LICK OBSERVATORY BULLETIN
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SOME MERIDIAN-CIRCLE CATALOGUES*

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The first step in the program to determine stellar proper motions with the 20-inch astrograph of the Lick Observatory is near completion. Of 1246 fields, all but about 70 had been photographed as of December, 1952.

The original program was conceived and planned by Dr. W. H. Wright.¹ The final adjustment of the instrument was made, and all the photographs were taken, by Dr. C. D. Shane and Mr. C. A. Wirtanen. The first fields were photographed in April, 1947, and the mean epoch of the set will be about 1950.5.

Recently investigations were started to determine the accuracy to be expected and to consider other aspects of the program. At present, plates of 10×10 inches are the largest that can be measured at the Lick Observatory. Three pairs of photographs of this size for three Selected Areas, Nos. 15, 35 and 59, were taken. The exposures were made in the same way as for program plates, i.e. a two-hour exposure (System I) and a one-minute exposure (System II), with the images in the two systems separated by about one minute of arc. In addition, an objective grating with four magnitudes difference between the central image and that of the first-order spectra was used, as is done for the main program. Results of the investigation of the accuracy from these S.A. plates were partly reported by Shane at the 1952 I.A.U. Meeting in Rome.² The present paper summarizes the foregoing results, and it indicates the relationship of the program to meridian-circle catalogues of faint stars.

The best extragalactic nebulae for position reference are those with nearly stellar nuclei of about 16th magnitude. Approximately 25 nebulae were chosen on each pair of plates, but this number by no means exhausted the supply of suitable nebulae. Since the area of the measured plates is only one-third that of the regular 17×17 inch program fields, no difficulties are to be expected in selecting an adequate number of well-measurable and uniformly distributed nebulae, except in the zone of avoidance.

Examination of the plates shows that stars of photographic magnitude 12 to 13, according to the *Bergedorfer Spektral-Durchmusterung*, can be used for a bridge between Systems I and II.

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About 25 such stars were also measured on each plate-pair.

Two plates of each field were compared and six linear plate-constants, with their probable errors, were deduced from measurements of nebulae, as well as of first-order grating images of stars. The agreement between the constants computed from the measurements of the stars and those of the nebulae is very good, and no systematic effect could be found. Furthermore, a comparison of the one-minute exposures (central image) with the two-hour exposures (first-order grating images) of the same stars gave six reduction constants from System I to System II for each plate.

The appearance of the nebular images is quite sensitive to quality of seeing; therefore a pronounced correlation between accuracy and seeing may be expected. The results in Table I support

TABLE I. ACCURACY IN POSITION COMPARISON OF A
NEBULA ON TWO PLATES

S.A.	Seeing for each plate of a pair	P.E. for a nebula
15	average, poor	$\pm 0''.24$
59	good, average	0.18
35	average, average	0.13

this conjecture. The poor plate of S.A. 15 was chosen only as an experiment, because fields having plates of low quality are usually rephotographed on the regular program. Nebulae in S.A. 35 were selected very carefully for measurability. Since particular care in the selection of nebulae contributes considerably to the accuracy, there is every reason to exercise careful judgment in selecting nebulae for the regular program. Therefore $\pm 0''.15$ may be taken as an average value of the probable error in the position comparison of a nebula on two plates of the same field. Fifty nebulae therefore would give a reference frame for stellar proper motions with a probable error $\pm 0''.02$.

The measurements of stars did not show a significant correlation with the quality of seeing. On the average, the probable error in the position comparison of a star is $\pm 0''.09$, so that 25 stars would give $\pm 0''.02$ as the probable error for the bridge between Systems I and II. The same value of the probable error, i.e. $\pm 0''.09$ for a single star, is expected for bright stars of approximately 8th magnitude, because a one-minute

exposure of these stars is identical with a two-hour exposure of the fainter stars around 12th magnitude.

It should be emphasized that the range in magnitude for measurable star images does not exceed one magnitude, if the first-order spectra of grating images are measured. The latter overlap with the central images for the brighter stars, or are not dense enough for the fainter images. The same limits of magnitude range apply to the group of brighter stars, around photographic magnitude 8, suitable for meridian-circle observations. Grating images of these stars are measured in System II, reduced by the bridge to System I and then referred to the frame of nebulae. The combination of the various errors gives $\pm 0''.10$ as a probable error in the difference of two positions of a star with reference to nebulae. Thus in 25 years proper motions can be obtained with a probable error of $\pm 0''.004$ for an individual star of this group. Measurements of bridge-stars and those of magnitude near 16 will yield proper motions of higher accuracy.

The foregoing conclusions are drawn from measurements on 10×10 inch plates. The full field of 17×17 inches, however, may show some additional field effects not found on smaller

plates, which may lower the accuracy. On the other hand, the overlap of fields on the larger plates may contribute to the reliability of the proper motions. It is planned to extend the investigation of the accuracy of measurement to the full-sized fields of the program.

Correction of the precession constant is another purpose of the program, as outlined by Wright. The position of the pole could be determined by star-trails and referred to nebulae; however, practical considerations do not indicate this method to be promising with the 20-inch astrograph. Meridian-circle observations of stars, whose proper motions can be determined in the Lick Observatory program, seem to offer a more reliable way to determine the precession. Furthermore, proper motions in the zone of avoidance cannot generally be referred directly to nebulae. Meridian circles offer again a solution in the way of a bridge, providing both ends of the bridge are securely referred to nebulae. Finally, there is great need for good positions of faint stars.

The problem of obtaining a catalogue of faint stars, and of referring stellar positions to the extragalactic nebulae, has been discussed mainly by Russian astronomers.³ A list for meridian observations north of declination -30° has al-

TABLE II. RELATIONSHIP OF ZVEREV'S CATALOGUE TO STARS MEASURABLE ON LICK PLATES

Centers of the Lick fields, $6^\circ \times 6^\circ$	$0^h, 0^\circ$	$2^h, 0^\circ$	$12^h, 0^\circ$	$14^h, 0^\circ$
Number of Catalogue stars				
1. Good for measuring on Lick plates	2	4	2	4
2. Faint, but still can be measured	3	1	5	2
3. Too faint	14	16	9	12
Total	19	21	16	18
Number of stars measurable on Lick plates				
1. Good for measuring	21	18	21	22
2. Faint	8	8	11	6
3. Bright	3	3	0	2
Total	32	29	32	30

ready been completed under the direction of Professor M. S. Zverev in the Sternberg Astronomical Institute, Moscow.⁴ Four plates of the regular Lick program have been inspected and stars in Zverev's catalogue identified. Table II shows that, of about 19 of these stars on each Lick plate, an average of only three per plate have images suitable for accurate measurements. At some sacrifice in accuracy, however, about three faint images per field could be measured, if badly needed. The remaining stars do not produce measurable first-order grating images, but their central images are still too large to yield accurate results. Figure 1 shows the distri-

bution of stars in the field at $0^h, 0^\circ$ as a typical example for the plates surveyed.

Larink's Bergedorf list⁵ may be even less favorable in relation to the Lick program because stars of magnitude 8.0 to 10.5 have been selected for this list, compared with 7.5 to 9.2 in the Russian catalogue. Although Figure 1 shows that relatively more stars can be selected from the AGK2A Catalogue⁶ for measurement on Lick plates, there are only six suitable stars from the total of 23 in the field selected. Two stars from the AGK2A are too bright, if their first-order grating spectra are measured. The second-order spectrum, however, is well separated and could

Figure 1. Distribution of measurable and unmeasurable star images on a Lick proper motion program plate centered at $0^h, 0^\circ$.

be measured. Thus there may be a possibility for extension of the magnitude range towards the bright end, but no definite conclusions can be made without a thorough investigation, particularly of the expected color and magnitude equations.

The catalogues mentioned above, therefore, do not include enough stars suitable for measurement on the Lick program plates. If the latter are adopted as a basis for proper motions, an ideal positional catalogue of faint stars should contain as many as possible of those stars which can be measured and are well distributed on the 20-inch program plates. After several decades the latter would give "absolute" proper motions for many stars of the catalogue. Moreover, such a list would supply Lick plates with valuable position references. Since a group of stars of magnitude 12 to 13 will, in any case, be measured for the bridge, the determination of accurate positions for these stars would not require additional measurements. Finally, if a group of stars around magnitude 16 also were measured for proper motion, accurate positions could likewise be deduced for these stars. This program would give accurate and uniform material for positions and proper motions at three levels of brightness: 8, 12, and 16 magnitude. Any object of interest in this magnitude range could be photographically referred with high accuracy to these positions. Appropriate gratings could be used to split the intervals in magnitude between the three groups of reference stars.

It seems that the only way to establish a close relationship between a list of position stars and the Lick program plates is to start with the latter.

Whether a star on a plate is measurable can readily be determined only by an examination of that specific plate. If it were desired to make up a list of meridian circle stars adapted to the Lick program, a survey of the 20-inch program plates should be made, and all the measurable stars around magnitude 8 should be recorded. On the basis of this list the final program for meridian circle observations could be prepared, or an existing program revised, with account taken of the desirable number, distribution and individual characteristics of stars.

The new list of the U. S. Naval Observatory is not yet available in print because all the stars have not yet been observed, nor selected.⁷ A paper on the Washington catalogue, as well as on the possibility of using the photographic catalogues (Yale and AGK2) in connection with the Lick program is under consideration for a future publication.

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