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# Theoretical Foundations of the Sunyaev-Zel'dovich Effect

The cosmic microwave background (CMB) is a powerful observational tool for probing the formation and evolution of structures in our universe, encoding information through both primary anisotropies, imprinted by primordial fluctuations, and secondary anisotropies, which arise from interactions with large-scale structures. Among the secondary anisotropies, a particularly powerful probe of ionized gas, such as that found in the intracluster medium (ICM) of galaxy clusters, is the Sunyaev-Zel'dovich effect (SZE), i.e., the spectral distortion induced in the CMB spectrum by the interaction of CMB photons with free electrons in the ICM via inverse Compton scattering.

Although the phenomenology of both the thermal and kinetic components of the SZE is well understood, a rigorous derivation of this effect is rarely presented in the literature. Therefore, in this work, we aim to provide such a derivation by formulating the Boltzmann equation in a curved spacetime framework and applying tools from quantum field theory to describe the underlying microscopic interactions responsible for the effect.

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