COMMISSION 8: POSITIONAL ASTRONOMY

1. Introduction

The scope of this report continues in the same vein as those made previously for Commission 8: wide-angle, optical astrometry with astrometry involving photographic techniques still being the province of Commission 24. However, the successes of new instrumentation and techniques, in particular Hipparcos and ground-based astrometry with CCD's, now require a more integrated approach. It is with this in mind that plans are underway to combine Commissions 8 and 24, and it is hoped that by the General Assembly in the year 2000 this integration will be achieved.

2. Meetings, Symposia, Colloquia

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

Colloquium 165, Dynamics and Astrometry of Natural and Artificial Celestial Bodies, Poznan, Poland, July 1996, eds. Wytrzyszczak, Lieske & Mignard, in preparation.

Symposium 179, New Horizons from Multi-Wavelength Sky Surveys, Baltimore, USA, August 1996, ed. McLean, in preparation.

Journees Systemes de reference spatio-temporels:
Paris, June 1994 - Les systemes de reference et les constantes astronomiques (ISBN 2-901057-29-2).
Warsaw, September 1995 - Earth Rotation, Reference Systems in Geodynamics and the Solar System (ISBN 83-902319-2-1).

3. Ground Based Astrometry

ARGENTINA. The San Fernando Automatic Meridian Circle (CMASF) was installed at the Astronomical Station *Carlos Ulrrico Cesco* of the Observatorio Astronómico Félix Aguilar (el Leoncito) in June 1996. It will be operated jointly by the Departmento Círculo Meridiano of San Juan and the Real Instituto y Observatorio de la Marina en San Fernando, Spain.

CHINA. This report covers the scientific research done under the Committee of Catalogs and Astronomical Constants which is part of the Chinese Astronomical Society

For the extension of the optical frame and its linkage to the radio frame four new instruments have been under preparation. These are:

The Photo-electric Astrolabe Type III of Beijing Observatory was being adjusted and the experimental observations are being carried out. The precision of observation for a single star is ~~0~~ "18.

The automated Horizontal Meridian Circle fabricated by Shaanxi Observatory and Copenhagen Observatory has been put into operation. A photoelectric moving-slit micrometer is installed to record the signals. The errors of the instrument and the signal detectors were analyzed (Publ. Shaanxi Obs., **18**, 92).

The Low Latitude Meridian Circle of Yunnan Observatory was adjusted. By December 1996 it will be installed at the Yunnan Observatory (Publ. Yunnan Obs.,**3**, 43).

I. Appenzeller (ed.), Reports on Astronomy, Vol. XXIIIA, 71–80.

The prototype Optical Interferometer was manufactured. The software of the control system is being investigated and will be completed in the end of 1996 (Publ. Shaanxi Obs., **16**, 44).

The instrument and the system software of the PDS microdensitometer of the Purple Mountain Observatory has been revised for the improvement of positional accuracy (Publ. Purple Mt. Obs., **12**, 197 & 205).

Utilizing the observations and the old plates of the double astrograph at Zô-Sè section of Shanghai Observatory, the proper motions of 924 stars in the central region of Praesepe and a catalog of reference stars for the astrometric standard region Pleiades on the system of FK5/J2000.0 were produced (A&AS, **113**, 419).

There are two VLBI stations in China: Shanghai and Urumqi. The radio astrometry is one part of the work of these VLBI stations. The contributions of Shanghai VLBI station for the radio reference frame in southern hemisphere was discussed. Two experiments for determining the precise positions of radio compact sources were carried out in Feb. 1994 and June 1995 (Ann. Shanghai Obs., **16**, 75). Based on differential VLBI techniques, two observational plans of the radio stars and extragalactic sources were proposed (Publ. Purple Mt. Obs., **13**, 32).

A series studies on the improvement and maintenance of the radio reference frame were undertaken. These include the identification and correction of relative deformations between frames, the selection of primary sources, the maintenance of the orientation of frames and the compilation of combined radio source catalogs (A&A, **303**, 276). For the linkage between the radio reference frame and the dynamic reference frame a method of predicting occultations of point sources (star or radio source) by planets and the Moon was proposed. A catalog of optical positions of extragalactic radio sources was compiled and compared with the IERS radio celestial reference frames. A tie of the optical and radio frames resulted (Li, J. & Jin, W., A&AS, in press).

DENMARK, GREAT BRITAIN & SPAIN. The Carlsberg Automatic Meridian Circle (CAMC) continued in regular use at the international observatory of the Roque de los Muchachos on the island of La Palma in the Canaries. It was operated jointly by Copenhagen University Observatory, the Royal Greenwich Observatory and the Real Observatorio y Instituto de la Armada en San Fernando.

Carlsberg Meridian Catalogue La Palma Number 8 (CMC8) was published in 1994. It is the first catalogue of the series to be observed regularly using the smallest section of the scanning slits (12 arcsec long) which improved the signal to noise ratio. The standard error of a single observation in the zenith was improved from 0".15 to 0".12 by night-to-night smoothing of observed star positions. This did not alter the system of the catalogue.

CMC8 contains 18 145 positions and magnitudes, and 16 896 proper motions of stars north of declination -40°. The bulk of the stars comprise= IRS (~2000) and stars in a global net with V ~12 (~7500). CMC8 also contains 2143 positions of Solar System objects.

Observation of CMC9 began in January 1994 and ended in April 1995, when a new computer-control system based on PC486s was introduced. It is being prepared for publication on a CD-ROM. Four major new observational programs were introduced in CMC9: (i) a dense net of reference stars with V ~12.5 straddling the equator, to be used in investigating magnitude equations in Schmidt plates, (ii) reference stars in the fields of Veron-Cetty galaxies, (iii) Luyten NLTT stars with $11 < V < 14$ and μ >0".3/yr, (iv) variable (GCVS) stars with $12 < V < 14$.

A series of CAMC positions and magnitudes of novae and supernovae were issued occasionally in IAU Circulars in the range Nos.5767-6233.

CMC5-7 were used to test the accuracy of the PPM catalogue (north) (Proc. 2nd Int. W/S, Valencia, 1993, p.249). A substantial magnitude equation was found in right ascension for stars south of +30°. Improving proper motions by re-observing stars with the CAMC was discussed [61.041.037]. CAMC observations were used to provide an astrometric grid for the Galactic center [63.041.005].

CAMC observations of planet positions in the years 1984-1991 were analyzed (Proc. 2nd Int. W/S, Valencia, 1993, p.301).

The San Fernando Automatic Meridian Circle (CMASF), having been equipped with the same moving-slit micrometer and control system as the Carlsberg Automatic Meridian Circle, was tested during 1995. A small catalogue was formed and the accuracy of a single observation was found to be 0.2 arcsec which was satisfactory, given the bad seeing at San Fernando. The instrument was then dismantled and shipped to Argentina in April 1996 under an intergovernmental agreement between Spain and Argentina to operate the instrument in the Southern hemisphere at Leoncito.

FRANCE. New reductions of differential observations made during 8 years by the Bordeaux automatic meridian circle have been completed, replacing the positions of the FK5 reference stars by those of the Hipparcos 30-month intermediate solution. After correction for small instrumental errors and improvement of the reduction model, the standard deviations of the differences (Bordeaux-Hipparcos) are 0.05" in RA and 0.07" in DEC for a set of 173 confirmed or suspected radio stars (A&A, **304**,121).

A first CCD camera working in the scan mode was tested during nine months on the Bordeaux meridian circle and then moved to the Sao Paulo meridian circle. An improved version of this camera with a 1024x1024 CCD corresponding to a larger declination field (28') is under test at Bordeaux. Using preliminary Tycho positions as a reference and preliminary proper motions obtained by S.Roeser from the Astrographic Catalog and the Guide Star Catalog, the accuracy of the positions obtained at Bordeaux with the first CCD camera is about 0."05 up to V=3D15, for a star measured at least 4 times in the declination range -16° to 62°. This accuracy is confirmed by comparisons with positions obtained in common fields by the CCD meridian circles of Flagstaff and Sao Paulo, and by observations of Pluto.

Observations of Saturn made with astrolabes from 1970 to 1978 at San Fernando and Paris were compared with DE200 and show a linear rate in declination (A&AS, **101**, 573).

GERMANY. Work continued on the data base ARIGFH at the Astronomisches Rechen-Institut. The main aim is to collect all the relevant astrometric data on stellar positions and proper motions in a comprehensive data bank. During the period of this report the main task was to bring older catalogues into machine readable form and to cross identify these observations with the stars in the master catalogue. More than 450 000 observations for about 150 000 stars from more than 300 catalogues are now incorporated in the data base. Work on the homogenization of the observations (e.g. the reduction to a common system) has been started.

A new determination of precession and nutation was done based on VLBI positions of extragalactic radio sources (A&AS, **308**, 1001). Cataloging of those radio stars that promise to be instrumental in establishing the link between optical and radio reference frames was prepared in collaboration with the Hamburg Observatory.

Observations continued at the Munich Observatory to obtain absolute declinations of fundamental stars

JAPAN. "The Tokyo PMC Catalog 89: Catalog of Positions of 3466 Stars Observed in 1989 with the Tokyo Photoelectric Meridian Circle" (Publ. Nat. Astron. Obs. Japan, **3**, 45) is the 5th catalog of the annual catalog series of the Tokyo PMC. The 6th, which is the final one of the series, will be published in 1996. It will contain the positions of about 6000 stars referred to the equator and equinox of J2000 based on the observations made in 1990 through 1992 with the Tokyo PMC. In the near future the Fundamental (Absolute) Tokyo PMC Catalog will be constructed by re-compiling all of the observations of the Tokyo PMC made in 1986 through 1992 together with the planetary and solar positions used to determine the independent equator and equinox of the catalog.

The apparent radius of the sun has been observed regularly since 1985 with the Tokyo Photoelectric Meridian Circle (Tokyo PMC) at Mitaka. It was found that the average value of the solar radius is 959."83 calculated from 755 observations made between 1985 and 1994. The uncertainty of a single (one-day) observation was found to be about 0."33. The annual mean values of the observed radii are the smallest near the solar-cycle maximum, in 1989 and 1990, and the largest ones around the solar-cycle minimum, in 1986 and 1994. The average peak-to-peak shift of the annual mean solar radius for the solar cycle is $\Delta R_\odot / R_\odot \sim 1.2 \times 10^{-4}$, which is close to the relative change of the frequency of the 5-minute p-mode solar oscillation within one solar cycle.

Planetary and satellite positions of selected solar system objects have been observed since 1994 by using the CCD Meridian Circle. The results for Pluto in 1994 are already published (Astron. J., **110**, 3050). In addition, the positions of all of the stars between magnitudes 12 and 16 in several selected regions of the sky have been observed since 1994 with the CCD Meridian Circle and reduced with respect to the FK5 system. Within the next several years more than a half million stars will be observed at least three times. The resulting database will contribute to= the determination of proper motions of stars fainter than those observed by Hipparcos.

A new technique of numerical filters to evaluate brightness, position of the photocenter, and other properties of celestial objects from their two-dimensional CCD images was developed (A&AS, **113**, 185). The construction of the numerical filters is based on a set of two-dimensional orthogonal functions. An appropriate linear combination of the orthogonal functions enables a filter to achieve the minimum-

variance estimation. The performance of the numerical filter= method was examined by comparing it with the performance of some other methods or techniques proposed so far for one or two-dimensional image location problems. The results of numerical simulations have also been checked for a verification of the theoretical expectations.

MIRA is a series of ground based optical and infrared interferometer arrays, promoted by the Japanese optical and infrared interferometer astronomy group for astrometry and astrophysics. MIRA-*I* (1995-) is an experimental two-element interferometer at Mitaka with 4m N-S baseline, constructed to gain experience with tracking stellar fringes. MIRA-*II* is the multi-element intermediate interferometer with a long baseline of about a hundred meters to be constructed at Mitaka by 2000. MIRA-*II* is going to be operated in the visible and near infrared wavelength regions up to K-band ($\lambda = 3D2.2\mu$m). The last of the series is MIRA-*III*, which will be constructed at one of the world best site for astronomical observations. The main structure of MIRA-*III* is an eight-element Y-shaped optical/infrared (up to K-band) interferometer with a maximum baseline length longer than 200m. The size of the mirror of each siderostat is planned to be 1.5 m in diameter.

The results from the meridian astronomy group which has been working with= the Tokyo Photoelectric Meridian Circle (Tokyo PMC) for the past ten years are presented in a review report by Yoshizawa et al. (1994, Publ. Natl. Astron. Obs. Japan, **3**, 289). The report also includes the descriptions of the early work at the installation stage of the Tokyo PMC and observational activities, as well as other astronomical contributions of the group in the field of Galactic Kinematics and the development of new instrumentation.

ROMANIA. Observations with the Gauthier-Prin Meridian Circle operated by the Meridian Division have ended. Efforts are now focused on the modernization of the astrolabe. After this work is completed it is intended to refurbish the meridian circle and return it to operation.

Results from the observing will be found in the Bucharest Bright and Double Stars Catalogue, declination zone (0,+20) degrees (Academic Publishing House, in press with a delay of two years). and the Bucharest Double Stars Catalogue, declination zone (-5,+5) that is in final reduction and will be ready in January 1997.

RUSSIA. At the Pulkovo Observatory successful observations of stellar declinations were continued with the Zverev Photographic Vertical Circle (PVC). For the period 1987-96 more than 12 000 observations of the fundamental stars from the FK5 were made. The reductions of 8500 observations of 1300 stars were completed. The compilation of the 1st version of the Catalogue of Declinations of 760 stars was finished. The mean error of a single observation at the zenith is +/-0".15, and the average mean error of a catalogue position is +/-0".07 (Pulkovo Obs., Lab. of Photom., Preprint No. 6).

Regular observations of the occultations of the stars by the Moon and Asteroids with AZT-7 telescope has been begun.

Regular meridian observations of the Sun, Mercury, Venus, Mars and day-time stars were made by the Struve-Erthel Vertical Circle and Struve-Erthel Large Transit Instrument at the Kislovodsk Mountain Station (H=3D2100 m). Altogether 810 Sun and planet observations and 2502 star observations have been made with the Vertical Circle and about the same number with the Large Transit Instrument. The mean error of a single observation at the zenith is +0".25.

The modernization of the Zverev PVC has been in progress. In particular, it was equipped by a CCD-camera for the registration of the star images. This replaced the photographic micrometer. PVC also was equipped with a modern computer which will collect observational data and fulfill some other functions. For a CCD-camera the ST-6 of the Santa Barbara Instrument Group was used. The use of the CCD-camera for the registration of observations will permit an increase in the efficiency and productivity and at the same time will increase the quality (IAU Symp. 167, 333 and Goncharov, IAU Coll. 165, in press). The experimental observations with Zverev PVC equipped with a CCD-camera began in August 1996, and this work was made possible with financial support of the Russian Foundation of the Fundamental Research.

The construction of the principal new astrometric instrument, a reflecting meridian circle, which will be used for observations in both the visual and infrared bands was proposed.

The research of systematic errors of in a number of catalogs, including the FK5, was completed at Pulkovo (Izvestia GAO, **20**, 124).

A new estimation of the zero-point of the FK5 Fundamental catalogue and its centennial change was made by V.A.Fomin on the basis of meridian observations of the Moon during 1923-1977 at Washington,

Greenwich, Tokyo and Cape. The results show that a new evaluation of the FK5 equinox is required.

New methods for the construction of the systems of compiled catalogues of positions and proper motions were developed. Using re-reduced material of the Bright Stars International Programme, a high precision reference system of positions and proper motions of stars up to 7.9 mag. for the whole sky was constructed. Using proper motions of the FK5 and PPM catalogs, corrections to precession constants, Oort constants and coordinates of the Solar Apex were determined. (Kinematics and Physics of Selected Bodies, **12**, No. 2, 77).

A new method of star identification in large catalogues with unknown or with poorly known proper motions was proposed. An investigation of the method of overlapping fields using the Guide Star Catalog (GSC) was made. The table of corrections from GSC to the FK5 system was compiled, and the programs for conversion of GSC catalogue to the FK5 system with precision up to 0.5 arcsec was prepared. The results of this investigation have been proposed as a standard for CCD observation of minor planets.

SPAIN. The automation of the San Fernando Meridian Circle was completed in 1993. After a period of evaluation of its performance and test observations in San Fernando during 1994 and 1995, the instrument and its electronics and computers were dismantled and packed in early 1996. In May of 1996 the complete system was shipped in two containers to the Estacion de Altura Carlos Ulrrico Cesco (CUC) of the San Juan University (Argentina) lat. 31.=F8 South and 69.=F8 West. The CUC Observatory is the place where the USNO 7" Transit Circle was situated for the SRS Program.

The San Fernando Automatic Meridian Circle was mounted during June - July of 1996 and the test observations began in August. It is expected that regular observations will begin in the first half of 1997

San Fernando has also continued its collaboration with the Copenhagen University Observatory (CUO) and the Royal Greenwich Observatory (RGO) in running the Carlsberg Automatic Meridian Circle (CAMC) at the observatory of the Roque de los Muchachos on the island of La Palma in the Canaries (Spain).

An acquisition system using a CCD camera in the focal plane was completed in early 1995 for the Danjon Astrolabe in order to better define the solar diameter. Visual observations of the Sun, planets and stars at two zenith distances (30.=F8 and 45.=F8) are also possible. The regular digital observation of the Sun at z =3D 45.=F8 commenced in April 1995 and the 5/8 of the whole apparent orbit of the Sun can be observed at San Fernando.

UKRAINE. Mykolayiv Astronomical Observatory: The observations of 2149 stars around 238 radio sources were finished with the semi-automatic Repsold meridian circle of the Mykolayiv Astronomical Observatory More than 14 500 observations resulted with accuracies of 0.012 sec (RA) and 0."12 to 0."19 (declination). Observations of Uranus, Neptune, the four Galilean satellites and Titan were continued. Solar system objects were also observed with the zone astrograph (D=3D120, F=3D2044 mm, plate 5x5 degrees): major planets (65 observations), minor planets (47), Jovian satellites (33), and comet 1996B2 (Hyakutake)(65). Mykolayiv also participated in the project of photographic fourfold coverage of the Northern Hemisphere (FON). Measurements of 130 plates were made on PARSEC (programme automatic radial-scanner coordinatometer).

The Axial Meridian Circle (AMC) went into operation in 1995. The AMC includes the horizontal telescope (D=3D180mm, F=3D2480mm) in the prime vertical and fixed aligned vacuum collimator (D=3D180mm,F=3D12360mm), (IAU Symp.166, 365). The AMC is equipped with a computer control system and CCD registering devices. The AMC has given good results: limiting magnitude 15; accuracy 0."02 to 0."05; systematic variation not more than 0."05-0."09 from 0° to +65° DEC and in temperature range 23° C. It is possible to observe 1500-2000 stars/hour. Starting in 1996 stars in the 12-14 mag range around 400 radio sources from +90° to −20° were observed. These stars were selected from the Guide Star Catalog, and the results are in the Hipparcos system. About three more years are needed for the completion of the catalog which will have an overall accuracy of 0."02. Thus far some 50 000 observations of stars around 150 radio sources have been made.

Astronomical Observatory of the Kiev Taras Shevchenko University: In order to study the northern polar zone thirteen catalogues with observational epochs after 1850 were combined to produce a compiled catalog of 4272 stars north of +80° in the FK5 system with a mean epoch of about 1940. The accuracy of the catalog is 0."2 at epoch and proper motion errors of 0."25/cy. The comparison of this new catalogue with the PPM and ACRS shows some striking systematic differences. It is planned to study the southern polar region as well. (V.Tel'nyuk-Adamchuk, O.Molotaj, and L.G.Taff from STScI, USA).

At the Kyiv University Observatory and the Bucharest Institute of Astronomy, Romania, plates are being taken to produce secondary reference stars in the magnitude range 12 to 14 around the ICRF extragalactic sources. Hipparcos, Tycho, CAMC and PPM stars are being measured. Observations, plate measures and reductions are currently underway. (S.Pasitchnyk, V.Tel'nyuk-Adamchuk, O.Molotaj, Kyiv; G.Bocsha, Bucharest).

Reductions have been completed for the 1986-1992 differential meridian observations made with the Kiev Repsold Meridian Circle. The results consist of 6180 IRS stars in the zone $+10°$ to $+30°$ with a single observation precision= of 0.025 sec in RA and 0".42 in DEC and of 1761 RRS2 stars around radio sources in the zone north of $-10°$ with precisions of 0.029 sec and 0".51 per observation.

Main Astronomical Observatory of the Ukrainian Academy of Sciences (Goloseevo Observatory): Observations are being carried out on the meridian axial circle. Coordinates (right ascensions) are measured with an accuracy of 0.3 arcsec and for stars brighter than 9.0 mag V, B-V and V-R values with accuracies of 0.09 m, 0.11 m, 0.06 magnitudes, respectively. The current observational programme includes FK5 stars and RRS2 radio reference stars. It is also planned to observe PPM and Hipparcos stars.

A new approach is suggested at the MAO for solving the problem of the relationship of the stellar to the planetary reference frame. Using this approach, new geometrical models have been developed for relating the dynamical and fundamental reference frames using differential observations of the Sun, the Moon, and planets. The difference between the dynamical and catalog equinoxes in these models is interpreted quite differently as compared with the analytical approach widely used up to this time. Equations for the differences between the catalog and dynamical zero-points as well as for the corrections to the external elements of the orbits of the Earth and planets have been derived within the framework of the models developed. The equations derived were compared with the equations used previously for the relation of the dynamical and fundamental reference frames. The nonprecessional motion of the equinox has been explained as a result of errors in the theory of the Earth's motion and of incomplete procedures in observation reductions.

The correlations between unknowns in the equations were studied, and it was found that these correlations depend on the orbit orientation of a planet in space. This dependence gives rise to bias in the estimates of the corrections to catalog zero-points and to the external elements of the orbits. For this reason, equinoxes and equators of dynamical reference frames specified by observations of different planets are in poor agreement. These inferences were confirmed by comparing the Washington (1949-1977) and Herstmonceux (1957-1982) meridian observations involving asteroids 1-4. It seems clear that the problem of relating the stellar and planetary reference frames has not yet been solved.

Thus it is advisable to study the correlations between the unknowns in the equations for all of major and 20 selected minor planets taking into account their synodic periods and periods of observation. Furthermore, the solutions for the relation of the dynamical and fundamental coordinate systems should be separated from the problems of the improvement of orbits and the construction of theories of the motions of the planets.

The phase corrections 0".07 +/-0".03 (Ceres), 0".02 +/-0".03 (Pallas), 0".05 +/-0".04 (Juno), and -0".02 +/-0".02 (Vesta) corresponding to the maximum phase angles were determined from Washington (1949-1977) and Herstmonceux (1957-1982) meridian observations of bright asteroids. These values are in good agreement with those calculated by the formulas for Lommel-Zeeliger's law and Lambert's law of light reflection, but in the case of Vesta these laws are not applicable. The phase corrections must be taken into account in high-precision astrometry of bright asteroids.

Astrometric work is being extended to the infrared. Instrumentation has been proposed and cataloging efforts are underway (IAU Symp. 166, 354).

USA. Absolute observations of the International Reference Stars made with the Seven-inch Transit Circle begun in June 1987 under the direction of the late Dr. James Hughes were completed in February 1996 with a total of approximately 158 000 observations. The Black Birch Astrometric Observatory outside Blenheim, New Zealand, was closed and the transit circle was returned to Washington. In conjunction with the observations made from Washington, DC, with the Six-inch Transit Circle, this will form a Pole-to-Pole catalog of absolute positions to be made available in 1997.

Absolute observations made with the Six-inch Transit Circle in the period September 1977 to July 1982 have been reduced and will be published as the W1J00 catalog. There are no current plans for further fundamental programs with either of the transit circles.

Work on the re-reduction of the Astrographic Catalog continues. All data have been entered and verified from the printed x-y coordinates and reduced using newly determined plate constants. The resulting coordinates on the FK5, J2000.0 system are made available as the zones are completed. Currently, 11 zones have been posted to the World Wide Web (http://aries.usno.navy.mil/ad/ac.html) and a CD-ROM containing these data is also available.

A new version of the Catalog of Positions of Infrared Stellar Sources (CPIRSS) was produced containing astrometric positions of infrared stars in the IRAS catalog. This work concentrates on the correlation of IRAS positions, using colors as a guide, with those of stars in the standard astrometric catalogs.

Work on the optical-radio reference frame link is being carried out jointly with Hamburg Observatory. Positions of optical counterparts are being obtained with large telescopes in both hemispheres using reference stars obtained from astrograph plates.

The Navy Prototype Optical Interferometer being constructed near Flagstaff, Arizona, by USNO and NRL achieved simultaneous, three-baseline fringe tracking on stars on 19 March 1996. These observations constitute the first optical phase-closure observations ever achieved on baselines significantly longer than the aperture of the largest monolithic telescopes (baselines of 19 m - 38 m). Observations for astrometry are expected to begin in October, 1996 when the metrology system will be largely operational.

Closure-phase data collected in May-June 1996 were used to construct the first aperture synthesis maps made with the NPOI (the second ever made in the optical with an independent-aperture optical interferometer). Images of the spectroscopic binary Zeta1 UMa (P =3D 20d, a =3D 9.6 mas), on seven dates, were derived from the 32 color, closure-phase data. All seven images are currently available on the World Wide Web at
http://aries.usno.navy.mil/ad/npoi.

Instrumental development was completed for the USNO (Flagstaff) 0.2cm CCD transit telescope, and observational programs were started, including CCD scans of 16 Sloan calibration regions along the celestial equator, FK5 and radio stars for linking the radio and optical reference frames, and numerous asteroids and the outer planets Uranus, Neptune, and Pluto. All positions are determined in the extragalactic referenced frame with an accuracy of +/-0.15 arcsec.

4. Wide-angle space astrometry

The great success of the Hipparcos/Tycho mission has completely changed both what is to be expected from the optical reference frame and how astrometry should proceed in the coming years. Twenty years ago ago milliarcsecond optical astrometry seemed a distant prospect, and when the FK5 appeared a decade ago it was state-of-the-art with positions in the 10 to 50 mas range. Hipparcos has demonstrated that from now on the standard will be at or below the milliarcsecond level. Thus wide-angle astrometry has now become a full partner to the radio reference frame established by VLBI observations. The report of the Hipparcos and Tycho results as they relate to the work of this Commission is presented in the Commission 24 report in which their results are also summarized.

A Tycho Reference Catalogue (TRC) will be produced by a team with participants at Copenhagen, Heidelberg, Lund and Moscow. The catalogue will be based on the Tycho Catalogue positions, and will include proper motions based on these positions and early epoch positions from a new reduction of the Astrographic Catalogue in the Hipparcos system. The resulting proper motions and positions of one million stars are expected to attain a typical accuracy for individual stars of respectively 2 mas/yr and 25 mas at the epoch 1991. Closely tied to the Hipparcos reference system, the TRC will constitute a dense, high-precision astrometric net of stars.

5. Future astrometry in space

The success of Hipparcos has demonstrated that making astrometric observations from satellites is not only feasible but necessary if the highest accuracy it to be attained. Building on the Hipparcos experience there are now a number of proposals under consideration. Reports were received on the following:

GAIA is a preliminary concept for an astrometric mission, proposed by Lindegren at al. [1993], recently recommended within the context of ESA's 'Horizon 2000 Plus' long-term scientific programme. In its present form, the experiment is estimated to lead to positions, proper motions, and parallaxes= of some 50 million objects, down to about V=3D15 mag, with an accuracy better= than 10 microarcsec, along with multi-color, multi-epoch photometry of each object.= The scientific case for such a mission

is dramatic: distances and kinematic motions for tens of millions of objects, throughout our Galaxy, would be obtained–the expected accuracy is such that direct (trigonometric) distance estimates to the galactic center would be accurate to 10%, with transverse motions accurate to about 1km/s at 20kpc. As 'by-products', the global measurements would yield unprecedented information on the space-time metric (gamma to a precision of about 1 part in 10^6 or better, close to values which might distinguish currently competing theories of gravity), angular diameters of hundreds of stars, and a vast body of information on double and multiple systems. Perhaps the most dramatic of these subsidiary goals would= be the possibility of screening some 100 000 stars within 100 pc for periodic photocentric motions, which would provide the most powerful and systematic method of detecting possible planetary companions proposed to date= [Lindegren & Perryman 1996, and references herein].

Technical and scientific aspects of GAIA, have been studied in Copenhagen. Designs were made for: an optimal eight-color photometric system, the CCD detector system, the scientific data analysis, and a satellite with sun shield. The observability of microlensing by an astrometric survey satellite was discussed as well as key questions in Galactic= structure with astrometric answers; see reports in ESA SP-379. An optical system for an interferometric satellite (GAIA95) utilizing dispersed fringes was described. This system is simpler than the previously proposed GAIA interferometer and good performance should be achieved even for 20th mag stars in a dense cluster.

DIVA. Schilbach, at Potsdam, and Röser, at Heidelberg, report on a German project, called DIVA, which is a precursor of the GAIA project. In= August 1996, a proposal for an interferometric mission on a small satellite DIVA (**D**eutsches **I**nterferometer für **V**ielkanalphotometrie und **A**strometrie) was submitted to= the Deutsche Agentur für Raumfahrtangelegenheiten (DARA). With a mission length of 15 months, DIVA will perform astrometric and photometric observations of at least one million stars and galaxies up to V =3D 14. For= all stars brighter than 10.5, DIVA will provide positions and parallaxes better than 0.8 mas, proper motions better than 2 mas/yr, broad-band photometry= with an accuracy of 0.002 mag and multi-channel photometry of 0.01 to 0.02 mag. Homogeneous data from DIVA, available around 2005, will have a huge= scientific impact on many fields of astronomy and astrophysics. The mission will= improve the Hipparcos optical reference system for the foreseeable future [Bastian= et al. 1996]. Geffert also reports on the participation of members of the Bonn astrometric groups in the planning and development of the proposal for the DIVA satellite.

STRUVE. Pulkovo's work on the STRUVE project (revision of the AIST project) is continuing. Numeric modeling of the process of obtaining an output catalogue from the observations is in progress under I.I.Kanaev's leadership. Previous investigations, devoted to scientific basis of project have been published in a monograph (Space Astrometric System "Struve" - Scientific foundation of the project, St Petersburg, 1995).

LIGHT (Light Interferometer satellite for the studies of Galactic Halo Tracers) is a scanning astrometric satellite for stellar and galactic astronomy planned to be launched between 2007 and 2010 by a M-V launcher of ISAS, Japan. Two sets of Fizeau-type 40cm-pupil interferometers with 1m baseline are the basic structure of the satellite optics. The multi-color (U, B, V, R, I, and K) CCD arrays are thought to be arranged in the focal plane of the interferometer optimized for detecting the precise locations of fringe patterns. LIGHT is expected to observe the parallaxes and proper motions of nearly a hundred million stars up to 18th visual (15th K-band) magnitude with a precision better than 0.1 milliarcsecond (about 0.050 mas in V-band and 0.090 mas in K-band) in parallaxes and better than 0.1 mas/yr in proper motion, as well as precise photometric characteristics of the observed stars. Almost all of the giant and supergiant stars belonging to the disk and halo components of our Galaxy within 10 to 15 kpc from the sun will be observed by LIGHT and will permit study of the most fundamental structure and evolution of the Galaxy.

FAME. The USNO is currently a collaborator with Jet Propulsion Laboratory and Naval Research Laboratory in proposing the Fizeau Astrometric Mapping Explorer. This would be a moderate-cost, 2.5 year interferometric satellite mission. The proposal calls for two 10 x 20 cm collectors on a 50 cm baseline with a common detector array of eight 4000 x 1000 CCD's. The bandpass would be 500 to 900 nm. The FAME program would produce positions, proper motions and parallaxes of some 20 000 000 stars to a limiting magnitude of 15. The accuracies would range from 0.02 mas at 8th magnitude to 0.80 mas at 15. The corresponding ranges of the proper motion and parallax accuracies would be 0.02 to 0.08 mas/year and 0.02 to 0.80 mas, respectively.

6. Working Groups

The Working Group on Reference Frames and the Working Group on Astronomical Standards are making separate reports that appear in the Division 1 report. The Working Group on the Re-measurement of Astrographic Plates is sponsored jointly by Commissions 8 and 24 and has submitted its report to Commission 24.

ASTROLABES (F. Chollet, Chairman). There are about 45 astrolabes in the world and a large part of them are not functioning or have stopped their activities after 1987. This report concerns the astrolabe groups which continue (or begin) to do astrometry= with astrolabes and maintain a connection with the WG.

The astrolabe activities are principally involved with the development of a new network of fundamental astronomy devoted to position measurements and instrumentation. The use of CCD cameras with astrolabes initiated by F. Laclare for solar diameter evaluations with an analog data is now changed in order to directly use the digital data coming from the camera. However, adaptation of this device needs a significant change in the instrument.

Stations from "Observatoire de la Côte d'Azur/CERGA" (OCA/CERGA) in France, from San Fernando in Spain, Saõ Paulo and Rio in Brazil are now equipped with CCD cameras in order to observe the Sun to obtain the solar diameter as well as its position. The instruments are, for the moment, only semi-automated.

This use of CCD's also requires some transformations of the original Danjon astrolabe. For the moment the preceding instruments continue to use the Wollaston prism, but in a fixed position, in order to correct the original optical defect of the Claude astrolabe. Now, cooperation is instituted between the Paris observatory and those of Poznan (Poland), Bucharest (Romania) and Antalya (Turkey). At Poznan, Bucharest, OCA/CERGA and in Antalya (Turkey), new prisms are installed or are soon to be installed to remove directly this astrolabe problem. A one image system as the one used now in China, is adopted. At Poznan, the first tests show that the same refractor used by the Danjon astrolabe is able to to observe stars of 9th magnitude instead of 6th. The same half-pupil is used but they are on the same horizontal line instead of a vertical line. It is hoped to begin the same observations next year in Bucharest, San Fernando and Antalya.

In South America, the stations of Saõ Paulo, and Rio in Brazil are not yet ready but they will begin observing campaigns in 1997. The Cerro Calan observatory in Santiago de Chile is equipped with a polyvalent astrolabe and continues Solar observations in a visual mode but is ready to receive a CCD camera. The station at San Juan in Argentina has received an automatic astrolabe (PHA= II) from China thanks to cooperation between Shanghai Observatory and San Juan Observatory. Observations of 1440 stars, of which 682 are FK5/FK4 SUP stars, 433 are FK5 Part II stars and 285 are CAMC stars, and radio stars, to a limiting magnitude of 11.5 have been observed with a precision of 0.0032s in RA and 0.061" in DEC resulting in the PASJ1 catalog. Other astrolabes work in Argentina but for the moment in the visual mode, but it is necessary to remember the situation of the old Danjon Astrolabe number 1 which works in Rio Grande in the extreme south of Argentina.

In China, the observing programs are essentially related to stellar position measurements with a set of automatic instruments. A New General Astrolabe Catalogue is under development under the responsibility of the Prof. Xu Jiayan from Shaanxi Observatory. A program of cooperation between Shaanxi and Irkutsk has led to the PHA I astrolabe being installed in Russia. With the observations of Photoelectric astrolabe type II of Yunnan Observatory the radio star catalogue, which consists of 20 radio stars, was compiled. The mean precisions are 2.2 ms in RA and 0".041 in DEC. Based on the observations a catalogue of positions and proper motions of 16 radio stars was compiled with precisions of 0.2 ms/yr in RA and 0".004/yr in DEC for the proper motions.

In Europe, as mentioned above, the station of OCA/CERGA, San Fernando and Turkey are mainly devoted to solar observations. The station of CERGA which use two astrolabes (one with 11 fixed zenith distances and one with a variable angle prism) began using a CCD Camera with a digital acquisition system. The first test, done in May and June 1996 with the variable angle prism, gives a set of results with an error, for one diameter, always less than 0.3". The other stations= in Spain and Turkey are under construction and should be able to give results next year. The station of Bucharest received a Danjon astrolabe from Belgium and the modification of the instrument and its automation are planned for the end of 1997 or 1998. Software is being developed in collaboration with the Paris Observatory. The next program at Bucharest will include fundamental stars, radio stars and Solar System objects. At the last

station, in Poznan, the first tests on stellar observations has begun, and the= increase of the limiting magnitude to 9th is very satisfactory. The automation of the instrument is also planned for the near future.

The results concerning stellar observations and catalogue construction are relatively numerous, and all the groups anticipate the results of comparing the astrolabe catalogues with Hipparcos. This may be a crucial test concerning the future of astrolabes. As the Hipparcos instrument was, in principle, nothing more than an astrolabe without vertical reference, we are relatively optimistic.

Another field in which a great effort is made concerns the solar observations. The research done at OCA/CERGA concerns mainly the measurement of the solar diameter and, consequently the astrolabes are modified in order to obtain the best results in this field. The other modified astrolabes (presently and in the future) should be able to do stellar to solar as well as planetary observations in order to increase the precision of the instrument, the field of observation, and the limiting magnitude. The connection between stellar and planetary reference systems will be the main objective, in conjunction with the very important problem of the solar diameter.