Program FYSICA 2019

Friday, April 5

Amsterdam Science Park

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Title: **Testing fundamental physics at the atomic scale**

Abstract: In high-precision measurements, it is no longer sufficient to describe atoms and molecules as consisting of protons, neutrons and electrons only, but it becomes necessary to include the zoo of virtual particles that surrounds them. This ushers AMO-physics into an area that has traditionally been reserved to particle physics. This sessions will explore a number of precision tests of fundamental physics theories at the atomic scale. Wim Ubachs will present measurements that test whether the forces of nature in the early universe had the same strength as they have today. Steven Hoekstra will present an experiment that looks for elementary particles with masses higher than can be generated at particle accelerators. Laura Dreissen will explain how spectroscopy on helium ions can shed new light on puzzling measurements in muonic hydrogen. Finally, Florian Schreck will show how ultracold atoms can be used to build clocks that go wrong by only one second over the age of the universe.

Convener: Rick Bethlem (VU)

Speakers (in order of appearance)

Wim Ubachs (VU)

Title: **Are the constants of nature rock-solid and eternal?**

Abstract: Spectroscopy of atoms and molecules is a way of testing the invariability of the values of fundamental constants. Laboratory wavelengths of transitions in hydrogen may be compared with the lines observed during the epoch of the early Universe using large telescopes, such as the VLT (Chile) and Keck (Hawaii). Other molecules may be probed as well; we have shown that methanol is a molecular system, very sensitive for a variation of the proton-to-electron mass ratio. The observation of alcohol, via radio astronomy, at an age of 7 billion years has put a severe constraint on drifting constants. There exist other scenarios than drift on a cosmological time scale. Values of fundamental constants may be connected to environmental effects, for example material density or gravitational fields. Such chameleon scenarios may also be tested by observation of spectroscopic lines, in cold clouds and in white dwarfs in our galaxy.

Steven Hoekstra (RUG)

Title: **Tabletop particle physics with cold molecules**

Abstract: According to theories that try to solve outstanding problems in the standard model of particle physics, the charge distribution of the electron is effectively slightly asymmetric, giving the electron an electric dipole moment (EDM). The determination of the electron's EDM is at the forefront of a range of experimental methods that probe physics beyond the standard model. In this talk I will present our NL-eEDM research program, which aims to determine the electron's electric dipole moment using a cold beam of heavy diatomic molecules. In an approach complementary to high-energy colliders, this tabletop precision experiment offers an exciting opportunity to find new physics!

Laura Dreissen (VU)

Title: **Towards testing fundamental physics in a single trapped helium ion**

Abstract: Spectroscopy of hydrogen has reached an accuracy of nearly fifteen digits and can be compared to theoretical predictions made by quantum electrodynamics theory to test fundamental physics. Moreover, precise determinations of parameters such as the charge radius of the proton can be extracted using this comparison. However, in 2010 a spectroscopic measurement in muonic hydrogen (where the electron is replaced by a muon) has led to a different proton size than from electronic systems. Shedding light onto this conundrum is the motivation for numerous experiments, which actually have led to more conflicting values so far. We aim to contribute to a solution by performing measurements in singly-ionized helium, which is very similar to hydrogen, but more sensitive to nuclear size effects. This can then be compared with muonic-He+, which has already been measured. In this talk I will elaborate on this experiment and the progress towards reaching this goal.

Florian Schreck (UvA)

Title: **Building the most accurate clocks with ultracold atoms**

Abstract: Clocks are only useful if they all show the same time, which requires them to tick at the same rate. With macroscopic frequency references, such as pendula, this is impossible since no two pendula can be manufactured identically. The quantum nature of atoms gives us a solution. Transitions between the quantised energy levels of an atom can be driven only by laser light of a specific frequency, intrinsic to the atomic species used. This frequency can be utilized to make a clock tick and any clock using that atomic species will tick the same. To measure the transition frequency precisely, we need to laser-cool the atoms to stand-still. This allows us to build clocks that go wrong

by only one second over the age of the universe. Perhaps one day they will show us that the constants of nature are changing, or guide our cars along streets with centimeter precision.