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For IRAM use

Registration N°:

Date:

PROPOSAL FOR 30M TELESCOPE

Deadline: 15 Mar 2012 Period: 01 Jun 2012 — 30 Nov 2012

TITLE

IRAM Chemical Survey of Sun-Like Star-Forming Regions

Type: *Solar system:* continuum ○ lines ○ other ○ *Extragalactic:* continuum ○ CO lines ○ other ○
Galactic: continuum ○ lines ● circumstel. env. ○ young stel. obj. ● cloud struct. ● chem. ● other ○

ABSTRACT

With the advent of the new generation of high-sensitivity, broad-band receivers at the IRAM 30m, we are now in position to address the question of our "chemical origins", namely to understand the chemical evolution of the matter during the long process that brought it from prestellar cores (PSCs) and protostars to protoplanetary disks, and ultimately to the bodies of the Solar System. We propose to carry out an unbiased spectral exploration of a carefully selected sample of template sources, which cover the full formation process of solar-type stars. This will provide a full census of the chemical species present in the gas neutrals (including complex organic species), anions, and cations, down to abundances as low as $\sim 10^{-12}$ wrt H_2. A complete modeling will allow to determine the physical and dynamical conditions of the targets. The resulting data set will remain as a reference database for astrochemists (astronomers, chemists, and theoreticians).

Is this a resubmission of a previous proposal ? no ● yes ○ – proposal number(s): ....
Is this a continuation of (a) previous proposal(s) ? no ● yes ○ – proposal number(s): ....

Hours requested for this period

Total **338** EMIR **338** HERA [ ] GISMO [ ]

LST range(s) and number of intervals
from: to: intervals:
from: to: intervals:

Special requirements: Large Program ● pooled obs ● service obs ○ remote obs ○ polarimeter ○

Scheduling constraints: 95.5hrs for this semester; pool observations only for winter

Receivers: EMIR ● HERA ○ GISMO ○ Other ○

List of Objects (give most common names)

Epoch: J2000.0

Source	RA	DEC	V_{LSR} or z
B1	03 33 20.8	+31 07 34.0	+6.5
L1448	03 25 38.9	+30 44 05.4	+5.3
IRAS4A	03 29 10.5	+31 13 30.9	+7.2
TMC1	04 41 41.9	+25 41 27.1	+6.0
L1527	04 39 53.9	+26 03 09.8	+5.9
SVS13A	03 29 03.73	+31 16 03.8	+6.0
L1544	05 04 17.21	+25 10 42.8	+7.3
L1157-mm	20 39 06.3	+68 02 15.8	+2.6
L1157-B1	20 39 10.2	+68 01 10.5	+2.6
AB Aur	04 55 45.84	+30 33 04.2	+6.0

(for additional sources which do not fit here use the \extendedsourcelist macro)

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Expected observer(s) Bachiller, Lefloch, Gonzalez...

join to this form: scientific aims ≤ 2 typed pages (≤ 4 pages for Large Programs) and ≤ 2 pages Figs., Tabs., and Refs.

Technical Summary

Variables used: T_A^* expected line antenna temperature; T requested telescope time per setup; Δv required velocity resolution; pwv precipitable water vapor: 1, 2, 4, 7, or 10 mm.

⋆ EMIR

Note that up to 8 IF signals can be recorded and up to 2 EMIR (always dual polarization) bands can be combined in one EMIR setup. For a summary of EMIR connectivity consult the EMIR webpage at www.iram.es/IRAMES/mainWiki/EmirforAstronomers or the Call for Proposals.

Transitions

setup	band	species	transition	frequency GHz	T_A^* mK	rms mK	Δv km s^{-1}	backend [a]
1	E0			81-90		6	0.25	FTS50
2	E0			80-116		6	1.2	FTS200,V
2	E1			130-174		7	1.2	FTS200,V
3	E2			200-276		6	1.2	FTS200,V

[a] V: VESPA, W: WILMA, 4: 4 MHz filterbank, FTS50 or FTS200: FTS @ 50 or 200 kHz resolution

Observing parameters

map size in arcmin

setup No.	map size $\Delta x \times \Delta y$	mapping mode [a]	switching mode [b]	pwv mm	T hours	remark
	×					Redundancy of 2 at 3mm and 1.3mm
1	×	none	FSw	4	4.7	E090 : 81-83 + 85-87 + 97-99 + 101-103 GHz
1	×	none	FSw	4	4.3	E090: 82-84 + 86-88 + 98-100 + 102-104 GHz
1	×	none	FSw	4	4.4	E090: 83-85 + 87-89 + 99-101 + 103-105 GHz
1	×	none	FSw	4	4.4	E090: 84-86 + 88-90 + 100-102 + 104-106 GHz
2	×	none	WSW	4	1.4	E090: 80-88; E150: 130.0-133.7
2	×	none	WSW	4	1.3	E090: 84-92; E150: 133.5-137.2
2	×	none	WSW	4	1.3	E090: 84-92; E150: 137.0-140.7
2	×	none	WSW	4	1.3	E090: 88-96; E150: 140.5-144.2
2	×	none	WSW	4	1.3	E090: 88-96; E150: 144.0-147.7
2	×	none	WSW	4	1.3	E090: 92-100; E150: 147.5-151.2
2	×	none	WSW	4	1.3	E090: 92-100; E150: 151.0-154.7
2	×	none	WSW	4	1.4	E090: 96-104; E150: 154.5-158.2
2	×	none	WSW	4	1.5	E090: 96-104; E150: 158.0-161.7
2	×	none	WSW	4	1.5	E090: 100-108; E150: 161.5-165.2
2	×	none	WSW	4	1.6	E090: 100-108; E150: 165.0-168.7
2	×	none	WSW	4	2.2	E090: 104-112; E150: 168.5-171.2
2	×	none	WSW	4	3.0	E090: 108-116; E150: 171.0-174.5
3	×	none	WSW	2	1.7	E230: 200-208 + 216-224
3	×	none	WSW	2	1.7	E230: 204-212 + 220-228
3	×	none	WSW	2	1.6	E230: 208-216 + 224-232
3	×	none	WSW	2	1.6	E230: 212-220 + 228-236
3	×	none	WSW	2	1.7	E230: 232-240 + 248-256
3	×	none	WSW	2	1.7	E230: 236-244 + 252-260
3	×	none	WSW	2	1.7	E230: 240-248 + 256-264
3	×	none	WSW	2	1.7	E230: 244-252 + 260-268
3	×	none	WSW	2	1.7	E230: 248-256 + 264-272
3	×	none	WSW	2	1.7	E230: 252-260 + 268-276
Total EMIR time requested:					338	

[a] none, OTF (on–the–fly), R: Raster

[b] PSw: position switching, FSw: frequency switching, Wsw: wobbler sw.

Chemical Origins.- We are living in a true golden age for Astrochemistry. Thanks to the recent spectacular progress of astronomical observations, particularly due to the Herschel and the IRAM telescopes, an enormous activity is being developed in the field extending from astronomical observatories to chemical laboratories and to theoretical quantum mechanics calculations (see e.g. Cernicharo & Bachiller, 2011). We are now in position to address the question of our "chemical origins", namely to understand the chemical evolution of the matter during the long process that brought it from prestellar cores (PSCs), to protostars and their associated shocks, protoplanetary disks, and ultimately to the bodies of the Solar System. Understanding this path, which leads to the origin of life on Earth, is one of the key questions in modern Astrophysics.

Evidence is mounting that Solar System bodies have at least partially inherited material from the first phases of the Solar System formation. For example, the chemical abundances in comet Hale-Bopp were found to be similar to those in the protostellar outflow L1157 (Bockelée-Morvan et al. 2000), and the HDO/H_2O ratio measured in the ice of comets is, within a factor of two, equal to the ocean value (Mumma & Charnley, 2011). Moreover, the large deuteration of amino acids in meteorites suggests at least a fraction of them was formed during the first phases of the Solar System (Pizzarello & Huang 2005). It then appears that **the molecular complexity of Solar System bodies is most likely intimately related to the earliest stages of star formation**.

Despite a wealth of fragmentary studies in the literature, the characterization and understanding of the chemical evolution along solar-type protostellar evolution is far from being understood. **We propose to address this issue by carrying out unbiased millimeter line surveys of a sample of template sources, which cover the full formation process of solar-type stars, from prestellar cores to protoplanetary disks.**

Chemistry along solar-type protostellar evolution.- Observations of the molecular composition of pre-stellar cores, the simplest sites where solar-type stars form, have revealed a very systematic pattern of chemical differentiation (Bergin & Tafalla, 2007). During the cold and dense pre-collapse phase, molecules freeze-out onto the grain surfaces, forming ices. Subsequent hydrogenation of atoms and CO on the grain surface leads to the formation of more complex organic molecules (COMs), like e.g. formaldehyde (H_2CO) and methanol (CH_3OH), in addition to other hydrogenated species (Ceccarelli et al. 2007).

Once gravitational collapse is underway, the newborn star is at the center of a thick envelope, from where it accretes matter. The innermost envelope regions, with a size of a few 100 AU, known as "hot corinos" are heated by the radiation emitted by the central object and the ices are sublimated. The molecules forming the ices are thus liberated and injected into the gas phase, where they may undergo further reactions. They share similarities with hot cores but are *not* just scaled-down versions of them (Bottinelli et al. 2007). Hot corinos are similar in size and composition to the nebula precursor of the Solar System. So their study can be considered as an archeological study of our Solar System.

Class 0 sources represent the first stages of the collapse (e.g. André et al. 2000). Simultaneously with matter accretion onto the protostar, fast jets, possibly surrounded by a wider angle wind, are powered by the nascent star and seen to interact with the parental medium through molecular bowshocks, producing a slower moving molecular outflow "cavity" (Bachiller 1996). Outflow shocks compress and heat the interstellar material and grain ice mantles are sputtered, resulting in an especially rich chemistry (Bachiller et al. 2001; Codella et al. 2010). The extremely-high-velocity (EHV) gas forming 'molecular bullets' is well differentiated from the gas traced by the standard outflow cavity wings and could represent material directly ejected from the prostostar or its immediate vicinity (Tafalla & Bachiller 2011). Outflows contribute to dissipate the circumstellar envelope, permitting the radiation of the central object to escape at increasing distances, until the central star and its surrounding protoplanetary disk become optically visible as a (Class II) T Tauri star.

In the subsequent phases (Class I/II), the envelope dissipates as the matter accretes onto the central object and is dispersed by the outflow/jet, as the surrounding protoplanetary disk becomes detectable. Chemistry is expected to be somewhat similar to that of Class 0 sources, with a corino region where ices sublimate. However, gas phase reactions may have time to alter the chemical composition of (at least some of) the sublimated species, causing to a further step in the molecular complexity.

In addition, all phenomena linked to UV/X-rays irradiation should be amplified with respect to the Class 0 sources and made more evident in the Class I and II sources. In conclusion, the study of the chemical composition during these late phases will teach us about the influence of both phenomena, gas phase reactions and UV/X-rays irradiation, which is otherwise very difficult to study in Class 0 sources. Gaseous disks are ubiquitous around Class II stars, and their chemical composition and physical properties regulate the efficiency and timescale of planet formation (e.g. Semenov 2011). Disk chemistry remains however a quite unexplored field from the observational point of view. Only a handful of molecules has been detected so far in disks, most of them towards DM Tau and TW Hya. Deep integrations providing high sensitivity are required to study the disk chemistry even in the most favorable cases.

Missing links.- The chemical composition of the gas is of paramount importance, among many reasons because the gas cooling is dominated by different species as a function of the gas temperature and density, and the elemental abundances (Goldsmith 2001). Besides, the dynamics of the collapse is regulated by its thermal status and the interaction of the matter with the magnetic field, both counteracting the gravitational force. So the chemical composition of the matter, and its evolution with time, is one of the important parameters determining the evolution of the forming star. Because of the interplay between dynamics and chemistry (magnetic field is coupled with matter through ions), a comprehensive picture of the gas and dust physical and chemical conditions are mandatory.

The existing fragmentary pieces of information reveal that even the dense cores, which are usually assumed to be particularly simple, are much more complex and chemically rich than previously thought, as testified by the recent discovery of COMs from the incomplete mm survey of TMC1 (Fig. 1; Marcelino et al. 2007). Propylene CH_2CHCH_3, an isomer of C_3H_6, was discovered in TMC1 as equally abundant as other well-known hydrocarbons, whereas it was ignored until then in the gas phase chemical networks! Such results illustrate the critical need of combining laboratory measurements and astronomical observations, but also the need for a re-evaluation of the chemical processes at play in the gas phase and the characterization of molecular species neglected until now.

Only a few hot corinos have been identified so far (Cazaux et al. 2003; Bottinelli et al. 2007) and their nature as well as their molecular composition remain unclear : IRAS16293, the unique hot corino investigated in detail until now (Caux et al. 2011), could not be representative of the whole Class 0. As a matter of fact, Sakai et al. (2008) have discovered a different type of chemically distinct Class 0 protostars, the so-called Warm Carbon Chain Chemistry (WCCC) sources, that are C-chain enriched, but -unlike hot corinos- poor in COMs. The actual composition of all these protostars, their similarities and differences, and their origin (that could be related to the infall dynamics) remain yet to be established.

Finally, one of the major results from Herschel is the almost ubiquity of molecular shocks in protostellar envelopes, which produce a rich molecular line spectrum (see e.g. Codella et al. 2010; Kristensen et al. 2011). The detection of simple O-bearing species, including water, in the EHV molecular bullets of protostellar outflows makes very timely to produce an inventory of molecular species in these bullets (Tafalla & Bachiller, 2011), that would permit to discriminate between the jet launching mechanisms proposed (Panoglou et al. 2012).

The need for systematic spectral surveys.- Systematic spectral line surveys constitute the most powerful diagnostic tool to carry out a comprehensive study of the chemical evolution of star-forming regions. In general terms, as different lines from transitions with different upper level energies and Einstein coefficients are excited in a range of temperatures and densities, line surveys permit to probe various regions along the line of sight. Star-forming regions are particularly complex because of the chemical differentiation of the regions (dominant chemical species depend on the cloud zone) and because, for a given species, the excited lines depend on the conditions (temperature, density, velocity field, etc), with sometimes complex kinematics, where infall and out flow motions are simultaneously present.

Despite numerous fragmentary observations at all stages of protostellar evolution, *unbiased* spectral surveys of low-mass, solar-type object have been carried out only towards IRAS16293 (Blake et al. 1994; Caux et al. 2011) and towards L1527 *at 3mm only* (Takano et al. 2011). The new capabilities of the IRAM 30-m telescope make possible to take a major step forward in the investigation of molecular complexity along with star formation, by observing with unprecedented sensitivity the emission of molecular rotational transitions in the millimeter domain in a greatly reduced amount of time.

Proposed observations.- We propose to carry out a legacy chemical survey of star-forming regions. The observations will consist of an unbiased spectral exploration of templates of dense cores, protostars, and young stars, which covers the full formation process of solar-type stars. We plan to obtain sensitive enough observations to detect abundances as low as $\sim 10^{-12}$ (wrt H_2). The measured abundances will be then compared to state of the art astrochemical models, providing a laboratory where the various parameters which any model depends on, are covered by the selected sources. Source intercomparison will permit to better constrain the parameter space, in particular assess the importance of age and/or the physical conditions. In addition to the discovery of new molecular species, and the revision of the astrochemical models developed in our team, we certainly expect new detections and surprises, which will trigger small, follow up observations with both IRAM instruments.

Selected sample.- We have selected a sample of *template* sources providing a complete view of the different types of objects encountered along protostellar evolution (Table 2) : 2 PSCs (one chemically evolved, one young), Class 0 sources with/without fully developed outflows, including solar-type hot corino and WCCC candidates, a more evolved (Class I) protostar, and a young star in the Class I/II transition, with an apparent protoplanetary disk and a residual protostellar envelope, and one outflow with EHV molecular bullets. These objects have all been/are the subject of molecular gas studies at millimeter wavelengths in our team, and maps of the molecular emission and the velocity field are available for several molecular species (Table 2). For most of the sample sources, the emission of the major gas cooling agents in the hot/warm gas phase has been observed with HIFI in the course of the Herschel Key-Projects WISH (van Dishoeck et al. 2010) and CHESS (Ceccarelli et al. 2010) and several open-time proposals in our team (see Table 2). The complementarity of the IRAM and Herschel data offers an unprecedented view on the protostellar environments and their chemical evolution. For instance, the IRAM and CHESS spectral surveys of L1157-B1 (see selected bands in Figs. 1-2) revealed a rich line spectrum with a great wealth of new molecular species (molecular ions, O-bearing molecules NO and PO). Linewidths clearly point towards a shock origin but comparison with the actual composition of the L1157-mm protostellar envelope itself is mandatory in order to conclude about the shock-driven production mechanism of these species. Herschel gives access to the hot protostellar gas regions, probed by heavy molecules, and to some cold gas regions, as probed by the low-energy transitions of light hydrides (e.g. Fig. 2; also Ceccarelli et al 2010). The IRAM contribution is essential: on the one hand, the mm-wave spectral range fully probes the physical and chemical conditions of the cold gas component; on the other hand, the high-sensitivity of the EMIR receivers permits now to obtain a full census of the chemical species, hence the molecular complexity present in the gas phase: neutrals (including complex organic species released/synthesized in the gas phase), anions and cations, which are involved in the chemistry, thermal state, and dynamics of the gas.

Observational strategy and time estimate.- Using the broad-band EMIR receivers and the FTS spectrometer in its 200kHz resolution mode, we aim at an rms of 4-5mK at 3mm and 1.3mm in a velocity interval of 1.2km s^{-1}, sufficient to detect and resolve the profiles of weak lines from e.g.hydrocarbon chains, COMs, and molecular ions, or more exotic (or unexpected) species possibly present, but in PSCs. Our strategy is supported by the previous IRAM survey of IRAS16293. With a lower spectral resolution and sensitivity, Caux et al. could identify about 1000 unblended lines with $S/N > 3$ and $E_{up} < 250K$ from 32 chemically distinct species plus 37 rare isotopologues.

The PSCs require larger velocity resolutions, ~ 0.25km s^{-1}, achieved with the 50 kHz mode of the FTS, in order to resolve the line profiles ($\geq 0.3 - 0.4$km s^{-1} in TMC1; Marcelino et al. 2007). The spectral line density of PSCs is low enough at 3mm that observations can be carried out without difficulty in Frequency-Switching. It is possible to cover the band 80-90GHz, with important lines of COMs and hydrocarbons (like propylene, see Fig. 1), in about 18 hours. For the more evolved sources with higher spectral line density, the Wobbler-Switching mode (WSW) appears as the best strategy, providing a flatter baseline. Contamination from the reference position in WSW could affect line profiles but experience shows that it is actually restricted to the brightest lines from abundant species, already known in the literature.

Time estimates were carried out with the IRAM Time estimator (good weather conditions both winter and summer) and an average source elevation of ~ 60 deg. All spectral bands at 3mm and 1.3mm will be observed with a redundancy of 2 (see Technical summary). In order to maximize the chance of good winter weather observations, the project will be carried out in the heterodyne pool; therefore we adopted larger overheads (tuning times of 5hr/source) for both winter semester 2 and 4 (Table 3).

Implementation.- The full project will be carried out over four semesters, finishing in Winter 2014/15. Three to five sources will be observed each semester, following the scheme of Tab. 2. Most of the sources are close in R.A., so there is some flexibility in the choice of sources actually observed. The project is articulated in 5 Work Packages (WPs).

WP	Obs., reduction modelling	Members
1	PSCs	**C. Vastel**(3), M. Tafalla(2), N. Marcelino(6), J. Cernicharo(4), A. Bacmann(1), E. Roueff(7), M. Gerin(7), C. Ceccarelli (1)
2	Class 0	**B. Lefloch**(1), N. Marcelino(4), E. Caux (3), N. Sakai(10), J. Cernicharo(4) C. Kahane(1), N. Rodriguez (1), S. Yamamoto(10) S. Bottinelli (3), K. Demyk(3), C. Ceccarelli(1)
3	Class I,II	**A. Fuente**(2), C. Codella (5),T. Alonso-Albi(2), P. de Vicente(2), J. Cernicharo(4), C. Ceccarelli(1), B. Lefloch(1)
4	Outflows	**R. Bachiller**(2), C. Codella(5), B. Lefloch(1), N. Rodriguez(2), M. Tafalla(2), L. Podio(1), M. Vasta(5), S. Cabrit(7)
5	Models	**C. Ceccarelli**(1), S. Cabrit(7), E. Roueff(7), G. Pineau des Forets(7), M. Gerin(7), P. Caselli (8), S. Viti(9), N. Sakai(10), A. Faure(1), L. Wiesenfeld(1)

Table 1: Working groups and Team members. The names in boldface mark the WP coordinators. The numbers in parenthesis give the affiliations: 1-IPAG, France; 2- OAN, Spain; 3- IRAP, France; 4- Centro de Astro-Biologia (CAB), Spain; 5- INAF Osservatorio Astrofisico di Arcetri, Italy; 6- NRAO, USA; 7-Observatoire de Paris, France; 8-University of Leeds, UK; 9-University College London, UK; 10-University of Tokyo, Japan

The data will be reduced and analyzed by the members of the relevant WP. For each source, we will obtain the full census of molecular species, likely including new detected ones, emitting in the observed bands. With the help of sophisticated radiative transfer models taking into account the density and temperature profiles of each source, we will then derive the species abundance profiles and, consequently, the fully physical and chemical structure of each source. The derived quantities will then be compared with astrochemical and physical models for the different components (cold clouds, envelopes, shocks, PDRs) developed in our team to better understand the process of the star formation in solar type protostars, in all its aspects. The resulting data set will remain as a reference database for astrochemists (astronomers, chemists, and theoreticians) for more than one decade.

Team and research context.- Our team has a long-standing, internationally recognized, experience in molecular line surveys at millimeter and far-infrared wavelengths, with the IRAM 30m telescope and with Herschel. Besides, during the years we have developed all the tools necessary to efficiently identify lines and species, as well as interpreting them with status-of-the-art radiative transfer and astrochemical models. The team is composed by 35 researchers with complementary expertise, from observing to modelling of the different sources composing the target sample. We emphasize the presence in the team of experts in theoretical chemistry, providing collisional coefficients for the radiative transfer models and reactions pathways and rates for astrochemical models. Therefore, the composition of the proposing team makes us highly competitive compared to other groups in the world working on astrochemistry.

The team is organized into five sub-teams, each associated with one of the five WPs, and with a relevant coordinator to ensure an efficient and timely data reduction and analysis. For each source, a team member with strong expertise in the 30m observations will guarantee the optimization of the observations and data reduction/analysis.

We plan to have plenary team meetings at least once at the end of the first and second years. Smaller team meetings and/or teleconfs will take place regularly at higher frequency (on a 2-months basis, after the first data are acquired). The project PIs will be responsible for the overall organization and circulation of the information, by being in monthly contact with the WPs coordinators. Finally, the team members have a long record of collaborations between them (including the most recent collaboration on the Herschel Key Programs), ensuring an efficient working environment. Visits among members are already ensured by bilateral funds for the 2-years period of the project.

A web site dedicated to the project will be created immediately after its approval by the TAC. It will be hosted by OAN, with a mirror-site at IPAG. The results of the project and the outreach activities (publications, conferences..) will be posted in the public access area, whereas the private access area will be used for the project working space. The fully reduced line spectra will be posted on the public access area at the end of the proprietary time, namely 18 months, easily accessible and retrievable.

Type	Source	Ref.	d (pc)	L ($L_{\odot}$)	3mm	2mm	1.3mm	Herschel	Comment
PSC	L1544	1	140	-	X	-	-	C, W	Evolved: high deuteration
	TMC1	2	140	-	done	X	-	OT1	Young: hydrocarbon rich
Class 0	B1	3	200	-	X	X	X	-	Early: no outflow, high deuteration
	IRAS4A	4	250	7.7	X	X	X	C,OT1	Hot Corino
	L1527	5	140	2	done	X	X	W	WCCC
	L1157mm	6	250	4	done	done	X	W	WCCC ? comparison with B1
Class I	SVS13A	7	250	43	X	X	X	W	Evolved
Class I-II	AB Aur	8	145	-	X	X	X	OT1	residual envelope, warm disk
Jet	L1448	9	250	(11.6)	X	X	X	W,OT1	EHV bullets
Bowshock	L1157-B1	10	220	(4)	done	X	done	C,W	MHD shock prototype

Table 2: Source sample, properties (distance, luminosity) and requested spectral bands. Note that the 1.3mm spectral line density of PSCs is too low to warrant a systematic line search. Sources observed in CHESS, WISH, and Open Time are indicated by C, W, OT1, respectively.

References:(1) Caselli et al. (2002); (2) Cernicharo & Guelin (1987); (3) Marcelino et al. (2005); (4) Bottinelli et al. (2007); (5) Sakai et al. (2010); (6) Bachiller et al. (2001); (7) Lefloch et al. (1998); (8) Fuente et al. (2010); (9) Bachiller et al. (1991); (10) Lefloch et al. (2010)

Source	Setting 1 3mm 50kHz (17.8hrs)	Setting 2 3mm+2mm (20.4hrs)	Setting 3 1.3mm (17hrs)	Summer 2012	Winter 2013	Summer 2013	Winter 2014	Responsible Observer
L1544	X	-	-	X				C. Vastel
TMC1	-	X (2mm;20hrs)	-			X		J. Cernicharo
B1	-	X	X			X	X	N. Marcelino
IRAS4A	-	X	X	X	X			S. Bottinelli
L1527	-	X	X	X			X	C. Kahane
L1157mm	-	-	X		X			M. Tafalla
SVS13A	-	X	X			X	X	C. Codella
AB Aur	-	X	X		X	X		A. Fuente
L1448	-	X	X	X	X			R. Bachiller
L1157-B1	-	X (2mm;10hrs)	-	X				B. Lefloch
Time				89	68	81.6	51	
Tuning time				+6.5	+20	+6.5	+15	
Total (hrs)				**95.5**	**88.0**	**88.1**	**66.0**	**337.6**

Table 3: Observational settings and time estimates. We ask for 10 (20) hours to complete the 2mm survey of L1157-B1 (TMC1).

References

- André et al. 2000, Prot. & Planets IV, p. 59
- Bachiller R., 1996, ARAA 34, 111
- Bachiller R., et al., 2001, A&A 372, 899
- Blake et al. 1994, ApJ 428, 680
- Bottinelli et al. 2007, A&A 463, 601
- Cazaux et al. 2003, ApJLet 593, L51
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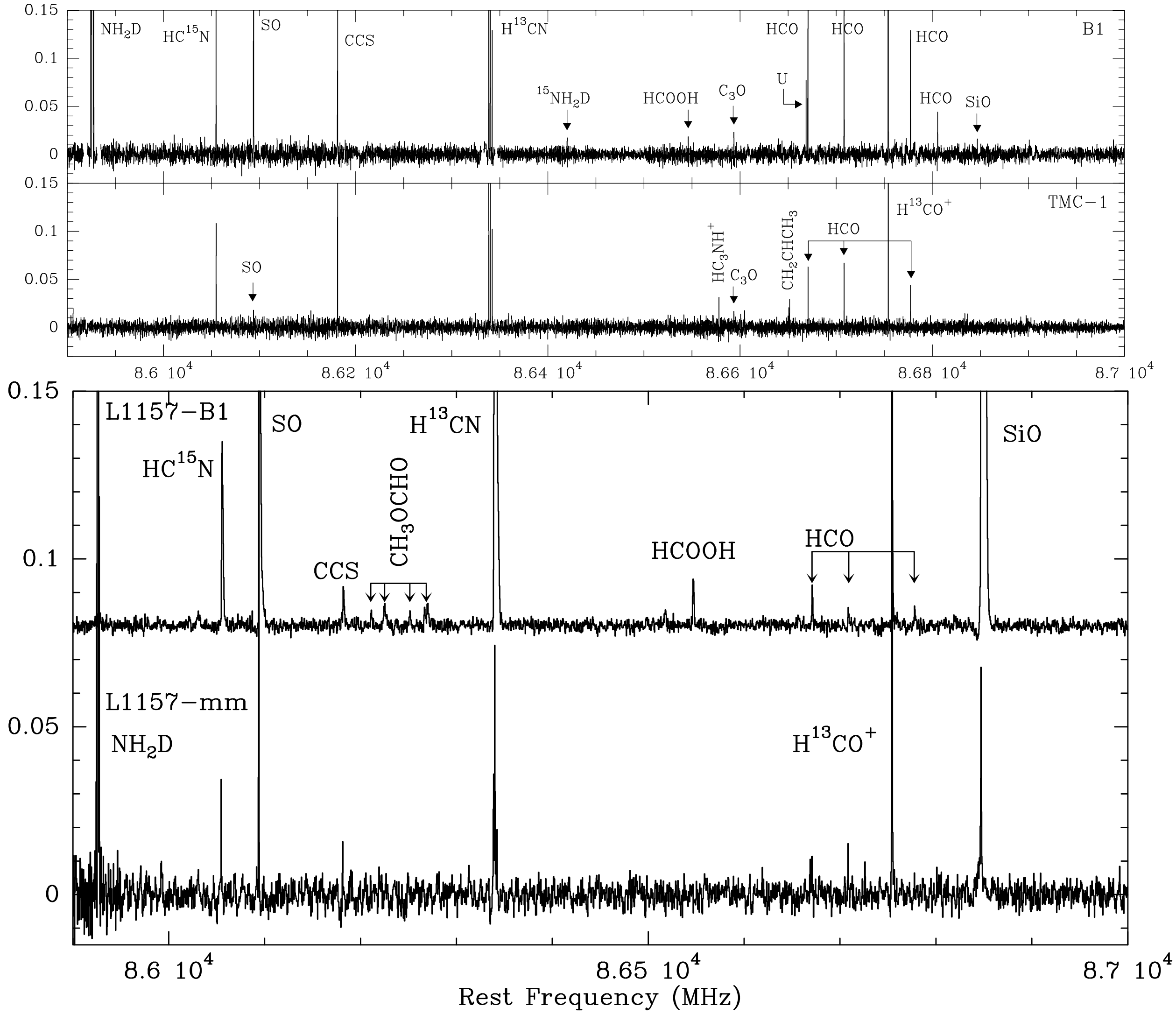

Figure 1: (top) Comparison of the molecular emission in the range 86-87 and 89-90 GHz observed towards TMC1 (PSC; hydrocarbon rich) and B1 (early Class 0; high molecular deuteration; COMs) at the IRAM 30m telescope; (bottom) Molecular emission in the range 86-87 GHz observed towards L1157-mm (WCCC candidate) and L1157-B1 (shock; COMs).

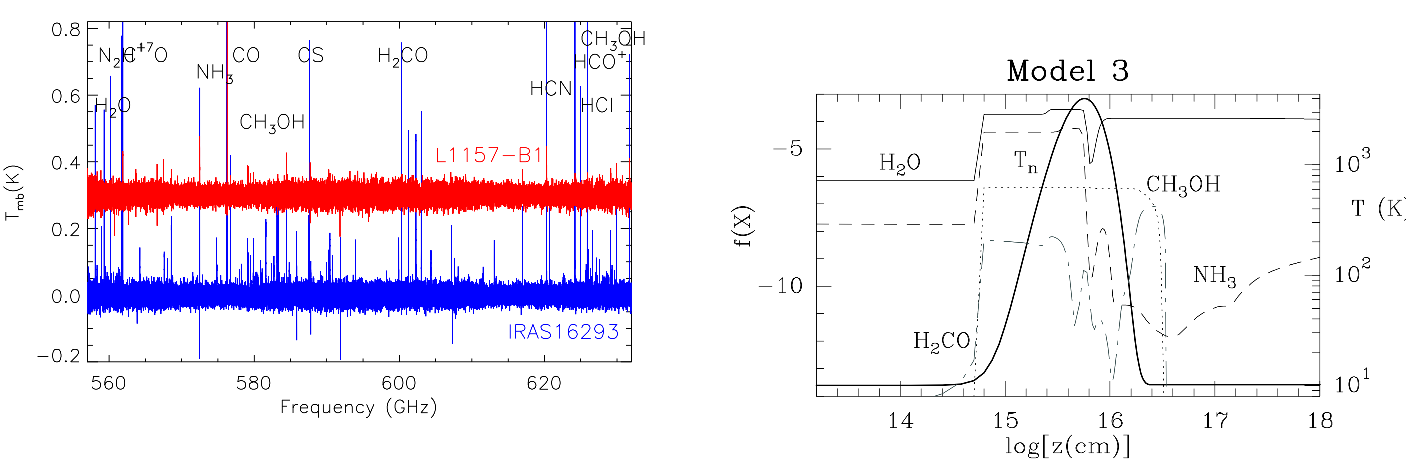

Figure 2: *(left)* Molecular line emission detected in HIFI/band 1b towards L1157-B1 and IRAS16293 (from Ceccarelli et al. 2010). The transitions of the brightest lines are marked. *(right)* Modelling of the H_2O and NH_3 gas phase abundances across the shock L1157-B1 as implied by the molecular line profiles in HIFI/band 1b (Viti et al. 2010).