Papers Presented

THE VALUE OF A THIRD AG CATALOGUE

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Abstract. A plan for the re-observation of the second zone catalogue of the Astronomische Gesellschaft (AGK2) in the years 1956–60, approximately, is considered. Remarkable simplification will result if the observations, measurements, and reductions for the new catalogue, tentatively designated by AGK3, are carried out as far as possible differentially with respect to AGK2. The immediate value of the AGK3 will be the derivation of absolute proper motions of very high systematic accuracy for approximately 180,000 stars with fainter magnitude limit of almost 12.0 photographic.

With these proper motions systematic corrections to many old catalogues can be obtained and any pair of plates of the Carte du Ciel may be used for deriving absolute proper motions of faint stars in the northern sky.

I. In the following we shall designate by AGK1 the *Catalog der Astronomischen Gesellschaft für das Äquinotium 1875*, which has been observed with meridian circles in declination zones, by AGK2 the *Zweiter Katalog der Astronomischen Gesellschaft für das Äquinotium 1950*.

The AGK2 is based on photographic exposures in areas of $5^\circ \times 5^\circ$. The reference stars for the reduction of the plates were observed with different meridian circles and compiled in the *Katalog der Anhaltsterne für das Zonenunternehmen der Astronomischen Gesellschaft*, designated AGK2A. In all these catalogues the Astronomische Gesellschaft has played an important role.

The third AG Catalogue (AGK3) until now exists only as a subject of discussions and non-committal plannings. It has no relation to the Astronomische Gesellschaft and it is quite uncertain whether it ever will have such a relation. The designation AGK3 only expresses the idea that the AGK3 may become as nearly similar to the AGK2 as possible.

II. It seems to us impossible to establish completely the value of the AGK3 without discussing in some detail the Astrographic Catalogue, designated CdC because of the French name Carte du Ciel. We refer in the first place to the catalogues which are based on plates of short exposure and on micrometer measurements, and secondly to the series of plates taken with longer exposures for the purpose of photographic reproduction, but not systematically measured. These too are—*mutatis mutandis*—dealt with in the following arguments. Strictly differential measurements of old and new plates as well as the comparison with other modern data of old plates which were carefully reduced by means of new reference star places have always shown the high value of the CdC. The intrinsic precision of the star positions is very high. The complete coverage of the whole sky makes the documentary value of the immense material valuable for the determination of the proper motions of faint

stars. Here we are dealing only with the northern sky, and consequently we need to discuss only the following zones of the CdC.

First Group		
	Dec.	Epoch
Catania	+46° to +55°	1898–1924
Helsingfors	39 47	1892–1903
Potsdam (incomplete)	31 40	1893–1900
Paris	17 25	1891–1906
Bordeaux	10 18	1893–1905
Toulouse	4 12	1893–1910
		1917–1933
Algiers	–3 +5	1891–1911
Second Group		
Greenwich	+90 to +64	1890–1905
Vatican	54 65	1898–1922
Hyderabad	35 40	1928–1935
Oxford	24 32	1892–1910

Group I contains all those zones for which the star coordinates were published as a result of precise micrometric measurements. In order to use them for the determination of proper motions it will be necessary either: a) to determine the plate constants anew with improved positions of the reference stars, because of lack of precision of their positions or because of large differences in epoch between reference star positions and the plates; thereafter the improved plates may be compared with any modern data. Or: b) One has to compare the old plates with new ones strictly differentially. For the purpose of facilitating the immense work the plates of group II were measured, with limited precision only, by estimates from the scale of a micrometer eyepiece. The published data are not suitable for the derivation of proper motions. For this group method b) is the only feasible method.

Method b) has been used frequently by deriving the plate constants from very faint stars with small proper motions and by taking into account parallactic motion and galactic rotation. This cannot be criticized where only limited aims are to be achieved. But this method will not be admissible if one wants to study the systematic

trends in the motions of the faint stars themselves over larger areas of the sky. In this case it will be necessary to bring the proper motions into one homogeneous and exactly defined absolute system. It is not necessary here to decide which one of the three larger systems: GC, FK3 or N30 will be the most useful. If we succeed in utilizing fully the intrinsic value of the CdC and if one combines equivalent modern data, say of epoch 1960, with the old ones, we shall have available the potential proper motions of all stars down to at least the 11th photographic magnitude, in many areas even down to a still fainter limit, with a precision of approximately ± 0.003 per annum (m.e.). We say potential for we do not suggest a repetition of all plates of the CdC and of their complete remeasurement. However, it is our opinion that it is possible in our generation to improve the foundation of the CdC by building up a limited homogeneous system of absolute proper motions. If, for astrophysical or stellar-statistical reasons, the need arises to furnish the proper motions of any special group of stars, it will be sufficient to combine the necessary modern plates of this group with the corresponding data of a revised CdC.

Such a homogeneous system should contain the proper motions of at least 100,000 stars equally distributed over one hemisphere; and there will be more than 20 reference stars for the new reduction of each plate of $2^\circ \times 2^\circ$ of the CdC.

III. Concerning the AGK2 we have been asked repeatedly why this catalogue does not contain the proper motions. Consider the following table of the accidental mean errors of proper motions to be derived from the differences AGK2 minus AGK1 arranged according to the different zones of the AGK1.

Catalogue	Zone		m.e. of annual p.m.	
			α	δ
Kasan	75° to	80°	± 0.009	± 0.014
Berlin C	70	75	15	16
Christiania	65	70	11	16
Helsingfors-Gotha	55	65	17	14
Harvard	50	55	11	15
Bonn	40	50	26	15
Lund	35	40	12	10
Leiden	30	35	09	11
Cambridge	25	30	16	11
Berlin B	20	25	08	08
Berlin A	15	20	09	11
Leipzig I	10	15	17	12
Leipzig II	5	10	13	12
Albany	+1	+5	12	12
Nikolajew	-2	+1	16	22

AGK3 (1958)

minus AGK2 (1930) -2° to $+90^\circ$ ± 0.007 ± 0.007

These mean errors are based on the table of weights in volume I of the GC. Obviously the precision of the proper motions varies to such a degree that no homogeneity can be expected. In addition, the detailed study of the systematic errors of the different zones shows that the systematic corrections of the AGK1 to a fundamental system are insufficiently known for faint stars. The reason is simply that our knowledge of proper motions of stars from the 8th to the 10th magnitude is so incomplete that the relation of the catalogues to a fundamental system cannot be guaranteed. Up to now the systematic errors of faint stars have been sought for mostly only in the form $\Delta\alpha_m$ although it has been known for a long time that the $\Delta\delta_m$ may become appreciable. Even the $\Delta\alpha_m$ (e.g. those of the GC) are found by extrapolations, a fact that was well known to the authors of the GC, and these values cannot be guaranteed. Discrepancies can arise on the border of two zones even after correcting the positions systematically according to the tables in GC vol. I, as we found, for example, at $+50^\circ$ declination in the μ_α and μ_δ derived from the differences AGK2 minus AGK1.

A different procedure was adopted by the authors of the Yale zone catalogues, F. Schlesinger and I. Barney. The magnitude errors in right ascension of AGK1 were evaluated by introducing the condition that the proper motions for suitably chosen intervals of magnitude averaged by hours of right ascension should average zero over an entire zone. The proper motions so obtained are not absolute but have been found to be very valuable for special purposes.

The authors of the AGK2, in Bergedorf, especially W. Kruse and R. Schorr, indeed studied the differences AGK2 - AGK1, but they abstained from computing the proper motions, because they perceived that this task would not only require a sizable amount of extra labor but also that there are no reliable old catalogues for comparison with the AGK2, nor could they be brought into existence by the most ingenious reduction of the old catalogues. We know moreover that F. Küstner was very skeptical of the value of the AGK1.

To these experienced astronomers an AGK3 appeared to be the only satisfactory approach. They visualized an entirely new undertaking for about 1970-80. They thought it especially desirable or even self-evident that an AGK3 would apply new techniques; new wide-angle lenses would be used to take the plates, which should

be measured with new measuring machines and reduced with positions of reference stars observed with photoelectric meridian circles. Nevertheless we have arrived at the conclusion that important advantages and simplifications arise when the AGK3 is not made with new methods but as nearly as possible derived differentially as compared with the AGK2, using the following steps:

a) The new plates can be taken with the same cameras as were employed in 1930; thus systematic differences between the AGK2 and the AGK3, as far as they depend on the objectives, cannot arise. Moreover the same measuring machines could be employed.

b) The tangential points, often incorrectly called zero points, of the new plates will be the same as in 1930; consequently all transformations from the plane to the sphere and back will be superfluous. Only differences of co-ordinates have to be reduced by least squares, and the old computing sheets from 1930 can be used a second time.

c) When the same reference stars are used, the coefficients in the normal equations of the least-squares solutions can be used without change, saving about two years' time of a special computer.

d) Lastly, only the proper motions need to be published, along with the reference numbers of the stars. This will require for the whole AGK3 only 2 or 3 volumes, instead of the 16 volumes of the AGK2.

There are two reasons for undertaking the AGK3 in the nearer future: 1) The present galactic research on special problems of motions and on the derivation of secular parallaxes depends on a utilization of limited portions of the material of the CdC to such an extent that one must be interested in as early an epoch of the AGK3 as possible. 2) By choosing the earlier epoch the same personnel who worked on the AGK2 would be able to work on the AGK3. One cannot overestimate the value of two decades of special experience which would help in the completion of the AGK3.

Let us assume for a moment that the AGK3 has been published, i.e. that we have a homogeneous system of absolute proper motions for about 180,000 stars down to the 11th photographic magnitude in the northern hemisphere. These proper motions would be interesting in themselves, because they would permit a direct solution of several problems. Furthermore, all

old meridian circle catalogues that contain faint stars could be put in an exact relation to a fundamental system without ambiguity. This would make it possible as a second step to take into account for instance the AGK1 and the Yale zone positions. The corresponding increase of weight would be gained only for part of the AGK2 stars and not for all declination zones. In this connection I mention the procedure in Dr. Ida Barney's work on the Nicolajew zone (*Trans. Yale Obs.* 21, 1950). For this zone the AGK1 was used in addition to two photographic epochs, 1914 and 1937.

Finally any CdC plate could be reduced completely and without recourse to hypotheses. One thought is especially tempting in this connection: Our experience at Bergedorf shows that most of the plates of the AGK2 contain 90 per cent or more of the stars of the CdC, i.e. far more faint stars than have been measured and published. By a suitable choice of emulsion type and exposure time for an AGK3 we should be able to have almost all the stars of the CdC for the epoch 1960 on the same plates that contain the AG stars, i.e. we should have with one effort in one plate collection a repetition of the AG catalogues and simultaneously of the CdC. In the first place only the AG stars would be evaluated, and the fainter CdC stars only in case of necessity in chosen areas and for special problems.

IV. The whole question of an AGK3 depends lastly on the possibility of establishing a good, i.e. very homogeneous, and a systematically as well as accidentally accurate system of reference star-positions from observations with meridian circles. It is not necessary that this system be the same as the AGK2A, although for this system the labor of the plate reduction would become a minimum. But a first and essential condition is that the relation of the system of reference stars to a fundamental system be carefully and rigorously achieved.

At present there exist three competing lists of stars, which were discussed frequently in the General Assembly of the I.A.U. in Rome 1952:

- 1) A list of the Naval Observatory in Washington (W),
- 2) The AGK2A (A),
- 3) The list by Zverev (Z).

In order to examine the relative value of these lists we have to consider further conditions which in our opinion have to be met by the catalogue

of reference stars for an AGK3, i.e. for an AGK3A:

a) Its stars must be distributed very evenly over the sky. It is of no advantage if the catalogue contains more stars per square degree in lower than in higher galactic latitudes. As we intend to use the same photographic instruments as in taking the plates for the AGK2, we have to consider plate-areas of $5^\circ \times 5^\circ$ with about 15 reference stars each. In this way we arrive at about 14,000 stars for the region from -5° to $+90^\circ$ declination. The star density of lists W and A, is sufficient. According to some diagrams we have made, W contains more stars in the Milky Way than outside; consequently the star density of W could be diminished in the Milky Way.

b) The magnitudes of the stars should be so chosen that the stars can easily be observed with available meridian circles. Opinions concerning the most suitable magnitudes seem to differ among the astronomers. In Germany we had no special difficulties in observing all the stars of list A with 6-inch meridian circles. Probably a faint red field illumination will be helpful. Moreover, one should use close double instead of single wires in the impersonal micrometer for the fainter stars, to avoid eye-strain. Lists Z and especially A contain much fainter stars than W.

But it is a much more essential condition that as many meridian circles as possible should participate in observing one list, rather than to persist in the doubtful advantage of faint stars, since all magnitude errors can be avoided by employing gratings for the meridian circle as well as for the photographic telescope. The argument occasionally expressed for the choice of faint stars, viz. to facilitate the reduction to the system of the extragalactic nebulae, overlooks entirely the possibility that the photographic plates of an AGK3 may fulfill all special wishes in every respect. When photographic plates are combined with meridian circle observations the reference stars are simply a system of fixed points favorably distributed over the celestial sphere. The system of photographic positions

then provides the data required for the solution of essentially astronomical problems. It is only in planning a large meridian circle catalogue, independent of photographic observations, that special care must be taken in selecting the stars according to magnitude, color, proper motions and occurrence in old catalogues.

c) In case several observatories agree on a list of reference stars, a last condition would be of some importance: The mean epochs of the meridian observations and of the photographic exposures should be fairly near in time in order to avoid a deterioration of the final results on account of proper motions of different weights for the reference stars.

Recapitulating the arguments, we believe that we are justified in stating the following: It seems highly desirable to concentrate the work of, say, six meridian circles on a list of reference stars so that the observations will be started and completed between 1956 and 1960. The observations should be made according to uniform methods with an exact relation to a suitable fundamental system. The simultaneous photographic coverage of the northern hemisphere with the same instruments as were used in 1930 for the AGK2 should be made. The reduction should be carried out by a rigorously differential method by comparison with the original plates and measures of the AGK2. This would furnish a homogeneous system of 180,000 proper motions and would make possible the full utilization of numerous older catalogues. This system of proper motions will also ensure for the CdC its full importance, which up to now it has had only in a latent form.

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