Pressure and Ionization Balances  
in the Circum-Heliospheric Interstellar Medium  
and the Local Bubble

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Abstract A disconcerting mismatch of thermal pressures for two media in contact with each other, (1) the warm, Circum-Heliospheric Interstellar Medium (CHISM) and (2) the very hot material within a much larger region called the Local Bubble (LB), has troubled astronomers for over two decades. A possible resolution of this problem, at least in part, now seems possible. We now understand that earlier estimates for the average electron density in the very hot LB plasma were inflated by an unrecognized foreground contamination to the low energy diffuse X-ray background measurements. This foreground illumination arises from photons emitted by charge exchange reactions between solar wind ions and neutral atoms from the interstellar medium that enter into the heliosphere. However, with the resolution of this problem comes a new one. The high ionization fraction of helium in the CHISM, relative to that of hydrogen, could be understood in terms of the effects from a strong flux of EUV and X-ray radiation coming from both the Local Bubble and a conductive interface around the CHISM. A revision of this interpretation may now be in order, now that the photoionization rate from radiation emitted by hot gas the Local Bubble is lower than previously assumed.

Keywords Galaxy: solar neighborhood · ISM: bubbles · ISM: clouds · X-rays: ISM

“When a thing ceases to be a subject of controversy,  
it ceases to be a subject of interest”—William Hazlitt (1778–1830)

1 Introduction: The Pressure Problem

The history of science has highlighted many instances where the need to resolve an incongruity in our perception of the natural world goaded us into abandoning an entrenched idea—a process that almost always has led to an important new threshold for progress. A ma-
The development of the conventional view of the Local Bubble (LB)

The diffuse soft X-ray background detected by instruments on sounding rocket flights in the 1970’s was recognized by Williamson et al. (1974) to originate from hot plasmas in spaces within and beyond the Milky Way (see also Burstein et al. 1977). Soon afterward, it became clear that much of this radiation at the lowest energies must come from an irregularly shaped volume surrounding the Sun, since the X-ray energy distribution showed little evidence for foreground absorption by cool, foreground material, and in directions away from the Galactic plane the intensities were anticorrelated with 21-cm emission by H I, probably as a result of the fact that the hot and cold gases displace one another (Sanders et al. 1977; Hayakawa et al. 1978; Marshall and Clark 1984).

From early evidence that a very limited amount of H I was present out to a radius of about 100 pc from the Sun (determined from various investigations, summarized later by Paresce 1984), Fried et al. (1980) estimated that the thermal pressure of the X-ray emitting gas was of order \( p/k = 10^4 \, \text{cm}^{-3} \, \text{K} \), a figure that was consistent with more refined estimates that came later (Marshall and Clark 1984; Cox and Reynolds 1987; Snowden et al. 1990, 1998). Determinations of the average electron densities that were perhaps the most straightforward to interpret came from measurements toward dense clouds whose distances were known and which were expected to block the radiation. A study of such cases by Snowden et al. (1993), Kuntz et al. (1997) and Burrows and Guo (1998) indicated that \( n(e) \approx 0.005 \, \text{cm}^{-3} \); for an assumed temperature in the range \( 1-2 \times 10^6 \, \text{K} \), this pointed toward a pressure \( 10^4 < p/k < 2 \times 10^4 \, \text{cm}^{-3} \, \text{K} \). Similar cloud shadowing measurements conducted by Bowyer et al. (1995) and Berghöfer et al. (1998), but using EUV radiation instead of diffuse X-rays, indicated that \( p/k = 19,500 \) and 16,500 cm\(^{-3}\) K, respectively. While these values for the thermal pressure inside the LB are higher than those generally seen elsewhere in the ISM (Jenkins and Shaya

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1 Throughout this paper, pressures will be stated in terms of real pressures divided by the Boltzmann constant, i.e., \( p/k = nT \) for thermal pressures, because they are easier to relate to particle densities and temperatures.

2 Many interpretations in the recent literature depict the heliosphere as being located close to the edge (but still inside) a cloud of warm gas called the Local Interstellar Cloud (LIC) that has coherent kinematics and is seen over much of the sky. However a recent investigation by Redfield and Linsky (2008) indicates that our location is in a transition region between this cloud and another cloud that is situated in the general direction of the Galactic center called the G Cloud. In recognition of this more complicated picture, we avoid calling the material that surrounds us as the Local Interstellar Cloud, since it now has a more restricted meaning, and replace it with the term Circum-Heliospheric Interstellar Medium (CHISM) that comprises both the LIC and G Cloud.