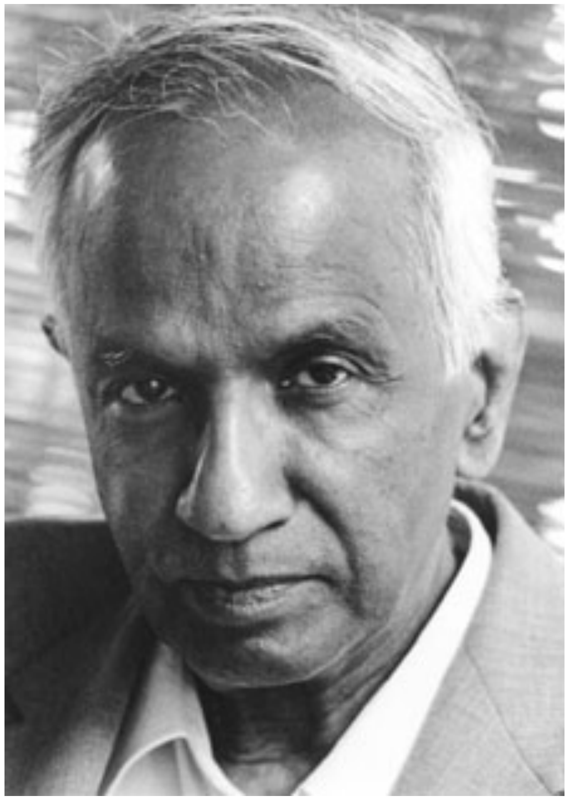
Southern California State Science Olympiad

Astronomy C Division Event

14 April 2012

Canyon High School

Anaheim, CA



TEAM NUMBER: _______________

TEAM NAME: ____

INSTRUCTIONS:

1) Please turn in <u>ALL MATERIALS</u> at the end of this event.

2) Do not forget to put your <u>TEAM NAME</u> and <u>TEAM NUMBER</u> at the top of all Answer Pages.

3) Good Luck! And May the Stars be With You!

A polytrope is a model of a star in which pressure varies as a function of density as follows: $P = K_n \rho^{1+\frac{1}{n}}$**, where P is pressure,** ρ **is density, and** K_n **is a constant that depends on the index (n) chosen. The Sun is modeled by an index (n) of 3, degenerate star cores with an index of 1.5, and neutron stars with an index of 1. This model formalism leads to the following equation for the maximum mass (in solar masses) of stars with index n:** $M = \frac{-4C_n}{\sqrt{\pi}} \xi_n^2 \left(\frac{d\theta}{d\xi}\right)_{\xi_n}$ **, where** θ **and** ξ **values are listed as a function of index n in the table below, and** C_n **is a function of the ionization fraction of the star as follows:** $C_n = \frac{0.953}{\left(\frac{2}{1+x}\right)^2}$**, where x is the ionization fraction.**

n	$-\xi_n^2 \left(\frac{d\theta}{d\xi}\right)_{\xi_n}$
1	**3.14**
1.5	**2.71**
3	**2.02**

Use the information given above to answer the following questions. "Deep Sky Object" refers to the objects listed in Section C of the 2012 rules.

1. What is the value of $-\xi_n^2 \left(\frac{d\theta}{d\xi}\right)_{\xi_n}$ for a white dwarf star?

2. Which Deep Sky Object is a white dwarf star found in the constellation Canis Major?

3. Can the ionization fraction of a white dwarf star be better approximated by a value of 0 or 1?

4. Using your approximation in question (3), calculate the maximum mass of a white dwarf star, in solar masses.

5. What is the last name of the person who first derived this limiting mass for white dwarf stars? Hint: a picture of him is shown on the exam cover page.

6. The actual value of this limit is slightly smaller than the value you should have computed. Why is this the case? Consider any approximations you might have utilized in your calculation.

7. What type of event occurs if a white dwarf reaches this limit?

8. Two Deep Sky Objects, first observed in the years 1572 and 1604, are examples of this type of event. Which two images are these objects displayed in?

9. Which image displays two Deep Sky Objects that are examples of white dwarfs that underwent this type of event much faster than astronomers thought possible?

The following questions refer to the Deep Sky Object list from the Science Olympiad Student Manual.

HD62166 is a white dwarf star with a radius of 1.9 x 10^4 km and absolute magnitude of -2.8.
10. What is the temperature of HD62166, in Kelvin?

11. The apparent magnitude of HD62166 is 17.5. How far away is it, in kiloparsecs?

12. Which image displays HD62166 and its surrounding planetary nebula?

13. What is the New General Classification identification of the surrounding planetary nebula?

An optical image of a supernova remnant is shown in Image B.
14. What is the name of this SNR, as seen on the Deep Sky Object list?

15. What interaction between the interstellar medium and the SNR is evident in this optical image?

Omicron Ceti is a long-period pulsating red giant star.
16. What is the period of o Cet, in days?

17. Which image shows o Cet in visible light?

18. o Cet has a dwarf companion, and the system has an orbital period of 400 years. What is the name of this companion star?

A image of a symbiotic variable star system made from radio array observations is shown in Image C.
19. Which Deep Sky Object is this variable star system?

20. What are the two blue/green spots visible on both sides of the system?

21. What are the three main components of a symbiotic star system?

Two of this year's Deep Sky Objects are prominent star-forming regions.
22. Which of these is shown in image L?

23. Which of these is shown in image D?

24. Which image, L or D, displays an object that appears brighter to observers on Earth?

25. These regions are called "HII" regions. What does that imply about hydrogen gas in the region?

26. Which image, L or D, displays a HII region that contains the Keyhole nebula?

A globular cluster is shown in image G.
27. What is the Messier catalogue identification of this object?

28. This cluster has been shown to have a collapsed core, with half of its mass contained within the central 10 light years of its structure. What object have astronomers speculated might be present in the center of this globular cluster due to its massive core?

29. Which type of variable star with extremely short periods, whose prototype is a Deep Sky Object, is abnormally prevalent in this object?

30. Why is this type of variable star so prevalent in globular clusters?

The light curve of a variable star is shown in image M.
31. Which Deep Sky Object's light curve is shown?

32. Which other image shows this object, along with Hind's variable nebula?

33. What is the New General Classification identification of Hind's variable nebula?

The light curve of a variable star is shown in image N.
34. Which Deep Sky Object is this?

35. What type of variable star is it?

36. In which year was this star's first observed outburst?

Image H displays an illustration of a red giant star.
37. Which Deep Sky Object is this?

38. The illustration shows an accretion disk around the star. Why does it have an accretion disk and jet system?

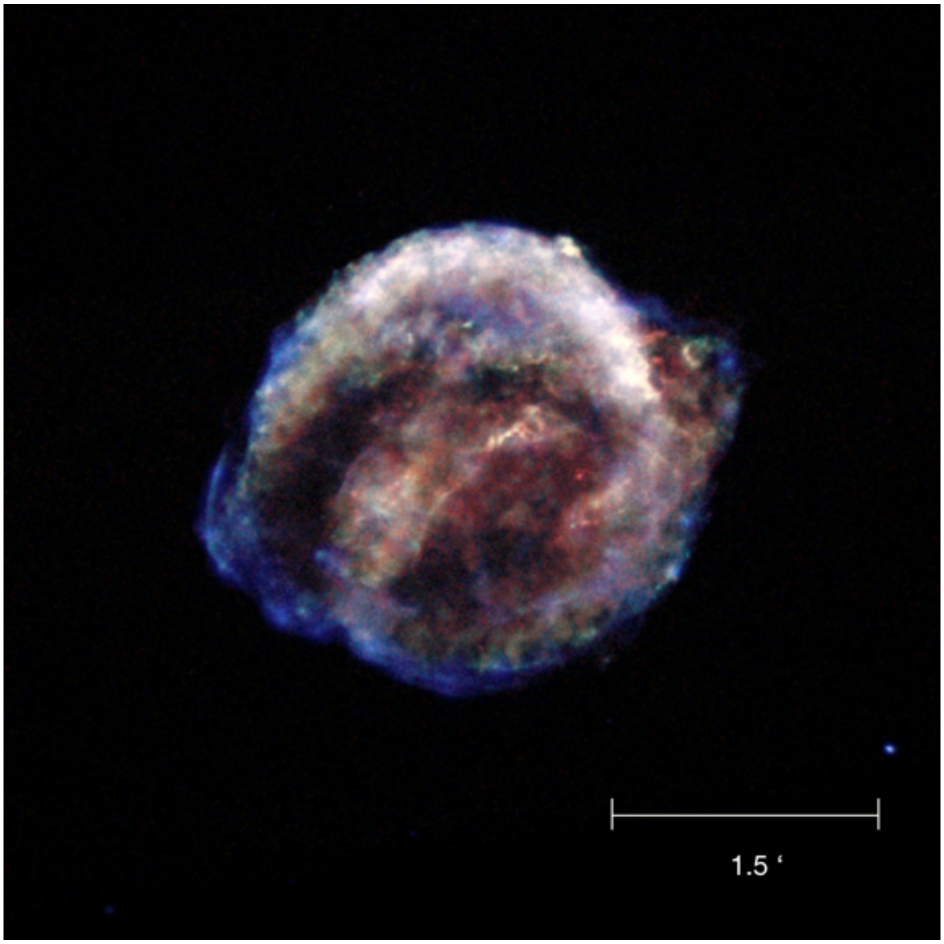
39. Is this star enriched or depleted in lithium relative to the Sun?

RX J0806.3+1527 is a star system bright in x-ray radiation.
40. Which image depicts this object?

41. Why is this object overabundant in carbon and oxygen?

42. Does image K or image I display the most similarity to the likely end result of this system?

Use the image (and associated scale bar) below to answer the following questions.



43. Which Deep Sky Object is shown?

44. This object is 13,000 light years away. What is its diameter, in light years?

45. This object is expanding at 2,000 km/s. Assuming that it has had a constant expansion velocity with time, how many years ago did the supernova that formed this object occurred?

46. Assuming that the supernova was formed by a white dwarf reaching its maximum mass as determined in question #4 of this exam, what is the kinetic energy of the expanding remnant in Joules?

47. In question #46 you should have computed a very large kinetic energy for the expanding shell. What happens to this kinetic energy, that we can observe and is visible in the blue in this image, as the supernova collides with the interstellar medium?

48. What is the energy density in the remnant, assuming it is spherical, in J/m^3?

Answer the following questions using the information given. Note that objects are designated using a letter (A, B, C, etc.) and that answers from one question may carry over to the next question if the same object is part of both questions.

49. Star A has a parallax of 0.4”. How far away is it, in parsecs?

50. Star A is also an RR Lyrae variable star. What is Star A’s apparent magnitude?

51. Sirius has an apparent magnitude of -1.5. How many times brighter does Star A appear in the night sky compared to Sirius?

52. Star A has a surface temperature of 7,000 K. What is its radius, in solar radii?

53. In which part of the electromagnetic spectrum (X-Ray, UV, Visible, or Radio) does Star A’s blackbody-like spectrum peak?

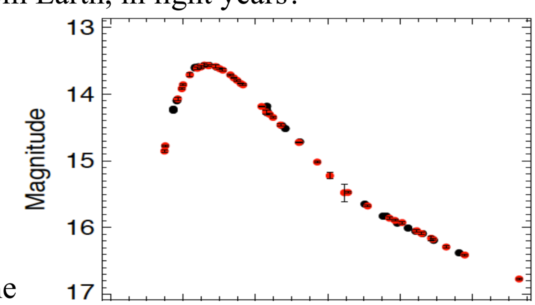
54. Star A undergoes a characteristic modulation of its amplitude and phase. What is the name of the effect that causes this behavior?

55. Star B is a main-sequence star with a B-V index of 0. Which general spectral class does star B belong to?

56. Does Star B have a higher or lower surface temperature than Star A?

57. Object C is a planetary nebula, 2 light years in diameter. It began to expand 10,000 years ago. Calculate its expansion velocity averaged over that 10,000 year span, in km/s.

58. Object C has an angular diameter of 2”. How far away is it from Earth, in light years?



59. An event was observed in Galaxy D, with a light curve shown to the right. How far away is Galaxy D, in megaparsecs?

60. Star E has a redshift of 1×10^{-3}. What is the recessional velocity of Star E, in km/s?

61. Star E is a found in Galaxy F. Use Hubble’s law to estimate the distance to this galaxy, in megaparsecs, assuming H_0 = 75 km/s/Mpc.

62. Estimate the maximum possible age of the universe, in billions of years, using Hubble’s constant as given above.

63. Star E has transverse velocity to our line of sight of 150 km/s. What is the speed of Star E through space, in km/s?

64. Stars F and G orbit one another in a binary system. Star F has four times the mass of Star G. How many times the orbital speed of Star F is the orbital speed of Star G?

65. Stars F and G are separated by 5 AU, and have an orbital period of a year. What is the mass of Star F, in solar masses?

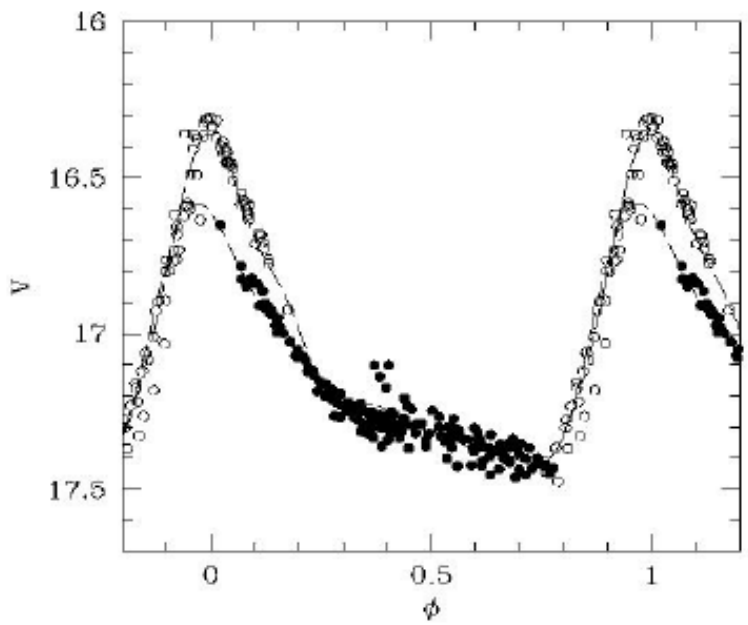
66. This system will likely result in a supernova event. What type of supernova will be formed?

67. What object would likely remain, in place of the destroyed star, after this supernova?

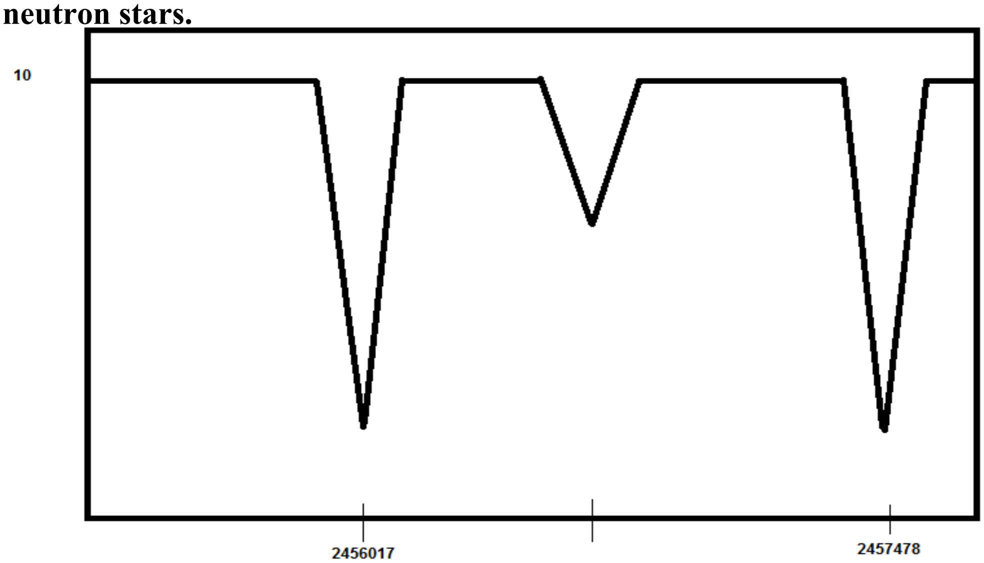
68. Star H and Star I have the same absolute magnitude, but Star I appears 25 times dimmer to observers on Earth. How many times farther away is Star I than Star H?

69. Star J is a 1 solar mass white dwarf gaining mass through mass transfer with Star K at a rate of 10^{15} grams/second. In how many billion years will Star J go supernova?

70. Star L is observed to have the light curve shown below. How far away is Star L, in kiloparsecs?



Consider the following light curve (apparent magnitude vs. Julian date) of a binary star system. One of the objects is a compact object whose mass just exceeds the upper limit for stable neutron stars.



71. Consider the compact object. What is this mass limit that it exceeds called and what is its approximate value, in solar masses? (Take this limit to be the mass of the compact object)

72. What type of object is the compact object?

73. Account for the two different periods of eclipse. Why are they different in magnitude?

74. What is the period of this system in Earth years?

75. The more massive object is observed to have a surface temperature of 3215 K. It also has a diameter 250 times that of the sun. What is the mass of this object, in solar masses, assuming Luminosity is proportional to a star's Mass raised to the $\frac{7}{2}$ power?

76. How far away from Earth is the system, in kiloparsecs?

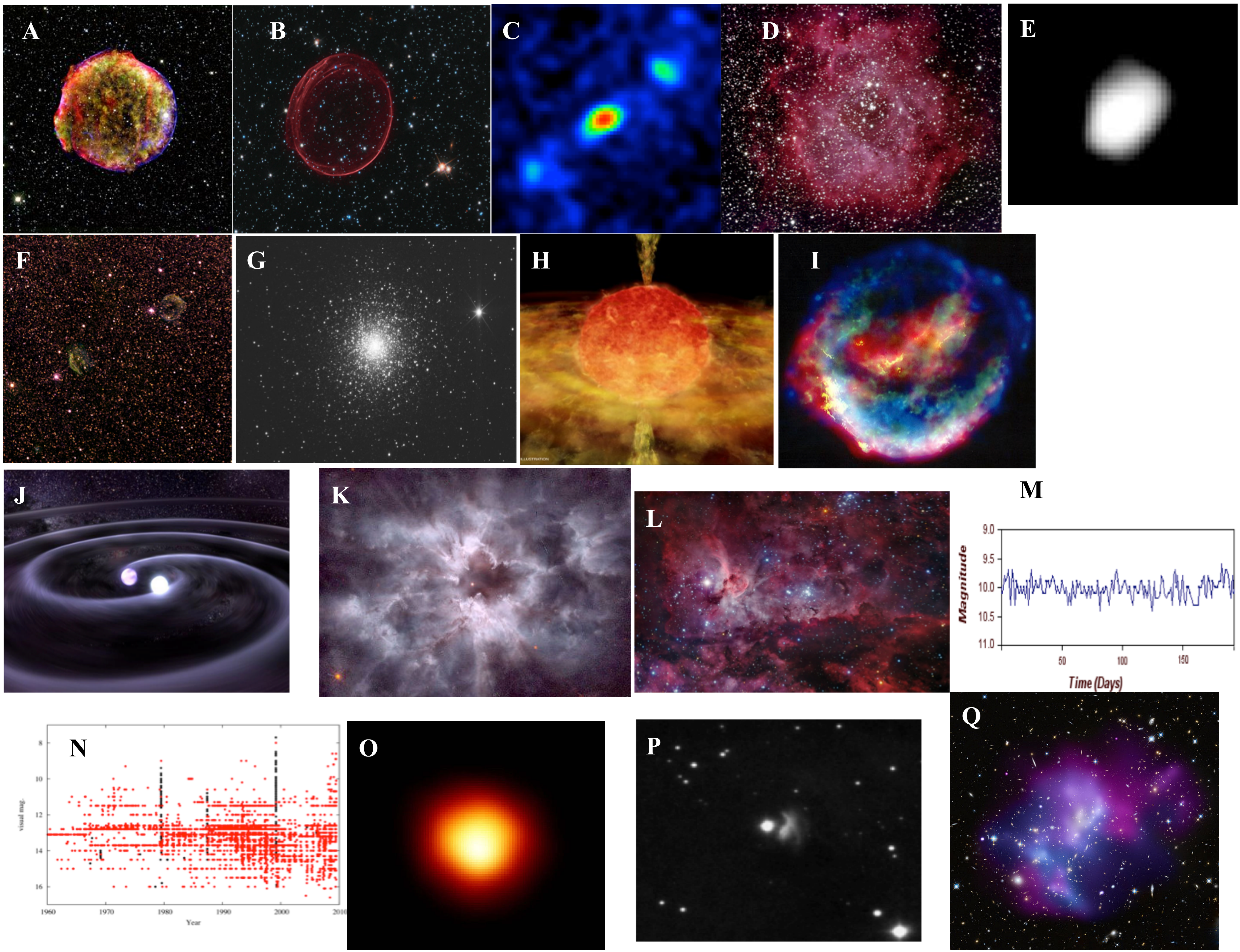
77. What is the semi-major axis of the system in AU?

78. What is the distance from the more massive object to the center of mass of this system, in AU?

79. Find the intersection of each object's Roche lobes for this system, given as distance from the more massive object in AU.

80. What is this point of intersection of Roche lobes called?

81. How many points exist in the system where the gravitational forces sum to give a centripetal acceleration of zero? How many of these are stable?


A
B
C
D
E
F
G
H
I
J
K
L
M
9.0
9.5
10.0
10.5
11.0
Magnitude
50
100
150
Time (Days)
N
8
10
12
14
16
visual mag.
1960
1970
1980
1990
2000
2010
Year
O
P
Q

Team Name:______________________________ Team Number: ________________

1) _________

2) _____________

3) ________

4) __________ Solar Masses

5) __________________________

6) ___________________________

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7) ___________________________

8) ________________

9) ________

10) ___________________ Kelvin

11) ____________ kpc

12) ________

13) ___________________

14) ___________________

15) __________________________

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16) _____________ Days

17) ________

18) ______________

19) ______________

20) __________________________

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21) __________________________,

___________________________,

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22) _____________________

23) _____________________

24) ________

25) __________________________

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31) ________________

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35) ___________________

36) __________

37) ________________

38) __________________________

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39) ______________

40) ________

41) __________________________

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42) ________

43) ___________________

44) _________ Light Years

45) _________ Years

46) _______________ Joules

47) __________________________

48) _______________ J/m^3

49) _________ Parsecs

50) _________ (App. Mag)

51) _________

52) ___________ Solar Radii

53) ______________

54) __________________________

55) _________

56) _______________

57) ___________ km/s

58) _______________ Light Years

59) ___________ Mpc

60) ___________ km/s

61) ___________ Mpc

62) ___________ Gyr

63) ___________ km/s

64) ________

65) ___________ Solar Masses

66) ______________________

67) ___________________

68) ________

69) ___________ Gyr

70) ___________ kpc

71) ________________________

____

____

72) _______________

73) _________________________

____

____

74) _______ Years

75) _________ Solar Masses

76) _________ kpc

77) _________ AU

78) _________ AU

79) _________ AU

80) _________________________

____

81) _________________________