

Lab 14. Hubble Deep Field

Equipment

- The Hubble Deep Field Poster
- Or a magnified image of HDF (from Web-Site) – which can be viewed on a computer.
- Ruler; Color Pens to mark Galaxies

Mini Lecture prior to Lab

- Please do this lab after the students covered Galaxies and some Cosmology
- No preparation is necessary; Lab can also be done at home.
- Please stress that Part IV is very important.

Procedure & Lab Setup

- In part I students visualize the size of the picture of the HDF in front of them. Refer the students to the toolkit if they still do not know how to convert degrees to arcseconds.
- The best procedure for part II is to take a subsection of the HDF, and count the number of galaxies in that, then assume the rest of the HDF has the same density... (and then assuming the HDF is representative of the rest of the universe, one can calculate the total number of galaxies)
- Check the total number of galaxies per square arc-minute. Acceptable values are roughly 1000 or more galaxies per square arc-minute.
- Also check what they get for the size of the visible universe. Arithmetic slips tend to be rather common at this point in this exercise.

Notes & Suggestions

- Some students find this lab to be one of their favorites others totally dislike it. It depends on how comfortable they feel about doing algebra. However, the calculations students do in this exercise are division and multiplication only – so generally any 100 level student should be able to do this lab.
- Some students can visualize what billions of galaxies actually mean, however they loose count when determining the mass of the universe in kilograms or the density in grams per cube centimeter.
- Students are often very sloppy with part IV, which however is very important because it demonstrates that this exercise really gives a far too uncertain for the density of the universe. [The uncertainty should turn out to be two to three of orders of magnitude, i.e. $>10^{+2}$]

General Concepts & What students might get out of this Lab

- A sense of how many galaxies there are in the universe
- A sense of just how small the Hubble Deep Field is

Scientific Methodologies

- Educated estimating is a rather useful method.
- Analyzing the uncertainties is extremely important when evaluating the answers.

Lab 15 & 16. CLEA Pulsars, CLEA The Large Scale Structure

Notes & Suggestions

- Please check the original CLEA manuals provided by Gettysburg College