The Cosmic Snake reveals huge molecular clouds

The star clusters are formed by the condensation of molecular clouds, made of cold and dense gas found in all galaxies. The physical properties of these clouds in our galaxy or in nearby galaxies have been known for a long time. But are they identical in distant galaxies, located more than 8 billion light-years away? Thanks to a resolution never achieved before in a distant galaxy, an international team, led by the University of Geneva (UNIGE), and with the participation of French researchers, was able to detect for the first time molecular clouds in a Milky Way in the making. Their observations, published in the journal *Nature Astronomy*, show that these clouds have a higher mass, density and internal turbulence than in nearby galaxies and produce far more stars. Astronomers attribute 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

Molecular clouds, the cradle of star formation, are well known in the Milky Way. But are they the same in distant galaxies that form more stars? Until now it was very difficult to isolate clouds in distant galaxies, for lack of spatial resolution. Astronomers then came up with the idea of benefiting from a natural telescope - the gravitational lens phenomenon - coupled with the use of ALMA (Atacama Large Millimeter / submillimiter Array), an interferometer of 50 millimeter-scale radio antennas that reconstruct the entire image of a galaxy instantly. Thanks to the alignment of a massive object between the observer and the distant object, the gravitational lenses produce a magnifying effect, and considerably enlarge the size of the distant object studied. This resolution, further improved thanks to the ALMA interferometer (resolution of 0.2 ’’) made it possible to characterize the clouds individually in a distant galaxy, nicknamed the Cosmic Snake, located at 8 billion light-years (see Figure 1).

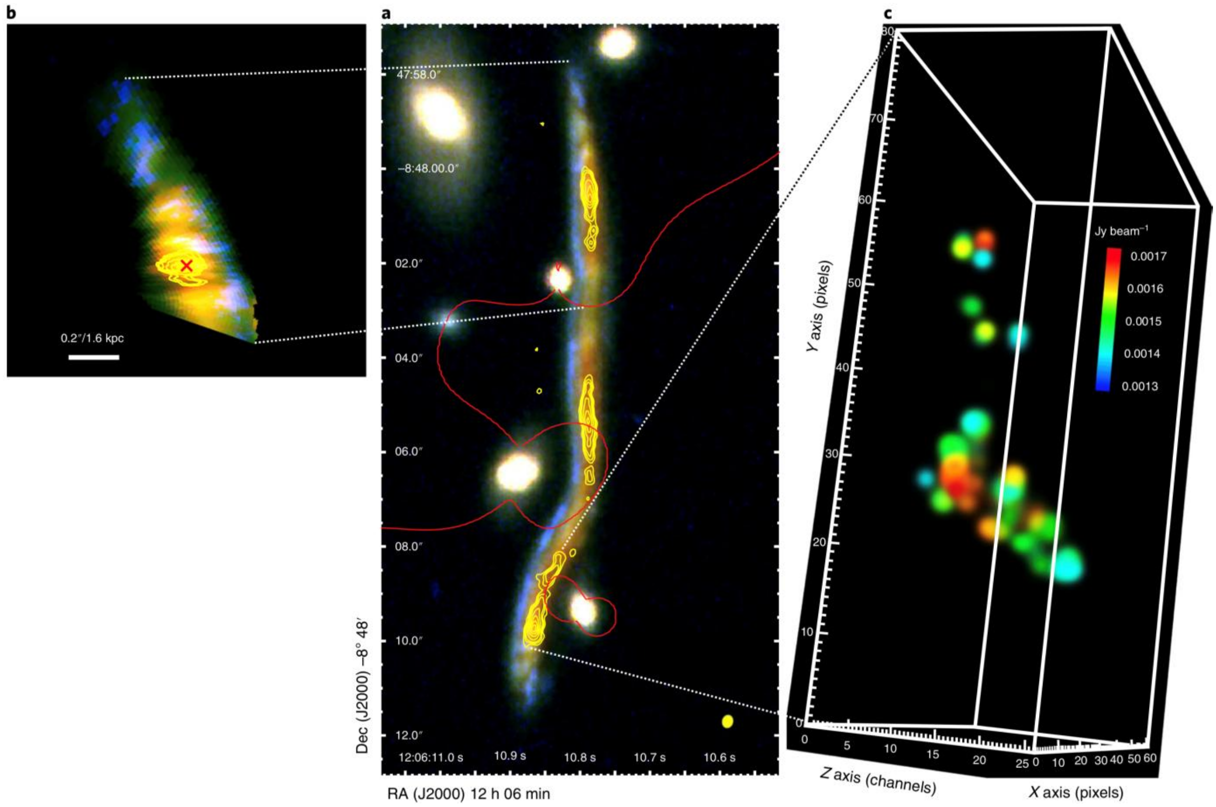

Figure 1:Distribution du gaz moléculaire dans la galaxie du Serpent Cosmique, distordue et amplifiée par lentille gravitationnelle. Au centre est l'image obtenue avec le télescope spatial Hubble, montrant les 4 images, délimitées par la courbe rouge, ligne critique de l'amplification correspondant au redshift 1.036 de la galaxie. A partir de ces 4 images, l'image de la galaxie non-distordue est reconstituée en haut à gauche. Les contours en jaune indiquent l'intensité de la raie d'émission CO(4-3) observée avec ALMA. La taille du lobe ALMA (ellipse en jaune) est de 0.22'' x 0.18''. L'image de droite représente le zoom de l'image la plus au sud du Serpent, et les nuages moléculaire identifiés, dans l'espace (X,Y) et en vitesse (Z).

These observations revealed that the molecular clouds of distant galaxies had a mass, density and turbulence 10 to 100 times higher than the clouds of nearby galaxies. Yet this galaxy is "normal" for its epoch, and is not subject to a starburst. The international team has also discovered that the level of star formation efficiency of the Cosmic Snake's molecular clouds is particularly high, favored by the large internal cloud turbulence. In nearby galaxies, a cloud forms about 5% of its mass in stars. In distant galaxies, this figure jumps to 30%.

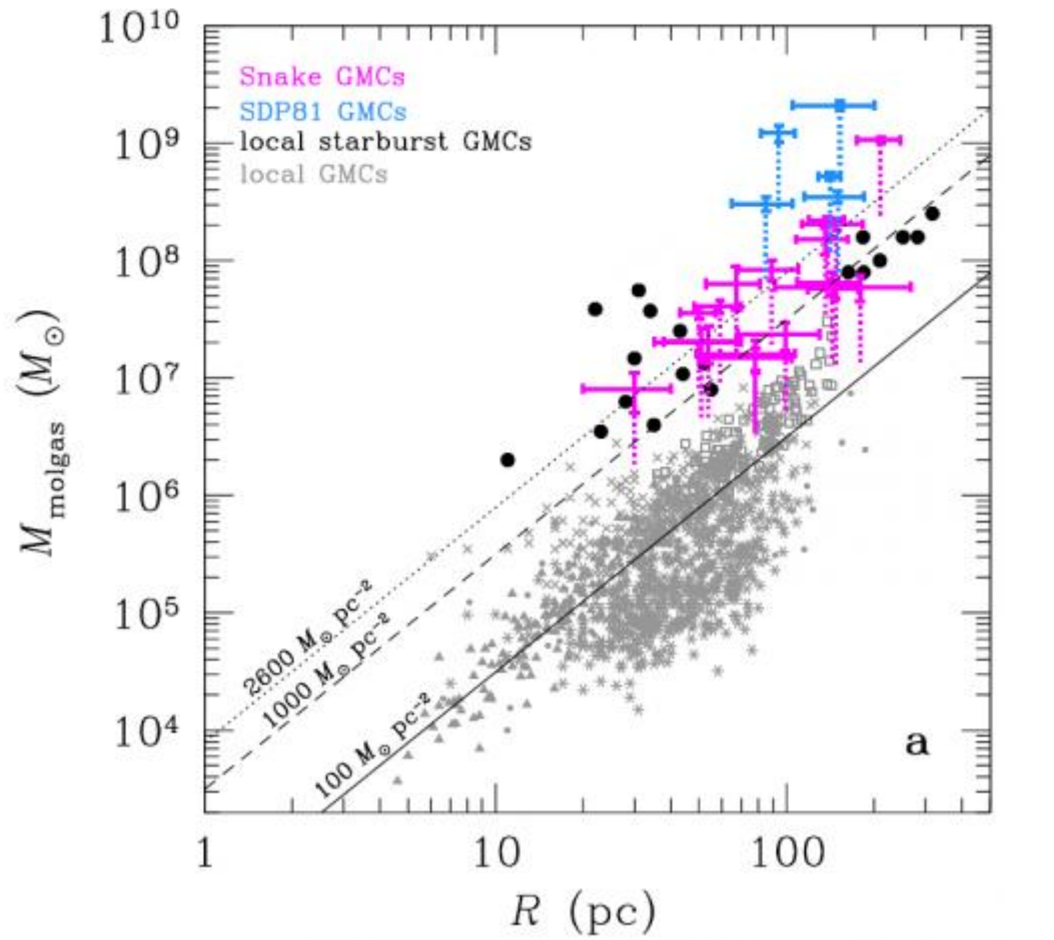

Figure 2: Masse de gaz moléculaire en fonction du rayon des nuages identifiés dans la galaxie du Serpent Cosmique (points magenta), dans les galaxies quiescentes locales (points gris), les galaxies starbursts locales (cercles noirs pleins) et la galaxie SDP81 à z=3.042 (points bleus). Les lignes en pointillés magenta et bleu indiquent la gamme de masses de gaz moléculaire possibles du Serpent Cosmique et SDP81, respectivement, tels que déterminés avec deux facteurs extrêmes de conversion CO / H2, le facteur calibré dans la Voie lactée (4.36) et celui dans les starbursts (1.0). Les lignes noires indiquent des densités de surface du gaz moléculaire de, respectivement, 100 Msol/ pc2 (ligne continue), 1000 Msol/ pc2 (tirets) et 2600 Msol/ pc2 (pointillés). Les nuages à grand redshift ont des densités de surface de gaz beaucoup plus élevées que les nuages locaux typiques.

Figure 2 compares the cloud surface densities in near galaxies, normal or starbursts, with those of distant galaxies, which are much larger.

Reference

- Molecular clouds in the Cosmic Snake, a normal star-forming galaxy 8 billion years ago, Dessauges-Zavadsky, M., Richard, J., Combes F. et al 2019, Nature Astronomy

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