Unraveling Star Formation in M51 with High-Resolution Molecular Line Mapping

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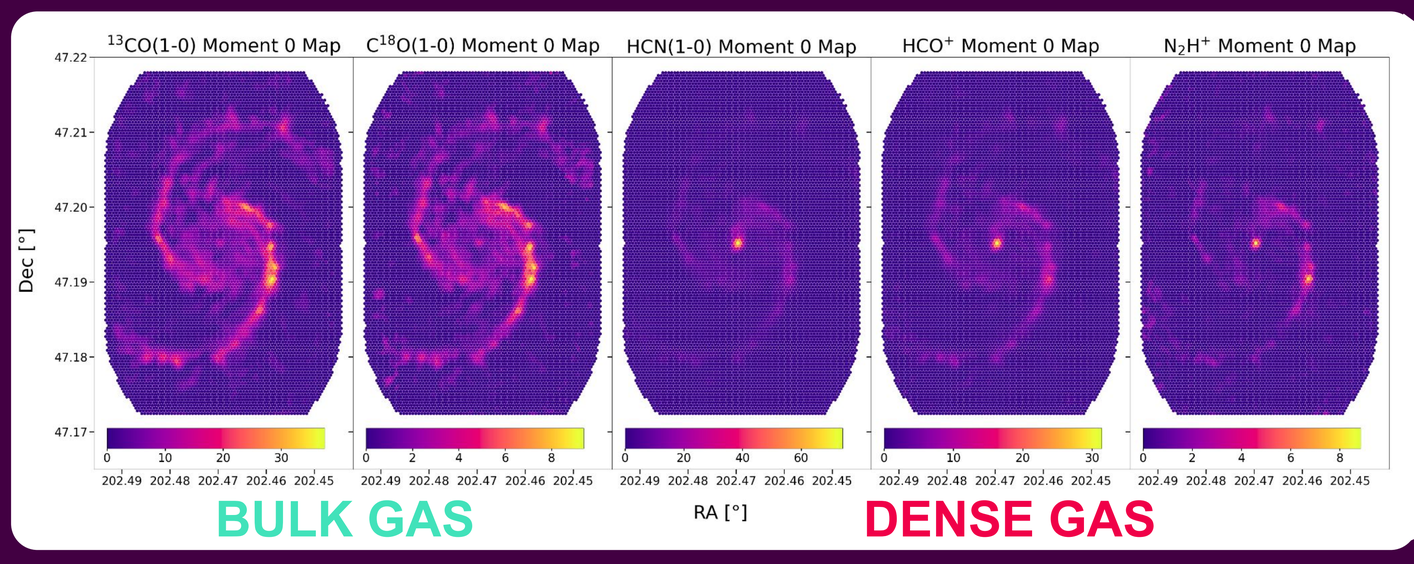
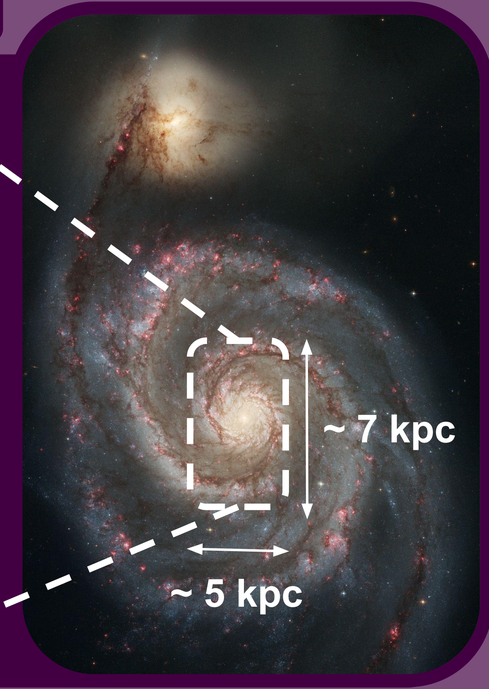
MOTIVATION: Star formation plays a key role in shaping the structure and evolution of galaxies. By probing the physical and chemical properties of molecular clouds through CO and other molecular emission lines, we can gain insight into the processes that regulate star formation across galactic environments.

The SWAN Survey

Surveying the Whirlpool at Arcseconds with NOEMA is an IRAM Large Program (PIs: F. Bigiel, E. Schinnerer) which mapped the central region of M51 using the NOEMA interferometer and the IRAM 30-meter telescope. Observations targeted 3 - 4 mm emission lines at a spatial resolution of ~3″ (~125 pc).

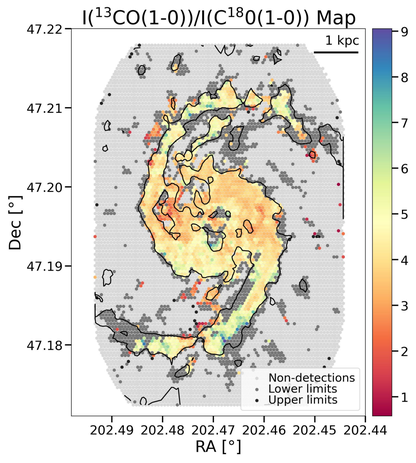
Stuber et al. (2025)



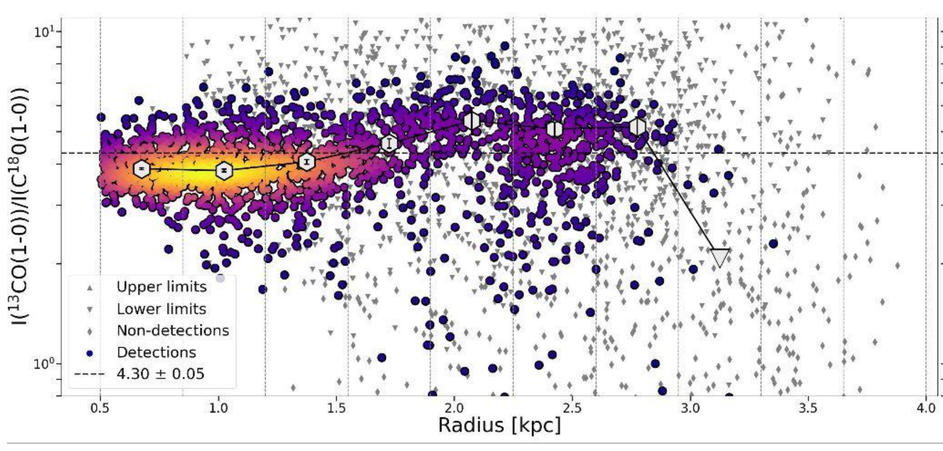


How do BULK molecular gas tracers relate to star formation on GMC scales across environments?

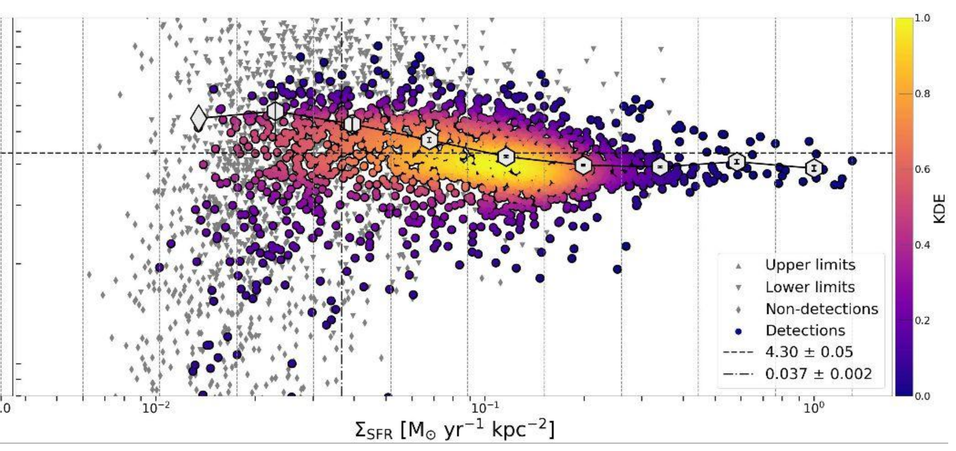
^{13}CO/C^{18}O ratio with respect to:

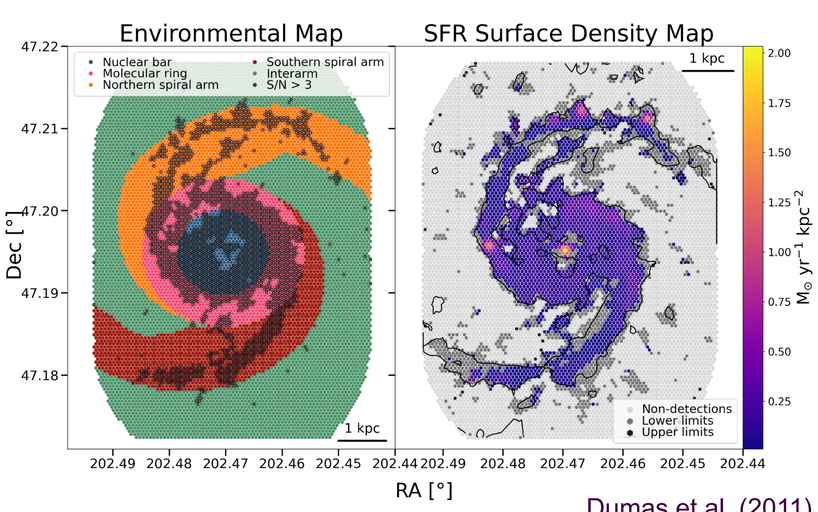


Radius



SFR Surface Density





Colombo et al. (2014a)

Dumas et al. (2011)
Kessler et al. (2020)

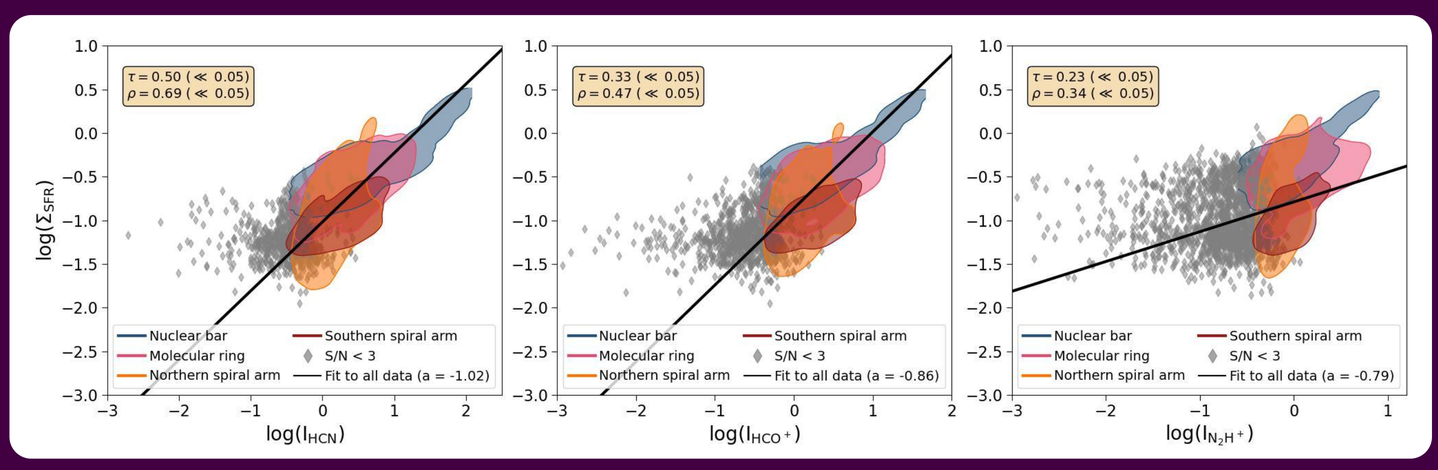
RESULTS:

1) The **^{13}CO/C^{18}O ratio of medians** across the FoV is **4.33 ± 0.05**, consistent with prior M51 studies but lower than typical values in the Milky Way and other nearby star-forming galaxies.
2) The **^{13}CO/C^{18}O** ratio shows **little correlation** with either **galactocentric radius** (τ = 0.22) or **star formation rate surface density Σ_{SFR}** (τ = -0.18) at GMC scales; however, stacking the data recovers the expected trends seen at kiloparsec scales.
3) The observed variations are likely driven by **selective nucleosynthesis** and/or **optical depth effects**.
4) The **northern** and **southern spiral arms** show notable differences, with the southern spiral arm having a higher ^{13}CO/C^{18}O ratio. This behaviour aligns with expectations from previous studies of M51's spiral structure.
5) Stacked data reveal a **strong correlation** between the ^{13}CO/C^{18}O ratio and Σ_{SFR} in the **molecular ring** and **northern spiral arm**.

Galić et al. (2025;submitted)

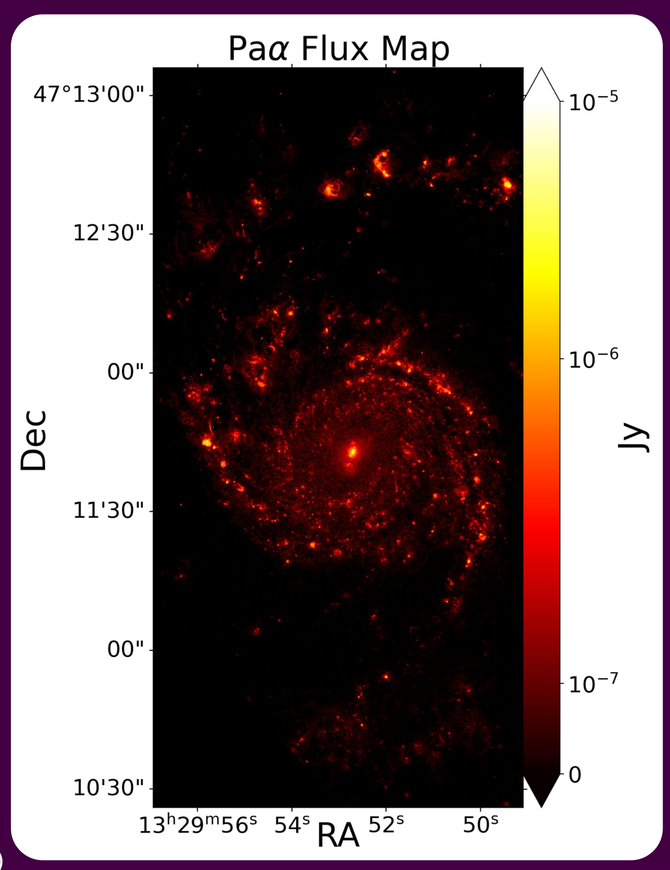
How do DENSE molecular gas tracers relate to star formation on GMC scales across environments?

In collaboration with the JWST-FEAST (*Feedback in Emerging extrAgalactic Star clusTers*; PI: Angela Adamo) team, we aim to further pin-down the impact of stellar populations and feedback processes on the ISM. Combining SWAN dense gas observations with SFR tracers and the subsequent emerging young stellar cluster (YSC) catalogue produced by JWST and LEGUS (*Legacy ExtraGalactic UV Survey*) data offers a novel view into the physical and chemical conditions closely linked to recent star formation.



Alongside PAWS environments, we want to look at these relations with respect to the chemical (^{13}CO/C^{18}O, HNCO(5-4)/(4-3), HCO$^+$/HCN) and dynamical (inflows/outflows, torque,...) environment as well as with respect to the YSCs properties (age and mass).

Galić et al. (in prep.)



Data references: Dumas+2011, Colombo+2014a, Kessler+2020, Stuber+2025, Adamo et al. (in prep.); References: Stuber+2023, den Brok+2022, Brown & Wilson+2019, Jiménez-Donaire+2017, Sliwa+2017, Querejeta+2016b, Meidt+2013, Tan+2011, Vila-Vilaró+2008, Wouterloot+2008, Aalto+1995, Sage+1991, Langer & Penzias+1990