ARTICLE IN PRESS

Progress in Particle and Nuclear Physics ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Contents lists available at ScienceDirect

Progress in Particle and Nuclear Physics

journal homepage: www.elsevier.com/locate/ppnp

Review

New experimental approaches in the search for axion-like particles

Igor G. Irastorza [a,b,*], Javier Redondo [a,c]

[a] Departamento de Física Teórica, Universidad de Zaragoza, 50009 Zaragoza, Spain
[b] Laboratorio Subterráneo de Canfranc, 22880 Canfranc Estación, Spain
[c] Max-Planck-Institut für Physik, 80805 München, Germany

ARTICLE INFO

Article history:
Available online xxxx

Keywords:
Axions
Dark matter
Axion experiments
Axion detection

ABSTRACT

Axions and other very light axion-like particles appear in many extensions of the Standard Model, and are leading candidates to compose part or all of the missing matter of the Universe. They also appear in models of inflation, dark radiation, or even dark energy, and could solve some long-standing astrophysical anomalies. The physics case of these particles has been considerably developed in recent years, and there are now useful guidelines and powerful motivations to attempt experimental detection. Admittedly, the lack of a positive signal of new physics at the high energy frontier, and in underground detectors searching for weakly interacting massive particles, is also contributing to the increase of interest in axion searches. The experimental landscape is rapidly evolving, with many novel detection concepts and new experimental proposals. An updated account of those initiatives is lacking in the literature. In this review we attempt to provide such an update. We will focus on the new experimental approaches and their complementarity, but will also review the most relevant recent results from the consolidated strategies and the prospects of new generation experiments under consideration in the field. We will also briefly review the latest developments of the theory, cosmology and astrophysics of axions and we will discuss the prospects to probe a large fraction of relevant parameter space in the coming decade.

Contents

---

[*] Corresponding author at: Departamento de Física Teórica, Universidad de Zaragoza, 50009 Zaragoza, Spain.
E-mail address: Igor.Irastorza@cern.ch (I.G. Irastorza).

https://doi.org/10.1016/j.ppnp.2018.05.003

Please cite this article in press as: I.G. Irastorza, J. Redondo, New experimental approaches in the search for axion-like particles, Progress in Particle and Nuclear Physics (2018), https://doi.org/10.1016/j.ppnp.2018.05.003.

1. Introduction

The 20th century witnessed a spectacular revolution in our understanding of the fundamental laws of nature, that culminated with the establishment of the Standard Model (SM) of particle physics, the theory that describes with accuracy (at least as far as our experimental and computational accuracy goes) the results of every experiment performed so far in particle physics. There are however many reasons to believe the SM is not an ultimate theory of nature. Some decades ago it could have been argued that the SM does not include the gravitational interactions –so successfully described at the classical level by Einstein's theory of general relativity – and so it has to be extended or embedded in a more complete theory. Nowadays we can count on a few other striking observations. Perhaps the most pressing come from cosmology, which seems to be also extremely well described by a classical solution of Einstein's gravity equations, a homogeneously expanding Universe with some primordial inhomogeneities seeded by tiny quantum fluctuations during an exponential expansion phase, so-called primordial inflation. And this excellent description requires a few ingredients that are nowhere to be found in the SM: Dark Matter (DM) — a substance that behaves under gravity as cold gas of non-baryonic weakly interacting particles, Dark Energy (DE), which gravitates as Einstein's famous cosmological constant, and at least a new field (not necessarily a fundamental field) whose potential energy drives inflation for some time and then transforms somehow into the radiation that will dominate the energy density of the Universe during Big Bang Nucleosynthesis. Amongst these three, the evidence for Cold DM is the most precious for particle physics as it is directly attributable to the existence of new species of particles, i.e. it has been convincingly proven that the majority of DM is not in the form of neutrinos or any other SM particle.

But the SM itself also provides compelling reasons to seek a more fundamental theory of nature. Most of them follow the same pattern: the lack of symmetry of the SM will be alleviated as we consider physics at higher energy scales. New particles/fields are expected to appear and restore symmetries that are not altogether evident in the SM. Couplings can

Please cite this article in press as: I.G. Irastorza, J. Redondo, New experimental approaches in the search for axion-like particles, Progress in Particle and Nuclear Physics (2018), https://doi.org/10.1016/j.ppnp.2018.05.003.