Snowmass LOI: Defining the WIMP

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In this letter of interest, I encourage the Snowmass 2021 conveners to adapt a uniform definition of the term *weakly-interacting massive particle* (WIMP) to be applied across the cosmic frontier white papers. I propose a working definition of a WIMP as a dark matter particle that is 'minimally' connected to the electroweak hierarchy problem. This definition identifies a broad class of models that are top-down motivated with similar phenomenology.

Given the breadth of communities involved in Snowmass, it would be helpful to establish a uniform definition of WIMP across white papers. We do not have to use the proposed definition in this LOI, but I urge the conveners to support a single definition across the cosmic frontier.

Different particles to different people. The different working (and often implicit) definitions of a WIMP can lead to confusion between colleagues in different sub-fields. For example[1],

- An astrophysicst: cold dark matter that produces standard CDM halos
- A direct detection specialist: any dark matter that could produce an observable nuclear recoil.
- A collider physicist: a particle described by effective contact interactions with visible particles.
- A model-builder may define a WIMP according to any number of properties: an abundance set by thermal freeze-out, direct couplings to the Standard Model, some range of interaction strengths.
- Colloquially, *weakly interacting* may be an upper bound on a coupling constant (e.g. are axions WIMPs[2]?) or an upper limit on Compton wavelength (versus ultralight scalar fields).

These 'working definitions' reflect the foci of each subfield. We rarely state these definitions explicitly, often leading to confusion in interdisciplinary communications[3]. Establishing an agreed upon definition will help communication between subfields beyond the Snowmass process.

Properties of a useful definition. By defining a class of dark matter candidates, we connect a set of common motivations, features, and phenomenology. As many of these properties are associated with 'classic' particle dark matter candidates, we also want the our definition to be useful to *contrast* how more recent theories are different.

A proposed Snowmass '21 definition for WIMPs. A glib working definition of the WIMP is *anything neutralino-like*. More specifically, a WIMP is a dark matter candidates coming from a symmetry-based solution to the electroweak hierarchy problem. Despite coming from different origins, the existence and properties of these dark matter candidates are similar because they all follow the same framework in Fig. 1:

1. A new symmetry (supersymmetry, extra dimensions, confining force) introduces new particles with *electroweak interactions*—by virtue of being symmetry-related to the Higgs sector.

[1] This is not to say that *all* physicists in these disciplines take these definitions, but the examples are motivated by individuals who have expressed these views.

[2] See, e.g. footnote 14 of Bertone & Hooper, arXiv:1605.04909.

[3] An example is a workshop where some astronomers pulled me aside after a particle physics talk and asked: *So are WIMPs ruled out or not? Because if they're ruled out, I'd like to know what we're looking for.*

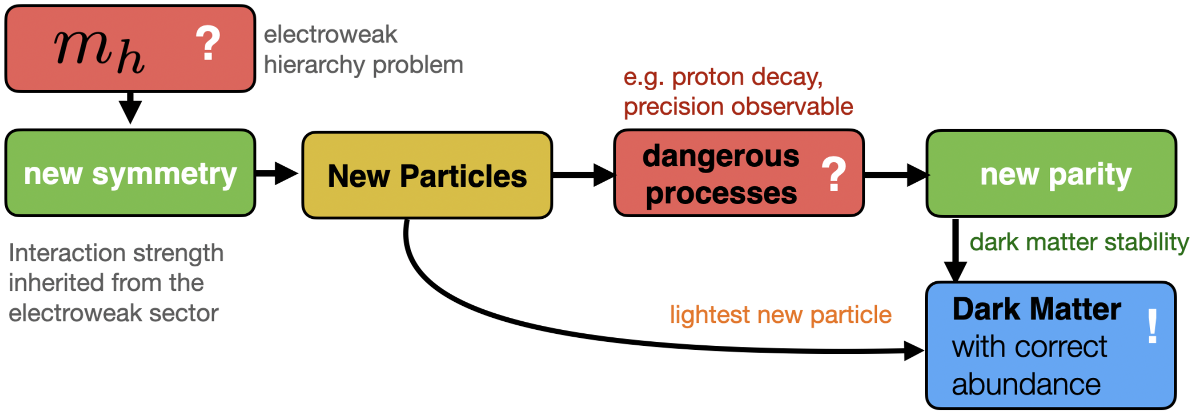

Figure 1: Proposed definition of a WIMP based on a symmetry solution to the hierarchy problem. New symmetries introduce new particles with electroweak coupling strengths. The lightest of these particles roughly electroweak-scale masses. These new particles induce problematic processes that require further 'small' symmetries—such as a new parity—to prohibit the offending interactions. The combination of the new particles with electroweak-masses, electroweak interaction strengths and the additional parity make the lightest new particle a dark matter candidate that *roughly* realizes the observed dark matter abundance.

2. The new particles have *electroweak-scale masses*, within some orders of magnitude[4].
3. These new particles typically mediate problematic processes like proton decay or large corrections to electroweak precision observables. To prohibit the vertices that induce these processes, we impose an additional 'smaller' symmetry: e.g. R-parity, KK-parity, T-parity.
4. This parity ensures that the *lightest new particle is stable*.

This lightest new particle is a dark matter candidate. WIMPs with different origins (e.g. neutralino versus lightest T-odd particle) have similar *make it, shake it, break it*[5] (collider, direct detection, and indirect detection) phenomenology related by crossing symmetry. The 'cherry on top' to this story is the so-called *WIMP miracle*: a stable particle with electroweak-scale mass and electroweak-scale interactions automatically produces the correct dark matter abundance by thermal freeze out—at least within an order of magnitude or two.

This definition of WIMP emphasizes its top-down motivation: the solution of the electroweak hierarchy problem. This gives some meaning to the question of whether WIMPs are viable: *is dark matter intimately connected to the solution of the hierarchy problem, or is it a completely separate sector of fundamental physics?* Separately from the theoretical motivation, one may define the adjective WIMP-*like*, to refer to models that are *not* connected to the hierarchy problem but have dark matter particles that otherwise realize similar phenomenology.

Beyond WIMPs. A clear definition of WIMP helps establish a target-of-interest in dark matter physics across different communities. Even more crucially, a universal definition for WIMPs identifies the ways by which non-WIMP models are different. By contrasting against the standard definition of a WIMP, we can motivate how non-WIMP theories offer unique phenomenology beyond the standard 'make it, shake it, break it' experimental program that has historically been motivated by WIMP properties.

[4]For example, this may due to soft symmetry breaking required to realize the Higgs mass.
[5]Apologies, I do not know the originator of this clever phrase.