IUE OBSERVATIONS OF NOVAE

Warren M. Sparks, Chi-Chao Wu*, Albert V. Holm* and
Francis H. Schiffer, III*
Laboratory for Astronomy and Solar Physics
Goddard Space Flight Center

INTRODUCTION

In addition to offering observing time on a regular schedule, the International Ultraviolet Explorer (IUE) satellite is also being used to observe "targets of opportunity." Novae represent one of the most exciting targets of opportunity and also one of the most difficult because of their rapid time behavior. During the first year of operation of IUE we were extremely fortunate to have three bright novae outbursts occur: Nova Cygni 1978, WZ Sagittae, and U Scorpii.

NOVA CYGNI 1978:

Nova Cyg 1978, a fast nova, reached a maximum apparent visual magnitude of 6.2 on September 12, 1978 (Slovak and Vogt 1979). Figure 1 shows the relative flux of Nova Cyg 1978 in the long ultraviolet wavelength range (1900-3200Å) at several different times. One day after maximum (Sept. 13), the nova is still in its absorption line phase. At this point it looks like a supergiant F star with mostly FeII absorption lines (also see Cassatella et al. 1979). Later spectra show the emergence of emission lines, which is the characteristic behavior of novae in the visual. Magnesium II at 2800Å is the strongest emission line in this part of the spectrum for at least a month after outburst. The last spectrum (Nov. 1) shows mainly semi-forbidden lines of carbon, nitrogen, and oxygen. It should also be noted that the slope of the continuum flattens as the nova evolves.

The short ultraviolet wavelength range (1200-1900Å) shows a similar development (Fig. 2). A complex emission line spectrum emerges and becomes less complex as mostly semi-forbidden carbon, nitrogen and oxygen lines persist together with N V, C II, Si IV, and C IV (also see Strickland et al. 1979). There is a significant shift of radiation energy into the UV, both in the continuum and in the lines. This can

*Computer Sciences Corporation

Patrick A. Wayman (ed.), Highlights of Astronomy, Vol. 5, 285–291.
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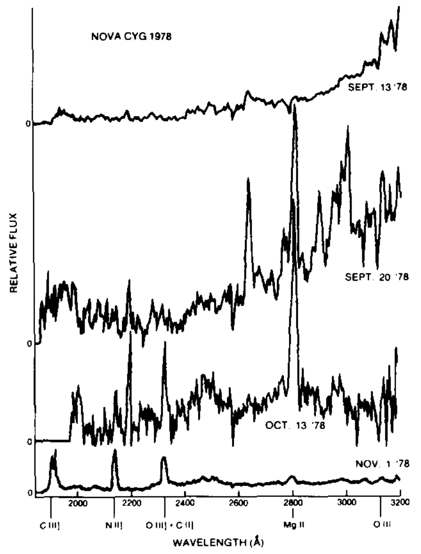

Figure 1: Relative flux of Nova Cyg 1978 in the long ultraviolet wavelength range.

best be seen in Figure 3, which is a plot of the visual magnitude and the magnitudes at 2740Å and 1450Å. The shift of the radiation energy to shorter and shorter wavelengths means that the temperature of the photosphere is becoming hotter and hotter. In an apparent contradiction the absorption feature near 2175Å, which is associated with grains, becomes stronger. At the same time the infrared flux (Gehrz 1979) increases strongly. By combining the ultraviolet, visual, and infrared magnitudes,

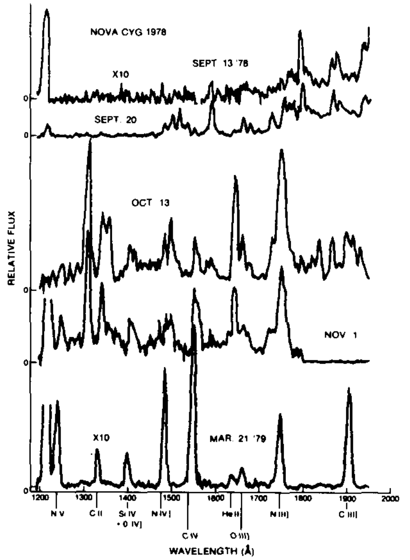

Figure 2: Relative flux of Nova Cyg 1978 in the short ultraviolet wavelength range.

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Stickland et al. (1979) found that the bolometric magnitude drops by a factor of 3 over the first 8 days after maximum, drops another factor of 2 over the next 20 days and is nearly constant during the next 20 days.

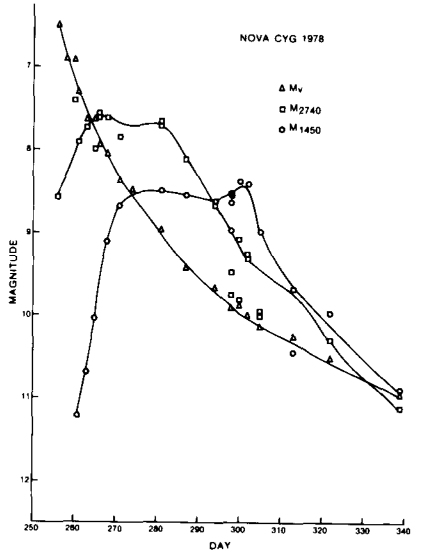

Figure 3: Visual magnitude and the magnitudes at 2740Å and 1450Å of Nova Cyg 1978 vs. time.

All of these features are qualitatively explained by the usual description of a nova ejection. Initially the photosphere expands with the ejecta giving rise to the cool supergiant characteristic of the nova. Later as the ejecta expands and becomes optically thinner, the photosphere shrinks. This in combination with the nearly constant luminosity causes the temperature of the photosphere to increase and shifts the maximum of the radiative energy in the continuum to shorter wavelengths (Sparks, Starrfield and Truran 1976). In the outer regions of the ejecta, the decrease in density allows the radiative decay of the metastable levels to give the semi-forbidden lines. At the same time the cooling in the outer regions results in grain formation and an increase in the infrared flux. Hydrodynamic calculations (Starrfield, Truran and Sparks 1978 and references therein) indicate that the thermonuclear runaway in the degenerate hydrogen envelope of a white dwarf results in a rekindled hydrogen-burning shell source. Its luminosity remains constant until the entire hydrogen envelope is ejected or burnt.

WZ SAGITTAE:

Let us next consider WZ Sge, a recurrent nova that last erupted in 1946. The observations of this nova demonstrate the versatile capability of the IUE. The outburst of WZ Sge was first discovered and observed in the visual by J. McGraw, and its occurance was relayed to us by Harlan J. Smith on the morning of December 1, 1978. Because of the rapid

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coordination by the IUE staff the first observations were taken that afternoon. This enabled us to obtain the first spectrum near maximum light (see Figure 4).

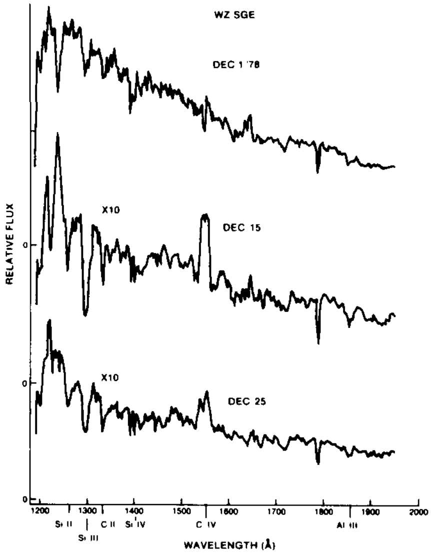

Figure 4: Relative flux of WZ Sge in the short ultraviolet wavelength range.

WZ Sge has a completely different behavior than Nova Cyg 1978. The slope of the continuum indicates a much hotter star at maximum, about 18,000 ^{o}K. Although the flux decreases with time at all wavelengths, the slope of the continuum changes very little. The absorption line spectrum also remains roughly the same with only the C IV in emission. Figure 5 shows the visual magnitude and the magnitude at 1450Å as functions of time. Both of these magnitudes decrease rapidly together with the ultraviolet being brighter than the visual. The color temperature shown at the bottom of Figure 5 remains roughly constant. The constant temperature and the decreasing luminosity imply that the surface area of the emitting region is decreasing. In both the visual and in the ultraviolet there is no evidence of mass ejection. In fact, in the visual the 82 minute binary period is observed (Nather 1978) implying that the luminosity originates within the Roche lobe.

The usual model of a cataclysmic variable is a white dwarf surrounded by an accretion disk. The disk is being fed by the red component overflowing its Roche lobe. The observations of WZ Sge can be explained by a sudden brightening and subsequent fading of the accretion disk. This could possibly be due to the disk becoming optically thick and then thin rather than by physical motions of the disk material.

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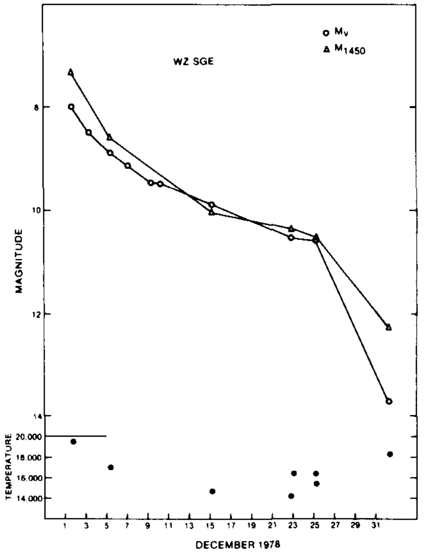

Figure 5: Visual magnitude, the magnitude at 1450Å and the color temperature of WZ Sge vs. time.

A similar model has been put forth by Bath (1973) and by Osaki (1974) to explain the dwarf nova outburst. In fact WZ Sge looks very much like a dwarf nova outburst (Wu 1976). At the risk of confusing the nomenclature, WZ Sge can be labeled as a super dwarf nova.

U SCORPII:

The latest nova, U Sco, is also a recurrent nova. IUE observations were started on June 28, 1979 about 3 days after the first report of its outburst (Narumi, 1979 forwarded to us by C. McCracken). Its behavior is characterized by the emission line development typical of common novae and unlike WZ Sge, whose absorption spectrum dominated throughout the outburst. Having only just received the data from this nova, we have not yet completed its analysis. Figure 6 is a comparison plot of U Sco with Nova Cyg 1978 when both were in the late stages of development. U Sco shows much stronger N V and He II emission lines but very weak or no semi-forbidden lines.

IUE observations of novae have presented us with a wealth of information. Untangling this information should greatly contribute to our understanding of the details of the nova phenomenon.

ACKNOWLEDGEMENTS

We would like to thank G. S. Kutter for suggestions that improved the manuscript.

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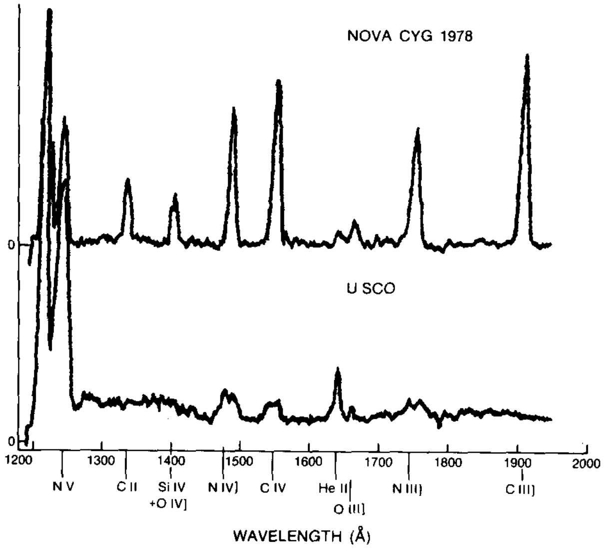

Figure 6: Comparison of U Sco with Nova Cyg 1978 in the short ultraviolet wavelength range.

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DISCUSSION:

M. Seaton: Extensive IUE observations of Nova Cygni 1978 have been made at VILSPA. The strength of nitrogen lines is particularly striking. According to our preliminary analysis, the N/C abundance ratio exceeds the solar value by a factor of at least 6.

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W.M. Sparks: We have not yet made any abundance analysis.

M. Friedjung: We have been analyzing IUE spectra of WZ Sge and Nova Cygni 1978 in Paris. In the case of WZ Sge, we see very strong N V absorption, probably formed in a region ionized by radiation from the boundary layer of the accretion disk. Nova Cygni shows narrow resonance absorption lines, but we are not yet certain whether they are circumstellar or interstellar. In any case they come from a cool region far from the nova.

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