Science Olympiad Astronomy C Division Event Golden Gate Invitational

University of California, Berkeley Berkeley, CA



January 27, 2018

Team Number:

Team Name:

Instructions:

1) Please turn in <u>all materials</u> at the end of the 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) Write all answers on the lines on the answer pages. Any marks elsewhere will not be scored.

4) Do not worry about significant figures. Use 3 or more in your answers, regardless of how many are in the question.

5) Please <u>do not access the internet</u> during the event. If you do so, your team will be disqualified.

6) Feel free to take apart the test and staple it back together at the end!

7) Good luck! And may the stars be with you!

Section A: Use Image/Illustration Sets A and B to answer Questions 1-18. Each subquestion in this section is worth one point.

- 1. DEM L241 is a supernova remnant in the Large Magellanic Cloud.
 - (a) Which image depicts this object?
 - (b) Research has indicated the presence of mass loss from a massive star within DEM L241 directed towards a highly compact companion. Why is this significant?
- 2. Image 7 depicts an object's brightness over time.
 - (a) Which object's behavior is represented by this image?
 - (b) What is significant about this particular object relative to others in this galaxy?
- 3. Regarding objects of the same type as the object in Question 2a-2b:
 - (a) What is the general classification of this kind of object?
 - (b) What other object(s) fall under this classification? Give name(s) and image number(s).
 - (c) What is the likely next stage of evolution for an object of this type?
- 4. Order the objects in the following images by relative age (i.e. youngest stage of evolution to oldest stage of evolution): 4, 5, 10, 14
- 5. NGC 7822 is a large star forming complex composed of an emission region and a young cluster of stars.
 - (a) What is the Sharpless Catalogue designation of the emission region?
 - (b) The young star cluster is highly energetic and luminous, sculpting the surrounding nebulosity with intense stellar winds. What effect will this likely have on future star formation in NGC 7822? Explain in detail.
- 6. Image 8 was taken by the Chandra X-Ray Observatory.
 - (a) What is the common name and Sharpless catalogue number of this object?
 - (b) What is depicted in the lower right inset of this image?
 - (c) What is odd about this inset?
 - (d) List two possible explanations for this oddity.
- 7. Using the HR Diagram in Image 16, assign the following objects to the best fitting letterdesignated location:
 - (a) Image 4
 - (b) Image 7
 - (c) Image 1
 - (d) Image 12
 - (e) Image 14

- 8. Circinus X-1 is an x-ray binary system that experiences periodic flaring.
 - (a) Which image depicts one of these flare events in X-rays?
 - (b) Such flaring would seem to indicate that Circinus X-1 has exceeded the Eddington Limit. Why is this surprising?
- 9. Image 11 depicts the brightest star in the constellation Orion.
 - (a) Which image shows the variability of this object?
 - (b) In 1920, this star was the first to have its photosphere directly measured. What technique was used to accomplish this?
- 10. Image 9 depicts two pulsars in x-ray and infrared composite.
 - (a) Which pulsar is on the left? Which is on the right?
 - (b) What is indicated by the extended patches of light seen in both images?
 - (c) Though structurally similar, why do the two objects appear different?
- 11. Which image depicts the activity of a supernova remnant rotating thousands of times slower than its age would suggest?
- 12. Image 6 depicts two x-ray sources in M82. One of these, a pulsar, exceeds the theoretical luminosity limit of an object of its mass. What is the name of this limit, and a reason the pulsar may be able to exceed it?
- 13. Image 10 depicts an artist's conception of the closest supernovae observed in modern astronomy.
 - (a) What is the name of this supernova event?
 - (b) What standard feature of a supernova is notably missing from this remnant?
- 14. The Geminga Pulsar is in part named as a transcription of the Milanese phrase gh'é minga, meaning "it's not there."
 - (a) Geminga is thought to be the first known example of what type of object?
 - (b) Why is the name "Geminga" appropriate in context of the above question?
 - (c) How might Geminga's magnetic field have influenced this phenomenon?
- 15. Order the objects in the following images by increasing distance from the Earth: 6, 8, 11, 13, 14
- 16. Image 3 depicts a hypernova event in nearby galaxy M101.
 - (a) Which object is potentially the most luminous of these events ever detected?
 - (b) How does this object's spectrum contradict such a conclusion?
 - (c) Based on this, what was likely this object's previous stage of evolution?
- 17. Which image depicts one of the most prominent sites of massive star formation in the Milky Way?

- 18. Westerhout 49 is a strong galactic thermal radio source discovered in 1958.
 - (a) Which image depicts a supernova remnant within this region?
 - (b) This remnant is bizarrely shaped compared to others produced by similarly massive progenitors. What likely caused this?

Section B: Each sub-question in this section is worth 1 point.

- 19. Use Image/Illustration Set B (Image 16) for the following questions.
 - (a) What physical quantity is typically represented by the x-axis of this diagram?
 - (b) What physical units does the x-axis of this diagram have?
 - (c) What two quantities are typically represented by the y-axes of this diagram?
 - (d) Select which of the following best describes both the x- and y-axis scale: linear, power-law, logarithmic.
 - (e) At which location (A-K) on this diagram would a Sun-like star be located?
 - (f) At which two locations (A-K) on this diagram is a white dwarf star found?
 - (g) At which location (A-K) on this diagram is a luminous blue variable star found?
 - (h) At which location (A-K) on this diagram is a main-sequence O-type star found?
 - (i) At which location (A-K) on this diagram is an M-dwarf star found?
 - (j) At which location (A-K) on this diagram is a red supergiant found?
- 20. Write the word or phrase that best matches each description below.
 - (a) Intrinsically pulsating variables that have regular periods of 1-100 days and are used to calculate distances to nearby galaxies.
 - (b) A star more massive than the Sun that has a radius 10^5 times smaller than that of the Sun.
 - (c) Observationally derived relationship between the radial velocities and distances of galaxies.
 - (d) A stellar binary system in which one star appears to occult the other periodically.
 - (e) Regions of ionized hydrogen in which stars form.
 - (f) Type of energy transport through spacetime that is caused by cosmic inflation, closeorbiting neutron star systems, and coalescing black holes.
 - (g) Stripped core-collapse supernovae that have lost both hydrogen and helium before collapse.
 - (h) Heaviest element to form in a stellar interior before core-collapse.
 - (i) Alpha Orionis is an example of this type of variable star.
 - (j) Neutron stars with magnetic fields of $10^4 10^7$ Gauss.



Figure 1: Schematic of on-axis weak short-hard gamma ray burst.

- 21. Figure 1 above shows a schematic of an on-axis weak short-hard gamma ray burst.
 - (a) The merger of which type of objects causes these gamma ray bursts?
 - (b) What is labeled by the letter C in the diagram?
 - (c) What is labeled by the letter A in the diagram?
 - (d) What is labeled by the letter B in the diagram?
 - (e) These gamma ray bursts result in the production of heavy elements by which nucleosynthesis process?

Section C: Each sub-question in this section is worth 2 points.

- 22. Star A is a main-sequence star with a temperature of 35,000 Kelvin and a luminosity 50,000 times that of the Sun.
 - (a) What is the stellar type of Star A?
 - (b) What is the radius of Star A, in Solar radii?
 - (c) Star A has a mass of 20 Solar masses. What is the bulk density of Star A, in g/cm^3 ?
 - (d) What is the absolute magnitude of Star A?
 - (e) Star A has an apparent magnitude of 5. What is the distance to Star A, in kilo-parsecs?
 - (f) What is the parallax of Star A, in milli-arcseconds?
 - (g) Our Sun has a radiative interior and a convective envelope. How does the internal structure of Star A differ from that of our Sun?
- 23. The H-alpha line of a distant galaxy is observed to have a wavelength of 657.3 nm. The wavelength of this line at rest is 656.3 nm. Assume Hubble's constant is 70 km/s/Mpc.
 - (a) What is the radial velocity of this galaxy, in km/s?
 - (b) How far away is this system in Megaparsecs?
 - (c) The hydrogen Lyman-alpha line occurs at 121.6 nm in the laboratory. What will the observed wavelength of this line be in the spectrum of the galaxy, in nm?
 - (d) Calculate the size of the observable universe in Giga-parsecs.
 - (e) Calculate the Hubble time in Giga-years.
- 24. Star B and Star C orbit one another in a binary star system. Star B is 5 times more massive than Star C, which has a mass of 1 Solar Mass. Stars B and C are separated by 1 AU. Assume that both stars have circular orbits.
 - (a) What is orbital period of this binary star system, in years?
 - (b) How many times faster is the orbital velocity of Star C than star B?
 - (c) What is the distance from Star C to the center of mass of the system, in AU?
 - (d) What is the orbital velocity of Star C, in km/s?
 - (e) What is the angular momentum of Star C, in kg m^2/s ?

Team name: _____ Team number: _____

Answer Page: Section A

1.	(a)	
	(h)	
	(0)	
2.	(a)	
	(b)	
9	(-)	
ა.	(a)	
	(b)	
	(c)	
4		
1.		
5.	(a)	
	(b)	
6.	(a)	
	(\mathbf{b})	
	(\mathbf{D})	
	(c)	
	(d)	
7.	(a)	
	(b)	
	(\mathbf{c})	
	(J)	
	(u)	
	(e)	
8.	(a)	
	(b)	
0		
9.	(a)	
	(b)	
10.	(a)	
	(b)	
	(\circ)	
	(6)	
11.		



Team 1	name:
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19. (a) _____ (b) _____ (c) _____ (d) _____ (e) _____ (f) _____ (g) (h) _____ (i) _____ (j) _____ 20. (a) _____ (b) _____ (c)(d) _____ (e) _____ (\mathbf{f}) (g) _____ (h)(i) _____ (j) _____ 21. (a) _____ (b) (c) _____ (d) _____ (e) _____

Answer Page: Section B

Team name:	Team number:	



Answer Page: Section C

IMAGE SHEET A



Image 1



Image 2



Image 3



Image 4



Image 5



Image 6



Image 7



Image 8



Image 9



Image 10



Image 11



Image 12

Image 13

Image 14

Image 15

IMAGE SHEET B



Image 16