibility of a small outburst amplitude already raised some doubt.

This was enough to monitor this object photometrically during the following nights. Fast photometry with a time resolution of 3 s was performed using the 1 m ESO and the 1.5 m Danish telescope, partly operating both telescopes simultaneously in the visual and near infrared wavelength regions. Soon after starting the measurements, short-time variations ("flickering") became visible, a characteristic property of most CVs.

More exciting, however, were quasi-periodic light variations, which occurred on a timescale of about one hour and sudden deep depressions of the light-curve that looked like eclipse features (Fig. 2). Since that night was by no means photometric and even some clouds could be recognized, we were not able

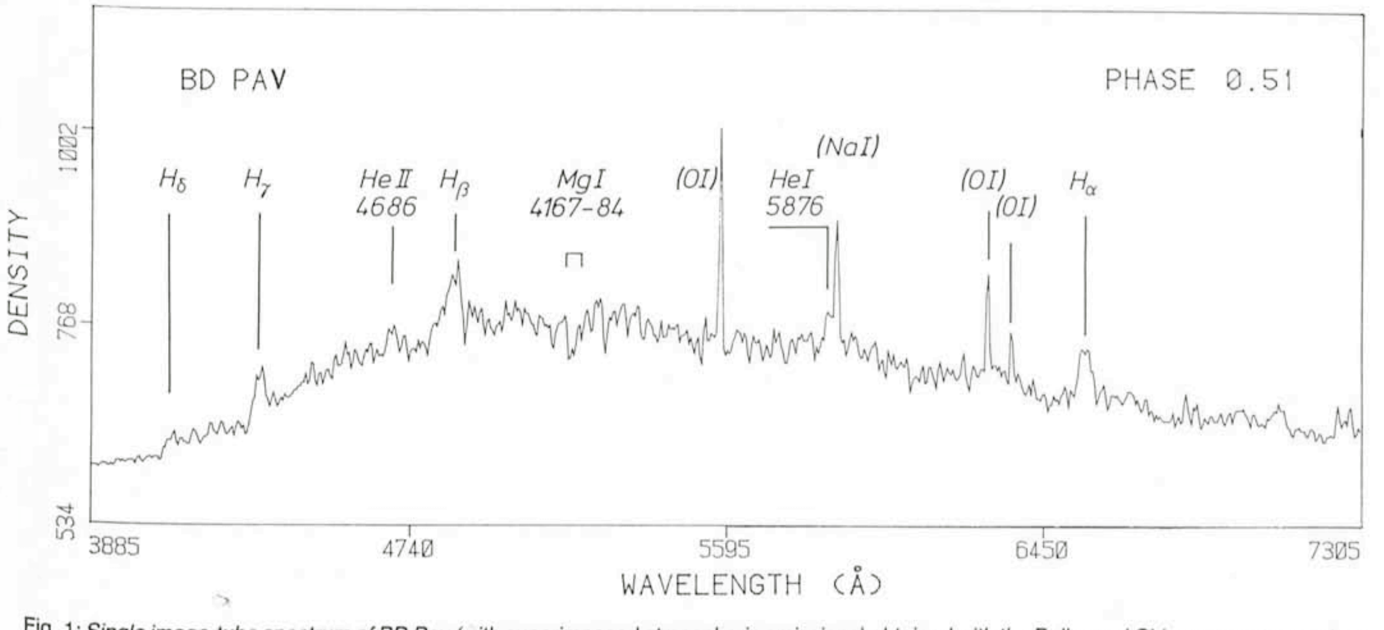

Fig. 1: *Single image-tube spectrum of BD Pav (with superimposed atmospheric emissions) obtained with the Boller and Chivens spectrograph at the ESO 1.5 m telescope. Dispersion: 114 Å/mm, exposure time: 20 min.*

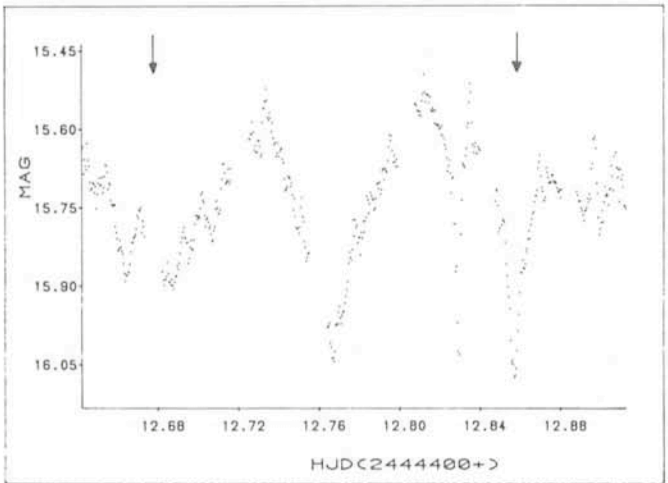

Fig. 2: *First light-curve (in white light) of BD Pav recorded in 1980 at the Danish 1.5 m telescope. The timings of primary eclipse, derived from the 1981 observations, are marked by arrows. The measurements are strongly affected by changing atmospheric transparency as can be seen by comparison with Fig. 3.*

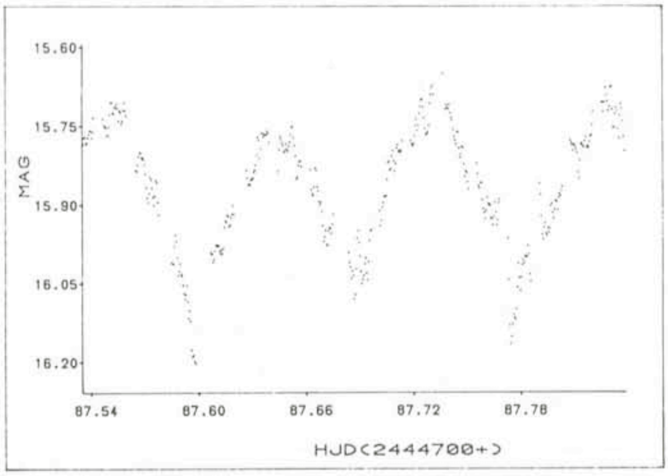

Fig. 3: *B light-curve of BD Pav, obtained in 1981, showing the double hump between two successive primary minima. Interruptions are due to comparison star monitoring.*

to distinguish between intrinsic or atmospheric variations by that time. Bad weather conditions closed down observation for the remaining observing time. So we had to learn this way one of the possible reasons why this object remained almost unobserved: The sky position of BD Pav ($\alpha = 18^h39^m$, $\delta = -57°35'$) makes it observable only during winter time, when the number of clear nights are considerably reduced.

A second observing run in 1981 was more successful. Five clear nights at the 1 m ESO telescope could be used for high-speed photometry, covering sequentially the wavelength region from ultraviolet to the near infrared. Furthermore 13 successive spectra were taken at the 1.5 m ESO telescope at a dispersion of 114 Å/mm.

Periodic light variations, already suggested one year before could now be clearly confirmed. The mean brightness of $m_v = 15.5$ had not changed. If we accept this value for the minimum brightness of BD Pav, the amplitude of the eruption in 1934 and its short timescale indicates a dwarf nova outburst. Since no other eruptions were reported, a long outburst cycle, however, has to be assumed.

A typical light-curve of BD Pav is shown in Fig. 3. It is characterized by a double hump ($\Delta m = .5$) and a sharp eclipse feature (primary minimum) repeating with strict phase stability. From the observed timings of this minimum an orbital period of $4^h18.2^m$ was derived. Whereas this short period is usual for CVs the shape of the light-curve is by no means usual. (A refined average light-curve can be found in a paper by Barwig, H., Schoembs, R.: 1983, *Astronomy and Astrophysics,* **124,** 287). Normally only a single hump is observed in the visual light-curve of CVs with suitable orbital inclination. It can be explained by the changing aspect of a hot spot on the accretion disk. In systems where the inclination is sufficiently high, an obscuration of this spot and of the primary or inner disk region can occur, yielding a sharp, short-lasting depression on the trailing edge of the hump. As opposed to this, BD Pav shows the eclipse centred in the middle between two humps.

Another surprising property of BD Pav is its red colour ($B–V = {}^{m}.63$) which corresponds to a cool G star like our sun. CVs with short periods usually show a very blue continuum caused by radiation from the spot-disk-primary configuration. Only in systems with orbital periods exceeding 6^h does the cool red secondary gain more influence in visual light due to its larger dimension.

What kind of star is BD Pav in fact? Sometimes we even doubted its classification as a CV.

However, beside the puzzling red colour and the strange shape of its light-curve this star certainly exhibits a lot of properties characteristic of CVs: The outburst, the short orbital period, the flickering activity, an emission-line spectrum and a short deep eclipse.

In order to get out of this dilemma, we might assume that BD Pav contains a luminous evolved secondary whose radiation significantly contributes to the visual system brightness. In this case the companion star could produce the observed "ellipsoidal variable" type light-curve as a result of its tidal distortion. Similar light-curves have been recorded for normal short period CVs when observed at infrared wavelengths, where radiation from the cool main-sequence secondary becomes dominant (Bailey et al. 1981, *Mon. Not. R. Astr. Soc.,* **196,** 121).

On the other hand one might expect that BD Pav should behave more like a normal CV at shorter wavelengths. Indeed, a phase shift of the ultraviolet light-curve relative to the visual curve is observed. Hence the eclipse feature which occurs at the same orbital phase in all colours appears now at a position where it is found usually for CVs.

From the theoretical point of view (H. Ritter, 1983, in: Proceedings of IAU Coll. No. 72, 257) the secondary of a cataclysmic binary could in fact be significantly evolved depending on the mass ratio of its progenitor system. However, no such system has ever been observed so far.

For a further investigation of BD Pav, a new observational programme has been proposed last year. Spectroscopy and simultaneous multicolour photometry should be performed in order to separate the radiation of the primary-disk-configuration and of the secondary.

Extreme weather conditions in July 1983 (i.e. heavy snowfall on La Silla lasting for days) permitted only one single, not even photometric night of observation at the 90 cm Dutch telescope used for 5-colour measurements with the Walraven photometer. BD Pav again could successfully hide away.

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