Determining Distances for Active Galactic Nuclei using an Optical and Near-Infrared Color-Magnitude Diagram

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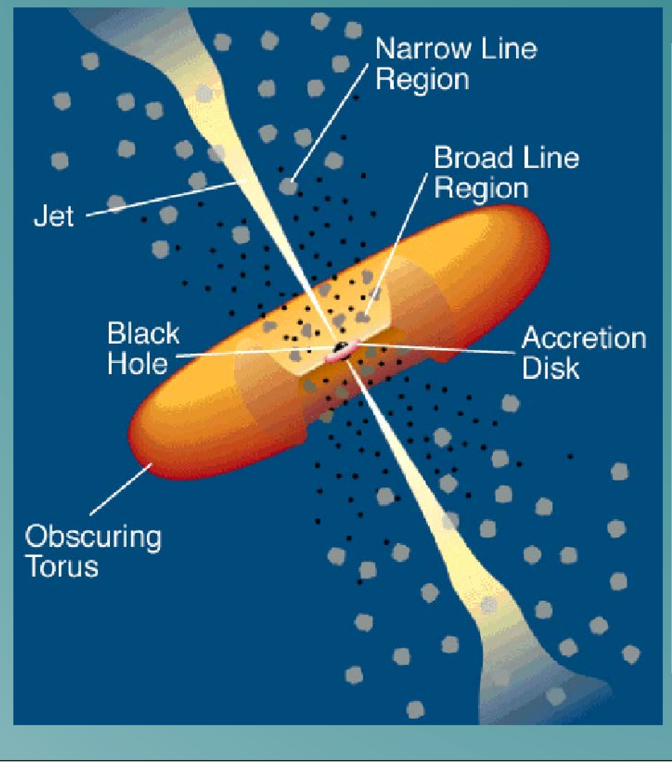
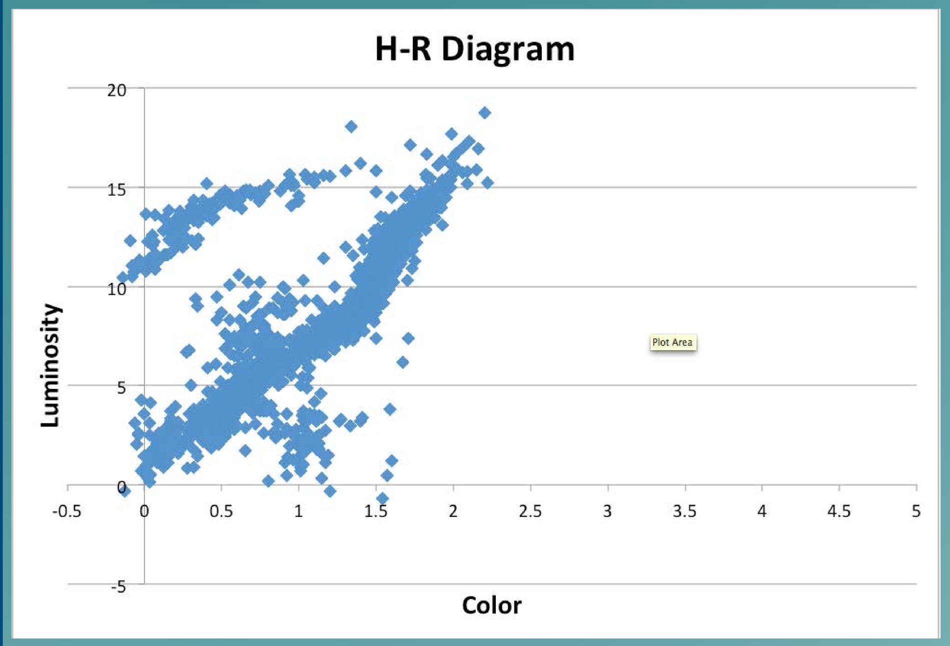
Introduction

Active galaxies are characterized by having supermassive black holes at their centers. As a result, active Galactic nuclei, or AGN, emit large quantities of light via accretion onto these supermassive black holes. As this accretion occurs, the black holes get hotter and emit more light, but before the gas flows into the black hole, all of the energy is released resulting in the AGN having high luminosities. AGN do not have single temperature emissions like stars because they do not consist of one single blackbody. Instead, an AGN is a merging of all the different parts of the accretion disk, which is formed by gas around the black hole and heated by the friction of the moving gas particles. The hotter the accretion disk, the more light it will emit, and the more it will heat the surrounding gas and dust. For this study, we are focusing on Type 1 Seyferts, which are unobscured AGN that can be viewed from a head-on perspective. Type 1 Seyferts are characterized by having a lot of broad-line emissions, meaning that there are fast-moving gas particles with redshift and blueshift emissions present. Studying AGN is very beneficial because if the luminosity of an AGN is determined, the distance can be calculated, and a color-magnitude diagram (similar to the H-R diagram for stars) can be created to help determine cosmic distances for many interstellar bodies.

Abstract

Photometry data surrounding Type 1 Seyferts and quasars from the 2 Micron All Sky Survey (2MASS) and the Sloan Digital Sky Survey (SDSS) was studied to create color-magnitude diagrams comparing the ratio of two wavelengths to the absolute magnitude of another. Overall, many of the diagrams created indicated a clear correlation between color and luminosity of AGN. Several of the diagrams, focused on portions of the visible and near infrared (NIR) wavelength bands, showed the strongest correlations. When the z-k bands were plotted against the absolute magnitude of the k band, specifically surrounding the bodies with redshifts between 0.135 and 0.150, a strong predictive relationship was seen, with a high slope (0.75) and R^2 close to 1 (0.69). These correlations have several real-world applications, as they help determine cosmic distances, and, ultimately, ages of cosmic bodies.

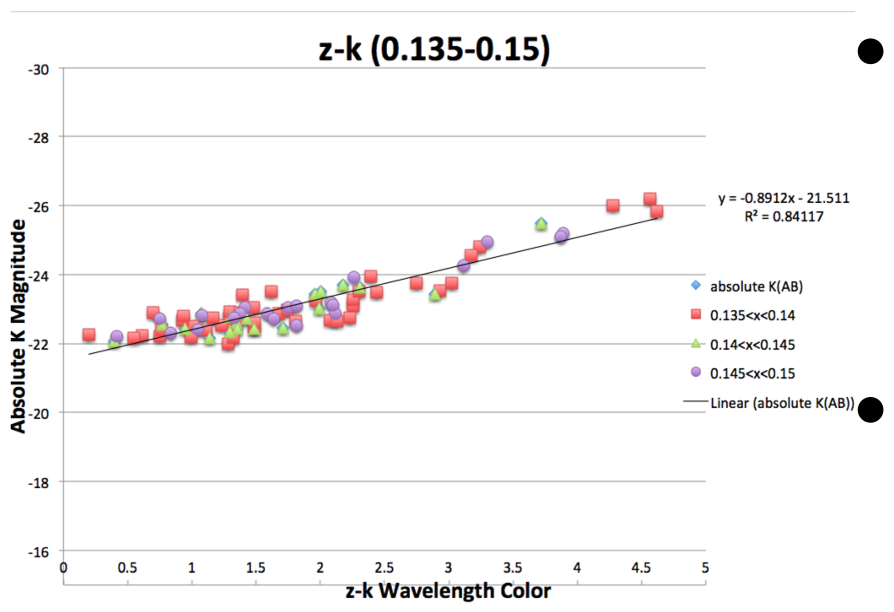


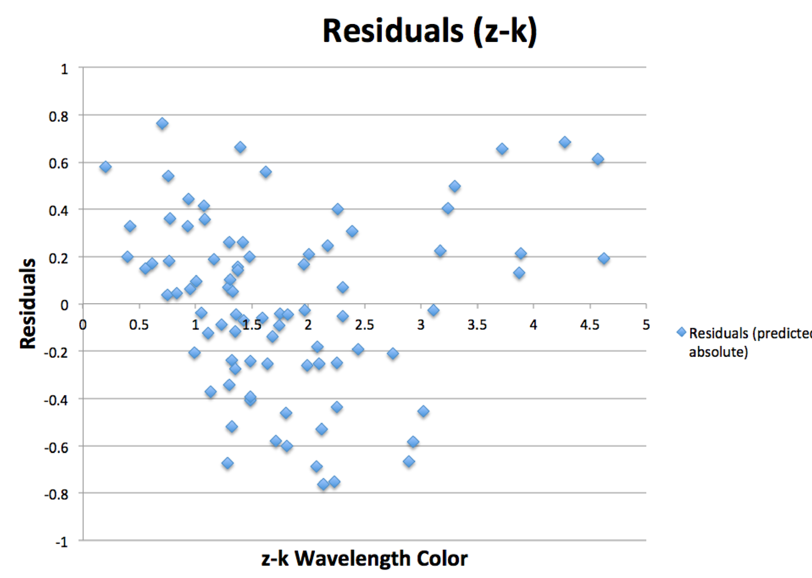


Methodology

The Sloan Digital Sky Survey (SDSS) and Two Micron All Sky Survey (2MASS) databases were used to collect data surrounding Type 1 Seyfert galaxies with minimal dust obscuration. The data set was further narrowed down to include the approximately 1200 objects with the greatest ratio of wavelengths (color). The data was particularly focused on galaxies with redshifts between 0.01 and 0.20. Using the redshifts and distances of each body, we were able to calculate the absolute magnitude for each object with the distance-modulus equation. We then created color-magnitude diagrams with a variety of filter combinations to see which combinations would yield the highest correlation between color and luminosity. A strong correlation appeared in the z-k bands, specifically between redshifts of 0.135 and 0.150, so AGN in the z-k bands at those redshifts were examined more closely.

Results





- z-k in the 0.135 - 0.150 redshift range had a promising relationship, as seen in the graph to the left
- Data was further categorized into smaller redshift increments as well
- A best-fit line shows a slope of -0.89 which shows there is a correlation between the two
- An R^2 value of 0.84 shows that the data points fit the line well

- We also plotted a graph of residuals, a visual representation of the R^2 value showing how well the points fit the line.
- This graph is not as predictive as an HR diagram (seen on the same x-axis scale to the left, but it still is indicative of a positive correlation).

Takeaways

- Our results indicate that there is a relationship between the color and luminosity of an AGN

- While the relationship is not as predictive as an HR diagram, with further research, perhaps using a different redshift range, or different data, it may be possible to find a predictive relationship for AGN

Acknowledgements

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