

MgII and CIII] in Active Galactic Nuclei

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ABSTRACT

This project was aimed at determining the velocity of two component chemicals, MgII and CIII], in the winds associated with active galactic nuclei (AGNs). We classified objects based on a thorough examination of spectra of AGNs in the region centered on 07 hours of Right Ascension. Focusing on the MgII and CIII] emission lines in the identified quasars, we were able to calculate the redshift, relative velocity, and distance of each element. We are confident that our MgII and CIII] lines are correctly identified: Earth's atmosphere cannot produce CIII] or MgII lines, and our MgII lines were consistent through multiple checks, and were found at predictable wavelengths. Furthermore, since the lines are redshifted, there is no concern of them being misidentified. MgII has lost an outer electron shell, while CIII] has lost an inner electron which takes more energy to pull away. MgII is farther away from the black hole than CIII], thus it is colder and has a slower velocity. We assumed that the MgII velocity was the quasar's velocity and the CIII] velocity was the velocity of the wind. The wind velocity was faster than the actual velocity of the quasar. Our research showed results in the quasars with MgII and CIII] lines that were similar throughout all of our data and demonstrated that there is an indirect relationship between distance from the central black hole and wind velocity.

INTRODUCTION

An Active Galactic Nucleus (AGN) is all of matter that surrounds a supermassive black hole. These galactic giants of the Universe are mostly unknown. There are four different types of AGNs, each with different characteristics. Radio Galaxies are galaxies that appear as normal galaxies in the optical spectrum, but they emit massive amounts of radio waves (*1*). Starburst galaxies are known for forming stars at a very fast rate. Many times this is caused by a gravitational interaction with another galaxy. *BL Lacertae* objects are known for having very weak emission lines, unlike quasars or radio galaxies. Spiral galaxies are the oldest type of galaxy; they consist of about a hundred billion stars, which are formed in HII regions and have characteristic arms that spiral out of the center. For our study, we will disregard the spectra for radio, starburst and *BL Lacertae* objects but focus on quasars.

Spectral emission lines can help to differentiate the different types of AGNs.

Spectroscopy allows us to study what types of light we see from an object; it is arguably the most important aspect of astronomy. Through spectroscopy we can determine the temperature, velocity, and composition of the object being examined. In terms of velocity, spectroscopy can be used to determine an object's velocity toward or away from us via the Doppler effect. Without spectroscopy, it would be very hard, if not impossible for astronomers to tell what all of the lights in the sky are.

Figure 1. Visible spectrum of Sky with spectroscopy. (1)



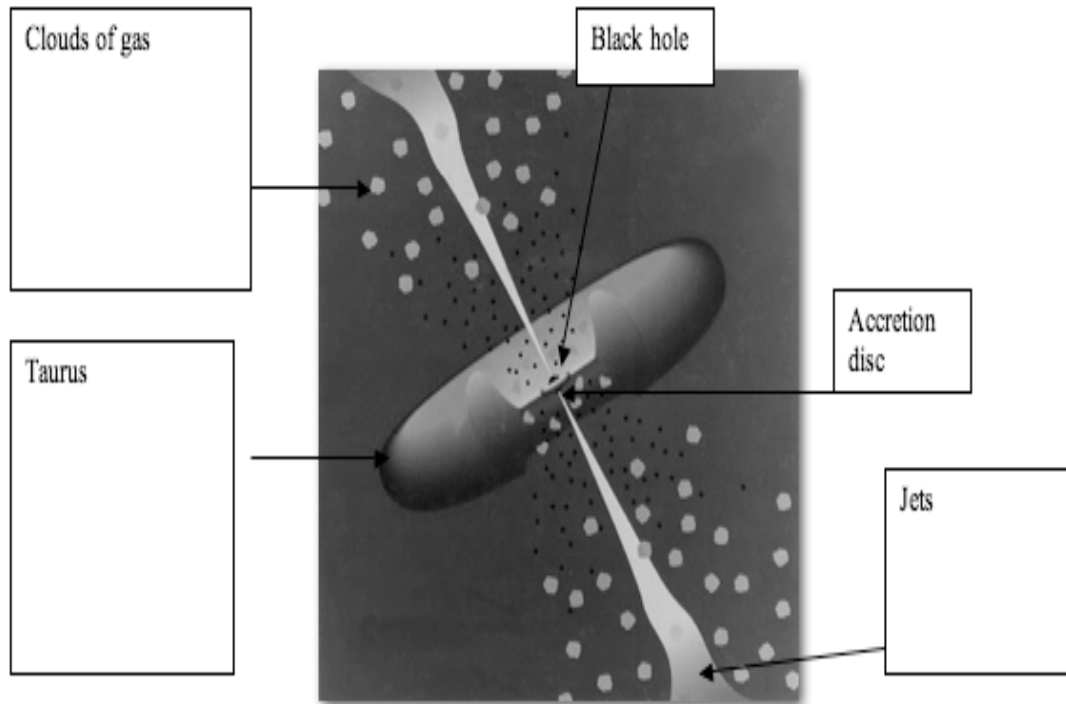
To find the shift of an object, the equation $\lambda_{obs} = (1 + z)\lambda_{rest}$ is used, where λ_{obs} is the observed wavelength, and z is the redshift of the object. If z is positive, then there is a redshift, and if z is negative, a blueshift. A redshift is seen when the object is moving away from us in the Universe, and a blueshift is seen when something is moving toward us in the Universe. Galaxies that are very far away move much faster than those that are close to our galaxy. For nearby objects, Hubble's Law, $v = H_0 d$, where v is the object's velocity, $H_0 = 75 \text{ km/s/Mpc}$ (the Hubble constant) and d is the distance, is used to determine the distance of an AGN. The objects in our study are so distant that a more advanced model, such as the "empty Universe" model needs to be used to calculate distance which is important because it provides a third dimension to something that we can only see in two dimensions.

The winds that come off an AGN are crucial in determining the velocity of the AGN, and can be seen in Figure 2. There is some speculation of a connection between the winds, especially the CIII] and MgII. To find the velocity of that wind, the equation

$$v = c \frac{(1 + z)^2 - 1}{(1 + z)^2 + 1}$$

is used, where v is the velocity, and z is the redshift.

Figure 2. Diagram of a typical AGN. (2)



In our project, we examined AGNs specifically near Right Ascension 07 hours. The data we are using will be from the *FIRST Bright Quasar Survey* taken at the Very Large Array with the optical spectra obtained with the Kitt Peak 2.1-meter telescope. The *FIRST* Survey is an acronym for “Faint mages of the Radio Sky at Twenty-centimeters”. Through the analysis of the quasar’s MgII and CIII] emission lines, we determined the quasar’s velocity, as shown in Figure 2. By analyzing the winds and where they occur, we were able to see what direction the AGN is moving in and other characteristics of that region of the sky. The velocity relates to the distance from the continuum source.

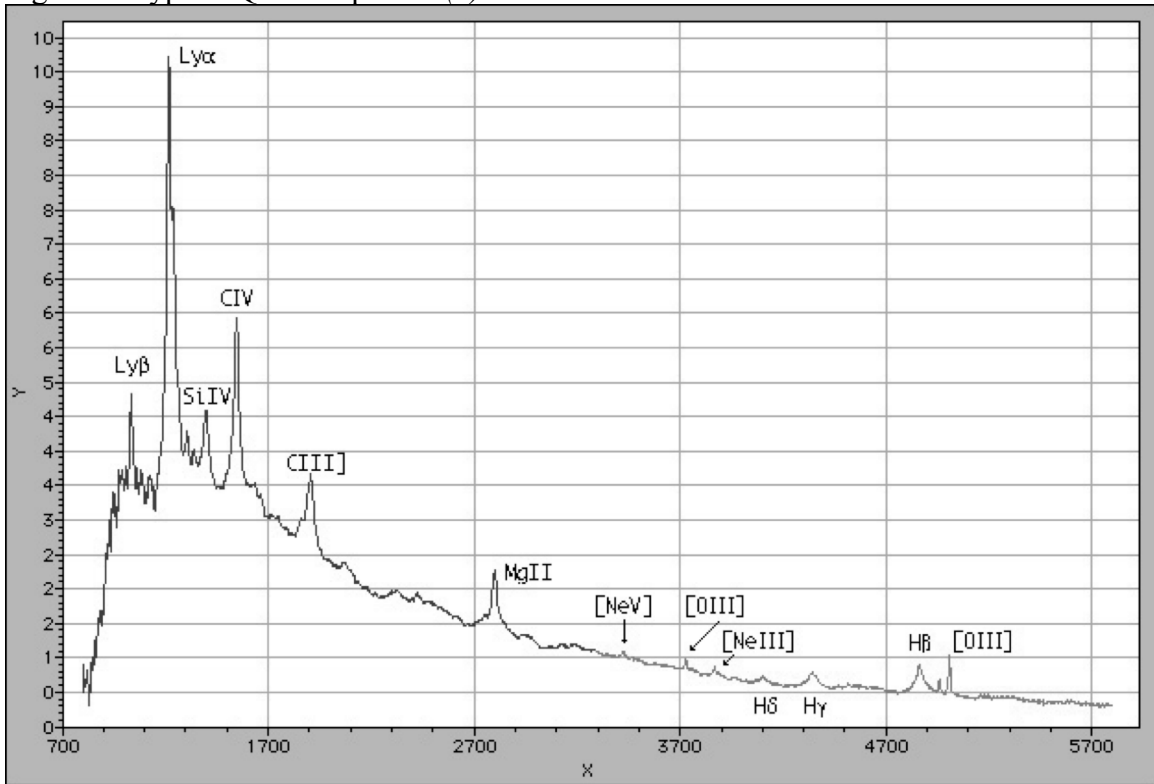
The difference in the velocities of the MgII and CIII] lines in the AGN spectrum indicate the velocity of the wind as the object is moving. MgII and CIII] lines don’t change based on high or low states of the spectrum, and both are fairly broad lines. In broad-line profiles, each velocity has a range of ionization, but there is a “preference for higher ionization at higher velocities” (4). Although MgII and CIII] are low-ionization and low-density atoms, CIII] is more highly ionized than MgII. High and low states of AGN cause ionization radii to expand or contract, and can be caused by changes in the continuum source radius or velocity. “Peaks in the emission-line profiles can be transient responses to variation of the continuum source. Averaging over time, there is equal flux from the blue and red sides of the profile, but the blue side is more likely to have a prominent narrow peak” (3). The terminal velocity of the wind is determined by the width of the emission lines and the ionization state.

High ionization lines are produced from an outflowing wind, while low ionization lines tend to come through a thick accretion disk. (3) Ionization increases as atomic radius

increases and the electron shells expand, thus increasing the velocity. Near the source of the emission, there is strong absorption and minimal velocity; however, for electron shells with an increasing radius, the width of the emission lines increase and absorption becomes weaker. “Velocity offset is largest for ions with the highest ionization” (3) because there is more obscuration, which is directly related to velocity (2, 3).

The quasars in our survey have a spectrum similar to that in Figure 3. (1) However, our spectra are not as clean as that shown due to the fact that it is a composite of over 100 quasars that have been averaged together. As illustrated, the CIII] and MgII lines stick out at distinct points and can be easily recognized. By determining the redshift or blueshift and its relation to the wind velocity of CIII] and MgII winds of some of the quasars in our region of the sky, we are hoping to be able to give more insight into the relatively unknown realm of AGNs.

Figure 3. Typical Quasar Spectra. (1)



ANALYSIS AND RESULTS

The purpose of our research was to determine how different elements, specifically MgII and CIII], and their distance from the black hole affects the velocity of their winds.

Energy from the accretion disks around the black hole in the center of the galaxy heats up the dust and galaxy, and creating emission lines that, if the galaxy is near enough we can see. The farther away from the black hole, the more slowly the clouds and dust move, and the colder they are. The torus circles the accretion disk, and is cold enough to see infrared radiation, however, it is too thick to see through, and can obscure the view.

Table 1. Redshift, Velocity and Distance.

location	MgII redshift	CIII] redshift	MgII velocity (km/s)	CIII] Velocity (km/s)	Relative Velocity	distance (Mpc)	Relative Distance (Mpc)
bq0713p3656	1.59	1.67	222159.806	226189.275	-4029.47	-8056938.3	8056938.27
bq0719p3307	1.37	1.63	209323.097	224212.76	-14889.66	-29777326	29777326.12
bq0721p2227	1.63	1.62	224212.76	223706.831	505.93	1013854.6	1013854.58
bq0722p2856	1.21	1.51	198030.285	217809.345	-19779.06	-39556120	39556120.04
bq0722p2941	1.2	1.79	197260.274	231694.767	-34434.49	-68866985	68866985.36
bq0724p2517	1.23	1.45	199546.284	214316.316	-14770.03	-29538063	29538062.97
bq0726p3019	1.29	1.05	203909.29	184670.831	19238.46	38478918	38478918
bq0733p4555.2	1.18	1.04	195695.71	183756.975	11938.74	23879470	23879469.9
bq0758p3222	1.2	1.21	197260.274	198030.285	-770.01	-1538019.5	1538019.465
bq0803p2727	1.2	1.22	197260.274	198792.254	-1531.98	-3061959.2	3061959.216
bq0809p4134	1.22	1.19	198792.254	196482.117	2310.14	4622273	4622273.03
bq0810p5025	1.19	1.2	196482.117	197260.274	-778.16	-1554310.8	1554310.8
bq0828p4922	1.53	1.49	218928.779	216667.824	2260.95	4523908.9	4523908.86
bq0835p4826	1.37	1.4	209323.097	211242.604	-1919.51	-3837012.2	3837012.221
bq0836p3455	1.39	1.46	210609.198	214912.928	-4303.73	-8605458	8605458.033
bq0846p2502	1.41	1.44	211869.685	213713.76	-1844.08	-3686149.2	3686149.192

In the region of the sky around 07 hours of Right Ascension, we examined 231 AGNs, 24% of which were quasars (see Figure 4. Classification of AGN). However, we disregarded spectra of quasars that did not meet our requirements of distinct MgII and CIII] emission lines. We are confident that the CIII] lines are from AGNs because Earth will never produce CIII] emission lines. Of the 231 spectra, we were able to successfully analyze 16 (7%) of the spectra (see Figure 5. Classification of AGN with MgII and CIII] Lines). Of these quasars, seven of the 16 (44%) had relative velocities within -5000 km/s to -1 km/s (see Figure 6. Histogram of Relative Velocities). This means that the quasar's wind is moving toward us at a relatively slow speed.

Figure 4. Classification of Selected AGN.

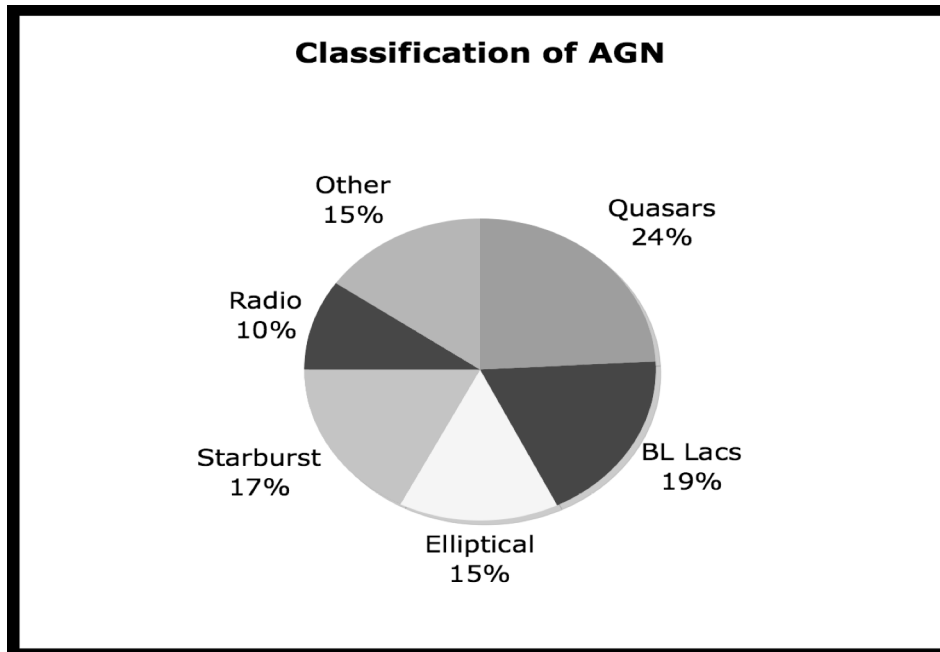


Figure 5. Classification of AGN with Distinct MgII and CIII] Emission Lines.

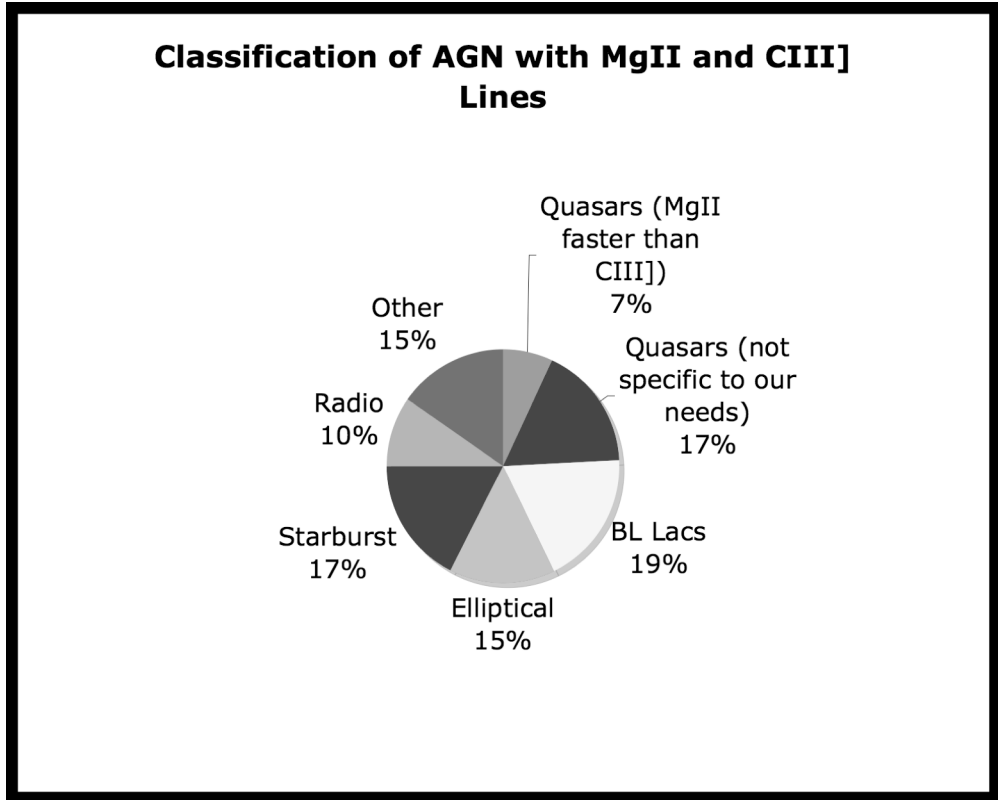
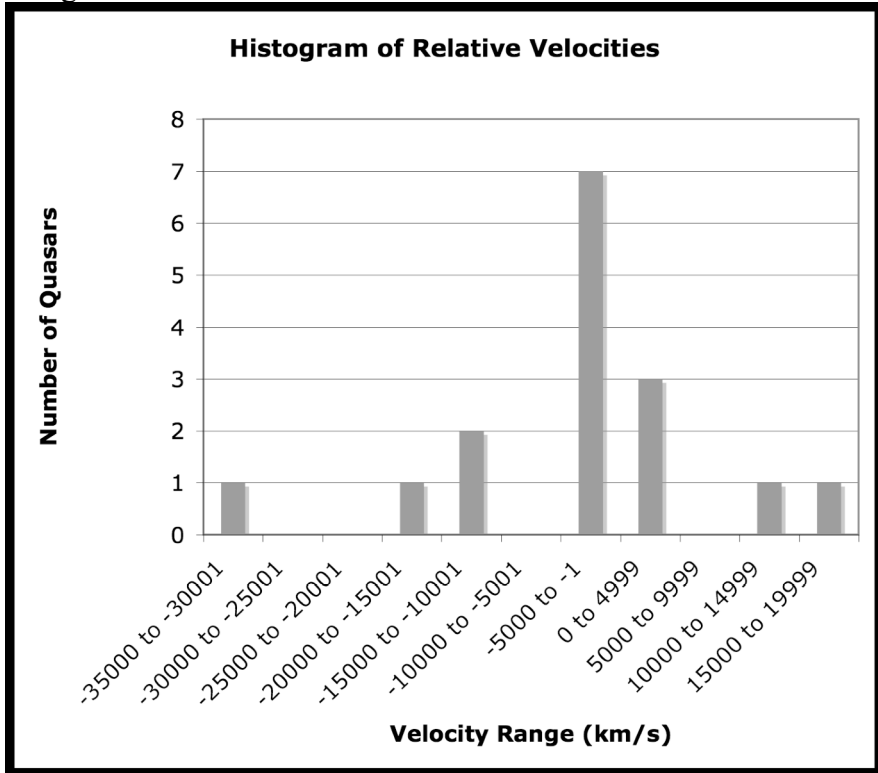


Figure 6. Histogram of Relative Velocities.



DISCUSSION

The ionization state of each atom affects its velocity and distance from the black hole. MgII, which is farther away from the black hole than CIII] has lost an outer shell electron. Because inner electrons take more energy to move, CIII] is a hotter gas, which results in its higher velocity than the MgII (see Table 1. Redshift, Velocity and Distance). From the positive velocities of the MgII and CIII] lines, we can determine that both the MgII and CIII] emission lines were redshifted and are in the part of the galaxy that is moving away from us. MgII is farther away from the black hole than CIII], therefore it also has a slower velocity. Due to this difference in distance, we assumed that the CIII] velocity is the velocity of the gas, while the MgII is the quasar velocity because of its large distance from the black hole.

Further projects could compare the MgII and CIII] lines with CIV emission lines, examining whether the CIV affects the MgII and CIII]. The difference between luminosity and distance could also be studied.

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