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Theoretical and numerical aspects of CMB spectral distortions from non-thermal electromagnetic energy injections

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CMB spectral distortions is one of the cleanest probe for electromagnetic energy injection scenarios in the pre-recombination universe. Energy injection without the addition of extra photons gives rise to CMB spectral distortion below $z < 2*10^6$ due to inefficiency of photon non-conserving processes. During this epoch, Compton scattering is the dominant process which drives the evolution of coupled CMB photons and the background electrons. Traditionally, the distorted CMB spectrum is evolved by solving the Kompaneets equation which assumes Compton scattering to be non-relativistic. We will verify the accuracy of this assumption by solving the exact Compton kernel equation. We will show that relativistic corrections to non-relativistic Compton scattering is important for predicting the precise shape of CMB spectral distortions. We will explore the implications of using the exact Compton kernel for non-thermal electromagnetic energy injections and deriving accurate constraints on dark matter decays or annihilation.

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