Astronomy — 2019

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. 'Oumuamua) but not for numbers (e.g. NGC 7283).

1. Which deep sky object on the Official Rule Sheet is the subject of the composite image at right?

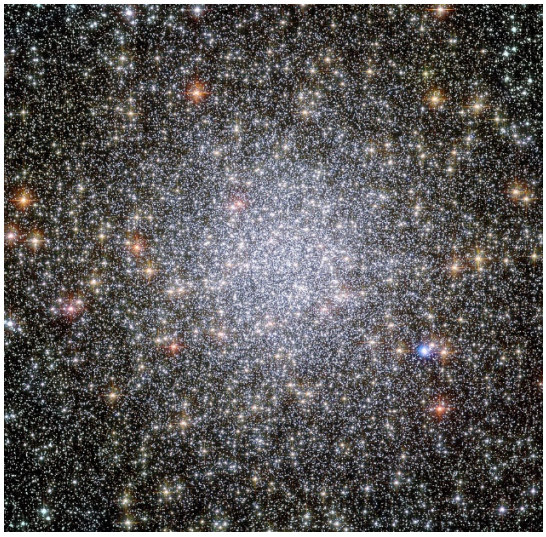
2. Which of the following is resolved in the image?
   A. Active galactic nucleus
   B. Ultra-luminous X-ray source
   C. Intermediate mass black hole
   D. Colliding binary

3. The purple in the image is data taken by the *Chandra* space telescope, in what part of the electromagnetic spectrum?

4. Which feature of the image is unusual for elliptical galaxies like the one at right?
   A. Long, collimated jet
   B. Mass of the galaxy
   C. Dark dust lanes
   D. Detection in radio

5. The object of the image is a starburst galaxy. The consensus among astronomers is that the burst of star formation was triggered by what kind of event?
   A. Galactic collision
   B. Cooling flow
   C. Intracluster shock
   D. Halo collapse

6. What kind of object appears in the image at right?
   A. Super star cluster C. Globular cluster
   B. Deep swarm D. Confused disk



7. Which deep sky object on the Official Rule Sheet is the subject of the image?

8. Objects like the one at right are usually found where in the Milky Way?
   A. The central bulge C. The thick disk
   B. The spiral arms D. The halo

9. Which of the following is extremely unlikely to appear in the image?
   A. Massive stars C. White dwarfs
   B. Red dwarfs D. Neutron stars

10. Name one of the two deep sky objects from the Official Rule Sheet that appear in the image below. (You surely know both, but you only need to write one.)

11. What kind of galaxy appears at the bottom of the image?
   A. Spiral C. Elliptical
   B. Irregular D. Lenticular

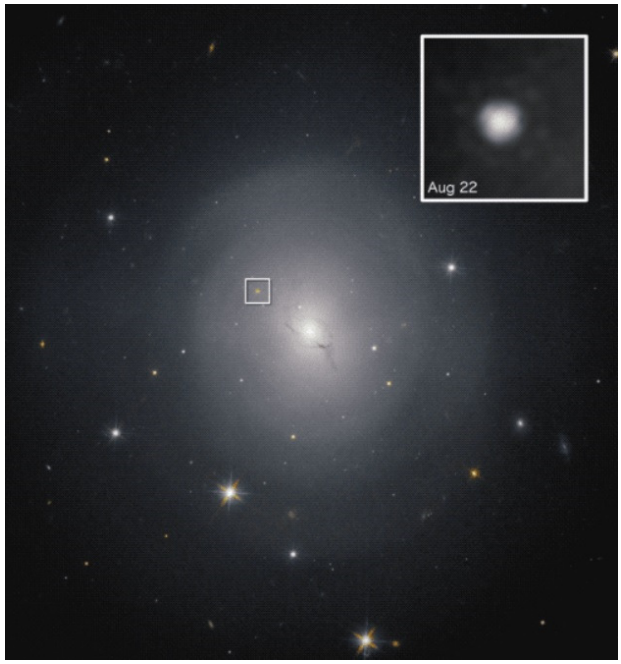
12. The pink spots in the bottom galaxy are caused by emission from what element?
   A. Hydrogen C. Oxygen
   B. Helium D. Iron

13. The pink spots in the bottom galaxy are associated with what astrophysical object or process?
   A. M class stars C. Gravitational waves
   B. Globular clusters D. Star-forming regions

14. If you used an <u>ultraviolet</u> filter to look at the galaxy at right, which (visible-light) color regions would be brightest?
   A. Blue C. Pink
   B. Yellow D. Brown

15. If you used an <u>infrared</u> filter to look at the galaxy, which color regions would be brightest? Use the answer choices from question 14.

16. The lenticular galaxy at right is which deep sky object on the Official Rule Sheet?



17. The galaxy is noteworthy for recently being the host of what kind of astrophysical event?
    A. Long gamma-ray burst
    B. Type Ia supernova
    C. Coronal mass ejection
    D. Binary neutron star merger

18. The inset shows the remnant of which transient?
    A. SN 2017ey
    B. GW 170817
    C. GRB 180724
    D. SOL2016-08-22T04:45

19. Comparing this image to the bottom one on the previous page (with two galaxies), what kind of stars are plentiful in the earlier image but mostly absent from this one?
    A. Neutron stars
    B. Young, massive stars
    C. Solar-mass stars
    D. Red dwarfs

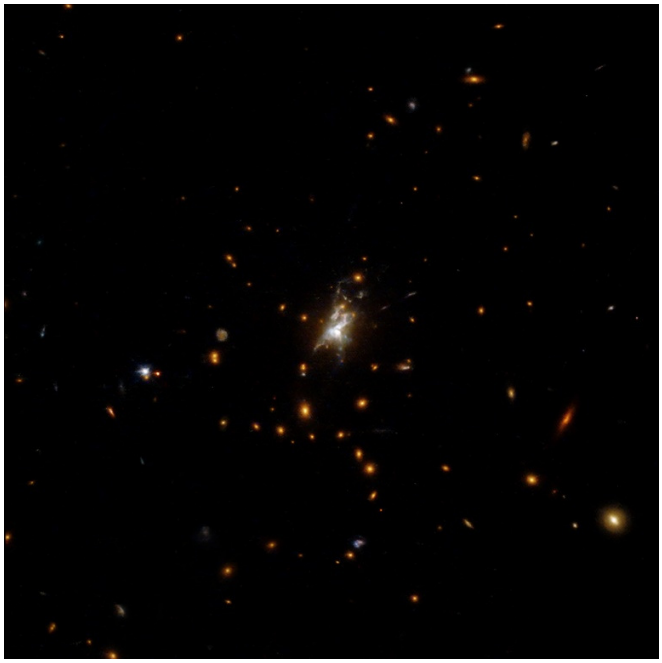
20. Near the bottom of the image, a few foreground stars show spiky features around their central points. What are these spikes?
    A. Light echoes off gas rings around the stars
    B. Evidence that the stars are binary systems
    C. Artifacts from the telescope
    D. Nascent planetary systems

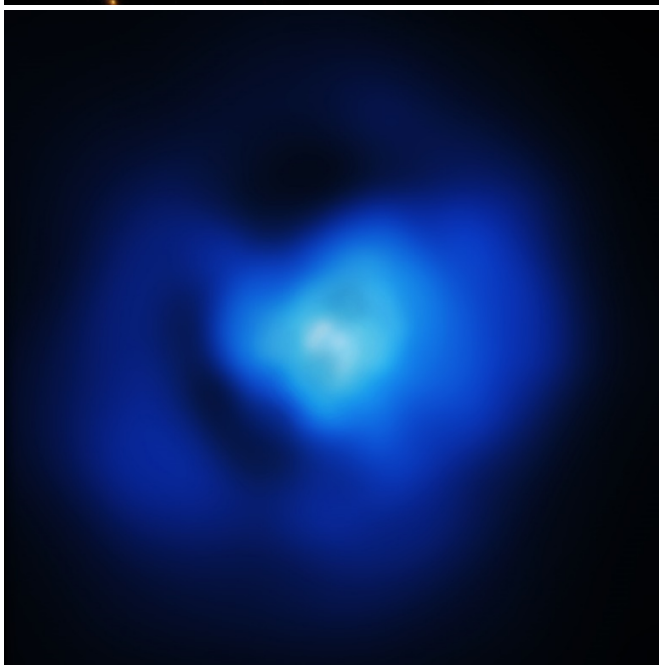
21. The images at right are of a distant object on the Official Rule Sheet. Which deep sky object is shown here?

22. The top image is true-color. Almost every spot of color in the image is a galaxy. Why are they (almost) all so much redder than the galaxies in the previous two pictures?
    A. Cosmological redshift
    B. Lots of old stars
    C. Excess dust compared to Milky Way
    D. More NC State fans than UNC fans

23. The central object in the top image is notably bluer than the other galaxies surrounding it. What conclusion can be drawn?
    A. It is producing lots of massive stars
    B. It is closer than the other galaxies
    C. It is gravitationally lensed
    D. All the UNC fans are there instead

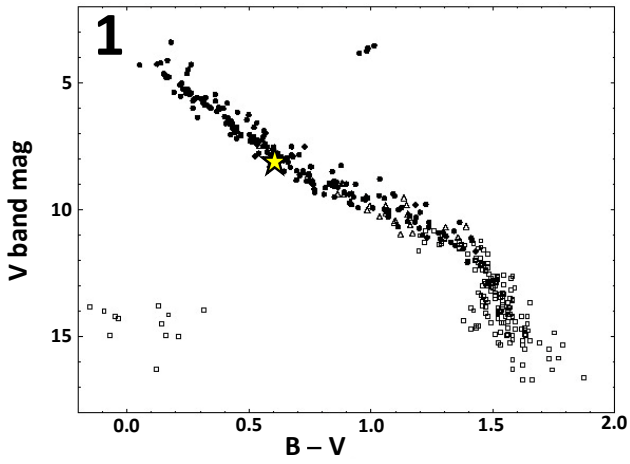
24. The bottom image is in X-rays, at the same scale as the top image. Multiple voids can be seen, which are interpreted as evidence for what in the central galaxy?
    A. Super-star-cluster formation
    B. Intermittent AGN activity
    C. Black hole mergers
    D. Large-scale cooling flows

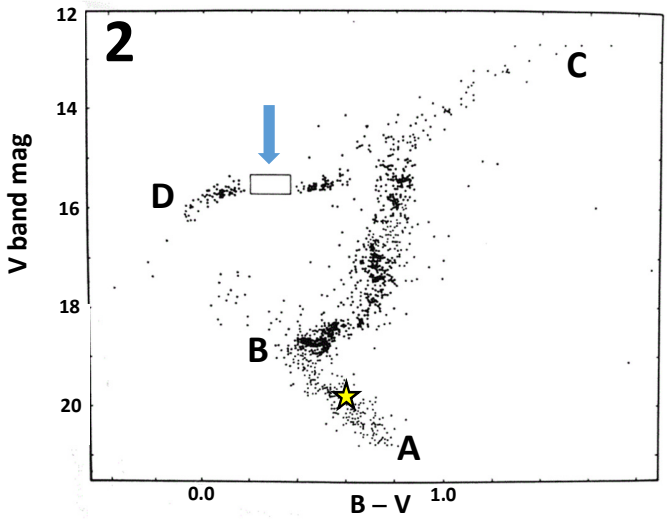




Section 2: Stellar evolution and clusters

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





All the questions in this section use the diagrams above, which show the distribution of stars in two clusters. One is an open cluster in the disk of the Milky Way, and the other is a globular cluster.

25. Which diagram is that of the globular cluster? Write the number on your answer sheet.

26. Which diagram shows an older population of stars? Write the number on your answer sheet.

27. The horizontal axis of both diagrams is the difference between stellar magnitude through a *B*-band filter and through a *V*-band filter. This is equivalent to what property of stars?
    A. Luminosity
    B. Mass
    C. Radius
    D. Color

28. The vertical axis of both diagrams is stellar magnitude through a *V*-band filter. This is equivalent to what property of stars? Use the answer choices from question 27.

29. In diagram 1, almost all the stars fall in a band running diagonally from top left to bottom right. What is the name of this feature?
    A. Main sequence
    B. Subgiant branch
    C. Population I
    D. Hertzsprung ridge

30. Still in diagram 1, there are four stars at $B - V \approx 1$ and magnitude ≈ 4. What color would these stars appear to a naked-eye observer?
    A. Orange-red
    B. Yellow
    C. White
    D. Blue-white

31. The stars at the bottom-left corner of diagram 1 are fusing what element at their cores?
    A. Hydrogen
    B. Helium
    C. Carbon
    D. Nothing; they are not powered by fusion

32. Now look at diagram 2. There is an empty box marked by an arrow. What is the name of that part of the diagram, where no stars appear?
    A. Kirkwood resonance
    B. RR Lyrae gap
    C. Tip of the horizontal branch
    D. Asymptotic giant zone

33. Why are there no stars plotted in the box mentioned in question 32?
    A. Stars move very quickly from one side of the gap to the other as they age
    B. The stars there are variable, and do not have a fixed position on the plot
    C. There was a pause in star formation corresponding to stars that age
    D. The stars there emit their light outside the V band, so are not seen in that filter

34. In diagram 2, the band mentioned in question 29 is warped. It runs from A to B, turns around to run towards C, then reverses again and continues towards D. <u>If all stars formed at exactly the same time</u>, stars near which letter were the most massive at birth?

35. In diagram 2, there is a small number of stars above and to the left of the letter B, which do not fall in the track mentioned in question 34. What are these stars called?
    A. Delta Scuti variables
    B. Close binaries
    C. Blue stragglers
    D. Subgiant spur stars

36. The main population in diagram 2 does not extend beyond magnitude 21 or so. Why are there no stars below (and to the right) of the letter A?
    A. Those stars died since the formation of the cluster
    B. Those stars are too faint to be detected by the telescope that was used
    C. Those stars were ejected from the cluster and are no longer part of it
    D. The stars that would be there never formed at all in this particular cluster

37. The yellow five-pointed star in both diagrams marks where the Sun would be placed if it were in both clusters. Which cluster is farther from Earth, and how can you tell?
    A. Cluster 1 is farther, because the Sun appears fainter at that distance
    B. Cluster 1 is farther, because the Sun has a lower apparent magnitude
    C. Cluster 2 is farther, because the Sun is closer to the base of the main population
    D. Cluster 2 is farther, because the Sun has a higher apparent magnitude

38. **(3 pts)** The absolute magnitude of the Sun is 4.83. On diagram 2 it has an apparent magnitude of 19.90. To **<u>three significant figures</u>**, what is the distance to cluster 2 in units of parsecs?

Section 3: Mathy questions

Note: all questions are worth the specified number of points. Some questions require the answer from previous questions; most of these have a 1-point option available if you did not get the required answer.

39. **(2 pts)** According to Pierce & Tully (1992), the calibrated Tully-Fisher relation between a galaxy's rotation velocity (in km/s) and its absolute magnitude is given at right. A distant galaxy is observed with a rotation velocity of 395 km/s. To the **nearest hundredth of a magnitude**, what is the galaxy's absolute magnitude according to the Tully-Fisher relation?

$$M = -10.00 \log_{10}(V_{\max}) + 2.00$$

40. **(2 pts)** The galaxy's apparent magnitude is measured to be 17.25. **To the nearest tenth of a magnitude**, what is its distance modulus? You will need the answer to question 39. If you did not get an answer, or do not trust your answer, you may use an absolute magnitude of -2.00 for one (1) point.

41. **(3 pts)** According to the distance modulus you calculated in question 40, how far is the galaxy in units of parsecs? If you did not get an answer, or if you used the 1-point option, you may use a distance modulus of 15.0 for one (1) point. Give your answer **to two significant figures**.

42. **(3 pts)** In some type Ia supernovae, carbon and oxygen are fused all the way to Nickel-56: $2\ ^{12}\mathrm{C} + 2\ ^{16}\mathrm{O} \rightarrow\ ^{56}\mathrm{Ni}$. The mass difference associated with this reaction is 9.11×10^{-29} kilograms, and an atom of Nickel-56 has a mass of 9.30×10^{-26} kg. How many solar masses of Nickel-56 must be produced to generate the 10^{44} Joules of energy normally associated with Type Ia supernovae? Give your answer **to two significant figures**.

43. **(2 pts)** Nickel-56 decays to Cobalt-56 with a half-life of 6.075 days. What fraction of the original Nickel-56 is still present at maximum light, 18 days after the explosion? Give your answer **to two significant figures**.

44. **(4 pts)** After about a month, the supernova light curve enters a steady period of decline, gaining 0.0152 mag/day. If this decline is produced solely by the radioactive decay of a single isotope, what half-life is required to match the observed decay? Give your answer **to three significant figures**, in units of days.

Questions 45-48 are about a star, S14, orbiting Sagittarius A*. Assume a distance from Earth to Sag A* of 8.32 kiloparsecs.

45. **(2 pts)** The semimajor axis of S14's orbit is 0.286 arcseconds. At that distance from Earth, what is the physical size, in AU, of S14's semimajor axis? Give your answer **to three significant figures**.

46. **(3 pts)** The period of S14's orbit is 55.3 years. What is the mass of Sag A* in units of $M_\odot$? You will need your answer to question 45. If you did not get an answer, or you do not trust your answer, you may use a size of 153,000 AU for one (1) point. Give your answer **to three significant figures**.

47. **(3 pts)** The eccentricity of S14's orbit is 0.976. Using the semimajor axis you found in question 45, find the minimum separation between S14 and Sag A*. If you did not get an answer to question 45, or you do not trust your answer, you may use a distance of 153,000 AU for one (1) point. Give your answer **to two significant figures**, in units of AU.

48. **(2 pts)** If the distance to Sag A* is not 8.32 kiloparsecs, which of the following change(s)? There may be more than one correct answer; you must give all the correct answers, and only the correct answers, to receive credit!

A. Sag A*'s mass
B. S14's minimum angular separation
C. Sag A*'s Schwarzschild radius
D. S14's orbital period