\textbf{Abstract}

The study of small hydrides such as CH, CH⁺, OH⁻ and H₂O⁺ is essential to understand the first steps of interstellar chemistry. In the framework of the Herschel-HIFI key project PRISMAS, we report the detections of CH⁺ and 1³CH⁺ absorption lines in the direction of several remote star forming regions. The CH⁺ lines are highly saturated. No emission line is detected in any of the three star forming regions. The resulting CH⁺ average abundances along W49N and W51 are found in excellent agreement with those derived from \(^{12}\)CH⁺ CSO submillimeter observations [1] and a few times larger than those inferred from visible observations of the local diffuse medium [2;3;4]. The average observed abundances still exceed by orders of magnitude those predicted by a UV-dominated steady-state chemistry because large endo-energetic barriers (several thousands Kelvin) have to be overcome in the cold gas. It has been proposed [6] that supersonic turbulence pervading the medium is a possible energy reservoir. We show that the predictions of the TDR (Turbulent Dissipation Regions) model, in which dissipation of turbulent energy in magnetised structures locally triggers a specific warm chemistry compare well with observations.

\section*{I HIFI observations of CH⁺ (0-1) and 1³CH⁺ (0-1)}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{image1.png}
\caption{Observations with HIFI on W49N and W51.}
\end{figure}

The above figures and the figure on the left show the CH⁺ (0-1) HIFI absorption spectra displaying the different LO tunings used to disentangle lines from the upper and lower sidebands. In some cases, the saturated parts of the profiles fall below half the continuum level (green line), suggesting a gain sideband ratio different from unity. Note that no CH⁺ (1-0) emission line is detected. The emission lines are from a different molecular species.

\section*{2. Data analysis}

\subsection*{2.1 \(^{12}\)CH⁺ and 1³CH⁺}

\(^{12}\)CH⁺ and 1³CH⁺ are displayed for the rest frequencies \(\nu = 854.715\) and \(\nu = 880.214\) MHz respectively [7;8]. The non-saturated parts of the absorption profiles are deconvoluted into distinct velocity components. The quality per component is inferred from a multi-Gaussian fitting procedure based on the Levenberg-Marquardt algorithm [9].

\subsection*{2.2 CH⁺ column densities}

The CH⁺ column densities inferred from the HIFI \(^{12}\)CH⁺ lines are computed for an isotopic ratio of 4 and compared to other samples: CSO submillimeter data in red [1] and visible data from absorption lines towards nearby stars [2;3;4]). They are displayed versus to the total H column density on the left hand side of the figure. The scatter of the data points is large. However, the average CH⁺ abundances are about 3 times larger among the inner Galaxy sources than in the Solar Neighborhood: [CH⁺]/[H] = (5 ± 2) \times 10⁻³ and (8 ± 5) \times 10⁻³ respectively.

\section*{II Model of turbulent dissipation regions (TDR)}

\subsection*{1. Chemical and thermal evolution of a magnetized vortex}

The TDR code is a 1-D model in which the chemical and thermal evolutions of a turbulent dissipative burst followed by a long lasting relaxation period are computed (right panel). The induced heating terms are sufficient to trigger a warm chemistry, i.e. not only driven by the UV photons. The chemical network is fundamentally modified because many endothermic and activation barriers are overcome (bottom panels). During both the dissipation and relaxation stages, the abundances of CH⁺, CH₂⁺, OH⁻, H₂O and CH₃⁺ are enhanced.

\subsection*{2. Modelling of a random line of sight across the diffuse ISM}

A random line of sight intercepts three kinds of diffuse gas (gas heated by the ambient medium (with a filling factor larger than 90 %) in which the chemistry is driven by the UV radiation field, (2) the active vortices where the chemistry is enhanced by the dissipation of turbulent energy, and (3) the relaxation stages where the gas previously heated and enriched cools down to its original state. The total number of active vortices is fixed by the average turbulent transfer rate \(\epsilon\) in the cascade.

\subsection*{3. CH⁺ column densities}

The CH⁺ column densities inferred from the HIFI \(^{12}\)CH⁺ lines are computed for an isotopic ratio of 5 and compared to other samples: CSO submillimeter data in red [1] and visible data from absorption lines towards nearby stars [2;3;4]). They are displayed versus to the total H column density on the left hand side of the figure. The scatter of the data points is large. However, the average CH⁺ abundances are about 3 times larger among the inner Galaxy sources than in the Solar Neighborhood: [CH⁺]/[H] = (5 ± 2) \times 10⁻³ and (8 ± 5) \times 10⁻³ respectively.

\section*{References}