Exploring the World of Science

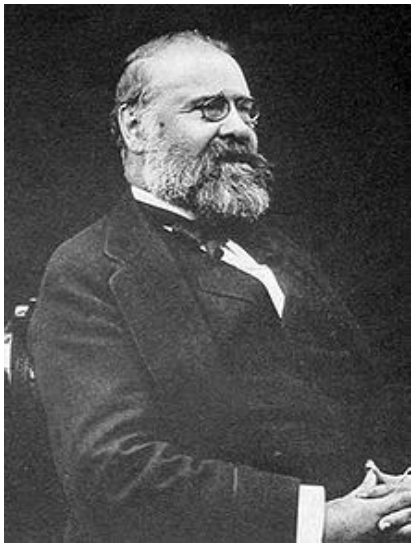
PENNSYLVANIA SCIENCE OLYMPIAD

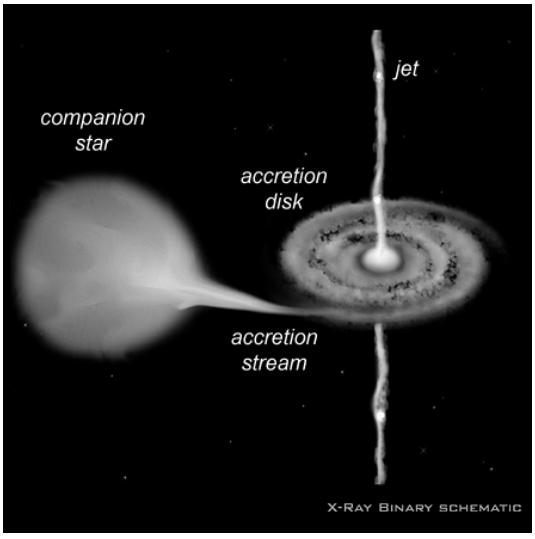
SOUTHEAST REGIONAL TOURNAMENT 2013

ASTRONOMY C DIVISION EXAM

MARCH 4, 2013

CABRINI COLLEGE





SCHOOL:_____ **TEAM NUMBER:**_____

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*. Continuing to write after the time is up risks immediate disqualification.

7. In the BONUS box on the answer sheet, name the gentleman depicted on the cover for a bonus point.

8. As per the 2013 Division C Rules Manual, each team is permitted to bring "either two laptop computers OR two 3-ring binders of any size, or one binder and one laptop" and programmable calculators.

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

Questions 1-30 refer to the objects listed in section 3c, page C2, of the 2013 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. NGC 3582
B. Cassiopeia A
C. V838 Mon
D. IC 1396
E. NGC 6888

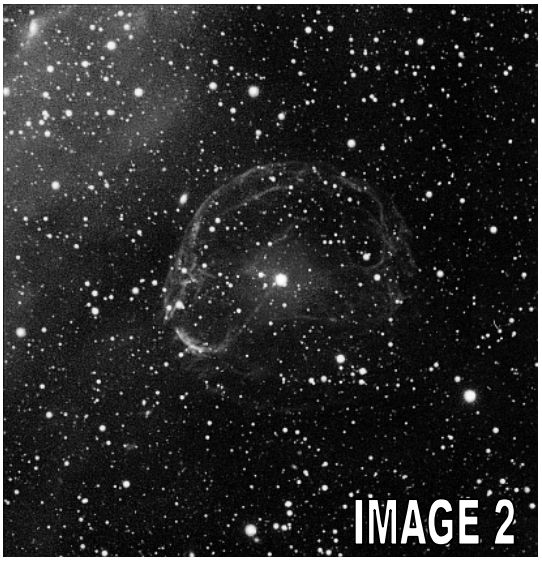
2. Which of the following most accurately describes the object in image 1?

A. Supernova remnant
B. Planetary nebula
C. Emission nebula
D. Star-formation region
E. Giant molecular cloud

3. What is the central object in image 1?

A. White dwarf star
B. Wolf-Rayet star
C. Red supergiant
D. Neutron star
E. Pulsar
F. Stellar-mass black hole

4. Which object is shown in image 2?



A. NGC 6888
B. V838 Mon
C. WR 136
D. Delta Cep
E. SXP 1062

5. Which of the following most accurately describes the object in image 2?

A. Supernova remnant
B. Planetary nebula
C. Emission nebula
D. Star-formation region
E. Giant molecular cloud

6. What is the central object in image 1?

A. White dwarf star
B. Wolf-Rayet star
C. Red supergiant
D. Neutron star
E. Pulsar
F. Stellar-mass black hole

7. Which object is shown in image 3?

A. SXP 1062
B. IGR J17091
C. PSR J0108-1431
D. LHa115-N19
E. Cygnus X-1
F. δ Cephei

8. This graph shows the light curve of the prototype of which kind of object?

A. X ray binary
B. Semiregular variable
C. Pulsar
D. Red supergiant
E. Cepheid variable
F. Protostar

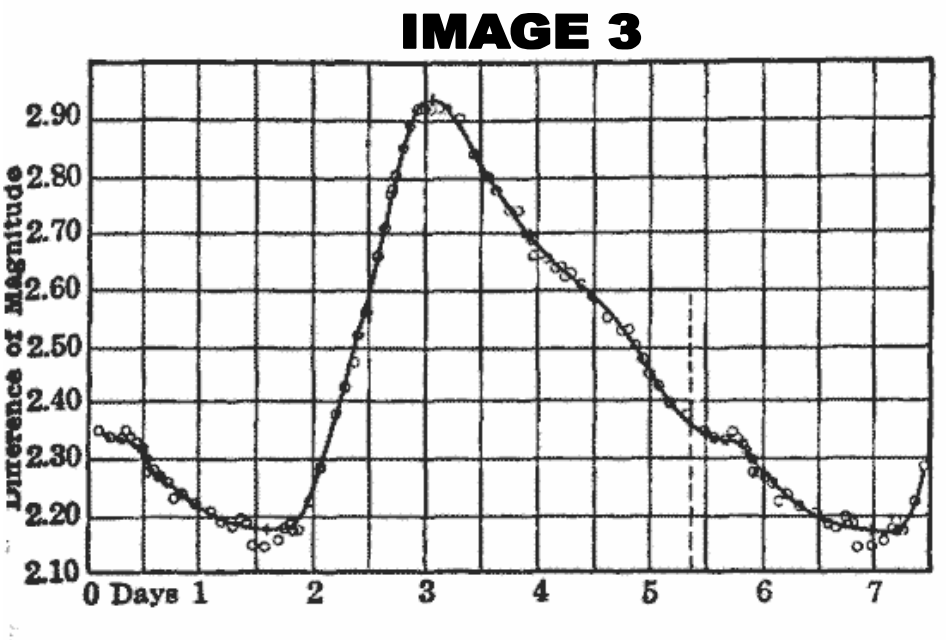
9. Which of the following drives the variability of such an object?

A. Slow neutron capture
B. The triple-alpha process
C. Helium ionization
D. Iron ionization
E. Hydrogen ionization
F. Stellar winds and mass transfer

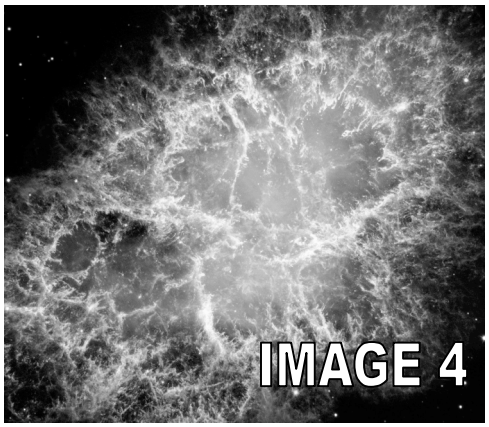
10. This type of object would be best classified as which of the following?

A. A rapidly rotating neutron star
B. A yellow supergiant star
C. A red supergiant star
D. A T-Tauri protostar
E. An emission nebula
F. A black hole with an accretion disk

IMAGE 3



11. Which object is shown in image 4?



A. M1
B. Rho Ophiuchi
C. SN 2010JL
D. NGC 6888
E. IC 1398
F. NGC 3582

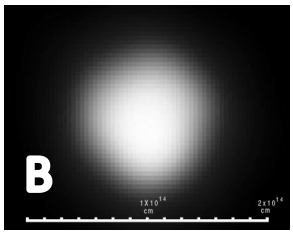
12. What is the central object in image 4?

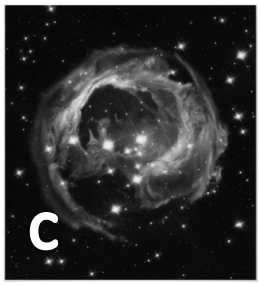
A. WR 136
B. Antares
C. PSR J0108-1431
D. Cygnus X-1
E. 3C 461
F. NP 0532

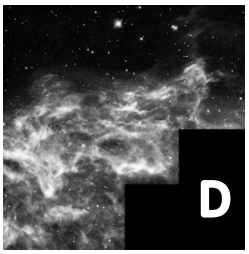
13. This object was visible in the sky during the day in what year?

A. 2010
B. 1794
C. 1054
D. 1987
E. 1801
F. 1731

14. Which image below shows the "heart of the scorpion"?







15. Which object is shown (in part) in image 5?

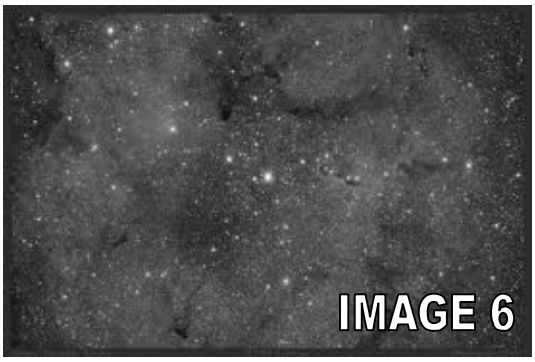
A. NGC 6888
B. M1
C. NGC 3582
D. LHa115-N19
E. Rho Ophiuchi
F. IC 1396

16. This object is part of which designation in the Rodgers, Campbell, Whiteoak catalogue?

A. 48
B. 147
C. 27
D. 105
E. 124
F. 57

17. Which object is shown in image 6?

A. M1
B. NGC 6888
C. NGC 3582
D. IC 1396
E. Rho Ophiuchi
F. Cas A



18. Which of the following is an alternate designation for the object in image 6?

A. The Crab nebula
B. The Elephant's Trunk nebula
C. J16271-2423
D. The Crescent nebula
E. The Lagoon nebula
F. The Bubble nebula

19. The object in image 6 would best be classified as a(n):

A. supernova remnant
B. dark nebula
C. emission nebula
D. planetary nebula
E. protoplanetary nebula
F. reflection nebula

20. Which object is shown in image 7?

A. Cas A
B. PSR J0108-1431
C. Cygnus X-1
D. SN 2010JL
E. SXP 1062
F. WR 136

21. The object in image 7 would best be classified as a:

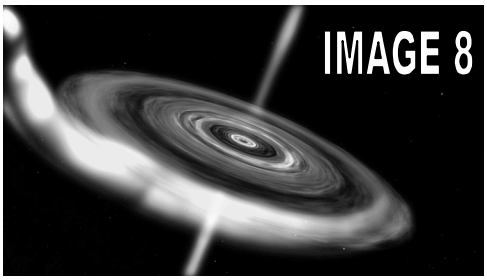
A. Type Ia supernova
B. Type Ib supernova
C. Type Ic supernova
D. Type IIn supernova
E. Type IIL supernova
F. Type IIP supernova
G. Type IIb supernova

22. This type of supernova typically results from which of the following?

A. Core collapse of a Wolf-Rayet star of type WO
B. Core collapse of a Wolf-Rayet star of type WC
C. Accretion of mass onto a white dwarf in a mass-transfer binary
D. Accretion of mass onto a white dwarf due to high stellar winds
E. Core collapse of a supergiant star within a cloud of expelled material
F. Core collapse of a hydrogen-depleted supergiant

23. Consider image 8. This image could apply to which object(s) listed?

A. PSR J0108-1431
B. Cygnus X-1
C. IGR J17091
D. A and C
E. B and C
F. A and B
G. A, B, and C

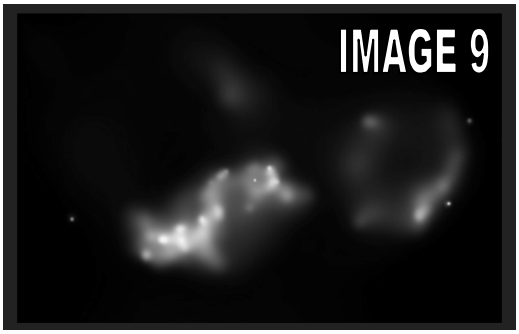


24. This object could be called which of the following?

A. pulsar
B. magnetar
C. microquasar
D. SNR Type I
E. SNR Type II
F. white dwarf

25. Which object is shown in mage 9?

A. LHa115-N19
B. Cygnus X-1
C. M1
D. WR 136
E. PSR J0108-1431
F. IGR J17091
G. IC 1396



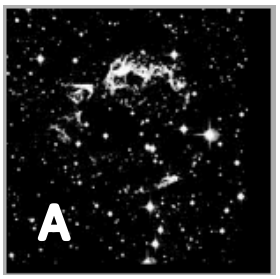
26. Which of the following best describes what is going on in image 9?

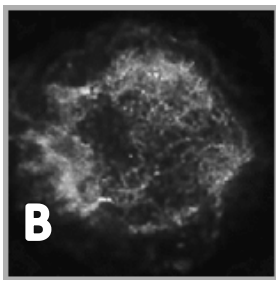
A. A mass stream flowing onto a compact object
B. A shock wave pushing through previously ejected material
C. Radio emission from a rapidly rotating neutron star
D. Turbulence around a Wolf-Rayet star
E. Formation of
F. Formation of a superbubble

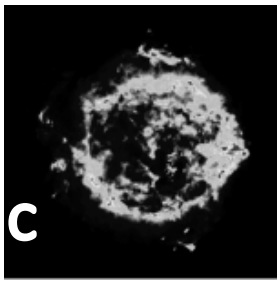
27. In which of the following would the object in image 9 be found?

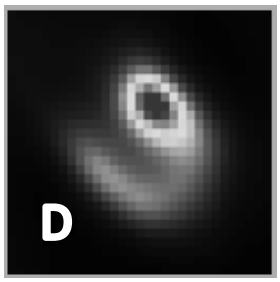
A. Milky Way
B. Small Magellanic Cloud
C. Large Magellanic Cloud
D. Andromeda galaxy

28. Which of the following images was made in the radio band?



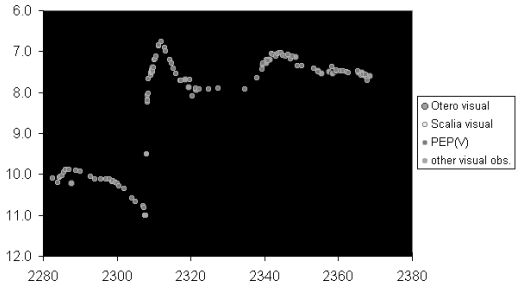






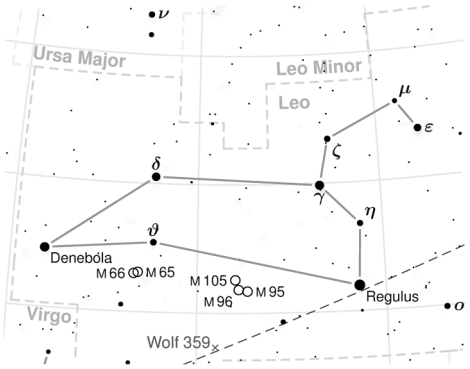
29. Which object produced the light curve shown below?

A. M1
B. Delta Cephei
C. Betelgeuse
D. WR 136
E. V838 Mon
F. Antares
G. Cygnus X-1

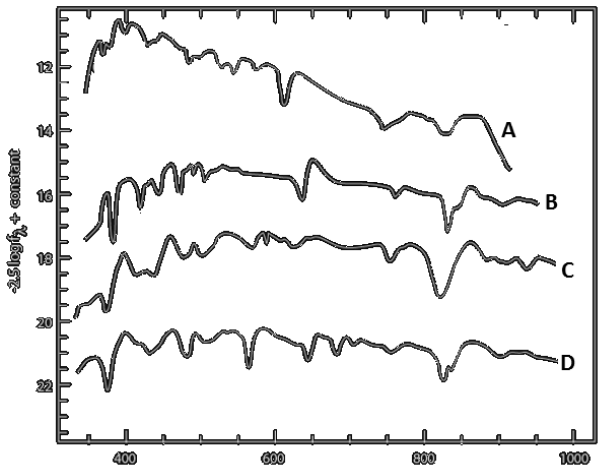


30. Which object appears in the constellation shown below?

A. NGC 3582
B. NGC 6888
C. Cas A
D. LHa115-N19
E. SN 2010JL
F. IGR J17091



31. Which of the following spectra belongs to a Type II supernova?



32. In the Type II supernova spectrum shown above, which spectral feature shows a P Cygni profile?

A. Ca II
B. Si II
C. O I
D. Fe II
E. Fe III
F. H α
G. H β

For questions 33 – 37, associate the numbered steps in post-main-sequence stellar evolution of a sun-like star with the appropriate lettered location on the HR diagram shown below.

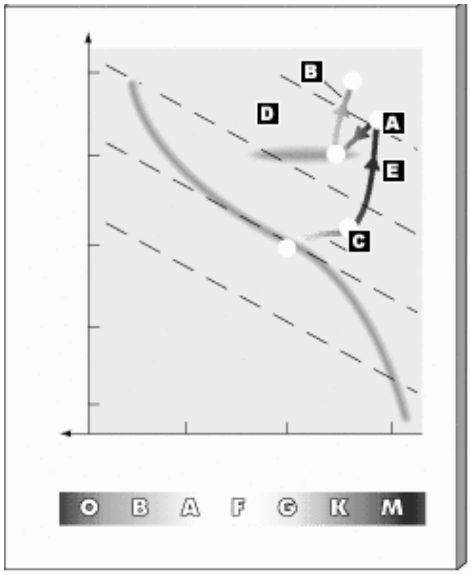
33. Helium flash

34. Red giant branch

35. Subgiant branch

36. Supergiants

37. Horizontal branch



38. Most stellar spectra are characterized by which of the following?

A. Emission spectrum
B. Featureless continuous spectrum
C. Continuous spectrum with superimposed emission lines
D. Continuous spectrum with absorption lines

39. W Virginis stars would be best classified as which of the following?

A. RV Tauri stars
B. Classical Cepheids
C. Population I Cepheids
D. Population II Cepheids
E. Anomalous Cepheids
F. RR Lyrae stars

40. Pulsars were first discovered in which waveband of the electromagnetic spectrum?

A. radio
B. infrared
C. visible
D. ultraviolet
E. X-rays
F. gamma rays

41. Pulsars would be classified as which of the following types of variable stars?

A. eruptive
B. pulsating
C. cataclysmic
D. rotating
E. eclipsing

For questions numbered 42 – 45, match the numbered GCVS classification code for semi-regular variables with the appropriate description.

42. SRA **A. Small-amplitude supergiants, spectral type M, C, S or Me, Ce, Se**

43. SRB **B. Giants and supergiants, possible emission lines, spectral type F, G, K**

44. SRC **C. Small-amplitude giants, persistent periodicity, spectral type M, C, S or Me, Ce, Se**

45. SRD **D. Poorly-defined periodicity, multiple periods, spectral type M, C, S or Me, Ce, Se**

46. Which of the following is FALSE regarding HII regions?

A. They are commonly present in the arms of spiral galaxies
B. They are commonly present in elliptical galaxies
C. They are characterized by ionized atomic hydrogen
D. They are frequently associated with star formation
E. They typically get dispersed quickly by supernova explosions and strong stellar winds

47. Protostars of roughly solar mass typically approach the main sequence:

A. from above and to the right
B. from below and to the right
C. from above and to the left
D. from below and to the left

48. Which of the following would NOT contribute to the collapse of a molecular cloud?

A. supernovae
B. intercloud collisions
C. density waves in spiral arms
D. virial equilibrium

49. Main sequence stars belong to which of the following luminosity classes?

A. Ia B. Ib C. II D. III E. IV F. V G. VI

50. Main-sequence stars of *more* than 1.5 solar masses use predominantly which process to generate energy?

A. Bremsstrahlung
B. matter-antimatter annihilation
C. proton-proton chain
D. CNO cycle
E. deuterium-tritium fusion

51. What is the main-sequence lifetime of a 3-stellar-mass star compared to the sun's main-sequence lifetime?

A. about 1/50 that of the sun
B. about 1/10 that of the sun
C. about the same as the sun
D. about 10 times that of the sun
E. about 50 times that of the sun

52. Which of the following is(are) TRUE?

A. All pulsars are magnetars
B. Some pulsars are magnetars
C. All magnetars are pulsars
D. Some magnetars are pulsars
E. A and C
F. B and D
G. A and D
H. B and C

53. Which of the following classes of objects are probably pulsars?

A. soft gamma-ray repeaters
B. gamma-ray bursts
C. anomalous x-ray pulsars
D. A and B but not C
E. A and C but not B
F. B and C but not A

54. Which of the following variable star classes' variability is considered to be due to rotation?

A. Wolf-Rayet stars
B. Classical Cepheids
C. W Virginis Cepheids
D. Semiregular variables
E. pulsars

55. Which of the following sequences properly places the classes in order of increasing luminosity?

A. giants – bright giants – supergiants – hypergiants
B. giants – supergiants – bright giants – hypergiants
C. giants – bright giants – hypergiants – supergiants
D. bright giants – giants – supergiants – hypergiants
E. bright giants – giants – hypergiants – supergiants

56. The stars in an OB association would tend to be:

A. Old, hot, and bright
B. Old, cool, and bright
C. Old, cool, and dim
D. Young, hot, and bright
E. Young, cool, and bright
F. Young, cool, and dim

57. Semiregular variable stars would tend to be found:

A. on the Hayashi track of stellar formation
B. on the main sequence
C. below the main sequence
D. on the subgiant branch
E. in the instability strip
F. on the asymptotic giant branch

58. Which of the following is TRUE?

A. X-ray pulsars' pulse periods tend to be decreasing
B. isolated pulsars tend to have unchanging pulse periods
C. X-ray pulsars tend to form from massive, isolated stars
D. X-ray pulsars tend to accrete mass from a binary companion

59. Which of the following is NOT one of the fundamental properties of a black hole?

A. magnetic field
B. mass
C. angular momentum
D. charge

60. Which of the following is NOT a characteristic of microquasars?

A. accretion disk
B. bipolar relativistic jets
C. radio lobes
D. strong stellar winds
E. X-ray emission

61. A stellar-mass black hole is also sometimes called a:

A. pulsar
B. collapsar
C. magnetar
D. primordial black hole
E. naked singularity

62. Describing the space-time geometry around a rotating, charged black hole would best be described by:

A. the Schwarzschild radius
B. the Kerr-Newman metric
C. the Reissner-Nordström metric
D. the Minkowski space
E. the van Stockum solution

63. Wolf-Rayet stars tend to have:

A. high temperatures
B. high rates of accretion
C. broad emission lines
D. A and B but not C
E. B and C but not A
F. A and C but not B
G. A, B, and C

64. A star of 30-40 solar masses (initially) would end its life as which type of star before it went supernova?

A. LBV
B. WC
C. WN
D. WO
E. BSG

65. These stars often create "giant outbursts" which are called supernova imposters:

A. WN
B. WO
C. WC
D. RSG
E. BSG
F. LBV

For questions numbered 66 – 69, match the numbered sub-class of Type II supernova with the description.

66. Type IIn	**A. Spectrum shows early Hydrogen lines, but later on shows Helium lines**
67. Type II-L	**B. Normal Type II spectrum with no distinct plateau in the light curve**
68. Type IIb	**C. Normal Type II spectrum with a period of constant luminosity in the light curve**
69. Type II-P	**D. Spectrum lacks broad emission lines**

For questions numbered 70 – 77, match the numbered sub-class of x-ray binary with the description.

70. HMXB	**A. Binary star system with a compact object and an intermediate-mass stellar companion**
71. LMXB	**B. Generates very low-energy x-rays, usually through *steady* fusion by an accreting white dwarf in a binary system**
72. IMXB	**C. High-mass binary systems in which the compact object orbits a very massive companion with periods of a few days, emitting hard x-rays**
73. BeXRB	**D. Binary star system with a compact object and a low-mass star; shows changing levels of soft x-ray emission probably due to variable mass transfer**
74. SXT	**E. Binary star system with a compact object and a massive, O or B type companion; much of the x ray emission results from strong stellar winds captured by the compact object**
75. SSXB	**F. High-mass binary systems in which a neutron star is in a highly elliptical orbit that passes through a disk-shaped stellar wind, showing hard x-ray flare-ups**
76. SFXT	**G. Exotic source of hard x-rays associated with massive O and B type stars; flare ups are brief and show very fast rise times**
77. SGXB	**H. Binary system with a compact object and a low mass companion; the accretion disk is the brightest object in the system**

78. Which of the following occurs at the distance of the Schwarzschild radius from a black hole?

A. the accretion disk
B. the hot spot
C. the mass stream
D. the event horizon
E. the singularity
F. the ergosphere

A classical Cepheid star in a distant galaxy has an apparent magnitude of 21 and a period of 22 days. Use this information for numbers 79 -

79. What is the absolute magnitude of this star?

A. 21
B. -5.1
C. 1.0
D. 16
E. -21
F. -1.0

80. What is the distance modulus for this star?

A. 0
B. -1.0
C. 1.0
D. -5.0
E. 27
F. 22

81. How far away is this galaxy?

A. 2.5 parsecs
B. 25 parsecs
C. 2500 parsecs
D. 250,000 parsecs
E. 2.5 million parsecs
F. 25 million parsecs

82. What is the approximate luminosity of this star, in solar luminosities?

A. 0.1
B. 10
C. 100
D. 1000
E. 10,000
F. 100,000

83. Which of the following classes of stars would best describe this star?

A. yellow supergiant
B. luminous blue variable
C. Wolf-Rayet
D. red supergiant
E. red giant
F. hypergiant

84. What is the name for the mechanism that drives the variability of this star?

A. magnetohydrodynamics
B. photodisintegration
C. electron degeneracy
D. stellar convection
E. inverse beta decay
F. the Eddington valve

V404 Cygni is a binary system, about 7800 light-years away. The two objects in the system orbit each other every 6.45 days at a separation of 24.0 million km. One of the objects is main-sequence star A, with a mass 75% that of the sun, and it has an *orbital* radius of 22.64 million km. The companion is star B. Use this information for numbers 85 – 89.

85. What is the total mass of the system, in solar masses?

A. 1.67
B. 2.85
C. 8.5
D. 11.2
E. 13.2
F. 22.75

86. What is the mass of star B, in solar masses?

A. 0.92
B. 2.10
C. 7.75
D. 10.5
E. 12.4
F. 22

87. What is the orbital velocity of star B, in km/s?

A. 15.4 km/s
B. 15400 km/s
C. 37.2 km/s
D. 37200 km/s
E. 94.3 km/s
F. 94300 km/s

88. What is the most likely candidate for star B?

A. white dwarf star
B. main sequence, M class star
C. red giant
D. Wolf-Rayet star
E. neutron star
F. black hole

89. What is the most likely candidate for star A?

A. white dwarf
B. red giant
C. K class
D. O class
E. A class
F. brown dwarf

90. At what amplitude is the (arbitrary) division between semi-regular variables and Mira variables?

A. 5 magnitudes
B. 2.5 magnitudes
C. 1.5 magnitudes
D. 1.0 magnitude
E. 0.5 magnitude

91. The pulsar wind nebula is also called:

A. thermal Bremsstrahlung
B. a Strömgren sphere
C. plerion
D. gravitational waves
E. the Blazhko effect
F. proplyd

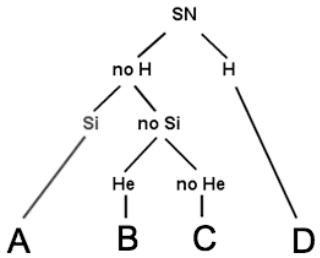
92. This type of particle carries away most of the energy from a Type II supernova:

A. photon
B. electron
C. gluon
D. neutron
E. neutrino
F. Z boson

93. When full redward evolutionary tracks develop for stars below about 40 solar masses, which of the following applies to the luminosity?

A. the Eddington limit
B. the Chandrasekhar limit
C. the Humphreys-Davidson limit
D. the Butcher-Oemler limit
E. the Hubble-Sandage limit

94. The "tree" shown below displays spectral features of supernovae. Which lettered option is Type II?



95. Which of the following products could be left behind by a type II supernova?

A. black hole
B. white dwarf
C. neutron star
D. A and B
E. B and C
F. A and C
G. A, B, and C

96. What principle is verified by the behavior of double neutron star binaries?

A. Pauli Exclusion
B. Hawking radiation
C. the Faber-Jackson relation
D. neutron degeneracy
E. General Relativity
F. Special Relativity

97. A massive star that has evolved through core silicon burning develops a core that is primarily:

A. Helium
B. Oxygen
C. Carbon
D. Silicon
E. Nickel
F. Iron

98. Which of the following stellar categories does not belong?

A. Wolf-Rayet stars
B. ZZ Ceti stars
C. S Doradus stars
D. LBV stars
E. Hubble-Sandage variables
F. Alpha Cygni variables

99. Which of the following sequences properly places the classes in order of increasing luminosity?

A. RV Tauri – BL Herculis – W Virginis – Classical Cepheid
B. Clasiccal Cepheid – RV Tauri – W Virginis – BL Herculis
C. BL Herculis – W Virginis – RV Tauri – Classical Cepheid
D. BL Herculis – RV Tauri – Classical Cepheid – W Virginis
E. W Virginis – Classical Cepheid – RV Tauri – BL Herculis

100. Large-amplitude Cepheid variable stars show variation in the shapes of their light curves. This phenomenon is called:

A. the Blazhko effect
B. the Zeeman effect
C. the Balmer series
D. the Hertzsprung progression
E. the Runge-Kutta algorithm