THE ASTROPHYSICAL JOURNAL, 236:L29–L31, 1980 February 15

A SPECTROSCOPIC STUDY OF WZ SAGITTAE DURING THE 1978 OUTBURST

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Received 1979 July 16; accepted 1979 October 30

ABSTRACT

The recurrent nova WZ Sge was observed spectroscopically during the first week after the discovery of its recent outburst in 1978 December. The spectrograms show Hα, Hβ, and features around λ4686 and λ4640 in emission. Higher Balmer lines up to H8 are seen in absorption. The lines Hα and Hβ have a double-component structure, as they do in the pre-outburst spectrum. The peak-to-peak separation between the components is, however, 500 km s^{-1} as compared to 1400 km s^{-1} in the quiet nova. We discuss briefly possible interpretations of the double-structure emission spectrum.
Subject headings: stars: binaries — stars: novae

I. INTRODUCTION

The recurrent nova WZ Sge erupted for the third time in its recorded history on 1978 December 1.1 UT (Patterson 1978). Following the discovery of the outburst we initiated a program to observe spectroscopically the early stages of the nova.

The pre-outburst state of the system has been studied intensively during the last few years (Krzeminsky and Smak 1971; Robinson, Nather, and Patterson 1978) and it is rather well known observationally.

On the other hand, spectroscopic information about the outburst event itself and about the stages immediately following it is much scarcer. In this *Letter* we wish to fill, to some extent, this important gap in the observational material about this system, by reporting the results of our study of the star during the first week after its recent outburst. We compare some features of our spectrograms with data related to the pre-outburst star, and discuss some immediate implications of the comparison in relation to this stellar system.

II. OBSERVATIONS AND RESULTS

Fourteen spectrograms of WZ Sge were secured with the Cassegrain spectrograph on the 1 m telescope at the Wise Observatory. An image-tube (ITT F4089) camera was used throughout, with an S20 photocathode, on Kodak 103a-D emulsion. Eleven plates were taken with a grating of 600 g mm^{-1}, covering the spectral range 3500–8000 Å with a dispersion of 120 Å mm^{-1}. Three plates were taken with a 1200 g mm^{-1} grating, one covering the range 3700–4800 Å at 27 Å mm^{-1} and two covering the range 5500–7500 Å with 54 Å mm^{-1}.

All our plates show that the continuum of WZ Sge during the first week after the outburst is characterized by a very intense emission in the ultraviolet-blue region of 3800–4800 Å, while the yellow-red region of 5000–7000 Å is rather weak. An eye comparison of spectrograms of WZ Sge with those of the A2 star HD 191083, which was taken as a standard in our program, shows that WZ Sge was much bluer than the standard. This is consistent with the published outburst color of $B - V = -0.09$ (Patterson 1978).

The line features shown on our spectrograms are (*a*) Hα and Hβ in emission, (*b*) He II λ4686 and C III + N III λ4640 in emission, and (*c*) higher Balmer lines in absorption. Not all these features appear on all our plates but this is probably due to exposure effects. There is, however, one change in the spectrum that we believe to be significant and a reflection of an actual evolutionary effect during the early stage of the outburst.

Plate No. 2587, taken during the first night of our observations, shows Hα in emission with a seemingly structureless round profile. All subsequent plates, taken during the second night and onward, show Hα in emission with a clear double component structure. On our better plates, Hβ, too, can be seen to have a similar structure. This double emission structure remained unchanged to the end of our observations. Thus, it appears that two different phases in the structure of Hα existed in the spectrum immediately following the outburst. Figure 1 displays these two profiles. Unfortunately, evidence for the first phase of a single component Hα

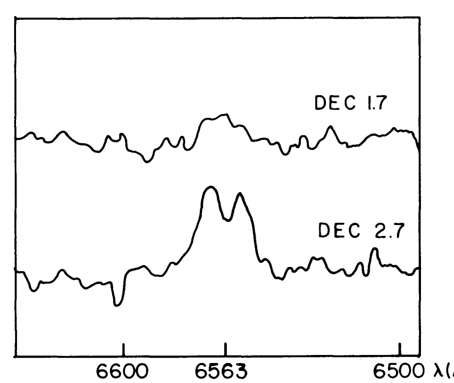

FIG. 1.—Density scan of the spectral plates Nos. 2587 (*top*) and 2590 (*bottom*) near Hα.

comes from one plate alone. The previous plate, No. 2586, is badly underexposed near Hα and only some trace of the emission shows a probably similar structure. Further observational evidence for the existence of this first phase is very much required.

When possible, the wavelengths of the Hα and the Hβ emission were measured with the Wise Observatory's Mann comparator, and the results are presented in Table 1. Most of the columns in the table are self-explanatory. In the third column we give the binary phase of WZ Sge for each exposure. The two numbers for each row correspond, respectively, to the pre-outburst binary period elements of Robinson, Nather, and Patterson (1978) and to the binary period elements derived after the outburst by Targan (1979). The sixth column shows the average of the red and the blue components. The entry in this column for the first night plate, No. 2587, is the velocity of the center of the round structureless Hα of that night. All the velocities refer to the Hα line and to its components. In two plates, Nos. 2590 and 2591, where Hβ could be resolved and measured, the velocities derived from this line are consistent, within the observational error, with the corresponding velocities of Hα.

III. DISCUSSION

The most conspicuous feature of the post-outburst emission spectrum of WZ Sge is the double-component structure of the Hα and Hβ lines. The peak-to-peak separation in the line profile is about 500 km s^{-1}. Such a structure has been frequently observed in the spectrum of galactic novae (e.g., V603 Aql) and is often interpreted as the spectral manifestation of an expanding fragmentary shell or gaseous clouds ejected during the outburst (McLaughlin 1960). Such interpretation might, perhaps, be adopted for WZ Sge, if we assume high enough density of the clouds ($N_e \gtrsim 10^7$–10^8) to explain the absence of forbidden lines from its spectrum (Gurzadian 1968), or by assuming a severe underabundance of oxygen and nitrogen in the ejecta. However, as Balmer spectra for the post-outburst and the pre-outburst nova are very much alike, in the emission as well as in the absorption lines, a similar origin is suggested for both spectra.

For the pre-outburst state, it is commonly believed that the Hβ double emission originates in a gaseous luminous disk around the compact star. The disk lies within the Roche lobe of a white dwarf and is maintained by mass transfer from a light secondary through the L_1 point (Robinson, Nather, and Patterson 1978). It is therefore more likely to assume a similar disk at the origin of the post-eruption structure of Hα and Hβ. We note, however, that the separation between the two emission components is significantly different: from ~1400 km s^{-1} separation in the quiet period (Greenstein 1957) it became ~500 km s^{-1} in the post-nova phase. If we assume that in both cases the observed emission peaks come from particles rotating in circular Keplerian orbits at the edge of the disk, then

$$\frac{d_{\rm post}}{d_{\rm pre}} = \frac{V^2{}_{\rm pre}}{V^2{}_{\rm post}} = 8$$

where d is the radius of the disk and V is the velocity of the particles. Thus, if the radius of the quiet disk is not smaller than one-eighth of the binary separation, the new disk should encompass both stars of this system.

According to Robinson, Nather, and Patterson (1978) the pre-outburst ring is much larger than this limit. It is also quite unlikely that the quiet disk is smaller than this limit within the framework of the two other quantitative models for the system (Fabian *et al.* 1978; Ritter and Schröder 1978). According to these models there is indeed a small permitted region in the parameter space where the quiet disk is small enough; however, in that region the orbital velocity of the white dwarf is quite large. If the disk, after the outburst, is still surrounding only the white dwarf, the average velocity of the two emission components represents the radial velocity of this star. Columns (3) and (6) of Table 1 show that no such high velocities are observed, although our measurements are distributed quite well over the entire period of the binary system. Therefore, it is possible that during the week of our observations the origin of the Balmer emission lines was in an enlarged disk rotating around the binary system of WZ Sge. The Hα profile in the first night of our observations which appears structureless could be a spectroscopic trace of the enlargement process of the disk. Although the proposed disk encompasses the whole system, binary phase dependence phenomena are still

TABLE 1

RADIAL VELOCITIES OF WZ SAGITTAE

Plate No. (1)	Time (Dec) (UT) (2)	Binary Phase (3)	Red Component[a] (km s^{-1}) (4)	Blue Component[a] (km s^{-1}) (5)	Average (km s^{-1}) (6)
2587.......	1.734	0.3	...	...	+78±29
2590.......	2.658	0.6 (0.0)	+197	−288	−46±23
2591B......	2.743	0.1 (0.5)	+155	−334	−90±23
2592.......	2.753	0.3 (0.7)	+165	−352	−94±27
2593B......	2.789	0.9 (0.3)	+206	−315	−55±12
2605.......	7.689	0.3 (0.9)	+183	−315	−66±12

[a] The estimated errors are as in the last column.

possible, due perhaps to the anisotropic interaction of the disk with the binary system. Our observations do show variations in the emission-line profiles, but its binary phase dependence is not clear. More observations are needed in order to establish the presence or absence of such phenomena.

We would like to thank I. Shlosman, S. Lehrer, and O. Lahav for helping in the observations, as well as A. Levite for his assistance. We thank Dr. H. Netzer for calling the Wise Observatory on the night of the discovery of the nova from McDonald Observatory, and enabling the very early beginning of this study. Special thanks are due to the referee for his comments and remarks. This research is partially supported by the Israel Commission for Basic Research.

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