Palomar 2

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1 Introduction to the reddening phenomenon

Interstellar space is permeated by interstellar medium (ISM). ISM is composed of gas and dust. The first tends to absorb and radiate at different directions, the second tends to scatter the radiation. Extinction is not uniform along the spectrum because varies as in the visible part of the spectrum. Recalling the Whitford law: $A_\lambda = 1/\lambda$, the extinction is more in the blue part than in the red part. As a consequence, the objects appear redder than they really are. Other important quantities connected with the reddening process are:

- The color excess: defined as $E(B-V) = (B-V)_{obs} - (B-V)_0$
- The R_V index defined as $R_V = \frac{A_V}{E(B-V)}$

In literature there is a wide discussion on the value of R_V that ranges from 3.1 to 3.3. With this quantity we can relate the color excess to the absorption coefficient.

$$A_V = 3.1 \cdot E(B-V) \tag{1}$$

The cloud, that causes this phenomenon, are located mainly on the galactic equator, hence on the galactic disk and around the bulge. The value of A_V change dramatically when we observe toward the galactic center. When astronomers study an astronomical object is important correct the data set for reddening. When they build the color-magnitude diagrams (CMDs) of galaxies or globular clusters, the position of each stars on the diagram is affected by reddening.

- The absolute magnitude is reduced due to reddening and as we saw before the flux is reduced more in the blue part of the spectrum. The points are shifted toward fainter magnitudes.
- The color is affected too, indeed we can defined the color excess that measure the excess of color due the reddening process. In particular points are shifted to greater value of color.

In the history, some astronomer manages to derive a reddening map to have a value of this process for each part of sky. Schlegel did a reddening map at 100 μm in 1998. Recently other astronomers, as Gonzales had derived a reddening map.

These maps are important tools in the analysis of astronomical data.¿The best resolution is 2'x2' arcmin, so a smaller field of view we can assume an unique value of A_V. This approximation is valid if between the observers and the object there are only one cloud of materials. If there are many clouds the value of reddening could change from a certain part of the field of view to another part, so we called this problem differential reddening.

2 The color-magnitude diagram of Palomar 2

In the figure 1 we can see a very strange CMD, we do not know the reason of this particular distribution. One possibility can be the presence of multi stellar population, another possibility can be that the cluster is affected by differential reddening. The first is a real and physical features that corresponds to presence of some crazy stellar population. The second possibility is an unreal features because is

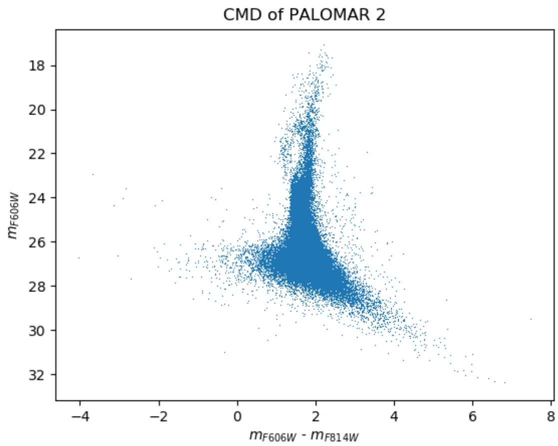

Figure 1: The color-magnitude diagram of the globular cluster Palomar2

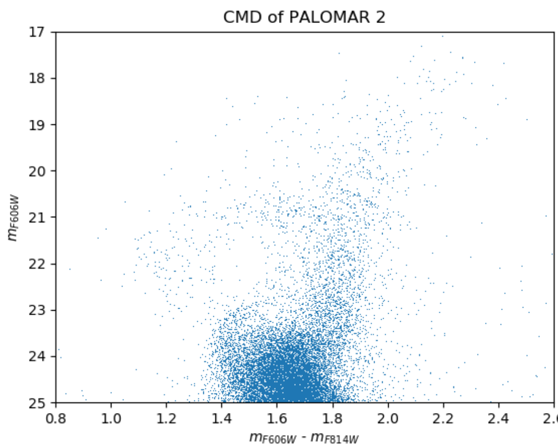

Figure 2: A zoom of the CMD.

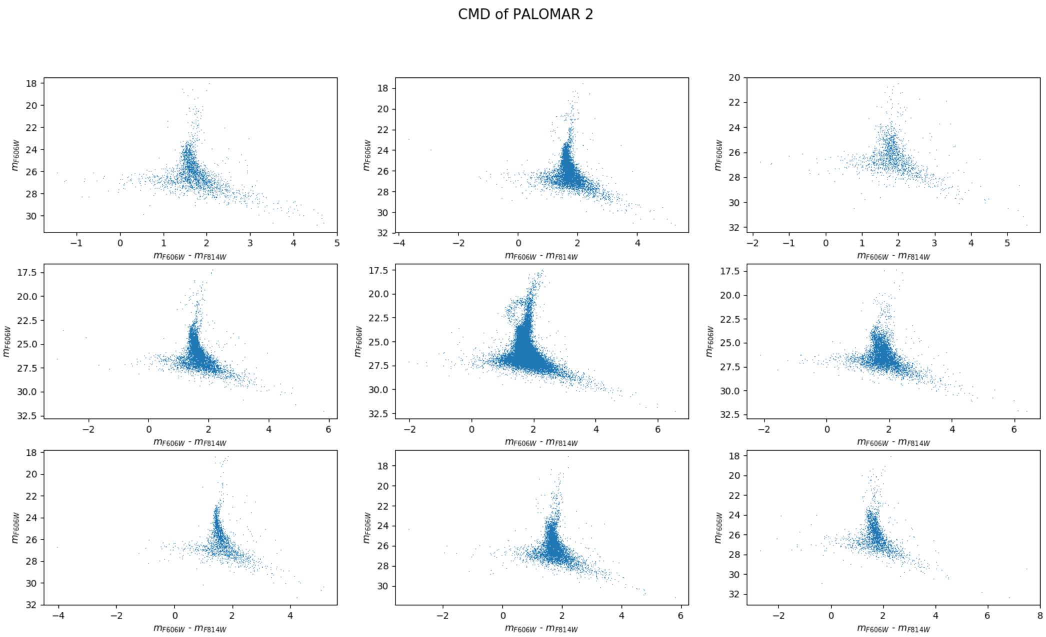

Figure 3: The nine CMDs from the nine squares in which I divided the field of view.

due to reddening process. The latter case needs the presence of some cloud in front of the cluster that absorb the radiation in different way across the field of view.

I assume that between us and Palomar 2 there are many clouds that causes a large difference in term of reddening across the field of view. Therefore, I dived the field of view in nine smaller squares. I have sorted the stars using a program and I build nine color magnitude diagram of each squares.

In figure 3 we can see the result of this first step. In the panels on left and at the center are distinguish now some features as the knee of the turn-off point and the RGB. In the panels on right there are no visible features, hence I exclude these from the analysis.

In the figure 4 there is a zoom of the turn-off point for the squares selected for the analysis.

With this first step is clear how a CMD appears more similar to common CMDs. Now I used the isochrones by Dartmouth to fit the points in the selected squares.

In figure 5 the result of the fitting is shown. For some panels I use only one isochrone because in the those diagram the path of the RGB is not spreaded a lot. In the others panels I use two isochrone to fit the edges of the spreaded RGB.

In the panel in the middle on left there is not a spreaded RGB but are visible two knee of turn off.

The isochrone that I used is the same for each panels, the only parameter that changes is the color excess. The value of this parameter is shown in the legends of figure 5.

Parameters	Values 1st isochrone
Y	0.245
$(m-M)_0$ [mag]	17.2
Age [Gyrs]	13.0
[Fe/H]	-2.0
[α/Fe]	$+0.2$

Table 1: Parameters from the fitting with isochrone.

The other parameters of isochrone are shown in the table 2.

3 The correction

To correct the CMD in figure 1 I use the following method:

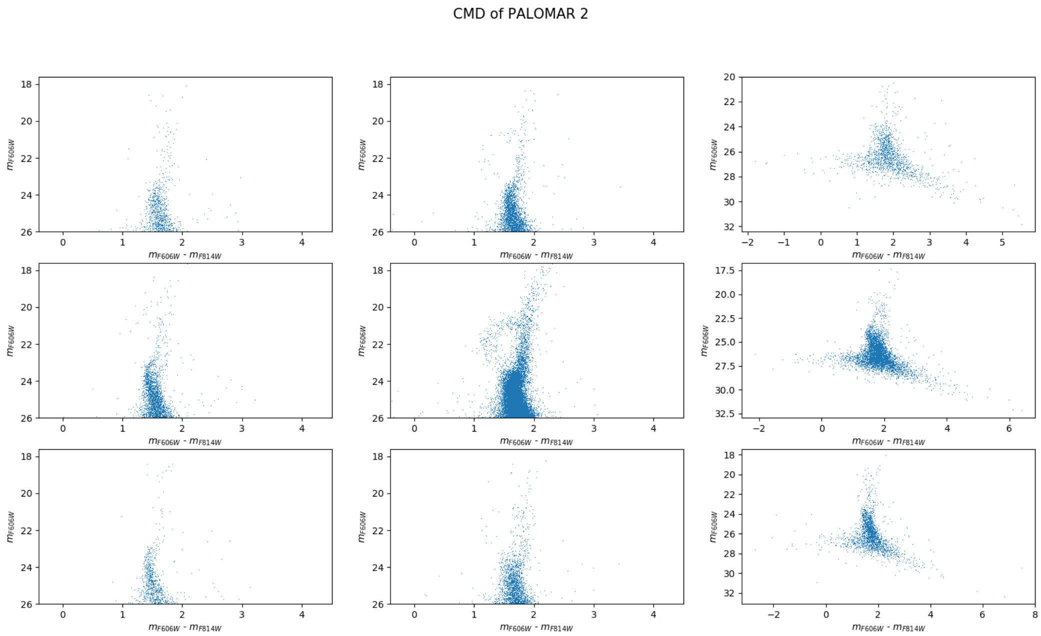

Figure 4: The nine CMDs from the nine squares in which I divided the field of view with a zoom for the selected panels.

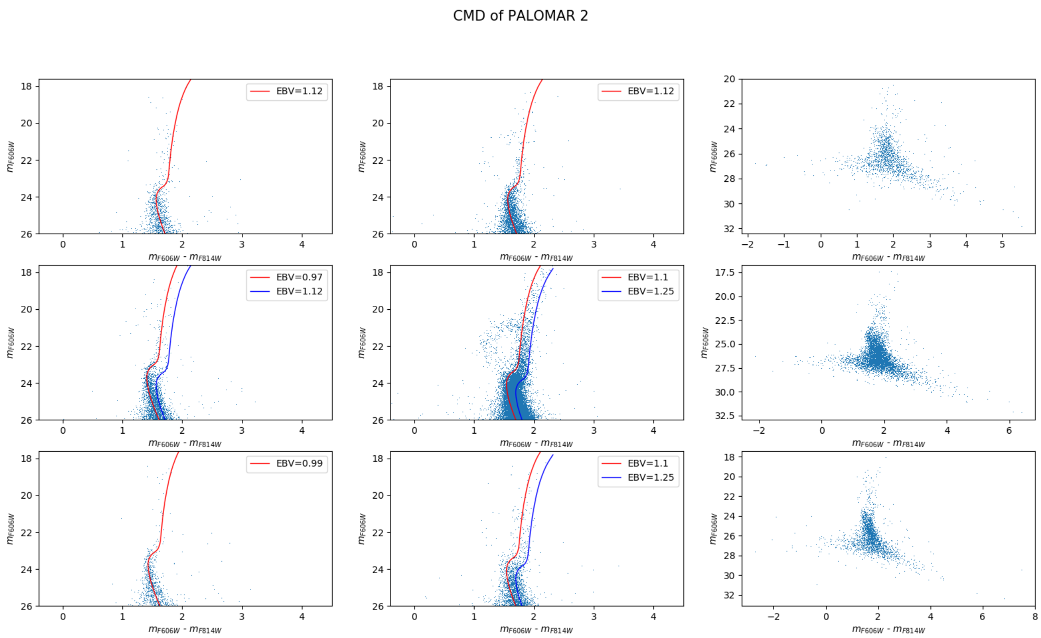

Figure 5: The nine CMDs with the fit of isochrones. In the legends there are the value of the color excess for each isochrones.

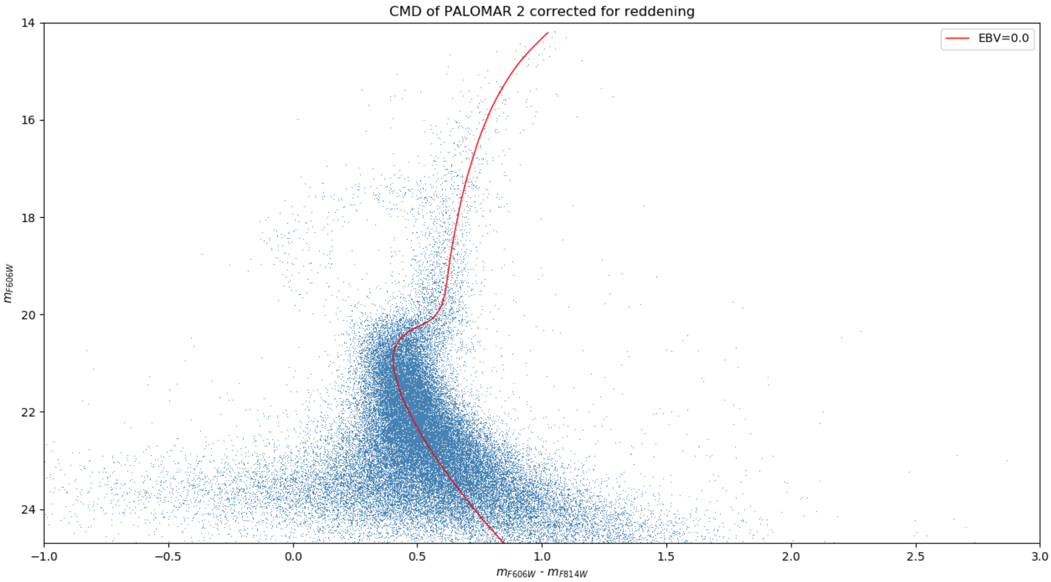

Figure 6: The color-magnitude diagram of Palomar 2 corrected for reddening.

- For each of the six panels, that I selected from figure 5, I assume a different value of color excess thanks to the fitting. Where I plot two isochrones I assume as value of color excess the arithmetic mean between two values from the two isochrones.
- For each panels, I correct the magnitudes of the stars of the panels for the reddening using these formulas:

$$\begin{aligned} A_{F606W} &= 2.8782 \cdot E(B-V) \\ A_{F814W} &= 1.8420 \cdot E(B-V) \\ F606W_c &= F606W - A_{F606W} \\ F814W_c &= F814W - A_{F814W} \end{aligned} \tag{2}$$

where A_{F606W} and A_{F814W} are the absorption index for two filters, F606W e F814W are the uncorrected magnitudes and $F814W_c$ and $F606W_c$ are the corrected ones.

After the correction, I plot all stars in the same diagram that is shown in the figure 6. I plot also the previous isochrone with no reddening correction.

4 Conclusion

Using this method I divided the field of view in nine parts hoping that the difference in term of reddening was smaller in each part. This fact results true, indeed, after the division, the six CMDs show some features typical of the CMDs. I use the isochrone to fit the points and derive the color excess, a proxy of reddening. For a population a few reddened the value of the color excess is of the order of 0.01. In this analysis the value ranges from 0.97 to 1.25. This means that the stars of Palomar 2 are a lot reddened and the the reddening change dramatically from a point to another. The Palomar 2 is affected by differential reddening, but I do not exclude the possibility of presence of multi stellar population, in fact in the main sequence the path is broadened for all panels.

I assumed that the color excess, that I derived from the fitting, is valid for all the stars in certain panel. Then I corrected the stars of each panels for the respective value of color excess and I ploted them on a CMD, shown in figure 6. The method that I explained in details in the previous section is very simple but the result is optimal if we compare the CDMs in figure 1 and 6.