PHYC30019 Astrophysics
Due: Friday 28 May

Motivation for Workshop 3:
During this workshop you will gain a clearer idea of how the expansion of the universe and its geometry affect the observation of very distant objects. In particular, we want to end by thinking about the sort of experiments you could perform to determine the type of expansion the universe is undergoing.
In this workshop, assume that the current values of the energy densities are: $\Omega_{r,0} = 10^{-4}, \Omega_{m,0} = 0.27, \Omega_{\Lambda,0} = 0.73$. You should use an H_0*=70km/sec/Mpc.*
For the order-of-magnitude problems this workshop, try to get to a solution with minimal effort – remember it is an order of magnitude solution you are looking for.

Order-of-Magnitude Estimate 1:
Suppose that you have been asked to find new extra-solar planets. You need to think about the techniques that you will use for these experiments. What accuracy is required to detect extra-solar planets by their astrometric wobble? By Doppler shift? Which would you expect to be easier to measure?

Calculation 1: when did dark energy become the key driver of expansion
Using the final form of the differential equation that describes the behaviour of the scale factor with time, work out the redshift when dark energy first dominated the expansion of the universe. The equation is given by:
$\frac{H^2}{H_0^2} = \frac{\Omega_{r,0}}{R^4} + \frac{\Omega_{m,0}}{R^3} + \Omega_{\Lambda,0} + \frac{1-\Omega_0}{R^2}$ where the subscript 0 refers to the present value and the subscripts *r, m* and Λ refer to radiation, matter and Lambda respectively.

Research Task 1:
When we consider the fluctuations in the CMB, we usually plot a power spectrum to describe the scales where there is most power. Describe the physical quantities that are measured on the two axes of the typical plot of the fluctuations – a full explanation is expected. Then describe the physical interpretation of the two main peaks in the plots.

Calculation 2:
For the cosmology given above, use the calculator from the previous workshop to determine the redshift where a galaxy of a standard size has the smallest angular extent or size.
http://www.ph.unimelb.edu.au/cosmocalc/session.php

Order-of-Magnitude Estimate 2:
Many galaxies rotate. Can you actually observe the rotation of nearby galaxies over a reasonable (ie measureable) timescale?

Order-of-Magnitude 3:
Consider a galaxy acting as a gravitational lens. You know that the galaxy comprises, stars, globular clusters, dark matter, gas etc. Estimate the probability that a background quasar is gravitationally lensed by a globular cluster, as a function of the probability that is it lensed by the whole galaxy. Can you make a similar estimate for the probability of lensing by a star?

Make sure that you provide details of the criteria that you are using.

Calculation 3:
Consider the surface brightness of a galaxy. How is it defined? Now explain how surface brightness changes as a function of distance in a Euclidean, non-expanding universe. How does surface brightness change in an expanding FRW universe.

What conclusions can you draw about the observations of very distant galaxies?

Conclusion:
You have considered some of the changes in observables in different FRW cosmologies. Which observations do you think might be easiest to undertake to measure the curvature of the universe accurately?