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Densification of the Optical
Reference Frame

TRIENNIAL REPORT 2006-2009

1. Scientific Highlights

van Leeuwen has completed and published the new reduction of the Hipparcos data. Parallax accuracies have improved by up to a factor 5 for the brightest stars and correlations effectively removed.

GAIA is now fully funded and is well into the development and construction phase. This mission will revolutionize astrometry in much the same way that Hipparcos did. The launch is expected in late 2011.

IAU Symposium 248 “A Giant Step: From Milli- To Micro-Arcsecond Astrometry” was very successfully held in Shanghai, China PR, October 2007.

2. Instrumentation and Reduction Methods

BRAZIL: At Observatório Nacional, with FINEP funds, a state of the art CCD heliometer is being developed aiming to the continuation of the solar diameter measurements – first light was reached in 2008 and regular operation is due in 2009 (Andrei et al., 2006). Assafin and colleagues (2007) developed PRAIA, a fully automatized software for the astrometric and photometric treatment of CCD images. The Observatório Nacional, from 2007, leases 90 nights/year at the ESO 2.2m Max Planck telescope enabling several long term projects. Specific projects are being pursued at the SOAR telescope, of which Brazil is co-proprietary.

CHINA PR: Wenjing Jin (Shanghai) reports that in order to reduce the cutoff height angle and improve the correction accuracy rigorous calculating formulae of the path-curving correction in the refraction delay of electromagnetic wave was derived. (Mao W. et al., 2008)

The observational astronomical refraction model toward the east, south, west, and north of the Yunnan Observatory was determined with a Lower Latitude Meridian Circle (D=40 cm, f=5 m). (Mao W. et al., 2007).

Chunlin Lu (Nanjing) reports that from October of 2006, the 1.0/1.2 m NEOST (Near

Earth Objects Space Telescope) equipped with a 4096×4096 SI CCD detector was installed completely and began test observations. Due to fast optics and the high quantum efficiency of the CCD detector, the Observational system can reach 22.46 in B band with only a 40s exposure, which enables an asteroid survey with great efficiency. (Zhao et al., 2008).

A method to improve binary orbits with a long-period is presented by using Hipparcos data and long-term data from ground-based observations. (Ren & Fu, 2007).

Additionally, simulations have shown that the reliability of orbits derived from GAIA data is high only for binaries with periods < 8 years otherwise the orbit should be derived from GAIA data and long-term ground-based data (Ren & Fu, 2008).

Zhenghong Tang (Shanghai) reports a method of accurate calibration for LAMOST (Large Sky Area Multi-object Fiber Spectroscopy Telescope). LAMOST is a reflecting Schmidt telescope, which will perform multi-object fiber spectroscopic observations. 4 CCDs are installed at the plate edge to perform the guiding and calibration. The prototype of LAMOST (300 fibers) was adjusted in May 2007. The alignment accuracy is better than $0.5''$ and the spectral lines are obtained from 97% fibers (Li et al, 2006, Yu et al. 2008).

After a CCD camera (Model S1C-077) in drift scan mode was installed on the 25cm telescope of Shanghai Astronomical Observatory (SHAO), observations for GSS (Geo-Stationary Satellite) were carried out and internal positional precision is better than $0.5''$ (Mao et al. 2007). Experiments with a rotating drift-scan mode was carried out in collaboration with Nikolaev Astronomical Observatory (NAO), Ukraine.

FRANCE: Arlot reports about a collaboration between IMCCE of Paris Observatory, USNO (Pascu), RBO (De Cuyper) for a new reduction of astrometric plates of the natural satellites of Jupiter, Saturn and Mars.

Souchay reports about the reduction of mosaic CCD images obtained at the 3.6m CFHT in order to derive coordinates of pulsars and QSOs in the optical at the mas level.

RUSSIA: Devyatkin (Pulkovo) reports the automatic telescope MTM-500M has been modernized for observations of Solar System bodies and is in operation at the Northern Caucasus station of the GAO RAS.

SPAIN: A new CCD camera with a Sloan r' bandpass filter has been bought for CMAF, to be delivered in June 2008. The CMAF will be operative again in autumn 2008. A collaboration between ROA, the Fabra Observatory and Barcelona University has undertaken the robotization of an old Baker Nunn camera. First light will take place in the second half of 2008. After testing the camera performance at ROA, it will be moved to the Montsec Observatory, northwest Spain.

UKRAINE: Shul'ga (Nikolaev) reports about the Fast Robotic Telescope of RI NAO for observations of NEAs, artificial satellites, and space debris on all orbits.

Filonenko (Kharkov) reports that the DSLR Canon 300D camera has been installed at the 20/190cm AZT-7 telescope for observations of small Solar System bodies up to 15m.

Kleshchonok (Kiev) reports that the automatic complex UNIT for fast photometry using a CCD camera Rolera MGI and telescope Celestron CGE 1400 has been developed for observation of stellar occultations by the Moon.

UK: The new reduction of the Hipparcos data was completed and presented as part of a book describing the new reduction and the proper use of the data in scientific applications (van Leeuwen, 2007). Parallax accuracies have been improved by up to a factor 5 for stars near magnitude 3 to 4, and correlations in the underlying data have been reduced by more than a factor 10 to an insignificant level. This has greatly benefited the study of parallaxes and proper motions of open clusters, while for Cepheids the number of stars

that can be incorporated in a parallax-based PL study has increased by a factor 4 (van Leeuwen, Feast et al., 2007).

USA: The StarScan plate measure machine (USNO) completed measuring all applicable Black Birch, AGK2, and Hamburg Zone astrograph plates (Zacharias et al. 2008).

3. Space Astrometry

Lindgren (Lund) reports on the European Space Agency's astrometry mission GAIA. This was proposed in 1994, included in the ESA Science Program in 2000, confirmed by the ESA Science Program Committee in 2006, and is now well into the development and construction phase with a target launch date in late 2011.

The scientific case for GAIA rests on its ability to obtain accurate astrometric measurements for very large and complete (flux-limited) samples of stellar, extragalactic, and solar-system objects, and the matching collection of synoptic, multi-epoch photometric, and radial-velocity data. The scientific objectives include an extremely broad range of topics in Galactic and stellar astrophysics, solar-system astronomy, reference frame, and fundamental physics, as exemplified in the Proceedings of the symposium *The Three-Dimensional Universe with GAIA* (Turon et al. 2005).

During its operational phase of 5 years, the GAIA mission will provide an all-sky optical astrometric and photometric survey completely to 20th magnitude. The scanning and measurement principle is similar to Hipparcos, but vastly more efficient and accurate thanks to the use of a large array of CCDs and bigger telescope (up to 1.4 m aperture). The expected sky-averaged parallax accuracy is 8–25 μ As for the brighter stars (< 15 mag) and ~ 300 μ as at 20 mag, with similar accuracies for the positions at mid-epoch (~ 2015) and the annual proper motion components. The photometric survey uses two slitless prism spectrographs with a resolution of $R \simeq 10$ –30 in two wavelength bands, 330–680 nm and 640–1050 nm. The photometric accuracy is difficult to quantify but the instrument has been designed with a view to enable determination of relevant astrophysical parameters (T_{eff} , $\log g$, [Fe/H]) for a broad range of stars. Radial velocities at the 1–15 km s^{-1} accuracy level will be measured for the brighter stars using a slitless spectrograph operating in the Ca II triplet region (847–874 nm, $R = 11500$). Thus, for many millions of stars, GAIA is expected to provide full phase-space information, accurate individual distances, and complementary astrophysical data together with a systematic analysis of stellar variability.

The satellite, including the scientific instruments, launch and mission operations, are fully funded by ESA. The prime industrial contractor for building the satellite and instruments is EADS Astrium. The production of the GAIA Catalogue is however the task of the scientific community and will be achieved by the GAIA Data Processing and Analysis Consortium (DPAC).

The ESA web site <http://www.rssd.esa.int/GAIA> maintains up-to-date information about the status of the mission, news items, information sheets, meetings, *etc.*

BRAZIL: Andrei and Colleagues from Observatorio Nacional, Observatorio do Valongo, SYRTE/Observatoire de Paris, Observatoire de Bordeaux, and Observatorio do Porto develop the Initial Quasar Catalogue for the GAIA mission (Souchay et al., 2007).

JAPAN: Mitsuru Soma reported about the JASMINE and Nano-JASMINE projects. JASMINE is an astrometric mission that observes in an infrared Kw band (2.0 microns) (Gouda, 2007 and 2008; Yano, 2008; Yamada, 2008). This project is in development, with a target launch date around 2015–2020. It is designed to perform a survey towards the Galactic bulge with a single-beam telescope, determining positions and parallaxes accurate to 10 μ as and proper motions to 10 μ as/yr for stars brighter than Kw=11

mag. JASMINE will observe about a few ten million stars brighter than the limiting magnitude ($K_w=14$ mag). JASMINE development proceeds mainly by staff at NAOJ, in collaboration with Japanese universities and engineers at JAXA. It should be noted that JASMINE has been identified as particularly significant for astrometry by the SOC of IAU Symposium 248.

Nano-JASMINE is planned to demonstrate the first space astrometry of Japan and to perform experiments for verification of some techniques and operations of JASMINE (Kobayashi, 2008; Sukanuma, 2008; Yamauchi, 2008). Nano-JASMINE has a size and weight of about 50cm^3 and 20kg. The telescope has a 5cm diameter with a focal length of about 1.7m. The detector will be a $1\text{k}\times 1\text{k}$ CCD (z-band). A candidate orbit for Nano-JASMINE is a sun-synchronous orbit. The accuracy will be about 3 mas at $z=7.5$ mag for parallaxes and for proper motions 0.1 mas/year by combining the results with Hipparcos data. Nano-JASMINE will probably be launched by Cyclone-4 rocket in July 2010. The development is by NAOJ and Kyoto University in strong collaboration with Prof. Nakasuka and his group (Tokyo).

RUSSIA: Kiselev from Pulkovo reports on a new observational programme of visual-binary and multiple stars proposed for Gaia observations. The stars with a history of 20–40 years were chosen from the Pulkovo List (Kiselev, 2007).

USA: Benedict et al. have used the HST Fine Guidance Sensors to carry out mas precision astrometry to determine parallaxes of Galactic Cepheids (Benedict, 2007, AJ, 133, and 1810) and AM CVn binary stars (Roelofs, 2007, ApJ, 666, and 1174). HST FGS data was obtained to establish perturbation orbits due to planetary-mass companions to nearby stars like ϵ Eri (Benedict, 2006, AJ, 132 & 2206), the M-dwarf companion to HD 33636 (Bean, 2007, AJ, 134 & 749) v And and others (Benedict et al 2008, 2009). HST FGS observations continue for RR Lyr and Pop II Cepheid stars to calibrate a Pop II Period-Luminosity relationship. Once HST has its last repairs, Benedict et al. will measure the parallaxes of 9 metal-poor stars to establish a Pop II main sequence and address distances and ages of Galactic Globular Clusters.

4. Reference Frames

BRAZIL: Work on the extragalactic frame concentrates on the reconciliation between optical and radio positions (Camargo et al. at the SOAR, NTT, ESO 2.2m), and, also, on the astrometric bearing of astrophysical quantities of quasars, as the morphology, the variability, the redshift, and color locus, as developed in theses by Melo and Antunes Filho.

CHINA PR: Wenjing Jin reports that a list of 173 candidate stable sources selected from ICRF-ext2 was proposed after comparing the solutions and performing statistical analysis. (Qiao et al. 2008).

The precession and equinox motion correction were obtained from various samples of PPM and ACRS proper motion data. The results show that obvious systematic difference 1.5 mas/yr was derived from two catalogues mainly due to the internal systematic error of the FK5 proper motion (Zhu 2007).

FRANCE: Souchay reports about the Large Quasar Astrometric Catalogue used to monitor the ICRS and maintain the ICRF. This product is available at ftp://syrtte.obspm.fr/pub/LQAC/LQAC_2008.ascii The increased number of observations of southern ICRF quasars will assess the astrometric quality of the QSOs.

Capitaine investigated high-precision methods for locating the celestial intermediate pole (CIP) and origin (CIO) at a few microarcsec.

ROMANIA: Popescu reports on work carried out by the Astronomical Institute of

the Romanian Academy in improving relative positions of reference stars around ICRF radio-sources. Observations have taken place since 2006, at Belogradchik Observatory, Bulgaria, in collaboration with the Bulgarian Academy. The 60-cm Zeiss telescope is used to observe ICRF defining and candidate northern sources with a 6x6 arcmin field. There are planned also observations of asteroids in the ICRF source fields.

A pilot investigation has been published on the astrometry of 59 northern ICRF sources using significant approaches of asteroids to these sources (A&A 476, 989-993, 2007). For the ICRF objects, the (x,y) errors per source ranged from 50 mas to 100 mas. The RA and Dec reduction mean errors were 46 mas. Investigations into the orbits of these asteroid have been carried out.

All astronomical (12989) plates observed since 1930 have been archived within the Wide-Field Plate Archive Program initiated by IAU Commission 9. 5000 of them have a preview stored in the WFPDB. The intention is to add the CCD images acquired for the last 5 years and form the origin of the future Bucharest Virtual Observatory.

5. Positions and Proper Motions

BRAZIL: Teixeira and Colleagues from the Bordeaux Observatory (Rappaport, 2006; Ducourant, 2006; de Souza, 2007) conducted position and proper motion studies based on CCD Meridian Circles observations.

CHINA PR: Li Chen (Shanghai) reports that the positions and absolute proper motions of stars in the regions of the young (2-4 Myr-old) open clusters NGC 2244 (the central cluster in the Monoceros R2 association) and NGC 6530 (the dominant cluster in the Sgr OB1 association) were determined based on photographic plate material obtained at Shanghai Astronomical Observatory, with time baselines of 34 and 87 years, respectively. Membership probabilities and velocity dispersions for both clusters were estimated (Chen et al. 2007).

Chunlin Lu (Nanjing) reports that 9 astrometric standard fields ($5^\circ \times 7^\circ$) for LAMOST have been primarily completed with NEOST at Xu Yi, an observing station of the Purple Mountain Observatory. These fields include 2 SDSS standard fields and 7 open clusters, such as Hyades, Pleiades, Praesepe, NGC2281 etc. in which 6 clusters are the targets of the WIYN project. The magnitude limit is 21.0. The internal precision of position is $0.07''$ at the observational epoch and external accuracy is $0.1''$ by using comparison between 2 SDSS fields and SDSS standard fields in the ACR (Astrometric Calibration Regions) catalog.

The systematic errors induced by CTE, variation of atmospheric Refraction, *etc.*, especially the displacement of the tangent point of CCD plane in the observations with drift scan mode were investigated by comparison between catalogues. The results of comparison between ACR-CMC13 and UCAC2 indicate that there are significant magnitude equations in declination of ACR and CMC13, and waves with period approximated to the size of the FoV of CCD drift scanning exist in the difference of position in both of UCAC2-ACR and UCAC2-CMC13 (Jiang 2008).

Zhanghong Tang (Shanghai) reports that the systematic errors of GSC 2.3 were investigated by using the comparison between GSC2.3 and UCAC2. The results indicate that the systematic error at the plate edges is $0.5''$ and the dividing line at radius 2.5° around the plate center is clear as well as a magnitude equation with non-linear features of about $0.2''$ from peak to peak. Reprocessing the plates can improve the final positional accuracy at 20th magnitude to $0.2''$ (Tang et al. 2008).

FRANCE: Ducourant has archived the PM2000 and CDC2000 catalogues at CDS (I/300 and I/303)

Fresneau (with Vaughan and Argyle) reports the archiving of the Sydney Observatory Galactic Survey (<ftp://cdsarc.u-strasbg.fr/pub/cats/J/A+A/469/1221>) with proper motion accuracies of 3 mas/y for half a million stars to B=14. Analysis of 600 astrographic plates archived at Macquarie University compared to GSC 1.2 suggests the detection in the solar neighborhood of the interface between the extreme disk and the thin disk of the Galaxy along the Galactic meridian $l = 330^\circ$.

Guibert reports of the discovery of a nearby M9 dwarf detected in the DENIS database with a proper motion of 2.5 arcsec per year.

GERMANY: Brosche (Bonn/Daun) reports that Brosche and Schwarz (Landau, now Siegen) have compared their results on the motions of K giants perpendicular to the Galactic plane with other data; the increase of the velocity dispersion with increasing distance was confirmed. This behavior leaves no room for essential dark matter in the disk. A more generalized treatment is foreseen for the future.

Röser (Heidelberg) reports that Röser, Schilbach, Schwan, Kharchenko, Piskunov, and Scholz (2008) compiled a new astrometric catalogue of positions and proper motions in the ICRS, called PPM-Extended (PPMX) (arXiv:0806.1009). The catalogue contains about 18 million stars with limiting magnitude 15.2 in the magnitude system of GSC 1. Besides the astrometric information, J, H and K_s magnitudes (from 2MASS) are given for 99.8 per cent of the stars, and, for the subset of stars, which are in Tycho-2, Johnson B and V magnitudes are published. The positions and proper motions are derived from a rigorous weighted least-squares solution from various source catalogues: Astrographic Catalogue, Tycho-2, GSC 1.2, UCAC2, CMC14 and 2MASS etc. For the subset of 4.5 million stars contained in the Astrographic Catalogue the typical mean error of the proper motions is 2 mas/y, for the remaining stars with first epoch in GSC 1.2 it is 10 mas/y. The catalogue is available from the CDS.

JAPAN: Proper motions of SiO maser sources around the Galactic Center were obtained with VLBA (Oyama et al. 2008). These results are important for studying the character and the mass of the super-massive black hole which is believed to be located at the center of the Galaxy.

RUSSIA: Khruyskaya (Pulkovo) reports that new high accuracy proper motions of 38,600 stars in the Pulkovo areas with galaxies have been obtained for zone -5 to $+40^\circ$. The new proper motion accuracy is 1–3 mas/y. Systematic errors of proper motions with stellar magnitude are detected in UCAC2 (Khruyskaya, 2006).

Kinematic study of proper motions in TYCHO-2 and UCAC2 showed the average rotation around Galactic axis Y to be -0.37 ± 0.04 mas/y for the most distant stars ($d \approx 900$ pc). The rotation is interpreted as the residual rotation of ICRS/Tycho-2 system with respect to the inertial coordinate system (Bobilev and Khovritchev, 2006).

A catalogue of 235 areas (ERS, the IAU main list) in declination zone -17° to $+80^\circ$ has been compiled. The positional accuracy of 21355 stars ($9-17^m$) is $0.04''-0.10''$. Only 10650 stars with $\delta < +50^\circ$ have proper motions from UCAC2. The comparison in 198 areas between ERS and UCAC2 has been fulfilled in the zone from -30° to $+45^\circ$ (V.P.Ryl'kov, 2007). Coordinates of more than 12500 stars for 78 areas with Galactic radio sources have been obtained.

SPAIN: ROA has continued observations in order to extend CMC14 because a small zone was not published in 2005 due to bad weather. Also the southern survey limit was increased -40° . A new catalogue (CMC15) will be published in 2009–2010 with the stars brighter than $r' = 17$ and declination between -40° and $+50^\circ$.

During the period September 2006 – June 2007, CMASF (Argentina) has continued CCD observations to produce a survey of stars with $V < 16$ for $-55^\circ < \delta < +30^\circ$. Unfortunately, the CCD camera has failed and it has not been possible to repair it. Thus

a sub-catalogue with $-30^\circ < \delta < 0^\circ$ is planned to be published by the end of summer of 2008.

UKRAINE: Ivanov (Kiev) reports the compilation of a catalogue of 555,200 stars with high-proper motions (> 0.04 arcsec/year) up to 16^m in zone $-2.5^\circ < \delta < +90^\circ$.

Fedorov (Kharkov) reports on an all-sky (excluding the Galactic center) absolute proper motion catalogue of 285 million stars ($12^m < B < 20^m$). The proper motions were derived from 2MASS and USNO-A2.0 positions. The absolute proper motions were calculated using about 1.45 million galaxies from 2MASS with mean error < 1 mas/yr.

Fedorov (Kharkov) reports that the first version of XC1 catalogue of positions and proper motions of 856,421 stars around ICRF sources in the Northern hemisphere was integrated into the CDS (I/302 XC1).

Basey (Odessa) reports about processing the catalogue of 4984 stars ($-3^\circ < \delta < 3^\circ$) in the FK5 system which has been observed at the meridian circle in 1931–1935.

Pinigin (Nikolaev) reports on a collaboration with Pulkovo Observatory (Ryl'kov) on a compiled catalogue of 22000 reference stars ($10 - 16^m$) in 235 fields around extragalactic radio sources of the ICRF list with $-17^\circ < \delta < +80^\circ$.

USA: Platais (Baltimore, MD) reports on the Deep Astrometric Standard (DAS) initiative intended to calibrate the focal plane arrays of large telescopes (Platais, 2006). First epoch imaging in all DAS fields has been obtained. The radio VLA observations of candidate compact sources are complete in three DAS fields and VLBI observations have been made in one field (Fey, 2007).

The Northern and Southern Proper Motion (NPM, SPM) data (Lick Observatories, Yale/San-Juan) were re-reduced in a joint Yale/USNO effort (SPM4, Girard, 2008). The UCAC3 (Zacharias, 2009) contains highly accurate positions and proper motions of about 80 million stars. The 20 cm USNO “red lens” astrograph has been refurbished for a new all-sky observing program with a 440 million pixel camera. This “U-mouse” astrometric survey will begin in 2009 from Cerro Tololo. For more details see the IAU WG on Densification of the Optical Reference Frame report and various contributions at IAUS 248.

NOFS participates in the PanSTARRS and LSST projects (D.Monet). The FASST instrument continues to observe mainly solar system targets for JPL. The Navy Prototype Optical Interferometer (NPOI) successfully observed a selected number of bright Hipparcos stars in global astrometry mode (Hutter, 2008).

6. Trigonometric Parallaxes (nearby and high proper-motion objects)

BRAZIL: Penna and Colleagues, in collaboration with the Observatorio di Torino, conducted a long term parallax program for a large sample of up to 200 L and M cool dwarfs. Teixeira and colleagues (Ducourant, 2007 and 2008) concentrated the work on milli-arcsecond parallaxes of specific nearby objects.

CHINA PR: Chunlin Lu (Nanjing) reports that a new reasonable weight assigning scheme and a three-piecewise continuous model were adopted to fit the data for 48 low-mass stars of the main sequence in the solar neighborhood. Taking into account the constraints from observational luminosity, the empirical mass-luminosity relation (MLR) in K, J, H and V bands, and mass-metallicity-luminosity relation (MMLR) in V band for low-mass stars are improved Xia, 2008).

GERMANY: Schilbach (Heidelberg) reports that Schilbach, Röser and Scholz measured trigonometric parallaxes of 10 ultra-cool subdwarf candidates. The observations extended over 3 years and were carried out with the OMEGA2000 IR-camera on the 3.5-meter telescope on Calar Alto (Spain). At the time of this writing, the final observations

were being obtained. Preliminary reductions yielded precisions of the parallaxes between 1 and 2 mas. Due to a relatively large and deep field, the parallaxes can be referred directly to galaxies.

Scholz (Potsdam) reports that Scholz, Kharchenko, Lodieu, and McCaughrean (2008) have discovered an extremely wide and very low-mass pair with a common proper motion. This pair consists of a late-type (M7) dwarf and an ultra cool subdwarf (sdM7) sharing exactly the same very large proper motion of about 860 mas/yr. The two stars are separated by about six degrees on the southern sky, corresponding to a projected physical separation of about 5 pc at the assumed common distance of about 50 pc. The large separation and the different metallicities of dwarfs and subdwarfs make a common formation scenario as a wide binary (later disrupted) improbable. It seems more likely that this wide pair is part of an old halo stream.

JAPAN: Hachisuka (2006) obtained trigonometric parallaxes of H₂O masers near the star-forming region W3(OH) with VLBA. Imai (2007) obtained a trigonometric parallax of an H₂O maser feature associated with the low-mass young stellar object IRAS 16293-2422 using VERA. Hirota (2007) obtained a trigonometric parallax of Orion KL with VERA. Honma (2007) performed high-precision astrometry of H₂O maser sources in the Galactic star-forming region S269 with VERA and successfully detected the smallest trigonometric parallax ever measured. Hirota (2008) obtained the trigonometric parallax of an H₂O maser feature associated with the young stellar object SVS 13 with VERA. Nakagawa (2008) have started trigonometric parallax measurements of the Galactic Mira variables, which are important to deduce the precise period-luminosity relation in the Galaxy.

USA: Gatewood (Allegheny Observatory) concludes the 100 year parallax program with new results on selected nearby stars and the Pleiades distances (Gatewood, 2008). The Naval Observatory Flagstaff Station (NOFS) Parallax Program continues (Dahn, H.Harris, 2006–2009).

7. Solar System

BRAZIL: V. Martins and Colleagues, in collaboration with B. Sicardy's group, keep several programs on the astrometry, dynamics, and astrophysics of asteroids, natural satellites and TNOs, notably on the Pluto/Charon system (Sicardy, 2006; Descamps, 2007; Gulbis, 2006).

CHINA PR: Chunlin Lu (Nanjing) reports that the PMOE planetary/lunar ephemeris framework was established in 2003, and has been improved in recent years. Various effects on the bodies in the solar system have been taken into consideration. The further improvement of PMOE 2003 by using the second post-Newtonian (2PN) theory is in progress. Based on the PMOE 2003 ephemeris framework, Li et al. have calculated the orbits of the LISA, ASTROD I and ASTROD spacecrafts, and proposed the methods for the orbital optimization of the LISA spacecrafts, cooperating with H. Gerhard et al. at ESA. Also the celestial phenomena and lunar phases in Xia Shang and Zhou dynasty in China (BC 2100-BC 771) have been calculated and published (Li, 2008).

Wenjing Jin (Shanghai) reports that it is the first time to observe the mutual events of Galilean satellites in China with the 1m telescope at Yunnan Observatory. The comparisons were made with the theoretical modes, Lieske's E5 and Lainey's L1. The accuracy of positions in RA and Dec are 103 and 88 mas for Lieske's theory and 74 and 80 mas for Lainey's theory (Peng & Noyelles 2007). In addition, some further reduction has also carried out by comparison of normal CCD observations and some mutual events observations. The results show a better agreement between internal and external observations

(Peng et al. 2008) The next campaign of mutual events will be in 2009 for the Galilean and in 2010 for Saturnian satellites.

210 positions of Phoebe (S9) were obtained with the 1 m telescope at the Yunnan Observatory during the years 2003–2005, using a CCD image-overlapping calibration method proposed by Peng et al.. After the observed positions of Phoebe were compared with its theoretical positions, computed by the new JPL ephemerides DE405 and SAT199, the mean residuals (O-C) are $0.21''$ and $-0.05''$ in right ascension and declination, respectively, with a standard deviation of $0.06''$ (Peng & Zhang 2006).

Kaixian Shen (Xian) reports that a total of 115 frames of Phoebe were obtained with the 1.56 m telescope at Shanghai in 2003–2004. A comparison with three high quality ephemerides, including the JPL SAT185 by Jacobson was made. The standard deviations in right ascension and declination are $0.058''$ and $0.078''$ respectively (Qiao, 2007). In order to enhance determination of the Phoebe's orbit, it is necessary that the observations cover the longest time span as possible, in this reduction the 686 Earth-based astrometric observations available from 1905 to 2004, including the 101 new CCD observations were used (Shen, 2008).

Previously there were less than 400 observations of Triton with an accuracy of better than $0.15''$. Recently the 943 astrometric observations of Triton with the 1.56 m telescope at Shanghai during the period of 1996–2006 were obtained and compared with the theoretical positions provided from JPL and IMCCE. The standard deviation of O-C is $0.04''$ (Qiao, 2006).

RUSSIA: Devyatkin (Pulkovo) reports on observations of Solar System bodies taken at the ZA-320M of GAO RAS (Descamps, 2008 and Devyatkin, 2008).

Kiseleva reports that astrometric investigations of the Galilean satellites of Jupiter are completed using the 26" Pulkovo refractor. Estimation of Galilean satellites motion theories gives accuracies up to $0.10''$ (Kiseleva, 2008). The observation results have been included in the PHEMU03 catalogue (J-E. Arlot, 2008). Absolute and relative ("satellite-satellite") astrometry using photographic observations (2006–2007) at the Pulkovo 26" has shown the presence of errors in the theoretical motion of Saturn. Pulkovo has taken part in the International Program of mutual phenomena of Saturn and Uranus. In 2006–2007 CCD-observations of asteroids by the Normal astrograph at Pulkovo were started (Khrutskaya, 2006 and 2007). Databases of astrometrical catalogues and Solar System and double star observations from Pulkovo Observatory are available at <http://www.puldb.ru> (Khrutskaya, 2007).

UKRAINE: Filonenko and Velichko (Kharkov) report on CCD observations of comets 17P/Holmes, C/2007 E2 Lovejoy, C/2007 F1 LONEOS, and 8P/Tuttle, processed using UCAC2 as a reference catalogue.

Kleshchonok (Kiev) reports that observations of stellar occultations by the Moon using a portable TV complex are continuing. The catalogue of contains more then 120 events.

Kazantseva (Kiev) reports about the first results in the network of synchronous television and visual observations of stellar occultations.

Baransky (Kiev) reports that 2164 CCD observations of 144 comets and minor planets have been obtained at the 0.7 m reflector and reported to MPC (code 585).

Pinigin and Hudkova (Nikolaev) report that CCD observations of selected asteroids were taken at the RTT-150 (Turkey) in 2004–2007 with cooperation with Turkish National Observatory TUBITAK (Aslan) and Kazan University, Russia (Gumerov). About 5,500 of topocentric positions of 68 asteroids and 517 positions of 17 NEAs have been obtained (2004–2007), with about 3,200 of them for 2004–2005 sent to the MPC (code A84).

Ivantsov (Nikolaev) reports about new values of 21 asteroid masses, which have been

determined by the dynamic method using ground-based CCD observations and based on DE405. The relative error of mass determination is less than 50% for 12 asteroids.

8. Open and Globular Clusters and the Galaxy

BRAZIL: Work on Galactic clusters continues by the use of high quality proper motions to determine cluster membership (Dias, 2006).

CHINA PR: Li Chen (Shanghai) reports that based on a most complete open clusters sample with metallicity, age and distance data as well as kinematic information, some preliminary statistical analysis regarding the spatial and metallicity distributions of the Milky Way disk is presented. In particular, a radial abundance gradient of 0.058 dex/kpc was derived. (Chen, 2008).

The orbits and theoretical tidal radii for a sample of 45 Galactic globular clusters were calculated. It is found that an orbital phase dependence between theoretical and observed tidal radii is evident (Wu 2008).

Using published accurate observational data of radial velocities and proper motions of stars in the open cluster M11, the distance of M11 was determined, which is in quite good agreement with the luminosity distances of the cluster given by some authors (Zhao & Chen 2007).

Beijing-Arizona-Taiwan-Connecticut (BATC) multi-band photometric data were used to determine the membership of open cluster M48. By comparing observed spectral energy distributions of M48 stars with theoretical ones, membership probabilities of 750 stars with limiting magnitudes of 15.0 in the BATC c band were determined. 323 stars with membership probabilities higher than 30 per cent were considered to be candidate members of M48 (Wu, 2006).

Absolute proper motions and radial velocities of 202 open clusters in the solar neighborhood, which can be used as the tracers of the Galactic disk, were employed to investigate the kinematics of the Galaxy in the solar vicinity. The results derived from the observational data of proper motions and radial velocities of a subgroup of 117 thin disk open clusters are: the mean heliocentric velocity components of the open cluster system $(u_1, u_2, u_3) = (-16.1 \pm 1.0, -7.9 \pm 1.4, -10.4 \pm 1.5) \text{ km s}^{-1}$, the characteristic velocity dispersions $(\sigma_1, \sigma_2, \sigma_3) = (17.0 \pm 0.7, 12.2 \pm 0.9, 8.0 \pm 1.3) \text{ km s}^{-1}$, the Oort constants $(A, B) = (14.8 \pm 1.0, -13.0 \pm 2.7) \text{ km s}^{-1} \text{ kpc}^{-1}$, and the large-scale radial motion parameters of the Galaxy $(C, D) = (1.5 \pm 0.7, -1.2 \pm 1.5) \text{ km s}^{-1} \text{ kpc}^{-1}$ (Zhao, 2006).

Zi Zhu (Nanjing) reports that 301 open clusters with complete spatial velocity measurements and ages were selected to estimate the disk structure and kinematics of the Milky Way. The distance of the Sun to the Galactic center was derived as $R_0 = 8.03 \pm 0.70 \text{ kpc}$. The mean rotation velocity of the Milky Way was obtained as $235 \pm 10 \text{ km/s}$. Using a dynamic model for an assumed elliptical disk, a clear weak elliptical potential of the disk with ellipticity of $\epsilon(R_0) = 0.060 \pm 0.012$ is detected, the Sun was found to be near the minor axis with a displacement of $30^\circ \pm 3^\circ$. The motion of clusters is suggested to be on an oval orbit other than the circular rotation (Zhu, 2008).

Stellar samples of main sequence (MS) and horizontal branch stars were obtained with spectral types O-B, A, F, G, K-M to calculate the scale height of the Galactic disk by using Hipparcos data. The results indicate that the scale height is $103.1 \pm 3.0 \text{ pc}$ and $144.0 \pm 10.0 \text{ pc}$ from the samples of O-B of MS stars and horizontal branch. The Sun is located at $15.2 \pm 7.3 \text{ pc}$ and $3.5 \pm 5.4 \text{ pc}$ above the mean plane of the disk for two of the samples. (Kong & Zhu 2008).

The Galactocentric distance by a pure kinematical model was determined from two components of the Galactic thin disk: 1200 O-B stars and 270 Galactic open clusters.

An estimated value of $R_0 = 8.25 \pm 0.79$ kpc was derived from the former one while $R_0 = 7.95 \pm 0.62$ kpc from latter one with a simple Oort-Lindblad model of Galactic rotation. A direct comparison shows that the above results are in good agreement with the best value suggest by Reid (Shen & Zhu, 2007).

Based on Hipparcos proper motions and available radial velocity data of O-B stars, the local kinematical structure of the young disk population of ~ 1500 O-B stars, not including the Gould-belt stars, have been re-examined. A systematic warping motion of the stars about the direction to the Galactic center has been reconfirmed. A negative K-term implying a systematic contraction of stars in the solar vicinity has been detected. (Zhu, 2006).

UKRAINE: Kharchenko (Kiev) reports that the all-sky compiled catalogue of 2.5 million stars (ASCC-2.5) has been made and 650 Galactic open clusters were identified in it (about 130 previously unknown objects). The cluster sample is complete within the Galactic disk area of about 1 kpc radius, and apparent integrated magnitudes brighter than $V = 8$.

Rybka (Kiev) reports that the local velocity field of more than 53,000 Red Clump giants within 1 kpc of the Sun were investigated using the three-dimensional Ogorodnikov-Milne model. It was shown, that Galactic rotation of the stellar group with $-b < 30^\circ$ has peculiarities, such as in values of the phase offset parameter $\phi = 6.9 \pm 0.6^\circ$ and the contraction parameter $K = 6.3 \pm 1.1 \text{ km sec}^{-1} \text{ kpc}^{-1}$.

USA: Platais (Baltimore, MD) reports on deep astrometry in the WIYN Open Cluster Study (WOCS) Program. A total of 645 old long-focus telescope plates have been scanned with the STScI GAMMA measuring machine, covering 54 open clusters. Catalogs of proper motions and positions are constructed for Blanco 1, IC 2391, M67, NGC 6253, and the globular cluster ω Cen. Astrometry for the last three clusters is based entirely upon the CCD mosaic frames.

9. Education in Astrometry

Zhanghong Tang (Shanghai) reports that the first Chinese-French Spring School on Astrometry “Observational campaign of solar system bodies”, was held in Beijing, April 7-13, 2008. 28 students and young astronomers participated. The purpose of organizing the spring school was to foster young students for their specialization. The lectures were given by astrometric scientists on fundamental astrometry, receptors, telescopes and images for astrometric purpose, astrometry through photometry and observational campaigns for phenomena, practical astrometry.

10. Symposia, Colloquia, Conferences

Journées 2007 The Celestial Reference Frame for the Future, Meudon, France, September 17–19, 2007.

IAU Symposium 248 “A Giant Step: From Milli- To Micro-Arcsecond Astrometry”, Shanghai, China PR, October 15–19, 2007 (Jin et al. 2008).

ADELA 2008 – IV Meeting on Dynamical Astronomy in Latin-America, Mexico City, February 12–16, 2008.

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