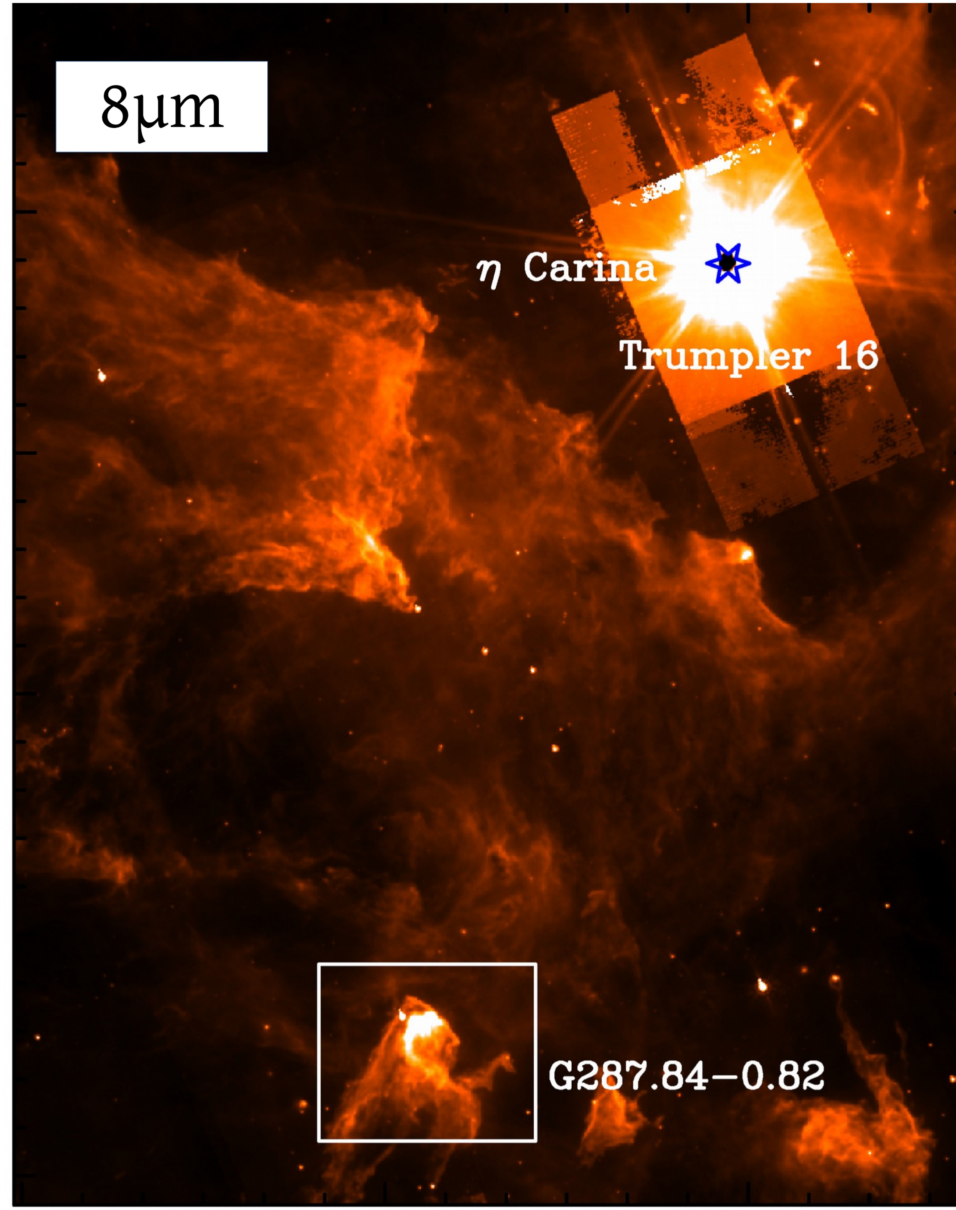
AN upGREAT VIEW OF THE TREASURE CHEST IN CARINA



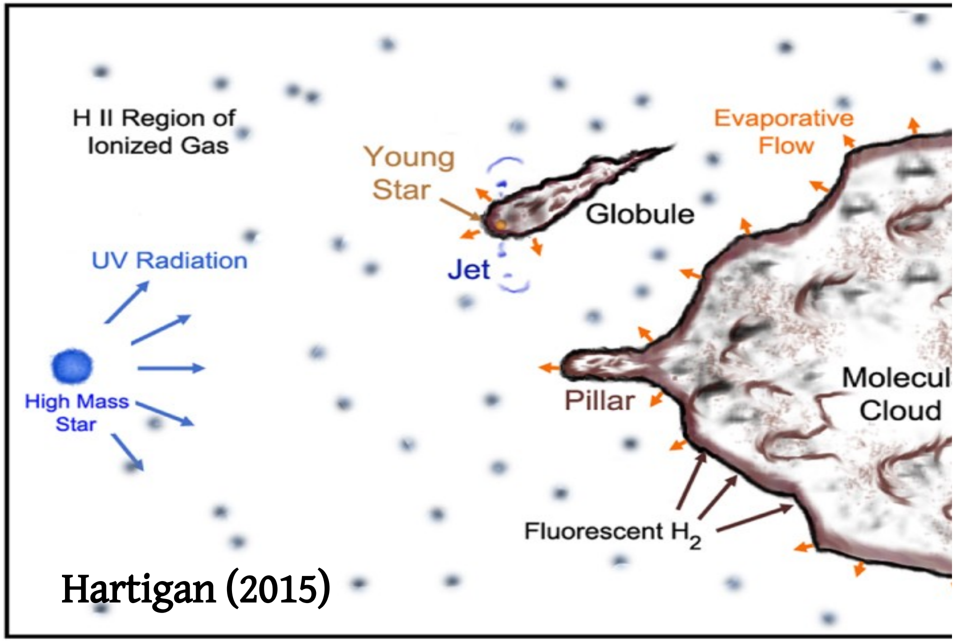
Bhaswati Mookerjea (TIFR, Mumbai, India)

Goeran Sandell (U of Hawaii), R. Guesten (MPIfR),

D. Riquelme (MPIfR), H. Wiesemeyer (MPIfR)

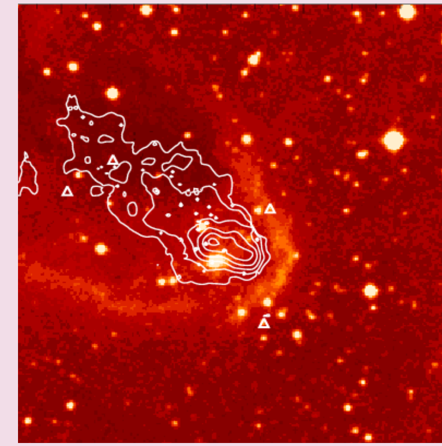
E. Chambers (SOFIA)

PILLARS & GLOBULES
IMPACT OF RADIATION & WIND ON MOLECULAR CLOUDS



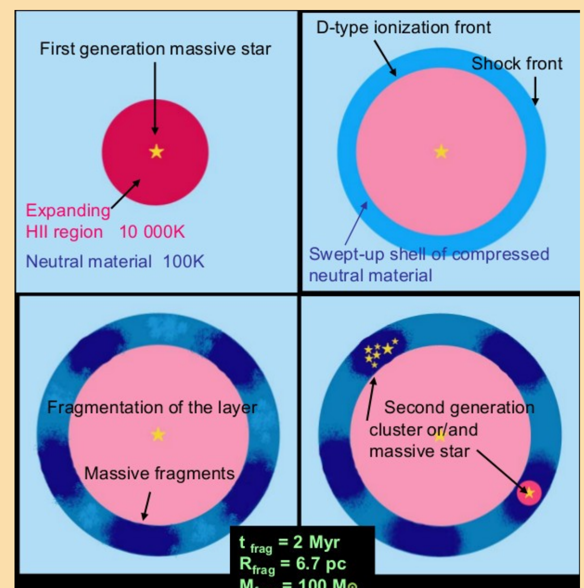
Hartigan (2015)

- I. Pre-existing neutral clumps in the H II region ------ Cometary globules



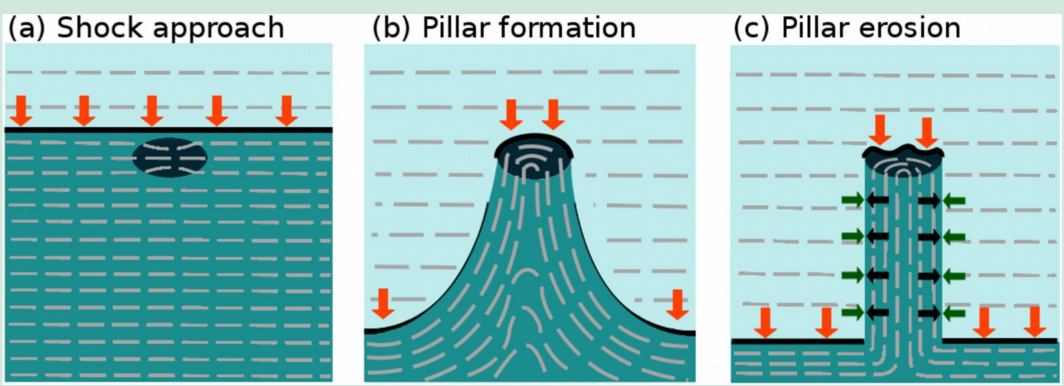
Morgan et al (2018)

- III. Expanding Dense Shells
  ----- Collect & Collapse



Elmegreen & Lada (1977)

- II. Pre-existing dense clumps in the neutral gas
  ----- Pillars



Pattle et al (2018)

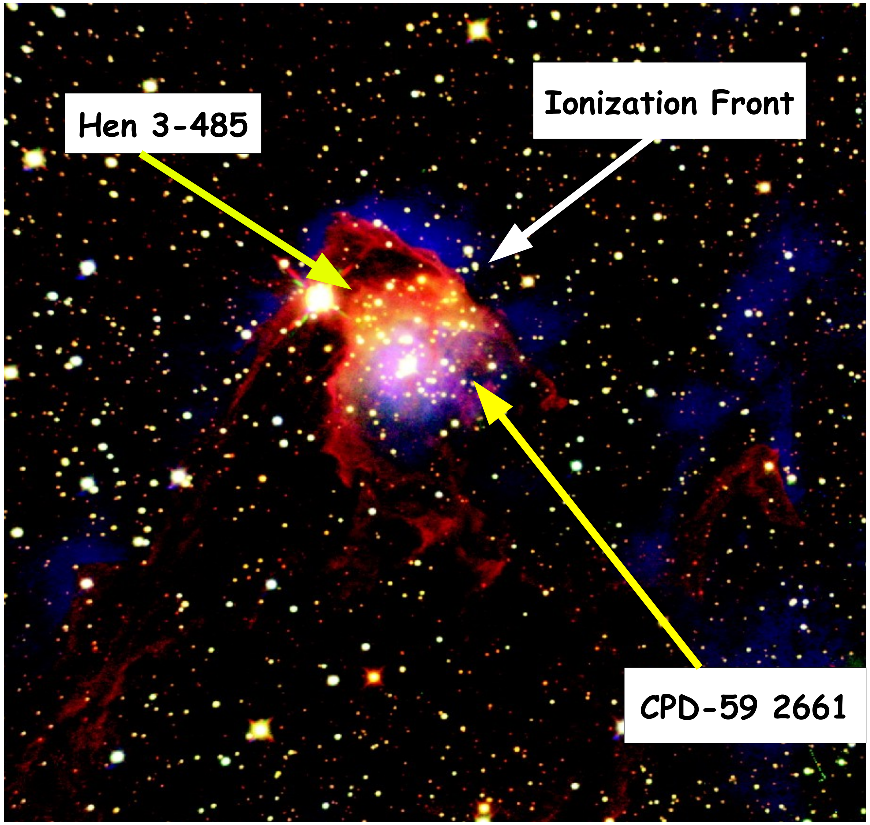
IMPACT OF RADIATION & WINDS ON MOLECULAR CLOUDS: OPEN QUESTIONS

- Analytical (Bertoldi 1989) & Numerical models (Lefloch & Lazareff 1994, Henney 2009) successfully reproduce many observed features

- Triggered star formation ? At what stage of evolution & where (core or periphery) does the star form?

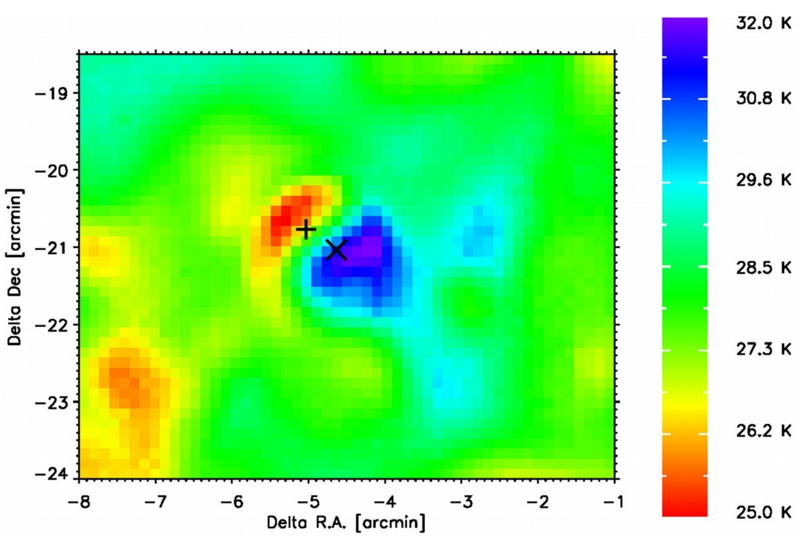
- Understand the role of radiation, magnetic field, turbulence in the evolution of such clouds and formation of cores
  ----> Systematic study of properties of photon dominated gas
  ----> Use [CII] at 158μm, high-J CO, [OI] at 63μm

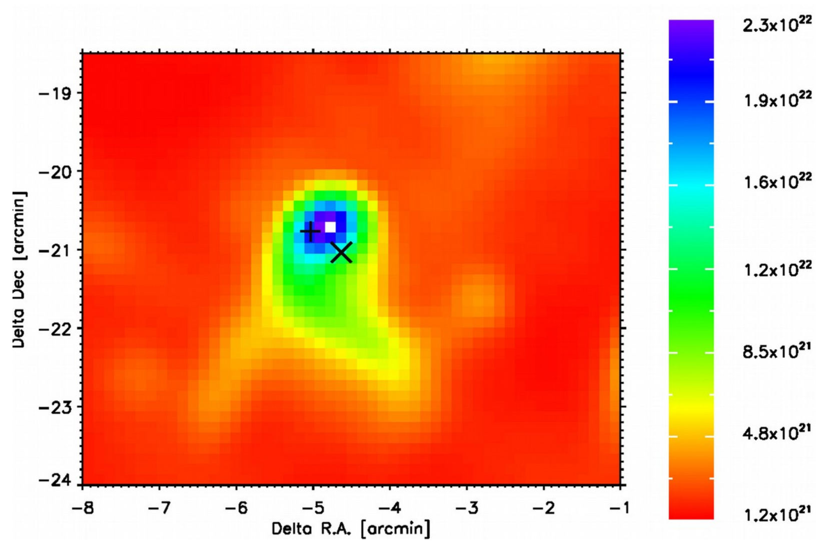
TREASURE CHEST NEBULA



Smith et al. 2005 NIR **Paβ**, **[Fe II]**, **H_2 1-0 S(1)**

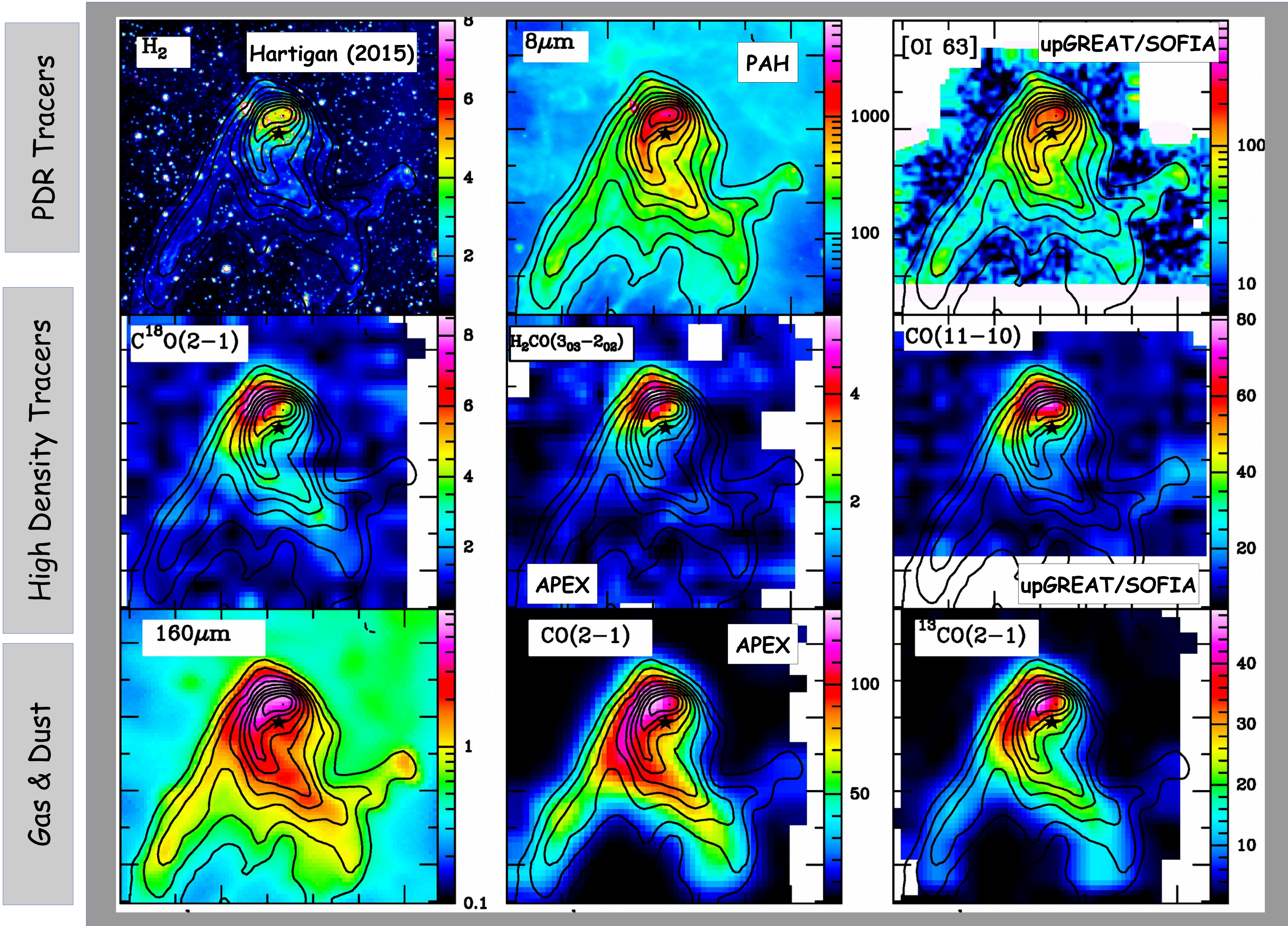
- Treasure Chest cluster with the brightest member CPD -59 2661 (O9V or B1Ve star)
- Size of H II region much smaller than Stromgren sphere → extremely young cluster and the region is still expanding
- Optical emission lines consistent with externally ionized photoevaporative flow from the surface of cloud
- Column density peak clearly offset from cluster
- Gas at column density peak colder and warmer close to cluster



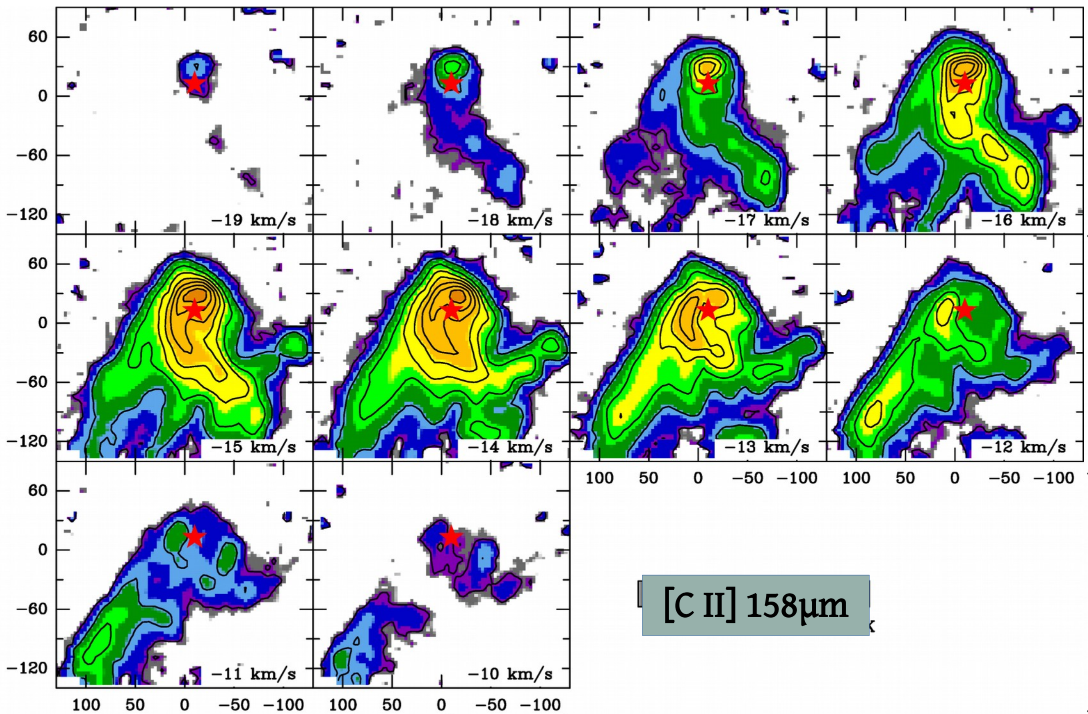


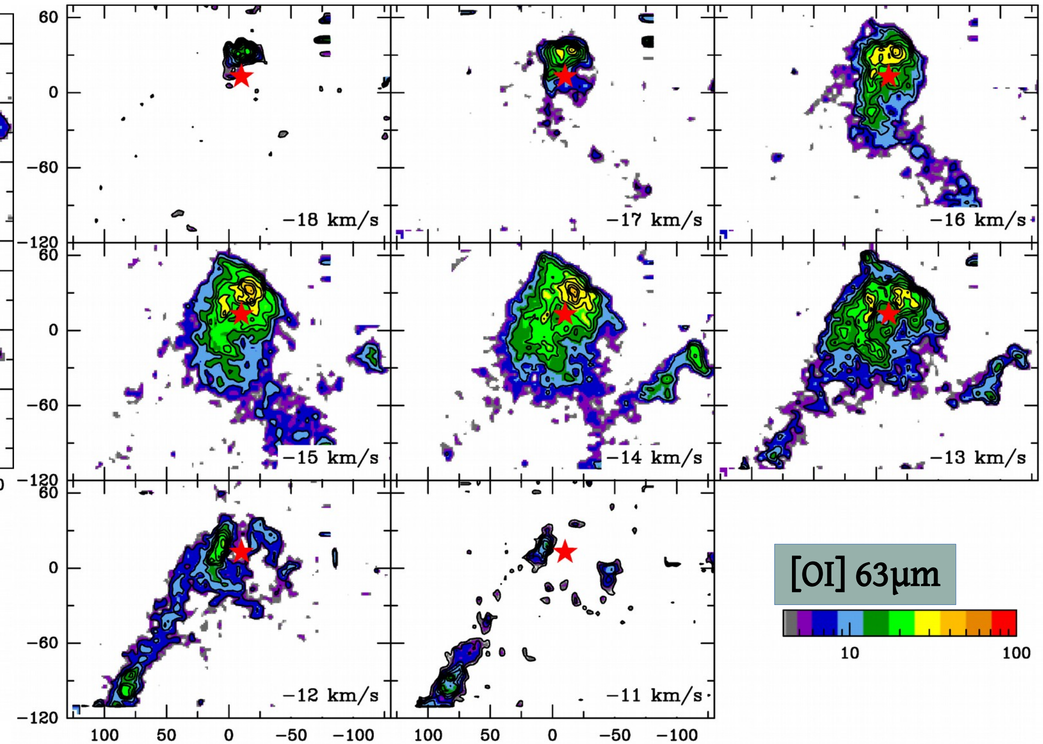
Roccatagliata et al 2013

DUST & GAS IN THE TREASURE CHEST GLOBULE

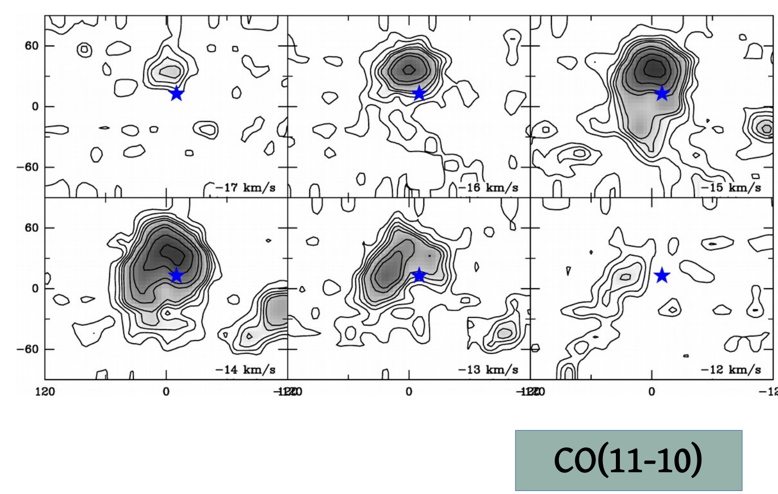


VELOCITY DISTRIBUTION OF PDR GAS

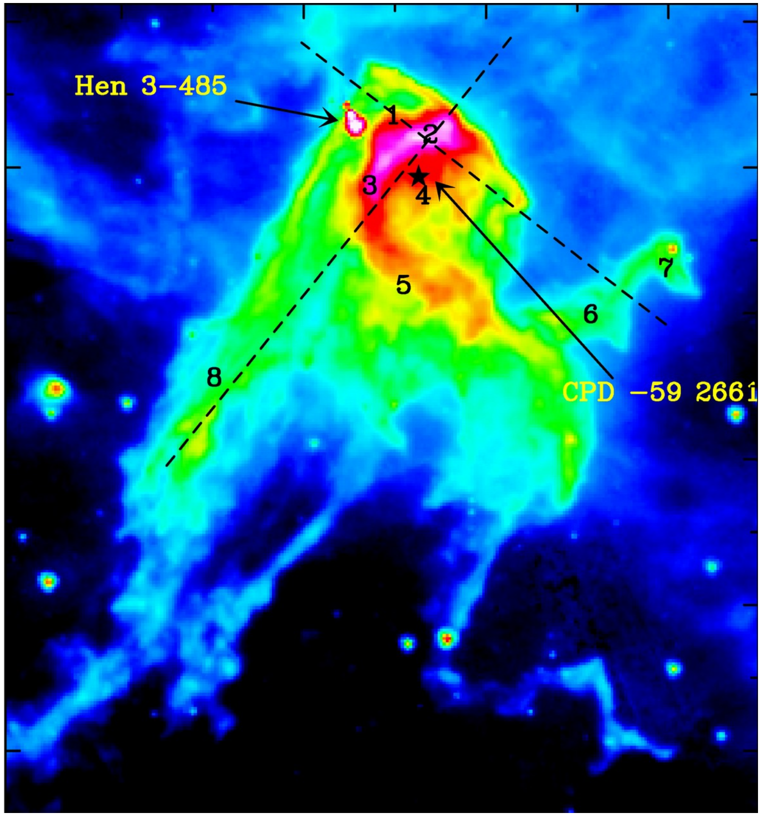




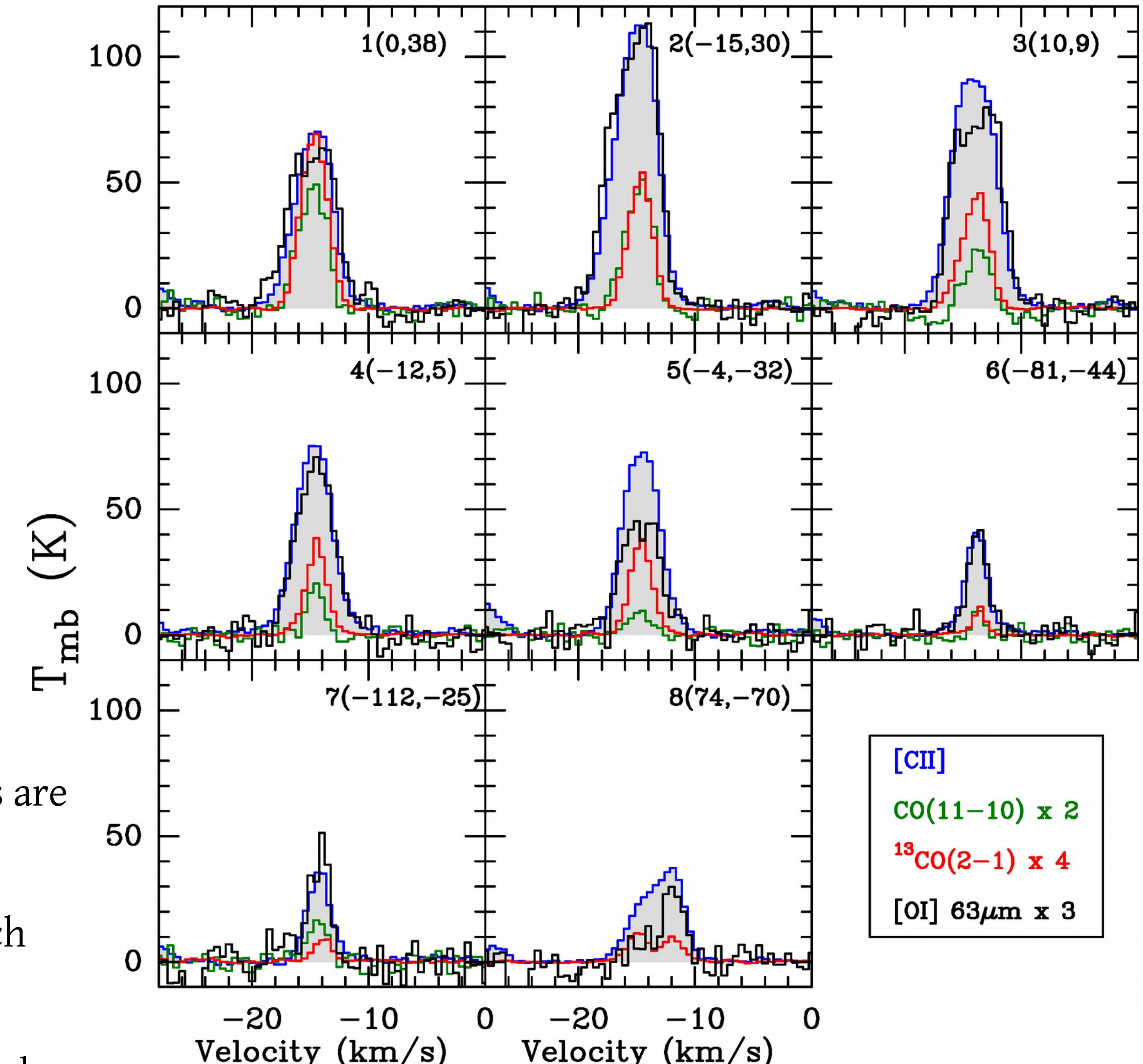
- Bulk of the gas in the head at -14.5 km/s; red-shifted tails
- η Car (v=-20 km/s) stellar wind & radiation pressure push the globule radially away along l.o.s.
- [OI] 63 μm clearly shows the dense PDR shell around CPD -59 2661 at v=-13 km/s
- Eastern tail shows more blue-shifted material in [C II] ----> lower density



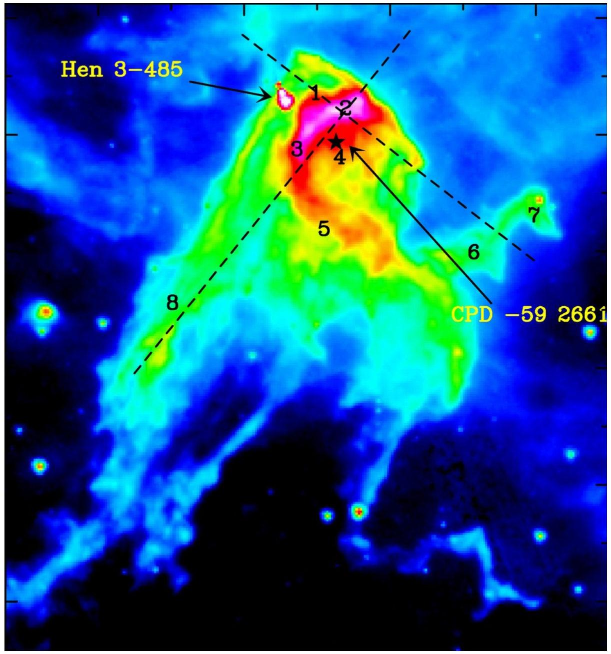
SPECTRAL PROFILES

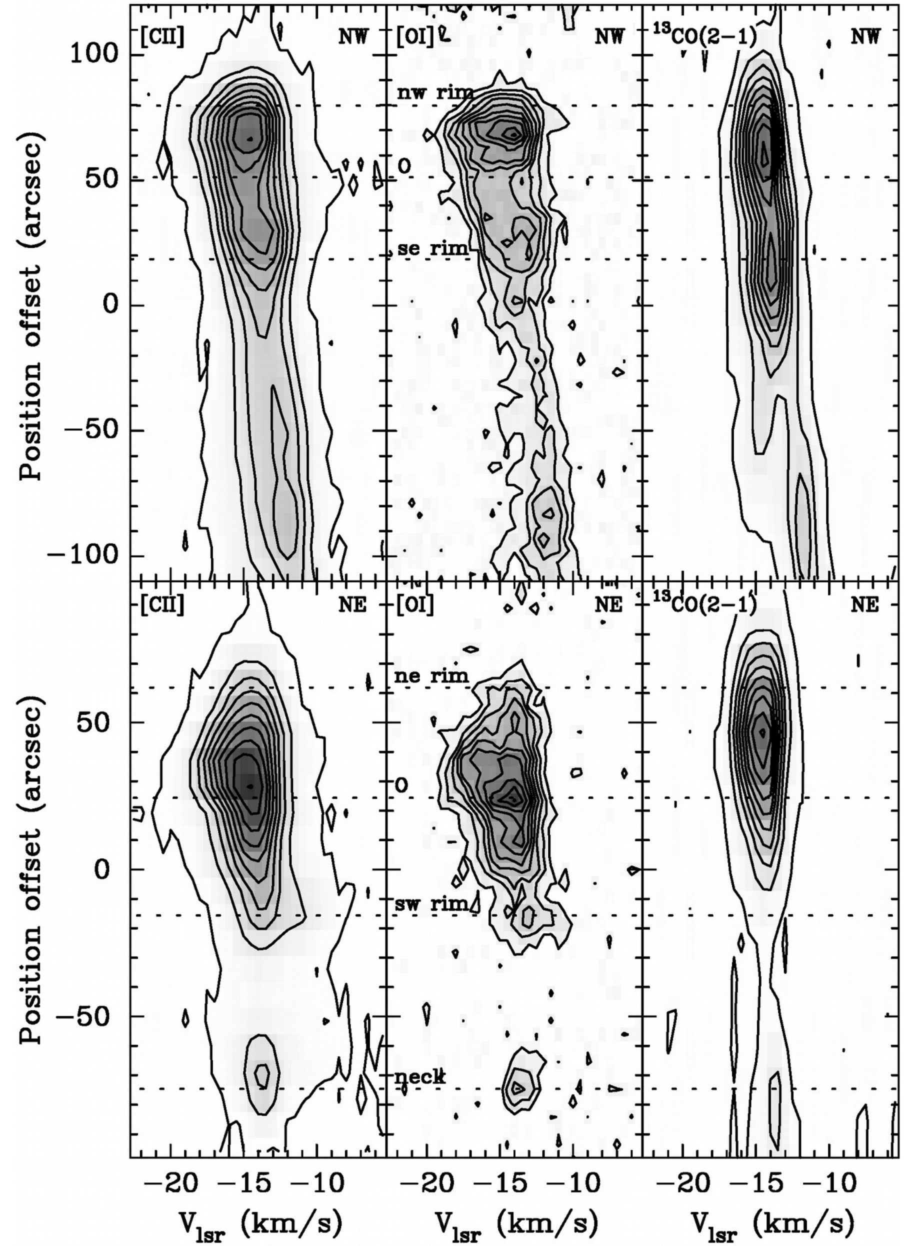


- At all (except #1) positions [C II] & [O I] lines are broader than CO lines by 1-1.5 km/s
- [C II] and [O I] line widths and profiles match ----> both primarily arise in PDRs
- [O I] spectra show flattened or double-peaked profile at #1, #3 & #5
- Position #8 located on eastern tail shows 2 components at -14 and -12 km/s



POSITION-VELOCITY PLOTS





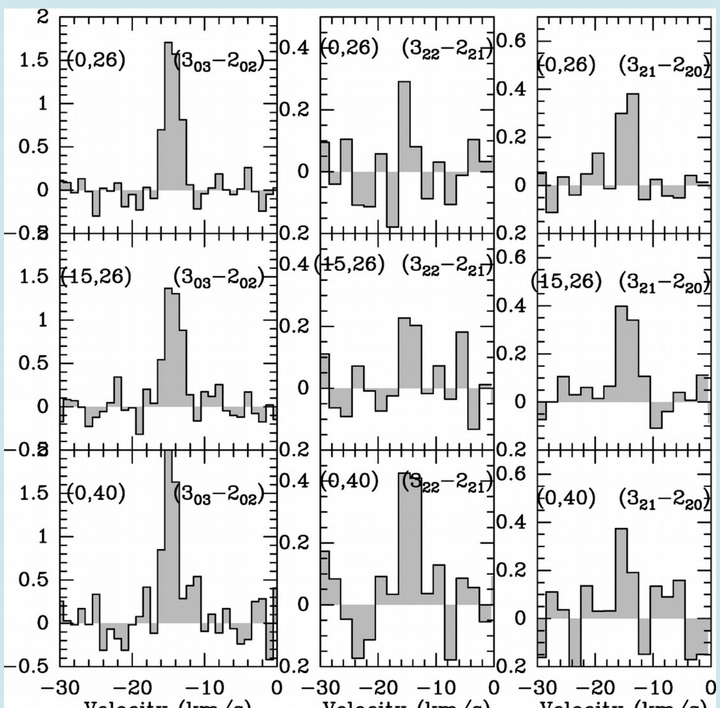
- NW-SE cut:
  - --- [CII] & [O I] peak on the PDR shell illuminated by CPD -59 2661
  - ---^{13}CO(2-1) line width same across PDR shell ---> molecular gas not yet affected by the expanding H II region

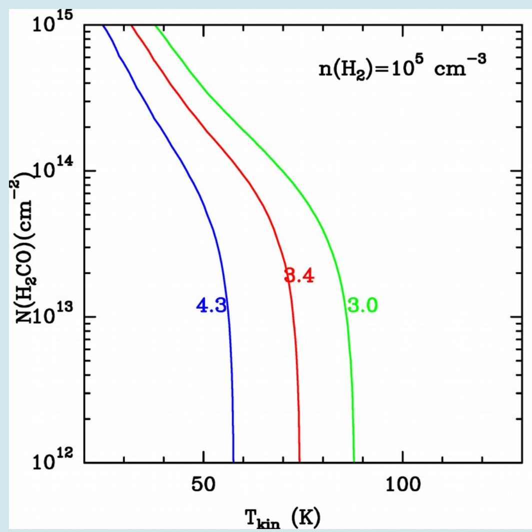
- NE-SW cut:
  ---- [C II] & [O I] peaks lie on PDR shell & on the south-western rim (duckneck)
  ---- [O I] and [C II] show extended emission on the side of neck facing Treasure Chest ----> neck is associated with PDR

N(H_2) & Mass from ^{13}CO(2-1)

- Kinetic Temperature from optically thick ^{12}CO(2-1) ~ 20-40 K
- N(^{13}CO) ~ (1-76)x10^{17} cm^{-2}
- N(H_2) = 8.5x10^{20} to 4.9x10^{22} cm^{-2}
- Mass ~ 600 Msun

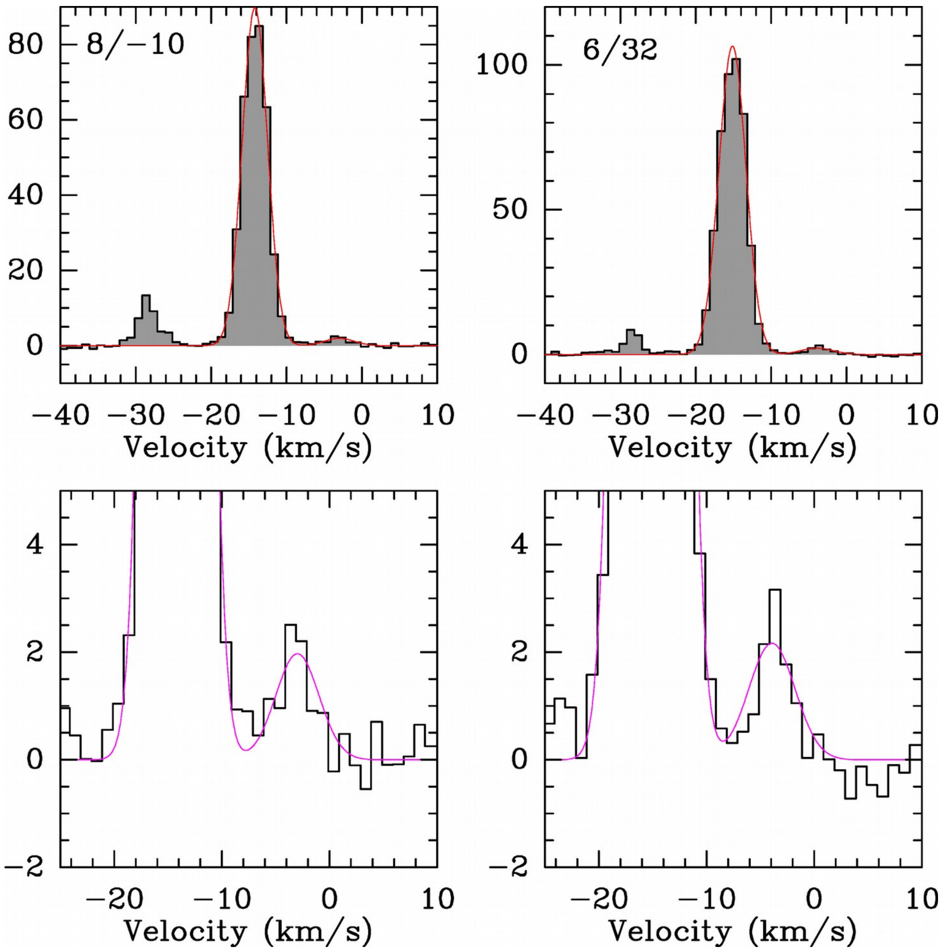
GAS TEMPERATURE FROM H_2CO



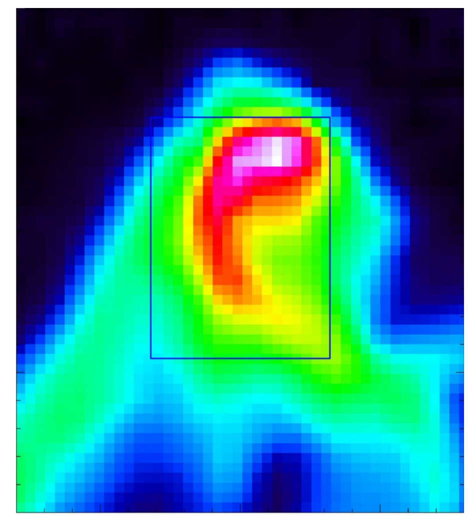


- 3_{03}-2_{02}/3_{21}-2_{20} transitions good thermometer
- Critical density of H_2CO = 1-6x10^5 cm^{-3}
- Non-LTE analysis of line ratios using RADEX
- Averaged over an area where all three lines are detected, T_{kin} ~60-70 K for n=10^5 cm^{-3}

COLUMN DENSITY OF C^+ : ANALYSIS OF [^{13}C II]



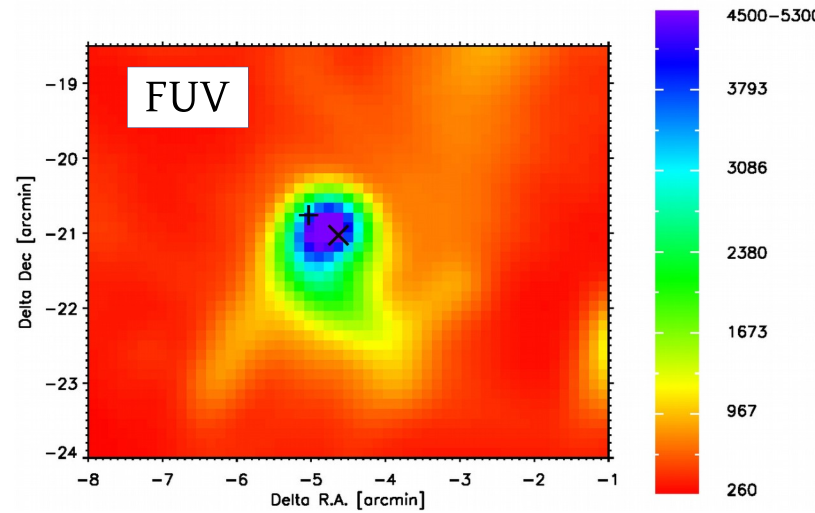
- Detected F=2-1 transition of [^{13}C II] at 50 positions
- Simultaneously fit [C II] and [^{13}C II] lines (constrain velocity) to determine intensities



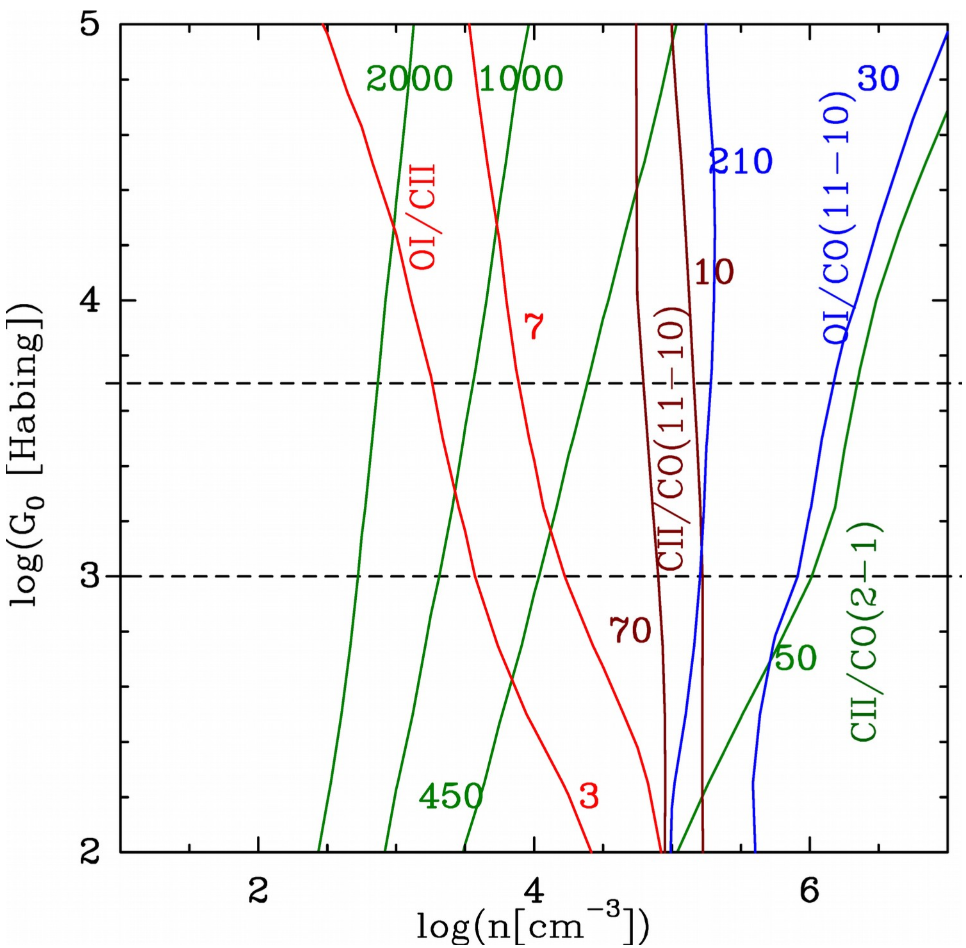
- [^{12}C II] optical depth using ^{12}C/^{13}C abundance ratio of 65: **τ ~ 0.9 to 4.7**
- T_{ex} ~ 80 to 255 K, with most positions having **110-130 K**
- **$N(C^+)$ ~ 3-7x10^{18} cm^{-2}**
- Total mass seen in C^+~**440 M_{sun}** (n=3000 cm^{-3}, Tex=100 K)

ANALYSIS OF [C II], [OI] & CO EMISSION USING PDR MODELS

- 1-D Photo Dissociation Region Models by Kaufman et al (2006)
- Calculate intensities of tracers of PDRs as a function of density ($n(H_2)$) and the FUV radiation field (G_0)



Roccatagliata et al 2013



- FUV estimated from FIR dust continuum ranges between 900 to 5000 times Habing field
- [C II]/CO(2-1) →---> diffuse $n(H_2)$~600 to 2200 cm^{-3}

  → dense $n(H_2)$~10^4 to 10^6 cm^{-3}
- [C II]/CO(11-10) →---> $n(H_2)$ ~ (0.8-1.6)10^5 cm^{-3}
- [O I]/CO(11-10) → n(H2) ~ (2-8)10^5 cm-3
- [O I]/[C II] ---> $n(H_2)$ ~ 2x10^3 to 1.8x10^4 cm^{-3}

[C II] emission dominated by diffuse PDR gas

PDR surfaces consist of gas in dense clumps immersed in diffuse medium

TRIGGERED STAR FORMATION IN TREASURE CHEST ?

- The Treasure Chest cluster estimated to be 1.3 Myr old is too old to have been triggered by the formation of the cometary globule.
- TC likelt pre-existed in the cloud before G287.84-0.82 became a globule
- The lower density gas from the region got blown away by the expanding Carina H II Region
- Globule continues to be eroded from the outside by the winds from η Car and Tr 16, but the expanding H II region of TC erodes it even faster
- Globule has enough dense gas (~1000 Msun) to form stars, but the timescale for formation is longer than the time needed to completely photo-evaporate the globule.

SUMMARY

- Study of distribution of dust and gas (and magnetic field) in pillars/globules/shells is a method of understanding the effect of radiation from massive stars on the ISM
- Overall structure of G287.84-0.82 consistent with being sculpted by radiation and wind from η Car & Trumpler 16
- The velocity-resolved [C II] and [O I] observations enabled separation of diffuse and dense PDR gas
- Compared intensity ratios with radiative transfer and PDR models to constrain the kinetic temperature and density of the gas in the globule
- Treasure Chest cluster unlikely to have been triggered by the expansion of the Carina H II region
- TC dominates the structure of the PDR inside the head of the globule & appears to be eroding the region faster than the star formation timescale.

THANK YOU