PHYS 1040: Solution
Assignment #4, Spring 2008

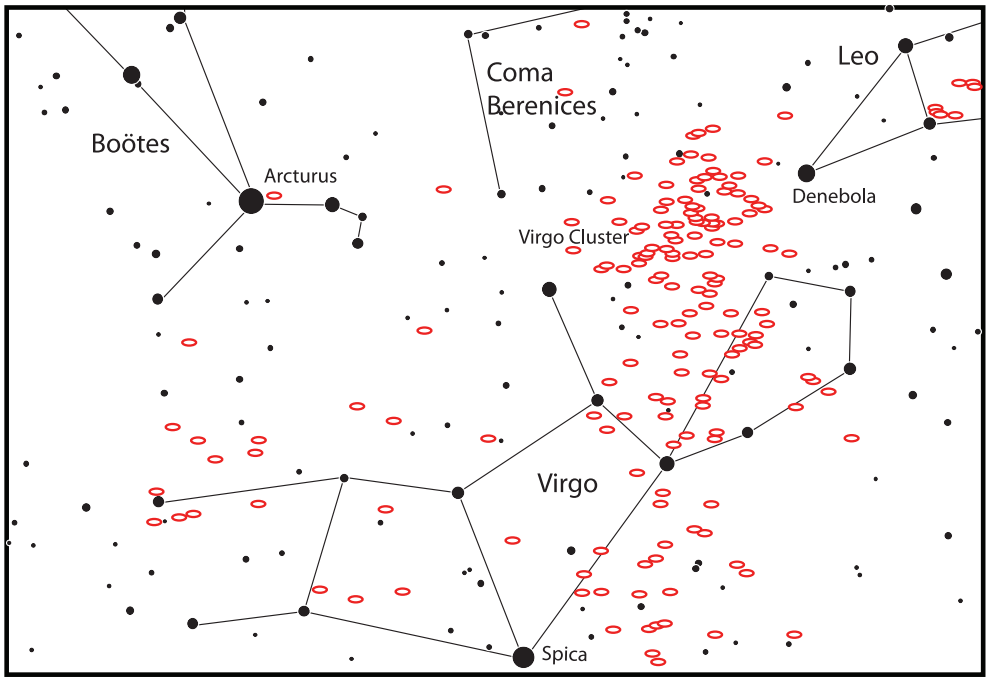
1: "I can't believe they pay you to do this!" (brotherly quote)

In astronomy, *metallicity* is a measure of how much the composition of an object (in particular stars) is in material heavier than hydrogen. "Metals" are any elements on the periodic table above hydrogen; this includes things you and I normally think of as metal (lead, silver, tin, aluminum, etc.), but also things that we don't always think of as metal (xenon, oxygen, carbon, sodium, etc.).

2: Clutter on all scales!

Hierarchical clustering is the idea that grouping of objects can occur on many different spatial scales. We see this in terms of cities on the surface of the Earth (there are large cities like Salt Lake, medium cities like Ogden, and tiny towns like Paradise). You can also see it in places like my office (there are big, medium and tiny piles of paper all over the place!).

In terms of galaxies, we see hierarchical clustering of galaxies. The largest scale clusters are called *superclusters* (such as the Virgo Supercluster, where we live), smaller *galaxy clusters* (such as the "Virgo Cluster", about 15 Mpc away in the direction of the constellation Virgo, as shown in the diagram below), and small groups (such as our own "Local Group").

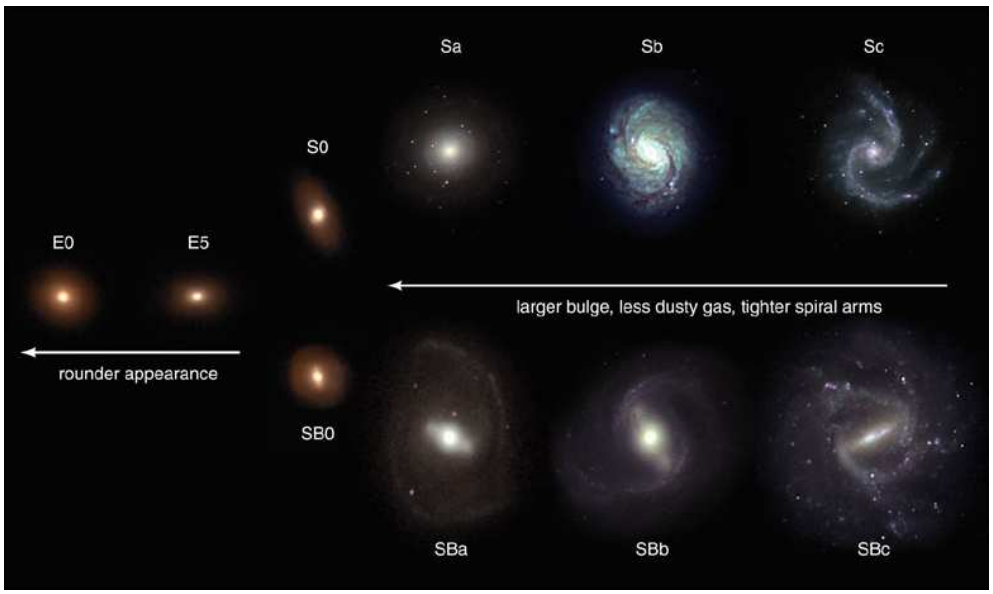


3: What?! No black hole?

There seems to be a correlation between the size of a galactic black hole and the size of the bulge of the galaxy hosting the black hole. Galaxies which have large central bulges seem to have large black holes. Elliptical galaxies, for instance, are "all bulge", and have massive black holes at their core. The Milky Way has a modest bulge, and a modest 4 million solar mass black hole at its core. By contrast, the Triangulum Galaxy (M33) is a very nice spiral galaxy which apparently has no bulge! After much searching and observing of the central regions of M33, astronomers have failed to turn up any evidence of a black hole. Thus the "bulge size correlates with black hole size" rule appears to hold.

4: Tune in for galaxies!
Hubble believed that elliptical galaxies evolved into spiral galaxies, but this is incorrect based on observational evidence. It is usually the case that elliptical galaxies are spinning very slowly if at all. By contrast, spiral galaxies have a significant spin associated with them. There is no known mechanism in astrophysics whereby you could easily make an elliptical galaxy spin as much as a spiral galaxy, making it unlikely that spiral galaxies are the descendants of ellipticals.

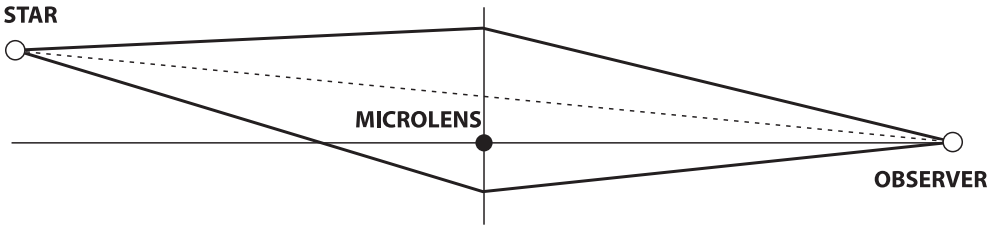
The *Hubble Tuning Fork Diagram* for galaxy classification is shown below.



5: Galactic Tides
Tidal forces are the force an object experiences because the strength of a gravitational field changes with distance.

In tidal stripping, a small companion galaxy experiences a tidal force from its much larger companion (such as the Large Magellanic Cloud, which is experiencing a tidal force from the Milky Way). The gravitational force from the large galaxy is much larger on the side of the companion closest to the large galaxy, and weaker on the far side. This difference in force slowly pulls the small companion apart, *stripping* it of gas and stars.

6: Cosmic Magnifying Glass
Microlensing is caused when a compact, massive object passes between an observer and a distant source of light (a star, galaxy or distant quasar), as shown in the image below.



In microlensing the angles are generally not as extreme as those shown in the figure. Light is redirected ("focused") by the lens to the observer, making the star look brighter. This is similar to how a magnifying glass works – it takes light and focuses it down to a brighter point.