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What does cosmology tell us about the mass of thermal-relic dark matter?

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The presence of light thermally coupled dark matter affects early expansion history and production of light elements during the Big Bang Nucleosynthesis. Specifically, dark matter that annihilates into Standard Model particles can modify the effective number of light species in the universe Neff , as well as the abundance of light elements created buring BBN. These quantities in turn affect the cosmic microwave background (CMB) anisotropy. We present the first joint analysis of small-scale temperature and polarization CMB anisotropy from Atacama Cosmology Telescope (ACT) and South Pole Telescope (SPT), together with Planck data and the recent primordial abundance measurements of helium and deuterium to place comprehensive bounds on the mass of light thermal–relic dark matter. We consider a range of models, including dark matter that couples to photons and Standard-Model neutrinos. We discuss the sensitivity of the inferred mass bounds on measurements of Neff , primordial element abundances and the baryon density, and quantify the sensitivity of our results to a possible existence of additional relativistic species. We find that the combination of ACT, SPT, and Planck generally leads to the most stringent mass constraint for dark matter that couples to neutrinos, improving the lower limit by 40%–80%, with respect to previous Planck analyses. On the other hand, the addition of ACT and SPT leads to a slightly weaker bound on electromagnetically coupled particles, due to a shift in the preferred values of Yp and Neff driven by the ground based experiments. In most scenarios, the combination of CMB data has a higher constraining power than the primordial abundance measurements alone, with the best results achieved when all data are combined. Combining all CMB measurements with primordial abundance measurements, we rule out masses below ~4 MeV at 95% confidence, for all models. We show that allowing for new relativistic species can weaken the mass bounds for dark matter that couples to photons by up to an order of magnitude or more. Finally, we discuss the reach of the next generation of the CMB experiments in terms of probing the mass of the thermal relic dark matter.

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