How to win a coin game called atomic clock

If you flip a hundred coins, you are unlikely to get exactly fifty heads and fifty tails; there is a statistical uncertainty in the outcome. Researchers at MIT have reduced the statistical uncertainty in the quantum mechanical equivalent of a coin toss. This quantum mechanical coin toss is more than a game: its uncertainty limits the precision of one of the world's most sensitive measurement devices, the atomic clock. An atomic clock consists of tens of thousands of atoms, each of which can be in either of two states, much like a coin that can show either of two faces. Each atom is placed in a quantum superposition of the two states—each coin, as it were, suspended in mid-air with the potential to land on either face. The researchers at MIT use light to probe an ensemble of such atoms in a way that allows them to count how many atoms are "heads" without revealing the state of any individual atom—without disturbing the superposition. Thereafter, the laws of quantum mechanics demand that the count remain the same on any subsequent measurement. Thus, while each individual coin continues to tumble at random, the tumbling of the different coins is now choreographed: as one twists towards heads, another must turn towards tails. In the jargon of quantum mechanics, the states of the different atoms are now entangled. When one ultimately measures the states of the individual atoms—letting the coins land—the statistical uncertainty in the outcome is reduced. Just such a measurement is used to read out an atomic clock; if the clock is operated in an entangled state, its precision is no longer at the mercy of an ordinary coin toss.

References:

(1) *Implementation of Cavity Squeezing of a Collective Atomic Spin*. I.D. Leroux, M. Schleier-Smith, and V. Vuletic, Phys. Rev. Lett. **104**, 073602 (2010); selected as Editors' Suggestion.

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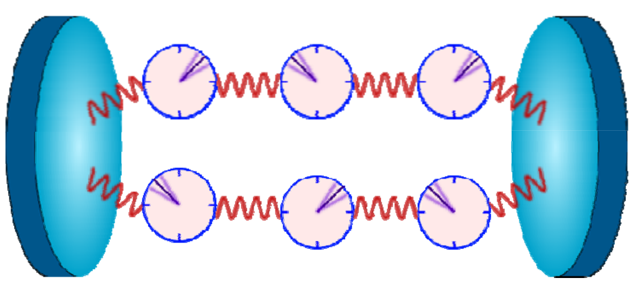
(3) *Squeezing the Collective Spin of a Dilute Atomic Ensemble by Cavity Feedback*. M. Schleier-Smith, I.D. Leroux, and V. Vuletic, Phys. Rev. A **81**, 021804(R) (2010).



The figure shows how distant atoms, operating as atomic clocks, can be coaxed into a collective state where there dials are correlated: For each clock being ahead when measured there is a clock being behind. The average reading of all clocks is more precise than if the clocks were not correlated. Light is used to synchronize the atoms, creating a kind of superatom which measures time more accurately than independent atoms.