Astronomy 1143 Galaxy and Exoplanet Review

Prof. Pradhan

December 8, 2021

Galaxies

1. What are the differenct sizes of large scale structure?
   - Groups: comprise 3-30 bright galaxies
   - Clusters: 30-1000s of bright galaxies, often surrounded by many dwarf galaxies, extending 1-10 Mpc across
   - Superclusters: clusters of clusters!
   - (Note that the largest of these structures often form across filaments in the cosmic web)
2. What is the name for the structure that the Milky Way is a part of?
   - The Local Group
   - Milky Way and Andromeda are the key members ut to about 1 Mpc
3. What are the main components of our Milky Way galaxy?
   - Central bulge
   - Spiral arms filled with star formation
   - Massive black hole at the center (106 the mass of our own Sun)
   - Large, extended halo with globular clusters and old stars
4. How far away is the Sun from the Galactic center?
   - About 8 kpc
5. How does the separation of galaxies in a cluster compare to the separation of stars in a galaxy?
   - In a galaxy, stars are incredibly far apart compared to their actual sizes
   - In a cluster, galaxies are separated by about 20 times their size
6. What is gravitaional lensing by galaxies?
   - When a galaxy is located behind another along a line of sight, the gravity of the foreground galaxy can bend its light as it travels to us and create multiple images.

Galaxy Classification

1. Who first came up with the galaxy classification system, and what is it based on?
   - Hubble first came up with the system that we still use today
   - It's based on the appearance and shape of the galaxy
2. What are the types of galaxies in the classification system?
   - Elliptical galaxies: Large collections of stars without any sort of features; no disks or spiral arms, no visible dust lanes. Varying amounts of ellipticity from spherical to very flat and oval.
   - Spiral galaxies: Central bulge of stars surrounded by a flattened disk made up of spiral arms. The arms have more dust and stars than other regions of the disk. There is also a sparse halo of stars in a sphere around the disk.
   - Barred spiral galaxies: Like spirals, but with a bar-shaped nucleus instead of just a bulge in the center.
   - Irregular galaxies: Doesn't fit into either elliptical or spiral classification. Usually dwarf galaxies (smaller galaxies) are classified this way, since they're not large enough to form a coherent disk or ellipse.
3. How old are the stars in each type of galaxy?
   - Elliptical galaxies have very old stars and no ongoing star formation. This makes them appear red, since big, bright, blue stars don't live very long.
   - Spiral galaxies have ongoing star formation, which makes them appear blue. Blue stars are big and bright, and don't live very long, so you only see them in galaxies that are still forming stars.
4. What kind of galaxy is the Milky Way?
   - Barred spiral

History of the Universe

1. What do overdensities in the CMB evolve into today?
   - Large superstructures such as galaxy clusters/superclusters
2. Why does the uniformity and isotropy of the CMB suggest an inflationary history for the early universe?
   - The CMB is too uniform- things that are far away know what temperature they should be despite light not having had time to reach them from the distant edge of the universe.
   - If everything was intitially ???touching??? and then expanded away very quickly (inflation), then it makes sense that temperature on one spot of the CMB knows about the temperature at another spot and is roughly equal.

Exoplanets and Life in the Universe

1. What is necessary for life as we know it?
   - Amino acids are required for all life forms that we know of, specifically in the production of DNA.
   - Water, methane, ammonia, and electricity can combine to form amino acids.
2. What was the experiment that showed a primitive atmosphere can produce amino acids?

- The Miller-Urey experiment combined some primitive chemicals like water, hydrogen, nitrogen, and carbon dioxide and ran an electric current through them. Amino acids, the building blocks of DNA, formed. We think this is how the necessary building blocks of life formed on our planet.

3. What is necessary for reproduction of living organisms?
   - DNA, which carries the genetic code that tells every living organism how to work, must be self-reproducing. This is a chemical process that is absolutely necessary for life to continue its existence.

4. What is the Drake Equation, and which parameters in it can we actually observe?
   - It gives the number of advanced civilizations that could exist at any given time for a galaxy.
   - $N =$ (star formation rate) $\times$ (fraction of stars with planets) $\times$ (average number of planets per star that can support life) $\times$ (fraction of life-supporting planets that actually develop life) $\times$ (fraction of planets with life that develop intelligent life) $\times$ (fraction of civilizations that develop technology that releases signals into space) $\times$ (length of time a civilization sends signals into space)
   - We don't know most of these parameters. The only one we know for sure is the star formation rate of the Milky Way, and exoplanet searches can help us get a handle on the average number of planets per star and the average number of planets in the habitable zone for a star.

5. In general, do astronomers think it's possible for there to be lifeform like those on Earth elsewhere in our galaxy? Why or why not?
   - Absolutely! There are lots of stars similar to our Sun, and we know from recent planet searches that lots of stars have lots of planets.
   - We can also see that new planetary systems are forming all the time, so even more planets are out there than we can find!
   - The trouble is actually finding signs of life... we can find planets that are similar to the Earth that may have life, but we can't get to them and we can't tell much more about them, so we really can't know if there's life unless they send us a radio signal.

6. What are the ways we determine a star might have a planet orbiting it?
   - Radial velocity: We use Doppler shifts of absorption or emission lines of the star to see how the star "wobbles" due to the gravitational pull of a planet.
   - Transits: Planets block out light from the star when they pass between the star and us.
   - Microlensing: Gravitational lensing (thanks to Einstein's general relativity) of a star as it passes behind another star.
   - Direct Imaging

7. What is direct imaging of a planet?
   - Once we know that a star has a planet around it using one of the other detection methods, we can carefully block the light from the star from reaching the telescope and take a picture of just the planets around it.
   - This is really hard to do because the star is always significantly brighter than the planets, and exactly blocking out the star without blocking out the planets is hard.

8. What is the easiest kind of planet to find with all of the detection methods?
   - Very large planets will either cause the star to wobble more with their large mass, thus producing a greater radial velocity, or will block out more light from the star during a transit with their large size. Therefore, big planets are easier to detect.

- Planets that are very close to their stars will transit more often (sometimes once every few days!), which increases the probability of seeing it at any time that you happen to be looking at the star. This is also true for radial velocity detections. Therefore, planets with very short periods are easier to detect.

9. How do planets form?

    - Not all of the giant gas and dust cloud that forms a star will go into the star itself. Some of it goes into the protoplanetary disk, which is a disk of material surrounding a star.
    - If there are enough metals in the disk, planets will start to form out of it.
    - Bigger and bigger rocks stick together until eventually they build up to the size of planets.

10. How is our Solar System different from other planetary systems we've found? Why is this a problem for planetary formation theory?

    - Most of the systems we've found have very massive gas planets, like Jupiter in size and composition, in very, very close to their host star. These are called "hot Jupiters."
    - Our Solar System obviously doesn't have any of these. All our planets are pretty far away from the Sun, and even the closest ones are pretty small and rocky, not gas giants.
    - This poses a problem to the theory of planetary formation, because it is generally thought that gas giant planets, like Jupiter, need ice to form, and ice just can't survive that close to the star. Maybe the planets migrated there after forming? We're not sure.

11. What is a star's "habitable zone"?

    - The distance from the star at which a planet would have temperatures we believe are conducive to life, such as ripe for liquid water formation
    - This is a narrow band

12. Are exoplanets common?

    - Yes!
    - The Kepler space mission has discovered thousands