Astronomy — 2018

Section 1: Images

Note: unless otherwise specified, all questions are worth one (1) point. For questions about the electromagnetic spectrum, choose from the following list:

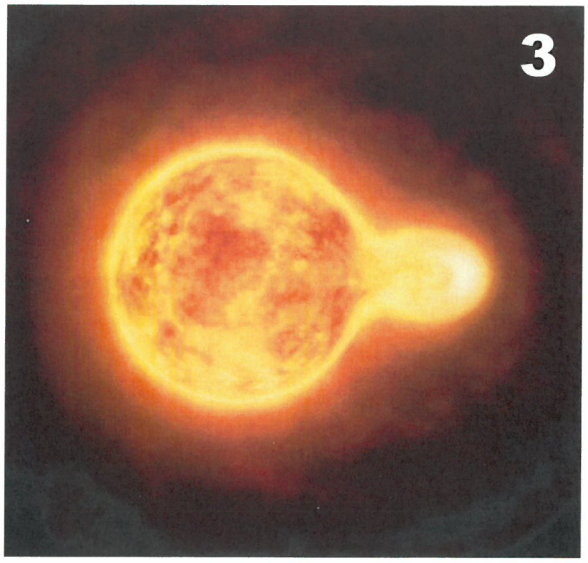
Gamma-ray, Infrared, Microwave, Radio, Ultraviolet, Visible, X-ray

Note: I'm not a stickler for spelling. Close is good enough for names (e.g. Altair) but not for numbers (e.g. NGC 7283).

1. Which of the following best describes the image at right?
   A. HII region
   B. Planetary nebula
   C. Supernova remnant
   D. Magnetar bubble
2. Which deep sky object is pictured here?
3. How is the central object typically classified?
   A. Red supergiant
   B. Neutron star
   C. Type II Cepheid
   D. LBV
4. There is some debate over this object's distance from Earth. If it is closer than previously thought, which of the following is true?
   A. Its luminosity is lower
   B. Its angular size is smaller
   C. Its temperature is lower
   D. Its proper motion is higher

5. Which deep-sky object is pictured at right?
6. This is an example of what class of objects?
   A. Planetary nebula
   B. X-ray binary
   C. Supernova remnant
   D. Bok globule
7. The pink regions are from Very Large Array observations in what part of the EM spectrum?
8. What is the typical interpretation of the barrel-like shape of this object?
   A. Jet-driven explosion
   B. Ambient galactic magnetic field
   C. Aspherical progenitor star
   D. Binary interactions

9. Which deep-sky object from the rule sheet is illustrated in the image at right?

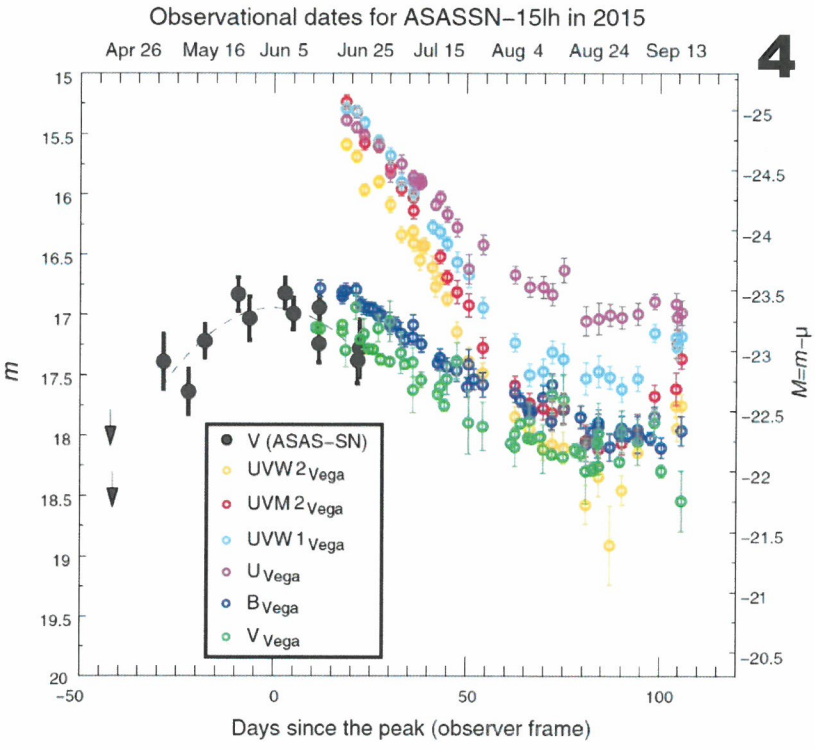


10. The system in the image is known to be a/an _____ binary system. (Fill in the blank)
    A. High-mass X-ray
    B. Eclipsing
    C. Black widow
    D. Cataclysmic

11. What is the eventual fate of the larger star in the image?
    A. Planetary nebula
    B. Quasi-stellar object
    C. White dwarf
    D. Supernova

12. The bolometric luminosity of the second companion star (widely-separated, and not shown in the image) is much greater than its visible magnitude suggests. Why is that?
    A. The orbital phase affects measurements
    B. The primary star blocks most visible light
    C. The companion star emits most light outside visible wavelengths
    D. Mass transfer between the A and C stars contributes to the spectra

13. The figure at right, taken from Dong et al. (2015), shows the light curve of ASASSN-15lh. **To the nearest whole number**, what was its peak V-band magnitude as observed from Earth?



14. Starting on June 24, 2015, ASASSN-15lh was observed by the UVOT instrument on which telescope?
    A. Swift
    B. Keck
    C. Hubble
    D. Chandra

15. **To the nearest whole number**, what is the distance modulus of ASASSN-15lh?

16. ASASSN-15lh was classified as what kind of supernova?
    A. Type Ia
    B. Type II
    C. Superluminous Type I
    D. Superluminous Type II

17. Which of the following best describes the image at right?
    A. HII region
    B. X-ray binary
    C. Supernova remnant
    D. Globular cluster

18. Which deep sky object from the rule sheet is in this image?

19. What lies at the center of the object, providing most of the energy that illuminates it?
    A. Black hole binary
    B. Recurrent nova
    C. Open cluster
    D. Herbig Ae/Be objects

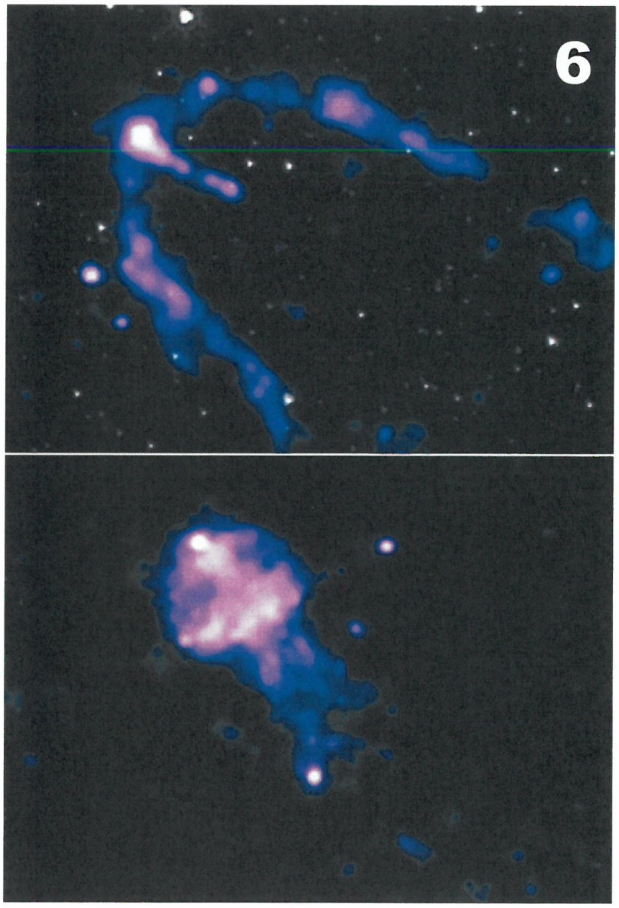
20. **(2 pts)** The angular extent of this object is 43 arcminutes. If it is at a distance of 8,000 light years, how many light years across is the object? Give your answer **to one significant figure**.

21. **(2 pts)** Two objects on the rule sheet are shown in this image. Which two are they, for **one point each**?

22. **Both** objects show regular pulsations in which part(s) of the EM spectrum?

23. Which of the following is the current explanation for the differing appearances of the two objects?
    A. Mass of the neutron star
    B. Orientation of the system relative to Earth
    C. Inhomogeneous ambient medium
    D. Age of the neutron star

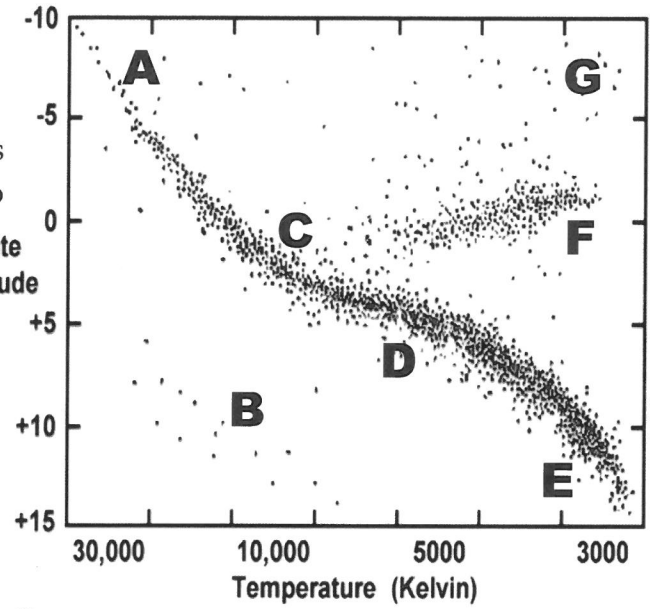
24. In which galaxy are both objects located?
    A. Small Magellanic Cloud
    B. Triangulum
    C. Andromeda
    D. Milky Way



Section 2: Stellar evolution & massive stars

Note: unless otherwise specified, all questions are worth one (1) point.

Questions 25-38 involve the figure on the right, called a Hertzsprung–Russell diagram.



25. The horizontal axis of an HR diagram shows temperature, which is roughly equivalent to what property of stars?
    A. Mass C. Luminosity
    B. Binarity D. Color

26. The vertical axis of this HR diagram shows absolute magnitude, which is roughly equivalent to what property of stars?
    A. Mass C. Luminosity
    B. Binarity D. Color

27. What additional quantity can be measured to allow astronomers to compute a star's absolute magnitude from its temperature?
    A. Distance C. Radius
    B. Parallax D. All of the above

28. Which letters lie on the Main Sequence? **You must give all of them for credit.**

29. Stars near which letters would appear red in color? There is more than one correct answer; you only need to give one for credit.

30. Stars near which letters would appear white in color? There is more than one correct answer; you only need to give one for credit.

31. Stars near which letter are not supported by nuclear fusion at their center?

32. Stars near which letter are the hottest?

33. Stars near which letter are the densest?

34. Stars near which letter are the most numerous in the Milky Way?

35. Alpha Orionis would be plotted closest to which letter on the HR diagram above?

36. Which letter is closest to where S Doradus would be plotted, when it is not outbursting?

37. The primary star of HR 5171 would be plotted on a line drawn between which two letters?

38. **(2 pts, all or nothing)** Stars near which letters will end their lives in core-collapse supernovae? **There is more than one answer; you must give all of them for credit.**

39. Which nuclear fusion mechanism provides most of the energy released by a Sun-sized star during its lifetime?

A. p-p chain
B. Helium capture
C. CNO cycle
D. s process
E. Triple alpha process
F. r process

40. Which nuclear fusion mechanism provides most of the energy released by a massive (>8 $M_\odot$) star during its lifetime? Use the answers from question 39 and write the letter on your answer sheet.

41. Which element is not produced by massive stars at some point during their lifetimes?

A. Hydrogen
B. Helium
C. Carbon
D. Silicon
E. Iron
F. Gallium

42. Which force is responsible for the collapse of gas clouds to form stars?

A. Strong nuclear force
B. Electromagnetic force
C. *The* Force
D. Weak force
E. Gravitational force

43. What halts the collapse mentioned in question 42?

A. Electrostatic repulsion
B. Demogorgons and Mind Flayers
C. Thermal pressure
D. Degeneracy pressure

For question 44, choose from the following list. You will **receive one point for each answer you include correctly**, and you will **lose 0.5 points for each answer you include incorrectly**. (Minimum score of zero, so at least this question can't harm your score.)

A. Magnetar
B. White dwarf
C. Active galactic nucleus
D. Pulsar
E. Black hole
F. Black dwarf
G. Planetary nebula
H. Neutron star

44. Which of the items above can be produced by the death of a massive (> 8 $M_\odot$) star?

Section 3: Mathy questions

Note: all questions are worth the specified number of points. Some questions require the answer from previous questions, but will always have a 1-point option available.

The light emitted by a perfect black body at temperature T is given by Planck's law:

$$B_\nu = \frac{A\nu^3}{e^{h\nu/kT} - 1}$$

where A is a constant (that you don't need to worry about here), ν is the frequency of the light in question, h is Planck's constant, and k is Boltzmann's constant.

45. **(2 pts)** Consider two measurements of a star, in red light (4.6×10^{14} Hz) and green light (5.9×10^{14} Hz). If the temperature of the star is 36,000 K, what is the ratio of luminosity in green light to luminosity in red light? Give your answer **to two significant figures**.

46. **(4 pts)** The star suddenly expands and cools, and its new temperature is measured to be 5600 K. Use Planck's Law to calculate the color index between green and red light, $V - R$ (use the frequencies given in question 45). Give your answer in magnitudes, **to two significant figures**.

47. **(3 pts)** Using interferometry, the star's radius is determined to be 85 $R_\odot$ at 36,000 K and 1300 $R_\odot$ at 5600 K. How many times brighter is the star when hot than when cool? If you determine that the star is brighter when cool, your answer should be less than 1. Give your answer **to two significant figures**.

The following table of magnitudes shows observations of an extragalactic Cepheid variable.

Day	0	3	6	9	12	15	18	21	24	27	30	33	36	39
mv	17.4	17.5	17.1	16.7	16.3	16.5	16.7	16.9	17.1	17.3	17.4	17.5	17.1	16.7

48. **(2 pts)** What is the period, in days, of this star's pulsations? Give your answer **to the nearest whole number**.

49. **(2 pts)** Using the Hubble Space Telescope, Benedict et al. (2007) found the following period-luminosity relation for classical Cepheid variables:

$$M_{\langle V \rangle} = -2.43 \cdot [\log_{10}(P) - 1] - 4.05$$

Based on the period you found in question 48, what is the mean absolute magnitude of this Cepheid variable? Give your answer **to three significant figures**. (If you did not get an answer to question 48, or do not trust your answer, you may use a period of 33 days for **1 point**.)

50. **(3 pts)** The mean apparent magnitude of this Cepheid is 16.9. How far away is it from Earth, in parsecs? Give your answer **to two significant figures**. (You will need to use the answer to question 49. If you did not get an answer, or if you used the provided value of 33 days, you may use a mean absolute magnitude of -7.05 for **1 point**.)

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51. **(3 pts)** The closest item on your list of deep sky objects (on the rule sheet) lies about 220 parsecs from Earth. Assuming this distance is exactly correct, what is its parallax in arcseconds? Give your answer **to three significant figures**.

52. **(1 pt)** Which DSO is described in question 51?

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53. **(3 pts)** Supernova 1987A was caused by the core collapse of a massive star. During this collapse, the central 1.6 $M_\odot$ of the star was converted from a 50-50 balance of protons and neutrons to 100% neutrons. Each proton→neutron conversion captured an electron and released a neutrino. How many neutrinos did the core collapse release? Give your answer **to two significant figures**.

54. **(4 pts)** SN 1987A happened at a distance of 51.4 kiloparsecs from Earth. How many neutrinos passed through each square meter of Earth? You may assume that the neutrinos were released isotropically (equally in all directions). Give your answer **to two significant figures**. (You will need to use the answer to question 53. If you did not get an answer, or if you do not trust your answer, you may use a value of 3.1×10^{41} for **1 point**.)

55. **(4 pts)** The Kamiokande neutrino detector has an effective area of about 320 m^2. Each neutrino had to pass 4.5×10^{10} water molecules as it traveled through the detector. Kamiokande detected 11 neutrinos from 1987A. Given all this, and the answer you found for question 54, what was the chance that any given neutrino would interact with any given water molecule—and be detected—as it passed by? Give your answer **to two significant figures**. (If you did not get an answer to question 54, or if you used the provided value, you may use 1.2×10^{10} neutrinos per m^2 for **1 point**.)

NOTE: answers in **RED** have clarifications at the bottom of the page!

Test #: _____ Time: _____

Astronomy — 2018 — Answer key

Section 1 (1 pt per question unless marked otherwise)

Subscore: _____/26

1. A
2. AG Carinae
3. D
4. A
5. SN W49B
6. C
7. Radio
8. A
9. HR 5171 A
10. B
11. D
12. C
13. 17* mag
14. A
15. 40* mag
16. C
17. A
18. NGC 6357
19. C
20. (2) 100* ly
21. (1) Geminga
    (1) PSR B0355+54
22. Radio
23. B
24. D

Section 2 (1 pt per question unless marked otherwise)

Subscore: ____/20+

25. D
26. C
27. D
28. A,C,D,E
29. E, F, or G
30. B or C
31. B
32. A
33. B
34. E
35. G
36. A
37. A,G
38. (2) A,G
39. A
40. C
41. A
42. E
43. C
44. (*) A,D,E,H

Section 3 (point values next to each question number)

Subscore: _____/31

45. (2) 1.5*
46. (4) 0.41* mag
47. (3) 7.3* times
48. (2) 30* d
49. (2) -5.21* mag
50. (3) 2.6×10^5 * pc
51. (3) 0.00455* arcsec
52. (1) Alpha Orionis (accept α Orionis, α Ori, or Betelgeuse)
53. (3) 9.5×10^{56} * ν's
54. (4) 3.0×10^{13} * ν/m^2
55. (4) 2.5×10^{-26} *

Scoring Notes

Answers with * must be exactly as written; use of scientific notation optional (see test for why).

5. Also accept W49B.
9. Also accept HR 5171.
21. Order does not matter. Also accept PSR B0355, or B0355.
28, 37, 38. No partial credit; no points if additional letters present.
29, 30. Only one letter needed for credit.
44. Award 1 point for each correct. Subtract 0.5 point for each other letter included. (Min score of 0)
49. Accept -5.31 for **1 pt**.
50. Accept 6.2×10^5 for **1 pt**.
54. Accept 0.0098 for **1 pt**.
55. Accept 6.4×10^{-23} for **1 pt**.

Tiebreakers: Section 2 subscore, section 1 subscore, time