National Science Olympiad
Astronomy C Division Event
18 May 2013
Wright State University
Dayton, OH

TEAM NUMBER: _____

TEAM NAME: _____

INSTRUCTIONS:

1) Please turn in <u>ALL MATERIALS</u> at the end of this event.

2) Do not forget to put your <u>TEAM NAME</u> and <u>TEAM NUMBER</u> 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-2013

4) Good Luck! And May the Stars be With You!

Section A:

Use Image/Illustration Set A (Pages 4 and 5) to answer the following questions.

1. (a) What is the name and number of the image that shows a star formation region in the constellation of Scorpius?
(b) What letter on the H-R diagram shows the location of the red supergiant star located in this region?

2. (a) What object do Images 10, 12 and 16 have in common?
(b) Place the images in order from youngest to oldest.

3. (a) What specific type of stellar behavior is indicated by letter F on the H-R diagram?
(b) What is the image number and name of the object that displays this type of behavior?

4. (a) List the numbers of the objects for which the next evolutionary stage is a core collapse.
(b) Which letter on the H-R diagram represents the behavior of these objects prior to core collapse?

5. Which of the following sequences of evolutionary stages on the H-R diagram leads to a Type II supernova event? A) G,J,A,F,X B) T,R,F,P,A, C) T,G,M,A,P

6. (a) What specific type of behavior is represented in the graph in Image 1?
(b) What is the name and image number of an object exhibiting this behavior?

7. Which images contain a supernova remnant?

8. (a) What is the name of the object on the left illustrated in Image 14?
(b) Which letters on the H-R diagram show the locations of both objects in the illustration?

9. What is the region of the H-R diagram that is occupied by the letter R called?

10. Which letters on the main sequence of the H-R diagram mark the locations of stars that will not evolve to a Type II supernova event?

11. (a) Which letter on the H-R diagram marks the location of the coolest red supergiant?
(b) What are the final evolutionary products for this object?

12. (a) What type of central object is located in the Deep Sky Object in Image 5?
(b) What is the initial spectral classification of this type of object?

13. (a) Which 2 Milky Way Galaxy images contain objects that are in the first stage of stellar evolution?
(b) Give the name and number of the image (of the two from Question 13a) which also contains several more highly evolved stars.

14. What type of system is shown in Images 7 and 14?

15. (a) What is the name of the object in Image 18?
(b) Which letter marks its location on the H-R diagram when it was at maximum magnitude?

16. Rearrange the following stages/processes into a chronological sequence: red supergiant, O/B star, supernova remnant, protostar, semiregular, wind driven pulsar, Cepheid.

17. (a) Which images contain objects from both extremes of stellar evolution?
(b) How is the formation of one of these objects caused by the object that is at the other extreme stage of stellar evolution?

18. Which letters on the H-R diagram show the locations of the central objects in Images 3 and 12?

19. (a) Which image shows SN 2010jl?
(b) What major recent piece of evidence was provided by the observation that acquired this image?

20. Which two images show the previous (closest to present) evolutionary stage of the object shown in Image 15?

Section B:

Use Image/Illustration Set B (Page 7) to answer the following questions.

21. (a) Which Deep Sky Object is shown in Image 19?
(b) Which part of the electromagnetic spectrum was this image taken in?
(c) Which color corresponds to the strongest observed emission in this part of the electromagnetic spectrum?

22. (a) An image of the Sun is shown in Image 20. In which part of the electromagnetic spectrum was this image taken in?
(b) Is the gas density higher or lower in the darker regions of the image? Explain why.

23. (a) A spectrum of Alpha Orionis is shown in Image 21. It displays two prominent absorption lines, the h and k lines. At what wavelength do these lines occur, in nanometers?
(b) The absorption from which element causes these lines?

24. SXP 1062 is shown in Image 22. In which part of the electromagnetic spectrum was this image taken?

25. (a) A field that has a pulsar within it is shown in Image 23. Which Deep Sky Object may be found in this image?
(b) In which part of the electromagnetic spectrum was this image taken?

Consider an eclipsing binary star system with the light curve and radial velocity curve (inferred from spectral lines) shown in Images 24, 25, and 26 on Image Page B. Star α has a photosphere temperature, inferred from spectral type, of 5150K, and star β has a temperature of 6540K. You may assume that star β has a larger radius than star α.

26. What is the semimajor axis of the stars' orbit, in AU?

27. What is the radial velocity of the system with respect to Earth, in km/s?

28. What is the mass of Star α, in Solar Masses?

29. What is the radius of Star α, in Solar Radii?

30. What is the radius of Star β, in Solar Radii?

31. What is the distance to this star system, in kpc?

Section C: ***Use Image/Illustration Set C (Page 9) to answer the following questions.***

The period-luminosity relationship in the V-band from the ASAS catalog for Type I Cepheids in the Large Magellanic Cloud is shown in Image 27 and compared to that from the OGLE catalog.

The least-squares fit of the ASAS data is:

$$V_{ASAS} = -2.366 \log P + 16.784 \quad \textbf{(1)}$$

while the least-squares fit of the OGLE data is:

$$V_{OGLE} = -2.762 \log P + 17.530 \quad \textbf{(2)}$$

32. Use the ASAS least-squares fit (Equation 1) to calculate the absolute magnitude of a Type I Cepheid in the LMC, at a distance of 49 kpc and with a period of 77 days.

33. What is the percent difference in apparent magnitudes of a Type I Cepheid with a period of 100 days between the ASAS and OGLE period-luminosity relationships?

34. Does this difference increase or decrease with increasing Type I Cepheid period? What might account for this, other than statistical bias?

The period-luminosity relationship in the visual band for a variety of Cepheid types from the OGLE catalog is shown in Image 28, and Image 29 shows a corresponding color-magnitude diagram.

35. Which type of Cepheids are shown by the black dots in these images?

36. Which type of Cepheids are shown by the blue squares in these images?

37. RV Tauri stars are one type of Population II Cepheids. Which stage of stellar evolution are they leaving on their way through the instability strip, and which will they enter next?

These questions focus on spectral analysis of a specific Type II Supernova, SN 1993J. Spectra taken at different times after the supernova event began are shown in Image 30. Image 31 shows the location of prominent lines in SN 1993J's spectrum. Image 32 compares the spectrum of a typical Type II Supernova with that of a typical Type IIn Supernova.

38. What is the name of the set of spectral lines that indicate the presence of a Type II Supernova?

39. What element is found in Type II Supernova spectra that is not seen in Type I Supernova spectra, and hence is the main distinction between the two types?

40. In Image 30, from April 7th to April 29th, what happens to the H-α lines in SN 1993J?

41. Which spectral line becomes notably stronger over time in the spectra from Image 30?

42. Based on your observations in the previous questions, what specific type of Supernovae is SN 1993J?

43. What do the broad lines in Image 32 represent about the material within Type II Supernovae?

44. The formation of which two elements signal the end of energy-producing fusion in the core of a Type II Supernova progenitor?

45. Without this energy, the massive star collapses on itself. However, it does not immediately explode. What phenomenon balances out the extreme gravitational force exerted on the center of the star in this phase?

Section D:

Answer the following questions using the information given. All figures necessary are on the test itself. Note that objects are designated using a letter (A, B, C, etc.) and that answers from one question may carry over to the next question if the same object is part of both questions.

Star A is a 1.2 Solar Mass red giant with a radius of 350 Solar Radii and temperature of 3000 K. Star A has an extended atmosphere, and at a radius of 1500 Solar Radii it is cool enough for dust to form.

46. What is the flux from the star, in Watts/m^2, at the radius at which dust begins to condense around Star A?

47. What is the luminosity of Star A, in Solar Luminosities?

The following questions refer to Object B, a supernova remnant with a pulsar observed in its center. After correcting for the motion of the object, the [O II] (3278.8 Å) line from Object B spreads to 3287.5 Å and 3270.0 Å. Object B has an apparent diameter of 152.24". Twenty years ago, Object B had an apparent diameter of 151.44".

48. Estimate the age of the Object B, in years.

49. Assuming spherical symmetry, calculate the distance to Object B in kpc.

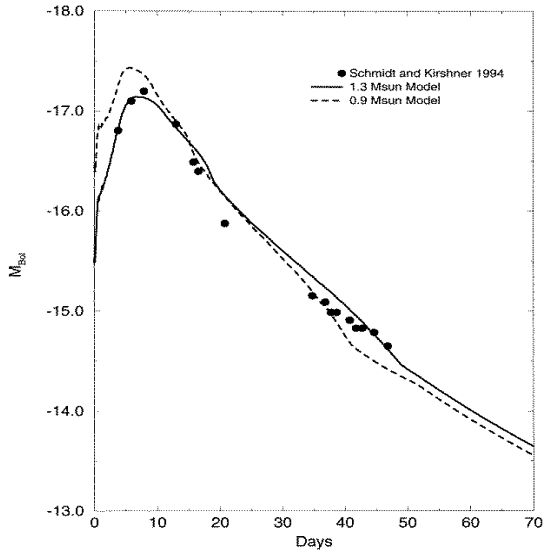
50. A pulse from the pulsar in Object B measured at 830 MHz is delayed from the same pulse at 880 MHz by 83.8 ms. What is the explanation for this effect?

51. Object C, a Type II Supernova remnant formed from a progenitor star of 20 solar masses, is found to have an average expansion velocity of 10 km/s. Estimate the kinetic energy released by the supernova which formed Object C, in Joules.

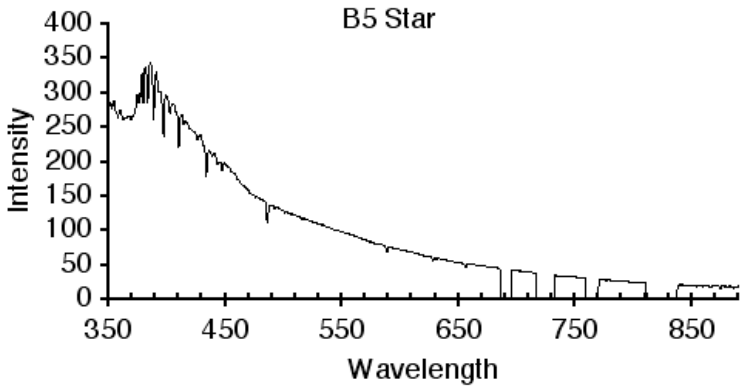
52. The interstellar medium surrounding Object C is isothermal with a temperature of 10 Kelvin, and can be assumed to be composed of only protons. What is the sound speed of the surrounding medium, in km/s?

53. What will occur when the speed of the ejected "wind" from Object C falls below the sound speed of the surrounding medium?

54. The light curve of the Supernova that formed Object C is shown to the right, with two model fits for the data points shown. Use the 0.9 Solar Mass model trendline to calculate the distance to Object C in Mpc, using the observed apparent bolometric magnitude of 10.



55. A spectrum of Star D, a B5 main-sequence star, is shown below. The wavelength on the x-axis is given in nanometers. Estimate the surface temperature of Star D, in Kelvin, using Wien's law.



56. Star D has a luminosity 20 times that of the Sun. What is the radius of Star D, in Solar Radii?

57. Star D has a parallax of 0.005". What is its apparent magnitude?

58. Star E is a main-sequence A0 star. What is its surface temperature, in Kelvin?