Snowmass 2021 - Letter of Interest

Exotic light dark matter signals at existing experiments

Thematic Areas:

(TF08) BSM model building
(TF09) Astro-particle physics & cosmology
(CF1) Dark Matter: Particle-Like
(NF03) BSM

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Null searches for weakly interacting mass particle (WIMP) dark matter at collider, direct detection, and indirect detection experiments all motivate the possibility of particle dark matter with alternative forms of interactions within a hidden sector or with the Standard Model fields. Detectability motivates models of light, sub-GeV dark matter with different kinds of interactions (see *e.g.*[?]). For light dark matter, the kinetic energy available to scatter off targets within detectors is often below the current energy thresholds at large direct detection experiments designed for WIMPs. This has prompted significant progress in new experimental techniques and materials to drop energy thresholds significantly.

New dark matter interactions open up the possibility of detecting dark matter well below typical energy deposited in elastic scattering, $\sim \mu_\chi v^2 \lesssim 10^{-6} m_\chi$ in detectors, where μ_χ and m_χ are the reduced and dark matter mass while $v \sim 10^{-3}$ is the typical dark matter halo velocity in our solar neighborhood. These models predict a different energy spectra and may be overlooked by current detection strategies. Thus, they present a new avenue of progress complementary to the detection of sub-GeV dark matter via novel detector materials and technologies designed to lower experimental thresholds. In this letter of interest (LoI), we propose to write a Snowmass white paper focused on models of sub-GeV dark matter which have detectable and possibly novel signals at *current* direct detection and neutrino experiments.

We now comment briefly on some of the models that fall into this category. The purpose of the white paper will be to provide a cohesive summary of these non-standard proposals and their unique experimental signals (often at multiple current experiments).

- **Inelastic Dark Matter**: Dark matter is composed of two states, χ_1, χ_2, with a small mass splitting, whose leading interaction is an up-scattering between χ_1 (which forms the dark matter) into χ_2. The dark matter direct detection rate will be enhanced by the inverse mass splitting between the states.[?]
- **Exothermic Dark Matter**: In this setup the dark matter consists of two or more light states with a small mass splitting. Direct detection signals involve an exothermic reaction in which an excited dark matter state down-scatters (in contrast with inelastic dark matter) off a nucleus to the lower energy state.[?]

- **Bosonic Absorption**: Bosonic dark matter can impinge on a detector target and covert into Standard Model states. If it is light enough (and weakly coupled) it may be observationally-stable and a viable dark matter candidate. The prototypical examples include axions and dark photons. Stability and experimental viability typically pushes searches to explore boson masses around an eV.[? ? ? ?]

- **Boosted Dark Matter**: A small population of dark matter is produced non-thermally by late-time processes and is relativistic i.e boosted. Large-volume detectors originally designed to search for neutrinos e.g. Super-K, IceCube, DUNE, etc, can be re-purposed to search for the large recoil energy imparted onto Standard Model targets in the detector upon scattering by the boosted dark matter.[? ? ? ? ?]

- **Self-Destructing Dark Matter**: Metastable dark matter can collide with the Earth or detectors to produce unstable hidden states. If these states decay sufficiently fast, it can produce spectacular signals in large volume detectors.[? ?]

- **Cosmic Ray Boosted Dark Matter**: Dark matter up-scatters on cosmic rays before interacting with the target material of a direct detection experiments. The dark matter-cosmic ray interactions accelerates the dark matter, so that it will have more energy to impart upon the detector target materials and can therefore lead to target recoil energies above detector threshold.[? ? ? ? ? ?]

- **Fermionic Absorption**: Fermionic dark matter can collide with a target of a large volume detector and convert its rest mass into the visible sector. Such interactions may be either eject a neutrino or a lepton in addition to a (dark matter velocity independent) nuclear recoil. Prototypical examples include variants of sterile neutrino models (often under the umbrella of heavy-neutral leptons). Dark matter in such models, by construction, may also decay into Standard Model states. Stability of the dark matter implies that the relevant parameter space for such models ranges from from dark matter of masses of order keV (the Tremaine-Gunn bound), to a bit above an MeV.[? ?]

- **other ideas?**

There is a wide range of novel and unique signals of dark matter that can be searched for in existing date, and as such is an important topic for a Snowmass white paper.

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