Name ____ Date ____________

Modern Day Cosmology: The Hubble Deep Field

Objective

Students will analyze the galaxies in and the structure of the Hubble Deep Field by noting possible clustering, identifying the Hubble types of some galaxies, recognizing patterns in the colors of galaxies versus Hubble type, and speculating what an even deeper image might reveal.

Materials

* Hubble Deep Field - hand-out
* Histogram of the cosmic redshifts
* Grid

Introduction

It is humbling to realize that as we look at galaxies at distances of 12 or 13 billion light years away, we are, in fact, viewing the Universe as it was 12 or 13 billion years ago. The concept of the finite speed of light and "look-back time" means we actually can "see" our Universe as it was a few billion years after its very creation.

As part of this activity, you need to take a look at the Hubble Deep Field (linked above), an image that takes us far out into space and far back in time. There are thousands of galaxies of many shapes and colors. By "deep," astronomers mean dim and distant. This is an image of the faintest objects ever detected. It reaches 30th magnitude, or about 4 billion times fainter than the naked human eye can see. To create it, the Hubble Space Telescope was programmed to expose its electronic detectors for about 100 hours over the course of 10 days, pointed at the tiny region of space near the constellation Ursae Majoris.

This image covers an area about 1/100 that of the full Moon. After this image was obtained, the 10-m Earth-based Keck telescope was used to observe the faint blue galaxies in the image. Astronomers have concluded that the small blue shards are among the most distant objects ever seen. These objects may represent galaxies caught in the act of formation. In all, the number of galaxies in the image implies that there are about 40 billion galaxies in the observable universe.

Take a closer look at the reproduction of the Hubble Deep Field. Noted next to many of the galaxies is the redshift, also known as *z*, for that galaxy (except for a few cases, the corresponding galaxy is usually the galaxy located to the upper left of the redshift number). The redshift is defined as:

$$\frac{\lambda_{measured} - \lambda_{true}}{\lambda_{true}} = \frac{v}{c} = z$$

or what you calculate in the "Hubble Law"exercise. If you take a close look at a few of the galaxies, you will note that there are redshifts of 1.36, 2.80, 3.23, even 4.02. Does this mean ***v/c*** is greater than 1 and these galaxies are traveling faster than the speed of light? To us, they appear to be moving faster than is physically possible; was Einstein wrong?

No. The galaxies are not moving that fast, space is expanding that fast and taking the galaxies with it. Do the following thought experiment: We observe the galaxies, record their redshifts, and conclude they are receding at a redshift of 4. Now, picture yourself as a student of astronomy living on a planet located in one of those galaxies looking back at the Milky Way. What is the redshift of the Milky Way? $z = 4$! We know that we are not flying through space at 4 times the speed of light; gravity has taken over. Dizzy yet?

Exercise

The calculations have been done for you for this part of the activity. In addition to the Hubble Deep Field image you will need to use the histogram of the cosmic redshifts for a selection of galaxies in this field. That is, the redshifts have been binned from $z = 0.0$ to $z = 4.0$ in 0.1 increments. Review this histogram of the cosmic redshifts and the image of the Hubble Deep Field and answer the questions.

Questions

1. Assume the Deep Field represents the actual distribution of galaxies in this portion of the sky. (Note: This is an extremely small slice of the cosmos. As more redshifts are observed, our conclusions here most certainly will need to be modified.) Take a look at the histogram for the redshifts.

    a) Can you see possible large scale structure such as clustering? If so, at what redshifts? (Look for redshifts where there are lots of galaxies.)

    b) Are there "voids" in this field? If so, at what redshifts? (Look for redshifts where there are few or no galaxies.)

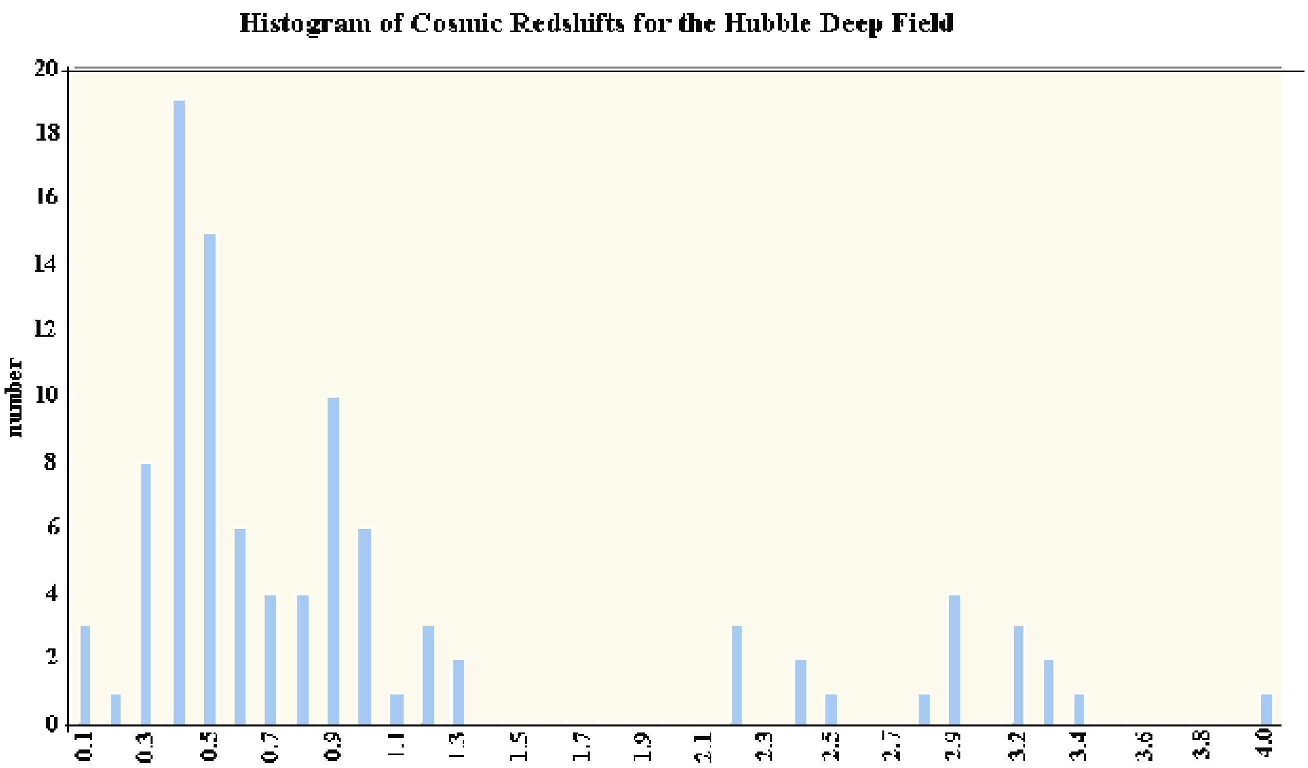
2. There are a number of clearly identifiable galaxy types included in the Deep Field image. Your instructor identified at least 5 spirals, 1 barred spiral, and more than a dozen ellipticals. There are also 4 (and only 4, look for diffraction spikes) dim stars from our Galaxy in the image. Locate at least 10 galaxies and 2 of the stars and sketch them, placing them on the grid according to their locations.

3. Label each galaxy sketched with the Hubble type of that galaxy.

4. This is an extremely small slice of the Universe. We could identify a cluster if we noted a number of galaxies close together in this 2-D image, each of those galaxies having similar cosmological redshifts. Look for a group of galaxies that you would classify as a cluster, and sketch 4 or more galaxies belonging to that "cluster" on the grid. Circle your cluster.

5. The galaxies have noticeably different colors. Do you see any overall pattern between the color of the galaxy and its Hubble type? Based on what you know about the colors of stars, give a brief description of the types of stars that make up the different types of galaxies.

6. Speculate on what astronomers would see if we had even bigger, more powerful telescopes and detectors and looked even deeper into space. Explain your answer based upon the history of our observations of the structure of the Universe and what we have discovered as our instruments and technology have improved.



Mapping the Hubble Deep Field and Identifying Galaxy Types and Clustering
