

Dark Matter — Skeleton of the Universe

Distribution of the Galaxies (Large Scale Structure)

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. Open the “Physics_Visit” folder to get a copy of *this* document. Replace all of the text in the white window with the following SQL text *exactly* as shown by copying and pasting.

```
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. 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 Megaparsecs. 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 *everything* from the browser window into a Microsoft Excel worksheet, then delete all of the text above the z, ra, and dec heading.

5. Type Mpc at the top of Column D on your spread sheet, and in the cell D2 copy and paste

$$=(3000.0*A2-607.8*A2^2-156.3*A2^3+138.3*A2^4)/0.71$$

then hit enter to convert the z-value to Megaparcres (Mpc). Your instructor will show you how to convert all of the z-values in Column A to Mpc values in Column D.

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

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

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

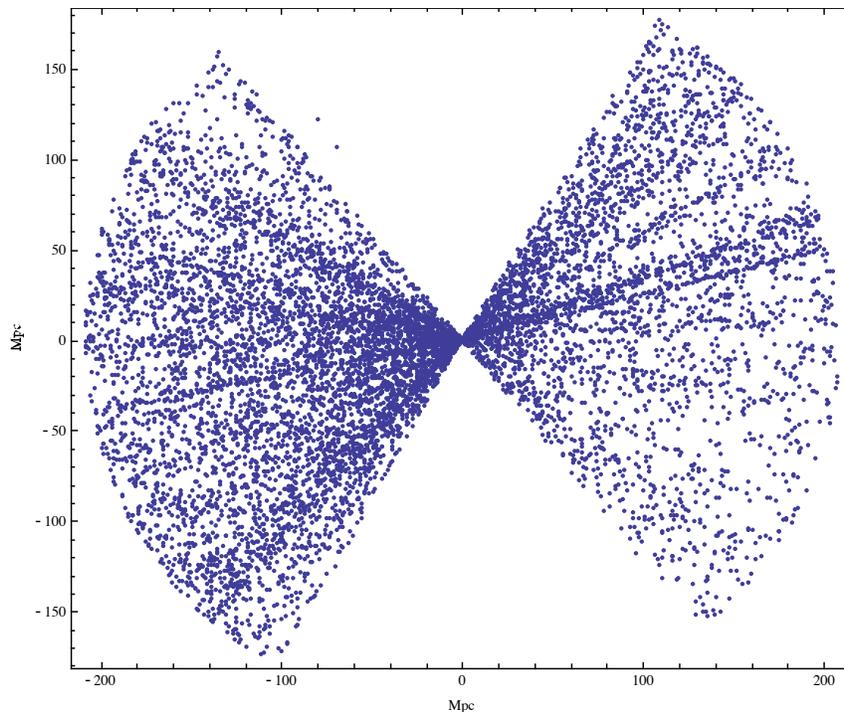
7. Type y at the top of Column F on your spread sheet, and in cell F2 copy and paste
 $=D2*\text{SIN}(B2*\text{PI}()/180)$

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 Gallery->Charts->xy Scatter ->Marked Scatter. You will need to wait for about a minute until the color ball stops spinning. *Do not try to enlarge the plot yet!* Double click on one of the points in the plot and when the Format Data Series menu comes up, choose a Marker Style like - , and make the size 2. Close the Format Data Series window, then grab a *corner* to enlarge the plot. The earth is at the point where the two wedges meet; gas and dust prevent astronomers from seeing the galaxies in the empty wedges of the “pie.” These galaxies are more than a million times farther away from us than the stars in our night sky.

Questions

1. Compare the pattern formed by the galaxies that you plotted to the random plot of those same galaxies 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?

Dark Matter Skeleton

Click on the Mathematica Player icon  in the Dock at the bottom of the screen. Now open the file 3D_Dark_Matter_ClusterGrowth.nbp (in the “Physics Visit” folder) to see what dark matter structure is most likely to give rise to the galaxy structure that you plotted. Set the simulator values as follows: angularSize=32, expansionTime=3, fractionFilled=0.15, and depth=8, then run the simulation by clicking on “Compare Cold-Hot Dark Matter.” Cold dark matter (not very energetic) is on the left and hot dark matter (very energetic) is on the right (enlarge the window if necessary). Wait until three pairs are generated. Note that the cold and hot dark matter start with exactly the same initial configuration.

Question 9. Which of the dark matter simulations, cold or hot, seems to you most likely to be the skeleton for your galaxy plot? Repeat the “Compare Cold-Hot Dark Matter” simulation as many times as needed to reach a definite conclusion. Justify your answer.
