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Probing the State of the IGM via the Thermal and Kinematic SZ-effect

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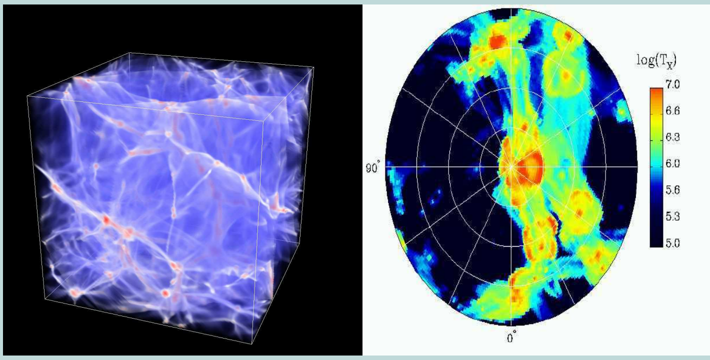
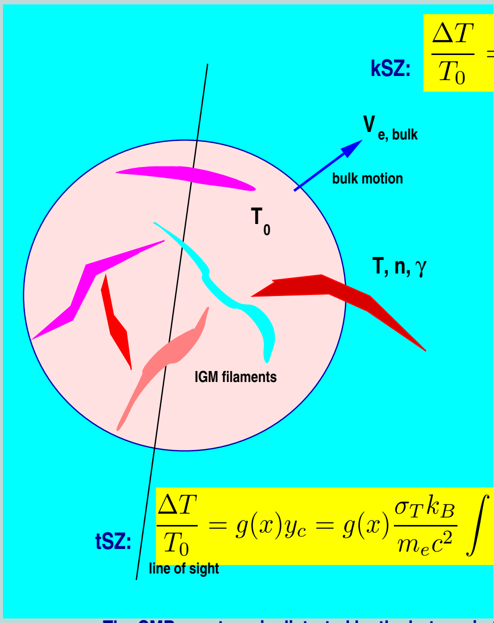
Simulations indicate that the 'missing baryon' fraction in the Universe resides in filaments in the Intergalactic Medium (IGM). This medium becomes highly ionized right after the reionization epoch at $z > 6$, and the reionization temperature determines the baryon Jeans length, fixing the scales that could grow. This highly ionized medium gives rise to thermal (tSZ) and kinematic (kSZ) Sunyaev-Zeldovich temperature anisotropies on the CMB, that we compute assuming the gas density distribution follows a log-normal PDF. The contribution of both effects is very sensitive to the effective polytropic index γ of the IGM, the mean temperature T_0 at background density, the amplitude of the matter power spectrum σ_8 and the fraction f_b of baryons residing in this medium. The kSZ and tSZ signals have similar amplitudes but at different angular scales. THe kSZ component is within reach of WMAP. Assuming the baryon fraction in the IGM as of $f_b \le 0.8$, $\sigma_8 \simeq 0.8$, WMAP 5yr data sets an upper limit for $\gamma T_0 \le 2\times 10^4 K$. PLANCK will be able to detect the tSZ component on angular scales corresponding to $l > 2000$ and set tighter constraints on the physical state of the IGM.



The filamentary network of the WHIM over scales of ~60 Mpc (credit to J.Klar) and the local (smaller scale) WIHM (credit to A.Kravtsov, A.Klypin & Y.Hoffmann)



kSZ:
$$\frac{\Delta T}{T_0} = \frac{\sigma_T}{c}\int v_{e,l} n_{e,l} dl$$

The kinematic SZ effect describes the distortion of the CMB spectrum due to the bulk motion of electrons.

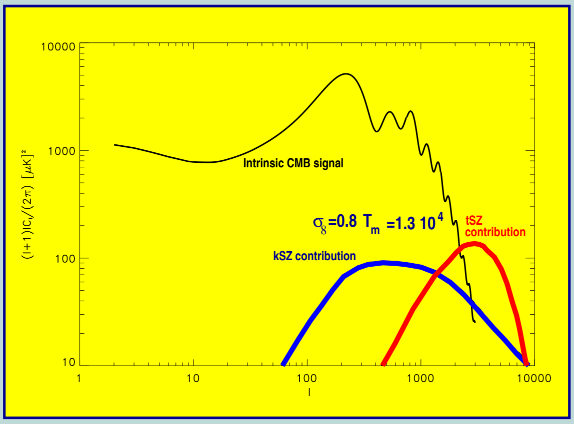
tSZ:
$$\frac{\Delta T}{T_0} = g(x) y_c = g(x)\frac{\sigma_T k_B}{m_e c^2}\int T_e(x,z) n_e(x,z) dl$$

The CMB spectrum is distorted by the hot gas in filaments. The tSZ effect is frequency dependent and is determined by the integrated electron pressure along the considered line of sight.

We have assumed that the IGM matter is distributed log–normal.

$$P(\xi) = \frac{1}{\xi\sqrt{2\pi}\Delta_B} e^{-[\log(\xi)+\Delta_B^2]^2/2\Delta_B^2}, \xi = \rho/\rho_0$$

TSZ and kSZ components produce anisotropies of similar amplitude, depending on physical parameters, but at different scales. The position of the maximum depends on the baryon Jeans length. The kSZ maximum occurs at l ~ 400 and the tSZ at l~3000, the former is within reach of the WMAP satellite.



The figure shows the tSZ and kSZ contributions for different parameters. Recent studies show that the WMAP data fit can be improved if adding the kSZ contribution (Atrio–Barandela, Mücket, Genova–Santos 2008) indicating on a possible detection of the kSZ effect.

Preliminar results obtained by running a Monte Carlo Markov Chain with a 6 parameter ΛCDM model and 3 physical parameters describing the state of the IGM showed that the kSZ contribution reaches a maximum of $l(l+1)C_l/2\pi \sim 100\,(\mu K)^2$ as indicated in the figure. For this parameter we also predict a tSZ contribution of comparable amplitude.

See also:

F. Atrio–Barandela & J.P. Mücket, ApJ 643, 1 (2006)
F. Atrio–Barandela, J.P. Mücket, & R. Genova–Santos, ApJ 674L, 61 (2008)

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