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# *Interactive comment on* "Distribution of the Earth's radiation belts protons over the drift frequency of particles" *by* Alexander S. Kovtyukh

**Anonymous Referee #1**

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General Comments

Dear author, I think that overall the paper itself is rather good. The topic introduced in this work is interesting and there is some novelty. The work has been conducted with care and all the calculations are explained in a clear way. Figures are well described in their captions and each one is recalled in the text. The description of the main body of the paper is a bit difficult in some points and they may not be easily followed by the reader. I propose a series of technical corrections that may help smooth the text a bit and make it a little easier to read. On the other hand, the conclusions are clearly explained and the discussion is rich. The references in the bibliography are targeted and complete.

Specific Comments



No specific comments

Technical Corrections

Line 1 Distribution of Earth's radiation belts protons . . .

Line 6-10 Thanks to the data on the proton fluxes of the Earth's radiation belts (ERB), with energy ranging from 0.2 to 100 MeV and drift L shell ranging from 1 to 8), their stationary distributions over the drift . . . are constructed. For this purpose, direct measurements of proton fluxes of the ERB in the period 1961–2017 near the geomagnetic equator were employed.

Line 12 . . . and their distributions in the space . . . have a more regular shape than . . .

Line 16 . . . is disrupted in advantage of transport . . .

Line 17 . . . with increasing solar activity, overpowers

Line 33 For the near-equatorial ERB protons, we have:

Line 36-37 with increasing amplitude of particles oscillation

Line 38-55 The frequency fc is different for different L shells (near the equatorial plane) and, as L increases (higher geomagnetic latitudes) the number of particles become less and less significant. For each given value of the frequency fb if L increases, then particles become more and more energetic (. . .) and their number becomes smaller . Compared to the frequencies fc and fb, the drift frequency fd for one particle species has a narrower range of values; it does not depend on the mass of the particles and it very weakly depends on the amplitude of their oscillations (. . .); in this case, on each L shell there are a significant number of particles corresponding to a certain value of fd . Therefore, it can be expected that the distributions of the ERB particles in the space {fd, L} will have a more regular shape than in the space {E, L}, and the main physical processes in these belts will manifest themselves more clearly in these distributions. Furthermore, it can be expected that on these more ordered background more fine features can be revealed that would not appear in the space {E, L}. Despite the importance of the drift frequency fd for the mechanisms of the ERB formation, reliable and sufficiently complete distributions of particles in the ERBs (over the frequency fd ) have not been presented nor analyzed; indeed, this is the first time.

Line 56-61 The analysis presented in this paper is limited to the protons of the ERB during magnetically quiet periods of observations, when the proton fluxes and their spatial energy distributions were stationary. In the following sections, the distributions of the ERB protons over their drift frequency fd are constructed from experimental data (Sect. 2) and analyzed (Sect. 3). Finally, the main conclusions of this work are given in Sect. 4.

Line 67 In my opinion the term generalized is out of context here (and in similar statements)

Line 67-75 From the data of averaged satellite measurements of the differential fluxes of protons with an equatorial pitch-angle . . .., the aforementioned distributions are constructed in (Kovtyukh, 2020) during quiet periods. Such distributions, separated between periods near minima and maxima of the 11-year solar activity cycle, are constructed from satellite data also for other ionic components of the ERB (near the equatorial plane), but the most reliable and detailed picture was obtained in for protons (see Kovtyukh, 2020). In Fig. 1 one of these distributions is reproduced for periods near solar maxima (from 1968 to 2017); here, data of different satellites are associated with different symbols.

Line 77 correspond to the . . .

Line 83-84 The red lines correspond to the drift . . .

Line 85-97 Only protons with energies less than some maximum values, determined by the Alfvén's criterion: . . .. plane) can be trapped on the drift shells .

Line 91 The distribution of the ERB proton fluxes shown in Fig. 1, refers to ...



Line 109 . . . of these fluxes . . .

Line 111 . . . as red numbers.

Line 119 Figure 2 was written as Fig. 2 before.

Line 122 . . . energy-independent . . .

Line 123 in Fig. 2 are due to the fact . . .

Line 129 each other and to the energy axis . . .

Line 129 refers to protons . . .

Line 138 motions (these issues were most fully . . .

Line 139-140 Both the local maximum at . . . and the region of low anisotropy at . . . in Fig. 2, are related to the ionization losses of protons.

Line 145 which were obtained at . . .

Line 157 I believe that the unit of measurements for the B field is Gauss, G not Gs

Line 161 . . . , it increases by only . . .

Line 198 calculated using the formula (1) together with Figs . . .

Line 205 of maximum solar activity . . .

Line 208 see Line 205

Line 211 during minimum periods of solar activity

Line 222 of the ERB protons is the radial . . .

Line 225 Figs 1 and 2 . . .

Line 228 The iso-lines of proton fluxes in Fig. 1 at sufficiently large E . . .

Line 230 The use of the verb “to reject” is extremely unclear here, please clarify

Line 237 the radial diffusion is decreased very rapidly . . .

Line 247 . . . have much less steeper outer edges and . . .

Line 252 This effect is mainly connected to the large . . .

Line 268 . . . is driven by increase in the . . .

Line 270 This sentence here is rather unclear. Maybe it would be better to put it like: "Fig. 5 demonstrates the closeness to the adiabatic transformations of the spectra . . ."

Line 291 have a power-law tail . . .

Line 297 . . . become gradually increasingly rigid with decreasing L, and . . .

Line 304 Fig. 5 show that at . . .

Line 311 The word "but" here seems to be written with a smaller font with respect to "protons" and "the power"

Line 313 are established at lower . . .

Line 316 With decreasing E (and . . .

Line 318 observed

Line 318 with decreasing solar activity . . .

Line 319 . . . we see in Fig. 5 the opposite effect

Line 318 Under the influence of . . .

Line 331 . . . activity is overpowered by a more . . .

Line 333-339 According to numerous experimental data, during magnetic storms, a wide variety of complex spectra of powerful pulsations of magnetic and electric fields in the considered frequency range (ULF) can be generate in the geomagnetic trap, which are non-regularly distributed over L; these pulsations can lead to local acceleration and



losses of the ERB particles (...). Such effects will violate the regular characteristics of the protons distributions shown in Fig. 4 and 5. However, during quiet periods, the amplitudes of such pulsations are small and they lead only to radial diffusion of particles.

Line 341-343 Starting from the data on near-equatorial ERB proton fluxes (with energy ranging from 0.2 to 100 MeV and drift L shell ranging from 1 to 8), their stationary distributions . . . were constructed.

Line 344 . . . of the ERB protons within . . .

Line 345 . . . for periods of maximum solar activity . . .

Line 348-352 . . . have only one maximum that shifts toward . . . In comparison to the proton fluxes ... have steeper inner edges and flatter outer edges. However ... have inner and outer edges with only slightly difference from each other for what concerns the steepness of their profiles.

Line 354 . . . are weakly dependent on . . .

Line 355 power-law shape . . .

Line 358 have a more regular shape than . . .

Line 359 In these regions, there is the majority of the ERB protons, and their radial diffusion overpowers . . .

Line 366 With increasing solar activity, the number of protons . . .

Line 371 . . . is mainly formed by the mechanism . . .

Line 372-373 . . . that with increasing solar activity, the average rates of radial diffusion of protons increase as well.

Line 374-375 . . . with increasing solar activity is overpowered by the increase of the rates of radial . . .

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