https://doi.org/10.18524/1810-4215.2023.36.290585

COMPARATIVE ANALYSIS OF MAGNETIC STORMS IN THE ODESSA MAGNETIC ANOMALY REGION WITH PLANETARY AND IONOSPHERIC STORMS DURING THE MONITORING PROGRAM AT RT "URAN-4" (1987 – 2010)

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ABSTRACT. This work is a continuation of the study of the response of the Odesa geomagnetic anomaly to the manifestations of solar and planetary geomagnetic activity. Not far from the territory of this magnetic anomaly there is the geomagnetic observatory "Odesa" and the decameter radio telescope "URAN-4" of the RI NASU. A catalogue of magnetic storms for the period 1987-1994 and 2000-2009 was compiled for the monitoring program of high-power space radio sources at RT "URAN-4" using the database of the geomagnetic observatory "Odesa". In this paper, a comparative analysis of the features of the manifestations of geomagnetic storms in the zone of the Odesa magnetic anomaly, planetary storms and ionospheric storms in the 22nd and 23rd cycles of solar activity is carried out. The main results are as follows. The magnetic anomaly amplifies the effects of regional manifestations of planetary magnetic storms. The number of different types of magnetic storms and the dynamics of their changes in the Odesa anomaly differ significantly in the 22nd and 23rd cycles of solar activity. Comparisons have shown that the duration of magnetic storms in the Odessa anomaly is longer than the duration of planetary magnetic and ionospheric storms. According to the data of the «URAN-4» radio telescope, geomagnetic storms form various manifestations of the effects of ionospheric flickers and flux changes for space radio sources depending on the time of their observations. For the region of the Odesa geomagnetic anomaly, such comprehensive studies have not been carried out before. The conducted studies will become an important basis for understanding the influence of magnetic anomalies on the dynamics of the ionosphere during periods of solar and geomagnetic activity.

Keywords: geomagnetic anomaly, geomagnetic storms, solar activity, low-frequency radio astronomy, space weather.

АНОТАЦІЯ. Дана робота є продовженням дослідження реакції Одеської геомагнітної аномалії на прояви сонячної та планетарної геомагнітної активності. Недалеко від території цієї магнітної аномалії знаходяться геомагнітна обсерваторія «Одеса» та декаметровий радіотелескоп «УРАН-4» РІ НАНУ. Для програми моніторингу потужних космічних радіоджерел на РТ "УРАН-4" з використанням бази даних геомагнітної обсерваторії "Одеса" складено каталог магнітних бур за період 1987-1994 та 2000-2009 років. У роботі проведено порівняльний аналіз особливостей проявів геомагнітних бур в зоні Одеської магнітної аномалії, планетарних та іоносферних бур у 22-му та 23-му циклах сонячної активності. Основні результати такі. Магнітна аномалія підсилює наслідки регіональних проявів планетарних магнітних бур. Кількість різних типів магнітних бур та динаміка їх зміни в Одеській аномалії суттєво відрізняються у 22-му та 23-му циклах сонячної активності. Порівняння показали, що тривалість магнітних бур в Одеській аномалії перевищує тривалість планетарних магнітних та іоносферних бур. За даними радіотелескопа «УРАН-4», геомагнітні бурі формують різні прояви ефектів іоносфери. мерехтіння та зміни потоку космічних радіоджерел залежно від часу їх спостережень. Для району Одеської геомагнітної аномалії такі комплексні дослідження раніше не проводились. Проведені дослідження стануть важливою основою для розуміння впливу магнітних аномалій на динаміку іоносфери в періоди сонячної та геомагнітної активності.

Ключові слова: геомагнітна аномалія, геомагнітні бурі, сонячна активність, низькочастотна радіоастрономія, космічна погода.

1. Introduction

The data of the geomagnetic field disturbance records in the area of the Odesa magnetic anomaly during the monitoring of the fluxes powerful space radio sources at the RT "Uran-4" from 1987-1994 and 2000-2009 were used.

Changes in the fluxes of space radio sources in the decameter range and their flickering depend on the state of the ionosphere and correlate with geomagnetic disturbances. On geomagnetic observatory "Odesa"

Institute of Geophysics NAS Ukraine since 1948 measurements of a magnetic field of Earth. Until 2009, recordings of geomagnetic field disturbances were carried out in analog mode with subsequent processing and calculation of hourly K indices.

At the same time measurements of K-index and three elements of a magnetic field (horizontal component (H), vertical component (Z) and inducement (D)) are registered. Basis of these data the catalog of magnetic storms in the 22nd and 23rd cycles of solar activity was compiled. The catalog magnetic storms for period monitoring program on RT “URAN-4” IRA NASU (1987-1994 and 2000-2009) indicates the date and time of the beginning and end of the storm, the duration of the storm, the amplitude for three elements of the magnetic field: H, Z, D, the characteristics of magnetic storms with indication of active periods. In this edition of the catalog, sum of hourly daily values measurements of the K-index have been added.

The magnetic station "Odesa" is located near a zone of a magnetic anomaly. On the other hand, Odesa magnetic anomaly located radio telescope “URAN-4” RI NANU. To identify changes in geomagnetic activity due to the presence of a magnetic anomaly, a comparative analysis of the catalogs of magnetic storms was carried out. The catalog of magnetic storms for the magnetic anomaly zone was compared with the catalogs of planetary magnetic and ionospheric storms.

From the beginning of observations in 1987 year at a radio telescope "URAN-4" the fluxes monitoring of high-power galactic and extragalactic radio sources is carried out. A comparative analysis of the catalogs is carried out in order to reveal the contribution of geomagnetic activity to the change in the flux of radio sources.

2. Geomagnetic observatory «Odesa»

The geomagnetic observatory «Odesa» was founded by the Novorossiysk Imperial University, in the territory of a Botanical Garden, at the beginning of the XX century. It was officially commissioned in 1896. In 1936 it was transferred to the village of Stepanivka (near Odesa) by the Odesa State University. World War 2th the station became to belong to the Institute of Geophysics NAS Ukraine. From 1948 to 2010, analog measurements of the Earth’s magnetic field were conducted at the «Odesa» magnetic observatory (Guglia et al., 2018). The magnetometers are located in a deep underground room, which makes it one of the best in Ukraine in terms of noise immunity, and the large distance from *Odesa* (36 km) excludes the contribution of technogenics noise to the measurements of the geomagnetic field induction. At the same time measurements of three elements of a magnetic field are registered: horizontal component (H), vertical component (Z) and declination (D). The recorded data on magnetic storms were presented in tabular form (Fig. 1).

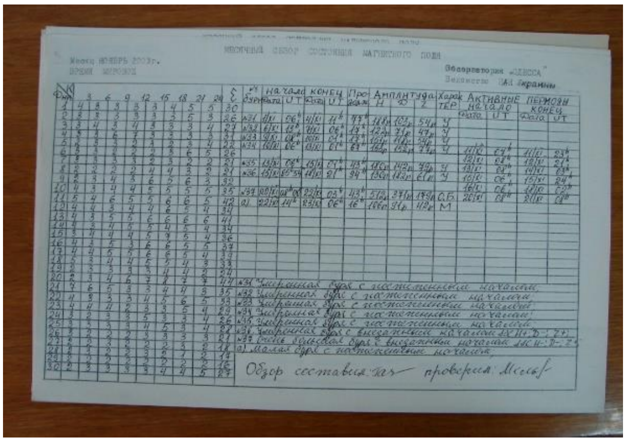

Figure 1: An example of the data table of the geomagnetic observatory "Odesa"

3. Magnetic anomaly zone

The magnetic observatory "Odesa" is situated near the intensive magnetic anomaly. Since the dome of the geomagnetic field extends to an altitude of about 90 km, into the ionosphere layer, where the variation (rapidly variable) component of the geomagnetic field is formed, regional magnetic anomalies can affect the manifestation of the variability of the geomagnetic field. When processing long-term, long-term observational data, the influence of the magnetic anomaly on the geomagnetic activity of the Earth was revealed (Maksymchuk & Orlyuk, 2018; Ryabov et al., 2019; Sukharev et al., 2018; Orlyuk et al., 2015).

The map of the distribution of the anomalous geomagnetic field over the territory of Ukraine (Orlyuk et al., 2018) is shown in Figure 2. The identification of the magnetic anomaly influence on geomagnetic activity comparison of characteristics of magnetic storms at according to the magnetic observatories "Odesa", planetary magnetic storms and ionospheric storms.

3.1. Electronic catalog of magnetic storms

On the basis of data of magnetic observatory «Odesa» the catalog the magnetic storms is made (Sobitnyak et al., 2018). This issue of the catalog for 1987-1995 and 2000-2009 years include: date and time of the beginning and end of a storm, the storm duration, and amplitude on three elements of a magnetic field are specified: H, Z, D, the characteristic of magnetic storms with the indication of the fissile periods (Orlyuk et al., 2009).

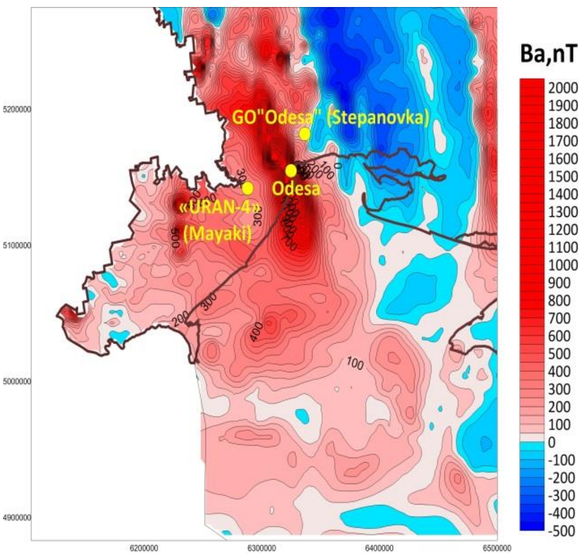

Figure 2: Map of the Odesa Magnetic Anomaly Zone

Figure 3: Radio telescope «URAN-4» IRA NASU

The catalog was compiled to identify the reasons for the change in the level of the flux of space radio sources, according to observations at the «URAN-4» radio telescope at the Odesa Observatory of the Radio Astronomy Institute of the National Academy of Sciences of Ukraine (Figure 3), which have been carried out since 1987.

Data on changes in the fluxes of powerful radio sources during periods of extreme states of solar activity are presented in (Sobitnyak et al., 2017). In paper Sobitnyak et al. (2017) also presents the results of calculating multiple correlation analysis models, which demonstrates the dependence of changes in the radio sources fluxes on the main indicators characterizing the state of space weather.

The total number of minor, moderate, strong and extreme storms shown Figure 4 (Period 22 solar cycle) and Figure 5 (period of 23 solar cycle).

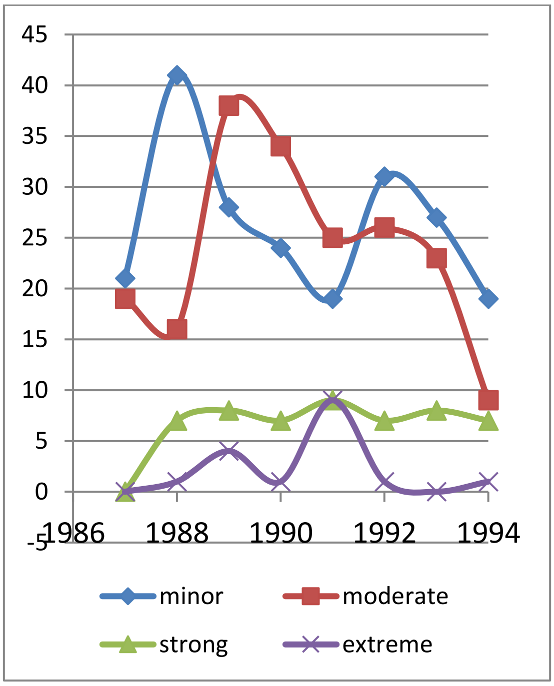

Figure 4: The number of magnetic storms in the Odesa magnetic anomaly in the 22nd cycle of solar activity.

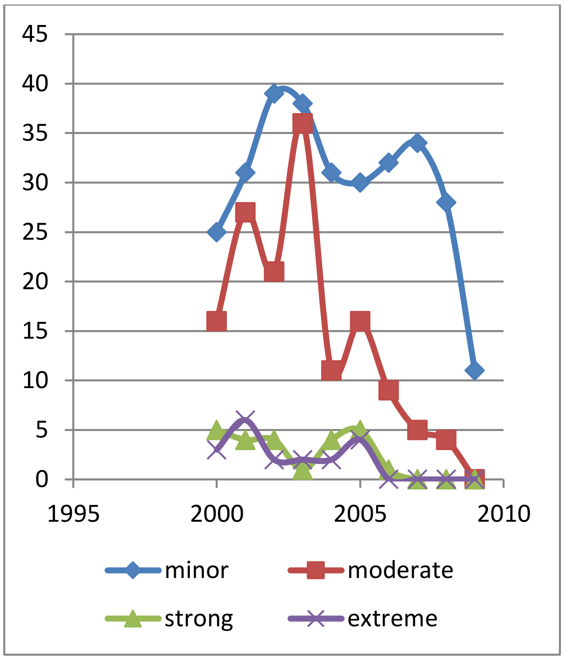

Figure 5: The number of magnetic storms in the Odesa magnetic anomaly in the 23nd cycle of solar activity

It is interesting that the maximum number of different types of magnetic storms in the zone of the Odesa magnetic anomaly falls on different phases of the solar cycle. Moreover, these trends differ in the 22nd and 23rd solar cycles.

Thus, in the 22-nd cycle, the number of minor magnetic storms shows a maximum in the growth phase of the cycle in 1988 (41 storms) and in the decline phase of the cycle in 1992 (31 storms). Moderate magnetic storms show a maximum number of them (38 storms) in the year of the maximum of the cycle in 1989 and a consistently high level of their number (23 – 26 storms) during the decline of the solar cycle in 1991-1993. Strong magnetic storms in cycle 22 are characterized by changes in their number in the range from 7 to 9 during the growth phase to the maximum and the phase of decline. The maximum number of extreme magnetic storms in cycle 22 was recorded during the maximum of the cycle in 1991 (9 storms).

The 23rd solar cycle is characterized by other trends in the distribution of the annual number of different types of magnetic storms. Thus, for minor magnetic storms, the maximum number of magnetic storms was observed during the maximum cycle in 2002 (39 storms) and the recession phase in 2003 (38 storms). The additional period of maximum number of minor magnetic storms was in the phase of the cycle decline in 2007 (34 storms). At the same time, the period with an annual number of storms of more than 30 (from 2001 to 2008) was quite long.

The number of moderate magnetic storms in cycle 23 is characterized by the presence of three maxima: in 2001 (27 storms), 2003 (36 storms), 2005 (16 storms). Strong magnetic storms were most severe during the maximum of the cycle in 2000-2022 (4-5 storms per year). The number of extreme magnetic storms peaked in 2001 (6 storms) and 2005 (4 storms).

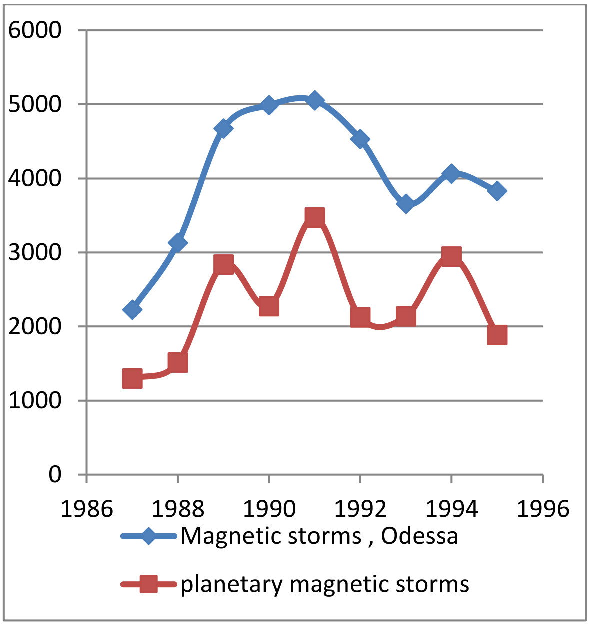

Figure 6: The total annual duration (in hours) of magnetic storms in the zone of the Odesa magnetic anomaly and planetary magnetic storms (22 cycles of solar activity).

3.2. Comparative analysis of the duration of magnetic storms in the zone of the Odesa magnetic anomaly with planetary magnetic storms

The peculiarities of the manifestation of magnetic storms in the Odesa magnetic anomaly are clearly manifested in the comparison of their total annual duration with similar data for planetary magnetic and ionospheric storms.

Figure 6 shows a comparison of these values for period 22-th of the solar cycle. Here, the total annual duration of magnetic storms in the zone of the Odesa magnetic anomaly significantly exceeds the duration of planetary magnetic storms. The maximum annual duration of magnetic storms in the Odesa magnetic anomaly is 5,000 hours (reached during the maximum of the 22nd solar cycle with a separate maximum at the phase of the cycle decline (1994 at the level of 4,000 hours). Planetary magnetic storms are characterized by the presence of three maxima in 1989 (3,000 hours), 1991 (3,500 hours) and the decline phase of the cycle in 1994 (3,000 hours).

Another trend appeared in the 23rd solar cycle (Fig. 7). Here, the maximum duration of magnetic storms in the Odesa magnetic anomaly, planetary storms (4,000 hours) was recorded at the phase of the cycle decline in 2003. The same trend is characteristic of ionospheric storms (lasting about 3,000 hours). The secondary maximum for all storms also occurred during the decline phase of the cycle in 2005.

In the period from 2017 to 2023, the magnetometer of the Institute of Geophysics of NASU measured the dynamics of geomagnetic storms and disturbances in the center of the Odesa magnetic anomaly (territory of the Astronomical Observatory of Odesa I.I. Mechnikov National University) and in the location of the radio telescope "URAN-4" of IRA NASU.

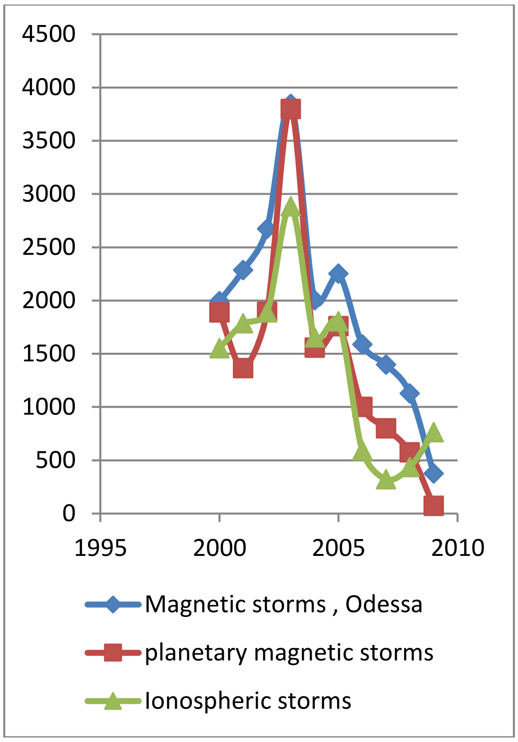

Figure 7: The total annual duration (in hours) of magnetic storms in the zone of the Odesa magnetic anomaly, planetary magnetic and ionosphere storms (22 cycles of solar activity)

The magnetic anomaly is strong enough for the dome of the anomalous field to be detected at a high altitude, about 100-150 kilometers according to high-precision satellite observations. Thus, it can affect the formation of ionospheric inhomogeneities, acoustic and "gravitational" ionospheric waves. The analysis of long-term data showed that even the classic solar-diurnal fluctuations of the geomagnetic field in the Odesa region differ from those in other regions, GO «Kyiv» (Dymer vill., Kyiv reg.) and GO «Lviv» (Yavoriv vill., Lviv reg.). The Odesa geomagnetic anomaly appears to be the only regional anomaly where the URAN-4 low-frequency telescope and the GO «Odesa» (Stepanivka vill., Odesa reg.) are located. Already the first works on the analysis of long-term data of geomagnetic variations showed that in the Odesa region the structure and manifestation of fast geomagnetic variations with periods of 1-2 minutes and 30-5 seconds are much different from the Lviv and Kyiv regions. For example, in the Odesa region, there are much more manifestations of quasi-periodic geomagnetic variations with periods of 1 minute - 30 seconds during geomagnetic storms. Also, the manifestation of geomagnetic pulsations of the Pc3 and Pc4 type during extreme magnetic storms is much clearer in measurements in Odesa than in other Ukrainian geomagnetic measurement points.

The range of periods of geomagnetic pulsations of the Pc5 type is from 150 to 600 seconds. They are usually caused by magnetospheric currents associated with magnetic storms. Pc5 type pulsations are the strongest and longest of regular geomagnetic pulsations. Pc5 pulsations effectively transfer solar wind energy into the magnetosphere and further into the ionosphere. During the powerful geomagnetic storms of 2022-2023, according to the data of the LEMI-008 magnetometer, which was installed at the Odesa Astronomical Observatory, the structure of frequency-time changes of Pc5-type pulsations, which have a range of periods from 150 to 600 seconds, and their amplitude of tens nanotesla, were studied. They are commonly observed during magnetic storms, when streams of solar wind and charged particles reach Earth's magnetosphere. Pulsations of the Pc5 type arise as a result of the interaction of these flows with the Earth's magnetosphere, which leads to the formation of electric currents. These currents, in turn, cause disturbances in the geomagnetic field. This is a fairly new work, and previously, there were no such detailed studies of the dynamics of fast geomagnetic variations and the features of their manifestation in geomagnetic storms of different types and strengths for the Odesa geomagnetic anomaly. In addition, dozens of manifestations of unusual wave activity were investigated in the range of periods from 3 hours to 1 hour, which appeared in the form of long-lived quasi-periods with a change in the value of the period and amplitude within 1-2 days (Sukharev et al., 2022; Sobitnyak et al., 2014).

4. Conclusion

1. On the base of data of geomagnetic observatory «Odesa» the catalog the magnetic storms is made. This issue of the catalog for 1987- 1995 and 2000-2009 years include: date and time of the beginning and end of a storm, the storm duration, amplitude on three elements of a magnetic field are specified: H, Z, D, the characteristic of magnetic storms. In the latest edition, the catalog has been supplemented with data on the daily total values of the K- index.

2. The comparison duration of magnetic storms according to the geomagnetic observatory "Odesa" is longer than at planetary magnetic and ionosphere storms in period 22 and 23 solar cycles.

3. The dynamics of the data on the number of types of magnetic storms in the zone of the Odesa magnetic anomaly in cycles 22 and 23 differs significantly.

4. Thus, the Odesa magnetic anomaly significantly intensifies the ionospheric effects of solar and geomagnetic activity.

5. It is planned to create a catalog of magnetic storms according to the Odesa station for the entire monitoring period of space radio sources at the RT «URAN-4» in order to identify manifestations of geomagnetic disturbances during radio astronomical observations and their contribution to changes in radio source fluxes on decameter waves.

6. These studies will be supplemented by a comparative analysis of the characteristics of magnetic storms in the magnetic anomaly zone (Odesa) with data from other magnetic observatories.

References

Guglia L.I., Orlyuk M.I., Ryabov M. I., Suharev A.L., Orliuk I.M.: 2013, *Odessa Astron. Publ*., **26**, No. **2**, 263.

Maksymchuk V., Orlyuk M.: 2018, *COBS Journa*l (Special Issue: IAGA Workshop 2018), No. **5**, 49.

Orliuk M., Sumaruk Yu., Sumaruk T., Romenets A., Melnychuk I.: 2009, in *Proc. of the IAGA11th Scientific Assembly in Sopron*, Hungary.

Orlyuk M. I., Romenets A., Marchenko A., Orliuk I. M., Ivashchenko I.: 2015, *Geofizicheskiy Zhurnal*, **37**, No. **2**, 73. DOI: https://doi.org/10.24028/gzh.0203-3100.v37i2.2015.111307.

Orlyuk M., Marchenko A., Romenets A., Bakarjieva M.: 2018, *COBS Journal* (Special Issue: IAGA Workshop 2018), No. **5**, 40.

Ryabov M.I., Sukharev A.L., Orlyuk M.I., Sobitnyak L.I., Romenets A.A.: 2019, *Radio Phys. Radio Astron.*, **24**, No. **1**, 68. DOI: https://doi.org/10.15407/rpra24.01.068.

Sobitnyak L.I., Ryabov M.I., Sukharev A.L., Orlyuk M.I., Orliuk I.M., Romenets A.A.: 2014, *Odessa Astron. Publ*., **27**, Iss. 1, 101.

Sobitniak L.I., Ryabov M.I., Sukharev A.L., Panishko S.K.: 2017, *Radio Phys. Radio Astron*., **22**. No. 4, 294. DOI: https://doi.org/10.15407/rpra22.04.294

Sobitnyak L.I., Ryabov M.I., Sukharev A.L., Orlyuk M.I., Romenets A.O., Sumaruk Yu.P.: 2018, *Odessa Astron. Publ*., **31**, 163. DOI: https://doi.org/10.18524/1810-4215.2018.31.146662.

Sukharev A.L., Orlyuk M., Ryabov M.I., Romenets A.A.: 2018, Radio phys. radio astron., **23**. No. **2**, 116. DOI: https://doi.org/10.15407/rpra23.02.116.

Sukharev A., Orlyuk M., Ryabov M., Sobitniak L., Bezrukovs V., Panishko S., Romenets A.: 2022, Astron. & Astrophys. Trans., **33**, Iss. **1**, 67.