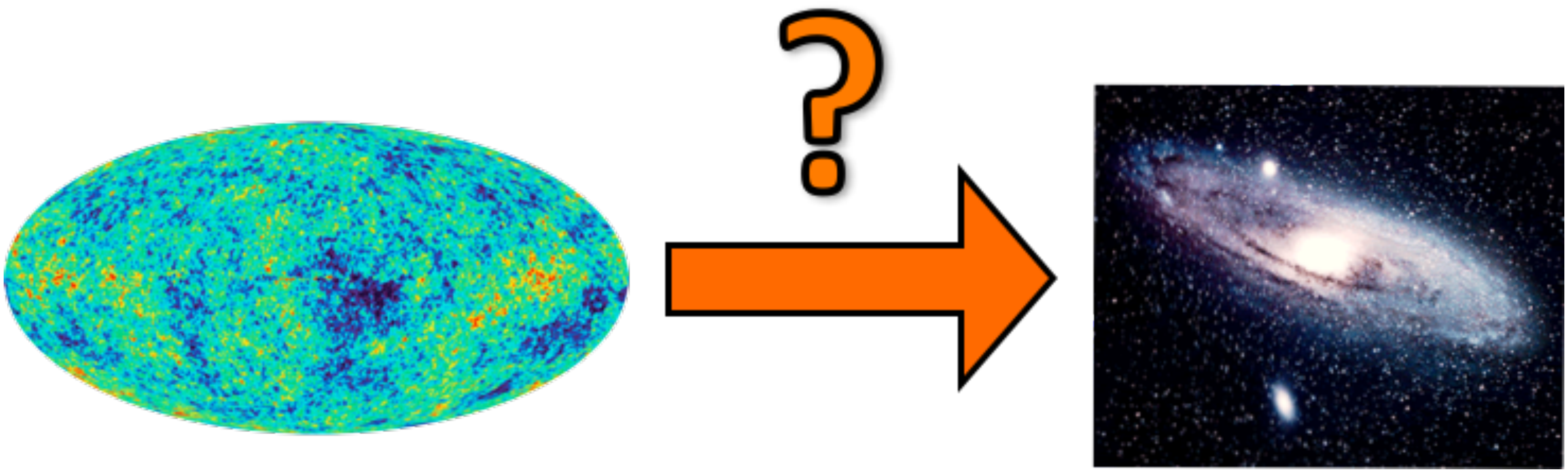
Sterrewacht Leiden

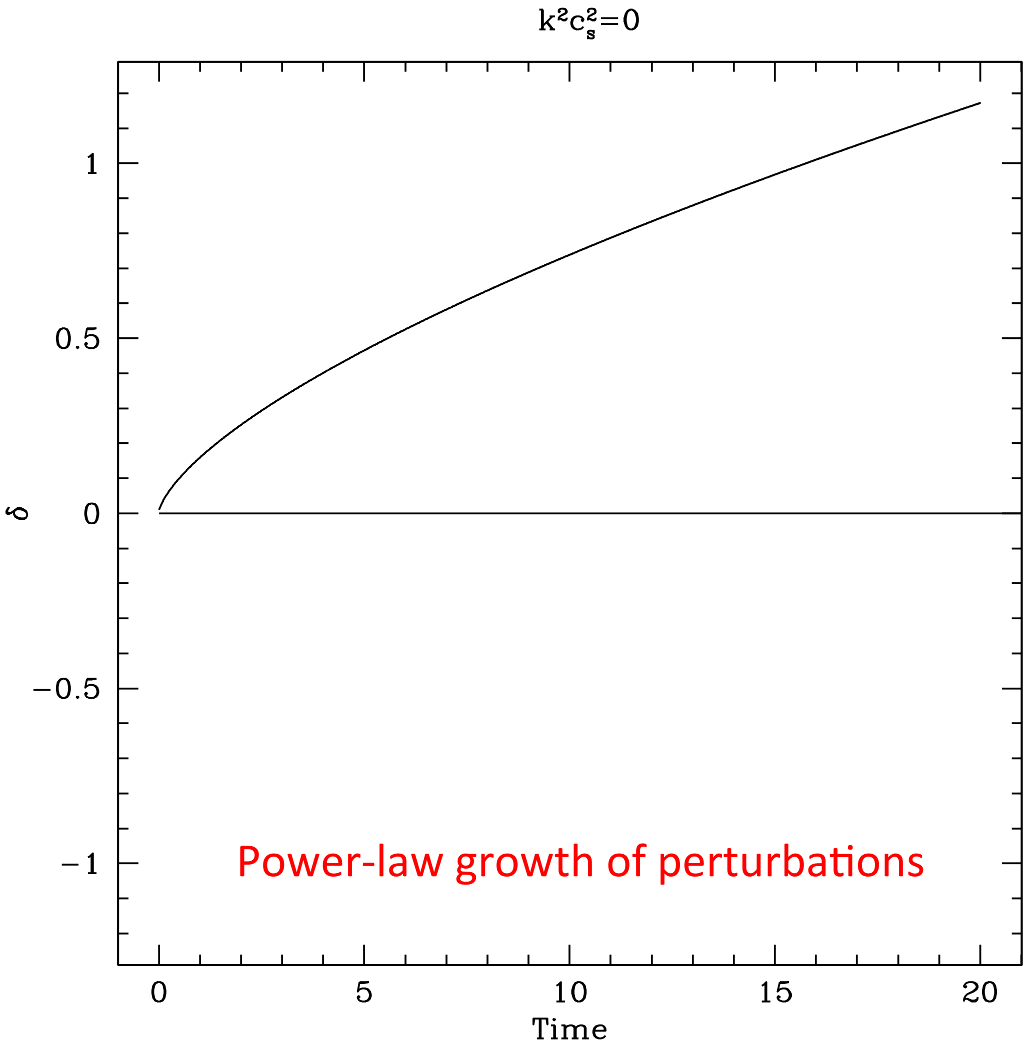
Origins & Evolution of the Universe

an introduction to cosmology – Fall 2014

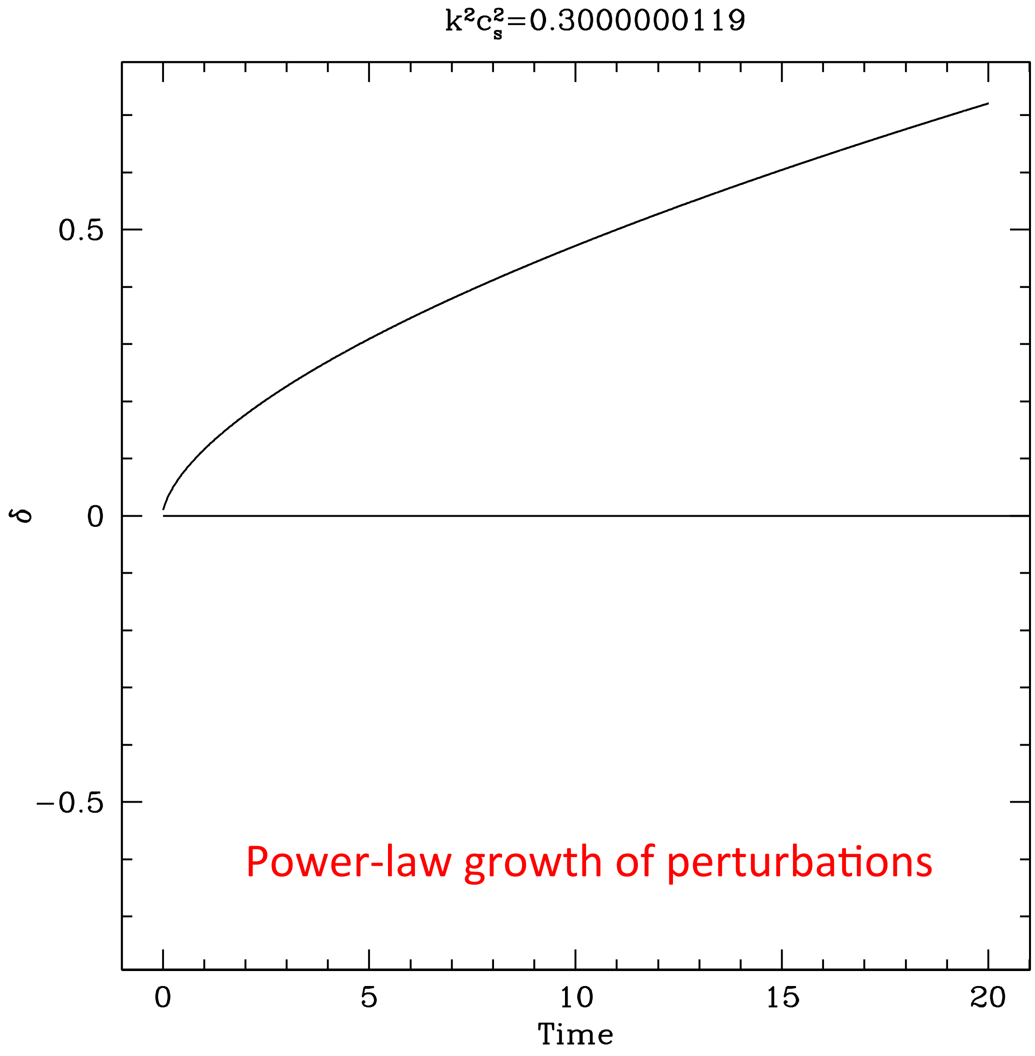
Gravitational instability



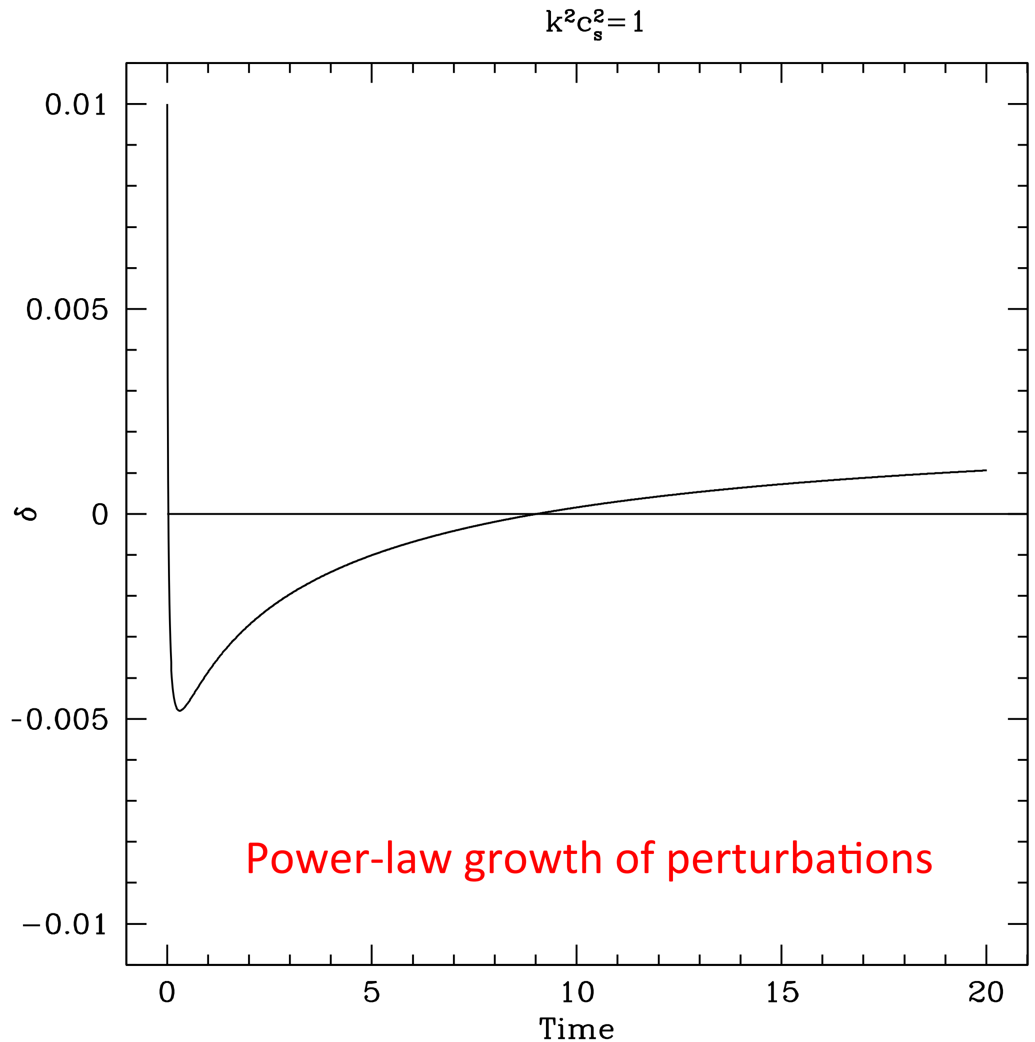
Gravitational instability



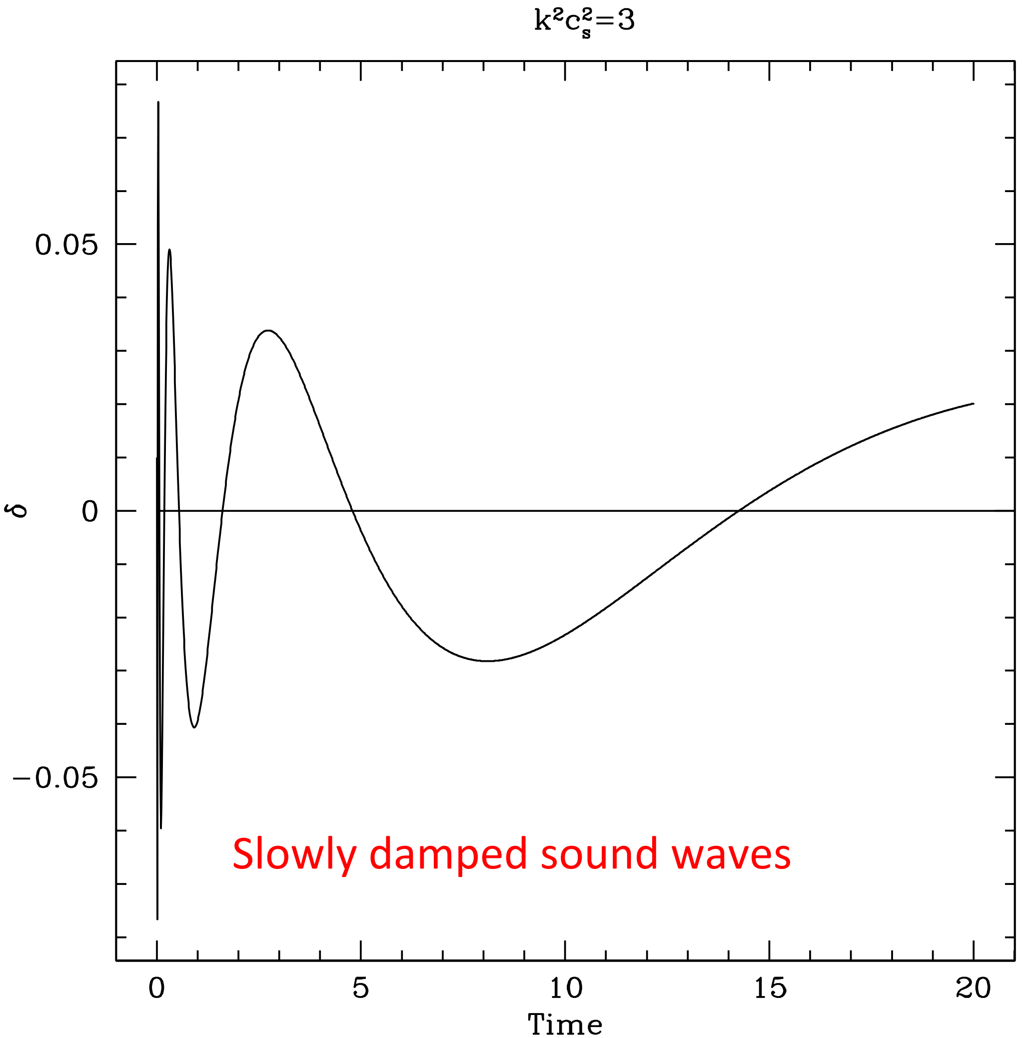
Gravitational instability



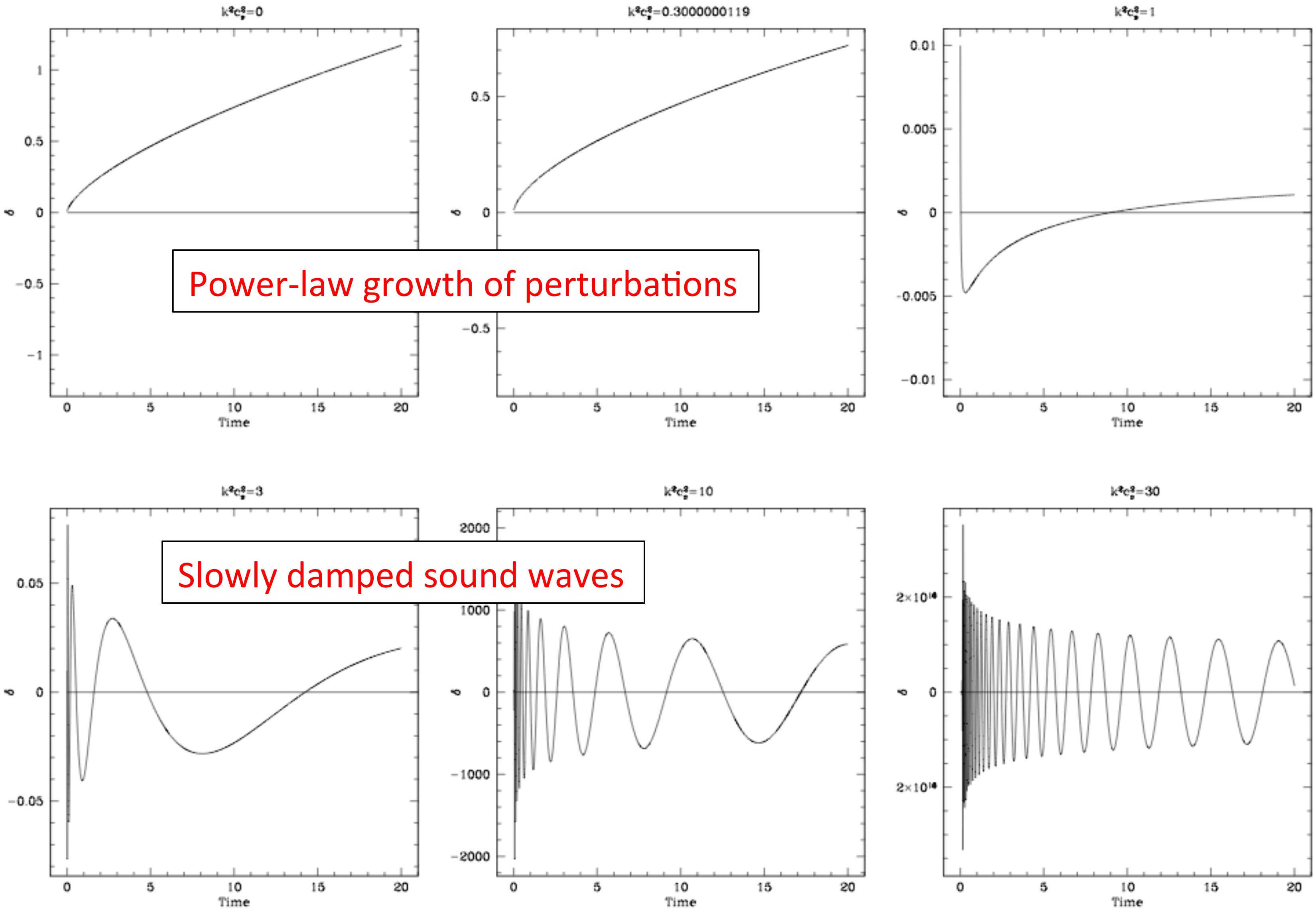
Gravitational instability



Growth of structure



Growth of structure

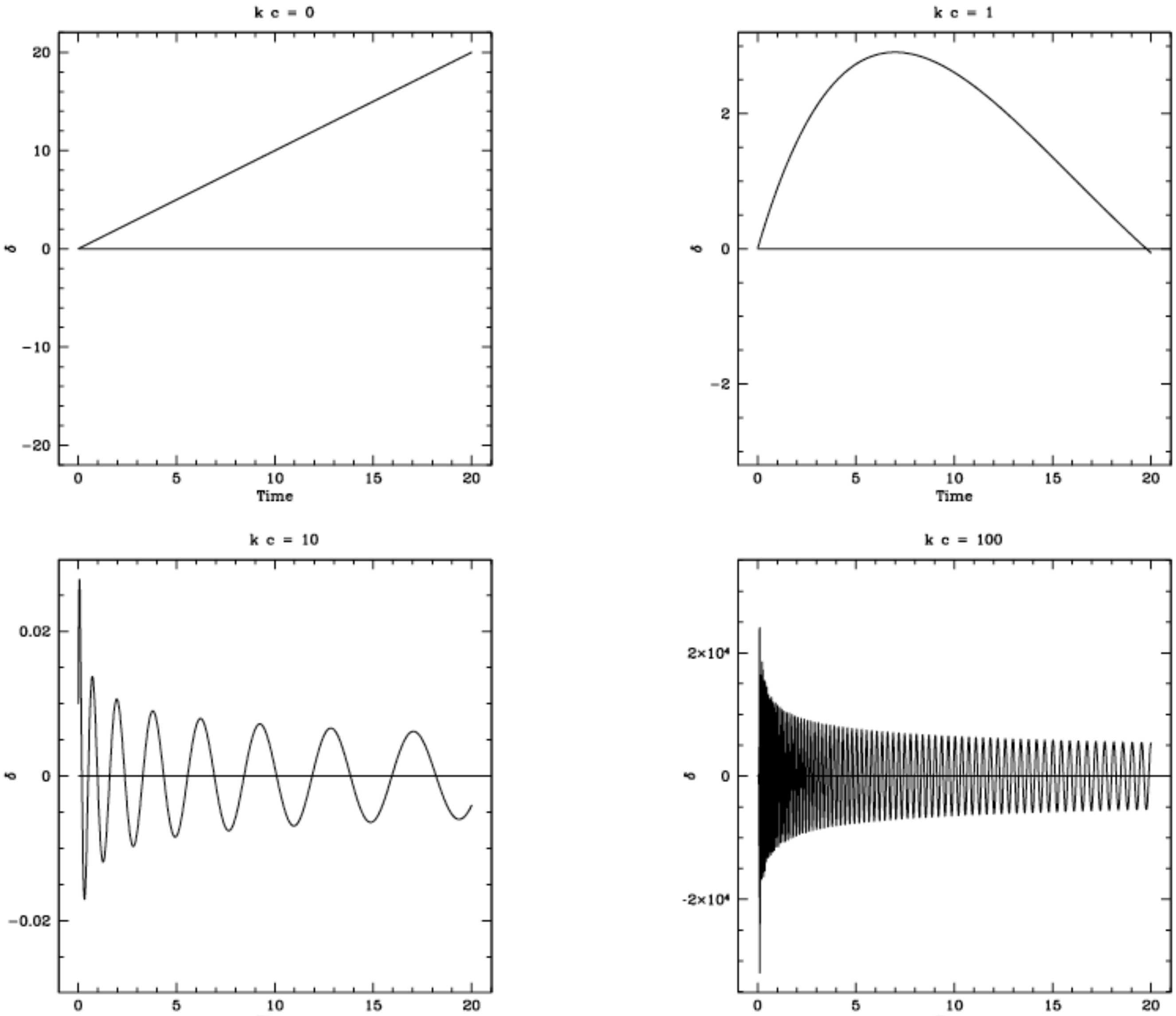


Growth factor

Ω_m	$\delta(now)/\delta_r$
0.01	10
0.1	300
1	1500

Useful approximation for growing mode in flat and zero-Λ models: $$\frac{\dot{\delta}_+}{\delta_+} \simeq \Omega_m^{0.6} \frac{\dot{a}}{a}$$

Radiation dominated case



Dark matter fluctuations

After t_{eq} the fluctuations in the dark matter can start growing in earnest.

The particles are non-relativistic and rather than the sound speed one should use the r.m.s. velocity of the particles and small structures can be formed.

After decoupling the baryons start following the gravitational potential defined by the dark matter, and hence they can form structures smaller than the baryonic Jeans mass.

Growth of structure

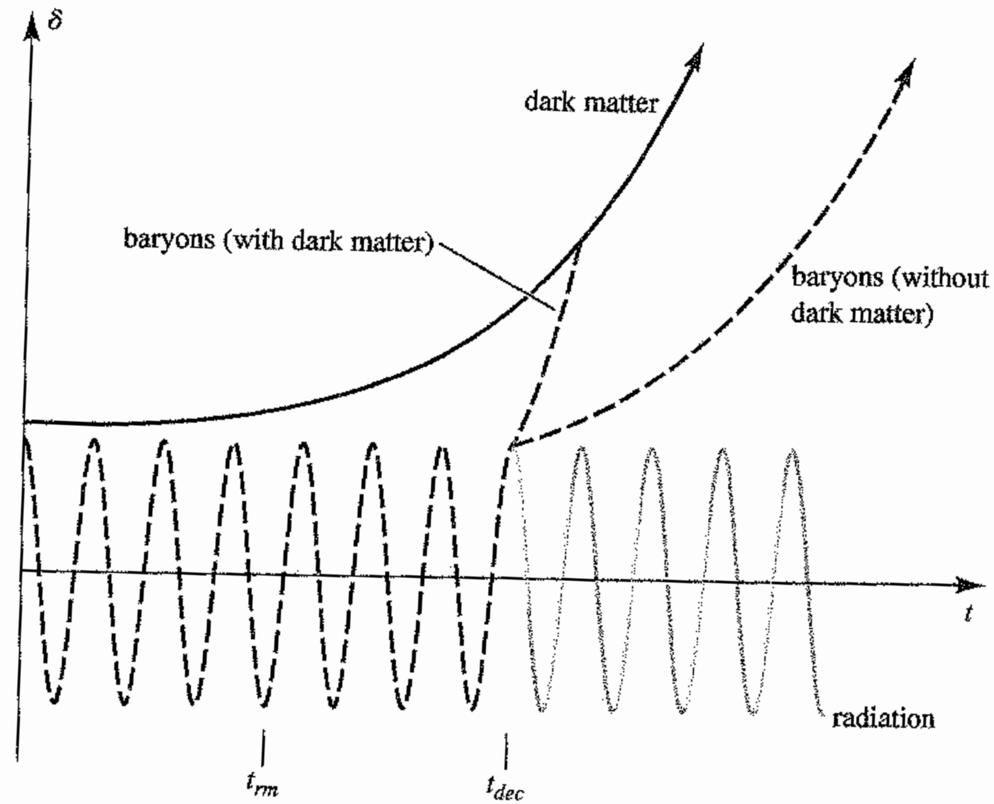
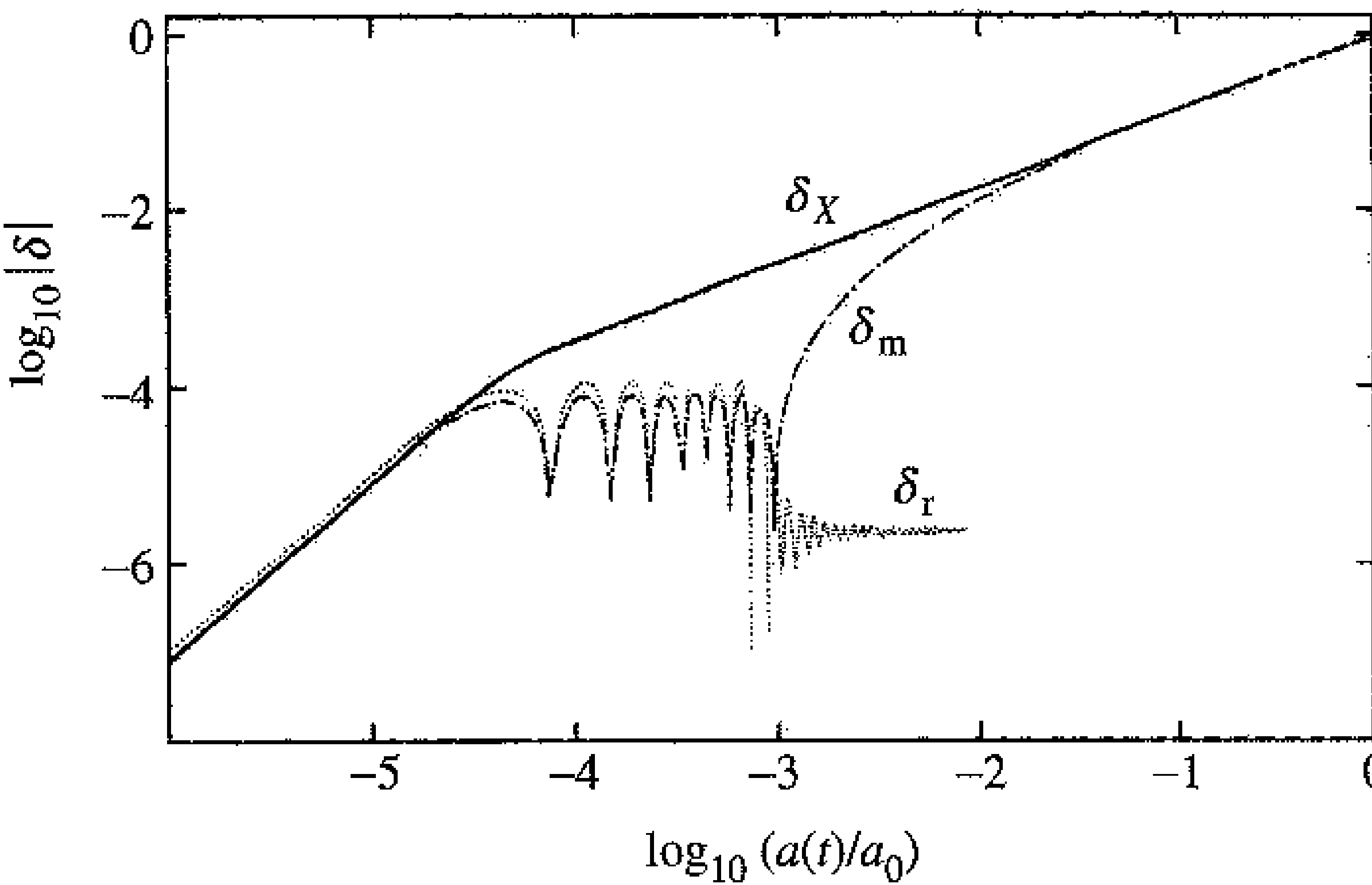


FIGURE 4 A highly schematic drawing of how density fluctuations in different components of the universe evolve with time.

from "Introduction to Cosmology" (Ryden, 2014)

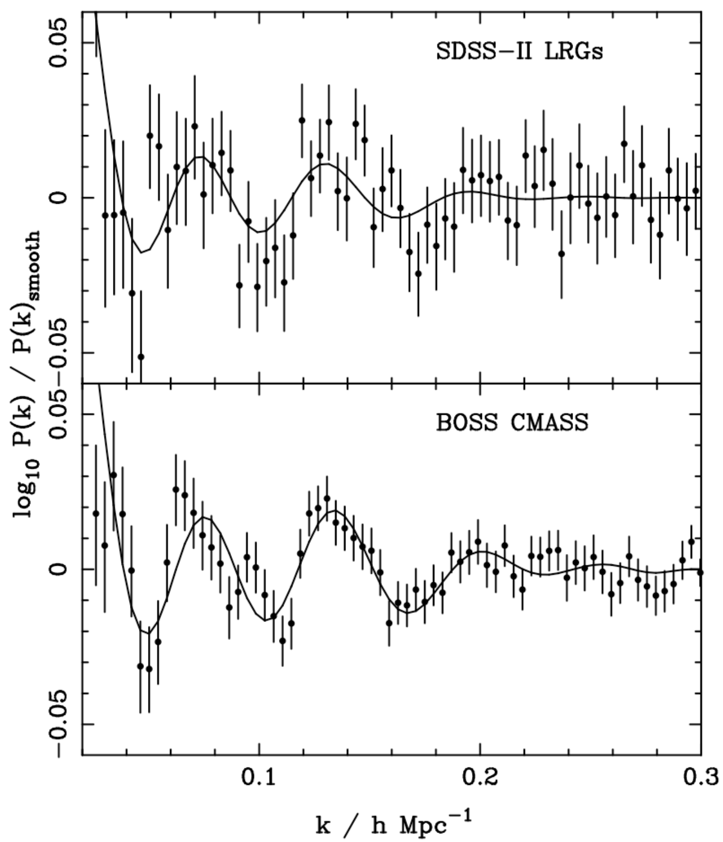
Growth function



From "Cosmology" Coles & Lucchin, 2nd edition

Dark matter fluctuations

After decoupling the baryons start following the gravitational potential defined by the dark matter but they retain some of the imprint of the sound-waves at decoupling: the baryon accoustic oscillations.



Anderson et al. (2012)