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X-RAY, OPTICAL AND UV OBSERVATIONS OF THE AM HER SYSTEM E2003+225

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ABSTRACT. The AM Her type object E2003+225 was observed with EXOSAT, IUE and ground-based telescopes on 1983 Oct. 12. The brightness of the ultrasoft X-ray component allowed the Objective Grating Spectrometer (OGS) to be used, which gave a model-independent determination of the temperature of the blackbody spectrum. The star was observed again on 1984 July 24 by IUE with simultaneous optical spectrophotometry. The high resolution of this observation revealed complex line profiles, and a systematic velocity much smaller than previously reported. The composite energy distribution is presented.

1. Introduction

The AM Her stars are close binary systems in which gas is radially accreting onto a magnetic white dwarf from a Roche-lobe filling secondary. Various components have been detected from AM Her stars: hard X-ray emission from bremsstrahlung, cyclotron emission in the optical and IR and a soft X-ray, blackbody component. Simultaneous observations in various wavelengths is essential to study the relationship between these components, and to study the blackbody spectrum. Coordinated UV and X-ray observations are necessary because most of this component is obscured by interstellar absorption. We therefore observed E2003+225, a recently discovered long period (222.51min) AM Her system (Nousek et al. 1984, hereafter N84) on two occasions using EXOSAT, IUE and ground-based telescopes.

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2. Observations

1983 Oct. 12. EXOSAT observed E2003+225 from 0300 - 0920 UT. Because the count rate was sufficiently high, it was decided to deploy the OGS on LE2. This is the second such observation for this class of stars (see Heise et al. 1984). No ME signal was detected with a limit of 2.8×10^{-12} erg s^{-1} (2-10keV) (90% confidence level). Simultaneous optical spectroscopy was performed from two sites: the Lick 120" with IDS (0300 - 0330 UT; non-photometric) and University of Hawaii 88" (0600 - 0900 UT). IUE observations were made later on the same day (1500 - 2200 UT). Two SWP exposures and one LWP exposure was obtained. All three IUE exposures lasted more than half an orbital period.

1984 July 24/25. IUE observed E2003+225 from 1925 to 0250 UT, thus covering ~2 orbital cycles, and obtained 6 SWP and 6 LWP spectra. Simultaneous high time (2.5 min) and spectral (1.5A) resolution spectroscopy was obtained with the 2.5m INT with RGO spectrograph and IPCS from 2300 to 0300 UT, thus covering slightly more than one orbital cycle. Five colour photometry was performed with the 1m JKT simultaneously, and again two nights later.

3. Results

In most cases, our results are consistent with those in N84. This includes the following features: X-ray luminosity and light curve; temperature and column density of the blackbody component; optical brightness and orbital modulation during the 1984 July observations; and the spectral features observed. We also used N84 orbital period and found no discrepancy, although their ephemeris is not accurate enough to extend to our observations. On the other hand, visual and blue magnitudes calculated from the Hawaii observations indicate that the star is approximately 1 mag brighter than its usual variability range of B=14.5-15.4. The systematic velocity is also found to be different from the N84 value (see below).

3.1. Optical Spectroscopy

For the first time for E2003+225, our high time and spectral resolution has enabled the complex time-varying structure of the emission lines to be presented in the form of a contour plot (Fig.1). This can be compared to similar diagrams for other AM Her stars (see Mukai & Charles 1985 and references therein). We distinguished a base (broad) component and two peak (sharp) components, and fitted composite profiles accordingly (for details see Mukai & Charles 1985). We find that the broad component has a systemic velocity of -30 km s^{-1}, which is very different from the 300 - 500 km s^{-1} reported in N84, although our semiamplitude of 370 km s^{-1} is similar to the N84 value. Our wavelength calibration is accurate to ~0.1A and the effect

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is therefore certainly real. The third independent spectroscopy was the Lick observation, which covered only a fraction of the orbital period, but nevertheless shows the center of light of HeII 4686 to be around 4682A. (Our Hawaii observation lacks accurate calibration and cannot comment on this effect.)

As for the sharp components, one of them has a similar velocity to that of the broad component, and probably originates in a slightly different part of the accreting stream. The other sharp component lags the broad component by 105^{o}, and probably originates on or near the secondary. This component has a systemic velocity of 50 km s^{-1} and a semiamplitude of 171 km s^{-1}. The peak positions of these two sharp components and the best fit sinusoids are displayed in Fig.2, together with the curve representing the base component.

3.2. IUE Spectra

The spectra taken on both occasions are very similar to those of other AM Her systems (e.g., Fabbiano et al. 1981; Patterson et al 1984). The continuum does not show any significant contribution from the Rayleigh-Jeans tail of the hot blackbody component. In the 1984 July spectra, which has better temporal resolution, a change in the line intensities is clearly seen. A particularly interesting feature is the NV 1620, which was observed in the first SWP spectrum, not seen in the subsequent two exposures, and reappeared in the fourth SWP spectrum, which was taken about one orbital cycle after the first. A comparison of optical events suggests that this transient feature appeared at linear polarization phase ~0.8.

3.3. EXOSAT Grating Spectrum

The grating image was analyzed with a multi-parameter fitting programme, which incorporates the dispersion relation, interstellar absorption, and the grating and detector efficiencies, and predicts the count rate at each pixel for a specific model. Then the parameters are automatically adjusted so as to search for the best fit value. The result (see Fig.3) of this fit is kT = 25eV and $N_H = 6.1 \times 10^{19}$ cm^{-2}. This temperature is somewhat lower than the value for AM Her (~50ev) (Heise et al.1984), but similar to that of VV Pup (Patterson et al. 1984), which was derived using an indirect method.

The inferred luminosity of the blackbody component (L_{bb}) is 2.6×10^{31} - 1.0×10^{32} erg s^{-1} corresponding to distances of 100 and 200pc, respectively. Similarly, the accretion rate is 6.5×10^{-12} - 2.6×10^{-11} M_{o} yr^{-1}, for a typical white dwarf. The radius of the emitting region is 45 to 90 km, and hence the emitting area as a fraction of the white dwarf surface (f) is 5.0×10^{-6} - 2.0×10^{-5}. L_{bb}/f is 5.0×10^{36}, which would mean, for a magnetic field of ~20 MG, that the losses by bremsstrahlung and cyclotron emission are roughly equal (Lamb and Masters 1979).

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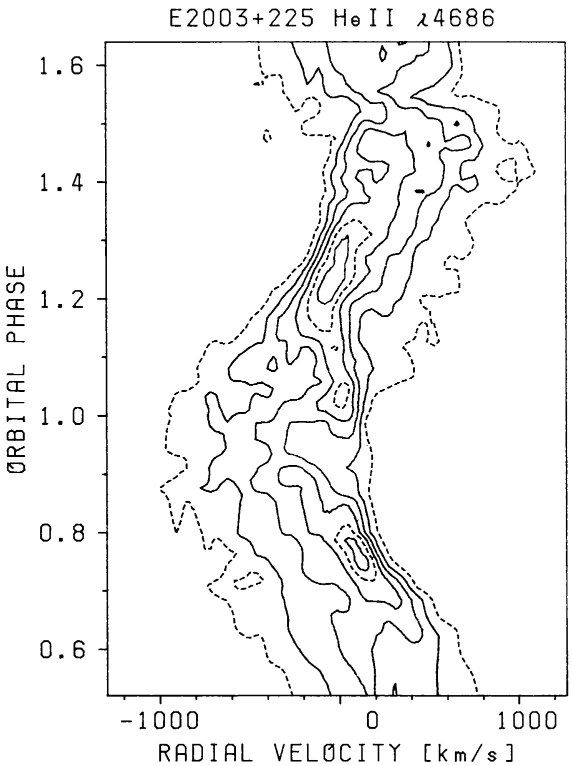

Fig.1 Contour plot of HeII 4686 from our INT observation. The levels are 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 x the continuum.

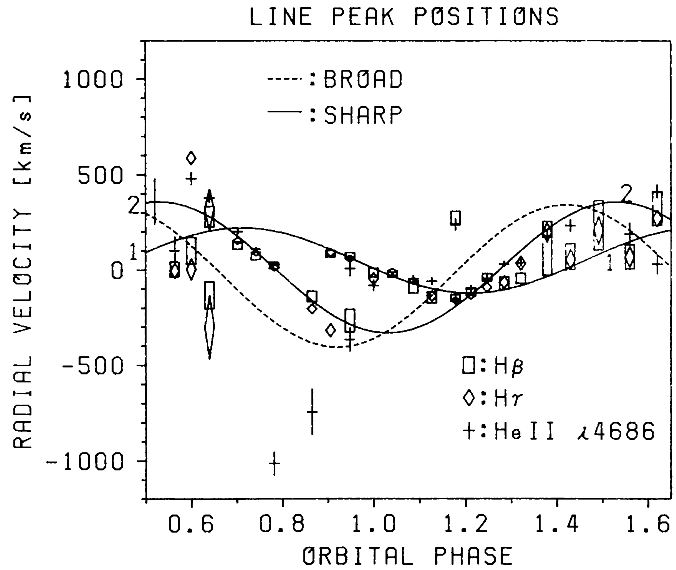

Fig.2 The positions of the peak components and the fitted curves for both the broad and the sharp components in E2003+225.

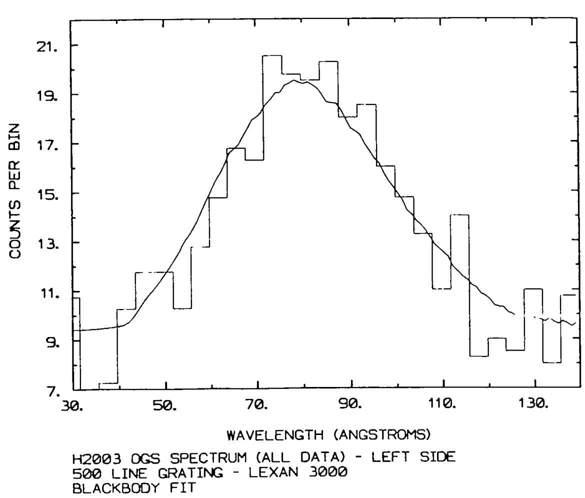

Fig.3 The counts in one half of the OGS image and the best blackbody fit.

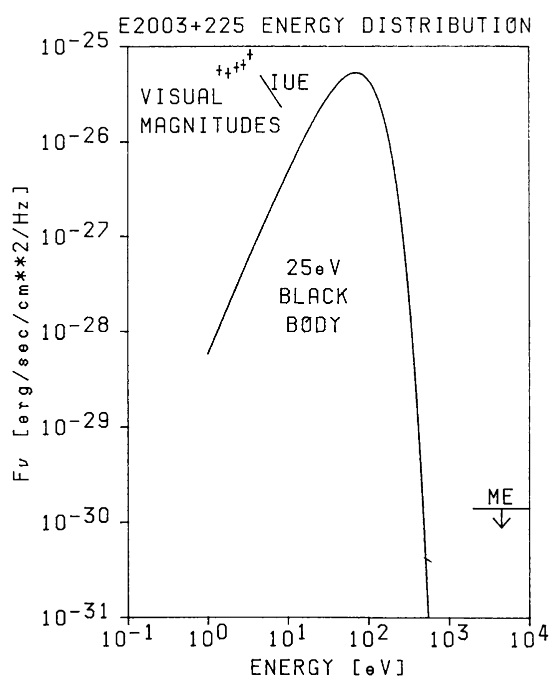

Fig.4 The composite energy distribution of E2003+225.

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4. Discussion

Change in the geometry? The observed change in the systemic velocity of the emission lines is very large and very puzzling. Possible asynchronism is suggested, because of the long orbital period of E2003+225 (N84), and this may lead to a change in the system geometry. Further high resolution spectroscopy is essential in order to follow up this phenomenon.

Overall energy distribution. The composite energy distribution calculated from our observations is presented in Fig.4. The diagram is dominated by the 25eV blackbody component, most of which is hidden by interstellar absorption. The optical and IR is dominated by the cyclotron emission, and the red dwarf secondary has never been detected. This figure is very similar to that for VV Pup (Patterson et al. 1984). This accurate determination of the physical parameters of the shock region will allow progress in our understanding of the radial accretion process, particularly if the bremsstrahlung component can be measured by further X-ray observations.

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