Observation of a periodic many-body system

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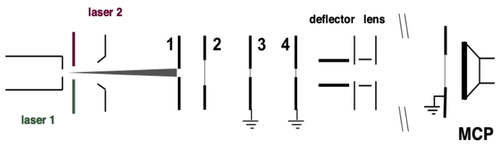
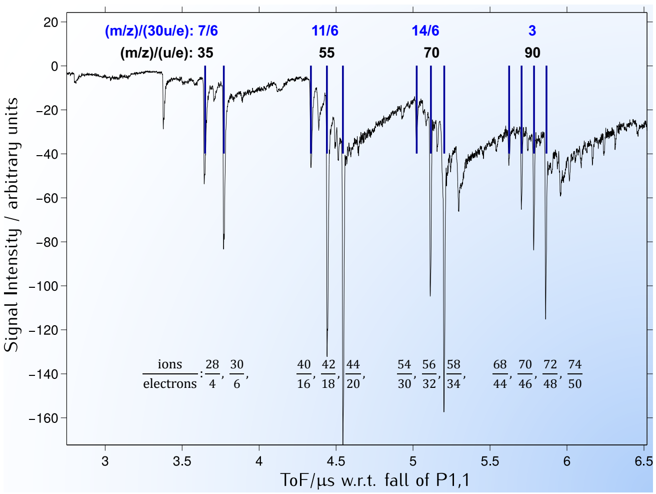
We report the experimental observation of a very striking periodicity in a many-body system--an ultra-cold plasma. A long life-time (>0.3 ms) *quantum degenerate* molecular Rydberg plasma is generated in the high-density region of a pulsed supersonic jet expansion by two-color resonant excitation of nitric oxide (10%) in neon (5bar) into the high-*n* Rydberg threshold region close to the ionization limit. For plasma densities of > 10^{16} cm^{-3} reached in our experiments the electrons should become quantum degenerate, *i.e.* the electron *de Broglie* wavelength becomes larger than the Wigner-Seitz radius *a* relevant to describe the mean distance between the particles.



The time-of-flight (ToF) mass spectrometer used is depicted in the *r.h.s.* figure. Experimentally, two synchronous UV laser pulses produce the plasma a few mm away from the jet nozzle. After 170μs, when the plasma cloud is still *ca.* 130mm in front of aperture plate 1 (ap.1), two successive high-voltage (HV) pulses of 3.6 kV with a 0.2μs gap are applied to ap.1. The first HV pulse (P1,1; length 5.5μs) is followed by a gap of 0.2μs and a second pulse: P1,2. The observed ToF spectrum *w.r.t.* the falling slope of P1,1 is shown in the *l.h.s.* figure (positive particle detection on MCP). The observed sharp peaks ("*slices*") in the ToF spectrum follow a strictly reproducible progression of (*m*/*z*) mass to charge ratios from 35 to 92.5 (blue: *w.r.t.* $m(NO^+)$ = 30u). From the *m*/*z* numbers one obtains the corresponding ion to electron ratios of the 12 slices (bottom of figure), from 7/1 to 37/25.



In conclusion, we observe a many-body system consisting of a series of objects that contain a magic number of ions and electrons for which the ion/electron ratio follows a periodicity. These objects are manipulated by fields in a ToF spectrometer without being destroyed, which shows that they behave as objects with a center of mass. The observation of such many-body states with periodic ion/electron ratios suggests a phase correlation and possibly quantum entanglement.

The path from *Structure* and *Phase* to *Quantum Entanglement* is of considerable interest in complex systems. Starting from the common textbook opinion that in many-electron atoms the electrons are entangled (a deeper reason for the periodic system of the elements), one can speculate that the observation of periodicity in the many-body system presented here might originate from quantum entanglement.