GALACTIC RESEARCH WITH SCHMIDT-TELESCOPES

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The use of Schmidt Telescopes for the determination of space density gradients is discussed. Space densities can be determined by a three colour photometry for main sequence stars with $M < 8.0$ and later type giants of population I and for metal poor stars in higher galactic latitudes with $M < 7.0$. A general synthesis of the present available results is not yet possible. But the determination of a density gradient for later type giants along a galactic radius, the distribution of metal poor stars in a galactic meridian and around the galactic centre seems to be possible with the existing observational material.

In order to obtain a correct idea about the Schmidt-telescope, it is useful to consider the situation before its invention and its actual and possible impact upon galactic research.

Up to this event around 1931, galactic research was dominated by the astrograph and by the parabolic mirror, the former allowing photometry as well as spectral classification of stars in larger fields, but with brighter limiting magnitude. As typical limits for an astrograph with four lenses of a diameter of, say, 40 cm, one may assume about $V = 16^m$ for photometry and $V = 13^m$ to 14^m for spectral classification. Photometry of fainter stars with a large parabolic mirror, however, may have been limited then, at about $V = 20^m$.

Already the first description of the Schmidt-telescope in 1931 let it appear as the ideal successor of the astrograph in galactic research: the error-free field size could be considerably enlarged and, even more important, the optics were no longer restricted by the diameter limit of about 40 cm given for multiple-lens astrographs.

It should, however, not be disregarded that the new frontiers for galactic research were opened up not only by the invention of the Schmidt-telescope but also by two other, approximately contemporary, discove-

M. Capaccioli (ed.), Astronomy with Schmidt-Type Telescopes, 247–256.

ries bringing about the access to larger fields and to fainter stars, as well as to the near ultraviolet spectrum barred to the astrograph, i. e.: UV-transparent glass and aluminization instead of silverplating of mirrors. All three accomplishments together opened up the great new possibilities for galactic research.

Those astronomers who continued to work with Schmidt-telescopes along Kapteyn's line were left to their own initiative with respect to their choice of galactic fields. The first such investigations stem from the Cleveland Observatory where a large program of nine galactic fields was carried out by Mc Cuskey and Nassau.

The situation was rather drastically changed by the first opportunity to realize a new photometric method at the Schmidt-telescope, i. e.: three-colour photometry, proposed already in 1938 in the form of the RGU-system with the purpose of replacing spectral classifications in pushing the limiting magnitudes by several unities practically to the limit of an optical telescope. Without spectral types, it brought about the determination of absolute magnitudes as well as of interstellar reddening. The reason for that is - roughly speaking - the first order deviation of stellar radiation from black body radiation being a function of luminosity, and its not being influenced by interstellar extinction.

The most informative among the three spectral regions of three-colour photometries is the ultraviolet one around about 3700 Å which became realizable only owing to the mentioned inventions of UV-transparent glass and mirror aluminization.

The method of three-colour photometry was applied first with the help of the Schmidt-telescopes of the Cleveland- Ann Arbor- and the Asiago-observatories, and later, from 1961 on, with the 48 inch Palomar Schmidt. The limiting magnitude reached about 19^m5 in G. The possibilities were enormously enhanced, thereby, leaving far behind the praxis, however.

I should like to talk just about this praxis and some of its results, i. e.: about the investigation of star fields in the Milky Way and in higher galactic latitudes. The ultimate goal of the photometry in these fields is the evaluation of density functions, possible for main-sequence stars not less luminous than about $M(G) = +8^m$. These functions are the basis for a synthetic view of the density distribution. Since it is hardly foreseeable if such a synthesis can be achieved, it is appropriate to choose the position of the fields such that they let expect at least partial synthesisses restricted to certain facts.

Therefore, the fields within the Milky Way were mainly chosen along the directions close to the galactic centre and anticentre, and the ones in higher galactic latitudes lie mostly close to the galactic meridian

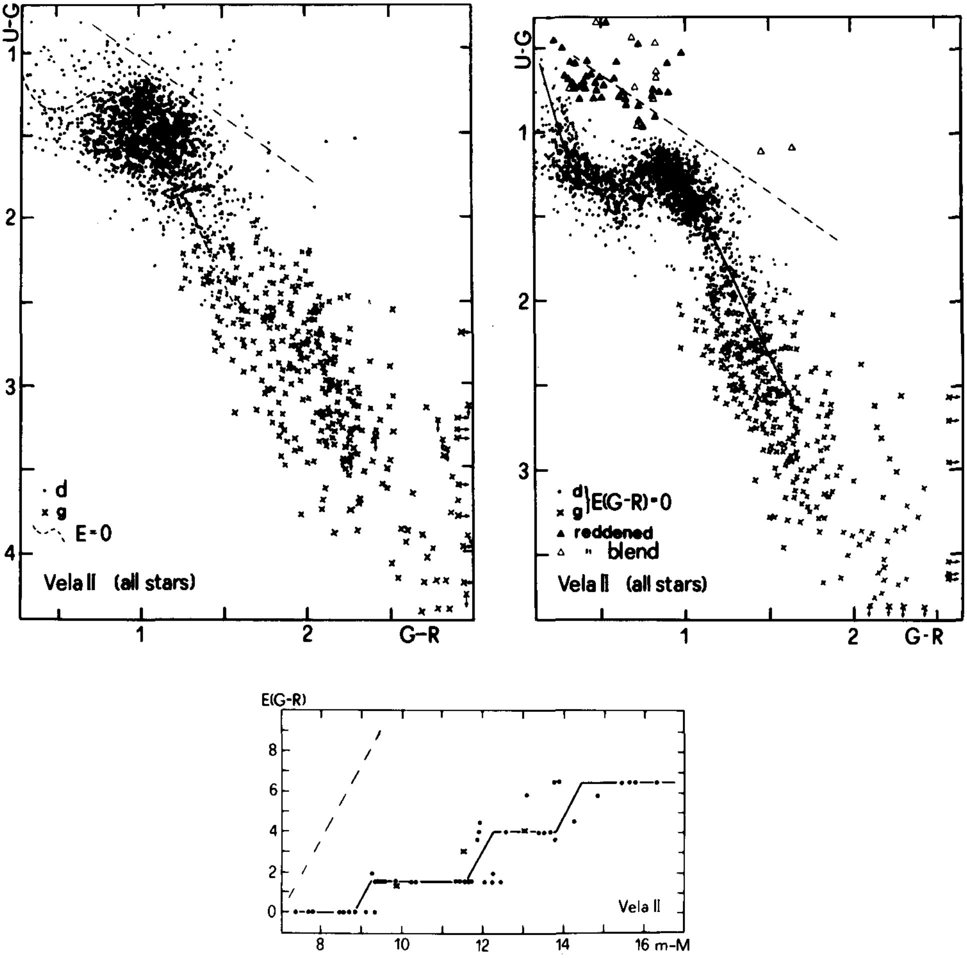

Figure 1: The distribution of all stars in the field, down to the limiting magnitude in the two-colour diagram; left: observed values of the colour indices, right: colour indices corrected for interstellar reddening (below).

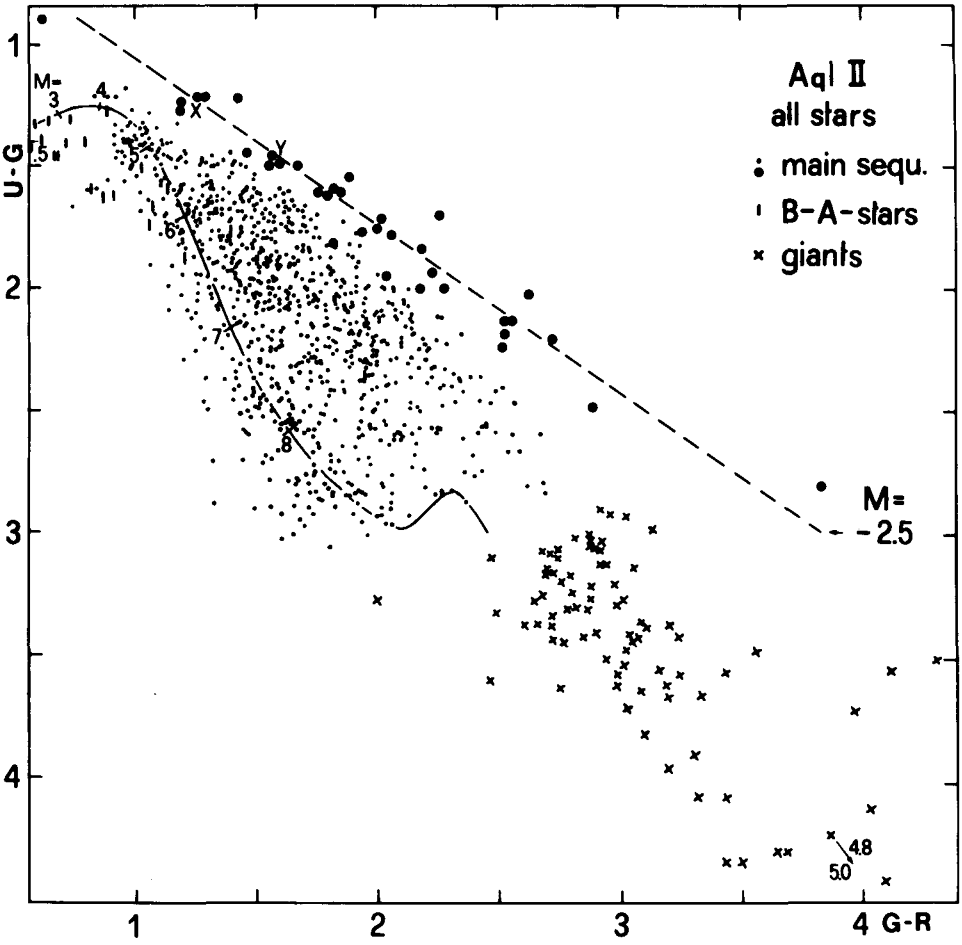

Figure 2: The distribution of all stars in this star-poor field in the two-colour diagram, being the result of an interstellar reddening which increases with increasing distance.

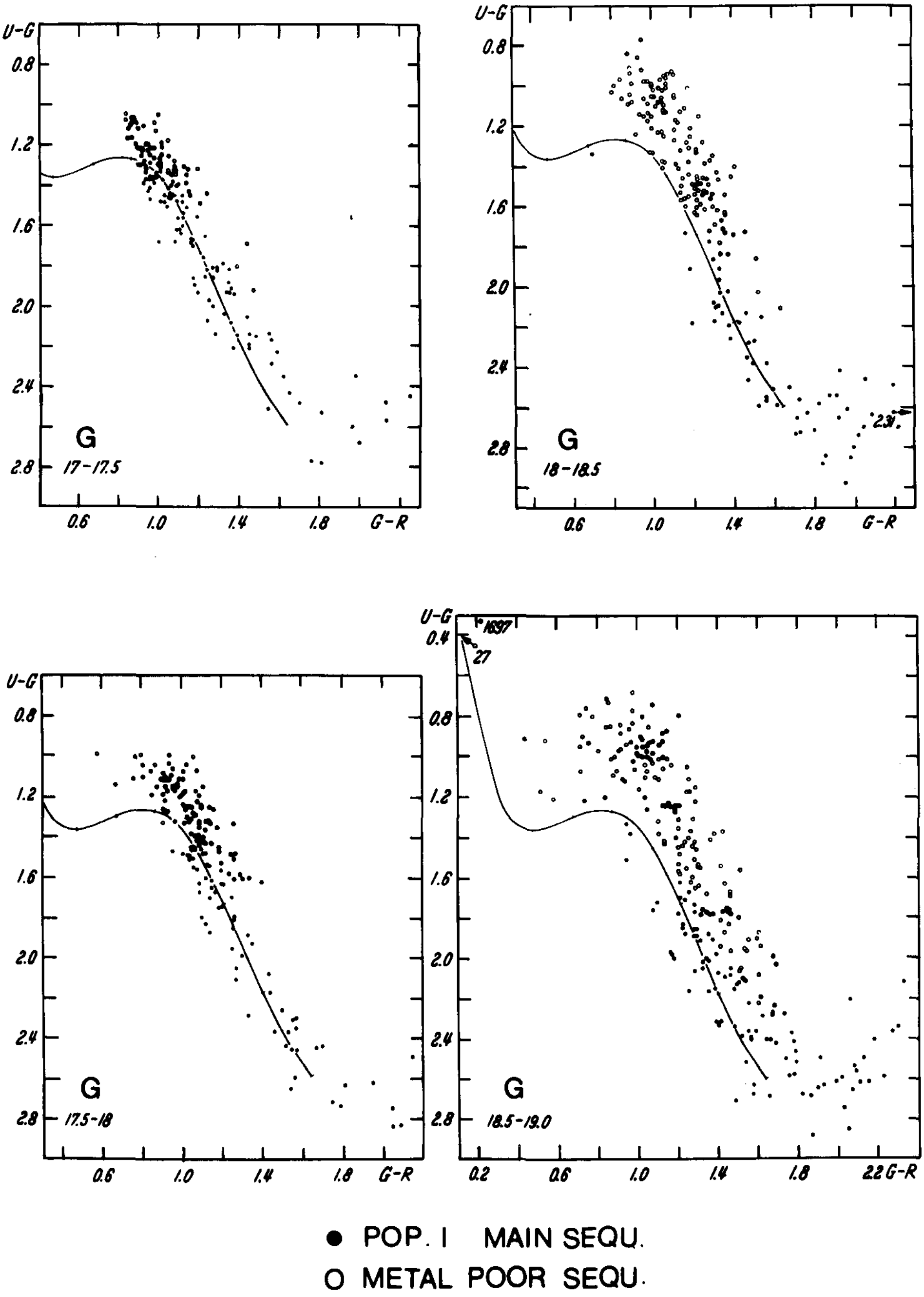

Figure 3: The metal-poor main-sequence stars shifted along the blanketing lines (up and to the left).

(perpendicular to the galactic plane and containing the sun and the galactic centre).

In all these fields, between 500 and 2500 stars should be measured down to the limiting magnitude, leading to field sizes of between 0.1 and 2.5 square degrees for star-rich and star-poor regions, respectively. These numbers can easily be managed without automatic reduction devices, even for at least five plates per colour, necessary for keeping the errors reasonably small. It is upon these errors, of course, that depends the accuracy of the absolute magnitudes and of the colour excesses and, therefore, the reliability of the density functions, too. Also the identification of the late-type giants and of the metal-poor main-sequence stars is sensibly influenced by the accuracy of the colour indices. The mean errors of the magnitudes lie predominantly between $\pm 0^{m}02$ and $\pm 0^{m}03$ and they increase to about twice these values for the faintest stars.

The interdependent discussion of the two-colour diagrams plotted for consecutive intervals in apparent G-magnitude presents a good control for the successful total elimination of systematic errors in the catalogue magnitudes of a given field. If the stars of a field, after correction for interstellar reddening, do not scatter evenly around the main-sequence and the late-type giant branch, but show, instead, a systematic deviation, it is due to a rest-error of up to several hundredth of a magnitude from previous experience, which can usually be identified and eliminated according to the specifications of the deviation.

Up to now, nine volumes, containing the magnitudes and colour indices of 7000 to 10 000 stars each, from totally 48 fields have appeared as Publications of the Basle Astronomical Institute.

Three typical examples shall give an idea about the vastly varying behaviour of two-colour diagrams in different star fields: the first gives the distribution of all stars in a star-rich Milky Way field with low extinction, the second the one in a galactic strong-absorption field and the last the distribution pattern in a field of higher galactic latitude. The first figure shows most prominently the abundance of stars in the middle spectral classes and their separation from the late-type giants. The discussion leads at first to the interstellar reddening function as seen in the figure. After the elimination of the reddening effect the stars are distributed in the two colour diagram as seen at the right side diagram in figure 1. The second figure is typical for a complete mixing of stars from almost all spectral classes, but also for the existence of a large amount of late-type giants. The discussion leads to an interstellar reddening which increases with increasing distance up to about 2.5 magn. The resulting density gradients are not as good as in the case before. The last figure reveals the deviating position of metal-poor main-sequence stars.

For the determination of the density-functions one does not use these overall diagrams, containing all the stars of a field, but rather the already mentioned partial diagrams, fractioned according to consecutive intervals in apparent magnitude, yielding much more detailed information. Unlike the methodic tool of the two-colour diagrams, the density functions for the different fields are directly comparable and form so the basis for a synthesis. This term, however, - as said before - should not awake exaggerated expectations. Even with a considerably increased number of fields, the region covered with our density functions will remain relatively limited. Due to the given limits for Schmidt-telescopes, the density functions will be complete within a few hundreds of parsecs for the absolutely faintest and up to about 10 000 pc for the absolutely brightest stars. Much more favourable is the situation if the synthesis aims at more specific points of view. As said before, the fields have actually been selected correspondingly. I should like to point to three such results here: First, to a density gradient for late-type giants along a galactic radius, from centre to anticentre, second, to the density distribution of metal-poor stars within the accessible part of the galactic meridian, and third, to the behaviour of the metal-poor population in the neighbourhood of the galactic centre.

For the density functions of the late-type giants in the directions to the galactic centre and anticentre, we had at our disposition four fields in each case, covering up to 3 and 11 kpc, respectively, depending on the limiting magnitudes and on the extinction situations. The density functions of all these fields (fig. 4) can be interpreted homogeneously: Assuming the galactic centre at a distance of about 8 kpc from the sun, a density maximum is reached at about 6 kpc towards the sun, where from, the density decreases steadily, passing the solar neighbourhood, out to a distance of about 19 kpc from the galactic centre by a factor of 200.

Within the distance interval from 2 to 5 kpc from the galactic centre, the density remains at a constant level about 2. 5 times below the maximum. Because of the strong extinction, it is not possible to approach closer distances from the centre.

The density distribution of the metal-poor main-sequence stars north to the disk can be evaluated from the results in seven fields, two of them pointing to the anticentre side, only. Figure 5 shows the isodensity lines in the galactic meridian for the three consecutive intervals in absolute magnitude M(G): ($4^m 5^m$), ($5^m, 6^m$) and ($6^m, 7^m$). On the whole, their behaviour is about similar, with the exception that the gradient for the absolutely brightest group ($4^m, 5^m$) is somewhat too steep for SA 54 and a bit too flat for SA 57. Apart from that, the systematic behaviour consists in the fact that the isodensity lines approach

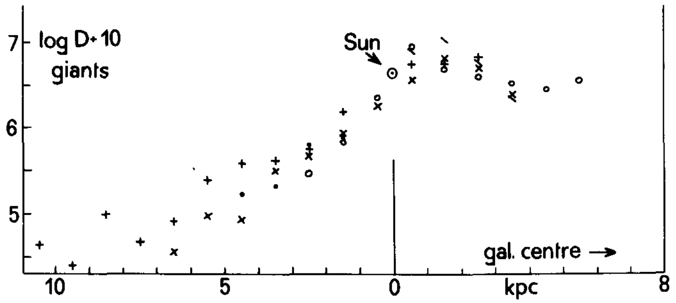

Figure 4: The density function for late-type giants obtained from four fields in the direction to the galactic centre and from four other fields in the one to the anticentre, reduced to z = 0 by use of the function D(z) for the solar neighbourhood, because of the different galactic latitudes (+2°5 to -3°6).

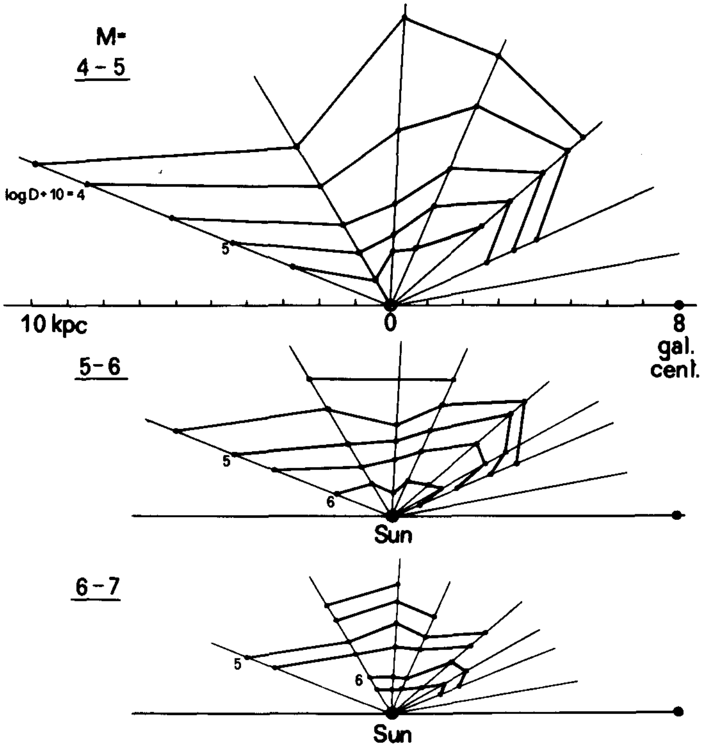

Figure 5: Isodensity lines for three consecutive intervals in M(G) in the galactic meridian (perpendicular to the galactic disk and containing the galactic centre and the sun).

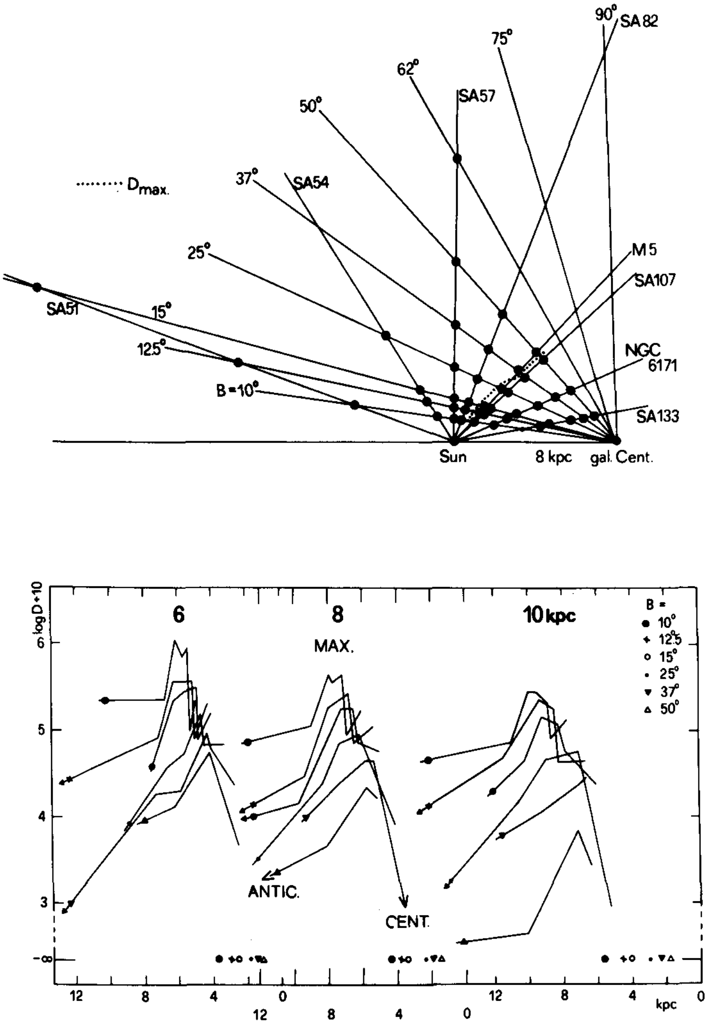

Figure 6: Upper part: Transformation of the heliocentric density gradients for the metal-poor main-sequence stars within the galactic meridian of figure 5 into galactocentric gradients. Lower part: Galactocentric density distribution for different galactocentric latitudes and different solar distances from the galactic centre (6, 8 and 10 kpc). The maximum densities follow the dashed line in the upper part.

continuously the galactic plane with increasing angular distance from the galactic centre, starting at about 40° to 65° (SA 107 to SA 82, respectively). At smaller angular distances, however, the isodensity lines behave completely different: approaching the galactic centre, the densities decrease strongly, and at about 10° from the centre the metal-poor stars are almost completely missing in the corresponding fields. The details of this drastic density drop, however, are not yet fully revealed by the available data.

One can visualize this density decrease towards the galactic centre more perceptually by transforming the observed (solar-centered) density gradients into such which have their origin in the galactic centre (fig. 6). In all their directions, the densities first increase from an undeterminably small value near the centre steeply to a maximum, where from, they decrease again but slowly. These maxima lie rather exactly on an ellipse centered in the galactic centre and with its major axis in the galactic plane. They are reached at distances between about 7.5 and 5.0 kpc from the galactic centre at 10° and 50° galactocentric latitude, respectively.

Further partial synthesisses might consider: the density distribution in the farther solar neighbourhood, the possible connection between densities and spiral structure, the density behaviour perpendicular to the galactic plane and the distribution of the interstellar absorption clouds whose distances follow as a by-product from the discussion.

All these results, of course, will obtain considerably more reliability if the number of fields will be increased, and they could penetrate into deeper space if the limiting magnitudes of the photometric measurements could be pushed to fainter values. To increase the number of fields presents no serious problem, more critical is, however, the supply of photoelectric scales down to sufficiently faint magnitudes. The spatial extension encounters principal difficulties, as far as Schmidt-telescopes are concerned. They stem from the fact that the exposure times for U-plates at the big Schmidt-telescopes (about 40 minutes at the 48" Palomar Schmidt) cannot be extended much more without darkening the plate background to a degree where the measurement of faint stars at the iris-photometer becomes too inaccurate. I suppose that only the use of large parabolic mirrors might help to overcome this threshold.