Quasar Characteristics and the Effects of Double-peaked Emission Lines

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Introduction: Quasars are very luminous and distant objects at the center of galaxies that emit large amounts of energy and are powered by supermassive black holes. We identify these by their distinctly high redshift. Observatories can detect quasars by recording the radiation that is emitted. Researchers analyze this information by focusing on the observable emission lines on the spectra that correspond with a specific wavelength. The emission lines give information about the broad line region of the active galactic nucleus. The overall goal of this project was to identify quasars with asymmetric Magnesium-II ion emission lines. In order to do that, we intended to create a composite fit, which can help compare qualities of all the appropriate spectra available from the Sloan Digital Sky Survey. The raw spectra included power-law continua and iron emissions that tainted the picture. This project required us to isolate the Mg-II lines and create programs that will average and compile the best data.

Data Sample: The data used in this project was drawn from SDSS DR7. Groups have analyzed over 140 characteristics for the 105,783 quasars identified in this collection. Among these characteristics was power-law slope for the continuum near H-α, H-β, Mg-II, and C-IV. We took time to analyze the patterns imbedded in these slopes. Power-law slopes are important when comparing different spectra. When one quasar has a redshift of 1 and another has a redshift of 3, astronomers can use the average power-law to standardize the spectra. Quasars can have a wide variety of redshifts, so we had to make a few assumptions about their shape, average value, and range.

For the purpose of analyzing asymmetric Mg-II lines, we used a parent sample of 40,000 quasars for which Mg-II was accessible between 3200Å and 9100Å, which was the range converted by SDSS filters for redshift. The original spectra were corrected for redshift, using the following relationship:

$$\lambda_r = \frac{\lambda_{obs}}{1+z} \quad (1)$$

This is true when λ_r is the rest wavelength, λ_{obs} is the observed wavelength, and z is redshift. Then, we fit a power-law continuum and Fe-II emission line template to each spectrum in order to subtract the unnecessary points. This left the residual spectra and a clear perspective of the Mg-II emission line. Next, we standardized these spectra at a common wavelength. The spectra were normalized using the flux value that corresponded with 3000Å, using the following equation:

$$F = k\lambda^{-\alpha} \quad (2)$$

where F is flux, k is the normalization constant, lambda is wavelength, and alpha is the power-law slope. This allowed us to determine the average of all the flux values. In some cases, the template had over-subtracted from the continuum, so we had to eliminate those spectra. After executing all those steps to narrow down the sample, we had a composite established to perform several other comparisons and calculations.

Results: We did several comparisons of the power-law slopes. Ultimately we came up with the following figure:

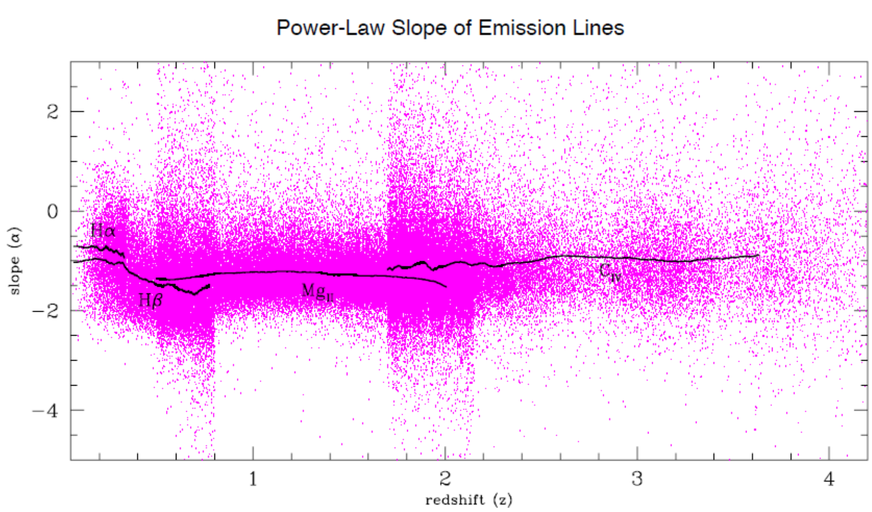

Figure 1: Power-Law Slope versus Redshift for H-α, H-β, Mg-II, and C-IV
We took time to analyze the patterns imbedded in these slopes. The data had caps at α=3 and -5, so we eliminated those values. Additionally the points at very high or low redshifts for each ion contributed to the error. We calculated running averages over 50, 100, 300, 500, 1000, and 2000 objects for each emission line. Ultimately, the typical values are between α=0 and α=-2.

which shows three main features. First, and foremost, the average slope is not -0.5, despite the common agreement that it is the average. Among these four lines, the average appears to be closer to -1. Second, the averages are not entirely constant. What would cause the change from lower redshifts to higher ones? And third, the averages are not continuous between ions. This makes one wonder what kind of evolution is occurring.

As for the Mg-II emission line analysis, it was an accomplishment to create a composite capable of cross-correlations. We are currently working on the program to cross-correlate the composite with individual spectra. When that is ready, we can make graphs that compare the change in wavelength to the linear least squares best fit. This form of error calculation relies on the following equation:

$$Error = \left(\frac{observed}{model}\right)^2 \quad (3)$$

For the graphs we would look at, the numbers are inverted so a peak indicates the best fit. These numbers work together to identify the point where the model is closest to reality. The following figure illustrates the different components of a given spectrum and how they are subtracted to produce the most accurate image.

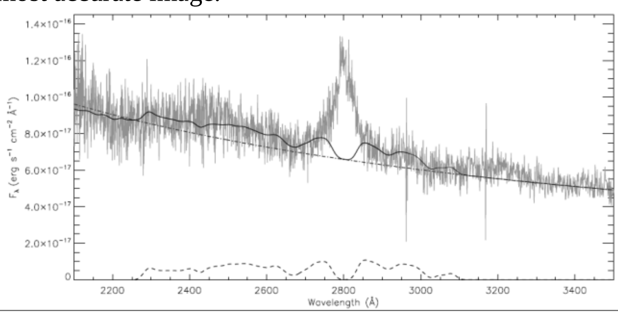

Figure 2: Wavelength versus Flux
Green is the Fe-II emission template, blue is the power-law slope, and red is the sum of those components

The cross-correlations we hope to perform in the future will amplify the peaks. However, if there were a double peak in the emission line, the peak would be wider and not as high. This is the asymmetry we are looking for.

Discussion: There have been several previous studies that also looked at the significance and prevalence of asymmetric emission lines. The double peaks can give information on the structure of the accretion disk around a black hole. It is a potential indicator of emissions directly from the accretion disk as opposed to the surrounding broad line region.

We are interested in the characteristics of these quasars because they give us a peek into the past. The information we are gathering today is billions of years old, but it is helping researchers better hypothesize the current state of the universe. What was happening back then to produce so many bright quasars? What has changed since then? Why aren't there active galactic nuclei nearby? What role does location play in galaxy evolution?

Conclusion: Before this program started, graduate students within the Arkansas Galaxy Evolution Survey office were manipulating the quasar data from SDSS DR7 and becoming familiar with its features. In the past ten weeks, the group has accomplished many things. The quasar catalog allowed us to compare numerous features against each other and look for trends. Ultimately, we focused on the redshift and power-law slope for the four emission lines available. A running average of these plots illuminated the fact that the slope is closer to -1, not the commonly assumed -0.5. Also, we saw variance in the trend line, which indicates some kind of evolution or change dependent on redshift and distance.

Additionally, a lot of time was spent improving the data set for the Mg-II spectra. We took note of which images were not fitting the expected trend and adjusted the programs accordingly. When we had a satisfactory sample, we managed to average the flux values and create a composite that will be used for several cross-correlations and other analysis.

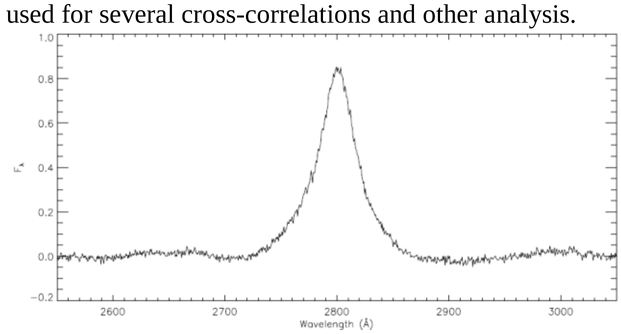

Figure 3: Wavelength versus Flux
This composite will be used to determine the most accurate cross-correlations for the Mg-II spectra.

The ultimate goal is to gain insight into the behavior and structure of accretion disks at the center of galaxies. This group wants to see how accurately they can fit a model of the emission line to actual spectra.

References:
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