SEARCHING FOR THE WHITE DWARF IN DWARF NOVAE

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Abstract

AAVSO observations of dwarf novae were used to select targets in a search by the International Ultraviolet Explorer (IUE) satellite for their white dwarf components. Twelve of fourteen attempts caught the dwarf novae in quiescence. Lyα absorption such as seen in white dwarf stars was found in three of the six observed systems, two of which, RX And and TZ Per, are described here.

The standard model for dwarf novae consists of a binary with a white dwarf and a cool star in close proximity, in which the cool component is losing material to an accretion disk around the white dwarf. The dwarf novae outbursts are caused by brightenings of the disk, due either to instabilities in the disk itself or in the rate of mass transfer.

Orbital velocity variations and, in some systems, eclipses, are seen, but light from the white dwarf itself is not seen in the visual because it is overwhelmed by light from the cool star and the accretion disk. The only possibility for direct detection of the white dwarf primary is to look in the far ultraviolet, where the radiation from the cool secondary is weak. If the white dwarf were hot enough and if the accretion disk were sufficiently faint at quiescence, then it should be possible to see spectral features arising from the white dwarf (e.g., Panek and Holm 1984). This paper is a progress report on a collaborative search for the white dwarf primaries involving AAVSO observations and spectra from the IUE.

The specific feature for which we searched is Lyα absorption from the transition between the ground level and the first excited level of atomic hydrogen. Most white dwarfs have a hydrogen-rich surface and often the only feature visible in the IUE spectral range is the Lyα line. The hottest stars, which are most likely to be brighter than the accretion disks in the ultraviolet, have the narrowest Lyα feature. Unfortunately, all long-exposure IUE observations are contaminated by geocoronal Lyα, which is sunlight-scattered by hydrogen atoms surrounding the earth. The amount of spectrum contaminated by this geocoronal feature can be minimized by using the IUE's small aperture, which has a 3-arcsec diameter, rather than the 10 x 20-arcsec large aperture. But to center a target in the smaller aperture it is necessary to detect it with IUE's fine error sensor, rather than using a blind offset from a nearby brighter star. This limited our search to eleven dwarf novae that are brighter than magnitude 14 minimum light.

NASA granted us nine 8-hour shifts with the IUE during 1989 and 1990 for this project. The shifts were blocked in three groups of three, in fall 1989, June 1990, and fall 1990. Shifts within each group were separated by intervals of 7 to 10 days. Because it was important that the targets be observed when quiescent, prior to each scheduled IUE shift we obtained the latest AAVSO information on the state of each of the potential targets. Then, at the IUE control center, we selected a target that was reported to be quiescent and that was near where the previous observer had left the telescope pointing.

This process worked fairly well. Twelve of fourteen attempts caught the dwarf novae in quiescence as the AAVSO observers had reported; twice the target was seen on a rise to maximum that had started after the last of the AAVSO observations. We obtained good observations of six of our dwarf novae while they were in quiescence. We attempted to observe RU Peg on three occasions and V426 Oph once, but these attempts failed due to technical limitations of the IUE. We never did make any attempts on three potential targets, HL CMa, SY Cnc, and BV Cen. Our observations are listed in Table 1.

Table 1. IUE Observations of Dwarf Novae

Star	*Date*	*Mag*	*Comment*
RX And	1989 Oct 6	13.55	broad Lyα absorption
Z Cam	89 Sep 22	13.23	only emission lines seen
SS Cyg	90 Jun 10	12.08	mostly emission, some absorption
	90 Jun 21	10.41	rise began after AAVSO report
	90 Oct 21	12.30	same as on June 10
EX Hya	90 Jun 21	13.42	emission line spectrum
	90 Jun 30	13.28	emission line spectrum
RU Peg	90 Jun 10	-	acquisition failed due to nearby star
	90 Jun 21	-	acquisition failed due to nearby star
	90 Jun 30	-	acquisition failed due to nearby star
TZ Per	90 Oct 11	14.08	emission and absorption superimposed
SU UMa	89 Sep 22	14.5	underexposed
	89 Oct 6	12.18	rise began after AAVSO report
	90 Oct 2	14.3	no Lyα absorption obvious

New spectroscopic evidence for a white dwarf star was found in two of the six observed systems, RX And and TZ Per. In addition, the spectra of SS Cyg were consistent with the broad Lyα reported by Holm and Polidan (1988).

Figure 1 shows the light curve for RX And in September and October of 1989.

Figure 2 shows the AAVSO light curve for TZ Per in September and October of 1990. Measurements by IUE's fine error sensor taken at the start of the observations of both these variables are consistent with the AAVSO reports. For both targets the IUE spectra were taken just in the nick of time, right before outburst. Without the advance AAVSO information on the state of these stars we could have used hit-and-miss tactics several times before we caught them in a quiescent state. We thank the observers for their careful monitoring and rapid notifications.

The IUE spectrum of RX And from IUE image SWP 37267 is shown in Figure 3. The dominant features are the broad Lyα absorption centered on 1216A and a strong emission line at 1550A, which is from triply-ionized carbon. The Lyα absorption feature resembles those seen in hot white dwarfs having a hydrogen-rich surface. We tried to match it with the predicted energy distribution of a 35,000° K hydrogen atmosphere white dwarf from Wesemael *et al.* (1980). The narrow emission spike which fills in the bottom of the absorption is geocoronal Lyα, which is sunlight scattered off hydrogen atoms surrounding the earth. The C IV emission shows that the accretion disk contributes something to the observed ultraviolet spectrum, but it is difficult to quantify how much.

Neglecting the contribution of the disk, we see that the agreement between the model and RX And is not bad. This does not necessarily mean that we have found the white dwarf, but it is a piece of evidence in its favor.

Figure 4 shows the spectrum of TZ Per from IUE image SWP 39812. The geocoronal Lyα is very strong. The C IV λ1550 emission is present, as is relatively strong N V λ1240 emission, from 4-times ionized nitrogen. There does appear to be broad hydrogen absorption. In the region longward of 1240A, the shape of the spectrum is best matched by an 18,000° K white dwarf model calculated by Nelan using techniques discussed in Nelan and Wegner (1985). However, we can not conclude that we have a good fit with the 18,000° K model because the model predicts zero flux at wavelengths shortward of 1230A, but the dwarf nova clearly radiates there.

Since emission lines from the disk are present, we considered that continuum radiation from the disk might be filling in the bottom of the stellar absorption line and confusing our results. Unfortunately we do not have a good model that can predict the strength and wavelength dependence of the continuum and emission lines seen from an accretion disk. Instead we have adopted an empirical approach to determine whether it is plausible that the TZ Per spectrum is a composite of a white dwarf and an accretion disk. This approach is illustrated in Figure 5. We used IUE observations of another dwarf nova, WX Hyi, as an empirical model of the accretion disk. WX Hyi was chosen because the ratio of the strengths of the N V and C IV lines is similar to the ratio for TZ Per and because there are no obvious white dwarf features in its spectrum. The broad absorption in the long wavelength wing of Lyα which would arise from a cooler white dwarf is not visible. Conversely, the energy distribution does not increase as rapidly toward shorter wavelengths as a hot white dwarf would. We scaled the WX Hyi spectrum by 8.85×10^{-2} to match the C IV flux from TZ Per. Then the 18,000° K white dwarf flux distribution was added to it to obtain an empirical model.

Figure 4 shows the comparison between this empirical model and the observed spectrum. Now we have a better agreement with the depth of the Lyα absorption. We can conclude that a white dwarf with a temperature somewhere around 18,000° K is possible in this system.

If we accept that the white dwarf primary has been detected in both RX And and TZ Per, we have difficulty in explaining the strong absorption at 1400A seen in both systems. Two possible identifications of this feature are a Lyα satellite line from the hydrogen ion quasi-molecule at 1405A and the Si IV lines at 1394A and 1403A. Cool white dwarfs show absorption due to the quasi-molecular hydrogen ion (Nelan and Wegner 1985), but the observed feature in TZ Per is much stronger than calculated for an 18,000° K white dwarf. In RX And the absorption clearly is doubled and has the right wavelengths for Si IV. Panek and Holm (1984) observed similar absorption in U Gem. They noted that single white dwarfs do not show metal lines, but suggested that in the case of U Gem the accretion might add metals to the atmosphere so that the absorption could be a feature of the photosphere of the white dwarf. This might be possible with RX And, too, because its apparent temperature is hot enough, but TZ Per is too cool to have triply-ionized silicon over a significant area of its surface. Holm (1988) previously noted Si IV absorption associated with WZ Sge when that star had an apparent temperature of only 14,500° K. One possibility is that the absorption does not arise in the photosphere at all, but rather in a corona associated with the disk through which we view the star.

Much work is still required in this study. We are working to model and to subtract the geocoronal component of Lyα. Then we will use an "optimal" extraction algorithm to attempt to improve the signal-to-noise ratio and to remove artifacts from the spectra. When we have finished the reductions and have derived accurate temperatures for the white dwarf, we expect to be able to predict the visual magnitude of the white dwarf, determine the size ratio of the two stars, and perhaps derive a new estimate of the distance to the dwarf nova.

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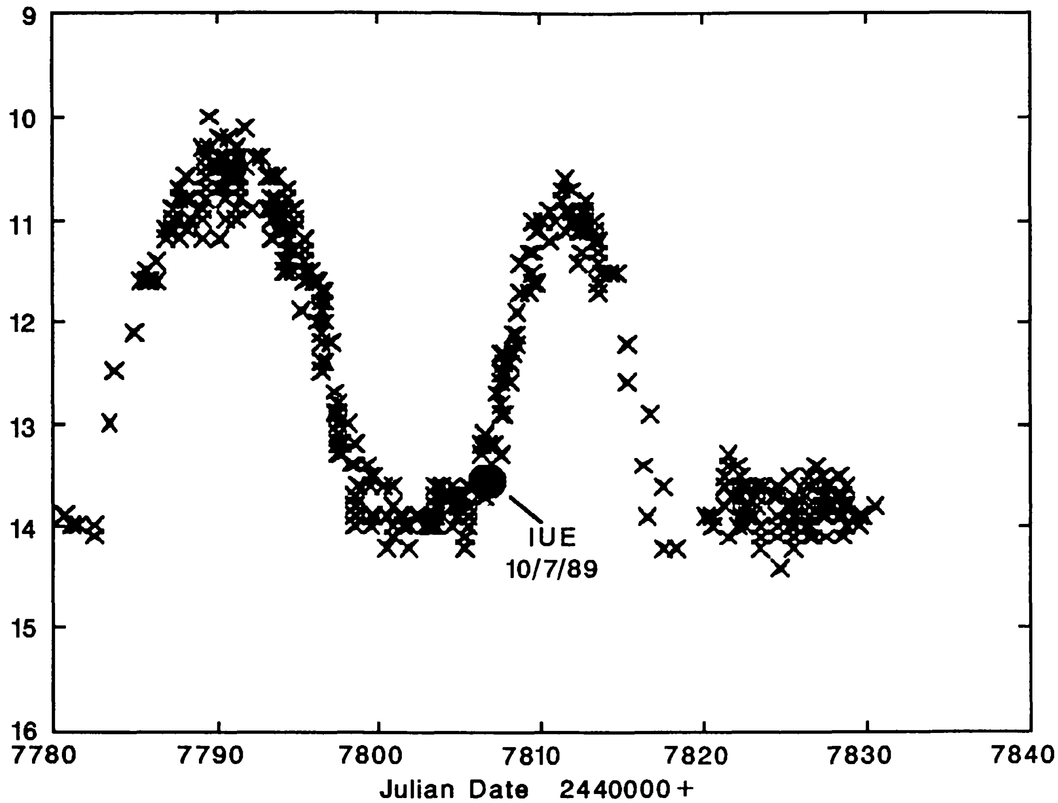

Figure 1. AAVSO light curve of RX And. The filled circle represents the magnitude derived from IUE's fine error sensor.

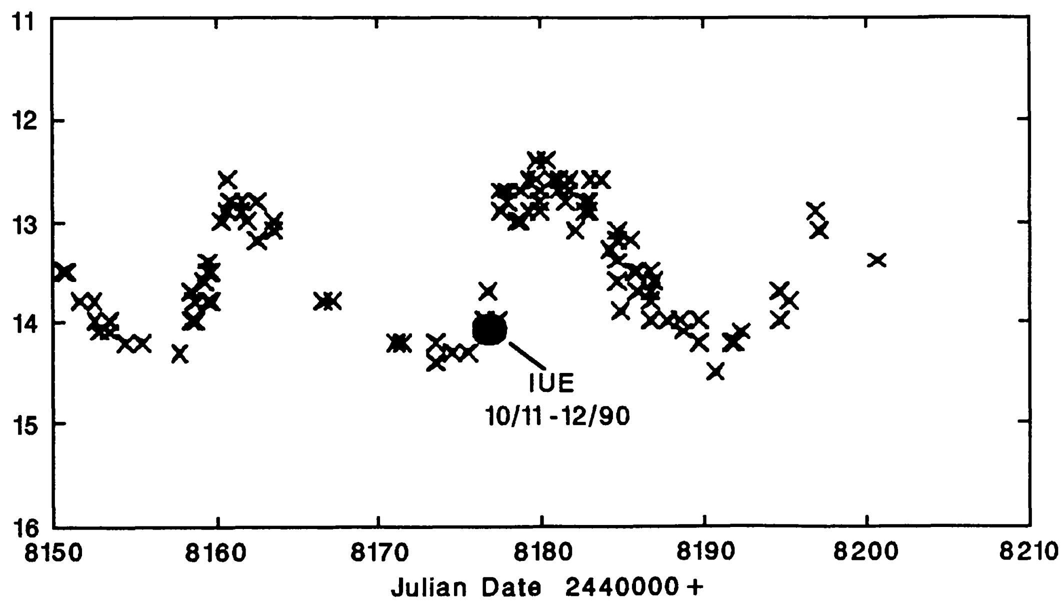

Figure 2. AAVSO light curve of TZ Per. The filled circle represents the magnitude derived from IUE's fine error sensor.

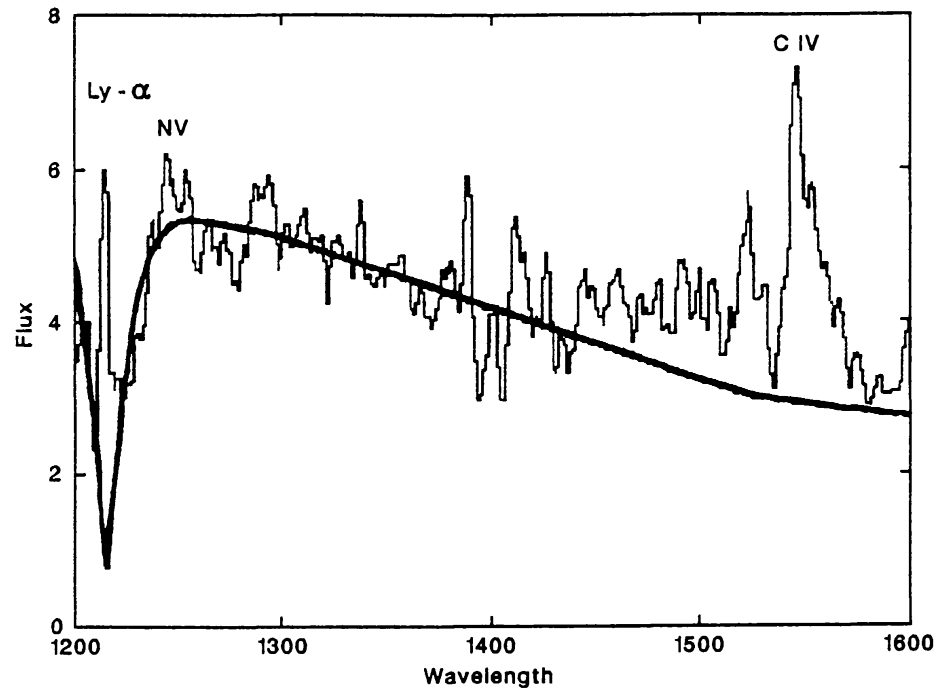

Figure 3. Spectrum of RX And at quiescence from IUE image SWP 37267 (histogram plot). This plot has been smoothed by a 3-point box filter to suppress partially the noise. The smooth line represents the predicted energy distribution of a 35,000° K hydrogen-atmosphere white dwarf (Wesemael *et al.* 1980).

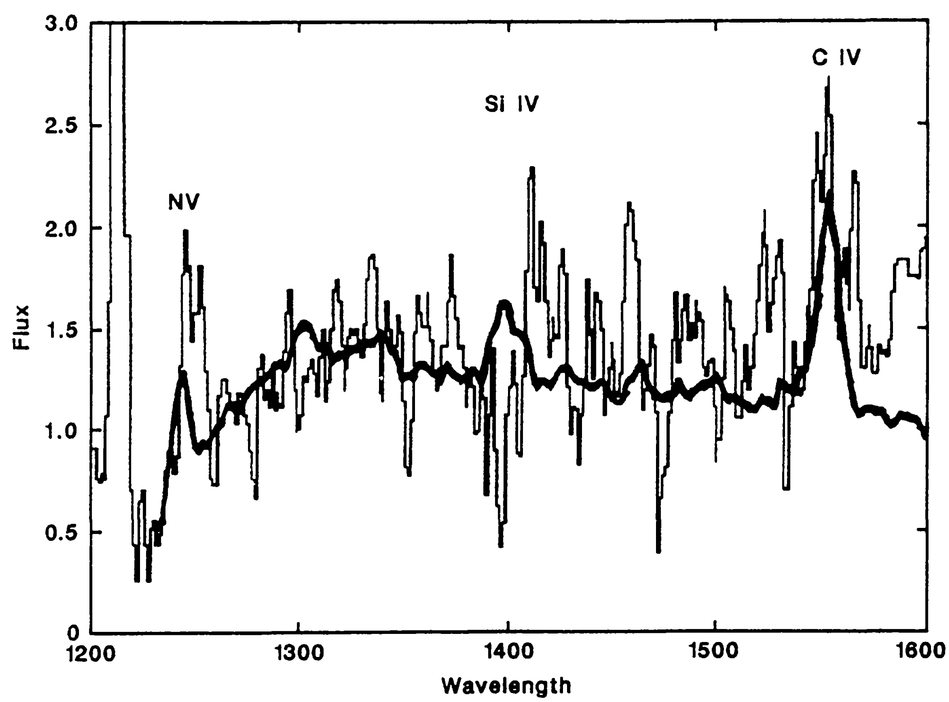

Figure 4. Spectrum of TZ Per at quiescence from IUE image SWP 39812 (histogram plot). This plot has been smoothed by a 3-point box filter to suppress partially the noise. The heavy line represents an empirical model combining an accretion disk with a white dwarf energy distribution as discussed in the text.

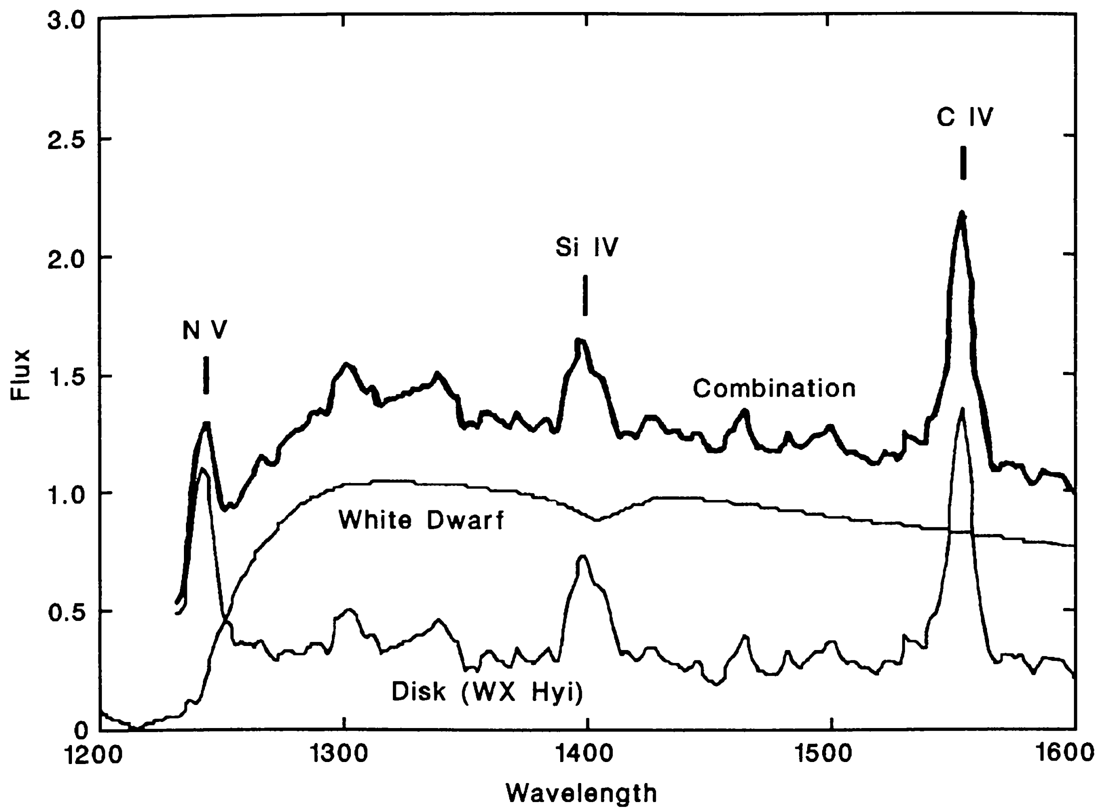

Figure 5. Empirical model for TZ Per. We used a spectrum of a quiescent WX Hyi from IUE image SWP 9704, taken on 1980 Aug 5/6 by J. Pringle to approximate the disk and then added the predicted energy distribution of a white dwarf model atmosphere. Note that, although we smoothed the WX Hyi spectrum with a 3-point box filter, there is noise in it that carries over into the model.