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IUE Observations of the 1987 Superoutburst of the Dwarf Nova Z Cha

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## ABSTRACT

We present low resolution IUE observations of the dwarf nova Z Cha during superoutburst. These cover most of the development of the outburst and have sufficient time resolution to probe continuum and line behaviour on orbital phase. The observed modulation on these phase is very similar to that observed in the related object OY Car. We interpret the results to imply the presence of a 'cool' spot on the edge of the edge of the accretion disk, which periodically occults the brighter inner disk. Details of the line behaviour suggest that the lines originate in an extended wind-emitting region. In contrast to archive spectra obtained in normal outburst, the continuum is fainter and redder, indicating that the entire superoutburst disk may be geometrically thicker than during a normal outburst.

## 1. INTRODUCTION

Z Cha is an eclipsing member of the SU UMa subclass of dwarf novae, which are characterized by the superoutburst mechanism and the 'superhump' phenomenon. Superoutbursts are brighter (0.6 mag in average) (Ref.1) than normal outbursts and last ~10 days. Although less frequent than normal outbursts, they are relatively speaking more predictable. In addition, an optical modulation, the 'superhump' appears after the superoutburst peak. In contrast with the quiescent orbital hump, the superhump systematically traverses the eclipses due to a period, 3-7 per cent longer than the orbital period. Z Cha displays a superhump with a period of about 111 min (orbital period : 107.3 min) and a beat period of 2.1 days. (Ref.2).

VW Hyi, although one of the best observed dwarf novae in the UV is harder to interpret than either of the two eclipsing SU UMa systems, OY Car and Z Cha, both of which have relatively frequent superoutbursts. OY Car was the subject of a multiwavelength campaign (Ref.3-4),

during which IUE observations were obtained resolved on orbital phase. These were the first to show distinct differences between eclipsing and face-on systems, and evidence for wind emission from a considerable volume in addition to the expected disc emission. Further observations on Z Cha, one of the cornerstones for dwarf nova studies, are crucial to investigate the superoutburst-superhump phenomenon. Although non-eclipsing SU UMa stars in superoutburst reveal strong blue continuum spectra with prominent absorption lines (IUE archive), differing from outburst spectra in overall flux level, Z Cha shows prominent emission lines as in its quiescent state. Here we present the first IUE observations of Z Cha in superoutburst which cover its overall development as well as providing good coverage of orbital phase on two dates.

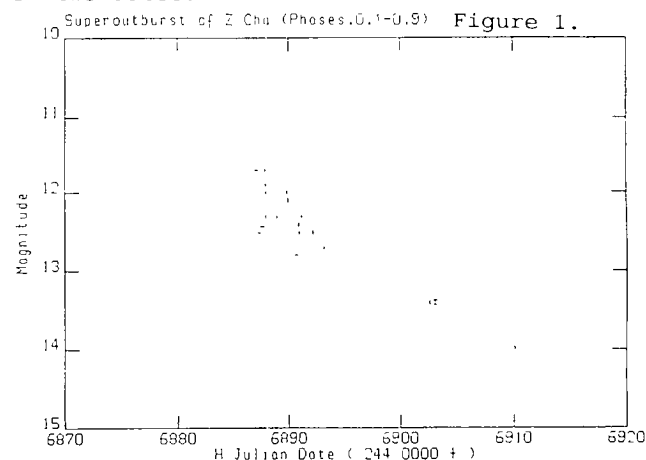


Figure 1. Optical light curve of Z Cha during the 1987 superoutburst. Crosses + mark actual visual observations and circles o upper limits (VSS RAS NZ). Horizontal lines show length of IUE Observations (mean FES magnitude)

## 2. OBSERVATIONS

Figure 1 shows the light curve of Z Cha during the 1987 superoutburst. Crosses mark actual visual observations and circles upper limits from the VSS RAS NZ. The times of IUE and SAAO observations are marked. The length of IUE observations are shown by horizontal lines that lie at the mean FES magnitude. VSS RAS NZ points within the phase range 0.9-0.1 have been omitted to decrease the scatter introduced by the eclipses. The exact time of the beginning of the outburst is uncertain but the peak was reached at HJD 2446887.1 after a brightening of at least 2 mag in under 1.7 days. The outburst decayed slowly over the next 18 days with a rate  $\sim 0.13$  mag/day.

The figure shows the timing of the IUE observations relative to the overall optical light curve. Low resolution spectra (28 swp and 11 lwp) were obtained utilizing the target of opportunity programme. On 31 March, 6 exposures gave a limited coverage of one orbital cycle. On 1 April, 2 exposures added to a total of 8 exposures during the rise and near the superoutburst peak. The remaining 5 exposures covered 3 orbital cycles and the 4th group of observations on 7 April with 9 exposures covered 4 cycles.

The IUE observations on 5 April are 4.5 days past superoutburst peak, so it is expected that the superhump had already developed. On 8 April, a complete orbital cycle of B filter photometry was obtained on the SAAO 1.0m telescope. From this run we estimate the superhump ephemeris.

## 3. IUE RESULTS

Figure 2 shows representative swp spectra from 1-2 April which have been arranged in order of orbital phase. The most prominent features are the strong emission lines which, except for eclipsing systems, are uncharacteristic for dwarf nova in outburst. Strong emission lines of Lyman Alpha (1215A), CIV (1550A), NV (1240A), SiIV (1400A), HeII (1640) are present. The above lines show some variability with orbital phase, both in strength and complex profile. Emission features at 1667A, 1594A, 1340A are evident as well as absorption lines SiIII (1300) and at 1608A, possibly FeII. The continuum is very weak in eclipse and the CIV profile loses its double peak structure (seen in out-of-eclipse spectra) becoming narrower and symmetrical. These spectra show asymmetry of CIV (1550) line away from eclipse, in the sense that the red wing falls more rapidly than the blue one. A structure at the left of the blue wing shows a stronger emission flux than the corresponding edge of the red wing, seen in eclipse too. This could be attributable to a weak blended line. Ly Alpha shows a double structure like the CIV line.

Spectrum swp30690 (phase 0.56-0.75) has a rather weak continuum flux compared to the other non-eclipse spectra which show a strong continuum. The continuum shows

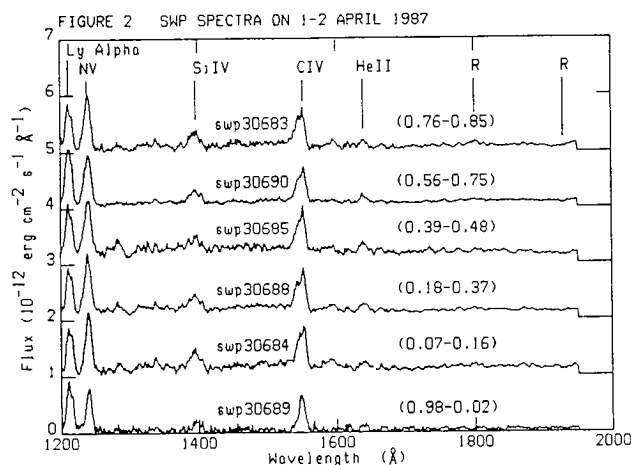


Figure 2. Representative SWP spectra from 1-2 April 1987 in order of orbital phase.

variability of the absolute flux on a time scale of hours, which could be caused by a thick, vertical structure at the outer rim of the accretion disk (stability timescale of a few orbital cycles). In contrast, the continuum is much weaker and redder during eclipse compared with non-eclipse spectra. Lwp spectra have a very weak continuum with no strong emission features except for some evidence for Mg II (2800A).

## 4. VARIATIONS ON THE ORBITAL TIMESCALE

The continuum flux for 1-2 April in the regions 1345-1360 A and 1470-1515 A is plotted as a function of orbital phase in Figure 3. The mean out-of-eclipse flux drops 80% at phase 0.0. In addition, Figure 3 shows a clear flux modulation over a large range of orbital phases. This smooth modulation peaks near phase 0.4 and has a minimum near phase 0.8 resulting in a final 50% drop in the continuum flux. Although the effect is less marked on other dates, it seems clear that there is cyclical modulation on the orbital timescale.

In Figure 4 we plot the strongest emission lines against orbital phase. The eclipse depth of C IV line is 20% of the out of eclipse mean flux. The total flux perhaps shows a smooth modulation. NV, Si IV, He II show eclipses of 30%, 65% and 70% respectively but not mid-phase orbital modulation, except NV for which a 17% variation is marginally significant.

The fraction of the line flux eclipsed at phase zero, is probably associated with material close to the centre of the accretion disc. (The apparent disappearance of the double-peaked structure supports this hypothesis). In contrast, modulation of the line flux away from eclipse indicates that a large emitting volume is involved, such as a wind or corona, comparable in size to the accretion Roche lobe.

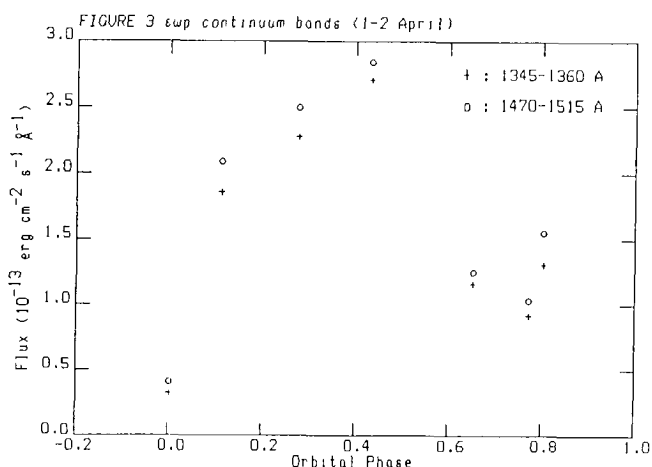


Figure 3. The continuum flux for 1-2 April 1987 in the regions 1345-1360 Å and 1470-1515 Å via orbital phase.

From the rough superhump ephemeris, we estimate that the orbital phase of the peak of the superhump was about phase 0.8 on 5 April. This coincides not with a peak in the UV flux, but rather a dip, rather similar to what was observed in the case of OY Car in superoutburst (Ref.4). There we interpreted the UV dip as the obscuration of the inner disc regions by the outer edges of the disc at certain orbital phases which were consistent with the location of a cool bulge (or dark spot) near the stream impact area. A future fuller discussion of the behaviour of Z Cha, because the observations cover a range of beat phases, will attempt to differentiate between superhump and orbital phase. However these observations have confirmed the result seen for OY Car, that the UV flux from the accretion disc in superoutburst is redder than in face-on systems, and variable on the orbital timescale. Both of these observations are consistent with the idea of an accretion disc with an opening angle of about 14 degrees, and some form of azimuthal structure.

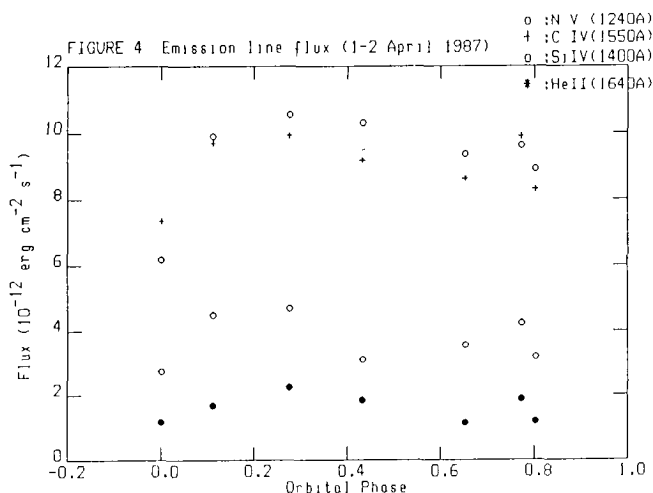


Figure 4. Variation of the Emission lines NV (1240 Å), Si IV (1400 Å), CIV (1550 Å), He II (1640 Å) on the orbital timescale

Spectra from the recent normal outburst at Z Cha in January 1988 show a strong blue continuum in contrast with the redder continuum in the 1987 superoutburst. This is indicative of the different phenomena appearing. Although an outburst is thought to trigger the superoutburst (Ref.5), the latter lasts about 10 times as long, and is probably only sustainable if there is a prolonged burst of mass transfer from the red star. Under these conditions, the steady accretion of matter onto the white dwarf (and associated outward transfer of angular momentum) leads to the growth of the accretion disc. Whitehurst (Ref.6) has pointed out that in short period systems the mass ratio is such that the disc may become dynamically unstable at a smaller radius than the normal tidal truncation with the Roche lobe. He associates the additional dissipation due to this phenomena in a slowly precessing disc with the observed superhumps which we know to originate in a large fraction of the outer disc. We propose in addition, that this dissipation, particularly in the presence of a high mass transfer rate may lead to a puffing up of the outer accretion disc during superoutburst. Thus, in superoutburst, the disk appears bigger and thicker at the outer rim whereas it appears smaller and thinner in normal outbursts. The rather cooler flux distribution is a further evidence for an extended vertical structure. This is because in high inclination systems such as Z Cha and OY Car the central hotter regions are obscured by the large opening angle of the disk.

## 5. DISCUSSION.

The strong continuum eclipses are in accordance with the expectation that the UV emitting region is a centrally condensed accretion disc. Comparison with LWP fluxes shows that eclipses of the SWP fluxes are deeper than those of LWP. From an inwardly increasing temperature distribution we expect more energy to be emitted from the center in the 1200-1950 Å band than in the 1850-3200 Å band.

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