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Probes of sub-GeV Dark Sector Physics - Two Showcases

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Abstract:

Besides the visible and known sectors of particles and interactions described by the Standard Model, it is possible that there exists a dark sector of light, sub-GeV particles attributable to dark matter. A rich phenomenology can be expected in laboratories, astrophysics and cosmology, when visible and dark sectors are connected. In this thesis, we scrutinize two dark sector scenarios. First, we study a so-called vector-portal model, in which fermionic dark states carry electromagnetic form factors and thus can interact with the photon. Second, we then focus on a fermion-portal model containing a scalar dark matter candidate coupled to Standard Model leptons via a new heavy fermion. The latter model has been entertained to explain the long-standing INTEGRAL 511 keV excess and the muon g - 2 anomaly. With detailed derivations of the current and future experimental sensitivity, we constrain the coupling strengths between the visible sector and dark sectors through a large number of probes. Concretely we consider collider and fixed-target/beam-dump experiments, Standard Model precision observables, direct/indirect detection, astrophysical/cosmological implications such as the stellar energy loss and extra relativistic degrees of freedom in the early universe. The combination of these results establish that 1) sub-GeV dark sector particles can only have feeble electromagnetic form factor interactions, and 2) the parameter space of the fermion-portal model for explaining the two mentioned anomalies is ruled out. In the bigger scheme of things, we develop a detailed framework to study light (sub-GeV) dark sectors, demonstrated with two minimal extensions of the Standard Model. Such a framework may be readily adjusted to accommodate more complicated dark sectors.