

ASTRONOMY 294Z  
The History of the Universe  
Professor Barbara Ryden

Problem Set # 7: The Last Problem Set  
Due Tuesday, March 4  
at class time

NAME (please print clearly): \_\_\_\_\_

SCORE (instructor use only): \_\_\_\_\_

Reminder: The Final Exam for this class will be on **Tuesday, March 11,**  
at **1:30 pm.** Be there!

1) [20 points] The age of the universe (that is, the time since the Big Bang) is 14 billion years. The age of the Solar System is 4.56 billion years. Thus, the Solar System has existed for 32.6% of the age of the universe. For what percentage of the total age of the universe have the following things existed?

- a) helium nuclei
- b) neutral atoms
- c) the first galaxies to have formed
- d) the United States of America
- e) you

2) [20 points] The Whirlpool Galaxy is at a distance  $d = 7.1$  Mpc from us. Using Hubble's law, what do you expect the radial velocity  $v$  of the Whirlpool Galaxy to be? What do you expect the redshift  $z$  of the Whirlpool Galaxy to be? When hydrogen is at rest, it produces an emission line with a wavelength  $\lambda_0 = 656.281$  nanometers; what wavelength  $\lambda$  would you measure for the corresponding emission line from hydrogen in the Whirlpool Galaxy?

3) [20 points] We can detect a star with our naked eyes as long as its flux is above some minimum threshold,  $F_{\min}$ . The flux of the Sun would be equal to  $F_{\min}$  if it were at a distance of 17 parsecs from us. In other words, the maximum distance at which you would be able to see the Sun with your naked eyes is  $d_{\text{sun}} = 17 \text{ pc}$ . The luminosity of a supernova (that is, an exploding star) is  $L_{\text{super}} = 3.6 \times 10^9 L_{\text{sun}}$ . What is the maximum distance  $d_{\text{super}}$  at which you would be able to see a supernova with your naked eyes? [Hint: what is the relation among flux, distance, and luminosity?] If a supernova went off in the Andromeda Galaxy, would we be able to see it here on Earth without the aid of a telescope?

4) [40 points] Our old friend “Flat-Earth Fred” is up to some new tricks. He now believes that the Big Bang Model is bogus; he thinks that he lives in a static universe that is both infinitely large and eternally old. Describe what evidence you could provide that would convince Fred that the universe *cannot* be static, infinitely large, and eternally old. (Remember, skeptical Fred prefers evidence that he can see directly with his own eyes.)