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LETTER

*Letter to the Editor*

# The LMC stellar complexes in luminosity slices

## Star formation indicators

**F. Maragoudaki**[1,2], **M. Kontizas**[1], **E. Kontizas**[2], **A. Dapergolas**[2], **and D.H. Morgan**[3]

[1] Section of Astrophysics Astronomy & Mechanics, Department of Physics, University of Athens, GR-157 83 Athens, Greece
[2] Astronomical Institute, National Observatory of Athens, P.O. Box 20048, GR-118 10 Athens, Greece
[3] UK Schmidt Telescope Unit, Royal Observatory of Edinburgh, EH9 3HJ, UK

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**Abstract.** An approach towards the investigation of the star formation mechanisms in galaxies can be achieved through the search of stellar complexes and the determination of their properties. A method has been developed for the detection of stellar complexes and the derivation of their fundamental properties in the LMC.

Photographic plates taken with the 1.2m U.K. Schmidt Telescope have been digitized by the APM and SuperCosmos machines to produce homogeneous data for extended regions. Star counts have been performed for extended areas in selected luminosity slices and colours (U, HeII, R filters). Isodensity contours have been used to identify the various structures with enhanced stellar number density ($3\sigma$ above the mean background density).

About 50 large stellar groupings have been revealed showing: 1) hierarchical structure, where the smallest are found within the large ones. 2) their size distribution has peaks at 250±50 pc (aggregates) and 600±50 pc (complexes), there are also a few cases with size 1200±50 pc (supercomplexes). 3) there is evidence that at the fainter magnitudes these structures are aligned to a general trend whereas at the most bright end (B1, O spectral types) they become more clumpy and symmetrical in shape. The relationship between the above complexes' properties and the various scenarios of star formation are discussed.

**Key words:** galaxies: stellar content – Magellanic Clouds – star formation

### 1. Introduction

In order to understand better the star formation mechanisms that govern the galaxies it is of vital importance to study their various stellar systems. It is well known that there are various such systems from single to multiple peak which are often related to the parent galaxy's morphology.

Stellar complexes are typical large-scale structures where recent star formation has occurred. They are dominated by recently formed stars, young stellar clusters, OB-associations and all kinds of young objects with ages up to $5 \times 10^8$ yr, (Efremov 1989; Efremov & Chernin 1994) and have dimensions of the order of 200–1200 pc.

Kontizas et al. (1996) have examined selected regions in the LMC and showed that large stellar complexes can be revealed from star count and spectral classification of their stars. The detected structures are found with sizes within the expected values.

Between the conventional scenarios of star formation in galaxies, the "top-down" and "bottom-up", the present observations favour an hierarchical structure which is more easily understood through the "top-down" mechanism (Efremov 1995).

It is generally believed that stellar complexes appear to be the result of the evolution of gaseous superclouds which are the largest in size and mass (up to $\sim 10^7 \mathrm{M}_\odot$), entities of diffuse matter distributed in the galactic disks. The "top-down" mechanism of gravitational instability assumes that these superclouds are the first entities formed whereas the denser star-forming clouds are developing inside them (Elmegreen & Elmegreen 1983, 1987; Elmegreen et al. 1994; Efremov 1989, 1995; Larson 1988, 1992). The "top-down" scenario implies the presence of a few fundamental scales of stellar groupings and the hierarchical arrangement of the developed structures. Therefore two questions have to be examined; 1) do structures exist on a few fundamental scales?, 2) if so, are these structures grouped hierarchically?

In this work we search for stellar complexes in the LMC in order to study their morphology and their properties and examine how the complexes can give evidence on the predominant star formation scenario.

### 2. Observational material and detection of stellar complexes

The large-scale structures in nearby galaxies require extended field observational material in order to be treated homogeneously. Therefore plates taken with the 1.2m UK Schmidt Tele-

*Send offprint requests to*: F. Maragoudaki
(e-mail: fmarag@titan.astro.noa.gr)

scope are ideal tools to detect and map the stellar complexes in the LMC.

We use direct photographic plates taken with the UK 1.2m Schmidt Telescope, in various wavebands: U, R and HeII ($\lambda = 4686$ Å) down to a magnitude limit of 19–20 mag. The plates were digitized with the fast measuring machines APM and SuperCosmos and the derived data give for the detected images positions, magnitudes etc.

Standard astronomical packages (MIDAS, IRAF) and software developed by us have been used for the identification of stellar complexes. The detection of the stellar complexes is based on:

1. *Star counts and isodensity contour maps*
   Star counts were performed on the U detected stellar images. The pixel size of the selected grid was chosen to correspond to $27.4 \times 27.4\,\mathrm{pc}^2$. This size seemed to be a satisfactory compromise for a good statistical analysis and details in the galaxy's structure. OB associations with dimensions larger than $55 \times 55\,\mathrm{pc}^2$ are expected to be the smallest young groupings which can be revealed using the adopted pixel size. The isodensity contour map of the field was produced with the minimum contour level $3\sigma$ above the mean background density and the step was set at $1\sigma$). The regions with enhanced stellar density were considered as large stellar groupings candidates. The local backgrounds were taken into consideration and were subtracted from the studied areas.
2. *Luminosity slices*
   The instrumental magnitudes have been calibrated by us using known CCD magnitudes from the literature (Will et al. 1997). The detected stellar images were divided in various luminosities according to their magnitude. Star counts and isodensity contour maps performed for various luminosities allowed us to study the distribution of stars at the various luminosity slices and see whether there exists a magnitude limit that corresponds to a certain mass or age at which the complex starts to be revealed.
3. *Various wavebands*
   Steps 1 and 2 were performed on U, R and HeII plates. In the U plates, the blue stars of the upper main sequence stand out against the older, background stellar populations, while the R plates cover a wider range of stellar populations and can go down to late A spectral types. The HeII waveband covers part of the B magnitude and the obscuration by the gas is minimal.

The structures found from the above three steps were accepted as stellar complexes under the following criteria:

1. Structures should be larger than 150 pc.
2. The stellar density of the structure is enhanced by at least $3\sigma$ above the mean density of the surrounding field in more than two slices in the U plate.
3. At least one of these slices must contain stars brighter than 17.5 mag.
4. The structure is also revealed in the isodensity maps of the HeII data.
5. If a structure is embedded in a larger one its density should be at least $5\sigma$ above the mean density of the surrounding field.

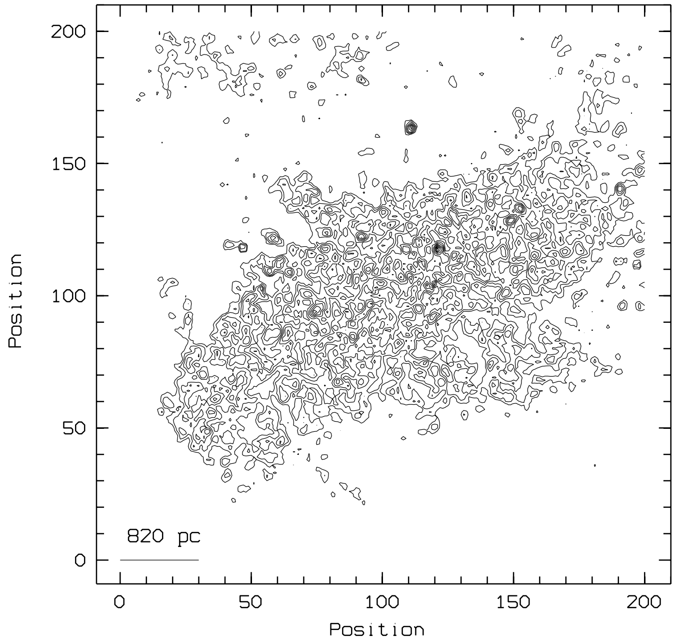


**Fig. 1.** Isodensity contour map for stars with magnitude $m_u > 18.7\,\mathrm{mag}$, corresponding approximately to spectral types B8-A0. The centre of the area is at $\mathrm{RA} \sim 05^{\mathrm{h}}26^{\mathrm{m}}$, $\mathrm{DEC} \sim -69°$. The stars at luminosity range 17.7 to 18.7 mag show a similar pattern, so it is ommited to save space.

For the very crowded Bar area, the regions are revealed in slices which contain stars brighter than 17.0 mag.

## 3. Discussion

The above criteria have been applied to a region of the LMC of about $6° \times 7°$ centered at $\mathrm{RA} \sim 05^{\mathrm{h}}26^{\mathrm{m}}$ and $\mathrm{DEC} \sim -69°$. Stellar structures have been revealed and can be summed in three different sizes: two groupings with size $\sim 1200$ pc (supercomplexes), 24 with mean size $600 \pm 50\mathrm{pc}$ (complexes) and 24 with mean size $250 \pm 50$ pc (aggregates). Moreover, the stellar associations defined as the single peak stellar systems (Kontizas et al., 1994) are the smallest groupings in the above hierarchical scale with sizes $< 100$ pc.

In most cases these structures are found within each other and all of them contain the known LMC stellar associations (Lucke & Hodge, 1970). The known Shapley LMC Constellations (Shapley 1956; van den Bergh 1981) and the superassociations reported by Martin et al. (1976) have been found to be associated with the corresponding stellar complexes.

The isodensity contour maps in the various luminosity slices of the whole LMC area (Fig. 1–5) show that: the stellar complexes begin to be prominent at U $\sim 17.5 \pm 0.5$ mag corresponding to spectral types of about B8 and masses $\sim 3M_{\odot}$ (Fig. 1, 2). At fainter magnitudes those structures disappear giving evi-

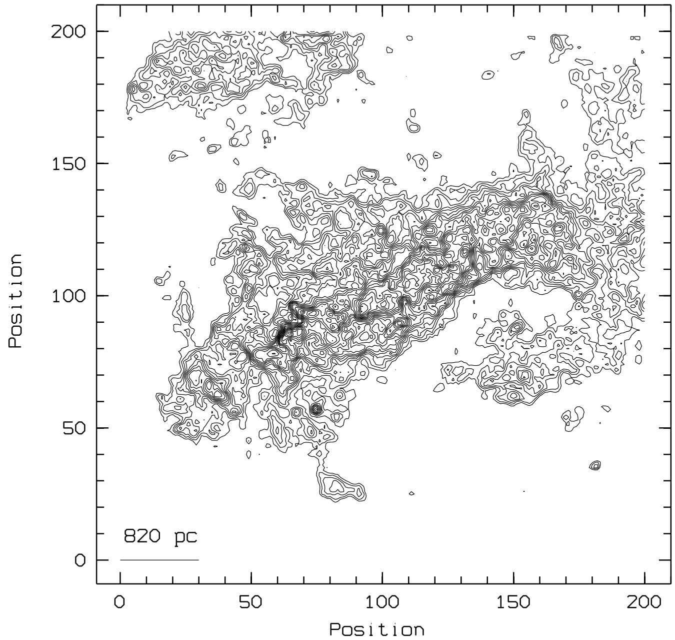


**Fig. 2.** The same as Fig. 1 for stars with $17 < m_u < 17.7\,\mathrm{mag}$ corresponding to spectral types B7-B6. Note that a general pattern of stellar concentrations appears with filamentary structure.

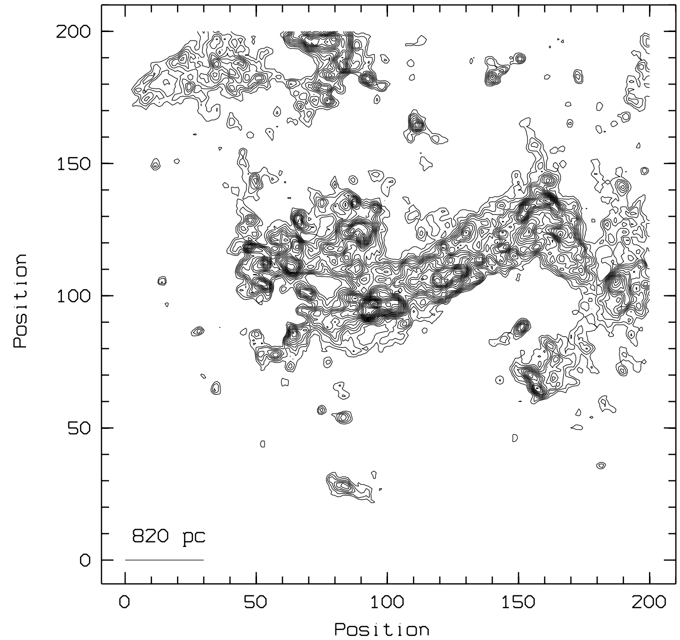


**Fig. 4.** The same as Fig. 1 for stars with $16.4 < m_u < 15.2\,\mathrm{mag}$ corresponding to spectral types B2-B4 and K,M supergiants. The filament-like structure revealed in the previous slices (fainter stars) shows fragmented in large stellar groupings of bright stars.

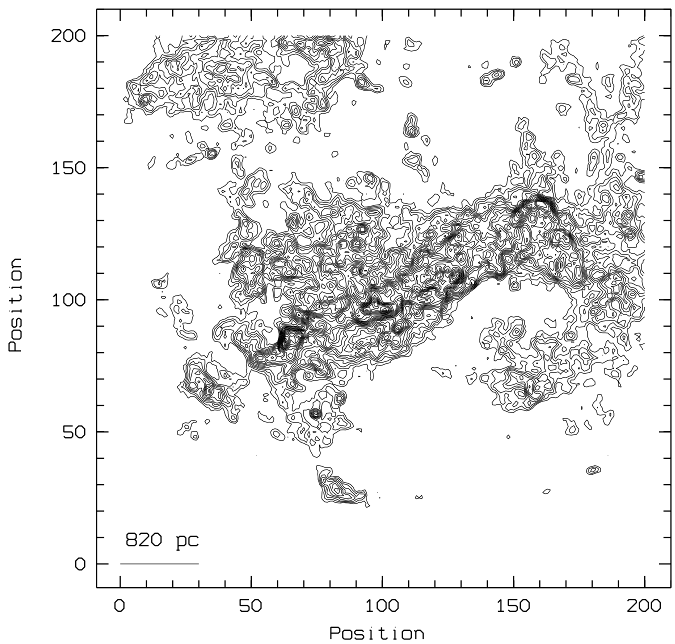


**Fig. 3.** The same as Fig. 1 for stars with $16.4 < m_u < 17\,\mathrm{mag}$ corresponding to spectral types B6-B4. The stellar concentrations first appeared in the previous slice show up prominently giving evidence of a filament-like structure.

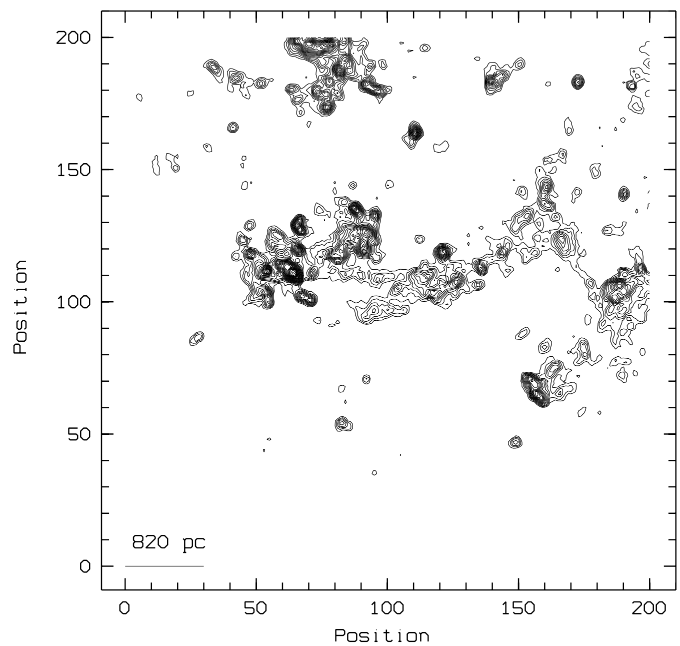


**Fig. 5.** The same as Fig. 1 for stars with $m_u < 15.2\,\mathrm{mag}$ corresponding to spectral types B1,B2 and G supergiants. The most bright stellar component shows smaller and symmetrical clumps, contained in the structures of Fig. 4.

dence of a real cut-off around this magnitude. This cut-off should be considered significant because it appears at two magnitudes brighter than the plate limit (U$\sim$ $19.5\,\mathrm{mag}$) and it's not an observational effect. The age of the stellar population corresponding to the faintest slices is about a few$\times10^8$ yrs, and could be associated to the time when the MCs had their nearest encounters with our Galaxy. Moreover, at these faint slices the complexes seem to be aligned along the whole extend Bar region in filament-like structures (Figs. 2, 3). These filamentary structures appear fragmented as we go to brighter magnitudes revealing the com-

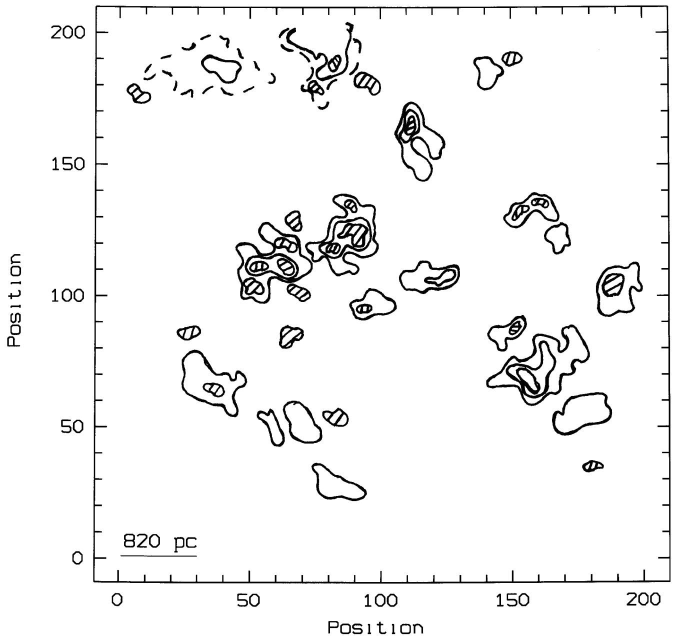


**Fig. 6.** The identified stellar supercomplexes (dashed), complexes(solid line) and aggregates (shaded). Inside all the above structures there are stellar associations which are not marked to avoid confusion.

plexes and become round at the brightest slices where we see the distribution of the O stars (Fig. 4, 5).

A similar hierarchical picture has been found by Battinelli et al. (1996) for the Andromeda galaxy, Ivanov (1987) for the M33 and other spiral galaxies, and Feitzinger et al. (1984) for the LMC, favouring also a "top-down" scenario for the star formation mechanism in these galaxies. This hierarchical picture of star forming regions and their association with the largest structures in galaxies is described by Efremov & Elmegreen (1998), who have given a scenario with the expected size distribution of the various substructures agreeing with our observational results for the LMC.

A detailed analysis of this work and the mapping of the complexes is in preparation.

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