ASTR 5770 Cosmology Fall 2018. Final. Due noon Wed 19 Dec

1. Galaxy power spectrum

(a) Numerical calculation

This is essentially Exercise 30.15 in the notes. Build on the code you wrote in Problem Set 9 to compute the transfer function $T_{\rm m}(\eta, k)$. Deduce the matter power spectrum $P_{\rm m}(\eta_0, k)$ at the present time, $\eta = \eta_0$. Use the normalization and tilt of primordial power measured from Planck (2018) https://arxiv.org/abs/1807.06209. Compute power spectra for a concordance ΛCDM model, $\Omega_{\rm m} = 0.3$, $\Omega_\Lambda = 0.7$, and a flat matter-dominated Universe, $\Omega_{\rm m} = 1$. Compare your matter power spectrum to data from Anderson et al. (2014) http://arxiv.org/abs/1312.4877, downloadable from https://www.sdss3.org/science/boss_publications.php. The best data set is the "post-reconstruction" DR11 set (Data Release 11). The "reconstruction" involves undoing at least some of the effects of nonlinear evolution by moving galaxies around. Note the units of the data: wavenumber k in $h\,{\rm Mpc}^{-1}$ and power $P(k)$ in $(h^{-1}\,{\rm Mpc})^3$, with $h \equiv H_0/(100\,{\rm km\,s^{-1}\,Mpc^{-1}})$. Anderson give a covariance matrix for logarithmic powers $\log_{10} P(k)$; for simplicity, take the error in $\log_{10} P(k)$ to be the square root of the diagonal of that matrix.

As in Problem Set 9, you may find that your integration routine gets stuck trying to integrate the oscillating radiation monopole and dipole once the mode is well inside the horizon, $k\eta \gg 1$. The strategy suggested in Problem Set 9 was to modify the radiation dipole equation by introducing an artificial damping term that damps radiation once it is well inside the horizon. Since the radiation fluctuation ceases to influence the gravitational potential or the matter fluctuation once the radiation has oscillated many times, the artificial damping has little effect on the model power spectrum.

A second problem you will encounter is that of power at superhorizon scales. Astronomers on Earth cannot measure power at scales larger than our horizon because they cannot distinguish a superhorizon fluctuation from a change in the mean density of the background FLRW geometry. To eliminate the unmeasurable superhorizon power, calculate power from the overdensity $\delta_k - \delta_0$ with a large-scale constant δ_0 subtracted.

A third problem is that galaxies do not necessarily trace the distribution of matter. A simple model is to suppose a linear relation between galaxy overdensity $\delta_{\rm g}$ and matter overdensity $\delta_{\rm m}$ (in Fourier space),

$$\delta_{\rm g} = b\delta_{\rm m} \ ,$$

where b is the bias parameter. Linear bias was introduced by Kaiser (1984) Ap. J. Lett. 284, L9, who showed that regions of a Gaussian field above a high threshold density are linearly biased.

(b) Baryonic Acoustic Oscillations

Does your computed power spectrum show Baryonic Acoustic Oscillations (called BAO by the cosmological community)? Why or why not? What causes BAO?