Mid-Latitude Auroras with Data from Optical Instruments of the National Heliogeophysical Complex

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Work goals: To study the capabilities of the optical instruments of the National Heliogeophysical Complex for the registration and study of geomagnetic disturbances and geomagnetic storms in the middle latitudes.

Midlatitude auroras (MA) are a rare geophysical phenomenon [Krakovetsky et al., 1989]. However, according to Shiokawa et al. (2005), subvisual MAs are observed more frequently. Additionally, the observation of stable red auroral arcs (SAR arcs) at mid-latitudes was previously considered to be extremely rare. During the monitoring observations at the Geophysical Observatory of the ISTP SB RAS (103°04`31"E 51°48`38"N) in the periods of the 23rd and 24th solar cycles, SAR arcs were registered only during four geomagnetic storms.

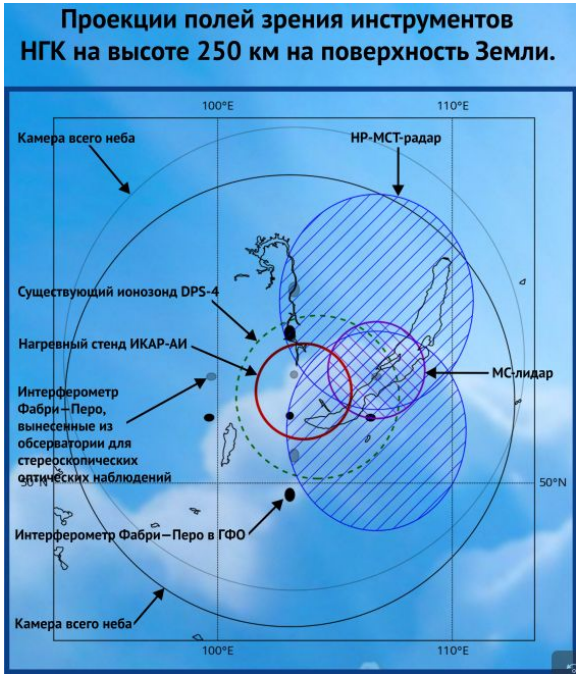
During the 25th solar cycle (from April 2021), the National Heliogeophysical Complex (NHC) optical instruments has registered 45 MAs. Of these, structures corresponding to SAR arcs were observed in the airglow in 26 cases. It is worth noting that in at least one case, a SAR arc with additional weak emissions of 557.7 nm and 427.8 nm was observed. Additionally, one of the recorded events was observed on two all-sky cameras that were spatially separated. The high number of registered MAs may be due to the high intensity of the 25th Solar Cycle and is undoubtedly associated with the commissioning of highly sensitive optical instruments of the NHC.

1. Krakovetsky Yu.K., Loisha V.L., Popov L.R. Chronologiya polyarnyh siyaniy za poslednee tysyacheletie // Solnechnye dannye. 1989. N. 2. p. 110–115. (in Russian)

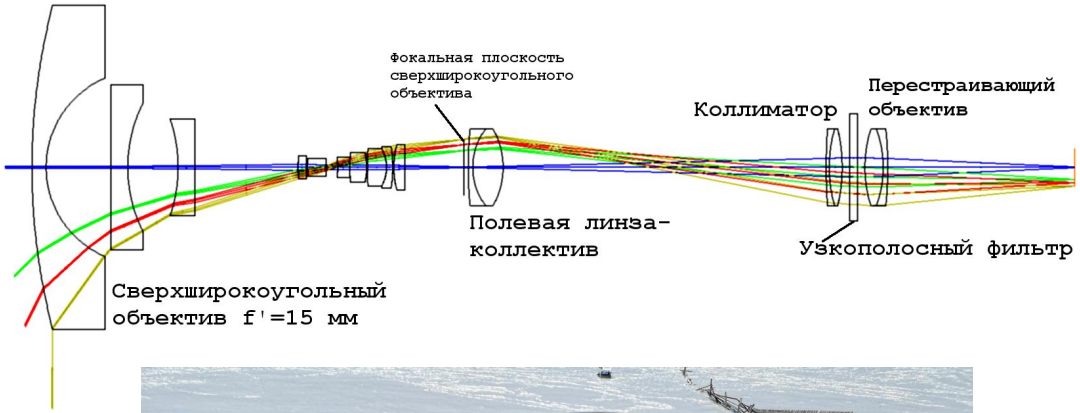
2. Shiokawa K., Ogawa T., Kamide Y. Low-latitude auroras observed in Japan: 1999–2004 // J. Geophys. Res. 2005. V. 110, iss. A5. A05202. DOI: 10.1029/2004JA010706.

Optical Instruments

Currently, the Geophysical Observatory of the ISTP SB RAS (51°48 N, 103°04 E, altitude 670 m) possesses a complex of optical instruments that perform monitoring of the night airglow in the spectral range of 400 - 1650 nm.



Optical Instruments



All-sky Imager "KEO Sentry 4"

Optical Instruments

Two all-sky imagers "KEO Sentry 4" (ASI0 and ASI1). The field of view is 180°. Spectral range selection is achieved through automatically interchangeable interference filters. The exposure time for channels with narrow spectral range is 55 seconds, while for the wideband OH channel it is 7 seconds. The installed filters (spectral channels) are listed below:

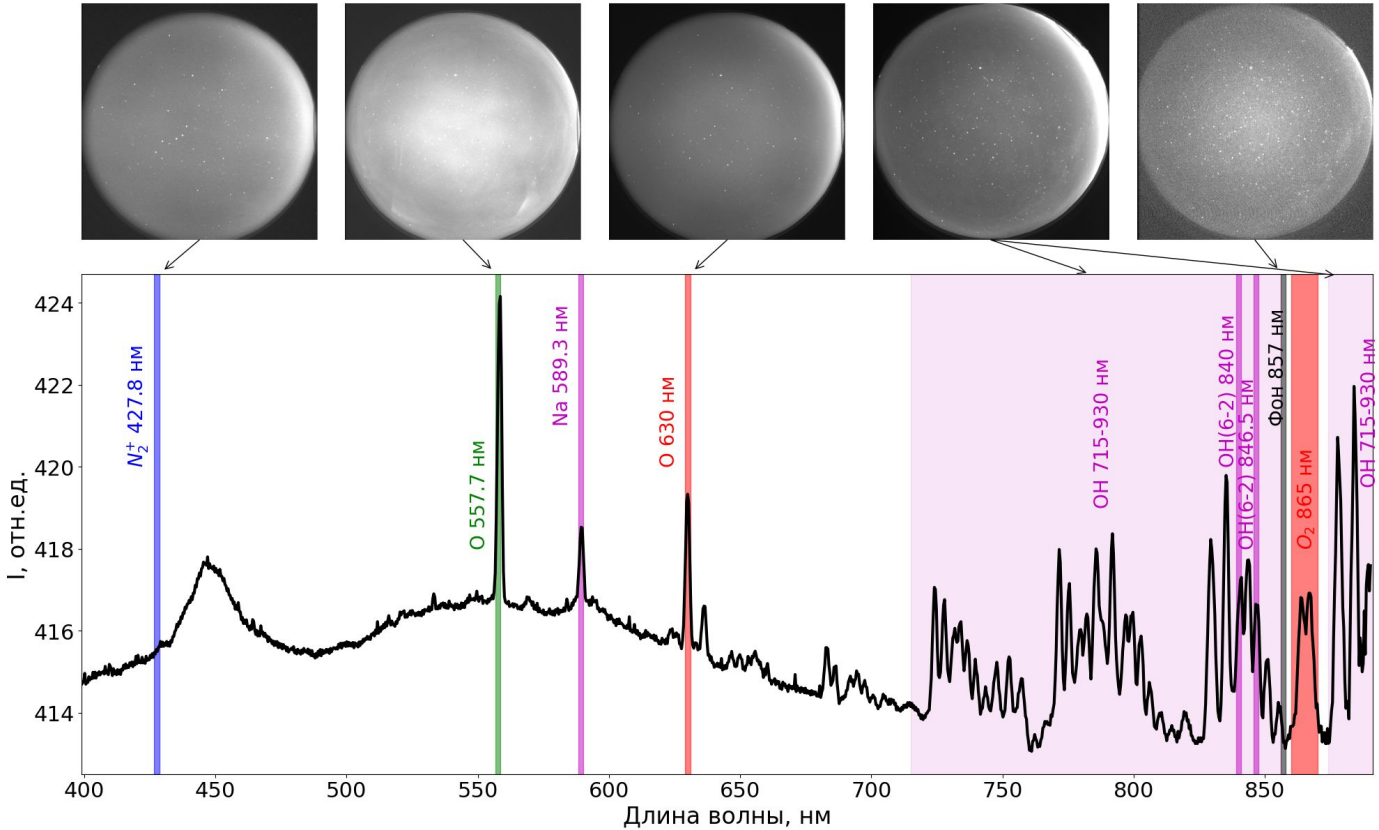
ASI0

- The bandwidth center is 557.7 nm. FWHM 2 nm.
- 630.0 nm. FWHM 2 nm.
- A broadband filter (OH) with a passband 715 — 930 nm and blocked spectral interval with a center at 865 nm and FWHM of 18 nm.
- 840.0 nm. FWHM 1.8 nm.
- 846.5 nm. FWHM 1.8 nm.
- 857.0 nm. FWHM 1.8 nm.

ASI1

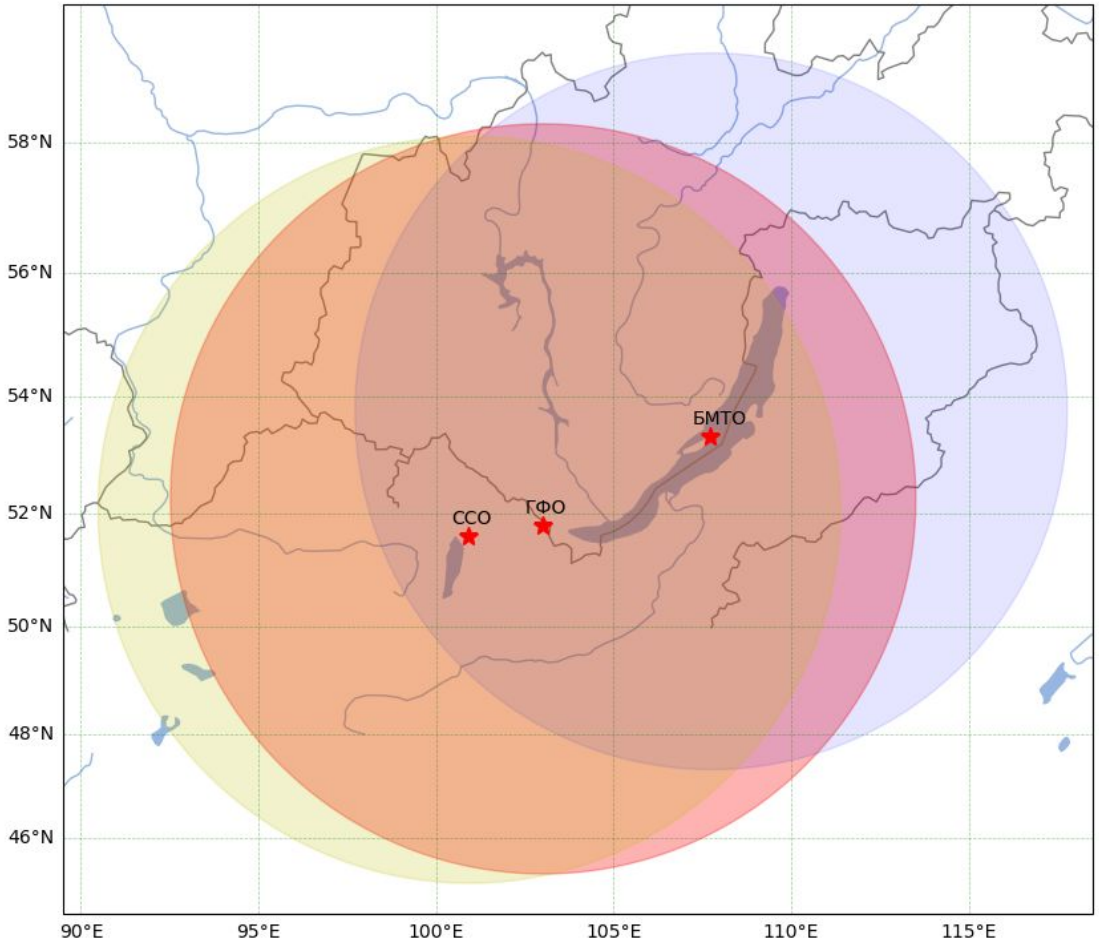
- The bandwidth center is 557.7 nm. FWHM 2 nm.
- 630.0 nm. FWHM 2 nm.
- A broadband filter (OH) with a passband 715 — 930 nm and blocked spectral interval with a center at 865 nm and FWHM of 18 nm.
- 865.0 nm. FWHM 10 nm.
- 427.8 nm. FWHM 2 nm.
- 589.3 nm. FWHM 2 nm.

Optical Instruments



Spectrum of the night sky luminosity in the range 400 - 900 nm (lower panel, averaged spectrum for 23.01.2023), obtained with the KEO Spectrograph::VISIBLE. The spectral channels of the ASI0 and ASI1 all-sky imagers are depicted in color. The upper panel exhibits examples of all-sky imager frames for certain spectral channels (indicated by arrows).

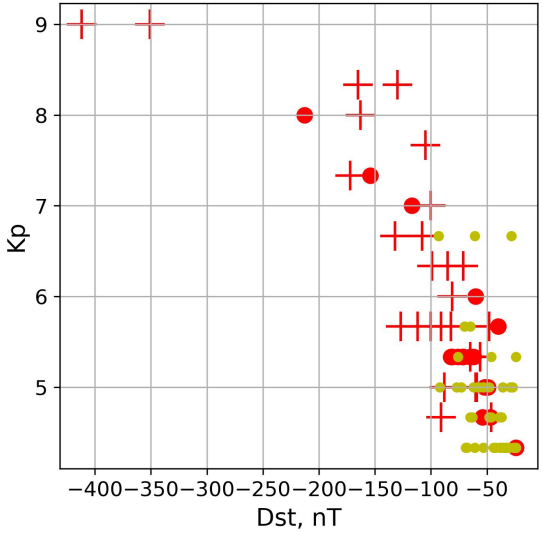
Optical Instruments

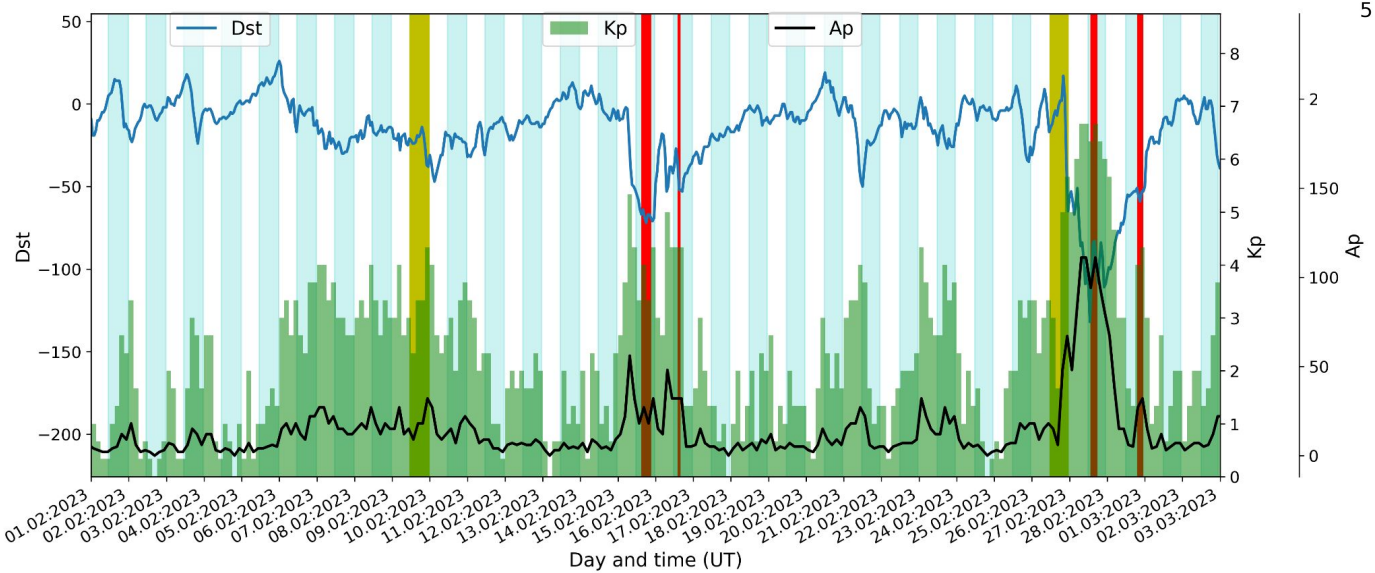


The fields of view of the all-sky imagers installed at the Geophysical Observatory (red), Baikal Magneto-Telluric Observatory (blue, test measurements), and Sayan Solar Observatory (yellow, planned).

Results

The distribution of recorded midlatitude auroras events (MA) as a function of the Dst and Kp indices is shown in the figure on the right (in red). MA with structures similar to SAR arcs are indicated with a plus marker. Yellow markers indicate possibly favorable geomagnetic conditions for MA during the operation of optical instruments (the MA were not registered on the cameras). A total of 45 events were registered, 26 of which had structures similar to SAR arcs. There were 43 "favorable" periods for the occurrence of MAs.

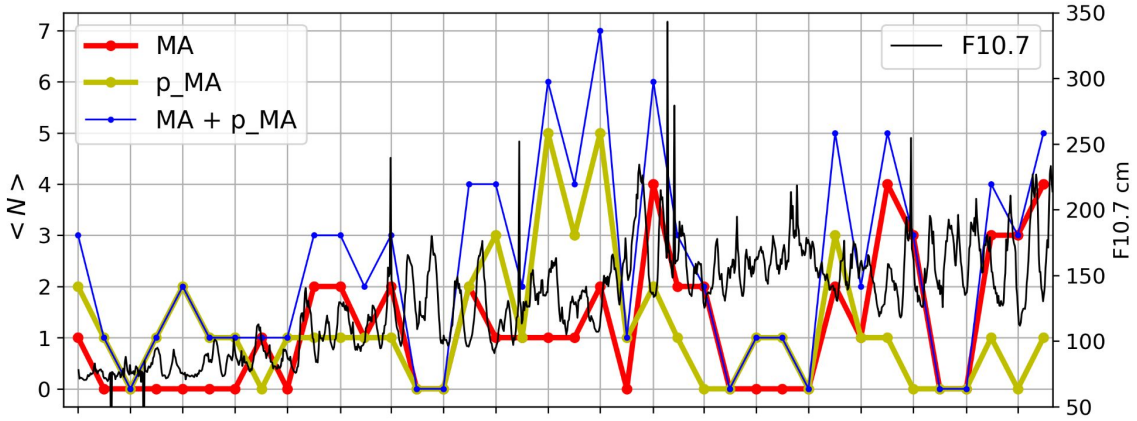




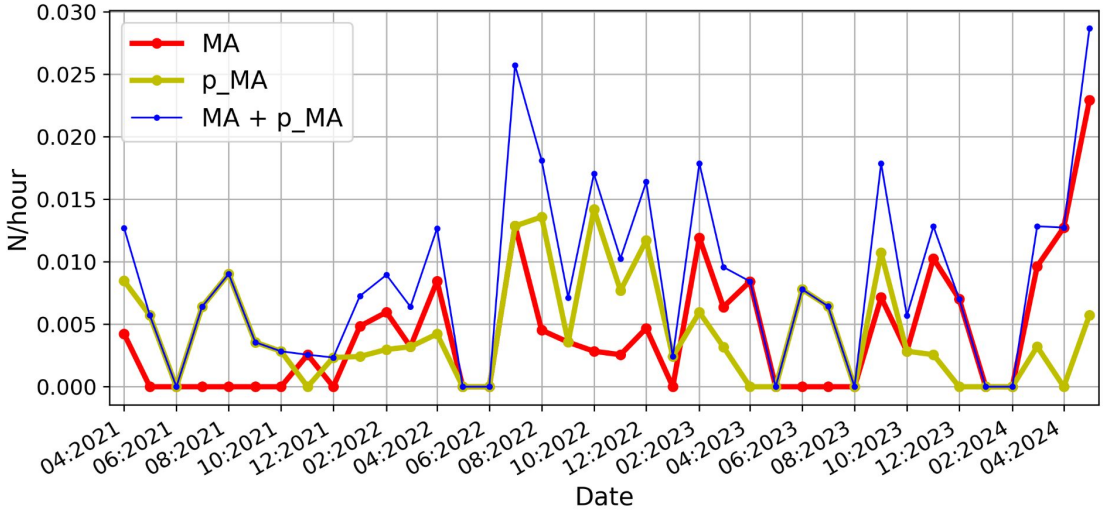
On the left is an example of Registered MA (in red) and periods with "favorable" geomagnetic conditions (in yellow. Dst<=25 and Kp>=4.3) during which MAs were not registered. The indices Dst, Kp, and Ap are also provided.

https://wdc.kugi.kyoto-u.ac.jp/wdc/Sec3.html, https://kp.gfz-potsdam.de/en/

Results

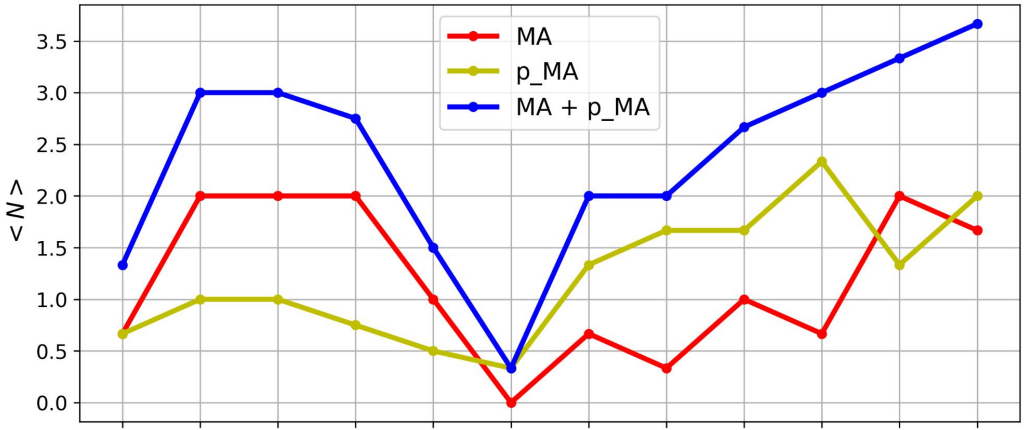


The graph displays the monthly number of recorded MAs from April 2021 to May 2024 (in red), along with the number of "favorable" periods for MA occurrence (in yellow) and their sum (in blue).. The F10.7 index time course is represented by the black curve (https://kp.gfz-potsdam.de/en/).

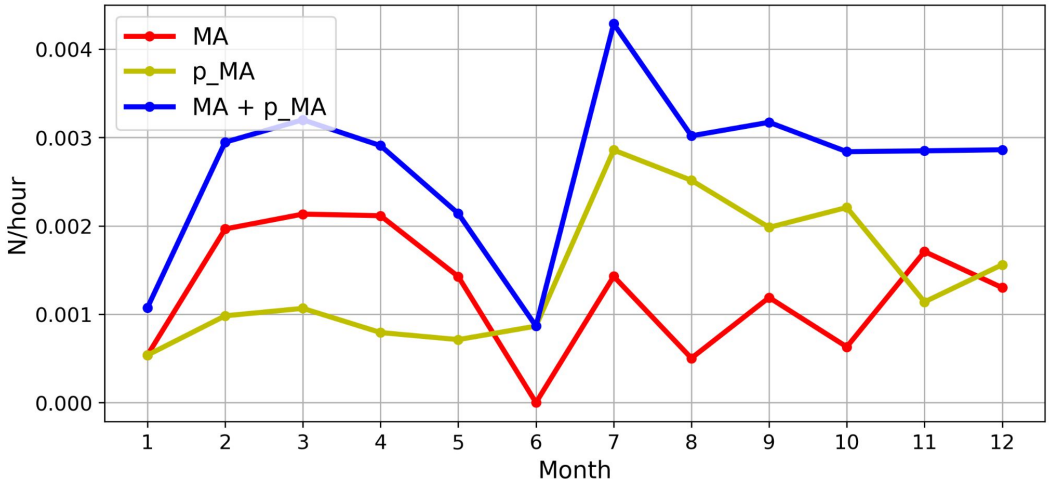


The graph displays the number of recorded MAs per month in relation to the number of hours of optical observations from April 2021 to May 2024. The yellow color indicates the number of "favorable" periods per month per hour for the occurrence of MAs and sum of MA and "favorable" MA events (in blue).

Results

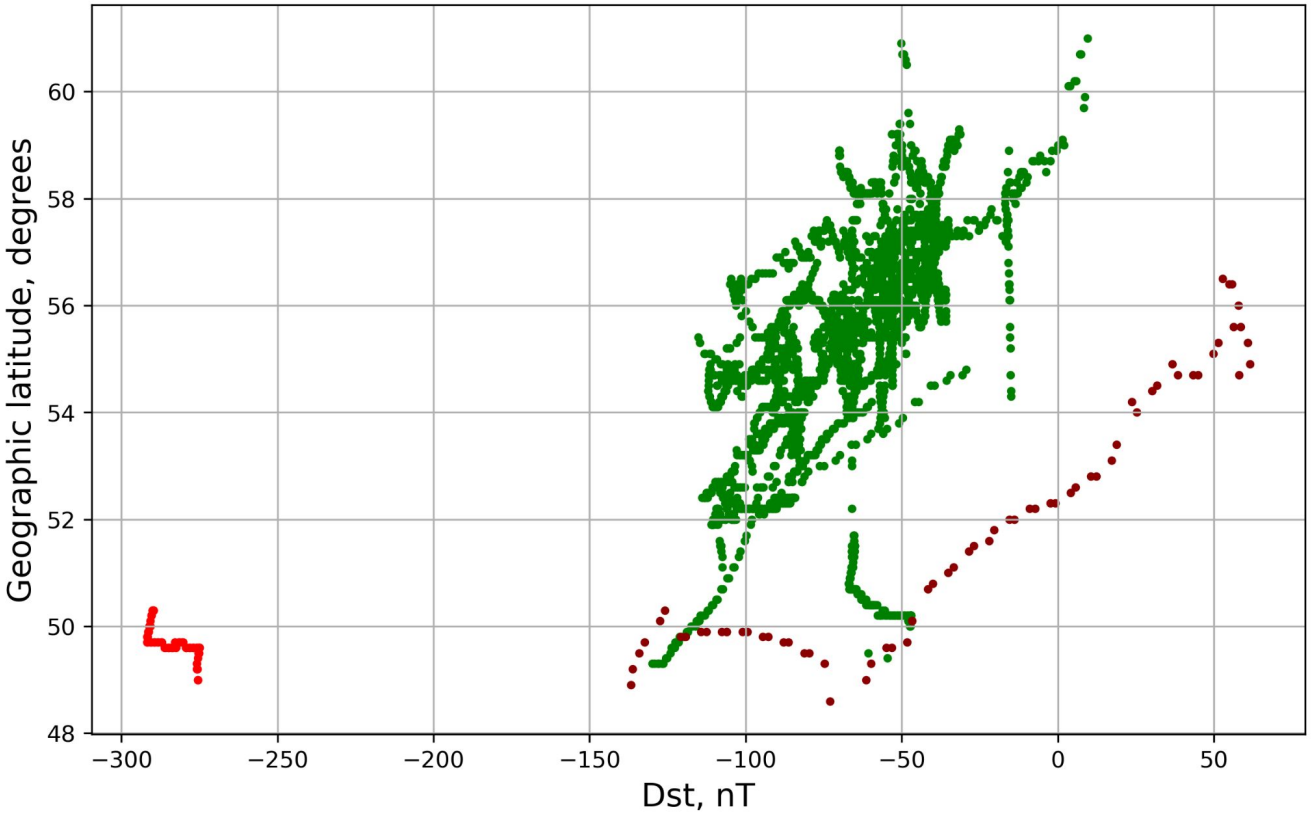


The figure displays the time course of the averaged number of registered MAs per month from 2021 to 2024 (in red). The averaged number of "favorable" periods per month for the occurrence of MAs is shown in yellow. The blue curve is the sum per month of the MA and the "favorable" MA events.



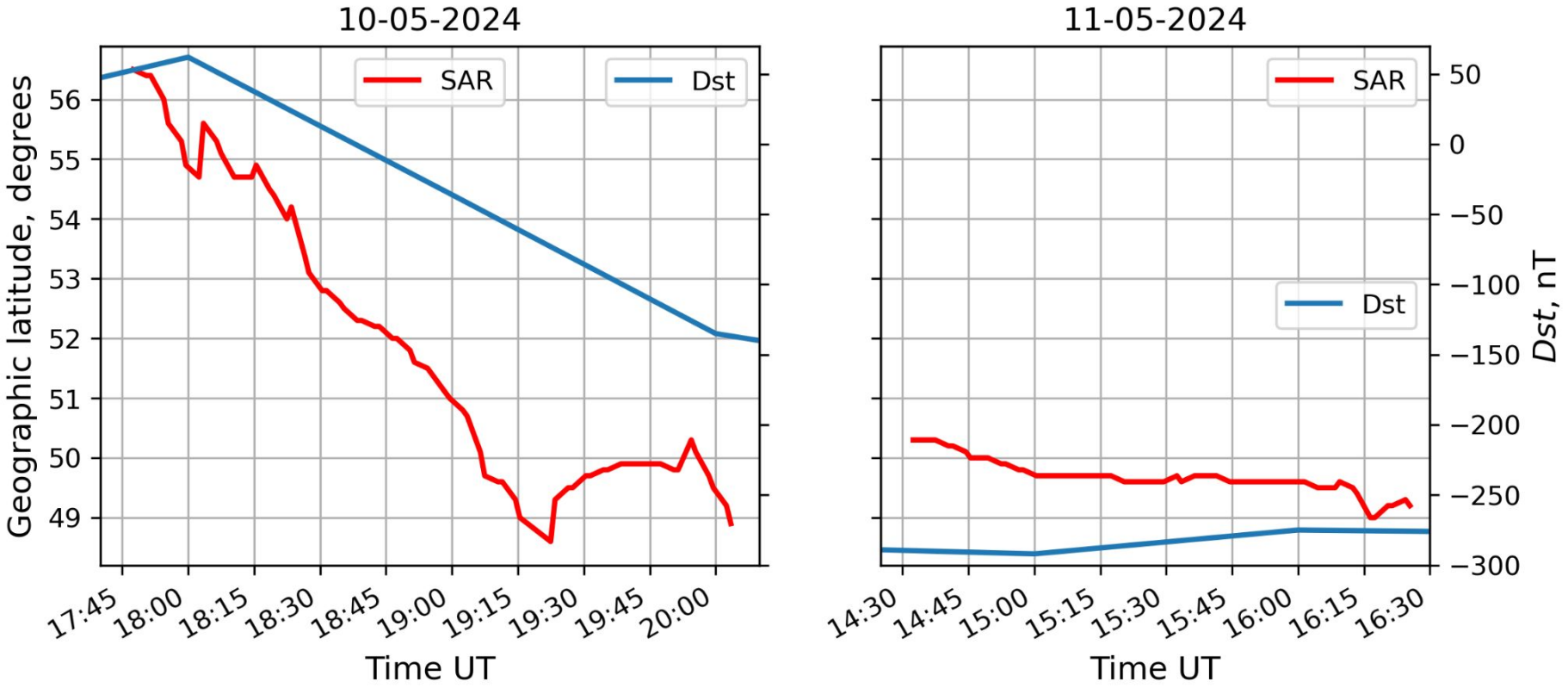
Averaged time course for 2021-2024 of the number of registered MAs per month in relation to the number of hours of optical observations (in red). The average number of favorable periods per month per hour for the occurrence of MAs is shown in yellow. The blue curve is the sum of the MA per hour and the "favorable" MA events per hour per month.

Results



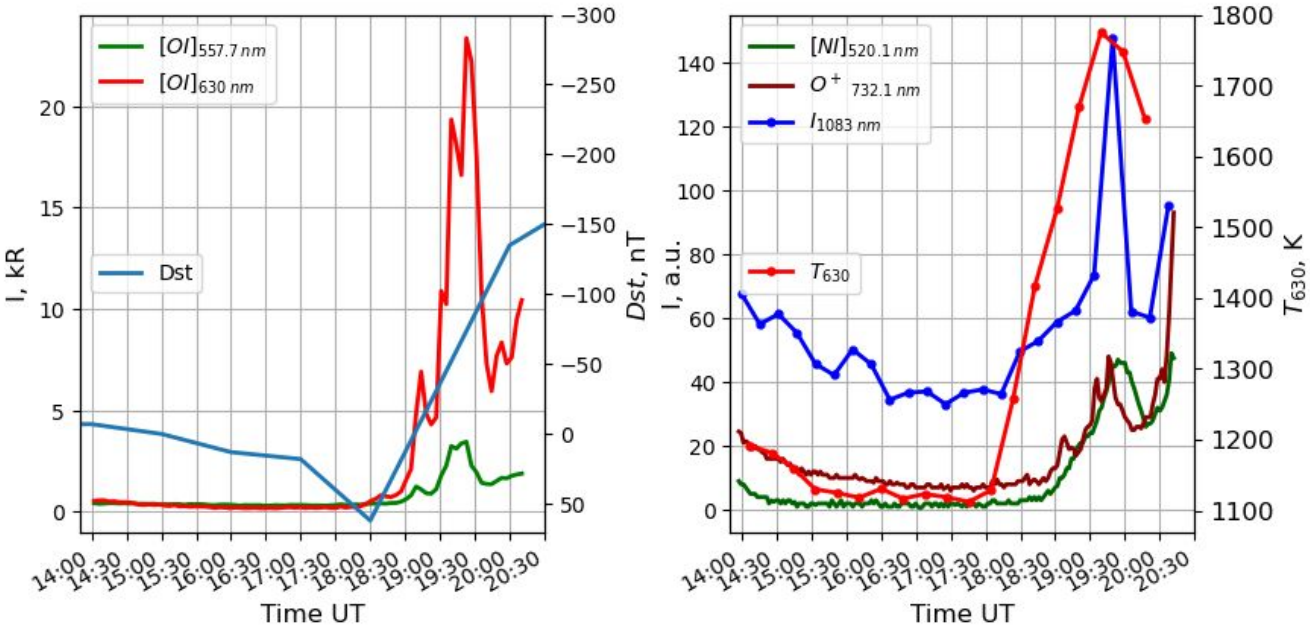
Distribution of the geographic latitude of the maximum SAR arc intensity location depending on the Dst index. Calculated for an altitude of 300 km. The distribution for May 10 and 11, 2024 is highlighted in dark red and red , respectively.

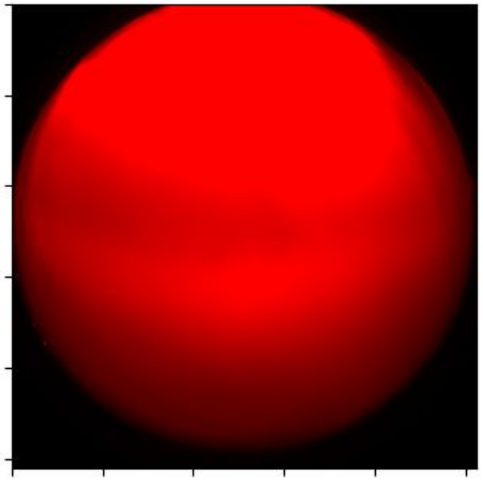
Results



Time course of the latitudinal position of the SAR arc and the Dst index on May 10 and 11, 2024.

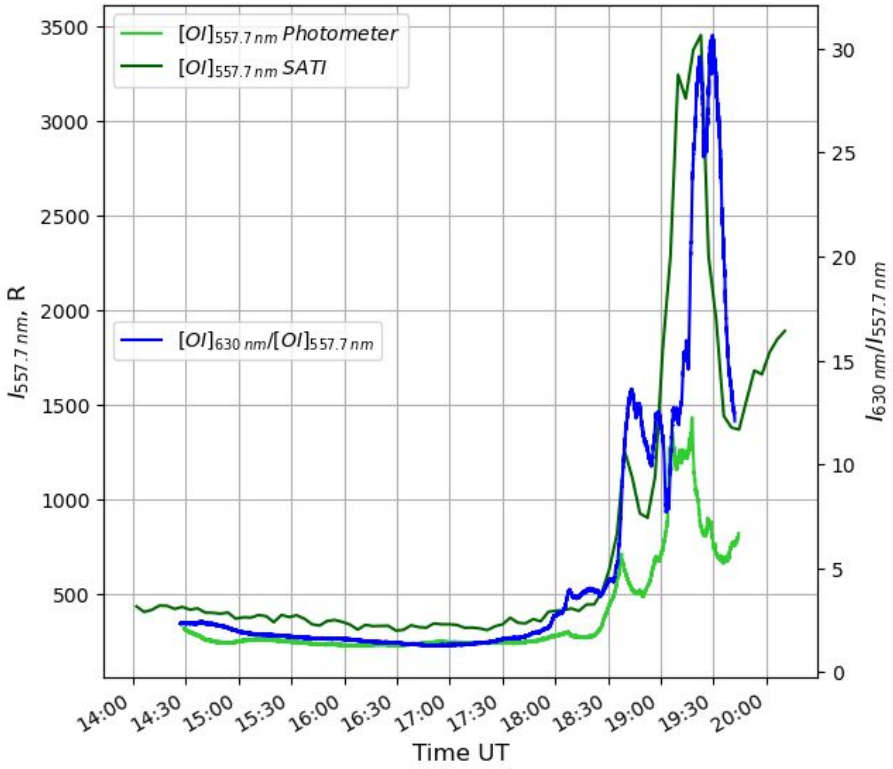
Results

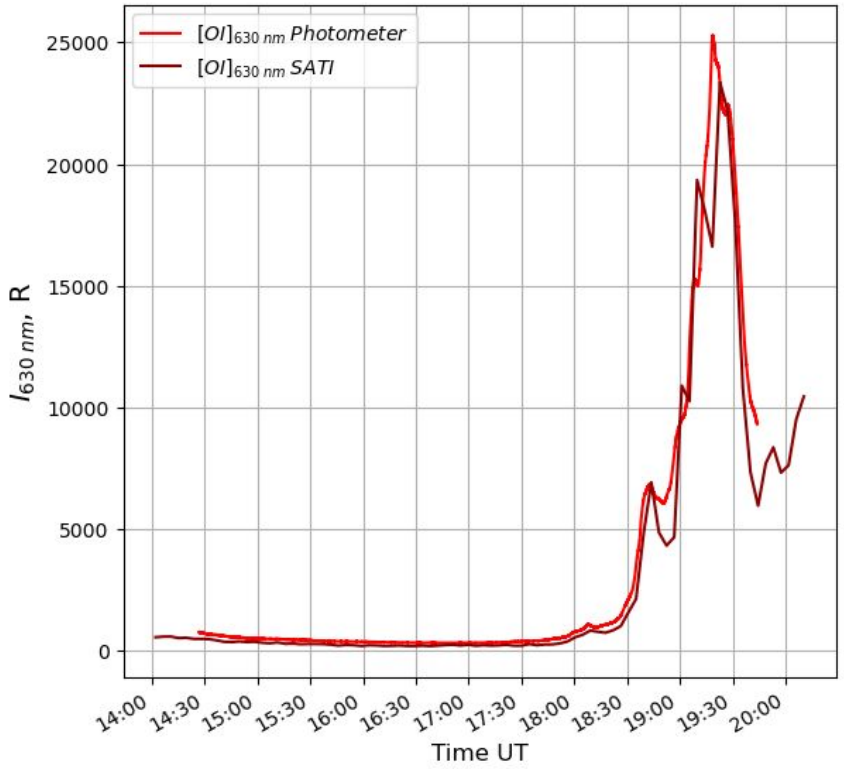




Dynamics of the intensities of the [OI] 630.0 nm, [OI] 557.7 nm emissions and the Dst index on May 10, 2024 (left), dynamics of the intensities of [NI] 520 nm, O^+ 732 nm, Doppler temperature of the [OI] 630.0 nm line and the intensity near the wavelength of 1083 nm, which includes He(2^3S) and OH(5-2) (in the center). All-sky camera frame in the 630 nm channel for 19:03 UT (right).

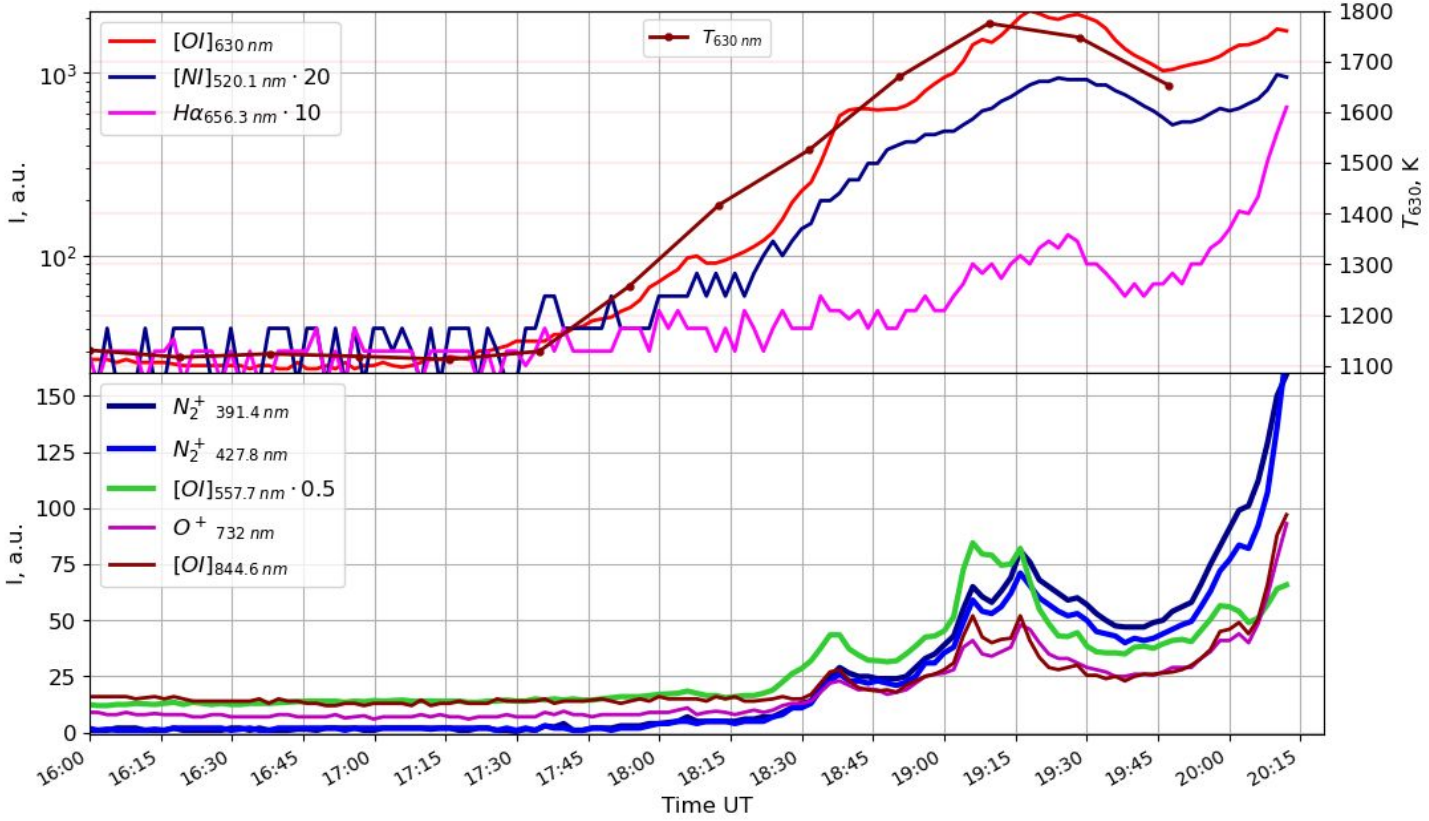
Results





Dynamics of the emission intensities of [OI] 557.7 nm (left) and [OI] 630.0 nm (right) according to the data of the SATI spectrometer (sighting direction ~10 degrees above the northern horizon) and the NGK photometer (sighting direction - the north pole of the world). The blue curve on the left panel is the ratio of the intensities of [OI] 630.0 nm and [OI] 557.7 nm according to the photometer data.

Results



Time course of some emission lines intensity of the upper atmosphere according to spectrometer data and Doppler temperature according to FPI data for May 10, 2024.

Conclusions:

According to the study [1], the probability of SAR arcs appears to decrease in Athabasca at subauroral latitudes during higher geomagnetic activity, but at the same time increases at lower latitudes. In addition, in [2], based on the analysis of 27-year observations of the all-sky cameras at Millstone Hill (42.6° N, 288.5° E), it is reported that the frequency of SAR arcs was minimal in the years of solar minimum and maximal in the years of solar maximum, in contrast to what is observed in Athabasca (subauroral latitudes). That is, according to the works [1, 2], we can assume a high probability of registering structures of the SAR arc type during observations at the mid-latitude Geophysical Observatory (GphO) of ISTP SB RAS in years of high solar activity.

1. Yadav, S., Shiokawa, K., Otsuka, Y., & Connors, M. (2022). Statistical study of subauroral arc detachment at Athabasca, Canada: New insights on STEVE. Journal of Geophysical Research: Space Physics, 127, e2021JA029856. https://doi.org/10.1029/2021JA029856.

2. Mendillo, M., Baumgardner, J., & Wroten, J. (2016). SAR arcs we have seen: Evidence for variability in stable auroral red arcs. Journal of Geophysical Research: Space Physics, 121(1), 245–262. https://doi.org/10.1002/2015JA021722.

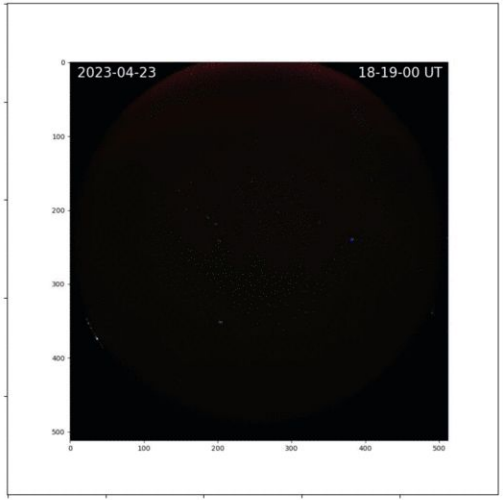
Conclusions:

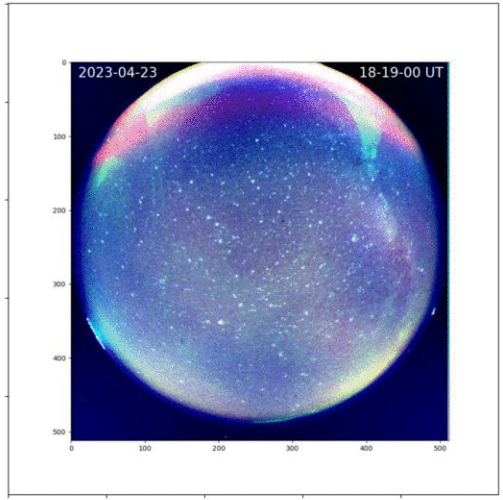
During the periods of high activity of the 23rd and 24th solar cycles, the GphO of ISTP SB RAS did not have highly sensitive instruments with good spatial resolution. The high number of registered MA in the 25th solar cycle can be associated with the high intensity of the solar cycle and is undoubtedly associated with the commissioning of highly sensitive optical instruments of the NGC. The optical instruments of the NGC make it possible to detect and record optical manifestations of geophysical and geomagnetic disturbances in the upper atmosphere in the range of geographic latitudes of ~46-58 degrees north. An example of multispectral observations in 2021-2024 of mid-latitude auroras and SAR arcs demonstrate high spatial, temporal and spectral characteristics and efficiency of the optical equipment used.

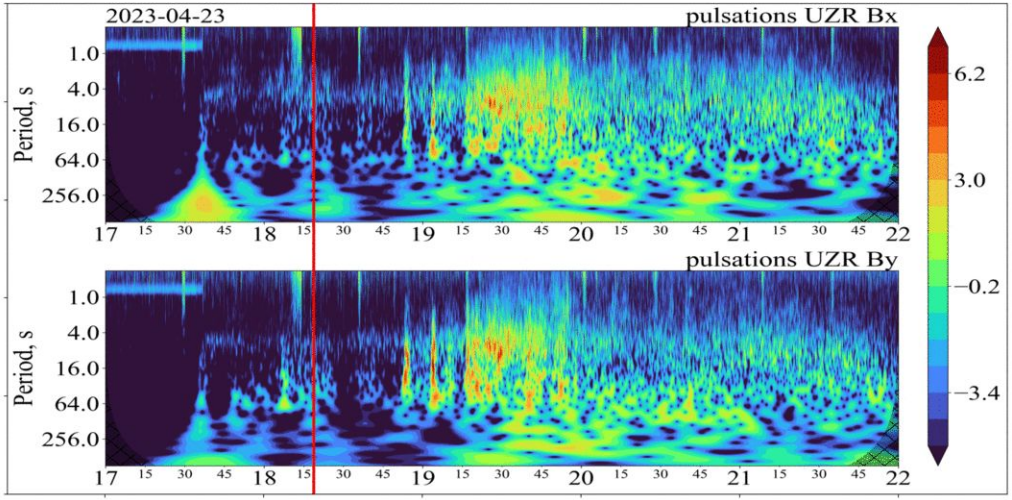
A detailed analysis of separate geomagnetic storms and the features of their optical manifestations is currently ongoing.

Thank you for your attention!

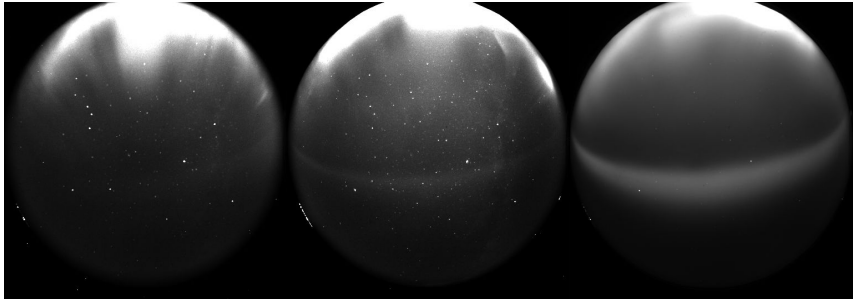
Experimental data were obtained using the equipment of the Angara Shared Equipment Center (ISTP SB RAS) http://ckp-angara.iszf.irk.ru/.
Data processing and storage were financially supported by the Ministry of Science and Higher Education of the Russian Federation (Subsidy No. 075-GZ/C3569/278).

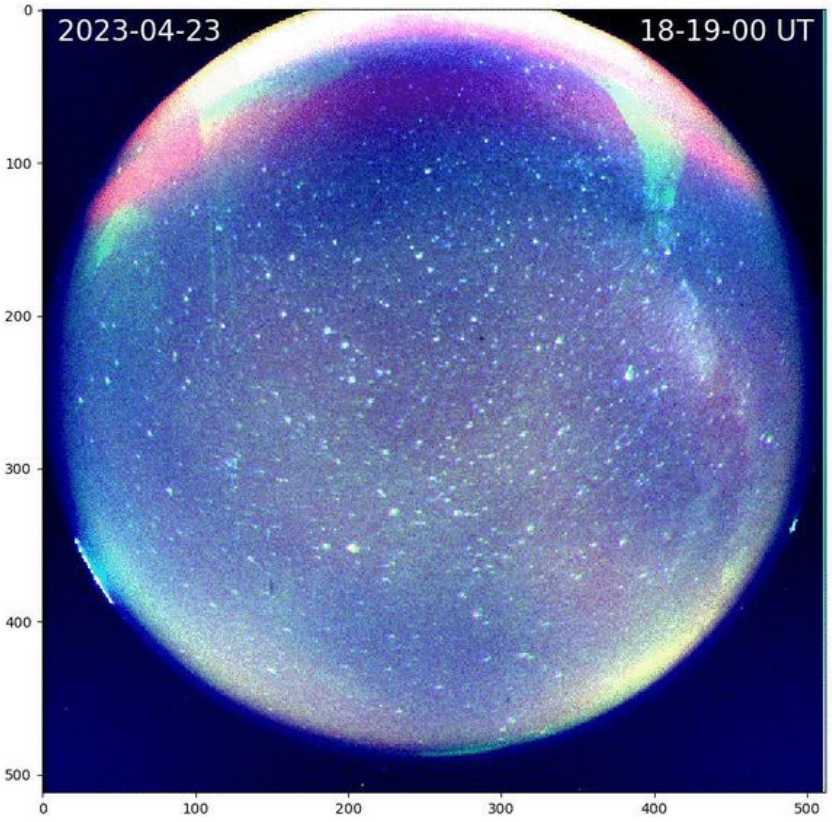






Midlatitude aurora registered on April 23, 2023 by optical instruments of ISTP SB RAS. The top panel displays video collected from three spectral channels (557.7 nm, 630 nm, and 427.8 nm). The left panel shows the frames contrasted over the entire time period, while the right panel shows the contrast over each set of frames. Lower left panel - data from the magnetotelluric station lemi-418 operating in the frequency range from 0.001 Hz to 20 Hz. Bottom right frames of the 427.8 nm, 557.7 nm, and 630 nm spectral channels, respectively.

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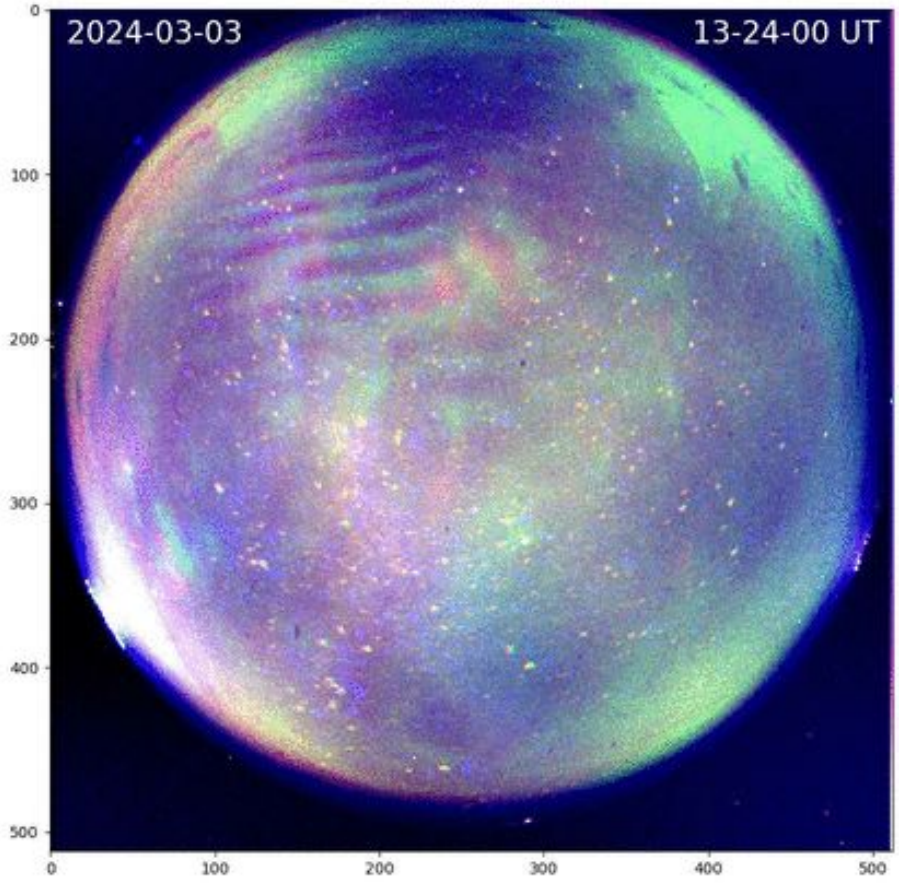
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