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中国小望远镜观测太阳系小天体项目的回顾

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摘要：回顾了中国用小望远镜进行的一些科研项目，如小行星的天体测量和测光观测，近地天体的观测和天然行星卫星的天体测量观测。介绍了小行星和近地天体轨道的测定，以及行星/月球历表的编制。简述了天体测量标准区的建立，从射电源光学对应体推算光学和射电参考架的联系，双星轨道的测定，以及星团成员星自行的测定。提出了改进 GSC2.3 的新项目，其中包括消除星等差和南天恒星自行的系统差，以及减小偶然误差，并建议加入新的观测作为 POSS 和 SERC 项目第三历元的观测资料。

关　键　词：太阳系；近地天体；参考架；星团

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Programs of Observing small Celestial Bodies in the Solar System with small Telescopes in China

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Abstract: Several programs, such as astrometric and photometric observations of asteroids, observations of NEOs and astrometric observations of the natural planetary satellites, with

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small telescopes in China are reviewed. The orbital determinations for asteroids and NEOs as well as development of planets/lunar ephemeris are introduced. Studies on establishment of astrometric calibration regions, linkage between optical and radio reference frames from optical counterparts of radio sources, orbital determinations for binaries and determinations of the proper motion for membership of stellar cluster are briefly described. The new program on the improvements for GSC2.3 such as eliminating the magnitude equation and systematic error in proper motion in the southern hemisphere as well as decreasing the accident error, adding new observations as data at third epoch of POSS and SERC projects etc. is presented.

Key words: solar system; Near Earth Objects; reference frame; stellar cluster

1 Introduction

It is well known that the solar system is a remnant after formed 4.5 billion years ago. The scientific goals to observe and study the small celestial bodies, such as asteroids, natural satellites etc. is to reveal the origin and evolution of the solar system and the formation of planetary system. Secondly, in the geological history the events of the collision of asteroids with the Earth happened several times so NEOs (Near Earth Objects) will be observed and their orbital parameters will be determined and predicated in order to avoid the natural disasters. These objects of NEOs called PHOs (Potential Hazardous Objects) are as many as several ten thousand. Their diameters are over 200 m and the nearest distance from the Earth is 7.5×10^6 km . In addition, the artificial satellites having various uses, such as measurement of Earth Gravity Field (CHAMP, GRACE, etc.), measurement of sea level (Starllite, Sella etc.), determinations of coordinates of the pole (Lageos, Etalon etc.) and navigation (GPS, Glonass etc.), have been launched and some of them are still operating in the NES (Near Earth Space). But it is beyond the content and will not be discussed here.

Before 2009, the aperture of the largest optical telescope in China is 2.16 m at National Astronomical Observatory (NAO). The second largest telescope with diameter 1.56 m at Shanghai Astronomical Observatory (SHAO) and the apertures of the most of telescopes are less than 1 m. In the recent years a new 2.4-m telescope has been operated regularly and is located at Gao-Mei-Gu, Yunnan Province. With these telescopes some programs concerning observations of small celestial bodies in the solar system and determinations of orbital parameters for asteroids and NEOs as well as some astrometric work, such as establishment of astrometric calibration regions, linkage between optical and radio reference frames from optical counterparts of radio sources, determinations of orbital parameters for binaries and determinations of the proper motion of the member star of stellar cluster and so on, are carried out.

In this paper the observations of small celestial bodies such as asteroids, and natural satellites with small telescopes are described in section 2. The method and algorithm for determination of orbital parameters for asteroids and NEOs as well as compilation of planets/lunar ephemeris are given in section 3. The research work on establishment of astrometric calibration regions, positional determinations of the optical counterparts of radio sources as well as determinations of the orbital parameters for binaries and the proper motion for membership of stellar clusters are shown in section 4. The new program on improvements of GSC2.3 is introduced in section 5. Finally, the future plan and suggestions on observing small celestial bodies in the solar system with small telescopes and relevant research work in China are presented.

2 Observations of small celestial bodies in the solar system with small telescopes

2.1 Asteroids

To study asteroids is a long-term research work at Purple Mountain Observatory (PMO) under the leadership of the first director Yuzhe Zhang. In the early 1960s, the observations were made with photographic plates, which have been kept over 8 000. In December 2006, a new 1.0/1.2 NEOST (Near Earth Objects Survey Telescope) was regularly operated [1]. It includes 4 096×4 096 SI CCD detector. The limited magnitude is 22.46 mag at B band.

The Schmidt CCD Asteroid Program（SCAP）of Beijing Astronomical Observatory (one of observatories in NAO founded on April 25, 2001) started in 1995 [2]. 575 asteroids were found by this scheme in the 1990s. Besides, the multi-color photometric observations in 3 bands (Johnson B, V, R) for satellites and GEO (Geostationary Orbit) debris have been carried out with 3 telescopes (apertures: 50, 80 and 85 cm) equipped 1 000 × 1 000 scientific grade CCDs at NAO. The positions of GEO debris can be also observed and tested at 532 nm (laser) and 436 nm (B) passbands. In addition, the physical characteristics for GEO debris are also observed by spectrograph of 2.16-m telescope with low resolution of ∼1 nm.

A series of CCD photometric observations of asteroids, such as 58 Concordia, 360 Carlova, 405 Thia etc. have been carried out with 1-m telescope at Yunnan Astronomical Observatory (YAO) since November 2000 [3].

The observations of asteroids and the studies of minor planets of the Flora group were implemented with the 40-cm refractor at SHAO. It is no longer used after 1987. But the observations of GEO satellite were tested in July 2006 by using a 20-cm telescope with 1 160×1 040 CCD in drift scan mode at SHAO. The total internal errors of optical positions are 0.2″ ~0.4″ [4]. Since 2009 the observations by using a new 40-cm telescope equipped 4 008×2 672 scientific grade CCDs and operated in drift scan mode for asteroids and NEOs have been initiated at "Jiang-Nan-Tian-Chi" where is a new observing site of SHAO located at Tian Huang Ping, Zhejiang Province and is 175 km away from SHAO headquarter.

During the past decade, the important results are obtained as follows:

(1) Till now more than 1 800 asteroids have been discovered from PMO group, and more than 180 asteroids have been numbered. From December 2006 to now, the observations ranked among the top-ten observational programs in the world. Until now, 800 new asteroids including an Apollo-type NEO-2007 JW2 have been found by NEOST. In the middle of September of 2007, a new Jupiter-family comet, P/2007 S1, was found [1].

(2) The synodic rotation periods of 58 Concordia, 360 Carlova, 405 Thia are (9.90±0.01) h, (6.18±0.02) h, (9.96±0.01) h determined with 1-m telescope at YAO as mentioned above. The *BV* and *UB*-colour indexes for these asteroids were also determined, and especially the rotation parameters of 360 Carlova were determined. In addition, synodic period of the asteroids 38, 168, 174, 206, 276, 346 and 205 were also given [3]. The preliminary results such as magnitude, shape, spin rate for more than 30 GEO debris are also obtained at NAO.

2.2 Natural Satellites

There are two groups work on the program of natural satellites. One is at NTSC (National Time Service Center), Shannxi province and the other is at Jinan University, Guangzhou. In 2006, scientists of SHAO joined the former group to work on this program. Both groups use 1.56-m telescope at SHAO and 1-m telescope at YAO and collaborate with IMCCE in 2001 to observe natural satellites. From 1994 up to now, the important results are obtained as follows:

(1) Based on an image processing method for planetary halo given by Brazilian scientists Veiga and Martins in 1995, Peng et al. (2003) [5] developed a new image processing method, i.e. halo-removal technique, to reduce the influence of the primary halo on positions of satellites and meantime to determine the positions of major planets. The positional accuracies for the satellites of Jupiter and Saturn reach to a high level. If the halo is asymmetrical a Laplacian of Gaussian algorithm (LoG) with a polynomial of degree 2 is adopted. LoG can be suitable not only to avoid mostly the asymmetric halo but also to detect a sharper and finer edge of Saturn's rings [6].

(2) Two shortcomings existed before 2002 in observations of the small field of view due to CCD detector having only a small size and low density of reference catalogue used. The "bright moon method" was used in astrometric calibration of the CCD. This method relies on positions predicted from pre-existing ephemeredes, in which positions of the bright satellites were used to define a known reference system in every frame [7]. Of course, after

2002 the situation is changed: a new large size CCD chip (2 048×2 048) to be used to replace the original one at 1.56-m of SHAO and the UCAC2, being high dense and more accurate, were used.

(3) Re-determined Phoebe's orbits [8] were carried out in 2005. In order to precisely determine Phoebe's orbit, it is necessary that the observations cover the time span as long as possible. In this reduction the 686 Earth-based astrometric observations available from 1905 to 2004, including the 101 new CCD observations from Qiao et al. (2006) [9] and 57 observations from Peng (2004) [10], were used. The residuals derived from this orbit are significantly smaller than those for the orbit computed by Arlot using old photographic observations only.

(4) In February 2003, the observations of mutual events of the Galilean satellites were made with 1-m telescope at YAO. Astrometric positions were deduced from 7 photometric observations by modeling the relative motion and photometry of the involved satellites during each event such as eclipse of J2 Europa by J4 Callisto, occultation of Callisto by J1 Io etc. The comparisons were made with two theoretical models: Lieske's E5 and Lainey's L1. The accuracies of positions in right ascension and declination are 103 and 88 mas respectively for Lieske's theory, while 74 and 80 mas respectively for Lainey's theory. In addition, some further reduction has been also carried out by comparison of normal CCD observations and some mutual events observations. The results show a better agreement between internal and external accuracies.

3 Determinations of orbital parameters for asteroids and Near Earth Objects

3.1 Asteroids and NEOs

The orbital parameters of asteroids and NEOs as well as satellites are studied with a long- term project at PMO and SHAO. The orbit determinations of pure analytical, semi-analytical and numerical integration methods are developed in 1960's, 1970's and 1990's with accuracies of km, hundred meters and cm. The reduction models are different for each mode. For example, the following catalogues, such as JGM3 50×50 for Geopotential, JPL DE405 for positions of perturbing bodies of the Sun and the Moon, DTM94/MSIS 1990 for atmospheric drag, and various effects including solar-radiation pressure, solid and ocean tidal perturbation, relativistic effects, earth radiation pressure, are adopted and considered in the numerical integration method. The software is still being improved today.

3.2 Planets/lunar ephemeris

The PMOE planetary/lunar ephemeris framework was established in 2003 [11] and has been improved in 2005. The following effects on the bodies in the solar system have been taken into consideration: (1) the post-Newtonian effects; (2) the figure perturbation effects arising from the finite size of the Sun, the Moon and the Earth; (3) the effect of the Earth tide on the motion of the Moon; (4) effects of gravitational forces of the Big 3 and 314 other large asteroids. With the identical astronomical constants, initial positions and velocities listed in DE 405 ephemeris, the orbits of the Earth-Moon barycenter, 7 planets, Pluto and the Moon around the Earth, are integrated for 1 200 d and 36 000 d (about 98 a). The accuracies obtained by using the PMOE ephemeris to predict the positions of the planets in the solar system are on the same level of JPL DE 405 [12].

4 Observations by using small telescopes in other projects

Besides the programs of observing small objects in the solar system with small telescopes, the following projects have been also implemented.

4.1 Astrometric standard areas

An astrometric calibration region, which is the Pleiades calibration region, has been made at SHAO. It contains the precise positions and proper motions of 441 stars. The observations of 11 plates with time span of 86 years (November 1901—November1987) were taken by 40-cm refractor. The positional accuracy is $\pm 0.05''$ and the standard error for proper motions is $\pm 0.001('')$/a for over 90% stars [13]. Besides there is LAMOST (Large Sky Area Multi-Object Fiber Spectroscopic Telescope) calibration regions, for which 15 sky areas, including 7 open clusters, 3 SDSS standard areas, 1 UCAC standard areas, Pleiades，Praesepe and Hyades calibration region as well as 1 areas in Gould belt, were selected [14]. The observations of 9 LAMOST calibration regions were performed by using 1.0/1.2 NEOST at Xu-Yi station of PMO during December 2006—May 2007. The size of each area is $5^\circ \times 7^\circ$ obtained by CCD mosaic of FoV $2^\circ \times 2^\circ$ with overlapping method. The positional accuracies for stars with magnitude from 12 to 16.5 mag is better than 50 mas and the mean density is over 800 deg^{-2} [15]. These regions were used for calibration of 1.56 m at SHAO in 1987 and LAMOST at NAO in 2008 respectively.

4.2 Optical counterparts for radio sources

A total of about 300 optical counterparts of the ICRF radio sources were observed mostly during 2000—2003 based on Joint Project (JP) between astronomical observatories from China, Turkey, Russia, and Ukraine. Observations were carried out with two telescopes equipped with CCD cameras: Russian-Turkish Telescope (RTT150), the fully automated Cassegrain telescope located at the TUBITAK National Observatory (TUG), Turkey, and the 1-m telescope located at YAO, China. In addition, there are 8 fields around Extragalactic Radio Sources(ERS) obtained on RTT150 with CCD AP-47p of size 1 024×1 024 pixels (FoV= $4'\times4'$), and 6 fields around ERS obtained on 2.16-m telescope of NAO with a CCD of size 2 048×2 048 pixels (FoV= $10.5'\times10.5'$).

The optical positions of the 126 ERS in the declination zone $-30^\circ \leq \delta \leq 50^\circ$ were measured with respect to the UCAC2 as reference catalogue and positions of 171 ERS in the declination zone $-40^\circ \leq \delta \leq 80^\circ$ were measured with respect to the 2MASS. The mean accuracies of the measured positions are 38 mas in right ascension and 35 mas in declination. A comparison between the measured optical positions referred to reference stars from UCAC2 catalog and the radio positions from the current ICRF has shown that the overall offsets, i.e. optical position minus radio position, are −3 and 14 mas in right ascension and declination respectively. The formal internal errors of these mean offsets are 4 mas. The optical positions with respect to reference catalogue 2MASS are also given. The estimation of the link between optical and radio reference frames has shown that orientation angles are near zero within their accuracy of about 5 mas. The link accuracy becomes 3 mas when the observations are combined with other studies [16].

4.3 Determinations of the orbital parameters for binaries

Over half of stars in the sky are binaries, and 20% stars in the Hipparcos catalogue are binaries and multiple star. The precise orbital determination of binaries is significant for stellar evolution. In 2004 a simulation calculation was made by Lattanzi, which reveals that Gaia astrometric data can only be used to reliably measure the orbits of binaries with periods less than 6 years [17]. But for those binaries with periods larger than 6 years, the reliability of orbital measurements becomes very low because the observational time span is shorter than the orbital period during Gaia mission. In other words, in order to obtain reliable orbit solutions of these binaries, one has to incorporate the other data based on long-term observations (pre-Gaia data). There are two kinds of pre-Gaia data namely radial velocity data and positional data. The former one is believed to be useful as it can be inferred from similar situations of Hipparcos binaries. Since 1990, the precision of the pre-Gaia positional data has already reached about several milli-arcseconds, but there are only a few data available for some binaries. Therefore, these data themselves are not sufficient to be used to derive reliable orbits of binaries. This is the case for some binaries in the fourth catalog of interferometric measurements of binary stars. Compared to Gaia astrometric data, these data have the advantage of long time span. It is then interesting to know whether these data of the long observational time span can play a role in determining binary orbits after Gaia mission. It is found from the simulation that if period < 8 a, solutions are all in accordance with those of simulation orbits, and if period > 8 a, solutions derived from combining Gaia and pre-Gaia data are still in good agreement with those of simulation orbits, which is not the case for the solutions from Gaia data only [18]

4.4 Stellar Clusters

It is well known that the stars in a globular cluster are dense while stars in some open clusters (OCs) spread to a large sky area, and therefore, all of these stars in the OCs can not be observed by astrometric satellite. Some new techniques are developed, e.g. determining the relative proper motions in small sky area by using adaptive optics and determining the radial velocities and metal abundance by using multi-objects fiber spectrometer. These new techniques can not only eliminate the main limitations of the limiting magnitude and observing accuracy with old plates in the past, but the determinations of proper motion for membership of stellar clusters can also be completed in a relatively short time [19].

A group at SHAO has studied stellar clusters, especially open clusters, since 1980's. The observations of OCs with 40-cm refractor and 1.56-m reflector were made. The advantage of this work is that the time baseline is quite long. For example, the observations for NGC 6530 have a time baseline of 87 years while for NGC 2244 the time baseline is 35 years. As we know there are WOCS(WIYN Open Cluster Study), SOCS(SEGUE Open Cluster Study), BOCCE(Bologna Open Clusters Chemical Evolution project), LOCS (LAMOST Open Cluster Survey) and so on in the world for studying OCs. LOCS is a Chinese project on study of open clusters. The purpose of LOCS is to obtain radial velocities and metal abundances for 600 OCs (magnitude to 16 mag and galactic distances expand to 13—16 kpc). During the last decade some important results are obtained as follows:

(1) Two kinds of OCs database were established at SHAO. In the first one (CAT1), there are 119 objects with ages, distance and metallicity available, while in the second one (CAT2), the kinematic information about 144 objects have both absolute proper motion and radial velocity data, of which 45 clusters also have metallicity data available. Now the number of OCs in updated both catalogues has expanded to 993 and 369 respectively for statistical studies of the OCs [20,21].

(2) From CAT1, a radial metallicity (iron) gradient of about (-0.063 ± 0.008) dex$\cdot$ kpc^{-1} for galactocentric distance ranging from about 7—17 kpc, was derived. By dividing cluster into age groups, it is also shown that the iron gradient is steeper in the past, and shallower for younger clusters. And it is consistent with the recent result from Galactic planetary nebulae data, and also consistent with inside-out galactic disk formation scenarios. Based on this sample, a disk age-metallicity relation could be implied but more observations are

needed for metal-poor clusters to obtain conclusive result. From CAT2, the 3D velocities for each open cluster relative to the Local Standard of Rest were derived. Some statistical analyses show that spatial distribution of young open clusters is symmetrically around the sun with low scale height from Galactic plane and small velocity dispersion while it is almost contrary for old open clusters [20].

(3) Two very young open clusters, NGC 2244 and NGC 6530, both with ages younger than 5 Ma were investigated. Taking NGC 6530 as an example, the proper motions for 364 stars in a one square degree region centered on the cluster were determined and their membership probabilities were estimated. Since these cluster stars are located at the same distance, and most of them are main sequence stars, the luminosity instead of mass can be used to study the segregation effects. The cumulative radial number density profile for bright and faint cluster stars shows that brighter (or massive) stars are more concentrated towards the inner part of the cluster is shown. This indicates an evident luminosity or mass segregation effect. A similar result was obtained for NGC 2244 [22].

5 A New Program

The catalogue GSC2.3 which contains nearly 1 billion objects down to R_F=20 mag for astrometry, photometry and classification was released in August 2008. The all-sky average absolute error in right ascension and declination ranges from 0.2″ to 0.8″ depending on magnitude. The proper motions are determined with an error of 6—12 mas/a. Stellar photometry is determined to 0.13—0.22 mag as a function of magnitude and photographic passbands (R_F,B_J,I_N). Outside of the galactic plane, stellar classification is reliable to at least 90% confidence for magnitude brighter than R_F=19.5. Various systematic errors such as magnitude-dependent and spatial dependent errors in position, proper motion error in the southern hemisphere etc. were discussed as well as the comparisons with UCAC and SDSS were made [23,24]. In order to refine this catalogue, the improvements of GSC2.3 have been proposed by SHAO and INAF-Turon Astronomical Observatory, Italy. Besides elimination of various systematic and accidental errors, the main improvement is to increase the accuracy of proper motions. In order to do so, the proper motions with respect to extragalactic galaxies will be adopted, and new observations as the observational data at third epoch of POSS and SERC projects, by using NEOST 1.0/1.2 m at PMO, Schmidt 60/90 cm at NAO and others located at the southern hemisphere, should be also adopted. The expected accuracy is 3—7 mas/a in the GSC2.4 [25].

6 Summary

Although Gaia will observe 10^5—10^6（65 000 presently）new moving objects down to 20 mag for asteroids including 300 Kuiper Belt objects and NEO (442, 455, 75 known today), these small celestial bodies are needed to be confirmed and classified, and loss of newly discovered objects with small telescopes on ground should be avoided.

The observations of small celestial bodies in the solar system will be implemented by a network of Gaia ground-based follow-up which includes a set of observatories and telescopes distributed in longitudes and latitudes. The international collaboration such as Gaia Follow-Up Network for Solar System Objects (Gaia- FUN-SSO), one of three ground-based networks for Gaia, is important. For example, the scientific cooperation between China, Russia, Turkey and Ukraine on the link of radio and optical reference frames is successful in the past. The campaigns of mutual events, which are carried out in the international collaboration, were made in 2009 for the Galilean satellites and in 2010 for Saturnian satellites. The technical interchange such as optical observations in drift scan or rotating drift-scan mode for small celestial bodies are fruitful.

In order to fully understand the origin and evolution for celestial objects from its kinematic and physical characteristics, the astrometric, photometric and spectroscopic observations of small celestial bodies such as asteroids, NEOs, and faint natural satellites etc. in the solar system and other objects such as binaries and stellar clusters with small telescopes are a longer term research work in China.

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参考文献:

[1] Zhao H B, Yao J S, Lu H. Proceedings of the IAUS 248, Jin W J, Platais I, Perryman M A C, eds.. Cambridge: Cambridge University Press, 2008: 564

[2] Ma Y, Zhao H, Yao D. IAUS 236, Milani A, Valsecchi G B, Vokrouhlicky D, eds. Cambridge: Cambridge University Press, 2008: 381

[3] Wang X B, Gu S H. EM&P, 2004, 93: 275

[4] Mao Y D, Tang Z H, Tao J, et al. Acta Astronomica Sinica, 2007, 48(4): 475
[5] Peng Q Y, Han Y B, Zhang C L, et al. A&A, 2003, 401: 773
[6] Peng Q Y, Vienne A, Wu X P, et al. AJ, 2008, 136: 2214
[7] Shen K X, Qiao R C, Harper D, et al. A&A, 2002, 391: 775
[8] Shen K X, Harper D, Qiao R C, et al. A&A, 2005, 2005, 437: 1109
[9] Qiao R C, Tang Z H, Shen K X, et al. A&A, 2006, 454: 370
[10] Peng Q Y, Vienne A, Han, Y B, et al. A&A, 2004, 424 : 339
[11] Li G, Ni W T. Publications of Purple Mountain Observatory, 2003, 22: 3 (in Chinese)
[12] Standish Jr E M. JPL IOM 312, 1998, F-98-048
[13] Wang J J, Chen L, Zhao J H, et al. Acta Astronomica Sinica, 1996, 37: 68
[14] Jin W J, Chen L. Progress in Astronomy, 2005, 23: 190
[15] Yu Yong. private communication, 2009
[16] Aslan, Z, .Gumerov R, Jin W, et al. A&A, 2010, 510: A10
[17] Lattanzi M G, Jancart S, Morbidelli L, et al. Proceedings of Symposium“The three-dimensional universe with Gaia”, ESA SP-576, Turon C, O'Flaherty K S, Perryman M A C eds. The Netherlands: ESA Publications Division, 2005: 251
[18] Ren S L, Fu Y N. Proceedings of the IAUS 248, Jin W J, Platais I, Perryman M A C, eds. Cambridge: Cambridge University Press, 2008: 16
[19] van Altena W. RevMexAA, 2008: 1
[20] Chen L, Hou J L, Wang J J. AJ, 2003, 125: 1397
[21] Chen L, Hou J L, Zhao J L, et al. Proceedings of the IAUS 248, Jin W J, Platais I, Perryman M A C, eds. Cambridge: Cambridge University Press, 2008: 433
[22] Chen L, de Grijs R, Zhao J L. AJ, 2007, 134: 168
[23] Lasker B M, Lattanzi M G, McLean B J, et al. AJ, 2008, 136: 735
[24] Tang Z H, Qi Z X, Yu Y, et al. Proceedings of the IAUS 248, Jin W J, Platais I, Perryman M A C, eds. Cambridge: Cambridge University Press, 2008: 334
[25] Jin W J. Progress in Astronomy, 2010, 28: 53