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Interacting neutrinos in cosmology: exact description and constraints

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We study and constrain the impact of non-standard neutrino interactions on the CMB angular power spectrum. Starting from the collisional Boltzmann equation, we derive the Boltzmann hierarchy for neutrinos including interactions with a massive scalar particle.
In contrast to the Boltzmann hierarchy for photons, our interacting neutrino Boltzmann hierarchy is momentum dependent, which reflects non-negligible energy transfer in the considered neutrino interactions.
We implement this Boltzmann hierarchy into the Boltzmann solver CLASS and compare our results with known approximations in the literature. We thereby find a very good agreement between our exact approach and the relaxation time approximation (RTA). The popular $\left(c^2_{\rm eff}, c^2_{\rm vis}\right)$-parametrization however does not reproduce the correct signal in the CMB angular power spectrum.
Using the RTA, we furthermore derive constraints on the effective coupling constant $G_{\rm eff}$ from currently available cosmological data. Our results reveal a bimodal posterior distribution, where one mode represents the standard ΛCDM limit, and the other
a scenario of neutrinos self-interacting with $G_{\rm eff} \simeq 3 \times 10^9\, G_{\rm F}$ (where $G_{\rm F}$ is the Fermi coupling).

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