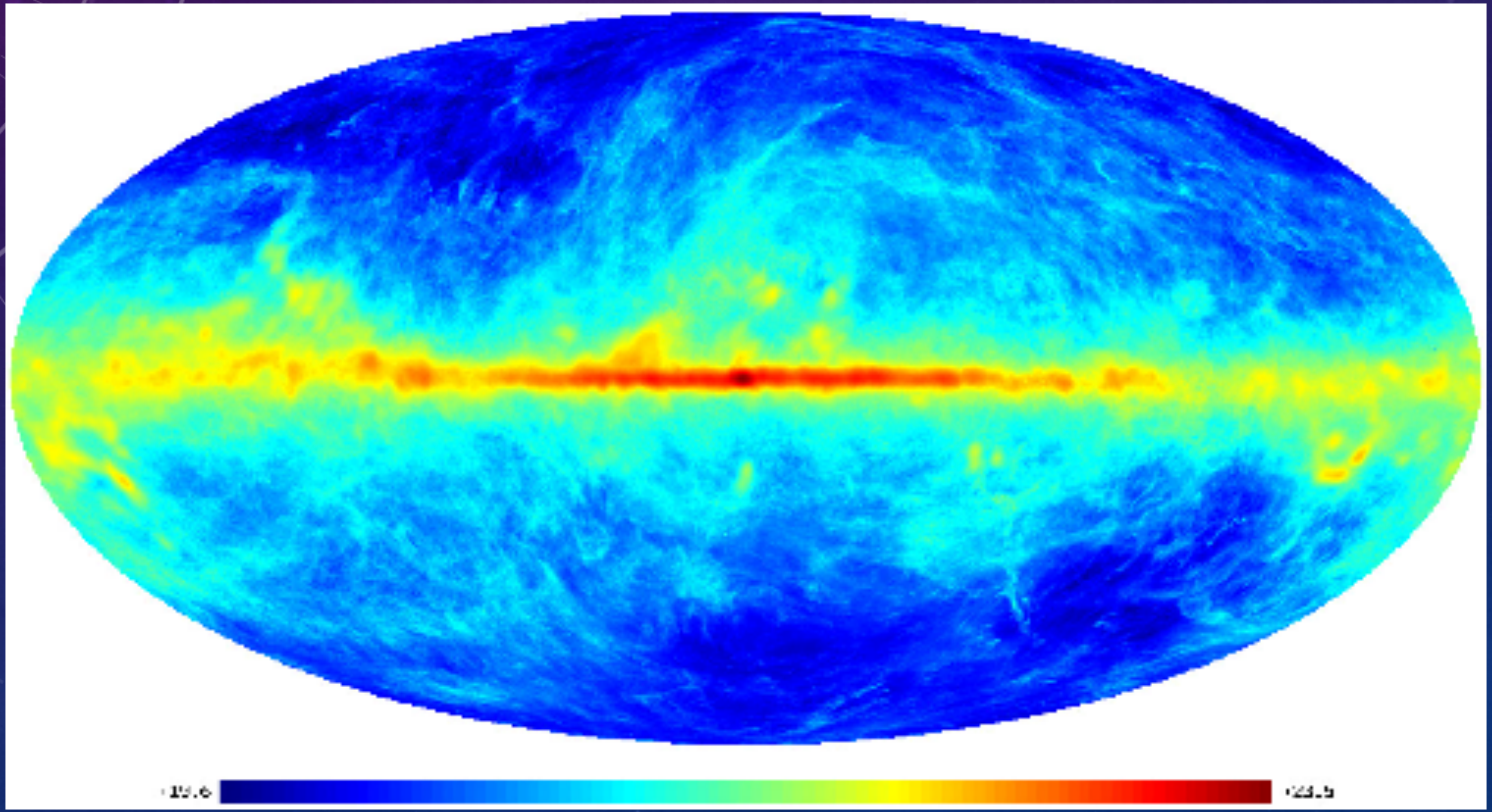
HI FILAMENTS ARE COLD AND ASSOCIATED WITH DARK MOLECULAR GAS

HI4PI-BASED ESTIMATES OF THE LOCAL DIFFUSE CO–DARK H_2 DISTRIBUTION

P. M. W. Kalberla, J. Kerp and U. Haud



GENERAL CONTEXT

- The interstellar medium (ISM) contains significant amount of H_2.
- H_2 is necessary to form stars.
- ISM is cold.
- H_2 gas does not radiate at radio frequencies at typical ISM temperature conditions
- UV observations are necessary in order to detect H_2.

CONTEXT

- CO is linearly correlated with H2.
- CO radiates at radio and it is used to trace the amount of H2 in the ISM (X_{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

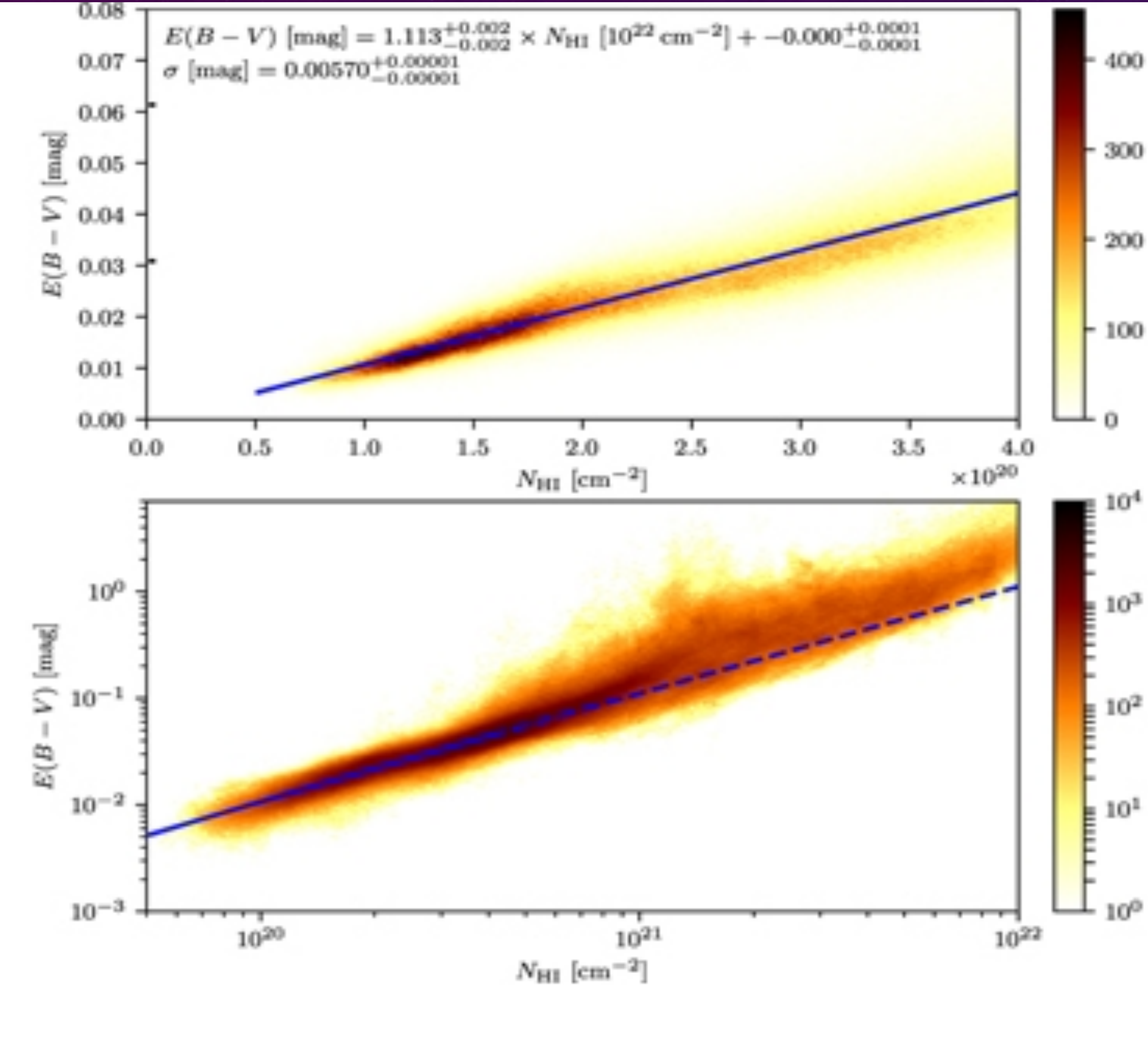
Find a way to identify the locations and column densities of CO-dark gas in the Milky Way.

OBSERVABLES

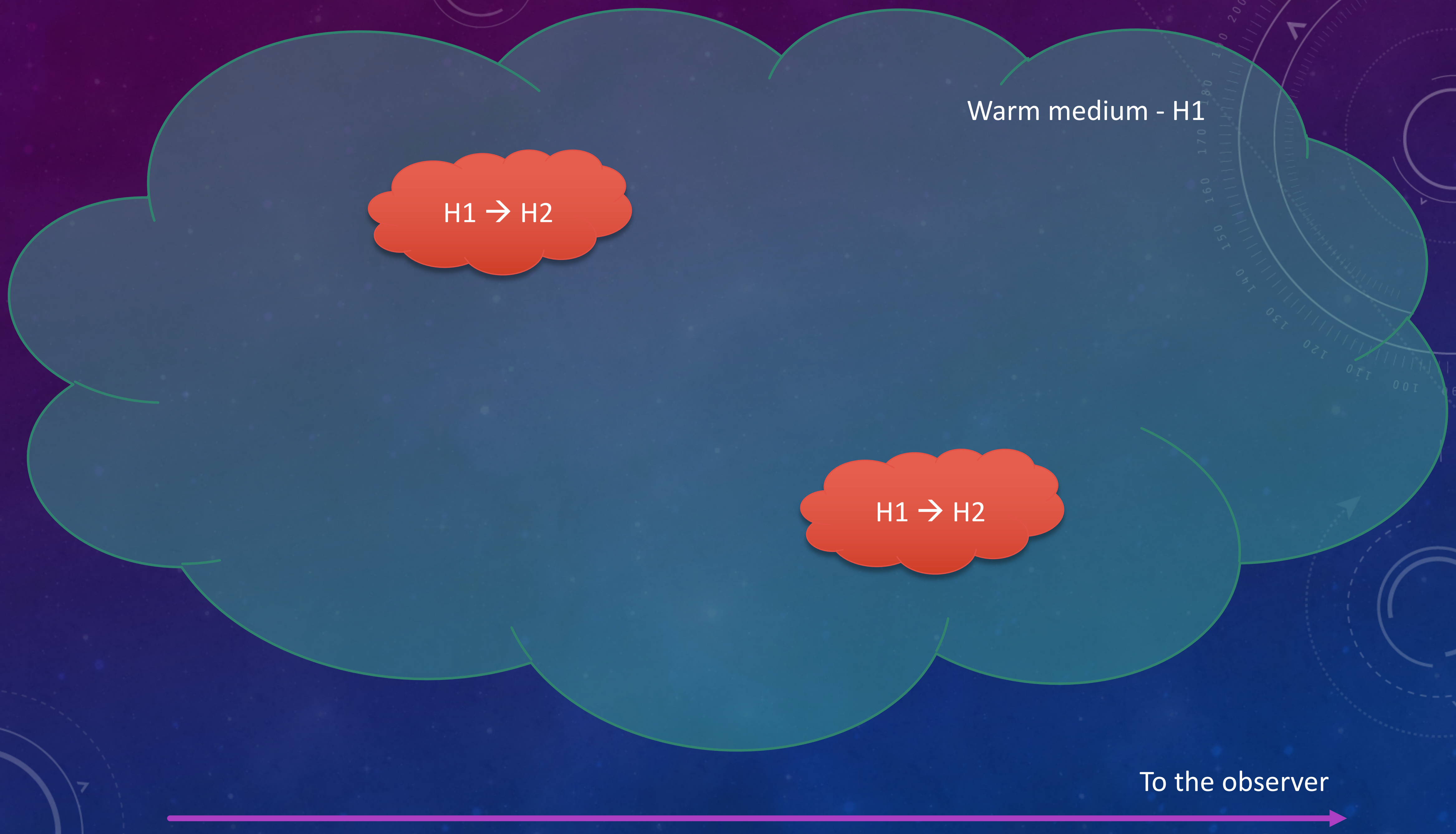
1. Dust extinction map E(B-V) [Schlegel et al. 1998].

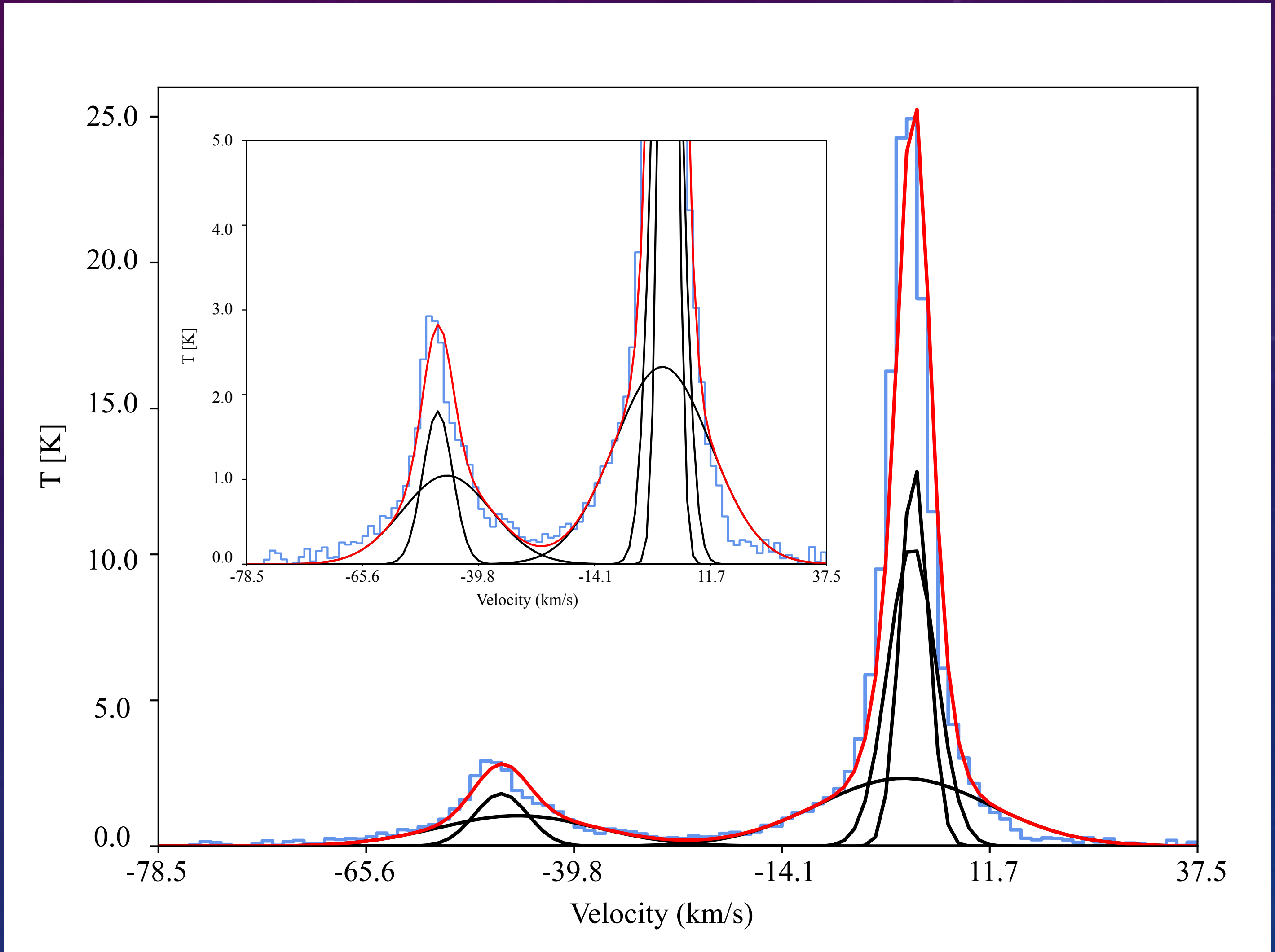
2.HI maps 21 cm line emission from the H14PI.

E(B-V) VS NHI



$$\langle R \rangle = \frac{E(B-V)}{N_{HI}}$$


Warm medium - H1
H1 → H2
H1 → H2
To the observer



25.0
20.0
15.0
10.0
5.0
0.0
T [K]
-78.5
-65.6
-39.8
-14.1
11.7
37.5
Velocity (km/s)
5.0
4.0
3.0
2.0
1.0
0.0
T [K]
-78.5
-65.6
-39.8
-14.1
11.7
37.5
Velocity (km/s)

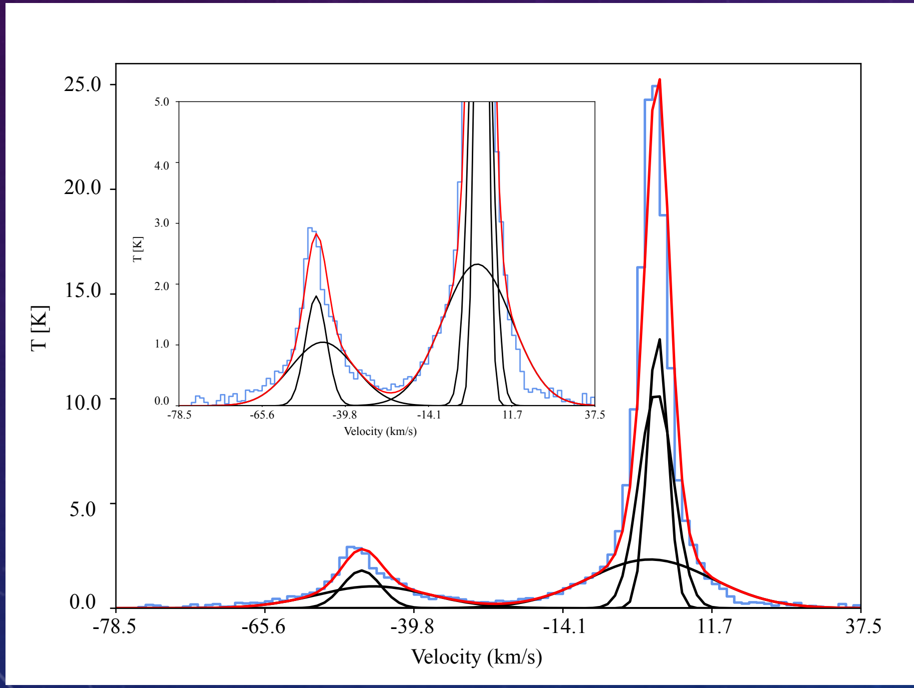
TEMPERATURE MEASUREMENT

- 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

$$E(B-V) = \sum_{i=1}^{N} R(N_{HI_i} + 2N_{H2_i}) = \sum R N_{HI_i} f_c(T_{D_i})$$



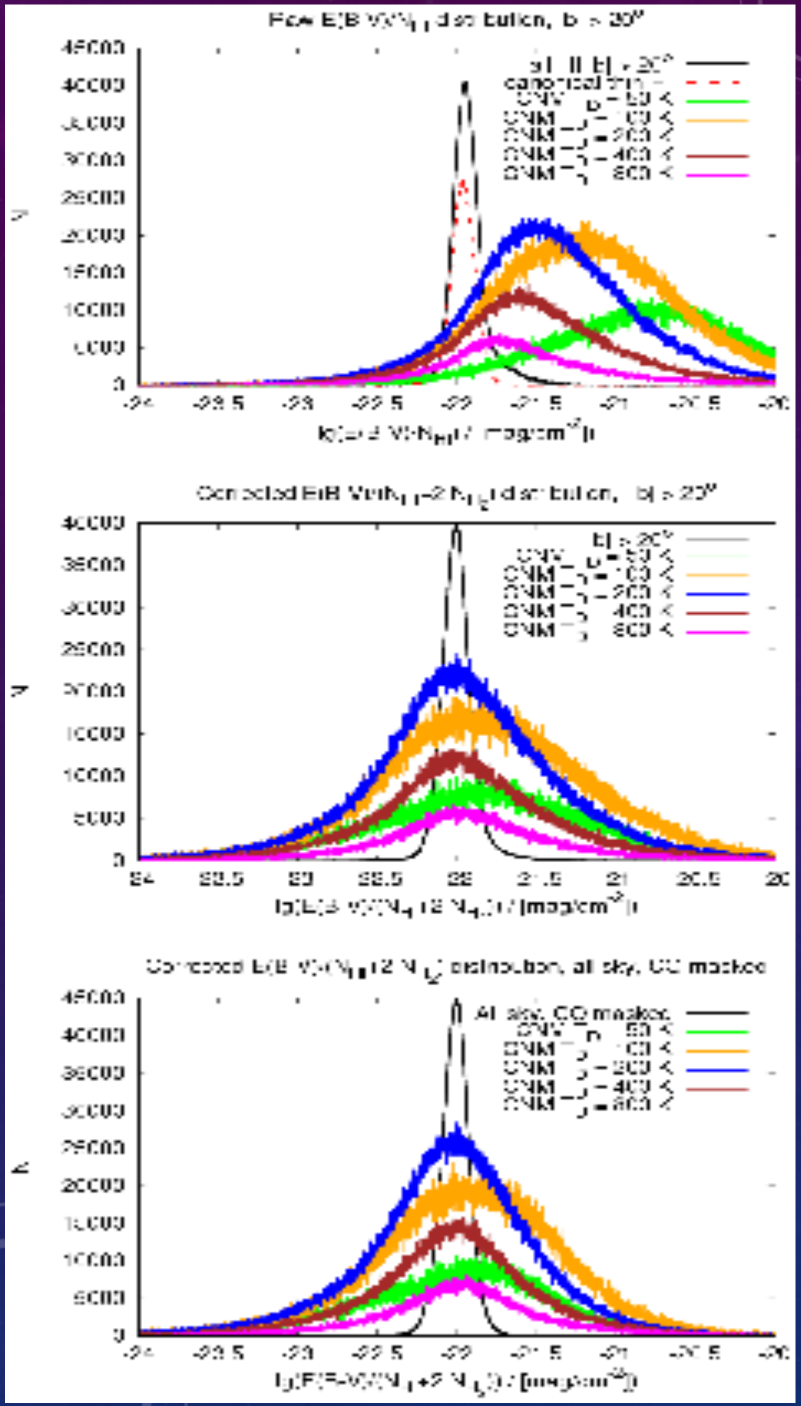
Assumption → R Constant

WNM → $f_c(T_D) = 1$

CNM → $f_c(T_D) \geq 1$

INITIAL CONDITIONS AND CONSTRAINS

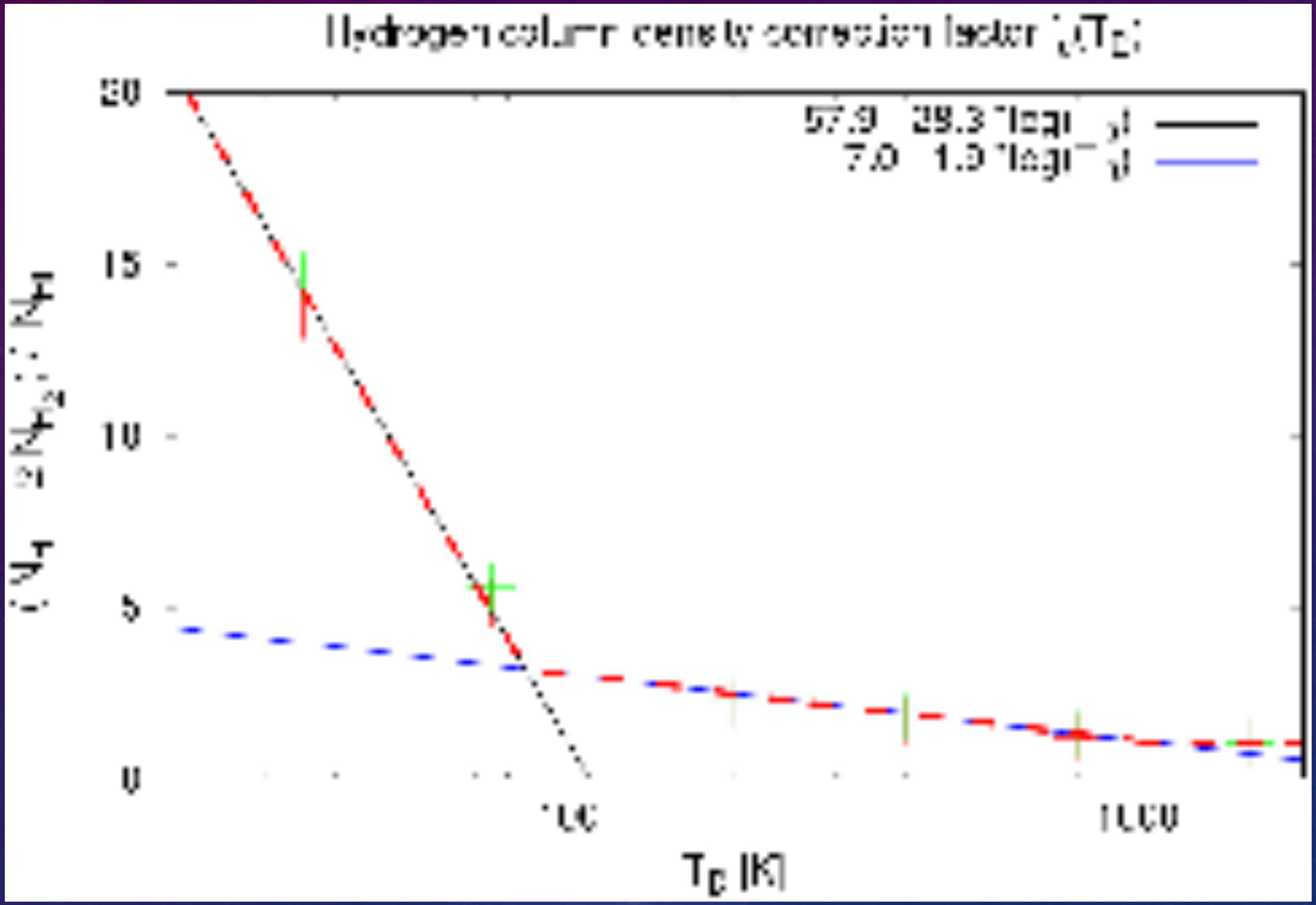
1. $E(B-V)/N_{HI}$ is well defined for $N_{HI} \lesssim 4 \times 10^{20}$ cm^{-2} and $E(B-V) \lesssim 0.08$ mag. They limit their first attempts to solve the equation in this range referred to in the following as canonical thin gas. We use the ratio $R = E(B-V)/N_{HI} = (1.113 \pm 0.002) \times 10^{-22}$ cm^2 mag.
2. They avoid $|b| \lesssim 8°$ 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 $|v_{LSR}| \lesssim 90$ 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.



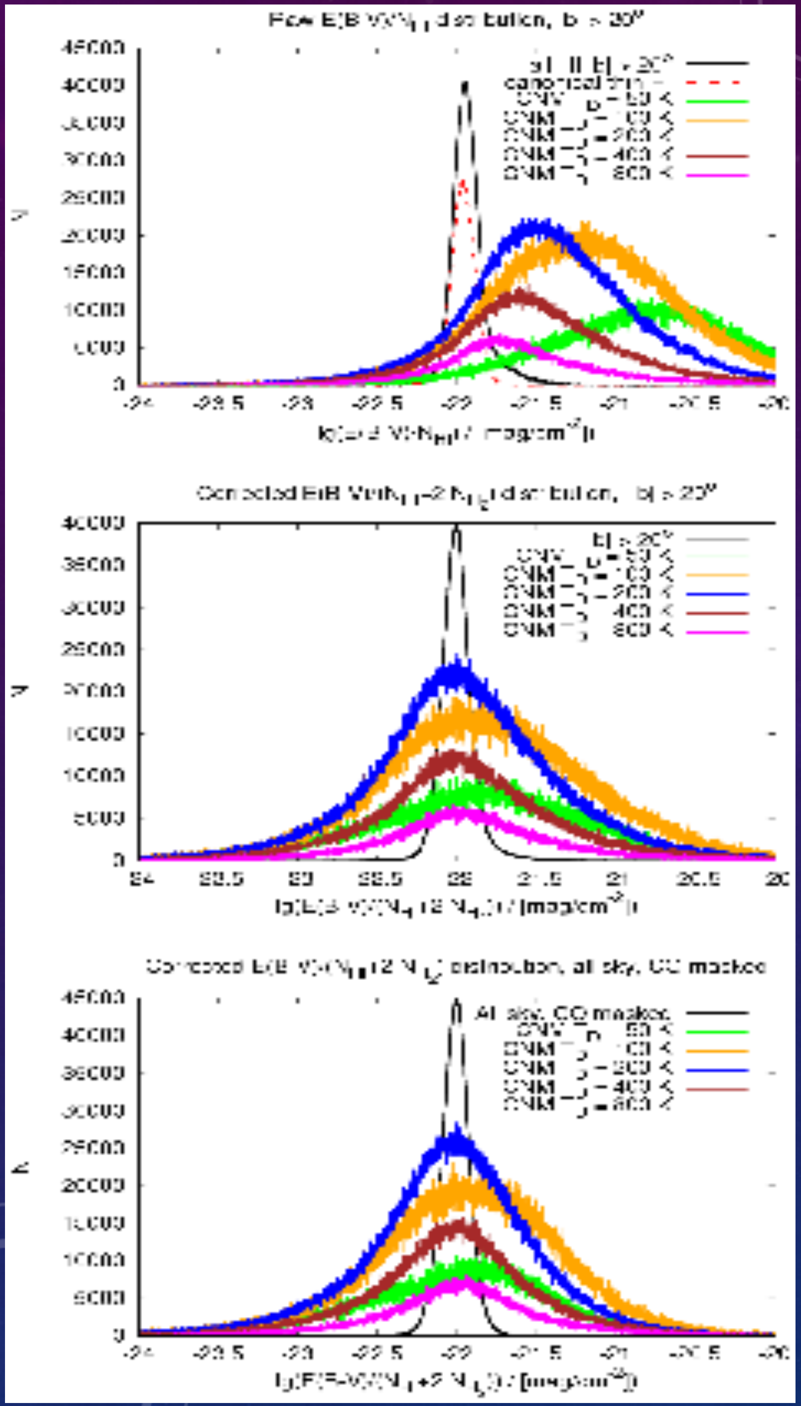
$$E(B-V) = \sum_{i=1}^{N} R(N_{HI_i} + 2N_{H2_i}) = \sum R N_{HI_i} f_c(T_{D_i})$$

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.



$$
\begin{aligned}
f_c(T_D) &= 57.9 - 28.3 \times \log(T_D) && \text{for } T_D < 85 \text{ K} \\
&= 7.0 - 1.9 \times \log(T_D) && \text{for } 85 \leq T_D \leq 1165 \text{ K} \\
&= 1.0 && \text{for } T_D > 1165 \text{ K.}
\end{aligned}
$$



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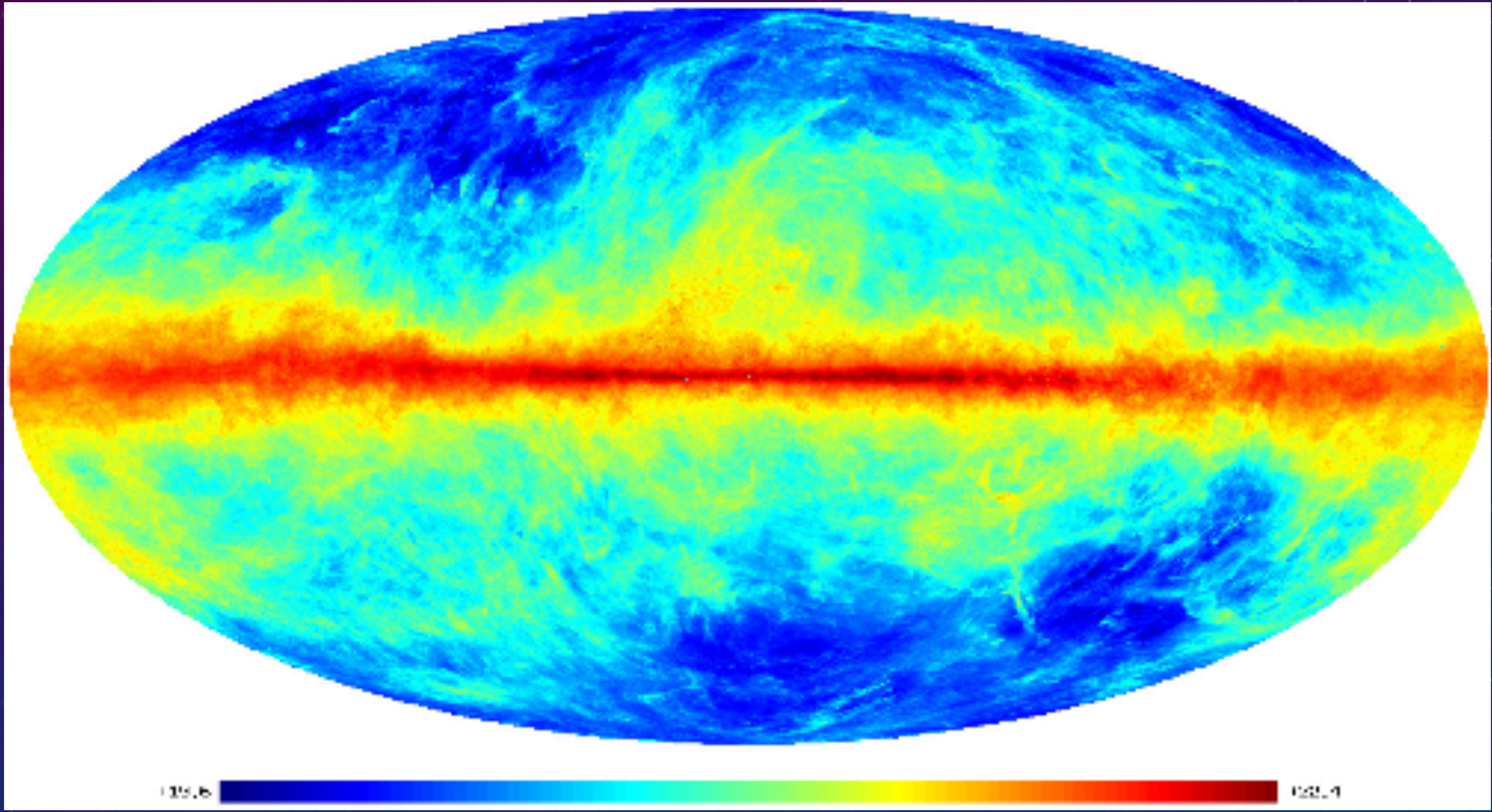
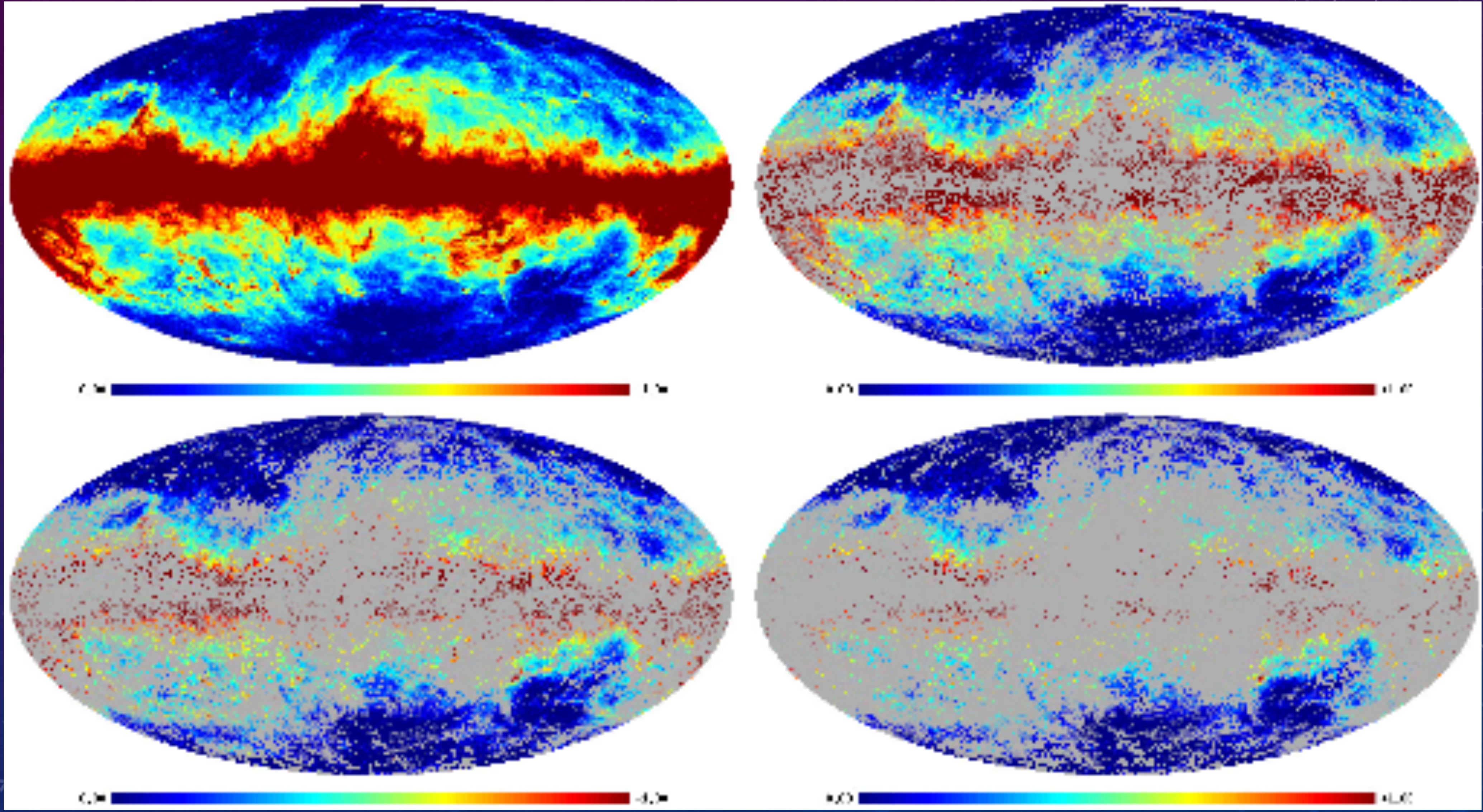
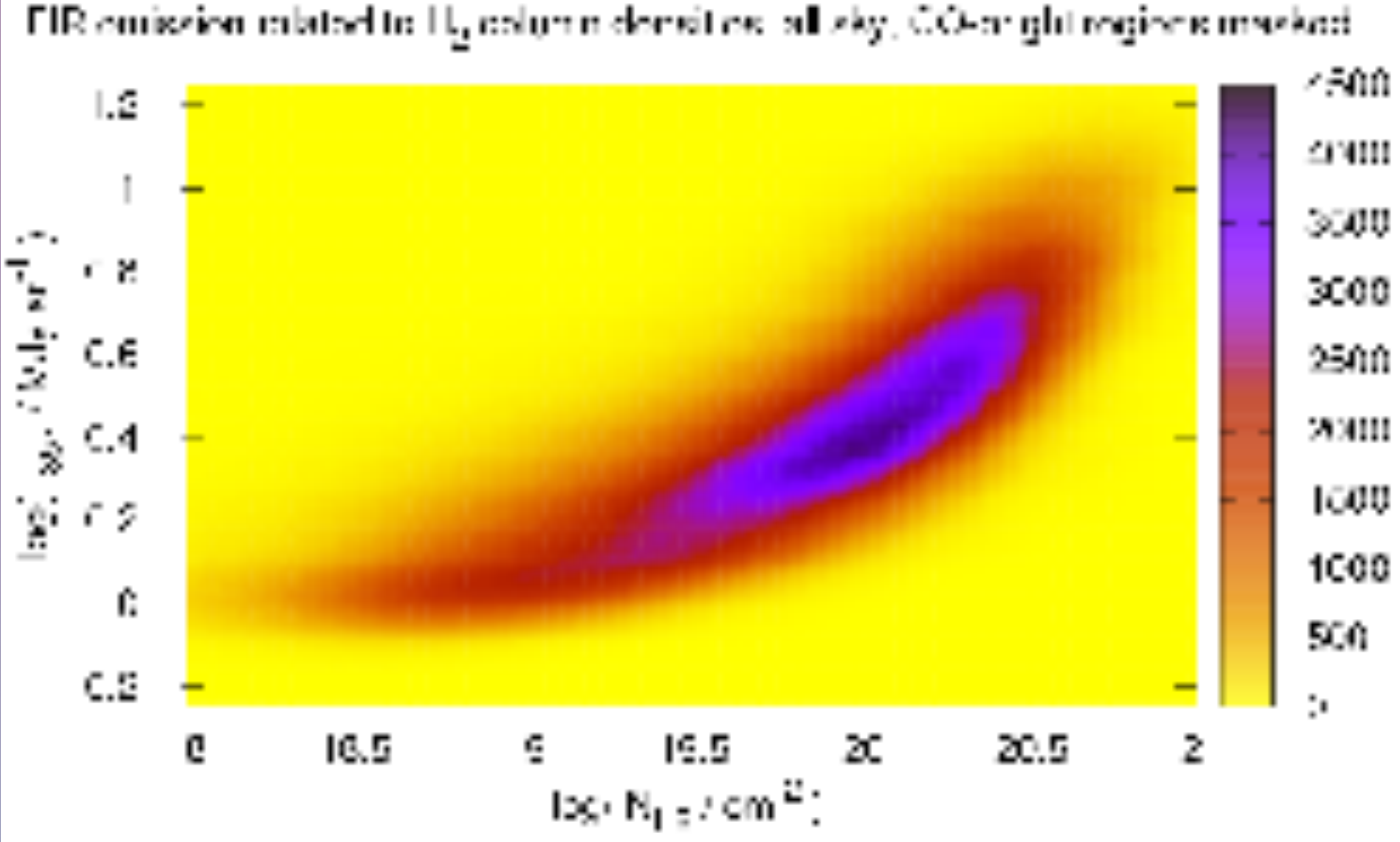


HI filaments – CO dark gas

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