The Interstellar Medium and the Soft X-ray Background

S. L. Snowden

USRA/Goddard Space Flight Center, Code 662, Greenbelt, MD 20771, USA

Abstract. Observations of the SXRB surface brightness provide the only means to study the tenuous $\sim 10^6$ K plasma of the local ISM of our Galaxy. In addition, the interpretation of the spatial structure in the SXRB is closely linked to our understanding of the distribution of other diffuse components in the ISM. Since one optical depth at $\frac{1}{4}$ keV is $\sim 1 \times 10^{20}$ H I cm^{-2}, the distance which can be probed in the Galactic plane is severely limited if the cooler, X-ray absorbing material is smoothly distributed. On the other hand, if the cooler material is sufficiently clumped to be self shadowing, greater distances can be probed. The use of H I, IRAS, and CO studies to search for negative correlation, or shadowing, of the SXRB coupled with ISM absorption-line studies to determine the distances to the shadowing material will lead to a three dimensional mapping of the X-ray emitting and absorbing components.

The local ISM is proving to be a complex region with many distinct components, including regions of diffuse, partially-ionized gas (e.g., the Local Fluff), a region of $\sim 10^6$ K plasma which extends on the order of 100 pc from the Sun (the Local Hot Bubble), regions of both neutral material and H II gas, and molecular gas (of limited filling factor). To further complicate the situation, the neutral material is apparently distributed in clouds, filaments, sheets, and probably even a truly diffuse component.

1. Introduction

The study of the soft X-ray background (SXRB) began in the late 1960's with the sounding-rocket observations of Bowyer, Field, & Mack (1968), Henry et al. (1968), and Bunner et al. (1969). From these first observations, the $\frac{1}{4}$ keV background exhibited a surface brightness which was both intense and varying with direction. With the relatively crude angular resolution of these experiments, the most obvious feature was the global trend of greater intensity at high Galactic latitudes than in the plane of the Galaxy. Bowyer, Field, & Mack (1968) arrived at the logical conclusion that the SXRB originated externally to the Galaxy and that the variation of intensity was due to absorption by the neutral interstellar medium of the Galactic disk. The measured non-zero flux from the Galactic plane was attributed to an additional non-cosmic background component which could not be identified and removed.

However, with additional independent observations it became apparent that the flux from the Galactic plane was very likely to be cosmic in origin. Further, the attempts which were made to model the negative correlation between the SXRB surface brightness and H I column density indicated that the required effective cross sections for absorption were significantly smaller than the theoretical values and, somewhat later, that they were relatively independent of energy, where there should be a strong ($\sim E^{-\frac{8}{3}}$) dependence (e.g., Morrison & McCammon 1983). These first inconsistencies of the "absorption model" (the postulation of an extragalactic source of emission absorbed by Galactic H I) were explained by having a local, unabsorbed component and by clumping the material of the ISM into optically thick (to $\frac{1}{4}$ keV X-rays) clouds. From this point, discussions of the origin of the SXRB became tightly linked to models of the ISM.

Over the next two decades great strides were made in improving the quality, sky coverage, angular, and spectral resolution of the data. During this time, there was comparatively little disagreement about the "facts" of the data. Different groups presented data collected using different instruments acquired by different means, which consistent with each other. By the late 1980's there were three independent all-sky surveys in the $\frac{1}{4}$ keV band, one from a campaign of sounding-rocket flights (Wisconsin, McCammon et al. 1983) and two from satellite experiments (*SAS-3*, Marshall & Clark 1984; *HEAO-1*, Garmire et al. 1992). Figure 1 shows the $\frac{1}{4}$ keV band map from the first of these (McCammon et al. 1983). For purposes of comparison, Figure 2 shows a map of Galactic H I (Dickey & Lockman 1990). The general negative correlation between the two data sets, dominated by the Galactic plane to high Galactic latitude variation, is readily apparent.

While the X-ray data were in good agreement, the interpretation of those same data engendered often lively discussions. Models were proposed ranging from having most of the observed background originating within the nearest few hundred parsecs (e.g., Sanders et al. 1977; Snowden et al. 1990) to having it originate over long path lengths even in the Galactic disk (e.g., Jakobsen & Kahn 1986; Hirth et al. 1992) or in the Galactic halo and beyond (e.g., Marshall & Clark 1984).

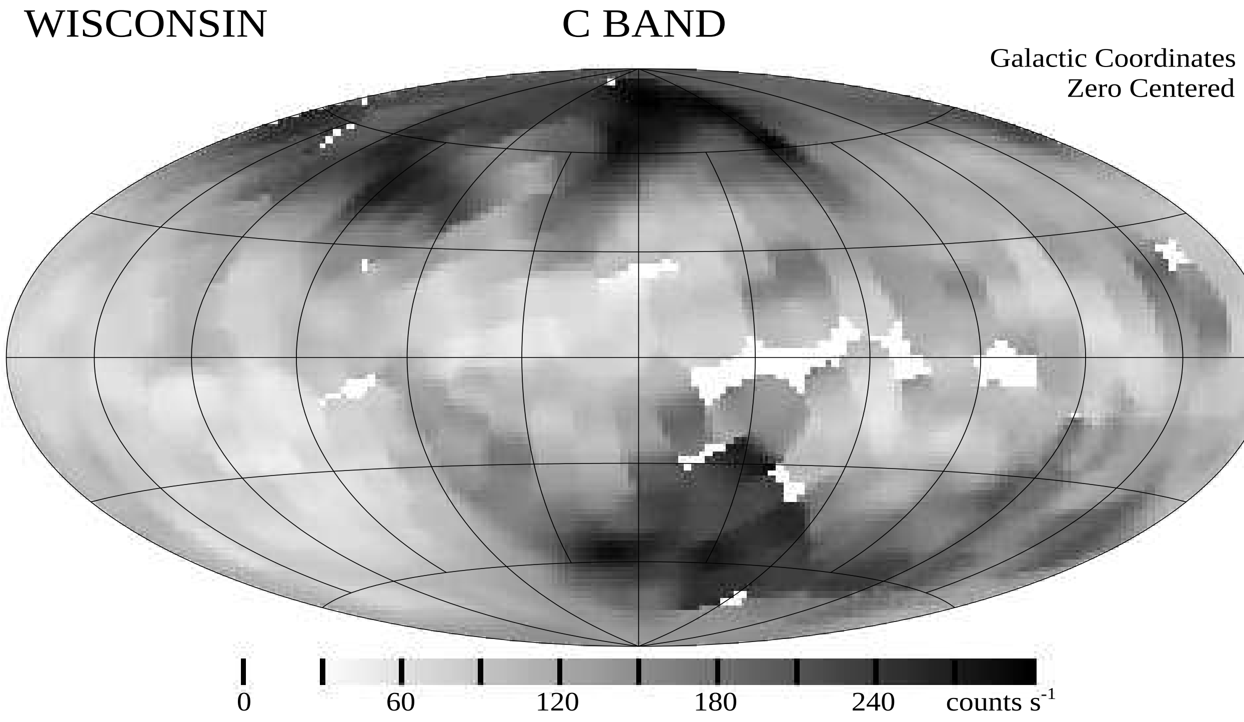

Fig. 1. Map of the $\frac{1}{4}$ keV diffuse background from the Wisconsin survey (McCammon et al. 1983). The projection is in Galactic coordinates centered on the Galactic center with longitude increasing to the left.

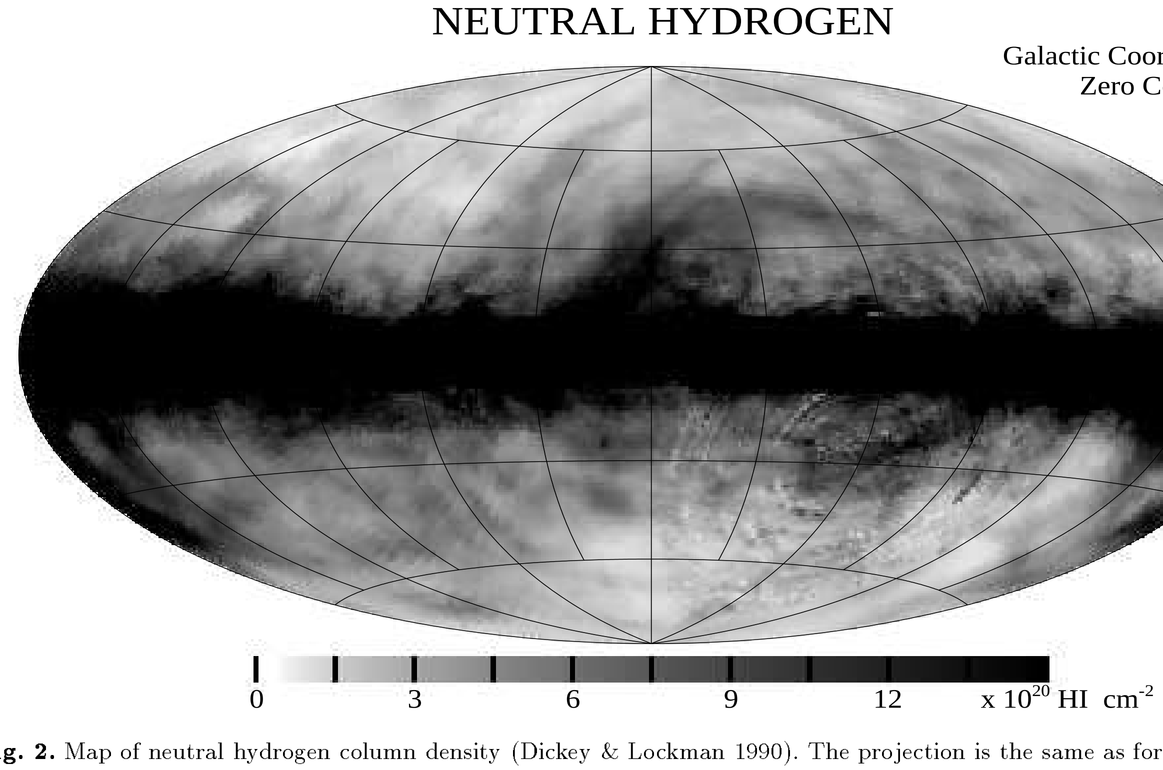

Fig. 2. Map of neutral hydrogen column density (Dickey & Lockman 1990). The projection is the same as for Fig. 1.

Because $\frac{1}{4}$ keV X-rays reach optical depth of one at a column density of about 10^{20} H I cm^{-2}, if Galactic H I is smoothly distributed we can "see" out to only a hundred parsecs or so (assuming an H I space density of $0.5\,\mathrm{cm}^{-3}$). Figure 3 demonstrates this by showing the ROSAT $\frac{1}{4}$ keV, $\frac{3}{4}$ keV, and 1.5 keV band effective area curves (Snowden et al. 1995) and X-ray mean free path in the galactic plane (assuming that galactic H I is distributed smoothly with the above space density) as a function of energy. Even at the highest energy in the $\frac{1}{4}$ keV band pass (the carbon Kα absorption edge at 284 eV) the mean free path is only $\sim$ 200 pc. On the other hand, if the H I is sufficiently clumped to become self shielding (e.g., as in the highly clumped two-component ISM model of McKee & Ostriker 1977), the ISM becomes relatively transparent and we can see considerably farther out from the Sun. Thus, a detailed knowledge of the cooler ISM is necessary to understand the distribution of hot plasma responsible for the SXRB.

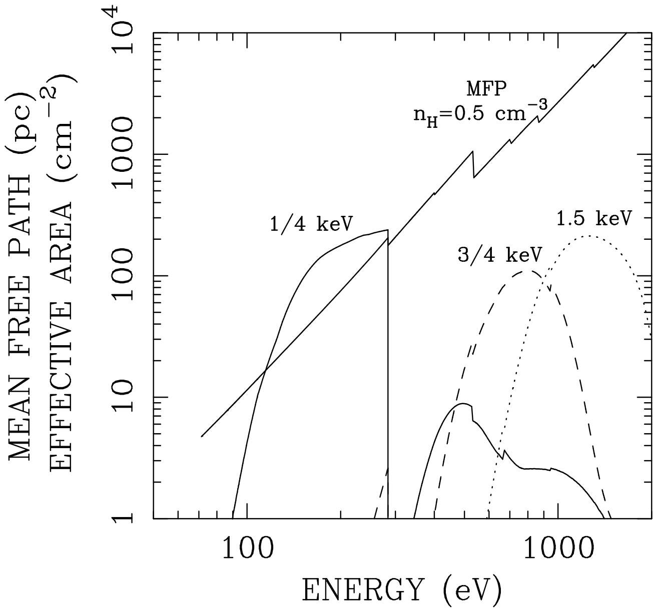

Fig. 3. ROSAT $\frac{1}{4}$ keV,$\frac{3}{4}$ keV, and 1.5 keV band effective area curves and X-ray mean free path in the galactic plane (assuming that galactic H I is distributed smoothly with a space density of 0.5 H I cm^{-3}) as a function of energy.

The late 1970's and 1980's saw considerable work in other energy ranges which had significant implications for our understanding of the local interstellar medium. Knapp (1975), using 21-cm observations, reported a local deficit in the Galactic H I. Frisch & York (1983) and Paresce (1984) used ISM absorption line measurements of the spectra of relatively nearby stars to show conclusively that there is a local cavity in the H I of the Galactic disk which surrounds the Sun. The path lengths of low H I space density vary considerably even in the Galactic plane with values ranging from tens to hundreds of parsecs. Even the "cavity" was shown to be a complicated region with a partially ionized component of limited extent surrounding the Sun (Berteau et al. 1985) and significant path lengths of H II gas in at least one direction (toward β CMa, Gry, York, & Vidal-Madjar 1985). Besides having regions of partially ionized and H II gas, the local cavity in the H I was a logical place to put the hot plasma responsible for the local component (that which is observed in the Galactic plane) of the SXRB.

The 1980's also saw an extensive study of the clumping of the neutral ISM. Between Lockman, Jahoda, & McCammon (1986) and Dickey, Salpeter, & Terzian (1978), significant clumping on nearly all relevant size scales was ruled out. However, this is not to say that Galactic H I is distributed in a smooth, plane-parallel manner in the disk. Indeed, the H I has a great deal of structure and is found in clouds, sheets, and filaments, as well as in a diffuse component (see Kulkarni & Heiles 1988). The filling factors of these various components remain obscure.

Data from IRAS have contributed considerably to our view of the ISM. While without the velocity information inherent in 21-cm H I observations, the cleaned IRAS 100μm data (Wheelock et al. 1994) show extensive structure in the neutral material at much higher angular resolution than allowed by single-dish, 21-cm observations. The tight correlation between H I column density and IRAS 100 μm intensity at high Galactic latitudes (Boulonger & Perault 1988) demonstrated that the IRAS data could be used as a tracer of the total neutral and (with some limitations) molecular column density at a few arc minute resolution.

By the end of the 1980's, the picture of the local ISM and its relationship to the SXRB was, and I'll show my bias here, best described by the displacement model (Snowden et al. 1990). This model postulates that the bulk of the observed $\frac{1}{4}$ keV flux (specifically, for the Wisconsin B band, $0.13-0.188$ keV, McCammon et al. 1983) originates as diffuse emission from a thermal plasma at $\sim 10^6$ K which is contained within the local H I cavity. The negative correlation between H I column density and SXRB surface brightness is a natural result of the cavity being more extended out of the plane of the Galaxy, which produces a larger emission measure of the hot plasma. While describing the relationship between N_{H} and SXRB reasonably well, the model had the advantage of being reasonably consistent with the rest of the observational data. It required no clumping of the neutral ISM and placed no constraints on the absorption cross sections. It also placed the hot plasma in the H I void so there was no problem with local filling factors of the different ISM components. "Bulk" is an operative word here as there were other, obvious components to the SXRB such as SNRs which contributed emission over large solid angles (e.g., the North Polar Spur) and non-obvious components such as *some* expected extragalactic emission from the low-energy extrapolation of the power law observed at higher energies. Three review papers from the same time deserve special mention for their contributions. Cox & Reynolds (1987) discussed the local ISM, McCammon & Sanders (1990) discussed the SXRB and its origins, and Dickey & Lockman (1990) discussed the H I in the Galaxy.

2. ROSAT Contributions

Now we will enter the ROSAT era. The all-sky survey has provided by far the best mapping of the diffuse background in the $0.1 - 2.0$ keV range of any previous or planned future mission. The $\frac{1}{4}$ keV band map shown in Figure 4 (for a clearer, color version, see Snowden et al. 1995) displays extensive detailed structure never before observed. At the same time, the large-scale features are entirely consistent with previous mappings (e.g., compare Figure 4 to Figure 1). The data show the same Galactic plane to high Galactic latitude variation in intensity and the same general negative correlation with Galactic H I (Figure 2). To this level there was nothing new. However, one of the first stunning results from the ROSAT observatory was the detection of a shadow in the SXRB cast by clouds of the Draco Nebula (Burrows & Mendenhall 1991; Snowden et al. 1991). The shadows were deep and the clouds were known to be at a distance of $\gtrsim 300$ pc, $\gtrsim 200$ pc above the galactic plane. These observations demonstrated that in at least this one direction, roughly half of the *observed* $\frac{1}{4}$ keV flux originates in at least the lower halo. The existence of X-ray-emitting, halo gas has since been confirmed in other directions as well. For instance, Snowden et al. (1994) analyzed the shadows cast by low- and intermediate-velocity clouds in the Ursa Major region while Herbstmeier et al. (1995) studied the shadows cast by the M complex of high-velocity clouds. The latter observation is of particular interest as it demonstrates the existence of X-ray emission in the halo above 1.5 kpc (Danly, Albert, & Kuntz 1993).

But what does this mean? Why do the ROSAT results appear to be so much at odds with the displacement model, the previous "best" model for the origin of the SXRB?

It turns out that there isn't so much of a problem in consistency as in nomenclature. To understand this, remember as noted above that the Snowden et al. (1990) results were based on the Wisconsin B band. This band is significantly softer than the ROSAT $\frac{1}{4}$ keV band (a high-energy cutoff of 188 eV compared to 284 eV) and therefore has an effective band-averaged absorption cross section which is twice as large. This in turn produces an optical depth of at least one for looking out of the Galactic disk and is more typically two to four at high Galactic latitudes. The model was therefore relatively insensitive to the existence of halo emission and the halo contribution could easily be hidden in the additional scatter of the data. Furthermore, as discussed below, ROSAT observations are showing that the local component of the SXRB does vary in a similar manner as that suggested by the displacement model. This bit of sophistry, however, does nothing to explain away the surprise at the time of observing such clear and deep shadows in the ROSAT data.

While ROSAT has revised our understanding of conditions in the Galactic halo, it is also providing information about the local emission region. By looking at regions of minimum surface brightness on the sky and the intensities toward optically thick shadowing targets, we can start to map the foreground emission measure and therefore the extent of the Local Hot Bubble. From Snowden et al. (1995), the $\frac{1}{4}$ keV background reaches a minimum of about 2.7×10^{-4} counts s^{-1} arcmin^{-2} near the Galactic plane. From Snowden et al. (1991), the foreground intensity in the direction of the Draco Nebula is about 5×10^{-4} counts s^{-1} arcmin^{-2}. From Snowden et al. (1994), the foreground intensity in the direction both the low- and intermediate-velocity clouds in the Ursa Major field is about 7×10^{-4} counts s^{-1} arcmin^{-2}. If both the Draco and Ursa Major foreground values are measures of the intensity from the LHB (as is likely the case), then there is at least a factor of 2.6 variation in the LHB, and the LHB is more extended out of, than in the Galactic plane. This is essentially the same picture of the LHB as we had before ROSAT, what ROSAT has shown us is the more complicated nature of the halo. To give an idea of the directional variation of the LHB surface brightness, Table 1 lists the $\frac{1}{4}$ keV band shadowing results of a number of ROSAT pointed observations. The values for the foreground (to the clouds) intensities, which can in all likelihood be attributed to the LHB, vary from 3.0 to 7.7×10^{-4} counts s^{-1} arcmin^{-2} while the background intensities vary between 1.6 and 44.0×10^{-4} counts s^{-1} arcmin^{-2}.

3. ISM

All in all, limited though they are, the foreground results are consistent with the model of Snowden et al. (1990). Because of this, it is important to note that the existence of halo emission does not negate the existence of the LHB. However, while the LHB may still rule the day locally, the complete picture is considerably more complicated than an isolated hot bubble in uniformly distributed cool material in the Galactic disk. To get a perspective on the situation, let's take a trip out from the Sun. Outside of the solar system, we first find a region of partially ionized gas (Bertaux et al. 1985) the existence of which is well established by optical ISM absorption line studies of the spectra of nearby stars (see Frisch 1994). This is a region of limited extent ($\lesssim 10$ pc) and limited column density ($\lesssim 5 \times 10^{18}$ H I cm^{-2}). It has an ionization fraction of perhaps ~ 0.69, an electron density of $0.22 - 0.44$ cm^{-3}, and a temperature of $6700 - 8000$ K (Frisch 1994), implying a thermal pressure of P/k ~ 5000 cm^{-3} K.

Table 1. SXRB $\frac{1}{4}$ keV shadow measurements.

ID	l	b	I_f [a]	I_d [a]	Distance[a] (pc)	Reference
MBM33	357	37	4.9	$-^c$	110	Kuntz, Snowden, & Verter (1996)
R CrA	0	-18	3.9	44.0	-	Wang (1994)
MBM36	4	36	3.2	$-^c$	110	Kuntz, Snowden, & Verter (1996)
Field 5	68	25	4.6	2.6	-	Wang & Yu (1995)
Draco	94	38	4.5	34.2	> 300	Snowden et al. (1991)
Field 4	113	62	7.7	3.6	-	Wang & Yu (1995)
Field 3	140	44	6.6	1.6	-	Wang & Yu (1995)
Field 2	145	43	5.6	2.5	-	Wang & Yu (1995)
UMa Region	~ 150	~ 53	7.0	7.0	-	Snowden et al. (1994)
MBM16	171	-38	5.2	$-^c$	$60 - 95$	Kuntz, Snowden, & Verter (1996)
L 1563	187	-17	4.0	$-^c$	< 85	Kuntz, Snowden, & Verter (1996)
MBM18	189	-36	3.5	$-^c$	$120 - 150$	Kuntz, Snowden, & Verter (1996)
MBM21	208	-28	5.2	$-^c$	< 210	Kuntz, Snowden, & Verter (1996)
MBM20	211	-36	4.1	$-^c$	< 100	Kuntz, Snowden, & Verter (1996)
Field 1	283	-45	3.0	5.8	$105 - 160$	Wang & Yu (1995)

[a] Units of 10^{-4} counts s^{-1} arcmin^{-2}.
[b] Distance, when known, to the absorbing feature.
[c] Galactic H I is optically thick through to the halo.

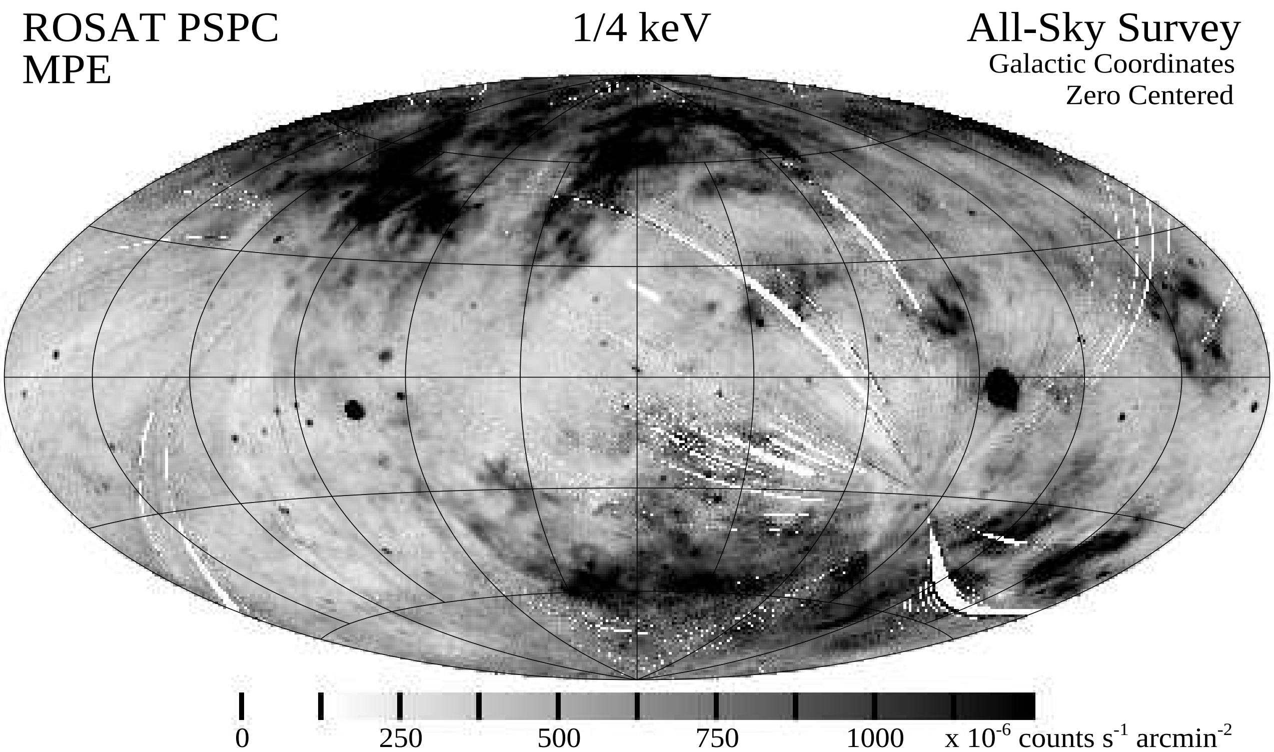

Fig. 4. Map of the $\frac{1}{4}$ keV diffuse background derived from the ROSAT all-sky survey data. The projection is the same as for Fig. 1.

Beyond the local cloudlet, we enter a region of hot plasma, the LHB, which is responsible for much of the observed $\frac{1}{4}$ keV diffuse background. Here the temperature is $\sim 10^6$ K and the thermal pressure is ~ 12500 cm^{-3} K based on a ROSAT PSPC observation (Snowden, McCammon, & Verter 1993) or ~ 19000 cm^{-3} K based on an EUVE observation (Bowyer et al. 1995). Both values are well above the thermal pressure of the cloudlet, although magnetic field pressure could bring the total pressures closer (e.g., Cox & Snowden 1986).

The diffuse background at slightly lower energies adds a useful constraint to our understanding of the LHB. The Be band ($70 - 111$ eV) and soft B band ($100 - 188$ eV) of the Wisconsin sounding-rocket experiment UXT track each other remarkably well over the $\sim 10\%$ of the sky which has been observed (Bloch et al. 1986; Juda et al. 1991; Edwards 1990). This tight correlation in surface brightness over a factor of three in dynamic range strongly suggests that they originate in the same medium and limits the foreground absorption to less than $\sim 5 \times 10^{18}$ H I cm^{-2} of absorbing material between that medium and the Sun (Juda et al. 1991). (There is a factor of ~ 4 difference between the band averaged absorption cross sections of the 100 eV and 150 eV bands.) Since this is true for data widely distributed over the sky, the hot plasma must enclose much if not all of the local cloudlet.

There is no reason to expect that the local cloudlet is unique in its drifting through the LHB. There is apparently at least one other relatively thin ($\sim 5 \times 10^{19}$ cm^{-2}) cloud which has been identified as lying within the LHB (Kerp, Herbstmeier, & Mebold 1993). The molecular cloud MBM12 (Magnani, Blitz, & Mundy 1985) may also lie within the LHB (Snowden, McCammon, & Verter 1993).

Next comes the tricky question of what bounds the LHB. In many directions, e.g., toward the Galactic center, significant columns of neutral material are found relatively nearby (~ 50 pc, e.g., Egger & Aschenbach 1995). In these cases where the "local" column exceeds the modest level of a few times 10^{20} H I cm^{-2}, *all* of the observed $\frac{1}{4}$ keV intensity must arise in the LHB. However, there are other directions even near the Galactic plane, e.g., the "void" toward β CMa ($l \sim 226°, b \sim -14°$), where the line of sight extends well beyond 200 pc before significant columns of H I are reached. If the hot plasma filled all of the region of low density, then the surface brightness in the direction of the void would be enhanced by a factor of $\gtrsim 4$ over nominal rates in the Galactic plane, which is not the case although there is a factor of ~ 1.5 increase. The work of Gry, York, & Vidal-Madjar (1985) show that some of the void ($40 - 90$ pc out of the distance of 210 pc to the star) is filled with H II gas. With a small amount of hand waving a simple picture can be built. Consider that the $\frac{1}{4}$ keV band surface brightness in that direction is $\sim 4.9 \times 10^{-4}$ counts s^{-1} arcmin^{-2}. Using the $\frac{1}{4}$ keV band intensity to emission path length relation determined from the MBM12 observation (~ 16 pc [10^{-4} counts s^{-1} arcmin^{-2}]$^{-1}$), the LHB path length of hot gas toward β CMa is ~ 80 pc (assuming that the emission is uniformly distributed). Adding the LHB path length to those of the diffuse ionized gas and local fluff comes gratifyingly close (within $\sim 30\%$) to the distance to the star. The important aspect of this direction relative to the ISM and regions of $\frac{1}{4}$ keV emission is the long distances of low column. This is the one direction in the Galactic disk that if there is a ubiquitous distribution of 10^6 K gas, we should see evidence for it as a strong enhancement in the $\frac{1}{4}$ keV surface brightness. But we don't see anything more than can be accounted for by the LHB (and perhaps even less).

In our travel out from the Sun, we have crossed regions of diffuse, partially ionized gas, hot plasma, and have run into cooler neutral or warm ionized material depending on which direction we have gone. The next step is also direction dependent. At higher, and hopefully less complex Galactic latitudes, we can still see a number of different ISM components. In the northern hemisphere, there is considerable neutral material moving toward us from low to intermediate velocities (the sky *is* falling). This material is apparently distributed in sheets, filaments, clouds, and perhaps even diffusely in some regions (Kulkarni & Heiles 1988). Above the disk of the Galaxy there is infalling diffuse ionized gas (Danly 1989; Danly et al. 1992; Reynolds 1991), high-velocity neutral clouds, and regions of $\sim 10^6$ K, $\frac{1}{4}$ keV X-ray-emitting plasma. And those are just the components which we *can* see.

At lower Galactic latitudes, there is much more room for debate and we return once again to global models of the ISM. Again, if the ISM is distributed smoothly then the story is over, at least as far as observing at $\frac{1}{4}$ keV is concerned. The first time that an H I wall (or total column) of $\gtrsim 3 \times 10^{20}$ cm^{-2} is reached the curtain has closed since the optical depth becomes prohibitively large. If the H I is clumped in optically-thick clouds, then it becomes possible to look past the clumped absorbers out to possibly much greater distances. Then if the Galactic disk has an extensive distribution (high filling factor) of hot plasma similar to the LHB, the Galactic plane ought to be quite interesting. But this is not the case. While there are several enhancements of varying size which are easily seen, the Galactic plane is in general rather boring. The Monoceros-Gemini enhancement centered on ($l \sim 205°, b \sim 5°$) with a radius of $\sim 12°$ is located ~ 300 pc away with a foreground column of $\sim 5 \times 10^{19}$ cm^{-2} (see Plucinsky et al. 1995). The Vela ($l \sim 265°, b \sim -3°$) and Cygnus Loop ($l \sim 75°, b \sim -5°$) SNRs are both also visible at $\frac{1}{4}$ keV but are considerably more limited in extent. But these are discrete objects of known origin not general enhancements to the diffuse background. As noted above, there is a slight general enhancement in the third quadrant, but it is not sufficient to require emission beyond the LHB.

Given the data and the above reasoning, the $\frac{1}{4}$ keV background provides no evidence for a pervasive distribution of hot gas in the Galactic disk. However, this lack of evidence should not be interpreted as evidence for a lack of an extensive distribution of such gas. The nearest few hundred parsecs are only a small sample of the disk and so extrapolation of the local ISM to general Galactic structure should be avoided. Be that as it may, if one *were* to extrapolate the picture would probably be similar to a modified Cox & Anderson (1982) sponge model. Their model suggested that with sufficient supernovae going off, the neutral ISM would be pushed around by the expanding remnants forming individual bubbles and then tunnels as the bubbles joined. Subsequent supernova in existing tunnels would serve to reheat the existing plasma. However, at least locally, the overlapping and interaction of bubbles does not seem to be the rule. Even the LHB and Loop I, which are physically very close to each other perhaps only separated by a sheet of H I (Egger & Aschenbach 1995), do not appear to be mixing their plasmas (the temperature of the Loop I plasma is significantly greater than that of the LHB). The modification of the Galactic sponge is then a Galactic Swiss cheese, where the cheese itself consists of a number of different, cooler components some of which are ionized and the holes (the hot plasma) are of more limited filling factor.

On the other hand, the Sun sits out in a relative backwater of the Galaxy and it is perhaps quite likely that the composition of the ISM changes radically closer to the Galactic center. The galaxies M101, NGC253, and NGC4258 all show extensive $\frac{1}{4}$ keV halo emission within $50-70\%$ of their D_{25} radii (Snowden & Pietsch 1995 and references therein). This is just within the equivalent solar position in the Milky Way. If the Milky Way is similar to these three galaxies, the local patchy $\frac{1}{4}$ keV X-ray emitting halo component is the fringe of more extensive emission toward the Galactic center. It would also suggest that the ISM could become considerably more active towards the Galactic center. If there is a more extensive distribution of hot gas in the halo above the more central regions, there must be more mechanisms such as superbubble blow outs or chimneys which can supply that hot gas.

4. Caveats and Questions

Particularly in the discussion of the LHB, I've used a few assumptions which need to be explicitly stated. The first concerns the validity of thermal emission models used in determining the pressure, temperature, density, and therefore distance scale of the local emission region. The Diffuse X-ray Spectrometer (DXS, Sanders & Edgar this issue) is a space shuttle experiment which was designed to observe the spectrum of the diffuse background in the $\frac{1}{4}$ keV band at relatively high resolution ($\lesssim 3$Å over the $83-44$ Å band). While, reassuringly, emission lines were observed confirming the thermal origin of the background, the data have proved to be difficult to model. As yet no combination of temperature, abundance, or non-equilibrium conditions have produced the observed lines in the correct ratios. Obviously, since the standard thermal emission models do not fit the data, it is of dubious utility to use the fitted parameters to parameterize the LHB. Since there are no better alternatives I'll continue to do so, but keep in mind this fundamental uncertainty.

A second assumption concerning the LHB is that the observed emission is distributed uniformly along the path length in the plasma. Many if not most models for emission from regions of hot gas tend to be edge brightened, quite often with much of the emission coming from the outer 10% of the radius.

5. Conclusions (well, sort of)

Perhaps the main conclusion out of all of this is that the local interstellar medium, and probably the entire Milky Way, is a very messy place. The wide variety of components from cold molecular gas to neutral gas to high-temperature plasmas, most with uncertain filling factors, make it a very complicated situation to model. Besides the static relation of this variety of components, there is also the question of their dynamic interactions. The question of pressure equilibrium has certainly not been decided even at a very local level (e.g., Bowyer et al. 1995) and there is the possible interaction of the LHB with the neighboring Loop I bubble.

On the other hand, there is no reason to be discouraged either. Our knowledge about the local interstellar medium has improved dramatically in the past decade and is continuing to do so. Combining the results of many observations at a wide variety of energies is allowing us to essentially map out our neighborhood in three dimensions. While naive models are being discarded along the way, we are indeed progressing towards the "truth" (whatever that may turn out to be). Besides, it's been a lot of fun.

References

Bertaux, J. L., Lallement, R., Kurt, V. G., & Mironova, E. N. 1985, A&A, 150, 1
Bloch, J. J., Jahoda, K., Juda, M., McCammon, D., Sanders, W. T., & Snowden, S. L. 1986, ApJL, 308, L59
Boulanger, F., & Pérault M. 1988, ApJ, 330, 964
Bowyer, C. S., Field, G. B., & Mack, J. E. 1968, Nature, 217, 32
Bowyer, C. S., Lieu, R., Sidher, S. D., Lampton, M., & Knude, J. 1995, Nature, 375, 212
Bunner, A. N., Coleman, P. L., Kraushaar, W. L., McCammon, D., Palmieri, T. M., Shilepsky, A., & Ulmer, M. 1969, Nature, 223, 1222
Burrows, D. N., & Mendenhall, J. A. 1991, Nature, 351, 629
Cox, D. P. & Anderson, P. R. 1982, ApJ, 253, 268
Cox, D. P. & Reynolds, R. J. 1987, ARA&A, 25, 303
Cox, D. P, & Snowden, S. L. 1986, Adv. Space Res., 6, 97
Danly, L. 1989, ApJ, 342, 785
Danly, L., Albert, C. E., & Kuntz, K. D. 1993, ApJL, 416, L29

Danly, L., Lockman, F. J., Meade, M. R., & Savage, B. D. 1992, ApJS, 81, 125
Dickey, J. M., & Lockman, F. J. 1990, ARA&A, 28, 215
Dickey, J. M., Salpeter, E. E., & Terzian, Y. 1978, ApJS, 36, 77
Edwards, B. C. 1990, Ph.D. Thesis, University of Wisconsin
Egger, R., & Aschenbach, B. 1995, A&A, 294, L25
Frisch, P. L. 1994, Science, 265, 1423
Frisch, P. L. & York, D. G. 1983, ApJL, 271, L59
Garmire, G. P. et al. 1992, ApJ, 399, 694
Gry, C., York, D. G., & Vidal-Madjar, A. 1985, ApJ, 296, 593
Herbstmeier, U., Mebold, U., Snowden, S. L., Hartmann, D., Burton, W. B., Moritz, P., Kalberla, P., & Egger, R. 1995, A&A, 298, 606
Henry, R. C., Fritz, G., Meekins, J. F., Friedman, H., & Byram, E. T. 1968, ApJL, 153, L11
Hirth W., Mebold U., Dahlem M., Müller P., 1992, Ap&SS 186, 211
Jakobsen, P., & Kahn, S. M. 1986, ApJ, 309, 682
Juda, M., Bloch, J. J., Edwards, B. C.,McCammon, D., Sanders, W. T., Snowden, S. L., & Zhang, J. 1991, ApJ 367, 182
Kerp, J., Herbstmeier, U., & Mebold, U., 1993, A&A 268, L21
Knapp, G. R. 1975, AJ, 80, 111
Kulkarni, S. R., & Heiles, C., 1988, in Galactic and Extragalactic Radio Astronomy, ed. G. L. Verschuur & K. I. Kellermann, (Springer-Verlag:Berlin), 95
Kuntz, K. D., Snowden, S. L., & Verter, F. 1996, in preparation
Lockman, F. J., Jahoda, K., & McCammon, D. 1986, ApJ, 302, 432
Magnani, L., Blitz, L., & Mundy, L. 1985, ApJ, 295, 402
Marshall, F. J., & Clark, G. W. 1984, ApJ, 287, 633
McCammon, D., Burrows, D. N., Sanders, W. T., & Kraushaar, W. L. 1983, ApJ, 269, 107
McCammon, D., & Sanders, W. T. 1990, ARA&A, 28, 657
McKee, C. F., & Ostriker, J. P. 1977, ApJ, 218, 148
Morrison, R., & McCammon, D. 1983, ApJ, 270, 119
Paresce, F. 1984, AJ, 89, 1022
Plucinsky, P. P., Snowden, S. L., Aschenbach, B., Egger, R., Edgar, R. J., & McCammon, D. 1996, ApJ, in press
Reynolds, R. J. 1991, in IAU Symp. 144, The Interstellar Disk-Halo Connection in Galaxies, ed. H. Bloemen (Dordrecht:Klewer), 67
Sanders, W. T., & Edgar, R. J. this issue
Sanders, W. T., Kraushaar, W. L., Nousek, J. A., & Fried, P. M. 1977, ApJL, 217, L87
Snowden, S. L., Cox, D. P., McCammon, D., & Sanders, W. T. 1990, ApJ, 354, 211
Snowden, S. L., Freyberg, M. J., Schmitt, J. H. M. M., Voges, W., Trümper, J. , Edgar, R. J., McCammon, D., Plucinsky, P. P., & Sanders, W. T. 1995, ApJ, 454, in press
Snowden, S. L., Hasinger, G., Jahoda, K., Lockman, F. J., McCammon, D., & Sanders, W. T. 1994, ApJ, 430, 601
Snowden, S. L., McCammon, D., & Verter, F. 1993, ApJL, 409, L21
Snowden, S. L., Mebold, U., Hirth, W., Herbstmeier, U., & Schmitt, J. H. M. M. 1991, Science, 252, 1529
Snowden, S. L., & Pietsch, W. 1995, ApJ, 452, 627
Wang, Q. D. 1994, in The Soft X-ray Cosmos - ROSAT Science Symposium, ed. E. M. Schlegel & R. Petre, AIP Conference Proceedings 313, 16
Wang, Q. D. & Yu, K. C. 1995, AJ, 109, 698
Wheelock, et al. 1994, *IRAS* Sky Survey Atlas Explanatory Supplement, (JPL Publ. 94-11; Pasadena:JPL)