S E S 2 0 1 8
Fourteenth International Scientific Conference
SPACE, ECOLOGY, SAFETY
7 – 9 November 2018, Sofia, Bulgaria

ANOMALOUS ENHANCEMENT OF COSMIC RAYS DURING G3 GEOMAGNETIC STORM ON 26.08.2018 IN SPECIAL POSITION OF SUN–EARTH–MOON SYSTEM

Lev Dorman[1], Peter Velinov[2], Dimitrinka Tomova[3], Alexander Mishev[4], Lachezar Mateev[2]

[1]IZMIRAN, Russian Academy of Sciences / Israel Cosmic Ray Center, Qazrin
[2]Space Research and Technology Institute – Bulgarian Academy of Sciences
[3]Sofia University „St. Kliment Ohridski“, Faculty of Mathematics and Informatics
[4]Space Climate Research Unit, University of Oulu, Finland
e-mail: pvelinov@bas.bg

Keywords: *Cosmic rays, Interplanetary physics, Particle acceleration; Space weather, Particle precipitation; G3 – Strong geomagnetic storm*

Abstract: *The strongest geomagnetic storm in 2018 was studied. It is accompanied by anomalous enhancement of cosmic rays, recorded by a large number of neutron monitors (NMs) on the global world network stations (http://www01.nmdb.eu/). The storm on 26.08.2018 has a maximum 3-hour planetary index Kp = 7+ and the magnitude of the planetary 24-hour Ap index, Ap = 67. This storm was not predicted by either our Space Weather Forecasting Center at the Institute for Space Research and Technology – BAS, or the other national and international centers and services. This work analyzes the causes of this phenomenon. The investigated storm coincides exactly with the full moon on August 26, 2018, when the Sun – Earth – Moon system is located on a straight line.*

АНОМАЛНО НАРАСТВАНЕ НА КОСМИЧЕСКИТЕ ЛЪЧИ ПО ВРЕМЕ НА ГЕОМАГНИТНАТА БУРЯ G3 НА 26.08.2018 ПРИ СПЕЦИАЛНО ПОЛОЖЕНИЕ НА СИСТЕМАТА СЛЪНЦЕ–ЗЕМЯ–ЛУНА

Лев Дорман[1], Петер Велинов[2], Лъчезар Матеев[2], Димитринка Томова[3], Александър Мишев[4]

[1]ИЗМИРАН, Руска академия на науките / Израелски Космически център, Казрин
[2]Институт за космически изследвания и технологии – Българска академия на науките
[3]Софийски Университет "Св. Климент Охридски", Ф-т по математика и информатика
[4]Изследователски отдел за космически климат, Университет в Оулу, Финландия
e-mail: pvelinov@bas.bg

Ключови думи: *Космически лъчи, Междупланетна физика, Ускорение на частиците; Космическо време, Изсипване на частиците; Силна геомагнитна буря – клас G3*

Резюме: *Изследвана е най-голямата геомагнитна буря през 2018 г. Тя е съпроводена от аномално нарастване на космическите лъчи, регистрирано от значителна част от неутронните монитори на световната глобална мрежа станции (http://www01.nmdb.eu/). Бурята от 26.08.2018 има максимален 3-часов планетарен индекс Кр = 7+ и значение на планетарния 24-часов Ар индекс, Ар = 67. Тази буря не беше предсказана нито от нашия Център за прогноза на космическото време при Института за космически изследвания и технологии – БАН, нито от другите национални и международни центрове и служби. В работата се анализират причините за този феномен. Разглежданата буря съвпада точно с пълнолунието на 26.08.2018, когато системата Слънце – Земя – Луна е разположна на една права линия.*

Introduction

We are presently at the minimum of the 24th solar cycle. Increased solar activity periods during the minimum are rare occurrences. Typically, such phenomena are 1–2 during a solar cycle [1, 2, 3]. This particularly concerned the period with CR anomalous effects in the end of August 2018.

Surprise G3 – Strong geomagnetic storm on August 26, 2018

On 26 August 2018 unexpectedly began the strongest geomagnetic storm for this year with a maximal 3-hour planetary index Kp = 7+ and the magnitude of the planetary 24-hour Ap index, Ap = 67 (Fig. 1a). This storm was not foreseeable for most of the world space weather prediction centers.

Mostly the space weather forecasts (of NOAA SWPC and other European and world centers) come true with a high probability. Relatively rare are some exceptions - one such case is the forecast for August 26, 2018.

„We were wrong! The coronal mass ejection we talked about back on 22 August did arrive at Earth and sparked strong G3 geomagnetic storming conditions today. A big surprise for everyone which goes to show how unpredictable space weather is.“ (NOAA SWPC)
(https://www.spaceweatherlive.com/en/news/view/352/20180826-strong-g3-geomagnetic-storm)

On Fig. 1b is shown the forecast of geomagnetic storms from 26 to 28 August 2018 from Laboratory for Roentgen Astronomy of the Sun, Lebedev Physical Institute of the Russian Academy of Science (http://tesis.lebedev.ru/).

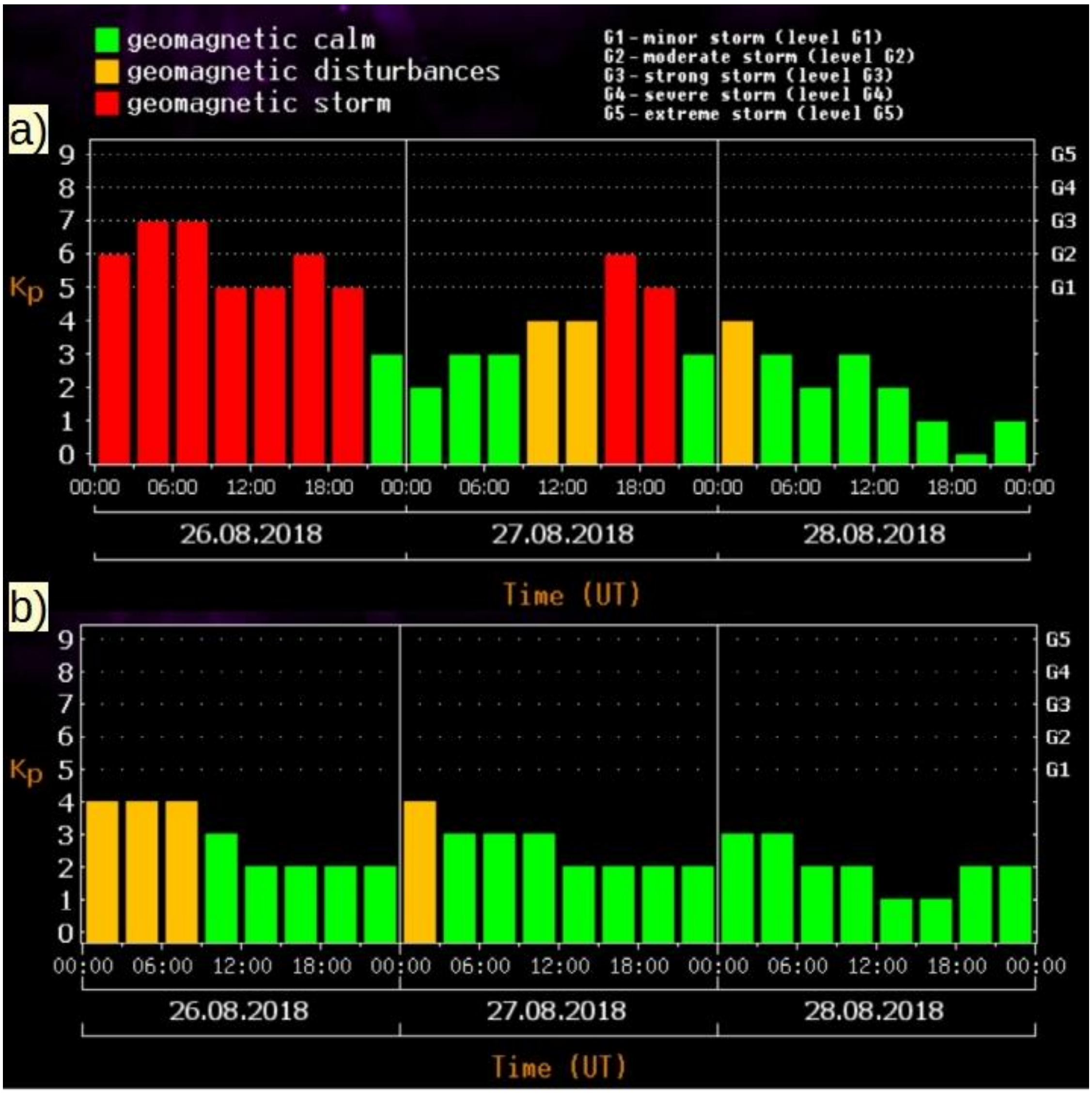

Fig. 1: a) The 3 hour Planetary K-index in the disturbed period August 26–28, 2018 with level G3 – Strong geomagnetic storm (August 26) and level G2 – Moderate geomagnetic storm (August 27), according to NOAA Space Weather Prediction Center (SWPC) – Boulder, Colorado. At the top of the Figure the 5 levels (G1–G5) of geomagnetic storms (all in red) are presented.

Fig. 1: b) The forecast of magnetic storms from 26 to 28 August 2018, prepared from Laboratory for Roentgen Astronomy of the Sun, Lebedev Physical Institute of the Russian Academy of Science (http://tesis.lebedev.ru/). According to them the probability of a magnetic storm is 20 % and the probability of a strong magnetic storm is 5 % for 26 and 27 August. For 28 August these probabilities are 10 % and 1 %, respectively.

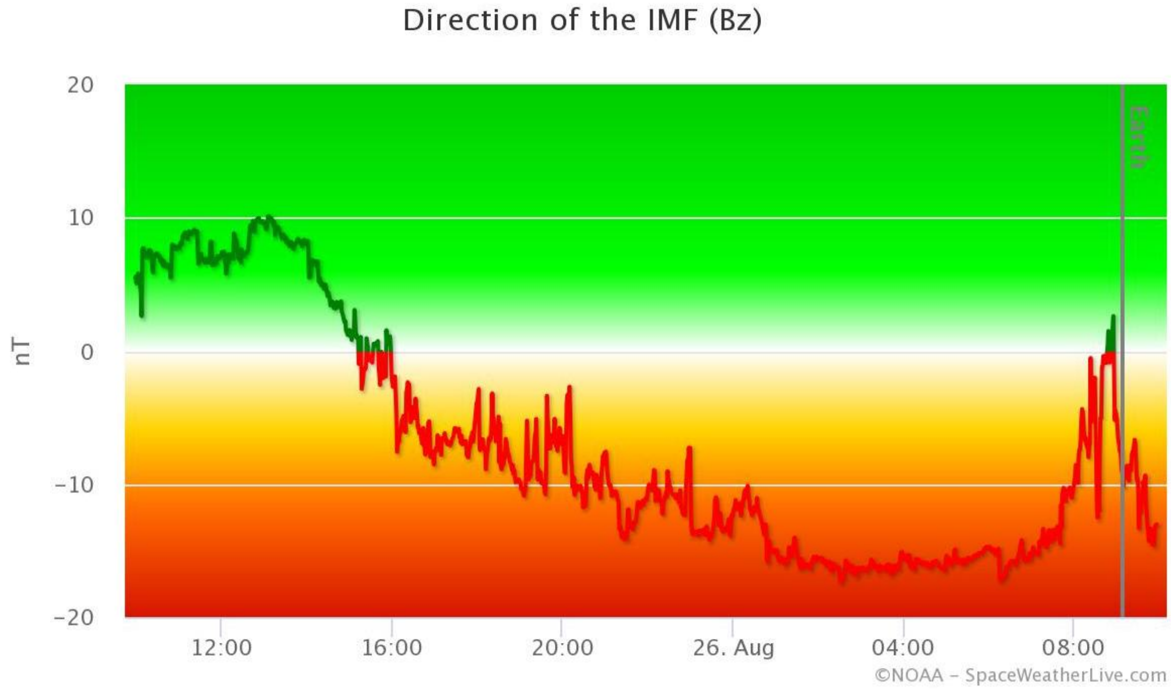

Fig. 2. Magnitude of the Interplanetary Magnetic Field (IMF), with a continuous southward orientation (Bz). Negative (southward) Bz values have been observed since around 15 UTC on 25.08.2018 and these values gradually increased to a minimum of –17 nT.

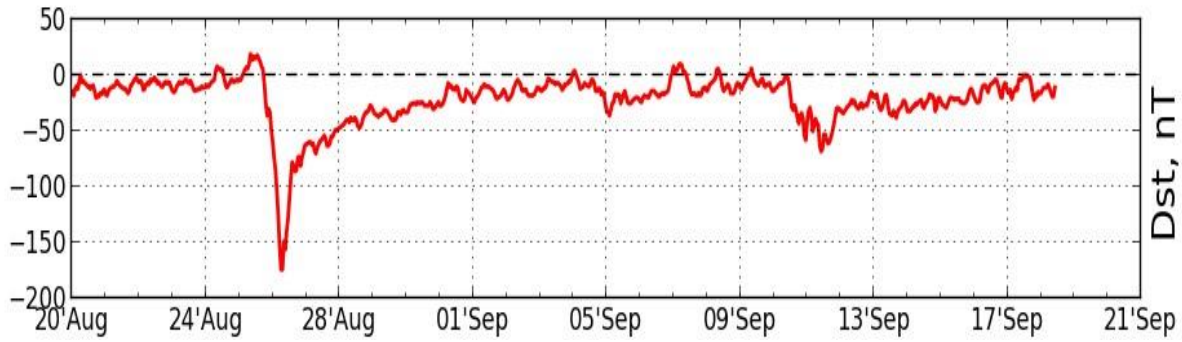

Fig. 3. Behaviour of Dst - index [nT] in the period August 20 – September 18, 2018, according to data from World Data Center for Geomagnetism, Kyoto, Japan. It is seen and another smaller storm on September 11, 2018.

This unexpectedly strong geomagnetic storm is caused by an enhanced magnitude of the Interplanetary Magnetic Field (IMF), with a continuous southward orientation (Bz) (Fig. 2), which is a common occurrence when the core of a Coronal Mass Ejection (CME) passes our planet. Negative (southward) Bz values have been observed since around 15 UTC on 25.08.2018 and these values gradually increased to a minimum of –17 nT (Fig. 2). The persistent southward orientation of IMF constantly fueled the auroral events above our planet resulting in surprisingly strong geomagnetic storm conditions (https://www.spaceweatherlive.com/images/news/2018/352-bz.jpg).

Magnetic storming gradually increased in strength until 05:59 UTC on 26.08.2018, when the NOAA SWPC reported that the G3 – Strong geomagnetic storm threshold was reached. Even the Disturbance Storm Time (Dst) index dropped deep to a lowest value of Dst = –186 nT (Fig. 3).

Forecasters did not see this coming. The stage was set for the storm when a minor CME arrived about 24 hours ago. First contact with the CME barely registered in solar wind data, and Earth’s magnetic field was unperturbed. The action began only after Earth entered the CME’s wake, where strong south-pointing IMFs opened a crack in planet’s magnetosphere. A surprise geomagnetic storm began.

The plasma cloud was slow and the solar wind velocity had a constant speed of around 400–450 km/s during the past 36 hours. There was no classic shock impact which we often see with faster coronal mass ejections so what gave away that this indeed was a coronal mass ejection?

The investigated storm coincides exactly with the full moon on August 26, 2018, when the Sun – Earth – Moon system is located on a straight line. Close and similar cases are considered and analyzed in the works [4, 5, 6]. There is also the relevant interpretation.

Cosmic ray enhancement and Forbush decrease on August 25–26, 2018

The behavior of cosmic rays in the period around August 26, 2018 was extraordinary and inexplicable. Obviously refers to new unknown effect in the near space associated with the additional acceleration of the particles in interplanetary space and Earth environment to relativistic energies.

Some examples of event from August 25-26, 2018 are shown in Fig. 4. A distinguishable signal was recorded by high latitude neutron monitor (NM) Apatity (APTY), Russian Federation (Fig. 4a) and by middle latitude Jungfraujoch (JUNG) NM, Switzerland (Fig. 4b). This suggest that it is a ground-level enhancement (GLE) event [7–14]. Similar is the situation with other stations located in Europe, North and Central Asia and Africa - for example neutron monitors: Dourbes (DRBS), Belgium; Lomnicky Stit (LMKS), Slovakia; Rome (ROME), Italy; Athens (ATHN), Greece; Moscow (MOSC), Baksan (BKSN), Novosibirsk (NVBK), Irkutsk (IRKT), Yakutsk (YKTK), Tixie Bay (TXBY) (all six NMs - Russian Federation); Oulu (OULU), Finland; Almaty (AATB), Kazakhstan; Castilla-La Mancha (CALM), Spain; Tsumeb (TSMB), Namibia; Hermanus (HRMS) and Potchefstroom (PTFM) (South Africa Republic) and others (www.nmdb.eu).

However, a number of stations in the American and Pacific sectors did not respond. For example, no GLE was recorded in US neutron monitors: Thule (THUL), Newark (NEWK) and Fort Smith (FSMT); also in Daejeon (DJON) NM, South Korea; Kerguelen (KERG) NM, District of the French Southern and Antarctic Lands, and many others (www.nmdb.eu).

A number of the above mentioned stations register pronounced Forbush decrease [7, 15–18], f.e. for NM APTY the magnitude is –3.3 %, Fig. 4a.

For the analysis of the presence of GLE, the results from neutron monitors in Antarctica will be decisive. At present there is a network of Antarctic neutron monitors: SOPO and SOPB (US); DOMC and DOMB (Finland) [19]; Mirny (MRNY), Russian Federation; Terre Adelie (TERA), French Antarctica – near the South Magnetic Pole; Jang Bogo (JBGO), S. Korea; Mawson (MWSN), Australia, and others.

The first two groups are high altitude NMs: SOPO/SOPB - located at the geographical South Pole, 90°00' S (2835 masl), and DOMC/DOMB – located in the Polar Cusp - Central Antarctica at 75°06' S, 123°20' E (3233 masl). The remainder NMs: MRNY, TERA, JBGO, MWSN are situated near sea level [19].

The high altitude NM DOMC (Fig. 4c), as well as other polar NMs did not register any significant response to GLE. They measured only the pronounced Forbush decrease, f.e. DOMC (–2.5 %), Fig. 4c, DOMB (–2.8 %) and other.

Cosmic ray enhancement is not a GLE, but an anomalous effect

Almost a simultaneous enhancement of the count rates of several ground-based cosmic-ray neutron monitors (NMs), that is caused by solar energetic particles (SEPs) is known as a ground-level enhancement (GLE) event. Observations of GLEs provide key information about the high energy part (above several hundred MeV.nucl−1) of strong SEP events, which cannot be continuously monitored by space-borne instruments.

The definition of GLE events requires implementation of the following conditions [20]:

„A GLE event is registered when there are near-time coincident and statistically significant enhancements of the count rates of at least two differently located neutron monitors including at least one neutron monitor near sea level and a corresponding enhancement in the proton flux measured by a space-borne instrument(s).“

Some places are exceptionally well suitable for ground-based detection of SEP – high-elevation polar regions with negligible geomagnetic and reduced atmospheric energy/rigidity cutoffs. At present, there are two neutron-monitor stations in such locations on the Antarctic plateau: SOPO/SOPB (at Amundsen–Scott station, 2835 m elevation), and DOMC/DOMB (at Concordia station, 3233 m elevation) [20].

From what has been said in the previous section, and also from the results shown in Fig. 4c, it can be seen that on August 26, 2018, there is no penetration of SEPs.

This is confirmed by the absence of SEPs that are registered on satellites and space stations. The data from GOES–14 to GOES –17 (The Geostationary Operational Environmental Satellite) and ACE (Advanced Composition Explorer) show that the instruments for measurements of high energy solar energetic particles did not record an increase in their integral fluxes on August 26, 2018. This applies to GOES Proton Flux ≥10 MeV, ≥50 MeV, and ≥100 MeV; and to the ACE instrument CRIS

(Cosmic Ray Isotope Spectrometer). CRIS has an energy interval, from 50 to 500 MeV/nucleon, with isotopic resolution for elements from Z ≈ 2 to 30. The nuclei detected in this energy interval are predominantly high energy particles and cosmic rays. (https://www.goes.noaa.gov/ and http://www.srl.caltech.edu/ACE/)

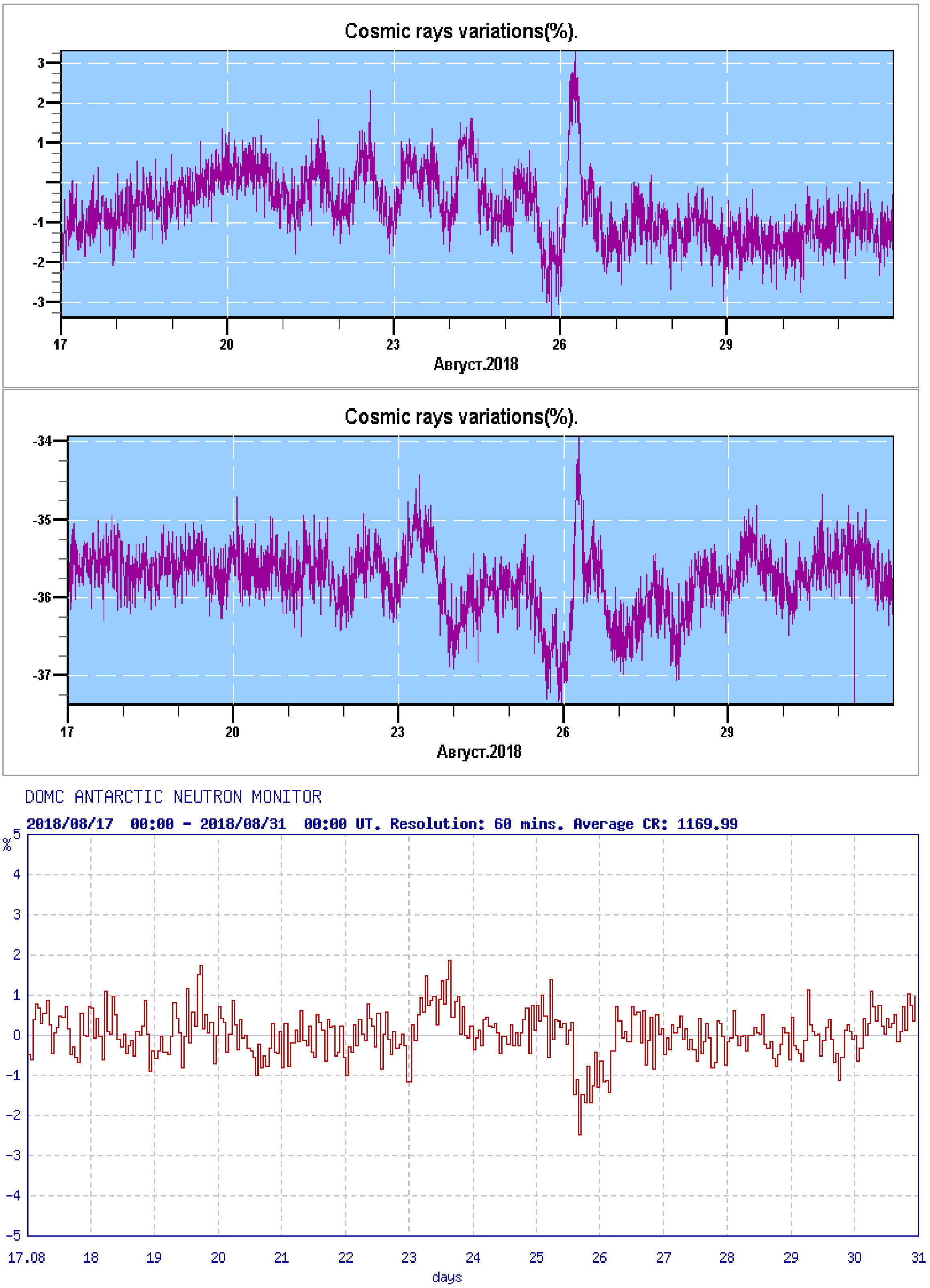

Fig. 4. The time course (during the period August 17-31, 2018) of cosmic rays measured by neutron monitors at:
a) high latitudes – Apatity (APTY), Russia with Effective vertical cutoff rigidity Rc = 0.65 GV, Altitude 181 masl,
b) middle latitudes – Jungfraujoch (JUNG), Switzerland with Rc = 4.49 GV, Altitude 3570 masl,
c) high elevation – DOMC research station (located in the Polar Cusp - Central Antarctica at 75°06' S, 123°20' E), with Effective vertical cutoff rigidity Rc < 0.01 GV, 3233 masl.

Conclusion

The enhancement of cosmic rays during G3 – Severe geomagnetic storm on August 26, 2018 represents an anomalous phenomenon, an anomalous effect, which is characterized by:

1) Strong anisotropy of the CR anomalous enhancement;

2) A great asymmetry of planetary impact, accompanied by CR enhancement in Europe, Asia and Africa, and absence of effect in America, the Pacific region and Antarctica;

3) Absence of CR effect even in high altitude (about 3000 m elevation) NMs: SOPO/SOPB and DOMC/DOMB - located at geomagnetic cutoffs almost zero GV ! Usually, the weakest GLEs, the so-called sub-GLEs [20], are registered here due to the relatively low atmospheric cutoffs.

4) The appearance of a new extraordinarily strong acceleration mechanism for the charged particles (to relativistic energies !) from interplanetary and extraterrestrial forces, fields and structures.

Acknowledgements:

Acknowledgements are due to the NMDB: Real-Time Database for high-resolution Neutron Monitor measurements (www.nmdb.eu), founded under the 7th Framework Programme (FP7) of the European Union, as well as the IZMIRAN – Moscow (Russian Federation) neutron monitor data base (http://cr0.izmiran.ru/common/ links.htm) for providing data.

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