

TASI Lectures on the Particle Physics and Astrophysics of Dark Matter

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These lecture notes on the particle physics and astrophysics of dark matter (DM) were delivered at TASI 2022 “Ten Years After the Higgs Discovery: Particle Physics Now and Future.” The focus of these lecture notes, aimed at the level of advanced graduate students and beginning postdocs, is on indirect (*i.e.*, astrophysical and cosmological) probes of particle DM models. While DM models and indirect detection are broadly discussed, the examples of weakly interacting massive particles (WIMPs) and axions are worked out in detail. The topics covered include: the role of DM in the cosmology and astrophysics of structure formation, including DM density profiles in galaxies, general constraints on particle DM models, the theory of minimal DM, with the higgsino as a relevant and illustrative example, indirect detection with gamma-rays, including with the upcoming Cherenkov Telescope Array, axions as a solution to the strong- CP problem and a DM candidate, including discussions of possible ultraviolet completions and of axion string cosmology, and astrophysical probes of axions such as with isocurvature perturbations, N_{eff} , black hole superradiance, radio telescopes, spectral modulations, stellar polarization, and stellar cooling, amongst other topics. Example Jupyter notebooks are provided that walk the reader through relevant analyses, including an example statistical analysis of a DM annihilation search towards the Segue I dwarf galaxy with gamma-ray data from the *Fermi* Large Area Telescope that is relevant for DM explanations of the *Fermi* Galactic Center Excess. We also provide an introduction to frequentist statistics for particle and astro-particle physics. These lecture notes are meant to be pedagogical, with the focus on explaining the underlying physical principles and analysis techniques that are set to play crucial roles in the search for particle DM in the coming decade.

*TASI 2022 – “Ten Years After the Higgs Discovery: Particle Physics Now and Future,”
June 6 - July 1 2022
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