Ion nose spectral structures observed by the Van Allen Probes

Poster #: 17

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GEM 2015 Summer Workshop, Snowmass, CO, 14-19 June 2015

1. Abstract

During the last decades several missions have recorded the presence of dynamic spectral features of energetic ions in the inner magnetosphere. Previous studies have revealed single "nose-like" structures occurring alone and simultaneous nose-like structures (up to three). These ion structures are named after the characteristic shapes of energy bands or gaps in the energy-time spectrograms of *in situ* measured ion fluxes. They constitute the observational signatures of ion acceleration, transport, and loss in the global magnetosphere. The HOPE mass spectrometer onboard the Van Allen Probes provides high-quality measurements of energetic hydrogen, helium, and oxygen ions near the inner edge of the plasma sheet, where these ion structures are observed. We present a statistical study of nose-like structures, using 21-month measurements from the HOPE instrument. The results provide important details about the spatial distribution (dependence on geocentric distance), species dependence, and geomagnetic conditions under which these structures occur.

2. Introduction

- Over the last 40 years several magnetospheric missions have detected ion structures which in the energy-time spectrograms appear as narrow energy bands, or "nose-like" structures [*Smith and Hoffman*, 1974; *Vallat et al.*, 2007; *Dandouras et al.*, 2009].
- Different types of nose structures have been observed and modeled: single noses [*Ganushkina et al.*, 2001], double noses [e.g., *Buzulukova et al.*, 2003], and triple noses [e.g., *Ebihara et al.*, 2004], although ion composition has barely been considered in the nose studies.
- The formation of these structures is credited to the combined effects that the electric and magnetic fields, ion losses, and changes in the plasma sources and field configuration have on the particles being injected into the inner magnetosphere.

3. Motivation

- Present the results of a computer program routine for the automatic identification of "nose-like" structures.
- Report for the first time a statistical study of ion structures for three major ion species: H^+, He^+, and O^+, using 21-month measurements from the HOPE instrument onboard the Van Allen Probe A.
- Investigate the spatial distribution, differences among species, and geomagnetic activity under which these structures occur.

4. Instrumentation

- The Van Allen Probes mission (2012-present) consists of two spacecraft (Probes A and B) in almost the same highly elliptical, low inclination (10°) orbits with a perigee of 1.1 R_E, an apogee of 5.8 R_E, and a period of 9 hours.
- The Helium, Oxygen, Proton, and Electron (HOPE) mass spectrometer [*Funsten et al.*, 2013] in the Energetic Particle Composition and Thermal Plasma (ECT) suite [*Spence et al.*, 2013] measures electrons and ions in the energy range of ~1 eV-~50 keV and distinguishes composition of three major ion species, H^+, He^+, and O^+.

5. Nose Structures

1

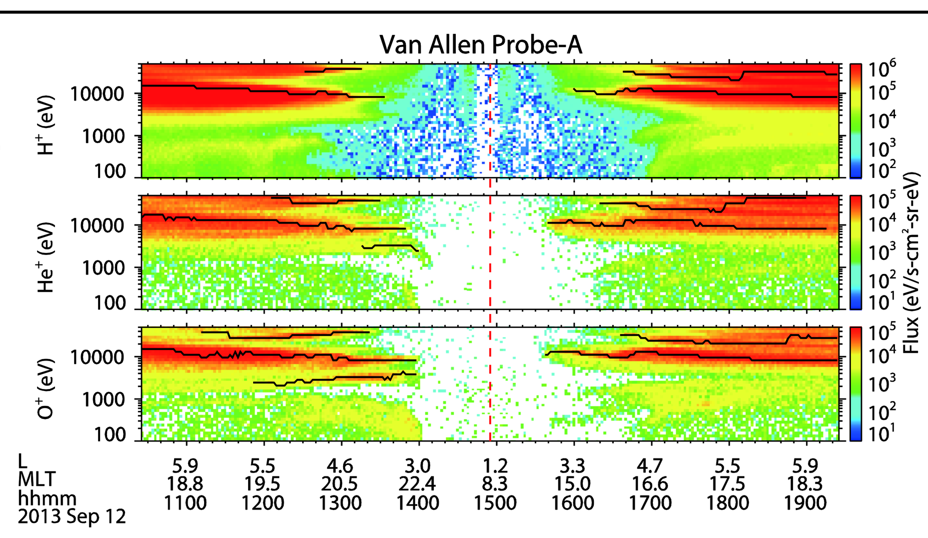


Fig. 1:
ECT-HOPE H^+, He^+, and O^+ energy-time spectrograms on the Van Allen Probe A during a whole orbit, centered at perigee (indicated by the vertical red dashed line), on 12 September 2013. The NIR identified two H^+ noses in the inbound and outbound passes, while it recognized three noses in the inbound and two noses in the outbound passes for both He^+ and O^+.

Event Selection

- The large amount of data provided by the Van Allen Probes motivated the development of a **Nose Identification Routine (NIR)** that automatically identifies the nose structures in the energy-time spectrograms and provides their spectral features.
- The NIR's basic procedure is to find the **flux maxima** in the time period of the spectrogram and their respective energies. It then traces these energies from the outbound towards perigee and stops when the flux drops below a given flux threshold.
- Ion data over a period of **twenty one months** (January 2013 - September 2014, almost full MLT coverage) allowed to analyze a total of more than **3,000** inner magnetosphere crossings (inbound and outbound passes). Only structures with energy above 1 keV were considered. From these crossings the NIR successfully identified the nose structures in:
  - 2,767 H^+ events
  - 2,549 He^+ events
  - 2,434 O^+ events

2

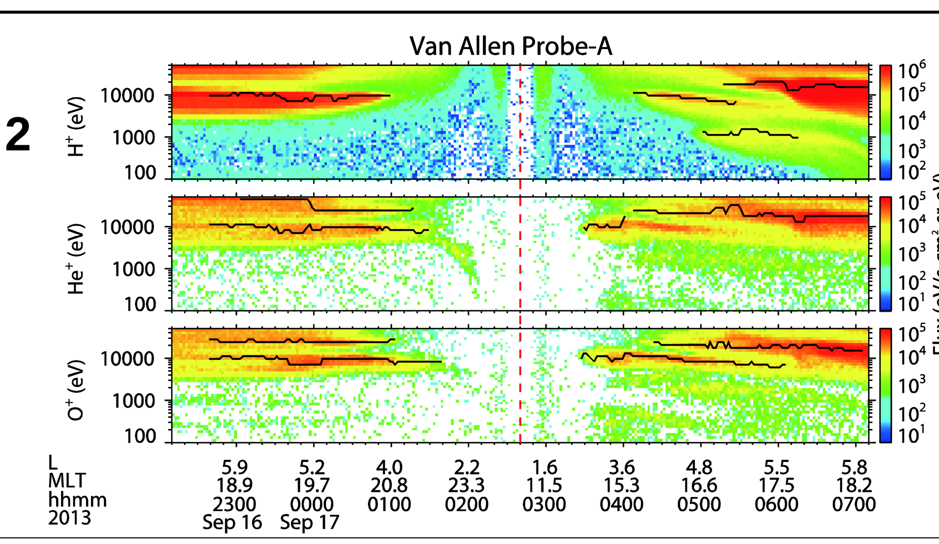
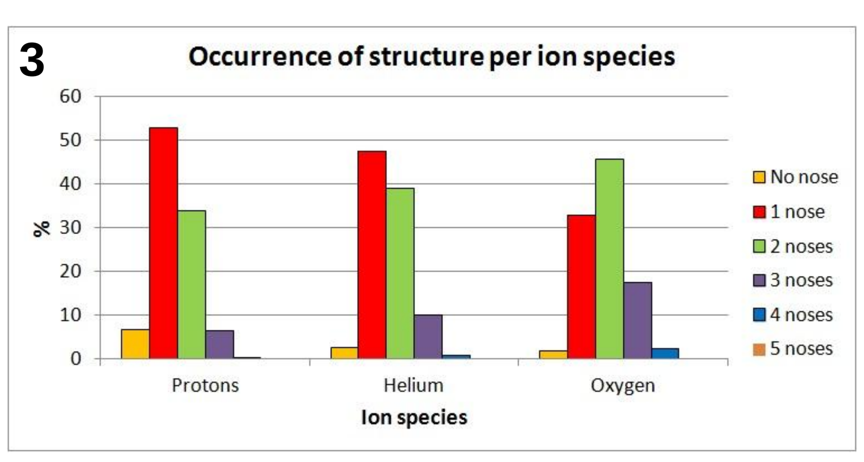


Fig. 2:
Energy-time spectrograms during one full Van Allen Probe A orbit on 17 September 2013 in the same format as Figure 1. One H^+ nose and three H^+ noses were detected by the NIR during the inbound and outbound passes, respectively. At the same time, two He^+ and O^+ nose structures were observed during both, the inbound and outbound passes.

6. Statistical Results

3



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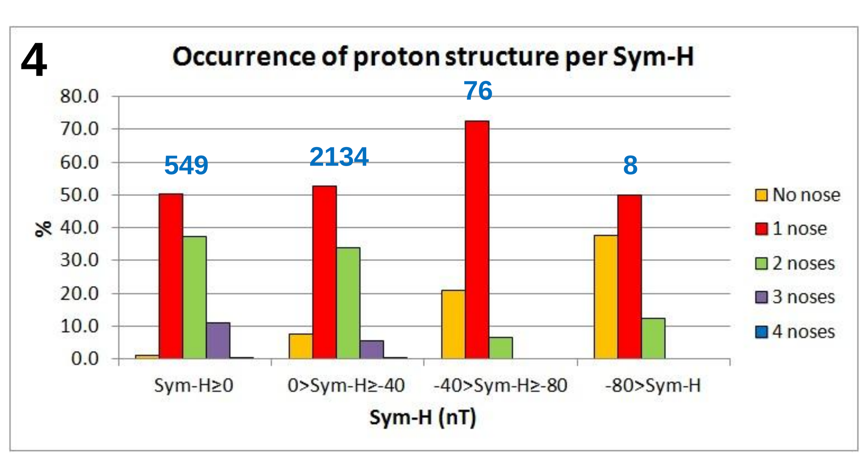

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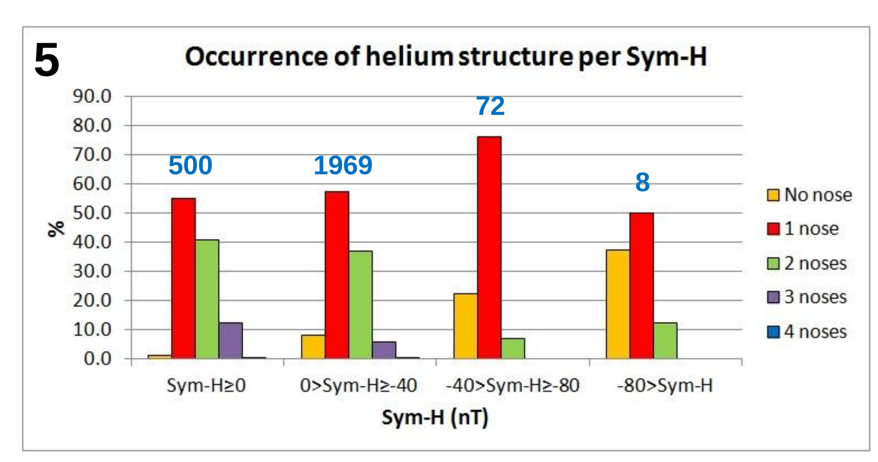

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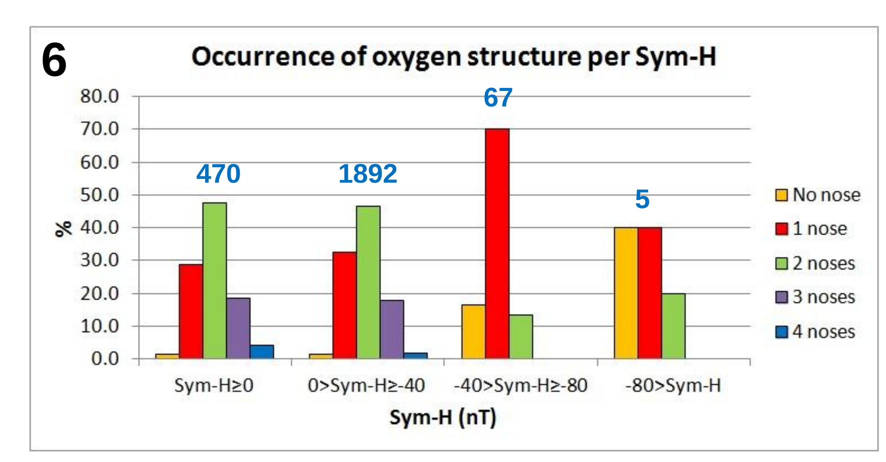


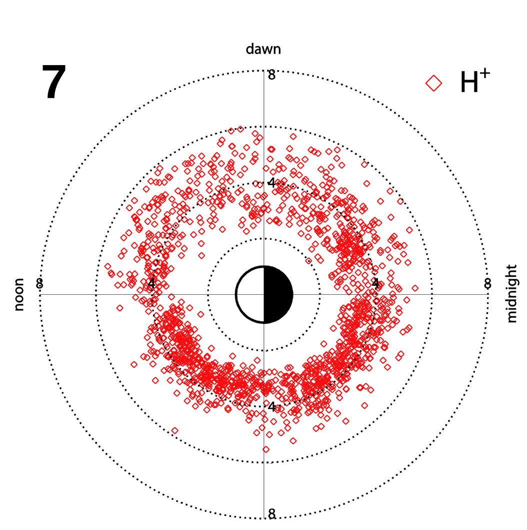
Fig. 3:
- Normalized occurrence of the **number of energy structures per ion species**. A distinction has been made between events presenting no nose structure (orange), one nose (red), two noses (green), three noses (purple), four noses (blue), or five noses (brown).
- During most passes at least one nose structure is observed.
- Multiple-nose structures (3 and 4 noses) are **more frequent in the heavy ions** than in the protons.

Figs. 4-6:
- Each figure shows the normalized occurrence of the **number of energy structures per *Sym-H* index range**, for each ion species. The four *Sym-H* intervals are: Sym-H≥0 nT, 0 nT>Sym-H ≥ -40 nT, -40 nT>Sym-H ≥ -80 nT, and -80 nT >Sym-H.
- The *Sym-H* value used is the **average** value over the time of the inbound or outbound passes.
- Regardless of ion species, three- and four-nose structures are **only observed when Sym-H >-40 nT**.
- Regardless of ion species, no-nose and single-nose events are observed **more frequently as *Sym-H* decreases**.

7. Spatial Distribution

L vs. MLT - 1 Nose

7



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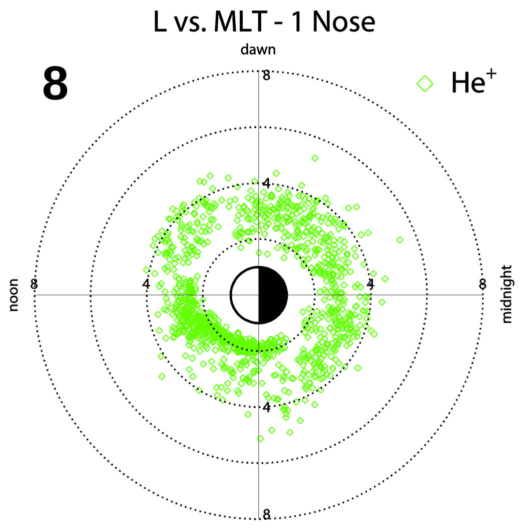

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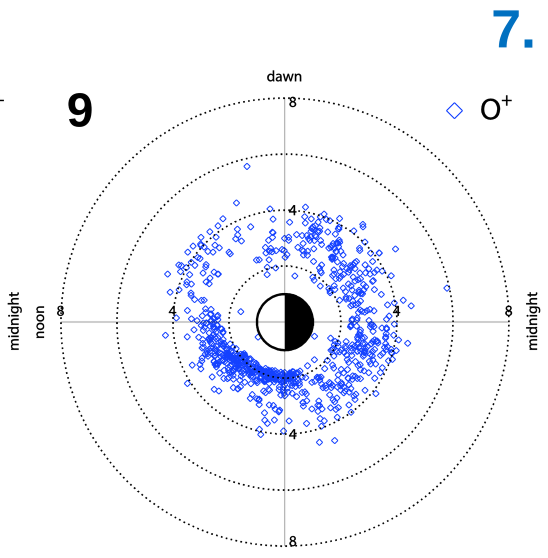

L vs. MLT - 3 Noses

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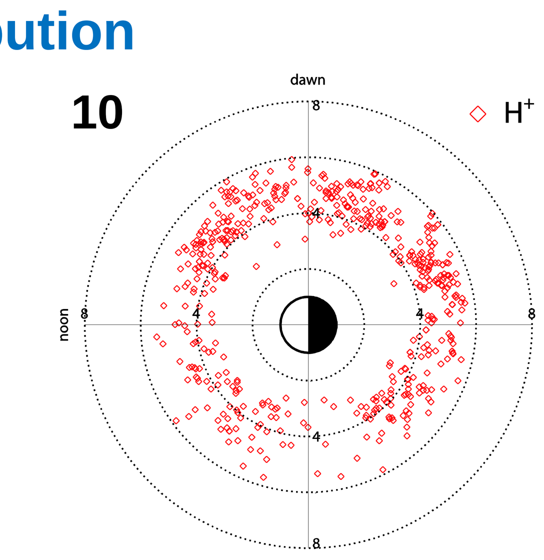

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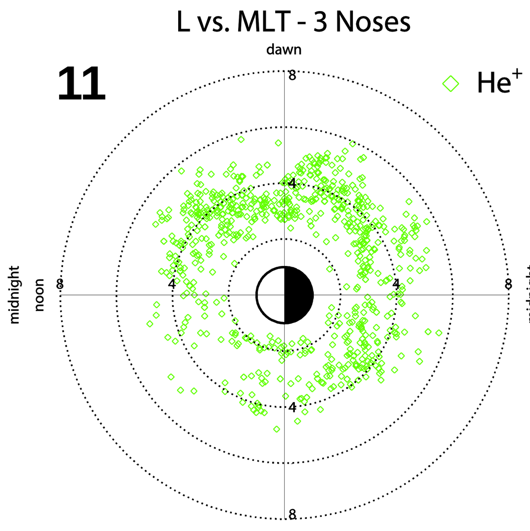

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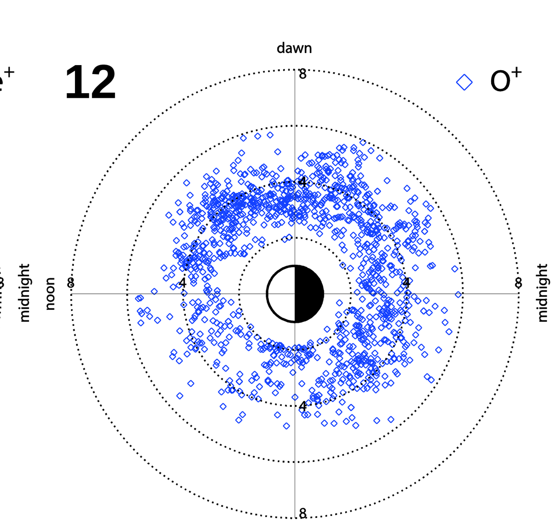

Figs. 7-9:
- Events where **one nose** was observed in the L-MLT coordinates. Only the tips (inner edge) of the noses have been plotted.
- The **heavy-ion structures** in general **penetrate deeper** that the proton structures.
- For all species, noses **reach deeper more frequently on the duskside** than on the dawnside.
- For all species, noses do not reach as deep inward particularly in the **morning sector** probably due to losses via charge exchange along long drift trajectories.

Figs. 10-12:
- Events where **three noses** were observed in the L-MLT coordinates. Only the tips of the noses have been plotted.
- For all species, there is a **higher occurrence rate on the dawnside** than on the duskside.
- This is consistent with previous results that show that the **dawnside** (especially the morning sector) **is less accessible to particle injections** during quiet times [*Ferradas et al.*, 2015], which would allow for the overlap of several structures leading to the formation of multiple-nose structures.

8. Summary and Discussion

- For the first time, a statistical study of **"nose-like" structures** in the spectrograms of three major magnetospheric ion species, namely H^+, He^+, and O^+, observed over 21 months by the ECT-HOPE instrument onboard Van Allen Probe A has been performed.
- Multiple-nose events (3 and 4 noses) are **only observed when Sym-H > -40 nT** possibly because during these times nose structures are able to overlap and become more dynamic. They are also more frequently observed in the heavy ions probably due to effects of **longer heavy-ion charge exchange lifetimes**.
- No-nose and single nose events are **more frequently observed as Sym-H decreases** possibly because during more active times particle injections penetrate deep wiping out the previously formed structures.
- The **L-shell dependence** of the nose tip, e.g., the heavy-ion nose structures reaching deeper than the proton noses, is consistent with **faster proton charge exchange losses** than heavy-ion losses.
- **Multiple-nose structures** are observed more frequently on the **dawnside** possibly because this sector is less accessible to fresh particle injections during quiet times [*Ferradas et al.*, 2015] which would allow for the overlap of several spectral structures leading to the formation of multiple-nose structures.
- Future work includes numerical modeling efforts to understand the observed features and extending the statistical study to other missions like THEMIS and Cluster.

9. References

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10. Acknowledgements

This work was supported by NASA under grant number NNX13AE23G. The work was also supported by RBSP-ECT funding provided by JHU/APL Contract No. 967399 under NASA's Prime Contract No. NAS5-01072.