Star Formation and Interstellar Matter in the Large Magellanic Cloud

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A glance on the very recent history of star formation in a galaxy seems to become possible by investigating the distribution of stars as function of their ages and comparing it with the distribution of interstellar matter. In our Galaxy such investigations are extremely difficult since distance determinations for stars and interstellar matter are not sufficiently accurate. This is due to the fact that neither the absolute magnitudes and intrinsic colours of luminous stars nor the reddening law of interstellar dust nor the kinematics of the neutral atomic interstellar hydrogen are precisely known.

The situation is far more favourable in the nearest extragalactic system, the Large Magellanic Cloud (LMC), which is very rich in young stars and interstellar matter. Kinematic investigations have shown that the luminous stars are concentrated to a rather flat rotating disk, which is seen nearly pole-on. Therefore the differences between the individual distances of the stars are small compared to their distances from the sun; in other words, all stars have nearly the same distance.

The Observations

Photoelectric photometry is needed for the age determination of the supergiants as well as for the determination of interstellar reddenings which are a measure of the amount of interstellar dust. Measurements in the UBV system are available now for approximately 1,600 members of the LMC. About 65 % of these have been obtained by the author during three

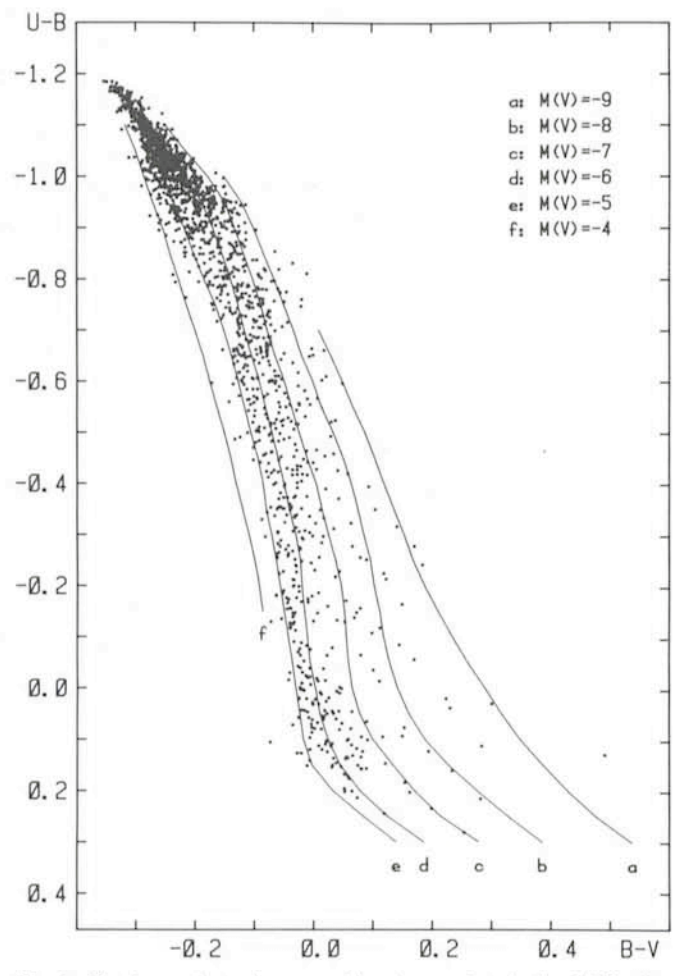

Fig. 1: *The two-colour diagram of luminous stars in the LMC after correction for interstellar reddening.*

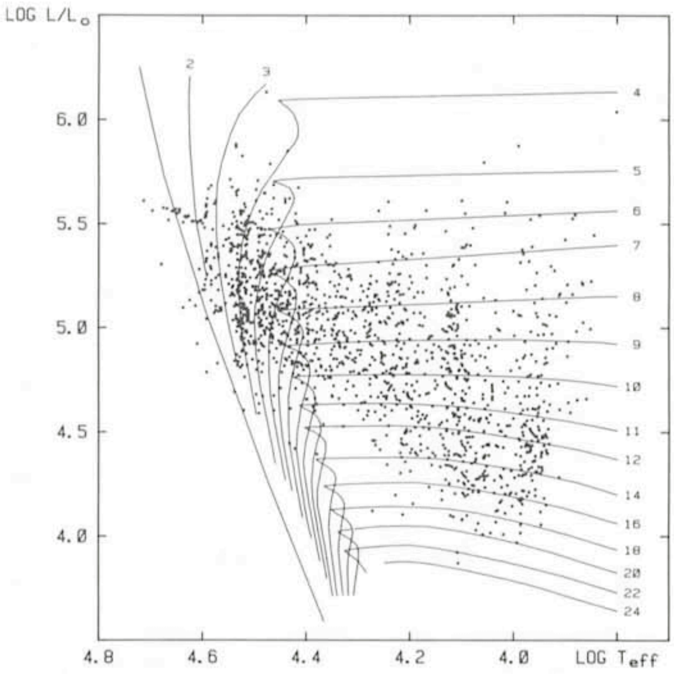

Fig. 2: *The theoretical Hertzsprung-Russell diagram. The lines are isochrones. The ages are given in million years.*

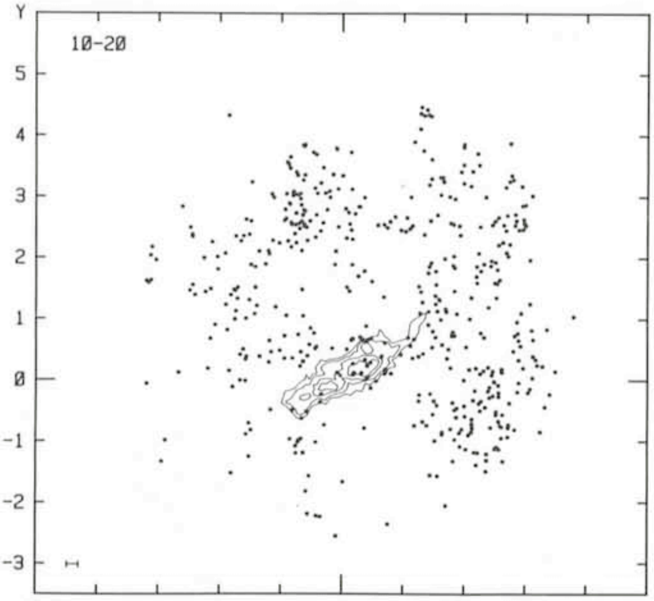

Fig. 3: *The distribution of supergiants (filled circles) and Cepheids (squares) with ages between 10 and 20 million years. The coordinates are standard coordinates, their origin is in the optical centre of the bar. The isophotes (blue light) of the bar were taken from de Vaucouleurs (1957,* Astronomical Journal **62,** *69). Due to their velocity dispersion of 10 km/s the stars have moved away from their places of formation by an average amount which is indicated in the lower left of the diagram.*

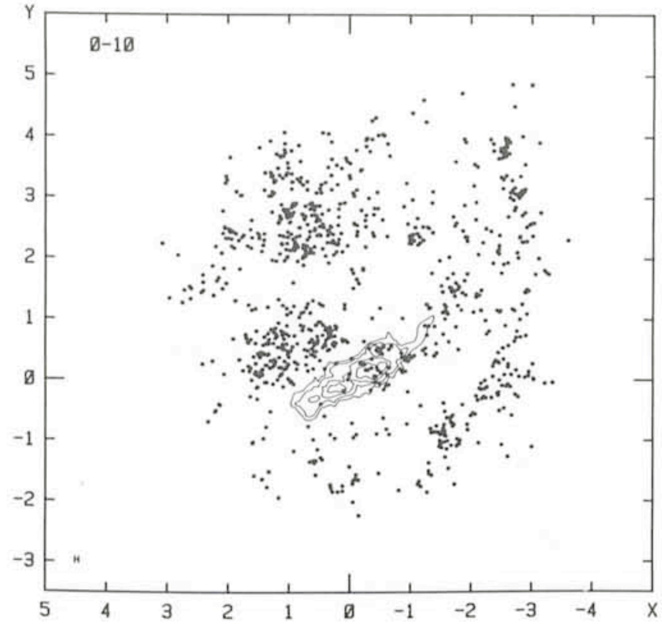

Fig. 4: *The distribution of stars with ages up to 10 million years. For further explanation see Fig. 3.*

observing runs at La Silla with the 61 cm telescope. The remaining part has been measured by various other groups mainly with the 1 m telescope and partly again with the 61 cm telescope. To carry out photometry for so many stars needs a lot of observing time, which is not available with the overrequested large telescopes. This emphasizes the importance of the smaller instruments for long lasting observing programmes.

The Determination of Interstellar Reddenings and Ages

The interstellar reddenings were derived from the positions of the stars in the two-colour diagram. For this purpose one has to know the intrinsic relations $(U\text{-}B)_o$ vs. $(B\text{-}V)_o$ for unreddened stars. It has been shown by several authors that these relations depend on the absolute magnitude of the stars and that they are in the Magellanic Clouds different from those in our Galaxy. A reliable age determination requires a very precise calibration of these intrinsic relations especially for those stars which are still rather near to the upper main sequence in the Hertzsprung-Russell diagram. To allow the present investigation it was therefore necessary to redetermine the intrinsic colours (Isserstedt, 1982, *Astronomy and Astrophysics* **115,** 97). Fig. 1 shows the two-colour diagram for the luminous stars in the LMC after correction for interstellar reddening together with the magnitude-dependent relations for unreddened stars. One realizes that most of the stars are early-type stars and that the data become very incomplete below absolute magnitudes $M_V = -5^m$.

The ages of the stars have been derived by comparison with evolutionary calculations (Maeder, 1981, *Astronomy and Astrophysics* **99,** 97; **102,** 401 case B with moderate mass loss). Fig. 2 shows the stars in the theoretical Hertzsprung-Russell diagram after transformation of the intrinsic colours and absolute magnitudes into temperatures and bolometric luminosities, respectively. Also shown are the isochrones which were interpolated from the evolutionary tracks.

The Distribution of Supergiants

The data on supergiants were combined with data on Cepheids available in the literature and used for the production of a little computer film displaying the distribution of stars as function of age. Two frames of the film are shown in Figs. 3 and 4. (The whole time series and a detailed discussion will appear in *Astronomy and Astrophysics* soon). Note the rapid structural change between these two age groups and especially the formation of the two huge associations 30 Doradus ($X = 1^{\circ}\!.2$; $Y = 0^{\circ}\!.7$) and Shapley III ($X = 0^{\circ}\!.6$; $Y = 2^{\circ}\!.4$). Figs. 5–8 present the distributions of supergiants and Cepheids for smaller age intervals together with the regions of ionized hydrogen (taken from Davies et al., 1976, *Memoirs of the Royal Astronomical Society* **81,** 89). Note again the formation and time-dependent growth of Shapley III and the burst of star formation around 30 Doradus.

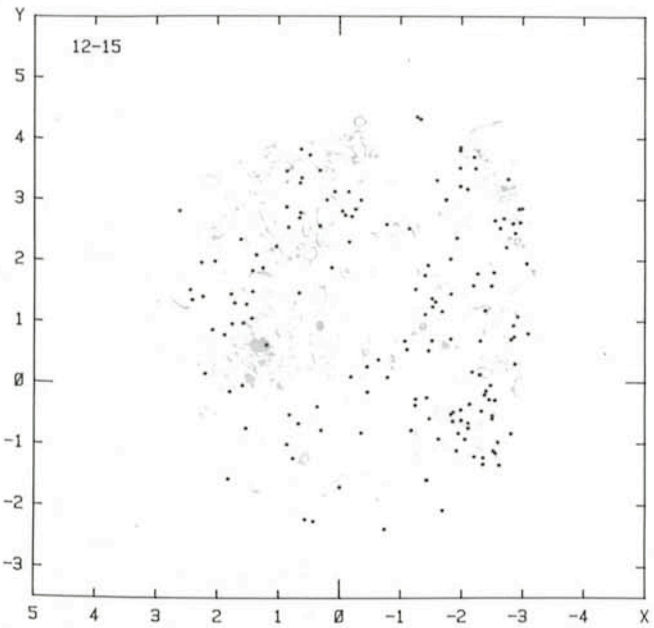

Fig. 5: *The distribution of supergiants (filled circles) and Cepheids (squares) with ages between 12 and 15 million years. Also shown are the HII regions.*

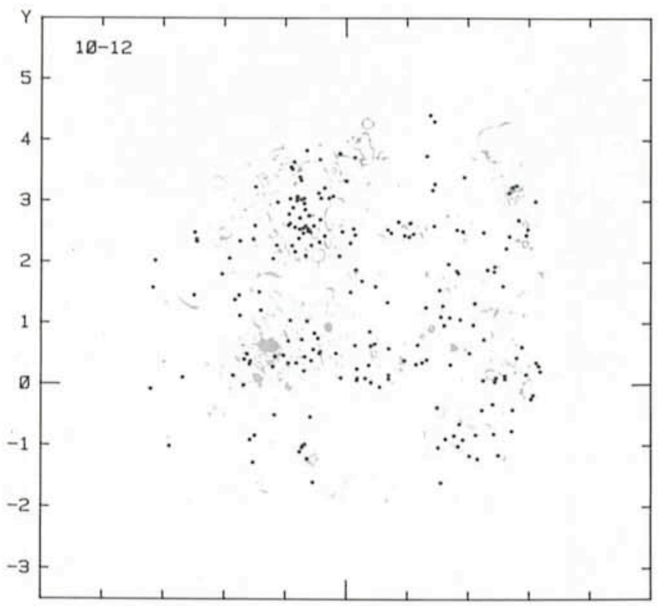

Fig. 6: *The distribution of supergiants and Cepheids with ages between 10 and 12 million years.*

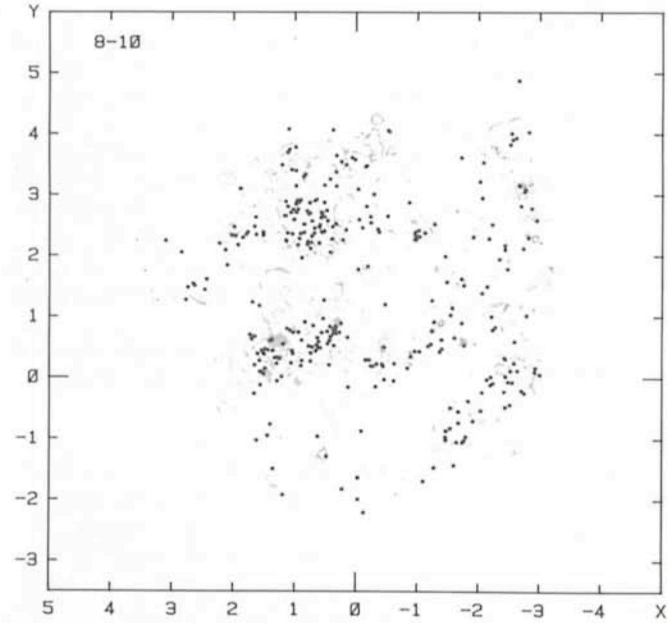

Fig. 7: *The distribution of supergiants and Cepheids with ages between 8 and 10 million years.*

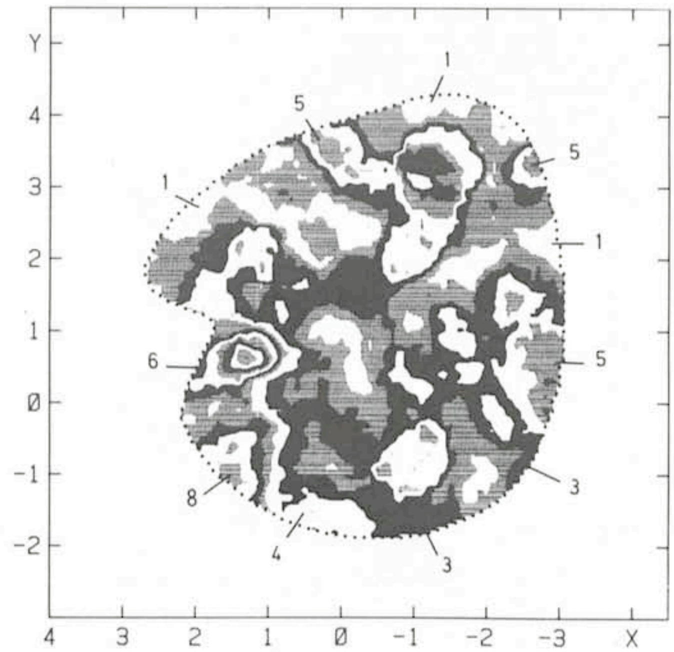

Fig. 9: *Isodensities of interstellar reddenings after subtraction of reddening from the galactic foreground. One step corresponds to* $\triangle E = 0^m.02$.

The Distribution of Interstellar Matter

In a forthcoming paper (Isserstedt and Kohl, in preparation) it will be shown that the star formation rate *in the past* $T \approx 10^7$ years) is on average over the LMC proportional to the *nowadays* observed column density of neutral interstellar hydrogen HI, but that there is no correlation whatsoever between this star formation rate and the density of interstellar dust. This leads to the hypothesis that the dust is partly embedded in clouds of molecular hydrogen H_2 which seem to occur more often in regions were the star formation rate in the past was rather low (and might perhaps be high in the future).

The isodensities in Fig. 9 are describing the distribution of interstellar dust in the LMC. Reddening from dust in the galactic foreground has been subtracted. The sequence "white-grey-black-white ..." denotes increasing reddening. One step corresponds to $\triangle E = 0^m.02$. Note that the Shapley III association has a low dust content but is surrounded by an extended cloud complex, while the otherwise similar association 30 Doradus contains far more interstellar dust. It is interesting to compare Fig. 9 with the distribution of atomic hydrogen from 21 cm measurements (McGee and Milton, 1964, *IAU Symposium* **20,** 291). In spite of some common features in both distributions they are mostly quite dissimilar. This again might be explained if the dust is partly embedded into extended regions of molecular hydrogen, which are otherwise not so easily observable. If these results could be confirmed by independent methods this might have severe consequences for our understanding of star formation and the development of large scale structures in galaxies.

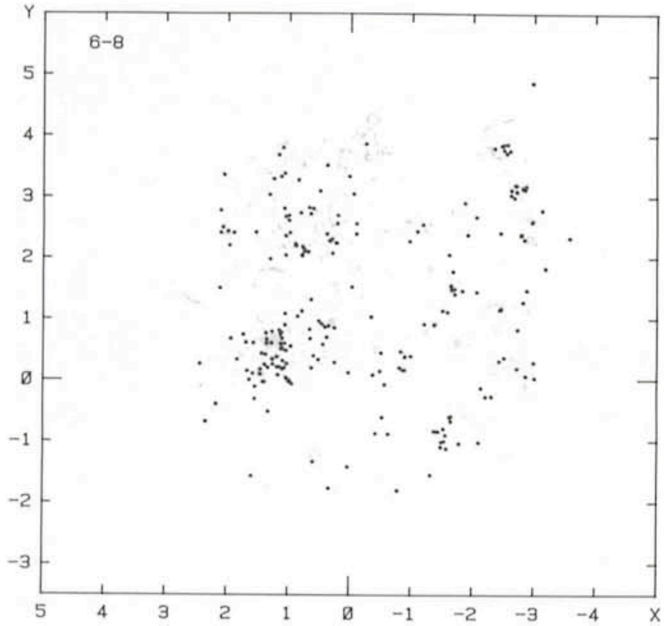

Fig. 8: *The distribution of supergiants and Cepheids with ages between 6 and 8 million years.*

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