Project Summary

This project is about identifying Active Galactic Nuclei around a specific coordinate using SDSS photometric data and WISE infrared data. This program takes data from all objects in a 500 arcsec cone around the given coordinate and filters them based on if they fulfill general requirements, outputting a color-color graph and a sky map.

Introduction

Active galactic nuclei (AGN) are unusually luminous galaxies that have supermassive black holes (SMBH) at their centers. There are various subtypes of AGN host galaxies, most notably quasars and Seyfert galaxies. The SMBH found in these galaxies accrete large amounts of mass, which causes them to emit large amounts of energy across all of the electromagnetic spectrum. Studying AGN properties helps to understand the origins of SMBHs and the early universe. This project will focus on characteristics of AGN in the infrared and optical bands. Quasars will be the main focus, but the general characteristics found in the project should apply to most AGN.

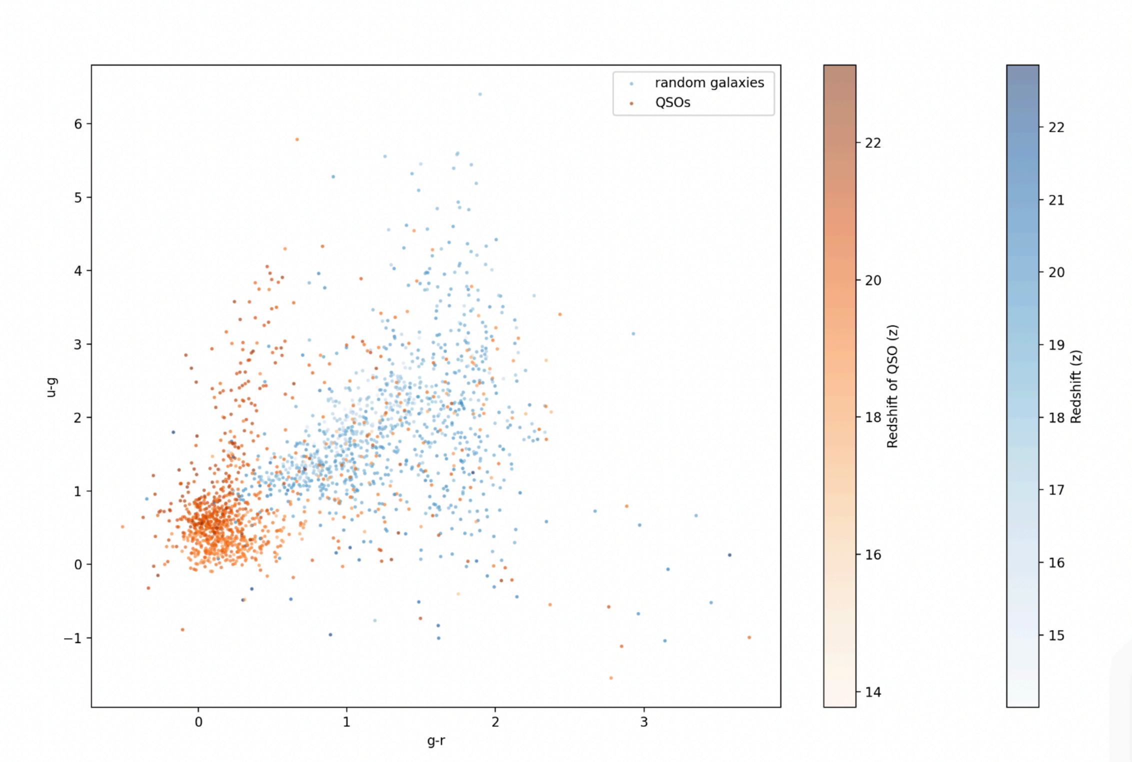
Quasars, or QSOs (Quasi-Stellar Objects) are brighter in both infrared and optical filters. Using data from WISE (Wide-field Infrared Survey Explorer), which photographed the sky in mid IR bands of 3.4, 4.6, 12, and 22 μm, or $W1$, $W2$, $W3$, and $W4$, it is possible to extract possible candidates for AGNs. One common method of finding an AGN is finding galaxies and stars that are brighter in mid-IR filters, eg. W1-W2 > 0.8 and W2-W3 > 2. AGNs appear brighter in infrared bands due to high quantities of dust and mass from the tori surrounding their centers. Therefore, a high W1-W2 or W2-W3 would indicate a lower magnitude (higher luminosity) in mid-infrared filters, which could be telling of the presence of AGN.

In optical filters, AGN will appear bluer because the radiation from the SMBHs are the highest in blue wavelengths. The temperature of quasars are unusually hot due to the process of forming an accretion disk, where fast moving gas and dust collide together and spin into the SMBH. Because of this hot temperature, the wavelengths emitted are shorter, which coincides with bluer wavelengths. Sloan Digital Sky Survey (SDSS) photographs the sky in 5 bands, *u, g, r, i , z.* U, g, and r are the most useful in this case. U (ultraviolet) is centered at about 354 nm and measures near-UV light. G (green) is centered at 477 nm and measures the blue-green part of the optical spectrum. R (red) is centered at 623 nm and measures red light. A lower u-g indicates a greater brightness in the UV light range, and a lower g-r indicates greater brightness in the blue-green light range.

This project consists of two different programs. The first one is designed to compare the traits of quasars to other galaxies and develop a generalized method of finding them in a random data set. The second one takes a coordinate and filters all objects within a radius of 500 arcseconds using these characteristics.

Finding constraints

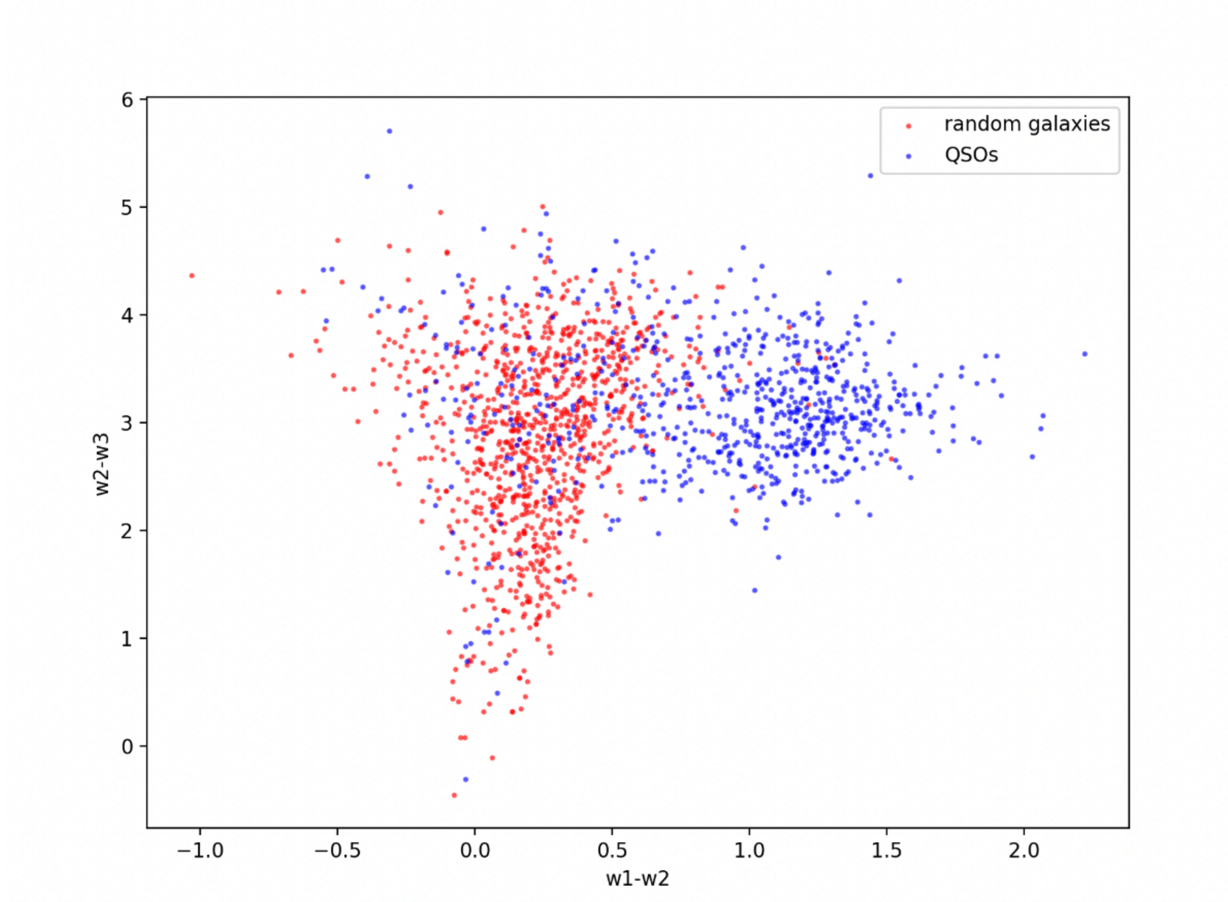
The first program takes datasets from SDSS (one with a thousand quasars and the other with a thousand random galaxies) and creates a color color diagram to show the difference in the colors of quasars and other galaxies. U-g represents how blue a galaxy is, while g-r represents how red it is. The graph below shows the relationship between these two while also taking redshift z into account.



From this graph, a conclusion can be made that **at z ~ 17 to 21**, quasars are much bluer than other galaxies, and that as redshift increases, u-g increases (the quasars get redder). Most of the quasars fall between about **-0.1 to 4 u-g and -0.3 to 0.5 g-r** compared to other galaxies.

Using the same coordinates within 10 arcsecs from the previous datasets to query WISE, a second color color graph showing the difference between W1-W2 and W2-W3 can also be created. W1-W2 measures the color difference between the near-infrared band W1 and the mid-infrared band W2, while W2- W3 measures the difference between the two mid-IR bands

W2 and W3. The graph below shows these differences.



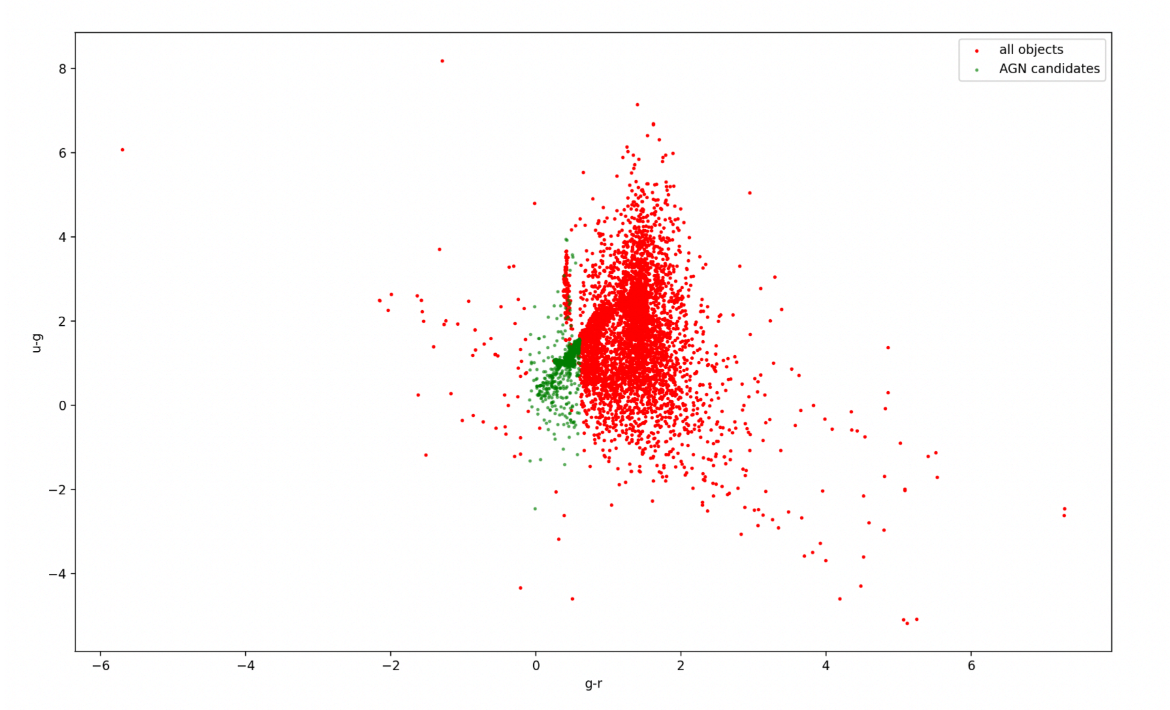
The most quasars appear from **W1-W2 > 0.8 and W2-W3 > 2.** Therefore, we can conclude that quasars tend to have a higher value of W1-W2 and W2-W3 and are more luminous in the mid-IR filters.

Finding possible candidates

The second program takes, as input, a coordinate in degrees, and sorts all objects found within a 500 arcsec radius of that coordinate based on if they fit the conditions or not. The specific conditions used are **z ~ 17 to 21, -0.1 to 4 u-g and -0.3 to 0.4 g-r, W1-W2 > 0.8.** W2-W3 was only used in the above graph to show a clearer difference and was not used as a condition. The final list of QSO/AGN candidates are then outputted to a separate file. The program also creates a color diagram of possible candidates in the optical filters using the constraints found above, and a sky graph in cartesian coordinates showing which stipulations were followed. The base coordinates used for this demonstration are ra=348.9563679, dec=1.2869483.

Color-color diagram in optical filters:

This diagram shows possible candidates that lie in the range 0 to 4 u-g, -0.1 to 0.4 g-r, and 14 to 23 in green, and all of the other galaxies and stars in red.



File outputted of possible AGN candidates:

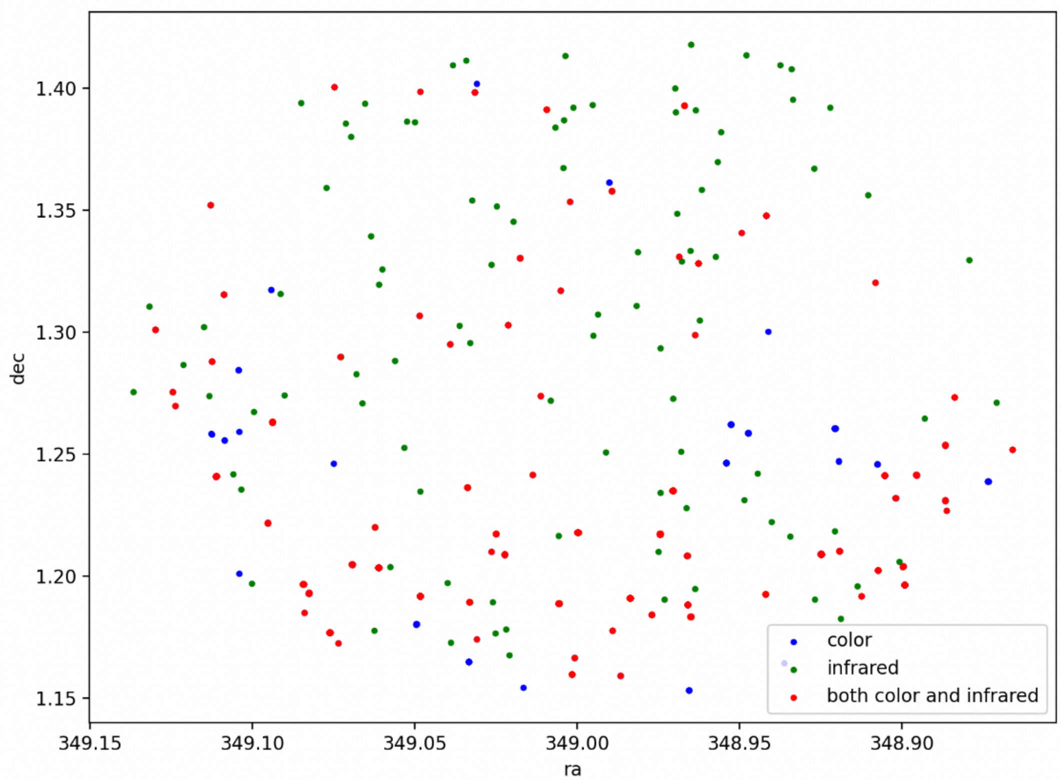
This text file shows all coordinates that are cross matched and fit both conditions.

finaltext.txt

```
ra,dec
349.03319,1.18923
349.03321,1.18925
348.94203,1.19255
348.94202,1.19254
348.94202,1.19255
348.94203,1.19256
348.94200,1.19255
348.94200,1.19253
348.94204,1.19256
348.94201,1.19255
348.94202,1.19256
348.94201,1.19256
348.94201,1.19252
348.94207,1.19253
348.94203,1.19252
348.94204,1.19255
348.94203,1.19254
348.94204,1.19252
348.94201,1.19253
348.94205,1.19254
348.94204,1.19253
349.02642,1.20991
349.07623,1.17686
349.07624,1.17686
349.07621,1.17686
349.07622,1.17686
349.07623,1.17685
349.07622,1.17685
349.07624,1.17685
```

Sky map in cartesian coordinates:

This map shows the location of each star/galaxy/QSO, with certain colors matching to which conditions were satisfied.



Test

To test accuracy, a set of 3000 random quasars, z=17-23 was selected by SDSS. Of those, 1880 were cross matched in a radius of 3 arcseconds to WISE. These quasars were then put through the program, and 1423 of them were shown to have fit both qualities. Out of the 3000 SDSS candidates, 2438 matched the u-g and g-r constraints, which is an 81.26% accuracy for the optical constraints. Out of the 1880 WISE candidates, 1423 were found to match the infrared constraints, which is a 75.69% accuracy. Overall, the program itself is about **75.69%** accurate. To make this program more accurate, more data would likely be needed, for example, from X-rays.

Conclusion

This project studied the various characteristics of quasars and general AGN in optical and infrared filters using cross-matched data from SDSS and WISE and found that quasars are brighter in blue optical filters and more luminous in mid-IR filters. Through the qualities found, a program to sort through a random dataset and return possible AGN candidates was formed.

Sources

- https://academic.oup.com/mnras/article/489/4/4741/5561523?login=false
- https://irsa.ipac.caltech.edu/cgi-bin/Gator/nph-dd
- https://www.icc.dur.ac.uk/~tt/Lectures/Galaxies/Images/Infrared/Regions/irregions.html#:~:text=Infrared%20is%20usually%20divided%20into,agreed%20upon%20and%20can%20vary.
- https://skyserver.sdss.org/dr1/en/proj/advanced/color/sdssfilters.asp
- https://skyserver.sdss.org/dr1/en/proj/advanced/quasars/whatare.asp