Quantum noise reduction method for enhanced precision in atomic clocks

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Noise: it affects us all by distracting us. Noise also occurs at the quantum scale and can e.g. interfere with the measurements of atomic fountain clocks or with quantum information processing. This is because at that scale, there are effects that don't exist at larger scales. As such, finding ways to reduce quantum noise can enhance the precision of measurement in the examples given above. Now a team of physicists including Aranya Bhattacherjee from Jawaharlal Nehru University, New Delhi, India and colleagues are investigating ways of improving the analysis of quantum noise measurement in the case of spectroscopic investigations; their preliminary findings were released in a study in *EPJ D*.

This method, called atomic spin squeezing, works by redistributing the uncertainty unevenly between two components of spin in these measurements systems, which operate at the quantum scale. The spin represents a degree of freedom of the quantum particles involved. Thus, the spin component with reduced uncertainty becomes more precise in delivering its measurement - as the two are inversely correlated. Potential applications include the development of future quantum networks.

The quantum mechanical uncertainty of spin operators limits the measurement accuracy of spectroscopic investigations. Reducing the noise can help entangle two distant objects such as two atoms that are spatially separated. In this study, the authors develop a new approach that relies on spin squeezed states and is designed to accurately analyse the reduction of quantum noise in atomic systems associated with the spectroscopic measurements of atomic clocks.

Their method involves reducing the spin fluctuations in one spin component perpendicular to the mean spin direction below the standard quantum limit. Until recently, accurately describing such complicated systems could only be done using numerical simulations. They demonstrate that this new method yields better results than the existing analytical methods and matches extremely well with exact numerical techniques.

More information: Aranya Bhuti Bhattacherjee et al, Heisenberg operator approach for spin squeezing dynamics, *The European Physical Journal D* (2017). DOI: 10.1140/epjd/e2017-80534-6

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