Precise Measurements of s-wave Scattering Phase Shifts with a Juggling Atomic Clock

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In our juggling cesium fountain clock, we have demonstrated an interferometric scattering technique that allows highly precise measurements of s-wave scattering phase shifts.[1] We juggle atoms by launching two laser-cooled clouds in rapid succession. The atoms in one cloud are prepared in a coherent superposition of the two clock states and the atoms in the other cloud are prepared in one of the $|F, m\rangle$ ground states. When the two clouds collide, the clock states experience s-wave phase shifts as they scatter off of the atoms in the other cloud. When detecting only the scattered part of the clock atom's wavefunction, the relative phase of the clock coherence is shifted by the difference of the s-wave phase shifts for the clock states. In this way, we unambiguously observe the differences of scattering phase shifts. These phase shifts are independent of the atomic density to lowest order, which enables measurements of scattering phase shifts with atomic clock accuracy. Recently, we have observed the changes in scattering phase shifts as inelastic scattering channels open and close. An ensemble of measurements will accurately test and constrain our knowledge of cesium-cesium interactions. With such knowledge, future measurements using this technique could place stringent limits on the time variation of fundamental constants, such as the electron-proton mass ratio, by precisely probing scattering phase shifts near a Feshbach resonance. [2] An overview of the current limitations to the accuracy of atomic clocks will also be presented.

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[1] R. A. Hart, X. Xu, R. Legere, K. Gibble, Nature 446, 892-895 (2007).

[2] C. Chin, V. V. Flambaum, Phys. Rev. Lett. 96, 230801 (2006).