Precision Measurements with Trapped Ions

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<u>Internal quantum state control</u>
State preparation, detection and single-qubit gates with > 99.9% fidelity

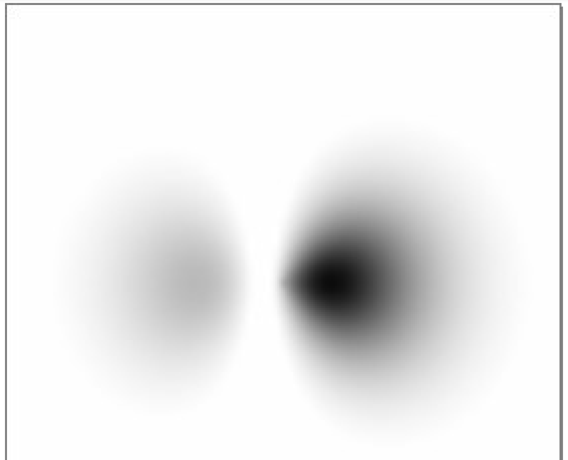
<u>Quantum-limited measurement precision</u>

<u>Long coherence times</u>
~ 10 s at optical frequencies
Q > 10^{16}

<u>Strong, switchable interactions</u>
2-qubit gates with >99.9% fidelity

<u>External quantum state control</u>
Cooling to the ground state of motion, heating rates ~ 1 quantum/s

Testing Fundamental Physics with Clocks



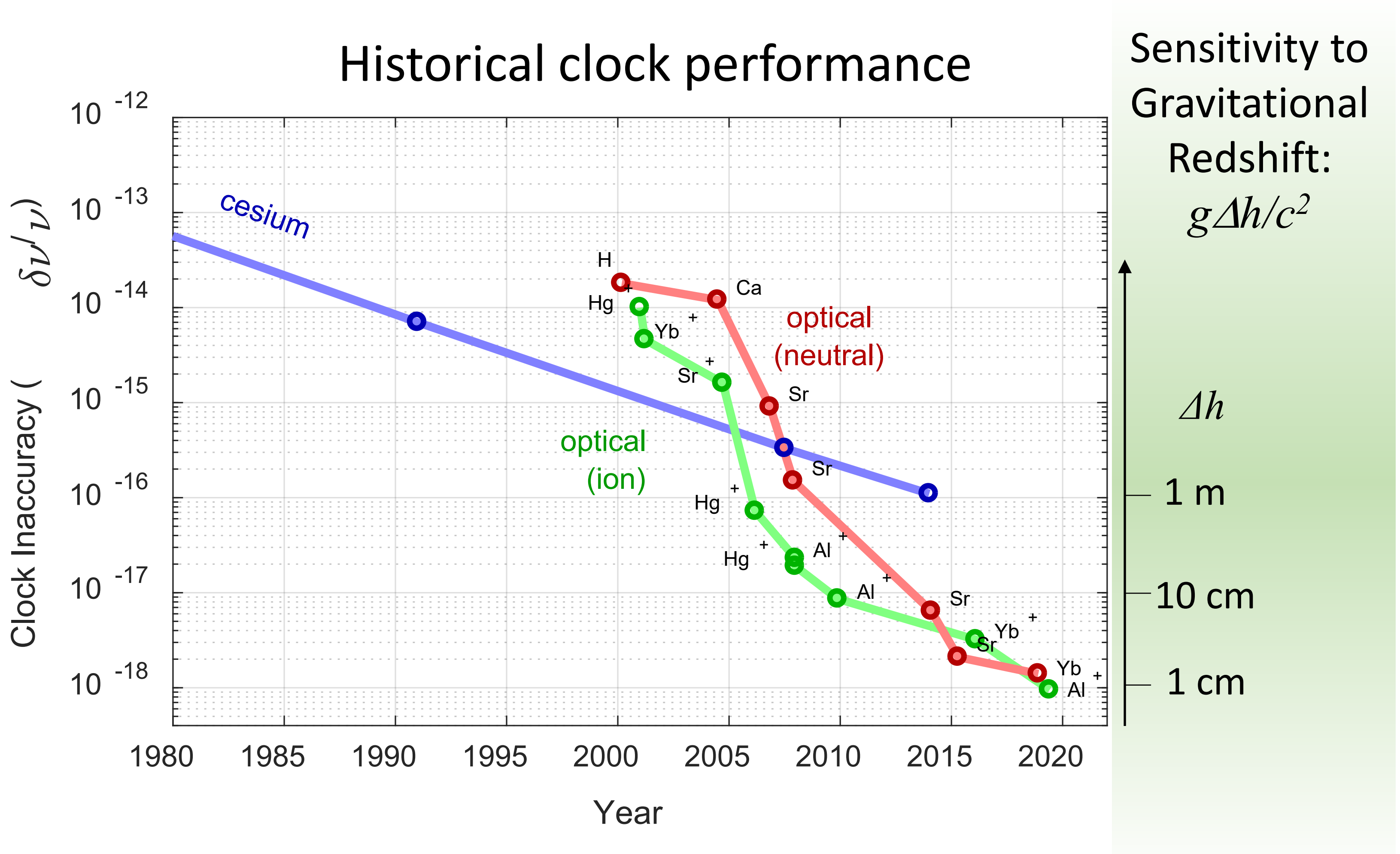
$$\Delta E = \hbar\omega$$

Relativistic effects

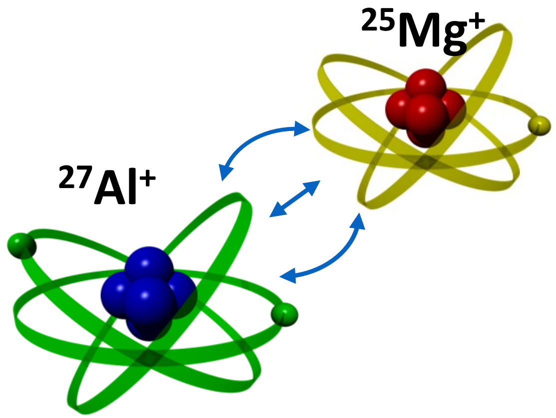
Fundamental Constants

Fundamental Symmetries

QED effects

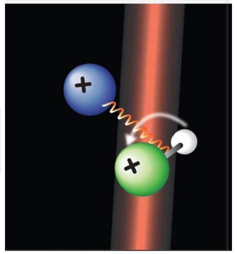


Quantum Logic Spectroscopy



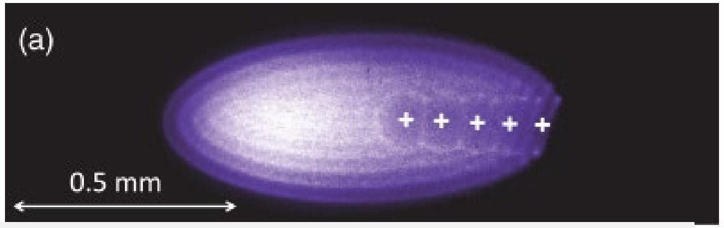
Other systems made accessible

Molecular ions, CaH^{+}

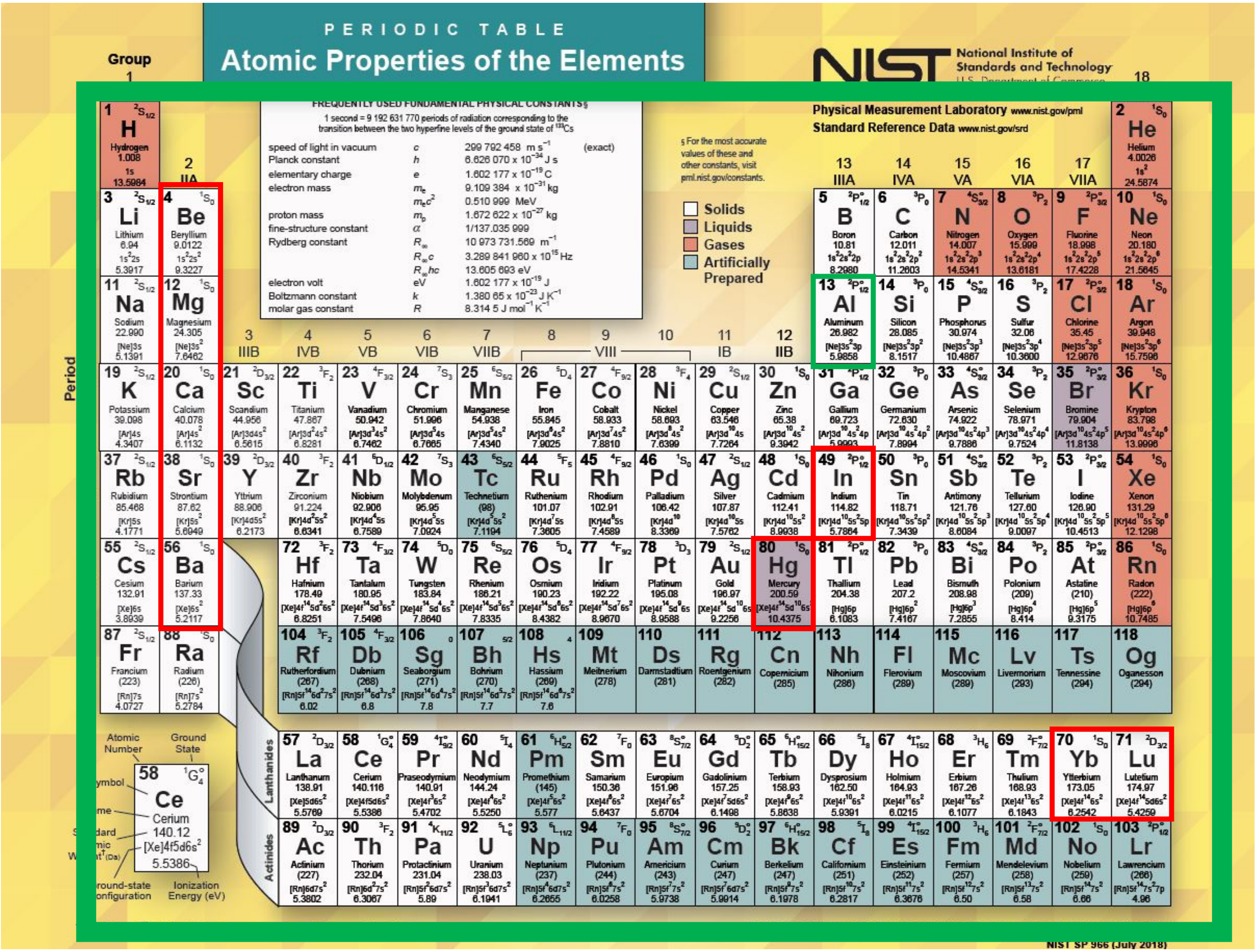


Chou et al., Nature **545**, 203 (2017)

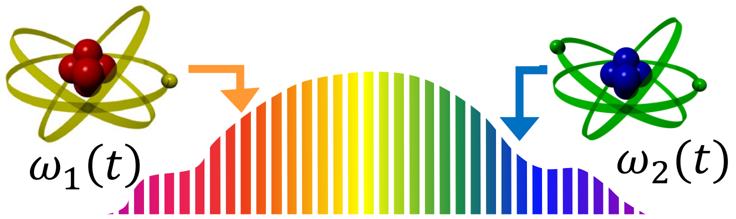
Highly-charged ions, Ar^{14+}



Schmoeger et al., Science **347**, 1233 (2015)



Searching for Ultralight Dark Matter

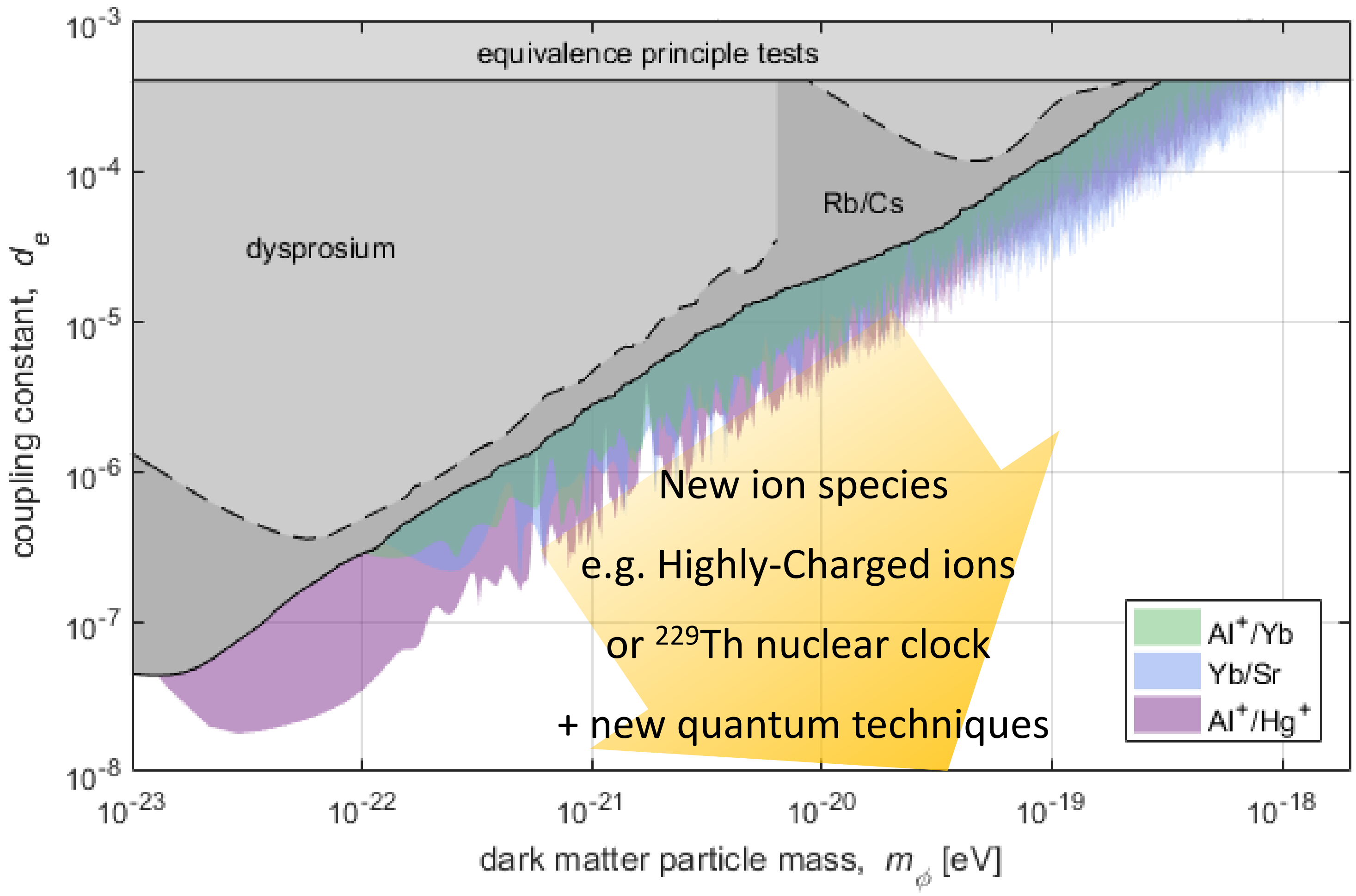


$$R(t) = \frac{\omega_1(t)}{\omega_2(t)}$$

Bosonic dark matter particles behave as a scalar field oscillating at the particle Compton frequency.

$$\omega_{DM} = \frac{m_\phi c^2}{\hbar}$$

Any coupling to SM fields would lead to an oscillation in the frequency ratio.



See also: **Tilburg et al., PRL 115, 011802 (2015)** and **Hees et al., PRL 117, 061301 (2016)**

Conclusions

- Trapped ions are a leading platform for atomic clocks and quantum computing.
- Quantum information technology has already had a profound impact on sensing applications, making this platform an interesting case study for quantum sensors.
- The precision and accuracy of atomic clocks coupled with their sensitivity to effects in fundamental physics make them useful in a variety of tests of the standard model.