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Possibilities of selected space weather and atmospheric studies in JEM-EUSO project?

Karel Kudela*
Institute of Experimental Physics, Slovak Academy of Sciences, Watsonova 47, 04001 Košice, Slovakia
E-mail: kkudela@saske.sk

Jan Błecki

Space Research Institute, PAS, Warsaw, Poland

for the JEM-EUSO Collaboration

The main scientific task of JEM-EUSO is to observe the ultra high energy cosmic rays by looking the atmosphere from space [1, 2, 3, 4]. The detailed description of various sources of the background is important. On the other hand, the study of selected magnetospheric, ionospheric and atmospheric processes related to temporal and spatial variability of UV (ultraviolet) on the orbit where JEM-EUSO is supposed to be situated, could be a useful by-product of the main task of the project (e.g. review [5]). We attempt to summarize selected processes connected with atmospheric electricity and with energetic particles having links to the events as TLE (transient luminous event), TGF (terrestrial gamma-ray flash) and TGE (thunderstorm ground enhancement), recently observed on mountains too. Our groups (in CBK Warsaw, in IEP Košice) have a long track of experience with measurements of waves and particles for magnetospheric/ionospheric research as well as with physical analysis/interpretation of the data obtained. The JEM-EUSO, if the experiment is augmented by a very simple device that monitors energetic particles, and coordinated with other satellite measurements and with ground based observations, may be of relevance for some space weather studies related to the effects in the chain magnetosphere/ionosphere/atmosphere. This can contribute to better understanding of electromagnetic responses of lightning on the Earth and of selected processes at high altitudes in the atmosphere.

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*Speaker.

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1. Introduction

The atmospheric monitoring system of JEM-EUSO is described recently e.g. in [3]. The slow mode data of JEM-EUSO will allow to monitor also Transient Luminous Events (TLEs). In the following sections we try to survey selected results on space weather-related topics which can be studied in JEM-EUSO mission, if additional simultaneous monitoring of energetic particles and comparison with ground based CR measurements will be done.

2. TLEs and Ionosphere

The ionospheric lightning refers to various short-lived electrical-breakdown phenomena that occur at higher altitudes than *usual lightning* and storm clouds. TLEs generally last from $<$ 1ms to $>$ 2s, and are associated with interactions between atmosphere, ionosphere and magnetosphere as well as with strong thunderstorm activity. Sprites, jets, elves, halos and trolls are names of various TLEs differing in altitude, dimensions, type of motions and duration (introduction e.g. in [11] and references therein).

Sprites are known as structured optical emissions in the mesosphere produced by lightning discharges, observed at $\approx$ 4090 km above thunderstorms (e.g. [28]). Their production is related to quasi-electrostatic heating and ionisation of the lower ionosphere [29]. [48] reports the ionospheric ELF/VLFmeasurement performed onboard the satellite DEMETER when it was at a distance $\approx$ 1200 km from a sprite event observed at the top of Śnieźka mountain observatory (1603 m asl) in Poland. A brief history of observations from the Space Shuttle at the beginning of sprite research is in [10].

Contrary to sprites, blue jets project from above a thunderstorm, in narrow structures, to the low ionosphere (40 - 50 km). Elve is the common name for short ($<$ 1 ms in visible and IR light) large extending flashes occurring in the lower ionosphere at $\approx$ 90 km due to very strong lightning strokes between a thundercloud and the Earth during night. [9] reports a blue jet propagating upwards from a thundercloud to $\approx$ 70 km. Above $\approx$ 42 km (upper limit for blue jets and lower altitude for sprites) - the flash exhibited some features normally observed in sprites.

ISUAL, on the Roscat 2 satellite, was a scientific instrument specifically devoted to observation of TLE's [51]. By analyzing sprites and halos paper [52] reports a clear transition at $\approx$ 75 km altitude from the upper-diffuse to lower -streamer region of sprites. In [53] the global distribution of various types of TLEs obtained by ISUAL during $\approx$ 3 years of observations is summarized. ISUAL can be used to perform elve survey, to infer the peak current of the elve- producing lightning, and possibly also to check other parameters [17].

Systematic global measurements of UV flashes were done by Tatiana space detectors [15, 16]. In [44] the UV flashes are classified according to the type of their time profiles, and the energy of the flash is estimated. Based on results [31] and experience obtained, project Tatiana-2 [32] improved the system of observation of UV flashes. Data from Tatiana-2 indicated the existence of UV flashes less intense than usual TLEs with a much higher rate than that of UHECR events and having wider latitudinal distribution [40]. The authors stress the importance of such events for the background estimate and for the trigger system. [41] shows two types of atmospheric flashes, namely flashes

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with high numbers of photons and those with lower fluxes, the two types differing in geographic distribution: the latter are distributed more uniformly.

Detectors on Tatiana-2 with a higher trigger rate observed a series of flashes not connected with lightning [45]. A review of several Russian missions with the experimental goal to investigate the origin of the high-energy electrons (***e***) and γ ray quanta for specific TLEs and their role in the ionosphere-magnetosphere system, namely Tatiana-2, CHIBIS, RELEC and TUS, is in [39].

3. Atmospheric electricity and Terrestrial Gamma Flashes (TGFs)

Wilson in 1924 predicted existence of short-lived light flashes over large thunderstorm clouds [12]. Reviews on planetary atmospheric electricity can be found e.g. in [50]. First observations of short pulses of γ rays with hard energy spectra consistent with bremstrahlung and related to atmospheric electrical discharges, have been reported from BATSE mission [24] by analysis of ≈ 2 years of measurements. The authors indicated that the corresponding flashes originate at altitude above ≈ 30 km and proposed an idea, namely that energetic e are related to rare types of high-altitude discharges above thunderstorm regions. TGFs started to be associated with phenomena of that type.

Dwyer [25] on the basis of TGF observations by RHESSI mission proposed that the observed γ ray bursts from the atmosphere originate deeper (< 21 km), and that the relativistic runaway ***e*** avalanches or EAS alone do not produce TGFs. Instead, the energetic seed particle production most likely involves either relativistic feedback or runaway ***e*** production in the strong electric field associated with lightning leaders or streamers, similar to the energetic radiation observed on the ground.

Runaway breakdown in air (RB) is stimulated by the presence of a high energy secondary CR. EAS are accompanied by an effective local growth of the number of secondary CR with strong influence on the RB process [19, 20]. The existence nowaday of satellite and ground based systems which obtain regularly a large amount of observational radio frequency (RF) data could allow to use them in combination with other methods for effective study of high energy CR. The improved sensitivity and absolute timing accuracy of Gamma-ray burst monitor (GBM) at Fermi brought new information about TGFs. A study associating RF discharges with e in the showers of particles that produce TGFs, based on Fermi measurements, is in [30].

A concept of an avalanche type increase of a number of runaway e in air under the action of the thunderstorm electric field which could take place during a thunderstorm, stimulated by CR secondaries was proposed in [21]. Authors of [22] found strong 511 keV e^+ annihilation lines, demonstrating that these TGFs also contain substantial e^+ components. Pair production occurs in conjunction with some terrestrial lightning and most likely all TGFs are injecting e^+ e^- beams into the near Earth environment. [23] analyzed 30 kHz RF emissions (sferics - broadband electromagnetic pulse occuring due to natural atmospheric discharges) from lightning discharges associated with TGFs recorded by the RHESSI satellite. Brief increases of dose at aircraft due to lightning discharge or a TGF event are estimated in [8]. Papers [42, 43] discuss (among other subjects) the experimental evidences of the relationships between CR flux and atmospheric current and lightning. Review of TGF studies is e.g. in [14].

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4. Energetic electrons and UV flux

Fluxes of suprathermal e as well as e accelerated to relativistic energies, present in the magnetosphere, are highly variable both in temporal as well as in spatial sense, especially during magnetospheric substorms, which leads to variable flux precipitating to the atmosphere (e.g. [33, 34]) and remain of interest in the research of sources, acceleration, losses and transport processes within the magnetosphere (e.g. [35]). The e have a specific link to the status of the ionosphere as well as to atmospheric electricity processes and thus also to UV emissions.

UV emissions of the nightside atmosphere have been simultaneously studied with e fluxes > 70 keV by the Universitetskii-Tatiana satellite. The analysis led to the conclusion that the mean intensity of UV radiation at high latitudes is correlated with the e fluxes (UV increases observed at higher latitudes than those of e), but it is not the case with the SAA [36]. Statistical analysis found three latitudinal regions of enhanced UV emission [37]. While at high geomagnetic latitudes ($L > 4$) the UV emission observed can be explained by ***e*** precipitation, at low geomagnetic latitudes ($L < 2.5$) the UV enhancements are higher than those expected just from e precipitation - other mechanism is needed for explanation. [37] concludes that the origin of UV enhancements at middle latitudes ($2 < L < 4$) is still unclear and requires further studies. Simultaneous measurement of UV, energetic ***e*** and other high energy particles on Tatiana 1 and 2 satellites allowed to obtain several results important also for understanding the energetic particle dynamics in near-Earth space [39]. Review of the results including those obtained in study of transient events in the atmosphere can be found e.g. in [38] and in references therein.

Lightning is related to whistler waves. The first satellite with simultaneous in-situ observations of whistlers and lightning-induced energetic particle bursts, namely DEMETER, brought new information about e bursts related to the lightnings and whistlers (e.g. [46]). Enhancement of hard X-rays (bremsstrahlung by energetic ***e***) was observed in regions geomagnetically conjugated to the site of thunderstorm activity on CORONAS-I satellite [47].

Detection of high energy ***e***, if added to the concept of JEM EUSO, is important not only for correlative studies with various types of optical flashes. Different orbit of ISS compared e.g. to that of Tatiana-type provides different parts in (L,B) space. Importance of e below radiation belts (quasi-trapped - drifting azimuthally before entering the SAA - named also as *forbidden*) for total electron content (TEC), was shown e.g. in [55]. There are known relations of seismic events to ELF/VLF waves (e.g. [56]), but also changes of high energy ***e*** flux is reported to be related to seismicity (e.g. [57, 58] among others).

5. Ground based CR / other particle observations related to atmospheric electricity

In past years, response to atmospheric electricity is reported from ground based observations of secondary CR and from thermal neutron (n) detection. [26] reports short and sharp increases in low energy n count rate simultaneous with a lightning discharge occurring in vicinity of the detector. Measurements with high time resolution at Tian Shan indicate highly correlated short n signals (bursts $\approx 200 - 400\mu$s) observed by three types of detectors placed at different positions: He3 counters (with and without polyethylene moderator) and neutron monitor (NM) in time coincidence

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with thunderstorms [27]. This implies n of various energies, temporary/spatially correlated, are generated during thunderstorm discharges.

Simultaneous enhancements of γ ray and n fluxes during thunderstorm ground enhancements at $\approx$ 3200 m in Aragats Space Environmental Center (ASEC) are reported in [18]. Photonuclear reactions of the γ rays born in the RB (now referred to as relativistic runaway e avalanche, RREA) process with the air were considered as the main process responsible for the copious n production. The authors of [18] consider also the mesoatom nuclei decay as a possible source of additional n observed by NM due to increase of μ-accelerated in the thunderclouds. A huge event observed at ASEC by several detectors supports the existence of long-lasting particle multiplication and acceleration mechanisms in the thunderstorm atmosphere [13]. Authors present the energy spectra of $\boldsymbol{e}$ and γ rays from particle avalanches.

Nowadays there are operating several systems/networks of lightning observations, some of them described e.g. in [6, 7]. At Lomnický štít (2634 m asl), in addition to measurements by NM, since February 2014 there is in operation detector system SEVAN [49]. Short spikes in the channel 1 not accompanied with increases in second and third channel (this corresponds mainly to e^- or e^+ impact) are observed sometimes in time coincidence with strong thunderstorms as deduced from LINET data and/or from the direct observations at the mountain.

6. Concluding remarks

Characteristics of TLE's have been described by different groups working with detectors on the orbit and on the ground. JEM EUSO is unique in its time and spatial resolution that allows it to see time evolution of the subtle structure (filamentation) of TLE's. There will be two more experiments dedicated to measuring of TLEs in orbit soon (ASIM and TARANIS [61], [62]). Data sets produced by all these experiments may create an exceptional chance to further investigate the physical nature of the TLEs.

Since [24] the intense γ ray flashes of atmospheric origin are observed. Energetic e are probably precipitating also in geomagnetically conjugated point to strong lightning. TGFs must be created $>$ 30 km to escape absorption in atmosphere. Few past years there are observations of *counterparts?* of lightning induced TGFs at high altitudes - the TGEs on the ground [54]. There are links between atmospheric processes and secondary CR. These processes, however, occur at lower altitudes and are observed on the ground.

In addition to the main JEM-EUSO physical tasks it may be of interest to check the possibility of putting additional energetic e (e.g. that based on [59] with high flexibility) and γ ray monitoring detector (using e.g. experience from CORONAS-F [60]) and to coordinate the JEM-EUSO observations with other satellites targeted to ionospheric/magnetospheric phenomena research as well as with ground based CR measurements, especially on mountains.

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References

[1] T. Ebisuzaki et al., *The JEM-EUSO mission*, Adv. Space Res., **53**, 10, 1499-1505 (2014)

[2] M. Bertaina, E. Parizot et al., *The JEM-EUSO mission: a space observatory to study the origin of Ultra-High Energy Cosmic Rays, Nucl. Phys. B - Proc. Suppl.*, **256-257**, pp. 275-286 (2014)

[3] M. D. Rodriguez Frias et al., *The Atmospheric Monitoring System of the JEM-EUSO Space Mission*, arXiv:1501.04821v1 (astro-ph.IM) 20 Jan 2015

[4] J.H. Adams Jr. et al., *An evaluation of the exposure in nadir observation of the JEM-EUSO mission*, Astroparticle Physics, **44**, 76, 90 (2013).

[5] J. Błecki, et al., *What New Science of TLE can be done with JEM EUSO Experiment*, presentation at JEM-EUSO meeting, Palermo, Italy, June 10, 2014.

[6] H.-D. Betz, et al., *LINET - An International VLF/LF Lightning Detection Network in Europe*, Atmospheric Research, **91**, p. 564âĂŞ573 (2009).

[7] H. Höller, et al., *Lightning characteristics observed by a VLF/LF lightning detection network (LINET) in Brazil, Australia, Africa and Germany*, Atm. Chem. Phys., **9**, 7795 (2009)

[8] J.R. Dwyer et al., *Estimation of the fluence of high energy electron bursts produced by thunderclouds and the resulting radiation doses received in aircraft*, J. Geopys. Res., **115**, D9 (2010)

[9] V.P. Pasko et al., *Electrical discharge from a thundercloud top to the lower ionosphere*, Nature **416**, 152-154, 14 March 2002

[10] W.L. Boeck et al., *The role of the space shuttle videotapes in the discovery of sprites, jets and elves*, J. Atmos. Solar-Terr. Phys., **60**, 669-677 (1998)

[11] E.R. Williams, *Sprites, elves and glow discharge tubes*, Physics Today, **54** (11), 41, (2001)

[12] C.T.R. Wilson, *The electric field of a thundercloud and some of its effects*, Proc. Phys. Soc. London **37** 32D (1924)

[13] A.A. Chilingarian et al., *Ground-based observations of thunderstorm-correlated fluxes of high energy electrons, gamma rays and neutrons*, Phys. Rev. D **82**, 043009 (2010)

[14] J.R. Dwyer et al., *High-Energy Atmospheric Physics: Terrestrial Gamma-Ray Flashes and Related Phenomena*, Space Sci Rev., DOI 10.1007/s11214-012-9894-0 (2012)

[15] G.K. Garipov et al., *Ultraviolet Flashes in the Equatorial Region of the Earth*, JETP Lett., **82**, 4, 185 (2005)

[16] G.K. Garipov et al., *Ultraviolet Radiation Detector of the MSU Research Educational Microsatellite Universitetskii-Tat'yana*, Instr. and Experim. Techn., **49**, 1, 126-131 (2006)

[17] S.C. Chang et al., *ISUAL far-ultraviolet events, elves, and lightning current*, J. Geophys. Res., **115**, A00E46, doi:10.1029/2009JA014861 (2010)

[18] A. Chilingarian et al., *Neutron bursts associated with thunderstorms*, Phys. Rev. D **85**, 085017 (2012)

[19] A.V. Gurevich and K.P. Zybin, *High energy cosmic ray particles and the most powerful new type discharges in thunderstorm atmosphere*, Phys. Lett. A**329**, 341-347 (2004)

[20] A.V. Gurevich et al., *Lightning initiation by simultaneous effect of runaway breakdown and cosmic ray showers*, Phys. Lett. A**254**, 79-87 (1999)

[21] A.V. Gurevich et al., *Runaway electron mechanism of air breakdown and preconditioning during a thunderstorm*, Phys. Lett. A**165**, 463âĂŞ 468 (1992)

[22] M.S. Briggs et al.., *Electron-positron beams from terrestrial lightning observed with Fermi GBM.*, Geophys.Res.Lett. **38**, L02808 (2011)

[23] S.A. Cummer et al., *Measurements and implications of the relationship between lightning and terrestrial gamma ray flashes*, Geophys. Res. Lett., **32**, L08811, (2005)

[24] G.J. Fishman et al., *Discovery of Intense Gamma-Ray Flashes of Atmospherc Origin*, Science, New Series, **264**, No 5163, 1313-1316 (May 27, 1994)

[25] J.R. Dwyer, *Source mechanisms of terrestrial gamma-ray flashes*, J. Geophys. Res., **113**, D10103

PoS(ICRC2015)113

(2008)

[26] I.M. Martin and M.A. Alves, *Observation of a possible neutron burst associated with a lightning discharge?*, J. Geophys. Res., **115**, A00E11, (2010)

[27] A.V. Gurevich et al., *The time structure of neutron emission during atmospheric discharge*, Atmos. Res., **164-165**, 339-346 (2015)

[28] D.D. Sentman et al., *Preliminary results from Sprites94 Aircraft Campaign: 1. Red sprites*, Geophys. Res. Lett., **22**(10), 1205-1208, doi:10.1029/95GL00583 (1995)

[29] V.P. Pasko et al., *Sprite produced by quasielectrostatic heating and ionization in the lower ionosphere*, J. Geophys.. Res., **102**(A3), 4529-4561, Doi:10.1029/96JA03528 (1997)

[30] V. Connaughton et al., *Radio signals from electron beams in terrestrial gamma ray flashes*, J. Geophys. Res., **118**, p 2313-2320 (2013)

[31] V.A. Sadovnichy et al., *First results of investigating the space environment onboard the Universitetsky-Tatiana satellite*, Cosmic Res., **45**, 273-282 (2007)

[32] G..K. Garipov et al., *Program of transient UV event research at Tatiana-2 Satellite*, J. Geophys. Res., **115**, A00E24, doi: 10.1029/2009JA01 (2010)

[33] M.J. Beharell et al., *Substorm-induced energetic electron precipitation: Morphology and prediction*, J. Geophys. Res. **120**, 2993-3008, doi: 10.1002/2014JA020632 (2015)

[34] L.L. Lazutin, *On radiation belt dynamics during magnetic storms*, Adv. Space Res., **49**, 302 (2012)

[35] J.C. Foster et al., *Prompt Energization of Relativistic and Highly Relativistic Electrons During a Substorm Interval: Van Allen Probes Observations*, Geophys. Res. Lett., **41**, 20-25, doi:10.1002/2013GL058438, Jan. 16, 2014.

[36] N.A. Vedenkin et al., *Atmospheric Ultraviolet Light and Comparison of its Intensity with the Variation of Electron Flux with Energies Higher than 70 KeV in Satellite Orbit (According to Universitetskii-Tatiana Satellite Data)*, Moscow Univ. Phys. Bull., **64**, 4, 450-454 (2009)

[37] A.V. Dmitriev et al., *Latitudinal profile of UV nightglow and electron precipitations*, Planetary and Space Science **59**, 733-740 (2011)

[38] V.A. Sadovnichy et al., *Investigations of the Space Environment Aboard the Universitetsky-Tat'yana and UniversitetskyâĂŞTat'yana-2 Microsatellites*, Sol. Syst. Res. **45**, 1, 3-29 (2011)

[39] M.I. Panasyuk et al., *Transient luminous event phenomena and energetic particles impacting the upper atmosphere: Russian space experiment programs*, JGR, **115**, A00E33, (2010)

[40] P.A. Klimov et al., *Analysis of UV flashes measured by Universitetsky-Tatiana-2 satellite as significant factor of TUS detector operation*, paper at 33rd ICRC, Rio de Janeiro (2013)

[41] V.S. Morozenko, *Background effects in night atmosphere of Earth for meaurements of Ultra high energy CR with use of orbital detector (in Russian)*, PhD thesis, Moscow, p. 141 (2014)

[42] Yu.I. Stozhkov, *The role of cosmic rays in the atmospheric processes*, J. Phys. G: Nucl. Part. Phys. **29** 913. doi:10.1088/0954-3899/29/5/312 (2003)

[43] A.K. Singh et al., *Impact of galactic cosmic rays on Earth's atmosphere and human health*, Atmos. Environ., **45**, 3806-3818 (2011)

[44] G.K. Garipov et al., *Time and Energy Characteristics of UV Flashes in the Atmosphere: Data of the Universitetsky-Tatiana Satellite*, Cosmic Res., **49**, 5, 391-398 (2011)

[45] N.N. Vedenkin et al., *Atmospheric Ultraviolet and Red-Infrared Flashes from Universitetsky-Tatiana-2 Satellite Data*, JETP, **113**, 5, 782-791 (2011)

[46] U.S. Inan et al., *DEMETER satellite observations of lightning-induced electron precipitation*, Geophys. Res. Lett., **34**, L07103, doi:10.1029/2006GL029238 (2007)

[47] R. Bučík et al., *Satellite observations of lightning-induced hard X-ray flux enhancements in the conjugate region*, Ann. Geophys., **24**, 7, 1969-1976 (2006)

[48] J. Błecki et al., *ELF and VLF signatures of sprites registered onboard the low altitude satellite DEMETER*, Ann. Geophys., **27**, 2599-2605 (2009)

PoS(ICRC2015)113

[49] A. Chilingarian et al., *Space Environmental Viewing and Analysis Network (SEVAN) - characteristics and first operation results*, J. of Physics: Conf. Series **409**, 012222 (2013)

[50] Y. Yair et al., *Updated Review of Planetary Atmospheric Electricity*, Space Sci Rev., **137**, 29-49 (2008)

[51] J.L. Chern et al., *Global survey of upper atmospheric transient luminous events on the ROCSAT-2 satellite*, J. Atmos. Sol. Terr. Phys., **65**, 647-659 (2003)

[52] T. Adachi et al., *Electric field transition between the diffuse and streamer regions of sprites estimated from ISUAL/array photometer measurements*, Geophys. Res. Lett., **33**, L17803 (2006)

[53] A.B. Chen et al., *Global distributions and occurrence rates of transient luminous events*, J. Geophys. Res., **113**, A08306, doi:10.1029/2008JA013101 (2008)

[54] A. Chilingarian et al., *Thunderstorm ground enhancements: Gamma ray differential energy spectra*, Phys. Rev. D **88**, 073001 (2013)

[55] A.V. Suvorova et al., *Long-duration positive ionospheric storm during the December 2006 geomagnetic storm: Ionizing effect of forbidden electrons*, Adv. Space Res., http://dx.doi.org/10.1016/j.asr.2015.06.001 (2015)

[56] M.Y. Boudjada et al., *Similar behaviors of natural ELF/VLF ionospheric emissions and transmitter signals over seismic Adriatic regions*, NHESS, **8**, 1229-1236 (2008)

[57] X. Zhang et al., *Burst increases of precipitating electrons recorded by the DEMETER satellite before strong earthquakes*, Nat. Hazards Earth Syst. Sci., **13**, 197-209 (2013)

[58] A.M. Galper et al., *Local perturbations of the Earth's radiation belt during seismic event development in Japan on March 11, 2011*, Bull. of the Lebedev Inst., **38**, 7, 209-214 (2008)

[59] J. Baláž et al., *Energetic Particle Measurements Onboard Spectr-R with MEP2*, Cosmic Res., **51**, 2, 90-95 (2013)

[60] S.N. Kuznetsov et al., *Scientific Set of Instruments âĂĲSolar Cosmic RaysâĂİ, in The Coronas-F Space Mission*, ed. by V.D. Kuznetsov, Springer, **301-326** (2014).

[61] F. Lefeuvre et al., *TARANIS-A Satellite Project Dedicated to the Physics of TLEs and TGFs*, Space Sci Rev **137:** 301-315 DOI 10.1007/s11214-008-9414-4(2008)

[62] Neubert, T. and the ASIM instrument team, *ASIM - an Instrument Suite for the International Space Station, CP1118, Coupling of Thunderstorms and Lightning Discharges to Near-Earth*, edited by N. B. Crosby,T.-Y. Huang, and M. J. Rycroft, AIP (2009)

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