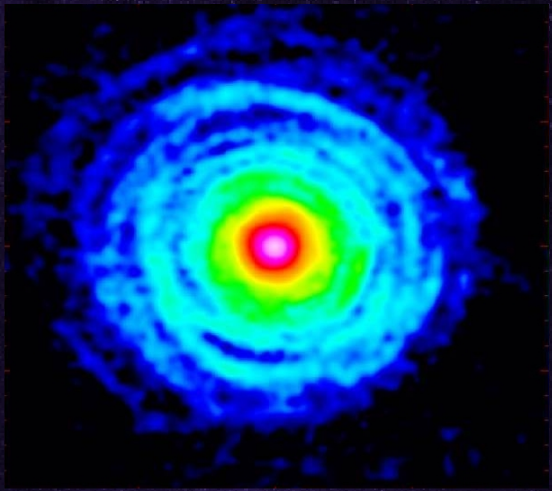
“Joint ALMA/Herschel Archival Workshop” - ESO, Garching. April 17 2015

Silicon bearing molecules towards IRC+10216: Herschel and ALMA unveil the molecular envelope of CWLeo



L. Velilla Prieto, J. Cernicharo, G. Quintana-Lacaci, M. Agúndez, A. Castro-Carrizo, J.P. Fonfría, J. Zúñiga, A. Requena, F. Lique and M. Guélin.

nanocosmos

GOBIERNO DE ESPAÑA

MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

CSIC

CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

ICMM

OUTLINE

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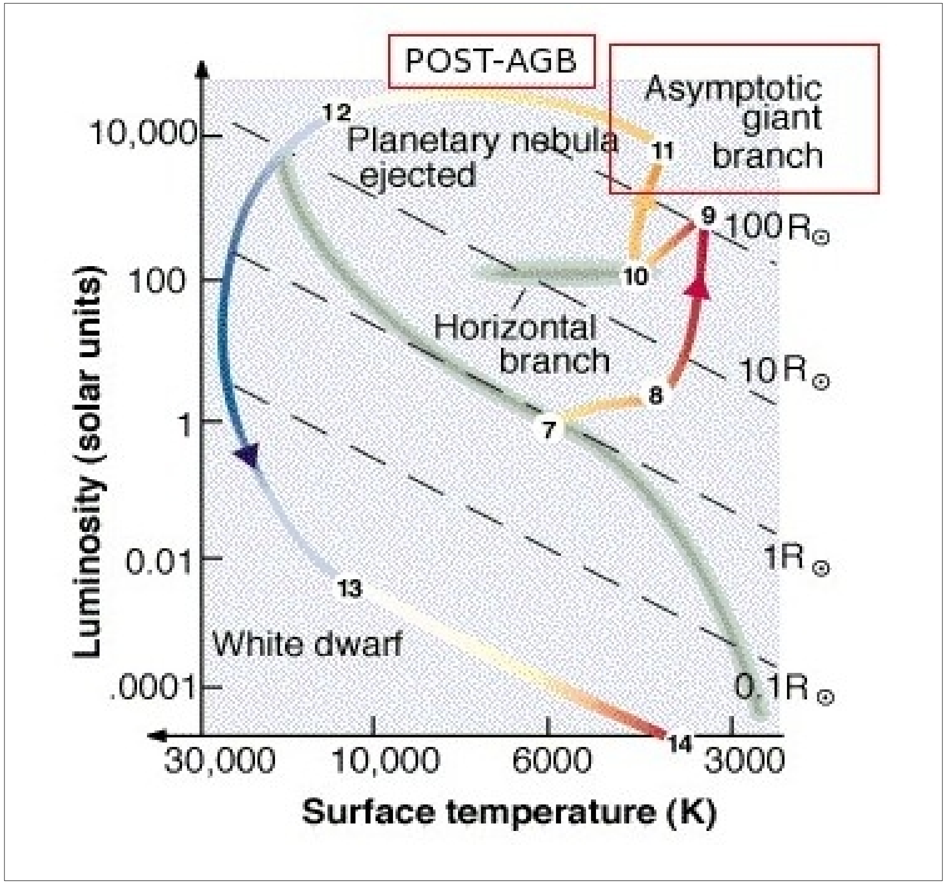
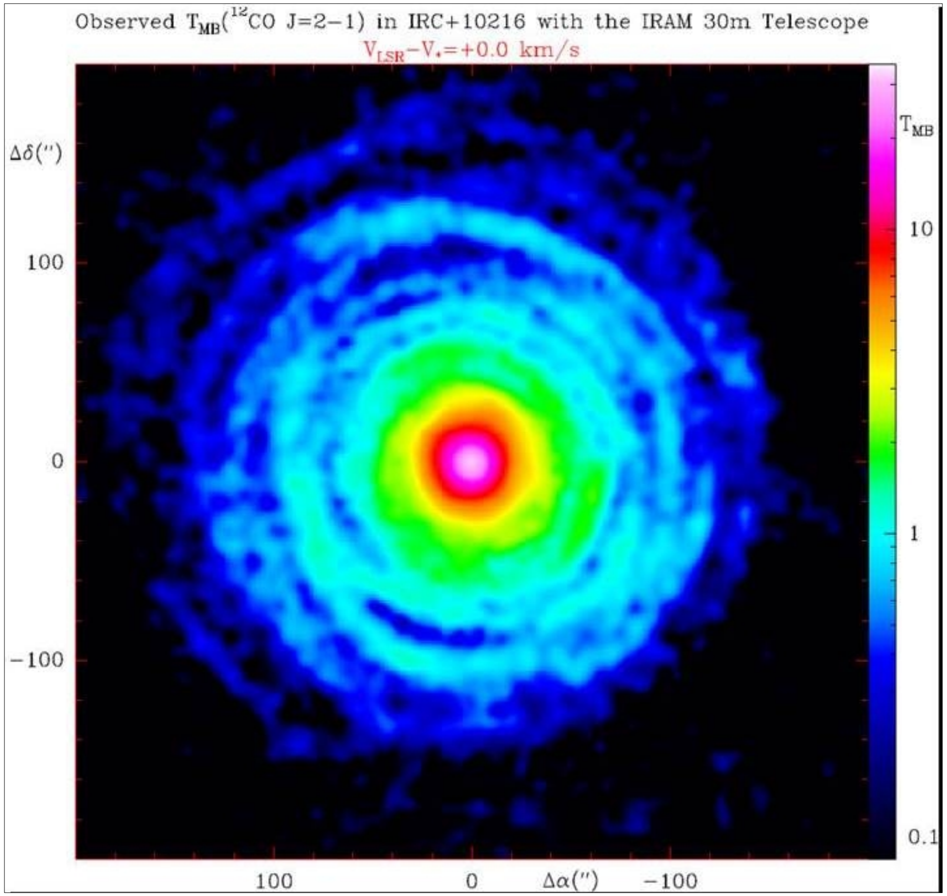
4. Conclusion: linking Herschel and ALMA

5. Future work

1. Introduction

- Circumstellar envelopes (CSE) around AGB stars: Mass loss

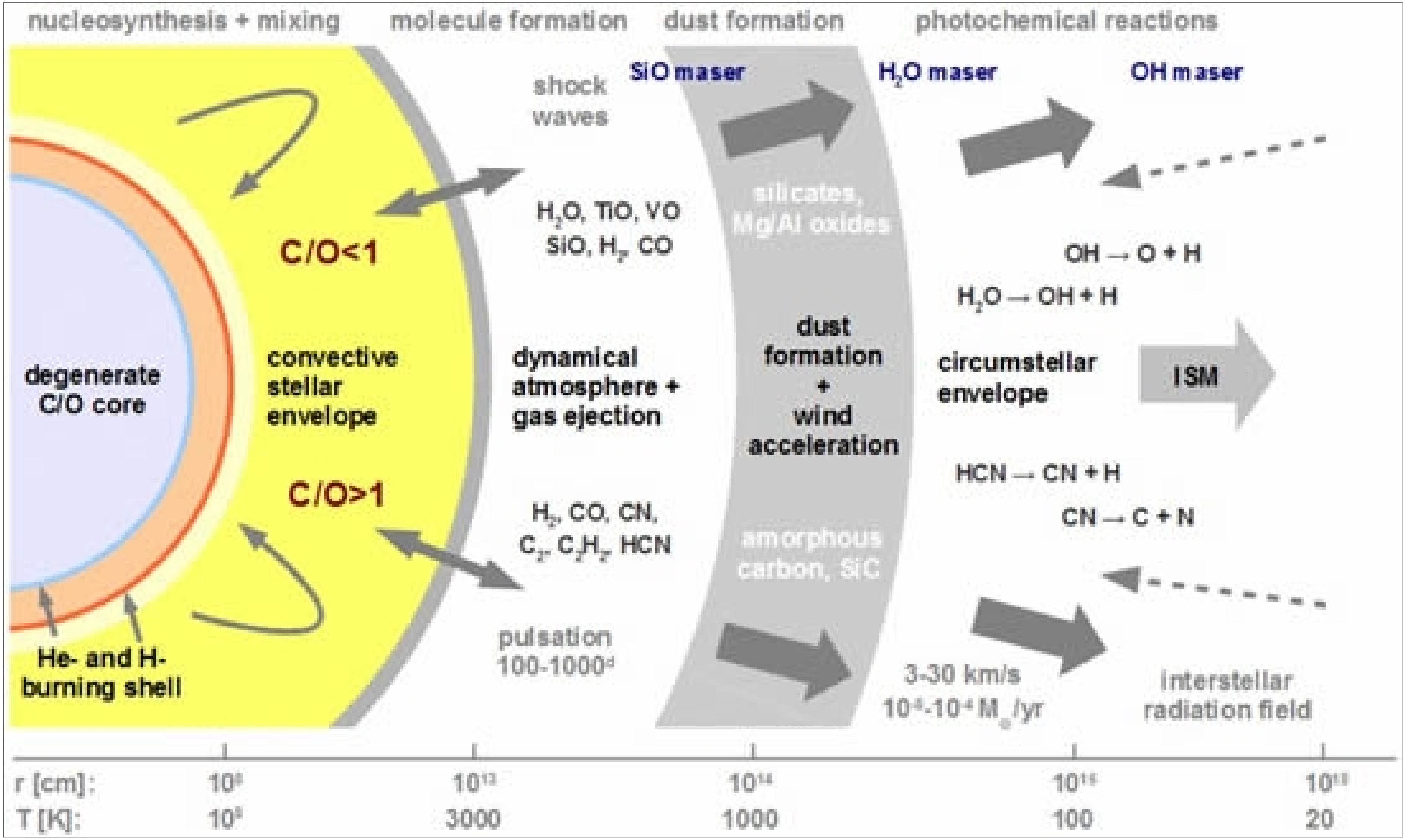




Cernicharo et al. (2015)

1. Introduction

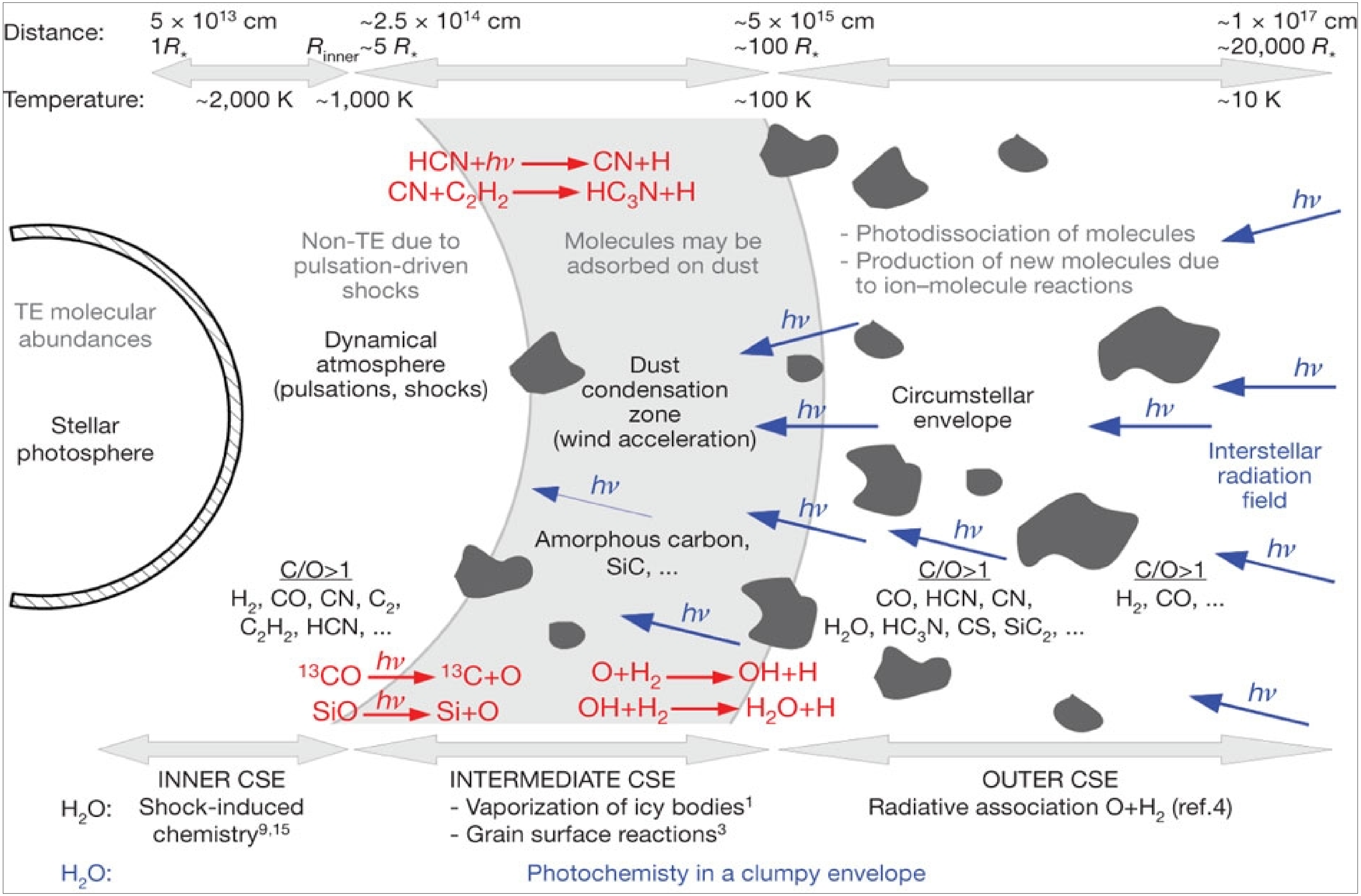
- Classification of AGB CSEs owing to its chemistry:



(Credits: https://www.asiaa.sinica.edu.tw/research/icsm.php)

1. Introduction

- Schematic view of a clumpy C-rich AGB CSE



Decin et al. (2010)

1.1. IRC+10216

- IRC+10216 / CWLeo: the archetype of C-rich AGB CSEs

Parameter	Value	Reference
L_*	$7790 \pm 150\ L_\odot$	Groenewegen et al., 2012
R_*	390-500 $R_\odot$	Men'shchikov et al., 2001
Distance	123 ± 14 pc	Groenewegen et al., 2012
Period	640 days	Dyck et al., 1991
Mass loss	$2\text{x}10^{-5}\ M_\odot$/year	Ramstedt et al., 2008
T_{eff}*	2330 K	Ridgway & Keady, 1988
Systemic velocity *	-26.5 ± 0.3km s^{-1}	Cernicharo et al., 2000
Terminal expansion velocity	14.5 ± 0.2 km s^{-1}	Cernicharo et al., 2000
[C]/[O]	1.4	Winters et al., 1994

1.1. IRC+10216

- Most studied AGB CSE: molecules detected > 80

Discovery of the C_8H radical

J. Cernicharo[1] **and M. Guélin**[2]

[1] Observatorio Astronomico Nacional, Apartado 1143, E-28800 Alcala de Henares, Spain
[2] IRAM, 300 rue de la Piscine, F-38406 Saint Martin d'Hères, France

DISCOVERY OF PHOSPHAETHYNE (HCP) IN SPACE: PHOSPHORUS CHEMISTRY IN CIRCUMSTELLAR ENVELOPES[1]

MARCELINO AGÚNDEZ,[2] JOSÉ CERNICHARO,[2] AND MICHEL GUÉLIN[3]

Received 2007 April 27; accepted 2007 May 8; published 2007 May 25

LABORATORY AND ASTRONOMICAL DISCOVERY OF HYDROMAGNESIUM ISOCYANIDE*

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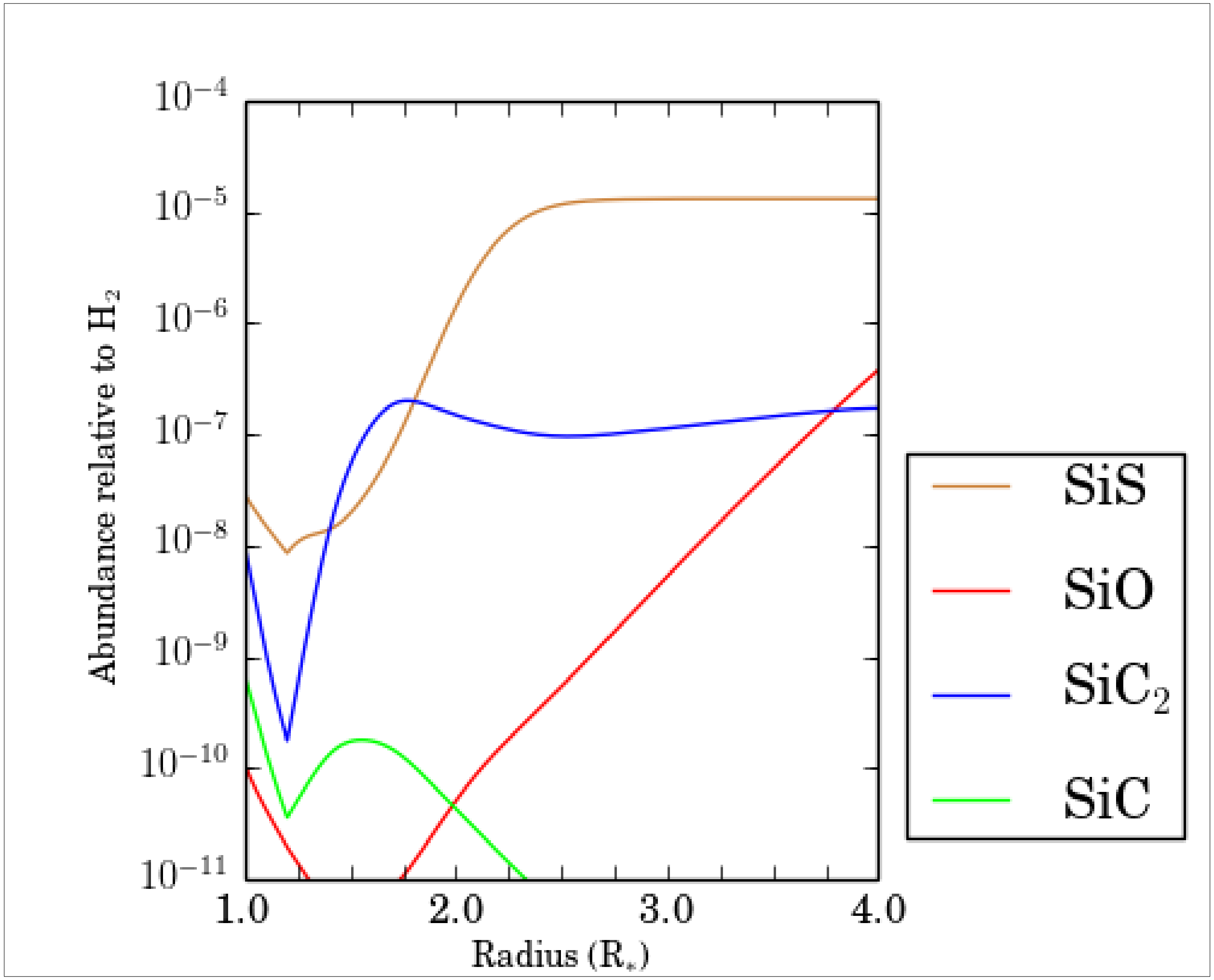
1.2. Si-bearing molecules towards IRC+10216

- SiS, SiO, SiC_2 and SiC:

Thermodynamical equilibrium



1.2. Si-bearing molecules towards IRC+10216

Formation under thermodynamical equilibrium

↓

Condensation onto dust grains

↓

Back to gas phase: grain-surface reactions /shocks

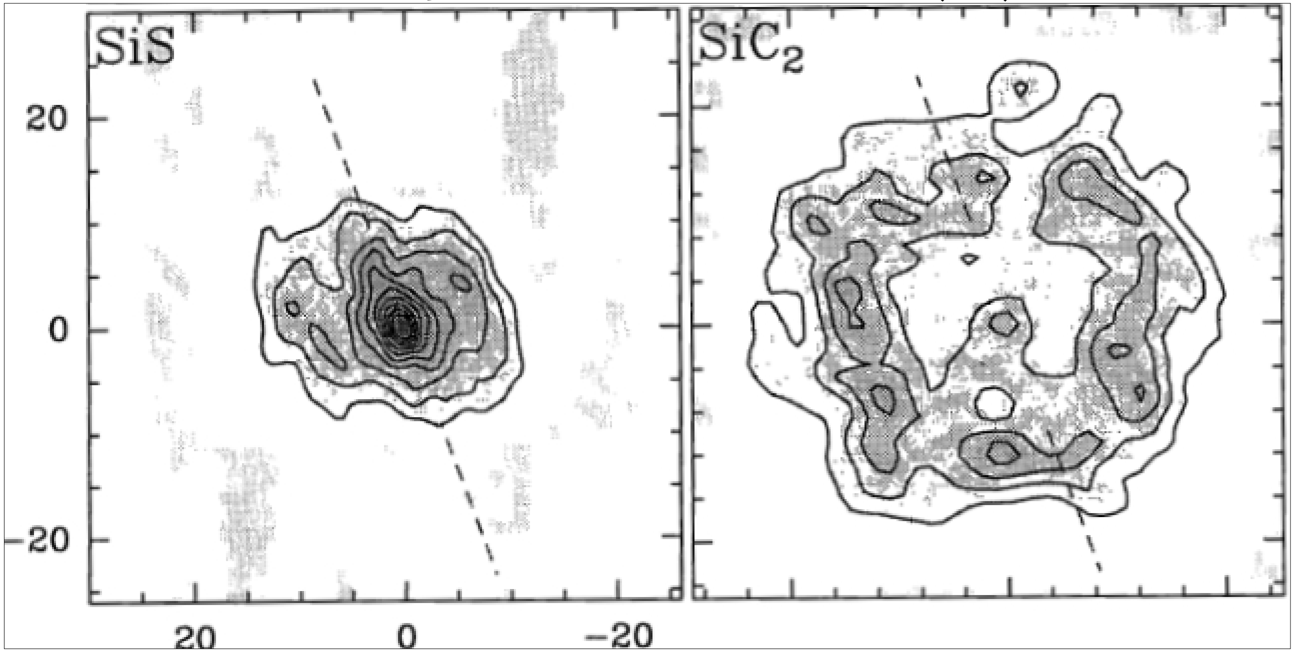
↓

Photodissociation owing to the UV Galactic field

1.2. Si-bearing molecules towards IRC+10216

- Spatial distribution:

SiS J=5-4 **SiC_2 J,K,k 4_{23}-2_{22}**



Lucas et al. (1995)

Plateau de Bure Interferometer

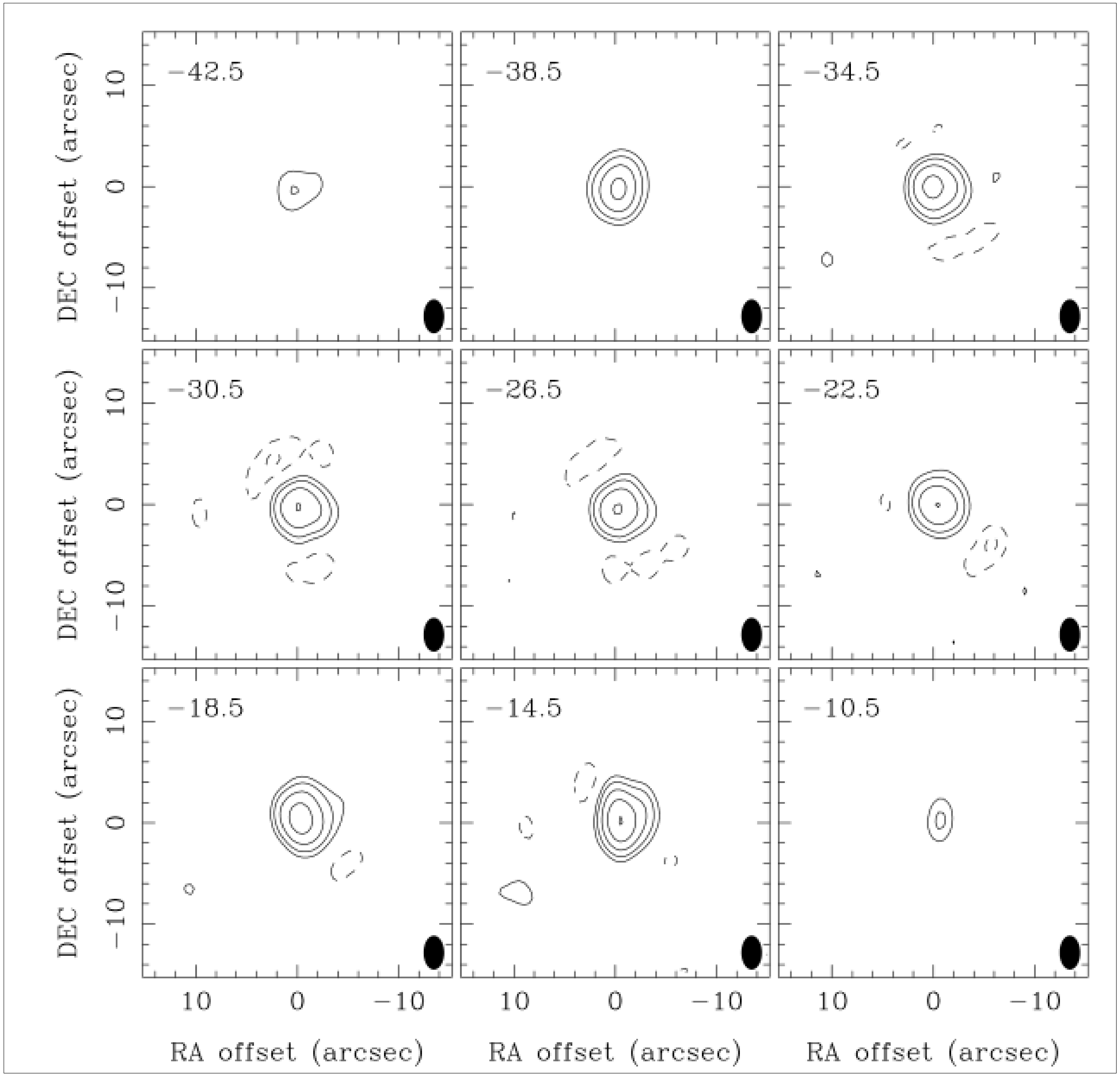
1.2. Si-bearing molecules towards IRC+10216

- Spatial distribution:

Schöier et al. (2006)

SMA observations

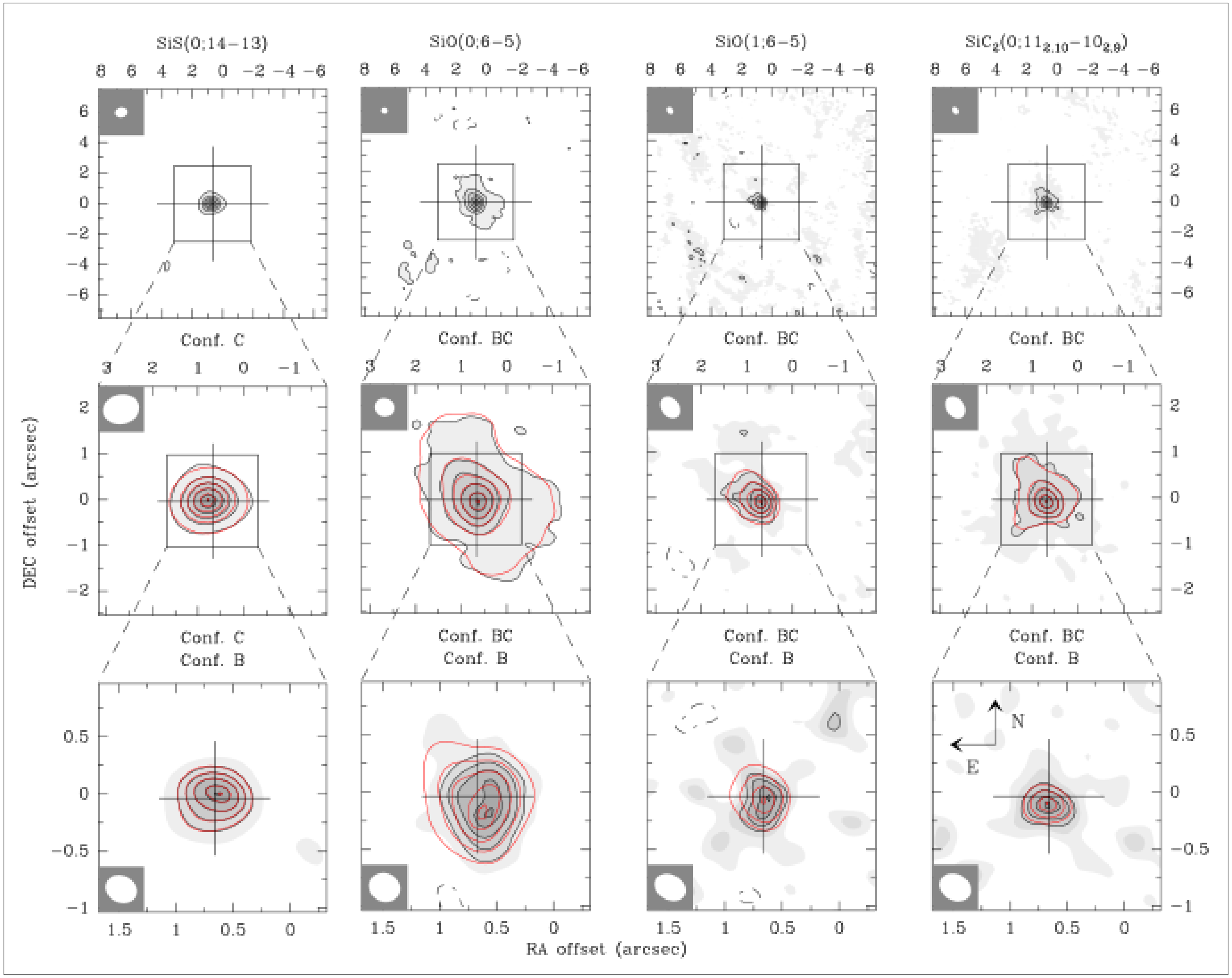
SiO J=5-4

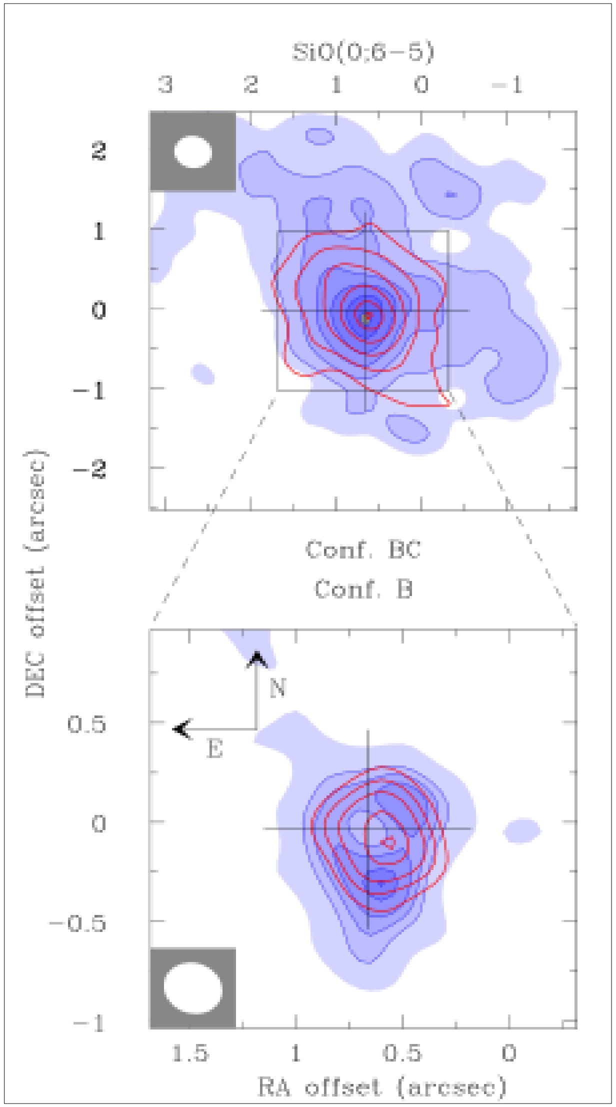


1.2. Si-bearing molecules towards IRC+10216

- Spatial distribution:

CARMA observations





Fonfría et al. (2014)

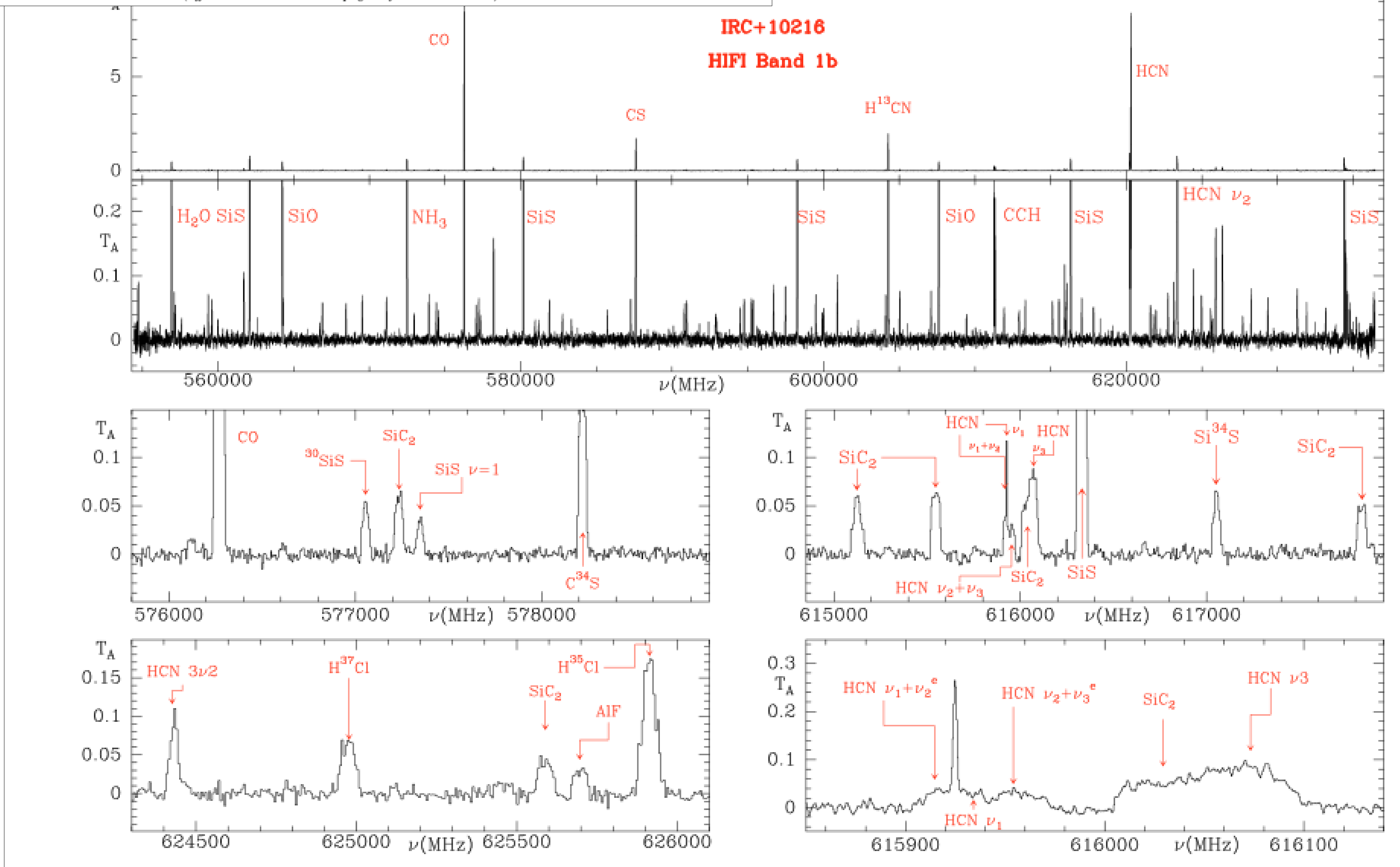
2. Herschel past studies

A high-resolution line survey of IRC +10216 with *Herschel*/HIFI★,★★

First results: Detection of warm silicon dicarbide (SiC_2)

J. Cernicharo[1], L. B. F. M. Waters[2,3], L. Decin[2,3], P. Encrenaz[4], A. G. G. M. Tielens[5], M. Agúndez[1,6], E. De Beck[3], H. S. P. Müller[7], J. R. Goicoechea[1], M. J. Barlow[8], A. Benz[9], N. Crimier[1], F. Daniel[1,4], A. M. Di Giorgio[10], M. Fich[11], T. Gaier[12], P. García-Lario[13], A. de Koter[2,14], T. Khouri[2], R. Liseau[15], R. Lombaert[3], N. Erickson[16], J. R. Pardo[1], J. C. Pearson[12], R. Shipman[17], C. Sánchez Contreras[1], and D. Teyssier[13]

(Affiliations are available on page 5 of the online edition)



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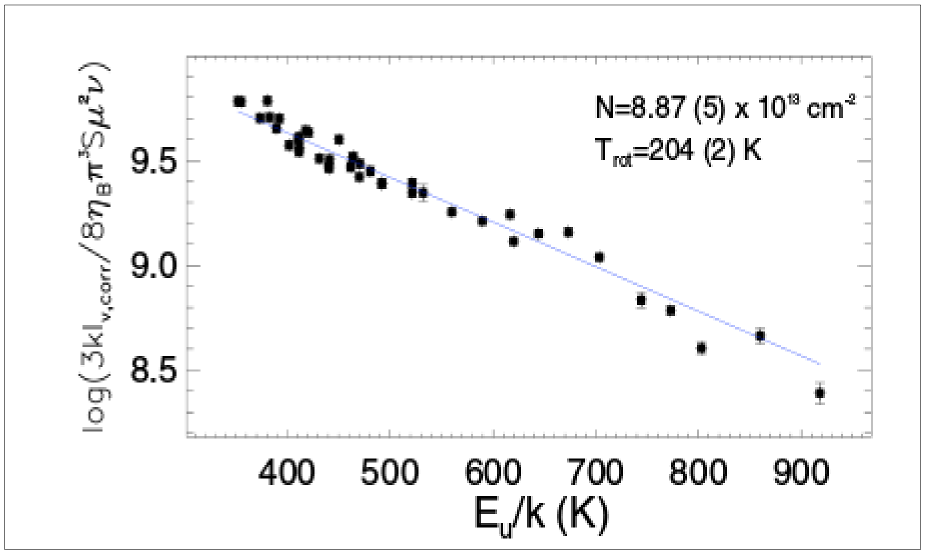
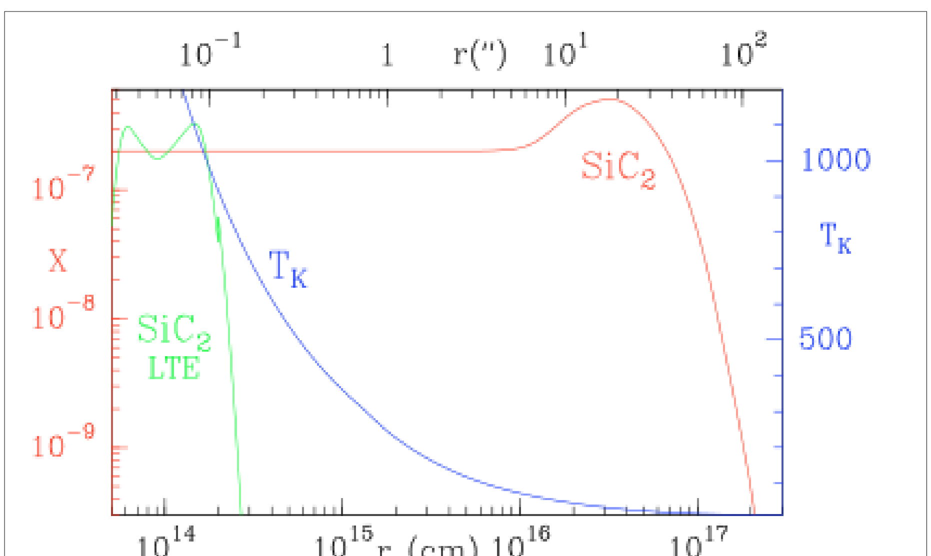




- HIFI 2010 obs.

- Trot = 204 K   Ntot ~ 9×10^{13} cm^{-2}

- SiC2 is a major Si carrier in the inner envelope (together with SiS and SiO)

- Abundance enhancement in the outer envelope:

$$Si + C_2H_2 \longrightarrow SiC_2$$

2. Herschel past studies

Spectroscopic parameters for silacyclopropynylidene, SiC_2, from extensive astronomical observations toward CW Leo (IRC +10216) with the *Herschel* satellite[☆,☆☆]

Holger S.P. Müller[a,*], José Cernicharo[b], M. Agúndez[b,c], L. Decin[e,f], P. Encrenaz[d], J.C. Pearson[g], D. Teyssier[h], L.B.F.M. Waters[e,f]

Parameter	All data	Lab. data only[b]
$A-(B+C)/2$	40673.821 (37)	40674.109 (60)
$(B+C)/2$	11800.14670 (66)	11800.14722 (89)
$(B-C)/4$	679.28139 (53)	679.28365 (87)
Δ_K	−1.2841 (89)	−1.2092 (153)
Δ_{JK}	1.538195 (69)	1.538100 (86)
$\Delta_J \times 10^3$	13.1962 (28)	13.2188 (38)
$\delta_K \times 10^3$	869.88 (20)	870.38 (29)
$\delta_J \times 10^3$	2.41187 (170)	2.42028 (374)
$\Phi_{KJ} \times 10^6$	381.0 (33)	426.9 (102)
$\Phi_{JK} \times 10^6$	−48.14 (81)	−61.19 (308)
$\Phi_J \times 10^9$	−84.9 (36)	
$\phi_K \times 10^3$	1.084 (16)	0.824 (59)
$\phi_{JK} \times 10^6$	−33.51 (43)	−29.96 (113)
$L_{KKJ} \times 10^9$	319.6 (225)	135.3 (207)
$L_{JK} \times 10^9$	−148.4 (43)	−92.9 (69)
$L_{JJK} \times 10^9$	−1.43 (31)	−5.94 (72)
$l_{JK} \times 10^9$	−1.575 (153)	
$P_{KKJ} \times 10^9$	−1.179 123)	
$P_{KJ} \times 10^{12}$	426.3 (271)	
$P_{JK} \times 10^{12}$	−49.50 (227)	

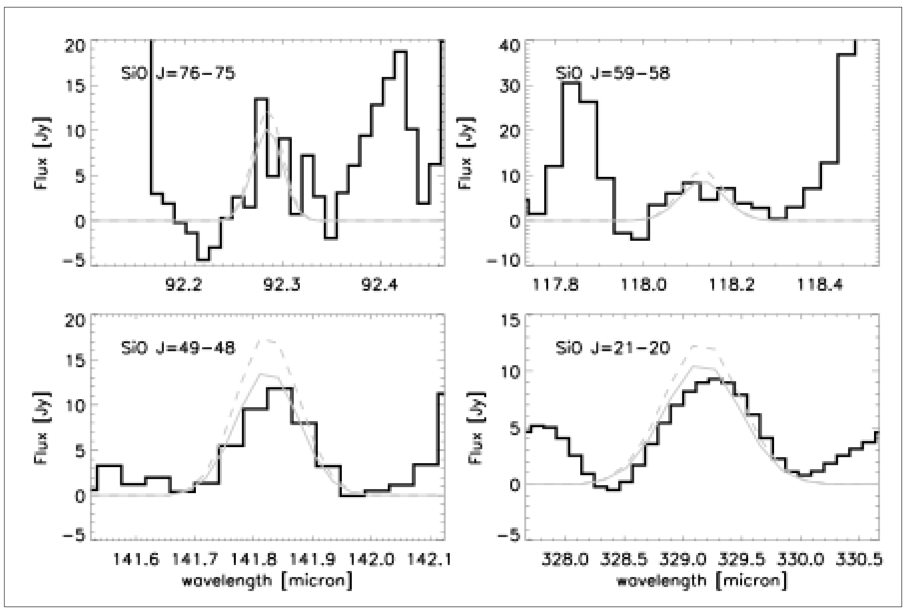
Parameters for the Watson-type Hamiltonian

- **Spectroscopic parameters improved thanks to HIFI 2011 obs.**
- **Included in the CDMS catalogue**

2. Herschel past studies

Silicon in the dust formation zone of IRC +10216★,★★

L. Decin[1,2], J. Cernicharo[3], M. J. Barlow[4], P. Royer[1], B. Vandenbussche[1], R. Wesson[4], E. T. Polehampton[5,6], E. De Beck[1], M. Agúndez[3,9], J. A. D. L. Blommaert[1], M. Cohen[8], F. Daniel[3], W. De Meester[1], K. Exter[1], H. Feuchtgruber[10], J. P. Fonfría[7], W. K. Gear[11], J. R. Goicoechea[3], H. L. Gomez[11], M. A. T. Groenewegen[12], P. C. Hargrave[11], R. Huygen[1], P. Imhof[13], R. J. Ivison[14], C. Jean[1], F. Kerschbaum[16], S. J. Leeks[5], T. Lim[5], M. Matsuura[4,17], G. Olofsson[15], T. Posch[16], S. Regibo[1], G. Savini[4], B. Sibthorpe[14], B. M. Swinyard[5], B. Tercero[3], C. Waelkens[1], D. K. Witherick[4], and J. A. Yates[4]



- PACS+SPIRE obs.

- SiO and SiS in the dust formation process

- Only v=0 and v=1 lines detected (confusion limited)

3. ALMA current study

- Cycle 0 ALMA data: ADS/JAO.ALMA#2011.0.00229.S

(Credits: ALMA ESO/NAOJ/NRAO C.Padilla)

3.1. ALMA: Cycle 0 observations

- 16 antennas used

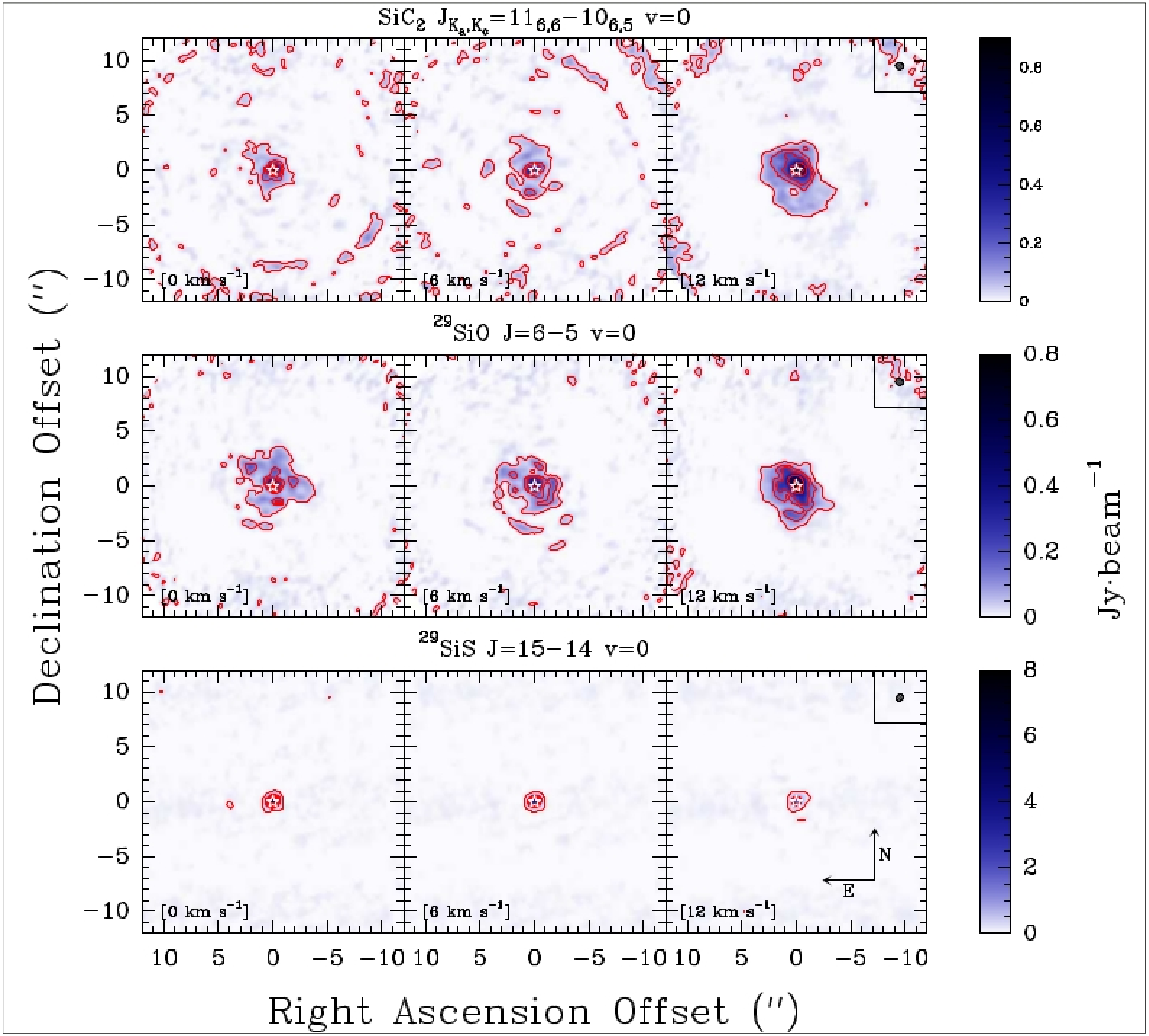
- Baselines from 20 to 402 m.

- Maximum recoverable scale ~ 0.6 λ / D ~ 12"
  https://science.nrao.edu/science/videos/largest-angular-scale-and-maximum-recoverable-scale

- Calibration and data analysis done with CASA and GILDAS

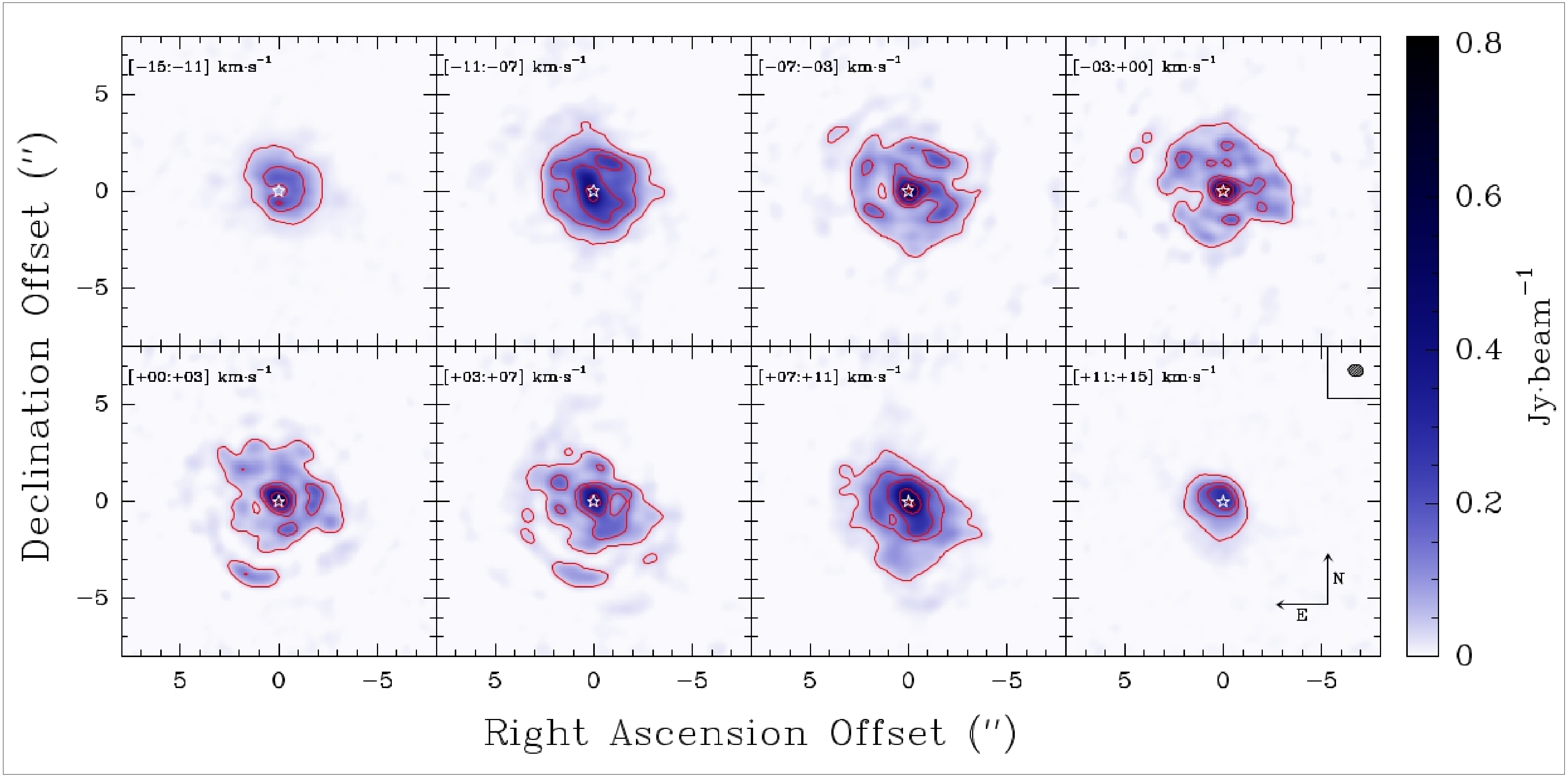
Setup #	Frequency range (GHz)	RMS (mJy beam^{-1})	Synthetic beam ("×")	FOV† (")
3	269.9-274.8	6	0.61×0.47	23.2-22.9
4	265.0-269.9	10	0.86×0.47	23.7-23.2
5	260.2-265.0	17	0.96×0.47	24.2-23.7
6	255.3-260.2	6	0.77×0.60	24.6-24.2

3.2. ALMA: Analysis and results



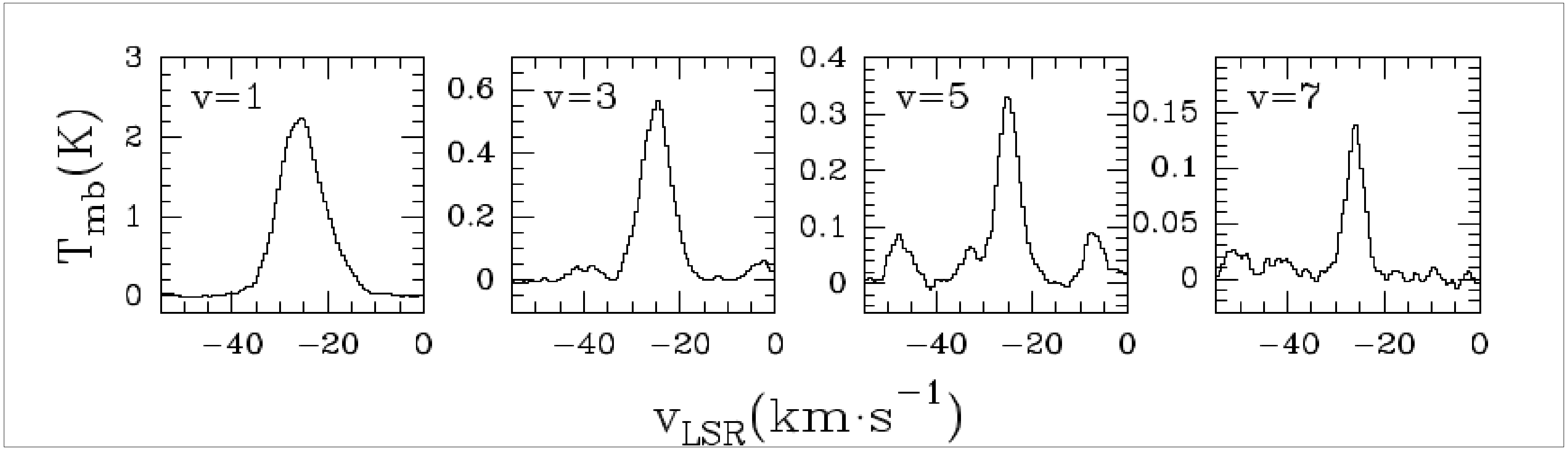
3.2. ALMA: Analysis and results

- ^{29}SiO J=6-5 v=0 :

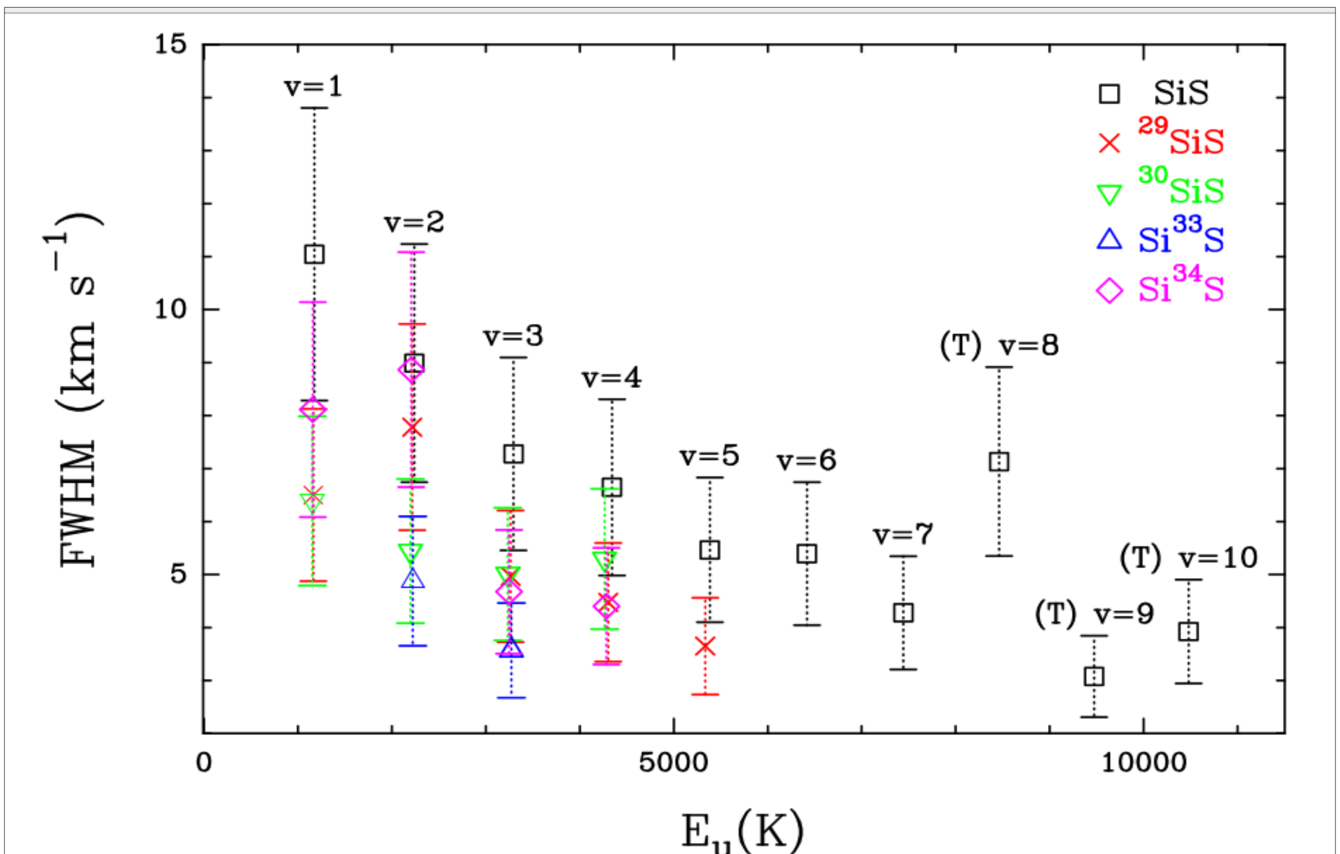


- SiC not detected with these observations

3.2. ALMA: Analysis and results



SiS J=15-14



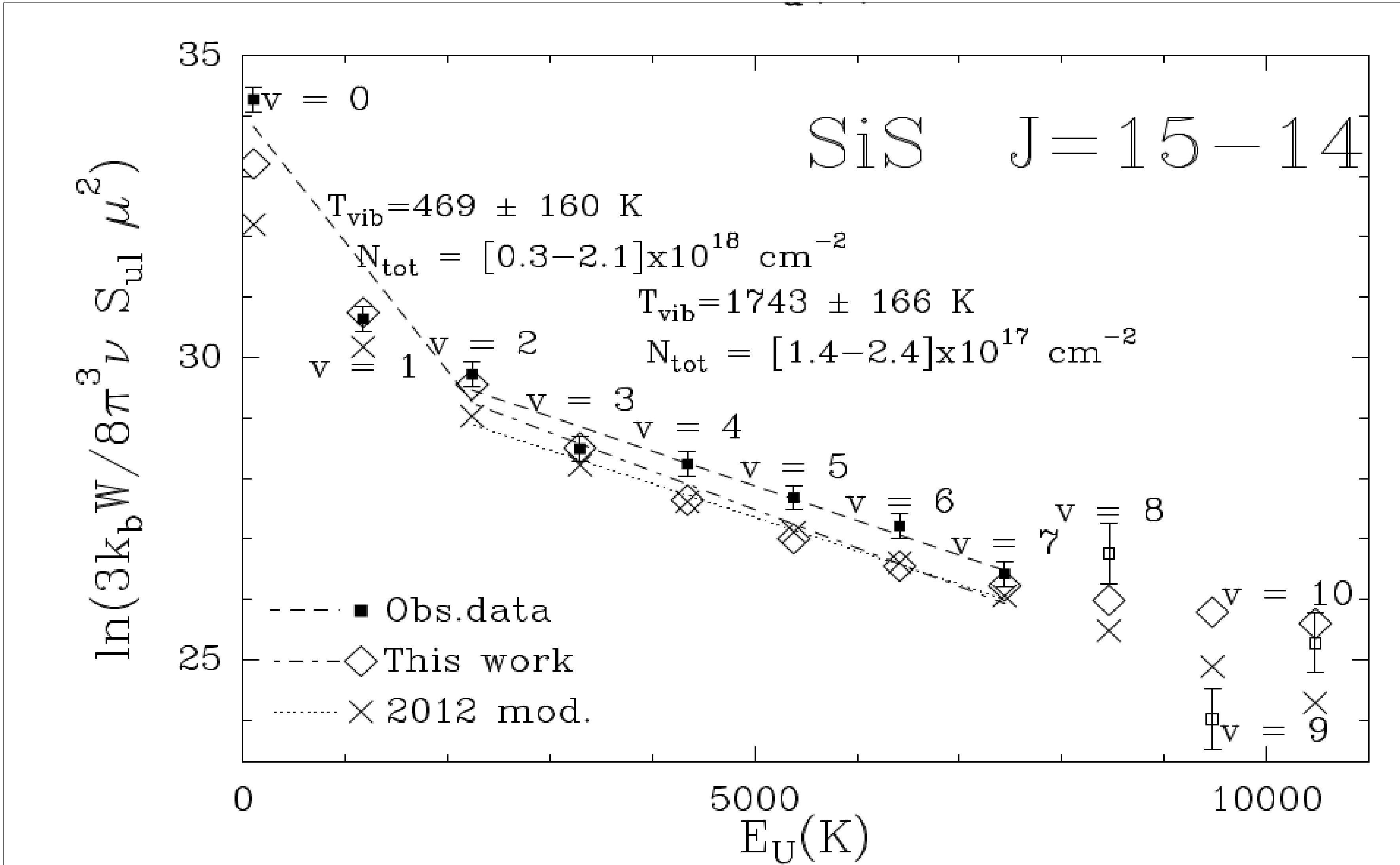
FWHM – Eup correlation

FWHM – Tkin correlation

FWHM – v_{exp} correlation

3.2. ALMA: Analysis and results

- Population diagram (Goldsmith & Langer, 1999) + LVG model (Cernicharo, 2012)



4. Conclusion: Linking Herschel and ALMA

- **Herschel spectral resolution + bandwidth**

- **Herschel: study of the excitation conditions**

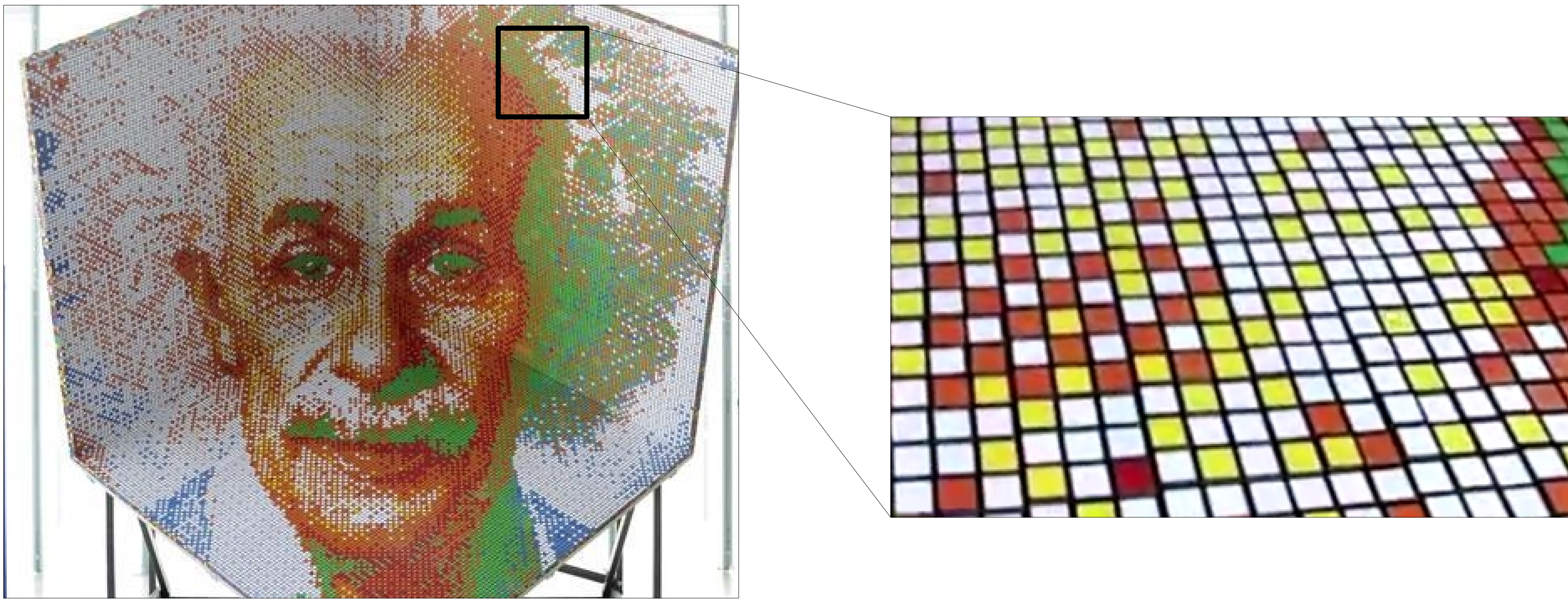
- **ALMA spatial resolution + sensitivity**

- **ALMA: study the spatial distributions**

- **Both are well suited to discover new molecules**

4. Conclusion: Linking Herschel and ALMA

- We need both for a complete explanation, otherwise we will be missing something



5. Future work

- Herschel + ALMA complete study

- Short-spacing observations with the IRAM 30m antenna

- ALMA Cycle 3

- The main goal is to understand the dust formation region

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