

# Creating an HR Diagram of NGC 3532 and Determining Several Key Components

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## ABSTRACT

We present a creation of the HR-Diagram of NGC 3532 with the age and distance of the cluster, along with some other components of our cluster, including the space velocity of our star and several organized plots of our data. We used data from SIMBAD to create, first of all, a color-color diagram, which we then used isochrone fitting technique to find the distance. Then, using the color-color diagram, we created the HR-Diagram, and found the age using its turnoff point. Our calculations found that the distance was around 416.87 parsecs, and the age was around 328.7 million years old. We also used data from GAIA, which we used to find some of the components we needed for the space velocity of our star. Overall, this research will add important information onto this cluster, as the data on this cluster is relatively lacking compared to clusters like M12, mainly because clusters that are nearby us are usually more researched on. The numbers we get from this study will come to aid other researchers when doing calculations on this cluster.

## **Introduction**

Open clusters are loosely bound star clusters that contain hundreds of stars, and have been observed to have a range of ages — some clusters contain extremely young stars, while others contain old stars. Additionally, open clusters are much smaller, brighter, and less populated than globular clusters, making them an easy object to study, as individual stars in an open cluster can be isolated and analyzed. Because all the stars in an open cluster are formed at the same time in the same initial molecular cloud, they all have the same age and chemical composition. For this reason, open clusters have been a research topic for astronomers for years now, as they allow astronomers to gain valuable insights into the formation and evolution of stars. Open clusters in the Milky Way are distributed along the thin-disc component, and thus provide valuable data that can be used to study the Galactic structure, stellar formation, stellar structure, and chemical composition of the Galaxy.

Open clusters also provide a way of measuring distances in space. Because all stars in a cluster have the same age and chemical composition, the main difference between them is their masses. Stars in the main-sequence phase have their colors determined by their masses. For stars that have a lower mass, they are dimmer and redder in color, and for stars that are heavier, they are brighter and more blue in color. Main-sequence fitting allows astronomers to know how far light emitted from stars in a cluster traveled to reach the Earth, resulting in a distance value.

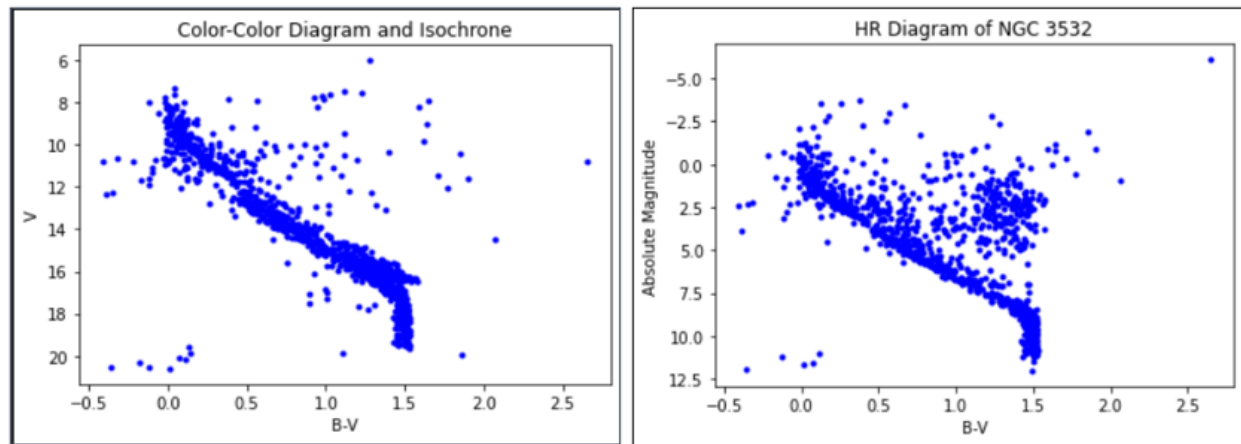
In this study, we aimed to use photometric data of the open cluster NGC 3532 to create an H-R Diagram, then determine some of our cluster's components. We used SIMBAD as our main database, as it contained a lot of useful and easy to find data on NGC 3532. Just searching up NGC 3532 on SIMBAD's identifier brought up data we were looking for, such as the magnitudes of different stars, radial velocities, declinations, and right ascensions. GAIA was also used, however, to a much lesser extent. As for software tools, we used Jupyter Notebook as our IDE, as its ability to split up our code into different cells was particularly helpful. Python and different Python libraries were also used, specifically Pandas, Numpy, and Matplotlib. These libraries helped us read in csv files, analyze and compute

our data, and plot our H-R Diagram and other graphs. The isochrone fitting method was used to calculate the distance to NGC 3532, so the Dartmouth Isochrone Generator was also used to aid us in finding a suitable isochrone.

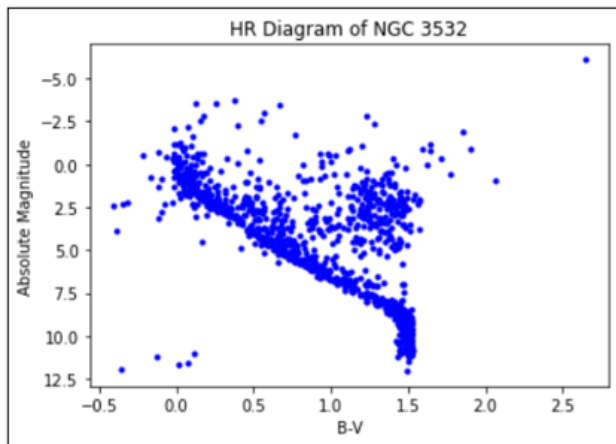
## Data Analysis

We first got our data from SIMBAD. We made sure to get the color filters, which we looked to see which ones were most readily abundant throughout our data. Initially, we attempted to use other color filters, as we thought of plotting a color-color diagram with the g-r indices as the x-axis and r filter as the y-axis. However, we could tell that our other color filters, b and v, were more available in our data. On top of this, we planned to use our color-color diagram and possibly compare it to other diagrams of other star clusters. In most of the references we looked at, the color filters used were the b-v and v color filters. As a result, we decided to use these for our color-color diagram.

Using Pandas and Jupyter notebook, we plotted the values we got from SIMBAD with b-v as the x-axis and the v filter as the y-axis to get our color-color diagram as you can see in the diagram below (Figure 1). We can see a clear grouping of stars diagonally, from the top-left to the bottom right hand side. Other stars are also scattered toward the bottom left and top right hand sides.



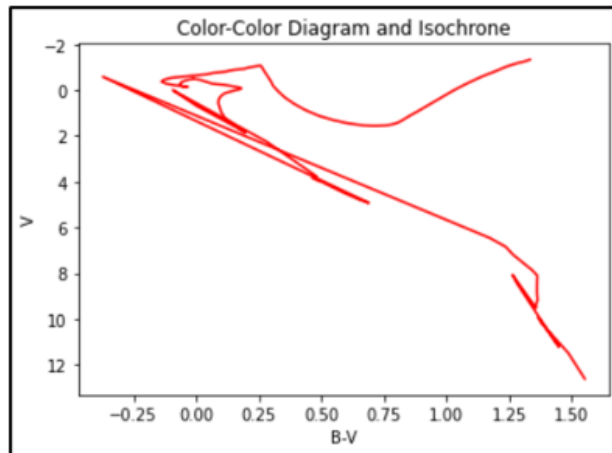
**Figure 1.**  
A color-color diagram of the star cluster NGC 3532.  
The x-axis is b-v, while the y-axis is the v filter.



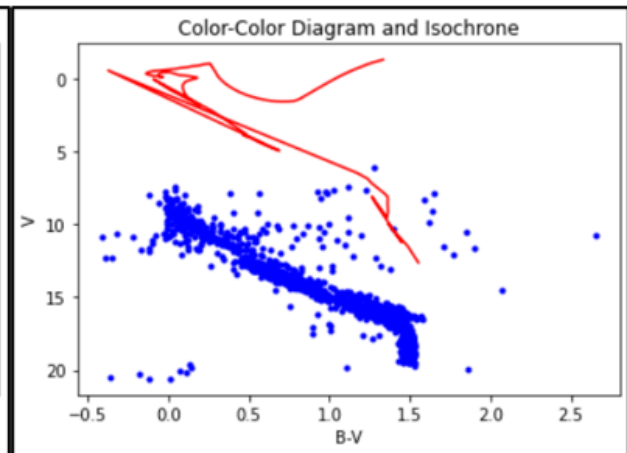
**Figure 2.**  
The HR-diagram of NGC 3532, with the absolute magnitude as the y-axis and b-v as the x-axis.

After creating our color-color diagram, we decided to change the y-axis to absolute magnitude so that we could get our HR-diagram. We initially tried to plot an HR-diagram using the spectral types from SIMBAD. However, we didn't have enough data for that, and as a result, we got an incomplete graph. As a result, we decided to just use our color-color diagram and change the y-axis. We got the absolute magnitude using the v color filter and the parallax from our data, which we used  $m-M = 5\log(d) - 5$ , or the distance modulus. With that, we got our HR-diagram as you can see above (Figure 2).

Then, we went back to our color-color diagram to plot an isochrone on top of it so that we could find the distance of our cluster. Using an isochrone generator from Dartmouth, we used several values as the age and plotted them before finding the isochrone that we needed (the one that fit our plot the best). Eventually, the isochrone we found is shown in Figure 3, which we then plotted onto our color-color diagram to get our final graph of the color-color diagram (Figure 4).

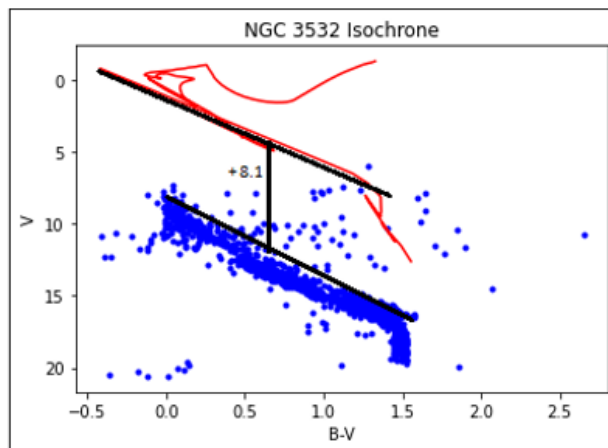


**Figure 3.**  
The isochrone of NGC 3532, generated from the isochrone generator.

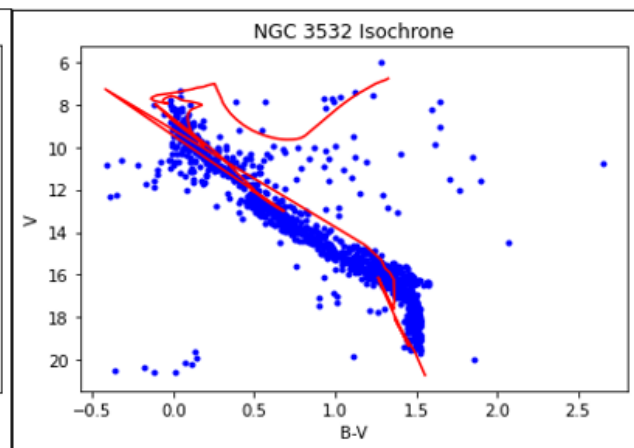


**Figure 4.**  
The isochrone from Dartmouth and the color-color Dartmouth diagram of NGC 3532 plotted together.

We could see that the isochrone, although it fit our diagram, was shifted so that it was not aligned with our plot. As a result, we shifted our isochrone, which we also knew was the distance modulus. We shifted it by a value of around 8.1, as we can see in Figure 5, which gave us an isochrone that fit our color-color diagram (Figure 6). We also calculated the distance of our cluster using the value of 8.1 and the distance modulus, or  $m-M = 5 \log(d) - 5$ , to find the distance of our cluster. We found it to be around 416.87 parsecs.

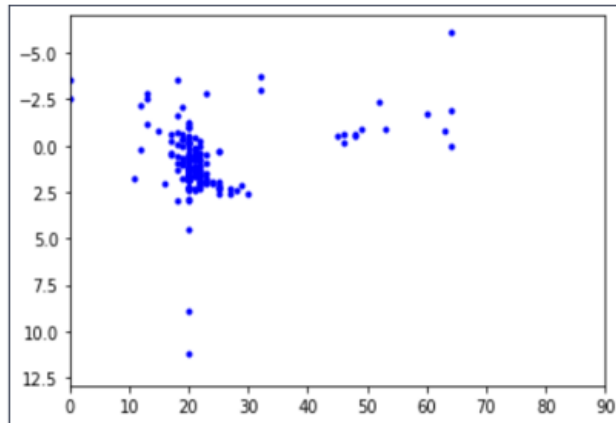


**Figure 5.**  
The isochrone and color-color diagram with lines as an indicator of our distance modulus of 8.1.

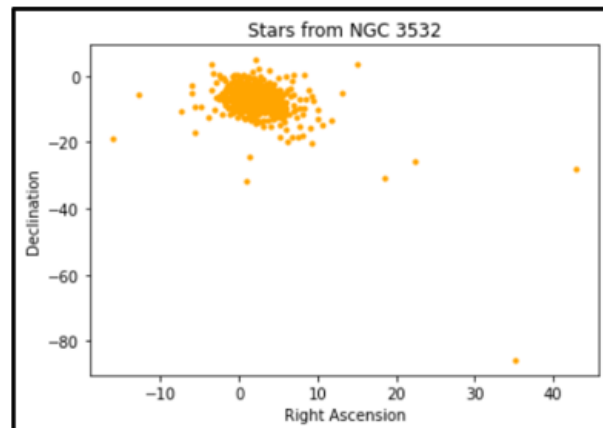


**Figure 6.**  
The isochrone and color-color diagram with the isochrone shifted downward to fit the color-color diagram.

Age was calculated using the turn off point of NGC 3532. As we said before, we attempted to use data from SIMBAD to graph an H-R Diagram of the open cluster, as shown in Figure 7. We still used this, however, to find the turn off point of our cluster. The turn off point would be at the blue end of the main-sequence — the next star to move off the main sequence and turn into a red giant. Because all of the stars in the cluster are the same age, simply computing the lifetime of the turn off star would give us the age of the whole cluster. Using the formula  $t_{MS} = 10^{10} * M^{-2.5}$ , the age of the cluster is calculated to be 328.7 million years old.



**Figure 7.**  
An incomplete HR diagram created using spectral types. Only part of the main sequence can be seen.



**Figure 8.**  
A plot of the pmra and pmdec of stars in NGC 3532. Data is from GAIA.

Another component we determined was the space velocity of our cluster. We first figured out the velocity dispersion by getting the mean and standard deviation of our radial velocities. Then, we removed outliers by removing the values that were more than 2 standard deviations away from the mean. Then, we got the standard deviation of the values that were left and multiplied by 3 as our velocity dispersion. However, the value we got for this was around 48.12 kilometers per second, which is much larger than the velocity dispersions of most open clusters and larger than other findings for NGC 3532's velocity dispersion, mainly from other articles. As a result, to get the space velocity, we used a value that D. J. Fritzewski, S. A. Barnes, D. J. James, A. M. Geller, S. Meibom and K. G. Strassmeier calculated, which was  $v_r = 1.46$  km/sec.

Next, we found the median proper motion in the right ascension direction and declination direction, which were around -0.006107 and 0.002108 respectively in arcsec/yr. With this, we calculated the proper motion to be 0.006461. We created a plot of the proper motion in the right ascension direction and declination direction in the figure above to help us in finding the median for both proper motions. (Figure 8)

Finally, we found the median parallax from our data and found the distance of our cluster using it. The median parallax we found after removing all the negative values was 2.04555 in milliarcseconds, and the distance we got using it was around 488.866 parsecs. This is larger than the value we got using isochrone fitting, although both are in the 400 range, but also closer to values found by other researchers like D. J. Fritzewski, S. A. Barnes, D. J. James, A. M. Geller, S. Meibom, and K. G. Strassmeier.

With this we found the tangential velocity using the equation  $v_t = 4.74\mu d$ , to be  $v_t = 0.014844$  with the distance being 488.866 parsecs. Finally, with all the components we needed, we found the true space velocity using the equation  $v_s = \sqrt{v_t^2 + v_r^2}$ , which gave us a value around 14.91574 (using the distance 488.866). On the other hand, using the distance 416.87 gave us a value of 12.74192 to be the true space velocity.

## Discussion/Conclusion

We are fairly confident in our results of the age and distance of NGC 353. Based on previous studies, our calculations were relatively close to values of others, falling into the error bound of the accepted value. On the other hand, we didn't find space velocity values for our star cluster in other articles, so we didn't have any values we could compare with. However, we are still confident in our procedure.

Literature searches yielded little results on our specific topic with our cluster, although we were able to find many studies that used the same methods as us, such as the use of isochrone fitting to measure distance and age, or

using the turn off point of the cluster to measure the age. An aspect of our research we would like to improve on is the H-R Diagram. Given our time constraints, data on spectral types of the stars in our cluster was also limited, so our H-R Diagram from spectral types seemed incomplete. If possible, and with more data, we would like to plot a new diagram using an updated list of spectral types of NGC 3532. We would also like to extend our research to compare NGC 3532 to different open clusters, or even other globular clusters. Comparing the color magnitude diagrams and studying how stars evolve in different types of clusters would be compelling, or even comparing the distribution of stars in different clusters.

## Acknowledgements

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