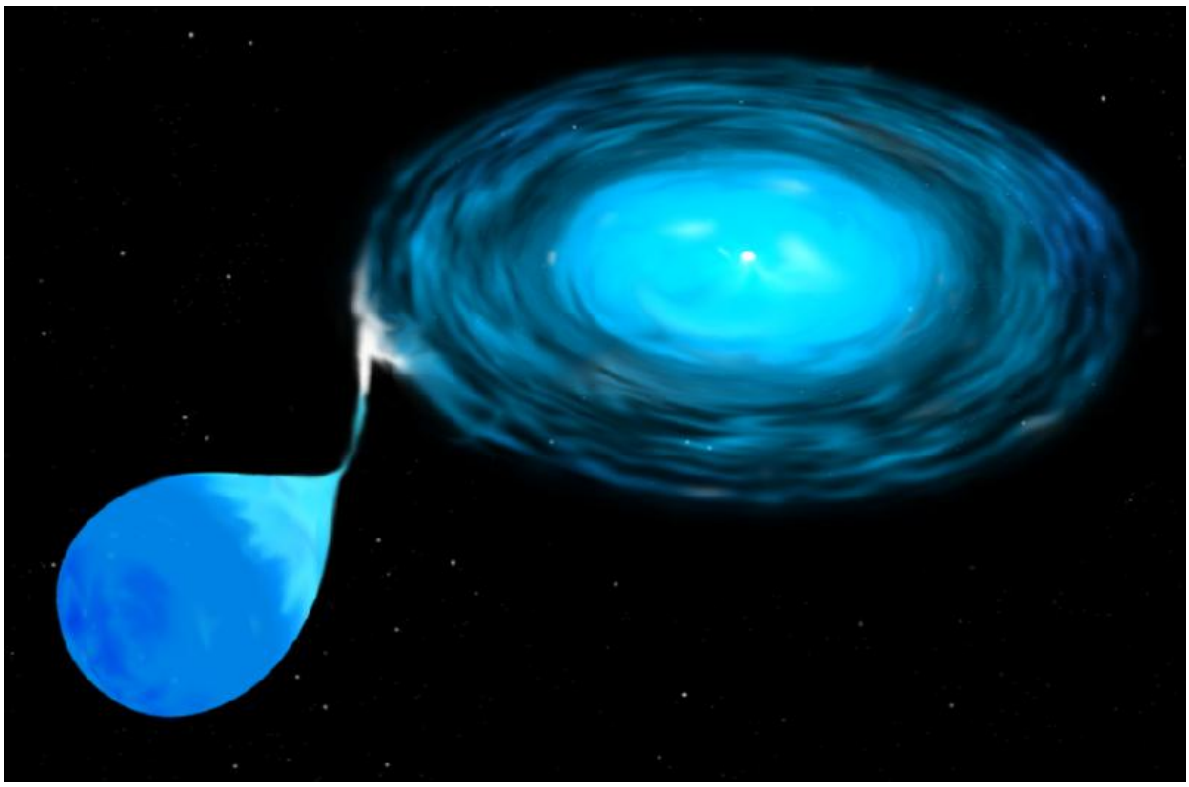
Science Olympiad
Astronomy C Division Event

Golden Gate Invitational

February 11, 2017



Team Name: _____

Team Number: _____

Directions:

~Answer all questions on the answer sheet provided.

~Please do NOT access the internet during the event.

~The tiebreaker for this test is total points on Part 1, then Part 2.

~Don't be afraid to guess (logically) for partial credit where possible, and remember to have fun!

Section A: Deep Sky Objects. Refer to Image Sheet to answer questions. If a question asks for multiple images, you gain credit for the net number correct.

1. Which images on the image sheet show DSO systems that involve possible progenitors for Type Ia SNe?
2. Which images on the image sheet show AM CVn systems?
3. Which images on the image sheet show DSOs that include Type Ia SNe or SNRs?
4. Which evolutionary paths are possible (more than one answer possible, consider images generally in terms of types and how many objects present in them)?

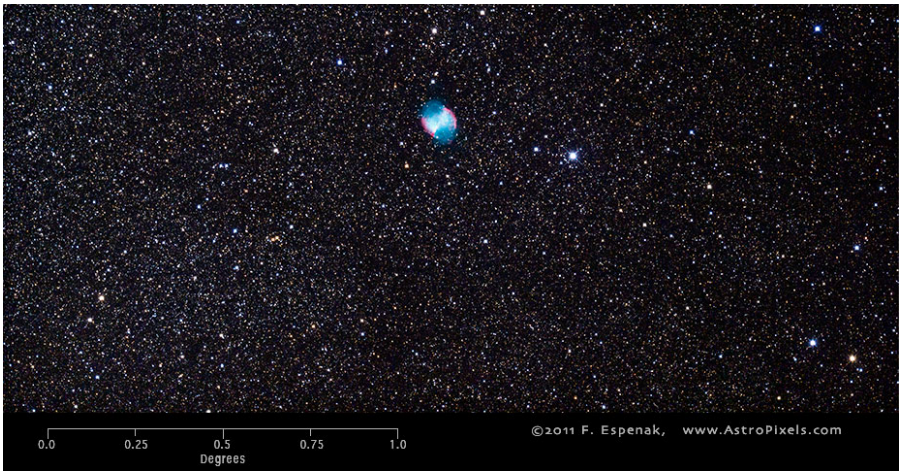
A) 14 → 25 → 3 → 1 → 13 → 10
B) 1 → 25 → 8 → 13 → 10
C) 28 → 15 → 5 → 13 → 10
D) 1 → 5 → 6 → 13 → 10
E) 28 → 15 → 3 → 13 → 10

5. Order images 3, 7, 14, 18, 23 from largest to smallest in physical size.
6. Refer to Image 29 (for locations use letter that best represents the object asked about):
   What is the name of this diagram?
   a. Where (what letter A – O) is the bright object in image 1?
   b. Where (what letter A – O) is the object in the DSO NGC 2440?
   c. Where (what letter A – O) is the variable star Mira?
   d. Where (what letter A – O) is the object in image 28?
   e. Where (what letter A – O) is the donor for the type of system that is representative of the light curve in image 27?
7. Image 19 comes after what stage of stellar evolution?
   a. The image shows radial velocity measurements using NII. During what stage was this NII likely brought to the surface of the star?
   b. Who discovered the DSO in image 19?
8. What image shows NGC 2440?
   a. The material around the central star of this object glows because it was ionized by what type of light?
   b. Assuming the multi-polar structure of NGC 2440 present in the image came from jets, what axial movement may have caused this?
9. What DSO is in image 5?
   a. This system's mass may exceed what mass limit for white dwarfs?
   b. The objects of this system will create what specific event?
   c. If one component of the system was more massive than the other, then the DSO may be what type of system?
10. The object in image 15 has ejected material that is visible. Just before this, the DSO was at what stage of stellar evolution?
    a. Image 15 was observed with what type of light?
    b. The DSO in image 15 has relatively low C abundance, so it may not have went through what period of stellar evolution where C is brought to the surface of the star?
11. Which image is the light curve of the DSO Mira? How can you tell?
    a. Which lobe (right or left) is the Mira variable star in image 25? Which radiation law (of Wien's Law, Stefan-Boltzmann Law, or Planck's Law) may be applied to most easily know this?
    b. Image 25 was observed with what type of light?
12. Which image shows the constellation that contains the DSO that is a dwarf nova?
    a. What are the two types of stars that make up this system?
    b. What is the energy source of dwarf nova outbursts?
13. What is the image of the constellation with the brightest DSO from Earth? What is the name of this DSO?
    a. What image shows the DSO?

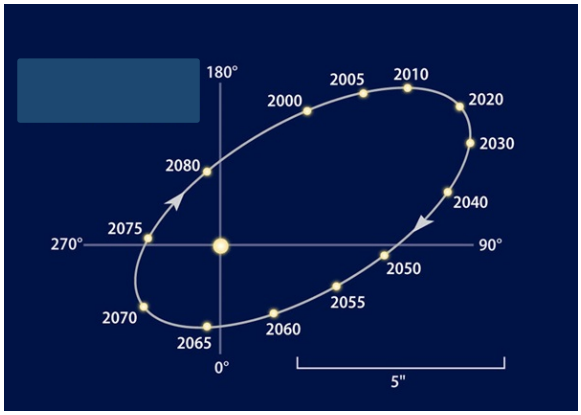
    b. The spectrum of the fainter component in this system has what characteristics based on its spectral type?
14. J075141 and J174140 are in what type of system?
    a. What is larger in size a more or less massive white dwarf? In these systems would the more or less massive white dwarf accrete off the other?
    b. Which white dwarf would have been larger on the main sequence, the more or less massive one? Which white dwarf would have evolved faster off the main sequence, the more or less massive one?
15. Which image shows the light curve of HM Cancri?
    a. What wavelength was the light curve taken in?
    b. By Einstein's General Relativity, this system should emit what type of waves?
16. Which image shows SN 2011fe?
    a. Much of the energy as the DSO brightened comes from radioactive decay of what element?
17. Which DSO is in image 9?
    a. The event that produced this DSO likely contributes to much of observed abundances for what element?
    b. This DSO likely had what type of progenitor based on the emptiness of the center of the SNR?
18. Which DSO is in image 14?
    a. What element distinguishes that this DSO was created by a Type Ia SN and not a Type II SN?
    b. This DSO is classified as what type of SNR?
    c. X-ray stripes detected in an image of this DSO may be a source of what extremely energetic particles that hit Earth?
19. Which constellation is SNR G1.9+0.3 in? What is the image that shows this constellation?
    a. The SN appears asymmetric, which is possibly due to what explanation?
    b. What particles are accelerated to produce the synchrotron radiation observed with this SNR?
20. Which image shows the color-magnitude diagram for the DSO in image 17? What is the designation of this DSO?
    a. What do the extended main sequence turnoff and the spread of the red clump in the color-magnitude diagram for this DSO indicate?
    b. What do astronomers fit to the main sequence turnoff and red clump on such color-magnitude diagrams to determine ages of clusters?
21. Which DSO is located in the constellation in image 11?
    a. This DSO contains Pease 1, which is what type of object?
    b. Why are there so few of objects like Pease 1 observed within the DSO?

Section B: Images are referenced in questions.

22. What is the distance in kpc to a star with a parallax of 8.91 milliarcseconds?



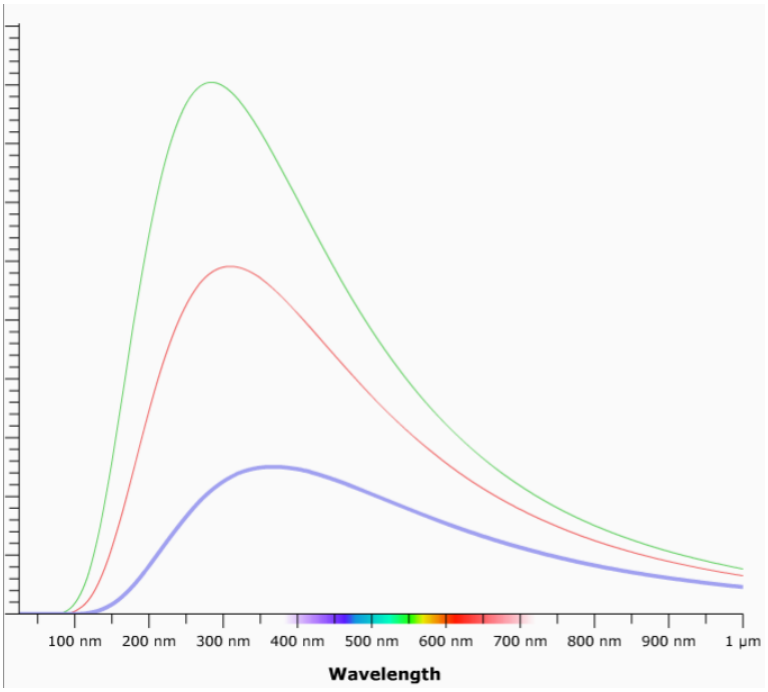
23. The distance to the object in the image above is 218 pc. What is the radius of the object in ly along its shortest axis?
24. You want to know the distance to a globular cluster. What horizontal branch stars can you use to find the distance?
    a. In this globular cluster, you observe a star with an apparent magnitude of +11.92. Assuming it is such a horizontal branch star, what is the distance to this globular cluster in kpc?
25. What is the luminosity in Lsun of a star with an absolute magnitude of -5.36?
26. You measure that the Balmer α line for a star has been Doppler shifted from 656.3 nm to 656.103 nm. What is the radial velocity of this star in km/s?
    a. What is the tangential velocity of this star given that the star travels 3.45 mas in 44 years at a distance of 167 pc?
    b. What is the total space velocity of this star in km/s?
    c. How far in AU does this star travel in a year?



27. Refer to the above image of a visual binary star. Assume the orbit is circular and that this system is also an eclipsing binary. What is the period of orbit in years for the system?
    a. What is the angular size of the semi-major axis for the system in arcsecs?
    b. You find from spectroscopic data that the ratio of radial velocities for the system is 3:1. From parallax you find that the system you find the system is a distance 41.8 ly away. What is the mass in solar masses of the less massive star of this system?
    c. What is the angular velocity of the less massive component in radians/sec?

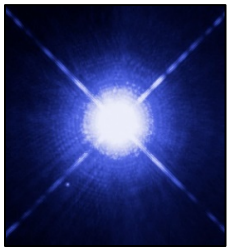
d. If the semi-major axis of the system was decreased by a factor of 16, what would the new angular velocity be in radians/sec?

28. You observe a Type Ia supernova at a distance of 7.10 Mpc that exploded in 2016. How many years ago did it occur (round to the nearest year)? If today we transported to where the supernova was, would we still see a remnant of the explosion if it takes 100,000 years for an SNR to disperse?
29. From images over time, you determine the expansion rate of a Type Ia SN to be 258 km/s. Assuming the mass of the SNR is approximately 0.5 solar masses, then what is the kinetic energy of the SN in ergs?
    a. You find that this kinetic energy is lower than that of other Type Ia SN, but it was as bright or brighter than other Type Ia SN when the supernova occurred. Modeling the progenitor system as two white dwarfs, why might this be the case? Explain why the system is better modeled with two white dwarfs than a single white dwarf, why this relates to the lower kinetic energy, and why it would be as bright or brighter than other Type Ia SN.

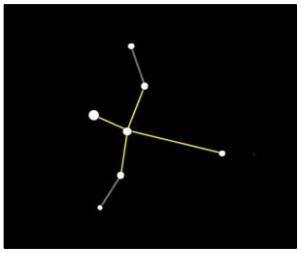


30. The above diagram represents approximate blackbody curves for observed stars of different temperatures? What is the temperature in K of the middle, red curve on the graph?
    a. Which curve represents the star that is the brightest of the three in the B-band?
    b. Which curve represents the star with the smallest output of radio emission?
    c. True or false: The middle curve would be representative of a star with neutral Fe in its spectrum.
    d. True or false: The top curve would be representative of a star with ionized He in its spectrum.
    e. True or false: The bottom curve would be representative of a star with ionized Ca in its spectrum.

Golden Gate Invitational Astronomy C Image Sheet



1



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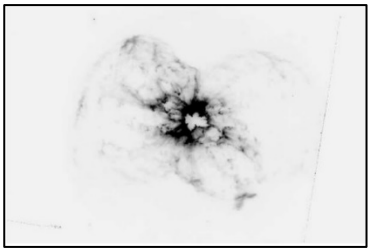

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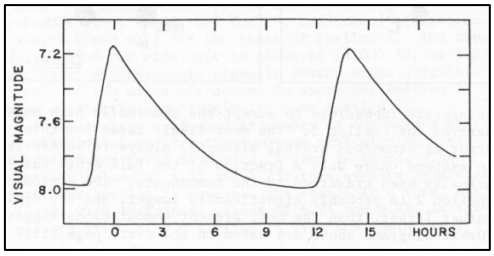

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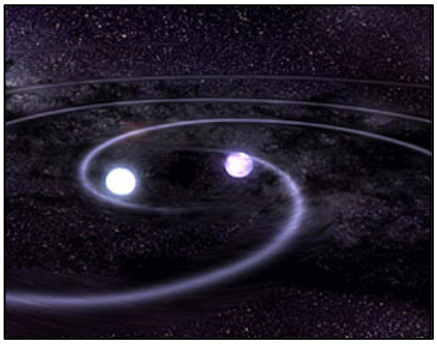

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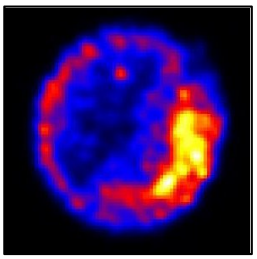

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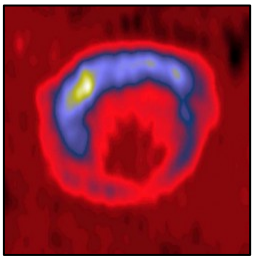

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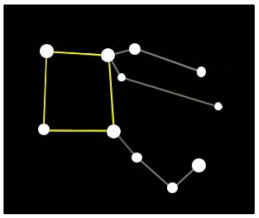

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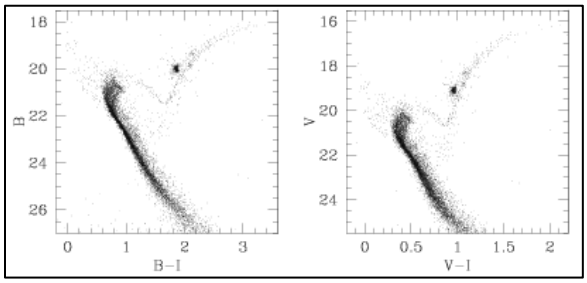

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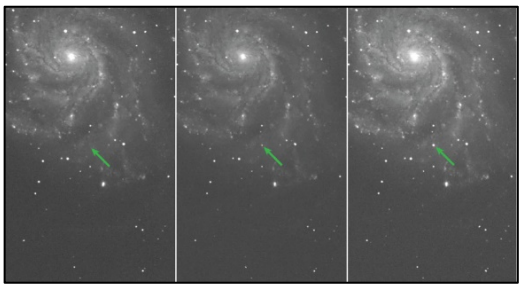

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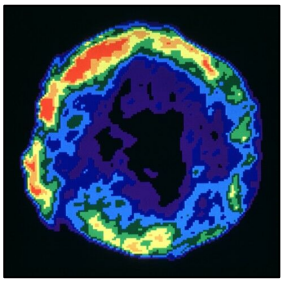

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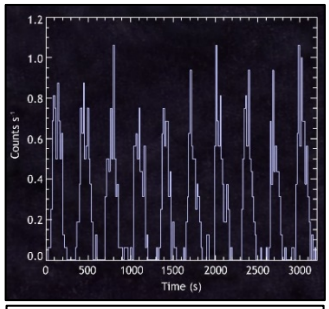

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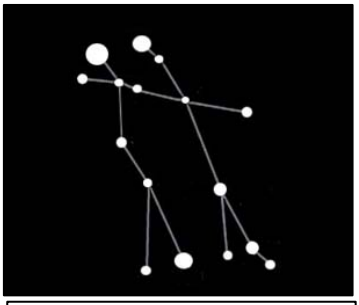

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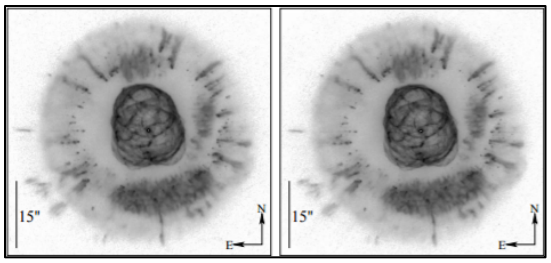

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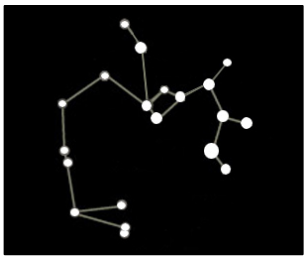

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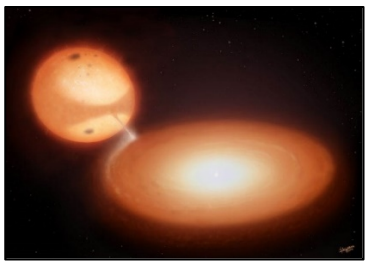

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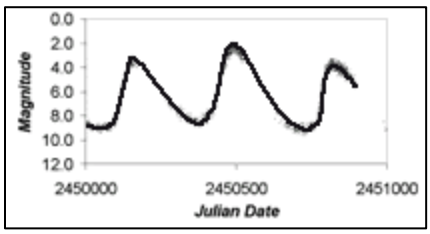

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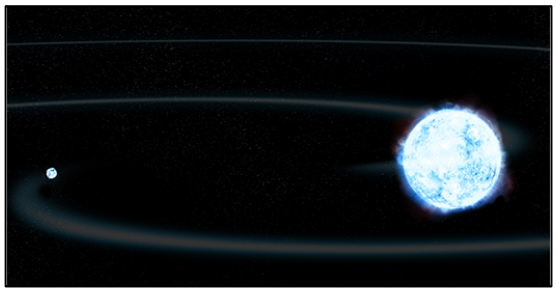

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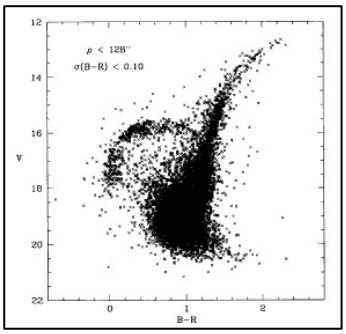

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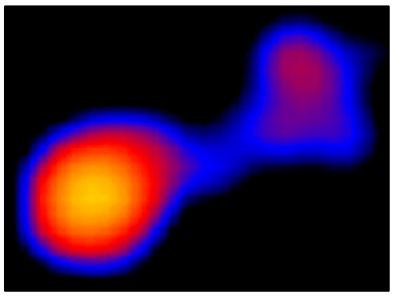

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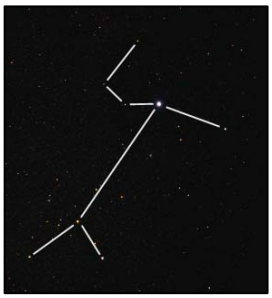

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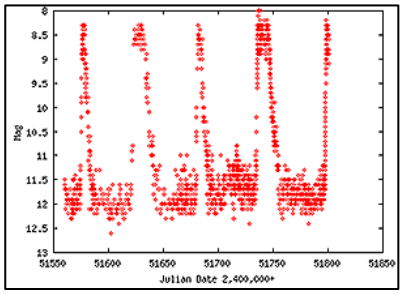

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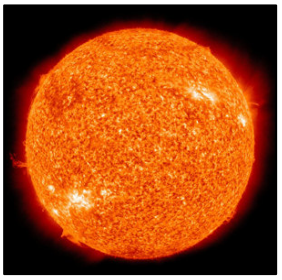
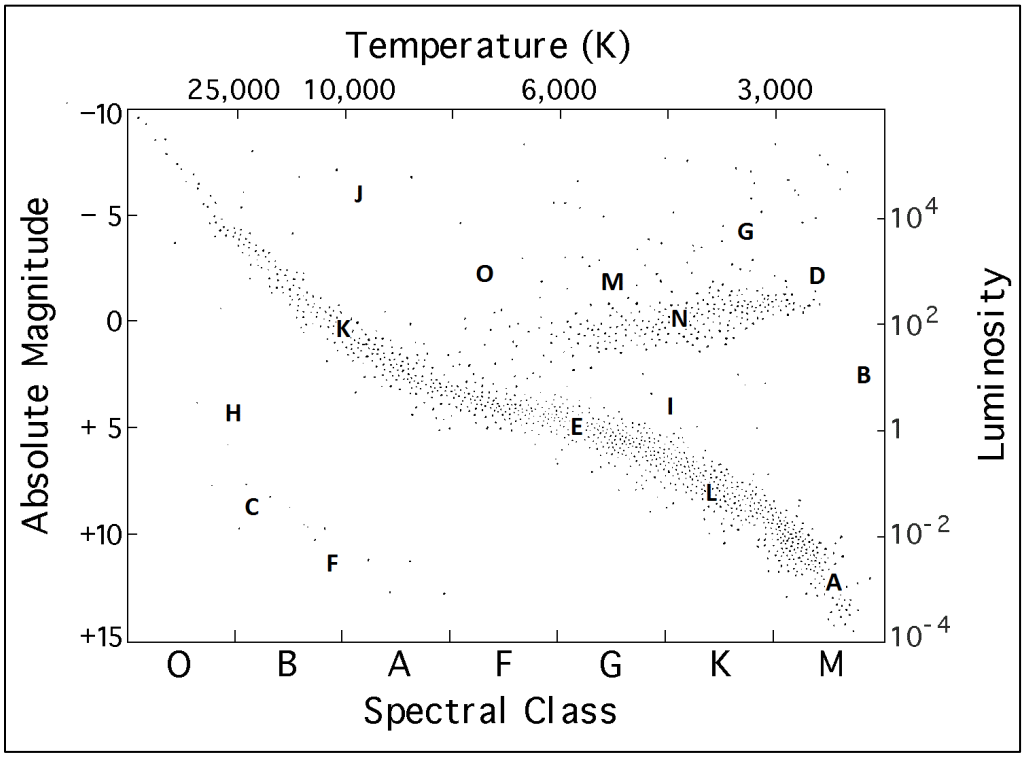


28



29

Team Name/Number: _____

Raw Score: _____

Section A

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
   a. _____
   b. _____
   c. _____
   d. _____
   e. _____
7. _____
   a. _____
   b. _____
8. _____
   a. _____
   b. _____
9. _____
   a. _____
   b. _____
   c. _____
10. _____
    a. _____
    b. _____
11. _____

    _____
    a. _____
    b. _____
12. _____
    a. _____
    b. _____
13. _____
    a. _____
    b. _____

    _____
14. _____
    a. _____
    b. _____
15. _____
    a. _____
    b. _____
16. _____
    a. _____
17. _____
    a. _____
    b. _____
18. _____

Team Name/Number: _____

a. _____

b. _____

c. _____

19. _____

a. _____

_____

b. _____

20. _____

a. _____

b. _____

21. _____

a. _____

b. _____

_____

_____

Section B

22. _____ kpc

23. _____ ly

24. _____

a. _____ kpc

25. _____ Solar luminosities

26. _____ km/s

a. _____ km/s

b. _____ km/s

c. _____ AU

27. _____ years

a. _____ ”

b. _____ Solar masses

c. _____ radians/sec

d. _____ radians/sec

28. _____ years

_____

_____

29. _____ ergs

a. _____

_____

_____

_____

_____

_____

_____

_____

30. _____ K

a. _____

b. _____

c. _____

d. _____

e. _____

Golden Gate Invitational Astronomy C Key

Team Name/Number: Astronomy

Raw Score: 89.5/89.5

Grading Instructions:

- 1 point per part of question except questions with multiple parts or longer answers (specified below)
- For questions with more than one answer in a single part of a question (1 – 5, 11, 11a, 12a, 13, 14a, 14b, 19, 20)
  - Each part of the answer is 0.5 pts
  - For example, question 4 has the answer B, E, so B and E are each worth 0.5 pts (and as a whole the question is thus worth 1 point)
  - The total point values for these questions are noted in parentheses next to the questions
- Questions with longer answers include 28, 29a
  - The main parts of an answer needed as well as the associated points for that part of the answer are noted by brackets []
  - These questions also have total point values in parentheses next to the questions

Section A

1. 1, 5, 6, 8, 16, 21, 23, 25, 27 (4.5)
2. 6, 16, 23 (1.5)
3. 9, 10, 13, 14 (2)
4. B, E (1)
5. 18, 7, 14, 3, 23 (2.5)
6. HR Diagram or color-magnitude diagram
   a. K
   b. H
   c. D
   d. E
   e. L
7. Asymptotic Giant branch or AGB
   a. First dredge-up
   b. William Herschel
8. 3
   a. Ultraviolet or UV
   b. Precession
9. Hen 2-428
   a. The Chandrasekhar limit
   b. Type Ia SN
   c. AM CVn
10. Post-AGB
    a. Optical/Visible
    b. Third dredge-up
11. 22, differentiated by characteristically long period (1)
    a. Left, Stefan-Boltzmann Law (1)
    b. X-ray
12. 2

Golden Gate Invitational Astronomy C Key

a. _Red Dwarf, White Dwarf_____(1)

b. _GPE / Gravitational Potential Energy_

13. _26, Sirius (or Sirius A and B)_____(1)

a. _1_____

b. _ Only Balmer lines (no He I or metals)_____

14. _ AM CVn _____

a. _Less, more_____(1)

b. _More, more_____(1)

15. _16_____

a. _X-ray_____

b. _Gravitational waves_____

16. _13_____

a. _ Nickel or Ni-56 _____

17. _ SNR 0509-67.5_____

a. _ Fe or Iron _____

b. _ Double-degenerate or two white dwarf binary system _____

18. _ Tycho's SNR _____

a. _ Silicon or Si _____

b. _ Shell-type _____

c. _ Cosmic rays _____

19. _20, Sagittarius _____(1)

a. _ Delayed detonation (a slow wavefront followed by a much faster one) _____

b. _Electrons_____

20. _12, NGC 1846 _____(1)

a. _ Multiple stellar populations _____

b. _ Isochrones _____

21. _ Messier 15 or M15 _____

a. _ PN (Planetary Nebula) _____

b. _ They may require more massive progenitors (or systems) to form, which is rarer OR planetary nebulae are dispersed quickly/have short lifetimes _

Golden Gate Invitational Astronomy C Key

Section B

22. 0.112 kpc

23. 0.886 ly

24. RR Lyrae stars
    a. 1.714 kpc

25. 11,900 Lsun

26. -90.1 km/s
    a. 364 km/s
    b. 375 km/s
    c. 79.1 AU

27. 87.71 yr
    a. 0.976”
    b. 0.191 solar masses
    c. $2.27 * 10^{-9}$ rad/s
    d. $1.45 * 10^{-7}$ rad/s

28. Occurred ~23.2 million years ago [**1 pt**]. We would be unlikely to see a trace (the SN would be dispersed). [**1 pt**] (2)

29. $3.31 * 10^{47}$ ergs
    a. Type Ia SN in general should explode with consistent amounts of energy based on the Chandrasekhar limit [**1 pt**]. Since the kinetic energy was lower, the ejecta may have been relatively heavy [**1 pt**]. This makes sense with a double degenerate progenitor (a Type Ia SN from two white dwarfs) because the companion of a single white dwarf progenitor system would be less evolved/would only fuse up to lighter elements by the time the SN occurred (OR that a system of white dwarfs would be more evolved/made of heavier elements) [2 pt]. (4)

30. 9700 K
    a. The top, green curve
    b. The bottom, blue curve
    c. False
    d. False
    e. True

Tiebreaker list (in order):

6, 30, 3, 29, 4, 1, 28, 14, 26, 2, 10, 17, 21, 24, 8, 11, 22, 20, 5, 13, 15, 23, 25, 7, 27, 18, 16, 19, 9, 12