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X-raying the Galactic interstellar medium: First all–sky correlation of X-ray and H I data

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Abstract. The 3-D structure and composition of the Galactic interstellar medium can be deduced from soft X-ray absorption observations. For this purpose, we cross-correlate the ROSAT all-sky survey with the H I 21-cm line all-sky distribution provided by the Leiden/Dwingweloo and Instituto Argentino de Radioastronomía surveys. We analyse the data for the whole ROSAT-PSPC energy window (0.1 keV to 2.1 keV) to derive a consistent model of the diffuse X-ray background radiation. This approach allows to deduce the 3-D structure of X-ray absorbing and emitting gas and to constrain the distance to some high- (HVC) and intermediate-velocity cloud (IVC) complexes.

1. Introduction. The surveys

In this work, we present first results of the correlation between the distribution of Galactic H I and the ROSAT all-sky survey (RASS), for the first time on arcmin resolution level across the *entire* sky. The correlation analyses of soft X-ray with H I 21-cm line emission provide a powerful tool to study the 3-D composition of the Galactic interstellar medium (ISM). This is because the H I column density is a very sensitive measure for the strength of the photoelectric absorption caused by the ISM on the diffuse soft X-ray background (SXRB) emission (Kerp et al. 1999). For example, at 0.3 keV a value of $N_{HI} = 1 \cdot 10^{20}\mathrm{cm}^{-2}$ yields an absorption of 50% of the X-ray photons. With $N_{HI} = 0.5 \cdot 10^{20}\mathrm{cm}^{-2}$ the absorption amounts to 30%. Therefore, the modulation of the X-ray intensity produced by individual H I structures with column densities of the order of $\sim 10^{19}\mathrm{cm}^{-2}$ is detectable in the softer bands of the RASS.

The RASS provides data in the X-ray energy regime from 0.1 to 2.4 keV, with an angular resolution of 12' (Snowden et al. 1997). The statistical significance of the X-ray data is roughly proportional to the inverse of the effective integration time. The average uncertainty is about 10% in the very soft energy regime (0.1 keV to 0.5 keV). We use the combined Leiden/Dwingeloo (Hartmann & Burton 1997) and Argentinian (Arnal et al. 2000) 21-cm line surveys (for details see Karberla et al. in these proceedings) as tracer for the absorption.

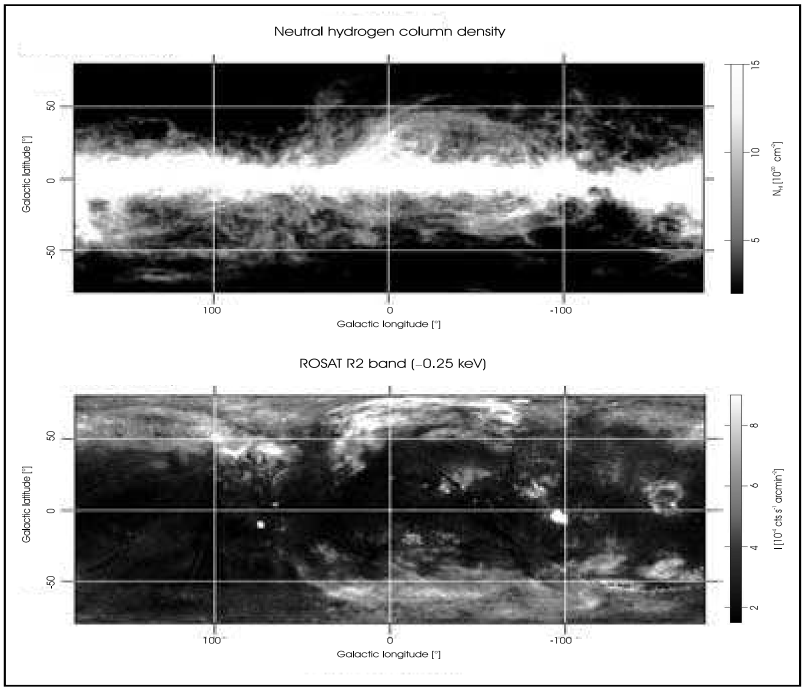

Figure 1. <u>Top</u>: H I 21-cm all-sky map of the column density distribution within the radial velocity interval covering $|v_{\rm LSR}| < 25\ \mathrm{km \cdot s^{-1}}$. The map shows a rich structured ISM, with individual clouds and filaments at high Galactic latitudes. <u>Bottom</u>: ROSAT all-sky survey in the energy band between 0.18 to 0.28 keV (R2 band). Apart from some individual supernova remnants within the Galactic Plane and in particular of Loop I, the X-ray map appears as the negative pattern of the H I map shown on top.

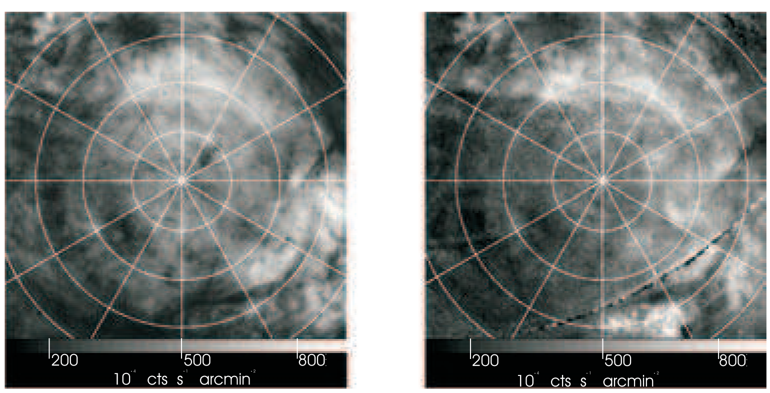

Figure 2. Modelled (*left*) and observed (*right*) R2 band distribution for the southern Galactic pole region. The Galactic latitude grid lines are separated by 15°. The separation in longitude is 30° (top = 0°, left = 90°). There is a good quantitative agreement between both maps. The most prominent deviating region corresponds to the Orion star forming region located at Galactic coordinates $(l,b) \simeq (160°, -45°)$.

2. Models of the soft X-ray background. Results

Basically (see Fig. 1), the H I vs. soft X-ray data show up with an obvious anti–correlation with the H I column density distribution. In detail, the situation is more complicated because the SXRB is produced by the superposition of different source components. Thus, a quantitative correlation between X-ray intensity and N_{HI} requires a precise knowledge of the different components, as well as of the photoelectric absorption in the ISM. In the following, we present a study of this quantitative correlation for the entire sky.

We use the approach introduced by Kerp et al. (1999), in which the SXRB is the superposition of a local unabsorbed emission (Local Hot Bubble), a Galactic absorbed emission (Galactic Halo) and an extragalactic absorbed component, and where H I is used as a tracer for the total attenuation of the diffuse X-rays through the ISM. The shape of the Galactic X-ray Halo is given by the Dark Matter Halo distribution by Kalberla (2003). The statistical methods presented by Pradas, Kerp, & Kalberla (2003) for the case of the northern Galactic sky, are used to find a consistent solution for the radiative transfer of the soft X-rays through the ISM across the *whole* ROSAT energy window for the *entire* sky.

With this solution, we produce an accurate model of the complete SXRB (see Fig 2.). The relative distance to the H I clouds with respect to the Galactic X-ray Halo is a critical parameter of the goodness of this model. The comparison of the results obtained with different assumptions on the 3-D structure of the Galactic H I is used to identify structures in the H I distribution that are not associated with any X-ray shadow of the SXRB (Pradas et al. 2003). We conclude that, in general, IVCs are located in front of the X-ray Halo and, on the contrary, most HVCs are located beyond.

The inclusion of the Argentinian H I survey allows to apply our method in the region of the Magallanic Stream (MS). Using only the radial velocities of the H I data it is not possible to distinguish between Galactic and MS material towards southern pole. With our models of the SXRB, we have a quantitative measure to disentangle the 3-D structure of the X-ray absorber in this area of interest.

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