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Interactive comment

Interactive comment on "An excitation mechanism for discrete chorus elements in the magnetosphere" *by* Peter Bespalov and Olga Savina

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Respond to all referee comments

(1) Comment from Referee

The manuscript claims to have proposed an VLF electromagnetic pulse excitation mechanism in the magnetosphere; however, the manuscript lacks data supporting its idea, and misses many key references for its claims and assumptions. I could only ïňĄnd an exhibition of a wave instability growth rate calculation. There is neither simulation based on this calculated growth rate nor any observation to be compared with,

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Discussion paper

therefore it is hard to guess any physical validity of this calculation, yet the authors still claim that it could explain many phenomena in their conclusions. The calculation relies on many key simpliïňĄcations and assumptions that lack enough reference to support, for example in the paragraph around Eq. (10). The calculation procedure appears to me as a composition of selected equations and results from textbooks, without enough explanation of their backgrounds or even physical meaning of symbols. Moreover, I don't see a clear logical link between these equations, for example, the Vlasov equation discussed in Eq. (1)âĹij(4) are never used in the later part of the manuscript, and it is hard to understand why they are there. In its current form, it is difïňĄcult to fairly evaluate the originality and scientiïňĄc contribution/signiïňĄcance of the manuscript. Therefore I suggest the authors to resubmit after serious and substantial improvement. Additional comments are shown below.

Figure 1, which is the only ïňĄgure in the manuscript, is not clear. Why particles (marked stars) move as shown in Figure 1? What are the two parallel lines?

Why a nearly step-like form of A in equation (2) is important in the beam pulsed ampliïňĄer mechanism proposed? This form seems lack of observational support.

The instability requires electrons, or even ideal beam with vz=Ug, which is not realistic either. Another mainstream idea for chorus generation, which is associated with inhomogeneity and cyclotron instability, is not discussed.

As equation 16 shows, the favorable wave normal from the proposed mechanism is quite oblique, which is not consistent with often observed quasiparallel propagation in the literature.

(2) Author's response

We would like to thank the Reviewer for the time he/she spent reading, and commenting our manuscript. We have prepared a point-by-point answer to his/her comments below. The responses are marked in bold.

Reviewer's Comments:

The manuscript claims to have proposed an VLF electromagnetic pulse excitation mechanism in the magnetosphere; however, the manuscript lacks data supporting its idea, and misses many key references for its claims and assumptions.

Response:

This short theoretical manuscript is addressed to professionals who are well aware of the published achievements of experimental and theoretical research on the chorus radiation in the magnetosphere. Therefore, the bibliography contained only references that are important for the original study. Nevertheless, we have extended the bibliography to make it more balanced in term of presenting the results of various scientific schools.

Reviewer's Comments:

I could only find an exhibition of a wave instability growth rate calculation.

Response:

The calculation of the conditional instability growth rate is the main new achievement of this work.

Reviewer's Comments:

There is neither simulation based on this calculated growth rate nor any observation to be compared with, therefore it is hard to guess any physical validity of this calculation, yet the authors still claim that it could explain many phenomena in their conclusions.

Response:

The study of the chorus emissions is the important geophysical problem. Several mechanisms of chorus excitation are discussed in the literature. Each of them explains some characteristics of the phenomenon, but has its limitations

on the conditions of applicability and the level of consistency with the experimental data. This manuscript is not a overview and we do not comment on known mechanisms, but draw attention to a new reason of chorus excitation.

In our opinion, before carrying out simulations, it is useful to understand the nature of chorus excitation. In the manuscript we try to do this. A comprehensive study of the simulation is beyond the scope of the present paper and it is left for future work. In turn, a detailed comparison of the theoretical conclusions with the experimental data is planned in another article.

Reviewer's Comments:

The calculation relies on many key simplifications and assumptions that lack enough reference to support, for example in the paragraph around Eq. (10).

Response:

Two inequalities (10) are the classical positions of plasma physics. The first inequality (10) makes it possible to expand the Bessel functions for small arguments (this so-called dipole approximation is used for obtaining the expressions of the permittivity tensor). The second inequality (10) makes it possible not to take into account the kinetic effects (like the Landau damping) for instability with a large hydrodynamic growth rate. We added this explanation to the text.

Reviewer's Comments:

The calculation procedure appears to me as a composition of selected equations and results from textbooks, without enough explanation of their backgrounds or even physical meaning of symbols.

Response:

We additionally checked the notations and made small corrections.

Reviewer's Comments:

Moreover, I don't see a clear logical link between these equations, for example, the Vlasov equation discussed in Eq. (1)-(4) are never used in the later part of the manuscript, and it is hard to understand why they are there.

Response:

As a result of the analysis of the Eqs. (1)-(4), we showed that the spectral components of the wave packets for which the Eqs. (8) are fulfilled interact with particles as in a homogeneous plasma with the distribution function (11). Thus, we reduced the problem of the electromagnetic pulse amplification to the standard task of plasma stability.

Reviewer's Comments:

In its current form, it is difficult to fairly evaluate the originality and scientific contribution/significance of the manuscript.

Response:

It is clear that the perception of a new mechanism of oblique electromagnetic chorus excitation is not easy, but a reasonable solution is required by researchers.

Reviewer's Comments:

Therefore I suggest the authors to resubmit after serious and substantial improvement.

Additional comments are shown below. Figure 1, which is the only figure in the manuscript, is not clear. Why particles (marked stars) move as shown in Figure 1? What are the two parallel lines?

Response:

Note that there is also Fig. 2 in the manuscript.

On the plane z, t the specific features of particles and wave, which satisfy Eqs.

(8), are explained in Fig. 1. Here z is the axis along the magnetic field, the start and finish lines correspond to the wave-particle interaction region boundaries, t is the time is counted from the pulse crossing the start line. The resonance particles (3) and the short electromagnetic pulse (2) are situated in the domain which moves along a narrow corridor between two parallel dashed lines. The corridor width is determined by the pulse duration. These particles and waves in the domain form a separated plasma subsystem. We added text to the manuscript.

Reviewer's Comments:

Why a nearly step-like form of A in equation (2) is important in the beam pulsed amplifier mechanism proposed? This form seems lack of observational support.

Response:

The chosen pulse shape is modeled and corresponds to the shot noise well known in electronics (see, e.g., (Rytov et al., 1989)). We added text to the manuscript. We extended the bibliography.

Reviewer's Comments:

The instability requires electrons, or even ideal beam with vz=Ug, which is not realistic either. Another mainstream idea for chorus generation, which is associated with inhomogeneity and cyclotron instability, is not discussed.

Response:

The beam under consideration is effective. It is effective only for waves from short electromagnetic pulses with appropriate frequencies and angles of the wave normal. At the same time, if an electromagnetic disturbance with other properties falls on the wave-particle interaction region, then the beam is not effective and the disturbance is decayed.

The study of the chorus emissions is the important geophysical problem. Sev-

eral mechanisms of chorus excitation are discussed in the literature. Each of them explains some characteristics of the phenomenon, but has its limitations on the conditions of applicability and the level of consistency with the experimental data. This manuscript is not a overview and we do not comment on known mechanisms (see, e.g., (Omura et al., 2008; Fu et al., 2014)), but draw attention to a new reason of chorus excitation. We have extended the bibliography.

Reviewer's Comments:

As equation 16 shows, the favorable wave normal from the proposed mechanism is quite oblique, which is not consistent with often observed quasiparallel propagation in the literature.

Response:

There are extensive data on the wave normal angle measurements on board THEMIS and Van Allen Probe. There is no theoretical model for oblique electromagnetic chorus. We replaced "chorus" to "oblique electromagnetic chorus" in several places.

(3) Author's changes in manuscript

Page 1 line 3

The text:

"chorus"

is replaced by

"oblique electromagnetic chorus"

Page 1 line 11

The text:

"Some problems connected with the theoretical analysis of chorus excitation remain unsolved."

is removed

Page 1 line 11

The text:

"For electromagnetic chorus with the wave vectors predominantly along the magnetic field important theoretical results were obtained."

is added

Page 1 line 17

The text:

"At present, there are significant achievements in the theoretical study of generation electrostatic chorus with the wave vectors near the resonance cone (see, e.g., (Li et al., 2016))."

is added

Page 1 line 17

The text:

"In (Omura et al., 2008; Fu et al., 2014) the generation process of the chorus emissions is analyzed by both in theory and simulation assuming that the initial cyclotron wave growth is driven by the strong temperature anisotropy of energetic electrons. To explain the chorus spectrogram, the authors take into account inhomogeneity of the magnetic field and nonlinear wave decay, or the non monotonic energy spectrum of particles."

is added:

Page 1 line 18

The text:

"Some problems connected with the theoretical analysis of chorus excitation remain unsolved, for example, the excitation mechanism of oblique electromagnetic chorus has not been studied. "

is added

Page 1 line 18

The text:

"chorus"

is replaced by

"oblique electromagnetic chorus"

Page 2 line 5

The text:

"are the electron velocity"

is replaced by

"are the components of the electron velocity v"

Page 2 line 7

The text is added:

"E and B are the electric and magnetic field disturbances"

is added

Page 2 lines 8-12

The expression:

"$z - v_{gz}t$"

is replaced by

"ξ"

Page 2 line 10

The text:

"The chosen pulse shape is modeled and corresponds to the shot noise well known in electronics (see, e.g., (Rytov et al., 1989))."

is addeed

Page 3 line 18

The text:

"Here z is the axis along the magnetic field, the start and finish lines correspond to the wave-particle interaction region boundaries, t is the time counted from the pulse crossing the start line." is addeed

Page 3 line 20

The text: "The corridor width is determined by the pulse duration."

is addeed

Page 4 line 5

The text:

"The first inequality makes it possible to expand the Bessel functions for small arguments (this so-called dipole approximation is used for obtaining the expressions of the permittivity tensor). The second inequality makes it possible not to take into account the kinetic effects (like the Landau damping) for instability with a large hydrodynamic growth rate. "

is added

Page 8 line 12

The text:

"Fu, X., Cowee, M.M., Friedel, R.H., Funsten, H.O., Gary, S.P., Hospodarsky, G.B., Kletzing, C., Kurth, W., Larsen, B.A., Liu, K., MacDonald, E.A., Min, K., Reeves, G.D., Skoug, R.M., and Winske, D. (2014). Whistler anisotropy instabilities as the source of banded chorus: Van Allen Probes observations and Particle-in-Cell simulations. Journal of Geophysical Research, 119, 8288-8298, doi: 10.1002/2014JA020364."

is added

Page 8 line 17

The text:

" Li, W., Mourenas, D., Artemyev, A.V., Bortnik, J., Thorne, R.M., Kletzing, C.A., Kurth, W.S., Hospodarsky, G.B., Reeves, G.D., Funsten, H.O., and Spence, H.E.: Unraveling the excitation mechanisms of highly oblique lower band chorus waves, Geophys. Res. Lett., 43, 8867. doi: 10.1002/2016GL070386, 2016."

is added

Page 8 line 19

The text:

"Omura, Y., Katoh, Y. , and Summers D. (2008). Theory and simulation of the generation of whistler-mode chorus. Journal of Geophysical Research, 113, A04223, doi:10.1029/2007JA012622."

is added

Some minor corrections were made to edit the manuscript.

Please also note the supplement to this comment:

https://www.ann-geophys-discuss.net/angeo-2018-38/angeo-2018-38-AC1-supplement.zip

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Interactive comment on Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2018-38, 2018.