HIGH SPECTRAL RESOLUTION OBSERVATIONS OF CORONAL X-RAY EMISSION FROM THE RS CVn BINARY SIGMA CORONA BOREALIS

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Results of a high spectral resolution observation of the RS CVn binary σ Cr B, made with the Focal Plane Crystal Spectrometer (FPCS) on the Einstein Observatory, are reported. A spectral scan in the 800-840 eV interval shows clear presence of an X-ray emission line at 826 eV identified with the $^1S_0$-$^1P_1$ transition of Fe XVII. A prominent peak at 1007 eV in the scan band 987-1013 eV is attributed to a blend of lines due to Fe XVII and Fe XXI. Using the observed line fluxes and the Raymond-Smith model, best fit values of corona temperature and volume emission measure, with associated 90% confidence level uncertainties, are derived to be $(6.9 \pm 0.8) \times 10^6$ K and $(1.7 \pm 0.7) \times 10^{53}$ cm^{-3}, respectively. Pressure and density of the X-ray emitting plasma and loop length are deduced by applying a Constant Pressure Coronal Loop Model.

INTRODUCTION

Sigma Corona Borealis (σ Cr B), a visual binary located at a distance of 21 pc, consists of the primary star HD 146361, (m_V = 5.76, spectral type F8V) and the secondary HD 146362, with an angular separation of 5.6". The primary HD 146361 itself is a double-line spectroscopic binary with a period of 1.14 day (Batten, Fletcher and Mann 1978). Strong chromospheric and transition region lines with surface fluxes comparable to those observed in RS CVn binaries, have been observed with the IUE from HD 146361, thus confirming its RS CVn-like nature (Tarafdar and Agrawal 1983). X-ray emission from σ Cr B was detected with the HEAO A-2 experiment (Agrawal, Riegler and Garmire 1980) and confirmed subsequently with Einstein observations (Walter 1981). Moderate spectral resolution observations carried out with the Solid State Spectrometer (SSS) on Einstein showed presence of X-ray emission lines due to ions of magnesium, silicon, iron etc. in its spectrum (Agrawal, Riegler and White 1981). This implied that the X-ray emission in σ Cr B originated in a corona which is most likely associated with the RS CVn binary HD 146361. The SSS spectrum required a two temperature Raymond-Smith plasma fit, a dominant low temperature component with a temperature $T=6 \times 10^6$ K and a high temperature component with $T > 3 \times 10^7$ K. The iron L-emission lines were not resolved in the SSS spectrum so that it was not possible to identify the dominant iron ions responsible for emission in the 0.8-1.0 keV band.

The FPCS is a curved crystal Bragg spectrometer designed for high spectral resolution ($E/\Delta E$ in the range 50-500) studies of X-ray sources in the 0.2 - 3.3 KeV band (Canizares et al. 1977). The spectral bands 12.24 - 12.56 Å and 14.76 - 15.50 Å were scanned with an exposure of about 2×10^4 s for each band on August 17, 1980.

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ENERGY SPECTRA

In fig. 1 we show plots of observed count rate vs. energy in the 987-1013 eV and 800-840 eV bands, corrected for exposure time and instrumental efficiency. The principal X-ray emission lines and their energies expected from a corona with log T = 6.84 (best fit value of T discussed below) from calculations of Raymond and Smith (1977) are marked by arrows in both graphs. The dashed horizontal lines show the average background from off-source observations. We identify the peak at 826 eV with the $^1S_0$ $^1P_1$ transition of Fe XVII. Counts detected in the 807-820 eV band are almost certainly due to the $^1S_0$ - $^3P_1$ (803 eV) and $^1S_0$ $^3D_1$ (813 eV) multiplets of Fe XVII. A prominent peak visible at 1007 eV is most likely due to a blend of Fe XXI and Fe XVII lines. We have shown the calculated spectrum from Raymond-Smith and Mewe-Gronenschild (1981, 1982) emissivities for the best fit value of log T = 6.84 by the continuous curves in fig. 1.

CORONA TEMPERATURE AND VOLUME EMISSION MEASURE

The observed flux values of the identified lines due to Fe XVII and Fe XXI ions are converted to line luminosities (L_X) using a distance of 21 pc for σ Cr B. Using these L_X values and the coronal emissivities in these energy bands taken from the calculations of Raymond and Smith as well as Mewe and Gronenschild we estimate the volume emission measure (VEM) for the various lines as a function of the corona temperature (T) separately for the 800-820 eV, 820-832 eV and 987-1013 eV bands. We find that the three VEM vs. T curves overlap, which demonstrates that all the lines can be explained as originating from a single-temperature corona. A χ^2-minimization analysis, using the criterion of Avni (1976), was used to generate 90% confidence contours for log VEM vs. log T. We obtain best-fit values of T = $(6.7 \pm 0.8) \times 10^6$ K and VEM = $(1.7 \pm 0.7) \times 10^{53}$ cm^{-3} at χ^2/d.o.f. = 0.83 for the Raymond-Smith model and T = $(6.5 {}^{+0.6}_{-1.2}) \times 10^6$ K and VEM = $(4.8 \pm 2.8) \times 10^{53}$ cm^{-3} at χ^2/d.o.f. = 2.0 for the Mewe-Gronenschild model. The corresponding low-temperature component value of the SSS data fit were T = $(5.9 \pm 0.5) \times 10^6$ K and VEM = 1.8×10^{53} cm^{-3}.

DISCUSSION

X-ray emission lines due to ions of Fe XVII and Fe XXI detected in the FPCS spectra confirm the coronal nature of the X-ray emission from σ Cr B. The values of T and VEM derived from FPCS observations are in excellent agreement with those obtained earlier with the SSS observations for the dominant low temperature component using the Raymond-Smith model (Agrawal, Riegler and White, 1981). The IUE observations strongly suggest that the spectroscopic binary HD 146361 is the X-ray source in σ Cr B. Since the two component stars of HD 146361 have nearly the same magnitude and mass and similar spectral type and Mg II emission (Tarafdar and Agrawal 1983) we assume that the observed X-ray emission arises due to equal contribution from the coronae of the two stars.

The constant pressure coronal loop model of Rosner, Tucker and Vaiana (1978) has been used to explain coronal X-ray emission from RS CVn binaries (Walter et al. 1980). We obtain a loop length L = 1.2×10^9 cm for filling factor $F_3 = 1$, pressure $P = 97$ dynes cm^{-2} and electron density $n_e = 5 \times 10^{10}$ cm^{-3}.

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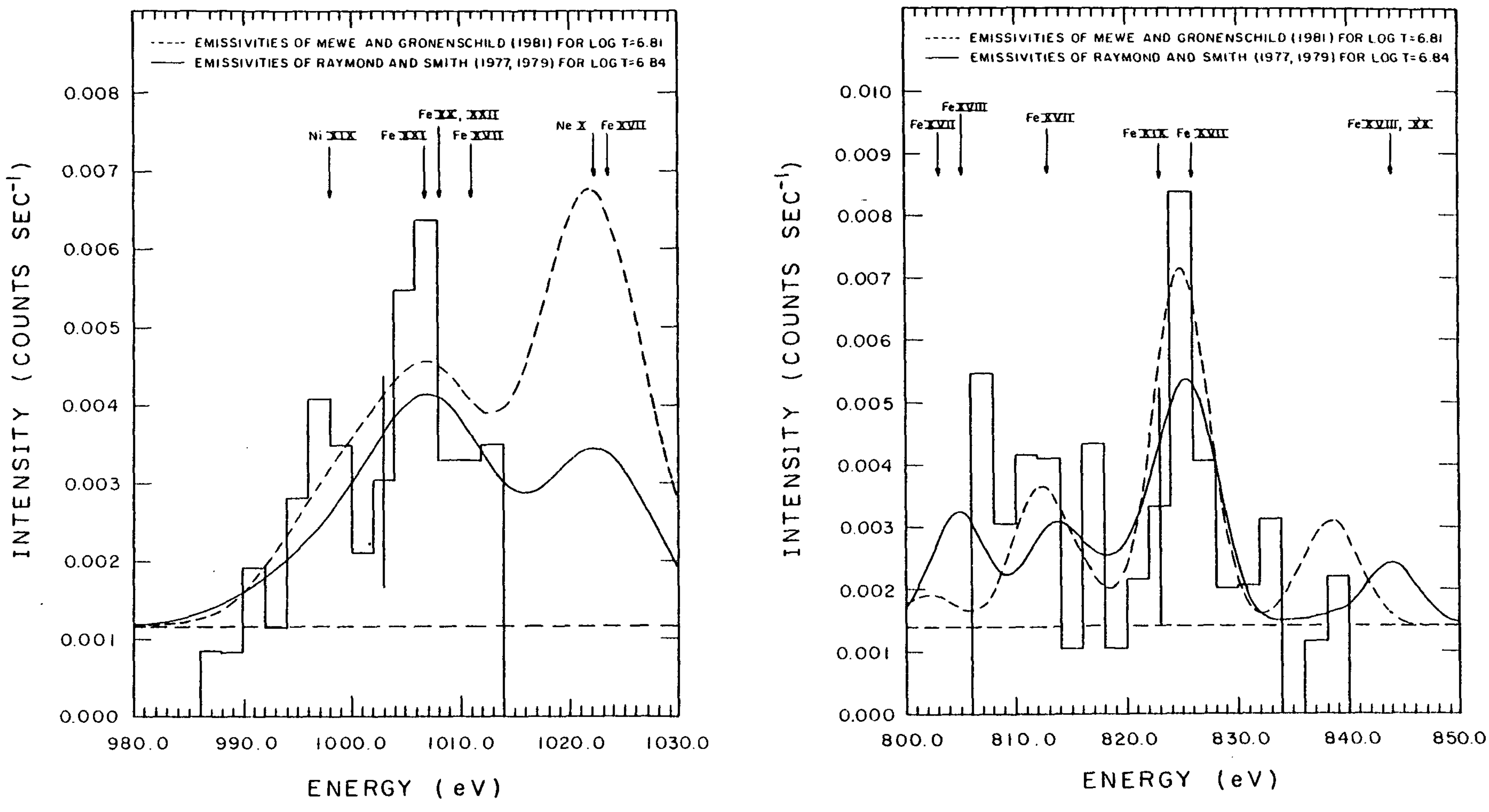

FIG. 1 SPECTRAL PLOT OF THE FPCS 987-1013 eV AND 800-840 eV SCANS OF THE X-RAY EMISSION LINES DUE TO Fe XVII AND Fe XXI FROM σ CrB. THE HORIZONTAL DASHED LINES INDICATE THE BACKGROUND LEVEL.

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