

UNIVERSITY OF KANSAS
Department of Physics and Astronomy
Physical Astronomy (ASTR 391) — Prof. Crossfield — Fall 2025

Problem Set 8

Due: Monday, Nov 24, 2025, 12pm Kansas Time
This problem set is worth **60 points**.

As always, be sure to: type the solutions, show your work, circle your final answer, and use the appropriate number of significant figures.

1. Active Galactic Nuclei [25 pts]

- (a) [10 pts] Draw a rough sketch of the “Unified Torus Model” of an AGN. Label and describe the different components of the AGN.
- (b) [5 pts] A spectrum of a Seyfert-I AGN shows a very broad emission line of $H\beta$ (hydrogen-beta, or H-beta) with a width of about 20 nm. Assuming that the line width is dominated by rapid rotation of material in the AGN’s inner accretion disk, estimate the speed of the material.
- (c) [5 pts] An astronomer takes a spectrum of a distant quasar and notes that the $H\beta$ line has been shifted to a wavelength of roughly 680 nm. Estimate the redshift, z , of this quasar.
An object with a redshift of $z = 0.4$ would be at a distance of roughly 2 Gpc — two *billion* parsecs.
- (d) [5 pts] The elliptical galaxy M87 is 16 million pc (Mpc) from Earth. Its central supermassive black hole is 240 AU across; estimate the angular diameter of the black hole (in arc seconds) as observed from Earth.

2. Large-scale Structure. [10 pts] Describe the various types of structure in the universe, from (relatively) small-scale individual galaxies on up to the largest scales.

3. The expanding universe [25 pts]

- (a) [10 pts] A classmate mentions to you that “Astronomers observe galaxies in all directions speeding away from us, so that means that we must be near the center of the Universe.” Explain why this student’s conclusion is incorrect, and what the proper interpretation is.
- (b) [5 pts] What is the approximate, currently-accepted value of the Hubble Constant? What is the significance of this quantity?
- (c) [5 pts] A distant galaxy is observed to have a redshift of $z = 0.6$. Estimate the apparent (cosmological-expansion) velocity of this galaxy relative to the Milky Way, and use that (with Hubble’s Law) to estimate its distance.
- (d) [5 pts] A Type-Ia supernova is observed in a distant galaxy. Since this supernova can be used as a ‘standard candle,’ the distance to the galaxy is measured to be ~ 700 Mpc (megaparsecs, or millions of parsecs). Use Hubble’s law to estimate the apparent (cosmological-expansion) velocity of this galaxy relative to the Milky Way, and its redshift z .