AstroRennes 2014
Physique et Chimie du Milieu Interstellaire
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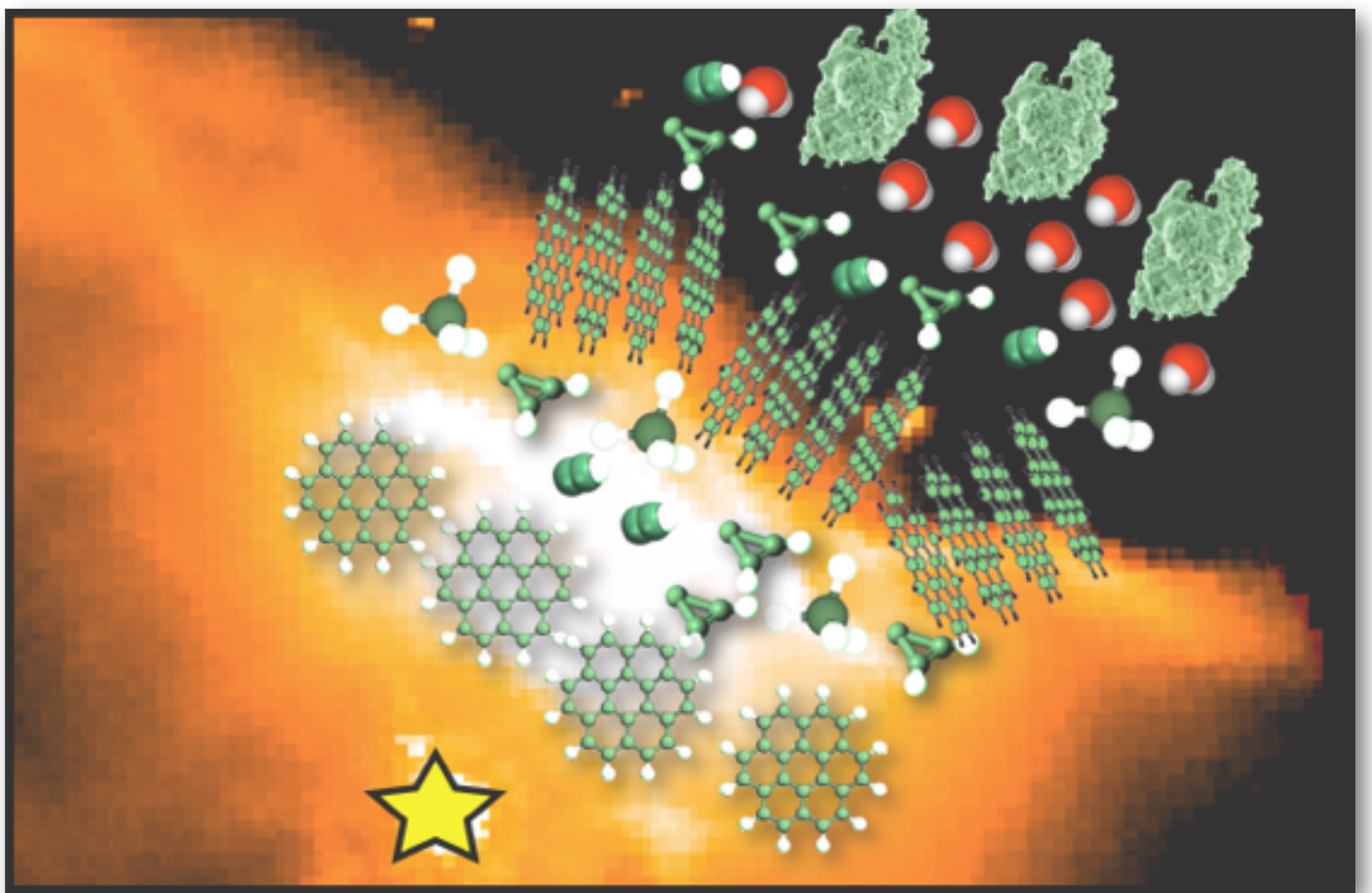
# *High spatial resolution observations of key hydrocarbon species in the NGC 7023 PDR*

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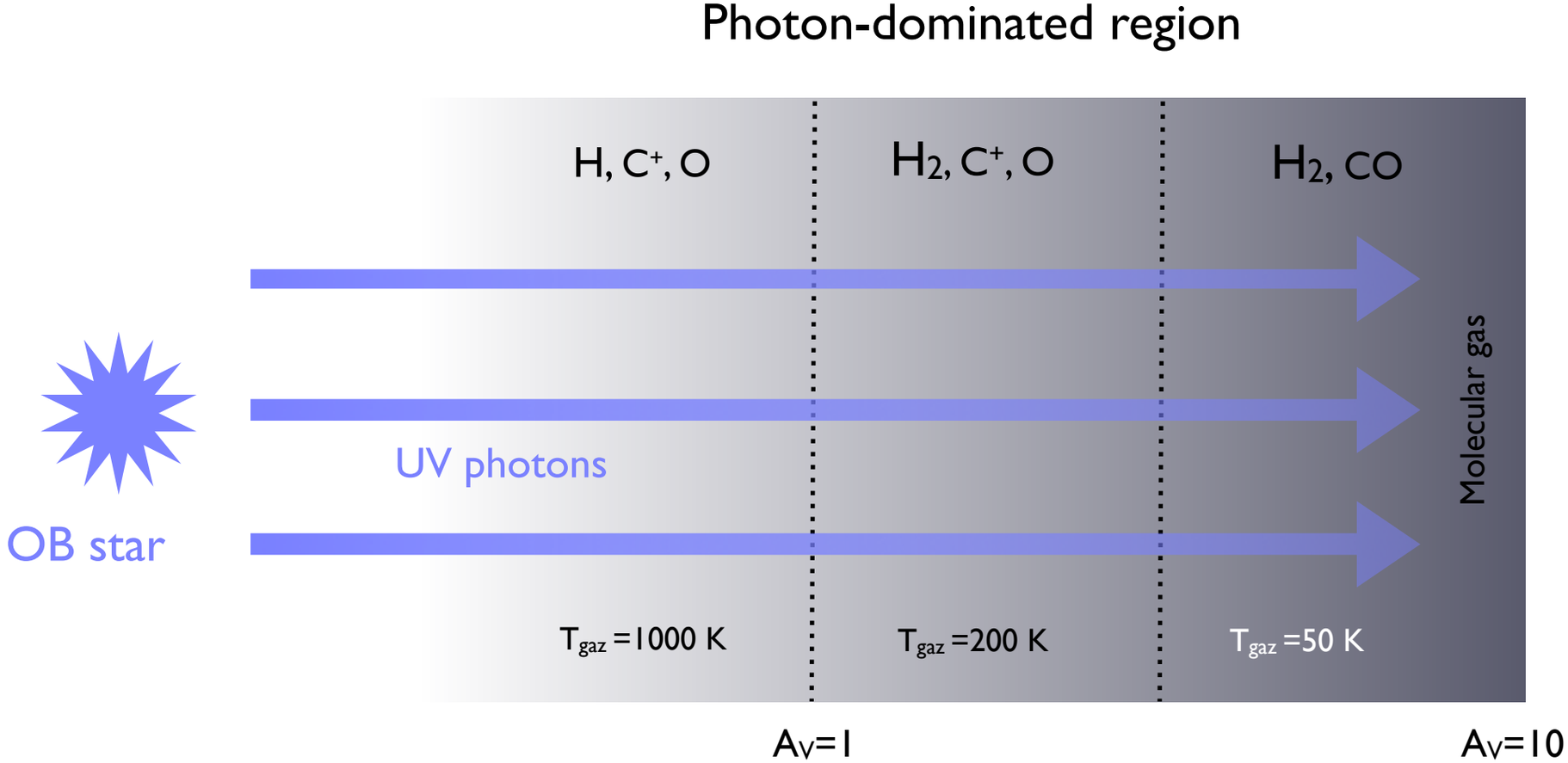
# Photo-dissociation regions




*[Tielens & Hollenbach ApJ 1985]*

# Outline

## Introduction

Small hydrocarbons in PDRs

Evolutionary scenario of PAHs

## The case of a mild-UV irradiated PDR: NGC 7023

The variations of the near-IR features seen by AKARI

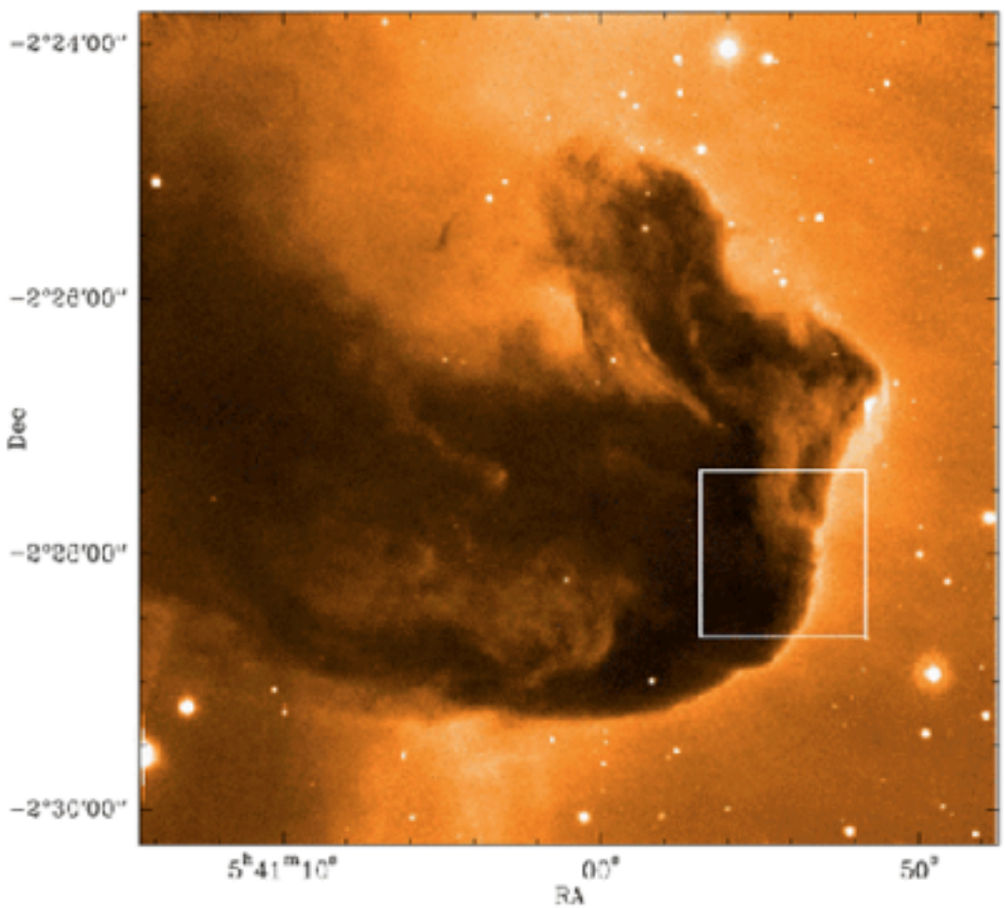
The small hydrocarbon emission: CCH and c-$C_3H_2$

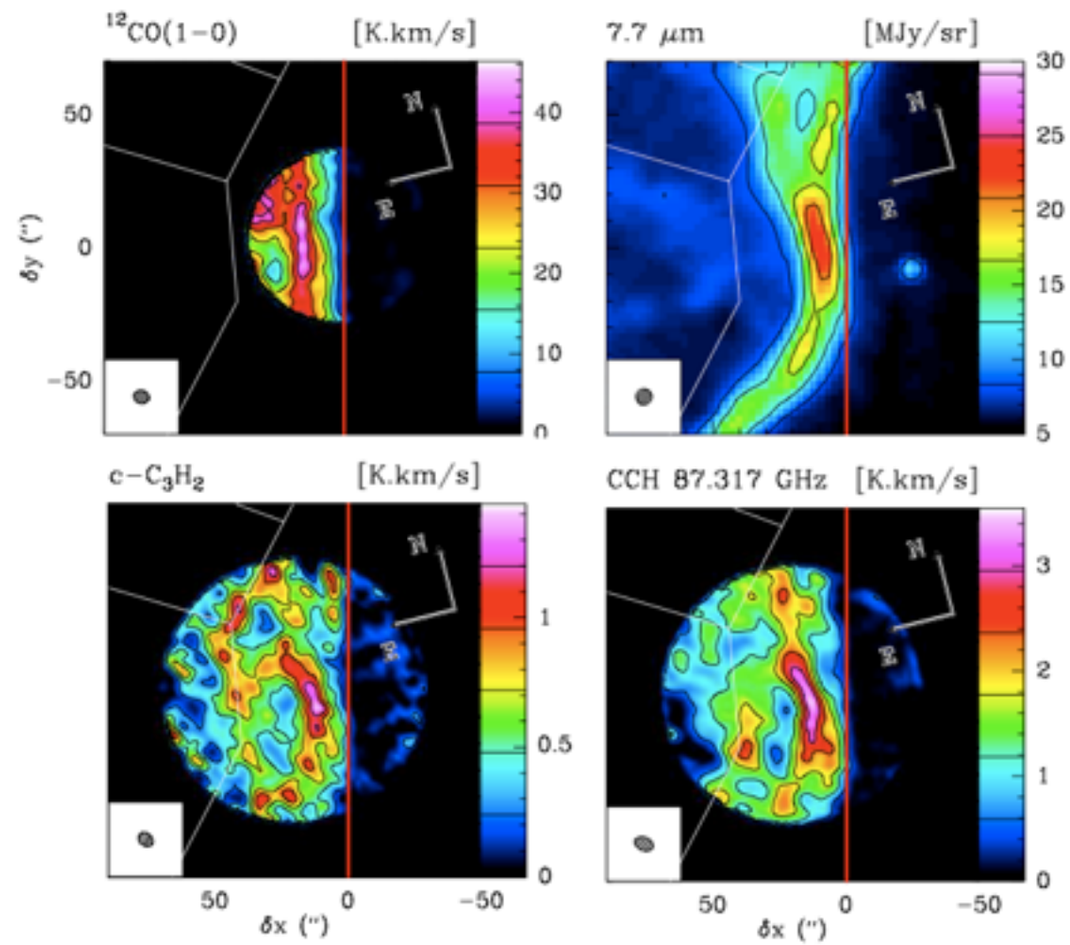
The evolution of the AIB carriers and small hydrocarbons

## Conclusions & perspectives

# The abundance of small hydrocarbons in PDRs

The abundances of small hydrocarbons (CCH, c-$C_3H_2$, $C_4H$) in low- and mild-UV PDRs are higher than predicted from gas-phase models by 1 or 2 orders of magnitudes



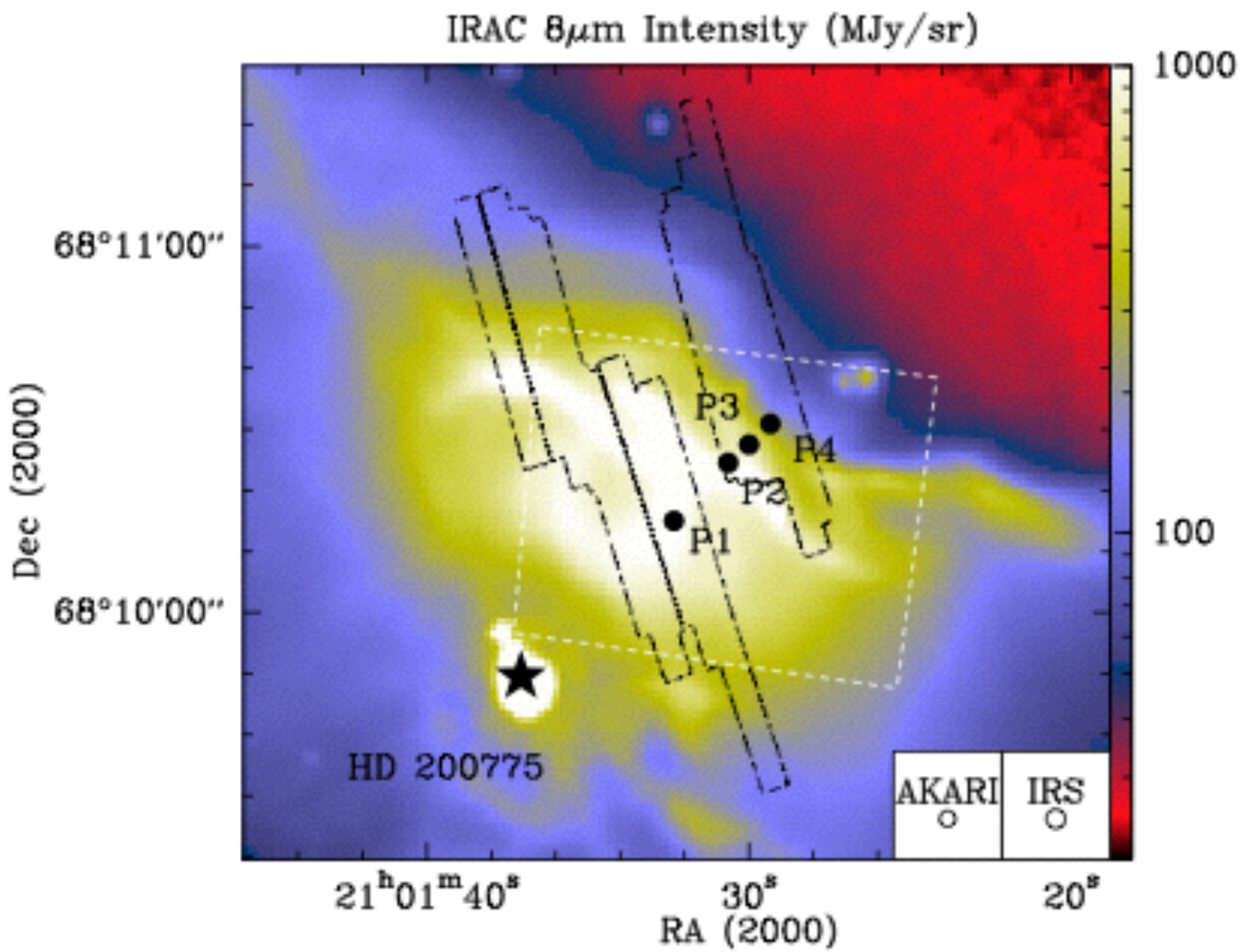

*Teyssier et al., 2004; Fossé et al., 2000; Pety et al., 2005, 2013*

The spatial relation between the emission of small hydrocarbons and aromatic infrared bands suggests that the evolution of their carriers (PAHs) is linked.

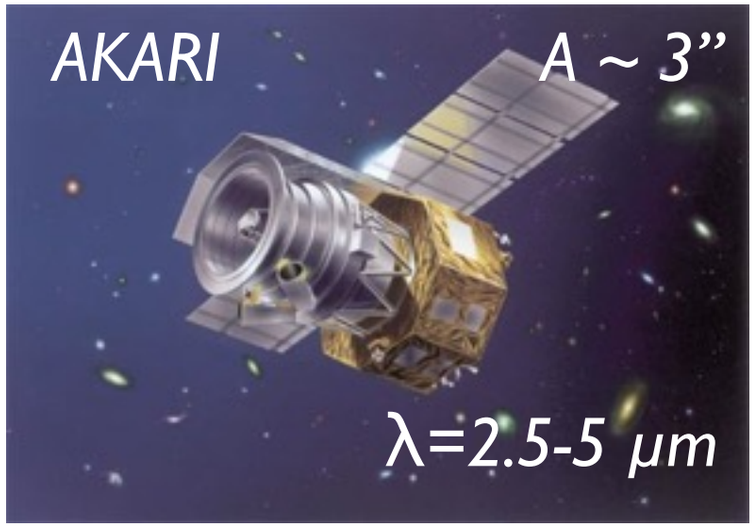
*Photo-destruction of PAHs can lead to hydrocarbon formation?*

# Observations of NGC 7023 NW

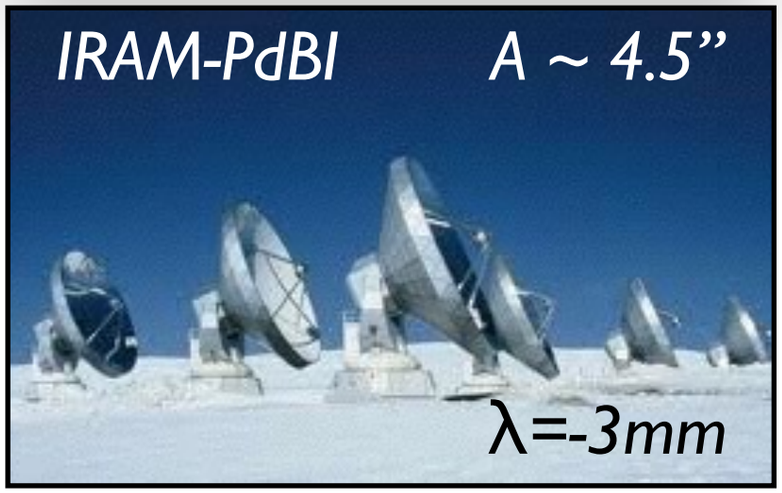
**A spatially resolved source: NGC 7023 NW, d = 430 pc**




*Werner et al., 2004*



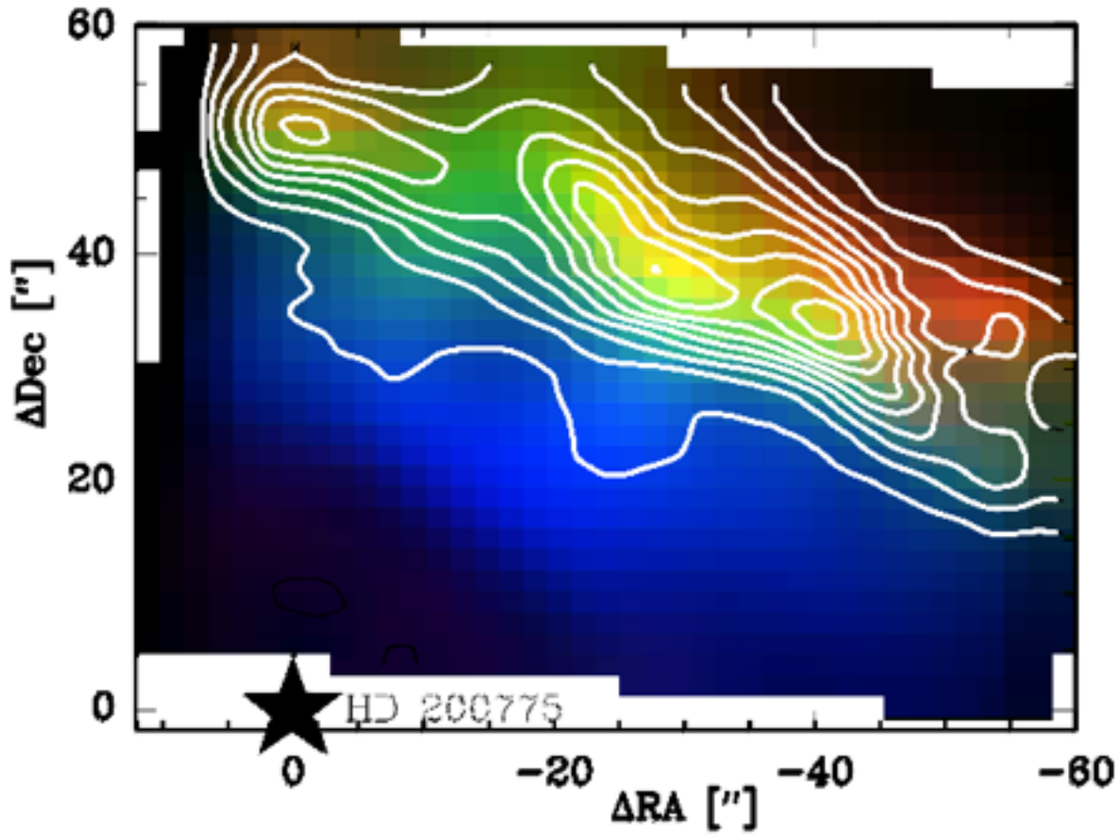




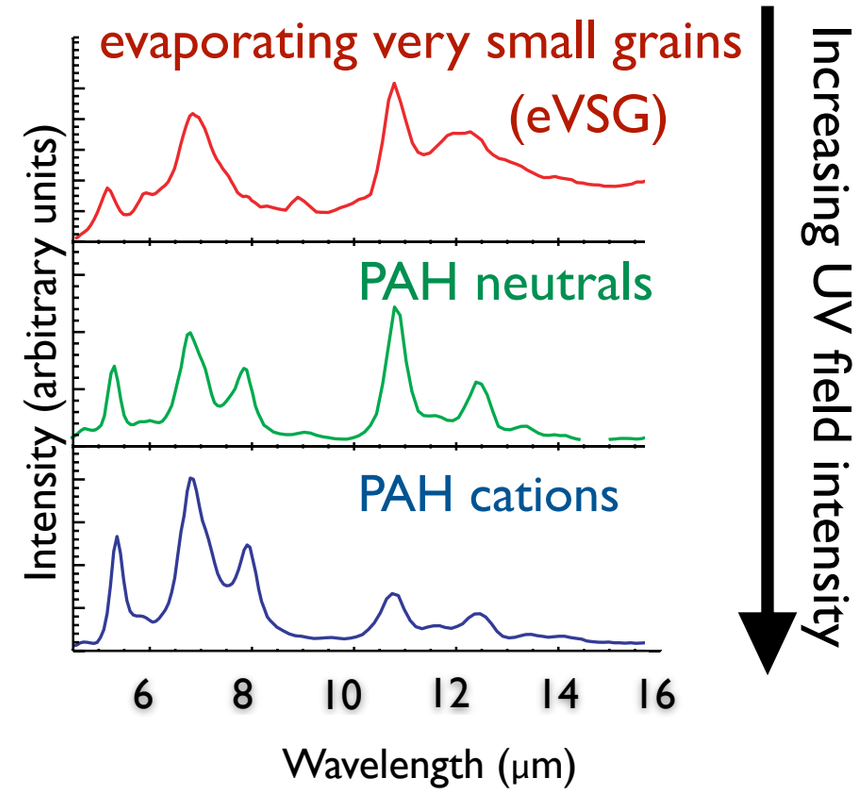

**$G_0 \sim 2600$** **$nH \sim 10^4 - 10^5\ cm^{-3}$** **$T_{gas} \sim 70\text{-}120K$**

# The evolution of the mid-IR AIB carriers

The mid-IR spectra of PDRs show variation in the shape and intensity of the AIBs, that indicate an evolution of the AIB carriers

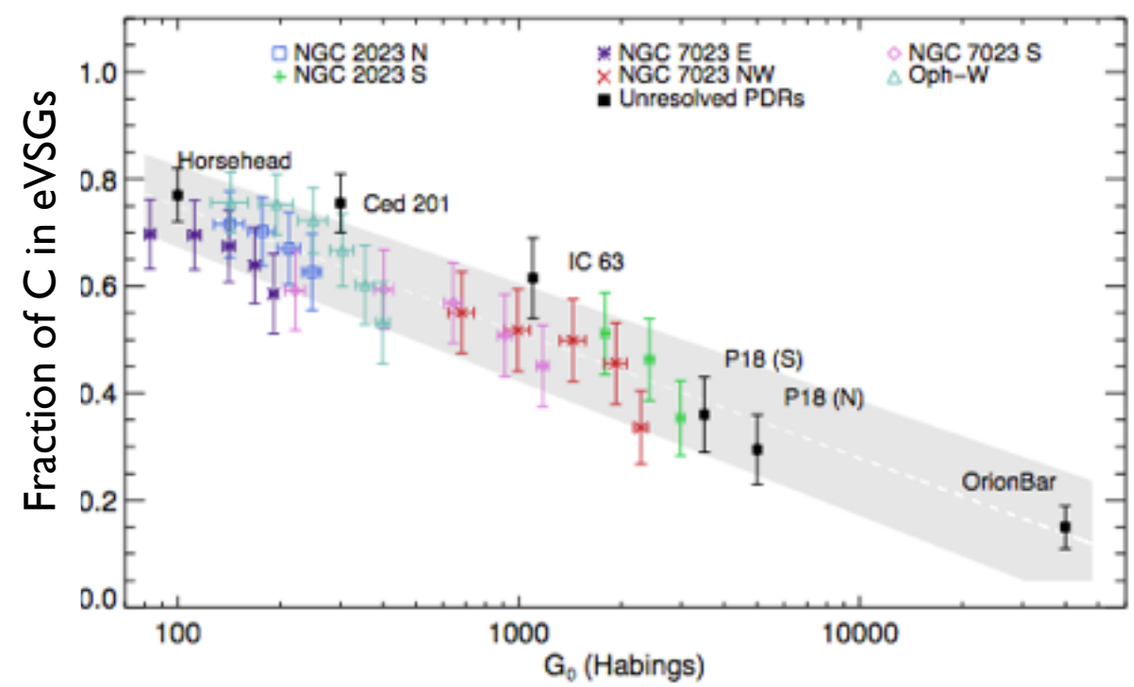



*Rapacioli et al., 2005, Berné et al., 2007*



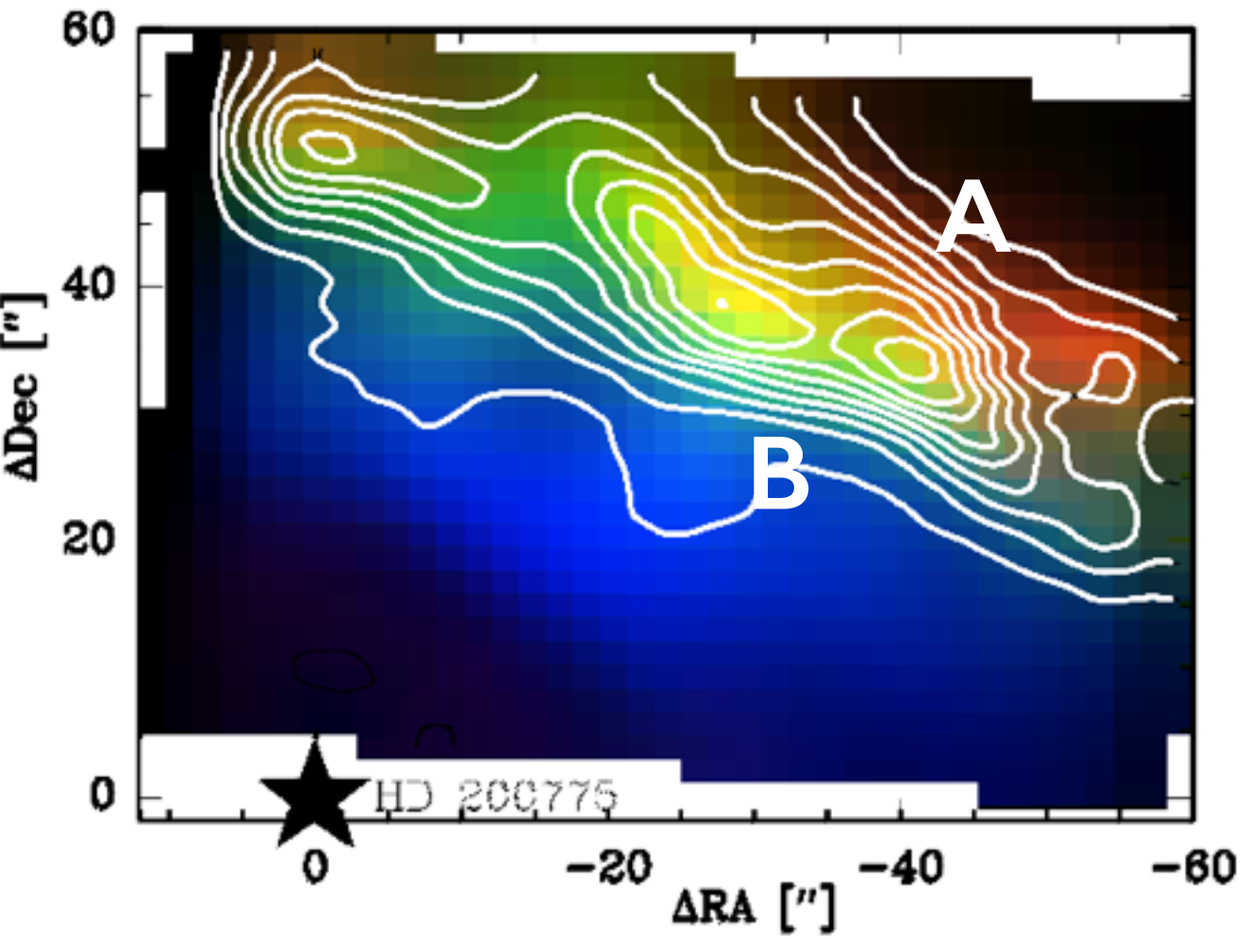

Gas-phase PAHs are produced by destruction of eVSGs by UV photons

*Pilleri et al., 2012*

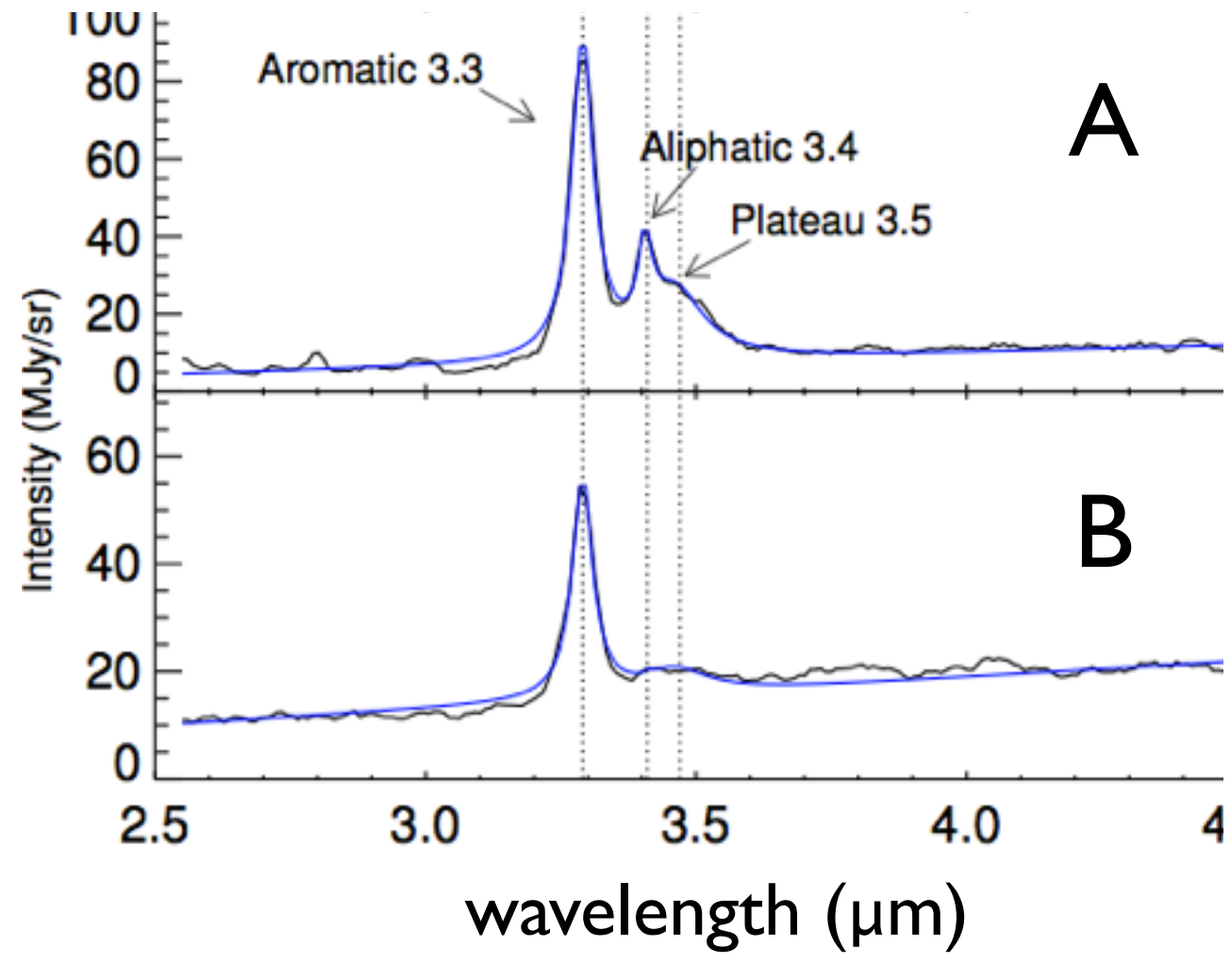



***Is there a link with the production of small hydrocarbons?***

# The differences in the near-IR spectra




Program NESID PI: F. Boulanger

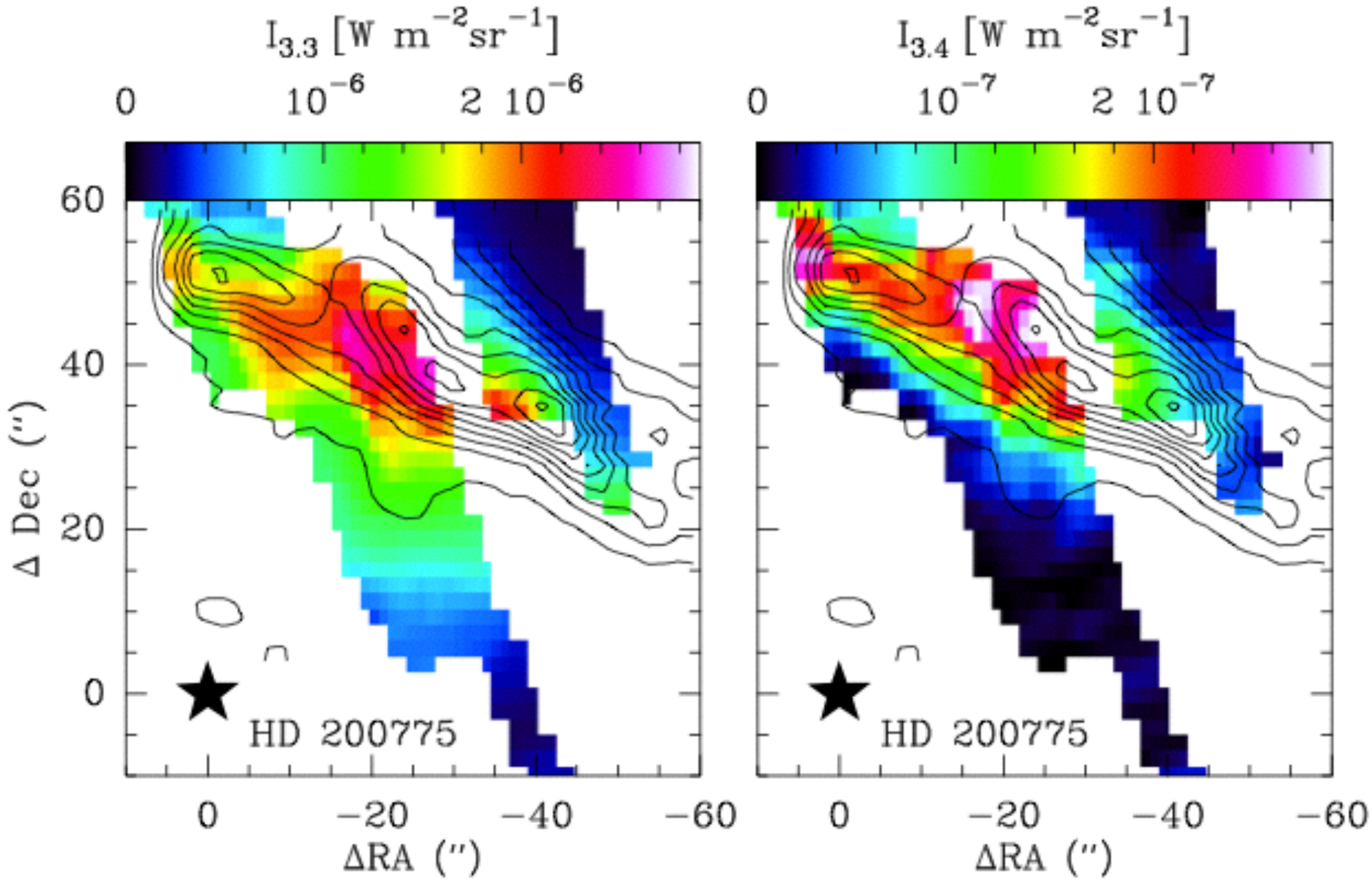



Evolution of the 3.4 μm band relative to the 3.3 μm band with the physical conditions ($G_0$)

The variation of the near-IR spectral features also indicates an evolution of the AIB carriers

*Pilleri et al, to be submitted*

# Spatial distribution of the 3.3 μm and 3.4 μm bands




*Pilleri et al., to be submitted*

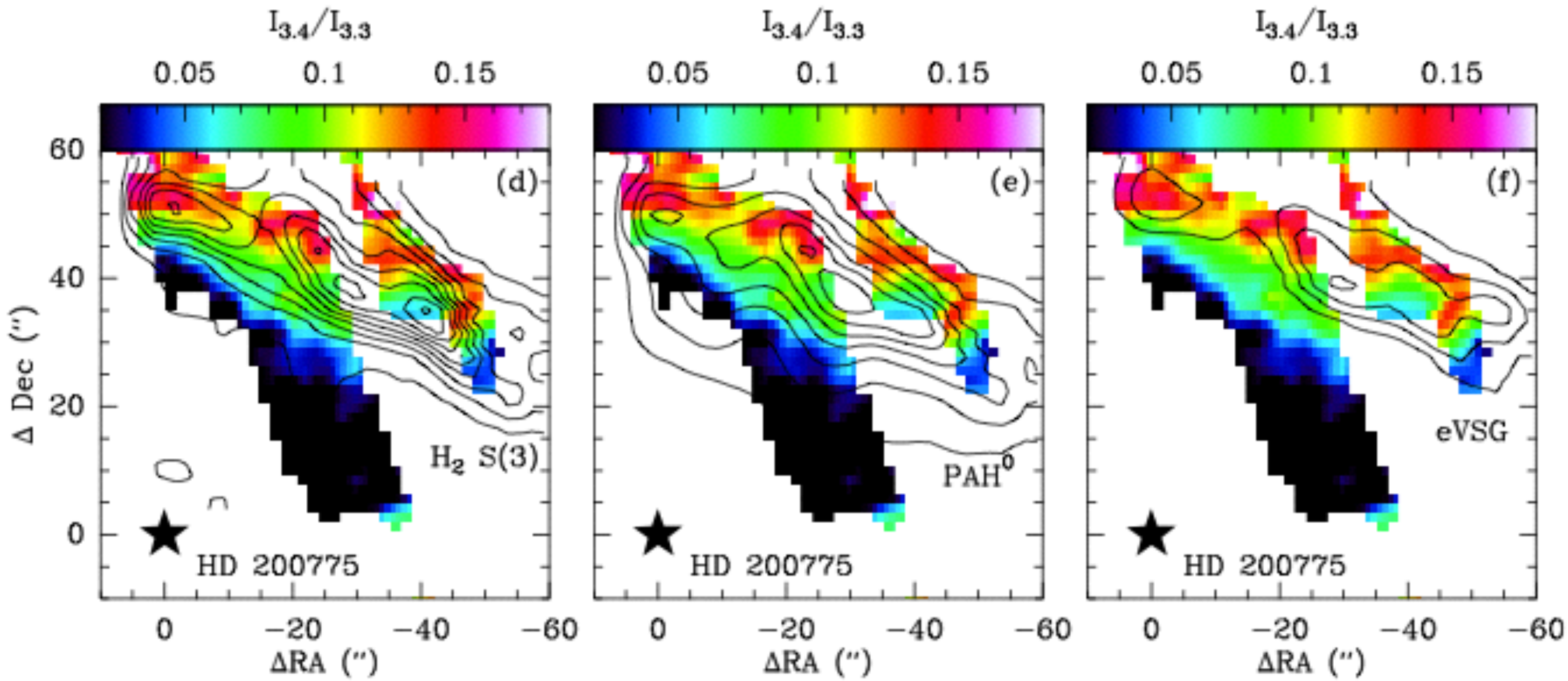
Both emissions peak in the filamentary region

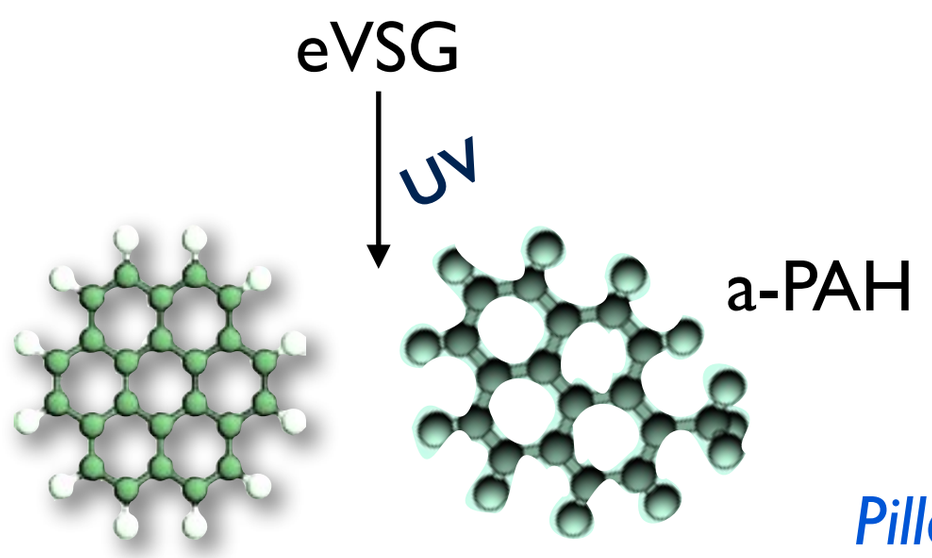
No emission of 3.3 μm or 3.4 μm band deeper in the cloud (no UV photons)

The 3.3 μm extends in the low-density, ionized cavity: partly due to ionized PAHs

***Absolute intensity comparison is biased by column density and $G_0$***

# The ratio of the 3.4/3.3 bands as tracer of chemical evolution



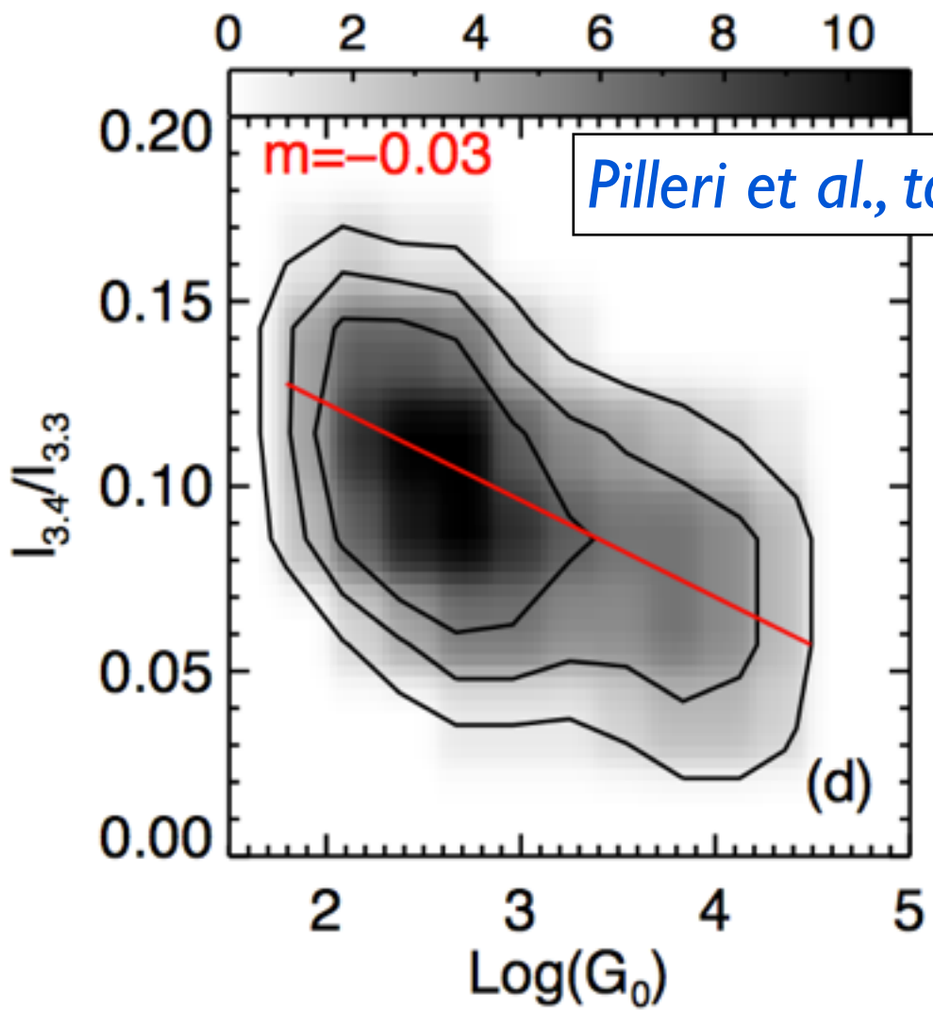




*Berné et al., A&A, 2007*
*Pilleri et al., A&A, 2012*

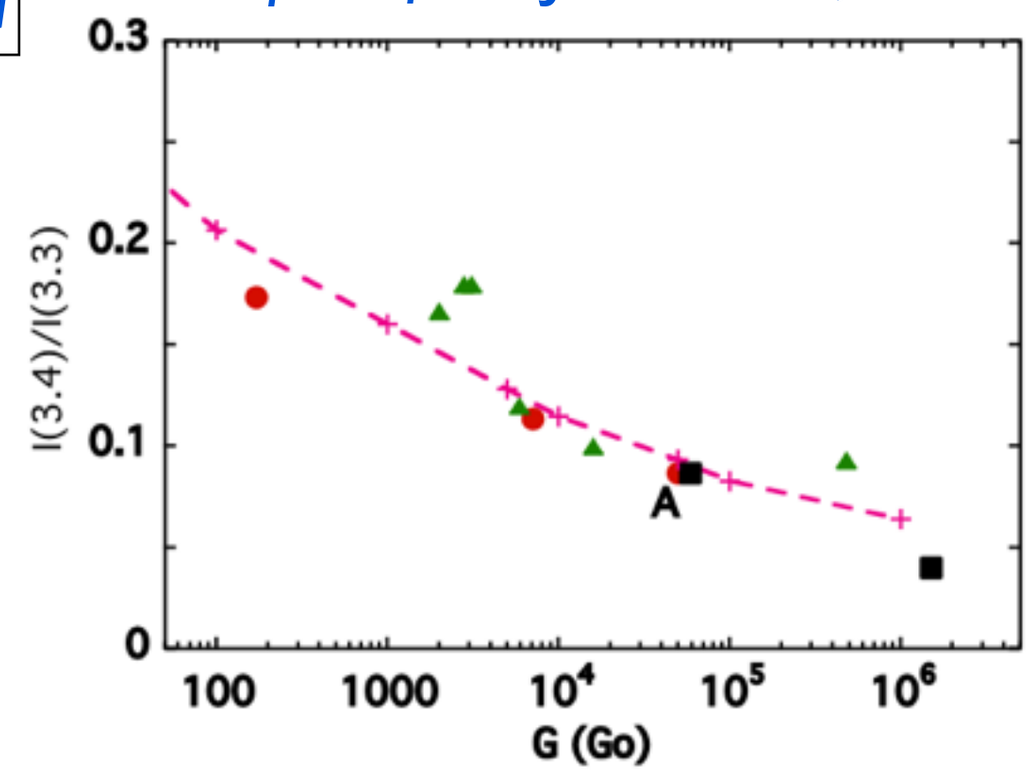
*Pilleri et al., to be submitted*

# The evolution of the $I_{3.4}/I_{3.3}$ ratio vs $G_0$

Decrease of the $I_{3.4}/I_{3.3}$ ratio with $G_0$

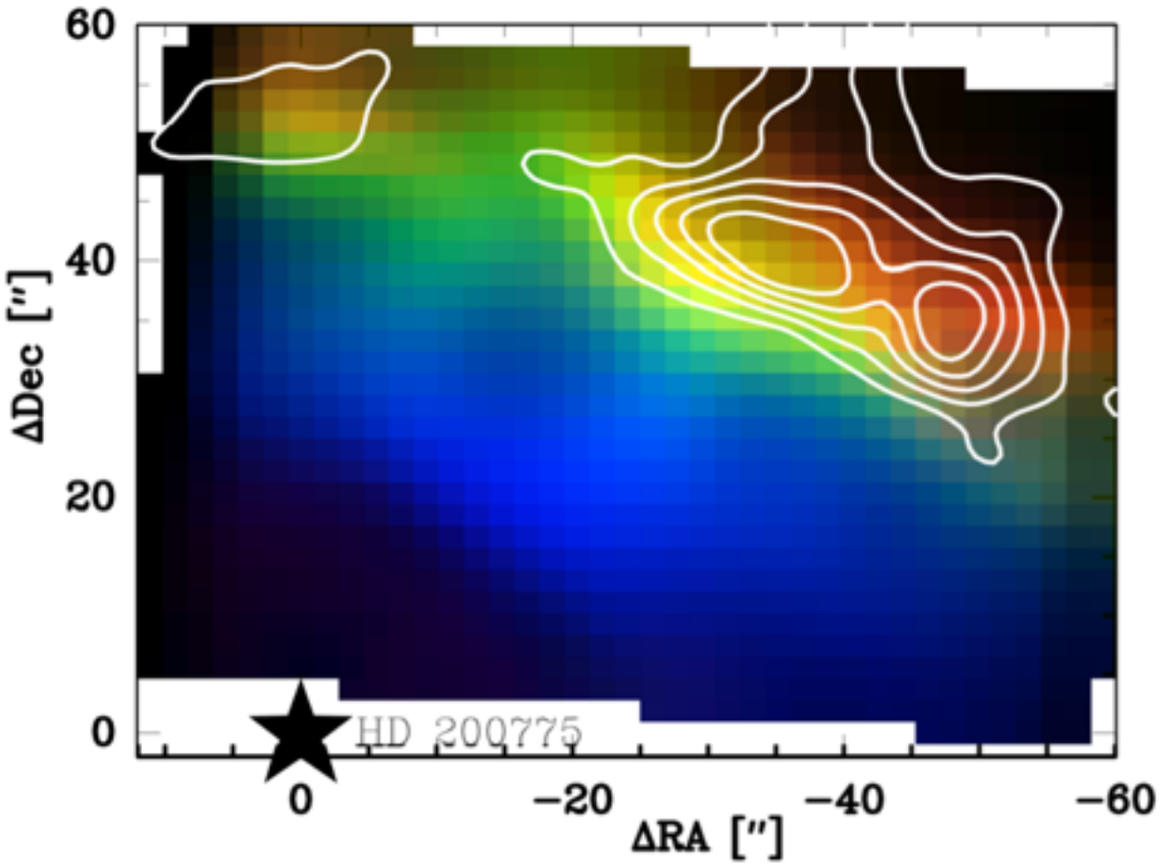



*Adapted from Joblin et al., 1996*




The evolution of the $I_{3.4}/I_{3.3}$ ratio is consistent with a photo-chemical model involving aliphatic methyl and methylene side-groups on PAHs

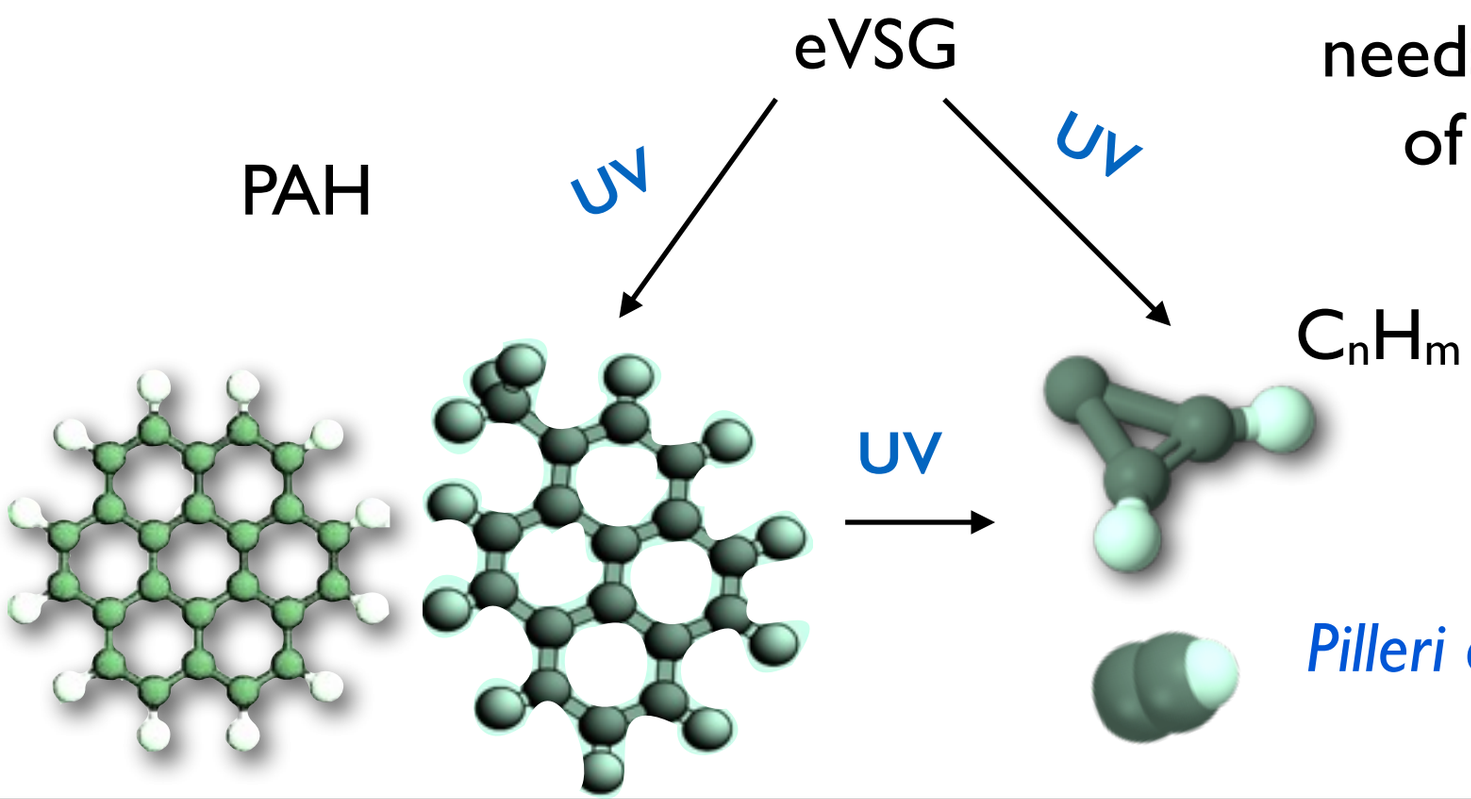
# A link with gas-phase hydrocarbons?




PdBI observations of
CCH and c-$C_3H_2$ in NGC 7023 NW
*PI: P. Pilleri*

faces the difficulty of the detailed geometry and physical conditions to derive molecular abundances

*Koheler et al., 2014*
*Joblin et al., in prep.*




needs to include the photo-products of PAHs and eVSGs in chemical networks

*Pilleri et al., in prep.*

# Take-home messages

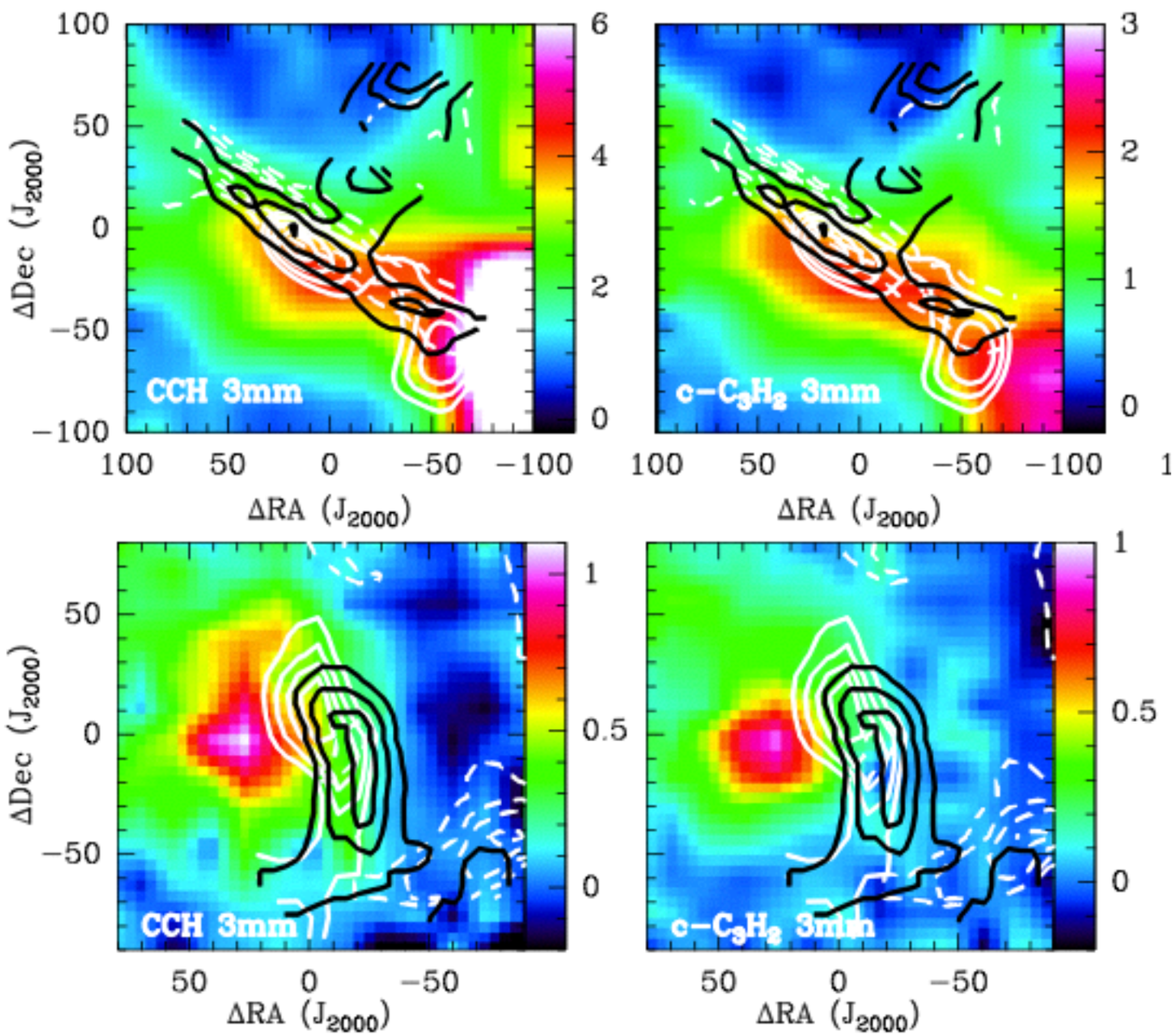
The question of the over-abundance of small hydrocarbons in PDRs needs a detailed study of the photo-processing of the AIB carriers.

Observations reveal a relation between the destruction of eVSG and the production of aliphatic C-H bonds on PAHs and of small hydrocarbons.

The main caveat concerns our poor knowledge on the properties of eVSGs.

# Systematic study

3D survey of small hydrocarbons in PDRs *PI: P. Pilleri*




Orion Bar ($G_0 \sim 4x10^4$)

*Cuadrado et al, 2014*

Monoceros R2 ($G_0 \sim 4x10^5$)

*Pilleri et al., 2013*

NGC 7023 NW / E / S
($G_0 \sim 2600, 1000, 200$)

NGC 2023 S / N
($G_0 \sim 4000,400$)

Test the dependence of the hydrocarbons abundance from $G_0$

*Pilleri et al., in prep.*

# Perspectives

**Constraining the physical conditions and the geometry of NGC 7023 NW**

High resolution observations of atomic/molecular lines

**Complete census of small hydrocarbons in the PDR**

Spectral survey of NGC 7023 NW at 3mm and 2mm

$C_2H$, c/l-$C_3H_2$, l-$C_3H^+$, c/l-$C_3H$, $C_4H$, …

**Application to other galactic PDRs and beyond**

Galactic PDRs: 3D mapping of galactic PDRs (Spitzer, IRAM, AKARI)
Galactic (proto-)planetary nebulae, proto-planetary disks (ALMA)
External galaxies

**Modeling**

Extension of chemical models to include hydrocarbon production