Astronomy 142 — Practice Midterm Exam #2

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Name: ____

You may consult *only* one page of formulas and constants and a calculator while taking this test. You may *not* consult any books, digital resources, or each other. All of your work must be written on the attached pages, using the reverse sides if necessary. The final answers, and any formulas you use or derive, must be indicated clearly (answers must be circled or boxed). You will have one hour and fifteen minutes to complete the exam. Good luck!

- First, work on the problems you find the easiest. Come back later to the more difficult or less familiar material. Do not get stuck.
- The amount of space left for each problem is not necessarily an indication of the amount of writing it takes to solve it.
- Numerical answers are incomplete without units and should not be written with more significant figures than they deserve.
- You must show your work and/or explain your answers to receive full credit.
- Remember, you can earn partial credit for being on the right track. Be sure to show enough of your reasoning that we can figure out what you are thinking.

$R_\odot = 6.96 \times 10^{10}$ cm

$M_\odot = 1.989 \times 10^{33}$ g

$L_\odot = 3.827 \times 10^{33}$ erg/s

$T_e = 5772$ K

$R_\oplus = 6.371 \times 10^{8}$ cm

1 AU $= 149,597,870$ km

$k = 1.38 \times 10^{-16}$ erg/K

$G = 6.674 \times 10^{-8}$ dyn cm^2 g^{-2}

$h = 6.6261 \times 10^{-27}$ erg s

$m_n = 1.6749 \times 10^{-24}$ g $= 939.6$ MeV/c^2

$e = 4.803 \times 10^{-10}$ cm$^{3/2}$ g$^{1/2}$ s^{-1}

$M_{\rm bol} = 4.74$

$m_V = -26.71$

$M_V = 4.86$

$BC_V = -0.12$

$M_\oplus = 5.9736 \times 10^{27}$ g

1 pc $= 206,625$ AU

$\sigma = 5.6704 \times 10^{-5}$ erg s^{-1} cm^{-2} K^{-4}

$c = 3 \times 10^{10}$ cm/s

$m_p = 1.6726 \times 10^{-24}$ g $= 938.3$ MeV/c^2

$m_e = 9.1094 \times 10^{-28}$ g $= 0.511$ MeV/c^2

1. **Short answers.** Please write in complete sentences, and feel free to use equations and/or sketches to help explain your thoughts.

   (a) (5 points) Who invented standard candles, and how?

   (b) (5 points) Are the Milky Way's globular clusters made primarily of Population I or II stars? Approximately how old are the oldest globular clusters?

(c) (5 points) Give two strong pieces of observational evidence for the existence of black holes within active galactic nuclei.

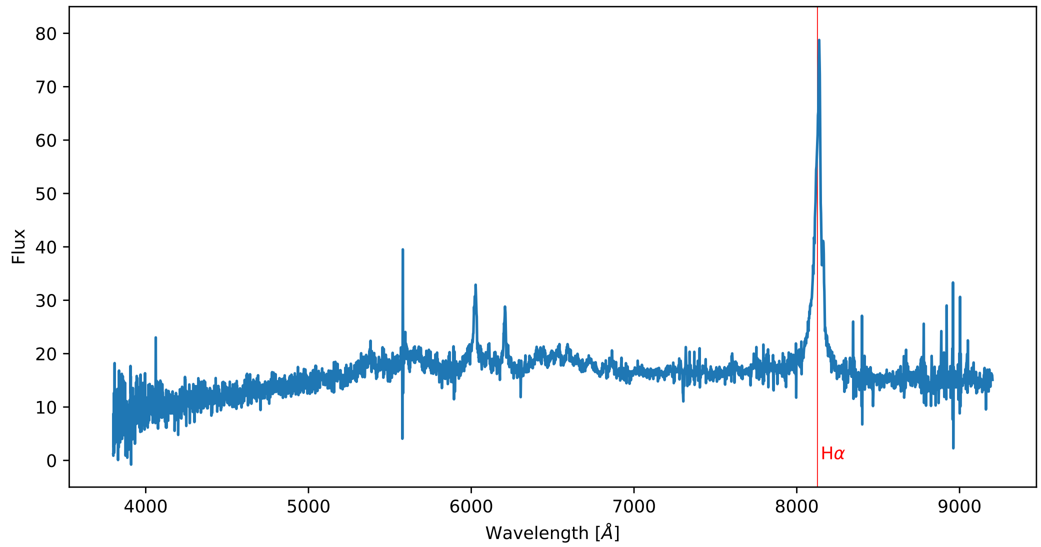
(d) (5 points) Give two strong pieces of observational evidence for the existence of dark matter in the Universe.

2. **Accretion from a disk**

   (a) (5 points) A very young $1 M_\odot$ protostar, still completing its formation, accretes matter from a surrounding disk at a rate limited by radiation pressure. What is the resulting luminosity (in $L_\odot$)?

   (b) (5 points) What is the rate (in $M_\odot$/year) at which this protostar must accrete mass in order to produce its luminosity?

3. An object with an apparent magnitude $m_r = 17.90$ has a measured spectrum that is shown below. The most prominent line in this object's spectrum is the Hα line, observed at 8137.67Å. (The Hα line is observed at 6562.8Å in the lab.)



(a) (5 points) Is this object an elliptical galaxy, a spiral galaxy, or an AGN? Explain your answer.

(b) (5 points) What is the redshift of this object?

(c) (5 points) How far away is the object?

(d) (5 points) What is the object's absolute magnitude M_r?

4. A giant elliptical galaxy lies 20 Mpc away. Observations are made of the total flux from starlight, and stellar velocity dispersion along the line of sight, within circles on the sky that correspond to radii of 100 and 1000 pc. Within these two areas, the results are as follows:

	100 pc radius	1000 pc radius
Total flux [erg s^{-1} cm^{-2}]	2.1×10^{-11}	1.5×10^{-9}
Radial velocity dispersion [km/s]	290	250

Use the above data to answer the following questions about the galaxy.

(a) (10 points) Calculate the mass, luminosity, and mass-to-light ratio, all in solar units, for the part of the galaxy contained within the large (1 kpc radius) area.

(b) (5 points) Repeat for the small (100 pc radius) area.

(c) (10 points) On the basis of your answers to parts a–b, argue for or against the presence of a supermassive black hole at the center of this galaxy. If a black hole is likely to be present, estimate its mass.

(d) (5 points) Estimate the stellar relaxation time for the 100 pc area and compare this to the likely age of the galaxy. Comment on the validity of the virial theorem in this case.

5. **The unified AGN model**

Suppose that the jets of an AGN that are within 45° of our line of sight appear as quasars, while those outside of this cone appear as radio galaxies.

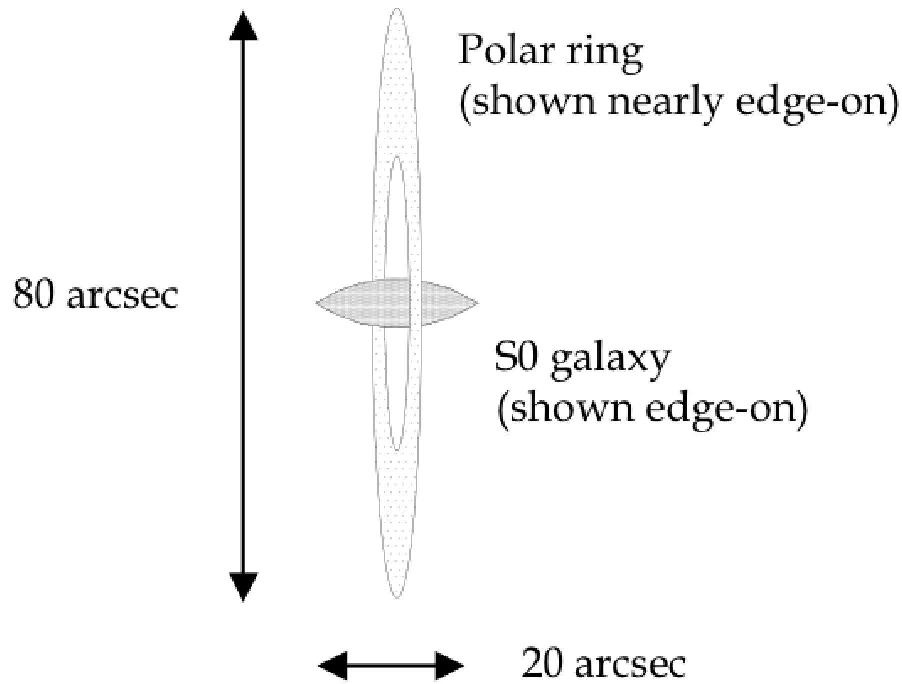
(a) (5 points) Sketch a diagram containing an AGN and its jets, and label the regions of the sky where we would detect it as either a quasar or a radio galaxy.

(b) (5 points) What is the solid angle of the sky that corresponds to our perception of the AGN as a radio galaxy? As a quasar?

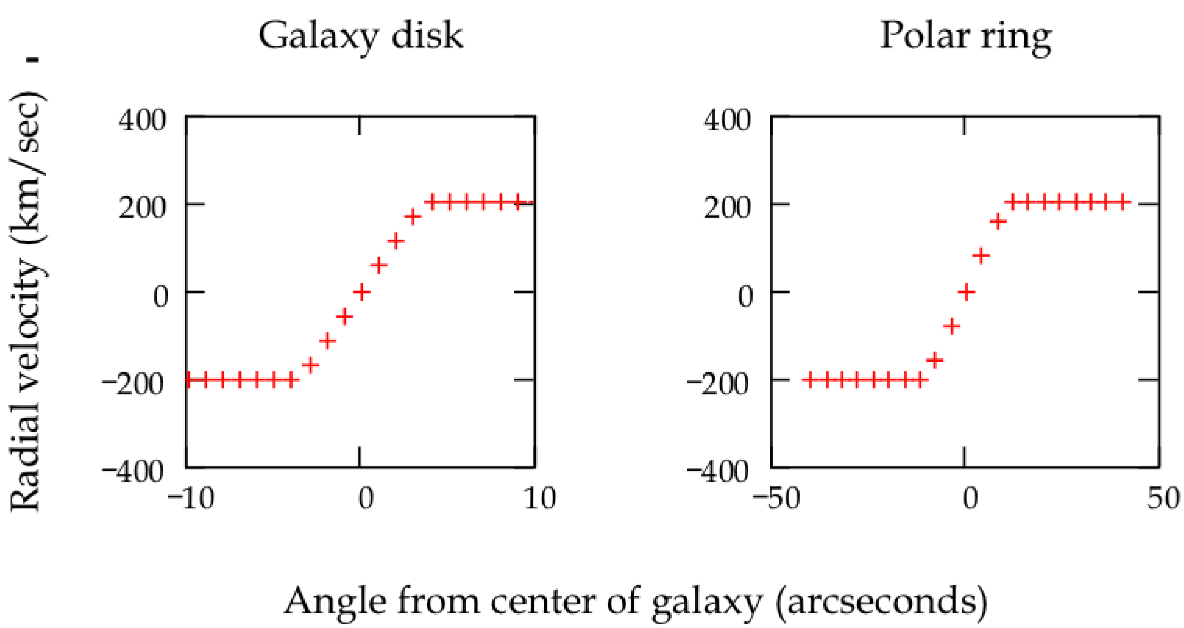
(c) (5 points) Are we more likely to observe an AGN as a radio galaxy or a quasar? By how much? Be sure to state any assumptions that you make. (*Hint:* Use your results from part b.)

(d) (5 points) Within the redshift range 0.5–1, we have observed 2.44 times as many radio galaxies as quasars. By comparing this to your answer from part c, what conclusions can you make about the unified AGN model? What can you say about the inclusion of blazars into this model?

6. A polar-ring S0 galaxy is observed to have both rotation axes nearly perpendicular to the line of sight. The disk is 20 arcsec long in the direction perpendicular to its rotation axis; the ring is about 80 arcsec long in the direction perpendicular to its own rotation axis. The system lies $d = 100$ Mpc away from us. A sketch of the appearance of this system at visible wavelengths is shown below.



Radial velocities have been measured for the entire visible extents of the galaxy disk and the polar ring, and appear below.



(a) (10 points) How much mass is seen?

(b) (5 points) What is the shape of the mass distribution? Is there likely to be very much dark matter in the system?