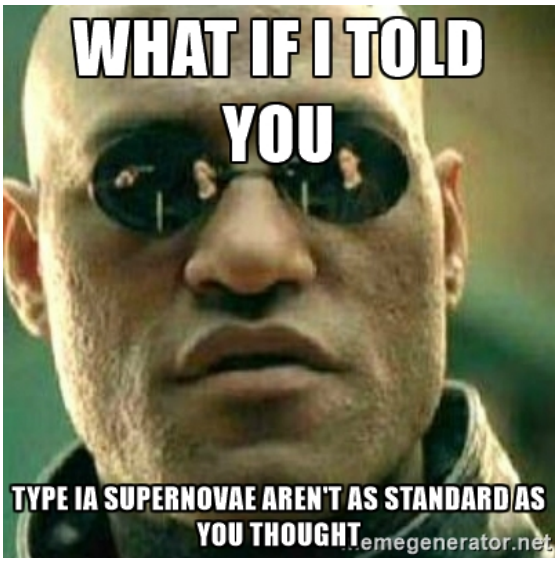
PENNSYLVANIA SCIENCE OLYMPIAD

STATE FINALS 2017

ASTRONOMY C DIVISION EXAM

APRIL 29, 2017



TEAM NUMBER _____ **SCHOOL NAME**_____

PARTICIPANTS_____

_____

INSTRUCTIONS:

1. **Turn in all exam materials at the end of this event. *Missing exam materials will result in immediate disqualification of the team in question*. There is an exam packet, an image packet, and 3 blank answer sheets.**

2. **You may separate the exam pages.**

3. ***Only* the answers provided on the answer page will be considered. Do not write outside the designated spaces for each answer. You may write in the exam booklet.**

4. **Write your team number, school name, and participants' names on the title page of the test booklet. By writing your participants' names, you agree to the General Rules, Code of Ethics, and Spirit of the Problem as defined on the Science Olympiad website: https://www.soinc.org/code-ethics-general-rules.**

5. **Write your team number, school name, and participants' names in the appropriate spaces on the answer sheets.**

6. **Each question is worth one point. Tiebreaker questions are indicated with a (T#) in which the number indicates the *order of consultation* in the event of a tie. Tiebreaker questions count toward the overall raw score, and are only used as tiebreakers when there is a tie. In such cases, (T1) will be examined first, then (T2), and so on until the tie is broken. There are 16 tiebreakers.**

7. **Pay close attention to the units given in the problem and the units asked for in the answer.**

8. **When the time is up, *the time is up*. Continuing to write after the time is up will result in a numerical penalty of -10 applied to the raw score.**

9. **Nonsensical, mocking, or inappropriate answers WILL RESULT IN DISQUALIFICATION.**

10. **In the bonus box on answer sheet 2, indicate the name of the woman shown in the image on the cover sheet.**

11. **DO NOT WRITE in the page score, score total, or place boxes. Marking in these boxes will result in a numerical penalty of -10 applied to the raw score.**

12. **Staple the exam booklet back together when your materials are submitted. The pages do not need to be in order but the title page MUST be on top.**

SECTION 1: Questions numbered 1-35 refer to the image pages and the Object list as published in section 3c of the Astronomy rules in the 2017 Science Olympiad Division C Rules Manual. "Object" means one of the objects from the list unless otherwise noted.

1. Consider image 5. Which object is indicated in this image?

(T13) 2. Which image on page 1 or 2 shows the *nova et nullius aevi memoria prius visa stella*?

3. The object referred to in question 2 has what designation in the 3rd Cambridge Catalogue of Radio Sources?

4. Which image shows the spectrum for the object referred to in question 2?

5. What *other* object's spectrum is also shown in the image referred to in question 4?

6. Which image shows a planetary nebula imaged in x-rays by the Chandra X-Ray Observatory?

7. The X-ray emission of the object in question 4 is unusually high. What most likely accounts for this?

8. Consider image 8. Which object is indicated by the intersection of the yellow bars?

(T9) 9. What is the Messier Catalogue number for the galaxy shown in image 8?

10. Which image on image page 1 or 2 indicates the object that produced the spectrum in image 15?

11. What is the prominent absorption feature near the peak of the spectrum in image 15?

12. Which image on page 3 or 4 was produced by the object shown in image 1?

13. What is the ROSAT observation ID for the object shown in image 1?

14. What will be the ultimate fate of the objects shown in image 1?

15. Which image on page 1 or 2 shows an object that could have produced one of the curves shown in image 16?

16. The image referred to in question 15 deals with a particular object. What does this object orbit?

17. What long-held belief about objects of this type was challenged by a particular discovery (in 2011) in the object in question 16?

18. What is the designation for the yellow smear in image 12 (it's not on the list)?

19. In which object is the structure referred to in question 18 found?

(T3) 20. Why is the structure referred to in question 18 considered notable?

21. Which image shows the object that created the light curve shown in image 18?

22. Which of the images shows a radio image of a supernova remnant?

23. The supernova remnant referred to in question 22 provided evidence for this particular theory in 2016.

24. Which image shows a planetary nebula with (perhaps) the hottest known white dwarf at its center?

25. Which image shows the SED for the object referred to in question 24?

26. The object referred to in question 24 has what designation in the Perek-Kohoutek catalog?

(T14) 27. Which image shows the object with a super-Chandrasekhar double-degenerate core?

28. When will the object referred to in question 27 end its existence in rather spectacular fashion?

29. What is the General Catalogue of Variable Stars classification for the type of object that produced the light curve shown in image 22?

30. Which object produced the light curve shown in image 22?

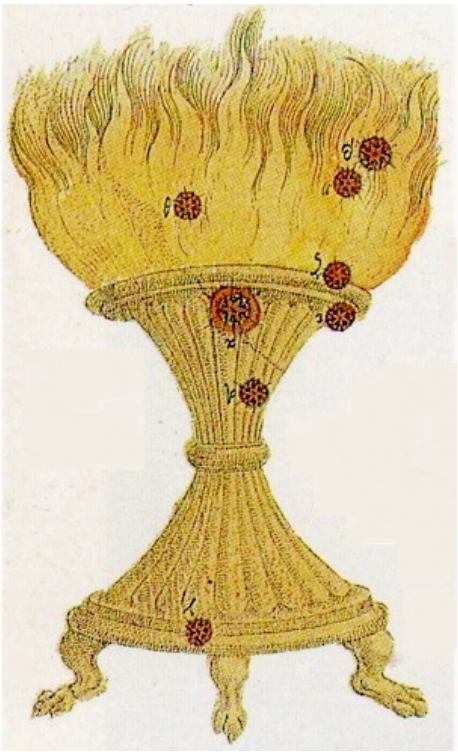
31. What is the primary reason for the variability shown in image 22?

(T4) 32. Which optical image shows the progenitor of a double white dwarf mass transfer binary?

33. When one of the white dwarfs overfills its Roche lobe and begins to lose mass to its companion, what then is the system called?

34. Which image shows the light curve from the type of progenitor system referred to in question 32?

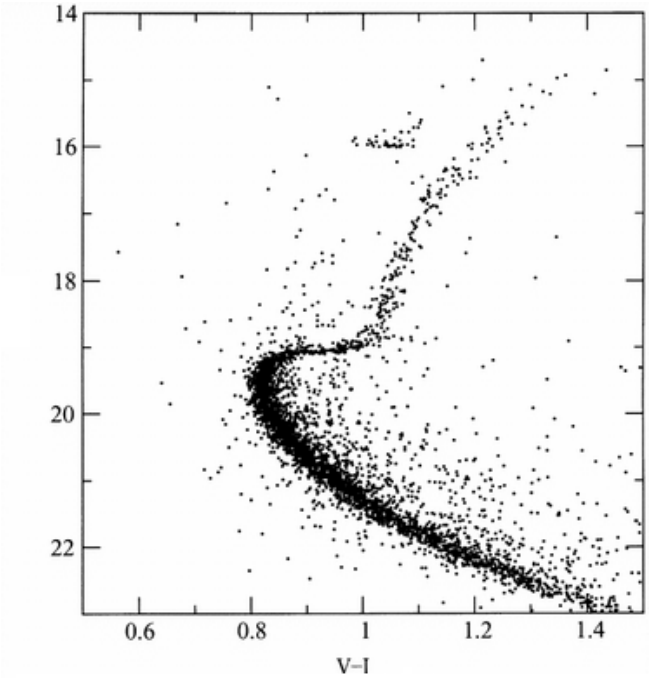
35. Which object appears in the constellation shown below?



SECTION 2: Questions numbered 36 - 65 deal primarily with the concepts, processes, and astronomical objects associated with section 3a of the Astronomy rules in the 2017 Science Olympiad Division C Rules Manual.

36. Where are Mira variable stars on the HR diagram? Be specific ("top right" is not good enough).

For questions 37 – 41, consider the HR diagram shown below.



37. What quantity is indicated on the horizontal axis of the diagram?

38. What is the apparent magnitude of stars currently in the horizontal branch?

39. What type of astronomical object produced this diagram?

40. What spectral class are the stars at main-sequence turnoff?

41. How old is the object that produced this diagram?

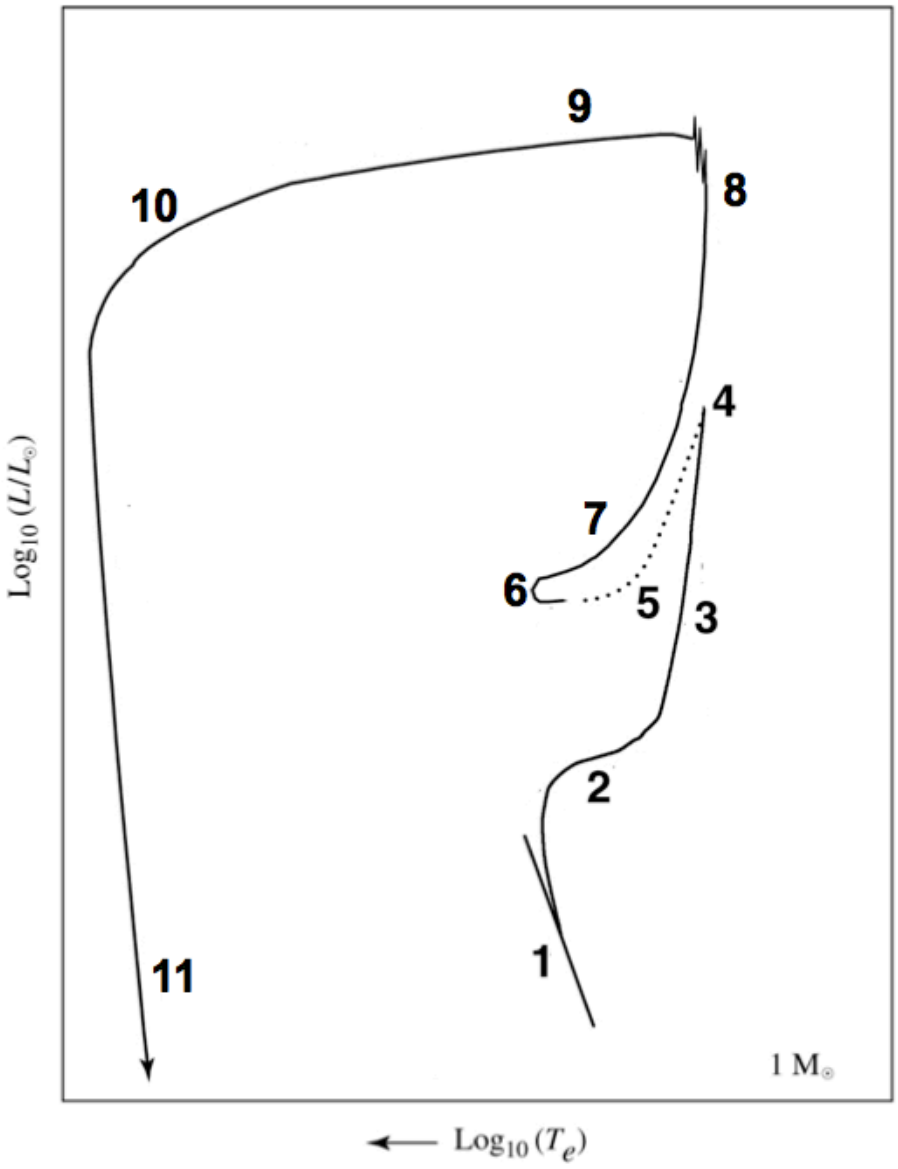
42. Why is the Hubble Law ineffective for objects closer than 10 Mpc?

43. There are a few possibilities regarding the nature of the donor star in an AM CVn system. What primary characteristic do all the possible types of donor star have in common?

(T15) 44. What causes the matter in an accretion disk to spiral inward toward the accretor?

45. Many globular clusters are located in the extended halos of the galaxies about which they orbit. How would you qualitatively describe the metallicity of the stars in such clusters?

Consider the following evolutionary transitions of a one-solar-mass star for questions 46-55.



(T6) 46. At which numbered region will the Helium core flash take place?

47. Which numbered region represents the thermal pulse asymptotic giant branch?

48. How would region 2 be described?

49. What is going on in region 10?

50. At which numbered region will the first dredge-up take place?

51. Why is region 5 represented as a dotted line?

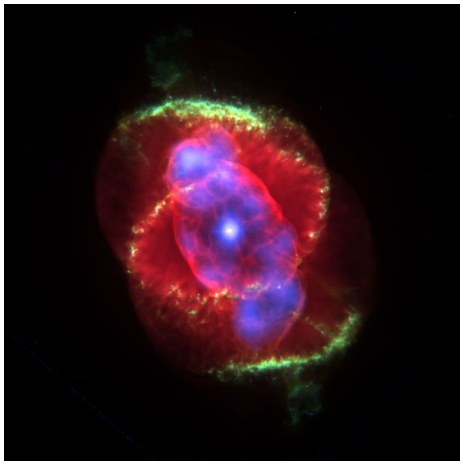
52. What is region 6 called?

53. What is the star actually doing in region 6?

54. What happens after region 11?

55. What is represented at region 1?

The Cat's Eye Nebula (NGC 6543) is a particularly beautiful planetary nebula in the constellation Draco. The nebula is at a distance of 3300 ly, has an apparent (core) diameter of 20 arcseconds and an apparent magnitude of 9.8. The image is a false-color composite of optical and X-ray images. One of the dominant emission lines in the Cat's Eye spectrum is the O[III] line, in lab spectra at 500.7 nm. In the spectrum from the Cat's Eye, this line appears at 500.662 nm.



56. Calculate the actual diameter of the nebula's core in ly.

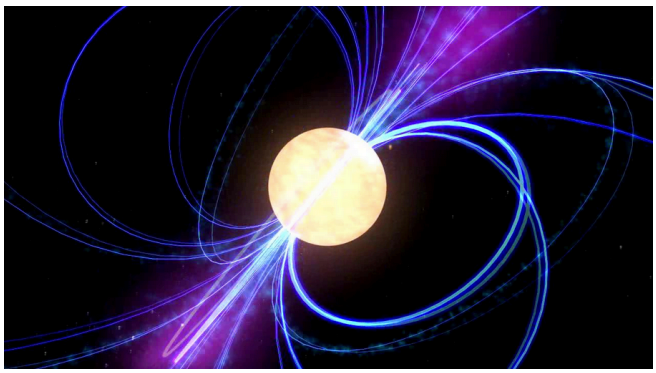
57. Calculate the absolute magnitude of the nebula.

58. Calculate the nebula's distance modulus.

(T12) 59. Calculate the radial velocity of the Cat's Eye in km/s, and specify if it is receding or approaching.

60. The central star, HD 1064963, is classified as O7. What is its surface temperature?

Neutron stars typically exhibit a characteristic period of rotation. This period is highly regular, but does have a "spin down rate" that is also highly regular (albeit very small).



(T8) 61. What physical principle justifies the high rotation rate of isolated neutron stars?

62. What is the reason for the gradual spin down?

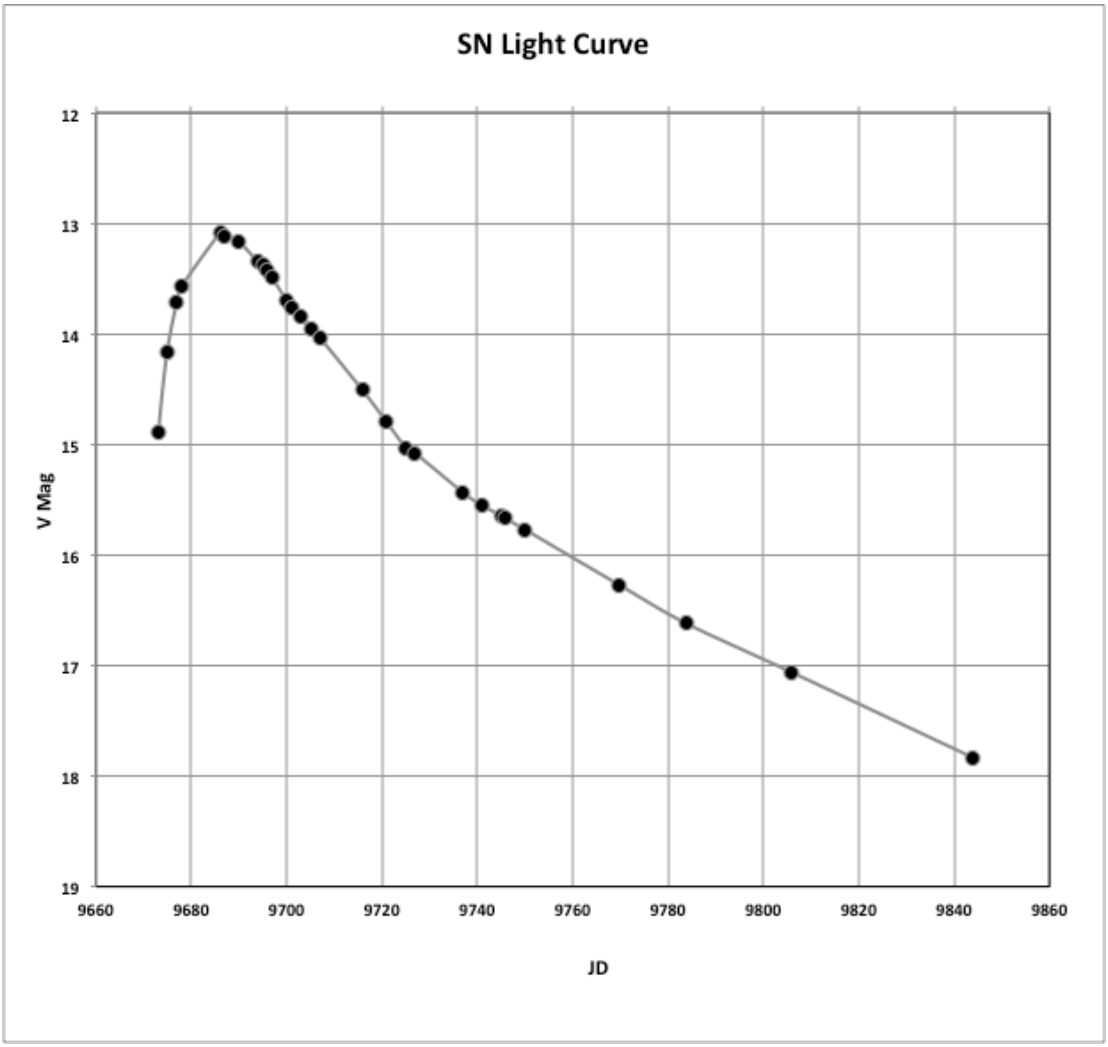
63. If the rotation axis and the magnetic axis of a neutron star are misaligned, what is the result from our perspective here on Earth?

64. Sometimes the slowly increasing period experiences a rapid adjustment to a slightly shorter period. What is this called?

65. Some pulsars spin *extremely* rapidly, more rapidly than even the mechanism in question 61 can provide. What accounts for this faster-than-predicted rotation rate?

SECTION 3: Questions numbered 66 – 89 deal with astrophysical measurements and calculations dealing primarily with section 3b of the Astronomy rules in the 2017 Science Olympiad Division C Rules Manual.

A particular supernova in a distant galaxy is identified and its apparent magnitude is measured and recorded over time as shown below. Use this information for questions 66-70.



66. What is the apparent magnitude of the supernova at maximum?

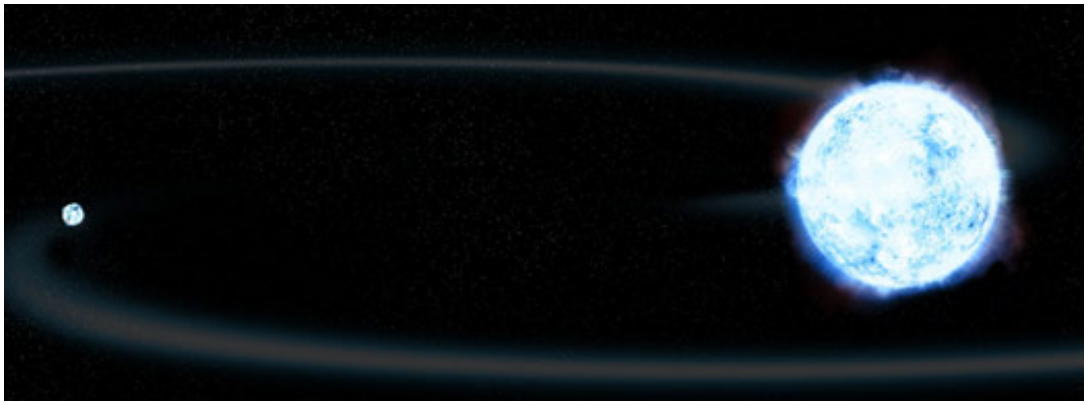
(T1) 67. What is the distance modulus for this supernova?

68. How far away in megaparsecs is the galaxy in which this supernova occurred?

69. Assuming H_0 = 70 km/s/Mpc, what would you expect the recessional velocity to be?

(T2) 70. Observations of this type of object led to a particular conclusion regarding the expansion of the universe in 1998, leading to a Nobel Prize. What conclusion was reached?

A double white dwarf binary system is discovered. The system consists of a 1.25$M_\odot$ primary and a 0.55 $M_\odot$ secondary, orbiting at a separation of 3.31E5 km. Use this information for questions 71-80. Your answers should have no more than 3 significant figures.



71. Where is the center of mass of the system, measured in km from the center of the primary star?

(T5) 72. Calculate the orbital period in minutes.

73. Calculate the orbital radius of the primary star in km.

74. Calculate the orbital radius of the secondary star in km.

75. Calculate the orbital velocity of the primary star in km/s.

76. Calculate the orbital velocity of the secondary star in km/s.

77. Calculate the total energy of the system.

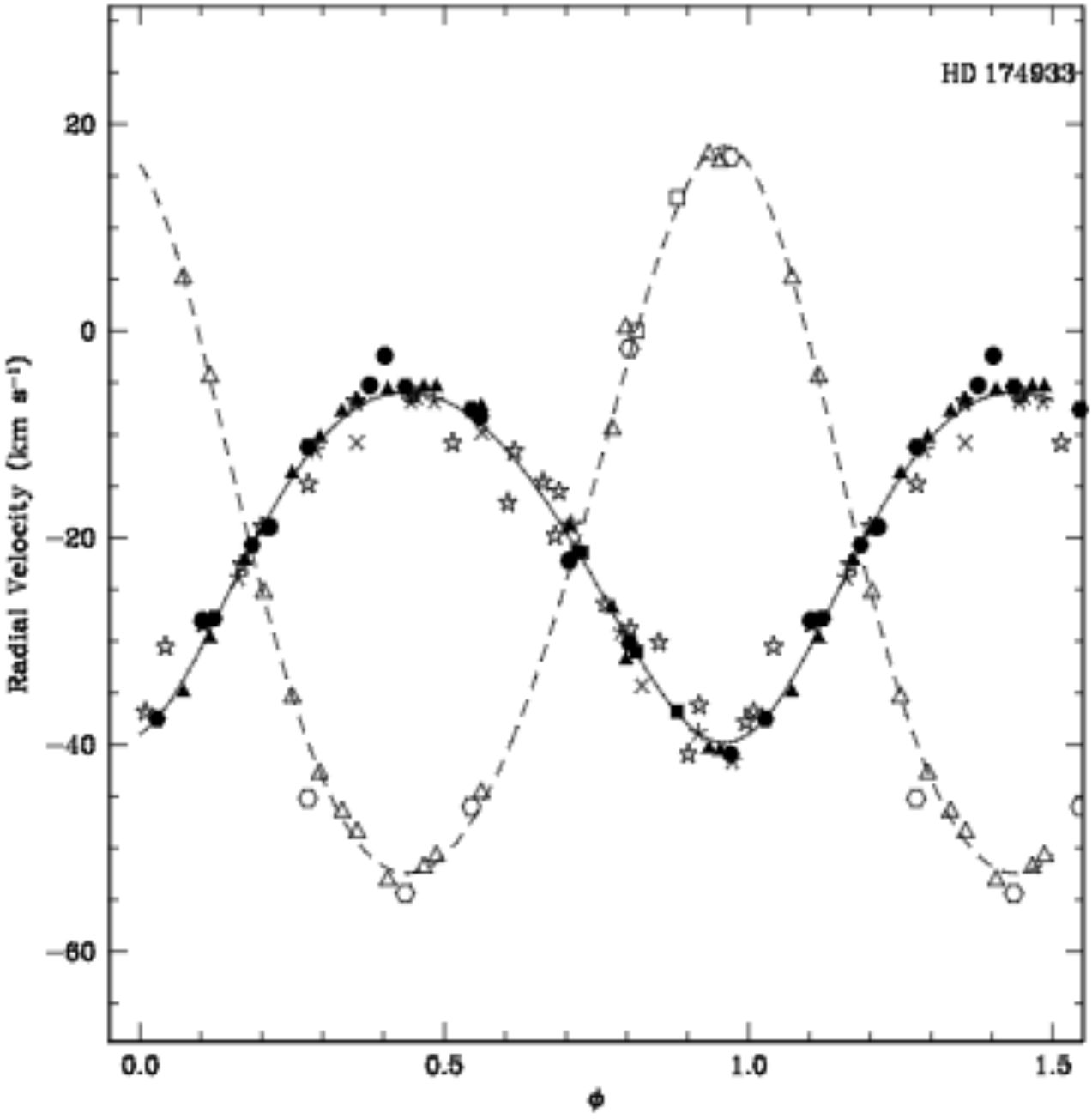
78. Calculate the angular momentum of the system.

79. Calculate the length of time it will take for the stars to collide in years.

80. The result of the collision presents a problem for use of a particular standard candle. Describe the problem.

81. In a paper published in January 2017, the Hubble constant was found to be H_0 = 71.9 km/s/Mpc. According to this data, what is the age of the universe?

HD 174933 is a double-line spectroscopic binary, first discovered in 1926 and extensively studied in the 1970s. Its radial velocity curve is shown below. Use this information for questions 82 – 85.



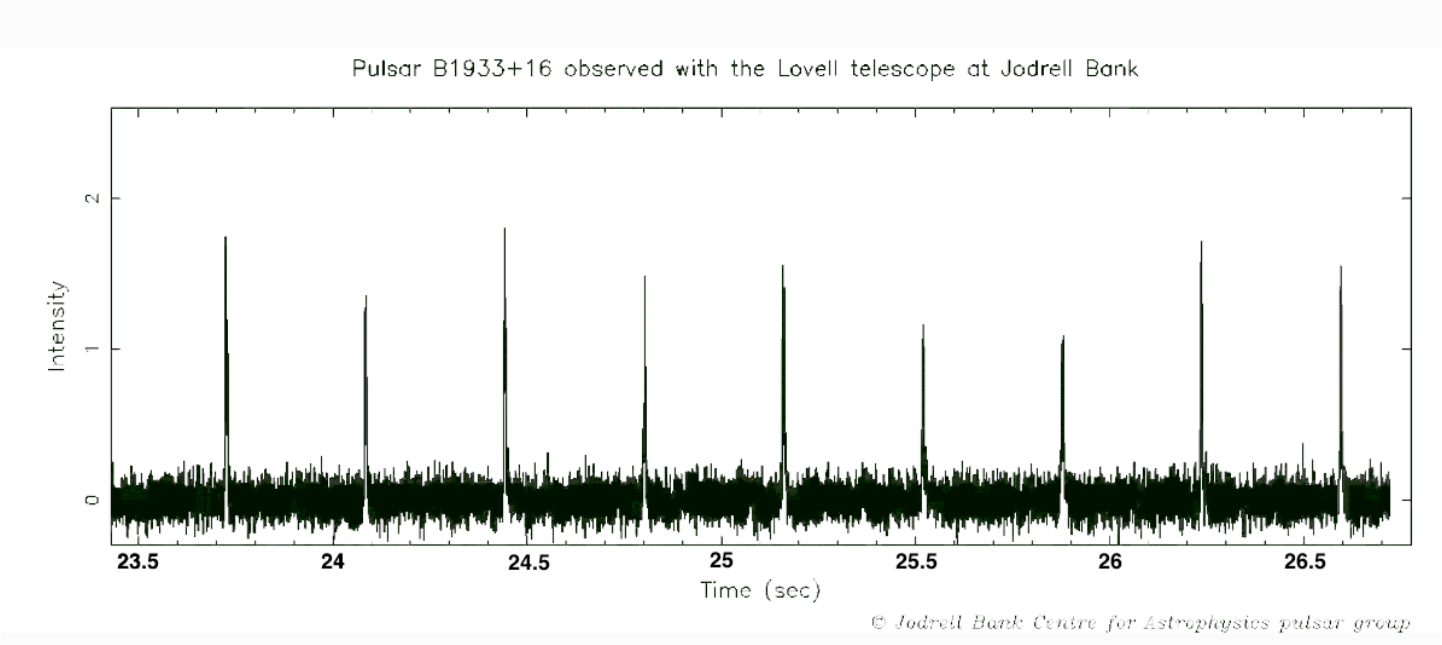
82. What is the radial velocity of the system?

83. What is the orbital velocity of the more massive star?

84. What is the orbital velocity of the less massive star?

(T10) 85. What is the ratio of the masses (larger/smaller)?

Radio observations of PSR 1933 + 16 produced the curve shown below. The pulsar has a mass of 1.6 solar masses and (presumably) a radius of 10 km. Assume the pulsar is a solid homogeneous sphere. Use this information for questions 86 – 89.



86. What is the rotation period of this pulsar?

87. Calculate the angular velocity of PSR 1933 + 16.

(T11) 88. Calculate the angular momentum of PSR 1933 + 16.

89. Calculate the rotational kinetic energy of PSR 1933 + 16.

SECTION 4: For questions numbered 90-100, provide the term, acronym, person, or phrase that best fits the description provided.

90. This describes the relationship between the peak luminosity of a Type Ia supernova and the speed of luminosity evolution after maximum light.

(T7) 91. This element was proposed to account for the unusual green emission lines found in early spectroscopic observations of planetary nebulae.

92. Classification scheme for planetary nebulae, based on element abundances, structure, and galactic location.

93. This Polish astronomer was the first to suggest that AM CVn systems were composed of double white dwarf binaries, in 1967.

94. This type of star system consists of a pulsar and another neutron star.

95. T Ursae Minoris is (or, was) a Mira-type variable star in the little dipper. It was extensively monitored since 1905, and for decades its period was between 310 and 315 days. In the late 1970s, however, its period suddenly began to decrease significantly, and is now pulsating as a semi-regular variable with a dominant period of 113 days. What has the star undergone in terms of its evolution?

96. SU Ursae Majoris stars are a subclass of the dwarf novae. They exhibit particular quasi-periodic oscillations that are also called:

97. This is the location where the mass stream from a donor star strikes an accretion disk.

98. A small group of stars that appear in globular clusters *above* the turnoff point, probably due to mass exchange or stellar mergers.

99. The burning front of carbon and oxygen in a Type Ia supernova if it occurs at subsonic speeds:

(T16) 100. Hubble's Law is associated with a particular equation: $\Omega_0 = \Omega_B + \Omega_D + \Omega_\Lambda$
In this equation, what does the symbol Ω_Λ mean?