HIGH AND MEDIUM RESOLUTION SPECTROSCOPY OF THE X-RAY TRANSIENT 4U1543-47

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ABSTRACT. Preliminary results of an EXOSAT observation of the transient X-ray source 4U1543-47 are presented. The source was observed in August 1983, during a high state, following a Tenma alert that the source was again active. Results from the GSPC and the LE 1000 l/mm grating are presented. The spectrum is complex, but in the 2-10 keV energy range can be well described by a Comptonised thermal distribution. Extrapolating the same model into the lower energy band of the grating requires an absorption column density equivalent to 2×10^{21} H cm^{2}. A marked under-abundance of Oxygen and overabundance of Nitrogen, along with a strong, unidentified line feature at 9.8 Å, are necessary to model the grating data.

1. INTRODUCTION

On 1983 August 18, a bright transient in the Lupus region was detected by Tenma (Kitamoto et al.1984). On 1983 August 28 EXOSAT observed the same region of sky while the transient was still active. The position of the source, determined in the LE telescopes, is RA = 15h 43m 34.1s, DEC = 47° 30' 59", consistent with the known transient 4U1543-47 (e.g. Li, Sprott and Clark, 1976). This position lead to the identification with a 14.9 mag star by Pedersen (1983). The source was observed by EXOSAT for about 4 hours. Both of the LE telescopes were configured with CMA's in focal plane and dispersion gratings interposed in the light path. An attitude trim was made in the middle of the observation to avoid exposing a small area of the CMA plates with too high a dosage. The LE1 telescope (with 1000 l/mm grating) was used throughout the observation with the thin Lexan filter, while the LE2 telescope (with 500 l/mm grating) was used with the thin Lexan filter and the Aluminium Parylene filter. Data were also obtained with the GSPC, while the ME data overflowed in

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the Argon counters because of the exceptional source strength. In the remainder of this paper we will confine the discussion to the data taken with the GSPC and the LE1 telescope.

2. GSPC DATA ANALYSIS

The GSPC data were not well fitted by any simple spectral form (power law, thermal or blackbody), but a good fit was achieved with more complex spectra. The following three models gave similar fits:

- The combination of a thermal spectrum with $kT \sim 1.3$ keV and a blackbody spectrum with $kT \sim 0.82$ keV;
- the combination of two blackbody spectra (with $kT \sim 0.5$ and 0.8 keV respectively);
- a spectrum of the form $\frac{dN}{dE} = N E^{-\Gamma} e^{-E/kT}$ (an unsaturated Comptonised spectrum) with $\Gamma \sim -1.5$ and $kT \sim 0.85$ keV.

In all three cases a broad iron line was required at an energy of 6.6 ± 0.4 keV, an equivalent width 220 ± 55 eV and an intrinsic full width half maximum of 2.0 ± 0.4 keV. The line parameters were poorly determined because of the steepness of the underlying spectrum. The nominal value of N_H obtained from the fit was $< 2 \times 10^{21}$ H cm^{-2}

3. GRATING DATA ANALYSIS

A spectrum extraction and background subtraction technique similar to that developed for the Einstein OGS was used (Kahn, Seward and Chlebowski 1984). A slice along the dispersion direction 12 pixels wide was accumulated from the data. This includes the zero order and the lower and upper higher orders. Six more slices at different angles with the dispersion direction (but excluding the perpendicular direction) were also taken and used to derive an average smoothed background as well as an average zero order profile. The latter provides the resolution of the spectrum and was used in the fitting procedure. The average background is added to the model during the fitting procedure and compared with the data. The results were found to be insensitive to the continuum model used and for simplicity initially a fit to a simple thermal bremsstrahlung continuum was used. This model has a temperature of 1 keV and a Hydrogen column density of 5×10^{21} H cm^{-2}. The result of this is shown in Fig. 1. A high reduced chi-squared of 4 was obtained and Figure 1 shows this to be principally a consequence of two points. First, there is no trace in the data of the Oxygen edge expected for normal cosmic abundances. Second, a marked excess over the model exists at about 10 Å.

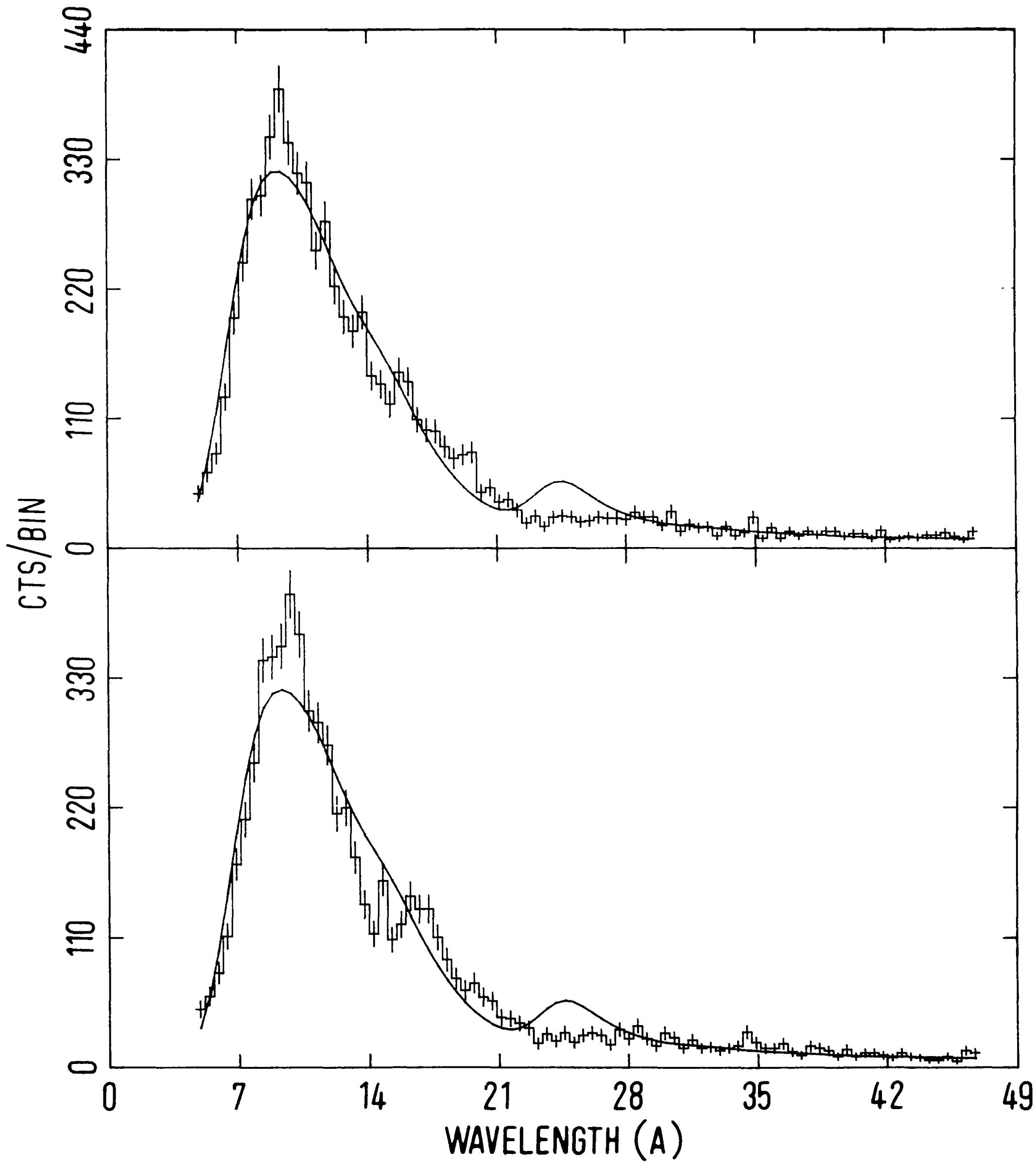

Figure 1: The 1000 line grating spectrum with the best fitting thermal bremsstrahlung model attenuated at low energies by absorption of cold cosmic abundance material. Both the data and the model include the background component. The upper and lower frames correspond to the two halves of the dispered spectrum. Note the lack of an oxygen edge in the data between 22 and 25 Å and the emission feature at ~ 10 Å.

If we allow the Oxygen and Nitrogen abundances to be free parameters, and exclude from the fit the region around 10 A, we obtain, with little change in the continuum parameters, that Oxygen should be 0.4 times underabundant and Nitrogen about 8 times overabundant. Similar values are obtained if we replace the thermal model with the Comptonised model found from the GSPC analysis. If a line is included around 10 Å (Fig. 2) the reduced chi-square decreases to 2.6. The wavelength of the line is 9.8 Å, its equivalent width 0.6 A, while the intrinsic width is narrow (<0.1 Å). A large range of values of kT and Γ provide a satisfactory fit, with no effect on the line and abundance parameters. If the values are fixed at the GSPC values, the best fit equivalent column density is 2×10^{21} H cm^{-2}, with Nitrogen 8 times overabundant and the Oxygen abundance zero. The value of 0.4 for the Oxygen abundance derived for a thermal model may be considered a conservative upper limit.

The fact the chi-square is still high can be attributed to the presence of a feature around 18 Å that probably originates from the iron L complex.

4. DISCUSSION

The outburst of 4U1543-47 during the early phase of the EXOSAT mission has afforded us the opportunity to study the spectral characteristics of X-ray transient sources in unprecedented detail. Not only have we been able to accurately position this source and thereby identify the optical counterpart, but the use of the GSPC and the objective transmission gratings has provided high resolution spectra of its X-ray emission across the entire X-ray bandpass.

The objective grating spectrum is complex. Of particular interest are the apparent abundance anomalies in the absorbing medium and the prominent emission line near 10 Å. The inferred underabundance of oxygen and overabundance of nitrogen are similar to those derived from Sco X-1 from objective grating spectra of that source taken with the Einstein Observatory (Kahn, Seward and Chlebowski 1984). In the case of Sco X-1, the companion star is known to be evolved, so the material currently being transferred to the compact object may have undergone nuclear processing. A depletion of oxygen and enhancement of nitrogen might then be expected due to the CNO cycle (Kahn, Seward and Chlebowski 1984). The fact that similar departures from cosmic abundances are observed for 4U1543-47 suggests that the companion star in this transient system is also significantly evolved.

The observed emission line at 9.8 Å is more difficult to understand. This wavelength does not correspond to that of any known prominent lines. Since the line is narrow, < 0.1 Å, it is also unlikely that it has been substantially Compton red or blue-shifted. There are however a number of weak lines (mostly due to partially ionised iron) throughout this wavelength band. For parameters which

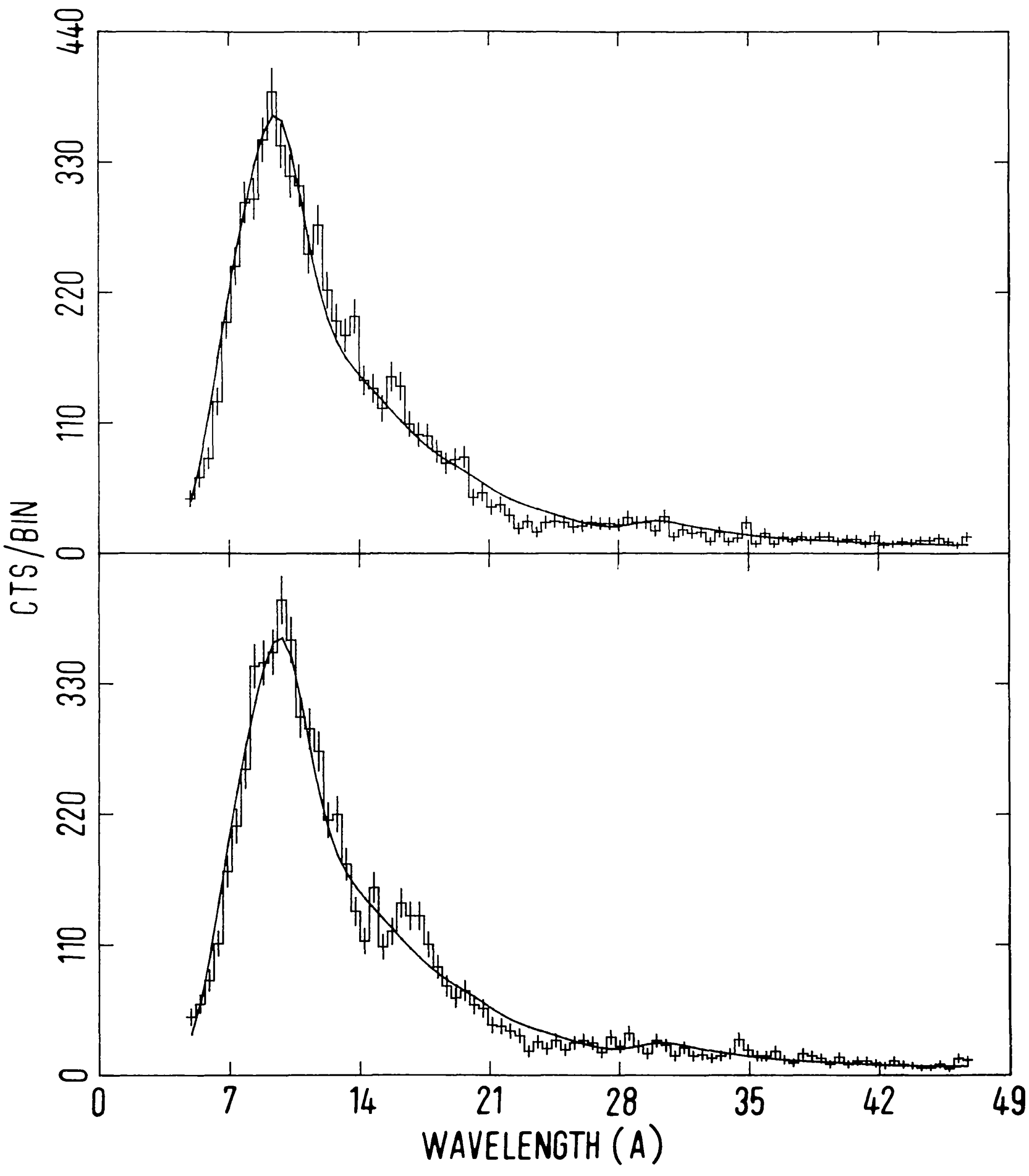

Figure 2: The 1000 line grating spectrum with the best fitting comptonised model, including a line at 9.8 Å and a variable abundance of Oxygen and Nitrogen.

are likely to be appropriate to the ambient environment (density ~ 10^{11} cm^{-3}, size~10^{10} cm), the prominent resonance line are optically thick, so it is possible that these weaker lines may be enhanced due to optical or collisional pumping.

REFERENCES

Li, F.M., Sprott, C.F., and Clark, G.W. 1976. Ap.J., 203, 187
Kahn, S.M., Seward, F.D., & Chlebowski, T. 1984. Ap.J., 283, 286.
Kitamoto, S., Miyamoto, S., Tsunemi, H., McKishima, K., & Nagkagawa, M., 1985. preprint.
Pedersen, H. 1983. ESO Messenger, 34, 21.