Dark matter search with atomic clocks and GPS

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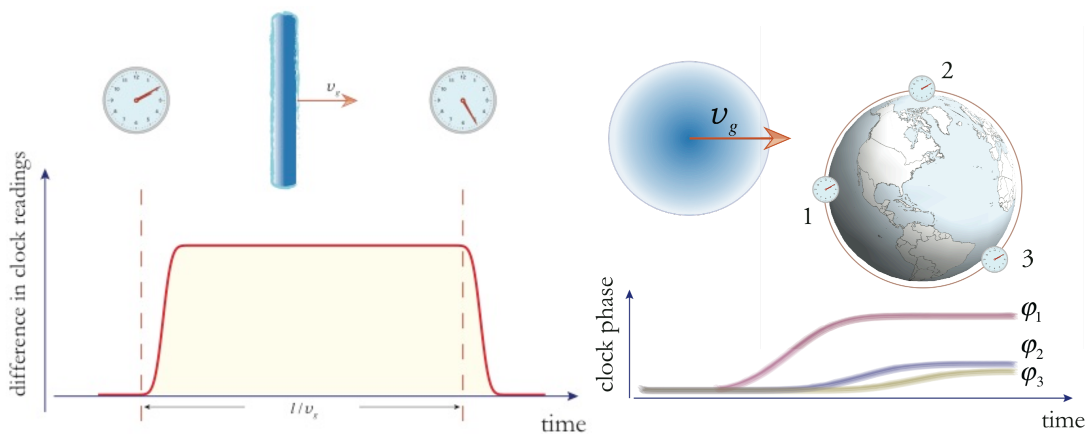
Atomic clocks are arguably the most accurate scientific instruments ever built. Modern clocks are astonishing timepieces guaranteed to keep time within a second over the age of the Universe. Attaining this accuracy requires that the quantum oscillator be well protected from environmental noise and perturbations well controlled and characterized. This opens intriguing prospects of using clocks to study subtle effects, and it is natural to ask if such accuracy can be harnessed for dark matter searches.



By monitoring correlated time discrepancy between two spatially separated clocks one could search for passage of topological defects (TD), such as the domain wall pictured here (left panel). Domain wall moves at galactic speeds ~ 300 km/s. Before the TD arrival, the two clocks are synchronized. As the TD sweeps through the first clock, it runs faster (or slower), with the clock time difference reaching the maximum value. Time difference stays at that level while the defect travels between the two clocks. Finally, as the defect sweeps through the second clock, clocks resynchronize. For intercontinental scale network, l~ 10,000 km, the characteristic time is 30 seconds. The right panel shows correlated response to a monopole TD.

The cosmological applications of atomic clocks so far have been limited to searches of the uniform-in-time drift of fundamental constants. We argue that a transient in time change of fundamental constants can be induced by dark matter objects that have large spatial extent, and are built from light non-Standard Model fields. The stability of this type of dark matter can be dictated by the topological reasons. A correlated network of atomic clocks (see figures), such as atomic clocks onboard satellites of the GPS constellation, can be used as a powerful tool to search for the topological defect dark matter. In other words, one could envision using GPS as a 50,000 km-aperture dark-matter detector.

[1] A. Derevianko and M. Pospelov, *Nature Phys. 10, 933 (2014)*, *arXiv:1311.1244*