Neutral Clouds Within the Local X-ray Plasma

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Abstract. We present new results based on the analysis of *ROSAT* PSPC observations towards nearby neutral clouds. These clouds are detectable as deep soft X-ray absorption features within the $\frac{1}{4}$ keV energy band. Towards one of these clouds, optical absorption line measurements determine an upper distance limit of $D \leq 60$ pc. The presented data suggest that this filament is only a part of a much more extended local–cloud structure. Here we demonstrate that we most probably detected a local neutral atomic hydrogen "wall" in the direction of a low–velocity arc (Pietz 1994).

1 Basic information

Our view is focused towards the galactic sky region centered at $l \sim 85°$, $b \sim 37°$ (Fig. 1). This area partly covers an arc-like high H I column density structure (Pietz 1994). Here the low–velocity gas reaches H I column densities of about $N_{\rm HI} \simeq 5 \cdot 10^{20} {\rm cm}^{-2}$, and the H I 21-cm linewidth indicates kinetic cloud temperatures of $T_{\rm kin} \simeq 100$ K.
Towards the nearby low-velocity cloud LVC 88+36-2, part of the cloud structure of interest, Wennmacher et al. (1992) determined an upper distance limit of 60 pc. This suggests that this cloud may either be inside the Local Bubble, or form part of its boundary region. Kerp et al. (1993) analysed a pointed *ROSAT* PSPC observation towards LVC 88+36-2 and confirmed the suggestion that the cold, dense neutral hydrogen filament is embedded *within* the local X-ray plasma. They derived a three-dimensional structure of X-ray emitting and absorbing matter from the analysis of soft X-ray "colours". Because of the strong energy dependence of the photoelectric absorption cross section ($\sigma \propto E^{-3}$), the quantitative comparison of different energy bands provides a means of disentangling the various components within the interstellar medium. The analysis of Kerp et al. (1993) suggests a three-component model of the soft X-ray radiation transfer equation (MODEL I):

$$I_{\rm obs} = I_{\rm foregr} + I_{\rm backgr} \cdot e^{-\sigma \cdot N_{\rm HI}({\rm LHB})} + I_{\rm halo/extra} \cdot e^{-\sigma \cdot N_{\rm HI}({\rm total})} \qquad (1)$$

Here, LVC 86+38–2 is embedded within the local X-ray plasma. A fraction of the local X-ray emission originates in front of the cloud ($I_{\rm foregr}$), while the residual local X-ray radiation is produced from beyond the low-velocity cloud ($I_{\rm backgr}$). Moreover, the H I 21-cm line data suggest that LVC 86+38–2 is only a part of a much more extended H I structure. We analysed four pointed PSPC

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observations towards this galactic sky area to search for evidence in soft X-ray colours that also these low-velocity clouds are probably located within the Local Bubble. We find that the above radiation transfer model provides a good quantitative fit to the observational data. This implies that also the very extended H I column density structure, which we called the "Basis" of the low-velocity arc, is embedded within the local X-ray plasma.

2 Alternative Explanation and Limits of the X-ray Data Analysis

We analysed the *ROSAT* PSPC data within the R1, R2, 1/4 keV and 3/4 keV energy bands. To improve the analysis we fitted the *ROSAT* PSPC R1:R2, 1/4 keV:3/4 keV band ratios as well as the 1/4 keV and 3/4 keV band count rate plotted versus the total $N_{\rm HI}$ column density (scatter diagrams) simultaneously. This method allows us to constrain the intensity of the individual soft X-ray source terms of Eq. (1) as well as the temperature of the local and distant X-ray plasma. The parameters of the extragalactic background are fixed for the representation by a power–law of $E^{-1.5}$ (Almaini et al. 1996) and a 1/4 keV intensity of $I_{\rm extra}(1/4\,{\rm keV}) = 2.3 \cdot 10^{-4}{\rm cts\,s^{-1}arcmin^{-2}}$ (Barber et al. 1996).
By fitting the X-ray data in all 4 diagrams simultaneously (Fig. 2) we determined, in the 1/4 keV band, for **MODEL I** (low–velocity clouds within the Local Bubble):

- $T_{\rm LHB} = 10^{5.8\pm0.1}\,{\rm K}$ and $T_{\rm halo} = 10^{6.2\pm0.1}\,{\rm K}$,
- $I_{\rm foregr} = (3.5 \pm 0.5) \cdot 10^{-4}{\rm cts\,s^{-1}arcmin^{-2}}$ and $I_{\rm backgr} = (3.0 \pm 0.5) \cdot 10^{-4}{\rm cts\,s^{-1}arcmin^{-2}}$,
- $I_{\rm halo} = (10 \pm 1.5) \cdot 10^{-4}{\rm cts\,s^{-1}arcmin^{-2}}$.

An alternative approach assumes that the low–velocity clouds are embedded within the *warm neutral medium* (WNM) . In this case $I_{\rm backgr} = 0$ and the WNM forms the boundary of the local void of neutral matter (MODEL II). Here, we found that the data are fitted best by a mixture of the hot halo plasma $T_{\rm hotter\ halo} \simeq 10^{6.2}\,{\rm K}$ (Pietz et al. and Wang, this volume) in addition to a cooler halo component with $T_{\rm cooler\ halo} \simeq 10^{5.9}\,{\rm K}$. For **MODEL II** we find:

- $T_{\rm LHB} = 10^{5.8\pm0.1}\,{\rm K}$, and a plasma mixture consisting of $T_{\rm cooler\ halo} = 10^{5.9\pm0.1}\,{\rm K}$ and $T_{\rm hotter\ halo} = 10^{6.2\pm0.1}\,{\rm K}$,
- $I_{\rm local} = (3.5 \pm 0.5) \cdot 10^{-4}{\rm cts\,s^{-1}arcmin^{-2}}$,
- $I_{\rm cooler\ halo} = (30 \pm 5) \cdot 10^{-4}{\rm cts\,s^{-1}arcmin^{-2}}$ and $I_{\rm hotter\ halo} = (6 \pm 1.5) \cdot 10^{-4}{\rm cts\,s^{-1}arcmin^{-2}}$.

This model of the X-ray emitting and absorbing matter also fits the X-ray data well and, if substantiated, would have the following important consequences:

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- The Local Bubble has an extent of less than 60 pc in this direction
- The WNM with $N_{\mathrm{HI}}(\mathrm{WNM}) \simeq 1 - 3 \cdot 10^{20}\mathrm{cm}^{-2}$ is located close to the low–velocity clouds ($D_{\mathrm{WNM}} \geq 60\,\mathrm{pc}$).
- The emission measure of the halo component in MODEL II is 4 times higher than that of MODEL I.

3 Discussion

Because of the limited energy resolution of the *ROSAT* PSPC the X-ray data do not allow to distinguish between the two models considered above. Therefore, supplementary data are necessary to find the most likely interpretation of the observed situation. Optical absorption line measurements will be ideal to serve for this supplementary information.

Wennmacher (1994) estimated the distance of the WNM towards the low-velocity clouds distributed within the field of interest. He came to the conclusion that the bulk of the WNM has an average distance of about $D_{\mathrm{WMN}} \simeq 300\,\mathrm{pc}$. This WNM structure has a neutral hydrogen column density ranging from $N_{\mathrm{HI}} = 1$ to $3 \cdot 10^{20}\,\mathrm{cm}^{-2}$. These values are close to the total neutral hydrogen column density observed in directions offset from the low–velocity clouds.

Quantitatively, this suggests that between the LVC 86+36–2 ($D_{\mathrm{LVC}} \simeq 60\,\mathrm{pc}$) and the WNM ($D_{\mathrm{WNM}} \simeq 300\,\mathrm{pc}$) there is only a weak increase of N_{HI}. Hence, most likely the low-velocity clouds are really embedded within the local low–volume density region. In this sense MODEL I is the most plausible solution. Therefore, we can suggest that also the "Basis" is located within the Local Bubble. Furthermore, the thin H I 21-cm filaments, which are connecting the LVC 86+38–2 with the "Basis" in position and velocity, seem to be also local. Probably we found an H I 21-cm wall within the Local Bubble located at a distance between 50 – 60 pc. This model has to be confirmed by further optical absorption line measurements towards the low-velocity arc and LVC 86+38–2.

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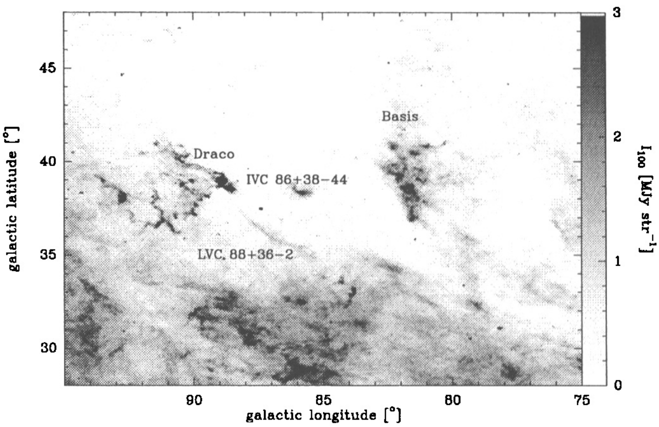

Fig. 1. *IRAS* 100μm map of the entire field of interest. The high-column-density clouds are located between $b = 35°$ and $42°$. The newly investigated field is called the "Basis" and is visible centered at $l \simeq 82°$ and $b \simeq 38°$. From this area the low-velocity arc emerges to high galactic latitudes. The low-velocity cloud LVC 86+38-2 is at a distance $D_{\rm LVC} \leq 60$ pc.

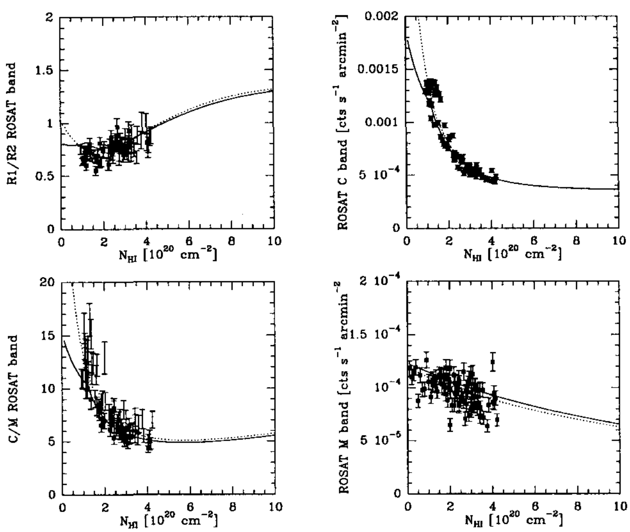

Fig. 2. Results of the analysis of four PSPC pointings towards the high-column-density filament centered at $l \sim 82°$, $b \sim 37°$ (Fig. 1). The X-ray data are simultaneously fitted for the R1:R2, 1/4 keV:3/4 keV band ratios and the 1/4 keV and 3/4 keV scatterdiagrams. The *solid* lines represent the best-fit of MODEL I (low–velocity clouds within the Local Bubble) and the *dotted* lines the best-fit of MODEL II (low–velocity clouds outside the Local Bubble).

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