FIRST RESULTS OF THE LICK PROPER MOTION PROGRAM

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Photography of the second epoch of the Lick Proper Motion Program (Wright 1950) was started in 1968. The original plan (Vasilevskis 1954) was modified in several respects. It was decided to carry out a pilot program first, before the start of a full coverage of the sky accessible from Lick. It was also decided to make use of the new lens corrected for yellow light (Vasilevskis 1964), in addition to the blue lens used for the first epoch. The aims of the pilot program were formulated: (1) carry out the necessary error investigations, (2) develop methods and procedures to a stage of routine, (3) derive proper motions of stars measured, and (4) attempt to arrive at some astronomical conclusions based on these motions. The program was limited to 97 fields nearly uniformly distributed over the sky north of -23°; all these fields were photographed, measured and reduced, 78 of them contain a sufficient number of galaxies for proper motion reference. This report will be limited to presenting a few results obtained from the first crude analysis of proper motions that became available only a week ago. These results, therefore may change significantly in the process of further analysis.

Types of images on plates are shown in Figure 1. Two exposures are made: two hours (System I) and one minute (System II), both systems separated by an offset of the order of one mm. The number and type of objects selected for measurement is also shown in Figure 1. The medium bright stars, approximately magnitude 12, served as a bridge between both systems of images; the bright ones, approximately magnitude 8, were selected mainly for comparison with AGK 3 and Yale Zones. The fainter AGK stars served also as bridge stars, in addition to the medium ones. The Gaertner Survey Machine and the Automatic Measuring Engine (Vasilevskis and Popov 1970) were used for selection and measurement, respectively.

The process of reduction of measurements is outlined in Figure 2. As mentioned above, the second epoch photographs were taken with the blue and yellow lenses, mainly for the purpose of two-color photometry. Since the error investigation was one of the principal aims of the pilot program, the position measurements of the yellow plates were used for comparison with blue ones. It was found that the reduction of measured postions of stars from the yellow to blue plates seems acceptable, and this reduction was done. There is no simple relationship between the iris photometer readings, and magnitudes and colors of galaxies; their positions, therefore, were reduced without using the color data. We realize that such a procedure may

https://doi.org/10.1017/S0252921100028098 Published online by Cambridge University Press
https://doi.org/10.1017/S0252921100028098 Published online by Cambridge University Press

cause some systematic errors, and this possibility is being investigated.

Each of the first epoch plates, taken in blue light only, was measured twice, in two orientations 90° apart. This procedure was used mainly for investigation of the precision and stability of the X and Y systems of the measuring engine, and also for elimination of possible spurious measurements. The experience gained will permit simplification of the measuring procedure in the future.

At present only photographic magnitudes have been derived; photoelectric measurements by W. L. Sanders (1966) were used as primary photometric standards. Magnitudes given in AGK 2 and Yale Zones were employed as secondary standards after the systematic zero point corrections were applied for reduction to the primary standards.

As Figure 2 indicates, the analysis of proper motions can be made in two separate directions. A comparison with a fundamental system, e.g. FK4, yields differences that consist of correction to precession and other systematic errors that affect both types of proper motions in a different way. Since proper motions with respect to galaxies do not contain errors of reference to the equator and equinox, their systematic trends are caused by the solar motion and systematic motions of stars. Every effort, of course, should be exercised to eliminate possible systematic observational errors.

Aside from the observational errors, the differences between the Lick proper motions and those in a fundamental system are expected to satisfy the relationships:

$$\begin{aligned} \Delta\mu_x &= \Delta\mu_\alpha \cos\delta = \Delta n \sin\alpha \sin\delta + \Delta k \cos\delta \\ \Delta\mu^y &= \Delta\mu_\delta = \Delta n \cos\alpha \end{aligned} \qquad (1)$$

if $\Delta p_1 = \Delta n \operatorname{cosec} \varepsilon$ is the correction to the lunisolar precession, and $\Delta\lambda + \Delta e = n \cot\varepsilon - \Delta k$ is the sum of the corrections to the planetary precession and the motion of the equinox.

Since stars given in the FK4 are too bright for measurement on the Lick plates, AGK3 was used as an intermediary and only proper motions north of -2° could be used for comparison. Moreover, only stars near the faint limit of the AGK3 can be reliably measured on the Lick plates. Consequently, an asymmetric distribution of positions on the sky and magnitudes in the catalogue weakens further the ties between the Lick and the FK4 systems.

Means of proper motion differences AGK3-Lick were formed for each plate in the process of this preliminary investigation, and then the relationship (1) was used for derivation of Δn and Δk. Least squares solutions were made in each coordinate separately and combined. Residuals were particularly large north of 55°, and solution was repeated for fields south of 60°. Results of all these solutions are given in Table I. The computed quantities, particularly Δk, depart significantly from the values derived by

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TABLE I

SOLUTIONS FROM COMPARISON WITH AGK 3, FOR Δn AND Δk ONLY, AND WITH ΔD ADDED

		All Fields			$\delta < 60°$	
Number of fields		59			55	
Number of stars		1573			1431	
Mean m_{pg}		10.23			10.23	
	Δn	Δk	ΔD	Δn	Δk	ΔD
In α	+.33±.18	-.77±.08		+.23±.22	-.74±.08	
In δ	.27 .11			.33 .10		
Combined	.28 .09	.77 .09		.31 .09	.74 .08	
In α	+.31±.18	-.68±.08	-.48±.19	+.26±.22	-.67±.08	-.36±.19
In δ	.29 .11		.13 .13	.35 .09		.26 .12
Combined	.30 .09	.70 .09	.21 .10	.34 .08	.67 .08	.29 .10

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W. Fricke (1967 a, b). Residuals seemed to indicate slight periodical trends in right ascension and declination. Empirical terms were added, therefore, to equations (1) in an attempt to study systematic differences, but these terms did not change significantly the values of Δn and Δk. Finally, terms for correction to the secular variation of obliquity, discussed by S. Aoki (1967) were added to (1), thus giving

$$\begin{aligned} \Delta\mu_x &= \Delta n \sin\alpha \sin\delta + \Delta k \cos\delta - \Delta D \cos\alpha \sin\delta \\ \Delta\mu_y &= \Delta n \cos\alpha + \Delta D \sin\alpha \end{aligned} \quad (2)$$

where ΔD is the correction to the secular variation of obliquity. The values obtained by least squares solution are given in Table I. Although the value of ΔD does not depart significantly from that suggested by Aoki, we are not prepared to assert the reality of the term at this preliminary stage. As Table I shows, the introduction of terms for ΔD did not change appreciably Δn and Δk.

Proper motion differences Lick-AGK3, corrected for the effects of Δn, Δk and ΔD obtained from (2) for the zone south of 60° and then averaged, are plotted in Figure 3 and 4 versus α and δ respectively. Figure 5 shows the averaged differences in various areas of the sky; if a single field falls within an area, differences are given in parenthesis.

No detailed study of the solar motion and galactic rotation could be carried out in time for this Colloquium, and the results given below were obtained in the process of testing computer programs.* Solutions performed in right ascension need some checking, and only results from proper motions in declination are presented here. Since the proper motions do not depend on reference to the equator, the usually employed equation (e.g. Fricke 1967 a) is simplified:

$$\begin{aligned} M\delta = {} & f\,(X \cos\alpha \sin\delta + Y \sin\alpha \sin\delta - Z \cos\delta) + Q \sin i \cos(\alpha - \Omega) \\ & + P\,(\cos 2\ell \cos b \sin\phi - 1/2 \sin 2\ell \sin 2b \cos\phi). \end{aligned} \quad (3)$$

The new system of galactic coordinates was used. All the 78 fields containing galaxies were used in solutions, assuming $f = 1$ without any regard to the galactic latitude; the distribution of fields is shown in Figure 6. Computation was performed separately for bright, intermediate and faint stars. In this first experiment three cutoffs were tried regarding the size of proper motions used, namely proper motions larger than 0."3, 0."1 and

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* Because of this fact the manuscript was slightly modified after the oral presentation.

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TABLE II

SOLAR APEX AND MEAN SECULAR PARALLAX
SOLUTION IN δ FROM PROPER MOTIONS SMALLER THAN 0''3/a

Number of Fields	77	78	78
Number of Stars	1069	3000	3197
Mean m_{pg}	9.08	11.59	15.96
A	289°6±12°0	298°1±10°2	320°3±16°0
D	38.4 7.9	43.3 6.4	46.1 8.0
(h/ρ)	2''67 0''45	1''76 0''20	1''11 0''15

TABLE III

CONSTANT B OF GALACTIC ROTATION
FROM PROPER MOTIONS IN DECLINATION

$\overline{m}_{pg}$	$\mu < 0''3/a$ No. of Stars	B	$\mu < 0''1/a$ No. of Stars	B
11.5	3000	-10.7±8.7	2945	- 9.7±7.2
16.0	3197	-15.0 7.3	3177	-15.0 5.7

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0''05 were successively omitted from solutions. Only a few stars were measured above the limit of 0''3, and most of them were selected because of large proper motions. Their omission, therefore, was justified for removal of a statistical bias. The cutoff at 0''05 seems to be too severe, and the corresponding results are not presented here.

Data obtained for solar motion, derived from the components X, Y, and Z are given in Table II. The right ascension of the solar apex agrees reasonably with that derived by N.V. Fatchikhin (1968) from proper motions with reference to galaxies, if our values are interpolated to the mean magnitude of stars used by Fatchkhin. The declination, however, is considerably larger than that usually derived from motions of heterogeneous types of stars.

No meaningful value of the Oort constant P = A/4.74 could be derived in this oversimplified way, and only a rough indication for Q = B/4.74 was found; the computed values of B in km/sec/kpc for intermediate and faint stars are given in Table III.

As was mentioned earlier, we do not claim a high degree of reliability for the results presented here. By the time of the XIV General Assembly of IAU we hope to have an output of a more thorough and detailed investigation of the proper motions available now, that constitute a sample of less than eight percent of all the proper motions expected to be measured within a few years. The work of this extension has been already started.

We are greatly indebted to C. A. Wirtanen for his major contribution in survey and measurement of plates. The project has been supported in part by the National Science Foundation.

References

Aoki, S. 1967, Pub. Astron. Soc. Japan 19, 585.
Fatchikhin, N. V. 1968, Russian Astron. J. 45. 365.
Fricke, W. 1967 a, Astron. J. 72, 642.
_______ 1967 b, ibid. 72, 1368.
Sanders, W. L. 1966, Astron. J. 71, 719.
Vasilevskis, S. 1954, Astron. J. 59, 40.
_________ 1964, Pub. Astron. Soc. Pacific 76, 14.
Vasilevskis, S. and Popov, W. A. 1970 (in press).
Wright, W. H. 1950, Proc. Amer. Philos. Soc. 94, 1.

DISCUSSION

Fricke: It is very interesting to hear these first results. I have many questions, but before asking them I would like to clarify one thing. The quantities presented were determined from proper motions with reference to galaxies, by comparing them with those in AGK 3. Your equations contain Δn, Δk, and another effect, ΔD.

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Vasilevskis: The ΔD was used by Aoki, and I tried it for the purpose of testing.

Fricke: How many stars are involved here? I suppose they are from AGK3.

Vasilevskis: Yes, they are. The total number of plates was 59; 54 of them south of 60°. On the average 30 catalogue stars were measured on a plate, giving a total of more than 1500 stars.

Fricke: My last question is regarding the secular parallax, on which Dr. Luyten could give valuable comments. It seems rather large; these should be very near stars.

Vasilevskis: This may be. The change of the secular parallax seems to be quite consistent with the mean magnitude of stars.

Fricke: Your value of Δk is about twice that usually derived.

Vasilevskis: Yes, but the value derived for Δk is very stable, practically it does not change if the term for ΔD is omitted.

Fricke: Well, finally I would say that one should not worry too much about these discrepancies at this time.

Vasilevskis: As mentioned earlier, these are preliminary data. By the time of the Heidelberg Colloquium I expect to have results of a more detailed analysis, and hope you will like them better.

Eichhorn: I wonder what would happen if one did not cut out any high proper motions at all. Let me go back a little further. All these calculations are made on the basis of a least squares solution. One assumes that the peculiar motions are randomly distributed. Is that right? I wonder if two or three things would improve the situation. One: What would happen if one would weight the proper motions that go into the solution according to the dispersion that can be expected for a proper motion of that star on the basis of magnitude and galactic latitude. Two: What would happen if one would try to devise an algorithm that is not based on a random distribution of the peculiar velocities.

Vasilevskis: One should be careful, of course, in rejecting stars above a certain limit of proper motions. Only a few stars were lost with a cutoff at $0\overset{''}{.}3$ per annum, and no significant bias can be expected in this case. In cutting off at $0\overset{''}{.}1$ an additional 47 bright, 55 medium and 20 faint stars were rejected. Even these numbers are not large compared with a total of more than 1500 stars. Also, I failed to mention that we were forced to include

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only the fainter AGK 3 stars. Errors of measurement increase significantly for stars brighter than magnitude 8. Regarding Dr. Eichhorn's comment, I admit that a primitive approach was used at this stage.

Vasilevskis: The present limited material would not justify to go into the details you mentioned, only the surface has been scratched of the potential wealth we have. Eventually it should be possible to look deeper into the problem of systematic stellar motions. Moreover, we are not planning to sit on the Lick proper motions until every avenue of their analysis will be explored by us. The proper motions will be published and made available to everyone, as soon as the initial discussion will be made by us.

Fricke: Let me add one thing, as an answer to this question. Such effects have been in the literature these more than 30 years, and they are mostly in the translational components. Of course, it is also known that with increasing dispersion sometimes one cannot get significant results. If you want to determine galactic rotation and you take the high velocity stars, it is unsuited, so of course one has to take suitable objects.

Dieckvoss: I have two remarks to make. In our solution of the 160,000 stars of the AGK 3, the value of the secular parallax is of the same order of magnitude as in Vasilevskis'. Two or three seconds of arc for the brighter stars - fifty to sixty thousand stars. And, another thing, if you are taking 30 stars of the AGK 3 then the mean error will be around 0.''8. You find the plate solution constant solely from the 72 galaxies. There were entered only the zero point of the magnitude of the proper motion. And I think it is not important just to enumerate the proper motion of the AGK3 by including the Astrographic Catalogue. I think it will be quite sufficient if you have a difference of 20 years in epoch to use the original AGK 3 proper motions.

Wesselink: If Clemence were present here, he would probably elaborate on the secular change of obliquity of the ecliptic that was mentioned earlier. He told me that this change is not significant.

Fricke: I think that is mostly from a paper which I sent him. I would like to say this concerning the change of the obliquity of the ecliptic. Now this is a very confusing thing, for a motion of the ecliptic is of no interest here at all because that does not change any results, but, if, say, the angle between the ecliptic and the equator changes that will also be because of the motion of the equator. And, if the equator is in motion, then, of course, these results in the proper motions are influenced by such motions, of course. First, one has to make the statement that the celestial mechanics behind these motions indicate that there is a motion of the ecliptic and not of the equator. However, observations of the planets say it is not the same for them if the equator is in motion or the ecliptic. So the equations look quite different

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and you get different results. Now, however, there is some indication that these celestial mechanics effects are insignificant. And, also, you can read in a recent paper in Astronomy and Astrophysics that for the motion of Eros an insignificant $\Delta\alpha$ change is shown. Next thing, however, is that, if the effect is in the motion of the equator, then this effect can be explained. As far as $0\overset{\prime\prime}{.}2$ can be traced to the old meridian circle observatories. There remains still the possibility that there is an additional motion of the equator. It is not true that we already know everything about the motion of the equator and the polar axis. There may still be unexpected effects, but these effects may all be of the order of $0\overset{\prime\prime}{.}1$, maybe $0\overset{\prime\prime}{.}15$ and cannot be determined more precisely at the moment.

Murray: I would like to congratulate Vasilevskis on his secular parallaxes. They agree very well with the ones that I introduced using Fatchikhin's results. I should say that in producing the curves I showed yesterday I did correct for the effect of Fatchikhin's rather low cut-off of the proper motions, for in fact, there are so few stars involved it does not make much difference, but I did correct it. But now the results from the solar apex that he got there was a drift with magnitude which is presumably a drift with distance which in turn is presumably a drift with height about the plane because we are dealing with stars at reasonably high latitudes. Have you considered the possibility of a solution with a more complicated model for the major galactic motions? We think of A and B as being sacrosanct, but really one ought to think of a model where there is a shear with height above the plane as well as a shear with distance from the galactic center. And, in that way, one might be able to produce, shall we say, a "unique" solar apex, and perhaps get better secular parallax and still show what the variation of the strong drift with height above the plane really is.

Luyten: I have several comments. First of all, you mentioned the difference between blue and yellow plates. The thing that surprised me so much, when I was measuring the proper motions of the Feige stars, was the lack of any difference between blue and yellow plates. The real value of the proper motion comes from the earliest plate and the last plate. The ones in the middle may give an appearance of lowering the probable error, but that is all they can do. They cannot really change the proper motion; that depends on the two end plates. And in this case the earliest plate was almost invariably a Carte du Ciel plate. Now, in practically all these cases from Helsingfors down to Algiers the particular zones that each observatory had was some 30° south of the zenith. The Feige stars are extremely hot and blue and the old plates taken in the 1900's were, of course, only blue sensitive, and most of the observatories involved were close to sea level. The new plates were taken with the Palomar-Schmidt where there is very little color difficulty, and the observatory lies at 5500 feet so refraction is less. Hence one would expect that the early plates would, because of the

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refraction, put the blue stars farther north and so systematic motions southward would be expected. There were none. Possibly this means that all the stars really move north, but this is very unlikely.

The other question is about your very high declination values for the apex; this is very surprising to me because, when I did the apex determinations for the large proper motion stars, in groups from 0."05 to 0."1, 0."2, etc., the apex ran a little higher for the same magnitude when the proper motion got larger. But there was very little difference. Most of them were lower in declination than your apex for non-selected stars. The secular parallaxes you showed are almost exactly the same as I used. If we knew anything about the radial velocities of these faint stars then we could translate these secular parallaxes, into annual parallaxes. We usually assume, for these non-selected stars, a solar motion of 20 kilometers per second, for even your 16th magnitude stars are only about 375 parsecs away. Now it is possible that the solar motions for them is 30 km/sec. But, until we get radial velocities we could only distill this from the apex; and since the apex has the same value for all of them, this is not a very safe method.

Finally, I would like to plug again for the one thing that I always talk about viz., why not use quasars as well, because there we get exactly what we want. With your method you get the motions for this particular faint star and for a second star and a third star etc., and to obtain the secular parallax you have to average them. On the other hand when you measure the proper motion of a quasar you measure the motion of that quasar relative to ten comparison stars. I do not think it matters whether Sandage and Maarten Schmidt are right that quasars lie at the cosmological distance given by the red shift or whether Arp and the others are right, that they are much closer. I think that it seems exceedingly unlikely now that the quasars as a whole lie within the galaxy. They are extra-galactic. They may be as close as some of the nearer galaxies, but they have a great advantage in having an exact point image, hence the setting errors on quasars are no larger than those on ordinary stars. On the other hand, the setting errors on galaxies are always larger. And from the quasar motions we immediately get the reflex of the motion of whatever large number of comparison stars we want to use - and you can find fifty comparison stars within a square centimeter of a good Schmidt plate. Also, I think that, there are even some quasars in fairly low galactic latitude, not many of course, but at least some. Maybe those could help in gettin across the zone of avoidance.

Wesselink: Well, in this context, I would like to say to Dr. Luyten that at Yale Philip Lu is identifying quasars on the same plate material which I have been discussing. Of course, primarily for the interest of the quasars to have optical identifications to the radio positions. But, of course, also, with your point of view of using them as reference stars in the future. At present, he has seventy-two quasars identified and I have motions for sixty. There are not enough.

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Vasilevskis: We have already discussed and agree with Luyten on most of his other points including the high declination of the apex. I, of course, could not just subtract all the figures the computer threw out, but I hope to take a look into this. What is there. We will certainly go into every detail not only just by computing procedures and say divide by something to change the program, but try to look into stars which are there. Because we have colors for and have some dispersions for their motions. So I feel that one important thing is to try to get at the nature of the stars with which you are dealing, to make sure whether this star can be used for this particular job. But, as usual, I always disagree with Luyten regarding the role of quasars. It is correct that they are very good point sources. And, if you are interested in a small area to determine actual proper motions, there is nothing better than a quasar, because if you take only one or two galaxies you will not get anything. But in our case here we would use a great many more, believe me. This is quite a job, more than I expected when I became involved in this program. Of course, you like to get everything you can from the whole plate or the whole field. You need a reference which would represent to you something fixed on the whole 6° x 6° field. And only galaxies are there in sufficient number so you can use them. In addition, there is no danger: just because the galaxy looks fuzzy. We believe that the least worry is about this reference to galaxies. There is no question, because the automatic measuring machine sets on the approximate center of the galaxy. We do not care again what the position of the galaxy is. I never believed in the position of the galaxy; because one may say this is the nucleus; another may say this is the densest part; another, something else. The main thing is that the same position is measured in both. And we see that the errors of galaxies are only sixty percent larger than on stars. So we are thinking of using 72 galaxies. If you would like to increase this we can take 144 without much difficulty: there are plenty. We have quasars, of course, and we may add them in this. But to base everything on quasars only this would not give us a solution for the whole plate.

Luyten: From the work that Sandage and I have been doing recently we find that in the higher latitudes, that is, in essentially the same regions where the galaxies are plentiful, we can guarantee you 200 quasars brighter than the 21st magnitude per plate. Perhaps I should not call them all quasars, they may be radio silent. But there are QSS's with a big red shift. And when we get down to the 21st magnitude, I am pretty sure we can get 200 of them. And they can be fairly easily identified from the photoelectric colors and if necessary the red shift. Of course, there is a lot of work to be done, but they are definitely better than just plain galaxies.

Murray: I could not agree more with Luyten about the necessity of radial velocities of faint stars as I said yesterday. I think we will have to wait 200 years for Eichhorn to do 15th magnitude stars in sufficient numbers.

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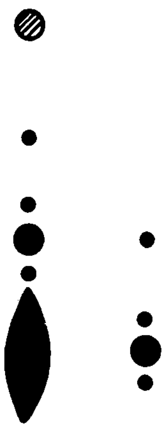
But there is one way in which we can check the motion, at least of the main sequence stars. If you look very carefully at the proper motion dispersions it is quite easy to separate out the main sequence stars from the others if one has good photometry. I did this in the M67 field which is of fairly high latitude. Taking only the main sequence stars fainter than 14 sorted out by their proper motion dispersion, and then given photometric parallaxes, you can get distances, and the solar motion came out as 27 km/sec. I think this is one way one can do it. One can not do anything about giants because one does not know what absolute magnitude they have. But if you can identify the main sequence stars, there is a chance one can.



SYSTEM I / II	OBJECTS	m_{pg}	NUMBER SELECTED
	GALAXIES	16	≈ 72
	FAINT ST.	16	≈ 36
	MEDIUM ST.	12	20 - 24
	BRIGHT ST.	8	25 - 35

Figure 1.

Types of images and numbers of objects selected for measurement. Spectra produced by an objective grating are measured when the central images were too bright.

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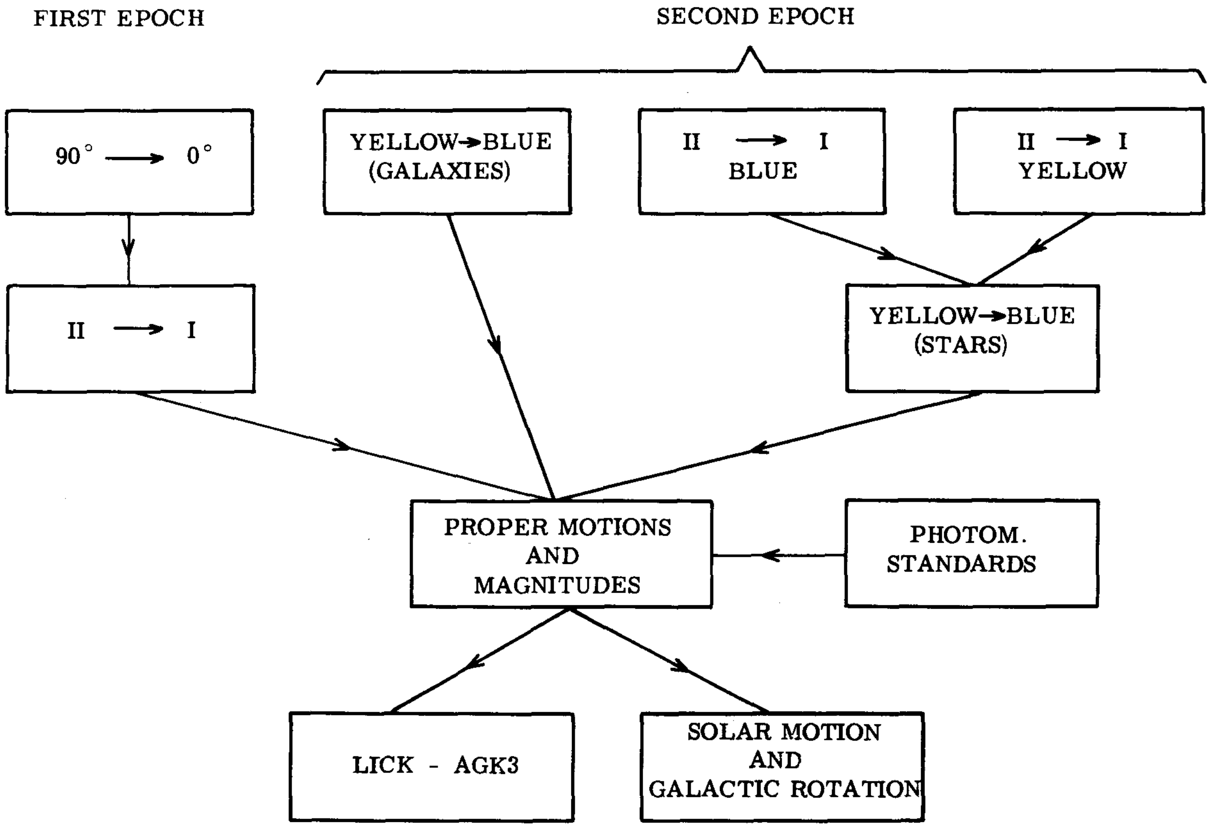

Figure 2. Flow diagram of reduction of measurements.

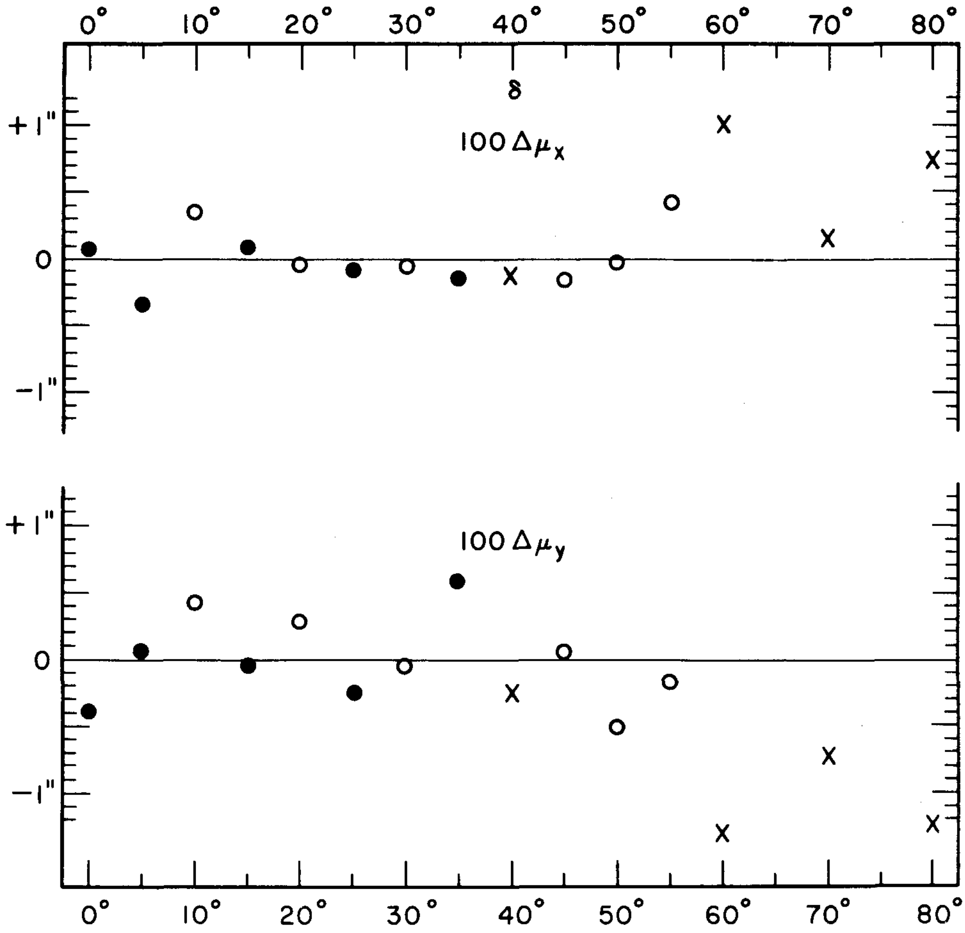

Figure 3. Average centennial proper motion differences Lick-AGK3 versus declination. Weights: 0 - highest, 0 - intermediate, X - lowest.

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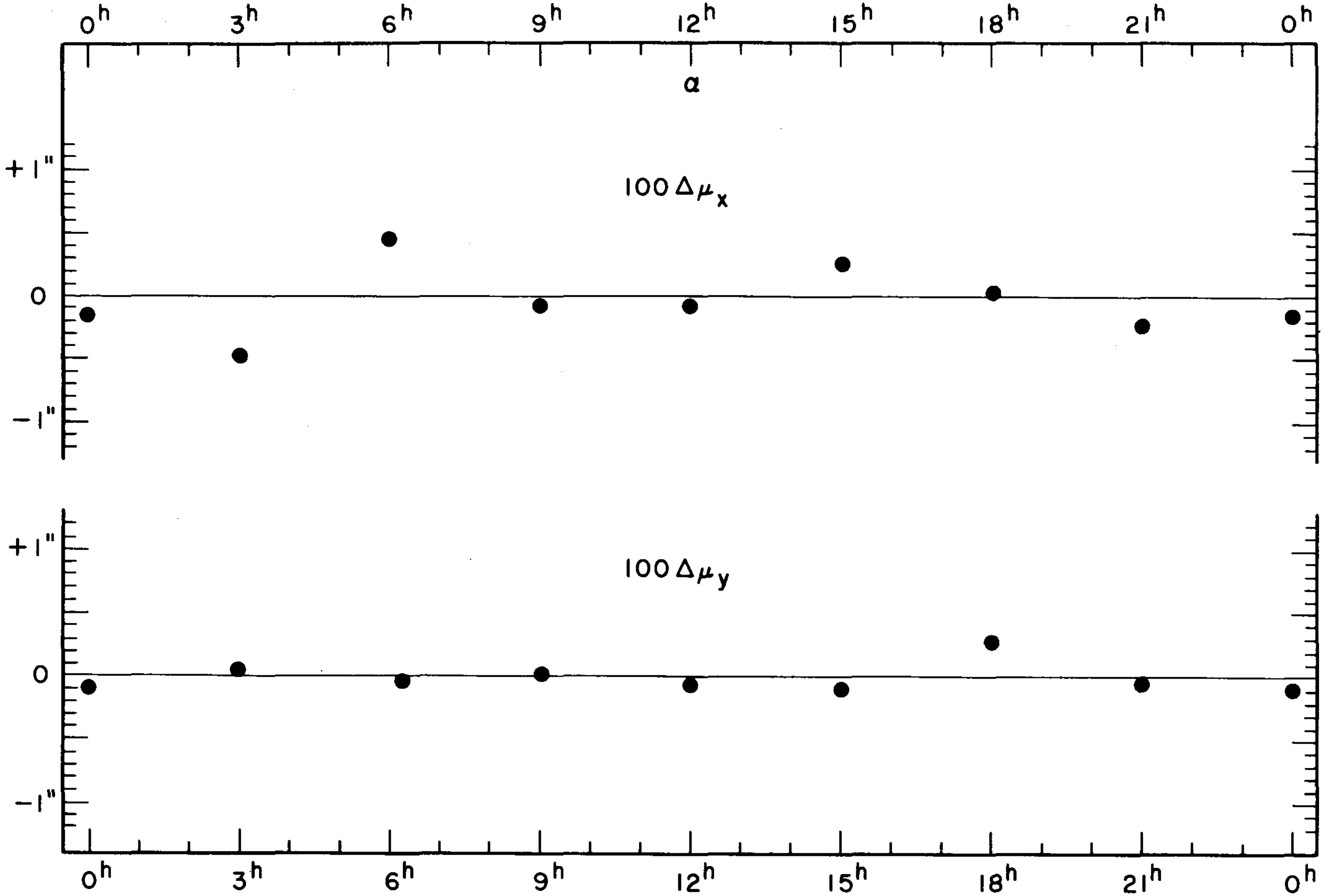

Figure 4. Average centennial proper motion differences Lick-AGK 3 versus right ascension.

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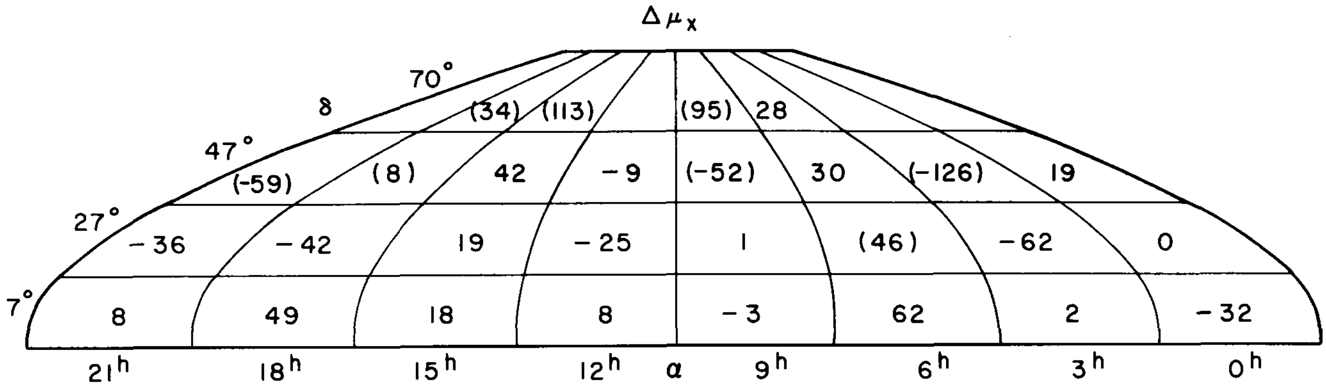

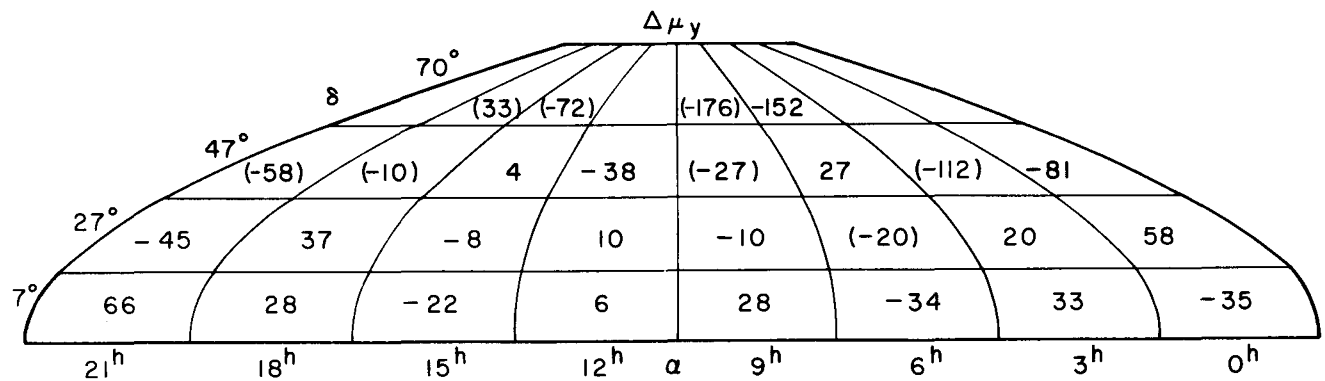

Figure 5. Average centennial proper motion differences Lick-AGK 3 in units of 0"01. Values in parenthesis obtained from a single field.

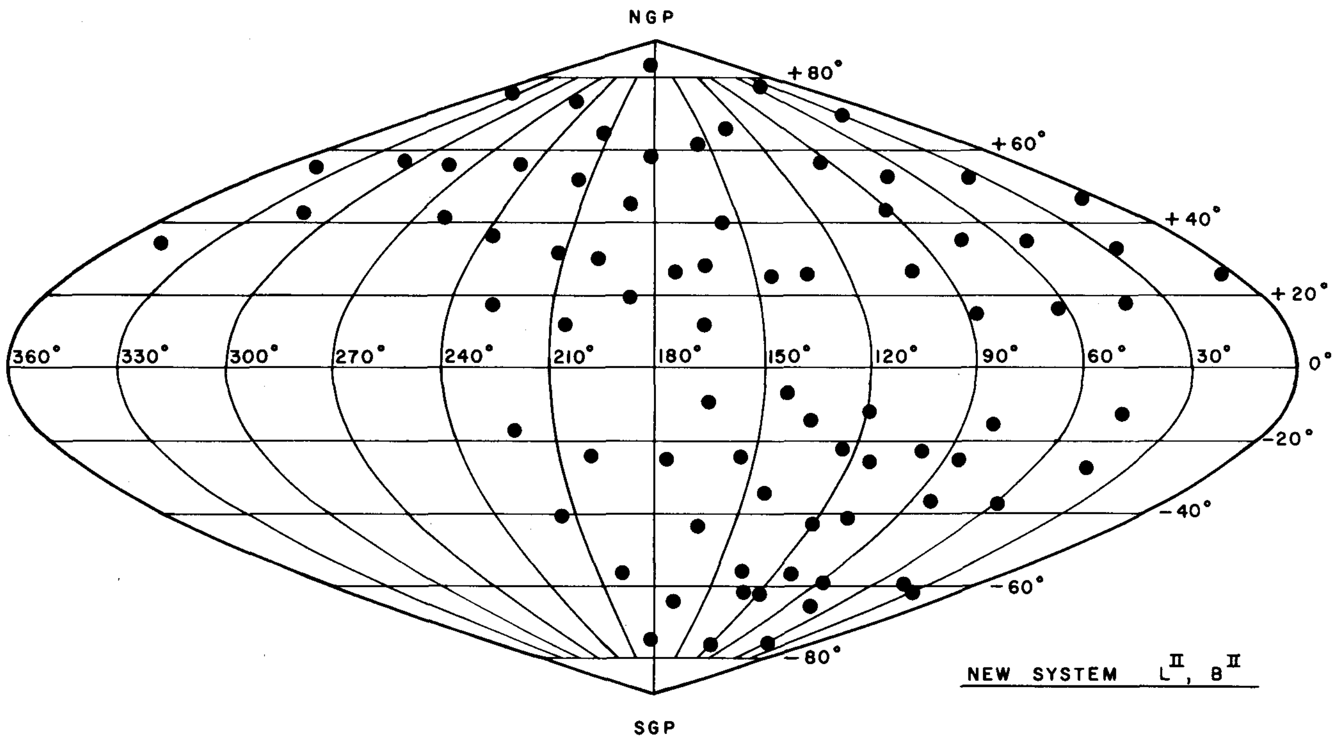

Figure 6. Distribution of fields used for derivation of the solar motion and galactic rotation. Grid represents the new system of galactic coordinates.