Entanglement-assisted tests of general relativistic proper time

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The ability to control individual quantum systems at ever larger scales has opened the prospect to probe quantum theory on curved space-time. Here we show how entangled pairs of atoms can be used to probe time-dilation induced entanglement and interference modulation, a recently proposed effect at the interface between gravity and quantum physics[1,3]. Our protocol uses two atomic spin systems entangled over large distances by means of single photon emission and detection. Internal atomic levels implement a non-local quantum clock that evolves under different proper times between distant points in space. The effect is transferred onto photons which then interfere, producing an interference effect between the two different proper time evolutions. This effect can only be explained if both quantum theory and general relativity are taken into account. The proposed protocol based on entangled atoms opens the route for experimental verification even at km-scale separations.

References

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Figures

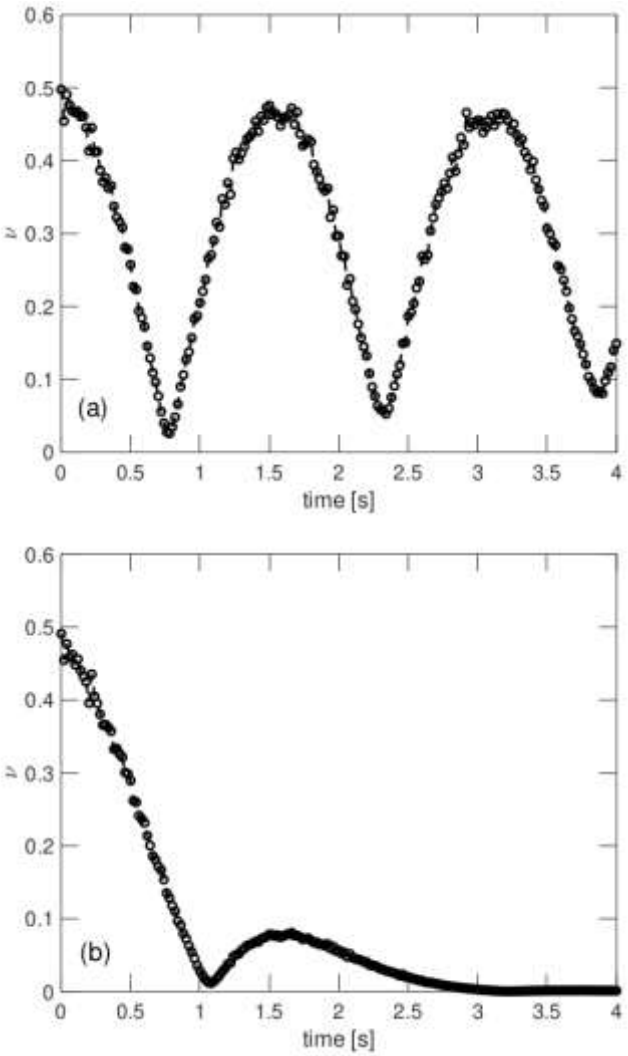

Figure 1: The visibility (v) as a function of the free evolution time for an implementation of the test with Ytterbium atoms (a) and NV-centers (b). The oscillations show the difference in proper time between the two atomic systems. (a) The separation between them in 10m, (b) the separation is 2000km.