

THE PLEIADES OPEN CLUSTER

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Within this use case you recognize a physical association of stars close in space as opposed to a superposition created by projection effects of stars very far one from the others. The key measure is distance derived from parallax. With the true members of the association (open cluster) you create a Hertzsprung-Russell diagram as in use case 2. The Hertzsprung-Russell diagram of stellar clusters is very important because of the low noise of few unrelated stars.

If used in the classroom this advanced use case requires a reasonable understanding of histograms and bidimensional scatter diagrams. It is also rather long to perform from beginning to end.

1 Introduction

Open star clusters are groups of stars close together, gravitationally bound and moving in space as a individual system.

In a open cluster stars are rather scattered surrounded by gas clouds. They contain few hundreds stars weakly gravitationally bound. They are called “open” distinguishing them from globular clusters that are round and compact.

In the Milky Way astronomers have observed about 300 open clusters. The best known and easiest to recognize is the Pleiades open cluster, which is observable by naked eye.

Star clusters are important for stellar evolution studies. The stars belonging to a cluster originate from the same gas cloud, so they have the same age and initial chemical composition. This allows

astronomers to obtain fundamental information on how the mass of stars affects stellar evolution. In fact, within a cluster, the mass is the only physical parameter free.

In this tutorial we learn how to use Aladin to visualize the parallax of stars, a distance measurement allowing us to assign stars to the cluster. Then we will build the color-magnitude Hertzsprung-Russell diagram to study the cluster evolution.

2 Parallax

Astronomers use the parallax to measure the distance of stars. The parallax is the angle between the directions in which we observe a nearby star, when we see it from two different positions either on the Earth, or at different positions of the Earth

along its orbit around the Sun. The parallax decreases as the distance of the star increases. Distances between observing locations have to be as large as possible in order to detect the parallactic angle. For this reason astronomers observe stars from two opposite points of the Earth orbit. They compute the position of the star once every six months, from two points at 300 millions kilometers one from the other. Astronomers use the "parsec" as unit of measurement for the distances of stars. One parsec is the distance from which the radius of the Earth orbit is seen under an angle of one arcsec. A star one parsec away from us has a parallax of one arcsec. Parallaxes are very small angles, as an example, one arcsec is the angle under which you would see a soccer ball 46 km far.

3 Stellar evolution

The Hertzsprung-Russell (HR) diagram displays absolute magnitude of stars versus their spectral type. It is a fundamental diagram for stellar evolution studies. During their life-cycle stars move along a path in the HR Diagram.

The Hertzsprung-Russell diagram of a cluster is easy to build because we can use apparent magnitude instead of absolute magnitude: we do not need information on distances. Stars belonging to a cluster are all at the same distance from us, they originate at the same time and from the same gas cloud. Hence they have the same age and initial chemical composition: the differences in luminosity between members of the same cluster are due only to the mass of stars. This is the fact that makes stellar clusters very useful for stellar evolution studies.

Looking at the Hertzsprung-Russell diagram of a cluster we can see that most stars lie in a limited region of the diagram,

called the "main sequence". This fact suggests that color and magnitude are related.

More massive stars run out their nuclear fuel in a little time and begin to move towards a new region in the upper right part of the diagram. This new region is called "giant branch". Giant stars are very big, and thus very luminous, but relatively cold. Astronomers use the end point of the main sequence to compute the cluster age.

The Hertzsprung-Russell diagram is the cornerstone of our knowledge on stellar structure and evolution.

4 Aladin

Aladin is an interactive sky atlas developed and maintained by the Centre de Données astronomiques de Strasbourg (CDS) for the identification of astronomical sources through visual analysis of reference sky images.

Aladin allows the user to visualize digitized images of any part of the sky, to superimpose entries from the CDS astronomical catalogues and tables, and to interactively access related data and information from various data servers (like SIMBAD, NED, VizieR).

In this usecase we use Aladin in the *undergraduate* mode (developed in the framework of the EuroVO-AIDA European project).

5 Load the image of the Pleiades

Start Aladin and switch to the undergraduate mode from the menu:

edit -> user preferences -> profile -> undergraduate.

Restart Aladin in order to validate the new configuration.

Our aim is to study the properties of stars belonging to Pleiades. We start loading in Aladin an image of the Pleiades and a catalog.

Open the server selector window:

File -> Load astronomical image
-> Aladin image server

In the field "target" enter "pleiades".



NOTE: In this tutorial when you find the mouse icon it means you have to click the button next to the icon.

Select the image "POSS II J 6.5 x 6.5 deg"



POSS is the acronyms of Palomar Observatory Sky Survey: it is a collection of digitalized photographic plates covering all the sky accessible from the Northern hemisphere (from a declination of +90 to -27 degrees), taken at the Palomar Observatory. All these images are astrometrically calibrated, i.e. coordinates have been assigned to each point.

Then we choose "The Hipparcos and Tycho Catalogues" which contains also data on parallaxes, measured by the Hipparcos satellite.

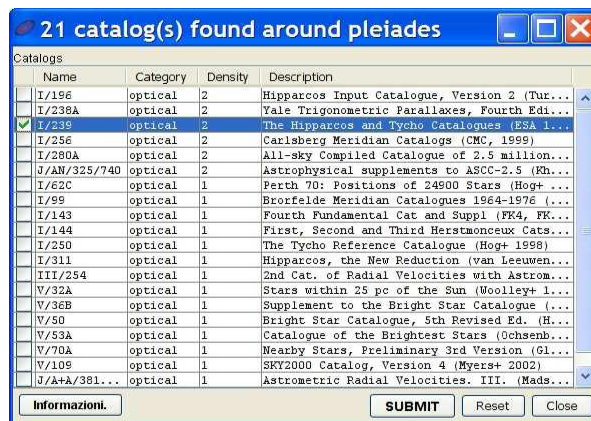


Fig. 1: List of catalogues available in Aladin.

In the server selector window (fig. 2) (in the right column)



In the field "Author, free text" enter "parallax".



Select "I/239" (The Hipparcos and Tycho Catalogues, fig. 1) and return in the server selector window. In the field "catalog" "I/239" appears, in the field "Radius" enter "5 deg".

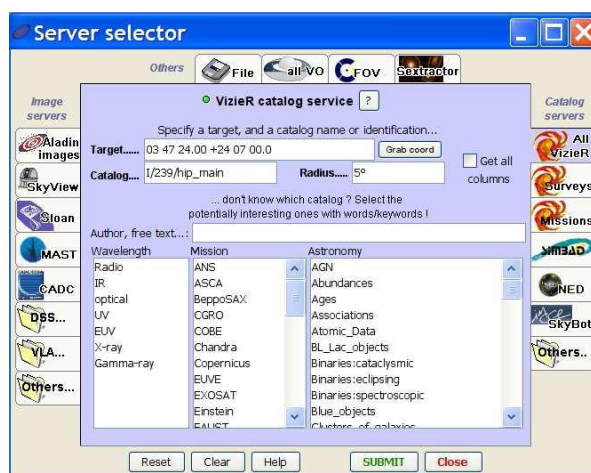


Fig. 2: The image and catalog selector window of Aladin.

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6 Compute the histogram of parallax

Open the tool VOPlot from the menu:

Tools -> Vo Tools -> VOPlot

Right click on the plane of the catalog “I/239/hip_main” and broadcast the data to VOPlot through (fig. 3):

Broadcast selected tables to -> VOPlot

Move in the VOPlot window (fig. 4).



In the field “X coordinate” select “parallaxes” (plx) and set “binwidth”=1.

The plot in figure 5 appears. It represents the histogram of parallaxes of stars of the Pleiades image loaded in Aladin.

Looking at the plot we can see that the parallax of the Pleiades cluster is around 8-9 mas (milliarcsec), that there are many background stars (smaller parallax) and a few foreground stars (larger parallax). The real value of Pleiades parallax is 8.46 +/- 0.22 mas.

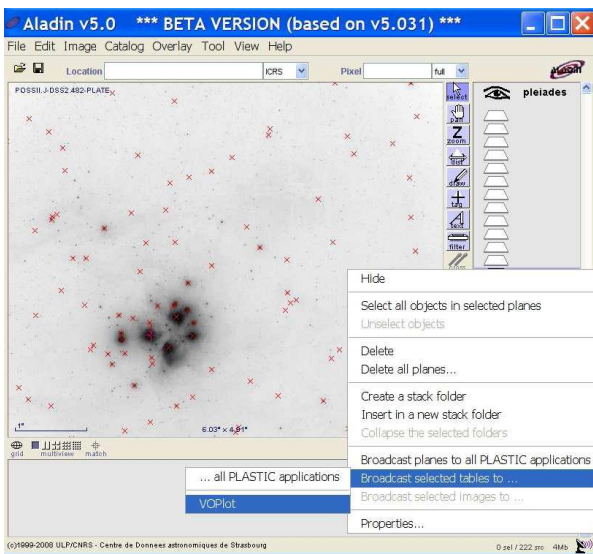


Fig. 3: Broadcast data to VOPlot.

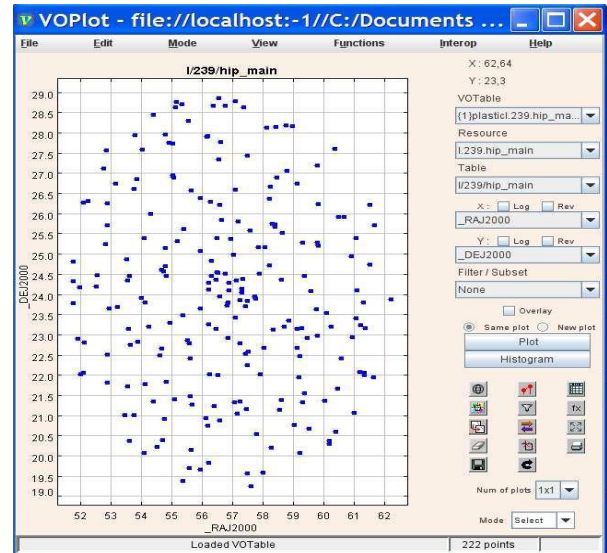


Fig. 4: Main window of the VOPlot tool.

7 Visualize the Hertzsprung-Russell diagram

In order to correctly build the H-R diagram we have to correct data for reddening. Astronomer call “color” of a star the difference between its magnitude in the Blue and in the Visual band (B-V). The matter in the Universe absorbed and scatter more blue light than red light: this effect is called reddening (see the box) because we see a star more red than how it really is.

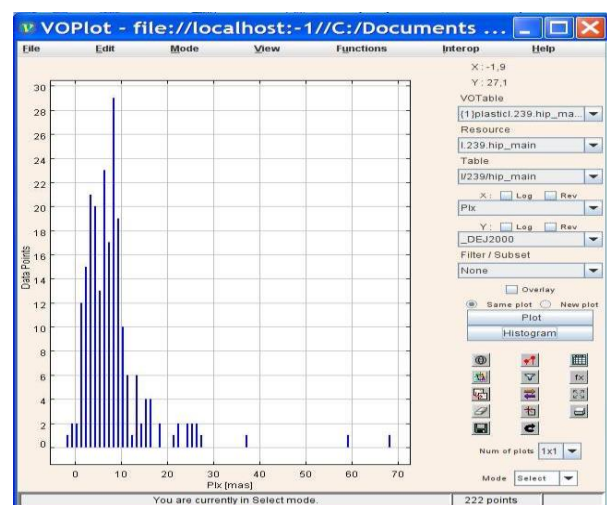


Fig. 5: Histogram of parallaxes of stars in the Pleiades image.

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Thus the observed color (B-V) has to be corrected for the reddening. For this cluster the reddening amounts at 0.04 mag, so:

$$(B-V)_0 = (B-V) - E(B-V) = (B-V) - 0.04.$$

Reddening

Reddening is one of the effects caused by the interstellar medium: blue light is absorbed and scattered more than red light. As a consequence the color index B-V (the difference between the magnitude in B band and the magnitude in V band) increases. Reddening is due to the grains of dust of the interstellar medium, between us and the Pleiades. Grains of dust absorb and scatter the light with wavelength comparable with their size: shorter wavelengths (blue light) are largely absorbed and scattered, while longer wavelengths (red light) can easily pass through the interstellar medium.

We add a new column in the catalog, with the (B-V) values corrected for the reddening (B-V)₀. Select the catalog plane and open the menu Catalog --> Add a new column

In the field "Name" enter "(B-V)₀". In the field "Expression" enter "\$ (B-V) - 0.04" (fig. 6).



Add new column

Select some stars of the image and look at the table in the lower part of the Aladin window. Move the scroll bar to the right and verify the new column (B-V)₀ has been added.

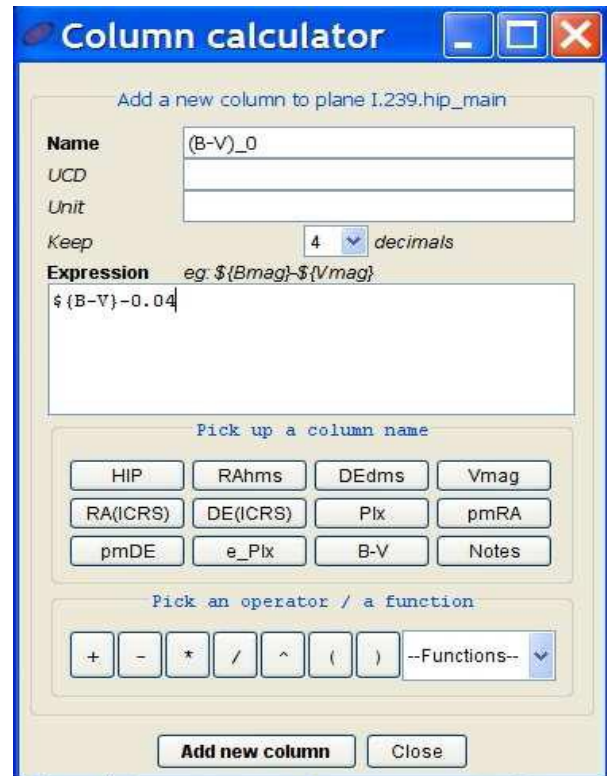


Fig. 6: The window to add a new column.

Broadcast the plane of the catalog to VOPlot as done before (fig. 3) and move in the VOPlot window.



In the field "X coordinate" select "(B-V)₀". In the field "Y coordinate" select "Vmag". Check the option "rev" of the Y axis (fig. 7).



Plot

The Hertzsprung-Russell diagram of the Pleiades appears in the VOPlot window (fig. 7), it is easy to recognise the main sequence. If you select some points in the plot the corresponding stars are highlighted in the image loaded in Aladin.

Mode -> select mode

Select some stars drawing a rectangle (drag and drop the mouse) around them, to share information between VOPlot and Aladin use the menu (in VOPlot):

Interop -> Show Objects in -> Aladin

In order to know if some stars belong to the cluster we have to select them and look at their parallax in the table loaded in Aladin. Select the points up left in the plot (brightest stars) and note that they correspond to the central stars of the image. From the data in the table you can see that their parallax is 8-9 mas: they belong to the Pleiades.

Now select some points in the bottom right (faintest stars) part of the plot: they correspond to stars at the edge of the image. Looking at their parallaxes we see that they are mostly background stars (parallax < 8 mas) with a few foreground stars (parallax > 8 mas).

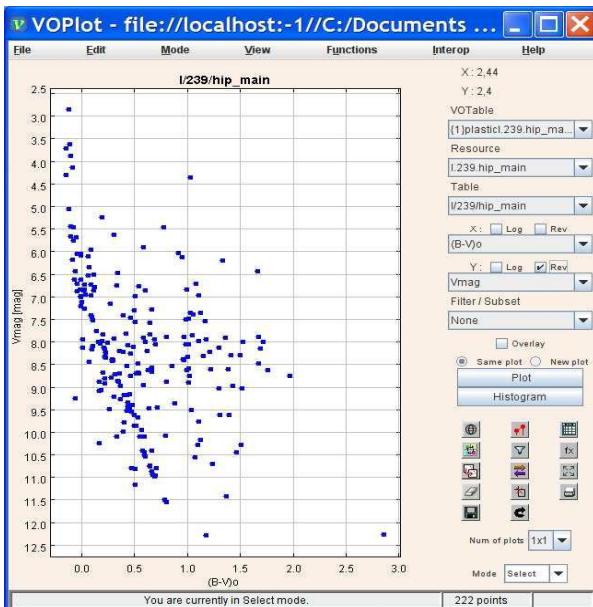
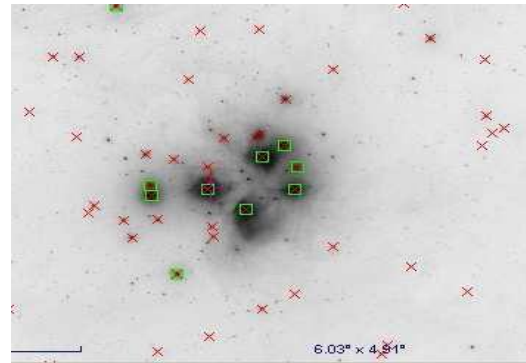


Fig. 7: The Hertzsprung-Russell diagram of the Pleiades cluster.

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