Direct Detection Theory: Past, Present, and Future

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Direct Detection Theory Past

Particle theory input is often treated as somewhat decoupled in direct detection experiments – cross-section is a "single input"
The WIMP paradigm has (for good or ill) defined most direct detection efforts!

- Detector technologies focus on masses from 10 GeV – 1 TeV
- Dark matter not milli-charged and single-scattering events
- Assume scattering is elastic
- Assume cross-sections consistent with a thermal relic
- Assume isospin-invariance $\rightarrow A^2$ enhancement

Moreso than indirect or collider probes, the theory bias is crucial for direct detection search strategies

- Collider probes (mono-everything, resonance searches) vary little based on mass and coupling
- Astrophysical probes shift to different wavelengths
- Direct detection changes dramatically

Direct Detection Theory Present

Z-mediated interactions long ago ruled out

Current sensitivity cutting into Higgs-mediated interaction parameter space, particularly for neutralinos

- The current generation of direct detection experiments are already having a profound impact on SUSY parameter space
  - Particularly important for models with heavy scalars

Multiple signatures for low mass dark matter which motivate theory input

- Inelastic interactions?
- Isospin-violating interactions?
- Consistency with thermal production?
- Non-standard halo model? Is particle physics informative?
- Non-standard velocity structure for interactions?
- Multiple candidates?
- Corresponding signals in other frontiers?

Direct Detection Theory Future

What can theory do to make generalizing results for existing and future experiments easier?

- Factoring out velocity distribution uncertainties
- Generalizing beyond isospin invariance
- What non-standard interactions are worth pursuing? What nuclear physics input is required?
- What is the best way to compare with indirect and collider searches?

How to go beyond the WIMP Paradigm? What models are sufficiently motivated for dedicated searches?

- Should there be more focus on axion and dark photon models?

Concrete suggestion: Theoretical concerns motivate multiple detector materials