HI FILAMENTS ARE COLD AND ASSOCIATED WITH DARK MOLECULAR GAS

HI4PI-BASED ESTIMATES OF THE LOCAL DIFFUSE CO–DARK H$_2$ DISTRIBUTION

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GENERAL CONTEXT

• The interstellar medium (ISM) contains significant amount of H2.

• H2 is necessary to form stars.

• ISM is cold.

• H2 gas does not radiate at radio frequencies at typical ISM temperature conditions.

• UV observations are necessary in order to detect H2.
CO is linearly correlated with H2.

CO radiates at radio and it is used to trace the amount of H2 in the ISM ($X_{\text{CO}}$).

Not all of the H2 is traced by the CO emission.

The H2 gas, which is not traced by the CO emission is termed as **CO-dark gas**.

CO-dark gas seems to be a significant H2 component of our Galaxy.
GOAL

Find a way to identify the **locations** and **column densities** of CO-dark gas in the Milky Way.
OBSERVABLES

1. Dust extinction map $E(B-V)$ [Schlegel et al. 1998].

2. HI maps 21 cm line emission from the H14PI.
$\langle R \rangle = \frac{E(B-V)}{N_{HI}}$
Warm medium - H1

H1 \rightarrow H2

To the observer
They define the Doppler temperature as a proxy for the temperature of the neutral medium.

\[ T_D = 21.86 \delta V^2 \]

This is an upper limit in the kinetic temperature of the medium.
\[ E(B - V) = \sum_{i=1}^{N} R(N_{HIi} + 2N_{H2i}) = \sum R N_{HIi} f_c(T_{Di}) \]

**Assumption** $\rightarrow$ $R$ Constant

**WNM** $\rightarrow$ $f_c(T_D) = 1$

**CNM** $\rightarrow$ $f_c(T_D) \geq 1$
INITIAL CONDITIONS AND CONSTRAINTS

1. $E(B-V)/N_{\text{HI}}$ is well defined for $N_{\text{HI}} \leq 4 \times 10^{20}$ cm$^{-2}$ and $E(B-V) \leq 0.08$ mag. They limit their first attempts to solve the equation in this range referred to in the following as canonical thin gas. We use the ratio $R = E(B-V)/N_{\text{HI}} = (1.113 \pm 0.002) \times 10^{-22}$ cm$^2$ mag.

2. They avoid $|b| \leq 8^\circ$ since there are no sight lines with small $E(B-V)$ in this range.

3. Initially they define $f_c(T_D) = 1$ for the WNM.

4. They exclude CO–bright regions with observed CO emission [using Planck maps].

5. The main body of the dust-bearing gas is associated with velocities $|v_{\text{LSR}}| \leq 90$ km s$^{-1}$ and they use this velocity range.

6. They consider corrections for optical depth effects by multiplying column densities with some constant factors.
The most important constrain is to distinguish between CO-bright and CO-dark regions.

An excess of $E(B-V)/NH$ may be affected by saturation of HI emission due to self-absorption or optical depth effects.
\[ f_c(T_D) = \begin{cases} 
57.9 - 28.3 \times \log (T_D) & \text{for } T_D < 85 \text{ K} \\
7.0 - 1.9 \times \log (T_D) & \text{for } 85 \leq T_D \leq 1165 \text{ K} \\
1.0 & \text{for } T_D > 1165 \text{ K.}
\end{cases} \]
The most important constrain is to distinguish between CO-bright and CO-dark regions.

An excess of $E(B-V)/NH$ may be affected by saturation of HI emission due to self-absorption or optical depth effects.

\[ E(B-V) = \sum_{i=1}^{N} R(N_{HI_i} + 2N_{H_2_i}) = \sum RN_{HI_i} f_c(T_{D_i}) \]
HI filaments – CO dark gas
FAR-IR EMISSION FROM HI FILAMENTS
FAR IR – NH2 CORRELATION
CONCLUSIONS

1. H$_2$ in the cold neutral medium contains 46% of CO-dark gas.

2. CO-dark gas resides in HI cold filamentary structures