Spectroscopy of Very Isolated S0 Galaxies

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I. Introduction

The goal of this project is to examine the spectra of a sample of very isolated S0 galaxies by studying the spectroscopic features that distinguish S0 galaxies from other early-type galaxies. As the theory of the formation and evolution of these types of galaxies is still developing, the observational study of S0 galaxies is essential to increase our knowledge of the behavior of these galaxies. Morphologically, lenticular galaxies exhibit features found in both elliptical and spiral galaxies. Similarly to spirals, S0 galaxies consist of a central bulge surrounded by an extended disk, but like elliptical galaxies, they do not possess any spiral structure. In the DeVaucouleurs galaxy classification system, lenticular S0 galaxies have a morphological type *T* ranging from -3 to -1. This corresponds to a velocity dispersion of the stellar population ranging from ~50 km s^{-1} to ~400 km s^{-1}, which a high concentration of galaxies displaying a ~200 km s^{-1} dispersion (McElroy 1995). One of the most important characteristics of S0 galaxies is that they are not actively forming new stars. Spectroscopically, this translates into an absence of emission lines in the spectrum of a lenticular galaxy. Consequently, the spectroscopic analysis of S0 galaxies focuses on the identification and study of absorption line features.

The heart of this project is the measurement of Lick/IDS absorption line indices, which measure the equivalent widths of specific absorption features. As presented in a paper by Trager et al. (1998), Lick indices can be partitioned into three groups, identified by their respective correlation to the velocity dispersion of the galaxy. A group of indices that possess a strong positive correlation to velocity dispersion, such as Mg, Na D, CN, and TiO_2 are considered α-element-like indices. The Fe-like indices, including all Fe lines, G band, Ca, and TiO, are weakly correlated to velocity dispersion. Finally, the Hβ index is strongly anti-correlated to both velocity dispersion and, by association, the α-element indices. The major scientific significance of Lick indices is that they can be used to describe relative chemical abundances and metallicities within a galaxy. This information is integral to the estimation of the age of the stellar population of a galaxy.

Lenticular galaxies are found in a variety of environments: while the sample we studied consisted of only very isolated galaxies, S0 galaxies are also found in fields and compact groups. This is a point of great interest for data analysis, because it is fruitful both to make comparisons internal to the data sample and to compare the sample as a whole to a study of lenticular galaxies found in a different environment.

II. Data Reduction

The reduction of our sample of spectra was the main focus of our work this summer. The spectral data was reduced from raw data using standard IRAF packages. Our sample consisted of 19 galaxies imaged with the McDonald Observatory 2.1m telescope using the ES2 spectrograph and 21 galaxies imaged with the McDonald Observatory 2.7m telescope using the IGI spectrograph. The IGI data sample was taken by a previous REU group, while most of the ES2 data was taken by Dr. Odewahn prior to our arrival and more data was collected at the beginning of our REU program. The data was reduced simultaneously and independently by both students, which proved to be an excellent check for errors during the data processing and reduction. Upon examination of the raw images, we decided that the only processing necessary for the images was overscan removal, trimming and flat fielding. Before we flat fielded the images, we created a master flat that was normalized according to the response curve of the instrument. After processing the raw images, we extracted a one-dimensional spectrum from the two-dimensional image by taking a cut perpendicular to the dispersion axis of the CCD image and extracting the aperture of the galaxy spectrum. Arc lamps were used to create a wavelength solution for the spectra, which allowed us to convert pixel values to wavelength in units of Angstroms. Flux standard stars were used to flux calibrate the spectra, which allowed us to convert from ADU to flux units of erg s^{-1} cm^{-2} $Å^{-1}$. Since we had multiple exposures of each galaxy, the final step of our reduction was to combine all of the reduced spectra for each galaxy, which increased the signal to noise ratio of the galaxy spectrum.

Once the reduction process was complete, examination of the spectra samples caused us to notice that, on the whole, the data from the IGI sample suffered from too many defects to render itself useful to our project. The blue and red ends of the CCD chip had very poor response, and as a result these parts of our spectra were dominated by noise. We also found that these spectra showed consistently low levels of flux, which propagated into very small absorption line features. We found that we were unable to identify the Lick indices with a sufficient degree of confidence, and decided it would be conservative to reject these spectra from our sample.

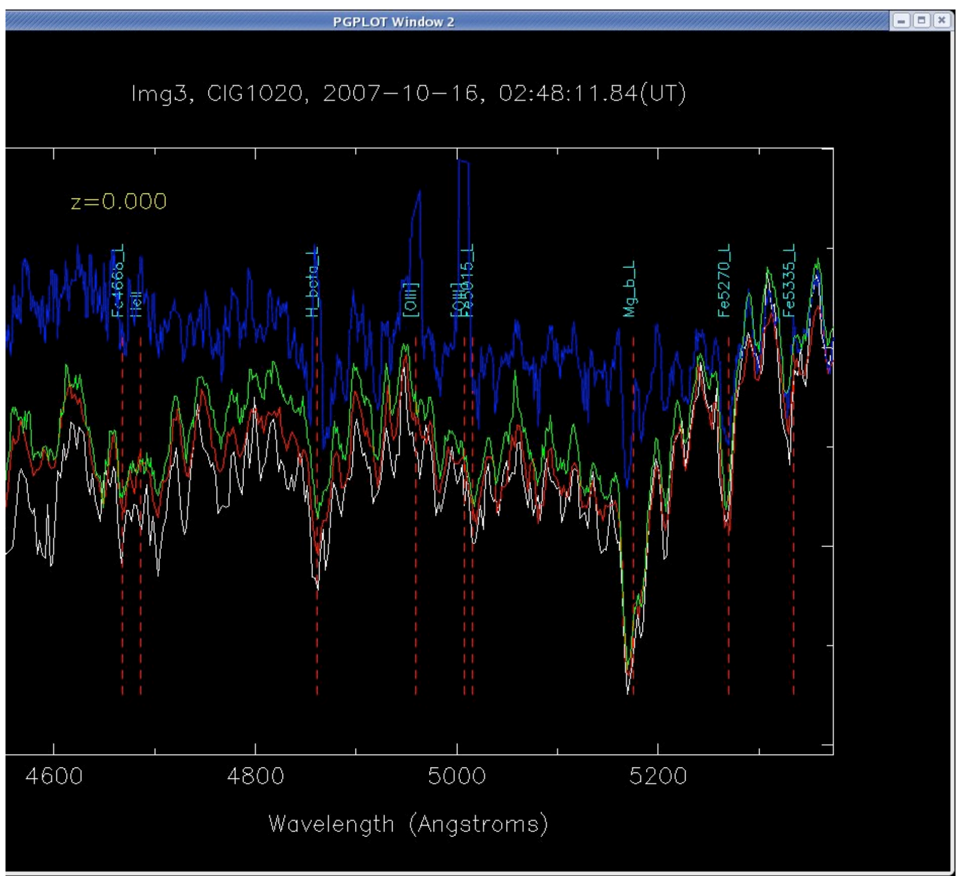
III. Data Analysis

Data analysis was performed primarily through the use of SPECTRA, a FORTRAN code written by Dr. Odewahn, and EZ AGES, a publicly available IDL code created by Genevieve Graves of UC Santa Cruz. SPECTRA was used to identify spectral lines and calculate redshifts for each of the galaxies. The measurement of redshifts for these galaxies served two purposes. First, we were able to check our measured redshifts against previously published redshifts available through NED. A linear regression plot shows that our redshift measurements agree with published redshifts within error margins. Our derived redshifts were then used to shift our spectra to vacuum wavelength in order to run the spectra through EZ Ages.

Our first task while using the EZ Ages code was to run our reduced spectra through a sub-program, Lick_EW, which computes the equivalent width of each Lick index found in the galaxy spectrum. We then used the resolution of our CCD chip to transform the line strength values for all of our Lick standard stars to the values given by Worthey et al. (1994) to test the validity of our results. One complication to our data analysis is that velocity dispersions have not yet been published for these galaxies, and so we tested several standard values for galactic velocity dispersion of 180 to 200 km s^{-1} by running the code for different dispersion values and looking for changes in the line strengths. During this process, we were careful to differentiate between the different categories of Lick indices, as the Fe-like indices show almost no dependence on velocity dispersion.

Once we verified our results from Lick_EW, we used the Lick line strengths as input to the program EZ Ages, which outputs a best fit age for the galaxy and relative chemical abundances including [Fe/H], [α/Fe], [Mg/Fe], [C/Fe], [N/Fe], and [Ca/Fe]. Our work with EZ Ages is an ongoing process: we are communicating regularly with Graves as we work out the computational details of the program, as it is crucial that we understand the code implicitly before we can establish confidence in its output. Our goal with regards to this program is to obtain publishable values for the ages and metallicities of our galaxies which we intend to use as a point of comparison against of samples of lenticular galaxies.

We were able to compare our results to data on S0 galaxies collected by Rolf Jansen et al. (2000) for the Nearby Field Galaxy Survey which focused on the study of field galaxies, without discriminating with regards to morphological type. We found that both samples of S0 galaxies had similar spectral energy distributions (SED), but we found that the lower luminosity galaxies presented by Jansen showed Hβ, OIII λ4960 and OIII λ5007 emission lines that are indicative of ongoing star formation. Our data sample, which consists solely of high luminosity galaxies ranging from -21 to -18 in absolute magnitude, does not show any such spectral features. This is an exciting preliminary discovery, because our findings may help to differentiate between the fundamental properties of field and very isolated S0 galaxies. This graph shows a comparison plot zoomed in around the Mgb line, which shows a sample of low luminosity (greater than -18 magnitude) NFGS galaxies plotted over a mean CIG spectrum and NFGS high luminosity galaxies (less than -18 magnitude). The low luminosity NFGS galaxies exhibit Hβ, and OIII lines in emission, while none of these features are visible in the high luminosity spectra.



IV. Conclusions

As our work on this project is not yet complete, we plan to continue our collaboration with Dr. Odewahn during the year. After we complete our work in spectroscopy, we will also work with a sample of BVR images for these same S0 galaxies taken on the 0.8m telescope Prime Focus Camera at Mc Donald Observatory. We intend to use these images for surface photometry and morphology, which we will analyze in conjunction with the spectra. We endeavor to find correlations between such parameters as absolute magnitude and concentration index and the features in the spectra, which will help us to draw observationally substantiated conclusions about the fundamental properties of S0 galaxies.

References

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