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ПРОЯВЛЕНИЯ ПЕРЕКРЫТИЯ КОЛЬЦЕВОГО ТОКА С ВНЕШНЕЙ ПЛАЗМОСФЕРОЙ В ДИНАМИКЕ SAR-ДУГИ И ПУЛЬСИРУЮЩИХ СИЯНИЙ

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MANIFESTATIONS OF A RING CURRENT OVERLAP WITH THE OUTER PLASMASPHERE IN SAR ARC AND PULSING AURORAE DYNAMICS

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Фотометрические наблюдения на меридиане Якутска (CGMC: 55–60° N, 200° E) показали, что во время фазы восстановления суббури на широтах SAR-дуги обычно наблюдаются всплески пульсаций свечения в эмиссии 427.8 нм. Эти пульсации отображают пульсирующие высыпания энергичных частиц кольцевого тока в области внешней плазмосферы. В этой работе, мы предлагаем возможный механизм возбуждения наблюдаемых пульсаций свечения. Рассмотрены несколько примеров наблюдений пульсаций свечения с частотами 0.05–1 Гц на широтах диффузного сияния и SAR-дуги.

Photometric observations at the Yakutsk meridian (CGMC: 55–60° N, 200° E) have shown that during the substorm recovery phase at latitudes of SAR arc the luminosity pulsation splashes in the 427.8 nm emission are usually observed. These pulsations map the pulsating precipitations of the ring current energetic particles in the outer plasmasphere. In this report we consider possible mechanisms for the observed luminosity pulsations. Few events of the luminosity pulsation observation with frequencies of 0.05–1 Hz at the latitudes of diffuse aurora and SAR arc are considered.

1. Introduction

The pulsating precipitations can be caused by electromagnetic ion-cyclotron (EMIC) waves due to the modulation of the pitch-angle diffusion and, consequently, particle flux in the loss cone with the wave frequency. We have performed the analysis of dependence of frequency of EMIC wave on the energy of the H^+ and O^+ ring current ions.

2. Methods and Results of Observations

The observation of DA and SAR arcs is carried out using the digital meridian-scanning photometer (MSP) with two channels of parallel registration of the 630.0 and 557.7 nm [OI] emissions. In order to analyze, the MSP data are presented in this work as isophots of the surface brightness of the 557.7 and 630.0 nm emissions in a projection to the Earth's surface for the luminosity heights of 110 (DA) and 450 (SAR arc) km, respectively (keograms). The keograms were calculated without taking into account the Van Rhijn effect.

The registration of pulsating variations of the N_2^+ band intensity (391.4 and 427.8 nm) in the nightglow and the diffuse aurora with a high time resolution (sampling frequency of 10–100 Hz) was carried out by four wide-angle photometers with fields of view of 20° and frequency characteristic widths of 0-10 Hz. Luminosity pulsations were registered at fixed zenith angles 45° S, 45° E, 0° (Z) and 73° N. The registration of the 427.8 nm and 630.0 nm emissions intensity in the magnetic zenith was carried out by four channel photometer.

Time intervals for a substorm expansion phase were identified using magnetograms at the low-latitude stations.

In fig. 1 shows the observation example of the subauroral luminosity dynamics on March 30, 2003. The DA equatorward extension occurred during the magnetospheric convection enhance in the evening sector MLT (see fig. 1, a). The substorm expansion phase onset at 1516 UT causes the red band formation (smearing SAR arc) equatorward of DA in the 557.7 nm emission (see fig. 1, b). Increase of the 630.0 nm emission intensity in the magnetic zenith of station took place during the extension of red band. From ~1545 UT the zenith photometer registered splashes of the 427.8 nm emission intensity at the red band latitudes. In the 630.0 nm emission these splashes were not observed(see fig. 1, c).

In fig. 2 the second example of photometric observations shows of the DA and SAR arc dynamics during the night of February 11, 2000. From 1430 UT took place the smoothly brightening and equatorward expansion of DA in the 557.7 nm emission. The intensification of quasi-stationary activity caused the formation of the red band and the short-term SAR arc equatorward of the observation station zenith. In the region of an amplified red luminosity at 16:30–19:00 UT the intensity splashes of the 427.8 nm emission were observed.

3. Spectral analysis of the observations data with a high time resolution

Fig. 3 shows the analysis example of photometric observations of the particle pulsating precipitations on March 30, 2003 (First situation). In fig. 2 it is seen that from 15:20 UT the N-photometer registered luminosity pulsations in the region of active DA after the onset of substorm expansion phase (see fig. 1). From 15:45 UT on the zenith and on the east observed the splashes of quasi-harmonic pulsations with discrete maxima in the power spectrum at frequencies from 0.3 to 0.8 Hz. These luminosity pulsations were developed at the red band latitudes equatorward of DA.

Fig. 4 shows the Dynamic spectra of luminosity pulsations at the latitudes of diffuse aurora and SAR arc on February 11, 2000 (Second situation). The development of luminosity pulsations began at ~ 16:30 UT synchronously on three directions. The N-photometer registered the pulsations in DA while Z- and S-photometers at latitudes of a forming SAR arc. Dynamic spectra of the pulsations in three directions are similar and have discrete maxima in the frequency range of 0.05–0.1 Hz. The amplitude of harmonics in DA is greater on the order of the amplitude of harmonics at latitudes of the SAR arc.

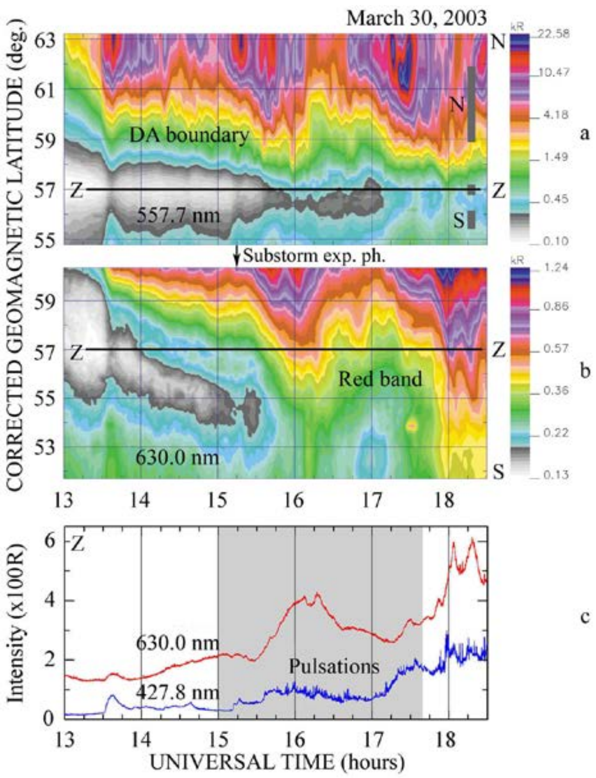

Fig. 1. Dynamics of the subauroral luminosity on March 30, 2003. (a) and (b) MSP data as keograms in the 557.7 and 630.0 nm emissions. In the keogram in the 557.7 nm emission the location of view field of photometers for the N_2^+ emissions registration is shown. Z is zenith of observation station. (c) Plots of the 427.8 nm and 630.0 nm emissions registered in magnetic zenith of the station.

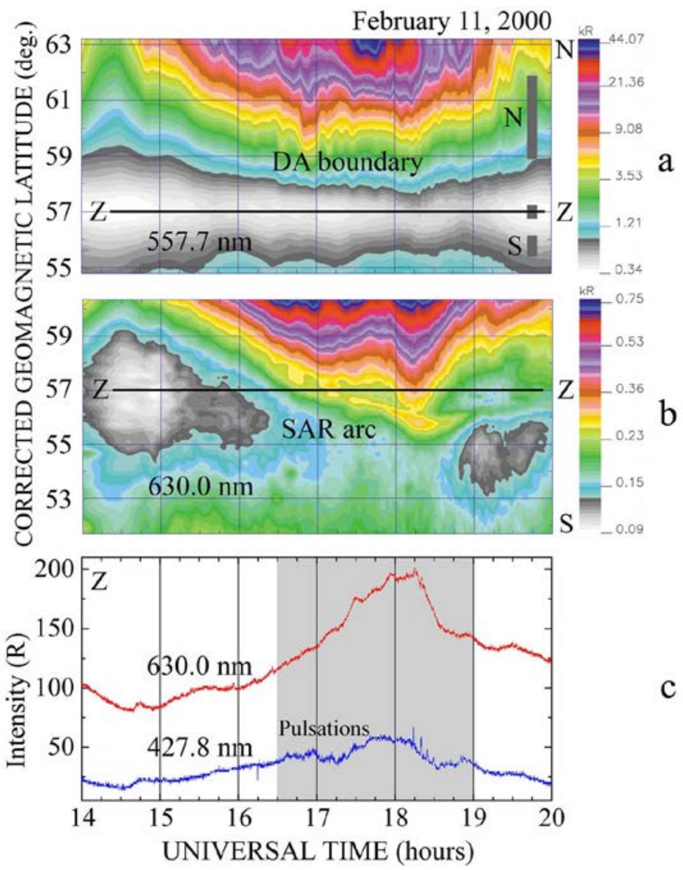

Fig. 2. Observation of luminosity pulsations at the latitudes of diffuse aurora and SAR arc on February 11, 2000. The data are presented as in fig. 1.

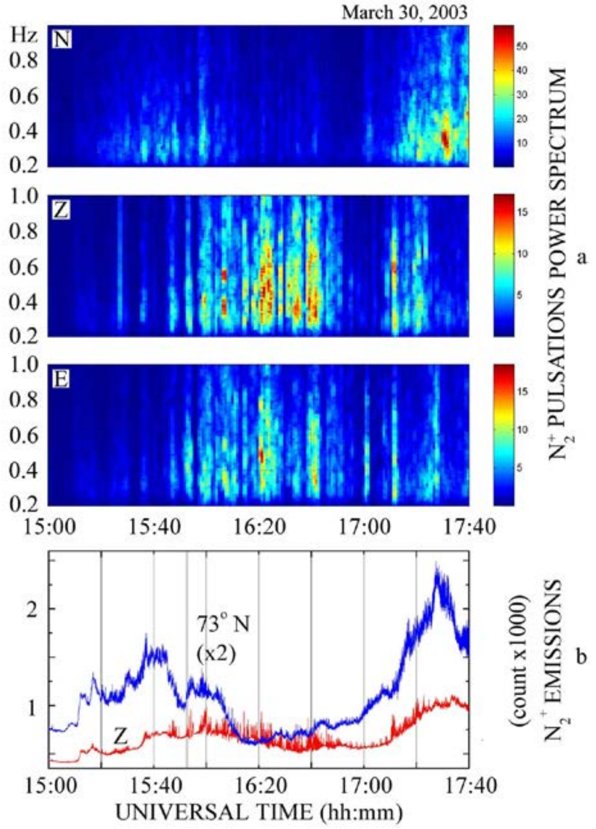

Fig. 3. Dynamic spectra of luminosity pulsations on March 30, 2003 (first situation). (a) power spectrum of luminosity pulsation in the frequency range of 0.2–1 Hz; (b) plots of the N_2^+ emissions variations for two registration directions on 73º N and Z with a sampling frequency of 20 Hz.

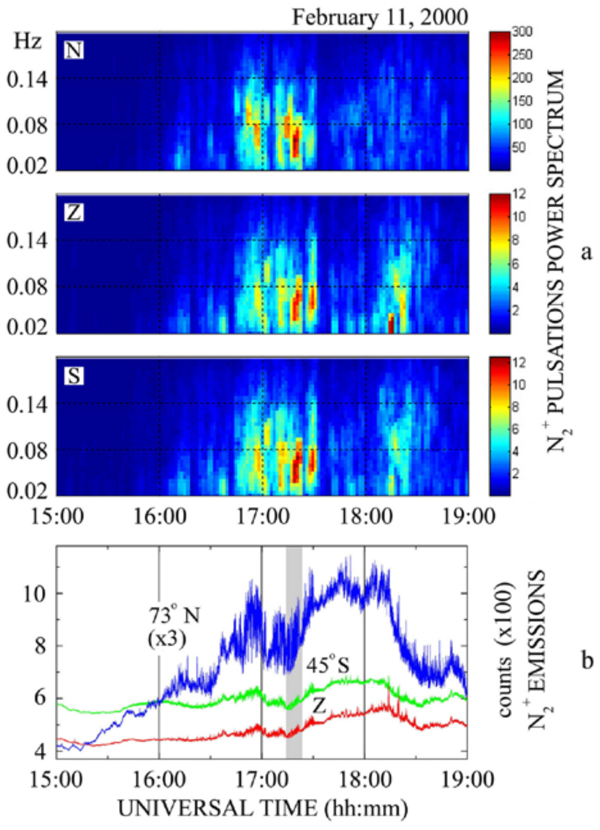

Fig. 4. Dynamic spectra of luminosity pulsations at the latitudes of diffuse aurora and SAR arc on February 11, 2000 (second situation). The data are presented as in fig 2. In the bottom panel the time interval of analyses cross correlation of luminosity pulsations is indicated by a gray column.

4. Features of the luminosity pulsations development for two situations

Two next observation examples show development features of two pulsation situations. In fig. 5 shows the registration fragment of luminosity pulsations in the N_2^+ emissions for two directions: Z and 45° E on March 30, 2003 (First situation). On the plot time delay in the development of pulsations between signals Z and E-photometers (along the azimuth) are specified. The time delay in the pulsations development on east-direction relative to the pulsations on zenith is equal to 45 s. These time delay considerable to the ions magnetic drift velocity.

Fig. 6 shows the registration fragment of luminosity pulsations in the N_2^+ emissions for two directions: 73° N and 45° S on February 11, 2000. The time delay of the pulsations at SAR arc latitudes relative to the pulsations in the diffuse aurora region in N_1 is equal to 0.3 and 0.5 s with the cross – correlation coefficients ~0.9 respectively. The revealed time delay in the luminosity pulsations development in the latitude interval of ~4° (ΔL=0.5–0.7 R_E) gives the basis to suppose, that the appearance of pulsating precipitations at latitudes of the SAR arc (outer plasmasphere) in these cases can be caused by the propagation of hydromagnetic waves from the region of source (pulsations in the diffuse aurora) inwards the magnetosphere.

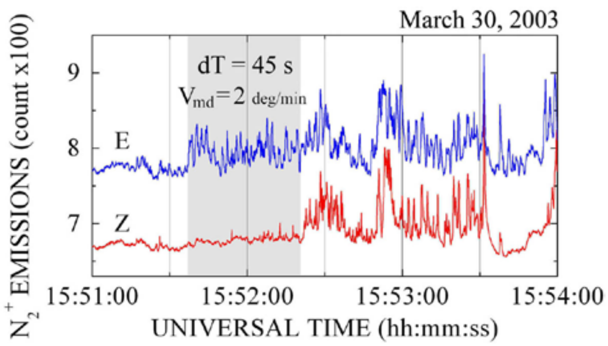

Fig. 5. Registration of delay in the development of luminosity pulsations along the azimuth on March 30, 2003 (first situation). The shift time between the onset of the splash of quasi-harmonic pulsations on 45° E and Z-directions is indicated by a gray column.

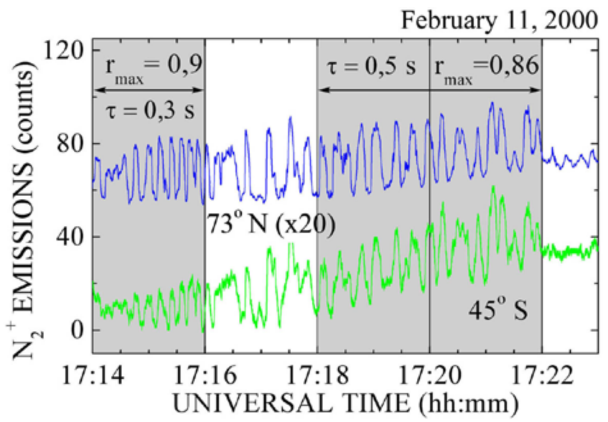

Fig. 6. Observation of the luminosity pulsations with delay along the meridian on February 11, 2000 (second situation). In Figure of the cross correlation coefficients and the time delays between signals 73° N and 45° S photometers for two time intervals are specified.

5. Simulation

It is known that the pulsating precipitations can be caused by electromagnetic ion-cyclotron (EMIC) waves due to the modulation of the pitch-angle diffusion and, consequently, particle flux in the loss cone with the wave frequency. We have performed the analysis of dependence of frequency of EMIC wave on the energy of the H^+ and O^+ ring current ions in the range L=3–6 for the cold plasma density from 100 to 800 cm^{-3}. Fig. 7 and 8 show the model calculations of the EMIC wave frequency dependence on L-shells for the various cold plasma density and the energy of the O^+ and H^+ ions respectively. In fig. 7 can see that EMIC waves frequency generated on O^+ ions can correspond to both situations. On the H^+ ions (see fig. 8) can be generated waves at frequency about 1 Hz (second situation) at L=4.2–4.8.

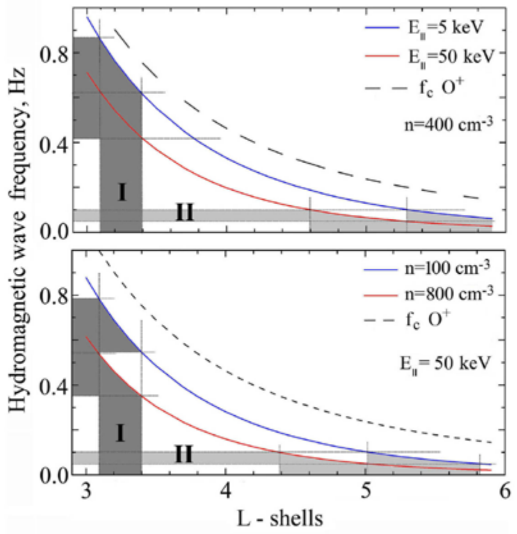

Fig. 7. Calculated dependence of the EMIC wave frequency on L-shells. The dependence are presented for various energy of the O^+ ring current ions and cold plasma density. Possible realization of the first and second situations is indicated by dark gray and light gray columns respectively.

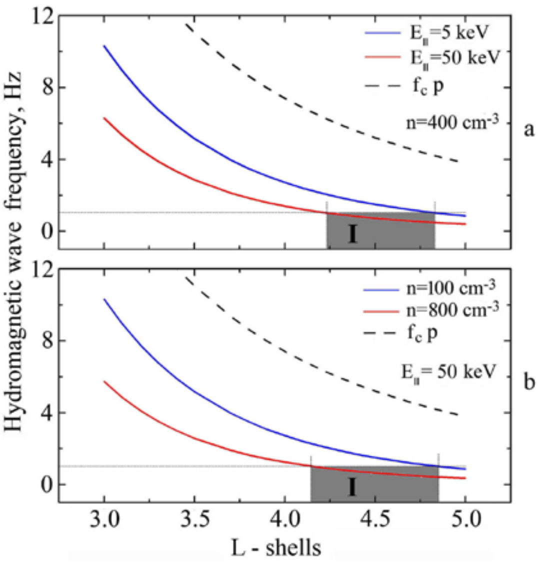

Fig. 8. Calculated dependence of the EMIC wave frequency on L-shells. The dependence are presented for various values of the H^+ ring current ions energy and cold plasma density. Possible realization of the first situation is indicated by a dark gray column.

6. Conclusion

For two observation situations of the luminosity pulsations it has been obtained the following:

The pulsation splashes with frequencies of 0.3–1 Hz are registered only in zenith and southward of the observation station at *L*=3–3.3. In this case, pulsating precipitations is likely due to the generation of EMIC waves at cyclotron resonance with O^+ ions.

The luminosity pulsations with frequencies of 0.05–0.1 Hz are observed in the latitudinal range of 4 degrees, in the diffuse aurora on the north and in the SAR arc region on the south. The pulsations in this case, we also associate with the generation of EMIC waves at *L*~4–6 and their propagation into the inner magnetosphere. In both situations, the observed modulation frequencies of precipitations can be explained only by cyclotron waves resonance with heavy ions O^+, which can dominate in the ring current during magnetic storms.

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