Il Colle di Galileo

Axions Across Boundaries between Particle Physics, Astrophysics, Cosmology and forefront Detection Technologies

Galileo Galilei Institute – Arcetri, April 26 – June 9, 2023

Organisers
Gianpaolo Carosi (Lawrence Livermore National Laboratory, CA, USA)
Kiwoon Choi (IBS, Daejeon, CTPU, KR)
Luca Di Luzio (University of Padua and INFN – Padua, IT)
Babette Döbrich (CERN, Geneva, CH)
Inma Domínguez (University of Granada, ES)
Maurizio Giannotti (Physical Sciences, Barry University, USA)
Igor Garcia Irastorza (University of Zaragoza, ES)
Enrico Nardi (INFN – Laboratori Nazionali di Frascati, IT)
Andreas Ringwald (DESY, Hamburg, DE)
Pierre Sikivie (University of Florida, FL, USA)
Julia Katharina Vogel (Lawrence Livermore National Laboratory, CA, USA)

Abstract. The workshop brought together scientists from different backgrounds and expertise to discuss open problems, recent developments and future directions in axion physics, a field notoriously replete with interdisciplinary connections. The aim of the workshop was to foster a fruitful cross-breeding between different theoretical areas, with a focus on certain open issues in axion particle physics, astrophysics and cosmology. The interaction between the experimental and theoretical communities fostered the merging of "how to search" with "where to search" into optimised strategies to hunt for the axion.

Keywords: axion physics, strong CP problem, axion astrophysics and cosmology, axion dark matter, axion detection strategies.

Scientific context and motivations

Quantitative assessments of the axion contribution to Cold Dark Matter (CDM) involve top-notch lattice simulations of non-perturbative QCD effects, as well as of the cosmic evolution of axionic topological defects. Astrophysical observations provide strong limits on axion properties because stellar evolution would be affected by the existence of axions and, intriguingly, some excesses in star energy

ISSN 2281-7727 (print)
ISSN 2281-9711 (online)
Vol. 13, 2, 2024, pp. 61-64
DOI: 10.36253/cdg-15672
www.fupress.com/cdg

losses have been reported. Cosmological scenarios in which the Peccei Quinn (PQ) symmetry is broken before inflation envisage axion imprints in the CMB, while in post-inflationary scenarios, axion miniclusters, with overdensities several orders of magnitude larger than the local density of CDM, are expected to form. A reliable assessment of their properties is therefore of the utmost importance. In experimental terms, a blossoming of potentially game-changing ideas, with an exciting crossover from experimental particle physics to materials science and cutting-edge technologies, is inspiring new methods for axion searches. Novel techniques which, besides exploiting the axion-photon coupling, aim to reveal axions via their couplings to nucleons and electrons, have been advanced. The programme of the workshop was tailored to synergistically address all these issues. Due to the wide variety of expertise required to coordinate targeted invitations and carefully select participants from the extensive pool of applications, an organising committee comprising eleven members was formed. Although the number of organisers was unusually large, their involvement proved instrumental in ensuring the highest scientific standards across all the areas covered by the workshop programme.

Scientific activity

The scientific activity was structured around one "Training week", five regular "Workshop weeks" and a final "Conference week", as shown in Fig. 1, taken from the workshop webpage.

Training week

The Training week was aimed at PhD students and young postdocs, as well as senior researchers unfamiliar with this specific field of research, but eager to grasp its fundamental concepts. The goal was to provide a basic introduction to the various aspects of axion physics. To this end, six lecturers encompassing the foundational principles of axion theory, axion electrodynamics, the essential in-

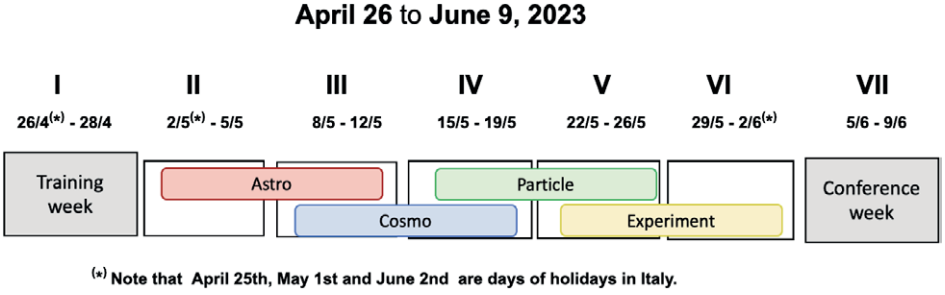

Figure 1. The scheduling format of the workshop.

gredients of axion model building and phenomenology, axion astrophysics, axion cosmology, and an overview of axion detection techniques, were scheduled.

Regular workshop activities

The regular workshop spanned five weeks. The activities were organised around four main topics: axion astrophysics, axion cosmology, axions in particle physics (theory and phenomenology) and axion detection strategies. Cross-contamination among the different areas was guaranteed by structuring the activities for each topic over two weeks, overlapping the second week of each subject with the first week of the next one (see figure 1). Consequently, experts in Astrophysics and Cosmology, Cosmology and Particle Physics, Particle Physics and Experimental Detection Strategies, were brought into close contact for a significant length of time, which was essential to interdisciplinary cross-contamination.

The planned workshop activities consisted of one invited talk each day, scheduled after lunch, with no time limits for questions and discussion. In several cases, these afternoon seminars lasted more than two hours. During the development of the workshops, additional topics emerged as common interests among large groups of participants, spurring impromptu presentations, often at the blackboard, to stimulate discussions and thorough analyses (see Fig. 2). These additional activities were typically scheduled in the morning, before lunch. The morning slots also hosted eight talks from young researchers who expressed their keen interest in presenting their results to an audience of leading experts.

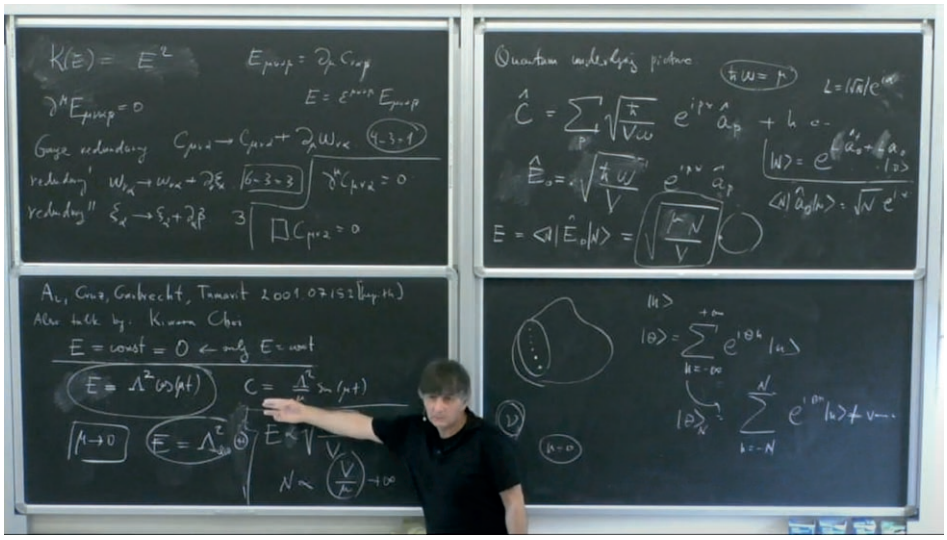

Figure 2. Gia Dvali during an impromptu discussion about an insidious issue concerning CP violation in the strong interactions.

Conference

The final week of the workshop was dedicated to a conference featuring a full-day schedule, comprising two 60-minute talks in the morning and three 40-minute talks in the afternoon. The most recent developments in axion physics were presented and discussed during the conference.

All the lectures, seminars, young researchers' talks, impromptu presentations and subsequent discussions, as well as the talks at the conference, were streamed. The recordings are available on the GGI YouTube channel.

Participation and impact within the community

The proposal for an interdisciplinary workshop on axion physics to be held at the Galileo Galilei Institute for Theoretical Physics was enthusiastically supported by the whole axion community. In the end, there were more than 180 requests to participate in the workshop, exceeding the hosting capacity of GGI. The organising committee was able to accommodate 125 participants. Their tenure at the GGI was strategically allocated over the seven weeks of the event, based on their scientific skills and interests. In total, 292 weeks of attendance were tallied, resulting in an average participant stay of 2.3 weeks.

Four outstanding "key scientists" received support from four Simons fellowships for a total of eight weeks, while another 160 weeks were supported through INFN GGI funds.

Final considerations and acknowledgements

Given the increasing interest in axion physics witnessed in recent years, this workshop was undoubtedly timely and, as expected, played a pivotal role in connecting and bridging different areas of expertise within the axion community. The enthusiastic participation and excitement that characterised the various activities, the thorough involvement of the participants in numerous discussions, alongside the positive feedback we, as organisers, received from various colleagues, convinced us that this was a highly successful workshop. We acknowledge the seamless logistical organisation provided by the GGI administrative staff, who played a fundamental role in achieving our goals.