Q 61: Precision Spectroscopy VI - neutrals and ions (joint session A/Q)

Time: Thursday 14:00–16:00 Location: K 1.016

Invited Talk Q 61.1 Thu 14:00 K 1.016

News from the "Proton Radius Puzzle" — •Randolf Pohl — Johannes Gutenberg Universität Mainz

The *Proton Radius Puzzle* [1] is the 5 sigma discrepancy between the charge radius measured in muonic hydrogen [2] on the one hand, and in regular hydrogen and elastic electron scattering on the other [3]. I will report on several new measurements in muonic and electronic atoms, which have recently started to shed light on the discrepancy. These include measurements in muonic deuterium [4], helium-3 and helium-4, as well as a new measurement in regular hydrogen [5]. In the outlook, I will present ongoing and planned measurements of the CREMA Collaboration targeting the (magnetic) Zemach radius of the proton [6], and the charge radii of other light nuclei.

[1] J.C. Bernauer, R. Pohl, Spektrum der Wiss., April 2014
[2] A. Antognini et al., (CREMA Collab.), Science 339, 417 (2013)
[3] P. Mohr et al. (CODATA-2014), Rev. Mod. Phys. 88, 035009 (2016)
[4] R. Pohl et al., (CREMA Collab.), Science 353, 669 (2016)
[5] A. Beyer et al., Science 358, 79 (2017)
[6] R. Pohl et al., J. Phys. Soc. Japan Conf. Proc. 18, 011021 (2017)

Q 61.2 Thu 14:30 K 1.016

A Network Approach to Atomic Spectra — •David Wellnitz[1], Julian Heiss[1], Armin Kekić[1,2], Sebastian Lackner[3], Andreas Spitz[3], Michael Gertz[3], and Matthias Weidemüller[1,4] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]École Normale Supérieure, Paris, Frankreich — [3]Institut für Informatik, Im Neuenheimer Feld 205, 69120 Heidelberg, Germany — [4]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

We demonstrate a network-inspired approach for treating atomic spectroscopy data. Nodes of the network represent states, while links represent transitions between them. We find that such spectroscopic networks exhibit an anti-community structure, microscopically characterized by equal quantum numbers of the electronic angular momentum. Using state-of-the-art methods for link prediction, transitions missing in the data can be identified without having to rely upon a microscopic model of the atom. We apply our methods to spectroscopic networks of hydrogen, helium and iron. Implications of our network approach for understanding complex atomic structure are discussed.

Q 61.3 Thu 14:45 K 1.016

Analytical methods for the extraction of an ionization potential from dense atomic spectra — •Pascal Naubereit, Reinhard Heinke, Dominik Studer, Marcel Trümper, and Klaus Wendt — Institut für Physik, Johannes Gutenberg-Universität Mainz, D-55128 Mainz, Germany

Complex atomic structures can exhibit intrinsic quantum chaotical behavior. Correspondingly, this prevents a clear identification and assignment of energy levels. However, for the determination of the ionization potential applying e.g. resonance ionization spectroscopy, the convergence of Rydberg series is the most precise direct measurement method. If the possibility to directly allocate and identify a series of Rydberg levels amongst hundreds of other resonances is not available, one may rely on more comprehensive analytical investigation methods for these atomic spectra. In this presentation, several approaches to extract a value for an unknown ionization potential from highly dense atomic spectra are compared. In addition, the applicability of the methods to atomic systems of increasing complexity, namely sodium, holmium, promethium and protactinium, is examined.

Q 61.4 Thu 15:00 K 1.016

Laser spectroscopy on the radioactive element promethium — •Dominik Studer[1], Holger Dorrer[2], Carlos Guerrero[3], Stephan Heinitz[4], Reinhard Heinke[1], Pascal Naubereit[1], Sebastian Raeder[5], Dorothea Schumann[4], and Klaus Wendt[1] — [1]Institut für Physik, JGU Mainz, Germany — [2]Institut für Kernchemie, JGU Mainz, Germany — [3]Universidad de Sevilla, Spain — [4]PSI, Villigen, Switzerland — [5]Helmholtz Institut Mainz, Germany

Promethium ($Z = 61$) is an exclusively radioactive element with short half-lives of up to 17 years. Consequently, Pm sample amounts that can be safely handled in laboratories are small and data on atomic transitions is scarce. Apart from the heavy actinides and transactinides, Pm is the last element where the first ionization potential (IP) has not been directly measured until now.

Here we present the results from resonance ionization spectroscopy of ^{147}Pm ($t_{1/2} = 2.6$ y) in a hot cavity laser ion source. More than 1000 new optical transitions were recorded in the spectral ranges from 415 - 470 nm and 800 - 910 nm using pulsed Ti:sapphire lasers. Although a straightforward analysis of Rydberg convergences was prevented by complex spectra for high excitation energies, the IP could be determined with a precision of better than 1 cm^{-1} by measuring the electric field ionization threshold for several weakly bound states. Finally the hyperfine structure of two subsequent transitions in a newly developed RIS scheme was measured with experimental linewidths of $\approx$ 120 MHz as preparation for the extraction of nuclear structure parameters in on-line spectroscopy experiments on short-lived Pm isotopes.

Q 61.5 Thu 15:15 K 1.016

Spectroscopy of the $6S_{1/2} \to 5D_{5/2}$ electric quadrupole transition of atomic cesium — •Sebastian Pucher, Alexandre Dareau, Philipp Schneeweiss, and Arno Rauschenbeutel — VCQ, TU Wien – Atominstitut, Stadionallee 2, 1020 Wien, Austria

The $6S_{1/2} \to 5D_{5/2}$ electric quadrupole transition of cesium is studied experimentally via Doppler-free spectroscopy in hot vapor. The hyperfine structure of this transition is resolved, and the line intensities and optical pumping dynamics are analyzed. In an additional experiment, the lifetime of the $5D_{5/2}$ state is determined by recording the fluorescence light associated to the decay of atoms from the intermediate $6P_{3/2}$ state to the electronic ground state, in excellent agreement with literature values. Based on these results, we plan future experiments with laser-cooled atoms close to surfaces, e.g., in order to enhance the quadrupole coupling.

Q 61.6 Thu 15:30 K 1.016

Absolute Quantum Gravimeter: an autonomous and mobile atom interferometer operating at the 1E-10 level of stability over months to support Geosciences — •Jean Lautier Gaud, Vincent Ménoret, Pierre Vermeulen, and Bruno Desruelle — Muquans, Talence, France

This paper reports recent remarkable achievements of cold-atom technologies and related operational devices in the area of Quantum Sensing and Metrology which occurred at Muquans in 2017. We will present in detail the status of the Absolute Quantum Gravimeter (AQG) that has left the laboratory for geophysical studies. The AQG is an industry-grade commercial gravity sensor which today meets the objective to provide a gravimeter based on atom interferometry with laser-cooled atoms as a mobile turn-key device. We report on an operational stability of the absolute measurements of g at the 1E-10 level in various types of environment during month-long continuous acquisition periods. The first unit of the AQG has traveled more than 7000 km, so we will comment on the last measurement campaigns and comparisons performed by the AQG. These have in particular validated the repeatability of the measurements at the 1E-9 level, the ease of use and the robustness of such technology. This paper will also be the occasion to describe in more details the high degree of maturity of several key enabling technologies such as intelligent integrated laser systems that can help Quantum Technologies with cold atoms taking-off for a wider range of applications in Quantum Computing, Quantum Simulation and Quantum Communication.

Q 61.7 Thu 15:45 K 1.016

Ba^+ Isotope shift studies in preparation of atomic parity violation measurement — •Nivedya Valappol[1], Elwin Dijck[1], Aswin Hofsteenge[1], Olivier Grasdijk[1], Amita Mohanty[2], Mayerlin Portela[3], Lorenz Willmann[1], and Klaus Jungmann[1] — [1]Van Swinderen Institute, FSE, University of Groningen, The Netherlands — [2]NISER, Bhubaneswar, India — [3]Laboratorio de Òptica Cuàntica, Universidad de los Andes, Bogotà D.C., Colombia

The Ba^+ ion, has a structure of spectral lines similar to heavy single valence electron alkali atoms. It is precisely studied by laser spectroscopy in presence of several light fields in order to prepare for a measurement of atomic parity violation (APV). Measurements in heavy alkali earth ions (e.g. Ba^+ and Ra^+) permit the precise determination of the weak mixing (Weinberg) angle $\sin^2\theta_W$ with improvement over the previous best measurement in neutral Cs by a factor of 5 in a week of actual measurement time. The transition frequencies for the $6s^2S_{1/2}$ - $6p^2P_{1/2}$, $6p^2P_{1/2}$ - $5d^2D_{3/2}$ and $6s^2S_{1/2}$ - $5d^2D_{3/2}$ transitions in $^{138}Ba^+$ have been measured to 10^{-10} relative accuracy employing a line shape model for single ions in a radio frequency Paul trap [1]. These measurements have been extended to $^{134,136}Ba^+$. Together with a determination of the lifetime of the excited $5d^2D_{5/2}$ state these measurements provide for a stringent test of calculations, the accuracy of which is pivotal for a determination of $\sin^2\theta_W$. The observed lifetime is 25.8(5)s. Being about 5s shorter than previous measurements and calculations agreeing with them, it provides for a puzzle.

[1] E. A. Dijck et al., Phy. Rev. A 91, 060501(R)(2015)