29:50 Stars, Galaxies, and the Universe
Second Hour Exam
November 10, 2010
Form A

There are 32 questions. Read each question and all of the choices before choosing. Budget your time. No whining.

Walk with Ursus!

1. Imagine you go into a time machine and fast forward 10 billion years. You come out and look up at the Sun. What do you see?
   (a) a black hole
   (b) a pulsar
   (c) a neutron star
   (d) a pre-main sequence star
   (e) a white dwarf ∗

2. What physical process generates the power by which the Sun shines?
   (a) nuclear fission reactions in the Sun's core
   (b) highly explosive chemical reactions in the Sun's convective zone
   (c) nuclear fusion reactions in the Sun's core ∗
   (d) nuclear fusion reactions in the part of the Sun's atmosphere called the corona
   (e) nuclear fission reactions in the part of the Sun's atmosphere called the photosphere

3. In class we discussed the remarkable fact that the Sun has been shining at an extremely high luminosity for an extremely long period of time. This places strong demands on the "fuel cycle" responsible for the Sun shining. Which of the following statements is true, and was an important clue for determining the power source for the Sun?
   (a) nuclear fusion reactions yield several million times more energy per kilogram than do chemical reactions ∗
   (b) chemical reactions yield several million times more energy per kilogram than do nuclear fusion reactions
   (c) chemical reactions and nuclear fusion reactions yield about the same amount of energy per kilogram
   (d) the conversion of gravitational potential energy to heat energy is the only

possible process for powering the Sun
(e) the high abundance of heavy elements in the Sun favors energy generation by fission reactions

4. Roughly what is the temperature in the core of the Sun?
   (a) 5800 degrees Kelvin
   (b) 15 million degrees Kelvin $*$
   (c) 32 billion degrees Kelvin
   (d) 350 degrees Kelvin
   (e) 3 degrees Kelvin

5. Think about the chemical composition in the core of the Sun. Which of the following statements is true?
   (a) the abundance of helium is higher than when the Sun formed $*$
   (b) the most abundant element in the core is oxygen
   (c) there is no element other than hydrogen in the Sun's core
   (d) the core of the Sun has been converted entirely to carbon and oxygen
   (e) the abundance of hydrogen is higher than when the Sun formed

6. Which of the following is direct evidence that nuclear reactions are occurring inside the Sun?
   (a) high energy protons are seen streaming from the solar interior
   (b) satellites outside the Earth's magnetosphere have detected high levels of radioisotopes
   (c) gamma rays produced in fission reactions in the solar core can be directly observed at Earth
   (d) the Sun appears as a source of neutrinos $*$
   (e) gamma rays produced in fusion reactions in the solar core can be directly observed at Earth

7. Which of the following equations of physics is crucial for understanding the energy source of the Sun and stars?
   (a) $a^3 = P^2$
   (b) $E = hf$
   (c) $E = mc^2$ $*$
   (d) $w_{max} = \frac{2.9 \times 10^{-3}}{T}$
   (e) $F = ma$

8. What is the most direct means for measuring the masses of stars?
   (a) making a precise measurement of the color of a star

(b) for a given spectral class or color, the mass is determined by the luminosity
(c) measuring the location in the Milky Way of the star
(d) measuring the properties of orbits of binary stars ∗
(e) determining the age of the star

9. Binary stars are grouped into three classes, depending on the type of observation that shows they are binaries. Which of the following categories is a type of binary star?
(a) spectroscopic binary ∗
(b) parallactic binary
(c) absolute binary
(d) Alfvénic binary
(e) Hertzsprung-Russell binary

10. Below are listed some attributes of binary stars. One answer gives a characteristic which is typical of *visual binary stars*. Pick the correct answer.
(a) major differences in the masses of the components
(b) substantial differences in the ages of the components
(c) very great distances from the Sun
(d) virtually always composed of red dwarf stars
(e) long periods ∗

11. There is a kind of star which has a mass comparable to that of the Sun, but has a diameter similar to that of the planet Earth. This type of star is a
(a) red dwarf
(b) white dwarf ∗
(c) blue supergiant
(d) green dwarf
(e) spectral class A main sequence star

12. What is the physical content of the *Doppler Effect* in physics?
(a) the mass of a star depends on its speed relative to the speed of light
(b) the energy levels in an atom depend on the presence or absence of a magnetic field
(c) the electrical current flowing through a gas depends on the electron energy
(d) the wavelength at which an object appears brightest depends on its temperature
(e) the measured wavelength of a wave depends on the relative motion of the observer and the source of waves ∗

13. The *Doppler Effect* is encountered in astronomy because it is used to
    (a) determine the surface temperatures of stars
    (b) measure masses of binary stars ∗
    (c) measure magnetic field strengths in the interstellar medium
    (d) determine the strength of electric fields in stars
    (e) measure the distances to stars

14. Consider three stars, A, B, and C. A has a mass of 10 solar masses, B has a mass of 3 solar masses, and C has one solar mass. What can you say about how long these stars will be main sequence stars?
    (a) A has a very short main sequence lifetime, B has a longer lifetime than A, but less than C. ∗
    (b) C has a very short main sequence lifetime, B has a longer lifetime than C, but less than A.
    (c) B has the longest main sequence lifetime, because there is an intermediate stellar mass with the longest main sequence lifetime
    (d) A has the shortest main sequence lifetime, C has the next shortest main sequence lifetime, and B has the longest main sequence lifetime
    (e) the main sequence lifetime is not dependent on mass; you cannot say which will have the longest lifetime

15. The main sequence lifetime of a star does not last forever. Why does the main sequence phase end?
    (a) a star converts the helium in its core to hydrogen
    (b) radioactive decay reduces the level of tritium, which is crucial for stellar energy generation
    (c) a star converts the hydrogen in its core to helium ∗
    (d) the strong magnetic field which is the source of energy for main sequence stars gradually leaks out of the core
    (e) The protons in the star decay into more complex subatomic particles. This takes billions of years.

16. The main sequence lifetime of a star depends most critically on what characteristic?
    (a) mass ∗
    (b) absolute magnitude
    (c) distance from the Sun
    (d) location in the galaxy
    (e) constellation in which it is located

17. The properties of a white dwarf star depend on the "equation of state", or an equation which says what the gas pressure depends on. Which of the following statements about the white dwarf equation of state is true?
    (a) the pressure depends only on the temperature
    (b) the pressure depends on temperature and density
    (c) the pressure is described by the perfect gas law
    (d) the pressure depends only on the density ∗
    (e) the pressure is dominated by a term containing the magnetic field

18. Think about a star cluster. Let's say you get the data you need and plot up a Hertzsprung-Russell diagram for a star cluster. You notice that the Main Sequence is not complete, but only extends from the lower right corner to a certain point on the graph, then "disappears". What does this tell you about the star cluster?
    (a) limits in the sample of stars it formed with
    (b) its age ∗
    (c) its distance from us
    (d) its absolute magnitude
    (e) the probability that binary stars occur in the cluster

19. Do neutron stars exist in nature? That is, is there an observed class of astronomical objects that is interpreted as being neutron stars?
    (a) red dwarf stars are neutron stars with an excess of heavy elements
    (b) white dwarf stars are thought to be neutron stars
    (c) there are no neutron stars in the Milky Way
    (d) Cygnus X-1 is interpreted as a neutron star
    (e) radio pulsars are rotating neutron stars ∗

20. Supernovas are an observed class of astronomical object. You might see one during your lifetime. Physically, what happens to cause them?
    (a) a star like the Sun suddenly evolves off the main sequence
    (b) the core of a massive star collapses, causing a huge explosion ∗
    (c) a white dwarf undergoes a catastrophic cooling event
    (d) a pair of stars that have been in a long eclipse come out of eclipse
    (e) a phenomenon similar to an Earthquake occurs in the crust of neutron star

21. One of the following is a description of a black hole, based on classical physics.
    (a) an object with a mass between 0.7 and 1.4 $M_\odot$
    (b) an object so compressed that the escape speed equals the speed of light ∗
    (c) an object with a temperature high enough that the photons break apart

the object
(d) an object which exerts a gravitational force on every other object in the universe
(e) an object rotating so fast that an observer standing on the surface would be traveling faster than the speed of light

22. Which of the following objects is believed to be a black hole
(a) the Sun
(b) 18 Scorpii
(c) Cygnus X-1 ∗
(d) the Andromeda Nebula
(e) Sirius B

23. If black holes cannot emit light, why have we discovered many of them?
(a) we see the photospheric light from companion stars to the black holes
(b) they emit radio waves, which we detect with radio telescopes
(c) the black holes serve as funnels of matter and radiation from parallel universes
(d) all known black holes are surrounded by accretion disks, which are very luminous ∗
(e) we directly measure their strong gravity on the orbit of the Moon

24. According to our present understanding of astrophysics, the most effective way of extracting energy from matter is
(a) nuclear fusion reactions involving the proton-proton cycle
(b) injecting matter into an accretion disk around a black hole ∗
(c) nuclear fusion reactions involving the triple-alpha process
(d) release of gravitational potential energy in the formation of a main sequence star
(e) transport of heat energy via convection

25. What does the term "Milky Way" mean as a technical term in the science of astronomy?
(a) another term for the great globular cluster in the constellation of Hercules
(b) the large system of stars that includes the Sun and all the stars we can see ∗
(c) a glowing column of plasma left in the Earth's atmosphere by a meteor
(d) a large system of stars outside of, and more distant than, the one in which we live

(e) a band of light seen in the night sky, due to reflected sunlight off of small particles of matter

26. The term "interstellar medium" refers to
(a) low mass stars fainter than red dwarfs
(b) strong magnetic fields which connect all stars
(c) an energy field which holds the stars rigidly in place
(d) matter in the space between galaxies
(e) gaseous matter in the space between the stars ∗

27. The reason that HII regions are seen around hot, bright stars is that
(a) the gas comes in contact with the hot stellar surfaces and begins to glow
(b) the gas in the HII regions reflects the starlight and creates a halo around the star
(c) such stars produce many photons that can ionize hydrogen ∗
(d) hot bright stars produce high energy proton radiation that ionizes hydrogen
(e) these are the only places in the galaxy where there is gas as well as stars

28. In class I discussed a solar phenomenon called *granulation*. The existence of granulation demonstrates that
(a) the interior of the Sun is cooler than the surface.
(b) several billion years ago, the Sun was more massive than it is now.
(c) the interior of the Sun is hotter than the surface. ∗
(d) several billion years ago, the Sun was less massive than now.
(e) there are planets orbiting the Sun.

29. A binary star consists of a main sequence A star (slightly more massive than the Sun), and a white dwarf star. In what follows, I will refer to the A main sequence star as "the primary". Which of the following statements about the white dwarf companion must be true?
(a) The white dwarf must have been captured from interstellar space.
(b) When it was a main sequence star, the companion must have been more massive than the primary. ∗
(c) When it was a main sequence star, the companion must have been less massive than the primary.
(d) The white dwarf was produced in a supernova explosion.
(e) The primary was produced in a supernova explosion.

30. Which of the following statements most accurately describes our understanding of where stars come from?
(a) Matter forms spontaneously from empty space in a process called the two

photon mechanism. Electromagnetic forces cause the matter to clump up into massive objects which correspond to stars.
(b) Stars form directly from atomic gas in the space between the stars. Gravity does not play an important role in the formation of stars.
(c) Dilute gas in the space between the stars is compressed, contracts under its own gravity to form molecular clouds, and clumps form within the molecular clouds to form stars. ∗
(d) The stars which are presently in the Milky Way did not form here, but formed in elliptical galaxies outside the Milky Way, and were subsequently captured.
(e) Stars are formed from the material which makes the interstellar grains. Electrostatic forces cause the grains to stick together into larger and larger clumps.

31. Which of the three sets of astronomical objects listed below constitutes a group of "dead stars", which are the end points of stellar evolution?
(a) white dwarf stars, main sequence G stars, Cepheid variable stars
(b) molecular clouds, globular star clusters, planetary nebulae
(c) white dwarf stars, neutron stars, black holes ∗
(d) Wolf-Rayet stars, UV Ceti stars, neutron stars
(e) open star clusters, globular star clusters, the Orion Nebula

32. What bright, well-known star has a white dwarf as a companion?
(a) Sirius ∗
(b) Vega
(c) Fomalhaut
(d) Capella
(e) No star visible to the naked eye has a white dwarf companion