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ASTR328 - HW3 - GROUP PROBLEM - TWO POINT CORRELATION FUNCTION

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ABSTRACT

To study structure in the universe, 8384 points of simulated cluster data were used to calculate a two-point correlation function for spiral galaxies and elliptical galaxies, as well for all galaxies within the data. By comparing the distributions of separations between galaxy pairs with randomly generated data, the slope of power law fits, which yield values of -1.74, -2.59, and -2.22 for all galaxies, spirals, and ellipticals, respectively, we show that ellipticals exhibit more clustering than spirals at scales less than 20Mpc. These results agree with observational measurements by Davis and Geller[1].

Subject headings: Cosmology

1. INTRODUCTION

Differences in clustering properties of early (ellipticals, SO's) type and late (Sb/Sc spirals) type galaxies may give information on the growth and evolution of clusters. In particular, if younger galaxies tend to exhibit more clustering than late types, this scenario corresponds more closely to a "top down" theory in which larger-scale structures (such as clusters and superclusters) take form earlier than galaxies and stars. On the contrary, if older type galaxies show greater clustering, this is evidence that the larger-scale structures may form in later times, known as a "bottom up" growth scenario. Clustering of galaxies may be characterized by a two point correlation function, given by:

$$\xi(r) = \frac{DD(r)}{RR(r)} - 1 \tag{1}$$

where $DD(r)$ is the number of galaxy pairs taken from data with separation r, and $RR(r)$ is the number of galaxy pairs of randomly distributed points with separation r. Because of the comparison random data, it is possible to determine if variations in the correlation function are significant enough to correspond to actual clustering, as opposed to a random density distribution. In this way, a characteristic curve may be plotted for the galaxies clustering in the $2-20$Mpc range. This range restriction is imposed because of the much greater level of interaction between galaxies which are close together. In other words, since a cluster of galaxies does not tend to be any larger than 20Mpc, separations larger than that do not characterize clustering, and are therefore not useful in this study.

This study includes simulated data from a cube of space measuring 140Mpc on a side, with 8384 total galaxies, each corresponding to a position and a star-forming rate, which indicates early- or late-type galaxies.

2. METHODS

Galaxy position and star-formation rate data were obtained and the complete set of (x, y) positions is plotted in Figure 1. If the star formation rate as greater than 1, the galaxy is considered a spiral, late type galaxy. Star formation rates less than 0.1 are considered elliptical, early type galaxies. Higher star formation rates indicate younger galaxies, making them more likely to be spirals, whereas the lower star formation rates indicate older, more mature elliptical galaxies. The (x, y) positions of spiral galaxies are plotted in Figure 2 and ellipticals in Figure 3. The spirals are more uniformly distributed while ellipticals are mostly found in small clumps. This clumping

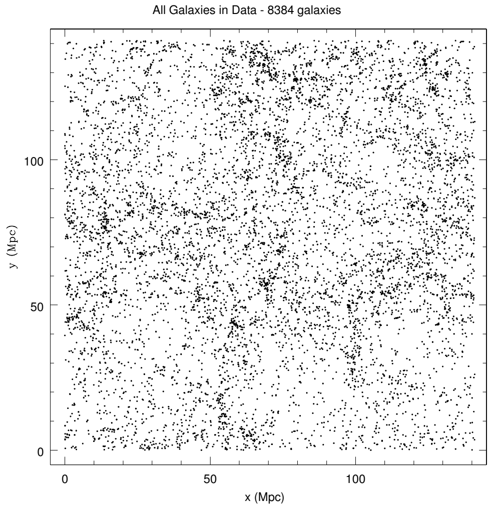

FIG. 1.— All galaxies in simulation

of ellipticals is a result of the probable formation of ellipticals in clustering[1].

To find the two point correlation function, the separation between every galaxy pair is calculated and put into a histogram with one-megaparsec bins. In order to avoid edge effects, separations were not included for pairs which would require both galaxies to be outside of the data set, since the relevant data lies between 2 and 20 Mpc. To study differences in clustering properties of early and late type galaxies, this separation calculation was done for the complete data set, for only ellipticals, and for only spirals. The resulting histograms are included in the appendix.

Randomly distributed data are needed to compute the two point correlation function, and from the definition of the two point correlation function they must contain the same number of galaxies as each set above (complete, spirals and ellipticals). The same calculations for galaxy pair separations were performed on these random data sets.

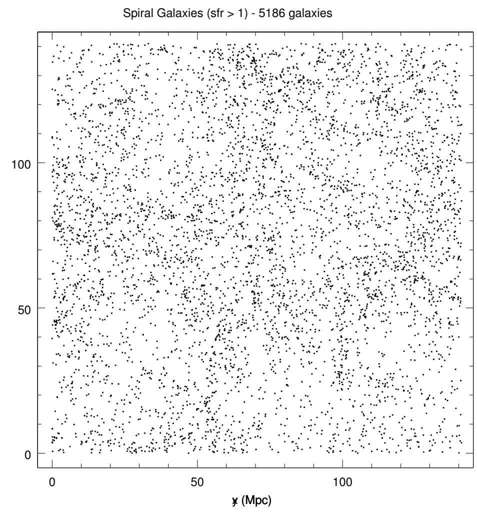

FIG. 2.— Spiral galaxies

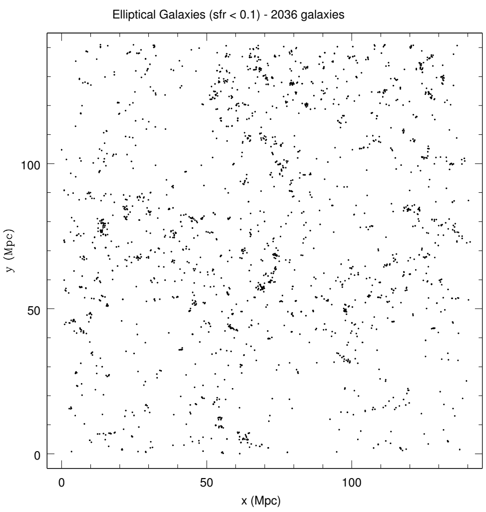

FIG. 3.— Elliptical galaxies

For each set, the histograms from the separations were cropped to include bins between 2 and 20 Mpc. The two point correlation function was calculated across these bins according to equation (1), as the ratio at each bin between the actual and the random data, minus one, for the complete set, spirals, and ellipticals. A power law is fit to these curves, which reflects the two point correlation function. Values of the resulting fits for each set of galaxies are included in Figure 4.

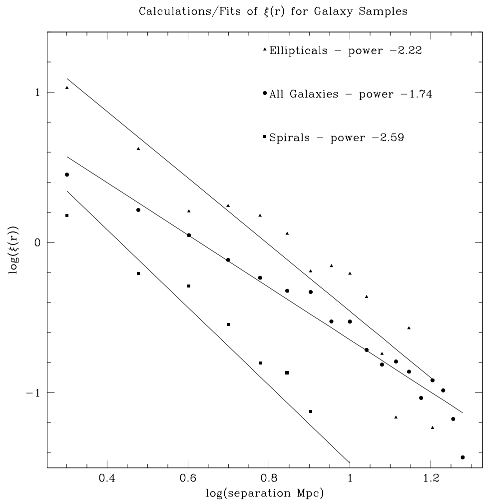

FIG. 4.— Correlation function vs pair separation for elliptical, spiral, and all galaxies from the 8384 galaxy simulation

The slope of this relationship is -1.74 for all galaxies, -2.59 for spirals only, and -2.22 for elliptical galaxies.

The results of our correlation function can be seen in Figure 4. The plot shows the likelihood (log(xi)) of finding a galaxy of morphological type at increasing separation values. As one can see, the powers for the ellipticals and spirals are similar but there is a majour difference where they begin on the y axis (log(xi)). The spirals do not start out with as strong a correlation with regards to separation as the ellipticals do. This makes sense given our xy plots of all, elliptical, and then spiral galaxies. In the plot of ellipticals the likelihood of finding another is rather high given the fact that they are found, usually, in clusters together. The correlation drops off as dV increases. The spirals in the xy plot, however, are not concentrated in one spot and are spread out rather evenly so the correlation for the spirals is, and should be, weaker than ellipticals but more steady than the elliptical slope. This is because spirals tend to be pretty much everywhere (except in voids) compared to ellipticals. The correlation for all galaxies should be a weighted average, taking into account intermediate morphological states likes S0s. This weighted average should, when fitted, fall between the two extremes of galaxy evolution. This is shown in Figure 4 as expected. Overall our results agree with what is qualitatively expected.

3. DISCUSSION

In 1976, M. Davis and M. J. Geller used the Uppsala Catalog to measure the two-point angular correlation function for galaxies grouped by their morphological type (spiral, lenticular, and elliptical). They found that the elliptical-elliptical clustering power law had a steeper slope than that for spiral-spiral clustering. Because Davis and Geller calculated the angular correlation, we cannot compare our results quantitatively, but we can see that the general behavior of their power law fits agree with our results. Davis and Geller also calculated the degree of population segregation for each galaxy type. They found that 20 to 30 percent of the neighboring galaxies within 1 Mpc of a typical elliptical galaxy were also elliptical, while only 10 percent of the galaxies studied were elliptical. Spirals, on the other hand, were found to have less variation with spatial separation. Our plots of the spatial distribution of ellipticals and spirals also show this clustering behavior, which suggests that our simulated data is similar to the data obtained by Davis and Geller[1].

The correlation function describes the probability, given one galaxy in a volume dV, of finding a second galaxy in a volume dV at a distance r from the first. Galaxies of different morphological types have different two-point functions. This may seem to depend on density environment alone. However, nothing ever seems to be that simple. According to G. Kauffmann et al, there is a high correlation between galaxy properties such as SFR, mass and internal structure are linked to density[2]. These properties of galaxies are not only linked to the environment but have the power to change it as well. So the 2-point correlation function can tell us a lot more about galaxy properties than just the likelihood of finding a galaxy of a certain type in a certain dV.

4. REFERENCES

[1] Davis M., Geller M. J., ApJ 208, 13. 1976

[2] Kauffmann, G., et al. Mon. Not. R. Astron. Soc. 353,713-731. 2004.

5. APPENDIX

Additional histograms of each type of galaxy, and attached code.

Attached code is:

graphit.sm - displays graphs of galaxy positions (figures 1 - 3)

makerandom.sm - generates (x,y) positions for random galaxies

twopointbin.sm - generates histograms (shown in figures 5 - 7) of separations

calcxi.sm - takes all the histogram data and calculates ξ for each set

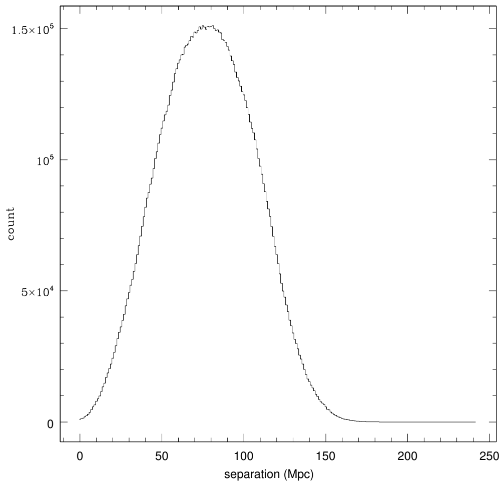

FIG. 5.— Separation histogram for all galaxies

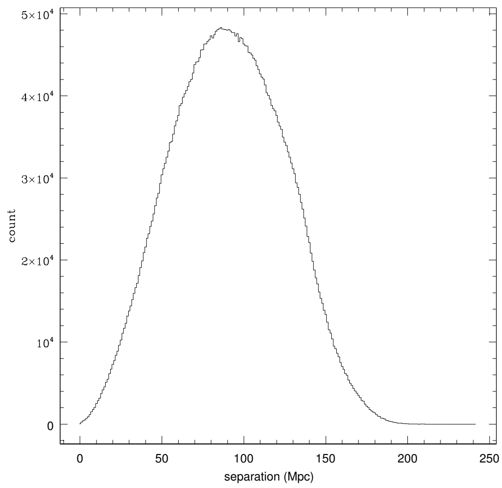

FIG. 6.— Separation histogram for spiral galaxies

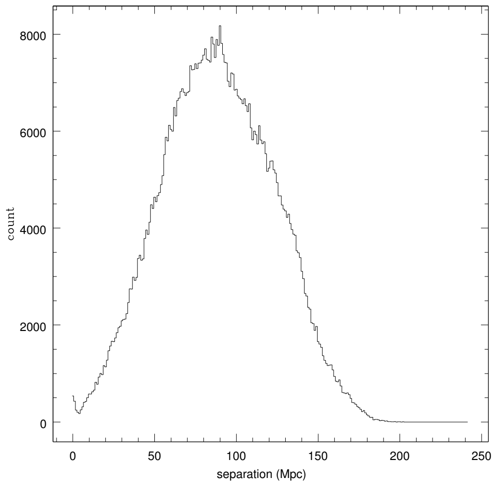

FIG. 7.— Separation histogram for elliptical galaxies