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Letter to the Editor

Outbursts in TV Columbae: Walraven photometry and CCD spectroscopy*

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Summary

Two outbursts of the intermediate polar TV Col/2A0526-328 have been observed with Walraven photometry. For one of the bursts we have also obtained simultaneous CCD spectroscopy. Both events lasted ≈ 5 h and showed an increase of about 2 mag in V over the quiescent brightness level with smaller changes on time scales of minutes. The burst spectra show strongly enhanced HeII λ4686 emission and several lines which have not previously been observed in this object. We give a brief qualitative discussion of these outbursts in terms of existing models for accretion instabilities in cataclysmic variables.

Keywords: stars,binaries,close; stars,novae.

1. Introduction

The variable star TV Columbae was identified as the optical counterpart of the X-ray source 2A0526-328 (Cooke et al.,1978) by Charles et al.(1979) on the basis of its accurate HEAO-1 position (Schwartz et al.,1978) and the strong emission lines in its spectrum.

The optical brightness of TV Col varies with a period of 5.19 h and (perhaps) ≈ 4 d (Motch,1981) while the radial velocity derived from the emission lines shows a 5.49 h variation (Hutchings et al.,1981). This spectroscopic period is generally accepted to be the orbital period. The 4 d modulation is probably the beat between the photometric (5.19 h) and spectroscopic (5.49 h) periods. It is remarkable that the UV brightness of the system varies with the spectroscopic but not with the photometric period (Bonnet-Bidaud et al.,1985).

The presence of three periods interrelated by a beat phenomenon, strongly suggests that TV Col is an intermediate polar. The presence of a relatively strong HeII λ4686 emission line (with an EW typically half that of Hβ) also bears this out. It was then natural to associate the photometric period with the rotation of the accreting , magnetised white dwarf. However, the discovery of a 1911 s X-ray period (Schrijver et al.,1985,1987) indicates (by analogy with the ≈ 1000s spin periods in other intermediate polars) that this model is incorrect.

Clearly, another clock is present in the system in addition to those of the spin and orbital motion. It has been suggested that this is the precession period of a tilted accretion disk (Bonnet-Bidaud et al.,1985). If the white dwarf has a large magnetosphere which possibly prevents the inner part of the accretion disk from forming, it is not obvious that such a precessing disk can be present.

During a photometric programme aimed at improving our understanding of this complicated system, we have observed two outbursts of TV Columbae. The second burst was also monitored spectroscopically. Here we present a brief discussion of these observations.

2. Observations

The photometric observations were made with the 0.91 m Dutch telescope at the ESO, La Silla site. The five colour Walraven photometer (Lub and Pel,1977) was used to monitor TV Col over several nights in November and December 1987. During some of these nights the 1.52 m ESO telescope with Boller and Chivens spectrograph and RCA CCD was used to take simultaneous spectra of TV Col. All data were reduced using the computing facilities at La Silla. The photometry was reduced using many Walraven standards and two nearby comparison stars which were observed frequently during the monitoring. All spectra were, after CCD bias removal and flatfielding, corrected for sky lines and extinction, and finally flux calibrated using a standard star.

The first outburst started at V≈ 14 on November 26.13 UT and reached its peak brightness of V≈ 11.9 on November 26.23 UT; the second burst started before December 04.06 UT and had decayed from V≈ 12 to V≈ 13 by December 04.31 UT.

Spectroscopy was done on the nights of 29 and 30 November and 3,4,5,27 and 28 December. Two gratings were used, with dispersions of 224 and 172 Å/mm and wavelength ranges of 3725-6790 Åand 4350-6850 Årespectively. A total of 83 spectra were recorded. Here we will discuss mainly the spectra taken during the second burst with the 172 Å/mm grating.

3. Results

The light curves obtained during the two outbursts are shown in Figure 1. The first was monitored during the rise, the second during (probable) maximum and decline. The rise of the first event took just over 2 h, i.e. nearly twice as long as for the outburst observed by Szkody and Mateo (1984). The fastest observed change in optical brightness (for burst 1 at day fraction 0.216) is ≈ 0.65 mag within 6 m.

Both outbursts showed a dip in the light curve; these dips are similar in strength and shape. When the curves are superimposed with the dips lined up, they form a smooth overall curve, suggesting that the light curves of the two events are similar.

In both outbursts V-B, B-U and B-L decrease with increasing brightness, corresponding to bluer colours (cf. Szkody and Mateo, 1984). Additionally, for the second event, B-U and (less clearly so) B-L show a dip associated with the dip in the light curve.

(*) Based on observations made at the European Southern Observatory.

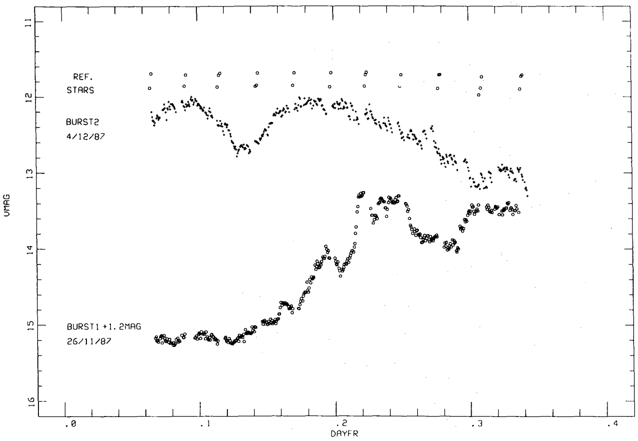

Figure 1.
The Walraven V magnitudes for both events are plotted against dayfraction. Two comparison stars are also shown as reference. The first light curve has been displaced downwards by 1.2 mag for clarity.

Figure 2 shows a spectrum taken during the peak of the second outburst and one taken in the quiescent state. All quiescent spectra show several emission lines characteristic of intermediate polars, the strongest of which are Hα, Hβ, HeI $\lambda\lambda$4471, 4922, 5016, 5876, 6678 and HeII λ4686. During outburst, additional lines appear eg. the CIII/NIII λ4640 complex, HeII $\lambda\lambda$5411, 6683 and NIV λ5794. Clearly, the excitation level is higher during the burst as shown by the increased strengths of the emission lines, especially HeII λ4686, which increased its flux by a factor of ≈ 40 over that in quiescence and became significantly brighter than Hβ. The equivalent widths of the three strongest lines are plotted in Figure 3 as a function of time, where the pre burst values have been set equal to more clearly show the different relative increases to peak values. Note that the post burst values are all similar and somewhat lower than before the event. Also interesting is the fact that the HeII line peaks before the hydrogen lines reach their maximum values.

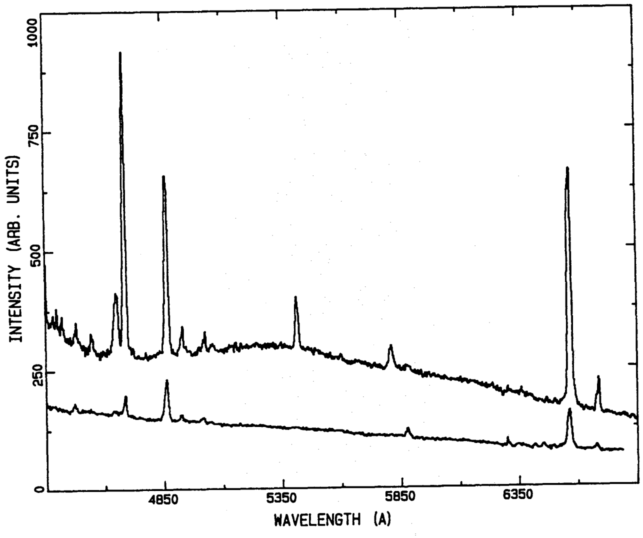

Figure 2.
The peak burst spectrum is shown together with a typical quiescent spectrum.

4. Discussion

Our observations increase the sample of short outbursts from TV Col from one to three. A similar short outburst has also been observed from the intermediate polar V1223 Sgr (van Amerongen et al., in preparation). This suggests, notwithstanding their apparent rarity, that these short events are a characteristic of the intermediate polars.

There is little doubt that the outbursts are caused by an instability in the accretion flow onto the white dwarf. They differ in a number of aspects from the well known dwarf nova outbursts. (i) They last about an order of magnitude shorter than dwarf nova events (between 5 and 24 hrs. as against 2 to 10 days respectively) while their magnitudes are within the normal range for dwarf nova events, albeit on the low side. (ii) During the outbursts both the UV and optical emission lines increase their strengths while in dwarf novae the lines disappear during the burst. (iii) While in dwarf nova events the UV flux increase is delayed with respect to the optical rise by about a day, no such delay was found in the TV Col event observed by Szkody and Mateo(1984). (iv) Dwarf novae redden during outbursts while TV Col became slightly bluer as it brightened.

The disappearance of the emission lines in dwarf novae is generally explained as being due to the strong increase in the optical thickness of the whole accretion disk. The rise time and UV delay (both ≈ 1 day) probably reflect the time needed for matter to travel from the cool outer parts of the disk to the hot inner region.

A straightforward explanation of the different properties of the outbursts from TV Col would therefore be that the system lacks the inner part of the accretion disk. The reason for the non-existence of the inner disk is the strong magnetic field of the white dwarf creating a magnetosphere within which the Keplerian motion of the accreting matter is disrupted. Although it is not possible to give an accurate estimate of the radius of the magnetosphere (we do not know the magnetic field of the white dwarf or have a sufficient understanding of the interaction between the inner disk and the magnetosphere), there is strong evidence that it is not small compared to the white dwarf Roche lobe radius (e.g. King et al.,1985).

The short rise time and absence of a UV delay would then qualitatively be explained by: (1) the relatively short time needed for matter to diffuse inwards to the magnetosphere; (2) the fact that the outburst luminosity is dominated by emission from the immediate vicinity of the white dwarf which is reached in approximately a free fall time scale (≈ 1 h).

We note that the dwarf nova SW UMa, which Robinson et al.(1987) found to be an intermediate polar, shows only super outbursts. The results for TV Col suggest that perhaps also in SW UMa normal events occur but that they have been missed due to their relative faintness and short duration. With respect to the absence of super outbursts, TV Col and V1223 Sgr are similar to dwarf novae with orbital periods above the gap.

Two types of model have been proposed to explain the accretion instability giving rise to dwarf nova outbursts. In the model proposed by Bath(1974) a dynamical instability of the secondary star causes sudden increases in the mass flow onto the accretion disk. In this model the rise and duration of the burst would mainly depend on the properties of the secondary star. In the other models (see e.g. Meyer and Meyer-Hofmeister, 1981) the mass flow onto the disk is constant but the inward transport of the matter to the white dwarf is unstable. In this model the outburst properties will depend on the average mass accretion rate and on the amount of matter stored in the disk.

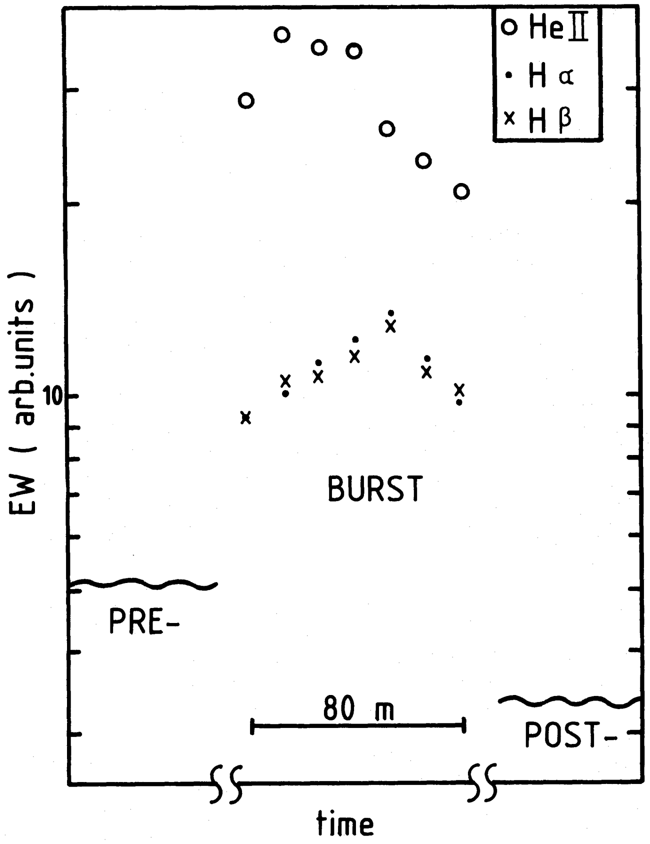

Figure 3.
The equivalent widths of HeII λ4686, Hα and Hβ , normalised such that they are equal before the burst, are plotted against time.

Thus, unless the strong magnetic field of the white dwarf affects the structure of the envelope of the secondary in TV Col (e.g. through its influence on the X-ray emission which heats the secondary star) it would appear that the peculiar properties of the outbursts from TV Col can be more easily explained by the disk instability model than by the mass transfer instability model.

5. Conclusions

Our simultaneous optical photometry and spectroscopy of TV Col in outburst shows that this event differs from normal dwarf nova outbursts in its much shorter rise time and duration and in the development of its colour and spectrum. If the underlying instability giving rise to the events in TV Col is the same as that of normal dwarf novae, these differences are probably related to the absence of the inner part of the accretion disk due to the strong magnetic field of the white dwarf. These outbursts cannot easily be fit into the framework of the mass transfer instability model.

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