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The Fluctuations of High-Energy Charged Particle Fluxes in the Near-Earth Space and the Earthquake Prediction

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Abstract

We present the possible approach of the geographic coordinates determination of the forthcoming earthquake epicenter using the results of analysis of the interrelation between high-energy charged particle bursts in the near-Earth space and earthquakes. This analysis is based on the experimental data obtained on board several spacecrafts and on the theoretical consideration of particle burst propagation on the inner boundary of the Radiation Belt.

1 Introduction:

In a number of experiments on board SALYUT–7, MIR, METEOR–3, INTERCOSMOS-BULGARIA–1300, OREOL–3 spacecrafts (Galper, 1987; Galper, 1995; Pustovetov, 1993; Galperin, 1992) the bursts of high energy (several tens of MeV) charged particles, precipitating from radiation belt (RB) were discovered. The duration of the bursts ranges from few seconds to several minutes These variations of particle fluxes can concern with the Earth's seismic activity (Galper, 1995).

It was shown the particle bursts can occur several hours (2÷4) before the main earthquake phase. Moreover, the spatial parameters of the RB precipitations correlate with coordinates of the earthquakes (L shell of the precipitation practically coincides with L shell of the earthquake epicenter (Galper, 1995)). Hence, these events can be considered as a short-term earthquake predictors.

The qualitative model of spatial-temporal correlation between high energy charged particle bursts on the atmospheric boundary of RB and the Earth's seismic activity, which is consistent with experimental facts, is the following (Galper, 1995). Ultra low frequency (ULF) electromagnetic waves are generated in the future earthquake epicenter several hours before the main shock and go upward through the atmosphere practically without losses (Molchanov, 1991). At the altitudes about 100 km. these waves are trapped in channel by corresponding L shell, propagate further along the strength line of the Earth's geomagnetic field (GMF), reach the inner boundary of the RB and interact resonantly with charged particles – protons and electrons in energy range several tens of MeV (the oscillation frequency between mirror points of these particles coincides with frequency of ULF waves). This resonant interaction changes the particle pitch-angle and, as a consequence, results in decrease of mirror point altitude (in comparison with stable trapped particles).

Particles drift around the Earth on the corresponding L shell, so these RB precipitations can be observed in the all regions under the RB, where the satellite orbit crosses given L shell.

Unfortunately, available today theoretical models (Stormer or Alfven theories), those describe the charged particle propagation in the Earth's magnetosphere can not correctly account for particle movement on the atmospheric boundary of the RB, where the gradients of geomagnetic field or atmospheric density are high enough even for one cyclotron revolution of the particle. In this paper we describe the numerical model, which allows to simulate the real trajectories of high energy particles as outside atmosphere and inside the atmosphere in the regions of high gradients of GMF.

2. The Model of Particle Transport:

In order to simulate the trajectory of high energy particle on the atmospheric boundary of the Earth's RB the following technique was utilized. Relativistic equation of the charged particle movement in GMF is solved using four order Runge-Kutta method. GMF model, which we used, is IGRF '95. The processes of particle interaction with residual atmosphere (the atmosphere model is MSISE90), namely ionization energy losses, bremsstrahlung, multiple scattering are simulated in every integration step. Thus, in the frame of this technique, one can correctly simulate the high energy particle movement on the atmospheric boundary of the Earth's RB. This method does not require introducing of additional restrictions for the region of particle movement or particle energy. Further, we accumulate the necessary statistics, which includes the particle trajectories with chosen model parameters, and construct different statistical distributions: temporal evolution of energy spectra and pitch-angles, etc.

This numerical model, which simulate the high energy charged particle transport in GMF, was published in paper (Galper, 1999).

3. The Results of Simulation of Particle Transport:

The processes resulting in particle losses in the Earth's atmosphere play significant role in the propagation of particle bursts on the atmospheric boundary of RB. Mainly, particle loses energy in SAA region, where the southern mirror point drops down into the atmosphere. Here, we utilize the probability of complete particle revolution (CPR) as a parameter, which characterizes the propagation of charged particle around the Earth. This value depends on many model parameters, those influence on particle losses (energy, L and B parameters, geomagnetic epoch, etc.). The main parameter determining the value of CPR, is the total amount of matter, which particle crosses in SAA region. The total amount of matter determines as total energy losses (ionization and bremsstrahlung) and the total particle scattering angle. The particle scattering is an additional process resulting in particle losses in atmosphere.

In fig. 1 the values of CPR versus particle energy for different values of GMF in mirror points are presented (L=1.13). These values of GMF in mirror points correspond the following minimal altitudes in SAA region (guiding center): ~130 km, ~100 km, ~70 km. The distinctions of these dependencies are sharp increase (at low energies), slow decrease (at high energies) and plateau on the level ~100% in energy range several tens of MeV.

Low energy particles lose fast enough in atmosphere as a result of ionization energy losses (ionization losses increase sharply with energy decreasing). Hence, the probability of particle to perform complete longitudinal revolution decrease sharply if the particle has enough low energy. On the other hand, the particles with enough high energy have large cyclotron radius, go down deeper and lose in atmosphere. So, in high energy range the value of CPR decreases too. It is necessary to pay attention to the intermediate energy range (from several tens of MeV to few hundreds of MeV), where energy losses in atmosphere are small in comparison with the particle energy. Particles in this energy range have value of CPR close to 100% and large life time. If the probability of particle crossing of SSA region is close to 100% and energy losses during one revolution around the Earth are negligible (in comparison with the particle energy), the particles can drift many times around the Earth creating the wave of particles. This wave will slowly damp due to the energy losses in residual atmosphere and spread in space over dispersion of particle angular velocity. This wave can repeatedly cross the same point of the near-Earth space and create quaziperiodical damped pulsation of particle flux.

In fig. 2 the examples of simulation of this process are presented for different values of geographical longitudes (λ) of particle burst creation. The peaks in fig. 2 concern the multiple particle crossing of the observation site. These data show that the pulsations of drift particle flux damp during 10÷20 minutes and the waves of particles can perform several revolutions around the Earth before their complete fading.

In general case the temporal behavior of particle counting rate depends on set of initial physical parameters (these parameters are determined by the specific process of particle burst creation). The temporal profile of the counting rate in site of observation depends not only on temporal and energetic parameters of the process but on spatial characteristics of event. It is obvious essential distinctions in temporal profiles of counting rates for different longitudes of particle burst formation (time of counting rate maximum, temporal width of first peak, ratio of counting rates in first and second peaks, etc.). It provides a possibility for determination of longitude of particle burst formation using comparison experimental temporal profiles of counting rates with the simulated ones.

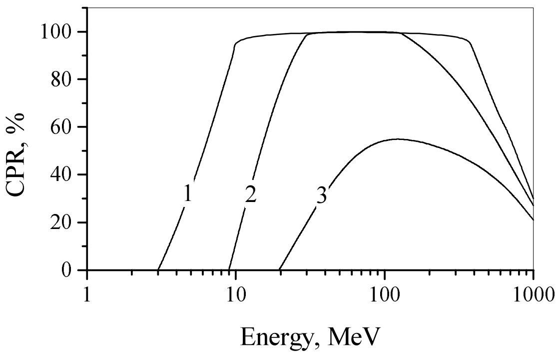

Fig. 1 CPR versus electron energy (1990, L=1.13, 1–B=0.22 Gs, 2–B=0.223 Gs, 3–B=0.225 Gs)

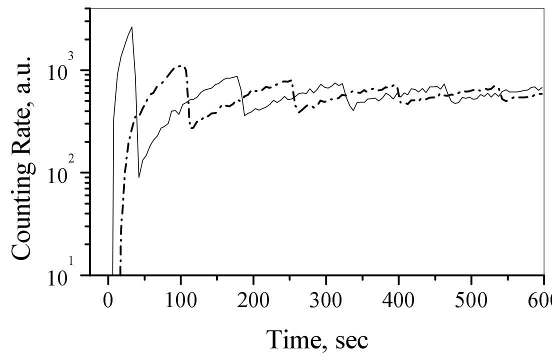

Fig. 2 Simulation of quaziperiodical pulsations of high energy electrons, solid line – λ=90°, dashed line – λ=270° (1990, L=1.13, B=0.22 Gs)

4 Discussion:

In order to estimate the possibility of restoring of local RB precipitation geographic coordinates (region of particle burst formation) the comparison of experimental data recorded by MARIA–2 instrument on board MIR space station with simulated data was carried out.

The magnetic spectrometer-telescope MARIA–2 is intend for the study of charge composition of electron-positron fluxes in energy range 20÷200 MeV. The instrument is described in details elsewhere (Voronov, 1991). Several tens charged particle bursts, correlated with the Earth's seismic activity, were observed in experiment MARIA–2 (Galper, 1995).

Events, those have quaziperiodical counting rates, have the particular interest from the point of view of the study and analysis of seismo-magnetosphere correlations. This temporal profile of counting rate concerns with multiple crossing of charged particles of the observation site due to the particle drift around the Earth. It should be noted that these quaziperiodical pulsations of particle fluxes on the atmosphere boundary of RB can be detected at any longitudes where the satellite orbit crosses L shell of drifting particles. As an experimental example we choose one event, recorded by the MARIA–2 (Galper, 1997).

The instrument recorded quaziperiodical pulsation of high energy electrons on the atmospheric boundary of the Earth's RB (L~1.15, B~0.23 Gs) in 31 march 1994 at 0613 UT. During the observation the instrument locates at longitude ~300° and was oriented for registration of particles on the atmospheric boundary of RB (minimal altitudes of mirror points in SAA region are 60÷150 km). The temporal profile of counting rate has quaziperiodical structure and temporal interval between the peaks is determined drift period of electrons around the Earth.

In order to compare of experimental temporal profile of particle counting rate with simulated one, obtained in frame of technique described above, we utilize chi-square method. In simulation of this event the difference between the local RB precipitation longitude and MIR space station site longitude (Δλ) were used as a free parameter. This parameter is varied in range 0°÷360°. The value of χ^2 versus Δλ is presented in fig. 3. It is seen from fig. 3 that χ^2 has pronounced minimum in the range of $\Delta\lambda \sim 0°\div20°$. So, knowing MIR space station site during the observation one can determine the range of geographical longitudes of particle burst formation $\Delta\lambda_{geo}$~280°÷300°.

In fig. 4 the experimental and simulated for minimal value of χ^2 (λ=290°) temporal profiles of counting rates are presented. Enough good agreement between these results should be stressed.

It should be noted, that the geomagnetic situation in this day was quite and, it is possible this particle burst served as a precursor for earthquake at 0834 UT (L=1.12) in longitude 291°. This earthquake took place ~2 hours on the same L shell after the burst.

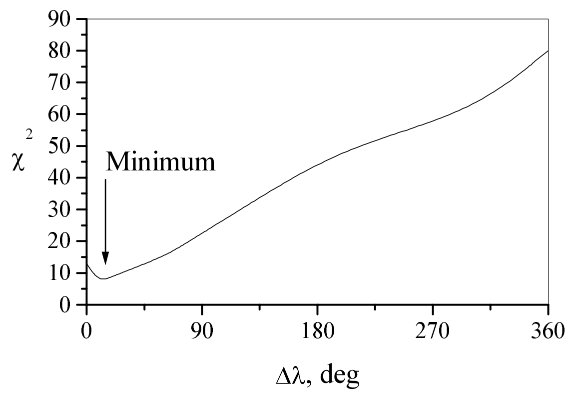

Fig. 3 The value of χ^2 versus $\Delta\lambda$ (31 march 1994)

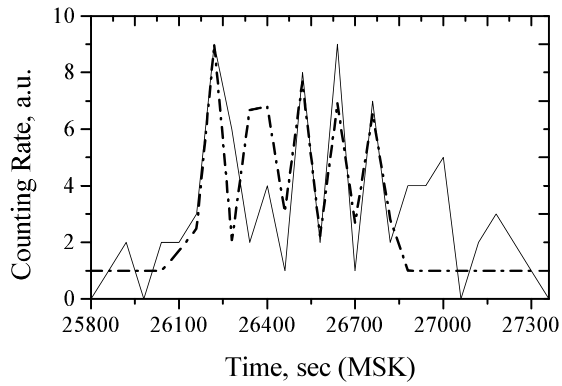

Fig. 4 Experimental (solid line) counting rate and the results of simulation (dashed line)

5 Conclusion:

In this paper we carried out the analysis of the processes of formation of quaziperiodical pulsations of high energy charged particles on the atmospheric boundary of the Earth's RB, initiated by the local RB disturbance. The possibility of determination of such local disturbance coordinates using the procedure of comparison of experimental temporal profiles of counting rates and simulated ones. If the RB precipitation has the seismic origin, the coordinates of future earthquake epicenter can be determined.

6 References:

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