PHAS3136 Problem Sheet 3 2010

Due in by 3PM Friday 19 March 2010

1. (a) Take the fundamental plane equation given in the lectures and estimate the mass to light ratio M/L as a function of galaxy luminosity for ellipticals. **[2]**

   (b) Take the Tully-Fisher relation observed in the b-band and use it to estimate the mass-to-light ratio for spiral galaxies in the b-band. **[4]**

2. In the lectures we derived an equation for the ISM metallicity $Z_{\rm ISM}(t)$ in terms of the total mass in stars $M_{\rm S}(t)$ for the open box model in which we assumed that the *ISM mass is constant with time*.

   (a) Explain why this might help to resolve the G-dwarf problem. **[2]**

   (b) Use this equation to derive an equation for $f(Z,t)$, the fraction of mass in stars of metallicity Z or less, at a time t. **[2]**

   (c) Observations show that $M_{\rm S} \simeq 0.9 M_{\rm Tot}$ and $Z \simeq Z_\odot \simeq 0.02$ in the solar neighbourhood. Calculate the yield, and thereby estimate the mass fraction of stars expected to have metallicity less than $\sim 0.25 Z_\odot$. **[4]**

   (d) Comment on how your result compares with that for the closed box model, and observations. **[2]**

3. Magnetic monopoles behave as non-relativistic matter. Suppose that at a temperature corresponding to the Grand Unified era, about 3×10^{28} K, magnetic monopoles were created with a density of $\rho_{\rm mon}/\rho_{\rm crit} = 10^{-10}$.
   (a) Assuming that the Universe has a critical density and is radiation dominated, what was the temperature when the density of monopoles equalled that of the radiation? **[3]**
   (b) In the present day Universe, the radiation has $T \sim 3$K. Compute the value $\Omega_{\rm mon}/\Omega_R$ at the present day. Is this compatible with observations? **[4]**

4. (a) Calculate the primordial Helium mass fraction ($Y_{\rm He}$) for a Universe in which the neutron half life is a factor of ten smaller. Compare this to the Helium mass fraction in our own Universe. **[3]**
   (b) Calculate the physical Hubble length at nucleosynthesis and calculate the approximate scale this corresponds to in the present day Universe (i.e. comoving Hubble length). Compare this scale to a similar size object. **[4]**

   [Assume that nucleosynthesis occurred ~ 1 minute after the Big Bang.]

END OF PAPER