PHYSICS 313 - Winter/Spring Semester 2017 - ODU

Astrophysics - Problem Set 11 – Solution

Problem 1

Mark each of the following statements with “Y” or “T” if they are correct, and with “F” or “N” if they are incorrect:

1a) Galaxies are distributed uniformly throughout the Universe. **F**

1b) According to the cosmological principle, the Universe should look roughly the same, no matter where you are (if you average over large enough volumes). **T**

1c) The largest structures observable in the Universe today are super clusters, voids and filaments. **T**

1d) According to the cosmological principle, the Universe should look roughly the same in all directions (if you look far enough). **T**

1e) All galaxies appear moving away from us because the Milky Way happens to be close to the center of the Universe. **F**

1f) On average, there are as many galaxies whose light appears redshifted as there are galaxies with blueshifted light. **F**

1g) Hot intergalactic gas can be detected because it can blueshift CMB photons. **T**

1h) The CMB radiation is the earliest phenomenon in the Universe that we can “see” directly. **T**

1i) The atoms who emitted the CMB photons we observe today are only 400,000 light years away from us today. **F**

Problem 2

The following is a set of multiple choice questions. Answer each with one single digit:

2a) Which of the following methods can **not** be used to measure the distance to other galaxies? **1**

1 – Parallax.
2 – Cepheid Variables.
3 – Supernovae Ia.
4 – Redshift of distinctive absorption or emission lines.

2b) Which of the following MIGHT you find in intergalactic space? **4**

1 – Highly ionized hydrogen gas.
2 – Supernovae.
3 – Quasars.
4 – Cosmic web filaments.

Problem 3 – Show your work (not only final results)

Assume you want to determine the distance to some distant open cluster of stars in the Milky Way. After observing the 100 stars of the cluster for several years, you have the following data:
a) On average, the stars have a "sideways" angular motion (perpendicular to the line of sight) of 1 μrad/yr = 10^{-6} radians per year
b) All these transverse velocity vectors seem to converge to a single point which is located 0.2 radians (11.46 degrees) away from the apparent position of the cluster.
c) The average redshift of the light from these stars is z = 0.001, i.e., their wave lengths are stretched by 0.1% relative to the same light from a source at rest.

Explain how you can combine this information to find the distance to the observed cluster, and give the numerical answer for the distance (don't forget appropriate units).

Note: I made all this numbers up randomly – this is just for illustration.
Here is the formula for (relativisitic) Doppler shift: $\frac{\lambda_{obs}}{\lambda_{emitted}} = (z+1) = \sqrt{\frac{1+v/c}{1-v/c}}$ (v is the velocity along your line of sight). If you get stuck, make sure you contact me BEFORE the due date – e.g., during my office hour (Monday 2:00 p.m.) or Learning Center duty (Tuesday 11:00 a.m.) or via email.

Answ.:
b) This tells me that the average angle between the motion of the stars and our line of sight is equal to 0.2 radians (see the drawing in Ostlie and my slides on the class website. This means, in turn that the average transverse velocity (in m/s) must be given by tan(0.2) times the radial velocity (away from me), also in m/s.
c) For the small redshift given, one can use the linear approximation $z = v/c$, which yields v_r = 300 km/s for the radial component of the average velocity. (You can check this by plugging it into the given formula). Using the previous result, it follows that the absolute magnitude of the average transverse velocity should be tan(0.2)*300 km/s = 61 km/s.
a) Now we can compare this with the measured apparent sideways motion: 61 km/s = $D*10^{-6}$ rad/yr = $D*3.17 \cdot 10^{-14}$ rad/s, so the distance must be D = 61 km/s / $3.17 \cdot 10^{-14}$ rad/s = $1.9 \cdot 10^{18}$ m or **62 pc.**