1. Quasar luminosities

- (a) Suppose that a quasar is as bright as a solar-type star (they share similar *apparent* magnitudes) but the quasar is a factor of a million further away than the star. What is the quasar's luminosity?
- (b) A certain quasar has an average luminosity of $3.3 \times 10^{13} L_{\odot}$ and an X-ray brightness that can vary substantially in as little as three hours. Assume that the quasar's black-hole engine is accreting at the Eddington rate and show that these two findings are consistent with each other.
- 2. Mass accretion can be used to power things besides active galaxies and can use engines besides black holes. A "junior" version of an AGN black hole is a $0.5M_{\odot}$ protostar accreting fully ionized hydrogen gas from its surrounding disk and producing luminosity from this accretion at the Eddington rate.
 - (a) What is its luminosity in L_{\odot} ?
 - (b) Suppose the accreted material falls freely to the star's surface from a distance much greater than the protostar radius of $1.5R_{\odot}$. At what rate in M_{\odot} yr⁻¹ is the protostar accreting matter?
- 3. M87 has an accretion disk around its central black hole for which the rotational velocity has been measured in HST spectra. The disk extends 20 pc from the center and exhibits Doppler velocities as large as ± 500 km/s with respect to the galaxy's overall radial velocity.
 - (a) Calculate the mass of the black hole in M87 to two significant digits. Comment on the assumptions under which you did your calculation (e.g., orbital plane viewed edge-on; note the appearance of the galaxy and its disk in the notes) and the effect this may have on the accuracy of your answer.
 - (b) M87 is 16 Mpc away. With the mass you calculated for its central black hole, calculate the diameter of the black hole's event horizon (in pc) and the angle the event horizon subtends (in arcseconds).
 - (c) Compare this result with the diffraction-limited angular resolution $\Delta \theta = 1.2\lambda/D$ (where D is telescope diameter) of the Hubble Space Telescope (D = 2.4 m) at a wavelength of 400 nm. Do the same for the VLBA (D = 8611 km) at a wavelength of 2 cm. Can we see details in images as small as the horizon? How far away would M87 have to be for the event horizon to subtend an angle equal to the best angular resolution?
- 4. The largest *apparent* superluminal motions seen so far in quasar jets are about 20c.
 - (a) What would this imply for the ejection speed v (in units of c to three significant figures) and jet angle with the line of sight θ (in degrees) if the jet is oriented for maximum apparent superluminal motion?
 - (b) If this ejection speed applies to 3C 273, at what angle from the jet axis (in degrees) do we view this quasar?