4300430: Introdução à Cosmologia Física

Final Project: Modified Gravity

(2016)

This project was not originally listed, but since one student asked to work on something related to this topic, I put some ideas for calculations that make this project somewhat similar to the other projects. I suggest the project is done for a $f(R)$ model of modified gravity, with the functional form from Hu & Sawicki 2007 and $|\bar{f}_{R0}| = 10^{-4}$ and $n = 1$. These results can then be compared to $\bar{f}_{R0} = 0$ which corresponds to GR and ΛCDM.

Theoretical Derivations

- *General*: Derive the modified Einsteins Eqs. from the the modified Einstein-Hilbert action $[R \to R + f(R)]$.
- *Background*: Specialize to a FRW metric and derive the modified Friedmann's Eqs. for $f(R)$ gravity.
- *Perturbations*: Consider metric perturbations in the Newtonian gauge (i.e. the potentials Ψ, Φ) and derive the perturbation equations in $f(R)$ gravity.

Numerical Implementations

Background:

- Solve numerically the modified Friedmann's Eqs. to find $a(t)$ and $H(z)$ for $f(R)$ gravity. How do these compare to ΛCDM?
- Compute the effective equation of state in this model $w_{\rm eff} = -1 - \frac{1}{3}\frac{d\ln[H^2/(\Omega_m H_0^2) - a^{-3}]}{d\ln a}$ as a function of z. (*Hint*: See Section II-B and Fig. 3 at Hu & Sawicki 2007)
- Compute the comoving distance $D(z) = \int dz/H(z)$ as a function of redshift z in $f(R)$ gravity. Compare to ΛCDM.

Perturbations:

- Follow the Halo Model project, but in the context of $f(R)$ gravity.
- Compute the modified linear matter power spectrum for $f(R)$ gravity from `MGCAMB` (http://aliojjati.github.io/MGCAMB/mgcamb.html). Just like `CAMB` evolve the linear perturbation equations for GR, `MGCAMB` does the same but including a modified Poisson equation for the corresponding gravity model.
- Use this linear spectrum to derive modified halo mass-function, halo bias and halo profiles. Assume that all functional forms remain the same as they were given in GR, and the only change is through the modified linear power spectrum for $f(R)$.
- After computing the Halo Model non-linear power spectrum, compare it to the power spectrum from `MGhalofit` (link). Just like `halofit` is a fit to simulations of GR, `MGhalofit` is a fit to simulations of modified gravity.

Now, for the actual project, I suggest you do one of the two possibilities:

1. All Theoretical Derivations+Numerical Background Implementations or
2. Numerical Perturbation Implementations.

Notice that option number 2 involves the same amount of work as the usual Halo Model project, but it is focused on exploring these ideas in modified gravity.