Researchers create ultracold triatomic gas of high phase-space density

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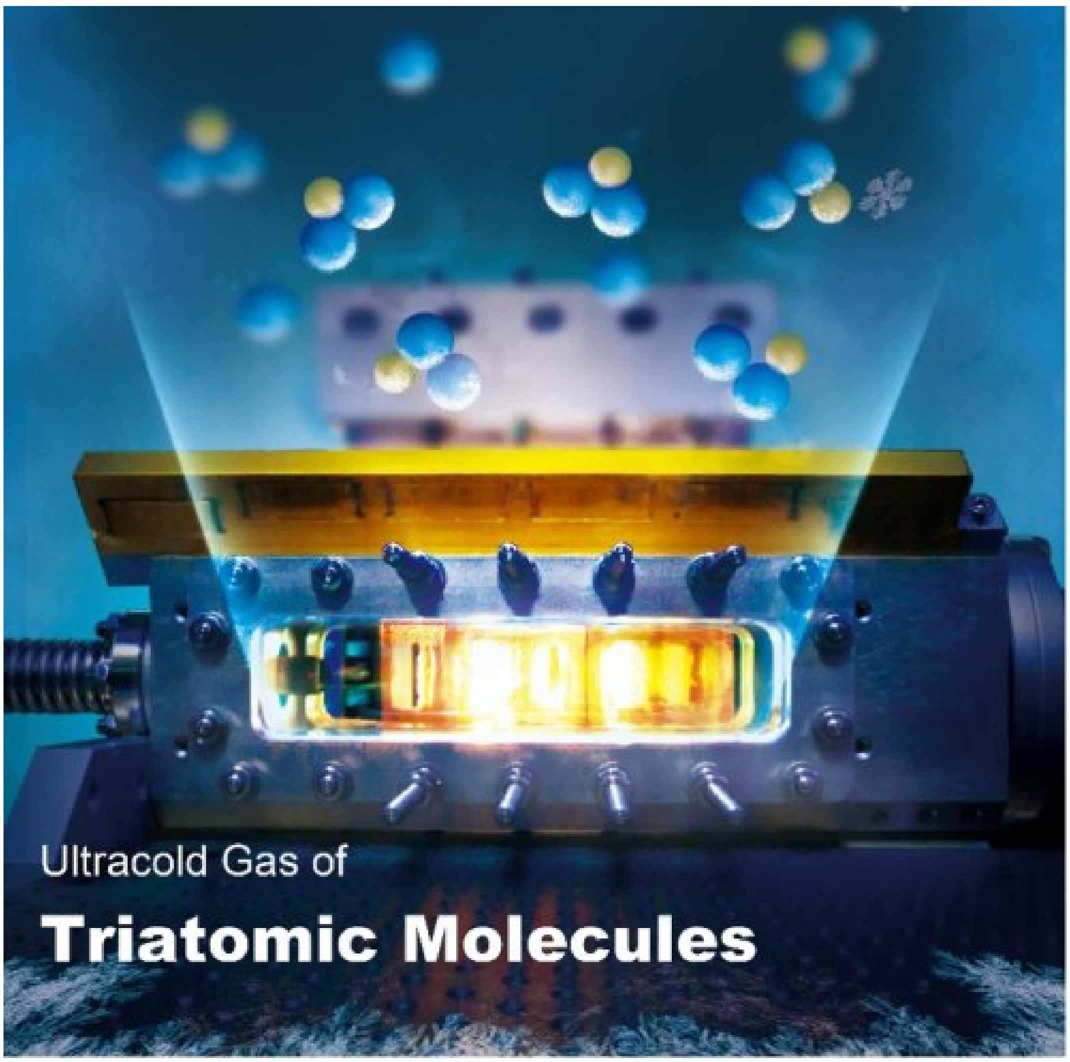

Creating ultracold gas of triatomic molecules through magneto-association. Credit: Prof. Pan Jianwei's team

Recently, a research team led by Prof. Pan Jianwei and Prof. Zhao Bo from the University of Science and Technology of China (USTC) of the Chinese Academy of Sciences (CAS), used adiabatic magneto-association to create an ultracold gas of triatomic molecules with high phase-space density from a degenerate mixture of $^{23}Na^{40}K$ molecules and ^{40}K atoms for the first time. This work was published in *Science*.

The use of highly controllable ultracold molecules in the simulation of complex chemical reactions allows for comprehensive study of complex systems. Direct cooling of ultracold molecules is challenging due to the complexity of the vibrational and rotational energy levels in molecules.

A method has been proposed for coherently converting ultracold atoms into ultracold molecules. Diatomic molecules, which benefit from high phase-space density and low temperature and can be coherently transferred to the ground state using a laser, have been created using the Feshbach resonance.

After successfully creating ultracold diatomic molecules, researchers have been discussing the possibility of using coherent conversion to produce ultracold triatomic molecules. In 2019, a team from USTC observed the Feshbach resonance between ultracold $^{23}Na^{40}K$ molecules and ^{40}K atoms.

Based on this, the association of ultracold triatomic molecules in the mixtures of $^{23}Na^{40}K$ molecules and ^{40}K atoms was accomplished using radio frequency pulses by researchers from USTC and the Institute of Chemistry of CAS. However, due to the short lifetime and low conversion efficiency of triatomic molecules, only evidence of association through the loss of diatomic molecules and atoms could be obtained.

To directly detect triatomic molecules, the researchers prepared a quantum degenerate mixture of $^{23}Na^{40}K$ ground-state molecules and ^{40}K atoms.

They created an ultracold triatomic molecular gas with high phase-space density for the first time by gradually increasing the magnetic field through a Feshbach resonance between $^{23}Na^{40}K$ molecules and ^{40}K atoms, which allowed them to adiabatically transfer the scattering state of $^{23}Na^{40}K$ molecules and ^{40}K atoms to the bound state of triatomic molecules.

In addition, the researchers dissociated triatomic molecules into free molecules and atoms through radio frequency (rf) dissociation, and acquired the dissociation spectrum of triatomic molecules, consequently realizing the direct detection of triatomic molecules. The results showed that the phase-space density of the obtained triatomic gas is about 10 orders of magnitudes higher than that of triatomic molecules created by other methods.

The creation of ultracold triatomic gases lays the foundation for the simulation of three-body study in quantum physics, and the high phase-space density enables the creation of Bose-Einstein condensates of triatomic molecules.

More information: Huan Yang et al, Creation of an ultracold gas of triatomic molecules from an atom–diatomic molecule mixture, *Science* (2022). DOI: 10.1126/science.ade6307

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