Ay 124 Winter 2016 – HOMEWORK #4

Due Friday, Feb 19, 2016 by 5pm, in Denise's mailbox in 249 Cahill

Problem 1 The giant elliptical M87 near the center of the Virgo cluster is orbited by a few thousand globular clusters. M87 has a distance modulus of $m - M = 31$. There are roughly equal numbers of globular clusters in every octave of projected radius, out to ~ 400 arc seconds from the nucleus of M87. Measurements of the radial velocities of the globular clusters show that they have a radius–independent line of sight velocity dispersion of 390 km s^{-1}, and a radius–independent rotation velocity of 110 km s^{-1}.

a) The surface brightness of M87 falls off as R^{-2} at projected radii $R > 60$ arc seconds from the center. How does the mass to light ratio scale with radius for $60'' < R < 400''$?

b) Calculate the total mass of M87 within 400 $''$. State any assumptions you make in obtaining your answer. The V-band luminosity internal to that radius is 7.6×10^{10} $L_{V_\odot}$. What is the mass-to-light ratio within that radius?

Problem 2

a) Neglecting cosmological redshift effects, show that any stellar system with V-band surface brightness given by μ mag arcsec^{-2} has a surface luminosity density in projection on the sky of

$$\Sigma = 10^{0.4(26.4-\mu)}\ \mathrm{L_{V\odot}\ pc^{-2}}\ ,$$

so that, for example, $\mu = 26.4$ V-mag arcsec^{-2} equals 1 $\mathrm{L_{V\odot}}$ pc^{-2}.

b) From the photograph of the Sbc galaxy (D= 8.0 Mpc) NGC 5055 appended on page 2 below, estimate the angle of inclination i between the disk plane and the plane of the sky.

c) Photometry in the V band along the major axis of NGC 5055 gives $\mu_V = 20.1$ at $1'$, 21.1 at $2'$, 22.7 at $4'$, and 25.25 at $8'$, where μ_V has units of V mag arcsec^{-2}. If the stellar disk, as viewed face-on, has an exponential surface brightness $\Sigma_V = \Sigma_0 \exp(-r/R_s)$, use your fit to the major axis photometry to calculate R_s, Σ_0, and the total luminosity of the disk in solar luminosities (the sun has $M_V = 4.83$).

Problem 3

Assuming the observational $M_{\rm BH} - \sigma$ relation $M_{\rm BH} = 10^8(\sigma/200\ \mathrm{km/s})^4$, calculate for $M_{\rm BH} = 10^{5,6,7,8,9}$ the following:

a) the orbital period (in years) of stars whose semi-major axes are equal to r_h, the radius where the black hole begins to dominate the galaxy potential

b) the relaxation time (in years) at r_h

c) the radius from which a 100 $\mathrm{M_\odot}$ black hole would sink to the center of the galaxy in 10^{10} years- you may assume that the galaxy density profile has $\rho \propto r^{-2}$ everywhere inside and outside r_h.)

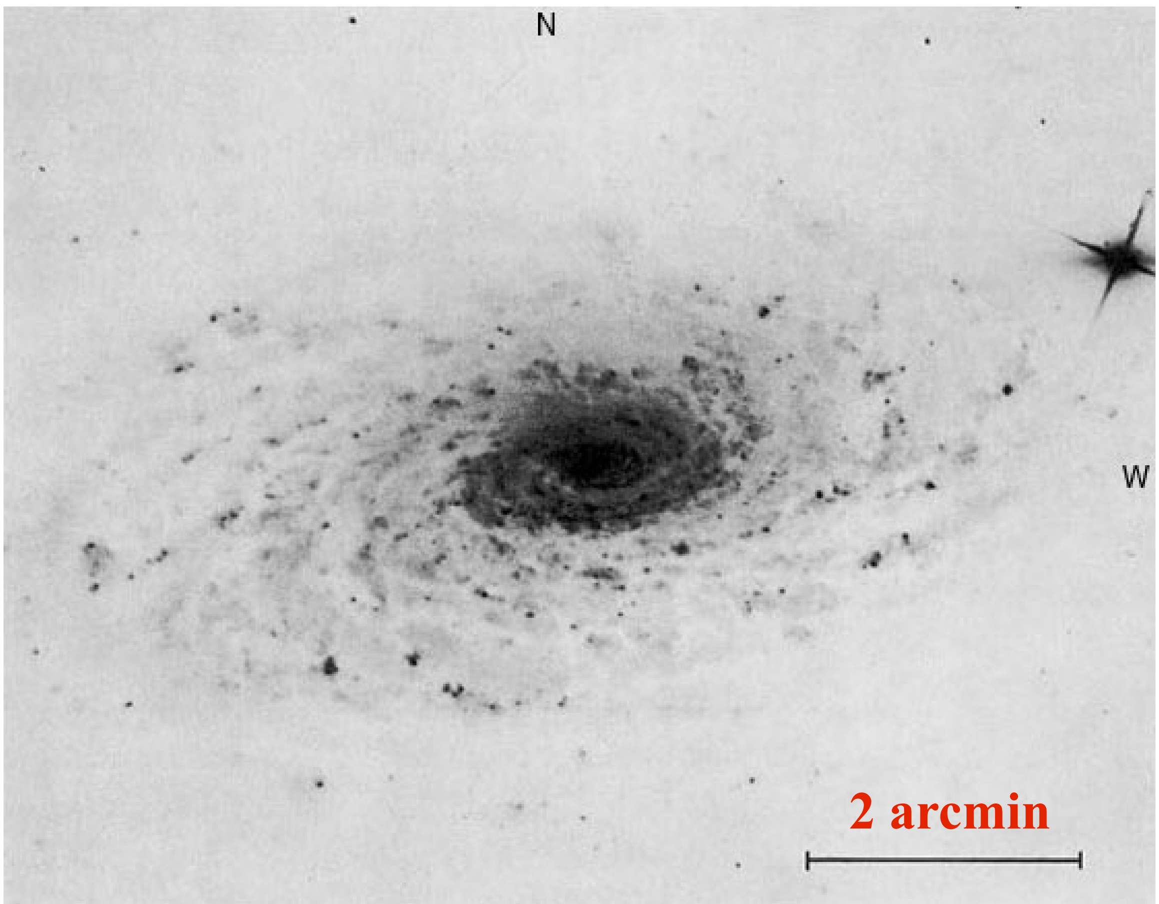

Figure 1: Photographic image of NGC 5055 from the revised Shapley-Ames catalog of nearby galaxies.