PHYS#215 - CH#15 - Q&A

Monday, April 26, 2021 9:48 AM

Concept Review

Gas and dust (small particles of matter) are present to some extent throughout a galaxy, between the stars; a **nebula** (plural **nebulae**) is a substantial cloud of such gas and dust (introductory paragraph). At night, from a good observing location, we see a band of stars, nebulae, gas, and dust – the **Milky Way** – stretch across the sky (Section 15.1). It is our internal, edge-on view of our Galaxy, the **Milky Way Galaxy**. With the unaided eye, we cannot see more than a few thousand light-years through the Milky Way because of the large amount of dust; thus, it appears that we are close to the center of our Galaxy, but this is only an illusion (Section 15.2).

Emission nebulae glow because ultraviolet radiation from hot stars ionizes the gas, and electrons jumping down to lower energy levels emit light (Section 15.3). **Absorption nebulae** (**dark nebulae**) block radiation that comes from behind them. **Reflection nebulae**, like those near the stars of the Pleiades, reflect radiation; they often look blue, for the same reason that the sky is blue.

By studying the distribution of globular star clusters in the sky, Harlow Shapley deduced that we are not at the center of our Galaxy (Section 15.4). However, he overestimated our distance from the center because he didn't know about interstellar extinction (obscuration), the dimming of starlight by dust. We now can measure this effect by noticing that it also **reddens** starlight: dust preferentially scatters (reflects) or absorbs the violet and blue light, while the longer wavelengths pass through more easily.

Our Galaxy has a **nuclear bulge** centered on the **nucleus**, and surrounded by a flat **disk** that contains **spiral arms** (Section 15.4). A spherical **halo** includes the globular clusters and has a much greater diameter than the disk. We can detect the very center of our Galaxy in infrared light, radio waves, x-rays, or gamma rays that penetrate the dust between us and it (Section 15.5). The Galactic center is a bright infrared source and almost certainly contains a very massive black hole, about 4 million solar masses.

Although mysterious **gamma-ray bursts** were at one time considered to be in our Galaxy, we now know that most of them originate billions of light-years away, probably from the formation of stellar-mass black holes (Section 15.6). NASA has sent the Swift satellite aloft to study them. The gamma rays and x-rays throughout our Galaxy and elsewhere are studied as part of **high-energy astrophysics**.

Our Galaxy is a pinwheel-shaped **spiral galaxy**, with spiral arms marked by massive stars, open clusters, and nebulae (Section 15.7). However, from our vantage point inside the Galaxy, it is difficult to accurately trace out the arms. These spiral arms appear to be caused by a slowly rotating **spiral density wave** (Section 15.8).

The matter between the stars, the **interstellar medium**, is mainly hydrogen gas (Section 15.9). Emission nebulae are mostly **H II regions**, regions of ionized hydrogen. Clouds of higher density in which the atoms of hydrogen are predominantly neutral are called **H I regions**. Hydrogen molecules (H_2) are very difficult to detect, but we think they are plentiful in regions where they are protected by dust from ultraviolet radiation.

Observations of our Galaxy at radio wavelengths have been very important (Section 15.10). Specifically, the observed **21-cm line** comes from the **spin-flip transition** of hydrogen atoms, when the spin of the electron changes relative to that of the proton. Studies of the 21-cm line have enabled us to map our Galaxy by finding the distances to H I regions (Section 15.11). Observations of interstellar molecules, primarily carbon monoxide, have also been valuable in this regard (Section 15.12).

Giant molecular clouds, containing 100,000–1,000,000 times the mass of the Sun, are fundamental building blocks of our Galaxy; they are the locations at which new stars form (Section 15.13). Infrared satellites and radio telescopes have permitted mapping of the **Orion Molecular Cloud** and others. The Atacama Large Millimeter/submillimeter Array is a major international array of telescopes to provide high-resolution images of giant molecular clouds and other objects at radio wavelengths (Section 15.14).

Questions

1. Why do we think our Galaxy is a spiral?

2. How would the Milky Way appear if the Sun were closer to the edge of our Galaxy?

3. Compare **(a)** absorption (dark) nebulae, **(b)** reflection nebulae, and **(c)** emission nebulae.

4. How can something be both an emission and an absorption nebula? Explain and give an example.

5. If you see a red nebula surrounding a blue star, is it an emission or a reflection nebula? Explain.

6. Discuss the key observations that led to the discovery of the Sun's location relative to the center of our Galaxy.

†7. If the Sun is 8 kpc from the center of our Galaxy and it orbits with a speed of 200 km/s, show that the Sun's orbital period is about 250 million years. (Assume the orbit is circular.)

8. Why may some infrared observations be made from mountain observatories while all x-ray observations must be made from space?

9. Describe infrared and radio results about the center of our Galaxy.

10. Discuss how observations of x-rays and gamma rays help us understand highly energetic phenomena in our Galaxy.

11. Why does the density-wave theory of spiral arms lead to the formation of stars?

12. (a) What are three tracers that we use for the spiral structure of our Galaxy? **(b)** What are two reasons why we expect them to trace spiral structure?

13. Discuss how infrared observations from space have added to our knowledge of our Galaxy.

14. While driving at night, you almost instinctively judge the distance of an oncoming car by looking at the apparent brightness of its headlights. Is your estimate correct if you don't account for fog along the way? Discuss your answer.

15. Describe the relation of hot stars to H I (neutral hydrogen) and H II (ionized hydrogen) regions.

16. Briefly define and distinguish between the redshift of a gas cloud and the reddening of that cloud.

17. What determines whether the 21-cm lines will be observed in emission or absorption?

18. Describe how a spin-flip transition can lead to a spectral line, using hydrogen as an example.

†19. Suppose the rest wavelength of the 21-cm line of hydrogen were exactly 21.0000 cm. **(a)** If this line from a particular cloud is observed at a wavelength of 21.0021 cm, is the cloud moving toward us or away from us? **(b)** How fast is it moving?

20. Why are dust grains important for the formation of some types of interstellar molecules?

21. Describe the relation of the Orion Nebula and the Orion Molecular Cloud.

22. Optical astronomers can observe only at night (except when studying the Sun). In what time period can radio astronomers observe? Explain any difference.

23. True or false? By measuring the wavelength of the peak of the reflected light received from a reflection nebula, we can determine the temperature of the nebula using Wien's law.

24. True or false? Globular clusters form a spherical "halo" around the center of the Milky Way Galaxy, and their observed positions suggest that our Solar System is far from the center of our Galaxy.

25. True or false? A dark (absorption) nebula blocks the light from background stars and is sometimes so dense that new stars are forming within it.

26. True or false? Our Milky Way Galaxy is a spiral galaxy, with arms in a flattened disk that surrounds a more spherical bulge.

27. True or false? An emission nebula can form when gas is ionized by a nearby young star, often of spectral type G, K, or

M.

28. True or false? When the relative spin directions of the proton and electron in a hydrogen atom change, a photon having a wavelength of about 21 cm is either emitted or absorbed.

29. True or false? The spiral arms in a galaxy such as the Milky Way consist of the same groups of stars throughout the entire lives of these arms.

30. True or false? We will underestimate the distance of a distant star in the plane of our Galaxy unless we take into account the dust that absorbs and scatters its light.

31. True or false? Direct observations of the trajectories of stars traveling near the center of our Milky Way Galaxy provide very strong evidence for the presence of a supermassive black hole, millions of times the mass of our Sun.

32. True or false? Interstellar dust and gas tend to absorb and scatter blue light more than red light, causing stars to appear redder than their true colors.

33. True or false? Most of the stars in the bulge and halo of our Galaxy are old, relative to the stars in the spiral arms.

34. Multiple choice: Gaseous emission nebulae in the Milky Way Galaxy look red because **(a)** they are moving away from us, so that the light is redshifted; **(b)** many electrons are jumping from the third to the second energy levels of hydrogen, producing Hα emission; **(c)** they absorb red light from their surroundings; **(d)** they have temperatures of only about 100 K, and Wien's law tells us that the light they emit is therefore red; or **(e)** they are made mostly of iron compounds, like rust.

35. Multiple choice: In 1917, our perception of the Milky Way Galaxy changed when Harlow Shapley noticed **(a)** a high concentration of neutron stars in the halo of our Galaxy; **(b)** pulsars concentrated around the region of our Galaxy surrounding the Sun; **(c)** open star clusters located around the center of our Galaxy; **(d)** a concentration of other planetary systems near the edges of our Galaxy; or **(e)** globular star clusters centered around a point far from the Sun.

36. Multiple choice: At the present time, stars in our Galaxy tend to form most readily in **(a)** giant molecular clouds in spiral arms; **(b)** the Galactic halo; **(c)** the central supermassive black hole; **(d)** the Galactic bulge; or **(e)** globular clusters.

37. Multiple choice: Which one of the following statements about our Milky Way Galaxy is *false*? **(a)** New stars generally form in the spiral arms. **(b)** Nebulae such as the Orion Nebula are stellar nurseries – regions where new stars are forming, or recently formed. **(c)** It is difficult to see the central regions of our Galaxy in optical (visible) light because intervening dust absorbs and scatters the light. **(d)** Rapid motions of stars near the center suggest that it harbors a black hole, millions of times the mass of our Sun. **(e)** Globular star clusters reside in the halo and contain main-sequence stars spanning all spectral types, from O through M.

38. Multiple choice: An emission nebula glows primarily because **(a)** it scatters light from young stars in all directions, and blue wavelengths are scattered more easily than red wavelengths; **(b)** it scatters light from a dying star in all directions; **(c)** it produces thermal radiation; **(d)** it is undergoing nuclear fusion; or **(e)** gas is ionized by ultraviolet light and then recombines, or electrons excite atoms and ions by colliding with them.

39. Multiple choice: Suppose over the next year, you go outside (far away from any light pollution) on every clear night and count individual stars with your unaided eyes (without binoculars, telescopes, or filters) along the plane of the Milky Way. What will you see, and why? **(a)** You see substantially more stars toward the center of the Milky Way Galaxy than away from the center; there are more stars near the center of the Milky Way Galaxy. **(b)** You see substantially more stars toward the center of the Milky Way Galaxy than away from the center; the nearest spiral arm to Earth is toward the center. **(c)** You see about the same number of stars toward the center of the Milky Way Galaxy and away from the center; dust absorbs and scatters much of the visible light from distant stars in the disk of the Milky Way Galaxy. **(d)** You see about the same number of stars toward the center of the Milky Way Galaxy and away from the center; our Solar System is very close to the center of the Milky Way Galaxy. **(e)** You see more stars away from the center of the Milky Way Galaxy than toward the center; the supermassive black hole at the center is preventing the visible light near the center from reaching Earth.

40. Multiple choice: The 21-cm line observed by radio astronomers comes from **(a)** electrons in hydrogen atoms jumping from the third to the second energy levels; **(b)** the rotation of hydrogen molecules; **(c)** the atomic hydrogen spin-flip transition; **(d)** dust grains in molecular clouds; or **(e)** carbon-monoxide (CO) molecules.

41. Multiple choice: Which one of the following statements concerning the Milky Way Galaxy is *false*? **(a)** It is flattened out into a disk because of its rotation. **(b)** It is a spiral galaxy. **(c)** Old globular star clusters are found primarily in its halo. **(d)** Open star clusters and emission nebulae are found primarily in its spiral arms. **(e)** Most of it can be seen from Earth at optical wavelengths with a small telescope.

42. Fill in the blank: To form some types of molecules in interstellar space, grains of ______ appear to be necessary.

Solid particles

43. Fill in the blank: A(n) Emission ______ nebula can form when gas is ionized by a nearby young star, usually of spectral type O.

44. Fill in the blank: The most distant parts of our Galaxy are most easily seen at ______ wavelengths.

Infrared & Radio

45. Fill in the blank: A(n) _________ nebula reflects (scatters) light from stars that are near the gas.

Reflection

46. Fill in the blank: Studies of the motions of stars near the center of our Galaxy suggest that a massive ________ is present there.

A massive object

47. Fill in the blank: Clouds of ionized hydrogen are called ______. †This question requires a numerical solution.

Hill region