National Science Olympiad
Astronomy C Division Event
22 May 2010
University of Illinois at Urbana-Champaign
Champaign, IL

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 following website:

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

Consider Images O P, S, and T

1. Which is produced from the longest wavelength electromagnetic radiation
2. Which is produced from the shortest wavelength electromagnetic radiation

3. A starburst galaxy has 3×10^{12} times the mass of the sun. 300 solar masses of this hydrogen gas is used to make stars each year. How many years does the starburst have sufficient hydrogen to support this rate of star formation?

Image V shows a deep sky object and Image X is its corresponding H-R Diagram.

4. What kind of object is this?
5. Assuming the distance to this object is 34,000 light years, what is the absolute magnitude of stars at the turnoff point of the cluster?
6. What is the age of the object in years?

Consider Images M, N, O, and T

7. Which is produced from the same portion of the electromagnetic spectrum as image Q
8. Which was produced from the same portion of the electromagnetic spectrum and P

The metallicity of a star is equal to log[(Fe/h)star/(Fe/h)sun]

9. What is the metallicity of a young population I star with a ratio of iron atoms to hydrogen atoms ten times greater than that of the sun?
10. Do Population I stars have higher or lower metallicities than Population II stars?
11. Why are their metallicities different?

12. If the temperature of the cosmic microwave background is 3 K, what is the frequency of the radiation from this background, in Hz?

13. Why do starbursts shine brightly in the infrared portion of the electromagnetic spectrum?

Object α and Star β are members of a binary star system. Object α is a 16 solar mass black hole. Star β is a 70 solar mass O6 star. The system has an orbital period of 3.45 days. Star β has an orbital velocity around the system's center of mass of 110 km/s. Object α has an accretion disk around it, due to mass transfer from star β.

14. Which object shown in Image Set 1 (Images A – T) is most similar to this system?
15. What part of the electromagnetic spectrum does this system radiate the most energy in?
16. What is the distance between the two objects, in AU?
17. If star β moves closer to Object α at a rate of 1 km/year, how many years will it take for the period of the system to shrink to 3 days?
18. Once star β goes supernova, what relativistic effect will be used to "map" its movements around object α?
19. Which absorption spectra shown in AD, AE, AF, and AG most resembles the absorption spectra for Star β?

For questions 20 – 24 , answer where (location i, ii, or iii) in the structure of the galaxy shown in Image D they are most likely to occur.

20. Image J
21. Image E
22. Most G2 Main Sequence Stars
23. The Galactic Bulge

The gravitational disruption of a smaller intruder galaxy passing through the Cartwheel Galaxy compressed the interstellar gas and dust causing a wave of star formation to move out from the impact point. The wave of new star formation from the head-on collision has produced the ring-like structure of bright blue knots seen in the Hubble optical image in figure AK. In figures AL - AP, the Chandra x-ray data (on the left) and the Hubble data (on the right) are aligned and displayed side-by-side in ds9 analysis software. The crosshairs are in different places in each figure to mark various features. In figures AM and AN, a green circular region has been drawn around the Cartwheel Galaxy in the optical image. The crosshairs are moved on the x-ray image to measure the diameter of the region in pixels (see the x and y physical coordinates in the upper left for the location of the crosshairs). In a Chandra observation, 1 pixel = 0.5 arc sec.

24. Determine the size of the ring in light years given a distance to the Cartwheel Galaxy of ~380 million light years.
25. Determine how long ago in years the collision of galaxies may have occurred using an expansion rate of ~321,860 km/hr.
26. From your comparison of the x-ray and optical images of the Cartwheel Galaxy, does it seem to have an AGN? Why?
27. What types of objects might the ultra and hyperluminous x-ray sources located along the ring be? Explain your answer using the information provided, previous calculations, comparisons of the x-ray and optical images, and knowledge of stellar life spans.
28. What types of object marked by crosshairs in figure AP be? Explain your answer using the information provided, previous calculations, comparisons of the x-ray and optical images, and knowledge of stellar life spans.

Treating a star as a spherical black-body, the luminosity, L, is equal to $4\pi R^2\sigma T^4$
Star γ has the same temperature and twice the radius of Star δ

29. How many times more luminous is Star γ than Star δ?

Treat a galaxy as a cylindrical black-body with a radius R, temperature T, and thickness H. Galaxy ε and Galaxy ϕ and have radii that are 100 times as large as their thicknesses. Galaxy ε has the same temperature and twice the thickness of Galaxy ϕ.

30. How many times more luminous is Galaxy ε than Galaxy ϕ?

Galaxy η and Galaxy λ have radii that are 100 times as large as their thicknesses. They have the same luminosities and are the same distance from the observer. However, the orientation of Galaxy η to the observer is edge-on (Image AI) and the orientation of Galaxy λ is face-on (Image AH)

31. How many times more energy reaches the observer from Galaxy λ than from Galaxy η?

32. What is the name of the object in image I?
33. What portion of the electromagnetic spectrum was image I produced from?
34. What type of object is image I?
35. What causes the "bubbles" in this image to form and radiate at the wavelength of Image I?

For question 36, use E=(efficiency)*mc^2
36. In M33 X-7, mass falls onto a black hole from its companion star. Assuming that the mass accretion rate onto the black hole is 1.11 x 10^{15} kg/s and the efficiency of the energy emitted with respect to mass accreted is .3, what is the luminosity of the energy released in watts?

Use the infrared image, Image U, to answer the following 4 questions.
37. Assuming that the supermassive black hole in Sagittarius A* has a mass of 3 x 10^6 solar masses, what is the semimajor axis of SO-1 in AU?
38. Consider a star in a circular orbit of radius 1000 AU around Sagittarius A* with an orbital speed of 1500 km/s. What is the period of this star in years?
39. Determine the sum of the masses of this star and Sagittarius A*in solar masses.

40. The graph shown in image W is a plot of the radius-luminosity relationship for Active Galactic Nuclei. The x axis shown is the luminosity of the AGN at 5100 angstroms in watts, and the y axis is the radius of the AGN in light-days. Using this plot, what is the distance in light years to an AGN with a radius of 10 light-days, assuming its apparent magnitude at 5100 angstroms is 1.23?

Consider objects in images A, B, G and I
41. Which is the most massive?
42. Which is the least massive?

43. Assume a civilization in a distant star system live on a planet twice the mass of Earth, with a year equivalent to a Martian year, 687 Earth days, and a sun with a mass equal to our sun. If they observe a parallax of .01 arcseconds for our sun, how far away are they from our solar system, in pc?

44. Which of the spectra shown in Z, AA, AB, and AC is that of a Starburst Galaxy?

Consider objects in images C, E, and K
45. Which is the most massive?
46. Which is the least massive?

Assume H_0 = 79.3 km/s/Mpc
47. What is the age of the universe, in billions of years?
48. What is the maximum radius of the universe, in Mpc?

49. What is the name of the object in image L?
50. What portions of the electromagnetic spectrum was image L produced from?
51. What type of object is image L?

52. What caused the burst of star formation in this object?

A star has a redshift of .000025. It is observed to move .04 arcseconds per year across the sky.
53. If the apparent magnitude of the star is 5 and it the star is an RR Lyrae star, what is its true velocity (in km/s)?

Tulley-Fischer is an empirical relationship between the rotational velocity of a spiral galaxy and its luminosity. Galaxy μ is a spiral galaxy and is rotating at twice the rate of spiral Galaxy ν. The radii of both galaxies are equal.
54. According to Tulley-Fischer, how many times more luminous is Galaxy μ than Galaxy ν?
Now consider a model of a galaxy where all of the mass of the galaxy is concentrated at the center as shown in Image AJ. Assume that the luminosity of a galaxy is directly proportional to its mass.
55. According to this model, how many times more luminous is Galaxy μ than Galaxy ν?
56. Why are the answers to Questions 54 and 55 different?
57. Why is it surprising that the Tully-Fisher relationship matches observations well?

Consider the object in image F and image R
58. What type of objects are they?
59. Which was formed by the core-collapse of a massive star?
60. Which was formed from a binary star system?
61. Which reached a brighter absolute magnitude?

A star at a distance of 1000 pc has a light curve shown in Image Y. At maximum the star has a temperature of 6000K, and at minimum its temperature is 5000K.
62. What kind of variable star is shown?
63. What is the luminosity of the star at maximum, in solar luminosities?
64. The ionization and recombination of what element drives this change in luminosity, temperature, and radius?

SN 1993J had a maximum apparent magnitude of 10.5. The expansion velocity of its shell was half of the speed of light. the shell of SN 1993J was observed to move .00248 arcseconds over 100 days.
65. How far away is M81 in Mpc?
66. What was the maximum absolute magnitude of SN 1993J?

Consider the spectrum in image H
67. What is the name of the name of the object that corresponds to this spectrum?
68. How many components of this system were are required to produce this spectrum?

Use a period luminosity relationship of M=-2.81logP – 1.43, P in days
69. A type I Cepheid variable star is 3 kiloparsecs away from the Earth, and it has an apparent magnitude of 6.89. What is the calculated period for this star in days?

A gas cloud has a mass of 10 solar masses, and is .5 pc from the galactic center.
70. What radius, in meters, must the cloud be compressed to before it becomes a black hole?

71. What is the name of the object in image M?
72. What portion of the electromagnetic spectrum was image M produced from?
73. What type of object is image M?
74. How do black holes control the rate of star formation in this galaxy?

75. The disk of the Milky Way Galaxy is elliptical, with a ratio of the lengths of the minor and major axes of 0.9. If the average solar galactocentric distance is 8 kpc, what is its distance from the Galactic center at apogalacticon, in kpc?