Extra-Galactic Astronomy I (Cosmology)

Project 8: Estimating sound horizon from spatial clustering

Total marks: 30

1 Background

The sound horizon at the epoch of decoupling between photons and baryons is imprinted in the present-day spatial clustering of galaxies in the form of ripples in the galaxy power spectrum. In this project we will use simulated power spectra of low-redshift galaxies (these will be provided) to numerically estimate the comoving size of the sound horizon. You will parametrise the shapes of the power spectra using smooth 'broad-band' shapes superimposed with the acoustic ripples, and use Markov Chain Monte Carlo techniques to constrain the model parameters, one of which will be the value of the sound horizon. You will compare the recovered estimate with the value obtained theoretically.

2 Data

The plain text file `Pk_010.txt` contains measurements of the power spectrum $P(k)$ of haloes from a set of N-body simulations. The first column gives the values of k in h/Mpc, the second gives the measured $P(k)$ in $(h/\mathrm{Mpc})^3$, the third gives the estimated error on the measurement. The last column gives the fitting function from BBKS (Bardeen et al. 1986), which is a reasonable first guess for a broad-band shape of the power spectrum.

3 What to do

3.1 Set-up

Use the ratio $R(k) \equiv P(k)/P_{\mathrm{BBKS}}(k)$ as your primary data set (appropriately changing the error bars as well). Restrict attention to the range $0.03 < k/(h/\mathrm{Mpc}) < 0.3$ (i.e., throw away the remaining data). Use the following model for $R(k)$:

$$R(k) = A f(k) \left(1 + B \sin^2(k r_{\mathrm{s}}/\sqrt{3})\, \mathrm{e}^{-k^2\sigma_v^2/2}\right)$$

where the broad-band function is given by

$$f(k) = 1 + C \log(k/0.08) + D(\log(k/0.08))^2$$

Here r_{s} is the sound horizon at last scattering, whose value we want to estimate. σ_v represents the nonlinear velocity dispersion which damps the acoustic oscillations: you can fix $\sigma_v = 10.8h^{-1}\mathrm{Mpc}$ in the analysis. A, B, C, D are nuisance parameters which you must vary along with r_{s} in the MCMC analysis.

3.2 MCMC

Use the code EMCEE to perform an MCMC analysis and find the best fitting parameters. You should show a triangle plot for the confidence contours and marginal distributions of $(r_{\mathrm{s}}, A, B, C, D)$, and also report the Chi-squared value, number of degrees of freedom and goodness of fit (p-value). Explore the effects of changing the broad-band function: can you find some shape that improves the goodness of fit while still returning an accurate estimate of r_{s}?