Effective Scientific Presentations

I. Presentation Design and Content

i. Know your audience
ii. Tell the audience why they should care
iii. Convey your excitement
iv. Tell *your* story
v. Keep it simple

II. Presentation Mechanics

i. Make sure all equipment is ready and slides work on the computer. Have water at the ready
ii. Breathe, visualize, rehearse, repeat
iii. Stand tall, smile, take your time
iv. Talk to the audience not the screen
v. Stick with your time frame
vi. Don’t drift near the end.

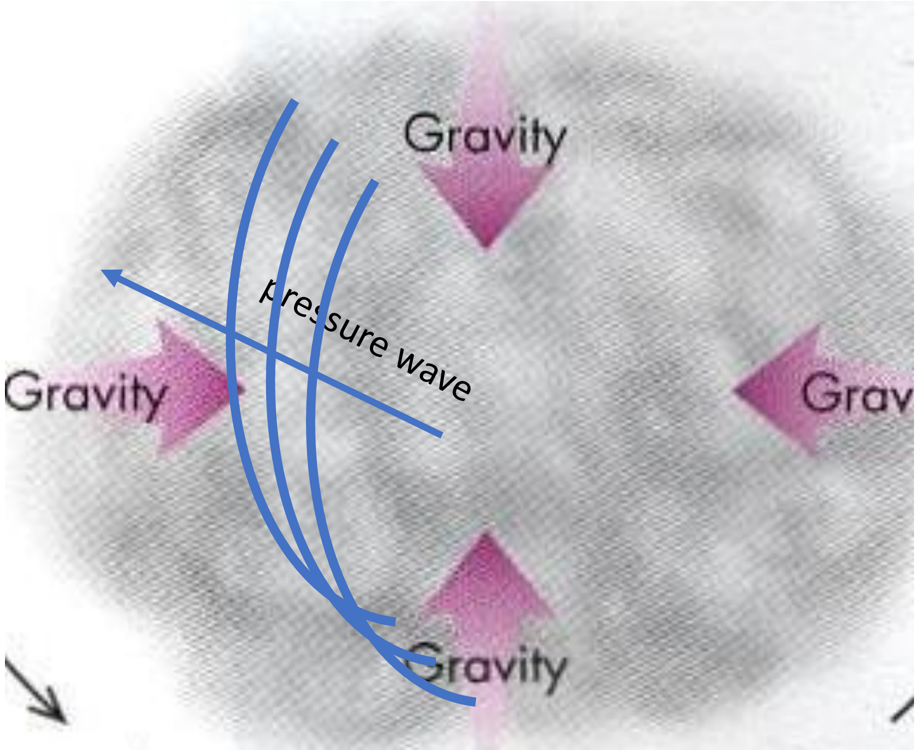
III. Slides

i. Less is more. For a 8 minute talk, 3—5 slides is the limit.
ii. Create sections
iii. Avoid clutter, 3 – 5 bullet points per slide at most. Bullet points should contain key words not necessarily complete sentences
iv. Make it readable, 18 – 28 font size for text
v. Use visuals, graphs, images, animations, etc
vi. Check your spelling.

Some logistics

- I have to travel to DC again next week, so no class on March 11th
    - Presentations on March 16th
    - Review for final on the 16th.

The Jean's Length



$$t_P < t_{dyn} \quad c_s \sim \frac{R}{t_P} \text{ or } t_P \sim \frac{R}{c_s}$$

$$\lambda_j = c_s \left(\frac{\pi c^2}{G\bar{\rho}}\right)^{1/2} = 2\pi\, c_s\, t_{dyn}$$

$$\lambda_j = 2\pi\, c_s\, t_{dyn} = 2\pi \left(\frac{2}{3}\right)^{1/2} \frac{c_s}{H}$$

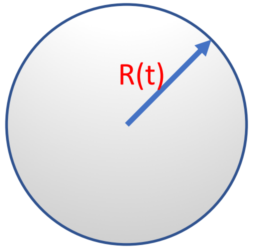
$$\lambda_j = 2\pi\, c_s\, t_{dyn} = \boxed{2\pi \left(\frac{2}{3}\right)^{1/2} \sqrt{w}\frac{c}{H}}$$

Thus far our quantitative study of structure formation assumed a static universe. But

- The timescale of growth from a density perturbation, $t_{\rm dyn} \sim \sqrt{c^2/G\bar{\epsilon}}$ is comparable to the Hubble expansion: $H^{-1} \sim \sqrt{c^2/G\bar{\epsilon}}$

- This means the universe is expanding as fast as gravitational collapse and our simplified analysis fails. We must take into account the expanding universe.

- We begin our more realistic exploration of how density perturbations grow by assuming the following: $\delta \ll 1 \text{ and } \rho(t) = \bar{\rho}(t)[1+\delta(t)]$



Once again, consider a spherical region of radius, *R.* Now apply Newton's law to a point on the surface of the sphere

$$\begin{aligned}
\ddot{R} &= -\frac{GM}{R^2} \\
\ddot{R} &= -\frac{GM}{R^2}\left(\frac{4\pi}{3}\rho R^3\right) \\
\ddot{R} &= -\frac{4\pi}{3}G\bar{\rho}R - \frac{4\pi}{3}G(\bar{\rho}\delta)R \\
\frac{\ddot{R}}{R} &= -\frac{4\pi}{3}G\bar{\rho} - \frac{4\pi}{3}G(\bar{\rho}\delta)
\end{aligned}$$

And as before, we have two unknowns, *R(t),* $\delta(t)$

$$\frac{\ddot{R}}{R} = -\frac{4\pi}{3}G\bar{\rho} - \frac{4\pi}{3}G\bar{\rho}\delta \qquad (1)$$

As before, we use conservation of mass as the auxiliary equation. In this context this is results in:

$$M = \frac{4\pi}{3}\bar{\rho}(t)\left[1+\delta(t)\right]R(t)^3$$ This stays constant so we can say that:

$$R(t) \propto \bar{\rho}(t)^{-1/3}\left[1+\delta(t)\right]^{-1/3}$$ Since $\bar{\rho}(t) \propto a^{-3}$ we have:

$$R(t) \propto a(t)\left[1+\delta(t)\right]^{-1/3}$$ Taking two time derivatives and substituting into Eq. (1) gives

$$\ddot{\delta} + 2H\dot{\delta} = 4\pi G\bar{\rho}\delta$$

Do question (1) on the worksheet

(1 a) The $2H\dot{\delta}$ acts like friction to slow down the growth of density perturbations

(1b) $\ddot{\delta} + 2H\dot{\delta} - \frac{3}{2}\Omega_m H^2 \delta = 0$

(1c) No it only works when the universe is matter dominated

(1d) $\ddot{\delta} + \frac{1}{t}\dot{\delta} \approx 0$ This has solutions $\delta(t) \approx B_1 + B_2 \ln t$ so perturbations grow only at a logarithmic rate

(1e) $\ddot{\delta} + 2H_\Lambda \dot{\delta} \approx 0$ which has solutions $\delta(t) \approx C_1 + C_2 e^{-2H_\Lambda t}$

So only when matter dominates the energy density do fluctuations grow appreciably.
In the matter dominated era, $\Omega_m = 1, \quad H = 2/(3t)$ so

$$\ddot{\delta} + \frac{4}{3t}\dot{\delta} - \frac{2}{3t^2}\delta = 0$$

This has two solutions, $\delta(t) \approx \underbrace{D_1 t^{2/3}}_{\text{growing mode}} + \boxed{\underbrace{D_2 t^{-1}}_{\text{decaying mode}}}$

Recall that for a single component universe consisting of matter,

$$a_m(t) \propto t^{2/3}$$

so

$$\delta \propto t^{2/3} \propto a(t) \propto \frac{1}{1+z}$$

If only baryonic matter, then density perturbations start to grow $z_{dec} = 1090$
With dark matter, the perturbations start to grow at $z_{rm} = 3440$

In our study of LSS thus far, we've acted as if there were only 1 density fluctuations. The universe consisted of many perturbations that were of all manner of size (or Jeans length).

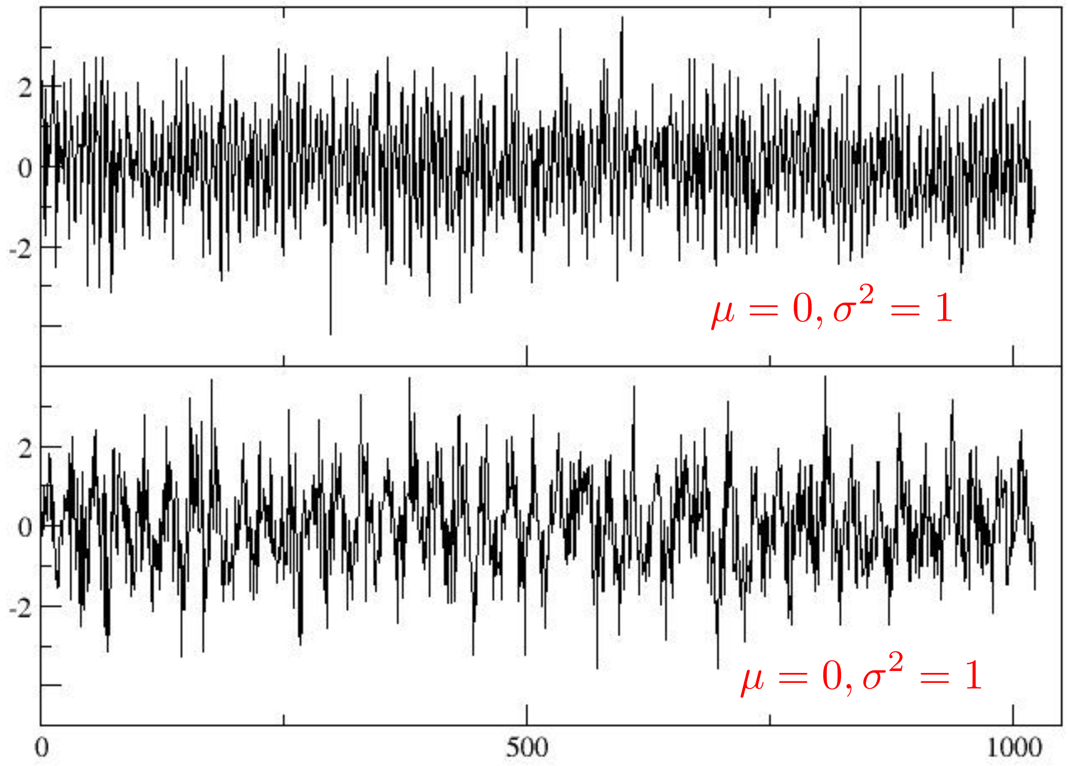
Thus what we are really interested in knowing is the density fluctuations as a function of *size (or scale).*

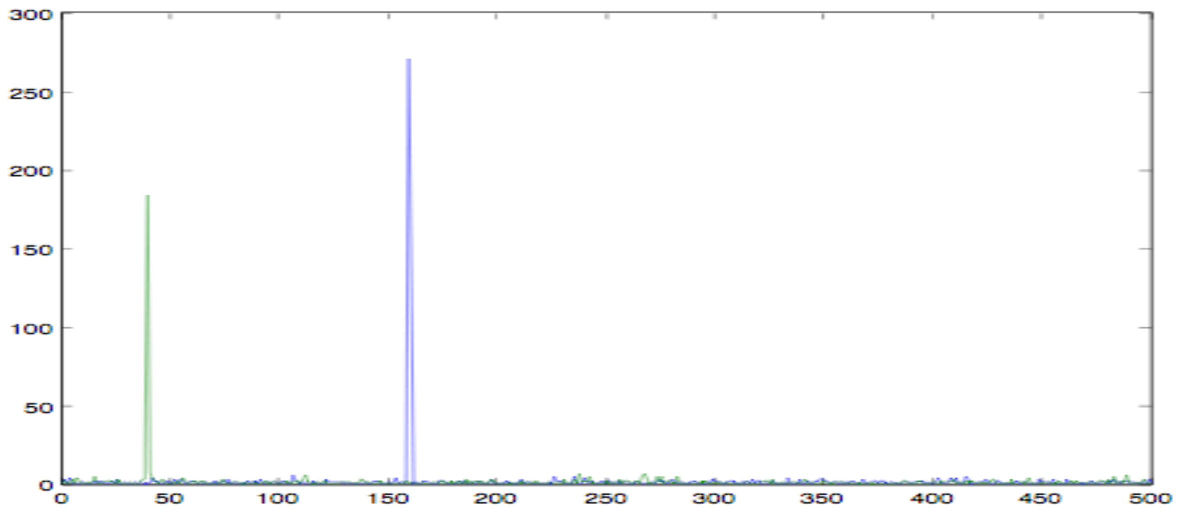
A very convenient tool for studying distributions as a function of scale is the *Power Spectrum*

To get there, first note that we can *Fourier expand* the density perturbation as $\delta(\vec{r}) = \frac{V}{(2\pi)^3}\int \delta_k e^{-i\vec{k}\cdot\vec{r}} d^3k$
where δ_k is the *Fourier coefficient.*

Then through *Parseval's theorem,* it can be shown that *variance* as a function of scale (*the Power Spectrum*) is given by

$$P(k) = \left\langle |\delta_k|^2 \right\rangle$$





What is different?

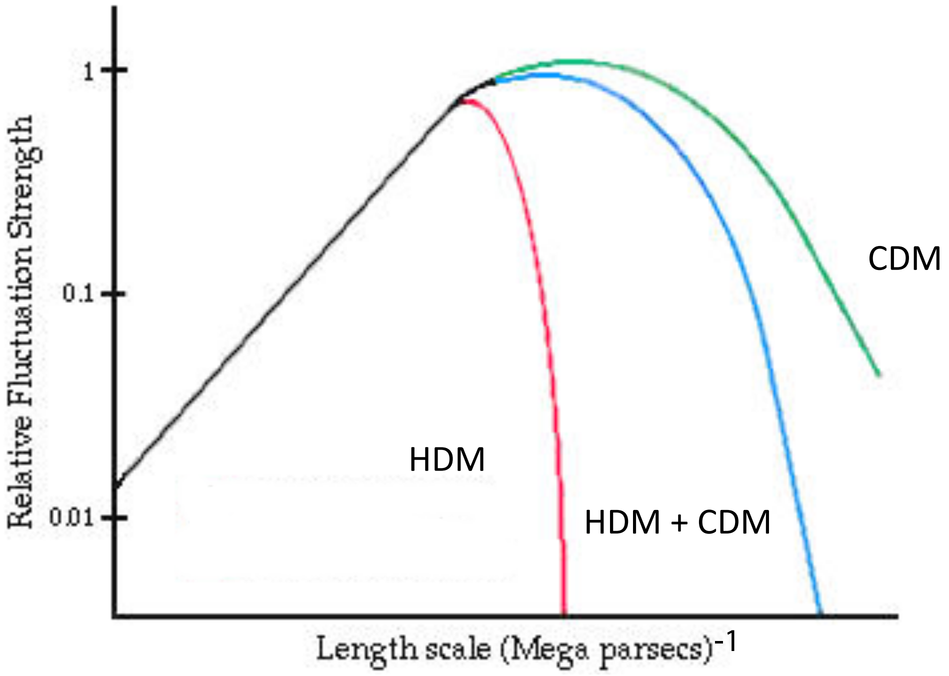
Most inflation models predict that the density fluctuations created by inflation are an isotropic, homogeneous, and Gaussian field. This leads to a power spectrum of the form,

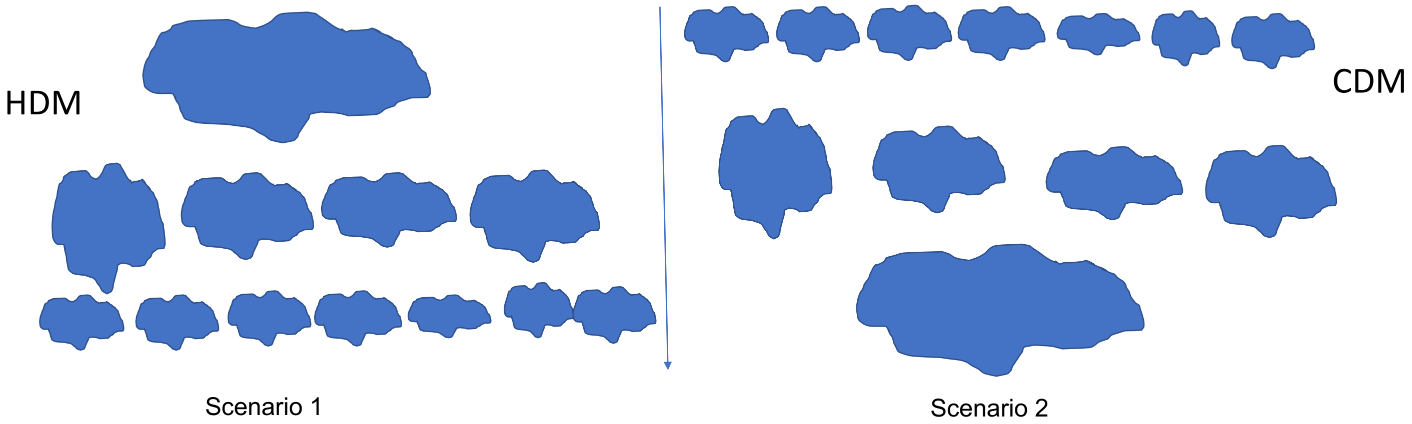
$P(k) \propto k^n$ With *n = 1*, this is called the *Harrison--Zel'dovich spectrum*

$P(k) \propto k^n$ is the spectrum immediately *after inflation.* The spectrum after this depends on the nature of dark matter.

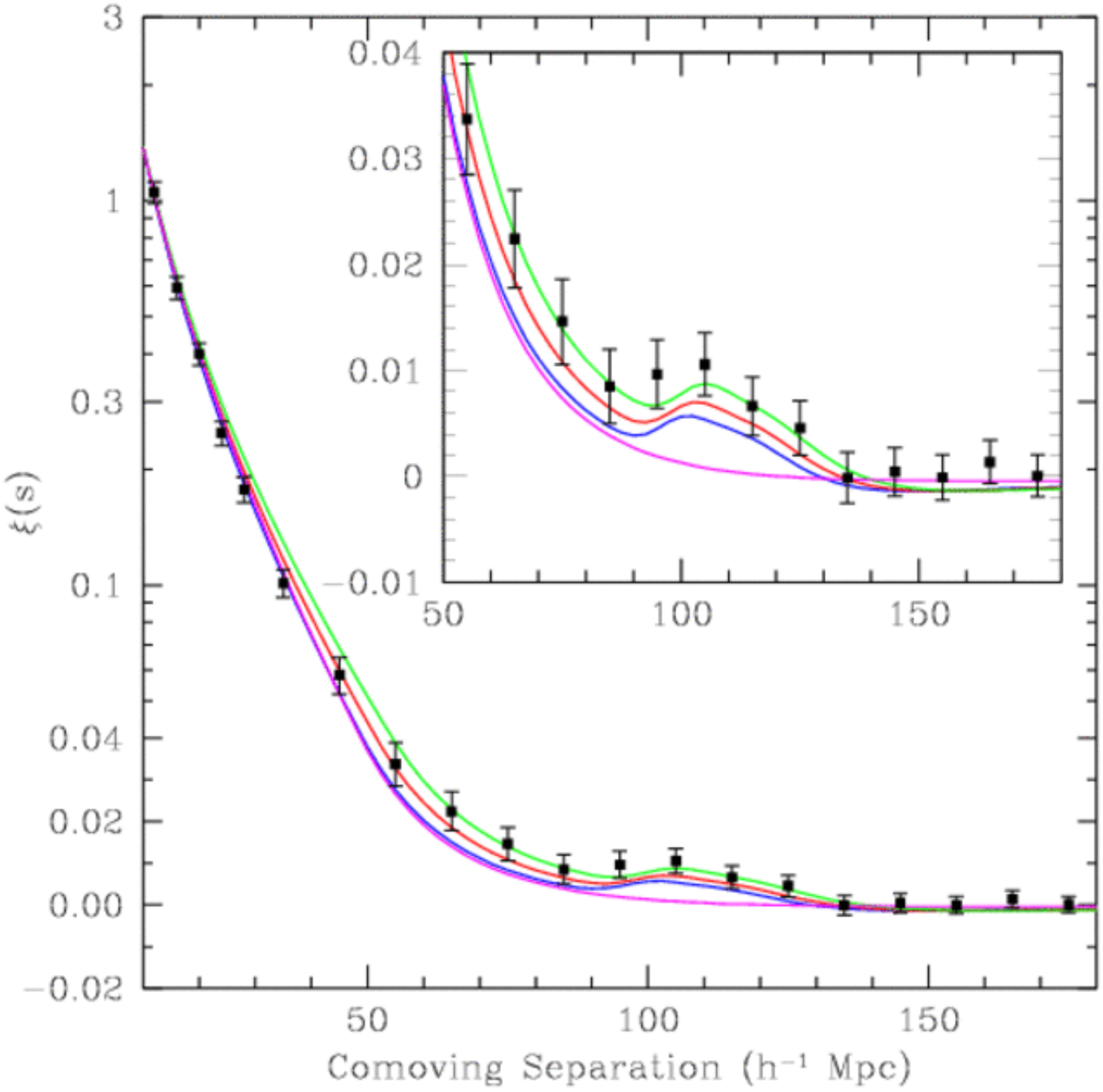
- Hot dark matter is matter in which the particles are moving at *relativistic speeds* after the decoupling.
- Cold dark matter is matter in which the particles are moving at *non-relativistic speeds* after the decoupling
- The *shape of the spectrum* will depend the mixture (or absence) of one or the other.
- This also means that we can use the spectrum to determine some of the nature of dark matter.
  - Hot dark matter particles are moving too fast to form structures smaller than about 55 Mpc. This corresponds to the scales of *superclusters,* so we would expect to see these *form first*
  - Cold dark matter particles can form structures on the order of *galactic scales*. If most of the dark matter is cold, we would expect to see *galaxies form first*.
  - We seem to find galaxies formed before superclusters.

Do question (2) on the worksheet.


1
0.1
0.01
Relative Fluctuation Strength
Length scale (Mega parsecs)-1
CDM
HDM
HDM + CDM


HDM
CDM
Scenario 1
Scenario 2

$$r_s \approx 160\,\mathrm{Mpc}$$



Eisenstein et al 2005 SDSS collaboration.