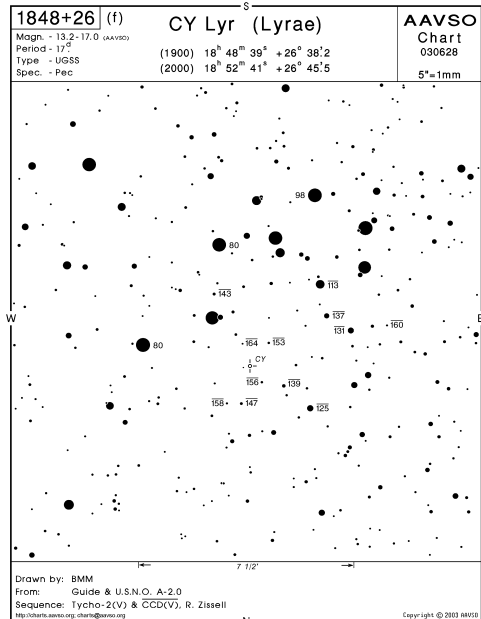


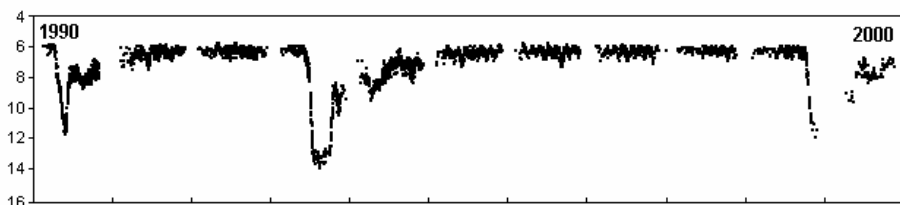
PENNSYLVANIA SCIENCE OLYMPIAD
STATE FINALS 2008
ASTRONOMY C DIVISION EXAM
APRIL 25, 2008



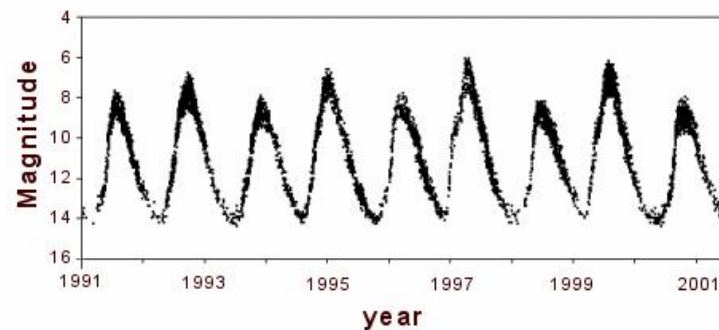
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15

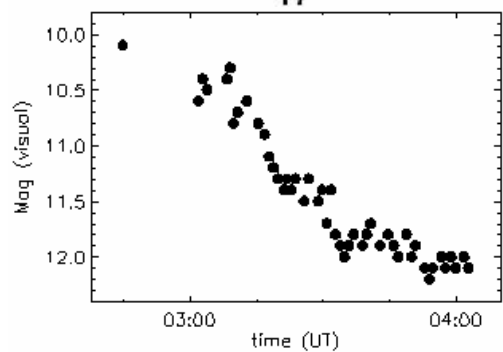
IMAGE PAGE 2



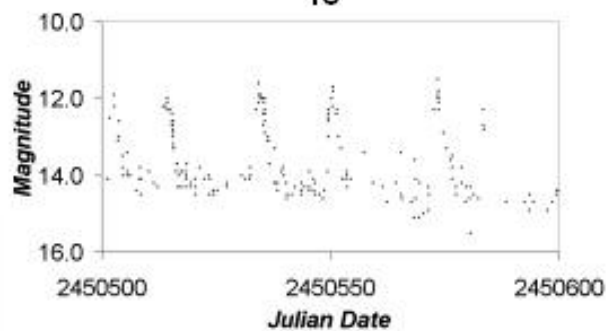
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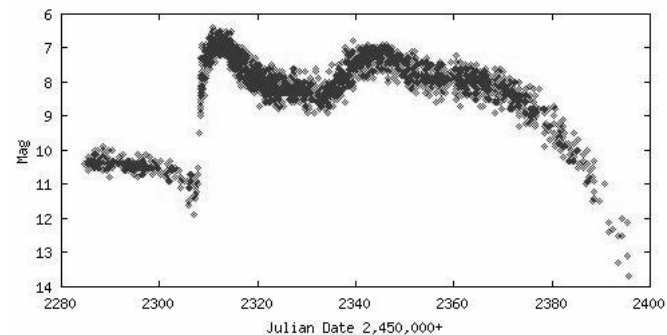
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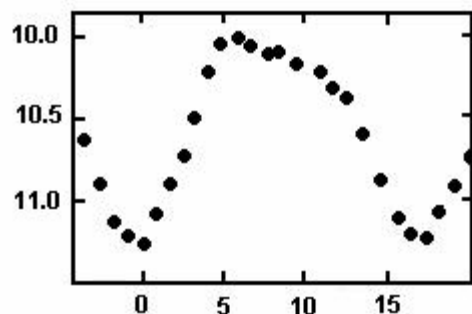
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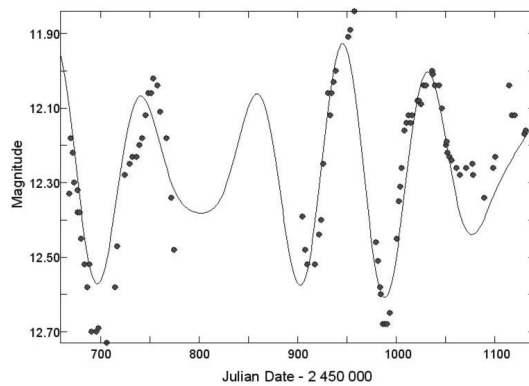
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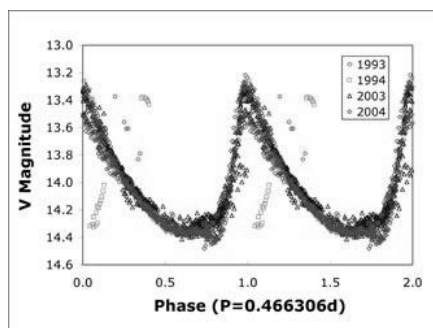
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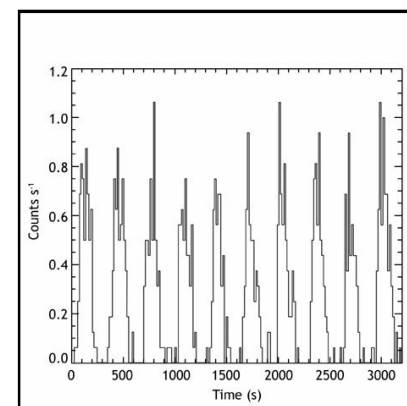
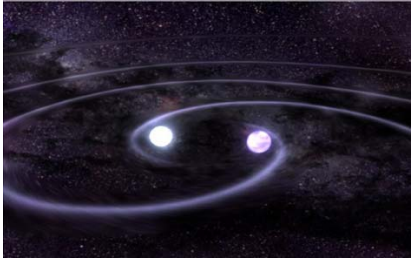
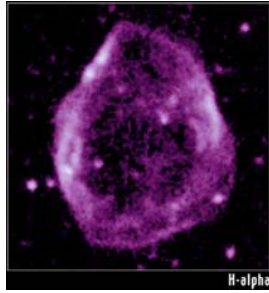


IMAGE PAGE 1

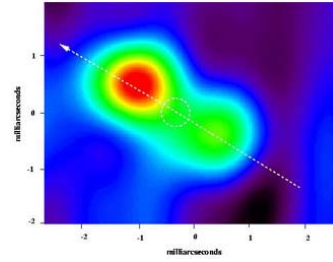
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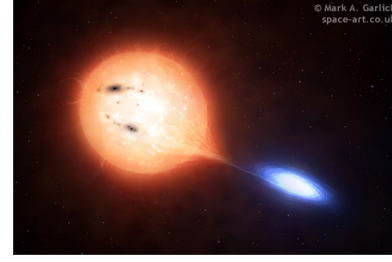
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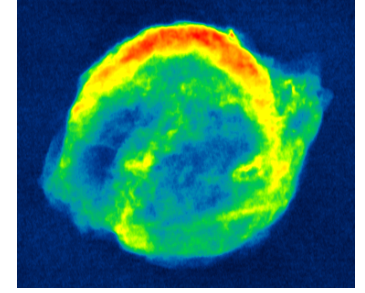
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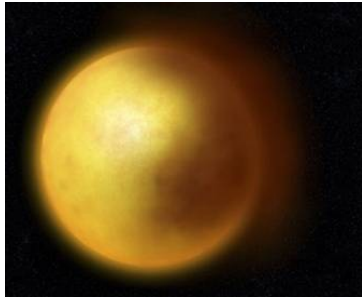
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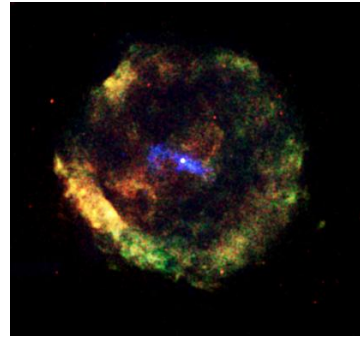
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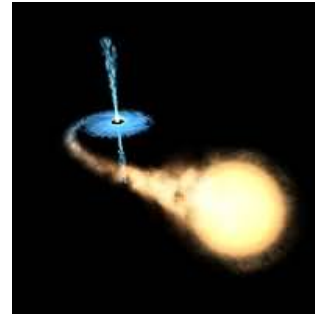
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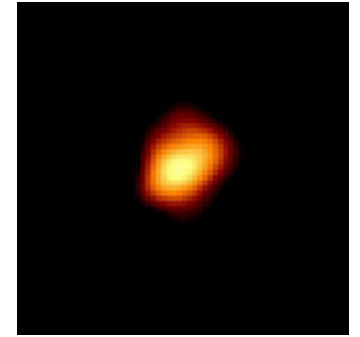
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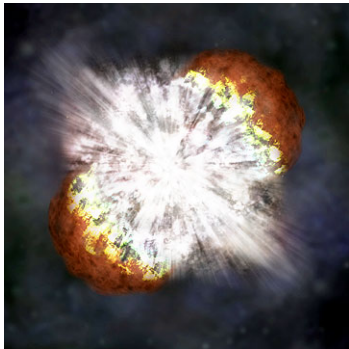
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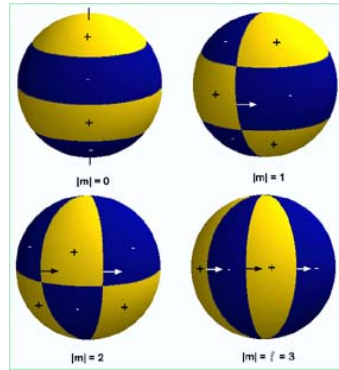
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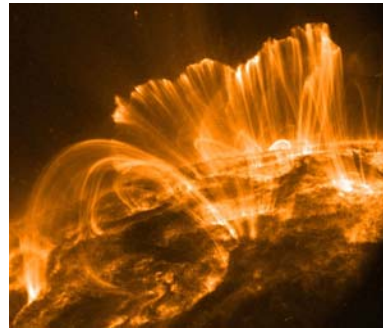
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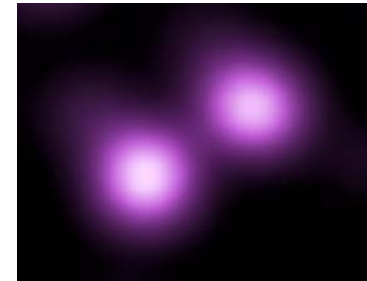
12



13



14



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 as well as a blank answer sheet.
2. You may separate the exam pages. Re-staple them as you submit your materials to the supervisor. Keep the answer sheet separate.
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. Include school name and school code number at the bottom of the answer sheet as well as on the title page. Indicate the names of the participants *legibly* at the bottom of the answer sheet. Be prepared to display your wristband to the supervisor when asked.
5. Point values for each question are in parentheses. 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 eight tiebreakers.
6. Pay close attention to the units given in the problem and the units asked for in the answer.
7. When the time is up, *the time is up*. Continuing to write after the time is up risks immediate disqualification.
8. The numbers used to refer to specific images are located *above* the associated image.
9. On the *back* of the answer sheet, name the gentleman depicted on the cover and note his major contribution to astronomy. 5 bonus points!
10. Nonsensical, mocking, or inappropriate answers **WILL RESULT IN DISQUALIFICATION.**
11. Use the following constants where applicable.

$$M_{\text{SUN}} = 2E30 \text{ kg}$$

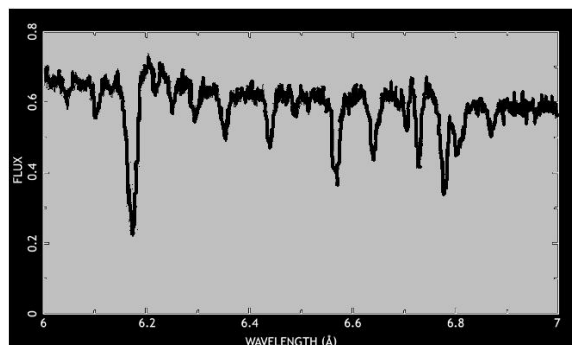
$$R_{\text{SUN}} = 696000 \text{ km}$$

$$L_{\text{SUN}} = 3.85E26 \text{ W}$$

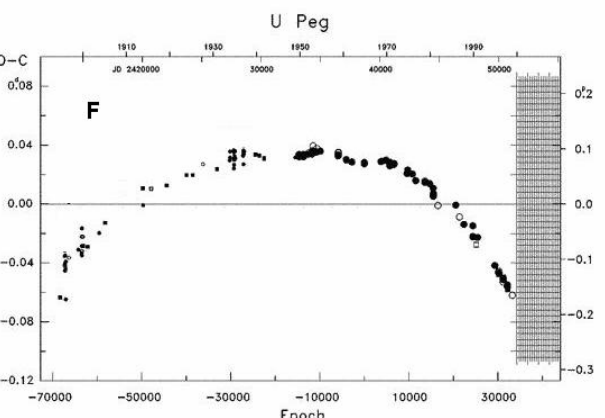
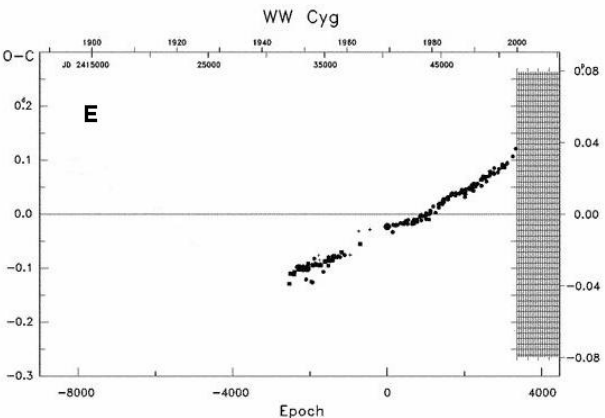
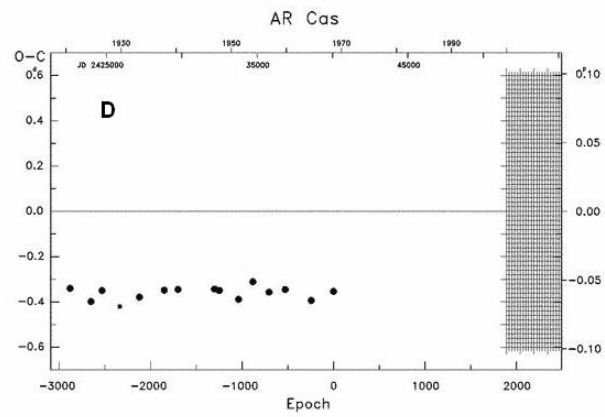
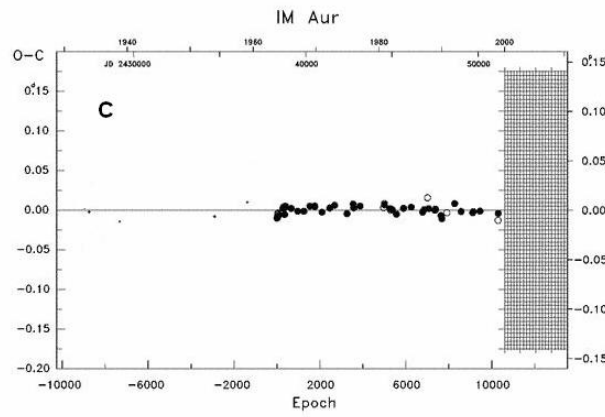
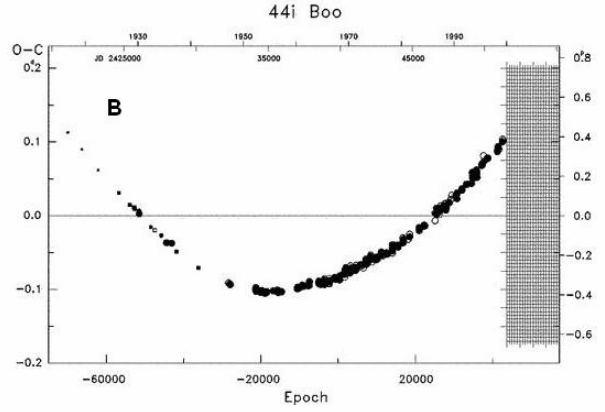
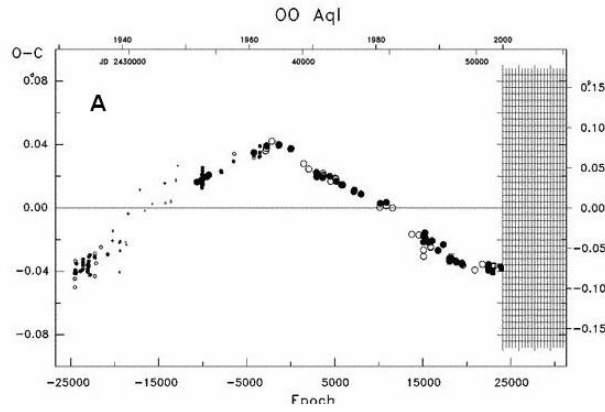
$$1 \text{ AU} = 1.5E11 \text{ m}$$

Questions 1-25 refer to image page 1, image page 2, and the DSO list as published in the Science Olympiad Student Manual.

- (2) 1. What is the name of the object in image 6 on image page 1? Which light curve from image page 2 is associated with it?
- (2) 2. Which two images on image page 1 show the remnants from type 1a supernovae?
- (2) 3. Which image on page 1 shows an R Coronae Borealis star? What is its name?
- (2) 4. Which image shows a flare star? Which image shows a close up of the flare mechanism?
- (2) 5. Image 11 shows an artist's conception of what particular event? Which DSO from the list would qualify as one of these?
- (1) 6. Roughly how massive is (or was) the object referred to in number 5?
- (1) 7. In what host galaxy (new general catalogue number) is the object referred to in number 5?
- (1) 8. Which image shows a microquasar?
- (2) 9. (T3) One of the objects on the DSO list has changed from a population II Cepheid into a semi-regular red giant in less than one hundred years. What object is it? Which light curve from image page 2 is associated with it?
- (1) 10. What is the object referred to in number 9 "doing" in terms of the HR diagram?
- (1) 11. What is the name of the DSO shown in image 1?
- (1) 12. What *should* be produced by the object in image 1 according to Einstein's general relativity?
- (1) 13. What is the orbital period of the objects shown in image 1?
- (2) 14. Which object on the DSO list is the prototypical population II Cepheid? Which light curve from image page 2 would be associated with it?
- (1) 15. What astronomer established the existence of populations I and II during World War II?
- (1) 16. Relative to its host galaxy, where would a population II star tend to be found?
- (1) 17. Which image shows an artists' conception of a dwarf nova?
- (2) 18. What object from the DSO list probably looks like the image referred to in number 17? Which light curve from image page 2 would be associated with it?
- (3) 19. (T8) What class of variable star is shown in image 10? Which DSO from the list is in this class? Which light curve from image page 2 is associated with it?
- (2) 20. What is the name of the object shown in image 8? What type of object is it?
- (1) 21. What is the name of the object from the DSO list that may show the modes of vibration in image 12?
- (1) 22. What is the name of the object shown in image 5?
- (1) 23. Which light curve from image page 2 would be associated with image 1 on image page 1?
- (1) 24. Which object from the DSO list is shown in image 2 on image page 1?
- (1) 25. From which object on the DSO list does the spectrum shown below originate?



Questions 26-30 refer to the following O-C diagrams.



(2) 26. In which graphs is the estimated period correct? C D

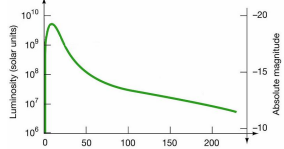
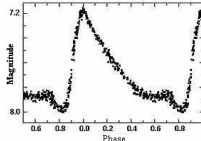
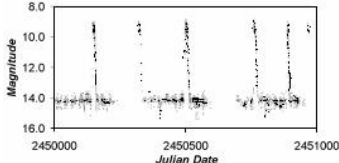
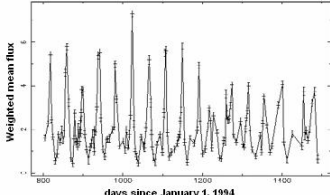
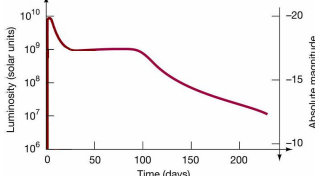
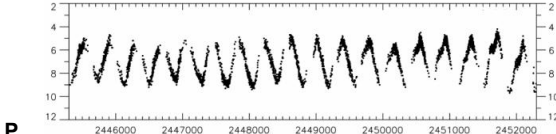
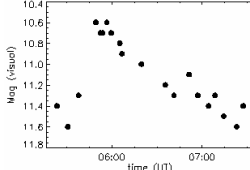

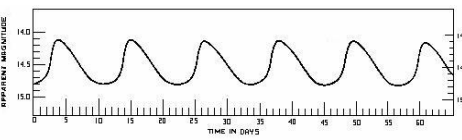
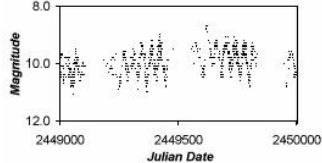
(1) 27. In which graph is the period increasing? B

(1) 28. In which graph is the period decreasing? F

(1) 29. In which graph is the period underestimated? E

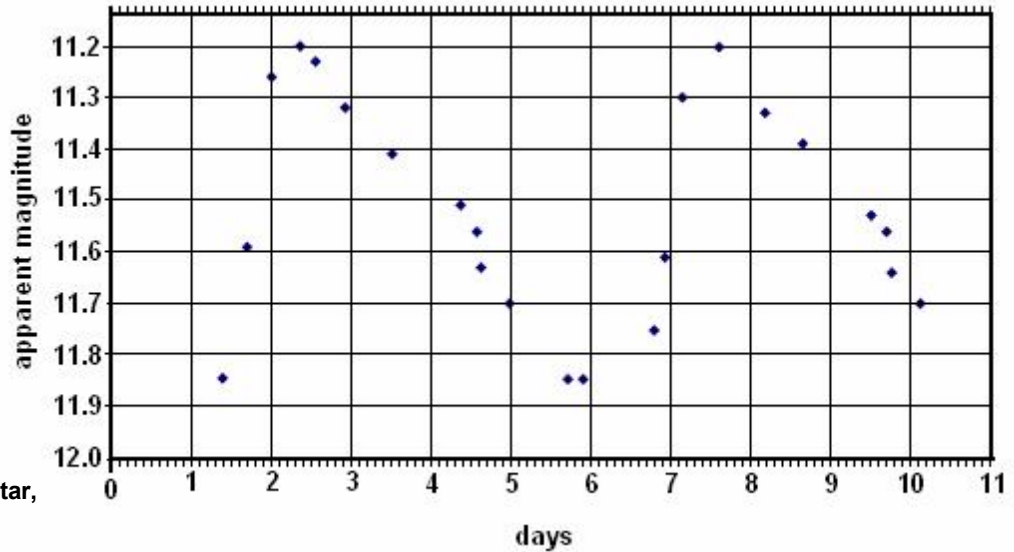
(1) 30. In which graph does the period change suddenly? A

There are three columns in the table below. In the first column there is a numbered list of variable star types. The second column lists a series of descriptions. The third column features a series of light curves. Associate a letter from each of the second and third columns with each numbered entry in the first column. Each associated letter is 1 point (so each number is worth two points); answers on the answer sheet should be in the form "X Y". Each letter is used only once.

31. Dwarf Novae	A. One of the components of the system is a hot compact object (white dwarf, neutron star, or possibly a black hole). Emission is caused by matter falling onto the compact object or its accretion disc, which then irradiates the companion star.	<p>K.</p> 
32. R Coronae Borealis	B. Red giants with emission spectra and well-defined periods from 80 to over 1000 days. Variations do not repeat exactly from one cycle to the next.	<p>L.</p> 
33. Cepheids	C. Close binary systems with an accretion disc around the white dwarf component. Outbursts from 2 to 9 magnitudes, lasting for a day or two, occur at quasi-periodic intervals of days to years.	<p>M.</p> 
34. Long Period Variables	D. Radially pulsating yellow to red supergiants with alternating primary and secondary minima.	<p>N.</p> 
35. RR Lyrae	E. Sudden catastrophic outburst of 20+ magnitudes in less than a week, caused by the total detonation of a white dwarf.	<p>O.</p> 
36. Type Ia Supernovae	F. Dim red dwarfs that can undergo unpredictable dramatic increases in brightness for a few minutes.	<p>P.</p> 
37. Type II Supernovae	G. Pulsating horizontal branch stars, with a mass of around half the Sun's.	<p>Q.</p> 
38. X-Ray Binaries	H. Hydrogen-poor, helium and carbon-rich stars showing small cyclic pulsations; and irregular fades up to 9 magnitudes lasting for weeks/months caused by carbon ejection.	<p>R.</p> 
39. RV Tauri	I. Sudden catastrophic outburst caused by the core collapse of a massive star.	<p>S.</p> 
40. Flare Stars	J. Radially pulsating white to yellow giants with variations up to 2 magnitudes and periods from 1 to over 100 days.	<p>T.</p> 

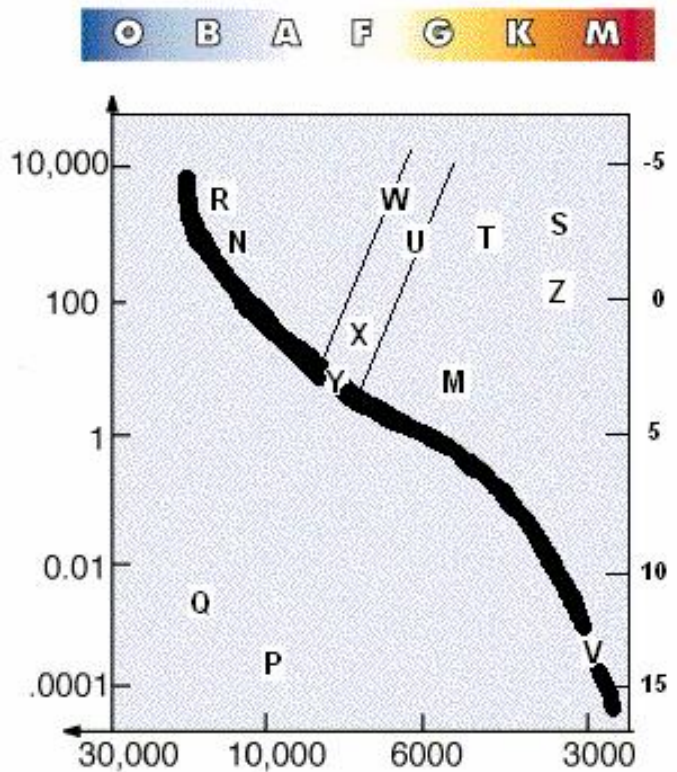
The image at below right shows a light curve from a variable star. Use the graph for questions numbered 41 - 48.

- (1) 41. What is the apparent magnitude of this star at maximum?
- (1) 42. What is the apparent magnitude of this star at minimum?
- (2) 43. What is the period of this star's pulsation?
- (1) 44. Based on the period, what type of variable star is this?
- (2) 45. What is the mean absolute magnitude of this star?
- (2) 46. (T2) What is the luminosity of this star, in solar luminosities?
- (2) 47. (T4) What is the distance to this star in parsecs?
- (2) 48. What is the distance to this star in light years?



Questions numbered 49 – 64 refer to the HR diagram shown.

- (1) 49. What are the units across the bottom of the diagram?
- (1) 50. What are the letters across the top of the diagram?
- (1) 51. What are the units on the left side of the diagram?
- (1) 52. What are the units on the right side of the diagram?
- (1) 53. Where would you find a δ -Scuti star?
- (1) 54. Where would you find a β -Cephei star?
- (1) 55. Where would you find a classical Cepheid?
- (1) 56. Where would you find an RR-Lyrae star?
- (1) 57. Where would you find an RV-Tauri star?
- (1) 58. (T5) Where would you find a ZZ Ceti star?
- (1) 59. Where would you find a flare star?
- (1) 60. Where would you find a long-period variable?
- (1) 61. Where would you find a slowly pulsating B star?
- (1) 62. Where would you find a W-Virginis star?
- (1) 63. Where would you find a solar-mass T-Tauri star?
- (1) 64. What is the name of the region bound by the diagonal lines and containing regions X, Y, W and U?



For problems 65 – 80, choose from the following options. The number of points available for each number indicates the number of correct responses.

A. RV Tauri	B. T-Tauri	C. Mira type	D. Type Ia SN
E. RR Lyrae	F. Dwarf novae	G. Recurrent novae	H. Classical novae
I. Classical Cepheids	J. BY Draconis	K. W Virginis	L. δ -Scuti
M. β -Cephei	N. UV Ceti	O. Z Andromedae	P. ZZ Ceti
Q. R Coronae Borealis	R. Type II SN	S. S Doradus	T. Wolf-Rayet

- (8) 65. In which of the options listed above is the variability due to pulsation only?
- (6) 66. In which of the options listed above is the variability cataclysmic?
- (3) 67. In which of the options listed above is the variability eruptive?
- (1) 68. In which of the options listed above is the variability eruptive and pulsating?
- (2) 69. In which of the options listed above is the variability due to rotation?
- (2) 70. A red dwarf with variability due to cool spots *and* flare activity could belong to which two classes?
- (1) 71. Stars in this class lie in the region where the instability strip crosses the main sequence.
- (1) 72. Stars in this class are pulsating white dwarfs with short periods of up to 30 minutes.
- (1) 73. Stars in this class are hot, massive, and luminous, and show mass loss and strong stellar winds.
- (1) 74. Stars in this class are also known as “Population II Cepheids.”
- (1) 75. Stars in this class are hot enough for the opacity of iron to drive the pulsation mechanism.
- (1) 76. (T6) Stars in this class can display the Blazhko Effect, a modulation of the amplitude of the lightcurve.
- (1) 77. Stars in this class are pulsating red giants with visual amplitudes greater than 2.5.
- (1) 78. Stars in this class demonstrate sudden *decreases* in brightness superimposed on a pulsation period.
- (1) 79. The spectra of this cataclysmic variable has virtually *no* hydrogen lines present.
- (1) 80. Stars in these close binary systems are also called “U Geminorum” stars.

Use the following information for questions numbered 81 – 89.

A particular binary system consists of a main-sequence star (A) and what is commonly called a “compact object” for a companion (B). The following information is available about star A: its apparent magnitude is 0.11, its parallax is 425 milliarcseconds, and the peak wavelength of its radiation is 255 nm. Object B has a Schwarzschild radius of 28.4 km. The system has an orbital period of 11.087 days at a separation distance of 0.29 AU.

- (2) 81. What is the surface temperature of star A?
- (2) 82. What is the distance to the system in parsecs?
- (1) 83. What spectral class is star A?
- (2) 84. (T1) What is the absolute magnitude of star A?
- (2) 85. What is the luminosity of star A, in solar?
- (2) 86. (T7) What is the mass of the system in solar masses?
- (2) 87. What is the mass of the compact object (B) in solar masses?
- (2) 88. What is the mass of star A in solar masses?
- (2) 89. What is the compact object, and how do you know?