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Modeling evolution of dark matter substructure and annihilation boost

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We study evolution of dark matter substructures, especially how they lose the mass and change density profile after they fall in gravitational potential of larger host halos. We develop an analytical prescription that models the subhalo mass evolution and calibrate it to results of N-body numerical simulations of various scales from very small (Earth size) to large (galaxies to clusters) halos. We then combine the results with halo accretion histories, and calculate the subhalo mass function that is physically motivated down to Earth-mass scales. Our results — valid for arbitrary host masses and redshifts — show reasonable agreement with those of numerical simulations at resolved scales. Our analytical model also enables self-consistent calculations of the boost factor of dark matter annhilation, which we find to increase from tens of percent at the smallest (Earth) and intermediate (dwarfs) masses to a factor of several at galaxy size, and to become as large as a factor of ~10 for the largest halos (clusters) at small redshifts. Our analytical approach can accommodate substructures in the subhalos (sub-subhalos) in a consistent framework, which we find to give up to a factor of a few enhancement to the annihilation boost. Presence of the subhalos enhances the intensity of the isotropic gamma-ray background by a factor of a few, and as the result, the measurement by Fermi Large Area Telescope excludes the annihilation cross section greater than ~4×10^{-26} cm^{3} s^{−1} for dark matter masses up to ~200 GeV.

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