Scattering resonances between ultracold atoms and molecules observed for the first time

With the support by the National Natural Science Foundation of China, the National Key R&D Program of China, and the Chinese Academy of Sciences, the research team led by Prof. Pan JianWei (潘建伟) and Prof. Zhao Bo (赵博) at the University of Science and Technology of China have successfully observed scattering resonances between atoms and molecules at ultralow temperatures, shedding light on the quantum nature of atom-molecule interactions. This work was published in *Science* (2019, 363: 261—264).

Quantum computation and quantum simulation holds the promise to solve the hard problems that classical computers cannot solve efficiently. In the research field of chemical physics, calculating the atom-molecule or molecule-molecule interaction potential energy surface and simulating the collisional dynamics under these potential energy surfaces belong to this kind of problem. In theory, describing the potential energy surface requires solving the Schrödinger equation involving many electrons and nuclei, which is notoriously difficult due to the electron correlations. Many powerful numerical methods have been developed to calculate the potential energy surface. These methods are very successful in calculating the potential energy face of the small molecule system. However, for heavy molecules with many electrons, the theory cannot give a reliable potential energy surface that can be used to simulate the collision and reaction dynamics.

The important information of the potential energy surface may be obtained by measuring the scattering resonances between atoms and molecules. The scattering resonances are the most accurate and global probe of the potential energy surface, which can be used to construct an empirical model of the potential energy surface. However, scattering resonances are a quantum phenomenon, which will manifest itself at ultracold temperatures. In recent years, with the development of ultracold atoms and ultracold molecules, well-controlled molecules can be prepared by assembling ultracold atoms. However, observing the scattering resonances in these molecule systems remains challenging. The research team at the University of Science and Technology of China prepare the ultracold $^{23}Na^{40}K$ molecules in the rovibrational ground state and mix them with the ^{40}K atoms. By tuning the magnetic field, they vary the energy differences between the trimer bound states and the atom-molecule scattering state. They successfully observed 11 resonantly enhanced loss features in the molecule loss spectrum. These resonances provide important information of the short-range portion of the potential energy surface between $^{23}Na^{40}K$ and ^{40}K, which contains 49 electrons and 3 nuclei and thus is too complex to be calculated.

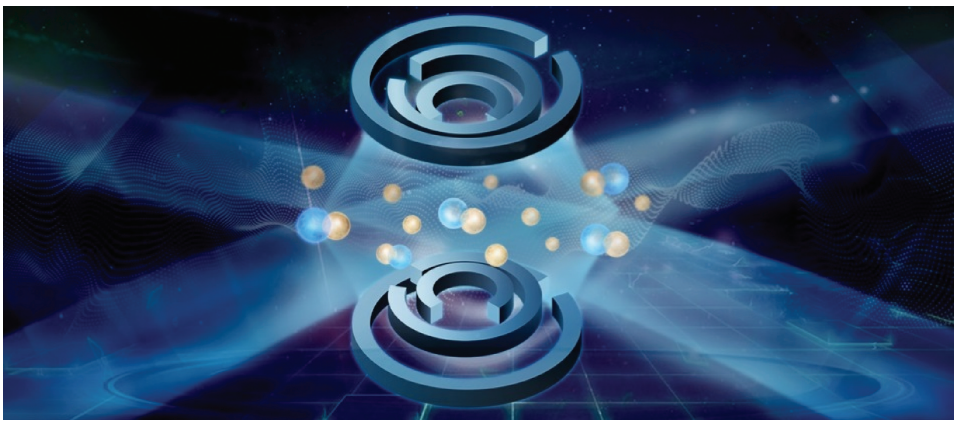

Figure Illustration of magnetically tunable atom-molecule scattering resonances.