

# Astronomy 128: Galaxies and Galactic Structure

Week 12, Thursday, April 13

**Topic:** Active Galactic Nuclei (AGN)

For our final regular seminar, we'll look at some of the most luminous objects in the universe, the active galactic nuclei (AGN). At first, different type of AGN thought to be very distinct objects (they had very different spectral features), but now we think it all has to do with a central super-massive black hole that's gorging on matter. We will discuss reasons (both theoretical and observational) why black holes are the most likely culprit. The differences in the spectral features among the AGN are related, like so many other things in astronomy, to the inclination angle. Are you looking at the AGN through the host galaxy's disk, or are you looking from above? We'll also take a look at the redshift distribution of quasars and the evidence that quasars were a lot more common in the past than they are today. To my knowledge, this is the clearest evidence that the Universe evolves<sup>1</sup>

**Break:** Micah

**Reading:** Section 8.1 of Sparke & Gallagher, and sections 4.6.2 to 4.6.4 (inclusive) in Binney and Merrifield.

**Problems:**

1. Come to class with at least one *written* question on the reading.
2. By next seminar (April 13), pick a topic from the list below that you will present in one of the last two seminars (April 20 and 27). I will keep a list of who's doing what on the webpage. First come, first served. **Submit, at the beginning of seminar Thursday (not on Wednesday), a list of the sources you will be using and a rough outline of what you want to talk about.** I will assign who presents when, mostly so that there is some continuity to the topics (but also, to be honest, so that there's no need to argue about who goes on the last day).

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<sup>1</sup>It was the last nail on the coffin for the Steady-State cosmology.

Here is a list of topics that you can choose from. If you really want to do something else, you need to talk to me about it first.

**NOTE:** I have changed these topics slightly since Thursday, consolidating two of them into one “intergalactic gas” topic, eliminating one (the Great Attractor—too vague), and adding one (the first galaxies).

- (a) Starburst galaxies.
- (b) Galactic and extragalactic magnetic fields.
- (c) High velocity HI clouds (HVC’s).
- (d) Galaxy evolution and the first galaxies.
- (e) High- $z$  supernovae and measuring the acceleration of the Universe.
- (f) Intergalactic gas: Absorption lines in quasar spectra, the “Lyman-alpha forest”, the Gunn-Petersen effect, and cosmic re-ionization.
- (g) The Sunyaev-Zel’dovich effect.
- (h) Photometric vs. spectroscopic redshifts, and “ $k$  corrections”.
- (i) The center of the Milky Way (Sagittarius A\*).

The motivation for these presentations is for you to do some research and present a clear summary of a topic to the class, at a level similar to Sparke & Gallagher. Given that there will be 3–4 presentations per seminar, you’ll have 40 minutes to present your material (plus time for questions from the audience). In addition to explaining your topic to your classmates, I want you to produce something that everyone can take away: a copy of your slides, a written summary of the topic, etc. You can’t talk about every detail in 40 minutes, so focus on the key issues, what’s cool, and what builds on the basic concepts we’ve covered during the semester.

I’ll give you feedback about your presentation style and mastery of the subject. You’ll get a grade, which will go toward the “class participation/presentation” grade.

3. Have a look at the spectrum of a “typical” quasar on page 314. Assuming the continuum is thermal (i.e. blackbody), what temperature would this correspond to? If it were caused by stars, what kind of stars would they have to be?
4. In the textbook, they mention that we use radio astronomy to probe one of the most energetic sources known and that this is somewhat paradoxical. Explain why, at first glance, this seem paradoxical and why it really isn’t.
5. SG 8.3. The term “bright” here is a bit vague. Calculate both the luminosity and the apparent  $V$  magnitude as seen from Earth.

6. No course in galaxies would be complete without a tour of the Sloan Digital sky survey (SDSS). Go to the SDSS data web site (<http://skyserver.sdss.org>) and check out their navigation tool . Click on “Visual Tools” (under “SkyServer Tools” in the left column) and then on “Navigate”. It’s a lot like MapQuest, so try zooming out, panning in the different directions and clicking on objects. The right-hand panel will show you the classification of the object as well as its magnitude in the  $u$ ,  $g$ ,  $r$ ,  $i$ , and  $z$  filters (roughly ultraviolet, green, red, and two infrared). If you click on the “Explore” link when an object is selected, it will give you many more details about the object. Let’s look for a QSO (Quasi-Stellar Object):

- (a) Go to the following coordinates:  $RA = 176.764^\circ$  and  $DEC = +1.412^\circ$ . You should see several star-like objects in the field. Find the quasar. Click on an object, and check out its “Explore” link. The QSO has a spectrum (most objects don’t) and it should certainly look like a QSO spectrum. Record the redshift of the QSO (it’s specified right on the spectrum of the object) and its coordinates ( $RA$  and  $DEC$ ).
- (b) If this really is a QSO, it might be “radio loud” (i.e., a quasar<sup>2</sup>). To find out, visit the VLA FIRST survey (Very Large Array Faint Images of the Radio Sky at Twenty Centimeters): <http://sundog.stsci.edu/>. Follow the “Retrieve Image Cutouts” link, plug in the coordinates of your quasar (note that  $RA$  needs to be in decimal hours, not degrees), and see if it has any radio flux.
- (c) Given the redshift and its apparent  $r$  magnitude, find the absolute luminosity of this quasar. Hopefully you found that the redshift is larger than 1.0. At this high redshift, we can’t simply use Hubble’s law as-is. The reason? You’re looking back so far in time that  $H_0$  has changed significantly in the time the photons have been traveling to get to you. Never fear, the distance to a cosmological object at high redshift can be computed using the following formula:

$$D(z) = \frac{c}{H_0} f(z)$$

so it looks a lot like Hubble’s law, but with the extra factor  $f(z)$ . Using general relativity, you can find out what  $f(z)$  is:

$$f(z) = \frac{z [(z+1) + \sqrt{1+z\Omega}]}{(1+0.5\Omega z + \sqrt{1+z\Omega})}$$

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<sup>2</sup>The term quasar originally came from the radio astronomers who found point-like radio sources which were associated with optical stars. They were called Quasi-Stellar Radio Sources (QSRS), which evolved into “quasars”.

Use this formula to find the distance in Mpc.

- (d) Assuming this quasar is emitting light at its Eddington limit, compute the mass of the central object.
7. It is sometimes said that an accretion disk is the most efficient way to generate energy. Let's say that a lump of matter of mass  $m$  orbits an object of mass  $M$  and radius  $R$  at a very large distance. Through friction, the potential energy of the object is converted into radiation and the lump "sinks" down toward the central object, ultimately ending up on the surface. If we define the energy released by

$$\Delta E \equiv \epsilon mc^2$$

show that if all the potential energy is converted to radiation, the efficiency  $\epsilon$  is

$$\epsilon = \frac{R_s}{2R}$$

where  $R_s$  is the Schwarzschild radius of the central object. What is the efficiency for accretion onto (a) a white dwarf; (b) a neutron star; (c) a black hole? How do these compare with the efficiency of nuclear burning at the center of the sun?

8. SG 8.5.  
9. SG 8.8.  
10. SG 8.9.