STATUS OF PHOTOGRAPHIC CATALOGS : AVAILABLE MATERIAL AND FUTURE DEVELOPMENTS

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ABSTRACT. Starting with the Astrographic Catalogue as the first example of an all sky coordinated international astrometric project, a considerable number of large photographic catalog projects has been accomplished in the last decades on both hemispheres. The accuracy properties and possible improvements of some catalogs by remeasurement, application of modern reduction techniques and the use of improved reference star catalogs will be discussed.
The optimal use of modern photographic technology and instrumentation for the construction of new global catalogs, capable of positional accuracies on the level of a few 0.01 arcsec, will be outlined with special view to an extension to fainter limiting magnitudes.

1. INTRODUCTION

Since the time of the pioneering international project of the Astrographic Catalog (AC), photography has become an indispensable tool for the determination of large numbers of stellar positions and proper motions provided by national and international astrometric catalog projects on both hemispheres. Due to its early epoch, global sky coverage and limiting magnitude of about mB=11, the AC will continue to serve as a basic source for the determination of proper motions of fainter stars, however the problem of a final reduction on a definite fundamental reference frame has still to be solved.
The availability of fast and very accurate measuring machines offers another possibility to improve old epoch catalogs by remeasurement of the original plates, if still existing, and to extend the magnitude range by incorporating measurements of additional fainter stars which have not been used for the establishment of the original catalog. As an example, stars down to mB =11-12 are recorded on the AGK2 plates but have not been measured for the catalog.
Furthermore, modern computer systems do no longer restrict astrometric reductions to the application of non-rigorous or approximative algorithms. Even the largest future catalog covering the whole sphere with multiple overlap can be solved rigorously by block adjustment techniques and a very detailed statistical analysis can be carried out with

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the total data material including many simulation runs to determine, for example, the most appropriate mapping model. However, whereas present measuring machines and reduction methods have reached the stage where all astrometric and photometric information stored on the plate, can be fully retrieved, it is still a problem to provide the necessary reference frame for the plate reduction. In many of the AC zones magnitude dependent systematic errors exist which are independent of the x,y coordinates. To determine those terms uniquely in the plate reduction process,faint reference stars down to the plate limiting magnitude 11-12 are required. With the beginning of Space Astronomy, needs for a dense net of fainter stars became obvious, the HST-Guide Star Catalog being the first and a prime example.The present construction of a new generation of very large optical groundbased telescopes provides another example where accurate positions of very faint objects have to be determined in a fundamental reference frame in order to perform subsequent observations or even first identifications in other spectral regions like the radio and infrared. Photographic catalog work therefore obviously has to be extended in at least two main directions: to determine accurate proper motions of fainter stars by combining available old epoch material with new catalogs which are constructed from observations obtained with astrographs and measuring machines of highest technological standard and, concurrently,to start the construction of new types of astrometric wide field telescopes capable of reaching at least 17th magnitude with a few 0.01 arcsec positional precision.
In what follows, the astrometric properties of a few selected large catalogs with a homogeneous hemispheric or global sky coverage will be discussed and key parameters for future new catalog projects will be evaluated. Particular details of the quoted catalogs and additional aspects of wide field astrometry have been discussed in two earlier papers (de Vegt,1978,1982a).

2. SURVEY OF SELECTED CATALOGS

In the present paper the discussion will be restricted to those catalogs which cover at least a hemisphere and are expected to contribute with high weight to the determination of absolute proper motions after transformation to a fundamental reference frame, in particular, these catalogs provide the basic material for faint stars up to mB=11 to 12. Therefore compilation- and zone catalogs are not discussed in much detail.
Figure 1 gives a global summary of distribution of epochs and sky coverage for those catalogs together with the corresponding data for new catalog projects which will be of utmost importance for the final reduction of old epochs and the extension of present catalog work to a much fainter limiting magnitude.
The inhomogeneous distribution with regard to both hemispheres is obvious; especially in the southern hemisphere an intermediate epoch catalog like the AGK2 is lacking. There only Yale and Cape zone catalogs with very inhomogeneous positional precision and observed with widely different instrumentation are available; for details see Eichhorn, (1975). A similar statement applies to the corresponding reference star

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catalogs, there is again no comparable coordinated work as was in the case of the AGK2A. This situation is a serious drawback for the determination of accurate positions from these old epoch catalogs, especially in a fundamental frame.The Yale and Cape zones therefore are important as intermediate epoch material and should be considered for a new reduction. Table 1 summarizes the basic parameters of the catalogs, again the AC is the only global data material for the determination of faint star proper motions.
Some of the principal aspects of the different catalogs will be discussed now.

2.1 The Astrographic Catalog

To evaluate the full potential of the AC at least three main goals have to be accomplished:

i) An adequate reference frame for a final reduction has to be provided, especially on the southern hemisphere and extended to the plate limiting magnitude, about mB= 11.
ii) All x,y measurements have to be converted to machine readable form.
iii) Some zones (e.g., Vatican) should be remeasured to yield substantially more precise x,y coordinates.

In recent years some more experience has been gained from both new reduction and remeasuring of the plates in various zones. New plate constants for the northern hemisphere were determined by Günther and Kox (1972) at Hamburg and Valbousquet (1977) at Strassburg Observatories.The AGK2/3 has been used as the reference frame. However, no general catalog reduction has been performed and because of systematic magnitude and color errors, the plate constants found by these authors are valid only for the range of the AGK stars, mostly mB >10.0.
In the course of an open cluster proper motion program (de Vegt 1978) selected plates in all zones from Vatican to Algiers were remeasured (Vatican) or newly reduced. Combined with new epoch plates from the Hamburg astrograph proper motions with an precision of 1.7 to 2.7 mas/yr could be determined. Converted to AC positional precision this corresponds to 0.11 -0.16 arcsec.However, only a small field of some degrees diameter has been modelled in each case, these numbers therefore do not display any large scale inhomogeneities.From unpublished work with the whole Helsingsfors zone by W.Dieckvoß ,the precision of the AC positions turned out to be 0.20 arcsec.
Assuming that it might be possible to model especially the magnitude and color dependent errors of the AC adequately, a final catalog precision of about 0.20 arcsec for the whole sky should be feasible.
Although this number seems to be optimistic, one has to remember that a catalog position is based on at least 2 plates where in most cases 2 exposures have been measured; see Table 1 and Eichhorn, 1975. Even if the measurement errors of the two exposures may be highly correlated, the m.e. of a single plate position will be about 0.28 arcsec this corresponds to a linear accuracy of 4.7 micrometers using the AC scale of 60 arcsec/mm. Modern emulsions have typical residual distortions of the order of 1 micrometer; the old AC emulsions are definitely inferior in this respect but due to the favourable scale this still corresponds to a reasonable angular precision. In addition to these geometric errors,

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optical imperfections of the single images as for example astigmatism, coma or irregular curvature of the focal plane will be present. A fully satisfactory treatment of that part of the positional errors which affect the structure of each image in a different way can, however, be achieved only if all plates had been digitized with a pixel size of not more than 15 micrometers and complex functional models had to be adopted to define and determine the geometric center of a degraded image. In addition the superimposed reseaulines could be measured to check and remove possible large scale emulsion shifts by an application of the least squares interpolation technique (Kraus 1972, Kraus and Mikhail, 1972).

This rigorous approach requires again a dense net of reference stars occupying the whole magnitude range of the plates.

For a final reduction of the AC a high precision reference star catalog must be provided therefore with a minimum density of about 20 stars sq.deg. and covering the whole magnitude range of the plates. This can be achieved by

i) combining a new epoch catalog (see section 4) which contains all AC stars with an intermediate epoch catalog (AGK2 N.H.; Yale,Cape zones S.H.) to provide proper motions for a subset of stars selected from a narrow magnitude interval (8.5−9.5).These stars will then determine the zero point of the coordinate independent m and c terms.

ii) performing a block adjustment with the AC plate constants and proper motion components of those AC stars (except (i)) which are contained at least in the new epoch catalog as the unknowns. Because each star appears on at least 2 plates the proper motions can be determined rigorously.The observation equations contain the new epoch positions of all stars (except (i)) and the positions of (i) at the AC epochs as the right hand sides.

In this way the whole magnitude and color range of the AC is covered for a statistically significant determination of those terms in the plate model without the need to provide old epoch positions for the faint stars which cannot be achieved in most cases because of the smaller limiting magnitude of the intermediate epoch catalogs.

This approach has been used successfully for the quoted Hamburg star cluster program. In principle, a more general block adjustment scheme treating as unknowns all positions and proper motions of all catalogs involved could be established

2.2 The AGK2 Plates

The AGK2 is based on plates taken at Hamburg and Bonn Observatories with two similar astrographs during a short period of less than three years centered around 1930. The Bergedorf part contains 1939 plates (+20° to +90°), the remaining 720 plates (+20° to −2°) were taken at Bonn. All plates are now stored at Bergedorf in a new plate archive under strictly controlled environmental conditions (+20 C ,50%r.h).

Each plate was exposed twice, 10 min +3 min, shifted by 60 arcsec=0.6mm in declination.No grating was used. For the AGK2 catalog only the 10 min exposure was measured (see Table 1). The limiting magnitude of this exposure is about mB=12.0, only the brighter (<10) AGK stars have, however, been measured for the catalog.

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The AGK2 plates therefore contain already most of the AC stars on the northern hemisphere with homogeneous limiting magnitude.

Remeasurement is highly recommended and feasible. Experience with measurement of selected cluster fields, using both exposures, has shown that a final catalog precision of 0.12 - 0.14 arcsec should be possible. Furthermore, the 3 min exposure images are measurable for most AGK2 stars. Finally excellent proper motions could be obtained on the northern hemisphere for all Tycho stars.

2.3 The CPC2 Catalog
This catalog,covering the southern hemisphere with fourfold overlap, provides the first modern data material for this hemisphere. A spectral bandpass in the visual region (5300Å-6400Å)has been used, thus minimizing substantially effects of atmospheric dispersion and any residual color errors of the optics; other parameters are listed in Tables 1 and 2. At present the complete astrometric reductions are under way at Hamburg Observatory. The final block adjustment solution has to await the completion of the SRS. Detailed descriptions have been given elswhere (de Vegt 1978; Nicholson et al. 1984; de Vegt et al. ,this Volume).

2.4 The Tarija-Pulkovo Catalog
As a part of a global astrometric catalog (Kolchinsky and Onegina, 1978; Kolchinsky et al., 1979; Polozhentsev and Potter, 1978) ,the southern sky has been photographed by a joint USSR/Bolivian effort.A fourfold overlap pattern has been adopted and practically all plates have been taken.For a detailed description see (Polozhentsev et al., 1987), the main parameters are listed in Tables 1 and 2.

2.5 The Sydney Southern Star Catalog
From 1964 to 1982.5 nearly the whole southern sky ($-36^{\circ}$to the S.Pole) was photographed at Sydney Observatory with a 23 cm,f=1776mm camera. Plates were taken with fourfold overlap in the blue spectral region on an Ilford Rapid Process Experimental Emulsion. A 2.3 magnitude grating was used.Thus far only the zone -51° to -63°could be published, based on the WL50 as an intermediate reference frame.For a detailed discussion see King et al. 1983; Wood 1981. Another zone (-48° to -54°) has been published recently by Eichhorn et al., (1983).

2.6 The USNO Astrographic Catalog (N.Hemisphere)
Between 1979 and 1985.9 the whole northern sky down to -27°has been photographed at Washington with 4 minute exposures on 103aO and 103aG plates with the 20 cm twin-astrograph in a B and V bandpass (see Table 1) with twofold overlap. No grating was used.This project is an extension of a Zodiacal Zone catalog (Routly , 1983) covering a band within 16 degrees along the ecliptic. All plates will be measured on the STARSCAN. Measurements for the zone catalog area have been completed. This preliminary catalog will contain mainly SAO stars together with proper motions derived from remeasures of Yale plates. The complete northern hemisphere catalog will probably contain all stars of the AC having magnitudes

between 7.0 and 11.0. About 10% of the plate material has been measured already.(Harrington, 1987).

3. POTENTIALITIES OF MODERN MEASURING MACHINES

The development of measuring machines for precise astrometry has resulted in a number of different technological solutions for the analysis of the images which may be characterized shortly as follows:

i) Analog Centering-type

Typical examples are the GALAXY (RGO) and STARSCAN (USNO) which use a hardware based null-method to determine the image center coordinates. No detailed information on the actual image structure will be provided. The best target objects are perfectly circular or at least symmetrical stellar images.These machines can measure about 1000 stars/hour, the overall measuring precision is 1.0 to 1.5 micrometers.

ii) Microdensitometer-type

The PDS is the best known example,these machines have full astrometric capabilities,i.e. allowing a general digitization of the images at full density range. With the granite version, equipped with a laser interferometer system for measuring the coordinates, an overall precision of 0.2 micrometer is feasible.However the measuring speed (in terms of stars /hour) is slow. In the raster scan mode ,working on single stars, typically 3-4 stars/min. can be measured, scanning of a complete plate as an alternative takes many hours.With a 10 micrometer pixel size, an AC plate (120x120 mm) will take > 3 hours, for a larger astrograph plate (240x240mm) >12 hours are required at a 130mm/sec. scanning speed. However the PDS-like systems can extract the whole astrometric and photometric information from a plate without degradation in precision (van Altena et al., 1983).

iii) Flying Spot Scanner-type

These are at present the fastest microdensitometer orientated systems. Examples are the COSMOS (ROE),the APM (Cambridge) and the APS (Minnesota U.) machines. The plates are scanned with a small spot-like laser beam (about 10 micrometer size) in consecutive strips.The overall precision is about 1.5-2 micrometers and these systems have a smaler density range (2-3) as compared with the PDS. However, the measuring speed is extremly fast, a complete 14x14 inch Schmidt plate can be scanned in 2 1/2 hours with 15 micrometer pixel size. A detailed comparison of the various machine-types was given by (Humphreys et al., 1986, 1987).

iv) Solid State Camera based Systems

For astrometric applications which require in the first place highest geometric precision (0.5 micrometer) and long term thermal stability (> 10 hours) of the measuring system, a very promising approach could be the combination of a very stable granite x-y table with fast (up to 200mm/sec.) continuous and start/stop mode operational capabilities. Such systems are now commercially available and achieve a

routine overall precision of better than 0.5 micrometers. Using a solid state camera as the detector system,the whole plate can be digitized at video rate (1/30 sec) speed with a 1x1 to 3x3 mm frame size. Again,a complete Schmidt plate could be measured in about 3 hours. Initial experiments at Hamburg Observatory using a Hamamatsu CCD-camera with the MANN 422F comparator have given very promising results. Similar experiences were reported by Monet (1983). Although the density range may be slightly inferior as compared to the PDS, the astrometric requirements are perfectly met if only well exposed images are measured which is in any case mandatory for high quality catalog work. Figure 3 shows the principal components of such a system. All parts are at this time commercially available at reasonable prices. Furthermore, present day micro computer systems and array processors will even now allow in most cases a real time image processing so that the amount of data to be stored can be reduced substantially.
For future large scale catalog work and -not to forget - remeasurement of available plates (e.g. AGK2 ,AC,Yale) to extract the full inherent astrometric information, the camera-type measuring machines combine submicrometer geometric precision with highest speed and therefore seem to be the most promising equipment type if the precision of the flying spot scanners cannot be improved by at least a factor of 3 to 4.

4. NEW CATALOG PROJECTS

Astronomical research is presently extended continuously to the investigation of very faint objects. This will be even more so the case as the consequence of the recent construction of 10-15 m class telescopes and space based telescopes in all wavelength regions. To match the requirements of the coming decades, present catalog work has to be extended and improved considerably. A much denser global net of high accuracy stellar positions (0.05-0.01 arcsec) and substantially increasing limiting magnitude (14-17) is indispensable for the determination of precise positions of faint objects, identification, space-guidance and general stellar kinematics.This goal can be achieved only by a stepwise approach.

i) Modern astrographs (e.g. USNO,Hamburg) can be used to provide a global sky coverage at a common epoch with a limiting magnitude of about 13-14.

ii) New type astrometric telescopes with substantially larger aperture have to be developed to extend this limit to about 17-18. To achieve the highest attainable accuracy and precision some basic requirements must be satisfied:

1) At least a hemisphere or the whole sky should be photographed with one or two similar instruments.
2) A fourfold plate overlap pattern (minimum 2-fold) with an additional 10 degrees area in common at the celestial equator should be adopted.
3) A narrow spectral bandpass in the visual region > 5000 Å, for example 5200 Å to 5800 Å ,should be used, optionally, an extension to the red < 7000 Å could be considered.This is the most criti-

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cal condition to minimize all effects of atmospheric dispersion and possible residual chromatic errors of the optical system.
4) One exposure per plate should be taken, a grating with 4-6 mag. difference should be applied to control possible magnitude and color effects.
5) The exposure time should be resticted to < 15 min. to limit the influence of differential refraction within the field.
6) Plates should be taken in two orientations of the telecope ,symmetrical and very close to the meridian.
7) Only microflat 0.25 inch thick plates and no plate sizes > 30 cm should be used to maintain highest metric stability .
8) Sites should be selected around 40 degrees latitude.Good seeing conditions (definitely < 2.0 arcsec) with a homogeneous distribution of nights/year is mandatory to utilize the high quality of modern telescope optics and to guarantee homogeneous quality of the catalog.

As color dependent atmospheric and optical errors become most severe toward shorter wavelengths, the blue spectral region, as presently used by most astrographs (see Table 1), should be totally avoided in future astrometric catalog work. To provide an example, the dependence of positions on spectral type, caused by atmospheric dispersion,is shown in Figure 2 for the AGK3. Table 3 quotes some numbers for the dependence of effective wavelength on the adopted bandpass and refraction constant. These numbers display the dramatic decrease of color dependence when switching to a visual or red bandpass.
Using modern glasses, high quality optical systems can now be constructed with a suitable visual bandpass ,as has been done successfully for several existing astrographs (see Table 1 and Figure 4).
From the aforegoing discussion, the epoch distribution and basic parameters of available catalogs (see Figure 1 and Tables 1 and 2),it is obvious that both hemispheres have to be considered for new catalog projects within the next years. The following projects are in accordance with the requirements of items i+ii).

4.1 The USNO Southern Hemisphere Project

The whole southern hemisphere, probably with an extension to $+10^{\circ}$ declination,will be photographed with the USNO twin astrograph (Routly, 1983) now installed at Black Birch Observatory, New Zealand. A fourfold overlap pattern will be adopted and a 4-mag. grating will be used.With the 4-element yellow lens (see Figure 4) a limiting magnitude of mV=13-14 is anticipated.Instead of using the original blue lens,a new high quality lens system (Figure 4) with an extended red bandpass is planned for the second camera. An optical design study has been finished already. With both cameras, two independent fourfold overlap patterns with identical field centers will be provided within the common magnitude range (about 13). Each catalog position will be based on 8 images plus additional grating images for the brighter stars;for other details see Table 1.

4.2 The HAMBURG Northern Hemisphere Project.

The only general source available for the astrometry of fainter stars

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on the northern hemisphere is still the AGK2/3 containing positions as well as proper motions of 180,000 stars down to −2 declination.With the low precision proper motions of 0.009 arcsec/yr, resulting in a present epoch positional precision of about 0.45 arcsec (see Fig.5d−1), a new catalog, based on substantially improved instrumentation is urgently needed. For a detailed earlier discussion see de Vegt,(1974,1978, 1979).With the 23−cm astrograph, which is optimized for a small bandpass in the visual region, a fourfold coverage of the northern hemisphere with an extension of at least 10 below the celestial equator is planned in close connection with the USNO project to match epochs of the common 20 wide area (-10° to $+10^\circ$ decl.). A 4−mag. grating will be used and a limiting magnitude of mV=12−13 is anticipated (see Table 1).For the catalog stars a plate field of 5x5 degrees will be used ,because of the high quality of the optics, a 6x6 degrees field can be used for the reference stars. Adopting the IRS density, 36 reference stars will be on the average available. As has been discussed in the previous sections, the combination of this catalog with the remeasured AGK2 plates will provide high accuracy proper motions for the AC stars. As the astrograph is easily transportable and adjustable for different latitudes, a high quality site outside Europe is suggested to exploit fully the optical capabilities of the instrument.

4.3 SKYMAP 2000 , the next step

As has been stated already, a new generation all−sky catalog is urgently required for many fields of astronomical research. With a suggested limiting magnitude of about 17−18, the future quasar based extragalactic reference frame could be utilized directly for the first time.
In particular, the availability of such a catalog could provide immediately an excellent reference frame for the astrometric reduction of the new Palomar Sky Survey and a substantial densification and improvement of the HST−Guide Star Catalog.
Due to the limitations set by optical constraints of lens design and atmospheric parameters, present day wide field astrographs are not adequate to extend considerably the limiting magnitude of about 13 without degrading the attainable positional precision. New type astrometric telescopes are required to reach a substantially fainter limiting magnitude of about 18 with short exposure times (10−15 min at maximum) to minimize effects of differential refraction and other mechanical and thermal instabilities in the telescope system. At the same time the telescope scale has to be increased to achieve a much better positional precision. Optical design studies,underway at Hamburg, have shown that a flat−field catadioptric−Cassegrain system could probably be modified and optimized for high quality astrometric applications.To provide an optimal image structure, the secondary mirror has to be integrated into the primary corrector elements to avoid any noncircular diffraction effects which are a basic limitation for precise astrometry over a larger magnitude interval if one uses conventional telescope systems (Schmidt, RC−Telescopes).From the preliminary design study the provisional telescope parameters are : aperture 1.3−1.5 m; F:5; scale 30arcsec/mmm ;field 2x2 deg.;optimized spectral range about 5000 Å − 7000 Å .
Based on a seeing of 2.0 arcsec ,astrometrically measurable images down

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to mV=17.0 could be obtained with 10 min. exposure.Adopting a twofold overlap pattern and the coordinated operation of two similar telescopes from both hemispheres, the whole catalog project could be finished in about 5 years.

5. REFERENCE STAR CATALOGS

Concerning the availability of a global reference frame for the reduction of catalog plates around 1990 ,the present situation has to be improved substantially.Both,the AGK3R and the SRS transit circle catalogs (Smith and Jackson,1985) need a proper motions system to bridge two decades of epoch difference.The USNO pole-to-pole fundamental program (Hughes et al.,1986),underway in New Zealand (7-inch TC),and Washington (6-inch TC),will provide new positions of the IRS stars with a mean epoch around 1990 and at the same time a proper motion system on both hemispheres will be derived from a rediscussion of other catalogs.(Corbin;Corbin and Urban,this Vol.) A further improvement could be achieved by a coordinated global observation campaign including other modern transit circles.The high qualitiy of modern astrographs definitely requires correspondingly high precision reference stars on the 0.05 arcsec level. A rigérous block adjustment reduction can be applied in the case of catalogs, covering at least a hemisphere which then will require only a smaller number of reference stars.
The most aequate reference frame would of course be provided by a successful ESA-Hipparcos-mission, the resulting positions could be considered as to be practically "error free" reference points ,thus providing an enormous improvement in the determination of unique mapping models and internal error propagation of the photographic net (de Vegt, 1982b).

6. SUMMARY OF CATALOG PRECISIONS

Table 2 gives estimates for the attainable positional precision of the principal catalogs under discussion. Again, for the early epoch catalogs, the inferior situation on the southern hemisphere is obvious. Based on these numbers ,most reasonable combinations of catalogs for the determination of proper motions have been performed; results are quoted in the right hand part of the table, Units are (mas/yr).
In summary it should be possible to obtain the following final results:

Whole Sky :	AC-based	proper motions :	1.5 => 3.4	(mas/yr)
Northern H.:	AGK2 -based	" " :	2.0 => 2.5	"
Southern H.:	CPC2 -based	" " :	2.5 => 3.9	"

However, concerning the proper motions only, one has to remember that all catalogs have widely different limiting magnitudes (Table 1) ,for the majority of stars > 11 the new epoch catalogs will provide a first epoch at all. For many applications stellar positions are needed at widely different epochs, the dependence of catalog precision on time is essential. In Figures 5a-d this relationship is shown for the most likely catalog combinations.Whereas in all cases a very satisfactory accuracy

can be achieved for several decades around the new epoch ,the effect of error propagation will become most severe at the beginning of the century. The key roles of the AC and the CPC2 for the southern hemisphere is clearly demonstrated by comparing 5b and 5c. For the northern hemisphere nearly similar results can be obtained if the AGK2 is used exclusively with a new epoch catalog (Fig. 5a-1,5d-2). The most optimistic solution is presented by Fig. 5e, whereas the present status on the northern hemisphere is shown by Fig. 5d-1. The substantial improvement by the suggested 5d-2 solution is obvious. Again, on the southern hemisphere no solution at all exists at present.
The error propagation of the Hipparcos positions is shown in Fig.5d-3. When one compares this graph with groundbased results (Fig.5d-2) at early epochs, one has to consider that all calculations are based on the assumption that there are only random errors. An improvement can be obtained by combining the anticipated Hipparcos results with the best groundbased catalogs.(de Vegt, 1982b). However the precision of reference star positions for photographic catalog reductions is only a secondary aspect.The superior global accuracy of the Hipparcos based reference frame is the basic progress for the formation of a future global faint star net by densification of the primary Hipparcos frame.

7. CONCLUSIONS

Photographic catalog work plays a key role in the densification of the primary reference frame of bright stars as given by the FK5 or IRS transit circle catalogs. Between 1970 and 1990 several large catalog projects have been finished or are under consideration. They are based on high quality instrumentation to determine stellar positions to about 14th. magnitude globally. Based on these results, a final reduction of the AC can be performed to provide proper motions of fainter stars with about 3mas/yr accuracy.A substantial extension of this stellar net to about 17-18th. magnitude could be provided soon by the construction of new astrometric wide-field telescopes ,capable of a few 0.01 arcsec precision. This new dense stellar net will met the needs of Space Astronomy and of future groundbased observations which will be extended soon to very faint objects. The great improvement of the present groundbased stellar reference frame by the results of a successful Hipparcos mission, which would provide then for the first time a practically error-free homogeneous net of reference points for the reduction of any photographic catalog cannot be overestimated.

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Table 1 **Main Catalog Properties**

						Northern Hem.			Southern Hem.		
F	Sc	Field	Epoch	Mag	OP	Catalog	N	λ, G	Catalog	N	λ, G
3.4	60	2°x2°	1900	11-12	2	AC	2(3)	B	AC	2(3)	B
2	100	5°x5°	1930	11-12	2	AGK2	2(1)	B			
2	100	5°x5°	1960	10	2	AGK3	1	B, G^1			
2	100	4°x4°	1970	10	4				CPC2	2	V^+
2	100	5°x5°	1980	10-11	2	$USNO^+$	1+1	B^*, V^*			
2.3	90	5°x5°	1984	12	4				Tarija-Pulkovo	1	B
2	100	6°x6°	1990	12-14	4	HAMB 90	1	V^o, G^2	$USNO^+$	1+1	V^*, R^+, G^3
6.7	30	2°x2°	2000	16-17	2	S K Y M A P 2 0 0 0				1	R^*, G^4

Zone - Work:
- Yale (N+S)
- Cape (S)
- $Sydney^*$ (S)
- B, * with grating

$USNO^+$ - USNO Twin Astrograph

Spectral-Bandpass:

B	unfiltered blue bandpass	≳ 3600 Å - 5000 Å
B^*	Filter GG 400 +103a O	4000 " - 5000 "
V^*	Filter GG 495 +103a G	5000 " - 5800 "
V^o	Filter OG 515 +103a G	5200 " - 5800 "
V^+	Filter ≈ 5300 Å + R40	5300 " - 6400 "
R^+	Filter OG 550 +098-04	5500 " — 7000 "

R^* bandpass between 5200 Å - 7000 Å TBD

Grating:

	Δ m
G^1	3,5
G^2	4
G^3	4
G^4	4-6 TBD

Table 2 ACCURACY BUDGET OF MAIN CATALOGS

EPOCH	CATALOG	m.e.["]	CATALOG	m.e	N-Hem.				S-Hem.					
1910	AC	0.13/18	AC	0.20	*	*	*		*	*	*	*	*	*
1930	AGK2	0.14	Yale/Cape	0.25		*								
1960	AGK3	0.21												
1970			CPC2	0.06						*	*		*	*
1980	USNO	0.12												
1984			TA-PU	0.14										
1990	HAMB90	0.06	USNO	0.05	*	*			*		*		*	
2000	---- S M 2 0 0 0 ----			0.02			*					*		*

Combination of different catalogs at their respective epochs as indicated by * ,numbers [mas/yr]:

AC =0.13 :	1.8	1.6	1.5	AC =0.20 :	2.6	3.4	2.3	2.2	3.9	2.5
AC =0.18 :	2.4	1.8	2.1							

Table 3 Dependence of Atmospheric Dispersion on Spectraltype and Bandpass

Spectraltype	Eff.Wavel.(Å)	R"(z=45)	D-Lambda	DR"
5500 Å - 7100 Å				
B0	6183.3	57.085	186.6	0.05
M2/3	6371.9	57.034		
5200 Å - 5800 Å				
B0	5479.7	60.38	38.2	0.02
M2/3	5517.9	60.36		
3800 Å - 5000 Å				
B0	4300.9	61.12	324.5	0.26
M2/3	4625.4	60.86		

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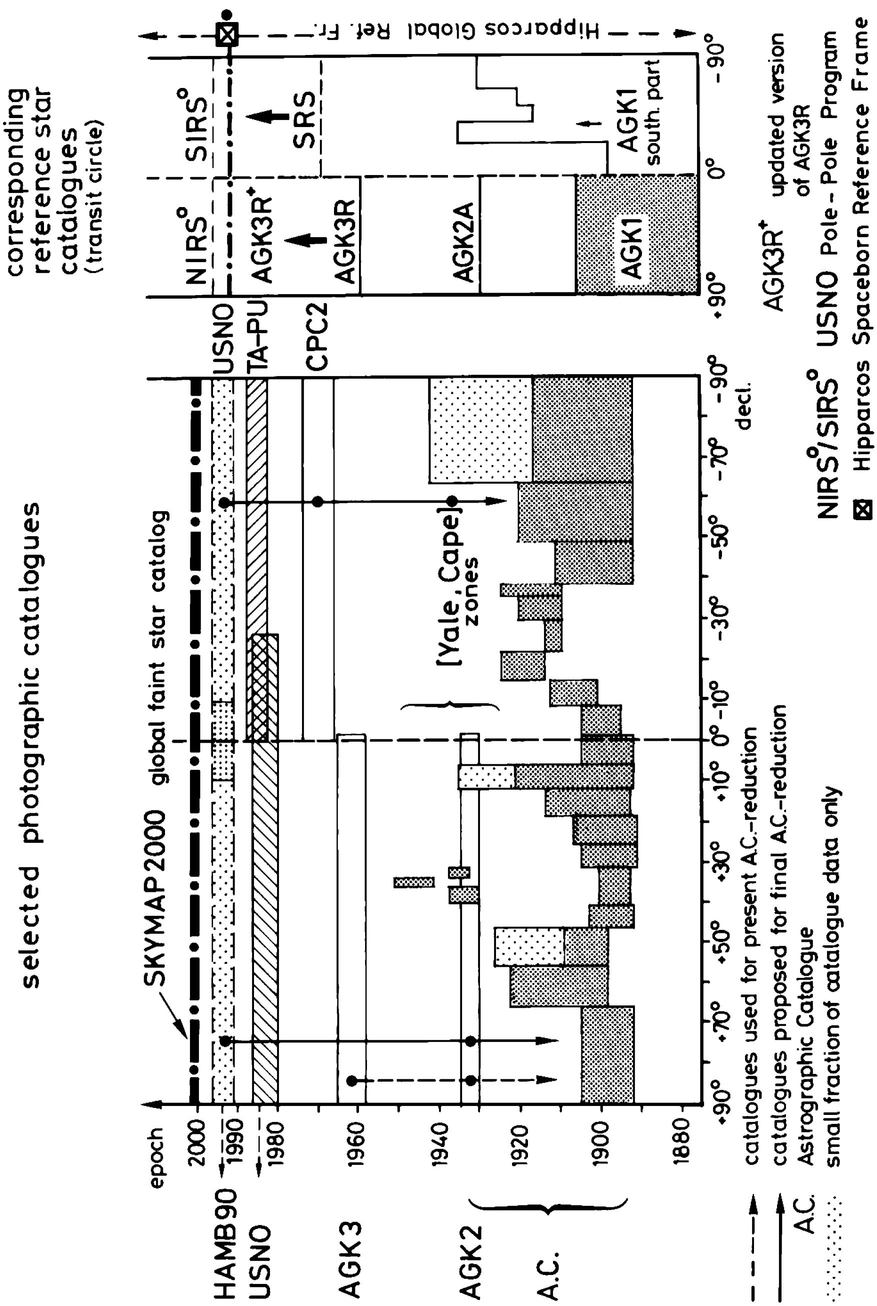

selected photographic catalogues
corresponding reference star catalogues
(transit circle)
SKYMAP2000 global faint star catalog
HAMB90
USNO
AGK3
AGK2
A.C.
epoch
2000
1990
1980
1960
1940
1920
1900
1880
+90°
+70°
+50°
+30°
+10°
0°
-10°
-30°
-50°
-70°
-90°
decl.
[Yale, Cape] zones
USNO
TA-PU
CPC2
NIRS°
SIRS°
AGK3R+
SRS
AGK3R
AGK2A
AGK1
AGK1 south. part
Hipparcos Global Ref. Fr.
catalogues used for present A.C.-reduction
catalogues proposed for final A.C.-reduction
A.C. Astrographic Catalogue
small fraction of catalogue data only
AGK3R+ updated version of AGK3R
NIRS°/SIRS° USNO Pole-Pole Program
Hipparcos Spaceborn Reference Frame
Tycho

Fig. 1

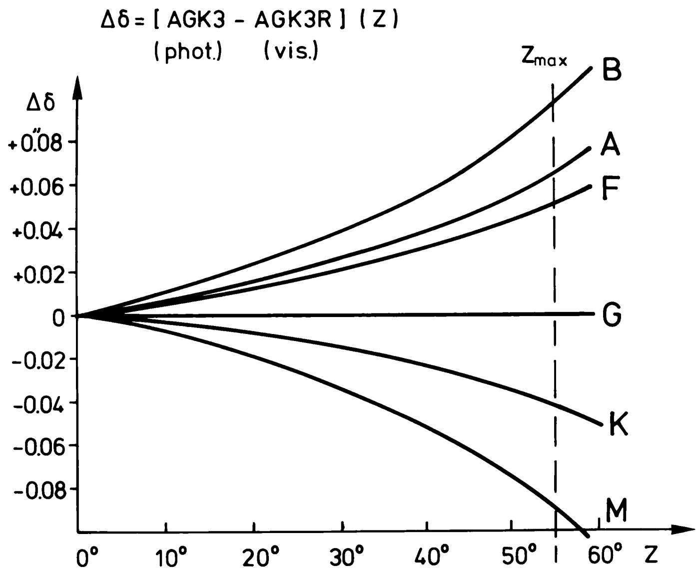


Fig. 2 Influence of Atmospheric Dispersion in AGK3

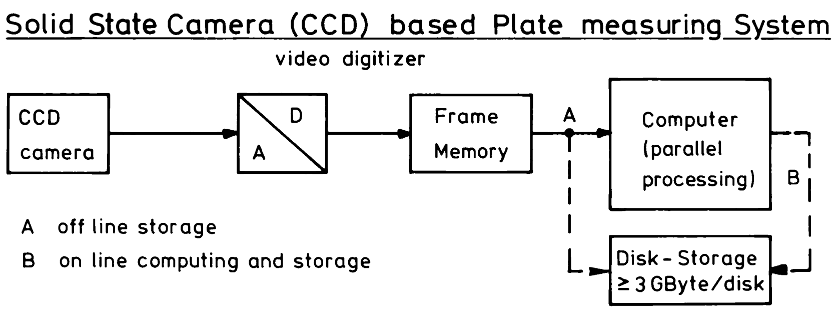


Fig. 3

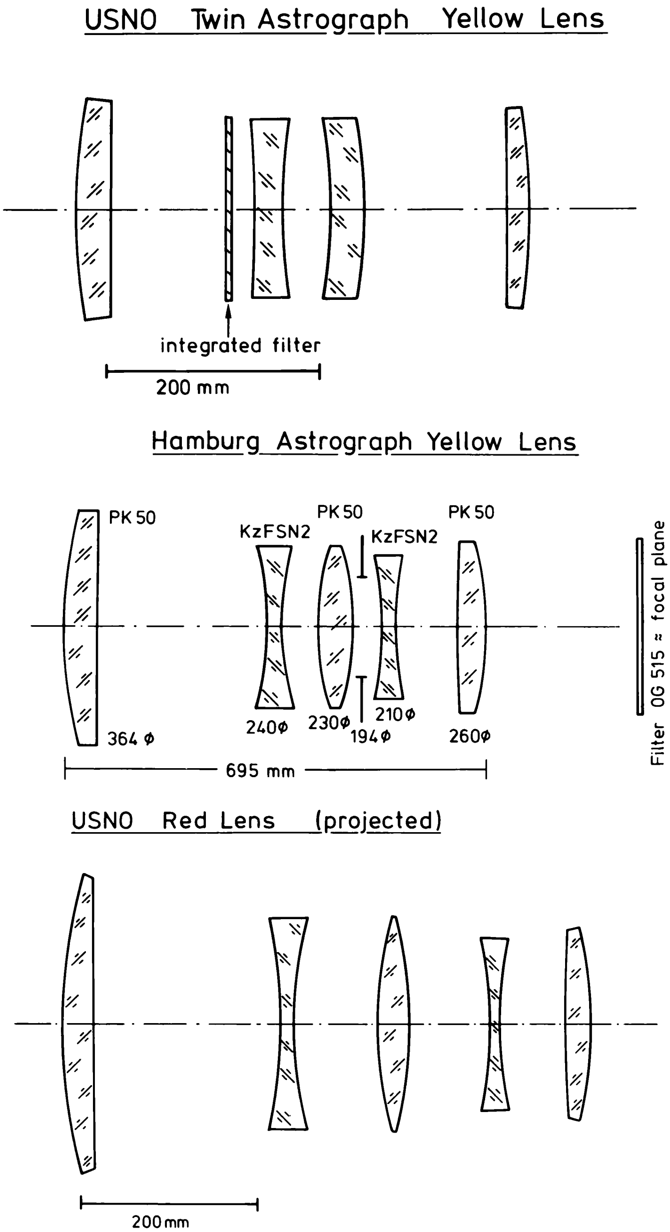
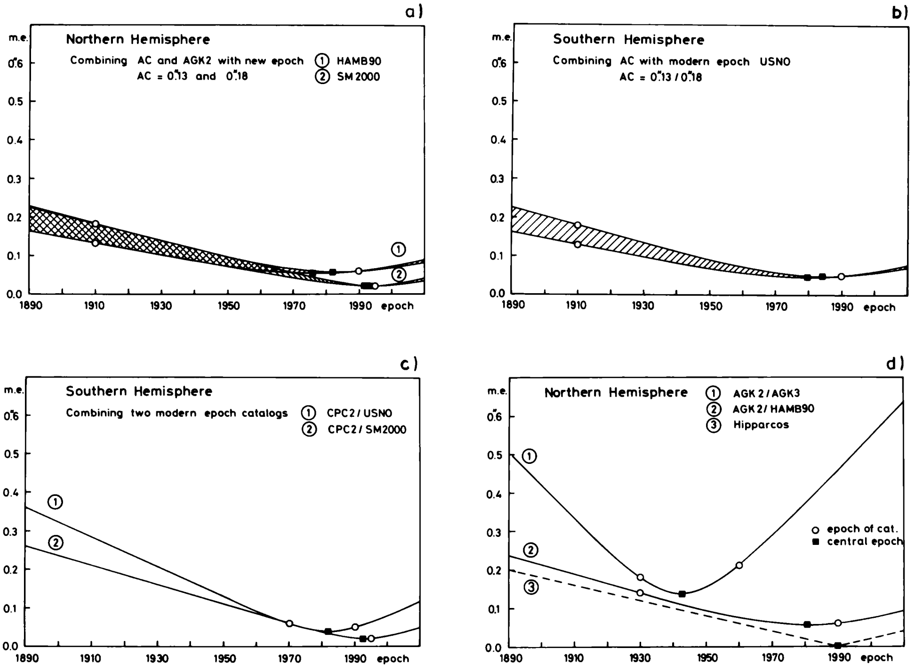


Fig. 4

Examples of modern Astrograph optics



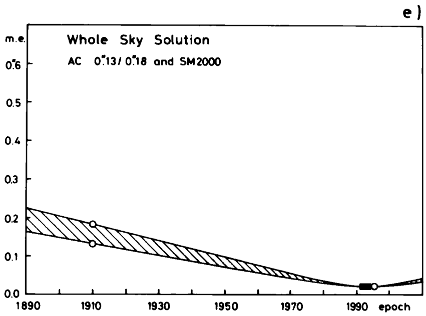


Fig. 5

Dependence of catalog positional accuracy on epoch

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Discussion:

JASCHEK Assuming that a reliable proper motion is 3ε, ε being the error of a proper motion, what percentage of stars have "reliable" proper motions, as a function of magnitude?

DE VEGT At least 60 percent.

MURRAY 1) You did not mention that some of the AC zones, such as Greenwich and Cape have repeated, giving good relative proper motion.

2) The first CPC and the Cape zone AC give a good Southern Hemisphere coverage at about 1930-1940 for $\delta < -30^{\circ}$.

DE VEGT My presentation was concentrated on the hemisphere or global catalogues, this important zone work will be addressed in the final version of my paper.

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