PHYSICS 313 - Winter/Spring Semester 2017 - ODU

Astrophysics - Problem Set 11 – DUE Tuesday, April 11

Please submit your solution using the following format. You can submit it as an email to skuhn@odu.edu anytime before midnight on the day on which the Problem Set is due; in this case, you **must** use an electronic file format (like MS Word, LaTeX, .pdf, Mathematica etc.) or simple text (follow the rules of some programming language like Fortran or C to write mathematical expressions like x**2 for the square of *x* etc.). Alternatively, you can write your solution by hand on paper and turn it in **in class** on the same day (no late submissions); please write clearly and cleanly!

For each problem (part), type the problem number (e.g., "1a." or "2c"), followed by a space, and then your solution. For "yes/no" questions, enter "Y" or "N", for multiple choice questions, enter the correct choices ("1" or "3" or…) without any additional characters, and for numerical questions, quote the result in the form "3.1415" or "3.1415e12". For conceptual questions, just write the text (no special formatting needed). Some problems require mathematical derivations or equations in addition to text or numbers (clearly stated in the problem text). **Only** for those cases may you use a **clean** scanned image of a handwritten derivation, included in your electronic submission (if you choose that route).

IN ALL CASES, make sure that your full name appears on all your submissions to guarantee you get credit for your work! Also, do NOT simply copy someone else's solution (honor code!) – you can ask for help if you get stuck, but you must submit your OWN work. (I will randomly ask questions during class to check whether you understand the solution you submitted.

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.
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).
1c) The largest structures observable in the Universe today are super clusters, voids and filaments.
1d) According to the cosmological principle, the Universe should look roughly the same in all directions (if you look far enough).
1e) All galaxies appear moving away from us because the Milky Way happens to be close to the center of the Universe.
1f) On average, there are as many galaxies whose light appears redshifted as there are galaxies with blueshifted light.
1g) Hot intergalactic gas can be detected because it can blueshift CMB photons.
1h) The CMB radiation is the earliest phenomenon in the Universe that we can "see" directly.
1i) The atoms who emitted the CMB photons we observe today are only 400,000 light years away from us today.

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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 – 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 (outside of galaxy clusters)?
1 – Stars.
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 $1\ \mu$rad/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 (relativistic) 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 (Friday 11:00 a.m.) or Learning Center duty (Tuesday 11:00 a.m.) or via email.