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THE INVESTIGATION OF THE PG PULSATIONS WITH USING DATA OF ARASE, GOES SATELLITES AND GROUND-BASED STATIONS

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Abstract. The physical nature of Pg (pulsation giant) pulsations, which were observed in the magnetosphere by the Japanese satellite Arase, geostationary satellites GOES, and ground stations of the THEMIS and CARISMA networks, was investigated in this work. Pg pulsations belong to the Pc4 frequency range and are characterized by a very monochromatic shape. For the event on 5 June, 2018, according to the data from the Arase satellite, the Pg pulsation wave packet was recorded in the dawn sector during 3 hours. The pulsations are most pronounced in the radial component of the geomagnetic field, their frequency was about 11 mHz. Pg pulsations observed in the magnetosphere were accompanied by pulsations with the same period according to data from a number of ground-based magnetic stations located near the conjugate point. According to the data of ground stations, the pulsations were most strongly expressed in the Y-component of the geomagnetic field. Pg pulsations were accompanied by pulsations in electron and proton fluxes according to the Arase, GOES satellite observations. There are no clear phase relationships between geomagnetic pulsations and pulsations in charge particle fluxes. Pg pulsations were excited under quiet geomagnetic conditions (SYM-H = -10 nT, AE = 100-400 nT) on the recovery phase of the small geomagnetic storm. It is assumed that the expansion of the plasmasphere at low geomagnetic activity leads to an increase in the plasma density in the region of the geostationary orbit, which creates favorable conditions for the excitation of Pg pulsations due to the drift-bounce resonance of protons with the geomagnetic field lines oscillations in the magnetosphere.

Introduction

There are many types of ULF waves in the Earth magnetosphere, which differ by their periods (Pc3-5, Pg, Pi2-3), waveforms (broadband or monochromatic), polarization structure (poloidal, toroidal, or compressional), etc [*Anderson et al.*, 1990]. ULF waves have two types of energy sources: external and internal. External sources, such as the Kelvin-Helmholtz instability and compression of magnetosphere by solar wind, excite large-scale perturbations on the magnetopause. ULF waves excited by external sources generally have a small wave number in the azimuthal direction (m-number), for example, $|m| < 10$. By contrast, internal sources, such as plasma instability and wave-particle resonance, excite perturbations with a large m-number, for example, $|m| \sim 100$.

Giant pulsations (Pgs) are a special class of ultralow-frequency (ULF) waves observed on the ground most often at auroral latitudes [*Birkeland*, 1901] with periods usually around 100s but at times as short as 60s or as long as 200s [*Brekke et al.*, 1987]. Pgs are characterized by a highly sinusoidal waveform, a strong magnetic field perturbation in the east-west direction, strong latitudinal localization, westward propagation, and an azimuthal wave number (m) in the range of 16–35 [*Takahashi et al.*, 1992].

An outstanding and unexplained feature of Pgs is that they occur most often during years of minimum solar activity and almost exclusively on the morningside [*Chisham and Orr*, 1991].

In this study we try to examine Pg pulsations and its connection with the fluxes of energetic particles in the magnetosphere by the Arase satellite.

Data used

The Arase (ERG: Exploration of energization and Radiation in Geospace) satellite was developed by the Institute of Space and Astronautical Science of JAXA (Japan Aerospace Exploration Agency) for the study Earth radiation belts (Miyoshi et al., 2018a). The apogee is about 5.0 Re (L~6.0, 32 110 km), and the perigee is about 460 km. It was launched at 20 December 2016. In this study, we have used the data from MEPe (*S. Kasahara et al.*, 2018), MGF (*Matsuoka et al.*, 2018), and PWE (*Y. Kasahara et al.*, 2018).

The GOES geostationary spacecrafts was used for the registration of the geomagnetic field variations, variations of the electron and proton fluxes. CARISMA network stations are used for the registration of geomagnetic field variations in conjugate to the satellite regions.

MGF data of Arase satellite are transformed to the mean field-aligned (MFA) coordinate system. The magnetic field averaged over a 5-min moving window is defined as the background field and gives the direction of the b||

(parallel) component, the direction of a (azimuthal) component is defined as $b_a = b_{||} \times \mathbf{r}$, where $\mathbf{r}$ is the satellite position vector from the center of the Earth, and the direction of b_r (radial) component is given by $b_r = b_a \times b_{||}$.

The event 5 June 2018

Pg pulsations were excited under quiet geomagnetic conditions (SYM-H = -10 nT, AE = 100-400 nT) on the recovery phase of the small geomagnetic storm, solar wind speed according to the OMNI database was about 550 km/s.

The wave packet of monochromatic pulsations was observed on GOES-14 spacecraft at time interval 09.30-14.00 UT (Fig. 1) in MFA coordinate system. The Pc4 pulsations were mostly seen in radial (he) and azimithal (hn) components with amplitude about 2-4 nT. Weaker pulsations can be seen also in the field-aligned component hp and in the total field intensity ht. This polarization indicates on the poloidal-type transverse wave structure. The wavelet spectrum (Fig. 2) shows that the pulsations were excited by the different wave packets in frequency range 8-15 mHz with the spectrum maximum near 10-12 mHz.

The pulsations on GOES-14 satellite were accompanied by the pulsations with the same frequency on the ground stations (Fig. 1). But on ground stations the Pg pulsations are seen only during some moments due to damping of the waves in the ionosphere. The pulsations are mostly evident in Y-component of the geomagnetic field at GILL station located near the conjugate point according to the GOES-14 satellite (Fig. 1). This fact testifies about the rotation of the polarization ellipse of the waves on 90 degrees during the propagations through the ionosphere.

There is no change of the frequency of the Pg pulsations with the change of the latitude. So the considered pulsations are generated not due to the field-line resonance (FLR). It is hard to determine the azimuthal wave number m of Pg pulsations with using longitudional pair of stations RABB-GILL due to low coherence between the pulsations.

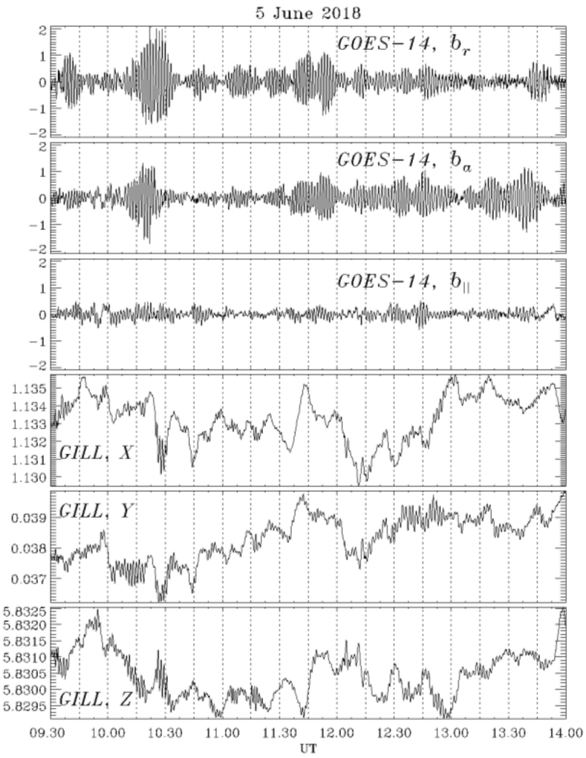

Figure 1. The geomagnetic field variations on GOES-14 spacecraft (radial, azimuthal and field-aligned component), goemagnetic field variations in GILL station (X, Y, Z components).

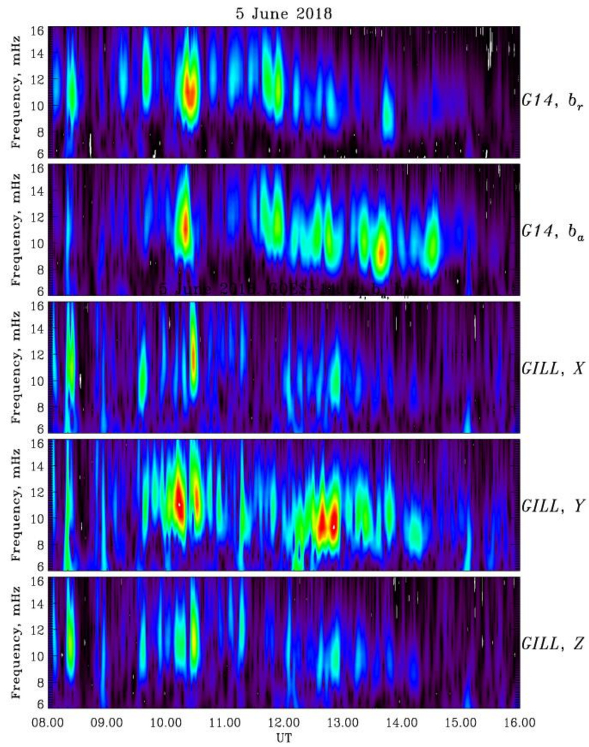

Figure 2. wavelet spectrum of the radial and azimuthal components on GOES-14 spacecraft, wavelet spectrum of X, Y, Z components on GILL station.

At the moment of the Pg pulsations excitation the GOES-14 satellite was located at the early morning sector (see the map on the Fig. 3). Near the GOES-14 the Arase satellite was located (Fig. 3). The GOES-15 satellite was located in 1.5 hours of MLT from the GOES-14 satellite.

The similar Pc4 pulsations were also observed in variations of the electric and magnetic field on Arase satellite (Fig. 5). The pulsations are better seen in electric field variations. But the wave forms of Pc4 pulsations are not well correlate on GOES-13 and Arase satellites. It means that the observed waves have small-scale structure.

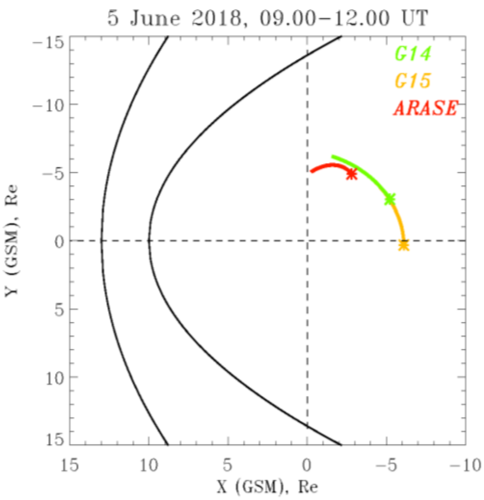

Figure 3. The location of GOES-14, GOES-15, Arase satellites in GSM coordinate system.

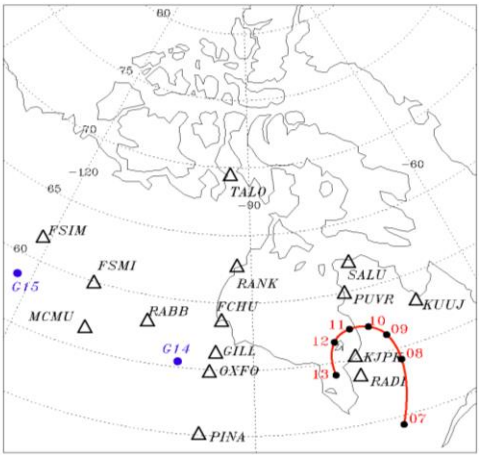

Figure 4. Map showing the location of the geomagnetic station, projection of the Arase, GOES-14, GOES-15 satellites.

Because we have magnetic and electric field measurements on Arase satellite we have calculated the Poynting flux for considered Pg pulsations (Fig. 5, last three panels). It is seen that the energy of the waves are mostly transferred in field-aligned direction which confirms the Alfven nature of these pulsations.

The geomagnetic Pc4 pulsations according to the GOES-14 and Arase data were accompanied by the pulsations in electron and proton fluxes with the same frequency in wide energy range. The Pc4 pulsations in electron fluxes at some wave packets are in phase with the geomagnetic pulsations while Pc4 pulsations in proton fluxes are in anti-phase with the geomagnetic pulsations (Fig. 6).

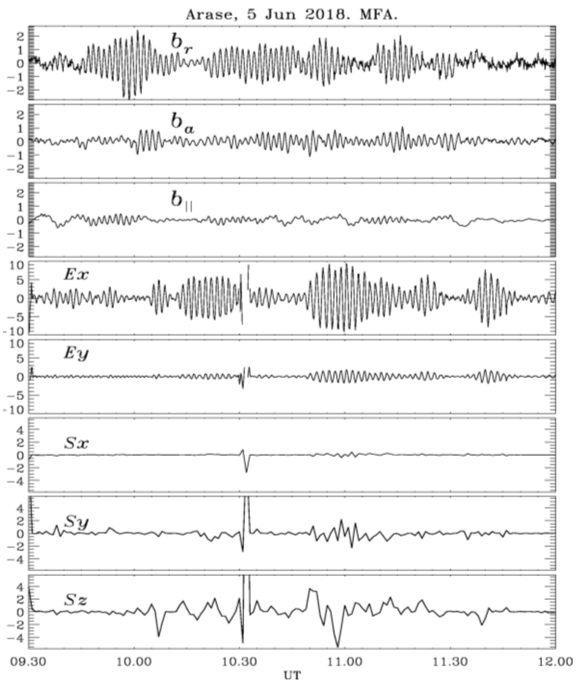

Figure 5. The geomagnetic field variations on Arase spacecraft (radial, azimuthal and field-aligned component), electric field components (E_X, E_y), vector of Poynting (S_x, S_y, S_z).

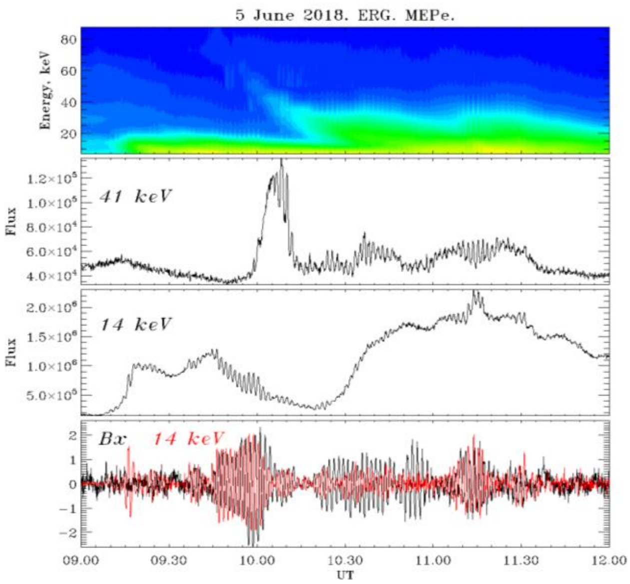

Figure 6. The spectrogram of the energetic electrons (5-90 keV), fluxes of the 41, 14 keV electrons, variations of the Bx-component of the geomagnetic field and flux of the 14 keV electrons.

Conclusions

It is considered the Pg pulsations with using data of Arase, GOES satellites and ground stations of the THEMIS, CARISMA networks for the event on 5 June, 2018. The pulsations are most pronounced in the radial component of the geomagnetic field, their frequency was about 11 mHz. Pg pulsations observed in the magnetosphere were accompanied by pulsations with the same period according to data from a number of ground-based magnetic stations located near the conjugate point. According to the data of ground stations, the pulsations were most strongly expressed in the Y-component of the geomagnetic field. There is no change of the frequency of the Pg pulsations with the change of the latitude. So the considered pulsations are generated not due to field-line resonance.

Pg pulsations were accompanied by pulsations in electron and proton fluxes according to the Arase, GOES satellite observations. The analyze indicate that the Pc4 pulsations in electron fluxes at some wave packets are in phase with the geomagnetic pulsations while Pc4 pulsations in proton fluxes are in anti-phase with the geomagnetic pulsations.

It is assumed that the expansion of the plasmasphere at low geomagnetic activity leads to an increase in the plasma density in the region of the geostationary orbit, which creates favorable conditions for the excitation of Pg pulsations due to the drift-bounce resonance of protons with the geomagnetic field lines oscillations in the magnetosphere.

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