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Astro 98: Python Decal

Astron 98 Final Project: Analyzing the Faber-Jackson Relationship in the form of the fundamental Plane

1. Introduction:

In this project proposal, I analyze the distribution of elliptical galaxies using the Faber-Jackson Relationship. This project involved the use of data analysis, data filtering, and explanations for what the model fit means.

2. Phenomenon And Data:

The chosen phenomenon for this project is the distribution of elliptical galaxies, and their three major components, surface brightness, velocity dispersion, and their effective radius (Half-Light Radius). This data set contains more information about these galaxies, but these are the three I will use for this project. This paper which contained the data set can be accessed, from [The SAO/NASA Astrophysics Data System] (https://ui.adsabs.harvard.edu/abs/2003AJ....125.1817B/abstract). And the actual data set that was used in the paper can be accessed from [SDSS Early-Type Galaxies Catalog] (https://cdsarc.cds.unistra.fr/viz-bin/cat/J/AJ/125/1817#/browse). From this paper I was able to download two table sets, which contained data from hundreds of elliptical galaxies.

3. Equation to Fit Data:

The equation of choice that fit the data set best after careful observation was a linear model. It was the best model that fit all the data plots. This was achieved using the python package "Polyfit". In my proposal I highlighted the use of "Corrective Equations," which were going to be used to find all data from only certain data. Since I was able to find all the data, these equations no longer proved to be necessary, hence they were not used.

4. Data Filtering:

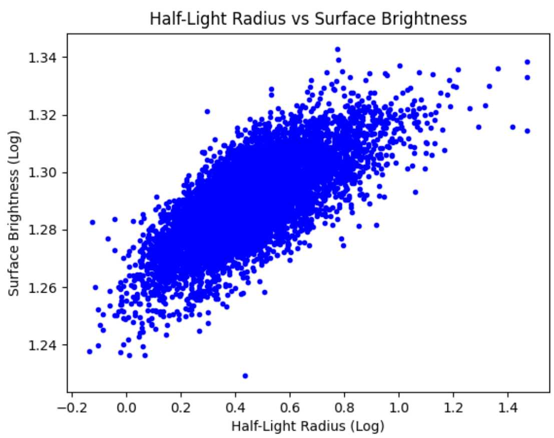
To ensure proper quality data, I applied a filter to the data.

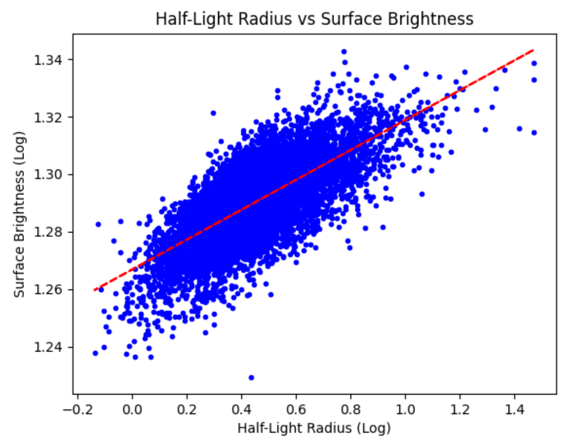
a. Duplicate Data: In order to ensure no duplicate data, and for the graph to come out unaffected, I applied this filter before graphing.

b. Outliers: Throughout the process of graphing, I noticed that there were not many outliers if in fact any that did not fit the data, so this filter I saw was not necessary.

5. Data Plotting and Fitting:

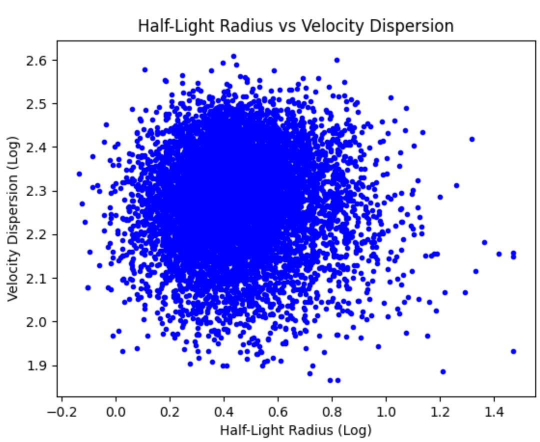
Surface Brightness vs. Half Light Radius:

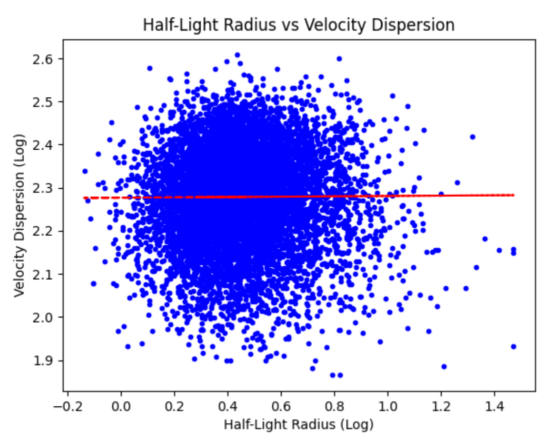




Here we have the relationship between the half-light radius and the surface brightness, and as we can see when applying a model fit, we see the relationship between these two variables are linear and are concentrated around a Half-Light (Log) = .5 and a Surface Brightness (Log) = 1.29. The explanation will come in the next part as to what this means.

Half-Light Radius vs. Velocity Dispersion:





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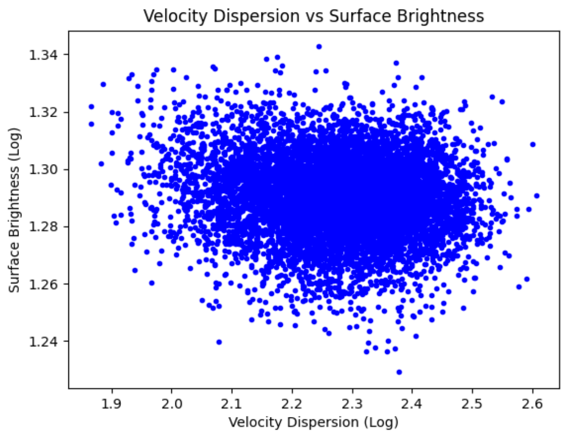
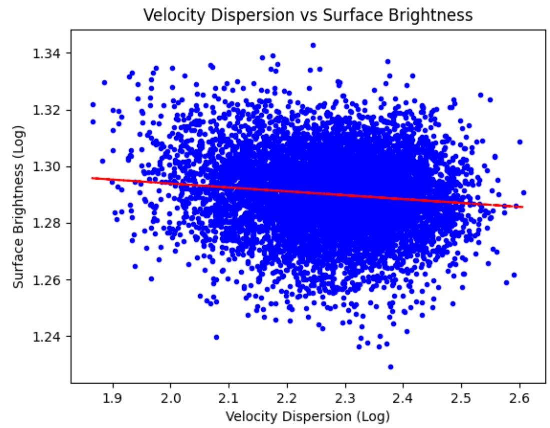
These next two graphs show the relationship between the half-light radius and the velocity dispersion. When applying a model fit, we see the relationship is like the previous graph but instead of being linearly upward it is linearly flat. With the concentration being in the center of the giant circle. More on that later.

Velocity Dispersion vs Surface Brightness:





The final two graphs before moving on to the fundamental plane are that of velocity dispersion and surface brightness. Shown to have a linear fit, but this time being a negative slope. Again, the graph has a concentration towards the middle of the image, showing the relationship between the two variables.

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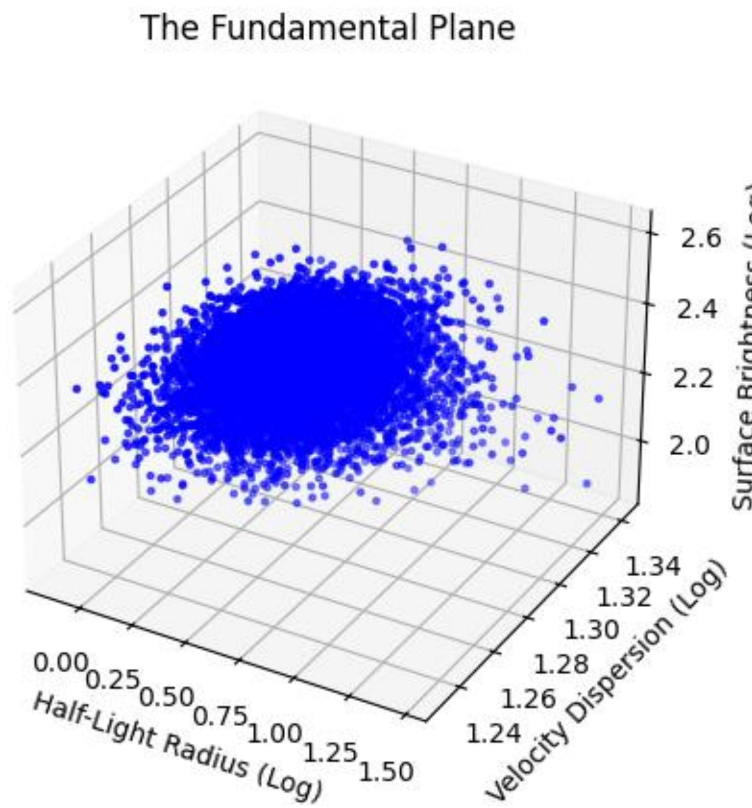
The Fundamental Plane:



Lastly, we arrive at the combination of all the variables, and what the Faber-Jackson relationship shows the fundamental plane. The picture does not do it justice, but I will describe it to you. When rotating the picture, we see that it has a crescent shape, with the direction of the crescent point linearly downwards, like a negative slope.

6. Explanation of Model and Fit:

Now onto what the data means, we will start with the first graph. The relationship between surface brightness and the half-light radius shows that the bigger the elliptical galaxies the brighter they are going to be. Most elliptical galaxies fall in the HL = .5, but the bigger galaxies or the result of galaxy mergers which give you massive elliptical galaxies contain an overall greater surface brightness. Similarly, in a couple billion years when the andromeda galaxy collides with us, it will result in a massive elliptical galaxy, like the galaxies on the far right of the graph.

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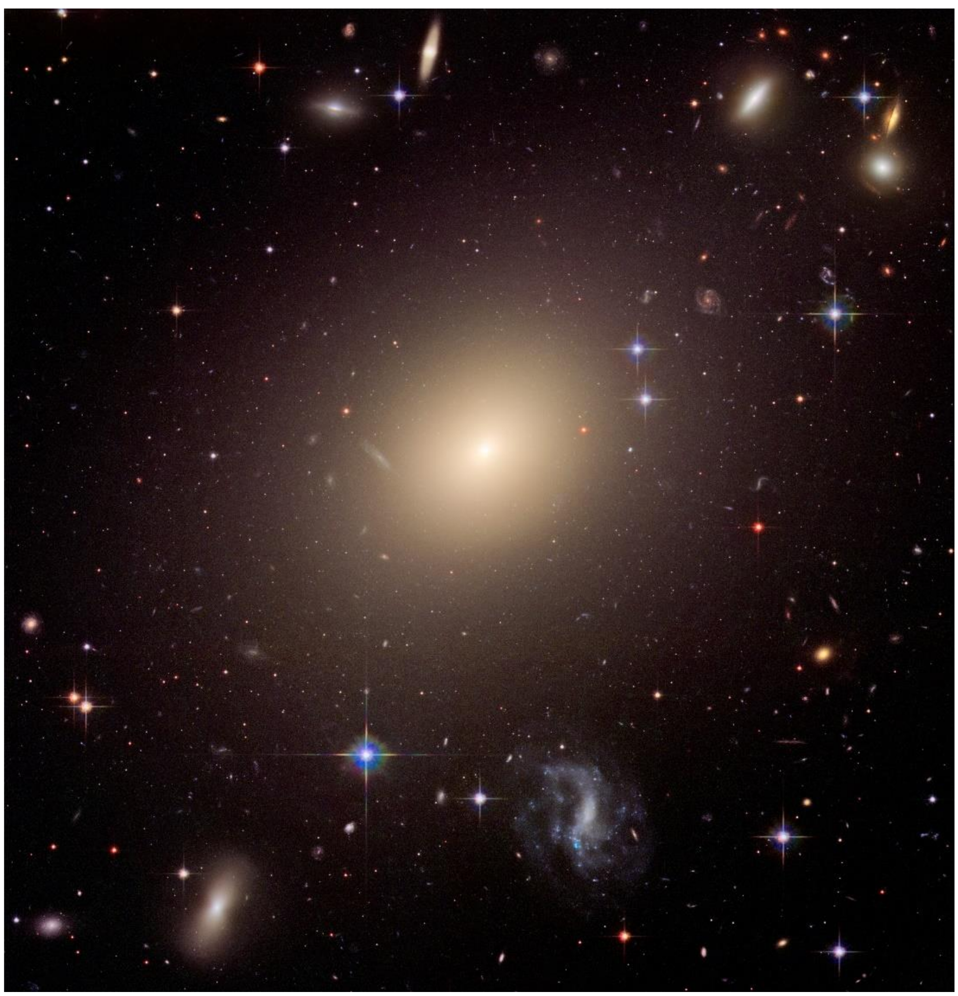
Moving forward, we now examine the relationship between the half-light radius and the velocity dispersion of the elliptical galaxies. This results in what is known as the Faber-Jackson relationship which states that larger galaxies tend to have larger velocity dispersions. This means that the stars within larger galaxies typically have higher average kinetic energies, indicating a more massive and dynamically hot system. The same being true for the opposite case of smaller ellipticals.

We then arrive at velocity dispersion and surface brightness. As seen by the plot, we observe a relation with galaxies of higher velocities displaying higher surface brightnesses. This special relationship is known as the Faber-Jackson-Tully relationship. The graph implies that the more massive and the same can be true for smaller ones, that elliptical galaxies have far more concentrated light distributions, such as in their center. With much of the light being emitted from it. The image below is a real elliptical galaxy which shows where the concentration of light can occur.



Lastly, we arrive at what the fundamental plane shows. It essentially states that elliptical galaxies are not randomly distributed in their properties but are tightly constrained to lie on a plane in this 3-dimensional space. In other words, knowing one or two of the three properties discussed, we can measure or calculate the other properties with high accuracy. This relation arises due to the balancing act between gravitational forces and pressure forces. This relationship allows astronomers to learn more about the evolution of these galaxies and how they came to be.

7. Conclusion:

In summary, the fundamental plane and the Faber-Jackson relationship has implications for our understanding of galaxy formation and evolution. Also, interactions between galaxies and their environment can influence where they lie on the fundamental plane and can have huge impacts on the galaxies themselves. The fundamental plane also provides constraints on the evolutionary paths of elliptical galaxies. By understanding how galaxies move within this parameter space over cosmic time, astronomers can infer the dominant mechanisms driving their evolution. For example, the evolution of galaxies along the fundamental plane can shed light on the relative importance of mergers, gas accretion, star formation, and feedback processes at different epochs in the universe's history. Overall, the project not only delves into the fascinating area of research of galaxies, but also demonstrates the application of statistical and data analysis to uncover patterns and to solve mysteries about these elliptical galaxies, that will allow us to understand more of the universe as we know it.