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Research Unit for Solar Activity Monitoring, Climate Change and Light Pollution

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Abstract

The Research Unit (RU) has been performing the following activities:

i) Monitoring of solar activity both by using the resources of the Astronomical Observatory (e.g., a small refractor) and by analyzing the data available from various satellites. The obtained measurements are used to inform the public about the Sun's activity and accompanying phenomena.

ii) Study of natural causes that may contribute to climate change.

iii) Study of light pollution, one of the least understood forms of pollution on Earth using various observational instruments mounted at the Astronomical Observatory and Astronomical Station Vidojevica (ASV), operated by the Astronomical Observatory using standard astronomical techniques. These activities are performed within the three-year PRISMA project (started in January 2024) of the Urban Observatory of Belgrade, UrbObsBel (Urban Observatory of Belgrade) funded by the Science Fund of the Republic of Serbia. Astronomical Observatory coordinates the research of light pollution in Belgrade and beyond. Researchers from the Institute of Physics, the Faculty of Science, University of Novi Sad, as well as the Faculty of Medicine, University of Belgrade participate in these activities regarding the study of this problem, and all four scientific research organizations will be at the center of all future initiatives aimed to analyze and carry out activities to solve the problem of light pollution (such as, for example, the creation of dark-sky parks, the implementation of adaptive lighting systems, etc.).

iv) In addition to the above-mentioned activities, the RU also deals with the monitoring of various effects in the Earth's atmosphere using instruments installed at the Astronomical Observatory.

Keywords: Sun, climate change, light pollution

1. Introduction

In Septembar 2023 at the Astronomical Observatory of Belgrade the Research Unit (RU) for monitoring solar activity, climate change and light pollution was formed (https://www.aob.rs/en/research-en/research-units/296-research-unit-for-solar-activity-monitoring-climate-change-and-light-pollution). The RU has been performing the following activities mentioned in the abstract of this paper.

The members of the RU are: Dr. Srdjan Samurović, principal research fellow, Astronomical Observatory, RU lead, Dr. Goran Damljanović, principal research fellow, Astronomical Observatory, Belgrade, RU member, Dr. Zoran Simić, principal research fellow, Astronomical Observatory, Belgrade, RU member and Dr. Ivan Živanović, research associate, RU member. In the work of the RU the following associates also participate: Dr. Zorica Cvetković, principal research fellow, Institute of Physics, Belgrade, Dr. Rade Pavlović, principal research fellow, Institute of Physics, Belgrade, Dr. Dragan Lukić, research associate, Institute of Physics, Belgrade, Dr. Branislav Rovčanin, senior research associate, Faculty of Medicine, University of Belgrade and Dr. Dajana Bjelajac, assistant professor, Faculty of Sciences, University of Novi Sad.

1.1. Solar Activity Monitoring

The main results are in area of investigations of the different physical parameters of the sunspots and small-scale structures on the Sun. First of them is the radial distribution of the vertical component of magnetic field which is obtained using the satellite data (SDO – Solar Dynamics Observatory) [Živanović et al., 2016]. Obtained radial distribution of the vertical component of the magnetic field is presented on Fig. 1.

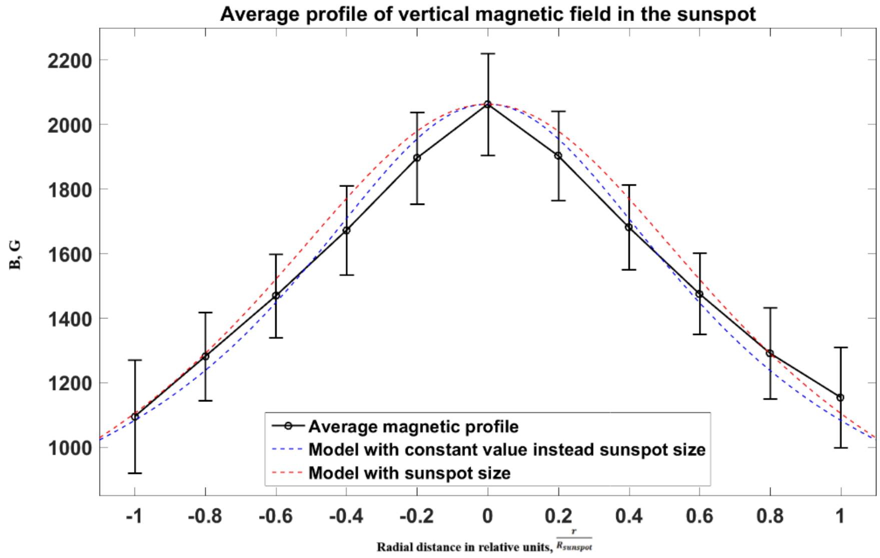

Figure 1. *The radial distribution of the vertical component of the magnetic field in sunspots obtained by the satellite (SDO – Solar Dynamics Observatory) data.*

Another important result is the evaluation of the superconvective cells depth with the analysis of the differential rotation of small-scale structures on the Sun and helioseismology data. In this research new method of the obtaining the differential rotation is used. This research is presented in work [Živanović et al., 2021]. Obtained result is presented on Fig. 2 and Fig. 3. The obtained estimation of the depth of the superconvective cells is about 30 Mm.

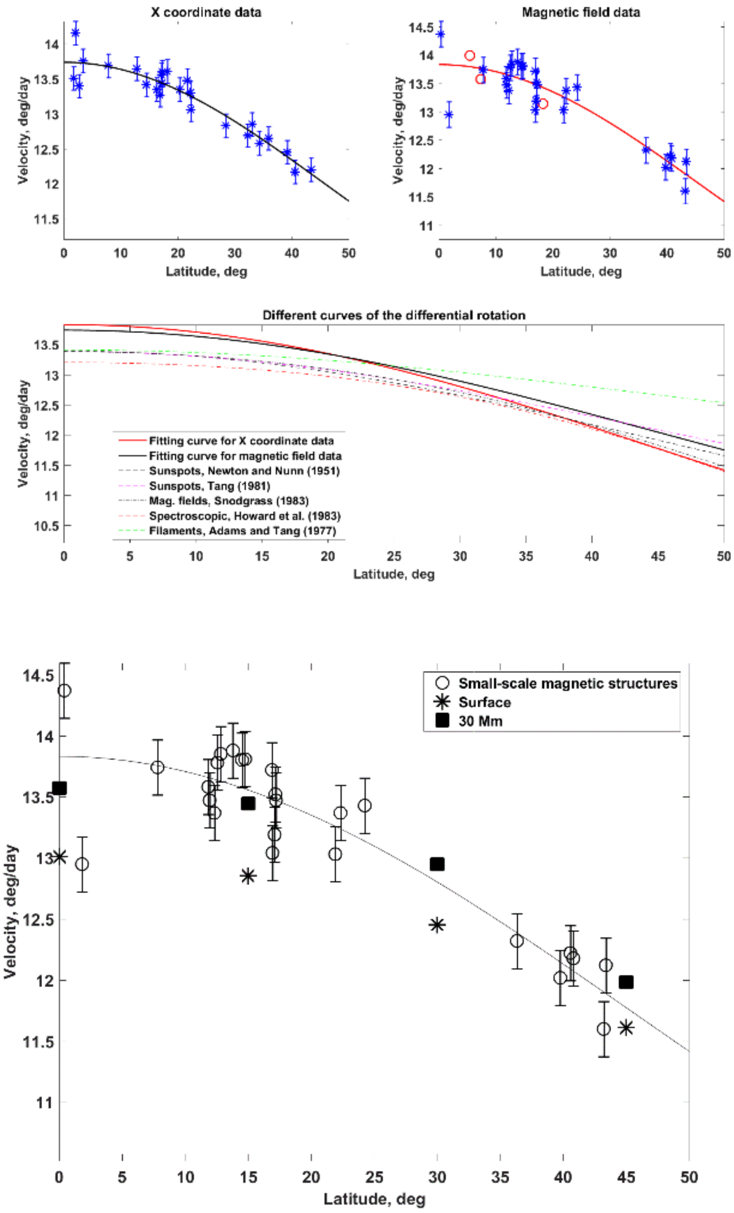

Figure 2. *Different curves of the differential rotation of the Sun are presented on the left side. These curves were obtained by different authors and different methods. Two of them are obtained by us [Živanović et al., 2021]. On the right side the curve of the differential rotation obtained by us is presented by the black line. Data from helioseismology marked by black squares presents the velocities of the differential rotation on the depth of 30 Mm, black asterisks marks the velocities of differential rotation on the surface of the Sun.*

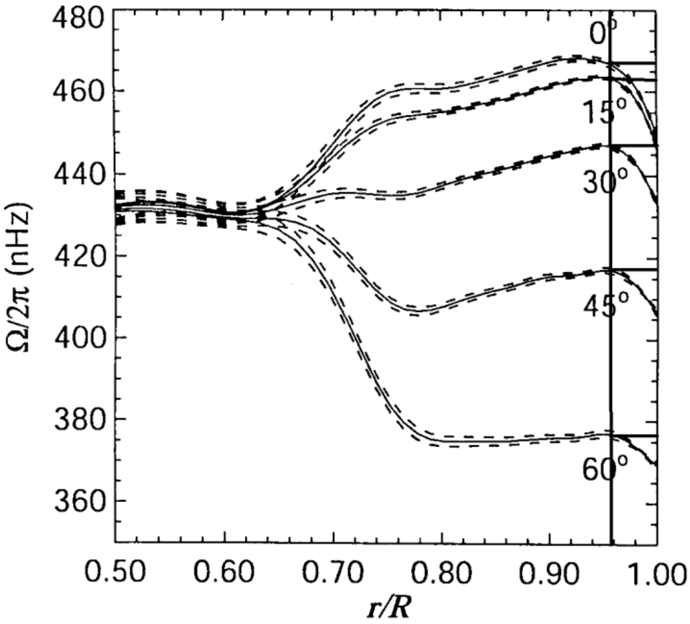

Figure 3. *Differential rotation of the different depth layers of the Sun by the helioseismology data. Our result [Živanović et al., 2021] is marked by the vertical black line.*

Other side of researches is the modeling of the magnetohydrodynamic processes on the solar atmosphere. For this research, we use the astrophysical code PLUTO, where the magnetohydrodynamic is realized for different physical situations. In our case, we simulate perturbations in the solar atmosphere and compare it with the actual models and observations [Živanović et al., 2025].

The dependency between the magnetic field strength and the brightness in the sunspots and small-scale structures is investigated using the SDO data [Živanović et al., 2020; Efremov et al., 2021]. The research includes the dependency between the time series with the brightness and magnetic field strength synchronized in time. In this timeseries the anticorrelation in the variations of this physical parameters [Efremov et al., 2021]. Another important research in this area is the research of the dependency between the magnetic field strength and brightness in case of the relations between the magnetic field and plasma convection. This is well known that in strong magnetic fields the convection of plasma is lower than in regions without strong magnetic fields. Due to this effect we can see sunspots as dark regions on the solar surface. In our research [Živanović et al., 2020] we show that this process of the suppression of the convection by the magnetic field have a point of saturation. In other words, with further growth of the magnetic field the brightness does not decrease any more. This result is presented on the Fig. 4.

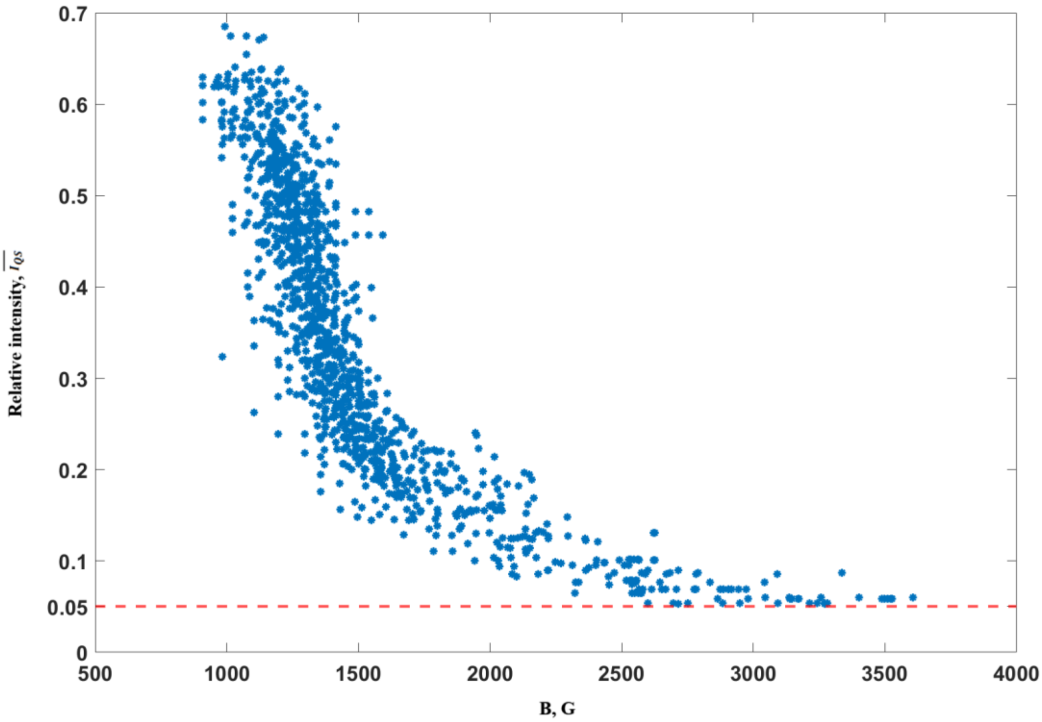

Figure 4. *Distribution of the brightness in the sunspot (vertical axis, normalized at the brightness of the Quiet Sun) and magnetic field strength at the same region of the sunspot (horizontal axis, in units of Gs).*

Another (and new) area of investigation is the relations between the solar activity and climate changes on Earth. This area of research is perspective in case of the new possibilities of observations of the markers for the reconstruction of the solar activity in the past. At the same time now we have a lot of observations of the climate markers. Hence we can find dependencies between the solar activity and climate changes on the Earth.

2.2. Climate Change

Climate change affects the physical environment and therefore poses a fundamental threat to human health. If these changes are frequent and intense, storms, extreme heat, droughts or, on the other hand, floods, erosion and loss of fertile arable land appear. Which obviously puts all life, including its inhabitants, at risk. This research area is in our unit's development plan for the next decade.

2.3. Light pollution

The main part of activities of the RU were lately dedicated to the problem of the light pollution (item iii listed above) and were performed within the UrbObsBel project and thus we describe them here in some detail. The instruments of the project are mounted at the top of the Tower of the Astronomical Observatory of Belgrade, Municipality of Zvezdara at altitude of approximately 250 meters which is the highest point of the urban part of Belgrade from which all parts of the city are perfectly visible. In Figure 5 we show the panoramic view to the West (downtown area of Belgrade).

Figure 5. *The panoramic view of the downtown area of Belgrade as seen from the top of the Tower of the Astronomical Observatory of Belgrade.*

We have the following instruments: two Sky Quality Meters (SQMs, one mounted in Belgrade and one at the ASV), two TESS-W instruments (again, one mounted at Zvezdara, and one mounted at the ASV), two FLIR A700 infrared cameras (both mounted at the Tower of the Astronomical Observatory, one pointed to the city center, see Figure 5, and one pointed to the outskirts of Belgrade), two visible and near-infrared (VNIR) hyperspectral imaging (HSI) detectors (again, one pointed to the city center and the other one pointed to the outskirts of town, see Figure 6 for FLIR and HSI detectors), the All Sky Camera Alcor OMEA 3C designed for continuous for continuous, day-and-night monitoring of the entire sky (see Figure 7) and a digital camera with a fish lens.

Figure 6. *The FLIR A700 infrared camera (on the right) and the HSI detector (on the left) mounted at the Tower of the Astronomical Observatory of Belgrade.*

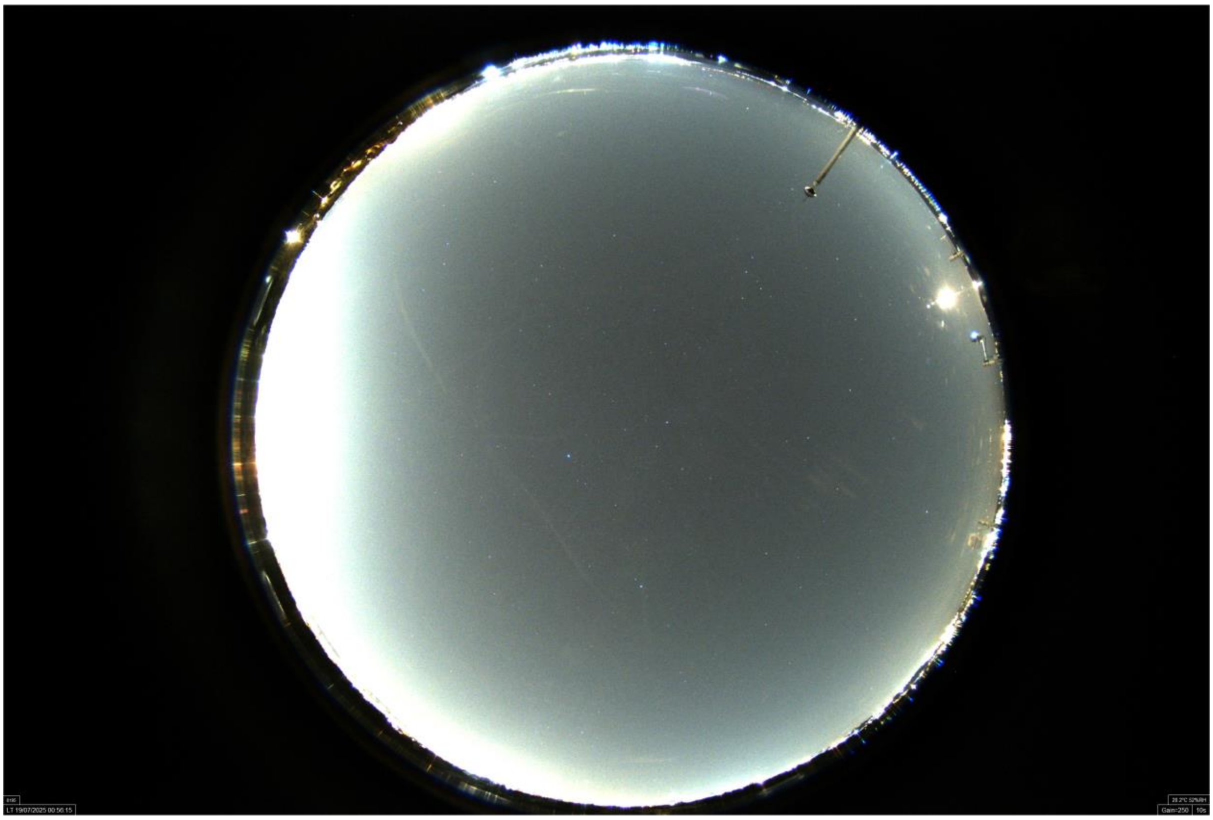

Figure 7. *The image of sky above the Tower of the Astronomical Observatory of Belgrade taken on July 19, 2025 (00:56:15 Local Time). In the upper right corner one can see a lighting rod.*

We plan to ask the citizens of Belgrade (various municipalities) to fill in our questionnaire regarding their experiences with the light pollution. Their responses, together with the results of the UrbObsBel project will be used by the Municipality of Zvezdara and the City of Belgrade because these measurements will provide elemets for making decisions in the direction of creating a better environment that will improve the health of the population of Belgrade and its surroundings.

Our preliminary results presented in Pavlović et al. (2025) suggest that at the ASV one can see fainter objects up to 4.5 mag than at the Astronomical Observatory of Belgrade due to the light pollution. Here, in Figure 8 we present another comparison, i.e., we compare two sets of ten SQM observations made on the same night at two different locations: the Tower of the Astronomical Observatory of Belgrade and the Tower of the Astronomical Society "Rudjer Bošković" in downtown Belgrade (altitude 110 m). The measurements started at 11:13 PM (Local Time) and 10 values were taken each 5 minutes (the last measurements were taken at 11:58 PM Local Time). One can see that the center of Belgrade clearly has larger light pollution (difference of the measured magnitudes is always greater than 1 mag).

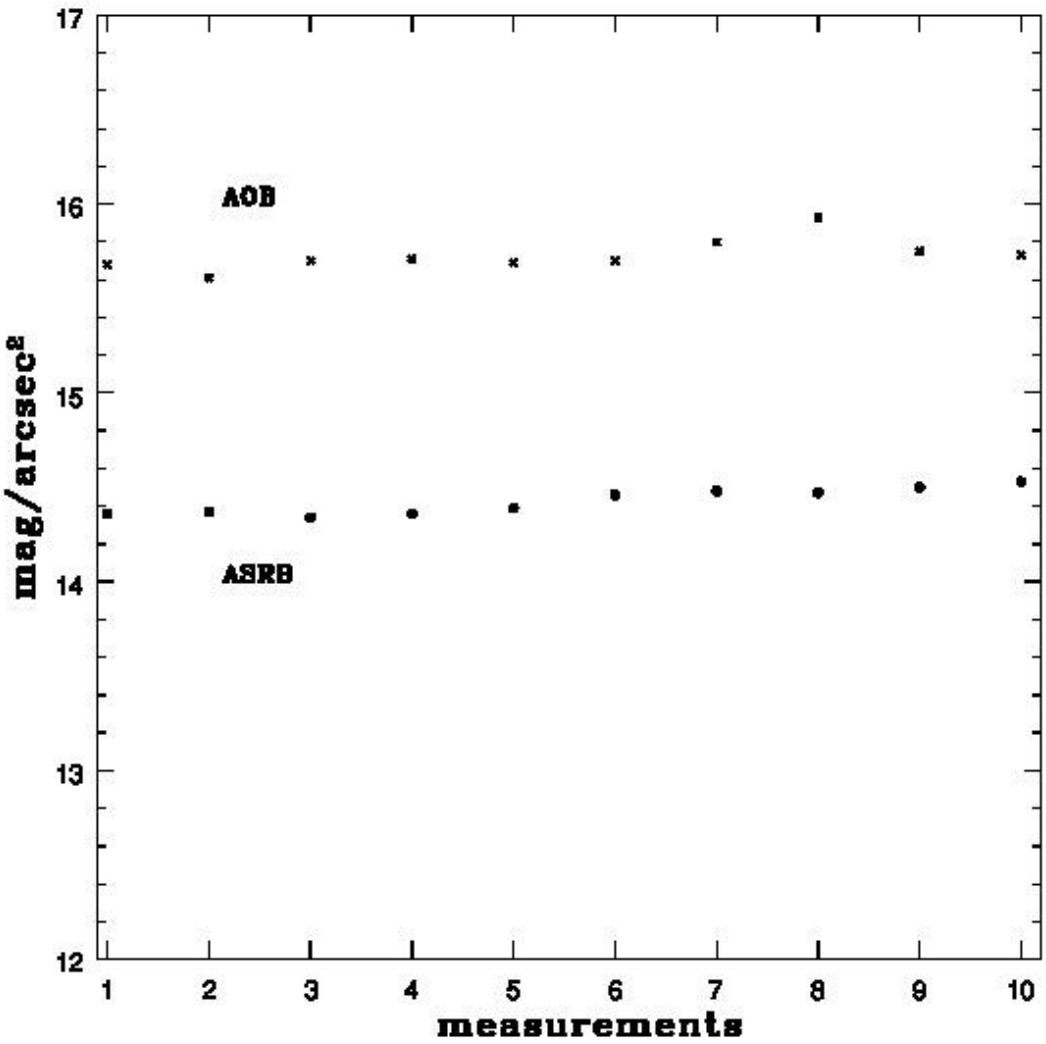

Figure 8. *Comparison of ten SQM measurements on the same night (July 27, 2025) at two different locations: the Tower of the Astronomical Observatory of Belgrade (AOB, crosses) and the Tower of the Astronomical Society "Rudjer Bošković" (ASRB, filled circles).*

The Web site of the UrbObsBel project is available at https://urbobsbel.aob.rs and contains all the relevant information about the project.

Acknowledgments

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