Ionization-driven star formation: the case of IR bubble N10

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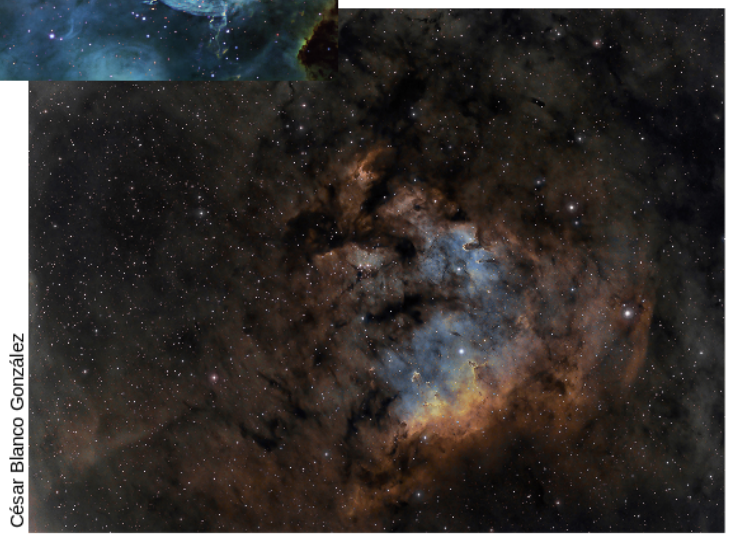
Overview

Introduction



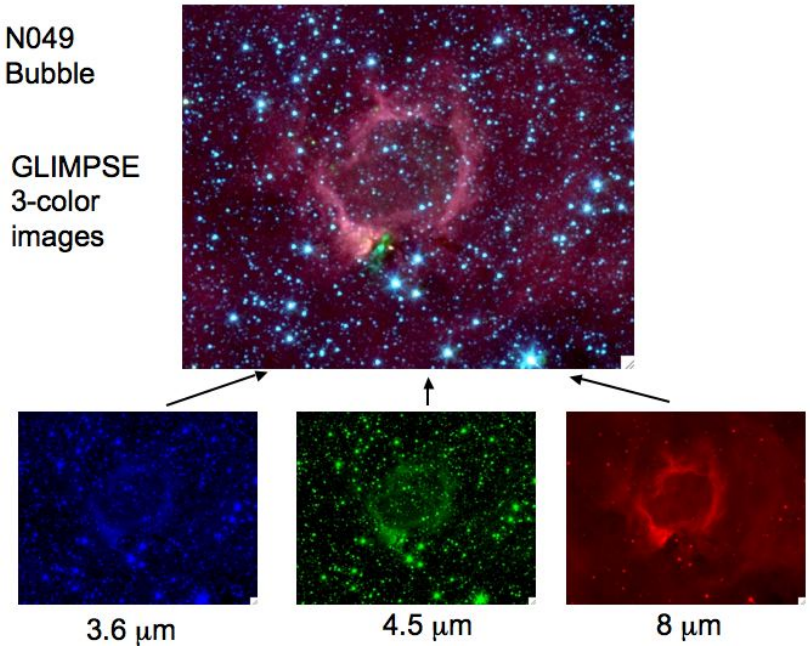
Interstellar Medium

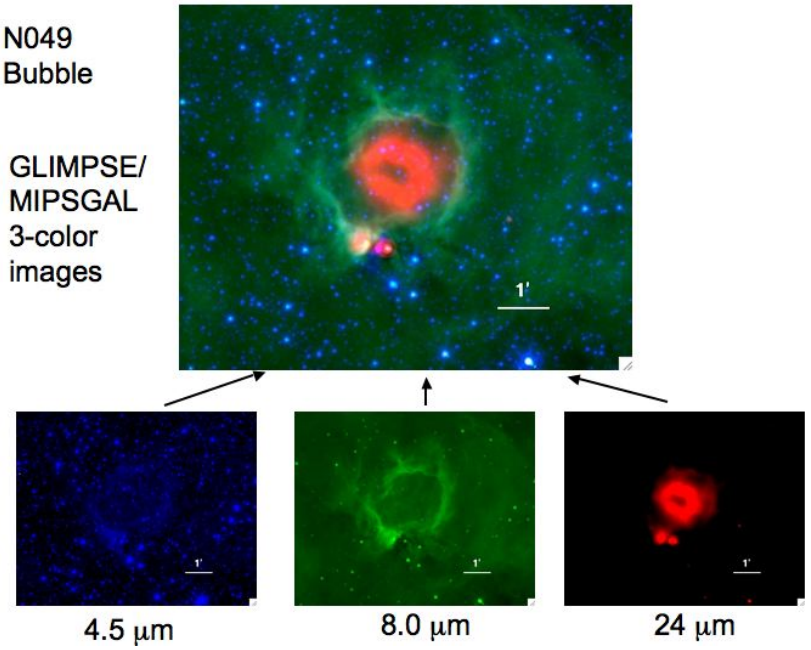
Table: Properties of molecular clouds, clumps and cores.

	Molecular Clouds	Clumps	Pre/protostellar Cores
Size (pc)	2–15	0.3–3	0.03–0.2
Density (cm^{-3})	50–500	10^3–10^4	10^4–10^5
Mass ($M_\odot$)	10^3–10^4	50–500	0.5–5
Temperature (K)	$\sim$10	10–20	8–12

Infrared Bubbles

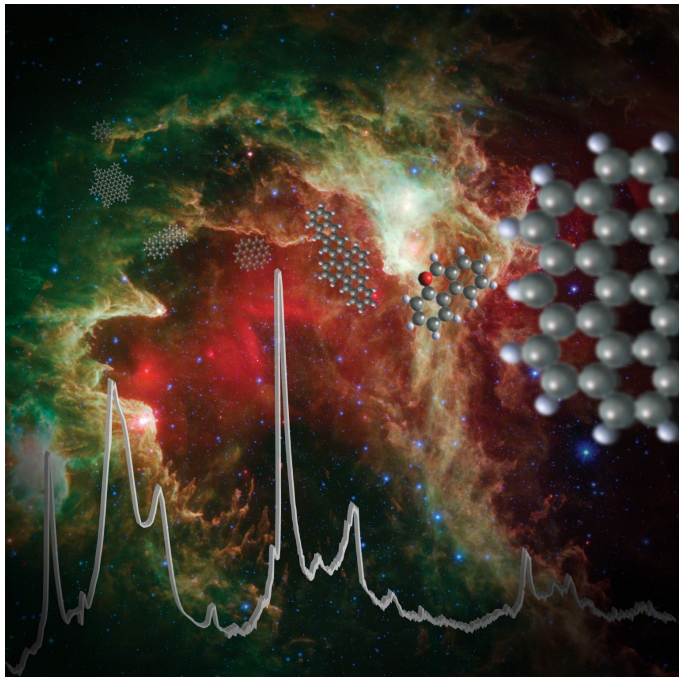
N49: an example of IR bubble

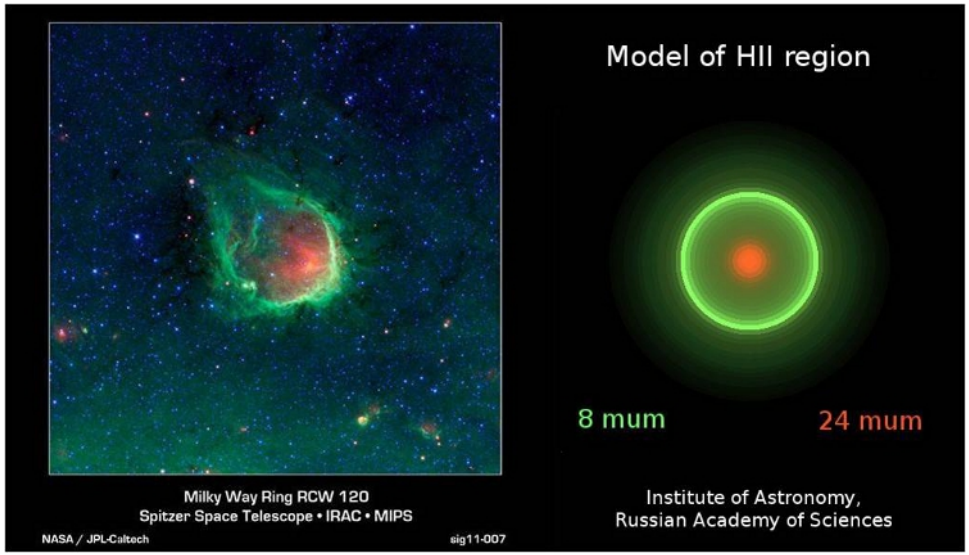




IR bubbles

8 μm emission: PAH features





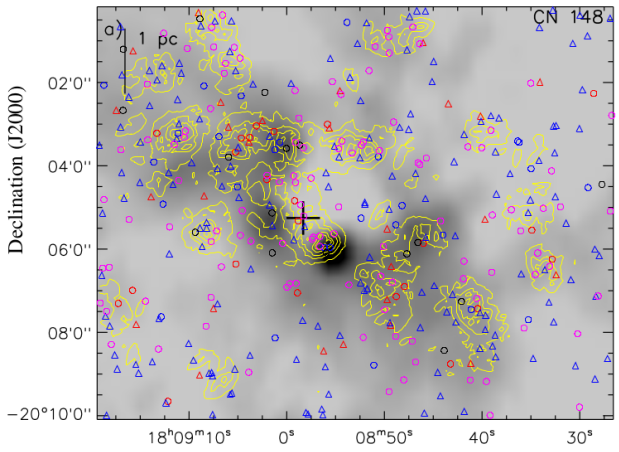


Figure: CN148. Dewangan et al. (2014)

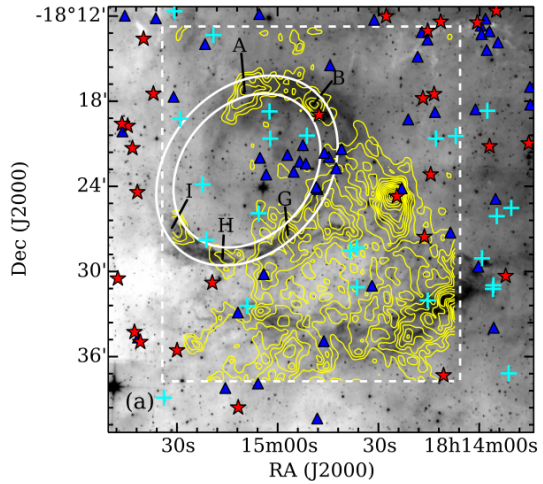


Figure: N6. Yuan et al. (2014)

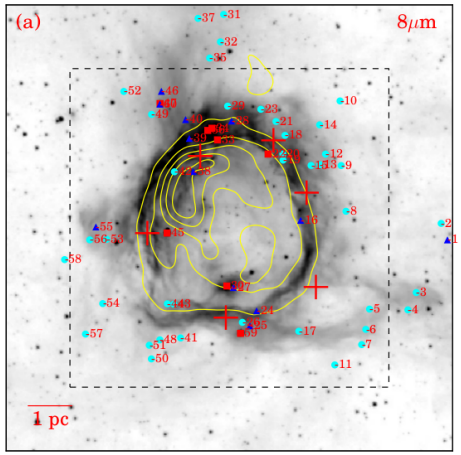


Figure: N4. Hong-Li Liu et al. (2016)

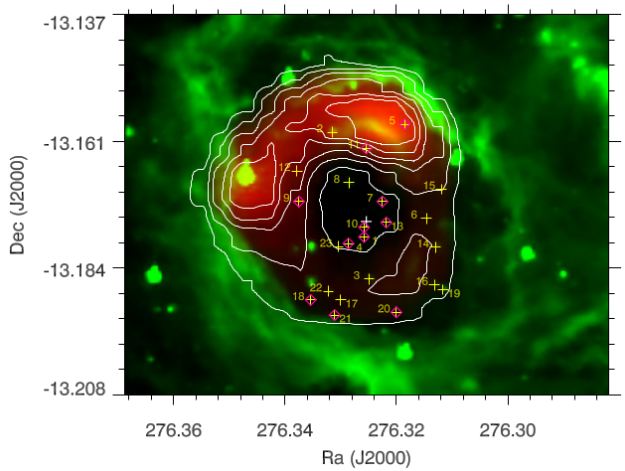
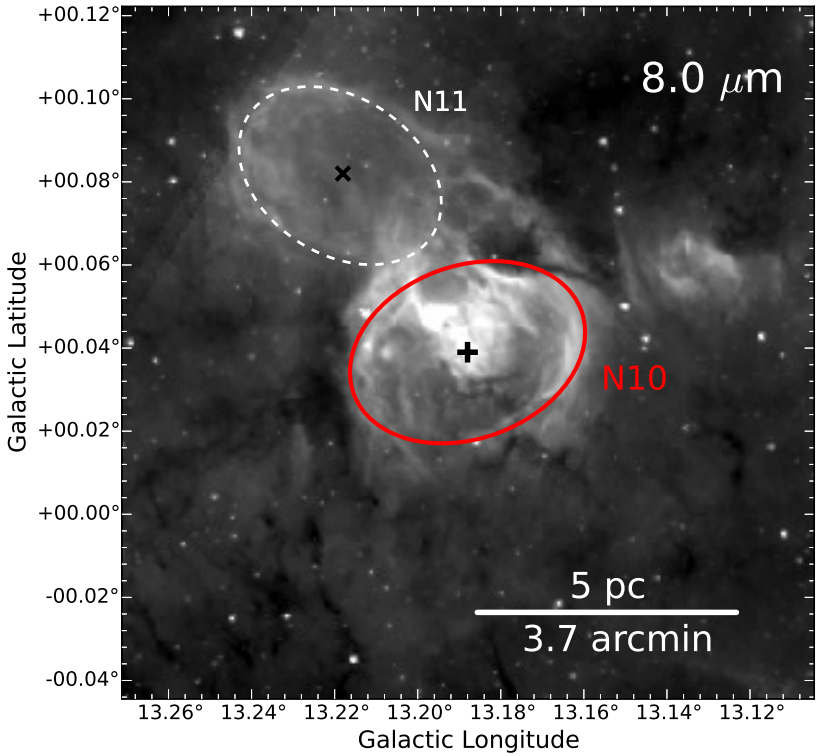
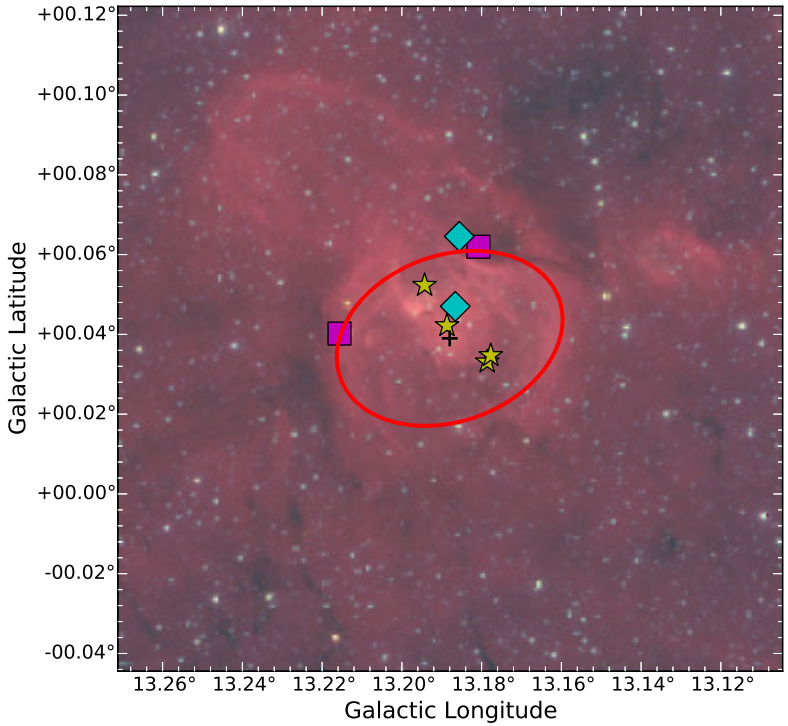


Figure: N22. Wu et al. (2016)

N10

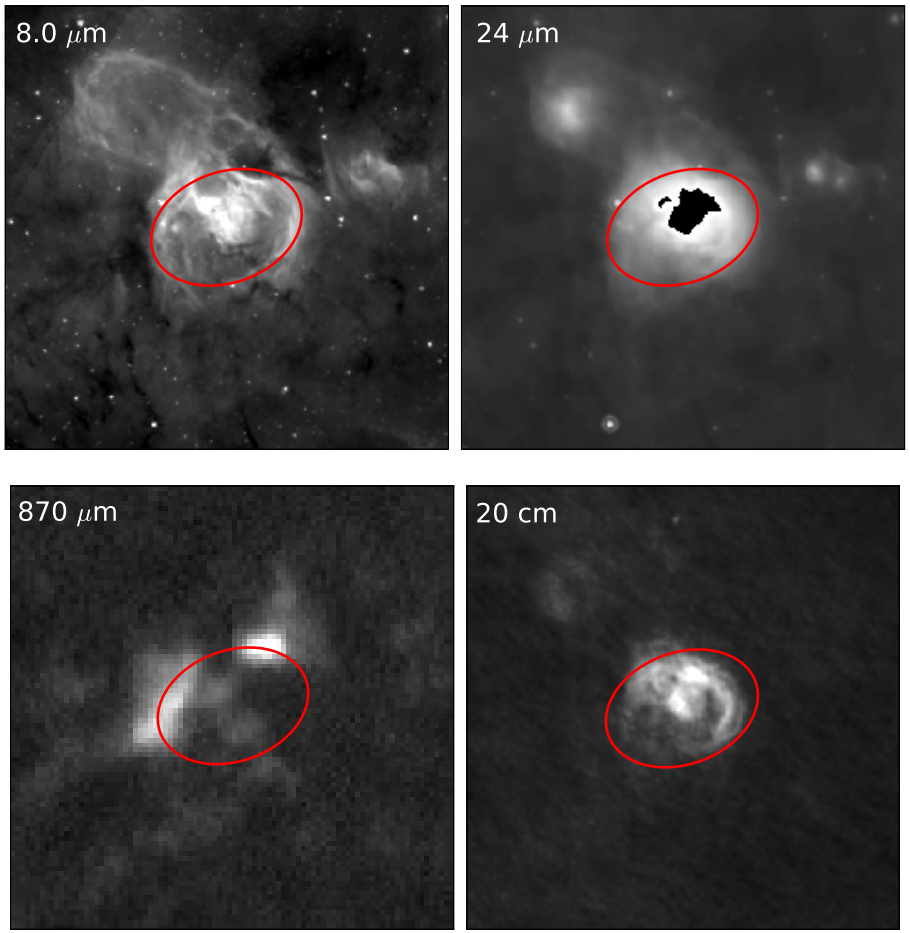




Gama et al. (2016)

N10

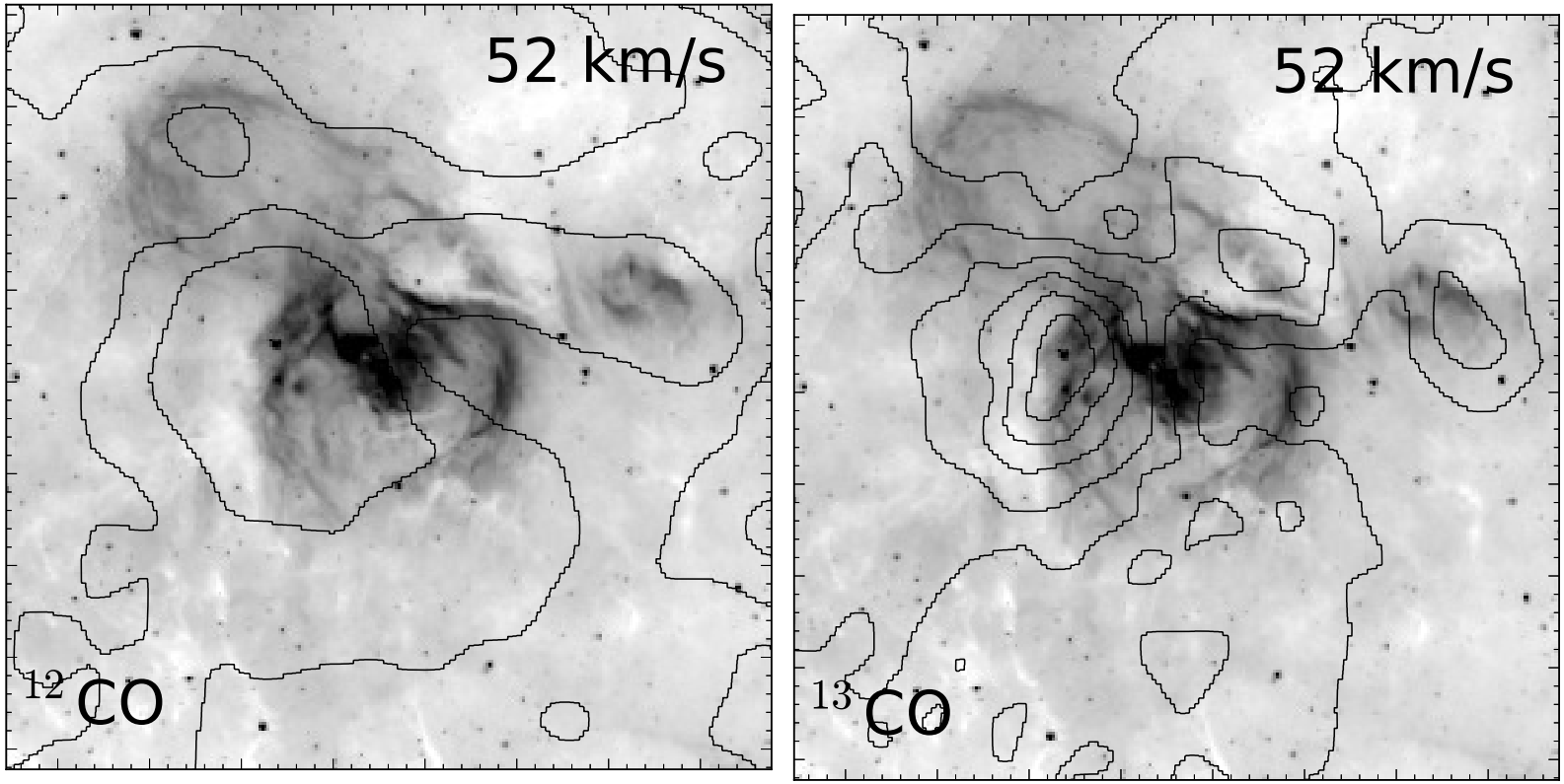
Multi-wavelength information



Gama et al. (2016)

Molecular Gas

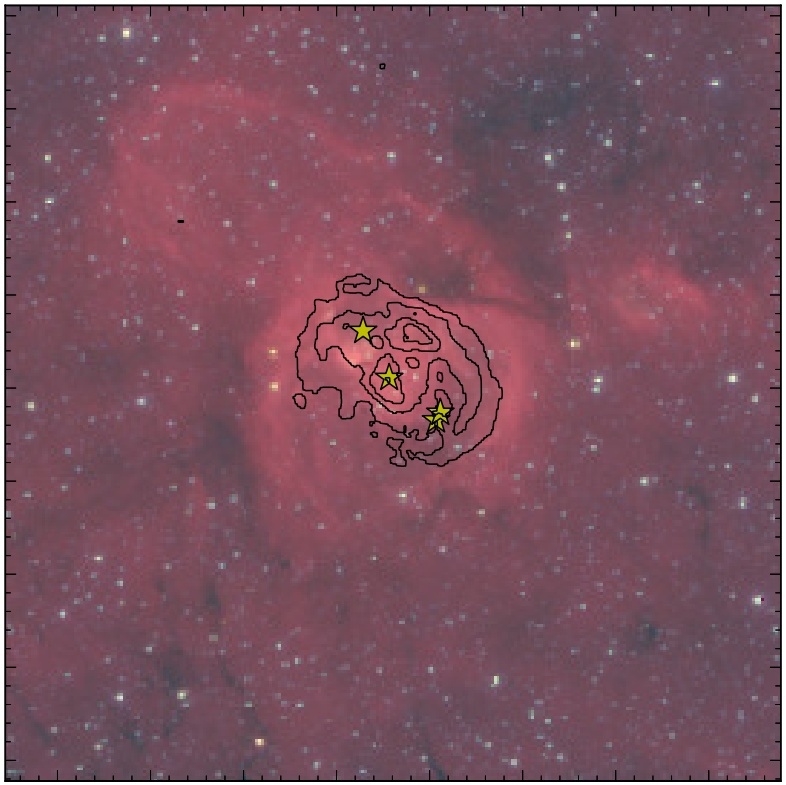
PMO 13.7-m observations ($\theta \sim 52$ arcsec)



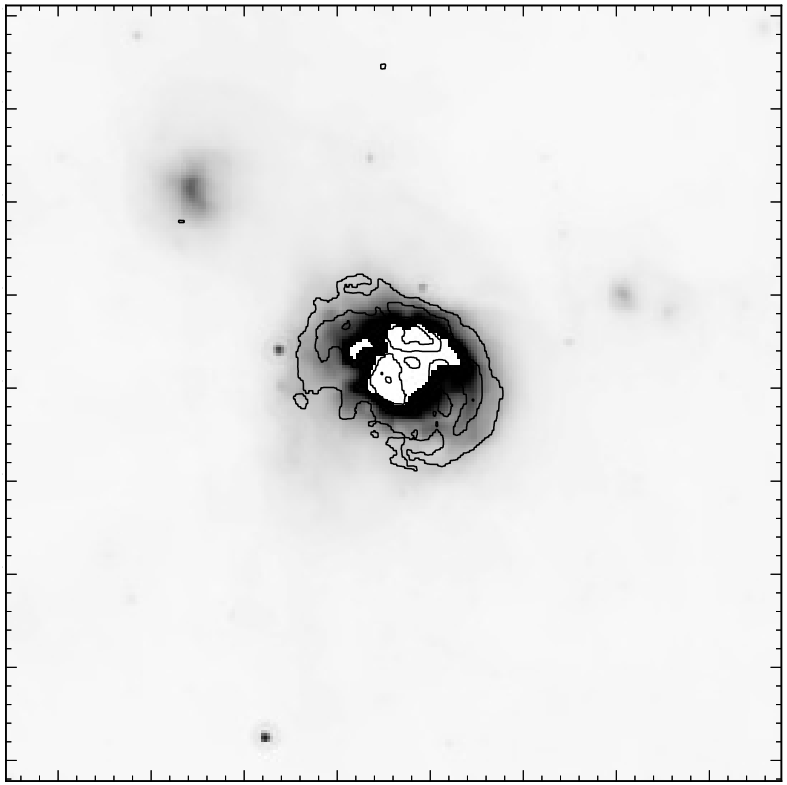
Gama et al. (2016)

Ionized Gas

Contours: 20 cm emission
RGB image: Spitzer



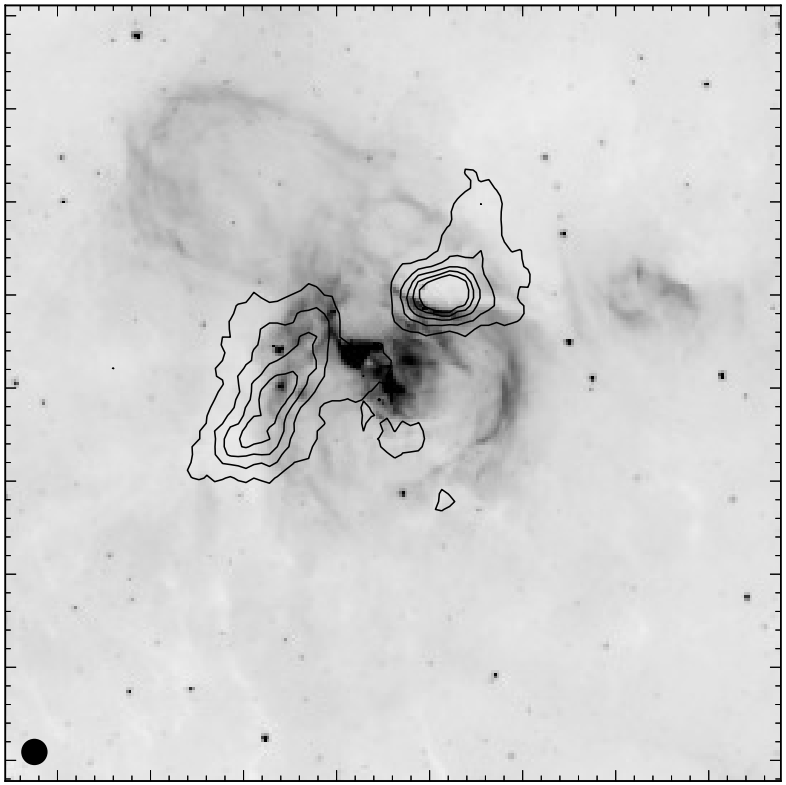
Contours: 20 cm emission
Grey image: 24 μm



Gama et al. (2016)

Cold Dust

Contours: 870 μm emission
Map: 8 μm



Gama et al. (2016)

Cold Dust

Classification of YSOs (Kenig & Leisawit, 2014)

Class I

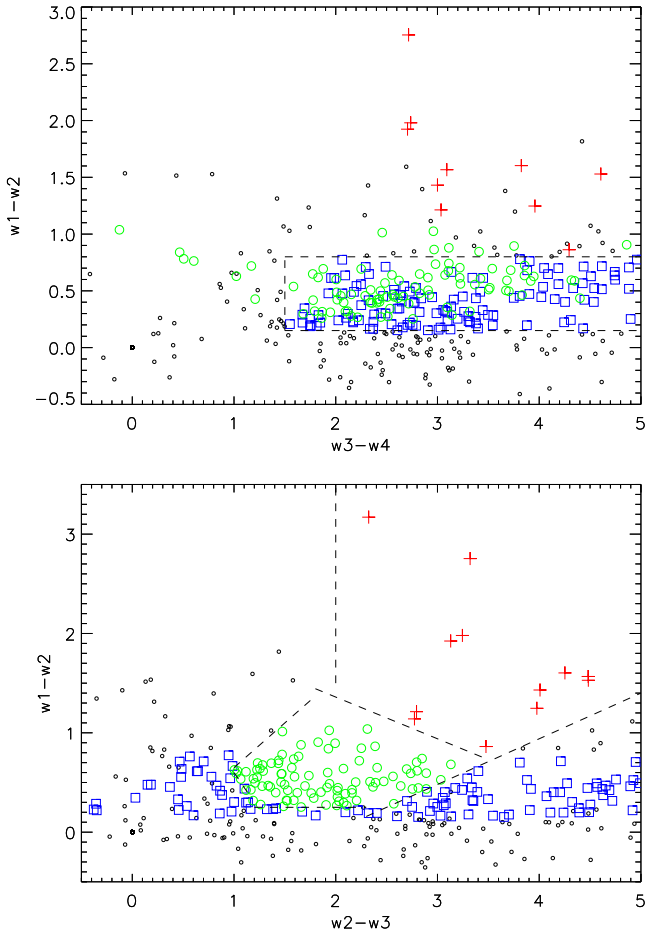
- w1 - w3 $>$ 2.0
- w1 - w2 $>$ - 0.42 $\times$ (w2 - w3) + 2.2
- w1 - w2 $>$ 0.46 $\times$ (w1 - w3) - 0.9
- w2 - w3 $<$ 4.5

Class II

- w1 - w2 $>$ 0.25
- w1 - w2 $<$ - 0.9 $\times$ (w2 - w3) + 0.25
- w1 - w2 $>$ 0.46 $\times$ (w2 - w3) - 0.9
- w2 - w3 $<$ 4.5

Transition Disk

- w3 - w4 $>$ 1.5
- 0.15 $<$ w1-w2 $<$ 0.8
- w1 - w2 $>$ 0.46 $\times$ (w2 - w3) - 0.9
- w1 $\leq$ 13.0



Gama et al. (2016)

Cold Dust

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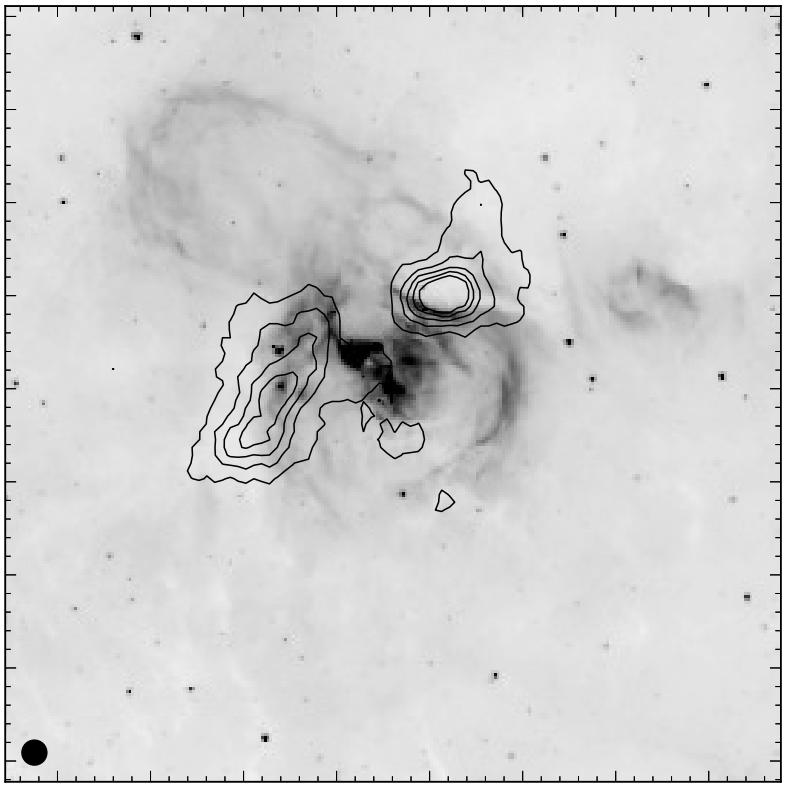
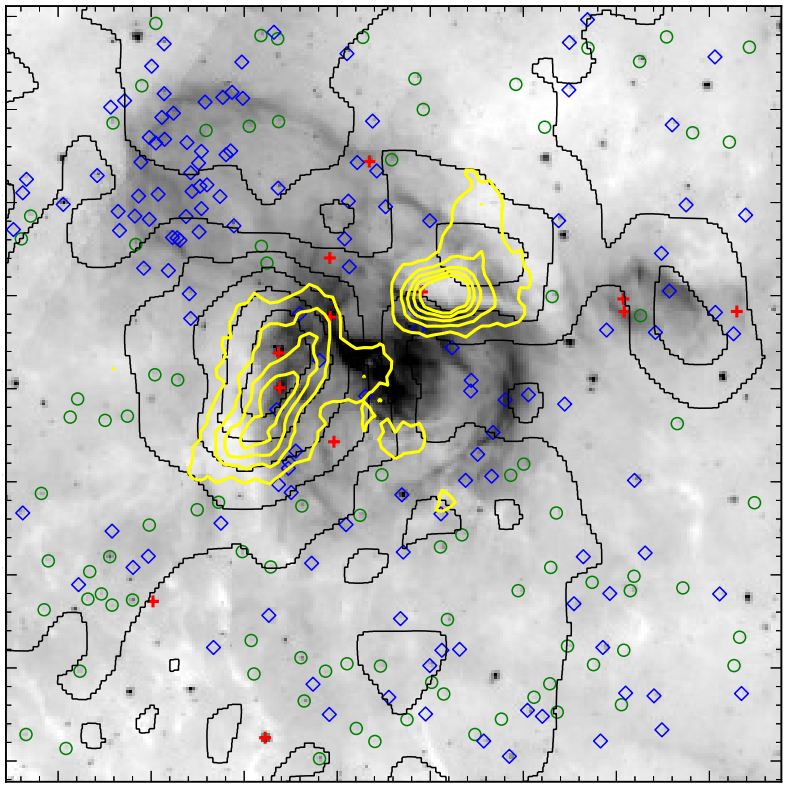


Black contours: ^{13}CO (1-0)



YSOs:
Class I; Class II; Transition Disk

Gama et al. (2016)

Molecular tracers of star formation

Ionization

HCO^+

- molecular ions:
  dense pre/protostellar regions
- cavities produced by *outflows*:
  infall accompanied by jets
- HCO^+ formation:

$$H_3^+ + CO \rightarrow HCO^+ + H_2$$

- H_3^+ formation:

$$H_2 + \nu_{cr} \rightarrow H_2^+ + e^-$$
$$H_2^+ + H_2 \rightarrow H_3^+ + H$$

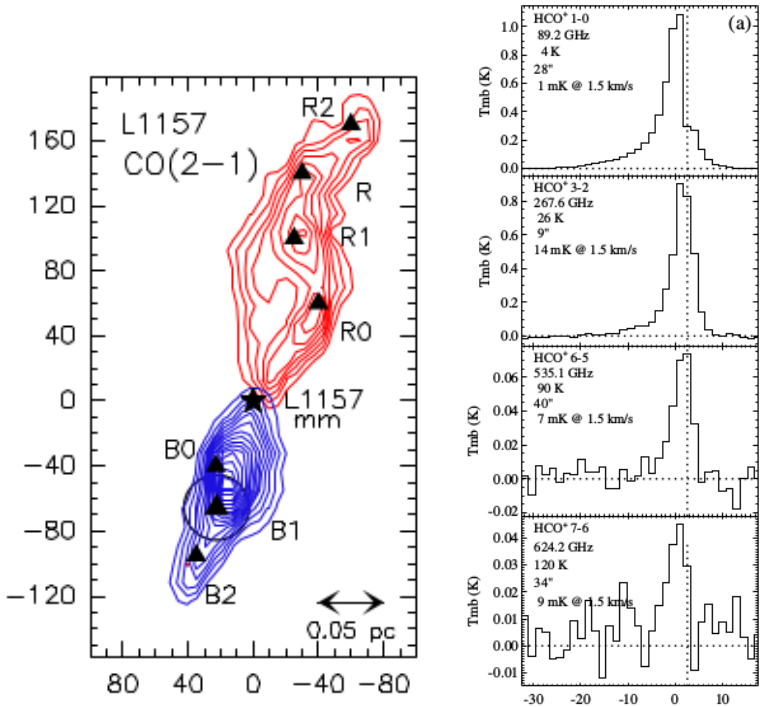
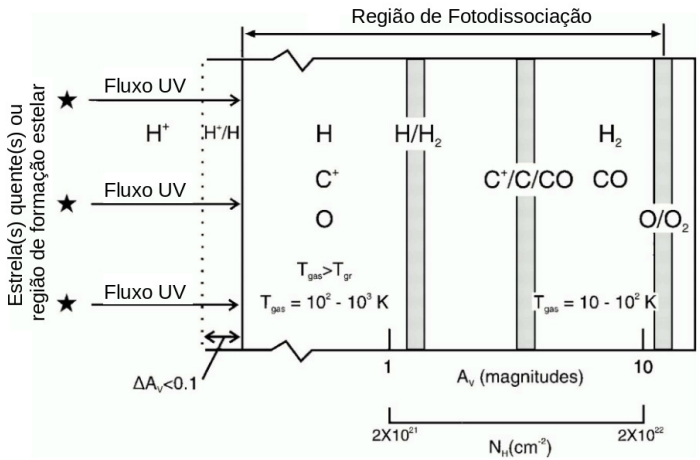


Figure: L1157-B1. Podio et al. (2014)

PDR

HCN

- ionizing UV radiation
- dense layers gas
- C^+ and H_2 can react



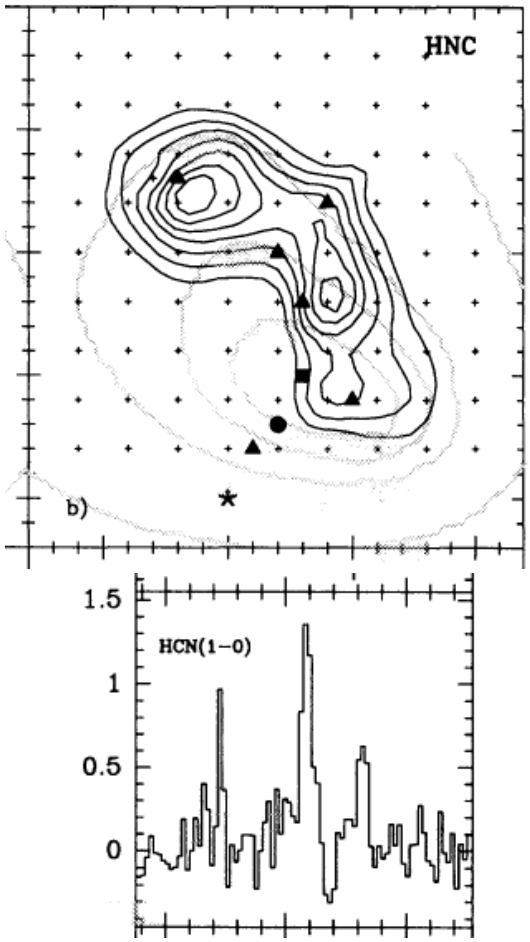


Figure: NGC 7023. Fuente et al. (1993)

Shocks ans outflows

SiO

- SiO produced by C-type shocks
- structures related with embedded YSOs
- gas under shock: young, energetic outflows
- gas-phase chemistry:

$$Si + O_2 \rightarrow SiO + O$$

$$Si + OH \rightarrow SiO$$

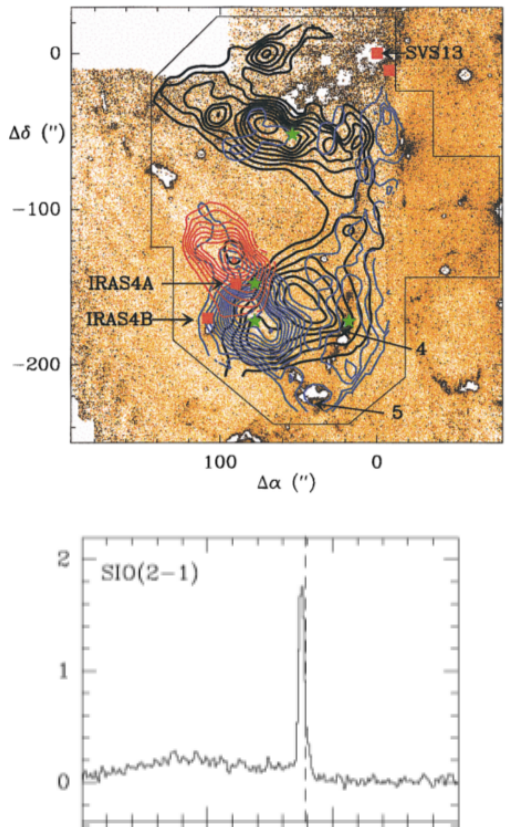


Figure: NGC 1333. Lefloch et al. (1998)

Prestellar cores

N_2H^+

- cold star-forming cores
- YSOs driving powerful outflows

$$H_3^+ + N_2 \rightarrow N_2H^+ + H_2$$

- final stages of SF: depletion of CO

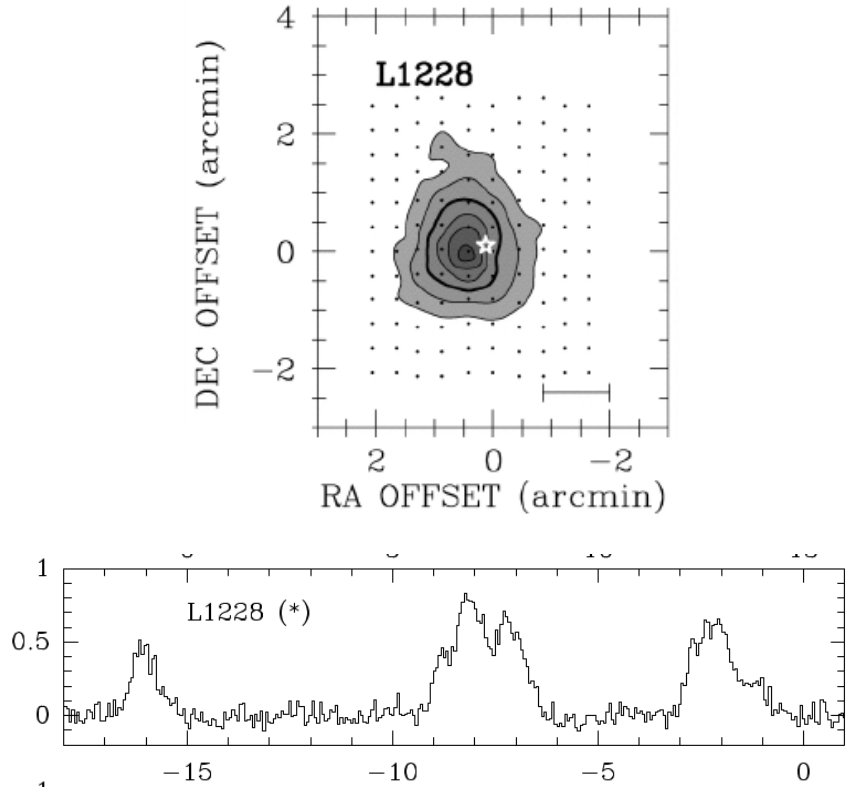


Figure: L1228. Caselli et al. (2002)

Dense Gas

CS

- typical dense gas tracer
- CS lines:
  regions $>$ 100 denser than CO
- CS distribution in IR:
  YSOs and gas surrounding interaction
- high density gas layers

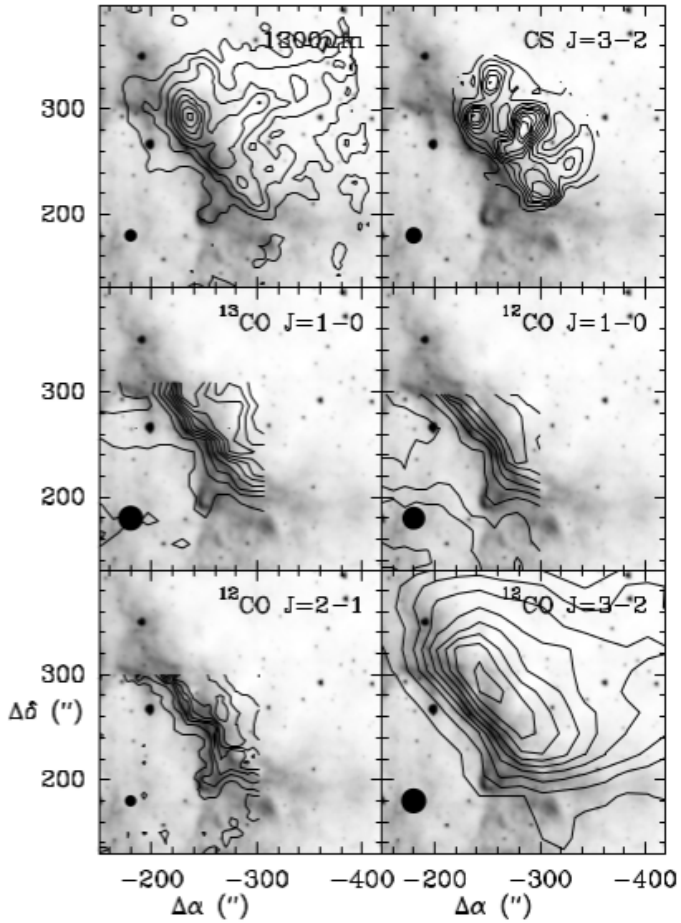


Figure: Trifid Nebula. Lefloch et al. (2008)

IRAM 30-m observations: On-the-Fly maps

Line	Frequency (GHz)	HPBW (arscec)
HCO^+ $(1-0)$	89.188	27.58
HCN $(1-0)$	88.613	27.76
SiO $(2-1)$	86.847	28.33
N_2H^+ $(1-0)$	93.173	26.40
CS $(3-2)$	146.969	13.40

Deep integration

3 mm band spectral line survey

Complex organic molecules				
NH_2CHO	CH_3CHO	$^{13}CH_3OH$	CH_3OH	
Nitrogen-containing molecules				
$HC^{15}N$	N2HD	$H^{13}CN$	$HN^{13}C$	HNCO
HCN	$H^{15}CN$	^{15}NNH	HCN	CH_3CN
HC_3N	^{13}CN	CN	DCN	
Sulfur-containing molecules				
SO	^{13}CS	$C^{34}S$	OCS	CS
NS	H_2CS	$C^{33}S$		
Molecular ions				
HCO^+	NNH^+	DCO^+		
Other molecules				
HCO	$H^{13}CO$	SiO	CCH	$C^{18}O$
^{13}CO	$C^{17}O$	CO	H_2CCO	H_2CO
$H_2^{13}CO$	c-C_3H_2			

Perspectives

Next steps...

- Characterize physical parameters
- Derive the relative abundance of the species
- Compare the abundances with models
- Investigate the evolutive stage of the clumps

Thank you!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