FROM GAS TO STARS – MODELS OF MOLECULAR LINE EMISSION IN RESOLVED OBSERVATIONS OF LOCAL SPIRAL GALAXIES

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The interstellar medium (ISM) is a turbulent, multi-phase, and multi-scale medium following scaling relations linking the surface density, volume density, and velocity dispersion with the cloud size. Galactic clouds range from below 1 pc to about 100 pc in size. Extragalactic clouds appear to follow the same range although they are only now becoming observable in atomic and molecular lines. Analytical models of galactic gaseous disks need to take into account the multi-scaleand multi-phase nature of the interstellar medium. They can be described as clumpy star-forming accretion disks in vertical hydrostatic equilibrium, with the mid-plane pressure balancing the gravity of the gaseous and stellar disk. Supernova energy injection maintains the gas turbulence.
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, infrared 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. Within the previous PhD project model (Lizee et al. 2022) radial profiles of IR, HI, CO, HCN, and HCO+ emission were compared to THINGS, HERACLES, EMPIRE, SINGS, and GALEX observations of 17 local spiral galaxies. The model free parameters were constrained for each galactic radius independently. The Toomre parameter, which measures the stability against star formation (cloud collapse), exceeds unity in the inner disk of a significant number of galaxies. In two galaxies it also exceeds unity in the outer disk. Therefore, in spiral galaxies the commonly used assumption of Q=1 is not mandatory. The model yielded gas velocity dispersions and CO/HCN conversion factors, which are consistent with observations. Thus, stellar feedback via supernovae is the dominant source of energy injection to maintain ISM turbulence.
The natural next step within the present PHD project is to apply the model to existing resolved infrared, HI, CO, HCN, and star formation maps of perturbed and isolated local spiral galaxies. In isolated spiral galaxies we want to measure the variations of the Toomre Q parameter and gas velocity dispersion in different environments (arm, interarm, bar, center). In perturbed Virgo cluster galaxies, we want to study these quantities in regions where the gas is compressed by ram pressure or tides. In the Virgo cluster galaxy NGC 4654, Lizee et al. (2021) could show that stellar feedback regulates star formation in such a region via an increase of the gas velocity dispersion. We want to confirm this result in other galaxies. Publically available ALMA PHANGS CO and THINGS/VIVA HI data will be used. The student will also work on existing IRAM 30m CO data of the perturbed Virgo cluster galaxy NGC 4396. The results of this thesis will significantly contribute to our knowledge on stellar feedback, which is an important issue in the field of galaxy formation and evolution.

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