The shock-dominated chemistry: from the Galactic Center to the Galactic Disk and External Galaxies

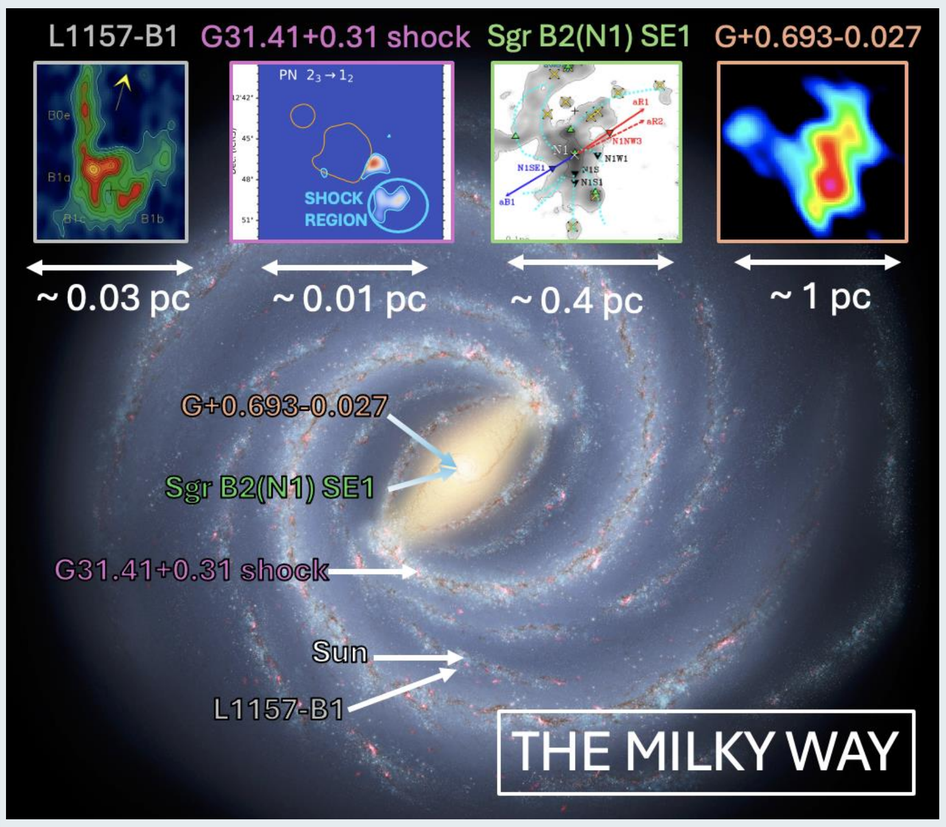
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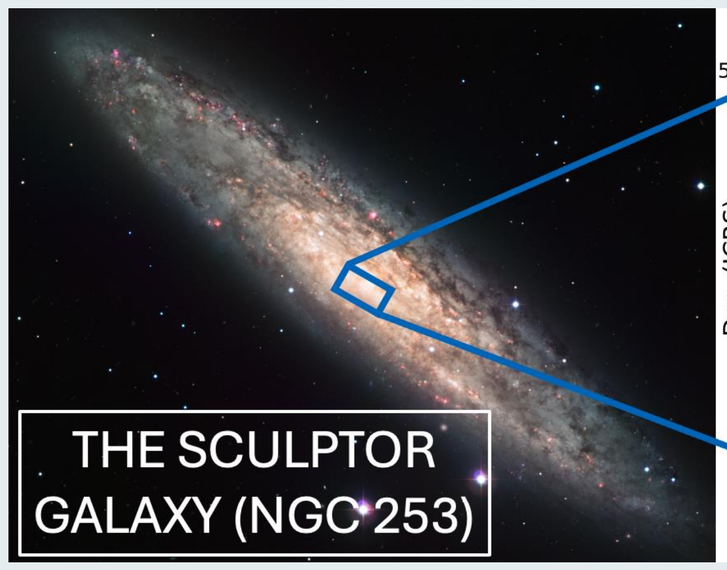
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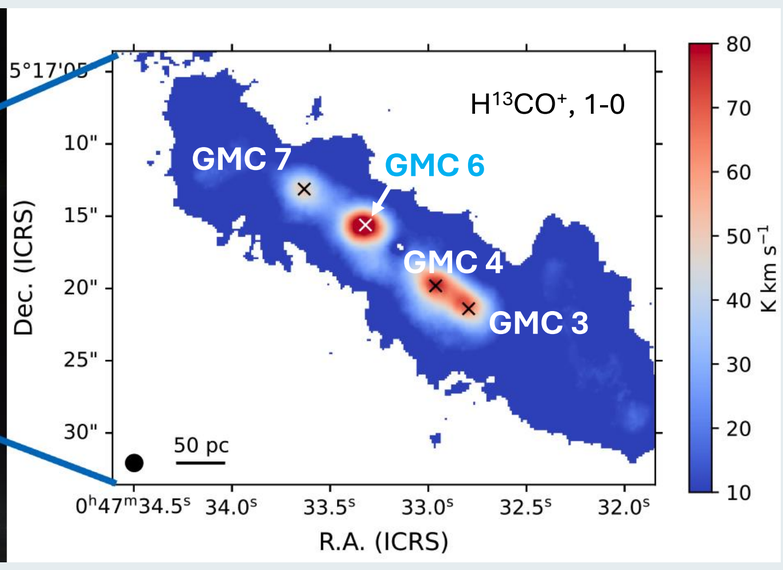


ABSTRACT. The study of the chemical composition of star-forming regions is key for constraining the initial inventory of planetary systems. Protostellar heating can modify this reservoir through thermal processing, complicating access to pristine material. Shocked regions offer an alternative sputtering dust grains and releasing mantle species into the gas phase through molecular outflows or cloud–cloud collisions on short timescales, limiting subsequent chemical processing. We present a comparative analysis based on >20 molecules in five shock-dominated environments (**G+0.693-0.027**, **L1157-B1**, **Sgr B2(N1) SE1**, **G31.41+0.31 shock** and **NGC 253 GMC 6**) observed with the Yebes 40m, IRAM 30m, and ALMA. The sample spans low- and high-mass protostellar outflows to molecular clouds in the Galactic Center and in the galaxy NGC 253. Despite large differences in scale and location, molecular abundance ratios are remarkably similar, and clearly distinct from thermally processed star-forming regions. This suggests a shock-driven chemistry and a relatively homogeneous ice mantle composition.

SOURCES ANALYSED







★ **G+0.693-0.027** is a shock-dominated molecular cloud in the Galactic Center (e.g. Zeng et al. 2018, Jiménez-Serra et al. 2020, Rivilla et al. 2022).

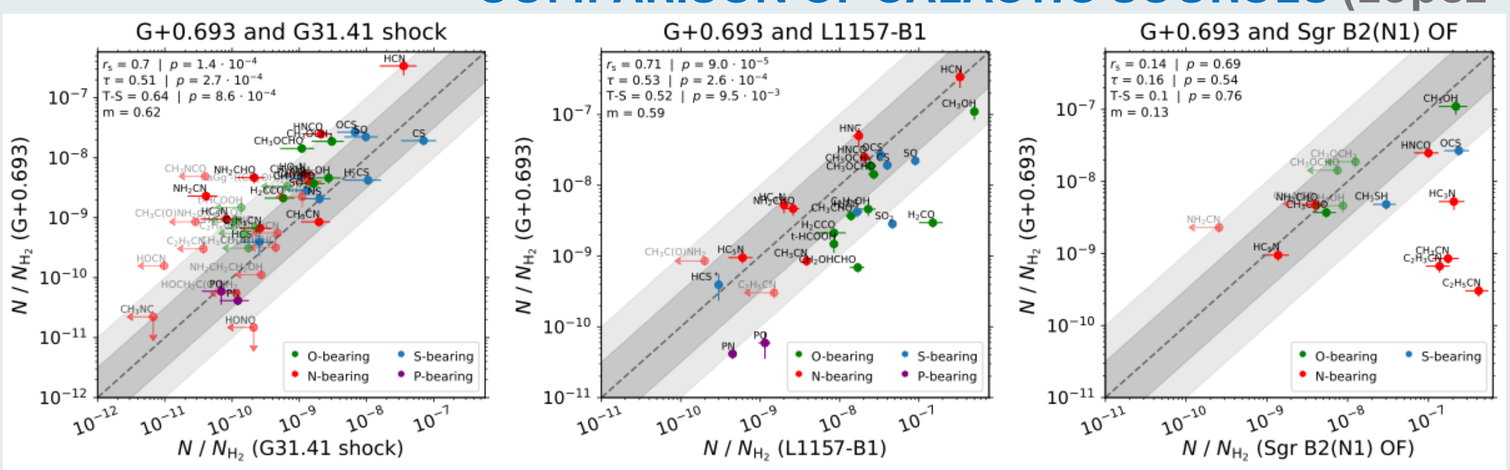
★ **L1157-B1** is an outflow powered by a low-mass Class 0 protostar (e.g. Lefloch et al. 2016, 2017, 2021).

★ **Sgr B2(N1) SE1** is a high-mass protostellar outflow that impacts the hot core Sgr B2(N1) (Busch et al. 2024).

★ **G31.41+0.31 shock** is an outflow driven by a massive protostar (Fontani et al. 2024, López-Gallifa et al. 2025).

★ **NGC 253 GMC 6** is a giant molecular cloud in the central molecular zone of the nearby galaxy NGC 253 (Martín et al. 2021).

COMPARISON OF GALACTIC SOURCES (López-Gallifa et al. 2025)



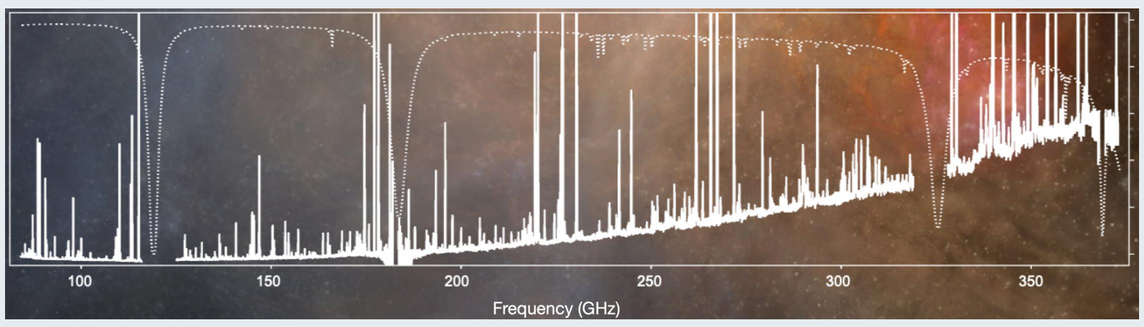
★ 3 complementary statistical methods (**Spearman, Kendall and Theil-Sen**) to characterize the correlations ranging from 0 (bad correlation) to 1 (good correlation).

★ **The correlation is good** for G+0.693, G31.41+0.31 shock and L1157-B1.

★ **Sgr B2(N1) SE1 shows a poorer correlation** (right plot) with G+0.693, which could be due to the contamination with the nearby hot core (Busch et al. 2024).

★ **Different shock-dominated regions with different locations and sizescales show similar molecular abundances.**

LINK TO THE EXTRAGALACTIC CHEMISTRY (López-Gallifa et al. in prep.)

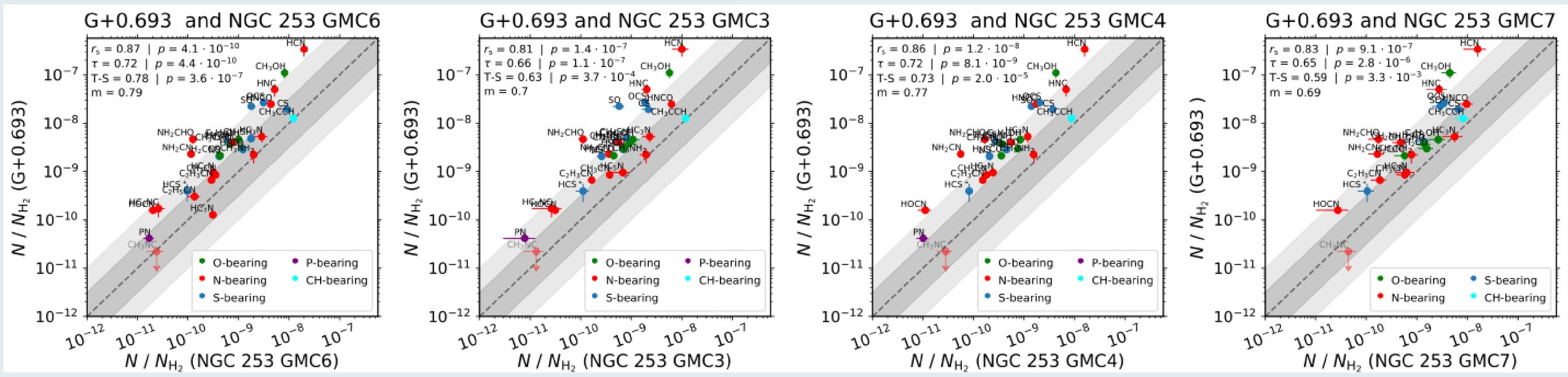


★ **ALCHEMI (ALMA Comprehensive High-resolution Extragalactic Molecular Inventory) spectral survey** is devoted to studying the nearby starburst galaxy NGC 253.

★ Ultra-broad **frequency coverage ranging from 84 to 368 GHz** (full ALMA Bands 3, 4, 5, 6, 7), with a good spatial resolution of 1.6'' (27 pc).

★ Huge opportunity for an **extragalactic full chemical inventory characterization.**

★ Unprecedented number of molecular detections towards an extragalactic source: **more than 30 detected molecules throughout 4 giant molecular clouds** (GMC 3, 4, 6 and 7).



★ **Very good correlations among G+0.693 and the 4 GMCs**, despite the different sizes (1 vs. 27 pc).

★ The chemical reservoir of 4 GMCs of the central molecular zone of NGC 253 are remarkably similar as well.

★ **Different molecular clouds** located in the central molecular zone of two different galaxies **have a very similar chemical inventory.**

CONCLUSIONS

★ Similar chemical inventories in 3 Galactic shock-dominated regions regardless of the location in our Galaxy and the size, suggesting a dominant surface chemistry.

★ The only different chemical inventory is the one contaminated with the nearby hot core, suggesting a different chemical processing in the shocks and in hot cores.

★ The chemical reservoir in other galaxy is also similar, suggesting that the central molecular zone of NGC 253 is dominated by large-scale shocks.

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