Probing InterStellar Molecules with Absorption line Studies (PRISMAS)

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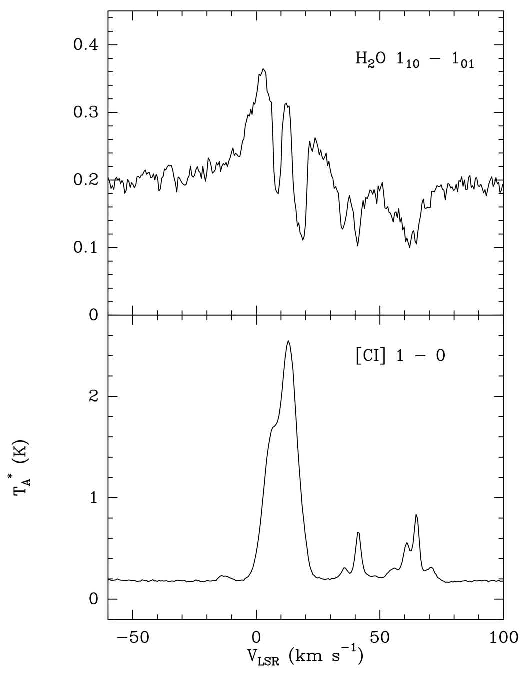

Figure 1: SWAS spectra obtained towards the star forming region W49 by Plume et al. (2004, ApJ 605, 247). Top : the ground state water line at 557 GHz, Middle : the fine structure line of carbon at 492 GHz. Diffuse clouds along the line of sight show up as absorption features in the H_2O spectrum and as emission lines in the [CI] spectrum. Absorption spectroscopy in ground state transitions provides sensitive means to probe the diffuse ISM.

Abstract

We will carry out a comprehensive spectroscopic study of key molecular line carriers, probing interstellar hydrides and carbon chains and rings. Our investigation will include high-resolution HIFI spectroscopy of some 20 molecules towards 8 sources, and several spectral scans with PACS. The target hydrides contain the elements H, D, C, N, O, F and Cl. We will take advantage of the strong dust emission from massive star forming regions to detect multiple absorption components from foreground clouds of diverse properties that are known to intersect the selected sightlines, along with emission and absorption intrinsic to the background sources. Our investigation will provide a wealth of new information about interstellar hydrides – addressing key puzzles posed by previous observations from the ground since the 1940's, and recently with ISO, SWAS, and ODIN – and leaving an important Herschel legacy to astrochemistry and ISM science. We will address the role of high temperature chemical reactions in the formation of interstellar molecules, and the question of how such reactions might be driven. We will also investigate the role of grain surface reactions in interstellar chemistry, and the growth of carbon molecules, bridging the gap between molecules and aggregates, as unique spectroscopic signatures of carbon chains and rings, are accessible in the FIR.
Many of the lines that are detectable with Herschel in the local Universe become accessible to ground-based observatories for redshifted sources. Our programme will provide an unique benchmark for the studies of molecular gas at high redshift with ALMA.

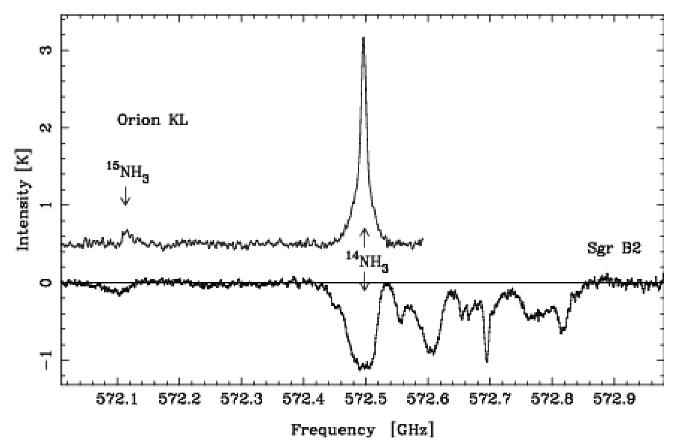

Figure 2: Spectra of $^{14}NH_3$ and $^{15}NH_3$ obtained by ODIN towards Orion and SgrB2 (Hjalmarson et al. 2006, Adv. Space Research , submitted). While the lines appear in emission in the nearby source Orion, the spectrum towards the distant, bright continuum source SgrB2 shows many absorption features, from the SgrB2 source and from diffuse clouds along the line of sight. The SgrB2 sight-line will be studied as part of the HEXOS programme, while other similar sight-lines will be sampled by us.

This Herschel programme is dedicated to key molecules, which are not accessible from the ground at FIR/submillimeter wavelengths, but which bear essential information on the physical and chemical processes ruling the ISM. Complementary investigations are proposed in the HEXOS and "The Warm and dense ISM" programmes.

Hydride molecules

Hydrides play a central role in interstellar chemistry, both as significant reservoirs of heavy elements and as critical intermediaries in the pathways leading to more complex molecules. In this Herschel key programme, we will carry out a comprehensive study of some 24 hydride molecules towards 8 bright submillimeter continuum sources. The target molecules comprise key hydrides and deuterides of the elements, C, N, O, F and Cl, and include both neutral species and molecular ions. The proposed observations will simultaneously provide both absorption-line spectroscopy of intervening clouds along the sightline to the target sources, together with emission-line spectroscopy of hydrides located within the sources themselves (Fig. ?? & ??). Two general scientific questions summarize our scientific goals :

- **What is the role of high temperature reactions in the formation of interstellar molecules, and how are such reactions driven?**
- **How do grain surface reactions affect the abundances of gas-phase molecules?**

Carbon chains and rings

It is our goal to make use of the excellent Herschel spectroscopic capabilities for making an inventory of the carbon clusters (Fig ??) in the diffuse ISM, along the same lines of sight as the hydride species. **Pure Carbon clusters are an important family for the carbon chemistry, good diagnostics of the ISM physical conditions, and closely related to larger carbon species and aggregates.** HIFI will be used to probe C_3, while PACS scans will be used to fully survey the far infrared domain including medium size carbon clusters. Once we obtain accurate frequencies from laboratory spectroscopy of heavy carbon clusters, we propose to perform deep integrations with HIFI on selected frequencies.

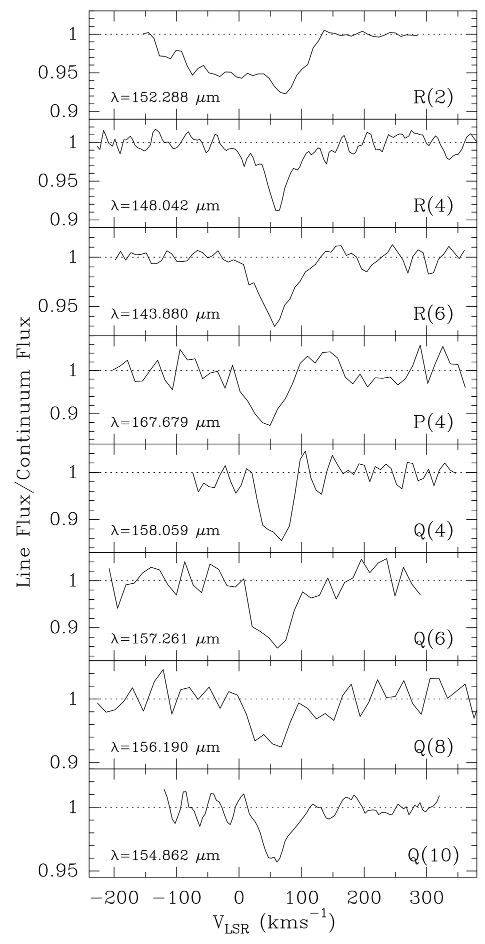

Figure 3: Detection of the C_3 FIR lines with the ISO-LWSspectrometer (Cernicharo et al. 2000, ApJ 534, L199).

Table 1: Absorption line sources

Name	R.A. (J2000)	Dec (J2000)	Priority
Sgr A*	17 45 39.95	–29 00 28.2	2
G005.88–0.39	18 00 30.4	–24 04 00	2
G10.62–0.39	18 10 28.7	–19 55 50	1
W33A	18 14 39.9	–17 51 59	3
G34.3+0.1	18 53 18.7	01 14 58.5	1
W49N	19 10 13.2	09 06 12	1
W51	19 23 43.9	14 30 31.5	1
DR21(OH)	20 39 00.9	42 22 38	1

Proposed observations

We will search for absorption lines using bright submillimeter continuum sources as background sources. We have selected a list of ∼ 30 lines and 8 bright FIR/submm continuum sources for this survey. To completely cover the FIR/submm domain, we plan to perform a full PACS scan for 2 – 3 background sources. The selected lines are listed in Tables ??, ?? and ??, depending on their priority. The background sources are listed in Table ??. Fig ?? shows spectra of the line of sight clouds towards G10.62–0.39 (W31C).

Table 2: High priority line frequencies

Molecule		Frequency (GHz)
o-$H_2{}^{18}O$	$1_{1,0} - 1_{0,1}$	547.676
o-H_2O	$1_{1,0} - 1_{0,1}$	556.936
p-H_2O	$2_{1,1} - 2_{0,2}$	752.033
p-H_2O	$2_{0,2} - 1_{1,1}$	987.927
p-$H_2{}^{18}O$	$1_{1,1} - 0_{0,0}$	1101.698
p-H_2O	$1_{1,1} - 0_{0,0}$	1113.343
o-$H_2{}^{18}O$	$2_{1,2} - 1_{0,1}$	1655.868
o-H_2O	$2_{1,2} - 1_{0,1}$	1669.905
OH^+	$^3\Sigma^-$ 1, 2, 5/2 – 0, 1, 3/2	971.804
o-H_3O^+	$0_0^- - 1_0^+$	984.697
p-H_3O^+	$1_1^- - 1_1^+$	1655.814
H_2O^+	$1_{1,1} - 0_{0,0}$	1115.150
H_2O^+	$1_{1,0} - 1_{0,1}$	607.224
H_2O^+	$1_{1,0} - 1_{0,1}$	631.773
$^{13}CH^+$	1 – 0	830.131
CH^+	1 – 0	835.079
CH^+	2 – 1	1670.16
CH	$^2\Pi_{3/2}$ 1, 2 –^{2} $\Pi_{1/2}$ 1, 1	532.724
CH	$^2\Pi_{3/2}$ 1, 2 –^{2} $\Pi_{1/2}$ 1, 1	536.761
CH	$^2\Pi_{5/2}$ 2, 3 –^{2} $\Pi_{3/2}$ 1, 2	1656.961
CH	$^2\Pi_{5/2}$ 2, 3 –^{2} $\Pi_{3/2}$ 1, 2	1661.107
^{13}CH	$^2\Pi_{3/2}$ 1, 2 –^{2} $\Pi_{1/2}$ 1, 1	532.104
^{13}CH	$^2\Pi_{3/2}$ 1, 2 –^{2} $\Pi_{1/2}$ 1, 1	536.113
^{13}CH	$^2\Pi_{5/2}$ 2, 3 –^{2} $\Pi_{3/2}$ 1, 2	1647.239
^{13}CH	$^2\Pi_{5/2}$ 2, 3 –^{2} $\Pi_{3/2}$ 1, 2	1661.107
o-CH_2	$1_{1,1} - 2_{1,2}$	945.839
NH	$^3\Sigma^-$ 1, 1/2 – 0, 1/2	974.479
NH^+	$^2\Pi_{1/2}$ $J = 3/2 - 1/2$	1012.561
NH_2		952.578
NH_3	$1_0 - 0_0$	572.498
NH_3	$2_0 - 1_0$	1214.859
NH_3	$2_1 - 1_1$	1215.245
HF	1 – 0	1232.476
p-D_2H^+	$1_{10} - 1_{01}$	691.660
C_3	$\nu 2$ P(10)	1654.082
C_3	$\nu 2$ P(8)	1696.528
C_3	$\nu 2$ Q(2)	1890.558
C_3	$\nu 2$ Q(4)	1896.706
C_3	$\nu 2$ Q(6)	1906.338

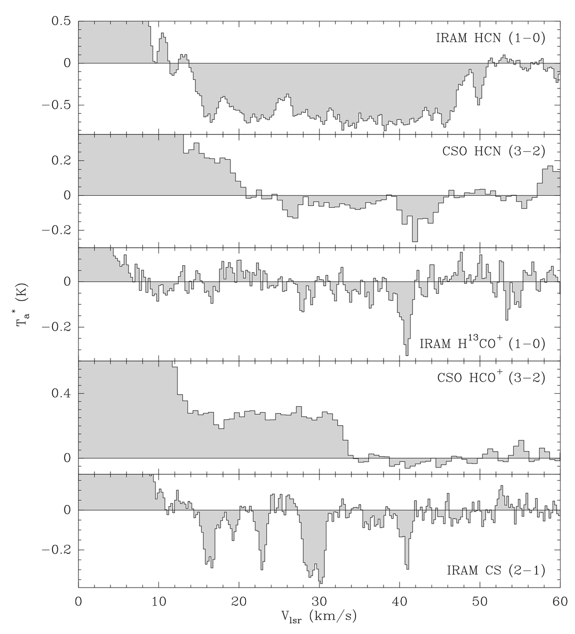

Figure 4: Spectra towards W31C obtained with the IRAM-30m and CSO telescopes.

Table 3: medium priority line frequencies

Molecule		Frequency (GHz)
HDO	$1_{1,1} - 0_{0,0}$	893.639
D_2O	$1_{1,1} - 0_{0,0}$	607.350
D_2O	$2_{1,1} - 1_{0,1}$	897.947
ND		522.077
NH_2D		494.454
$H^{37}Cl$	1 – 0	624.978
$H^{35}Cl$	1 – 0	625.919

Table 4: Low priority line frequencies,

Molecule		Frequency (GHz)
HCl^+	$^2\Pi_{3/2}5/2 - 3/2$	1444
DF	1 – 0	651.099