Temperature Fluctuations of the Cosmic Microwave Background Radiation: A Case of Nonextensivity?

Armando Bernui,[1] Constantino Tsallis,[2,3] and Thyrso Villela[1]

[1]Instituto Nacional de Pesquisas Espaciais, Divisão de Astrofísica
Av. dos Astronautas 1758, 12227-010 – São José dos Campos, SP, Brazil
[2]Centro Brasileiro de Pesquisas Físicas
Rua X. Sigaud 150, 22290-180 – Rio de Janeiro, RJ, Brazil
[3]Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, New Mexico 87501, USA

Temperature maps of the Cosmic Microwave Background (CMB) radiation, as those obtained by the Wilkinson Microwave Anisotropy Probe (WMAP), provide one of the most precise data sets to test fundamental hypotheses of modern cosmology. One of these issues is related to the statistical properties of the CMB temperature fluctuations, which would have been produced by Gaussian random density fluctuations when matter and radiation were in thermal equilibrium in the early Universe. We analysed here the WMAP data and found that the distribution of the CMB temperature fluctuations $P^{\mathrm{CMB}}(\Delta T)$ can be quite well fitted by the anomalous temperature distribution emerging within nonextensive statistical mechanics. This theory is based on the nonextensive entropy $S_q \equiv k\{1 - \int dx\,[P_q(x)]^q\}/(q-1)$, with the Boltzmann-Gibbs expression as the limit case $q \to 1$. For the frequencies investigated ($\nu = 40.7$, 60.8, and 93.5 GHz), we found that $P^{\mathrm{CMB}}(\Delta T)$ is well described by $P_q(\Delta T) \propto 1/[1+(q-1)B(\nu)\Delta T^2]^{1/(q-1)}$, with $q = 1.05 \pm 0.005$, which exclude, at the 99% confidence level, exact Gaussian temperature distributions $P^{\mathrm{Gauss}}(\Delta T) \propto e^{-B(\nu)\Delta T^2}$, corresponding to the $q \to 1$ limit, to properly represent the CMB temperature fluctuations measured by WMAP.