**Invited talk**

# Precision Spectroscopy in Ion Coulomb Crystals and Search for New Physics

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Trapped and laser-cooled ions allow for a high degree of control of atomic quantum systems. They are the basis for modern atomic clocks, quantum computers and quantum simulators. In our research we use ion Coulomb crystals, i.e. many-body systems with complex dynamics, for precision spectroscopy. This paves the way to novel optical ion frequency standards with ultra-high stability and accuracy for applications such as relativistic geodesy and quantum simulators in which complex dynamics become accessible with atomic resolution.
On the other hand, the high precision obtained in the spectroscopy of trapped cold ions enables sensitive tests of the Standard Model and the search for new physics. The long-lived F-state of the $Yb^+$-ion has a high sensitivity to both relativistic and nuclear effects. We use isotope-shift spectroscopy as a sensitive probe for nuclear structure and fifth forces mediated by a new boson that couples to electrons and neutrons[1]. Deviations from a linear relation in the King-plot analysis can indicate new physics or higher-order SM effects. This powerful technique revealed large King-plot nonlinearities in Yb[2]. We present two-orders-of-magnitude improved spectroscopic measurements in all five stable spinless isotopes of this element. The transition frequency of the forbidden $^2S_{1/2}$ to $^2D_{5/2}$ and $^2S_{1/2}$ to $^2F_{7/2}$ transitions are determined with an accuracy of 6 and 16 Hz, respectively, yielding isotope shifts with a relative precision as low as $10^{-9}$. We combine these spectroscopic results with new mass measurements with a relative precision of a few $10^{-12}$. With this, we can extract a new bound on the mass and coupling strength of the potential new bosons. The results are also used to investigate higher-order nuclear structure effects along a chain of Yb isotopes. In combination with ab initio nuclear structure calculations, this provides a window to nuclear deformation and nuclear charge distributions along isotopic chains towards exotic, neutron-rich nuclei.

[1]J. C. Berengut *et al.*, 413 *Phys. Rev. Lett.* **120**, 091801 (2018)
[2]J. Hur *et al.*, *Phys. Rev. Lett.* **128**, 163201 (2022)