Astronomy C

Michigan Region 8
March 11, 2017

Names: _____

Team: _____

Team Number: _____

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 will be the total score on Part II. Further tiebreakers are indicated as [T1], [T2], etc.
5. Time is NOT a tiebreaker.
6. Numerical answers should be in MKS units unless otherwise specified.

Useful Constants

$b = 0.0029\ m * K$
$c = 3.00 * 10^8\ m/s$
$G = 6.67 * 10^{-11}\ \frac{N\ m^2}{kg^2}$
$H_0 = 72\ \frac{km/s}{Mpc}$
$h = 6.63 * 10^{-34}\ J * s$
$k = 1.38 * 10^{-23}\ J/K$
$\sigma = 5.67 * 10^{-8}\ \frac{W}{m^2\ K^4}$

$L_{sun} = 3.84 * 10^{26}\ W$
$M_{sun} = 1.99 * 10^{30}\ kg$
$R_{sun} = 6.96 * 10^8\ m$
$T_{sun} = 5800\ K$

$1\ pc = 3.26\ ly = 206265\ AU = 3.08 * 10^{16}\ m$
$1\ ly = 0.307\ pc = 63240\ AU = 9.46 * 10^{15}\ m$
$Abs.mag\ of\ Type\ Ia\ SNe = -19.6$

Bonus (+1)
NASA has recently announced the (exciting) discovery of an exoplanetary system with several planets. How many planets in this system are considered to be within the "habitable zone"?

Part I – DSOs [40 pts total]

1. By what name is the DSO in Image [1] better known?
2. Why does this DSO appear to be enriched in metals?
3. [T5] What other feature of this DSO has been revealed by UV observations?

4. Which DSO is depicted in Image [2]?
5. The inner (bluish) and outer (reddish) components of this DSO were imaged in which portions of the EM spectrum, respectively? [2 pts]

6. How was the binarity of the DSO in Image [3] discovered?
7. Which of the two components is brighter in the image?

8. Which DSO is depicted in the light curve in Image [4]?
9. [T10] What is thought to be produced due to the shortening period of this DSO?

10. Which DSO is depicted in Image [5]?
11. What is the estimated lifetime of this system before it explodes in a Type Ia supernova?

12. Which DSO is depicted in Image [6]?
13. The concentration of stars in this DSO grows all the way to the center. What term describes this?
14. What is the name of the small blue/green dot circled in this image?

15. Which DSO is depicted in Image [7]?
16. [T4] Why was it important to take x-ray observations of this system?
17. Which of the AM CVn progenitors on the DSO list will most likely not explode as a Type Ia supernova?

18. Which DSO is depicted in Image [8]?
19. What part of the EM spectrum was this DSO first discovered in?
20. What is one argument (either for or against) the discovery of the past companion to the star that produced this DSO?

21. Which DSO is depicted in the light curve in Image [9]?
22. Why was the discovery of this DSO fortuitous for astronomers?

23. What is the Caldwell designation of the DSO in Image [10]?
24. What causes the "filaments" seen around the outer edge of this DSO?

25. Which DSO is depicted in Image [11]?
26. [T9] What does the combination of these two observations show about this DSO?
27. Why was this DSO not observable in the past?

28. Which DSO is depicted in the light curve in Image [12]?
29. What are the two leading theories for why this DSO undergoes periodic outbursts? [2 pts]

30. Which DSO is depicted in Image [13]?
31. What is one explanation for the double Main Sequence turnoff in this DSO?
32. What is the name of *this* small blue/green dot?

33. Which DSO is depicted in Image [14]?
34. How was the progenitor of this DSO different from a normal Type Ia supernova?
35. What allowed astronomers to determine the spectrum of the original supernova?

36. What is the common nickname of the DSO in Image [15]?
37. What distinguishes this DSO from other nebulae of its type?
38. The central star in this nebula rapidly increased in temperature before cooling off again, suggesting it is an example of what rare occurrence in stellar evolution?

Part II – Stellar Evolution [60 pts total]

39. Which property of a star determines the course of its entire evolution?
40. How is energy primarily transported in solar-mass stars?
41. How is energy primarily transported in stars less than ~0.5 solar masses?
42. What does the quantity [Fe/H] measure?

43. What causes globular clusters to be red in color?
44. What component of the galaxy are globular clusters primarily found in?
45. What classification scheme describes how centrally concentrated a globular cluster is?
46. How can large globular clusters be distinguished from small dwarf galaxies?
47. What is thought to be one source of "blue straggler" stars in globular clusters?

48. What mass must a star have for it to end up as a C/O white dwarf instead of a He white dwarf?
49. What is name of the upper mass limit for white dwarfs, and what is its value in $M_\odot$? [2 pts]
50. What force supports a white dwarf against collapse?

51. Why does gas in accretion disks orbit at sub-Keplerian velocities?
52. What quantity must be transported outward in order for the mass of an accretion disk to fall inward?
53. What type of binary system is characterized by only one star filling its Roche lobe, resulting into accretion onto the other star?

54. [T6] Hydrogen lines peak in their intensity in A-type stars (~10,000 K). Why are H lines weak in stars hotter than A-type?
55. Why are H lines also weak in stars cooler than A-type?
56. Which spectral lines dominate in Sun-like stars (~6000 K)?
57. Which spectral lines dominate in very cool stars (~3000 K)?

58. Why do Type Ia supernovae always have approximately the same luminosity?
59. Which two elements (in order) contribute to the shape of the light curve of Type Ia supernovae? [2 pts]

60. What spectral feature(s) distinguish AM CVn systems?
61. What is one term for the sub-luminous supernovae that may result from AM CVn systems?
62. [T3] AM CVn systems often have large brightness variations with a period distinct from the orbital period. What is the term for this additional broad variability?
63. What is thought to be the cause of this further variability?

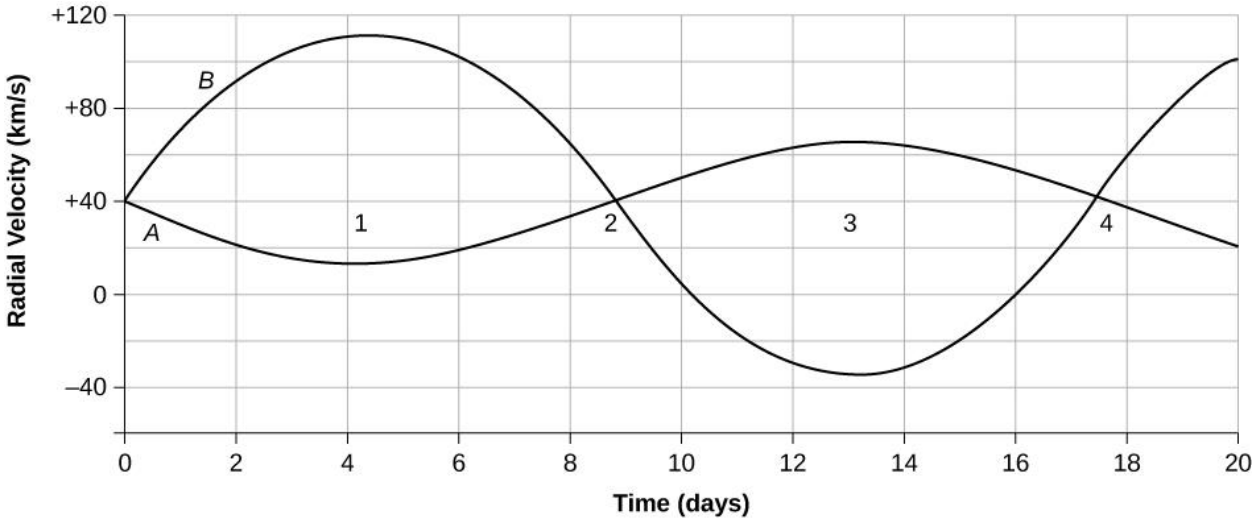
64. What stage of stellar evolution is the mass of a planetary nebula ejected?
65. What is one potential cause of a more complex shape (i.e. non-spherical) for a planetary nebula?
66. What kind of radiation is primarily responsible for illuminating planetary nebulae?

67. What are the 3 main subtypes of dwarf novae, and how are they distinguished from each other? [3 pts]
68. What causes the outburst to eventually fade?

69. Why do stars increase in size as they become red giants?
70. [T7] What is the name for the explosive ignition of He burning at the tip of the Red Giant Branch?
71. Why does He burning only begin "explosively" in low-mass stars?

72. What happens during a neutron star "glitch"?
73. What is the name of the upper mass limit for neutron stars?
74. [T8] Why do we see "pulses" of radiation from pulsars?
75. What is the term for neutron stars with particularly strong magnetic fields?
76. What is the term for a nebula that shines due to radiation from a neutron star?

Suppose you observe a binary star, with the radial velocity curve shown below (for the system as a whole). You know that the two stars orbit each other at an orbital separation of $4.08 * 10^7\ km$.



77. What is the orbital period of this system, in days?
78. What is the mass ratio of the two stars in this system, m_A/m_B?
79. What is the total mass of the system, in $M_\odot$?
80. What is the mass of Star A, in $M_\odot$?
81. [T1] You later discover that this binary system has an inclination of 70°. What are the masses of the two stars now, in $M_\odot$? [2 pts]

82. If we have evenly-spaced astrometry measurements (position on the sky), how can we differentiate between an orbit that is circular and inclined, and one that is just elliptical? [2 pts]

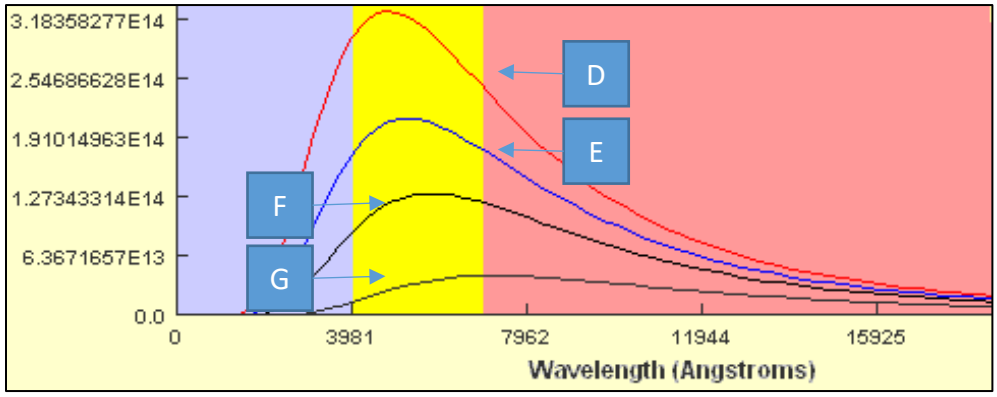
We observe a Type Ia supernova to have a peak apparent magnitude of +18.6.

83. [T2] What is the approximate distance to its host galaxy, in kpc?
84. What is the recessional velocity of this galaxy, in km/s (assuming there are no additional effects)?

Star C has an angular diameter of 3.82 mas and a parallax of 0.157".

85. What is the distance to Star C, in pc?
86. What is the diameter of this star, in $R_\odot$?
87. Assume this star is spherical and has a mass of about 1 $M_\odot$. What type of star is Star C, choosing from the following options: dwarf, giant, supergiant, white dwarf, or neutron star?

You find four stars – which you label as D, E, F, and G – with B-V color indices of -2.7, +3.4, +0.32, and -1.9 (note that the color indices are NOT listed in order). You also observe the following blackbody spectra:



88. Which blackbody curve (D – G) would have the hottest color index?
89. If the B-band magnitude of this star is +7.6, what is its V-band magnitude?
90. Which blackbody curve (D – G) would have the second coolest B-V color index?
91. What is its temperature, in K?
92. Suppose stars D through G are all the same distance away. If they all have the same B-band magnitude, then which star would visually be the brightest?