Extra-Galactic Astronomy I (Cosmology)

Project 4: Spherical Collapse for flat LCDM

Total marks: 30

1 Background

In the spherical collapse model, one follows the evolution of an overdense spherical ball of matter as it initially expands with the Hubble flow and then turns around and collapses. The relevant equation in a matter dominated universe is just Newtons gravitational force law for the radius of the ball, and the solution can be written analytically and one can derive expressions for a critical threshold of initial overdensity and the final, non-linear overdensity at the time of virialisation. In this project, we will explore the effects of adding a positive cosmological constant to the system. The resulting equations must now be solved numerically, and you will be required to produce plots of the resulting virial overdensity for various values of the cosmological constant.

2 What to do

2.1 Research

Reproduce the results of Appendix A of the paper Eke, Cole & Frenk (1996) MNRAS, **282**, 263-280, starting by showing that their equation (A1) is indeed an integral of the spherical evolution model in the presence of a positive cosmological constant in a spatially flat universe. Show that, in the limit $\Omega_{\rm m0} \to 1$ (equivalently, $\Omega_{\Lambda 0} \to 0$), this model recovers the familiar Einstein-deSitter (EdS) result $\Delta_{\rm c} = 18\pi^2$ for the virial overdensity.

2.2 Code

Set up code to evaluate all the integrals required in the calculation of the virial overdensity $\Delta_{\rm c}$, equation (A15).

2.3 Final result

Make a plot of the present-day virial overdensity as a function of present-day matter density contrast $\Omega_{\rm m0}$ in the range $0 < \Omega_{\rm m0} < 1$. For comparison, in the same plot also show the constant EdS result and the appropriate fitting function from equation (6) of Bryan & Norman (1998) ApJ, **495**, 80-99.