The Radiation Transfer of Soft X-rays

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Abstract. We discuss the link between the halo plasma temperature and the power-law spectral index of the extragalactic background radiation. This link is of strong influence for the derivation of the Galactic halo intensity distribution.
In principal, we can distinguish between two combinations of Galactic halo plasma temperature and power-law slope. The first combination consists of a halo plasma of $T_{\rm halo} = 10^6$ K and an E^{-2} approximation of the extragalactic background radiation. The second combination is $T_{\rm halo} = 10^{6.2}$ K and $E^{-1.5}$. Both combinations are in agreement with recent observational results, thus it is not feasible to discriminate between both models on the basis of X-ray data available. But, the soft X-ray background intensity distribution in the 1/4 keV and 3/4 keV *ROSAT* energy bands differs significantly. The $T_{\rm halo} = 10^6$ K, E^{-2} allows a patchy 1/4 keV intensity distribution while the $T_{\rm halo} = 10^{6.2}$ K, $E^{-1.5}$ predicts a much smoother intensity variation since the hotter halo plasma accounts for a significant fraction of the 3/4 keV background radiation.

1 The Soft X-ray Background Models

ROSAT data established three soft X-ray background (SXRB)source terms. The first one is the local X-ray gas. The second source term is the extragalactic X-ray background radiation. Hasinger et al. (1993) determined within the 0.5 – 2.0 keV *ROSAT* energy band a power-law index ($E^{-\Gamma}$) of $\Gamma \simeq 2.0$ for the bright discrete sources. Almaini et al. (1996) found for fainter sources a power-law index of $\Gamma \simeq 1.5 \pm 0.1$ within the *ROSAT* energy window ranging from 0.1 keV to 2.0 keV. The exact value of this power-law slope is of high importance, because it determines the derived temperature, and in consequence the halo intensity distribution. The Galactic halo plasma is the third component of the SXRB. The plasma is located beyond the galactic neutral hydrogen layer (Kerp & Pietz 1996).

2 The Method

The *ROSAT* data allow only to differentiate between two main combinations of plasma and the extragalactic background radiation. A $T_{\rm halo} = 10^6$ K plasma can only fit the observational data in addition to an extragalactic power-law spectrum of $\Gamma \simeq 2$, while a $T_{\rm halo} \simeq 10^{6.2}$ K plasma fits the data well in combination with a $\Gamma \simeq 1.5$ spectral slope.

https://doi.org/10.1017/S0252921100071220 Published online by Cambridge University Press

To show this we fitted the scatter diagrams (1/4 keV and 3/4 keV versus N_{HI}) as well as the energy band ratios (R1:R2 and 1/4:3/4 versus N_{HI}) of deep pointed *ROSAT* PSPC data simultaneously. In Figure 1 we present the fits to the data. The dashed line marks the $T_{halo} = 10^6$ K, $\Gamma = 2$ combination while the solid line represents the $T_{halo} = 10^{6.2}$ K, $\Gamma = 1.5$ combination.
The R1:R2 band ratio is better represented by the hotter Galactic X-ray halo. But within the statistical uncertainties both models fit the data very well.
The main difference between both combinations is hidden in the *unabsorbed* X-ray intensities. In Figure 2 we plotted the amount of photons emitted from each SXRB source normalized to the total number of photons emitted from all three soft X-ray background sources. Obviously in the 1/4 keV energy range there is no significant difference between a ($T = 10^6$ K, $\Gamma = 2$) and ($T = 10^{6.2}$ K, $\Gamma = 1.5$) combination. But in the 3/4 keV energy band (Fig. 2 *upper panel*) 56% of the observed 3/4 keV emission is produced by the $T_{halo} = 10^{6.2}$ K plasma while in case of the cooler $T_{halo} = 10^6$ K plasma only 23% of the observed 3/4 keV emission originates from the Galactic X-ray halo. This significant difference has several consequences, since the higher the contribution of the Galactic halo plasma to the 3/4 keV radiation the smoother the intensity distribution of the Galactic X-ray halo. This is the reason why the 3/4 keV X-ray background intensity distribution is much smoother than the 1/4 keV one. Therefore, the hotter the Galactic X-ray halo plasma the smoother its intensity distribution.

3 Results

Based on fits to the scatter diagrams it is *not* feasible to distinguish between a cooler Galactic halo in addition to a steeper extragalactic power-law index ($T_{halo} = 10^6$ K, $\Gamma = 2$) and a hotter halo plasma in combination with a flatter extragalactic power-law slope ($T_{halo} = 10^{6.2}$ K, $\Gamma = 1.5$).
In our model the $T_{halo} = 10^6$ K, $\Gamma = 2$ combination predicts a 1/4 kev background intensity of $I_{extra}(1/4\,\text{keV}) = 5{\cdot}10^{-6}\,\text{cts}\,\text{s}^{-1}\,\text{arcmin}^{-2}$ which is consistent with the upper limit intensity value derived by Cui et al. (1996). The $T_{halo} = 10^{6.2}$ K, $\Gamma = 1.5$ combination however is consistent with $I_{extra}(1/4\,\text{keV}) = 2.3{\cdot}10^{-6}\,\text{cts}\,\text{s}^{-1}\,\text{arcmin}^{-2}$ which was derived by Barber et al. (1996). Nevertheless, all recent investigations of the extragalactic intensity contribution to the soft X-ray background emission do not allow to differentiate between both combinations.
One key to discriminate between both combinations is given by the analysis of the extragalactic background radiation (e.g. Gendreau et al. 1995). According to Almaini et al. (1996) the contribution of faint emission line galaxies increases towards fainter flux limits. This new population of faint X-ray galaxies reveals a flatter averaged spectral slope than the bright discrete X-ray sources studied by Hasinger et al. (1993). This indicates that the

$T_{\text{halo}} = 10^{6.2}$ K, $\Gamma = 1.5$ is the most likely combination for the representation of the diffuse soft X-ray background radiation.

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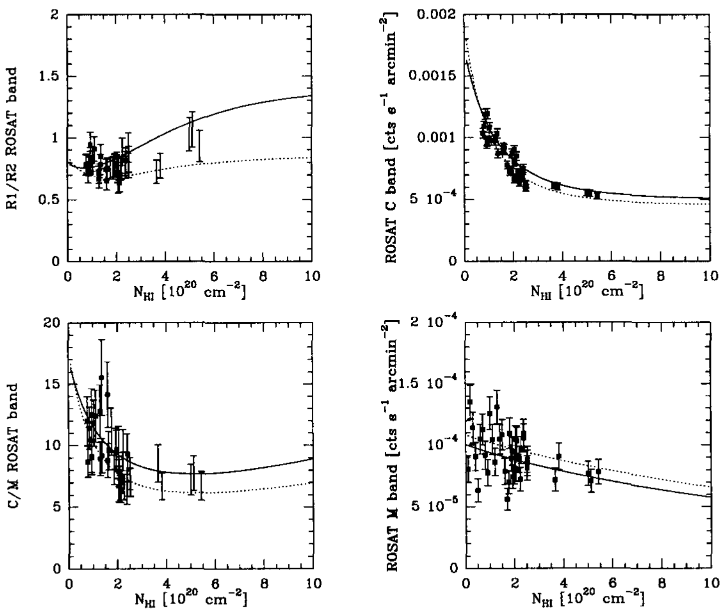

Fig. 1. Several PSPC pointings were analysed towards a high galactic latitude cloud $l \sim 90°$, $b \sim 60°$. Plotted is the 1/4 keV (C-band) and 3/4 keV (M-band) emission as well as the R1:R2 and C:M band intensity ratio versus the neutral atomic hydrogen column density (N_{HI}). The dashed line denotes the superposed emission of a Galactic halo plasma with $T_{\text{halo}} = 10^6$ K combined with the extragalactic background radiation described by a power-low E^{-2}. The solid line marks an alternative approach of $T_{\text{halo}} = 10^{6.2}$ K in combination with $E^{-1.5}$.

https://doi.org/10.1017/S0252921100071220 Published online by Cambridge University Press

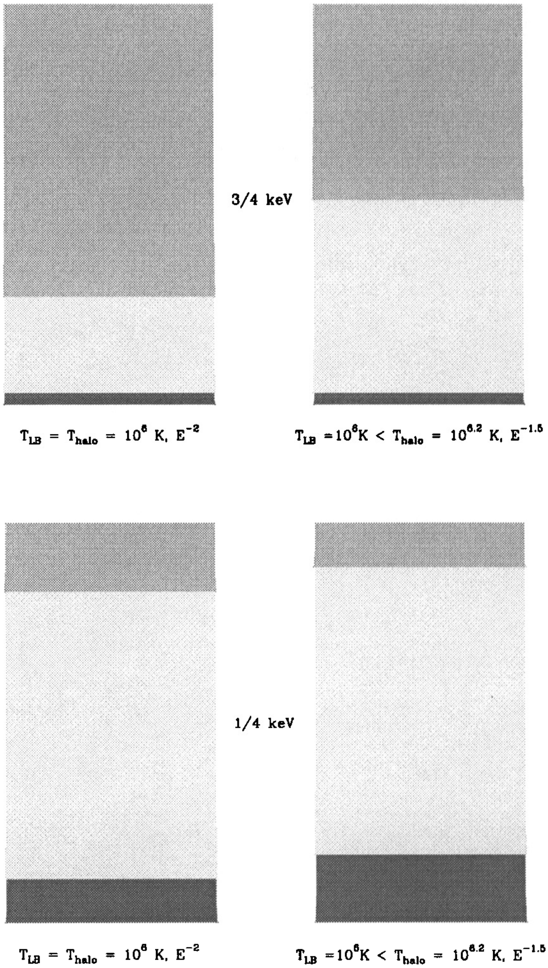

Fig. 2. The number of photons produced by the local X-ray plasma (bottom), Galactic X-ray halo (middle), and extragalactic X-ray background (top) normalized to the total number of emitted soft X-ray photons. The lower panel displays the 1/4 keV energy range while the upper panel shows the situation in the 3/4 keV energy band. On the left-hand side the combination $T_{\rm halo} = 10^6$ K, E^{-2} is displayed in each panel, while on the right-hand side $T_{\rm halo} = 10^{6.2}$ K, $E^{-1.5}$ is shown. Obviously the combinations are very similar in the 1/4 keV band while the combinations differ significantly in their Galactic halo contribution to the 3/4 keV energy band.