AST425-Mid Term Report: Internal Kinematics of Galaxies in Relation to their Morphological Evolution Using the MaNGA Survey

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1 Research Goal

The goal of this research project is to focus on the rapid transition period of galaxies when they go from SFGs (star-forming, younger galaxies) to QGs (quiescent, older galaxies). The main aim of this research will be to examine kinematic properties of GVGs (green valley galaxies) and compare them to those of SFGs and QGs galaxies. This is being done by using information from the MaNGA (Mapping Nearby Galaxies at APO (Apache Point Observatory)) survey which gives spectrographic data on galaxies. Unlike previous Sloan Digital Sky Survey (SDSS) surveys which obtained spectra only at the centers of target galaxies, MaNGA enables spectral measurements across the face of each of 10,000 nearby galaxies thanks to 17 simultaneous "integral field units" (IFUs), each composed of tightly-packed arrays of optical fibers[1]. I am working with 15^{th} data release of this survey[3]. The main parameters that I am currently comparing amongst these galaxies are their stellar velocities and the velocities of various ionized gases that give us information about the star forming going on within the galaxy. This comparison is being done using PCA (principal component analysis) on the individual pixel data that MaNGA allows us to have access to. The goal is to be able to find kinematic trends among galaxies of the same type (SFG, GVG, and QG), as well as kinematic trends that emerge during the transition phase. The hope is that these kinematic trends can tell us about the internal physics that leads to morphological change we observe in galaxies as they evolve. These trends can help explain why SFGs have spiral structures and why QGs have elliptical structures. The trends across the various types of galaxies can help explain the physical phenomena that are happening inside GVGs, and how such phenomena can lead to the morphological change we observe in SFGs versus QGs.

2 Research Progress To Date

2.1 Log SFR vs Log Mass Classification

The first thing that was accomplished thus far on the project was creating a log(SFR) vs log(M), with Hα flux as the depth parameter, using the MaNGA data. This was done in order to create a way to differentiate SFGs from QGs, following a method outlined in an astronomical survey [5]. A distinction line was drawn to separate the clusters visually as seen in Fig 1. Galaxies within a certain distance to the line were defined as GVG, anything above this was defined as SFGs and anything below was defined as QGs. This is illustrated in Fig 2.

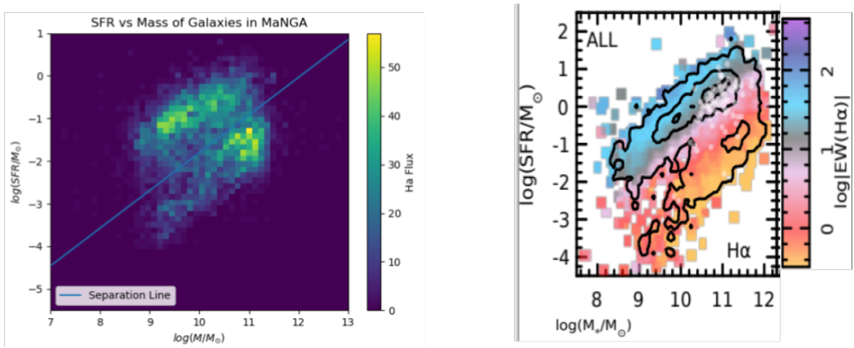

Figure 1: **Left**: My generated plot of SFR vs Mass using galaxy data from the MaNGA Survey. A distinction line is added visually to separate the two visually clear clusters. **Right**: A similar plot to the one on the left taken from an astronomical survey outlining the definition of the GVGs [5]

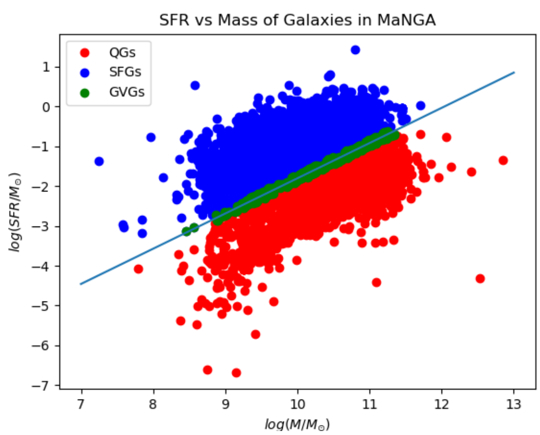

Figure 2: A 2D version of the plot on the left of Fig 1, where galaxies within a certain distance of the separation line have been defined as GVGs.

2.2 Clustering Algorithms

Since the classification above was rather rudimentary, we attempted to find a more concrete way to cluster the galaxies using Python-based clustering algorithms. Three algorithms were used: DB scan, K-Means, and Spectral Clustering. They all differed in exactly how they went about clustering data, so all three were tried out on the data to see how they performed. Of these DB scan was the most effective, but it turned out that the separation line method outlined in the previous subsection was still the most accurate as the clustering algorithms struggled to find clusters in the data where we wanted them.

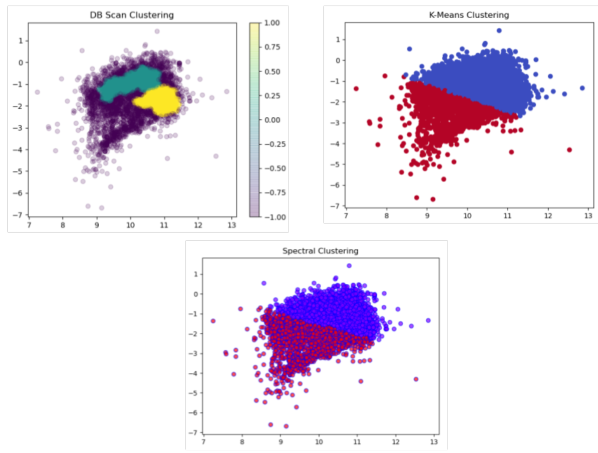

Figure 3: The three methods of clustering used

2.3 Gaussian Definition of GVG

In order to get a better definition for GVGs a classification method was adopted from a recent paper[4]. The process entails taking the data in Fig. 2, and binning the data into 5 bins based on mass and whether the galaxy is defined as SFG or QG. Then we construct normalized histograms of their $D_n(4000)$ spectra at 1 effective radius. These are then fitted with Gaussian. The point of intersection of the SFG and QG Gaussian in a given bin is taken as the mean of the GVG Gaussian and its standard deviation is taken to be half of the QG standard deviation.

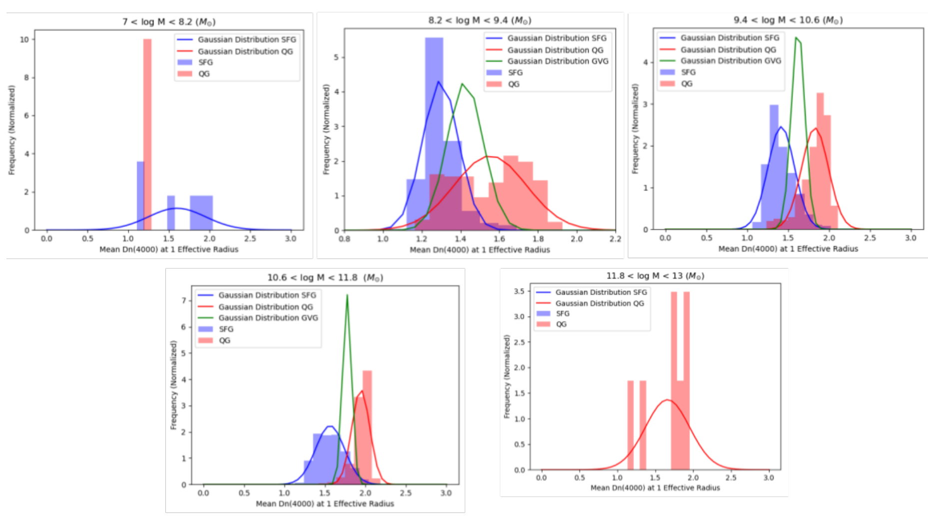

Figure 4: 677 of the 4901 (about 14%) of the galaxies in MaNGA were classified as GVG

2.4 Preliminary PCA Analysis

Some preliminary PCA work has been completed in the project thus far. A function was designed in Python with the use of the Marvin API[2] in order to extract the galaxy maps from MaNGA and apply PCA to them. So far 6 variables of a handful of GVGs have been tested on the PCA algorithm. Below is a PCA profile plot for one such galaxy. Along a given line of the same colour (same PC vector) variables with similar y-values are correlated to each other. Variables with vastly different y-values are anti-correlated to each other.

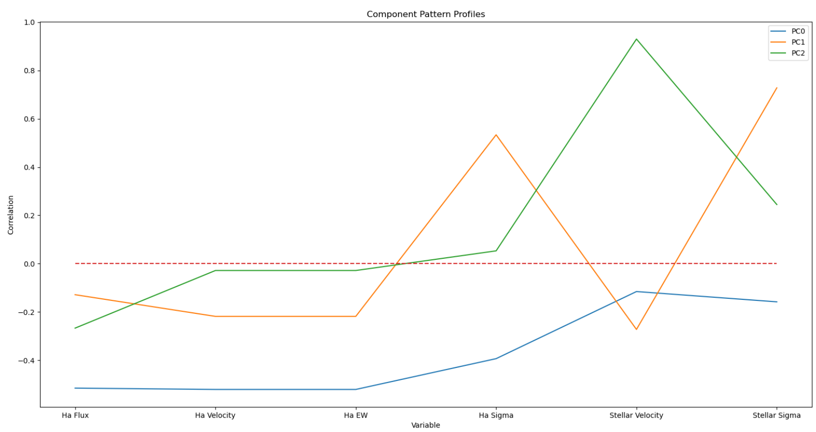

Figure 5: PCA Profile Plot for a GVG

3 Future Research Plan

From here, the goal is to expand this created PCA function (discussed in section 2.4). The immediate goals as of right now is to take the existing function and preform bootstrapping on it. This means basically running the same PCA multiple times and observing any changes in between different trials. This can give an idea of how much noise the actual process of PCA is generating and allow the PCA method to have error bars, i.e. a range of certainty we can have about results it finds. After that is established the goal is expand the function so that it can take various pixel maps from various galaxies and compare across them rather than taking all the pixel maps from the same galaxy every time. On top of this, I will also explore adding in non-pixel specific data of the galaxies (Mass, SFR, effective radius, etc) into a PCA with pixel maps and seeing if it yields any significant insights into the physical nature of the galaxies. Finally, one last avenue I will also be exploring is taking the PC vectors and changing them into the basis on the original pictures of the galaxies taken by MaNGA. This is to say plot the PC vectors accordingly (by doing a change of basis) on the picture of the galaxies and explore if this can give any visual insights to any observed kinematic trends. The most meaningful part of the project will come in trying to explain the trends that emerge during this phase of the project in terms of physical phenomenon and the laws that govern them.

References

[1] Mapping Nearby Galaxies at APO (MaNGA) https://www.sdss.org/surveys/manga/.

[2] Brian Cherinka, Brett H. Andrews, José Sánchez-Gallego, Joel Brownstein, María Argudo-Fernández, Michael Blanton, Kevin Bundy, Amy Jones, Karen Masters, David R. Law, Kate Rowlands, Anne-Marie Weijmans, Kyle Westfall, and Renbin Yan. Marvin: A Tool Kit for Streamlined Access and Visualization of the SDSS-IV MaNGA Data Set. , 158(2):74, Aug 2019.

[3] D. S. Aguado et al. The Fifteenth Data Release of the Sloan Digital Sky Surveys: First Release of MaNGA-derived Quantities, Data Visualization Tools, and Stellar Library. *The Astrophysical Journal*, 240, 2019.

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