QUaerere AXion

A proposal in a search for Galactic axions

Abstract

An outstanding result of the modern cosmology shows us that a significant fraction of the universe is made of dark matter. However, the nature of such component is still unknown, apart its gravitational interaction with ordinary barionic matter. A favored candidate for dark matter is the axion: a new particle introduced by Peccei and Quinn [1] to solve the strong CP problem, i.e. the absence of CP violation in the strong interaction sector of the Standard Model. Axions have properties similar to a π_0 particle and have mass m_a inversely proportional to the Peccei-Quinn symmetry breaking scale f_a.

For certain ranges of f_a and m_a (typically with masses ranging from μeV to meV), large quantities of axions may had been produced in the early universe that could be able to account for a large portion of the cold dark matter forming today galactic halos. Axions have extremely small coupling to normal matter and radiation, but they can be converted into detectable photons by means of the inverse Primakoff effect as shown by Sikivie [2]. The idea of Sikivie has been exploited by the american experiment ADMX[3]. This experiment is still running, and for the moment it has been capable of searching for cosmological axions in the few μeV mass range.

The QUAX (QUaerere AXion) proposal explores in details the ideas of Krauss [4], Barbieri et al [5], and Kolokolov and Vorobyev [6]. These authors proposed to study the interaction of the cosmological axion with the spin of fermions (electrons or nucleons). In fact, due to the motion of the Solar System through the galactic halo, the Earth is effectively moving through the cold dark matter cloud surrounding the Galaxy and an observer on Earth will see such axions as a wind. In particular, the effect of the axion wind on a magnetized material can be described as an effective oscillating magnetic field with frequency determined by m_a, and strength related to fa. Thus, a possible detector for the axion wind can be a magnetized sample with Larmor resonance frequency tuned to the axion mass by means of an external polarizing static field (e.g. 0.6 T for 17 GHz, corresponding to a 70 μeV axion mass). The interaction with the axion effective field will drive the total magnetization of the sample, and so producing oscillations in the magnetization that, in principle, can be detected. In order to optimize the detection, the sample is placed inside a microwave cavity and a pump rf field is applied in a direction orthogonal to the polarizing field in order to amplify the equivalent rf field generated by the axion wind. The induced change in the magnetic flux along the polarizing field is then fed to a SQUID magnetometer through a superconducting transformer. It is worth noticing that the magnetized sample must be cooled to ultra-cryogenic temperature to avoid fluctuations of the magnetization due to the thermal bath.

The QUAX project will try to exploit this detection scheme, starting at a precise value of the axion mass (around 70 μeV).

Other possible detection schemes will be shortly presented covering also other possible type of interactions.

---

1 R.D. Peccei, H.R. Quinn, Phys. Rev. Lett. **38**, 1440 (1977).

2 P. Sikivie, Phys. Rev. Lett. **51**, 1415 (1983).

3 S. Asztalos et al, Phys. Rev. D **64**, 092003 (2001).

4 L.M. Krauss, et al., "Spin coupled axion detections", Preprint HUTP-85/A006 (1985);
L.M. Krauss, "Axions … the search continues", Yale Preprint YTP 85-31 (1985).

5 R. Barbieri, M. Cerdonio, G. Fiorentini, S. Vitale, Phys. Lett. **B226**, 357 (1989).

6 A.I. Kakhizde, I. V. Kolokolov, Sov. Phys. JETP **72**, 598 (1991).