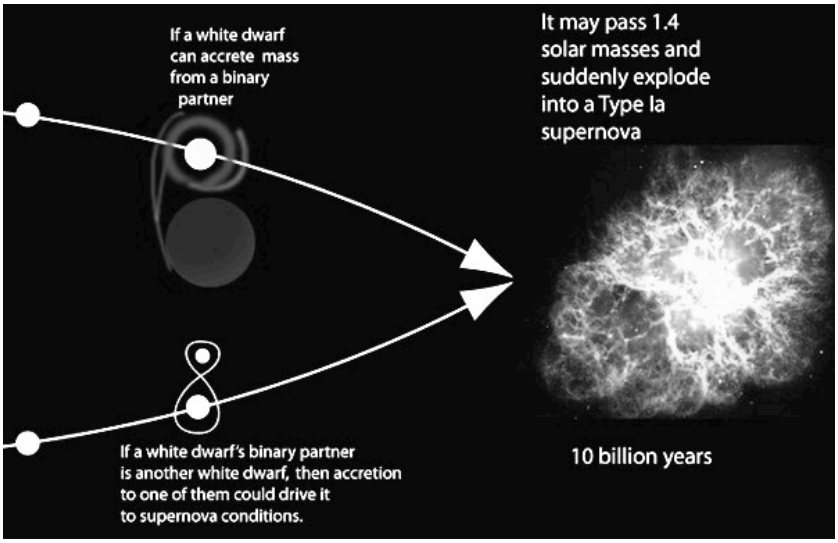
Pennsylvania Science Olympiad

SCIENCE OLYMPIAD™

REGIONAL TOURNAMENT 2017

ASTRONOMY C DIVISION EXAM



SCHOOL:_____ **TEAM NUMBER:**_____

NAMES:_____

_____

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. You may write in the exam.

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

4. Include school name and school code number at the bottom of the answer sheet. 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. 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 12 tiebreakers.

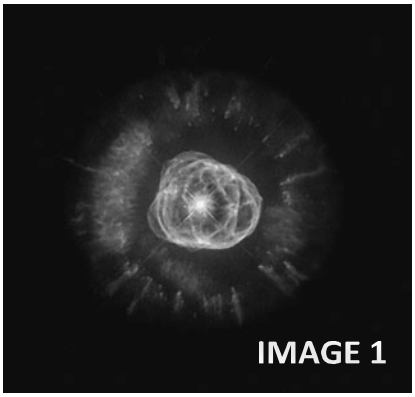
6. When the time is up, *the time is up*. Teams continuing to write after the time is up will incur a penalty of 10 points.

7. As per the 2017 Division C Rules Manual, each team is permitted to bring "either two computers (of any kind) OR two 3-ring binders of any size, or one binder and one computer" and programmable calculators.

8. In the bonus box on the answer sheet, write the name of the gentleman shown on the cover of the exam. Correct response is worth a bonus point.

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

Questions 1-25 refer to the objects listed in section 3c, page C2, of the 2017 Science Olympiad Division C Rules Manual. "Identify, know the location and answer questions relating to the content areas for the following objects."



1. Which object is shown in image 1?

- **A. Omicron Ceti**
- **B. NGC 2392**
- **C. Tycho's SNR**
- **D. NGC 2440**
- **E. Hen 2-428**

2. What is another designation for the object in image 1?

- **A. Eskimo nebula**
- **B. SN 1572**
- **C. Stingray nebula**
- **D. Mira**
- **E. ARO 186**

3. The object in image 1 belongs to a particular class of astronomical objects. Why is the term for these objects erroneous and potentially misleading?

- **A. The class is called "supernova remnants" and there was no supernova associated with this object**
- **B. The class is called "nova," which means "new," but the star is actually very old**
- **C. The class is called "condensation nebula" and the object is expanding, not condensing**
- **D. The class is called "planetary nebula" and has nothing to do with planets**
- **E. The class is called "protoplanetary disk" and there is no evidence of planet formation**

4. Which object is shown in image 2?

- **A. NGC 1846**
- **B. NGC 2440**
- **C. Hen 2-428**
- **D. M15**
- **E. SS Cygni**

5. The stars in objects like that shown in image 2 tend to be:

- **A. Old and metal-poor**
- **B. Old and metal-rich**
- **C. Young and metal-poor**
- **D. Young and metal-rich**

(T2) 6. Objects such as that shown in image 2 tend to be found:

- **A. in the galactic bulge, close to the galactic center**
- **B. in the galactic disk, far from the galactic center**
- **C. in the galactic halo, far from the galactic center**
- **D. in star-forming regions associated with molecular clouds**
- **E. in the Kuiper belt**

7. Image 3 shows parts of the spectra from 3 discrete objects. What type of object produces this spectrum?

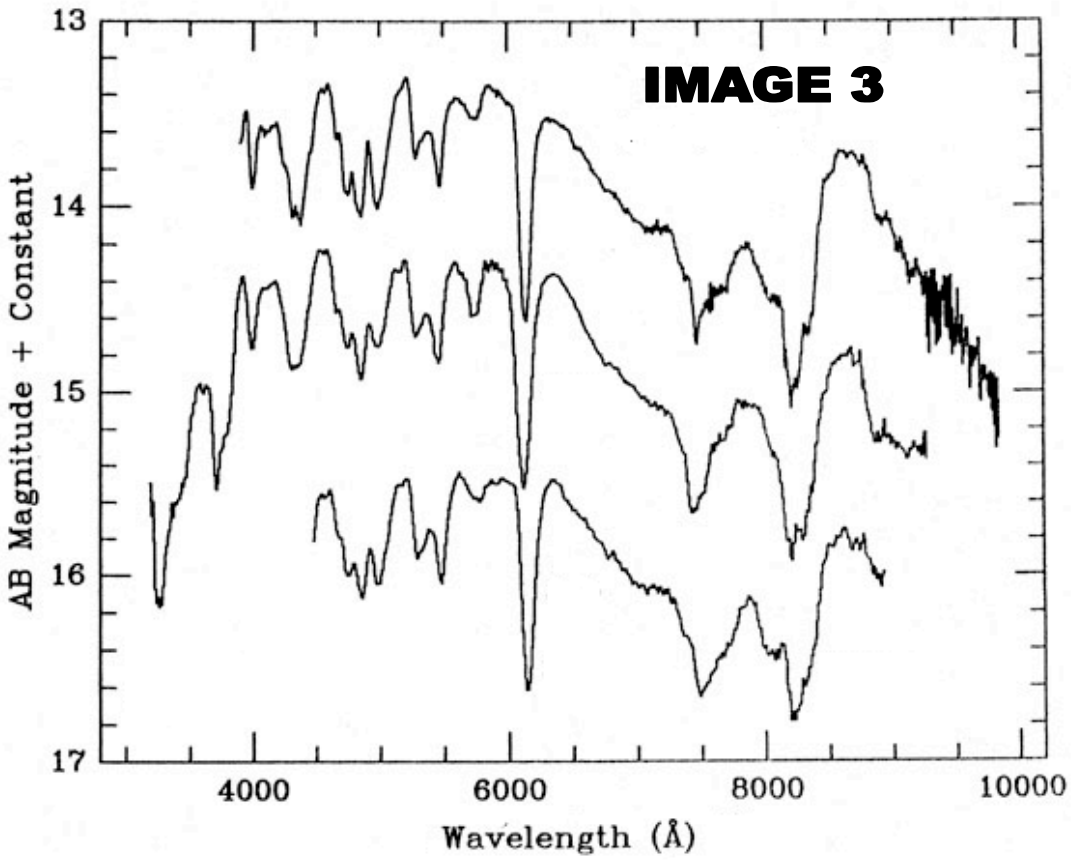
A. Dwarf nova outburst
B. Type Ia supernova
C. Accretion disk instability
D. Emission nebula
E. Globular cluster

(T6) 8. What does the significant absorption feature at just above 6000 Å indicate?

A. Singly ionized silicon absorption
B. Hα absorption
C. Cobalt 56 absorption
D. Early ionization states of iron
E. Forbidden nitrogen absorption

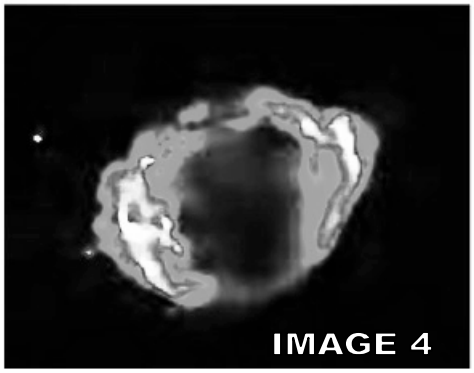
9. Which of the following best describes the light curve associated with objects of this type?

A. Consistent, slow increase in luminosity as the molecular cloud collapses
B. Periodic increases of 2-6 magnitudes over one or two days, followed by return to original magnitude
C. "Normal" outbursts (increases in magnitude) interspersed with "supermaxima"
D. Rise to maximum over about 20 days, followed by a rapid decline, which then flattens out
E. These objects don't have "light curves" in the traditional sense; their luminosity is unchanging



10. Which of the following objects could be classified as U Geminorum?

A. SS Cygni
B. Hen 3-1357
C. J075141
D. Omicron Ceti
E. NGC 2392



11. Which object is shown in image 4?

A. SNR 0509-67.5
B. Tycho's SNR
C. SNR G1.9+0.3
D. Hen 3-1357
E. HM Cancri

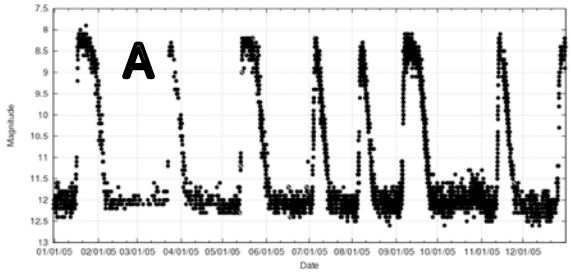
12. What would you expect to happen to this object into the distant future?

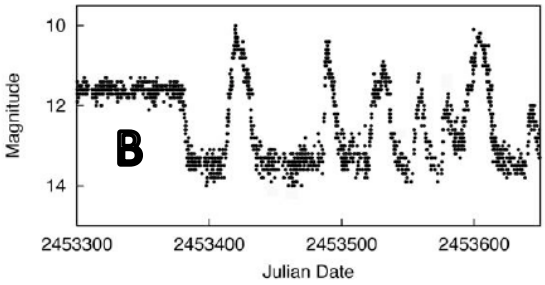
A. The object will condense and get brighter
B. The object will condense and get dimmer
C. The object will expand and get brighter
D. The object will expand and get dimmer
E. The object will remain static in its current state

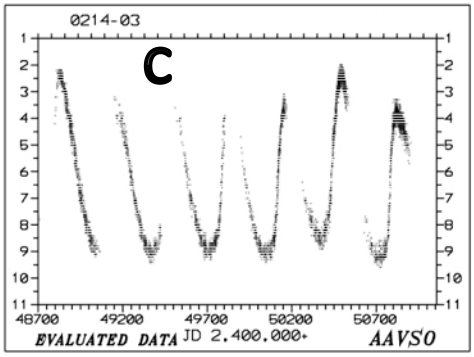
(T10) 13. What wavelength is image 4?

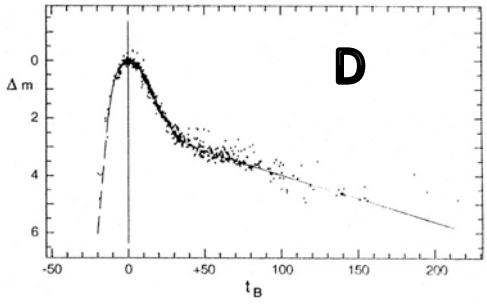
A. near infrared
B. far infrared
C. UV
D. radio
E. X-ray

14. One of the images shown below indicates the light curve for Omicron Ceti. Which is it?

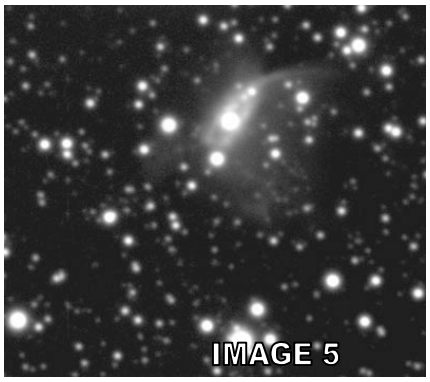








15. Which object is shown in image 5?



A. NGC 2440
B. SN 2011fe
C. M15
D. NGC 1846
E. Henize 2-428

16. What is the best description for the object shown in image 5?

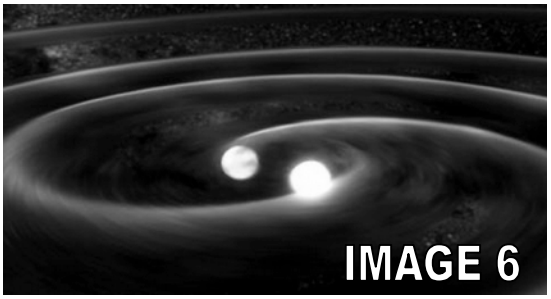
A. Double degenerate type Ia supernova precursor
B. Young type Ia supernova remnant
C. U Geminorum dwarf nova
D. Z Camelopardalis dwarf nova
E. Symbiotic main sequence star with accreting white dwarf companion

17. Which of the following objects was discovered in the Pinwheel galaxy?

A. SNR G1.9+0.3
B. SN 2011fe
C. J174140
D. Hen 3-1357
E. HM Cancri

18. Image 6 shows an artist's rendering of which of the following objects?

A. SS Cygni
B. HM Cancri
C. Omicron Ceti
D. Hen 2-428
E. J075141



19. What is indicated by the spiral lines emanating from each of the objects in image 6?

A. Synchrotron radiation
B. X-ray pulses
C. Shock waves
D. Gravitational waves
E. Mass loss due to tidal stripping

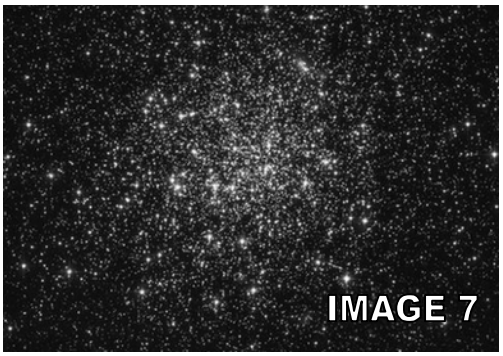
20. What is the orbital period of the objects shown in image 6?

A. 5 seconds
B. 5 minutes
C. 5 hours
D. 5 days
E. 5 years

21. Which of the following descriptions does not apply to Omicron Ceti?

A. It is a symbiotic system with mass transfer
B. Its magnitude changes by a greater amount in infrared than in visible light in one cycle
C. It is a prototypical long period variable
D. It has a white dwarf companion
E. It is on the asymptotic giant branch of the HR diagram

22. Which object is shown in image 7?



- **A. Hen 3-1357**
- **B. NGC 2392**
- **C. M15**
- **D. NGC 2440**
- **E. NGC 1846**

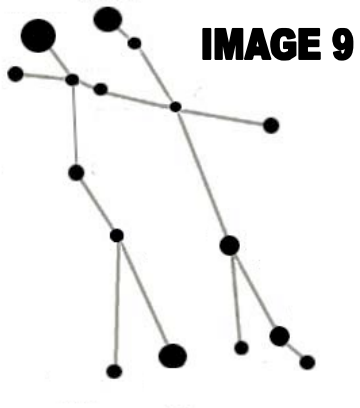
23. What is unusual about the object shown in image 7?

- **A. It is the youngest known planetary nebula**
- **B. The expansion velocity of its inner region is more than double the typical value**
- **C. It appears to have two distinct stellar populations of different ages**
- **D. It contains a double neutron star system**
- **E. The white dwarf at its center is among the hottest known**

24. What is the significance of the letters "fe" in the designation of SN 2011fe?

- **A. Iron is present in the spectrum**
- **B. It was the 161st supernova reported in 2011**
- **C. It was the 30th supernova reported in 2011**
- **D. The spectrum has "forbidden energy" levels in it**
- **E. The light curve has a "fast" rise and "exponential" decay**

25. Which object appears in the constellation shown in image 9?



- **A. NGC 2440**
- **B. SNR 0509-67.5**
- **C. SN 2011fe**
- **D. SNR G1.9+0.3**
- **E. NGC 2392**

Questions 26-60 refer to the concepts listed in section 3a, page C2, of the 2017 Science Olympiad Division C Rules Manual.

26. Stellar evolution refers to which of the following?

A. The effects of the changing chemical compositions of sequential stellar populations
B. The various spectral types or "species" of star
C. The changes undergone by an individual star throughout its existence
D. The differences we observe in stars as a function of their distance from the Earth
E. The central role of solar (or stellar) energy in the process of biological evolution

27. Which of the following classes of stars is a part of the main sequence?

A. red dwarfs **B. white dwarfs** **C. brown dwarfs** **D. black dwarfs** **E. blue subdwarfs**

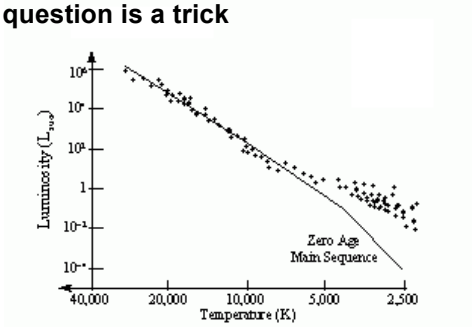
28. A star is described as B9IV. Which of the following best describes the star?

A. A hot white dwarf with a mass somewhat less than the sun
B. A hot blue subgiant
C. A cool giant at the tip of the asymptotic giant branch
D. A relatively cool subdwarf
E. A hot luminous supergiant

(T3) 29. Why is the post-main sequence behavior of a red dwarf based on purely theoretical models?

A. Red dwarf stars have a main sequence lifetime longer than the age of the universe
B. Red dwarf stars are too dim to observe directly
C. Red dwarf stars are relatively low mass, and burn their hydrogen too quickly to observe changes
D. Red dwarf stars tend to be parts of young, loose associations and are shrouded in dust and gas
E. Red dwarf stars are not part of the main sequence, so this question is a trick

30. Consider the HR diagram shown at right. The Main Sequence is indicated by the solid line, and individual stars are indicated by crosses. Why are the stars on the right side of the diagram above the Main Sequence?



A. These stars have burned all their hydrogen and are leaving the Main Sequence
B. These stars are entering the horizontal branch
C. These stars are moving left and up in the diagram as they gather more mass and get hotter and brighter
D. These stars are moving left and down in the diagram and have not yet reached the Main Sequence
E. These stars will never reach the Main Sequence because they are not massive enough

31. Below is the spectrum from a star (violet is on the left, red on the right). To which spectral class does the star belong?

O B A F G K M

32. Why are the hydrogen absorption lines weak (or moderate) in the visible spectrum from a B-class star?

A. There is very little hydrogen in B-class stars
B. Most of the hydrogen in B-class stars is ionized
C. Most of the hydrogen in B-class stars is molecular hydrogen
D. The hydrogen in B-class stars is concentrated in the interior, and it is surrounded by heavier elements
E. The hydrogen produces an emission spectrum rather than an absorption spectrum

33. Star A has a lesser B-V color index than star B. Both stars are on the main sequence. Which of the following is true?

A. Star A is hotter and more massive than star B
B. Star A is hotter and less massive than star B
C. Star B is hotter and more massive than star A
D. Star B is hotter and less massive than star A
E. The color index does not provide enough information about temperature or mass

34. When a very massive (> 10 $M_{\odot}$) leaves the main sequence, it:

A. moves to the right and up on the HR diagram
B. moves to the right and down on the HR diagram
C. moves directly to the right on the HR diagram
D. moves directly up on the HR diagram
E. immediately explodes in a supernova explosion

(T12) 35. As a protostar moves along the Hayashi track:

A. its luminosity and temperature both increase significantly
B. its luminosity and temperature both decrease significantly
C. its luminosity and temperature both remain the same
D. its luminosity decreases but its temperature remains the same
E. its luminosity remains the same but its temperature decreases

36. It its lifetime, when does a one solar-mass star become a red giant?

A. One-solar mass stars do not have a red giant stage
B. Before the star reaches the main sequence
C. When the white dwarf remnant cools and moves to the right on the HR diagram
D. Between the main sequence and the planetary nebula stages
E. Between the planetary nebula and the white dwarf stages

(T7) 37. A TP-AGB star is undergoing:

A. helium shell flashes
B. main sequence turnoff
C. runaway thermonuclear carbon fusion
D. radial pulsation due to the κ mechanism
E. expulsion of its outer layers as a protoplanetary nebula

38. Which of the following designations is used for pulsating white dwarf stars with spectral type DAV?

A. ZZ Ceti
B. PNNV
C. GW Vir
D. RV Tauri
E. β Cep

39. Which team of astronomers devised a classification scheme for globular clusters?

A. Shapley and Sawyer
B. Pickering, Draper, and Fleming
C. Baade and Zwicky
D. Hewish and Bell
E. Morgan and Keenan

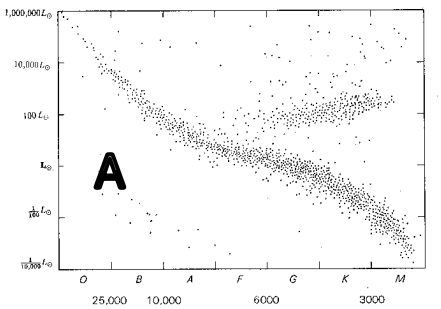
40. What is the classification scheme referred to in #39 based on?

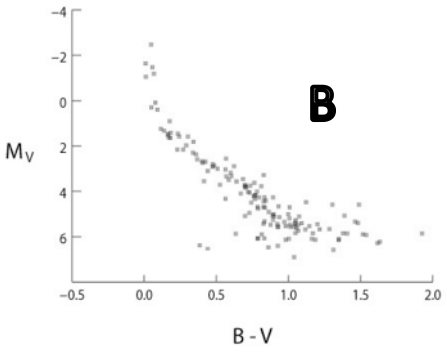
A. Ellipticity of the cluster
B. Age of the cluster
C. Metallicity of the stars in the cluster
D. Central star concentration of the cluster
E. Apparent magnitude of the cluster

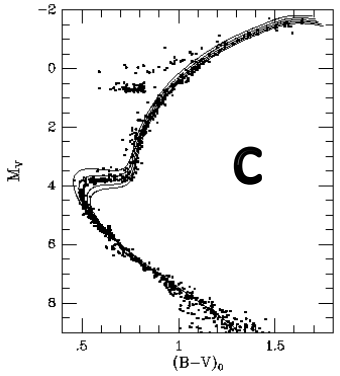
41. Which of the following types of stars were known as "cluster variables" because of their prevalence in globular clusters?

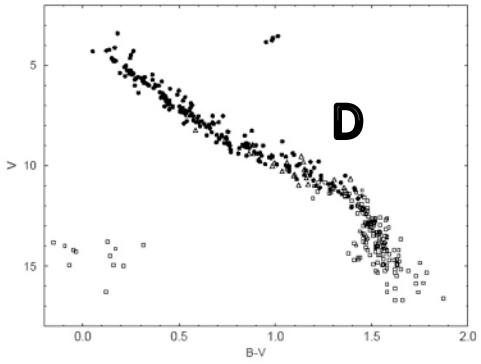
A. Cepheid
B. RR Lyrae
C. Recurrent Novae
D. U Geminorum
E. Mira

42. Which of the following HR diagrams was produced by observation of a globular cluster?









43. The stars in a typical globular cluster are likely to have:

A. different ages and different chemical compositions
B. the same age and different chemical compositions
C. different ages and the same chemical composition
D. the same age and the same chemical composition

Questions 44 – 46: Match the numbered variations of neutron stars to the lettered description.

44. Rotating Radio Transient	**A. Radio-quiet, non-pulsating x-ray source**
45. Anomalous x-ray pulsar	**B. Sporadic emission with high pulse-to-pulse variability**
46. Central compact object in SNR	**C. Young, isolated magnetar**

(T8) 47. Which astronomer coined the term "planetary nebula"?

A. Tycho Brahe
B. William Huggins
C. Boris Vorontsov-Velyaminov
D. Charles Messier
E. William Herschel

48. What is typically the brightest emission line in the spectrum from a planetary nebula?

A. Hydrogen-α at 656.3 nm
B. Doubly-ionized oxygen at 500.7 nm
C. Singly-ionized helium at 468.6 nm
D. Singly-ionized magnesium at 448.1 nm
E. Doubly-ionized sodium at 589.6 nm

49. The planetary nebula stage of a star's evolution tends to be _____ its main sequence lifetime.

A. much shorter than
B. a little shorter than
C. roughly equal to
D. a little longer than
E. much longer than

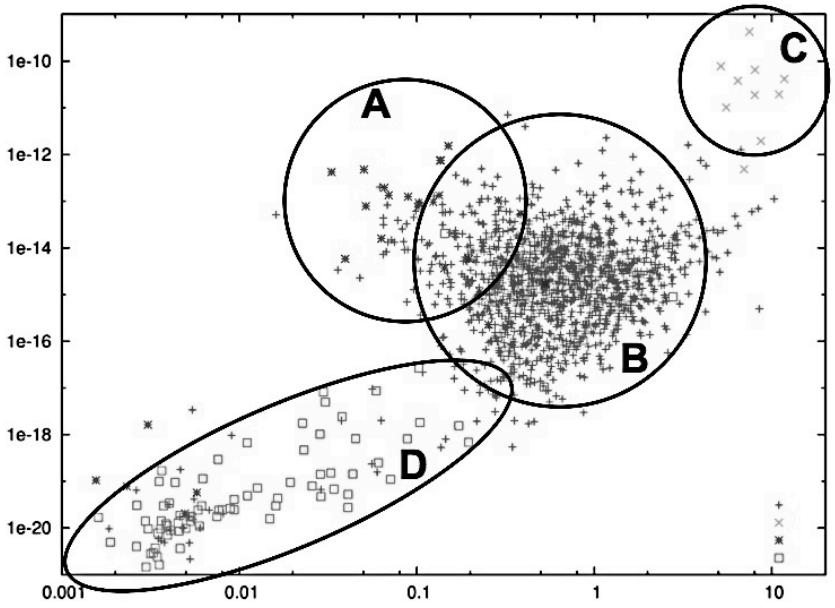
50. What makes the gas shell in a planetary nebula shine?

A. Conversion of gravitational energy into radiation
B. Friction between particles of the gas
C. Ionization from the radiation of the central star
D. Collisions between the gas and the stellar wind
E. The gas is still fusing hydrogen

51. A planetary nebula with class 2b would best be described as:

A. a ring-like structure
B. a smooth disk, brighter toward the center
C. a smooth disk with uniform brightness
D. an irregular shape
E. a stellar appearance

Consider the diagram shown below. Use this information for questions numbered 52 – 55.



(T4) 52. Which quantity is displayed on the vertical axis of this plot?

A. pressure B. angular momentum C. spin-down rate D. magnetic field E. period

53. Which quantity is displayed on the horizontal axis of this plot?

A. pressure B. angular momentum C. spin-down rate D. magnetic field E. period

54. What type of object would be found in the oblong region marked D?

A. white dwarf stars
B. symbiotic systems
C. AM CVn systems
D. dwarf novae
E. binary pulsars

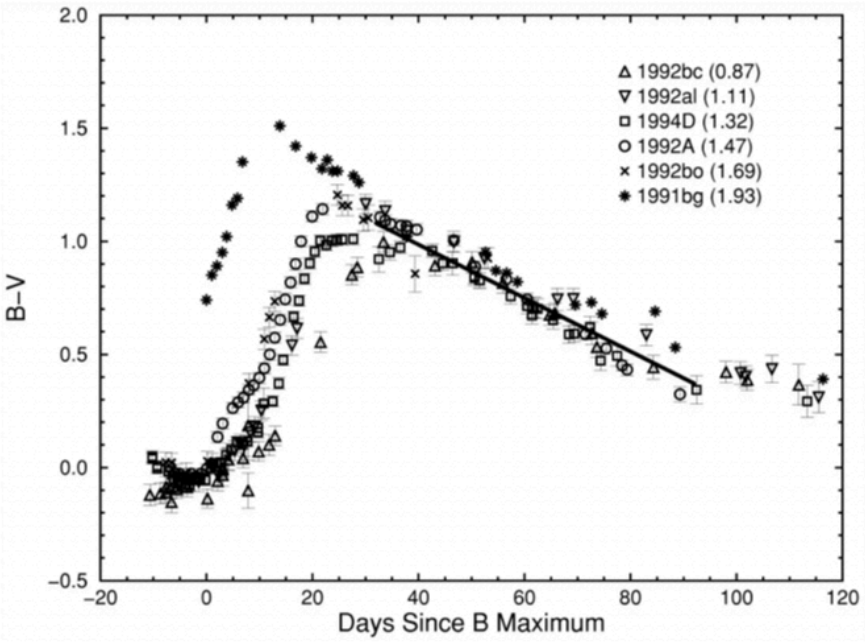
55. What type of object would be found in the region marked C?

A. Mira-type stars
B. protoplanetary nebulae
C. isolated magnetars
D. symbiotic systems
E. preon stars

56. What causes the pulses that caused particular objects to be named "pulsars"?

A. Radial pulsation modes in the star's outer layers
B. Periodic thermal instabilities in an accretion disk
C. Synchrotron radiation of charged particles in a strong magnetic field around a compact object
D. A neutron star's rotation axis and magnetic poles are misaligned
E. Eclipses of photometric binaries including a compact object

Consider the graph shown below for questions 57 - 59. The various objects plotted in the graph are supernovae.



57. What is shown in the graph as a function of time?

A. ejection speed
B. color
C. absolute magnitude
D. apparent magnitude
E. interstellar extinction

58. The "best fit" line applies to the interval from 30 days to 90 days "since B maximum." What trend is indicated by this best fit line?

A. The magnitude of the supernova is decreasing
B. The magnitude of the supernova is increasing
C. The supernova is getting "bluer"
D. The supernova is getting "redder"
E. The supernova ejecta is slowing down

59. The supernovae in the graph were chosen because they "likely suffered little or no reddening." Which of the following locations for a supernova would most likely NOT have been chosen?

A. In a globular cluster
B. In a small elliptical galaxy
C. In the extended halo of a large elliptical galaxy
D. In the arms of a spiral galaxy
E. In the halo of a spiral galaxy

60. Why might Type Ia supernovae NOT be the standard candle that has been assumed until about a decade ago?

A. The model that relates peak magnitude and decline rate
B. The effect of reddening is very difficult to quantify systematically
C. The range of magnitudes at peak brightness has been underestimated
D. Models of the Chandrasekhar limit have shown that the deflagration wave is prohibited
E. Most Type Ia supernovae probably originate with double-degenerate progenitors

Questions 61-75 refer to the concepts listed in section 3b, page C2, of the 2017 Science Olympiad Division C Rules Manual.

M87 is a supergiant elliptical galaxy located in the constellation Virgo. It has an absolute magnitude of -21.5 and an apparent magnitude of 9.59. Use this information for questions 61 – 65.

(T5) 61. What is the distance modulus for M87?

A. 31.09 B. 11.91 C. 0.446 D. -31.09 E. 2.24

62. How far away is M87?

A. 12.3 pc B. 28.1 pc C. 0.0415 pc D. 16.5 Mpc E. 2.41 kpc

63. Assuming Hubble's constant is 67 km/s/Mpc, what is the recessional velocity of M87?

A. 16.1 km/s B. 1110 km/s C. 40.6 km/s D. 8230 km/s E. 1880 km/s

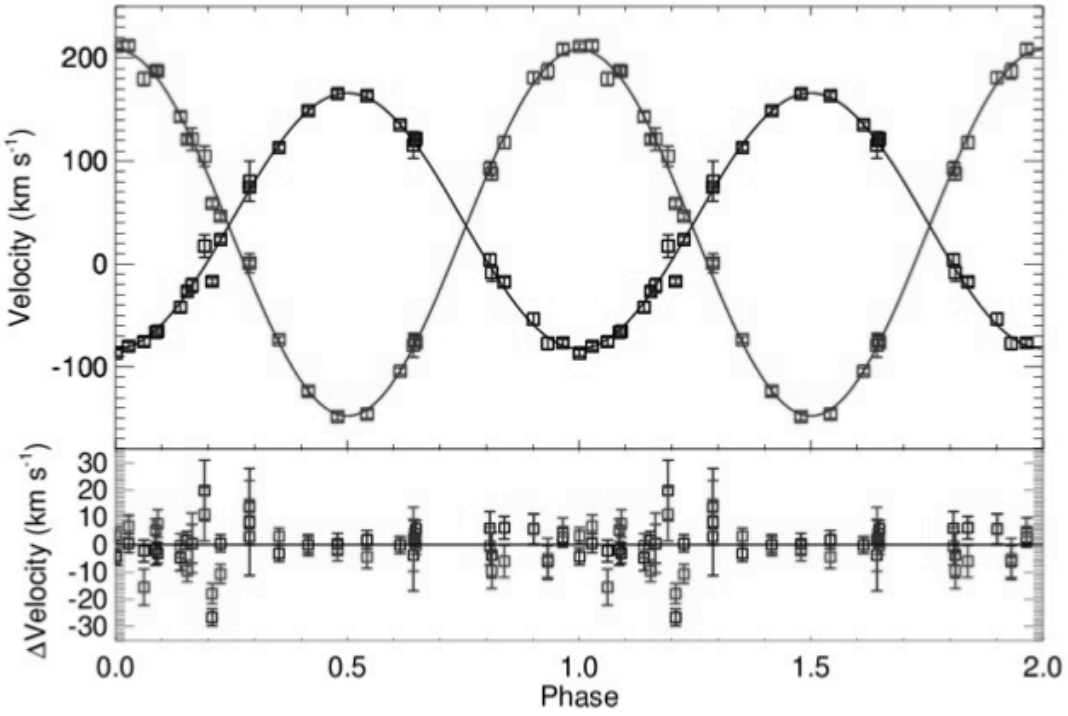
64. What would be the apparent magnitude of a type Ia supernova that appeared in M87?

A. -19.3 B. 11.8 C. 7.39 D. -21.5 E. 8.62

65. A spectral line in type Ia supernovae normally appears at 635.5 nm. Where would this line appear in the M87 supernova?

A. 653.0 nm B. 639.5 nm C. 637.9 nm D. 633.1 nm E. 618.0 nm

Consider the graph shown below. The plot indicates radial velocity vs. phase for the binary white dwarf system WD 1242-105. The stars in this system orbit each other with a period of 2.85 hours. The more massive star has a mass of $0.56M_{\odot}$, and the other has a mass of $0.39M_{\odot}$. Use this graph for questions 66 – 71.



66. What is the recessional velocity of WD 1242-105?

A. 175 km/s B. 150 km/s C. 220 km/s D. 40 km/s E. 80 km/s

(T1) 67. What is the orbital separation of the stars, in km?

A. 851 km B. 5.71E6 km C. 7.72E6 km D. 4.72E4 km E. 6.93E5 km

68. Where is the center of mass of the system, measured from the more massive star?

A. 350 km B. 2.34E6 km C. 3.17E6 km D. 1.94E4 km E. 2.84E5 km

69. What is the *apparent* orbital velocity of the more massive star?

A. 120 km/s B. 150 km/s C. 220 km/s D. 40 km/s E. 175 km/s

(T11) 70. What is the *actual* orbital velocity of the more massive star?

A. 120 km/s B. 150 km/s C. 220 km/s D. 40 km/s E. 175 km/s

71. What is the inclination of the orbit to the line of sight?

A. 0° B. 90° C. 45° D. 30° E. 60°

Pulsar J1301+0833 produces a signal 544 times each second. Use this data for questions 72 and 73.

72. What is the rotational period of J1301+0833?

A. 0.0907 ms B. 1.84 ms C. 2.19 ms D. 9.07 ms E. 544 ms

(T9) 73. What is the maximum diameter of J1301+0833?

A. 551 km B. 658 km C. 2720 km D. 958 km E. 456 km

A sun-like star collapses into a neutron star. To simplify calculations, assume the star does not experience any mass loss during the collapse. The star (before the collapse) has a mass of 2E30 kg and a radius of 6E5 km, and rotates once every 25 days. After the collapse, the neutron star has a radius of 30 km.

The rotational inertia of a solid sphere is $\frac{2}{5}mR^2$

74. What is the angular momentum of the star before the collapse?

A. 2.01E43 kg m^2/s
B. 2.01E43 kg m^2/s
C. 8.38E35 kg m^2/s
D. 8.38E41 kg m^2/s
E. 4.80E37 kg m^2/s

75. What is the angular velocity of the neutron star after the collapse?

A. 2.79E4 rad/s
B. 2.79E-2 rad/s
C. 6.67E-2 rad/s
D. 1.16E3 rad/s
E. 1.16E-3 rad/s