ISSN 0884-5913, Kinematics and Physics of Celestial Bodies, 2012, Vol. 28, No. 2, pp. 85–102. © Allerton Press, Inc., 2012.
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ASTROINFORMATICS

Astroinformation Resource of the Ukrainian Virtual Observatory: Joint Observational Data Archive, Scientific Tasks, and Software

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Received June 24, 2011

Abstract—This paper reviews the most important components of the national project of the Ukrainian Virtual Observatory (UkrVO). Among them, there is the establishment of a Joint Digital Archive (JDA) of observational data, which has been obtained at Ukrainian observatories since the 1890s, including an astronegative JDA (more than 200 thousand plates). Since this task requires VO-oriented software, such issues as content verification software, integrity and administration of the JDA, compliance of image formats with the IVOA standards, and photometric and astrometric calibration of images are considered as the most important directions of software development, which carried out by members of the UkrVO. The scientific projects using local data archives of the UkrVO are discussed, namely: an analysis of a long observational series of active galactic nuclei, the study of solar flares and solar active regions based on spectral observational archives, research and discovery of variable stars, and the study of stellar fields in the vicinity of gamma-ray bursts. Particular attention is devoted to the CoLiTec Program that permits us to increase a number of observed solar system bodies and allows us to discover new bodies; for example, the C/2010 (Elenin) and P/2011 N01 comets were discovered using this program at the ISON-NM Observatory. The paper notes the creation of the UkrVO JDA prototype that provides access to the databases of the Main Astronomical Observatory, National Academy of Sciences of Ukraine (MAO NAS of Ukraine); Nikolaev Astronomical Observatory (NAO); and Lvov Astronomical Observatory.

DOI: 10.3103/S0884591312020067

INTRODUCTION

The establishment of an integrated infrastructure is the long term prospect of the International Virtual Observatory Alliance (IVOA). The integrated infrastructure permits data centers to render a competitive or cooperative services with extensive tools for visualization and analysis of astronomic data. The services are constantly updated by new software and web interfaces for information access, search, as well as data processing.

The development of a standard infrastructure that will make such a creative diversity of software products is the most important priority for all the projects of virtual observatories. The IVOA supports the observatories, universities, and projects from the entire world attracted to the VO as providers of data, information, and computational services as well as users of the "all-wave survey" of the universe (for example, see the reviews on virtual technologies [https://hub.vscse.org/resources/169/download/vo-

2010-bigdata.pdf, http://arxiv.org/PS_cache/astro-ph/pdf/0504 0504006v1.pdf, http://www.elbib.ru/index.phtml?page=elbib/eng/journal/2010/part3/MDBZ, as well as scientific projects of the IVOA [www.ivoa.net].

The suggested paper briefly discusses the state and tasks of the joint digital data archive of the UkrVO. The data has been obtained as a result of observations in a broad wave range with ground-based telescopes of the Ukrainian observatories since the late 1890s. Particular attention in the article is paid to the software created by the Ukrainian authors and data processing methods in accordance with the IVOA standards. The scientific tasks using the UkrVO databases are presented [http://ukr-vo.org].

1. JOINT DIGITAL DATA ARCHIVE OF THE UKRVO

Under the scope of the UkrVO concept, a series of top-priority projects for its development was determined. One such project concerns with development of the JDA, which consists of the data stored on different carriers at Ukrainian observatories [9, 54]: (a) photographic observations, which were obtained in 1898–1990; (b) CCD observations, which have been obtained since the early 1990s; and (c) spectral observations (including glass collections) in the optical, UV, radio, and gamma ranges, which have been obtained since the 1940s. Most of them are presented today as local data archives (LDAs) of the Ukrainian observatories. The LDAs have been systematized and certified in accordance with the IVOA standards.

Table 1 shows the state of the JDA as of late 2011 [10] (the data are updated on the site of the UkrVO). The joint astronegative archive is clear to be among the major resources of the UkrVO. The greatest collections are at the disposal of the Astronomical Observatory of Odessa National University (the glass collection that ranks the third in the world after Harvard and Sonneberg Observatories) that numbers 105 000 photoplates as well as MAO NAS of Ukraine (approximately 85 000 photoplates). A unique archive of observational data is at the disposal of the Crimean Astrophysical Observatory (CrAO) [31, 32]. The information capacity of this LDA can be estimated only very approximately: more than 60 devices combined with more than 30 optical, UV, gamma, and, radio telescopes have been used for the centennial history of observations at the CrAO (and at its forerunner Simeiz Observatory, whose collection is stored in Odessa). The information on the photographic databases of the CrAO is presented in Table 2.

Simultaneously with solving the task of creating the JDA, much effort is being made to develop the information system for administration of the JDA, including the instruments for administration of a register and interrelated/joint astronomical databases, search interfaces for remote users, online data analysis and processing services, instruments for learning the methods for work with the tools of the VO, etc., as well as instruments for proper development and involvement of new participants and new scientific projects into the UkrVO project.

The LDAs at the Ukrainian observatories are created in accordance with the common standards. The need for establishing such standards is caused by a significant heterogeneity of observational data and different readiness of the LDAs to be included into the JDA. The links to databases are integrated on the UkrVO website. In particular, the joint data from the archives of the MAO NASU and NAO are accessible through the interfaces of two different databases. The information on the databases of the JDA is systematized in Table 3.

2. MAJOR SCIENTIFIC FIELDS OF DEVELOPMENTS OF THE UKRVO SOFTWARE

2.1. Calibration of Digitized Photoplates

Digitization of observational archive of MAO NAS of Ukraine enables the enhancement of FONAC stellar catalogue [51] down to fainter objects (the FONAC archive contains above 2800 plates). The software for primary processing of digitized images [5,6,53] and evaluation of astrometric and photometric parameters of registered objects by proper data of the image itself was developed in MAO NASU on the basis of the LINUX/MIDAS/ROMAFOT package [38]. This package initially intended to process small CCD frames was not meant to process files similar to scanned images with linear dimensions of tens of thousands of pixels led to the necessity of preliminary preparation of the digital image by the transformation of a file into the FITS-format (with the inevitable decrease of color depth from 16 to 8 bits, which hardly worsened the results for the plates of the FONAC program for the stars $B_{pe} \leq 13^m$ [10]), software cutting of image edges (a plate edge of 500 pixels), and transformation into the special graphic newfile.bdf format. The suggested methods for processing digital plates [7] in order to subsequently use them in scientific projects (for example, see sections 3.1–3.3) implies the following stages:

Table 1. General information on the state of the joint observational data archive databases of the UkrVO (as of late 2011)

Member of the UkrVO	Type of information	Years	Objects, scientific programs of observations	Degree of readiness of an archive to the UkrVO	Notes
MAO NASU	Plates ~85000	1949–1999	Galaxies, quasars, variable stars, open stellar clusters, fundamental stars, comets, minor planets, AESs; FON, MEGA programs	Catalogued, established database, online access	~26500 direct frames; $mpg = 11–16^m$; 3500 digitized plates
	CCD 16000	2001–2003	Stellar fields with ICRF-objects	Noncatalogued, nonsystematized	KMAC1 catalogue (equatorial zone $V = 17^m$)
	Plates with spectra 1440 (AtsU-5 and AtsU-26 telescopes)	1976–1981, 1984, 1985, 1989, 1990	Sun (active formations)	Systematized; 60% digitization	Each plate contains 8 spectra of 10 nm in width and 1 cm in height; the spectra were obtained for gamma gamma 490, 520, 540, 590, 610, 630, 650 nm
NAO	Plates ~200	1929–1931		Catalogued, database, online access	Digitized; VO tools are used
	Plates 8405	1961–1999	Stellar clusters, zodiacal stars, minor planets, comets	Catalogued, database, online access to a part of the archive	4500 digitized plates; VO tools are used
	CCD 23300	1986–2009		Catalogued, database, online access to a part of the archive;	
CrAO	(See Table 2)				
AO KNU	Plates 200	1898–1916	Fundamental stars, Nova 1916, moon, sun	Catalogued, database, local access	Digitized
	Plates >20000	1945–1996	Fundamental stars, scattered clusters, QSO, moon, sun	Approximately 4500 systematized plates	Digitization process has started
AO LNU	Plates ~160	1939–1945	Variable stars, small solar system bodies	Catalogued, database, online access	Digitized
	Plates ~8000	1946–1976	Novae and variable star, Star occultation by the Moon, comets, minor planets, variable stars	Catalogued, database, online access	2700 digitized plates

Table 1. (Contd.)

Member of the UkrVO	Type of information	Years	Objects, scientific programs of observation	Degree of readiness of an archive to the UkrVO	Notes
AO ONU	Plates of the "Simeiz Collection" ~10000	1909–1953	Minor planets	Systematized, catalogued	Ordered observation journals, nondigitized
	Plates of the old collection 10000	1945–1956	Variable stars, comets, minor planets, AESs, QSO		
	Plate collection of a 7-camera astrograph 84000	1957–1998	Variable stars, comets, minor planets, AESs, QSO	Catalogued 10%; 10% online access	80% of direct images (α: 0–24^h; δ: $-15°$–$+90°$), photometrically uniform
ONMU	CCD (obtained with six foreign telescopes)	2004, 2007–2011	Variable stars	Systematized, online access	
RI NASU	Radio spectra		Extragalactic sources of the Northern Sky in the decameter range	Catalogued, systematized, online access	
UzhNU	Plates (the SBG camera of the Karl Zeiss Company)	1970–1995	Geostationary AESs	Catalogued	[13]
	CCD	1971–2010	Brightness curves for 170 AESs	Catalogued, accessible electronic version	

Note: The MAO NASU is the Main Astronomical Observatory of the NAS of Ukraine.
The NAO is the SRI "Nikolaev Astronomical Observatory."
The CrAO is the Crimean Astrophysical Observatory of the Ministry of Education and Science of Ukraine.
The AO KNU is the Astronomical Observatory of the Shevchenko Kiev National University.
The AO LNU is the Astronomical Observatory of the Franko Lviv National University.
The AO ONU is the Astronomical Observatory of the Mechnikov Odessa National University.
The RI NASU is the Institute of Radio Astronomy of the NAS of Ukraine.
The UzhNU is the Space Research Laboratory of the Uzhgorod National University.
The ONMU is the Odessa National Maritime University.
See the detailed description of the archive on the site http://ukr-vo.org as well as in [10].

(1) Overexposured image search and markup, analysis of overexposured double images, restoration of overexposured images by top “cap” raising (the calculation and photometric construction of the absent Gaussian-like cap).

(2) In order to eliminate the photometric field errors flat field frame for every scan is derived individually over image data itself by the method of spatial computation. The flat field for every plate is estimated after the registered objects computational removal. Iterative procedure is used for objects' removal and the spatial envelope curve (large scale and noise ones) of inherent plate field isolation (plate background).

(3) Search and isolation of objects (stars, galaxies and so on) over the previously given noise level. Practically the photometric section is made above the accepted level (conventionally this is a sum of calculated average flat field value and its threefold dispersion) and pixels exceeding this level are marked.

(4) Thus transformed frame is then processed in ROMAFOT software for astrometric and photometric calibration and estimation of detected objects' characteristics in the full range of star magnitudes in package mode. As initially ROMAFOT was destined for CCD frames processing so the formats of data exchange and registration were changed and frames of large dimensions (13000 ×13000 px) on the final step were automatically cut into overlapped (50 pixels wide) strips along X-axis and processed separately (the time of one frame processing takes one to three hours).

2.2. Administrations of Local and Joint Databases

2.2.1. The digitized archive of the MAO NAS of Ukraine. After the completion of the preparational efforts for MAO NASU archive database including into the UkrVO JDA the large-scale software verification of the content and integrity of the databases (DBs) was started. The second version of the DBGPA V2.0 software package was implemented.

The major goal of the Database of Golosiiv Plate Archive (DBGPA) project is to create suitable instruments for the remote access to open digital archives of photographic plates. The archives are positioned as an astrometric component of the UkrVO JDA in a broad spectral range, which makes it necessary to organize the access to them according to VO protocols and formats. At the stage of transition from the online archive to the VO resource, the proper software instruments for data control were developed, that were necessary to continue the content extension and further development of its structure as well as to join it with the analogous archives of other Ukrainian observatories.

DB of GPA is built in MySQL environment. In the current version of the online software package DBGPA V2.0 PHP with JavaScript and Flash ActionScript technologies are used. DBGPA V2.0 consists of three functional interfaces targeted the different user groups. Editor interface with authorized access of different set of privileges is aimed at new instrumental archive creation, data correction and verification, arrangement of digitization in user friendly way, its control, etc. Administrative interface is developed for database integrity support, monitoring of error and correction logs, current database backup, user access control etc, and structurally is a component of the editor interface with the highest privileges level. User interface provides the open access to data search engine and includes the tools for the visualization of search results such as star map on star catalogue data over the area of the photographic plate, overlapping scheme for the selected plates, graphic presentation of archive statistic data as bar charts, distribution of plate centers on the celestial sphere etc.

Since digitized plate images are the major component of the electronic archive, the arsenal of the visualization instruments was expanded with software developments on the JAVA and Flash ActionScript platform. Supplemental modules are designed and developed as applets, embedded into pages of user interface, and on this stage actualize functions of image zooming and scaling as well as, format transformations between GIF, JPEG,TIFF and FITS graphic formats “on the fly”. The applets were developed based on standard graphical libraries and use all their advantages (the rate of processing, entire set of graphical formats, etc.).

During the elaboration of major stages of online archive transformation into the VO resource the broader ways of UkrVO software development were outlined. They are as follows:

(1) Developing the DB user interface by creating the user services that would permit a DB search page to be transformed into the tools enabling one to get access to not only data but also to instruments for their processing, including those created and developed by the IVOA.

(2) Developing the editorial interface by adding tools for operative addition of archives of any type to DB (CCD-observations, spectral observations, etc.).

(3) Developing DBs of digitized images and more flexible instruments for work with them.

Table 2. General information on the state of photographic databases as of early 2011 (negatives and spectra) of the CrAO obtained in 1909–1999. (Methods for preliminary processing, obtained accuracies, and some aspects of using the results with the IVOA instruments are described in [8])

No.	Type of information, quantity	Years of observations	Instrument	Objects and programs of research, obtained results and discoveries	Notes, readiness to the UkrVO
1	Plates 10000	1909–1953	120-mm "Unar" objective lens	900 nonnumbered asteroids, 10 comets and 200 variable stars were discovered; 15000 positions of small bodies were determined [27]	Negatives are stored at the AO ONU ("Simeiz collection")
2	Negatives 10000	1963–1999	Double 400-mm astrograph	15000 nonnumbered asteroids were found; 1100 asteroids were discovered; 60000 positions of small bodies were determined [28]	Digital database was prepared and verified in the IVOA standards; 400 negatives were scanned, and their astrometric calibration was started
3	Plates several thousand	1948–1960	450-mm astrograph and 640-mm Richter-Slefogt telescope (RS-640)	Research on diffusion nebulae [30] and structure of the Milk Way (300 new nebulae were discovered) [18]	
4	Plates 1500	1947–1965	Direct images taken through an objective prism with a 167-mm astrograph with the "Dogmar" objective lens and 400-mm astrographs	Program "G.A. Shain's Plan" [18]; data on spectra, stellar magnitudes, and color indices of 35 000 stars were obtained; 4000 earlier unknown *O-B* stars were discovered [8]	Digital database was prepared and verified in the IVOA standards; 600 preview-images were scanned; astrometric calibration was made for 500 of them, which enables the work with them in IVOA ALADIN
5	78000 images (television photographing)	1971–1973	500-mm telescopes (MTM-500) and 700 mm-telescopes (AZT-8) with the use of television equipment	Images of the Mars in 10 spectral areas (including the large number frames of the Venus, Jupiter, Saturn, Uranus, and Pluto) [1]	
6	20000 images (television photographing)	1969–1992	Television telescope MTM-500	Stellar fields photographed without a filter and in the *U*, *B*, *V*, *R* color system	
7	1340 spectra	1929–1941	1-m telescope in Simeiz		Archives 7–10 were catalogued; prepared databases are brought into compliance with the IVOA-formats
8	5570 spectra	1953–1990	1220-mm Zeiss reflector	Spectra of different spectral resolution in different bands	
9	2900 spectra	1963–1987	2.6-m telescope named after academician G.A. Shain (ZTSh) with different spectrographs	Spectra of different spectral resolution in different bands	
10	3450 spectra	1982–1992	ZTSh, spectrograph in the Nesmith focus, with a digital-optical transformer	Spectra of different spectral resolution in different bands	

Table 3. Databases of the joint digital archive of the UkrVO (as of late 2011)

Observatory	Number of observational archives/images	Number of instruments	Years of observations	Type of information	Observational programs
MAO NASU*	2.6/3.5 thousand	14	1949–2003	Direct images	Galaxies, radio sources; fundamental stars, clusters, variable stars, multiple stars, review of the Northern Sky (FON), solar system objects, geostationary satellites
CrAO	7/1033 thousand	7	2001–2010	CCD	Variable stars, galaxies, gamma-ray bursts, Sun
	10/96 thousand	4	1968–2010	Spectrum	
NAO**	2.4 thousand	2	1929–1931 1961–1999	Direct images	Comets, minor planets, large planets and their satellites, zodiacal and circumpolar area
	3/23.3 thousand	3	2002–2009	CCD	Equatorial area
AO LNU	1/2.7 thousand	1	1939–1976	Direct images	Variable stars, solar system objects

Notes: * The observational archives of the MAO NAS of Ukraine, Nikolaev AO, as well as AO LNU are accessible at present through the search interface of the JDA UkrVO prototype.

** The observational archives of the MAO NAS of Ukraine are accessible at present through the search interface of the Nikolaev AO.

(4) Creating the instruments for providing any astronomical information (catalogues, tables, publications, etc.) that will be published on pages of the UkrVO and DBGPA in the formats developed by the IVOA for data visualization, storage and transmission.

Currently the details of common software package are discussed in order to make digital photographic archives actually virtual.

2.2.2. The observational database of NAO. The task of creating the “System of Search for the Data on Observations of NAO” [24] for all the observations accumulated at NAO was fulfilled based on scripts written in the PHP programming language and MySQL DB management system (MS). The DB includes textual data and separate images obtained for the entire history of photographic and CCD observations at NAO and is placed on the site of the observatory [www.mao.nikolaev.ua/index.php?catalog_id=345]. The web-interface enables one to assign the center and radius of search, observational period, type of a photoelectric receptor as well as any combinations of objects, parameters of photoplates and CCD frames, and names of telescopes. The search yields a table with photoplates and/or a table with CCD frames that correspond to all the assigned criteria of the search. The program for filtrating CCD images from the PUMA [22] software package was used with a view to place observation images into the DB to preview them as files in JPG format. After leveling an image and normalizing the background, CCD frames were transformed into images in the JPG format that were subsequently placed in the observational DB using a special command file for the ImageMagick program.

A separate DBMS written in the FoxPro programming language “The System for Keeping the Information Base of the Photoplate Archive of the RI NAO” was used to keep and fill the database of the glass archive [25]. The database presents all the accessible information on 8405 photoplates from the glass archive of NAO. Information from paper log books has a large potential for editing, analyzing, and displaying it as well as additional potential for astronomical calculations, editing primary files of scanned images, and exporting data in different formats. The software for searching for and visualizing processed astrometric observations [23] is intended to introduce the data of processed images obtained with different telescopes into the database managed by the MySQL server, to select the data according to the assigned user criteria for browsing and saving the results of a search in the table form, to generate graphical files with found objects in the standard FITS-format, and to visualize the obtained FITS-files for subsequent study and analysis.

With a view to provide the access to the observational DB through the web-interface of the ALADIN program, the PHP script and file describing the parameters of Nikolaev AO server were created. Twentyseven stellar catalogues of NAO were transferred into the VOTable format by scanning paper carriers and semi-automatic recognition of printed symbols, and they are open to free access [www.mao.nikolaev.ua/index.php?catalog_id=407].

2.3. Automatic Search for Small Solar System Bodies and Comets on a Series of CCD Frames

The modern level of the tasks of searching for the small solar system bodies requires that the automatic discovery of objects with the subsequent visual check of the obtained results be introduced. The unique CoLiTec software developed at the Kharkov National University of Radio Electronics (KhNURE) by the group headed by V. Savanevich and implementing this approach was successfully tested in 2009–2010.

A series of CCD frames with an image of a coelosphere area as well as stellar catalogue are the input data of the CoLiTec program (Fig. 1).

The intra-frame processing module performs the accounting of defect ("beaten" or "hot") pixels of a CCD matrix, divides the frames into subseries with determining a basic frame, adds the frames of the subseries together with accumulating a signal from a moving object with obtaining super-frames based on the "area approach" and using a digital smoothing filter, and preliminarily selects signals from celestial objects on the super-frames based on comparison with the threshold of values for a spatial convolution between the received radiation in the environs of an image peak and form of an expected signal. Then the intra-frame processing module estimates the coordinates and amplitudes of the signals on the super-frames (formation of marks) based on the mathematical tool of grouped samples using the model for the falling coordinates of noisy photons in the form of a flat base plate [19]. After that it joins the super-frames of one subseries obtained for the different hypothetical rates of visible motion of the objects, and estimates the equatorial coordinates of the objects by the method of astrometric reduction using the uniform selection of reference stars and performing a multipass LSM-estimate (the least square method) with culling anomalous observations during passes. Meanwhile, when the weight matrix for errors in measurements by the LSM is formed, the dependence of the value of errors in the estimate of equatorial coordinates on the value of apparent brightness of the objects and their coordinates in the coordinate system (CS) of a CCD frame is taken into account [20]. The obtained data are presented as an assembly of marks. The marks contain the estimates of amplitudes and equatorial coordinates of the supposed celestial objects as well as estimates of the coordinates for these objects in the CS of the CCD matrix of the basic frame. The module for forming the internal catalogue of immovable objects (internal catalogue) culls the objects that are immovable on a series of frames.

The marks from the immovable objects are identified with the objects of the stellar catalogue in the identification model using the Hungarian method to solve the problem about assignments on the bipartite graph, whose first partite presents the marks of a frame and whose second partite presents the objects of the stellar catalogue.

The module for estimating the apparent brightness of objects performs the LSM-estimate of the coefficients of the two-range piecewise-linear model for the dependence between the value of the apparent brightness of an asteroid and amplitude of its signal according to the assembly of objects from the internal catalogue identified with stars, estimates the apparent brightness of objects, and forms the culling threshold for apparent brightness. The introduction of this model is related to the fact that use of the linear single-range model of photometric recalculation for a large amplitude range results in the decreased accuracy in estimating apparent brightness in the small-amplitude range that is typical for the signals from asteroids, and use of the quadratic single-range model of photometric recalculation does not result in increased accuracy [21]. The model for culling by apparent brightness leaves only the marks whose estimate of apparent brightness does not exceed the indicated threshold value.

The module for preliminary discovery of trajectories forms trajectories based on accumulating the statistics proportional to the energy of signals along the possible movement trajectories of an object. This accumulation of signals is performed by using the multivalue transformation of object coordinates that allows a multistage implementation. The estimate of the apparent brightness of an object is used as energy statistics. The work of the module results in forming the assemblies of marks belonging to one object with a nonzero visible motion. Meanwhile, only the marks that were not culled by the estimate of apparent brightness are used [15, 16].

The module for amplitude-coordinate discovery performs the LSM estimate of the parameters of discovered trajectories and makes the decision about the presence of trajectories formed by the small solar system bodies. The decisive rule (DR) for discovering a new object on each frame selects the "best" mark to follow a trajectory. The "best" (kinematic) mark must not have very large deviations. Using a similar

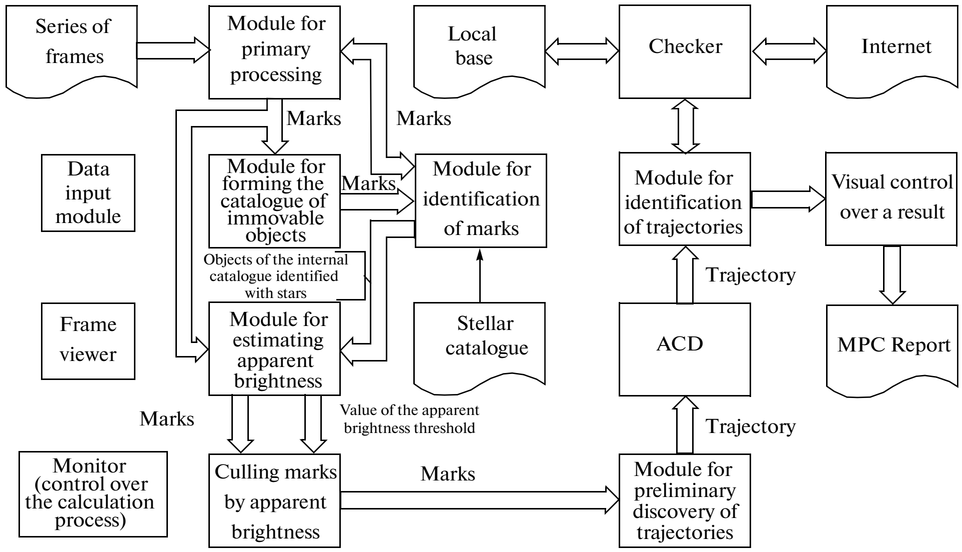

Fig. 1. Functional scheme of the CoLiTec program for automatic discovery of minor planets on a series of CCD frames.

amplitude component in the DR is related to the large variation in the amplitudes of signals from celestial objects in case of the abrupt changes in the observation conditions for an observation period.

The module for identification of trajectories compares the trajectories formed by small bodies, for example, asteroids, with the trajectories of well-known asteroids. The data about well-known asteroids are obtained from the base of parameters of asteroid orbits or from the server of the Minor Planet Center (MPC). The module for visual control over a result gives an observer the opportunity to make a final decision about the relation of a trajectory to an asteroid by the method for blinking a sky area. The data about the discovered asteroids are transformed into the report on the observations in the format assigned at the MPC (MPC-report). The obtained report with measurements is sent by the observer to the MPC server via e-mail.

2.4. Virtual Programs for Analyzing Time Series and Obtaining the Data about the Characteristics of Variable Stars

The presence of many types of star variability results in the need for developing the new methods for analyzing time series and improving the old methods, in particular, with account for the frequent temporal irregularity of observations that is typical for patrol observations included in the VO projects. In order to perform the statistically optimal mathematical modeling, an expert system was developed to analyze signals (that are possibly multi-channel): mode and multi-periodic signals and multi-harmonic, quasiperiodic, and stochastic signals.

At this stage, the UkrVO project suggests the following programs that imply determining the parameters of variable stars and their accuracy:

“Four” [35] performs the periodogram analysis using the sinusoidal approximation with the subsequent method for differential corrections to a period.(1) FDCN (“Four-M”) [35] determines the statistically optimal degree of a trigonometric polynomial in order to optimally model a multi-harmonic signal and determine the characteristics of variable stars required for registration in “The General Catalogue of Variable Stars” [http://cdsarc.u-strasbg.fr/viz-bin/Cat?cat=B%2Fgcvs&].(2) “O” (OL, OM, OW for different types of computers [36]) rapidly visualizes and transforms one-dimensional time series, carries out approximation by the Running parabola method, performs scale-gram and correlation analysis, marks observational intervals with a view to subsequently determining the extremum by different methods, builds phase curves; totally, there are approximately hundred functions.(3) “VSCalc” (Variable Stars Calculator) [39, 40] visualizes one-dimensional time series, determines the characteristics of the extrema by the polynomial approximation of the optimal degree, builds a phase curve, simplifies the processing of visual and photographic estimates of brightness, performs the periodogram analysis by the Lafler–Kinman–Kholopov method, etc.(4) MCV [4] visualizes and analyzes multichannel signals, inclusively, measures the brightness of a star group on multicolor CCD images.

Let us briefly dwell on the potential of the MCV program [4] for processing the time series of variable stars. After the series of CCD observations are processed by the popular programs (Maxim-DL, WinFit, IRAF, MIDAS, MuniPack, MuniWin, etc.), an observer obtains the time series of data. These series usually need to be subsequently processed: the exclusion of out-of-order points (caused by cosmic rays or hot pixels), account for extinction, heliocentric correction, search for periodicities, etc. are required.

The features for visualization in the MCV program. The program performs the major functions needed when browsing and processing observation series: the simultaneous displaying of variable and/or standard stars; removal/editing of separate points, columns, and lines; transformation of stellar magnitudes into intensities and vise versa; transformation of periods into frequencies and vise versa; linear transformation of a signal and time; account for a heliocentric correction; building of phase and smoothed curves; approximation of data by usual and/or trigonometric polynomials; calculations of color indices during simultaneous and quasi-simultaneous multicolor observations, as well as other features.

Using several comparison stars in the MCV program. The standard method for photometry of a variable (Var) star during CCD observations is to use one of nearby stars as a standard (Comp). In order to control the constancy of its brightness, one more (sometimes several) star called “control” (Contr) is measured, and the time dependences of differences of Var-Comp and Contr-Comp stellar magnitudes are often presented in graphs. Meanwhile, the measurements of brightness for a comparison star are evident to be aggravated with statistical errors; therefore, it is desirable to use the smoothed values of counts instead of individual values. Under good sky conditions, it is permissible to smooth counts by the air mass and time. However, nights most often are not “photometric” owing to the significant variation in the extinction coefficient. The method for CCD camera photometry with the simultaneous observations of stars and the background is efficient enough to take the “instantaneous” extinction coefficients into account. The program implements the algorithm of an average weighted comparison star. The use of this algorithm enables the accuracy of a “standard” star to be improved by tens of percent (depending on the brightness and number of comparison stars). In this case, a user can decide himself what standard stars he will use and what he will not.

Searching for periodicities in the MCV program. In order to search for periods, one of the most efficient methods for searching for possible periodic components of a variable signal is implemented: the approximation of the light curve by the multi-harmonic function of the degree s with the additional polynomial trend of the degree p is used:

$$x_c(t) = a_0 + \sum_{i=1}^{P} a_i t^i + \sum_{k=1}^{s} (b_k \cos k\omega t + c_k \sin k\omega t) = a_0 + \sum_{i=1}^{P} a_i t^i + \sum_{k=1}^{s} r_k \cos k\omega (t - T_{0k}),$$

where the coefficients are determined using the Least Squares Method. The periodogram analysis implements the possibility of simultaneous accounting and a polynomial trend, which makes it possible to avoid systematic errors that can arise when the trend is determined before the periodogram analysis. This method is particularly efficient when analyzing the brightness curves such as “super-humps,” when fluctuations of brightness are imposed on a significant trend. The method can also be recommended to search for the periods of asteroids, whose average brightness changes every night.

2.5. The Software for the Work with Supermassive Stellar Catalogues (>100 million objects)

Software for work with supermassive catalogues of celestial objects is worked out by an international group of virtual observatories, firstly, by specialists from the Center of Astronomical Data in Strasburg (CDS) [http://cdsweb.u-strasbg.fr/]. The XPM catalogue of absolute proper motions of 314 million stars of up to 22^m [42, 43] that presents an independent implementation of the inertial coordinate system was created at the SRI of Astronomy of the Kharkov National University by P. Fedorov et al.

In order to perform the prompt joint analysis of mass stellar catalogues (“Tycho-2”, UCAC2, PPMXL, XPM), the authors of the XPM catalogue created original software based on the SQL and joint database of modern astrometric catalogues. The estimates of corrections to the constant moon–sun precession were obtained using this software according to the data from the catalogues of the HCRF system and according to the data of the XPM catalogue in a stellar magnitude range from 10 to 22^m. In particular, the developed OGMUI program enables the kinematic parameters of the galaxy to be obtained in the express mode within the framework of the Ogorodnikov–Milne model according to the data of catalogues with a total capacity of up to 1 billion stars.

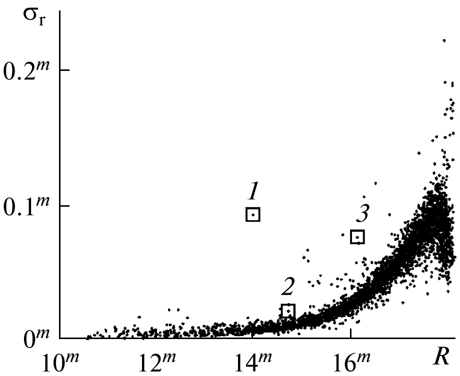

Fig. 2. Mean square dispersion of measurements depending on an average stellar magnitude. Numbers *1–3* mark the stars that proved to be periodic variable [44].

SCIENTIFIC PROJECTS OF THE UkrVO

3.1. Searching for, Discovering, Classifying, and Studying Variable Stars

Studies on variable stars by photographic plates have already been carried out for more than hundred years; nevertheless, photoplates still contain much information that is inexpedient to be neglected. Research on the behavior of newly discovered variable stars (outbursts, changes in a period, and other characteristics) in the past can be of large significance. In particular, the data from photographic plates can be used to discover new variable stars. Before the CCD observations became widespread, almost all variable stars had been discovered using photographical observations, and only a small part had been discovered by visual observations. The "blink-comparison" method was the most efficient method for searching for new variable stars on photographic plates for a long time. When the possibility of making the qualitative scanning of photographic plates appeared, it became possible to search for new variable stars by the same method as that used for CCD images.

The major idea of search by the VaST method [http://saistud.sai.msu.ru/vast] developed by Sokolovskii and Lebedev (the ShSAI MSU) is that the brightness curves, according to which a diagram is built for the dependence of a mean-square dispersion in photometric measurements on an average stellar magnitude, are obtained for all the stars that get into the viewing field of a CCD frame (or photoplate). The major array of points in such a diagram will be represented by "nonvariable" stars (or those whose seeming "variability" is determined by the accuracy of observations) as well as stars whose time scale of variability is significantly larger than a covered observational interval. As for variable stars, they are worth being searched for among points "falling out above" (Fig. 2), since the contribution of proper variability (if it is present), as well as contribution of image defects (hot pixels, cosmic rays, motes, etc.), are added into the spread. Thus, three new variable stars were discovered by A. Golovin based on the described method according to the brightness curves for 3712 objects in the environs of the magnetic cataclysmic variable star CD Ind [44] (Fig. 2).

The sufficiently successful method for searching for new variable stars based on analyzing the dependence of standard deviation in the estimate of brightness of a star on its average brightness is C-Munipack. More than sixty new periodic variable stars were discovered by N. Virnina using this software. Some variable stars were discovered near other eclipsing and cataclysmic stars: CL Aur [50], RXJ 2133 [55], TT Ari [56], AK Cnc [57].

The works on search for long-period variable stars using the plates of the Sonneberg Observatory [58], search for novae in M31 using the Tautenburg Schmidt plates [49], as well as research on semi-automatic search for variable stars in the environs of Oph 66 using the plates from the collection of the ShSAI MSU that enabled 274 new variable stars to be discovered, should be marked out among the works on search for variable stars [52] on digitized images of photoplates.

Variable stars with periods of from several hours to several years can be discovered using the plates from the collection of the MAO NASU and other observatories included into the joint archive of the UkrVO. The archives that enable such works must contain the series of observations over the same sky area. On the one hand, solitary frames do not give a desirable result. On the other hand, solitary frames from different archives can be joined into a common series (under the conditions that they were obtained in the analogous color system with identical instruments). The CCD observations continued with a view to discovering, classifying, and subsequently investigating new variable stars are a source for constantly filling not only the Variable Star Index ([http://aavso.org]) but also the database of the JDA UkrVO.

The use of photographic collections significantly supplements the modern CCD observations of stars activity. Thus, the search for the outburst activity of dwarf novae as well as cyclical changes in brightness of stars with the activity of the solar type that were included into the newly created catalogue of these objects is carried out at the CrAO with consideration of glass collections [11].

Analysis of the average and individual light curves of pulsating variable stars was performed using the developed algorithms and programs based on the archive of photographic observations obtained with the 7-camera astrograph of the AO ONU (Table 1) as well as international databases of the French (AFOEV), American (AAVSO), and Japanese (VSOLJ) associations of variable star observers [37]. Additions to the classification of semi-regular variable stars reflecting their evolutional status were suggested according to the results of studies on phenomenological parameters [14]. The observations over the group of symbiotic stars under the framework of the international campaign organized by L. Hric and A. Skopal (Astronomical Institute of the Slovak Academy of Sciences) using the photonegative collection of the 7-camera astrograph of the AO ONU, as well as photograph collections of the ShSAI MSU, resulted in analyzing the measurements of brightness, determining the characteristics of individual outbursts or pulsation cycles, investigating the changes in average brightness, amplitude and photometric period for stars from two classes: symbiotic pulsing stars and symbiotic Novae [41].

3.2. Stellar Catalogues

3.2.1. Creating the Catalogue of Positions and Proper Motions of 17 000 Stars in Selected Areas in the Ecliptic Zone. Images of 50 selected photographic plates with a size of 20 × 20 cm (5 × 5°) included in the glass archive of the Nikolaev AO were scanned and processed in 2009. The obtained catalogues of positions and proper motions of 17000 stars in the selected areas in the ecliptic zone contains stars with a stellar magnitude of 7–14^m for the observation epoch 1977.4 in the ICRS system (the "Tycho-2" reference catalogue). The overwhelming majority (more than 13 000) stars have a stellar magnitude of 11–13^m. When the catalogue was composed, the number of scanned images from the glass archive of the Nikolaev AO averaged six per object. The average standard deviation in one measurement of position is 62 mas (arch millisecond) for right ascension and 67 mas for declination. The mean-square error (*O*–*C*) was 84 mas for both coordinates. The external estimate of the accuracy of proper motions was obtained during comparison with the PPMX catalogue. The mean-square error of proper motion was approximately 5 mas/year for both coordinates. In the future, it is planned to obtain the catalogue of positions and proper motion of more than 100 000 stars near the galactic plane using old photographic observations and modern CCD observations from the Nikolaev AO DB with attracting the materials of the UkrVO DB.

Other scientific projects of the Nikolaev VO with the UkrVO DB are to accumulate CCD observations of sky areas with selected asteroids with a view to improving their orbits and determining masses, to observe asteroids approaching the earth, to observe stars in the selected coelosphere areas with a view to creating the catalogues of positions and proper motions of stars, and to observe objects of the near space (AESs and space waste) with the purpose of improving elements of their orbits and keeping a catalogue. Attracting the additional data of other observations from the UkrVO and IVOA DBs yields significant growth in the accuracy of obtained results for most objects (stars, asteroids, AESs).

The obtained results in the form of catalogue DBs and observation DBs are presented on the site of the Nikolaev AO and included into the UkrVO DB.

3.2.2. The catalogue of stellar positions of the FON program (MAO NASU). The catalogue of positions and stellar magnitudes of 1 108 603 stars from the 60° Northern Sky Area of the FON program is the practical implementation of the developed programs for processing images of the stellar sky in the LINUX/MIDAS/ROMAFOT software environment [33]. The plates were obtained during the observational campaign in 1980–1998 with a double wide-angle astrograph of the MAO NAS of Ukraine with twofold overlap in a working area of 4 × 4° and fourfold overlap for edge plate areas [12]. Exposition is double, the duration of the first is 45–60 s, and that of the second is 16–22 min. The procedures for astrometric image calibration were developed, and the catalogue of 1 108 603 stars was obtained based on 102 plates (204 frames).

The reduction of plates was performed according to the "Tycho-2" catalogue by polynomial of the third degree with added members depending on brightness. The discrepancies of conditional equations for all reference stars were averaged in a radius of 10–20 pixels and used as corrections for the instrumental errors of a scanner, after which the solution was repeated. The mean-square errors for a weight unit without the joint processing of two scans average 230 and ±330 mas for the coordinates *X* and *Y*, respectively, and ±230 mas in case where both scans are used. The characteristic curves for two expositions built according to the photoelectric and CCD standards for separate plates give an estimation of the photometric accuracy of the catalogue that is from ±0.19 to ±0.21 (the *B*-value). The total number of all registered objects on plates was approximately 5.5 million. After averaging (separately for fields with fourfold overlap and fields with twofold overlap), the catalogue of 1.1 million stars was obtained, whose positional and photometric accuracy were ±230 mas and $\pm 0.18^m$, respectively (according to the external convergence from the comparison with the PPMX and UCAC). For stars of $10-13^m$, the accuracy of coordinate determination by scans can be compared with the accuracy of coordinates obtained by measurements on the PARSEC measuring machine.

3.3. Identifying Gamma-Ray Burst Objects Using the Archives of the UkrVO

Being a unique observation collection, the glass library of the CrAO drew attention earlier and will attract it in the future when different astrophysical problems are solved. An analysis of the areas in which gamma-ray bursts (GRBs) were registered became one of the first fields where the archival astronegatives of the CrAO were used. Thus, the search for peculiar objects was made for 29 gamma-ray bursts registered in the WATCH-GRANAT and BATSE/GGRO experiments that had localization areas of less than one degree [48]. An analysis of 71 negatives from the collection of the CrAO for 15 areas did not detect objects with a variability of more than 0.5^m. This work aimed at studying other GB localization areas with the purpose of searching for objects with a long-term variability is continued.

At present, the results of regular observations over gamma-ray bursts from space vehicles are published in the GCN Circulars and transmitted to observatories to register and detect GRBs by the modern ground-based methods as well as to study any objects in the sky areas around GRBs. The latter task can also be solved by attracting the data of digitized photographic or CCD archives. The objects that can potentially appear on the plates of the archive (the observational accuracy is within 0.3–7.5″; stellar magnitudes are in a range of $14-9^m$) are selected for this purpose at the MAO NAS of Ukraine according to the publications of the GNS Circulars. For the search we use the digitized plates of the double wide-range astrograph of the MAO NAS of Ukraine ($D/F = 40/2000$, $M = 103''$/mm, a field is 8 × 8°), on which areas with a radius of several tens of minutes are selected, and all the objects getting into this area are identified. Thus, the bright objects, whose coordinates do not coincide with those indicated for the GRBs, and objects, which are absent in the well-known stellar catalogues, were detected for a part of areas by analyzing the coordinates of 67 GRBs that took place in 2010. Research on these objects is carried out using other observational instruments, and the catalogue of the objects in the areas around GRBs has been composed [45–47].

3.4. The Research on Active Galactic Nuclei Based on the Observational Archives of the CrAO and Data of Space Missions

The search for and research on the correlation of variation in the radiation fluxes of active galactic nuclei (AGN) in the optical and X-ray bands with the purpose of determining the mechanism of re-radiation that takes place in the "accretion disc–central black hole" system can serve as one of examples for the joint use of the archive of long-term optical observations at the CrAO (Table 2) and databases of space missions. The sample of the NGC 5548, NGC 7469, NGC 3227, NGC 4051, NGC 4151, Mrk 509, Mrk 564, Mrk 79, Ark 564 Seyfert galaxies, for which a large array of photometric data was accumulated in the optical band according to observations at a 70-cm AZT-8 telescope of the CrAO, was investigated in [29]. The archive of spectral observations over these objects obtained with a 2.6-m ZTSh telescope at the CrAO was used together with these data. The database of the brightness curves obtained from an RXTE space vehicle was used to solve the task of searching for the correlation of reradiation of a part of X-ray flux in the optical band and connection between the characteristics of the brightness curves for AGN [http://heasarc.nasa.gov/db-perl/W3Browse/w3browse.pl]. New results were obtained using the method of the interpolation cross-correlation function based on the linear interpolation of the brightness curves in case of shift by the value of delay and method of echo-cartography for determining the spatial location of the AGN areas radiating in different electromagnetic bands. Thus, the delay in measurements of radiation flux in the optical band with respect to the X-ray flux was first measured for the NGC 5548 and NGC 4051 galaxies: $2.8^{+3.7}_{-1.0}$ days for the NGC 5548 and $2.1^{+3.9}_{-0.4}$ days for the NGC 4051 with a reliability at the level of 97 and 98%, respectively. This result points to the reradiation of a part of X-ray flux in the optical band (the Compton effect) and speaks for the theory, according to which the common physical process of the activity of a galactic nucleus is observed to manifest itself in different AGN areas, namely, radiation in the optical band is created in an accretion disc, and that in the X-ray band is created in the area located above the central black hole (BH).

Using the archive of long-term spectral observations over the 1E 0754+3928 Seyfert galaxies obtained at the CrAO in 1998–2004 with the 2.6-m ZTSh telescope using a spectrograph installed in the Nesmith focus enabled the variability amplitude for the nucleus of this galaxy to be estimated in the continuum F (510 nm) and in the line H_β as well as permitted the mass of the central BH $M = (1.05 \pm 0.28) \times 10^8\ M_\odot$ and luminosity $\lambda L_{510} = 7.2 \times 10^{37}$ J/sec to be determined for the first time (in the reference system bound with an observer) [26]. The result is proved by the fact that the position of the 1E 0754+3928 galaxy is in good agreement with the position of other galaxies of the NLS1-type (with the exception of the NGC 4051) on the "mass of the BH—luminosity" diagram.

3.5. The Research on Solar Flares and Active Regions Based on Spectral Observations

Spectral research on flares was one of the major fields in the work of heliophysicists in the 1960s–1970s. In those times, flares were considered to be purely chromospheric, since their manifestations are the most noticeable in chromospheric spectral lines. Therefore, the efforts of researchers were focused on studying the changes in the physical state in the area of the chromosphere during flares. The spectral photographic observations over active regions and flares were started in 1976 with the purpose of investigating the role of the photosphere in the flare processes by the joint efforts of the workers from the MAO NAS of Ukraine and Astronomical Observatory of Kiev National University. They were carried out using ATsU-5 and ATsU-26 horizontal telescopes of the MAO NAS of Ukraine (Elbrus Area, Terskol Peak, an altitude of 3100 above sea level). At present, the solar spectrogram archive of the MAO NAS of Ukraine contains approximately 1500 WP1, WP3, and WO3 photoplates of the ORWO Company with spectra of active formations (flares of different power, flames, follicles, chromospheric bursts, and spots). Each photoplate contains height spectra with a height of 1 m, and each spectrum includes an area with a width of 10 nm. The spectra were obtained in different wavelengths: λλ 490, 520, 590, 610, 650 nm. The spectra were photographed with simultaneously photographing on a film or shooting with a video camera the solar images obtained using the interference-polarization Halle H_α-filter.

The photometry of spectrograms is performed using a unique two-coordinate automatic measuring complex created by V. G. Parusimov. The complex enables one to obtain high-quality records of spectra in the digital form that are subsequently used together with the developed spectrum processing software to investigate the sun.

The archive of the solar spectrograms accumulated from 1976 to 1990 together with the data of new observations enables the following tasks to be solved:

(1) Studying the changes in the physical state of the photosphere and chromosphere at different development stages of flares of different power. Building semi-empirical models of the photosphere and chromosphere. Studying the relation of the flare processes in the solar photosphere, chromosphere, and corona. Investigating homological flares.

(2) Studying the state of the photosphere and chromosphere before flares, which promotes the development of the physical methods for forecasting space weather.

(3) Generation of active regions on the sun.

(4) Morphological studies on the development of active regions and flares.

(5) Investigating physical conditions in flames, follicles, chromospheric bursts, spots, and pores in different cycles of the solar activity.

(6) Comparing the observational data with theoretical models of active formations and perfecting models.

Thus, the very first results showed that the photosphere was in the disturbed state during solar flares. The significant changes in photospheric lines speaking for the differences in the physical state of the photosphere during flares and in their absence were revealed in one of the first works when analyzing the spectrograms obtained using a spectrograph of the ATsU-5 horizontal solar telescope [2]. Subsequent research based on the obtained spectral observational material enabled the discovery of changes in the thermodynamic parameters in the lowest layers of the photosphere of active regions that began several hours before flares of different points and abruptly grew half-hour before their beginning [34]. The disturbance was shown later in [3] to expand during flares from the upper solar atmosphere into the photosphere and to cover its lowest layers.

At present, the archive of the data on spectral observations over flares is actively used by the workers of the solar physics department at the MAO NAS of Ukraine to solve the above-mentioned tasks of heliophysics.

3.6. Discovering New Small Solar System Bodies Using the CoLiTec Software

The working capacity of the CoLiTec program was checked [19–21] based on the Andrushevka Astronomical Observatory (the village of Andrushevka, Zhitomir oblast) using a telescope of the Karl Zeiss Company with a mirror diameter of 60 cm (equipped with a FLI PL09000 CCD camera) and based on the Russian remotely controlled ISON-NM1 observatory [http://spaceobs.org/ru] located in New Mexico (United States) (an Astroworks Centurion-18 astrograph with a mirror diameter of 45 cm equipped with a FLI ML09000-65 CCD camera).

In May 2010, an asteroid was discovered in the automatic mode by the workers of the Andrushevka AO for the first time in the Post-Soviet countries. Twenty-five asteroids were discovered during the subsequent testing of the program from May to December 2010 (MPC 70135–70574; MPC 71009–71492; MPC 71493–71888; MPC 71889–72344; MPC 72345–72992; MPC 72993–73612; MPS 366899–368492).

The application of the program at the ISON-NM observatory significantly increased the number of observed asteroids and observations related to them, having enabled the observatory to get into the top ten of observatories by the number of observations over asteroids and to become the most "observing" amateur observatory of the world in December 2010 [http://spaceobs.org/ru/2011/01/13polgoda-obzornoj-programme-ison-nm]. Thus, 140 asteroids were discovered during the operation testing of the CoLiTec software for a month and a half from November 27, 2010, to January 13, 2011 [http://lfvn.astronomer.ru/forum/ndex.php?topic-628.mgs14976#mgs14976]. Thirty-nine asteroids were discovered on the night of January 3, 2011, using CoLiTec, which is an absolute record of this observatory; 3868 observations over 967 asteroids were made on this night by an observer of the ISON-NM using CoLiTec, which is also an absolute record of this observatory [http://spaceobs.org/en/2010/12/13/c2010-x1-elenin-wj08b04].

The C/2010 X1 comet (Elenin) was discovered on December 10, 2010, using the CoLiTec software by L. Elenin at the ISON-NM (IAU Electronic Telegram N 2584, CBAT, 2010; MPEC 2010-X101: COMET C/2010 X1 (ELENIN), and COMET P/2011 N01.

The National Space Facilities Control and Test Center (Yevpatoria, Ukraine) carried out 1640 measurements of 142 asteroids using the 70-cm AZT-8 telescope equipped with the FLI PL09000 CCD camera (the size of a frame during shooting with single binning was 1528 × 1528 pixels) and using the CoLiTec software in 2010. This program is also used in the observations and cataloguing of space waste.

CONCLUSIONS

The work reviews the most important components in the national project of the UkrVO that has been actively developed in Ukraine for recent years.

One of the major tasks of the UkrVO is to create a joint digital archive of the observational data obtained at the observatories of Ukraine since the 1890s, where astronegative collections are of particular interest. The importance of creating the astronegative JDA is determined by both its significant science intensity and laboriousness of its creation and administration (more than 200000 plates) in the IVOA standards. The joint digital archive of astronomical observations enables the local data archives of the Ukrainian observatories characterized by the significant heterogeneity and different state of their readiness to inclusion into the joint archive to be formatted according to the common standards. To perform this task, it is necessary to create VO oriented software. With this purpose, the large-scale program verification of the content and integrity of the joint database is performed under the scope of the UkrVO, for which the second version of the DBGPA V2.0 software package, providing the convenient instruments for the remote work with digitized archives of photographic plates that are in the open access, has been implemented. In order to efficiently organize the work with the JDA, the arsenal of the visualization instruments has been supplemented with the software developments on the JAVA and Flash ActionScript platform that provide flexible tools for image zooming and scaling as well as for graphical formats "on the fly" conversion. Since the data of the JDA UkrVO are standardized, they can be accessed through different interfaces and applications developed by separate observatories. In particular, the joint archival data of the MAO NAS of Ukraine, Nikolaev AO, and Lvov AO are accessible through interfaces of two different databases. The unity of the IVOA formats and standards will enable the VO-tools, such as ALADIN, VO-Spec, etc., to be used for not only local archives but also the JDA as a whole. Thus, the integration of the Nikolaev

AO server with the web-interface of the ALADIN program permits the archive to be worked with by both proper software instruments and VO instruments.

Using the VO instruments requires the compliance of image formats with the IVOA standards, which makes it necessary to perform photometric and astrometric calibration. For this purpose, software for processing digital images of large sizes with a high accuracy has been developed based on the LINUS/MIDAS/ROMAFOT package. For example, the task of extending the FONAC stellar catalogue to fainter objects is solved at the MAO NAS of Ukraine using this package, and the observational archive is processed at the Nikolaev AO in order to obtain the catalogue of positions and proper motions of more than 100000 stars near the galactic plane.

The advanced fields of creating the tools of the UkrVO include the development of the instruments for automatic registration of moving celestial objects against the background of the stellar sky with the subsequent visual checking of the results obtained. Thus, the CoLiTec program developed at the KhNURE enables the number of the registered small solar system bodies to be increased and permits new bodies to be discovered. Several dozens of asteroids were discovered only in 2010 with its help using telescopes of Ukraine and the United States, and the C/2010 X1 (Elenin) and P/2011 N 01 comets were discovered at the ISON NM observatory.

In addition to these tasks, the article presents the scientific programs using the local archives of the UkrVO that includes the research and discoveries of variable stars, search for optical analogues of gamma-ray bursts and investigation of objects in stellar fields around them, analysis of long observational series of active galactic nuclei, research on solar flares and active solar regions based on the archives of spectral observations.

It is necessary to note that, despite the general large scale of the solved scientific tasks, the developed software and mathematical complexes in general remain single-purpose and are still weakly oriented to the standards and formats of the virtual observatory. This requires the most rapt attention of the UkrVO Consortium [10], since the success of the UkrVO project as a whole depends on the level of the software implementation of the VO tools.

ACKNOWLEDGMENTS

The work was performed under the scope of the projects “Establishment of the Astronegative Database of the UkrVO” (2010) and “Establishment of the Digital Archive of the UkrVO” (2011) of the Ukrainian Astronomical Association as a part of the Target Program for Scientific Research of the Astronomy and Physics Department of the National Academy of Sciences of Ukraine “Determination of the Kinematic Parameters of the Universe Objects in the International Coordinate System,” for which the authors thank the manager of the program Ya.S. Yatskiv. The authors are grateful to S.G. Kravchuk for valuable remarks on the manuscript of the article.

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