The Large-Scale Clustering of Quasars

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Abstract

Quasars are the most luminous sources in the universe and can be seen to great distances. They are likely powered by accretion onto supermassive black holes, emitting enormous amounts of energy from a compact volume. Because they are so luminous, they are used to probe the local and distant universe (Jastrow 1972). In this study, quasars will be used to study the large-scale distribution of matter in the universe. The data set is drawn from the Sloan Digital Sky Survey (SDSS), which is an astronomical project that will map one quarter of the sky. Quasars in the survey are identified and the distances are measured by using spectra. The spectra that will be examined have been automatically classified using a computer algorithm. However, the algorithm fails approximately ten percent of the time, causing contamination in the quasar data set. An important part of this project has been to inspect the quasar spectra which are likely to be misclassified, assign proper classification, and use the clean sample to investigate large-scale quasar clustering. Studies of galaxies in the local universe show that matter is not randomly distributed, but clusters on large scales. This study will help determine how galaxy clustering and quasar clustering are related, and how clustering in general has evolved throughout the history of the universe.

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I. Introduction

Quasars are the most luminous sources in the universe and can be seen to great distances. Quasars have existed since the earliest years of the universe. We use these objects to get a better idea about the earliest history of the known universe. The most distant known quasars show us an image of the universe when it was only a few percent of its current age. (http://www2.astronomy.com/Content/Dynamic/Articles/000/000/001/119dhwtd.asp)

Quasars appear faint to the human eye, but only because they are so far away. The amount of energy that they emit is equivalent to 10^9-10^{12} times that of the Sun. The power source of these objects is believed to be mass accretion onto supermassive black holes. (Rees, 1984; http://www1.msfc.nasa.gov/NEWSROOM/background/facts/PKS_0637-752_Fact_Sheet.htm) This theory satisfies the idea of the quasar having a compact volume, with diameter only a few light-days or light-hours across.

The discovery of quasars began in 1960s, when these objects were thought to be stars. Around 1960, Alan Sandage of Mount Palomar Observatory determined that these ordinary "stars" turned out to be radio sources. The unexplainable "radio stars" were investigated by collecting spectra, which did not match any known star spectra. In 1963, Maarten Schmidt discovered that the spectra were shifted toward the red part of the spectrum, much like the galaxies but very extreme. This shift was discovered to be much like the Doppler effect and is proportional to the speed of the object's recession from earth for relatively nearby quasars. In 1973, the most widely accepted quasar model is proposed, which suggests quasars are powered by supermassive black holes. In 1979, a quasar image distorted by gravity of a foreground galaxy confirmed Einstein's theory of general relativity. Today the most distant quasars are found by large surveys which have uncovered quasars when the universe was only a few percent of its current age.

(http://www2.astronomy.com/Content/Dynamic/Articles/000/000/001/119dhwtd.asp)

Throughout the universe, it has been shown that matter is not just randomly distributed. It as been known for over 70 years, that local galaxies observed have shown web-like clustering. As we look at the distribution of quasars, they also show clustering. By using statistics, quasars have shown clustering patterns that are comparable to galaxy clustering.

II.Data Set and Data Analysis

The spectra that are being used to make the sample are from the Sloan Digital Sky Survey (SDSS). The survey will have created a map of about 10,000 square degrees, which is equivalent to one-quarter of the entire night sky. The survey will determine the positions and brightness of more than 100 million objects. This will include spectra for a million galaxies along with 100,000 quasars. (http://www.sdss.org) Currently the survey is about half completed with 50,000 quasars. The data set being used consists of 40,000 spectra that have so far been analyzed by the computer.

The survey selects candidates based on the colors of objects found in image scans with the 2.5 meter telescope and survey camera. (Stoughton et al., 2002) Spectra of the candidates are obtained using the telescope and the spectrograph. The spectra of the candidates are then used to classify the objects. An automated computer program classifies the spectra as stars, galaxies, or quasars and measures their redshifts. About 60-70% of the candidates are quasars.

A projected quarter of the 40,000 spectra that are available will be manually inspected for my research purposes. This manual inspection is necessary in order to clean up the misclassified spectra. The computer algorithm typically has problems with spectra at certain redshifts and will improperly categorize spectra around 5-10% of the time. The manually inspected quasars are generally sorted using previously known spectra, such as stars or galaxies, for comparison. Fig. 1 shows a composite quasar spectrum, which is a helpful reference guide for all standard quasar spectra.

The objects which turn out to be quasars using manual inspection are further classified based on the presence of certain spectra features. Examples of characteristics for distinguishing these particular quasar spectra are broad absorption lines (BAL), associated absorption line systems (AALS), damped Lyman alpha lines, spectra with glitches, low signal to noise (S/N), etc. Quasars with improper redshifts must also be identified and corrected if possible. Examples of a few of these different quasar characteristics are shown in Fig. 2-3.

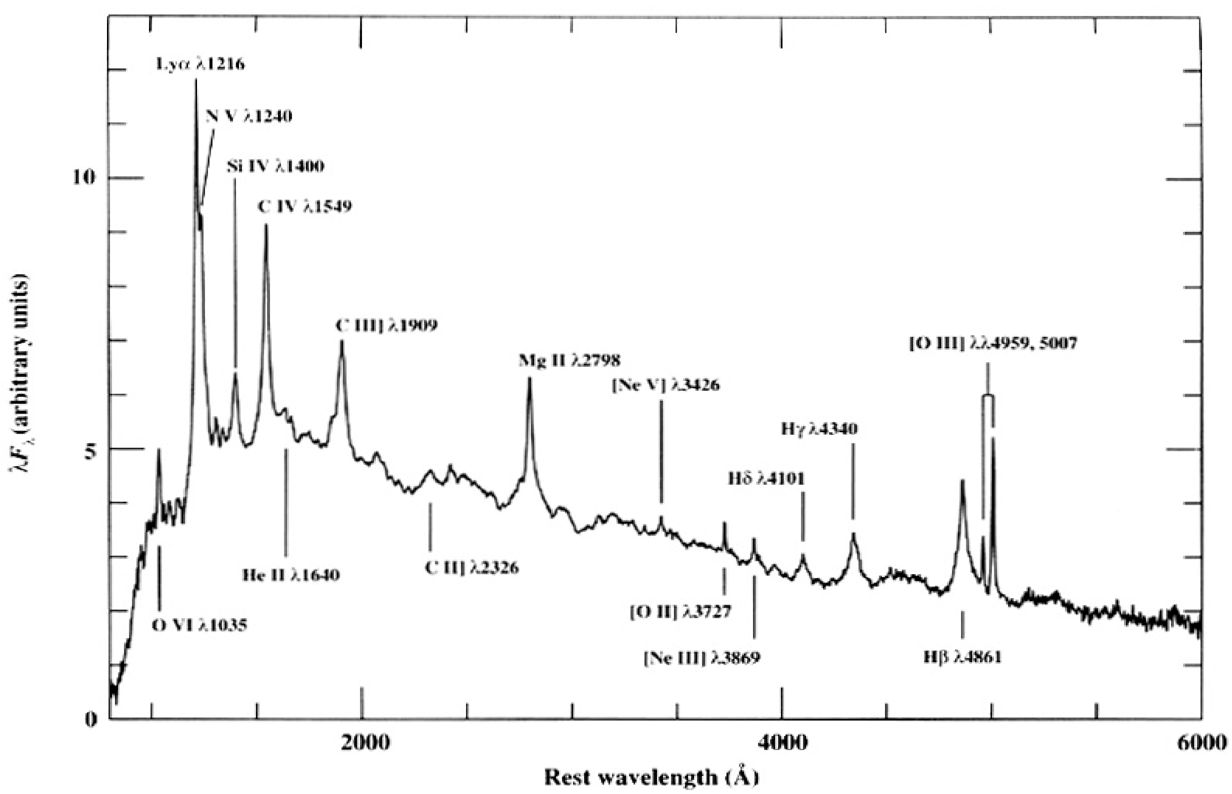

Fig 1. This is a reference guide that displays the prominent emission lines which are used to identify the redshift of the quasar spectra we look for. The individual spectra will only have less than half of these lines.

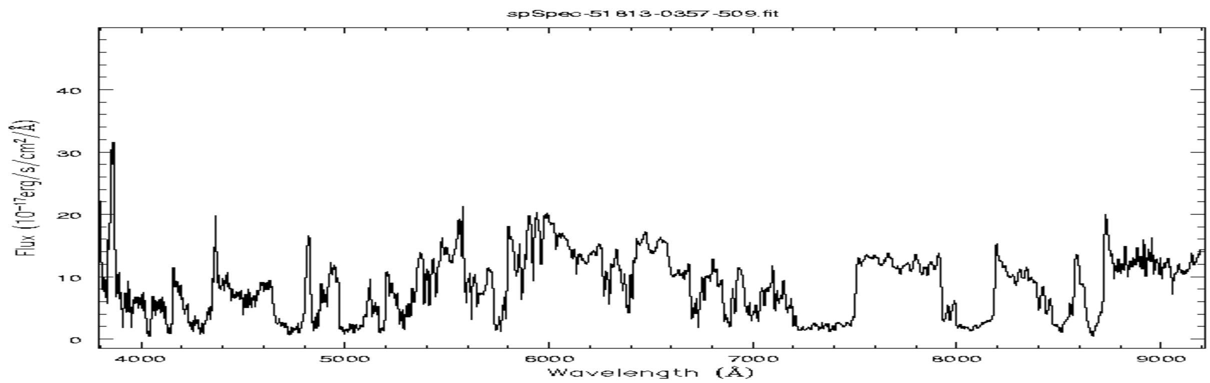

Fig 2. An extreme broad absorption line quasar. These are often highlighted for other possible research.

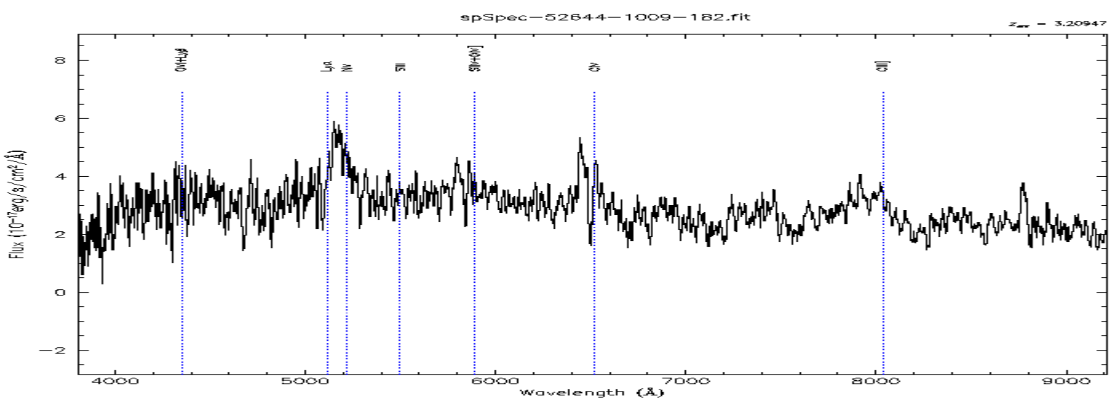

Fig. 3 A low signal to noise quasar. These are manually inspected because of the doubt that the computer might have been incorrect

An important part of the classification is the removal of spectra that were misclassified as quasar spectra. This can happen for different reasons. Typical reasons for this can be the similar shape or emission of another type of spectra. Examples of spectra found in the survey that sometimes require manual filtering are stars (particularly of M-type), galaxies, stellar composites, odd objects, unknown objects, and bad spectra. Some examples of these different types of spectra are shown in Fig. 4-6.

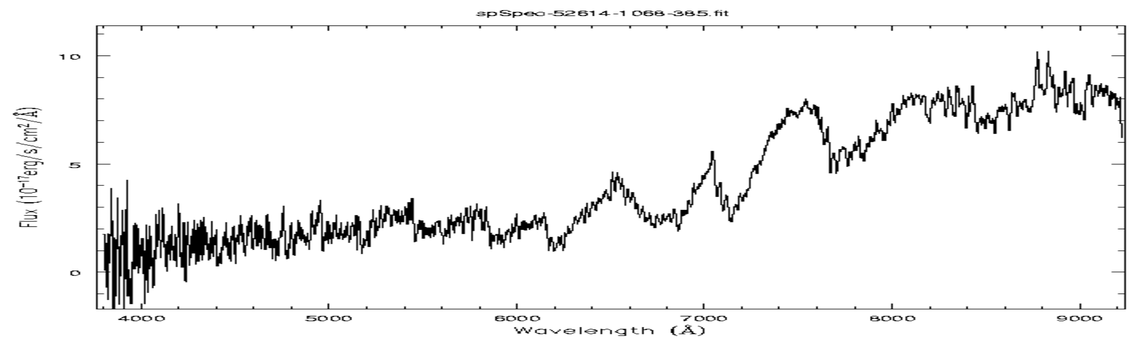

Fig 4. An M-star. These objects are misclassified as quasars more than any other type of object in the data set.

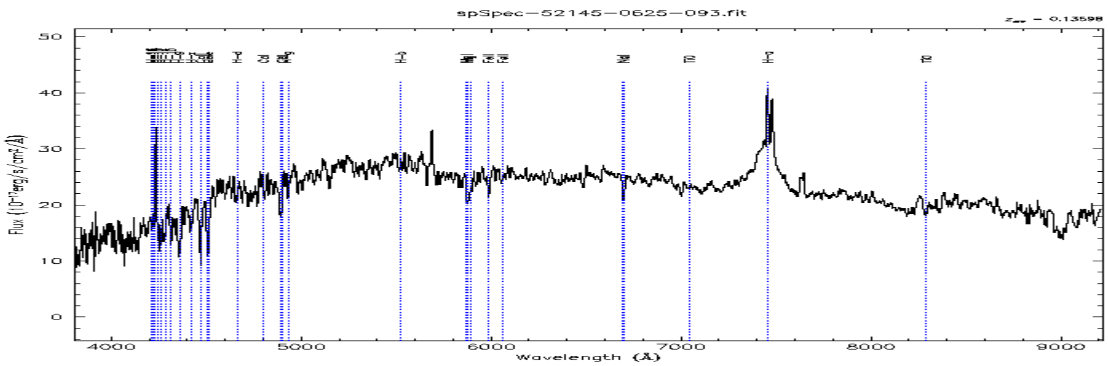

Fig 5. Galaxy with redshift of .136. It is often misclassified by its one characteristic broad emission line.

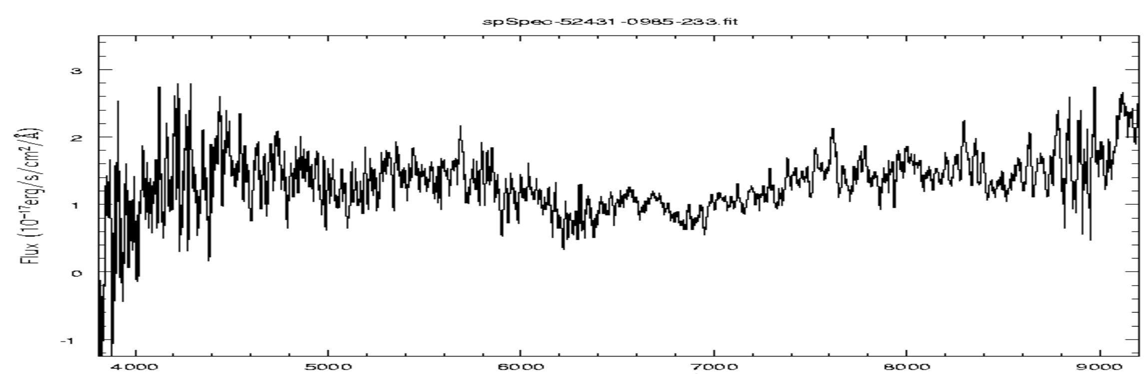

Fig. 6. A stellar composite consisting of 2 different star spectra. This is one of the many types of odd spectra that are misclassified as quasars.

III.Science Analysis

The large-scale distribution of galaxies in the universe shows that matter is not randomly distributed. When our local universe is viewed, it shows a web-like clustering of galaxies (see left side of Fig. 7). The form of this clustering tells us about the physical processes that gave rise to the formation and evolution of our universe. We want to see what this clustering signature was like in the distant past. Quasars are the only objects luminous enough to enable us to do this. Quasars are however much less dense on the sky than galaxies, and so their clustering patterns are not immediately evident to the eye (See right side of Fig. 7).

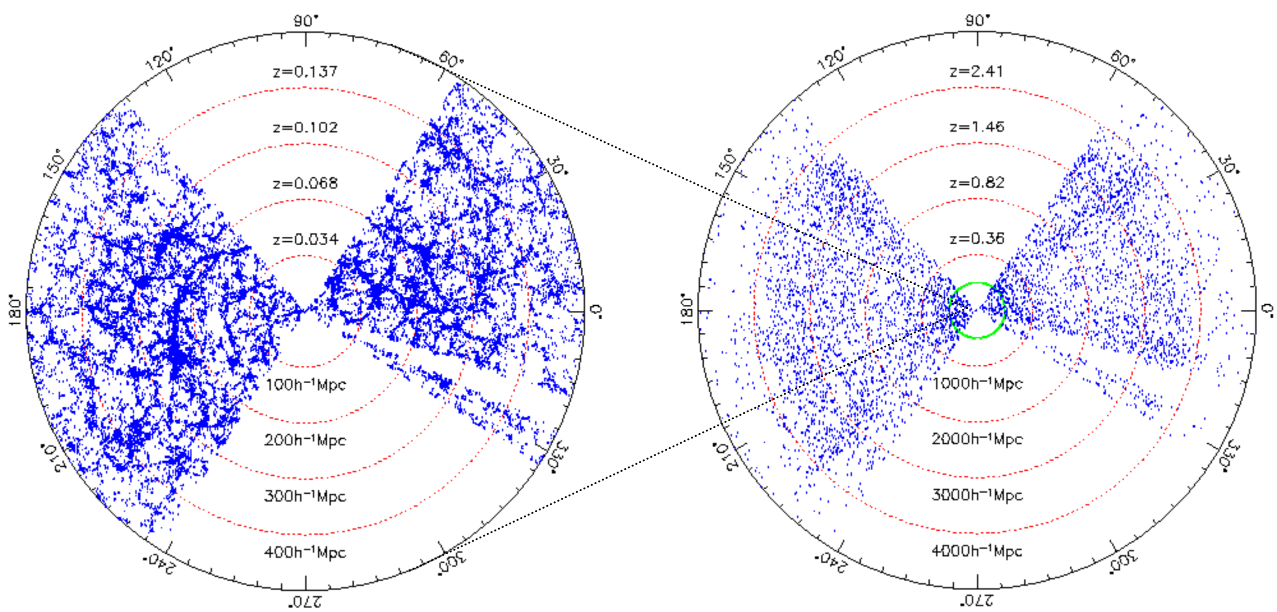

Fig 7. On the left side is the local web-like clustering of galaxies showing that matter is not randomly distributed. The radius of the plot is 1.5 billion light years. The right side shows the distribution of quasars up to a radius of 15 billion light years.

To characterize the clustering of quasars statistical tools are used such as the two point correlation function. This expresses the excess number of pairs of quasars, as a function of quasar separation, over a random distribution. Positive numbers show that quasars are clustered more than a random distribution. Negative values show scales on which quasars are fewer than expected from random distribution. Fig. 8 shows the two point correlation function for the quasars in our sample. Despite the sparse nature of quasars, we can see that they are positively clustered on scales in excess of a few hundred million light years even in the early universe.

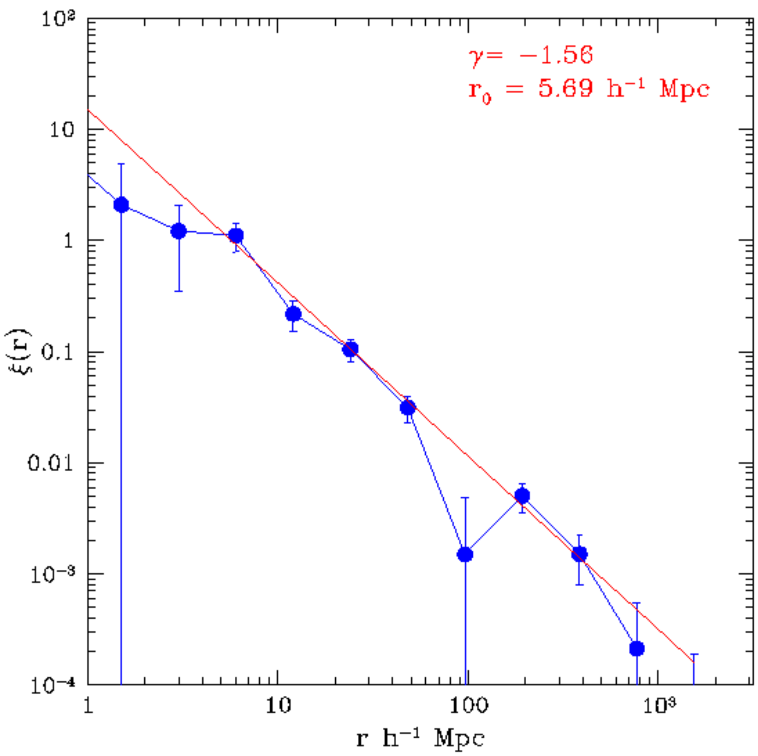

Fig. 8 Two point correlation function. this explains the ratio of real density of quasars at a given separation composed to a random distribution.

The two point correlation function we find for the quasars is very similar to the one we find for galaxies in the local universe. This indicates that quasars and galaxies are likely tracing the same underlying distribution of matter in the universe.

IV. Summary

The clean sample that is being made in this project will be used for getting a better idea of clustering. The new data will be processed later for an improved look on the large-scale clustering of quasars. We will be able to use this information to better understand the relationship between galaxy clustering and quasar clustering. The changes that have been found will help to understand better the distribution of matter in the universe. The objects that are filtered out may be used for later purposes.

References

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