Galaxies and Cosmology
Exam, 30 August, 2006

You may use a pocket calculator, physics and mathematical handbooks, and the handed out sheets with additional astrophysical formulae.

1. Give brief explanations to the following concepts/questions (4p):
   - Blazar
   - Thin vs thick disk
   - population III objects
   - Tully-Fisher relation

2. Spectra of active galaxies commonly show narrow “forbidden” emission lines, e.g. [OIII], and Balmer lines which are very broad but contain a narrow component in their cores.
   Discuss the explanation of this phenomenon, and discuss what the variability of these lines tell us about the sizes of the sources of the emission? (4p)

3. Show how the scale factor varies with time for a universe with critical density and in which the cosmological constant is zero (3p).

4. An elliptical galaxy has $M_V = -20, B - V = 1, V - K = 3$, and mass to light ratio for the stellar population of $M/L_V = 5$ (in solar units). Suddenly it collides with a small gas-rich galaxy with the following properties: $M_V = -18, B - V = 0.5, V - K = 1, M/L_V = 1$, and a gas mass fraction $\mu = M_{\text{Gas}}/(M_{\text{Gas}} + M_{\text{Stars}}) = 0.9$.
   a) If no new stars would form as a result of the merger, what would be the $M_V, B - V, M/L_V$ and gas mass fraction of the resulting galaxy? (3p)
   b) In this example the merger leads to vigorous star formation in which of half the available gas is converted into a young stellar population with the following properties: $M/L_V = 0.05, B - V = 0, V - K = 0$. What would now be the total luminosity ($M_V$), colour ($B - V$) and $M/L_V$ of the whole new galaxy? Discuss your result. (4p)

5. a) How does the energy densities of matter and radiation vary with cosmic scale factor $R$ and redshift (2p)?
   b) The observed cosmic microwave background contains $X = 4 \cdot 10^8 \text{m}^{-3}$, number of photons per cubic meter and has a temperature of 2.7K. Assuming that the present matter density is $\Omega_{\text{mat}} = 0.3$, and $H_0 = 75 \text{km/s/Mpc}$, calculate at what redshift the energy densities of matter and radiation would be equal (3p).
6. A galaxy cluster is observed to contain 10000 galaxies, within a radius of 5 Mpc from the centre. Spectral analysis show the cluster to have a mean redshift of $z = 0.03$ with a standard deviation of $\sigma_z = 0.004$.

a) Estimate the dynamical mass of the cluster. (2p)

b) Estimate the mass of all the galaxies taken together by assuming that they follow a luminosity function: $dN \propto L^{-1.5}dL$ between $M_V = -15$ and -22, and that they have an average mass to light ratio of $MM/L_V = 5$ in solar units. (3p)

c) Discuss the difference between regular and irregular rich galaxy clusters. (2p)