**Reviewer #1 Evaluation #1**

**This is my review of the paper by Shumko et al., submitted to GRL. This paper describes observations made by the twin FIREBIRD cubesats of the scale size and bounce period of a bouncing microburst. Understanding properties of microbursts is important as they may be an important source of electron loss in the outer radiation belt.  
  
I find the results and methodology of this paper to be mostly acceptable. However, the prose needs much fixing as certain explanations are confusing/lacking as written. Certain sections seem to be lacking proper lead-in sentences, etc.  
  
Some reorganization may also be necessary. For example, in Section 3.3, describing the bounce period comparison, it is described how the observed bounce periods are calculated, and how the models are used to calculate bounce period. But, there is no conclusion to this section describing the results, or why this is important. It reads more like a plot caption than a proper Analysis section. Some of the results are discussed later, but there needs to be something here to, at the very least, motivate this section.**

**There are also other parts of the Discussion and Conclusions sections that may be better suited for the Analysis section. Missing from the Discussion and Conclusions sections, I feel, are some reasons why these results are important!!! Perhaps not everybody is convinced that microbursts are important to study, or that multi-observation Cubesats are useful tools (for example, we're now, after decades of study, just beginning to have proper instrumentation, like FIREBIRD, to determine the scale size of microbursts). A few sentences seem to be in order. I'll leave it to the authors to decide how to organize things, but as it stands, some of the sections don't feel complete or properly motivated.**  
  
**My detailed comments follow. Suggested wording changes are typically in quotes.**

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Dear Reviewer,

Thank you for your thorough feedback on this manuscript. We rewrote a few paragraphs, not limited to lines 148-159, 192-209, and 289-314 (in the track changes version). There were many places where our manuscript needed improvement, and we addressed those issues and replied to each of your comments in green highlighted text.

For simple fixes, we replied with “Done”, otherwise we went into detail on the changes we have made.  
  
L22: "similar to whistler-mode chorus" Done  
  
L22: which further support  "which supports" Done  
  
L23: maybe: "are a product of scattering by chorus waves." Done  
  
L36: Sentence is quite awkward. Perhaps try: "Some of these electrons may be scattered into the loss cone impulsively. These are termed microbursts, and may be predominantly caused by chorus waves." Also, this needs references. Done, and added example references to Thorne et al. 2005 and Breneman et al. 2017

L39: "from scattered electrons impacting the atmosphere" Done  
  
L42: "the SAMPEX > 1 MeV channel" Done  
  
L45: Perhaps state one or two other reasons why people think there may be a connection. (e.g. both are bursty, etc.). Otherwise this sentence seems odd and isolated. Done, and added the result from Breneman et al. 2017.  
  
L49: Breneman17, a paper just published, uses FIREBIRD data and seems to be the most recent estimate Thank you for brining up this up. Their work has been referenced in numerous sections.  
  
L53: "multiple bounces, observed with SAMPEX,…" Done

L59: Is the date important here? Even so, it's stated weirdly, like Crew published their paper on that day. Rewrote the sentence.  
  
L61: "over a period" Done  
  
L62: "The analysis in this paper…" Done  
  
L65: "Section", not section. AGU’s grammer and style guide states that sections should be lower case (https://publications.agu.org/agu-grammar-and-style-guide/#capitalization)  
  
L72: define "U" and make sure it isn't confused with the U in FU3 and FU4. Also, defining FU3, FU4 will help people to remember… We have clarified that “Flight Unit 3/4” = FU3/4 in the manuscript.  
  
L78: "54 and 90 deg, respectively." Done  
  
L82: What is HiRes? It is the High Resolution data product that was sampled at 18.75 ms at the time. This was added in the manuscript.  
  
L83: collimated misspelled Done  
  
L90: awkward sentence Fixed up the sentence  
  
L93: I believe you mean the drift loss cone We meant the bounce loss cone since the electrons would be lost within one bounce.  
  
L101: "......of a geomagnetic storm." Done  
  
L102: sentence is awkward. Fixed up the sentence  
  
L102: Is this actually McIlwain L or just simple dipole? It is McIlwain L calculated using the T89 model.  
  
L110: Awkward sentence. Maybe try: "At the beginning of the FIREBIRD-II mission, the two spacecraft clocks had not yet been synchronized, resulting in an uncertainty in spacecraft separation."  
Also, you don't explicitly mention that the clocks can drift at different rates There were two different issues that has been clarified in first paragraph in section 3.1. We also pointed out that the clock drift of ~20 ms/hour is relative between both spacecraft.

L105: Are you sure this is smoothed over 150 msec? I see details on shorter timespans than this. Maybe 15 msec? We did a 150 ms boxcar average. From looking at the non-smoothed data, the finer details show up after smoothing due to larger relative Poisson noise at low fluxes.  
  
Figure 1: What are the tick marks for? They are Poisson error bars. It is now clarified in the Figure caption. These changes are not tracked, since the AGU Latex template had an error when tracking changes inside of figure captions.

L112: "using temporal events.". Also, how can they be observed simultaneously if they have a delta-t separation? (also L116) This was a confusing paragraph so we rewrote the entire intro of section 3.1. In addition, we included plots of the microbursts used for the temporal analysis in the supporting information.   
  
L117: maybe replace "and it was" with ", giving a value of dt = 2.28…" Done  
  
L119: "it"? I understand what you're saying, but I think this section needs to be written more carefully. It's a very important section - needed to convince the reader that you've done things correctly - but it's too difficult to read at the moment. Removed the ambiguity and cleaned up the sentence.  
  
L112: clarify "their" Done  
  
L123: Perhaps, "was applied to events that are assumed to be stationary." Done  
  
L125: "to move to the leading satellite's position." --> Not technically true, since the trailing satellite is not catching up to the leading satellite. Please restate more carefully by adding something like "...at the time of the observation…" Done. The sentence should be technically correct now.  
  
L126: Please describe what TLEs are Done  
  
L131: Would it be possible to describe briefly what this algorithm does? Done  
  
L134: "...is reasonable" Done  
  
L138: "latitudinal scale size of the microburst". Also, provide more detail here. What does this mean. Is this expected? As it is, the number is just stated and no context is provided. The first paragraph in section 3.2 was rewritten to clarify the lat-lon map and elaborate on the latitudinal scale size, as well as explain how the uncertainty in the latitudinal scale size were estimated.   
  
Equation 1: do you have a reference for this, or can you derive it in appendix? It was derived using geometrical arguments which were added to section 3.2.  
  
L147: Are you saying that the valid limit is well-approximated by alpha0=0 b/c the FIREBIRD value is 3.7 deg? Not sure what you're trying to say here. Yes we are. The sentence has been restructured to be more clear.  
  
L149: "is defined as…" Done  
  
L~152: How are you obtaining the error bars in this section? We have added a brief error analysis explanation to section 3.2.  
  
L164 (Figure 2): Confusing. I spent about 20 sec trying to find the "N's" on the plot. To help the reader, we modified the caption to state that the peak labels are P1-5 for FU3 and P1-4, as well as modified first paragraph in section 3.2 to point those labels out. These changes are not tracked, since the AGU Latex template had an error when tracking changes inside of figure captions.

L172: I think you mean "We used the baseline flux definition given in O'Brien04...." There's nothing canonical about this particular definition, as far as I'm aware. It is one possible definition, and the manuscript was edited to reflect that.  
  
L173: do you mean: "time interval, which in this analysis we take to be 1/2 second?". Yes, the sentence has been reworded.   
  
L174: By multiple Gaussians, do you mean that for each microburst you fit a single Gaussian to each energy channel? No, we fit a superposition of Gaussians for all peaks for each energy channel. I’ve clarified that sentence.

L178: I don't understand this. What does this hint at? This has now been clarified in the manuscript.  
  
L184: Seems that the results should be discussed somewhat here. There seems to be a discrepancy b/t models and some observations. Done  
  
L189 (Figure 3): Is there something special about the "Schulz and Lanzerotti" dipole? Isn't it just a dipole, centered dipole, etc? Nothing special about the dipole defined in Schulz and Lanzertotti, but we are using their bounce period in a dipole calculation. We referenced the book in the text, and renamed the Figure 3 legend to “Dipole”.  
  
L196: Discussion needs an intro sentence or two...like "Using the twin FIREBIRD cubesats, this study has.…" Done  
  
L198: Maybe mention that Parks' observations were at much lower energies. Done. Also specified the energies from which Blake et al. 1996 calculated the microburst scale sizes.   
  
L205: "The"  "the" Done  
  
L206: Regarding chorus scale sizes: Santolik03 had estimates that were lower (~100 km). As far as I know, these haven't been refuted. This should probably be mentioned. The scale size calculations may have significant variation. The Agapitov values were case studies, as I recall, and I don't think they're the final word on the matter. We have added a few sentences in the discussion section that elaborate on the chorus scale size results found by Gurnett et al. 1979, Santolik et al. 2003 and Agapitov et al. 2010, 2011 and 2017.   
  
L207: Regarding chorus, this statement may be a bit strong. Are there any satellite observations in the region that show evidence for chorus or other types of waves? Can other waves that may scatter microbursts have a similar scale size. Also, though you briefly discuss this in the background section, it may be beneficial to cite some research here indicating that chorus is indeed thought to scatter microbursts. We toned down the language slightly, please let us know if it is still too strong. In light of the recently published Breneman et al. 2017 paper, we added their results to the introduction. We added to the discussion section that there were no spacecraft nearby at the time (we checked THEMIS, RBSP, and CLUSTER) and AE ~ 400 at this time which is associated with an increased amplitude of chorus waves in the dusk sector [Li et al 2009]

L207: "by whistler mode chorus" Done  
  
L215: This is more of a technical matter, and as such should be in the section discussing the bounce calculations. Moved to section 3.3  
  
L219: Should mention that these observations were made possible (or facilitated) using the twin FIREBIRD cubesats. Done  
  
L227: This is technical and doesn't seem appropriate for a conclusion section. Removed the technical information and just summarized the results from section 3.3.

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**Reviewer #2 Evaluation #1**

**The paper, “Microburst Scale Size Derived from Multiple Bounces of a Microburst Simultaneously**

**Observed with the FIREBIRD-II CubeSats” by Shumko et al. reports the observation performed by**

**CubeSats. The microbursts are electron precipitating events believed to be caused by wave-**

**particle interaction. To confirm the theory that resonance interaction between electrons and**

**Chorus waves, measuring the spatial scale of microbursts is crucial. Therefore, I believe this**

**manuscript handles important physical issues and should be published in GRL. However, current**

**article has some critical errors, so I recommend to revise the manuscript properly before**

**publication.**

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Dear Reviewer,

Thank you for your thorough feedback on this manuscript. We appreciate your questions and we hope we have adequately replied to all of them. Our replies are in green highlighted text. For simple fixes, we replied with “Done”, otherwise we went into detail on the changes we have made.

1. The main key point of this manuscript is “The lat/lon scale at LEO were 28.8 ±0.8 km and

50.8 ±11.4 km, respectively.” However, as the authors mentioned, these numbers are lower

bound of spatial scale. This article does not provide the measurements of average

microburst scale or upper bound. I think the second key point also should be changed

like this, “Magnetic equator scale sizes seem to be larger than the chorus wave source

scales”. Wording in the key point has been changed to point out that the lower bound is consistent.

2. The authors assumed the bounced microburst is caused by energetic electron’s bounce

motion. However, this assumption might have some arguments. First, the bounced

microburst structure is not general. Why do some microburst structures have just a single

peak? Second, are there no possibility bounced waves generate such multifold electron

structures?

We have added reasoning on why bouncing packets are not commonly observed to section 2; typically the background flux in the drift loss cone will hide returning bounces.

We have addressed that it is unlikely that a bouncing or repeating wave could have caused the peaks with a consistent energy-dependent dispersion signature shown with the bounce periods in Fig. 3.

3. Line 96, Page 4, The corresponding mirror point in opposite hemisphere is 95 km

altitude. I think the 95 km altitude atmosphere is enough dense to scatter the electrons.

How do you calculate 40 – 60 % loss?

For the 95 km altitude comment, we have added a reference to *Fang et al.* 2010 and described their work. Essentially, most of the electrons with energies 100 keV < E < 1 MeV could make it down as far as 60-80 km altitude, where they deposit most of their energy.

We calculated the 40-60% loss by looking at the change in peak amplitudes from the first to second peak. A similar result was found by Thorne et al. 2005 who used a bouncing microburst seen by SAMPEX to estimate that ~33 % of that microburst’s electrons were lost at each bounce. We added this to section 2 of the manuscript.

4. In Figure 1, If the bounced electrons make the second and the third peaks, there should

be time shift depending energy. However, I cannot see such time shifts while the authors

say there are energy dispersions. Can you show such energy dispersion more clearly?

In this manuscript, the time correction is a key technique in deriving conclusion. Though

JRL has length limitation, more detail description of time correction should be provided

by supplement material.

Thank you for pointing this out. We have added black vertical bars in Figure 1 to help the reader see the dispersion. While for some peaks it is hard to see the dispersion due to Poisson noise, it is easiest to compare the first dispersionless peak to the last peak which shows substantial dispersion. In addition, the dispersion signature is clearly visible from the bounce period calculations (Fig. 3). This has been pointed out on lines 258-260.

The plots with the cross-correlation lag analysis have been added to the supporting information.

Minor comments

- Line 92, Page 4, latitude = 63°  latitude = 63°N, longitude = 15°  15° E Done

- In Figure 1, What are the vertical lines? Is it error bars? Describe it.

They are error bars. We have added a description in the caption.

- In Figure 1, Add information of latitude, longitude, and altitude in bottom labels. Added.

- Refer following paper. This article describes wave-particle interactions conditions of

electron microbursts.

Lee, J. J., Parks, G. K., Lee, E., Tsurutani, B. T., Hwang, J., Cho, K. S., Kim, K.-H., Park, Y. D.,

Min, K. W., and McCarthy, M. P.: Anisotropic pitch angle distribution of ~100 keV microburst electrons in the loss cone: measurements from STSAT-1, Ann. Geophys., 30,

1567-1573, https://doi.org/10.5194/angeo-30-1567-2012, 2012. Added this reference to the introduction.