Spatial Distribution of Stellar Components in the Magellanic Clouds

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Abstract Gaia, an ESA mission planned for launch in 2012, will create the largest and most precise three dimensional chart of our Galaxy by providing unprecedented positional and radial velocity measurements for about one billion stars in our Galaxy and throughout the Local Group. It is expected to resolve nearby galaxies in stars, improving greatly our knowledge of them. Our main goal is to obtain the spatial distribution of different stellar components in these galaxies and work towards producing a model of the Magellanic Clouds to be used, among others, in simulations by CU2 (a part of the Gaia Data Processing and Analysis Consortium) during the Gaia mission preparation. In this study the Magellanic Clouds are the main targets. Using ground based data from infra-red and optical surveys such as 2MASS and the Magellanic Clouds Photometric Survey we investigate the spatial distribution of various stellar populations in these galaxies using isodensity maps and radial surface density profiles.

1 Data

We use archive data – both all-sky surveys and dedicated catalogues, which are homogeneous, have a good coverage of the galaxies, and are deep enough. These are the Magellanic Clouds Photometric Survey (MCPS) by [13,14], the Two-Micron

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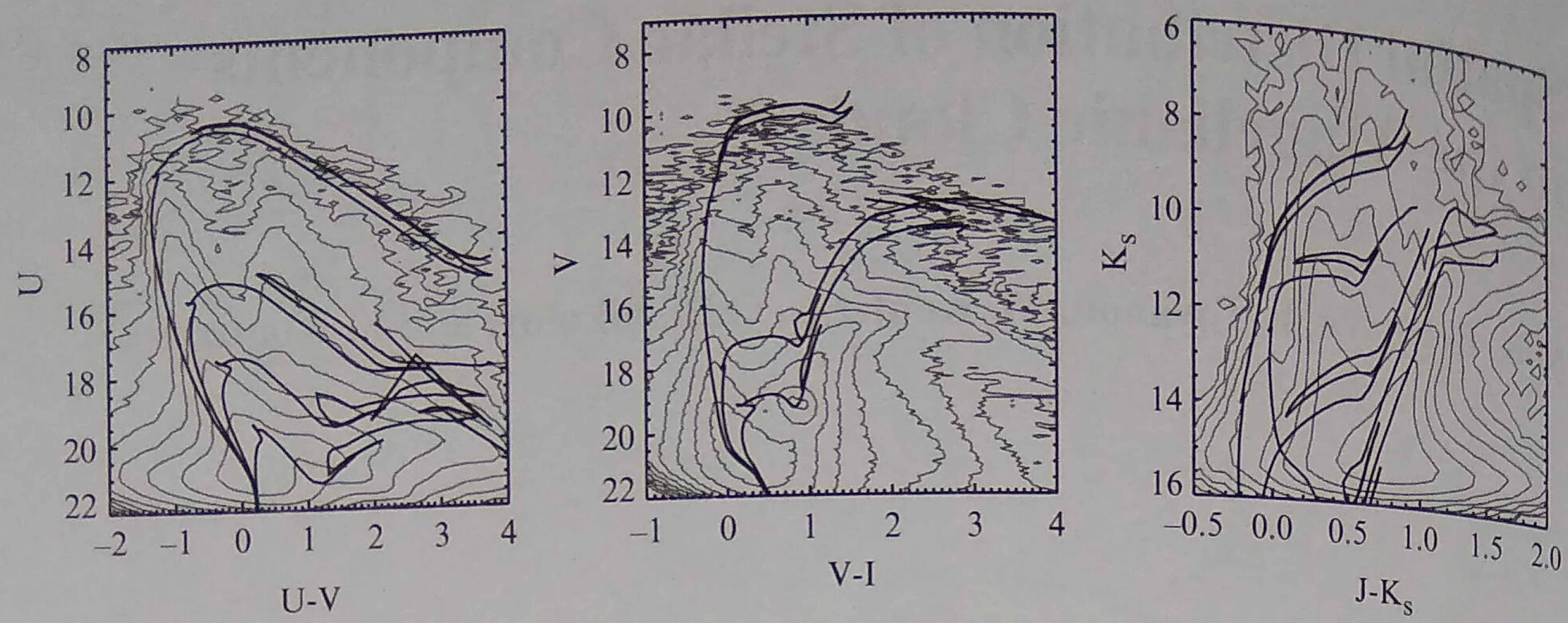

Fig. 1 Colour magnitude diagrams of the LMC from the MCPS (*left and middle panel*) and 2MASS (*right panel*). The density levels are logarithmic. Isochrones for 10, 100, 300 Myr and 1 Gyr are displayed on top of the contours

Table 1 Age groups/MCPS

	Age	Magnitude	Colour
A	<0.1 Gyr	11<U<16	−1.5<U-V<−0.6
B	0.1–0.3 Gyr	16<U<18	−1.3<U-V<0.2
C	0.3–0.9 Gyr	18<U<21	−0.8<U-V<1.2
D	>1 Gyr	17<V<20	0.4<V-I<1.8
E	<0.1 Gyr	K<15	−0.5 <J-K<0.2
F	>1 Gyr	13.5<K<15.5	0.2<J-K<1.2

All Sky Survey (the data used here are from the 2MASS All-Sky PSC, http://irsa.ipac.caltech.edu/applications/Gator), and the catalogues of carbon stars in the LMC and SMC from objective-prism plates by [7, 11] and [10]. The colour-magnitude range from the data sets was divided in a grid with different number of cells for each data set. The size of the cells should provide a fine grid and at the same time contain enough stars for the statistics. The colour-magnitude diagrams (CMD) are shown in Fig. 1. We divided the stellar content of both Magellanic Clouds in several age groups, matching features of the CMDs with isochrones obtained from http://stev.oapd.inaf.it/cmd. The isochrones for 10, 100, 300 Myr and 1 Gyr are displayed on top of the contours in the Hess diagrams in Fig. 1. The selection criteria we use are summarized in Table 1.

2 Methodology

In order to determine approximately the shape and the distribution of the stars in the galaxies, first star counts are performed in a rectangular grid. Then, radial density profiles (RDPs) are obtained. The size of the grid cell is different for the various stellar populations and chosen in such a way as to include a sufficient number of stars and also to provide enough detail for the isodensity contour maps. The contours in these maps trace areas with equal stellar density and show the overall shape of the galaxies. The RDPs correspond to the projected radial surface-density (or number-density) of objects contained in concentric rings around the LMC and SMC centroids. The derived density profiles for each age and/or object group are compared with existing theoretical models. For the centres of the Magellanic Clouds we adopt the following coordinates given by the SIMBAD Database (http://simbad.u-strasbg.fr/simbad) – for LMC RA: 05h 23m, Dec: –69d 45m and for the SMC RA: 00h 52m, Dec: –72d 48m.

A conventional first approach to describe the spatial distribution of various stellar populations from the RDPs is to use an exponential-disk profile

$$f(r) = f_{0D} \times e^{-r/h_D}\,, \qquad (1)$$

where h_D and f_{0D} are the scale length and the central density of objects respectively and r is the distance from the centre. Additionally the following King-like profile based on the King law [5] is used

$$f(r) = f_{0K}\left(\frac{1}{\sqrt{1+(r/r_c)^2}} - \frac{1}{\sqrt{1+(r_t/r_c)^2}}\right)^2, \qquad (2)$$

where r_t and r_c are the core and tidal radii respectively, f_{0K} is the central density of objects and r is the distance from the centre. It is often used to describe the radial profile of globular clusters, but also applies to dwarf spheroidal galaxies.

The best fitting profiles are found by performing the Levenberg-Marquardt least-squares fit to the considered functions. This fit was performed with IDL (http://www.ittvis.com/) with the use of the procedure MPFITFUN [9].

3 Results

The isodensity contour maps and the RDPs obtained from the MCPS, 2MASS and carbon stars catalogues, along with additional conclusions and discussion, can be found in [1].

The spatial distribution of the various age groups is expected – older stars have a more regular and smooth appearance, while younger stars form fragmented and less symmetric structures [4, 8, 12]. The spatial distribution of stars from 2MASS and of the carbon stars in the LMC suggests that there are two subsystems, whose major axis are almost perpendicular to one another. The same behaviour was detected recently by [2] for the star clusters in the LMC. This effect was previously described by [6] and later by [3], who found that the young clusters, occupying mainly the bar, are rotated with respect to the older clusters.

The RDPs for the SMC from MCPS show an interesting feature. Both the King and the exponential-disk models can be used to describe the stellar distribution.

However, the older stars follow the King law and the younger stars are better fitted by the exponential-disk model. This is not observed in the LMC and is possibly due to the small area available. A similar behaviour is observed in the RDPs from 2MASS. Both younger and older stars in the LMC are distributed on an exponential disk, while the SMC radial distribution is better described by the King profile. The structural parameters of the LMC and SMC obtained by fitting RDPs from the adopted data sets from the various catalogues in the optical, near infra-red and specific objects such as carbon stars can also be found in [1].

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