Astronomy C

Michigan Region 8

March 24, 2018

Team Number ________________

Team Name ____

Type (select one) ________________ Varsity

________________ Junior Varsity

Student Name(s) ____

Directions

1. There is a separate answer sheet. Answers written elsewhere (e.g. on the test) will not be considered.
2. You may take the test apart, but please put it back together at the end.
3. This test is 100 points total. Questions are worth 1 point each unless otherwise specified.
4. The first tiebreaker is the section score for Part II. Further tiebreakers are indicated as [T1], [T2], etc. Time is NOT a tiebreaker.
5. For any answers that have units, be sure to use the units that are specified in the question. Answers in other units will be marked wrong.

Bonus (+1)

LIGO has already detected gravitational waves from multiple black hole mergers, but in August 2017, it found something new – an event that was also detected in gamma rays, and later in multi-wavelength observations. What did LIGO find?

Useful Constants

$b = 0.0029\, m * K$

$c = 3.00 * 10^8\, m/s$

$G = 6.67 * 10^{-11}\, \frac{N\, m^2}{kg^2}$

$H_0 = 72\, \frac{km/s}{Mpc}$

$h = 6.63 * 10^{-34}\, J * s$

$k = 1.38 * 10^{-23}\, J/K$

$\sigma = 5.67 * 10^{-8}\, \frac{W}{m^2\, K^4}$

$L_{sun} = 3.84 * 10^{26}\, W$

$M_{sun} = 1.99 * 10^{30}\, kg$

$R_{sun} = 6.96 * 10^8\, m$

$T_{sun} = 5800\, K$

$1\, pc = 3.26\, ly = 206265\, AU = 3.08 * 10^{16}\, m$

$1\, ly = 0.307\, pc = 63240\, AU = 9.46 * 10^{15}\, m$

$Abs. mag\ of\ Type\ Ia\ SNe = -19.6$

Part I: Deep Sky Objects (50 points)

1. Image [1] shows Geminga in what wavelength of light? (Choose from gamma-ray, x-ray, ultraviolet, visible, infrared, microwave, or radio.)
2. In this image, there is both a torus of emission from Geminga's equator and a jet of radiating material from its poles. Which one of these is seen edge-on?
3. Many systems like Geminga show the same structure of a torus and jets. What is the name for this material illuminated by a pulsar?

4. Which DSO, a massive star-forming region, is shown in Image [2]?
5. The many hot, massive stars in this DSO collectively form what type of star cluster?
6. These massive stars irradiate the surrounding matter, creating what type of nebula? (Choose from emission, absorption, reflection, or dark.)

7. Another star-forming region is depicted in Image [3], containing the young star cluster Berkeley 59. What is the name of this DSO?
8. The stars within this DSO are pushing matter away as they form, creating what pillar-like structures?
9. [T2] Why is it useful to take infrared images of star-forming regions like this one?

10. Image [4] shows the spectrum of which DSO, the prototypical Luminous Blue Variable?
11. Variable stars of this type have spectral lines with blueshifted absorption and redshifted emission, together referred to as what type of profile?
12. What do the blueshifted absorption lines indicate about the DSO?
13. This star is not located in our Milky Way galaxy. What galaxy is it located in?

14. Which DSO, a rare Yellow Hypergiant, is shown in Image [5]?
15. Where would this DSO be found on the HR diagram (upper/middle/lower & left/center/right)?
16. [T4] Why is this DSO not likely to become a Type II supernova?

17. Image [6] shows PSR B0355+43 in what wavelength of light? (Choose from gamma-ray, x-ray, ultraviolet, visible, infrared, microwave, or radio.)
18. Why do we see radio pulses from this pulsar, but not gamma ray pulses?

19. Which barrel-shaped supernova remnant is shown in Image [7]?
20. Supernovae like this one are thought to be the source of what mysterious astrophysical events?
21. What type of object may have been formed as a result of this supernova?
22. How does the shape of this DSO differ from that of most normal supernova remnants?

23. Which incredibly luminous star is shown in Image [8]?
24. What is the cause of the ring of material surrounding this star?
25. This DSO will eventually evolve into what type of star?

26. Which DSO is shown in Image [9]?
27. A very massive star was discovered near the center of this DSO through observations in what wavelength of light? (Choose from gamma-ray, x-ray, ultraviolet, visible, infrared, microwave, or radio.)
28. How can we tell that this massive star is gravitationally bound to a compact object?

29. Image [10] shows an artist's depiction of the x-ray binary Circinus X-1. What kind of compact object (white dwarf, neutron star, black hole) is in this system?
30. What is the general term for the process by which a compact object collects matter from its companion?
31. Why does the material form a disk around the compact object instead of falling straight in?

32. The light curve of which very famous supernova is depicted in Image [11]?
33. Why was it odd that the progenitor of this supernova was a blue supergiant star?
34. A few hours before it was seen in visible light, this supernova was detected by what other method?

35. In Image [12], which spectrum is most like the spectrum of Alpha Orionis?
36. [T9] What type of spectral lines (absorption, emission, both, neither) are shown in the image?
37. By what name is this DSO more commonly known?
38. What is the expected fate of this DSO within the next few million years?

39. Image [13] shows the light curve of which DSO, also known as SN 2015L?
40. What is one of the two leading theories for why this DSO was so bright?

41. Image [14] shows several x-ray sources glowing brightly at the center of the galaxy M82. Which source is actually M82 X-2?
42. This DSO is an ultraluminous x-ray source, meaning it is brighter than the maximum luminosity predicted by what limit?
43. Which observatory discovered that this object was in fact a pulsar, not a black hole?

44. Which DSO, also known as the Jellyfish Nebula, is shown in Image [15]?
45. What type of object is at the center of this DSO?
46. The northern and southern subshells of this DSO behave differently. Why is this?

47. Image [16] shows one of the slowest pulsars currently known. What is the name of this DSO?
48. What wavelength of light was primarily used to produce this image? (Choose from gamma-ray, x-ray, ultraviolet, visible, infrared, microwave, or radio.)
49. What source of energy produces the light observed in this image?
50. This DSO is an example of a highly-magnetic pulsar, also referred to as what term?

Part II: Stellar Evolution (50 points)

51. [T10] What spectral class of star (O, B, A, F, G, K, M) has the strongest hydrogen lines?
52. Why do O stars barely have any hydrogen in their spectra?
53. What compound is primarily responsible for broad bands in the spectra of late-type (K, M) stars?

54. What is color (or color index)?

55. [T6] What distinguishes Type I and Type II supernovae?
56. What element distinguishes Type Ib and Type Ic supernovae?
57. Which stars are thought to be the causes of Type Ib/Ic supernovae?

58. Which element is the heaviest that can be produced by stellar core fusion?
59. Elements heavier than this *can* be produced during a Type II supernova. What is the name of one of these two processes?

60. What force keeps neutron stars from collapsing to form black holes?

61. [T8] Why do we see "pulses" of radiation from pulsars?

62. How do we know that pulsars must be rotating objects, rather than eclipsing systems or radial pulsations like Cepheids?

63. We know stellar mass black holes exist, but we cannot see them directly. How can we infer the presence of stellar mass black holes in binary systems?

64. [T7] Binary star systems are very common (it's often said, "three out of every two stars are binaries"). Why do we see far fewer eclipsing binary systems than there exist binary systems?

65. Cepheids can be found with several other type of variable stars in a particular region on the HR diagram. What is the name of this region?

66. [T3] What causes the variability of Cepheids?

67. How are semiregular variables different from Mira-type long period variables?

68. Large outbursts from Luminous Blue Variables are sometimes mistaken for what other astronomical phenomenon?

69. Hypergiant stars are typically classified as what luminosity class?

70. What term is given to the path that high mass stars take on the HR diagram as they (repeatedly) evolve from blue supergiants to red supergiants and back again?

71. You observe a star with a parallax angle of 9.33 mas (milliarcseconds).

    a. [2 pts] How far away is this star, in pc?

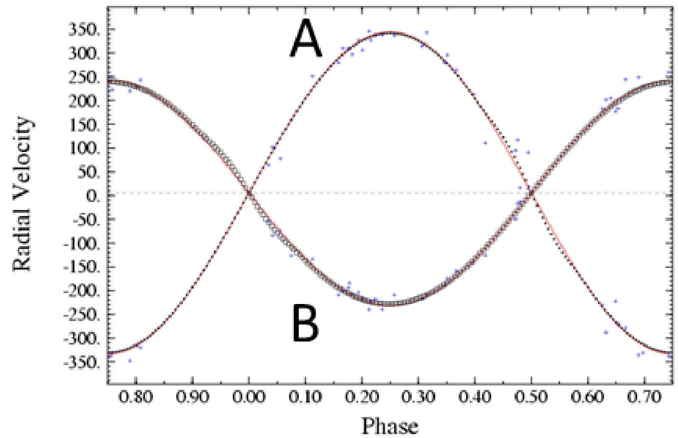
72. You observe a star whose blackbody spectrum peaks at a wavelength of 670 nm. You also determine that it has a radius of 0.8 solar radii ($R_{\odot}$).

    a. [2 pts] What is its temperature, in K?

    b. [2 pts] What is the flux (luminosity per area) from this star, in W/m^2?

    c. [T1] [2 pts] What is its luminosity, in solar luminosities ($L_{\odot}$)?

73. You observe a binary system with a period of 13.5 days, and manage to piece together some radial velocity curves (as shown at right).



a. [2 pts] What is the semi-major axis of this system, in AU?

b. [T5] [2 pts] What is the ratio of masses, m_B/m_A?

c. [2 pts] What is the combined mass of the system, in solar masses ($M_\odot$)?

d. [2 pts] What is the mass of component A, in solar masses ($M_\odot$)?

74. You observe a variable star with a period of 32 days and an apparent magnitude of +9.7. Through your amazing astronomy skills, you determine this star to be a Type I Cepheid.

Use the following form of the Leavitt Law (period-luminosity relationship), with the period P in days.

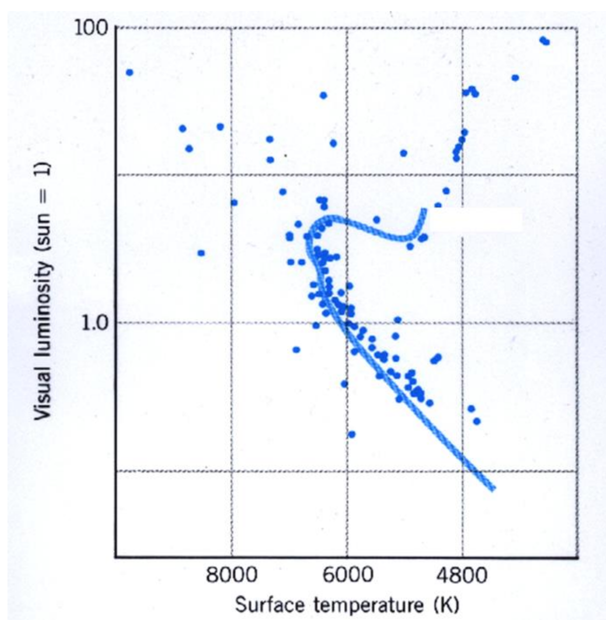
$$M_V = -1.43 - (2.81 * \log_{10}(P))$$

a. [2 pts] What is the absolute magnitude of this star?

b. [2 pts] What is the distance to this star, in kpc?

c. [2 pts] If this star were a Type II Cepheid instead of a Type I, what would be its absolute magnitude and its distance (again in kpc)?

75. You observe a cluster of stars, and plot them on an HR diagram (as shown at right).



a. [2 pts] What is the approximate luminosity at the main sequence turnoff – where stars appear to start diverging from the main sequence – in solar luminosities ($L_\odot$)?

b. [2 pts] Using a main sequence mass-luminosity relation of $\left(\frac{L}{L_\odot}\right) = \left(\frac{M}{M_\odot}\right)^4$, what is the mass at the main sequence turnoff, in solar masses ($M_\odot$)?

c. [2 pts] Given that the main sequence lifetime of the Sun is about 10 billion years, what is the age of this cluster, in Gyr?

d. [2 pts] What type of cluster is this, and how do you know?