Molecular Hydrogen In Cosmological Simulations of Two Dwarf Galaxies
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Abstract:
We use numerical simulations to examine the connection between star formation and the cold interstellar media (ISM) in dwarf galaxies. Dwarf galaxies, because of their low surface densities and metallicities, contain small amounts of molecular hydrogen. Furthermore, these same properties make the detection of molecular hydrogen through CO emission extremely difficult. Simulations have the advantage of allowing us to study the evolution of the large-scale properties of cold ISM in dwarf galaxies, including the distribution of molecular hydrogen. Our Smoothed-Particle Hydrodynamic (SPH) cosmological simulations include the creation and diffusion of metals, shielding from interstellar radiation, and the non-equilibrium formation and destruction of molecular hydrogen. We compare the stellar and cold ISM properties for two hierarchically formed, simulated dwarf galaxies with varying masses but with similar merger and gas infall histories. With galaxies such as these, we have reproduced both realistic rotation curves and bulge-to-disk ratios. We mimic observations of these galaxies and relate them to the underlying physical properties of the cold ISM.

The Galaxies:
The initial conditions for the two galaxies used in our simulation differ only in their mass scaling. This ensures that they have the same merger and gas infall history while allowing us to examine the effect of mass and metallicity. The smaller of the two, h516, is of sufficient mass resolution to produce a rising rotation curve, Fig 2, as seen in (Governato, 2010). Global properties of the galaxies are listed in Table 1.

We simulated these two galaxies to redshift zero using the Smoothed-Particle Hydrodynamic code, GASOLINE before adding our H2 recipe. We integrated these galaxies for 150 Myr (h603) or 370 Myr (h516) with the inclusion of H2. Throughout the entire integration, our simulations included UV background radiation, metal diffusion, metal cooling, and blastwave model supernova feedback, and we adopted the best parameters for star formation. Our simulations show H2 forming in the densest regions of galaxies where recent star formation is occurring. Radiation from recently formed stellar populations, in turn, is seen to dissociate within H2. Relating our star formation recipe to the amount of H2 in a gas particle limits the total star formation. This potentially offers an additional method of simulating regulated star formation. Comparing the fraction of H2 versus surface density for both galaxies demonstrates the dependency of shielding on metallicity. In future simulations, we will implement our H2 formation and destruction recipe throughout the entire cosmological run. This will enable us to compare the star formation histories in galaxies with and without H2-based star formation. We are continuing to refine our approximation for the flux of Lyman-Werner radiation at each gas particle, as well as determining the best parameters for star formation.

References:
Governato, F. et al., 2010, Nature, 493, 7278

Molecular Hydrogen Recipe:
We model the non-equilibrium formation and destruction of H2, with a method similar to Gnedin et al. (2008).

Formation: H2 forms primarily on dust grains, which are assumed to be directly proportional to the gas metallicity. In low metallicity environments, H2 forms at a slower rate from gas-phase interactions.

 Destruction: H2 is destroyed primarily by Lyman-Werner photons from massive stars. We approximate the flux of Lyman-Werner photons at a given location to be a function of the number of Lyman-Werner photons emitted from nearby stars.

 Shielding: The rate of H2 destruction from radiation is controlled by self-shielding and shielding from dust. Shielding is a function of the column density of both HI and H2. When calculating column density we assume the column length for shielding is a function of large scale turbulence and related to the gas shear.

 Cooling: Cooling from H2 and all gas-phase reactions are based on the models from Abel et al. (1997).

 Star Formation: When determining the probability of a particle forming a star, p, the efficiency of star formation for a given gas particle is proportional to the fractional H2 abundance, fH2: $p = \frac{1}{1 + e^{\Delta t(t_f / t_H)}}$, c = 0.1

Conclusions and Future Work:
Our simulations show H2 forming in the densest regions of galaxies where recent star formation is occurring. Radiation from recently formed stellar populations, in turn, is seen to dissociate nearby H2. Relating our star formation recipe to the amount of H2 in a gas particle limits the total star formation. This potentially offers an additional method of simulating regulated star formation. Comparing the fraction of H2 versus surface density for both galaxies demonstrates the dependency of shielding on metallicity. In future simulations, we will implement our H2 formation and destruction recipe throughout the entire cosmological run. This will enable us to compare the star formation histories in galaxies with and without H2-based star formation. We are continuing to refine our approximation for the flux of Lyman-Werner radiation at each gas particle, as well as determining the best parameters for star formation.

Table 1: Final global properties of the two galaxies analyzed here.