Week three summary of:

"Simulating the Formation of Cosmic Structure" by C.S. Frenk

In "Simulating the Formation of Cosmic Structure," Frenk analyzes recent simulations in two areas of cosmological importance: the clustering of dark matter and processes that lead to galaxy formation. He matches simulation outputs with actual data from astronomical databases in order to show the plausibility of the current cosmological model, ΛCDM[1].

Before diving into the details of the simulations, Frenk gives an overview of what quantities factor into the construction of a cosmological model. He summarizes the content on the universe in Table 1, and proceeds to justify their inclusion and discuss their properties[2]. Frenk goes on to discuss the initial conditions for the formation of the universe, including the use of inflation as a possible method of amplification of quantum fluctuations to produce the Doppler peaks observed in the CMB. He briefly mentions gravitational instability and how it is the primary factor for the growth of structure. Frenk finishes his overview with a paragraph on the values of fundamental constants like the Hubble constant.

The first half of Frenk's discussion on simulations deals with the spatial distribution of dark matter. The primary method of simulation discussed is the N-body simulation. It is worth noting that one of the often cited simulations in Frenk's paper, the "Hubble Volume" simulation, has been superceded by a simulation from the same group, namely the "Millennium Simulation" (There is a link on the class website to results from this simulation). Frenk presents quantitative evidence of the success of the dark matter simulation in Figure 2 in the dotted line representing the two-point correlation function for dark matter in the top right of Figure 1. He says the error bars on this line are smaller than a line width, but doesn't present any observational distribution of dark matter to match, only the closely related galaxy correlation. Though the distribution of dark matter on the scale of dark matter halos is up for debate, Frenk asserts that the distribution of dark matter in the universe using the ΛCDM is solved; but new research is being done in the simulation of galaxy formation.

Frenk begins his discussion of modeling galaxy formation by introducing a hybrid method of simulation – the semi-analytic modeling technique. In order to frame the modeling of galaxies as tractable pursuit, the semi-analytic method seems to be about finding symmetries and using them to the advantage of the experimenter. In his example on page ten, Frenk justifies this new method by saying a semi-analytical model of gas dynamics matches a N-body simulation. Frenk goes on to discuss the results of simulations and how them match up with observation. Figures 3 and 4 are mostly visual proof of simulation – the simulated distribution of galaxies matches the observed data from the APM and 2dFGRS galaxy surveys. Information derived from Figure 6 shown in Figure 8 says that models predict brighter galaxies are more likely to show up in large super clusters, which matches

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[1] The ΛCDM model, or Lambda Cold Dark Matter model, is theoretical framework the simulations use. The Λ is included in the acronym to emphasize that the model predicts the existence of dark energy. Cold Dark Matter is included because the model assumes the existence of dark matter that can't be observed by its emission of EM radiation and moved at non-relativistic speeds when the density of radiation = density of matter.
More at: http://en.wikipedia.org/wiki/Lambda-CDM_model

[2] Current values for the densities mentioned in Table 1 can be found in the above link.

data from the 2dFGRS survey reasonably well. Frenk also revisits Figure 2, this time to discuss the galaxy portion of the figure. He notes that the observational and theoretical distribution of galaxies match, but the galaxy and dark matter distributions do not match at small distances. However, Frenk explains this discrepancy as being a result of "interplay between the clustering of dark matter halos and the occupation statistics of galaxies in halos."[3]

Frenk concludes by summarizing his work and reiterating his point that the ΛCDM model produces simulations that match what we have observed.

[3] I wish I could say I understand that.