Morphological Studies of the Large Magellanic Cloud on ESO Schmidt Plates

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This article, by Dr. Edward H. Geyer of Observatorium Hoher List, Fed. Rep. of Germany, touches upon a somewhat controversial subject in contemporary astronomy. The structure of the Large Magellanic Cloud is the focus of much research with southern telescopes. Originally classified "irregular", it now appears that it may be possible to break down the LMC into two components, a central ellipsoidal and a somewhat offset spiral structure. Dr. Geyer discusses the problems of identifying the various stellar components (the populations) in the LMC, by means of Schmidt plates from La Silla.

Schmidt telescopes are the most efficient information gathering instruments in optical astronomy. Besides the wide field (up to 10°) with nearly perfect image definition also at the field edges, the small focal ratio (normally f/1 to f/4) permits resolution-limited photographs to be obtained within tolerable exposure times, even on fine-grain emulsions.

These advantages are especially useful for the structural study of the Magellanic Clouds (MC). The author has received several ESO Schmidt plates in U-, B-, V-colours of the Large Magellanic Cloud (LMC), taken by H.-E. Schuster in 1973/74, and carries out different studies of the structure of this nearby galaxy and its stellar sub-aggregates.

One degree of arc on the sky corresponds to about 1 kpc at the distance of the LMC. Plate-resolution-limited faint stellar images taken with the f/3, F = 306 cm ESO Schmidt telescope have typically diameters of about 20μ, which is about 0.3 pc at the LMC's distance. This is the order of magnitude of the geometrical resolution of structural features in the LMC.

The Structure of the LMC

More than ten years ago, I derived the following picture of the overall structure of the LMC from colour composites of U-, B-, V-, R-photographs with the duplicate of the original Schmidt camera at the Boyden Observatory: it consists of two components, (a) an extended ellipsoidal galaxy, representing the old stellar population of the bar, and (b) an asymmetric and peculiar Sc-spiral, the centre of which seems to be near the 30 Doradus nebula complex. At least three spiral features can be traced, the most conspicuous one emanates from that centre, crosses the long side of the bar in north-west direction, and splits at its outer part. These spiral features have recently been rediscovered by Drs. Schmidt-Kaler and Isserstedt from a study of the distribution of typical spiral tracers like luminous blue stars and HII-regions.

A further possibility for a morphological study of the LMC is based on surface photometry, although in principle the interpretation is much more difficult, because integral values along the line of sight are observed. However, photographic isodensity contours from a single Schmidt plate give higher spatial resolution than what is obtained photoelectrically which moreover demands about one hundred times more observing time! Such isodensity contours have been obtained by the Agfa Contourfilm technique. By this simple method, which does not need complex isodensity tracing machines, photographic density differences of about 0.1 or less can easily be separated. Besides the sub-threshold stars (the limiting magnitude of the Boyden Schmidt telescope is $< 17^{\mathrm{m}}$, and that of the ESO Schmidt telescope is $< 21\overset{\mathrm{m}}{.}5$), the emission- and reflection-nebulae and the dark cloud areas in the LMC contribute significantly to the isodensity contours.

Isodensity Contours

In figure 1 are only shown the less chaotic composites of isodensity contours in the V spectral region, from which figure 2 was obtained by the suppression of smaller details. The outer contour also embraces the OB association of the Shapley constellation III. The brightest stars ($< 16\overset{\mathrm{m}}{.}5$) are resolved and do not contribute to the contours. This means that the fainter stars (with $M_V > -2\overset{\mathrm{m}}{.}5$) decisively contribute

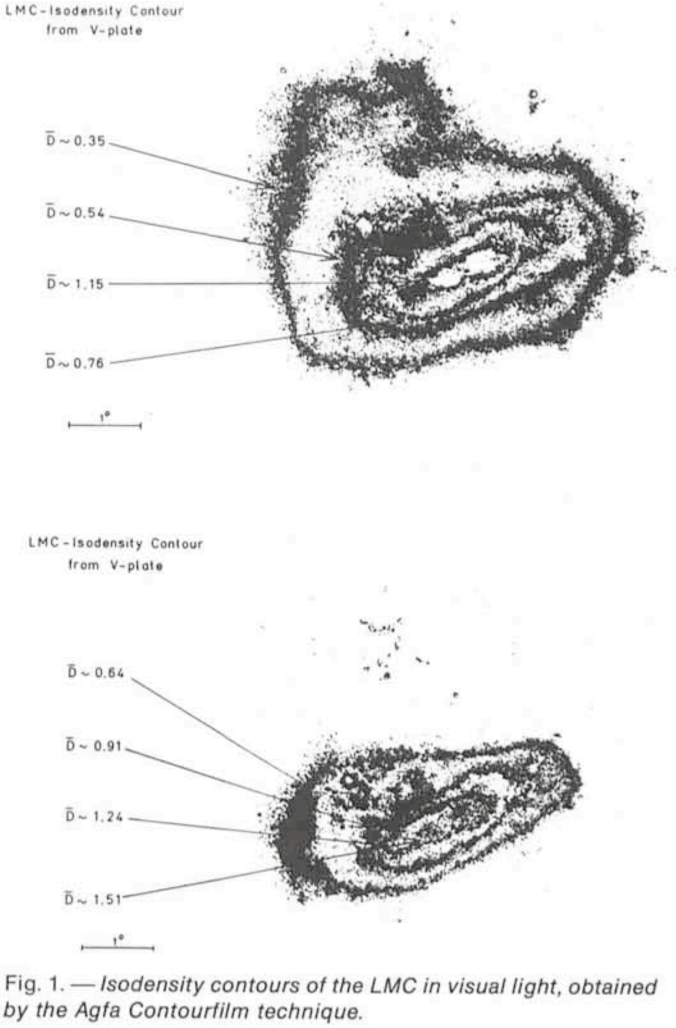

Fig. 1. — *Isodensity contours of the LMC in visual light, obtained by the Agfa Contourfilm technique.*

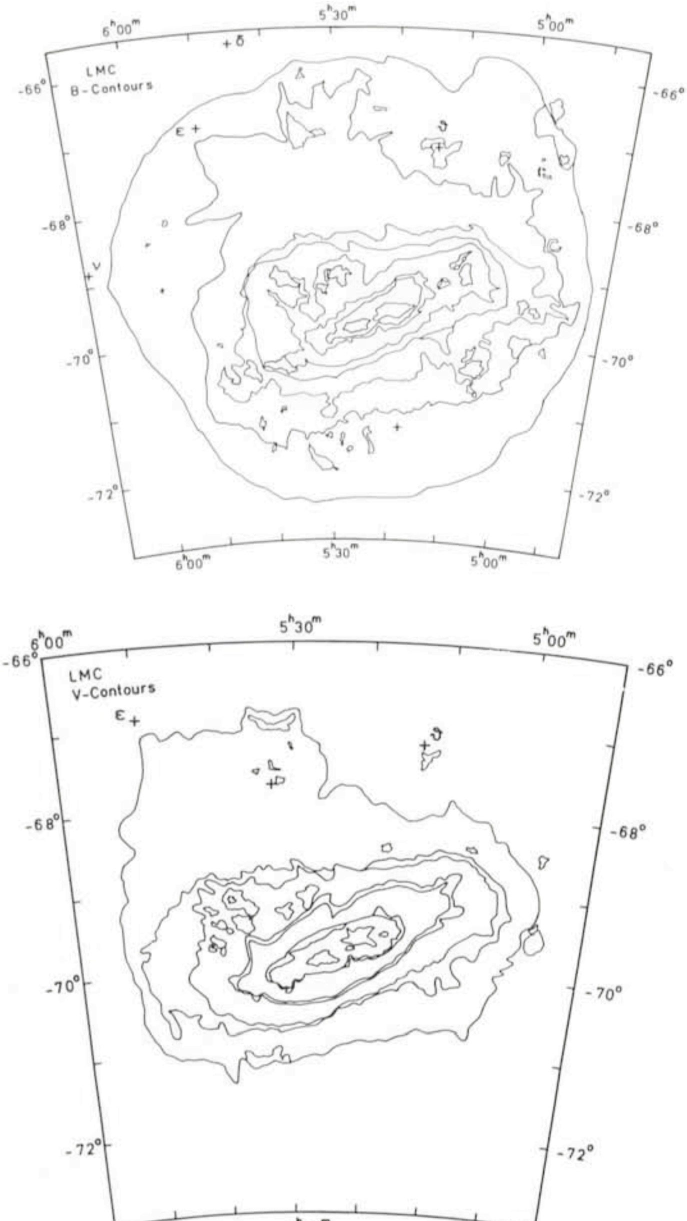

Fig. 2a+b. — *Schematic isodensity contour lines of the LMC from B- and V-Schmidt plates.*

to the brightness distribution within the LMC (and of course in all galaxies), although the faint young population I stars no longer can be distinguished from the old population II stars of the elliptical component. The ellipsoidal structure of the bar is clearly recognized from the V-contours.

The density levels of the contours were calibrated by star counts in the following way: at positions which appeared undisturbed by interstellar material, the isodensity contour is solely determined by the total number of sub-threshold stars per surface area. They contribute according to the luminosity function. At the relevant positions of the contours, star counts to the limiting magnitudes were made on the two Schmidt plates, reaching absolute magnitudes of $M_V \sim -2^{\mathrm{m}}.5$ and $M_V \sim +2^{\mathrm{m}}.1$, respectively. Though the luminosity function is still increasing towards stars of fainter absolute magnitude, those below $M_V \sim +6^{\mathrm{m}}$ hardly contribute to the surface brightness. Therefore a correlation should be expected between the average photographic density D of the corresponding isodensity contour and the counted star number N ($m_V \sim 21^{\mathrm{m}}$). This relation is shown in figure 3.

Separation of Populations I and II

As mentioned above, the very conspicuous young stellar population I stars and HII-regions, which so clearly outline the spiral features, are no longer distinguishable from the old stellar population II of the LMC below a certain absolute magnitude. How can we then separate the young stars from the old stars in such a faint amorphous substratum? An observational approach for solving this problem is to look at the distribution of those stars, which can easily be recognized, and which exhibit specific features that permit us to classify them as either old or young objects. In the case of population II these are the RR Lyrae variable stars; for population I, we have the A- and F-type Algol eclipsing binaries (mainly before mass exchange), which appear to be absent in the population II aggregates of our Galaxy.

A search for rapid variables and RR Lyrae stars in the LMC on ESO Schmidt plates is now well under way: I am blinking in a Zeiss comparator a pair of $5^{\circ}.5$ by $5^{\circ}.5$ ESO Schmidt B-plates of the LMC, separated in epoch by 1 day. Though the progress is slow because of the enormous surface density of stars, several hundreds of variables have been found on about 25 per cent of the searched plate area. Their amplitudes are between $0^{\mathrm{m}}.3$ and 2^{m} and most of them are apparently fainter than $17^{\mathrm{m}}.5$. They add to the approximately 2,500 known variables in or in the foreground of the LMC, most of which are brighter than $16^{\mathrm{m}}.5$. Of course all types of intrinsic and geometric variables with fairly rapid variations contribute to the new sample and no type designations can be given at this moment. However it is known from the recent investigation of Dr. J. Graham that the RR Lyrae stars in the LMC have mean apparent B-magnitudes of about $19^{\mathrm{m}}.6$. A large portion of the detected variables will therefore turn out to be RR Lyrae stars and the rest mainly eclipsing binaries.

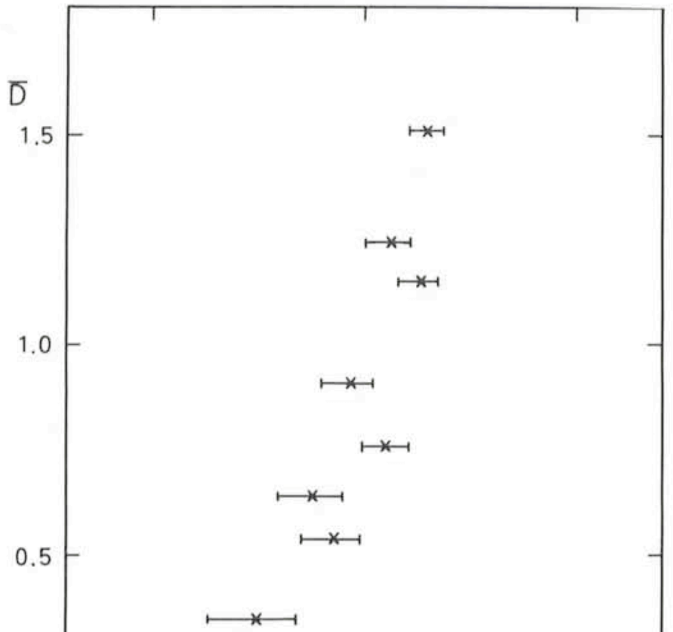

Fig. 3. — *Relation between star numbers N (m_V) and the mean density $\bar{D}$ of the contour lines of the LMC in visual light.*

Red Stars in the LMC

Another method to discriminate between the population I and II stars in the Magellanic Clouds is to search for red stars with (B-V) > $1^m_.3$. Such red stars have different absolute magnitudes depending on their evolutionary status and therefore on their age. The extremely young, red stars are *supergiants* with absolute magnitudes $-6^m \leqq M_V \leqq -4^m$, or *subgiants* with $0^m < M_V < +7^m$ in the pre-main sequence evolutionary stage. In contrast, the reddest population II objects are *giants* with $M_V \sim -2^m$.

Red stars are easily found in a blink comparator by intercomparing U-plates with V-plates, which have nearly the same limiting magnitudes for A-type stars. In a first pilot survey, I blinked an ESO Schmidt U- and V-plate set along a small strip in the E-W direction, crossing the bar and the 30 Doradus complex. Hundreds of red stars were found by this method; they are especially numerous in and around the 30 Doradus nebula.

Globular Clusters

Finally, I should like to report about my study of globular clusters in the LMC. In contrast to the Galaxy where the globular clusters represent the oldest known stellar population and in which the brightest stars are red giants, very populous and young clusters have also been found in the Magellanic Clouds. Their brightest stars are blue supergiants and main-sequence objects. These enigmatic "blue" populous stellar aggregates have the same geometrical appearance as the "red" globular clusters which are quite numerous in the MC's. Obviously the formation of such rich clusters is still going on in the MC's, whereas this process died out long ago in the Milky Way and in other giant galaxies.

By studying the spatial density distribution of stars in globular clusters of very different age we may perhaps learn something about this mechanism and, above all, about their dynamical age status. The relaxation time of globular clusters is typically about $2 \cdot 10^9$ years, which is $^1/_{10}$ the age of the "red" globular clusters. These should therefore show a non-isothermal density distribution, contrary to the "blue" globular clusters, because the ages of the latter are only about $^1/_{100}$ of their relaxation time. Observationally the density distribution of spherical stellar systems can be obtained by star counts or surface photometry along parallel strips. Strip counting has now been carried out on V and B ESO Schmidt plates for two "blue" and two "red" globular clusters of the LMC. The first results indicate that differences are present in the density distribution between the two types of globular clusters.

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