CORRELATION FUNCTIONS, MICROWAVE BACKGROUND, AND PANCAKES

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The isothermal theories of galaxy formation encounter serious difficulties in accounting for the existence of large voids (see, e.g., Aarseth and Saslow 1982). The alternative picture of adiabatic fluctuations and pancake collapse (see, e.g., Doroshkevich et al. 1978 and references therein) faces difficulties due to: i) observed correlation functions, and ii) the absence of small-scale fluctuations in the microwave background.

As far as i) is concerned, a puzzling aspect is the absence of any trace of the damping scale, M_D (this scale should have already reached a sufficient density to fragment into galaxies). All published results on M_D based on reliable recombination physics agree, within 60%, with the relation:

$$M_D/M_\odot = 10^{12.25} (\Omega h^2)^{-1.4}.$$

Here we discuss some results concerning ii). Let us suppose that, before recombination, $|\delta_m(k)|^2 = |\delta\rho_m/\rho_m|^2 = Ak^n$ from a scale k_J up to a scale k_D. We shall assume $\lambda = 2\pi/k$, and $M = (\pi/6)\rho_m\lambda^3$.

Below λ_D fluctuations are damped because of photon diffusion (see, e.g., Bonometto and Lucchin 1979). From λ_D up to λ_J (Jeans length), fluctuations oscillate from their entry in the horizon (at $z_H(\lambda)$) until recombination. Thence, above λ_J, the amplitude of fluctuations is greater by a factor $z_H(\lambda)/z_{rec}$, depending upon λ.

For $k < k_J$, therefore, A is increased by a factor $(z_H(\lambda_J)/z_{rec})^2$, while n becomes n + 4. Moreover, let the mass variance, after recombination, be $\delta M/M \propto M^\alpha$. If n is unchanged (for $\lambda_D < \lambda < \lambda_J$) during recombination, it turns out that $\alpha = -n/6-1/2$. Therefore, for $n > -3$, $\delta M/M$ has its maximum just above M_D. We then normalize $\delta_m(k)$ by requiring that $\delta_m(k_D)$ becomes nonlinear at $z \sim 3$. For $n \lesssim -3$ the situation is different and the most sensible normalization procedure refers to correlation functions. This case was treated by Silk and Wilson, who considered n = -3, -4, -5. They found fluctuations in the microwave radiation nearly independent of n and exceeding radiation observational limits.

The results we present here concern the values n = 1, 0, -1.

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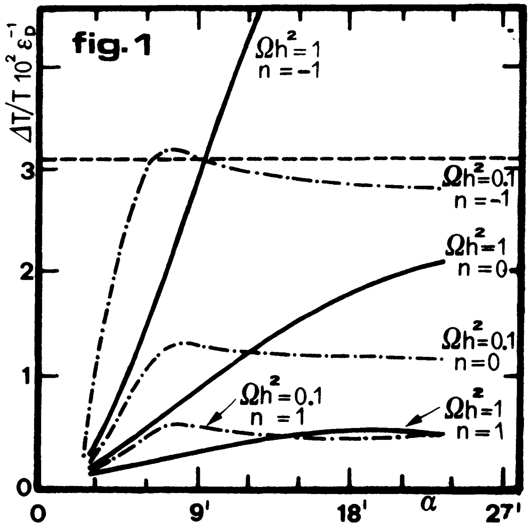

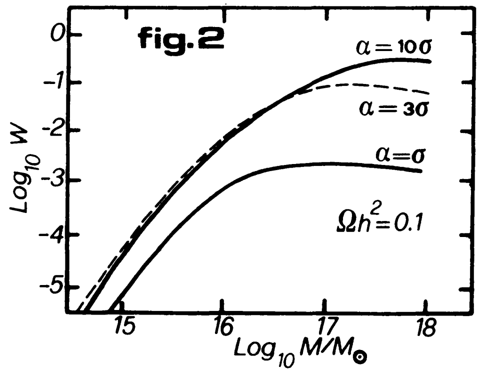

Figure 2. The weight, W, of the different mass scales in determining $\Delta T/T$ is plotted for $\sigma = 1.8'$ and several values of α.

Figure 1. The square average $\Delta T/T$ of the relative temperature difference between two directions at angle α is plotted for a beamwidth $\sigma = 1.8'$; here $h = 0.75$; A is normalized in order that the initial mass variance over the scale M_D is ε_D. Values $\varepsilon_D \gtrsim 10^{-2.5}$ are required. The dashed horizontal line yields the level corresponding to $\Delta T/T = 10^{-4}$.

This result is obtained by using a full kinetic treatment of radiation; we made an expansion of the phase space distribution into spherical harmonics and checked that considering 50 of them is sufficient down to a redshift where γ-e scattering can be neglected and the evolution of photon density perturbations can be treated exactly (see Bonometto *et al*. 1982). In Figure 1 we plot the amplitude of the expected small-scale fluctuations of the microwave radiation which are compatible with observational limits and dependent on n. In fact, the scales from which microwave fluctuations are mostly generated widely exceed the normalization scale M_D (see Figure 2); a larger n (steeper spectrum) causes smaller microwave fluctuations.

It has been suggested that a nonzero neutrino mass could result in microwave fluctuation limits that are consistent with observations. Our point here is that this is not a necessary requirement.

References

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Discussion

Szalay: The formula for the damping mass assumes that the universe is fully dominated by baryons. If the universe contains a large amount of dark matter (e.g., neutrinos), the expression for the damping mass should be:

$$M_D = 3 \times 10^{13} \, \Omega_B^{-3/2} \, \Omega_T^{1/4} \, h^{-5/2} \, M_\odot ,$$

as given by Bond, Efstathiou and Silk (1980, Phys. Rev. Lett., 45, 1980-1984). If $\Omega_B < 0.1$, then $M_D \gtrsim 10^{15} M_\odot$, and the problem with the absence of a feature in the correlation function disappears.

Bonometto: I feel that it is fairly important that all computations of M_D for a baryon-dominated universe, based on different but acceptable approximations, arrive at results in good agreement. This is not directly evident from the literature, where different relations among k, λ, M, and different values of h are used; furthermore, the evolution of fluctuations before decoupling is sometimes mixed up with transmission through decoupling.

Certainly, the "use" of massive neutrinos helps to solve quite a number of problems. My main point here was that at least one of these problems (microwave radiation small scale fluctuations) can be solved without the need for massive neutrinos.

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