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The State of the Gas and the Relation Between Gas and Star Formation at Low Metallicity: the Small Magellanic Cloud

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We compare atomic gas, molecular gas, and the recent star formation rate (SFR) inferred from H-alpha in the Small Magellanic Cloud (SMC). By using infrared dust emission and local dust-to-gas ratios, we construct a map of molecular gas that is independent of CO emission. This allows us to disentangle conversion factor effects from the impact of metallicity on the formation and star formation efficiency of molecular gas. On scales of 200 pc to 1 kpc we find a characteristic molecular gas depletion time of ~1.6 Gyr, similar to that observed in the molecule-rich parts of large spiral galaxies on similar spatial scales. This depletion time shortens on much larger scales to ~0.6 Gyr because of the presence of a diffuse H-alpha component, and lengthens on much smaller scales to ~7.5 Gyr because the H-alpha and H2 distributions differ in detail. We estimate the systematic uncertainties in our measurement to be a factor of 2-3. We suggest that the impact of metallicity on the physics of star formation in molecular gas has at most this magnitude. The relation between SFR and neutral (H2+HI) gas surface density is steep, with a power-law index ~2.2+/-0.1, similar to that observed in the outer disks of large spiral galaxies. At a fixed total gas surface density the SMC has a 5-10 times lower molecular gas fraction (and star formation rate) than large spiral galaxies. We explore the ability of the recent models by Krumholz et al. (2009) and Ostriker et al. (2010) to reproduce our observations. We find that to explain our data at all spatial scales requires a low fraction of cold, gravitationally-bound gas in the SMC. We explore a combined model that incorporates both large scale thermal and dynamical equilibrium and cloud-scale photodissociation region structure and find that it reproduces our data well, as well as predicting a fraction of cold atomic gas very similar to that observed in the SMC.

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