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ИННОВАЦИЙ И ИНФОРМАТИЗАЦИИ УКРАИНЫ

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НИКОЛАЕВСКАЯ АСТРОНОМИЧЕСКАЯ ОБСЕРВАТОРИЯ

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научной конференции
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от ближнего космоса до Галактики”

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ПРЕДИСЛОВИЕ РЕДАКТОРА

В 2011 г. Николаевская астрономическая обсерватория отмечает свой 190-летний юбилей. Она прошла славный путь от Морской обсерватории Черноморского флота до Южного отделения знаменитой Пулковской обсерватории, а на пороге XXI века получила статус самостоятельного научного учреждения Украины. Одним из главных событий в рамках празднования нынешнего юбилея обсерватории стало проведение международной конференции "Астрономические исследования: от ближнего космоса до Галактики" (НАО190), которая проходила с 26 по 29 сентября 2011 г. в Николаеве (Украина) в Научно-исследовательском институте "Николаевская астрономическая обсерватория". Конференция состоялась при поддержке Государственного агентства по вопросам науки, инноваций и информатизации Украины, Украинской астрономической ассоциации, при содействии и помощи Облгосадминистрации и городской мэрии г. Николаева. В конференции приняли участие более 50 специалистов из 14 астрономических учреждений и обсерваторий Украины, России, Франции и Китая.

В настоящий сборник вошли обзорные статьи по направлениям научных исследований, проводимых в НАО в течение последних 20 лет, которые были представлены в докладах на конференции НАО190. Они включают изучение объектов ближнего космоса, результаты наблюдений малых тел Солнечной системы, создание каталогов положений звезд, использование информационных и виртуальных технологий в астрономии, астрономическое приборостроение. Широкое освещение получили вопросы международного сотрудничества, проводимого Николаевской обсерваторией в последние десятилетия с коллегами из Шанхайской астрономической обсерватории (Китайская Народная Республика), а также в рамках международного проекта по наземному сопровождению космического аппарата GAIA с астрономами из Франции, Турции и России. В ряде статей отражены историко-астрономические исследования, проводимые в НАО, в частности, о многолетней связи двух известных астрономических династий Струве и Кнорре на основе архивов Пулковской и Николаевской обсерваторий, архивов РАН и ВМФ, а также личных архивов потомков В.Я. Струве и К.Х. Кнорре.

Мемориальная часть книги посвящена высокоширотной научной экспедиции Николаевской обсерватории на остров Западный Шпицберген, которая работала в 1974-77 гг. В ней собраны воспоминания и дневниковые записи участников, которые раньше не публиковались.

Предлагаемый вниманию читателей сборник является логическим продолжением вышедшего в 1998 г. сборника “Николаевская астрономическая обсерватория. Звездный путь длиною в 175 лет”, в котором впервые за историю обсерватории были описаны различные стороны ее деятельности на протяжении 175 лет. Впоследствии эта тематика была расширена серией биобиблиографических сборников, посвященных директорам и выдающимся личностям в истории НАО, которая в настоящий момент насчитывает семь книг на четырех языках.

Мы надеемся, что данное издание будет интересным для читателей и займет достойное место среди книг, посвященных истории Николаевской астрономической обсерватории.

Г.И. Пинигин, директор НИИ НАО

The collaboration between ShAO and NAO: Celebration of the 190th anniversary of NAO

Wenjing Jin [1], Gennadiy Pinigin,
Zhenghong Tang [1], Alexander Shulga

History of ShAO and NAO

ShAO of the Chinese Academy of Sciences (CAS), is the amalgamation of the former Zi-Ka-Wei and Zô Cè observatories, which were founded by the French Mission Catholique in 1872 and 1900, respectively. Before December 1950 two observatories belonged to Purple Mountain Observatory (PMO) and in August 1962 ShAO was established. A 40 cm double astrograph, which was the largest telescope in East Asia at that time, was installed in 1900 on top of Zô Cè hill. It was one of a few telescopes in the world used to observe Halley's comet in both 1910 and 1986. The outstanding works such as determination of proper motions of RR Lyrae variable stars, determination of proper motions of some faint stars in KZS catalogue (KZS means the first word of Katalog Slabykh Zvezd in Russian) etc. were obtained. Besides, before 1988 the instruments such as Danjon astrolabe, photoelectric transit, photoelectric astrolabe (type II) were also operated for study of Earth rotation parameters, compiling star catalogue etc.

At end of the 1970s the new techniques such as SLR, VLBI etc. were developed. The first SLR station was set up at ShAO in 1975. In August 1983 a new telescope with 60 cm aperture, which was the second generation system, was regularly operated and attended the MERIT (Monitoring of Earth-Rotation and Inter comparison of the Techniques of Observation and Analysis) campaign. In December 1985 many improvements such as automatic tracking with computer, Nd:YAG laser with mode lock and high power were made. It was the third generation system of SLR. The accuracy was ±5~6 cm. In December 1991 the observations of ranging to LAGEOS in daytime was successful (SLR group, 1993) and the accuracy reached to ±2~3 cm in May 1992. Since July 2009, a New kHz Laser which repetition rate, energy, wavelength, pulse width and diverge are 1 kHz, 2-3 mJ per shot, 532 nm, 15 ps and 0.5 mrad respectively, has been used. After November 1987, a 25 m radio telescope, as a station for the Chinese VLBI (Very Long Baseline Interferometry) network, and a 1.56 m optical telescope have been operated regularly. Currently a new radio telescope of 65 m is being fabricated and will be operated in 2012. Because of the light pollution the new optical observation base is at

1 - Shanghai Astronomical Observatory, Shanghai, China

“Jiang-Nan-Tian-Chi”, which is located at Tian Huang Ping, Zhejiang Province and is 175 km away from ShAO headquarter. These facilities are in frequent usage today for many research work on the fields of astrophysics, astrometry, geodynamics and so on.

There were three periods of the developing history for NAO. The first period was in 1821-1911. One of the older observatories of Eastern Europe, was founded in 1821 by Admiral A. Greig as the Naval Observatory to provide the Black Sea Navy with charts, to train mariners in astronomical navigation, and to certify the navigation equipment. Astronomical work such as compilation of star maps and catalogues, positional determinations of comets and planets was started.

In 1912-1991, NAO was one of southern departments of the famous Pulkovo Observatory (St. Petersburg, Russia). During this period the observatory had to spread the system of Pulkovo absolute star catalogue to southern sky and carried out regular observations of the Sun and the solar system bodies. The time service of NAO was founded in 1931 to take part in international programs of time determination and to provide high-precision time signal for astronomical observations. Visual and photographic observations of the Earth artificial satellites were carried out in 1957-1969. In 1970-1990, the observatory was an initiator and principle organizer of several scientific expeditions with the aim of observations under polar night conditions in Western Spitsbergen Island and under high-latitude conditions in the North Caucasus. Positional determinations of stars in Nikolaev were included in international series of fundamental catalogues with high accuracy. Long-term series of observations of the solar system bodies were taken as a foundation of a new relativistic theory of planet's motion. More than thirty-five catalogues were compiled.

The third period is from 1992 to present. NAO becomes an independent scientific organization. During the last decade, two main directions of scientific activities, positional determinations of the celestial bodies and astronomical instrument making, are formed in NAO. Considerable experience is gained in these fields. At present four CCD instruments: Axial Meridian Circle (AMC), Multi-Channel Telescope (modernized Zonal Astrograph), Fast Robotic Telescope (FRT) and Mobile Telescope (KT-50) are operated regularly for observations.

Collaboration between ShAO and NAO

In August 1979 the seat of Chinese Astronomical Association (CAS) was restored at the International Astronomical Union (IAU) during the 17th IAU General Assembly. Since then Chinese astronomers have attended various meeting organized by the IAU and exchange scientific view with many astronomers from various countries. Many astronomers visited Purple Mountain, Shanghai, Beijing, Yunnan and Shaanxi Astronomical observatories as well as some departments of astronomy in universities in China. Chinese astronomers visited and worked with astronomers as visit scholars in other countries. The agreements of collaborative research have been curried out between China and other countries.

In December 1993 Professor Pinigin, the director of NAO visited Shaanxi and Shanghai Astronomical observatories. During this visit astronomers in both sides have changed scientific view and discussed the collaboration on "Reference System", a topic in the frontier of astrometry. Then, the first collaborative agreement from October 1996 to December 1999 was signed by the directors of ShAO and NAO in October 1996 after Dr. Shuhe Wang attended the International Conference "The Role of Ground-Based Astrometry in Post-Hipparcos Period" dedicated to 175th anniversary of NAO in September. Since then the exchange of visitors is frequent each 2-3 years.

In June 1999 Professor Wenjing Jin and Dr. Wang visited NAO and took part in the International Conference "Research of the Solar System Bodies by CCD Methods" and the conference devoted to the 90th anniversary of Evgenii P. Fedorov at Kiev. During this visit the statue of implementing the first agreement was reviewed and the second agreement (1999-2002) was suggested and prepared. Then, it was signed by directors. The first collaborative project "Angles refinement of connection of radio and optical reference frame on basis CCD observations for optical counterpart of radio sources" was implemented during October 1996 - December 2003. The positions of optical counterpart of extragalactic radio sources (ERS) were determined by ShAO using several telescopes in China, such as 1 m telescope at Kunming and 2.16 m telescope at Beijing. The catalogue of second reference stars around the ERS was complied by NAO using observations of Axial Meridian Circle (AMC). The papers, containing the intermediate results, written by Kovalchuk et al. (1997), Tang et al. (2000), Pinigin et al. (2000), and so on were published. With time this project is expanded to Russia and Turkey.

The agreement with new content, which is interesting for both scientists, is re-signed by directors every three years. In November 2003, Dr. Shulga, vice director of NAO, and Dr. Protsyuk visited ShAO. The first collaborative project was almost finished. The astronomers of both sides were interested on the observations of NEOs (asteroids, satellites, spacecrafts and space debris). The CCD drift-scan technique will be used to observe NEOs. Besides, China and Ukraine are members of the Inter-Agency Space Debris Coordination Committee (IADC) which is an international governmental forum for the worldwide coordination of activities related to the issues of man-made and natural debris in space. They are responsible for collection and distribution of data on space debris. In order to determine precisely the orbit of NEOs and monitor them the observing network is necessary and the test was curried out. The third agreement of collaborative project on “Manufactory, Installation and Application of CCD Drift Scan Technique”, was implemented during January 2004 - December 2006.

During November 21-30, 2005, Prof. G. Pinigin and Dr. A. Shulga, were invited to visit ShAO and a new agreement (2006-2008) was signed by Directors of ShAO and NAO on November 30, 2005, which covers some new research fields.

In order to search the NEOs in all direction of the sky the rotating CCD camera in drift-scan mode should be useful. The first discussion on this topic was on September 19-28, 2006, when Drs. Zhenghong Tang and Yong Yu of ShAO were invited to visit NAO and took part in the international conference “Enlargement of collaboration in ground-based astronomical research in SEE countries: Studies of the near-Earth and small bodies of the solar system” (SEE means South East Europe). Then, Drs. Shulga and Yevgenia Sybiryakova, a young scientist of NAO, were invited to visit ShAO during November 8-22, 2008, the latest collaborative project on “Joint observation of space debris with rotating CCD drift-scan camera”, i.e. the fifth collaborative agreement from January 1, 2009 to December 31, 2011, was discussed and signed by directors. This project is being implemented now.

According to these agreements about exchange visitors during 1996-2010, Drs. Yindun Mao, Yan Li etc. from ShAO and Drs. Alexander Kovalchuk and Yevgen Kozyryev from NAO visited and worked at collaborative observatories, NAO and ShAO respectively.

Scientific results from collaboration

(1) Link between optical and radio reference frame

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. The details are listed in tabl. 1. In addition, there were 8 fields around ERS (Extragalactic Radio Sources) obtained on RTT150 with CCD AP-47p of size 1024×1024 pixels (FOV = 4'×4'), and 6 fields around ERS obtained on 2.16 m telescope of National (Beijing) Astronomical Observatory with a CCD of size 2048×2048 pixels (FOV = 10.5'×10.5').

Table 1

Telescopes and CCD cameras

Telescope	RTT150, TUG	1.0m YAO
Location	Antalya, Turkey	Kunming, China
Coordinates (λ, φ)	+30°20', +36°49'	+102°47', +25°02'
Height, m	2500	1000
D (mm) / F (mm)	1500 / 11600	1000 / 13000
CCD	ST8[a], AndorDW436	TI
Size, pix	1530x1020, 2048x2048	1024 x 1024
Pixel, mkm	9 x 9, 13.5 x 13.5	24 x 24
Scale, arcsec/pix	0.16, 0.24	0.37
FOV, arcmin	4.1 x 2.7, 8.2 x 8.2	6.5 x 6.5

One of the main problems in astrometric reductions in these small fields was the absence of reference catalogues with precise positions and proper motions. In small CCD fields, one can not use such well-known catalogues with low star density as Hipparcos, TYCHO, or TYCHO2. The first reduction of our observational data was made with USNO catalogues (version USNO A2.0 and USNO B1.0) as reference catalogues. Results of the reduction with reference stars from USNO B1.0 catalogue showed large systematic errors of about 200 mas in declination. Due to their low precision, the optical stellar positions from these catalogues can not be used to refine the link parameters between the radio and optical systems. The UCAC2 and 2MASS are more accurate catalogues, which have made possible to partly re-process the available observational data. But it should be noted that the UCAC2 has not enough star density to be used as a reference catalogue in small CCD fields and the distribution is not over the whole celestial sphere, only till 48º (somewhere -52º) in northern declination. On the other hand, the 2MASS catalogue has no proper motions. But the mean epochs of 2MASS catalogue and our optical observations are very close to 2000. This is why 2MASS is used here as reference catalogue for precise reduction of optical positions.

Table 2

A comparison between the measured optical positions referred to reference stars from UCAC2 and 2MASS catalogues and the radio positions from the current ICRF list

Reference Catalogue	(O-R) in RA, mas in mean (Cat-ICRF)	(O-R) in DEC, mas in mean (Cat-ICRF)	N *
UCAC2	-4 ± 5	15 ± 4	130
2MASS	9 ± 6	27 ± 6	182

* - Some ERS are observed at more than one telescope

Finally, the optical positions of the 126 ERS in the declination zone $-30° \leq \delta \leq 50°$ were measured with respect to the UCAC2 as reference catalogue and positions of 171 ERS in the declination zone $-40° \leq \delta \leq 80°$ 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 and 2MASS catalogues and the radio positions from the current ICRF list are given in tabl. 2.The estimation of the link parameters values between optical and radio reference frames has shown that orientation angles are near zero within their accuracy about 5 mas. The link accuracy becomes 3 mas when the observations are combined with other studies (Aslan et al. 2010).

(2) CCD drift- scan technique

In July and August 2006 the observations of GEO satellite were tested by using 20 cm Maksutov telescope with CCD of size 1160×1040 pixels in stare mode and drift scan mode at ShAO. Not only the good circular images of reference stars and GEO satellite, but also positional coordinates of objects with high precision were obtained. The total internal errors of optical positions were 0.2"~0.4" (Mao et al., 2007).

(3) Optical observations with Ukrainian-Chinese network

This project is directed towards creation of the first Ukrainian-Chinese network of optical telescopes for observations of the Space Debris on the low orbits (less than 2500 km). The telescopes are equipped with the short focus objectives and sensitive Watec CCD cameras in TV mode. A list of telescopes is given in tabl. 3.

Table 3

Ukrainian-Chinese network

Institute	Telescope	Aperture, mm	Focal ratio	FoV
RI NAO	FRT	47	1.8	4.2° × 3.2°
RI AOONU	KT-50	500	2.5	0.24° × 0.18°
AOLNU	TPL1M	100	2.5	1.5° × 1.1°
LSRUNU	TPL1M	49	1.5	4.2° × 3.2°
ShAO		47	1.8	4.2° × 3.2°

Orbit modeling of the Earth artificial satellite taken from the USSTRATCOM (United States Strategic Command) catalogue in observation zone of the network has shown that up to 1000 from 10500 objects can be tracked with a period of data update not more than 10 days. It allows that a forecast accuracy, which is not worth than in the USSTRATCOM catalogue, is obtained. The observations have shown that used equipment allows us to observe objects with reflective square of 0.1 m^2 and mass of 50 kg.

During the first observational campaign held in 2009, measurements were carried out by two methods: TV and stare modes, along all visible orbital arcs, in the limited sky zone with the largest density of objects. The first method is aimed at obtaining of maximum data volume to estimate the highest possible accuracy of orbit determination. The second method is designated to estimate a possibility of catalogue maintenance and enlargement for observations with several static telescopes. A quality of measurements for orbit improvement and the forecast accuracy for each method were estimated (Shulga et al. 2010).

(4) Rotating CCD drift-scan technique

Normal CCD drift-scan system is often used to survey the sky and to get images of stars in the time-delay and integrate (TDI) mode at the apparent sidereal rate. With CCD drift-scan camera, the track of stars can be realized even when the telescope keeps idle state. The orbits of middle and low orbit space debris are in different directions. To observe these objects for a long exposure, a CCD drift-scan camera needs to be rotated to make the direction of a pixel line parallel to the orbit of the object which also has bad prediction. Since the drift-scan mode can track objects for some time, the small telescopes with CCD in rotating drift-scan mode can catch small and faint space debris. The first test using a prototype telescope (D = 10 cm, F = 50 cm,

Table 4

The parameters of telescope and rotating CCD camera

Optical parameters of telescope		Parameters of the CCD camera	
Parameter	Value	Parameter	Value
Aperture	300 mm	Chip	Kodak KAF-09000
Focal length	250 mm	Number of pixels	3056 × 3056
Plate Scale	825.1 "/mm	Pixel size	12 μm × 12 μm
FoV	8.35° × 8.35°	Pixel Scale (Binning = 2)	20"
FWHM	30"	Dark curret	0.3e-/pixel/sec
Point accuracy	10'	Operating temperature	-20°C
Moving speed in AZ	14.4 °/sec	Photosensitive ares	36.7mm×36.7mm
Moving speed in EL	10.4 °/sec	Limiting Magnitude *	11.2 mag (SNR=5.7) 1sec
Rotating speed	3.14 °/sec		11.4 mag (SNR=3.1) 1sec

* - If the aperture of 15 cm and Binning 2 are used, it could detect the object in 12.7 mag (SNR = 5.7) in a dark sky background (19 mag)

FoV = 4×4 deg^2) mounted at 1.56 m telescope with CCD camera (Apogee U9000) in rotating drift-scan mode was implemented in October 2007 and some preliminary observational results such as observing COSMOS 2289, COSMOS 2275, LEO 14521 in altitude 19 000, 19 000, 1526 km respectively are given. It is shown that a space debris with size of 10×10 cm^2 using a telescope of D = 400 mm and F = 600 mm equipped with a Alta U9000 CCD can be observed (Tang et al. 2010).

In order to make observations regularly 2 sets of telescopes with rotating CCD camera (type Alta U9000) are fabricated. The optical parameters of ShAO telescope and CCD camera are listed in tabl. 4.

On Nov. 25 – Dec. 6, 2009 the AJISAI (Japanese satellite) with size 2 m and COSMOS 2439 (one of Russian civilian relay satellites) with size 60 cm in altitude of 1500 km were observed successfully (Tang et al. 2009).

Future prospect of collaboration

The collaboration between ShAO and NAO has near 15 years. Both observatories have longer development of history and research work on astrometry. Based on their duty from the State Scientific and Technological Commission or State Agency on science, innovation and information of Ministry for Education and Science of Ukraine and current operating instruments, the following projects will be suggested and cooperated in the future.

(1) After the first campaign with Chinese-Ukrainian network of optical telescopes for observations of the Space Debris on the low orbits, these observations will be carried out regularly. Professor Zhu, Drs. Zhang and Tang of ShAO discussed in more detail about the construction of optical telescopes network with Ukrainian astronomers from Nikolaev, Odessa, Lviv and Uzhgorod Astronomical Observatories on May 22-26, 2010, after the International Workshop "Methods and Instruments in Astronomy: From Galileo Telescopes to Space Projects", held at NAO, on May 18-21, 2010. Following the previous collaborative work and the Meeting Minutes of "Construction of Chinese-Ukrainian Space Monitoring Network", the network will be extended to more and bigger telescopes and able to monitor small space debris to obtain its position and photometry jointly.

(2) ShAO and NAO are the member of IAU working group "Astrometry by Small Ground-Based Telescopes" in Division I (Fundamental Astronomy) which was initiated during the XXVIth General Assembly of the IAU in Prague, in August 2006 and has been extended for a new triennium at the XXVIIth IAU General Assembly held in Rio de Janeiro in August 2009. Both observatories also are the members of working group "Gaia Follow-Up Network for Solar System Objects (Gaia- FUN-SSO)" in the Coordination Unit 4 of the Gaia Data Processing and Analysis Consortium (DPAC) , which is one of three ground-based networks distributed in longitudes and latitudes for Gaia. There are two distinct objectives for the collaboration: (a) the observations of Solar System Objects (SSO) by the space astrometry mission Gaia will be constrained by a scanning law. Several detections of interesting objects may be done with no possibility of further observations by the probe. These

objects will then require complementary ground-based observations. It will provide orbits to avoid loss of newly discovered objects by Gaia based on observations in a short time-scale basis, (b) it will allow better characterization of new objects and selected targets (asteroids, possibly comets, planetary satellites), such as the determination of asteroid mass or the Yarkovsky effect based on astrometric and photometric observations in a longer time-scale. In particular, the observations of the Gaia satellite itself can be performed to provide the orbitography of the observing platform to the precision required by the DPAC data-reduction pipeline.

(3) Both observatories have studied on astrometry in a long term period. Some projects, such as extension of the observations to the South declination zone and observations of faint stars (17-19 mag) for determination of the Solar apex, discovering the companion star of binary or multiple star, determination of proper motion in GSCII catalogue with high precision etc., are interesting for both astrometists (Jin, 2010).

(4) Both observatories have long history in photographic astrometry (Jin et al, 1998). Many photographic plates are accumulated. The Working Group on the Preservation and Digitization of Photographic Plates (PDPP) in IAU Commission was initiated in 2000 and maintained to now. ShAO is the center of preserving and digitizing photographic plates in China. About 30 000 plates have been preserved in a half underground room under the observing room of 40 cm refractor at Sheshan section with air condition and humidity controlled (Jin et al., 2007).

This work will be divided two steps. One is complication of plate archive with unified format and materials will be entered to International Wide Field (>1°) Photographic Database (WFPDB) at Institute of Astronomy and National Astronomical Observatory Rozhen, Bulgarian Academy of Sciences, Sofia, Bulgaria. Another work is plate digitization. It will be tested with commercial scanner. A large number of plates will be digitized step by step, but the plates along ecliptic zone and some plates including some interesting targets will be measured firstly. After plate digitization the material will be released on the Virtual Observatory (Protsyuk et al., 2008, Cui et al, 2008). Some projects will be curried out with these material and current new measurements in collaboration.

Because of the collaboration between ShAO and NAO near 15 years the collaboration will be expanded to other observations in China and Ukraine. The following topics will be under consideration.

(1)SLR Network

From the end of 80's to the end of 90's last century the Chinese SLR network including Shanghai, Wuhan, Changchun (Liu et al., 1996), Beijing, Kunming (Jiang et al., 1996) and two mobile stations was established and the network of Ukraine includes Golosiiv-Kiev, Lviv, Simeiz and Katzively stations. These stations are being operated regularly and attend the ILRS (International Laser Ranging Service). It is useful to improve the orbital parameters using observational data, especially less observations due to the bad weather, because of this set observatories distributed in longitudes and latitudes widely.

(2) VLBI

The Chinese VLBI network includes Shanghai (25 m), Beijing (50 m), Urumqi (25 m), Kunming (40 m) and one mobile station (1 m). The larger radio telescopes, such as 65 m at ShAO etc, are being fabricated. There are some radio telescopes in Ukraine, such as RT-70, one of three 70 m radio telescopes and planetary radars set up by the former Soviet, at the Center for Deep Space Communications, Yevpatoria (Yevpatoria is sometimes romanized as Evpatoria), Crimea. If these stations, expanding the distribution in longitudes and latitudes, especially in longitude, join together, it is useful for deep space exploration and determination of the orbit of spacecraft, space debris and asteroids as well as the radio astronomical science.

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