Surveying the Molecular Gas Fueling Early Star Formation: Present Results and Future Directions

Garrett K. Keating[1], Daniel P. Marrone[2], and Geoffrey C. Bower[3]

[1] Smithsonian Astrophysical Observatory, Cambridge, MA USA
[2] University of Arizona, Tucson, AZ USA
[3] Academia Sinica Institute of Astronomy and Astrophysics, Hilo, HI

As a precursor to star formation, gas within galaxies plays a powerful role in driving their cosmic evolution. In the early Universe, large gas reservoirs dominated the baryonic mass of galaxies, and fueled a rapid rise in cosmic star formation, peaking at 10 times higher than the present-day rate. Most of our knowledge of these early galaxies comes from studying stellar light and emission lines from the hot, ionized gas of the interstellar medium (ISM). However, it is cold molecular gas that provides the natal material in which stars form. Thus, understanding the nature and evolution of this cold gas is crucially important for understanding star formation in the early Universe.

However, measurements of the cold gas contents of "normal" (i.e., low-mass) galaxies at high redshift are typically observationally expensive. Through tracers like carbon monoxide (CO) and ionized carbon ([CII]), direct detection measurements of this gas has typically been restricted to massive, luminous systems that are not likely representative of the vast majority galaxies in the early Universe. In recent years, the method of "intensity mapping" – wherein emission from galaxies are detected in aggregate as large-scale fluctuations of line intensity – has shown significant promise exploring moderate and low-mass systems, over sufficiently large volumes to allow for the exploration of *thousands or millions* of such galaxies in a single experiment.

We present results from the CO Power Spectrum Survey (COPSS), an intensity mapping experiment targeting molecular gas in the early Universe. In the second phase of COPSS, which utilized 5000 hours of new observations with the Combined Array for Research in Millimeter-wave Astronomy (CARMA), we report a potential detection of the aggregate CO signal, constraining the CO power spectrum to $P_{\rm CO} = 3.0 \pm 1.3 \times 10^3 \mu{\rm K}^2\ h^{-3}\,{\rm Mpc}^{-3}$ at $z \sim 3$. We discuss what astrophysical constraints can be placed on the cosmic molecular gas density and the CO galaxy luminosity function. We also discuss upcoming intensity mapping experiments, including the ASIAA Intensity Mapping of CO (AIM-CO) experiment, which will probe CO emission from $z \sim 1-3$ and will be capable of cross-correlation with our CARMA data set. Finally, we will discuss current results from analysis of data from the Very Large Array (VLA), the Atacama Large Millimeter Array (ALMA), and the Submillimeter Array (SMA) to explore molecular gas via CO and [CII] intensity mapping of galaxies over a broad redshift range of $z \sim 0.2-6$.