The Galactic X-ray Halo

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Abstract. We analyzed the soft X-ray background (SXRB) source intensity distribution of the 3/4 keV and 1/4 keV photons by correlating the public *ROSAT* PSPC All-Sky Survey data with the new Leiden/Dwingeloo H I Survey. We found that the 3/4 keV and 1/4 keV distant background source intensity distribution can be modelled by an isothermal ($T = 1.5 \cdot 10^6$ K) disk-like (scale length $A_1 = 15$ kpc) X-ray halo in addition to the radiation of the extragalactic X-ray background.

1 Introduction

Early investigations of the soft X-ray background at photon energies below $E \leq 1$ keV suggested the existence of a hot thermal plasma component, absorbed by the neutral galactic interstellar matter (Nousek et al. 1982, Marshall & Clark 1984). Using the new Leiden/Dwingeloo H I Survey (Hartmann 1994, Hartmann & Burton 1997) as quantitative tracer for the photoelectric absorption we analyzed the 1/4 keV and 3/4 keV data of the *ROSAT* All-Sky Survey (Snowden et al. 1995) to construct an X-ray halo model for the distant hot plasma, explaining the observed X-ray background intensities.

2 Method

At photon energies above 1 keV the X-ray background is predominantly of extragalactic origin (Hasinger et al. 1993), whereas at lower energies additional soft X-ray emitting components become important (e.g. Chen et al. 1997). In our approach we made use of the different contributions of three individual spectral soft X-ray background (SXRB) components to the different PSPC energy bands (Kerp & Pietz, this volume):

- **3/4 keV:** comprising an extragalactic, approximated by a power-law $E^{-\Gamma}$ with a photon index of $\Gamma \sim 1.4$, plus a distant hot thermal component with a plasma temperature of $T \sim 1.5 \cdot 10^6$ K; both components are absorbed by the galactic interstellar matter.
- **1/4 keV:** consists of extragalactic plus distant thermal radiation, with both components being absorbed by the galactic interstellar matter, and

https://doi.org/10.1017/S0252921100071451 Published online by Cambridge University Press

the emission of an unabsorbed foreground component with a temperature of $T \sim 0.9 \cdot 10^6$ keV.

Because the unabsorbed foreground component accounts only for an insignificant fraction of the 3/4 keV emission, the observed intensity distribution in the 3/4 keV energy band is caused by the combined effects of photoelectric absorption and "real" X-ray source intensity variations across the sky. Using the Leiden/Dwingeloo H I survey as a main tracer for the absorption by the galactic interstellar medium – neglecting the absorption by H_2 and HII – it is possible to disentangle both components.

3 Results

An analysis of the 3/4 keV energy band reveals that the photoelectric absorption cannot account for the observed intensity variations in contrast to the 1.5 keV energy band where we found no intensity variations. We found that a model for the distant thermal component has to fulfill the following conditions:

- The modelled halo X-ray count rate decreases smoothly from the galactic center towards the galactic anticenter.
- The halo X-ray count rate decreases smoothly from the galactic plane to the galactic poles.

In the following, we assume that the galactic X-ray halo is caused by an isothermal hot gas which is in hydrostatic equilibrium with the gravitational potential of the Galaxy. The pressure $p(z) = n(z)T(z)$ is assumed to balance the gravitational potential $\Phi(z)$:

$$n(R,z) = n_0 \cdot \frac{\mathrm{sech}^2(R/A_1)}{\mathrm{sech}^2(R_\odot/A_1)} \exp\left(-120 \cdot \Phi(z)/T)\right) \qquad (1)$$

According to Taylor & Cordes (1993) the scale length parameter A_1 defines a density gradient as function of the galactocentric radius, R, normalized to $R_\odot = 8.5\,\mathrm{kpc}$. We used the potential $\Phi(z)$ derived by Kuijken & Gilmore (1989). The normalization n_0 is determined by the emission measure assuming a collisional ionization equilibrium plasma model (Mewe-Kaastra). The temperature of the distant plasma is constrained by the count-rate ratios between the 1/4 keV and 3/4 keV energy bands (Pietz et al. 1997), confirming the used plasma temperatures of $T = 1.5 \cdot 10^6$ K. Such a model distribution with best-fit parameters of $n_0 \approx 1.4 \cdot 10^{-3}\,\mathrm{cm}^{-3}$ and $A_1 = 15$ kpc can explain simultaneously the background intensity variations of the 3/4 keV and 1/4 keV energy bands (see Fig. 1).

4 Comparison with a Galactic Fountain Model

Bregman (1980) constructed a galactic fountain model to explain the origin of high velocity clouds (HVCs). Note that the halo parameters of the isothermal

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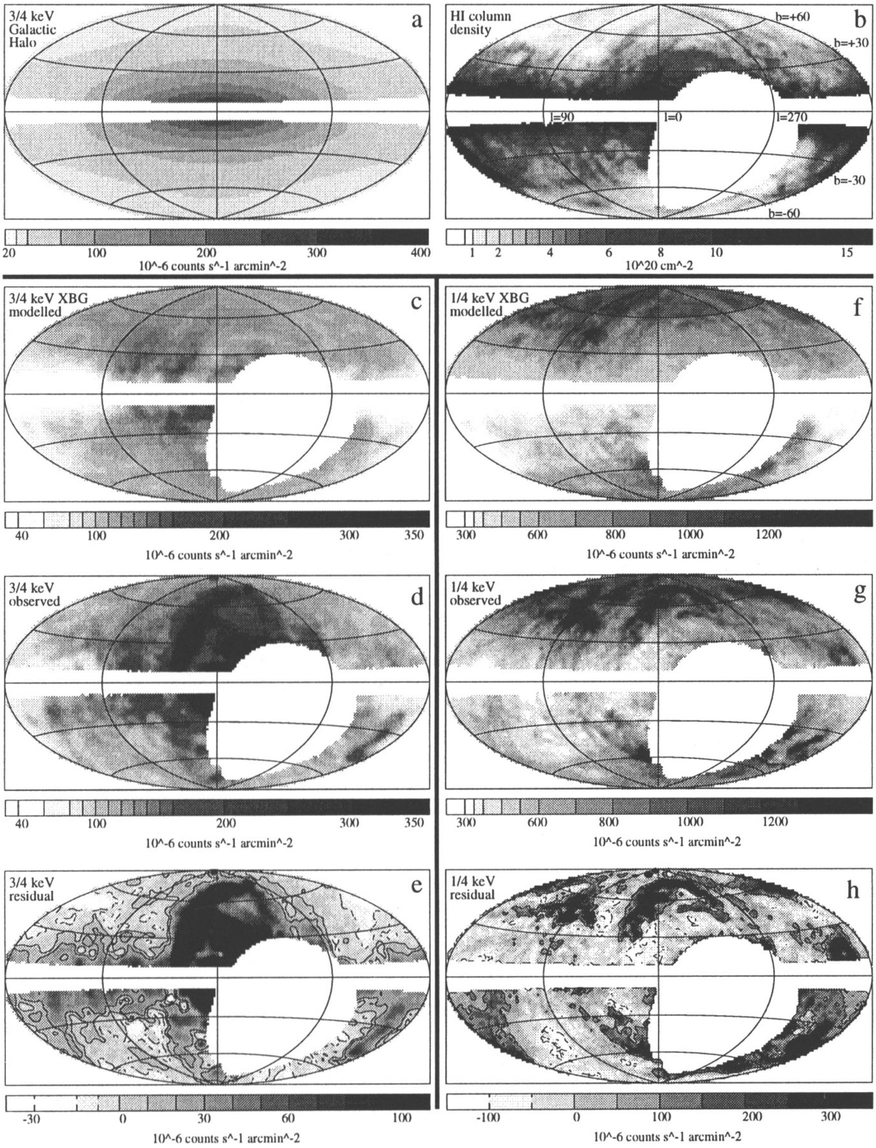

Fig. 1. Comparison of the modelled and observed 3/4 keV and 1/4 keV SXRB maps centered on the galactic center in Hammer-Aitoff projection. (a) proposed unabsorbed 3/4 keV intensity distribution of the distant galactic X-ray halo; (b) observed H I column density distribution derived from the Leiden/Dwingeloo survey; (c) modelled 3/4 keV SXRB intensity distribution; (d) observed 3/4 keV intensity distribution; (e) difference map representing observed minus modelled SXRB intensities; (f) modelled SXRB intensity distribution of the 1/4 keV energy range; (g) observed 1/4 keV intensity distribution; (h) the difference map between the observed X-ray intensity distribution and the model situation.

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model (temperature $T \sim 1.5 \cdot 10^6$ K and density $n_0 = 1.4 \cdot 10^{-3}\,\mathrm{cm}^{-3}$) are in the range of the values preferred by Bregman (1980), although his parameters are only valid at the base of the galactic fountain flow, since the temperature decreases with increasing z height in a fountain model. In Bregman's model (1980) radial pressure gradients cause a radial outflow of the rising hot gas, resulting in a center/anticenter asymmetry of the X-ray intensity distribution. Comparison between the count-rate ratios of the isothermal model (Eq. (1)) and the Bregman's galactic fountain model demonstrates that both models can reproduce the observed center/anticenter asymmetry:

Count-rate ratios	isothermal model	galactic fountain
$\frac{C(l=0^\circ,b=30^\circ)}{C(l=180^\circ,b=30^\circ)}$	2.1	1.9
$\frac{C(l=0^\circ,b=60^\circ)}{C(l=180^\circ,b=60^\circ)}$	1.2	1.4

Finally, we analyzed the X-ray shadow of a high-velocity cloud in a similar way as the X-ray shadow analysis of the extragalactic background by galaxies (e.g. Barber et al. 1996). H I spectra of HVC87+41–120, belonging to HVC complex C, were studied to derive the H I column densities of the high velocity and the low velocity matter. Our result is the detection of an extremely weak HVC X-ray shadow in the PSPC pointing 200721p which suggests that this HVC is located close to the upper boundary of the galactic halo ($|z| > 2.5$ kpc) or outside[1]. To estimate the HVC distance by this X-ray shadow we have to know the exact extragalactic 1/4 keV count rate, which is still not available with the needed accuracy (e.g. Barber et al. 1996).

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[1] Note that if the HVC is located *outside* the galactic X-ray halo the observed X-ray shadow implies a value of $\Gamma = 1.5^{+0.25}_{-0.5}$ for the extragalactic power-law index, consistent with the results by Almaini et al. (1996).

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