From molecular gas to stars

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Star formation within galactic disks was proceeding much faster in the first half of the history of the Universe: the cosmic star-formation rate density declined by a factor of approximately ten since the redshift of z=1. The mean star-formation rate with respect to the total stellar mass also decreases with decreasing redshift: star-forming galaxies form a `main sequence' in the star-formation/stellar-mass space. In addition, galactic starbursts (e.g., ultraluminous infrared galaxies (ULIRGs) or smm-galaxies) represent outliers from the main sequence. The slope and offset of the star formation-stellar mass main sequence relation change with redshift. The most prominent change is an increasing offset with increasing redshift, that is, the specific star-formation rate increases significantly with increasing redshift (by a factor of ~6 for galaxies with masses comparable to that of the Galaxy). The slope and scatter of this correlation, the evolution of its normalization with cosmic time, contain crucial and still poorly known information on galaxy evolution. Two factors can be invoked to explain the higher star-formation efficiency: (i) higher gas fractions and (ii) dynamical trigger of interactions, whose frequency increases with redshift.

In a recent work (Vollmer et al. 2017), we took a closer look at the gas content or fraction and the associated star-formation rate in main sequence and starburst galaxies at z=0 and z ~ 1 - 2 by applying an analytical model of galactic clumpy gas disks to samples of local spiral galaxies, ULIRGs, submillimeter (smm), and high-z star-forming galaxies. Our innovative model includes supernova driven turbulence, a proper treatment of the gas clumpiness, heating/cooling, molecular fraction, and molecular line emission. The model reproduces the observed CO, HCN, and HCO^+ luminosities, CO spectral line energy distributions, IR dust spectral energy distributions, and gas velocity dispersions of all sample galaxies within the model uncertainties. Our relatively simple analytic model together with the recipes for the molecular line emission appears to capture the essential physics of galactic clumpy gas disks. The proposed PhD thesis represents a continuation of this project in collaboration with P. Gratier (LAB, Bordeaux) and J. Braine (LAB, Bordeaux).

The aim of the thesis is to better understand the physical state of the molecular gas and its relation to star formation in local spiral galaxies and ULIRGs. The PhD thesis project has an observational and theoretical part. The student will work on existing IRAM 30m telescope CO data of the Taffy 2 galaxy system UGC 813/6, which had a recent head-on collision and shows a massive gas bridge. We would like to understand why the star formation efficiency with respect to the molecular gas is greatly suppressed in the gas bridge compared to what is usually observed in spiral galaxies. The results will be compared to the study of the Taffy system UGC 12914/5 (Vollmer et al. 2012). In addition, the student will ask for IRAM 30m telescope time for a ram pressure stripped Virgo galaxy, NGC 4396.
The theoretical part of the thesis consists in the extension of existing analytical model code to (i) higher HCN transitions and (ii) the CS, ^{13}CO, and $H^{13}CN$ molecules whose emission provides further information on the physical state of the dense gas. The inclusion of the chemical network (Bordeaux) can also be improved. The extended code will be applied to radial profiles of local spiral, dwarf, and ultraluminous infrared galaxies. The results of this thesis will significantly contribute to our knowledge of the conversion factor between molecular line emission and the mass of molecular hydrogen, an important open issue in extragalactic research. Moreover, it will establish physical star formation laws based on H_2 mass and not CO or HCN line emission.

HDR: Bernd Vollmer (ObAS), 22.08.2007 à l'Université Louis Pasteur, Strasbourg

[1] Vollmer, B., Braine, J., Soida, M. 2012, A&A, 547, 39
[2] Vollmer, B., Gratier, P., Braine, J., Bot, C. 2017, A&A, 602, 51