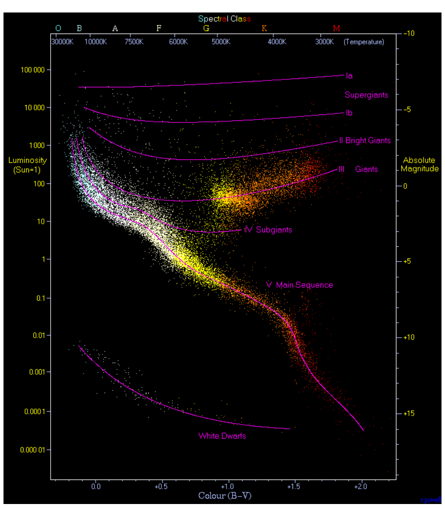
Introduction

The project that we are going to do is finding out some important data and information about the stars in some clusters by getting the HR diagrams of them and finding the positions of some certain stars in the plot. Until now, we have chosen 3 clusters, one is the Messier 2, which is also called M2, the second is the beehive cluster, which has another name M44, and the final one is NGC 2070. The reason we choose these three clusters is that they have significantly different ages: the age of Messier 2 is about 13 Gyr, which is very old; the Beehive Cluster is about 900 million years old, much younger than the Messier 2 but still old; and the cluster NGC 2070's age is only about 1.5 million years, which means it is very young. In that case, we are planning to get the HR diagram by using Python processing data we get by using Astroart aligning all of the images we get from observing by telescope in different filters: including Bessel Blue, Bessel Visible, SDSS Ultraviolet, SDSS Green, SDSS Red, and SDSS Infrared. After that, we will find the corresponding positions of some stars in the two clusters on the HR diagram in order to get some useful information about them. Finally, we will compare and contrast the three clusters, and also the stars inside them.

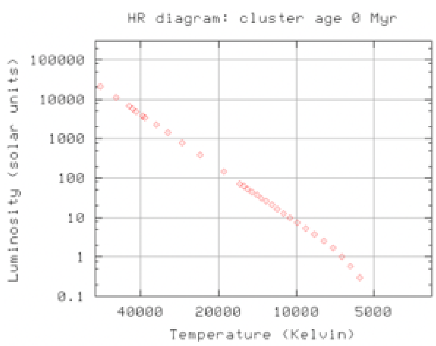
Historical Background:

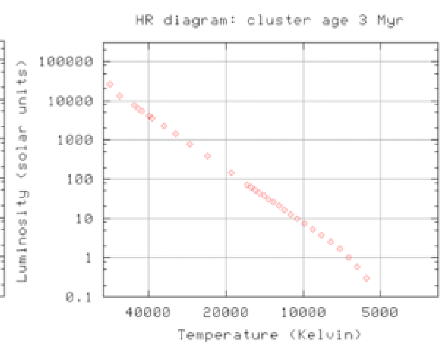
HR diagram, whose complete name is "Hertzsprung- Russell Diagram" because it was developed independently by Ejnar Hertzsprung and Henry Norris Ruseell in the early 1900s. It is a diagram that plots the relationship between the luminosity of some stars and their temperature, or the color against their absolute magnitude. From the diagram, the scientists are able to get the internal structure and the stage of revolution of a star by observing the position of it in the HR diagram because the revolutionary stages of stars are dictated by their internal structure and how they produce energy, which means that during each stage of revolution, there is a corresponding change in the temperature and luminous intensity of the star. In that case, when a star evolves, its position also can be seen changing from one region on the diagram to another. In one HR diagram, we can see revolutionary stages of a lot of stars, and there are mainly 3 regions of the HR diagram. The first one is the main sequence, which stretches from the upper left to lower right and dominates the whole diagram. It is a stage where stars burn hydrogen inside their cores into helium and it occupies 90% of the life of stars. The second one is the region above the main sequence, which is occupied by red giant and supergiant stars. In this revolutionary stage, the stars have already exhausted all of the hydrogen and start to burn helium and other heavier elements. The final region is the bottom left part of the HR diagram, which is occupied by white dwarf stars, which are very hot but with low luminosity due to their small size. All in all, with the help of HR diagrams, scientists are able to observe the properties of a collection of stars and it is especially useful to learn about the stars in a cluster: compared with the distance between us and a cluster, the distance between stars inside the cluster is just approximately negligible, which means that all of the stars can be seen as having same distance from us.

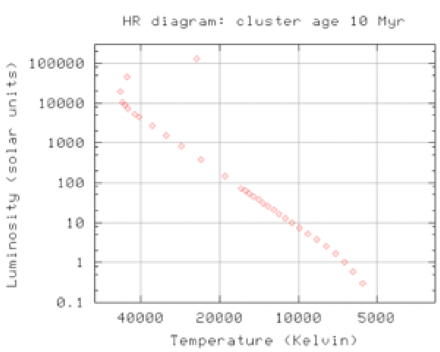
Here is one example of HR diagram:

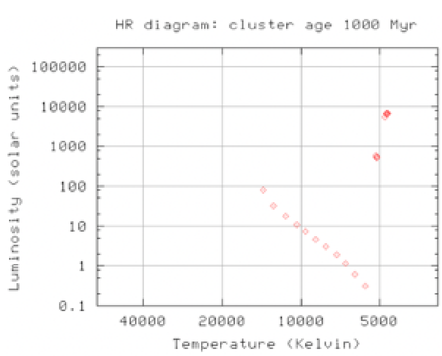


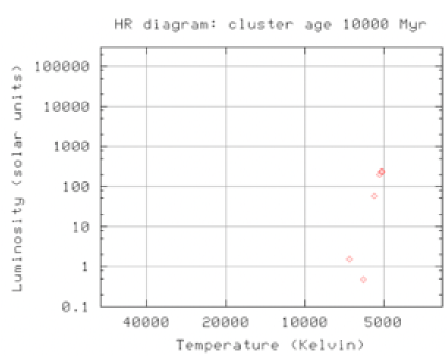
We also have gained a series of HR diagrams for clusters with different ages. For the clusters with age less than 10 Myr, most of the stars are in the main sequence; when a cluster is getting older, we are able to see the turn-off point; and finally when the cluster is very old, there just be few stars in the main sequence of the HR diagram.









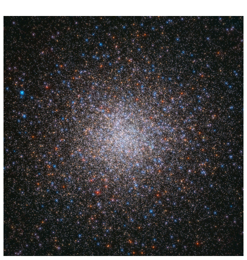


Clusters chosen for project:

The cluster Messier 2 is one of the clusters that we use as the topic of our new project. It is a globular cluster in the constellation Aquarius and 5 degrees north of the star Beta Aquarri. It is also called M2 and it was firstly discovered in 1746, by a French astronomer, whose name is Jean-Dominique Maraldi and at that moment, he was observing a comet with another astronomer Jacques Cassini. However, this cluster is not named “Maraldi 2”. Instead, it was called “Messier 2”, for which it was rediscovered by another French astronomer whose name is Charles Messier in 1760. Nevertheless, even at that time, this cluster was still thought to be a nebula and there were no stars associated with it. Finally, in 1783, William Herschel, who is a German-born British astronomer, resolved individual stars in the cluster for the first time, which makes me feel that it is really weird because this cluster should be named either “Maraldi 2” or “Herschel 2”.

The most significant reason we choose M2 as one of the clusters for our new project is that it has a high level of visibility: it is visible even to the naked eye when being under extremely good conditions. What is more, even a binocular or a small telescope is able to identify it as non-stellar and larger ones can even resolve individual stars, the brightest of which are of apparent magnitude 13.1. In addition, it is also one of the known largest globular clusters, with 175 light-years in diameter, and one of the oldest globular clusters associated with the Milky Way galaxy, which means that the study of this cluster may be really helpful for us to know about the globular clusters. It has about 150,000 stars, including 21 known variable stars (the stars whose brightness as seen from Earth changes with time), and the brightest stars inside the cluster are red and yellow giant stars.

Here is one image of Messier 2:



Another cluster of stars that we are going to study is just the Beehive cluster, which is also known as Praesepe, M44, NGC 2632, or Cr 189. It is one of the open clusters in the constellation Cancer and also one of the nearest open clusters to Earth (which is one of the most important reasons that we decided to choose this cluster as a topic of our project). It holds a larger number of stars than those nearby bright open clusters. Under dark skies, it looks like a small nebulous object to naked eyes. Since it has such a high level of visibility, people in the ancient time were also able to see it. At that time, it was seen as a manger that two “donkeys" are eating from (the two donkeys are just the two adjacent stars by ancient Greeks and Romans: the two adjacent stars are known as Asellus Borealis and Asellus Australis and the two “donkeys" are regarded as the two being ridden by two gods, Dionysos and Silenus, in the battle against the Titans. A Greek astronomer Hipparchus referred to the cluster with the name “Nephelion ", which means “Little Cloud " in his star catalog and another astronomer named Clausius Ptolemy included Beehive Cluster as one of the seven “nebulae”, describing it as “The Nebulous Mass in the Breast (of Cancer)”. What is more, it was also called the cluster Achlus and “Little Mist” by the poet Aratus. In ancient Chinese astrology, it was named as “Gui Xiu ", which is the 23rd lunar mansion. Since it is nebulous, the skywatchers just saw it as a ghost (which in Chinese is read as “Gui”) riding in a carriage and likened its appearance to a “cloud of pollen blown from willow catkins”, which is also known as “Jishi qi”, which means the “Exhalation of Piled-up Corpses".

The Beehive Cluster has a right ascension 08 hour and 40.4 minute, and its declination is $19^{\circ}59^{'}$. The distance between it and the Earth is 610 light years (in the cosmos, it should not be a large value), its apparent magnitude is 3.7, and its mass is about 500 to 600 times that of the

Sun. The estimated age of this cluster is about 600 to 700 million years, which means that it is much younger than the Earth, which is already more than 4.5 billion years old.

Here is one image of Beehive Cluster:

The final cluster that we choose for our project is just the NGC 2070, which has another name Caldwell 103. It is a large open cluster in the center of the Tarantula Nebula. The central condensation of this cluster is the star R136, which is one of the most energetic stars that we have known. The apparent magnitude of this cluster is 7.25, and it is very far away from our earth, about 157 kilo light-years.

Here is one image of NGC 2070:

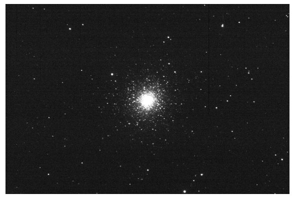
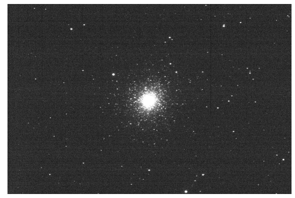
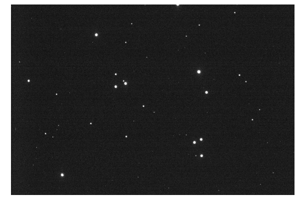
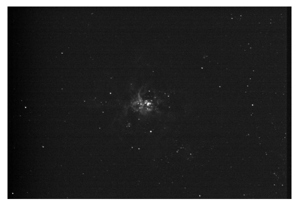
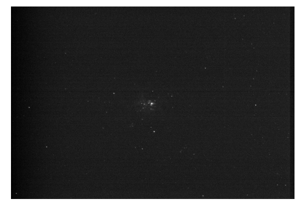
Importance of our project:

One of the most important things about celestial bodies is just their ages. From the HR diagram, we can know a lot of important information about the stars plotted on it. After constructing an HR diagram, we can just estimate many important properties of the stars, including the diameters, masses, ages, and evolutionary states of them. By analyzing the different regions on the HR diagram, we can know how many and which stars are blue giants, which ones are red giants and red supergiants, which ones are white dwarfs, and which ones are in the main sequence, in other words, which ones are still at the beginning or middle of their ages (generally, this part contains most of the stars).

Data collections:

We have done the data collection: we submitted the observation request sheets for the three clusters and gained a set of images, which are uploaded onto Google Drive. However, the problem is that we are still not able to get the HR diagrams now even though we already know the codes. The thing is that we need to do some more work to get the data from the images uploaded on Google Drive. What is more, we have wasted a lot of time on another project while there is not much data for that one, which means that now we do not have enough time to finish all of the tasks that include getting the plot and analyzing it. In other words, we are unable to reach any conclusion yet.

After we gained the images from red, green, and blue filters, we summed all of the 10 images in each filter and get the base images using Astroart:

	red	green	blue
M2			
Beehive Cluster			
NGC 2070			

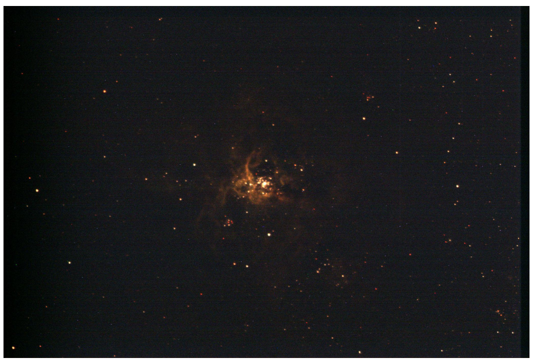
Then after we align the base images for each cluster, we finally get a set of tricolor images that can be used to get our HR diagrams.

Summary images:

Final image of M2:

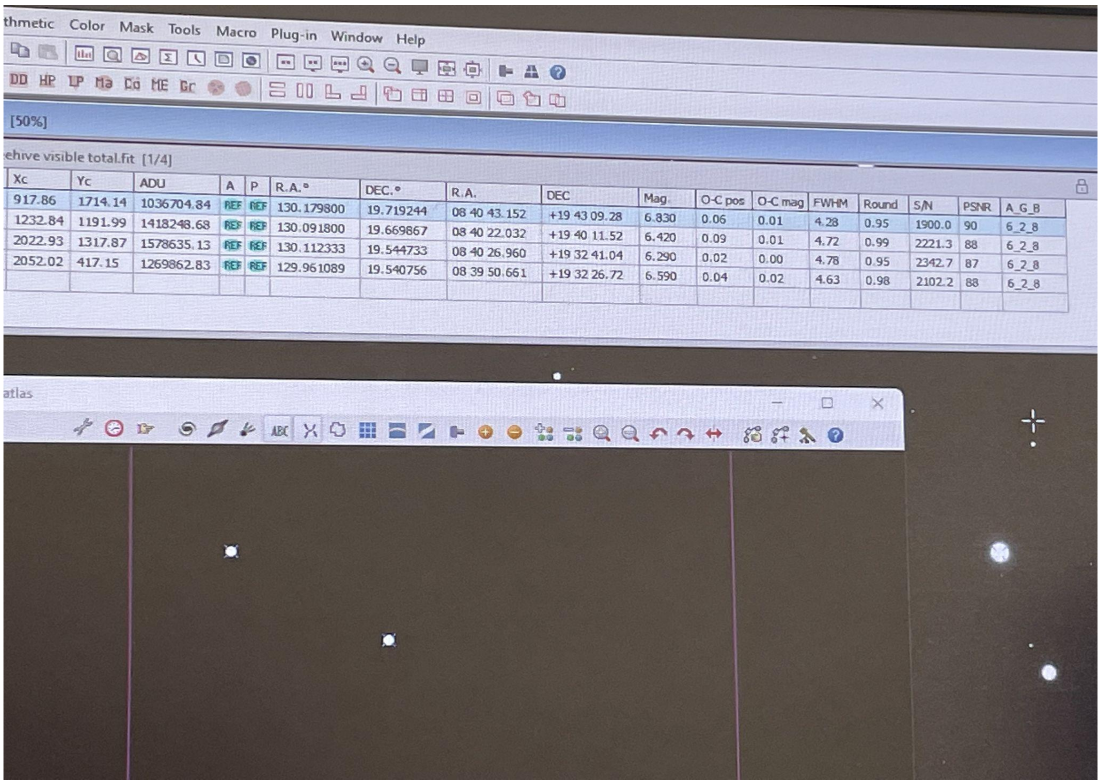
Final image of Beehive Cluster:

Final image of NGC 2070:



We can see that the stars in the M2 are very close, most of which are at the center of the image, which is really bright, while those in the Beehive cluster are relatively far away from each other Referring to the NGC 2070, even though many stars are also at the center of the image, the visibility is much lower, which may contribute to the fact that this cluster is too far away from the earth. What is more, all of the images are more occupied by the color red instead of blue. It makes sense for M2 and Beehive Cluster because they are relatively old. Nevertheless, the image of NGC 2070 should not be like this: the NGC 2070 is very young, which means that it should be much more blue. The possible reason we found out is also that this cluster is too far away from earth so that images we got should be that of the nebula in which contains the NGC 2070 cluster, while even though NGC 2070 is relatively young, the clusters nearby are not. What is more, the reason can also be that it is difficult for the blue light to reach earth so that even though the image should be blue, it does not look like this. Maybe if we observe NGC 2070 in space, we can get a series of more correct images.

Next, by using the Filters- Stars and Tools-Star Atlas in the Astroart, we get some useful information about 4 stars in each cluster. Here are our results:



Xc	Yc	ADU	A	P	R.A.°	DEC.°	R.A.	DEC	Mag.	O-C pos	O-C mag	FWHM	Round	S/N	PSNR	A_G_B
917.86	1714.14	1036704.84	REF	REF	130.179800	19.719244	08 40 43.152	+19 43 09.28	6.830	0.06	0.01	4.28	0.95	1900.0	90	6_2_8
1232.84	1191.99	1418248.68	REF	REF	130.091800	19.669867	08 40 22.032	+19 40 11.52	6.420	0.09	0.01	4.72	0.99	2221.3	88	6_2_8
2022.93	1317.87	1578635.13	REF	REF	130.112333	19.544733	08 40 26.960	+19 32 41.04	6.290	0.02	0.00	4.78	0.95	2342.7	87	6_2_8
2052.02	417.15	1269862.83	REF	REF	129.961089	19.540756	08 39 50.661	+19 32 26.72	6.590	0.04	0.02	4.63	0.98	2102.2	88	6_2_8

Messier 2 Reference Stars

	X	Y	Mag
1	714.2 px	343.0 px	11.02
2	1167.4	837.9	10.08
~~3~~	~~1947.8~~	~~2097.3~~	
3	2355.7	316.1	10.32
4	1945.3	2099.7	9.92

Beehive cluster Reference stars

	X	Y	MAG
1	937.1	419.0	6.83
2.	1252.0	933.5	6.42
3.	2042.1	806.1	6.29
4.	2072.7	1710.2	6.59.

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NGC 2070 Referene stars.

	X	Y	Mag.
1	589.3	469.9	20.33
~~2~~	~~1125.0~~	~~908.9~~	
2	1569.9	1332.3	19.96.
3	2136	631.0	20.03
4	2694.9	1041.3	19.79

- Calculate S/N For
- Plot of $\boxed{\text{S/N vs Time For Diffent Mag.}}$

What we are going to do:

The first thing we need to do is to get more data so that we can finally get the HR diagrams of the three clusters. After that, once we get the HR diagrams of the clusters, we will choose four stars in each cluster and find their position on the HR diagrams, getting some useful information such as the ages, masses, distances from earth, and revolutionary states of them. Finally we are just able to do the comparison and find out some conclusions from the plots and the positions of the stars, while now we are even unable to get the plots, not to say doing the analysis and drawing the conclusions. Nevertheless, now there is a huge problem for us, which is that the HR diagrams of the clusters we have got are said to be incorrect. If we have a lot more time to do this project, we should be able to draw more conclusions while now all we can get are just these.