

**National Science Olympiad  
Astronomy C Division Event  
19 May 2012  
University of Central Florida  
Orlando, FL**



Artist Illustration of Red Giant, White Dwarf and Accretion Disk (Wikimedia)

TEAM NUMBER: \_\_\_\_\_

TEAM NAME: \_\_\_\_\_

**INSTRUCTIONS:**

- 1) Please turn in ALL MATERIALS at the end of this event.**
- 2) Do not forget to put your TEAM NAME and TEAM NUMBER at the top of all Answer Pages.**
- 3) This event and the answer key will be available on the AAVSO website:  
<http://www.aavso.org/science-olympiad-2012>**
- 4) Good Luck! And May the Stars be With You!**

**Question Set A: Use Image/Illustration Set A (Pages 9-10) to answer the following 20 questions.**

1. (A) What specific stage of stellar evolution is shown in Images 5 and 14?  
(B) What letter(s) on the H-R diagram show the location(s) of the progenitor object that resulted in Images 5 and 14?
2. What is the number of the image that contains stellar objects located at position J on the H-R diagram? (B) What is the name of the object displayed in this image?
3. (A) Which one of the three following sequences of evolutionary tracks across the H-R diagram is possible? A) N,D,E,F,G B) J,F,R,H,A C) K,C,E,F,B  
(B) Which image(s) show regions where star formation begins?
4. (A) What is the location of Image 13 on the H-R diagram? (B) Which image shows the behavior of this object during its next evolutionary stage?
5. (A) What type of star does Image 13 become when it begins exhibiting the behavior in question 4B above? (B) What location(s) on the H-R diagram show plots of this type of behavior?
6. (A) What type of object is shown in Image 15? (B) What type of highly evolved variable stars are located in this type of object?
7. (A) Which image shows the behavior of the stars identified in question 6B?  
(B) Which letter on the H-R diagram is a plot of this behavior?
8. What two scenarios lead to a Type Ia supernova event?
9. Which images show configurations that are necessary to produce a Type Ia supernova event?
10. (A) On the H-R diagram, F and G are located on what branch? (B) Which object is the youngest?
11. (A) What is the name of the object in Image 4? (B) Which image shows the next evolutionary stage for this object? (C) Classify the object(s) in the image that displays this next evolutionary state.
12. (A) Which Image shows a protostar? (B) What number shows its location on the H-R Diagram?
13. (A) What is the area of the H-R diagram called occupied by the letters E, N and O?
14. Which images contain Type Ia supernova remnants?
15. (A) What type of object is shown in Image 12? (B) Which image is the next evolutionary stage for the object in Image 12?

16. Rearrange the following stages/processes into a sequence from formation to destruction for a younger mid-sized star in a close binary system with an older mid-sized star: planetary nebula, Type Ia supernova, Mira variable, stellar nursery, white dwarf, T-Tauri, main sequence star, mass transfer.
17. (A) What objects are shown in Image7? (B) What are the possible outcomes for this type of system?
18. (A) What letter on the H-R diagram is located in a region where low metallicity stars are fusing helium? (B) What is this region on the H-R diagram called?
19. (A) What letter(s) on the H-R diagram are located in the dimmest and hottest area? (B) What is or are the possible future(s) for the object(s) located there?
20. What is the evolutionary sequence for a star located at position N on the H-R diagram?

**Question Set B: Use Image/Illustration Set B (Pages 11-12) to answer the following 14 questions.**

**1. The Sirius star system is comprised of the 2.3 solar mass Sirius A, the brightest apparent star in the sky, and its companion, the 1.0 solar mass Sirius B. It lies at a distance of 8.6 light years from Earth.**

- Which image shows this object?
- The angular separation between the two stars as seen from Earth is  $10''$ . What is the period of their concentric orbit, in years?
- How far away from the center of mass of the system is Sirius A, in A.U.?
- The luminosity of Sirius A is approximately 100 times that of Sirius B, and the radius of Sirius A is approximately 100 times that of Sirius B. What is the temperature of Sirius B, in Kelvin, knowing that the temperature of Sirius A is 10,000 K?
- Because Sirius B is very small and hot, it is also very dense. What effect does this have on hydrogen absorption lines in the spectra of the object?

**2. U Scorpii is a recurrent nova, first discovered in 1863. It is also the 'fastest' novae ever observed.**

- Which image shows this object's light curve?
- What factor determines the speed class of a nova?
- What general type of object comprises the primary of U Sco?
- In what year did the most recent eruption of this system occur?
- Which light curve on image set B best displays the eventual end result of this system?

**3. Image N shows a summer constellation, which contains a variable deep sky object with an absolute magnitude of approximately +0.6 and a period of 13 hours.**

- Which element is fused into heavier elements by nuclear processes in the core of this object?
- Why does this object have a lower metal abundance than the sun?
- This object has a characteristic modulation in its light curve due to the Blazhko effect. Name one characteristic change in the light curve due to this effect.

**4. HD 62166 is a white dwarf in the Milky Way galaxy.**

- Which image contains this object?
- What is the NGC classification number of the material surrounding this object?
- HD 62166 is 1,100 times brighter than our sun, and has a radius of 0.03 solar radii. What is the temperature of this object, in Kelvin?

**5. Four RR Lyrae class light curves are shown in image P.**

- Which of the light curves (1-4) corresponds to the star with the longest period?
- Why is there an upward bump near minimum light in most RR Lyrae-type light curves?

**6. Image BB shows a Chandra X-Ray light curve of a binary star system.**

- What is the full ROSAT identification of this object?
- Use the light curve to find the orbital period of this binary, in seconds.
- This system has been observed to be moving closer together at a speed of 2 feet a day. What phenomenon, postulated by Einstein, causes the energy loss in this system that enables the stars to be moving towards one another?
- The two stars are 50,000 miles apart. What is the combined mass of this system, in solar masses?

**7. Mira, in the constellation Cetus, is a prototype Long Period Variable.**

- a) Which image shows this object in the visible region of the electromagnetic spectrum?
- b) Which element is found in the very core of this star?
- c) As this object's photosphere expands, it preferentially absorbs visible light. The formation of which molecule causes this?
- d) What is the period of this object, in days?
- e) Mira itself is the prototype of Mira-class variables, but the system it resides in is also another type of variable besides a long-period. What other class of variable do Mira and its companion belong to?
- f) What repeated process causes ejection of a red giant's outer layers over time to form a white dwarf in the center?

**8. CH Cygni is unpredictably variable, changing in magnitude over month-long time scales from +5.6 to +10.4.**

- a) What specific class of variable is CH Cyg the brightest member of?
- b) Which image shows this object's light curve?
- c) Image T shows CH Cyg. In what part of the electromagnetic spectrum does this image reside?
- d) What specific feature of CH Cyg does image T display?

**9. T Tauri is shown in image Q.**

- a) What is the New General Classification number of the nebula located next to T Tauri in image Q?
- b) Image R shows T Tauri's Hydrogen-alpha profile. Why does it have a broad peak?
- c) Image L shows a P Cygni profile of a T Tauri-type star. What dynamical process, occurring due to the accretion of material onto the star, can be found to occur using the profile?
- d) Which two images show regions that stars similar to T Tauri would likely be found in?
- e) What largely causes the ionization of the hydrogen in these regions?

**10. Image M displays the color-magnitude diagram for M15.**

- a) What is the B-V color index of stars at M15's turnoff point?
- b) Which region (1-6) would one find blue straggler stars?
- c) Would the B-V color index of stars at the turnoff point change as M15 ages? If so, in what way would the index change?

**11. Image X shows a composite image of a star found 1,000 light years from Earth.**

- a) What is shown by the green streaks on the image?
- b) What catastrophic interaction caused these streaks, along with a disk surrounding the star?
- c) The purple dots in image X are far-field X-Ray sources. What causes most of these X-Ray peaks?

**12. The Carina and Rosette diffuse nebulae house two of the most studied HII regions in the Milky Way.**

- a) What is the NGC identification of the Carina nebula?
- b) Image V shows the center of the Rosette nebula. In what part of the electromagnetic spectrum was this image taken in?
- c) The Chandra X-Ray observatory recently discovered a diffuse X-Ray glow in the Carina nebula through its mapping of the nebula, seen in image Y. Name both types of contributors to this glow.
- d) At which point (1,2,3,4) in image Y does Eta Carina lie?

**13. Two separate Type Ia supernova remnants are seen in images W and CC.**

- a) Which two deep sky objects are seen in these images?
- b) Which Image (W or CC) shows an object that belongs in a new class of SNR characterized by bright interior emission?
- c) Is SNR 0509-67.5 an older or younger SNR than the object shown in image W?
- d) Which SNR is seen in image DD?
- e) The supernova remnant in image DD is expanding into dense material that is rich in nitrogen, unexpected material to be found near a Type Ia SNR. What does this imply about the life time of the progenitor of image DD compared to the progenitor star for a normal Type Ia SNR?
- f) Tycho's SNR has an expansion velocity of 4500 km/s and explosion energy of  $4.5 \times 10^{50}$  erg, where  $1 \text{ erg} = 10^{-7} \text{ Joules}$ . Approximately how much mass is swept up by this remnant, in solar masses?
- g) Tycho's SNR lies 2.75 kiloparsec away from Earth, and has an angular diameter of 4 arcminutes. Assuming a constant expansion velocity, how long ago did this supernova occur, in years?

**14.** Though all Type Ia Supernovae have similar absolute magnitudes, they are not exactly the same. What is this difference in magnitude a function of, i.e., what observable difference is there between two Type Ia Supernovae with different absolute magnitude?

**Question Set C: Use the same Image/Illustration Set B from Question Set B (Pages 11-12) to answer the following 10 questions.**

**1. Use the table of information below to answer the following questions.**

Object	Average Luminosity (Solar Units)	Distance (Parsecs)
Mira	9000	130
CH Cyg	34	240
M15	360,000	10300
T Tauri	1	180
RR Lyrae	45	260
Rosette Nebula	550	1600
NGC 2440	1500	1230

- What is the distance, in light years, to the object whose light curve is shown in image H?
- What is the average apparent magnitude of the object whose light curve is shown in image G?
- What is the average absolute magnitude of the object whose light curve is shown in image I?
- The radius of the object shown in image J is 80 light years. What is its angular radius, in arcminutes?
- What is the distance to the object shown in image S, in kilometers?

**2.** A light curve of Object A is shown in image A. What is the distance to object A, in megaparsecs?

**3.** Object B's light curve is shown in image B. What is the parallax of this object, in arcseconds?

**4.** Object C is a planetary nebula that began expanding 5,000 years ago with an expansion velocity of 1000 m/s. The angular radius of the nebula is currently 8.8 arcminutes. What is the distance to this planetary nebula, in parsec?

**5. Object D, a globular cluster, is measured to have a parallax of 0.01'' and an angular radius of 0.25 radians.**

- What is the diameter of object D, in parsec?
- Star E, located 24 pc from the center of object D, orbits around the center of the globular with the same period as Star F, located 12 pc from the center. How many times greater is the orbital velocity of the Star E than star F?
- Object D has a 10,000 solar mass black hole located at its center. Star G is located 10 light years from the center of this black hole. What is the orbital velocity of Star G around the black hole, in km/s?

**6. Stars H and J are members of a symbiotic eclipsing binary system whose light curve is shown in image C. Star J has an orbital velocity of 5 km/s, and is located 20 AU from Star H. Star J is 50 times brighter than star H.**

- What is the combined mass of the system, in solar masses?
- Star H's maximum and minimum H-alpha lines are found to be 656.5 nm and 656.1 nm, while the laboratory line of H-alpha is 656.3 nm. What is the mass of star H, in solar masses?
- What is the density of star H, in  $\text{kg/m}^3$ ?
- What type of star is star H?

7. The spectra of Star I, a main sequence star with an apparent visual magnitude of +11, is shown in image D. How far is Star I from Earth, in pc?
8. The spectra of Star L, a main sequence star, is shown in image E. What is the B-V color index for Star L?
9. Star M and Star O both have the same mass, and orbit in a binary system with a period of 20 days and a separation of 1 AU. What is the angular speed of Star M, in radians/second?
- 10. The peak wavelength of radiation received at Earth from Star N is 200 nm, and Star N has a radius 5 times that of the Sun.**
- What is the temperature of Star N, in Kelvin?
  - What is the luminosity of Star N, in solar luminosities?