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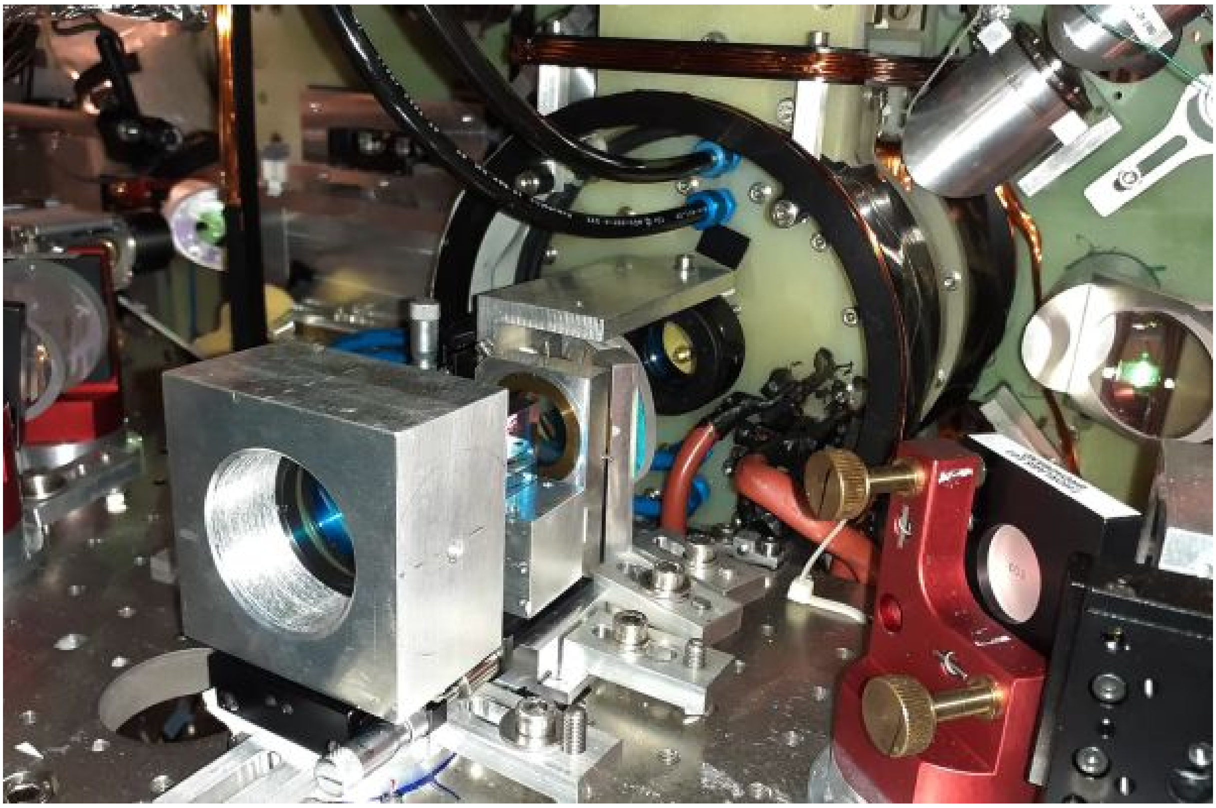

Lattice geometry gives rise to anomalous fluctuations in Bose-Einstein condensates

Fluctuations lie at the core of our universe, from thermal phase transitions to cosmic evolution. Scientists study these fluctuations using Bose-Einstein condensates (BECs), in which the number of atoms in the condensate naturally fluctuates over time.
In a new Physical Review Letters study, ICFO researchers and collaborators have investigated, for the first time, the particle-number fluctuations in a BEC placed in a triangular optical lattice. Combining theoretical modelling and experimental measurements, the team has observed strongly anomalous fluctuations and demonstrated the central role of lattice geometry. These results deepen our understanding of atom-number fluctuations in BECs.

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Fluctuations are central for physical systems, driving phase transitions and limiting control of quantum systems. It is therefore not surprising that scientists are so interested in studying such fluctuations. One of the most suitable platforms is atomic Bose-Einstein condensates (BECs), where a large number of atoms occupy the lowest-energy state and naturally exhibit intriguing fluctuations.

A recent article in Physical Review Letters reports the first investigation of particle-number fluctuations in **a BEC embedded in an optical lattice**. By combining the theoretical expertise of Donostia International Physics Center in San Sebastian Spain, Adam Mickiewicz University in Poznan Poland and ICFO researchers **Dr. Zahra Jalali-Mola** and **Dr. Utso Bhattacharya**, led by **ICREA Prof. Maciej Lewenstein**, with the experimental support of the University of Hamburg and TU Dortmund University in Germany, the team observed **strongly anomalous fluctuations in the condensate's number of atoms**, while also revealing that **the confinement in a lattice deeply influences such fluctuations**.

Unlike previous work on continuous BECs, where the atoms move freely within a harmonic trap, the current study traps the atoms at discrete sites forming a triangular pattern through an optical lattice. The lattice is combined with a 3D harmonic potential, which confines the atoms in each site into elongated, tube-like regions. ï¿½This geometry alters the way ato
s move and interact, leading to an unusual scaling of fluctuations with the total partic
e number,ï¿½ states Prof. Christof Weitenberg from TU Dortmund University, lead author of
the arti
le. To observe this effect, the experimentalists cooled, trapped, and loaded rubidium atoms
nto the lattice. By varying temperature and initial atom number, they monitored the p
ase transition from a normal gas to a BEC. They then used matter-wave microscopy to image
the condensate and subsequently determine atom number, temperature, and conden
ate fraction. In parallel, ICFO, Donostia International Physics Center and Adam Mickie
icz University led the theoretical effort, performing numerical simulations that combined
two different frameworks, and whose results closely matched the experimental observati
ns. According to first author Dr. Zahra Jalali-Mola, ï¿½these results substantially advan
e our understanding of the role of interactions and trap geometry on the cond
nsate fluctuations.ï¿½ This brings us one step closer to reveal new quantum m
ny-body phenomena in lattice systems and, in the long-term, could enable applications in
quantum me

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Zahra Jalali-Mola, et. al., Anomalous fluctuations of Bose-Einstein condensates in optical lattices, Phys. Rev. Lett. **136**, 083401 (2026)

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