Physics 214 - Problem Set 1

Due in Class on Wednesday, Feb 7, 2006 (Time allowed=three weeks)

Numbers like the mass of the Sun, distance of the Earth, number of meters in a light year, etc, can be found in the text or on the Internet.

Show all working.

(1) In this question you will calculate the angular sizes of a number of astronomical objects and then compare these to some more familiar everyday objects placed at a certain distance. Use the small angle formula $\theta = \mathbf{D/d}$ (see lecture 2) in the following questions.
(a) The Andromeda Galaxy has a diameter of about 250,000 light years and is at a distance of 2.9×10^6 light years. What is the angular diameter in radians? What about in degrees? How does this compare to the angular size of the Moon?
(b) The black hole at the center of our galaxy is 26,000 light years away. Its diameter is about one astronomical unit (AU). What is the angular diameter in radians? What is the angular diameter in arcseconds?
(c) What is the angular size of a dime (1 cm across) at a distance of 2 km? How many times larger or smaller than this is the angular diameter of the black hole at the center of the Milky Way?
(d) Given the angular size, θ, and the diameter of the object, D, the small angle formula can be rearranged to give the distance to the object, d. The star Betelgeuse has an angular diameter of 0.054 arcseconds. If Betelgeuse has a diameter of about 500 million km, how far away is it in light years?

(2) In this question you'll make your own estimate of the Hubble Constant H_0. Distances and recession velocities of five galaxies are given in the table below:

Galaxy in	Distance/Mpc	v/km s^{-1}
Virgo	16	1200
Ursa Major	200	15,000
Corona Borealis	300	22,000
Bootes	520	39,000
Hydra	810	61,000

Plot the velocities of the five galaxies versus their distance on a piece of graph paper. Alternatively, if you would rather you use a spreadsheet and produce the graph that way you may do so. Fit a straight line to the data and calculate the slope of that line. What will the units of the slope be? What is the value for the slope you derive? The current best estimate of Hubble's constant is $70^{+2.4}_{-3.2}$ km s^{-1} Mpc^{-1}, how does your value compare? Calculate the age of the Universe using the value of Hubble's constant that you derived.

(3) In the notes I gave the equation for the distance modulus, (m-M), which is the relation between the apparent and absolute magnitudes and the distance of an object:

m - M = 5log(D) - 5

where m = apparent magnitude
M = absolute magnitude
D = distance in parsec (pc)

(a) (i) Quasar APM 08279+5255 has a distance modulus, (m-M) = 46.7, and an absolute magnitude M = -34.2 (at some wavelength which doesn't matter). What is its apparent magnitude m?
(b) Suppose we have a distant quasar, 3C48, for which we can measure its cosmological redshift (which is denoted by the letter z), z = $\Delta\lambda/\lambda$ = 0.367 (*i.e.* its spectral lines are shifted towards the red part of the spectrum by 37%). What is the velocity, v, at which 3C48 is receding away from us?
(c) Next, using Hubble's law: $v = H_0 d$, where v is the recession velocity in km s^{-1}, H_0 is Hubble's constant (units of km s^{-1} Mpc^{-1}), and d is the distance in Mpc. Taking H_0 = 70 km s^{-1} Mpc^{-1}, what is the distance of 3C48?
(d) Using the distance modulus equation given at the start of this question, if the absolute magnitude of 3C48 is $M = -25.0$, calculate the apparent magnitude, m, using the distance, D, you calculated in part (c).