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Characterizing the Molecular Interstellar Medium of Nearby Galaxies with Herschel, ALMA and SOFIA

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From Herschel observations of molecular gas in nearby galaxies, we find that high-excitation warm molecular gas, traced by high-J CO lines, is ubiquitous in star-forming galaxies and dominates the total CO luminosity and hence the energy budget (Rangwala et al. 2011, Kamenetzky et al. 2014). The pressure of the warm gas is about two orders of magnitude higher than the cold molecular gas, which dominates the total mass of the molecular gas. The heating source of this warm gas is still unclear. Comparison of the observed CO spectral line energy distributions and far-infrared luminosities to theoretical models indicates that the gas heating is dominated by some mechanism other than UV or X-ray photons (as in photon-dominated and X-ray dominated regions) or cosmic rays. Mechanical energy, from shocks generated by SNe and stellar winds, is the most plausible source of heating of the warm gas (e.g., Panuzzo et al. 2010, Rangwala et al. 2011, Kamenetzky et al. 2014, Meijerink et al. 2013, Greve et al. 2014, Rosenberg et al. 2014).

We will present results from our ongoing archival survey, which is systematically modeling CO rotational ladders for all the galaxies (∼300) observed by the SPIRE-FTS instrument on Herschel. This analysis is providing robust determinations of the physical conditions of the molecular gas, which are essential for understanding star-formation in galaxies and effects of feedback into the interstellar medium by star formation and AGN.

We will also present recent high-resolution observations of the highly-excited warm molecular gas in the nearby ULIRG, Arp 220, taken from the Atacama Large Millimeter Array (ALMA) (Rangwala et al. 2015). The exceptional sensitivity and spatial resolution of ALMA has allowed us to probe the detailed morphology and kinematics of the warm molecular gas associated with the two merging nuclei, which are in the final merger stage. We find strong evidence for foreground absorbing gas that is causing an apparent offset between the peak of the line and continuum emission. We also clearly detect highly redshifted CO absorption, a possible signature of an infalling molecular filament.

We will also briefly discuss our accepted Cycle-2 proposal SOFIA EXES, which will provide the first direct comparison between the warm CO observed by Herschel/ALMA and warm H_2 observed by EXES.

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