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Radio shadow reveals tenuous cosmic gas cloud

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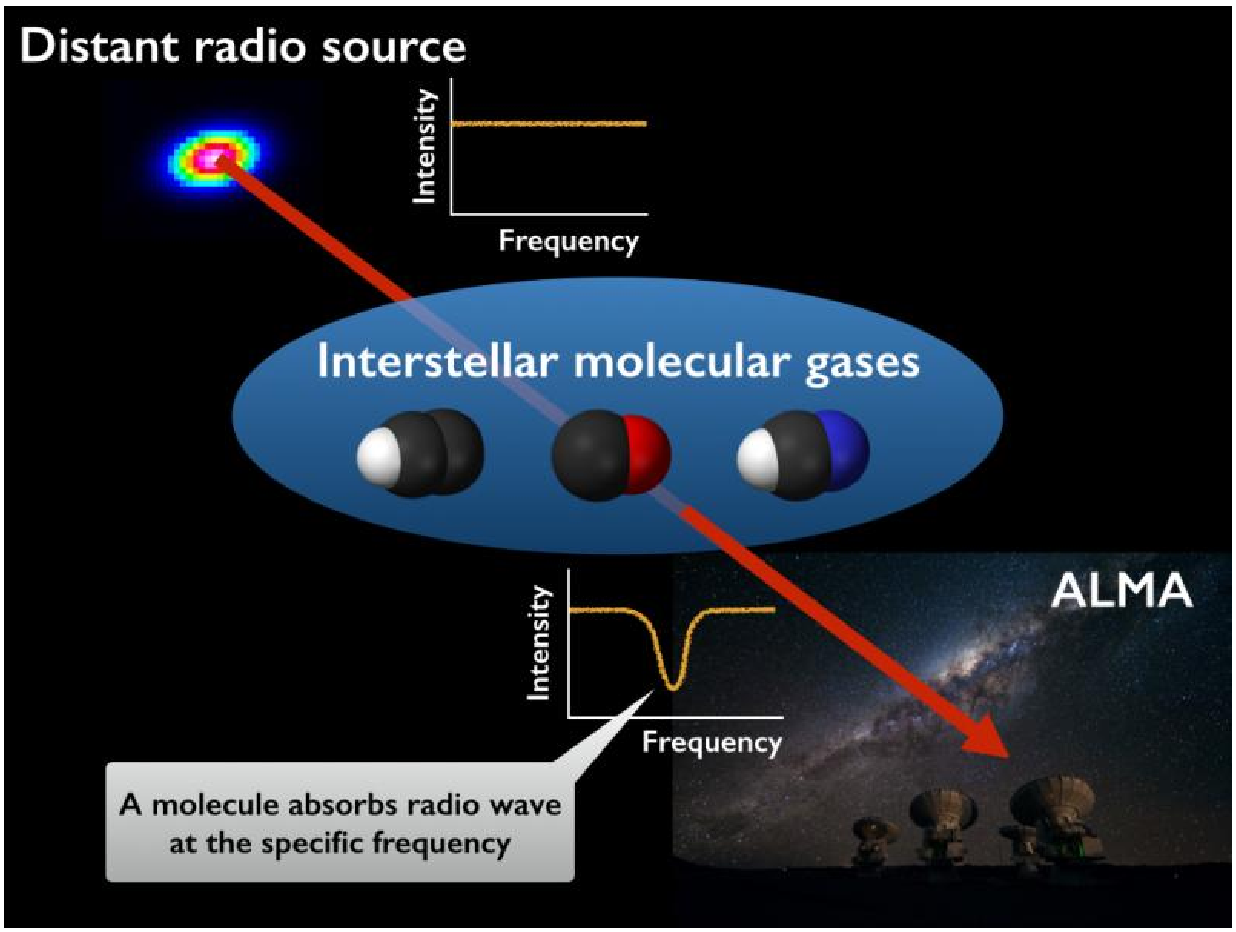


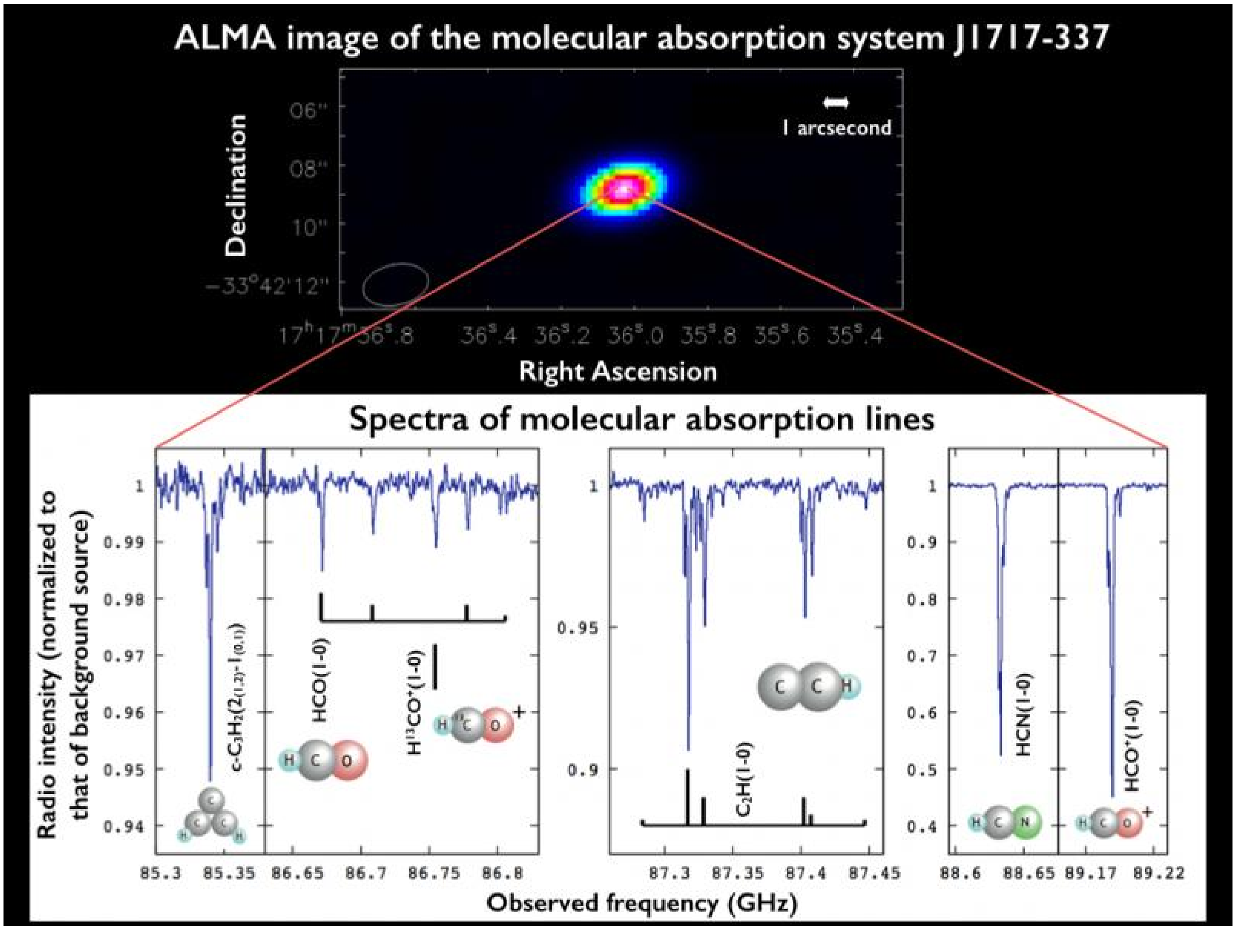
Calibrator sources have flat radio spectra. Molecules in the intervening gas clouds absorb radio waves at specific frequencies determined by the type of molecules. Credit: R. Ando (The University of Tokyo), ESO/José Francisco Salgado

Astronomers using the Atacama Large Millimeter/submillimeter Array (ALMA) have discovered the most tenuous molecular gas ever observed. They detected the absorption of radio waves by gas clouds in front of bright radio sources. This radio shadow revealed the composition and conditions of diffuse gas in the Milky Way galaxy.

To calibrate its systems, ALMA looks at objects emitting strong radio waves (radio 'bright' objects). On rare occasions, the signals from distant calibrator sources have specific radio frequencies absorbed out of them by foreground gas. This process is similar to how a piece of tinted glass casts a colored shadow when light passes through it. These absorption features contain valuable information about the intervening gas clouds which absorbed the radio signals. However, the number of known molecular absorption systems seen in millimeter/submillimeter waveband has been very limited: only about 30 in the Milky Way galaxy and a limited number in other galaxies.

To find more absorption systems, a research team including Ryo Ando (a graduate student at the University of Tokyo), Kotaro Kohno (a professor at the University of Tokyo), and Hiroshi Nagai (a project associate professor at the National Astronomical Observatory of Japan) collected the calibration data from the ALMA Data Archive.

By examining data from 36 calibrator sources, the team discovered three new absorption systems and confirmed one previously known system. For one calibrator source, J1717-337, they found absorptions caused by ten different molecules, such as C3H2, CS, and HCS+. In addition, the team found absorption signals caused by HCO molecules for two of the calibrator sources, J1717-337 and NRAO530. The HCO absorption signal is very rare; only three other examples are known in the Milky Way galaxy.

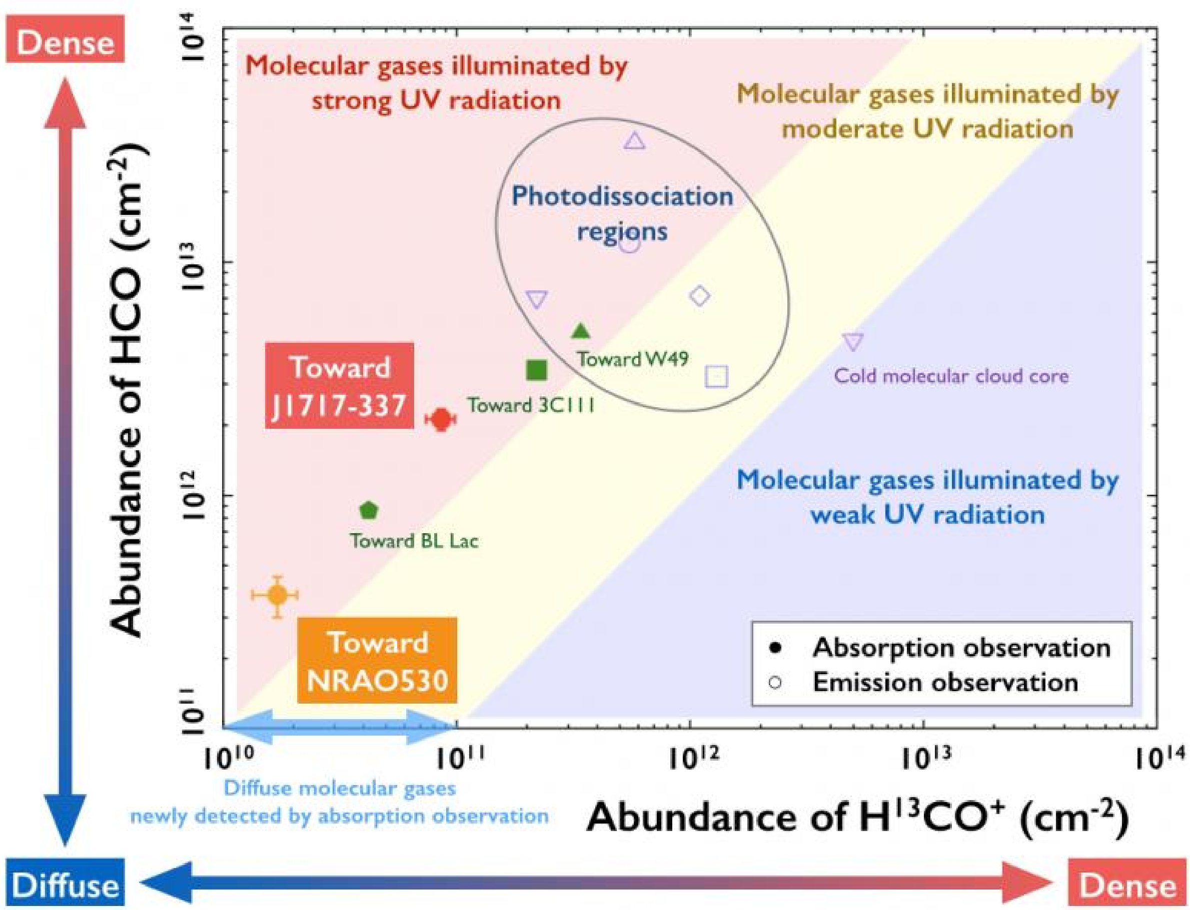


Thanks to its high sensitivity, ALMA detects many absorption lines caused by various molecules such as HCN and HCO+. Credit: ALMA (ESO/NAOJ/NRAO), R. Ando (The University of Tokyo)

Absorption systems allow researchers to investigate very tenuous gas clouds. A gas cloud too diffuse to emit sufficient radio waves to be detected can still absorb enough radio waves to produce a detectable radio shadow. The team estimated that the amount of HCO in the cloud backlit by NRAO530 is only half that of other known systems. This shows that it is one of the most diffuse gas clouds ever discovered in the Milky Way galaxy. Even though astronomers assume that tenuous gas clouds account for a considerable fraction of the total mass of the Milky

Way galaxy, very little is known about them.

The absorption signals help us determine the environment around the foreground gas clouds. HCO molecules are thought to be formed in special environments full of intense ultraviolet light from giant young stars. The diffuse gas clouds backlit by J1717-337 and NRAO530 show chemical composition similar to the gas in active star forming regions, indicating that the diffuse gas is bathed in strong ultraviolet light. Astronomers believe that ultraviolet light affects the properties of diffuse clouds. The HCO absorption systems found by ALMA provide an opportunity to verify that idea.



The HCO absorption lines in J1717-337 (red) and NRAO530 (orange) were detected for the first time by this research. For comparison, we plot the three previously known HCO absorption systems (green), five photo-dissociation regions (blue), and a cold molecular cloud core (purple). The abundances are shown in column density, which indicates the number of molecules integrated along the line of sight towards a source. The ratio of HCO to H13CO+ indicates the strength of the ultraviolet light. Credit: Credit: R. Ando (The University of Tokyo)

This research revaluates the importance of the ALMA calibration data. Usually the calibration data are considered supplementary, but this research shows that the calibration data themselves may contain significant scientific discoveries. The data for the more than 1000 calibration sources stored in the ALMA Data Archive are publicly available, and ALMA continues to take calibration data as part of normal observations. For astronomers, the Archive is a gold mine with the potential to yield more absorption systems or other unexpected mysteries of the universe.

More information: Ryo Ando et al. New detections of Galactic molecular absorption systems toward ALMA calibrator sources, *Publications of the Astronomical Society of Japan* (2015). DOI: 10.1093/pasj/psv110

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