The effects of galaxy formation on the matter power spectrum

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Marcel van Daalen, Joop Schaye,
Craig Booth & Claudio Dalla Vecchia

Sterrewacht Leiden

Introduction

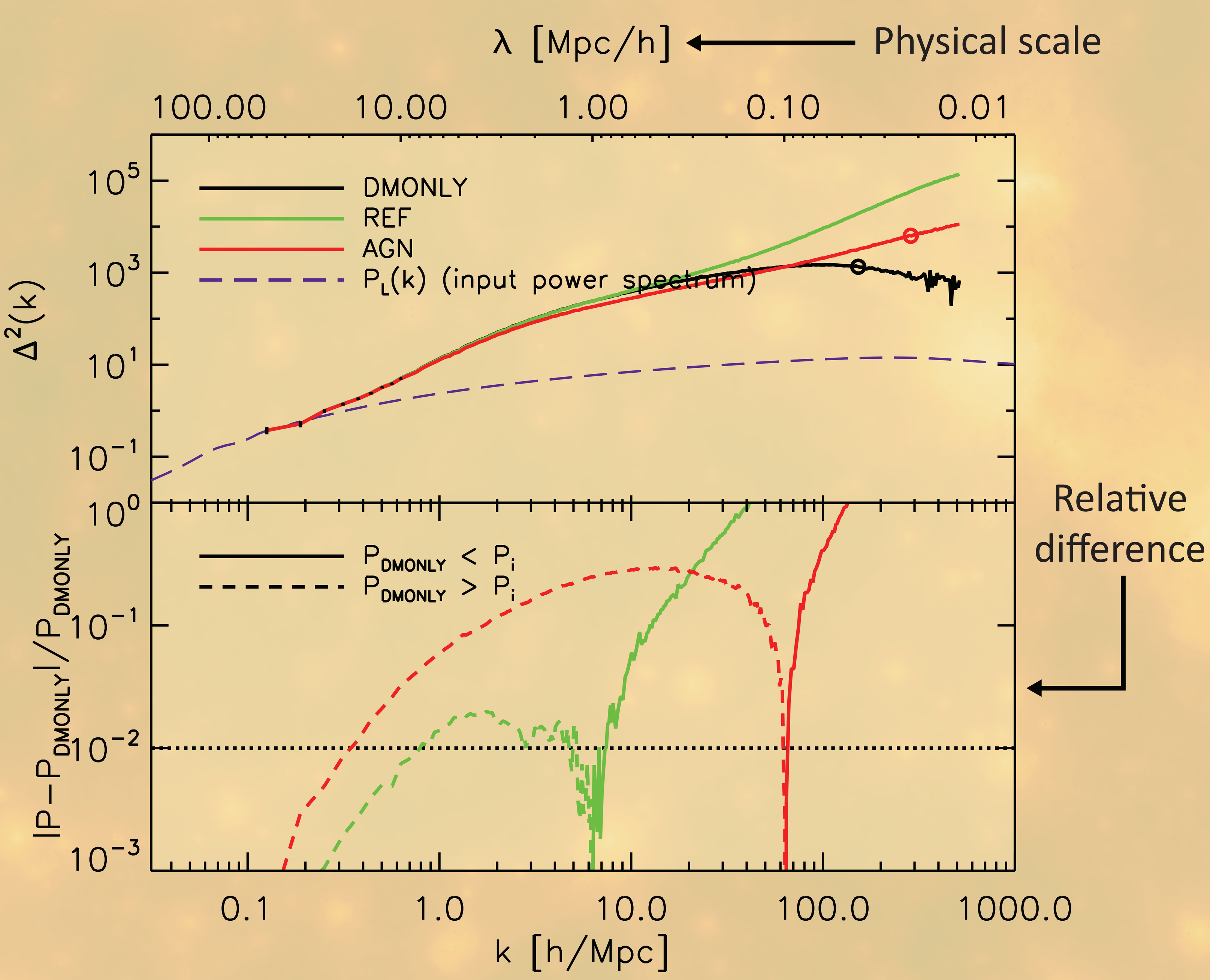
Upcoming weak lensing surveys, such as LSST, EUCLID, and WFIRST, aim to measure the matter power spectrum with unprecedented accuracy. In order to fully exploit these observations, models are needed that, given a set of cosmological parameters, can predict the non-linear matter power spectrum at the level of 1% or better for scales corresponding to comoving wave numbers 0.1<k<10 h/Mpc. We have employed the large suite of simulations from the OWLS project to investigate the effects of various baryonic processes on the matter power spectrum. In addition, we have examined the back-reaction of the baryons on the CDM.

Simulations

DMONLY: No baryons, cold dark matter only
REF: CDM+baryons, radiative cooling and heating (including metals and background radiation), star formation, metal enrichment and supernova feedback
AGN: Same as REF, but also includes AGN

All simulations use a 100 Mpc/h box and 2×512^3 particles.
A WMAP3 cosmology was used, but the main results are unchanged when switching to a WMAP7 cosmology.
All results are shown at z=0.

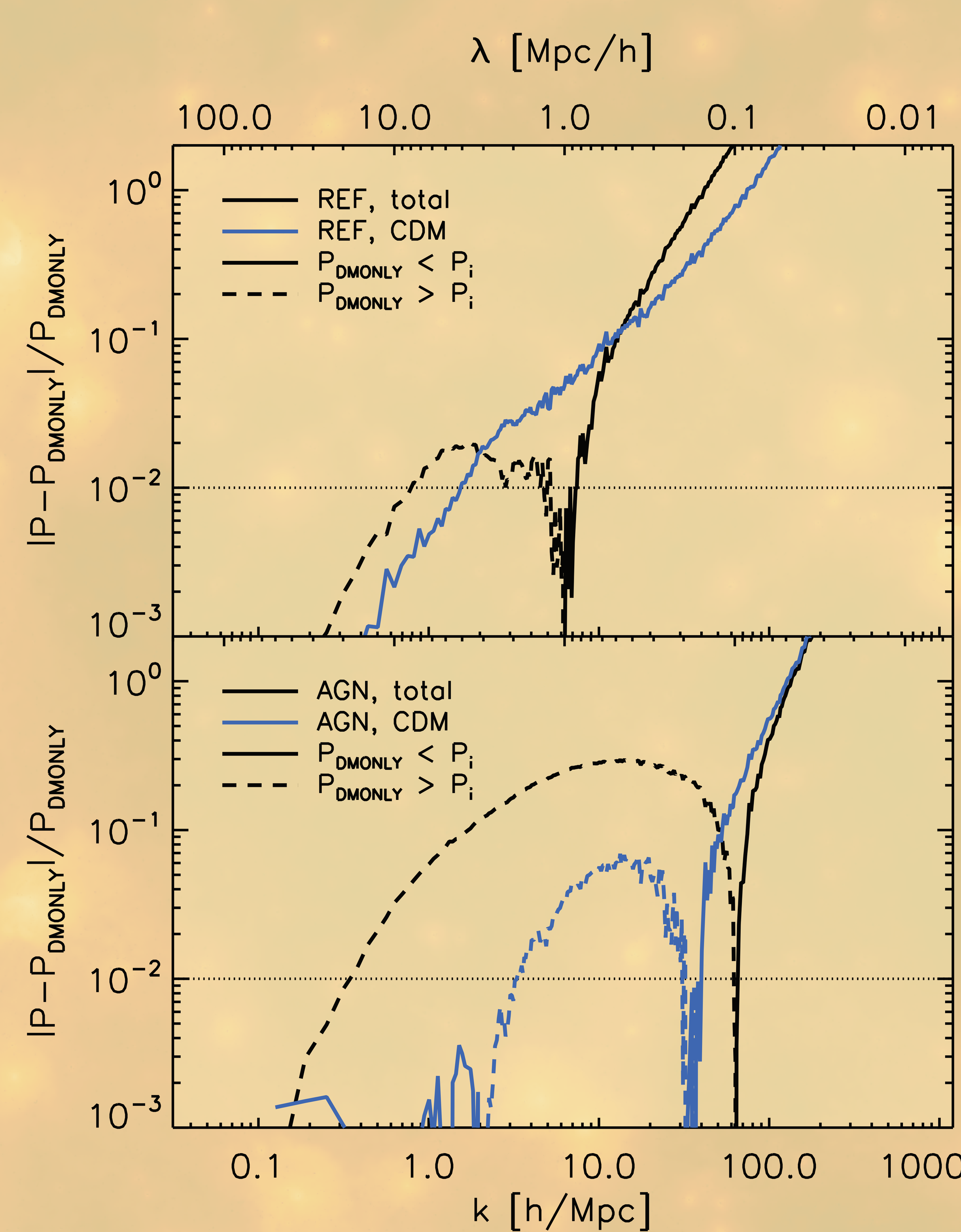
Main result



Basic baryonic processes (green line) decrease the power by ~1% for 1<k<10 h/Mpc, relative to a simulation including only dark matter (black line), because of the pressure of the gas at large scales. The power is greatly increased at small scales due to cooling.

However, when AGN feedback is included (red line), the results change drastically. The power is decreased by >1% for 0.3<k<60 h/Mpc, by up to several tens of per cent. This is caused by the removal of large quantities of gas from galaxies, and in some cases from the haloes entirely.

Back-reaction



The back-reaction of galaxy formation on the dark matter itself (blue lines) also radically changes when AGN are included. The effect of galaxy formation without AGN is a monotonic increase in power towards smaller scales (top panel), which can be modelled in dark matter only models by increasing the concentrations of haloes. However, due to large amounts of gas removed by AGN, the power actually decreases by up to 10% around k=10 h/Mpc (bottom panel). This effect is too complicated to model by just changing the concentrations of haloes.

Conclusions

AGN feedback completely changes the way galaxy formation and the associated baryonic processes affect the matter power spectrum. It is usually assumed, based on studies similar to this one that did not include AGN, that dark matter only models are accurate to 1% up to k=10 h/Mpc. We have shown that this is no longer the case when AGN are taken into account, in which case differences of >10% are observed for 2<k<50 h/Mpc.

We refer to Van Daalen et al. (2011) for more information, and Semboloni et al. (2011) for the effects this has on weak lensing measurements.

Link to the paper (scan me!)

Poster by Marcel van Daalen, July 2011
PhD-student at Leiden Observatory & MPA Garching
daalen@strw.leidenuniv.nl | daalen@mpa-garching.mpg.de

Link to my website (scan me!)