

THE ASTRONOMICAL OBSERVATORY IN BELGRADE – THEN AND NOW

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Abstract. *Astronomical observatory in Belgrade (AOB)* was established in 1887 by a Serbian astronomer and enthusiast Milan Nedeljković. In the following years, the observatory grew into an eminent research institute and remains the only astronomical institution in Serbia. Today the Astronomical Observatory in Belgrade engages 45 researches working in different fields of astronomy, including observation, numerical simulation, data processing, theoretical work and promotion of science. Herewith we give a short review of the institute's historical development and its scientific activities.

Key words: Astronomy – Observatory – Projects – History.

1. HISTORICAL DEVELOPMENT OF AOB

Astronomical Observatory of Belgrade (AOB) was founded by the Ministry of Education and Church Affairs of Kingdom of Serbia on April 7, 1887. Accordingly, it is considered one of the oldest scientific institutions in Serbia. The initiator and its first director Milan Nedeljković* (1857 – 1950) organized the research in the field of astronomy, meteorology, seismology and geomagnetism. At the same time he took care of the observatory supporting it from its private funds[†]. Unfortunately, the observatory and all its instruments were destroyed or taken away in the World War I. However, in the 1920s Nedeljković managed to gather new, at that time very modern astronomical instruments, mainly financed by the war reparation from Germany.

In 1926, Vojislav V. Mišković[‡] (1892 – 1976) was appointed the new director of the AOB. He constructed a new observatory with additional pavilions for the in-

*Milan Nedeljković (1857 – 1950) studied natural sciences at the Higher School in Belgrade (today the University of Belgrade) and at the Collège de France in Paris (1879–1884). After returning to Serbia, he devoted himself to the development of astronomy, first as a professor of the Higher School, and later as the founder and director of the observatory.

[†]Tomanija Nedeljković born Radaković (1866–1959), the wife of Milan Nedeljković, financially supported the observatory with funds derived from her heritage. She was also involved in astronomical observations and measurements.

[‡]Vojislav V. Mišković (or Michkovitch) completed his university studies in Marseille (France) in 1919 and obtained his doctoral degree in 1924 in Montpellier (France). In 1925 he won the Valz Prize (Prix Valz) and became a member of the French astronomical society.



Fig. 1 – Milan Nedeljković (1857 – 1950), the founder and the first director of the Astronomical observatory in Belgrade.

struments, and raised the AOB to the level of one of the most successful observatories in Europe at that time (Janc *et al.*, 2018). The brand new and well equipped observatory was built on another location, 6 km away from the center of Belgrade, where it is today. Later, the area around the observatory and its municipality was named Zvezdara (“zvezdarnica” is the Serbian word for astronomical observatory). The observatory’s building, which was drawn by the Czech architect Jan Dubovy (1892 – 1969), is considered as a remarkable architectural complex built in the Modern style.

The first and probably the most important scientific achievement of the AOB at that time, was the contribution to the acknowledged theory of the climate change by Milutin Milanković[§] (Milanković, 1941).

In 1935 Mišković organized the time service on AOB. Six highly precise Riefler and Leroy clocks were used to provide accurate time for astronomical observations and other purposes, while in the 1960s the service was improved with a Rhode-

[§]The secular evolution of Earth’s orbital elements for the past 600 000 years, used in the Milanković theory, were numerically integrated on AOB using a hand calculating machine. The calculations were provided by mathematicians Dragoslav Mitrinović and Stanimir Fempl, while the project and correspondence with M. Milanković was managed by V. Mišković (Janc *et al.*, 2018; Fempl, 1979).

Schwartz cesium clock (Đurović, 1989). Besides the collaboration with other institutes in Yugoslavia (back then Serbia was part of Yugoslavia), the AOB time service was included into the international time services *e.g.* *International time bureau* in Paris, *International polar motion service* in Mizusawa (Japan) and the *Soviet time service*. In 1991, the AOB provided the time standard for Yugoslavia. The AOB time service operated until 1997.

In 1936 by Mišković founded two new sections: the group for Minor planets, comets and satellites (in assistance with M. Protić) and the group for the Sun observation (in assistance with P. Đurković).

World War II (1941–1945) brought new devastation and large damage of the central building and the pavilions. The largest and most important telescope, the "Zeiss" 650/10550 mm retractor and its dome were significantly injured. However, in the post war years the observatory was successfully repaired, including some major expansions. This time the reparation was lead by Milorad Protić (1911–2001), who was the director of AOB from 1956–1960 and from 1971–1975. Protić was also a passionate observer who discovered 34 asteroids and one comet. The full list of asteroids discovered from AOB, and the list of asteroids with Serbian names can be found in Todorović (2019). In the middle of the 1980s, minor bodies and their orbits were also studied in the framework of classical and modern celestial mechanics. Minor planets (now called asteroids) are still largely studied on AOB. This is one of the oldest research activities of the AOB, since the first minor bodies observation started in the early 1930s.

Another active group with a long AOB tradition (it began in 1949), provides observations and orbit determination of double stars. Within this group more than 250 new double and multiple stars are discovered, and countless orbits were determined.

The astrophysical group was founded in 1960, which started with spectroscopic and photometric observations of the Sun and other various astronomical objects. This group involved studies of large scale photometric motions on the Sun, tracking the solar spectral lines during one solar cycle, atmospheres of stellar objects, modeling of active tight double stars, polarization in cool supergiants, Stark broadening of spectral lines of various objects. This group, which operates in different subgroups, has grown into one of the most successful and most productive groups at the AOB (more details is given in the next section).

Large part of the activity on AOB in the second half of the 20th century was dedicated to fundamental astrometry and geodetic astronomy. One of the main tasks in this field was the production of the observational catalogs of star positions. AOB contributed with observations on the Large meridian circle (unfortunately, this instrument was destroyed during the NATO bombing of Yugoslavia in 1999). The fundamental astrometry and geodetic astronomy groups were active in a network of collaborations with the Pulkovo Astronomical Observatory (formal USSR) and the



Fig. 2 – The central building of the Astronomical Observatory of Belgrade, constructed between 1929–1932 in the style of modern architecture. The project of this valuable complex was drawn up by a Czech architect Jan Dubovy, providing him a doctoral degree in Prague. The photo was taken in September 2018.

observatory in Tokio. Here we would like to mention that the Meridian astrometry group from Romania participated in the same network of catalogs production (Popescu , 1998). Ljubomir Mitić, a member of the group of absolute right ascension, invented a new method for the determination of the right ascension by using vacuum tubes (Mitić , 1968). More details on this method can be found in Pakvor (1989).

Milutin Milanković, one of the most famous Serbian scientists world-wide, served as the director of the AOB from 1948 until 1951. In recognition of his great achievements, the AOB named its newest telescope on the mountain of Vidojevica, located in the South of Serbia, after him.

2. SCIENTIFIC RESEARCH AT ASTRONOMICAL OBSERVATORY BELGRADE

Today, AOB employs 45 researches, engaged in seven projects funded by the Ministry of Education, Science and Technological Development of Serbia. Some researchers are active in international collaborations as well. In the following, we give a brief description of the current research projects on AOB.

- **Project No 176001 «Astrophysical spectroscopy of extragalactic objects»**
The main interest in this group is understanding of *active galactic nuclei (AGN)* physics, although some members are interested in solar physics, spectral line shapes, supernova remnants, kinematics and gravity of galaxies, gravitation lenses etc. More details about the latest research of this group can be found

in Popović *et al.* (2018). Most of the published papers are about AGN (type 1 and 2) and their characteristics that are often found from optical, X-ray or infrared spectra or continuum modeling. Investigated characteristics of AGN are variability, periodicity, various correlations, possibility of using quasars in the cosmology, spectral line characteristics, spacial orientation, polarization of broad emission lines, black hole mass estimation etc.

This group collaborates with various astrophysical groups such the ones from Italy, Germany, Russia, Mexico, China and Spain. Recently, they have been investigated the method for finding potential candidates of Supermassive binary black hole systems in collaboration with prof Jian-Min Wang from the Institute of high energy physics of Chinese academy of sciences. They have been mapping the dynamics of the broad line region of AGN as a tool for recover information on periodicity from the temporal structure of AGN light curves.

The project gathers 13 researches: 2 students, 6 Assistant Research Professors and 5 Full Research Professors. Project director is dr Luka Č. Popović. The members of the staff in 2018 published 8 papers and 13 proceedings.

- **Project No 176002 «Influence of collisional processes on the astrophysical plasma».** This project is the continuation of a long standing research on the influence of atomic collisional processes on the spectra of astrophysical and laboratory plasmas. Results on determination of parameters of Stark broadening and investigations of its influence on spectral lines of white dwarfs and of chemically peculiar A and B type stars entered in the FP7 project VAMDC 239108, international base data STARK-B and Serbian Virtual Observatory. Experimental studies on the influence of solar activity on the characteristics of waveguide Earth-ionosphere, are performed in the framework of European action COST ES0803. This project involves investigation of the influence of inelastic atom-Rydberg atom and radiative ion-atom collision processes on the kinetics of weakly ionized plasma of the Sun, white dwarfs and Earth's ionosphere. Also, studying interactions of beams with highly energetic electrons, formed in various violent events on the Sun with interplanetary plasma are studied within this project. This project gathers 5 researches (two from AOB and three from other institutes). Project director is dr Zoran Simić.
- **Project No 176003 «Gravitation and the large scale structure of the Universe».** This project has several lines of research – *supermassive black holes* (SMBH), *supermassive black hole binaries* (SMBHB), gravitational lenses and modified gravity as alternative to dark matter (Borka Jovanović *et al.*, 2018). Regarding the SMBH, located in the center of most of galaxies, researches in this project study the effects of strong gravity in their vicinity, as well as their activ-

ity and radiation from their accretion disks. Also, electromagnetic counterparts of gravitational waves are studied. Since SMBHB originate in galactic mergers, periodicity in electromagnetic radiation from their host-galaxies in AGN is used for their detection. The project also focuses on gravitational lensing effects on radiation from AGN in different spectral bands. Modified gravity (R^n , Yukawa, Sanders, hybrid, scalar-tensor, non-local gravity), is tested using astronomical observations of motion of S-stars around SMBH in the center of our Galaxy, as well as at extragalactic scales.

Members of this project have intensive international collaboration and actively participate in several European projects (ERASMUS+ Mobility Program, Bilateral cooperations, COST actions and AstroMundus). This project gathers 7 researches: 3 Full Research Professor and 4 Assistant Research Professor. Project director is dr Predrag P. Jovanović. In 2018 staff members published 19 papers in total (of which 4 were in the leading astronomical journals).

- **Project No 176004 «Stellar physics».** The Stellar Physics group conducts observational and theoretical studies of close binary stars and binary evolution, stellar oscillations and radiative transfer. Such studies primarily aim to determine the global stellar parameters (masses, temperatures and radii), but also to elucidate the physical conditions in the atmospheres and interiors of stars, their evolutionary history, status and fate. Recent research of the group is focused on double-periodic variables and late-type contact binaries, characterization and statistics of type II cepheids and spectropolarimetric methods for modeling stellar atmospheres.

There are individually collaborations with many various astrophysical groups such the ones from Chile (Universidad de Concepción), Hungary (Konkoly observatory, Budapest) and France (Observatoire de la Cote d'Azur, Nice). The project gathers 14 researches (of which 2 are retired): 2 Full Research Professor, 2 Associate Research Professor, 3 Assistant Research Professor, 1 Research Assistant, 1 Junior Researcher, 1 Full Professor, 1 Associate Professor, 1 Teaching Associates. Project director is dr Attila Cséki. The members of the staff in 2018 published 11 papers in total (of which 7 were in the leading astronomical journals and 4 proceedings).

- **Project No 176011 «Dynamics and Kinematics of Celestial Bodies and Systems».** This project covers dynamical and kinematical studies for a wide range of astronomical objects, starting from the close neighborhood of Earth, to stars, galaxies and other extragalactic objects. Solar system studies mostly involve dynamics of small bodies (asteroids, comets, spacecrafts, space debris) using both numerical and theoretical methods. Observations of double and multiple

stars and analysis of their orbital motion, is performed as well. The Galactocentric orbits of Milky Way stars are studied by using the Lagrange equations, and in studies of the galactic disc two modifications of the Miyamoto-Nagai formula are used. Observations within this project are performed on the new telescopes at the mountain Vidojevica (Serbia) and at the National Astronomical Observatory Rozhen (Bulgaria). CCD observations of quasi stellar objects visible in the optical domain were started in accordance with the GAIA mission, for the purpose of obtaining more reliable reference systems.

Participants of the project are active in international collaborations (GAIA, COSMOS2020plus, WEBT, Stardust-R etc.) and in individual collaborations with astronomers from Italy, Greece, USA, Brazil, Bulgaria, North Macedonia etc. The project gathers 13 researches: 1 Academic, 2 Full Research Professors, 1 Full Professor, 2 Associate Research Professors, 2 Assistant Research Professors, 2 Research Assistants, 2 Assistant Professors and 1 Assistant. Project director is dr Rade Pavlović. The members of the staff in 2018 published 39 papers in total (of which 6 were in the leading astronomical journals).

- **Project No 176021 «Visible and invisible matter in nearby galaxies: theory and observations».** The goal of the project is the study of the visible (stars, gas, dust) and invisible (hypothetical, dark) matter in the nearby galaxies of various morphological types. The sample which includes both early- and late-type galaxies was created and the objects from the sample are studied using their photometric and spectroscopic data which come from large available catalogs and databases. The photometry of the studied objects is also obtained using the new 1.40 m «Milanković »telescope at the ASV.

All participants of the project are active in international collaborations. The topics include: the study of dynamics of nearby galaxies, the observations of blazars, the problems of astrobiology, numerical simulations of galaxies, study of supernova remnants and the study of binary stars. The most important international project in which the participants of the project collaborated was the project BELISSIMA (BELgrade Initiative for Space Science, Instrumentation and Modelling in Astrophysics, call FP7-REGPOT-2010-5, contract No. 256772) funded by the European Commission through which the “Milanković” telescope was procured with the support from the Ministry of Education, Science and Technological Development of the Republic of Serbia.

The project gathers 21 researchers from 5 distinguished Serbian research institutes and university departments. Most of them (15 researchers) are members of the staff of the AOB. Project director is dr Srdjan Samurović. The members of the staff in 2018 published 29 papers in total (of which 12 were in the lead-

ing astronomical journals) and one book (*The Great Silence: The Science and Philosophy of Fermi's Paradox*, by Dr. M. Ćirković, Oxford University Press).

- **Project No 44002 «Astroinformatics: Application of Internet technologies in astronomy and related fields of research»** The project is a continuation of the previous project Serbian Virtual Observatory (2008–2010). It covers wide variety of IT applications - from building and handling different databases (MOL-D, BEAMD - both members of Virtual Atomic and Molecular Data Centre Consortium of databases), through preparation for and application of super-computing (two small clusters - members of four other project used them) and most importantly it coordinates Serbian involvement in Large Synoptic Survey Telescope which is going to be forefront of Survey Astronomy in 2020's. We also maintain repository of the published work for several groups from AOB. Apart from those projects, our members are involved in more six COST actions and several bilateral collaborations.

There are 22 researchers from Serbia who were funded by the project through almost ten years, They belong to seven different institutions and eleven of them were/are associated with AOB. Project associates published over 110 references in 2018 and over 420 bibliographical units in the period 2014–2018.

3. THE ASTRONOMICAL STATION VIDOJEVICA

Because of the light pollution and the urban spread, the observational activity of AOB had to be displaced to a location with a darker night sky. The selected site was 280 km south of AOB, at the 1150 m high mountain Vidojevica, where a new astronomical station was build. The Astronomical station Vidojevica (ASV), was finished in 2011, and it was firstly equipped with a small 60 cm Cassagrain telescope. Five years latter in May 2016, a larger 140 cm Ritchey-Chretien telescope was installed. It was named «Milutin Milanković telescope»(MMT), in the honor of the renominated Serbian scientist. Although mounted in a temporal roll-roof pavilion, MMT successfully started to operate and to produce high quality images. In September 2018, MMT was relocated in a newly built pavilion with a rotating dome and was fully equipped for remote control, allowing observations from any point on the globe with internet connection.

ASV and its instruments were gained from two main sources, the project BELIS-SIMA (BELgrade Initiative for Space Science, Instrumentation and Modelling in Astrophysics) funded by the European Commission, and the Ministry of Education, Science and Technological Development of the Republic of Serbia.

Ten observational projects are currently performed on the ASV: study of eclipsing binary stars, study of visual double and multiple stars, GAIA photometric follow-

up program, WEBT follow-up program, study of asteroids, study of cataclysmic variable stars, study of galaxy formation and evolution, as well as three educational projects. More detailed description of the observational projects on ASV can be found in (Vince *et al.*, 2018).

Practice for students from different Universities in Serbia is organized every year. Occasionally, visits and educational programs for amateur astronomers and astronomy enthusiasts are organized as well.

4. PUBLISHING AND THE PROMOTION OF ASTRONOMY

The AOB scientific journal is founded by V. Mišković in 1936 under the name *Bulletin de l'Observatoire astronomique*. In 1992 it merged with the *Publications of the Department of Astronomy*, into the *Bulletin astronomique de Belgrade*. From 1998 this journal is published under the title *Serbian Astronomical Journal* (SAJ). SAJ is published semi-annually as a peer-reviewed journal, covering a wide range of astronomical subjects. The chief editor is dr Dejan Urošević from the Faculty of Mathematics in Belgrade, the current impact factor of SAJ is 0.833, and its web address is <http://saj.matf.bg.ac.rs/>.

AOB also publishes proceedings from conferences, monographs, other specialized books and materials in different fields of astronomy and astrophysics, under the title *Publications of the Astronomical Observatory of Belgrade*. This edition is established in 1947 and can be found at <http://publications.aob.rs>. Its chief editor is dr Zoran Knežević, a member of the *Serbian Academy of Science and Arts* (SASA) and a former director of AOB. All AOB publications are supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia and are available in the online data bases.

Regarding the activities directed to the general public, Doors open days are organized on last Saturdays in the month. Numerous visitors have the opportunity to see the complex, the telescope, the library and to learn about the historical and scientific achievements of this institution.

And finally, as one of the newest public activities, we will mention the exhibition «Asteroids, little rocky worlds», that was held in the SASA Gallery of Science and Technology, from December 2018 to February 2019. (some of its content can be found at <https://www.sanu.ac.rs/asteroidi-mali-kameni-svetovi/>). The goal of the exhibition was to introduce a wider audience to the small Solar system bodies, to the historical achievements of AOB in this respect, to the nature of asteroids and future perspectives in their exploration. Special focus was given to the youngest visitors, encouraging them to further studies of the universe.

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