# Observation of the Efimov state of the helium trimer



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# Observation of the Efimov state of the helium trimer

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**Synopsis** We report experimental observation of the long predicted but experimentally elusive Efimov state of $^4$He trimer by means of Coulomb explosion imaging. We show spatial images of an Efimov state, confirming the predicted size and a typical structure where two atoms are close to each other while the third is far away.

In 1970 Vitali Efimov predicted remarkable counterintuitive behavior of a three-body system made up of identical bosons. Namely, a *weakening* of pair interaction in such a system brings about in the limit appearance of *infinite* number of bound states of a huge spatial extent [1]. The helium trimer has been predicted to be a molecular system having an excited state of the Efimov character under natural conditions without artificial tuning of the attraction between particles by an external field. Though many theoretical works predict the existence of this state in the helium trimer, it has not been observed experimentally so far. Main reasons for that are the tiny binding energy and a huge spatial extent that makes it fragile for preparation and elusive for detection.

Here we report experimental observation of the Efimov state of $^4He_3$ by means of Coulomb explosion imaging of mass-selected clusters. Helium trimers were prepared under supersonic expansion of the gaseous helium through a 5 μm nozzle. The clusters were selected from the molecular beam by means of matter wave diffraction [2]. Each atom of a trimer was singly ionized by a strong ultrashort laser field resulting in Coulomb explosion of the cluster. The momenta, the ions acquired during Coulomb explosion, were measured by COLTRIMS. These momenta were utilized for reconstruction of the initial spatial geometry of the neutral trimer at the instant of ionization using Newton's equation of motion.

The spatial extent of the excited Efimov state of the $^4He_3$ (Figure 1A) is about eight times larger than that of the ground state (Figure 1B). Whereas the ground state corresponds to an almost randomly distributed cloud of particles [3], the excited Efimov state is dominated by configurations in which two atoms are close to each other and the third one further away (Figure 1C).

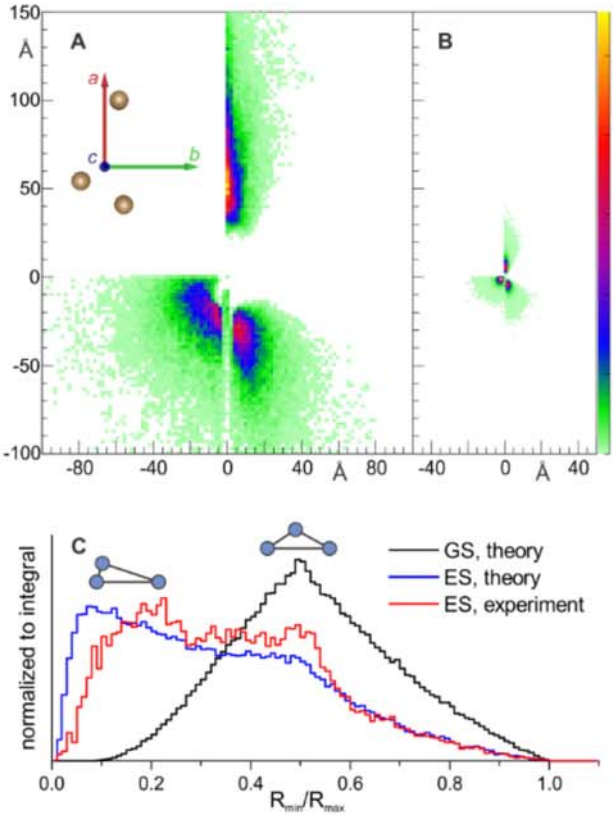


**Figure 1.** Structures of the helium trimer: A – excited state, experimental, B – ground state, theoretical. Three helium atoms of each trimer are plotted in the principal axis frame *abc*. C: Distributions of the ratio of the shortest interparticle distance to the longest interparticle distance for ground state structures (black), theoretical excited state structures (blue) and experimental excited state structures (red).

## References

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[3] J. Voigtsberger *et al* 2014 *Nat. Comm.* **5** 5765

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