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ASTRONOMICAL VIRTUAL OBSERVATORY AND THE PLACE AND ROLE OF BULGARIAN ONE

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Abstract: Virtual observatory could be defined as a collection of integrated astronomical data archives and software tools that utilize computer networks to create an environment in which research can be conducted. Several countries have initiated national virtual observatory programs that combine existing databases from ground-based and orbiting observatories, scientific facility especially equipped to detect and record naturally occurring scientific phenomena. As a result, data from all the world's major observatories will be available to all users and to the public. This is significant not only because of the immense volume of astronomical data but also because the data on stars and galaxies has been compiled from observations in a variety of wavelengths - optical, radio, infrared, gamma ray, X-ray and more. In a virtual observatory environment, all of this data is integrated so that it can be synthesized and used in a given study.

During the autumn of the 2001 ***(26.09.2001)*** six organizations from Europe put the establishment of the **Astronomical Virtual Observatory** (***AVO) – ESO, ESA, Astrogrid, CDS, CNRS, Jodrell Bank*** (Dolensky et al., 2003). Its aims have been outlined as follows:

- To provide comparative analysis of large sets of multiwavelength data;
- To reuse data collected by a single source;
- To provide uniform access to data;
- To make data available to less-advantaged communities;
- To be an educational tool.

The Virtual observatory includes:

- Tools that make it easy to locate and retrieve data from catalogues, archives, and databases worldwide;
- Tools for data analysis, simulation, and visualization;
- Tools to compare observations with results obtained from models, simulations and theory;
- Interoperability: services that can be used regardless of the clients computing platform, operating system and software capabilities;
- Access to data in near real-time, archived data and historical data;
- Additional information - documentation, user-guides, reports, publications, news and so on.

This large growth of astronomical data and the necessity of an easy access to those data led to the foundation of the ***International Virtual Observatory Alliance*** *(IVOA).* IVOA was formed in June 2002. By January 2005, the IVOA has grown to include 15 funded VO projects from Australia, Canada, China, Europe, France, Germany, Hungary, India, Italy, Japan, Korea, Russia, Spain, the United Kingdom, and the United States.

At the time being Bulgaria is not a member of European Astronomical Virtual Observatory and as the Bulgarian Virtual Observatory is not a legal entity, we are not members of IVOA. The main purpose of the project is **Bulgarian Virtual Observatory** to join the leading virtual astronomical institutions in the world.

Initially the **Bulgarian Virtual Observatory** will include:

- BG Galaxian virtual observatory;
- BG Solar virtual observatory;
- Department Star clusters of IA, BAS;
- WFPDB group of IA, BAS.

All available data will be integrated in the Bulgarian centers of astronomical data, conducted by the Wide Field Plate Archive data centre. For the above purpose POSTGRESQL or/and MySQL will be installed on the server of BG-VO and SAADA tools, ESO-MEX or/and DAL ToolKit to transform our FITS files in standard format for VO-tools. A part of the participants was acquainted with the principles of these products during the “Days of virtual observatory in Sofia” – January, 2008.

1. BASIC KNOWLEDGE

Virtual observatory could be defined as a collection of integrated astronomical data archives and software tools that utilize computer networks to create an environment in which research can be conducted. The VO consists of a number of data centers each with unique collections of astronomical data, software systems and processing capabilities (Djorgovski & Williams, 2005).

The idea for the Virtual observatory foundation originated long before but its realization became possible in the latest 6-7 years, i.e. this is a new field of worldwide significance

The need for the development of a VO is premised by:

- There is an explosion in the size of astronomical data sets delivered by new large facilities. The processing and storage capabilities necessary for astronomers to analyze and explore these data sets will greatly exceed the capabilities of the types of desktop systems astronomers currently have available to them.
- There is a great scientific gold mine going unexplored and underexploited because large data sets in astronomy are unconnected. If large surveys and catalogues could be joined into a uniform and interoperating "digital universe", entire new areas of astronomical research would become feasible.

During the autumn of 2001 ***(26.09.2001)*** six organizations from Europe put the establishment of the **Astronomical Virtual Observatory** (***AVO)* – *ESO, ESA, Astrogrid, CDS, CNRS, Jodrell Bank*** (Lawrence, 2002)**.** This large growth of astronomical data and the necessity of an easy access to that data led to foundation of the ***International Virtual Observatory Alliance (IVOA).*** IVOA was formed in June 2002 (Quinn et al., 2004). The International Virtual Observatory Alliance: recent technical developments and the road ahead.. By January 2005, the IVOA has grown to include 15 funded VO projects from Australia, Canada, China, Europe, France, Germany, Hungary, India, Italy, Japan, Korea, Russia, Spain, the United Kingdom, and the United States – ***Tab.1***.

Table 1:

Current National Virtual Observatory Projects		
Name	***Country***	***Internet address***
Astrogrid	United Kingdom	www.astrogrid.org
AUS-VO	Australia	www.aus-vo.org
Canadian VO (CVO)	Canada	service.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/cvo

China-VO	China	www.china-vo.org
DataGrid for Italian Research in astrophysics and coordination (DRACO)	Italy	wwwas.oat.ts.astro.it/draco/
Euro-VO	Europe	www.euro-vo.org
German Astrophysical VO (GAVO)	Germany	www.g-vo.org
Hungarian VO (HVO)	Hungary	hvo.elte.hu/en/
Japanese VO (JVO)	Japan	jvo.nao.ac.jp
Korean VO (KVO)	Korea	kvo.kasi.rc.kr
National VO (NVO)	USA	www.us-vo.org
Russian VO (RVO)	Russia	www.inasan.rssi.ru/eng/rvo/
Spanish VO (SVO)	Spain	laeff.esa.es/svo/
VO France	France	www.france-vo.org
VO-India	India	vo.iucaa.ernet.in/~voi/

1.1 Major technical initiatives:

There are nine working groups (WG) and five interest groups (IG) in the IOVA – ***Tab.2***:

Table 2:

working groups	***interest groups***
• Resource registry • Data modeling • Unified contend descriptor • Data access layer • VOtable • VO query language • Grid and WEB services • Standards and processes • VO events	• VO architecture • VO applications • VO theory • Global GRID forum – Astronomical Grid community research group • Data curation and preservation

Table 3 gives technical details of these initiatives. The last column marks the stable version of the software.

Table 3:

Technical Specifications Title	***Group***	***Most stable***
IVOA Astronomical Data Query Language	VQL	1.01
Data Model for Astronomical Dataset Characterization	DaM	1.00
Ontology of Astronomical Object Types	Semantics	1.00
Simple Cone Search	DAL	1.00
IVOA Document Standards	SDP	1.00
IVOA Identifiers	ReR	1.12
Maintenance of the list of UCD words	Semantics	1.20
IVOA Registry Interfaces	ReR	1.00
Resource Metadata for the Virtual Observatory	ReR	1.12
Simple Image Access	DAL	1.00
IVOA Single-Sign-On Profile: Authentication Mechanisms	GWS	1.00
IVOA SkyNode Interface	VQL	1.01
Space-Time Coordinate for the Virtual Observatory (STC)	DaM	1.30
An IVOA standard for Unified Content Descriptors	Semantics	1.10
UCD1+ Controlled Vocabulary	Semantics	1.11
Sky Event Reporting Metadata (VOEvent)	VOE	1.11
VOResource: an XML Encoding Schema for Resource Metadata	ReR	1.02
VOSpace service specification	GWS	1.00
IVOA Spectral Data Model	DaM	1.00
VOTable Format Specification	VOT	1.10

In its January 2003 meeting IVOA marked *six major technical initiatives* for development of Virtual Observatories. Details follow:

Registries. Registries function as the “yellow pages” of the Virtual Observatory, collecting metadata about data resources and information services into a query able database. But, like the VO resources and services themselves, the registry is also distributed. Replicas will exist around the network, both for redundancy and for more specialized collections. The VO projects are investigating a variety of industry standards for implementation of registries, including the Open Archive Initiative (OAI) developed in the digital library community. Registry metadata are using the Dublin Core definitions, also developed for the library community, wherever possible (Plante et al., 2004).

Data Models. Although the international astronomy community has long agreed on a common format for data, the FITS standard, there are many variations in which metadata can be encoded in FITS files, and many options for storing associated data objects (a spectrum, its wavelength scale, and its variances, for example). FITS is a syntactic standard, not a semantic standard. The VO data models initiative aims to define the common elements of astronomical data structures and to provide a framework for describing their relationships. Data models will allow software to be designed to operate on many data storage variants without needing to modify the source data structures (Hanish, 2006).

Uniform Content Descriptors. The CDS in Strasbourg pioneered the development of UCDs in order to make semantic sense of its large collection of astronomical catalogues and tables. Among the tens of thousands of column names in its collection, they found that there were only about 1500 unique types of content. Astronomers are creative, having found some 250 labels for a Johnson V magnitude! UCDs will provide a lingua franca for metadata definitions throughout the VO.

Data Access Layer. Building on the VO data models and UCDs, the data access layer provides standardized access mechanisms to distributed data objects. Two initial prototypes for the DAL have been developed thus far: a ConeSearch protocol and a Simple Image Access Protocol. The former returns catalogue entries for a specified location and search radius on the sky, and the latter returns pointers to sky images given similar selection criteria. Work is under way to extend the DAL to other data types and to enable legacy software systems to incorporate DAL interfaces (Budavári et al., 2003).

VO Query Language. The many and distributed databases of the VO will need a standard query language. Although most, if not all, modern astronomical databases are queryable with SQL, SQL has limitations in areas fundamental to astronomical research, such as region specifications on the sky. The concept of a join based on spatial coordinates must be “fuzzy”, allowing for uncertainties in the coordinates, differences in spatial resolution of detectors, and different physical scale sizes of objects at different wavelengths. Some groups are experimenting with very high-level query languages that would allow natural language query expressions.

VOTable. The first international agreement reached by the VO projects was VO-Table, and XML mark-up standard for astronomical tables. The heritage of VO-

Table comes from FITS, the CDS Astrores format, and the industry-standard eXtensible Mark-up Language. The data access layer ConeSearch and SIAP services return results in VOTable. VOTable software libraries have been developed in perl, Java, and C++, and VO India has developed a general purpose VOPlot program in Java for data display. VOTable has been in use for just over a year, and the IVOA is now looking into what enhancements or extensions might be necessary.

The VO Table format is an XML standard for interchange of data represented as a set of tables. A table itself is an unordered set of uniform rows, as specified in the table metadata. Each row in a table is a sequence of table cells. Derived from the Astrores format [xx] and modeled on the FITS table format [yy], VO tables are as closed as possible to the FITS Binary Table Format (Ochsenbein et al., 2004).

1.2 Virtual Observatory Tools

Astronomy is at a turning point. Major breakthroughs in telescope, detector, and computer technology allow astronomical surveys to produce massive amounts of images, spectra, and catalogues. These datasets cover the sky at all wavelengths from γ- and X-rays, optical, infrared, through to radio. The VO is an international, community-based initiative, to allow global electronic access to available astronomical data, both space- and ground-based. The VO aims also to enable data analysis techniques through a coordinating entity that will provide common standards, wide-network bandwidth, and state-of-the-art analysis tools (Kim et al., 2005) .

The Astrophysical Virtual Observatory Project (AVO) is conducting a research and demonstration programme on the scientific requirements and technologies necessary to build a VO for European astronomy. The AVO has been jointly funded by the European Commission (under FP5 - Fifth Framework Program) with six European organizations participating in a three year Phase - A work programme (Padovani et al, 2004).

The AVO project is driven by its strategy of regular scientific demonstrations of VO technology. For this purpose an "AVO prototype" has been built. The prototype consists of a suite of interoperable software, plus a set of conventions or standards for accessing remote data, and for launching remote calculations. The main component of the software is based on the CDS Aladin visualization interface (Bonnarel et al. 2000). This prototype VO portal (v. 1.003-β) allows efficient interactive manipulation of image and catalogue data, and provides access to remote data archives and image servers via the GLU registry of services.

The Aladin image server is an example of such a VO service. It describes the images stored in the Aladin database using a data model (Images Distributes Heterogenes pour l'Astronomie; IDHA5), and provides image cutouts on request. In this paper we make heavy use of cutouts of the GOODS data available via this service. The prototype is also interoperable with the other long standing CDS Vizier and

SIMBAD services (Ochsenbein, Bauer, & Maicout 2000), and significant interoperability gains are achieved by use of the VOTable format for astronomical tables.

The prototype includes a catalogue cross matching service. This service allows positional cross matching of two catalogues to find the best matched source, all matching sources, or sources not matching within some given threshold radius (in arc seconds). These three modes, plus the ability to compare directly with the images from which the catalogues were generated, make for an extremely efficient tool for which to perform cross matches and check for multiple or aberrant matches.

In addition to the AVO software, we have also made intensive use of the Starlink topcat tool, and the VOIndia VOPlot plug-in to the prototype (Padovani, P. 2005).

1.3 Guidelines and How-To for Scientists

Here astronomers can find answers to some of the most common "how to" questions they might have on finding data in a VO context.

Finding data for a given source. This thread illustrates how to answer a typical VO question: what sorts of data do exist for an astronomical source? And how does one find them and access them? *Use Aladin to answer this question and accomplish this task with just a few mouse clicks.*

Finding images for a given source. This thread illustrates how to answer a typical VO question: do images in a given wavelength range exist for an astronomical source? If so, how does one find them and display them?? *Use Aladin to answer this question and accomplish this task with just a few mouse clicks.*

How to generate the Spectra Energy Distribution of a source in an image. This thread illustrates how to answer a typical VO question: do spectra in a given wavelength range exist for source in a given field-of-view? Can one seamlessly build their Spectral Energy Distribution? The interoperability between Aladin (catalogue browsing, image visualization) and VOSpec (Spectral Energy Distribution visualization and analysis) allows you to answer these questions and accomplish these tasks with just a few mouse clicks.

How to generate and analyze Spectral Energy Distributions. This recipe shows how to generate and display a Spectral Energy Distribution with VOSpec, combining spectra from various observatories in different energy bands, as well as user-produced spectra uploaded from the local disk. It also illustrates the usage of simple fitting tools in VOSpec, as well as the access to theoretical models and absorption/emission line databases, which have been incorporated in Virtual Observatory servers around the world.

Visualizing, manipulating and cross-correlating catalogs. There are a number of tools available for visualizing, manipulating and cross-correlating catalogues. Some of these tools are applications that are downloaded and run on the desktop, some can be started with "webstart" technology and others may be used as a service where the calculation is performed on a remote computer.

Data Access Worksheet. Step by step worksheet that demonstrates some ways to retrieve and visualize astronomical images, spectra and catalogue data using the Astrogrid/Euro-VO access mechanisms to VO services.

Merlin Imager. Of special interest for the radio community is Merlin Imager.

The MERLIN radio interferometry archive contains visibility data. If an observation has been suitably calibrated, an image can be extracted on demand from anywhere in the field of view.

1.4 VOTECH project

The VOTECH project is an EU FP6 funded design study which aims to complete the technical preparation for the construction of the European Virtual Observatory (Euro-VO). The Euro-VO is an integrated and coordinated program designed to provide the European astronomical community with tools, systems, research support, and data interoperability standards necessary to enable astronomers simplified access to the information they need to complete their research.

The idea of the Euro-VO is to make it feel as if all the astronomical data and tools are available on the astronomer's desktop, even though they are actually located on systems spread out over the whole of Europe and even the rest of the world. The VOTECH project is responsible for completing the design work and feasibility studies on the backbone software components that will make the Euro-VO possible. For more information on the VOTECH project a more thorough summary is available here.

1.5 GRID and VO:

Virtual Observatory is an outstanding Grid application involving (Jacob et al., 2005) the federation of many distributed astronomy data sources.

A good illustration along these lines is The European Grid of Solar Observations (EGSO) (Bentley 2002) that is a Grid test-bed based on solar data resources, which represents a step toward a virtual solar observatory. It is a parallel effort to projects such as the Virtual Solar Observatory (VSO) in the United States (Gurman, 2002), and the Astronomical Virtual Observatory (AVO) led by ESO. The EGSO project aims to produce the framework for a coordinated community-wide resource for obtaining and reducing solar observation (Reardon, 2002). The EGSO project is funded by the European Commission through Information Society Technology (IST) Program of the Fifth Framework (Grid Test Bed, Digital Collections) and the primary objectives are respectively (Messerotti et al. 2003):

– Federate solar data archives across Europe (and beyond!);

– Create tools to select, process and retrieve distributed and heterogeneous solar data (including data mining);

– Provide mechanisms to produce standardized observing catalogues for space and ground-based observations;

– Produce catalogues of solar features through automatic feature recognition;

– Explore application of Grid technologies to distributed data analysis.

The EGSO is employing Grid computing concepts to federate heterogeneous solar data archives into a single 'virtual' archive, allowing scientists to easily locate and retrieve particular data sets from multiple sources. To enlarge the reach and utility of the Grid, collaborations are in progress with other projects and consortia such as: Virtual Solar Observatory (USA); SpaceGRID (ESA); GRIDSTART (IST Cluster); and Astrogrid (UK), as well as the Space Weather and astronomical communities.

There is greater interest in cross-correlating the datasets to find new phenomena. Each project will likely publish a database externalized as a set of Web services. Searches involving both spatial and time-domain constraints are typical tasks for the Virtual Observatory. The benefits of the existence of such VOs become obvious with the first major discovery made with the Virtual Observatory – the discovery of 31 previously undetected powerful supermassive black holes in the so-called GOODS (Great Observatories Origins Deep Survey) fields (Padovani et al., 2004).

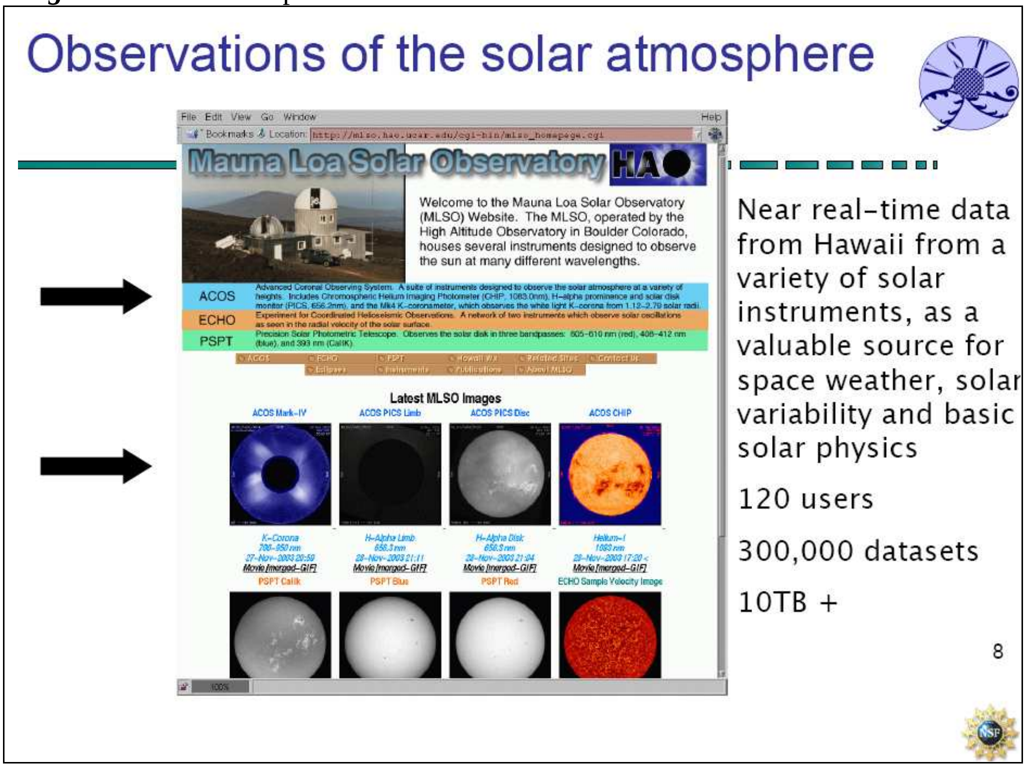
A good illustration of the above mentioned is Peter Fox's illustration – ***Fig.1***.

More than 400 papers have been published related to "Virtual Observatories". In the references below the basic ones are selected. They all cover all important aspects of the problem. These publications indicate that Virtual Observatories have a very high potential to enable new astronomical research.

1.6 Advantages of a Virtual Observatory

- new, more, better, faster, and easier science;
- comparative analysis of multi-instrument data;
- improving the preparation, development, building of new ground-based and space-based projects;
- improving new observation proposals;
- comparison of real data with simulated data – to provide feedback to new insights, new models, new physics;
- permits new approaches to research and multi-wavelength exploration, opening discovery capabilities not otherwise possible (Wu et al., 2003).

Figure 1: Solar atmosphere observations



1.7 Following are some basic keys from Euro-VO WEB page:

Science Reference Mission

- Circumstellar disks: from pre-Main Sequence stars to stars harboring planets
- Intermediate Velocity Clouds
- Which star will go Supernova next?
- Initial Mass Function within 1 kpc: from planetary to stellar masses
- Initial Mass Function for massive stars (de Grijs and Alvensleben, 2004)
- The contribution from low and intermediate mass stars to the interstellar medium
- Galaxy Formation and Evolution from z = 10 to z = 0.1

- Build-up of supermassive black holes
- The Formation and Evolution of Galaxy Clusters
- Correlation of Cosmic Microwave Background, radio/mm and optical/NIR Galaxy Surveys.

The sphere of scientific problems that is being solved and can be solved by means of Virtual

Observatory is limited ONLY by the level of our knowledge as VO practically unifies all achievements of modern astrophysics into a powerful product for scientific research.

Key Science and Exemplar Science Themes:

Extragalactic Case: Clustering of clusters of galaxies

- Background
- Required Data and Applications
- VO Workflow
- End Results

The Initial Mass Function of massive stars

- Background
- Data Requirements
- Theoretical Models

tools for data manipulation and comparison

- Initial investigations
- Future Developments

Individual Objects: 3C295 and its cluster

- Multi-wavelength data
- Spectral Energy Distribution of 3C295
- Spatially resolved Radio Spectral Index and X-ray properties
- Identification of neighboring galaxies by color
- Detailed spectral analysis

Time Domain Cases

Requirements extracted from the AVO SRM

Data and Tools

1.8 VO-Software

In the section scientists can find available VO-compatible applications for their immediate use to do science.

DATA DISCOVERY

Aladin: An interactive software sky atlas allowing the user to visualize digitized images of any part of the sky, to superimpose entries from astronomical catalogues (Fernique et al., 2004).

VO Desktop: A desktop application for working with the Virtual Observatory. It can explore data resources, query remote catalogues, and construct workflows to automate tasks.

Datascope: A Web Service for discovering and exploring data in the Virtual Observatory from archives and data centers around the world.

SPECTRAL ANALYSIS

VOSpec: A multiwavelength spectra analysis tool, with access to both Spectral services (SSAP) and Theoretical Spectral services (TSAP) (Osuna et al., 2004).

SPLAT: A spectra analysis tool.

Specview: 1-D spectral visualization and analysis.

Euro3D: Analyze datasets in Euro3D FITS format.

DATA VISUALISATION AND DATA HANDLING

Topcat: An interactive graphical viewer and editor for tabular data. (It understands a number of different astronomically important formats (including FITS and VO-Table) and more formats can be added).

VOPlot: A tool to visualize astronomical data.

VisIVO: A visualization and analysis software for astrophysical data. VisIVO can handle both observational and theoretical data.

SED BUILDING AND FITTING

VOSED: SED Builder & Fitting Tool.

Yafit: An SED fitting tool.

2. BULGARIAN VIRTUAL OBSERVATORY (BGVO)

At the time being Bulgaria is not a member of European Astronomical Virtual Observatory and as the Bulgarian Virtual Observatory is not a legal entity, we are not members of IVOA. The main purpose of the project **Bulgarian Virtual Observatory** is Bulgaria to take its place amongst the leading astronomical institutions in the world. Initially the available data of external galaxies observations and star clusters and associations will be incorporated in the Bulgarian astronomical data centre and data from solar observations will be added.

a) Basic astronomical institutions in Bulgaria

Potential Bulgarian centers for astronomical data are: Rozhen National Astronomical Observatory, Belogradchik astronomical observatory, Institute of Astronomy - Bulgarian Academy of Sciences, Department of Astronomy, University of Sofia, University of Shoumen, University of Plovdiv and several People Astronomical observatories.

b) Main goals, expected effect and results:

- To unite Bulgarian astronomical data, to provide them to the rest of the world and to integrate them into the IVO
- To provide Bulgarian astronomical community with a convenient access to the world data grid
- To use Bulgarian instrumentation to provide observational data in remote mode when needed
- To develop Bulgarian electronic astronomical education resources

c) what's done?

Bulgaria participated in the Astrogrid project with the HyperLeda (Prugniel et al., 2004) database (http://draco.skyarchive.org/~hyperleda/) and with WFPDB (Wide-Field Plate DataBase). With the support of COST Action 283 in Bulgaria was organized one of the main working conferences: iASTRO MC MEETING & WORKSHOP – "VIRTUAL OBSERVATORIES: Plate Content Digitization, Archive Mining and Image Sequence Processing" 27-30 April 2005, Sofia, Bulgaria, with more than 70 participants from 17 countries, (http://www.bgvo.org/WS-SOFIA_2005). In February 2007, the Institute of Astronomy, BAS initiated its participation into the EURO-VO Data Center Alliance (EuroVO-DCA) of the European Virtual Observatory. A regional working meeting of the VO was held in January 2008 in Sofia: Virtual Observatory Info-Workshop, Sofia, Bulgaria, January 24-25, 2008, http://www.bgvo.org/VODAY2008/. It was organized in collaboration with leading Bulgarian scientific institutions: Institute of Astronomy, BAS, Institute of Mathematics and Informatics, BAS, Space Research Institute, BAS and Sofia University. The Following VO Data Centers attended the workshop: Serbian BELDATA, Romanian ROVO, German GAVO and Hungarian HVO.

In the frame of the Bulgarian Virtual Observatory the department "Sun" (Institute of Astronomy, BAS) started web site www.astro.bas.bg/sun/SVO (**fig. 5a**) and the department "Galaxies" (Institute of Astronomy, BAS) started web site Galaxian Virtual Observatory – http://www.astro.bas.bg/galaxies/gvo/bgvo_galaxies.html (**fig.5b**).

2.1 Bulgarian Virtual Solar Observatory

The ambition is to present in the database section newly received data from the solar coronagraph in the National astronomical observatory "Rozhen". In the near future we plan to drive database section by means of MySQL or PostgreSQL databases. As part of this project a grid of solar observational centers located mainly in the People's observatories around the country should be built. The provided data (mainly disk images) also will be stored in that section.

Many of the research problems in solar physics require access to large amounts of data of different observables in various wavelength bands. Analysis can only start following the identification of events, features and phenomena and the location and retrieval of the required data. The rapidly increasing volumes of data and the desire to share data with other communities have led to several projects intended to create virtual solar observatories to facilitate access (Bentley et al., 2004).

There are three main initiatives: the European Grid of Solar Observations (EGSO), funded by the European Commission; the US Virtual Solar Observatory (VSO), funded by NASA; and the Sun Earth Connector (CoSEC), founded by NASA under the International Living with a Star (ILWS) program. EGSO and CoSEC are coordinating these activities and, where possible, share resources (Bentley, 2002)

***Fig.2* –** an example of WEB pages of Solar and Galaxian Bulgarian virtual observatory.

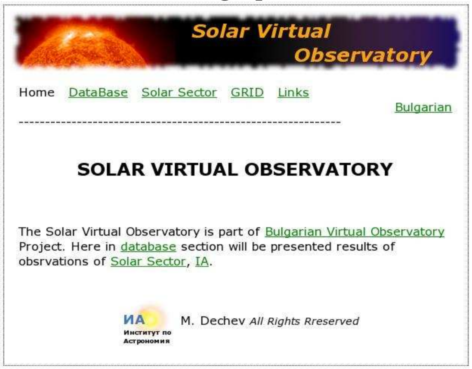
The VSO is a set of data archives and analysis tools distributed in physical location at sites that already host such system (Hill, 2000). The technical concepts of the VSO include federated distributed archiving, an adaptive metadata thesaurus, a single unified intuitive graphic user interface, context-based searches, and distributed computing. The development of a VSO would greatly facilitate solar physics researches since a user no longer need to have detailed knowledge of all solar archive sites.

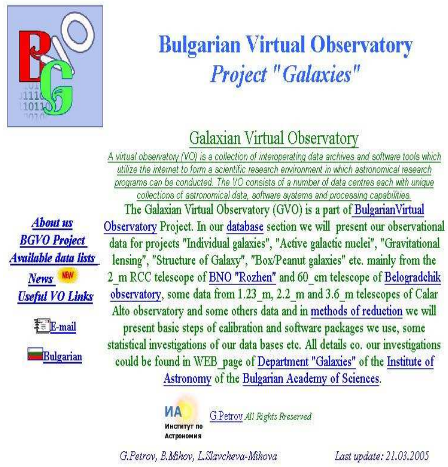
In solar physics, observations, especially synoptic ones are used to construct a picture of the plasma in multi-dimensional parameter space, time, temperature and density. The observations are made at different wavelengths originating at different levels in the solar atmosphere and the combined information allows the user to build up an understanding of the changes in structures, motion of material, sites of energy release, etc. Observations from both ground and space are both important.

Satellite-based observations are made at wavelengths that do not penetrate the Earth's atmosphere, including UV, EUV and X-rays. Ground-based observations, mainly in optical and radio wavelengths, compliment those from space.

Figures 2: **a)** Solar virtual observatory WEB_page. b) Galaxian virtual observatory WEB_page

a) Site of Solar virtual observatory (main page); Database section where the data from solar coronagraph will be stored





There are several large fields of solar research that would be accelerated by a VSO (Hill, 2000). These fields include:

- Space weather would greatly benefit from more reliable and detailed knowledge of the solar surface signature of the eruptive events, such as solar flares, eruptive prominences (filaments) and especially imminent CMEs. This requires correlating time series of coronal images, filament positions, and surface quantities such as vector magnetic fields and x-ray emission in several wavelengths.

- The structure of a sunspot atmosphere, which is still poorly understood. A composite data set of vector magnetic field maps, space-based UV spectra, and temporal sequences of EUV images could yield a more complete description of the density, magnetic field, velocity, and turbulence with height above sunspots.

- The mechanism, which blocks solar energy in sunspots and creates fluctuations in the solar irradiance, is poorly understood. Observations of the surface vector magnetic field and the spatial intensity distribution in several wavelengths are needed for comparisons with theory.

- The statistics of active region life cycles are not known. Such a study requires multi-day time series of surface magnetic field, Doppler velocity, and intensity in several wavelengths.

- The subsurface structure of active regions is beginning to be probed by local helioseismology, in which subsurface properties are determined in small patches rather than globally averaged. These results must be placed in context, which requires both surface magnetic field measurements and time series of the Doppler velocity. This technique may eventually be able to locate active regions before they emerge on the surface, which would be useful for space weather predictions.

- The statistical evolution of the solar granulation properties over the course of an 11-year solar activity cycle has only been sparsely sampled. A consistently sampled study could reveal clues about the long-term behavior of the underlying near-surface flow field as well as provide insight into the driving and damping mechanisms of the solar oscillations. This problem requires multiyear time series of surface magnetic field, Doppler velocity, and intensity in several wavelengths.

- A long-standing mystery is the heating of the outer solar atmosphere. It is now known that substantial areas of the atmosphere are actually much cooler than the surface. Unraveling the complex thermodynamic and energy budget of the solar atmosphere requires the spatial and temporal correlation of observations in the infrared, visible, and UV with magnetic and velocity fields at different heights above the solar surface.

- The solar wind is believed to originate near the boundaries of coronal holes where the solar magnetic field is open to interplanetary space. However, the details of the physical process that accelerates the wind are still unknown. Research on this question requires images that show the location of coronal holes at either x-ray or infrared wavelengths in conjunction with data on solar wind speed, and surface quantities.

Present and potential status of solar observation in BG:

The department “Sun” is the youngest one in the Institute of astronomy and the solar observations have been carried out since 2005. This is advantage for the development of the observational instruments and facilities, as well as for the observational methods and data storage according to VSO requirements. The basic instruments in the solar tower at NAO – Rozhen are two. The Lyot-coronagraph (150/2250) with Hα filter (1.8Å) is intended for observations of the low corona and solar prominences. The second instrument, the solar refractor (150/1600), is in preparation for observations in white-light and Hα line (photosphere and chromosphere).

Observations of the Sun in white-light have been carrying out in seven Public AOs located in different towns in Bulgaria, especially those in Haskovo and Dimitrovgrad that have close, long-lasting collaboration with the department “Sun”.

Main goals:

The project of the department “Sun” for solar observation plans implementation of synoptic solar observations of the basic activity events in the three levels of the solar atmosphere – photosphere, chromosphere and corona. The basic phenomena of solar activity, for which one have real and potential conditions for observations with instruments in the solar tower at NAO – Rozhen are given in **Table 4**. The effective synoptic observations of the Sun in our country need the creation of a national set for solar observation. Except for NAO – Rozhen, AO - Belogradchik, as well as the seven Public AOs will be gradually included in this set. Such national set for solar observations will provide more homogeneous archives of solar data for VSO.

What's done?

The VSO is a part of the Bulgarian Virtual Observatory. In the frame of the Bulgarian Virtual Observatory the department “Sun” (Institute of Astronomy, BAS) started a web site www.astro.bas.bg/sun/SVO (***fig. 2a***). The ambition is to present in the database section newly received data from the solar coronagraph in the National astronomical observatory “Rozhen”.

Table 4. Types of solar data that could be provided from solar observations at NAO – Rozhen for the VSO archives

Instrument	**Wavelength**	**Data type**	**Atmospheric level**	**Activity events**
Coronagraph 150/2250	Hα (6563 Å)	Limb images	Low corona	• eruptive prominences • surges • quiescent prominences
Refractor 130/1600	Hα (6563 Å)	Full disk images	Chromosphere	• prominences at the limb • filaments on the disk • active regions • Hα flares
Refractor 130/1600	White-light	Full disk images	Photosphere	• sunspots • active regions • faculae • white-light flares

2.2 Extragalactic astronomy and cosmology:

Scientific tasks to be solved with Virtual observatory tools (see e.g. Briukov et al.: 2005)**:**

Individual objects – cross-references from

- NED (morphology, z, direct images, SED);
- Skyview (multiwavelength images);
- DSS (direct images);
- NVSS, FIRST (radio images);
- SDSS (multicolor images, spectra);
- LEDA (direct images, morphology, different parameters).

Almost solved tasks:

- Selecting objects by different parameters;
- Construction of the spectral energy distribution;
- Determination of morphological parameters;
- K-correction;
- Evolution of galaxies…

Next steps:

- Power spectrum and correlation analysis;
- Cluster analysis for groups of objects;
- Study of the photometric evolution of groups of objects;
- Star Formation Histories in Galaxies (new VO computing concepts: towards the Grid; access to models);
- Galaxy Clusters as Probes of the LSS and its Evolution;
  - Cluster selection using a variety of methods: galaxy overdensity, x-rays, Sjunaev-Zeldovich effect …
  - Understanding of the selection effects;
- Data Mining in the Image Domain: Can We Discover New Types of Phenomena Using Automated Pattern Recognition? (Every object detection algorithm has its biases and limitations) (Hanisch et al., 2006)
- Effective parameterization of source morphologies and environments;

- Multiscale analysis (Grupe, 2004).

BG-Galaxian Virtual Observatory with its (to the end of 2007):

- Ca. 1800 FITS frames for 9 selected voids with ca. 6000 faint galaxies identified, together with 2 planetary nebulae in B, V, R, I.
- Spectral observation of galaxies and PlN (ca. 700 spectra, *all the spectra have to be scanned*), **including:**
    - Spectral observations of PlN (27 spectra for 9 PlN);
    - Spectral observation of active galaxies (ca. 100 spectra);
    - Spectral observation of High Surface Brightness Galaxies (ca.300 spectra);
    - Image-tube system spectra of galaxies and standard stars, ca. 90% with 50

    A/mm reverse dispersion, spectral region around Hα;
- Ca. 500 CCD images of Box/Peanut galaxies and control sample galaxies in (U, B), V, R, I – bands in FITS format;
- Ca. 1850 NIR frames for Box/Peanut galaxies in FITS format;
- Hundreds of CCD frames of quasars/gravitational lenses in FITS format (current project, observational data are added continuously);
- Hundreds of CCD frames of Active galactic nuclei in FITS format (current project, observational data are added continuously);
- Ca. 900 CCD frames of Open Clusters -12 probable binary clusters, 10 open clusters in the direction of the anticenter and 8 bright clusters in FITS format;
- Ca. 50 plates from the 2-m RCC telescope of Active galaxies and High Surface Brightness Galaxies. *All the plates have to be scanned.*

2.3. Sector Star clusters:

At the time being the department **Star clusters** with its ca. 300 plates from NAO-Rozhen is a part of the future BG-VO. *All the plates have to be scanned in IA-BAS.* As a result of this project a step-by-step instructions for scanning process of astronegatives – plates and spectra, will be created. Some astronegatives will be selected as standards and the results of scanning and analysis of these standards will be a part of this instruction.

The basic problems to be solved after the integration of data into the total data base include:

- Discovery of new and detailed study of the known variable stars in these aggregates;
- The combined study allows us to use the results as a test of theoretical models of stellar structure and evolution;
- The generalization of all available data for variable stars in star clucters enables the creation of a modern data base for their physical, pulsationary and evolutionary parameters;
- Study of the spatial structure of star clusters to defferent limiting magnitudes.

2.4. The group of Wide Field Plate Data Base (WFPDB):

The research team WFPDB from IA-BAS has the know-how for the preservation of astronomical data, received through the methods of astronomical photography. They are developing WFPDB as a main source of information for the world-wide astronomical archives of wide-field observations and the therein preserved photographic plates. The data for about 530 000 astronomical plates is searchable through the web-based system of WFPDB, http://www.skyarchive.org/search.html. The digitalization of the available data is planned at the very beginning of the creation of the WFPDB.

Next step – probably on the second stage, is the incorporation of tremendous quantity of high dispersion stellar spectra from other sectors of IA-BAS.

3. CONCLUSION

The aim of this project is Bulgaria to be a member of the European and International Virtual observatory society. As the 2-m RCC telescope is in operation more than 25 years and 3 smaller telescopes are widely used, there are a lot of observational astronomical data in almost all the fields of astronomy and astrophysics, unfortunately only in the optical region of the spectrum. Large quantities of our data are from the telescopes of other observatories, too. ***Reducing all our data to the common system***, constructing **good working data server** and ***using unified astrophysical tools*** for analysis of astrophysical data are the main purposes of this project facing the future.

Step-by-step instructions for scanning process of astronegatives – plates and spectra, will be created; selected standards and the results of the scanning and analysis of these standards will be a part of this instruction.

For the above purpose ***POSTGRESQL and/or MySQL*** will be installed on the server of BG-VO and ***SAADA tools, ESO-MEX and/or DAL ToolKit*** to ***transform our FITS files in standard format for VO-tools***.

Tasks like this do not finish with the end of the project time. They always stay open for updating, upgrading, adding new data and ideas. **The project is facing the future.**

During the work a ***Bulgarian terminology of Virtual observatory specification*** will be checked and distributed amongst our astronomical community.

Virtual Observatory may turn out to be young astronomers' destiny. Knowledge they acquire is on a higher level (science is developing all the time) and presumes the use of more and more heterogeneous data. Science without Internet and access to data bases happens very rarely.

The participants in the project have the unique chance to be the founders of the Bulgarian Virtual Observatory. The overall complete vision over the available observational data gives us a chance to assign research projects on a large scale practically with no limitation on the topics, level of complexity, and expected results.

These are the future experts who will teach the young scientists, who have chosen astronomy to be their destiny, to work on a modern level, to „speak one and the same language“ with colleagues of theirs worldwide – i.e. their results to be useful and comprehensible for everyone.

Virtual Observatory is open for everyone by default. Potential participants and users (invited already at the first stage) are all Bulgarian astronomers and scientists using or applying our results and knowledge – Department of Astronomy – Sofia University, the astronomical staff at Plovdiv and Shumen universities, the Space Research Institute, the Solar-Terrestrial Influences Laboratory, various ecological organizations („light“ pollution and Earth atmosphere cleanliness are astronomical problems, as well) , etc. The last but not least are the various cases of dating and identification of events and products, e.g. criminology, archaeology, history, etc.

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