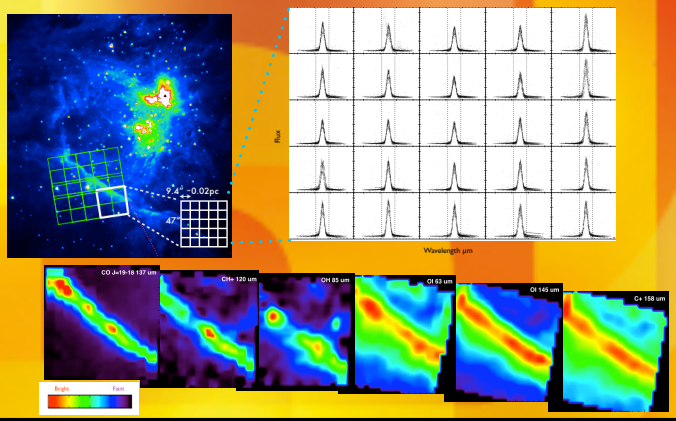
Unveiling the origin and excitation mechanisms of the warm CO, OH and CH^+

A. Parikka[1], E. Habart[1], J. Bernard-Salas[2], M. Köhler[1], J. Goicoechea[3], C. Pinto[4], C. Joblin[5], E. Dartois[1], A. Abergel[1]

1) Institut Astrophysique Spatiale (IAS), Orsay, France 2) The Open University, Milton Keynes, UK 3) Centro de Astrobiología (CSIC/INTA), Madrid, Spain 4) Laboratoire d'Astrophysique de Marseille (LAM), Marseille, France 5) Université de Toulouse, Toulouse, France

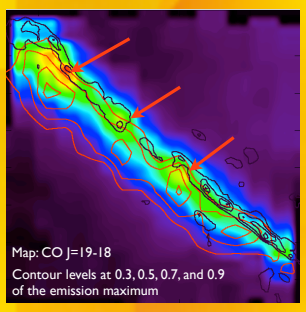


Observations

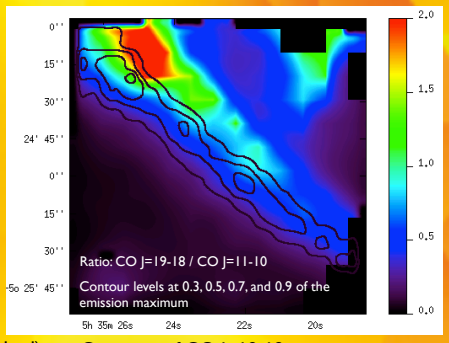
- Fully sampled observations with PACS: 4×4 rastermap (OH 85 µm: 5x5) covering an area of ~100" x 100". Each position is composed of 5 × 5 spatial pixels (spaxel). For the spaxels, the line is observed in 25 positions
- Spatial resolution between 6" to 10" (0.01-0.02 pc)
- Targeted lines: CO J=19-18 (137µm), CH^+ J=3-2 (cube includes: CO J=22-21, OH 119µm), OH 84µm, [OI] 63µm, [OI] 145µm (cube includes: CO J=18-17), and [CII] 158 µm (Bernard-Salas et al. 2012).
- PACS data was processed with HIPE 10 standard pipeline, and further with PACSman (Lebouteiller et al. 2012).
- SPIRE observations on ^{12}CO (transitions: J=5-4 to J=13-12) and ^{13}CO (transitions: J=5-4 to J=11-10). The data was processed with HIPE 11 standard pipeline. Supreme method (see poster by H. Ayasso, Köhler et al. (submitted)) also used with HIPE 8 as HIPE 11 version is still under development. This method resolves the structures in the bar with more detail than the standard pipeline (see next section).

Spatial distribution and excitation of the warm CO

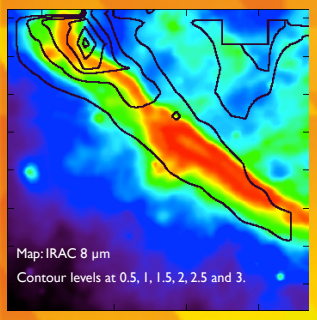
The morphologies of CO J=19-18 and the ^{13}CO J=11-10 are very similar, only shifted as the ^{13}CO is a lower transition.
The edge of CO J=19-18 agrees well with ro-vibrationally excited H_2 (H_2^*) which is very sensitive to UV field, we thus conclude that **high-J CO directly traces the irradiated dense structures.**
The excitation temperature is high where the PAH (poly-aromatic hydrocarbons) emission peaks due to UV heating. This puts strong constraints on the origin of the CO excitation: **UV heating dominates**.



Contours of ^{13}CO J=11-10 (Supreme method) and H_2 1-0 S(1) line (Walmsley et al. 2000). The clumps are seen in the high-J ^{12}CO and intermediate-J ^{13}CO (see the arrows).



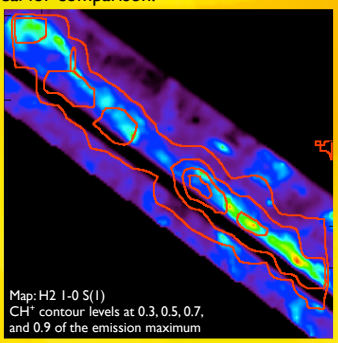
Contours of CO J=19-18.
The ratio peaks in front of the bar.



Contours of ratio:
CO J=19-18 / CO J=11-10

CH^+ and OH comparison with H_2

CH^+ J= 3-2 and OH 85 µm have similar critical densities (~10^{10} cm^{-3}) and upper energy levels (~250 K) which make them ideal for comparison.



<u>CH^+ comparison with H_2:</u>

CH^+ formation:
$H_2 + C^+ \Rightarrow H + CH^+$
(endothermicity: 4300 K)

CH^+ destruction:
$H + CH^+ \Rightarrow H_2 + C^+$

To overcome the energy threshold to form CH^+, H_2 ro-vibrational energy can be used when available.

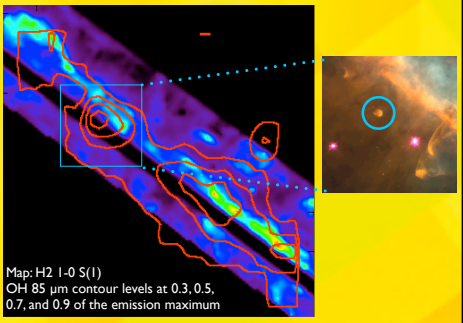
CH^+ correlation with H_2^* suggests that the formation process of CH^+ depends on H_2^* (in agreement with Lambert & Danks 1986, Agundez et. al 2010)

<u>OH comparison with H_2:</u>

OH formation:
$H_2 + O \Rightarrow H + OH$

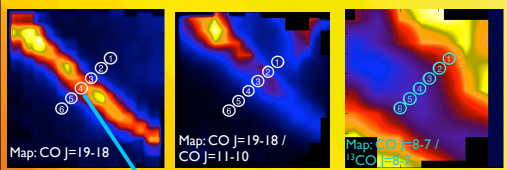
OH destruction:
$OH + photon \Rightarrow H + O$
$H + OH \Rightarrow H_2 + O$

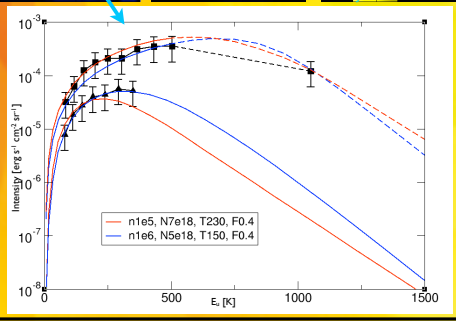
The non-correlation between OH and H_2^* suggests that the formation process of OH does not depend on H_2^*
(in agreement with Agundez et. al 2010).



As well as corresponding to the irradiated structures (Goicoechea et al. 2011), the OH emission seems to also correspond with a bright young object, identified as a proplyd (see the zoomed image).

Physical properties of the Orion bar





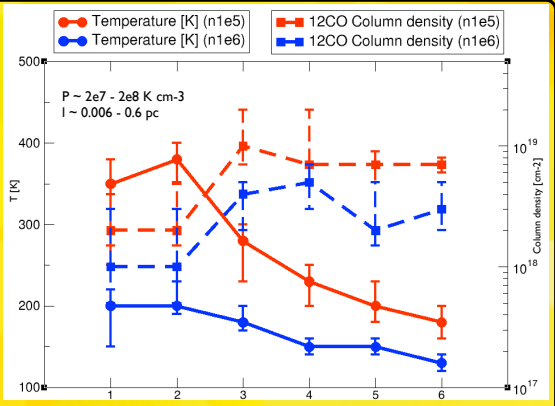
We have selected a few positions across the bar and derive the physical properties using the radiative transfer code RADEX.

The best fits were found with **H_2 density of 1x10^5 and 1x10^6**.

The temperature is higher closer to the ionizing stars (in front of the bar), and decreases further away from it. Column density is lower in front and behind the bar and higher in the bar.

The CO fit produces a high thermal pressure and small length, which confirm the presence of bright and dense structures in the bar.

The collisions can explain the excitation of warm CO, thus we conclude that the photoelectric heating is the dominant heating mechanism.



<u>Ongoing work:</u> We will use the constraints given by the RADEX models for input into PDR Meudon code. For the isobar model with P ~3x10^8 K cm-3, the model published in Joblin et al. (in prep.) reproduces all the observed CO line intensities towards the Bar at the CO^+ peak position.

<u>See also talk by E. Habart on WED 16.10. at 12:20 (session 7b):</u>
PET AL. Diagnostics as Observed by PACS and SPIRE

REFERENCES:
Agundez et al. (2010), ApJ, 713, 662
Bernard-Salas et al. (2012), A&A, 538, A37
Goicoechea et al. (2011), A&A, 530, L16
Joblin et al. (in prep.)
Köhler et al. (2013, submitted)
Lambert & Danks (1986), ApJ, 303, 401
Lebouteiller et al. (2012), A&A 548, A91
Walmsley et al. (2000), A&A, 364, 301