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Revealing the Drivers of CO-to-H_2 Conversion Factor Variation and its Impact on Star Formation Efficiency across Nearby Galaxies

Yu-Hsuan Teng[1] Karin Sandstrom[1] Jiayi Sun[2] Adam Leroy[3] Alberto Bolatto[4] I-Da Chiang[1] Munan Gong[5] Antonio Usero[6] Daizhong Liu[5] Eva Schinnerer[7] Frank Israel[8] PHANGS Team

[1]University of California, San Diego, [2]Princeton University, [3]Ohio State University, [4]University of Maryland, College Park, [5]Max-Planck-Institut Für Extraterrestrische Physik, [6]Observatorio Astronómico Nacional (IGN), [7]MPIA, [8]Leiden Observatory

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Star formation in galaxies is governed by the amount of molecular gas and the efficiency that gas is converted into stars. However, assessing the amount of molecular gas relies on the CO-to-H_2 conversion factor (α_{CO}), which is known to vary with molecular gas conditions like density, temperature, and dynamical state – the same conditions that also alter star formation efficiency. The variation of α_{CO}, particularly in galaxy centers where α_{CO} can drop by nearly an order of magnitude, thus causes major uncertainties in current molecular gas and star formation efficiency measurements. Using ALMA observations of multiple ^{12}CO, ^{13}CO, and C^{18}O lines in several barred galaxy centers, we found that α_{CO} is primarily driven by CO opacity changes and therefore shows strong correlations with observables like velocity dispersion and ^{12}CO/^{13}CO line ratio (Teng et al. 2022, 2023). Motivated by these results, we have constructed a new α_{CO} prescription which accounts for emissivity effects in galaxy centers and verified it on a set of barred and non-barred galaxies with measured α_{CO} values from dust (Teng et al., to be submitted). Applying our new prescription to 65 galaxies from the PHANGS-ALMA survey, we found an overall 3x higher star formation efficiency in barred galaxy centers than in non-barred centers, and such a trend is obscured when using a MW α_{CO} or other existing prescriptions. Our results suggest that the high star formation rate observed in barred centers is not simply due to an increased amount of molecular gas but also an enhanced star formation efficiency compared to non-barred centers or disk regions.