

# Chemical complexity in the Galactic Centre GMCs and the imprint of cosmic rays: the nitrogen family

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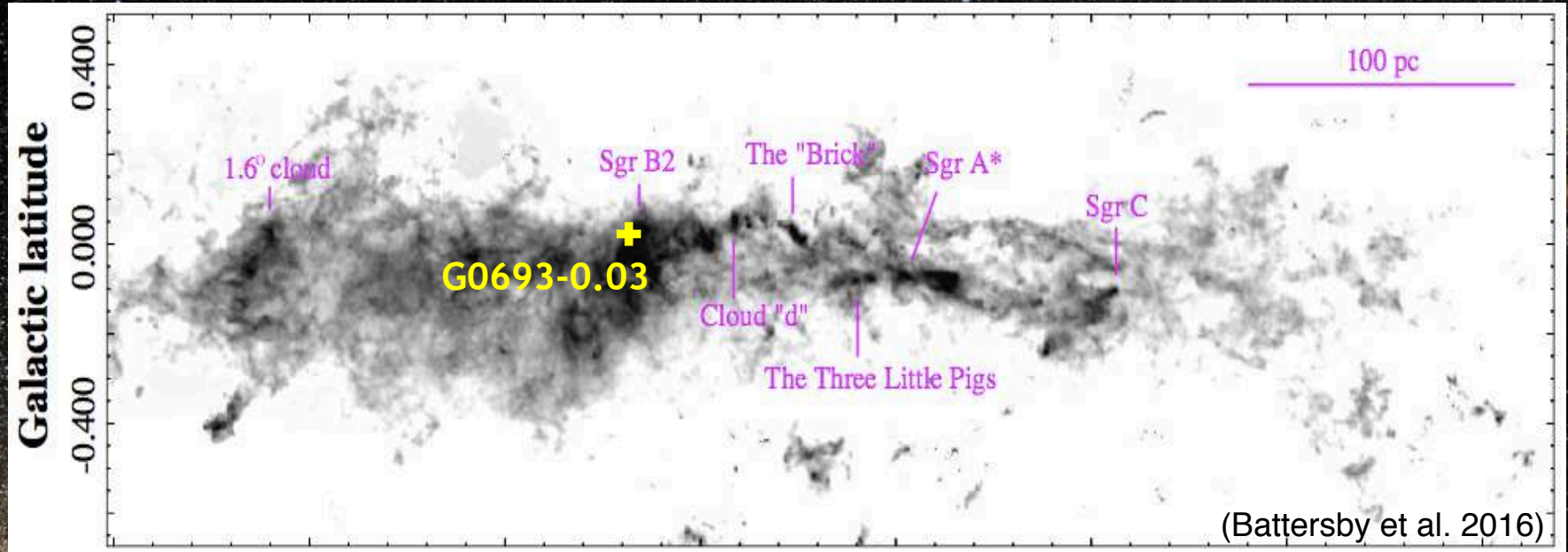
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D. Riquelme (MPIFR), and R. Aladro (MPIFR)



# © Galactic Centre GMCs

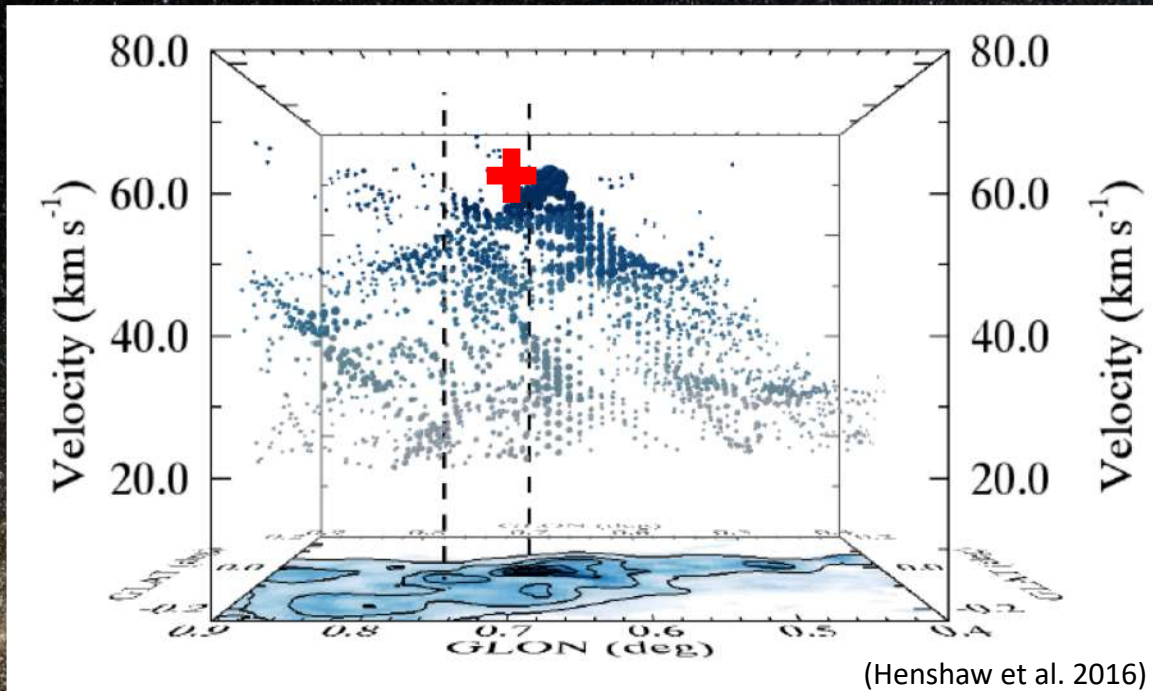
Galactic Centre (GC) → Central Molecular Zone (CMZ) → Sagittarius B2



- Size  $\approx$  20-30 pc
- $T_{\text{dust}} = 10 - 20$  K
- $\zeta = 1-10 \times 10^{-15} \text{ s}^{-1}$
- $n(\text{H}_2) \approx 10^4 \text{ cm}^{-3}$
- $T_{\text{gas}} = 50 - 120$  K
- Quiescent giant molecular cloud (QGMC)

(Huttemeister et al. 1993; Martín-Pintado et al. 1997; Rodríguez-Fernández et al. 2001; Requena-Torres et al. 2006; Yusef-Zadeh et al. 2013; Goto et al. 2014; Ginsburg et al. 2016; Krieger et al. 2017; Oka et al. 2017)

# © Origin of COMs



Located at a position where **two streams of gases that seem to be merging**.  
(Hasegawa et al. 1994, Henshaw et al. 2016)

**Cloud-cloud collision** that drives **large-scale shocks** in the region, which sputters dust grains icy mantles efficiently, ultimately activates the rich chemistry.

G+0.693



## Nitrogen-bearing molecules ?

### The Galactic Center: The Largest Oxygen-bearing Organic Molecule Repository

M. A. Requena-Torres<sup>1</sup>, J. Martín-Pintado<sup>1</sup>, S. Martín<sup>2</sup>, and M. R. Morris<sup>3</sup>

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[The Astrophysical Journal, Volume 672, Number 1](#)

### Phosphorus-bearing molecules in the Galactic Center

V M Rivilla ✉, I Jiménez-Serra, S Zeng, S Martín, J Martín-Pintado, J Armijos-Abendaño, S Viti, R Aladro, D Riquelme, M Requena-Torres ... [Show more](#)

Monthly Notices of the Royal Astronomical Society: Letters, Volume 475, Issue 1, 21 March 2018, Pages L30–L34, <https://doi.org/10.1093/mnras/lsx208>

**The role of cosmic rays and other energetic phenomena in the chemistry of P-bearing molecules in the Galactic Center**

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- Phosphorus (P) is essential for the development of Life due to its central role in biochemical processes.
- The chemistry of P remains poorly understood.
- We present observations of P-bearing molecules across the Central Molecular Zone (CMZ) in the Galactic Center, whose chemistry is affected by energetic phenomena: **cosmic rays, X-rays, UV radiation, and shocks.**

Tau < 30 K, too cold for the evaporation of ice.      The Central Molecular Zone (CMZ) of the Galaxy      Dust grain sputtering by widespread low-velocity shocks.

G+0.693-0.03 SgrB2 N SgrB2 M      S+0.24+0.01      M+0.02-0.02 SgrA\* (-30', -30') M-0.02-0.07

THE SAMPLE: IRAM 30m observations of PN(2-1) towards 7 regions of the Galactic Center

Shock-dominated regions	Radiation-dominated regions
Colder envelopes of protostellar hot molecular cores COMs-rich quiescent clouds	Cosmic-rays X-rays UV radiation
✓ PN detections	✗ PN non detections

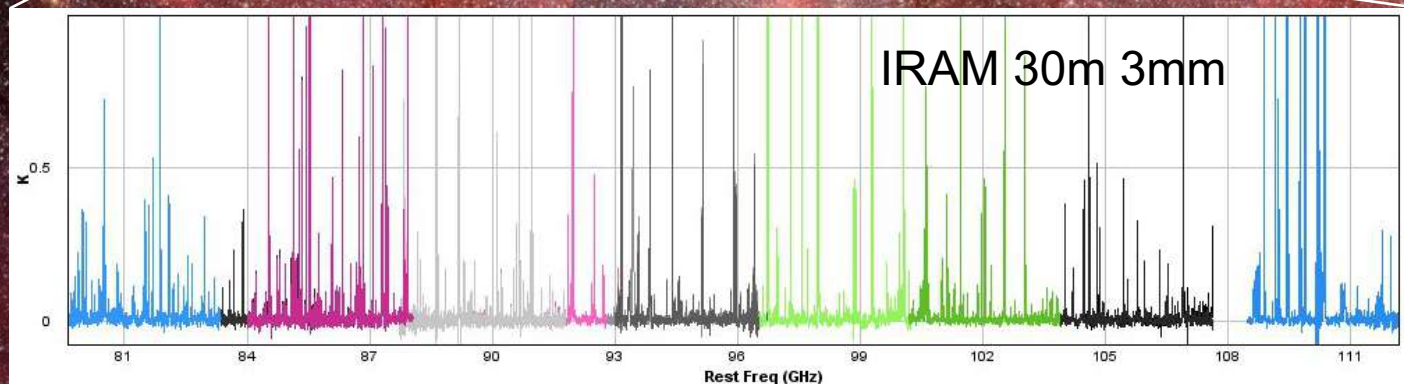
Rivilla et al. 2018

**Conclusions**

- P-bearing molecules likely form in shocked gas as a result of dust grain sputtering.
- P-bearing molecules are destroyed by intense Cosmic-ray / UV / X-ray radiation.
- Observational results confirmed by new chemical models of P-bearing molecules under energetic phenomena (Jiménez-Serra et al., submitted.)

# © Spectral Surveys

G+0.693



GBT

Frequency coverage (GHz)	Spectral resolution ( $\text{km s}^{-1}$ )	Beam size (")	Telescope
12-15, 18-26 <sup>a</sup>	2.2-8.6	29-55	GBT
80-116	5.2-7.5	22-29	IRAM 30 m
128-176	6.9-9.4	14-19	IRAM 30 m
240-272	2	9-10	IRAM 30 m

(Zeng et al. 2018)

IRAM 30m



# © Molecules Search

Over 60 species

~20 COMs

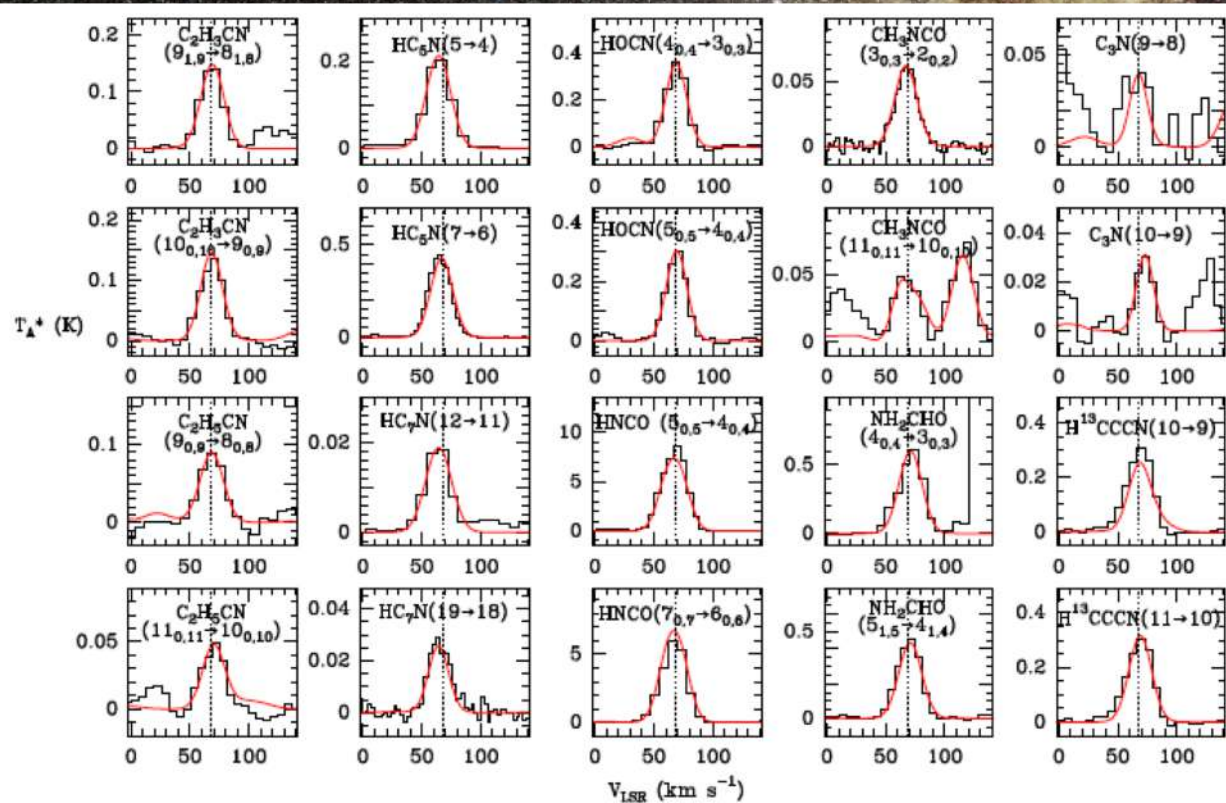
Nitrogen-bearing:  
17 clear detections

MADCUBA\_IJ

(Centre of Astrobiology Madrid, INTA-CSIC)

[http://cab.inta-](http://cab.inta-csic.es/madcuba/MADCUBA_IMAGEJ/ImageJMadcuba.html)

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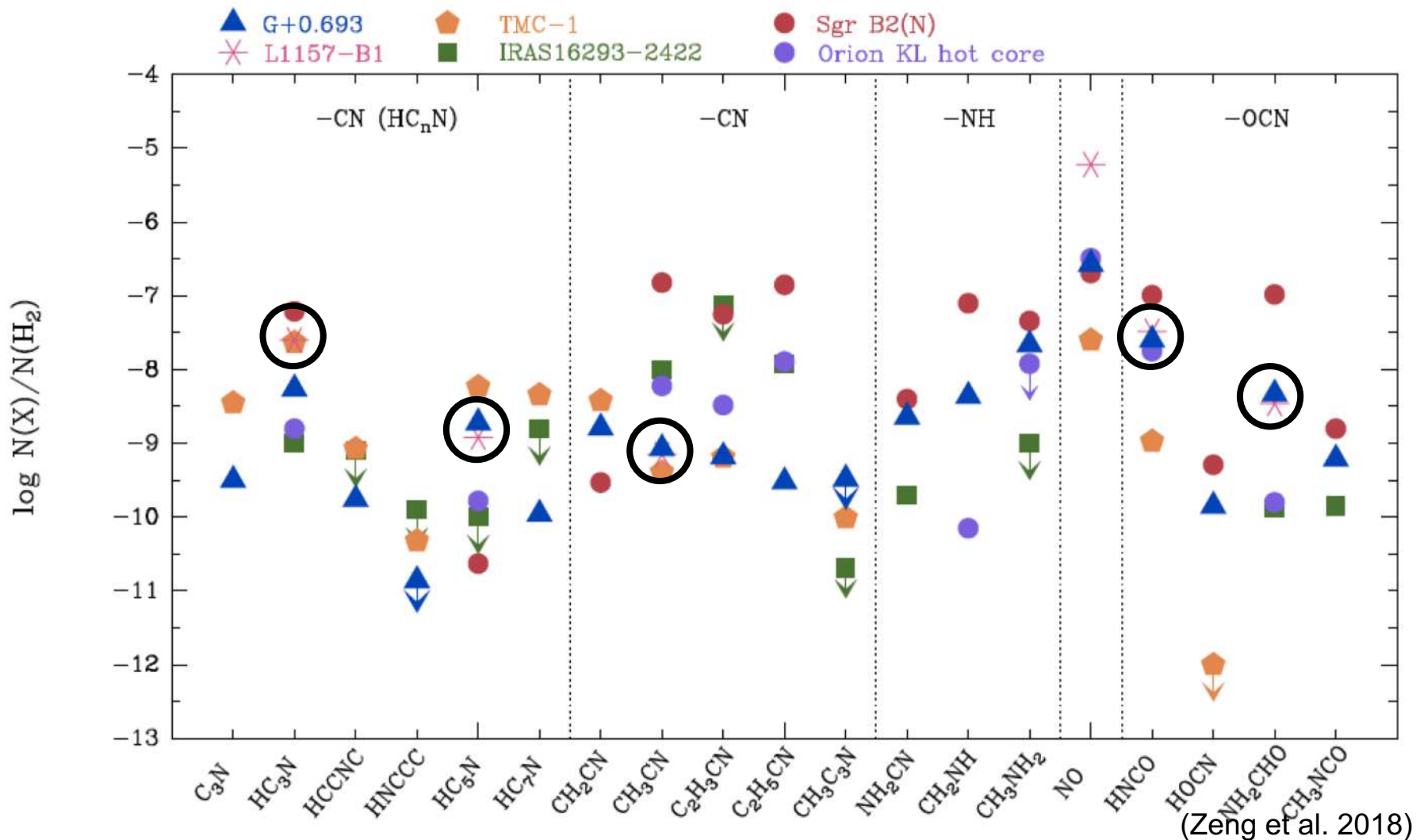
- Line width  $\sim 20$  kms $^{-1}$
- $T_{\text{gas}} = 70 - 140\text{K}$
- $T_{\text{ex}} = 9 - 30\text{K}$

Sub-thermal excitation

- $N(\text{H}_2) = 1.3 \times 10^{25} \text{ cm}^{-2}$   
(Martín et al. 2008)

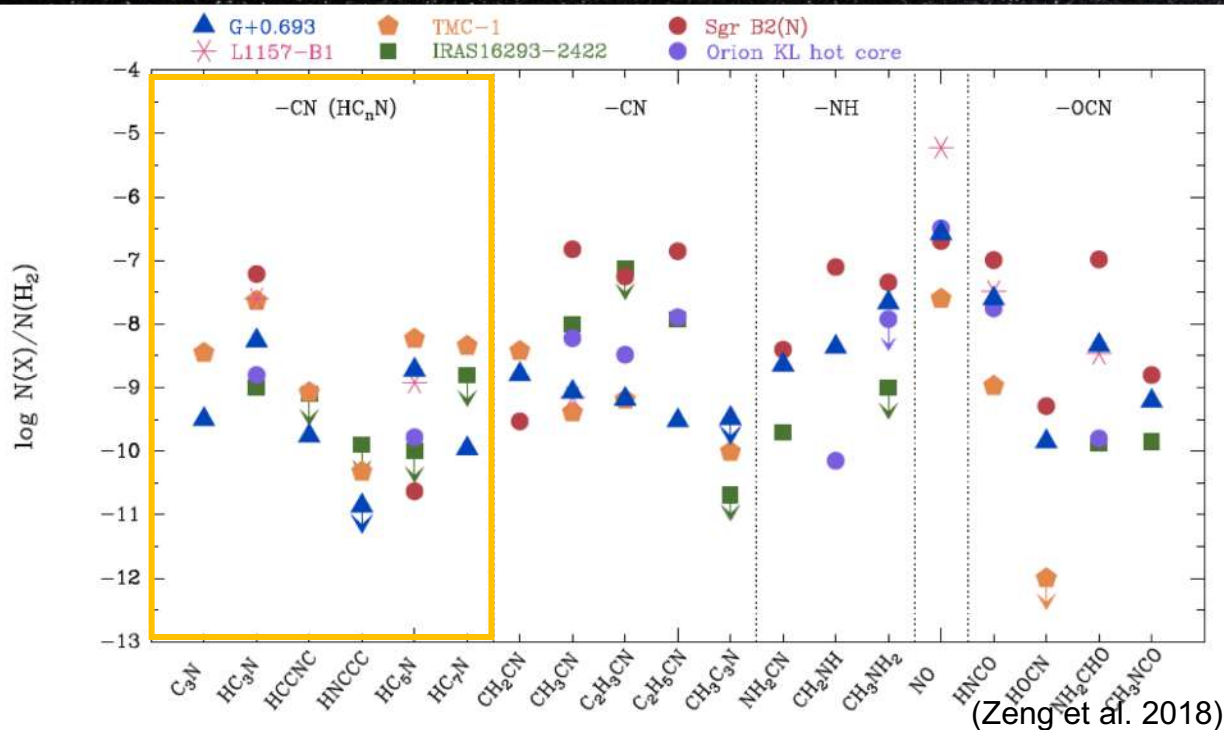
- Abundance:  $10^{-11} - 10^{-8}$

(Zeng et al. 2018)



**Remarkable agreement between G+0.693 and L1157-B1 (e.g.  $\text{HC}_3\text{N}$ ,  $\text{HC}_5\text{N}$ ,  $\text{CH}_3\text{CN}$ , HNCO,  $\text{NH}_2\text{CHO}$ ) indicates large fraction of the ices from dust grains has been injected into the gas phase via **grain sputtering** in **SHOCK** waves.**

# © Cyanopolyynes $\text{HC}_n\text{N}$



$\text{HC}_3\text{N} / \text{HC}_5\text{N} :$

OMC2- FIR4 = 4 – 12  
 $(\zeta = 4 \times 10^{-14} \text{ s}^{-1})$

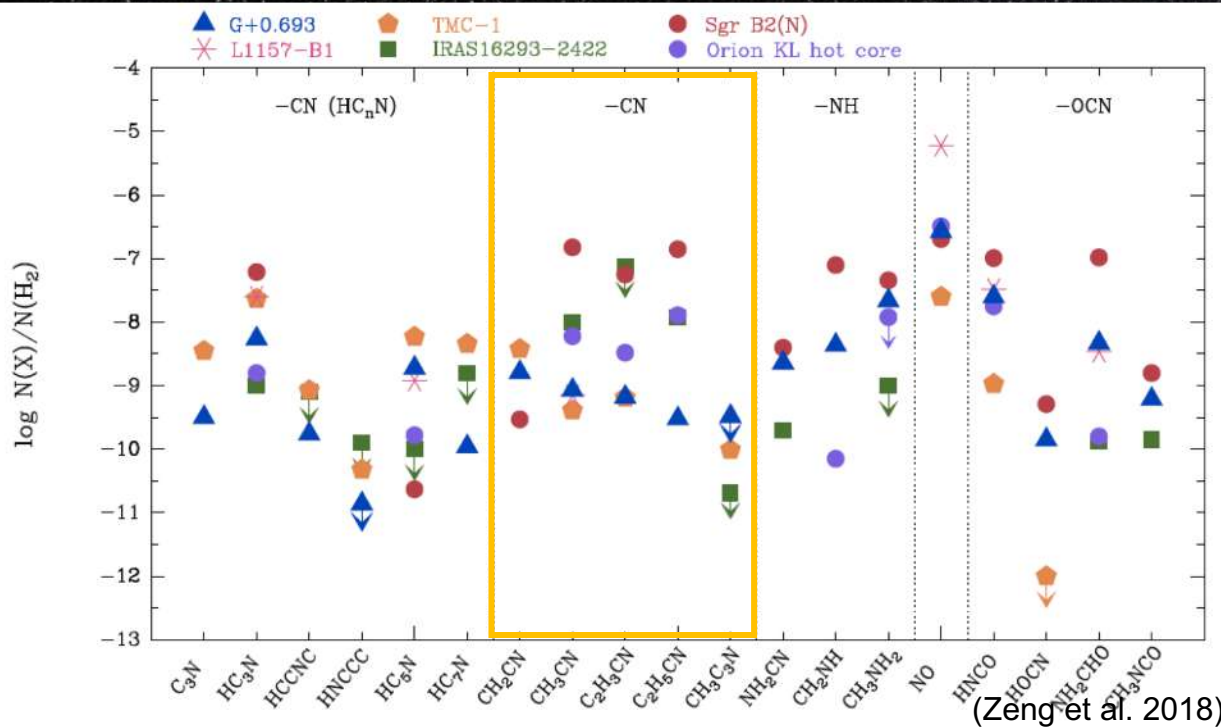
(Fontani et al. 2017)

G+0.693 = 3.3  
 $(\zeta = 1-10 \times 10^{-15} \text{ s}^{-1})$

Low  $\text{HC}_3\text{N} / \text{HC}_5\text{N}$  abundance ratio is possibly due to an **enhancement of cosmic ray ionisation rate**



# © Nitrile -CN



$C_2H_5CN / C_2H_3CN$ :

HMCs = 2-3.3

(Fontani et al. 2007)

Sgr B2N = 2.3

(Belloche et al. 2013)

Orion KL = 2.2

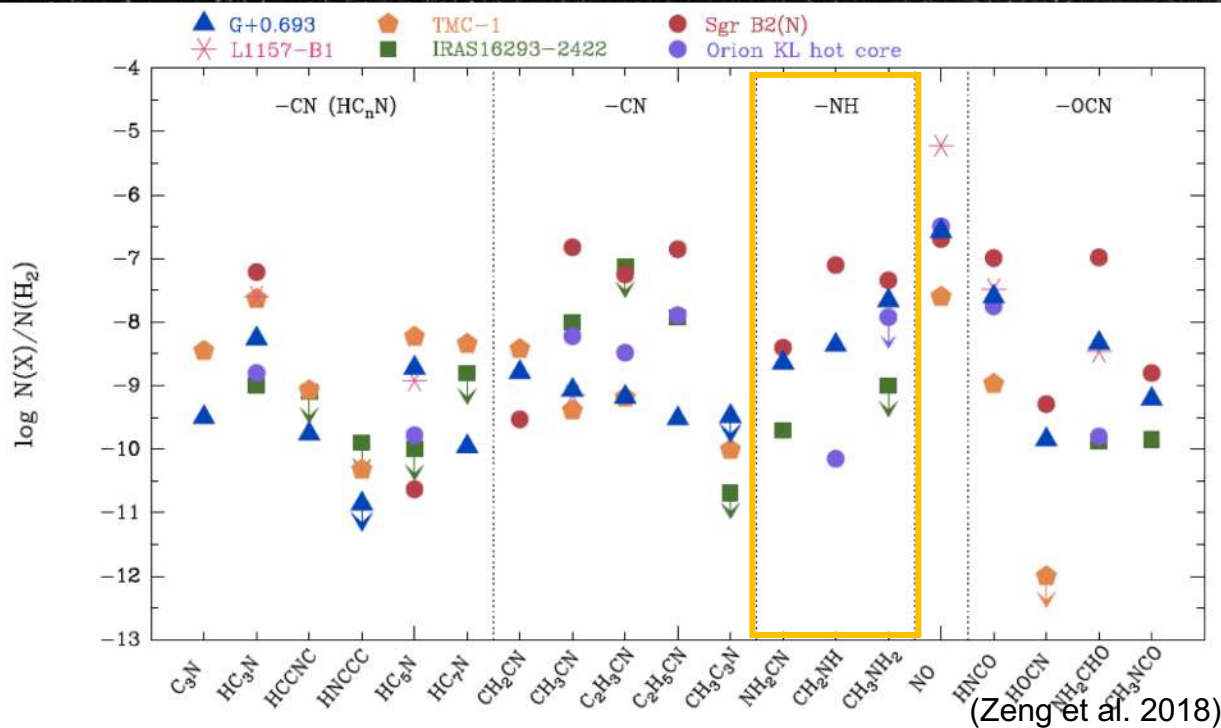
(Blake et al. 1987)

G+0.693 = 0.5

$C_2H_5CN$  can convert into  $C_2H_3CN$  efficiently due to  
 i) **high cosmic ray flux** → increase the fractional ionic abundance;  
 ii) **low  $n(H_2)$**  → yield higher ion densities in gas

(Caselli et al. 1993)

# © Amine -NH



$\text{CH}_2\text{NH} / \text{CH}_3\text{NH}_2$   
abundance ratio

$\text{G10.47+00.3} = 6$   
(Ohishi et al. 2017)

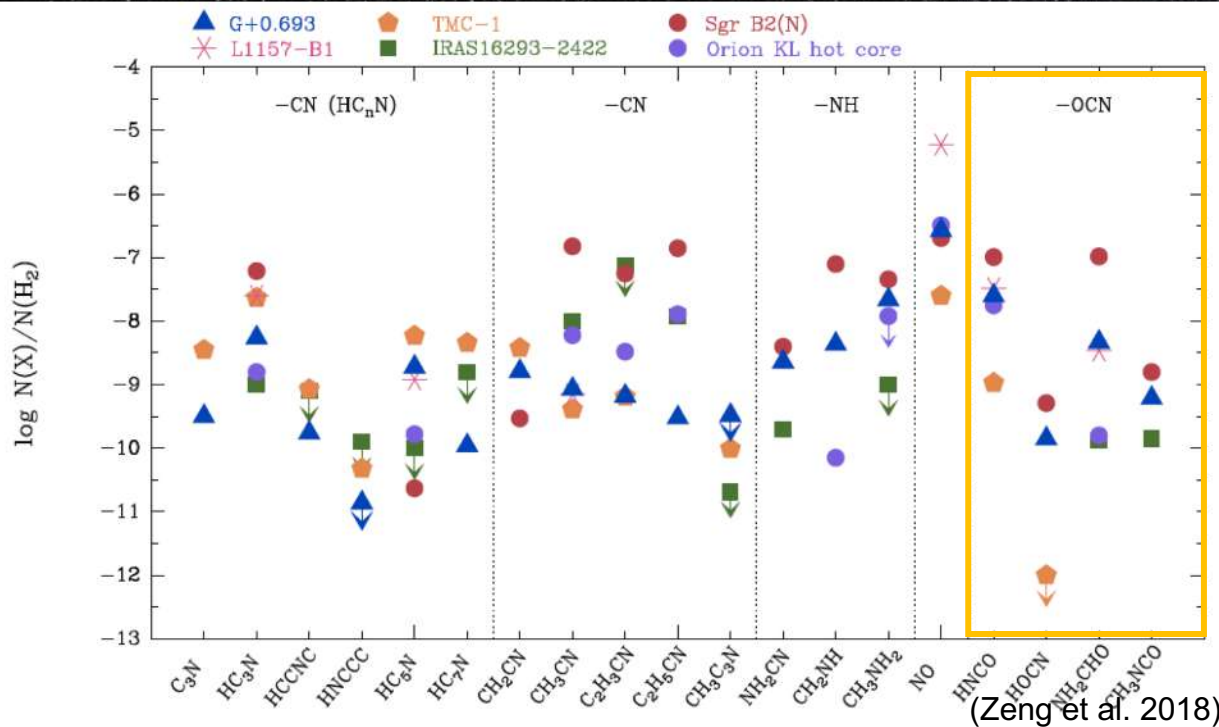
$\text{Sgr B2N} = 1.3$   
(Belloche et al. 2013)

$\text{G+0.693} = 0.1$

**Grain surface hydrogenation of  $\text{CH}_2\text{NH}$  can lead to formation of  $\text{CH}_3\text{NH}_2$**  (Theule et al. 2011)

**Suggests more efficient hydrogenation on dust grains in G+0.693 than in hot cores → Cosmic rays and/or X-rays can increase the availability of atomic H in the gas phase and subsequently, in the grain mantles.**

# © Cyanate –NCO



$\text{HNCO} = 2.5 \times 10^{-8}$   
 $\text{HOCN} = 1 \times 10^{-10}$

$\text{HOCN} / \text{HNCO} : \sim 0.005$   
 in both G+0.693 and  
 Sgr B2N

**Chemical modelling:**  
**David Quénard's talk**

**Large abundance of HNCO observed in galactic nuclei and L1157 molecular outflow → shocks** (Martín et al. 2008, Rodríguez-Fernández et al. 2010)

**Enhancement of HNCO abundance may indicate the presence of a slow shock  $\sim 20 \text{ km}^{-1}$**  (Kelly et al. 2017, Yu et al. 2017)

**Low-velocity SHOCKs are responsible for the observed abundance of HNCO in these regions**

## © Conclusions

We have explored the **chemical complexity** of QGMC G+0.693 in terms of presence and abundance of **N-bearing molecules**

G+0.693 is one of the **largest inventory of COMs** in the CMZ.

Unique chemistry as it presents **chemical footprints of different types of sources** at the same time.

Possible mechanisms responsible for the rich and diverse chemistry :

**SHOCKS + COSMIC RAYS/X-RAYS**