An optical and near infra-red color-magnitude diagram for type I Active Galactic Nuclei

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Abstract

Data from the Sloan Digital Sky Survey (SDSS) AND 2MASS (2 Micron All Sky Survey) were used to construct a color magnitude diagram of Type I AGN using redshift values of 0.001<z<0.20. This study improved on previous studies by using both optical and 1-2 micron near-infrared (NIR) wavelengths as a better color discriminator of the transition between the accretion-dominated and dust/torus dominated emission. Color was plotted against absolute magnitude in several bandwidths and several redshifts. Highest correlation was found in the z-K_S bandwidth at the 0.07<z<0.08 redshift range.

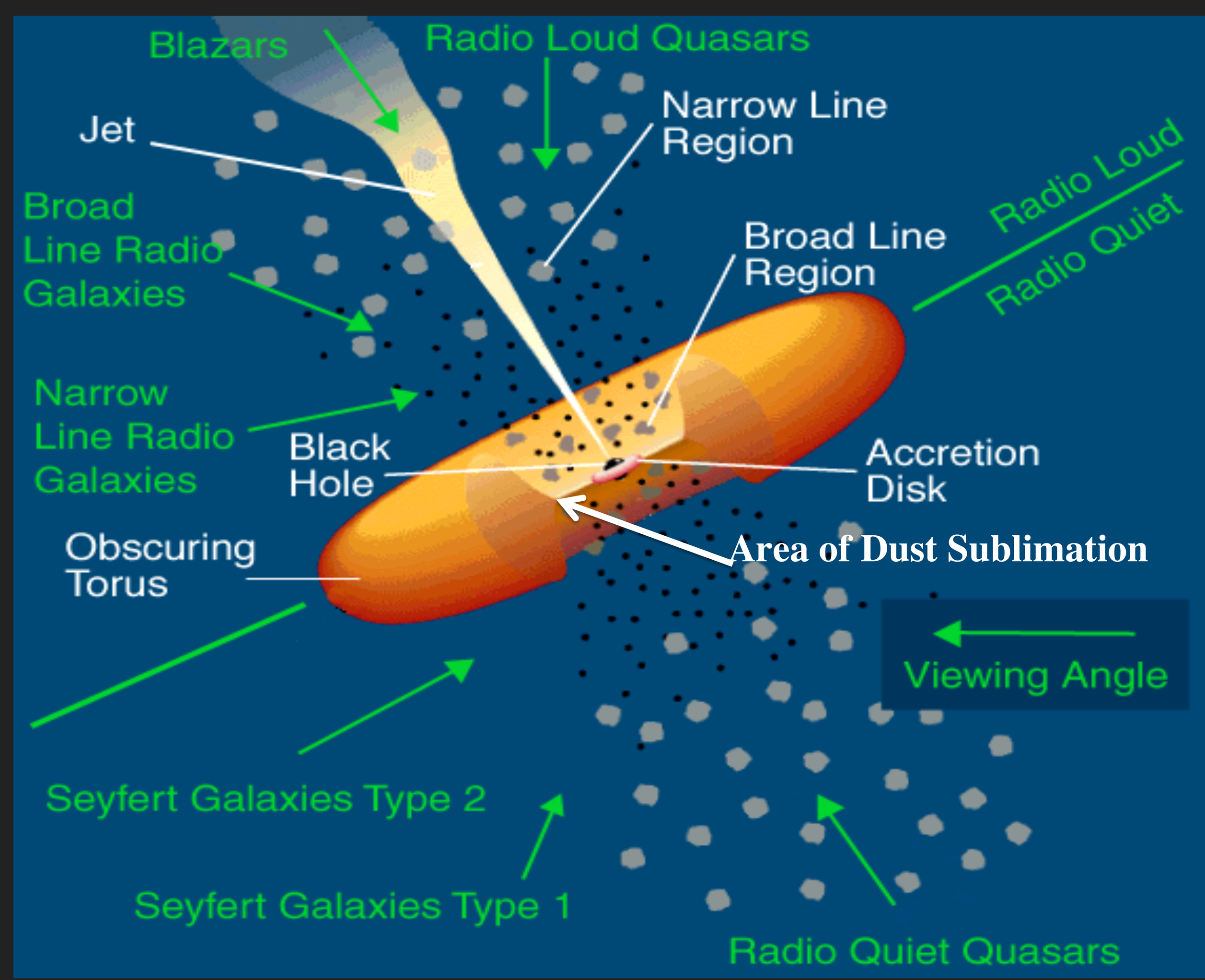


Figure 1. Schematic of a black hole, an accretion disk and surrounding dust (Urry and Padovani, 1995)

Introduction

Active galaxies are 'active' due to the presence of super massive black holes at their centers (Figure 1). While all galaxies have central black holes, in AGN the black holes are accreting large amounts of dust and gas. This in-falling material is heated to very high temperatures, emitting very large amounts of energy across the entire electromagnetic spectrum[1].

The study of AGN provides benefits in several different areas; those relevant to this project are:

- Black holes accretion is very efficient at converting matter into energy, making AGN some of the most luminous objects in the universe, thus making them visible for enormous distances.[2]
- If the luminosity of an AGN is known, then its distance can be discerned by calculation.

This would allow the making of a color-magnitude diagram (not unlike the HR diagram) in order to help refine the distance scale of the universe. For this study we are focusing on Type I AGN.

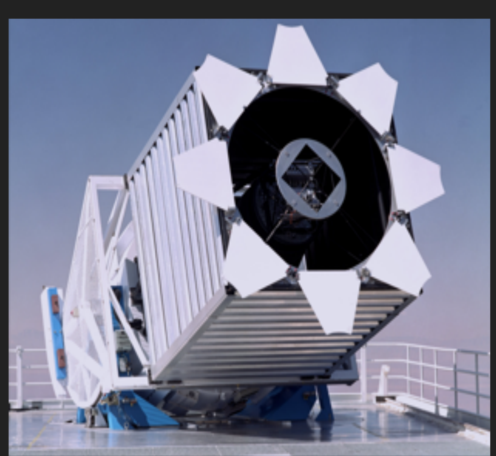


Figure 2 The Sloan Foundation 2.5m Telescope at Apache Point Observatory

Figure 3 The Northern 2MASS Telescope on Mt Hopkins

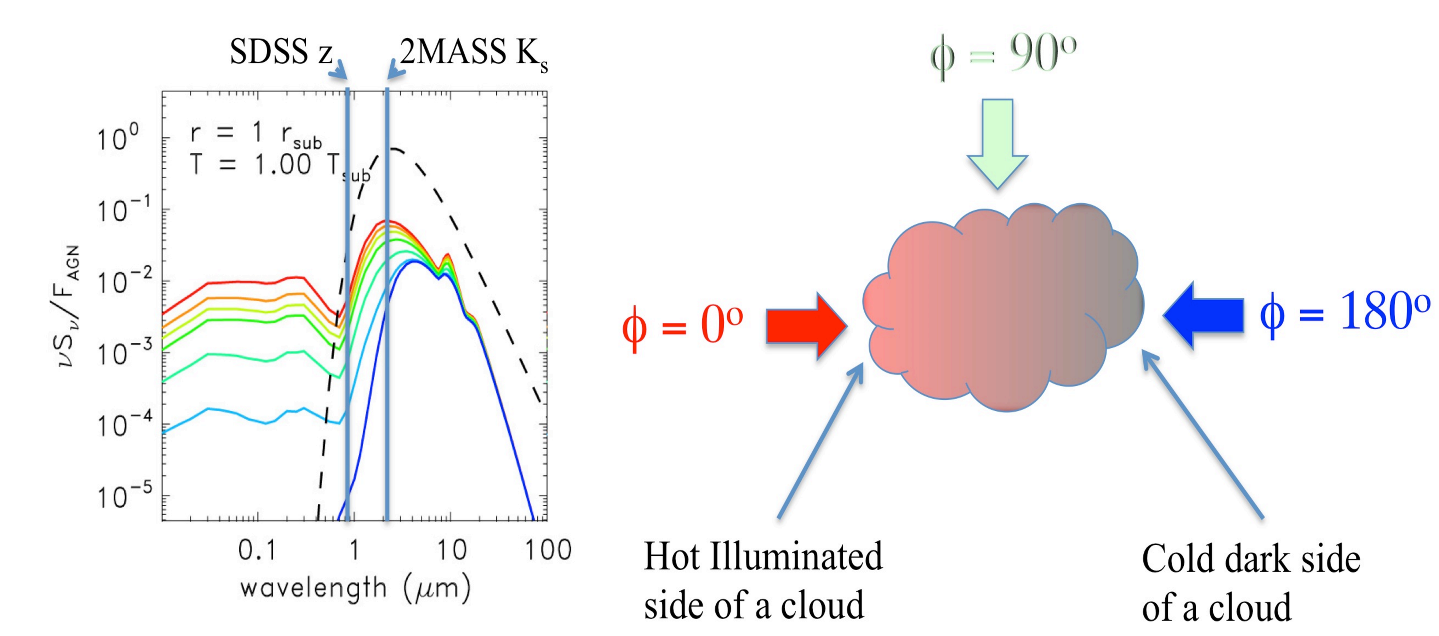
Methods

Those objects identified as Type I AGN were chosen from the SDSS (Figure 2) and then their infrared data was obtained from 2MASS (Figure 3). Data focused on the sublimation boundary between the coolest part of the accretion disk and the hottest region at the inner edge of the dusty torus surrounding the disk (Figure 4). Approximately 1200 objects had high quality SDSS and 2MASS data.

- The redshifts of these objects were used to calculate their distances for absolute magnitude using an H_o of 72km/s/Mpc.
- Once the absolute and apparent magnitude were known, color-magnitude diagrams were built using a variety of filter combinations.
- Strong correlations (r^2> 0.6) were pulled for further study.

The overall study looked at redshifts of 0.01<z<0.20. The highest correlations appeared at the 0.07<z<0.08 and 0.135<z<0.150 range so AGN at those redshifts were examined more closely.

Figure 4 An example of source functions S_ν of a directly AGN-heated cloud for ISM standard configuration with Draine (2003) silicates from Hoenig & Kishimoto (2010). This figure shows the emission of a cloud with $\tau_V = 50$ at $r = r_{sub}$, scaled to the total incoming flux of the AGN, $F_{AGN} = L_{bol}/(4\pi r^2)$. The corresponding hot-side temperature in units of T_{sub} = 1500K is also given.



The various lines represent a specific phase angle, ϕ, of the cloud in steps of 30° (red: ϕ = 0°, i.e. full hot side; dark blue: ϕ = 180°, i.e. full cold side) shown schematically on the right side. Although this is for an individual cloud from multiple angles, a Type 1 AGN will be a combination of multiple clouds being viewed mostly from the ϕ = 90° direction. For comparison, the corresponding black-body emission $B_\nu(T)$ is plotted as a dashed line with the same temperature as the hot side of the cloud, at the same distance from the AGN.

Results

High correlations were noted in several redshift bins with the greatest correlations in the 0.9134 µm (z) vs 1.66 and 2.16µm series (H,K_s) at the 0.07<z<0.08 and 0.135<z<0.150 redshift range. Those regions were selected for further study. Additional analysis showed that the 0.07<z<0.08 range had fewer outliers driving the correlation. Values for the 0.07<z<0.08 redshift in z-H and z-K_s showed high correlations, with the z-K_s group being the best on a comparative color-magnitude diagram (Figure 5).

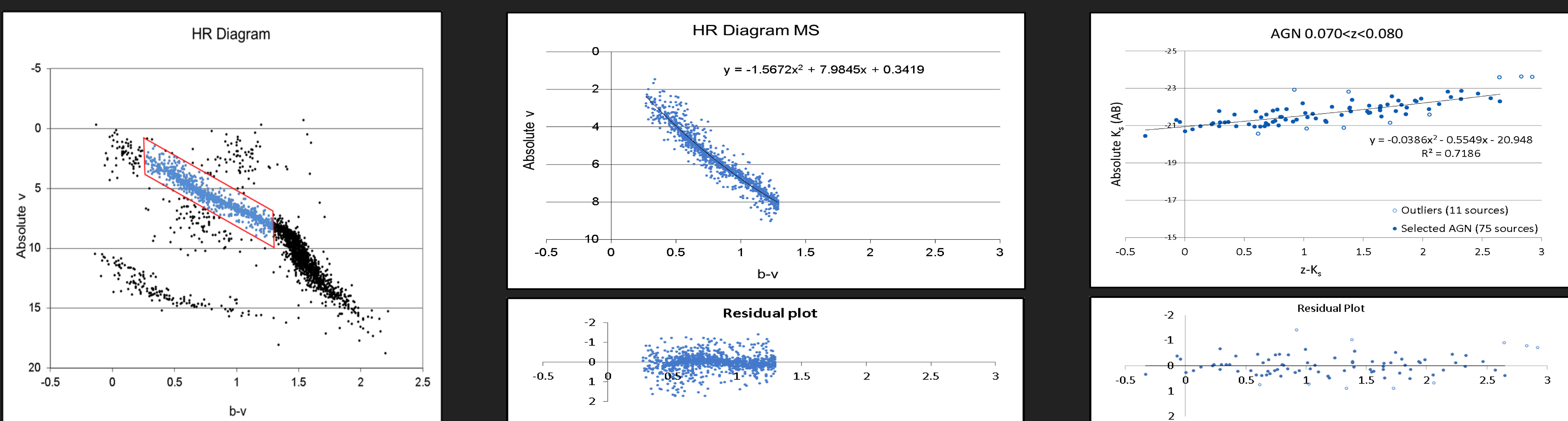


Figure 5 The graph on the **left** depicts the HR diagram (a color magnitude diagram for stars), which was our model for developing a similarly predictive relationship for AGN. The graph in the center depicts the residuals for the first order regression of this data. The graph on the **right** depicts the color magnitude diagram for the z-K bandwidth at the 0.07<z<0.08 redshift range for Type I AGN. The entire dataset is shown, with the removed outliers indicated by open circles.

Conclusion

The accretion disk/torus color difference of a Type I AGN is correlated to its absolute magnitude at the 0.07<z<0.08 redshift range. This relationship allows a color magnitude graph, similar to an HR diagram, to be constructed. Such a diagram will potentially provide a method, at the above redshift range, for determining the distance to these objects which can then be applied to other filters and hence other redshifts.

1. An introduction to Active Galactic Nuclei by B. Peterson; Cambridge University Press 1997
2. The Cosmic Perspective 3rd Ed. By Bennett, Donahue, Schneider and Voit; Pearson Education Inc. 2004
3. Draine (2003) Draine, B. T. 2003, ARA&A 41, 24
4. Hoenig & Kishimoto (2010) Sebastian,. H. F. and Kishimoto, M. 2010, A&A, 523, 27