The Promise of HIFI

Xander Tielens (HIFI project scientist)
on behalf of the HIFI consortium

SRON
Netherlands Institute for Space Research

HIFI science

- HIFI is a versatile instrument
  - Wide spectral coverage and high spectral resolution
  - Physical conditions & chemical inventory
  - Kinematics: 3rd dimension in complex sources

- HIFI is specifically built:
  - To probe the role of water in the physics and chemistry in the Universe
  - For unbiased spectral line surveys which will provide a new view of the molecular inventory and the physical conditions in space
  - In addition:
    - Biased spectral surveys to probe chemistry
    - Atomic fine structure lines (CII/NII) to probe the ISM of galaxies, in particular the dynamical aspects

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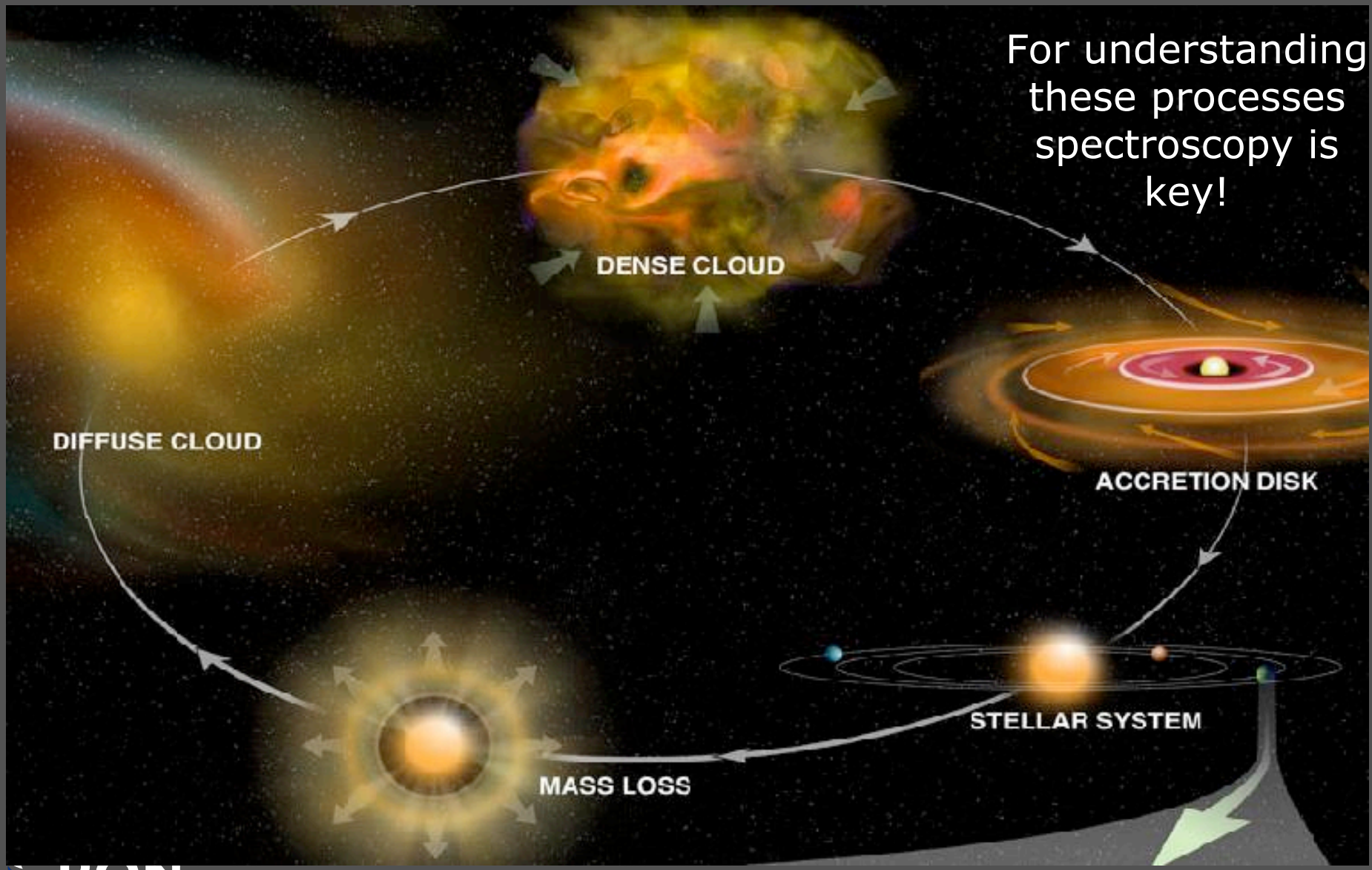
The life-cycle of gas in the ISM of galaxies



Initial science results from the HIFI Performance Verification Phase

- HIFI has had 10 Operational Days (ODs) in the Performance Verification Phase used for AOT validation
- In these days several checks have been made on the data regarding performance, intercomparison of different observing techniques, LO-spur finding, standing waves etc.

- This data was NEVER intended for use as science data

- With the HIFI switch-off no data was gathered for SDP
- This presentation gives a FIRST scientific assessment of some of the PV data

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Science topics for today

- Water in C/2008 Q3 Garradd
- Spectral survey of an outflow source L1157
- Spectral survey of IC 1795
- Water and CO in GL2591 and DR21
- PDR modelling of DR21:
  - CH+,
  - CO and HCO+

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Thanks to….

- Paul Hartogh and his HSSO team for the Comet water analysis
- Cecilia Ceccarrelli and her CHESS team for spectral survey of L1157
- Ewine van Dishoeck and her WISH team for the analysis of the high-mass star-forming regions
- Volker Ossenkopf and his WADI team for the analysis of CH^+
- Pepe Cernicharo and his team for the analysis of HCl

- And above all, the HIFI-ICC: a.o. Michael Olberg, Pat Morris, David Teyssier, Raphael Moreno

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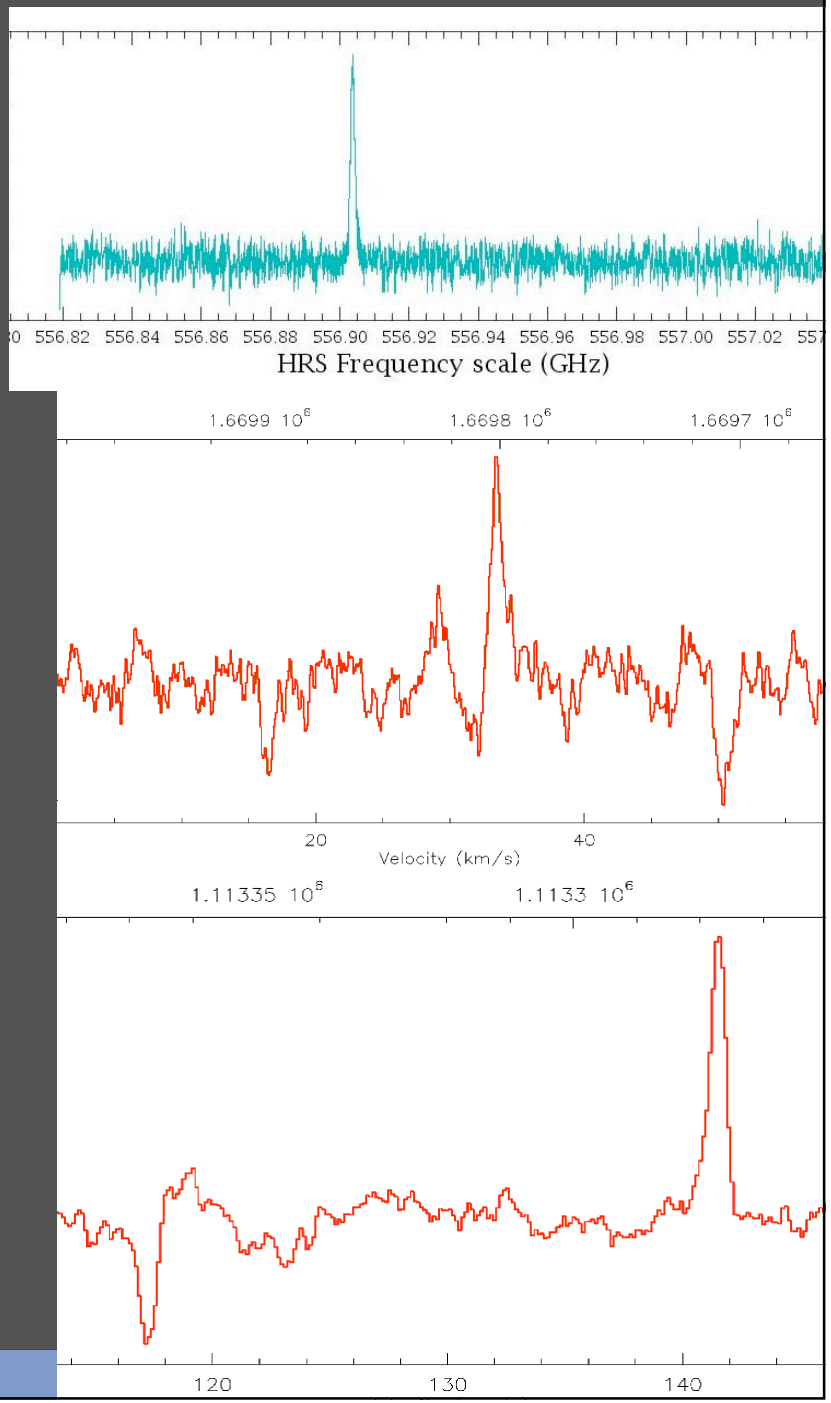
Water in C/2008 Q3 Garradd

- HSSO (PI Paul Hartogh)
- Three lines have been measured o-H_2O 1_{10}-1_{01}; 2_{12}-1_{01} and p-H_2O 1_{11}-0_{00}
- Production rate first assessment: less than the Q[H_2O] = 8.E28 s^{-1} from correlation model
- Next steps include:
  - Excitation analysis & the physical conditions within the cometary atmosphere
  - The kinematics of the cometary atmosphere
  - Inventory of water in comets: 81P/Wild 2 and 103P/Hartley



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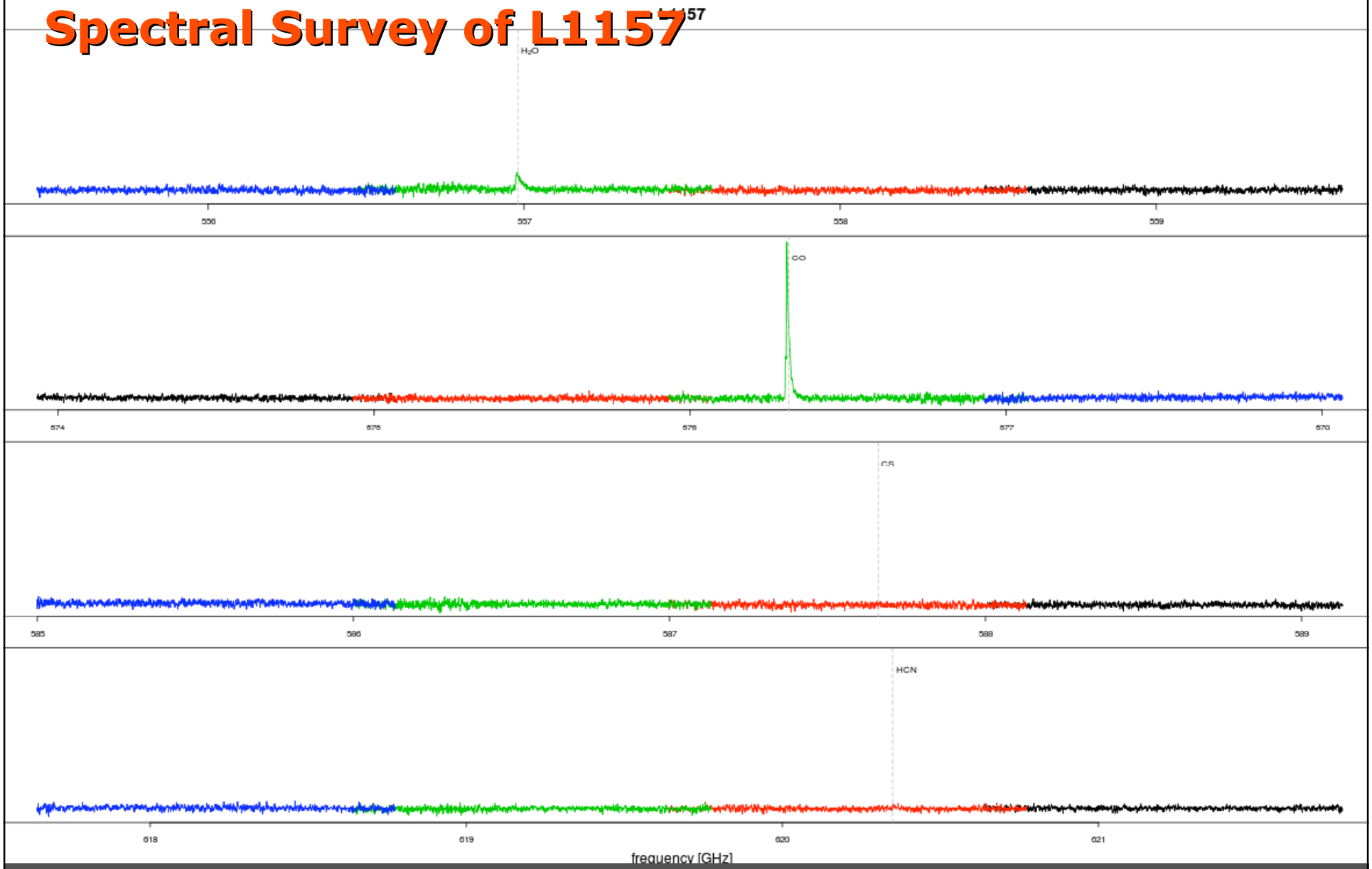
Spectral Survey of L1157



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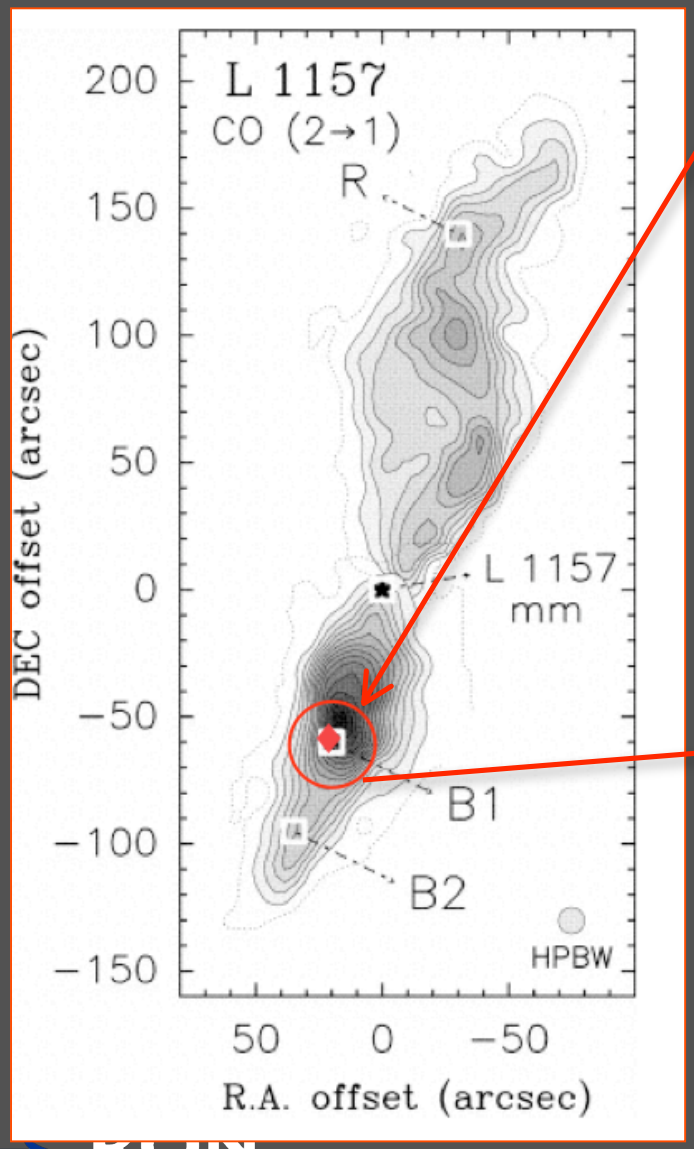
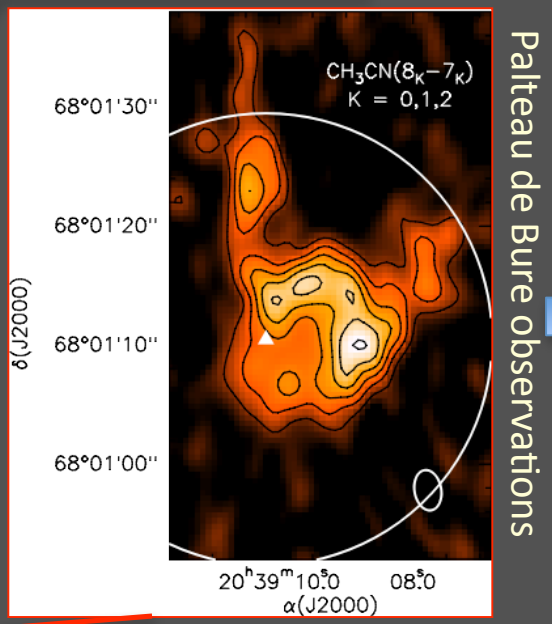
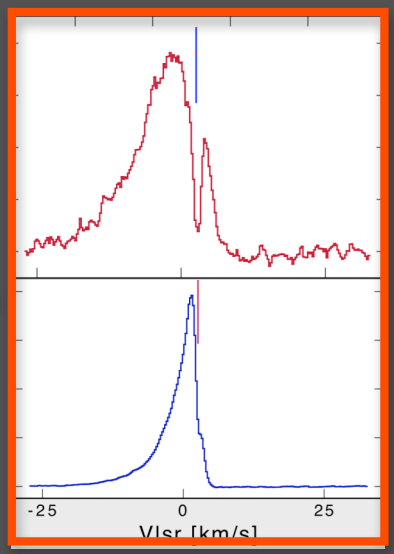
L1157-B1 & HIFI: peering into a shock



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



Plateau de Bure observations



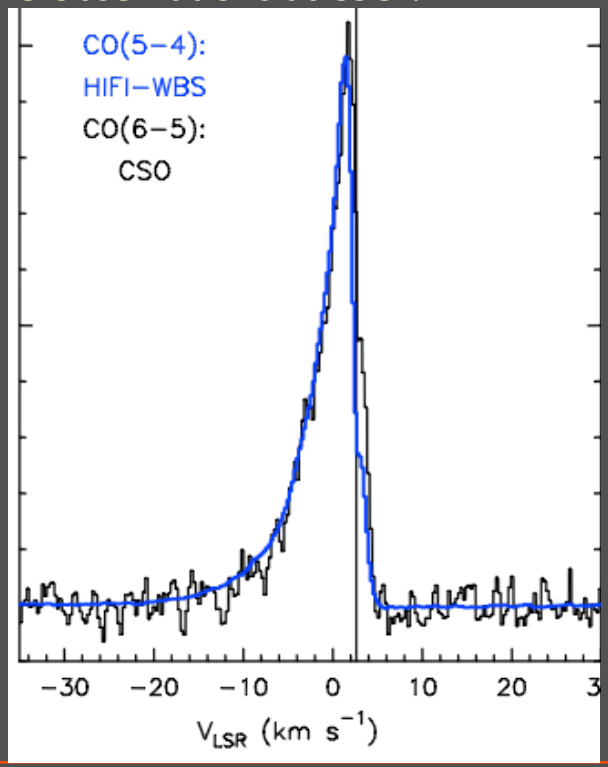
WARM SHOCKED GAS probed by the CO (5-4) and H_2O (1_{10} -1_{01}) lines,

and plenty of weaker lines from CH_3OH, H_2CO, NH_3, HCN, HCl…

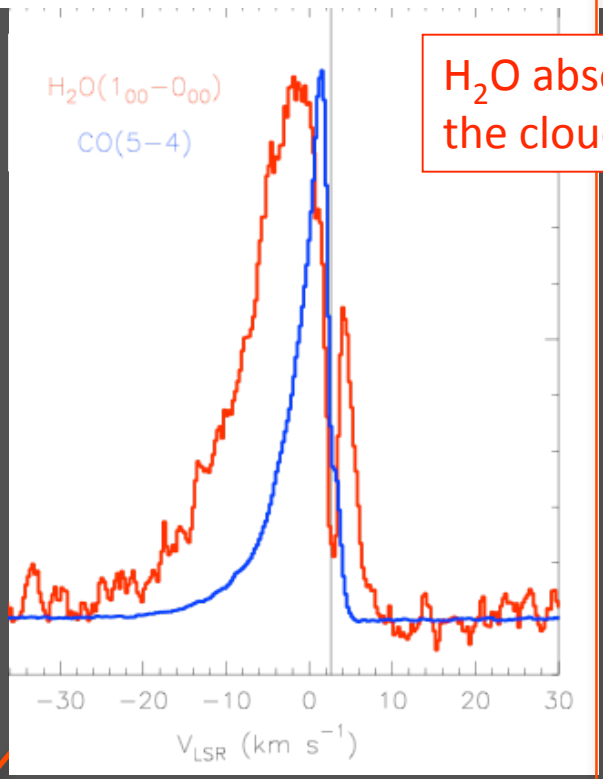
L1157-B1 & HIFI: peering into a shock

WARM SHOCKED GAS probed by the CO (5-4) and H_2O (1_{10} -1_{01}) lines

PERFECT agreement with ground CO 6-5 observations at CSO !



H_2O emitted by gas faster than CO



H_2O absorbed by the cloud gas

DOES H_2O PROBE THE INTERFACE OF THE (WIND/JET) SHOCK , WHEREAS CO PROBES THE GAS ENTRAINED BY THE SHOCK ?

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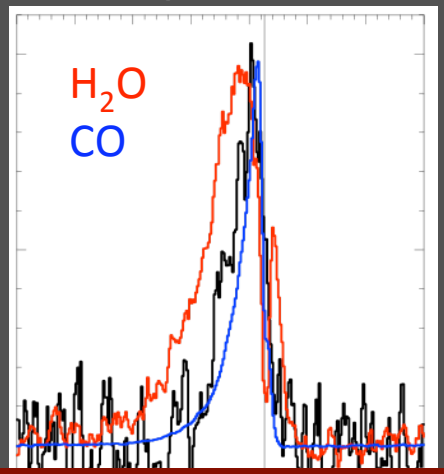
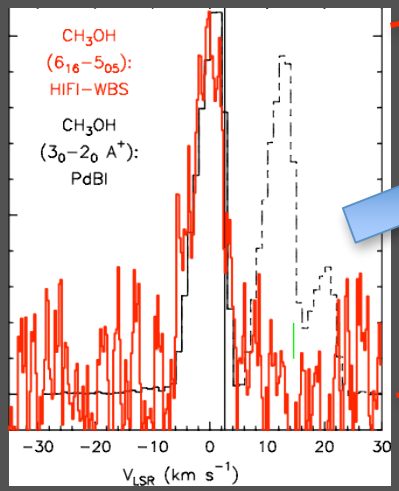
L1157-B1 & HIFI: peering into a shock

MOLECULAR RICHNESS

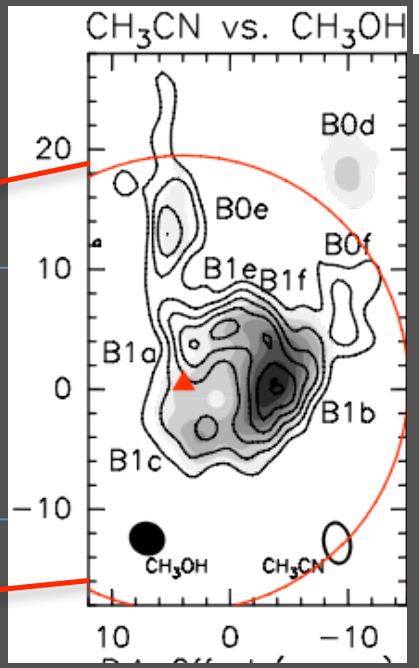
AMMONIA



METHANOL

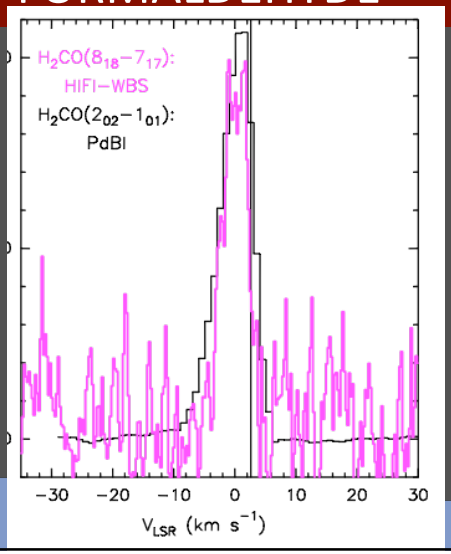


DETECTED GAS AT >150K

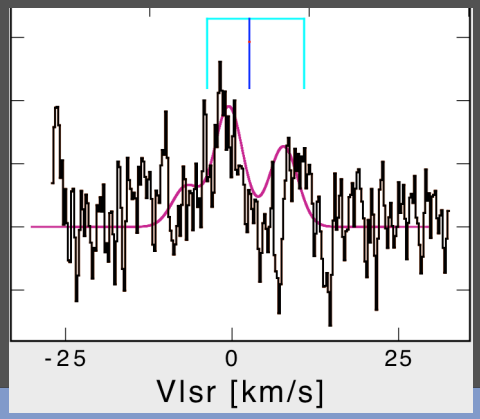


Plateau de Bure observations

FORMALDEHYDE



HYDROCHLORIC ACID



Species	No of lines	Abundance /CH_3OH
CH_3OH	15	1
H2O	1	1/3
NH_3	1	1/10
H_2CO	3	1/40
HCl	1	1/50?
HCN	1	1/150

IC1795 & HIFI: "alchemical" evolution of the galaxy

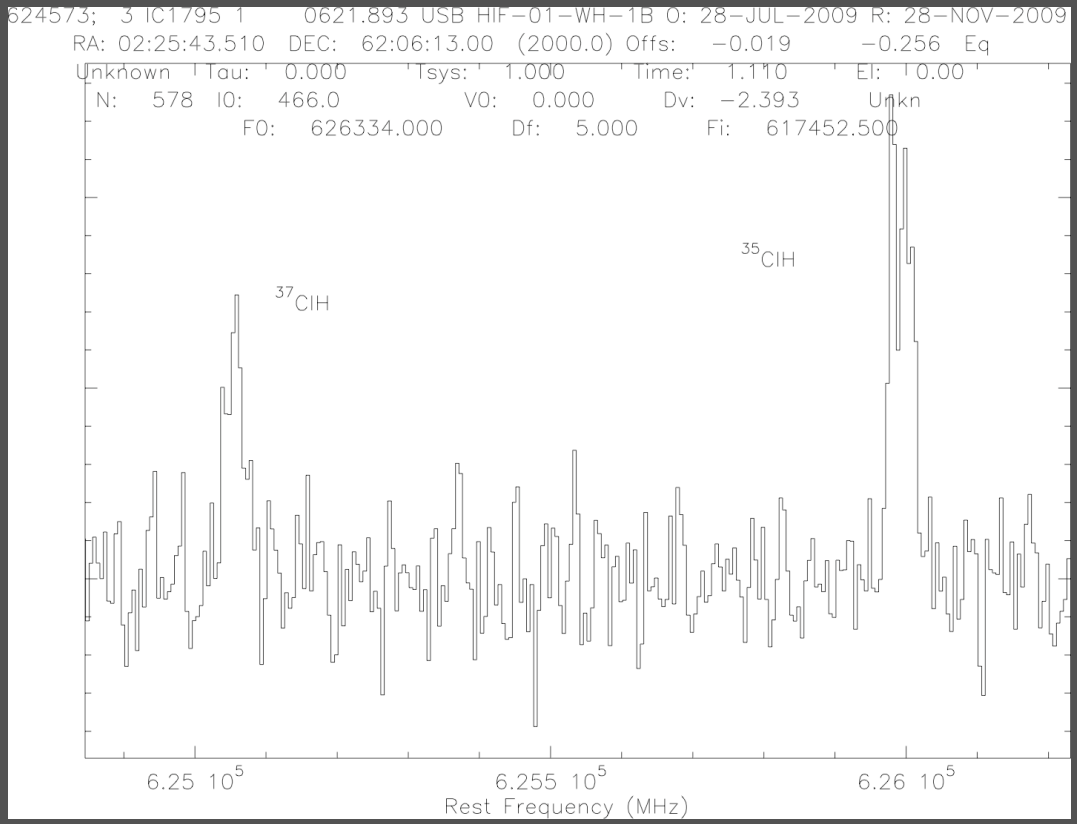
Pepe

Rotational spectroscopy provides an excellent probe of isotope ratios

High spectral resolution provides hyperfine splitting and accurate abundance ratios

First analysis yields:
$^{35}Cl/^{37}Cl = 2.2 \pm 0.7$

Solar = 3
Comparable to IRC+10216 but less than measured for Orion



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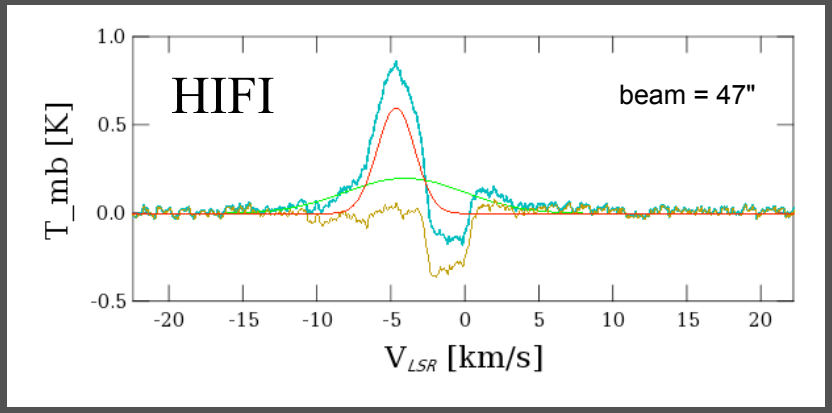
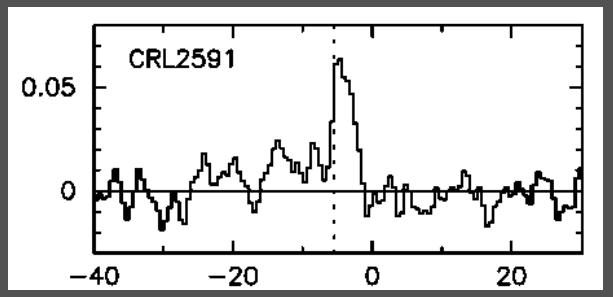
AFGL 2591 a high mass protostar at 1.7 kpc

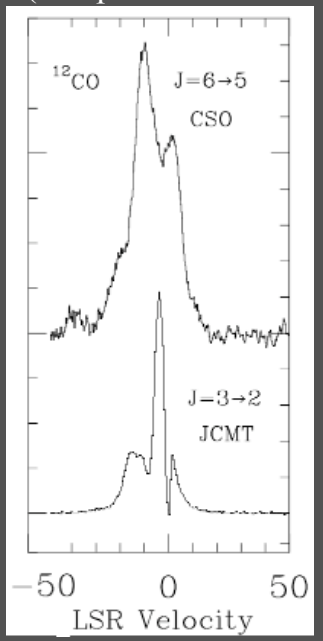




$I_{HIFI} \leq I_{ISWAS\ corrected}$

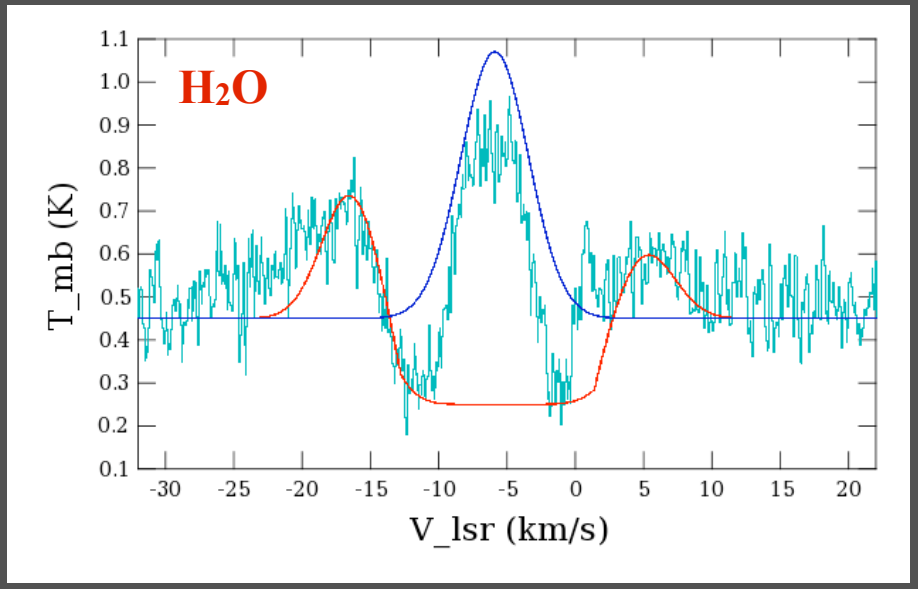
•absorption takes place on a small scale (compact continuum

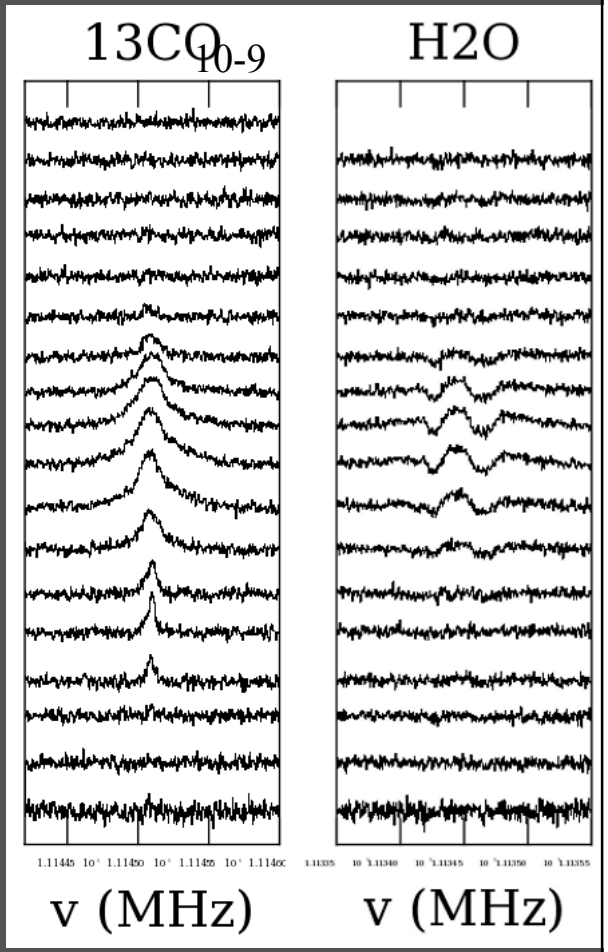
ortho-$H_2{}^{16}O$ 1_{10}-1_{01} @ 556.9 GHz



- absorption at v=0 km/s from the foreground cloud also seen in low-J lines of CO and HCO^+ (cf. Boonman et al. 2003)
- absorption at v=-8 km/s as seen by van der Tak et al. (1999).
- a narrow emission centered at the systemic velocity which represents the outer ring of cool water
- broad water emission centered at v_{lsr} produced in the outflows.

para-$H_2{}^{16}O$ 1_{11}-0_{00} @ 1113.3 GHz





The profile consists of an emission and an absorption component:

- double-horn profile coming from the massive dense core,
- gaussian emission coming from the surrounding molecular cloud,
- significant continuum detected, with a maximum of 0.5 K.

^{13}CO 10-9 only shows emission.

Emission is extended in the North-South direction.
H_2O emission: ~50'' ; ^{13}CO & continuum: ~90''

DR21 Cygnus Region at 1.7 kpc

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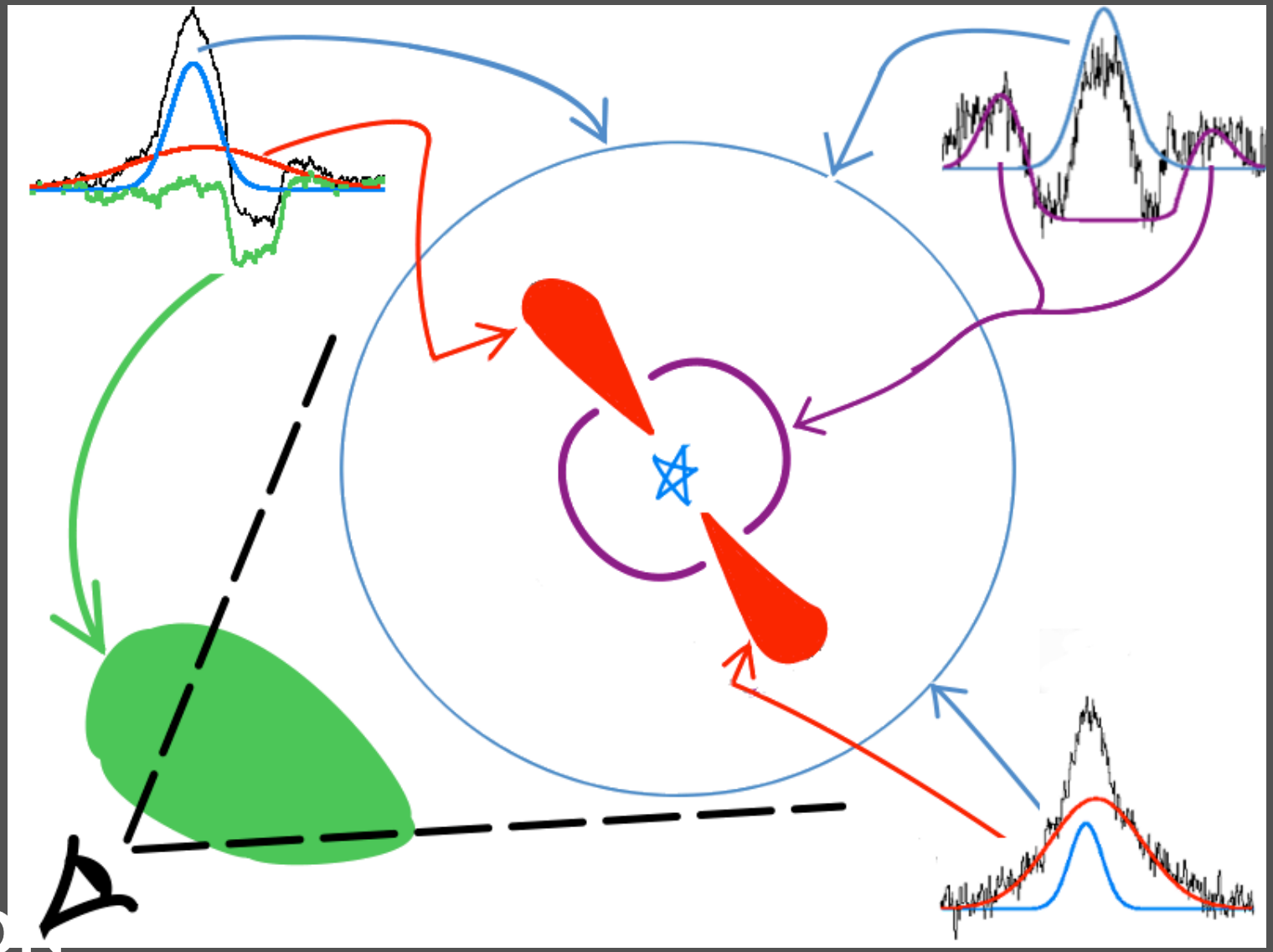
A cartoon of a high-mass SF region based on HIFI



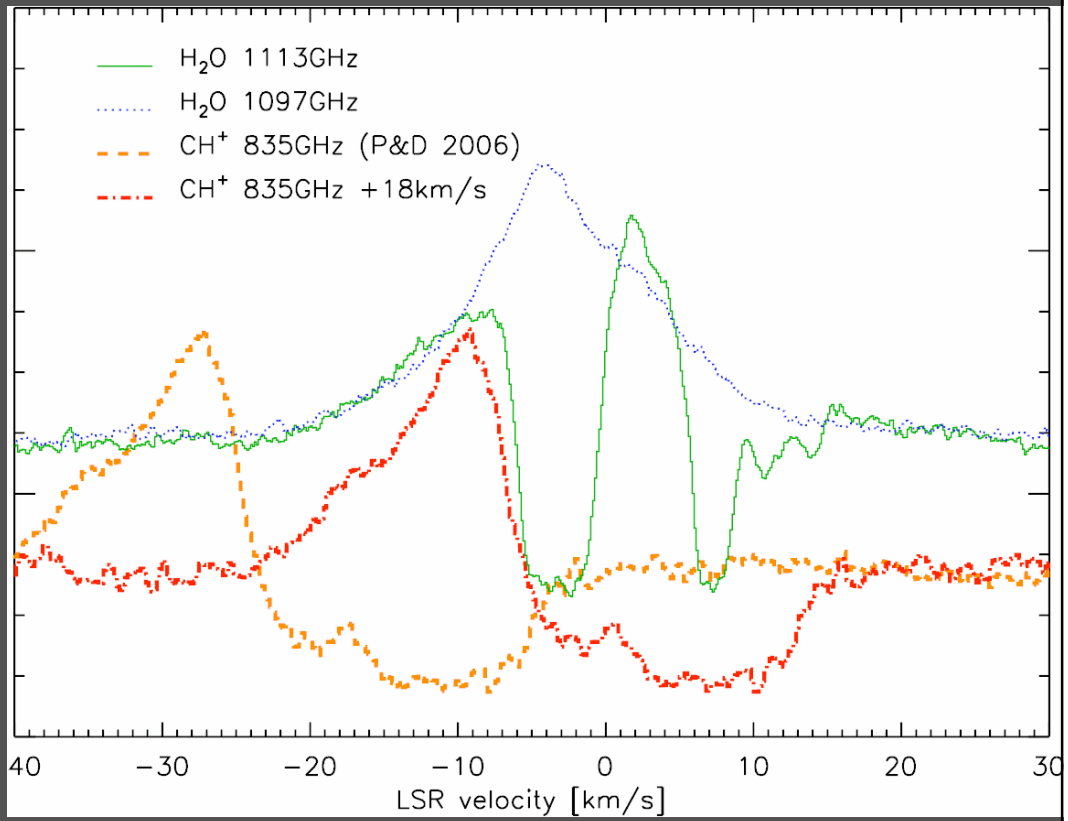
The CH+ puzzle

WADI

- CH+ is a reactive molecule abundant in shocks and the diffuse medium, expected to be weak in molecular clouds.

  Frequency of 835.079 GHz measured by Pearson & Drouin (2006)
- Comparison of the CH+ HIFI spectrum in DR21 with other tracers clearly contradict that laboratory measurement
- The correct CH+ frequency must be 835.135±0.007 GHz

- This would be in agreement with a 13CH+ assignment to extended CO emission by Falgarone et al. (2005)



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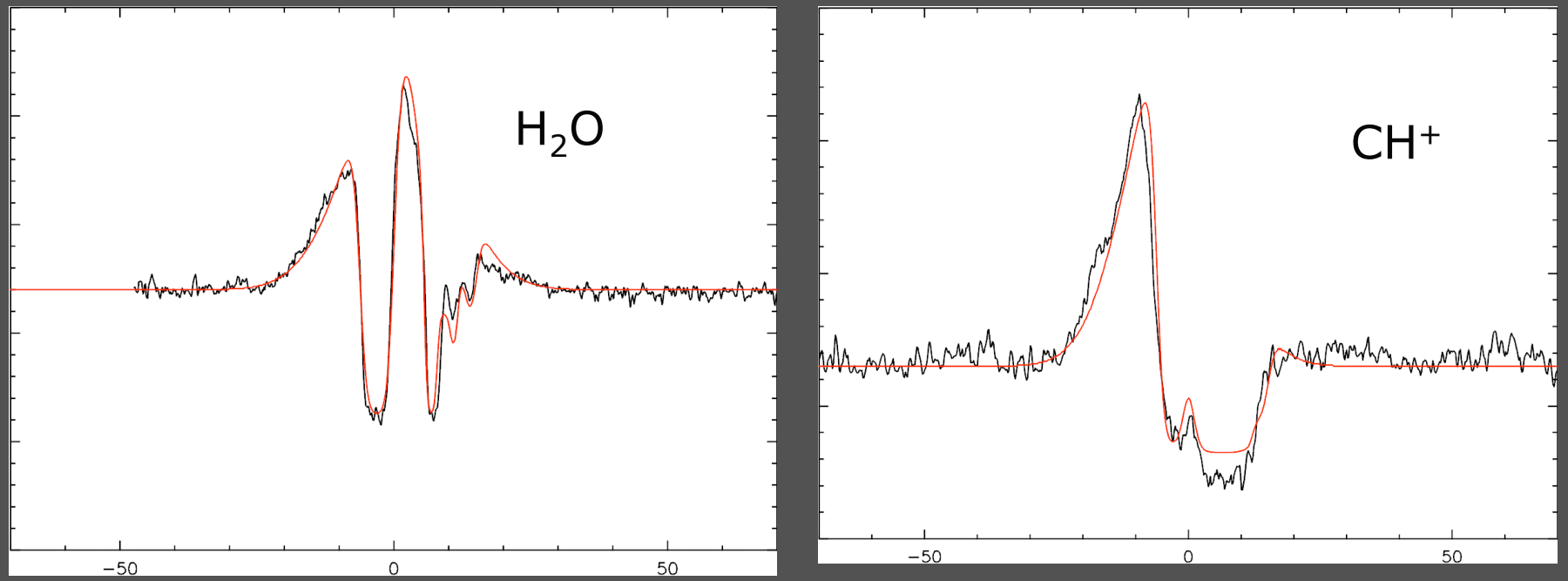
The CH+ puzzle

WADI

- The CH+ profile can be explained by fitting the water ground-state profile, applying the same emission and absorption components to both species



- Emitting core: N(CH+) ~ 3.6E13 cm-2
- Absorbing foreground: N(CH+) ~ 1.9E14 cm-2
  → Largest column of CH+ recorded so far (ζ Oph: 2.9E13 cm-2)

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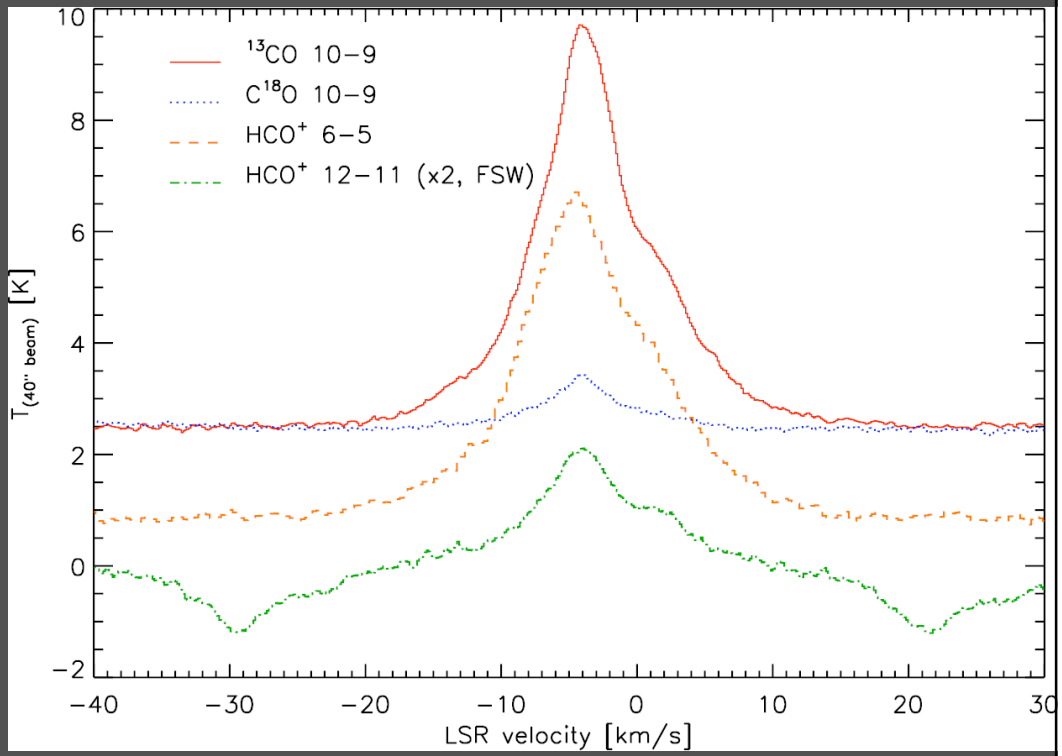
PDR modelling

WADI

- DR21 is a well known Photon-Dominated Region (PDR)
- HIFI observed typical PDR tracers at high temperatures
  - Isotopes of CO give the column density of hot material
  - HCO+ is a reactive species formed in PDRs
  - The underlying continuum measures the dust temperature profile



- The combination of the different tracers allows to fit strength of the UV field, the mass and density of the molecular material

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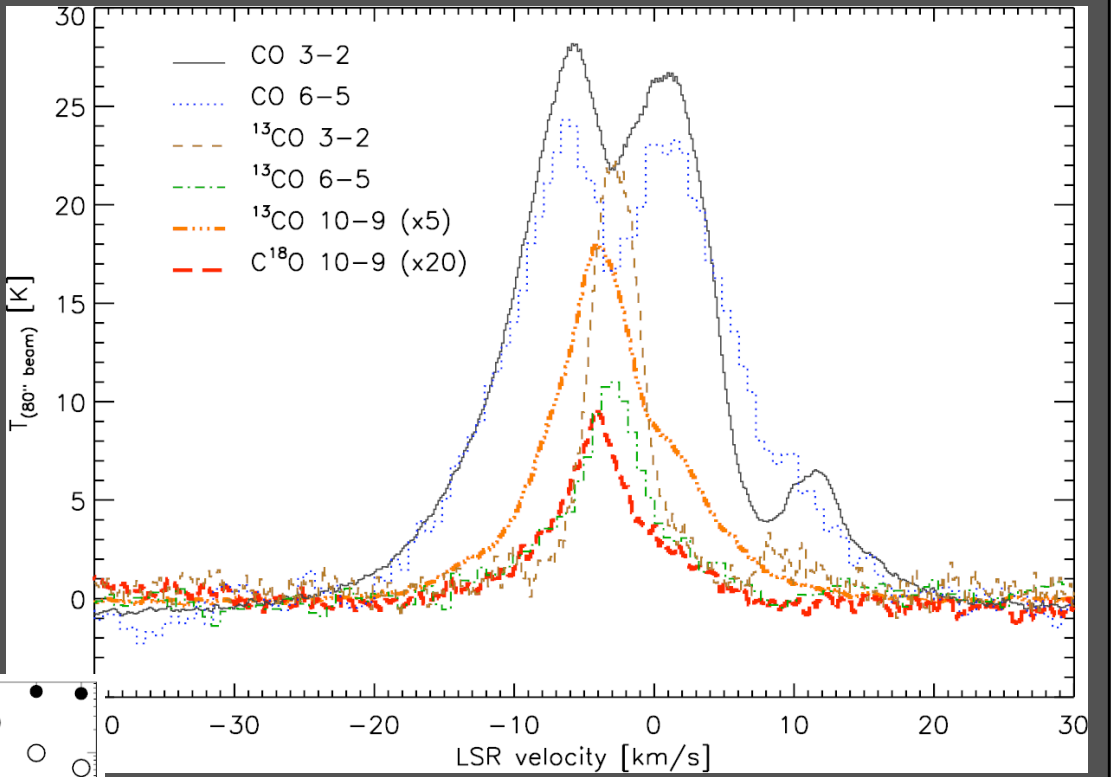
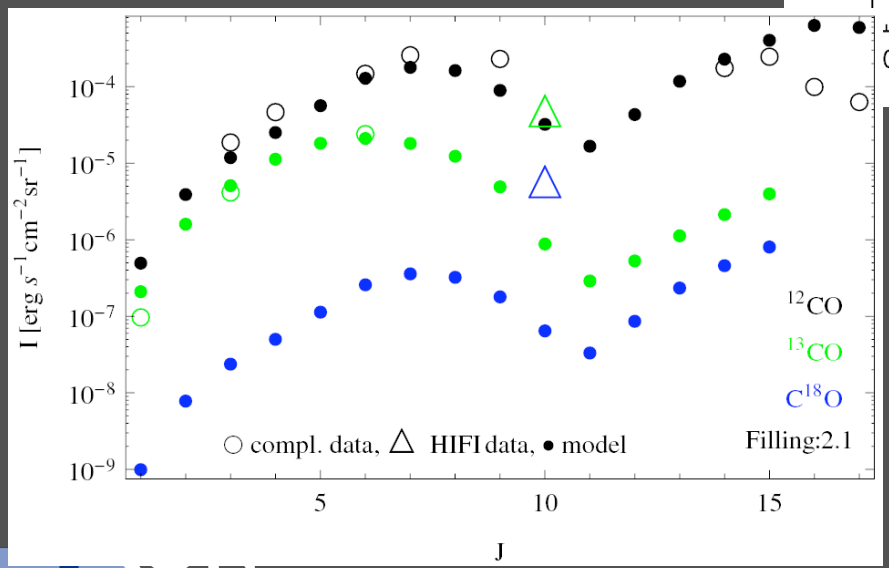
PDR modeling

- Comparison of ground-based CO isotope lines with new HIFI observations
- Correlation between temperature and velocity gradient



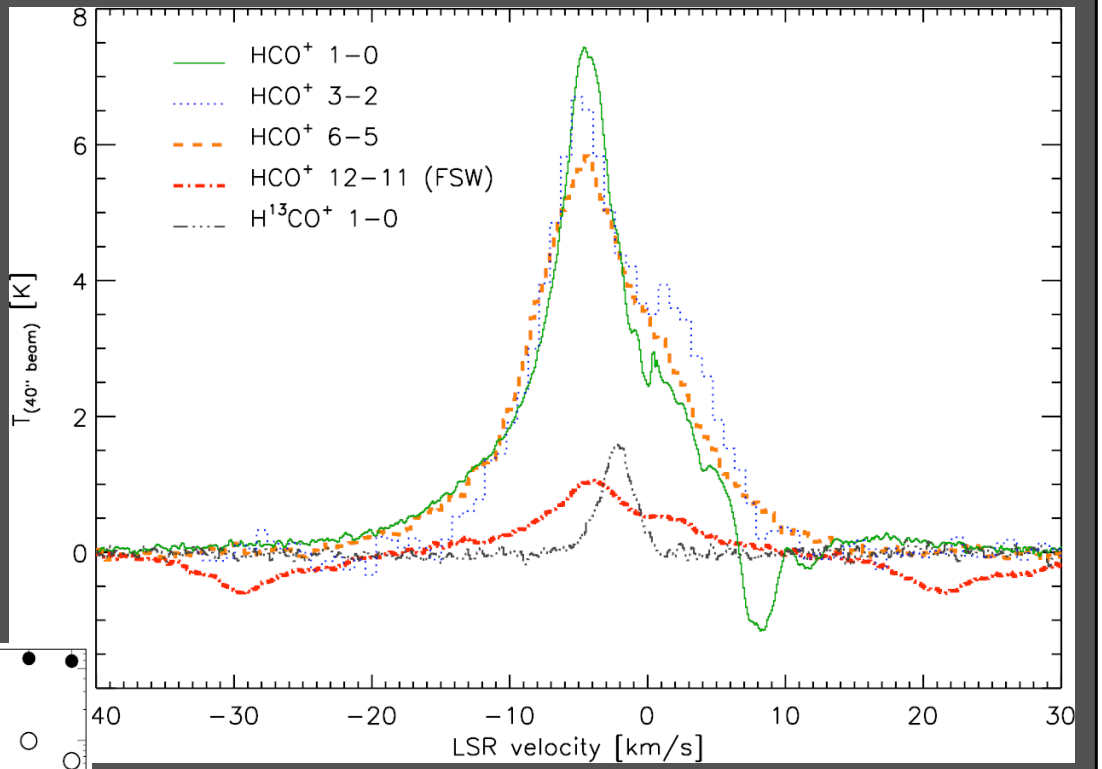


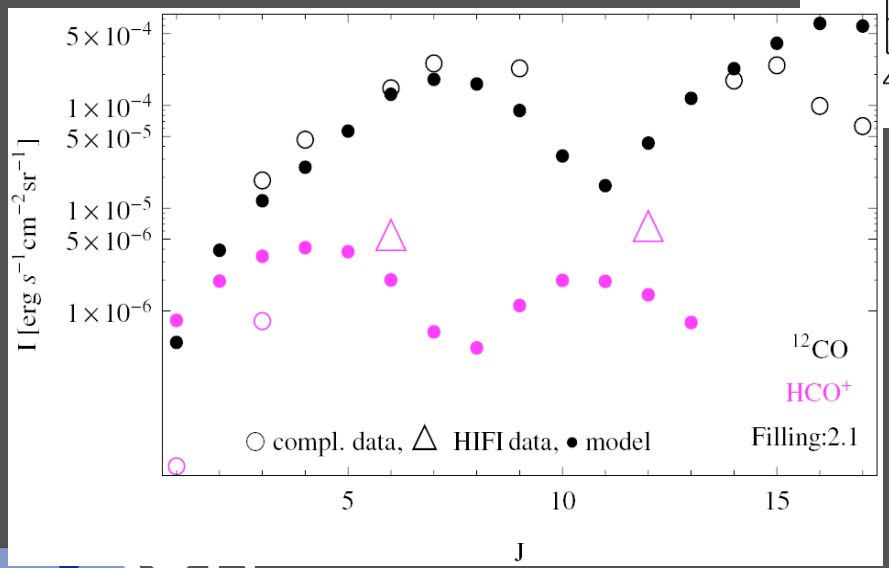
- Fits of the available ground-based and ISO LWS data by a clumpy PDR model (KOSMA-τ, $n=10^{6.3}cm^{-2}$, $M=10^{3}M_{\odot}$, $UV=10^{2.6}\chi_{\odot}$) are incompatible with the new HIFI measurements at J=10

PDR modelling

WADI

- HCO+ is confirmed to trace the PDR structure
- The HIFI line profiles for the hot gas match the ground-based profiles at low frequencies
- H13CO+ 1-0 is puzzling. 6-5 will be extremely interesting





- As for the HIFI CO lines, existing models do not fit the HCO+ lines in detail either

The promise of HIFI

- HIFI is a versatile heterodyne instrument with high sensitivity, high spectral resolution, and wide spectral coverage
- HIFI will be able to address a wide array of astrophysical and astrochemical questions on the lifecycle of the interstellar medium
- In particular:
  - The role of water in the Universe including regions of star and planet formation
  - The chemical inventory of the Universe, including simple hydrides, and the processes driving this chemical complexity
  - The physical conditions in atomic and molecular gas, including regions of star and planet formation
  - The dynamics of interstellar and circumstellar gas

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