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Ion spectral dynamics on the inner edge of the plasma sheet: Observations and simulations

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Abstract

Ion "nose-like" spectral structures, often observed by spacecraft on the inner edge of the plasma sheet, are due to the single or combined effect of several factors on ion access to the inner magnetosphere: convection, corotation, gradient and curvature drifts, losses, and changes in the convection electric field and/or the ion source population. Several different mechanisms have been suggested as being involved in the formation of nose structures, but it is not clear which is the dominant one or how they all combine to produce the observed phenomena. In this study, we report our initial results of the Rice Convection Model (RCM) or RCM-Equilibrium (E) simulations of the nose structures on 18 May 2004 (single-nose detected by Cluster), 29 May 2010 (single-nose by THEMIS), 11 April 2002 (multiple-nose by Cluster). It is indicated that combining simulations and observations to investigate nose structures can provide new insight into the physics of inner-magnetospheric ion access and into the limitations of the theories and modeling of the inner magnetosphere.

Nose Structures

1. Named after "nose-like" features in the energy-time spectrograms of *in-situ* measured ion fluxes in the inner magnetosphere [e.g., *Smith & Hoffman*, 1974; *Vallat* et al., 2007; *Dandouras et al.*, 2009]

2. Still a significant outstanding issue in Space Physics because of the critical but unanswered questions concerning them, e.g., the dominant mechanism of their formation

3. Constitute a test ground for the inner-magnetospheric theories and modeling

Questions to Be Answered

1. How do ions access the inner magnetosphere, and what affects the ion transport into the inner magnetosphere?

2. What factors control ion injection and the formation of the ion spectral features?

3. How well do RCM and RCM-E, state-of-the-art inner-magnetospheric models, reproduce ion dynamics in the inner magnetosphere?

RCM, RCM-E & Their Setup

* RCM: self-consistently computes particle drifts, electric currents, & electric fields to describe the motion of plasma in the inner & middle magnetosphere, w/ prescribed magnetic fields
* RCM-E: combines the RCM machinery with a friction-based magnetic field equilibrium solver
* Initial Condition: empty magnetosphere, run for 12 hours before realistic inputs are applied
* Inputs: 5-min OMNI solar wind number density, bulk flow speed, IMF B_z, polar cap potential drop, and *Dst*
* Magnetic Field for RCM: T96 [*Tsyganenko & Stern*, 1996]
* Tailward Plasma Boundary: an empirical plasma-sheet model [*Tsyganenko & Mukai*, 2003]
* Ion Composition: a *Kp*- & *F10.7*-based formula [*Young et al.*, 1982]
* Internal Ion Losses (i.e., Charge Exchange): not applied

Single Noses on 18 May 2004

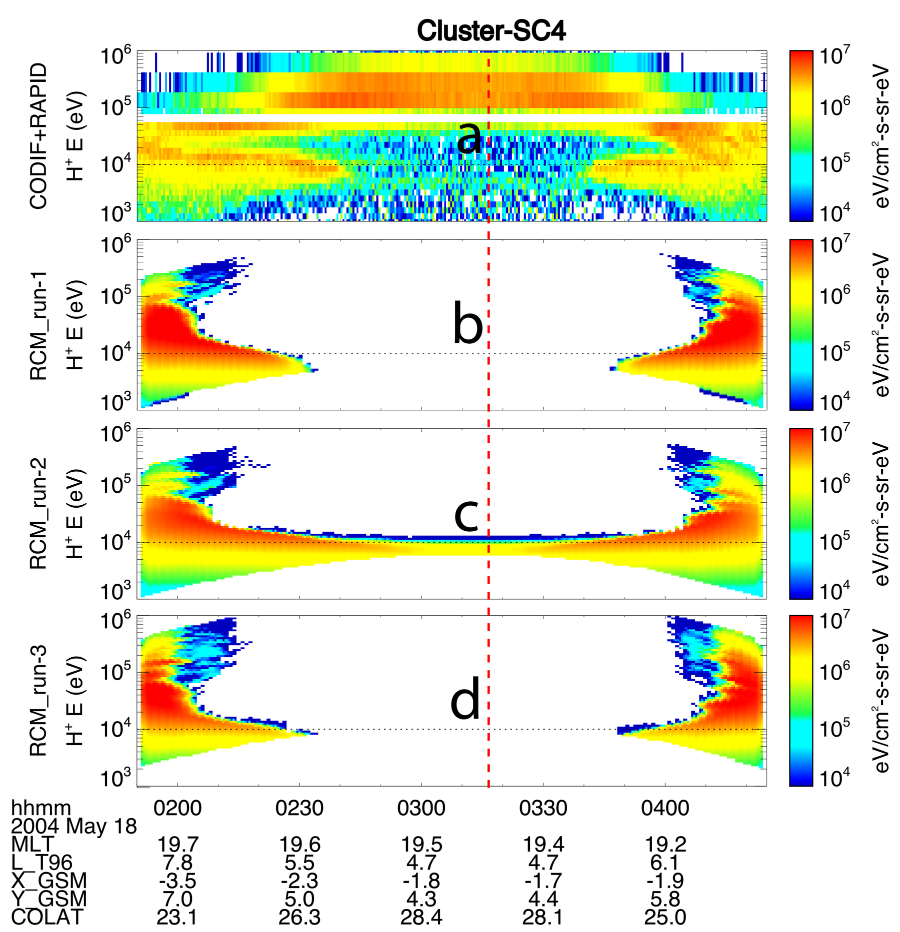

Fig. 1: CODIF (0.04-40 keV) & RAPID (> 40 keV) data (Panel a) vs. RCM simulation results from three runs (Panel b: standard, Panel c: halved plasma-sheet *N*, & Panel d: doubled plasma-sheet *T*) during the perigee pass of the spacecraft (the vertical dashed line).

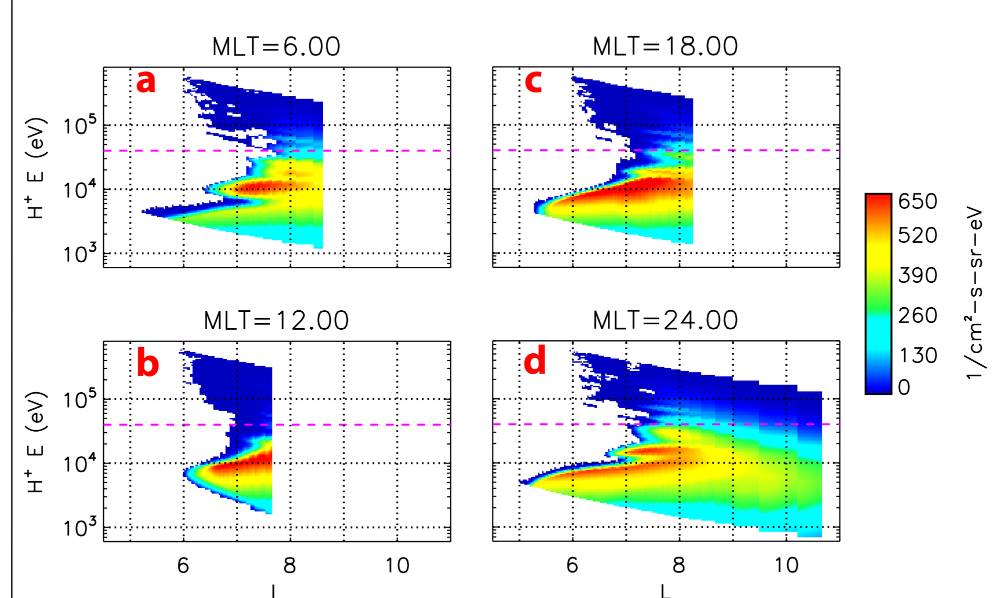

Fig. 2: RCM simulated H⁺ spectrograms at four magnetic local times, MLT = 06 (a), 12 (b), 18 (c), and 24 (d), at 04:00 UT on 18 May 2002 in the standard run (Fig. 1b).

Fig. 1:

❖ Panel a [Cluster Data]: The H⁺ spectral structures observed on the inbound & outbound passes are single noses. Another flux-enhanced structure, appearing at higher energies over the noses, is due to trapped ions in the pre-existing ring current.

❖ Panel b [Standard RCM Run]: Noses on both the inbound & outbound passes are fairly well reproduced by RCM. However, the fluxes in the simulated noses are clearly higher than observations and the tips of the noses do not extend to low enough L values.

❖ Panel c [RCM Run with halved *N* but same *T* @ boundary]: Flux values become more comparable to the Cluster data and H⁺ penetrate onto much lower L-shells (obviously too low).

❖ Panel d [RCM Run with doubled *T* but same *N* @ boundary]: Though not affecting the depth of the nose tips, the higher temperature reduces the simulated fluxes in the noses and increases the energy of the nose tips.

Fig. 2:

❁ As a large-scale magnetospheric model, RCM can provide a more complete picture of the nose structures than the observations themselves could provide.

❁ As also shown in Fig. 1b-1d, the energy increase along the decreasing L in the discrete-energy bands above the CODIF energy upper limit, i.e., 40 keV (the dashed lines), is due to the Betatron-Fermi acceleration when H⁺ adiabatically drifts to lower L-shells.

❁ It is surprising that some secondary structures, overlapping the bigger and deeper nose structure, exist at all the four local times. In a test run in which the RCM solar wind inputs are fixed at 01:00 UT, all those fine structures disappear but the big nose is still there (not shown).

Single Noses on 29 May 2010

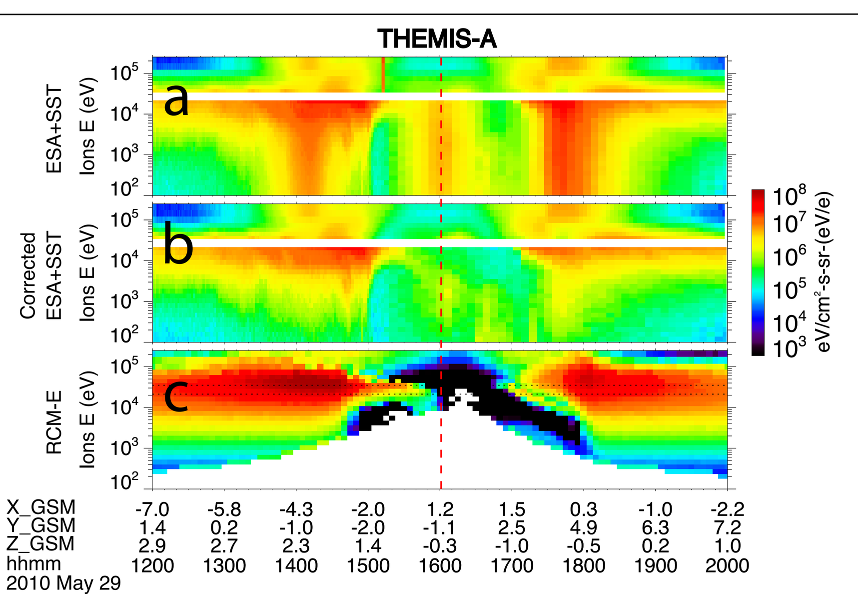

Fig. 3: ESA & SST (Panels a & b) vs. RCM-E simulation results (Panel c) during the perigee pass of the probe. Panel b shows the corrected data. In Panel c, two horizontal dotted lines mark the energy gap between ESA (lower energies) & SST (higher energies).

Fig. 3:

✼ Panels a & b [THEMIS Data]: Original and corrected ESA and SST data on the probe during the perigee pass (marked by the vertical dashed line). The spectral features of the nose structures have been fairly well recovered after the background correction. Note that penetrating relativistic e⁻ are still there for both ESA and SST ions up to 300 keV.

✼ Panel c [Standard RCM-E Run]: While the RCM-E results have generally larger fluxes than the data in the energy range of 10-100 keV, most ion spectral features on both the inbound & outbound passes are reasonably well reproduced.

Multiple Noses on 11 April 2002

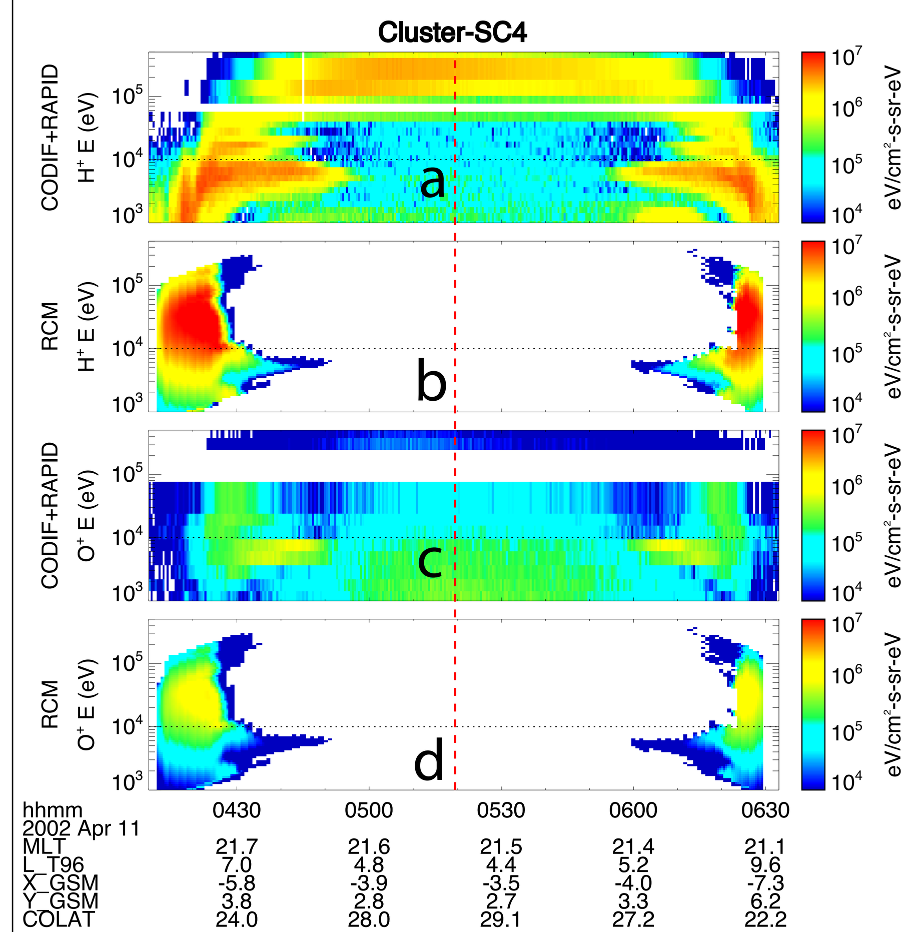

Fig. 4: CODIF & RAPID (Panels a & c) vs. RCM (Panels b & d) for H⁺ and O⁺, respectively, on the perigee pass (the vertical line)

Fig. 4:

✼ Panel a: Triple noses were detected on both the inbound & outbound passes, when AE ≤ 75 nT.

✼ Panel c: Low CODIF energy-resolution for O⁺ makes the multiple O⁺ noses less distinct, especially the second & third noses.

✼ Panels b & d: The second & third noses are not reproduced, though there is a weak secondary nose at either higher or lower energies. Fine structures similar to Fig. 2 are also present in the run.

Summary & Discussion

- Preliminary results indicate that RCM and RCM-E, two of the best self-consistent electric field models, are sophisticated enough to investigate the dominant formation process of nose structures on the inner edge of the plasma sheet.
- Ion density & temperature in the plasma sheet are two of the factors that control the formation and characteristics (e.g., min. L or depth, energy at the nose tip, and peak flux value) of nose structures, i.e., the access of ions to the inner magnetosphere.
- Secondary structures over the single nose (Fig. 2) are caused by variations in RCM inputs, which in turn could result in ion drift echoes, i.e., high-energy ions drifting faster than low-energy ions so that their population is superposed on the slower one locally [*Li et al.*, 2000]. The relationship between the secondary structures and multiple noses will be further examined.
- Using a boundary condition for substorm/bubble injection in RCM [e.g., *Zhang et al.*, 2009] and RCM-E might be a way to better reproduce the multiple nose. Note that brief southward-IMF periods on April 10, 2002 have not been included in the RCM inputs.
- We will continue to investigate nose structures with RCM and RCM-E by evaluating previously proposed nose formation mechanisms as well as those singled out from our data-model comparisons.
- This type of study will be of benefit to NASA missions, particularly the Radiation Belt Storm Probes (RBSP). Better physical knowledge of ion access to the inner magnetosphere will be critical for interpreting the 2-point RBSP measurements.

References

Dandouras, I., et al. (2009), *JGR, 114*, A01S90.
Li, X. L., et al. (2000), *GRL, 27*, 10.
Smith, P. H., & R. A. Hoffman (1974), *JGR, 79*, 7.
Tsyganenko, N. A., & D. P. Stern (1996), *JGR, 101*, A12.
Tsyganenko, N. A., & T. Mukai (2003), *JGR, 108*, 1136.
Vallat, C., et al. (2007), *AG, 25*, 1.
Young, D. T., et al. (1982), *JGR, 87*, A11.
Zhang, J.-C., et al. (2009), *JGR, 114*, A08219.

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