NASA Goddard SPACE FLIGHT CENTER

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Correlation between the Interplanetary Magnetic Field and Energetic Ion Structures in the Magnetosphere

Science

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Abstract

It is well-known that the solar wind drives the dynamics of the Earth's magnetosphere. Particularly, the sun's magnetic field that is carried across space by the solar wind, otherwise known as the Interplanetary Magnetic Field (IMF), is a key driver for magnetospheric phenomena. In this study, some prominent features that appeared in the Van Allen Probes ion flux data on energy-time spectrograms were explored in detail. These features have been called "nose structures" due to their unique shape in these spectrograms. While single noses are well-understood, the formation of multiple noses has been vaguely studied. These multiple noses present themselves as flux enhancements at narrow energy bands separated by spectral gaps. A southward orientation and certain magnitudes of the IMF z-component (thus B_z) have been known to drive magnetospheric convection for the particles. The study aims to find the correlation between this IMF component and the resulting multiple noses. The methods utilized in the study include conducting data analysis of solar wind and satellite data and implementing a program in Python that thoroughly sorts through and provides valuable information about each multiple nose occurrence. The minimum B_z value and time of observation both provide a measure of the convection intensity during events. The statistical analysis was then complemented by performing simulations of ion drift paths in IDL. This study is significant because it explores what conditions leads to these noses and introduces findings in the relation between a new parameter and an intriguing inner magnetosphere occurrence, possibly opening the door to future studies to explore this connection further.

Background

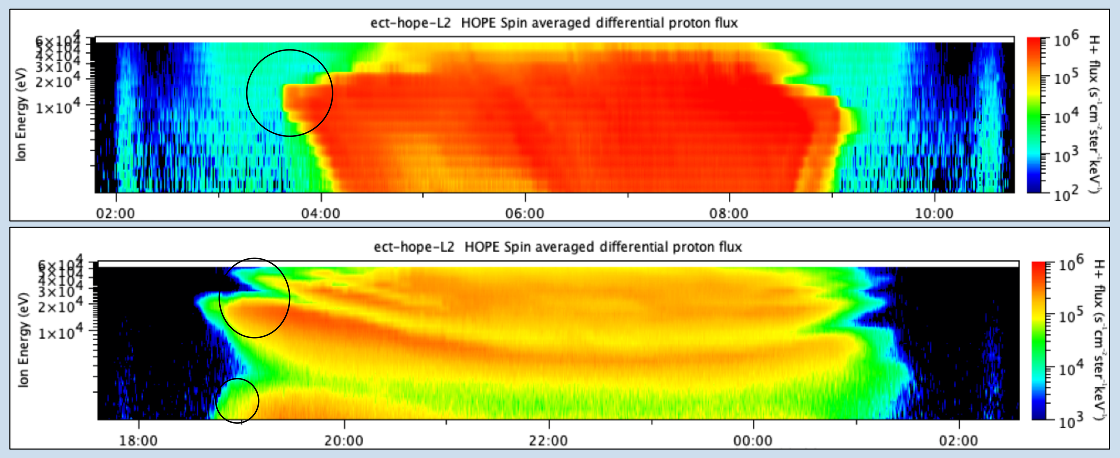

Fig. 1 - Different date energy-time spectrograms from the Van Allen Probes

- The top panel shows a single nose and we can observe multiple noses in the bottom panel.

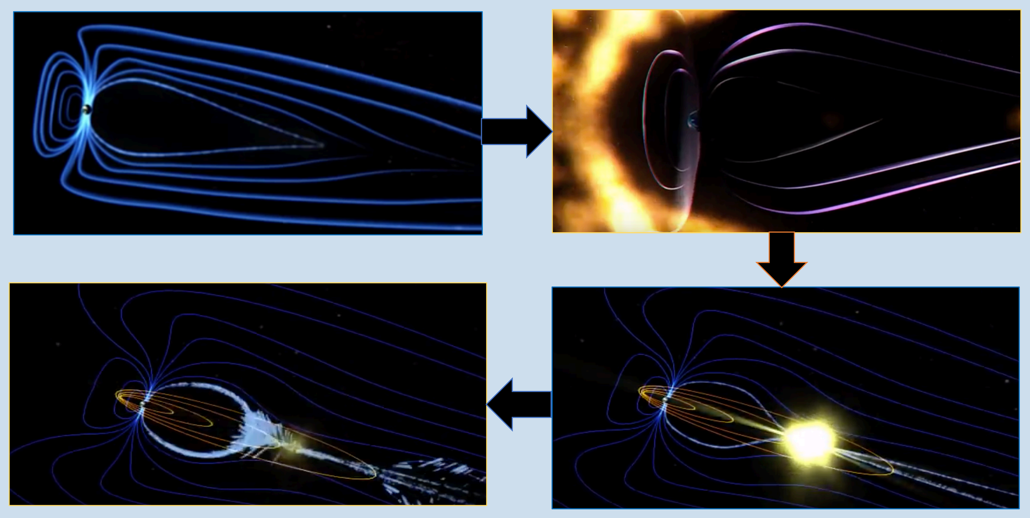

Fig. 2 - The process of magnetic reconnection

- When the solar wind has a **southward** z-component, it interacts with the northward geomagnetic field of the Earth and the field lines from both sources reconnect.
- This meeting forces them to travel backwards, ultimately reconnecting again at the magnetotail.
- Plasma sheet particles then drift earthward driven by **convection**.

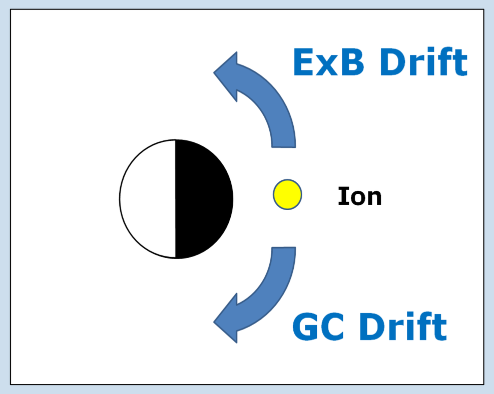

Fig. 3 - An ion subject to two drift directions when they encounter Earth

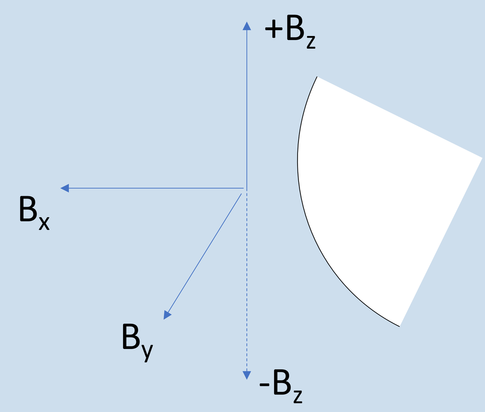

Fig. 4 - IMF components

- E x B drift is due to co-rotation, where **low** energy ions are dominated by this eastward drift.
- The Gradient-Curvature drift dominates over **high** energy ions and is the westward drift.

- A **negative** B_z value means the component is southward, and possible reconnection.
- B_z values during storms will vary, but B_z values during quiet times are **greater than -15**.

Methodology

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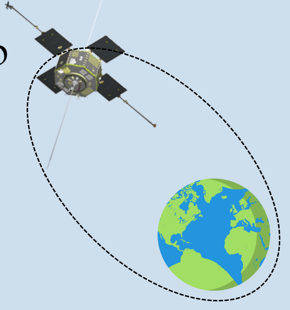
- The initial step of the study was to choose a time period for concentration.
- One full precession of Van Allen Probes is **22 months**, giving full MLT coverage.
- January 2013 – October 2014 were the dates chosen.



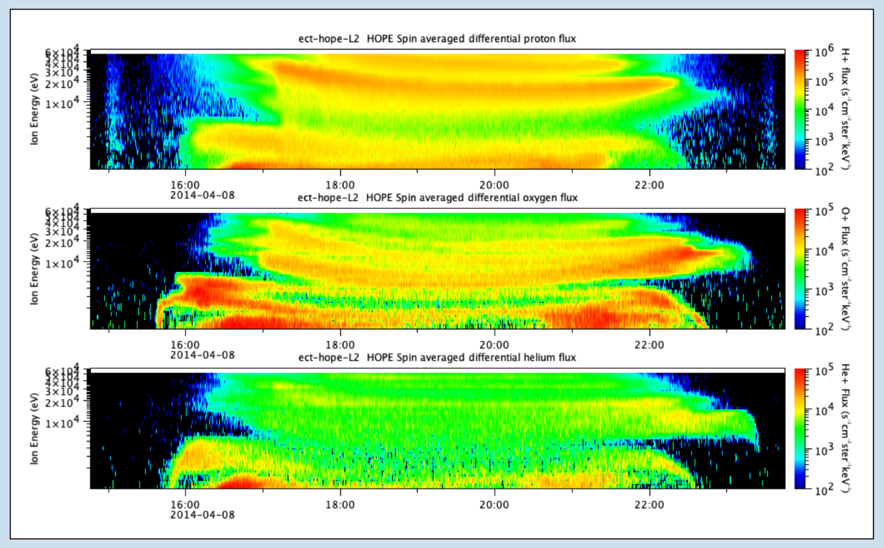


Fig. 6 - One perigee orbit of ion fluxes for April 8th, 2014

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- Figure 6 respectively displays three ion species: proton, oxygen, hydrogen.
- Date and time of all multiple nose appearances in these orbits were recorded.

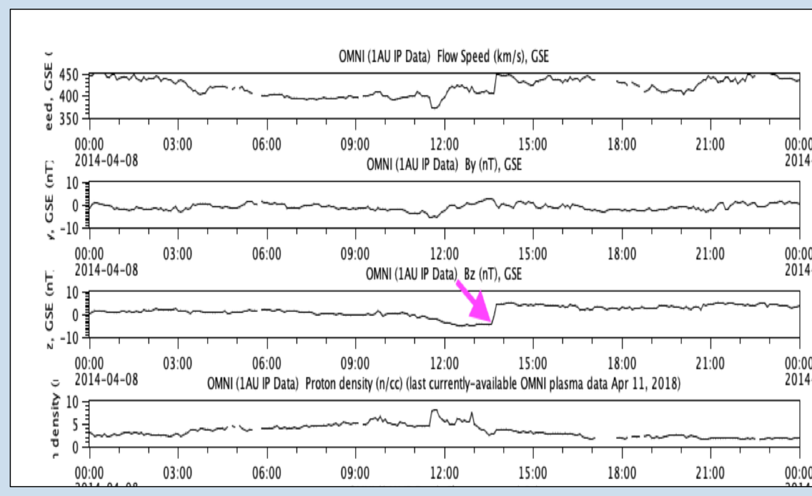

Fig. 5 - Plot of multiple magnetospheric parameters for April 8th, 2014

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- All events that had **quiet** conditions were plotted.
- The minimum B_z value was indicated by a pink arrow for each event.

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- A Python script was written to efficiently sort through the data.
- For 12 & 24 hours before all recorded multiple nose occurrences, the date, time, and minimum B_z value were outputted in a text file.
- Below displays a sample output line.

```
EVENT DATE: 20140408.0 EVENT TIME: 21:00 ||| (12) DATE: 20140408, TIME: 12:35, MIN. VALUE: -5.23 ||| (24) DATE: 20140408, TIME: 12:35, MIN. VALUE: -5.23
```

Results

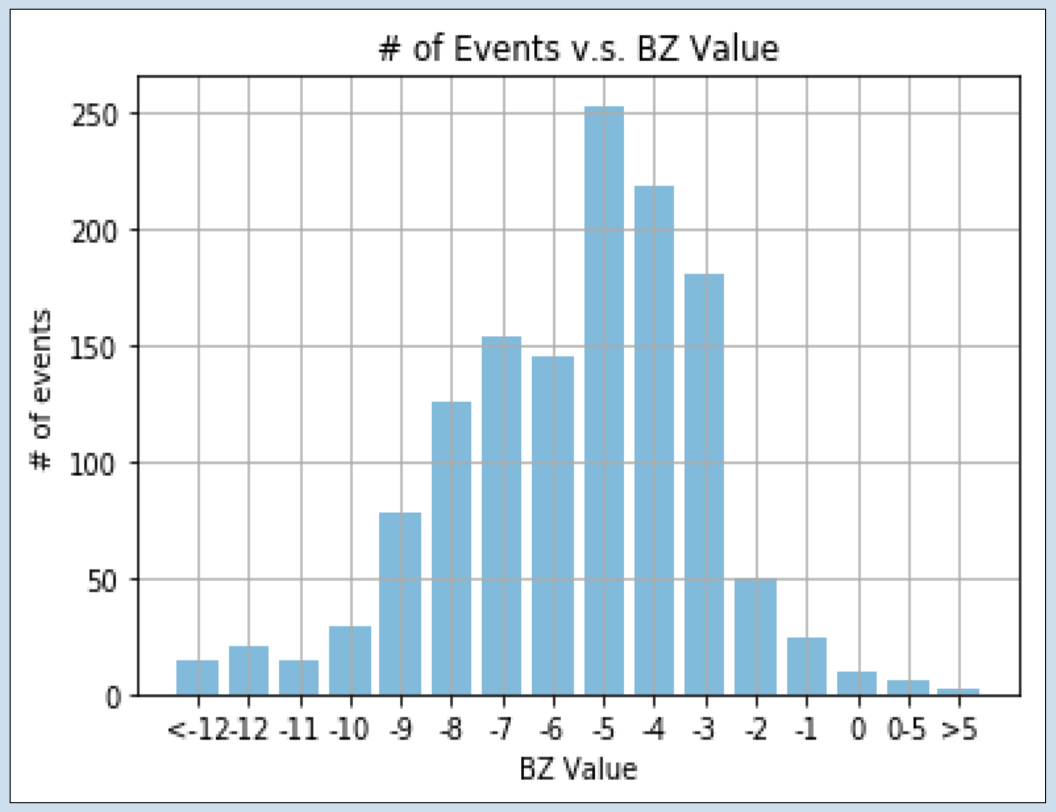

Fig. 7 - # of multiple nose events v.s. Minimum B_z Values

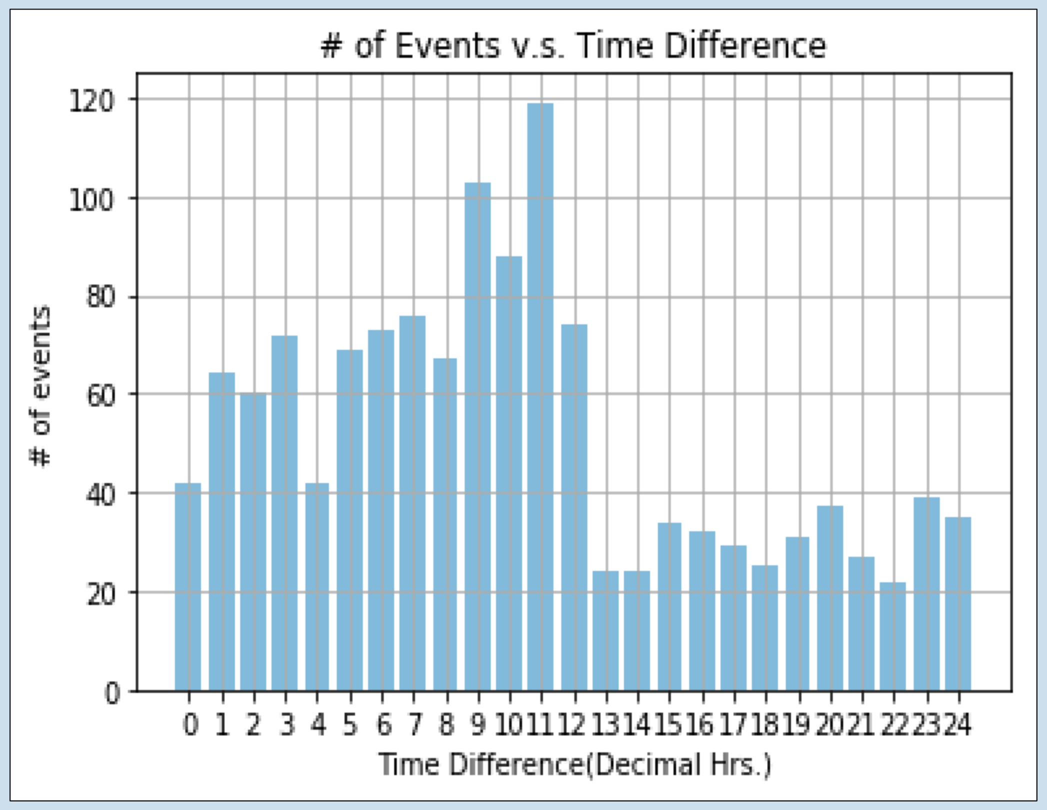

Fig. 8 - # of multiple nose events v.s. Time Differences

- 661 total number of multiple nose events and 1322 total B_z values gathered.

- An apparent **bell curve** shape is produced.
- Time difference is the calculated minimum B_z value time subtracted from multiple nose event time.

Plots created by Python to further support the study.

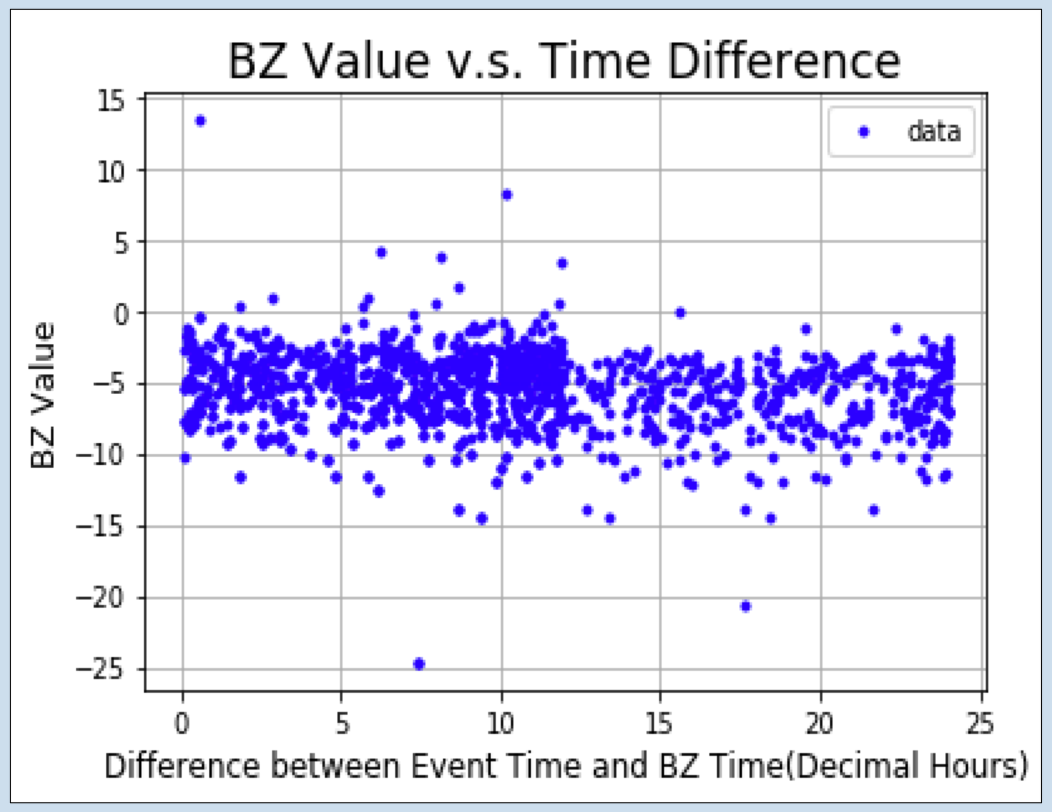

Fig. 9 - Minimum B_z values v.s. Time Differences

- We observe a trend in figures 8 & 9 regarding a **cluster** of data points around -5 B_z value with a few outliers in high activity levels.

Acknowledgements

I would like to sincerely thank my two mentors, Mei-Ching Fok and Cristian Ferradas, for guiding me throughout and NASA for providing the opportunity to participate in research and work this summer internship at GSFC.

Simulations

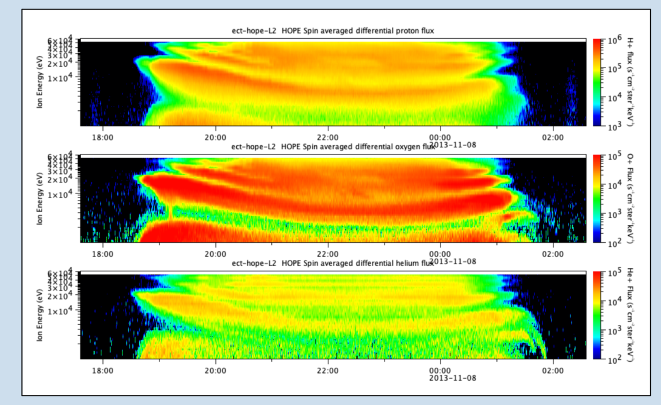

Fig. 11 - One perigee orbit of ion fluxes for November 7th, 2013

- To further complement the statistical study, particle drift simulations were performed in IDL for this date.

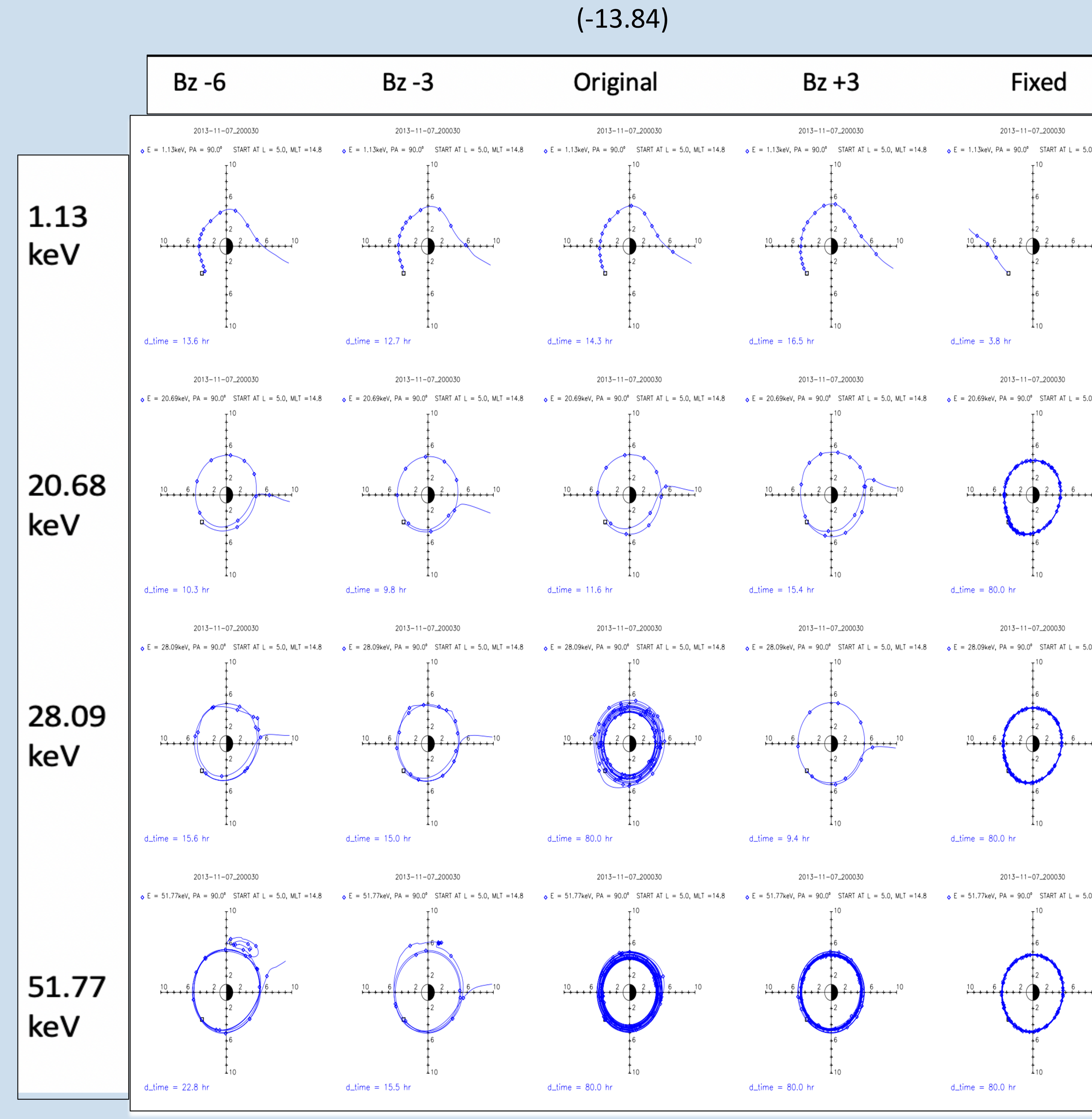

Fig. 12 - Particle Drift Simulation Chart

- The particle tracing was performed using a dipole magnetic field and Weimer 96 electric field model except fixed.
- Fixed contained all constant inputs.
- An **open** orbit and **short** drift time(< 24 hr.) signifies the occurrence of a multiple nose at that energy band.
- A closed orbit and long drift time signifies a trapped particle.

Discussion & Conclusions

- The high occurrence of multiple noses during **quiet** times confirms that these are a common feature during periods of **low** activity.
- During **storm** times, single or no noses are most likely observed. (Ferradas et al, 2018).
- The mean minimum B_z value of -5 nT shows that multiple nose formation requires some level of convection, which is driven by the IMF B_z.
- The data indicates that if convection is low for an extended time **after** the minimum B_z occurrence(> 12 hr.), the prolonged quiet conditions would favor the loss of these ions due to charge exchange interactions and **not** be observed by the spacecraft.
- The particle tracing showed that only ions with **certain** energies had **open** orbits connected to the source region in the tail.

References

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