Herschel detection of C_3 in star forming regions

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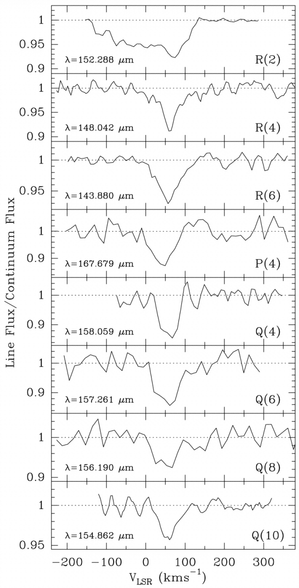
Quest for Carbon Chains in the ISM

- Building blocks for more complex carbon-rich molecules in space.
- Candidates for the diffuse interstellar bands (DIBs).
- Carbon chains have conspicuously high abundance in the interstellar medium

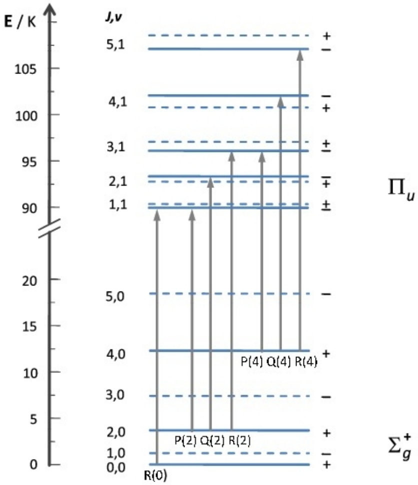
Transitions of C_3 & Pre-Herschel Status

- **Electronic:** in the optical & UV (Poster by Krelowski et al.) in absorption towards stars, in comets and in circumstellar shells.
- **Asymmetric stretching modes** around 5 μm also in diffuse ISM.
- **Low-energy bending modes** in the FIR toward Sgr B2: ISO-LWS (Cernicharo et al. 2000) & KAO (Giesen et al. 2001)



Cernicharo et al. 2000

ν_2 Bending Modes of C_3



Name	Transition $(J',v')\leftarrow(J,v)$	Frequency [MHz]
$P(10)$	$(9,1)\leftarrow(10,0)$	1654081.
$P(6)$	$(5,1)\leftarrow(6,0)$	1741122.
$P(4)$	$(3,1)\leftarrow(4,0)$	1787890.
$Q(2)$	$(2,1)\leftarrow(2,0)$	1890558.
$Q(4)$	$(4,1)\leftarrow(4,0)$	1896706.

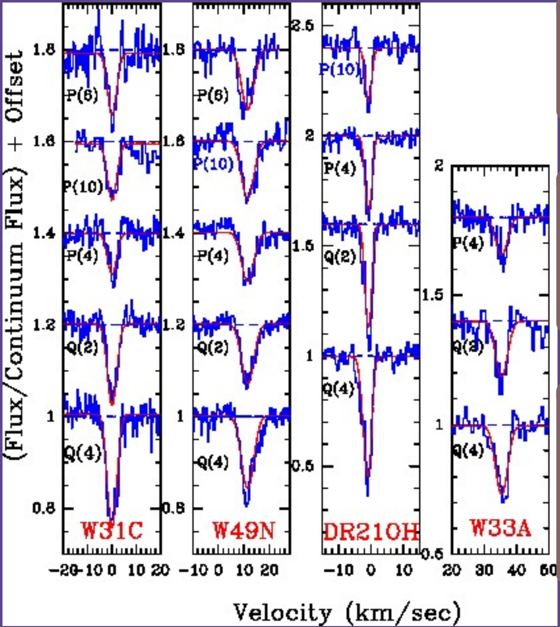
- **THz sideband laboratory spectroscopy in Cologne & Berkeley to determine the frequencies accurately**
- **Herschel/HIFI accesses the C_3 population in high A_v**

PRISMAS Observations of C_3

- As a part of **PR**obing the **ISM** using **A**bsorption **S**tudies GTKP (PI: M. Gerin) **5 bending mode transitions** of C_3 at $\nu > 1.6$ THz were observed in absorption towards **8 bright continuum sources.**
- Multiple J lines to determine column densities and temperature for the ground vibrational state.
- Observations are complete. Baseline issues remain for some of the sources.

Mookerjea, Giesen, Stutzki et al. 2010, A&A

Detection of C_3 in FIR

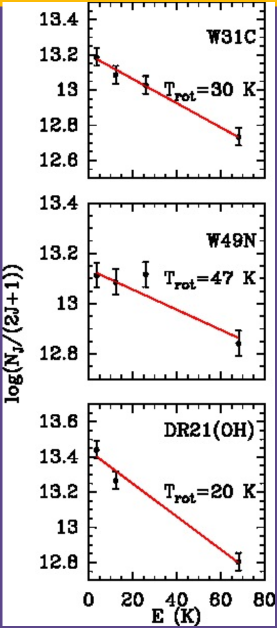


C_3 in the warm envelope around the hot core is detected in absorption.

HIFI observations not sensitive enough to detect C_3 in diffuse clouds along the line of sight.

All C_3 lines from one source are fitted simultaneously with gaussians to derive opacities.

Rotational Diagrams



W31C: $N(C_3) = 3.5\times10^{14}$ cm^{-2}

W49N: $N(C_3) = 5.2\times10^{14}$ cm^{-2}

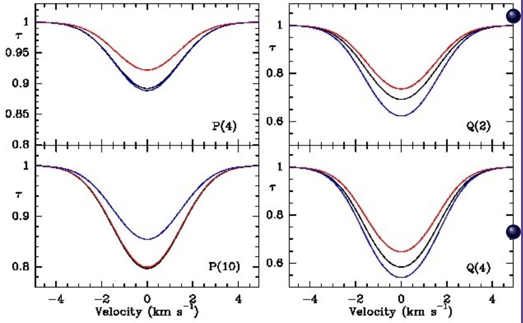
DR21 (OH): $N(C_3) = 4.4\times10^{14}$ cm^{-2}

- $T_{\rm rot}$ **consistent with** $\mathbf{T}_{\rm dust}$
- x**(**C_3**)** $\sim$ **a few** 10^{-9} **relative** to H_2

Radiative Transfer Model

- Continuum source is coexistent with the gas absorbing C_3 $\implies$ IR pumping of C_3 is significant.
- Source intrinsic continuum partially fills in the line absorption.
- Radiative Transfer Models : FIR pumping by the dust continuum and a temperature gradient along the line of sight.

Results for W31C



Black: $n(H_2) = 10^5$ **cm**$^{-3}$, $x(C_3) = 5 \times 10^{-8}$, $T_{\rm kin}$ **= 50 K.**
Red: $n(H_2) = 5{\times}10^5$ **cm**$^{-3}$, $x(C_3) = 10^{-8}$, $T_{\rm kin}$ **= 50 K.**

Blue: $n(H_2) = 5{\times}10^5$ **cm**$^{-3}$, $x(C_3) = 10^{-8}$,

$T_{\rm kin}$ **= 30 K.**

- In the presence of strong IR radiation the ground vibrational states are always thermalized irrespective of the adopted collision rates
- $\nu_2 = 1$–0 transitions dominated by IR pumping.
- Results are most sensitive to the adopted kinetic temperature.
- $N(C_3) = 1.5 \times 10^{15}$ cm^{-2}.

C_3 so far ....

- Diffuse gas traced by UV & optical transitions and dense star forming regions in FIR transitions of C_3
- In the FIR all sources analyzed so far contain similar amounts of C_3 and this matches well with the column densities found in Sgr B2 with ISO.
- Abundance in the diffuse clouds $< 10^{-8}$ and in star forming regions $\sim 10^{-8}$
- $x(C_3) \sim 10^{-8}$ consistent with warm-up chemical models of the environment of hot cores (Hassel et 2008).
- Detailed radiative transfer models for all sources are being constructed.