COMMISSION 8 : POSITIONAL ASTRONOMY (ASTRONOMIE DE POSITION)

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The Commission deeply regrets the death of our colleague G. Teleki who passed away on February 1987.

After the retirement of T. Dambara, S. Lautsen and W. Gliese and the arrival of C. Turon-Lacarrieu as a new member, the membership of our commission is 142.

I. INTRODUCTORY REMARKS

Due to the size of the reports received from the observatories and according to the recommendations of the I.A.U. Executive Committee this triennal report will be (instead of a list of topics worked on by Commission members) a comprehensive review around the main objectives of our commission : Galactic reference frame, link to the Extragalactic and Solar reference frames, related instrumental research and reduction methods.

The overlap of the areas of interest and techniques of Commission 8 and Commission 24 is more and more important and it would be the time to clarify the proper responsibilities of our individual commissions. Renaming of Commission 8 into "Stellar (or Galactic) Reference Frame" could be the best way to state clearly our main practical objective in front of the astronomical community.

One of the milestones of this triennum was during the last General Assembly at Delhi the creation of a pluridisciplinary Working Group to give recommendations for the definition of the Conventional Celestial Reference System and ways of specifying practical realizations of this system. The establishment and the maintenance of the future primary extragalactic reference frame based on VLBI groups involved in determination of Earth rotation parameters should be obviously under the responsibility of Commission 19 whereas the control of the optical counterpart of this primary frame could be the duty of Commission 24 within its Working Group "Optical-radio reference frame". But improvement and extension of the stellar system to fainter stars with link to the planetary and extragalactic systems will remain the huge task of our Commission 8.

II. INSTRUMENTATION

During the past three years an intensive effort of modernization and automation of the classical instruments was made by many observatories, opening out new horizons for the ground-based astrometry : improved accuracy, increase in observing speed and limiting magnitude. New instruments are under development or nearly completed. Waiting for the success of space astrometry we enter already in an exciting period of renewal when the asymptotic limit of 20-30 milliarcseconds seems to be within reach for most of our photoelectric instruments even up to the magnitude 12-13 for several ones.

It is important to mention that progress in modernization is also beginning in the Southern hemisphere and these efforts should be strongly encouraged.

1. Automatic Meridian Circles

The *Carlsberg automatic meridian circle* was run jointly by Copenhagen University Observatory, the Royal Greenwich Observatory and the Instituto y Observatorio of Marina at the Spanish Observatorio del Roque de los Muchachos situated on the island of La Palma (lat. 28.8° Nord, alt. 2 400 m). The telescope was operated completely automatically under the control of two H.P. mini-computers. Instrumental calibrations were carried out hourly using collimators, nadir pool and since 1986 azimuth marks (40.032.021). Also for azimuth determination, 29 polar pairs and 3 faint polarissimae were introduced to the regular observing programme in 1986. Internal refraction in the telescope tube was greatly diminished by tangetial ventilation following an investigation of Høg (41.032.069). The method of observation was essentially differential, but only in the sense that one rigid rotation in R.A. and DEC was carried out nightly to fit to the FK4 system, the drift of the instrument having been removed using the hourly calibrations. From May 1984 to December 1986, more than 200 000 star positions, 840 planet positions and 4 800 asteroid positions were obtained. The internal standard error for one observation was found to be : R.A. 0.19" $(\sec z)^{0.6}$, DEC 0.18" $(\sec z)^{0.9}$, MAG 0.06 $\sec z$ (Morrison et al.). Futhermore a new photoelectric micrometer is under development.

The *Tokyo photoelectric meridian circle* has been in regular operation since the end of 1984. The operation and data acquisition, together with meteorological data acquisition, are fully automatized. Stars brighter than V = 8 are observed with the oscillating slit micrometer during 30 seconds whereas fainter stars are scanned during a longer time. About 40-45 objects up to V = 12.2 are observed every hour with regular determinations of the instrumental constants, including horizontal and vertical flexure, and monitoring of the pivot irregularities by means of axial collimators. From the first catalogue the internal standard error of a single observation depends on the apparent magnitude : R.A. 0.18" to 0.22", DEC 0.20" to 0.27", MAG 0.07 (Yoshizawa and Miyamoto). Running in parallel is the development of a two-dimensional CCD micrometer which is expected to increase the productivity of future observations.

The *Bordeaux automatic meridian circle* is also in regular operation. Observations are strictly differential (without determination of physical constants) for objects up to V = 12.5 with internal standard errors of 0.11" in R.A. and 0.16" in DEC. The apparent magnitude is also obtained with a standard error of ± 0.15, providing a sure identification of faint stars.

The *Washington seven-inch automatic transit circle* at the New Zealand Black Birch Station became fully operational with solar system objects being regularly observed since late 1986.

The automation of the *Pulkovo horizontal meridian circle* (Pinigin et al., 40.032.001, 40.034.205, 40.034.207) and of the *Pulkovo and Nikolaev classical meridian circle* (Ershov, Streletsky et al., 40.034.209, 40.034.210) were completed and regular observations have begun.

2. Automatic Astrolabes

In *China* the photoelectric astrolabe Mark III with its 260/5000 mm optical system and photon counting micrometer working up to V = 11-12 is in the debugging phase. Meanwhile the classical instruments still in operation are being improved for automatic observation indluding planets. After 1988 limiting magnitude of photoelectric astrolabes will be increased to V = 9 (Luo et al.).

In *France* the CERGA photoelectric astrolabe is now completely automatic (Billaud).

3. New Instruments

Li, Hu and Høg report that an agreement between three astronomical institutes in China (Shaanxi and Nanjing) and Denmark has been signed about the development and operation of the *automatic glass meridian circle*. The instrument with 24 cm aperture is being manufactured in China after some of its components have been developed and tested in Denmark. After first tests of the instrument in Nanjing it is planned to erect it in Brorfelde for an optimization period of a year. It shall be finally operated in Shaanxi where a new observatory site is presently beeing selected in the Li Shan mountains near Xian.

At Goloseevo and Nikolaev new *axial meridian circles* were designed, built, investigated and tested (Kharin, Minyailo, Lazorenko, Shorik, Pinigin, Shornikov, Konin, 40.032.070).

At Pulkovo new designs for a pentag meridian circle (Nemiro, 39.032.52) and a reflecting meridian circle (Nemiro, Streletsky) were proposed.

The U.S. Naval Observatory is undertaking the construction of a phase coherent, *astrometric optical interferometer*. Building upon the experience gained from the Mark III interferometer at Mount Wilson (Shao et al., 42.034.028), the U.S.N.O. instrument is currently in the early stages of conceptualization and initial design. Accuracies of 0.02" up to V = 12 are expected but the final goal could be the milliarcsecond level.

4. Modernization of Meridian Instruments

Automation of the San Fernando meridian circle, in a similar way to the Carlsberg meridian circle, started in September 1986. The photoelectric micrometer and other major parts for the automatic telescope setting are being manufactured in the Brorfelde workshop (Quijano, Sanchez).

The Pulkovo photographic vertical circle (Bagildinsky, Shkutov et al.) and the Odessa Repsold meridian circle (Volyanskaya et al., 40.032.073) have been modernized.

CCD matrices were incorporated in circle reading devices at Moscow (Golovko) and Pulkovo (Ershov et al., 42.032.004).

A photodiode array device (Reticon 512) to measure automatically the circle readings will be installed on the Santiago Repsold meridian circle (Carrasco) and some similar device is planned for the San Juan meridian circle (Carestia).

Considerable progress has been realized on the Washington six-inch transit circle. An average of 35 000 observations per year were made during the first two years.

5. Solar Astrolabes

In France the CERGA solar astrolabe observes the Sun at 10 different zenith distances in order to follow the whole apparent orbit. Replacement of the visual micrometer by a CCD camera with real-time image processor gave encouraging results (Laclare, Journet, 40.080.004, 42.041.004).

Modifications of classical astrolabes for solar and planetary observations are being introduced at many observatories. The classical prism is replaced by several "cervit angles" which allow observations at different zenith distances. Sun observations are planned with a convenient solar filter at Paris (Chollet), San Fernando (Sanchez), Cagliari (Proverbio), Santiago (Noel), Sao-Paulo (Benevides).

6. The Hipparcos-Tycho Space Mission

The Hipparcos mission preparation has progressed in a very satisfactory manner since the last IAU General Assembly. In 1986, the project passed successfully the critical Design Review, and the construction of the engineering and of the flight models has followed the fixed schedule, so that it is still expected that the satellite will be finished in March 1988. But, due to the delays of the Ariane launcher, the launch is now scheduled only in 1989, for a 2.5 year mission. This means pratically one year delay in delivering the final Hipparcos and Tycho catalogues, so that their delivery to the general scientific community is to be expected only in 1995.

The supplementary accuracy analyses and the results of tests on the various subsystems already constructed confirmed the expected accuracies that should not exceed 0.002"in positions and parallaxes and 0.002" per year in proper motions for stars brighter than visual magnitude 9 with a degradation of a factor 2 for magnitude 12, provided that the next solar maximum that will occur during the mission is not exceptionally active.

The structure and the tasks of the four consortia responsible for producing the input catalogue and for reducing the data have been presented to the New-Delhi General Assembly (Transaction XIXth IAU General Assembly, Highlights, vol. XIX) and to the IAU Symposium 109 (H. Eichhorn ed., Gainesville) and this will not be repeated in this report.

Since 1985, the two main mission data reduction consortia, FAST and NDAC, have finalized their reduction algorithms and are preparing the final engineered softwares that will be used during the actual data reduction. An important exchange of simulated data between the two consortia and the comparison of the results obtained in using them have permitted to verify that the algorithms, although different, give comparable results and no systematic differences seem to exist. These comparisons are very important, since the final result of the reduction should be a combined unique catalogue.

The TDAC Consortium is now finalizing the preliminary softwares and checking the adopted algorithms for the reduction of the continuous flow of data produced by the star mapper. The TDAC input catalogue consisting of some 1 ½ or 2 million stars up to V = 11 from the Guide Star Catalogue and the CDS (Centre de Données de Strasbourg) data bank should be ready in 1988 and will be used to identify the stars giving detectable signals.

The INCA Consortium, responsible for the production of the Hipparcos input catalogue, i.e. the selection of about 115 000 stars that will be observed by the Hipparcos main mission among the 210 000 proposed stars, has produced a first tentative version of the input catalogue, result of numerical mission simulations taking into account the scientific requirements from the about 200 proposals but also the observational constraints inherent in the Hipparcos satellite operation. The preliminary ground-based observations are nearly over : about 9 000 stars observed with the automatic meridian circles of Bordeaux and La Palma, nearly 100 000 star positions measured on ESO and SRC Sky Survey plates, about 8 000 stars observed in multicolour photoelectric photometry. It is intended to publish by 1990 the 210 000 stars proposed for Hipparcos, including old and new acquired astrometric and astrophysical data for the stars. This will hopefully encourage further ground-based observations of these stars (Høg, Kovalevsky, Turon).

III. STELLAR REFERENCE FRAME AND OBSERVING PROGRAMMES

The main event of this triennal period was the completion of the basic FK5, resulting in a spectacular improvement (as already confirmed by the La Palma and

Bordeaux meridian circles from a preliminary version). The extension of the FK5 to fainter stars, the final compilation of the SRS and the observing programmes related to the whole IRS are also important steps towards the improvement of the stellar reference frame.

1. The Basic FK5

At the Astronomisches Rechen-Institut (Heidelberg) the work on the FK5 has been continued and partially finished. Systematic corrections to the FK4 positions and proper motions were determined on the basis of suitable absolute and quasi-absolute observations with mean epochs later than 1900, altogether about 70 (50) catalogues in right ascension (declination). These corrections were determined using the analytical method developed by Bien et al. (25.041.067) for the determination of the systematic relations Cat-FK4, and by Schwan (34.041.052) for the derivation of the resulting corrections FK5-FK4. The systematic errors in the FK4 as indicated by the deviations Cat-FK4 for the modern observations which are not yet included in the FK4, were demonstrated by Fricke (40.041.028). Individual corrections to the FK4 positions and proper motions were derived by incorporating the new observations which have become available after the completion of the FK4 into the FK4 mean positions and proper motions. Altogether about 90 catalogues could be used for the individual improvement of the FK4. Weights were assigned to the catalogue positions according to a method developed by Bien (Astron. Astrophys., in press). The final mean positions and proper motions in the FK5 were computed for the mean equinox and equator of J2000.0 in accordance with the resolutions adopted by the IAU. The publication of the basic part of the FK5 consisting of the classical 1535 fundamental stars is in preparation (Fricke, Schwan, Lederle et al.), and the printed version of this catalogue will become available in the near future.

2. The FK5 Extension

The selection of the new fundamental stars and the determination of mean positions and proper motions for these stars is being made jointly by the U.S. Naval Observatory, Washington, and Heidelberg.

Mean positions and proper motions for about 1000 FK4 Sup stars with apparent magnitudes 5.5 to 7.0 will be derived at Heidelberg. The major part of this work, the identification of the observations in about 300 catalogues which have been considered, and the determination of the systematic relations Cat-FK4 for the relevant catalogues, is near to completion.

A list of more than 2 000 fainter stars was selected at the U.S.N.O. (Corbin, 41.041.022) in the IRS catalogue according to distribution in magnitude and spectral type, quality of the observational history, mean error of the proper motion and distribution over the sky, absence of component. These criteria were difficult to satisfy at the faint end of the magnitude range and south of -50°. The list of faint fundamental stars was completed and forwarded to Heidelberg.

It is expected that the average accuracy of the new fundamental stars will be inferior to that of the classical fundamental stars in the FK5 at least by a factor of two. For this reason the new fundamental stars will be published in a separate volume, presumably in the course of the year 1988.

Absolute and quasi-absolute observations of the FK5 and of its extension have obviously priority in the programmes for many meridian circles, but also for photoelectric transit instruments and various astrolabes in U.S.S.R., China and South America, resulting in many individual accurate catalogues. A general catalogue of astrolabes is in construction for the Southern hemisphere.

3. The IRS Catalogue

Compilation of the SRS. The joint work by the U.S.N.O. and the Pulkovo Observatory on the SRS catalogue of positions has progressed through several stages : compilation of preliminary catalogues independently at both observatories, exchange of the preliminary catalogues and of the data bases of FK4 and SRS observations made at the individual observatories during the SRS observing campaign, comparison and rectification of differences between the compiled catalogues and the data bases and discussion of discordant observations (Zverev, Polojentsev et al., 40.002.054, Hugues, Smith et al., 41.041.021).

Definitive compilations were exchanged recently. It has been agreed that the Pulkovo SRS right ascension system should be brought closed to the FK4 by first making a detailed reduction to the Washington SRS right ascension system for right ascension and declination dependent systematic differences. Then the Washington and revised Pulkovo right ascensions can be combined with equal weight without any revisions.

It is expected that the joint Washington-Pulkovo work on the compilation of the SRS catalogue will be completed by the end of 1987. Proper motions for this catalogue are always under study at the U.S.N.O.

Re-observation of the IRS. In U.S.S.R. the following observatories have given their consent to participate in new observation of the IRS programme : Pulkovo, Moscow, Kiev, Engelhardt, Nikolaev. Meridian observations have been already started at Pulkovo and Kiev.

At the U.S.N.O., the Six-Inch transit circle is engaged in the observation of the AGK3R while the Seven-Inch installed in New-Zealand begins to observe the whole SRS.

On the other hand, 35 900 IRS stars are in the observing programme of the La Palma meridian circle and 20 000 AGK3R stars will be observed by the Tokyo meridian circle.

At last, the San Juan Repsold meridian circle is used for a re-observation of the SRS San Juan 72 catalogue (Carestia).

4. Bright Stars

In China, as a suggestion from Purple Mountain Observatory, a general programme will be put into practice with the classical instruments at Beijing, Shaanxi, Shangai, Wuchang and Yunnan, including bright and faint stars in a fundamental catalogue. The observations of the brightest part, i.e. about 2 000 stars of geodesic and other catalogues, will be completed before the end of 1989.

In U.S.S.R., a catalogue of 4 949 bright stars (geodetic) has been completed. The standard errors are ± 0.004 s and ± 0.11" on positions, ± 0.012 s/cy and ± 0.17"/cy on proper motions. This catalogue has been reduced to the FK5 (Khrutskaya, 40.041.038).

At Pulkovo and Leningrad new reduction of original U.S.S.R. Time Service catalogues concerning 300 000 positions was performed (Afanasieva et al., 39.002.032). The result is an accurate catalogue of right ascensions KSV2.

5. Faint Stars

Photoelectric instruments are now or will be shortly able to observe stars up to V = 12-13. On the other hand, for photographic astrometry it would be important to have a reference system in that range of magnitude. Compilation of a list of such faint stars with a density of 1 star per square degree is currently carried out, jointly by Brorfelde and the Royal Greenwich Observatory. First epoch positions are to be found in the Astrographic catalogue and other photographic catalogues.

6. Other Programmes and Catalogues

Double stars. A programme of 2 500 double stars unsuitable for photoelectric instruments is currently observed at Kiev, Moscow, Karkov, Odessa, Engelhardt, Belgrade and Cerro-Calan. Two DS catalogues are already published (Chernega et al., Golovko).

High luminosity stars (39.002.107). About 3 000 stars with magnitudes between 6.5 and 9.5 are observed at Nikolaev, Moscow, Kharkov, Odessa, Kiev and Belgrade. At Moscow a first HLS catalogue was published (42.002.046).

Polar stars. In U.S.S.R., corrections to the declinations and proper motions of 524 polar stars were obtained at Karkov (Dergach). A catalogue of declinations for 1 407 polar stars has been completed (Pavlenko et al., 41.041.039). Observations of 308 bright polar stars were completed with the Large transit instrument of Belgrade (Pakvor).

Equatorial stars. Observations of 1 300 equatorial stars within ± 1.5° have been made by the photoelectric meridian circle at Nikolaev.

Latitude stars. At Engelhardt a catalogue of declinations of 2 910 latitude programme stars using 75 original catalogues obtained between 1930 and 1980 has been compiled (standard errors ± 0.07" on positions, ± 0.28"/cy on proper motions). Its application to the latitude observations reduces the annual wave in the mean latitude (Urasina, 41.002.037-038).

The Pulkovo catalogue of latitude stars was reduced and published (Bagildinsky et al.).

O-B stars and nearby stars. A catalogue of 1 059 O-B stars observed by the visual meridian circle at Tokyo has been published (Yasuda et al., 41.002.057). Furthermore 5 000 O-B stars are in the observing programme of the Tokyo photoelectric meridian circle.

The La Palma programme includes also 5 700 O-B stars and 10 500 F stars within 100 pc. Positions are to be found in the CAMC catalogues published yearly by San Fernando (catalogues 1984, 1985 and 1986 are available, 40.002.094, 42.002.073).

Miscellaneous programmes. A preliminary catalogue of 931 FKSZ stars for the whole sky has been constructed (Yatskiv, Polojentsev). At Goloseevo and Leningrad new proper motions of the PFKSZ-2 catalogue were obtained giving an improvement of the accuracy by a factor 1.5. A right ascension catalogue of 549 FKSZ was compiled at Tashkent (Boroditsky). Observations of 651 FKSZ were completed at Cerro-Calan with the Repsold meridian circle (Carrasco).

Absolute observations of fundamental bright and faint stars declinations were completed with the Wanschaff vertical circle at Goloseevo (Kharin et al.).

At Pulkovo a catalogue of absolute declinations of 1 425 stars was compiled on the basis of observations with the Zverev photographic vertical circle made in Chile (1965-1966).

IV. LINK TO THE EXTRAGALACTIC AND PLANETARY REFERENCE FRAMES

The connection between the different reference frames appears as one of the main problems of this decade (see Joint Discussion on Reference frames, New-Delhi General Assembly). Many observatories have already begun observing programmes related to this question : radiostars and reference stars around extragalactic sources with optical counterpart, Sun, major and minor planets. Construction of the future primary extragalactic reference frame and compilation of a suitable list of radiostars are reported by the Working Group on Optical-Radio Reference frame (to be found in the Commission 24 report).

1. Radiostars

Various lists are in the programmes of the observatories. An extensive masterfile including about 800 confirmed, suspected or potential radiostars has been compiled at Heidelberg (Walter) from different Hipparcos proposals and preliminary list from De Vegt, Florkowski and Johnston. But the data continuously updated have to be submitted to a severe critical examination (40.041.018). A subset of this list including 152 radiostars has been integrated in the Hipparcos Input Catalogue and classified as "superpriority stars".

Bright radiostars are being observed by visual astrolabes and meridian circles (Paris, San Fernando, San Juan, Sao Paulo, Santiago, Cerro-Calan, Torino). At Beijing, Shaanxi and Yunnan observatories, these objects are also observed with photoelectric astrolabes. The initial result at Beijing shows a precision of about ± 0.05".

A list of 275 radiostars is regularly observed with the La Palma automatic meridian circle whereas 300 Mira variable stars (H_2O maser sources) are in the programme of the Tokyo photoelectric meridian circle. The Bordeaux Observatory is completing observations of 180 radiostars with its automatic meridian circle : with 20-30 observations per star the expected accuracy should be at least ± 0.05". Comparisons with JPL VLBI positions shows a satisfactory agreement (40.041.020).

Radiostars have been also incorporated into the U.S.N.O. Washington and New-Zealand absolute observing programmes.

At last, study on connection between optical and radio reference frames is being actively carried out at Shangai (40.043.005, 42.041.028), Purple Mountain and Beijing.

2. Reference Stars around Extragalactic Sources

At Odessa, Kiev and Belgrade a list of about 1 500 reference stars was observed and first results were published (Chernega et al.).

The La Palma meridian circle programme includes 11 400 faint stars ($11 < B < 12$) around 360 extragalactic sources (20 to 30 stars per field).

Observations of radiosource reference stars continue on the 8-inch transit circle in Flagstaff. Comparisons with photographic positions show results quite successful.

A list of 164 "super high priority" stars has been incorporated in the Hipparcos Input Catalogue in order to link the Hipparcos sphere to the extragalactic reference frame. The fine guidance sensors of the Hubble Space Telescope are expected to measure the angular separation between one of these selected stars and the nearby extragalactic object (within 18') with an accuracy of 2 milliarcseconds.

3. Sun and Major Planets

In U.S.S.R. day time meridian observations of the Sun, Mercury, Venus and Mars are made traditionally at Nikolaev (41.041.016), Tachkent (40.041.061), Goloseevo (39.041.014) and Kharkov. Since 1984 regular meridian observations of these bodies have been carried out at the Kislovodsk high altitude station of the Pulkovo Observatory (h = 2 210 m). The accuracy of these observations is 1.5 times better than those made at Pulkovo.

Uranus and Neptune have been observed regularly by the automatic meridian circles of La Palma and Bordeaux. The results show clearly a systematic deviation on right ascensions of these planets of about -0.3" with respect to the standard ephemerides DE200 (Rapaport et al.).

Sun and major planets are always observed in the absolute programmes of the U.S.N.O. transit circles and now with the Tokyo photoelectric meridian instrument.

As already mentioned many modified astrolabes are now participating in these observations and should make an important contribution to the link between the FK5 system and the planetary reference frame.

The analysis of the Sun observations made during the past ten years by the C.E.R.C.A. solar astrolabe (Laclare and Journet) shows a satisfactory definition of the equinox and of some elements of the orbit. Furthermore this kind of observation gives a good determination of the solar diameter : variations appear during the measurement period with possible correlations with some activity parameters.

4. Minor Planets

The brightest minor planets were observed many times by the classical instruments. With limiting magnitude of 12-13 photoelectric meridian circles can observe fainter minor planets. A list of 63 minor planets introduced in the Hipparcos Input Catalogue for link to the planetary frame was incorporated in the programmes of La Palma (4 800 observations) and Bordeaux (2 200 observations).

At Leningrad (ITA) work for organization and reduction of 30 000 observations of 20 minor planets according to the ITA programme has been continued for the improvement of zero-points and determination of systematic errors of the FK4 and other catalogues. Forty observatories in the world participated in this programme (Batrakov et al.).

The systematic errors of Yale, SAO and AGK3 catalogues were determined using 424 minor planet observations at Goloseevo (Maior, 39.041.010).

V. MOVING BACK THE LIMITS OF GROUND-BASED ASTROMETRY

The ground-based astrometry is mainly limited by refraction. During these last three years, research in that domain was taking steps forward. Meanwhile meridian workers realized the necessity to monitor regularly the division errors of their declination circles which may introduce random and systematic errors in their catalogues. At last theoretical studies were beginning to show the interest of global reduction and statistical methods for best processing of the astrolabe and meridian circle measurements.

1. Refraction

New refraction tables of Pulkovo Observatory were published in 1985 (39.082.045). These tables were compiled using modern results on the physical and optical properties of the Earth atmosphere. It is the result of intensive research made at Pulkovo and Engelhardt (Guseva, Nefedeva, Kolchinsky et al., 40.082.106-108, 41.082.029, 41.082.059-060). Inclinations of atmospheric layers of equal density were calculated. New computing method of the Hartmann refraction was proposed. At Pulkovo chromatic refraction was carefully studied (Bagildinsky, Zhilinsky, Shkutov, 40.082.107).

In China study of the effects of refraction on astrometric observations was going further. Experiments have been done on astronomical instruments in Misuzawa, Tokyo, Wuchang and Tianjin (Hu et al., 39.082.050, 41.082.072).

A new efficient method to evaluate by numerical integrations the astronomical refraction as a function of the wavelength was applied to the Tokyo PMC catalogues (Fukaya and Yoshizawa, 40.082.086).

Test observations were made at the high altitude Moscow Observatory station in central Asia with a Repsold meridian circle and seeing was investigated (Golovko, Guliaev et al., 38.041.037, 40.032.071, 41.041.027). Furthermore the high-altitude Kislovodsk station of Pulkovo Observatory was equipped by the Struve-Ertel vertical circle and large transit instrument.

A practical method to detect and correct the room refraction in the pavilion was investigated at Tokyo, the benefit of this method to improve the observational accuracy is now under examination.

Influence of anomalous refraction was the object of interesting studies (Gubanov, 42.082.056), particularly the effect on day time observations (Fedorov, 39.082.102) and on time determinations (Yang, 41.044.066). Furthermore the influence of detection noise and atmospheric turbulence on the accuracy of stellar position measurements has been studied at CERGA (Gay and Pochet, 41.036.012-013).

Conclusive and quite surprising results about internal refraction (INR) in the telescope tube of conventional meridian circles have been reached. Evidence of a variable INR of 1" to 2" has been found in three meridian circles at U.S.N.O., La Palma and Tokyo and in the vertical circle at Kiev, Golossejevo. It is shown that all determinations of the flexure term (F sin z) have been completely dominated by INR - although everybody has believed to be measuring mechanical flexure. The INR has been removed in the MC at La Palma by a simple ventilation inside the tube installed in 1985. As a further result determination of the atmospheric refraction constant of each night by means of the FK5 stars has become more accurate and now, in fact, agrees with the one calculated from meteorological data within ± 0.09" rms. The variable INR has corrupted all previous determinations of the refraction constant (Høg and Miller, 42.032.051, Høg and Fabricius, submitted to Astron. Astrophys.).

2. Meridian Declination Circle Errors

Application of an efficient method for measuring graduation errors to the Tokyo automatic meridian circle showed that the annual change of the glass circle error amounts up to about 0.05" for some circle readings (Miyamoto et al., 39.032.024, 42.036.078). The yearly corrections of the annual change are stored in computer and applied to the observations. A quick scheme to monitor a possible diurnal change was developed but no meaningful change of the graduation error was found within a clear day.

An efficient method was also elaborated and applied to a full determination of the division errors of the Moscow meridian circle (Tauber, 42.034.007). Complete determinations of the division errors were also carried out and repeated at different ambient temperatures on the Bordeaux automatic meridian circle (Requième et al.) and on the Pulkovo horizontal meridian circle (Gumerov, Pinigin et al., 42.032.043).

Results of determinations of graduation errors by different circle scanning systems of the U.S.N.O. are reported in 42.032.001 (Rafferty et al.). Analysis of the effect of errors on the reading of a graduated circle is also reported in 41.036.143 (Mao). Comparison of classical methods of determination were carried out in Bordeaux (Rapaport, 39.036.079).

3. Reduction Methods

A method of global reduction of fundamental astrometric data was at first proposed at Sao-Paulo (41.036.212) and applied to astrolabe observations (Benevides and Clauzet). Application to global adjustment of star position in the compilation of meridian circle catalogues is under investigation at Sao-Paulo, Bordeaux and Tokyo.

Techniques for dealing with discordant observations were proposed (Branham, 41.041.006). Error estimates with solution in the L_1 norm of overdetermined systems were given (Branham, Celes. Mech., in press).

At Pulkovo a method was elaborated for a parametric adjustment of the absolute astrometric observations taking into consideration the errors of the initial data (Gubanov). Optimum stable estimations of the errors of astrometric measurements were proposed at Engelhardt (Tokhtaseva).

Statistical problems about astrometric reductions were investigated at Paris with application to the detection of poor observations and catalogue errors in the Paris astrolabe data (Bougeard).

VI. MISCELLANEOUS

The rediscussion of older meridian circle catalogues has been started at Heidelberg. The aim is to establish a rather complete astrometric data bank and to derive from this material improved proper motions for a large number of stars. Even the Hipparcos proper motions could be improved by combining the Hipparcos data with suitable ground-based measurements (Wielen et al.).

Data collected by the U.S.N.O. from meridian circle and astrographic catalogues should have about 360 000 stars with an average of about 4 catalogue positions per star. Work has been started to adapt Schwan analytical method to the systematic reductions (Smith et al.).

Other extensive researches around the reference frames are scattered in the Commission 4, 19, 24 and 40 reports. A Joint Discussion will be held at the next Baltimore General Assembly (chairman : P. Seidelmann) on observations, theory and computation at the milliarsecond level, use of millisecond pulsars, report of the Working groups on reference frames, nutation and astronomical constants. Members of Commission 8 are obviously invited to participate actively in that important meeting.

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