Particle Astrophysics (171.697) Spring 2012

Problem Sets 10-11

Due: In class, first class of week 12

1. In the CMB temperature power spectrum C_ℓ, there is a characteristic multipole moment ℓ (or equivalently, angular scale, $\theta \simeq \pi/\ell$) that separates small angular scales from large angular scales. That multipole moment is the $\ell_{\rm sh}$ corresponding to the sound horizon at the surface of last scatter at redshift $z \simeq 1100$. Usually when you see plots of the CMB power spectrum, it is $\ell^2 C_\ell$ that is plotted. For $\ell \lesssim \ell_{\rm sh}$, $\ell^2 C_\ell \sim$constant, and for $\ell \gtrsim \ell_{\rm sh}$ there are a series of acoustic peaks that result from oscillations in the photon-baryon fluid before recombination. The multipole moment $\ell_{\rm sh}$ is, roughly speaking, the value of ℓ at which the first acoustic peak in the CMB power spectrum appears. (a) Calculate the angle $\theta_{\rm sh}$ $(= \pi/\ell_{\rm sh})$ subtended by the *sound* horizon at the surface of last scatter as a function of Ω_m and Ω_Λ. Assume that the sound speed in the baryon-photon fluid is $1/\sqrt{3}$ times the speed of light. (b) Plot iso-$\ell_{\rm sh}$ contours in the Ω_m-Ω_Λ parameter space. (c) Next, calculate the sound speed in the baryon-photon fluid just before recombination. How far does it differ from $1/\sqrt{3}$ for the currently preferred values for Ω_m and Ω_b? Which way would the first acoustic peak in the CMB power spectrum move if Ω_b was increased? (d) Suppose that instead of a cosmological constant (i.e., equation-of-state parameter $w = -1$), the dark energy had $w = -0.9$. Which way would the first acoustic peak move (holding all other parameters fixed)? You can answer this simply in words; no need for detailed calculation.

2. Do Exercises 3 and 5 in astro-ph/04003392.