# Dissecting low metallicity PDRs and molecular clouds: CO-dark gas properties in the LMC

Suzanne C. Madden[1] and LMC$^+$ Consortium

[1] *AIM, CEA, Saclay*

The fundamental processes of star formation in galaxies involve the intricate interplay between the fueling of star formation via molecular gas and the feedback from recently formed massive stars. This process, by which galaxies evolve, is closely connected to the global and intrinsic ISM properties, such as the structure, density, pressure, metallicity, thermal balance, etc. The necessary fuel to feed star formation is considered to be molecular with CO as our convenient proxy to assess the total molecular gas and thus a calibrator of star formation activity in the local universe as well as at high redshifts. Our unresolved studies of local universe, low metallicity dwarf galaxies, show that the meagre quantity of molecular gas deduced via CO, confronted with the high efficiency with which these galaxies are forming stars, is enigmatic, leaving the conversion of observed CO to total $H_2$ in low-metallicity galaxies a veritable challenge to ascertain. This complicates our understanding and simulations of molecular clouds to star formation in metal-poor, early-universe galaxies for which our local low-metallicity galaxies may be references. On the other hand, our modeling of unresolved dwarf galaxies demonstrates the that *the relatively bright far-infrared [CII] line can be used to quantify the total $H_2$ reservoir*.

To better understand the effect of local conditions on the $H^+$-$H^0$-$H_2$ and the $C^+$-$C^0$-CO transitions in molecular clouds, we have zoomed into the Large Molecular Cloud (LMC) with a SOFIA Legacy Program (LMC$^+$), targeting the southern molecular ridge (45' x 20'; 660pc x 300 pc) at 2.5pc resolution, along with a new ALMA CO map. This study exploits the new observations of [CII]158 μm and [OIII]88 μm creating the largest spectral map obtained by SOFIA in the LMC, to be confronted by photodissociation region and photoionisation modeling to quantify the fractions of CO-dark gas reservoir compared to the CO-bright gas and the local intrinsic conditions which control these fractions. The LMC$^+$ map shows that the [CII] emission peaks toward the massive star forming regions (N158, N159, N160), while clearly extended throughout the mapped region, in contrast to the CO, most often found in clumps, some of which do not coincide with [CII]. Preliminary analyses show variations of [CII]/CO varies over several orders of magnitude in just this region. Some questions this project is addressing include: How do the properties and structure of ISM phases vary from the proximity of star- forming sites to the extended, more diffuse, lower visual extinction (Av) phases? What local conditions favor CO-dark vs.CO-bright molecular gas?

These data bring the first extensive study of the heating and cooling variations in low-metallicity star forming and quiescent regions at 2.5 pc scales and by extension will bring new insight on the physical conditions of PDRs-molecular clouds and star formation in early very high-z galaxies, where [CII]158μm and [OIII]88μm are now observed.