Triple Conjunctions between Cluster, FAST, and Ground Based Observatories – Events Identification

Costel Bunescu[1], Octav Marghitu[1,2]

(1) Institute for Space Sciences, Bucharest, Romania

(2) Max Planck Insitute for Extraterrestrial Physics, Garching, Germany

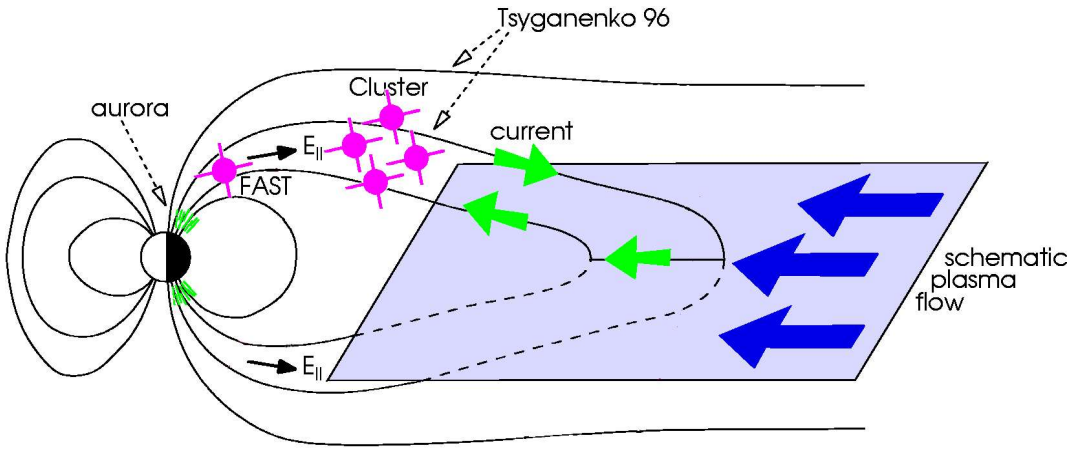
Contact: costel@venus.nipne.ro

Abstract

Satellite conjunctions are used to investigate how phenomena occurring at one spacecraft location correlate with processes observed by another spacecraft or/and a ground based observatory (GBO) – all of which are located around the same magnetic field line. In this study we search for Cluster and FAST conjunctions above the auroral oval, with Cluster close to perigee (at ~20,000 km) and FAST close to apogee (at ~4,000 km). Ideally the two spacecraft should be in the evening/pre-midnight sector, and conjugated also with a GBO which observes an elongated and stable arc. These rather strict conditions are motivated by the prospect to use the outcome of this work in comparing measured data with results yielded by a hybrid simulation code for the auroral circuit.

Although the 5.5 years of operation overlap between FAST and Cluster (since January 2001) include many conjunctions, the constraints mentioned above reduce the number of events considerably. We started by checking about one hundred triple conjunctions from the northern hemisphere, selected via SSCWeb. Since the number of potentially interesting events was quite small, we continued with a more systematic examination. Based on the precession in local time of the FAST and Cluster orbits, and on the variation of the apogee/perigee latitude, it is possible to identify promising time intervals when 'good' conjunctions between the two spacecraft are to be expected. For each selected conjunction it is further possible to find the corresponding GBO.Thus, one can optimize the search for promising triple conjunctions and minimize the risk to miss interesting events.

Introduction



A schematic sketch of the auroral current circuit (not to scale; adapted from Hamrin et al., 2006). Above auroral arcs, at about 1-2 R_E altitude, the electrons are accelerated to keV energies by the parallel electric field inside the auroral acceleration region (AAR). Conjugated data from the Cluster and FAST spacecraft may be used to cross-check simulation results and probe the processes that lead to aurora.

- Here we look for conjunctions between Cluster and FAST, with Cluster near the perigee (and near the top boundary of the AAR) and FAST close to apogee (and to the bottom of the AAR).

- We focus on the evening-midnight sector of the auroral oval, where the arc generation mechanism has a good chance to fulfill the assumptions in the simulation code [Vedin and Rönnmark, 2006].

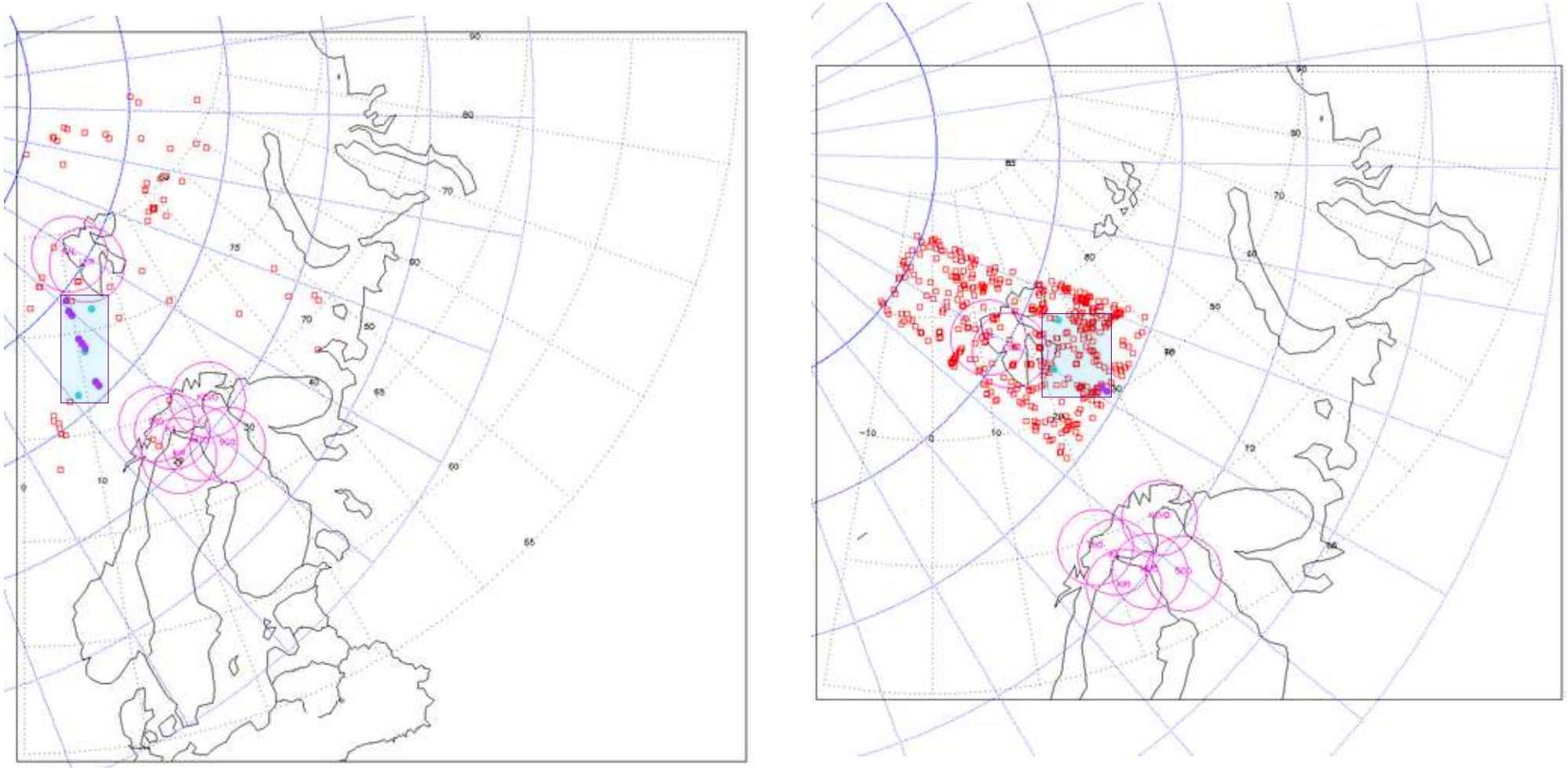
- This condition emphasizes the winter time as main search interval, roughly November to March, when the Cluster perigee is properly located.

- During winter there is also a better chance for ground optical data. Such data are needed to check the longitudinal extension of the auroral form, as assumed in the simulation code.

SSCWeb Search

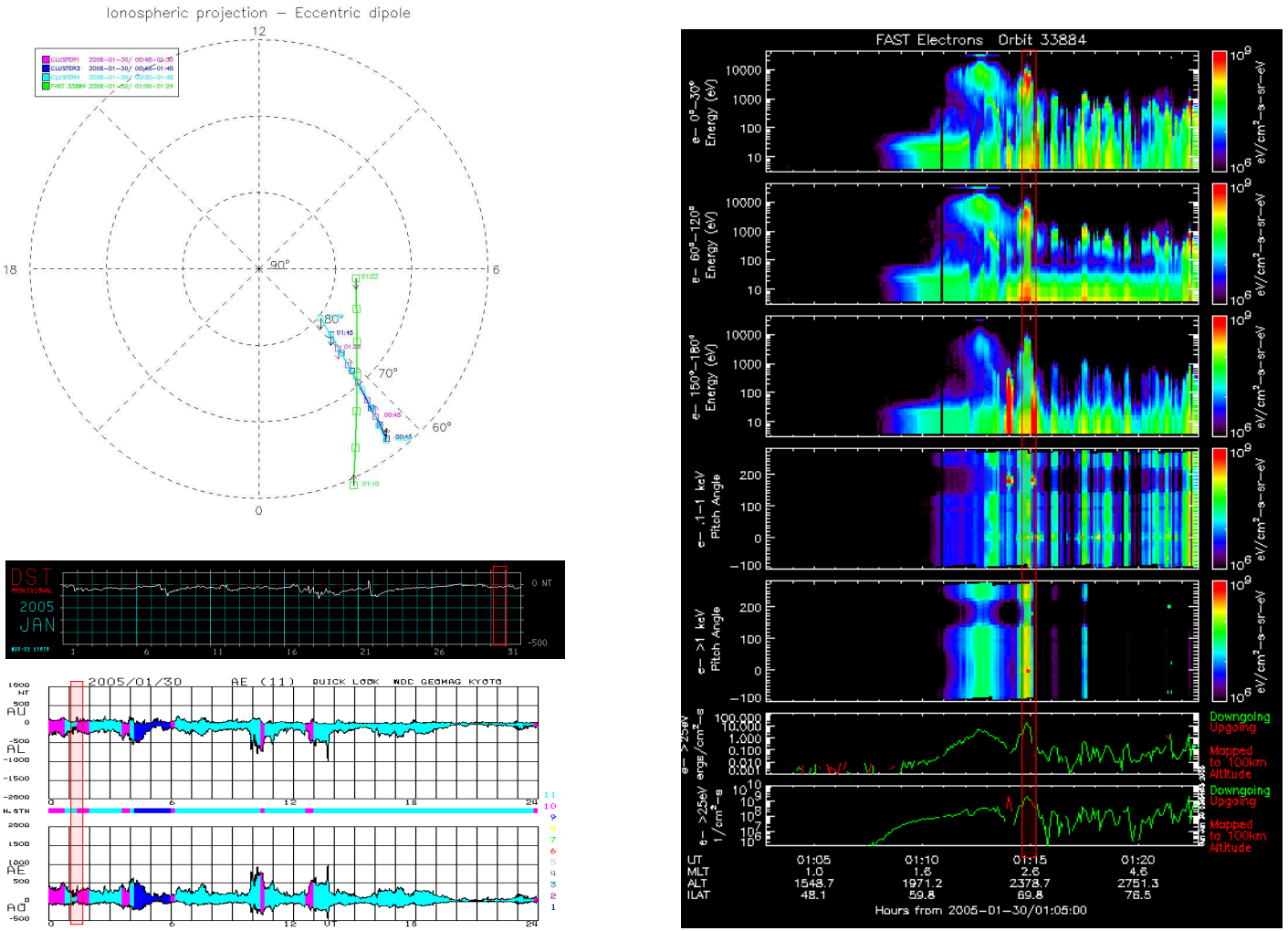
- We started to look for conjunctions by using the SSCWeb facility (http://sscweb.gsfc.nasa.gov/), both interactively and in batch mode:
  - Step 1: Triple conjunctions between Cluster, FAST, and the GBO in Kiruna. No good event was found. The extension of the GBO area by including a few MIRACLE stations (Sodankyla, Kilpisjärvi, Kevo, Tromsø, Ny Alesund etc) did not improve the event statistics.
  - Step 2: Cluster – FAST conjunctions, then manual selection of those with the footprint in or close to Scandinavia, Canada, Alaska. Just two promising events were found.
  - Step 3: Automatic search of 'triple conjunctions' between Cluster, FAST, and large areas well equipped with GBOs, by adjusting the latitude and longitude range in the SSCWeb. The data volume resulted was quite substantial, and explored just partially. At this stage no additional event was found.
- Maps of the satellite footprints above northern Scandinavia, as identified at Step 2, and of the footprints close to the Svalbard island, as identified at Step 3, are shown in Slide 4.
- One of the two events selected at Step 2 is presented in Slide 5.

SSCWeb Search



Scatter plots showing the conjunctions occurrence for two of the surveyed regions. **Left**: Conjunctions above northern Scandinavia. **Right**: Conjunctions above the Svalbard island, obtained with a box of 20° LAT x 20° LON in GM coordinates. Ground optical observatories are indicated by circles which show roughly their field of view. The blue shadowed rectangles indicate the two events presented in the Slides 5 and 8. The doted lines show the geographic (black) and geomagnetic (blue) coordinates.

SSCWeb Search



Left: Conjunction configuration, Kp, and AE index, which show the global context of the event. **Middle**: FAST electron data. The conjunction with Cluster 3 occurs when FAST measures energetic electron precipitation. **Right**: Cluster/CIS data. The pass over the auroral oval takes about 30 min, shortly after leaving the radiation belts. The red stripes indicate the conjunction time.

Systematic Search

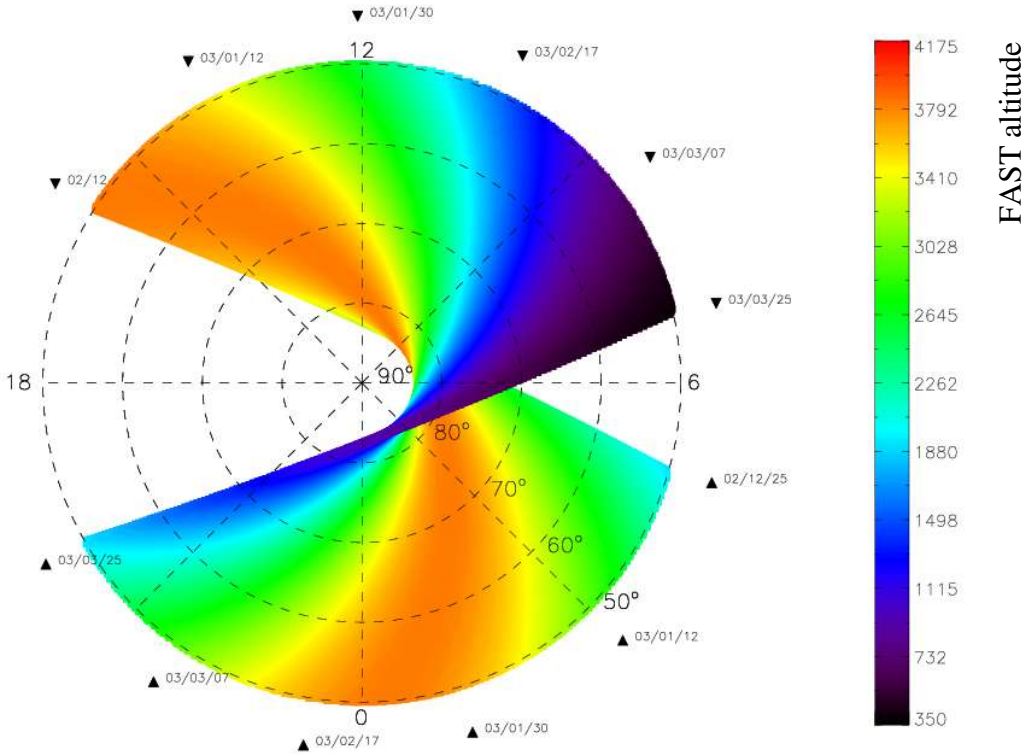
- SSCWeb does not provide the possibility to select all the criteria needed for a particular configuration. For instance, one cannot select the MLT intervals in which to look for conjunctions. Consequently, a manual examination of each conjunction is required. This approach is quite slow, and can miss potentially interesting events.
- In order to find the time intervals when Cluster and FAST are in the appropriate configuration we performed a thorough examination of all FAST orbits, by plotting the altitude as a function of latitude and local time for every set of 1000 orbits (about 3 months).
- Although representing the data in magnetic coordinates may seem to be the natural choice, the daily rotation of the magnetic dipole leads to overlapping. Therefore, we finally decided for geographical coordinates.
- The obtained plots, two of which are shown in Slide 7, provide a convenient selection tool. The most promising time intervals for triple conjunctions, under the conditions described above, are:

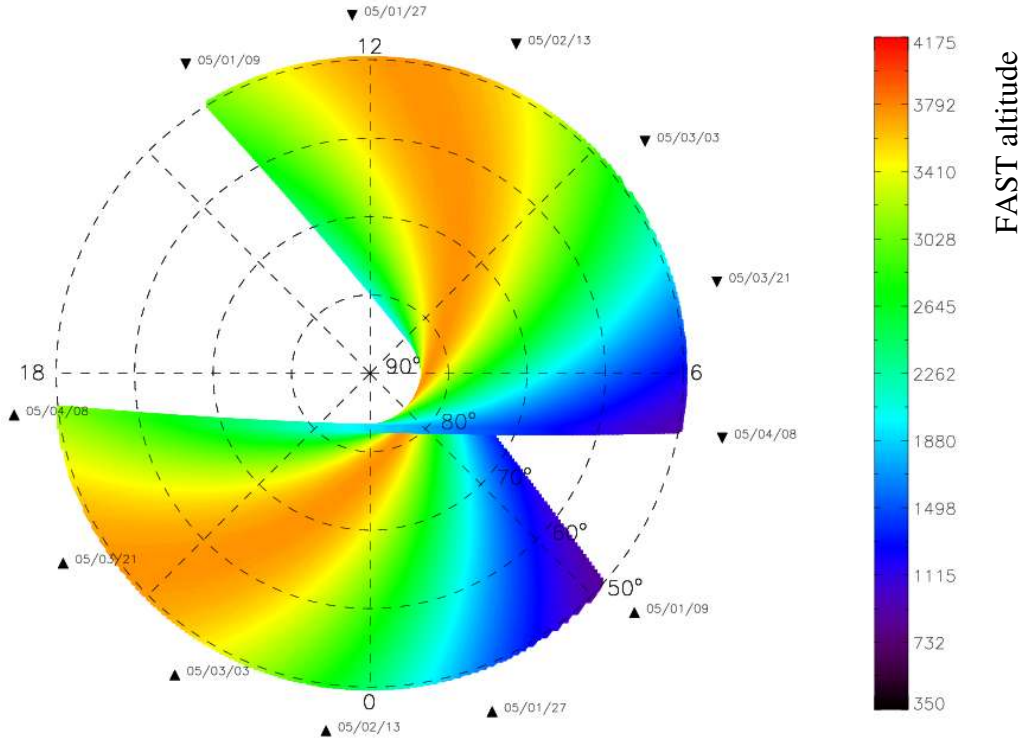
  n**orthern hemisphere**: Jan – Feb 2003, Jan – Feb 2004, Feb – Mar 2005, Feb – Mar 2006

  southern hemisphere: Jan – Feb 2001

- These plots help in a closer inspection of the conjunctions identified by SSCWeb, by reducing the data volume to be examined in detail. After intersecting the promising time intervals from above with the pool of conjunctions above the Svalbard island, we retained only 15 cases, two of which proved to be of potential interest. One of these two cases is shown in Slide 8.

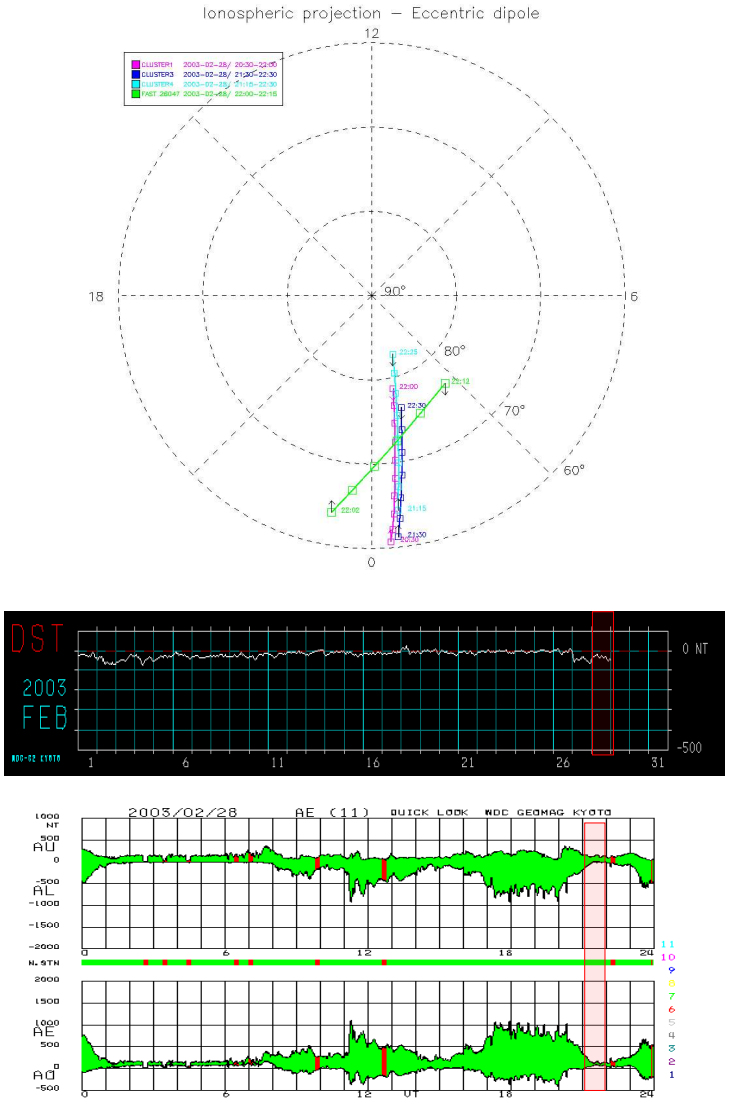
Systematic Search

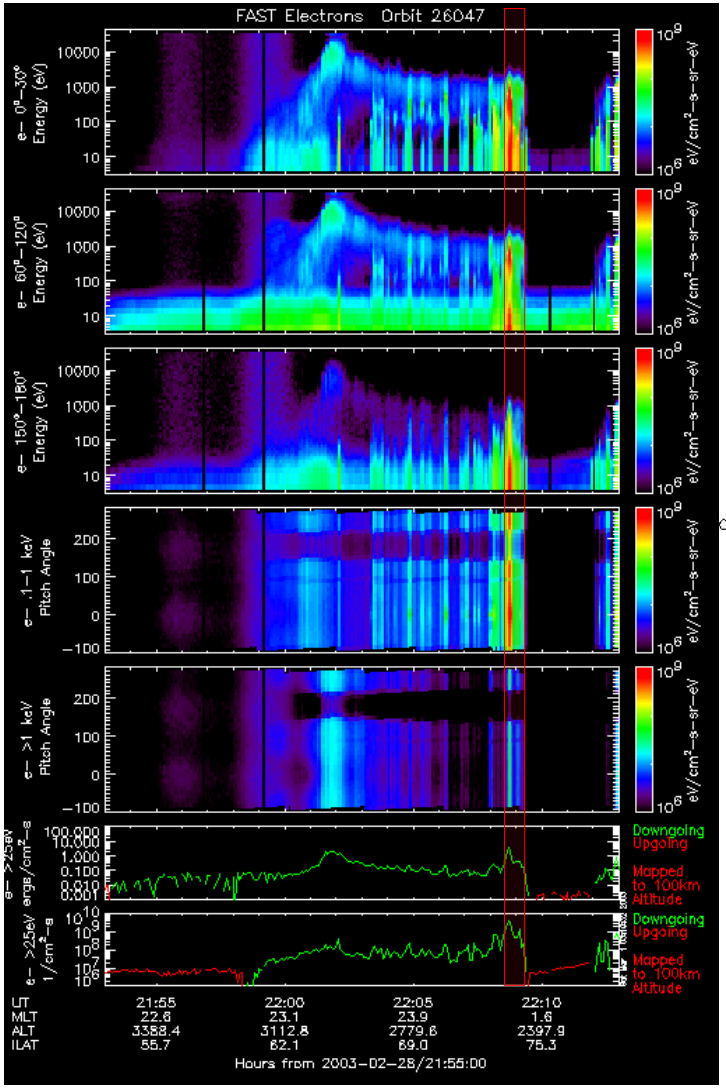


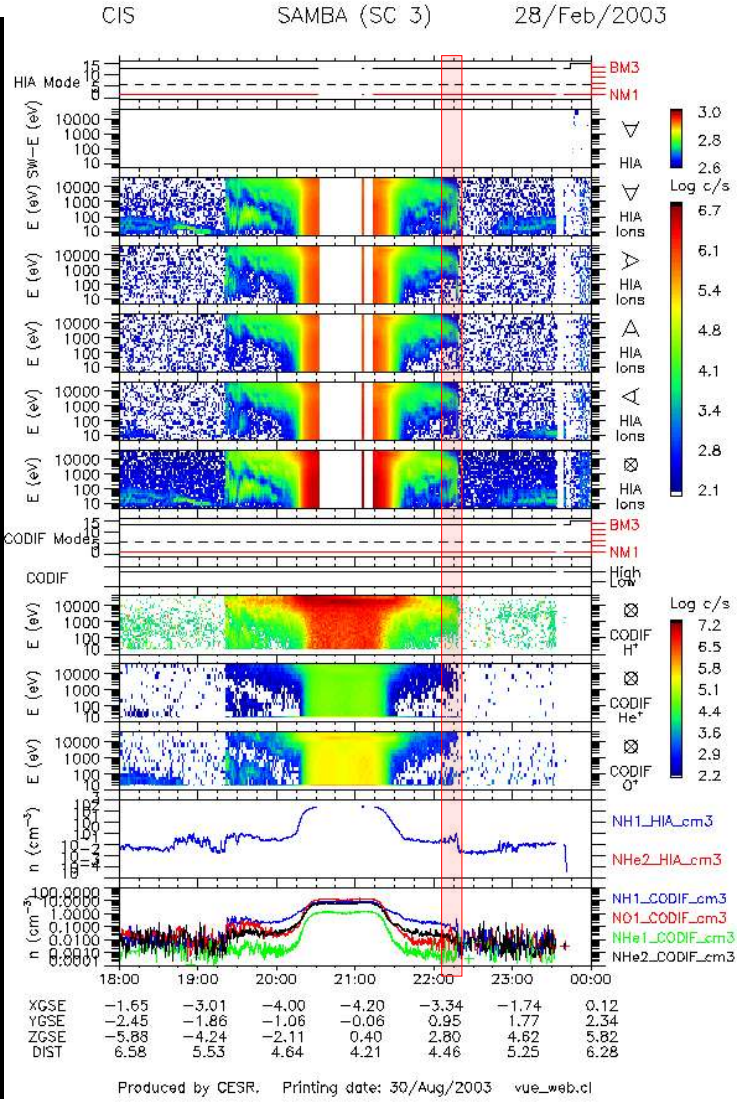


FAST altitude (color) as function of latitude and local time. The orbit rotation in local time is indicated by printing the date for a few orbits. The motion along the orbit is from the upward triangle to the downward triangle.

Systematic Search







Event identified close to the Svalbard island. Same plots as in Slide 5. The conjunction occurs again when FAST measures energetic electron precipitation.

Future work

- List of times when Cluster passes above the auroral oval near perigee, within the intervals listed in Slide 6.
- Selection of the corresponding FAST orbits, and check of FAST data availability.
- Conjunction quality check.
- When the conjunction is good enough, go further and check if there is any GBO at the foot of the magnetic field line.
- When a triple conjunction is found, check for optical data.
- If no triple conjunction is identified, with good satellite and optical data, we could extend the search by looking for good Cluster – GBO conjunctions, and then for an additional low latitude satellite.

Summary

- The search for triple conjunctions, Cluster-FAST-GBO, using SSCWeb, involves manual processing and is not very efficient when a particular type of event is needed.
- The systematic search allows a faster examination, focusing on certain time intervals, when potentially interesting events are expected. By systematic search the risk to miss such events decreases as well.
- Triple conjunctions with good satellite and optical data seem to be extremely rare, although the five years database is quite big – about 20.000 FAST orbits and 700 Cluster orbits.
- By SSCWeb search we have only been able to identify two events of which one was presented here.
- The systematic search has produced so far just two more events. Since the data examination has just started we hope to find more events by the end of this work.

References

[1] Particle-fluid simulation of the auroral current circuit, J. Vedin and K. Rönnmark, submitted to J. Geophys. Res., 2006.

[2] Hamrin, M., O. Marghitu, K. Rönnmark, B. Klecker, M. André, S. Buchert, L. M. Kistler, J. McFadden, H. Rème, A. Vaivads, Observations of concentrated generator regions in the nightside magnetosphere by Cluster/FAST conjunctions, Ann. Geophys., 24, 637 – 649, 2006.