Non-Standard Structure Formation Scenarios

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Abstract. Observations on galactic scales seem to be in contradiction with recent high resolution N-body simulations. This so-called cold dark matter (CDM) crisis has been addressed in several ways, ranging from a change in fundamental physics by introducing self-interacting cold dark matter particles to a tuning of complex astrophysical processes such as global and/or local feedback. All these efforts attempt to soften density profiles and reduce the abundance of satellites in simulated galaxy halos. In this contribution we are exploring the differences between a Warm Dark Matter model and a CDM model where the power on a certain scale is reduced by introducing a narrow negative feature (”dip”). This dip is placed in a way so as to mimic the loss of power in the WDM model: both models have the same integrated power out to the scale where the power of the Dip model rises to the level of the unperturbed CDM spectrum again. Using N-body simulations we show that that the new Dip model appears to be a viable alternative to WDM while being based on different physics: where WDM requires the introduction of a new particle species the Dip stems from a non-standard inflationary period. If we are looking for an alternative to the currently challenged standard ΛCDM structure formation scenario, neither the ΛWDM nor the new Dip model can be ruled out with respect to the analysis presented in this contribution. They both make very similar predictions and the degeneracy between them can only be broken with observations yet to come.

Keywords: cosmology: theory – cosmology: large scale structure of Universe

1. The Setup

The so-called Cold Dark Matter crisis has led to a vast number of publications trying to solve the problems which seem to be associated with an excess of power on small scales. One possibility to reduce this power is to introduce Warm Dark Matter (i.e. Knebe et al. 2002; Bode, Ostriker & Turok 2001; Avila-Reese et al. 2001; Colin et al. 2000). But another way to decrease power on a certain scale is to introduce a negative feature (“dip”) into an otherwise unperturbed CDM power spectrum (cf. Knebe et al. 2001). Several mechanisms have been proposed that could generate such features in the primordial spectrum during the epoch of inflation. Among these are models with broken scale invariance (BSI) (Lesgourgues, Polarski & Starobinsky 1998), and particularly BSI due to phase transitions during inflation (Barriga et al. 2000).

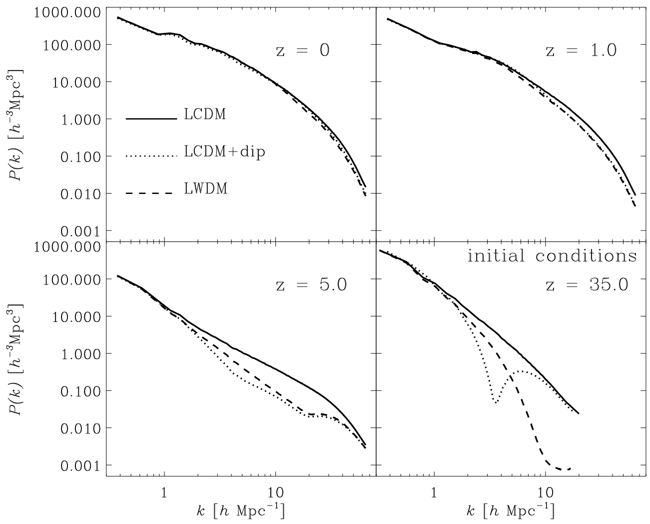

Figure 1. Evolution of the power spectrum as measured on a regular 512^3 grid.

The ΛWDM and the fiducial ΛCDM model used in this paper are the same as those presented in Knebe et al. (2002) with the cosmological parameters $\Omega_0 = 1/3$, $\lambda_0 = 2/3$, $\sigma_8 = 0.88$, $h = 2/3$, and $m_{\mathrm{WDM}} = 0.5$keV for ΛWDM. For the Dip model we are using the same prescription to introduce a Gaussian feature into an otherwise unperturbed CDM power spectrum as outlined in Knebe, Islam & Silk (2001) with the parameters A=-0.995, σ_{mod}=0.5, and $2\pi/k_0$=1.8h^{-1} Mpc.

2. The Outcome

In Fig. 1 we show the evolution of the dark matter power spectrum. We clearly see that the features are well represented in the initial conditions. But it is important to note that the non-linear transfer of power from large to small scales has washed out these features completely by redshift z=0. Therefore it is impossible to use current observations of the (galaxy) power spectrum as for instance measured by the 2dF team (Percival et al. 2001) to set constraints on features on such small scales (e.g. 1.8h^{-1} Mpc) in the primordial power spectrum.

One of the major problems with Cold Dark Matter is the overprediction of satellite galaxies orbiting within a galactic halo (Klypin et al. 1999, Moore et al. 1999). In Table I we summarize the number of satellites found in the most massive dark matter halo. It indicates that both non-standard models are able to overcome that problem. However, Fig. 2 shows that the mass history of that halo is indistinguishable for

Table I. Number of satellite galaxies within the virial radius of the most massive halo.

redshift	ΛCDM	ΛCDM+Dip	ΛWDM
$z = 0$	42	30	29
$z = 1$	29	29	29

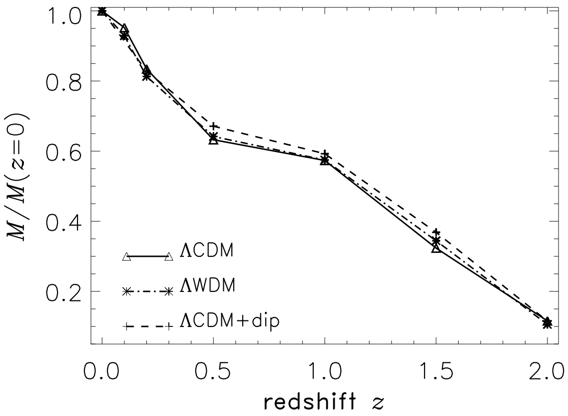

Figure 2. Evolution of the mass of the most massive halo in all three models.

all three models and hence the differences for $z = 0$ (along with the agreement for $z = 1$) in Table I can now only be explained by a different ratio of satellite accretion to satellite destruction throughout the models; in our non-standard models satellite galaxies are more easily disrupted because they are less concentrated.

Another interesting outcome is the formation history as well as the formation sites of low-mass galaxies $M \in [10^{10}, 10^{11}]h^{-1}$ M$_\odot$. Fig. 3 demonstrates that such halos do form at later times compared to the standard ΛCDM model and a detailed analysis of their formation sites shows that they are preferably forming along the filaments.

3. The Conclusions

We conclude from the given analysis that both our non-standard models work equally well even though they are based on completely different physical processes; where WDM requires the introduction of a new particle species the Dip model is based on a non-standard inflationary period. The only way of breaking their degeneracy might lie within

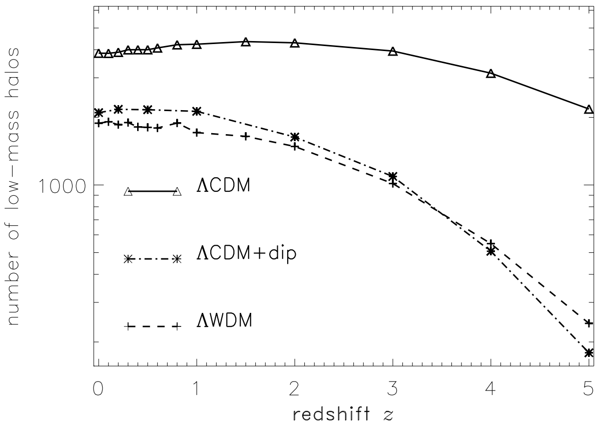

Figure 3. Abundance evolution of objects in the mass range $10^{10}h^{-1}$ M$_\odot$$< M < 10^{11}h^{-1}$ M$_\odot$.

the filamentary structures of the Universe and the low-mass end of the mass function. But to strengthen these findings we need more detailed and much better resolved simulations in the future.

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