

Intro to Galaxies & AGN

FINAL exam, 2-5pm, May 13, 2008

Answer all five (5) questions.

Closed book exam, no calculators, notes or textbook allowed.

Show all working and reasoning, partial credit will be given.

1. (a) The Tully-Fisher relation is of the form

$$L \propto V_{max}^4.$$

- (i) Explain what the symbols stand for, paying particular attention to  $V_{max}$  [10pts].  
(ii) For which Hubble-types of galaxies does this relation hold? [5pts]  
(iii) Derive an expression showing how the motions with amplitude  $V_{max}$  are related to the gravitational mass distribution, being careful to explain all assumptions made (useful equations are given in the formula sheet), and use this to show how the Tully-Fisher relation can be obtained, by adopting reasonable assumptions about the ratios of total mass to total stellar luminosity in galaxies, and the mean stellar surface brightnesses of galaxies [25pts].

(b) Under what circumstances is the profile of an HI 21cm-line ‘double-horned’? Include a discussion of the HI distribution, the motion of the gas and the spatial resolution of the telescope [20pts].

2. (a) Explain in words why one might expect a steady increase in metallicity with time in a star-forming galaxy [10pts]

(b) What then would one expect for the relationship between stellar age and observed stellar metallicity? [10pts]

(c) What are the main features, including estimates of maximum and minimum values of each parameter, of the age-metallicity relationship for Milky Way stars near the Sun? Is the Sun ‘typical’? [25pts]

(d) What are the mean metallicities and ages of stars in (i) the bulge of the Milky Way and (ii) the stellar halo of the Milky Way. Give your answers for ‘metallicity’ in terms of each of  $[Fe/H]$  and mass fraction  $Z$ . Comment on your answers. [20pts]

3. (a) Which galaxy has a younger mean age, considering two galaxies where the first has a B-V color corresponding to spectral class F5 and the second has color corresponding to spectral class G5? [10pts]

(b) The Tully-Fisher relation is the topic in Q1. List and discuss three other relations between the stellar luminosity of a galaxy and another parameter. [30pts]

4. (a) An approximate expression for the Jeans length can be obtained by arguing that it is the distance that sound can travel in a crossing time. Go through this argument for a medium assumed to be a monatomic ideal gas of given density, temperature, pressure, to derive the expression:

$$R_J \propto T^{1/2} \rho^{-1/2} \quad [15\text{pts}].$$

(b) What then is the scaling of the Jeans *mass* in these parameters ( $T, \rho$ )? [5pts]

(c) Consider a cloud of monatomic, ideal gas that is initially unstable to gravitational collapse:

(i) is its mass greater than, or less than, the Jeans mass? [5pts]

(ii) If the gas cloud is optically thick, so that no heat can flow out, how does the Jeans mass scale as the density increases during the collapse? Show your reasoning [15pts]

(iii) If the gas can instead remain isothermal, how does the Jeans mass vary with density during the collapse? [15pts]

(iv) Explain the term ‘opacity limited fragmentation’ [10pts]

5. (a) Explain why, when mapping the ‘rotation curve’ of the Milky Way galaxy, stars are useful for only locations close to the Sun. [5pts]

(b) If the Oort constant A has the value 12 km/s/kpc, and Oort’s constant B has value  $-14$  km/s/kpc, does that imply that the rotation curve of the Milky Way is increasing, or decreasing, beyond the solar Galactocentric distance? [10pts]

(c) For these values of A and B, what is the amplitude of the rotation curve at the solar Galactocentric distance, in km/s? [10pts]

(d) Why is it a reasonable assumption that the angular frequency,  $\Omega(R)$ , declines with increasing Galactocentric radius,  $R$ ? [15pts]

(e) Explain what is meant by the Tangent Point along a given line-of-sight, using the definitions in the Figure given. Show that gas at the Tangent Point is at the closest distance to the Galactic Center and give the expression for that distance in terms of the solar Galactocentric distance and longitude [20pts]

(f) Using formulae given argue that gas at the Tangent point will have the highest observed line-of-sight velocity relative to the Sun [10pts]