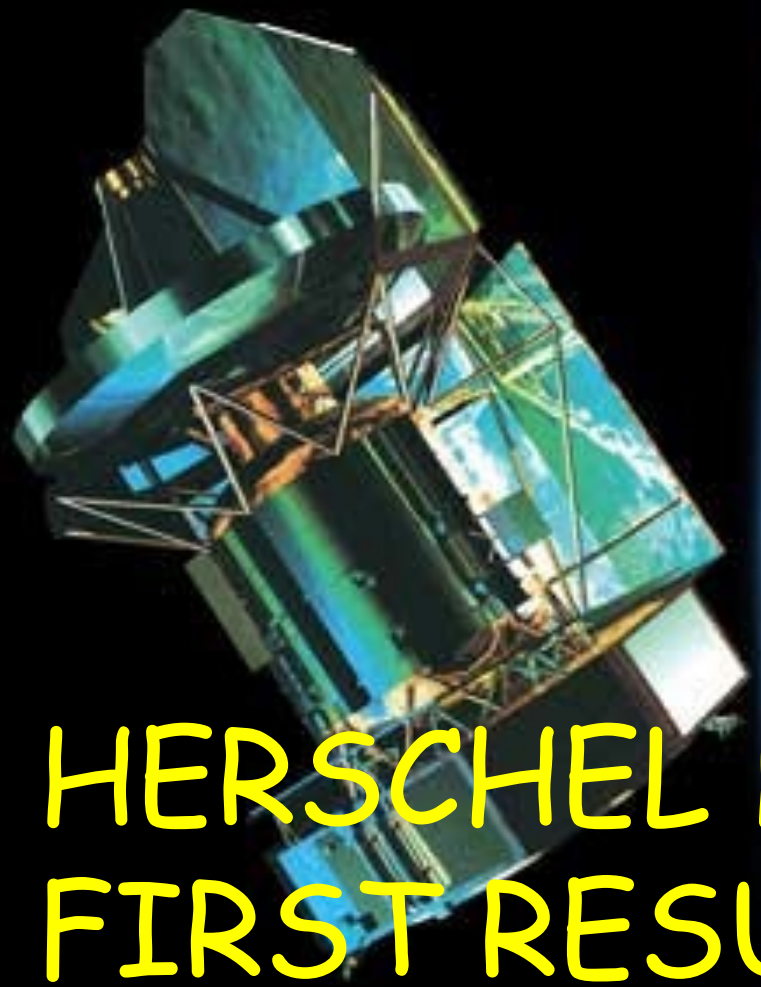

HERSCHEL HIFI FIRST RESULTS

Cecilia Ceccarelli

OUTLINE

1. INTRODUCTION TO HERSCHEL & HIFI
2. HIFI FIRST RESULTS from HEXOS
3. HIFI FIRST RESULTS from CHESS

HERSCHEL in a nutshell

1. A 3.5-mt passively cooled telescope
2. Payload cooled at the Helium superfluid temperature
3. Launched last year in a L2 orbit around the Earth-Moon
4. Will work for about 3 years -> 2012
5. 3 instruments on board : **PACS**: imaging photometer or an integral field spectrometer over the spectral band from 57 to 210 μm.

SPIRE: spectral and photometric observations in 200 - 670 μm.

HIFI: high resolution spectrometer between 500 and 2000 GHz (200 and 500 μm).

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HERSCHEL observations

Two types of "times" for observations:

Guarantee Time (GT): instruments + HSO Instrument Scientists + ESA team

Open Time (OT): ~70%, open to the general community

Two "types" of observations:

Key Programs: about 50% of HSO is allocated to large programs, i.e. programs requiring more than ~200 hrs and that are key for the astronomical community

Proposals: standard "little" (in time) focused proposals

OT PROPOSAL SUBMISSION: 22 JULY

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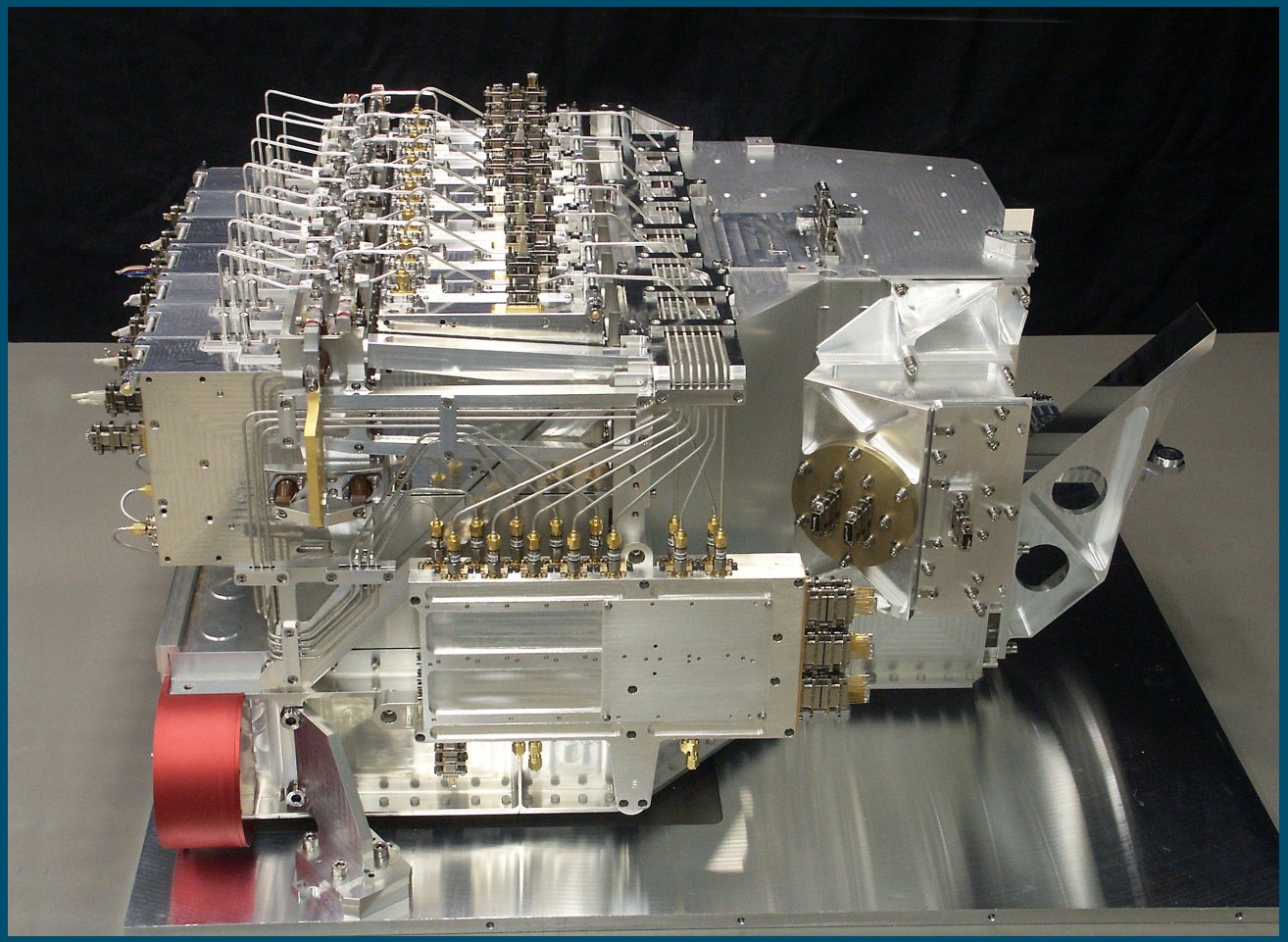
HERSCHEL HIFI

Heterodyne Instrument for the Far-Infrared



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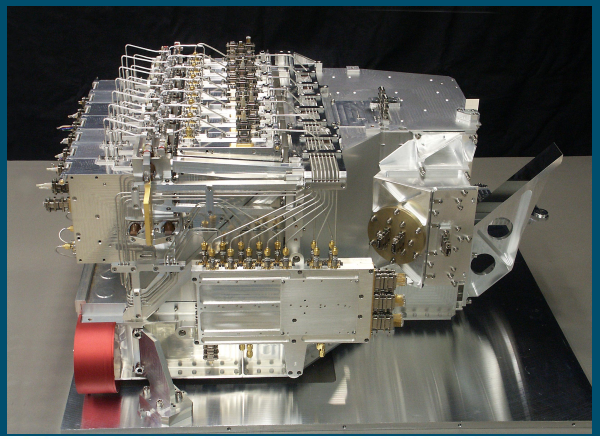
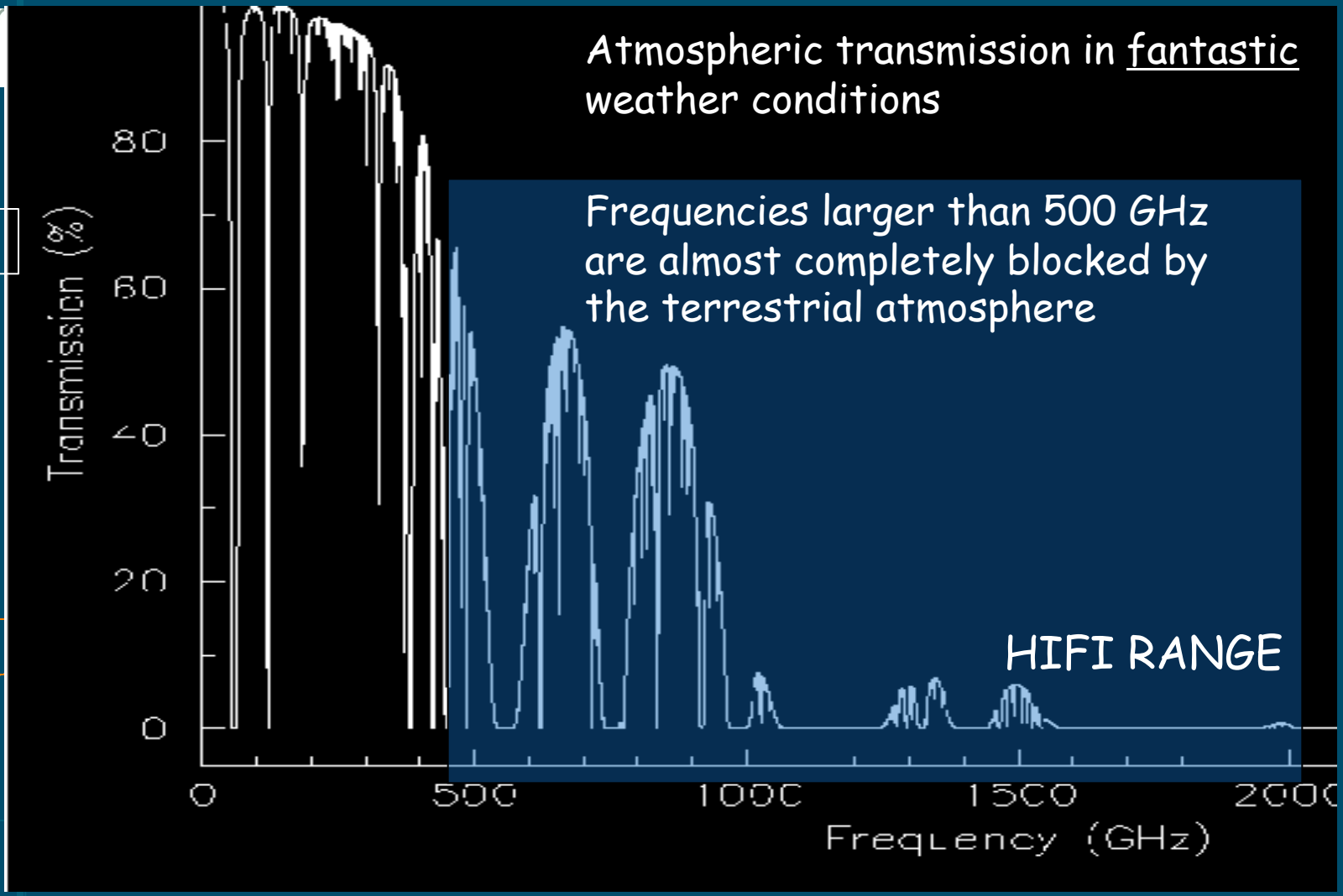
HERSCHEL HIFI



The Herschel-Heterodyne Instrument for the Far-Infrared (HIFI)*

Th. de Graauw[1,2,3], F.P. Helmich[1], T.G. Phillips[4], J. Stutzki[5], E. Caux[6,7], N.D. Whyborn[1,3], P. Dieleman[1], P.R. Roelfsema[1], H. Aarts[1], R. Assendorp[1], R. Bachiller[8], W. Baechtold[21], A. Barcia[9], D.A. Beintema[1], V. Belitsky[10], A. Benz[11], R. Bieber[5], A. Boogert[4], C. Borys[4], B. Bumble[12], P. Caïs[13,14], M. Caris[15], P. Cerulli-Irelli[15], G. Chattopadhyay[4], S. Cherednichenko[10], M. Ciechanowicz[15], O. Coeur-Joly[6,7], C. Comito[15], A. Cros[6,7], A. de Jonge[1], G. de Lange[1], B. Delforges[1,19,20], Y. Delorme[19,20], T. den Boggende[1], J.-M. Desbat[13,14], C. Diez-González[9], A.M. Di Giorgio[15], L. Dubbeldam[1], K. Edwards[1,17], M. Eggens[1], N. Erickson[23], J. Evers[1], M. Fich[17], T. Finn[25], B. Franke[5], T. Gaier[12], C. Gal[5], Gao, J.R.[28], J.-D. Gallego[9], S. Gauffre[13,14], J.J. Gill[12], S. Glenz[5], H. Golstein[1], H. Goulooze[1], T. Gunsing[1], R. Güsten[15], P. Hartogh[18], W. A. Hatch[12], R. Higgins[1], E.C. Honingh[5], R. Huisman[1], B.D. Jackson[1], H. Jacobs[1], K. Jacobs[5], C. Jarchow[18], H. Javadi[12], W. Jellema[1], M. Justen[5], A. Karpov[4], C. Kasemann[15], J. Kawamura[12], G. Keizer[1], D. Kester[1], T.M. Klapwijk[27], Th. Klein[15], E. Kollberg[10], J. Kooi[4], P.-P. Kooiman[1], B. Kopf, M. Krause[5], J.-M. Krieg[19,20], C. Kramer[5], B. Kruizenga[27], T. Kuhn[5], W. Laauwen[1], R. Lai[29], B. Larsson[22], H.G. Leduc[12], C. Leinz[15], R.H. Lin[14], R. Liseau[22], GS Liu[16], A. Loose[18], I. López-Fernandez[9], S. Lord[13], W. Luinge[1], A. Marston[1,33], J. Martín-Pintado[30], A. Maestrini[13], F.W. Maiwald[13], C. McCoey[17], A. Megej[21], M. Melchior[11], L. Meinsma[1], H. Merkel[10], M. Michalska[23], C. Monstein[11], D. Moratschke[5], I. Mehdi[12], P. Morris[12], H. Muller[5], J.A. Murphy[26], A. Naber[1], E. Natale[32], W. Nowosielski[23], F. Nuzzolo[16], M. Olberg[1,34], M. Olbrich[5], R. Orfei[16], P. Orleanski[23], V. Ossenkopf[1,5], T. Peacock[26], J.C. Pearson[12], I. Peron[19,20,31], S. Phillip-May[15], L. Piazzo[16], P. Planesas[3,9], M. Rataj[23], L. Ravera[6,7], C. Risacher[18], M. Salez[19,20], L.A. Samoska[12], P. Saraceno[16], R. Schieder[5], E. Schlecht[12], F. Schlöder[5], F. Schmülling[5], M. Schultz[5], K. Schuster[31], O. Siebertz[5], H. Smit[1], R. Szczerba[25], R. Shipman[1], E. Steinmetz[18], J.A. Stern[12], M. Stokroos[1], R. Teipen[5], D. Teyssier[1,33], T. Tils[5], N. Trappe[26], C. van Baaren[1], B.-J. van Leeuwen[1], H. van de Stadt[1], H. Visser[27], K.J. Wildeman[1], C.K. Wafelbakker[1], J.S. Ward[11], P. Wesselius[1], W. Wild[1,36], S. Wulff[5], H.-J. Wunsch[15], X. Tielens[1,2], P. Zaal[1], H. Zirath[10], J. Zmuidzinas[4], and F. Zwart[1]

Why Herschel HIFI



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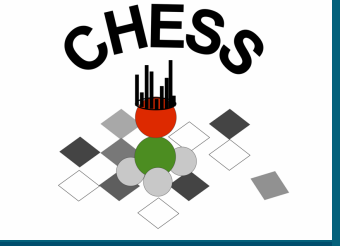

HIFI in a nutshell

HIFI is an instrument with a continuous frequency coverage from 480 to 1250 GHz in five bands, 1410-1910 GHz, in two further bands at an unrivalled spectral resolution and ultimate sensitivity.

HIFI is able to perform rapid and complete spectral line surveys with resolving powers from 10^5 up to 10^7 (3 - 0.03 km/s) and deep line observations.

After a false start in August, HIFI is now working at full speed !

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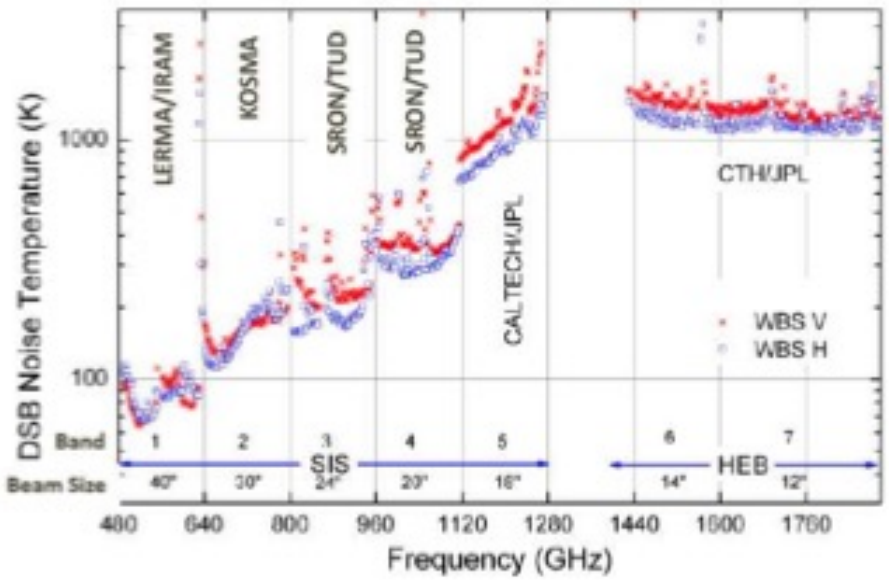
Laboratoire d'Astrophysique de Grenoble

HIFI in a nutshell

IN-ORBIT SYSTEM TEMPERATURES



De Grauuw wt al. 2010 – A&A Herschel Special Issue

For comparison:

- ✓ JCMT Sys. Noise @ 465GHz is 1300K for excellent (=never seen) weather conditions
- ✓ To cover 40 GHz with 30 mKrms at CSO takes ~ 36 hours. *In 50 hours of HIFI time we have covered 1150 GHz!*

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HIFI in a nutshell

THE TWO MAJOR DRIVES FOR HIFI:

1. COMPLETE SPECTRAL SURVEYS
2. WATER LINES

HI GT Key Programs	Hours (Fr)	PI-country
Solar System: HSSO	263 (9)	GE
Water in SFRs: WISH	425(38)	NL
Spectral Surveys in SFRs: CHESS	224 (89)	FR
Orion &SgrB2: HEXOS	355 (25)	USA
Water in AGB: HIFISTARS	187 (0)	SP
Warm ISM: WADI	136 (17)	GE
ISM Molecular Carriers: PRISMA	112 (31)	FR
Extra-galactic Nuclei: EXGAL	286(0)	GE

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HIFI in a nutshell

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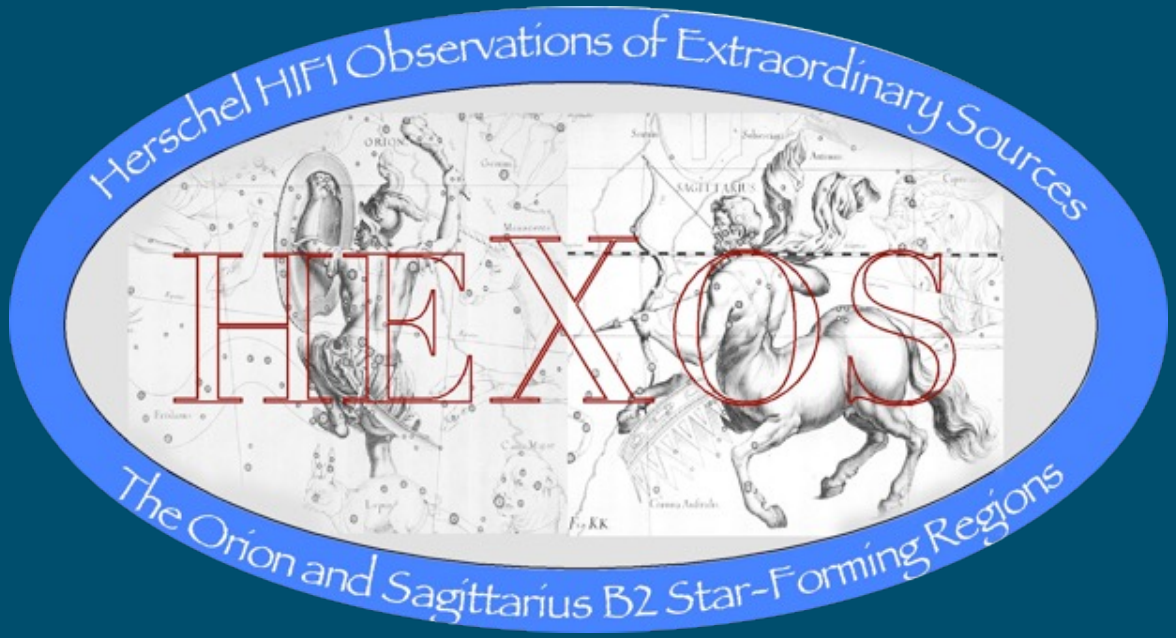
2. HIFI FIRST RESULTS from HEXOS
3. HIFI FIRST RESULTS from CHESS



First Results from the Herschel observations of EXtra-Ordinary Sources (HEXOS) Key Program

E. Bergin (Univ. of Michigan)
on behalf of the HEXOS Team

HEXOS

Cecilia Ceccarelli

Orion and Sgr B2: Extra-Ordinary Objects

- Contain THE CLASSIC EXAMPLES of phenomena found throughout the ISM
  - Hot Cores: Orion KL, Sgr B2 N
  - Photodissociation Region: The Orion Bar
  - Shocks: Orion KL
  - Diffuse gas in Milky Way: Sgr B2 M peers through the galaxy
- Main part of program:
  - Full HIFI spectral scans of Orion KL, Orion S, Orion Bar, Sgr B2 (M), Sgr B2(N)
  - PACS range scans of same sources
  - Water Maps of shock/deep integrations/search for large molecules

CHESS

HiFi

HEXOS

Herschel HIFI Observations of Extraordinary Sources
HEXOS
The Orion and Sagittarius B2 Star-Forming Regions

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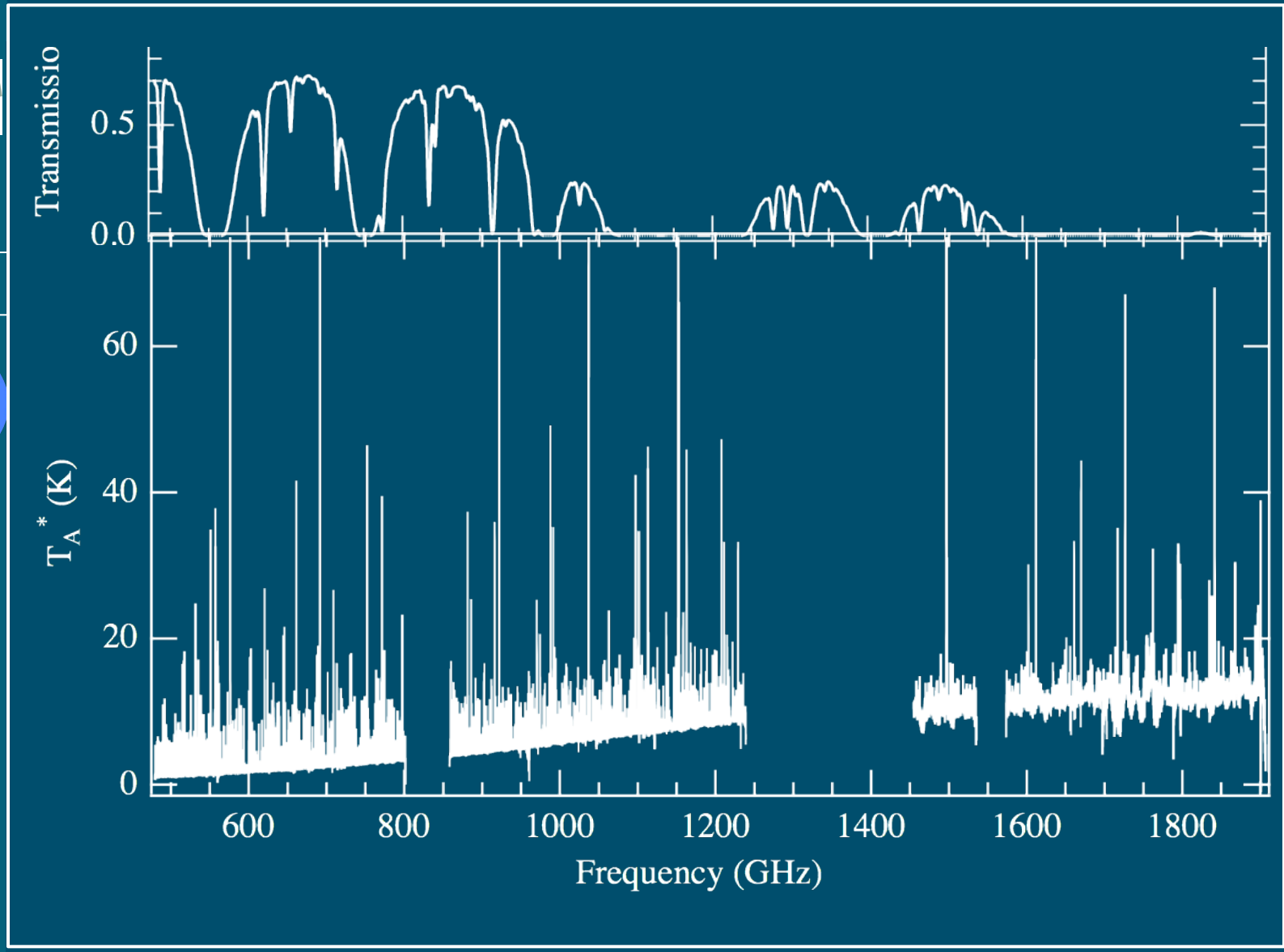
The ORION KL spectrum



CHESS

HiFi

HEXOS

Herschel HIFI Observations of Extraordinary Sources
HEXOS
The Orion and Sagittarius B2 Star-Forming Regions

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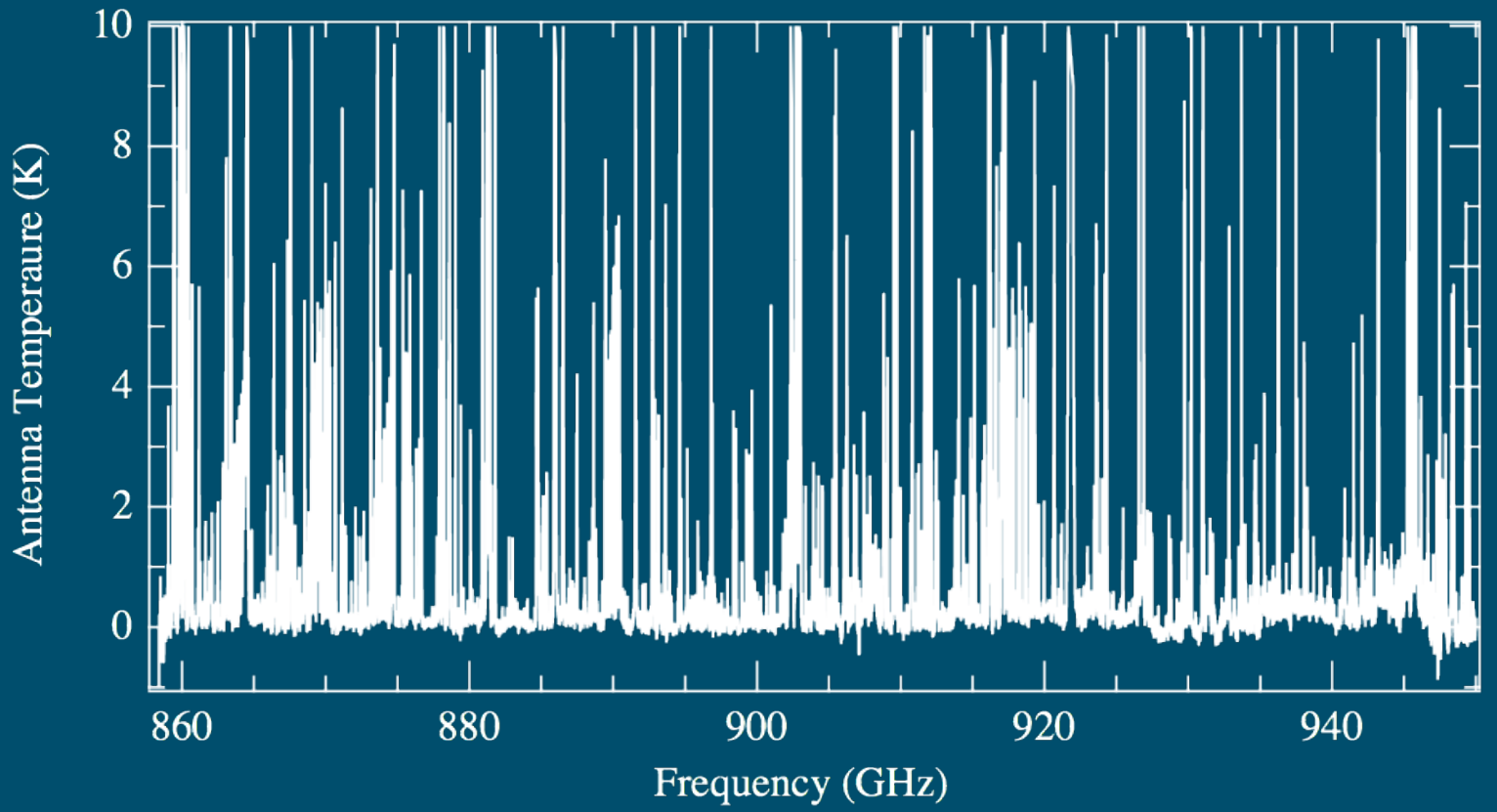
ORION KL spectrum around 900GHz



CHESS

HiFi

HEXOS

Herschel HIFI Observations of Extraordinary Sources
HEXOS
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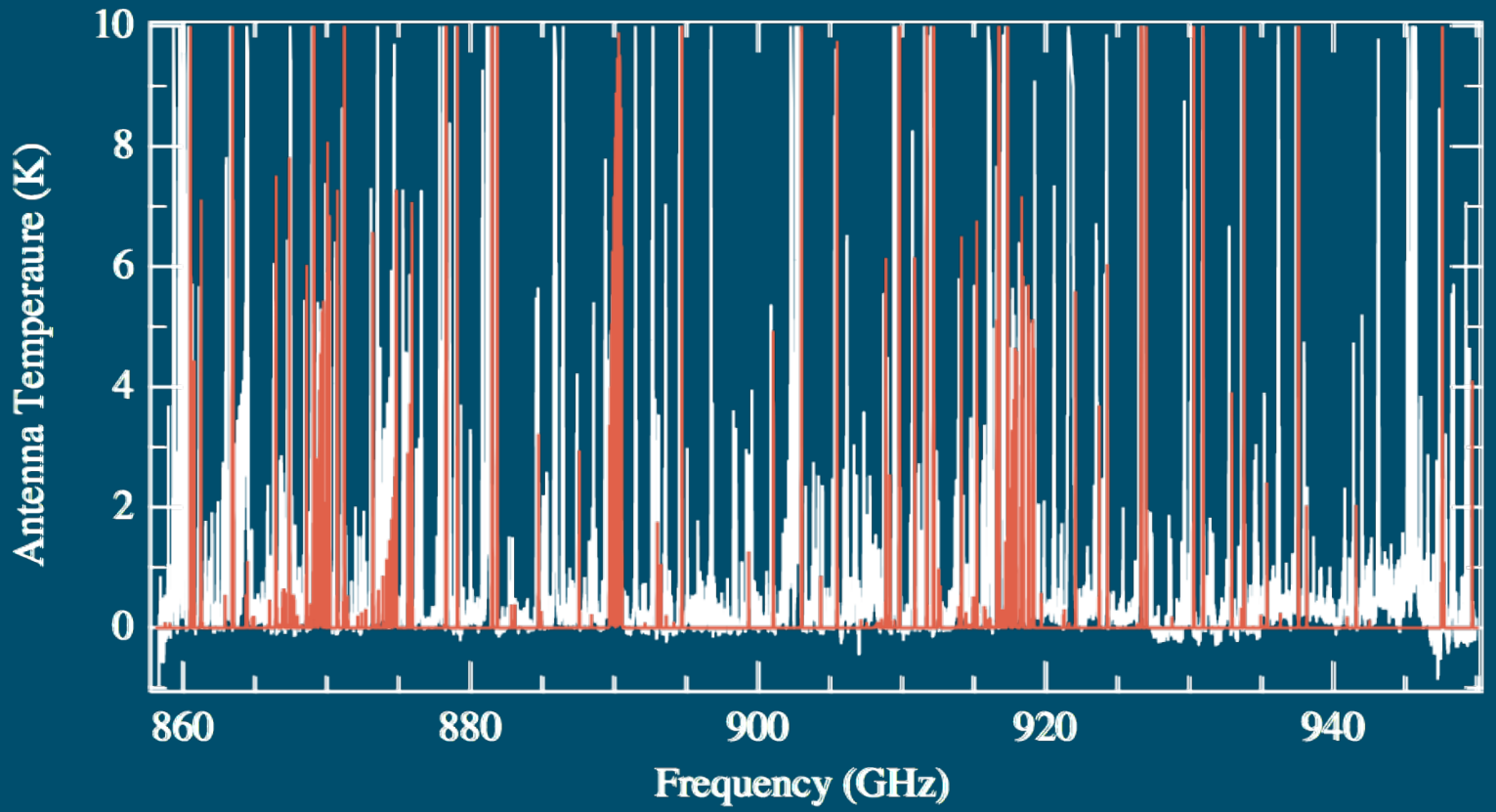

methanol (CH_3OH)

HEXOS

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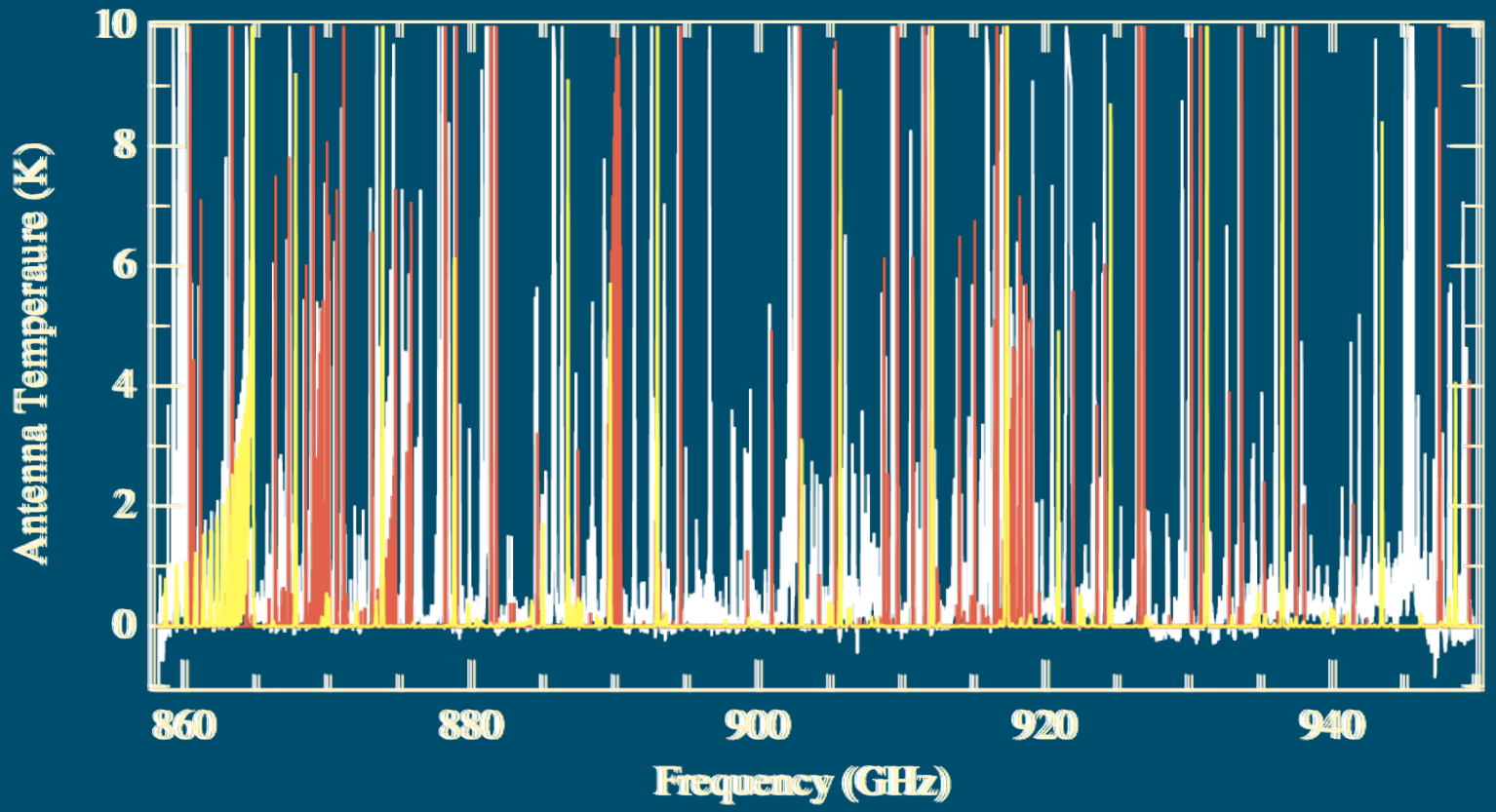
ORION KL spectrum around 900GHz



methanol (CH_3OH) sulphur dioxide (SO_2)

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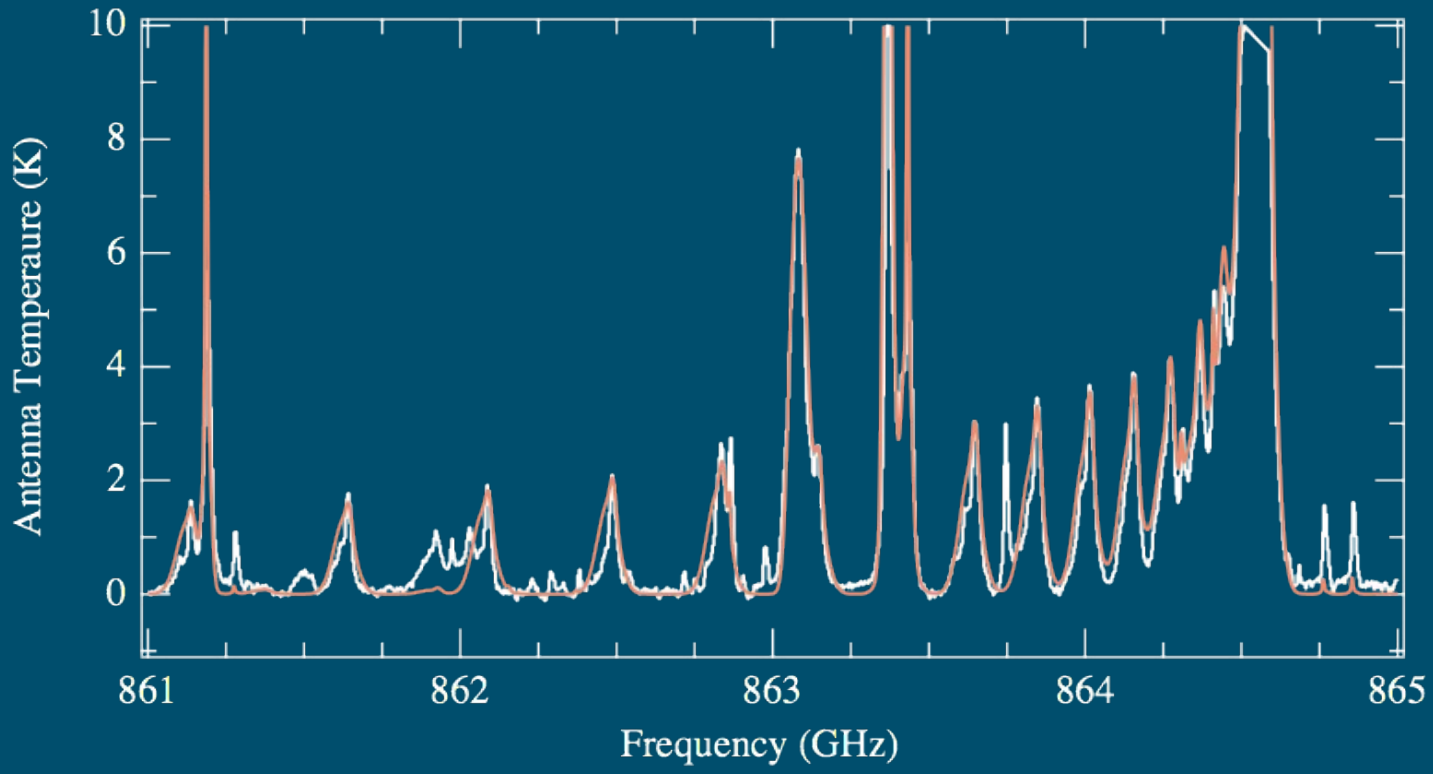
ORION KL spectrum around 900GHz



sulphur dioxide (SO_2)

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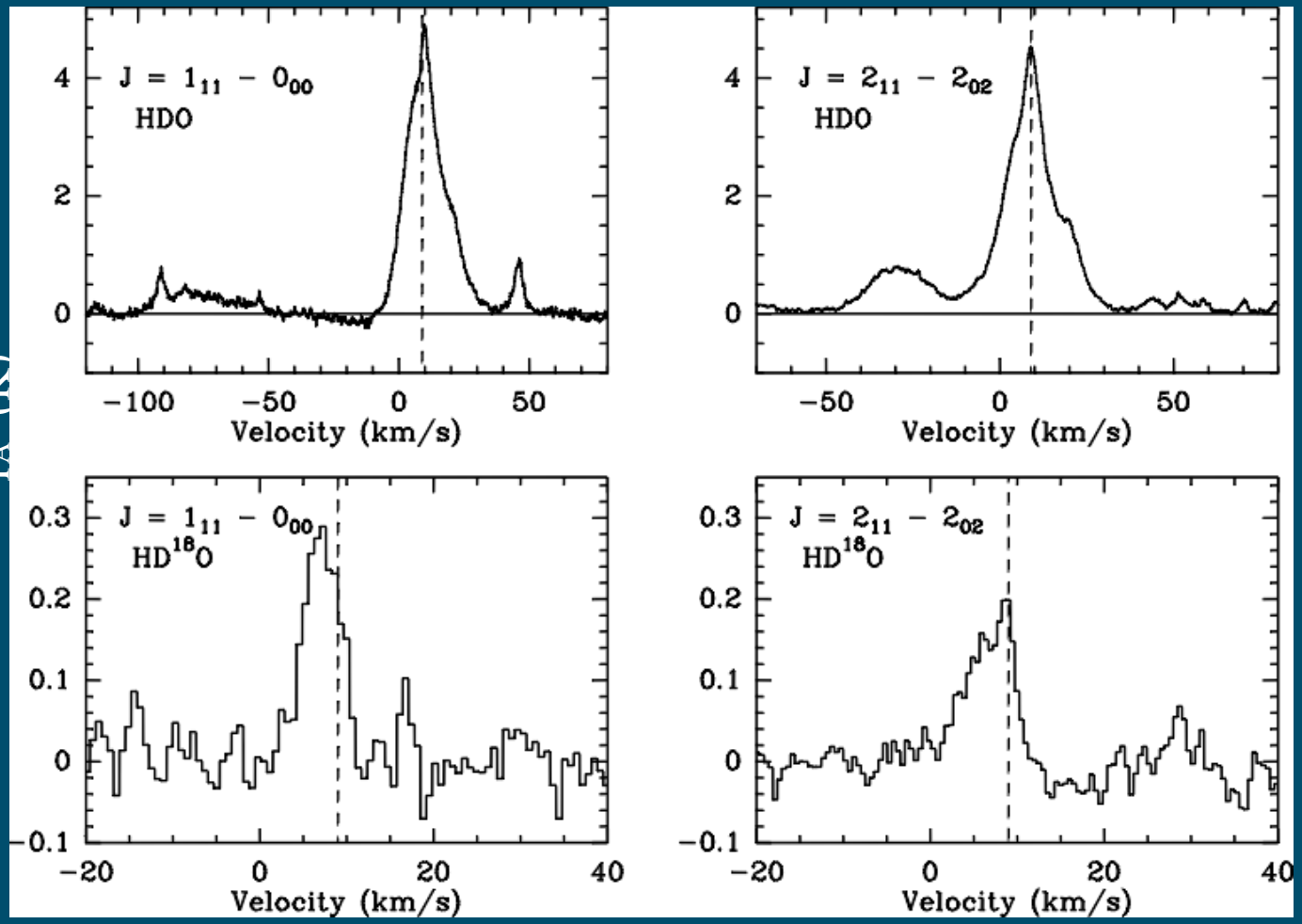
ORION KL : HD^{18}O DETECTION

Preliminary Estimate: HDO/H_2O ~ 3 x 10^{-3}
Previous value ~ 10^{-4}



HEXOS

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OUTLINE

1. INTRODUCTION TO HERSCHEL & HIFI
2. HIFI FIRST RESULTS: HEXOS & WISH
3. CHESS HIFI FIRST RESULTS

CHESS FIRST RESULTS

Cecilia Ceccarelli
A.Bacmann, A.Boogert, E.Caux, C.Comito, C.Dominik, B.Lefloch, D.Lis, F.vanderTak
and the CHESS team

The CHESS KP in a nutshell

ULTIMATE GOAL

CHEMICAL SURVEYS during the EARLY PHASES of STAR FORMATION

FOCUS

A coherent study of the line spectra in the HIFI frequency range of Star Forming Regions

METHOD

HIFI (and PACS) unbiased spectral surveys in sources representative of SFRs and processes

QUESTIONS

What atomic/molecular lines are present? In emission or absorption? How many and when?

IMMEDIATE GOALS

Guide successive HIFI observations & provide a legacy database for the general community

The CHESS KP in a nutshell

WHY ARE FIR/submm LINE SPECTRA SO IMPORTANT?

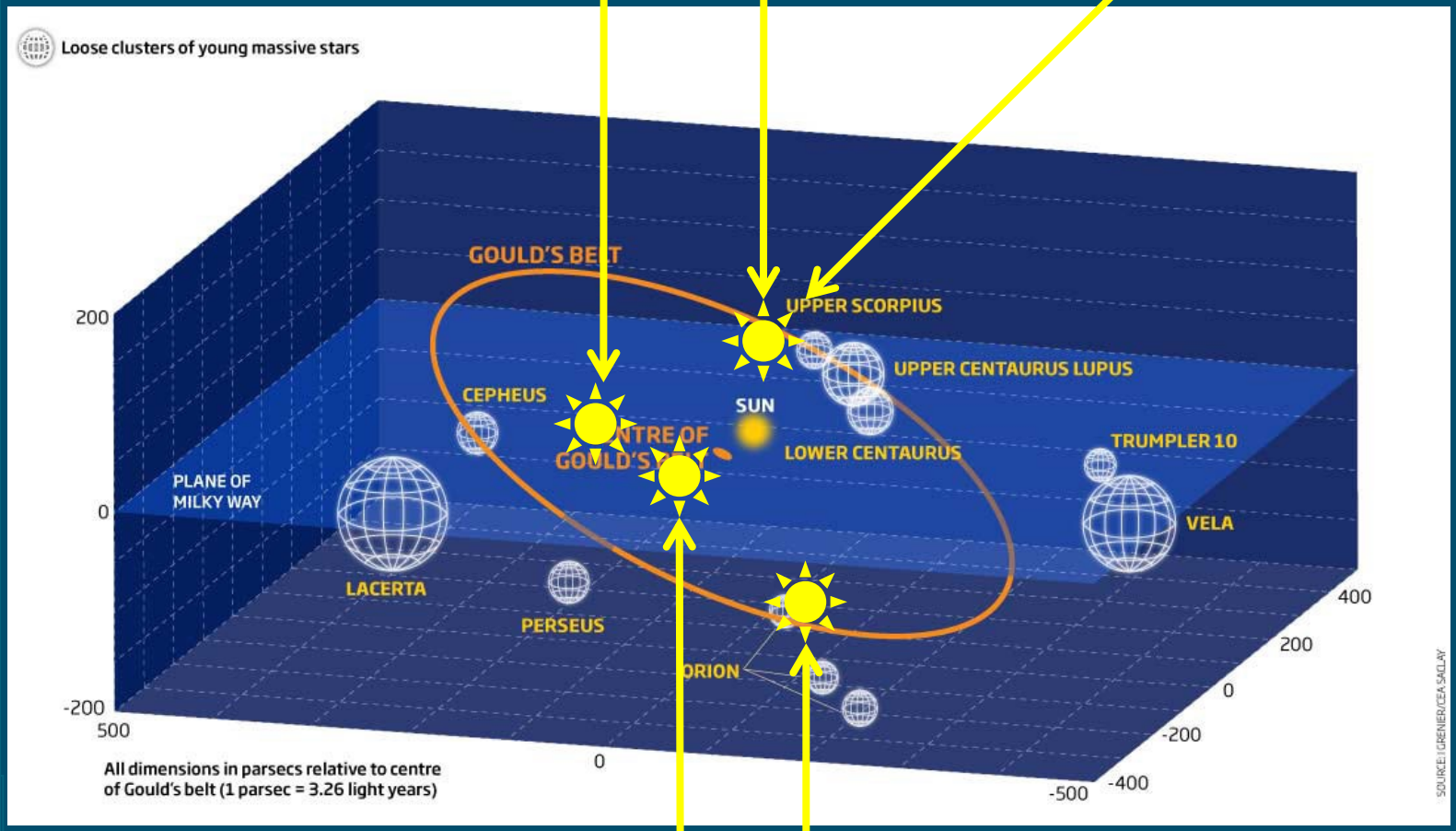
1. because FIR/submm lines are a very powerful *diagnostic of the physical conditions* in the Star Formation Regions (SFRs);
2. because FIR/submm lines spectra permit to reconstruct the *chemical composition* of the gas, which greatly affects the *physical and dynamical* evolution of the SFRs, and viceversa;
3. because the chemical composition in the first phases of star formation may *affect* the chemical composition of the objects that will eventually form the *planetary system*: planets, comets and asteroids.

CHESS TARGETS

From low- to high- mass protostars;
From pre- to post- collapse;
From the source to the surroundings.

Source	Distance (pc)	Luminosity (Lo)	Type
L1544	120	-	“Cold” Pre-Stellar Core
I16293E	120	-	“Warm” Pre-Stellar Core
L1157-B	220	-	Outflow shock spot
IRAS16293-2422	120	21	Class0 low mass protostar
OMC2-FIR4	440	$1x10^3$	Intermediate mass protostar
AFGL2591	1000	$2x10^4$	High mass protostar
NGC6334I	1700	$2x10^5$	High mass hot core
W51e	7000	$2x10^6$	High mass hot core

CHESS NEARBY LOW LUMINOSITY (<1000Lo) TARGETS



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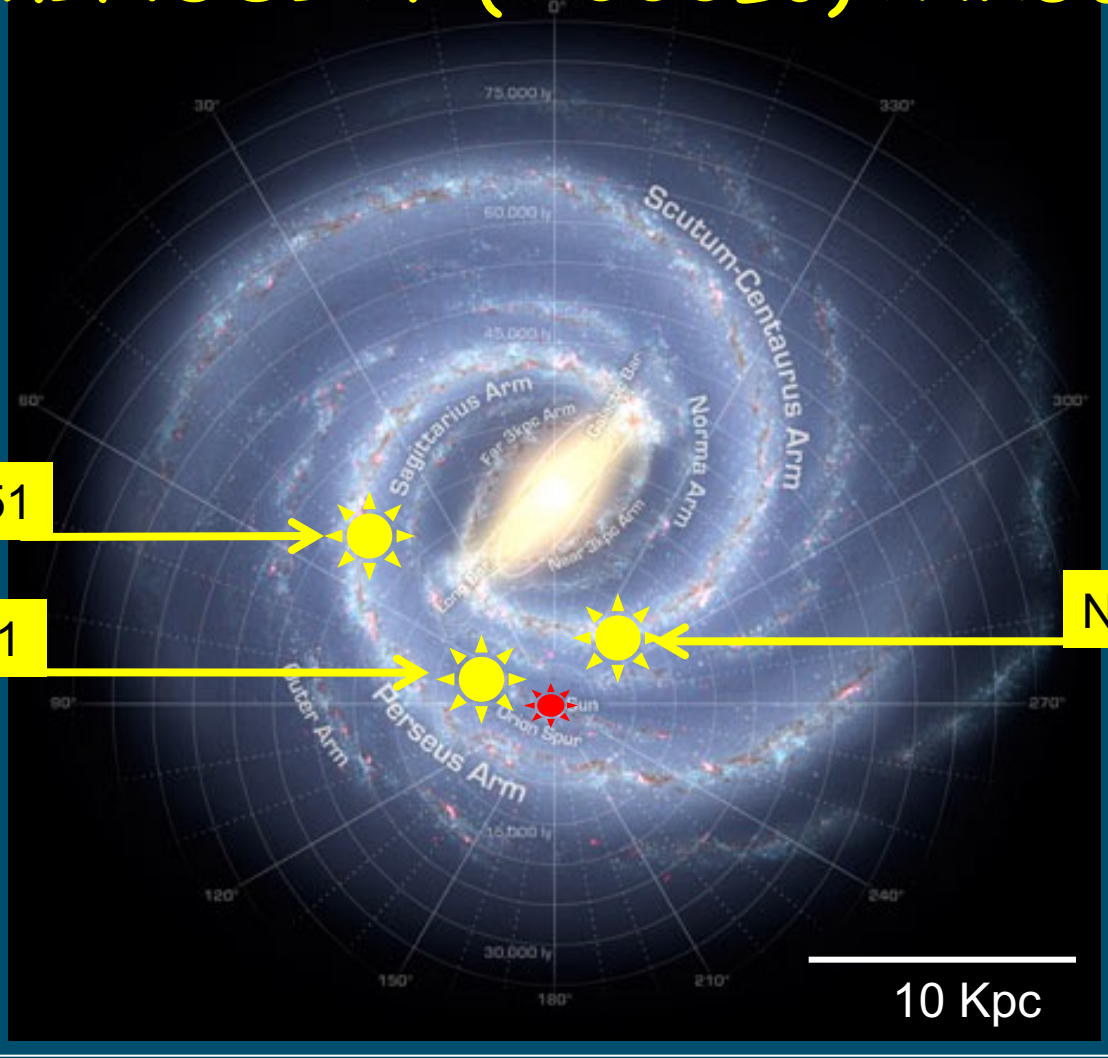
Herschel HIFI first results

CHESS DISTANT HIGH LUMINOSITY (>1000Lo)TARGETS



NOTE: ISM clouds at different galactocentric distances in the line of sight

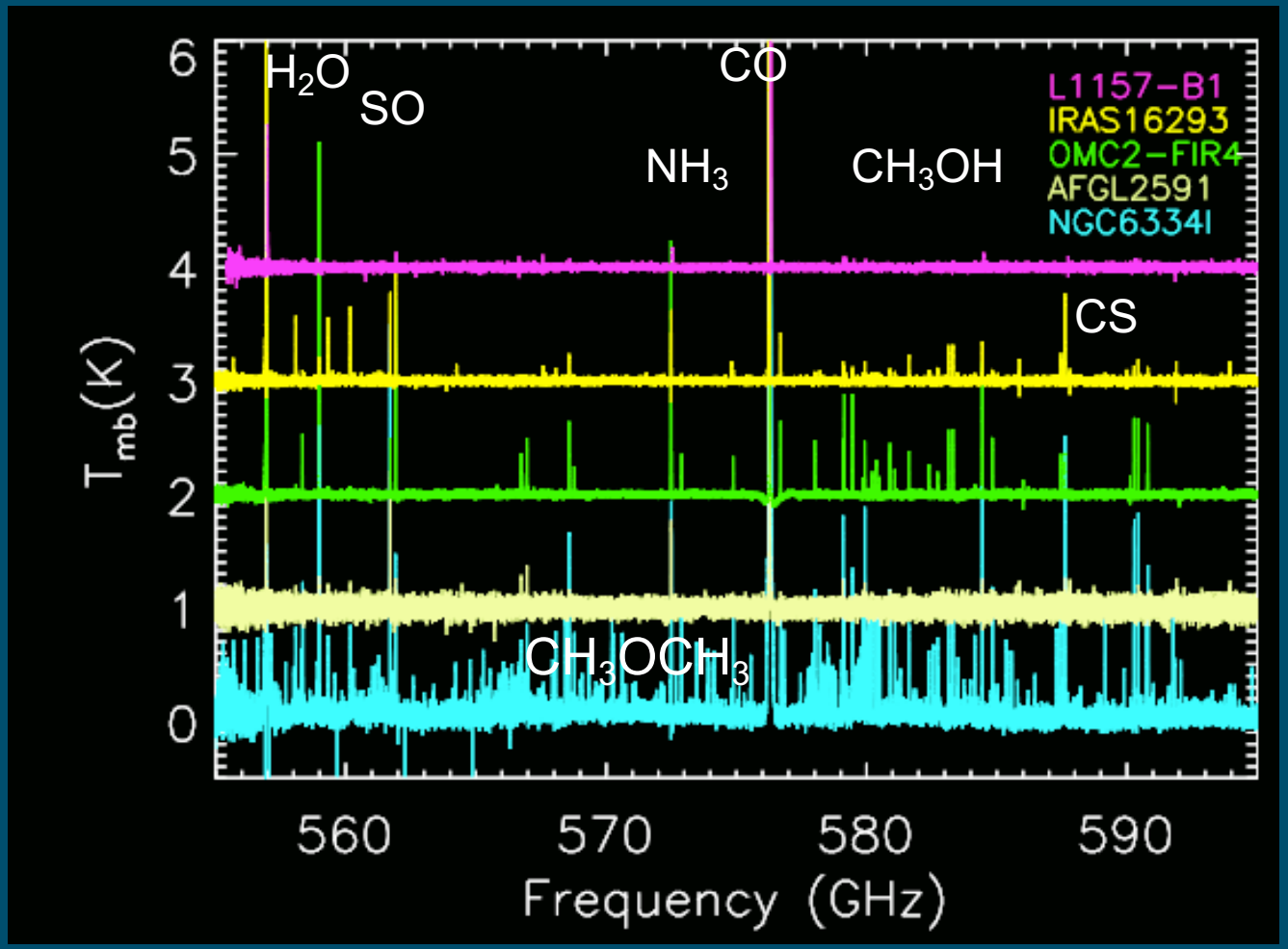
OBTAINED OBSERVATIONS

NOTE: OBTAINED DURING MARCH-APRIL, SOME ONLY TWO WEEKS OLD….

Source	Hr	Range (GHz)	Type
L1544	0	-	“Cold” Pre-Stellar Core
I16293E	0	-	“Warm” Pre-Stellar Core
L1157-B	2	555-636	Outflow shock spot
IRAS16293-2422	32	480-1790*	Class0 low mass protostar
OMC2-FIR4	6	480-960*	Intermediate mass protostar
AFGL2591	6	480-960*	High mass protostar
NGC6334I	14	480-1185*	High mass hot core
W51e	0	-	High mass hot core

NOTE: not fully covered frequency range

OVERVIEW of 555-635GHz SPECTRA



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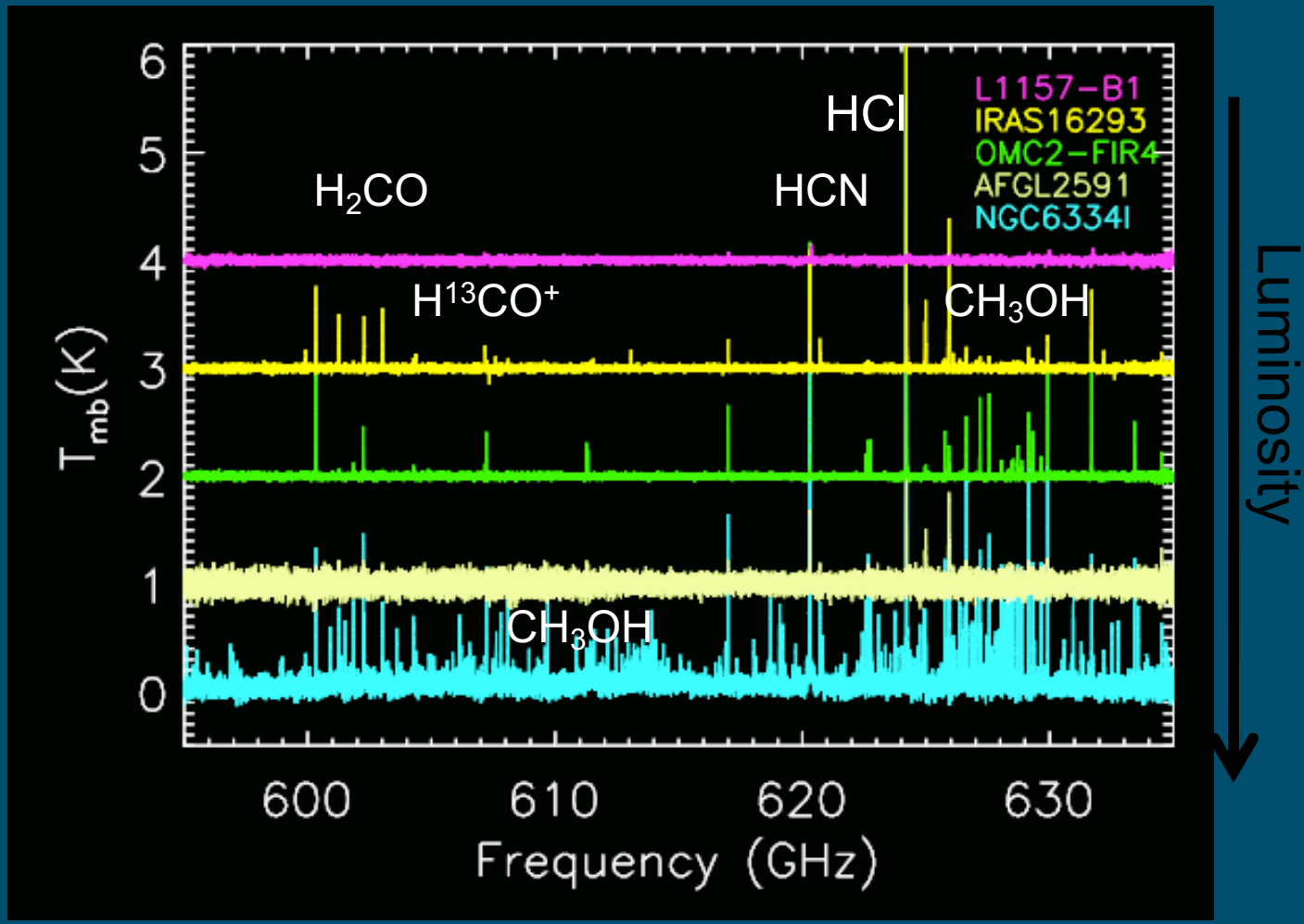
OVERVIEW of 555-635GHz SPECTRA



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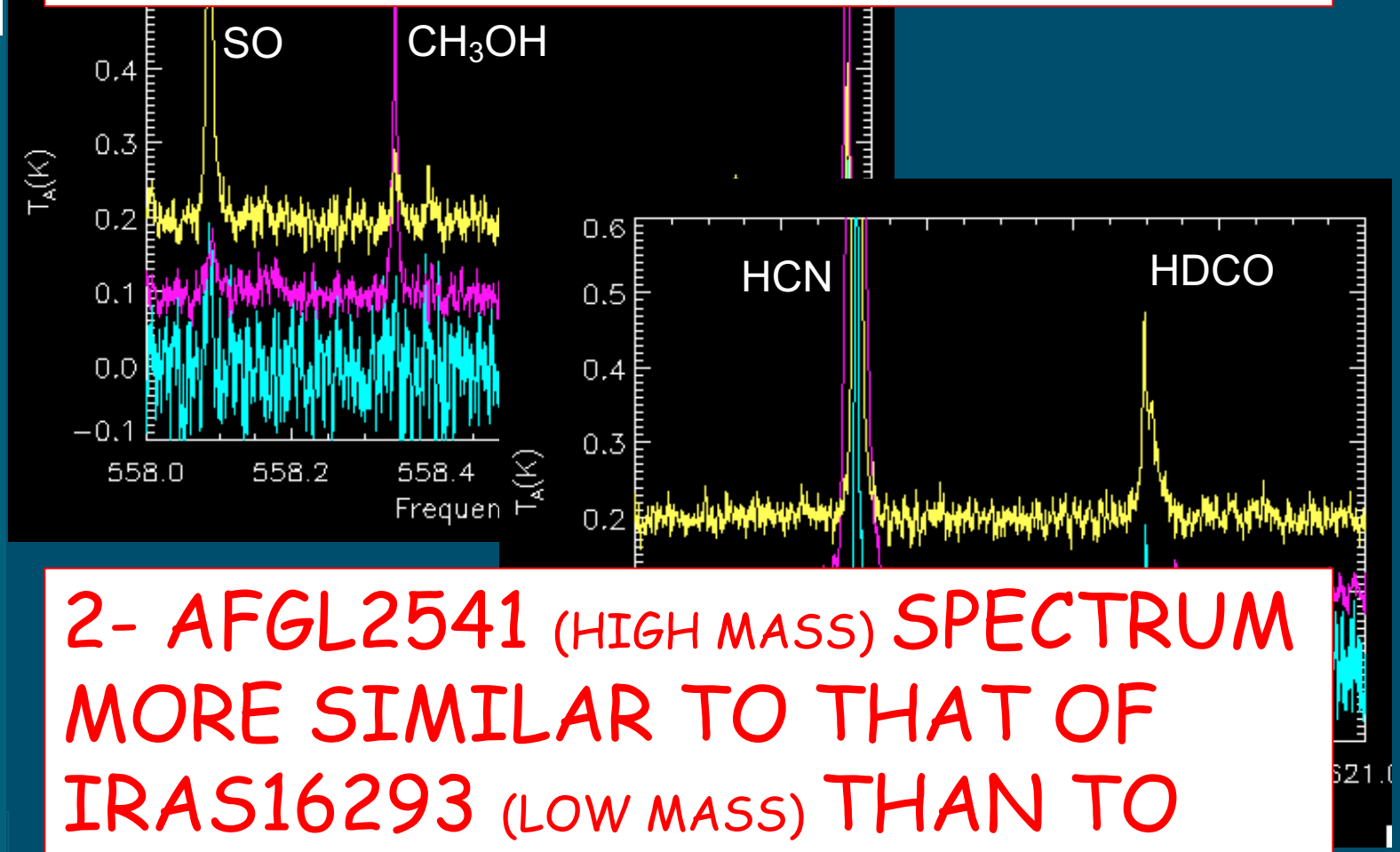
SAMPLEs OF OBSERVED SPECTRA

1- ONE SIZE DOES NOT FIT ALL

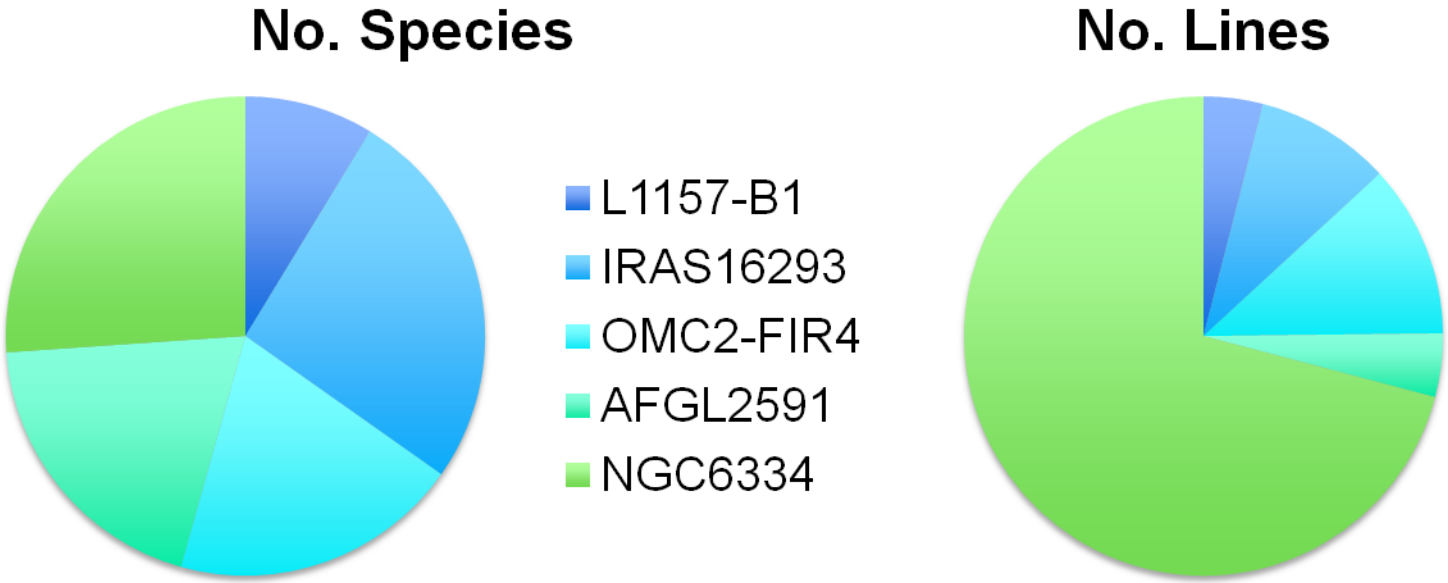


2- AFGL2541 (HIGH MASS) SPECTRUM MORE SIMILAR TO THAT OF IRAS16293 (LOW MASS) THAN TO OMC2-FIR4 (INTERMEDIATE MASS) ONE

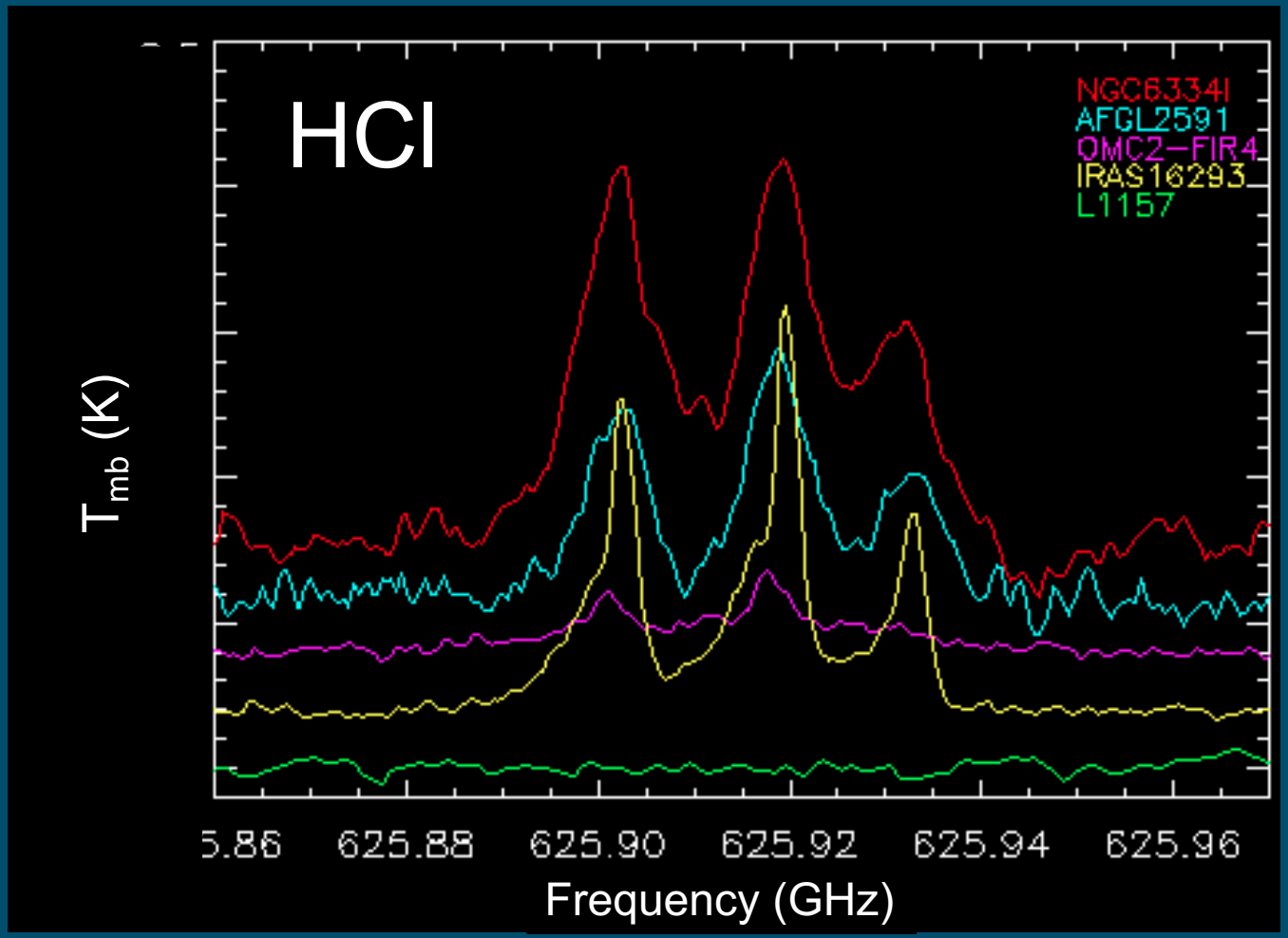
OVERVIEW of 555-635GHz SPECTRA

A bit of statistics

Source	Luminosity (Lo)	No Lines	No Species
L1157-B1	-	27	8
IRAS16293	21	62	24
OMC2-FIR4	$1x10^3$	79	18
AFGL2591	$2x10^4$	29	18
NGC6334I	$2x10^6$	480	24



ZOOM ON HCl



REACHED RMS ~ 10-20 mK

IN OPTICALLY THIN LINES, THE HYPERFINE COMPONENTS INTENSITY ARE 2:3:1

ZOOM ON HCl

PRELIMINARY ESTIMATES from CHESS obs

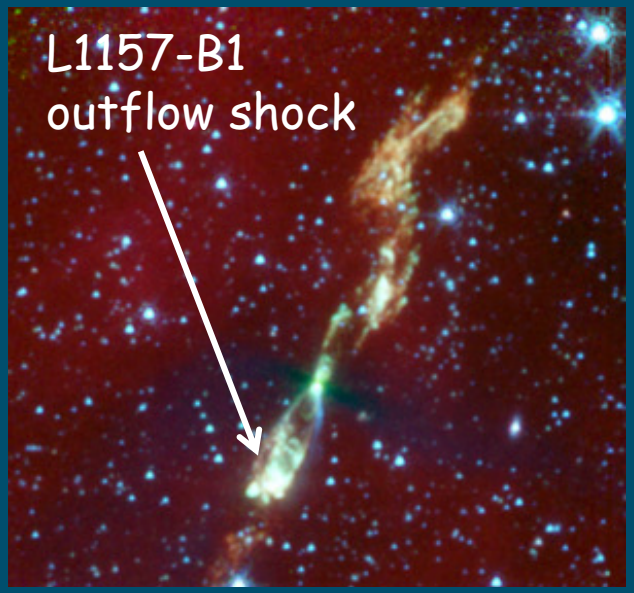
SOURCE	SIZE S	N(HCl)	*x*(HCl)	N($H^{35}Cl$)	$^{35}Cl/^{37}Cl$
IRAS16293	35”	$1.5x10^{13}$	$\sim5x10^{-10}$	$1.2x10^{12}$	3.3
OMC2-FIR4	35”	$2.5x10^{12}$	$\sim1x10^{-11}$	$3.3x10^{11}$	3.9
AFGL2591	35”	$1.6x10^{13}$	$\sim6x10^{-11}$	$7.0x10^{12}$	2.2
NGC6334I	10”	$4.0x10^{14}$	$\sim1x10^{-10}$	1.5x	
				Solar	3.1

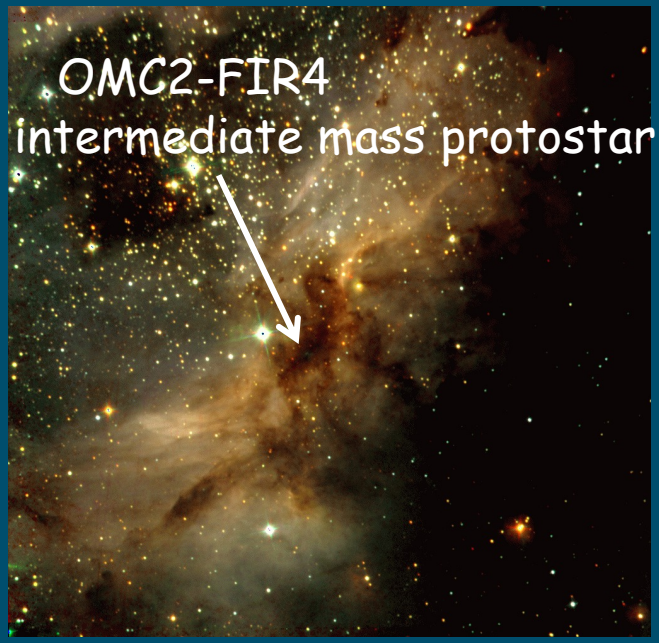
HCl PREDICTED TO BE THE MOST ABUNDANT Cl RESERVOIR IN MOLECULAR GAS, ~70% (e.g. Neufeld &Wolfire 2009).

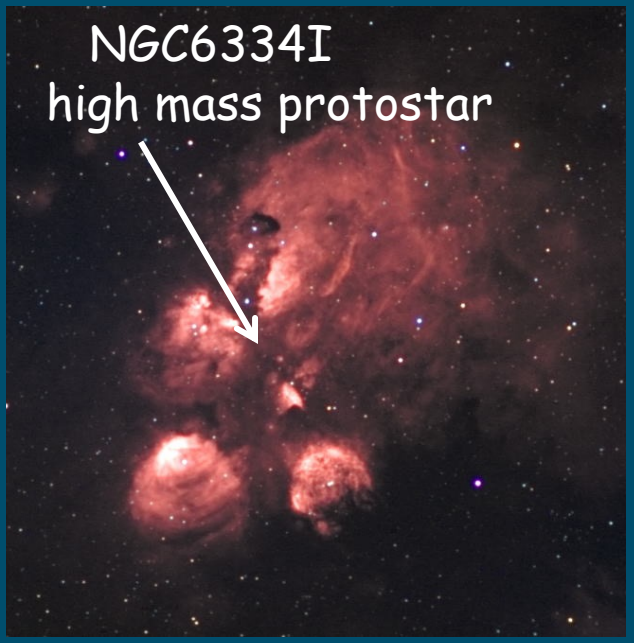
Cl FORMED IN >10Mo STARS IN SN EXPLOSION

OBSERVED DIFFERENCES DUE TO DIFFERENT “INITIAL” CONDITIONS ?

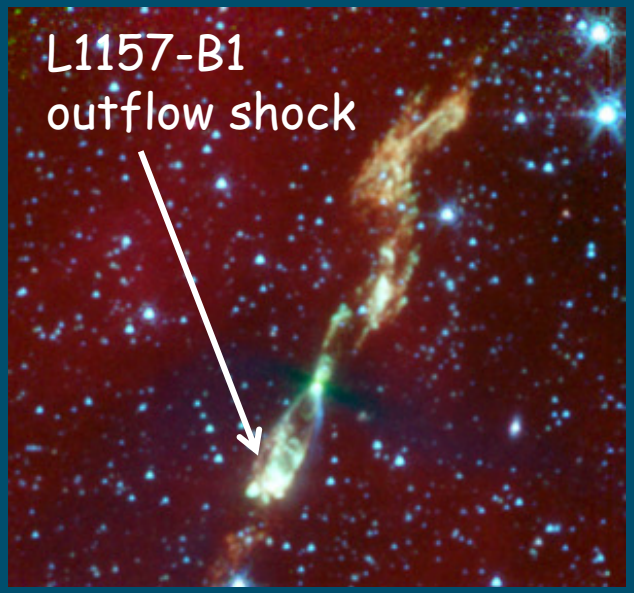
The CHESS observed targets



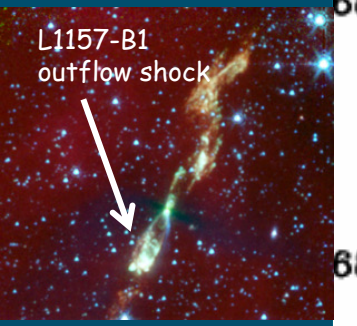


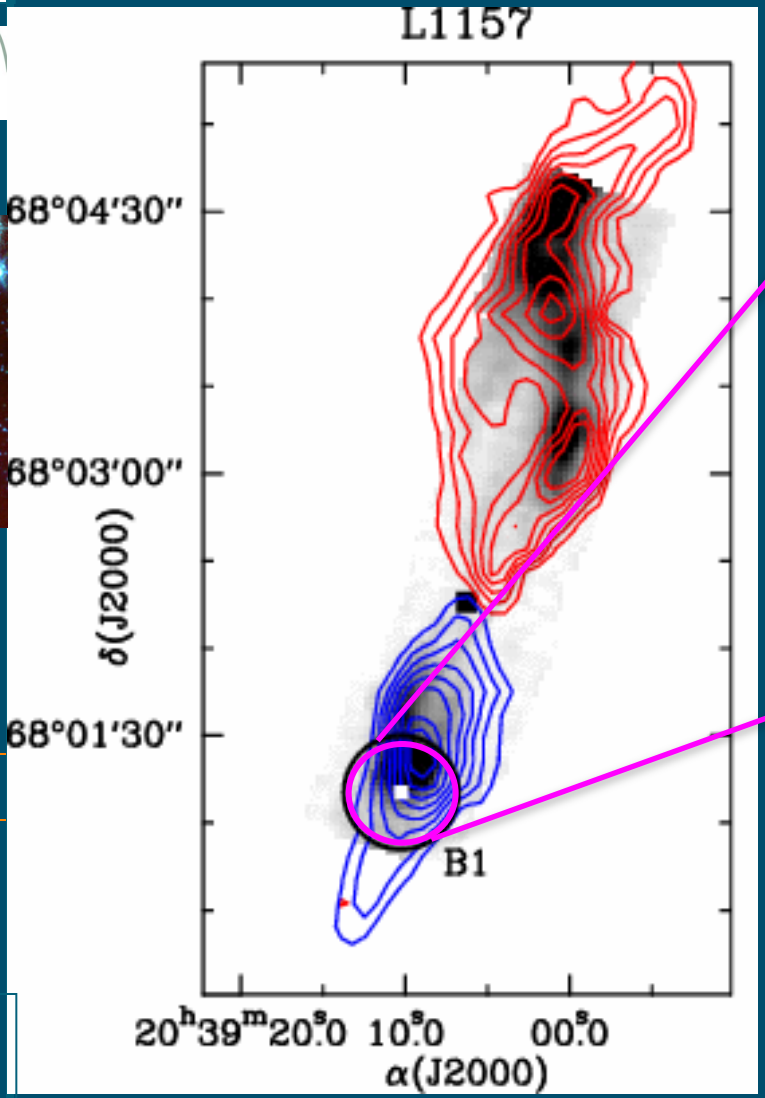


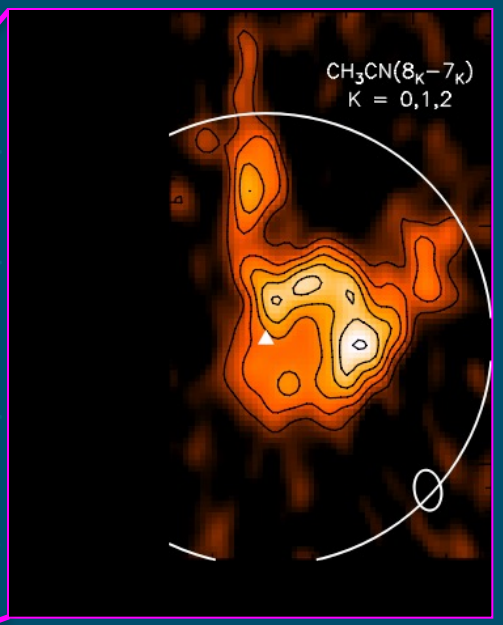
The CHESS observed targets



The CHESS PV observations of L1157-B1







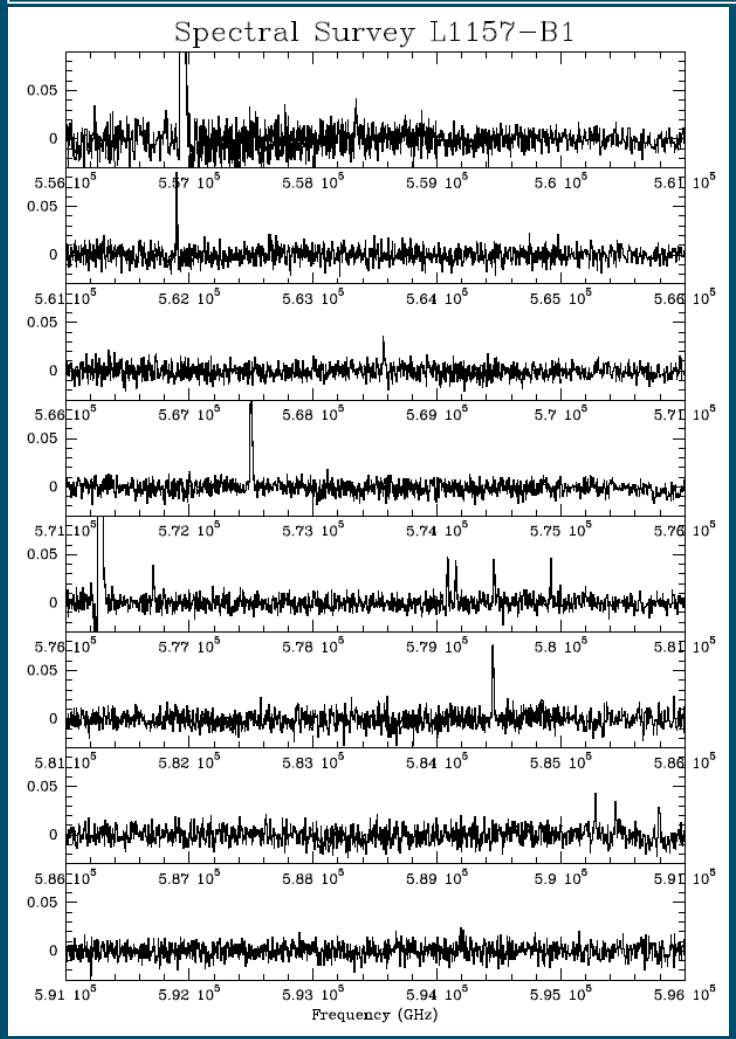
HIFI PV data, Aug 2009

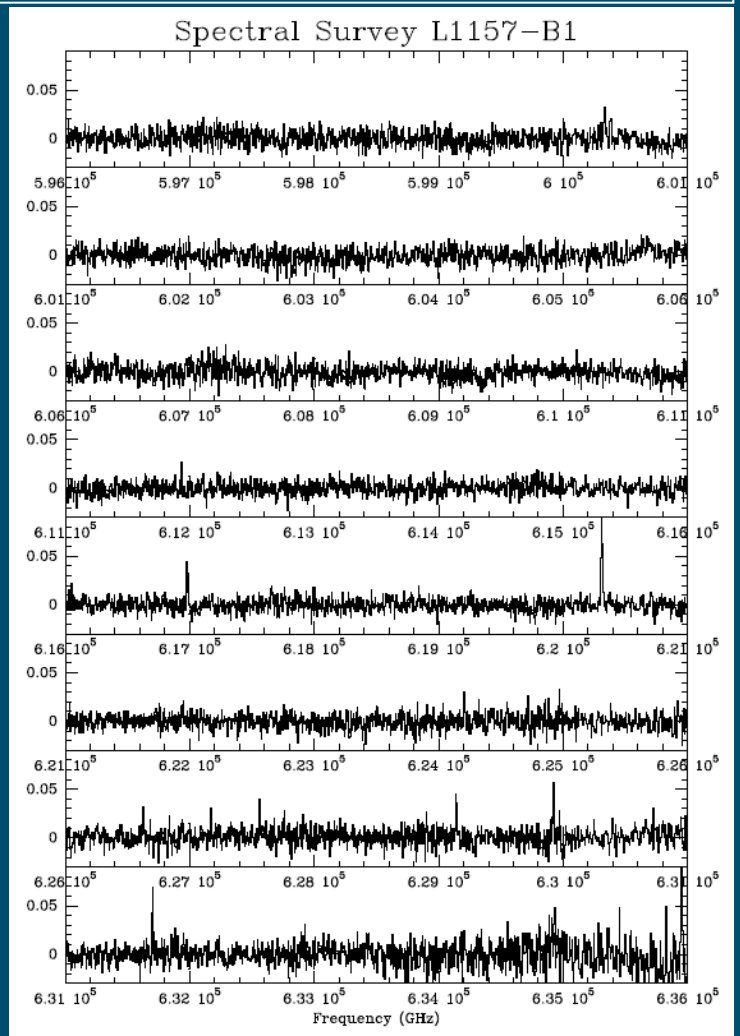
Spectrum between 561 and 633GHz (HIFI band 1b) at the position B1, a spot with a molecular shock.

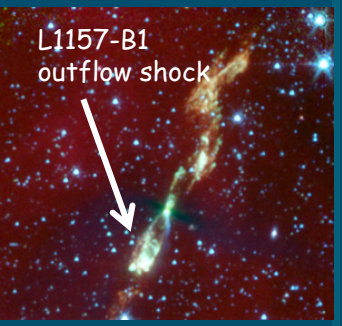
Cecilia Ceccarelli

An unbiasedview of HIFI Band 1b

DETECTED SEVERAL LINES FROM SEVERAL SPECIES





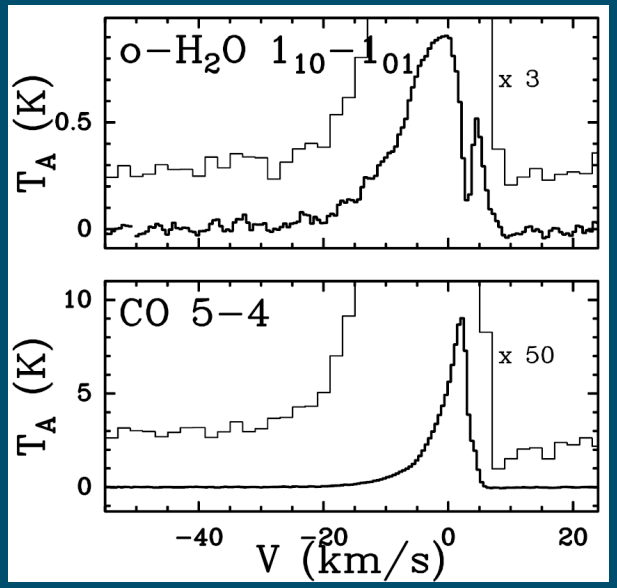


Cecilia Ceccarelli

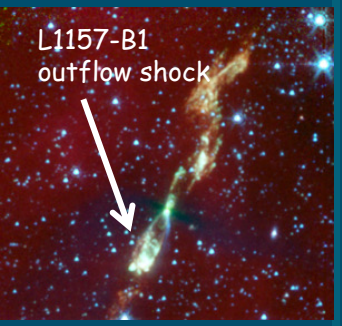
LAOG
Laboratoire d'Astrophysique de Grenoble

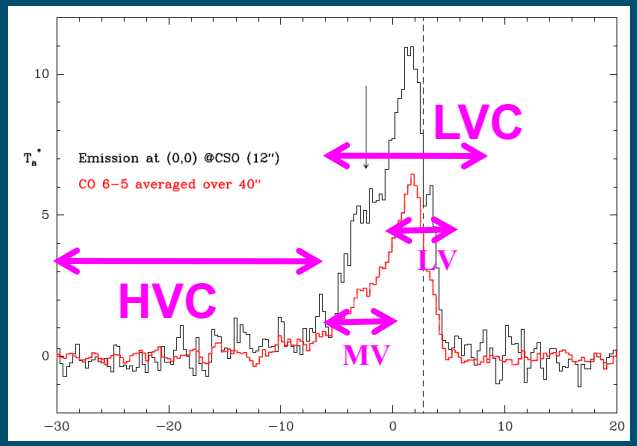
Herschel HIFI first results

Origin of the Molecular Emission



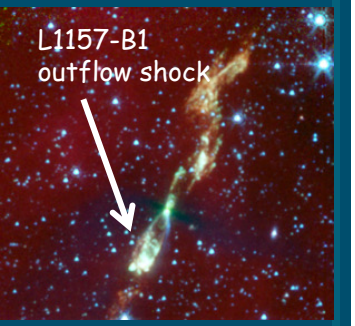
High-sensitivity of HIFI → emission in CO and H_2O detected up to v ≈ -30 km/s
Broad H_2O line





ThreeVelocity Components :
HVC : v < - 7 km/s
LVC : v > -7 km/s :
MV / LV

WATER ABUNDANCE in L1157-B1



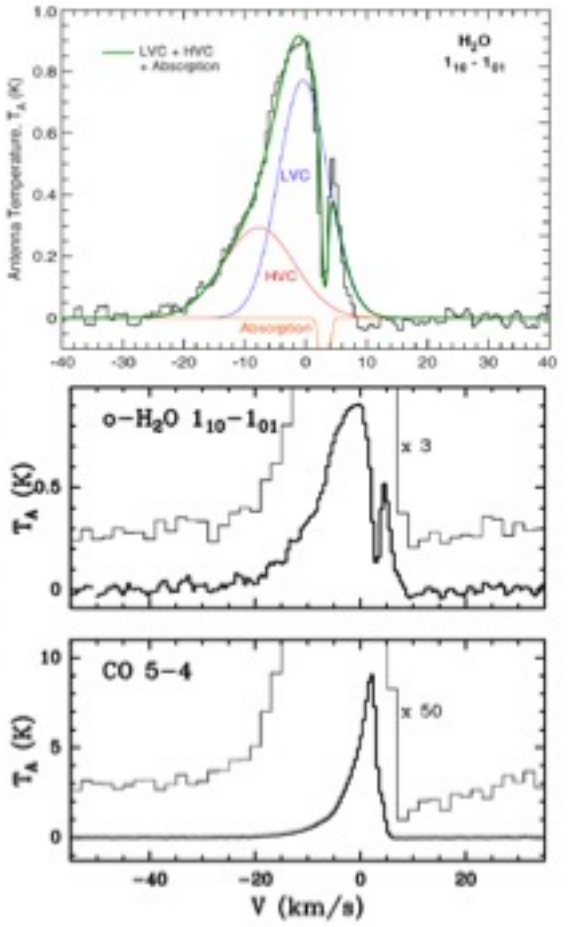
The CHESS Spectral Survey of Star Forming Regions : Peering into the protostellar shock L1157-B1. ⋆

II. Shock Dynamics

Lefloch B.[1], Cabrit S.[2], Codella C.[3], Melnick G.[4], Cernicharo J.[5], Caux
Ceccarelli C.[1], Gueth F.[10], Hily-Blant P.[1], Lorenzani A.[3], Neufeld D.[11]
J.R.[5], Parise B.[13], Salez M.[2], Schuster K.[10], Viti S.[14], Bacmann A.[1], Ba
Comito C.[13], Coutens A.[6], Crimier N.[1,5], Dominik C.[17,18], Demyk K.[6], E
M.[2], Goldsmith P.[20], Helmich F.[21], Herbst E.[22], Jacq T.[15], Kahane C.[1],
Lord L.[16], Maret S.[1], Pearson J.[20], Phillips T.[16], Saraceno P.[7], Schilke
Wiel M.[18], Vastel C.[6], Wakelam V.[15], Walters A.[6], Yorke H.[20], Bachiller
Kramer C.[23,25], Larsson B.[26], Lai R.[27], Maiwald F.W.[20], Martin-Pintad
Stutzki J.[23], and Wunsch J.H

(Affiliations can be found after the refe

Preprint online version: March 31, 2



Vel. comp	Size (“)	N(CO) 10^{16}cm^{-2}	n(H_2) cm^{-3}	T K	x(H_2O)
LVC	25	8	~10^5	100	~10^{-6}
HVC	7	5	~10^4	400	~10^{-4}

Lefloch et al.Herschel Special issue

Cecilia Ceccarelli

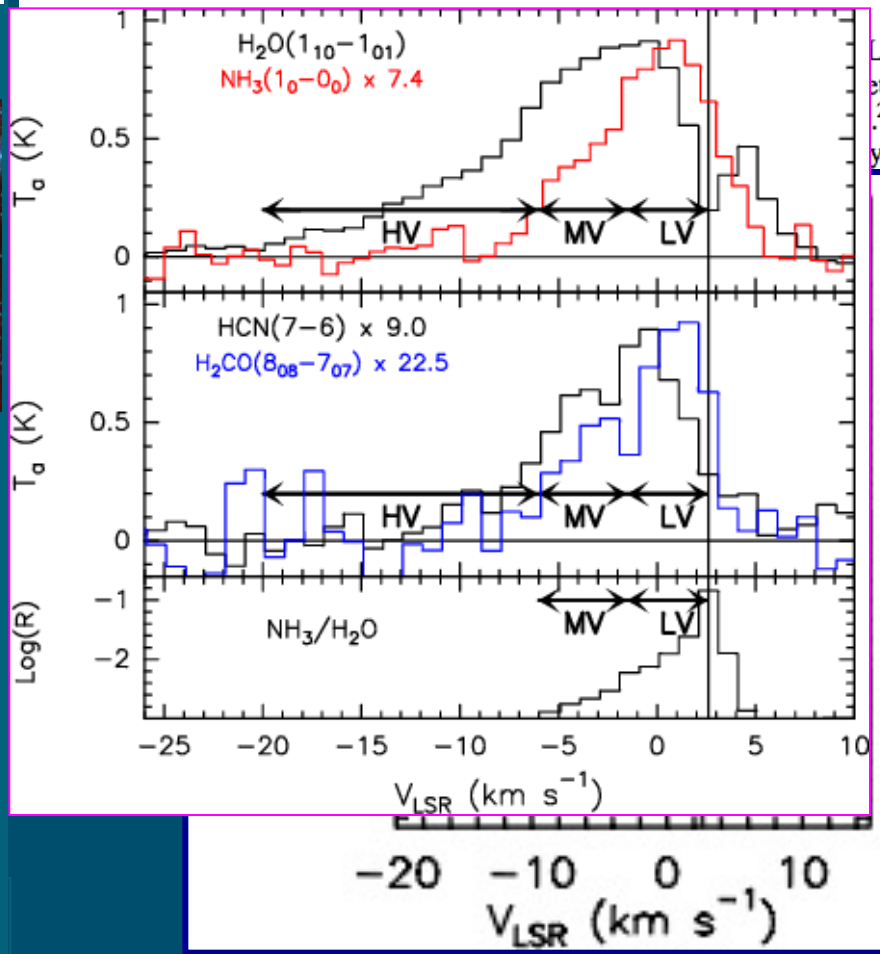
Herschel HIFI first results

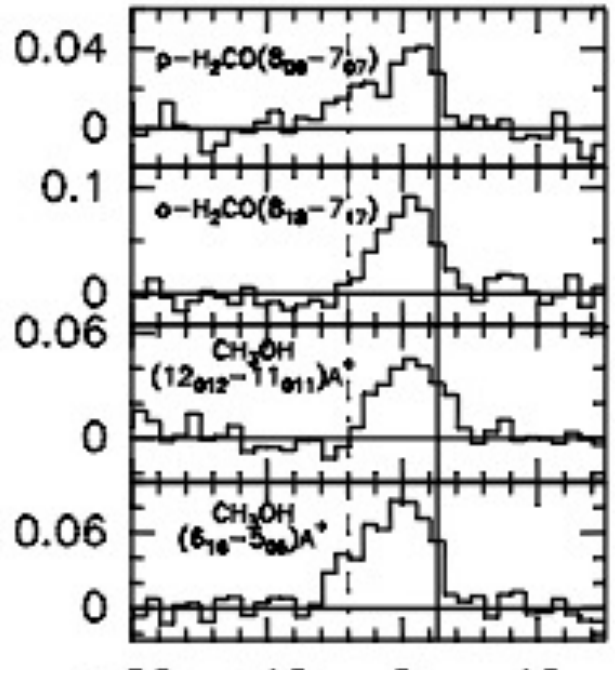
Differenttracers at differentvelocities

The CHESS Spectral Survey of Star Forming Regions: Peering into the protostellar shock L1157-B1

I. Shock Chemical Complexity*

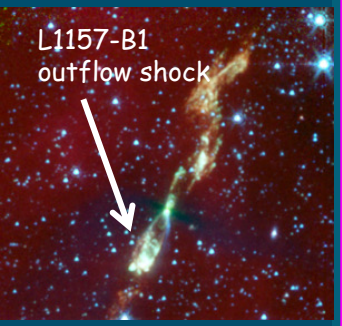
Lorenzani A.[1], Viti S.[5,6], Hily-Blant P.[2], Parise B.[7], ettini M.[6], Boogert A.[11], Gueth F.[12], Melnick G.[13], .[2,15], Baudry A.[15], Bell T.[16], Blake G.[16], Bottinelli yk K.[4], Encrenaz P.[10], Falgarone E.[10], Fuente A.[19],





T_{gas}>200K and a rich chemistry: CH_3OH, H_2CO, NH_3,HCN,….

Codella et al.Herschel Special issue



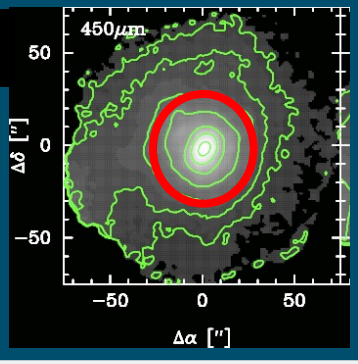
Cecilia Ceccarelli

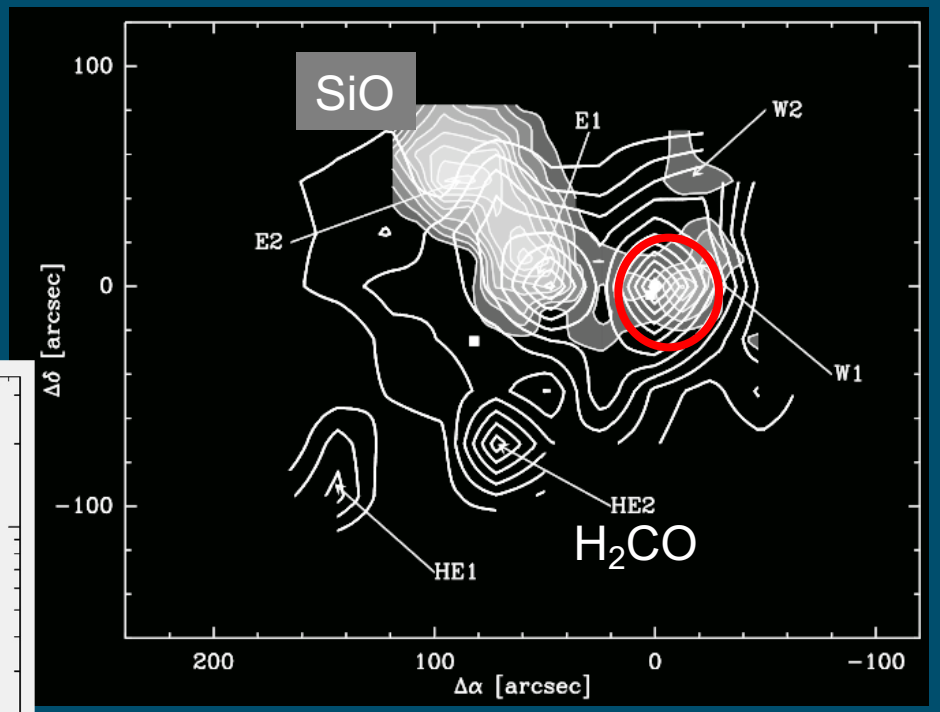
Herschel HIFI first results

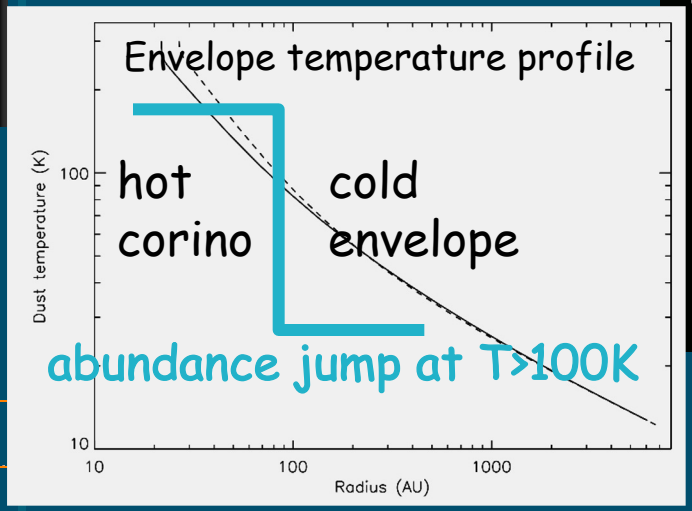
The CHESS observed targets

The low mass protostar IRAS16293-2422

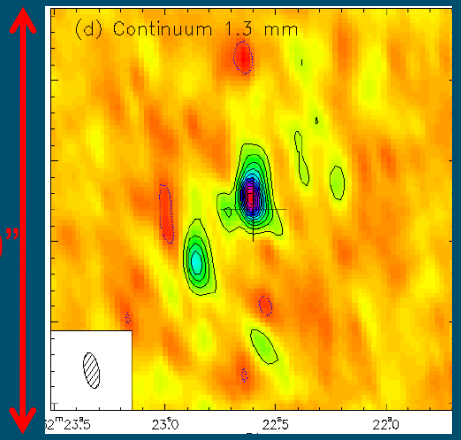
450μm







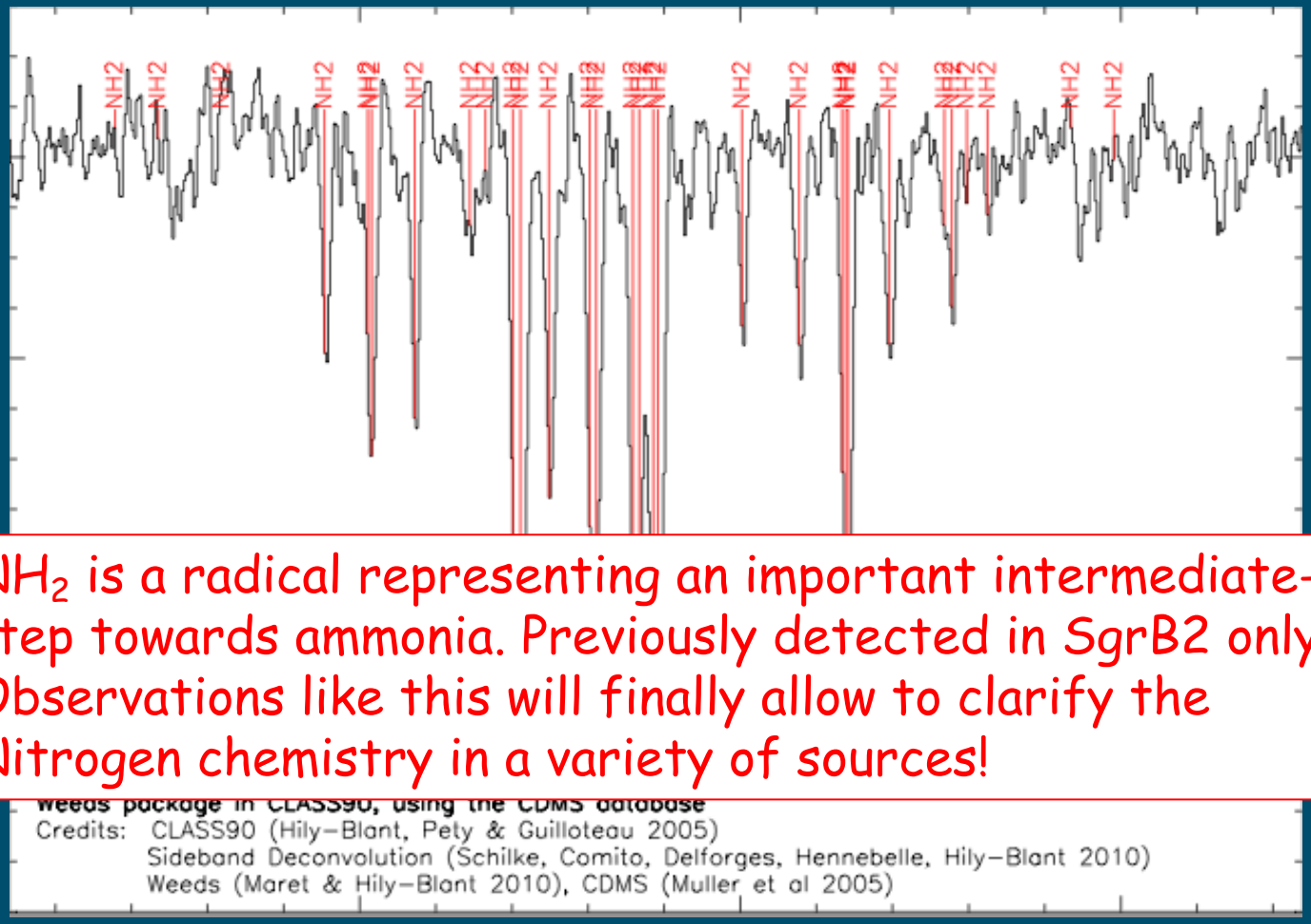
ENVELOPE +
BINARY SYSTEM +
a little of OUTFLOW
in the HIFI BEAM (~36" in band 1)



Cecilia Ceccarelli
LAOG

Herschel HIFI
first results

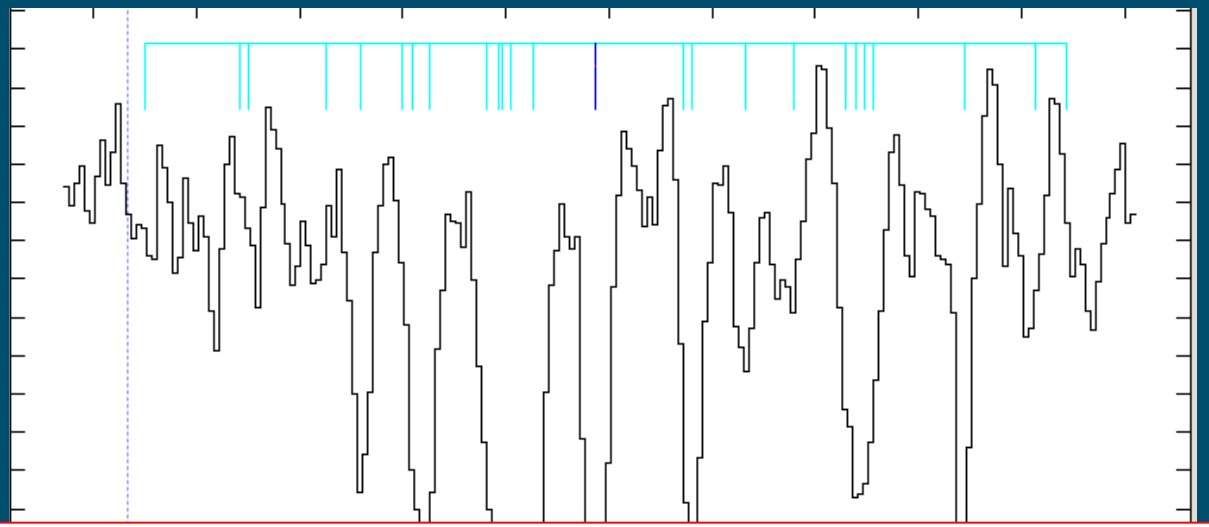
HIFI observations of IRAS16293-2422: first results



NH_2 is a radical representing an important intermediate-step towards ammonia. Previously detected in SgrB2 only. Observations like this will finally allow to clarify the Nitrogen chemistry in a variety of sources!

P.Hily-Blant et al. : THEABSORPTION SPECTRUM of NH_2

HIFI observations of IRAS16293-2422: first results



First firm detection of ND !

Previously tentatively detected in Orion by ODIN.

ESTIMATED ND/NH~30%

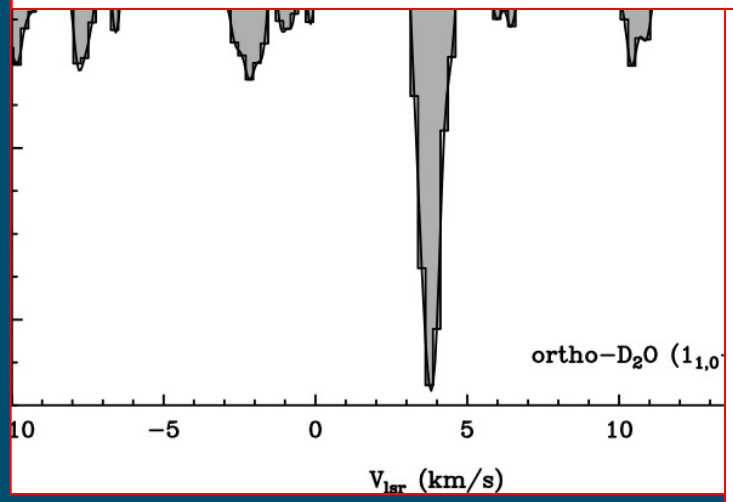
Credits: CASSIS (Caux et al.) at http://cassis.cesr.fr/

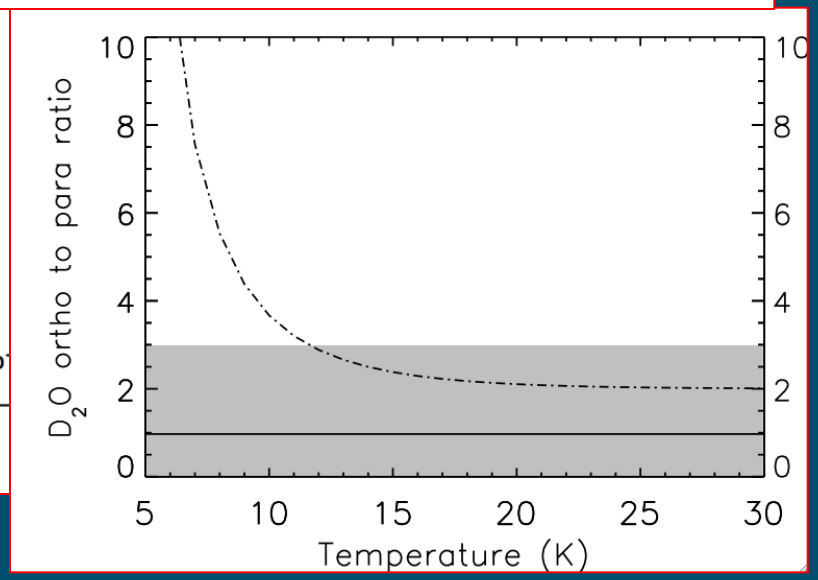
Bacmann et al. : THE ABSORPTION SPECTRUM of ND

HIFI observations of IRAS16293-2422: first results

First detection of ortho-D_2O

ESTIMATED ORTHO/PARA RATIO=2

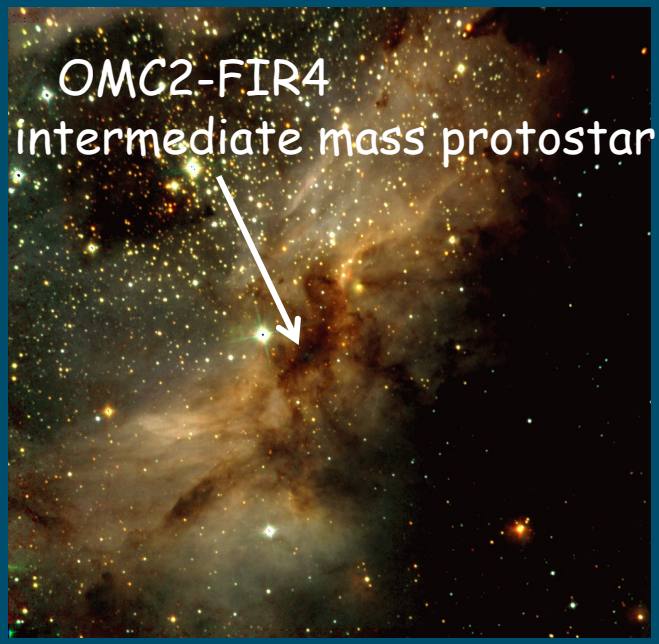




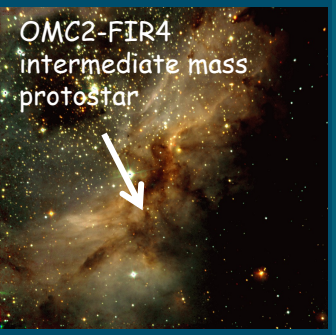
Vastel et al. : THE ABSORPTION of the fondamental line of ortho-D_2O

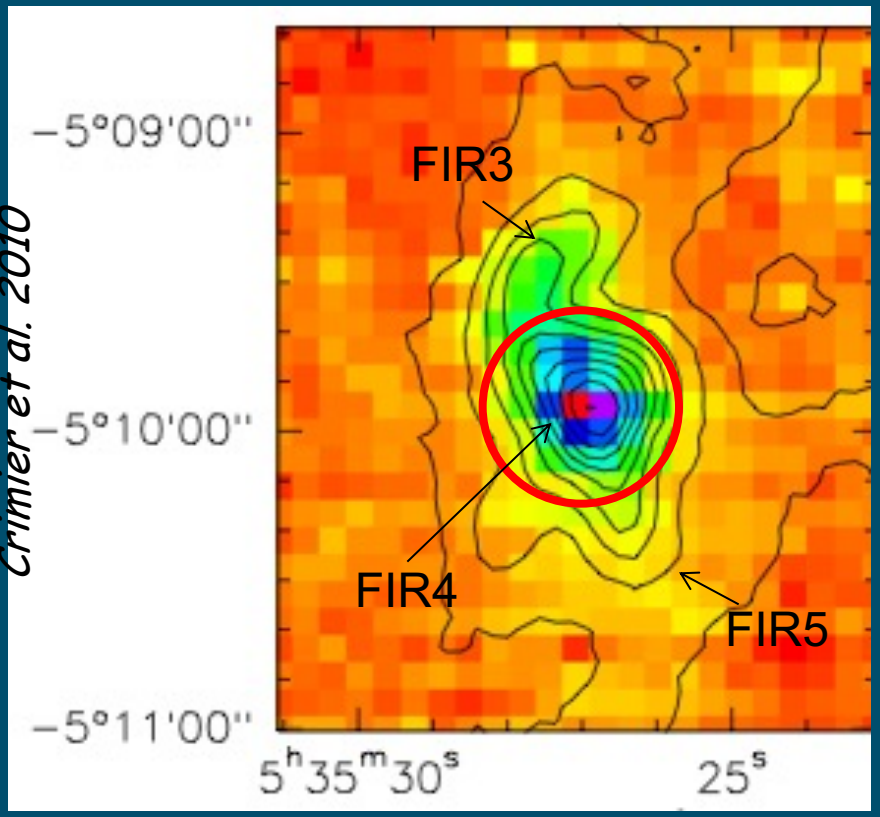
Cecilia Ceccarelli

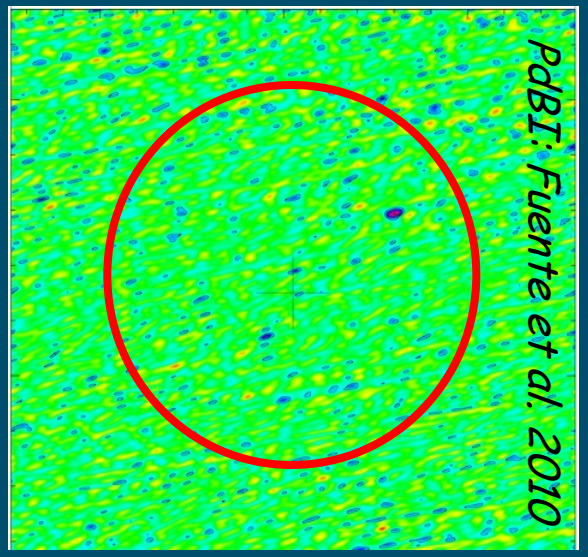
The CHESS observed targets



HIFI observations of OMC2-FIR4





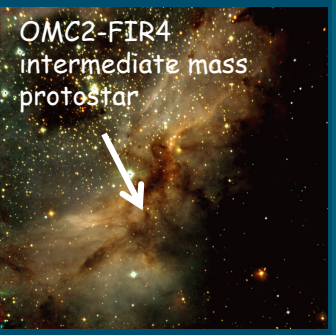


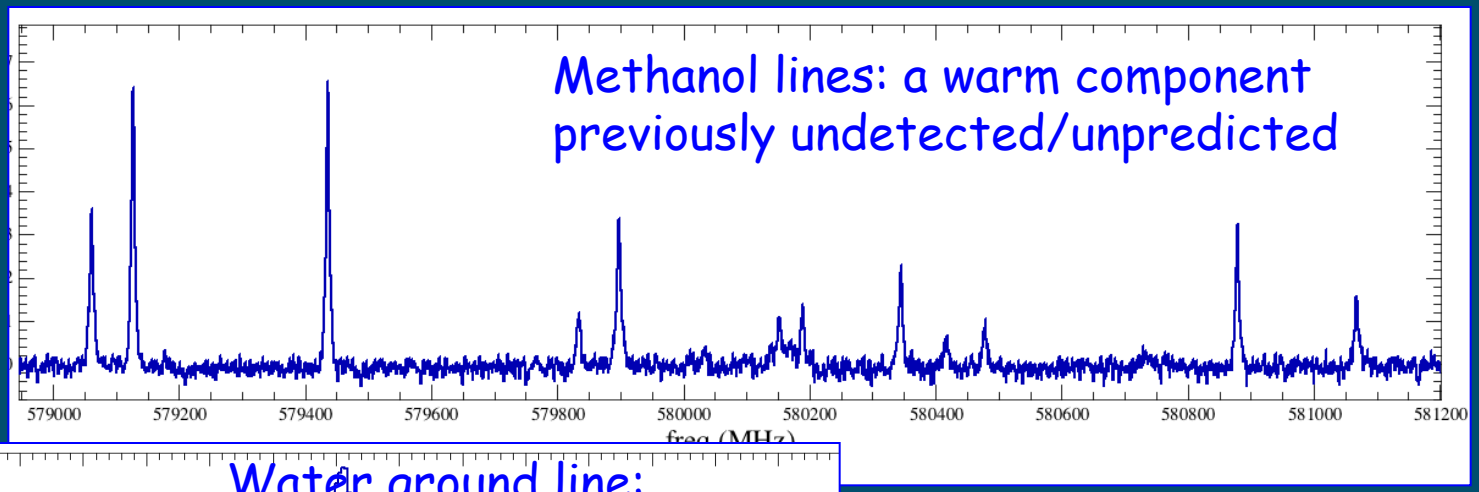
ENVELOPE +
a little of OUTFLOW
in the HIFI BEAM (~36" in band 1)

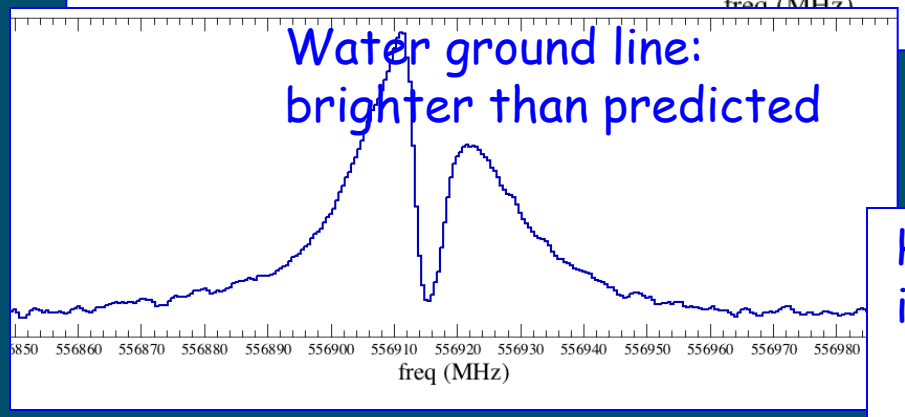
Cecilia Ceccarelli

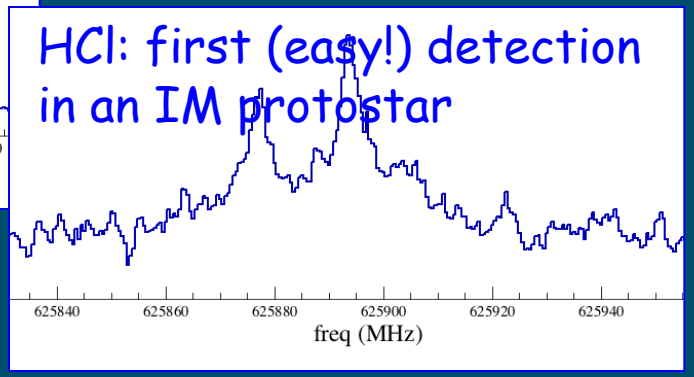
HIFI observations of OMC2-FIR4: first results

Band 1b in PSP2: rich spectrum
Some examples:





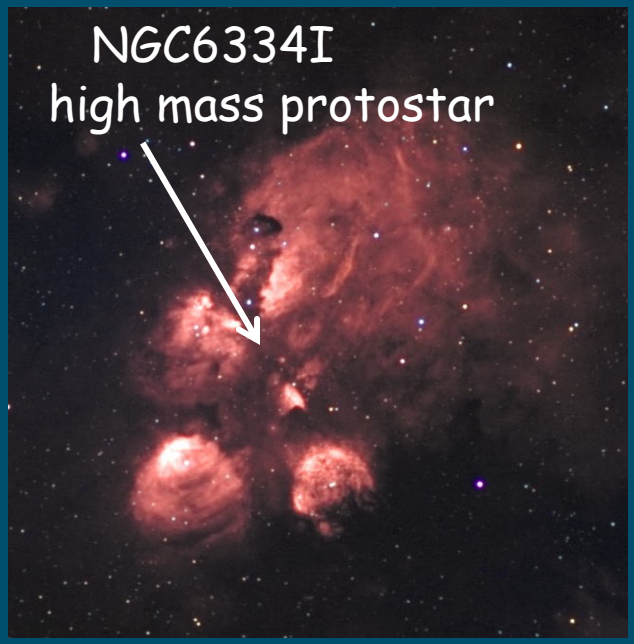




Kama et al. HIFI Special issue
Crimier et al. HIFI Special issue

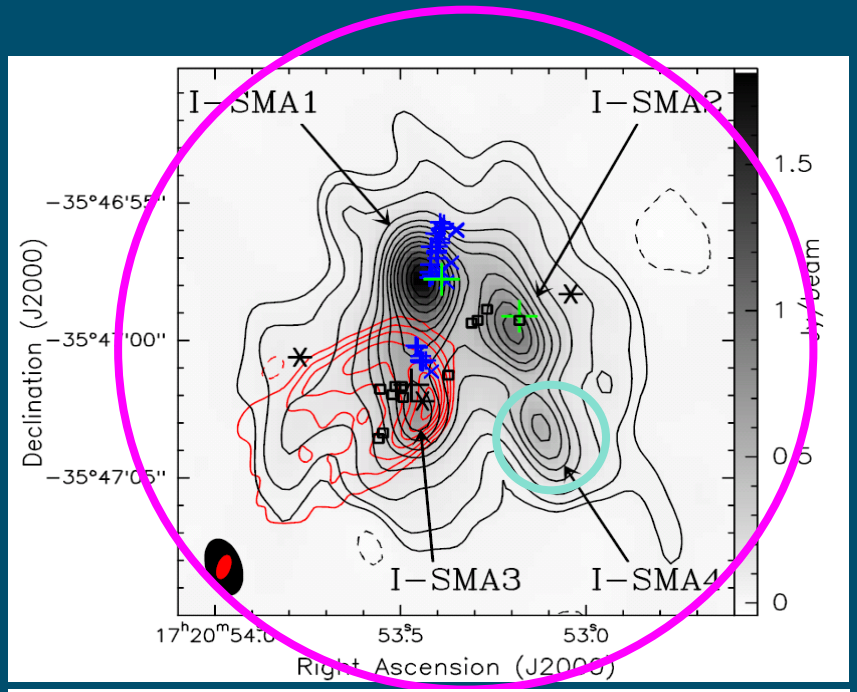
Cecilia Ceccarelli

The CHESS observed targets



Cecilia Ceccarelli

HIFI observations of NGC6334I: first results

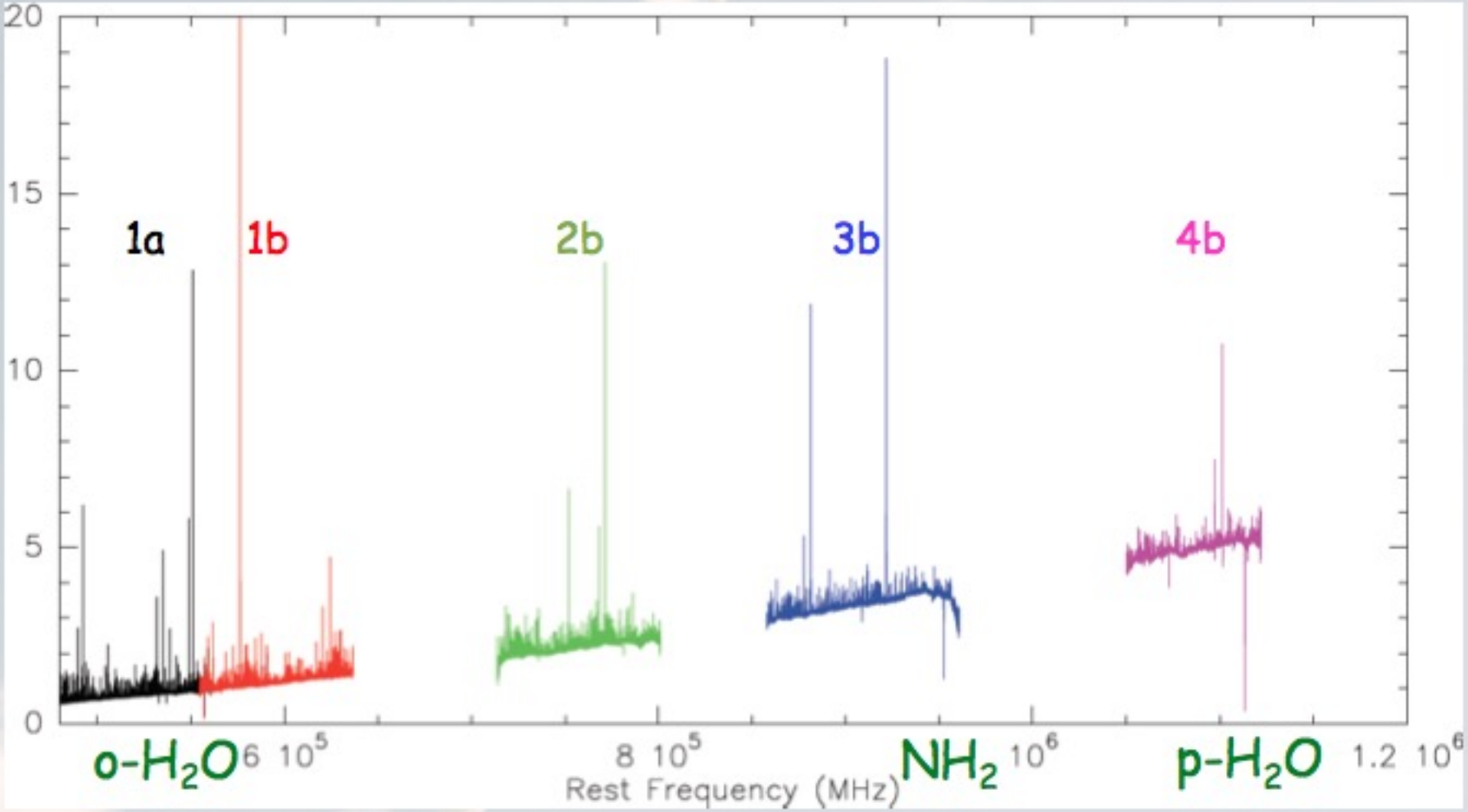


SMA 1.3 mm: Hunter et al. 2006

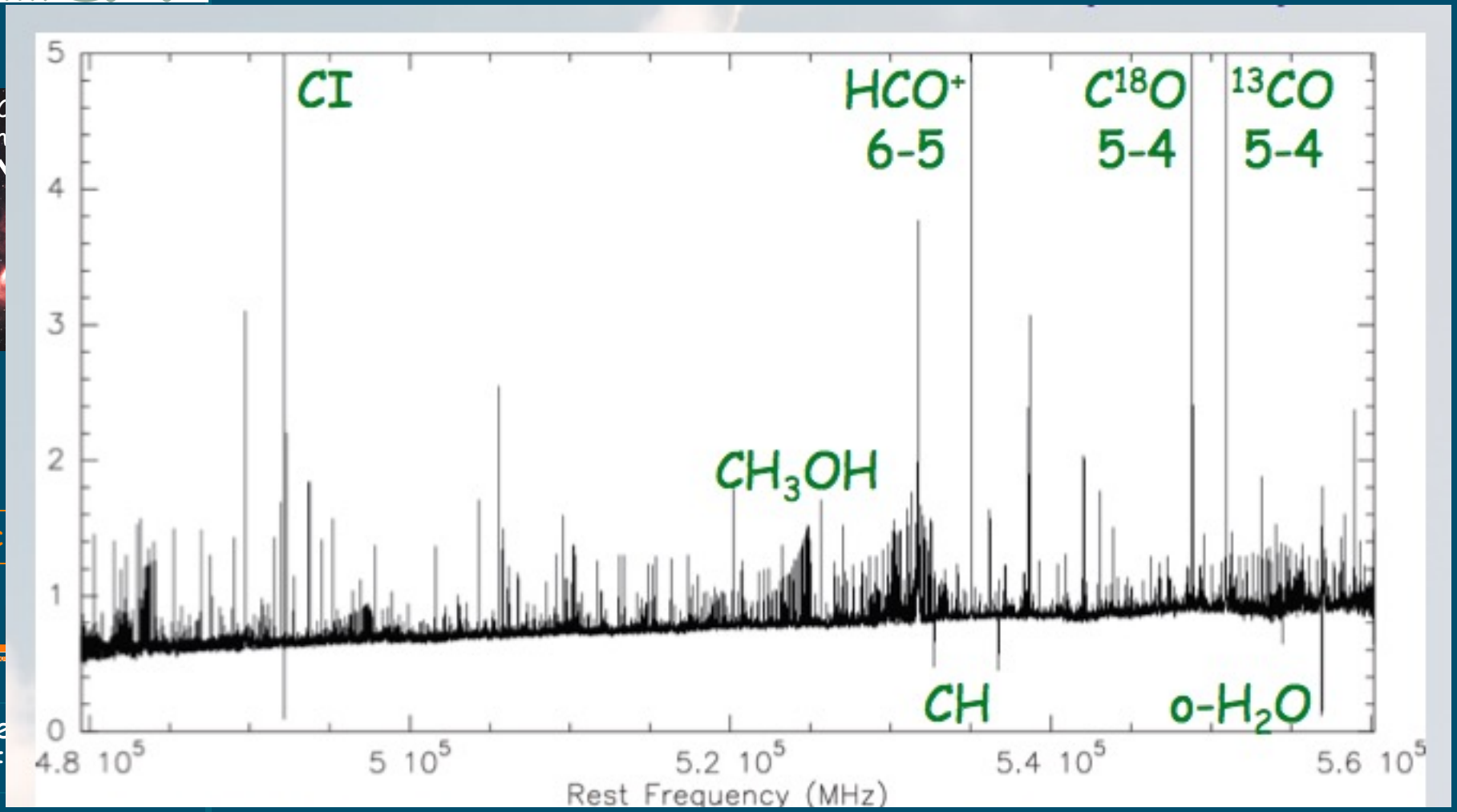
HIFI band 3 beam ~26" FWHM

- Nearby (1.7 kpc) molecular cloud/HII region complex
- Infrared source "I" ~$2.6 \times 10^5 L_{sun}$
- Four compact submm continuum sources located near the center of the NIR cluster
- Several cold foreground absorption components seen in OH, NH3, CH3OH

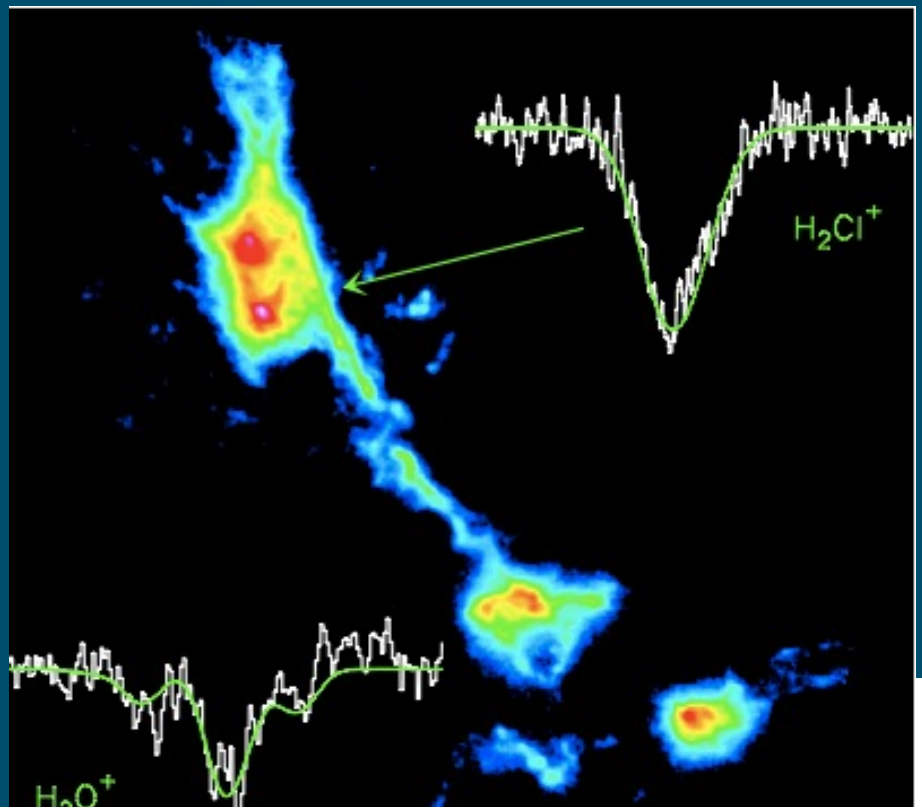
HIFI observations of NGC6334I: overview



HIFI observations of NGC6334I: band 1a



HIFI observations of NGC6334I: detection of new molecules in the diffuse clouds in the line of sight



2 NEW DETECTIONS: H_2O^+ and H_2Cl^+

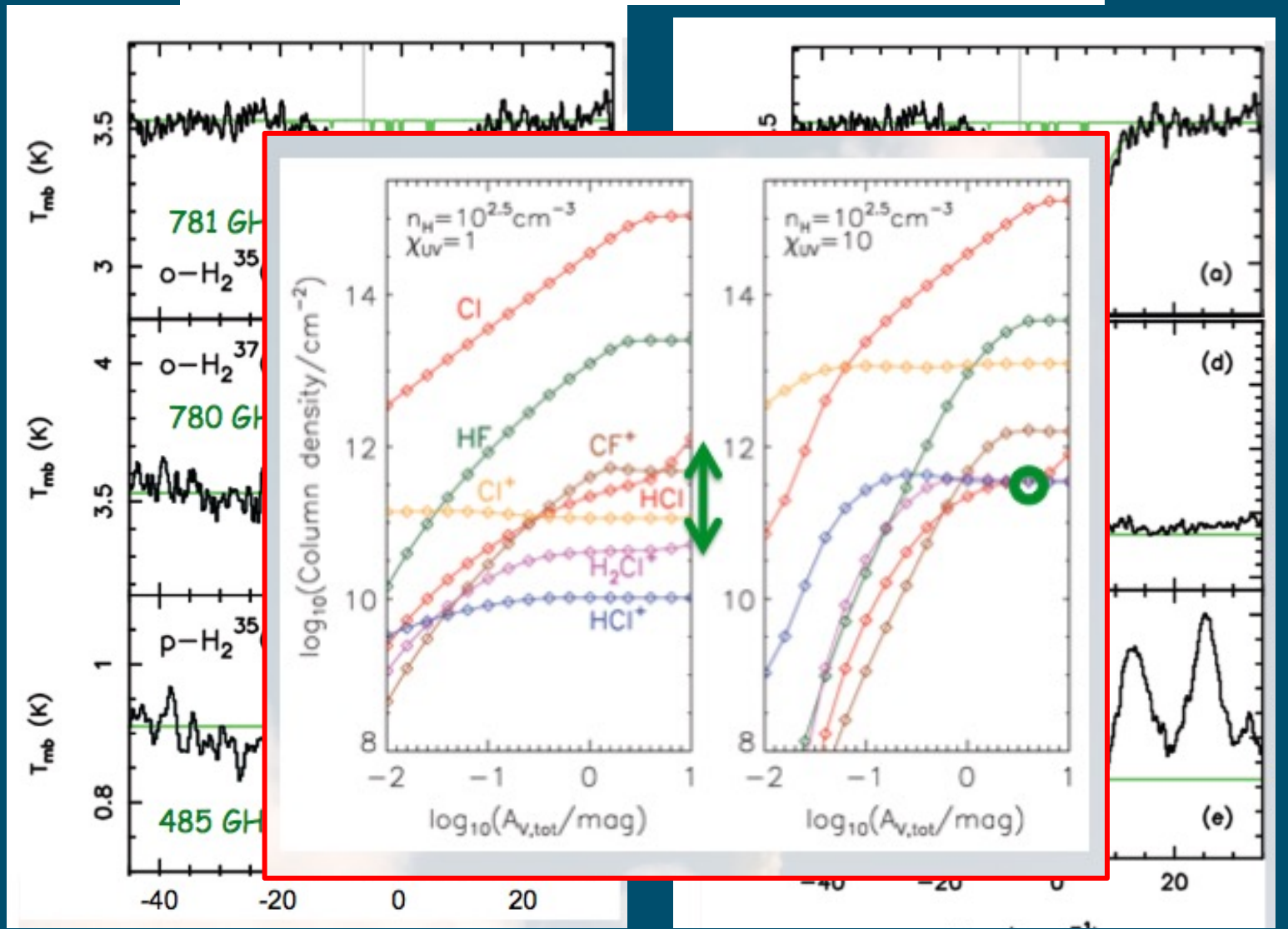
Ossenkopf et al.Herschel Special issue

Detection of interstellar oxidaniumyl: abundant H_2O^+ towards the star-forming regions DR21, Sgr B2, and NGC6334⋆

V. Ossenkopf[1,2], H.S.P. Müller[1], D.C. Lis[3], P. Schilke[1,4], T.A. Bell[3], E. Bergin[5], C. Ceccarelli[6], C. Comito[4], J. Stutzki[1], S. Bruderer[8], A. Bacman[6,7], A. Baudry[7], A.O. Benz[8], M. Benedettini[9], O. Berne[37], G. Blake[3], A. Boogert[3], S. Bottinelli[13], F. Boulanger[10], S. Cabrit[11], P. Caselli[12], E. Caux[13,14], J. Cernicharo[15], C. Codella[16], A. Coutens[13], N. Crimier[6,15], N.R. Crockett[5], F. Daniel[17], K. Demyk[13], P. Dieleman[2], C. Dominik[18,19] M.L. Dubernet[20],

HIFI observations of NGC6334I: H_2Cl^+ and the Cl chemistry

Lis et al. HIFI A&A Special issue



Cecilia Ceccarelli

HIFI & CHESS : a very successful **molecule-hunter couple** !

- LOADS OF NEW SCIENCE
- FOUR NEW DETECTIONS OF SPECIES IN ONLY HALF A BAND (1A), 80 GHz….
  (and after 1 month from the data reception)
- MUCH MORE EXPECTED IN THE REMAINING 1400 GHz OF UNEXPLORED FREQUENCIES!

THANKS