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Signals from the early Universe

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The cosmic microwave background (CMB) has been measured with the COBE, WMAP and Planck space missions. Its black-body Planckian spectrum as determined by COBE-FIRAS corresponds to a mean temperature of T_{CMB} = (2.725 ± 0.001) K, and Planck accurately mapped the spatial temperature fluctuations at the level of T/T 6×10^{-6}, thus allowing for conclusions about structure formation in the early universe. However, it has not yet been possible to observe residual spectral lines from the recombination phase some 380,000 years after the Big Bang when the first elements hydrogen and helium were formed [1].

As the most prominent spectral line emitted during recombination, the time-evolution of the hydrogen Lyman-alpha line has recently been investigated in a nonlinear diffusion model that can be solved analytically [2]. The shift of this line emitted at 2466 THz towards lower frequencies in the course of scattering with free electrons and other damping processes, as well as its simultaneous broadening is considered in the model together with the expansion and cooling from $T \simeq 3000$ K at recombination, to 2.725 K now. The thermalization of the Lyα line remains incomplete, such that it could in principle be observable in today's CMB. Based on the calculation [2] in a non-linear model, the signal from the hydrogen Lyman-alpha line is likely to be about seven orders of magnitude lower than the CMB signal –too weak to be detectable with today's technology, as is evidenced by the recent Planck measurement [1].

The result is in accordance with numerical models [3] that have also been compared with CMB observations. Both approaches call for more sensitive equipment in future space missions to actually measure remnants of recombination lines in the CMB.

[1] Aghanim, N., et al.: Planck 2018 results: VI. Cosmological parameters. Astron. Astrophys. 641, 6 (2020).

[2] G. Wolschin: Partial Lyα thermalization in an analytic nonlinear diffusion model. Scientific Reports 14, 4935 (2024).

[3] R.A. Sunyaev, J. Chluba: Signals from the epoch of cosmological recombination. Astron. Nachr. 330, 657–674 (2009); J. Chluba, R.A. Sunyaev: Cosmological hydrogen recombination: influence of resonance and electron scattering. Astron. Astrophys. 503, 345–355 (2009)

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