A Search for the Signature of the Diffuse Soft X-ray Background in the *ROSAT* Wide-Field Camera All-Sky Survey

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We present the results of an attempt to locate the signature of the diffuse soft X-ray background in the *ROSAT* Wide-Field Camera (WFC) all-sky survey. After removal of non-cosmic background sources (eg. energetic charged particles), the field-of-view integrated count rate in the WFC S1a filter (90–185 eV) shows no consistent variation with Galactic latitude or longitude. We place limits on the signal from the soft X-ray background (SXRB) in the WFC, and show that these limits conflict with the observations of the Wisconsin Sky Survey if the SXRB in this energy range is assumed to be produced by a thermal plasma of cosmic abundance and a temperature $T \sim 10^6$ K within $d \sim 100$ pc of the Sun.

1. Introduction

The *ROSAT* X-ray satellite was launched in June 1990 in to a circular orbit at an altitude of 575km, and an inclination of 53°. It carries two co-aligned telescopes, the German X-Ray Telescope (Trümper 1984) working in the 0.1–2keV energy band, and the UK Wide-Field Camera (Sims et al. 1990) which is an imaging telescope with a field-of-view of 2.5° operating in the extreme ultraviolet (90–200 eV).

2. The Wide-Field Camera All-Sky Survey

The dataset produced by the *ROSAT* WFC all-sky survey, carried out between August 1990 and February 1991, has been extensively searched for point sources with the final cataloguing of 479 EUV sources (Pounds et al. 1993, Pye et al. 1995). In addition to locating point sources, the WFC also presented an excellent opportunity to map with unprecedented sensitivity and spatial and spectral resolution the hot X-ray emitting gas thought to fill the local cavity in the interstellar medium. The bandpasses of the WFC survey filters ("S1" and "S2", Figure 1) are comparable to the "B"- and "Be"-bands of the sky surveys performed by the Wisconsin group (McCammon et al. 1983, Bloch et al. 1986), and although the throughput of the WFC is much smaller than the instruments used in those rocket flights, the average sky exposure in the WFC survey ranges from ~ 2 ks in the plane of the Ecliptic to ~ 80 ks near the poles yielding potentially much greater sensitivity. The WFC survey also confers the advantages of a six-month baseline over which to measure slowly varying extraneous background components, and the imaging capabilities of the WFC allow unequivocal exclusion of the contribution of point-like and extended sources (SNRs) from the detected diffuse emission.

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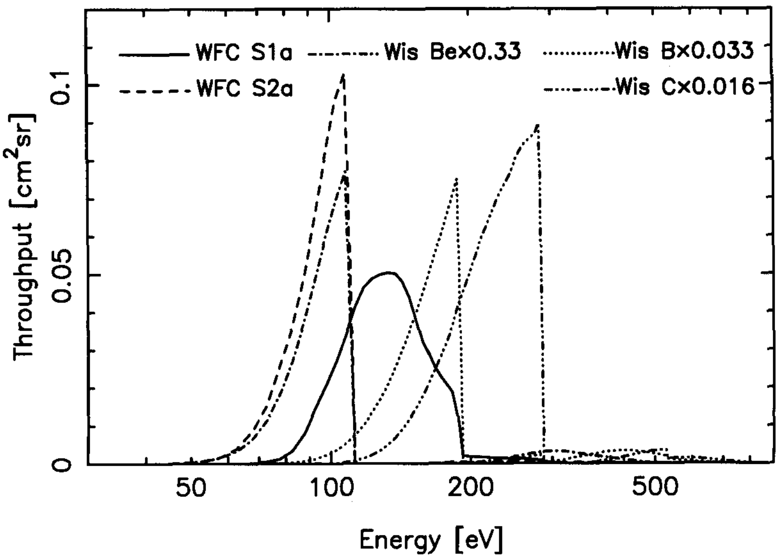

FIGURE 1. Throughput of the WFC survey filters and the Wisconsin "Be"-, "B"- and "C"-bands

TABLE 1. Typical count rates from various background components in the WFC

Component	Intensity ($ct\,s^{-1}$)
Spacecraft glow	0–1000
He II geocorona	$\ll 1$ (S1)
	10–40 (S2)
Auroral electrons	0-1000
Cosmic rays	4–25
MCP intrinsic noise	1.97 ± 0.17

3. Extraneous Background Components

Five sources of non-cosmic background have been identified in the WFC survey and are listed below. Typical count rate ranges experienced under normal operating conditions during the survey are given in Table 1.

(*a*) **Spacecraft glow** A persistent background phenomenon which shows a clear correlation with the orientation of the spacecraft with respect to its velocity vector, and is thought to be due to an interaction between those surfaces and the impinging atmosphere producing a "spacecraft glow" in the far ultraviolet, possibly via a chemiluminscent reaction on the exposed spacecraft surfaces (West et al. 1994). This background component has been well characterised in terms of orbital parameters and the affected time periods can be reliably removed from the dataset.

(*b*) **He II 304 Å geocoronal radiation** Solar helium line emission resonantly scattered from the He II in the plasmasphere. The WFC filters are designed to suppress

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geocoronal radiation and the S1 survey filter is highly opaque at the wavelengths (transmission $\lesssim 10^{-9}$). This component has been positively identified in the survey data taken in the S2 filter, which has allowed us to show that this background source is not present in the S1 survey data.

(*c*) **Auroral electrons** Soft ($E \sim 50\,\mathrm{keV}$) electrons precipitated at high geographic latitudes ($\sim$ 50–70°). Excluding data taken while the spacecraft is in the auroral zones is highly effective at excluding this background component.

(*d*) **Cosmic rays** are modelled by correlating the WFC count rate (after removal of the spacecraft glow and auroral components) with the contemporaneous Master Veto Rate (MVR) from the *ROSAT* PSPC . A convincing linear correlation is found at low geomagnetic latitudes ($|\Lambda_{\mathrm{B}}| \lesssim 40°$) which allows the cosmic ray induced background in the WFC to be modelled to better than $\sim$ 10%.

(*e*) **MCP intrinsic noise** caused by β-decay of ^{40}K in the substrate of the microchannel plate detector. The half-life of the decay process is extremely long ($t_{1/2} \simeq 1.28 \times 10^{9}\,\mathrm{yr}$) and this background component is essentially constant throughout the survey.

4. Limits on the Diffuse Background in the WFC

After removal (by discrimination) of the spacecraft glow and auroral background, and subtraction of the cosmic ray contribution, cleaned data are available covering $\sim$ 40% of the sky, with a total exposure of $\sim$ 130 ks. The residual field-of-view averaged count rate shows no statistically significant variation with Galactic longitude or latitude, and the sky averaged count rate (2.00 ± 0.12 counts s^{-1}) is consistent with the intrinsic noise in the WFC microchannel plate detector (1.97 ± 0.17 counts s^{-1}). Clearly this result cannot be regarded as a detection of a signal from the diffuse background in the WFC, rather we interpret this as a conservative upper-limit on the field-of-view averaged count rate in the S1 band of around 0.5 counts s^{-1}.

To compare the cleaned WFC survey data with the results from the Wisconsin survey we have prepared "simulated" WFC skymaps from the data of McCammon et al. (1983). Proceeding under the assumption that the measured B-band count rate represents emission from an optically thin thermal plasma (Raymond & Smith 1977) with Solar abundance with intervening neutral hydrogen column $\mathrm{N_H} = 2 \times 10^{18}\,\mathrm{cm}^{-2}$, we can predict S1/B band ratios for a range of plasma temperature. By scaling the Wisconsin B-band map by the relevant factor, adding a constant 1.97 counts s^{-1} to represent the MCP intrinsic noise and masking areas of sky for which clean WFC data are not available, we can produce synthetic WFC skymaps for comparison with the data. These maps (Figure 2) show that large-scale structure should be visible in the WFC survey data and is demonstrably not present. Typically the error in the WFC skymap is dominated by uncertainties in the MCP intrinsic noise ($\sim$ 10%) and in the correlation with the MVR, rather than by counting statistics.

Jelinsky et al. (1995) have recently presented the results of an analysis of around 15% of the data taken with the *EUVE* Deep Survey Spectrometers during the *EUVE* sky survey, and have also derived limits on the plasma emission measure which are a factor around 5 to 10 below those implied from the Wisconsin C-band measurements. In Figure 3 we plot the emission measure derived from the Wisconsin Be, B and C-bands compared to the upper-limits from the WFC and *EUVE* data. The latter are taken directly from Jelinsky et al. and are calculated using a different plasma code (Landini & Monsignori-Fossi 1990). Jelinsky suggests that these values may differ from equivalent limits calculated using the Raymond & Smith code by 40% in the temperature

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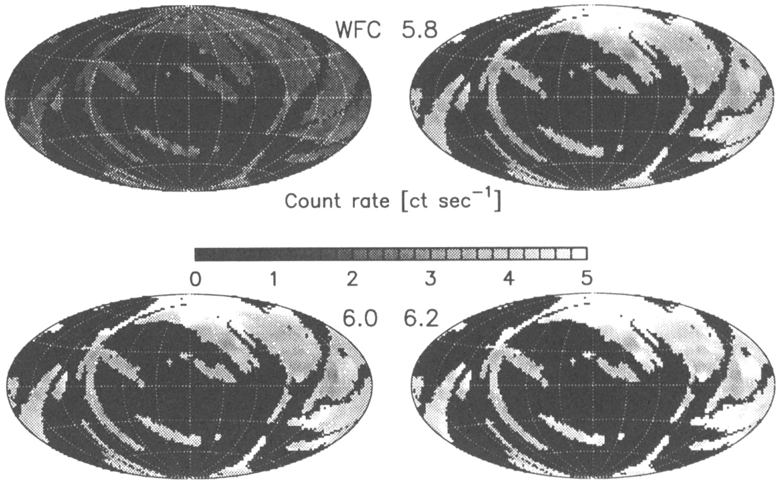

FIGURE 2. Comparsion of WFC survey data with maps synthesised from the Wisconsin B-band assuming optically thin thermal plasma ($\log T = 5.8, 6.0$ and 6.2) with Solar abundance and intervening column $N_H = 2 \times 10^{18}\,cm^{-2}$. Errors in the WFC count rate are typically less than 20%. Areas for which no clean data are available are displayed as zero count rate, i.e., filled black.

range $T = 10^5$–10^6 K and by a factor 2 in the range $T = 10^6$–10^7 K. This uncertainty aside, however, it is evident from the plot that the WFC and *EUVE* results are in conflict with the higher energy Wisconsin measurements over a broad temperature range $5.5 \lesssim \log T < 6.3$.

An additional complication is that probably not all the B-band count rate is from a local cavity as evidenced by the Draco shadow (Burrows & Mendenhall 1991). In fact Sidher et al. (1995) have shown that there seems to be a global non-local component which accounts for about 50% of the B-band count rate and which they associate with the Galactic halo.

5. Conclusion

We have presented an analysis of the WFC all-sky survey database tuned to locate the signature of the diffuse soft X-ray background. This work, unlike previous efforts (Lieu et al. 1992), utilises the entire survey dataset and incorporates a more detailed understanding of the non-cosmic background sources to which the WFC is subjected in-orbit.

Our conclusions are that no identifiable signal from the diffuse background is visible in the WFC S1 dataset at a level $\gtrsim 0.5$ counts s^{-1}. Our results are inconsistent with predicted WFC count rates made using the Wisconsin Be, B and C-band intensities and assuming that the spectrum of the SXRB is that of a hot ($T \sim 10^6$ K), optically thin gas in thermal equilibrium with normal metallic abundances, and foreground column of absorbing neutral material is that solely of the "local fluff" ($N_H \lesssim 10^{19}\,cm^{-2}$). To reconcile our results with the Wisconsin surveys may require depletion of heavy elements in the hot gas or non-equilibrium ionization.

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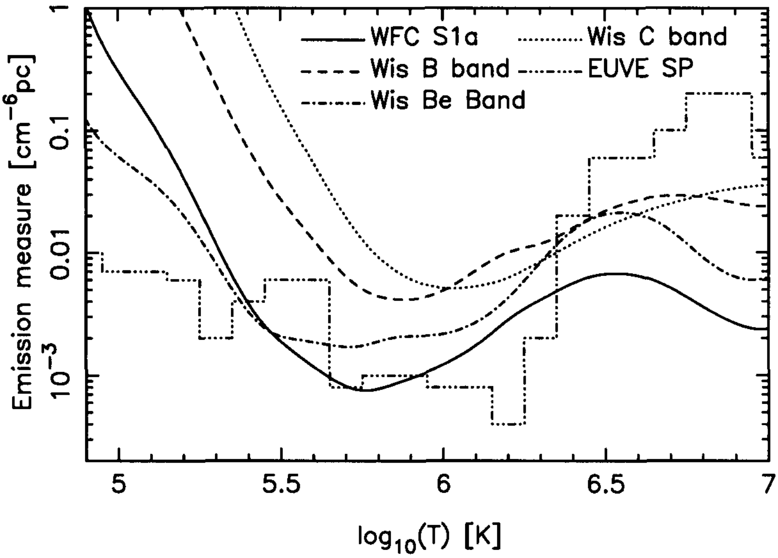

FIGURE 3. Emission measure calculated from Wisconsin survey results compared to the upper-limits derived from the WFC and *EUVE* surveys. Assumed count rates are B = 49 counts s^{-1}, C = 133 counts s^{-1} and Be = 5.4 counts s^{-1} (calculated from the B-band assuming Be/B = 0.11). The assumed plasma model is that of Raymond & Smith for the Wisconsin and WFC curves, and Landini & Monsignori-Fossi for the *EUVE* limit. Solar abundance is assumed, and an intervening neutral column of $N_H = 2 \times 10^{18}$

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