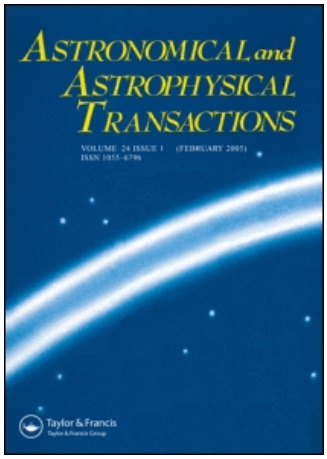

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FIFTY YEARS OF THE FESSENKOV ASTROPHYSICAL INSTITUTE

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The development of astronomical investigation in Kazakhstan during the 50 years in which the Fessenkov Astrophysical Institute has existed is surveyed. An overview of the main scientific research is presented.

Keywords: Astronomical investigation in Kazakhstan, Fessenkov Astrophysical Institute

1 INTRODUCTION

Academician K.I. Satpaev considered that in the Academy of Sciences of Kazakhstan, among fundamental sciences, a noteworthy place should be occupied by astronomy. In his report on founding the academy in 1946 he remarked: 'The Institute of Astronomy and Physics of the Academy of Sciences Kaz SSR, headed by the academician V.G. Fessenkov and associate member of the Academy of Sciences USSR G.A. Tikhov, occupies an honourable place in the web of astronomy–physical establishments of the Union. Within the Great Domestic War this institute played the role of the centre of astronomical thought of the USSR. The institute carries out a series of research and development operations' (Satpaev, 1968). In the first session of the Academy of Sciences Kazakh SSR the astronomers V.G. Fessenkov and G.A. Tikhov were elected as members of the National Academy of Kazakh SSR. In astronomical science in Kazakhstan at that time, K.I. Satpaev was successful concerning his ideas. In the book by Idlis (1997) the list of approximately 500 astronomers known is reduced; it contains astronomers living at present, where names appear in the global manual *The Astronomers*: *a Biographic Manual* (Kolchinskii *et al.*, 1997). Ten of these, B.A. Vorontsov–Velyaminov, R.E. Gershberg, G.M. Idlis, A.V. Markov, V.I. Moroz, G.M. Nikolskiy, T.B. Omarov, N.N. Paryiskiy, G.A. Tikhov and V.G. Fessenkov, worked in Alma-Ata for at least, some time.

Astronomy is an observational science. The main scientific results in astronomy are interlinked with the presence of telescopes. Originally the Institute of Astronomy and Physics had no base for observations and was restricted to laboratory research on spectroscopy and astrophotometry, and also operations in the field of atmospheric optics.

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After the war years in the Kamenskoe plateau region of the city of Alma-Ata, construction of the astrophysical observatory began. Alma-Ata (nowadays Almaty) is at a height of 1500 m above sea level. The first considerable tool of the new observatory was the 50 cm reflector of a Hertz telescope, which was utilized for star spectrophotometry investigations.

In 1950 the Institute of Astronomy and Physics of the Academy of Sciences Kazakh SSR (an independent astrophysical institute), headed by the academician V.G. Fessenkov, became separate. In the observatory, first a large telescope constructed according to D.D. Maksutov's system and with a diameter of 50 cm was installed. The photographic observations of diffuse nebulae obtained using this instrument have become very popular in the Soviet Union and abroad. The important values were published by the Fessenkov Astrophysical Institute under the title *The Atlas of Gas-and-Dust Nebulae* (1953).

Another important moment in the development of Astrophysical Institute of the Academy of Sciences of Kazakh SSR was the installation in 1964 of the 70 cm telescope AZT-8. The equipment for the telescope consist of spectrograph with a cascade electronic image converter has enabled us to compete successfully with observatories that have larger telescopes in research on rather weak objects in the depths of the Universe. In particular, a series of observations with our telescope has allowed us to detect almost all the bright active galaxies with strong ultraviolet radiation (Markaryan galaxies) in the northern sky, providing much detailed research of 400 galaxies, approximately 28 were researched for the first time.

In 1978 a Zeiss-600 telescope (manufacturer Carl-Zeiss) was installed in the observatory and successfully utilized for photographic and spectrophotographic observations of large planets. The workings of the Institute in this area have also received wide recognition as a USSR establishment for coordination of the study of giant planets.

After 70 years, because of the ongoing requirements for astrophysical observations, the Institute began the construction of a new Assy-Turgen Observatory, in a highly mountainous region 100 km to the east of Almaty at a height of 2700 m above sea level. A 1 m Carl-Zeiss telescope equipped with an electropolarimeter became the first instrument installed in this Observatory. Observations in astroclimate conditions appropriate to the best world standards began in 1981. In particular, a large amount of observational material on photometric and polarimetric data for stars such as T Tau and Herbig–Haro objects was obtained. Also, based on the 1 m telescope at the new Observatory a laser location complex was created; this allowed us to carry out systematic soundings of the atmosphere of the Earth up to heights of 60–80 km.

After 90 years a 1.5 m AZT-20 telescope was installed at the Assy-Turgen Observatory; this telescope made by the Leningrad optical–mechanical joint team. Telescopes of such diameters are widely applied in modern astronomical practice, and the mirror in the telescope was of high quality. The final starting-up and adjustment operations were delayed by financial difficulties. The program for the telescope equipment with light receivers and instrumentation for analyses also required extra funding. With the AZT-20, the observational base on the Assy-Turgen plateau would become one of the best astrophysical observatories in the world.

In the last few years the Astrophysical Institute of the Tyan-Shan Astronomical Observatory, which originally belonged to Moscow State University, has joined us. Here there are two 1 m Carl-Zeiss telescopes, a 60 cm horizontal NSFA solar telescope, two 50 cm AZT-4 telescopes and a 15 cm Opton solar telescope. In the same region (the Large Almaty Lake) at a height of 2700 m above sea level is situated the Coronal Station of the Astrophysical Institute, which was constructed 60 years ago. Its scientific inventory was completed to develop reseach into solar–Earth connections; it possesses a horizontal ATSU-5 solar telescope, a 50 cm coronograph and other instruments. In 1982 a 50 cm wide-angle Schmidt-type camera was transferred here. It is used as a basic instrument for monitoring near-Earth space.

In 1987 the Astrophysical Institute adopted the name of the academician V.G. Fessenkov. In June 1989 in Alma-Ata the astronomical scientific researchers of the USSR celebrated the hundredth anniversary of the date of his birth. The publication of the book *Reminiscences about V.G. Fessenkov* (1989) was published.

The year 2000 was the 125th anniversary of the date of birth of the academician G.A. Tikhov; he created the Department of Astrobotany at the Academy of Sciences of Kazakh SSR in 1947. Unfortunately, soon after G.A. Tikhov's death in 1960, this department was closed. However, in due course in the USA, astrobiology has undergone rather intensive development, particularly in those fields that were developed for 50 years in G.A. Tikhov's department. In 1960 at the Californian exploratory centre at the National Aeronautics and Space Administration a special institute of astrobiology was opened. It should be noted that the phenomenon of the astrobotany which was developed in Kazakhstan science in the time of K.I. Satpaev is the beginning of the modern search for forms of life outside Earth.

Thus, we give a brief summary of the initiation and development of astronomical research in Kazakhstan during the 50 years of existence of the V.G. Fessenkov Astrophysical Institute. Further, we shall emphasize the main scientific outcomes and some perspectives for further research.

2 RESEARCH ON THE INTERSTELLAR MEDIUM AND PROCESSES OF STAR FORMATION

Study of an interstellar medium and its interaction with star-shaped components are scientific topics traditional for the Fessenkov Astrophysics Institute. Many nebulae from their mass and gas-and-dust composition are relevant media for the formation of stars, and star clusters signify prolonged formation of stars. To solve the problem of the modern shaping of stars from the gas and dust of a medium a major amount of observational information was required, essential contributions to which were made by the Institute. From a great many photographs of objects obtained by the Fessenkov Astrophysics Institute in two spectral ranges *The atlas of gas-and-dust nebulae* containing valuable information on the structure of researched objects was published. On the basis of the analysis of these photographs it was assumed that the dense filaments in nebulae can break up into separate bunches of substances from which, under favourable conditions, stars will be formed. The discovery of 'star chains' in the nebula in the Cygnus constellation has confirmed this possibility.

Main attention was given to a study of the physical properties of gas-and-dust nebulae, on the basis of which *the Photometry Directory of Reflective Nebulae* was published. The analysis of the directory has shown the existence not only of physical but also, in many cases, of genetic connection between the kernel nebulae and diffuse clouds. By polarimetric observations it was proved that the filamentary structure of nebulae is formed under the action of a magnetic field, and the substance of nebulaes, despite the high temperature of the exciting stars, contains a dust.

The fact that huge gas-and-dust complexes (the centres of formation of stars) existed became a conventional concept. It is known that the formation of compact areas of ionized hydrogen is a stage in the evolution of a young star. The search for and study of similar formations is possibly closely connected to the birth of stars. Spectral observations of more than 150 emissive nebulae have allowed us to detect and explicitly to study 20 new compact H II lines of these regions. In further research in the infrared and radio-frequency ranges from other observatories it has been confirmed that many of these compact areas are the places where stars form.

Other manifestation of the close interaction between stars and the interstellar medium are planetary nebulae, the objects generated at later stages of evolution. They represent huge envelopes of gas, which formed from high layers of atmosphere thrown out of stars-giants. The outcome of long-term research on planetary nebulae at the Fessenkov Astronomical Institute is published in *The spectral directory* listing 75 objects which permits one to select criteria for the estimation of the age of a planetary nebula. Research on young planetary nebulae has enabled us to put forward the supposition that the strong stellar wind could be the reason for high-speed motions in the atmosphere of central stars at the early stage of evolution.

After 80 years of the Assy-Turgen Observatory, a 1 m Carl-Zeiss telescope equipped with an electrophotopolarimeter became operational. Owing to this it became possible to carry out research connected with gas-and-dust complexes of non-stationary stars at early stages of evolution. Major observational material on photometric and polarimetric data for stars such as T Taurus and Herbig–Haro objects was obtained. The analysis of the observational data allowed us to find criteria for identification of the separate stages of the evolution of young stars from the moment of their appearance.

Operations on the absolute spectrophotometry of stars were also added to the above-mentioned research. The energy distribution in a spectrum expressed in absolute photometry units is one of the most important characteristics of a star. Absolute spectrophotometry of celestial bodies, which is extremely laborious and is a complex method for observational tasks and data on the energy distribution of spectras (even for the brightest stars) are extremely scarce in the astronomical literature prior to the last 60 years. At the Fessenkov Astrophysical Institute and in some observatories the first results in this direction were obtained at this time. In the last 60 years at the Institute the energy distributions of the spectra of several tens of stars have already been investigated. Work for the creation of a stellar catalogue data obtained over 20 years. As a result a directory containing data on the energy distributions of the spectra of 1159 stars was published. The *Spectrophotometric Directory of Stars* is one of most extensive in the world astronomical literature. Thus, in comparison with the data from other workers, the Gaussian curves of energy are based on much greater and photometrically homogeneous observational material. Now the future plan is to undertake the definition of the effective temperatures and other parameters of stars.

3 RESEARCH ON ACTIVE GALACTIC NUCLEI

The study of active galactic nuclei became one of the leading topics in astrophysics, since the establishment of the cosmological nature of the red shift in spectra of quasars 60 years ago. The subsequent poor development of research on this problem has reduced the number of large discoveries. It was established that quasars are the brilliant objects of the Universe and are visible at extreme major distances. Their huge luminosity is stipulated by the formation of supermassive black holes (mass from millions up to billions of solar masses) at the centre of galaxies. A wide class of objects has common physical properties: the nuclei of Seyfert galaxies, the quasars, the radiogalaxies and other objects denoted by the term ‘the active galactic nuclei’. The indicated properties of the active galactic nuclei determine the importance of their study in modern cosmology, in the theory of gravitation and in the theory of evolution of galaxies. The urgency of research on active galactic nuclei is obvious from the fact that, for the last 15 years, only 1662 publications have been devoted to observations of these objects. Since 1968 at the Fessenkov Astrophysical Institute the work in this direction has been carried out.

The development, manufacture and use of a spectrograph equipped with an electronic image converter have allowed us to make a quality jump in observational astrophysics, to begin research of weak objects with the help of a telescope of small diameter and successfully to compete with other observatories possessing large instruments. About 400 active Markaryan galaxies were researched for the first time at the Fessenkov Astrophysical Institute.

In the last 15 years the main topic at the Fessenkov Astrophysical Institute in the field of extragalactic astrophysics became research on the spectral variability of Seyfert galaxies. 3000 spectrograms of 40 such objects were approximately obtained. The theoretical research carried out at the Fessenkov Astrophysical Institute define the stability of superstars interacting with stars. The inevitability of formation of massive black holes at the centres of galaxies was shown; the problems of dissipate capture of stars by central active objects were investigated; the theoretical models of active nuclei were developed taking into account the gas dynamics and spectral properties of these objects. The theory of quasars with wide lines of an absorption in spectra was simultaneously constructed, and a new approach to the uniform theory of activity of the galactic nuclei based on the theory of interacting subsystems evolved. Work on the active galactic nuclei is carried on in cooperation with the Institute of Astrophysics of the University of Cambridge, with Medon Observatory, with the Sternberg Astronomical Institute at Moscow University and with the Heidelberg Astronomy Institute.

4 DYNAMIC PROBLEMS OF STELLAR AND GALACTIC SYSTEMS

The Fessenkov Astrophysical Institute has major traditions in the study of problems of celestial mechanics, stellar dynamics and cosmology. The theory of the motion of cosmic dust in interplanetary space in view of the Poynting–Robertson effect created by the founder of the Institute in 1947 is one of his fundamental contributions to astronomical science. In the 50 years of the Institute, a so-called antropic principle of modern cosmology was proposed for the first time. At that time an innovative theory was developed at the Institute called the antropic theory of the origin of Magellanic clouds (satellites of the Galaxy) as a result of probable collision of our star-shaped system with galaxy NGC 55. In subsequent years at the Institute, work was devoted to the development of non-stationary models of stellar systems and selection of convenient approximations for a galactic potential with the purposes of defining stellar orbits and analysing stellar encounters. The new theory of relaxation of stellar systems which appear as turbulent diffusion of stars in velocity space has also been developed. At the Institute, based on the combination of stellar dynamics and celestial mechanics, research into non-stationary dynamic problems was introduced. These problems are connected with the analysis of the role of some factors in the development of gravitating systems of the Universe (such as the change in the masses of interacting bodies and the degrees of openness of systems as a whole), with the influence of a gravitating background (such as an expanded cosmological substratum and a contracted protogalactic gas) and with the manifestation of a probable decrease in the gravitational constant with time. In particular, the solution of the two-body problem inside dusty gravitating substance of the Einstein–de Sitter world was obtained and the non-stationary cumulative distribution function in the N-body problem of a variable mass was constructed. Also the generalized virial theorem for a system of fluctuating composition was obtained and the gross evolution of galaxies, dissipated owing to asymmetric outbursts of supernovae, was researched. The inverse problem of dynamics for a system with a non-stationary Lagrangian, formulated at the Institute, was also studied.

With usage of the general equation of such problems, some aspects of non-stationary regular potentials of axisymmetric galaxies of variable mass on evolved forms of orbits

used in the dynamics of stationary stellar systems were constructed. It is possible to relate our work on the dynamics of systems on 'a supergalactic scale' to research on adjacent problems of stellar dynamics and cosmology. The relativistic models of clusters and superclusters of galaxies were considered with the purpose of analysing them from the viewpoint of the dynamics of effects of the global extension of the Universe. The analytical dynamic estimation of the forming epoch of clusters of galaxies as non-equilibrium systems of gravitating bodies in a metagalaxy of critical cosmological denseness was obtained. The substitution here of observational data on the sizes of these objects and the variance of the velocities in them gives the value of an epoch as 1010 years. Research on the theory of motion of non-collisional gravitating ellipsoids was carried out at the Institute in connection with the urgent problem of simulation of an early non-stationary stage of the evolution of galaxies. In particular, Dirichlet's problem on non-collisional stellar dynamics has been formulated and solved. Ideas on the numerical theory of nonlinear oscillations of non-collisional gravitating ellipsoids were advanced. It is necessary to point out that the latest research of the Laboratory of the Dynamics of the Gravitating Systems of the Fessenkov Astrophysical Institute is devoted in particular to the physics of space strings. The metrics for the oscillating and nonlinear models of these exotic objects of Universe were obtained, and the dynamic processes near to them considered.

The research from the Institute on the development of problems of celestial mechanics, dynamics of stellar systems and cosmology has been published in fundamental books entitled *Development of Astronomy in the USSR*, *1917–1967*, *Advances in Astronomy and Astrophysics*, (1967) and *Research on the History of Physics and Mechanics*. The active work of the scientists at Almaty in the field of the dynamics of galaxies has been mentioned in the book by Vorontsov-Veljaminov (1978) entitled *Extragalactic Astronomy* which is intended for astronomy students at universities. The monographs published by the Institute entitled *Structure and Dynamics of Stellar Systems* (1961) and *Dynamics of Gravitating Systems of a Metagalaxy* (1975) are popular among astronomers. The active research of the Institute is shown in the terms 'the Idlis potential', 'the Idlis third integral', 'the Idlis–Omarov problem', 'the Omarov–Hadjidemetriou elements' and 'the Gelfgat–Omarov problem' used in the scientific literature on the dynamic problems of astronomy. Some employees of the Institute were honoured (by the Nobel Committee on Physics) with the right to promote candidates for the Nobel Prize in this area.

5 RESEARCH ON THE PHYSICS OF THE SUN AND PLANETS

One of the main scientific fields studied at the Institute is research on the physics of the Sun. On the basis of a photometry study of high-quality homogeneous observational material, it was established that the temperature of sunspots does not depend on their size and is $4100 + 140$ K. This has allowed the construction of a new magnetohydrodynamics model of a sunspot. Regularities in the manifestation of the Wilson effect in the classical representation framework were detected for the first time. The empirical structural model of a solar facula was suggested which has in comparison with a photosphere an informative ionization continuum and which is enclosed by a hot wall.

The phenomenological theory of a solar flare was advanced. Within the framework of this model the coefficient of thermal conductivity of substance was found and the expression for the calculation of the total energy of optical flares was obtained. An original method for the long-term prognosis of solar cycle was designed. On the basis of this a prognosis over 22 cycles was completely justified. The Institute participated in a range of large international

programmes on research into solar activity in a crown. Further, Substantiation and practical development of new methods of the analysis of the appearances of solar activity were carried out using special observational programs.

The study of planets and other bodies of the Solar System is one of the traditional scientific topics dealt with at the Fessenkov Astrophysical Institute. In the last 50–90 years the study of the physical nature of the giant planets Jupiter and Saturn, in whose spectra there are strong absorption bands of methane, was mainly carried out. Research on the behaviour of these bands in discs of planets, as well as observations on different lengths of the waves in an ionization continuum, enabled us to realize remote exploration of their atmospheres and cloudy layers and to study dimensional and temporal variations in the structure of their cloudy covers. In the last few years, the observation of planets were carried out with the help of modern panoramic cameras with charge-coupled device matrixes enabling us to gain an immediate map of a planet or its spectrum on the computer.

As a result, rather extensive observational material was obtained, atlases of the latitude and longitude of the absorption of methane on the discs of Jupiter and Saturn composed, and the probable structure of the aerosol (cloudy) component of their atmospheres suggested. Theoretical calculations of the shape of clouds in the atmospheres of the giant planets were carried out. Observations of other planets and, first of all, of Mars were also made. In the atmosphere of Mars the so-called 'blue' clouds, of nature similar to the silvery (mesopheric) clouds appearing at heights about 80 km on Earth, were noted. Many observational operations on planets were performed and there was much involvement in a series of international programmes (International Jupiter Watch, Mars Watch, Vesta, PHEMU 95, PHEMU 97, etc.). Special photometry observations of the gyration of the Vest asteroid, relative eclipses and junctions of satellites of Jupiter and Saturn were realized. Data on these observations together with data of other participants of the international programmes PHEMU 95 and PHEMU 97 were utilized to improve the theory of motion of the satellites of planets. There was special interest in observations of a completely unique event, namely the collision of the Shoemaker–Levy comet with Jupiter in 1994. These observations have shown what disastrous processes could take place on the Earth if it underwent a collision with the kernel of a comet or small asteroid. It is important to provide ground and space astronomical observations in order to search for and to detect objects (kernels of asteroid and comet) that are dangerous if they collided with the Earth; this is a potential global catastrophe.

6 OPTICAL RESEARCH ON THE EARTH'S ATMOSPHERE

The investigations made at the Institute involve problems of optical radiation transfer in the Earth's atmosphere and development of methods to determine its composition and structure. An aim of this research is the use of methods of active and passive detection and range of an atmosphere.

Essential results were obtained by study of the transmission of solar radiation by the Earth's atmosphere. The urgency of this problem is determined by the significance of solar radiation in the physical and biological states of a planet. In particular, the need for standardized calculations of a field of scattered solar radiation by both a cloudless atmosphere and a cloudy atmosphere was justified; the key requirement for extraction of information on the structure of an atmospheric aerosol was shown. The commissions on Radiation of the Interdepartmental Geophysical Committee have allowed the Institute to investigate the solution to the problems of the direct and inverse tasks of shaping a field of descending solar radiation in the conditions of condensing atmsophere.

In the Institute, intensive research on the development and application of twilight methods of exploration of the upper atmosphere were carried out, which are based on the ideas of the academician V.G. Fessenkov. In the last few years a new method of the 'passive' sound of the aerosol layers of an atmosphere was developed at the Institute on the basis of the twilight sound of the water steam band. Thus a common interpretation of the underlying method of the 'Getz effect' was given for the first time; the conditions for implementation in the Earth's atmosphere for absorption bands of various gases and possible use in the localization in an atmosphere of the appearance of an abnormal increase in luminosity of the twilight sky were indicated.

For 80 years, work on the laser sound of atmosphere had been developed. The laser location complex was created on the basis of the 1 m telescope, and this allowed us to carry out work in the systematic sound of an atmosphere up to a height of 60–80 km. As a result of those investigations the division into layers and the synchronous height variations in the aerosol layers of the stratosphere were discovered for the first time. The availability of productions of aerosols in similar clouds in the upper troposphere and stratosphere has been experimentally confirmed. It is assumed that the Institute will take part further in other national and international programmes including the following: study of global and regional allocations of aerosols; wave processes in the upper atmosphere; lidar sound in the troposphere and stratospheric aerosols; day time and twilight sound from the Earth's atmosphere; solution of the direct and inverse optics of an atmosphere; creation of optical atmosphere models; definition of the transfer functions of an atmosphere. The topics indicated can be utilized to solve fundamental problems of the physics of an atmosphere and applications connected with the operation of optical systems in an atmosphere, resources and ecological research.

7 OBSERVATIONS OF ARTIFICIAL SATELLITES

In Kazakhstan, observations of artificial satellites were started in 1957 immediately after the first satellite was launched. The Astrophysical Institute was included in a network of scientists making optical observations of the Soviet Union's artificial satellite intended to monitor circumterrestrial cosmic space. Since 1967 to observe the artificial satellite the 70 cm AZT-8 telescope with an electronic-image television system was utilized. For many years, observations of long-distance space objects starting with the Moon, Mars and Venus were carried out. The principal astronomer working on these operations, V.S. Matyagin was awarded the rank of Winner of the State Premium of the USSR. Now operations will be carried out according to the programme of the UN Committee on the usage of space for Peace Purposes. To derive precise photometry information about space plants a special automated system established on the 1 m Carl-Zeiss telescope (at the Assy-Turgen Observatory) will be utilized. Simultaneous use of coordinate and photometry information allows us to classify plants from the viewpoint of the evolution of orbital parameters and performance properties such as the form, the orientation in space, mirroring the properties of surfaces, and phases of gyration around a figure. On the basis of the observations in 1991–1996 a database was created and *The Directory of Geo-Stationary Satellites* including information on 259 GSSs. From results of observations during 1991–1999 a second edition of *The Directory of Geo-Stationary Satellites* including information on about 670 GSSs was published.

It is planned to carry out the following operations in the future:

(i) monitoring and improvement of the existing directory of GSSs;
(ii) creation of advanced automated system of observations;

(iii) software engineering for calculation of the resonant perturbations of the orbits of passive GSSs;
(iv) development of programs for the long-term prognosis of driving GSSs;
(v) creation of programs for the calculation of optical and physical performance properties of GSSs on the basis of observations and modern mathematical models.

There is a problem in the creation in Kazakhstan of a centre for monitoring of space on the basis of observational items available outside Kazakhstan. The presence of several automated systems essentially will expand the number of solved tasks and will allow us to report a centre that is carrying out operations to provide a directory of almost any class of artificial objects.