ROSAT X-ray sources in the field of the LMC

I. Total LMC gas from the background AGN spectral fits *

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Received 22 November 2000 / Accepted 27 March 2001

Abstract. We analyzed a sample of 26 background X-ray sources in a ∼60 square degree field of the Large Magellanic Cloud observed with the ROSAT PSPC. The sample has been selected from previously classified and optically identified X-ray sources. In addition pointlike and spectrally hard sources with at least 100 to 200 observed counts have been used for the analysis. We performed X-ray spectral fitting and derived total hydrogen absorbing column densities due to LMC gas in the range \(10^{20} \leq N_\text{H} \leq 2 \times 10^{21}\) cm\(^{-2}\). We compared these columns with the H\(_1\) columns derived from a 21-cm Parkes survey of the LMC. For 7 optically identified sources we find, within the uncertainties derived from the X-ray spectral fit, agreement for both columns. For further 19 sources we constrain the LMC columns from the X-ray spectral fit assuming that the powerlaw photon index is that of AGN type spectra. We derive for 20 sources gas columns which are within the uncertainties in agreement with the H\(_1\) columns. We derive for two background sources (RX J0536.9-6913 and RX J0547.0-7040) hydrogen absorbing column densities due to LMC gas, which are in excess to the H\(_1\) columns. These sources - located in regions of large \((\sim 3 \times 10^{21}\) cm\(^{-2}\)) LMC H\(_1\) column densities - could be seen through additional gas which may be warm and diffuse, cold or molecular. For 10 sources we derive upper limits for the gas columns additional to H\(_1\) and constrain the molecular mass fraction to \(<(30–140)\%\).

Key words. galaxies: individual: LMC – galaxies: active – galaxies: ISM – radio continuum: galaxies – X-rays: galaxies

1. Introduction

The study of the interstellar medium (ISM) in the Large Magellanic Cloud (LMC) is of prime interest for the understanding of star formation and stellar evolution under different chemical conditions. A lower metal content of the interstellar medium results most likely in a smaller amount of molecules in the ISM, thus reducing or at least affecting the star formation efficiency. Studies of the properties of the ISM of the LMC have been made through observational work by Cohen et al. (1988) in CO with a spatial resolution of 12′. A \(^{12}\)CO survey of the LMC with a resolution of 2.6 has been performed with NANTEN (Fukui et al. 1999; Mizuno et al. 1999). Luks & Rohlfs (1992) and Luks (1994) made 21-cm surveys of the LMC with the Parkes radio telescope with an angular resolution of 15′. Dickey et al. (1994) made a 21-cm absorption survey of the Magellanic system with the Australia Telescope Compact Array (ATCA) towards a sample of 30 lines of sight and detected 21-cm absorption in 19 cases. Kim et al. (1998, 1999) obtained H\(_1\) aperture synthesis mosaics of the LMC with a resolution of 1′ using the ATCA telescope. The cool gas phase of the LMC gas in the 30 Dor, LMC 4 and the eastern H\(_1\) boundary of the LMC has been studied by Marx-Zimmer et al. (2000).

X-ray background point sources like active galactic nuclei (AGN) and quasars (QSO) can be used to probe the gas columns of a “foreground” galaxy like the LMC by measuring the X-ray absorption or the hydrogen column density \(N_\text{H}\) in the line of sight between the AGN or QSO and the observer. From X-ray observations the total absorbing column density in the line of sight of the AGN is derived. It is required that the contribution to the X-ray absorption due to the Milky Way (the galactic component) is inferred from other information (e.g. 21-cm H\(_1\) surveys covering the Magellanic Clouds). Also it has to be assumed that there is no intrinsic absorption due to the AGN and also no absorbing gas between the LMC and the AGN.
Recent studies of the X-ray spectra of AGN and QSO have shown that most of these spectra can be well described by a single powerlaw model with a powerlaw index $\Gamma$ which is confined to a narrow range of values. Using a large number of observations from different missions like EXOSAT, ROSAT and ASCA it has been found that AGN and QSO may all have the same powerlaw photon indices (cf. Brinkmann & Siebert 1994; Schartel et al. 1996a,b; Brinkmann et al. 1997; Laor et al. 1997; Sambruna et al. 1999; George et al. 2000; Brinkmann et al. 2000). However in several works a dependence of the powerlaw photon index on the energy band has been found. The detectors (LE and ME used with EXOSAT, PSPC with ROSAT, and SIS and GIS used with ASCA) cover different energy ranges of $0.1 - 20$ keV, $0.1 - 2.4$ keV, and $2 - 10$ keV respectively. The ROSAT PSPC covers the softest spectral band and especially in this band somewhat steeper powerlaw photon indices have been derived.

In a related article (Kahabka et al. 2001, hereafter Paper II) the sample of classified spectrally hard X-ray sources in the field of the LMC was extended by making use of a theoretical color – color diagram (the HR1 – HR2 plane) derived from simulations. A tentative classification for a large fraction of the spectrally hard X-ray sources was made in the central 20’ of the ROSAT PSPC detector which have been detected by Haberl & Pietsch (1999, hereafter HP99) in a $10^\circ \times 10^\circ$ field of the LMC.

Here we investigate the spectral energy distribution of the X-ray point sources toward the LMC to derive the total gas column density of the LMC for different lines of sight. We compare the X-ray derived LMC gas columns with the gas columns derived from 21-cm radio observations performed with the Parkes and ATCA radio telescopes. From comparison of the X-ray derived total hydrogen column and the 21-cm (atomic) hydrogen we deduce constraints on the content of molecular hydrogen.

2. The AGN sample

Several background AGN in the field of the LMC have been identified in the sample of X-ray sources detected in Einstein and ROSAT observations during optical follow-up observations (Cowley et al. 1984; Schmedtke et al. 1994; Crampton et al. 1997; Cowley et al. 1997; Schmedtke et al. 1999; Tinney 1999). One ROSAT PSPC source, RX J0515.1-6511, has been identified by HP99 with an optical galaxy from the sample of 96 galaxies behind the LMC which are brighter than $V=16.5$ (Gurwell & Hodge 1990).

In addition during recent radio surveys of the Magellanic Clouds (and in particular of the LMC) discrete radio sources have been detected and in part classified as background sources by Dickey et al. (1994), Marx et al. (1997, hereafter MDM97) and Filipović et al. (1998a,b).

The sample of X-ray selected background AGN has been extended by HP99 by correlating the catalog of ROSAT PSPC X-ray sources in the field of the LMC with optical and radio catalogs. Additional candidate AGN in the field of the LMC have been found by Sasaki et al. (2000, hereafter SHP00) by comparing ROSAT PSPC X-ray sources with ROSAT HRI X-ray sources which are contained in their ROSAT HRI LMC catalog. We note that we could detect one of the unclassified LMC HRI sources (RX J0536.9-6913) in one of our merged PSPC observations. The source correlates with a radio source of Dickey et al. (1994) and MDM97. It has recently been studied in detail with the Epic-PN detector of XMM-Newton and is a strong candidate for a background AGN (Haberl et al. 2001).

In addition we investigated the 35 sources classified as [hard] by HP99. We find that 10 of these sources are consistent with pointlike and spectrally hard sources which we classify as AGN. They have $\sim$200 to 800 observed counts and have been used in this work for X-ray spectral fitting. Two further sources (RX J0530.1-6551 and RX J0524.2-0620) are consistent with X-ray binaries. This classification is confirmed by making use of simulated powerlaw
tracks in a color–color diagram (the $HR_1 - HR_2$ plane, cf. Paper II). Further 8 sources have $\gtrsim 150$ observed counts and have not been used for X-ray spectral fitting. The remaining sources have been found to be either extended or too faint for a spectral analysis.

The AGN sample used is given in Table 1.

3. Observations

The observations of the general LMC area were carried out with the PSPC detector of the ROSAT observatory from 1991 till 1998. They have been retrieved from the public ROSAT archive at the Max-Planck-Institut für extraterrestrische Physik (MPE). The satellite, X-ray telescope (XRT) and the focal plane detector (PSPC) are described in detail in Trümper (1983) and Pfeffermann et al. (1987). For each AGN given in Table 2 (excluding those AGN which have not been observed with ROSAT PSPC) we determined all ROSAT PSPC observations in a $2^\circ \times 2^\circ$ field centered on the AGN and merged all observations for which the AGN was observed at an off-axis angle of $<50'$ by using standard EXSAS procedures (Zimmermann et al. 1994).

In Fig. 1 we show a merged image of 533 ksec exposure of the ROSAT PSPC observations of the LMC field. Time intervals with a high particle background rate have been removed by selecting data with a master veto rate in the interval 10 to 170 s$^{-1}$ (cf. Snowden et al. 1995). In addition time intervals with a large soft (channel 11–41) X-ray count rate above the mean (by more than 7 counts s$^{-1}$) have been excluded. Such events may e.g. be due to scattered solar X-rays (cf. Kerp 1994). The image is generated in the energy band 0.4 – 1.3 keV and it has a binsize of 100''. It shows the brighter X-ray sources and the distribution of the hot diffuse X-ray flux and X-ray dark regions (X-ray shadows). We overlayed on the image with square boxes of $1^\circ \times 1^\circ$ the fields in which AGN have been analyzed (AGN for which X-ray spectral fitting has been performed in Sect. 4, which are included in Tab. 2 and which are not flagged with b).

We analyzed 139 ROSAT PSPC observations with exposure times of at least 1000 sec each in a $10^\circ \times 10^\circ$ field covering the LMC. For most of the X-ray sources which we analyzed it was required to merge several observations. In Fig. 2 we show the exposure corrected images (0.1 – 2.0 keV) of $1^\circ \times 1^\circ$ fields centered on 35 AGN (and candidate AGN) observed with ROSAT PSPC (cf. Table 2) and which in part have been analyzed in this work (cf. Table 2). The positions of the AGN at the center of the image are marked with a circle. Some images show low or unexposed (white) regions which are not due to LMC gas structure.

4. X-ray spectral fits and gas absorption

We extracted the source plus background photon events in a circular region centered on the position of the AGN and the background events from a nearby second circular region using EXSAS procedures. We binned the spectral data with a signal to noise ratio of 3 to 5. We corrected the
Table 1. The sample of background X-ray sources (AGN) in the field of the LMC. For individual AGN we give in Columns (1) to (5) the ROSAT and the Einstein name, the source number from the ROSAT PSPC catalog of HP99, from the ROSAT HRI catalog of SHP00 and from the radio continuum catalog of MDM97. In Columns (6) and (7) we give the optical V-magnitude and the redshift $z$. The source type is given in Column (8), the galactic hydrogen absorbing column density in Column (9) and references to earlier papers and notes to individual sources are given in (10).

| ROSAT name | Other name | $V$ | $z$ | Type | $N_{\text{HI}}^{\text{gal}}$ ($10^{20}$ cm$^{-2}$) | References and notes |
|------------|------------|-----|-----|------|---------------------------------|---------------------|
| RX J Ein HP SHP MDM | | | | | | |
| 0436.2-6822 | 653 | 18.2 | 0.228 | galaxy? | 4.3 | 1; a |
| 0454.1-6643 | 411 10 | 16.8 | 0.064 | AGN | 3.9 | 1–4 |
| 0503.1-6634 | CAL F | 380 20 | 18.5 | 0.175 | AGN Sy1 | 3.9 | 1–3,5,6,16 |
| 0509.2-6954 | CAL 16 | 1040 | 17.7 | 0.151 | AGN Sy1 | 6.2 | 1,7 |
| 0510.4-6737 | 559 49 | 18.5 | 0.195 | AGN | 4.5 | 1,3,b |
| 0515.1-6511 | 100 | 18.5 | 0.195 | galaxy | 4.2 | 1,21; c |
| 0516.6-7237 | 1367 | radio, AGN? | 6.7 | 1,8,14; d |
| 0517.3-7044 | CAL 21 86 | 18.2 | 0.169 | AGN | 5.8 | 2,3; e |
| 0522.7-6928 | 931 112 | [hard] | 6.2 | 1,3, f |
| 0523.2-7015 | 1109 116 | [hard] | 6.8 | 1,3; f |
| 0524.0-7011 | CAL 32 124 | 17.7 | 0.151 | AGN Sy | 5.1 | 1–3,6,7,9 |
| 0528.8-6539 | 147 181 | [hard] | 4.6 | 1,3; f |
| 0529.0-6603 | 233 | AGN? | 4.6 | 1; f |
| 0530.1-6551 | 183 205 | XRB ? | 4.6 | 1,3; b,f |
| 0531.5-7130 | CAL 46 220 | 19.2 | 0.221 | AGN Sy | 5.2 | 1–4,6,7,9 |
| 0532.0-6919 | 876 224 | 18.8 | 0.149 | AGN Sy1 | 4.8 | 1–3,6 |
| 0532.4-6406 | 44 | Galaxy group | 4.7 | 1; g |
| 0532.9-7040 | CAL 51 1178 53 | radio | 4.8 | 1,5,7; f |
| 0534.0-7145 | 13.8 | 0.024 | S0 galaxy | 13.8 | 0.024 | 5.6 | 2,4; e |
| 0534.1-7018 | 1124 250 | [hard] | 5.7 | 1,3,f |
| 0534.1-7037 | 1169 57 | radio | 4.8 | 1,5 |
| 0534.6-6738 | 561 | 17.8 | 0.072 | AGN | 4.6 | 1,2,7,10; h |
| 0536.0-7041 | 1181 272 | [hard] | 4.8 | 1,3,7; f |
| 0536.9-6913 | 280 65 | radio | 5.0 | 3,5 |
| 0540.3-6234 | 1 | AGN | 4.4 | 1 |
| 0541.6-6511 | 101 | [hard], galaxy? | 4.5 | 1 |
| 0546.0-6415 | 54 | 0.323 | QSO | 3.7 | 1,17; i |
| 0546.8-6851 | 747 364 | AGN | 5.6 | 1,3,7; b,j |
| 0547.0-7040 | 1179 | [hard] | 7.3 | 1,7; f,k |
| 0547.8-6745 | 100 20.5 | 0.390 | radio, AGN | 4.8 | 2,5,12; e |
| 0548.4-7112 | 1247 376 | [hard] | 6.4 | 1,3; f |
| 0550.5-7110 | 1243 385 | 19.9 | 0.443 | AGN Sy | 6.7 | 1–3 |
| 0550.6-6637 | CAL 91 | 17.0 | 0.076 | AGN Sy | 4.2 | 2,9; e |
| 0552.3-6402 | 37 389 | AGN | 3.7 | 1,3,19; l |
| 0561.1-7036 | 1166 | AGN | 7.0 | 1,11,18; m |
| 0562.9-7102 | 1231 | 0.079 | AGN Liner | 7.2 | 1,15; n |
| 0563.3-7043 | 1189 | AGN | 7.8 | 1 |
| 0566.0-7042 | 1184 87 | [AGN], galaxy? | 6.8 | 1,3,19; o |
| 0567.6-6651 | 433 | galaxy? | 4.8 | 1,13; p |
In Table 2 we list the number of source photons in the X-ray error circle. We performed a spectral fit only in case the number of source photons was >100 after background subtraction. We verified for a few sources for which a large (> 10^{21} \text{ cm}^{-2}) absorbing column density is derived that the result of the spectral fitting does not depend on the chosen spectral binning.

In Table 2 we list the number of source photons available for the spectral fit of the individual AGN. RX J0515.1-6511 has not been detected in the ROSAT observations and has not been included in the table. In case the AGN is in an area of hot diffuse LMC gas then the background can be uncertain and depends on the location where the background has been determined.

### 4.1. Powerlaw with galactic foreground and LMC intrinsic absorption

We fitted the observed X-ray spectral flux with AGN model fluxes in order to characterize the source as well as to find the amount of absorption by gas. For the AGN we adopted a powerlaw spectrum for the X-ray spectral flux (cf. Laor et al. 1997). For the neutral gas we use two different absorption models making use of the photoelectric absorption cross sections given in Balucinska-Church & McCammon (1992) and using cosmic and LMC abundances with reduced metallicities respectively. We used an absorption model with galactic foreground absorption (EXSAS model gamm) and LMC intrinsic absorption using reduced metallicities (EXSAS model gabs). We do not account for gas between the LMC and the AGN and gas intrinsic to the AGN in the spectral fit.

We determined the spectral parameters (the powerlaw photon index $\Gamma$ and the normalisation of the flux $f_0$) in the rest frame of the AGN in case the redshift has been determined (cf. Table 1). But we note that consideration of the low values of the redshift measured for the AGN in the LMC field (z<0.5, cf. Table 1) has little effect on the derived spectral parameters (we confirmed this finding for the X-ray brightest optically identified AGN, RX J0524.0-7011).

We used in the spectral fit galactic foreground absorbing columns $N_{\text{H}}^{\text{gal}}$ which we determined from a Parkes survey of the galactic H1 in the direction of the LMC (Brinks et al. 2001). The value of $N_{\text{H}}^{\text{gal}}$ varies by a factor of 2 (cf. Table 1).

We determined the LMC intrinsic absorption $N_{\text{H}}^{\text{LMC}}$ by adjusting the abundances of individual elements. We used for the abundances the values log(X/H) + 12 = 8.25, 6.99, 8.47 and 7.74 for C, N, O and Ne respectively (Pagel 1993). For the other elements we used a logarithmic decrement of ~0.4 dex.

We first applied a spectral fit to the sample of AGN which had been optically identified, for which a redshift had been determined and for which at least ~200 counts have been observed. We derive best-fit total hydrogen column densities due to the LMC, $N_{\text{H}}^{\text{LMC}}$, which are in the range of $10^{20} \text{ cm}^{-2}$ to a few $10^{21} \text{ cm}^{-2}$ (cf. Table 1).

We derive for the five AGN in this sample with the best determined powerlaw photon index a value of $\Gamma = 2.13 \pm 0.46$ (cf. Table 1 and Fig. 3). These powerlaw photon indices fall into the interval of powerlaw photon indices derived by Laor et al. (1997) for radio loud AGN in the ROSAT band (0.1 – 2.4 keV). Brinkmann et al. (2000) de-
Table 2. Counts, spatial selection and integration time for AGN observed during ROSAT PSPC observations (cf. Table 1).

| Name RX J | Number Obs. | Source counts a | Extract radius (') | Exposure (10^3 sec) |
|-----------|-------------|-----------------|-------------------|-------------------|
| 0436.2-6822 | 2 | 235±30 | 6.4 | 5.0 |
| 0454.1-6643 | 4 | 951±48 | 2.1 | 50.8 |
| 0503.1-6634 | 4 | 3173±91 | 4.2 | 50.8 |
| 0509.2-6954 | 3 | 546±31 | 2.1 | 12.4 |
| 0510.4-6737 | 4 | 158±36 | 2.3 | 26.2 |
| 0516.6-7237 a | 2 | 111±49 | 5.0 | 24.1 |
| 0522.7-6928 | 25 | 265±52 | 1.5 | 114.6 |
| 0523.2-7015 | 25 | 307±46 | 1.7 | 91.6 |
| 0524.0-7011 | 21 | 3679±83 | 2.1 | 80.2 |
| 0528.8-6539 | 25 | 801±68 | 2.1 | 105.3 |
| 0529.0-6603 | 25 | 373±59 | 1.7 | 117.2 |
| 0530.1-6551 | 25 | 554±59 | 1.7 | 117.2 |
| 0531.5-7130 a | 3 | 6±13 | 5.0 | 35.4 |
| 0532.0-6919 | 12 | 888±75 | 1.5 | 124.7 |
| 0532.4-6406 a | 10 | 59±27 | 2.5 | 21.3 |
| 0532.9-7040 a | 6 | 219±42 | 2.9 | 28.5 |
| 0534.1-7018 | 18 | 520±42 | 1.5 | 88.4 |
| 0534.1-7037 | 6 | 130±19 | 1.2 | 28.5 |
| 0534.6-6738 | 9 | 117±26 | 3.8 | 16.8 |
| 0536.0-7041 | 6 | 193±21 | 1.2 | 28.5 |
| 0536.9-6913 | 25 | 214±43 | 0.9 | 180.0 |
| 0540.3-6241 | 2 | 265±24 | 5.0 | 3.1 |
| 0541.6-6511 | 3 | 405±35 | 2.5 | 7.6 |
| 0546.0-6415 | 5 | 881±33 | 2.5 | 7.2 |
| 0546.8-6851 | 8 | 837±73 | 5.0 | 42.0 |
| 0547.0-7040 | 3 | 269±52 | 2.9 | 37.6 |
| 0548.4-7112 | 3 | 281±29 | 1.0 | 43.6 |
| 0550.5-7110 a | 2 | 95±34 | 1.8 | 35.7 |
| 0552.3-6402 | 2 | 179±24 | 5.0 | 3.2 |
| 0601.1-7036 a | 1 | 45±10 | 1.3 | 6.0 |
| 0602.9-7102 a | 1 | 40±28 | 5.0 | 6.0 |
| 0603.3-7043 a | 1 | 47±13 | 1.7 | 6.0 |
| 0606.0-7042 | 2 | 291±46 | 3.3 | 12.0 |
| 0607.6-6651 | 2 | 649±72 | 3.0 | 20.7 |

a Source counts and errors in counts in amplitude range 11 − 256 and for the given size of the source circle.

b No X-ray spectra fitted.

Table 3. Results of X-ray spectral fit applied to the sample of optically identified background AGN in the field of the LMC and for which a redshift has been determined (cf. Table 1). A powerlaw model is used with galactic absorption (fixed to NHI gal) and LMC intrinsic absorption (EXSAS spectral model gasb with modified abundances, see Sect. 4.1). In column (2) the powerlaw photon index Γ is given with 68% confidence errors, in column (3) the normalisation f0, in column (4) the galactic hydrogen absorption column density NHI gal, in column (5) the LMC intrinsic hydrogen absorbing column density NLMC, in column (6) the chi-square and the degrees of freedom (dof) of the spectral fit.

| Name RX J | Γ a | f0 b | NHI gal | NLMC c | χ2 | dof |
|-----------|-----|------|---------|--------|-----|------|
| 0454.1-6643 | -2.0±0.7 | 1.9 | 3.9 | 22±28 17 | 16.6 | 22 |
| 0503.1-6634 | -2.3±0.2 | 5.3 | 3.9 | 5.0±1.5 | 18.4 | 22 |
| 0509.2-6954 | -2.3±0.7 | 3.3 | 6.2 | 6±1.8 | 9.8 | 14 |
| 0524.0-7011 | -2.05±0.15 | 4.2 | 5.1 | 6.0±1.2 | 78 | 68 |
| 0532.0-6919 | -2.15±0.55 | 0.58 | 4.8 | 8±0.1 | 11.5 | 12 |
| 0534.6-7378 | -1.7±0.14 | 1.8 | 4.6 | 0±0.3 | 10.8 | 11 |
| 0546.0-6415 | -2.0±0.25 | 10.4 | 3.7 | 1.2±0.1 | 16.6 | 25 |

a In the rest frame of the AGN.
b In units of 10−4 photons cm−2 s−1 keV−1, at 1 keV.
c In units of 1020 cm−2.

We also applied a spectral fit to further 19 background X-ray sources for which the number of available counts is given in Table 1. The uncertainties in the hydrogen column densities derived for these sources from the X-ray spectral fit are considerable. We will discuss the result of the spectral fit for these sources in Sect. 5.1 where we apply additional constraints to the powerlaw photon index.

a counterpart in the VLA 20cm FIRST catalog. If one excludes the galaxies then the range in powerlaw photon indices of the AGN and quasar sample cover the same values as the powerlaw photon indices of the radio loud and radio quiet AGN sample of Laor et al. (1997). But for their AGN sample Brinkmann et al. (2000) do not find evidence for a bimodal distribution in the radio-loudness parameter. In Fig. 3 we show as dashed band the 1σ range of powerlaw photon indices covered by the AGN sample of Brinkmann et al. (2000).
ground is a region of lower background taken and variable diffuse emission. One choice for the background location where the background is taken. Clearly, a careful scales then the result of the spectral fit depends on the AGN. But if the hot gas component varies on small we determine the background spectrum in a region close to be properly accounted for in the spectral fit. For that (the absorbing column and the photon index) is some- to an AGN. But if the hot gas component varies on small 1994). This hot gas adds to the X-ray spectrum and has hot diffuse gas which emits in X-rays (Snowden & Petre it has been found that these regions are associated with it has been found that these regions are associated with 4.2. Uncertainties in the spectral fit

Now we discuss uncertainties in the spectral fit which may affect the value of the deduced hydrogen column density. We use in our analysis AGN lying behind a wide range of LMC neutral hydrogen column densities as inferred from the 21-cm radio observations (cf. Sect. 5). A few of these AGN are located in regions of LMC column densities \( \gtrsim 10^{21} \text{ cm}^{-2} \), behind a large cloud complex at the eastern side of the LMC and another cloud complex at the northern side. From ROSAT PSPC observations it has been found that these regions are associated with hot diffuse gas which emits in X-rays (Snowden & Petre 1994). This hot gas adds to the X-ray spectrum and has to be properly accounted for in the spectral fit. For that we determine the background spectrum in a region close to an AGN. But if the hot gas component varies on small scales then the result of the spectral fit depends on the location where the background is taken. Clearly, a careful selection of the background region is required.

We briefly discuss the effect of background subtraction on the result of the spectral fit by choosing different areas for the background. We use as an example the AGN RX J0532.0-6919 which is located in a region of extended and variable diffuse emission. One choice for the background is a region of lower background taken \( \sim 6' \) east of the AGN, a second choice is a region of a higher but more appropriate background. The result of the spectral fitting (the absorbing column and the photon index) is somewhat dependent on the chosen background. Depending on the chosen background region we derive total LMC hydro-
Fig. 4. (a) Background subtracted ROSAT PSPC spectrum of RX J0532.0-6919 (data points with error bars) using the best background model (cf. text) and best-fit spectral model (solid curve). (b) Background subtracted ROSAT PSPC spectrum of RX J0536.9-6913 (data points with error bars) and spectral model for fixed powerlaw index \(-\Gamma = 2.0\) (solid curve).

1 \times 10^{20} \text{ cm}^{-2} \text{ to at least } 3.2 \times 10^{21} \text{ cm}^{-2}. The largest column densities are found in the 30 Dor region which is contained in a large cloud complex with an area of 4.25 square degrees at the eastern side of the LMC.

We now compare the hydrogen absorbing column densities towards the AGN in the LMC field derived from the X-ray spectral fitting in Sect. 4 with the column densities of neutral hydrogen H\(_1\) as inferred from 21-cm line measurements. In Sect. 4.1 we have applied a spectral fit to the ROSAT PSPC AGN spectra by fixing the galactic contribution to the absorption. We used the values derived from the Parkes 21-cm line measurements of the galactic absorption in the direction of the AGN.

In Fig. 5 we demonstrate there is excess absorption (additional to the galactic absorption) which is assumed to be due to the LMC gas. As expected we find that the total hydrogen column (galactic & LMC) lies above the hydrogen column determined from the 21-cm for the Milky Way. The excess absorption varies from a few \(10^{20} \text{ cm}^{-2}\) up to \(\sim 2 \times 10^{21} \text{ cm}^{-2}\).

Next we compare the LMC hydrogen column density derived from the X-ray spectral fit in Sect. 4 with the LMC column density of neutral hydrogen H\(_1\) as inferred from a Parkes 21-cm line survey of the Magellanic system with a resolution of \(\sim 14'\) (Brüns et al. 2001). We show the result in Fig. 6 for the sample of optically identified background AGN given in Table 3.

Fig. 5. Total hydrogen X-ray absorbing column densities towards the the sample of optically identified AGN in the LMC field (cf. Table 3) as derived from the X-ray spectral fit and in addition for RX J0546.8-6851 (cf. Table 3) in comparison which the galactic foreground absorption. The excess hydrogen column due to the LMC (above the galactic value, dashed line) can be clearly seen.

Fig. 6. Hydrogen absorbing column density towards the sample of optically identified AGN in the LMC field (cf. Table 3) in comparison which the LMC H\(_1\) column density derived from 21-cm line measurements.

The LMC column densities inferred from the X-ray spectral fit cover the range from about \(10^{20} \text{ cm}^{-2}\) to \(2 \times 10^{21} \text{ cm}^{-2}\).
10^{21} \text{ cm}^{-2}. We find that the values obtained from the spectral fit are within the uncertainties consistent with the hydrogen column densities determined from the 21-cm line measurements. Only for the background source RX J0503.1-6634 a somewhat lower value for the LMC column densities is derived from the X-ray spectral fit.

5.1. Constraints on the hydrogen column density for AGN type spectra

For many of the background X-ray sources given in Table 1 the uncertainties in the hydrogen column densities derived from the X-ray spectral fit are considerable and a comparison with the column densities derived from the 21-cm line measurements is not very conclusive. In order to further constrain also for these background X-ray sources the values of the hydrogen column densities (derived from the X-ray spectral fit) we make use of the assumption that all AGN have powerlaw photon indices which are consistent with the powerlaw photon indices determined by Brinkmann et al. (2000) for their AGN sample.

We already have found in Sect. 4 that the AGN which have well constrained spectral parameters have powerlaw photon indices which are consistent with the powerlaw photon indices derived by Brinkmann et al. (2000) for their AGN sample. We now use the constraint on the photon index \( \Gamma=(2.0 - 2.5) \) as the 68% confidence contours in the \( \Gamma - N_{H}^{LMC} \) parameter plane. The best-fit value given for the hydrogen column is in general the value for the minimum \( \chi^2 \) found by the grid search in the parameter plane. In Fig. 4 we compare the value for the LMC hydrogen absorbing column density in the direction of 21 of the AGN from Table 2 as inferred from the spectral fit with the value for the LMC hydrogen absorbing column density derived from a Parkes 21-cm line survey (Br"uns et al. 2001). We find that most of these \( N_{H} \) values are consistent with the \( H_1 \) values inferred from the \( H_1 \) survey.

\begin{table}[h]
\centering
\begin{tabular}{cccccc}
\hline
Name & \( N_{H}^{\text{tot}} \) & \( N_{H}^{LMC} \) & \( N_{H}^{\text{X-ray}} \) & Comparison \\
\hline
RX J0530.1-6551 & 4.6 & 6.8 & 60 & 5 & < 0.0 \\
RX J0532.0-6919 & 4.8 & 11 & 8 & 6 & > 0.0 \\
RX J0534.1-7018 & 5.7 & 19.5 & 35 & 5 & > 0.0 \\
RX J0534.7-6928 & 4.6 & 18 & 0 & 30 & < 0.0 \\
RX J0536.9-6923 & 4.6 & 18 & 0 & 30 & < 0.0 \\
RX J0540.3-6241 & 4.6 & 53 & 2 & 5 & > 0.0 \\
RX J0546.0-6603 & 4.6 & 7.6 & 4 & 6 & > 0.0 \\
RX J0546.8-6851 & 5.6 & 38 & 25 & 5 & > 0.0 \\
RX J0547.0-7040 & 7.3 & 29.6 & 130 & 7 & > 0.0 \\
RX J0548.7-6712 & 6.4 & 6.6 & 20 & 5 & > 0.0 \\
RX J0552.3-6402 & 3.7 & 0.16 & > 0.0 & < 0.0 \\
RX J0607.6-6651 & 4.8 & 0.68 & 0 & 4.5 & < 0.0 \\
\hline
\end{tabular}
\caption{Constraints (68% confidence) on the LMC hydrogen absorbing column density \((10^{20} \text{ cm}^{-2})\).}
\end{table}

\(^{a}\) Inferred from Parkes 21-cm line survey (Br"uns et al. 2001).
\(^{b}\) The constraint used is \( -\Gamma=(2.0 - 2.5) \) and is about the range in \( \Gamma \) derived for the AGN sample of Brinkmann et al. (2000).
\(^{c}\) Comparison between the X-ray derived value of the LMC column density and the 21-cm line derived value.
\(^{d}\) Value is determined from the 21-cm emission line measurement in the direction of the AGN (Dickey et al. 1994).
\(^{e}\) A dominant H\(_1\) absorption component of \( 3.7 \times 10^{22} \text{ cm}^{-2} \) has been determined from 21-cm line measurements.
\(^{f}\) Constraint used is \( -\Gamma=(3.0 - 3.5) \) as the 68% confidence error ellipse extends over \( \Gamma < -3.0 \).
\(^{g}\) \( N_{H} \) constraint for \( -\Gamma = (1.0 - 2.0) \) as the 68% confidence error exceeds over \( \Gamma > -2.0 \).

But for two sources substantial amount of absorbing gas would be derived which is in excess of the value inferred from the \( H_1 \) survey. One of these sources, RX J0536.9-6913, is located between 30 Dor and 30 Dor C, a region where high \( H_1 \) columns have been measured. In this region also copious emission of diffuse gas is seen

\footnote{The values given for the total LMC \( N_{H}^{\text{tot}} \) determined from X-ray spectral fitting differ from \( N_{H}^{\text{LMC}} + N_{H_2} \). They are the values resulting from the spectral fit and they have not been corrected taking the different photoionisation cross section for atomic and molecular hydrogen into account. \( N_{H}^{\text{LMC}} + N_{H_2} \) can be determined with Equ. 1.}
structure on smaller scales. But this may be required as aperture synthesis mosaics from the LMC with the ATCA revealed structure in the H\textsc{i} on scales up to the resolution of \(\sim 1\)\arcmin\ (Kim et al. 1998; 1999). We illustrate this effect in Fig. 5 where we show the positions of the ROSAT AGN marked as a cross inside a circle of the size of the Parkes beam. In several cases small scale H\textsc{i} structure is found in the 14\arcmin beam centered on the ROSAT AGN. The map of Kim et al. (1998) does not give the value of the \(N_{\text{H}}\) associated with H\textsc{i} structures and we cannot determine the uncertainties of the \(N_{\text{H}}\) determination if we integrate across the Parkes beam.

A hierarchial structuring of the H\textsc{i} gas clouds up to small scales (the resolution of their H\textsc{i} survey of \(\sim 1.5\)\arcmin) has been found by Staveley-Smith et al. (1997) and Stanimirovic et al. (1999) with ATCA observations of the SMC. A similar structuring of the LMC H\textsc{i} gas clouds has been found by Kim et al. (1999). Such a structuring of the gas may affect the integrated column density of the gas along the line of sight towards a background source.

5.3. Comparison of LMC results with those of the SMC

In order to investigate the uncertainties associated with the determination of the LMC column density towards an AGN in the field of the LMC we made use of the high-resolution H\textsc{i} survey of the Small Magellanic Cloud (SMC) performed with the ATCA radio telescope by Stanimirovic et al. (1999). We used the ROSAT PSPC catalog of point sources detected in the field of the SMC by Kahabka et al. (1999). We integrated the \(N_{\text{H}}\) map of Stanimirovic et al. (1999) in a circular region of size 14\arcmin\ (the Parkes beam) centered at the location of the X-ray sources detected with the ROSAT PSPC in the direction of the SMC.

In Fig. 6 we show the correlation between the \(N_{\text{H}}\) determined from the ATCA map and integrated over the Parkes beam with the \(N_{\text{H}}\) determined from the ATCA map at the location of the ROSAT source.

In Fig. 7 we show in a histogram the number of SMC sources for which the determination of the \(N_{\text{H}}\) by these two different evaluations differs by a given percentage. Assuming this distribution is Gaussian one derives a FWHM for this distribution of \(\sim 30\%\) (a Gaussian \(\sigma\) of \(\sim 13\%\)).

From Fig. 8 one can see that the column densities at the location of a ROSAT PSPC source in the field of the SMC as derived from the ATCA map are systematically lower for H\textsc{i} column densities below \(\sim 3.5 \times 10^{21} \text{ cm}^{-2}\) compared to the column densities inferred from the same map but integrated within the Parkes beam. For column densities above \(\sim 3.5 \times 10^{21} \text{ cm}^{-2}\) such a trend appears not to exist. We also show the histograms for these two ranges of column densities in Fig. 9.

There appears to be one straightforward explanation for this difference in the \(N_{\text{H}}\) determination. For lower hydrogen column densities the SMC gas is transparent to a ROSAT source. So one expects to detect preferentially the

5.2. Uncertainties in the 21-cm line measurements

We have used Parkes 21-cm line measurements to infer the H\textsc{i} column densities in the direction of the AGN. The Parkes beam has a FWHM of \(\sim 14\)\arcmin\ and cannot resolve H\textsc{i} in X-rays. In addition RX J0536.9-6913 lies in a region where high columns due to molecular gas (Sect. 6) have been measured and also a dark cloud complex is seen in this region. The second source, RX J0547.0-7040, coincides with a molecular cloud complex measured with NANTEN (Fukui et al. 1999; Mizuno et al. 1999). But if we take into account the constraints applied to the powerlaw photon index and the assumption for the metallicity of the LMC gas in the direction of these two background sources the significance for absorbing gas in excess of the measured H\textsc{i} may not be that large.
Fig. 8. Positions of 34 AGN (and candidate AGN) from the ROSAT PSPC catalog of HP99 (* MDM97) with indices 37, 44, 54, 100, 101, 147, 183, 233, 380, 411, 433, 559, 561, 653, 747, 65a, 876, 931, 1040, 1094, 1109, 1124, 1166, 1169, 1178, 1179, 1181, 1184, 1189, 1231, 1243, 1247, 1279, 1367. The position of the AGN is marked with a cross inside a circle of the size of the Parkes beam (14′ diameter) drawn over the H\textsc{i} finding charts as derived from the peak H\textsc{i} surface brightness map for the LMC (Kim et al. 1998). North is up. Dark regions have the larger peak H\textsc{i} columns. Note that the AGN HP 433 is at the edge of the H\textsc{i} map.

sources seen through lowest columns. This is a selection effect. In addition, at lower columns fewer gas structures are expected to add up and inhomogeneities in the gas (the contrast of structures) will be better recognized. At higher columns background sources are difficult to detect and sources found are mostly sources not too deep inside the SMC. Also the contrast in H\textsc{i} decreases as more different structures add up. This means that the symmetry of the distribution for the higher column range, having a FWHM of ∼20% or a σ∼9%, (see Fig. [4]) represents the H\textsc{i} structure which still exists in the large column regime.

6. Molecular gas

Molecular hydrogen is abundant in regions of high hydrogen column densities (Savage et al. 1977). The fraction of molecular hydrogen with respect to atomic hydrogen (expressed in the molecular mass fraction \( f \)) can vary locally and may depend on the gas column density. Richter (2000) presented the molecular mass fraction of the LMC and the SMC gas in the direction of 7 stars from UV absorption. He found that the molecular mass fraction is low (less than 10%) while strongly depending on the hydrogen column density. Only in regions of hydrogen columns \( > 10^{21} \text{ cm}^{-2} \) a molecular mass fraction \( > 1\% \) has been found.

We derive the column density of molecular hydrogen \( N_{\text{H}_2} \) from the total hydrogen column density of the gas \( N^{\text{tot}}_{\text{H}} \) as derived from the AGN X-ray spectra and the column density of atomic hydrogen H\textsc{i} \( N_{\text{H}_1} \)

\[
N_{\text{H}_2} = \frac{1}{2.8} \left( N^{\text{tot}}_{\text{H}} - N_{\text{H}_1} \right) \tag{1}
\]

Here we make the assumption that the photoionisation cross section is 2.8 times larger for molecular hydrogen than for atomic hydrogen (cf. Cruddace et al. 1974, Yan
We note that we do not consider the contribution of warm diffuse gas to the total absorbing column density $N_{\text{H}1}^{\text{tot}}$. The molecular mass fractions derived with Equ. 2 are uncertain due to the uncertainties in the values of the hydrogen column densities inferred from the X-ray observations. But also the H1 values are uncertain due to the beam size of the Parkes beam of 14′. We therefore can derive in most cases only upper limits for the molecular mass fraction from

$$\Delta f = \frac{1.4\sqrt{(N_{\text{H}1} \Delta N_{\text{H}1}^{\text{tot}})^2 + (N_{\text{H}1}^{\text{tot}} \Delta N_{\text{H}1})^2}}{(N_{\text{H}1}^{\text{tot}} + 0.4N_{\text{H}1})^2}$$

In Table 5 we give the derived values ($f \pm \Delta f$) for the molecular mass fractions for 6 AGN from Table 4 with accurate $N_{\text{H}1}$ determinations making use of Equ. 2 and 3 and assuming $\Delta N_{\text{H}1} = 0.1 \times N_{\text{H}1}$. For further 6 AGN we determine only 1σ upper limits for the molecular mass fraction.

Table 5. Molecular hydrogen column density $N_{\text{H}2}$ (with 68% errors) and molecular mass fraction $f$ (with 68% errors $\Delta f$) as derived with Equ. 2 and 3. For a fraction of the sources only 1σ upper limits are given for $N_{\text{H}2}$ and $f$.

| Name | $N_{\text{H}1}$ | $N_{\text{H}2}$ | $f \pm \Delta f$ | Remarks |
|------|----------------|----------------|-----------------|---------|
| RX J | $(10^{21}$ cm$^{-2}$) | $(10^{21}$ cm$^{-2}$) | (%) | |
| 0454.1-6643  | 1.4 | 0.39±0.54  | 36±32 | (a) |
| 0503.1-6634  | 1.0 | $\leq 0.0$ | $\leq 0.0$ | (b) |
| 0509.2-6954  | 0.6 | $\leq 0.36$ | $\leq 120$ | (b) |
| 0524.0-7011  | 0.7 | $\leq 0.08$ | $\leq 30$ | (b) |
| 0528.8-6539  | 0.53 | $\leq 0.1$ | $\leq 180$ | (b) |
| 0532.0-6919  | 1.1 | $\leq 0.61$ | $\leq 180$ | (b) |
| 0534.6-6738  | 1.8 | $\leq 0.43$ | $\leq 63$ (b) | |
| 0536.9-6913  | 3.3 | 7.8±3.2 | 82±6 (a) | |
| 0546.0-6415  | 0.12 | $\leq 0.04$ | $\leq 60$ (b) | |
| 0546.8-6851  | 3.8 | $\leq 0.62$ | $\leq 67$ (b) | |
| 0547.0-7040  | 3.0 | 3.6±2.5 | 71±15 (a) | |

(a) The value of $f$ is given derived from $N_{\text{H}1}^{\text{tot}}$ as determined in the spectral fit.
(b) Upper limits (1σ) are given for $N_{\text{H}1}$ and $f$.
(c) Constraint obtained using $N_{\text{H}1}^{\text{SMC}} = 7\pm 1$ as derived from the hardness ratio analysis (cf. Paper II).
(d) Constraint obtained using $N_{\text{H}1}^{\text{SMC}} = 15\pm 3$ as derived from the hardness ratio analysis (cf. Paper II).
(e) Using the $N_{\text{H}1}$ determination from the strongest H1 absorption component (cf. Dickey et al. 1994).
a region with a large ($\gtrsim 10^{21}$ cm$^{-2}$) LMC H\textsc{i} column density (cf. Table 4). The total hydrogen column density inferred from the \textit{ROSAT PSPC} X-ray spectral fit is within the uncertainties consistent with the H\textsc{i} column density inferred from the 21-cm line measurements. We derive for RX J0532.0-6919 a rather large upper limit for the molecular mass fraction of $\lesssim 18\%$.

RX J0454.1-6643, and RX J0524.0-7011 are close to regions with detected molecular gas as would be inferred from the CO map of Cohen et al. (1988). We derive upper limits for the molecular mass fraction of RX J0454.1-6643 and RX J0524.0-7011 of $\sim 70\%$ and $30\%$ respectively.

For RX J0536.9-6913 ($=$ MDM 65), which is located in the 30 Dor complex, a very large column density of $(1.6 - 3.4) \times 10^{22}$ cm$^{-2}$ has been determined from the spectral fit to a deep (200 ksec) merged \textit{ROSAT PSPC} observation. This is the largest hydrogen column determined for a LMC background X-ray source. From \textit{Parkes} 21-cm line data we get here a H\textsc{i} column of $3.3 \times 10^{21}$ cm$^{-2}$. The molecular mass fraction in the direction of RX J0536.9-6913 is found to be $82\pm 6\%$. However, Dickey et al. (1994) have detected H\textsc{i} in absorption with the ATCA radio telescope in the direction of a background radio source which coincides in position with RX J0536.9-6913. The absorption is, given the radial velocity, due to gas associated with the disk (D) component of the LMC. The column density determined for the strongest absorption component is $3.7 \times 10^{22}$ cm$^{-2}$ (Dickey et al. 1994) and consistent with or even larger than the total column density derived from the X-ray absorption. This would mean that no large contribution due to molecular hydrogen is required to explain the X-ray absorption.

There is another \textit{ROSAT PSPC} source in the 30 Dor complex, RX J0546.8-6851, for which also a large H\textsc{i} column density of $3.7 \times 10^{21}$ cm$^{-2}$ is determined with the \textit{Parkes} radio telescope. An X-ray spectral fit gives for this source a total gas column density of $2.0 \times 5.5 \times 10^{21}$ cm$^{-2}$ assuming constraints on the photon index for AGN type spectra. This value for the absorption is consistent with the value determined from the 21-cm line measurements. The source has been classified as a likely AGN (or perhaps an X-ray binary) by SHP00. The molecular mass fraction derived for this source of $< 67\%$ is somewhat lower than the fraction derived for RX J0536.9-6913. But if the absorption inferred for RX J0536.9-6913 from the 21-cm absorption line measurements is taken into account then a consistent constraint for the molecular mass fraction is derived for both sources. RX J0546.8-6851 was not studied in the ATCA 21-cm absorption line surveys of the LMC, so nothing is known about 21-cm absorption. The X-ray source does not appear to be located in an X-ray dark area of the LMC.

From these two highly absorbed \textit{ROSAT} background sources we would conclude that the mass fraction of molecular gas in the 30 Dor complex is probably less than $\sim 70\%$. We infer for the other less absorbed \textit{ROSAT} background sources (and excluding RX J0528.8-6539 for which the value determined for f is very uncertain) upper limits for the mass fraction of the molecular gas of about 30 to 140\%. An alternative explanation for observed increased gas columns in the 30 Dor complex could be a higher metal content of the star forming complexes (cf. Haberl et al. 2001; Dennerl et al. 2001).

Our result for the H$_2$ appears to be in qualitative agreement with the measured distribution of CO in the LMC (Cohen et al. 1988). According to these measurements, the CO intensity is larger in the 30 Dor complex than 20$\circ$ east of it. According to Cohen et al. (1988) a maximum column density due to H$_2$ of $2.6 \times 10^{21}$ cm$^{-2}$ is expected for the 30 Dor complex assuming an X factor of $X_{\text{LMC}} = 1.7 \times 10^{21}$ cm$^{-2}$ K$^{-1}$ km s$^{-1}$.

We would determine for RX J0536.9-6913 a rather high column density due to molecular hydrogen of $N_{\text{H}_2} = (7.8 \pm 3.2) \times 10^{21}$ cm$^{-2}$ if we make use of the hydrogen column inferred from the 21-cm emission line measurements. We note that such a H$_2$ column density would imply the CO component would be above the detection limit of $\sim 10^{21}$ cm$^{-2}$ of the NANTEN $^{12}$CO survey (cf. Mizuno et al. 1999 and Fukui et al. 1999). But if we use the hydrogen column density of $3.7 \times 10^{22}$ cm$^{-2}$ inferred from the dominant 21-cm absorption line component (Dickey et al. 1994) then we would not require molecular hydrogen to explain the result of the X-ray spectral fit. RX J0536.9-6913 is located in an “X-ray shadow” or “dark cloud”, a region of reduced diffuse X-ray emission which could indicate for a molecular cloud complex (or alternatively a cool cloud complex). From inspection of the \textit{ROSAT PSPC} image (Fig. 2) centered on the AGN we estimate the size of the cloud to $\sim 3.2\prime$ which is equivalent to $\sim 50$ pc for a distance of 50 kpc. We note that the value for the total hydrogen column density in the direction of RX J0536.9-6913, $N_{\text{H}_1} + N_{\text{H}_2}$, is similar to the value $N_{\text{H}_1} + N_{\text{H}_2} = (1.2 - 2.4) \times 10^{22}$ cm$^{-2}$ as determined by Poglitsch et al. (1995) for 30 Dor.

For RX J0546.8-6851 on the other hand a lower value of the column density due to molecular hydrogen of $N_{\text{H}_2} \lesssim 6 \times 10^{20}$ cm$^{-2}$ is derived from the X-ray observations. Such a H$_2$ column density is below the detection limit of $\sim 10^{21}$ cm$^{-2}$ of the NANTEN $^{12}$CO survey. The derived value for the $N_{\text{H}_2}$ corresponds for the assumed X factor to a CO intensity of 0.35 K km s$^{-1}$ which is consistent with the lowest contour in the CO map of Cohen et al. (1988).

7. Conclusions

We have set up a sample of 35 background X-ray sources in a $10^5 \times 10^5$ field of the LMC observed with the \textit{ROSAT PSPC} using the X-ray catalogs of HP99 and SHP00 and the radio catalog of MDM97. A fraction of these sources are candidate background X-ray sources which have been constrained from X-ray spectral properties.

For 7 of the background X-ray sources which are optically identified and for which a redshift has been determined we perform X-ray spectral fitting and we constrain the photon index and the hydrogen absorbing column den-
sity due to the LMC gas. We use for the galactic absorbing component values inferred from a 21-cm Parkes survey. We find for these sources powerlaw photon indices which are consistent with the powerlaw photon indices of AGN type spectra (with values in the range $-\Gamma = 2.0$ to 2.5). The total LMC absorbing columns which we derive from the X-ray spectral fit are within the uncertainties consistent with the H\textsc{i} columns measured with a Parkes 21-cm line survey.

For further 19 background X-ray sources we cannot constrain the powerlaw photon index accurate enough to derive secure constraints on the LMC hydrogen column density. For these sources we make the assumption that the powerlaw photon index is that of AGN type spectra $-\Gamma = 2.0$ to 2.5. With that assumption we then derive constraints on the LMC hydrogen column density for these sources.

We compare for 20 X-ray background sources the LMC absorbing columns derived from the X-ray spectral fit with the LMC H\textsc{i} columns derived from a 21-cm line Parkes survey. We find in general, within the uncertainties of the values derived from the X-ray spectral fit, agreement between the X-ray and 21-cm derived absorbing columns.

For two background sources RX J0536.9-6913 and RX J0547.0-7040, which are located in regions of large ($3 \times 10^{21} \text{ cm}^{-2}$) H\textsc{i} columns, we derive hydrogen columns from the X-ray spectral fit of $\sim (0.6–2) \times 10^{22} \text{ cm}^{-2}$ which are in excess of the H\textsc{i} columns. These sources probably are seen through additional gas which may be warm and diffuse, cold or molecular. But if we take into account the constraints applied to the powerlaw photon index and the assumption made for the metallicity of the LMC gas in the direction of these two background sources the significance for absorbing gas in excess of the measured H\textsc{i} may not be that large.

We derive constraints on gas columns additional to H\textsc{i} for 10 background X-ray sources. Assuming that these columns are due to molecular gas we derive upper limits for the molecular mass fraction for these sources of $\sim 30 – 140\%$.

Acknowledgements. The ROSAT project is supported by the Max-Planck-Gesellschaft and the Bundesministerium für Forschung und Technologie (BMFT). We have made use of the ROSAT Data Archive of the Max-Planck-Institut für extraterrestrische Physik (MPE) at Garching, Germany. This research has made use of the SIMBAD data base operated at CDS, Strasbourg, France. We have made use of the publicly available H\textsc{i} peak temperature image of the LMC (Kim et al. 1998) and of the H\textsc{i} image of the SMC provided by S. Stanimirovic. We have made use of the Karma software developed at ATNF. PK is supported by the Graduiertenkolleg on the “Magellanic Clouds and other Dwarf galaxies” (DFG GRK 118). We thank the referee W. Pietsch for the useful comments.

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