

Final Summary of Research

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Research Title: The Diffuse Interstellar Medium

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A major component of this research is to extend existing models of thermal processes in the local interstellar medium to the inner and outer Galaxy. In completing this goal we have calculated the thermal equilibrium gas temperature of the neutral diffuse gas and constructed phase diagrams (gas pressure versus density) for gas at galactic radii between 3 and 18 kpc. An important ingredient in this computation is the far-ultraviolet (FUV) radiation field in the Galactic disk. This radiation is important since photoelectric heating via FUV radiation on dust grains is expected to be a dominant heating process in the diffuse gas. As a check of our calculated FUV field, we compared the infrared luminosity predicted by our theory with the observations of the COBE DIRBE space satellite and found the two to be in quite good agreement. Using our phase diagrams we have predicted the thermal pressure in the Galactic plane for which a multiphase equilibrium can be maintained. In addition, by using the maximum thermal pressure allowed by the observations, we have constrained the Galactic radii over which both cold and warm gas must exist, may exist, and cannot exist.

We first used observations to derive the gas phase abundance of coolants, the mean gas density, and the OB star distribution. For the metal abundances we scaled the local values using an exponential radial distribution with scale length $R_A = 5.3$ kpc based on the work of Shaver et al. (1983). Local values [$n(C)/n = 1.3 \times 10^{-4}$, $n(O)/n = 3.0 \times 10^{-4}$] are from Cardelli (1996). The mean H I density was derived by scaling the local value ($n = 0.51 \text{ cm}^{-3}$; Dickey & Lockman 1990) with the ratio of H I surface density to H I

scale height. The surface density was found by averaging the results of Diplas & Savage (1991) and Henderson et al. (1982) and from Dickey & Lockman (1990), while the scale height was taken from the work of Diplas & Savage (1991). We use the work of McKee & Williams (1996) to scale the local OB surface density with an exponential scale length of $R_{OB} = 3.5$ kpc. The space density of OB stars is then estimated by using the ratio of OB star surface density to scale height. Having determined the distribution of the sources of FUV radiation (OB star density) we then calculated the sink of FUV radiation - the FUV opacity. Due to the small volume filling factor of H_2 gas, we assumed that the FUV opacity was dominated by dust in the H I phases, and thus the opacity scales with the mean H I density and the metal abundances. The mean intensity of the FUV radiation field in the disk was found by carrying out a numerical integration of the transfer equations. To check our model assumptions and numerical results we calculated the far-infrared luminosity as a function of Galactic longitude which is predicted by our FUV field. The results compared well to the observations of Sodroski et al. (1994) using the COBE DIRBE data.

Phase diagrams at Galactic radii at 3, 8.5, 11, and 18 kpc were constructed by solving simultaneously for the equilibrium chemical abundances and gas temperature. The calculations were carried out in a manner similar to that of Wolfire et al. (1995), who constructed phases diagrams for the local medium. Our new work accounts for the differences in physical parameters with Galactic radii. The phase diagrams predict the range of thermal pressures, $P_{min} - P_{max}$, over which a multiphase (cold+warm) equilibrium can exist. At pressures greater than P_{max} only the cold phase can exist, and at pressure less than P_{min} only the warm phase can exist.

We find that thermal processes will allow a multiphase equilibrium in the Galactic disk between 3 kpc and 18 kpc *provided* that the thermal pressure is in the range between P_{min} and P_{max} . The mean thermal pressure which is required ranges from about $P/k \sim 11,000$ K cm⁻³ at 3 kpc to $P/k \sim 1,000$ K cm⁻³ at 18 kpc. We have also considered the limiting case in which all of the observed H I gas is in the warm phase and is supported by hydrostatic equilibrium

in the Galactic gravitational potential. This gas distribution provides the maximum thermal pressure in the Galactic disk and can be compared to the calculated P_{max} . From this limiting case we deduce that two (cold+warm) phases must exist in equilibrium between 3 kpc and 11 kpc, they may exist between 11 kpc and 14 kpc, but only the the warm phase may exist beyond 14 kpc.

Papers resulting from this collaboration:

“Neutral Phases of the ISM in the Galaxy”, Wolfire, M.G., Hollenbach, D. J., McKee, C.F., & Tielens, A.G.G.M in preparation.

