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Using the Milky Way as a template for understanding star formation in extreme environments across cosmological timescales

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Abstract. Recent surface- and volume-density star formation relations have been proposed which potentially unify our understanding of how gas is converted into stars, from the nearest star forming regions to ultra-luminous infrared galaxies. The inner 500 pc of our Galaxy – the Central Molecular Zone – contains the largest concentration of dense, high-surface density molecular gas in the Milky Way, providing an environment where the validity of these star-formation prescriptions can be tested.

We have used recently-available data from HOPS, MALT90 and HiGAL at wavelengths where the Galaxy is transparent, to find the dense, star-forming molecular gas across the Milky Way [Longmore *et al.* (2012a), Longmore *et al.* (2012b)]. We use water and methanol maser emission to trace star formation activity within the last 10^5 years and 30 GHz radio continuum emission from the Wilkinson Microwave Anisotropy Satellite (WMAP) to estimate the high-mass star formation rate averaged over the last $\sim 4 \times 10^6$ years.

We find the dense gas distribution is dominated by the very bright and spatially-extended emission within a few degrees of the Galactic centre [Purcell *et al.* (2012)]. This region accounts for ~80% of the NH_3(1,1) integrated intensity but only contains 4% of the survey area. However, in stark contrast, the distribution of star formation activity tracers is relatively uniform across the Galaxy.

To probe the dense gas vs SFR relationship towards the Galactic centre region more quantitatively, we compared the HiGAL column density maps to the WMAP-derived SFR across the same region. The total mass and SFR derived using these methods agree well with previous values in the literature. The main conclusion from this analysis is that both the column-density threshold and volumetric SF relations over-predict the SFR by an order of magnitude given the reservoir of dense gas available to form stars. The region $1^\circ < l < 3.5^\circ$, $|b| < 0.5^\circ$ is particular striking in this regard. It contains $\sim 10^7\,M_\odot$ of dense molecular gas — enough to form 1000 Orion-like clusters — but the present-day star formation rate within this gas is only equivalent to that in Orion. This implication of this result is that any universal column/volume density relations must be a *necessary but not sufficient* condition for SF to occur.

Understanding why such large reservoirs of dense gas deviate from commonly assumed SF relations is of fundamental importance and may help in the quest to understand SF in more extreme (dense) environments, like those found in interacting galaxies and at earlier epochs of the Universe.

References

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