PHYS 231: Introductory Astrophysics

Winter 2020

Homework #1

(Due: January 15, 2020)

Each problem is worth 20 points.

1. (a) Barnard's star lies 1.8 pc away and has a transverse velocity relative to the Sun of 90 km/s. Calculate its parallactic angle p (half the parallactic shift, note), in arc seconds, and its proper motion, in arc seconds per year.

   (b) The star's diameter is 270,000 km. What is its angular diameter, as seen from Earth?

   (c) The star's radial velocity (from Doppler measurements) is 110 km/s toward the Sun. Calculate its total speed relative to the Sun.

   (d) Assuming that this relative velocity remains constant, calculate how close Barnard's star will come to the Sun, and when this will occur.

2. An Oort cloud comet moves on an orbit so eccentric that it can be well approximated by a radial straight line through the Sun. The comet starts at a large distance from the Sun, with zero velocity, and falls inward.

   (a) What is the comet's speed when it reaches a distance of 1 AU from the Sun?

   (b) As luck would have it, Earth is right there when the comet arrives. Assuming a circular orbit, calculate Earth's orbital speed and hence determine the relative speed at which the comet hits our planet.

   (c) The comet is 100 m in diameter and is composed of icy material having an average density $500\,\mathrm{kg/m^3}$. Approximating the comet as a sphere, estimate its mass, and hence compute the total energy released in the (inelastic) collision. Express this energy (i) in joules, and (ii) in tons of TNT, where 1 ton of TNT is equivalent to 4×10^9 J.

3. Two "stars" of masses M_1 and M_2 orbit one another. Star #2 is not visible, but star #1 is observed to be a bright main-sequence star of mass $20M_\odot$. The orbit is circular, and we happen to be in the orbital plane, so we see the motion "edge-on." Doppler measurements reveal that star #1 is moving at speed 121 km/s relative to the center of mass and has an orbital period of 6 days. What are the mass M_2 of the unseen companion and the distance r between the two stars?

   [*Note: You may find yourself solving a nonlinear equation to determine the mass* M_1*. You can accomplish this by trial and error using a calculator, or you can write a short program to do it.*]

4. (a) A variable star in the globular cluster M15 is observed to have apparent magnitude $m_V = 15.8$. Similar stars closer to the Sun are known to have absolute magnitudes of $M_V \approx 0.7$. What is the distance to M15?

   (b) Light from stars in M15 is blueshifted by 0.036 percent, and the cluster's proper motion has been measured by HST to be 7.7×10^{-3} arcsec/yr. What is M15's total velocity relative to the Sun?

   (c) M15 lies 9.3 kpc from the Galactic center. How much mass would be required to keep an object moving at the speed determined in part (b) in a circular orbit at this distance from the center?

5. Vega is one of the brightest stars in the sky. It has a V-band apparent magnitude of $m_V = 0.03$. Its surface temperature is $T \approx 9700$ K.

   (a) Assuming a blackbody spectrum, at what wavelength does Vega's specific flux (per unit wavelength) f_λ peak?

   (b) Again assuming a blackbody spectrum, calculate the total flux at the surface of Vega. Assume that this is the same as the V-band flux.

   (c) Vega's radius is 2.7 times that of the Sun. What is Vega's total luminosity (in solar luminosities)?

   (d) Vega's parallax is 0.13 arcsec. What is its absolute V-band magnitude?

   (e) A certain telescope has a limiting V-band magnitude of $M_V = 20$ — i.e. it can't detect anything fainter than 20th magnitude. What is the maximum distance at which it could detect a star like Vega?