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Multiscatter Capture of Intermediate Mass Dark Matter by Population III Stars

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Self-annihilating dark matter, captured in the gravitational field of stars or other compact objects, can produce detectable fluxes and impact the evolution and observability of Population III stars. In the regime between WIMP dark matter masses (10^2 GeV) and superheavy masses ($> 10^8$ GeV), the number of scattering events required for capture increases from of order unity to thousands of scatters. Using the analytic formalism of multi scatter capture, combined with the latest constraints on dark matter cross section and Pop. III stellar evolution simulations, we calculate upper bounds on the capture rates of dark matter inside Pop. III stars. Assuming that a non-zero fraction of the capture dark matter thermalizes inside the star, we find that the additional heating from self-annihilating dark matter can become significant. Requiring that these stars shine at sub-Eddington luminosities, we impose upper bounds on the masses and luminosities on the first stars at the Epoch of Reionization, opening up the possibility of constraining dark matter properties using the initial mass function of extremely metal-poor stars.

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