

Solar and space weather research at the Institute of Astronomy (BAS)

Научни изследвания в областта на слънчевата
физика и космическо време
в Института по астрономия - БАН

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<https://bulgarianspace.online/nafski2023/>

Institute of Astronomy with NAO - BAS



- BAS-Sofia <https://astro.bas.bg/>
- AO-Belogradchik
<https://www.astro.bas.bg/AOBel/index.php>
- NAO-Rozhen (1981) <https://nao-rozhen.org/>



Topics of research

- Sun & Solar system
- Star & Stellar systems
- Galaxies & Cosmology



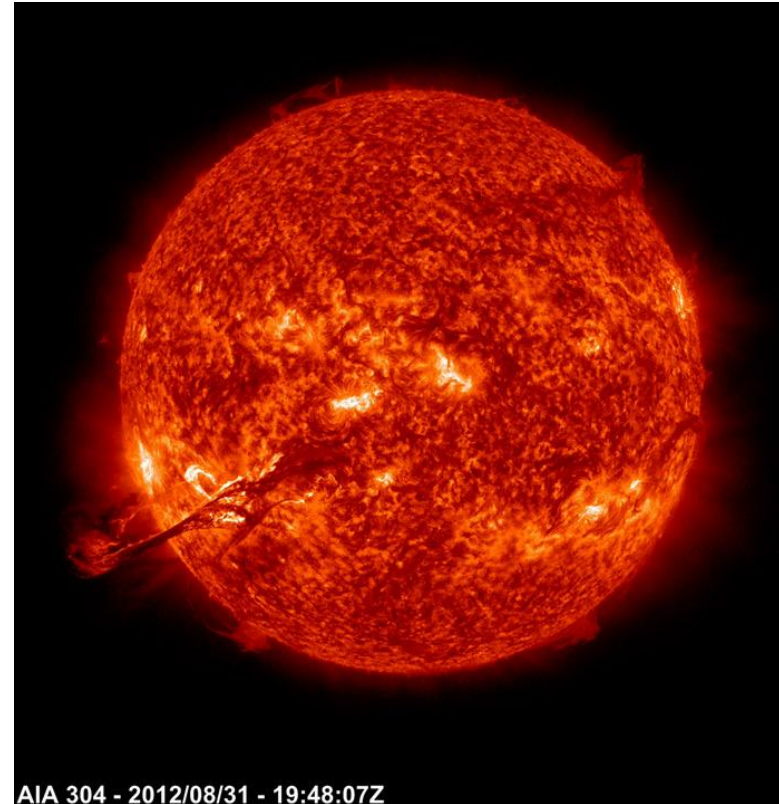
History: Solar research in BG

Topics of research (1990s, 2000s)

- Solar activity:

filament/prominence eruptions

- Total solar eclipses
- Theoretical research (2D MHD models)



AIA 304 - 2012/08/31 - 19:48:07Z

<https://sdo.gsfc.nasa.gov/gallery/main/item/157>

Present: Sun & space weather group

Topics of research (2010 - now)

- Solar activity: solar flares, filaments, radio bursts
- multiwavelength analysis (focus on optical, EUV & radio data)
- Space weather
- particles (data analyses, modeling & forecasting)
- geomagnetic storms (statistics)
- Machine learning in solar/space weather

→ WHAT IS SPACE WEATHER?

1 Our Sun is an enormous ball of hot gas and plasma. Dark sunspots are visual indicators of active regions, caused by local intense magnetic activity. Active regions are sources of solar flares and Coronal Mass Ejections (CMEs).

2 Solar flares are huge explosions in which electromagnetic energy is emitted into space as radio waves, visible light, ultraviolet radiation and X-rays. Flares can be associated with ejections of energetic protons, electrons and heavier particles into space at near light speed.

3 Active regions can give rise to CMEs, when billions of tonnes of matter are flung into space at speeds reaching 3000 km/s. CMEs are often associated with solar flares but can also occur independently.

4 The interplanetary magnetic field. Pressure from the solar wind gives Earth's magnetic field its characteristic shape, compressed on the day side and extended into a long tail on the night side. CMEs are slowed by the effect of pushing through the solar wind. The fastest CMEs reaching the Earth are usually combinations of two CMEs, where the second propagates in the 'wake' cleared by the first.

5 When a CME hits Earth's magnetic field, it can trigger a geomagnetic storm that affects satellites in space and critical infrastructure, such as power grids, on ground.

6 Auroras are spectacular phenomena that occur at northern and southern polar latitudes. During strong geomagnetic storms, aurora can be visible also at latitudes nearer the equator.

7 Geomagnetic storms can affect or damage satellites in space as well as induce currents in power grids, damaging transformers, on ground. They also disturb radio signals travelling through the upper atmosphere. In 1989, a CME caused a geomagnetic storm that led to a 9-hour power blackout in Quebec. In 2003, many satellites were damaged or temporarily affected by the Halloween storms, a series of powerful solar events. In 2012 a massive CME just missed Earth.

8 ESA has established the European Space Weather System, which links existing European space weather expertise – located at scientific institutes, national research centres, industry and observation systems on ground and in space – with ESA's Space Weather Coordination Centre, Brussels. Working with regional Expert Service Centres, the coordination centre provides processed data and 'products' that serve customers across a wide range of industries and economically vital activities like power grid operations, shipping, transport and telecommunication.

[#Space19plus](#) [#SolarHazards](#) [#LagrangeMission](#)

Space19



Completed projects

- **SPREADFAST**

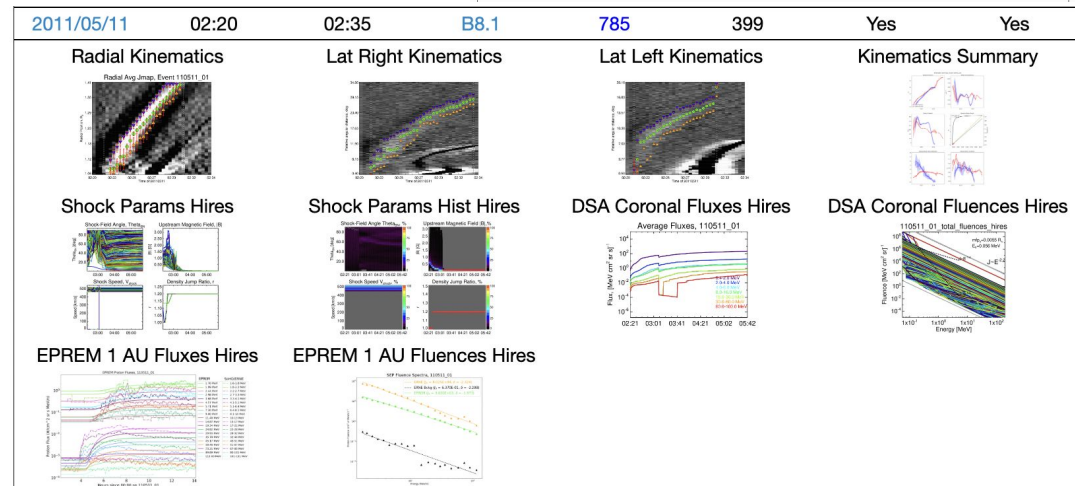
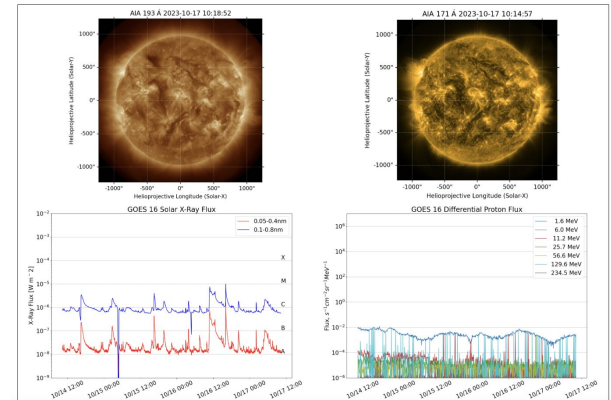
<https://spreadfast.astro.bas.bg/synoptic/>

Prototype of a **forecasting** system, based on physics-based model for acceleration of solar energetic particles and their transport to Earth (ESA project); featured in SEP review

- **STELLAR**

<https://stellar-h2020.eu/>

Near-Realtime Space Weather (Data from NASA/NOAA)



Projects in progress

- **MOSAIICS:**

Modeling and Observational Integrated Investigations of Coronal Solar Eruptions

<https://mosaiics.astro.bas.bg/>

Home MOSAIICS Project Description Team Results Blog Contact

MOSAIICS

Modeling and Observational Integrated Investigations of Coronal Solar Eruptions

COMPUTER VISION AND DEEP LEARNING

Develop cutting-edge methodology for solar eruption detection and characterization, based on computer vision and deep learning methods.

READ MORE >

METRIC SOLAR RADIO IMAGING

Unlock the discovery potential of uniquely rich low-frequency radio imaging data, showing the early stages of solar eruptions.

READ MORE >

ENERGETIC PARTICLE ACCELERATION

Transform our understanding of energetic particle acceleration in solar eruptions, combining radio imaging and energetic particle modelling.

READ MORE >

MOSAIICS is a 5-year research project, part of the National Science Program “VIHREN”. It is hosted at the Institute of Astronomy and National Astronomical Observatory of the Bulgarian Academy of Sciences. The project PI is Assoc. Prof. Kamen Kozarev.

MOSAIICS aims to improve our understanding of the physics of solar eruptions by integrating modern computer vision, advanced solar radio imaging, and energetic particle modeling.

You can learn more about the project, or each topic link.
Or let us know if you have any questions, on our Contact form.

Projects in progress

- New chromospheric telescope at NAO-Rozhen
<https://helio.astro.bas.bg/observations>



- New radio station:
LOFAR-BG <https://lofar.bg/bg/>

- New neutron monitor
<https://helio.astro.bas.bg/observations>

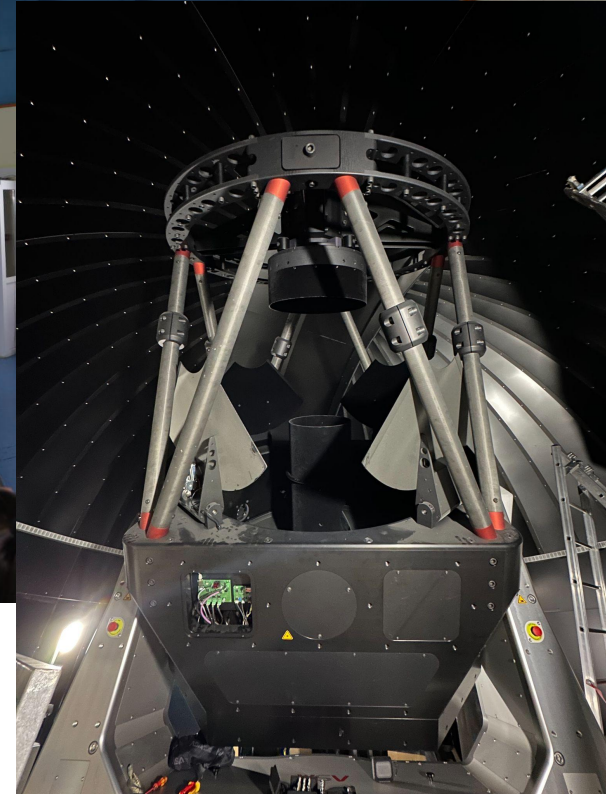
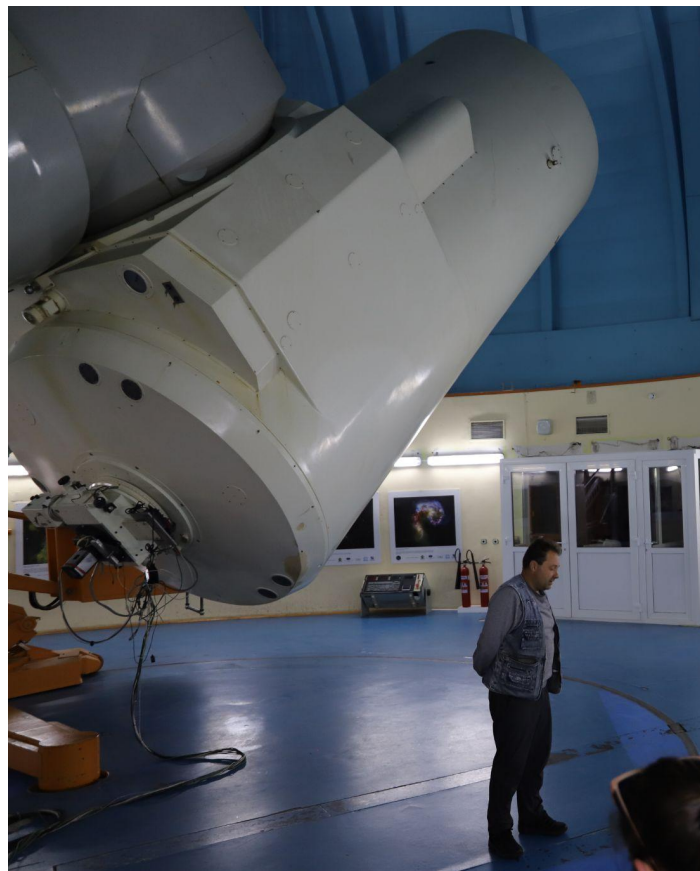


Credit: Petrov (2021)

Infrastructure

NAO-Rozhen: Bulgarian center of astronomy, solar and space weather research

- 2-m & 1.5 m telescopes
- 30-cm solar telescope
- Radio station
- Neutron monitor
- Weather station, etc.



Present: Bilateral collaborations

Serbia (past & ongoing)

- **Active events** on the Sun, **catalogs of proton events** and electron Signatures...

India (past)

- **Eruptions, flows and waves** in the solar atmosphere and their **influences on the space weather**

Egypt (ongoing)

- relationship between major **space weather phenomena** in solar cycles 23 and 24
- **space weather effects** at near Earth environment - from remote observations and in situ particle forecasting to impacts on satellites

Austria (past & ongoing)

- The **origin of solar energetic particles**: solar flares vs. coronal mass ejections
- solar chromospheric and **coronal activity**

http://edu-pro.astro.bas.bg/sun/?page_id=368

Research: Catalogs of space weather events

Database of analysed events:

<https://catalogs.astro.bas.bg/>

- Protons
- Solar flares
- Radio bursts
- Geomagnetic storms

CATALOGS OF SOLAR ENERGETIC PROTONS AND SPACE WEATHER EVENTS

AIM PROTON EVENTS SXR FLARES RADIO BURSTS GEOMAGNETIC STORMS TYPE II BURSTS

Solar Cycle 23 – Protons

Show entries Search:

Year	m	d	Class	flare start	flare max	latitude	longitude	CME onset	CME speed	CME AW	Channel 1	onset UT	peak UT	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7	Channel 8	Channel 9	Channel 10	
1996	7	9	X2.6	09:05	09:11	-10	30	gap	gap	gap	0.004401	09:44	10:52	0.002427	0.001022	0.000979	no	no	no	no	no	no	no
1996	8	13	u	u	u	u	u	16:09	620	153	0.008504	18:15	22:03	0.005586	0.002268	0.001914	0.00121	0.000892	no	no	no	no	no
1996	11	26	B9.0	20:48	24:32	u	u	21:36	548	78	0.001545	24:31	26:39	0.000702	0.000657	no	no	no	no	no	no	no	no
1996	11	27	u	u	u	u	u	u	u	u	0.001879	14:33	15:11	0.000916	0.000431	no	no	no	no	no	no	no	no
1996	11	28	C1.3	15:35	17:32	u	u	16:50	984	101	0.009031	19:38	22:12	0.005472	0.001592	0.00116	0.000721	no	no	no	no	no	no
1996	11	29	u	u	u	u	u	u	u	u	0.006815	05:30	13:49	0.002708	0.001147	0.000987	no	no	no	no	no	no	no
1996	11	30	u	u	u	u	u	u	u	u	0.02436	06:22	07:13	0.013896	0.004013	0.003175	0.001388	0.000415	no	no	no	no	no
1996	11	30	M1.0	20:16	20:44	-6	47	n	n	n	0.002383	23:29	28:38	0.00101	0.000519	no	no	no	no	no	no	no	no
1996	12	24	C2.1	13:03	13:11	5	95	13:29	325	69	0.010562	15:05	18:06	0.006228	0.003103	0.002215	0.001172	0.000794	0.000459	no	no	no	no

Showing 1 to 9 of 9 entries Previous Next

Note: Only a preview of the results during 1996 is shown. The channel selected for the proton event identification is Channel 2.

Abbreviations:

- AW – angular width
- CME – coronal mass ejection
- gap – data gap
- no – no proton event
- u – uncertain

Notations:

- all times are in UT
- Channels (in MeV): 1: 14–17; 2: 17–22; 3: 21–28; 4: 26–32; 5: 32–40; 6: 40–51; 7: 51–67; 8: 64–80; 9: 80–101; 10: 101–131
- class: flare peak in GOES soft X-ray flux (W/m^2)
- CME speed: linear speed (km/s) from https://cdaw.gsfc.nasa.gov/CME_list/index.html
- flare latitude: North (positive); South (negative)
- flare longitude: West (positive); East (negative)

Research: Catalogs of space weather events

Database of analysed events:

<https://catalogs.astro.bas.bg/>



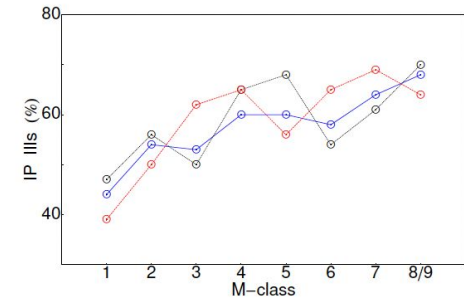
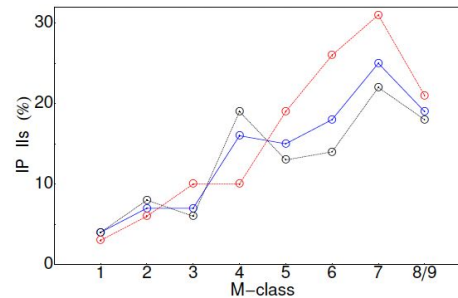
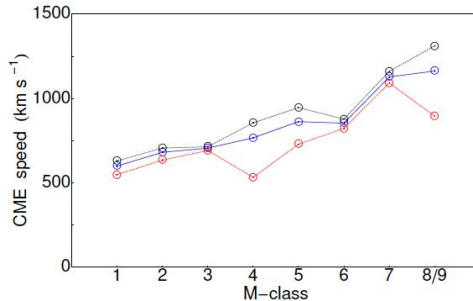
Article

M-Class Solar Flares in Solar Cycles 23 and 24: Properties and Space Weather Relevance

Rositsa Miteva ^{1*} and Susan W. Samwel ²

- Protons
- **Solar flares**
- Radio bursts
- Geomagnetic storms

Solar Event	SCs23 + 24
SFs	2177 (100%)
CMEs	889 (41%)
β	655 (30%)
β - γ	481 (22%)
β - γ - δ	663 (30%)
SEPs	133 (6%)
SEEs	247 (11%)
IP-III	1078 (50%)
IP-II	148 (7%)



Research: Catalogs of space weather events

Database of analysed events:

<https://catalogs.astro.bas.bg/>

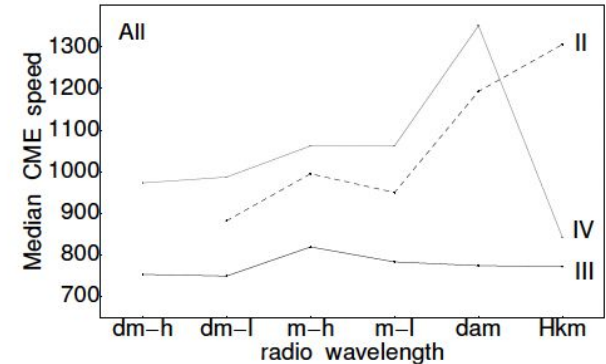
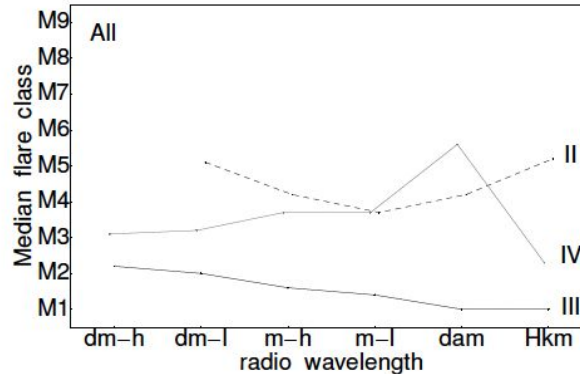
- Protons
- Solar flares
- **Radio bursts**
- Geomagnetic storms



Article

Solar Radio Bursts Associated with In Situ Detected Energetic Electrons in Solar Cycles 23 and 24

Rositsa Miteva ^{1,*}, Susan W. Samwel ² and Svetoslav Zabunov ³



Research: Catalogs of space weather events

Database of analysed events:

<https://catalogs.astro.bas.bg/>

- Protons
- Solar flares
- Radio bursts
- **Geomagnetic storms**



Advances in Space Research
Volume 72, Issue 8, 15 October 2023, Pages 3440-3453



Correlations between space weather parameters during intense geomagnetic storms: Analytical study

Susan Samwel^a , Rositsa Miteva^b

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<https://doi.org/10.1016/j.asr.2023.07.053>

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- strong correlation between $|\text{Dst}|$ and both B_{total} and $|B_z|$;
- moderate correlation between $|\text{Dst}|$ and solar wind parameters, except with solar wind density N_{SW} which shows almost no correlation;
- the $|\text{Dst}|$ is highly correlated with $|V_{\text{SW}}B_z|$ when compared with its correlation with V_{SW} and $|B_z|$ separately;
- with the exception to V_{ICME} which shows high correlation with $|\text{Dst}|$, the solar activity parameters (V_{CME} , AW , and I_{SXR}) show weak/no correlation with $|\text{Dst}|$;
- poor correlations are found between the parameters (flux and fluences) of the solar energetic particles, whether protons or electrons, with $|\text{Dst}|$.

Completed

$\text{Dst} \leq -100 \text{ nT}$
 $\sim 100 \text{ GSs}$

In progress

$\Rightarrow \leq -50 \text{ nT}$
 $\Rightarrow +\sim 400 \text{ GSs}$

Research: Space weather effects on satellites

Orbit:

210 km orbit (VLEO)

Facts:

2022-02-03

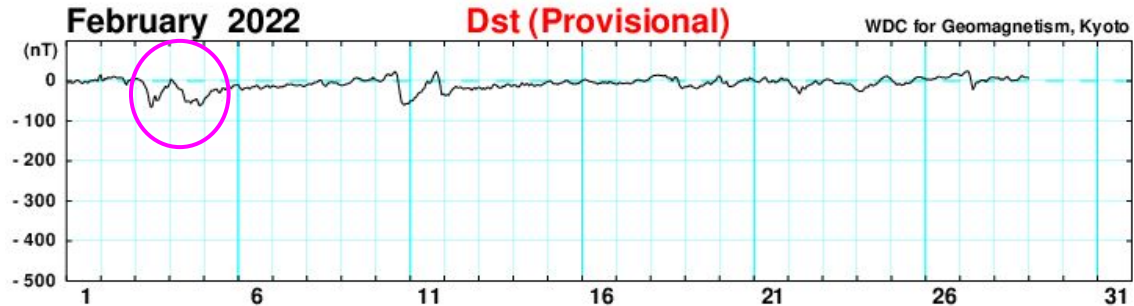
38/49 loss

minor geo-storms:

-66, -62 nT

Possible causes on the failure:

- (1) Increased atmospheric drag - increased mass density
- (2) GSs in close succession



Although the majority of the previous research [57–62] concluded that the notable Starlink failure was due to the increased atmospheric drag, ranging from 20–30% up to 150% at the staging orbit of 210 km, some doubts are raised if that it is the sole cause [63]. Despite the fact that the latter also estimated an increased thermospheric mass density by 35%, these authors proposed that GSs occurring in close succession (within about one day) are accountable for more negative SW effects on spacecraft operation and stability. The effects of the atmospheric drag on LEO satellites has been the topic of intense research, e.g., [48,49] and the references therein. Although it is well known that GSs lead to a global increase in the thermospheric neutral density, Joule heating due to EUV flare emission, and particle precipitation cause additional expansion in the 100–200 km region (or VLEO) [62].



Research: Space weather effects on satellites

Focus:
solar (**solar flares**) &
(near-Earth) IP
contributions
(**protons, electrons**)
at the time of selected
Starlink launches

<https://doi.org/10.3390/astronomy2030012>

Table 2. Starlink launches and accompanied magnetospheric and IP phenomena: date (yyyy-mm-dd) and time (hh:mm) of the Starlink launches; day (dd), nearest hour (hh), and value (in nT) of the Dst index of the GS; day/time/speed (in km s^{-1}) of the ICME; day/time/speed (in km s^{-1}) of the IP shock, density jump at the shock surface (in cm^{-3}); day/time/value (in nT) for B_z component. All times are in UT. No reported events are denoted with 'no'.

Starlink Launch		GS Dst	ICME	IP Shock		B_z
Date	hh:mm	dd/hh/nT	dd/hh/ km s^{-1}	dd/hh/ km s^{-1}	cm^{-3}	dd/hh:mm/nT
2020-04-22	19:31	20/13/-59	20/09/330	20/01:33/336	6.7	20/11:52/-15
2020-10-06	11:30	05/22/-40	05/17/350	no	no	05/19:34/-9
2020-10-24	15:32	24/07/-38	no	no	no	23/20:16/-12
2021-02-16	04:00	17/06/-54	no	no	no	13/03:07/-12
2021-03-04	08:25	03/05/-39	no	no	no	01/04:05/-14
2021-03-14	10:01	14/10/-43	no	no	no	13/05:06/-13
2021-05-26	18:59	27/09/-28	26/05/410	26/11:45/369	10.9	27/06:15/-11
2021-12-02	23:12	02/23/-25	no	no	no	02/15:02/-5
2022-01-19	02:03	19/04/-44	19/05/610	18/22:58/820	1.2	19/05:05/-6
2022-02-03	18:13	03/11/-66	02/16/460	01/22:27/543	4.2	03/09:37/-19
2022-04-29	21:27	30/08/-37	no	no	no	27/13:01/-11
2022-05-13	22:08	13/22/-39	no	no	no	11/19:55/-10
2022-07-07	13:11	07/23/-81	07/12/380	no	no	07/12:48/-16
2022-09-05	02:10	04/17/-72	no	no	no	04/05:24/-10
2022-12-28	09:34	27/16/-68	no	no	no	26/12:24/-10

Aim:
in order to evaluate
the additional impact
of the EM and
radiation environment
on satellite stability

Input:
Timing of all (~100)
Starlink launches
2019-2022 => 15 with
Dst <=-25 nT

Research: Space weather effects on satellites

Results:

- Minor to moderate effects due to solar flares, particle radiation & IP plasma density, B-field, velocity

Open ?s:

- Double GSs as a possible cause for satellite failure

Table 3. Starlink launches and accompanied solar/SW phenomena: date (yyyy-mm-dd) and time (hh:mm) of the Starlink launches; SF day/start/peak/end time/class; SEP day/peak time; SEE day/peak time. All times are in UT. Abbreviations: on: ongoing; pr: preceding; s: start time; su: succeeding.

Starlink Launch		SFs	SEPs	SEEs
Date	hh:mm	dd/hh:mm/class	dd/hh:mm	dd/hh:mm
2020-04-22	19:31	no	no	no
2020-10-06	11:30	no	no	no
2020-10-24	15:32	no	no	no
2021-02-16	04:00	no	no	no
2021-03-04	08:25	no	no	no
2021-03-14	10:01	no	no	no
2021-05-26	18:59	26 ^{on} /18:51/18:58/19:47/B7.0	no	no
2021-12-02	23:12	no	no	no
2022-01-19	02:03	no	no	18 ^{on} /19:26 ^s
2022-02-03	18:13	02 ^{pr} /17:42/17:47/17:59/C1.1	no	03 ^{su} /22:35
2022-04-29	21:27	29 ^{su} /22:42/22:56/23:14/C3.0	29 ^{on} /17:03	29 ^{on} /09:12
2022-05-13	22:08	13 ^{on} /22:07/22:26/22:34/C2.6	no	no
2022-07-07	13:11	no	no	no
2022-09-05	02:10	05 ^{on} /01:53/02:05/02:19/C5.0	no	no
2022-12-28	09:34	22 ^{on} /09:34/09:42/09:49/C2.4	no	no



Education

University courses

- Solar physics & solar activity; Radio astronomy (Master program, “Astronomy and Astrophysics” https://www.phys.uni-sofia.bg/?page_id=3443)
- Introduction to Space weather (Master program "Aerospace Engineering and Communications" https://www.phys.uni-sofia.bg/?page_id=6373)
<https://astro.phys.uni-sofia.bg/p9/>

(New) Summer practice (start 2024: under development): students, PhDs, young scientists

Knowledge transfer

Summer schools & practices

- Project-related <https://stellar-h2020.eu/>
- LOFAR-BG <https://lofar.bg/>
- Branch Cosmos <https://bulgarianspace.online/archive-schools/>

Workshops

- Radio Astronomy

(external school 15-19 Apr 2024: <https://indico.astron.nl/event/315/>)

Deadline: 30 Nov 2023!)

- Astropy

(20-24 Nov 2023: <https://astro.bas.bg/astropy2023/> Registration closes today!)

Dissemination & outreach

- News (<https://astro.bas.bg/>)

<http://195.96.236.171/news>

Преследване на слънчевата корона до Западна Австралия
Лекция на гл. ас. д-р Цветан Цветков в МГУ „Св. Иван Рилски“



Dissemination & outreach

- News

<http://195.96.236.171/news>

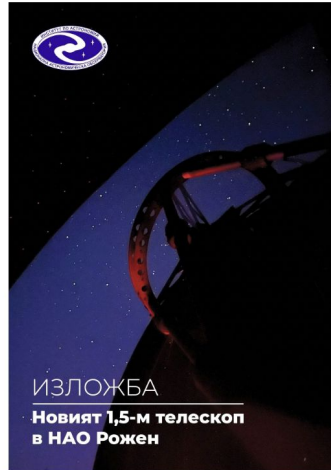
- exhibitions

Ongoing: New 1.5-m telescope (BAS)



Начало Администрация Академията Документи

понеделник, 9 октомври 2023 | Категории: [Астрономия](#), [космически изследвания и технологии](#) | Етикети: [ИА с НАО](#)



Изложба на изображения на космически обекти, заснети с новия 1,5-м телескоп в Националната астрономическа обсерватория (НАО) Рожен, беше открита в Българската академия на науките. Телескопът работи в полуавтоматичен режим и може да бъде управляван дистанционно, каза директорът на Института по астрономия с НАО проф. Евгени Семков. Той представи автора на фотографиите – астрономът гл. ас. г-р Милен Минев.

В експозицията са включени снимки на планетата Юпитер и на звезди, мъглявини, галактики, звездни купове и образувания от междузвезден газ и прах като известните „Стълбове на сътворението“ в мъглявината Орел на съзвездие Змия.

Телескопът е първата мащабна научна инфраструктура, която е изградена изцяло с българско финансиране, каза председателят на БАН акад. Юлиан Ревалски и допълни, че средствата, вложени

в проекта, са 3,5 милиона лева.

В зала „Проф. Марин Дринов“ на БАН беше излъчен премиерно документален филм „Новият телескоп“, с автори журналистът Димитър Сотиров и операторът Валентин Паскалев.

Dissemination & outreach

- News

<http://195.96.236.171/news>

- exhibitions

Ongoing: New 1.5-m telescope (BAS)



МЗР и планетарна мъглявина, известна още като планетарна дъбилка или NGC 6164, разположена в съзвездие Мена. Тук се намира и най-близкият галактически спътник на Земята – малката мъглявина в рамото от около 2000 светлинни години и още 506 съвкупни мъгли. МЗР може лесно да се наблюдава с бинокли или малки любителски телескопи.

Снимката е резултат от 340min експозиция в BVG филтрите.
Автор: Милан Минева Обработка: Емил Иванков



Съвкупности на Отварението са образувани от мекобулбарен газ и прах в най-високата точка на галактиката. Милан Минева е автор на първата снимка. Снимките на съвкупности Минева са направени за целия път на галактиката. Шемата е дело на астрономите от обсерваторията на Обсерваторията в Ню Йорк.

Снимката е резултат от 3 експозиции по 30 мин в UVB филтрите.
Автор: Милан Минева Обработка: Емил Иванков



NGC 6164 или планетарна мъглявина се намира на 22 хиляди светлинни години от нас в съзвездие Мена. NGC 6164 е една от най-ярките мъглявини в съзвездие Мена. NGC 6164 е една от най-ярките мъглявини в съзвездие Мена. NGC 6164 е една от най-ярките мъглявини в съзвездие Мена.

Снимката е резултат от 760min експозиция в BVG филтрите.
Автор: Милан Минева Обработка: Емил Иванков

Dissemination & outreach

- News

<http://195.96.236.171/news>

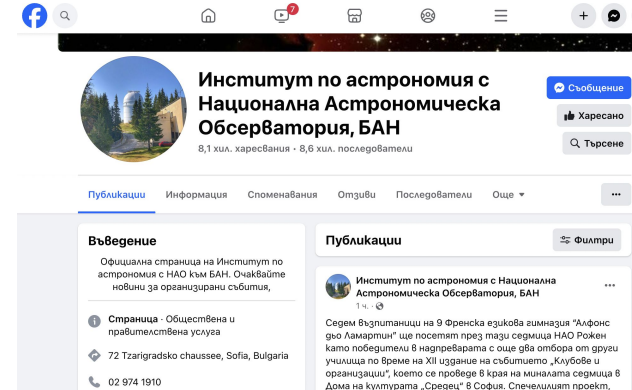
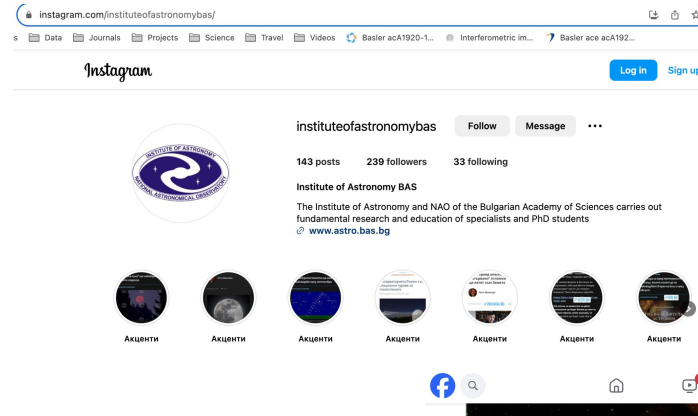
- exhibitions

Ongoing: New 1.5-m telescope (BAS)

- science & public events

<https://www.astro.bas.bg/reports/>

- social media: facebook, instagram, youtube



<https://www.youtube.com/@instituteofastronomyandnao6152>

<https://www.instagram.com/instituteofastronomybas/>

<https://www.facebook.com/ianaoban>

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'On the relationship between major space weather phenomena in solar cycles 23 and 24'

Interacademy bilateral project (BAS): Bulgaria-Egypt
'On space weather effects at near Earth environment - from remote observations and in situ particle forecasting to impacts on satellites'
IC-EG/08/2022-2024'

Bulgarian National Science Fund: Bulgaria-Austria
'Joint observations and investigations of solar chromospheric and coronal activity' KP-06-Austria/5 (14-08-2023)

European Space Agency (ESA): <https://spreadfast.astro.bas.bg/>

EU-Horizon 2020 (twinning project): STELLAR (Scientific and Technological Excellence by Leveraging LOFAR Advancements in Radio Astronomy) <https://stellar-h2020.eu/>

Ministry of Education, Bulgaria: LOFAR-BG <https://lofar.bg/>



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