Decaying Neutrinos and the Electron Density in the Local Interstellar Cloud Near the Sun

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Abstract

No known, or postulated, conventional ionisation source can account for the recently determined large electron density in the Local Interstellar Cloud (LIC) near the sun, if the LIC is in photoionisation equilibrium. Yet Frisch (1994) has argued from various considerations that the LIC is indeed in such equilibrium. We propose to resolve this dilemma by invoking ionising photons emitted by decaying dark matter neutrinos in the two quadrants of the Local Bubble which appear to contain little HI out to a distance exceeding 50 pc. This proposal may be numerically reasonable if Frisch (1994) is correct in her deduction that the edge of the LIC nearest to the sun lies only about 0.1 pc away, corresponding to an optical depth for the absorption of photons at the HI edge of only 0.2. The resulting flux of decay photons near the sun could be approximately $10^4 \text{ cm}^{-2} \text{ sec}^{-1}$, which would account for the observed electron density near the sun if it is at the lower end of its allowed range.

If this new large estimate for the flux in the decay line near the sun is correct, it would facilitate the planned search for this line by EURD, which is due to be launched by a Spanish minisatellite early in 1996.

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It has been known for some time that the sun is immersed in a cloud with an HI density \( \sim 0.1 \text{ cm}^{-3} \) (the Local Interstellar Cloud or LIC) and that this cloud is surrounded by an irregularly shaped Local Bubble containing hot x-ray emitting gas with \( T \sim 10^6 \text{K} \) and \( n \sim 5 \times 10^{-3} \text{cm}^{-3} \) (e.g. Cox and Reynolds 1987, Frisch 1994). The electron density \( n_e \) in the LIC near the sun has been rather uncertain, but recent measurements indicate that it is unexpectedly large, in the range 0.15 to 0.4 cm\(^{-3}\) (Bertin et al 1993 as interpreted by Crawford 1994, Lallement et al 1994, Frisch 1994, Gry et al 1995). One possible explanation for this large value of \( n_e \) is fossil ionisation resulting from a supernova explosion which may have produced the Local Bubble. However, Frisch (1994) has argued from her detailed studies that the LIC is actually in photoionisation equilibrium. In that case, with an LIC temperature of 7000 K (Cox and Reynolds 1987, Linsky et al 1993) one would need near the sun an effective ionising flux at the HI edge of at least \( \sim 10^4 \text{ photons cm}^{-2} \text{ sec}^{-1} \) to account for the observed value of \( n_e \).

No previously known ionising source comes close to what is required (Cheng and Bruhweiler 1990), including the recently discovered powerful EUV source \( \varepsilon \text{ CMa} \) (Vallerga et al 1993, Cassinelli et al 1995, Vallerga and Welsh 1995). The source postulated by Slavin (1989), namely, the conductive interface between the LIC and the Local Bubble, falls short of what is required (Frisch 1994), and is itself inconsistent with recent observations of the background made by EUVE (Jelinsky et al 1995). We would therefore like to suggest here that the high ionisation may be due to photons emitted by decaying dark matter neutrinos (Sciama 1990, 1993) in the Local Bubble.

Until recently this suggestion would have been regarded as unacceptable. It used to be thought that in all directions from the sun the column density of HI out to the edge of the LIC was at least of order close to \( 10^{18} \text{ cm}^{-2} \) (e.g. Frisch and York 1989), so that the photoelectric optical depth for photons with an energy close to the HI edge (such as decay photons) would be at least of order 6 in each direction. Thus
decay photons which may have accumulated in the Local Bubble would not have been able to penetrate to the vicinity of the sun. Accordingly the flux of decay photons near the sun, produced within one optical depth, was predicted to be \( \sim 600 \text{cm}^{-2}\text{sec}^{-1} \) (Sciama 1993), with a possible increase by a factor of order 2 to allow for photons which were produced in the Local Bubble.

This situation might change dramatically if Frisch's (1994) recent analysis of the properties of the LIC is correct. According to her detailed studies the sun actually lies at a distance of only 0.05 to 0.16pc to the nearest edge of the LIC (in the direction l\( \Pi \sim 155^0 \)). The optical depth of the LIC at the HI edge in this direction would then be only 0.1 to 0.3. If this is the case, we must reevaluate the flux of decay photons at the sun coming from the Local Bubble.

We cannot carry out a definitive calculation, because the fine details of the distribution of HI in the Local Bubble are unknown. However, spectroscopic studies of nearby stars have shown that there is very little HI out to distances of 50pc or even greater in the longitude range 110\(^0\) to 270\(^0\) (Frisch and York 1989) with the exception of the direction towards Capella (Linsky et al 1993), where the material may be sufficiently wispy as not to block out from the sun's location an appreciable solid angle. There is also an exceptionally vacant tunnel in the vicinity of the star \( \beta \) CMa (Gry et al 1985, Welsh 1991), which has a width of at least 50pc and stretches out to \( \sim 300 \text{pc} \). We therefore tentatively assume that we may use an effective solid angle of \( \sim \pi/2 \), and a depth \( \sim 100 \text{pc} \), for the region from which decay photons arrive essentially unattenuated at the sun. With a source function for decay photons in this region of the Galaxy of \( \sim 3 \times 10^{-16} \text{photons cm}^{-3}\text{sec}^{-1} \) (Sciama 1990, 1993) we would then obtain at the sun a flux of decay photons of \( \sim 10^4 \text{cm}^{-2}\text{sec}^{-1} \). This flux would occur in the form of a spectral line, with an energy close to the HI edge. It would be consistent with the Holberg (1986) upper limit for a line in the EUV background of \( 7 \times 10^4 \text{cm}^{-2}\text{sec}^{-1} \). Our estimated line flux would account for the recently determined
local electron density if the actual value of this density is at the lower end of the observed range.

A further consequence of our discussion should be pointed out; our proposed new large value of \(-10^4\text{cm}^{-2}\text{sec}^{-1}\) for the flux at the sun in the decay line, if correct, would facilitate the task of searching for this line by direct observation using the detector EURD (Sciama 1993) which is due to be launched above the atmosphere by a Spanish minisatellite early in 1996.

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References


