"Physics of Auroral Phenomena", Proc. XLII Annual Seminar, Apatity, pp. 164-167, 2019

DOI: 10.25702/KSC.2588-0039.2019.42.164-167

FAST VARIATIONS OF THE UPPER ATMOSPHERE AIRGLOW DUE TO THE METEORS AND HUMAN ACTIVITY

R.V. Vasilyev[1], A.B. Beletsky[1], M.V. Eselevich[1], K.I. Ivanov[2], E.S. Komarova[2], A.V. Mikhalev[1], A.V. Podlesny[1], S.V. Podlesny[1]

[1]*Institute of Solar-Terrestrial Physics SB RAS*
[2]*Irkutsk state university, Physical department*

Abstract. We report about recent researches of the long-lived meteor trails at the mesopause region and artificial increasing of the red airglow in the thermosphere due to the spacecraft engine activation. Observing with all-sky cameras show that the events appear as a spot or ring of the enhanced glow with diameter of hundreds of kilometers and have a lifetime from several minutes till tens of minutes. The phenomena appear at different height levels and have a different origin, whereas the dynamic in temporal and spatial domain as observed on the ground are similar. The data obtained can conclude that both phenomena have the same nature - influence of meteor matter or satellite engine products on the chemical reactions in the upper atmosphere. Statistics and stereoscopy of the events can give us the possibility to separate and control the moments of the satellite engine operations and perform the additional investigations of the mesopause region.

Introduction

Long-lived meteor trails rarely observed by the photographic cameras and attract the high interest of researchers as they appear. The physical nature of the airglow lasting till one hour after the meteor blast is still exactly unknown. The multispectral observations of the 17 minutes trail by CCD device [*Clemesha et. al.,* 2001] get the serious doubts about an earlier suggestion that the infrared light from long-lived meteor trails corresponds to emissions from molecular oxygen excited by the Chapman mechanism. [*Kelly et. al.*, 2000] using simultaneous LIDAR and optical observations show the sodium emission enhancement in the lingering meteor trail but based on [*Chapman et. al.,* 1939; *Chapman et. al.*, 1956; *Baggaley et. al.*, 1977; *Baggaley et. al.,* 1981] conclude that although the catalytic sodium reaction chain with the ozone does occur in the lingering trail phenomenon, the 589 nm line is too weak to explain the total light intensity. At the initial phase the meteoroid produces very wide spectra dominantly contain metallic lines, but with significant part of the ultraviolet radiation [*Abe et. al.,* 2004]. And it obviously that the blasting meteors provide the ionization is proportional to the optical brightness as reported by the simultaneous radar and camera observations of [*Michell*, 2010]. The spacecraft which are switch on the engines produce events similar with the long lived meteor trails. But in contrast with the sodium enhancement they are increase the red airglow with 630 nm wavelength (atomic oxygen, 1D – 3P transition) in the thermosphere [*Mendillo et al.*, 1975]. In spite of the amount of products released by the spacecraft in thermosphere can be small (8-9 kg) in the work (*Beletsky et. al.*, 2016; *Mikhalev et. al.*, 2016] was shown that the brightness of such event is enough in order to be detectable with the ground-based CCD device. The duration of the bright spot, it expansion in angular size and lifetime was similar with the long-lasting meteor trails. In this work we describe and make re-analyses of some events recently detected in the geophysical observatories of Institute of solar-terrestrial physics SB RAS.

Long-lived meteor trail

Long-lived meteor trail observations was made at the ISTP SB RAS Geophysical Observatory (GPhO) (52° N, 103° E), located in the Tunka valley (the village of Tory) in the south of Eastern Siberia and at ISTP SB RAS Sayan Solar Observatory (SSO) near the village of Mondy (51.6° N, 100.9° E). In this study, we have used observations made with all-sky cameras, fine spectrograph based on Fabry-Perot etalon and by an ionosonde of vertical and oblique sounding of the ionosphere by chirp signals. The all-sky KEO Sentinel camera placed in GPhO is designed to record the spatiotemporal dynamics of 630 nm emission intensity (180–300 km spontaneous emission heights). The half-width of the interference filter is ~2 nm. The viewing direction is zenith, the field of view is 145°, and the exposure time is 60 s [*http://atmos.iszf.irk.ru/ru/data/keo*]. The AllSky-340 camera with placed in SSO has a 640×480 CCD receiver Kodak KAI-340, fisheye lens with a focal length of 4 mm and a focal ratio of 1:4, which ensures an angular field of view of 185°×145°. The scale of image in zenith is 18 arcmin/pix. The typical exposure in the nighttime is 60 s, the interval between successive frames is 140 s. Cameras placed apart each other by 150 km distance. The Fabry–Perot interferometer is designed to measure atmospheric temperature and wind speed in an altitude range 80–300 km. The measurement technique in this research was based on recording the Doppler shift and Doppler broadening of 557.7 nm airglow line.

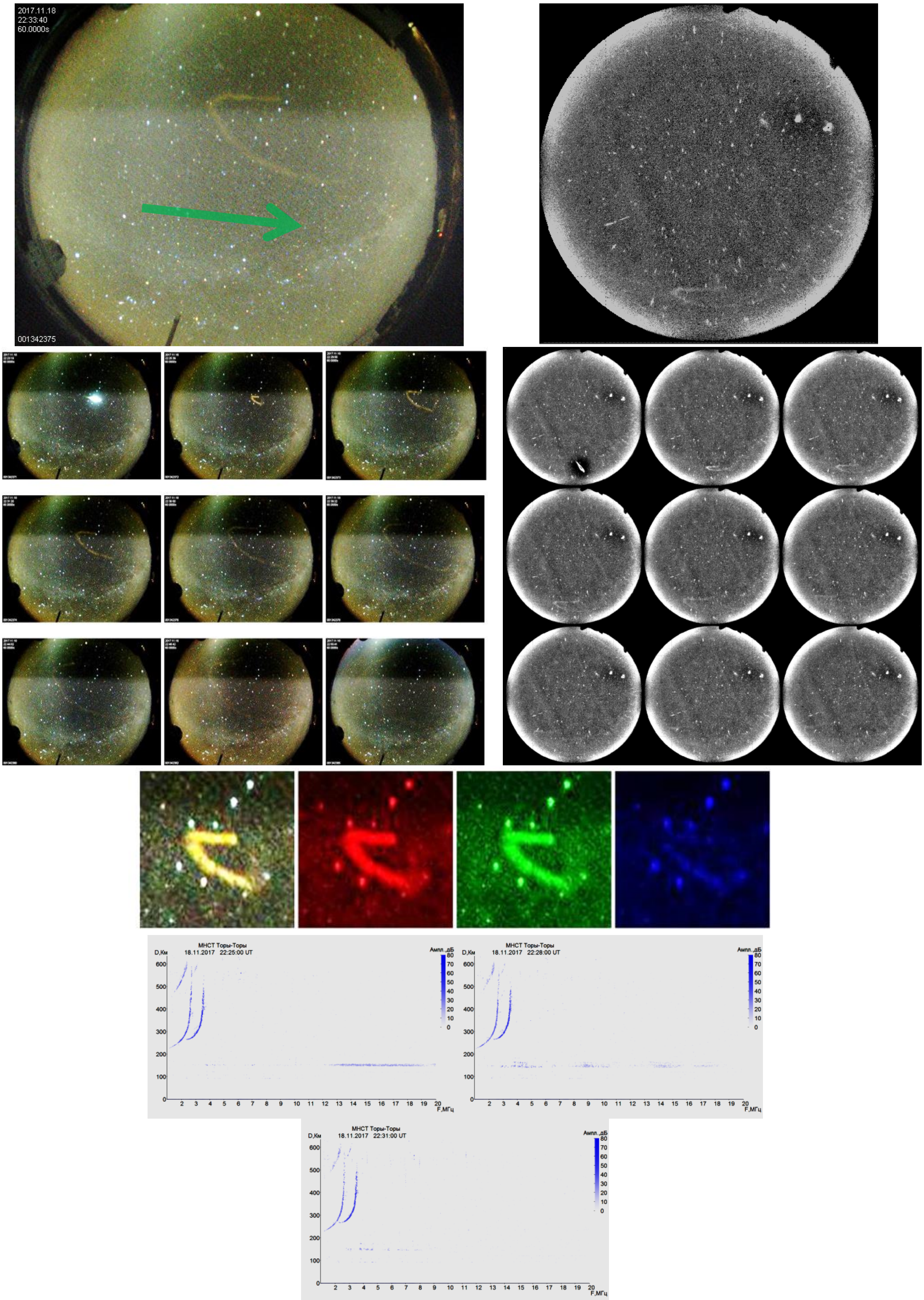

Figure 1. See description in the text.

During the observations, we scan a part of the celestial sphere to restore the complete wind velocity vector as well as to estimate the atmospheric temperature gradient in an area with linear dimensions of several hundred kilometers. Details of the operation can be found in [*Vasilyev et. al.*, 2017]. The Ionosonde-MS operates in the chirp sounding network of ISTP SB RAS. Transmitters of the network are located near Usolye Sibirskoye (point Usolye), Norilsk, Khabarovsk, and Magadan. Besides receiving oblique and near-vertical sounding signals from the network transmitters, the Ionosonde-MS performs vertical ionospheric sounding every minute [*http://dep1.iszf.irk.ru/CHIRP_ionogrames*]. The meteor was blasted over at the atmosphere near the observatories at November 18, 2017 at 22:23 UT. The results of observation one can see in Fig. 1. The upper raw of the figure contain two images, left from SSO and right from GPhO about 10 minutes after the blast. The meteor trail looks like a horseshoe shape enhanced airglow. Middle pallets exhibit the dynamic of the trace at SSO (left) and GPhO (right) from 22:23 UT to 23:00 UT. The total observation time was about 40 minutes. The RGB channels of SSO all-ksy placed down next give us the bright yellow trail which apparently is due to sodium emission as come from [*Kelly et. al.,* 2000; *Clemesha et. al.*, 2001]. The bottom part of Fig. 1 contains the ionosonde data at 22:25, 22:28 and 22:31 UT. The trace is present here as sporadic layer lasting significantly less than optical trace - less than 10 minutes. In the work (*Ivanov et. al.,* 2019) was defined the vertical position – 86-91 km. and velocity – 320±20 m/sec of the lasting meteor trail observed. The probability to have such a wind speed at the height obtained is low. The FPI at the 557.7 nm emission height (about 95 km) measured the wind speed as 70 m/ces. The [*Vasilyev et. al.*, 2018] work show that wind is only slightly changed in speed a nd direction for 89 and 95 height levels. The direction of the wind measured (green arrow in the fig. 1) is opposite the trail movement. The observed facts allow to suppose that the trail movement in this case is not due to the wind, but possibly is due to the circular shock-wave propagation. The asymmetric brightness can be explained by the passing of airglow activation threshold whiles the wave going opposite the wind.

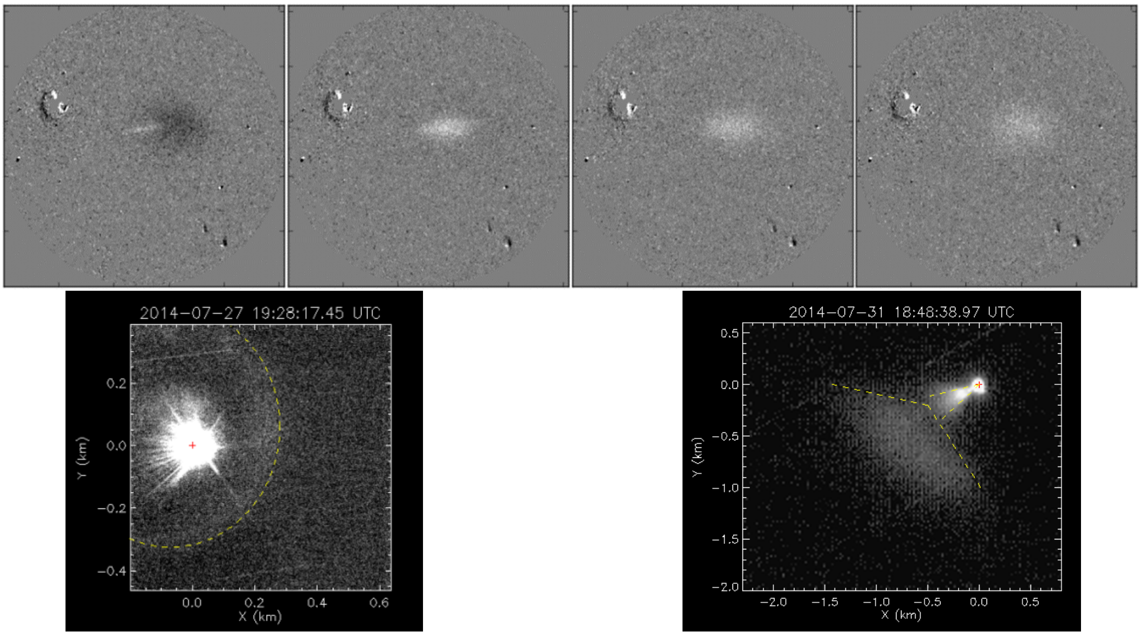

Figure 2. *Upper line* – sequence of all-sky KEO Sentinel snapshots during “Radar-Progres” experiment April 4 2017. Time of snapshots (left-to-right) 13:24:31, 13:25:02, 13:25:33, 13:26:04 UT engine activation at 13:24 UT. *Lower line* – AZT-33IK data during “Radar-Progres” experiment June 27-31 2017. *Left* – emission of engine products parallel to the LOS, *right* – emission perpendicular to the LOS, both just after about 10 seconds after engine activation.

Progress-m spacecraft engine activation

The active experiments with emissions of the spacecraft “Progress-M” engine products were performed many times. Main goals of the experiments were to evaluate the influence of spacecraft engine work on the radio wave propagation near the spacecraft. To understand the chemical process responsible for the charged component variation the different optical means were involved. The optical emissions were observed using telescopes of SSO [*Eselevich et. al.,* 2016] and all-sky cameras of GPhO [*Mikhalev et. al.*, 2016, *Beletsky et. al.*, 2016] but non-simultaneously because the weather conditions. In the described space experiment sessions, optical signals were registered using the wide-field optoelectronic system installed in the AZT-33IK telescope. The wide-field visible-range optoelectronic system consists of a PDNK lens and a CCD camera VS-CTT-423, which are fixed on the mount of the telescope. Some parameters of the system: field of view – 0.1°; pixel scale – 0.9 arcsec / pixel; spectral range – 7.7–9.5 um; CCD-sensor size – 320×256 pixels; pixel size – 30×30 µm; exposure time – 15–700 µs; cooling up to 77 K (liquid nitrogen).

Fig. 2 contain some results of the observations. One can see, that in the time second and sub-second time domain the shape of engine products emission rather different. The bright shapes in telescope data are produced by the ice particles due to emission of non-burned fuel [*Eselevich et. al.,* 2016], while the airglow enhancement in minutes time domain observed by all-sky camera is due to the increasing of 630 nm airglow line due to the chemical reactions with the exhaust products [*Mikhalev et. al.,* 2016; *Beletsky et. al*., 2016]. The electron density at the increasing of the airglow is decreasing [*Shpynev et. al.,* 2017] and additionally authors first examined observations of plasma temperature variations, as well as an interesting and little-studied effect of formation of the region with high positive hydrogen ions content in place of the ionization "hole". The resulting irregularity of ion composition has a much longer lifetime than the ionization "hole" (over half an hour). This can be used for modeling to estimate rates of chemical reactions occurring at different ionospheric heights and require detailed analysis of the chemical reactions involved in the phenomena needed.

Conclusion

The both observed phenomena are similar in optical signs while they are appearing at different altitudes. The lifetime of the optical events appears in the thermosphere are lower in compare with the events in mesosphere, but not so much, so they may be mixed up in observations without spectrophotometry and without radiophysical support. If the stereoscopy technique will available the exact distinguishing will be possible, but the effectivity of the observational system will be low due to the weather conditions. Detailed analysis of the chemical reactions involved in the phenomena needed is required.

Acknowledgements. The work was supported by RFBR grant No. 17-05-00492 and by the program of the Presidium of the Russian Academy of Sciences No. 56 "Fundamental foundations of breakthrough technologies in the interests of national security". Astrometric processing of observations of meteor trails was carried out under Project No. 3.9620.2017/BCh within the basic part of the state task. This work is based on data from the optical complex of the Center for Common Use "Angara".

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