Serb. Astron. J. № 201 (2020), 49 - 57
DOI: https://doi.org/10.2298/SAJ2001049V

UDC 929 : 52
Professional paper

LIFE, EDUCATIONAL AND SCIENTIFIC ACTIVITIES OF PROFESSOR MIRJANA VUKIĆEVIĆ-KARABIN (1933-2020)

I. Vince[1] and O. Atanacković[2]

[1] *Astronomical Observatory, Volgina 7, 11060 Belgrade 38, Serbia*
E–mail: *ivince@aob.rs*

[2] *Department of Astronomy, Faculty of Mathematics, University of Belgrade*
Studentski trg 16, 11000 Belgrade, Serbia
E–mail: *olga@math.rs*

(Received: December 16, 2020; Accepted: December 21, 2020)

SUMMARY: We present a short biography and brief review of contributions of professor Mirjana Vukićević-Karabin to the development of astrophysics education at the University of Belgrade and to the research in physics of the Earth ionosphere and the Sun. The bibliography of her papers is given as well. We hope that the review of the two aspects of her work will elucidate her important role in the development of astrophysics in our country.

Key words. History and philosophy of astronomy – Obituaries, biographies

1. INTRODUCTION

This fall, on October 2, professor Mirjana Vukićević-Karabin, the first woman professor of astronomy at the University of Belgrade, the founder of the Belgrade school of astrophysics and the pioneer researcher of the influence of solar activity on the Earth ionosphere has suddenly passed away. Professor Mirjana Vukićević-Karabin brought out twenty eight generations of students, who will remember her for her devotion to astronomy, determination, sharp spirit and intellect, and eagerness to help. She was known to astronomers from all over the former Yugoslavia for her perseverance in developing the school of astrophysics at the Department of Astronomy, Faculty of Natural Sciences and Mathematics, University of Belgrade. Her work in solar physics had a significant influence on the development of this research area in our country.

Fig. 1: Professor Mirjana Vukićević-Karabin.

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2. BIOGRAPHY AND PROFESSORSHIP

Professor Mirjana Vukićević-Karabin was born on November 25, 1933 in Skopje, where her father worked as a leading engineer on construction of a hydroelectric power station. She grew up in a harmonious family as the only and beloved child of mother Sonja and father Mihailo. From their love and support she drew stability and strength for life, and with her innate optimism she grew up into a cheerful, pleasant, settled and a resolute person.

Mirjana Vukićević-Karabin finished both elementary and high school in Belgrade as an excellent student. In the 1952/1953 school year she enrolled studies of Physics at the Faculty of Natural Sciences and Mathematics of the University of Belgrade. As a student, in May 1956, she was employed as an associate at the Mihajlo Pupin Institute in Belgrade, in the Group for the Ionosphere. Upon graduation in February 1957 (average grade 9,0), she worked in the Mihajlo Pupin Institute first as assistant and then as a research associate. She received a grant from the Indian Government to spend the school year 1962/63 at the National Physical Laboratory in New Delhi and to work on her PhD thesis. Under the mentorship of professor Ashesh Prosad Mitra she investigated the influence of solar flares on Earth's ionosphere. She defended her doctoral dissertation "Sudden Ionospheric Disturbances - SIDs and Methods of Their Detection and Study" in 1965 at the Department of Physics at the Faculty of Natural Sciences and Mathematics in Belgrade. Her work on the ionospheric effects following distant nuclear detonations, published in 1963 in the Journal of Atmospheric and Terrestrial Physics was quoted in the UNESCO Resolution banning nuclear probes in the Earth's atmosphere. It presents the results of measurements of radio interference in India caused by a nuclear explosion, which was carried out in the atmosphere over the island of New Land (Novaya Zemlya, Soviet Union) at a distance of 12,000 km.

In January 1966 Mirjana Vukićević-Karabin was elected a principal research fellow at the Mihajlo Pupin Institute.

While working at the Mihajlo Pupin Institute, she probably never thought that her career would take a completely new path. Namely, in 1966 she was offered a position of assistant professor of General and Theoretical Astrophysics at the recently established study group for astrophysics (1962) at the University of Belgrade. In 1968 she sailed into university waters and dedicated her life to development of the studies in astrophysics, thus creating one of the most esteemed astrophysics study groups in Europe.

2.1. Beginnings of astrophysics in Serbia

In order to better understand professor Mirjana Vukićević-Karabin's role in the mid 1960s let us recall briefly the state of astrophysics in Serbia in that period.

The first astrophysical research in the former Yugoslavia was conducted at the Astronomical Observatory of Belgrade (AOB)[1]. The studies of the Sun, monitoring its activity and studying variable stars have started in 1950s. Vasilije Oskanjan, who graduated from the Department of Astronomy at the Faculty of Natural Sciences and Mathematics in 1949, started photometric research of variable stars in 1950. While studying astronomy, Jelisaveta (Jeca) Arsenijević[2] and Aleksandar (Aks) Kubičela[3] were employed at the Observatory as members of the Division for Solar Activity with the task to participate in the programme of observations of the Sun during the International Geophysical Year, an international scientific project that lasted from July 1, 1957 to December 31, 1958. Upon his return from a specialization in Armenia in 1959, V. Oskanjan initiated research on the polarimetry of the UV Ceti type stars at the Astronomical Observatory Belgrade. He received his PhD degree in the field in 1961. Formally, the Astrophysical Group was founded in mid-1960 by Vasilije Oskanjan (Head of the Group), Jelisaveta Arsenijević and Aleksandar Kubičela. However, in 1966 Oskanjan left Serbia. After his departure Jelisaveta and Aleksandar managed to preserve the existence of the Astrophysical Group and to continue the research work in solar physics and physics of variable stars. In 1972 Ištvan Vince was employed at the AOB in the Astrophysical Group and, since 1980s, the Group has evolved, so that today 80% of the researchers employed at the AOB are engaged in astrophysics.

At about the same time, at the University of Belgrade there was a student of physics, Ivan Atanasijević interested in astronomy. After completing his studies in physics Ivan received his PhD in the field of radio-astronomy in 1956 and became an assistant professor at the Department of Physics at the Faculty of Natural Sciences and Mathematics. He lectured a course on astrophysics. In 1958/59 he transferred to the Department of Astronomy and introduced astrophysics as a separate subject. Jelena Milogradov-Turin, who was his student and who graduated from the Department of Physics in 1959, was employed as a teaching assistant at the Department of Astronomy in 1960. The conditions were met and a new study group Astrophysics was founded at the Department of Astronomy in 1962. In 1964 Vasilije Oskanjan transferred from the AOB to the Department of Astronomy at the Belgrade University and became an assistant professor while Ivan Atanasijević became an associate professor. However, at the beginning of 1966, during their professional training abroad, (professor Atanasijević was in the Netherlands and as-

[1] The first scientific papers in astrophysics among the Serbs are published by Djordje Stanojević (1858-1921) during his stay at the Meudon Observatory where he was working with famous French astronomer Jules Janssen. In the period 1885-1889 he published several papers on solar physics and spectroscopy in Communication à l'Academie des Sciences de Paris.

[2] Jelisaveta Arsenijević - employed in July 1956, graduated in April 1958, MSc degree in 1977 (on polarization of cold supergiant stars)

[3] Aleksandar Kubičela - employed in November 1958, graduated in September 1962, PhD in 1973 (on super-granular motions)

sistant professor Oskanjan at the Biurakan Observatory in Armenia), both decided not to return to Serbia. Moreover, the teaching assistant J. Milogradov-Turin got a grant (1966-1969) from the University of Manchester to work there on her MSc thesis in radio-astronomy.

Thus, soon after the new study group was established, the Department was left without teachers for the newly introduced astrophysical subjects. Moreover, in 1966 the postgraduate studies in astronomy and astrophysics began and the first students were enrolled.

2.2. Professor Mirjana Vukićević-Karabin and Belgrade school of astrophysics

Professor Branislav Ševarlić, then the head of the Department of Astronomy, invited Dr. Mirjana Vukićević-Karabin, a principal research fellow at the Mihajlo Pupin Institute, who defended her PhD thesis on the influence of solar flares on the Earth's ionosphere, to come to the Department of Astronomy as the only teacher of astrophysics. In 1968 she was elected assistant professor of General and Theoretical Astrophysics, but she taught all astrophysical subjects in a study group curriculum. Plans and programs in a written form did not exist, so Mirjana Vukićević-Karabin, who was a physicist by education and who had never attended such courses, faced a difficult task and a huge challenge. Not only did she bravely overcome this challenge but, developing the Department of Astrophysics, she paved the way for one of the most influential schools of astrophysics in Europe.

She set up programs for both undergraduate and the newly introduced (1966) graduate studies in astrophysics. In doing that she had a considerable help of the greatest names of French astrophysics: academicians and professors J-C. Pecker and E. Schatzman, but also of J. Heyvaerts, P. Mein and P. Léna. She met professor Jean-Claude Pecker when he visited the Department of Physics in Belgrade and gave a lecture. Jean-Claude Pecker was a professor at the Department of Theoretical Astrophysics at the Collège de France. In 1960s there was a rapid development of theory and modeling of stellar atmospheres in the world, and key conferences were organized aimed at better understanding of the spectral line formation in conditions far from the local thermodynamic equilibrium. Professors Shatzman and Pecker participated actively in this research. Moreover, they laid the foundations of astrophysics teaching in France in the 1960s. So, after the lecture of professor Pecker in Belgrade Mirjana Vukićević-Karabin asked him for advice on preparation of educational materials for astrophysics students. He invited her to come to France for a week. There she got programs for courses of General and Theoretical Astrophysics taught at the University of Paris and all the literature needed. Thus, Mirjana Vukićević-Karabin had the best scientists she could learn from and thanks to this the Department of Astronomy had the same programs for these two important astrophysical subjects as the most elite universities in Europe.

Mirjana Vukićević-Karabin was elected associate professor in 1977 and full professor in 1983. In several terms, she was the head of the Institute of Astronomy (the Department of Astronomy changed its name several times). She organized the Department of Astrophysics (1971) and was its head until her retirement in 1996.

Professor Mirjana Vukićević-Karabin was a mentor or committee member for several MSc and PhD theses. She wrote two university textbooks: "Theoretical Astrophysics" (1994) and "General Astrophysics" (2004, 2010, with O. Atanacković as the coauthor).

In the early 1980s, she institutionalized cooperation with professor Pecker, by signing a bilateral agreement on scientific cooperation between Yugoslavia and France in the field of astrophysics. Together with professor Ševarlić, she organized bilateral scientific cooperation with Hungary (Eötvös Loránd University - Budapest) and Czechoslovakia (Ondřejov Observatory). Thus, professor Mirjana Vukićević-Karabin was especially meritorious for raising the scientific and research staff in the new fields of astrophysics in our country.

With colleagues from Czechoslovakia, with professor Petković from Zagreb and A. Kubičela (Astronomical Observatory, Belgrade) she participated in organizing the Hvar Observatory, where students of astrophysics had a regular practice in observations.

With professor Ševarlić, she invested a lot of effort in various activities related to high school astronomy education. She constantly pointed out to the educational authorities in Serbia the necessity of teaching astronomy in high school. She wrote two astronomy textbooks for the 4th grade of high school (one of them with professor Branislav Ševarlić and Sofija Sadžakov). At her initiative, classes in the methodology of teaching astronomy for astronomy students were introduced. She took care of hiring astronomy graduates and worked on curriculum revisions to enable graduate astronomers to get jobs as physics and math teachers.

The main areas of her research were the ionosphere physics and solar physics. In her scientific work in the field of solar physics, she collaborated with colleagues from the Astronomical Observatory in Belgrade, mostly with Dr. Kubičela. Professor Mirjana Vukićević-Karabin published about 40 scientific papers, some of them in leading international journals (Sol. Phys., Jour. Atm. and Terr. Phys.), as well as in monographs and conference proceedings. She led a scientific project of the Institute of Astronomy. She was a member of the International Astronomical Union (IAU) and the Commission for Solar Activity and Radiation and Structure of the Sun.

Professor Mirjana Vukićević-Karabin was the president of the Rector's Expert Council for Astronomy, Astrophysics and Mechanics. She was a member of editorial boards of journals Publication of the Institute of Astronomy and Bulletin Astronomique de Belgrade.

She participated in popularization of astronomy by giving numerous lectures at the Kolarac People's University (KPU). At that time there wasn't so much information available as today and the students were eager to hear the most recent news in astronomy by

attending the lectures of their professors held at the KPU. The latest discoveries when told by professor Mirjana Vukićević-Karabin completely captured attention of the audience. Each new astrophysical discovery was an eagerly awaited solution to the riddle posed at the beginning of her lecture, the solution to an intricate detective task that astronomers were working on. For her significant contribution, professor Mirjana Vukićević-Karabin received the KPU plaque in 1984.

After retirement in 1996 professor Mirjana Vukićević-Karabin didn't continue with research, but she was working on both editions of the textbook "General Astrophysics" with Olga Atanacković who succeded her courses. The book was published in 2004, and its second edition in 2010. While working on the textbook professor Mirjana Vukićević-Karabin and her former student Olga became also very good friends.

Professor Mirjana Vukićević-Karabin was always sincerely interested in scientific and teaching paths of her younger colleagues. Her dedication to the development of the Belgrade school of astrophysics resulted in more than 200 students of astrophysics who, so far, successfully graduated from the Department of Astronomy.

3. RESEARCH ACTIVITIES

At the beginning of professor Mirjana Vukićević-Karabin's working career, research was her main occupation. However, later she devoted much more time to teaching. Mirjana Vukićević-Karabin's contribution to research in her teaching era also had a significant managerial character.

Instead of citing some scientometrics quantitative indicators of Mirjana Vukićević-Karabin's research work, we have decided to briefly present those results from some selected articles that will show the reader her research character and spirit, bearing in mind that these were the modern research topics at the moment of publication. We hope that these several examples will clearly testify to the fact that Mirjana Vukićević-Karabin tried to follow modern research trends and that she attempted to select from them those current issues, whose solutions were significant for the development of the studied field. She gladly took part in creating appropriate research strategy for such exploratory activities and happily participated in their implementation. Those interested in her scientometrics facts can find them in the Bibliography.

Mirjana Vukićević Karabin's research interests can be divided into two areas: the Earth's ionospheric disturbances, and the Sun. The switch from the first to the second topic was most likely due to her transfer from the Mihajlo Pupin Institute to the Department of Astronomy.

3.1. Research in the field of Earth's ionosphere

Mirjana Vukićević-Karabin started her research career at the Institute Mihajlo Pupin in the Group for the Ionosphere. Her early published papers testify that her topic of interest was study of disturbances of ionospheric layers detected by various methods and using a number of different instruments. She studied changes in ionospheric layers induced by solar activity and by severe and extreme events on Earth.

Along the investigation of the solar activity influence on the ionosphere, it is interesting to mention the study of changes of ionospheric parameters during the solar eclipses. For example, on the occasion of the total solar eclipse on 15th February 1961, she participated in probing the ionosphere above Belgrade (a partial eclipse could be seen from Belgrade). From the ionospheric data collected during the annular solar eclipse on 20th May 1966 she determined the flux of solar X- and UV radiation.

Another area of Mirjana Vukićević-Karabin's research interest is related to the study of influence of solar flares (eruptions) on the ionosphere using various methods that register sudden ionospheric disturbances (SIDs). As an example, out of several papers on the subject, let us focus on an article published in JATPh (Mitra et al. 1964). During one year stay at the National Physical Laboratory (NPhL), New Delhi, India in 1962/63, Mirjana Vukićević-Karabin participated in analysis of correlation between solar optical flares, solar radio-bursts, and occurrence of various indicators[4] of sudden ionospheric disturbances. It was found that not every optical flare of class 2 and above would cause an SID. Only those solar flares cause SIDs, which occur in the period when the average daily value of Sun's radio flux in the centimeter domain is above a certain threshold. The threshold value of 220 SFU (SFU = 10^{-22} W/(m^2 Hz)) for 3 GHz was determined by analysis of data collected during the International Geophysical Year. This result was interesting because an observational criterion was established when the correlation between solar flares and SIDs disappears. An important conclusion of the article in which the results of this analysis are published is: "In patrolling for solar flares, it is thus advisable to watch periods when the flux continuously exceeds the threshold value."

Another interesting research topic from the period of her stay at the NPhL refers to disturbances in Earth's ionosphere caused by distant nuclear explosions. Preliminary results of these studies were published also in the journal JATPh (Saha et al. 1963). The paper presents the results of observations of disturbances in the ionosphere that followed the Russian nuclear tests during August and September 1962. Disturbances were detected in Delhi (India) by various measurement techniques. An increase in critical frequency of the ionospheric F2 layer (foF2) lasting for several hours following the nuclear detonations was observed. In some cases, abnormally low values of foF2 were noted one day after detonation. An inversion of the enhancement of the magnitude of atmospheric noise levels of the measured radio signals at 27 kHz and 100 kHz was observed after nuclear detonations in comparison with observed magnitudes caused by solar flares of medium intensity (class 2).

[4]Short wave fadeouts (SWFs), enhancement of low frequency atmospherics (SEAs), sudden increases in cosmic noise absorption (SCNA), magnetic crochets.

Fig. 2: II workshop "Astrophysics in Yugoslavia" held in September 1987 on the occasion of centenary of the Astronomical Observatory of Belgrade.

Enhancement levels due to nuclear detonations were greater at 100 kHz than at 27 kHz. As authors state "The magnitude reversal of 27 Kc/s and 100 Kc/s effects is an important distinguishing feature for a nuclear detonation effect from a solar flare effect". At the time of this research (in the era of intensive nuclear tests), such a possibility of discriminating atomic explosion effects on the ionosphere from other ones fell into pioneering methods.

By moving from the Mihajlo Pupin Institute to the Department of Astronomy, Mirjana Vukićević-Karabin slowly abandoned the work in this interesting solar radio-emission and ionospheric research, although there were opportunities to continue working in the field of radio observation of the Sun at the Department of Astronomy. Namely, the Department already had a radio-interferometer laboratory with two radio-telescope antennas for observing the Sun. This laboratory is still located at the Astronomical Observatory of Belgrade and is supplemented with additional antenna. We assume that Mirjana Vukićević-Karabin's interest in more contemporary research areas was the main reason for her sluggish digressive interest in solar radio astronomy and ionosphere. Namely, Mirjana Vukićević-Karabin's scientific interest was focused on studying large scale (of the order of solar radius) motions of matter on the Sun.

3.2. Research in the field of solar physics

In 1970's there were clear hints from researchers that there should exist non-stationary streams of small speeds (several tens of m/s) on the Sun, but of huge sizes - of the order of solar radius. Mirjana Vukićević-Karabin and Aleksandar Kubičela aimed at contributing to this research field with observational evidence of the existence of assumed streams. Because of that, the double astrograph of the Astronomical Observatory of Belgrade was transformed into a special solar spectrograph restricted for studying the streams of matter on the Sun by measuring the line-of-sight (radial) component of their velocity vector using the Doppler method. For that purpose, the influence of structures (granulation, oscillations, supergranulation) of much smaller dimensions, but much higher speeds (several hundred m/s) than those intended to be measured had to be removed from the measured velocity values. For that purpose, an original method was applied: optical averaging, i.e. spatial filtering. Spatial filtering of the desired velocity scale was achieved by defocusing the image of the Sun on the slit of the spectrograph. In this way, the integration of solar radiation from a square shaped surface (side length of 0.2 solar disk radius) was achieved. Thus, the small scale velocities, in fact, manifested themselves as random noise in these measurements.

As a part of analysis of observation, it was assumed that the distribution of the average values of the measured radial velocities completed in a sufficiently long time interval (e.g. several tens of days or months) with a heliocentric angle contains the mean limb effect and the mean value of the radial component of the velocity vector of some long-term stationary motion. It was declared that the averaged radial velocities of other structures (including the non-stationary large scale features) within the observed square are equal to zero.

The first results of the analysis of observations during the autumn and winter observation seasons in 1974/75 yield the following three interesting conclusions: (Kubičela and Karabin 1977)

(i) Non-monotonic distribution of radial velocity (RV) in dependence on heliocentric angle (hereafter: the radial velocity curve); an obvious deviation from the so-called limb effect curve which was generally accepted to be parabolic in shape. A possible explanation may be the presence of a stationary photospheric meridional motion towards the interior of the Sun near the equator and towards the equator at some distance from it.

(ii) North-south asymmetry of the radial velocity curve, which suggests the existence of a constant meridional velocity of the photosphere from the southern to the northern edge of the solar disk. However, as the authors of the article pointed out, this asymmetry is the result of an unreduced systematic error caused by the apparent annual oscillation of the solar globe. Presumably, it was the first case that the significance of this systematic error is pointed out. Until then, this systematic error had been neglected in reducing the measured radial velocities on the Sun!

(iii) The change in structure of the distribution of deviations of daily measured values of radial velocities in several successive days along the central meridian of the Sun from their multi-day/monthly mean values indicates the possibility of existence of non-stationary large-scale motions. Namely, the regularity of changes in the obtained structure of radial velocity with heliocentric angle in consecutive days can be interpreted as a result of the existence of non-stationary large-scale motions.

Noticing that in the measurements of the radial velocity of matter on the Sun with accuracy of about a few m/s, the influence of the annual apparent precession of the Sun introduces unnegligible systematic error (up to ± 18 m/s), Aleksandar Kubičela and Mirjana Vukićević-Karabin developed and published a simple method to eliminate this systematic error to an accuracy of $\pm 3.5\%$. Later they improved the method by applying a more sophisticated approach to this subject taking into account not only the influence of Earth's revolution on measured velocities on the Sun but also the influence of the difference in orientations of the synodic and sidereal axes of rotation of the Sun (Kubičela and Karabin 1983).

Observations of radial velocities of large-scale motions on the Sun were regularly performed until 1987. The results of processing and analysis of these observations have been published in various journals and conference proceedings (see Mirjana Vukićević-Karabin's bibliography).

Unexpected discoveries in the 1980s concerning the variation of the solar constant and parameters of some spectral lines of solar flux with solar activity cycle contributed to the abrupt outbreak of large-scale motions research at the Astronomical Observatory of Belgrade. Namely, in the first half of 1980s, satellite observations in the declining phase of solar activity (1980-1986) definitely showed that the solar constant, contrary to expectations, decreases with decreasing solar activity. In addition, the results of long-term observations initiated earlier (1976) indicated a slow change in the equivalent width and depth of the profile of some photospheric spectral lines of integral solar radiation. From the observed data collected so far, it could be inferred that the time scales of these changes are at least of the order of duration of one solar activity cycle or may even have a secular character.

Theoretical considerations based on these observations have made one guess that the photosphere as a whole most likely has a slowly changing, so far unidentified, component of some of its physical parameters.

Certainly, one of the unanswered questions referred to the diversity of the observed changes of the parameters of different spectral lines. Encouraged by these facts, and with aim to contribute to the explanation of observed results, Mirjana Vukićević-Karabin, Jelisaveta Arsenijević and Aleksandar Kubičela, along with a widespread consultation with other solar physicists in the world, planned an adequate research program. In order to realize the observational part of that program, the solar spectrograph was rearranged into a scanning spectrometer, which interrupted the program of long-term observation of radial velocities on the Sun at the AOB. In 1990s, with the acquisition of a new type of detector (CCD camera), the solar spectrometer was again converted into a spectrograph.

So, in August 1987, at the AOB observations of about 30 carefully selected spectral lines sensitive to various photospheric parameters started within the program entitled "The Belgrade Program for Monitoring of Activity Sensitive Spectral Lines of the Sun as a Star". Some of selected lines showed changes, while others did not exhibit significant variations with solar activity. The observation program, with some corrections in the selection of spectral lines, lasted for about a decade. Mirjana Vukićević-Karabin participated in the analysis of the obtained observational data until 1993 when she published her last article in that field with the co-authors. Whereas the line of Mn I 539 nm, a line with an unusual profile from the list of the observation program, remained the subject of our research for about three decades! The latest research results related to this line were published in 2016. Theoretical research was also conducted in order to find those variable parameters of the photosphere that are responsible for the observed changes of this spectral line.

About twenty of our researchers and students worked on the research of the Sun as a star. They also conducted research at a dozen observatories around the world and attracted other researchers to partici-

pate in the study of the Sun as a star.

We hope that the selected research results presented in this section clearly testify to Mirjana Vukićević-Karabin's wise choice of contemporary research tasks at a given moment.

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5. INSTEAD OF CONCLUSION

In this article, we presented the teaching and research work of professor Mirjana Vukićević-Karabin. We highlighted only those results of professor Mirjana Vukićević-Karabin's work that illustrate well her approach to teaching and research tasks. Some historical data have also been provided to support the significance of the topic under discussion.

Being the first woman professor of astronomy at the University of Belgrade, Mirjana was dedicated to teaching and successful in science. The best evidence of her dedication and perseverance in development of the Belgrade school of astrophysics is a great number of the students of astrophysics who upon graduation from the Department of Astronomy continued their careers in astrophysics in Serbia and all over the world. She will be dearly missed by all her students, colleagues and friends.

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ЖИВОТ, НАСТАВНЕ И НАУЧНЕ АКТИВНОСТИ ПРОФЕСОРКЕ МИРЈАНЕ ВУКИЋЕВИЋ-КАРАБИН (1933-2020)

I. Vince[1] **and O. Atanacković**[2]

[1] *Astronomical Observatory, Volgina 7, 11060 Belgrade 38, Serbia*

E–mail: *ivince@aob.rs*

[2] *Department of Astronomy, Faculty of Mathematics, University of Belgrade Studentski trg 16, 11000 Belgrade, Serbia*

E–mail: *olga@math.rs*

УДК 929 : 52

Стручни чланак

У раду су приказани кратка биографија и преглед доприноса проф. Мирјане Вукићевић-Карабин развоју наставе из астрофизике на београдском универзитету и истраживањима у физици Земљине јоносфере и Сунца. Дата је и библиографија њених радова. Надамо се да ће овај преглед два аспекта њеног рада осветлити значајну улогу коју је имала у развоју астрофизике код нас.