Snowmass2021 - Letter of Interest

Dark Matter Complementarity

Thematic Areas: (check all that apply □/■)

■ (CF01) Dark Matter: Particle Like
■ (CF02) Dark Matter: Wavelike
■ (CF03) Dark Matter: Cosmic Probes
■ (CF07) Cosmic Probes of Fundamental Physics
■ (TF09) Astro-particle Physics & Cosmology
■ (EF10) Dark Matter at Colliders
■ (RF06) Dark Sector Studies at High Intensities

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Note that this list of signatories is preliminary, and everyone will be welcome to contribute to the studies towards the whitepaper within each Topical Group.

Abstract:

Dark matter is a science driver that crosses multiple Snowmass Frontiers. A complementary approach that combines theory, experiment, observation, instrumentation, and computation is necessary to make progress in this domain. This LOI is intended to emphasize that complementarity between these various fields of research must receive attention in the Snowmass process.

Determining the fundamental nature of dark matter (DM) is one of the major open questions that confronts our understanding of physics. A broad and comprehensive approach to this question is needed to make progress in the next decade. This requires expertise, results, and planning from the theoretical, computational, experimental, and instrumentation communities and involves nearly all Frontiers of the Snowmass 2021 process. Further exploitation of synergies between different dark matter search strategies is also recommended by European Strategy Update. [1,2]

The 2013 Snowmass process had a topical group (CF4) specifically devoted to the complementarity of different dark matter studies. The white paper produced by that group, *"Dark Matter in the Coming Decade: Complementary Paths to Discovery and Beyond,"* [3] reviewed existing and planned dark matter efforts in direct detection, indirect detection and collider experiments, as well as in astrophysical probes. Using two simple theoretical frameworks for quantitative comparisons, this whitepaper highlighted the complementarity of these different dark matter search programs.

We note that no topical group on dark matter complementarity has been formed within the Snowmass 2021 process. However, the need for diverse and complementary approaches to the dark matter problem are even more pressing now than they were in 2013. The dark matter search domain has broadened significantly; many promising new avenues for understanding dark matter are being developed now and will yield results in the next decade. Developing a cohesive structure within which to interpret these results is critical to guiding the field in the coming decade. While the stated need for complementarity presented in the 2013 still stands, significant effort is required to re-cast the scope and definition of complementarity in terms the context of the current state of the field.

We propose to bring together the dark matter community within the context of the Snowmass 2021 process to assemble an updated vision of dark matter complementarity in the coming decade. Some examples of topics that could be covered by such a report:[a]

- how to combine data from different detection techniques to enhance sensitivity (e.g., the recent IceCube/PICO combined analysis [4]);
- how the same light dark matter models can be probed by newly designed accelerator (e.g. fixed target and beam dump), direct detection, and collider experiments [5];
- is there evidence for dark matter in the neutrino sector?
- how cosmological/astrophysical measurements of dark matter complement and inform terrestrial searches (e.g., how the measured distribution of dark matter affects the sensitivity of different terrestrial detectors);
- how terrestrial signatures of dark forces would manifest as astrophysical signatures such as anomalous stellar cooling; [6]
- in the event that a dark matter signal is detected in one experiment, what insights can be gained through other experimental techniques.

This LOI proposes an update of the 2013 dark matter complementarity white paper that accounts for advances in this field and gives an outlook for the next decade. Work towards this goal will follow the Snowmass "bottom-up" approach, building on community input and discussions in cross-frontier meetings.

[a] Neither this list of topics nor the references cited are meant to be inclusive .

References

[1] R. K. Ellis et al., *Physics Briefing Book: Input for the European Strategy for Particle Physics Update 2020 (Outlook of Chapter 9)*, 1910.11775.

[2] The European Strategy Group, *Deliberation document on the 2020 Update of the European Strategy for Particle Physics (page 13)*, Tech. Rep. CERN-ESU-014, Geneva, 2020. 10.17181/ESU2020Deliberation.

[3] D. Bauer, J. Buckley, M. Cahill-Rowley, R. Cotta, A. Drlica-Wagner, J. L. Feng et al., *Dark matter in the coming decade: Complementary paths to discovery and beyond*, *Physics of the Dark Universe* **7** (2015) 16 [1305.1605].

[4] ICECUBE, PICO collaboration, *Velocity Independent Constraints on Spin-Dependent DM-Nucleon Interactions from IceCube and PICO*, 1907.12509.

[5] M. Battaglieri, A. Belloni, A. Chou, P. Cushman, B. Echenard, R. Essig et al., *US Cosmic Visions: New Ideas in Dark Matter 2017: Community Report*, *arXiv e-prints* (2017) arXiv:1707.04591 [1707.04591].

[6] XENON collaboration, *Observation of Excess Electronic Recoil Events in XENON1T*, 2006.09721.