Astronomy 274: HW #1

Due date: Thursday, January 27th

1. **Local Galaxy Luminosity Function**

   The local galaxy B-band luminosity function is characterized by the following Schechter parameters: faint-end slope, $\alpha = -1.03$; characteristic absolute magnitude, $M_B^* = -20.04$; and normalization, $\phi^* = 5.90 \times 10^{-3}$ Mpc^{-3}.

   (**a**) What is the B-band luminosity density, j_B, associated with this luminosity function? Express your answer in units of solar luminosity per Mpc^3.

   (**b**) What fraction of j_B is contributed by galaxies with $M_B \leq -20.00$?

   (**c**) What is the number-density of galaxies integrated down to $M_B = -20.00$?

   (**d**) Galaxies in the local universe are described by a bimodal distribution in optical color, i.e. they can be divided into samples of "Blue" and "Red" objects. The parameters of the Blue-galaxy luminosity function are: $(\alpha, M_B^*, \phi^*) = (-1.24, -20.09, 2.396 \times 10^{-3})$, while corresponding parameters for the Red-galaxy luminosity function are: $(\alpha, M_B^*, \phi^*) = (-0.76, -19.91, 3.596 \times 10^{-3})$. What fractions of the total B-band luminosity density are contributed by Blue and Red galaxies, respectively? How does this answer change if you only integrate down to $M_B = -20.00$?

2. **The Exponential Profile of NGC 5055**

   NGC 5055 (The Sunflower Galaxy) is an Sbc galaxy at a distance of $d = 9$ Mpc. A photograph of the galaxy can be found on-line or in the *Hubble Atlas of Galaxies*.

   (**a**) From the photograph, estimate the angle of inclination, i, between the disk plane and the plane of the sky.

   (**b**) r-band photometry along the major axis of NGC 5055 gives $\mu_r = 20.1$ at 1', $\mu_r = 21.1$ at 2', $\mu_r = 22.7$ at 4', and $\mu_r = 25.25$ at 8' (units of μ_r are r mags arcsec^{-2}). Suppose the stellar disk, as viewed face-on, has an exponential surface-brightness profile, $\Sigma_r = \Sigma_0 \exp(-r/h)$. From your fit to the major axis photometry, calculate h, Σ_0, and the total luminosity of the disk in solar luminosities (the sun has $M_r = 4.74$).

3. **Deep into the Fundamental Plane**

The Fundamental Plane (FP) of elliptical galaxies is often expressed in the form:

$$\log R_e = \alpha \log \sigma + \beta \mu_e + \gamma$$

where R_e is effective radius (in kpc), μ_e is the the surface brightness at the effective radius (in magnitudes/arcsec^2), and σ is the central velocity dispersion (in km s^{-1}).

(**a**) In class, we wrote down the FP relation as: $R_e \propto \sigma^A I_e^B$. Using the conversion between I_e (in luminosity/kpc^2) and μ_e (in magnitudes/arcsec^2), express the exponent, β, in terms of the exponent, B.

(**b**) The "tilt" of the FP can be expressed in terms of a relationship between mass and luminosity, of the form $L \propto M^\eta$, or $L = CM^\eta$. Re-express this equation in terms of the relationship between mass-to-light ratio, M/L, and mass, M.

(**c**) Given the relationship between mass and luminosity, and the FP equation, what do you derive for the relationship between the exponents, α and β? Next, express the exponent, η, in terms of α and β. [Note: the FP relation observed in the Coma cluster yields $\alpha = 1.25$, $\beta = 0.32$, and $\gamma = 8.97$].

(**d**) The FP is measured for elliptical galaxies at high redshift, and evolution is observed in its zeropoint, γ. This offset in zeropoint is commonly interpreted as evidence for evolution in the mass-to-light ratios of elliptical galaxies with lookback time. Express the evolution in the logarithmic mass-to-light ratio, $\Delta \log \frac{M}{L}$ in terms of the observed evolution in zeropoint, $\Delta\gamma$. If elliptical galaxies had lower M/L ratios in the past, would you expect them to be displaced *above* or *below* the $z \sim 0$ FP relation? Draw a diagram of the FP, with x-axis $\alpha \log \sigma + \beta \mu_e$ and y-axis $\log R_e$. On this diagram, show both the local FP and the direction in which an object moves as its M/L decreases.