Cosmic Rays: the salt of the star-formation recipe 2nd – 4th May, 2018

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

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Shaoshan (Sandy) Zeng (QMUL)

I.Jiménez-Serra (QMUL), V. M. Rivilla (INAF),

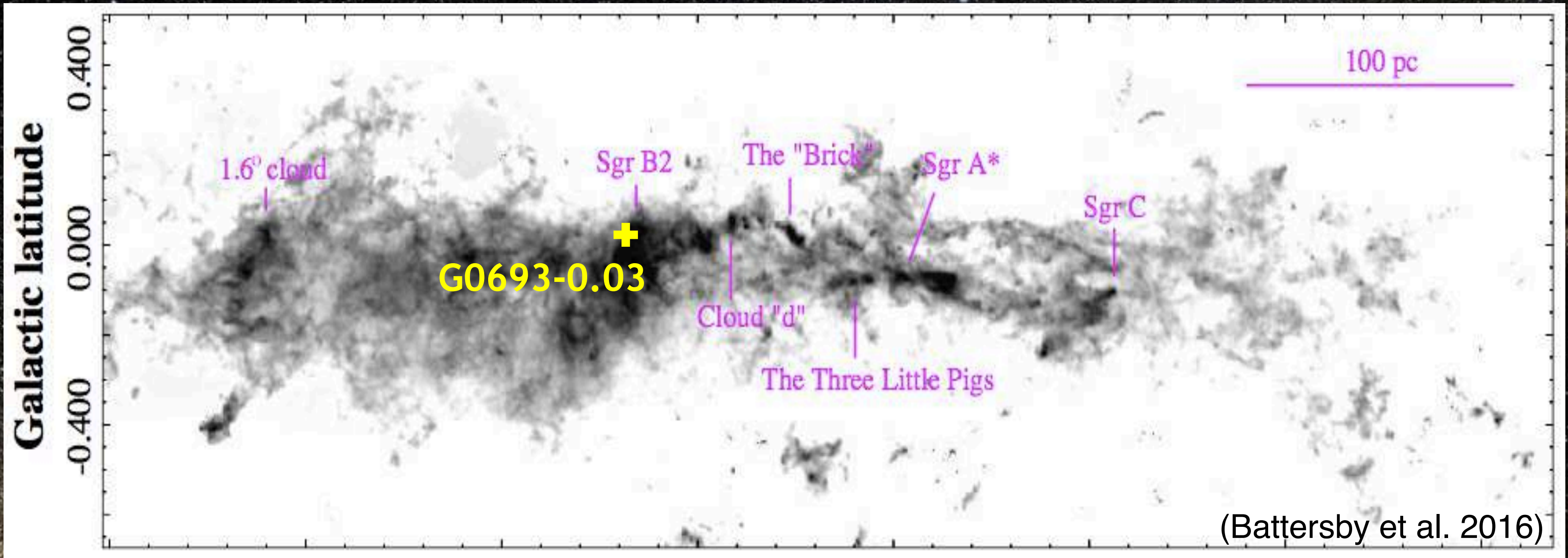
J. Martin-Pintado (INTA-CSIC), M. A. Requena-Torres

(UMD), S. Martin (ESO/ALMA), J.A.Armijos(EPN),

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

◎ Galactic Centre GMCs

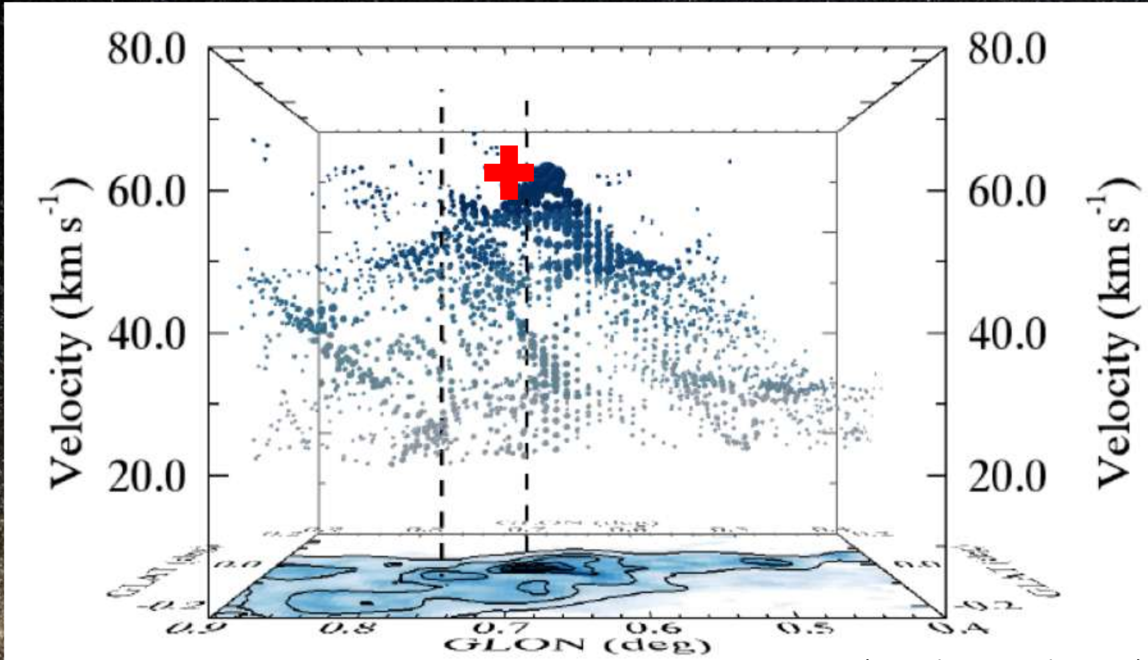
Galactic Centre (GC) ➜ Central Molecular Zone (CMZ) ➜ Sagittarius B2



- **Size ≃ 20-30 pc**
- **$n(H_2) \simeq 10^4$ cm^{-3}**
- **T_{dust} = 10 – 20 K**
- **T_{gas} = 50 – 120 K**
- **ζ = 1-10 x 10^{-15} s^{-1}**
- **Quiescent giant molecular cloud (QGMC)**

(Huttemeister et al. 1993; Martin-Pintado et al. 1997; Rodríguez-Fernádez 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



(Henshaw et al. 2016)

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.

◎ Molecular Repository

Nitrogen-bearing molecules ?

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

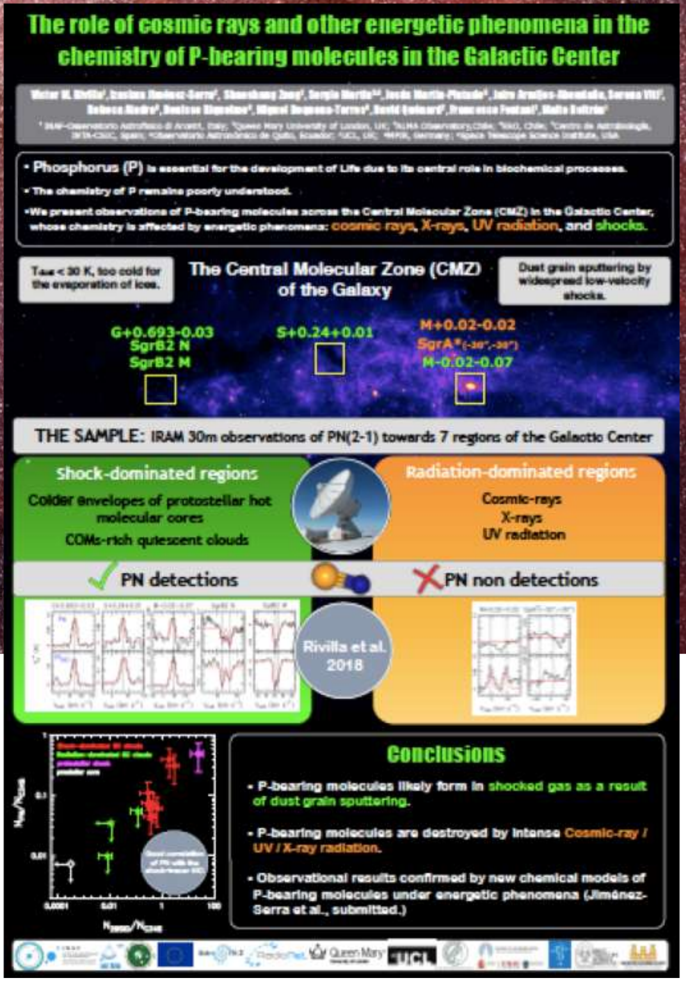
M. A. Requena-Torres[1], J. Martín-Pintado[1], S. Martín[2], and M. R. Morris[3]

The Astrophysical Journal, Volume 672, Number 1

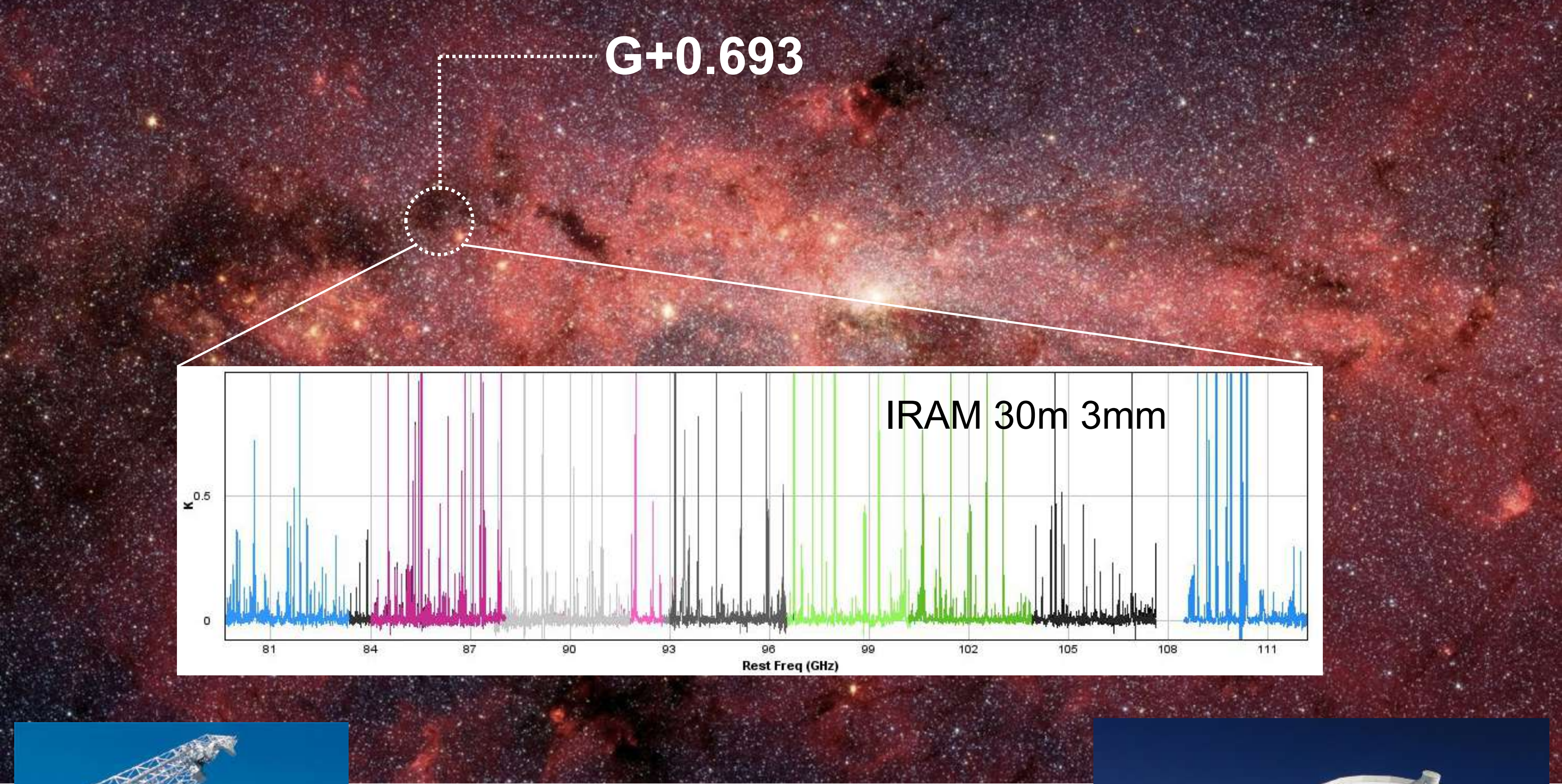
Phosphorus-bearing molecules in the Galactic Center

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/mnrasl/slx208



◎ Spectral Surveys



Frequency coverage (GHz)	Spectral resolution (km s^{-1})	Beam size ($''$)	Telescope
12-15, 18-26[a]	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)

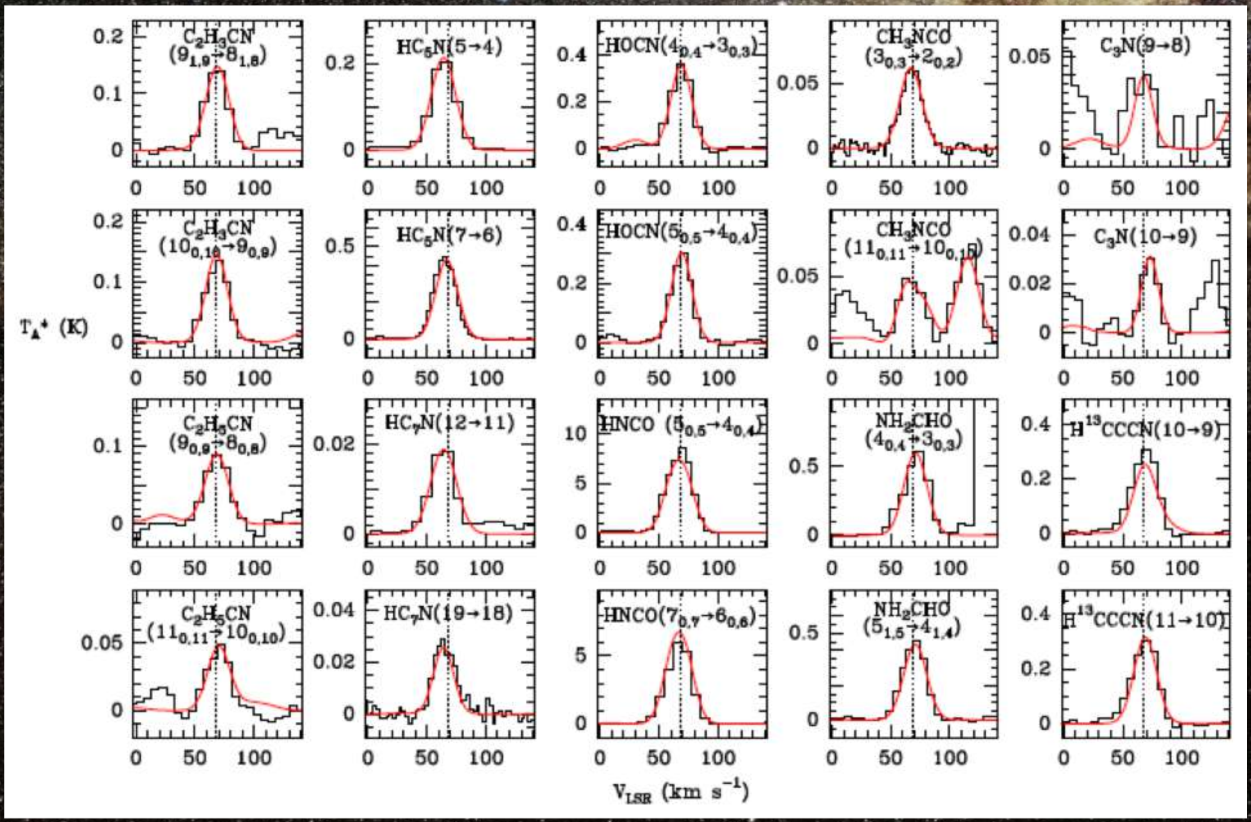
◎ Molecules Search

MADCUBA_IJ
(Centre of Astrobiology Madrid, INTA-CSIC)
http://cab.inta-csic.es/madcuba/MADCUBA_IMAGEJ/ImageJMadcuba.html

Over 60 species

~20 COMs

Nitrogen-bearing:
17 clear detections



- **Line width ~ 20 kms^{-1}**
- **T_{gas} = 70 - 140K**
- **T_{ex} = 9 - 30K**

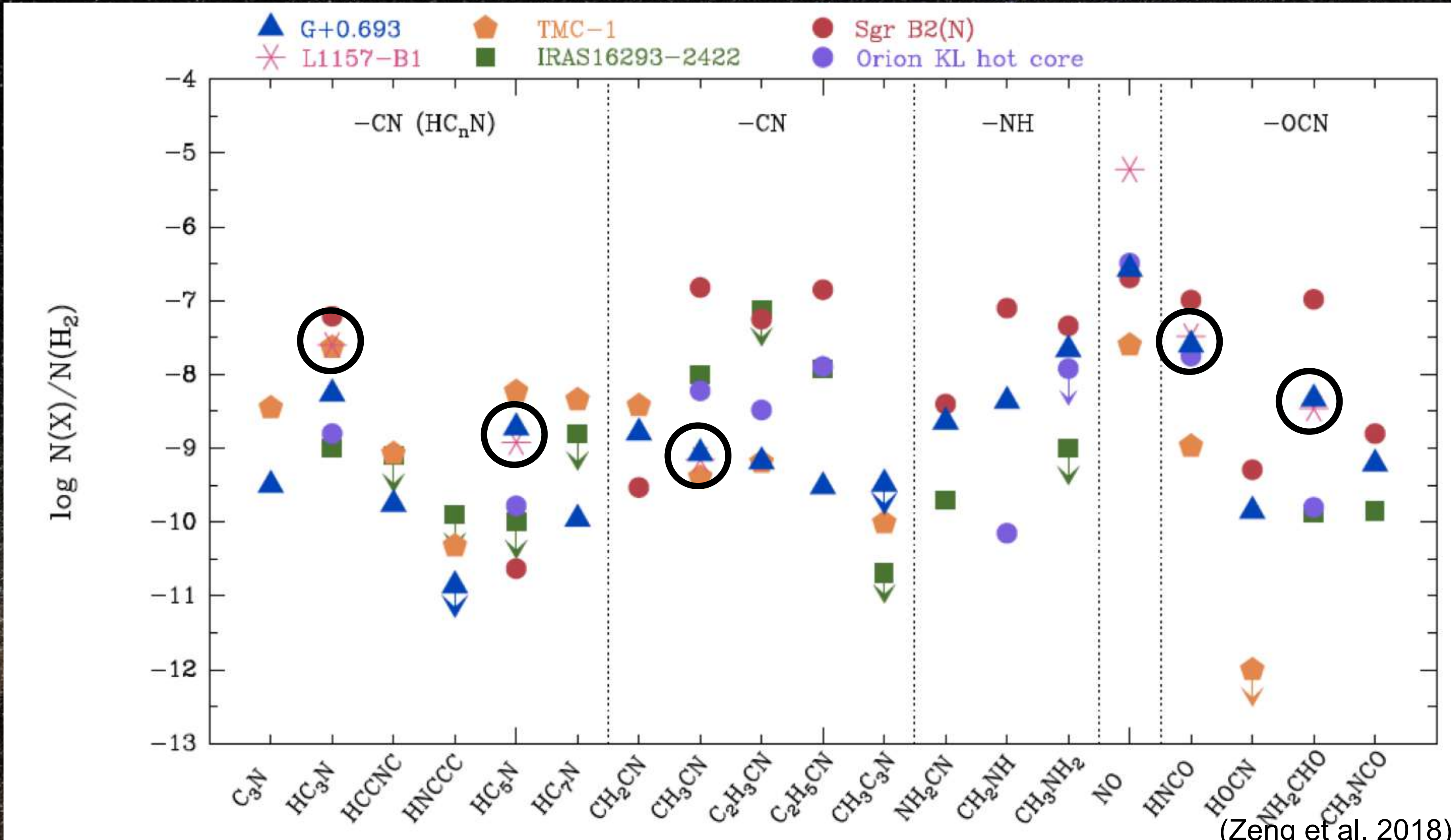
Sub-thermal excitation

- **$N(H_2)$ = 1.3 x 10^{25} cm^{-2}**

(MartÍn et al. 2008)

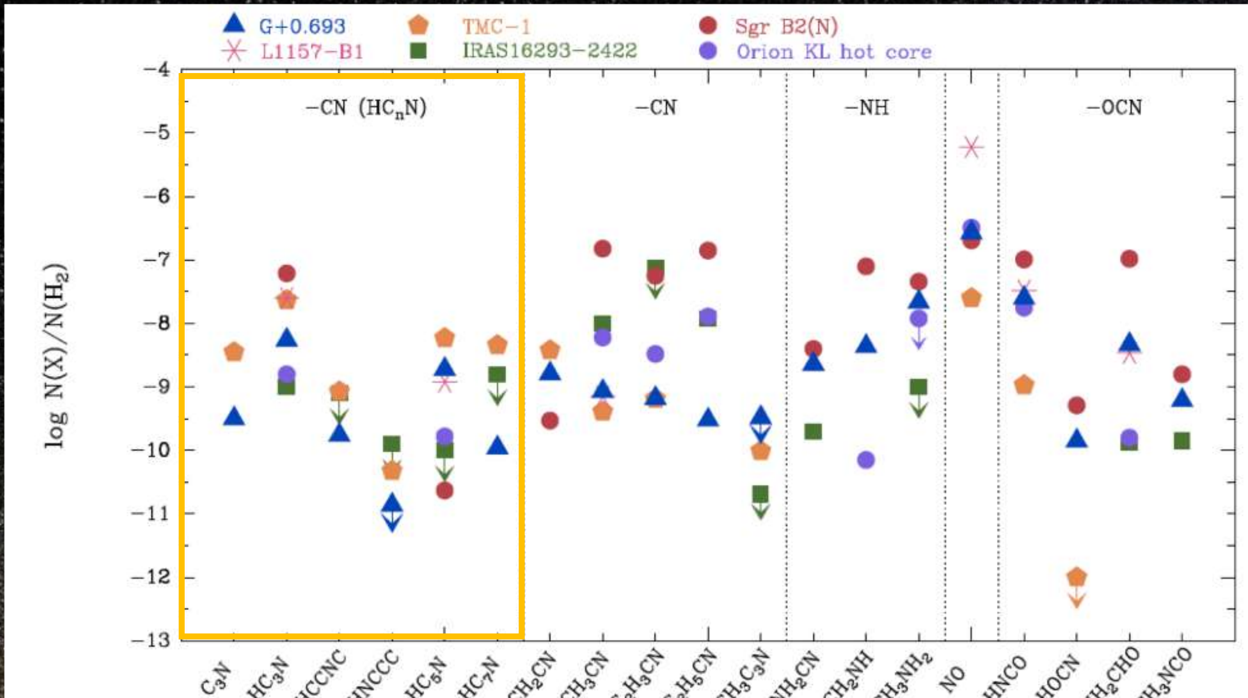
- **Abundance: 10^{-11} – 10^{-8}**

(Zeng et al. 2018)



Remarkable agreement between G+0.693 and L1157-B1 (e.g. HC_3N, HC_5N, CH_3CN, HNCO, NH_2CHO) indicates large fraction of the ices from dust grains has been injected into the gas phase via grain sputtering in SHOCK waves.

◎ Cyanopolyynes HC_nN



(Zeng et al. 2018)

HC_3N / HC_5N :

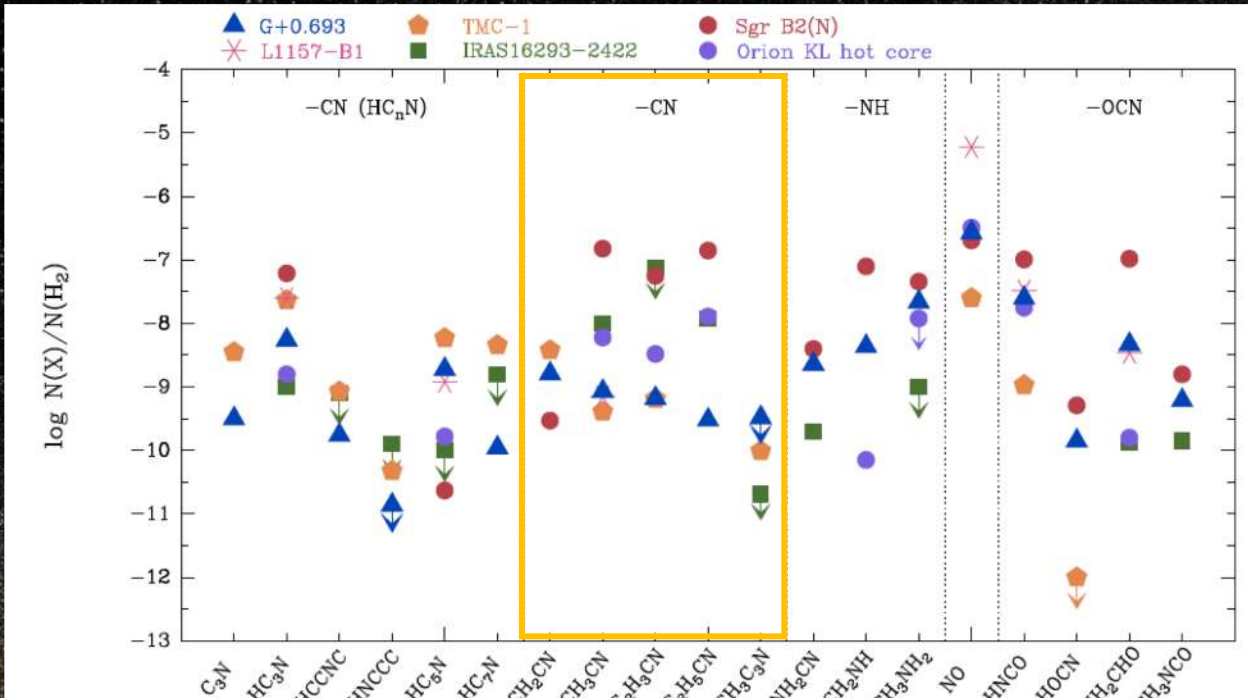
OMC2- FIR4 = 4 – 12
(ζ = 4 x 10^{-14} s^{-1})

(Fontani et al. 2017)

G+0.693 = 3.3
(ζ = 1-10 x 10^{-15} s^{-1})

Low HC_3N / HC_5N abundance ratio is possibly due to an enhancement of cosmic ray ionisation rate

◎ Nitrile -CN



(Zeng et al. 2018)

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

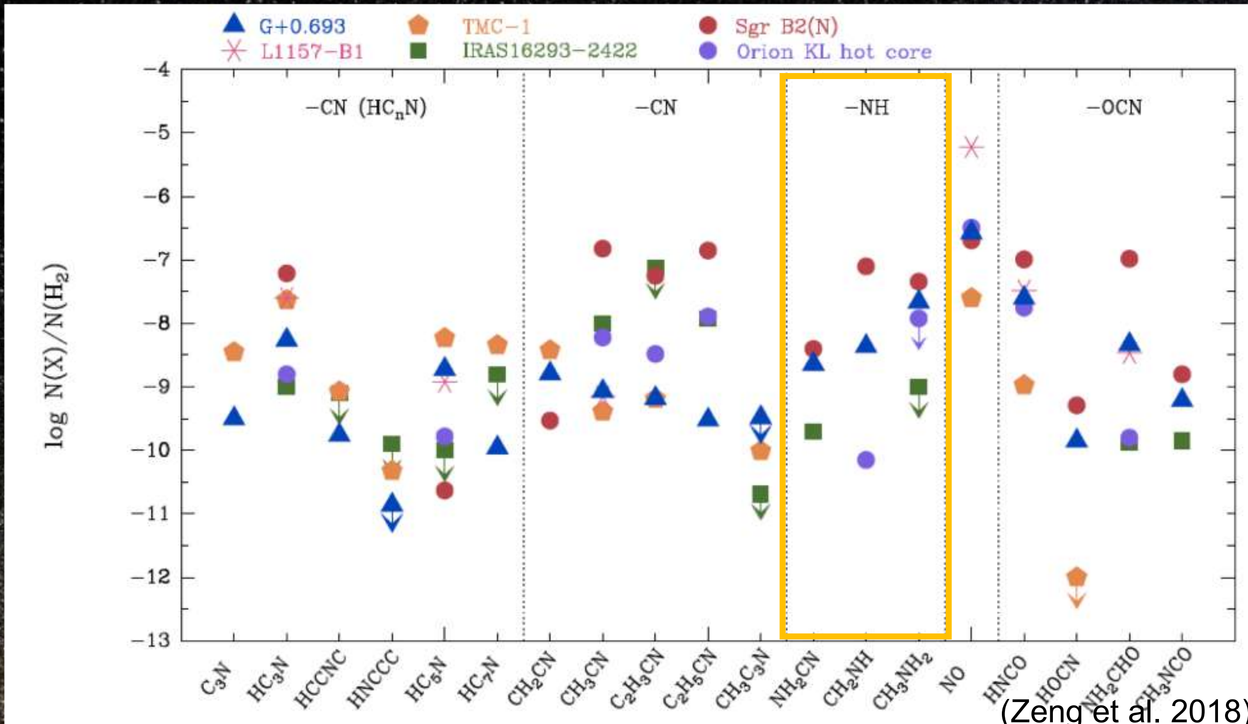
(Blake et al. 1987)

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



(Zeng et al. 2018)

CH_2NH / CH_3NH_2 abundance ratio

G10.47+00.3 = 6

(Ohishi et al. 2017)

Sgr B2N = 1.3

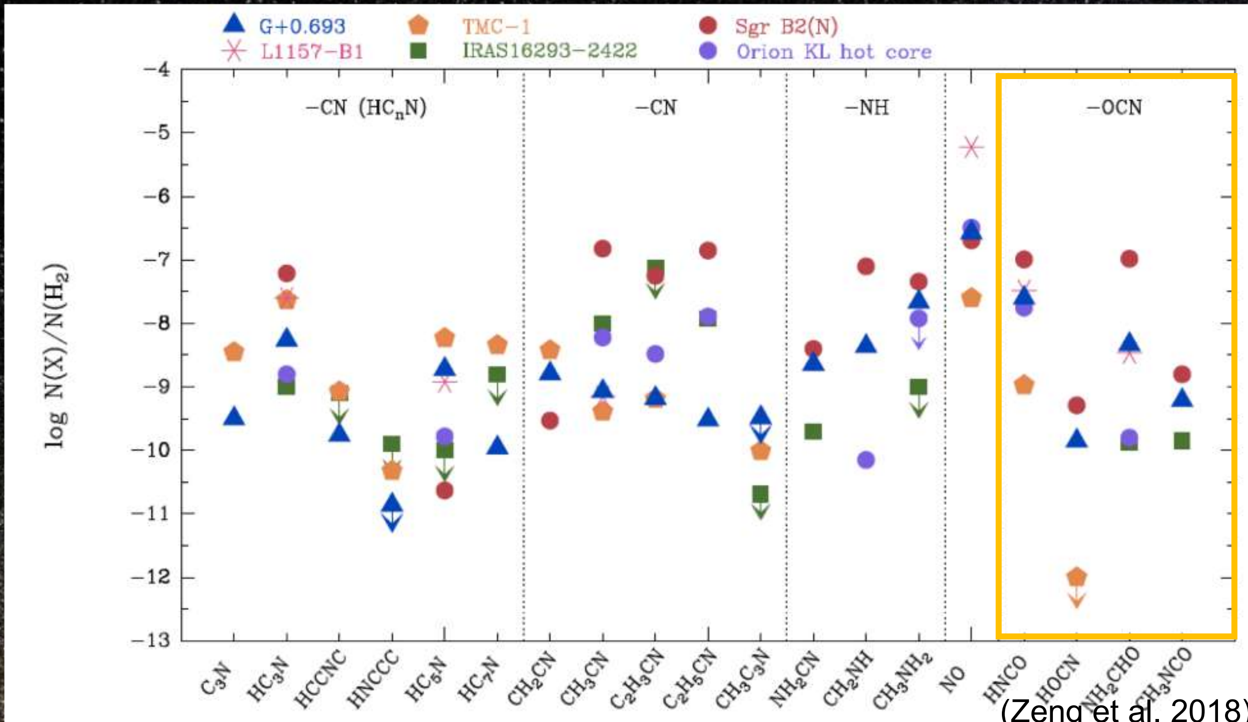
(Belloche et al. 2013)

G+0.693 = 0.1

Grain surface hydrogenation of CH_2NH can lead to formation of CH_3NH_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



(Zeng et al. 2018)

HNCO = 2.5 x 10^{-8}
HOCN = 1 x 10^{-10}

HOCN / HNCO : ~ 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 ~ 20 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 (Zeng et al. submitted)