ASTR 102

B08

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6: Colour-Magnitude Diagrams

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Objective/Purpose

The objective of the “Colour-Magnitude Diagrams” lab to discover the distance and age of both open and globular clusters of stars using software and colour-magnitude diagrams. By fitting a curve to the colour diagrams in the given software, we are able to determine the approximate age, distance and composition of the clusters.

Introduction/Theory

When we look up at the sky, we can only make out a few clusters on a good night with the naked eye. Using special equipment we can examine the colour spectrum that is coming from certain clusters and the stars within them. With the data collected, we can determine what exactly we are looking at when we look up at the sky. The groups of stars that we find in the sky are from collapsed dust and gas clouds. The colours of the stars vary from red to blue. When we are evaluating the data, we will be plotting the brightness against the colour of the star, then using the Hertzprung-Russel Diagram, called the Colour-Magnitude Diagram we will find a line of best fit on the data points.

Equipment

The following is the equipment required to complete this lab:

- Computer (with peripherals)
- ‘isochrone’ software

Procedure

The following steps will outline the required procedure to complete this lab.

1. I began by opening an X-Term and running the command 'isochrone' to launch the piece of software that I used to complete the lab.
2. For each cluster of stars available (except the Hipparcos cluster), I fitted the given line using the constraints.
3. After the line was fitted, I was able to determine further details on the cluster.
4. There was a line fitted to all of the images associated with each of the clusters.
5. Once all of the data was collected and charted, I was then able to examine each cluster to determine if our sun were to be part of the cluster, would it be visible to our naked eye.
6. With the collected data, I calculated the new distance modulus based on any reddening, and then I further used the data to calculate the distance away each of of the clusters were in parsecs.
7. With all of this information I felt well informed enough to complete the lab questions.

Observations

There were not very many observations for this lab as it was mostly data collection from pre-existing data.

Tables/Measurements

	MORPHOLOGY (y/n)					SUN		Isochrone Fitting					
	Main Seq.	Red Giant Branch	Horiz. Branch	Field Stars	Blue Strag.	V = 0.62	y/n (<6?)	Gyr	Fe/H	m-M	E(B-V)	$(m\text{-}M)_0$	D(pc)
Hyades	y	n	n	y	n	7.318	n	0.06	0	4.5	0.33	3.477	49.59067275
Praesepe	y	n	n	y	n	10.492	n	ZAMS	0	7.7	0.34	6.646	213.4027443
Pleiades	y	n	n	n	n	9.975	n	0.06	0	5.7	0.07	5.483	124.9108029
NGC 188	y	y	n	y	y	N/A		7.08	-0.04	11.25	0.07	11.033	1609.162859
M 67	y	y	n	y	y	14.107	n	3.98	-0.04	9.65	0.04	9.526	803.8962449
NGC 6611	y	n	n	y	n	N/A		ZAMS	0	11.15	0.01	11.119	1674.171714
h+X Persei	y	n	n	y	n	16.19	n	ZAME	0	11.35	0	11.35	1862.087137
NGC 6791	y	y	y	y	y	N/A		10	0.2	13.25	0.13	12.847	3710.222886
NGC 104	y	y	y	y	n	18.107	n	16	-0.71	13.05	0.02	12.988	3959.132167
M15	y	y	y	y	n	21.19	n	18	-2.14	15.15	0.08	14.902	9558.725719

Calculations

The only two calculations that had to be done are recorded in the table in the prior section.

The $(m\text{-}M)_0$ and the Distance in parsecs were calculated with the following equations:

$$(m-M)0 \ = \ (m-M)-3.1\ x\ E(B-V)$$

and

$$D = 10^{\frac{(m-M)0+5}{5}}$$

Uncertainty calculations:

	m-M	$(m\text{-}M)_0$	D(pc)
Hyades	4.5	3.477	+/- 1.023
Praesepe	7.7	6.646	+/- 1.054
Pleiades	5.7	5.483	+/- 0.217
NGC 188	11.25	11.033	+/- 0.217
M 67	9.65	9.526	+/- 0.124
NGC 6611	11.15	11.119	+/- 0.031
h+X Persei	11.35	11.35	+/- 0
NGC 6791	13.25	12.847	+/- 0.403
NGC 104	13.05	12.988	+/- 0.062
M15	15.15	14.902	+/- 0.248

Questions

1. When you increase the isochrone's distance, the distance modulus changes and the line goes down. The line goes down because it is decreasing in brightness as it gets further away.
2. When you increase the isochrone's dust content, E(B-V) goes up and the line moves to the right. The increase in dust causes the colour data to be shifted a certain amount to account for dust shifting the actual colour spectrum of the cluster.
3. When you increase the isochrone's age, the Gyr goes up and the curve changes it's shape. Based on pre-known results of the types of objects in clusters at certain ages and the light values of a cluster associated with the objects, the line will fit to a cluster that matches the correct cluster composition.
4. None of the clusters with age = 0, or ZAMS have a red giant branch. This is because they are not yet old enough to have stars that would have reached that point in their life cycle.
5. Yes, there are some clusters older than the earth, and there are some that are listed to be older than the universe itself. As the clusters theoretically couldn't be older than the universe, we have to assume that they have a large quantity of old stars.

6. In approximately 5 billion years, the sun will begin its helium burning process and proceed to engulf Mercury, Venus, and likely Earth as well. Earth will die.
7. I think that the fact that they are globular clusters over open clusters emphasizes the extreme age gap between the two sets of clusters. Both of the clusters are very far away, especially M15 compared to the rest of the examined clusters, and they are both the oldest of the bunch. Their Fe/H values are also the most negative. This is because their Metallicity acts as a cosmic clock. As the clusters get older, the stars within cycle their H into He then into C, and into Fe. Fe accumulates more over time. If we say that a star has Fe/H = 0, it has the same metal abundance as our Sun.

Results

None of the clusters would have a star visible in them if it were the same size and type as our Sun.

Conclusion/Discussion

When discussing the concept of metallicity, it was confusing at the beginning. The reactions within a star produced metal, but the metallicity scale and the 3 different star Populations indicated that the older the star, the less metal they had. If stars produced metal how come the older stars had less? This is because at the end of a star's life, it recycles some or all of the elements it has produced in it's core over it's lifetime back into the interstellar medium. This processed material becomes mixed into clouds where the next generation of stars are born. So each subsequent generation of stars is enriched with the metals produced in previous generations. Because of this, we can infer in a closed system like our galaxy that the stars with a lower metal content are older than stars with a higher metal content. The estimations within the isochrone software overestimated the actual age of some of the clusters, and we can only assume that they are possibly a set of some of the first stars created at the beginning of the universe. The only sources of error present in this lab would have to be any assumptions or estimates that the software we were using made in regards to the actual characteristics of the examined clusters. The calculated distance uncertainty is listed above in the calculations section. Most of the clusters can be considered Population 1 stars, but M15 is definitely part of the Population 2 set of older clusters.

References

No external information was required for the completion of this lab.

Evaluation

This lab actually had the most evaluation on a subject that we have done all the semester, but it was still a "fill-in-the-blank" type of lab. I wish that the labs were actually interesting material. I'm rather disappointed.