

COMMISSION 24: PHOTOGRAPHIC ASTROMETRY

Report 1993-1996

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1. Introduction

An investigation performed during 1995 throughout the commission showed that the main fields of activity of the members of our commission are much more wider than its title would indicate. The overlap is huge with Commission 8, and many of the topics, such as space astrometry, CCD or radio astrometry, are clearly relevant of both commissions.

A second enquiry was therefore made in 1996, in both commissions, about the feelings of the members with respect to a possible merging of Commissions 8 and 24. A vast majority of answers were enthusiastically positive. Only one answer gave arguments against. It is currently suggested that the two commissions remain separate for the next triennium (1997 – 2000), and that there would be a possible merger at the XXIVth General Assembly in the year 2000.

For a complete overview of the subjects related to astrometry, the reader is also referred to the reports of Commission 8, and of the Working Groups on Reference Frames and on Astronomical Standards.

2. Membership and main fields of activity

The opportunity of these circular letters was also taken to ask for membership updates, new requests for membership, and a brief description of the main fields of activity of the members.

Taking account of errors, retirements and of the members who left us, there are now 128 members in Commission 24 and 5 requests for membership.

The main fields of activity in our Commission, as reflected by the answers received, are the following:

- ground-based parallax programmes, using photographic (down to 15th mag) and CCD astrometry (from 5th down to 21st mag). Main applications: low mass stars, dark matter, gravitational lenses, planetary nebulae, binary stars, etc.
- ground-based proper motion programmes, using Schmidt or wide angle astrographic plates, old plates or data from the Astrographic Catalogue, Meridian Circles equipped or not with CCD (in many cases, photometric observations in parallel). Main applications: links between various reference frames (optical and radio), link of the Hipparcos reference frame to an extragalactic reference system, open and globular cluster studies, galactic rotation, solar motion, kinematics of various stellar populations, galactic evolution, Magellanic Clusters studies, high redshift QSOs, multi-wavelength cross-identifications, etc.

- radio astrometry and interferometry. Main applications: establishment of extragalactic reference system, links between various reference frames, structure of sources (comparison radio and optical), etc.
- global space astrometry (and photometry). Participation to the Hipparcos mission. Prospective towards post-Hipparcos space projects. Narrow-field space astrometry: Hubble observation of stars for the link of the Hipparcos reference frame.
- double star astrometry: photographic, CCD, speckle (astrometric and photometric observations)
- instrumentation and digitisation, reduction techniques (astrometric and photometric), image reconstruction
- astrometric catalogue and database compilations: parallaxes, proper motions, radio stars, nearby stars
- miscellaneous: observations of radial velocities; celestial mechanics and relativity; solar system astrometry; ephemerides; time scales; laser ranging; etc.

Proposed participations to the maintenance and/or extension of the Hipparcos reference frame: observations of optical counterparts of IERS objects and of radio-stars, additional radio-observations, structure of sources, speckle observations for binarity detection, observation of secondary reference stars near to IERS objects, etc.; extension and densification of proper motion measurements; re-reduction of AC, GSC, Tycho Catalogue; new reductions using AC in conjunction with GSC, USNO Twin Astrographic Catalogue, Tycho Catalogue; multi-wavelength cross-identifications and structure observations; project of an IR meridian circle; post-Hipparcos space projects.

3. Meetings, Symposia, Colloquia

3.1. OF DIRECT INTEREST TO COMMISSION 24

RGO and the Institute of Astronomy Workshop, Galactic and Solar System Optical Astrometry, Cambridge, UK, June 1993, Morrison & Gilmore (eds), Cambridge University Press.

IAU Symposium 161, Wide-Field Imaging in Astronomy, Potsdam, Germany, August 1993, MacGillivray et al. (eds), Kluwer.

IAU Colloquium 148, Future Utilization of the Schmidt Telescopes, Bandung, Java, Indonesia, March 1994.

Journées Systèmes de référence spatio-temporels. Les systèmes de référence et les constantes astronomiques, Paris, France, June 1994, N. Capitaine (ed), Observatoire de Paris.

IAU Symposium 166, Astronomical and Astrophysical Objectives of Sub-milliarcsecond Optical Astrometry, The Hague, The Netherlands, August 1994, Høg & Seidelmann (eds), Kluwer.

IAU Symposium 167, New developments in Array Technology and Applications, The Hague, The Netherlands, August 1994, Davis Philip, Janes & Upgren (eds), Kluwer.

RGO-ESA Workshop, Future Possibilities for Astrometry in Space, Cambridge, UK, June 1995, Perryman & van Leeuwen (eds), ESA SP-379.

IAU Symposium 179, New Horizons from Multi-Wavelength Digital Sky Surveys, Baltimore, USA, August 1996, Mc Lean (ed), in preparation.

3.2. WHERE ASTROMETRY IS ONE OF THE ESSENTIAL INPUTS

IAU Symposium 164, Stellar Populations, The Hague, The Netherlands, August 1994, van der Kruit & Gilmore (eds), Kluwer.

IAU Symposium 169, Unsolved Problems of the Milky Way, The Hague, The Netherlands, August 1994, Blitz & Teuben (eds).

IAU Colloquium 155, Astrophysical Applications of Stellar Pulsation, Cape Town, South Africa, February 1995, Stobie & Whitelock (eds), ASP Conference Series.

IAU Symposium 172, Dynamics, Ephemerides and Astrometry in the Solar System, Paris, France, July 1995, Ferraz-Mello, Morando & Arlot (eds).

Journées Systèmes de référence spatio-temporels. Earth Rotation, Reference Systems in Geodynamics and the Solar System, Warsaw, Poland, September 1995, N. Capitaine, B. Kolaczek & S. Débarbat (eds), Observatoire de Paris.

Colloquium 165, Dynamics and Astrometry of Natural and Artificial Celestial Bodies, Poznan, Poland, July 1966, Wyrzyszczyk, Lieske & Mignard (eds), in preparation.

4. Highlights

The event of the year 1996 is the completion of the Hipparcos and Tycho Catalogues, and the availability of data to the Hipparcos Consortia principal investigators of approved observing programmes. Data will be available to 1982 proposers in January 1997 and to the general scientific community in June 1997. A major symposium presenting the final mission results to the scientific community will be held in Venice, 13-16 May 1997.

The Hipparcos mission

The satellite was launched, by Ariane, in August 1989, and after collecting more than three years of extremely high quality scientific data, communications were terminated with the satellite in August 1993. Differential angular measurements were made over large angles, at many different orientations and epochs. The parallaxes are consequently absolute, and this has been shown by comparing the Hipparcos parallaxes with astrophysically known parallaxes (Magellanic clouds, B stars, etc.). Similarly, it is considered that regional or systematic errors in positions and annual proper motions are well below the milli-arcsec level. They are referred to the extragalactic reference system by relating the final catalogue to observations of extragalactic objects.

The entire scientific programme of the Hipparcos mission, and the satellite's sky scanning and its attitude determination, was based upon the *Hipparcos Input Catalogue*, the compilation of the 120 000 stars forming the pre-defined observing programme. It includes the state-of-the-art positional and photometric information for each star before launch. All results have confirmed the positional and photometric performances around which the catalogue was defined. The catalogue, compiled by the Input Catalogue Consortium, was published by ESA as ESA SP-1136 in March 1992. A tape version is deposited at the *Centre de Données astronomiques de Strasbourg*, and can be interrogated through their Web pages (VizieR and SIMBAD), a CD-ROM version with extensive interrogation, sampling, and mapping facilities was released in early 1994.

The telescope was continually determining the relative (along-scan) positions of the programme stars which appeared first in the preceding field of view and then in the following field of view due to the rotation of the satellite. In this way several comparisons with different stars were made. As the scans also overlapped 'sideways' when the satellite axis of rotation changed on each sweep of the sky, the stars appeared again, but this time compared with other stars. In this way, a dense net of measurements of the relative angular separations of the stars was progressively built up.

In addition to the main instrument, the payload included two star mappers (one redundant). A star mapper consisted of a non-periodic modulating grid located at the sides of the primary modulating grid, and two photomultipliers measuring the light transmitted by the whole star mapper grid in two different spectral bands, roughly corresponding to the Johnson B (blue) and V (visual) bands. Its function was to provide data allowing precise satellite attitude determination performed on-board the satellite, and the a posteriori reconstruction of the attitude. The star mapper data are also used by the Tycho experiment to perform astrometric and two-colour photometric measurements of about one million stars down to about 10-11 mag.

Within the main data reduction consortia (FAST and NDAC) and the Tycho consortium (TDAC), effort over the last two years turned from a full validation of the complex data processing chains to the *mass* data processing which was started within the groups in mid-1991. The data processing methods were described in ESA SP-1111 (June 1989) and in an A&A issue dedicated to Hipparcos [Vol.258, 1, May 1992]. Preliminary results and statistics using the first 30 months of data together with some additional insights in the reduction methods were given in 20 papers published in A&A, Vol. 304, 1, December 1995.

Final Hipparcos catalogue

Due to the concerted effort by the data reduction teams, the final stages of the data analysis have proceeded according to the planning projected before launch. The lengthy Hipparcos star catalogue construction process terminated in July 1996, and the resulting quality of the star positions and proper motions, of distance determinations, of double and multiple star parameters, of the positions of 48 minor planets, and of photometric results emerging from the data analyses gives a dramatic indication of the outstanding scientific results that the Hipparcos mission is providing.

Final sphere iterations and merging of the solutions have been carried out, and the final positions and proper motions have been rotated to the IERS extragalactic reference system using an extensive set of data acquired by a specific working group dedicated to the establishment of the best possible approximation to an inertial reference frame. Use was made of VLBI, VLA, and MERLIN observations, many photographic multi-epoch observations, Lick, Yale, and KSZ catalogues referred to galaxies, Hubble Space telescope observations, and comparisons between VLBI and Hipparcos reduced Earth rotation results. Details of this link are given in the report of the Working Group on Reference Frames, by Leslie Morrison.

The results of the mission will comprise some 14 printed volumes, tabulating not only the primary astrometric and photometric results, but also including detailed information on double and multiple systems, and variable stars. The results will be made available simultaneously on ASCII CD-ROMs, and a specific CD-ROM with a dedicated software, Celestia 2000.

Hipparcos astrometric results

They may be summarised by the following numbers

- 117 955 entries with associated astrometry, out of 118218 entries
- Median precision of positions ($H_p \leq 9$ mag): 0.77 mas in $\alpha \cos \delta$ and 0.64 mas in δ
- Median precision of proper motions ($H_p \leq 9$ mag): 0.88 mas/yr in $\mu_\alpha \cos \delta$ and 0.74 mas/yr in μ_δ
- Median precision of parallaxes ($H_p \leq 9$ mag): 0.97 mas
- Distances determined to better than 10 per cent: 20853
- Distances determined to better than 20 per cent: 49399
- Number of solved or suspected double/multiple systems: 23882
- Component data for double or multiple systems: 12195 (2996 new)
- Orbital systems: 235
- Astrometric binaries: 2910
- Suspected non-single: 8542

Data on Double and Multiple stars are presented in more detail in a dedicated annex.

Hipparcos photometric results

It is an impressive by-product of the astrometric mission that star magnitudes or brightnesses can be determined from the modulated stellar signal at the same time as the positional information is extracted. Stars over the entire sky were measured with the same instrumental set-up, and observations were repeated on each star on numerous occasions throughout the mission. The main results may be summarised as follows:

- 118 204 entries with associated photometry, out of 118218 entries
- Median photometric precision of H_p ($H_p \leq 9$ mag): 0.0015 mag
- Number of variables or possibly variables: 11597 (8237 new)

- Recognised periodic variables: 2712 (970 new)
- Non periodic or unsolved variables: 5542 (4145 new)
- Not investigated (including micro-variables): 3343 (3122 new)

Each programme star was observed roughly 110 times all along the mission, varying approximately in the range 30–380, depending principally on the object's ecliptic latitude. These 13 million transits are presented in the Hipparcos Catalogue Epoch Photometry Annex. Variability data and light curves are presented separately for stars with a significant variation (periodic or unsolved), in a specific annex.

Overview of the Tycho catalogue

The Tycho Catalogue provides positions, parallaxes, proper motions and two-colour photometry (in B_T and V_T) for 1 052 031 stars brighter than $V_T = 11.5$ mag. The median precision (standard error) is 25 mas in position and 0.10 mag in the $B_T - V_T$ colour index. These values apply at the median magnitude $V_T = 10.5$ mag for stars of median colour index $B_T - V_T \simeq 0.7$ mag. The Tycho Catalogue contains roughly 40 000 stars brighter than $V_T = 9$ mag which are not contained in the Hipparcos Catalogue. For these stars the median precision is 7 mas in position, parallax and annual proper motion, and 0.019 mag in $B_T - V_T$. Positions and proper motions are given within the International Celestial Reference System. Double stars with separations larger than 2 arcsec and with moderate magnitude difference are usually resolved.

The reduced data comprise two parts. The main catalogue (the Tycho Catalogue, or TYC) contains the astrometric and summary photometric data for each star. The Tycho Epoch Photometry Annex contains summary photometric data for all stars, along with 'epoch photometry' (photometry at each epoch of observation) for a subset of stars observed with sufficiently high signal-to-noise ratio.

It is to be noted that the Tycho Catalogue and its photometric annex is strictly an observational catalogue. It contains data derived exclusively from the Hipparcos satellite's star mapper observations, with the exception of certain cross-identifications.

Some additional details and some insights in future works based on the Tycho Catalogue are given in the reports of Commission 8 and of Division 1.

Solar system objects

The Hipparcos observing programme included a careful selection of all solar system objects observable by the satellite: 48 minor planets and three planetary satellites (Europa, Titan and Iapetus). Five minor planets were also observed by Tycho, three satellites (Ganymede, Callisto, and Titan), and two major planets (Uranus and Neptune).

All these observations, positions and proper motions given within the International Celestial Reference System, and the photometry, are contained within a dedicated annex.

5. Trigonometric parallaxes and nearby stars

Monet, at Flagstaff, reports on the USNO CCD parallax programme, which has demonstrated an accuracy of 0.5 mas. About 200 parallaxes have been measured to date, with an accuracy of better than 2 mas [Monet et al. 1992, Stone & Dahn 1995]. The next detectors to be used for the CCD parallax programme have neutral density spots (one with 5 mag and one with 9 mag of attenuation). These will allow the observation of bright (perhaps to 5th magnitude) stars with respect to distant reference objects.

Let us also mention the on-going USNO photographic parallax programme [Harrington et al., List IX, 1993].

Ianna, at Charlottesville, reports on the Leander McCormick Observatory parallax programme: with the apparently permanent demise of the Kodak 103 emulsion, parallax observations with the Leander McCormick refractor have come to an end. However the Fan Mountain 1 m (15"/mm) has been refurbished and a SITe SI-424 2048 x 2048 CCD has been acquired along with the San Diego State controller boards, and they plan to commence parallax observations with this system shortly. In Australia only limited

observations continue with the Yale-Columbia refractor at Mount Stromlo, but regular CCD observations are carried out on the 1 m reflector (25"/mm) at Siding Springs Observatory. The latter programme includes LHS stars and other new nearby star candidates, and is reaching precisions of 1-2 mas in the parallaxes [Ianna et al. 1996].

Fredrick reports on the parallax programme of the University of Virginia: programmes on the old 26-inch refractor, on the 1-meter reflector, on a 26-inch refractor at Mr. Stromlo and a 1-meter reflector at Siding Springs. The photographic parallax programme goes to about 15th mag, the CCD to about 21st mag.

Let us also mention: the CCD parallax programme of the Allegheny Observatory, using the Multichannel Astrometric Photometer (MAP), which regularly obtains precisions better than 1 mas [Gatewood 1995, Gatewood et al. 1995], and the Hubble Space Telescope possibilities in term of relative parallax measurements, with a precision better than 1 mas obtained for Proxima Centauri and Barnard's star [Benedict et al. 1995].

Catalogue: Jahreiß, at ARI, Heidelberg, reports on the progress on the Third Catalogue of Nearby Stars [Preliminary version, Gliese & Jahreiß 1991].

6. Positions and Proper motions

6.1. OBSERVING PROGRAMMES AND CATALOGUES

Klemola, Hanson, and Jones, at Lick Observatory, report on the completion of Part I of the Lick Northern Proper Motion (NPM) programme (900 fields outside the Milky Way) in 1993. Three catalogues have been deposited with the data centers (ADC and CDS): *NPM1 Catalog* [ADC 1199 = CDS I/199; August 1993]. Absolute proper motions, positions, and photometry for 148 940 stars north of declination -23 degrees; *NPM1 Reference Galaxies* [ADC 1200 = CDS I/200; September 1993]. Positions and photometry for 50 517 galaxies north of -23 degrees; *NPM1 Cross-Identifications* [ADC 1214 = CDS I/214; November 1994]. Identifications and other data for NPM1 stars (41 858 entries). Klemola began plate measurements in 1996 for Part II of the NPM programme (350 Milky Way fields north of -23 degrees). The 200 000-star NPM2 Catalog will complete the NPM programme about 5 years from now. Hanson and Klemola, with Layden (CTIO) and Hawley (Michigan State), have used the NPM1 proper motions in a major new statistical parallax study of RR Lyrae variables. Other applications of the NPM1 data underway at Lick include studies of solar motion and Galactic rotation, corrections to precession, kinematics of the Galactic halo, and comparisons with other proper motion catalogs (PPM, ACRS, Hipparcos).

Platais, at Yale, reports on the Southern Proper Motion programme (SPM): it is done using the 51-cm Yale/San Juan double astrograph (scale 55.1 "/mm), and will produce positions and absolute proper motions with respect to faint galaxies, and B, V-magnitudes for approximately one million stars south of -17 deg declination. Limiting magnitude is V=18.0-18.5. The first epoch plate material consists of two plates (blue and visual) for each field taken in 1966-72. The second epoch has been currently taken. Its completion depends upon the availability of unexposed plates from factory. CCD frames in B, V-bandpass are also planned to calibrate the plates photometrically.

Gauss reports on the work performed at the Astrometry Department of the USNO, at Washington. A new catalogue of photographic star positions has been produced from the plates taken with the Twin Astrograph (yellow and blue lenses) and measured on the Starscan measuring machine. This catalogue, called TAC (*Twin Astrograph Catalog*) contains 705 000 stars with internal mean error of 86 mas in RA and 91 mas in Dec. Some areas have already been combined with the AC data to produce proper motions. The TAC is available on the World Wide Web at <http://aries.usno.navy.mil/ad/tac.html>. Plans are underway to begin an observing programme in the Southern Hemisphere using the 8-inch CCD astrograph to produce a high-accuracy catalogue complete to magnitude R=15.5. The telescope is being assembled, the camera acquired and the site investigated. It is expected that this programme will take place in the 1997-2000 time frame.

Bronnikova, Kanaev and Polojentsev, at Pulkovo Observatory, report on observations of positions and photographic magnitudes of stars (13-16 mag) around 73 extagalactic radiosources in the declination

zone +30 to +90 degrees (*Pul ERS*), and of 110 radio stars (*Pul GRS*) in the declination zone -5 to +90 degrees [Dementieva et al., 1996]. They give a progress report on the *FOCAT catalogue*: final version of the FOCAT-S catalogue (about 20 000 stars from southern pole to equator, made from photographic observations performed in Bolivia) by Bystrov, Polojntsev, Yagudin et al. [1994]; preliminary version of the FOCAT-Dushanbe catalogue in the declination zone -16 to -30 degree (photographic observations made in Tadjikistan in 1983-1986, 55 000 stars) by Matveev and Galieva [1996]; improvement of the FOCAT catalogue in the declination zone 10 to -18 degree (photographic observations with the wide-angle Zeiss astrograph and 4 fold overlap) by Dautov, Rizvanov, Polojntsev et al. [1996]. These two parts of the work were supported by an ISF (Soros) grant. They also report on the work in the KSZ plan (determination absolute proper motions of stars relative to galaxies). The catalogue of absolute proper motions of stars in 10 selected areas has been published [Bobylev, 1996]. The calculations of secular parallaxes of stars 12.5-15.5 mag were made by Bronnikova.

Rizvanov, at Engelhardt Observatory, reports on the construction of an astrometric catalogue of 30 000 stars up to 11 mag within the zone of declination -10 to -18 degrees. This catalogue will be used within the frame of FOCAT. It is also prepared for publication.

Kislyuk, at Kiev, reports on the measurement of about 1200 plates obtained in Golosiiv (Kiev) according to the programme of Photographic Survey of the Sky (FON programme). Also, using Kiev astrograph and Tautenbourg Schmidt telescope observations, some models of the Galaxy were constructed to obtain the distributions of proper motions, mean parallaxes, stellar magnitudes and colour indexes.

Schilbach reports on Potsdam's programme in the main galactic meridian plane: proper motions, magnitudes and colours of about 60 000 stars in this zone were used to specify the three-component model of the Galaxy. For each subsystem, the distribution of the kinematical and stellar parameters were modelled in different directions of the Galaxy.

Guibert, at the Centre d'Analyse des Images, Paris, reports on programmes held using the MAMA facility (0.6 micron internal accuracy): Hipparcos link and cluster studies (see sections below); proper motion programmes (for good plates with more 10 years exposure separation: accuracy on relative proper motions: 2 mas/yr down to mag 17): completion of the Besançon programme towards selected galactic directions (Besançon, Strasbourg, Nainital); accurate measurements of large proper motions detected with the Blink Microscope (Lyon/Paris); search for high proper motions for the detection of parallax candidates (Bordeaux); and a new programme starting on the search for high proper motions in 4 000 square degrees close to the Galactic Plane (ALAMOS project, aimed at the *direct* mass determination of nearby stars from microlensing on background distant stars + relative proper motion and relative parallax of the lens, Princeton, Paris).

Wang, at Shanghai, reports on photographic astrometry of galactic field RR Lyrae stars: determination of absolute proper motions of Galactic field RR Lyrae stars, method and an example, SW Aqr [Wang & Mao].

6.2. COMPILATIONS AND RE-REDUCTIONS

J. Morrison and S. Röser at ARI, Heidelberg have prepared *GSC 1.2*, a new, astrometrically improved version of GSC 1.1. GSC 1.2 is reduced to PPM, using a spatial filtering technique. Plate-dependent systematic distortions, essentially close to the plate edges, and magnitude-dependent systematic errors have been removed. GSC 1.2 is available via the Web from the Space Telescope Science Institute. In cooperation with Sternberg Institute, Moscow, Röser and Bastian compiled *Starnet*, a catalogue of 4.3 million positions and proper motions based on GSC as second epoch, and a new reduction of the Astrographic Catalogue (AC) as first epoch. The average rms-accuracy of the proper motions is 5 mas/yr, that of the present-day positions 0.3 arcsec.

Gauss reports that the work on the re-reduction of the *Astrographic Catalogue* continues at USNO. All zones have been keypunched from the printed x-y coordinates, verified, and reduced using newly determined plate constants. The resulting coordinates are made available as the zones are completed. Currently, 11 zones have been posted to Web (<http://aries.usno.navy.mil/ad/ac.html>) and a CD-ROM containing these data is also available.

Réquième reports on proper motions obtained by H. Jahreiß from Astrographic Catalogue plates and Bordeaux meridian circle observations of stars with $10 < V < 11$. Comparison with the 30-month Hipparcos solution for 1029 stars in common shows that the accuracy of these proper motions is about 6 mas/yr, i.e. a factor two less accurate than internally determined. This is obviously due to the fact that the adopted errors of the AC positions of fainter stars were underestimated [A&A,1995].

6.3. MULTI-WAVELENGTH CROSS-IDENTIFICATIONS

M. Irwin, at Cambridge, reports on an optical catalogue to roughly 21st magnitude based on sky survey Schmidt plates using the APM measuring facility. This currently covers the Northern sky to 20 degrees from the Galactic Plane and the Southern sky is being added to the catalogue. The astrometric precision internal over say 1 degree regions is better than 0.2 arcsec whilst the global external precision is typically 0.5 to 1 arcsec. This catalogue is routinely used for fibre observations at telescopes all round the world and can be used to generate finding charts of objects or offset stars for blind offsetting onto targets. Routine radio, X-ray and IR identification is also carried out.

7. The Extragalactic Reference Frame

For details on this chapter, see report of the Working Group on Reference Frames. See also section 6.

De Vegt, at Hambourg, reports on the determination of precise optical positions (10-30 mas accuracy level) of selected compact radio sources, in particular those of the IAU WG-list [IAU Bul. 74, p3, Jan. 1995] in the Hipparcos based reference frame using photographic and CCD-based wide field observations from astrogaphs and selected large telescopes globally. Corresponding VLBI/VLBA radio programme on the 0.1-1mas level are progressing in parallel. He also reports on the determination of precise optical and radio positions of selected radio stars. The programme is carried out in collaboration with USNO.

Schilbach, at Potsdam, reports on their contribution to the final extragalactic link of the Hipparcos catalogue, based on MAMA and APM measurements of plates taken with the Tautenbourg Schmidt telescope. Proper motions of 256 Hipparcos stars were derived with respect to galaxies in 24 fields well distributed over the Northern sky. The determination of the rotation vector parameters yields uncertainties of 0.5 mas/yr.

Geffert and Tucholke report on the work performed at Bonn for the link of the Hipparcos proper motion system to the inertial system by absolute proper motions [photographic method, 1996]. The final link solution was obtained using absolute proper motions for 88 stars in twelve fields. Internal errors of the angular velocity components are 0.3 mas/yr [Geffert et al. 1996, Tucholke et al. 1996].

Kislyuk, at Kiev, reports on the compilation of the *General catalogue of absolute Proper Motions* (GPM) of stars relative to galaxies, within the programme of Catalogue of Faint Stars. The GPM catalogue was applied to the Hipparcos catalogue extragalactic link.

Kumkova, at St Petersburg, reports on the determination of parameters of relative orientation between the Hipparcos reference frame and the radio reference frame using extragalactic radio sources positions, obtained by means of photographic astrometry. This programme will be continued with the extension of the frame to stars of 12-14 mag in the vicinity of extragalactic radio sources.

Wang, at Shanghai, reports on 'Proper motions' of the counterparts of extragalactic radio sources and the precession constant, and on high-precision study of proper motions of 22 Hipparcos stars with photographic plates (mean errors 0.51 mas/yr and 0.47 mas/yr in RA and dec respectively, Wang et al.).

Walter, at ARI, Heidelberg, reports on the revision of the catalogue of radio stars for linking celestial reference frames.

8. Astrometry of Galactic open and globular clusters and Magellanic Clouds

Schilbach reports on Potsdam's deep proper motion and photometric surveys used for kinematical studies in fields of open and globular clusters. An essential part of the observations is based on MAMA and APM measurements of Schmidt plates (Tautenbourg, OCA). The investigations have been carried out in cooperation with the observatories in Tautenbourg, Paris, Kiev, Bonn and Cambridge. Proper motions and photographic U, B, V, R magnitudes for about 40 000 stars up to $V=18$ were obtained in the 16.5 square degree region of the Pleiades. The data was used for the determination of the cluster membership and for the study of the mass function of the Pleiades down to $0.3 M_{\odot}$. From proper motions and B, V magnitudes for 36 500 stars, four open clusters (two were unknown before) towards the Galactic Centre were identified. For each cluster, the distances and ages were estimated. New absolute proper motions were obtained for five globular clusters (M3, M5, M12, M15, M92) and two dSph galaxies (Draco, UMi). The results were used to re-determine their space motions. From more than 80 Tautenbourg plates in the field around M3, accurate absolute proper motions were obtained for all objects down to $B = 19.7$. Together with *UBV* photographic photometry the results are used in a QSO survey based on long-term variability and zero proper motion.

Turon, at Paris-Meudon, reports on a programme on nearby open clusters, in cooperation with Lausanne and Potsdam, using MAMA measurements of Schmidt plates (ESO, OCA, Tautenbourg, Palomar) and Hipparcos, Tycho and Coravel data.

Geffert and Tucholke, at Bonn, report on the determination of relative and absolute proper motions of several globular clusters M2, M3, M15, M53, NGC 6934, M92 [Tucholke et al. 1996], M56 [Tucholke 1996]. The galactic orbits of five of these clusters were computed and discussed [Scholz et al. 1996]. Deep proper motion studies of M71 and Ω Cen have been started [Bausen et al.]. These studies rely mainly on CCD observations for the second epoch. Optical positions of the X-ray sources in M15 and NGC 6712 were determined with respect to the FK5 system. For NGC 6712 – for the first time by astrometric data – an earlier identification was confirmed. A reinvestigation of the optical identifications of the central X-ray sources in 47 Tuc was undertaken [Geffert et al. 1996].

Geffert also reports on the determination of high accuracy proper motions of the Pleiades [Geffert et al. 1995]. The astrometric accuracy of Carte du Ciel plates for the determination of proper motions of stars in the region of the open cluster NGC 1647 has been analysed [Geffert et al. 1996]. A programme has been started to combine proper motions with CCD photometry of stars in the region of the open clusters NGC 581, 1245, 1960, 2158, 2194, 2323, 2422, 2437, 2548, 6940, for a better determination of cluster members and the luminosity function of these clusters. First results have been published [Geffert et al., 1995].

Geffert and Tucholke reports on the *MACS*, a catalogue of 244 000 uncrowded stars in the fields of LMC and SMC down to $B=16.5$ [1996].

Wang and Jin report on photographic astrometry of open clusters: determination of the proper motions of 296 AC stars in the central part of the Praesepe region (accuracies higher than 0.005 arcsec/yr and mostly at about 0.001 arcsec/yr, Wang & Jiang, 1993); high-precision study of proper motions and membership of 924 stars in the central region of Praesepe (accuracies of proper motions ranging from ± 0.2 to ± 5.0 mas/yr, of which 60% were better than ± 1.0 mas/yr, and the completeness was nearly down to $B=15.5$; membership probabilities estimated by an improved maximum likelihood method leading to a very good sample of 198 members, Wang et al., 1995); high-precision positions and proper motions of 441 stars in the Pleiades astrometric standard region (standard errors of positions less than ± 0.05 arcsec, standard errors of proper motions for 90% of stars less than ± 0.001 arcsec/yr, Wang et al., 1996); study of proper motions in the region of the open cluster M67 and membership of stars (average standard errors of proper motions from ± 0.0004 arcsec/yr for bright stars in the inner part of the field, to some ± 0.0015 arcsec/yr for faint stars in the outer part of the field, membership probabilities of 1064 stars, Zhao et al., 1993); proper motions of stars in the region of the open cluster NGC 2286 and its membership study (average standard errors of proper motions varied from ± 0.0007 arcsec/yr for bright stars in the inner part of the field, to some ± 0.0016 arcsec/yr for faint stars in the outer part of the field, membership probabilities of 2400 stars, Tian et al., 1994); Study of the open cluster M11:

proper motion measurement and membership determination (accuracies of 85% of the stars better than ± 0.001 arcsec/yr, 872 stars, Su et al.).

Wang also reports on photographic astrometry of globular clusters: review of proper motions and membership probabilities, internal motions, and space motions of the globular clusters since the middle of 1970s (Wang).

9. AC Working Group

At the 1994 IAU, Commissions 8 and 24 set up a new working group to consider the re-measurement of the Astrographic Catalogue. The membership was T.E. Corbin, C.C. Dahn, D.H.P. Jones (Chairman), M. Lattanzi, S. Röser, R. Smart (Consultant), S.E. Urban (Consultant) and Chr. de Veig.

In September 1995, Urban sent statistics regarding positional accuracies of several AC zones to all WG members. He suggested an investigation of re-measuring Vatican plates, which, according to his findings, are measured with the lowest accuracy. In March 1996, Jones borrowed 6 plates from the Vatican Observatory. He re-measured them and found that an accuracy around 0.18 arcsec is possible, in accordance with other recent work. The published measures have an accuracy around 0.42 arcsec. He gave a progress report at IAU Symposium 179 'New Horizons from Multi-Wavelength Sky Surveys'. In May 1996, Urban contacted Alan Vaughan of MacQuarie University about obtaining a sub-set of Sydney plates to be re-measured on a USNO machine, probably the PMM located in Flagstaff.

10. Double star astrometry and structure of sources

Bronnikova, Kanaev and Polojentsev, at Pulkovo Observatory, report on photographic observations of the visual double stars made with the 26-inch refractor, for aim of the orbit and mass determination, the search of invisible companions and the determination of trigonometric parallaxes.

Dommanget, in cooperation with Nys, at Buxelles, reports on double star work related to the construction of the Hipparcos Catalogue: identification of systems observed by the satellite, creation of new CCDM (Catalogue of the Components of Double and Multiple stars) numbers for systems newly discovered by the satellite.

Catalogue: A first edition of the CCDM (1994) has been deposited at the *Centre de Données Astronomiques de Strasbourg*. A second edition is being prepared, using new ground-based measurements, in particular those collected in the WDS (Washington Double Star) Catalog, and the new systems discovered by Hipparcos.

Geffert reports on the study of the influence of undetected binaries on the Hipparcos extragalactic link.

Gauss reports on the Navy Prototype Optical Interferometer which will have the capability of observing bright stars. It has seen 'first fringe' and is expected to be operational very shortly. The initial goal is to produce a catalogue of 1500 star positions with a precision around 2 mas. In addition it will have imaging capability, allowing the resolution of so-called problem stars. The problem of the resolution of images from astrometric satellites will be extremely important for the future. Sub-milliarcsecond astrometry will require considerable research into the structure of optical images (just as is being done in the radio reference frame work). The optical interferometer will have high resolution imaging capability and will contribute substantially to this effort.

11. Instrumentation

Bronnikova, Kanaev and Polojentsev report on the modernisation of the Pulkovo astrographs (26-inch and 10 cm double astrograph), equipped by CCD-cameras which replaced the photographic plates. This work was made under the leadership of Kiselev (26-inch) and of Guseva (10 cm). Experimental observations with the CCD cameras are being done with both astrographs since 1994.

Réquième reports on the transformation of the Bordeaux and Sao Paulo Meridian Circles. A first CCD camera working in scan mode was tested during 9 months on the Bordeaux meridian circle and then moved to the Sao Paulo meridian circle. An improved version of this camera with a 1024 x 1024 CCD corresponding to a larger declination field (28') is under test at Bordeaux. Taking as reference preliminary Tycho positions and preliminary proper motions obtained by S.Röser from the Astrographic Catalogue and the Guide Star Catalog, the precision of the positions obtained at Bordeaux with the first CCD camera is about 0.05" up to $V=15$, for a star measured at least 4 times in fields from -16 to 62 degrees.

12. Reduction Methods and New Investigations

Guibert reports on programmes held using the MAMA facility: 1) investigation of the accuracy reachable using Hipparcos and Tycho data in the reduction of a Schmidt plate (better than 0.1 arcsec, Robichon et al. 1995); 2) Schmidt plate reductions in view of multi-wavelength identification of various objects (IR, X,...), and observations with large telescopes (many groups, many countries). Typical accuracy obtained with the PPM catalogue: Southern sky, 0.25 arcsec; Northern sky, 0.3-0.4 arcsec; 3) contribution to the ALADIN interactive Atlas of the deep sky (Centre de Données astronomiques de Strasbourg).

Geffert reports on the modelling of the triple images on Carte du Ciel plates. Various refinements of this method are under investigation. A special multithreshold technique for the determination of the positions of the triple images of the Carte du Ciel plates has been successfully applied in the field of NGC 1647. The cross-correlation technique for differential astrometry of objects with complicated structure was applied successfully in the fields of M 51 and M 81. The astrometric accuracy of wide field (20' x 20') CCD observations has been tested.

Rizvanov reports on the development of a new method to account for spherical and instrumental corrections in the astrometric reduction of the wide-field plates (Schmidt, Menisc, Refractor).

Monet reports on the USNO (Flagstaff station) contribution to the astrometric algorithms, observing, and reduction techniques of the Sloan Digital Sky Survey (SDSS) and the Two Micron All Sky Survey (2MASS). In addition, the Precision Measuring Machine (PMM) at Flagstaff has digitised and processed all of the POSS-I plates and is about 25% finished with the POSS-II plates. These data will be assembled into various catalogues and will be merged with SDSS and 2MASS data.

13. Prospects for space astrometry

The informations provided by members of commission 24 on new space astrometry projects have been combined with similar information sent to Commission 8. It can be found in the report of Commission 8.

14. Acknowledgements

I would like to warmly acknowledge all the members who responded to my request for information in view of this report.