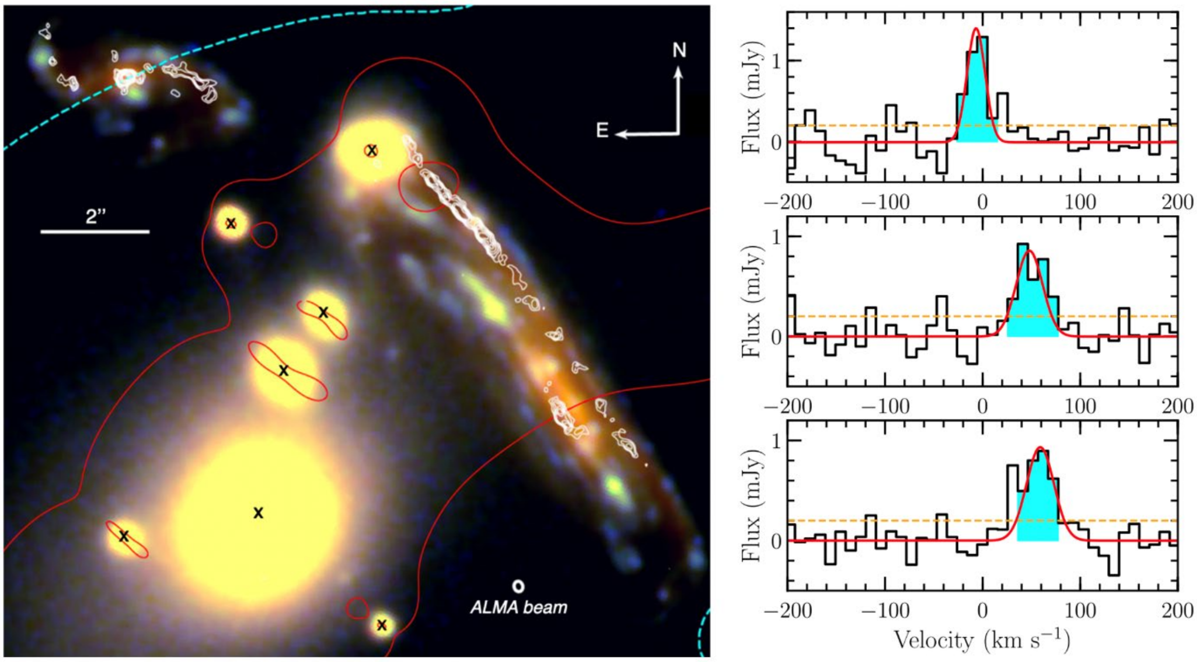
ALMA resolves the molecular clouds of a strongly lensed Milky Way progenitor observed at z=1



The left panel shows the HST RGB-colour composite image of the strongly lensed A521-sys1 galaxy at z=1 together with the foreground Abell 521 galaxy cluster members (black crosses). The critical line of the lens model is shown by the red solid line. The entire A521-sys1 galaxy can be seen in the north-east uniformly lensed image, while the 11 arcsec-long arc, where one reaches the higher magnification factors, provides a zoom-in on the western spiral arm of the galaxy. The overlaid white contours correspond to the ALMA CO(4-3) velocity-integrated intensity in levels of 4, 5, 6, 7, 8, 10, 12, and 14σ. The ALMA synthesized beam with a size of 0.19" x 0.16" is represented by the white ellipse. The right panel shows examples of the integrated CO(4-3) emission line spectra, together with their best Gaussian fits in red, of three molecular clouds among the 14 that were detected in A521-sys1.

Star clusters are formed via the condensation of molecular clouds, which are made out of cold and dense gas and are found in all galaxies. While UV-bright and massive star cluster complexes are ubiquitously observed in galaxies at the peak of the cosmic star formation rate density, located more than 8 billion light-years away, the molecular clouds that gave birth to these clusters remained undetected so far. ALMA has recently confirmed the presence of these molecular clouds in a Milky Way in the making, the A521-sys1 galaxy at redshift 1. Galaxy cluster Abell 521 acts as a natural telescope, magnifying and enlarging the size of A521-sys1. Observations with the ALMA interferometer, at an angular resolution of 0.15 arcseconds, made it possible to resolve the molecular clouds in A521-sys1 individually down to 30 parsecs.

These superb ALMA observations of the CO(4-3) spectral line emission, used as the tracer of the cold molecular gas, enabled Dessauges-Zavadsky et al. (2023) to reveal that the molecular clouds of distant galaxies have a mass, density and internal turbulence 10 to 100 times higher than the clouds of nearby galaxies. The authors attributed these differences to the ambient interstellar conditions of distant galaxies, which are too extreme for the survival of the molecular clouds typical of nearby galaxies. Yet this galaxy is "normal" for its epoch and does not host a starburst. They also suggested that these distant molecular clouds appear to form a fairly high fraction (about 30%) of their mass in stars, a particularly high efficiency of star formation with respect to less than 5% observed in nearby galaxies, likely triggered by the highly supersonic internal turbulence of the clouds.

These results highlight the capabilities of ALMA to investigate the small-scale structure of the molecular gas in the interstellar medium of high-redshift galaxies, and hence open the perspective to analyze the star formation process across cosmic time at molecular cloud scale. Specifically, ALMA in synergy with JWST observations will allow to confirm and understand the ability of molecular clouds in distant galaxies to form stars so efficiently.

Reference:

Dessauges-Zavadsky, M., Richard, J., Combes, F., et al. : Molecular gas cloud properties at z $\simeq$ 1 revealed by the superb angular resolution achieved with ALMA and gravitational lensing, 2023, MNRAS 519, 6222