

RELEVANCE OF COSMIC GAMMA RAYS TO THE MASS OF
GAS IN THE GALAXY

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ABSTRACT

The bulk of the diffuse γ -ray flux comes from cosmic ray interactions in the interstellar medium. A knowledge of the large-scale spatial distribution of the Galactic γ -rays and the cosmic rays enables the distribution of the target gas to be examined. An approach of this type is used here to estimate the total mass of the molecular gas in the Galaxy. It is shown to be much less than that previously derived, viz., $\sim 6 \times 10^8$ solar masses within the solar radius as against $\sim 3 \times 10^9$ based on 2.6mm CO measurements.

1. Introduction. Hitherto, the standard way of determining the mass of the molecular gas (H_2) in the Galaxy has been by way of the derivation of the integral $\int T^{12} dv$ for the $J = 1 + 0$ transition of ^{12}CO and its subsequent conversion to the column density of the molecular hydrogen $N(H_2)$ through the relation $N(H_2) = \alpha_{20} \int T^{12} dv$, where the conversion factor α_{20} is in units $10^{20} \text{ atoms cm}^{-2} \text{ K}^{-1} \text{ km}^{-1} \text{ s}$. Many workers have employed this procedure, most notably Sanders et al. (1984, to be denoted SSS). The constant value of 7.2 adopted by SSS for α_{20} over the whole galaxy leads to a mass of $3 \times 10^9 M_{\odot}$ for Galactocentric radii $R < 10 \text{ kpc}$, to be compared with $\approx 1 \times 10^9 M_{\odot}$ for the atomic hydrogen, HI.

The actual value to be used for α_{20} has been the subject of a considerable contemporary argument. Here we enter the fray by way of the cosmic γ -ray evidence.

2. The method and the results therefrom. The γ -ray method relies on (i) a demonstration that cosmic ray particles can penetrate the bulk of the gas in the interstellar medium (ISM), and (ii) a reliable knowledge of the local γ -ray emissivity of gas locally. The first has recently been shown to be valid by Houston and Wolfendale (1984) in the case of the local Orion molecular clouds, and should as such hold generally, since the Orion clouds appear to be representative of most other H_2 clouds in the Galaxy.

Referring specifically to the Orion clouds, we assume that the cosmic ray intensity is the same as that locally. We further take the corresponding γ -ray emissivity to be identical with that estimated for high Galactic latitudes ($|b| > 10^\circ$). The result (Bhat et al., 1985) is that we find a value for α_{20} at $R \sim 10 \text{ kpc}$ which is only 40-50% of that adopted by SSS.

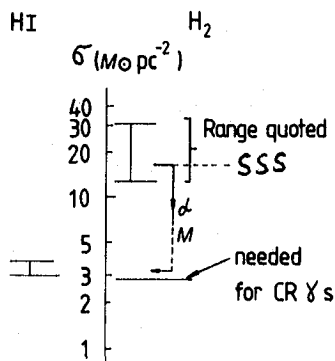


Fig. 1. Surface densities of HI and H₂ at R=6 kpc. The range of quoted values from CO observations (using various α values) is indicated, as is the value from SSS. The value needed to satisfy the cosmic γ -ray results is shown. Also indicated is the effect of reducing the surface density of H₂ by 0.37 times (to allow for the change in α) and by 0.5 (to allow for metallicity).

There is also a wealth of other supplementary data involving absorption studies at the X-ray and infra-red wavelengths and virial mass estimates of molecular clouds, which we have used and which we find to be consistent with our newest estimates of α_{20} , both locally as also in the inner Galaxy.

3. Conclusions. Figure 2 gives our results on the distribution of H₂ mass as a function of R.

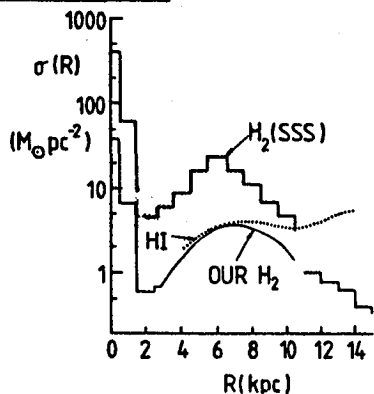


Fig. 2. Dependence of H₂ and HI on R. SSS denotes a widely quoted estimate from CO alone, by Sanders et al. (1984).

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Furthermore, we argue that there is clear evidence for a cosmic-ray (CR) electron gradient in the inner Galaxy. These electrons are responsible for γ -rays in the SAS II energy range 35-100 MeV and the (model-fit) electron intensity is found to be a factor ~ 2.3 higher at 6 kpc than R ~ 10 kpc. The consequence of this on the surface density σ of gas in the inner Galaxy (Fig. 1) is that it is a factor ~ 5 lower than that given by SSS using a constant $\alpha_{20} \sim 7.2$.

As is indicated in Fig. 1, the reduced value of σ (R=6kpc) also follows naturally by another route, involving the use of a metallicity correction factor M for deriving α_{20} in the inner Galaxy from its local value (Bhat et al. 1985).

Here we have used various methods for determining α_{20} , and the Galactic centre region has been treated separately. We find H₂ masses $\sim 2 \times 10^7 M_{\odot}$ for the Galactic Centre region (R<0.5 kpc) and $\sim 6.5 \times 10^8 M_{\odot}$ for the inner Galaxy (R<10 kpc).

References

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