Far-infrared deficient and molecular intermediate velocity clouds

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1 – Abstract

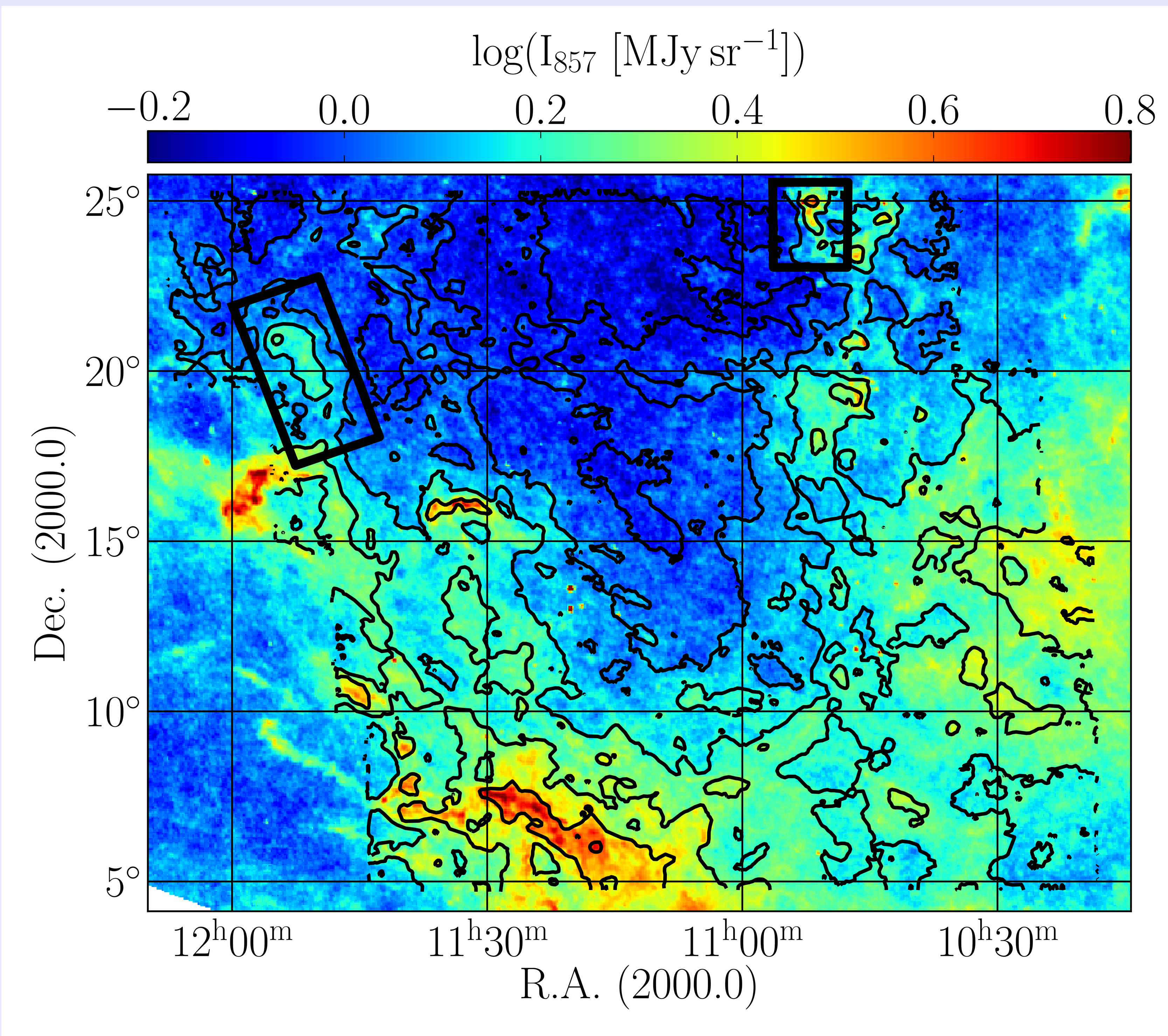
The correlation of H I emission to the far-infrared (FIR) brightness in the ISM reveals the presence of molecular hydrogen by deviations from a simple linear behaviour. We correlate new data in H I and the FIR, from the Effelsberg-Bonn H I Survey (EBHIS, Kerp et. al 2011, AN 332) and the Planck Satellite. We find two clouds that, despite their similarity in H I, show very different FIR properties which is due to molecular hydrogen. It is proposed that the two objects are at different stages in the transition from atomic to molecular clouds.

2 – The H I-FIR correlation

Dust grains, mixed to the interstellar gas, radiate a thermal spectrum in the FIR. The sky is covered with diffuse cirrus clouds which show a linear correlation between gas and dust (e.g. Boulanger et al. 1996, A&A 312): $I_\nu = a_\nu + \epsilon_\nu \cdot N_{\mathrm{H\,I}}$. This translates the H I column density $N_{\mathrm{H\,I}}$ into a FIR brightness by the dust emissivity per nucleon ϵ_ν.
At high $N_{\mathrm{H\,I}}$ molecular hydrogen can form. If hydrogen is not neutral, it is "missing" in the H I-FIR correlation leading to a steepening at large H I column densities.

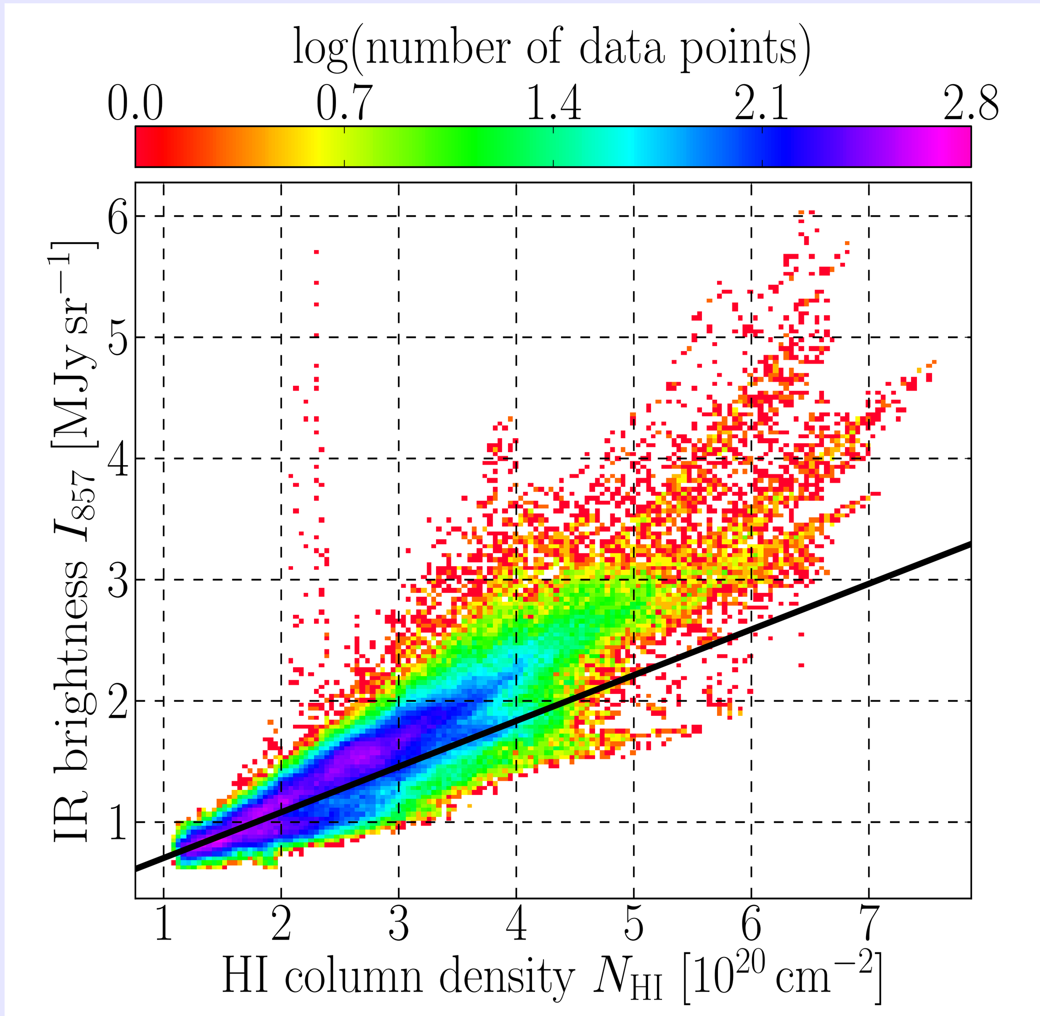
3 – The studied field in H I and FIR emission

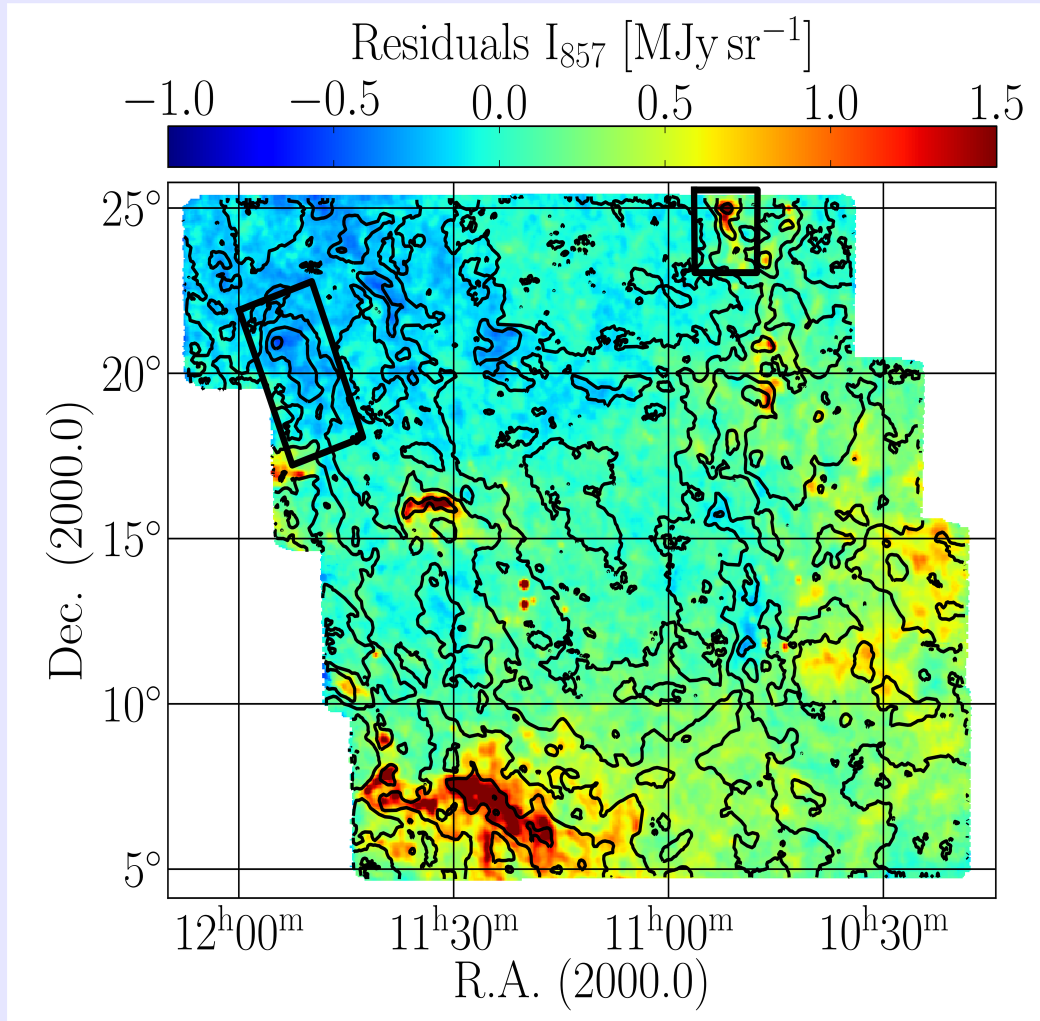
There are H I clouds that show a radial velocity incompatible with a simple model of galactic rotation. For $90 \gtrsim |v_{\mathrm{LSR}}| \gtrsim 30\,\mathrm{km\,s^{-1}}$ these are called Intermediate Velocity Clouds (IVCs). The IVCs in the field of interest have near solar metallicities and distances below roughly 2 kpc.
The black boxes below mark two IVCs which are similar in their H I properties but completely different in the FIR. The one on the top left is called IVC1, the other one on the top right IVC2.



In colour the FIR brightness at 857 GHz is shown observed by Planck. Black contours are H I from EBHIS integrated between ±100 km s^{-1} covering the total H I in this region.

4 – Global H I-FIR correlation

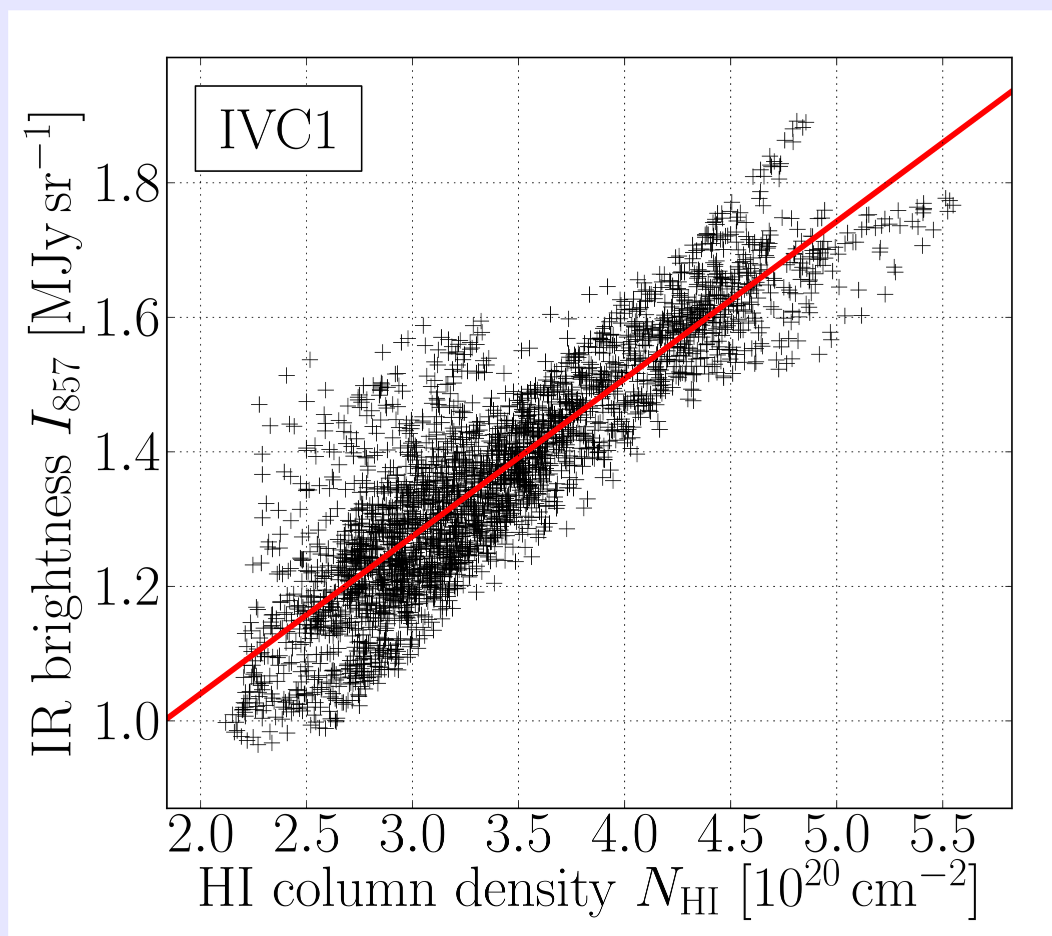


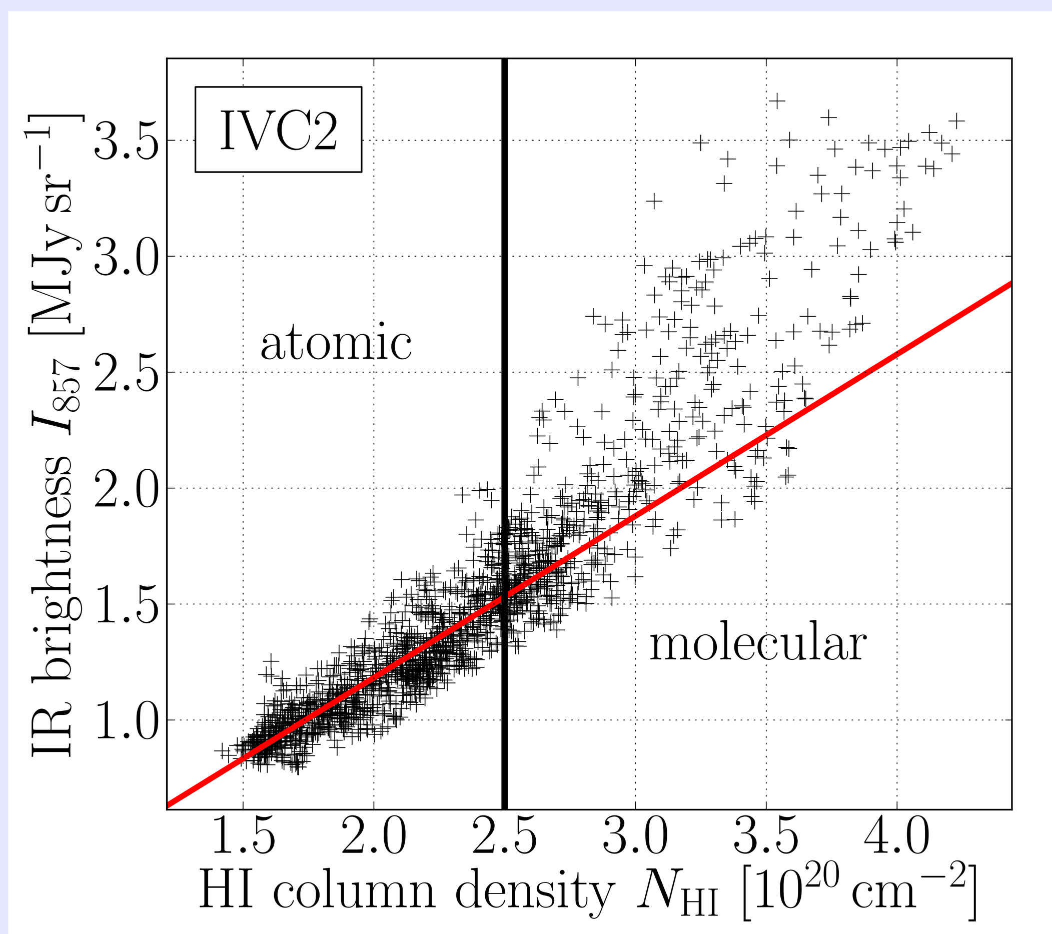


There is no unique linear correlation valid across the entire field of interest but individual infrared cirrus clouds show different emissivities. The objects are separated due to the high angular resolution of the new data, especially in H I.
Each branch in the scatter plot (left) corresponds to a cirrus cloud in the residual map (right). The residual map is derived by subtracting the black curve in the scatter plot from the observed FIR emission. Many clouds show an excess relative to a simple linear relation suggesting molecular hydrogen, some have less emission implying an excess of neutral gas over dust.

5 – FIR-deficient and molecular IVC

IVC1 has a H I-FIR correlation with a shallower slope compared to the entire field. The correlation is linear throughout indicating no molecular hydrogen.
For IVC2 a much steeper slope is derived. Above a threshold of $2.5 \cdot 10^{20}\,\mathrm{cm^{-2}}$ the correlation steepens again because of molecular hydrogen. From CO emission a column density of $N_{\mathrm{H_2}} \lesssim 1.9 \cdot 10^{20}\,\mathrm{cm^{-2}}$ is deduced (Désert et al. 1990, ApJ 355).
Because of the similarities in H I and their surroundings, we suggest that the IVCs undergo a phase transition from atomic to molecular gas. This may lead to the formation of large amounts of H_2 in IVC1 also.





6 – A transition from atomic to molecular clouds

Molecular hydrogen forms most efficiently on the surfaces of dust grains. The key factor in an enhanced formation rate of H_2 is an increased volume density. Also the gas can cool more efficiently by fine-structure line emission from C II and a better shielding from the UV radiation field is provided.

In this picture the observed FIR-deficient IVC1 is at an initial state of this transition and it may turn into a molecular one like IVC2. For this transition the volume densities have to be increased. This may be caused by their infall onto the galactic disk or dynamical interactions.