Membership Determination in Open Clusters

with *CLUSTERIX*

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ABSTRACT

The web-based application *Clusterix* has been developed as a collaboration between the Masaryk University (Czech Republic) and the Universitat de Barcelona (Spain) to calculate proper-motion based membership probabilities in open clusters on the WEBDA Database using a completely non parametric method (Galadí-Enríquez et al., 1998). WEBDA is a site devoted to observational data on stars in Galactic open clusters (http://webda.physics.muni.cz). *Clusterix* is an interactive tool where the user can define the default values to configure the membership estimation for the area of a cluster. *Gaia*'s capabilities to study the kinematics of clusters of stars with great accuracy is one of the main motivations for the development of this tool. The applet first version can be found at: ***http://clusterix.cerit-sc.cz/***

1. Main page

Clusterix is an user-friendly tool (Sezima 2014) designed to estimate proper-motion based membership for stars in a cluster making use of a non parametric method, in an easy and interactive way. The easiest way to start with *Clusterix* is using the form in the main page that allows you to select an open cluster by choosing the Database and the name of the cluster. So far 1755 open clusters are available from WEBDA Database (Netopil et al 2012).

2. Lists of open clusters

Each database may be inspected for available clusters by following the corresponding link on the main menu. Brief description of the database is followed by an alphabetic list of available open clusters:

- **Cluster name** corresponds to the most commonly used designation of the open cluster
- **Right Ascension and Declination** values describe central coordinates of the open cluster
- **Radius** refers to the cluster radius proposed by the corresponding database
- **Evaluate** header indicates that by following the link, users will be redirected to the cluster details webpage to be able to evaluate membership probabilities

You can also make use of your own data from the main page with the option **File upload** following the simple format specified there.

3. Cluster details

Once you have selected an open cluster from the list, the system takes you to the **Cluster details** page, the most important of the system. First of all basic information about the cluster is summarized in a table that allows you to get an overall picture of the available data:

- **Diameter** of the open cluster in arcminutes as stated in the chosen database. Many databases offer only rough estimates of it, so this value should be used with caution.
- **Central coordinates** of the cluster also as given by the database, to be used also with caution.
- **Membership selection**: according to the non parametric method followed, the first step of the procedure is to separate two spatial groups: first one ("cluster + field" selection) corresponds to the spatial area covered mainly by the cluster (but obviously having also the unavoidable contribution of the field population), while the second group ("field" selection) corresponds to a close-by area of mainly field (background and foreground) stars. One of the critical assumptions of this approach is that the kinematics of the field stars in the area of the cluster is well represented by the kinematics of the population contained in this close-by "field" area. The number of stars quantified in those groups depends on the **Requested parameters** described in the following section.
- **Stars in database** is the total number of available stars in the database corresponding to the addition of the member selection counts.

4. Requested parameters

This page contains the input parameters required for successful calculation of the membership determination. They are configurable parameters that can be adjusted on the view of the results obtained in previous runs. By default standard parameters are taken from the WEBDA database or proposed by the *Clusterix* system.

- **Cluster parameters:**

  - **Central coordinates** of the cluster by WEBDA. They can be modified to a user's determination of the center of the cluster..
  - **Radius** of the cluster and **Outer radius** of the field in arcminutes to define the corresponding areas of the "cluster + field" selection and the "field" selection. In a future release *Clusterix* will be able to consider "user-defined" areas, not circular, but arbitrary in shape.

- **Restrictions that can be applied to the data used:**

  - **Proper motion cutoff** to limit the area of calculation in μ
  - **Proper motion error cutoff** to limit the error level of the data used on the calculations.
  - **Magnitude cutoff** to avoid completeness problems or too high number of stars.
  - **Smoothing parameter** h of the frequency function. A large h would blur out the details of the true frequency function, while a small h would yield a noisy result.
  - **Noise Threshold**, where γ is the typical noise level.

See the bibliography (especially Galadí-Enríquez et al (1998) and Balaguer-Núñez et al. (2004)) for details on the measuring and implications of these restrictions.

Once all parameters are set you can either **Replot** or **Submit** your query!

http://clusterix.cerit-sc.cz/
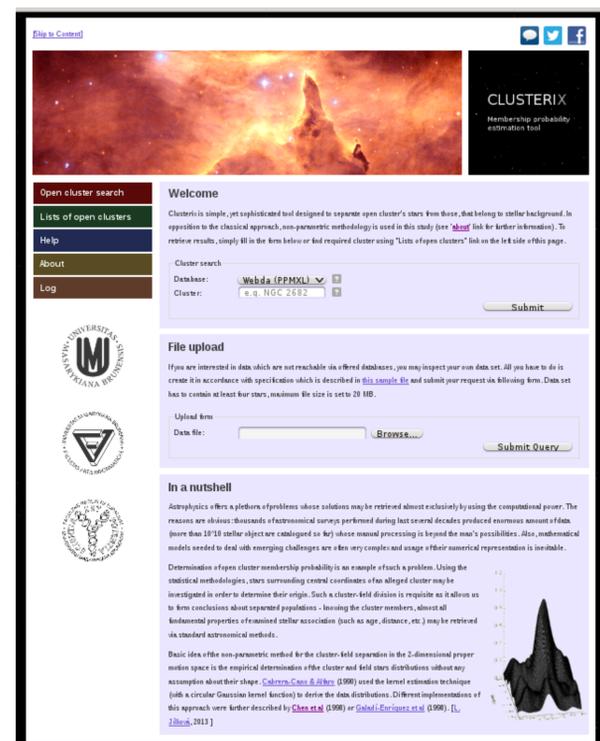
Screenshot of actual *Clusterix* website

5. Results

Clusterix gives as a result a **Number of cluster members**, a **Mean cluster proper motion** and a **Mean field proper motion**. This is thanks to the fact that the non parametric approach provides an expected number of cluster members from the integrated volume of the cluster frequency function in the vector point diagram areas of high cluster density.

The table of results consists of membership probabilities associated to each star, only for stars with non-zero probabilities. Stars are sorted in descending order of membership probability. The parameters included are:

- **Star number**
- **Right ascension** and **Declination**
- **Magnitude**
- **Cluster star** (true/false the star belongs to the cluster)
- **Membership Probability** of the star

The true/false assignation is performed according to the quantitative criteria provided by the non parametric method (see details in the bibliography).

5. Future work

Future developments, among others, will include:

- User-defined, arbitrary in shape, areas for "cluster + field" and "field" selection
- More added databases
- More freedom in input data format
- More interconnection of the retrieved results with third party software (VO Tools,..)
- More user suggested improvements…

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