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Observations of the evolution of ion outflow during a sawtooth event

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Motivation

- Sawtooth events are quasi-periodic injections of ions at geosynchronous orbit [e.g., *Cai and Clauer*, 2009]
- Modeling suggests heavy ion feedback is needed to produce sawtooth events [*Brambles et al.*, 2011]
- However, ion composition profile of sawtooth events does not significantly differ from non-sawtooth storm-time substorms [*Liao et al.*, 2014]
- Further modeling suggests heavy ion loading only important for CME-driven events [*Brambles et al.*, 2013]
- Simultaneous Cluster (in situ tail), FAST (in situ ion outflow), and IMAGE (global UV aurora) observations can be used to test this hypothesis

Sample Event: 24 October 2002

- One of three events meeting the following criteria:
  - Cluster in central plasma sheet
  - FAST near noon-midnight meridian
  - Identified as sawtooth event [*Cai and Clauer*, 2009]
- SIR-driven event
- Event has also been simulated [*Brambles et al.*, 2013]

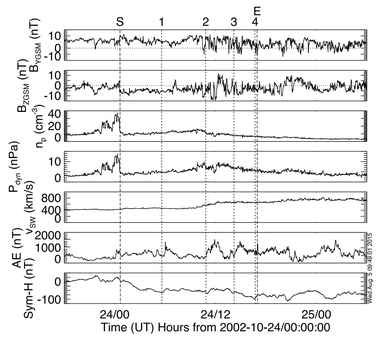

Figure 1. OMNI solar wind and geomagnetic indices surrounding the event. **Oscillating IMF is a candidate driver for injections seen during the latter half of the event**

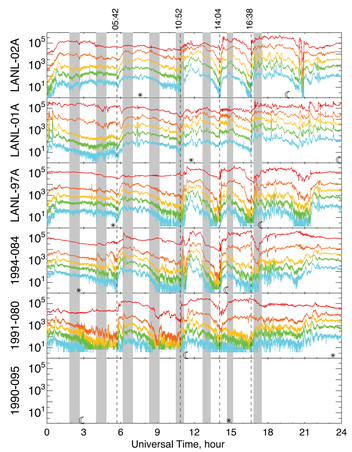

Figure 2. LANL geosynchronous data showing four sawtooth injections. Gray bars show times of FAST passes during the event

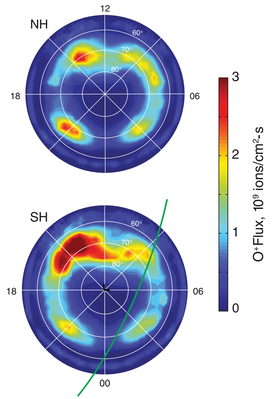

Figure 3. Average ionospheric outflow from the northern (top) and southern (bottom) hemispheres in the simulation of *Brambles et al.* [2013]. The FAST trajectory (invariant latitude vs. MLT) from the orbit containing the second injection is overlaid on the southern hemisphere plot. **The southern cusp/ postnoon sector is the dominant outflow source region**

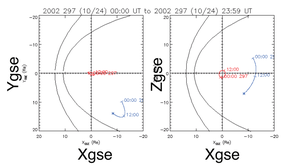

Figure 4. Spacecraft locations during the event, per SSCWeb

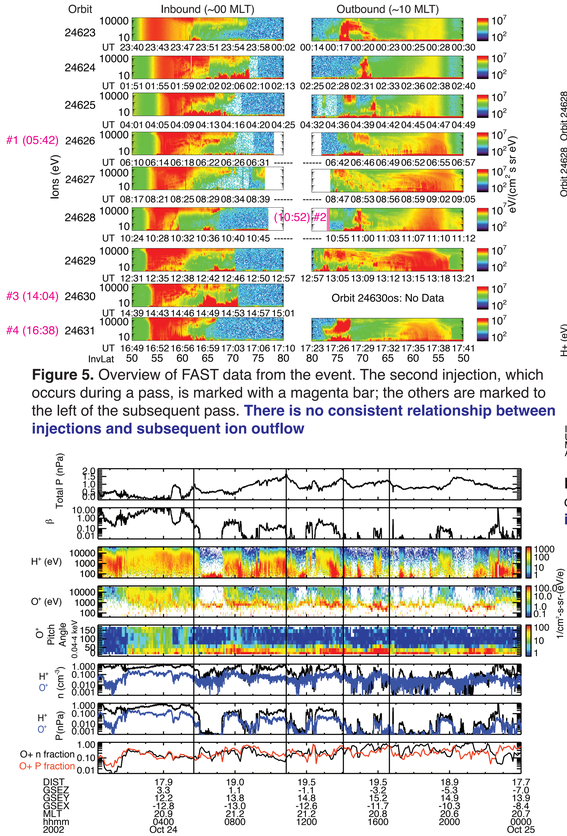

Figure 5. Overview of FAST data from the event. The second injection, which occurs during a pass, is marked with a magenta bar; the others are marked to the left of the subsequent pass. **There is no consistent relationship between injections and subsequent ion outflow**

Figure 6. Overview of Cluster data from the tail. Note the loading prior to, and the unloading after, each injection. **The oxygen fraction is observed to decrease prior to two of the four injections.** The cold oxygen beam in the lobe originates in the southern postnoon cusp, **consistent with the simulation results**

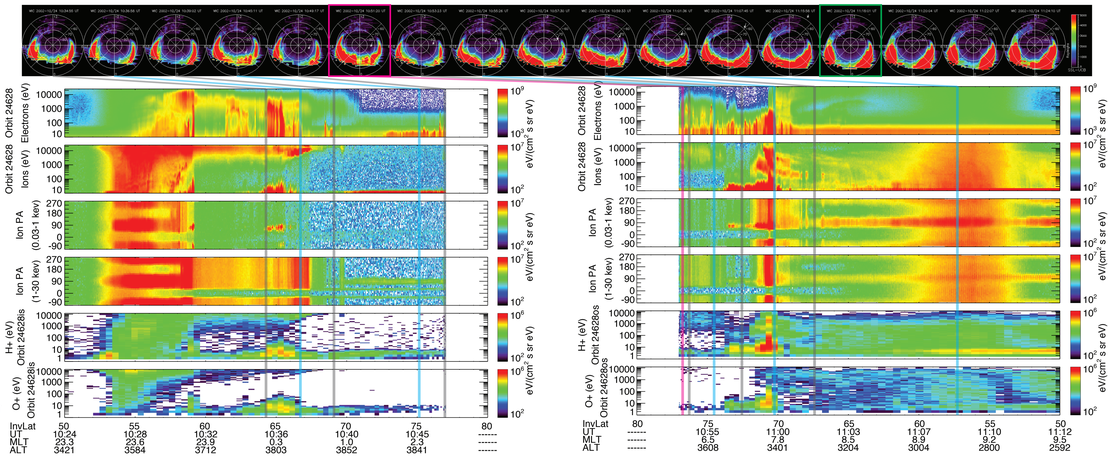

Figure 7. Top: Selected IMAGE WIC stills from around the second injection. Magenta and green boxes mark the nearest image to the injection time and an identified optical substorm onset [*Frey et al.*, 2004], respectively. Bottom: Detail of FAST data from the nightside (before the injection, left) and dayside (after, right). **Ion outflow is both stronger and more energetic on the dayside, after the injection, in contrast to the usual pattern of more energetic outflow on the nightside**

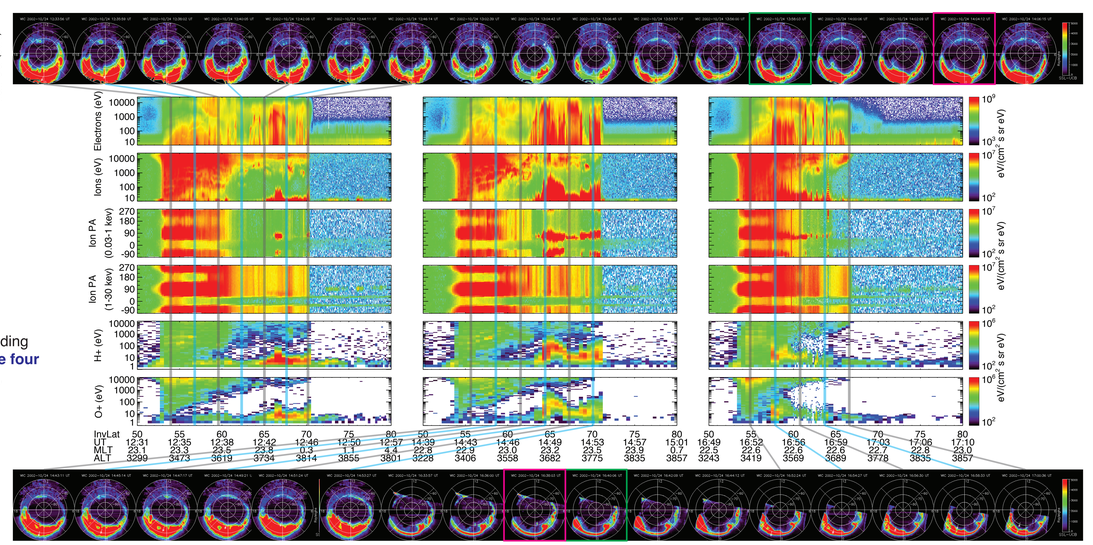

Figure 8. Top: IMAGE WIC stills from the FAST pass prior to and during the third injection. Middle: Detail of three consecutive FAST nightside passes bracketing the last two injections. Bottom: IMAGE WIC stills from the fourth injection and the two FAST passes on either side. Injection and optical onset are marked as in Figure 5. **Although strong ion outflow is observed after the third injection, the outflow is much weaker in the other two passes, and the substorm associated with the fourth injection is especially weak**

Summary

- Sawtooth event observed simultaneously by Cluster, FAST, and IMAGE
- Ion outflow can increase or decrease subsequent to onsets/injections
- Cluster observes oxygen beams in lobes
- No evidence that heavy ion feedback is occurring
- Consistent with *Brambles et al.* [2013] result for SIR-driven event

References

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