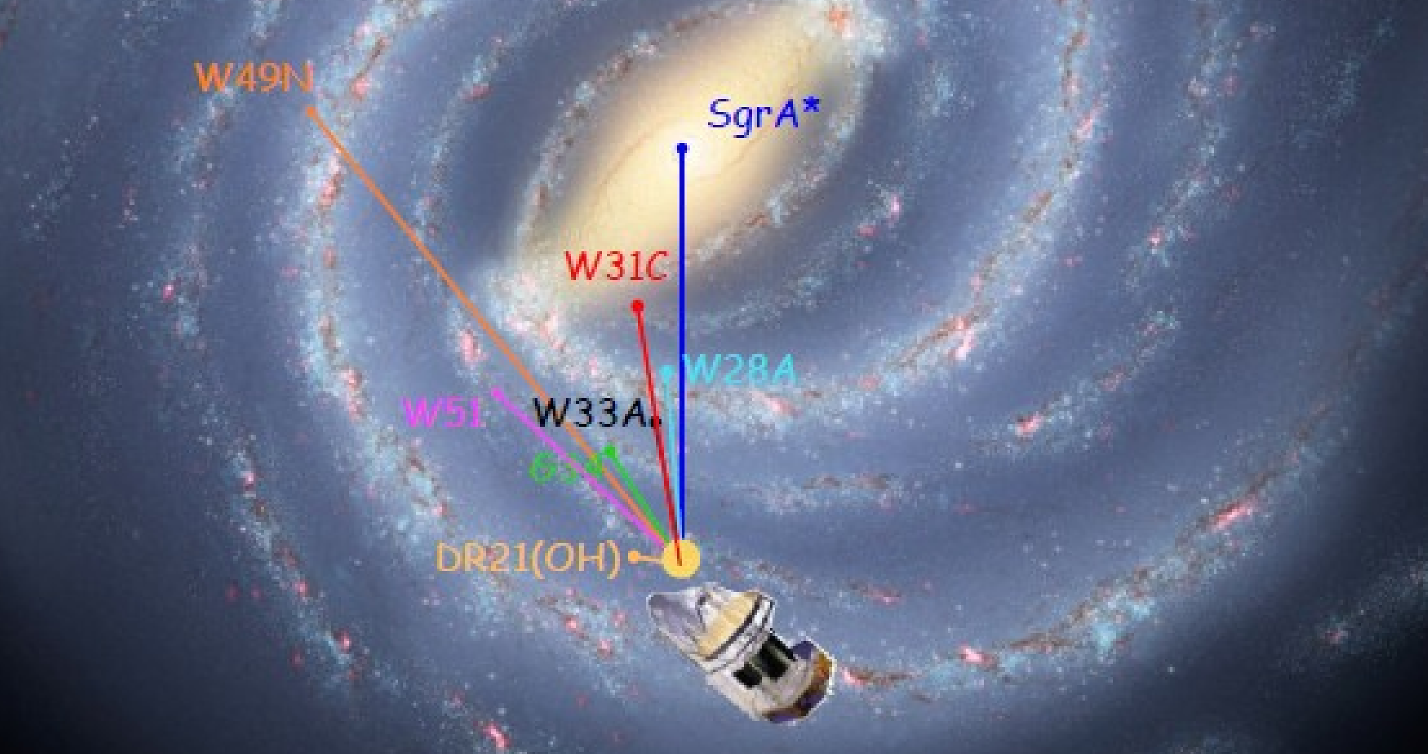
Detection of a Dense Core in HDO & CCC towards W51e

Bhaswati Mookerjea & Charlotte Vastel

G. Hassel, M. Gerin + PRISMAS team



The Universe Explored by Herschel, Noordwijk, 16 October 2013

CCC Towards PRISMAS Sources

- Detected from the dense & warm envelopes of hot cores

- Not detected in diffuse clouds in FIR -- not enough S/N

- Typical T~30 K and $n(H_2) > 10^5$ cm^{-3}

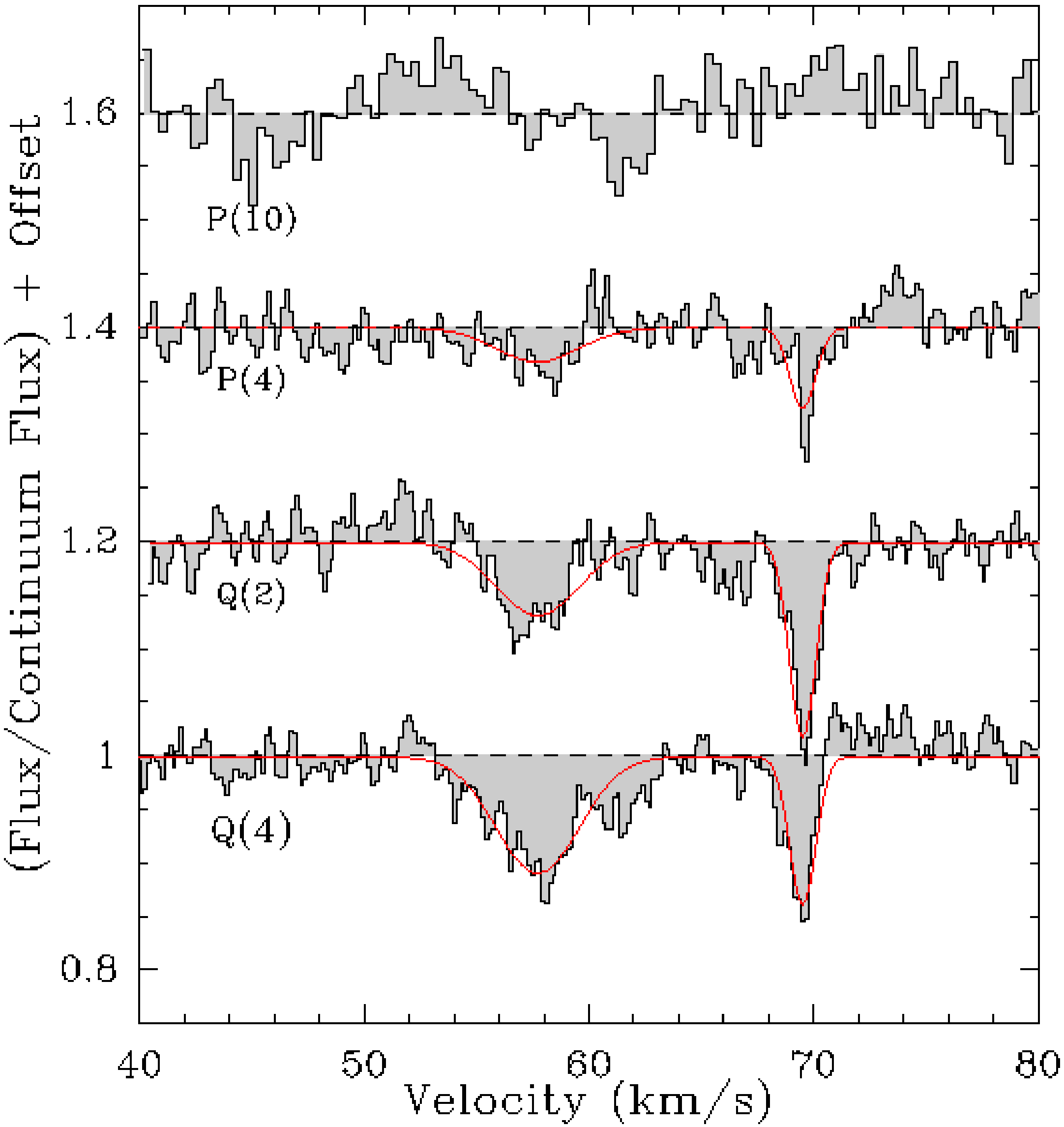
- 10 times less abundant in dense clouds than in diffuse clouds (optical spectroscopy)

- Formation in dark dense clouds begins with C^+ and not with the photoionization of C_2 as in diffuse clouds

- Abundance in dense clouds interpreted in terms of grain warm-up models.

Mookerjea et al. (2010,2012,in prep)

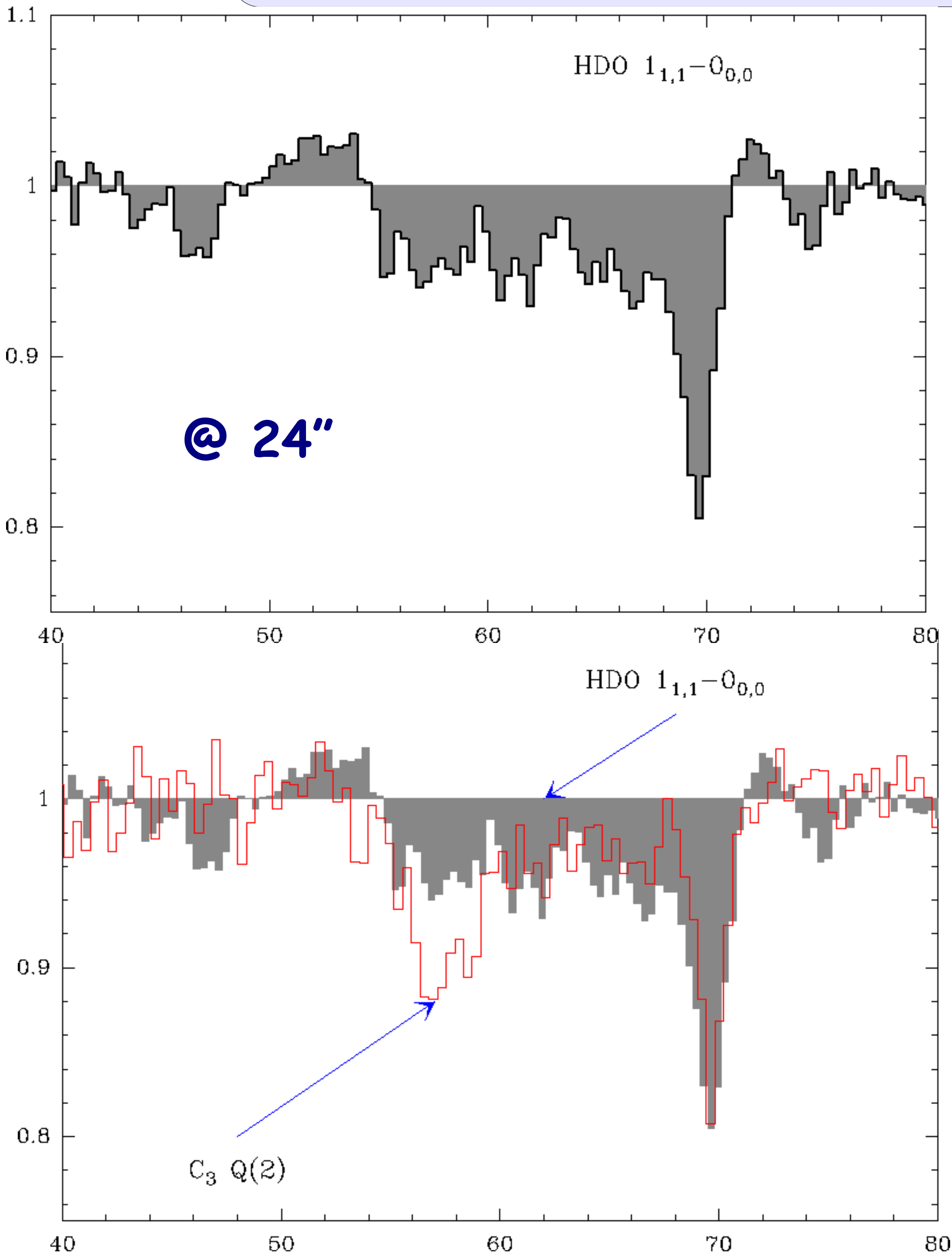
CCC towards W51



@ ~14"

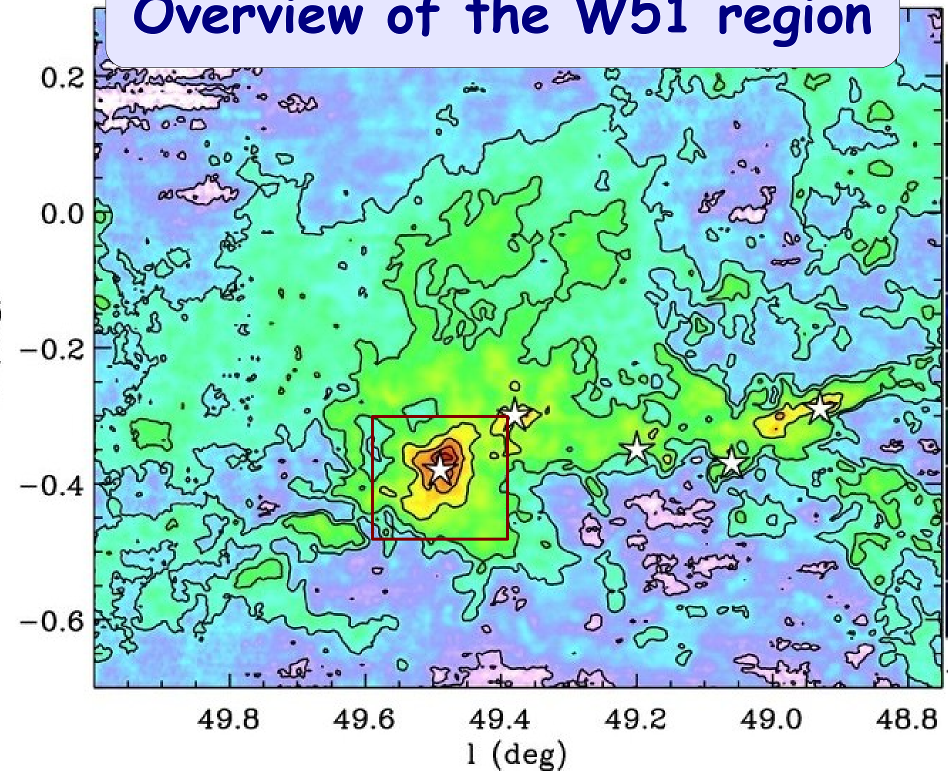
- Observed 4 transitions, detected 3
- Two velocity components detected :
  I. Broad (Δv=4.3 km/s) at 57.8 km/s
  II. Narrow (Δv=1.4 km/s) at 69.6 km/s
- Component I is due to the source itself
- Narrow and detectable C_3 line ----> compact cloud with reasonably high density
- Essentially transitions with 2 J values (J=2 and J=4) for LTE analysis
- T_{rot} = 14 K and N(C_3) = 6.4x10^{13} cm^{-2}
- Collision rates for C_3 not known

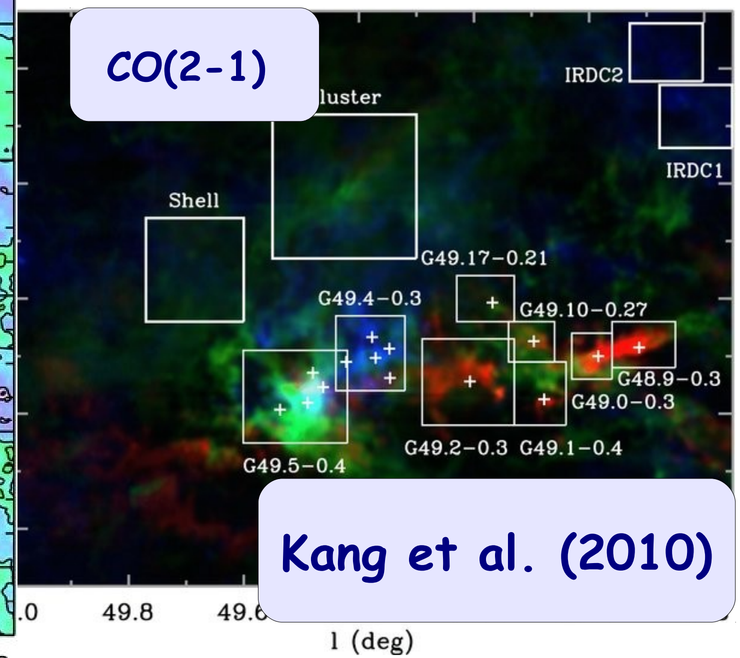
HDO towards W51



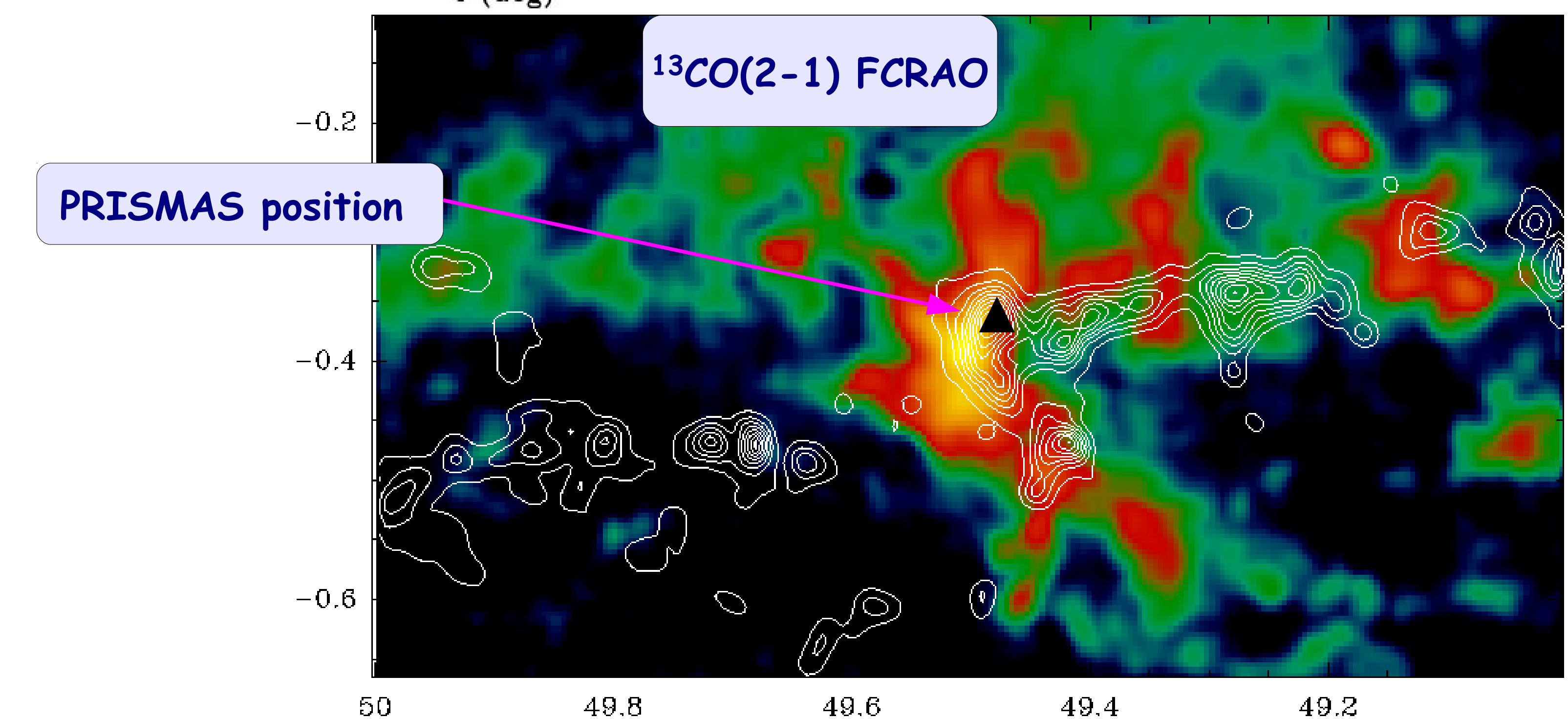
- ***All other PRISMAS sources:*** HDO detected at the 893 GHz ground transitions always at source velocity. No detection at other velocities.
- Two transitions observed at 893 & 464 GHz
- Narrow 70 km/s component detected only in the 893 GHz component
- Profile matches CCC absorption dip
- Both ground state transitions have $n_{cr} > 10^7$ cm^{-3}

Overview of the W51 region





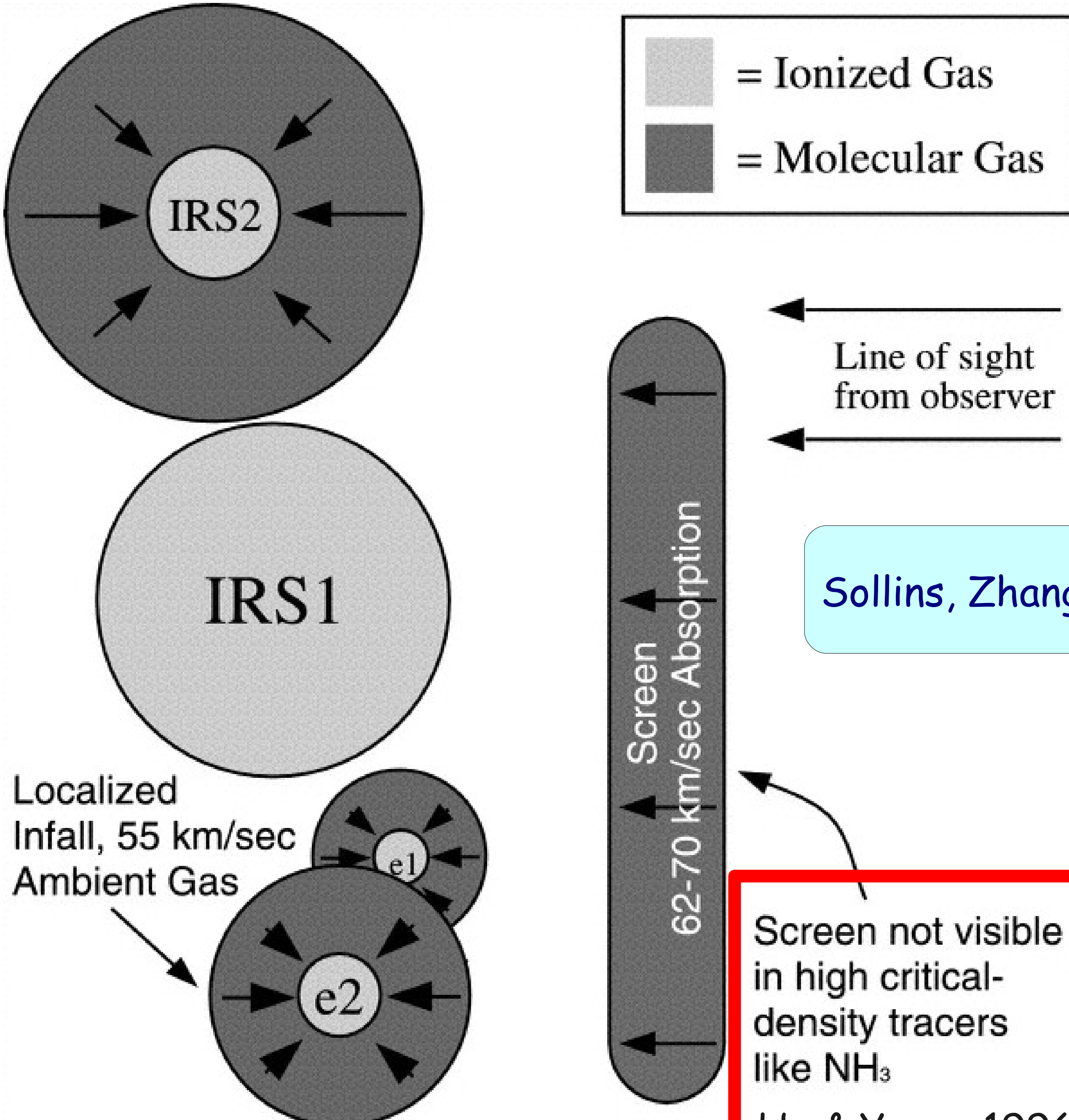
Blue: 30-55 km/s
Red: 56-65 km/s
Green: 66-85 km/s



Main Cloud (Color)

70 km/s Filament (white contour)

The Filament in W51



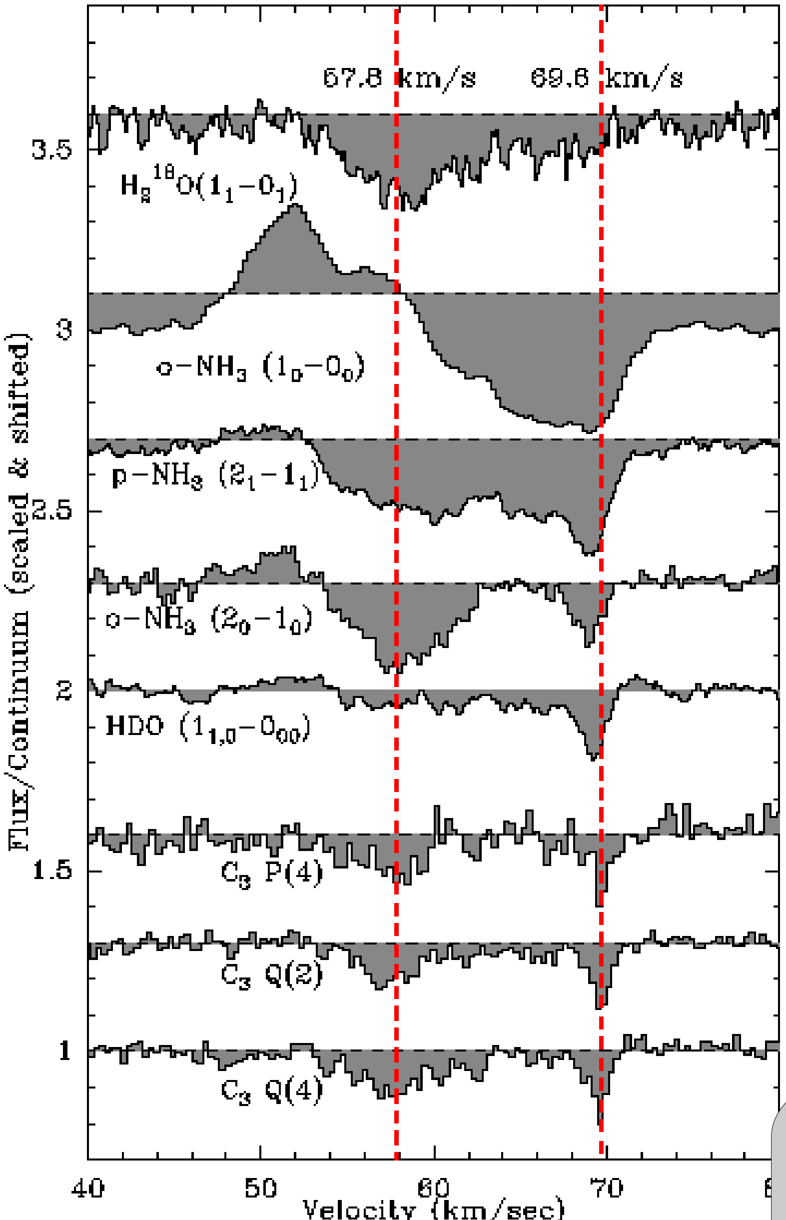
Sollins, Zhang & Ho 2004

Screen not visible in high critical-density tracers like NH_3

Ho & Young 1996

No longer True

HIFI Observations towards W51e



$H_2{}^{18}O$ (Flagey 2012)

Main Cloud: 58 km/s
Filament : 70 km/s

o- & p-NH_3

@574,1214.8,1215.2GHz

NH_3 & HDO indicate $n>10^5$ cm^{-3}

HDO
@893 GHz

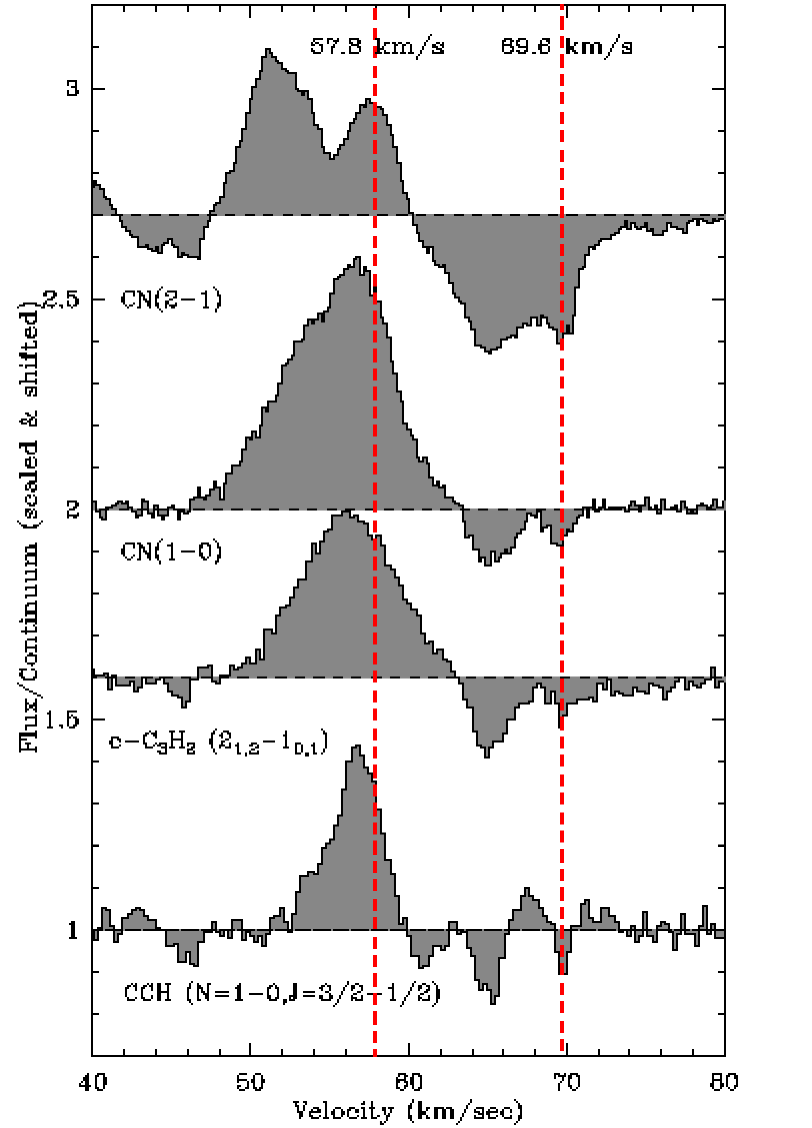
C_3

@1787,1891,1897 GHz

First ever detection of HDO & CCC in dense cloud not known to be forming stars

Ground-based detection of 70 km/s component

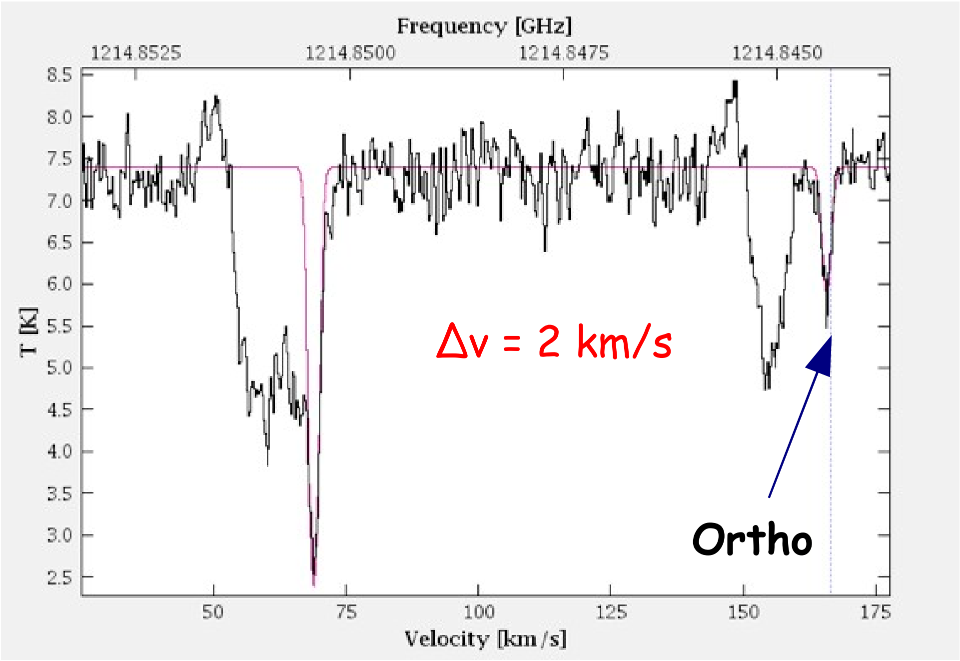
- Absorption profiles of CN(1-0) and CN(2-1) somewhat complicated by the presence of 4- & 6-component multiplets
- The upper energy states of CN transitions suggests Tex less than 4 K (113GHz) and 6.3 K (226GHz) in order for the lines to appear in absorption
- Feature extends over 5" in CCH map observed with PdBI (J. Pety) . Detected at positions where background emission is strong.
- Size of the filament D=5.41 kpc, 5"=0.13pc (similar to sizes predicted by Arzoumanian et al. 2011)
- Detection of NH_3 and HDO ----> $n > 10^5$ cm^{-3}

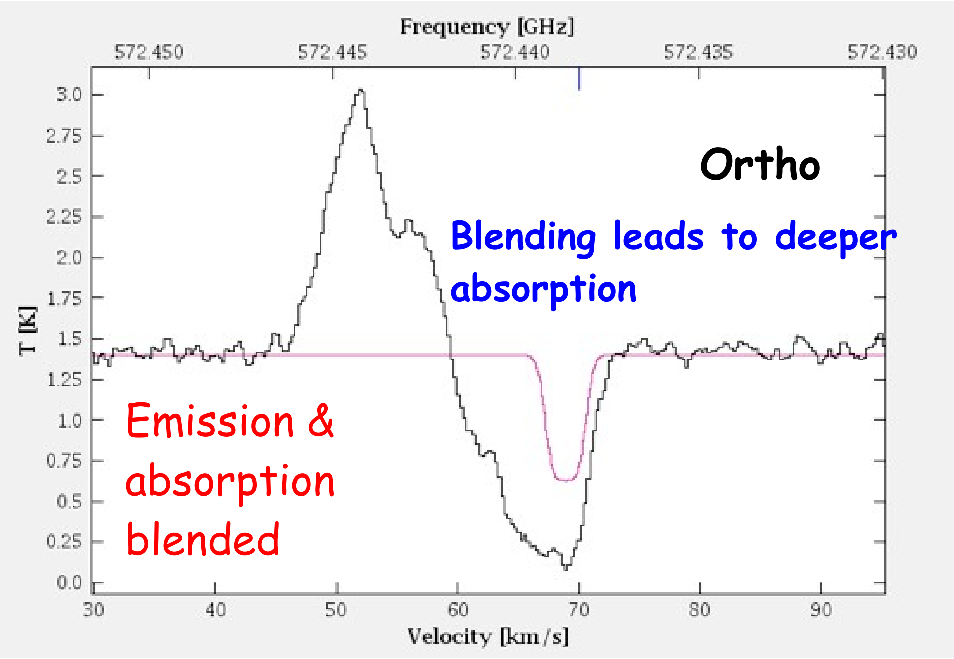


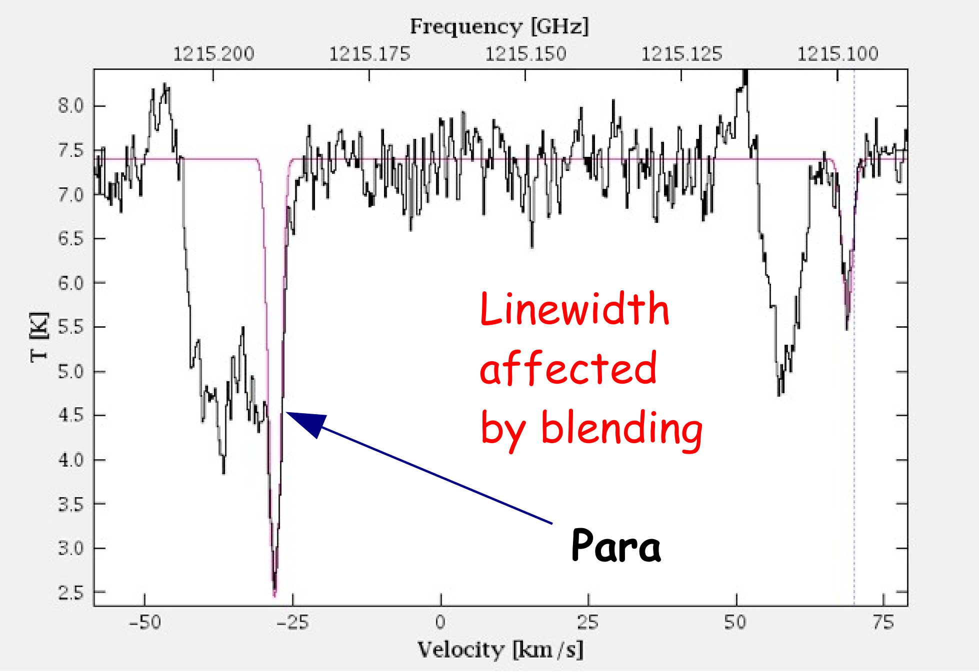
- For $n=10^5$ cm^{-3} and size = 0.13pc

  ---> **$N(H_2)$ = 4×10^{22} cm^{-2}**

Characterization of the 70 km/s component: non-LTE Analysis of NH_3







Assume ortho/para = 1

$n(H_2) = 5\times10^5$ cm^{-3} T=30K

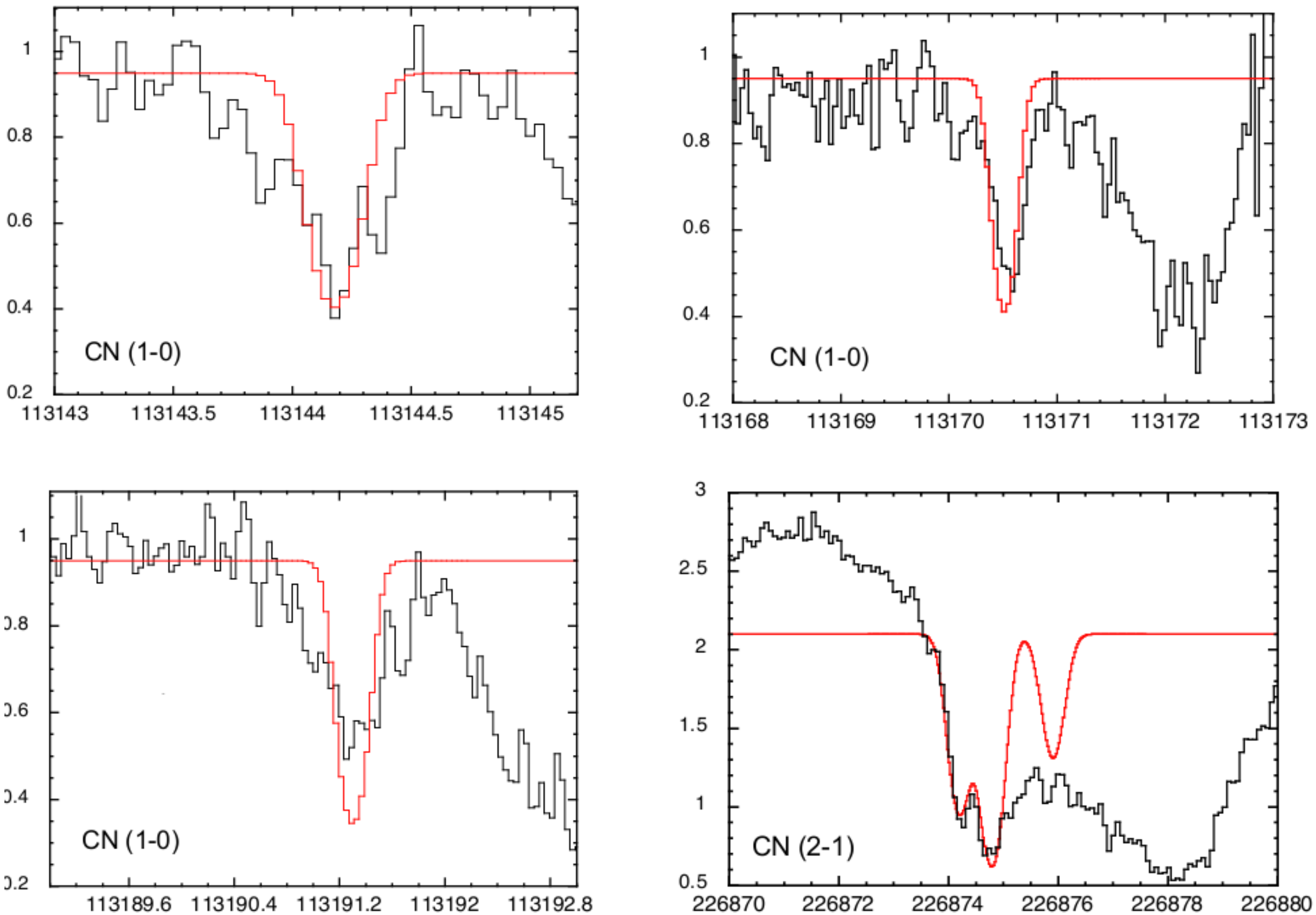
$n(H_2) = 5\times10^6$ cm^{-3} T=13K

$n(H_2) > 5\times10^5$ cm^{-3}

$T_{kin} < 30$ K

$N(NH_3) \sim 3\text{-}4\ 10^{13}$ cm^{-2}

Non-LTE (RADEX/Cassis) Analysis of CN & $c\text{-}C_3H_2$



- Collision rates with $p\text{-}H_2$ taking all CN hyperfine levels recently became available (Kalugina et al. 2012)

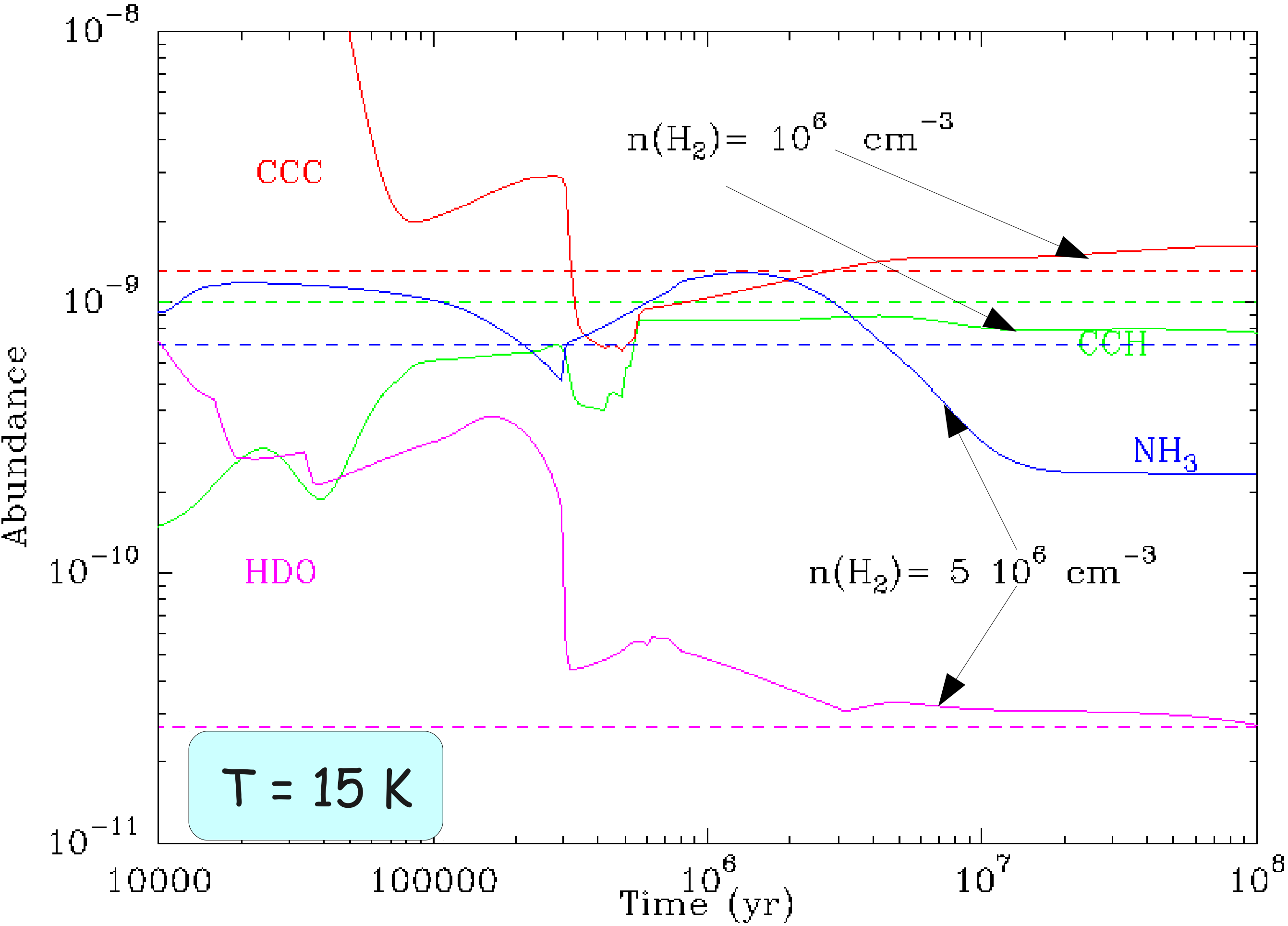
- Considering only collisions with $p\text{-}H_2$, non-LTE RADEX model

- Δv = 0.6 km/s:
  T_{kin} = 6 K, n = 10^5 cm^{-3}

$c\text{-}C_3H_2$ n=10^4 cm^{-3} for T=15 K

Not consistent with result of NH_3 analysis & HDO detection
→ do not directly trace the dense core

Chemical Model for 70 km/s Component: OSU Gas-Grain



- Chemical evolution of a homogeneous parcel ---> a cold prestellar phase (0.1 Myr) at T=10 K followed by a gradual increase of temperature up to T_{max} for 0.2 Myr (Hassel et al. 2011).
- Subsequently considers grain surface and gas-phase chemistry

- Observed abundances consistent with models with T=15 K and n=10^6 cm^{-3} (CCH & CCC) and n=5x10^6 cm^{-3} (HDO & NH_3)
- Abundances of all species require desorption of precursor molecules from grain-surface
- At 15 K desorption is primarily dominated by cosmic ray ionization
- Reasonable agreement for between 0.7 to 2 Myr

Conclusions

- Towards W51 we have detected a narrow (<2 km/s) component at a velocity greater than the source velocity in CCC, HDO, CN, CCH & c-C_3H_2

- First ever detection of CCC and HDO in dense (n $\geq 10^6$ cm^{-3}) cloud not directly associated with star forming regions

- The 70km/s feature arises from a dense core formed due to the interaction of the filament with the W51 main cloud.

- Two different values of n(H_2) required to explain the abundances, possible density gradient

- Protostar? Fortuitously located along the line of sight to the bright W51e?