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SIMULTANEOUS IUE, EXOSAT, AND OPTICAL OBSERVATIONS OF THE UNUSUAL AM HER TYPE VARIABLE H0538+608

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ABSTRACT

We report on simultaneous observations of the AM Her type variable H0538+608 made with IUE, EXOSAT, and the 1.3 m McGraw-Hill Observatory telescope. Subsequent optical spectrophotometry at high and low resolution was also performed. The X-ray and optical data show clear evidence of a 3.30 ± 0.03 hour period. Three SWP spectra were taken outside of eclipse and during overlapping phase intervals. The UV spectra contain strong emission lines characteristic of this class of objects and a flat continuum which appears to be deficient, given the brightness of source at optical and X-ray wavelengths. There is evidence for intensity variations in emission lines, particularly CIV. The X-ray light curves for H0538+608 reveal some interesting behavior which may be related to irregularities in its accretion flow.

Keywords: X-ray Binaries, Cataclysmic Variables

1. INTRODUCTION

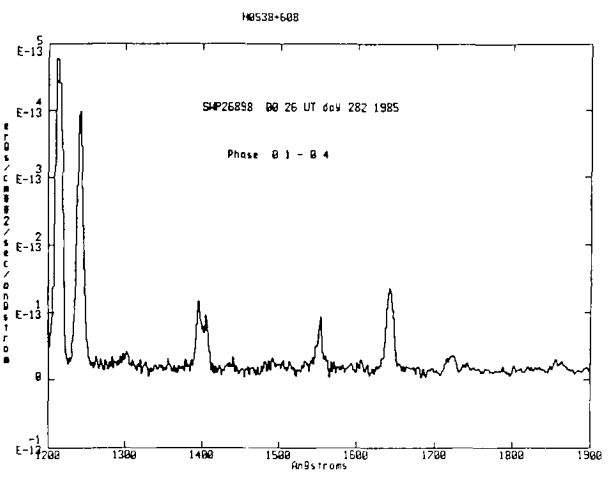
AM Her type objects are widely believed to consist of a magnetic white dwarf in synchronous rotation with a late type secondary and with magnetically channeled accretion flow onto the white dwarf. They are characterized by substantial optical polarization modulated at the orbital period, rapid optical flickering as well as periodic photometric variations, strong emission lines, UV excess and X-ray emission. They tend to be faint with periods are on the order of hours (Ref 1). Most are not phase resolvable with IUE.

The X-ray source H0538+608 (also 4U0541+60, Ref. 2 and 1H053+607, Ref. 3) was identified with a V=14.6 blue (U-B=-0.81) object using positional information from the HEAO A-3 modulating collimator experiment (Ref. 4). Its optical spectrum was found to contain broad emission lines of H, HeI and HeII. Photometric variations were modulated at the nominal 3 hour period as were measurements of circular polarization. These properties are all characteristic of AM Her type CVs.

On day 281-2 (UT), 1985 a comprehensive program of optical, X-ray and UV monitoring of H0538+608 was carried out. This report is a presentation of the data obtained with IUE and a preliminary discussion of its implications. Parts of the optical and X-ray are also presented.

2. OBSERVATIONS AND DATA ANALYSIS

Since the cataloged X-ray intensities for H0538+608 are comparable to AM Her itself and since we expected the UV continuum to scale to optical and X-ray fluxes in a similar manner we expected to be able to obtain well exposed SWP spectra in 30 - 45 minute integrations, ie. much less than the three hour period. What we found however, was that this object was deficient both in its soft X-ray and UV intensity. Figures 1 and 2 show the 1150 -2000 A (SWP) spectra obtained for H0538+608 and a composite X-ray, UV and optical spectrum. The integration times for the SWP spectra are 70, 100 and 50 minutes. The optical and X-ray points on figure 2 are for approximately quarter phase; the UV points are based on integrations outside of eclipse.



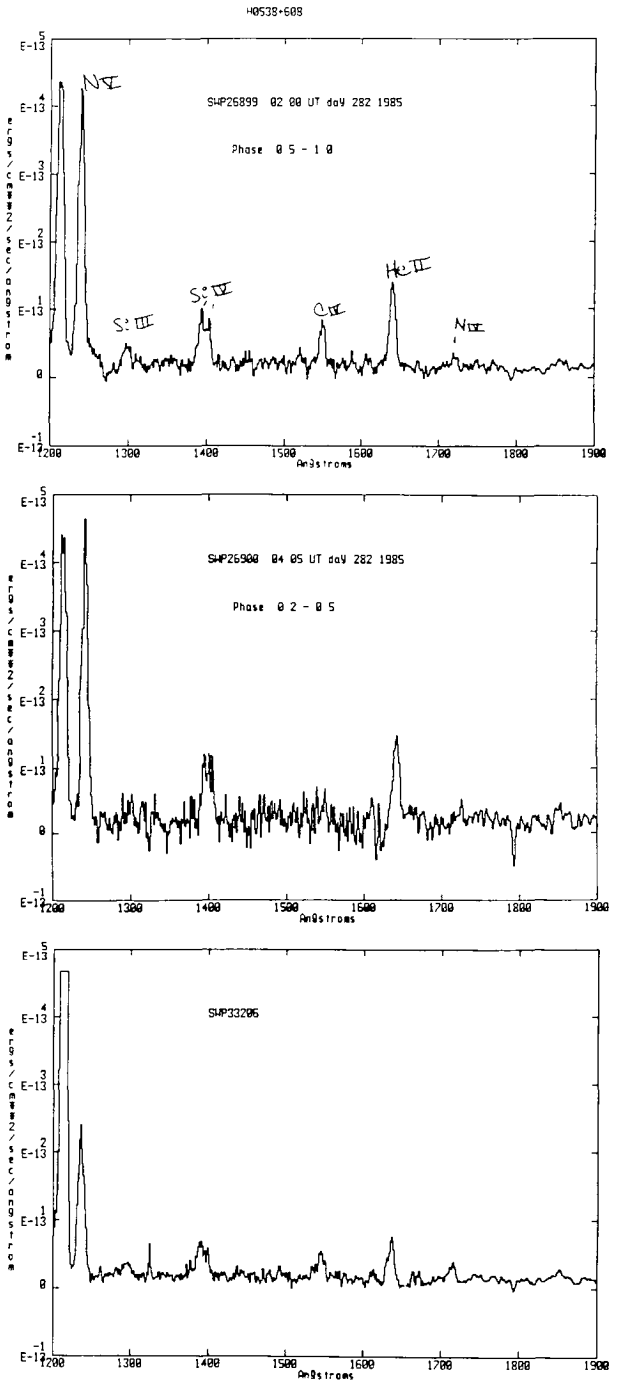


Figure 1. SWP spectra of H0538+608, (a) day 282, 1985 phase 0.1-0.4, (b) day 282, 1985 phase 0.5-1.0, (c) day 282, 1985 phase 0.2-0.5, (d) day 95, 1988 unknown phase

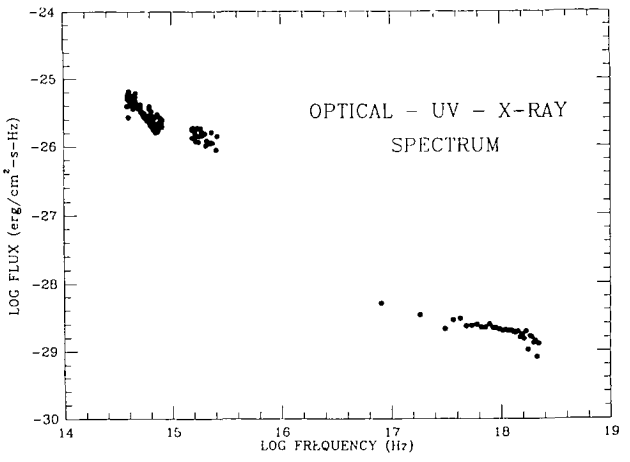


Figure 2. Composite X-ray, UV and optical spectrum for H0538+608

We had hoped to use the shape of the UV continuum as a function of phase to test the hypothesis that the net flux is a combination of cyclotron emission from the accretion column and the Rayleigh-Jeans tail of a black body. The later would result from the reemission of hard photons off the white dwarf surface at the base of the accretion column (Ref. 5). This feature should appear as a steepening of the SWP flux as seen for example, in AM Her itself (Ref. 6) when the base of the accretion column is visible.

Since we do not have phase resolved spectra and owing to the low S/N of the continuum in each of the spectra we obtained, we cannot unambiguously rule out the presence of a Rayleigh-Jeans component. However, a power law in wavelength was fitted to two of the three spectra of day 282, 1985 by binning portions of the continuum containing no apparent features. The resulting power law indices were -1.1 ± 0.5 and -1.2 ± 0.6. This is consistent with the notion that the Rayleigh-Jeans component is absent. It also reflects the overall (flat) nature of the composite spectrum (figure 2).

As is the case with other Am Her objects observed by IUE the SWP spectra have a number of strong emission lines. The lines identified are NV(1240A), SiIII(1299A), SiIV(1394A), CIV(1549A), HeII(1640A) and NIV(1718A); table 1. Some of the emission lines are variable in intensity and some line ratios are variable. In particular, the CIV is nearly absent in one of the three SWP spectra of day 282, 1985 (SWP26900). This spectrum was the result of a 50 minute integration starting at about phase 0.2. Another spectrum, SWP26898, also covers this phase interval, but the CIV is clearly present. CIV is generally weak relative to the other lines when compared to other AM Her objects observed with IUE. Another notable feature of the SWP spectra of H0538+608 is the anomalusly large (relative) strength of the NV feature, as first pointed out by Bonnet-Bidaud and Mouchet (Ref 7). This is more pronounced for the day 282, 1985 spectra than for the April 1988 spectra. The HeII feature appears broadened towards its blue wing on some of the spectra. In SWP26900, there is marginal evidence for a P-Cygni profile in HeII, although the data quality is poor.

The EXOSAT light curves (figure 3) have several notable features. The soft X-ray flux (LE; 0.2 - 1.0 keV) clearly shows intensity modulation with eclipsing at the 3.3 hour period. There are also appear to be slight intensity dips at around phase 0.5. The duration of the eclipses seems to vary. The hard X-ray (ME; 1.0 - 8.0 keV) intensity does not show eclipsing. This type of behavior is similar to that seen in EF Eri, for which the eclipses are presumed due to obscurations of the magnetic polar cap (Refs. 8, 9). However, the ME light curve is rather erratic, particularly on day 281. It clearly shows aperiodic variation with surges by up to a factor of ≈6. It is apparent from figure 3 that these are uncorrelated with the LE light curve. The ME hardness ratio does not reflect the intensity surges. The ME light curve of day 282 varies less dramatically than on day 281.

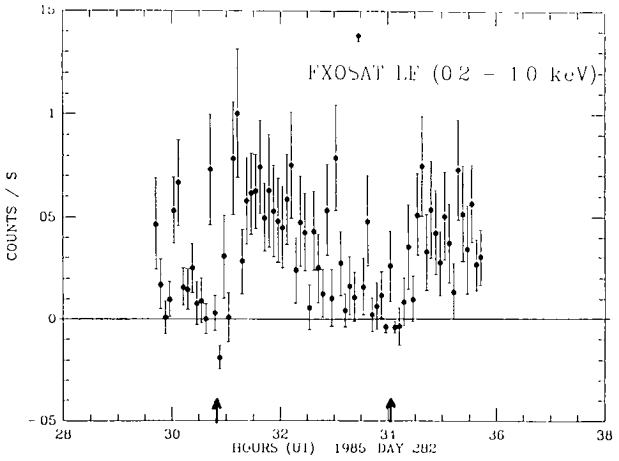
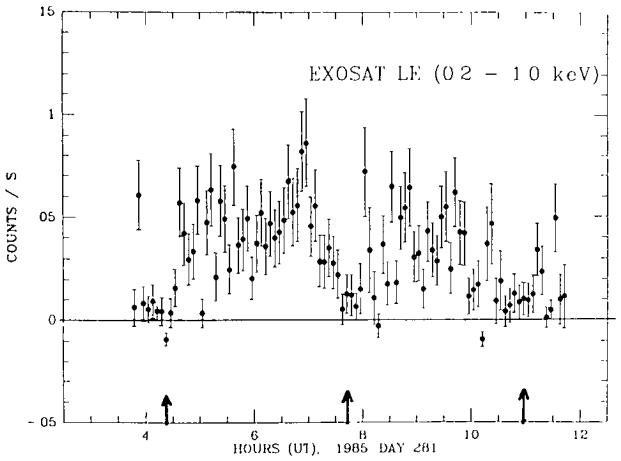


Figure 3. X-ray light curves



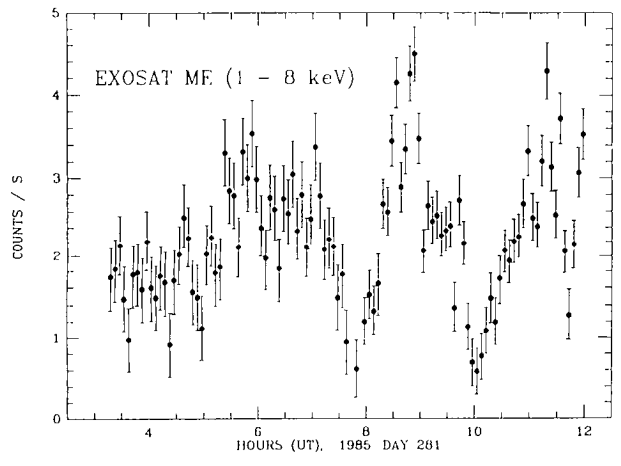


Table 1

Net Flux (/ 10^{-12} erg/cm^2/sec) and Equivalent Width (angstroms) of prominent emission lines

	NV	CIV	HeII	NIV
SWP26898	3.7	0.65	1.4	0.36
	160	37	107	35
SWP26899	3.7	0.65	1.3	0.16
	158	43	105	12
SWP26900	4.0	0.24	1.4	---
	252	16	115	
SWP33205	2.4	0.49	0.61	0.25
	114	53	57	27
SWP33206	2.3	0.47	0.75	0.45
	163	35	260	27

Most of the planned photometric montoring of H0538+608 concurrent with the EXOSAT and IUE observations was lost to clouds. However, low resolution optical spectra taken during November, 1985 clearly show spectral modulation at one half of the orbital period (1.67 hours). The spectra alternate between a reddish continuum with weak emission lines and a bluish one with strong lines. November 1986 observations showed similar modulations, but at the full 3.3 hour period. This could be an indication that accretion to a second magnetic pole undergoes transitions between a high and low state.

Our preliminary interpretation of the X-ray light curves is that H0538+608 exhibits accretion flow variability on time scales less than the orbital period. These instabilities could be a variable accretion rate or distortions of the flow geometry. The latter case would involve complex magneto-hydrodynamic effects with an entangling of the gas stream and magnetic field lines. One might reasonably expect these type of phenomena to be evident in the UV. The broad emission lines seen by IUE are believed to originate in the base of the accretion column (eg. ref. 5). The UV continuum is probably also variable, but it is beyond the capability of IUE to study this system on the required time scale. However, several possibly related effects are seen in the IUE data.

The emission line intensities for H0538+608, particularly CIV are variable. Line ratios as well as individual intensities show variability. It has been pointed out by Bonnet-Bidaud and Mouchet (ref. 7) that the NV feature is anomalously strong relative to other lines. They suggest that this may be indicative of non-solar abundances such as produced in nova-type outbursts. H0538+608 may be representative of some short term evolutionary stage for this class of objects. The classical nova V1500 Cyg has been identified as an AM Her type CV with non-synchronous rotation (ref. 10). It is possible that non-synchronisity could cause accretion instability if the angle if the angle between the magnetic and spin axes is sufficiently large. Although there is no direct evidence of asynchronous rotation in H0538+608 , we cite the possibility of a connection between its erratic high energy behavior, its anomalous abundances and the system V1500 Cyg.

3. DISCUSSION

H0538+608 appears to have several unique characteristics among AM Her type objects studied. It has a high X-ray to optical luminosity ratio, yet it has a relatively flat spectrum and surprisingly low UV continuum luminosity. The emission lines observed by IUE are variable, with CIV being virtually undetected in one SWP spectrum. Its X-ray light curves display an erratic behavior which may be indicative of either a variable accretion rate or distortions of the accretion geometry on time scales less than the orbit period. Optical data taken about one month later show a spectral modulation as well as intensity modulation at one half of the orbital period. Later optical monitoring shows modulation at the orbital period indicating that one pole may exhibit high/low states.

The X-ray light curves and the optical data of November, 1985 are atypical of AM Her objects. The SWP spectra also have unusual characteristics. Could H0538+608 be representative of some transient evolutionary state? We speculate on a possible link between the type of behavior seen in H0538+608 and the system V1500 Cyg. In subsequent work, using additional data we plan to address this issue in more detail.

REFERENCES

1) Cordova, F. and Mason, K.
1983 in Accretion Driven Stellar X-ray Sources, ed. W. Lewin and van den Heuvel (Cambridge University Press).

2) Forman, W. et al.
1978 Ap. J., Supp., 38, 357.

3) Wood, K.S. et al.
1984 Ap. J., Supp., 56, 507.

4) Remillard, R. et al.
1986 Ap. J., Lett., 302, L11.

5) Lamb, D.Q.
1985 in Cataclysmic Variables and Low-Mass X-Ray Binaries ed. D.Q. Lamb and J. Patterson (Reidel).

6) Raymond, J. et al.
1979 Ap. J. Lett., 230, L95

7) Bonnet-Bidaud, J.M. and Mouchet, M.
1987 Astr. Ap., 188, 89

8) Patterson, J., Williams, Glen and Hiltner, W.A.
1981 Ap. J., 245, 618

9) Beuerman, K., Stella L., and Patterson J.
1987 Ap. J., 316, 360

10) Stockman, et al.
1987 Bull. AAS, 19, 1058