Astronomy 313000
Spring Quarter 2007

Problem Set 1

Due: Friday, April 20

If you have any questions, please contact me *before* the due date by e-mail: frieman@fnal.gov.

1. The Sersic model profile for galaxy surface brightness is of the form

$$I(R) = I_e \exp\left(-b_n\left[(R/R_e)^{1/n} - 1\right]\right)$$

where $I_e = I(R_e)$. If the coefficient b_n is chosen to be $b_n = 1.999n - 0.327$, then the effective radius R_e is the half-light radius, i.e., the radius containing half the total luminosity. Special cases include the deVaucouleurs profile, $n = 4$, and the exponential profile, $n = 1$.

Find an analytic expression for the total luminosity $L(\infty)$ of the Sersic model in terms of R_e, I_e, and b_n. Using the expression for b_n above, plot $L(\infty)/I_e R_e$ vs. n, for n between 1 and 4.

2. For the deVaucouleurs $R^{1/4}$ profile, find an analytic expression for the luminosity $L(R)$ enclosed within radius R, in terms of I_e and R_e. Calculate the mean surface brightness inside radius R_e in terms of I_e.

3. In class, we discussed the Petrosian flux as one measure of galaxy total flux; e.g., the SDSS uses Petrosian r magnitude of 17.7 as the upper limit in selecting galaxies for spectrosopic targeting. It is of interest to know how much of the total galaxy light is counted in the Petrosian flux, and how that fraction depends on galaxy type.

   (a) For simplicity, define the Petrosian ratio $R_p(r)$ at radius r to be the ratio of the surface brightness in an infinitely thin annulus at radius r to the mean surface brightness of the region at radius less than r. For the deVaucouleurs profile, define a dimensionless radius $x = r/R_e$ and plot the Petrosian ratio $R_p(x)$. Find the value of r at which $R_p = 0.2$; this is the Petrosian radius, r_p. The SDSS calculates the Petrosian luminosity L_P as the total luminosity contained within a radius of $2r_p$. For the deVaucouleurs profile, calculate the ratio of the Petrosian luminosity to the total luminosity, i.e., $L(2r_p)/L(\infty)$.

   (b) Repeat this calculation for the exponential SB profile, i.e., for the Sersic profile with $n = 1$. Near the flux limit of the SDSS spectroscopic survey, do we expect the survey to be more 'complete' for early or late type galaxies?

4. One method of galaxy classification that we discussed in class uses the degree of concentration of the surface brightness profile. In the SDSS, the concentration index is defined as $C = r_{90}/r_{50}$, where r_{90} is the radius containing 90% of the Petrosian luminosity, i.e., $L(r_{90}) = 0.9L(2r_p)$, and similarly for r_{50}.

(a) For the deVaucouleurs profile, calculate r_{90}/R_e, r_{50}/R_e, and thus the concentration index C.

(b) Repeat this calculation for the exponential profile ($n = 1$).

(c) This difference in concentration between deVaucouleurs and exponential profiles in principle provides a way to quantitatively distinguish ellipticals from very late (e.g., Sd) spirals, at least in the absence of noise, seeing, etc. However, earlier spirals, e.g., Sa, show both bulge and disk components. Model an early-type spiral as a deVaucouleurs bulge plus an exponential disk, where the effective radii are related by $R_{e,disk} = 1.7R_{e,bulge}$ and the fraction of total light contributed by the bulge is characteristic of that for Sa galaxies, $f_{bulge} = L_{bulge}/(L_{bulge} + L_{disk}) = 0.3$. Repeat the calculation of r_{90}, r_{50}, and C for this case.