39. The nearest large galaxy to our Galaxy is about 2×10^6 ly away. If both galaxies have a mass of 3×10^{41} kg, with what gravitational force does each galaxy attract the other?

40. Estimate what neutrino rest mass (in eV) would provide the critical density to close the universe. Assume the neutrino density is, like photons, about 10^9 times that of nucleons, and that nucleons make up only (*a*) 2% of the mass needed, or (*b*) 5% of the mass needed.

41. Two stars, whose spectra peak at 600 nm and 400 nm, respectively, both lie on the main sequence. Use Wien's law, the Stefan-Boltzmann equation, and the H–R diagram (Fig. 33–6) to estimate the ratio of their diameters. [*Hint*: see Examples 33–4 and 33–5.]

42. Suppose we can measure distances with parallax at 100 parsecs. What is our minimum angular resolution (in degrees), based on this information?

43. Through some coincidence, the Balmer lines from singly ionized helium in a distant star happen to overlap with the Balmer lines from hydrogen (Fig. 27–22) in the Sun. How fast is the star receding from us?

44. What is the temperature that corresponds to 1.8-TeV collisions at the Fermilab collider? To what era in cosmological history does this correspond? [*Hint*: see Fig. 33–25.]

45. Astronomers have recently measured the rotation of gas around what might be a supermassive black hole of about 2 billion solar masses at the center of a galaxy. If the radius from the galactic center to the gas clouds is 60 light-years, what Doppler shift $\Delta\lambda/\lambda_0$ do you estimate they saw?

46. A galaxy is moving away from Earth. The "blue" hydrogen line at 434 nm emitted from the galaxy is measured on Earth to be 650 nm. (*a*) How fast is the galaxy moving? (*b*) How far is it from Earth?

47. In the later stages of stellar evolution, a star (if massive enough) will begin fusing carbon nuclei to form, for example, magnesium:

$$^{12}_{6}\mathrm{C} + {}^{12}_{6}\mathrm{C} \rightarrow {}^{24}_{12}\mathrm{Mg} + \gamma.$$

(*a*) How much energy is released in this reaction (see Appendix B). (*b*) How much kinetic energy must each carbon nucleus have (assume equal) in a head-on collision if they are just to touch (use Eq. 30–1) so that the strong force can come into play? (*c*) What temperature does this kinetic energy correspond to?

48. Consider the reaction

$$^{16}_{8}\mathrm{O} + {}^{16}_{8}\mathrm{O} \rightarrow {}^{28}_{14}\mathrm{Si} + {}^{4}_{2}\mathrm{He},$$

and answer the same questions as in Problem 47.

49. How large would the Sun be if its density equaled the critical density of the universe, $\rho_c \approx 10^{-26}\,\mathrm{kg/m^3}$? Express your answer in light-years and compare with the Earth–Sun distance and the size of our Galaxy.

Answers to Exercises

A: Ourselves; 2 years ago.

B: 600 ly (estimating L from Fig. 33–6 as $L \approx 8 \times 10^{26}$ W; note that on a log scale, 6000 K is closer to 7000 K than it is to 5000 K).

C: 1.4.