

# The Ultra-Light Frontier

A brief report on the Workshop that was held at the

Mainz Institute for Theoretical Physics, Johannes Gutenberg University

on  
15-19 June 2015

and was co-organized by Profs.

Surjeet Rajendran (University of California, Berkeley) and Dmitry Budker (Helmholtz-Institute, JGU Mainz)

The Workshop started on Monday with an overview talk on axions and ALPs by Prof. Georg Raffelt (Munich), who described how these particles arise in the context of the early universe, and what we can learn about them from astrophysics. Following the general trend of the Workshop of mixing theoretical and experimental talks, this was followed by an overview of the cosmic axion spin precession experiment (CASPEr) currently being setup at Mainz (to search for the “axion-wind” effects) and Boston University (to search for the axion coupling to gluons via induced electric dipole moment EDM, of the nucleus). CASPEr is searching for axions, axion-like particles (ALPs), and other ultralight bosons whose fields are predicted to oscillate at a frequency corresponding to their mass. The workshop was designed to leave ample space for interactions among the (about 35) participants, and so there were only two additional talks on the first day: an overview by Prof. Yannis Semertzidis of the experimental activities on EDM and axion searches in Korea, and an overview of the progress of the ADMX-HF (the high-frequency version of the axion-dark-matter-search experiment) given by graduate student Maria Simanovskaia.

On Tuesday morning, there were two theory talks with two experimental talks sandwiched between them. In the first talk, Surjeet Rajendran (Berkeley) explained the remarkable and “brand-new” ideas of how axions, rather unexpectedly, may provide a solution to the hierarchy problem of particle physics (in addition to possibly solving most if not all other outstanding problems of cosmology and the standard model). The talk of Dr. Joseph Pradler (Vienna) tackled the theoretical aspects of axions of lowest masses. The experimental talk by Prof. Michael Romalis described testing Lorentz Invariance, CPT, and the equivalence principle with an atomic-physics experiment conducted at the South Pole, while the talk by Dr. John Blanchard (Mainz) dealt with the nuclear magnetic-resonance aspects of the CASPEr experiment. Tuesday afternoon was marked by the public event of the Workshop, a Physics colloquium given by Prof. Victor Flambaum (Sydney).

The third day of the Workshop (Wednesday) began with an overview of dark matter possibilities by Prof. Maxim Pospelov (UBC and Perimeter) over 80 orders of magnitude (!) of energy scales. This was followed by experimental talks by Prof. Szymon Pustelny (Krakow) who described the global network of optical magnetometers (GNOME) searching for the correlated transients that would signify the Earth’s crossing the “walls” of cosmic, non-oscillating ALP domains and a talk by Dr. Lutz Trahms (PTB, Berlin) who described low-frequency co-magnetometry experiments that are prototypical for the CASPEr-Now experiments seeking to reanalyze existing experimental data and to “re-tool” currently running experiments to search for oscillating axion and ALP fields of lowest frequencies. The afternoon and evening of Wednesday were devoted to the conference excursion to a

famous Kupferberg wine cellars in Mainz (a.k.a. the “underground physics session) and the conference dinner.

Thursday morning began with a theoretical overview by Prof. Andreas Ringwald (DESI) in possible hints for axions and ALPs, followed by an experimental talk by Dr. Nathan Leeper (Mainz) on the results of a search for dark-matter dilatons with atomic dysprosium, which is the first “atomic-clock” search for ultralight dark matter, with a promise of significant additional developments in the future. The morning session concluded with a talk by Dr. Harald Merkel (Mainz) describing the searches for dark photons and the Mainz accelerators, MAMI and MESA. In the afternoon, Ben Roberts (Sydney) described theoretical ideas for looking for various cosmic fields with atoms and molecules, followed by experimental talks by Dr. Samer Afach (Mainz) describing the recent experiment at the Paul Scherrer Institute (PSI) to search for axion-mediated interactions with ultracold neutrons (UCN) and a talk by Dr. Grey Rybka (Seattle) on the status of the ADMX experiment.

The last day of the meeting started with the talk of Dr. Javier Redondo (Zaragoza) who reviewed various approaches to searching for meV and lighter axions and motivating the proposed International axion observatory (IAXO), followed by talks by Prof. Oleg Sushkov (Sydney) who gave a tutorial on EDM searches with ferroelectric solids, and a talk by Prof. Andrey Derevianko (Reno) describing using the GPS timing network to search for topological dark matter. Clock networks use a similar approach to that of the magnetometer network (GNOME) but is sensitive to different “portals” for the dark-matter interactions. The final afternoon sessions were devoted to topics at the interface between the main focus of the Workshop and the broader areas of physics. In a joint event with the Mainz Magnetic Resonance Seminar, Dr. Alexander Sushkov (Harvard) described the recent spectacular experiments on detecting single nuclear spins using nitrogen-vacancy (NV) centers in diamond. Prof. Victor Flambaum (Sydney) gave an inspiring and thought-provoking discussion of possible manifestations of dark matter in atomic and astrophysical phenomena such as, for instance, pulsar “glitches.” The Workshop concluded with a talk by Prof. Dmitry Budker (Mainz and Berkeley) introducing an idea of a novel kind of literally a quantum-mechanical (precessing ferromagnetic needle) magnetometer that may open the way to explore the electron-spin couplings of ultralight dark-matter candidates.

The Workshop was highly appraised by the participants, and has resulted in new ideas and currently ongoing collaboration. Its success is due, to a large degree, by the excellent organizational support provided by the MITP staff.

Dmitry Budker and Surjeet Rajendran  
Mainz and Berkeley, October 3, 2015