

Large Scale Structure of the Universe

Group worksheet:

group members

Introduction:

Since the mid-1980's astronomers have gathered data allowing, for the first time, a view of the structure of the Universe in three-dimensions. You might speculate that an image of this structure could be determined by photographing stars to see if they form some kind of pattern. An example of a star is our own Sun. Although the Sun is extremely bright for earth's inhabitants, it would not appear to be bright at all if it were 100,000 times farther away from us. And if it were a billion times farther away, the Sun would be extremely faint, visible only through telescopes. But to get something like a picture of the whole Universe, stars near and far must be photographed. The difficulty in observing dim images of stars is overcome by taking advantage of the fact that a single star is usually part of an extremely large aggregation of stars called a *galaxy*.

A typical galaxy contains 100 billion stars, so it is obviously much brighter than a single star. So our original question of whether or not the stars form some kind of pattern changes to the question of whether or not the galaxies form some kind of pattern. In this lab, you will answer this question by downloading and plotting the same data used by professional astronomers.

Stars and Galaxies:

Goals: - Observe galaxy images
 - Compare star distances to galaxy distances

Large Scale Structure (LSS):

Goals: - Download and plot astronomical data for galaxies
 - Take measurements on the plots to characterize the LSS

Stars and Galaxies

Before making a plot that reveals the Large Scale Structure, it is necessary to understand the distances to stars, and the distances to galaxies. And it is useful to know how galaxies look when seen through a powerful telescope.

Directions

1. Visit the web site

<http://csep10.phys.utk.edu/astr162/lect/distances/stardistance.html>

and click on the *table* link to get a list of the brightest stars. Record distances to five of these stars, from the top, middle and bottom of the list, in the table below. Be sure to include Sirius A, the brightest star in the night sky that you have probably seen.

2. Calculate how many times farther each star is from the earth compared to the earth-sun distance. The distance between the earth and Sun is 150 billion meters. This distance can be converted to another measure of distance, the light-year. A light-year (ly) is the distance that light travels in 1 year.

Earth-sun distance = 150 billion meters = 150,000,000,000 meters = 0.0000159 ly

Name of Star	Distance to Nearby Star in light years (ly)	How many times farther than Sun

3. Visit the web site

<http://messier.seds.org>

and click on the link to the list of galaxies. Click on individual links to five galaxies, and in the table below record their distances. Be sure to include M100 because it resembles the galaxy that we live in, the Milky Way. Go to

<http://zebu.uoregon.edu/messier.html> to look at the images of the galaxies whose distances you have recorded.

4. Calculate how many times farther each galaxy is from the earth compared to the earth-sun distance (given above).

Name of Galaxy	Distance to Galaxy in light years (ly)	How many times farther than Sun

Questions

1. Briefly describe the appearance of a spiral galaxy, and compare it to the appearance of an elliptical galaxy.
2. What is the range in ly (smallest and largest) of distances to the stars closest to the earth?
3. What is the range in ly (smallest and largest) of distances to the galaxies that you have recorded? You need $1\text{kly} = 1000\text{ ly}$.
4. Complete the sentence below to explain to a lay person how much farther galaxies are from the earth compared to nearby stars.

Galaxies are approximately a _____ times farther away from the earth than nearby stars.
5. Explain why galaxies are visible through telescopes even though they are so far away from earth compared to the nearby stars.
6. What kind of pattern do you think the galaxies will form? Use many dots to make that pattern below by representing one galaxy by one dot.

Large Scale Structure (LSS)

You are now ready to see what type of pattern (if any) the galaxies form. This pattern provides evidence to astronomers who are trying to understand how the Universe has evolved over time. Astronomers have gathered the data that you will access by observing almost a million galaxies over the last eight years using a telescope in New Mexico dedicated to what is called the Sloan Digital Sky Survey (SDSS).

Directions

1. Visit the web site that gives you access to the server where the SDSS data is stored:

<http://cas.sdss.org/dr7/en/tools/search/sql.asp>

2. You should be on a web page labeled SQL Search. SQL (Structured Query Language) is a computer language used to access databases. Replace all of the text in the white window with the following SQL text *exactly* as shown.

```
SELECT STR(z,10,6) z, ra, dec
FROM specObj
WHERE specClass=2 AND dec BETWEEN -3 AND 3 AND ra BETWEEN 0 AND 360
AND z BETWEEN 0 AND 0.05
```

3. After typing this text, click the HTML button, then Submit. Position data for 9660 galaxies will appear in a browser window. Three columns of data should appear labeled z, ra, and dec to give the position of each of the galaxies. The z (called the redshift) tells how far the galaxy is away from earth; we will convert this to Mega (million) light years. And ra and dec give the angular position of the galaxy in the sky. Notice from the SQL above that dec ranges only from -3° to $+3^\circ$, while ra ranges from 0° to 360° . So you will plot only a small slice of the Universe on an x-y plot.

4. Copy all of the data from the browser window, starting from the z, ra, dec heading, then paste the data into a Microsoft Excel worksheet.

5. Type Mly at the top of Column D on your spread sheet, and in the cell D2 type $=3.26*(3000.0*A2 - 607.8*A2^2 - 156.3*A2^3 + 138.3*A2^4)/0.71$ then hit enter to convert the z-value to Mega (million) light years (Mly). Your instructor will show you how to convert all of the z-values in Column A to Mly values in Column D.

6. Type x at the top of Column E on your spread sheet, and in cell E2 type

$=D2*\text{COS}(B2*\text{PI}()/180)$

- then hit enter to convert the ra-value to the x-position of the galaxy. Get the x-values for the entire column.

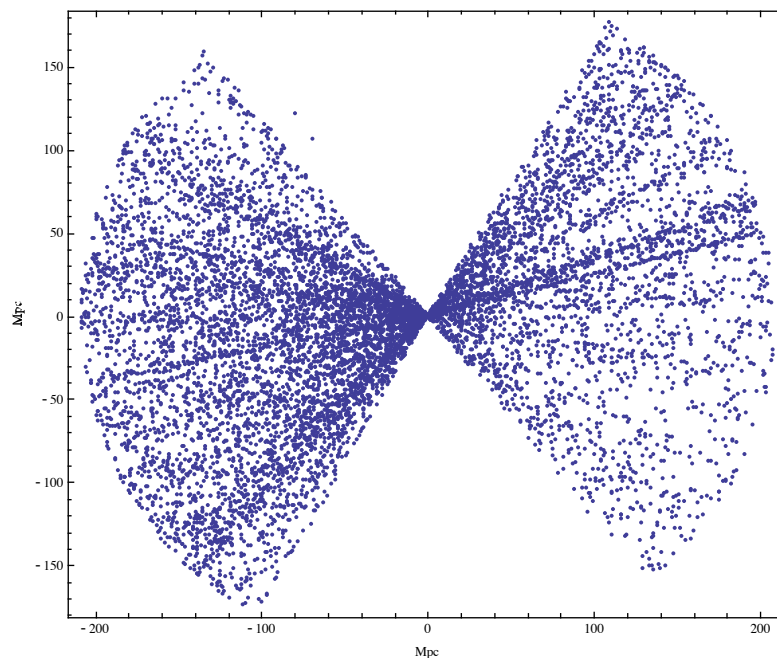
7. Type y at the top of Column F on your spread sheet, and in cell F2 type
 $=D2*\text{SIN}(B2*\text{PI}()/180)$

then hit enter to convert the ra-value to the y-position of the galaxy. Get the y-values for the entire column.

8. Select columns x and y, then make the plot by choosing the scatter plot under the Chart Wizard. Double click on one of the points in the plot and when the Format menu comes up choose a Style of point like this - , and make the size 2. After clicking on OK, you can begin to see the pattern formed by the galaxies, but the pattern is distorted unless the x and y-axes are adjusted so that they are the same length.

Questions

1. Compare the pattern formed by the galaxies that you plotted to the pattern that the galaxies would have if they were randomly distributed, as shown below? Is it at all likely that the galaxies that you plotted are distributed randomly?



2. What explanation would you propose for the pattern of galaxies that you plotted if you were an astronomer?
3. Write the distance to just one of your galaxies from the Stars and Galaxies part of this lab in units of Mly (for example, 20,000 kly = 20 Mly). The point on the graph where the two pie-shaped wedges touch is where earth is located. How do the distances of the galaxies in the SDSS survey compare to the distances of the galaxies that you found before?
4. Estimate the diameter of the voids (where there are no galaxies) in Mly using the scale of the x and y-axes.