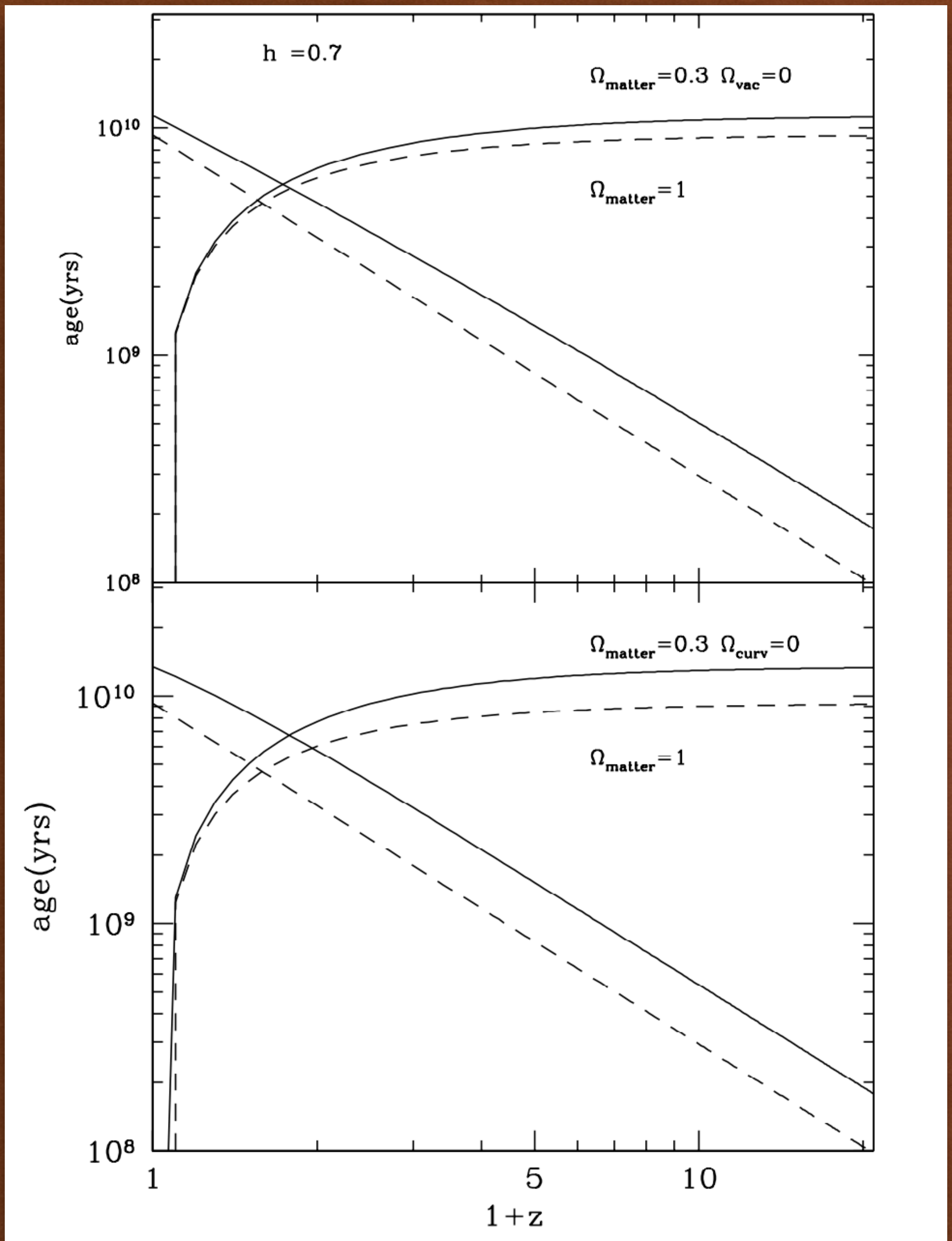
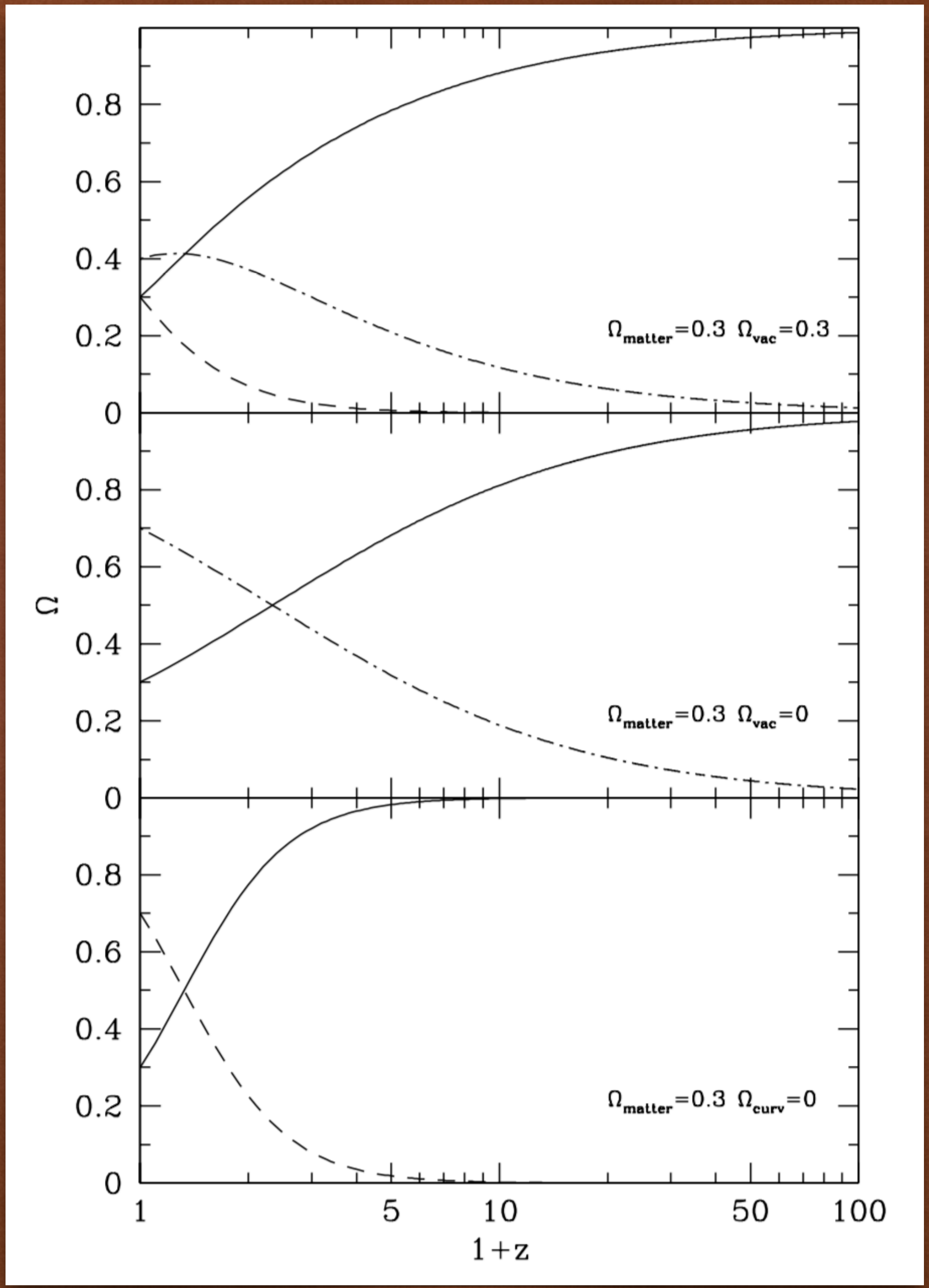
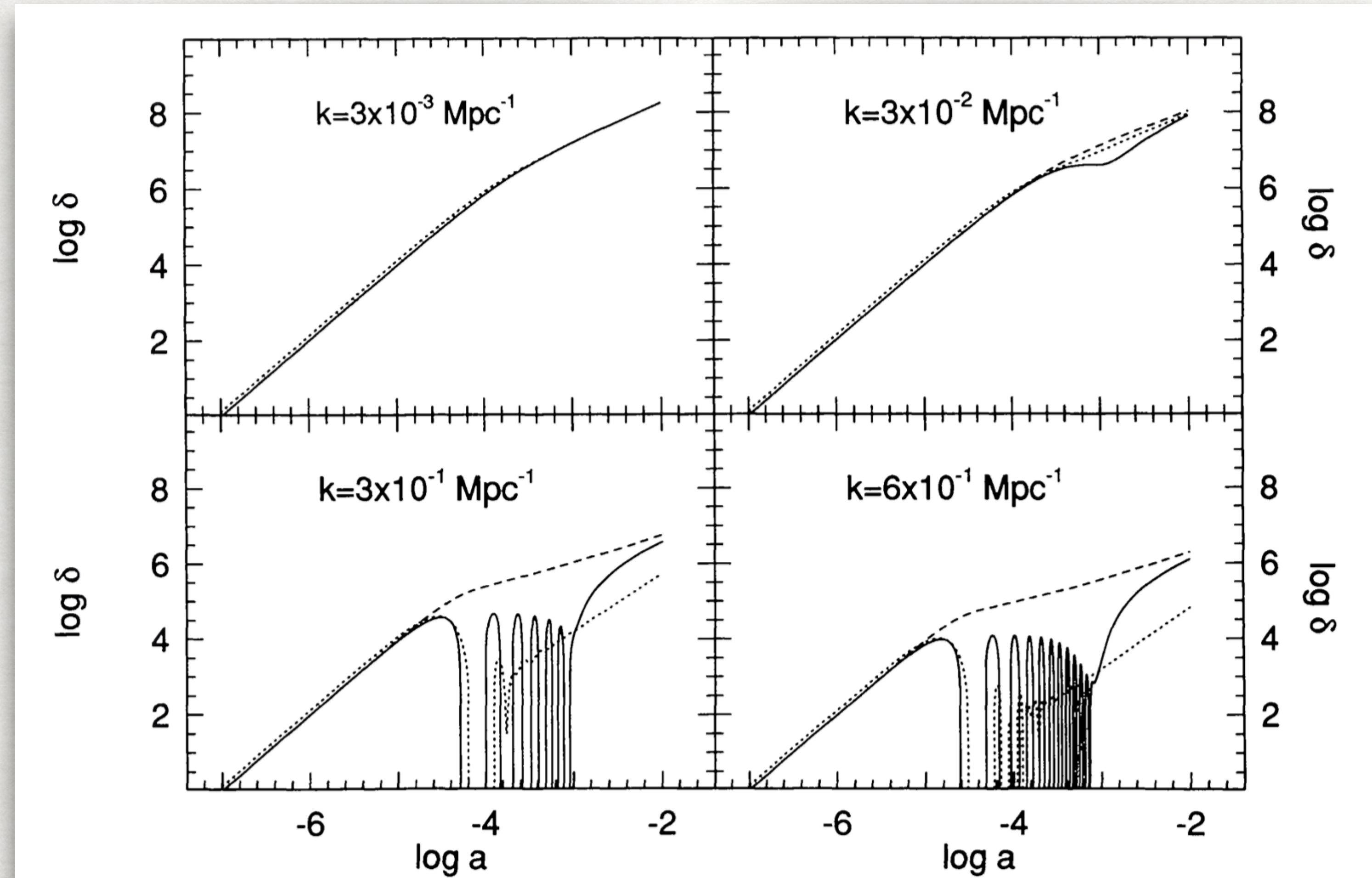
Ages and Omegas

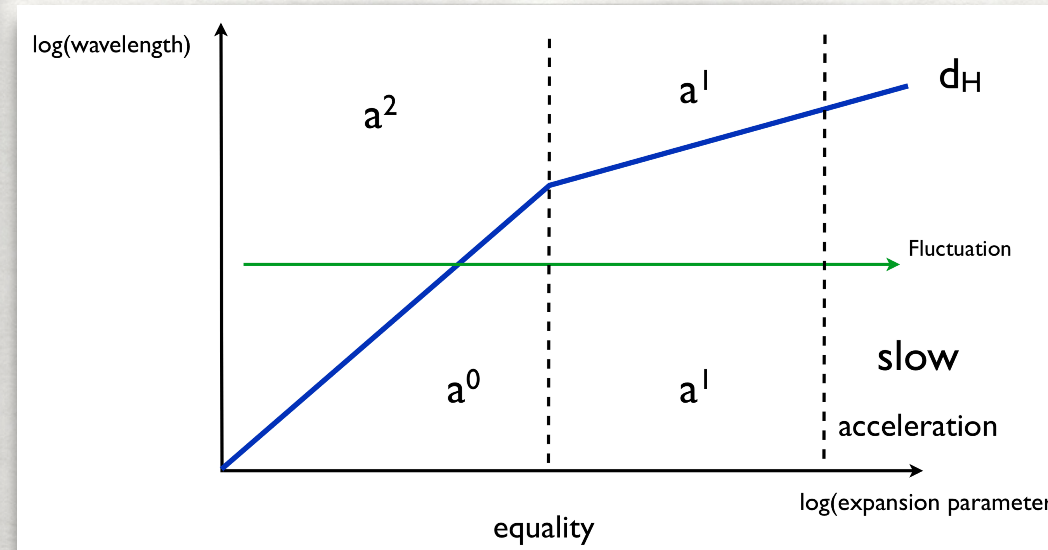




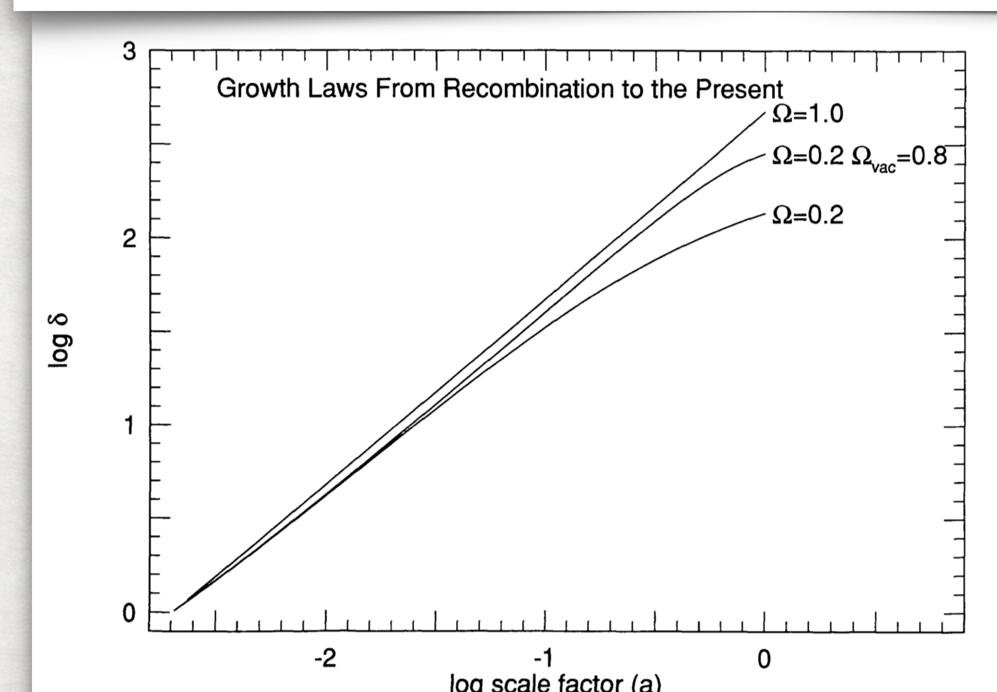
Growth of perturbations

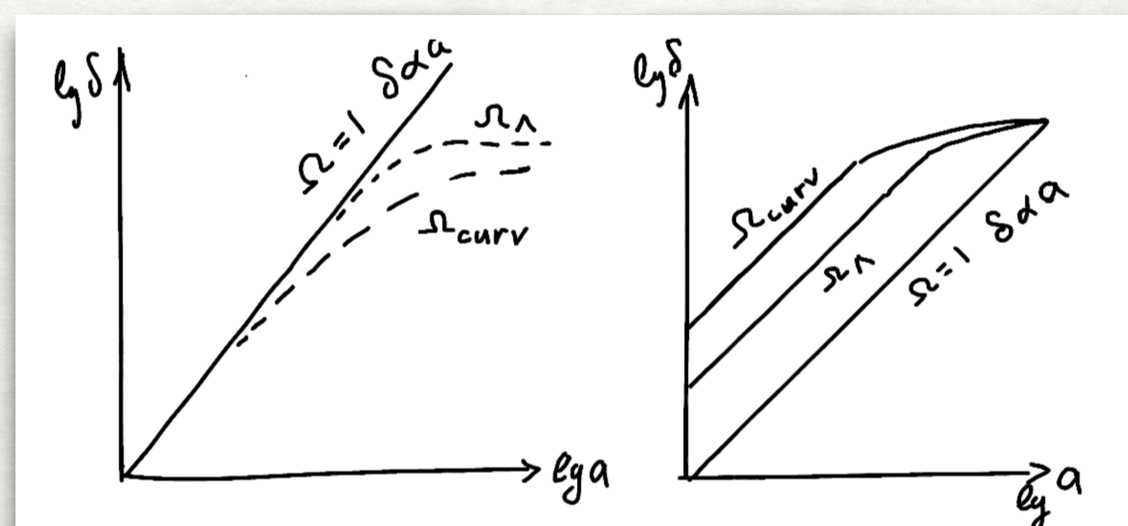
Evolution of adiabatic CDM and baryons from early times through recombination for $\Omega_b \ll \Omega_{CDM}$ and $\Omega_\nu \ll \Omega_{CDM}$.
Solid lines represent the baryon perturbations, dashed lines the CDM perturbations, dotted lines the massive neutrino perturbations.
Perturbations on four size scales are shown; each scale is normalized to have the same initial amplitude





Holtzman 1989





Power spectra and Correlation functions

We define the **power spectrum** as

Here the averaging is done over all
Waves with given k and over the whole space

$$P(k) = \langle |\delta_{\vec{k}}|^2 \rangle$$

Correlation function is defined as

$$\xi(r) = \langle \delta(\vec{x})\delta(\vec{x}+\vec{r}) \rangle$$

The averaging is done for the whole volume and over angles of vector $\vec{r}$

Initial spectrum of fluctuations, which was produced during the inflation, is distorted during the evolution of the Universe by different processes.
If δ_k^2 is the square of amplitude of fluctuations at given wavevector $\vec{k}$,

Then we can write:

$$\delta_k^2 = A\, k^n\, T(k,t)$$

Where A is a normalization constant, k^n is the initial spectrum of perturbations, and
T(k,t) is the transfer function.

One important case: n=1 is called the Harrison-Zeldovich spectrum.

For some cases we can disentangle the dependencies on k and t. For example, for LCDM or open CDM models the shape of the spectrum did not change much after the recombination :

$$T(k,t) = T(k)\, D^2(t)$$

Where D(t) is the growth-factor of fluctuations. Models with hot neutrinos or warm dark matter with some rms velocities of dark matter particles may still experience late changes in growth of perturbations.

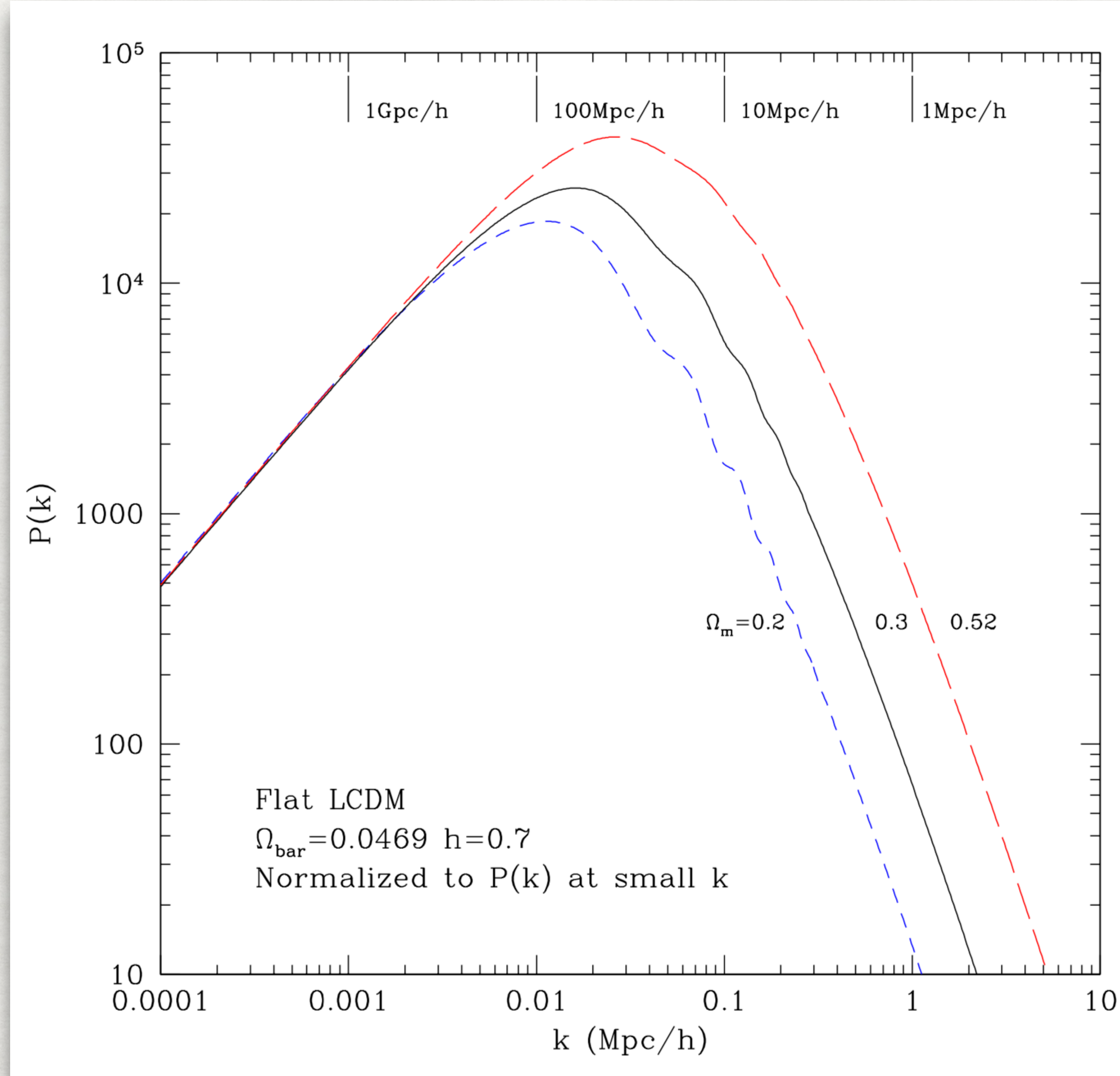
Thus, we get the relation between the correlation function and the power spectrum:

$$\xi(r) = \frac{1}{2\pi^2}\int_0^\infty k^2 dk\, \frac{\sin kr}{kr}\, P(k)$$

There is an inverse relation:

$$P(k) = 4\pi \int r^2 dr\, \xi(r)\, \frac{\sin kr}{kr}$$

Dependance of power spectrum on different cosmological parameters

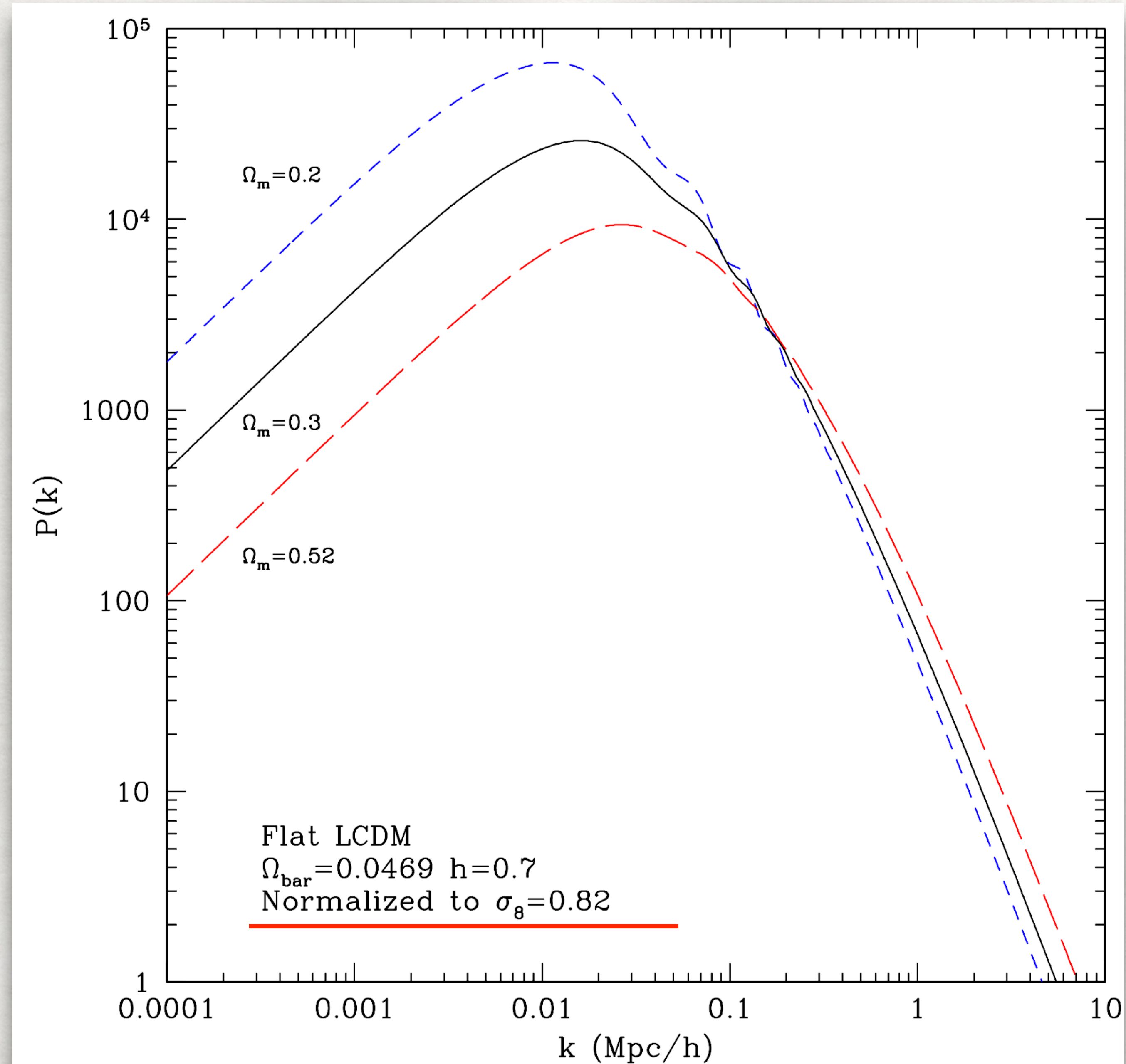


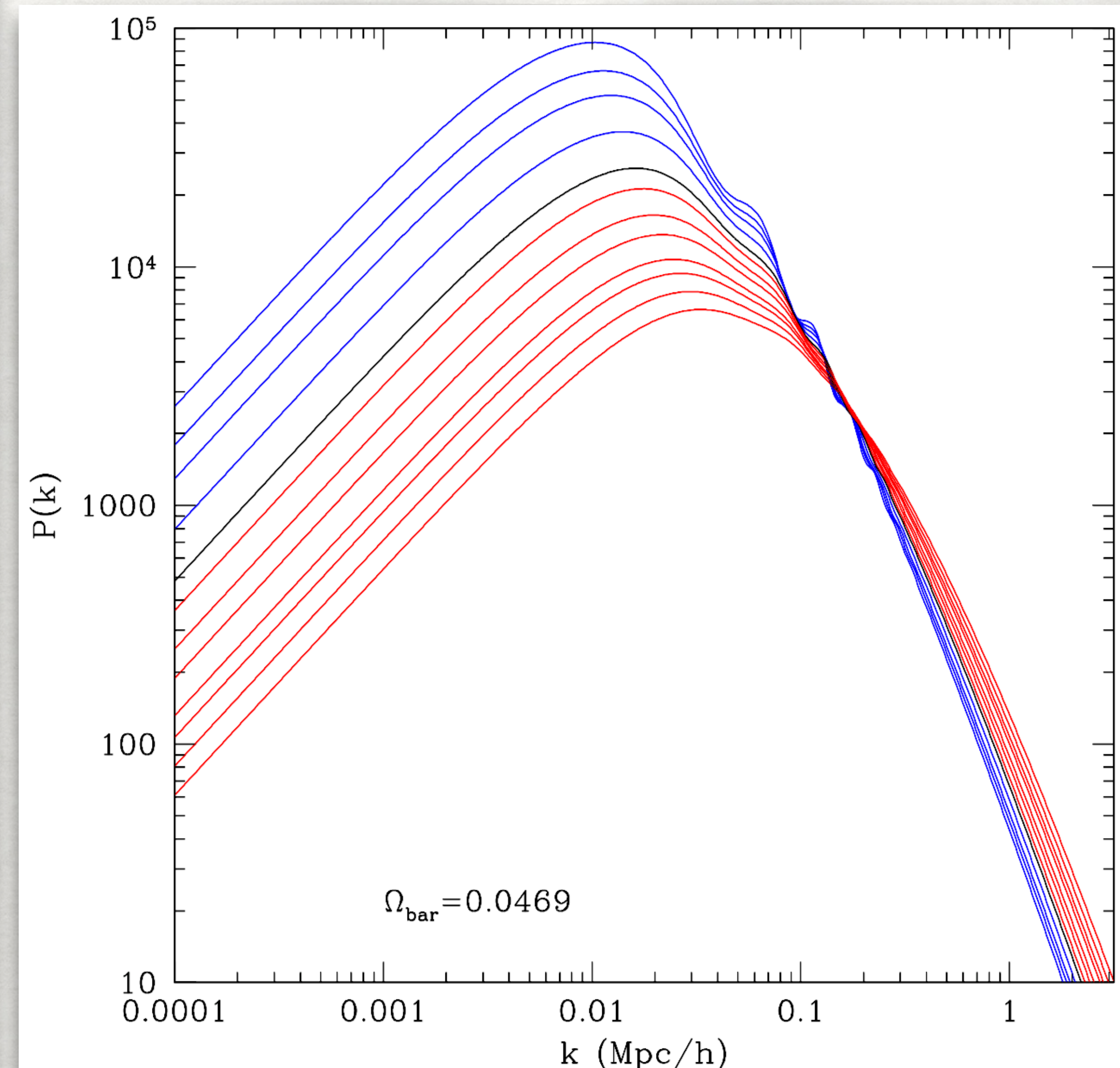
Questions:

what are the slopes at small and large k?
why the position of the peak depends on Om?
why P(k) is smaller for smaller Om?
why the wiggles get stronger for small Om?

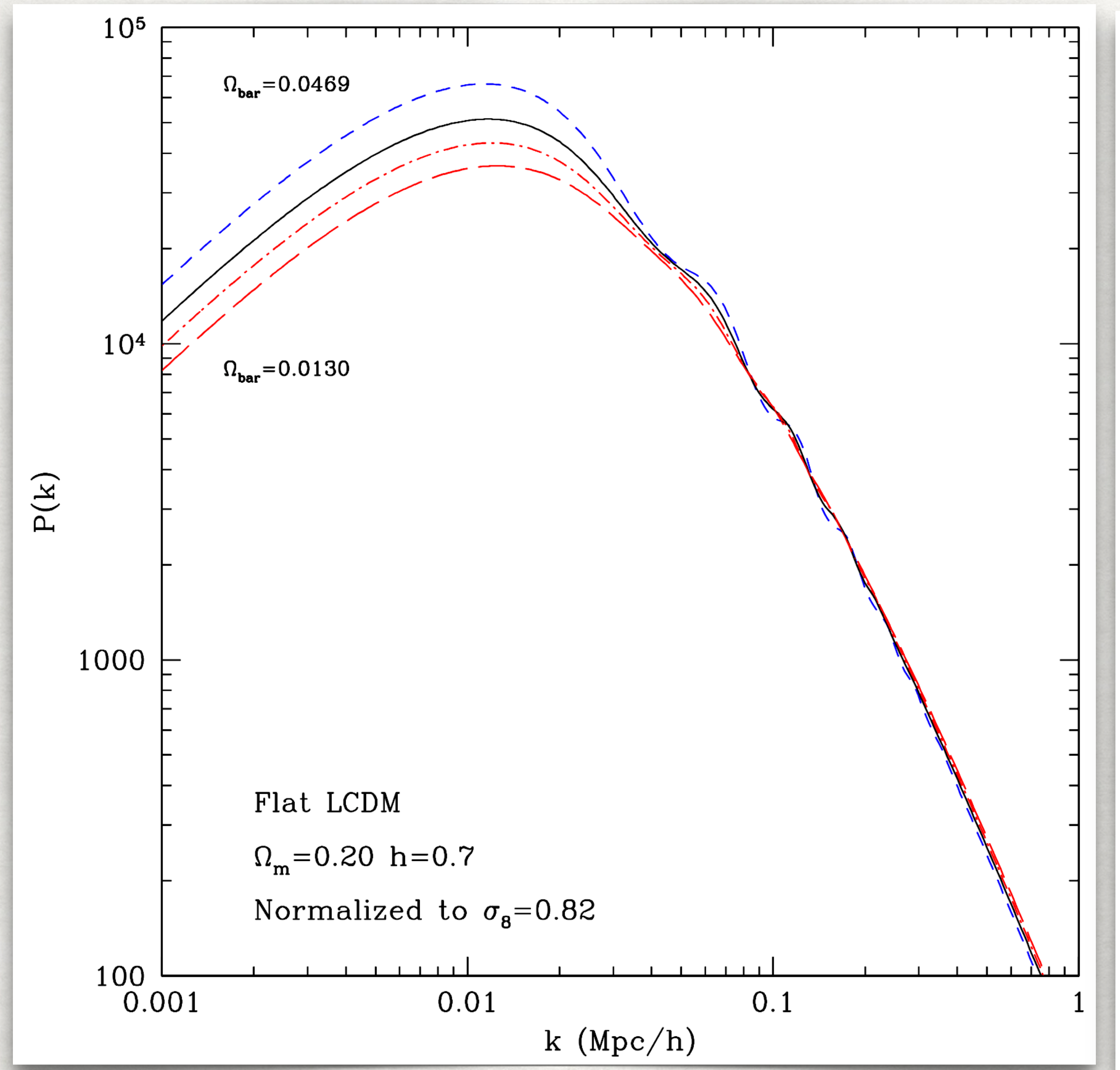
Questions:

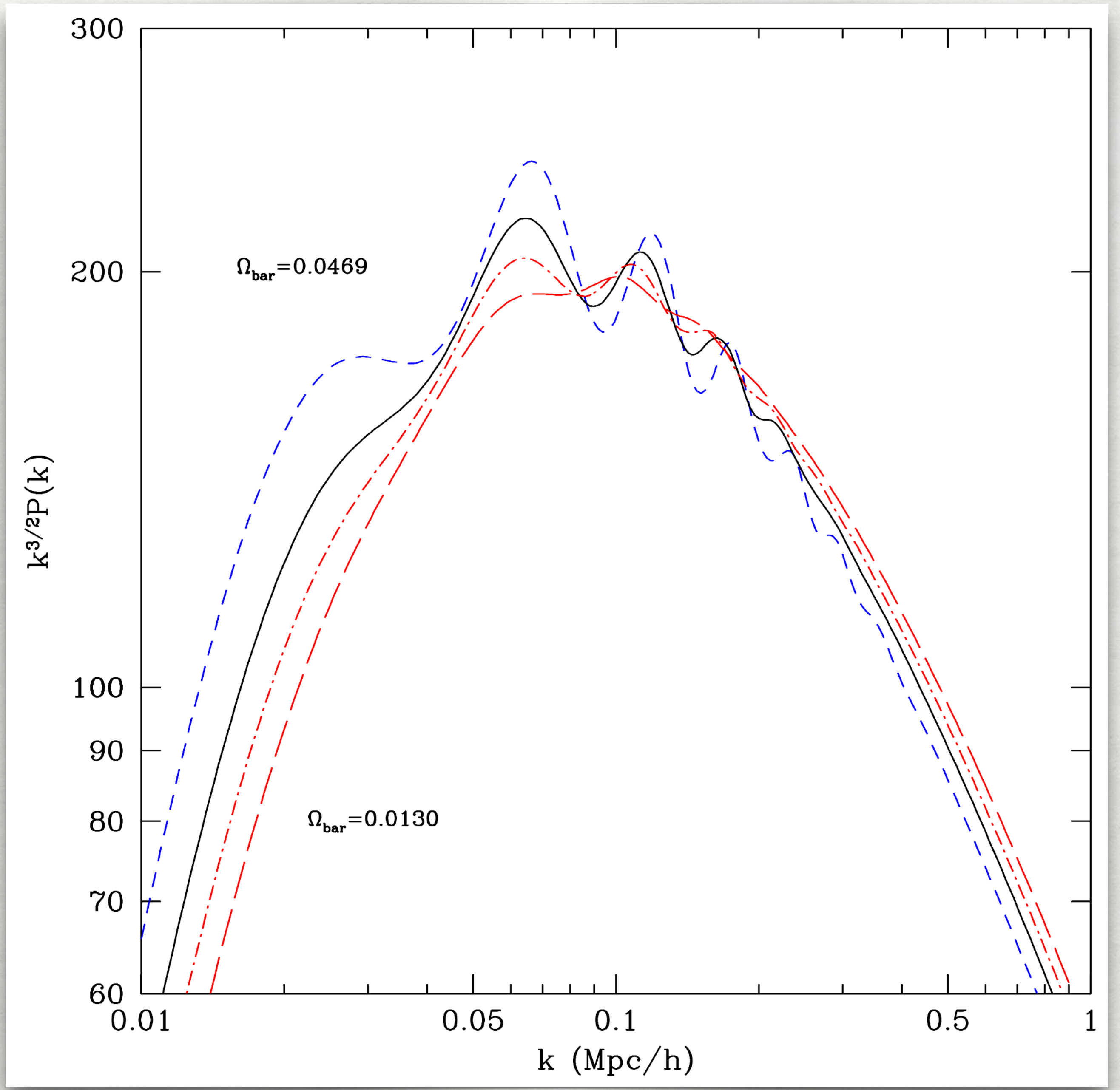
why the differences are much larger at small k and much smaller at large k?





Effects of baryons





Correlation function: dependance on radius

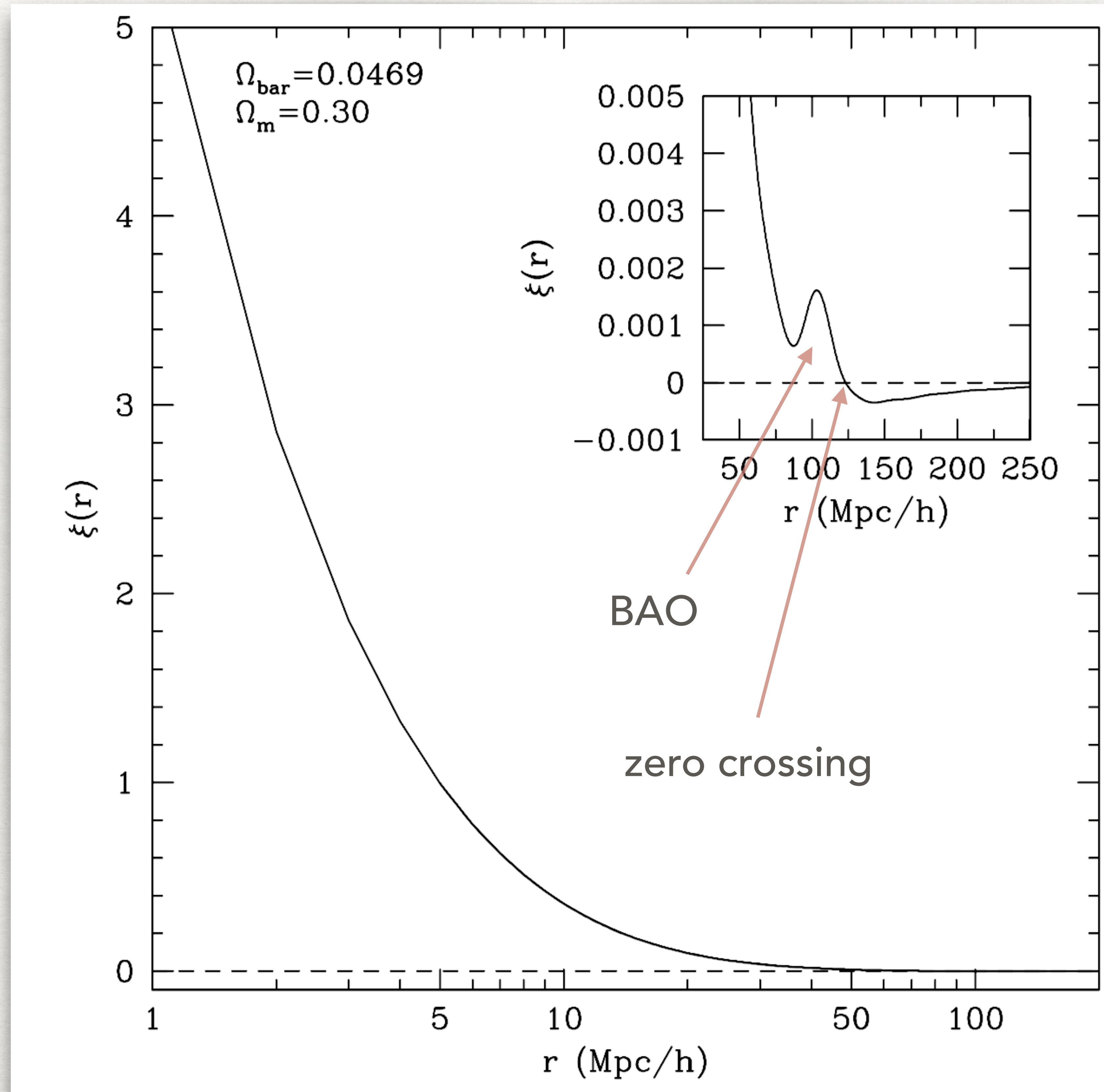
Steeply declines at r<20Mpch

Has a BAO peak at 100Mpc/h

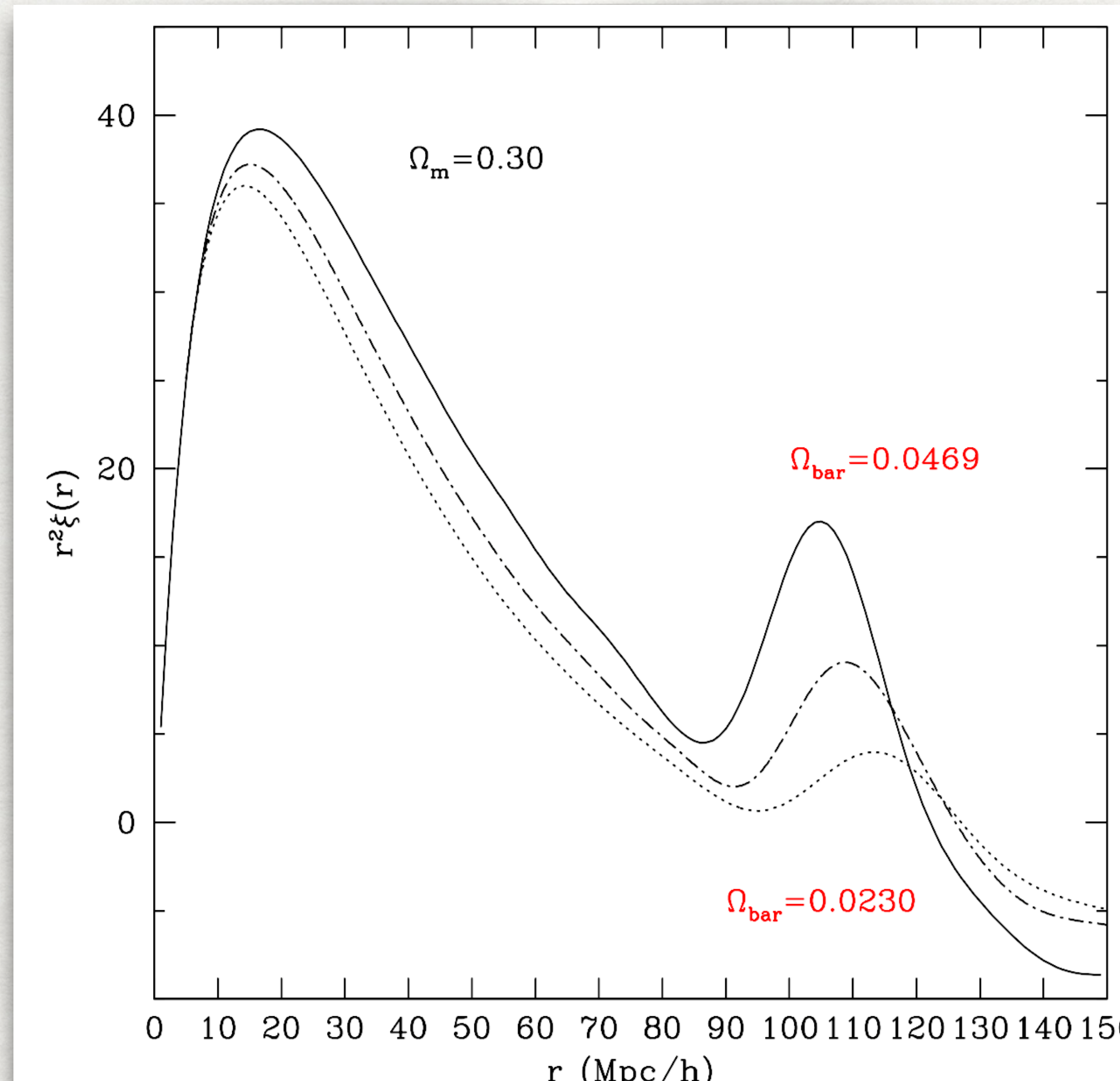
Crosses zero at 120Mpc/h

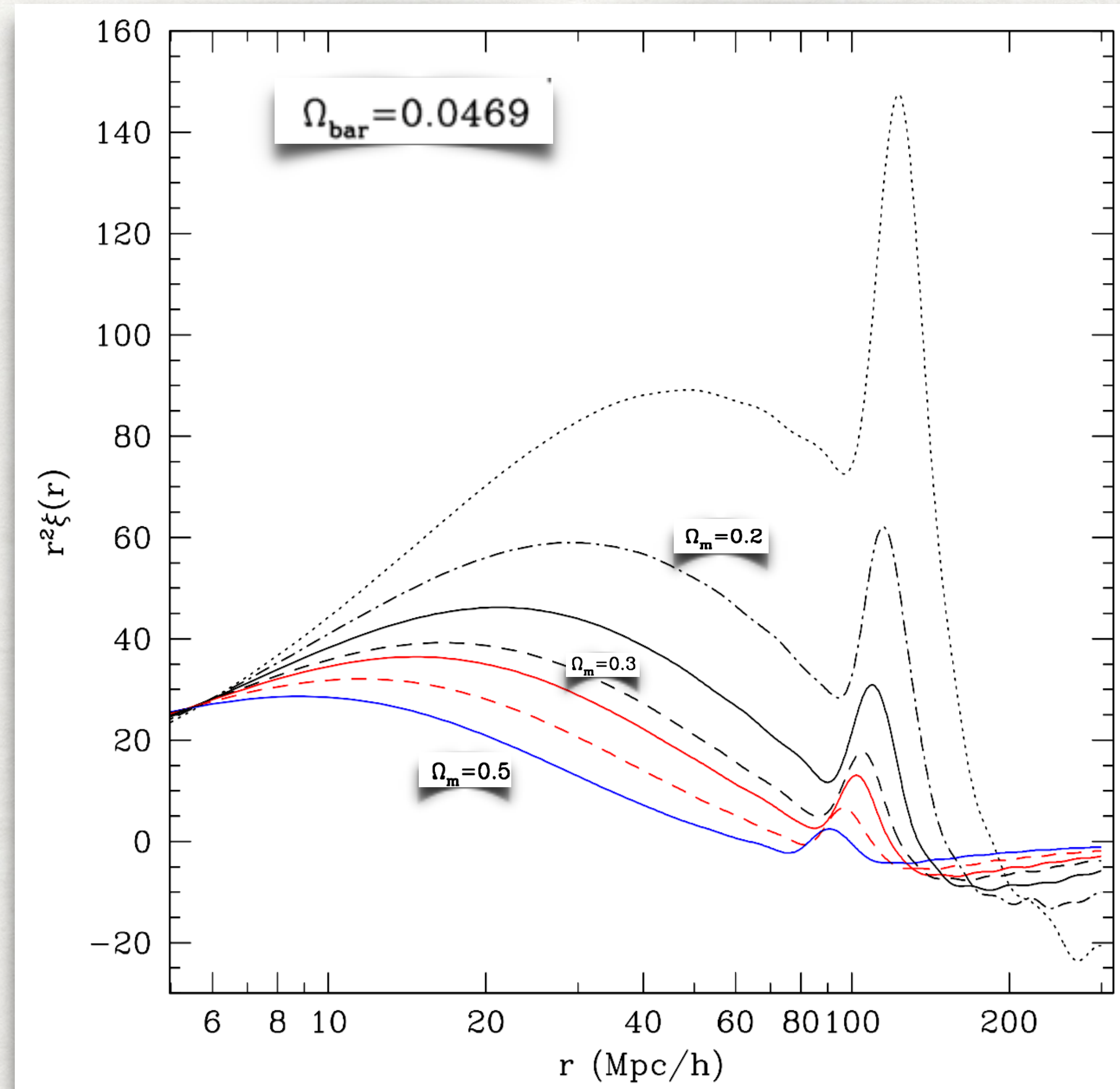
Becomes negative at r> 120Mpc/h

Approaches zero   at r>> 120Mpc/h



Correlation function: dependance on cosmological parameters



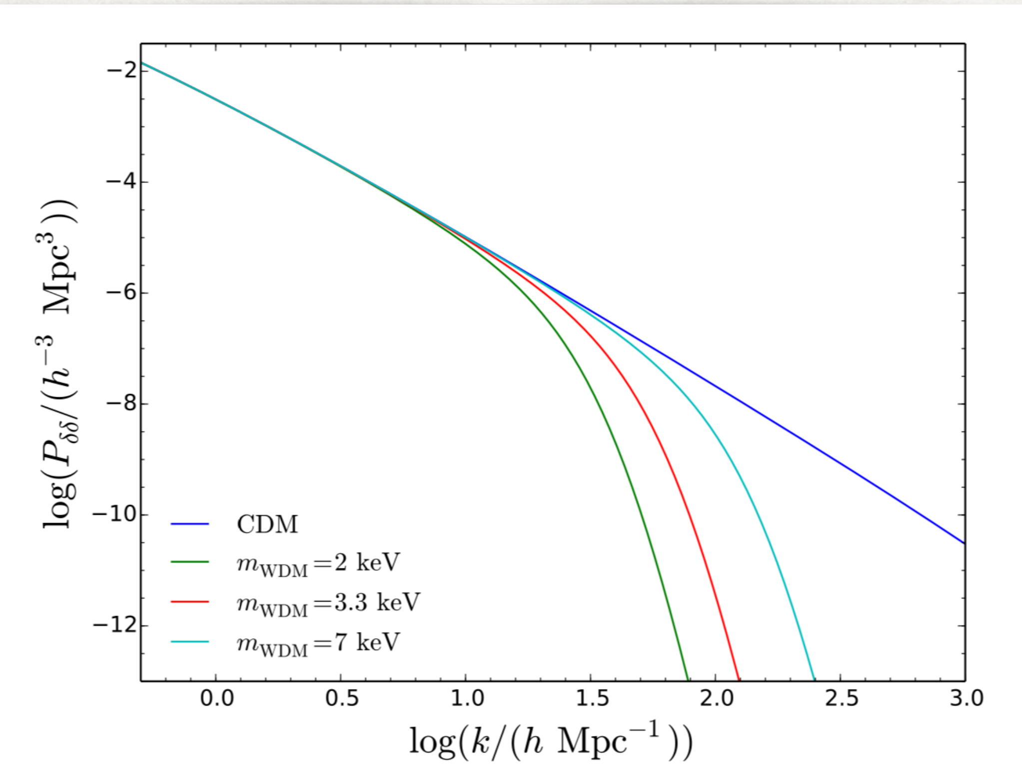


Position (radius) of BAO peak is sensitive to Om_bar: the bigger is Om_bar, the smaller is R_BAO

Position (radius) of BAO peak is sensitive to Om_m: the bigger is Om_m, the smaller is R_BAO

Zero-crossing is sensitive to Om_m: the bigger is Om_m, the smaller is R_zero

Power spectrum for warm dark matter



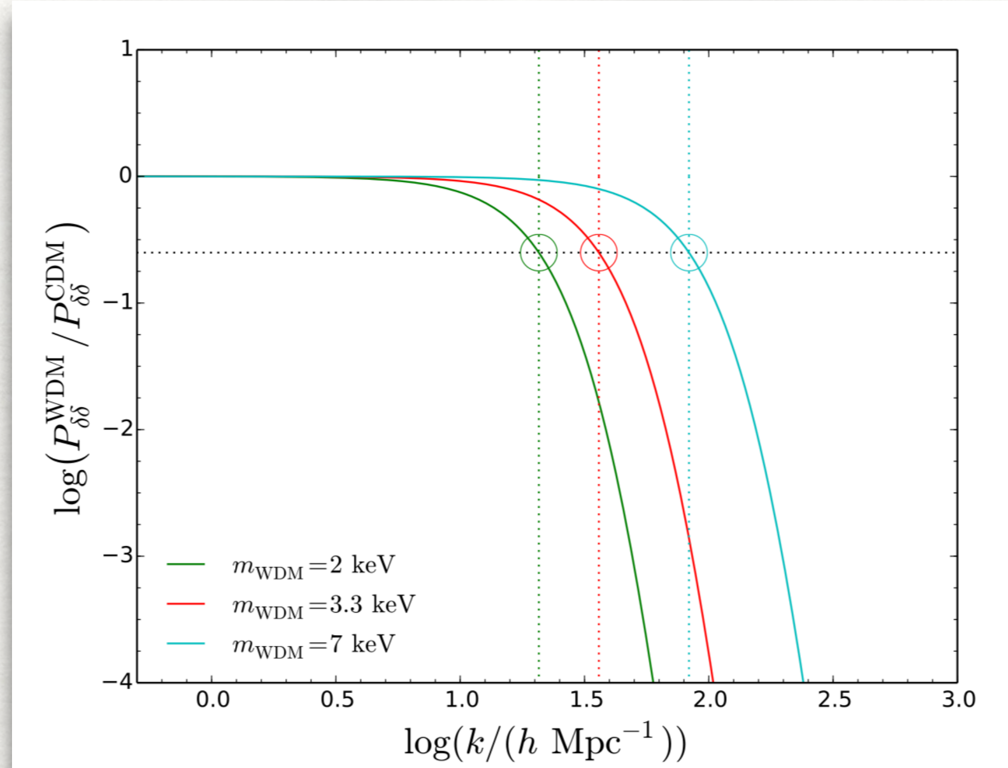
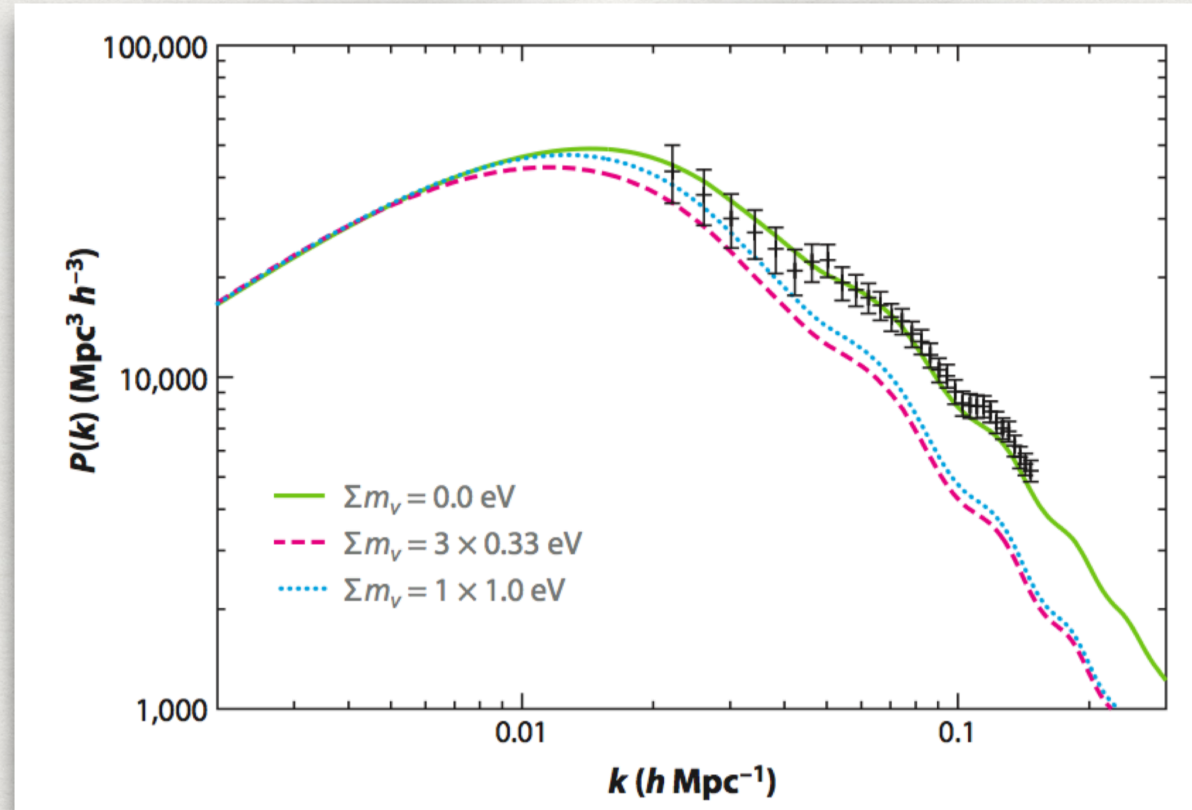


Figure 1. (a) Linear theory matter power spectra at redshift $z = 199$ for CDM and three WDM models with masses $m_{\mathrm{WDM}} = 2, 3.3, 7$ keV as labelled. (b) Squared transfer functions $T^2(k) \equiv P^{\mathrm{WDM}}/P^{\mathrm{CDM}}(k)$ for the three warm candidates. The dotted black horizontal line represents the scale at which the transfer function is suppressed by a factor of two. The intersection between the

Leo et al. 2017

Power spectra for different models with hybrid Cold Dark Matter and massive neutrinos.



The large-scale matter power spectrum for a model with massless neutrinos and two models with massive neutrinos. The data points are from the 2dF survey