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Testing Star Formation Models in Nearby Galaxies: A Focus on Dense Gas

Regions with higher star formation rates are thought to have more dense, molecular gas that serves as the direct fuel for star formation. However, resolved studies of nearby galaxies find systematic variations in the star formation efficiency of dense gas (SFEdense) with local galactic environment. One physical explanation for this behaviour is the suppression of star formation in dense galactic environments, potentially due to high stellar potentials or enhanced turbulence. For example, variations in the SFEdense are a prediction of turbulent models of star formation. Another possibility is that there are systematic uncertainties with observational proxies of dense gas fraction (i.e. HCN/CO). In recent work, we test this paradigm by modelling emissivities of HCN and CO over a broad range of cloud properties encompassing those found in PHANGS galaxies, as well as nearby mergers and LIRGs. Our CO emissivities and optical depths well-match those produced by simulations as well as recent observational work using multi-J observations of CO in the PHANGS galaxies and Antennae. Additionally, our HCN emissivities agree with those found in Milky Way clouds. We find that the fraction of "star-forming"gas predicted by turbulent models of star formation appears anticorrelated with the dense gas fraction, as well as the modelled HCN/CO intensity ratio in our sample of cloud models. This results in an apparent decrease in SFEdense in models with high dense gas fraction and HCN/CO, which agrees with observations of nearby galaxies. Additionally, we find that the HCN/CO intensity ratio most directly tracks the fraction of gas above moderate (~10^3 cm^-3) densities in our models, but has a steeper relationship with the fraction of dense (>10^4 cm^-3) gas. Combined, these results suggest that while there is potentially a physical origin to variations in SFEdense, we must also consider the systematic effects that impact the emissivities of our observational tracers.

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