Color-Magnitude Relationships Among Quasars and Type I Seyfert Galaxies

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Abstract

Data from the Sloan Digital Sky Survey (SDSS) and the Galaxy Evolution Explorer (GALEX) satellite were used to construct color-magnitude diagrams of quasars combined with Type I Seyfert galaxies with redshift values of 0.05 < z < 0.85. This study improved upon previous studies by including quasars and by having a much larger sample size. The covered wavelengths were from 0.15 to 0.90 microns. Color was plotted against absolute magnitude in several bandwidths revealing correlations at multiple wavelengths at certain red-shifts.

Introduction 1

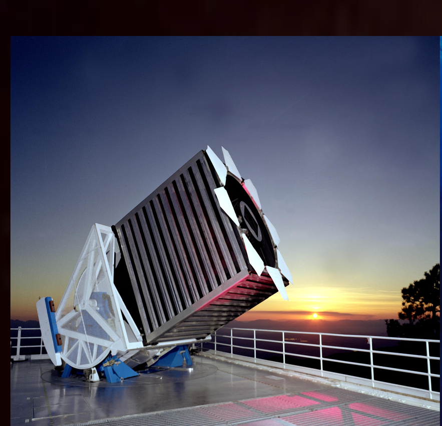
Active galaxies are "active" due to the presence of supermassive black holes at their centers. While all galaxies harbor such black holes, in AGN they are accreting large amounts of dust and gas. This in-falling material is heated to very high temperatures, emitting large amounts of energy across a large portion of the electromagnetic spectrum.

The study of AGN provide benefits in several different areas– two areas, relevant to this project, are listed below:

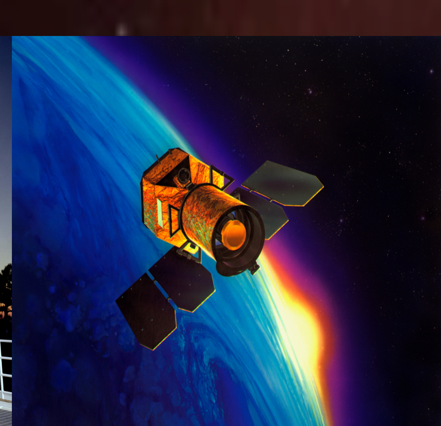
- Black hole accretion is very efficient at converting matter into energy, making AGN some of the most luminous objects known[1].
- This high luminosity makes them visible from large distances (z≈7).

If the luminosity of an AGN is known, its distance can be calculated– it can then be used as a "standard candle" in order to help refine the distance scale of the universe.

While the term "AGN" encompasses several types of objects, this study focuses on quasars and Type I Seyfert galaxies.



Sloan (SDSS) Image credit: University of Chicago



GALEX

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Methods 2

Objects identified as quasars and Type I Seyfert galaxies were selected from the NASA Extragalactic Database (NED). These specific targets were then cross-checked against objects imaged by GALEX and SDSS. Those AGN which appeared in both surveys and which had redshifts of z < 0.85 were used, giving a total of 10,877 objects.

Distances to the AGN were calculated using the redshift values given by SDSS. This calculation was based on the Javascript applet supplied by Wright[2] using values for a Flat universe and a Hubble constant of 71 km/s/Mpc.

Once distances were determined, the absolute magnitudes of the AGN in each filter-band were calculated. After the absolute and apparent magnitudes were known, color-magnitude diagrams were constructed (fig. 4, fig 5).

In each case, absolute magnitude used either GALEX Far-UV (FUV) or Near-UV (NUV) data. Color-index was determined by taking the FUV or NUV magnitudes and subtracting the brightness of each of the SDSS filters in turn. Those filter combinations which gave strong correlations were singled out for further study (fig. 6).

As the AGN moved to greater redshifts, the SED moved toward longer wavelengths. Based on the z=0 rest frame, different filter combinations were utilized in order to track chosen portions of the SED as they were red-shifted (fig.1).

This study looked at AGN at redshifts of 0.05 < z < 0.85. The data were broken down into bins with z-value sizes of 0.1. Strong correlations appeared at certain z-values, when certain filter combinations used (fig. 4).

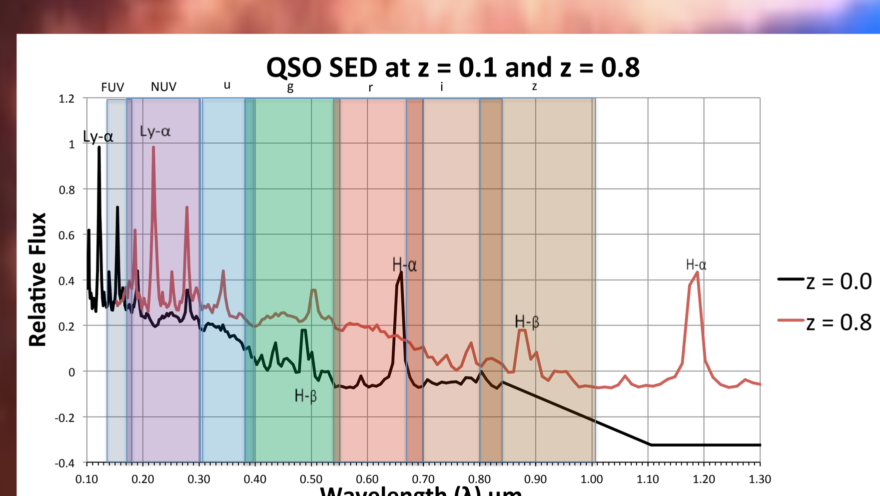

Figure 1. The redshift of the SED means that different filter combinations are needed in order to track areas of strong correlation.

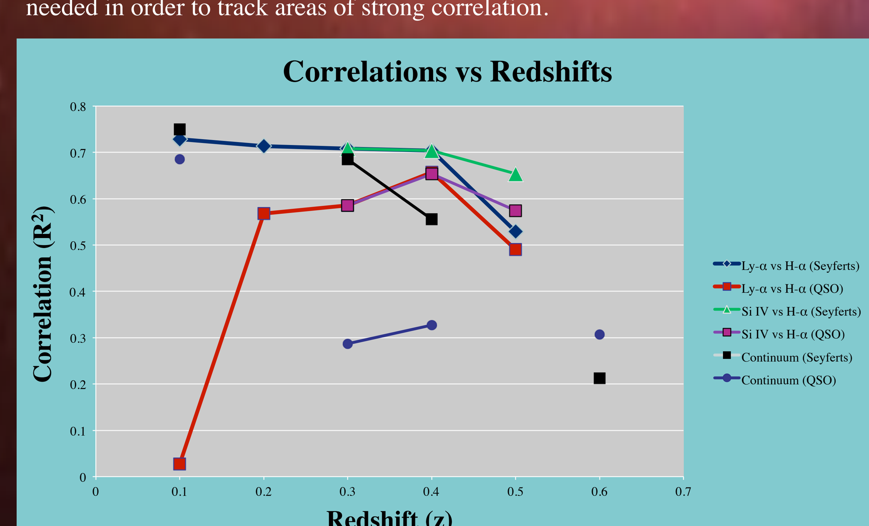

Figure 2. Attempts to follow various features of the QSO SED as the red-shift increased produced the best results when certain emission lines were tracked. Results for the continuum-dominated portions (0.3-0.4µm; 0.54-0.7µm at z=0.1) were less well correlated as emission lines intruded the filters at certain redshifts.

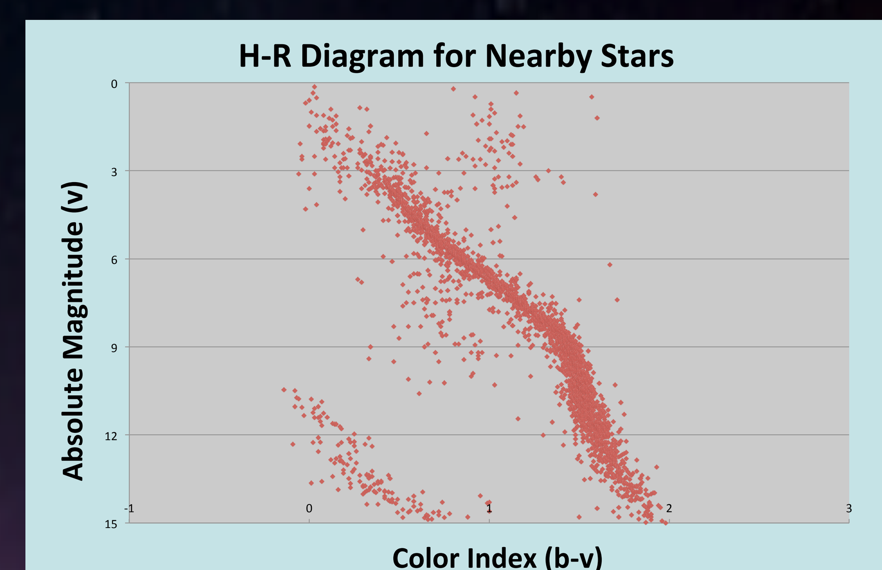

Figure 3. A color-magnitude diagram of nearby stars to compare to the AGN color-magnitude diagram at right (fig. 5).

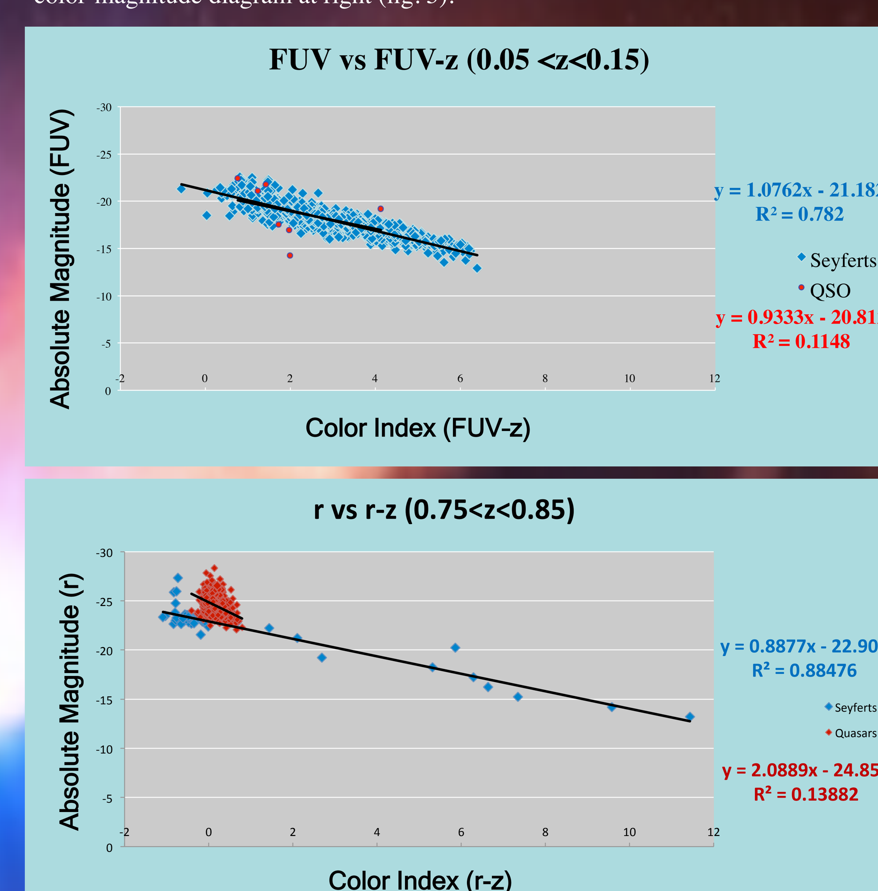

Figure 4. Two graphs above show one of the strongest correlations at z=0.1 and at z = 0.8. In each case, the Seyferts have a higher correlation than the Quasars.

Results 3

High correlations were noted in several of the redshift bins, particularly those where the filters used were furthest apart (NUV-z and FUV-z). Highest correlations were found in the FUV vs. FUV-z. Seyferts were always more highly correlated than QSOs at any given redshift (fig. 5).

Highest correlations were noted at a redshift of z=0.1 for most of the filter combinations studied, although in some cases, the highest values occurred at other redshifts. High correlations were also found at the highest redshifts (z>0.8) in the study when the filters were very close together (r vs r-z) among the Seyferts (fig. 4).

Attempts were made to follow certain emission lines as the SED shifted toward longer wavelengths with increasing redshift. High correlations were noted in some cases (fig. 2).

Continuum-dominated portions of the SED (0.3-0.4µm; 0.54-0.7µm at z=0.1) were also examined as the SED moved toward longer wavelengths (fig 1). Correlations dropped for both QSOs and Seyferts at higher z-values, but were especially pronounced at around z=0.6 (fig. 2).

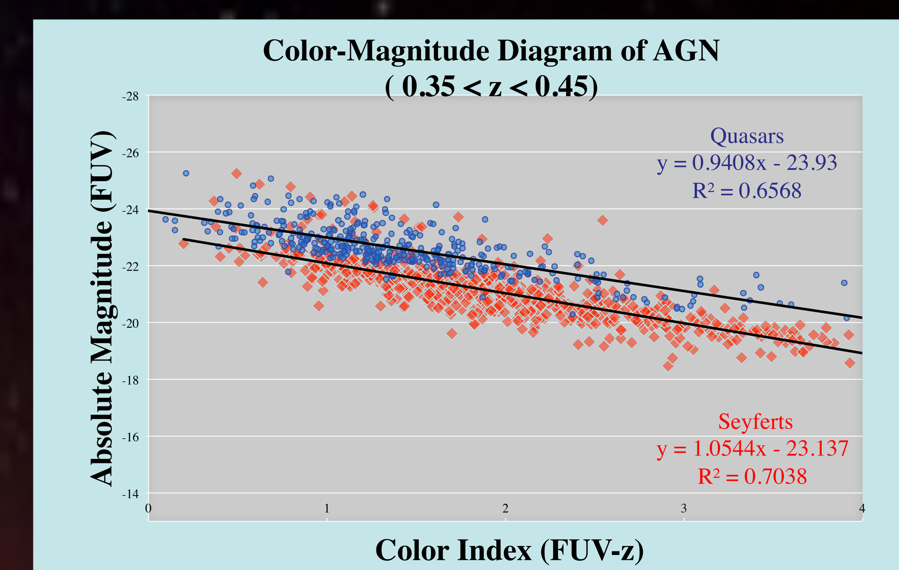

Figure 5. A color-magnitude diagram of quasars and Type I Seyfert galaxies.

Conclusions 4

The color of an AGN is strongly correlated to its absolute magnitude in certain filter combinations, mainly those which are furthest apart (NUV vs NUV-r, i, z and FUZ vs FUZ-r, i, z). Highest correlations tended to occur at a redshift of z=0.1. Correlation were greater for Seyferts than for QSOs in every case.

This relationship allows a color-magnitude graph, analogous to an H-R diagram, to be constructed. The slope of the resulting C-M diagram is shallower than that of an H-R diagram.

A color-magnitude diagram such as this will potentially provide a method, in addition to redshift, for determining the distances to these objects.

Color Index	Highest Correlations Seyferts (R^2)	Highest Correlations QSO (R^2)
FUV-u	0.5367	0.5152
FUV-g	0.6859	0.5765
FUV-r	0.7400	0.5963
FUV-i	0.7413	0.641
FUV-z	0.7820	0.6568

Figure 6. The highest correlations were noted in the FUV band of various redshifts. Highest correlations did not overlap with same redshifts for Seyferts and QSO.

References

[1]http://www.ast.cam.ac.uk/research/x-ray.astrophysics/accretion

[2]http://www.astro.ucla.edu/~wright/CosmoCalc.html

[3]The New Generation Atlas of Quasar Spectral Energy Distributions from Radio to X-rays, Shang et al, 2011, ApJS,196, 2.