Name	
PID	
Signature	
1	/9
2	/13
3	/7
4	/6
5	/6
6	/4
7	/11
8	/9
Total	/73

You may use 1 sheet of notes during this test. You may not have any books or other notes. Some of the information in the table below is not used on this test.

Write brief answers. Your time is limited, and the graders do not like to read answers that address off-topic ideas.

You may pick up the exam next year in room 3260. If you want your grade by e-mail, send me an e-mail at Loh@msu.edu.

Good luck.

Star	App mag	Abs mag	Spectral type	Distance (pc)
Sun	–26.74	4.83	G2	1/200,000
Sirius	–1.45	1.41	A1	2.7
Canopus	–0.73	–4.7	F0	60

Kepler's 3rd Law	$P^2 = R^3/M$ (in AU, year, & M_{sun})	Hubble's Law	v = H D
	$M = 233\, v^2 R$ (in parsec, km/s, & M_{sun})	Wien's Law	$\lambda_{peak}\, T$ = constant
Redshift	$z = 1/a - 1$;	Hubble's Constant	70 km/s/Mpc
	$a = 1/(1+z)$		
	$v = c\, z$;	Speed of Light	300,000 km/s
	$v = c\, (\lambda_{rec}/\lambda_{emit} - 1)$		
Present temperature of radiation from Big Bang	2.728 K	Parsec	3.09×10^{13} km
		AU	1.50×10^{8} km
		Year	3.16×10^{7} s

1. Motions. Write very brief answers.
    a. (2 pts.) Explain why the sun moves with respect to the stars.

       Since the Earth orbits the sun, we view the sun from a slightly different direction each day.

    b. (2 pts.) Explain why the planets sometimes moves east to west with respect to the stars, which is opposite the way the sun moves.

       The planets orbit the sun too. When an inner planet overtakes an outer one, the direction with respect to the stars appears to reverse.

    c. (2 pts.) Explain why Mars moves east to west with respect to the horizon.

       The spin of Earth around its axis causes Mars to rise and set.

    d. (3 pts.) Copernicus's theory displaced Ptolemy's theory.

       Ptolemy explained the motion of the sun with respect to the stars by making the stars orbit Earth in slightly more than a day. Ptolemy explained the rising and setting of Mars by making it orbit Earth. He explained prograde and retrograde motion of the planets by making the planet move on a small circle, which in turn moved on a large circle around Earth. When the two motions were opposite, the planet was in retrograde motion.

2. About the sun. Write very brief answers.
    a. (2 pts.) At the present time, how does the sun produce energy? What is used up and what is created?

       The sun produces energy by fusing hydrogen into helium 4.

    b. (1 pt.) What is the approximate age of the sun and earth?

       4.5 billion years.

    c. (1 pts.) What will the sun become when it completely exhausts its fuel? (1 pt.) How big will it be? (1 pt.) What will prevent gravity from making it collapse?

       It will become a white dwarf, which is Earth-sized. The pressure of moving electrons opposes gravity. The electrons move because they are degenerate.

    d. (2 pts.) The sun is losing more mass than can be accounted with the loss of protons, neutrons, and electrons. Explain how that is possible.

       The sun loses mass because Einstein said mass disappears when it turns into energy.

    e. (2 pts.) What elements were present in the material from which the first stars were made? (1 pt.) Was the material from which the sun was made different or the same in composition? (2 pts.) Explain.

       Hydrogen and helium 4 (and trace amounts of Li 7, H 2, and He 3) were present in the material from which the first stars were made, since those were the only elements made in the Big Bang. (Hydrogen was primordial.) The sun has other elements, those that were made in previous generations of stars.

3. Suppose the main-sequence star Sirius and the sun swapped places and the path (not the speed) of the earth remains the same. See table of front.
    a. (2 pts.) Would daytime be brighter or fainter? Why?

Since Sirius has a brighter absolute magnitude, daytime would be brighter.

b. (3 pts.) Find the new apparent magnitude of Sirius?

Sirius is 4.83–1.41=3.42 mag brighter than the sun. The new apparent magnitude is –26.74–3.42 = –30.16, since Sirius would be at the same distance as the sun was.

c. (2 pts.) Would the year be longer or shorter? Explain.

Since Sirius is a hotter main-sequence star (Spectral class A is hotter than G), its mass is greater. Kepler's 3rd Law says $P^2=R^3/M$. Therefore the year is shorter.

4. The first stars formed when the expansion parameter of the universe was 1/10. (That means the universe has expanded by a factor of 10 since that time.)

   a. (2 pts.) Compute the temperature of the radiation from the Big Bang at this time.

   The temperature is inversely proportional to the expansion parameter. T=2.7K/(1/10)=27K.

   b. (2 pts.) One of these first stars emitted some light at a wavelength 1215 Å. At what wavelength do we observe this light?

   Since wavelength expands by the same factor as the universe, we observe the wavelength to be 10×1215 Å=12150 Å.

   c. (2 pt.) Was the distance between the proto Milky Way and the proto Andromeda Galaxy 70 kpc when the first stars formed? The present distance between the Milky Way and Andromeda is 700 kpc, and it is moving at 200km/s toward us. Explain.

   No, the Milky Way and Andromeda are no longer moving apart. They no longer obey Hubble's Law.

5. (2 pts.) What did astronomers observe that indicated the presence of a black hole in the center of our galaxy? (2 pts.) How did they deduce the mass of the black hole from these observations? (2 pts.) What evidence indicated the size of the mass was small?

   Astronomers observed the orbits of stars near the center and got their periods and size of their orbits. From Kepler's 3rd Law, they determined the mass of the black hole to be 3 million times the mass of the sun. Since the orbits are ellipses, the mass must be inside the smallest orbit, which is roughly the size of Pluto's orbit.

6. In 1962 Penzias and Wilson discovered radiation that was "isotropic and free of seasonal variations." That it was isotropic was used to argue that the radiation was from the Big Bang. Simplicio says, "In 2003, the WMAP satellite found that the radiation is not isotropic. Therefore the radiation is not from the Big Bang." (1 pt.) Is Simplicio correct? Explain. (3 pts.)

   Simplicio is not correct. The deviation from isotropy can be easily explained by our motion with respect to the rest of the universe and to small density fluctuations. These deviations from isotropy in no way indicates the source of the radiation is something nearby.

7. A supernova exploded when the expansion parameter was ½.
   a. (1 pt.) If the universe has more mass, would its flux be fainter or brighter? (3 pt.) Explain.

      In a universe with more mass, it takes a shorter time to expand by a factor of 2, since the stronger gravity has slowed the expansion from a higher rate to the present rate. Because the time is shorter, the light has traveled a shorter distance. Therefore the flux is brighter.

   b. (2 pt.) What two parameters of the supernovae were measured to measure the mass density of the universe?

      Flux and wavelength of the light

   c. (3 pts.) State the results of the measurements.

      The distant supernovae are fainter than they would be in a universe with no mass at all. This means the expansion of the universe is speeding up

   d. (2 pts.) What was discovered? Why was this one of the most significant discoveries in cosmology?

      The universe has a large amount of dark energy, which has a negative pressure. This discovery showed the major part of the universe is unlike matter, which attracts other matter.

8. Dark matter

Planet	**Period (yr)**	**Semi-major axis (AU)**
Real Solar System		
Earth	1.00	1.000
Mars	1.88	1.523
Solar system around Nus		
Htrae	1.00	1.000
Sram	0.94	1.523

   a. Explain the evidence for dark matter in galaxies. (2 pts) What was measured? (4 pts.) What in the measurements indicate the presence of dark matter?

      The orbital speed of gas in a galaxy was measured at various distances from the center of the galaxy. In the outer parts of the galaxy, the orbital speed did not change with radius. In the outer parts, Kepler's 3rd Law ($M(R) = v^2 R$) implies that the mass increases linearly with radius, even though there are fewer stars there. Therefore the mass is due to something that does not produce light.

   b. (3 pts.) Imagine a star Nus with two planets Htrae and Sram. The periods and semi major axes of Nus' planets and the Sun's planets are shown in the table. Nus has no other planets and no other visible objects. Does Nus have dark matter? Explain.

      "Yes, Nus has dark matter. Using Kepler's 3rd Law, I found from the viewpoint of Sram, $M=1.523^3/.94^2=4M_{sun}$ and from the view of Htrae, $M=1^3/1^2=1M_{sun}$. Thus somewhere between Htrae and Sram, the amount of mass increases by $3M_{sun}$. Since there are no other visible objects, it must come from something dark."—J. Ryan