ASTRONOMY ACROSS STATE LINES: A Collaborative Project for Astronomical Research

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Abstract

Scientists do not work in isolation, nor should student scientists. In a collaborative effort, students from three high schools examined plates from the Sloan Digital Sky Survey (SDSS) to estimate the number of galaxies that contain evidence of a black hole. Working under the direction of Don York, former SDSS director, the three teachers used Google hangouts to discuss weekly progress. At their home institutions, students examined optical spectra from SDSS Data Release 10 to determine if a quasar could be discerned. Both Type I and Type II quasars can be seen in the SDSS data. Seven teams of students from different schools compared their findings and collaborated online to discuss potential discoveries.

This project can serve as a model for high school teachers who want to facilitate their students participating in an authentic research project. The keys to a successful project are working with a mentor who can guide the group through difficult concepts and communicating frequently throughout the project.

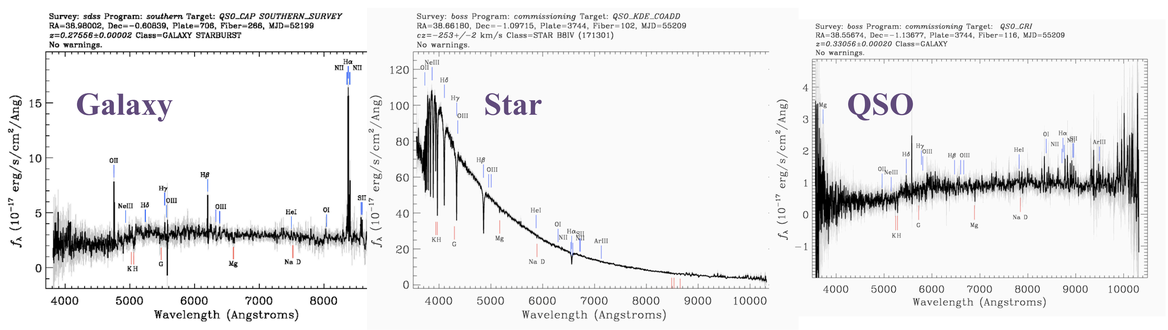
Background

Students from three high schools collaborated on an astronomy research project using archival data from the Sloan Digital Sky Survey (SDSS) under the mentorship of Dr. Donald York, University of Chicago. Through Google Hangouts and video chats, over the course of four months students were able to observe data and identify possible quasars together. Although black holes cannot be directly observed, the infall radiation can be detected by examination through spectral analysis. Black holes are essential to the functions of the universe. It is believed that at the center of each galaxy lies a supermassive black hole. Quasars represent a brief energetic period in a galaxy's evolution when matter accretes onto the supermassive black hole. Doppler shifts can be used to determine velocity widths of the galaxies' movement away from us. In the Data Release 10 Quasar (DR10Q), there have been over 170,0000 quasars identified (Paris 2014). The SDSS algorithm has classified objects as a point source (star) or a fuzzy patch (galaxy). It is at this point, that the human element enters the classification process.

Methods

- For this project, seven groups of high school students analyzed data from seven plates (701 through 707) of SDSS DR10Q for emission galaxies that were potential quasar (QSO) candidates. Each group eliminated those objects classified as stars and quasars. They then evaluated 100 emission galaxies per plate, looking for active galactic nuclei (AGNs) fitting specific criteria.
- For each of the 100 emission galaxies, we looked at the spectra to determine the Hα flux of each SDSS-classified galaxy. We calculated the full-width at half max (FWHM) of this peak.
- The FWHM was used to calculate the velocity width of the galaxy. If the calculated velocity width greater than 100 km/s, the object was further investigated for two other requirements: $flux_{[NII]} > 50\% flux_{[H\alpha]}$ and $flux_{[OIII]} \sim flux_{[H\beta]}$. If one of these two criteria was met, it was considered a candidate.
- The data from each group's 100 emission galaxies on a BPT diagram (Baldwin et al. 1983 and Kauffman et al. 2004). Data points in quadrant I were considered to be worthy of further investigation as AGNs.

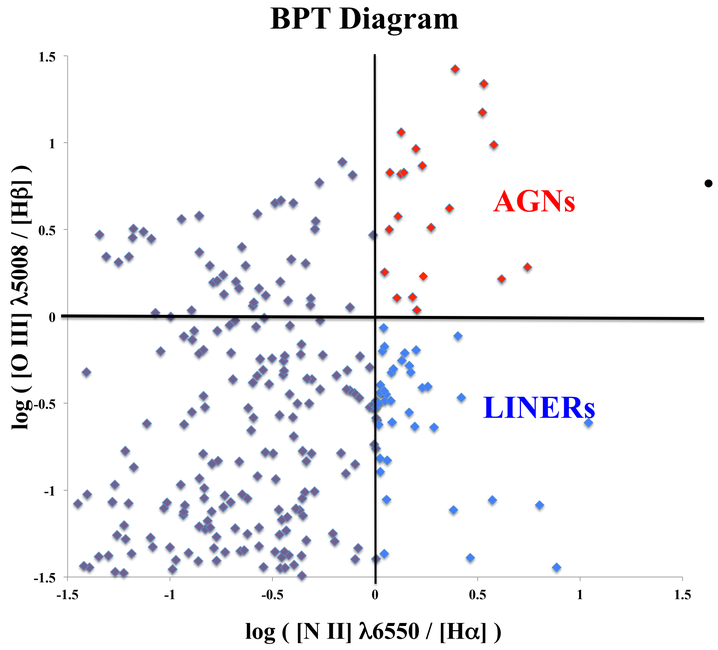
	Rest Wavelength (Å)
H β	4862.7
[OIII]	5008.2
[NII]	6549.9
H α	6564.6
[NII]	6595.3



Results

- The students compared their results and agreed upon the AGN candidates through online discussions. A composite BPT diagram was created. Observing the ratio between [NII](6583Å)/Hα and [OIII]/Hβ, our data show QSO candidates, which can be divided into AGNs and LINERs.
- The AGN candidates on the top right side of the graph show positive ratios, indicating possible candidates worthy of being considered by other telescopes. The top right quadrant represents broad line emissions, while the lower right quadrant represents narrow-line (LINER) emission. The two quadrants on the left represent regular galaxies and stars.

Plate	Potential Candidates
701	21
702	20
703	5
704	3
705	22
706	10
707	12



- Looking at the BPT diagram, there were 21 (3.1%) AGN candidates and 32 (4.6%) LINER candidates out of 700 emission galaxies examined.
- These results are lower than our initial list of candidates. The 50% criteria we used to regulate the candidates may have been too strict. It may have limited the number of AGN candidates in comparison to using a 30% criteria.

Conclusions & Future Work

- If all galaxies have black holes and if broad emission lines of Hα, Hβ, [OIII] and [NII] indicate the presence of infall of material, then a minimum of 3% of galaxies have infall at any one time.
- In our future work, we are considering a lower limit for the [NII] λ6550 / [Hα] ratio to 30% (compared to our current 50%) in anticipation that this would provide create a larger pool of viable AGN candidates.
- Research leads to more questions than it answers. This collaborative project has generated new questions that will lead to future research projects.

References

Baldwin, JA, et al., 1981, *PASP 93: 551.*
Kauffman, G, et al., 2004, *MNRAS 353: 713.*
Paris, I, et al., 2014, *A&A 563: A54.*