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# Crowdsourcing Broad Absorption Line Properties and Other Features of Quasar Outflow Using Zooniverse Citizen Science Project

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## Abstract

The Sloan Digital Sky Survey (SDSS) regularly publishes catalogs of quasars and other astronomical objects. Until the most recent catalog, which added 150,000 quasars that have never been seen before, spectra from quasars have been visually inspected by one or two members of the SDSS quasar working group. Quasars that show Broad Absorption Line (BAL) properties are indicative of outflowing gas from the quasar which are of great interest to researchers. Due to the number of quasars in the catalog, the BAL information in the new DR14 catalog was recorded entirely computationally and currently lacks flags for confirmed BAL quasars. These flags are helpful for researchers to easily select the quasars with BAL properties and study their outflows as well as objects between them and Earth such as invisible gas clouds and intervening galaxies. This project uses the Zooniverse citizen science platform to visually inspect quasar spectra for BAL properties to check the accuracy of the current pipeline code as well as properties of ionized gas from the quasar's accretion disk and find candidates for in-falling gas into the quasar central engine. Through this platform a number of quasars with BAL properties have already been detected as wrongly identified by the automated code as having no balnicity. The layout and format of a Zooniverse project provides an easier way to inspect and record data on each spectrum output and share the workload via crowdsourcing. Work done by the quasar group members will serve as a beta test for a public project upon the official release of the DR14 quasar catalog by SDSS.

## 1. Introduction

The term 'quasar' comes from the original classification of 'quasi-stellar radio source'. The first quasars were discovered by their radio emission but no visual source could be found. More in-depth study found small star-like point sources of light where the radio sources occurred. Yet, when observing their spectra, these point sources showed very different emission properties from stars and had a higher redshift than any star in our Milky Way or nearby galaxy. Eventually the accreting black hole model was accepted to explain this phenomenon. The model states that quasars are made by accreting gas around a black hole, the friction and pressure of which begins to heat up the surrounding gas to a point where the intensity of the produced light outshines the accretion disk itself.

It is believed that many galaxies have gone through this early stage as a quasar on the way to their current formation. Once the black hole has fed off of all the immediately surrounding gas, it no longer produces intense enough light to outshine its disk and the disk becomes more visible. This would also explain why quasars are usually found to occur in the early universe, where many galaxies are thought to have their beginnings [1].

In 2000, the Sloan Digital Sky Survey (SDSS) began mapping the sky for everything from asteroids in our own solar system to mapping the Milky Way to observing distant, high redshift galaxies and quasars. Currently, SDSS has the largest catalog of observed quasars and their spectra. In previous catalogs, the spectra has been visually inspected by one or two members of the quasar working group. Most recently, this job has belonged to the chair of the working group, Dr. Isabelle Paris of the Osservatorio astronomico di Trieste (Astronomical Observatory of Trieste, Italy). After her departure from astronomy, no one has picked up this job for DR14Q to the same extent as Dr. Paris. Visual inspection serves to check the accuracy of the automated pipeline code that creates the majority of the catalog data as well as flag for special properties, such as BAL quasars and errors in the pipeline estimate redshift. For the new quasar catalog, DR14Q (Data Release 14 Quasar), these flags were not created as Dr. Paris began to move out of astronomy leaving no one to visually inspect most of the new data.

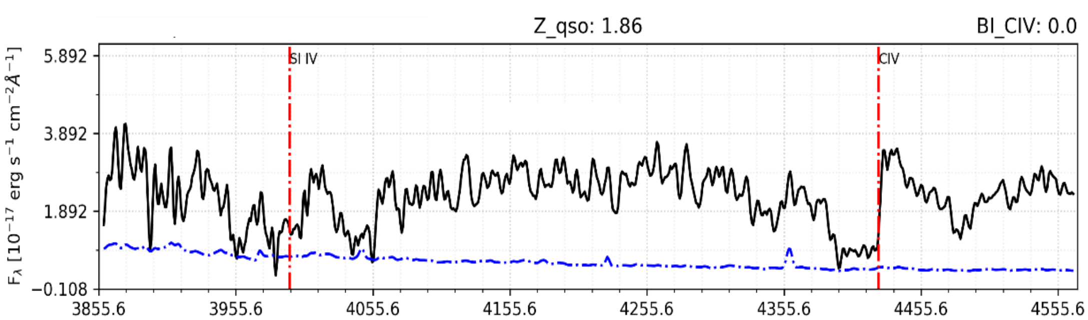
## 2. Building BAL Quasar Flag

Every quasar catalog builds upon the catalog before it, adding new observations and looking again at earlier objects. The date of every observation is recorded as the modified Julian date (MJD). The beginning MJD for the new data in DR14Q is 56837. This is the beginning of how the data was narrowed down. The next step was to make sure that the triple-ionized Carbon (C IV) and single-ionized Magnesium (Mg II) regions would both be visible in the spectrum. To do this, the redshift (z) range was narrowed down to between 1.57 and 3.29. Next was to separate out what the pipeline determined to have balnicity and what it didn't. Balnicity is a term to used describe the strength of possible BAL properties in a spectrum. The pipeline does this automatically by subtracting the individual quasar spectrum from a model spectrum at the same redshift. In DR14Q only the C IV region is looked at for balnicity so the result is called BI_CIV. A BI_CIV greater than zero means that the pipeline picked up an absorption effect in the spectrum. BI_CIV equal to zero means that it didn't pick up any strong BAL properties. This is the primary thing this project wants to check the accuracy of. There are over 800 new quasars that are within this redshift range and have a positive balnicity index. To check the accuracy of those that had a BI_CIV of zero or below, another 800 were randomly pulled matching the redshift range. These spectra were pulled as fits files from the catalog which were then run through code to zoom in on the C IV and Mg II regions and print out an image file of each region.

Once all the images were made, the last step was to build the Zooniverse project and distribute it to the quasar working group. Zooniverse provides a project builder to anyone who wants to build their own project for any reason. Projects are initially set as private so only the project owner and whoever they manually add can access it. Once volunteers were added, the volunteers were allowed to go through the project and classify the data. The properties that the project asks the users to classify are 'Normal Troughs', 'Mini-BALs' and 'Possible Inward Falling Gas'. Normal troughs are the more common type of trough that appears in BAL quasars and don't change shape over multiple observations. They tend to be picked up accurately by the automated pipeline because of their large size with a BI_CIV greater than 2000 km/s. Mini-BALs are much smaller and less common than normal troughs. They're defined to have a BI_CIV between 500 and 2000 km/s [2].

## 3. Data so far

The project has been running for two weeks as of October 30, 2017. So far 50 quasars have been classified by the quasar working group. As time goes on more quasars will be classified and the following numbers will likely change. In particular, the results so far shows error in the automated pipeline is in need of improvement and would benefit from visual inspection. They also detail the results of data that has not been recorded by the pipeline at all, such as mini-BAL occurrence and candidates for inward falling gas.



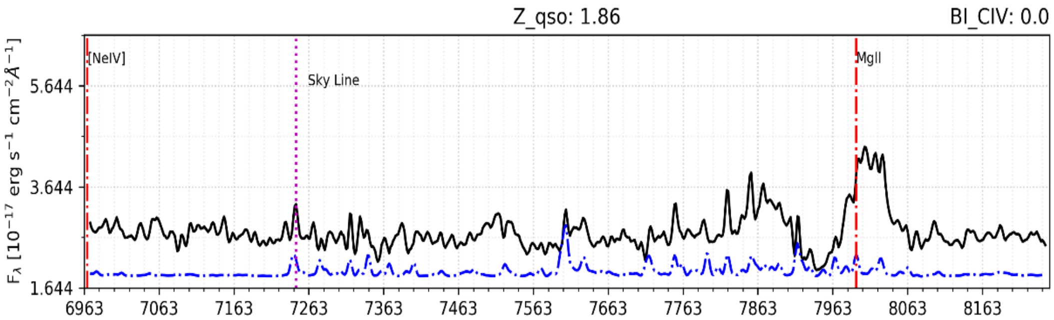



Figure 1: Spectra of a quasar showing the CIV region in the top image and the MgII region in the bottom image.

Both show a BAL property on the blue/left side of the CIV and MgII emission peaks that also line up. This means that they're likely gas clouds that were thrown out of the accretion disk at the same time if not in the same cloud together

Of the data gathered so far, eight out of fifty classifications are quasars that show some kind of absorption property that was not picked up by the pipeline, i.e. the pipeline recorded the BI_CIV to be zero. If this rate carries through the project then this would result in an error of sixteen percent. Of those spectra with a BI _CIV recorded by the pipeline as greater than zero, 15 had mini-BALs. Two of these did not have an accompanying normal trough and one spectrum had a normal trough, a mini-BAL, and possible inward falling gas. In all these results are impressive, especially since this project is in the early stages. These numbers are expected to change and likely increase as more data is acquired and updated accordingly.

## 4. Conclusion

This research project is ongoing with preliminary data. As shown above, the data gathered already shows a need for further improvement of the pipeline if inspection is to continue being done fully by a computer. This also shows a basis for the need of visual inspection. Without people checking the computer, important data may be missed that sheds a light on the hidden mysteries of quasars and their history.

## 5. Acknowledgments

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## 6. References

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