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Molecular clouds in a Milky Way progenitor observed 8 billion years ago

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Invited talk

Abstract:
Thanks to the remarkable ALMA capabilities and the unique configuration of the Cosmic Snake galaxy behind a massive galaxy cluster, we could, for the first time, resolve molecular clouds down to 30 pc linear physical scales in a typical Milky Way progenitor at z=1.036 through CO(4-3) observations performed at 0.2" angular resolution. We identify 17 individual giant molecular clouds (GMCs) that occupy the 1.7 kpc central region of the Cosmic Snake galaxy. These high-redshift molecular clouds are clearly different from their local analogues: with radii between 30 to 210 pc, they are two orders of magnitude more massive (8x10^6-1x10^9 Msun), one order of magnitude denser (with a median molecular gas mass surface density of 2600 Msun/pc2), and on average more turbulent (with internal velocity dispersions of 9-33 km/s). They thus are offset from the Larson scaling relations, well established for the local GMCs, and challenge the universality of molecular clouds. We argue that GMC physical properties are dependent on the galactic environment: GMCs must inherit their physical properties from the ambient ISM particular to the host galaxy. We find these high-redshift GMCs in virial equilibrium, and derive, for the first time, the CO-to-H2 conversion factor from the kinematics of independent GMCs at z~1. The measured large clouds gas masses demonstrate the existence of parent gas clouds with masses high enough to allow the in-situ formation of similarly massive stellar clumps seen in the Cosmic Snake galaxy in a comparable number to the GMCs. The comparison of the GMC masses and star cluster masses suggests a high efficiency of star formation, which anchors at z~1 the recently proposed scaling of the star formation efficiency with gas mass surface density. Our results corroborate the formation of GMCs by fragmentation of distant turbulent galactic gas disks, which then turn into the stellar clumps ubiquitously observed in galaxies at cosmic noon.

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