DOI: 10.31401/WS.2020.proc.12

Variations of the Ionosphere Scintillation Parameters on the Observations of the Cosmic Radio Sources at the Decameter Wave Range During Two Cycles of the Solar Activity

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Abstract.

Effect of the ionosphere scintillations is caused by interaction of ionosphere plasma with radio emission that propagating through ionosphere and it is very essential at decameter radio wave range. Scintillations are reflected the state of irregularity structure of ionosphere in the time and in the certain place and thus they are connected with cosmic weather. Index (intensity), period (characteristic time) and also spectral index (slope of the time spectrum of intensity fluctuations) are used as characteristics of the scintillations. Estimations of the indices, periods and spectral indices of the ionosphere scintillations were obtained on the observations of the power cosmic radio sources on the radio telescope URAN-4 at the frequencies 20 and 25 MHz for two time intervals from 1998 up to 2007 and from 2011 up to 2018. These time intervals are coinciding to a large extent with 23-th and 24-th cycles of the solar activity. This data allowed the studying of the long time variations of the irregularity structure of ionosphere that can be attributed to the category of cosmic climate and as well allow the investigations their connection with other parameters of the cosmic climate. Also the variations of the ionosphere scintillation parameters are considered for several time intervals during two cycles of the solar activity.

Introduction

Investigations of the variations of the cosmic weather components during time intervals comparable to duration of solar cycle allow getting more clear understanding about interconnection of active processes that occurred on the Sun and in the near-earth space. In particular, the variations of parameters of ionosphere scintillations which are part of the cosmic weather reflect the state of the irregularity structure of ionosphere. In early investigations that carried out in the equatorial and polar regions where scintillation effect expressed most strongly it was found that scintillations with large intensity sooner appeared during increasing of solar activity [Aarons J., 1982]. In the region of middle latitudes where scintillations are considered weak the investigations of ionosphere scintillations are not such numerous [Kintner P. M. et al, 2007]. Interaction of the parameters of the midlatitude ionosphere scintillations with the indices of solar and geomagnetic activity expressed not so clearly. Long series of measurements of the parameters of ionosphere scintillations were obtained from observations of the power cosmic radio sources on radio telescope of decameter wave range URAN-4 during two time intervals that coincide to a large extent with periods of two cycles of the solar activity. This data permits researching of long duration variations of irregularity structure of ionosphere that can be attributed to the category of cosmic climate. Further in the works the behavior of parameters of ionosphere scintillations during 23th and 24th cycles of solar activity were analyzed and also the comparison of these parameters with others indices of cosmic climate was fulfilled.

Observations data

Observations of the power cosmic radio sources – 3C144, 3C274, 3C405, 3C461 – are carry out on the radio telescope URAN-4 at frequencies 20 and 25 MHz in monitoring regime. They have compact components that scintillate on ionosphere irregularities. The most complete series of observations with digital registration of data were obtained during two time intervals and information about them presented in Table 1. In result of the processing of radio source records the parameters of ionosphere scintillations were obtained for each record: *SI* – index; *ST* – characteristic time (period); *SP* – spectral index. The observation technique and processing method are presented in work [Derevyagin V. G. et al, 2019]. These parameters were compared with indices of solar and geomagnetic activity – with solar flux at radio wave 10.7 cm *F10* and with planetary *Ap*-index.

Table 1. Characteristics of the solar cycles and the time intervals of observations

Number of cycle	Start date	Finish date	Date of maximum	*F10*, SFU	*Ap*	Time intervals of observations
23	05.1996	12.2008	11.2001	119.8	12.1	1998-2007
24	12.2008	05.2019	04.2014	99.6	8.0	2011-2018

Also the characteristics of two solar activity cycles are presented in Table 1. Values of solar flux measured in Solar Flux Units (SFU). Proceeding from the mean over the cycle values of solar flux and of index *Ap* you can see that the level of solar and geomagnetic activity much decreases in 24th cycle in comparison with 23th cycle. As can see from Table 1 observation intervals in a large extent coincide with periods of 23th and 24th solar cycles.

Results and their discussion

Mean values of parameters of ionosphere scintillations calculated over the cycle for 4th radio sources during 23th and 24th solar cycles are showed on Fig. 1. For regulation data for sources placed in dependence of right ascension of radio source. Total form of graphics is similar for both cycles. As peculiarities the following can be noted. Values of scintillation index at two frequencies change in larger limits in 24th cycle in comparison with 23th. At frequency 25 MHz values of index *SI* decreased in 24th cycle and in case of frequency 20 MHz the situation is not so clear. Values of scintillation period *ST* increased in 24th cycle for two radio sources that observed on the lower heights (3C144, 3C274) and they do not change for radio sources that observed near zenith (3C405, 3C461). On the one hand such combination testifies to invariability of mean over the cycle drift speed of irregularities. On the other hand, one can assume that changing for 3C144 and 3C274 was associated with anisometry of ionosphere irregularities which was higher in 24th cycle that can be caused by the lower geomagnetic activity. Values of spectral index *SP* increased or do not changed for 'low' sources and decreased for 'high' sources.

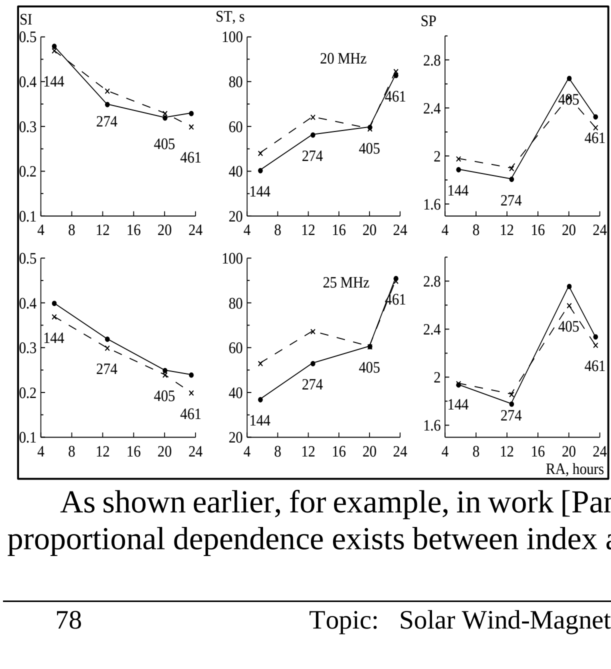

Fig. 1. Mean of the ionosphere scintillation parameters over the cycle for 4th radio sources during 23th (dots and solid lines) and 24h (crests and dash lines) cycles of the solar activity at frequency 20 MHz (top) and at frequency 25 MHz (bottom). Abscissa axis – right ascension of the radio source

As shown earlier, for example, in work [Panishko S. K., Lytvynenko O. A., 2109] inversely proportional dependence exists between index and period of ionosphere scintillations therefore only values of index and spectral index will be considerate in further analysis. Investigating parameters of ionosphere scintillations have notable daily-seasonal dependence [Lytvynenko O. A., Panishko S. K., 2015] consequently the meaning of parameter values over year was used that allowed smoothing the daily-seasonal dependence.

Graphics of yearly mean values index and spectral index of ionosphere scintillations for 4th radio sources at two frequencies during 23th and 24th solar cycles were showed in Fig. 2 and 3. As you can see from figures the graphics of both index and spectral index cannot be interpreted unambiguously. In order to show the behavior of spectral index during 23th cycle of solar activity in work [Panishko S. K., Lytvynenko O. A., 2109] data was transformed in the following way. The polynomials of second order fitted to the yearly mean series of values of indices *SI*, *SP*, *F10* and *Ap* for designation of low frequency trend. These trends were normalized to maximum value. Graphics of obtained rows are showed in Fig. 4 and 5 but already for two cycles of solar activity.

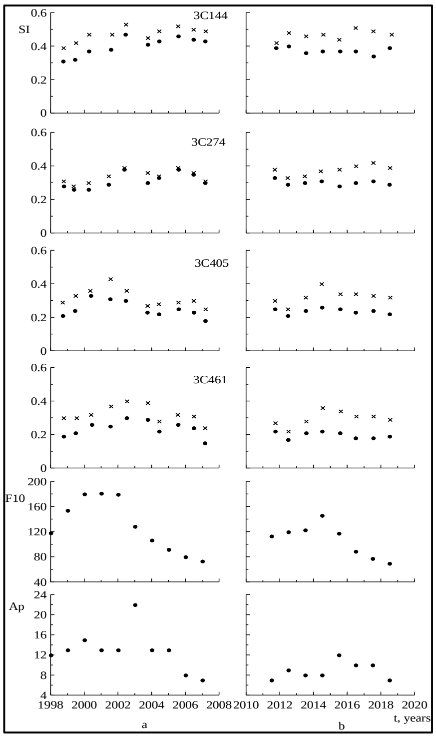

Fig. 2. Yearly mean indices of the ionosphere scintillations for 4th radio sources: data at frequency 20 MHz marked by crests, at frequency 25 MHz – by dots. Graphics of solar flux on wavelength 10.7 cm (in SFU) and geomagnetic Ap-index are presented on the bottom, a – data

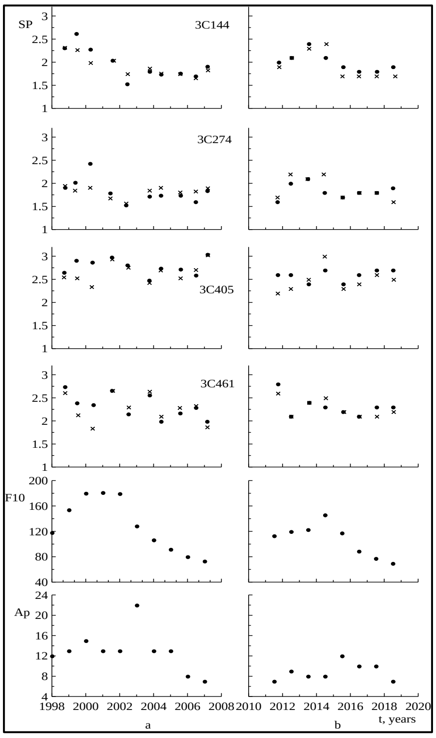

Fig. 3. Yearly mean spectral indices of the ionosphere scintillations for 4th radio sources: data at frequency 20 MHz marked by crests, at frequency 25 MHz – by dots. Graphics of solar flux on wavelength 10.7 cm (in SFU) and geomagnetic Ap-index are presented on the bottom, a – data

In general, the trends of scintillation index during 23th cycle follow to trends of the indices of solar and geomagnetic activity with the exception of that the curves for two 'low' radio sources descend slower on the falling part of the cycle. During 24th cycle such behavior continues in the case of two 'high' radio sources. The rest data sooner is characterizes by the small correlation or weak anti-correlation. The values of spectral index change less than values of scintillation index during both cycles. The distinction in the behavior of this parameter is that the notable anti-correlation changes to the small correlation with the trends of solar radio flux and geomagnetic index.

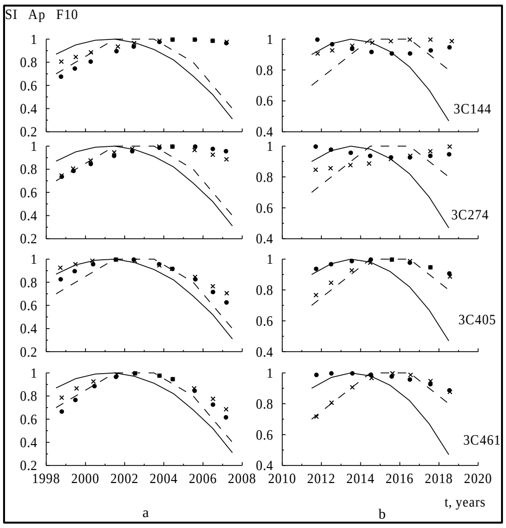

Fig. 4. Trends of the yearly mean values of index of scintillations, solar flux F10 (solid lines) and Ap-index (dash lines). Data at frequency 20 MHz marked by crests, at frequency 25 MHz – by dots; a – data for 23th, b – for

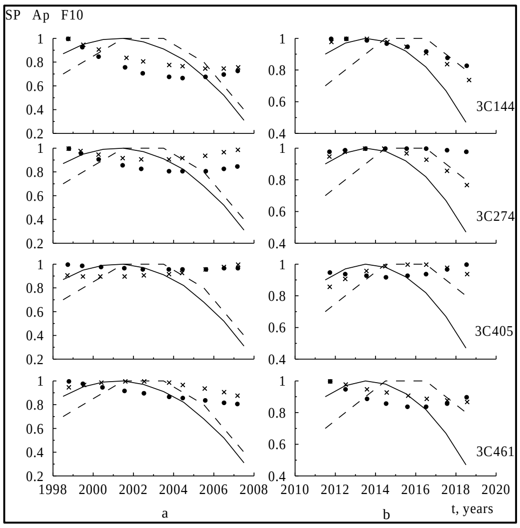

Fig. 5. Trends of the yearly mean values of spectral indices of scintillations, solar flux F10 (solid lines) and Ap-index (dash lines). Data at frequency 20 MHz marked by crests, at frequency 25 MHz – by dots; a – data for 23th, b – for 24th

Conclusions

The analysis of behavior of the yearly mean values of index and spectral indices of ionosphere scintillations on observations obtained on the radio telescope URAN-4 of power cosmic radio sources – 3C144, 3C274, 3C405, 3C461, at the frequencies 20 and 25 MHz during 23th and 24th solar cycles was fulfilled. The distinction is observes in the behavior of the ionosphere scintillation characteristics during the investigating cycles of solar activity. Scintillation index sooner follows to trends of indices of solar and geomagnetic activity during 23th cycle and scintillation index values have weak anti-correlation with them in 24th cycle. Spectral index is more characterizes by the small anti-correlation in 23th cycle and by the weak correlation in the next. This data agrees with others investigations which carried out in the region of the midlatitude ionosphere [Aarons J., 1982]. The preliminary conclusion was made about the increasing of the anisometry of ionosphere irregularities in 24th solar cycle.

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