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Identify the Stars in the M13 and their Motion Across the Sky

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Abstract. In this project, we decided to collect and analyze the data about this cluster from several perspectives. Due to the consideration of distance, we used python to simulate their motion trajectory and position and choose Gaia data release as our data source. Hence, we listed four diagrams out of those data. By analyzing these graphs, we can get some information, such as the distance between M13 and earth and the age of those stars.

Keywords: Stars, M13, Astronomy.

1. Introduction

M13 cluster, also known as NGC 6205 is a globular cluster with about 300000 stars in the constellation Perseus. The study of the nebula is of extraordinary significance to the study of the evolution of stars. With the development of astronomy, the mysteries of the universe are gradually revealed, which make an important difference in human civilization. Studying the feasibility of Gaia can provide a new way of thinking for our astral research.

Figure 1. M13 cluster.

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2. Distribution of M13

2.1. Relative position of stars in M13

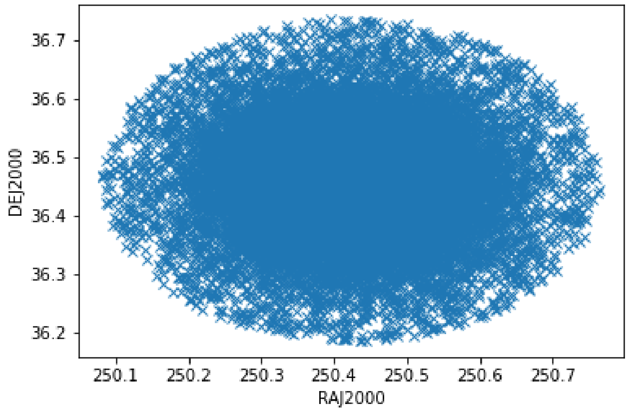

Figure 2. Relative position of the stars in M13.

As can be seen in figure 2, we are aiming to disclose the relative position of the stars in M13. Usually, only one graph in each group is enough to represent. However, the reason we have two versions of the graph is that not all the dots in the chart are part of the cluster M13, so under the condition of the histogram of the parallaxes that suggests a peak of about 0.1 mas, corresponding to 25000 lightyears, we successfully create the second images, which shows far fewer dots than the first image in the first group.

In our first graph, two subjects are mentioned: the RAJ2000 and the DEJ2000. These are the acronym of the name: Right Ascension Julian year 2000, and Declination Julian year 2000. The Right ascension refers to the longitude-like celestial coordinate that varies from 0-24hrs, taken from a reference point of the vernal equinox, and declination means the angular distance of a body north or south of the celestial equator. The Julian year refers to a year with exactly 365 days divided into 12 months, used in the Julian calendar, unlike the tropical year, which has 365.242 days for each [1]. Then the x-axis and y-axis of our first group of graphs is the scale of the position in the cluster, and the chart plots the stars in the cluster. It is a map. By analyzing the graph, we can see that most of the dots scatter near the center. The stars in the cluster tend to stay deeper into the cluster, and the more the position is to the edge of the cluster, the fewer stars will it has. The map shapes into an oval centered on M13, with a radius of 0.275 degrees. That is the area we select from the Gaia catalog, which contains both the stars of M13 and others that are not included in M13, and that's why we need to exclude those stars from the research, or there may be an error for our result.

2.2. Motions of stars in M13

In our next image, the figure 3 has the same range and the shape to the first one, but it shows a different subject. The graph is composed of lines in different directions and lengths. These arrowheads represent the stars' motion, the direction of the star's motion, and the size of the arrowheads are related to the proper motion angle, which is studied in our next image: the right motion angle. There are also two images in this group, with one which has no selection done and another which is dealt with the proper motion angle histogram that has a peak around -140 degrees, resulting in a selecting range of -130 to -150 degrees [2]. When comparing the two images, we found an interesting consequence: the resulting arrowheads are not only like each other in directions, but also their absolute magnitude. We create the second group to reduce the error and make the result of the first image more precise.

Under the selections on the parallax and the proper motion angle, we successfully exclude the stars that do not belong to the cluster and make the research's result more authentic. Most of the stars remaining will be likely to be member of cluster M13.

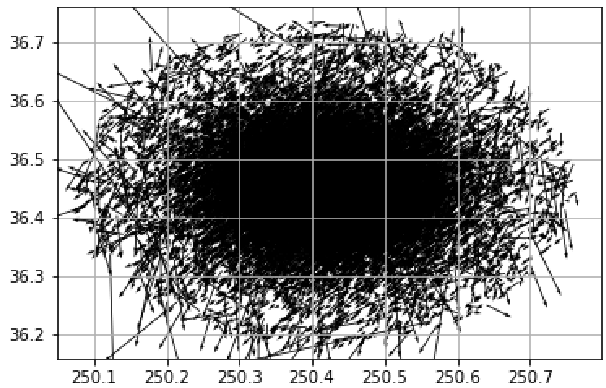

Figure 3. Motions of stars in M13.

3. Proper motion angle

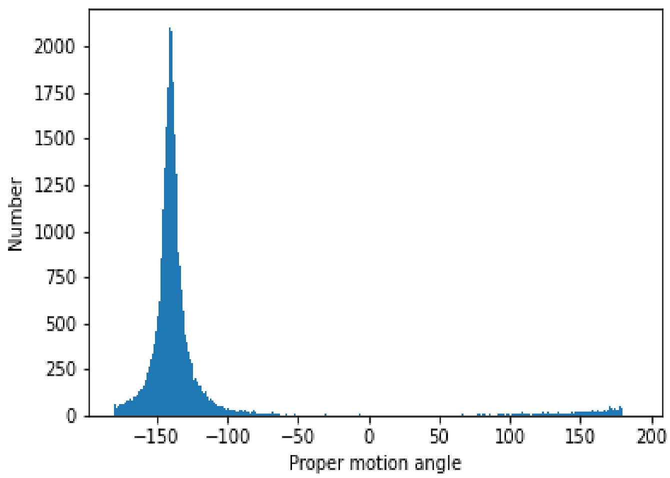

Figure 4. Proper motion angle.

Firstly, the parallax image is modeled, and its model is analyzed. After searching the data on the Internet, we can get a feature: the disparity of stars and star clusters except the sun is generally within 0.5[3]. This data is consistent with the characteristics of left and right concentration and rapid growth at the 0 value of the obtained image. However, the results obtained by the angular second difference are somewhat different from those obtained by the formula (D (PC)=1/ P (arcsec)). However, the extreme disparity value around 0 is also very similar to our calculated value of 0.022494Arc milliseconds. Therefore, we initially suspected that it was an error in model building, however, when we checked the program and substituted the results into the calculation, we came to this conclusion, and we have mixed units 0.022494 milliseconds, which is 0.022494 milli arc seconds, so the distance to M13 is 50,000 PC or 163,000 light years.

4. Parallax

The graph of proper motion Angle is analyzed. As can be seen in figure 5, its peak value is between -

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150 - -125, that is, right ascension 16H 41.7m and declination [11] +36°28 '. This suggests that it is not moving in the same plane as the Earth, but at a large deflection Angle. It is suspected that another large cluster should be nearby to pull it. During subsequent investigations, we suspected that Abell 2151[4] was nearby pulling it. But the next data show that Abell 2151 is a cluster of galaxies about 500 million light-years away. It may look close to M13 in the sky, but they are not actually close to each other. M13 is in the halo of our Milky Way galaxy, it lies 22kpc from the Milky Way and orbits almost perpendicular to the galactic plane.[5] So the primary gravitational influence on M13 will be the stars in our galaxy. This confirms our idea that other clusters are pulling on it, too. The higher peak (around 2015) indicates that the cluster is moving toward the red end of the spectrum, which is moving away from the solar system.

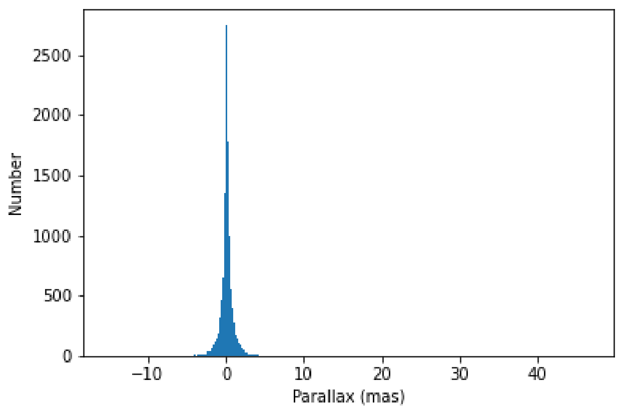

Figure 5. the peak of parallax.

According to our data, the value of parallax is around 0.127. We used this value to calculate the distance between M13 and the Earth (Figure 6).

distance to star in parsecs
= 1/parallax angle in arcseconds

Notice how small the parallax to the nearest star is: ~1 arcsecond

1 arcsecond = 1 arcsec = 1”
= 1/3600 of a degree.

Figure 6. Equation.

$$D = 1/\ (0.1 * 10^{\wedge} - 3)\ = 7.874 * 10^{\wedge}3 parsec = 25669.29133 ly$$

5. Radial velocity method

A popular method of exoplanet detection, known as the Radial Velocity, is also called Doppler Spectroscopy [6]. This method relies on observing the spectra of stars for signs of “wobble”, where the star is found to be moving towards or away from Earth. This movement is caused by the presence of planets, which exert a gravitational influence on their respective sun (Figure 7).

Essentially, the Radial Velocity Method consists not of looking for signs of the planets themselves, but in observing a star for signs of movement. This is deduced by using a spectrometer to measure the way in which the star's spectral lines are displaced due to the Doppler Effect, like how light from the star is shifted toward the red or blue end of the spectrum (redshift/blueshift).

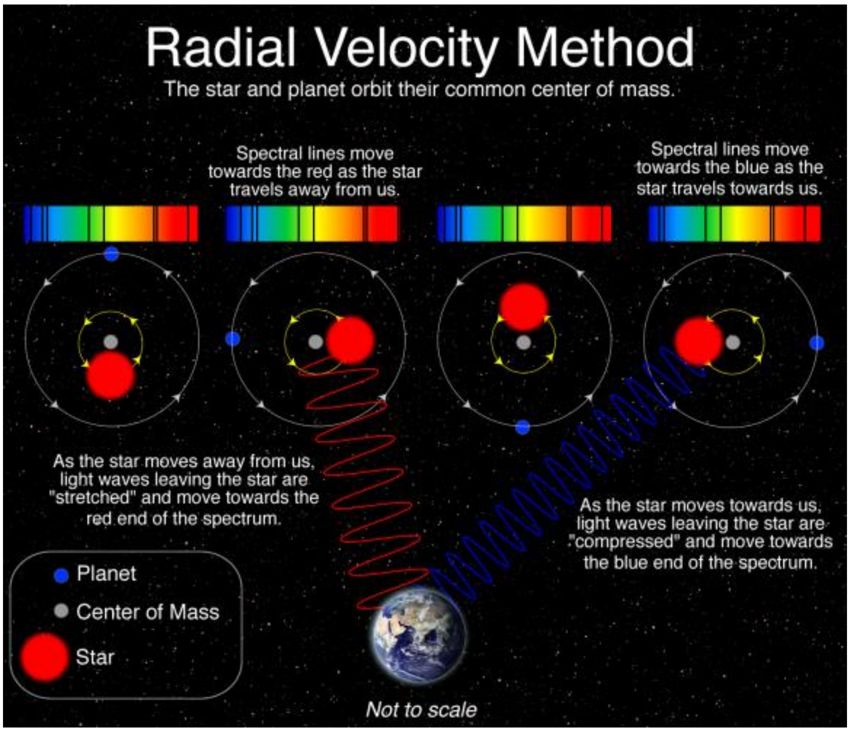

Figure 7. Radial Velocity Method.
(Image from the universe today https://www.universetoday.com/138014/radial-velocity-method/)

As we observed figure 8 below, we found that the plots has zero radial velocity, which means Gaia did not measure any radial velocities for stars in M13 [7]. The Simbad database, on the other hand, indicates a radial velocity of -244.49 km/s, which was measured from the ground. Thus M13 is moving toward our solar system, What causes this blueshift? Because of gravity, we first wondered if the Earth was affecting the radial velocity, but through calculations, we found that compared to M13, the Mass of the Earth was too small and too far away, and the calculated was much smaller than the value in the data. So we're wondering if other galaxies around M13 are attracting it. By looking up the data, we found that there is indeed a galaxy called NGC 6207 near M13, which affect the radial velocity of M13.

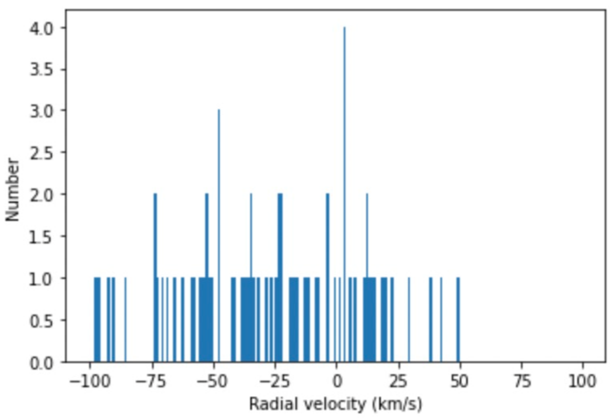

Figure 8. Results.

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6. H-R diagram

The full name of the H-R diagram is the Hertzsprung Russell diagram (Figure 9). From the diagram, the y-axis shows the absolute magnitude, and the x-axis shows the color index of stars. In order to know the age and evolution process of stars in M13 cluster, we used python to run a diagram showing the stars' luminosity and color distribution.

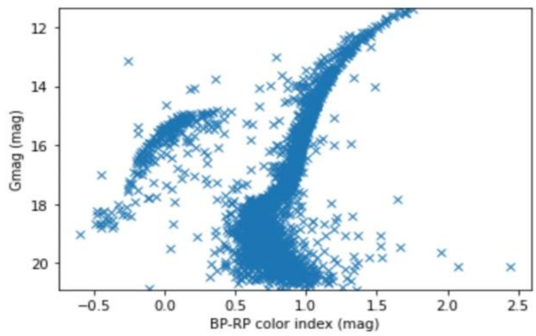

Figure 9. H-R diagram.

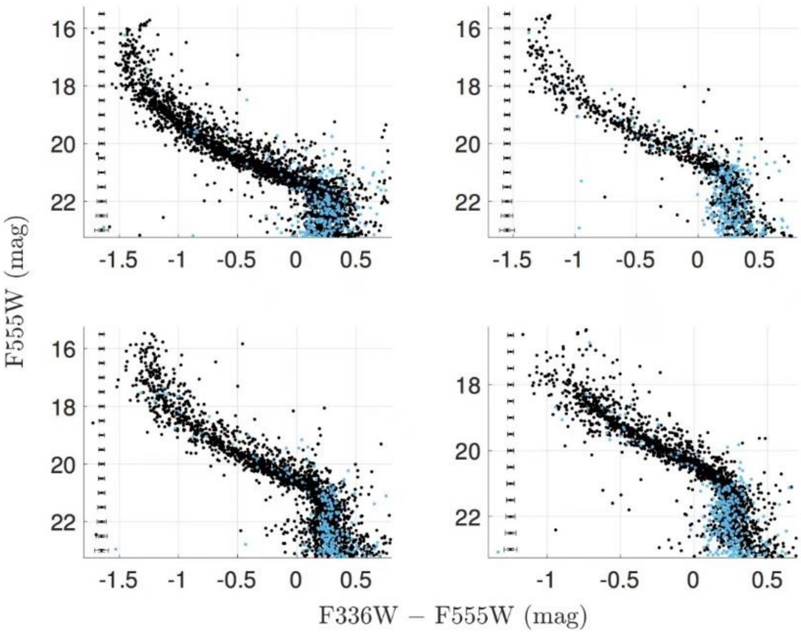

Figure 10. H-R diagram that respectively represent NGC 330(upper left), NGC 1850(upper right), NGC 1818(lower left) and NGC 2164(lower right).
(Image credit: The Astrophysical Journal, Volume 844, Number 2 Citation Chengyuan Li et al 2017 ApJ 844 119)

In this diagram, most stars are concentrated on the belt from the upper left corner to the lower right corner, which is the central sequence belt of M13 cluster. In the process of time, dying stars will leave the main sequence zone and moves to the upper right part of the diagram. Therefore, the upper right region is the region of red giant stars and red supergiant stars. Those stars contain relatively low temperature which is only about 5000 kelvins but have high luminosity. It can be understood that the red giant star is in the senile stage of a main sequence star. Diverse from the red giants, blue giant stars are high quality main sequence stars with large internal nuclear reaction rates, which can be regarded as oversized stars. Blue giant stars contain extremely high temperatures which can be up to 10000 kelvins. For their high temperature and luminosity, they are concentrated in the left upper region.

From the information above, we can infer that M13 cluster is actually an aging cluster. For a young cluster, most of the stars should be concentrated in the left half region but for M13 cluster most stars are shifted to the right side and the main sequence turn-off point is about the index 0.5 to 1.0, of magnitude 19.

Here is a picture of four H-R diagrams that respectively represents NGC 330(upper left), NGC 1850(upper right), NGC 1818(lower left), and NGC 2164(lower right) (Figure 10).

These clusters are relatively young, as a result, it seems that there are no red giant stars present in this picture and the main sequence turn-off point are all over 20 for the magnitude. The differences between old clusters and young clusters are obvious.

Through this formula, we can get the absolute visual magnitude is about 4.52(19+5lg (32.6/25669))

$$M = m + 5log_{10}\frac{d_0}{d}.$$

Therefore, we can get the age of M13 cluster is between 7.1*10^9 and 2.9*10^10 years, most likely to be about 1.3 billion years old.

H-R diagrams and age of stars are shown in figure 11.

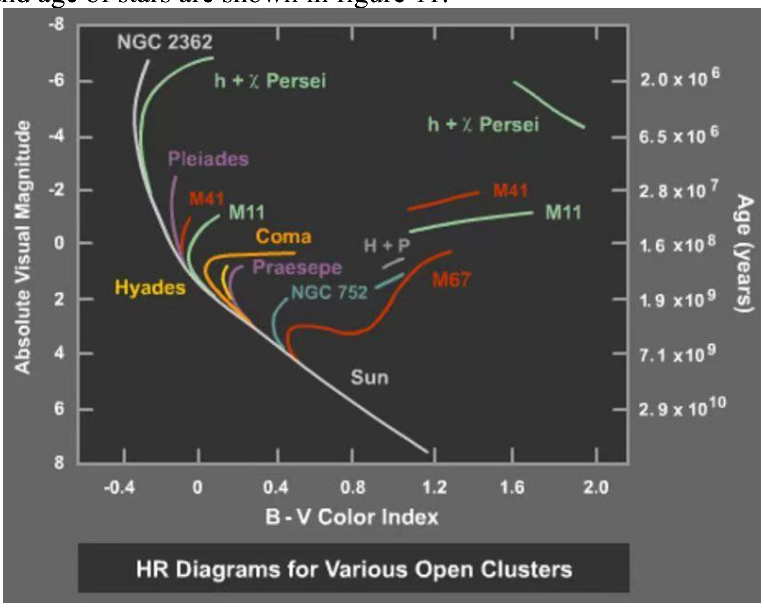

Figure 11. HR Diagrams for Various Open Clusters (Image credit: Mike Guidry, University of Tennessee, from e-education.psu.edu.)

7. Conclusion

7.1. Result

The four diagrams can clearly show some information about the M13 cluster. From the first graph, we can know that this cluster is obviously of an oval shape. On this basis, we set another graph that not only shows the distribution of the stars but also shows the direction of motion of those stars with different velocities. Then it comes to the third graph, which is a histogram that can exhibit the concentration of stars with different proper motion angles. Besides, we successfully exclude those stars that do not belong to the M13 cluster. This graph shows M13 cluster was not moving in the same plane as the earth but at a larger deflection angle which can prove there should be another cluster affecting it. From the parallax graph, most stars are with small parallax angles, even almost zero due to the far distance from earth. Using the parallax value (around 0.127), we can still calculate the distance and the result turns out to be 25669.29133ly. When we used the radio velocity method to make the fifth graph, we surprisingly found

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most values are concentrated at the negative half axis and there must be something that caused the blue shift of this cluster. Finally, we find there is indeed a galaxy called NGC 6207 near M13 attracting it. From the last picture, the H-R diagram of M13, we determined that its age is about 1.3 billion years by comparing it with relatively young clusters and calculating its absolute magnitudes. Most of our data matches the data that we have searched. However, there are some differences, for example, the distance we searched is about 22000ly, the brightness is about 5.7. Besides, the age of the M13 cluster has always been controversial. But we think these differences are within the acceptable error range because our data are not precise enough.

7.2. Analysis

According to the data obtained from our first figure, we found that the shape of M13 is roughly an ellipse, and its major axis and semi-major axis are also close to our theoretical values. It can be said that the model drawn with the Gaia datasheet has a certain accuracy. Our third graph also fully matches and proves this. The proper motion angle of the M13 is mostly concentrated at -150 degrees. From this, it can be said that his shape does tend to be elliptical. Our fourth picture simulates the time difference of M13, which is approximately equal to 0.127. We bring it into the distance formula for verification, and the result is within the specified error range. So, using Gaia to simulate parallax can also get a reasonable value. Our fifth graph depicts the radial velocity of the M13. Since most of the data is concentrated on the negative semi-axis, we speculate that M13 is moving toward Earth. The final HR diagram can help us estimate the age of M13 based on its absolute magnitude. By calculations, we conclude that the age of M13 is about 16 billion years old. It is currently in its prime gram.

Acknowledgement

All the authors contributed equally to this work and should be considered as co-first author.

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