TAsP: Theoretical Astroparticle Physics

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Main scientific activities and achievements during the year 2018.

Axion Physics: A class of generalized DFSZ axion models with generation dependent Peccei-Quinn charges that allow to simultaneously suppress the axion couplings to nucleons and electrons was put forth in Ref. [1]. We have shown that astrophysical limits from the SN1987A burst duration and from white dwarf cooling can be relaxed, allowing for axion masses up to the order of 0.1 eV. However, the axion-photon coupling remains sizeable and hence the proposed IAXO helioscope will be crucial to search for the astrophobic axion. An unavoidable consequence of astrophobia are flavor off-diagonal axion couplings at tree-level, so that experimental limits on flavor-violating processes can provide a powerful tool to constrain this scenario. We have argued that the astrophobic axion can be a viable dark matter candidate in the heavy mass window, and can also account for anomalous energy loss in stars.

In Ref. [2] we have investigated to what extent a generic, generation-dependent U(1) symmetry acting on the quark Yukawa operators can reduce the number of free parameters by forcing some entries in the Yukawa matrices to vanish. The maximal reduction compatible with CP violation yields nine real parameters and one phase, which matches the number of physical observables, implying that such models have no free parameters. We derive a set of results, the most important of which is that the U(1) symmetries that generate the Yukawa textures all have a QCD anomaly, and hence are Peccei-Quinn symmetries, reinforcing the idea of a possible connection between the quark flavour puzzle and the axion solution to the strong CP problem. Intriguingly, in some cases the contributions to the QCD anomaly of two generations cancels out, and this opens the possibility that the axion coupling to nucleons could be strongly suppressed. Flavour-violating axion couplings to quarks are completely fixed, up to the axion decay constant, providing a non-trivial complementarity between low-energy flavour-violating processes and standard axion searches.

Dark Sectors: Positrons beam dump experiments have unique features to search for very narrow resonances coupled super-weakly to e^+e^- pairs. In Ref. [3] we have proposed a new mechanism for resonant production of dark photons that, with a proper adaptation of the experimental setup, can extend the sensitivity of the LNF PADME experiment to a parameter space region much wider than previously thought. In particular we have explored the foreseeable sensitivity of the experiment in searching with this technique for the 17MeV dark photon invoked to explain the ^{8}Be anomaly in nuclear transitions. Resonant dark photon production has been proved to be an important process that must be taken into account also in analyzing the results of electron beam dump experiments, since positrons are in any case copiously produced in electromagnetic showers. In Ref. [4] we have applied this idea to a reanalysis of the data from the SLAC E137 experiment. Including resonant dark photon production in e^+e^- annihilation we were able to push the current limits on dark photon couplings downwards by a factor of two, for dark photon masses in the range 35 MeV/c2 - 120 MeV/c2. In Ref. [5] we have shown that this idea, applied to planned Beam Dump Experiments and *active* Beam Dump Experiments, can improve the sensitivity of these experiments by up to an order of magnitude.

Leptgenesis: The general theory of leptogenesis, with special attention to its most striking phenomenological consequences, and including all the most recent refinements, keeps being one of the main research topic of the group, whose scientific leadership in this field is internationally recog-

nized. In relation with leptogenesis studies, in Ref. [6] we have analyzed realistic possibilities of testing leptogenesis from out-of-equilibrium decays. We have identified the necessary conditions for having successful leptogenesis at the TeV-scale, and we have further discussed possible new realizations of leptogenesis based on extended seesaw models, models with extended gauge sectors, and supersymmetric leptogenesis, focusing on their specific possibilities of being experimentally confirmed, or at least falsified.

In Ref. [7] we have remarked that Leptogenesis could have occurred at temperatures much lower than generally thought, if the cosmological history of the Universe underwent a period of accelerated expansion, as is predicted for example in a class of scalar-tensor theories of gravitation. We have discussed how non-standard cosmologies can open new pathways for low scale leptogenesis. Within these scenarios, direct tests of leptogenesis could also provide information on the very early times Universe evolution, corresponding to temperatures larger than the TeV.

Publications

1 Astrophobic Axions
Luca Di Luzio (Durham U., IPPP), Federico Mescia (ICC, Barcelona U.), Enrico Nardi (Frascati), Paolo Panci, Robert Ziegler (CERN).
Published in: Phys.Rev.Lett. 120 (2018) no.26, 261803

2 $U(1)$ flavour symmetries as Peccei-Quinn symmetries
Fredrik Bjorkeroth (Frascati), Luca Di Luzio (Durham U., IPPP & Durham U.), Federico Mescia (ICC, Barcelona U.), Enrico Nardi (Frascati).
arXiv:1811.09637 [hep-ph] Accepted for publication in JHEP.

3 Resonant production of dark photons in positron beam dump experiments,
Enrico Nardi, Cristian D.R. Carvajal, Anish Ghoshal, Davide Meloni, Mauro Raggi.
Published in Phys.Rev. D97 (2018) no.9, 095004

4 Dark photon production through positron annihilation in beam-dump experiments,
L. Marsicano (INFN, Genoa & Genoa U.), M. Battaglieri (INFN, Genoa), M. Bondì (INFN, Catania), C.D. R. Carvajal (Antioquia U.), A. Celentano (INFN, Genoa), M. De Napoli (INFN, Catania), R. De Vita (INFN, Genoa), E. Nardi (Frascati), M. Raggi (Rome U.), P. Valente (INFN, Rome)

5 Novel way to search for Dark Photon in beam-dump experiments,
L. Marsicano, M. Battaglieri, M. Bondí, C.D.R. Carvajal, A. Celentano, M. De Napoli, R. De Vita, E. Nardi, M. Raggi, P. Valente.
Published in Phys.Rev.Lett. 121 (2018) no.4, 041802

6 A cosmological pathway to testable leptogenesis
Bhaskar Dutta (Texas A-M), Chee Sheng Fong (Sao Paulo U.), Esteban Jimenez (Texas A-M), Enrico Nardi (Frascati)
Published in JCAP 1810 (2018) no.10, 025.

7 Probing Leptogenesis,
E.J. Chun, G. Cvetič, P. S. B. Dev, M. Drewes, C. S. Fong, B. Garbrecht, T. Hambye, J. Harz, P. Hernández, C. S. Kim, E. Molinaro, E. Nardi, J. Racker, N. Rius, J. Zamora-Saa
Published in Int.J.Mod.Phys. A49 (2018) no.05n06, 1842005-262.