Energy transfer in the auroral magnetosphere as derived from CLUSTER and FAST data

The energy transfer between the magnetosphere (M) and the ionosphere (I) is an important theme in the M–I coupling studies. We contribute to this theme by analyzing conjugated data from the CLUSTER fleet and the FAST spacecraft. From a wide pool of conjunctions between these satellites, we select several events in the auroral region whose common feature is the detection of energetic precipitating electrons by FAST. In order to establish if CLUSTER crosses a possible generator region, we examine the the variation of J·E. The J·E profile at the CLUSTER level is then compared with the energy flux derived from the FAST data.

Because of the divergent geomagnetic field configuration, CLUSTER needs considerably more time than FAST to cross a specific flux tube. We discuss the difference in the crossing time and the consequences it has for the analysis of conjugate data from the two spacecraft.

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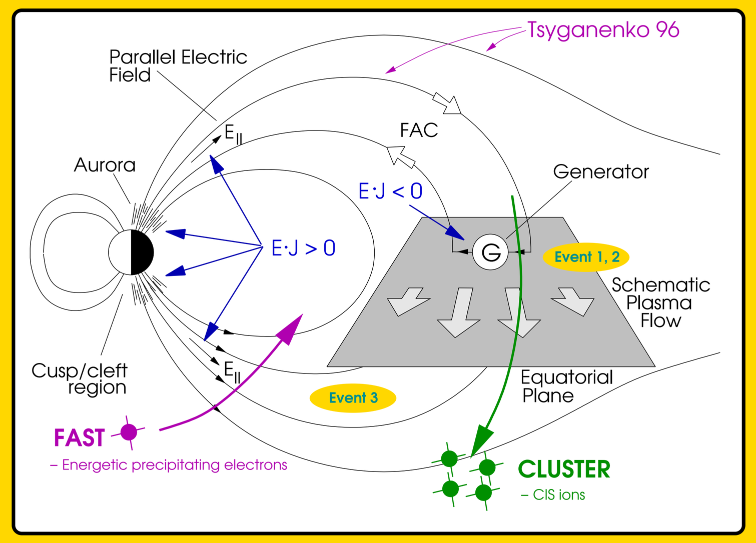
Conjugated data from FAST and CLUSTER

– Mapping according to Tsyganenko 96 model.
– Low magnetic activity (hence more stationary processes).
– 3 events in the southern hemisphere.

Schematic overview



Order of magnitude estimate of generator region

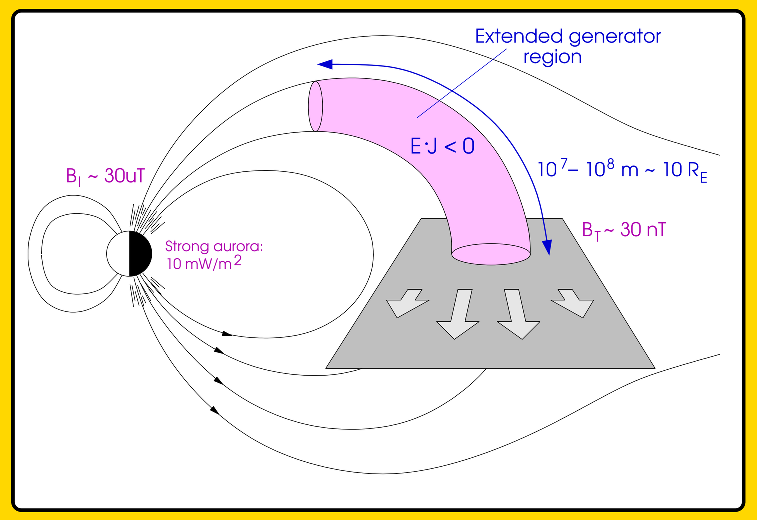
Mapping factor between ionosphere (I) and tail (T): $M = \frac{B_I}{B_T} = \frac{30\ uT}{30\ nT} = 1000$

Energy flux in strong aurora (10 mW/m^2) mapped to tail: 10^{-5} W/m^2

Estimated power density in extended generator region:

$E\cdot J \sim \frac{10^{-5}}{10^8}$ to $\frac{10^{-5}}{10^7}$ W/m^3 ~ 10^{-13} W/m^3 to 10^{-12} W/m^3 ~ 1 nA/m^2 · 1 mV/m

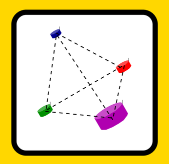
What to expect?



CLUSTER data

● Current density J:

– J from Curlometer method:
– Full vector J=curl(B)/u_0 from B measured on all 4 spacecraft (SC).
– Only scale sizes of J larger than the CLUSTER tetrahedron are retained.
– J defined at the center of the tetrahedron.
– The shape of the tetrahedron influences the quality of J.
– div(B) can provide a quality estimate for J.



● Electric field E:

– E measured by 3 different experiments: EFW, CIS and EDI.
– Data only believed when at least 2 instruments agree.
– E measured locally on each SC.
– E averaged over all SC: E and J roughly defined in the same sense.

● Coordinate systems:

– GSE: X–from Earth toward the sun; Y–toward dusk.
– DSI: Satellite system. XY–in spin plane; Z–along spin axis.
– MAG: Field aligned coordinate system. X–along B.
Y–Perpendicular to satellite velocity, Vsc, and B.
To make MAG and GSE as similar as possible, –B and –Vsc are used for Event 1 and –Vsc for Event 2.

Conclusions

A net tendency of E·J<0 is sometimes seen in our events where precipitating auroral electrons are observed in the conjugated FAST data. Often E·J<0 is observed at the boundaries between different regions in the plasma. The size of E·J is of the estimated order. In one of our tail events we see a clear tendency of E·J>0 (i.e. a load instead of a generator).

The tendency of E·J<0 is seen both in the distant magnetotail and also at somewhat lower altitudes on auroral field lines.

Mapping to the distant magnetosphere is complicated, but similarities between particle data from FAST and CLUSTER support the mapping. Hence the true conjunction may differ to some extent from the mapped one.

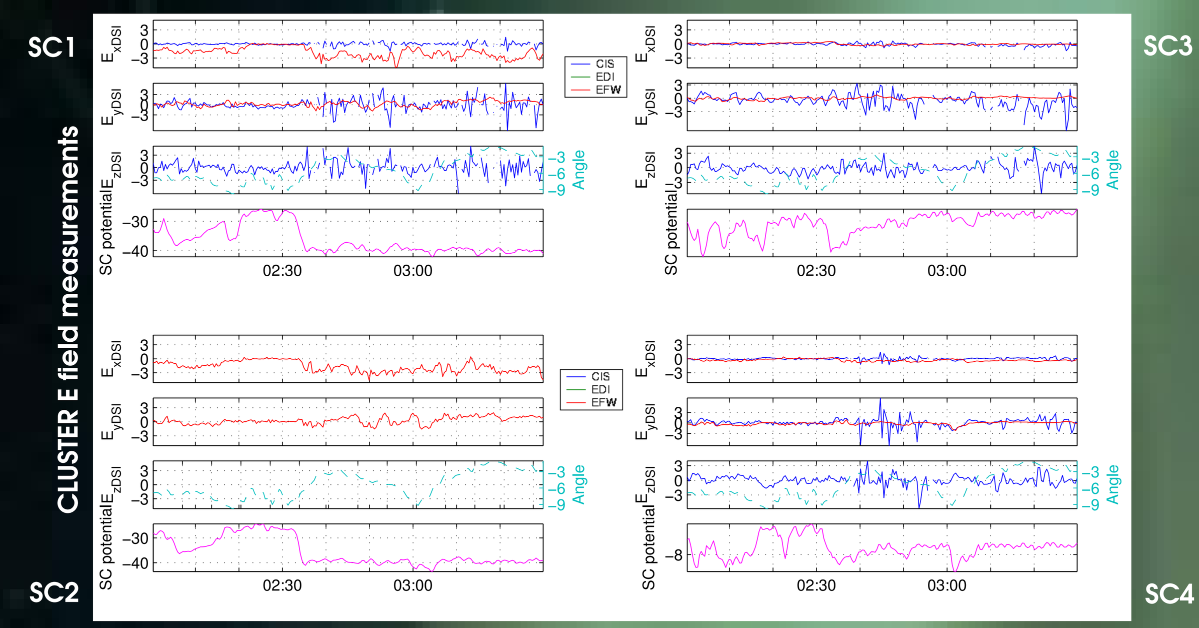
The quality of the current estimate via the Curlometer method is due to the shape of the CLUSTER tetrahedron. For example, scale lengths smaller than the CLUSTER tetrahedron cannot be addressed. Also, when the satellites are flying after each other, the Curlometer method is impossible to use.

Measurements of the electric field, E, especially in the distant magnetotail can be subject to significant errors. By comparing the result from more than one experiment, we get better estimates of E. However, the estimated and measured E·J is consistent with an E close to the error margins.

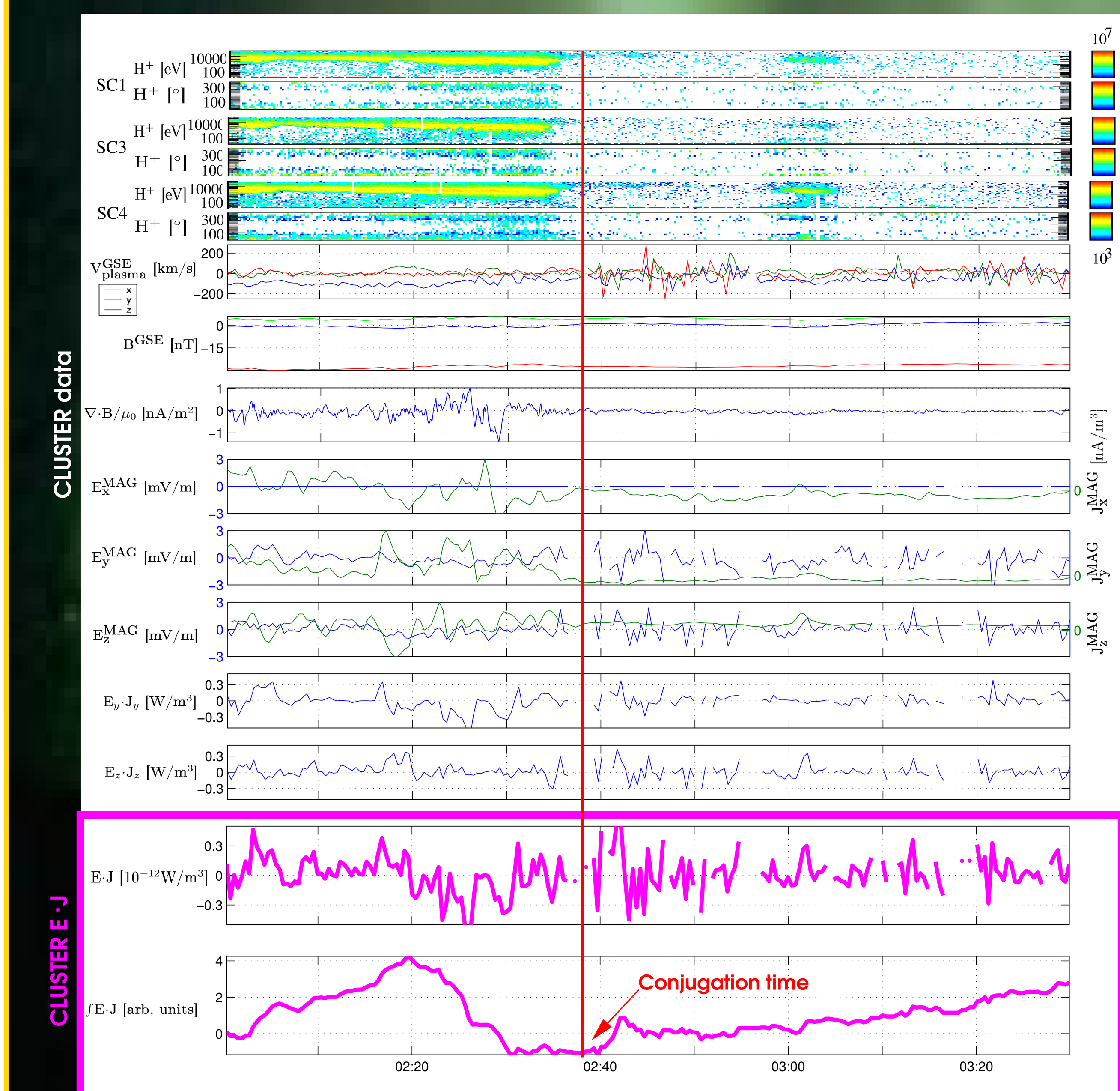
To investigate magnetospheric generator regions more throughly in the future, new multi–spacecraft satellite missions are needed. More advanced E field experiments would then be valuable. Also the shape and size of the tetrahedron should be carefully adjusted to improve current estimates.

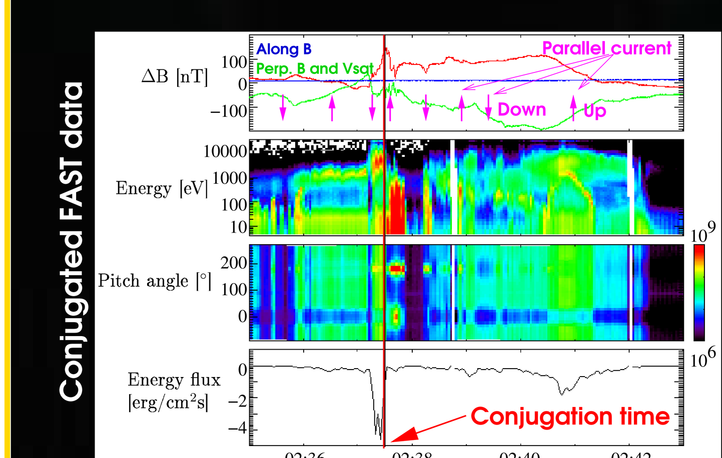
Event 1: 2001–09–20

Characteristics: Kp=1; SC–velocity=1km/s
FAST–altitude=4000km; CLUSTER–altitude=110000km
Tetrahedron: Size=1500km; Elongation=0.03; Planarity=0.01 ("Pseudo–Sphere")



– Due to the nice shape of the tetrahedron, the Current estimate is rather reliable.
– The E field measurements are more complicated. Around 02:30, the conditions are quite good, but CIS and EFW may sometimes differ in sign.
– A tendency of E·J<0 can be found between 02:20 and 02:30. This is close to the plasma sheet boundary as seen from the CIS spectrograms.
– This is near the time for the conjunction.
– It takes CLUSTER, close to apogee, more than 2 hours to cross a distance covered by FAST in 1 minute.

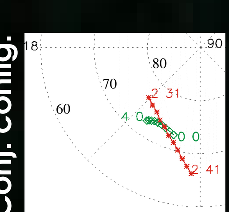




Energy spectrogram for precipitating electrons

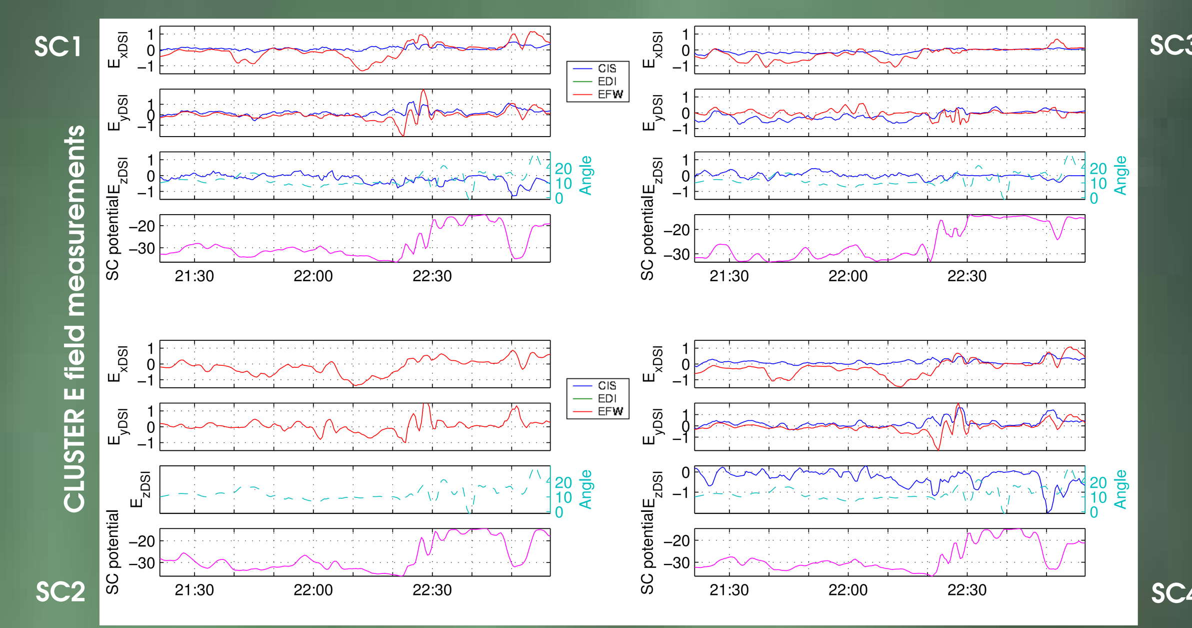
Energy flux in precipitating electrons (the dip corresponds to an earthward flux)

Conj. config.

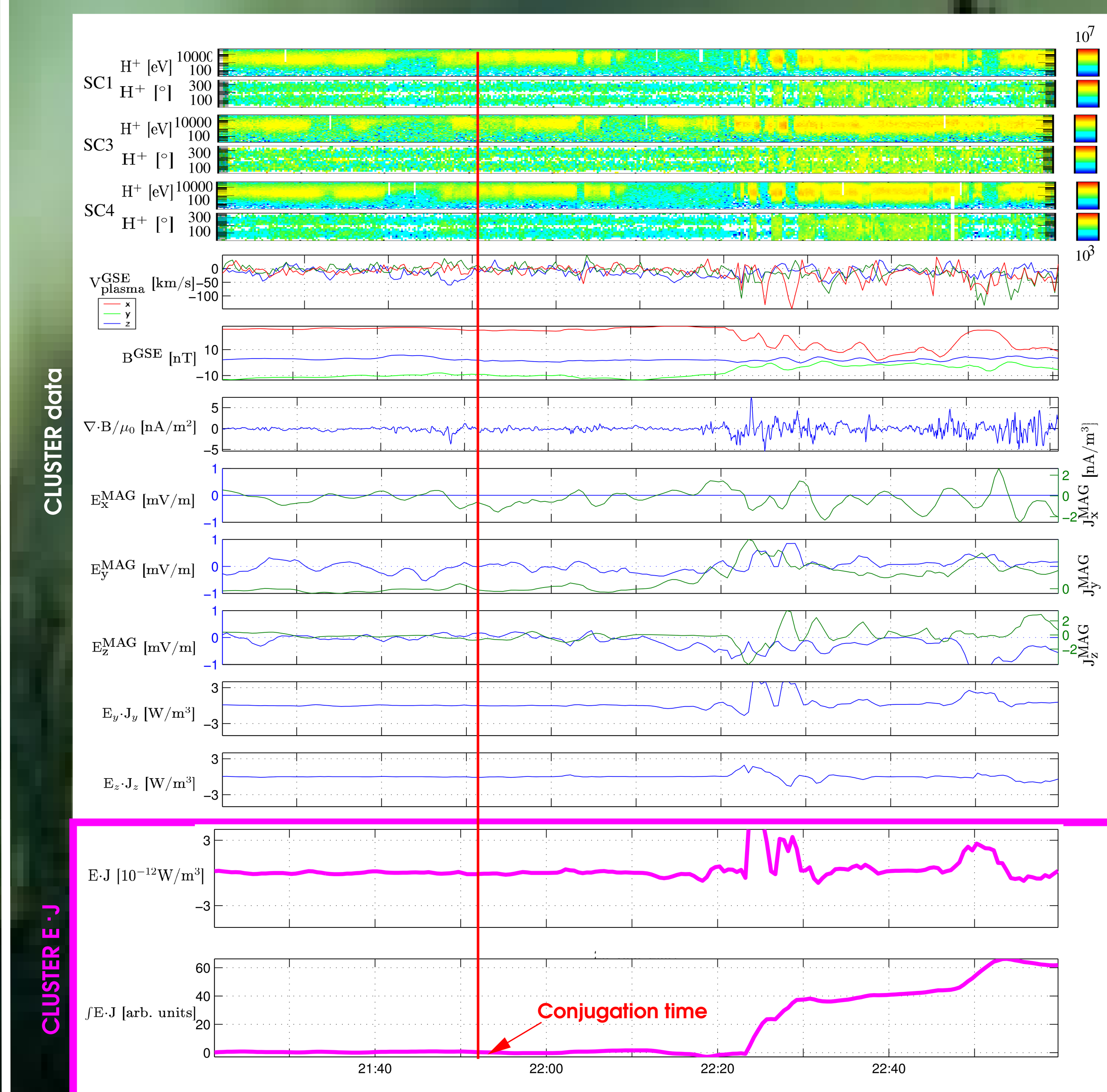


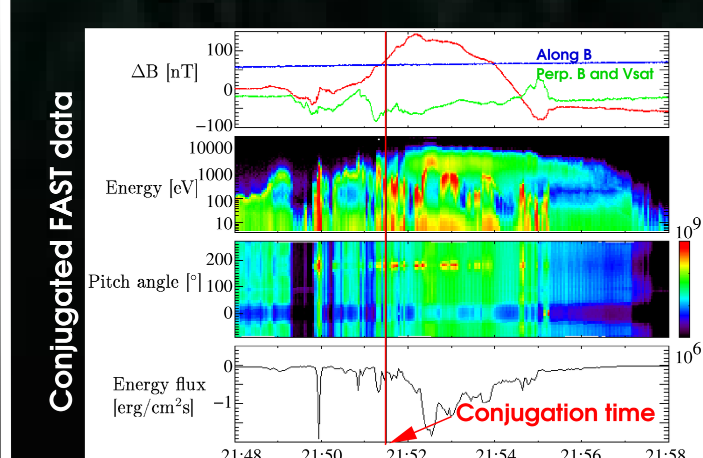
Event 2: 2001–09–26

Characteristics: Kp=2; SC–velocity=1km/s
FAST–altitude=3000km; CLUSTER–altitude=120000km
Tetrahedron: Size=1500km; Elongation=0.07; Planarity=0.1 ("Pseudo–Sphere")

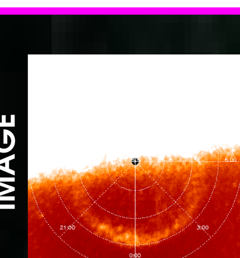


– There is a tendency of E·J>0 (hence a load) starting about 22:23.
– The E field estimate is complicated. During the latter part of the event the agreement between the instruments are quite good. However, CIS do not see the same large positive and negative fluctuations as EFW.
– The reason for the large E field fluctuations around 22:30 are not fully elucidated.
– Conditions (tetrahedron shape) are favourable to a reliable current estimate. However, the quality estimate div(B) shows that the current could be afflicted with significant errors during the latter part of the event.
– In this region the magnetic field shows structures smaller than the size of the tetrahedron.

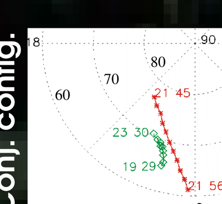




IMAGE

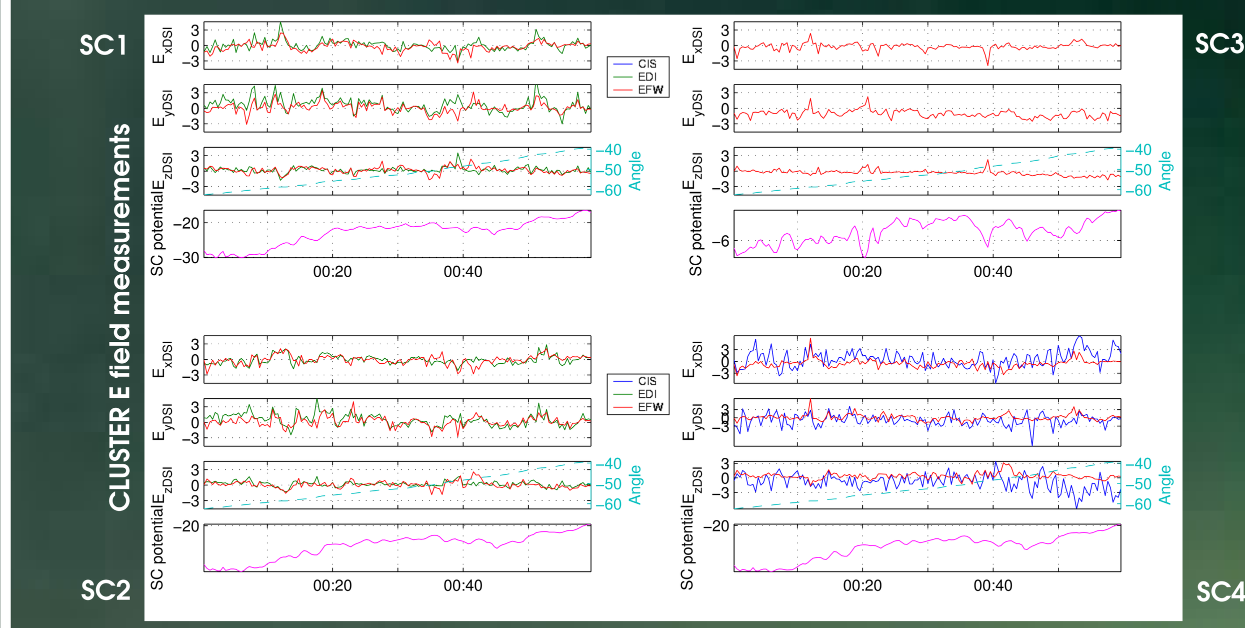


Conj. config.

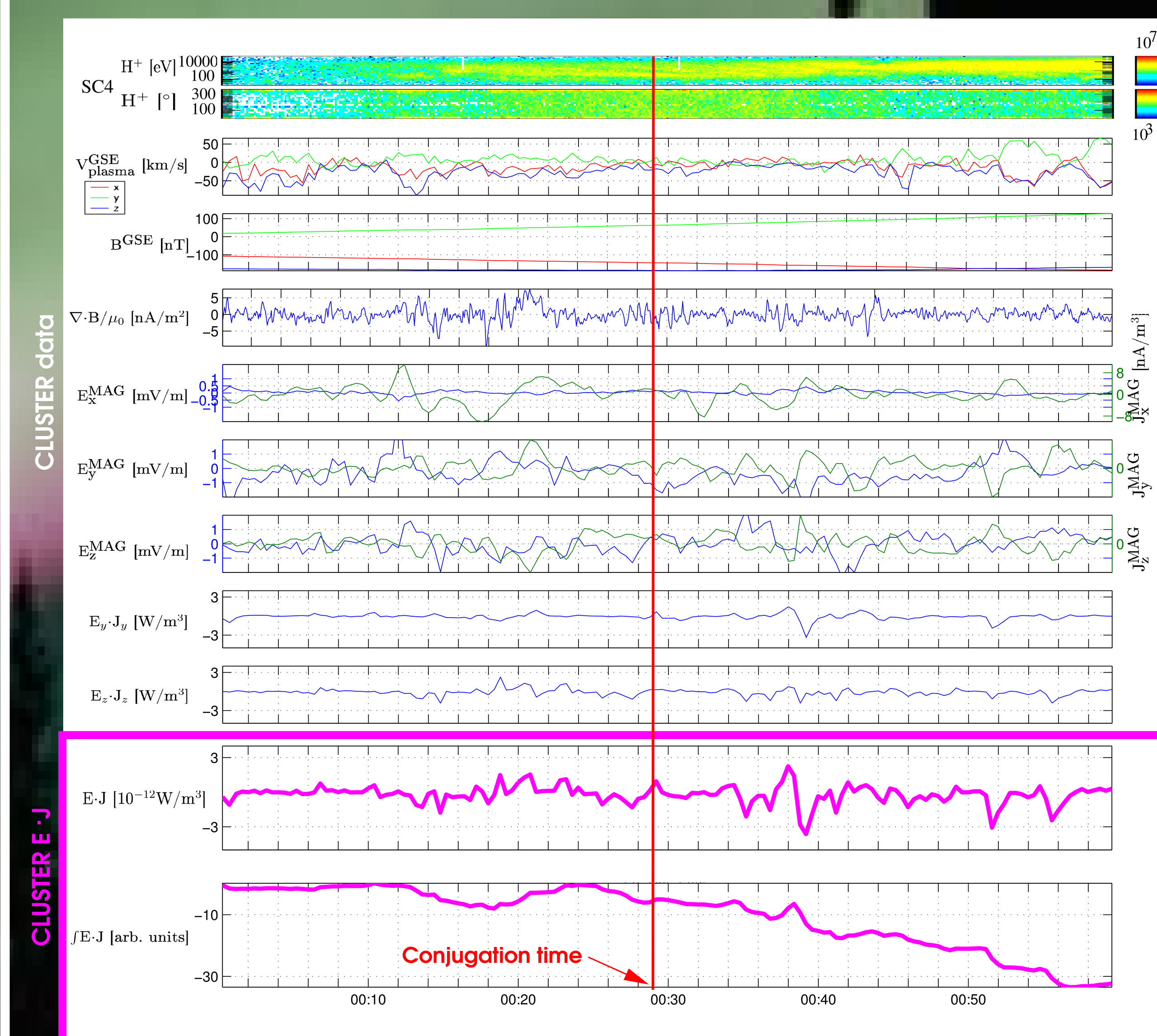


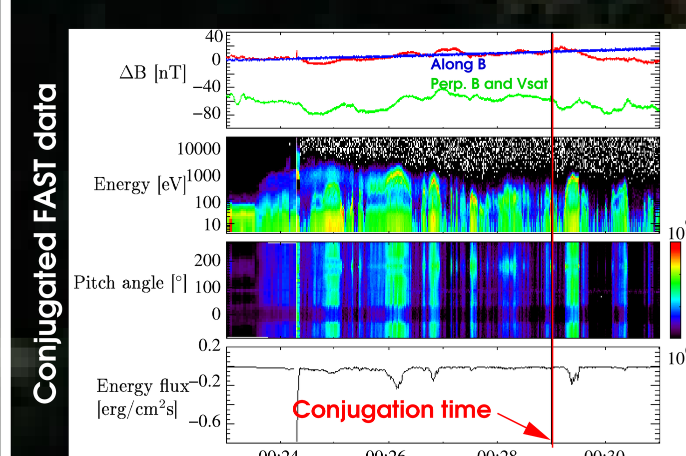
Event 3: 2002–04–23

Characteristics: Kp=1; SC–velocity=4km/s
FAST–altitude=3000km; CLUSTER–altitude=33000km
Tetrahedron: Size=150km; Elongation=0.7; Planarity=0.7 ("Potato")



– There is a tendency of E·J<0 starting about 00:12. This is about the same time as CLUSTER meets the plasma sheet boundary as seen in the CIS spectrograms.
– The E field estimate is reliable.
– The shape of the tetrahedron is not optimal for the Current estimate.





The CLUSTER and FAST spacecraft meet approximately head on.

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