ASTR 323 Spring 2009

Solution for Problem Set 3 (27 points total)

Due: April 21, 2009
(CO = Carroll & Ostlie)

1. (7 pt) Do the exercise found at

   `http://cas.sdss.org/dr5/en/proj/advanced/galaxies/spectra.asp`

   answering all four questions. You can number the galaxies 1-11.

   (1/2 pt per galaxy)

Galaxy	Color (u-r)	Type	Lines
1	1.27	Irr	Hβ, OIII, Hα, SII
2	1.51	SBb	Hβ, Hα, SII
3	1.68	Sa	Hβ, Hα, SII
4	1.88	E0	OI, Hβ, Hα, SII
5	2.20	S0	Hα, CaII
6	2.47	S0	G, Mg, Na, CaII
7	2.76	E7	K, H, G, Mg, Na, CaII
8	2.84	E0	K, H, G, Mg, na, CaII
9	3.11	E0	G, Mg, Na
10	3.33	E0	K, H, G, Hβ, Mg, Na
11	3.61	E5	K, H, G, Hβ, Na

   (1 1/2 pts)

   Redder galaxies have larger $u - r$; bluer galaxies have smaller $u - r$. The colors range from blue to red, from 1.27 to 3.61. This is a factor of 8.6 difference in u flux divided by r flux! The galaxy types going from blue to red tend to correlate with the Hubble tuning fork - bluer are later type, redder are earlier type. The later type galaxies have stronger emission lines due to the HII regions in the spiral arms; the earlier type galaxies have stronger absorption lines due to the cooler red giants that dominate the spectrum.

2. (4 pt) CO 25.3

   Solution: (a) (2 pt) Adding up contributions from the thin disk, thick disk, bulge and halo, the total luminosity of the Milky Way in the B-band is about $L_B = 2.2\times10^{10}L_\odot$. The absolute magnitude of the Sun in the B-band is about 5.47, so this gives $M_B = M_{B,\odot} - 2.5log_{10}(L_B/L_\odot) = -20.4$.

   (b) (2 pt) Using Tully-Fisher relation for an Sa galaxy (equation 25.5) gives $V_{max} = 233$ km s^{-1}. This compares well with the V_{max} in figure 24.25 which is about 235 km s^{-1}.

3. (5 pt) CO 25.7

   Solution: (a) (1 pt) Taking 10 raised to the power of each side of equation (24.13), one gets: $I(r) = I_e 10^{-3.3307((r/r_e)^{1/4}-1)}$. Now, $10^x = e^{\ln 10 x}$, and $3.3307\ln(10) = 7.67$, so $I(r) = I_e e^{-b[(r/r_e)^{1/4}-1]}$.

   (b) (2 pt) Actually this question is a bit misleading since L_{tot} is *not* the luminosity of the galaxy, but the total flux from the galaxy. Since the surface brightness is over the surface of the disk which has an annular area of $2\pi r dr$, then changing variables to $x = b(r/r_e)^{1/4}$ and $dr = r_e 4x^3 b^{-4} dx$,

$$L_{tot} = \int_0^\infty 2\pi r I(r) dr = 8\pi I_e r_e^2 e^b b^{-8} \int_0^\infty x^4 e^{-x} x^3 dx = \pi I_e r_e^2 8! e^b b^{-8} = 7.214\pi r_e^2 I_e. \quad (1)$$

   (c) (2 pt) Now integrating out to $r = r_e$ where $x = b$,

$$L(< r_e) = 8\pi I_e r_e^2 e^b b^{-8} \int_0^b x^4 e^{-x} x^3 dx = 8\pi I_e r_e^2 e^b b^{-8} 2520 = 3.607\pi I_e r_e^2, \quad (2)$$

   which is exactly half of the equation in part (b). I evaluated the integral using Mathematica.

4. (6 pt) CO 25.8

   Solution: (a) (1 pt) The absolute magnitude from equation (25.5) is about $M_B = -21.83$. (b) (1 pt) Using the distance modulus, $D = 10\text{pc}10^{0.2(B-M_B)} = 6.5\times10^7$ pc $= 65$ Mpc. (c) (1 pt) From equation (25.11), $R_{25} = 27$ kpc. (d) (1 pt) Assuming that the mass distribution is spherically symmetric, and using equation (24.49), $M = R_{25}V_{max}^2/G =$

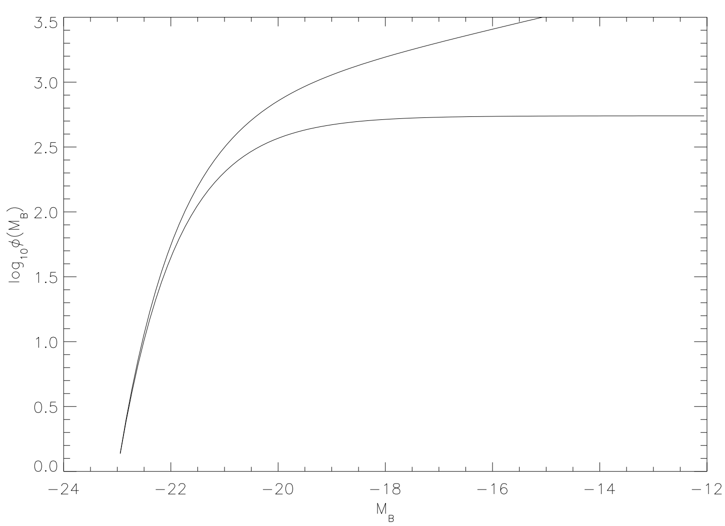
$6.5 \times 10^{11} M_\odot$. (e) (1 pt) $L = L_\odot 10^{0.4(M_{B,\odot} - M_B)} = 8.3 \times 10^{10} L_\odot$ in the B-band. (f) (1 pt) $M/L = 7.8 M_\odot / L_\odot$ in the B-band. This is just a bit higher than the average value given in Table 25.1.

5. (1 pt) CO 25.21

   Solution: The slope is about $(2.6 - 0.8)/(-23.5 - (-8)) = -0.116$. The slope is pretty close. You shouldn't expect them to be exactly the same since the mass-to-light ratio changes slightly with galaxy mass.

6. (4 pt) CO 25.24

   Solution: Taking the logarithm of the expression for $\phi(M)$ given in the text, $log_{10}(\phi(M)) = C - 0.4(\alpha + 1)M - log_{10}(e)10^{-0.4(M_* - M)}$ where C is a constant (this is the constant of proportionality in the expresssion for $\phi(M)$). Now the problem says to make $log_{10}(\phi(-23)) = 0$ in the plot, which means $C = 9.2(\alpha + 1) - log_{10}(e)10^{-0.4(M_* + 23)}$. The two different functions for $\phi(M_B)$ are shown in this figure. They aren't a perfect match for the mass functions in Figure 25.36, but get the qualitative overall shape roughly correct. What is interesting is that the Virgo cluster has many more faint galaxies than the local group - this is due to the large number of dwarf ellipticals in Virgo. So someting about the environment of Virgo makes it easier for small elliptical galaxies to form - maybe they are captured by the cluster, or maybe the overall larger density of the region means that it is easier for small scale perturbations to collapse, or probably both occur.



3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
log10φ(MB)
−24
−22
−20
−18
−16
−14
−12
MB