Probing C_3 formation in DR21(OH)

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Spitzer IRAC image, Courtesy NASA/JPL, Caltech

Linear Carbon Chains

- Building Blocks for more complex carbon-rich molecules found in space
- Candidates for the Diffuse Interstellar Bands
- Carbon chains are found to be conspicuously abundant in ISM
- No permanent dipole moments ==> electronic transitions in UV/optical or Ro-Vibrational transitions in THz.
- C_2 detected in optical/UV and C_3 detected both in FIR, MIR, optical and UV ----> C_3 suitable for high A_v regions
- Frequencies for bending mode transitions of larger chains are yet to be determined

C_3 detections so far

- Commonly detected in comets
- First tentative detection of v_2 bending mode in interstellar gas by van Orden (1995) in far-infrared
- Electronic transitions in translucent clouds in optical (Maier et al. 2001, Roueff et al. 2002, Oka et al. 2003) ;. $x(c_3)\sim10^{-9}$
- v_3 Antisymmetric stretching modes in the **circumstellar envelope** in mid-infrared (Hinkle et al. 1988); $x(c_3)\sim10^{-6}$
- v_2 bending mode transitions towards **SgrB2** (Cernicharo et al. 2000) with ISO. $x(c_3)\sim10^{-9}$
- First detection of C_3 in **star forming regions (hot cores)** using far-infrared with Herschel (Mookerjea et al. 2010); $x(c_3)\sim10^{-8}$

C_3 formation routes

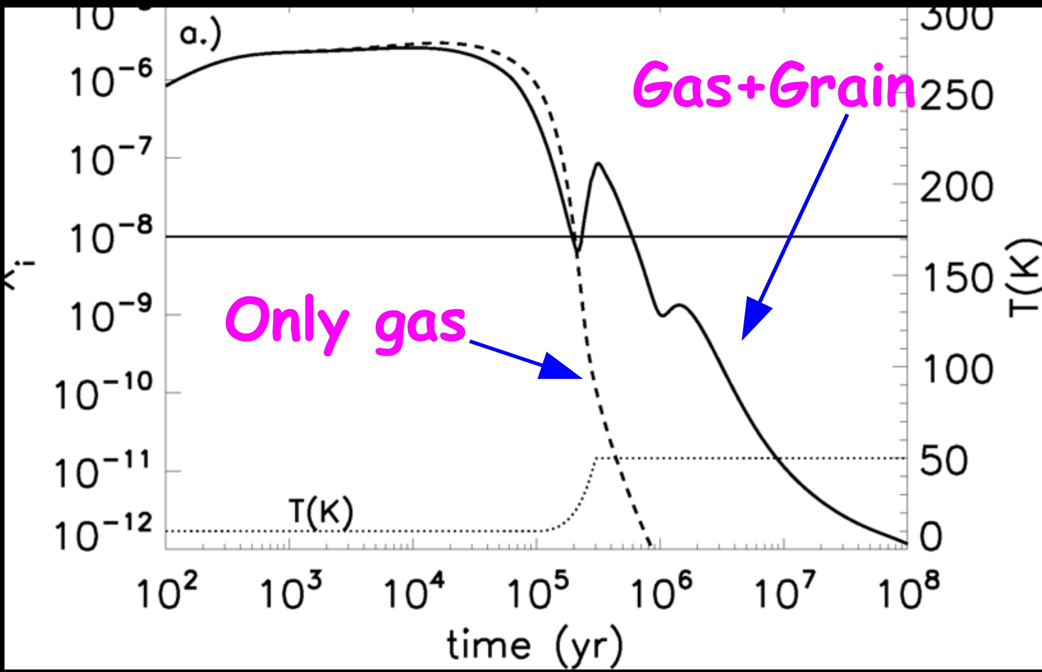
- **Comets :** Multistep reactions starting from C_3H_4 **(Helbert et al. 2005)**
- **Translucent Clouds (Oka et al.2003):** C_2 & C_3 intensities are correlated : Start with C_2 and reaction chains involving formation of C_2H, C_3H_2 etc.
- **Circumstellar envelope (Hinkle et al. 1988):** $x(C_3) \sim 10^{-6}$

  Direct photolysis of C_3H_4

  Photolysis of C_2H_2+ Gas Phase Chemistry

  On carbon-rich grains via photolysis or catalytic reactions

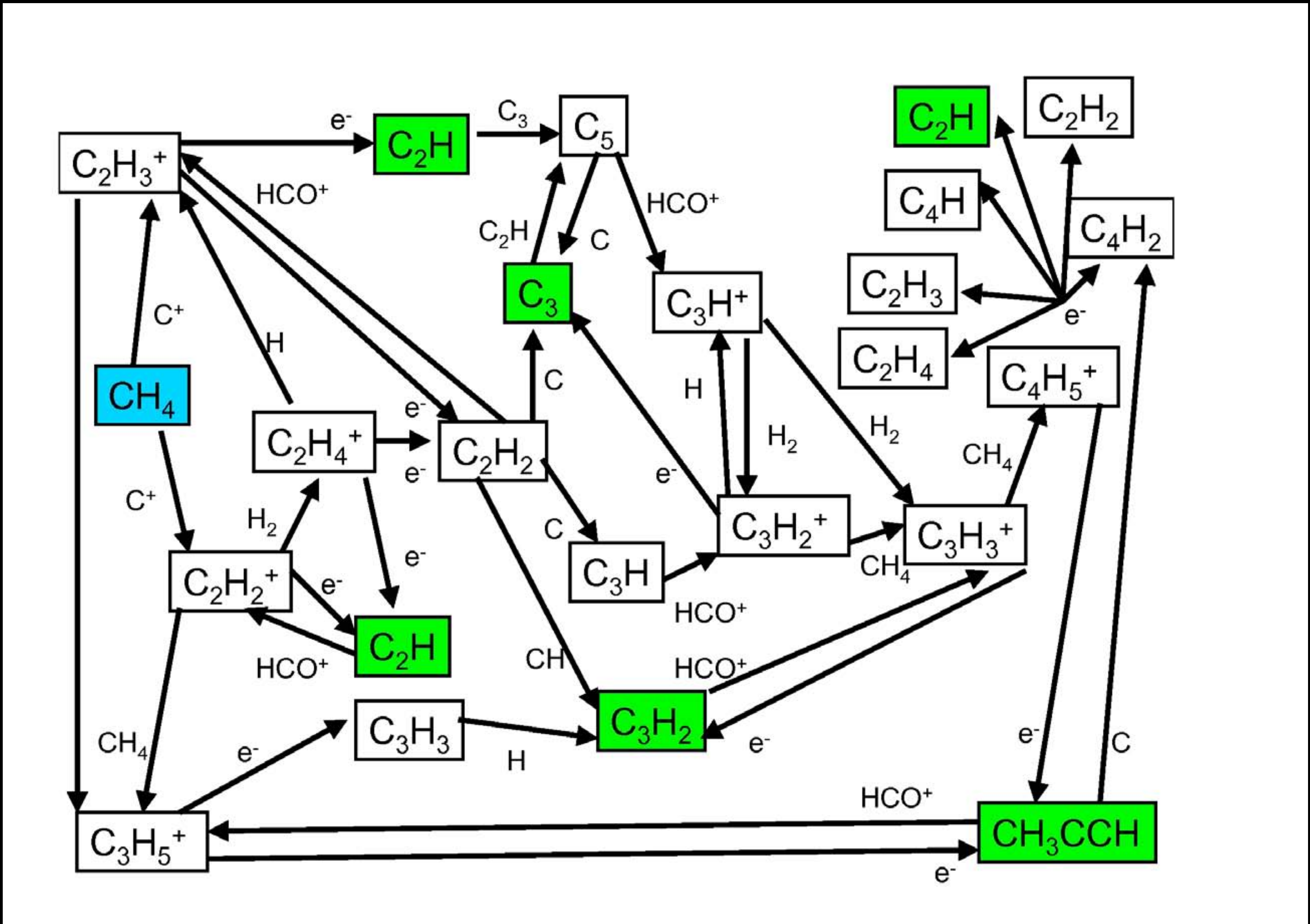
Gas-Grain Models for hot cores with warm-up: C_3 (OSU: Hassel et al. 2011)



- Homogeneous physical conditions at any given time
- Initial cold period of T=10 K for 10^5 yr
- Significant solid phase abundance of CH_4, H_2O and CO
- Beyond 10^5 yr grains warm up to 30 K, 50 K, 100 K & 200 K.

- Role of surface chemistry is not direct … produces CH_4 which evaporates at 30 K.
- Secondary peak due to gas-phase reaction $C + C_2H_2 \dashrightarrow C_3 + H_2$
- Able to obtain $x(c_3) \sim 10^{-8}$

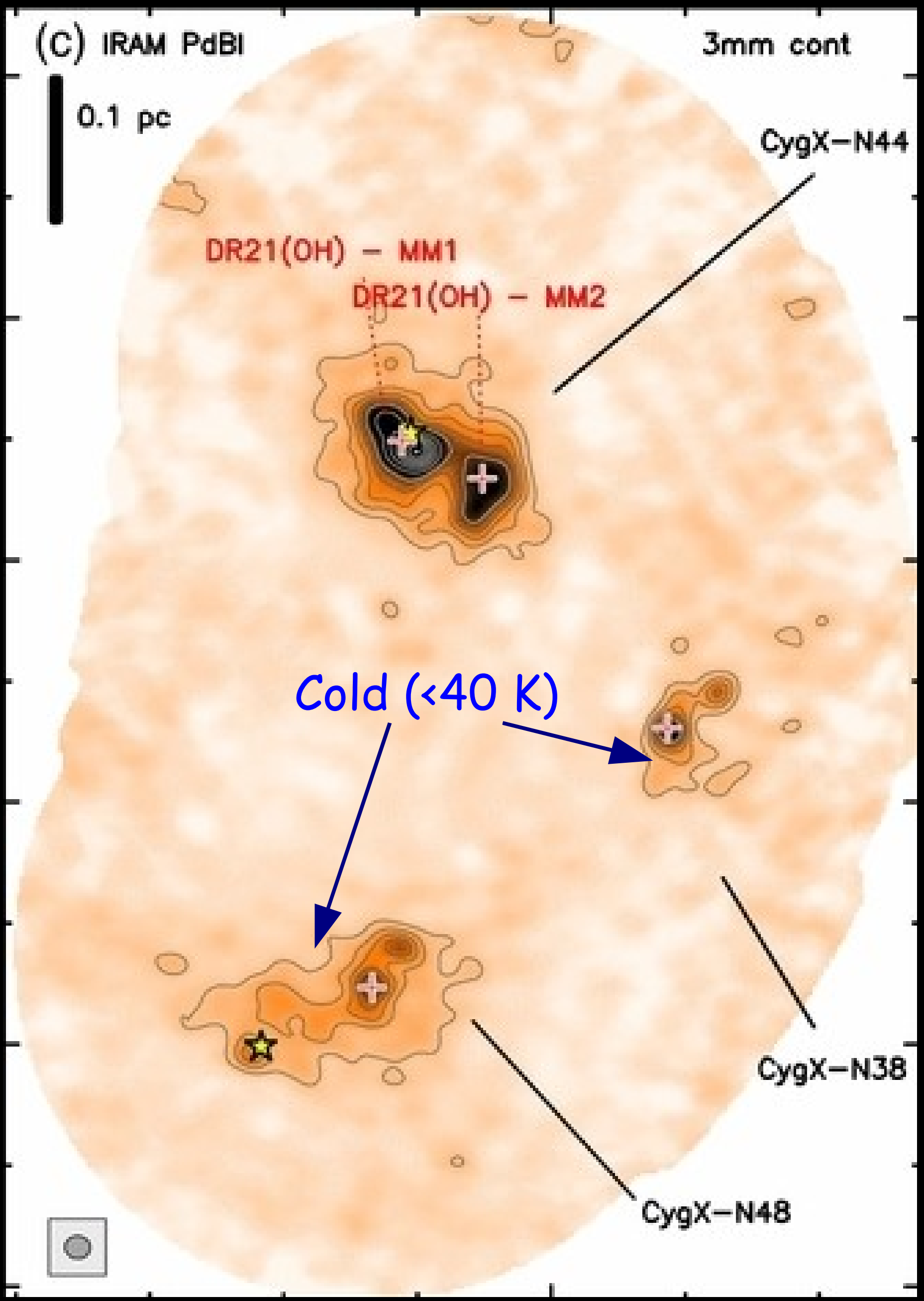
Chemical Reactions in the Gas-Grain Model



DR21(OH)

- DR21(OH) is the most massive 1 pc scale clump in Cygnus-X
- Three 0.1 pc scale massive dense cores
- CygX-N44: MM1 & MM2 separated by ~7"
- V_{LSR} of quiescent gas -3.1 km/s

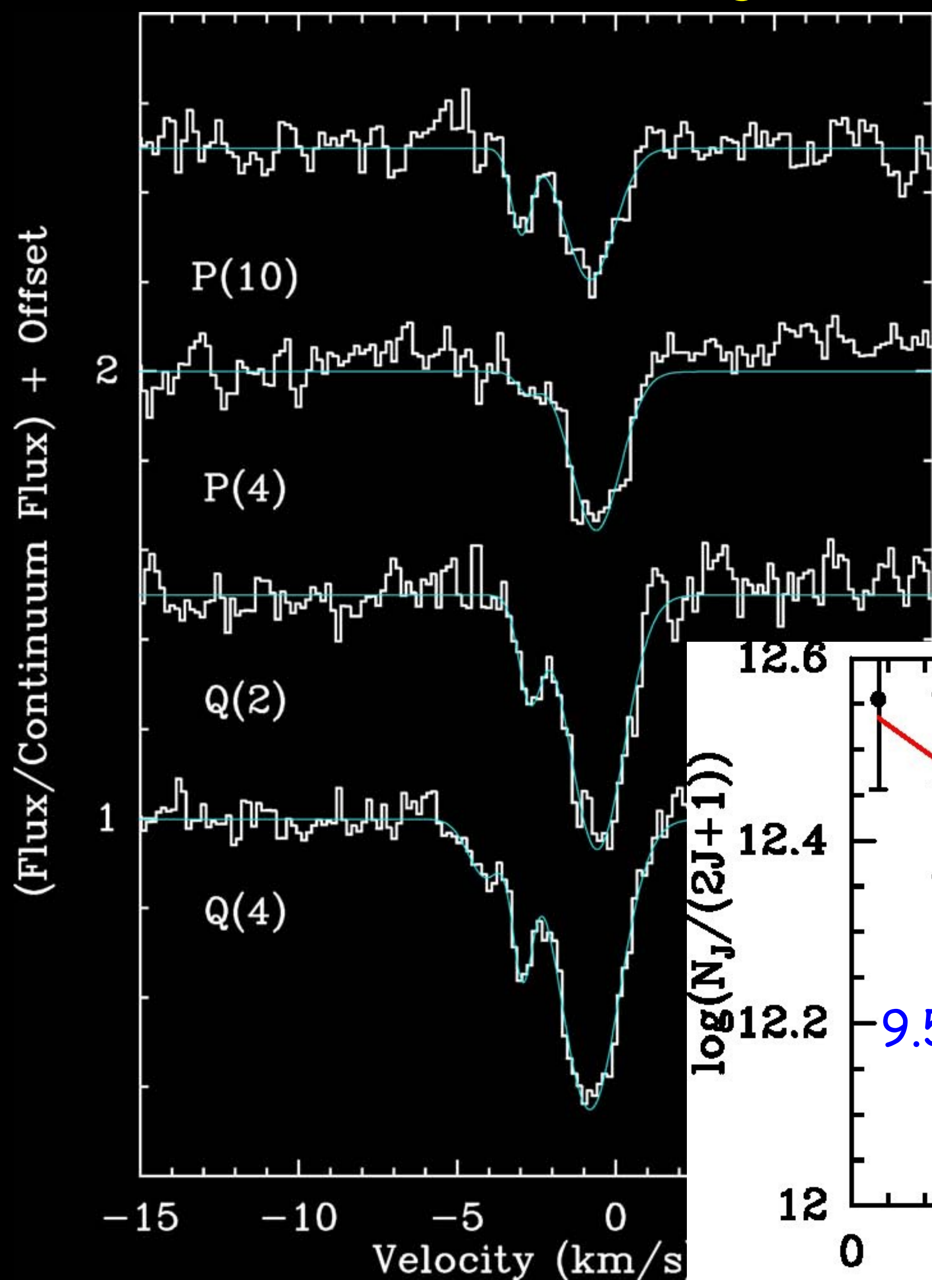
Component	v_{LSR} (km/s)	T_{dust} (K)
DR21(OH)-MM1	-4.1±0.3	58
DR21(OH)-MM2	-0.7±0.3	30



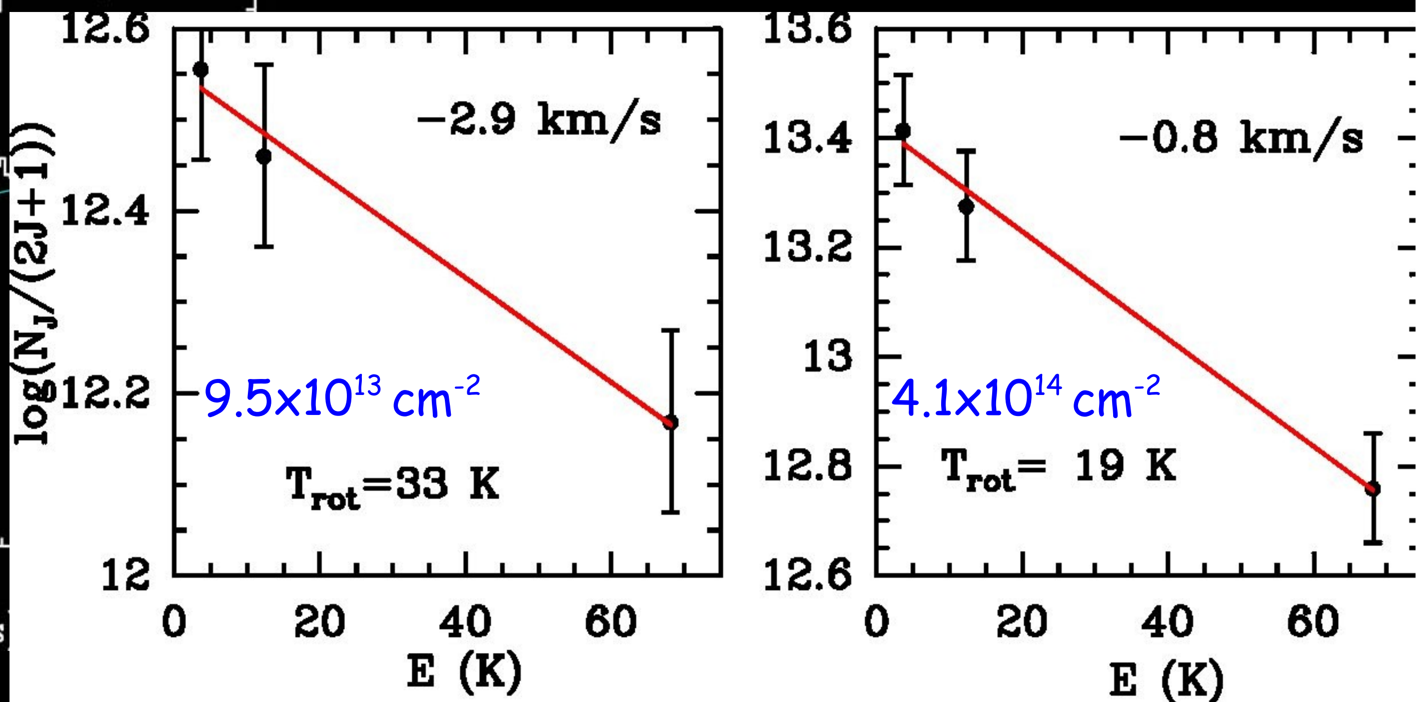
PRISMAS : HIFI GTKP

DR21(OH) was chosen as a continuum background source for absorption studies of foreground clouds in FIR

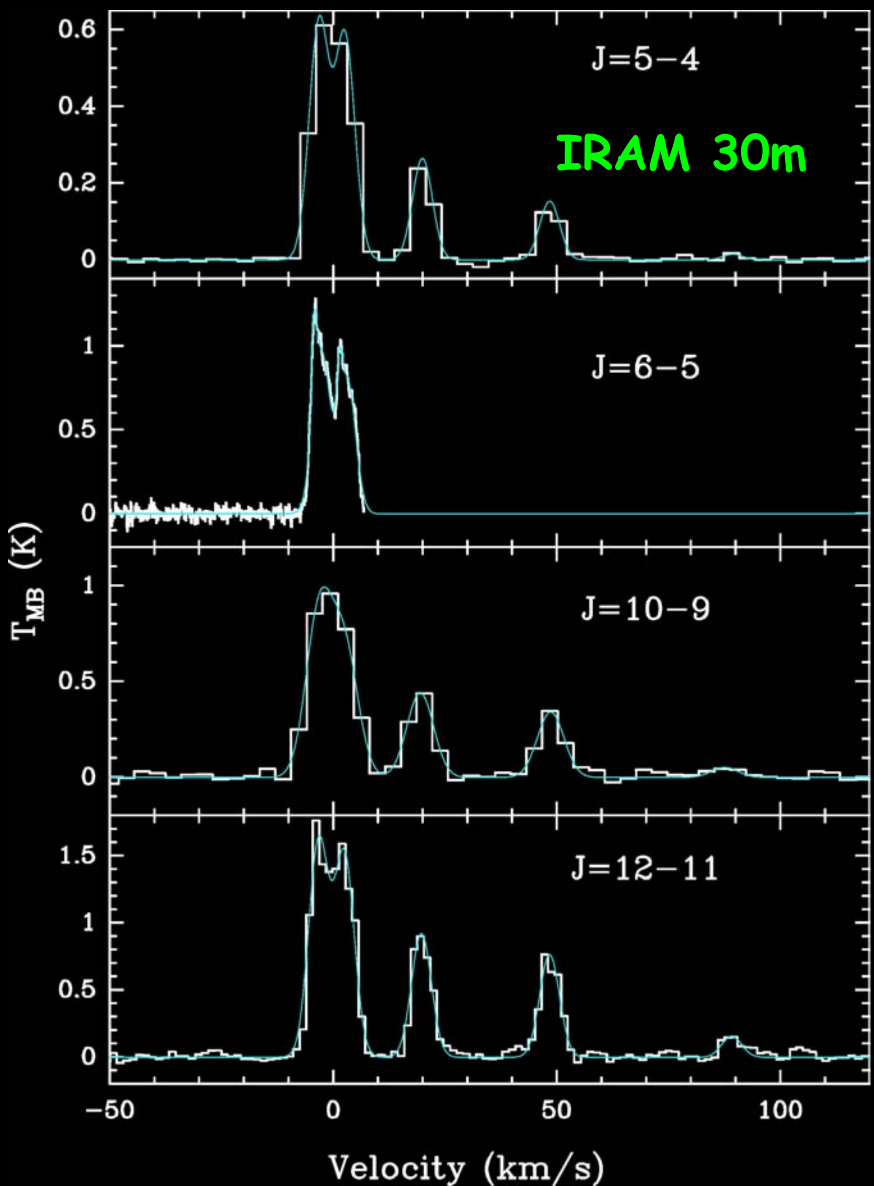
C_3 in DR21(OH)



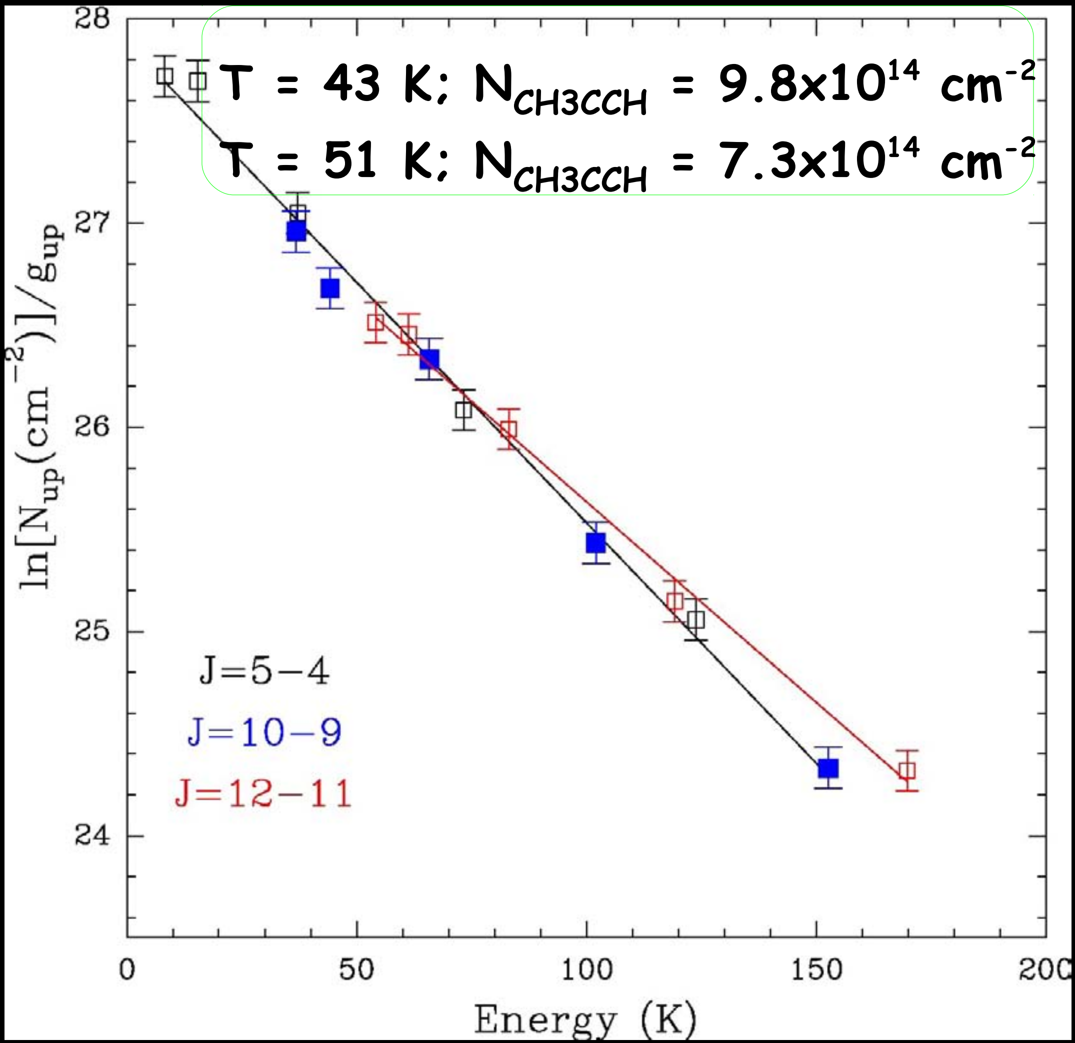
- Herschel/HIFI Observations
- Angular resolution ~ 10″
- Strongest absorption dip at -0.8 km/s (MM2)
- Secondary dip at -2.9 km/s (envelope)



CH_3CCH: A temperature probe

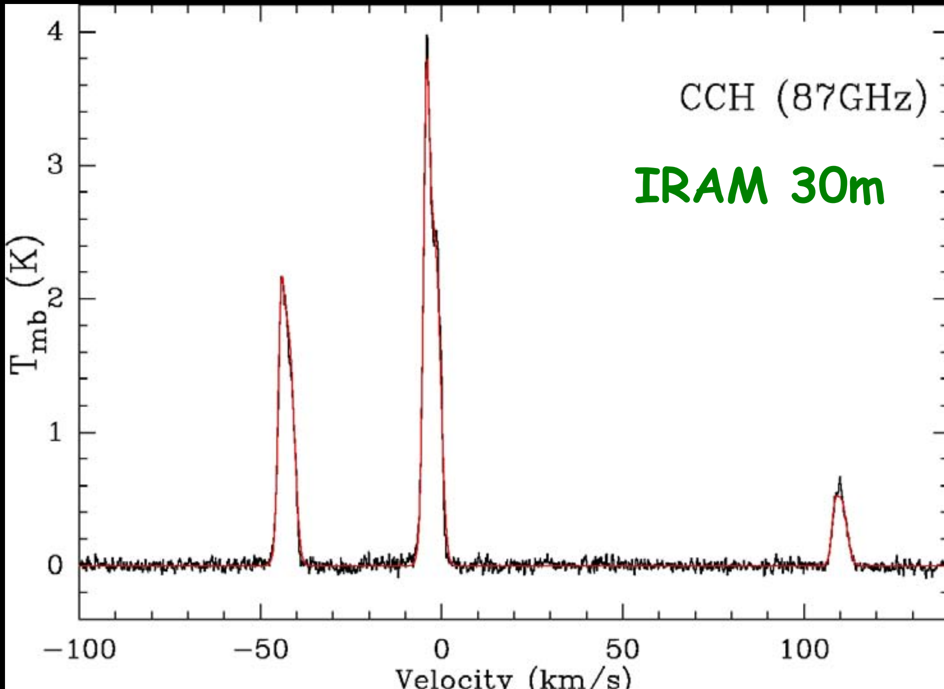


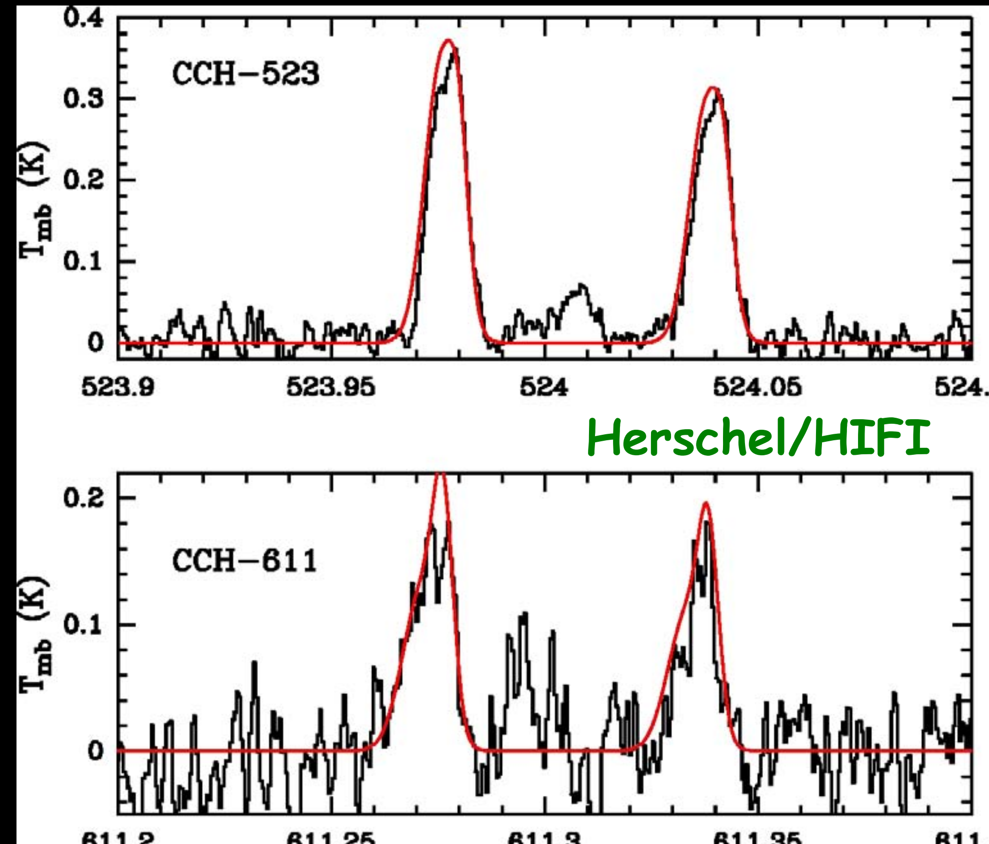
- Methyl acetylene has low dipole moment
- Within a given J-state K-levels consistent with kinetic temperature



Single Velocity component
-3.1 km/s

Non-LTE excitation of CCH in DR21(OH)





2-Velocity components HFS fit:

<u>-2.5 km/s</u> T_{ex} = 6K $N_{CCH} = 1.4\times10^{15}$ cm^{-2}

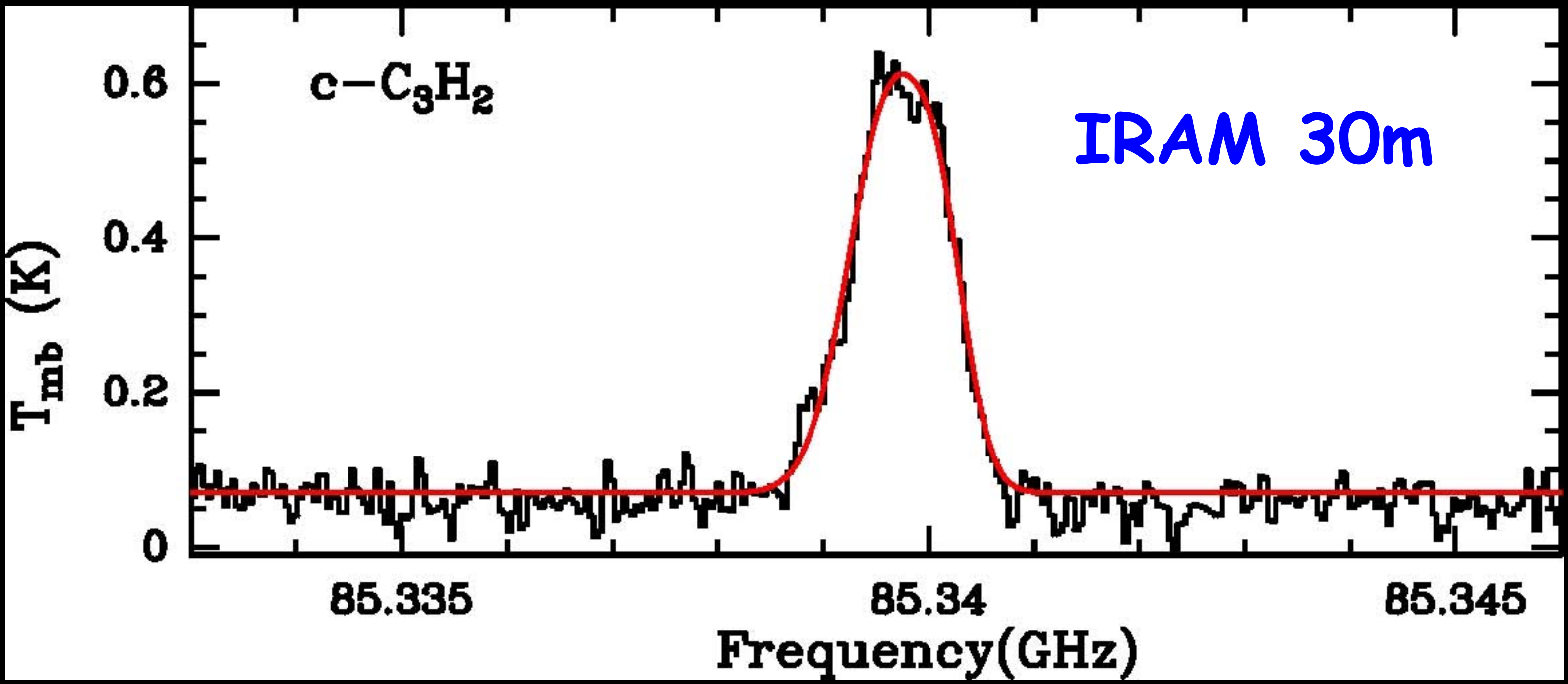
-4.3 km/s T_{ex} = 23 K $N_{CCH} = 4.6\times10^{14}$cm^{-2}

2 Temperature & Velocity Component LTE fit with XCLASS

<u>-2.9 km/s</u> T = 21 K $N_{CCH} = 4.4\times10^{14}$ cm^{-2}

-5.4 km/s T = 82 K $N_{CCH} = 1.2\times10^{14}$ cm^{-2}

c-C_3H_2 in DR21(OH)

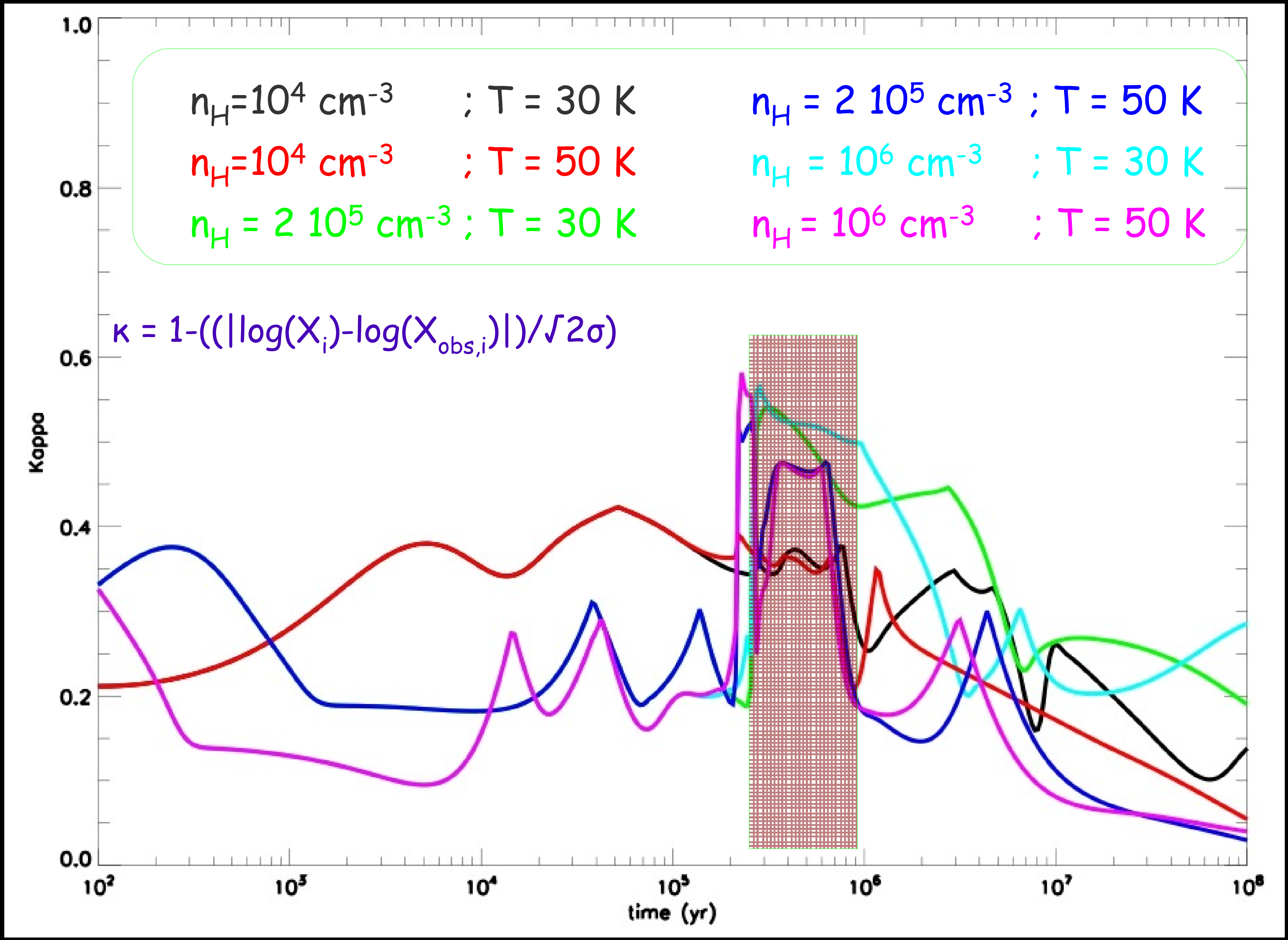


2 Component LTE model with XCLASS (Schilke et al.)

-2.7 km/s T = 33K N(C_3H_2) = 6.5×10^{13} cm^{-2}

-4.4 km/s T = 79K N(C_3H_2) = 1.3×10^{14} cm^{-2}

Chemical Model for DR21(OH)



Summary

- C_3 detected in absorption in the hot core DR21(OH), main component at the v_{LSR} corresponds to MM2; the envelope is also detected.

- For CCH, C_3H_2 and CH_3CCH the envelope is the brightest emission feature

- Abundance in MM2 is 10^{-8} and in the envelope is 10^{-9}

- **For the envelope:** Warm-up (to 30K) grain-gas models with n_H between 2 10^5 and 10^6 cm^{-3} reproduce the observed abundances reasonably well at timescales between 0.2 to 1 Myr.