How Do Elliptical Galaxies Form?

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Background

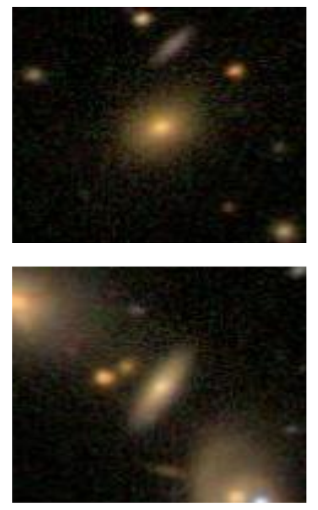
We were accepted in the NASA Experience project for the Chicago Public Schools, and learned about astronomy at the University of Chicago. The program included lectures and laboratories about stars, galaxies, and the Universe, as well as the tools astronomers use to study them. We learned about optics, and how astronomers use diffraction gratings to produce spectra of objects in the sky to classify and study them. We learned that astronomers make use of large data bases of pictures and spectra of stars, galaxies and other objects to locate interesting objects to study. One such database is the Sloan Digital Sky Survey (SDSS). We learned how to find objects of interest in the Sloan data base using Structured Query Language (SQL). Using SQL, we can download information about stars' and galaxies' coordinates, color magnitudes, redshift, etc.

Project Introduction

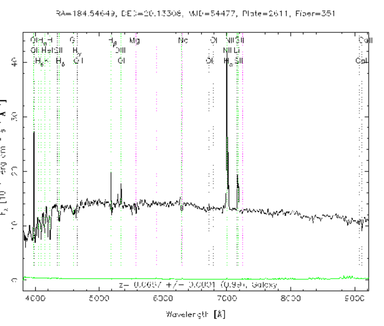
We became interested in galaxies. There are two types of galaxies: spiral and elliptical. Spiral galaxies are relatively young and are composed of young, hot stars. These young, hot stars burn hydrogen, and shine in the blue portion of the color spectrum. Spiral galaxies also appear to have "arms" of stars that swirl around a center, looking like glowing spirals. Elliptical galaxies are much older. Its stars have pretty much burned their supply of hydrogen in the core, and have cooled. They burn helium and other elements, and generally have spectra that are bright in the red portion of the color spectrum.

Spiral Galaxy Images

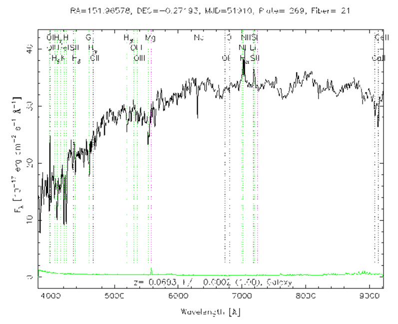
Elliptical Galaxy Images



Typical Spiral Spectrum
(Note the strong emission lines.)



Typical Elliptical Spectrum
(Note the lack of strong emission lines.)



Our Project

We became interested in how elliptical galaxies formed. We were curious about how a spiral galaxy "loses" its spiral arm structure to become a more homogeneous distribution of stars seen in a typical elliptical galaxy. One theory some astronomers have is that spiral galaxies merge, and as they do, gravitational interactions degrade the arm structure. This led us to want to find galaxies in the process of merging.

Data Analysis

We made a color separation graph between spiral galaxies and elliptical galaxies. We plotted the magnitude in a blue filter(u) minus the magnitude in a red filter (r) against the magnitude in a green filter (g). The graph shows galaxies with blue spectra toward the left side and galaxies with red spectra on the right. We examined pictures and spectra for 120 galaxies at random in the blue region and another 120 in the red area. The galaxies in the blue region were all spirals, based on their individual spectra and images. Similarly, the galaxies we looked at from the red area all had spectra that showed them to be elliptical galaxies. About 60 galaxies were selected from the area between the blue and red regions, and we found a mix of spiral and elliptical galaxies. This area is where we suspected we might find spiral and elliptical galaxies merging, because their spectra were neither strongly blue nor strongly red. We conducted further analysis to pinpoint this region where we expected to find merging galaxies.

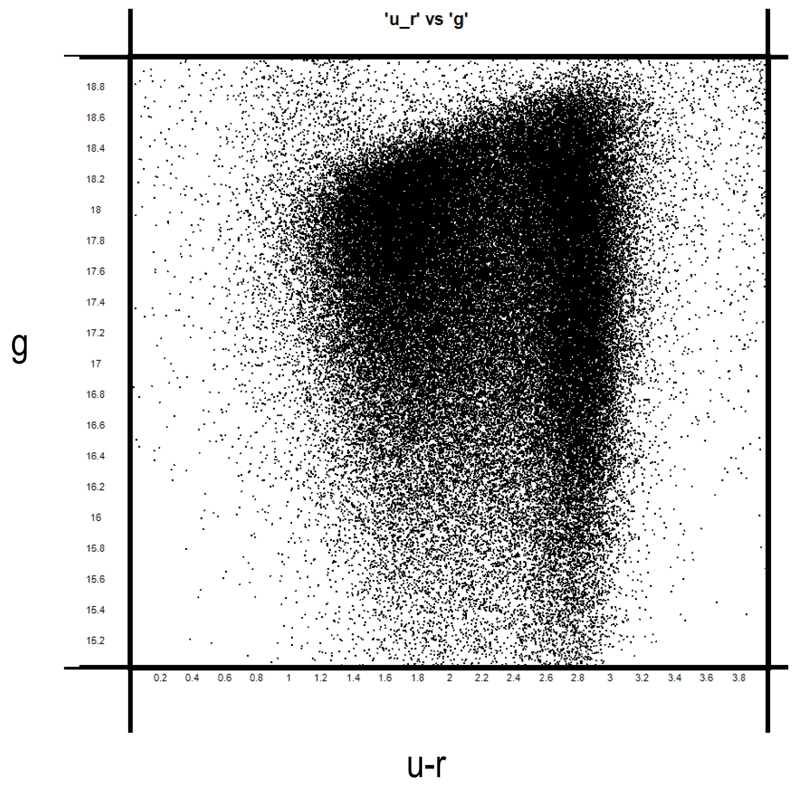
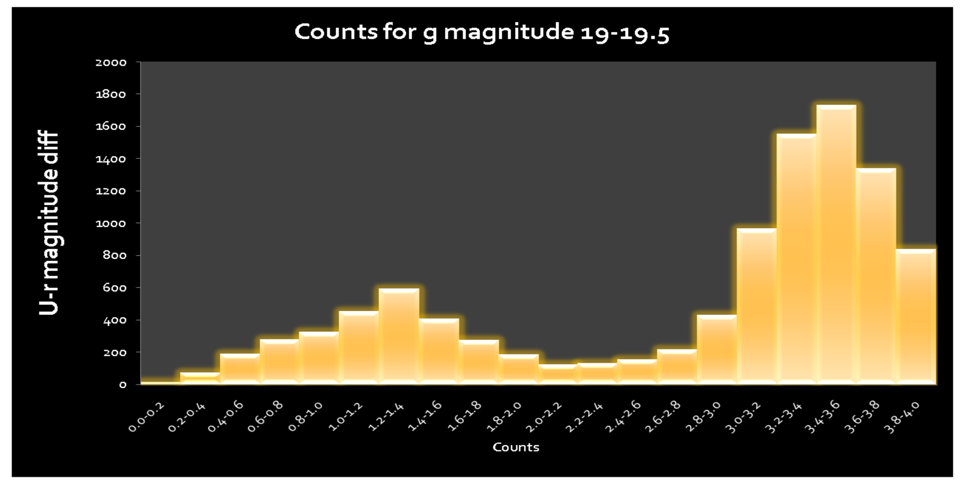
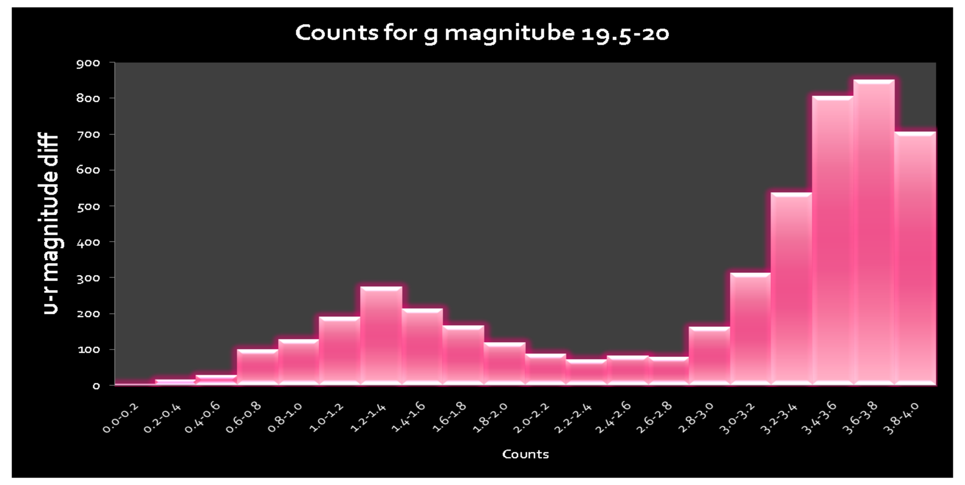


Figure 1. Galaxies in the left section are blue and galaxies in the right are red. The less dense area near the center (u-r around 2.2) is called the "Green Valley."

Looking for Merged/Merging Galaxies

The bar graphs (histograms) below show how many galaxies there are in selected ranges (bins) of u-r magnitudes for two ranges of g-magnitudes (19-19.5 and 19.5-20). The purpose of these histograms is to find the "Green Valley," where neither blue nor red galaxies are dominant in the spectra. If you look at the histograms below, you can see that the minimum occurs at u-r=2.2, and defines the "Green Valley."



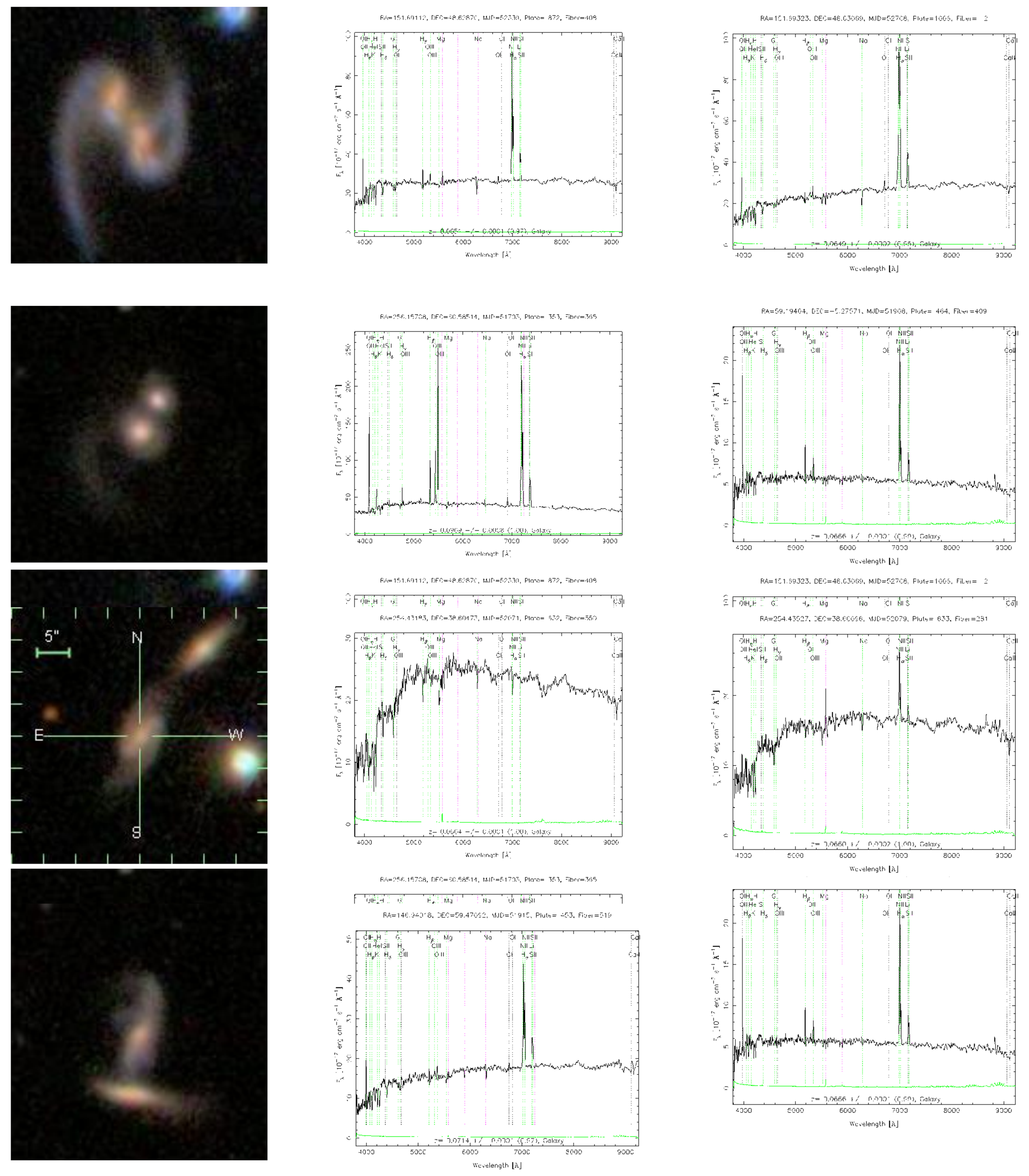


Search

Using the SQL searches we extracted the coordinates (right ascension and declination) of over 2500 objects, and used the SDSS DR7 Image list tool to examine the images of the galaxies from SDSS. Our hope was to find two galaxies in a single image that might be close to merging. Our search involved certain ranges of the g magnitude of the galaxies and their position in the "Green Valley". To determine whether two galaxies were merging we obtained the redshift of each galaxy from its spectrum and examined their color. If the redshift of the two galaxies was the same, that meant that they were at the same distance from us. Finally we looked at angular separation of the two galaxies, to determine whether they were close enough to each other to interact gravitationally. If our two galaxies satisfied these conditions we can be pretty sure that they were merging.

Results

Below are images and their associated spectra, where available, of galaxies we found in the "Green Valley" and determined to be merging.



Conclusion

We have studied over 2500 galaxies, and explored the "Green Valley" to see if we can see the process of merging of galaxies. We have found 4 mergers using a simple technique and have only explored a small subset of galaxies, based on the color index u-r and the g magnitude. In reality there are many more mergers, and we discuss possible improvements in the next section.

Further Research

During our search, we found several interesting objects such as the one pictured here (which might be a merger), that are worthy of further study, perhaps as a Science Fair Project. Also, we used a fairly simple SQL search. In order to find many more mergers we could implicitly search for objects that were separated by less than the size of a typical galaxy.

Acknowledgements

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