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ASTR 469 Project #3: Astronomical Catalogs

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ABSTRACT

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1. INTRODUCTION

Infrared astronomy is a type of astronomy which has been around since the 1960s, it is a well established method of studying the universe. Viewing the universe in this light allows us to see certain object in better detail, and allows us to study a large range of topics which include, but are not limited to, gas, dust, stars, planetary disks, galaxies, and the early universe. Most infrared light is blocked by the earth's atmosphere, which means that the best methods for capturing infrared light come from space telescopes or even telescopes in high altitude, such as the SOPHIA Telescope which is located on an airplane (Krabbe 2000). Although the data for this project were taking from ground based telescopes.

In this project, data has been taken from the 2MASS infrared survey, which provided the students with data from infrared point sources from the entire sky which could then be analyzed to look at different properties of different groups of stars. This then allowed the survey to produce a catalog of 500 million stars and galaxies (Skrutskie et al. 2006). It was taken by 1.3-m telescopes at Mt. Hopkins (shown in figure 1) and CTIO, Chile. The Mt. Hopkins Telescope is located at the Whipple Observatory in Santa Cruz, Arizona. It is the largest installation of the Smithsonian Astrophysical Observatory, outside of the main site in Cambridge, Massachusetts. The Whipple Observatory hosts many other telescopes as well, including a 6.5 meter telescope and different arrays.

Many studies have been conducted with the 2MASS data, for example, *Empirical Modeling of the Stellar Spectrum of Galaxies* (Li et al. 2005), *The 2MASS Color-Magnitude Diagram of the Globular Cluster Lyngå 7* (Sarajedini 2004), and *Tracing the Galactic anticenter stellar stream with 2MASS M giants* (Rocha-Pinto et al. 2003). These studies all go very in depth with the 2MASS data in order to analyse specific objects and arrive at important conclusions. For this project, however, instead of looking at specific already determined objects, we will be looking at a specific subgroup of object which stick out from the rest of the data and determine the type of object based on their properties. The best way to look at this data will most likely be a color-color diagram, which will then be able to help us indicate where certain stars lie in relation to the main sequence.

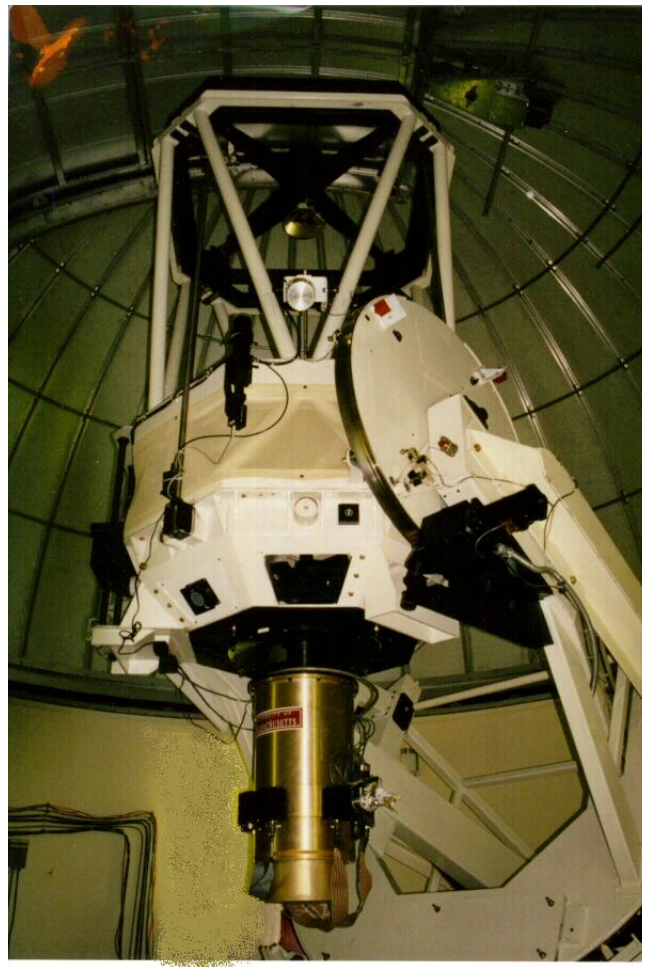

Figure 1. Image of the Mt. Hopkins Telescope. Credit: NASA/IPAC

2. METHODS

2.1. *Data*

This data was taken from 1997 to 2001 and observed in the J-band (1.235 µm), the H-band (1.662 µm), and the K_s-band (2.159 µm). The detectors were composed of 3-channel cameras using 256x256 arrays of HgCdTe detectors. This means that we are observing our data at infrared wavelengths and producing point source of hot gases. This means that most of the point sources are most likely stars, however, it is also possible that other objects were detected in this survey such as AGNs (Gogoi et al. 2018).

The initial step in this project was to download the data as a CSV file and import it in a way which was readable by python. For this project, we chose to use the pandas implementation to create dataframes of the data. This was a useful way to organize the data, as it was easy to compare different characteristics of the data and create graphs which helped create clean visualizations of the data.

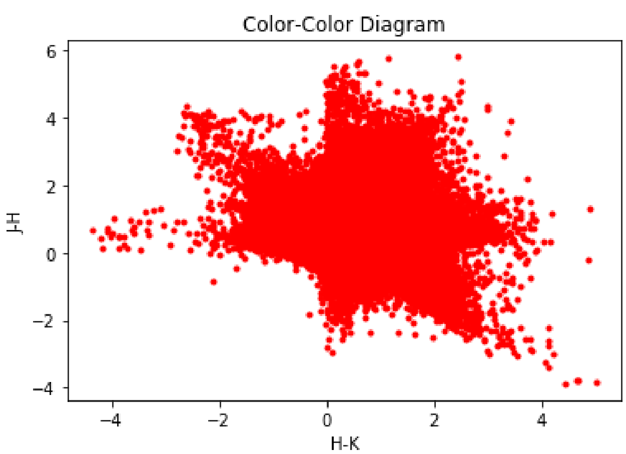

Figure 2. Color-Color diagram of the 2MASS data. Here you can see on the left side of the diagram, the group of stars which are distinctively separated from the others, and which we will be studying.

2.2. *Color-Color Analysis*

The first step in looking at the data was to create a color-color diagram and thereafter find a group of point sources which where different from the main data which we could then further analyze. Color-color diagrams are often used in astronomy to compare the apparent magnitude of stars at different wavelengths. Data is taken at specific wavelengths, and then the difference in wavelength is what is referred to as the color. This figure was created fairly easily, and as seen in figure 2 most of the data generally falls close to each other, with the exception of the group of source points in the left side with low H-K and J-H values around zero. There are other points which look like outliers, however, as they are in low numbers, they would not be as interesting for this study and probably should be studied in a different project. By analyzing the cluster of data in the left side, we will then be able to determine if there are any significant properties which could be interesting to this group, and determine if their cause for a low H-K value is at all related.

We can then select only the data which is in this group. For this project, we decided the cutoff point to be values from -4.5 to -3 for the values of H-K and from -2 to 2 for the values of J-H. This allows us a closer view of the selected population as seen in figure 3. In order to identify any trends in the data, a least-squares fit was performed using Numpy. If the data is a perfect fit, we would see the sum to be zero, however, for a poor fit, the sum is large. We would also be able to determine if it is a good fit by looking at how closely these points lie to the line, and if the trend is significant, almost all the points should follow this line.

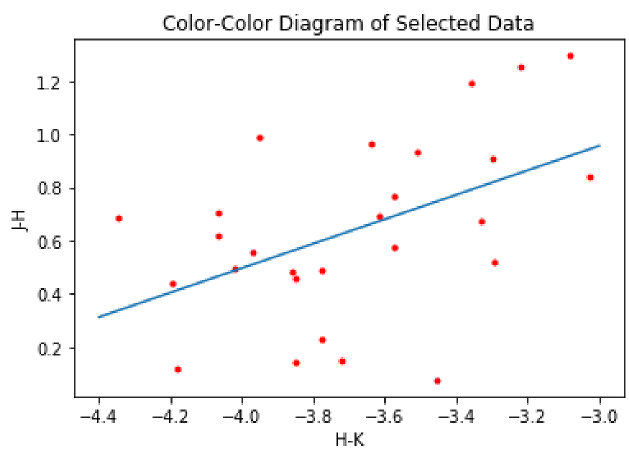

Figure 3. In this plot, we see the population we are studying in better detail with a least-squares fitted to the data.

3. RESULTS

We can determine from our data, that the population we have selected have low H-K values, however, the J-H values mostly lie around 0.6. The fit in this plot has a slightly positive linear increase but may not be a good indication of the actual structure, as we will mention in the discussion.

4. DISCUSSION

4.1. *Selected Population Properties*

Since the H-K ratio is very negative, this means that the point sources are on the side of a high temperature peak. Meaning that the point sources are hotter when emitting in this wavelength. In the J-H band, these stars do not have much a large difference in bands and therefore there is not much reddening at these wavelengths. Overall, this data suggests that our population mostly consists of hotter stars. Because our stars have a J-H of around zero, from looking at a main sequence plot, we can then determine that the stars are not particularly massive nor small, but are most likely to be very hot stars with average sizes.

Although there is no way to verify this in the context of this project, it is very possible that this group could be stars which are in between the process of dying and becoming white dwarfs. This would explain their very hot colors which come from the larger star's death, and their average size as they slowly start to become less and less massive until they are considered white dwarfs.

4.2. *Least Squares Fit*

The plot shown if figure 3 is rather interesting, since although in the original data there seemed to be a clear shape to everything, when we select the data alone, we see what looks more like a random scatter plot and not a definitive shape to the population. This is further evidenced when we fit a least-squares fit. The data does not closely fall into the line of best fit, and it is obvious that this line is not indicative of real structure in the data, but it is merely a statistical analysis which does not well describe the data. It is likely that this data does not have a specific structure, due to the fact that these are not main sequence stars. If these stars are in the process of becoming white dwarfs, as mentioned above, this somewhat random distribution makes sense with what we would expect to see, since different dying stars will have different masses, temperatures, and would be at different points in their life-cycle, therefore creating a pattern of data which is not easily described by a linear fit.

5. CONCLUSION

From our results, we conclude that the population we have selected have low H-K values and J-H values which lie around 0.6. The fit in this plot has a slightly positive linear increase but may not be a good indication of the actual structure, however this may not be important to the data since it was determined that it is likely that these point sources are stars which have fallen off the main sequence and are at the last moments of their life-cycle. However, this cannot be said with certainty and would need to be investigated further before such claims could be made.

6. ACKNOWLEDGEMENTS

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APPENDIX

Facilities: Whipple Observatory, Cerro Tololo Inter-American Observatory

Software: astropy (Astropy Collaboration et al. 2013; Price-Whelan et al. 2018), numpy (Harris et al. 2020), matplotlib (Hunter 2007), pandas (Wes McKinney 2010; Reback et al. 2021)

REFERENCES

Astropy Collaboration, Robitaille, T. P., Tollerud, E. J., et al. 2013, Astronomy & Astrophysics, 558, A33, doi: 10.1051/0004-6361/201322068

Gogoi, R., Shalima, P., & Misra, R. 2018, New Astronomy, 59, 21, doi: https://doi.org/10.1016/j.newast.2017.08.006

Harris, C. R., Millman, K. J., van der Walt, S. J., et al. 2020, Nature, 585, 357, doi: 10.1038/s41586-020-2649-2

Hunter, J. D. 2007, Computing in Science & Engineering, 9, 90, doi: 10.1109/MCSE.2007.55

Krabbe, A. 2000, Airborne Telescope Systems, doi: 10.1117/12.389103

Li, C., Wang, T.-G., Zhou, H.-Y., Dong, X.-B., & Cheng, F.-Z. 2005, AJ, 129, 669, doi: 10.1086/426909

Price-Whelan, A. M., Sipőcz, B. M., Günther, H. M., et al. 2018, The Astronomical Journal, 156, 123, doi: 10.3847/1538-3881/aabc4f

Reback, J., McKinney, W., Jbrockmendel, et al. 2021, pandas-dev/pandas: Pandas 1.2.1, Zenodo, doi: 10.5281/ZENODO.3509134

Rocha-Pinto, H. J., Majewski, S. R., Skrutskie, M. F., & Crane, J. D. 2003. https://arxiv.org/abs/astro-ph/0307258

Sarajedini, A. 2004, AJ, 128, 1228, doi: 10.1086/422736

Skrutskie, M. F., Cutri, R. M., Stiening, R., et al. 2006, AJ, 131, 1163, doi: 10.1086/498708

Wes McKinney. 2010, in Proceedings of the 9th Python in Science Conference, ed. Stéfan van der Walt & Jarrod Millman, 56 – 61, doi: 10.25080/Majora-92bf1922-00a