Increasing atomic clock precision with and without entanglement

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The precision of an atomic clock based on the standard Ramsey spectroscopy, involving the measurement of the population of the atomic excited state, essentially a measurement of energy, is determined by the free evolution time T between successive s/2 pulses. The longer the time T, the narrower the Ramsey interference fringes and thus the greater the precision. The stability of an atomic clock is also increased with increased T. But there are practical limits to the degree to which T can be extended. The main approach so far has been through the introduction of the so-called atomic fountain clocks. In this talk we present alternative approach not based on extending T but based on collective atomic states where a non-classical observable, an observable having no classical counterpart, is to be measured. This is the collective atomic, or SU(2), parity for an ensemble of two-level atoms. We show that with this observable the corresponding Ramsey-like fringes can become remarkably narrower with an increasing number of atoms in the ensemble even when the atomics are not prepared in an entangled state. By preparing the atoms in an entangled state, such as a state known to be spin-squeezed, the precision can be further increased through atomic parity measurements. The issue of performing the required collective atomic parity measurements will be discussed.