

Galaxies final exam, course 2004-2005

Please write down your name and your student ID on every page. You can answer the questions in English or in Dutch. Please explain clearly all the steps you have used to derive a result, and make sure your handwriting is readable.

1. Practical exercises for a total of 30 points. Explain clearly the steps you have used to derive the final results
 - (a) Luminosity and surface brightness of galaxies
 - Write down the expression for the total luminosity of a galaxy whose surface brightness is given by $I(R)$.
 - Prove that the total luminosity for a Hubble profile $I(R) = I_0/(1 + R/a)^2$ diverges.
 - Show that the total luminosity of an exponential disk profile $I(R) = I_0 e^{-R/R_0}$ is $2\pi I_0 R_0^2$.
 - (b) The motion of stars in the Galactic disk
 - Show that the difference $A - B$ of the Oort constants, along with $v_c = 220$ km/s, gives the solar Galactocentric distance R_\odot . *Hint:* Remember that A and B are measured in units of km/s kpc^{-1} , and that $A = 0$ in the case of rigid body rotation.
 - Show that the combination $\beta = (A + B)/(A - B)$ is dimensionless, and that its sign tells whether the circular speed is increasing or decreasing with Galactic radius. Briefly state what we know about the rotation curve of our Galaxy. Finally, if we have $v_c(r) \propto r^\alpha$, calculate the value of β and comment on the meaning of the result.
2. Answer briefly the following questions (50 points in total)
 - Draw the Hubble Tuning Fork diagram. What are the characteristics of each galaxy on this diagram? Why isn't the tuning fork diagram an evolutionary sequence?
 - What is the difference between absolute and relative distance indicators? List four distance indicators and describe when each is used.
 - Describe the luminosity and colour evolution in time of a single stellar population.
 - How do we know that the Milky Way and other disk galaxies have massive halos around them and that these halos are composed primarily of dark matter?
 - Describe the scaling laws for elliptical galaxies.
3. Mark with T for true or F for false the following statements (16 pt for 16 questions).
 - (a) The de Vaucouleurs brightness profile describes an exponential distribution of light.
 - (b) Faber-Jackson and Tully-Fisher relations show that the typical velocities of stars in elliptical and disk galaxies scale with the (approximately) $1/4$ -power of luminosity L of the host galaxy.
 - (c) The motions of stars in the stellar halo of the Milky Way are well described by a Schwarzschild distribution.
 - (d) Pitch angle (openness of spiral arms), gas content, number of OB associations and HII regions, and the fraction of mass contained in the bulge all increase along the Hubble sequence from type Sa to Sc.
 - (e) The G-dwarf problem consists in the fact that there are too many old G-type main sequence dwarf stars in the Galaxy compared to old A and F-type stars.

- (f) The closed-box chemical enrichment model with zero initial metallicity solves the G-dwarf problem.
- (g) From the principle of angular momentum conservation it follows that the vector of angular momentum of a star in an axisymmetric galaxy is constant in time.
- (h) An average star has a very small chance of colliding with another star in the Galaxy during one Hubble time.
- (i) After one relaxation time of a globular cluster, which may be as short as 10^9 years, the cluster changes direction of motion in the galaxy by 90 degrees (on the average).
- (j) In ellipticals, the massive stars have essentially died. This is one reason they are reddish in color.
- (k) We can determine the distance to a galaxy that contains Cepheid variables by using the period-mass relation.
- (l) Galactic globular clusters do not appear uniformly distributed on the sky.
- (m) One scenario for the formation of some elliptical galaxies involves collisions between spiral galaxies.
- (n) The shape of the rotation curve of a disk galaxy depends only on the mass profile of its dark halo.
- (o) The gravitational force exerted by a person on a black hole equals the gravitational force the black hole exerts on the person.
- (p) All elliptical galaxies have the same intrinsic shape.

4. Choose for each question the *best* answer (4 pt for 4 questions)

- Bulges are red / disks are blue / the reason for that / is given by you!
 - (a) young bright massive stars are generally found in disks, not bulges
 - (b) interstellar reddening is stronger in bulges than disks
 - (c) blue light is scattered less by disks than bulges
 - (d) there are very few red giants in disks
 - (e) most star formation occurs in bulges rather than disks
- The rotation velocity of a spiral galaxy can be measured by observing
 - (a) the motion of the globular clusters
 - (b) the number of turns in the spiral arms
 - (c) the differential doppler shift of its 21-cm radiation
 - (d) the size of the halo
- Radio astronomy is useful in studying galactic structure because
 - (a) radio waves are caused by spiral density waves
 - (b) dark matter only emits at radio wavelengths
 - (c) most of the Galaxy is ionized and can only be seen by radio telescopes
 - (d) dust clouds stand out at radio wavelengths because they are so cold
 - (e) neutral hydrogen emits at 21-cm and can be detected across the Galaxy
- How do we know that stars in the galactic disk are rotating about the center of our Galaxy?
 - (a) by measuring the apparent magnitudes of stars lying in different directions from us
 - (b) by using Hubble's Law to measure the velocities of stars in the galactic disk
 - (c) by measuring the Doppler shifts of galactic disk stars lying in different directions from us
 - (d) by plotting galactic disk stars in the HR diagram
 - (e) by measuring the luminosities of galactic disk stars lying in different directions from us