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THE UNIFICATION OF ASTROMETRIC CATALOGUES

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RESUMEN

Se desarrolla un método de interpolación para detectar diferencias sistemáticas entre catálogos de posiciones y movimientos propios y se aplica a los catálogos AGK3 y Santiago 67, usando los catálogos No. 1 y No. 2 del Círculo Meridiano Carlsberg como sistema de referencia.

ABSTRACT

An interpolation mechanism is developed for the detection of systematic differences between position and proper motion catalogues and is applied to the AGK3 and Santiago 67 catalogues, using the Carlsberg Meridian Circle catalogues No. 1 and No. 2 as reference sources.

Key words: **ASTROMETRY**

I. INTRODUCTION

The need for a unified astrometric catalogue, based on a compilation of all existing catalogues led a number of decades ago to the production of the SAO catalogue. In spite of many criticisms concerning the reduction methods, it has served its purpose. Since then new and more accurate catalogues have become available. The most notable recent contributions are without doubt the position catalogues of the Carlsberg Meridian Circle of La Palma Observatory. Another important step forward is expected within a few years when the *Hipparcos* data become available. At the same time, it is desirable not to lose the wealth of information contained in older catalogues, in particular that contained in the Astrographic Catalogue which soon will span an epoch difference of a whole century with positions for several million stars.

If every existing catalogue is to be reduced to one common system, a decision has to be made as to which system to adopt as the standard system, and which method has to be employed for the determination and the removal of the corresponding systematic differences. The purpose of this paper is to propose one such method and to test it in two specific cases.

II. THE STANDARD SYSTEM

The principal contributor to a standard system will obviously be the *Hipparcos* – catalogue. The latter, however, will contain rotation terms in its proper motions, which can be removed only with the help of either extragalactic objects, or with the FK5 – catalogue.

The closest approximation to such a system at present, seem to be the Carlsberg Meridian Circle Catalogues, of which two are already available while the third is about to be published. With more than 16000 stars among the two first catalogues, the star density is sufficient to test reduction methods for the rectification of a series of existing position and proper motion catalogues.

III. THE RECTIFICATION METHOD

Practically all existing position catalogues are on the B1950.0 system or at least nearly so, while the Carlsberg catalogues are on the J2000.0 system. Conversion from one to the other after allowing for the epoch differences, has been elaborated explicitly by Standish (1982), and does not concern us here. The nature of the remaining differences is unpredictable because of the many sources which may have contributed to them, including accidental errors. Many different schemes have been developed to extract the systematic part from differences between two catalogues. The nature of the schemes depends on the total number of stars available and on the size of the area of the sky they cover. Some authors simply apply the results they find and use the corrected data for their particular purpose. Others give the corrections in tabulated form and leave it to future users to apply them.

The simplest method to arrive at systematic differences is to take the arithmetic mean in a given restricted area. The area has to be chosen small enough in order to be capable of resolving local pattern, but at the same time, large enough to contain a significant number of stars. The optimum size of the area depends strongly on the accidental errors, whose distribution may also have to be determined as one goes along.

If a large catalogue is to be corrected, one may chose evenly spaced areas or bins, thus obtaining a grid of corrections. Adequate functions can then be constructed to interpolate the grid. Brosche (1966) and more recently Taff (1981) have used spherical harmonics for this purpose. Once all coefficients of the interpolating function are known, these can readily be applied to the entire content of the catalogue.

One could also consider to center a bin on each of the stars to be corrected, thus avoiding the need for the construction of an interpolating function. In this way, the corrections calculated for one point on the sky will be totally independent from those to be applied at other remote areas. To select an appropriate method, we have to decide first what properties we wish to impose on the correction functions $\Delta\alpha(\alpha,\delta)$, and $\Delta\delta(\alpha,\delta)$, where α and δ are the right ascension and declination, respectively. The properties we wish to impose are:

1) The function must exist for every α and δ,

2) m partial derivatives of these functions must exist for every α and δ,

3) for every α and δ the mean error of the function must be less than a given tolerance. This tolerance does not necessarily have to be uniform over the entire area covered by the catalogue. In areas of low star density, we may have to be satisfied with less rigorous requirements.

Naturally, the method used by Brosche or by Taff fulfills these requirements. Their execution, however, requires a large computational effort. We shall propose a simpler and more straightforward procedure. Let us suppose that we wish to determine the most probable correction $\Delta\alpha$ for the point α_0, δ_0 in Figure 1. Values of $\Delta\alpha$ are known for all stars shown on the map. We may sample the area within the solid circle around α_0, δ_0 and calculate the mean value of $\Delta\alpha$ together with its mean error.

If the latter satisfies the condition imposed by the tolerance, we have solved the problem. As we move on in α and δ, maintaining a constant radius of the circle, the mean value of the correction remains constant as long as no star enters or leaves the area defined by the circle. A discontinuity in our correction function is produced every time a point leaves the area or a new point enters, thus violating at least the first of the above conditions. This problem can easily be avoided by assigning weights to the points in such a manner that these are zero when a point is located at the edge of the encircled area, and reaches a maximum when located at the center. Let r be the distance of a point from the center, and r_0 the radius of the circle. The weight p can then be calculated from

$$p = (1 - r^2/r_0^2)^{n/2} \quad , \qquad (1)$$

where n is an integer value which has to be chosen. One of us (Abad 1987) has shown that n−1 derivatives exist for the interpolating function. In Figure 2 the weight as function of r/r_0 is shown for different values of n.

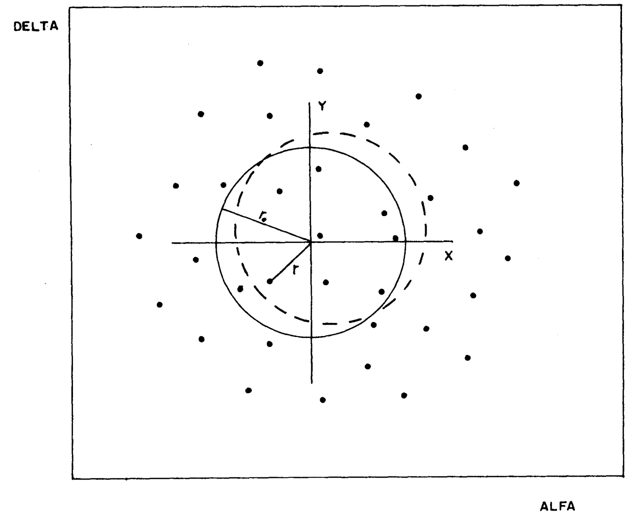

Fig. 1. Definition of a local coordinate system within a circle of radius r_0.

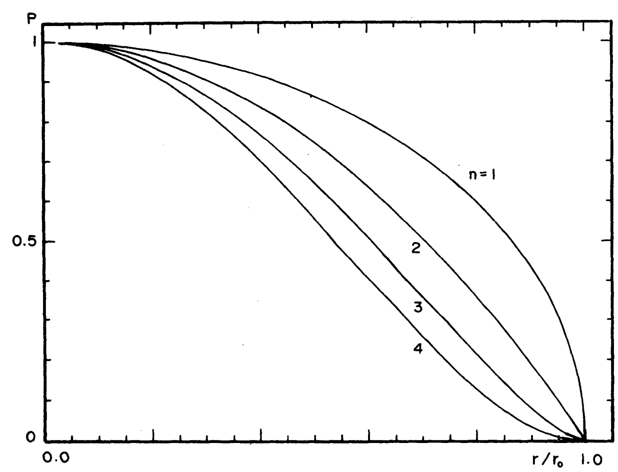

Fig. 2. Profile of the weight p as function of r/r_0 for different values of n.

Two more problems have to be taken into account. The first is that the values of the corrections may show a certain tendency across the field covered by the circle. This, together with an asymmetric distribution of the stars within the circle, would lead to an erroneous value for the interpolating function. The other problem is related to the fact that right ascension and declination are not adequate arguments near the poles. These problems can be overcome in the following manner.

We project the celestial sphere on a tangential plane, using the point in the center as the tangential point. Furthermore, we represent the corrections as a polynomial in the plane rectangular coordinates. Thus, if x and y are the plane coordinates, with their origin at the center of the circle, we may write

$$\Delta\alpha = a_{00} + a_{10}x + a_{01}y + a_{20}x^2 + + a_{11}xy + a_{02}y^2 + \ldots \quad (2) \; ,$$

$$\Delta\delta = b_{00} + b_{10}x + b_{01}y + b_{20}x^2 + + b_{11}xy + b_{02}y^2 + \ldots \quad (3) \; ;$$

where a_{00} and b_{00} are evidently the values of the interpolating functions for the central point. The degree of the polynomial depends on the number of stars available within the circle, and on the scale length of the pattern of the correction function.

IV. RECTIFICATION OF THE AGK3 CATALOGUE

There are 9157 stars in common to the AGK3 catalogue and the Carlsberg catalogues I and II. The distribution of the stars is shown in Figure 3. For the comparison of the positions, we have transformed the Carlsberg data to the B1950.0 system and to the individual epochs of the AGK3 stars. The remaining differences in right ascension and declination are then treated as explained above using different circles sizes and a first order polynomial for the local adjustments. The results for the two different circles for one part of the sky are shown in Figures 4 and 5 in the form of arrows. A solid arrow indicates that the length of the arrow is larger than 3σ, σ being the mean error of the total correction. Correction arrows between 2σ and 3σ are shown as dashed arrows, while a length between 1σ and 2σ is indicated by dotted arrows. When the length is less than σ, only a circle with the radius σ is shown. Neighbouring arrows are not strictly independent of each other because the two corresponding circles overlap. However, in the overlapping area in both cases, the points enter with a relatively low weight. Arrows remote by one diameter are totally independent.

Both Figures 4 and 5 show the same tendency. In Figure 4, calculated with a smaller circle, more local pattern is resolved, which may not be real. Thus our impression is that a rectification with the circle size employed in Figure 5 is at present the best treatment that can be given to the AGK3.

V. RECTIFICATION OF THE SANTIAGO 67 CATALOGUE

The Santiago 67 catalogue is based on meridian circle observations. In this case, it is possible to look also for correction terms which would depend on the magnitude or on the color of the stars. Such corrections may also exist for photographic position catalogues. However, they would be a function of the original coordinates on the plates which cannot be extracted from the final catalogue. To allow for magnitude –and color-terms, we added to the equations (2) and (3) two linear terms, one proportional to the magnitude (actually we used magnitude –8.0) and the other proportional to the color index. The latter was inferred from the spectral type. As a first step, we used rather large circle diameters because of the larger number of unknowns and determined point by point the magnitude and color terms. These then were averaged over all points, leading to the corrections $\Delta\alpha_m$, $\Delta\alpha_c$, $\Delta\delta_m$, $\Delta\delta_c$, which are, with their rms errors

$$\Delta\alpha_m \quad 0.''0152_{12} \quad (m-8.0)$$

$$\Delta\alpha_c \quad 0.''0197_{130} \quad (B-V)$$

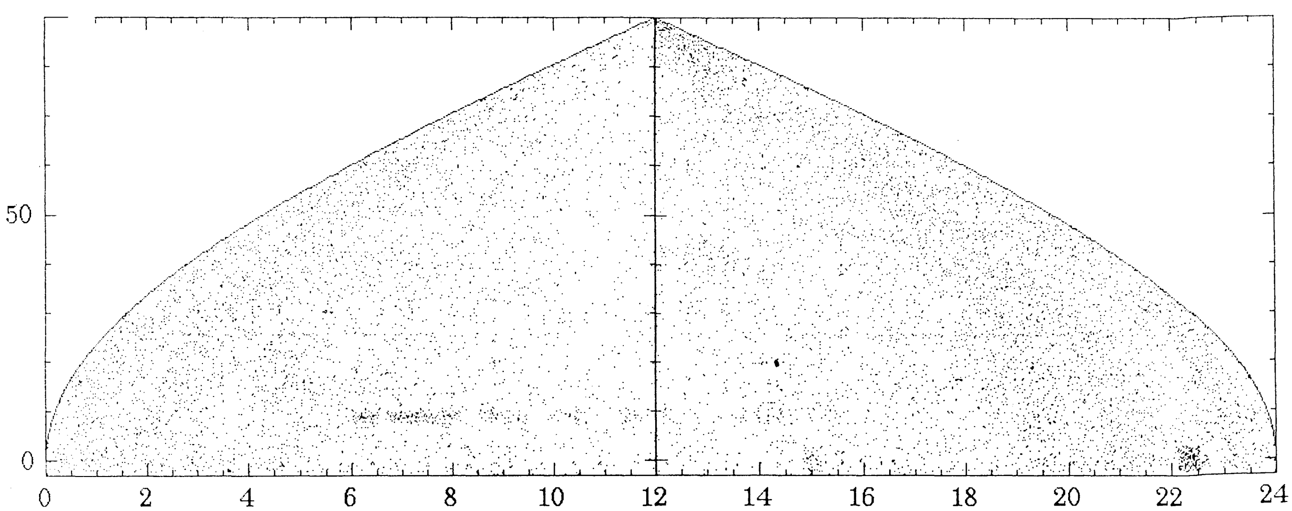

Fig. 3. Distribution of the stars common to the AGK3 catalogue and the two Carlsberg catalogues.

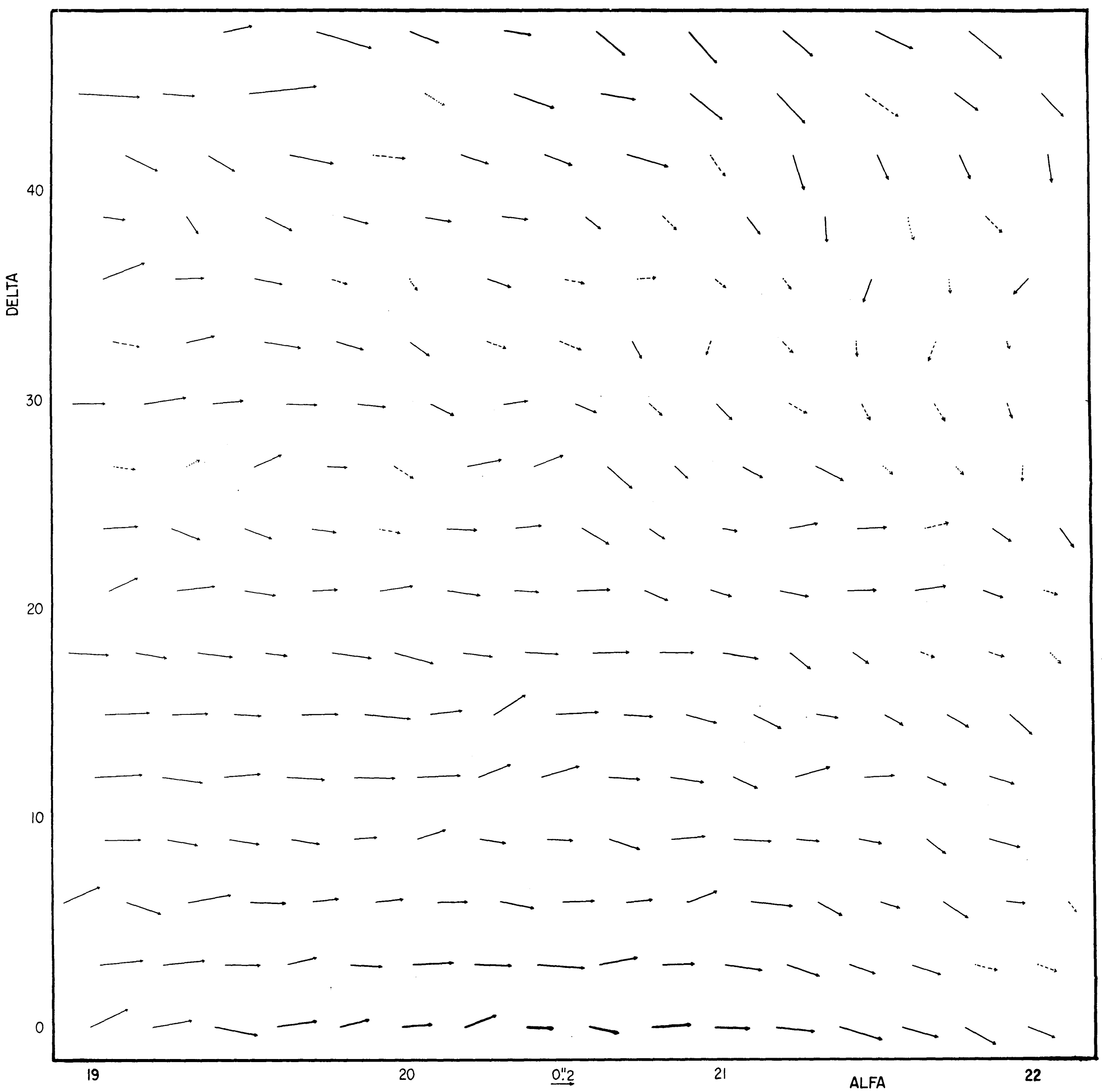

Fig. 4. Corrections for the AGK3 catalogue calculated with a radius of the sampling area of 3.5 degrees and n = 2. For definition of Symbols. see text.

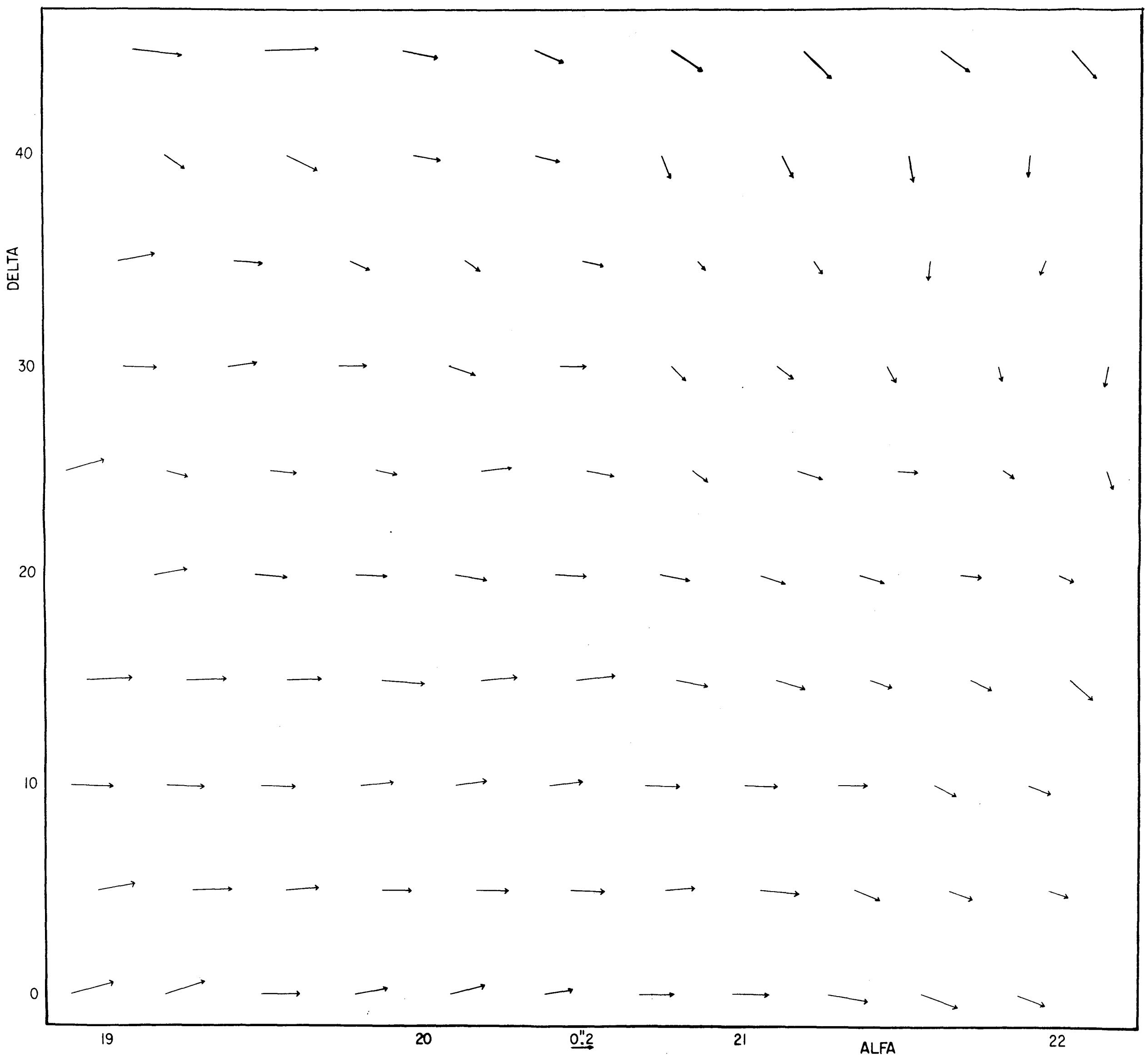

Fig. 5. Corrections for the AGK3 catalogue with a radius of the sampling area of 4.5 degrees and n = 2. Symbols as in Fig. 4.

$$\Delta\delta_m \; 0.''0073 \; (m-8.0)$$
$$131$$

$$\Delta\delta_c \; 0.''0118 \; (B-V)$$
$$99$$

where m is the apparent magnitude and $(B-V)$ the color index. Evidently, with the restricted data sample analyzed only the $\Delta\alpha_m$ term led to a significant determination. Even so, all positions of the Santiago 67 catalogue were corrected for the above terms and the process repeated, again confining equations (2) and (3) to the absolute and linear terms, and omitting magnitude and color terms.

The distribution of the stars common to the Santiago 67 catalogue and the Carlsberg catalogues is shown in Figure 6. An example of the systematic corrections we found, is given in Figure 7.

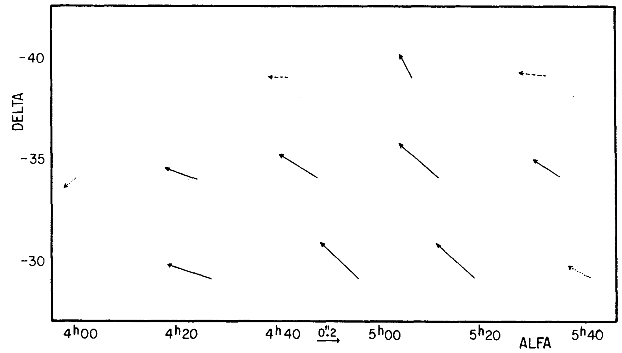

Fig. 7. Corrections for the Santiago 67 catalogue, calculated with a radius of 4.0 degrees of the sampling area and n = 2. Symbols as in Fig. 4.

VI. CONCLUSIONS AND FUTURE PLANS

The material presented above is naturally of provisional character and serves only as a demonstration since the final reference system, namely the *Hipparcos* catalogue, is not yet available. Nevertheless, the proposed method is evidently suitable for detecting systematic errors in catalogues. It can easily be applied to entire catalogues or to portions thereof. As the number of comparison objects increases, more detailed structure of the systematic errors can be resolved.

With such a method on hand, all existing catalogues can be reduced to a common system and a unified general catalogue can be produced. In a forthcoming paper, we shall present examples of such a unified catalogue.

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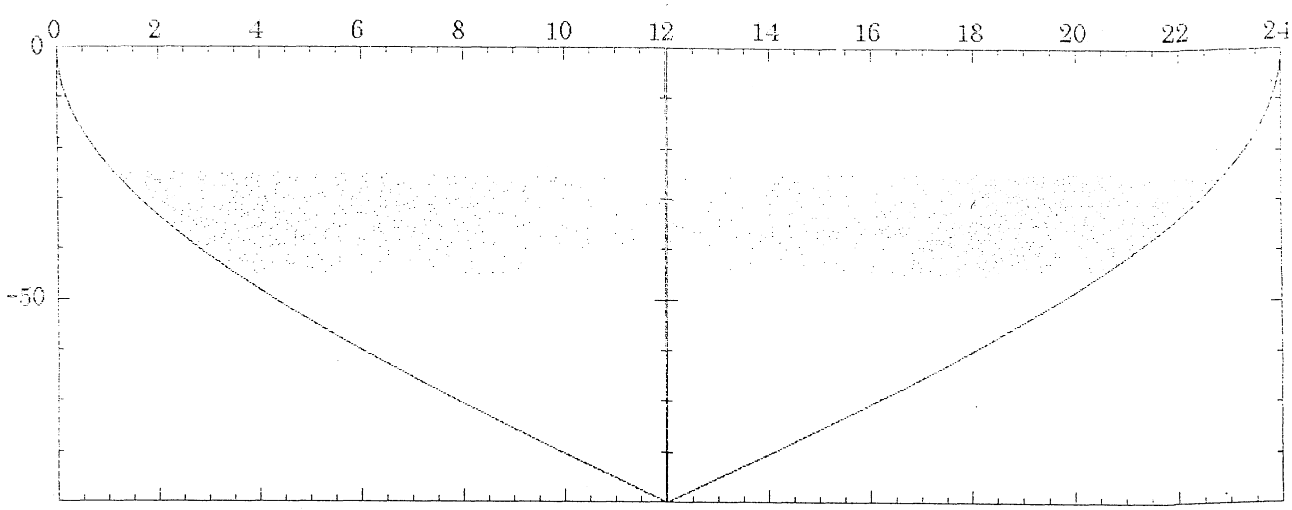

Fig. 6. Distribution of the stars common to the Santiago 67 catalogue and the two Carlsberg catalogues.

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