Symposium Variations of Fundamental Constants: Theory and Experiment (SYFC)*

jointly organized by
the Quantum Optics and Photonics Division (Q) and
the Atomic Physics Division (A)

*supported by the cluster of excellence "Centre for Quantum Engineering and Space-Time Reasearch" (QUEST)

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Overview of Talks and Sessions

(lecture room A 001)

Talks

SYFC 1.1	Mo	14:00–14:30	A 001	**Fundamental constants, gravitation and cosmology** — •Jean-Philippe Uzan
SYFC 1.2	Mo	14:30–15:00	A 001	**Molecular hydrogen in the lab and in the early universe; search for varying mu** — •Wim Ubachs
SYFC 1.3	Mo	15:00–15:30	A 001	**Stability of the proton-to-electron mass ratio tested with molecular spectroscopy using an optical link to frequency reference** — •Anne Amy-Klein, Alexander Shelkovnikov, Robert J. Butcher, Olivier Lopez, Christophe Daussy, Haifeng Jiang, Fabien Kéfélian, Giorgio Santarelli, Christian Chardonnet
SYFC 1.4	Mo	15:30–16:00	A 001	**Optical clocks with trapped ions and the search for variations of fundamental constants** — •Ekkehard Peik
SYFC 2.1	Mo	16:30–17:00	A 001	**Gravitational and cosmological probes of varying fundamental parameters** — •Thomas Dent
SYFC 2.2	Mo	17:00–17:30	A 001	**The astrophysical search for varying fundamental constants** — •Nils Prause
SYFC 2.3	Mo	17:30–17:45	A 001	**Variability of the proton-to-electron mass ratio on cosmological scales - quantification and handling of systematics** — •Martin Wendt
SYFC 2.4	Mo	17:45–18:00	A 001	**Towards Direct Frequency Comb Spectroscopy of Metal Ions** — •Boerge Hemmerling, Daniel Nigg, Ivan V. Sherstov, Piet O. Schmidt

Sessions

SYFC 1.1–1.4	Mo	14:00–16:00	A 001	**Variations of Fundamental Constants I**
SYFC 2.1–2.4	Mo	16:30–18:00	A 001	**Variations of Fundamental Constants II**

SYFC 1: Variations of Fundamental Constants I

Time: Monday 14:00–16:00 Location: A 001

Invited Talk SYFC 1.1 Mo 14:00 A 001
Fundamental constants, gravitation and cosmology — •Jean-Philippe Uzan — Institut d'Astrophysique de Paris, 98 bis bd Arago, 75014 Paris (France)

The tests of the constancy of fundamental constants is a test of Einstein equivalence principle, and thus of general relativity. This talk will summarize the links between the constants and general relativity and higlights the necessity of such tests focusing on cosmology. Some new results concerning the effects of the variations of fundamental constants on stellar evolution will also be mentioned.

Invited Talk SYFC 1.2 Mo 14:30 A 001
Molecular hydrogen in the lab and in the early universe; search for varying mu — •Wim Ubachs — Laser Centre VU University, Amsterdam, Netherlands

Variation of the proton-to-electron mass ratio (mu) can be assessed by comparing spectra obtained at zero redshift (in the laboratory) and similar spectra at high red-shift observed at large telescopes equipped with high-resolution spectrographs. We have performed accurate calibration measurements of H_2 and HD lines by laser-based and Fourier-transform spectroscopic methods to result in accuracies of 5×10^{-9}. Recently we made observations of a single object, the J2123 absorbing cloud at z=2.05 via the Keck-Hires system (Hawaii) and the VLT-UVES system (Paranal Chili) to derive a new constraint on a possible variation of mu. The analysis includes, for the first time, also lines of the deuterated HD molecule besides H_2.

Invited Talk SYFC 1.3 Mo 15:00 A 001
Stability of the proton-to-electron mass ratio tested with molecular spectroscopy using an optical link to frequency reference — •Anne Amy-Klein[1], Alexander Shelkovnikov[1,3], Robert J. Butcher[1,4], Olivier Lopez[1], Christophe Daussy[1], Haifeng Jiang[2], Fabien Kéfélian[1], Giorgio Santarelli[2], and Christian Chardonnet[1] — [1]LPL, CNRS, Université Paris 13, Villetaneuse, France — [2]LNE-SYRTE, Observatoire de Paris, CNRS, UPMC, France — [3]Lebedev Physical Institute, Moscow, Russia — [4]The Cavendish Laboratory, Cambridge, UK

Time and frequency metrology has experienced a lot of developments since ten years leading to the possibility of many fundamental tests of physics, as, for example, the search for a temporal variation of fundamental constants. However these tests are limited to macroscopic resonators or atomic systems while molecular systems are still difficult to probe with a high sensitivity, since experiments on molecules lacks of absolute frequency measurements set-ups. In that context, we have developed an optical link between our lab and the LNE-SYRTE, which allows us to benefit from their frequency references. Using this link, we performed the first experimental comparison of a molecular clock to an atomic clock, which gives a direct line to the proton-to-electron mass ratio stability. Recently, we extended the frequency dissemination technique to non-dedicated fibers of the telecommunication network simultaneously carrying digital data from the Internet traffic. This is very challenging for the development of transcontinental atomic and molecular clocks comparisons.

Invited Talk SYFC 1.4 Mo 15:30 A 001
Optical clocks with trapped ions and the search for variations of fundamental constants — •Ekkehard Peik — Physikalisch-Technische Bundesanstalt, 38116 Braunschweig

Optical clocks with laser-cooled trapped ions have now reached an accuracy that surpasses those of the best atomic clocks in the microwave domain. The comparison of different optical transition frequencies over time can be used in a laboratory search for a possible time dependence of the fine structure constant α. We investigate two reference transitions with very low natural linewidths that are promising candidates for precise clocks and also offer high sensitivity to variations of α: the electric octupole transition at 467 nm in $^{171}Yb^+$ and the optical nuclear transition at about 7.6 eV in $^{229}Th^{3+}$.

SYFC 2: Variations of Fundamental Constants II

Time: Monday 16:30–18:00 Location: A 001

Invited Talk SYFC 2.1 Mo 16:30 A 001
Gravitational and cosmological probes of varying fundamental parameters — •Thomas Dent — Cardiff University

If fundamental parameters of physics such as gauge couplings and particle masses (mass ratios) vary over spacetime then the equivalence principles and framework of general relativity must be altered. As one result, test objects of different composition do not feel the same acceleration: hence local variations can be tested by Eötvös experiments. This provides the strongest bound on variations within the Solar System tracking the gravitational potential.

For physical consistency, an extra degree of freedom is required to exist as a cause of variation. If there is a cosmological time variation such a field will contribute to the expansion of the Universe via its stress-energy. This contribution can be bounded by probes of 'dark energy', putting interesting bounds on the magnitude of time variation in different scenarios.

Invited Talk SYFC 2.2 Mo 17:00 A 001
The astrophysical search for varying fundamental constants — •Nils Prause — Hamburger Sternwarte, Germany

The currently favoured model of an accelerated universe with a cosmological constant gave rise to a number of theories, most of them including a variation of fundamental constants. Next to laboratory measurements, astrophysical observations are of great importance to probe these variations. Using the light of distant background quasars, the evolution of fundamental constants can be traced back to the the early stages of the universe. Molecular rotational and atomic resonance transitions were studied, using high resolution spectroscopy covering a wide wavelength range, to set constraints for the fine structure constant α and the proton to electron mass ratio μ.

SYFC 2.3 Mo 17:30 A 001
Variability of the proton-to-electron mass ratio on cosmological scales - quantification and handling of systematics — •Martin Wendt — Hamburger Sternwarte, Germany

Cosmology contributes a good deal to the investigation of variation of fundamental physical constants. High resolution data is available and allows for detailed analysis over cosmological distances and a multitude of methods were developed. The raised demand for precision requires a deep understanding of the limiting errors involved. The achievable accuracy is under debate and current observing proposals max out the capabilities of todays technology. The question for self-consistency in data analysis and effective techniques to handle unknown systematic errors is of increasing importance. Evidently systematics are not yet under control or fully understood since findings by different groups are partially in disagreement witch each other . We try to emphasize the importance to take these errors, namely i.e. calibration issues, into account and put forward some measures adapted to the problem.

SYFC 2.4 Mo 17:45 A 001
Towards Direct Frequency Comb Spectroscopy of Metal Ions — •Boerge Hemmerling, Daniel Nigg, Ivan V. Sherstov, and Piet O. Schmidt — QUEST Inst. for Experimental Quantum Metrology, PTB Braunschweig & Leibniz University of Hannover, Germany

The possible variation of fundamental constants is a highly debated subject. Laboratory experiments that compare ultra-precise clocks to probe the variation of the fine-structure constant are within their errors compatible with $\dot{\alpha}/\alpha \sim 0$. However, experiments on astronomical time scales that compare quasar absorption spectra with today's spectra of metal ions yield contradictory results reaching from no variation to $\Delta\alpha/\alpha \sim 10^{-5}$. The latter observations are amongst other obstacles limited by inaccurate spectroscopy data on certain transition lines in complex ions such as Ca^{+}, Ti^{+} and Fe^{+} [1].

We plan to investigate these ions by sympathetically cooling them via magnesium ions in a linear Paul trap to the motional ground state. By employing well-developed quantum logic techniques [2], we plan to elude difficulties, such as state preparation and detection in these multi-level systems. Furthermore, a frequency comb will be used as a spectroscopy probe to cover the few 10 nm wide band of interesting transition lines. We will present the latest experimental results of our ground state cooling scheme where we compare pulsed and cw approaches to reach the ground state of the harmonic trap.

[1] J. C. Berengut et al., arXiv:physics/0408017 (2006)
[2] P. O. Schmidt et al., Science 309, 749-752 (2005)