Comments for the manuscript: "Earth's radiation belts ions: Patterns of the spatial-energy structure and its solar-cyclic variations" by A. S. Kovtyukh

The manuscript addresses the scientific topic of understanding the spatial distributions of protons, Helium nuclei and CNO-group ions in the Earth Radiation Belts together with their variations during various solar minima and maxima. Even if it does not contain new data (it analyzes a wide range of older data from satellites), it offers a new interpretation of the mechanisms behind the different distributions of particle populations inside the magnetosphere. The exposition is fairly linear and the theoretical approach is sufficiently explained by the author, even if the description of the 3 sections seems rather repetitive, but it is something due to the very nature of the manuscript. The abstract reflects the content of the manuscript very well. Overall, it appears a little too long and with quite a few grammatical errors that make reading pretty hard and not fluent. Nevertheless, the topic is interesting, figures are simple but explanatory and the conclusions are satisfactory; thus, in my opinion, could be published after some fairly substantial grammar revision.

I have a few more comments, then I will provide a table with some suggestions on how to correct some grammatical mistakes.

1. lines 96-97: what does "averaged" means here? And what does it mean that "All values of differential fluxes reduced to one dimension"? I think that this sentence should be rewritten more clearly

2. lines 144-147: this whole sentence, in my opinion, is not suitable for a scientific paper. The method used is the result, I believe, of your careful reasoning. Therefore the scientific community will evaluate and judge it by its own. You do not have to show doubts about your choice. You can just address the fact that the uncertainties are linked to the errors of the experimental points shown in the various Figures.

3. lines 148-157: in my opinion, describing in too much detail a procedure or a method that has not been used in the paper, does not help the linearity of the text and distracts the reader. This whole paragraph could be restricted to just two sentences. For example: "[...] Representing plots in a different space of variables would lead only to more significant methodological errors and uncertainties, because of the natural differences in the instrumentation of the experiments taken into account; thus, a series of approximations or interpolation/extrapolation techniques would become inevitable.".

4. lines 179-180: I would remove this sentence because it does not add much to the description of the Figures.

5. line 184: the function $f(\mu, K, L)$ is not previously cited nor defined. I guess it is a reference to line 30 and to the curves in the {E,L} plane, but maybe this implicit formula could be at least introduced earlier in the text.

6. line 201: What is γ? I can infer it is the slope of the flux (spectral index) but maybe in this occasion it could be useful to, at least, describe (with a couple of words) what it means explicitly in these plots.

Line	Comment
1	I think that after ":" the P in "Pattern" should be lowercase
6	In my opinion the word "ions" appears two times in too little space. I would write "[...] protons, helium and ions of [...] "
8-9	"[...] considered here using data from satellites in the period 1961–2017"
9-10	"It has been found that the results of these measurements line up [...] following some regular patterns"
10-11	see line 6
11-14	This sentence is a little bit convoluted and it may result difficult for the reader to understand. I would suggest: "[...] It has been observed that in the inner regions of the ERB, ion fluxes decrease with increasing solar activity and that the solar-cyclic variations of fluxes of $Z \geq 2$ ions are much greater than for protons; moreover, it seems that they increase with increasing atomic number Z."
14	"Finally, the possible physical [...] "
21-22	"The ERB consist mainly of [...] "
23-24	The use of $Z \geq 2$ here is redundant, in my opinion. Helium and Oxygen are already ions with $Z \geq 2$ so I think that you can modify the sentence as "In ERB there are also helium nuclei and other $Z > 2$ ions (like Oxygen etc) [...] "
25	"[...] disturbances, ion fluxes and their distributions are changed"
28	I think that "[...] between a local vector [...] " should be "[...] between the local vector [...] " because in a well-determined region you can have only one specific vector of the magnetic field. Moreover, I would put a "the" also in front of "vector of a particle velocity"
29	"which are injected [...] "
30	"[...] drifted conserving [...] "
31	"This layer is called the drift shell"
32-33	I will suggest adjusting the following sentence as follows, to maintain the text more easily readable: "Therefore, experimental data on the ERB are often represented in coordinates {L, B}, where L is the drift shell parameter and B is the local induction of the magnetic field [...] "
35	"center of the dipole itself (in Earth's radii R_E)"

36	In my opinion, the use of the passive form here should be avoided: "fluxes [...] decrease [...] "
37	"[...] to higher latitudes [...] "
41	I would add a "respectively" at the end of the sentence, to better distinguish between B and B_0
42-43	"Outer and inner regions of the ERB are maintained in dynamic equilibrium with the environment by different mechanisms "
44-46	I would suggest to slightly modify this sentence as follows: "The outer belt [...] is formed mainly by the mechanisms of radial diffusion of such ions towards the Earth under the action of fluctuations of both electric and magnetic fields resonating with their drift periods"
46-48	I would avoid the repetition of the word "ions" here. Moreover I would re-write these parts: "This transport is accompanied [...] " and "as a result of their interactions [...] "
49-53	I think that there is a temporal mismatch between "[...] protons with $E > 10$ MeV is formed [...] " and "The inner belt of ions with $Z > 4$ was formed [...] "
54-55	"[...] the mechanism of ion capture from Solar Cosmic Rays takes place [...] "
57	"[...] ERB, together with the sources of injection and losses of ions, are known"
58-61	The sentence here is very important, in my opinion, because it introduces the problem that this paper tries to solve, so it should be written more clearly. "However, for comprehensive verification of the physical models and to identify the mathematical models and their parameters, the formulation of complete and reliable empirical models of the ERB for each of the ion components, is necessary; it is also necessary for ensuring the safety of space flights [...] "
62-67	"These models can be created only using experimental data, obtained over many years and decades; such models [...] were already created for protons (AP8/AP9) and they are widely used in space research. On the contrary, measurements of $Z \geq 2$ ion fluxes suffer from technical problems due to small statistics and high background of protons and electrons. For this reasons, empirical and semi-empirical models for $Z \geq 2$ particles, are applicable [...] "
68-72	I think that the first part of this sentence is just a repetition of what already said in lines 62-67; therefore I would leave only the part "One of the main problems of this work is to consider the possibility to create a sufficiently complete and reliable [...] "
73-76	"In the following sections, the spatial-energy structure [...] (Sect. 2) together with the possible physical [...] are considered [...] , and the main [...] are given (Sect. 4) "
78-79	The sentence here is a bit confused. I would suggest to change it as "There can be ions trapped in drift shells only with energies less than some maximum values, determined by [...] "
79	gyroradius
83	"[...] The green line in Figs 1-6 represents this very boundary [...] "
87-88	I would remove the second "satellites " here and just leave the phrase as: "[...] with the differences in their trajectories [...] "
89	"[...] sets of energy channels [...] "
90	I would substitute "Solar" with "Sun"
91	"[...] of the Earth during various periods of data-taking [...] "
91-92	"[...] influence the fluxes of [...] with respect to proton fluxes [...] "
94-95	"[...] In this section, experimental data of various [...] $90°$ have been used."
97-98	"[...] L shells, where these data were obtained, the ion fluxes are not distorted by the background [...] "

99-103	"In many important experiments, the instruments were not able to separate fluxes of ions by their charge. Moreover, for the ions of the CNO group, the separation by mass are not usually performed. For heavier species, for example for Fe ions, we have very small data-sets. Therefore, this work presents data on helium ions (without any charge separation) and CNO ions (without any mass or charge separation)."
104-108	"To solve the aforementioned problems, it is important to choose the form of representation (space of variables), in which the results of the single experiments can be compared to each other. In our case, the space {E. L} has been used; this choice is very efficient to better organize fragmentary experimental data obtained in different ranges of E and L."
112-113	"Experimental points on these figures are connected by lines [...] "
113-115	I think that a wide number of small sentences can break the fluency of the discussion. So, in this case, I would suggest removing the last one and write: "[...] the decimal logarithms of the fluxes J, in unit of $(cm^2 s$ ster $MeV/n)^{-1}$, are shown near each iso-lines"
116	"[...] but also very convenient [...] "
118-119	I think that both sentences inside the parenthesis () could be removed here.
120-143	This whole paragraph is crucial for the reader to better understand the meaning of Figures 1-6 and how they were built. So, the concept should be expressed in a more concise and linear way; therefore, I strongly suggest to review this paragraph. Meanwhile, I suggest a possible rewording: "The points in Figs. 1-6 have been obtained from the values of the single ion fluxes J(L) as a function of energy (the average energy for each channel of the instrument) and with an equatorial pitch angle close to $90°$. Unlike electron fluxes or ion fluxes measured during geo-active conditions, the ion fluxes considered here (i.e. during quiet periods), usually have only one maximum. As a result, for each experiment, 1 or 2 points were obtained (both shown on the outer/inner edges of the E vs L profiles). Sometimes, especially for low fluxes, only one point was obtained: in these cases, the radial profile of the ion fluxes was cutoff at small values of L due to a significant background of contaminating particles and no interpolation/extrapolation has been performed whatsoever. Each iso-line, shown in these figures, has been evaluated separately from the corresponding set of experimental points (icons); thus, in more abundantly populated sectors of the plots (i.e. for protons with $E > 1$ MeV at $L > 2$) such iso-lines are mixing in Figs. 1-2. In case of a large distance between neighboring points, the corresponding segments of the iso-lines are shown as dashed arcs. The radial profiles of the differential fluxes J(L) of particles with different energy tend to intersect with each other in those regions where the energy spectra present some local maxima or minima. On the contrary, the iso-lines cannot intersect with each other: because this would mean that, at the same point in the {E, L} space, proton fluxes differ very significantly (by an order of magnitude). Such uncertainty does not have a physical sense and a special analysis is needed to identify other possible sources of error."
159-161	"[...] There is a large number of experimental data concerning ERB protons; the most important of them are presented in Figs. 1 and 2. These figures serve as a comparison with similar distributions of $Z \geq 2$ ions (Figs. 3–6)."
162	"[...] Figure 1 represents results from the satellites [...] "
164	"[...] have been collected during minimum periods of various solar cycles, i. e. between [...] "
173-174	"[...] These results were obtained during maximum periods of solar cycles: 20th (1968-1971), 22nd (1990-1991), 20rd (2000), and 24th (2012-2017) [...] "
175-178	"The data [...] are given in both Fig 1 and 2 because solar-cyclic variations of the ERB proton fluxes are negligible [...] "
181-184	"[...] the proton fluxes during solar minima (Fig. 1) are higher than during maxima (Fig. 2). In addition, in the former the inner edge of the proton belt is less steep and it can reach smaller L shells [...] "
191	"[...] The red line corresponds to the [...] "

192-194	"[...] can be connected to a discrepancy between the real configuration of the magnetic field lines of the magnetic field and the dipolar configuration (used here for L shell calculation) [...] "
197-198	"[...] correspond to certain values [...] "
199	"[...] changes of fluxes with changing L [...] "
200	"[...] transformations in a magnetic field [...] "
201	"[...] It results from these [...] "
202	"distances [...] increase [...] "
206	"In this work, a wider range of L and E is considered [...] "
208-210	"[...] This is due to the fact that the energy range is significantly extended toward higher values (up to 200 MeV), but here the ionization losses for protons rapidly decrease [...] "
214	I would put "are presented " at the end of this sentence
215	"Figure 3 represents [...] "
220	"Figure 4 represents [...] "
215-224	For these sentences, I would suggest following the comments on lines 162-174
229	I suggest removing "are observed "
229-230	"[...] but the distribution of helium ions is slightly shifted towards higher values of L shell [...] "
231	I think that could be useful to better define "white spots". Do you mean that there are few experiments on ERB helium studies?
232	"corresponds to the lower [...] "
234	"[...] If one takes into account [...] "
238	"[...] , which pass above the red line at L > 2.5, correspond to an average value of [...] "
239-240	I would summarize a bit this sentence, writing only "[...] For helium ions spectra, as for protons ones, the values of the parameters of the power-law tail are in good agreement with what has been found in [...] "
243	It is not clear to me what you intend here... I guess "[...] deviate from the slope of the red line [...] " - is that correct?
244-245	"[...] increase with decreasing L slower than expected from adiabatic transformation. "
245-247	"This means that the ionization losses of the ERB helium ions significantly exceed these losses for protons, in agreement to well-known calculations [...] "
249-256	See comments on lines 162-174, 215 and 220
257	"[...] of the ion fluxes of the CNO group [...] "
258	See my comments on line 230
262	"[...] but the fluxes of the CNO group increase by one order of magnitude or more [...] "
263-264	"[...] it is seen also that the fluxes of the CNO group change several times more than the fluxes of helium ions do [...] "
265	"[...] This means that [...] "
269-270	"[...] to adiabatic laws that are not reported here, but this line let us estimate such deviations [...] "
281	"[...] If one takes into account [...] "
287	"[...] following the results [...] "
289	"[...] of the ERB have been studied in many works [...] "
291-292	"[...] These variations reach one order [...] "
300	"[...] This density depends on [...] "

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303	"decrease "
306	"[...] the stationary proton fluxes will increase with the decreasing solar activity [...] "
307-308	"[...] and this leads to a decrease in the amplitude of the solar-cyclic variations of proton fluxes [...] "
308	"[...] depends on its energy [...] "
313	"[...] These variations can be explained by the same mechanism that has been suggested for protons at $L < 2.5$ [...] "
315-316	"[...] For ions with $Z \geq 2$ in the ERB, ionization losses are more significant than for protons and this can be connected to the absence of ion [...] "
317-318	"[...] Such short lifetimes are manifested also [...] "
320	"[...] $Z \geq 2$, the regions in which variations can manifest, should be [...] "
322	"[...] in the energy ranges considered here [...] "
324	"[...] of the same energy of the other ions under study [...] "
326	"[...] These are very rough estimations, but they are in agreement with the results presented in [...] "
329-330	"[...] for protons with $E > 10\text{-}20$ MeV at $L < 2.2$; in fact, protons form mainly under the action of the CRAND mechanism [...] "
331	"form mainly [...] "
333-335	"[...] the solar-cyclic variations of $Z \geq 2$ ion fluxes can be motivated only under the assumption that the effect related with an increase in the ionization losses of such ions significantly exceeds the effect connected with the possible enhance of radial diffusion of ions on the rising phase of solar activity [...] "
339 "in logarithmic scale "	
340-341	"[...] the range of L, in which these dependencies for two energy channels are parallel to each other is connected to the power-law tail of the spectra [...] "
341-343	"[...] Instead, on smaller values of L, these fluxes begin to converge and the radial dependencies of these fluxes intersect with each other, which is related to the maximum in the spectra. [...] "
343-345	I suggest to remove this sentence here, or at least merge it with the following one on lien 345: "Concerning the physical mechanisms leading to the formation of power-law distributions of ions, the main source of ions in the outer [...] "
346	"[...] usually spectra have an exponential shape [...] "
352	"[...] The most likely region for this to happen is the plasma sheet [...] "
354	"[...] the exponents of these spectra are close [...] "
356	I think that the acronym for IMP-7 and 8 is well known to people reading this paper, I would leave only the reference to Sarris et al.
357	"[...] the shape of the ion spectra of the PS usually do not change during [...] "
359-360	"[...] in the PS exceed the times of substorms [...] "
364	"[...] representations of the mechanisms [...] ". I would also suggest to remove "and character"
365	"[...] this part of the ion energy spectra is formed in the PS by stochastic mechanisms of ion acceleration; this hypothesis is supported by many experimental results [...] "
367-372	"[...] The statistical aspect of these mechanisms reveals itself, in particular, in the fact that the ratios of fluxes (and partial densities) of ions with different Z can differ, even greatly, at low and high energies. During their passage in the phase space, ions gradually loose information about their origin and, therefore, the high-energy tails of their spectra contain ambiguous information on the partial densities of different components of ions in the source [...] "

373-378	The high-energy portion of the ion spectra of the PS can be generated by the mechanisms of acceleration of particles on magnetic irregularities moving with respect to each other (Fermi mechanism). The fractal structures of the PS are revealed on scales from ~ 0.4 to ~ 8 thousands kilometers, for example, in the data of the satellite Geotail [...] If the mass of the ions are small compared to the mass of the magnetic irregularities in the PS, the average values of the index γ of the power-law tail should not depend on mass and charge of such nuclei "
381	"it follows "
382	"[...] <1, γ increases monotonically [...] "
385-386	"[...] and their spectral density decreases rapidly with increasing [...] "
388	"corresponds to the condition [...] "
393	"[...] form analogous to that of ion spectra in the ERB [...] "
398-399	"[...] In this work, the experimental results [...] plane, have been analyzed [...] "
401-404	"[...] The degree of such similarity increases with [...] and it is linked to the nature of the main sources and on the universality [...] "
405-407	"[...] Moreover, solar-cyclic (11-year) variations of the spatial-energy distributions of the ERB ion fluxes have been investigated, It has been noted that the ERB ions fluxes are weaker with increasing solar activity and this effect increases with increasing atomic number Z. "
408	"[...] is typical, also, for faster [...] "
409-410	"[...] as has been underlined in [...] "
412	"[...] their radial diffusion can be neglected [...] "
417-418	"[...] As Z and energy become larger and L becomes smaller, the uncertainties in the values of the ERB fluxes become larger [...] "
418-421	"These gaps must be filled by the results of future experiments on satellites; for now, the extensive gaps in the experimental data for fluxes of ions with $Z \geq 2$ do not allow to create sufficiently complete and reliable empirical models of the ERB for these ions. "
599-603	"The numbers on the curves refer to the values of the decimal logarithms of J where J [...] is the differential flux of protons with [...] . Data of satellites are associated [...] symbols. The red lin corresponds to [...] , while green line corresponds to [...] "
605-609	See comments for lines 599-603
611-615	See comments for lines 599-603
617-621	See comments for lines 599-603
623-627	See comments for lines 599-603
629-633	See comments for lines 599-603