MULTI-WAVELENGTH OBSERVATIONS OF DWARF NOVAE DURING OUTBURST

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ABSTRACT. Multi-wavelength observations of dwarf novae during outburst are presented here. Thirty three objects were observed, of which seventeen were at outburst. Six objects were caught during the rise, and a short flare was detected in SU UMa. It lasted 20 hours and reached a maximum increase of 3.6 in flux at 5500 Å. The flare was simultaneous at all observed wavelengths.

1. INTRODUCTION

Dwarf novae are a group of binary stars where a white dwarf primary coexists with a Roche-Lobe-filling red dwarf secondary, which transfers matter to an accretion disc formed by the high angular momentum of the system (Warner & Nather 1971). The accretion disc may become unstable producing an outburst, either by a sudden mass transfer increase from the secondary (Bath *et al.* 1974) or by internal instabilities (Meyer & Meyer-Hofmeister 1984). This is seen as a rapid increase in flux by a factor of 10 to 100 in the optical, and has a time scale of about one day. The duration of maximum light is also of the order of one day, although in the SU UMa systems it may last for several days at a higher flux level. Time scales for the decrease in flux to minimum light depend on the orbital period (Bailey 1975) and range between 1 to 10 days.

The accretion disc temperature structure, and consequently the emitted flux distribution, are correlated with disc radius (Pringle 1981) . Therefore simultaneous observations at different wavelengths should give information on the whole disc. X-Ray and UV photons are emitted mostly in the inner disc and its boundary with the white dwarf (Pringle 1977), while visual and IR photons are produced in the outer disc and in the cool secondary star (Tylenda 1981; Berriman, Szkody & Capps).

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To understand the physics of the outbursts of dwarf novae we have to observe them at minimum and during early development. This poses an observational challenge, as the outbursts are not periodic and also because dwarf novae at minimum are relatively faint. A few objects have been observed during the rise like VW Hyi (Hassall *et al.* 1983; Schwarzenberg-Cerny *et al.* 1986) and WX Hyi (Hassal *et al.* 1986). These systems show a flux increase delay in the UV with respect to the Visual during early ouburst.

To follow the effort of other groups, we have undertaken a large program to observe dwarf novae during the first day of outburst. The observations and results are summarized here. A full analysis and discussion of the data can be found elsewhere (Echevarria *et al.* 1986 and Jones *et al.* 1986).

II. OBSERVATIONS

Simultaneous observations from UV to Radio wavelengths were carried out at several sites within the period 1986 February 5 to 18. Table 1 summarizes the telescopes, instrumentation and observers. Due to general bad weather in the northern hemisphere some observing sites were not able to carry out any observations. These are also shown in Table 1.

TABLE 1. TELESCOPES AND INSTRUMENTATION

Telescope and Site	Instrument and	Spectral Range	Date Feb86	Observers
IUE Vilspa/ Goddard	SWP/LWP Cameras	1200-3200 Å	8-9	Echevarria/Shara Tapia/Gilmozzi Bohigas
1.0m Lick	ESP+CCD	4200-7100 Å	9-10	Stover
2.6m Byurakan	ESP+PL	3600-5500 Å	8-9	Tovmassian
1.0m Tonantzintla	Photom	UBV	6-10	Costero/Barral
1.0m Konkoly	Photom	UBV	6	Zsoldos
1.0m E.S.O.	Photom	UBV	5-8	Vogt
0.7m S.A.A.O.	Photom	UBV	5-18	Wallis
1.5m S.P.M.	Photom	uvby	5-10	de Lara
1.0m L.P.O.	Photom	UBVRI	5-11	Jones
2.1m S.P.M.	Photom	BVRI	5-11	Alvarez
several	Many	eye	5-8	Mattei *et al.*
several	Many	eye	5-8	Bateson *et al.*
1.5m Tenerife	Photom	JHK	8-10	Martínez/Garzón
1.2m K.P.N.O.	Photom	JHK	8-10	Szkody
VLA N.R.A.O.	Photom	4885/4835MHz	7-13	Rodríguez

Other facilities affected by bad weather and/or by other technical problems

EXOSAT E.S.O.C.	-	-	-	Osborne
2.7m Mc Donald	-	-	-	Robinson Shafter
1.5m Mt Lemmon	-	-	-	Roth Lopez
0.7m Tokyo	-	-	-	Isobe
0.6m Skalnate P.	-	-	-	Urban Chochol
0.5m Lembang	-	-	-	Hidayat

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III. RESULTS

67 objects were selected for the program on the basis of IUE availability. Out of this sample 33 were observed, 24 were not detected at the telescopes and 10 were not tried. Table 2 summarizes the results during the observing season. No system was detected with the VLA. In particular SS Aur was observed two days after the rise in the optical and YZ Cnc was observed during the rise. Flux limits and full details can be found in Jones *et al.* (1986).

Since the reduction of all the data and the analysis is still in progress, only a preliminary discussion on SU UMa, SS Aur, YZ Cnc and MU Cen is given here.

TABLE 2. RESULTS OF OBSERVATIONS

Object	State	Observations
SU Uma	flare	IUE CCD UBVRI IR VLA
SS Aur	rise	UBVRI uvby IR VLA ESP
YZ Cnc	rise	UBVRI uvby IR VLA
BI Ori	rise	UBV
BX Pup	rise	UBV
MU Cen	rise	UBV
CN Ori	rise	UBV uvby
T Leo	minimum	IUE CCD UBVRI uvby IR
U Gem	minimum	UBVRI uvby IR VLA
CH UMa	minimum	UBVRI IR VLA
AQ Eri	minimum	UBVRI
CW Mon	minimum	UBVRI
DO Dra	minimum	ESP UBVRI
VW Hyi	minimum	UBV
SW UMa	minimum	UBVRI
BZ UMa	minimum	UBVRI
BV Cen	minimum	UBV
EK TrA	minimum	UBV
OY Car	minimum	UBV
V436 Cen	minimum	UBV
Z Cha	minimum	UBV
HL CMa	minimum	UBV
V373 Cen	minimum	UBV
IR Gem	maximum	UBV
V422 Cen	maximum	UBV
Z Cam	standstill	UBV
CZ Ori	standstill	UBVRI uvby
SV CMi	standstill	UBV
EX Hya	decline	UBVRI
TW Vir	decline	UBVRI
UY Pup	decline	UBV
BV Pup	decline	UBV
AG Hya	decline	UBV

25 percent of the objects in the whole sample were detected in outburst, 24 percent were observed at minimum and 10 percent were

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observed during the rise. Since the elapsed time of the observations was 13 days, the number of objects caught during outburst per day was 1.3. This is close to 1.1, the mean number of objects per day reported in outburst by the AAVSO during the preceding year. The number of objects caught during the rise per day during the observations is 0.54, i.e. more than half of the objects in outburst.

A rare event was the detection of a flare in SU UMa. This object has recurred irregularly during the last year. Its behaviour is shown in Figure 1.

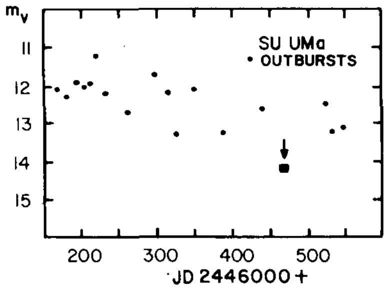

Figure 1. Recurrence behaviour of SU UMa during the last year.

The frequency of the large outbursts has decreased notably during the last months, and it is possible that other flares are taking place instead. Figure 2 shows the overall development of the flare.

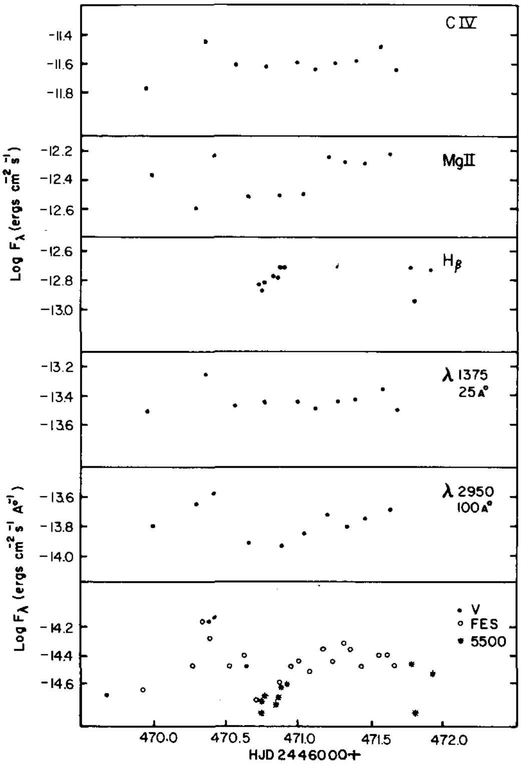

Figure 2. Simultaneous UV and optical observations of SU UMa.

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The system brightened in the visual from 15.7 mag to 14.3, i.e. a factor of 3.6, and decreased to its quiescent level in less than 20 hours. Another brightening followed a few hours later until the system reached 14.7 mag, when the observations ended. Simultaneous IUE observations show that the UV continuum changed at the same time as the optical, but by a factor of 1.8 around 1375 Å and 2.3 around 2950 Å. UV emission lines like CIV and MgII also changed simultaneously with the optical but by factors of 1.8 and 2.2 respectively. Although the visual spectra cover small fractions of the flare the Hβ emission and the continuum around 5500Å does vary synchronously with other wavelengths. This behaviour suggests that the time scale at which the disturbance propagates within the disc is rather short since the observed lines and continua must be produced preferentially at different radii of the disc. YZ Cnc and SS Aur were both observed at the beginning of an outburst and followed through to maximum. The Stromgren and UBVRI photometry of SS Aur are shown in Figure 3.

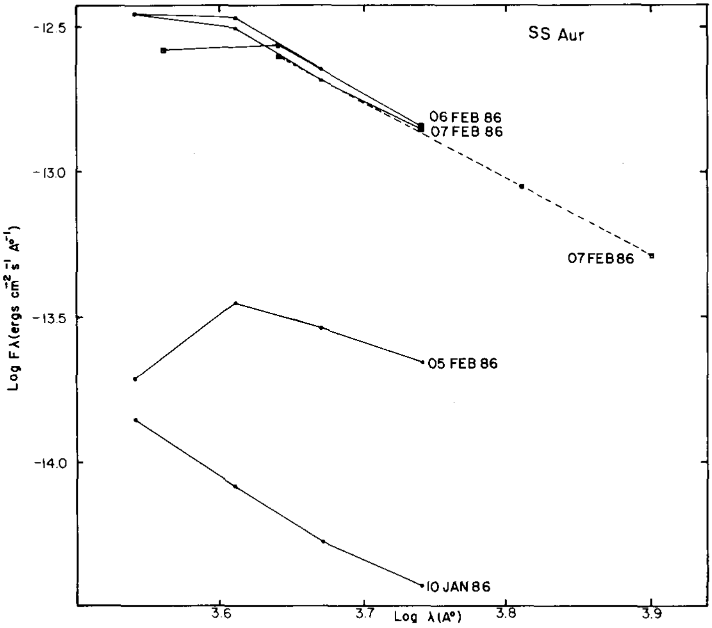

Figure 3. Stromgren and UBVRI photometry of SS Aur.

uvby observations of SS Aur at minimum, obtained on January 10 1986 are also shown for comparison. On February 5 the **u** flux increases only a factor of 1.4 with respect to minimum, while at **y** the flux increases by a factor of 5.8. This is only seen during the first day, after which the **u** flux increases faster than the **y** flux.

The same phenomenon is seen in Figure 4 for YZ Cnc. The observations cover both minimum and rise. These are compared in the diagram with observations obtained by other authors. The flux distribution at maximum (open squares) and supermaximum (asterisks) (Patterson 1979) reveal a steeper continuum than the observations during decline and minimum (black dots) (Echevarría 1984). In contrast the flux distribution during late rise shows that the **u** flux has not reached its maximum. This cannot be accounted for by a strong Balmer continuum in absorption only, but must be due to the time-delay effect.

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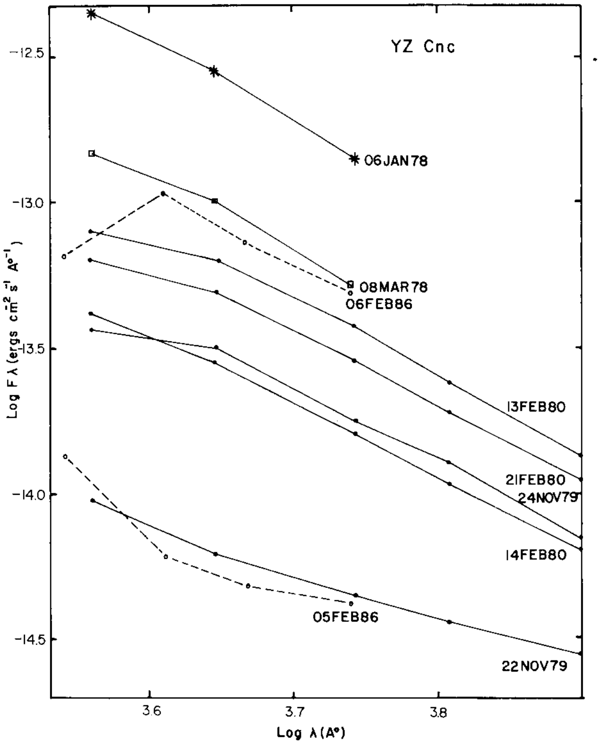

Figure 4. Photometric observations of YZ Cnc.

MU Cen was followed for several days during quiescence and during a very slow outburst. Figure 5 shows only the late part of the rise when the U flux is increasing faster than the B and V fluxes.

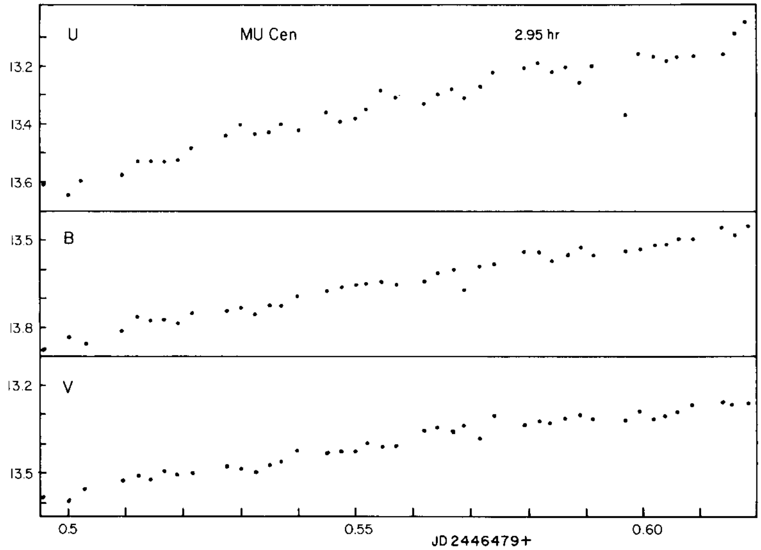

Figure 5. Observations of MU Cen during late rise.

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