THE ASTROGRAPHIC CATALOGUE AS A SOURCE OF OLD EPOCH PLACES

Harley Wood
Sydney Observatory

At the General Assembly of the I. A. U. in Prague in 1967 I became involved in a discussion on the merit of using stars with positions taken from the Astrographic Catalogue as reference stars in finding positions of faint members of the solar system. The answer was that little choice exists if the positions are being found from photographs of small field taken with large telescopes.

In the Sydney section of the Astrographic Catalogue there are recorded, including repetitions, 744,751 star places and in the Melbourne section, which has also been our responsibility, 392,615. Allowing for overlap of the plates and of the two zones the positions of over 424,000 different stars are given in about one ninth of the sky. This may be compared with 259,000 over the whole sky for the Smithsonian Astrophysical Observatory Star Catalogue. The average number of published places per star is over 2.5 and so most of the stars are recorded at least twice. This may be sufficient to illustrate the great mass of material in the Astrographic Catalogue and to suggest the value of incorporating the data in the best way possible into our system of star places and proper motions. Eichhorn and Googe (1969) suggest a method of using additional observations of position to improve places and proper motions. Although positional astronomy may find it difficult to obtain substantial resources, it still may be possible to secure observations in the future, but those of the past need to be exploited to the limit and the astrographic data might well be more widely adapted to this purpose.

The problem of using this material has naturally been considered, sometimes effectively and confidently but often with justifiable feelings of doubt, and the usefulness of the AGK3 in providing reference stars for northern zones has been demonstrated by Eichhorn, Herget, the Hamburg astronomers and others. However, in 1967 the President of Commission 23 raised the questions of extending the calculations of plate constants, the way of presenting the results, whether a new astrographic project was yet appropriate and whether remeasurement of old plates was practicable. Naturally the relation of all this to automatic measurement has to be discussed. Similar questions had been posed in 1964 at Hamburg and remain open especially in Southern zones where improvement in the availability of good reference star positions must soon occur due to the meridian and photographic programmes now in progress. It is an advantage of the astrographic catalogues that the published results do not usually obscure the original data behind a mass of insufficiently described analysis, and the information is essentially in the basic form made available by the original observer.

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It can be said that the accuracy of the measures published in the catalogues does not usually correspond to what would now be expected of the plate material. On the other hand, the positions deduced from the existing plate constants frequently are not as good as the measures could yield from investigation using reference stars with really satisfactory positions for the epoch of the plates.

The plates have been measured in several ways. In the Sydney and Melbourne Catalogues many measures were made at a bureau established in Melbourne using Repsold machines similar to one described by David Gill (1898) at the Cape Observatory. With these machines measures relative to the reseau lines depended on a short screw, and were recorded to the fourth decimal place of a reseau interval of five minutes of arc. Machines used at Sydney were of the Turner type in which a glass graticule in the plane of the image of the photographic plate produced by the microscope objective was used to measure the position of each star relative to the reseau lines.

In the Sydney Catalogue the measures have all been published to three decimal places of the reseau interval, the ones made with screws having been rounded from four places. To gauge how well the measures repeat, a number of plates was remeasured by the original methods and the results compiled in manuscript in the same form as the published ones. The frequency of occurrence of the differences of the manuscript measure minus the published measure was compiled. The frequency follows a normal distribution and corresponds to a standard error of one measurement of a coordinate with a short screw machine in Melbourne of $\pm 0''.39$ and for a measurement with the Turner type machine of $\pm 0''.25$.

To estimate the effect of remeasurement and of recomputation of the constants using better reference star places, the plate material has been treated using:

A the original published measures with the original reference star places and published plate constants,

B the original published measures with the reductions using places and proper motions from the Cape photographic catalogues, and

C new measures made with a long screw measuring machine with reductions using places and proper motions form the Cape photographic catalogues. In this case comparison of separate rectangular coordinate measures indicates a standard error of ± 1.4 micron (corresponding to $\pm 0''.08$). These measures are made with the thought of associating them with new measures from photography with our wider angle camera.

In each case the results were treated in two ways:

I The residual differences between the standard coordinates computed from the measures using the plate constants and the standard coordinates derived from the original equatorial coordinates of the reference stars were examined and a standard deviation in seconds of arc derived.

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II The differences beteen the positions of stars so derived from two plates were found in a large number of cases and the standard error in seconds of arc of a single coordinate measure derived.

The results are as follows:

	I	II
A	±0".66	±0".53
B	±0.51	±0.44
C	±0.41	±0.30

These reductions were made using only linear terms as was the case with the original reductions. In the case of the original measures it makes little difference whether the results are from measures made with the short screw machines or the Turner type machines. The Melbourne results, considered only in category A, give essentially the same standard error even though the measures are published to 0.001 mm. The results in category B depend on less data. Those in category C show the value of the new reduction and of remeasurement by a better machine, and the agreement between the pairs of positions indicates that inclusion of results of this kind would undoubtedly improve the individual Cape proper motions.

Additional terms beyond the linear ones are naturally considered in any auxiliary reduction or new reduction to standard coordinates of measures of the astrographic material. Inspection of the images on all of the astrographic plates I have seen reveals the effect of coma. The corresponding term, $H(m-m_1)x$ in the x coordinate, is the one that appears most unambiguously and reliably in the solution. The variable m, magnitude, can be replaced by one which represents the image diameter.

The magnitude term, $J(m-m_1)$, persists fairly obstinately but may vary, sometimes quite significantly, from plate to plate. A term proportional to colour index might be expected to be appreciable and stable, but in my examination has not appeared large enough relative to the probable errors to deserve inclusion.

The photographic observer wishes to reproduce, at least systematically, the positions of the reference stars provided for him by the meridian observer. Naturally if additional terms are taken in the reduction formula, adding more degrees of freedom to the solution, the representation of the reference star positions used in the solution improves. However, the question may be asked: Do the additional terms improve the representation of positions of equally good stars of the same system, or the accuracy of derived places of the field stars? When the answer is negative or uncertain, the terms might be viewed with some suspicion.

We have tried quadratic and higher order terms with somewhat uncertain results. They vary for different areas and when large amounts of

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material are included, they tend to become small compared with the probable errors of the derived places.

At Sydney we used seven reseaux during the astrogtaphic programmes. We have measured these to find the errors which might be introduced into positions which have been measured relative to them and in two cases found errors of the form xy, small, but apparently large enough to have appreciable effect on the results. These reseaux were used on isolated plates, and examination of the measures of the plates did not in fact yield corresponding terms. Possibly reseaux could sometimes give rise to terms not explained by optical considerations.

What to do with the great body of material in the Astrographic Catalogue has rather baffled discussion in I. A. U. Commission 23 although the Hamburg astronomers and Eichhorn and Lacroute have made some profitable excursions. These astronomers and a few others have made a good case for the application of overlapping reductions. Directors of Observatories who have toiled so long on their projects tend to recoil at the suggestion of remeasurement. The natural suggestion is to look to the possibility of using automatic machines, but some of the plate material we have from Sydney and Melbourne has deteriorated somewhat and might baffle the discrimination of an automatic pointing device. We have remeasured the stars of the Cape photographic catalogues in about a third of our zone. Fortunately these include some fainter stars. The results may justify the suggestion to remeasure stars which, like these, have been otherwise measured and to the proper motions of which a contribution could be made. A disadvantage that might exist in this programme is that Eichhorn and Gatewood (1967) have shown the advantage of the presence of the field stars in overlapping reductions. It would be proper to include as well sufficient fainter stars of the astrographic catalogues to extend the system of proper motions to fainter limits and to make more secure any discussion of effects which are a function of magnitude. This has been suggested by Eichhorn and clearly justified in his reduction of astrographic zones. Something like two or three stars per square degree, which would then be included as a part of the future basis of astrometry, might be appropriate.

References:

Eichhorn, H. and Gatewood, G. D., 1967. Astr. J. 72, 1191.
Eichhorn, H. and Googe, W. D., 1969. Astr. Nachr. 291, 125.
Gill, D., 1898. Mon. Not. R. astr. Soc., 59, 61.

DISCUSSION

Dieckvoss: We had some experience with the Astrographic Catalogue in Bergedorf, and colleagues who did the reductions always found tems of the third order. In representing the reference stars they applied polynomials

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to the third order, and always these terms were found for the range of magnitude reference stars. If you should use, say, stars of ninth magnitude it would be good to have some estimate of the so-called distortion - this is not a real distortion, it is the effect of coma, but it looks like distortion to the third order. I can assure you that this is very important; just now in the Vatican zone it gave a very good improvement in the new measurements. But on plates measured on a machine with long screws it does not improve things as much.

Vasilevskis: With the third order terms, Dr. Dieckvoss, you find that they are repeated from plate to plate? Are they the same or different?

Dieckvoss: It was the same for the whole zone; 30,000 pairs of residuals.

Vasilevskis: If one determines these for the whole zone can one then obtain some value which can be applied to the plate before the least-squares solution is made?

Dieckvoss: Yes. These systematic errors, as we call them, are applied to the coordinates before the real solution of the single plate is made.

Vasilevskis: It was my feeling that this has to change from plate to plate because of a difference in the guiding error.

Wood: This is the first step. The coma and the magnitude errors I omitted, of course. The pure distortion as opposed to coma, besides the coma - that may depend on the lens you have. I don't know. I've had contradictory results.

Eichhorn: When you got the coma terms, did they change significantly from plate to plate?

Wood: They changed. It would be a feasible thing, in my experience, to use them to find a common value over wide areas. The magnitude one did change from plate to plate.

Eichhorn: If I may make a comment on adding terms. In 1963, Miss Williams and I developed a criterion to find out whether the actual systematic errors in the material would be improved if you add an extra term in any particular case. It turns out that quite frequently you do decrease the chance for a systematic error if you add on a new term. But it sometimes happens that systematic terms, or additional terms put into a solution, represent something that is really in the reference stars. Therefore, it would be better to leave it out.

Wood: I am not too sure that this is in accordance with my experience.

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Luyten: I would like to express my wholehearted agreement with what Wood said about the invaluable old astrographic plates. When we are dealing with stars of the tenth, eleventh, and twelfth magnitudes which are too faint for the old meridian catalogues there is nothing better than one of the good, old astographic catalogues. There are some which are not as good as others, I mean, theyare all equal but some of them are more equal than others. If you get some of the good old astrographic positions like Helsingfors and so on and compare them with any good recent set of plates, especially Schmidt plates, you can get errors for the relative proper motions from the printed astrographic positions and the measures on the new plates that are as good as the GC. If there are no astrographic catalogue positions or plates, you simply don't get proper motions.

Wood: I agree very heartily with the suggestion that has been made by Eichhorn that some fainter stars should be included in any possible remeasurement or reduction. This extends your power of view along these proper motions as a function of magnitude.

Lacroute: In France we also tried to use the Astrographic Catalogue, between -2° and +31°, but without new measurements. Perhaps in some zones it will be necessary to make new measurements.

Murray: May I just make a general comment. There is a lot of information in the Astrographic Catalogue. This is a truism. Has anyone got an idea how we can have it in machine-readable form? Is anyone willing to pay for it? There are one or two problems which have come up recently where it would have been very nice to have the whole of our Greenwich Zone in machine-readable form. When we went into the economics of it, we found it is a prohibitive task. Has anyone got any idea of any agency that would be interested in it, or could be pursuaded to be interested in it?

Herget: Did you consider the underdeveloped nations? I mean this very seriously. This is nothing but a key punching job.

Wood: Unless CDC develops a good reading machine.

Herget: I doubt if that would be astronomically competitive.

Murray: That's why I brought the matter up here.

Herget: The difficulty is that the format, certainly in the Greenwich Catalogue, is most unsuitable for key punching. If you know the layout for particularly the Greenwich one, and I think some others have their own peculiarities, that they could not have been more awkward for keypunching, and then collating.

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It seems unfortunate that you came all the way here and that you didn't bring all your plates with you so we could have measured them on one of our automatic machines.

Wood: I probably would have broken them on the way.

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