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Editors

The Digitized First Byurakan Survey
Foreword

Stars and Galaxies in the Universe are evolving objects: their physical conditions change with time, and consequently the radiation emitted by them which brings us information about their nature also changes. This evolution generally happens on time scales much longer than human life, so that it cannot be detected. Sometimes, however, large variations happen on time scales extremely shorter than cosmic evolution, down to fractions of a second. Examples of such processes are the explosion of a star at the end of its life (Supernova explosions) or fast variations in the nuclei of some distant active galactic nuclei. One of the most important achievements of modern astronomy was the understanding of the role of such phenomena in the general evolution of the Universe.

The “historic” nature of astronomical research has become therefore more evident, and the need for keeping observational data collected over the years to discover changes in astronomical objects is more and more important to the astronomical community. Furthermore, in a more general context, it is important to keep track of the intellectual legacy that made possible the realization of astronomical discoveries, which are part of the general history of human Science.

For these reasons, in the framework of a collaboration between the members of the group of High Energy Cosmic Sources (SCAE) within the Department of Physics at the University La Sapienza, Rome, and scientists of the Byurakan Astrophysical Observatory, we decided to preserve the large collection of spectral astronomical plates known as the First Byurakan Survey (FBS) by transforming it into an electronic archive, accessible by computers through the World Wide Web. This collection was obtained by Benjamin E. Markarian and collaborators in the years 1965-80 and covers a large part of the sky observable at our latitudes. The Infrared Projects Group within the Department of Astronomy at Cornell University (USA) joined this project. The project has been carried on during several years and required a substantial effort, largely sustained by funding from the Sapienza University and the Italian Ministry of Research (MIUR), with additional support from the US Civilian and Research Development Foundation. Today the results are freely accessible to the world astronomical community through a dedicated web interface and include digitization of 90% of the
The Digitized First Byurakan Survey

FBS. This book describes the history of the FBS, the most important results obtained with it, and presents the electronic version (Digitized First Byurakan Survey, DFBS) developed by us. It describes also in detail the procedures for its scientific use and some examples of research with the DFBS.

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Prefazione

Le stelle e le galassie sono sorgenti in evoluzione. Le loro condizioni fisiche cambiano modificando la radiazione che esse emettono e che noi osserviamo per studiarne la natura. Questa evoluzione in genere avviene su scale temporali molto più lunghe della vita umana ed i cambiamenti non possono essere osservati. A volte si osservano fenomeni che presentano grandi variabilità su scale di tempo estremamente più brevi di quella della lenta evoluzione cosmica, raggiungendo anche frazioni di secondo. Si tratta di processi quali l’esplosione di una stella alla fine della vita, come il fenomeno delle Supernovae, o delle intense variazioni di luminosità che si osservano nelle regioni nucleari di alcune galassie lontane. Una delle più importanti conquiste dell’astronomia moderna è stata la comprensione del ruolo di questi fenomeni nella generale evoluzione dell’universo.

Ciò ha reso sempre più evidente la natura ‘storica’ della ricerca astronomica e la conseguente importanza di conservare i dati raccolti nelle osservazioni per confrontare se, come e quando sono avvenuti i vari cambiamenti. A questo si aggiunge, proprio degli storici della scienza, di conservare il patrimonio intellettuale che ha portato alle grandi scoperte.

Per questi motivi, nell’ambito della collaborazione tra il personale del Dipartimento di Fisica afferente al gruppo di ricerca delle Sorgenti Cosmiche di Alta Energia (SCAE) e l’Osservatorio Astrofisico di Byurakan, si è deciso di preservare, trasformandola in un archivio accessibile via calcolatore, la grande raccolta di immagini spettroscopiche, nota come FIRST BYURAKAN SURVEY, che copre una larga parte del cielo osservabile alle nostre latitudini, realizzata da Benjamin E. Markarian e dai suoi collaboratori dal 1965 al 1980. A questa iniziativa ha subito aderito l’Università di Cornell.

Questo lavoro si è protratto per alcuni anni ed ha richiesto un considerevole impegno, sostenuto in gran parte con i fondi ricevuti dall’Università Sapienza e dal Ministero dell’Università e Ricerca. Oggi i suoi risultati sono accessibili all’intera comunità astronomica tramite pagine web. La digitizzazione delle lastre non è purtroppo completa in quanto una parte, circa il 9%, non era rimasta nell’archivio dell’Osservatorio di Byurakan.

Questo libro descrive la storia e gli importanti risultati ottenuti con la FBS e presenta la versione informatizzata (DIGITIZED FIRST BYURAKAN SURVEY) da noi realizzata, descrivendone anche le procedure per il suo uso. Ci auguriamo di poter completare questo lavoro e di raccogliere
i frutti con nuove analisi delle popolazioni di stelle e galassie che popolano il nostro cielo.

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Chapter 1

The “V.A. Ambartsumian” Byurakan Astrophysical Observatory

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1. History and main achievements

The Byurakan Astrophysical Observatory (BAO) was founded in 1946 on the initiative of academician Victor A. Ambartsumian. It is one of the most important astronomical centres in Eastern Europe and is affiliated with the Armenian National Academy of Sciences (NAS RA). The observatory is situated on the southern slope of Mt. Aragatz, near the village of Byurakan, some 30 km NW of Yerevan, the capital city of Armenia. Geographic coordinates are $2^h57^m10^s$ E, $40^\circ20'07''$ N, and the altitude is 1405 m. A more complete historic report on the BAO is that of Mickaelian (2001, 2008a).

V.A. Ambartsumian became the first Director of the Observatory, and the primary areas of astrophysical research were initially determined by him Mickaelian (2008b). The first studies at the Byurakan Observatory were related to instability phenomena taking place in the Universe, and this trend became the main characteristic of science activity at Byurakan.

In 1946 the Communications of the Byurakan Observatory were founded as the main journal for Byurakan astronomers, and Ambartsumian became the first editor-in-chief.
Construction of buildings began in spring, 1946, under the supervision of the famous Armenian architect Samuel Safarian. The first structures were the central building, the guesthouse and the towers of the first astronomical instruments: 12.7 cm double astrograph, 20/30 cm Schmidt telescope, 25 cm telescope-spectrograph, nebular spectrograph, 40 cm Cassegrain telescope, and the 53 cm Schmidt telescope. All were constructed between 1951 and 1955. The 53 cm telescope was the main instrument for those years, being used for the investigation of structure and radiation properties of galaxies.

Construction of radiotelescopes began in 1950. Two couples of antennae for observations at 4.2 m and 1.5 m wavelengths were organized.

Scientific results came soon after the foundation of the Byurakan Observatory. In 1947 stellar systems of a new type, termed “stellar associations”, were discovered by V.A. Ambartsumian. It was demonstrated that star-forming processes are presently occurring in the Universe, and stars are being formed in groups. Ambartsumian put forward the idea of star formation within stellar associations associated with gas and dust. In November 1951, the first of a rich series of scientific meetings was held in the BAO, and "Stellar Associations" was the subject of the conference. On September 19, 1956, the official opening of the Byurakan Observatory was celebrated by holding a conference on Non-stable Stars. In the middle years of the 1950s, Ambartsumian suggested a new explanation for radio galaxies and proposed a new concept relating these and other phenomena to activity within galactic nuclei. By now, the concept of Active Galactic Nuclei (AGN) is a topic of widespread research in astronomy. The discovery of stellar associations and Ambartsumian’s emphasis on activity of galactic nuclei, as well as investi-
gations on radiative transfer theory based on Ambartsumian’s principle of invariance, guided further development of research activities at BAO.

In 1960, a new Schmidt telescope with 102 cm correcting plate and 132 cm mirror was installed in Byurakan. It was also equipped with an objective prism and became the largest telescope in the world ever to have a full aperture objective prism. Using this telescope with the objective prism, B.E. Markarian started a survey in 1965 with the goal of revealing UV-excess galaxies. This survey is what we define as the First Byurakan Survey (FBS). It was continued for 15 years and became one of the most famous surveys in modern astronomy. The best known product of the survey is 1500 galaxies with UV-excess, now called Markarian galaxies. Further investigations of Markarian galaxies with other telescopes throughout the world revealed many new phenomena within the collection of Markarian galaxies. For example, E.Ye. Khachikian of BAO and D. Weedman in the US used the Markarian galaxies to discover many new Seyfert galaxies beginning in 1967, which led to a widely used classification of AGN.

In 1965, a journal of astrophysical research, Astrofizika, translated into English as Astrophysics, was founded, and Byurakan astronomers began to publish their papers primarily in this journal. Astrofizika became one of the main astrophysical publications in the Soviet Union.

In 1968, for its great merit to the development of science, the BAO was awarded the highest prize of the Soviet Union - the Order of Lenin. A conference was held, devoted to V.A. Ambartsumian’s 60th birthday. He presented new work on the statistical investigation of flare stars and predicted that all dwarf stars pass through the stage of flare activity.

The investigation of flare stars became one of the main subjects of the Byurakan Observatory. Hundreds of flare stars in star clusters and associations were discovered by L.V. Mirzoyan and colleagues. The dedication of the 2.6m in October 1976 was accompanied by a symposium on Flare Stars.

The Second Byurakan Survey (SBS) was begun with the 102 cm Schmidt telescope in 1978. The main goal was to obtain a homogeneous sample of quasars, emission-line galaxies and UV-excess galaxies for further cosmological investigations. More than 600 deep-limit plates were obtained during 15 years.


Since 1998 the Byurakan Observatory bears the name of “V.A. Ambartsumian”.

The Byurakan Observatory celebrated its 60th anniversary in 2006.
2. Scientific instruments

2.1. The 2.6 m telescope

The Byurakan 2.6 m telescope was installed in 1975 and began operations in 1976. It was constructed by the Leningrad (now St. Petersburg) Optical Equipment Works (LOMO), and the chief designer was Bagrat K. Ioannisian, who was also the chief designer of the SAO 6 m and Crimean 2.6 m telescopes.

This telescope is often called ZTA-2.6, which means in Russian "Armenian Reflecting Telescope of 2.6 m diameter". In 1996-1999, various telescope upgrades were carried out. A new instrument was designed and assembled in the Marseille Observatory (France), within the framework of the French-Armenian collaboration PICS/Jumelage. This new prime focus instrument is ByuFOSC - Faint Object Spectral Camera for the Byurakan 2.6 m telescope, or ByuFOSC-2 after modifications. It consists of the pointing and auto guiding system “Bonnette”, a focal reducer (similar to ESO’s EFOSC) and CCD detector (Thomson 1060×1028 pix, 19 µm pixel size).

In 2000, another new instrument, the spectral camera SCORPIO (Spectral Camera with Optical Reducer for Photometric and Interferometric Observations) was built at the Russian Special Astrophysical Observatory in framework of the Russian-Chinese-Armenian trilateral collaboration. A new 2063×2058 pix Loral CCD (16µ pixel size) was part of this camera. A unique instrument, the VAGR (“tiger”) integral field unit (IFU) was built in the Byurakan Observatory also within the framework of the French-Armenian collaboration. The micro-lenses array consists of 40×40 lenses, and a 600 groves/mm grism is used.

At present the following modes are being used at the 2.6 m telescope:

**Imagery.** ByuFOSC-2: 11′×6.3′ field, 0.63″/pix scale; SCORPIO: 14′×14′ field, 0.42″/pix scale. B,V,R,I and narrow-band (interferometric) filters, limiting magnitude for 1 hour exposure and 2″ seeing: V=24.5 mag; R=
Fig. 3. The Byurakan Observatory 1m Schmidt telescope and its dome.

25.0 mag; I=22.5 mag.

**Spectroscopy.** ByuFOSC-2: $2'' \times 5'$ slit; 2.7 Å/pix dispersion, spectral range 4200-6900 Å, 9 Å resolution with the “green” grism; and 2.1 Å/pix dispersion, spectral range 5400-7650Å, 6Å resolution with the “red” grism; approximate limiting magnitude for 1 hour exposure: 18 mag; SCORPIO: $2'' \times 6'$ slit; 1.5 Å/pix dispersion, spectral range 3950-7250Å, 5Å resolution with the “green” grism; and 1.3 Å/pix dispersion, spectral range 5100-8050Å, 4Å resolution with the “red” grism.

**3D spectroscopy (integral field spectroscopy).** VAGR (multi-pupil fiberless 3D spectrograph). Field: $20'' \times 40''$, scale: 1.2''/pupil, spectral range: 400 Å, resolution: 1.75 Å/pixel (R=1800).

2.2. The 1 m Schmidt telescope

The Byurakan 1 m Schmidt telescope (Fig. 3) was constructed by LOMO, with the exception of the mirror that was made in Germany, and was installed in 1960. The correcting lens has 102 cm diameter, and the Pyrex mirror’s diameter is 132 cm. The focal length is 213 cm, and the aperture ratio (D/F) is 1:2.1. The telescope has a 4.1°×4.1° non-vignetted field. 16.1×16.1 cm size photographic plates have been used. The scale is 96.8 ”/mm. Due to a Piazzi-Smith lens, the telescope has a flat field.

A unique advantage of the 1 m Schmidt telescope is the presence of three objective prisms (1.5°, 3°, and 4°), which make possible wide-field spectroscopic observations with various dispersions: 1800 Å/mm, 900 Å/mm, 285 Å/mm dispersion near Hγ for 1.5°, 3°, and 4° prisms, respectively. The objective prisms can rotate into position angles that allow obtaining spectra of any orientation.
The First Byurakan Survey (FBS) is the most famous work done with this telescope. More than 2000 photographic plates were obtained and led to the discovery of 1500 objects which are now known as Markarian galaxies. The Second Byurakan Survey (SBS) was initiated with improved photographic plates.

In 1991, however, operations of the 1 m Schmidt telescope stopped, and no observations have been carried out since then. Recently, a project for reconstruction of this telescope was put forward in collaboration with the Russian Special Astrophysical Observatory, including equipping it with a contemporary detector and an advanced control system. Photometry with wide-band filters and slitless spectroscopy with objective prisms will be the main observing modes. The refurbishment of the 1 m telescope must include the installation of a CCD camera at the focus with pixel size of about 1″ and field of view of ~2 deg²; a set of filters covering all of the visible range (3400–10000Å); creation of a fully-automated control and monitoring system of the telescope including guiding system, CCD controller, filter selection, dome control, etc. The principal goal is to create the ability to obtain samples of objects up to R~23 mag with signal-to-noise ratio of ~5 and images better than 2″. Such data can ensure the successful classification of objects and measurement of photometric redshifts.

The Byurakan Observatory library keeps the observational material of all the Byurakan telescopes, including about 2000 plates of the First Byurakan Survey (FBS). Altogether, 20,000 plates are collected at present. Users may have access to the plates in right ascension or declination, author name, plate numbers, or epoch of observation. One of the tasks for the Armenian Virtual Observatory (ArVO) is the digitization of all of these plates and creation of an electronic plate database for further research with the plate archive. BAO is connected to world basic astronomical sites through the Internet, and the ArVO is a part of the International Virtual Observatory Alliance (IVOA, http://www.ivoa.net) that allows a quick and standard access to any astronomical database and catalogue.