

Dense Molecular Gas at High Redshift: First Detection of Emission from HCO⁺

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Abstract. Using the Very Large Array (VLA), we have detected the HCO⁺(1–0) emission line towards the Cloverleaf quasar ($z = 2.56$; Riechers et al. 2006). This is the first detection of ionized molecular gas emission at high redshift ($z > 2$). HCO⁺ emission is a star formation indicator similar to HCN, tracing dense molecular hydrogen gas within star-forming molecular clouds. We find a HCO⁺/CO luminosity ratio of 0.08 and a HCO⁺/HCN luminosity ratio of 0.8 for the Cloverleaf. These ratios fall within the scatter of the same relationships found for low- z star-forming galaxies. However, a HCO⁺/HCN luminosity ratio close to unity would not be expected for the Cloverleaf if the recently suggested relation between this ratio and the far-infrared luminosity (Graciá-Carpio et al. 2006) were to hold. We conclude that a ratio between HCO⁺ and HCN luminosity close to 1 is likely due to the fact that the emission from both lines is optically thick and thermalized and emerges from dense regions of similar volumes. We conclude that HCO⁺ is potentially a good tracer for dense molecular gas at high redshift.

Keywords. galaxies: active, starburst, formation, high redshift, cosmology: observations, radio lines: galaxies

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References

Graciá-Carpio, J., García-Burillo, S., Planesas, P., & Colina, L. 2006, *ApJ* 640, L135

Riechers, D. A., Walter, F., Carilli, C. L., et al. 2006, *ApJ* 645, L13