PC 3392 – Cosmology
Lectures 1-2

- Study of the universe as a whole
- Pushes known physics beyond the limit!
- Non-mathematical (there are equations, but not as many as usual). The aim is for a "feel" for current knowledge, which will lead on to more specialized courses in following years:
    - PC 4771: Gravitation (M): General Relativity
    - PC 4772: The Early Universe (M): more detailed development of the cosmological model

Books:

- Little, A, *An Introduction to Modern Cosmology*, 2nd edition (Wiley)
- Don't bother with the other ones…
- Use the web to find more info! Via Google:
    - Ned Wright's Cosmology Notes
    - Nick Strobel's Cosmology
    - J. P. Leahy Cosmology (in the "Old Course Homepage"; this was the previous lecturer).

NB: all images and presentations will be available on the web. Any exam questions on these images will require only sketches.

Lecture 1: "Overview of most things"
Done as a slide show.

Lecture 2: History and Observational Overview
History of Astronomy: increasingly denotes mankind from a special place in the universe.

The Earth is not at the centre of the solar system. (Copernicus, 16th century) This is not obvious from day-to-day life: it was not until the 17th century when Galileo proved it by observing the phases of Venus (like the moon's phases). Newton (also 17th century) put it on a firm physics foundation, i.e. the law of gravity.

The sun is not at the centre of the galaxy (a mass of stars). This wasn't known until the American Harton Shapely, in the early 20th Century, found that we are 2/3 of the ay out from the center of the galaxy. He did this by counting the "globular clusters", which tend to lie in a distribution around the centre of the galaxy, and measuring their directions and distances. *(Pictures 1 and 2)*. He found that most of them are all in one direction, and often a fair distance away from us (non-isotropic). So things aren't as symmetrical as they would be if we were in the middle of the galaxy.

The "Milky Way" is not the only galaxy. This debate happened after the 1st world war, and into the 1920's. Hubble, in the late 1920's, measured distances to galaxies (using Cepheid Variables), and showed that they must be about the same size as ours. *(Pictures 3 and 4)*.

The Milky Way is a very typical galaxy; it is a spiral. This was found by radio astronomers using the 21cm spectral line of atomic hydrogen, and measuring the Doppler shift to find out the velocity of gas. Optically, this is an impossible task due to obscuring dust *(Pictures 5, 6 and 7)*.

This leads to the developing idea of the "Cosmological Principle", sometimes called the Copernican Principle.

- We are not in a special place.
- The universe looks the same from any point within it.

To some extent, this is an article of faith… (1930's → 1950's). It is obviously not true on small scales, i.e. on the scale of the solar system, the galaxy, or clusters of galaxies. (looking at similar scales; not the entire universe). It depends on where you are. It only starts to be true when you're looking at scales of 100's of parsecs (remember: $1pc \approx 3.16 light\ years$, $1Mpc \approx 3.1 \times 10^{22} m$).

The natural next step is that our place in the universe is not special, but this has not (yet) been proved.

NB: this does not mean that the universe is the same at all times. We now know that the universe is evolving with time. There is not a cosmological principle in time; only in space. (In the 1950's / 60's there was the perfect cosmological principle, which said that it was the same in time and space, but this was disproved in the 1950's by radio astronomers).

Liddle, Chapter 2:
We don't need to know about stars (they are too small on this scale).

What are Galaxies? They are basically the sum of 10^{11} stars, on the scale of 10's of kiloparsecs. They come in various shapes and sizes *(Picture 9)*. For cosmology, the details are largely irrelevant. We are considering bigger scales.

Group of galaxies: a few MPc across. *(Picture 10)* ~ The local group consists of 10 members separated by around 10 times their diameter. The volume is about $10^{67} m^3$. This is still too small to consider…

Clusters of galaxies, "superclusters", and "voids". Survey the universe on scales of 100MPc. Additional structures become evident. *(Pictures 11 [a map of directions and distances – "cluster" in the centre called the "coma cluster", due to the constellation it's in], 12 [a picture of the same region in the optical], 12a, 13)*

Most galaxies are not in clusters, but are in "filaments" and at lower densities in "voids" of order 50MPc across. This is the structure (statistical) which cosmology has to account for as part of its task.