Baltic Astronomy, vol. 20, 609–612, 2011

THE INFLUENCE OF SOLAR SPECTRAL LINES ON ELECTRON CONCENTRATION IN TERRESTRIAL IONOSPHERE

A. Nina[1], V. Čadež[2], V. A. Srećković[1] and D. Šulić[3]

[1] *Institute of Physics, University of Belgrade, Pregrevica 118, Zemun, 11080 Belgrade, Serbia; sandrast@ipb.ac.rs*

[2] *Astronomical Observatory, Volgina 7, 11060 Belgrade, Serbia; vcadez@aob.rs*

[3] *Faculty of Ecology and Environmental Protection, Union – Nikola Tesla University, Cara Dušana 62, 11000 Belgrade, Serbia; dsulic@ipb.ac.rs*

Received: 2011 August 8; accepted: 2011 August 15

Abstract. One of the methods of detection and analysis of solar flares is observing the time variations of certain solar spectral lines. During solar flares, a raise of electron concentration occurs in Earth's ionosphere which results in amplitude and phase variations of the recorded very low frequency (VLF) waves. We compared the data obtained by the analysis of recorded VLF signals and line spectra for different solar flares. In this paper we treated the DHO VLF signal transmitted from Germany at the frequency of 23.4 kHz recorded by the AWESOME system in Belgrade (Serbia) during solar flares in the period between 10:40 UT and 13:00 UT on 2011 April 22.

Key words: solar flares, line spectra, terrestrial ionosphere

1. INTRODUCTION

Solar radiation has a dominant external influence on the sunlit Earth's atmosphere. The rate of photo-ionization processes in the ionosphere depends on composite particles as well as on the solar radiation spectrum at the considered altitude. The data on some solar spectral lines could be of significant importance in studies of solar flares (see Valníček & Ranzinger (1972) and references therein). For example, Valníček & Ranzinger (1972) studied the observed widths of the Hα line for different types of flares.

During the transmission through the terrestrial atmosphere, the solar radiation is being attenuated and, at the altitude of about 70 km, only X-rays and Lyman α line remain important, i.e., with sufficient energy to induce a noticeable photo-ionization of particles in the ionospheric D-region. The main subject of this paper is a study of the intensity of these lines and comparison of their time dependences on the corresponding electron concentrations in the cases of unperturbed and perturbed ionosphere during different solar flares.

The electron concentration of plasma was calculated by using the developed and elaborated method in Grubor et al. (2008), Zigman et al. (2007) and Sulic

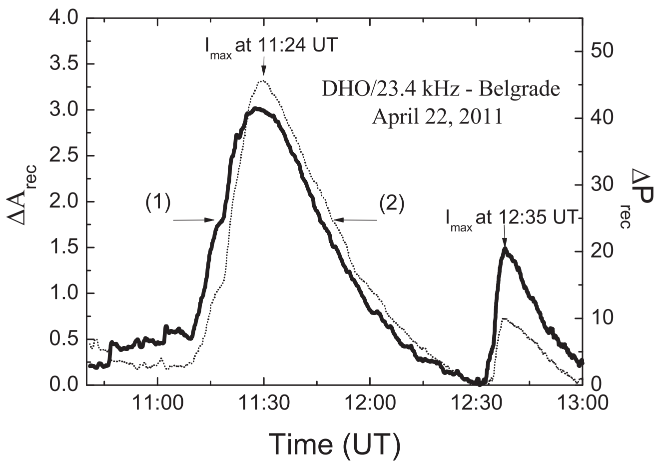

Fig. 1. Perturbed amplitude (1) and phase (2) of a signal emitted from DHO transmitter (Germany) and recorded by the AWESOME receiver in Belgrade (Serbia) during the observed flares. Null values correspond to the amplitude and phase recorded for the unperturbed ionosphere.

et al. (2010). These calculations are based on electron concentration influence on propagation properties of very low frequency (VLF) waves. We used the time-dependent solar spectrum during solar flares according to the model presented in Chamberlin et al. (2008).

2. THEORY AND RESULTS

Within the time interval 10:40 – 13:00 UT on 2011 April 22 the DHO signal (transmitted from Germany at frequency 23.4 kHz), recorded at Belgrade station, has two dominant amplitude and phase increases. The measurable features of the VLF signal refers to the change in amplitude $\Delta A_{\rm rec}$, measured in dB, relative to the ambient levels prior to the event. The associated phase change $\Delta P_{\rm rec}$ is measured too (Figure 1).

To calculate the electron concentration $N(t,h)$ in the D-region at the altitude h, we used the equation (Wait 1964):

$$N(t,h) = 1.43 \cdot 10^{13} e^{-0.15H'(t)} e^{(\beta(t)-0.15)(h-H'(t))} \, . \tag{1}$$

The parameters of the Wait model of ionosphere, the reflection height $H'(t)$ and sharpness $\beta(t)$, are calculated by the LWPC computer program (Ferguson 1998). The time distributions of the electron concentration at four altitudes, where the dominant electron gain and electron loss processes are the photo-ionization and recombination, respectively, are presented in Figure 2. One can see that at higher altitudes the photo-ionization processes strongly dominate the recombination ones. Enhancements of $N(t,h)$ result from increased solar radiation but the question remains which particular lines in solar irradiance spectrum are important for the photo-ionization processes in D-region. In introduction, we noted that these can be the lines in the X-ray spectrum and Lyman α line. The time distribution of these lines is presented in Figure 3. Here we can see that two X-flares and two increases of the Lyman α line intensity (121.5 nm curve) occurred within the observed time

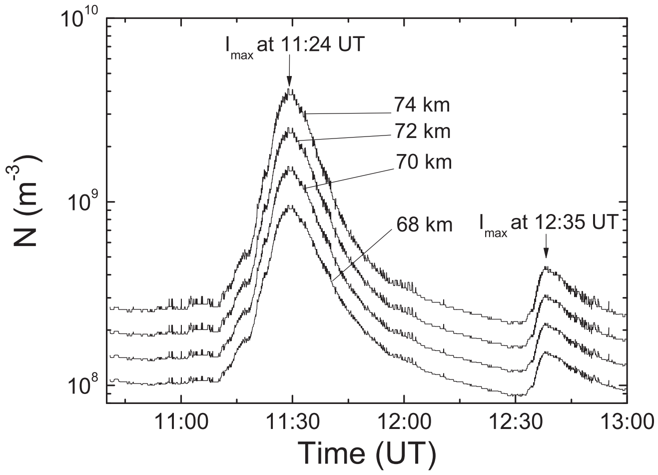

Fig. 2. Electron concentrations at different altitudes related to the two flares of classes C7.7 and C3.0.

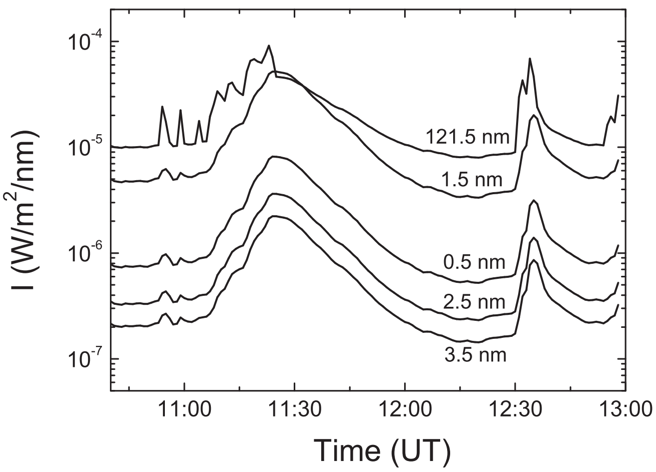

Fig. 3. Time distribution of the solar radiation intensity I which has the dominant role in perturbing the ionospheric D-region.

interval. Comparing Figure 2 with Figure 3 we can notice that the peaks in the time distribution of the electron concentration follow the time variation pattern of the X-ray emission but not that of the Lyman α line intensity. This leads to a conclusion that the influence of the X-ray spectrum lines is dominant for electron concentration at ~ 70 km altitudes. Two intensity maxima of all considered X-ray spectral lines occur at 11:24 UT and 12:35 UT, which is 5 min before the corresponding maxima which appear in the electron concentration curve.

The spectrum of solar radiation below 150 nm, presented in Figure 4, shows that the analyzed lines in Figure 3 exhibit a larger rise of intensity than the other lines in the time interval of two maximum X-ray intensities occurring at 11:24 UT and 12:35 UT. Also, we can see that the first X-ray flare produced the higher line

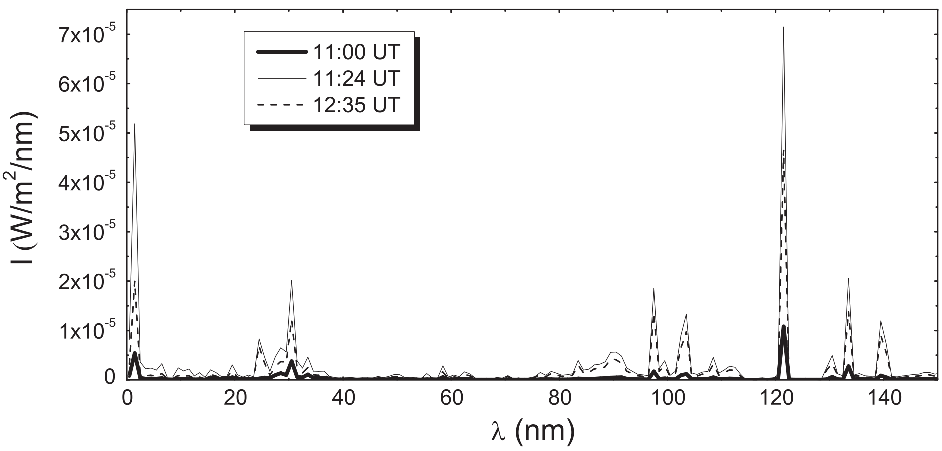

Fig. 4. Spectrum of the solar radiation for the unperturbed ionosphere (dotted line), at the maximum of the first flare (dashed line) and at the maximum of the second flare (solid line).

intensities which followed by a higher rise of electron concentration.

3. CONCLUSIONS

The analyzis yields to a conclusion that the dominant influence on the enhancement of the electron concentration in the D-region during the observed solar flares was due to the increased intensity of radiation lines in the X-ray spectrum, i.e., X-ray flares with larger line intensities produce larger rises of electron concentration. This conclusion follows from the fact that the rate of the photo-ionization process is higher than that of the recombination process within the time interval between the start of the irradiance increase to a few minutes after the irradiance maximum. In the case of these two flares, the maximum of electron concentration occurred after the appearance of the maximum intensity of lines produced by the X-ray flares.

ACKNOWLEDGMENTS. The authors are thankful to the Ministry of Education and Science of the Republic of Serbia for support (project Nos. III 44002, 176002, 176004).

REFERENCES

Chamberlin P. C., Woods T. N., Eparvier F. G. 2008, Space Weather, 6, S05001
Ferguson J. A. 1998, Space and Naval Warfare Systems Center, San Diego, CA
Grubor D., Šulić D., Žigman V. 2008, Annales Geophysicae, 26, 1731
Šulić D., Nina A., Srećković V. 2010, Publ. AO Belgrade, 89, 391
Valníček B., Ranzinger P. 1972, Bull. Astron. Inst. Czechoslovakia, 23, 318
Wait J. R., Spies K. P. 1964, National Bureau of Standards, Technical Note, 300
Žigman V., Grubor D., Šulić D. 2008, J. Atmosph. & Solar-Terrestrial Physics, 69, 775