Exploring the World of Science

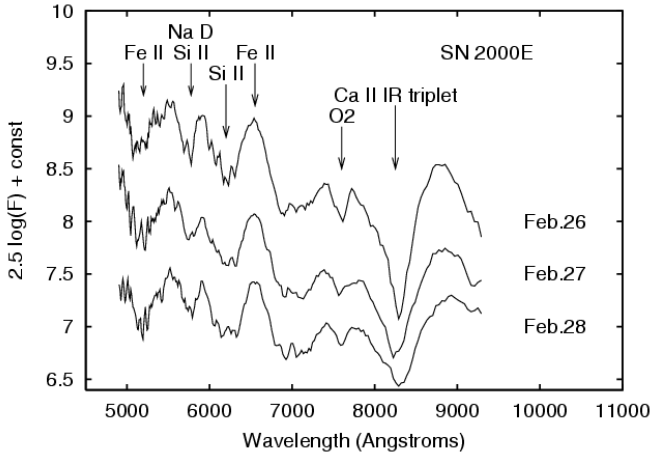
PENNSYLVANIA SCIENCE OLYMPIAD

SOUTHEAST REGIONAL TOURNAMENT 2012

ASTRONOMY C DIVISION EXAM

MARCH 5, 2012

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.

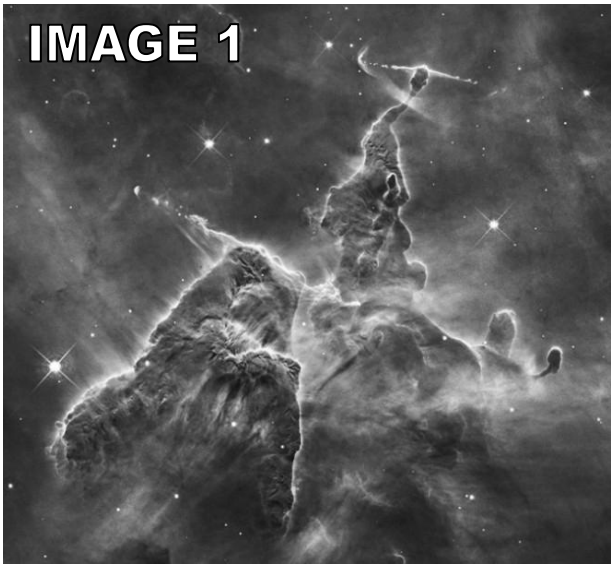
7. In the BONUS box on the answer sheet, name the gentleman depicted on the cover for a bonus point. It's not George Washington, even if they share the same fashion sense.

8. As per the 2012 Division C Rules Manual, each team member is permitted to bring "either a laptop computer OR one 3-ring binder of any size" and a programmable calculator.

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

1. **Which object is depicted in image 1?**

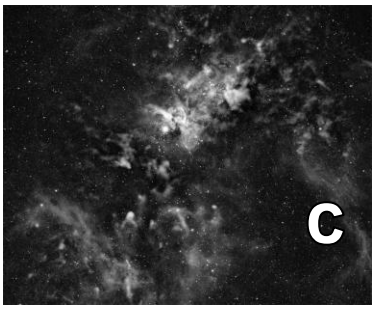
   A. DEM L238
   B. Tycho's SNR
   C. Kepler's SNR
   D. SNR 0509-67.5
   E. Carina Nebula



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

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

3. **Which of the following images shows the same object as image 1, but in X-rays?**



4. **Which DSO is depicted in image 2?**

   A. CH Cyg
   B. T Tauri
   C. Sirius B
   D. BP Psc
   E. U Scorpii

5. **How is the object in image 2 classified?**

   A. Recurring nova
   B. Supernova remnant
   C. Old sun-like star with jets and debris disk
   D. Protostar
   E. Symbiotic star system

6. **Systems of this type *could* demonstrate which of the following?**

   A. Eclipses
   B. Hot and cool star spectral components
   C. Pulsation
   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

7. Which object is depicted in image 3?

A. Sirius B
B. Omicron Ceti
C. RR Lyrae
D. U Scorpii
E. CH Cyg
F. BP Piscium

8. (T6) What units are displayed across the vertical and horizontal axes, respectively?

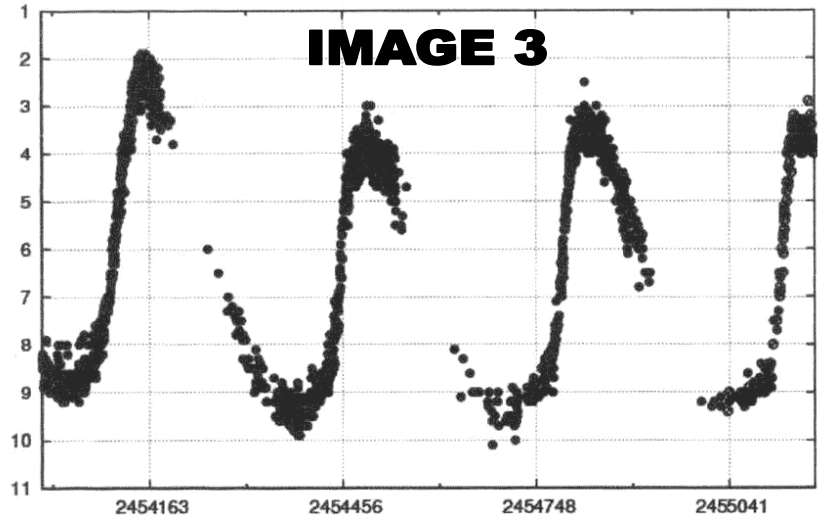
A. Intensity and hours
B. Magnitude and Julian Date
C. Luminosity and phase
D. Intensity and Lilian date
E. Luminosity and Gregorian calendar date
F. Magnitude and Rata Die

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. What is the *typical* final stage of stellar evolution for such an object?

A. Planetary nebula and white dwarf
B. Emission nebula and brown dwarf
C. Type Ia supernova
D. T-Tauri object
E. Type II supernova and neutron star
F. Type II supernova and black hole



11. Which object is depicted in image 4?

A. U Scorpii
B. Carina Nebula
C. Rosette Nebula
D. RX J0806.3+1527
E. Mira
F. T Tauri

12. According to the 4th (current) edition of the GCVS, this object has which variability code?

A. NR
B. UG
C. ZAND
D. INT
E. SRB
F. M

13. (T12) What is the New General Catalogue Number for the Herbig-Haro object in image 4?

A. 3372
B. 2237
C. 1555
D. 1527
E. 2244
F. 14386

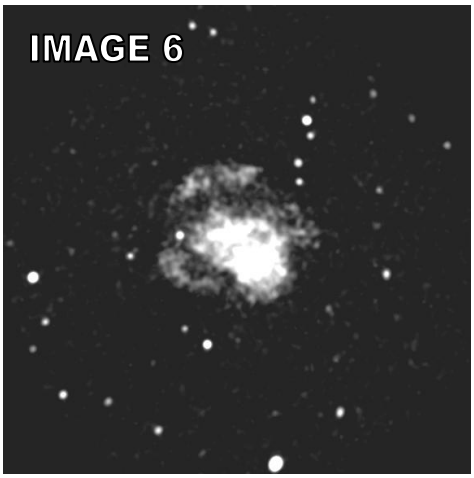
14. What is the Henry Draper Catalogue number for the object at the center of image 5?

A. 14386
B. 2440
C. 62166
D. 48915
E. 284419
F. 238

15. What type of object is shown in image 5?

A . Symbiotic star system
B. Red giant with evidence of stellar wind
C. T-Tauri star with debris disk
D. White dwarf and planetary nebula
E. Molecular cloud and protostar
F. Supernova remnant and neutron star

16. Image 6 features an image from the Chandra X-Ray Observatory. Which object does it show?



- **A. SNR 0509-67.5**
- **B. Tychos's SNR**
- **C. Kepler's SNR**
- **D. DEM L238**
- **E. DEM L249**
- **F. RX J0806.3+1527**

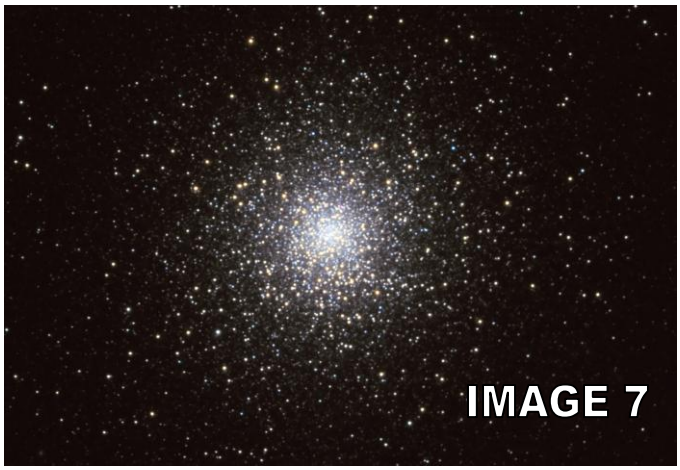
17. The bright, central portion of the image indicates the presence of medium-energy X-rays, indicating the presence of what substance in unusual abundance?

- **A. Iron**
- **B. Molecular hydrogen**
- **C. Atomic hydrogen**
- **D. Carbon monoxide**
- **E. Lithium**
- **F. Silicon**

18. The object in image 6 is located in the:

- **A. spiral arms of the Milky Way**
- **B. central bulge of the Milky Way**
- **C. halo of the Milky Way**
- **D. Small Magellanic Cloud**
- **E. Large Magellanic Cloud**

19. What is the Messier Catalogue number of the object shown in image 7?



- **A. 15**
- **B. 71**
- **C. 7078**
- **D. 40815**
- **E. 4670**

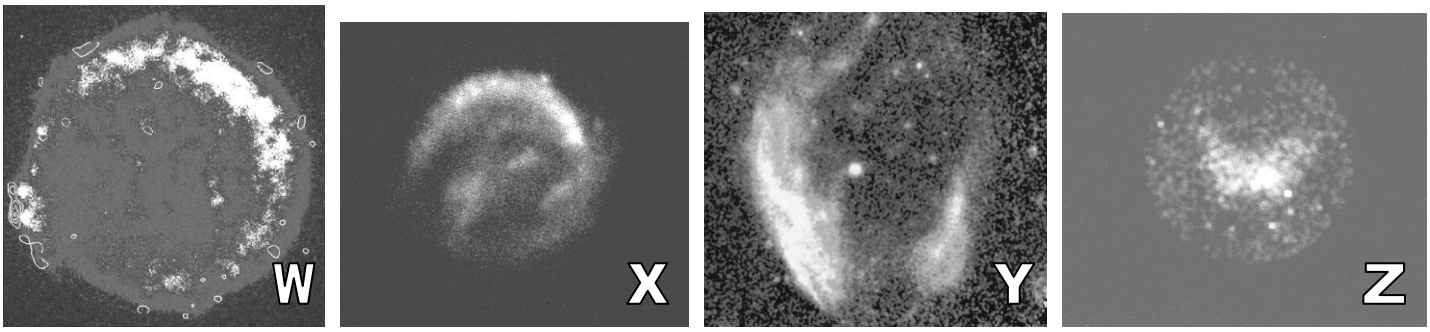
20. The object in image 7 is well-known for revealing the first planetary nebula in an object of its type. What is the designation for this planetary nebula?

- **A. NGC 7078**
- **B. Pease 1**
- **C. NGC 2440**
- **D. Rosette Nebula**
- **E. Carina Nebula**

21. The object in image 7 is also known for containing an unusually high number of which of the following?

- **A. Blue stragglers**
- **B. W Virginis stars**
- **C. RR Lyrae stars**
- **D. Brown dwarfs**
- **E. Pulsars**

22. Consider the ROSAT images below. Which one(s) is a (are) Type Ia supernova remnant(s) from the object list?



A. W only
B. W and Z
C. X and Y
D. W and X
E. Y and Z
F. Z only

23. Which object is shown in image 8?

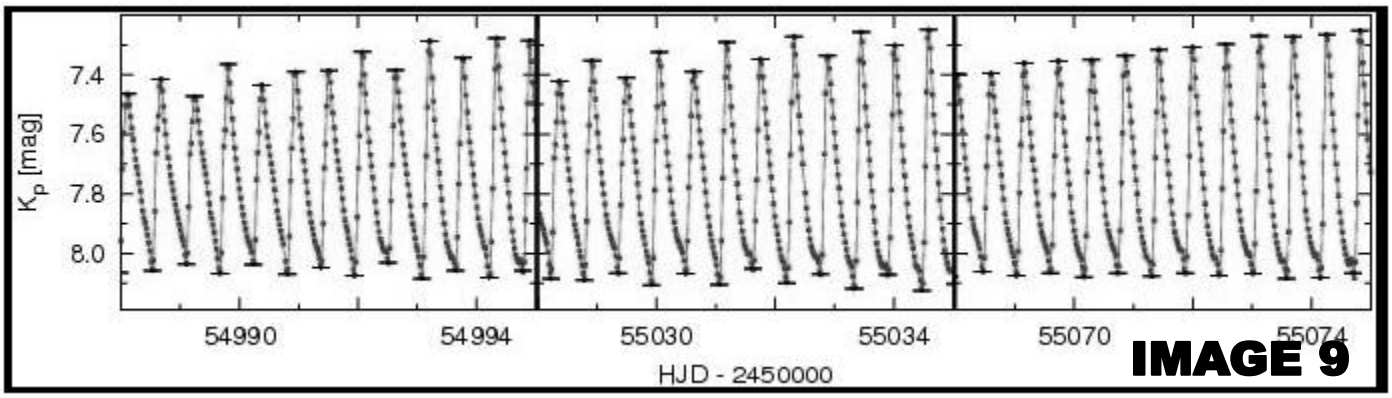
A. Mira
B. U Scorpii
C. T Tauri
D. Sirius B
E. RR Lyrae
F. BP Psc

24. What is the evidence that the object in image 8 is relatively young?

A. Herbig-Haro objects fluorescing in Hα
B. A circumstellar disk and bipolar jets
C. P-Cygni profiles in its emission lines
D. Intense X-ray emission
E. Young stars in the immediate vicinity
F. Numerous forbidden lines

25. What is the explanation for the fact that the object in image 8 is actually relatively *old*?

A. A star expanded into its red giant phase, engulfing stars or planets in the vicinity
B. The X-ray emission is higher than expected due to s-process nucleosynthesis
C. The X-ray emission is higher than expected due to RGB dredge-up of heavy elements
D. The P-Cygni profiles are sometimes inverted
E. Forbidden lines are typically present in a dense stellar wind
F. The apparent HH objects are not associated with the object



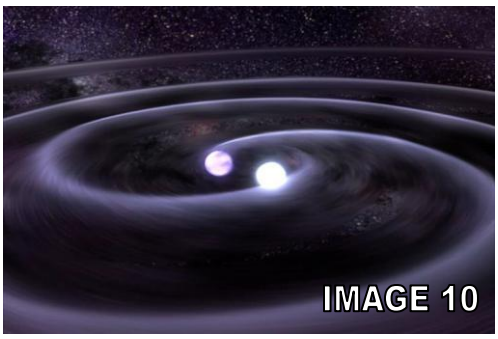
26. What object is shown in image 9?

- **A. Sirius B**
- **B. CH Cyg**
- **C. T Tauri**
- **D. RR Lyrae**
- **E. Mira**
- **F. U Scorpii**

27. (T7) What is the cause of the variations in the peak magnitude?

- **A. Convection**
- **B. Alternating mass accretion and mass loss**
- **C. Ionized hydrogen**
- **D. Ionized helium**
- **E. Ionized iron**
- **F. The Blazhko Effect**

28. There are letters and two sets of numbers in the designation for the object shown in image 10. What is indicated by the first 2 letters in the designation?



- **A. The constellation the object is found in**
- **B. X-Ray source from ROSAT**
- **C. Supernova remnant**
- **D. Bruce Proper Motion**
- **E. Magellanic HII regions**
- **F. Variable star designation**

29. What is indicated by the first set of numbers in the designation?

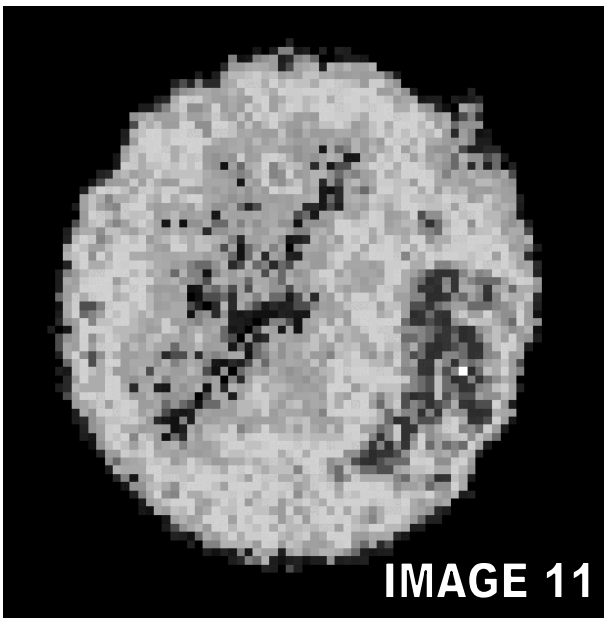
- **A. Month and year of discovery**
- **B. Degrees of declination**
- **C. Degrees of Galactic latitude**
- **D. Degrees of Galactic longitude**
- **E. Hours and minutes of right ascension**
- **F. Rossiter double star catalog number**

30. The orbital period of the object in image 10 is slowly decreasing. What is the primary reason?

- **A. Tidal distortion of the objects**
- **B. Slow neutron capture**
- **C. Gravitational waves**
- **D. Beta decay**
- **E. Mass transfer**

31. Which object is shown in image 11?

A. DEM L238
B. DEM L249
C. SNR 0509-67.5
D. Kepler's SNR
E. Tycho's SNR
F. U Scorpii



32. (T3) A particular model describes the origin of the object in image 11. Which of the following is it?

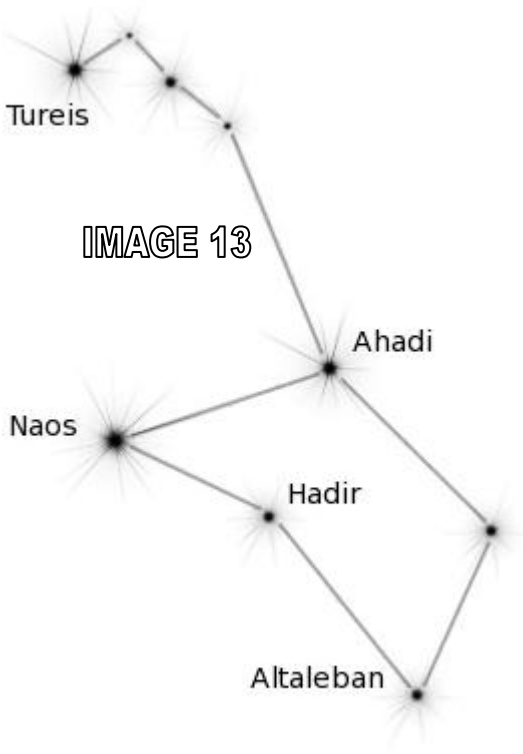
A. Geodetic Proper Motion
B. Double Degenerate Progenitor
C. Nuclear Double Beta Decay
D. Coulomb Barrier Penetration
E. Quantum Fluctuation
F. Strong Force Neutron Degeneracy

33. Which limit was exceeded by the object that led to what we see in image 11?

A. Tolman-Oppenheimer-Volkoff Limit
B. Schwarzschild Limit
C. Eddington Limit
D. Chandrasekhar Limit
E. Pauli-Fermi-Dirac Limit
F. Planck Limit

34. Which object is located in the constellation shown in image 13?

A. NGC 2440
B. BP Psc
C. Sirius B
D. Mira
E. U Scorpii
F RR Lyrae



35. This particular object type of object has a code in regard to its variability. What is its code?

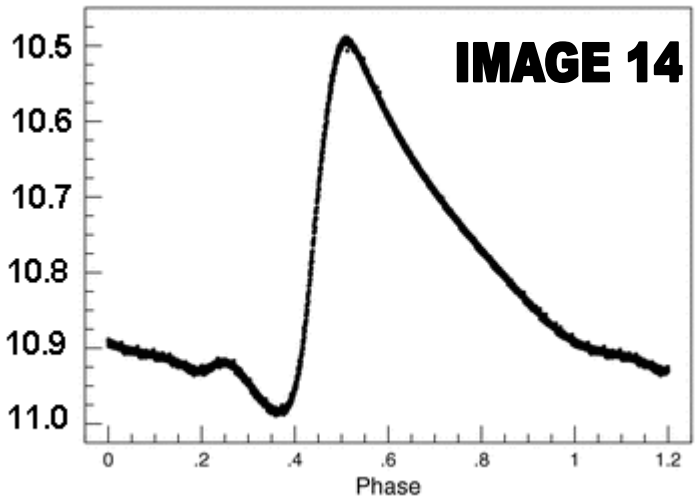
A. M
B RRAB
C. XF
D. SNI
E. PNNV
F. WR

36. (T8) Where would T-Tauri stars tend to be located in an HR diagram?

A. Above and to the right of the main sequence
B. Above and to the left of the main sequence
C. Below and to the right of the main sequence
D. Below and to the left of the main sequence

37. What type of object is indicated by the light curve shown in image 14?

A. A pulsating horizontal branch star
B. A pulsating red giant
C. A pulsating white dwarf
D. A main-sequence star
E. An irregular protostar
F. A Type Ia supernova



38. What is the amplitude of the object shown in image 14?

A. 10.5
B. 11.0
C. 10.75
D. 0.5
E. 0.4
F. 1.2

39. What is the apparent magnitude of the object shown in image 14?

A. 10.5
B. 11.0
C. 10.75
D. 0.5
E. 0.4
F. 1.2

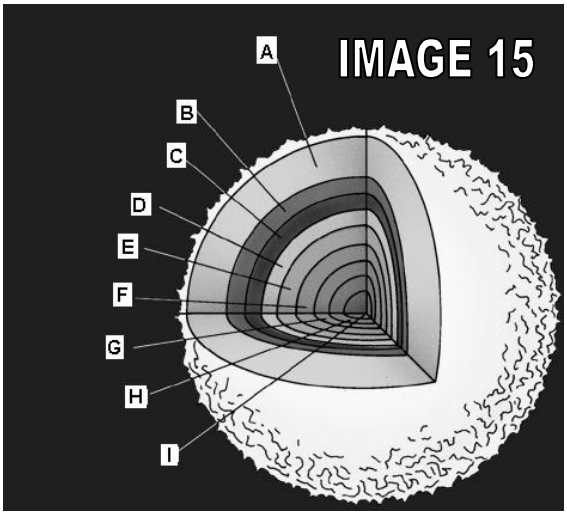
40. What is the approximate distance to this object?

A. 1 pC
B. 10 pC
C. 1 kpC
D. 10 kpC
E. 1 MpC
F. 10 MpC

41. A red giant star has a surface temperature of 3200 K and luminosity 1000 times that of the sun. What is its approximate radius in solar radii?

A. About 10 solar radii
B. About 50 solar radii
C. About 100 solar radii
D. About 500 solar radii
E. About 1000 solar radii

42. **Consider image 15, a highly evolved star. In which lettered region does helium fusion take place?**



For numbers 43-51, match the terms on the left with the proper description on the right.

43. Planetary nebula	A. A molecular cloud with sufficient density to form H_2
44. T-Tauri object	B. Stars with this description have luminosity class III
45. Mira variable	C. Stars with this description have luminosity class VII
46. RR Lyrae	D. Ejected dust and gas illuminated by the newly exposed core
47. White dwarf	E. When a white dwarf exceeds the Chandrasekhar limit
48. Main sequence	F. Stars with this classification are pre-ZAMS
49. Red giant	G. Stars with this description have luminosity class V
50. Stellar nursery	H. Stars with this description are on the horizontal branch
51. Type Ia supernova	I. Stars with this description are at the end of the AGB phase

52. **Star A has a magnitude of -1, and star B has a magnitude of +4. Which of the following most accurately describes the relative brightnesses of star A and star B?**

A. Star B is 4 times brighter than star A
B. Star B is 5 times brighter than star A
C. Star B is 100 times brighter than star A
D. Star A is 4 times brighter than star B
E. Star A is 5 times brighter than star B
F. Star A is 100 times brighter than star B

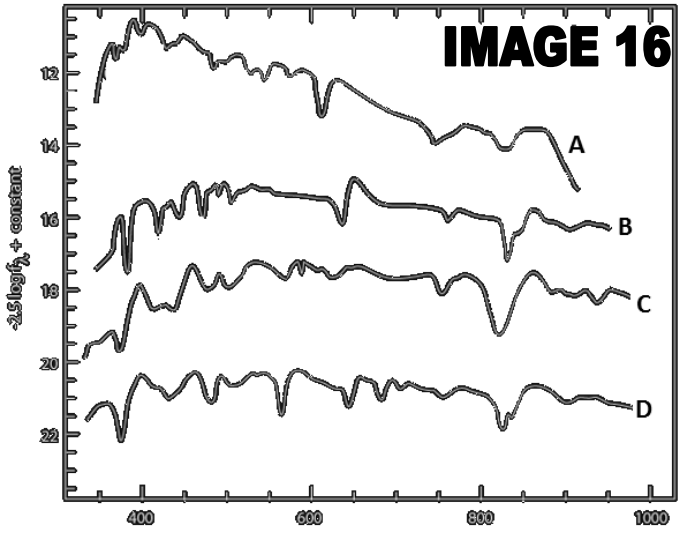
53. **(T4) Type Ia supernovae are primarily classified as such due to:**

A. The presence of hydrogen lines in the spectrum
B. The absence of hydrogen lines in the spectrum
C. A plateau in the light curve
D. The presence of silicon lines in the spectrum
E. A and D
F. B and D
G. A, C, and D

54. What is the absolute magnitude of most Type Ia supernovae?

A. 10
B. -29.6
C. 15.6
D. 1.44
E. -19.3
F. -10

55. Consider the spectra shown in image 16. Which belongs to a Type Ia supernova?



For questions numbered 56 – 59, match the numbered codes with the descriptions provided.

56. WTTS	**A. "Naked" T-Tauri stars with no appreciable accretion disk**
57. CTTS	**B. Hot, massive versions of T-Tauri stars**
58. HAEBE	**C. T-Tauri stars that show brightenings**
59. FUOR	**D. T-Tauri stars with an accretion disk**

60. (T9) White dwarf stars that reside in the instability strip are given which designation?

A. β Cephei
B. D Cephei
C. T Tauri
D. δ Scuti
E. U Geminorum
F. ZZ Ceti

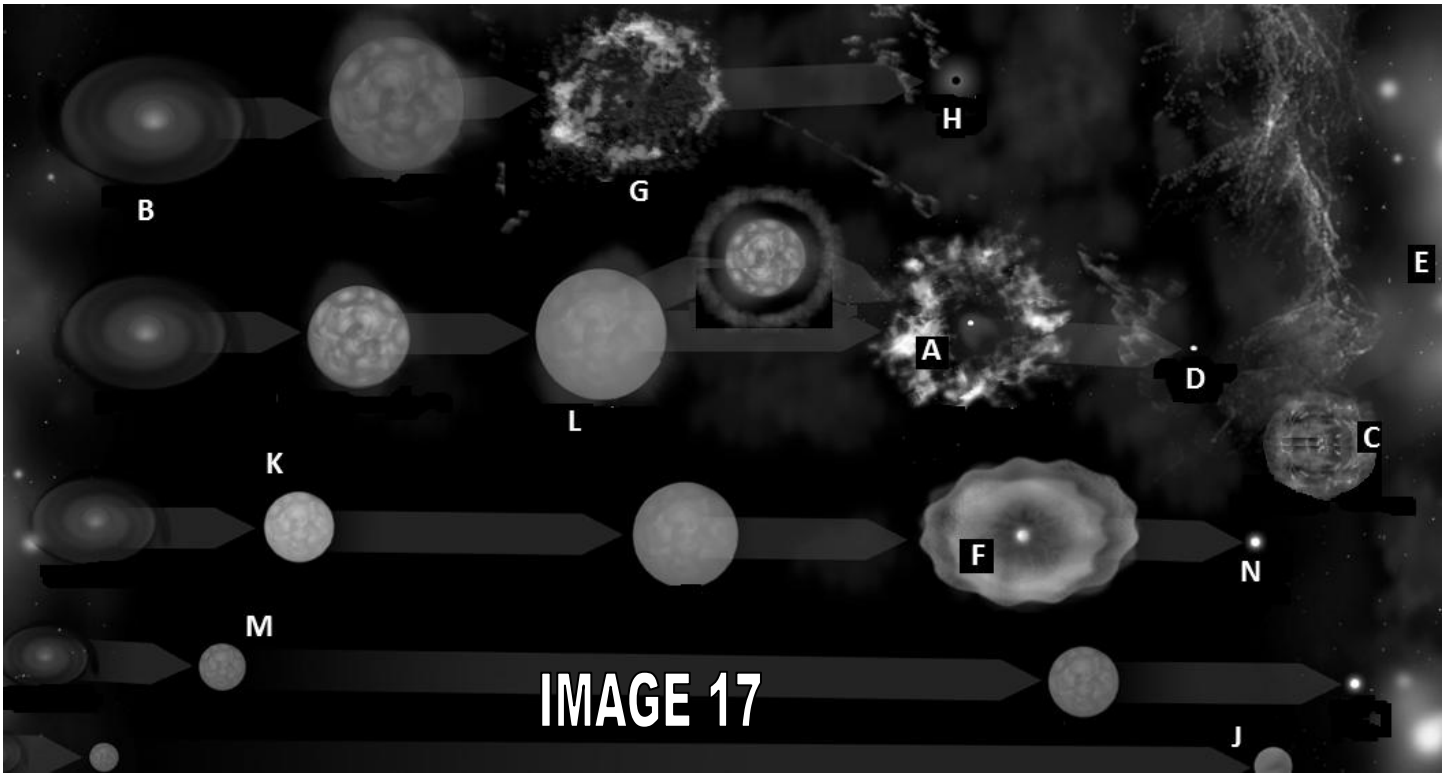
61. White dwarf stars are held up against gravitational collapse by:

A. Radiation pressure
B. Electron degeneracy
C. Neutron degeneracy
D. Gravitational waves
E. Thermal pulses
F. Superwind mass loss

62. (T5) A star has a color indices U − B = −1.19 and B − V = −0.33. This star is most likely:

A. Cool
B. Hot
C. Dim
D. Bright

Match the numbered events and objects (63 – 70) in the possible evolutionary sequences for stars. Use the letters in image 17. Not all letters will be used.



63. Planetary nebula

64. Stellar nursery

65. Type Ia supernova

66. White dwarf

67. Protostar

68. Red dwarf

69. Black hole

70. Neutron star

71. For stars *less* massive than the sun, the dominant reaction during the "hydrogen burning" stage is:

A. The CNO cycle
B. The triple alpha process
C. Carbon burning
D. Oxygen burning
E. The proton-proton chains

72. During the evolution of a star, when does the helium core flash take place?

A. In the main sequence
B. In the subgiant branch
C. In the horizontal branch
D. In the red giant branch
E. In the asymptotic giant branch
F. In the T-Tauri stage

73. T(11) During the evolution of a star, when does helium shell burning take place?

A. In the main sequence
B. In the subgiant branch
C. In the horizontal branch
D. In the red giant branch
E. In the asymptotic giant branch
F. In the T-Tauri stage

74. Why do the HR diagrams for open clusters show a Hertzsprung gap?

A. Gas and dust absorb the visible light from young stars
B. Massive stars have not reached the ZAMS yet
C. O and B stars move through the subgiant branch very rapidly
D. Thermal pulses cause the stars to move to the left on the HR diagram
E. The turnoff point is in the region of F or G stars

A particular star A has a parallax of 18.8 milliarcsec and a proper motion of 234 milliarcsec/year. Its peak wavelength is 411 nm, its apparent magnitude is 6.90, and its z value is 1.29E-4. Use this information for numbers 75 – 84.

75. What is the surface temperature of this star?

A. 3930 K
B. 5790 K
C. 7050 K
D. 11400 K
E. 24600 K

76. What is this star's spectral class?

A. O
B. A
C. G
D. F
E. M

77. How far away is this star?

A. 53 pC
B. 10 pC
C. 134 pC
D. 16 pC
E. 144 pC

78. What is its radial velocity in km/s?

A. 144 km/s
B. 81.9 km/s
C. 302 km/s
D. 73.2 km/s
E. 38.7 km/s

79. What is its transverse velocity in km/s?

A. 73.2 km/s
B. 106 km/s
C. 19.3 km/s
D. 59.0 km/s
E. 45.4 km/s

80. What is its true space velocity in km/s?

A. 151 km/s
B. 68.4 km/s
C. 70.6 km/s
D. 320 km/s
E. 172 km/s

81. What is its absolute magnitude?

A. 3.27
B. 6.90
C. 1.26
D. 1.11
E. 5.88

82. What is this star's luminosity in solar units?

A. 0.15
B. 26.7
C. 4.2
D. 0.38
E. 30.8

83. What is this star's mass in solar units?

A. 0.58
B. 0.76
C. 1.51
D. 2.56
E. 2.66

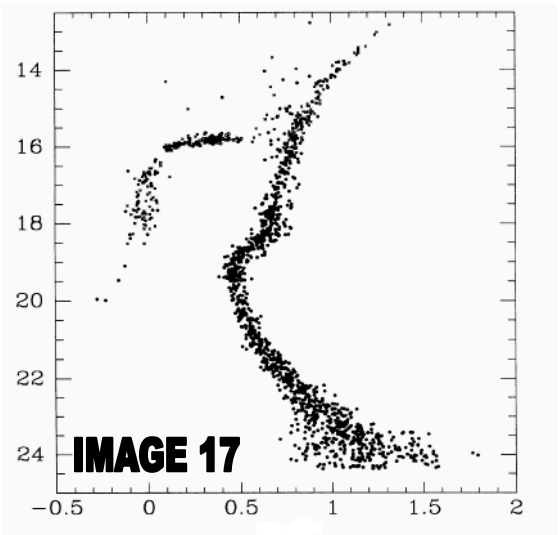
84. What is this star's radius in solar units?

A. 0.034
B. 1.37
C. 5.53
D. 5.94
E. 0.124

Consider the diagram shown in image 17. Use this diagram for questions numbered 85 - 89.

85. This object might contain RR Lyrae stars. If so, what would their apparent magnitude be?

A. 0.2
B. 0.4
C. 1.2
D. 14
E. 16
F. 18



86. What quantity is displayed across the bottom of the diagram?

A. Color
B. Apparent magnitude
C. Absolute magnitude
D. Mass
E. Metallicity
F. Specific flux

87. Stars in an object of this type typically have the same:

A. Metallicity
B. Mass
C. Age
D. A and B, but not C
E. A and C, but not B
F. B and C, but not A

88. What is the approximate distance modulus for this object?

A. 0.5
B. 1.5
C. 16
D. 19
E. 10,000

89. What is the approximate distance to this object?

A. 1 pC
B. 10 pC
C. 1 kpC
D. 10 kpC
E. 1 MpC
F. 10 MpC

90. The 21 cm line indicates the presence of what substance?

A. Neutral hydrogen
B. Ionized hydrogen
C. Carbon monoxide
D. diatomic carbon
E. ammonia
F. formaldehyde

91. "Reddening" refers to which of the following?

A. A shift to longer wavelength due to relative motion of the emitter
B. Differential refraction by the atmosphere according to wavelength
C. Differential scattering by interstellar dust according to wavelength
D. The change in a variable star's "color" as its surface temperature decreases
E. Emission of the red H-α line at 656.3 nm in the Balmer series
F. Fluorescence of HII regions

92. Which of the following components of the interstellar medium would be the densest?

A. Coronal gas
B. H I clouds
C. H II regions
D. Molecular clouds
E. The WIM

93. Recurrent novae tend to be which of the following in comparison to classical novae?

A. Recurrent novae tend to have shorter decline times
B. Recurrent novae tend to have larger amplitudes than classical novae
C. Recurrent novae tend to have brighter minima than classical novae
D. A and B, but not C
E. B and C, but not A
F. A and C, but not B

94. (T1) Symbiotic stars that demonstrate significant variability are called:

A. AM Herculis
B. Z Andromedae
C. SU Ursae Majoris
D. U Geminorum
E. Z Camelopardalis
F. AM Canum Venaticorum

95. Which of the following relationships regarding Type Ia supernovae is TRUE?

A. Brighter Type Ia SN light curves decline more slowly
B. Brighter Type Ia SN light curves decline more quickly
C. More massive white dwarfs remain at maximum for longer periods
D. More massive white dwarfs remain at maximum for shorter periods

96. The presence of the forbidden lines [O I] and [S II] in the spectra of T-Tauri stars implies which of the following?

A. High temperatures
B. Low temperatures
C. High gas density
D. Low gas density
E. Mass accretion
F. Mass loss

97. Globular clusters tend to be populated by _____ stars.

A. Old
B. Metal-rich
C. Population I
D. A and B, but not C
E. A and C, but not B
F. B and C, but not A

98. The slow migration of neutral particles in a dense molecular core, inhibited (by ions) from moving across magnetic field lines, is called:

A. The Virial Theorem
B. Bonner-Ebert collapse
C. Ambipolar diffusion
D. Magnetic subcriticality
E. Adiabatic fragmentation
F. The Hayashi Track

99. (T10) The minimum mass necessary to initiate spontaneous collapse of a cloud is described by:

A. The Schönberg-Chandrasekhar limit
B. The Jeans criterion
C. The Kerr metric
D. The Planck mass
E. The Eddington approximation
F. The Gamow peak

100. (T2) Radial pulsation allows astronomers to use radiant flux and photometric color at different times to estimate the mean radius of a pulsating variable star. What is the term for this process?

A. Kapteyn's method
B. The (O-C) method
C. The Lagrangian Integration
D. The Runge-Kutta algorithm
E. The Baade-Wesselink method
F. The Schwarzschild metric