ASTR 121
Final Exam
100 points
May 13, 2006
Do not open this exam until instructed to do so.

1. General Information

WRITE your NAME on your exam booklet.

SIGN the Honor Pledge.

It is a good idea to read the entire exam, then answer first the questions you are most certain about. Do not spend time on difficult problems before answering easier ones.

The value of each part of each question is noted. Answer written questions with concise, complete sentences. Show all work for quantitative problems.

All exams will be collected at 10:00 AM. You are welcome to leave early if you finish early. If you do so, please exit as quietly as possible so as not to disturb those still working.

2. Useful Numbers

$G = 6.67 \times 10^{-11}$ m^3 s^{-2} kg^{-1}
$c = 3 \times 10^8$ m s^{-1}
$g = 9.8$ m s^{-2}
$k_B = 1.38 \times 10^{-23}$ kg m^2 s^{-2} K^{-1}
$\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}
Wien's constant $= 2.9 \times 10^{-3}$ K m.
1 year $= 3.16 \times 10^7$ s
1 AU $= 1.5 \times 10^8$ km
1 radian = 206,265 arcseconds (so 1 pc = 206,265 AU $= 3.086 \times 10^{13}$ km)
The sun is a G2 **V** star with surface temperature $T = 5800$ K
1 $M_\odot = 2 \times 10^{30}$ kg
1 $L_\odot = 4 \times 10^{26}$ W
1 $R_\odot = 7 \times 10^5$ km
Absolute magnitude and color of the sun: $M^B_\odot = 5.48$; $(B-V)_\odot = 0.68$.

3. General Knowledge Questions

1. (5 points) In a paragraph, describe our location in the universe.
   Start at the planetary scale and work your way up, being sure to give an idea of scale.

2. (4 points) What is the difference between Type I and Type II supernova?
   Distinguish between them both observationally and in terms of the physics involved.

3. (2 points) How would the composition of the universe be different if the neutron had a very long lifetime?

4. (9 points) Sketch the Unified Model for Active Galactic Nuclei.
   Label the various parts and note how viewing angle affects the type of object seen.

5. (5 points) Describe how spiral and elliptical galaxies are supposed to have formed in the monolithic collapse picture.

6. (3 points) What is the difference between a nova and a Type Ia supernova?
   Describe what occurs in each.

7. (3 points) What happens in the collision of two spiral galaxies of roughly equal mass?

8. (3 points) The lightest elements, the heaviest, and those in between (carbon through iron) form in different environments. Where do each come from?

9. (3 points) Describe what occurs at recombination.

10. (2 points) Why do we expect the relic neutrino background to have a slightly lower temperature than the cosmic microwave background?

11. (2 points) Give two reasons why most cosmologists think that the dark matter is some form of new, non-baryonic, sub-atomic particle.

12. (4 points) How do stellar populations differ in spiral and elliptical galaxies?

13. (8 points) Sketch two HR diagrams: one for a globular cluster, and another for a young cluster. Label the various branches of stars in the HR diagrams and point out the main sequence turn off points.

14. (3 points) Why do the progenitor stars of Type II supernovae undergo core collapse?

15. (3 points) Explain why neutrinos can not account for all of the dark matter in the universe.

16. (6 points) Consider 4 events, A, B, C, and D, with space-time coordinates (x, y, z, ct) given in the table. For each of the pairs A-B, A-C, and A-D, is the connection time-like, light-like, or space-like? Can event A affect the other event?

Event	x	y	z	ct
A	0	0	0	0
B	1	0	0	2
C	0	2	0	2
D	1	2	3	2

4. Quantitative Questions

17. Lurking Monster (3 points)

    You observe a circular region on the sky that is totally devoid of light. If this region has a diameter of 20 arcseconds and the object causing it is a black hole 10 pc distant, what would the mass of the black hole be?

18. Interstellar Travel
    Consider a spaceship large enough for maybe a dozen of people to travel in modest comfort, say with a mass of 1,000 Tonnes (10^6 kg, a bit bigger than a Boeing 747).

    i) (3 points) One would like to get somewhere within a reasonable amount of time. In making a 100 light-year trip, how much would the passengers age if the speed $v = 0.5c$? $0.9c$? $0.99c$?

    ii) (3 points) Compute the kinetic energy it takes to move this ship at half the speed of light. (You may ignore relativistic corrections here.) Express your answer in Joules, Megatons of TNT, and as a fraction of the rest mass of the ship.
    1 Megaton $= 4.2 \times 10^{15}$ J

    iii) (2 points) Based on your answers above, and the fact that relativistic corrections exacerbate the energy requirements, comment briefly on the practicality of our hypothetical space ship. Can it carry enough fuel?
    Hint: recall the efficiency of the fusion process. For scale, all of the nuclear weapons in the world today probably have a cumulative yield of around 10,000 Megatons.

19. Vanilla ΛCDM

Consider a universe with $H_0 = 72\ \mathrm{km\,s^{-1}\,Mpc^{-1}}$, $\Omega_{m,0} = 0.3$ and $\Omega_{\Lambda,0} = 0.7$.

i) (1 point) What is the age of this universe (= 1 Hubble time)?

ii) (2 points) What is the critical density of this universe?

iii) (1 points) What is the functional dependence of the density of matter ρ_m on redshift z?

iv) (3 points) At what redshift did this universe switch from deceleration to acceleration?

v) (3 points) Matter and radiation had equal mass-energy densities at $z = 3000$. What is the density of radiation $\Omega_{rad,0}$ today?

20. Milky Way dark matter

The sun orbits in the Milky Way at velocity of 200 $\mathrm{km\,s^{-1}}$ about 7.4 kpc from the galactic center.

i) (2 points) How much mass is enclosed within the solar circle?

ii) (2 points) The total mass of baryonic matter in the Milky Way — the observed stars and gas — is $8 \times 10^{10}\ M_\odot$. Bearing in mind that much but not all of this matter is within the solar circle, does you answer to part (i) imply the need for dark matter?

iii) (3 points) The rotation curve of the Milky Way remains flat at roughly 200 $\mathrm{km\,s^{-1}}$ out to at least 50 kpc, and perhaps twice as far out. What is the mass contained within 50 kpc? Does this imply the need for dark matter?

21. (4 points) Proper motion of Vega

The most prominent star in the northern summer sky is Vega. Vega has a space motion of 18.9 $\mathrm{km\,s^{-1}}$ and a radial velocity of $-13.9\ \mathrm{km\,s^{-1}}$. Its parallax $p = 0.129$". What is its proper motion?

22. (3 points) Hidden Galaxy?

Suppose the Andromeda galaxy ($M = -20$, D = 750 kpc) happened to fall in the Zone of Avoidance. How much galactic extinction would be necessary to prevent us from seeing it in a survey sensitive to $m \leq 20$?