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UPGRADED 1 METER TELESCOPE AND SCIENCE PROJECTS

Shuhrat A. Ehgamberdiev[1], Alisher S. Hojaev[1], Gang Zhao[2,3] , Zhou Fan[2], Xiaojun Jiang[2,3], O. Burkhanov[1], Wei Wang[2,7], Yu-Qin Chen[2,3], Yu-Juan Liu[2], Jing-Kun Zhao[2], Jie Zheng[2,3], Ke-Feng Tan[2], Wei He[2,3], Hai-Ning Li[2], Yi-Han Song[2], Jiang-Feng Wang[2], Xiao-Ming Zhang[2], Liang Ge[2], Xian-Qun Zeng[2], Zhi-Gang Hou[2], Jin-Hu Wang[2], Lu Ma[4], Ali Esamdin[4], Jinzhong Liu[4] , Richard Green[5], Guo-Min Wang[6], Zhi-Yong Zhang[6], Jin Xu[6], Liang Chen[6], D. Mirzakulov[1], R. Karimov[1], Q. Yuldoshev[1]

[1]Ulughbeg Astronomical Institute, Uzbek Academy of Sciences, Tashkent, Uzbekistan
[2]National Astronomical Observatories, Chinese Academy of Sciences, China
[3]School of Astronomy and Space Science, University of Chinese Academy of Sciences, China
[4]Xinjiang Astronomical Observatories, Chinese Academy of Sciences, China
[5]Steward Observatory, University of Arizona, USA
[6]Nanjing Institute of Astronomical Optics & Technology, Chinese Academy of Sciences, China
[7]Chinese Academy of Sciences South America Center for Astronomy, National Astronomical Observatories, Chinese Academy of Sciences, China
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Мақолада ЎзР ФА Астрономия институти Майданак обсерваториясининг 1 м телескопи ва асбоб-ускуналарининг ҳозирги ҳолати, шунингдек обсерваторияда бажарилаётган илмий лойиҳаларнинг тавсифи келтирилган. Обсерваториянинг 1 м Карл Цейсс (Германия) телескопи реконструкция қилинди. Телескопнинг барча тизимлари замонавий андозалар асосида тўлиқ модернизация қилинди ва модернизациянинг асосий натижалари ушбу мақолада ёритилди. Модернизация бўйича ишлар, шунингдек мазкур лойиҳа бўйича бажарилган илмий тадқиқотлар ЎзР ФА Астрономия институти билан ХХР фанлар академияси Миллий астрономик обсерваторияси ҳамкорлигида ушбу ташкилотлар ўртасидаги битим доирасида амалга оширилган. Телескопнинг кўриш майдони кенгайтирилди ва янги ЗАҚ камераси ўрнатилди. Кузатишларни такомиллаштириш учун телескоп билан боғланган кузатув жараёнини мониторинг қилиш тизими ва фотогальваник станция каби қўшимча асбоб-ускуналар яратилди. Телескоп ва янги камера 1 м телескопнинг илмий лойиҳаси учун текширилади ва фойдаланилади. Ҳамкорлик тўғрисидаги битимга мувофиқ, махсус фотометрик тизимдаги (юлдузларнинг кимёвий таркиби ва Галактика эволюцияси (SAGE) шимолий осмоннинг тўлиқ обзори бўйича кенг қамровли илмий лойиҳа модернизация қилинган 1 м телескоп ёрдамида бажарилади. Лойиҳанинг асосий мақсади шундан иборатки, 500 миллиондан ортиқ FGK юлдузларнинг атмосферасини параметрлари ўлчанади. GRB, SNe ва ўзгарувчан юлдузлар каби тайм-домейн тадқиқотлар ҳам қўшимча лойиҳалар сифатида бажарилади.

В статье представлены современное состояние 1 м телескопа Майданакской обсерватории Астрономического института АН РУз, связанных с ним инструментов и оборудования, а также выполняемые на нём научные проекты. Проведена реконструкция 1 м телескопа Карла Цейсса (Германия). Все системы телескопа полностью модернизированы на основе современных стандартов, и основные результаты модернизации описаны в статье. Все работы по модернизации и научные исследования по этому проекту выполнены в тесном сотрудничестве АИ АН РУз с Национальными астрономическими обсерваториями АН КНР в рамках соглашения по сотрудничеству. Поле зрения телескопа увеличено и установлена новая ПЗС-камера. Для поддержки наблюдений создано дополнительное оборудование, связанное с телескопом, такое как система мониторинга процесса наблюдения и фотогальваническая станция. Телескоп и новая камера будут проверяться и использоваться для научных проектов 1 м телескопа. Согласно

соглашению о сотрудничестве, крупномасштабный научный проект по полному обзору северного неба в специальной фотометрической системе – обзор по звездному химсоставу и галактической эволюции (SAGE), будет выполнен с модернизированным 1 м телескопом. Главная цель проекта состоит в том, чтобы измерить параметры звездных атмосфер для более 500 миллионов FGK звезд. Тайм-домейн исследования, а именно GRB, поиск SNe, переменные звезды, будут выполнены в качестве дополнительных проектов.

The article presents the latest status of the Maidanak 1 m telescope, instruments and the related facilities of the Observatory as well as the science projects. The renovation of the 1 m telescope of Carl Zeiss (Germany) at the Maidanak observatory of the Ulug Bek Astronomical Institute (UBAI) AS of Uzbekistan has been made. All systems of the telescope were completely modernized based on modern standards, the main results of modernization are also described. All modernization works, as well as scientific research on this project are carried out in close cooperation of UBAI with the National Astronomical Observatories of the Academy of Sciences of the PRC in framework of the Agreement on cooperation between these organizations. The FOV has been enlarged and new CCD camera is mounted. The related facilities, like the observing circumstance monitoring system and the photovoltaic station, are also built for the observing support. The telescope and new camera will be tested and used for the science projects of the 1 m telescope. According to the collaboration agreement, a large-scale scientific project on a full survey of the northern sky in special photometric system - Stellar Abundance and Galactic Evolution (SAGE) survey will be carried out with the upgraded 1 m telescope. The main goal of the project is to measure the stellar atmospheric parameters for more than 500 million FGK stars. As other projects, the time domain science, like GRB, SNe searching, variable stars, also will be performed.

I. INTRODUCTION

Multi-band all-sky surveys, especially in intermediate and narrow band systems, are among worthwhile projects of observational astronomy and astrophysics. A few years ago, such a survey has been started by the National Astronomical Observatories of the Chinese Academy of Sciences (NAOC) in the special photometric system similar to the Strömgren-Crawford, SDSS, DDO systems. The idea to involve Zeiss-1000 telescope of Maidanak Observatory of Astronomical Institute named after Ulugh Beg of Uzbek Academy of Sciences (UBAI) was arisen in the frame of the Agreement between the People's Republic of China and the Republic of Uzbekistan on "Development of cooperation in fundamental and applied research in astronomy between the Academies of Sciences of the two countries".

The Maidanak Observatory is a unique scientific astronomical observatory in terms of its geographical location and astro-climatic indicators, which were explored during more than forty years. The observatory, with over 2000 clear night hours per year and excellent stability and quality of the resulting images of stars with an average of about 0.7 seconds of arc (the last measurements were summarized in [1]), can confidently compete with the observatories of ESO in Chile and with observatories in the Hawaiian and Canary Islands.

The second telescope of the observatory by main mirror diameter is 1 m Zeiss-1000 telescope observations on which started in 1981. Its location within area of the observatory is shown in Fig. 1. In summer and autumn (June–November) the stellar photometry, mainly in the medium-band Vilnius photometric system, was conducted and in the winter some spectroscopy and radial velocity measurements were made (see, e.g., [2-5]). Some photometric observations of close binary stars, especially the contact ones and binaries in star forming regions were made in UBVRI system. Moreover, during the impact of S-L/9 comet with Jupiter in 1994 the speckle-imaging observations were carried out as well [6].

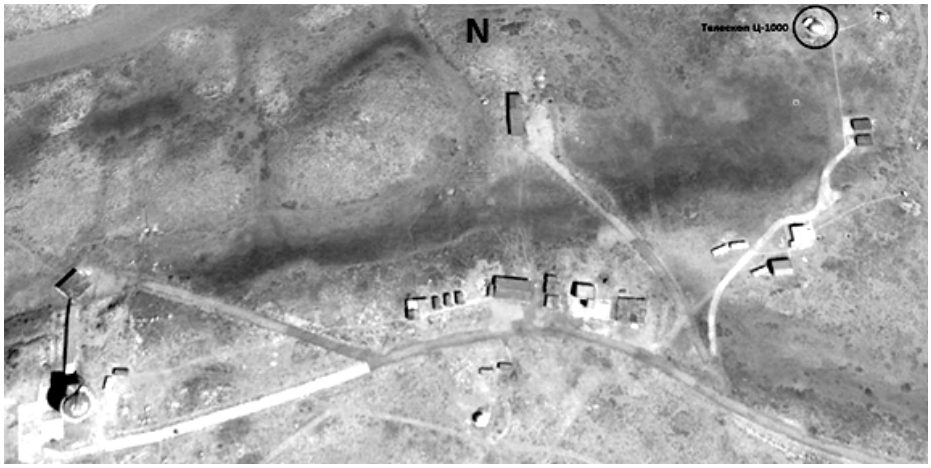


Fig. 1. Aerial view of the Maidanak Observatory: the Zeiss-1000 telescope is in black circle at the N-E part (top right).

Naturally, the telescope electronics, mechanics, optics, dome became old and outdated during this time thus making observing inefficient. In 2001-2005 the first renovation of Zeiss-1000 telescope was made funded by Taiwan-Baltic collaboration [7-9], however it has been able to cover only the computer control system and synchronizing the dome. The project of full large-scale renovation of the telescope has been realized recently jointly by NAOC and UBAI in the frame of aforesaid agreement.

II. LARGE-SCALE RENOVATION OF 1 METER ZEISS TELESCOPE

Works on the total modernization of the Zeiss-1000 telescope and the launch of the photovoltaic station (PVS) were carried out in cooperation with the National Astronomical Observatories of the Chinese Academy of Sciences (NAOC). This cooperation is carried out within the framework of the Strategic Partnership Development Program between the Republic of Uzbekistan and the People's Republic of China, which stipulates "Development of cooperation in fundamental and applied research in astronomy between the Academies of Sciences of the two countries".

II.1. Major Overhaul and Modernization of Mechanics and Electronics of Zeiss-1000 Telescope

The large-scale modernization was carried out on all parts of the telescope ansamble, including its optics, mechanics, control system, dome (tower), etc. Because of modernization, obsolete mechanics, electronics and telescope control engines were replaced, and remote telescope control via a personal computer become available. The view of the renovated Zeiss-1000 telescope and its dome is presented in Fig. 2.

It is important to note that remote control of equipment from a PC without the need for a person in the building, makes it possible to significantly reduce energy consumption for heating and ventilation. The lack of heat generation in the telescope building as a result of heating itself, as well as the economical operation of new electronic equipment and engines, leads to a decrease in thermal turbulence and better astronomical images on the telescope.

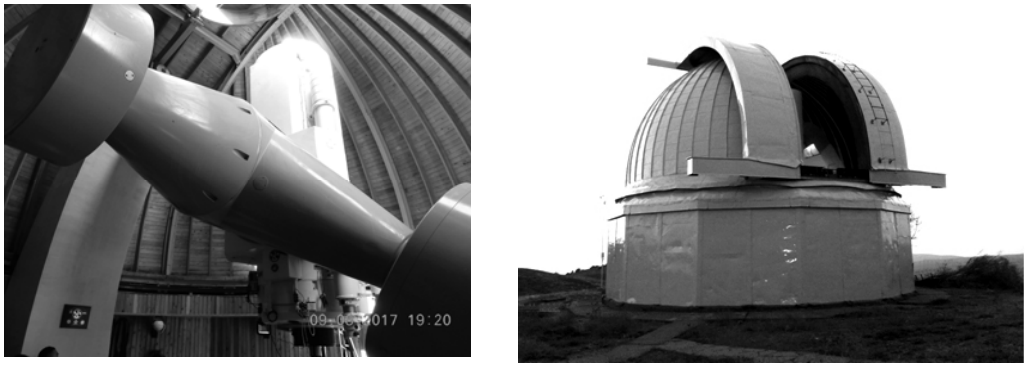


Fig. 2. The common view the Zeiss-1000 telescope (left panel) and the dome (right panel) after the renovation completed.

The astronomical optical telescope usually includes three main components that require certain energy consumption. The first is the telescope itself with two-axis rotation motors, an hourly drive engine and an electronic control unit. The second is the telescope tower with the dome rotation motor, the valve opening engine, the dome ventilation motors and the heated observer room. The third is a telescope attachment with control electronics such as a CCD camera, a spectrograph and computers for obtaining observational data.

The astronomical optical telescopes of the Maidanak Observatory being as equipment which is balanced and mobile in two axes, theoretically require minimal power for their movement, and have a great potential for energy-efficient modernization with the possibility of autonomous minimum energy consumption. With a good balance of the telescope, the main energy is spent on overcoming the inertia of the mass, for moving the mount and pointing the telescope tube to a certain area of the sky. We should also note that the power consumption and power of the engines of telescopes designed in 1970-1980 was determined by the level of technology at that time and technical requirements for high speed with acceptable accuracy of guidance (for observations of rapidly moving celestial bodies, comets, artificial satellites, etc.). For example, 1.5 m AZT-22 telescope and 1.0 m Zeiss-1000 telescope are belonging to such energy-intensive telescopes.

If the telescope is using for scientific observations in a calm mode according to predetermined programs and the targeted objects are stable on the celestial sphere, with a total number of 15–25 objects per night, then there is possible to significantly reduce of the telescope energy consumption by replacing obsolete engines with more economical, servo-motors with digital control.

Such a modernization also has a great potential for further remote control of the telescope at a remote distance without the direct observation of the observer under the telescope dome or in the observer's room near the telescope tower and, thus, not creating local heating deteriorating the quality of observations. So, for example, for the Zeiss-1000 telescope for only one axis of Right Ascension, the manufacturer installed 4 different engines with a complex system of mechanics and gearboxes, which are now replaced by a modern digital servo drive.

The very nature of obtaining high-quality and stable images from optical telescopes requires a minimum, or zero, heat generation created and accumulated by the telescope, dome, equipment and observer, i.e., ideally the whole telescope during the observations

should be "cold", and not differ from the ambient air temperature outside the dome thereby not creating thermal turbulence for the deteriorating images of the observing stars. Since the Maidanak Observatory has good astro-climatic parameters with minimal turbulence of the atmosphere above the observatory, telescopes and equipment should not significantly degrade these stability indicators by generating heat pullutions and turbulence from engines, equipment and the observer's room, as well as heating the dome in the daytime.

Let us consider the main possibilities of energy efficient modernization of astronomical telescopes given in continuous numbering mode. For the telescope mechanics they are following:

– replacement of old and installation of new more economical engines on the axes of Right Ascension (α axis) and Declination (δ axis) of the telescope with external control electronics to provide only the medium and low telescope guidance speed with speed values in range of 5–15° per minute. The possible reduction of energy consumption might reach up to 70–80%.

– replacement of the telescope hour angle movement engine for an engine with a lower operating voltage or the use of a newly installed direct-axis motor for this purpose in the case of its smooth running sufficient for celestial body guidance with the possible reduction in energy consumption by 5–10%.

For the tower and dome of the telescope they are following:

– replacement of engines for the dome rotation and opening of dome flaps to low-power engines with additional gears. The possible reduction in energy consumption is estimated of 40–50%.

– the paint coating of the tower and dome outer area using an atmosphere-resistant, ultra-white color with maximum reflection of solar thermal radiation to reduce energy for conditioning and cooling the dome inner space leading to the possible reduction in energy consumption by 40–50%.

For the observer room and telescope control they are following:

– the isolation of observer's room with heating systems and locate it apart of the dome inner space and providing the remote control of several telescopes simultaneously from one room. The possible reduction in energy consumption estimated up to 50–80%.

– the ensuring of the telescope operation in an autonomous, robotic mode without human intervention. We estimate a possible reduction in energy consumption by 80–90%.

– the effective observation planning with sequential observation of closely located objects of various observing programs could lead to the possible reduction of energy consumption by 10–20%.

We note once more that the main advantage for carrying out astronomical observations in the Maidanak Observatory is the high quality of the obtained images at seeing < 1.0 seconds of arc, which makes it possible to compete with the leading foreign optical observatories worlwide. Therefore, for this purpose, the use of additional modern systems for improving of the image stability and creation of conditions for ensuring its high quality should be justified on such telescopes. For these purposes the increase of additional ventilation power and establishment of automatic control of natural and forced ventilation of the dome inner space, as well as the use of digital and optical image stabilization systems such as adaptive optics (AO), autofocusing (AF), auto-hydration system (AG) and others.

In turn, these procedures may lead to an increase in energy consumption up to 10–30% on the contrary to the measures of energy-efficient modernization. But this is quite justifiable, if it is possible to significantly improve the quality of astronomical images obtained at the Maidanak Observatory and increasing the possibility of participating in the leading international monitoring projects.

II.2. Creation and Instalation of Photovoltaic Station

During the installation of the PVS, the engineering and technical work has been carried out to install the photovoltaic panels of YEG-72 CELL model from the manufacturer YINGLISOLAR (China), the electronic transformation and control system as well as the bank of 6-GFMJ-200 type (12 V, 200 Ah) helium batteries with the total working capacity of 43 kWh. The entire PVS system was also connected, configured and started in a test mode of 10 kW with solar power supplied by the PVS to the upgraded Zeiss-1000 telescope (Fig. 3).

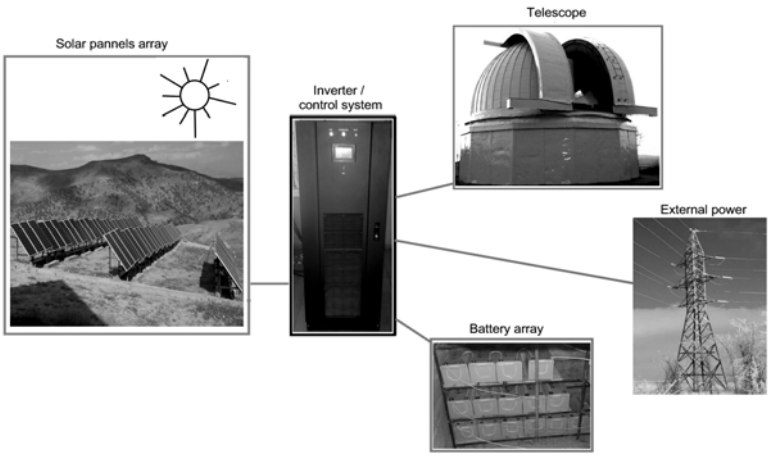


Fig. 3. Scheme for connecting of the PVS at the Maidanak Observatory.

The central connection node is the intelligent control unit of the inverter-controller ETS-30KVA, which performs the function of controlling the charge of batteries and monitoring the point of maximum power on the current-voltage characteristics of the solar cells. The array of solar panels, energy accumulators, the Zeiss-1000 telescope and an external power network are connected to the inverter-controller ETS-30KVA.

The array of solar panels has been installed taking into account the meteorological features of the Maidanak Observatory. In particular, this refers to the reserves of strength of construction against the wind loads. To fix groups of solar panels (3 pieces each), a special design was developed with elements to counteract bending and twisting of solar panels. To increase the resistance to tipping forces that occur during strong gusts of the wind, the mass of the frame structures of the array of solar panels has been increased by pouring reinforced concrete elements at the points of penetration of the frames into the ground. Before pouring concrete, the frames were rigidly connected to each other and between the rows by corners of the size 75 mm.

To exclude the loads arising in the process of thermal expansion, as well as the expansion of the water interlayer during freezing, a special method of solar panels fixing has been applied.

This PVS at the Maidanak Observatory was launched on September 22, 2016 and continues to operate in a test mode with a small, permanently connected electrical load in the form of the ETS-30KVA inverter controller itself and 36 helium batteries used in the charging mode, as well as the periodically activated Zeiss-1000 telescope for debugging and testing purposes.

The daily outcome from the PVS is given in Fig. 4. As the analysis of the data of daily electricity production shows, in the winter season, the days both with maximum solar insolation and with a complete absence of receipt on the solar radiation panel are possible. The periods of time with maximum insolation, on some winter days, can be explained by the maximum cleanness of the sky from dust, aerosols and negative temperature with freezing and precipitation of all water from the atmosphere above the Maidanak Observatory. The dates with absence and minimum of insolation could be explained by heavy snowfall in previous dates and the accumulation of a dense layer of snow on photovoltaic panels, as well as by absolute windlessness these days and continuing precipitation.

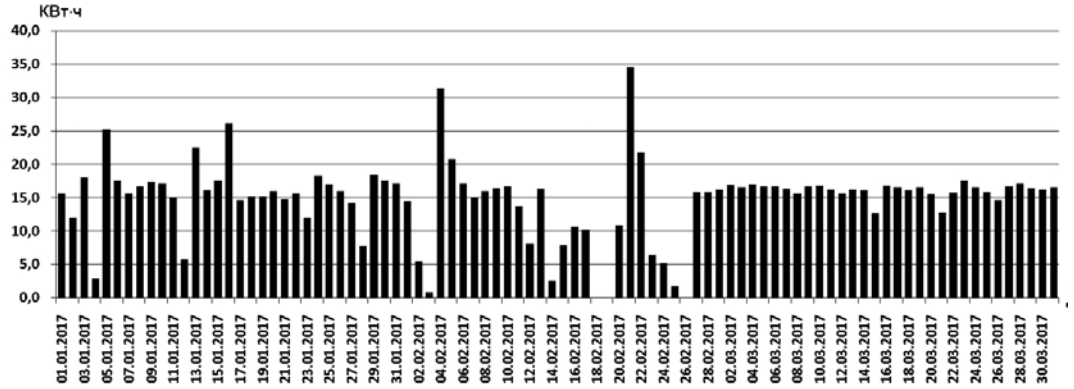


Fig. 4. The graph of daily electricity production of Maidanak PVS from January to March 2017, which also reflects the weather conditions and incoming radiation from the Sun during these periods at the Maidanak Observatory.

The winds in the winter months at the Maidanak Observatory do not allow for the accumulation of loose and crumbly snow on the planes of photovoltaic panels, although they can lead to sweeping snow volumes behind the solar panels.

PVS at the Maidanak Observatory is continuing its uninterrupted work from September 22, 2016 in the test mode. The total PVS generated electrical energy until May 31, 2017 was 3692 kWh. Thus, the creation of an alternative PVS energy source at the Maidanak Observatory will allow for continuous and stable observations on astronomical telescopes and will also serve as a long-term operational capacity for expensive astronomical equipment.

III. THE SCIENCES AND PROJECTS

The SAGE (Stellar Abundance and Galactic Evolution) survey (PI: Gang Zhao, http://sage.bao.ac.cn/~sagesurvey/), adopts a new photometric system (the SAGE system, u_{SC} /v_{SAGE} /g/r/i/$H\alpha_n$/$H\alpha_w$/DDO51 bands, defined by the SAGE team), it is extremely powerful and sensitive to stellar atmosphere parameters ($T_{\rm eff}$, log g, and z) of FGK types

of stars. The SAGE photometric system is the combination of the advantages of Stromgren-Crawford u_{SC} (sensitive to the log g), a self-defined $v_{\rm SAGE}$ (covering the CaII H&K lines, which is a good indicator of metallicity), gri bands (sensitive to T_{eff}), $H\alpha_n/H\alpha_w$ (for constraining the interstellar extinction) and DDO51 (which is helpful to separate the dwarf and giant stars) [10-13]. The filter parameters of the SAGE system or the central wavelengths and bandwidths of the system are given in Table (for details see Fan et al. 2018 [14], Zheng et al. 2018 [15]).

Table. The filter parameters of the SAGE photometric system, where u_{SC} is the Strömgren-Crawford (SC) system defined; $v_{\rm SAGE}$/ $H\alpha_n$/ $H\alpha_w$ are our own design; gri is from the SDSS system, and the definition of DDO51 is the DDO system.

Band	u_{SC}	$v_{\rm SAGE}$	g	r	i	$H\alpha_n$	$H\alpha_w$	DDO51
Central wavelength, Å	3425	3950	4686	6166	7480	6563	6563	5130
Band width, Å	300	290	776	687	766	29	136	154

The SAGE survey area is as shown in Fig. 5, and the declination is from Dec=− 5 deg to +90 deg and the Galactic latitude $|b|$ > 10 deg, avoiding the Galactic plane, and the total area is ~12000 square degrees.

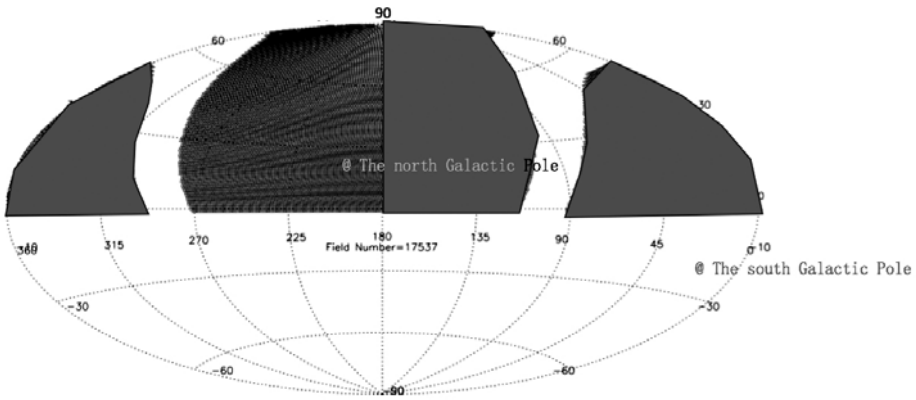


Fig. 5. The SAGE sky survey area. The declination is from Dec= − 5 degree to +90 degree, with $|b|$ > 10 degree and the total survey area is ~12000 square degrees.

Since the SAGE survey focuses on the FGK late type stars, the limiting magnitudes of the system are matched for all bands. Therefore, we require u_{SC} and $v_{\rm SAGE}$ reach $17^{\rm th}$ mag, and gri band reach $15^{\rm th}$ mag, with the signal-to-noise ratio of 50–100 sigma (corresponds to photometric errors of 0.01–0.02 mag), which can meet our requirements of study on stellar parameters.

All the observations, flux calibrations, astrometry and obtain a homogenous 8-band photometry will be carried out in 3–4 years. For the $u_{SC}/v_{\rm SAGE}$ band observations: 90 inches (~2.3 meter) Bok telescope of Steward observatory, University of Arizona for the observations of $u_{SC}/v_{\rm SAGE}$ bands is used. The telescope has a larger field of view (1 deg×1 deg) and equipped with blue-sensitive CCD mosaic (four 4k×4k CCD array). For the SDSS's gri-band observations: the 1-meter wide-filed-of-field telescope of Xinjiang Observatory of CAS, is located at the Nanshan observatory, with a large field of

view (1.5 deg×1.5 deg) and equipped with a whole set of SDSS filters. For $H\alpha_w/H\alpha_n$/DDO51 observations: 1 m Zeiss-1000 telescope of Maidanak Astrophysical Observatory (MAO) will be used for the observations in $H\alpha_w/H\alpha_n$/DDO51 bands. In 2014, Ulugh Beg Astronomical Institute (UBAI) of Uzbekistan, National Astronomical Observatories, CAS (NAOC) of China, have signed an agreement on cooperation for the MAO 1 m Zeiss-1000 telescope renovation work. The upgraded telescope will have an enlarged field of view 32.9'×32.9', with the focal reducer. Due to the agreement, the NAOC will obtain 70% of the observation time on the upgraded telescope in the first 5 years. The site has an excellent transparency and seeing condition (for 80% of time, seeing <0.8"), is preferable for the survey

The main scientific directions and research tasks which should be considered and solved during the SAGE project realisation could be expressed as following items.

1. Determination of the foreground extinction, the evolutionary stage, and the stellar atmosphere parameters (T_{eff}, [Fe/H], log g) of all stars in the field of our survey area. The high accuracy for stellar atmosphere parameters of 1 million stars and an average accuracy (moderate and low precision) of 500 million stars are expected.

2. Distribution of the metallicity index [Fe/H] for the Milky Way Galaxy. The distribution of the metallicity index for the Galaxy will be obtained in the study of thick disk and in a vertical direction, which can provide the key to understanding the formation and evolution of the Milky Way Galaxy.

3. Search for stars extremely depleted in metals (stars with extremaly poor with metal content or “extremely metal-poor stars”). Having a color band sensitive to the metallicity index [Fe/H], we will be able to detect candidates for extremely metal-poor stars on a two-color diagram.

4. Search for and study of exoplanets: since the Maidanak Observatory has the excellent conditions for observations, such as good image quality (seeing) and high transparency of the atmosphere above, we will be able to perform high-precision photometry of these objects and obtain their parameters.

5. Investigation of variable stars (young stars, eclipsing binary stars or binaries as well as close, contact and detached binary stars): discovery of new ones and research of them and known variables in the field of the SAGE survey.

The time-domain astronomy studies, such as GRB follow-up observations, search for SNe, time-series for variable stars and so forth, are among perspective scientific tasks for the 1 m telescope.

In order to understand the chemical evolution and formation of the Galaxy we intend to measure and carefully study the metallicity distribution and age-metallicity relationship. Another important aim of the project is to discover and classify blue stars in the solar vicinity, including WDs, sdBs and HBs, which were not optimized in the blue in the previous surveys. The search and comprehensive study of metal-poor and, especially, the extremely metal-poor stars would give us a clue to understand the physics of such unique stars and clarify the situation with star-formation at the early stage, nucleosynthesis and stellar evolution in such special cases.

IV. CONCLUSION

The 1 m telescope of Carl Zeiss (Germany) at the Maidanak Observatory of the Ulugh Beg Astronomical Institute of the Academy of Sciences of Uzbekistan including all systems of the telescope have been completely renovated and upgraded based on the

modern standards the main results of which were described in this article. All modernization works, as well as scientific research on this project are carried out in close cooperation of the Ulugh Beg Astronomical Institute of the Academy of Sciences of Uzbekistan with the National Astronomical Observatories of the Academy of Sciences of the PRC within the framework of the Agreement on cooperation between these organizations. According to the NAOC-UBAI collaboration agreement, a large-scale scientific project on a full survey of the northern sky photometric system − Stellar Abundance and Galactic Evolution (SAGE) survey will be carried out with the upgraded 1 m telescope and the main goal is to measure the stellar atmospheric parameters (T_{eff}, log g, and [Fe/H]) of FGK types for more than 500 million stars using 70% of the observation time in the first five years. In addition, the interstellar extinction also will be measured. As for other scientific projects, such as the time domain science, the GRB observations, SNe searching, variable stars investigations and so on will also be performed.

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