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FIRST OBSERVATIONAL DATA FROM THE MINI-NEUTRON MONITORING STATION AT THE ROZHEN NATIONAL ASTRONOMICAL OBSERVATORY (MNMS-ROZH)

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Abstract. We demonstrate the first observational data from the newly built mini-neutron monitoring station at the Rozhen National Astronomical Observatory. The data is freely accessible with search option in the up-to-date archive. Provided are the main parameters of the station and equipment. The station is equipped with sensors for measuring and storing in accessible online data base of meteorological parameters, which are also provided.

1. INTRODUCTION

The study of cosmic rays began after their discovery in 1912 by Victor Hess. Observations and reports of cosmic radiation affecting the Earth's environment began in the early 1930s with ionization chambers, and in the early 1950s the construction and use of neutron monitors began. Records of the state of the Earth's ionosphere date back to 1942, and ozone data to about 1957.

Cosmic rays (CRs) are high-energy particles traveling at close to the speed of light. There are two types of CRs according to their origin – Galactic cosmic rays (GCRs) and Solar cosmic rays (SCRs). GCRs generally originate in supernova explosions and/or stellar fusion processes. The energy of protons and helium nuclei of GCRs mostly lies in the range $100 - 3000$ MeV, yet extreme energies as 1000 of EeV are observed. SCRs or solar energetic particles (SEPs) arise mainly from solar flares (large eruptions of electromagnetic radiation; a burst of radiation) and coronal mass ejections (solar material of charged particles (plasma)) and the energy of protons and helium nuclei is between 5 and 100 MeV. SEPs (and secondary particles) are produced through eruptive and non-thermal processes. About $85 - 90\%$ of CRs are protons (nuclei of hydrogen atoms) and about $9 - 13\%$ consisting of alpha particles (helium nuclei). The remaining $1-2\%$ are electrons and nuclei of heavier atoms (HZE ions).

Direct observations and registration of high-energy particles from outer space ("primary" CRs) are impossible from the Earth's surface. But their interaction with the molecules in the Earth's atmosphere leads to the reproduction of new particles called "secondary" CRs, which are able to reach the ground so we can register and study them. A significant leap in scientific research in this area was made by J. A. Simpson (Simpson 1948), who established the possibility of studying temporal variations of primary CRs at lower energies with ionisation chambers or muon counters by establishing the first network of ground-based detectors. He established the strong variability of the intensity of CRs (200-400%) by latitude and altitude, by the change in the intensity of the geomagnetic field, but also by the systematic changes in the intensity of cosmic radiation with respect to the 11-year solar cycle (Meyer and Simpson 1955; Simpson 2000). These and similar studies (Forbush 1954) are fundamental to develop a new type of detector that measures secondary CRs (neutrons) in the Earth's atmosphere in the GeV range (the energy of primary CRs is from 500 MeV to 30 GeV). The neutron monitor designed by Simpson (Simpson 1957) was adopted as the standard detector during the International Geophysical Year (IGY) 1957/58 and was called the IGY neutron monitor (Btikofer 2018). This is the beginning of the systematic investigations of the effects of the Earth's magnetic field on the CRs as observed on the ground. Lately the IGY detectors were considerably improved, leading to development of NM-64, as a standard device. The secondary CR (neutron) flux detectors created more than 7 decades ago by Simpson are still in use today, of course, improved over time.

Almost half a century of intense observation, research and significant modeling of CR and heliosphere physics was summarized in two notable works at the end of the last century (Fisk et al. 1998; Balogh et al. 1999).

2. THE NEW MINI-NEUTRON MONITORING STATION AT ROZHEN OBSERVATORY

In our modern world of rapidly developing technologies, CRs and especially the sporadic manifestation of the influence of SEPs on the Earth's magnetosphere, ionosphere and our surrounding environment are an increasingly significant and determining factor. Their impact on our environment is a key factor in understanding short-term (up to a few tens of years) and long-term (more than hundreds or thousands of years) changes in our climate. Their influence on communications and generally electrical devices and appliances is essential to the tense rhythm of our existence. The greater the need for knowledge in this area, the more relevant is the issue of presenting better opportunities for CRs research. There is increased interest in the scientific community to build a denser ground-based network of CR detectors to cover observations from different latitudes and altitudes. We present our new mini-neutron detector (MNM-ROZH), based on gas-filled proportional counters type LND2043 BF3 (Figure 1). This type of NMs are effective detectors of CRs, by detecting a raid of the secondary flux of cosmic rays (neutrons).

Each of our three detectors has a cylindrical design with an outer diameter of 350 mm, a length of 750 mm, and a weight of almost 300 kg. The outermost cylinder of the detector is a polyethylene reflector. This reflector (75 mm thick) shielding the instrument from external thermal neutrons, while containing neutrons produced within the NM. Under the external reflector there is a 206-mm lead cylinder producing additional low energy neutrons via nuclear interactions to increase the monitors detection efficiency. The next layer is again made of polyethylene – an internal moderator of thickness 15 mm thermalizing the newly produced neutrons. The gas-filled

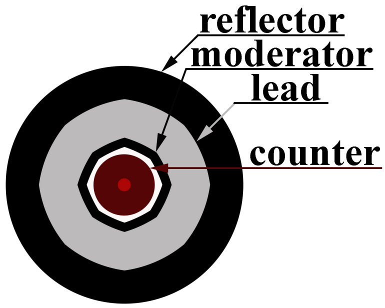

Figure 1: Cross-sectional sketch of the mini-NM-ROZH. The outer part of the detector (black) is a polyethylene reflector, then the lead sheath (gray), again a polyethylene moderator (black), which houses the proportional counter (red).

proportional counters type LND2043 BF3 are located in the middle of the cylinder. The pressure in a mini-NM detector is 930 mbar. The completed mini-NM set-up, while undergoing testing, is shown on Figure 2.

Figure 2: Completed and installed system of 3 mini-neutron counters on the territory of the National Astronomical Observatory. MNM-Rozh is currently still running in calibration mode.

Neutrons in the energy range of tens to thousands of MeV are produced and moderated to thermal energy before reaching the interior of the counter, which is filled with BF3 and operates as a proportional gas counter. At this low energy level, neutrons are adsorbed by boron, which splits into ^{7}Li and alpha-particle (Knoll 2010). The kinetic energy of these two ions is dissipated by ionizing the gas. The charge momentum induced by these ions is counted.

Gas-filled proportional counters type LND2043 are cylindrical BF3 neutron detectors produced by LND Inc., USA. The detector control electronics were completely designed and assembled to the detectors by the Center for Space Research, North West University, the Republic of South Africa (RSA). A Raspberry Pi 3 B, a fully-functional single-board computer is used to interface with the system components. The on-board computing power enables data processing and data validation in real-time. This allows functionality like digital filters and enables units to alert or automatically reset if an error occurs. The built-in network interface allows remote monitoring, administration, and data synchronization. The USB (universal serial bus) interface allows for a local data backup when network connectivity is interrupted or unavailable.

Our neutron monitor (NM) station is located at 41°41′43.4″N, 24°44′22.3″E at altitude 1730 m (Figure 3). The trajectories of charged particles are influenced by the magnetic field generated by the Earth's core. We use the new open-source tool for magnetospheric computations and modelling of CR propagation in the geomagnetosphere, named OuluOpen-source geomagneToSphereprOpagation tool (OTSO), available on GitHub (`https://github.com/NLarsen15/OTSO`) and Zenodo (`https://doi.org/10.5281/zenodo.7516233`) (Larsen et al. 2023).

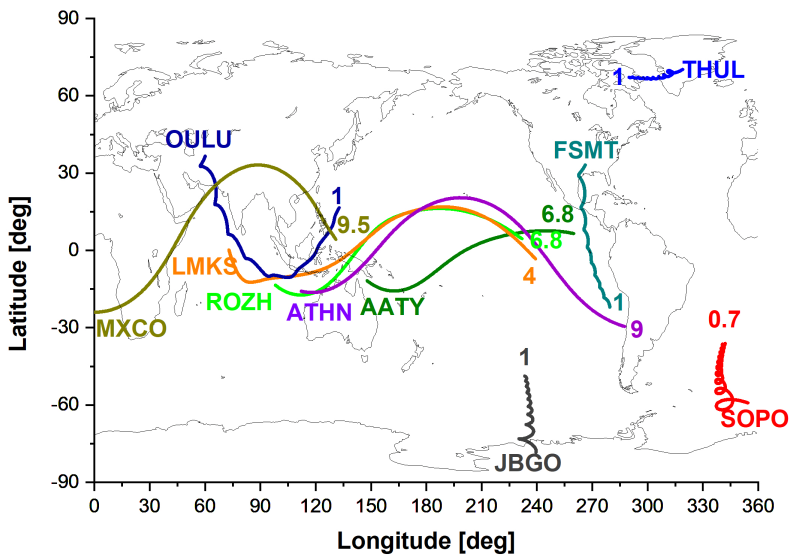

Figure 3: Computed asymptotic cones over various rigidity ranges for several selected neutron monitors stations including ours (ROZH).

Figure 4 shows the first test results for our three detectors individually – a binned 2D histogram of the pulse width and pulse histogram. The data is the sum of three consecutive days for the period 19-21 September 2024. The distributions are projected onto each plane. From the 2D histogram, we can clearly identify low amplitude noise below 0.5 V, consisting of short and longer pulses. Calculating and monitoring these distributions (e.g. on an hourly basis) allows us to determine and track the accuracy of the detector. Any external noise (e.g., mechanical vibrations or high-voltage ripple currents) will change the shape of the distributions. Visualizing the pulses in such a 2D plane also permits performing a detailed separation of the pulses into noise and/or data (counts) by applying an appropriate cut through the pulse amplitude/width plane (Strauss et al. 2020).

In addition to our equipment for observing and recording cosmic rays, we have been able to add detectors for various meteorological components of the Earth's atmosphere. Neutron flux data are related to atmospheric pressure, humidity and tem-

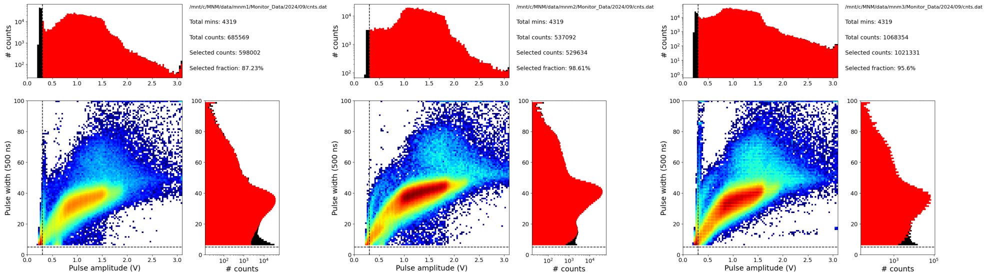

Figure 4: A 2D pulse width-amplitude histogram as registered MNM-RZH (for each individual detector). The distribution is projected onto each plane. The dashed lines show the cut applied to the pulses in order to discriminate between measurements and noise. On the projected histograms, all the pulses are indicated by a black histogram, while the red histogram indicated pulses assumed to be measurements free from noise.

perature. For this purpose, a meteorological tower was built in close proximity to the neutron monitoring station to reliably measure multiple meteorological parameters (Figure 5).

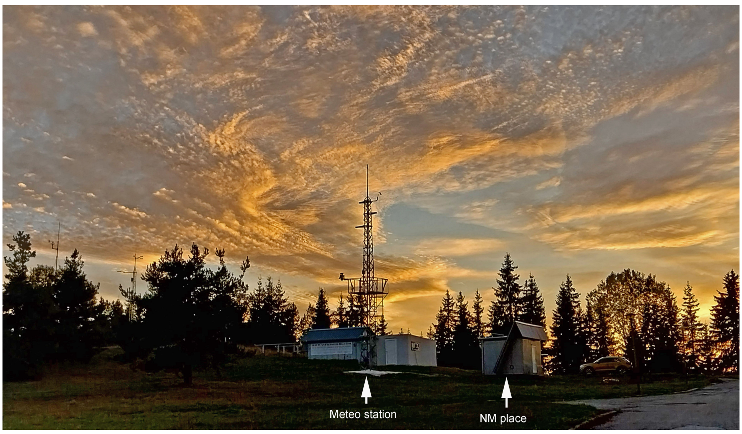

Figure 5: Part of the infrastructure of NAO Rozhen, including a tower with installed detectors for various meteorological parameters and a pavilion that houses the newly built MNM.

The data we currently monitor are the total solar radiation, UVA, temperature, humidity, pressure, etc. The open-access database is still under construction, but will be fully accessible soon on `https://helio.astro.bas.bg/livecam/`. The data is partially available on: `https://meter.ac/gs/meteo/M16/history.html` (solar radiation) and `https://meter.ac/gs/meteo/M161/history.html` (temperature/humidity).

3. SUMMARY

The construction of cosmic ray detectors is important scientific task for solving current issues related to near-Earth space. Determining the problems of space weather are of prior importance for our new and modern world. These problems are related both to the study of purely scientific phenomena as well as their influence on our environment, which is beginning to become an increasingly broad concept as it includes various parameters of space weather in our solar system as a whole.

NM stations located at different locations are an important step in networked research, which enables better scientific activities between different international teams. Currently MNM-ROZH is working and accumulating data, which after additional calibrations and tests will be presented online with open access through an active database. We believe that the results will find their significance in future scientific research in several directions such as the importance and influence of space factors on global climate changes on Earth (both short-term and long-term), finding new solutions for the prevention and protection of the population from the influence of space factors time, including protection and prevention of all activities related to electricity/electrical engineering and communications.

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References

Balogh, A., Gosling, J. T., Jokipii, J. R., Kallenbach, R., Kunow, H. (eds.): 1999, Corotating Interaction Regions, Kluwer Academic Publishers, Dordrecht, doi: 10.1007/978-94-017-1179-1

Larsen, N., Mishev, A., Usoskin, I.: 2023, , *Journal of Geophysical Research: Space Physics*, **128**, e2022JA031061, doi: 10.1029/2022JA031061

Strauss, D. T., Poluianov, S., van der Merwe, C., Kruger, H., Diedericks, C., et al.: 2020. *J. Space Weather Space Clim.*, **10**, 39, doi: 10.1051/swsc/2020038

Simpson, J.A.: 1948, *Phys. Rev.*, **73**, 13891391, doi: 10.1103/PhysRev.73.1389

Simpson, J.A.: 1957, *Bulletin of the Atomic Scientists*, **13**, 351356, doi: 10.1080/00963402.1957.11457599

Simpson, J.A.: 2000, *Space Sci. Rev.*, **10**, Edited by J. W. Bieber, E. Eroshenko (eds), Cosmic rays and earth, Proceedings of an ISS/ Workshop, pp.11-32, doi: 10.1023/A:1026567706183

Btikofer, R.: 2018, *Astrophysics and Space Science Library*, **444**, doi: 10.1007/978-3-319-60051-2_6

Fisk, L. A., Jokipii, J. R., Simnett, G. M., von Steiger, R., and Wenzel, K.-P. (eds.): 1998, Cosmic Rays in the Heliosphere, Kluwer Academic Publishers, Dordrecht, doi: 10.1007/978-94-017-1189-0

Forbush, S. E.: 1954, *J. Geophys. Res.*, **59**, 525, doi: 10.1029/JZ059i004p00525

Meyer, P., Simpson, J. A.: 1955, *Phys. Rev.*, **99**, 1517, doi: 10.1103/PhysRev.99.1517