View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by SEDICI - Repositorio de la UNLP

Terceras Jornadas de Astrofísica Estelar
AAA Workshop Series, Vol. 9, 2016
L. P. Bassino, Z. L. López García, L. S. Cidale & M. Lares, Eds.

CONTRIBUCIÓN MURAL - POSTER

Viewing angles of the Magellanic Clouds obtained via cluster analysis

G.I. Perren[1,2] & R.A. Vázquez[1,2]

(1) Instituto de Astrofísica de La Plata, CCT La Plata - CONICET – UNLP, Argentina
(2) Facultad de Ciencias Astronómicas y Geofísicas, UNLP, Argentina

Resumen. Realizamos un estudio sobre los ángulos de rotación (o visión) de las Nubes Mayor y Menor de Magallanes (L/SMC), basado en las posiciones y distancias estimadas de 239 cúmulos estelares.

Abstract. We performed a study of the viewing angles of the Large and Small Magellanic Clouds (L/SMC), based on the estimated position and distance of 239 observed star clusters.

1. Introduction

The recently introduced Automated Stellar Cluster Analysis (`ASteCA`, Perren et al. 2015) package is employed to analyze 150 star clusters located in the LMC, and 89 in the SMC. All clusters are observed in the CT_1 Washington photometric system (Canterna 1976). Distance moduli are obtained in an homogeneous and semi-automatic way by `ASteCA`. Three different methods are applied to derive the position and inclination angles of both Clouds, with varying degrees of freedom.

By fitting the distance modulus as a free parameter, we can obtain individual distance values for each observed cluster. With these values plus their center coordinates, we can estimate their deprojected (i.e., real) distances to the galaxy center, without the need to force the cluster to reside on a plane with arbitrary rotation (viewing) angles.

Based on the distance moduli of the 239 star clusters, we can estimate the viewing angles of each galactic disk. These are the position and inclination angles, (Θ, i) respectively, as defined in van der Marel & Cioni (2001). Each one represents a rotation of an (x,y,z) system defined with its origin on the center of the galaxy, and its (x,y) plane representing the plane of the sky (that is: the plane perpendicular to the line of vision). The position angle Θ rotates the (x,y) plane around a line that points towards the observer (the z axis). The inclination i is the angle between the plane of the sky and the tilted plane of the galaxy disk.

2. Methods

The three methods employed to obtain the (Θ, i) pair for the S/LMC, are summarized. For all of them, a Monte Carlo algorithm is applied to assign errors for both estimated viewing angles.

Method 1 (M1): models the disk of a galaxy as a 2-dimensional plane (thus flat) that pivots around a fixed origin, given by the coordinates and distance to the center of that galaxy. Forcing a cluster to be positioned over this plane, allows us to obtain its deprojected distance to the galaxy's center. The concordance correlation coefficient (CCC, Cox 2006) is then used to derive the (Θ, i) values which produce the deprojected distances for our set of clusters, that best matches those found for the set employing the distance moduli estimated by `ASteCA`.

Method 2 (M2): assumes a plane that pivots around the same origin as **M1**, but lifts the condition that it must be flat (i.e., it doesn't force all clusters to be positioned directly on it). Using the distance moduli obtained by `ASteCA`, we calculate the averaged sum of the perpendicular distances ($\overline{|d_p|}$) of our clusters, to a given plane defined by a (Θ, i) pair. Minimizing $\overline{|d_p|}$ across all the defined planes, gives the values for (Θ, i) that best estimate the galaxy's disk rotation angles.

Method 3 (M3): this is the more general method, as it fits the 3-dimensional positions of our set of clusters (estimated using `ASteCA`'s assigned distance moduli values for each of them) to a non-fixed plane. This means that the fitted disk of the galaxy is not forced to pivot around the galaxy's assumed origin, and the clusters are also not required to lay directly on the fitted planes. As in **M2**, we minimize the perpendicular distances $\overline{|d_p|}$ to estimate the of angles (Θ, i) that define the best fit plane for the S/LMC.
All three methods are applied on subsets of clusters, separately for each galaxy. These subsets are generated by filtering the clusters, according to a minimum projected angular distance to the center of their corresponding galaxy. We separate our observed clusters in 9 subsets, using the minimum angular distances: $[0°, 0.5°, 1°, 1.5°, 2°, 2.5°, 3°, 3.5°, 4°]$.

3. Preliminary results

In Figure 1 we show the results from the three methods, as a density map of the statistical parameters used to asses the best fits for each pair of viewing angles. The subset of clusters used to obtain these best fit viewing angles is that which groups clusters with a projected angular distance greater than 1°. This means that the central parts of the S/LMC are not considered.
In Figure 2 we show the results obtained for the S/LMC galaxies, left and right figures respectively. The best values found for each (Θ, i) viewing angle are displayed in the top and bottom rows. The plotted points represent subsets of clusters, generated by filtering their angular (i.e, projected) distances to the center of their parent galaxy. The top x axis displays the number of clusters in each subset after filtering the entire set of 150 LMC clusters, and 89 SMC clusters. The bottom x axis shows the minimum angular distance ρ_{min} used to filter the clusters. Each point corresponds to the value of either angle (Θ, i), for a given method. The symbols that identify the three methods can be seen in the top right corner of the top left plot. The colors of each point are associated to the colorbar shown on the right, which maps the averaged sum of perpendicular

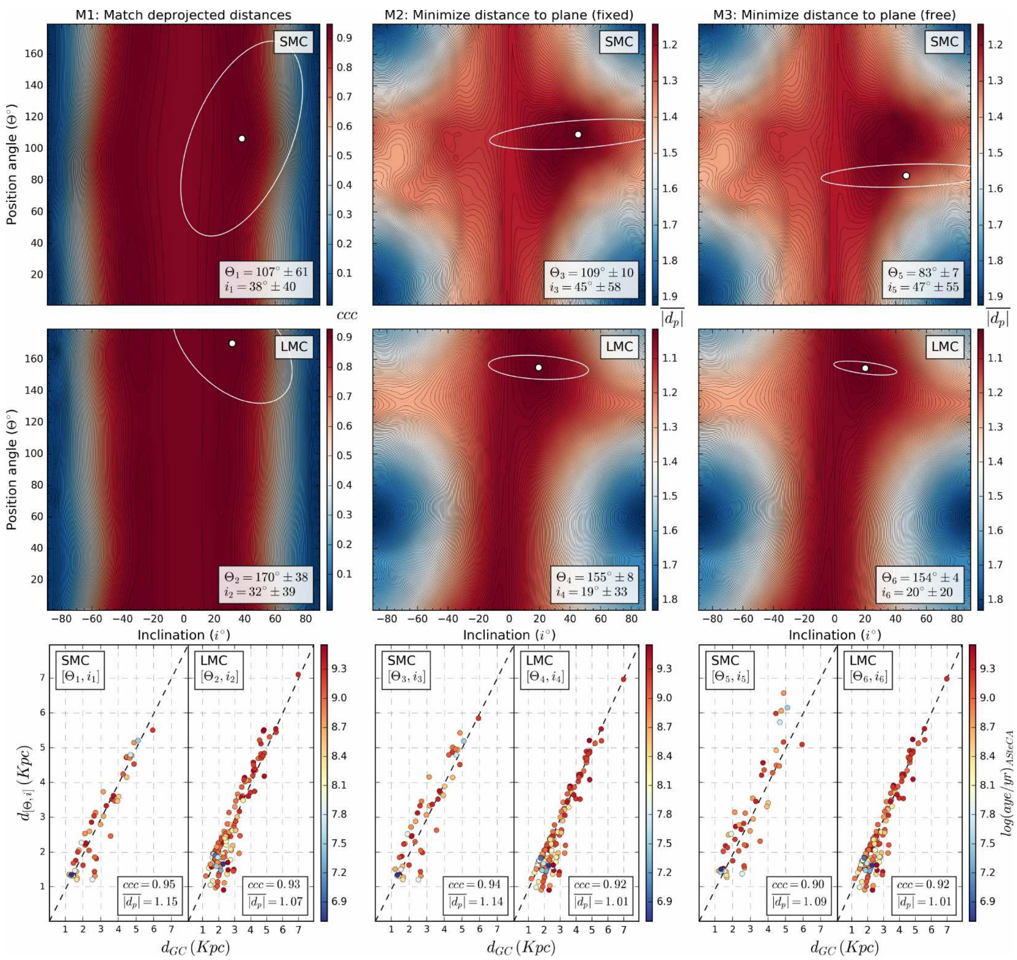

Figure 1. *Left panels:* (Θ, i) density map for the **M1** method applied in the SMC (upper panel) and the LMC (middle panel). The bottom panel shows the deprojected distance for this subset of clusters (minimum angular distance 1°) found with `ASteCA` (x axis), and with the best fit angles obtained with **M1** (y axis). *Central panels:* idem for **M2**. *Right panels:* idem for **M3**.

distances $\overline{|d_p|}$, to the best fit plane found. This plane is determined by the obtained best fit values for both viewing angles (for a given galaxy, method, and subset). A small $\overline{|d_p|}$ value indicates the clusters in the subset are located, on average, close to the best fit plane (for a given method and galaxy).

The position and inclination angles found for the SMC show a large dispersion for the different subsets of clusters. In both cases, the values obtained are positioned mostly below the gray area that represents the range of values found in the literature. The (Θ, i) values closer to the literature are those found between 1° and 3°, i.e. excluding the central region but not too far away. Note that the number of clusters drops significantly beyond 1°, which can affect the statistics. No clear trend is discernible for either angle in the SMC. For the LMC, the values for both viewing are much closer to the region of values found in the literature.

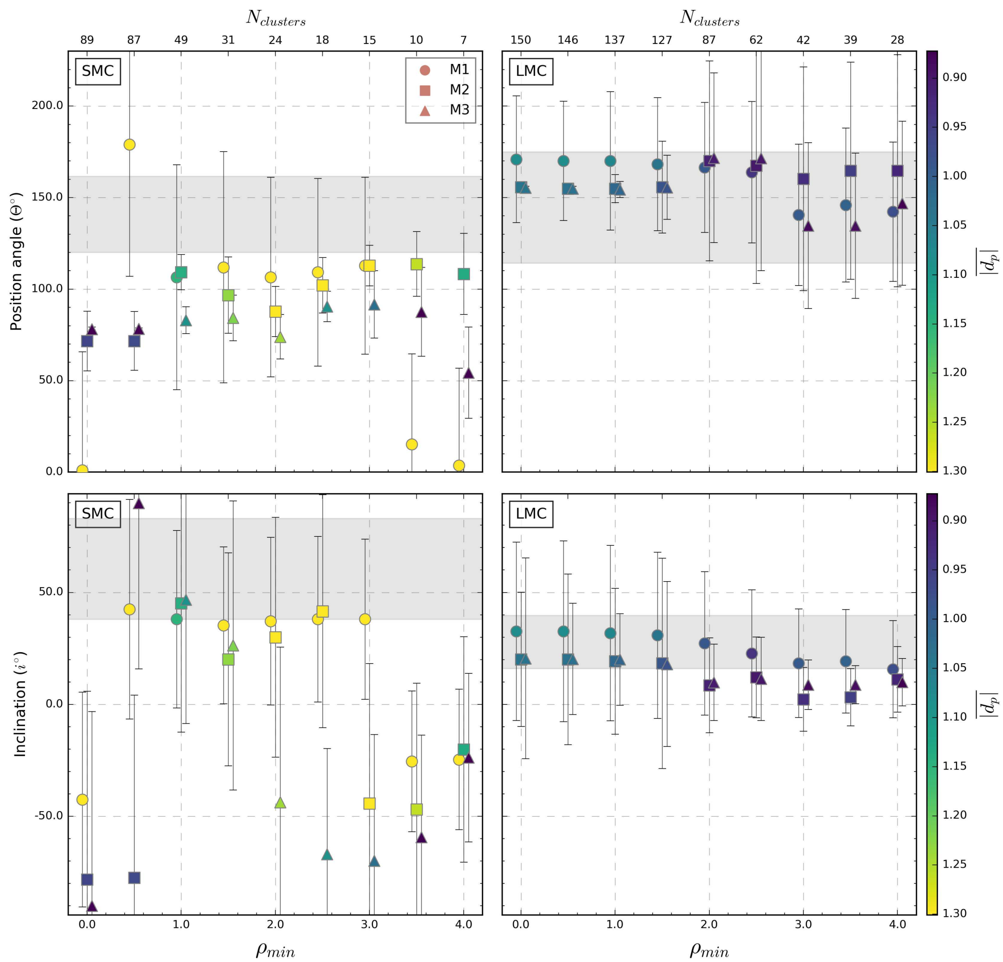

Figure 2. *Top panels:* position angle Θ obtained for each galaxy, for the different subsets of clusters. *Bottom panels:* idem top row, for the inclination angle i. Symbols identifying the three different methods are shown in the top right corner of the top left panel.

Unlike what happens for the SMC, we can see a clear trend towards smaller values for clusters located farther away from the center of the galaxy. This decrease is mostly visible for the inclination angle, beyond an angular distance of 1.5°.

References

Canterna R. 1976, AJ, 81, 228

Cox N.J. 2006, Geomorphology, 76, 346

Perren G.I., Vázquez R.A., & Piatti A.E. 2015, A&A, 576, A6

van der Marel R.P. & Cioni M.L. 2001, AJ, 122, 1826