Optical magnetometry with mesospheric sodium atoms

Felipe Pedreros Bustos[1], Domenico Bonaccini Calia[2], Mauro Centrone[3] , Joschua Hellemeier[4], Paul Hickson[4], Ronald Holzlöhner[2], Simon Rochester[5], and Dmitry Budker[1,6]

[1] Johannes Gutenberg University, Helmholtz Institute Mainz, Mainz, Germany
[2] European Southern Observatory, Garching b. München, Germany
[3] Istituto Nazionale di Astrofisica, Osservatorio Astronomico di Roma, Italy
[4] Department of Physics and Astronomy, University of British Columbia, Vancouver, Canada
[5] Rochester Scientific LLC, CA, USA
[6] Department of Physics, University of California Berkeley, Berkeley, CA, USA

Magnetic fields sensing has contributed to the formulation of the plate-tectonics theory, mapping and discovery of underground structures on Earth, and the study of planetary magnetospheres. Closing the gap between space-based and near-earth observation, we demonstrate a method for remote measurement of the geomagnetic field at an altitude of 85–100 km. The method consists in optical pumping atomic sodium in the upper mesosphere with an intensity-modulated or polarization-modulated laser beam, and simultaneous ground-based observation of the resultant magneto-optical resonance when pumping at the Larmor precession frequency [1] (Fig. 1). The experiments were carried out at the Roque de Los Muchachos Observatory in La Palma (Canary Islands) where we validated this technique and remotely measured the Larmor precession frequency of sodium as 260.4(1) kHz, consistent with a mesospheric magnetic field of 0.3720(1) G [2,3]. Remote detection of mesospheric magnetic fields has potential applications such as mapping magnetic structures in the lithosphere, monitoring space weather and electric currents in the ionosphere.

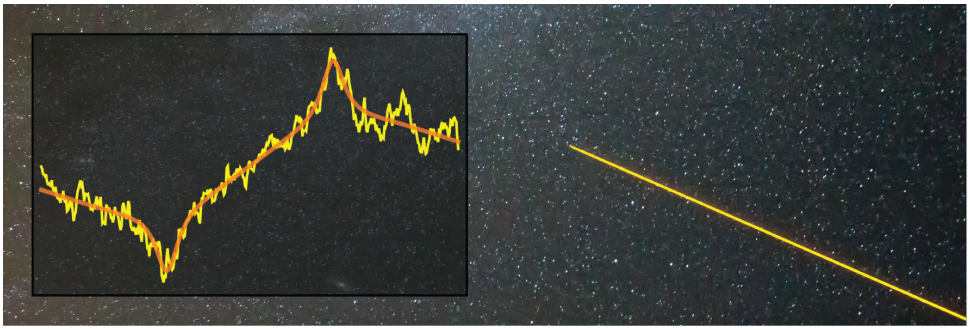

Figure 1. Optically pumped atomic sodium at 85–100 km altitude and observation of a magnetic resonance.

[1] M. Higbie, S. M. Rochester, B. Patton, R. Holzlöhner, D. Bonaccini Calia, D. Budker, Magnetometry with mesospheric sodium, PNAS. **108**, 9, (2011)
[2] F. Pedreros Bustos, et al., Remote sensing of geomagnetic fields and atomic collisions in the mesosphere, Nature Communications **9**, 3981, (2018)
[3] F. Pedreros Bustos, et al., Polarization-driven spin precession of mesospheric sodium atoms, Optics Letters, **43**, 23, (2018)