**Pamela Thompson – Version 1**

**Background**

The term, “active galactic nucleus”, or AGN, is used to describe the energetic central region of galaxies. The energy being emitted in this region of galaxies with an AGN is equal to or greater than all the stars in the galaxy combined. Most galaxies exhibit only absorption lines in their spectra, as the upper atmospheres of their stars are absorbing most of the light they generate. A galaxy with an AGN will additionally have emission lines as gas becomes super-heated in the nucleus.

The basic structure of an AGN consists of a super-massive black hole at the center of the galaxy, surrounded by an accretion disk. As gases flow onto this disk they are heated and become luminous. Although the accretion disk has a blackbody emission that peaks in the ultraviolet, it has no spectral emission lines. However, near the accretion disk there is a separate region of fast moving hydrogen gas that, being heated by the accretion disk, produces Doppler broadened emission lines (the motion is broadened to speeds equivalent to at least 10,000 km/sec.) This area of gas although not resolved, is known to be separate from the disk due to it’s lag time in emissions during brightening events. Clouds of cooler gas farther from the accretion disk have characteristic narrow emission lines. Along the same plane, surrounding the accretion disk is theorized to be a dense torus of gas and dust. Perpendicular to the disk and issuing from the central region are two opposing jets, which are mainly synchrotron radiation. These jets can continue outward for great distances many light years across, and have strong radio signatures.

AGNs are divided into two main subclasses, Seyfert galaxies and quasars. Since they were both discovered independently of each other, at first it was not realized that they were actually related objects. This is due in part to the fact that quasars are seen at very great distances, so that only the super luminous core is resolved, and the relatively faint outer portion of the galaxy is lost in it’s brightness. Seyfert galaxies accrete material at a lower rate than quasars, and are therefore less luminous at their cores. Consequently, their outer regions are visible, making them easier to be identified as galaxies.

Additionally, there are two types of AGN, that according to the Unified Model are thought to be the same objects when viewed from different perspectives. Both types of AGN are theorized to have a torus of dense dust surrounding the accretion disk. In AGN Type I, the view is face on, looking up/down on the ring of the torus, enough to detect the fast moving gas near the accretion disk, so that both the narrow and broad emission lines are apparent. In AGN Type II, the view is thought to be looking through the torus, edge on, so that the fast moving gas, and the broad emission lines are obscured by the dust, leaving only the narrow emission lines visible in the spectra. Since most quasars have been discovered visually, and are extraordinarily bright, they are reasoned to be Type 1, where there is no interference from the dust of the torus. Type II quasars are relatively rare, since they are harder to identify because the dust of the torus obscures our view.

**Scientific Goals**

The goal of this study is to search for a correlation between color and magnitude for AGN, and to use the color magnitude relationship to gauge the inherent luminosity of the AGN (similar to the way that we use color magnitude correlations to determine the luminosity of stars)

This correlation has been investigated previously, most notably in 2010 by a NITARP team. This current study will continue the work of the 2010 NITARP team, additionally broadening the base number of targets by using data from quasars instead of Seyfert galaxies, as well as recently released data from WISE. We intend to;

(i) focus on Type I quasars so that absorption effects can be minimized

(ii) use emission data obtained at relatively simultaneous times for different wavelengths of interest (within approximately a 5 year period)

(iii) use data from GALEX, SDSS, and WISE, allowing for an increased number of samples, at an increased number of wavelengths.

The color magnitude plot requires data for the absolute magnitude of the center of the galaxy as well as a color measurement. The specific output of this study is to create a Color-Magnitude graph of the type:

(i) Magnitude at 4.6 microns (WISE) vs, Color, measured as the difference in magnitudes at 227.5 nm (near ultraviolet, GALEX) and u-band at 365 nm (SDSS)

(ii) Magnitude at 12 microns (WISE) vs, Color, measured as the difference in magnitudes at 227.5 nm (near ultraviolet, GALEX) and u-band at 365 nm (SDSS)

(iii) Magnitude at 22 microns (WISE) vs, Color, measured as the difference in magnitudes at 227.5 nm (near ultraviolet, GALEX) and u-band at 365 nm (SDSS)

**Instruments**

The Galaxy Evolution Explorer (GALEX) instrument is a 50 cm Ritchey-Chretien telescope, with a large field of view in four different optical paths, two UV simultaneous channels. The GALEX survey has imaged all of the galaxies that are relevant to our study. Their data archive will provide our near UV flux values for the targets, and with the u-band flux value from SDSS will be used to estimate the color (temperature) of the AGN. The color will then be compared to the IR energy emitted by the surrounding dust in the torus. As the temperature increases in the accretion disk at both the NUV and the u-band, we expect that there will be a corresponding increase in the temperature of the surrounding dust in the IR.

The Sloan Digital Sky Survey (SDSS) uses a ground-based 2.5-m wide-angle optical telescope, and takes images using a photometric system of five filters; u (ultraviolet), g (green), r (red), i (infrared) and z (900 nm). Although these are all close to the visual part of the spectrum, and some of these filters may be contaminated with varying degrees of star-light, the u-band flux values will be clean enough for us to use for our study without any corrections.

The Wide-field Infrared Survey Explorer (WISE) instrument is a four-channel imager which operates in a single mode. It includes a 40-cm telescope with 47 arcminute field of view, and has detector arrays at 3.4, 4.6, 12, and 22 µm. It has a resolution of 6 arcseconds (12 arcseconds at 22 µm). At 3.4 µm the data is contaminated with starlight. Since most galaxies have a large number of stars that emit at this wavelength, as do the AGN, there could be confusion as to the source of the flux. At 4.6 µm, there could still be some interference with starlight, but this channel may provide some useful information. Although the 22 µm data has less resolution, we do not expect there to be emissions from polycyclic aromatic hydrocarbons (PAHs) at 12 µm, or 22 µm, and it is these two channels that will prove to be the most useful to our study.

**Target Galaxies**

A broader range of AGN will be investigated than in the NITARP 2010 study, and will adhere to the following criteria:

(i) Type 1 quasars - The vast majority of all quasars are Type 1 AGN. We will assume that the quasars on our list fall into this category, and revise our criteria to eliminate Type II quasars as necessary to tighten the correlation.

(ii) Redshift 0.1 < z < 0.5 - The target quasars will all have a redshift that is nearby and at a similar relative distance so that variabilities associated with the redshift can be miminized.

**Archived Data**

The Sloan Digital Sky Survey was used to search for objects that fit the above search criteria, while cross-referencing for compatibility with GALEX. In all, 3037 targets were identified that were observed by both the SDSS and GALEX missions. Since the WISE mission is all-sky we are confident that most of our targets will be included in the upcoming March 2012 release.

There will be three sets of archival data extraction for this project. GALEX data will use extracted magnitudes from the 6th public release of data in 2010. These magnitudes will be in the Near UV (175-280 nm). The Eighth SDSS Data Release (DR8) took place in January 2011, and will provide our u-band (365 nm) magnitudes. Both GALEX and SDSS are available through a web interface, and can be easily downloaded. The other will be extracted magnitudes from the newly released (March 2012) WISE database. The WISE magnitudes are at 3.4, 4.6, 12, and 22 µm. They are also available through a web interface, and can be easily downloaded.

The initial list of targets will be attached in Appendix A.

**Education and Outreach Goals**

It’s been said that “Informal learning happens throughout people's lives in a highly personalized manner based on their particular needs, interests, and past experiences. This type of multi-faceted learning is voluntary, self-directed, and often mediated within a social context. It provides an experiential base and motivation for further activity and subsequent learning.” (NSF) It is within an informal, small group setting that the impact of this NITARP experience will be implemented into my classroom, after school club, and extracurricular activities. The overreaching goal is to make the use of “real” data and research in astronomy available, and accessible to my high school students, to enrich their educational experience and to inspire them to seek vistas in STEM professions.

As part of the educational goals of the NITARP program at Monrovia High School, this issue will be addressed directly, introducing teachers (through professional development) and students at our Math and Science Academy (MASA) to the process of conducting an original research project;

(i) How to pick a topic to research in astronomy

(ii) What data bases are available to the public, and how to use them

(iii) Methods to analyze their results

(iv) How to present their results, and the venues open to high school students

(v) Make this information public so that other students, teachers and schools will have access to it.

Another less formalized goal is to connect and network with the local amateur astronomers around our community. Many amateurs are working/retired STEM professionals that may be able to give my students insights and support for their research projects. Some amateur astronomers may also be interested in doing some research of their own, and being involved in the NITARP Program.

(i) Many amateurs are retired professionals that can easily disseminate the research process, and work with small groups of students to complete original research.

(ii) Amateurs can assist in hosting a star party, which can be an anchor for a larger science fair that can reach, and inspire many people of all ages and cultures.

(iii) Community members as well as amateurs can participate with the students in established “Citizen Science” projects.