

# Astronomy 2115

Fall 2023

# Homework #8

Due Tuesday, Nov 7 in class

For full credit you must write your solutions neatly and include all work. Do not forget the units.

- 1) It was suggested in the 1960s that quasars might be compact objects ejected at high speeds from the centers of nearby ordinary galaxies. Explain why the absence of blueshifted quasars disproves this hypothesis. (Note: We only see quasars with redshifted lines).
- 2) How does the unified model of active galaxies explain that radio galaxies and blazars are the same kind of object viewed from different angles?
- 3) How does the spectrum of a quasar differ from that of an ordinary galaxy? How do spectral lines help astronomers determine the distances to quasars?
- 4) What is a Seyfert galaxy? Why do astronomers think that Seyfert galaxies might be related to radio quiet quasars?
- 5) Some blazars and quasars appear to be ejecting material at speeds faster than light. Is the material really moving that fast? If so how is this possible? If not, why does the material appear to be moving faster than light?
- 6) What is the Eddington limit? Explain how it can be used to set a limit on the mass of a supermassive black hole and explain why this limit represents a minimum mass for the black hole.
- 7) What is Faraday rotation? Explain how we can use observations of Faraday rotation to determine the magnetic field strengths in galaxy clusters?
- 8) Some galaxy clusters host huge (Mpc scale) diffuse radio emission called radio haloes. What is the emission mechanism for these and how are these produced?
- 9) (a) Calculate the maximum luminosity that could be generated by accretion onto a black hole of  $3.7 \times 10^6$  solar masses. (b) Compare this to the total luminosity of the Milky Way at about  $2.5 \times 10^{10}$  solar luminosities. (c) How would the appearance of our galaxy change if it lit up to its full potential as you calculated in (a)?
- 10) You measure the jets of the blazar BL Lac to be at an angle of 5 degrees from the line of sight with an apparent motion of  $6.3c$ . What is the intrinsic velocity of the jet expressed as a fraction of the speed of light?

11) The galaxy NGC 5548 hosts an AGN with a H  $\beta$  line of width 4000 km/s. Assuming that the width of the line is due to rotation of gas at a distance of 0.1 pc, estimate the black hole mass in solar masses.

12) The visual binary black hole system 0402+379 at  $z = 0.055$  (1 mas = 1.06 pc) has two black holes separated by 7.02 milliarcseconds. (a) If the relative velocity between the two is 0.00157 mas/year, calculate the characteristic orbital timescale in years. (b) Assuming a circular orbit is in the plane of the sky, calculate the combined mass of the two black holes in solar masses.

13) In the radio we see spectacular jets emerging from AGN. (a) Assuming that these jets are created at 0.1 pc from a billion solar mass black hole, calculate their escape velocity. (b) Use this idea to estimate the smallest scale (in pc) that the jets can be launched from.

14) Suppose you discover a quasar at  $z=8$ . (a) At what speed would the quasar appear to be moving away from us as a fraction of the speed of light? (b) At what frequency will the 21cm Hydrogen line be observed?