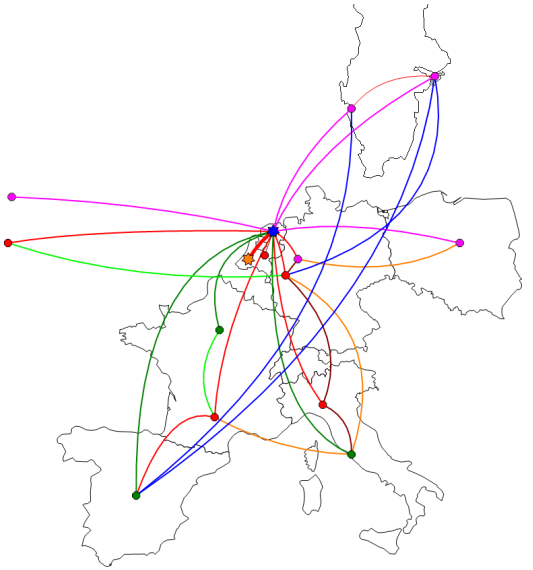
Astrochemistry with HIFI

V. Ossenkopf

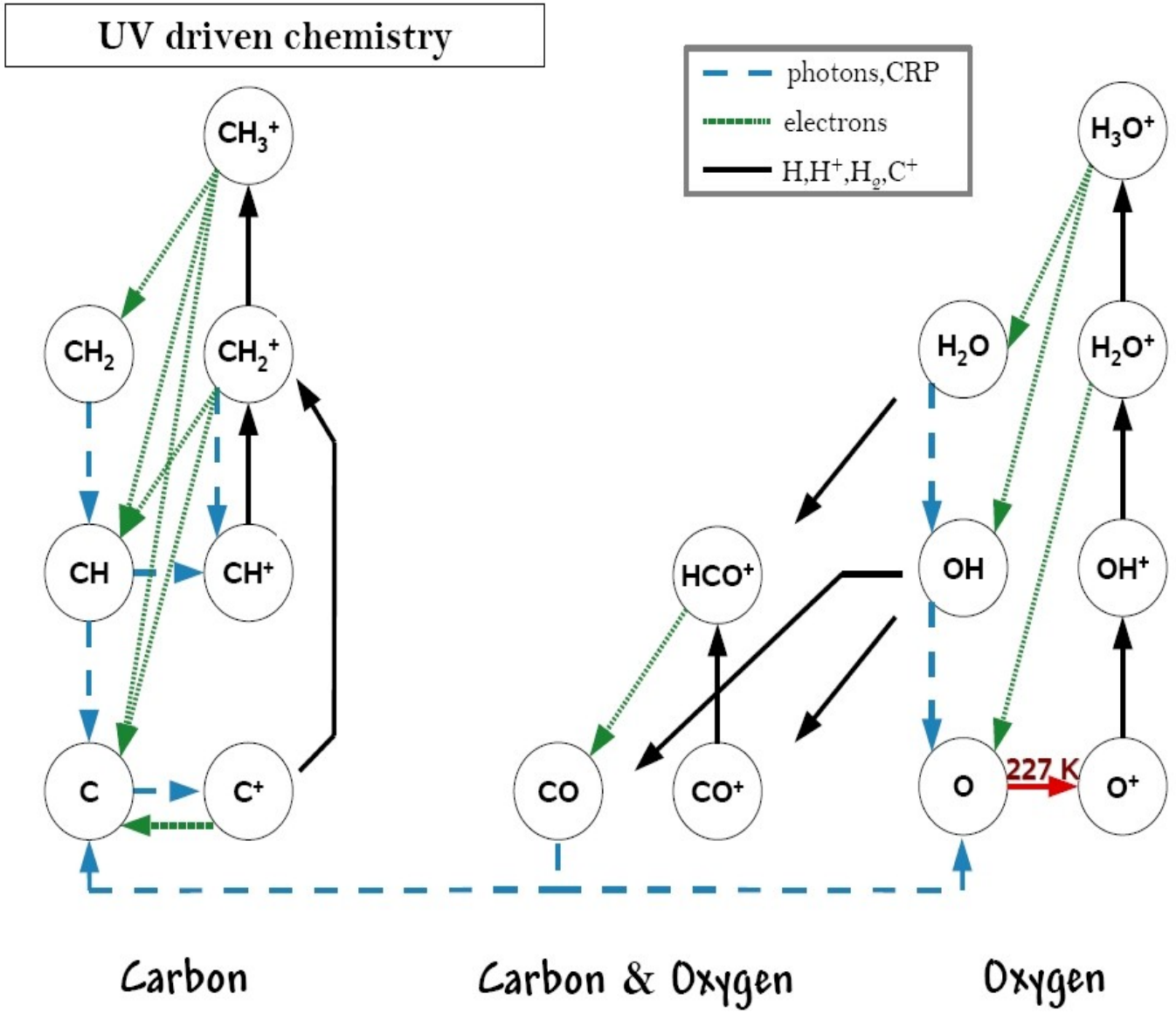


SRON
Netherlands Institute for Space Research

Questions

- How are interstellar molecules formed ?
- How does UV radiation from young stars change the local chemistry?
- How are high-temperature reactions driven ?
- How do surface reactions & solid phase processes affect the abundance of gas phase molecules ?
- What is the role of turbulent mixing?

Questions

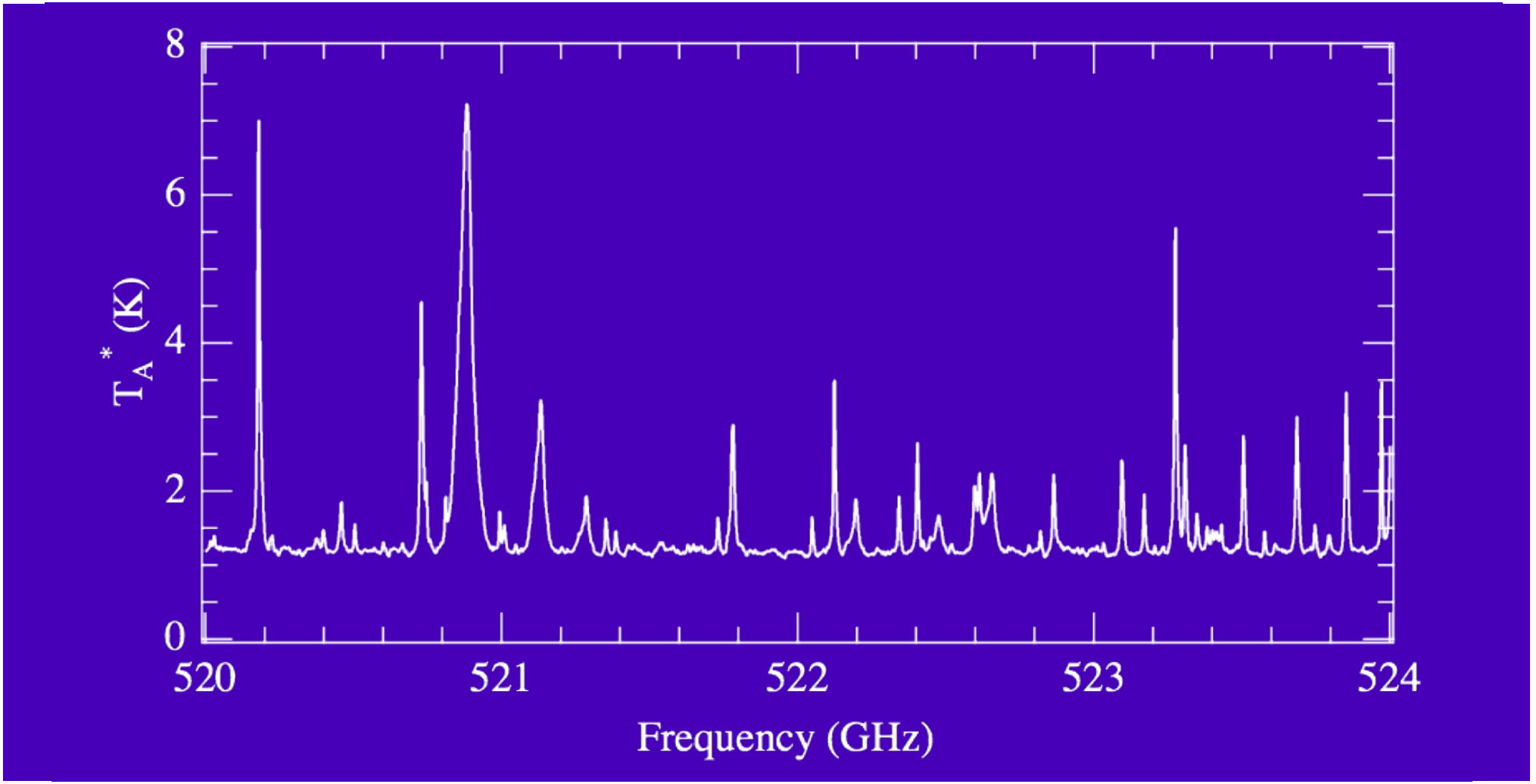


Simple hydrides are central nodes: CH, NH, H_2O, OH, CH^+, NH^+, OH^+, H_3O^+

➔ Only observable by Herschel

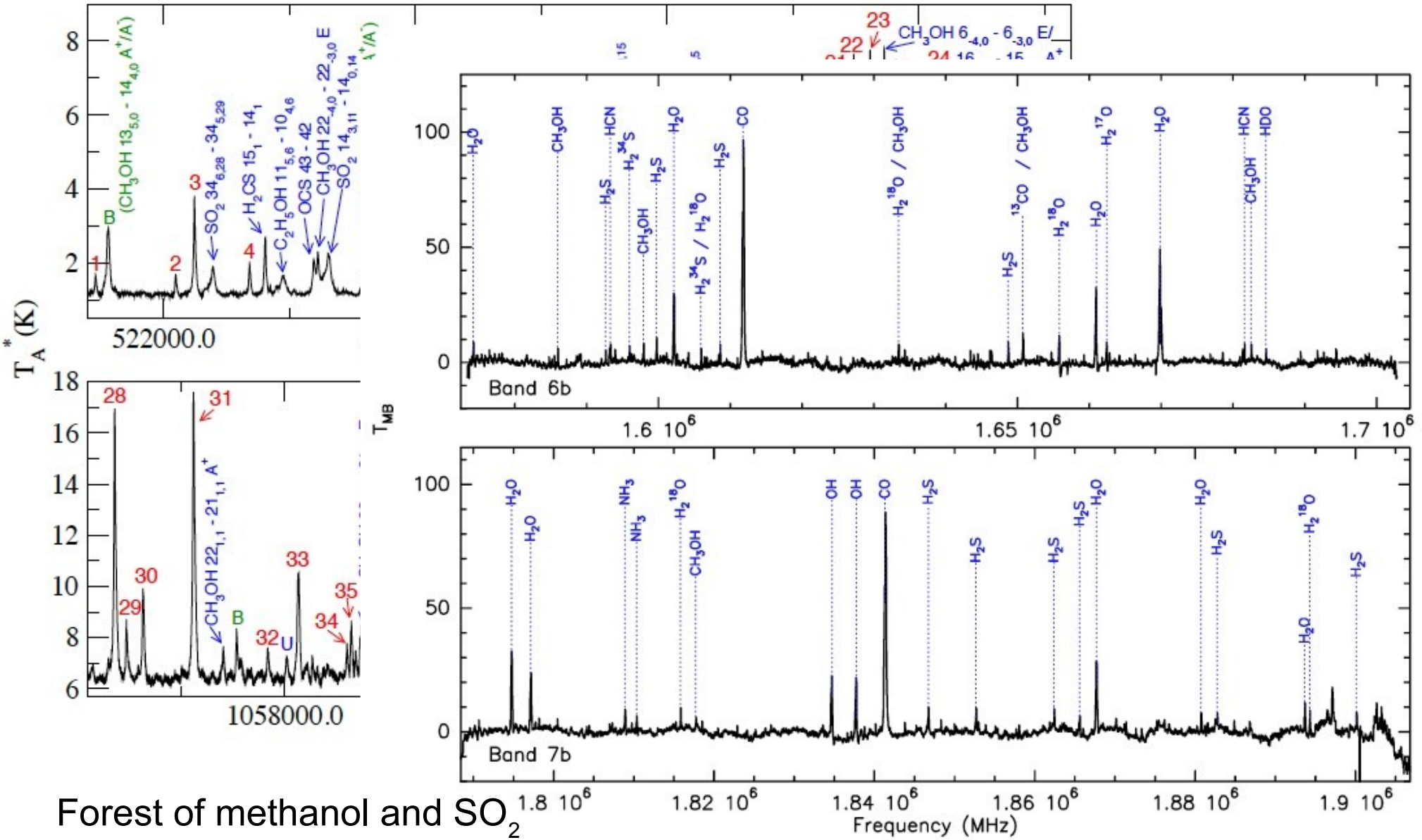
Input

Wealth of information from spectral scans



Spectral scan in Orion KL (Bergin et al. 2011)

Identifications

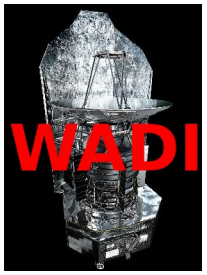


Forest of methanol and SO_2 lines “hiding” other species

Crocket et al. 2012

Scientific goals

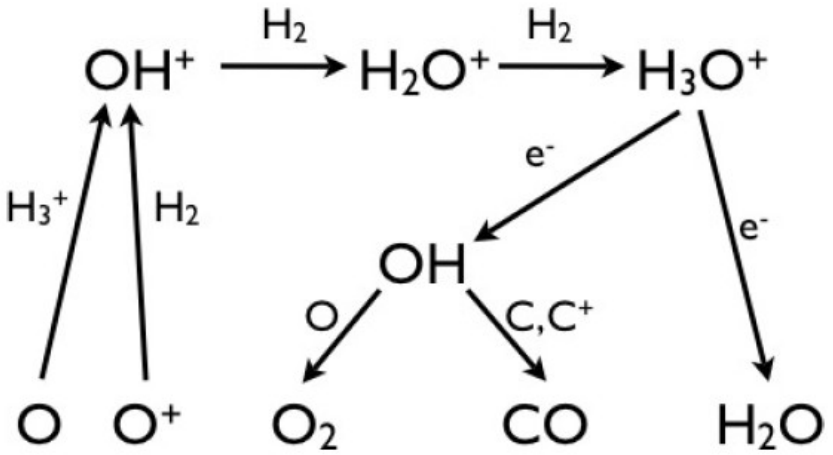
- Simple molecules - PRISMAS
- Complex molecules – HEXOS, CHESS
- Water – WISH
- UV chemistry - WADI

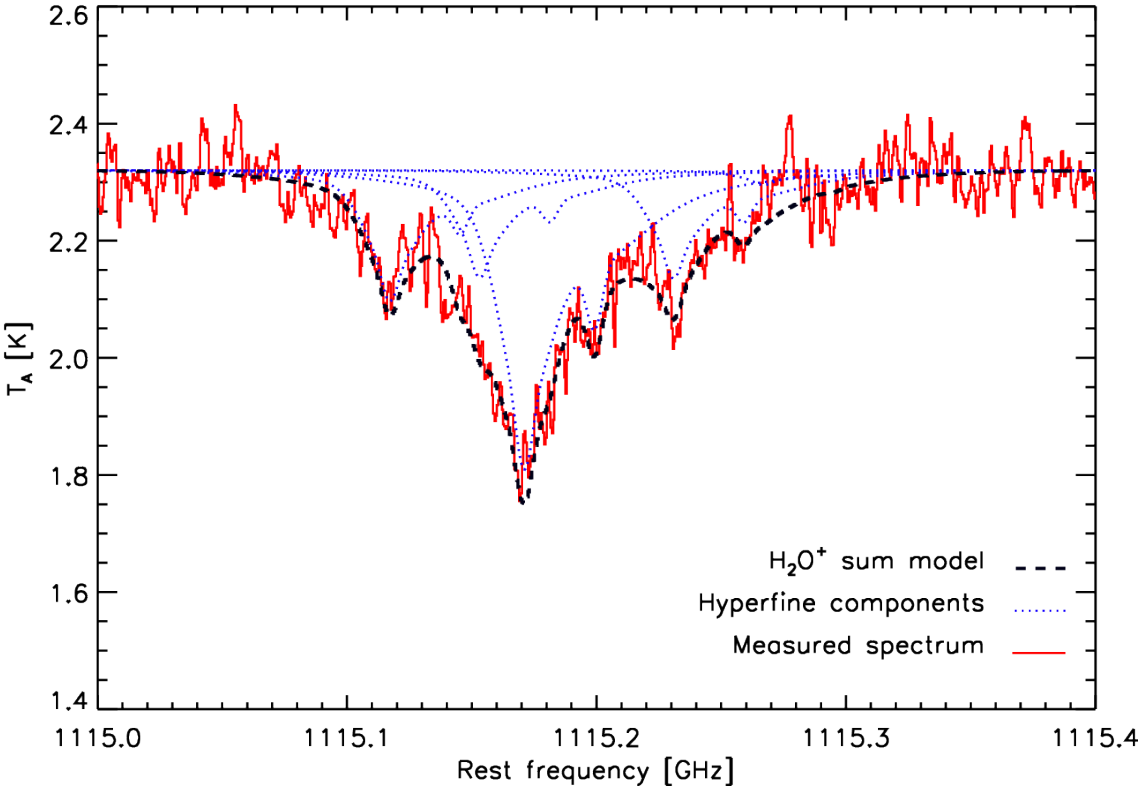


First detections

- Interstellar H_2O^+
- Identification by

  "spectroscopic fingerprint"
- In DR21C





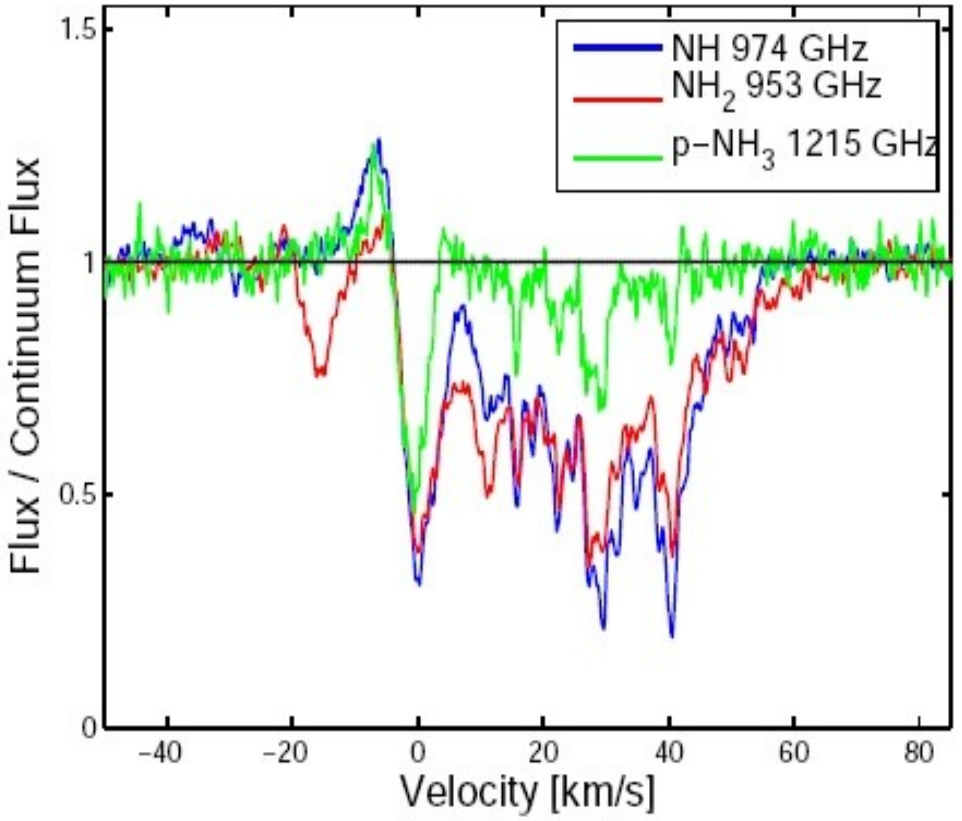
- Column density: > 2.3 10^{13} cm^{-2}

H_2O^+ more abundant than H_3O^+ → Contradiction to previous models

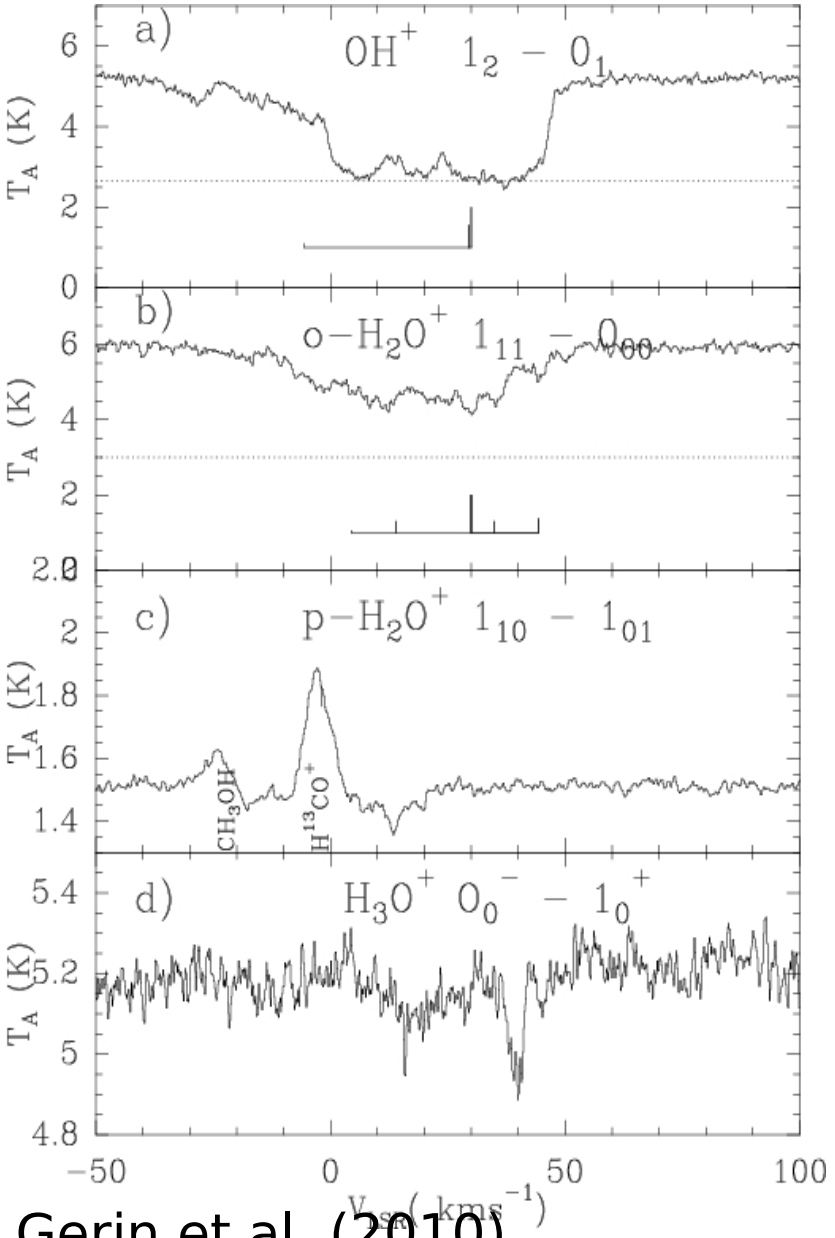
Reactive hydrides everywhere

Diffuse medium full of reactive hydrides

- Oxygen network → path to water
- Nitrogen network → path to NH_3



Persson et al. 2011



Gerin et al. (2010)

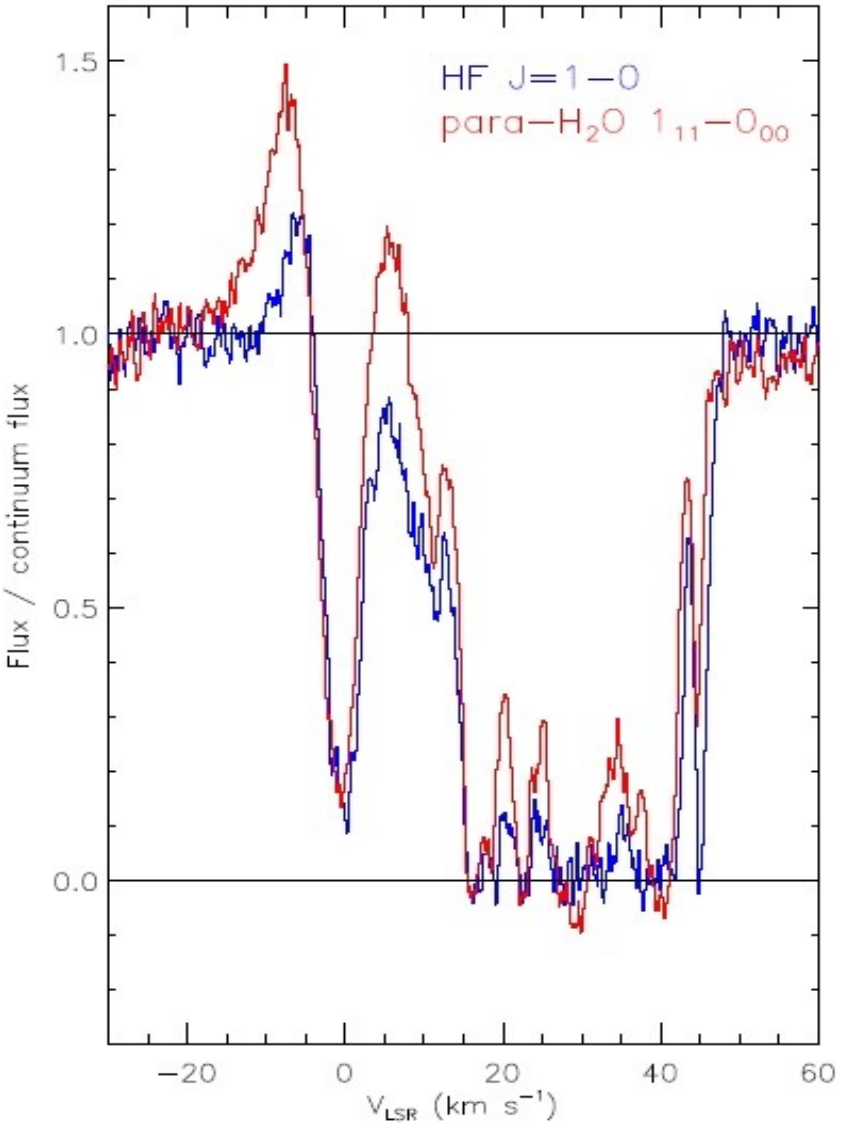
The best proxy to H_2

Ubiquitous HF absorption at 1.2THz

- Fluorine reacts with H_2, making HF
  - HF uses all the gas phase F
  - HF reveals H_2
  - Best tracer for H_2 is present, even in clouds with no detectable CO or H_2O.

- Exceptions: HF in emission in Orion Bar and star-burst galaxies

Problem: Needs background continuum source



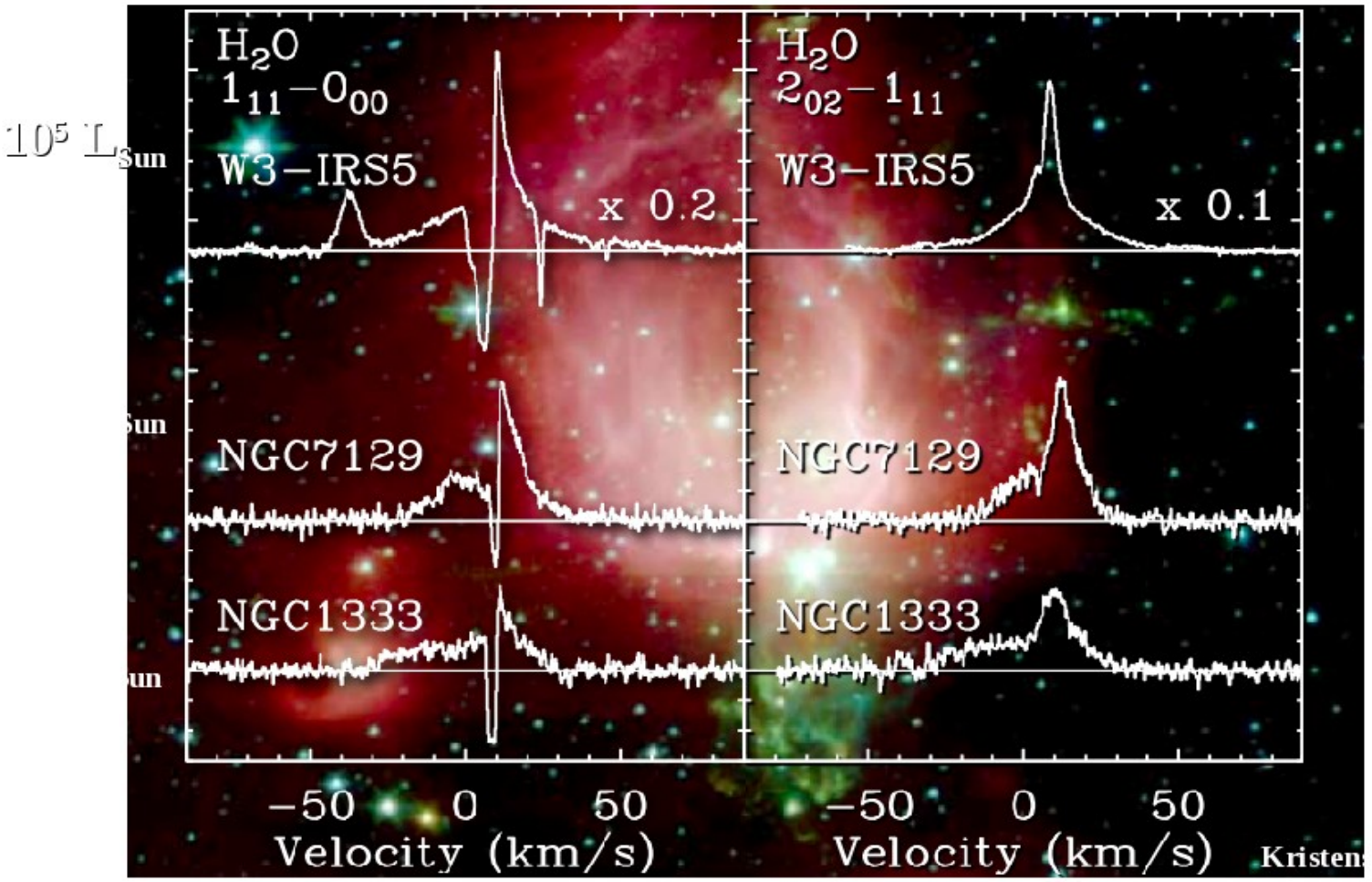
G10.6-0.4

Neufeld et al. (2010)

Water

Water less abundant that promised in all the Herschel planning, but

- Extremely sensitive tracer for shocks and outflows
- Also produced in PDRs due to ice evaporation



Water lines from high-to low-mass protostars

(note broad wings)

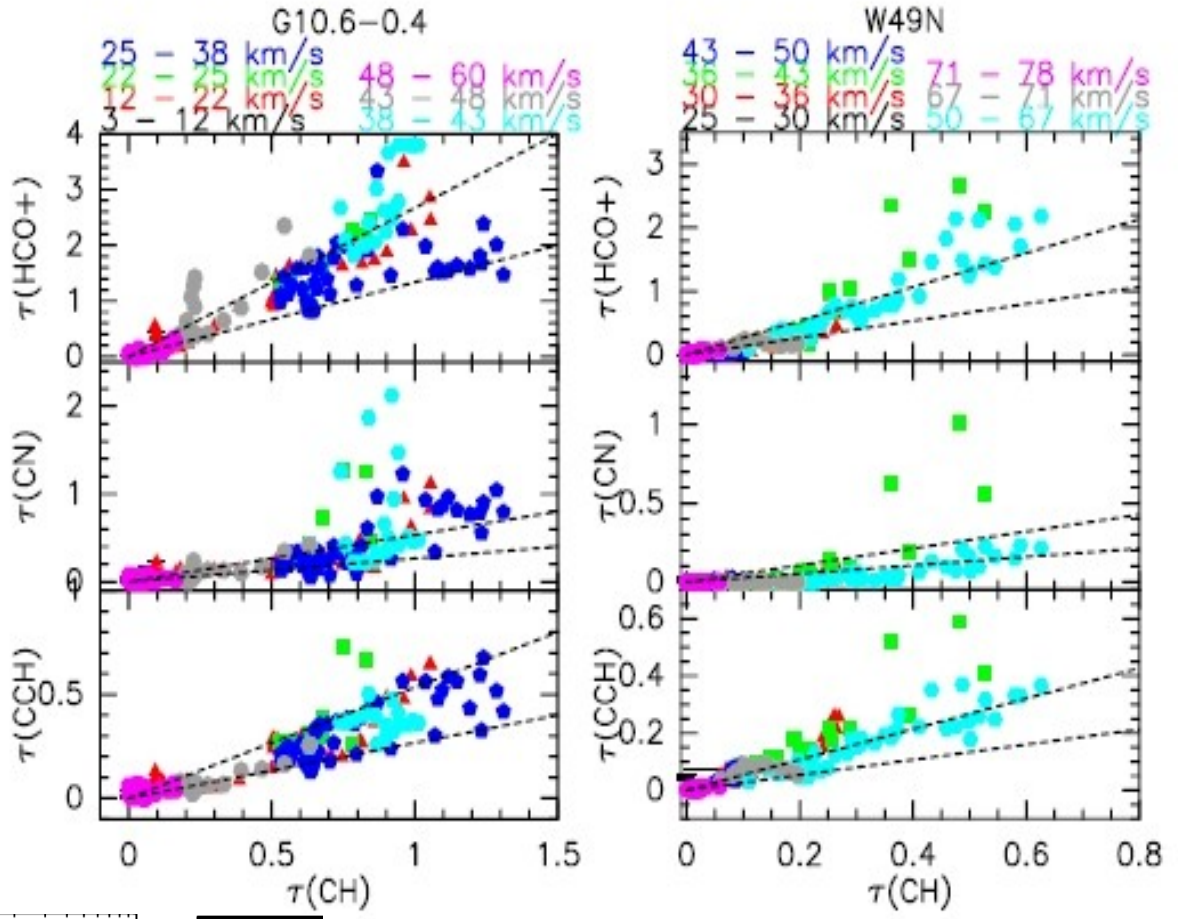
Kristensen et al. (2010)

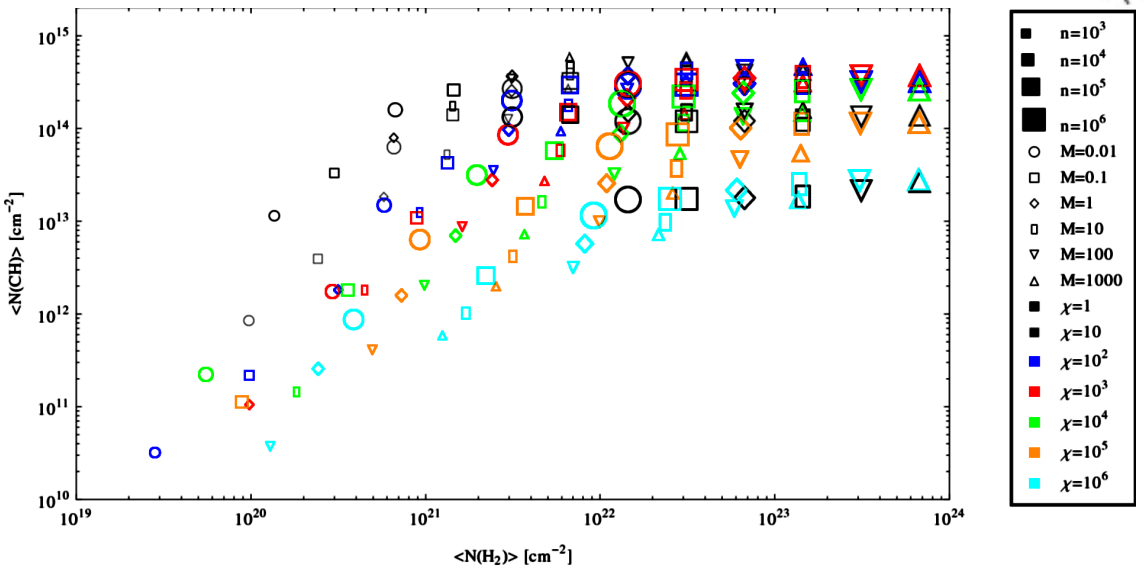
Understanding the chemistry

CH:

- Well defined trends & deviatic narrow velocity intervals
  - CCH/CH ~ 0.6 – 1.2
  - CN/CH ~ 0.5 – 1
  - HCO^+/CH ~ 0.04 - 0.08

→ Re-calibration of models:

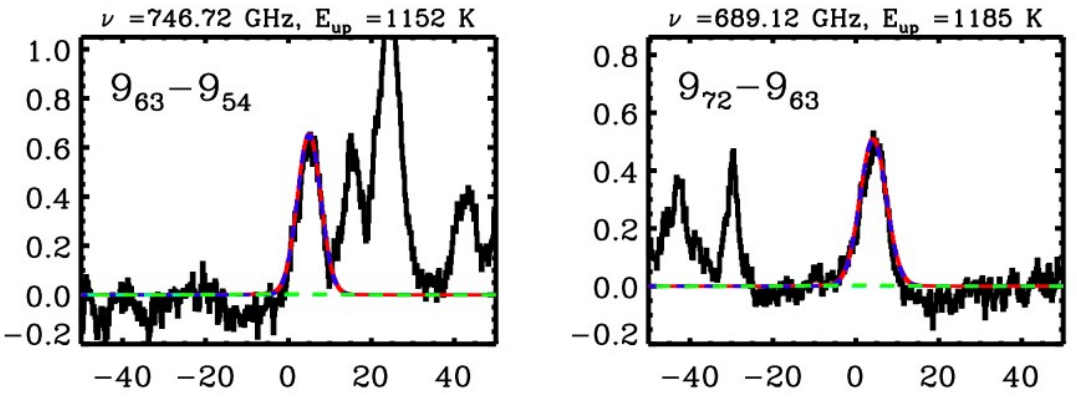




- KOSMA-τ PDR model reproduces the “saturation” of CH column densities

Understanding the chemistry

Complex species in Orion KL:



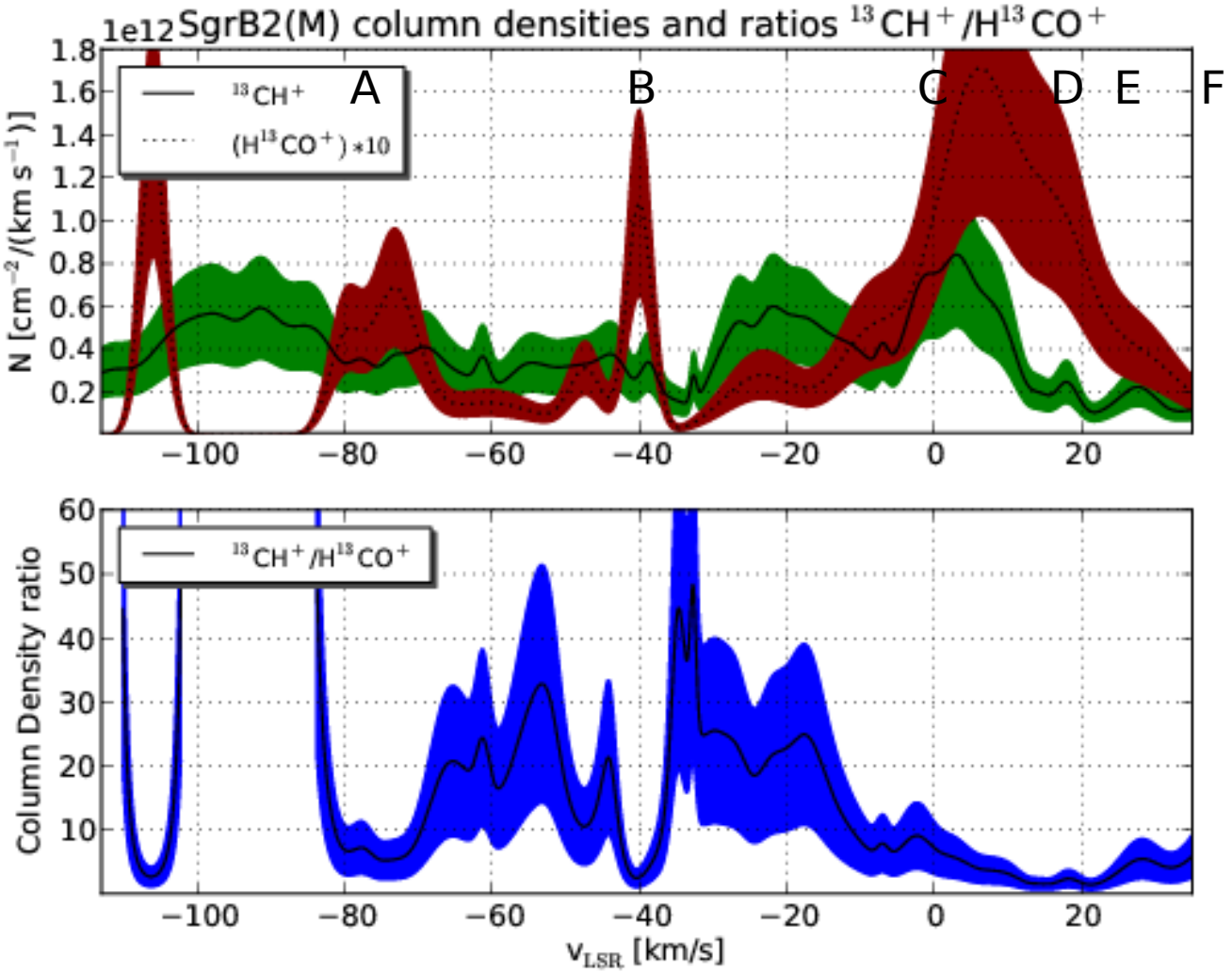
Example fit to 2 of the 70 detected H_2S lines

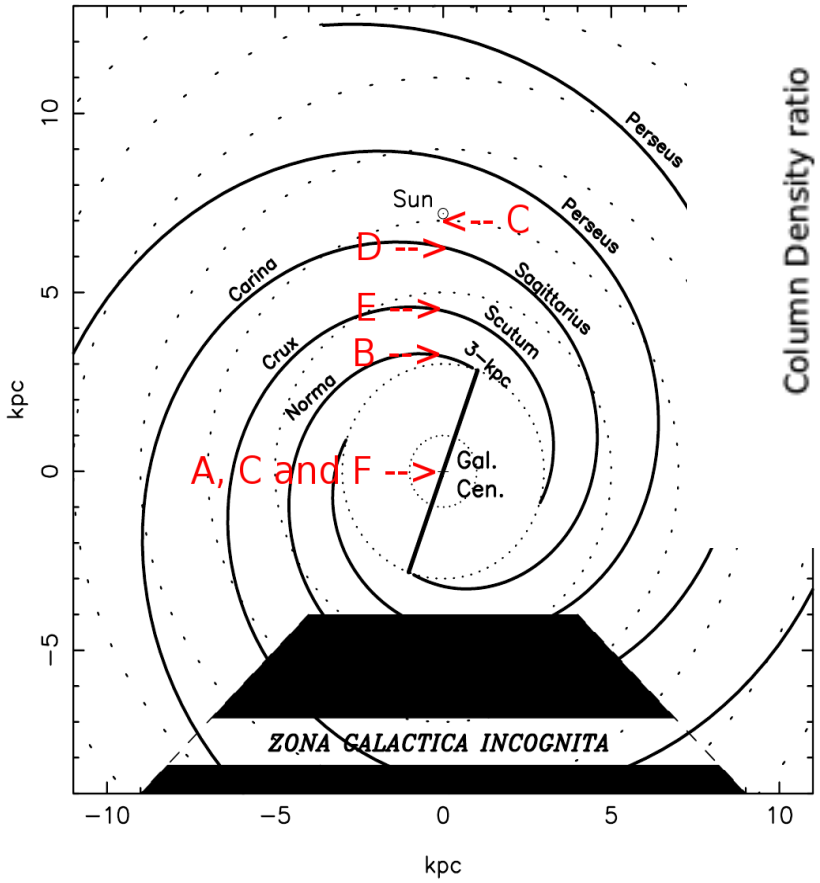
- Combined model for
  - NH2CHO
  - SiS
  - C2H5OH
  - H2CS
  - NO
  - NS
  - SO -> S-34-O, S-33-O, SO-18
  - SO2 -> S-34-O2, S-33-O2
  - HCN -> HC-13-N, HCN-15
  - HNC -> HN-15-C, HNC-13
  - SiO
  - CH3CN -> C-13-H3CN, CH3C-13-N
  - NH3 -> N-15-H3, NH2D
  - HCl
  - H2S -> H2S-33, H2S-34
  - H2CO -> H2C-13-O, HDCO
  - HCOOCH3
  - CCH
  - CN
  - HC3N
  - H2O -> HDO, HDO-18, D2O, H20-18, H2O-17
  - CH3OH -> C-13-H3OH, CH3OD, CH2DOH
  - C2H5CN
  - HNCO -> HNC-13-O
  - HCS+
  - H2CCO
  - OCS
  - CH3OCH3
  - CS -> CS-34, CS-33, C-13-S
  - CO -> C-13-O, CO-17, CO-18
  - HCO+

- Crocket et al. 2012

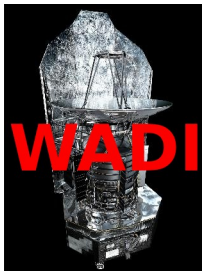
Understandir the chemistry

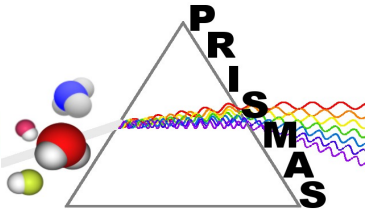
$^{13}CH^+/H^{13}CO^+$ in Sgr B2:





- Modelling extremely complex
- Separate fits for different clouds
  - Work for generations of PhD students





Summary

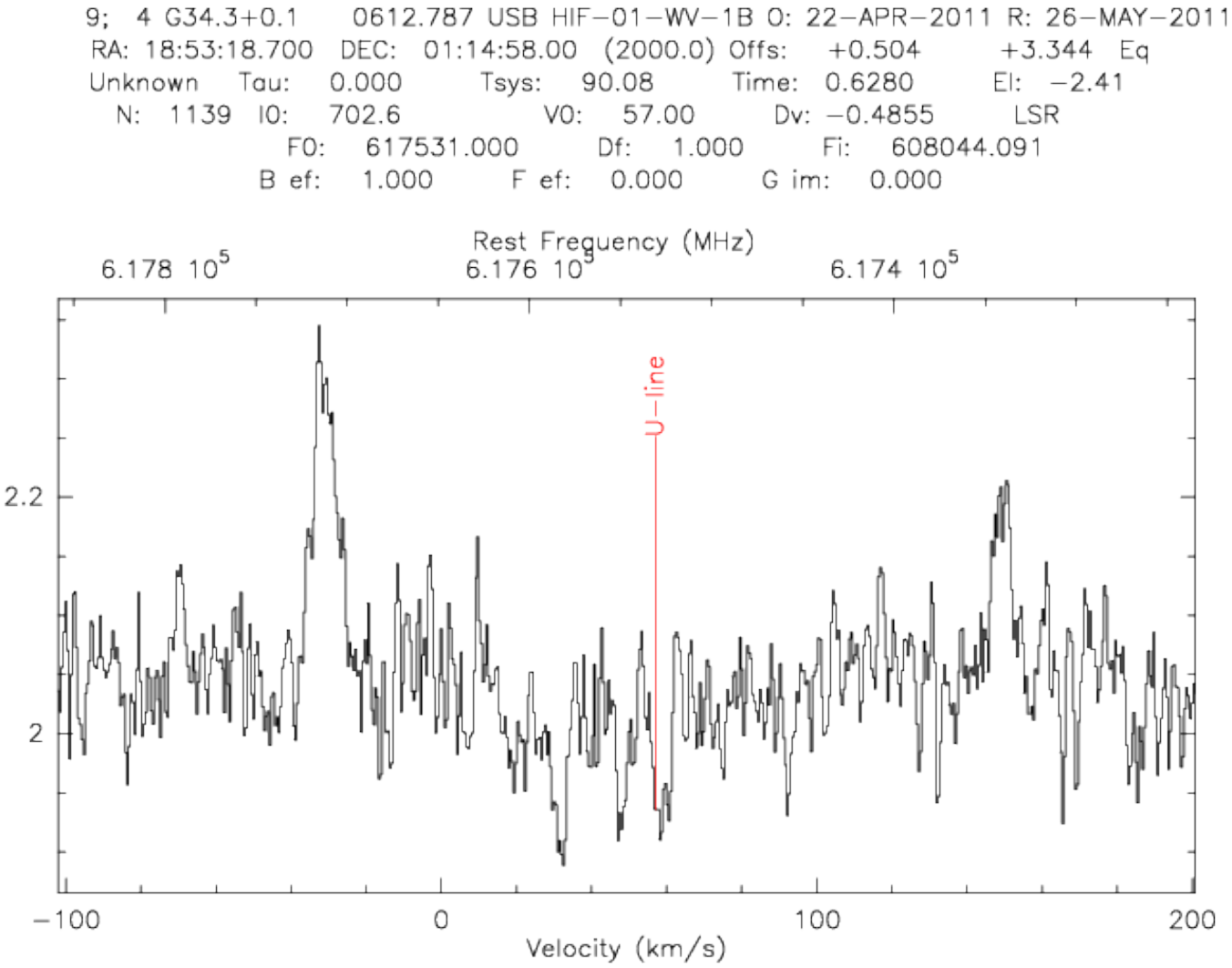
- Big step ahead towards complete chemical inventory
  - HIFI is hunter for new molecules
- Emission at low frequencies dominated by H_2O, CH_3OH, NH_3, H_2S, SO_2
- New probes of interstellar medium and processes :
  - Gas with small fraction of H_2 : HF, OH^+, CH^+
  - Cosmic ray ionization and dissipation of turbulence driving : CH^+, SH^+, OH^+, H_2O^+, H_3O^+
  - CII and OI as UV tracers, HCO as low frequency complement
  - Water as best shock/outflow tracer
- Modelling/interpretation has only started

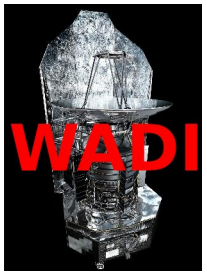
U lines

Most prominent example:

Tentative frequency: 617.531 GHz

Seen e.g. in
- Sgr B2
- W51
- G34.3 (shown)





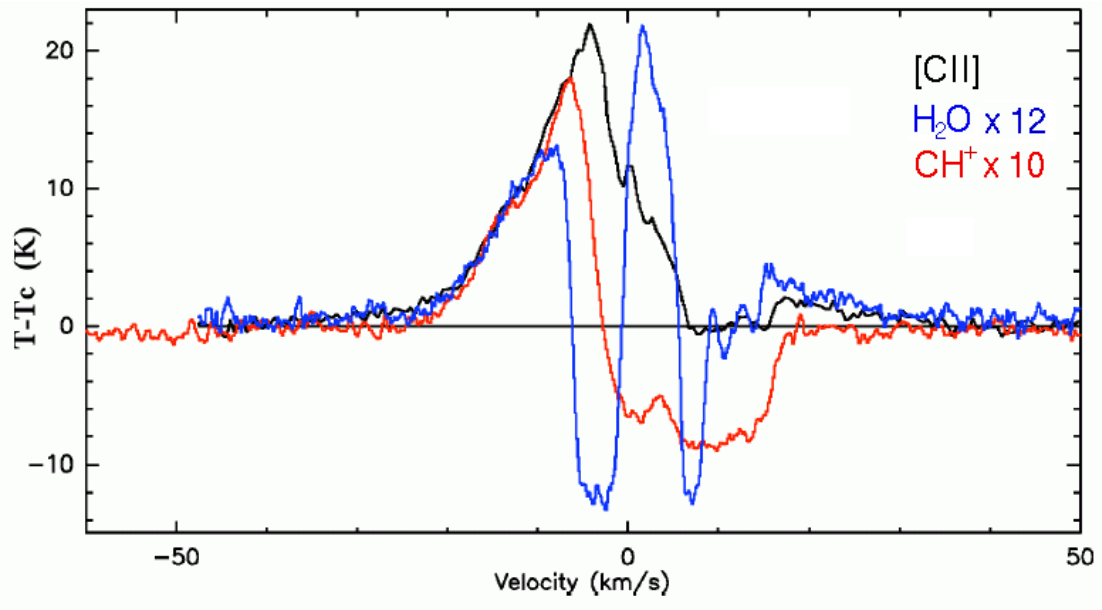
First detections

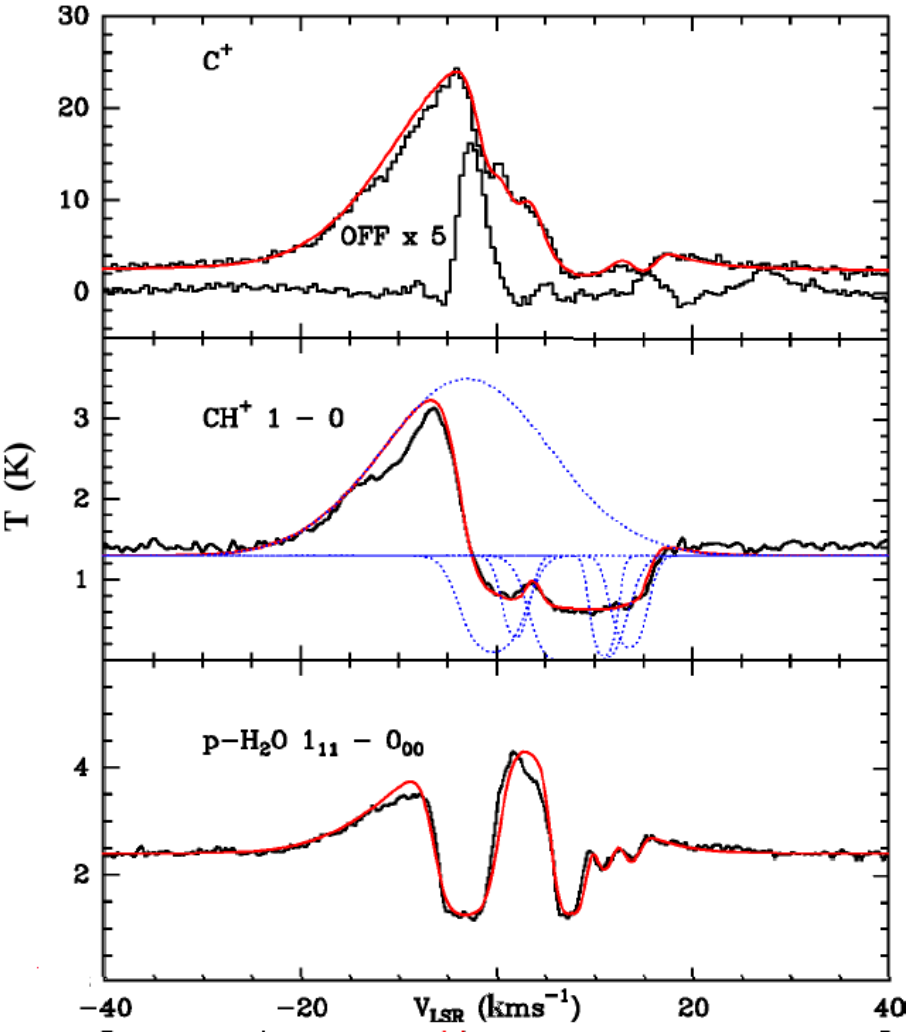
- First frequency resolved CH^+ line

  → correction of line frequency

- Detailed modelling of absorption and emission profile:

  - 2.5 10^{14} cm^{-2}





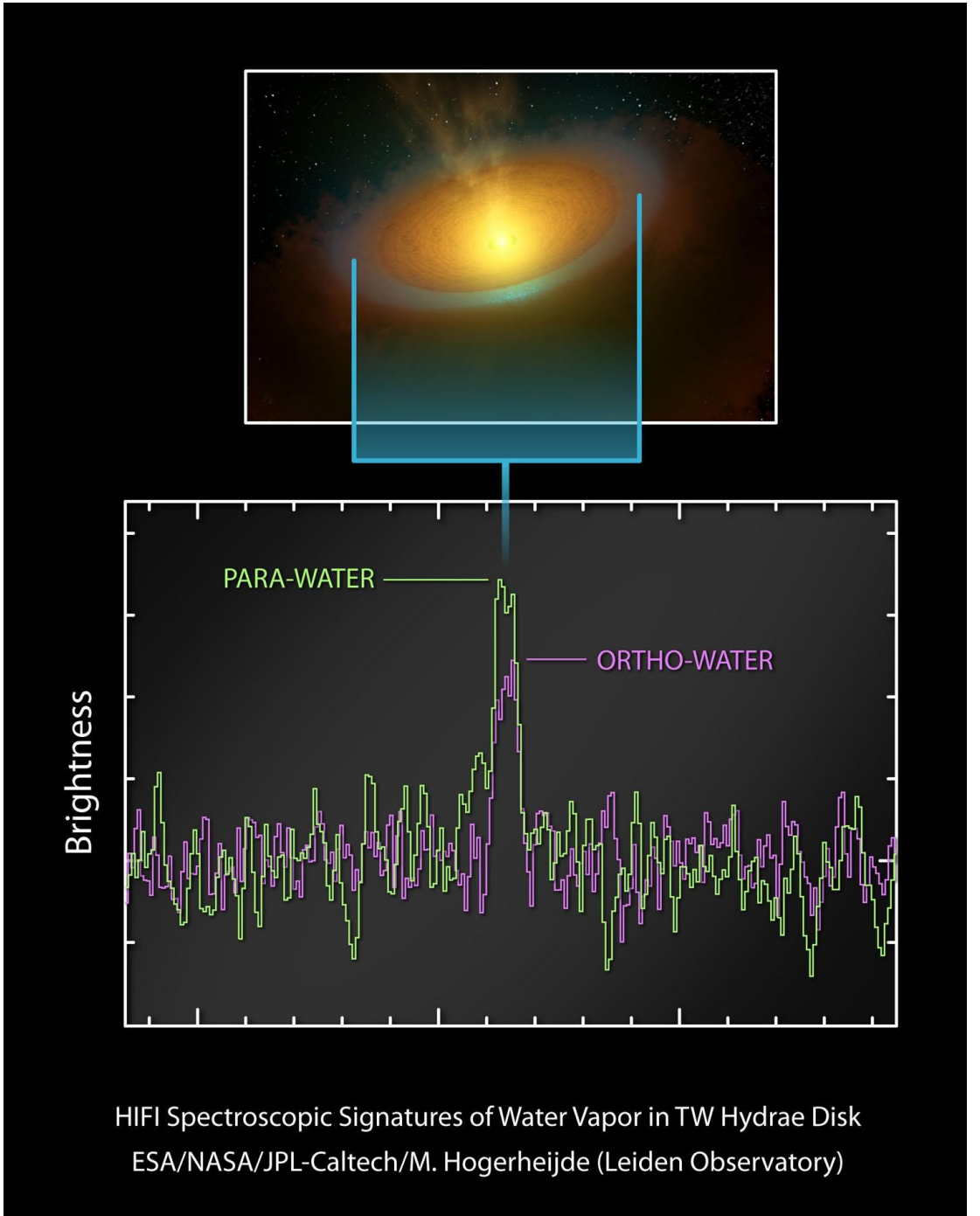
Falgarone et al. (2010)

Water

Large water reservoir in proto-planetary discs, but:

- Only tiny fraction in gas phase:
  - $< 10^{-6}$

Integrated water spectra from protoplanetary disc around TW Hya



Hogerheijde et al. (2012)