Rapid Spectral Variations of Old Novae

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Novae are a subclass of cataclysmic variables. The latter all appear to be binary with a white dwarf component and a companion usually near the main sequence. This companion seems to fill its Roche lobe and lose mass to the white dwarf via the inner Lagrangian point. Unless the magnetic field of the white dwarf is very strong, the transferred mass is expected to spiral slowly to the white dwarf in an accretion disk, whose presence explains many observations. Different kinds of cataclysmic variable exist, such as different sorts of dwarf novae with outbursts generally having an amplitude of a few magnitudes at intervals of the order of weeks. The orbital periods determined up to April 1987 (Ritter 1987) lie between 2.00 days (the nova GK Per) and 0.052 days (the dwarf nova AF Cam), with a "period gap" between 0.118 and 0.086 days (only one known period inside the gap).

Classical novae brighten very rapidly by a factor in the majority of cases of more than 10,000 in the optical, then fading to what is normaly the pre-outburst brightness. This brightening is associated with the ejection of material at velocities of the order of 10^3 km s^{-1}. After optical maximum, novae go through a number of stages in their development; the speed of this development is referred to by the expression "speed class", and can be quantitatively measured for instance by t_3 the time to fade 3 magnitudes. An approximate anticorrelation exists between t_3 and the absolute brightness at optical maximum; however, novae in outburst show important differences, which appear hard to describe by only one parameter.

More or less all who study the causes of the outbursts of classical novae agree that outbursts are due to thermonuclear runaways in the material accreted by the white dwarf, though the situation is less clear for recurrent novae, i.e. for novae for which more than one outburst has been observed. A great success of the theory was the prediction that fast nova outbursts (that is with a rapid development and a small t_3 required overabundances in the CNO elements, confirmed by analyses of observations. However, many "details" are far from clear, including in particular the effects of departures from spherical symmetry.

The relation of the characteristics of novae in outburst to those before outburst is not really known. This is especially the case because the processes after the initial explosion are badly understood. It appears necessary, however, to invoke the presence of a very strong wind, which should play a major role in these processes (Friedjung 1987a, 1987b).

The fourth edition of the catalogue of cataclysmic binary orbits by Ritter (1987) lists 13 classical novae for which periods have been measured. However, all of those were not well observed during their outbursts: t_3 is even not known for 2 of them. No clear relation between t_3 and the period emerges for the others, which is not surprising in view of the fact that outburst properties can be expected to depend on a number of different characteristics of the binary such as period, white dwarf mass (which when near the Chandrasekhar limit should radically change element abundances according to theory), inclination of the orbit to the line of sight, etc. Therefore, far more orbital data are needed, particularly for novae well observed during outburst.

It was for such reasons that we started our programme to observe the spectra of old novae. Rapid spectral variations should be produced by orbital motion, but if the white dwarf is strongly magnetic, its rotation could cause other variations (DQ Herculus star), while flickering can also be present.

In our first observing run in May 1984 with the ESO 1.5-m telescope and the IDS, we obtained striking first results for the old nova CP Pub (which had a very small t_3 in outburst). Rapid variations were seen, suggesting a very short period. In a first examination (Bianchini et al. 1985a, 1985b) we studied the radial velocity variations of the Hα, Hβ and He II 4686 Å emission lines. Periodicity was investigated using the method of power spectra, and several possible periods were detected (see Fig. 1). The reason for the detection of so many periods was that observations were only made during a few hours (generally of the order of 0.1 day or less) on 4 successive nights for Hβ and He II 4686 Å at 59 Å/mm (and one night for these lines plus Hα at 114 Å/mm). Therefore, there was a lot of aliasing between the true period and the period of rotation of the earth. We sought the periods which gave the least scatter about the radial velocity curves for Hβ and He II 4686 Å. We also used physical and geometrical arguments suggested by various effects such as an apparent Hβ eclipse in one observation. We concluded that a period of 0.06115 days was the most probable, but others such as 0.05765 or 0.06977 days could not be excluded. If really orbital, this is the first classical nova period determined below the period gap, and contradicts a suggestion made some years ago that such a period is impossible for a nova.

However, the radial velocities were obtained by eye estimates of the profile peaks, and in view of the noise, doubt can be cast on this procedure. Indeed, the first author of this article was quite disgusted when he saw profiles on a screen! We therefore decided to reduce our first observations differently. We found the mean wavelength of lines averaging the emission over the profile (Bianchini et al. 1985c). Power spectrum analysis however gave results which were less clear than previously! There was an indication of a possible secondary period at 0.04 days, as well as a main period defined by Hβ of 0.0605 or 0.0571 days, though He II 4686 Å gave a better fit for a period below the minimum for cataclysmic variables.

If we had been alone this would not have been too encouraging. But thank God for colleagues! Our discovery of a very short period for CP Pup was confirmed soon after by two independent studies. Warner (1985) studied CP Pup

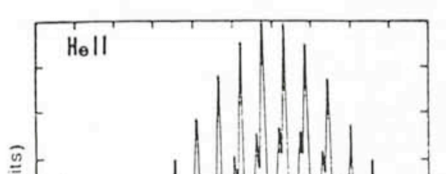

Figure 1: *Power spectra of H II λ 4686 and Hβ radial velocities in CP Pup.*

photometrically and found a period of 0.06196 days or its alias 0.06614 days. Duerbeck et al. (1987) analysed radial velocities from spectra, and obtained a period of 0.0614215 days. The lesson, especially if one wished to go further, was that more observations were required, if possible with more powerful instrumentation. The line flux variations also needed more study.

We again obtained time in March 1988 on the ESO 1.5-m telescope with a CCD. Reductions are not yet complete; up to now we have concentrated on the analysis of observations of the very old nova V 841 Oph (1848) for which we did not detect variations in 1984. The study of this nova is especially interesting, as theory and observation have both been used to support models in which very old novae go into "hibernation". The idea is that mass transfer decreases or stops, so the accretion disk disappears or becomes very faint. At present these ideas have run into theoretical problems, and the situation is not clear . . .

Our 1988 results for V 841 Oph are for 14 epochs. He II 4686 Å emission is stronger than that of Hβ, the latter being apparently in broad absorption. Line flux variations seem to be large. The best preliminary period is 0.385 days but 0.63 days or perhaps even a period near 2 days are possible. The semi-amplitude of the velocity variation is about 130 km s^{-1} for Hβ, but only about 80 km s^{-1} for He II 4686 Å. Reductions are proceeding, but in view of the probably rather long period, more observations, if possible in two runs a few weeks apart, are desirable.

The recurrent nova T Pyx also observed in the last 1988 run may be mentioned. No variations were immediately apparent.

The main conclusion that can be drawn is that far more observations are required, if one wishes to relate the properties of novae in outburst to those of their orbits. This is necessary if theoretical speculations are not to become too wild!

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NEWS ON ESO INSTRUMENTATION

Status of the ESO Infrared Array Camera – IRAC

IRAC is currently being tested in Garching in preparation for its installation and first test on the 2.2-m telescope at the end of June 1988. Assuming there are no unpleasant surprises, it is intended in July/August 1988 to issue a formal announcement of its availability for visiting astronomers in Period 43, i.e. as of April 1989. In the meantime, it is hoped that this article will serve as a useful introduction to this new instrument and its observational capabilities.

IRAC Characteristics

With its presently installed Hg:Cd:Te array detector, this camera provides for direct imaging over the wavelength range 1 to 4.3 μm. In addition to the standard near infrared broad-band filters, it is also equipped with circular variable filters (CVF) for imaging spectral features and the nearby continuum at R ≃ 50. There is also a choice of four magnifications which are selectable on-line. Table 1 summarizes the most important parameters required for planning observational programmes. The detector performance figures quoted were derived from the first test measurements of a new array received only a few weeks ago. Some caution is therefore necessary. In principle, however, it should be possible to reach sky background limited magnitudes of 20–21 mag. in the J, H and K bands with this array. In practice, of course, this will depend on whether or not the required stability and accuracy of flat-fielding (~ 1 in 10^4) can be achieved.

Optical Design

Figure 1 shows the optical arrangement. The input doublet acts as the cryostat window and forms a small (2.5 mm) image of the telescope pupil at the position of the filter wheel which carries both the broad-band and CVF filters. Behind this is located a second wheel carrying the various objectives which re-image the field on the array at a variety of magnifications. For each magnification there are, in fact, two objectives which are coated and adjusted separately for the 1–2.5 μm and 2.5–5 μm ranges. In addition to positioning the various objectives, the lens

TABLE 1: *IRAC Characteristics*

Array Detector:	Hg:Cd:Te/CCD 64 × 64 pixels, 48 μm pitch Wavelength cut-off ≃ 4.3 μm Overall efficiency ≃ 70 % Read noise ≃ 200e Dark current ≃ few 10^3 e/s (52 K) Well capacity 2.10^6e
Optics:	Magnifications (remotely selectable) 0.3, 0.5, 0.8, 1.6″/pixel (2.2 m) Maximum field ∅ = 1.6′ (2.2 m)
Filters:	J (1.25 μm), H (1.65 μm), K (2.2 μm), L′ (3.8 μm) CVF (R ≃ 50) 1.45–2.65 μm, 2.5–4.5 μm
Magnitude Limits: (3 σ, 1 hr)	20–21 mag./pixel in J, H, K bands (highly provisional)