ASTRONOMY 1102 – 1

Instructor: Juhan Frank

Study Guide for Final Exam

Wednesday December 8, 1999 – 12:30 – 2:30 PM

This test will be comprehensive and based on material we have covered in class. I have followed quite closely the content but not always the order in which this material is presented in "The Cosmic Perspective". This guide only deals with the material covered since the second test. Please refer to the two earlier test guides for the material included in the first two tests.

The third test was based on Section 15.6 (p. 505) and the entire chapters 16 and 17. There was consisderable emphasis on the HR diagram and its uses. Please review this since it is one of the most important tools for understanding stars, their properties and their evolution. The HR diagram will feature again in the final exam. Also a basic understanding of stellar evolution, how stars die and what kind of remnants they produce is required to understand the star-gas-star cycle described in chapter 18. Since Cepheids are an important step in the cosmic distance ladder, please review Cepheids (p. 504).

New material covered since the third test:

Chapter 18 Our Galaxy

Overwiew of main components of our Milky Way (Fig. 18.1): disk, spiral arms, bulge, halo, globular clusters, the interstellar medium (ISM). Qualitative idea of the sizes and distribution in space of these components. The star–gas–star cycle: main events along the cycle. Net result: the chemical enrichment of the ISM. "Metal" abundances increase, being higher in later generations of stars. Bubbles, superbubbles and galactic fountains. How do we detect the atomic hydrogen gas in the galaxy? 21cm radio radiation. Molecular clouds. How do all these phases coexist? Check Table 18.1: Pressure balance everywhere except when the densest cores collapse to form stars (P is higher in that case since a stronger gravity must be balanced). The Milky Way in motion: orbits of disk and halo stars. The rotation curve of our galaxy shows more matter is present than can be seen, especially in the halo: dark matter. This problem is not limited to our Galaxy (Fig 18.19) but occurs also in other spiral galaxies (see Fig. 21.4). Dark matter dominates the mass of the halo (Fig. 21.1). Spiral arms and the Spiral Density Wave Theory. Spiral arms are the result of the passage of a wave rather than "material" arms: they cannot be made up of the same stars and HII regions that live for many galactic rotations. The differential rotation of the Galaxy would wind them up tightly (the interior rotates faster than the outer parts). What traces the spiral arms? Young blue stars, OB associations, HII regions, galactic clusters and dust lanes. Spiral arms are "trailing": they bend back (with respect to the sense of rotation of the whole galaxy) as they go out.

The Galactic center: Sagittarius A* and the central cluster of stars. These stars can only be seen in the IR because of the dust in the galactic plane. The radial velocities and proper motions of these stars (Fig. 18.24) reveal the presence of more than $2 \times 10^6 M_\odot$ in the form of invisible matter. Could it be a cluster of dead stars? Maybe a single massive black hole.

Chapter 19 Galaxies: From Here to the Horizon

The Hubble Deep Field (Fig. 19.1). The variety of galaxies. The number of galaxies in the Universe estimated from counts in the HDF is $\sim 5 \times 10^{10}$. Galaxy Classification. Basic Types: Spiral (S), Elliptical (E) and Irregular (Irr). Main parts of a spiral galaxy: disk component and spheroidal component (bulge and halo). Hubble's Tuning Fork Diagram. E subtypes: E0, E1, ...E7. Meaning of the numbers 0...7 from spherical to most elliptical. Spirals: the S0 type (big bulge, small disk with no arms). Two main branches: Normal Sprals (S) and Barred Spirals (SB). Meaning of the subclasses a, b, c: decreasing bulge to disk ratio and increasing openinig of arms.

Stellar Populations: Pop. I (disk, young, relatively high "metal" abundances) and Pop. II (spheroidal, old, relatively low "metal" abundances). Orbits of Pop. I and Pop. II stars (Fig. 19.9). The sun is a Pop. I star or "I live in I" (why?).

Distances: Standard Candle Concept. Use of the inverse square law for apparent brightness:

$$Flux = \frac{L}{4\pi d^2}$$

where L is the star's luminosity and d is its distance. If I know L and measure the apparent brightness, I can calculate d. Examples: Spectroscopic Parallax (G2V has $L_\odot$); MS fitting applied to clusters (Fig. 19.12). Cepheids: the P-L relation (Fig. 19.13). In 1924 Edwin Hubble used Cepheids to show that M31 is extragalactic. Hubble also showed in 1929 that more distant galaxies move away from us faster according to Hubble's Law

$$v = H_0 \times d$$

The velocity is obtained from the Doppler shift of spectral lines. It turns out to be always a redshift except for a few nearby galaxies. Definition of redshift: $z = \Delta\lambda/\lambda_{\rm rest} = v/c$. Current record is over 5. Does this mean motion with $v > c$? No: use relativistic Doppler formula. Units and value of the Hubble constant $H_0 \approx 65$ km/s/Mpc. Meaning. Once calibrated (H_0 determined), Hubble's Law can be used to determine distances. Examples. measure redshift, deduce v and get d from Hubble's Law.

Problems: 1) Galaxies are subject to gravitational pull from other galaxies but if d is large these effects are relatively small. 2) To calibrate H_0 accurately need to measure d for *distant* galaxies accurately.

Distant Standard Candles: SN Type I (WD SN) and Tully-Fisher Relation (Fig 19.12). Why are these standard candles? The distance chain/ladder (Fig. 19.22).

The Expansion and Age of the Universe. The "Rising Raising Cake" analogy. But balloon is better: since the Universe has NO CENTER and NO EDGE. But Universe is likely infinite in extent while balloon is not. The age of the Universe for constant expansion rate. Effects of gravity on expansion. Concept of *critical density*. Expansion rates as function of cosmic time for critical, subcritical and overcritical Universes (Fig. 19.24). Age of an "empty" Universe is $1/H_0 = 15$ billion yr for $H_0 = 65$ km/s/Mpc.

The horizon of the visible Universe. Nature of the redshift: cosmological redshift. Lookback time. Cosmological Horizon (Fig. 19.27).

SAMPLE:

Refer to HW7 for further examples.

Part I – Multiple Choice questions (5 pts/question; total = 60 pts)
Identify the correct answers by placing a check between the brackets [ ]. Check **ALL** correct answers in the questions identified by a *.

1) The redshift of distant galaxies
   [ ] is always the same no matter what the distance.
   [ ] increases approximately linearly with distance.
   [ ] increases like the square of the distance.
   [ ] is inversely proportional to the distance.
   [ ] is inversely proportional to the square of the distance.

2) The Hubble classification for a barred spiral with very open arms and a small bulge:
   [ ] Sa.
   [ ] S0.
   [ ] SBb.
   [ ] SBc.
   [ ] E0.

*3) These are Population I objects
   [ ] globular clusters.
   [ ] massive blue O stars.
   [ ] halo stars.
   [ ] open clusters.
   [ ] HII regions.

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Part II – Problems (10 pts/problem; total = 40 pts) **NO CALCULATORS!**
Problem 1: Powers of Ten: Show your calculations.

a) Until recently the measured values of the Hubble Constant varied between $H_0 = 50$ km/s/Mpc and $H_0 = 100$ km/s/Mpc.
Which describes a faster expansion? Which corresponds to an older Universe ? (4pts).

b) What would be the age of a nearly empty Universe with $H_0 = 65$ km/s/Mpc (6 pts)

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Problem 2: Compare the spectra of two blackbodies of the same dimensions placed at the same distance from your spectroscope. One body is at 3000K and the other at 9000K. What do the spectra look like? Which is brighter and by how much? Compare the wavelengths of the peak. Sketch the two spectra on the same graph in arbitrary units.