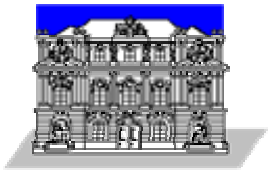


# Cluster Results on Ion Emitter Operation

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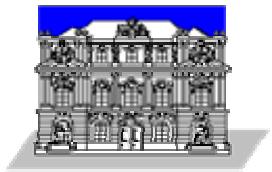
5th SPINE Workshop, ESTEC, 16-17 September 2003

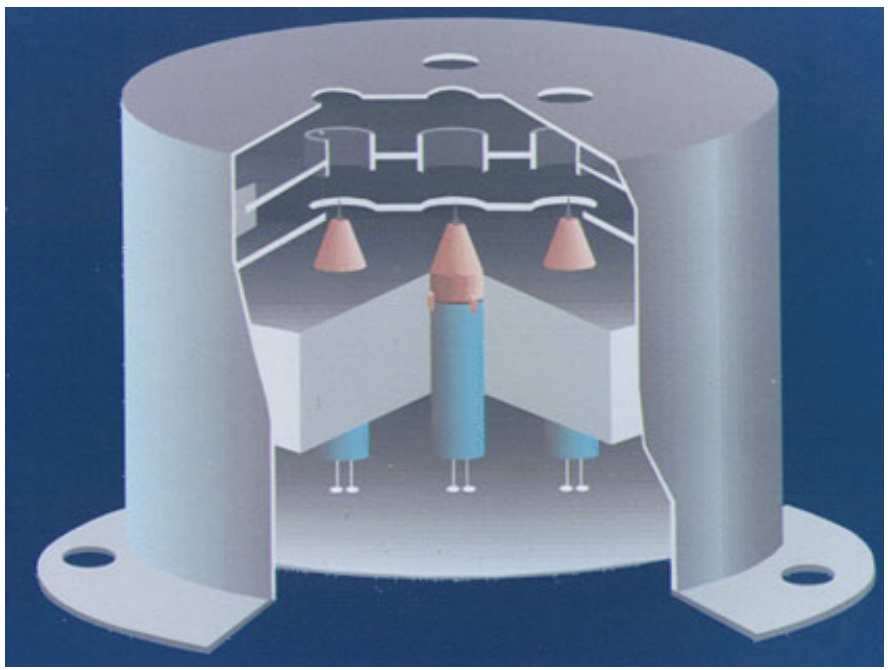


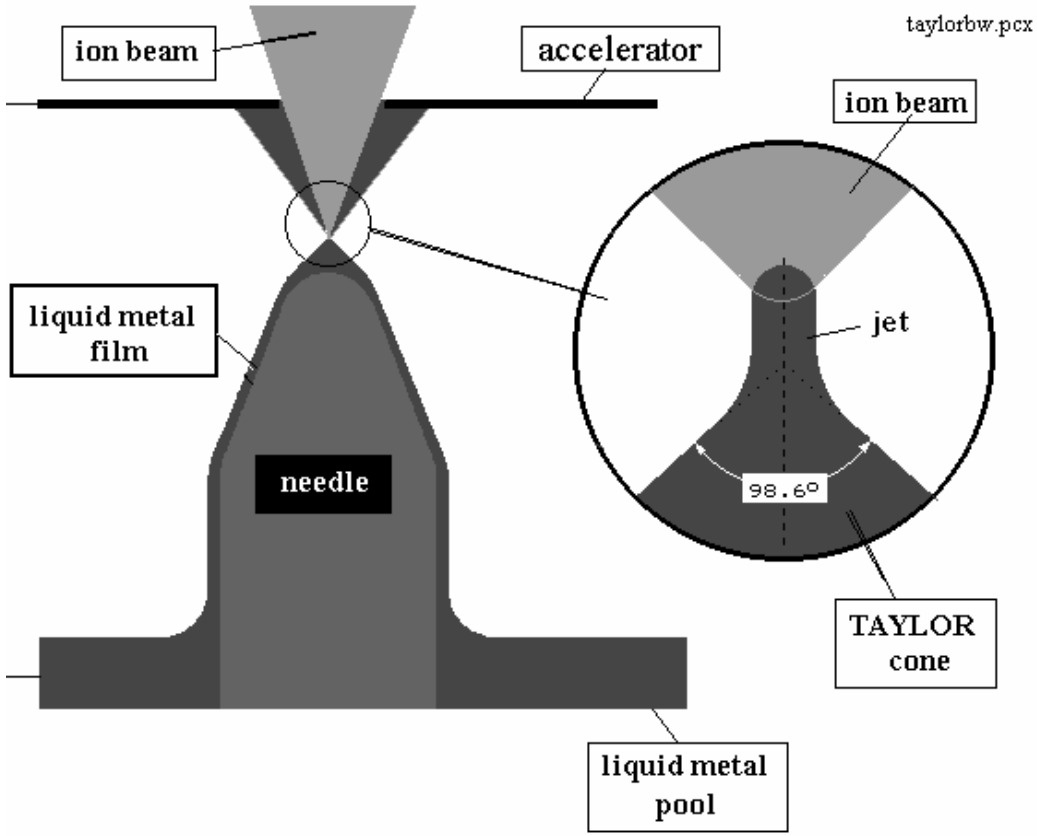
# Contents

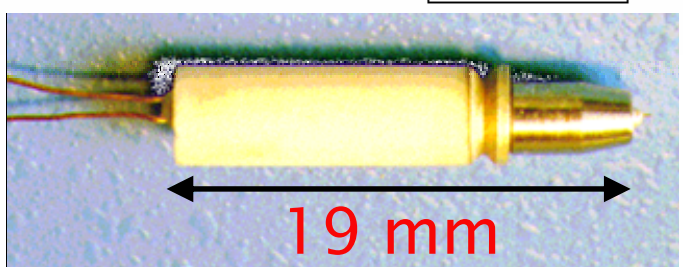

- Instrument set-up
- Principle of operation
- Ion beam properties
- Cluster operations summary
- Effect on spacecraft potential
  - Comparison between spacecraft
  - Histograms of potential
  - Beam current – spacecraft potential characteristics
- Effect on PEACE electron measurements
- Effect on CIS ion measurements
- Effect on EFW electric field measurements
- Conclusion

# Liquid Metal Ion Source

- Liquid Indium (heated to ≈200 C) covers needle
- Field emission of ion beam
- Four emitters integrated in "module"

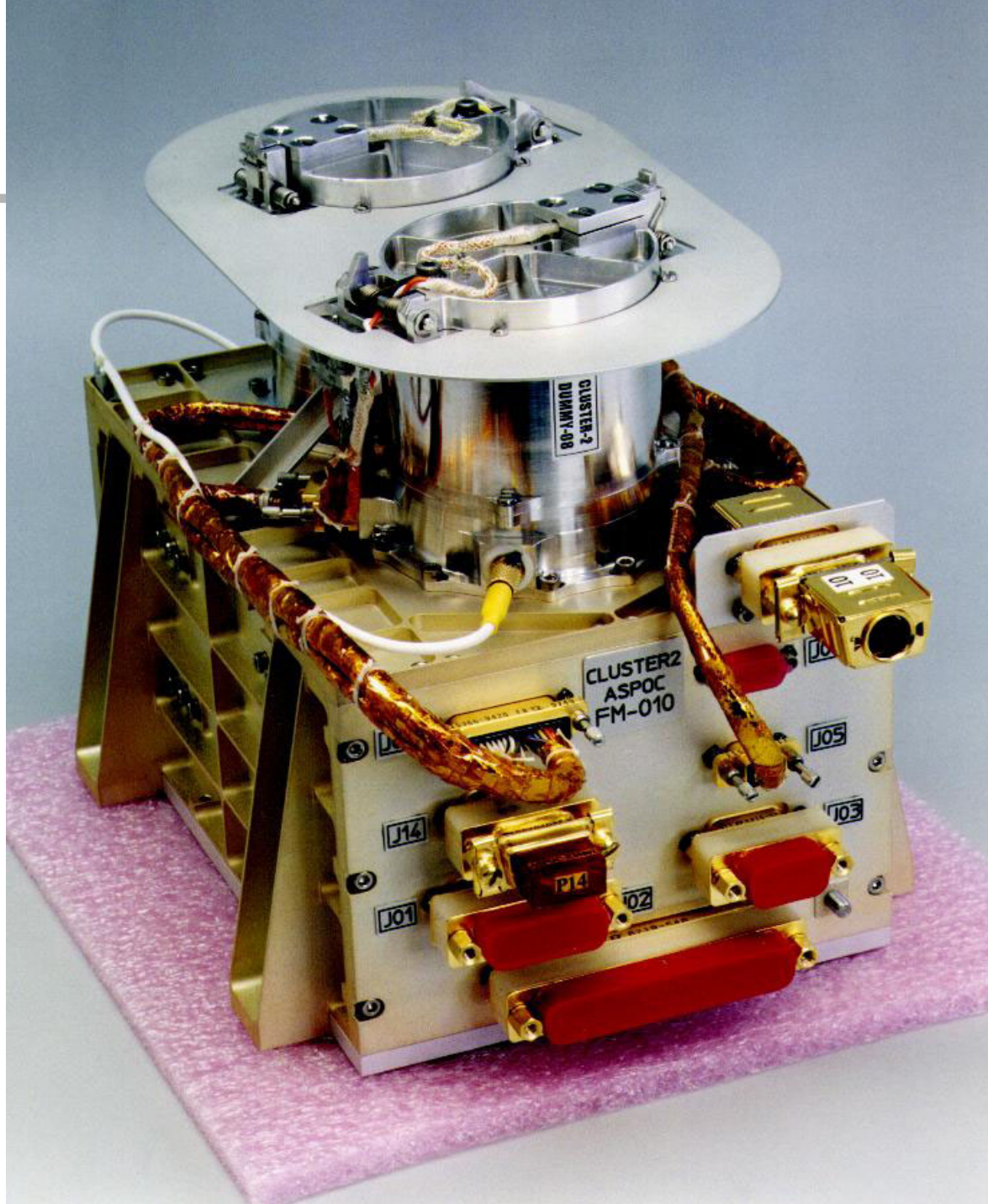




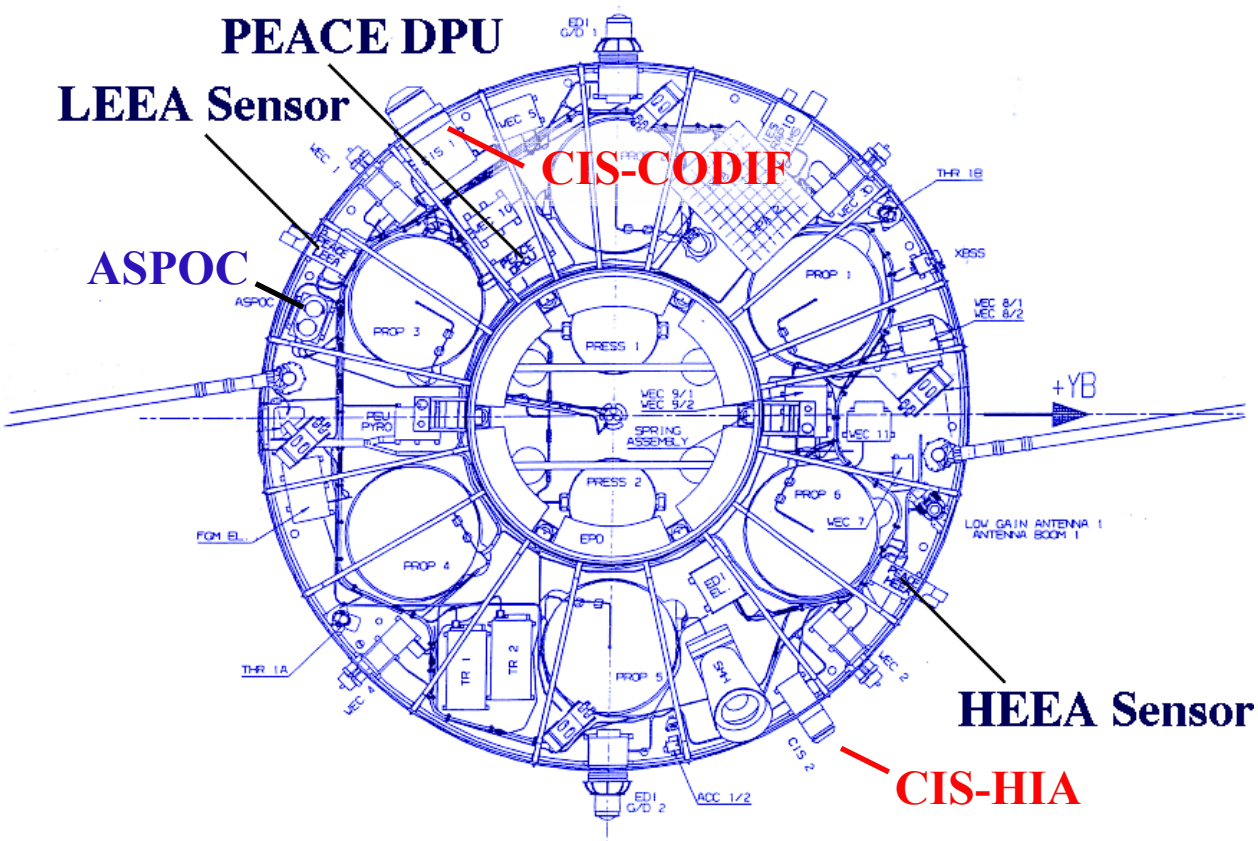
# Instrument ASPOC

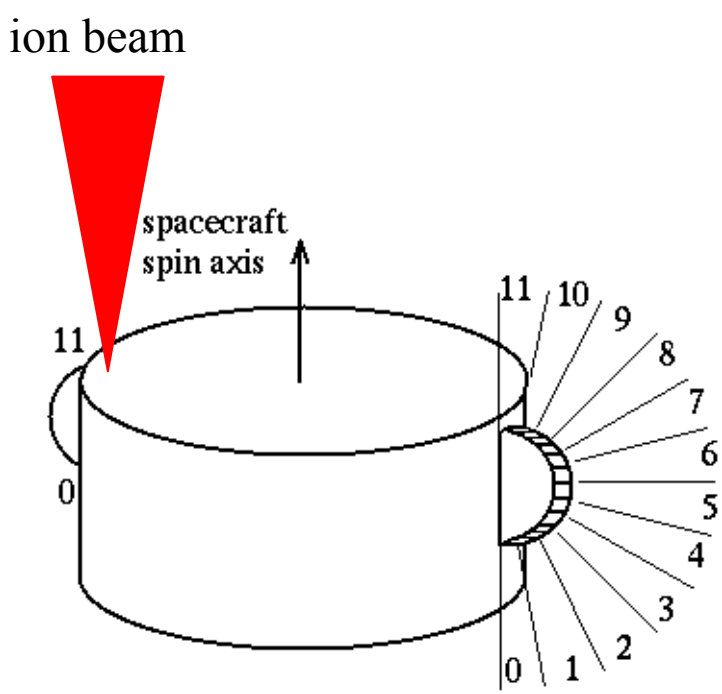
- Active Spacecraft Potential Control
- Mass: 1.9 kg
- Power: 2.1 ... 2.7 W
- Lead: IWF Graz
- Major partners: RSSD/ESA, ARC/Seibersdorf, FFI/Norway, UNH/USA



# Configuration

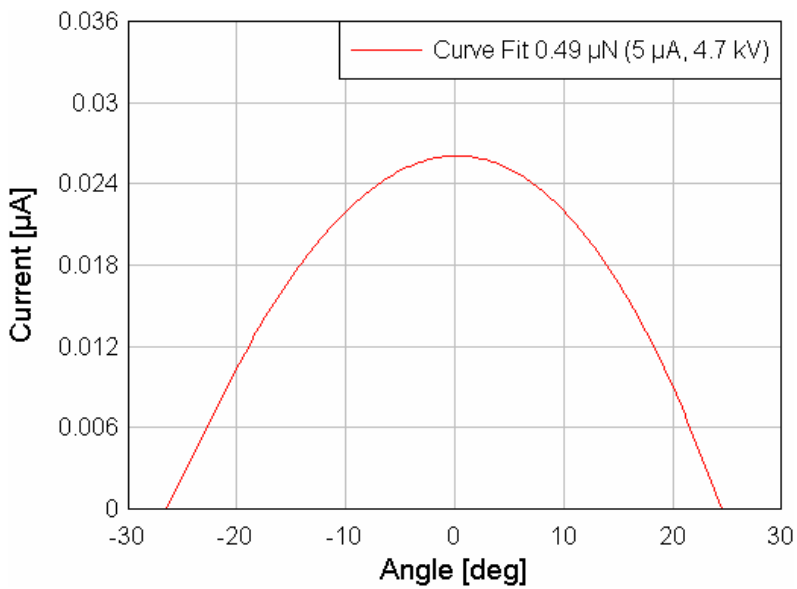
## Location of ASPOC and electron / ion sensors on spacecraft



# Ion Beam Properties

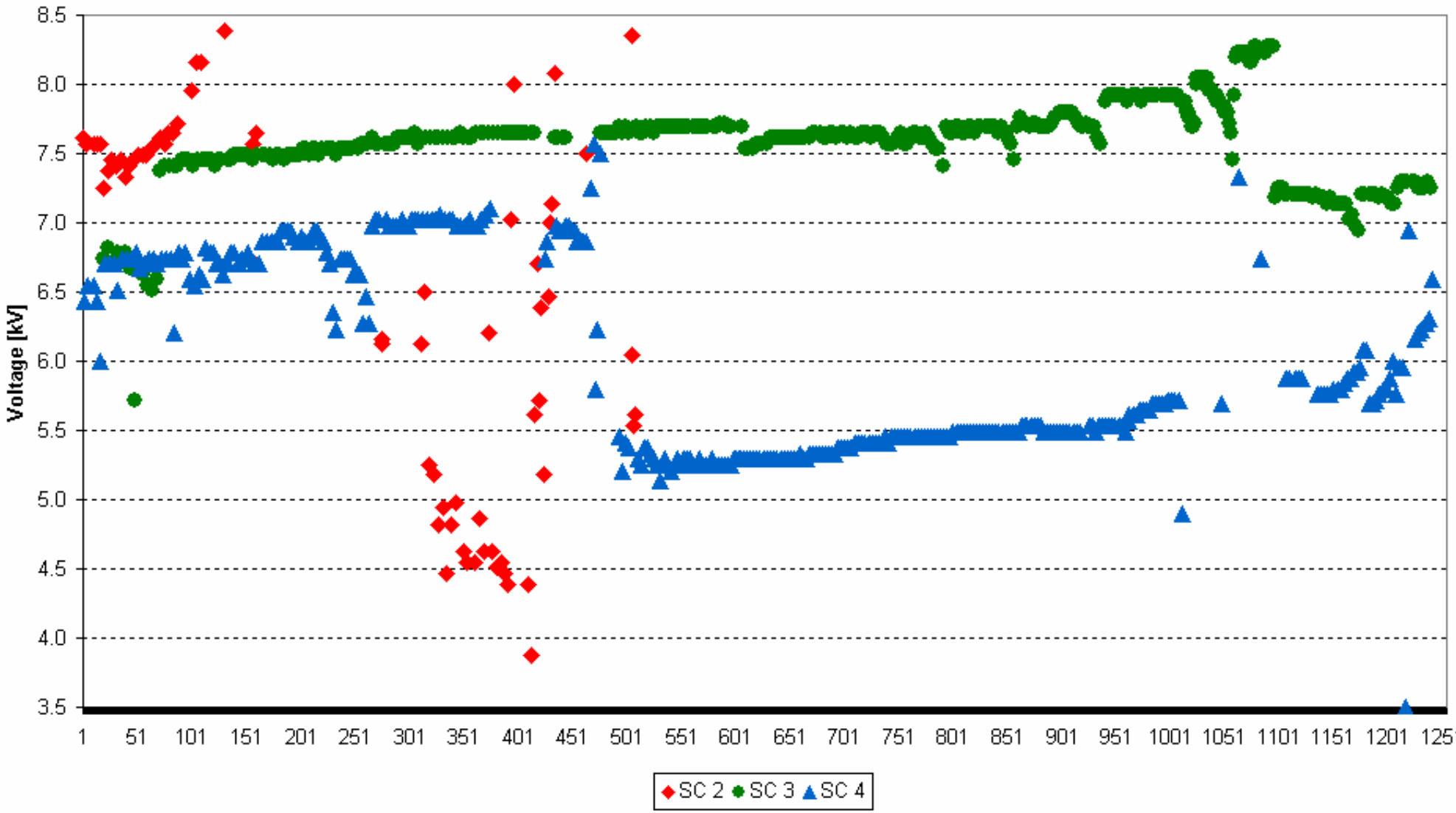
- Energy width at 10 µA: ≈150 eV; low intensity, low energy tail down to ≈500 eV below nominal beam energy
- Species: >90% single charged $In^+$, Minor contributions of other charge states and clusters
- Isotopic composition:
  115 amu (95.7%),
  113 amu (4.3%)




Typical beam profile

| | Spacecraft | | |
|---|---|---|---|
| | **Salsa** | **Samba** | **Tango** |
| **Typ. Beam Energy [kV]** | **5.4, 7.4** | **7.7** | **5.5, 6.8** |
| **Typ. Beam Current [µA]** | **10** | **12.2, 13.7, 14.5** | **10, 14.5** |

# Development of Beam Energy



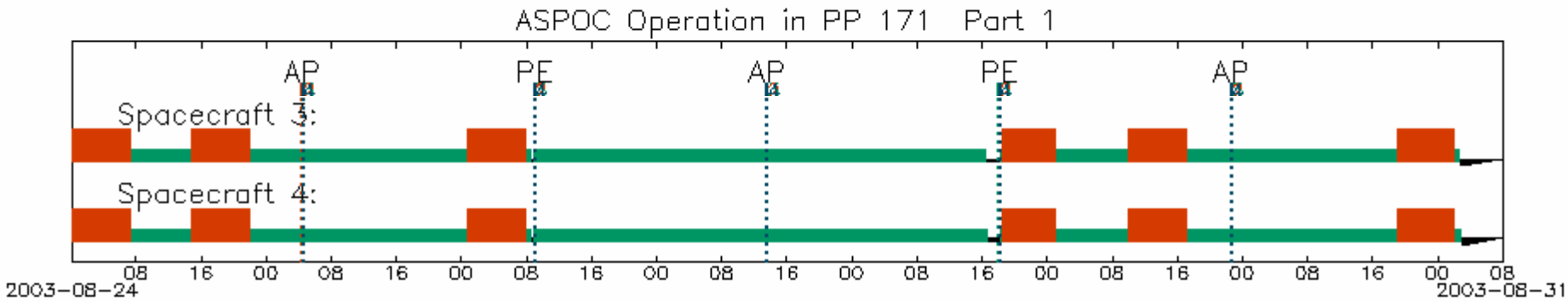
# Cluster operations summary

## Table shows status of 21 August 2003

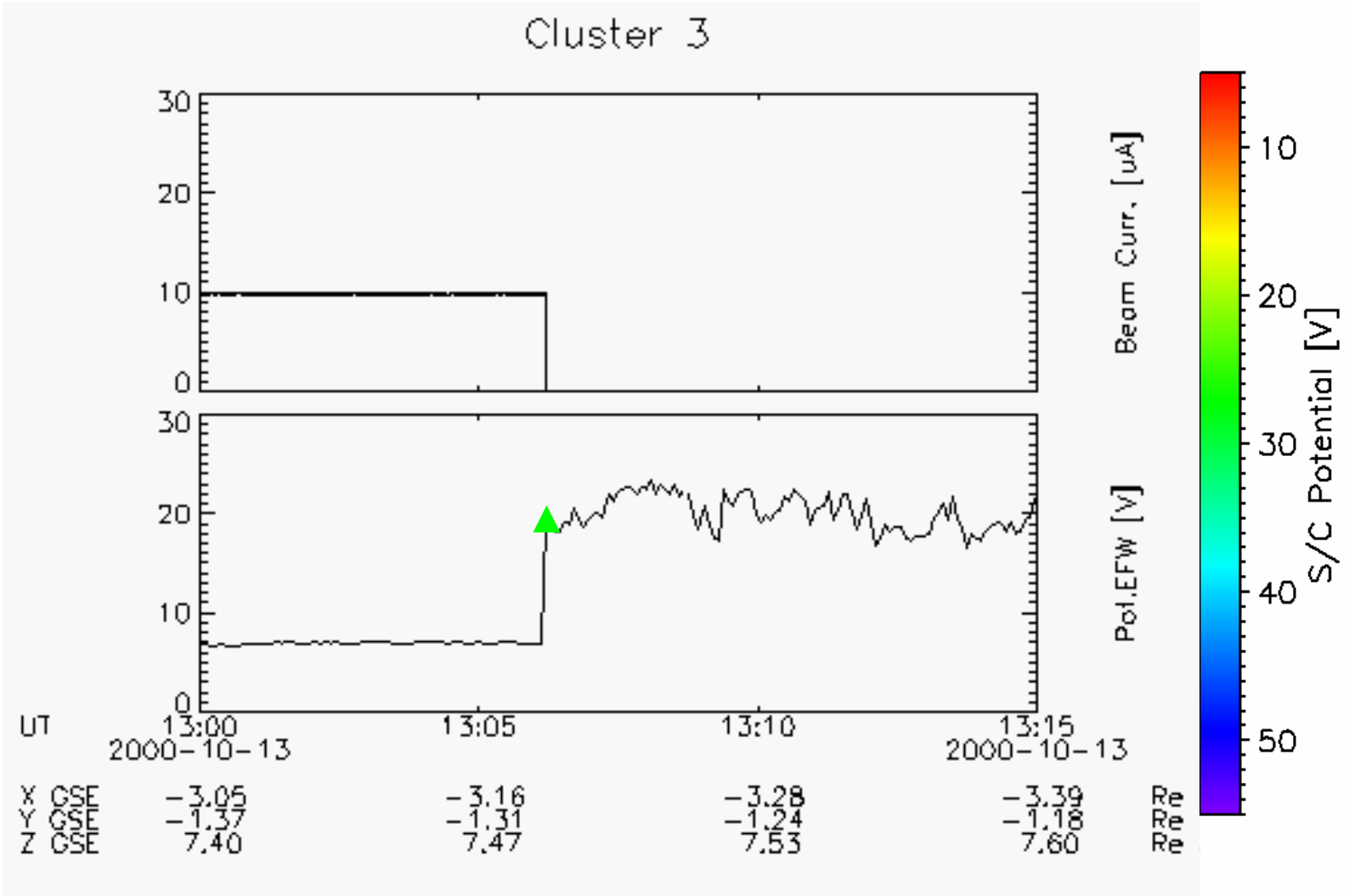
| | Spacecraft | | | |
|---|---|---|---|---|
| | Salsa | Samba | Tango | Total |
| Total operation time (hours) | 234 | 2543 | 2115 | 4892 |
| Maximum total operation time of a single emitter (hours) | 128 | 2525 | 1468 | |
| Number of operations | 107 | 450 | 373 | 930 |
| Average duration of single operation (hours) | 2.4 | 5.9 | 5.8 | 5.5 |
| Maximum duration of single operation (hours) | 7.8 | 36.4 | 35.8 | |

# Operational status

- Operations on all even-numbered orbits
- Typical sequence with Cluster apogee in magnetotail:
  - 7 hours around outbound cusp crossing
  - 7 hours centred at neutral sheet
  - 7 hours around inbound auroral zone crossing
- Ion current: between 10 and 15 µA

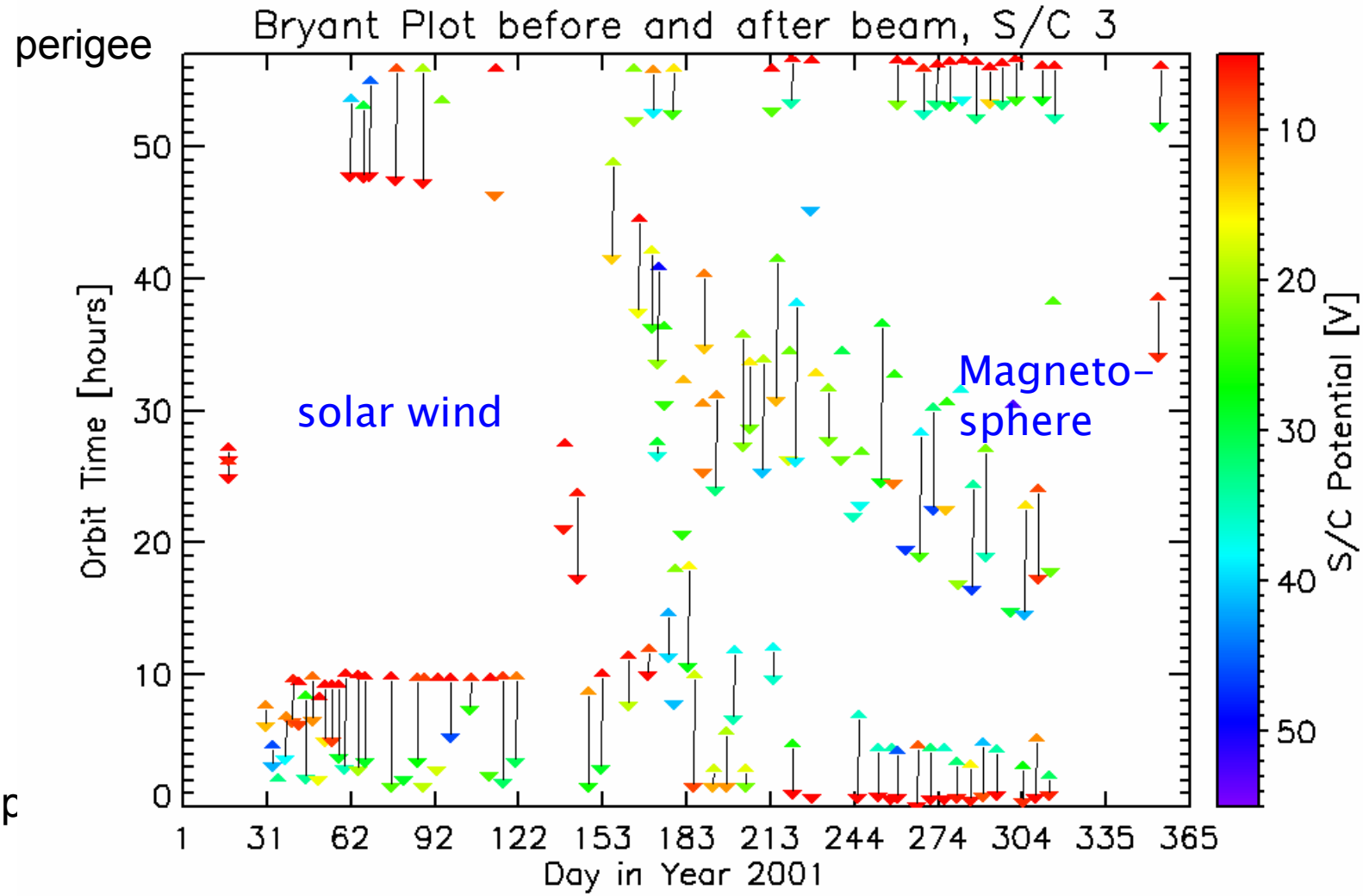


# Example of ASPOC ion beam turn-on

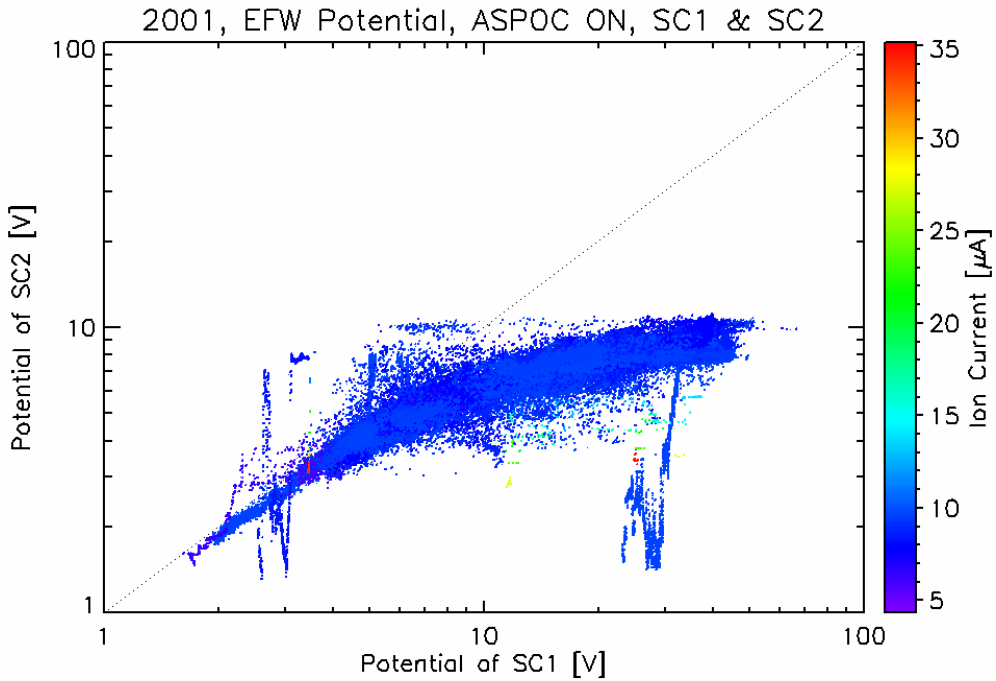


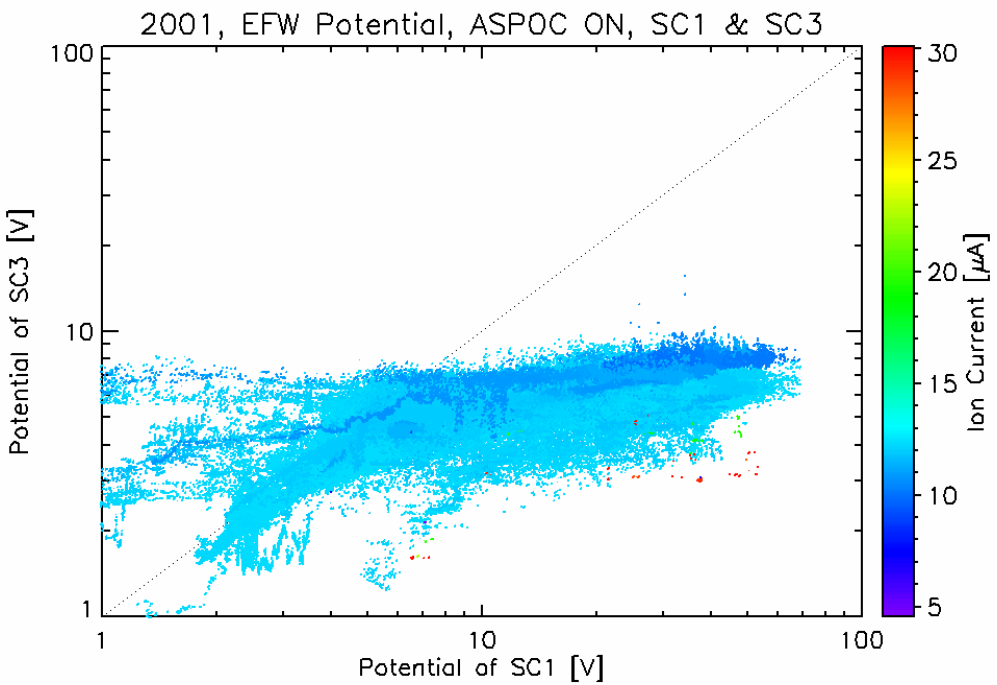
# ASPOC Operations on Cluster 3 in 2001; Measured Potential Before and After

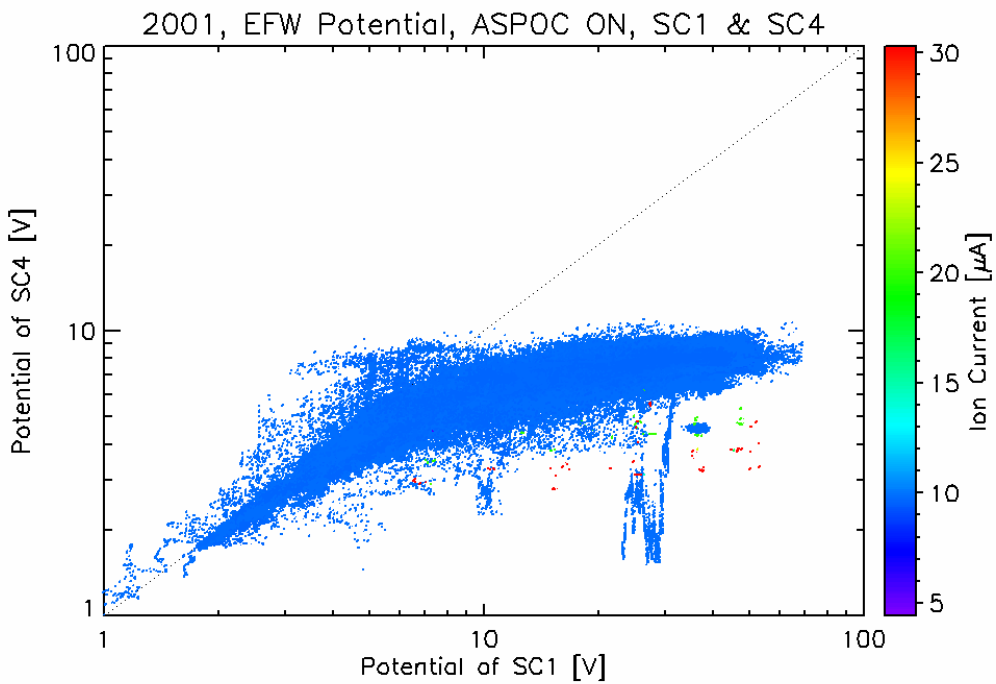
- Lines show operation times
- Spacecraft potential measured by double probes (EFW) shown as colored triangles



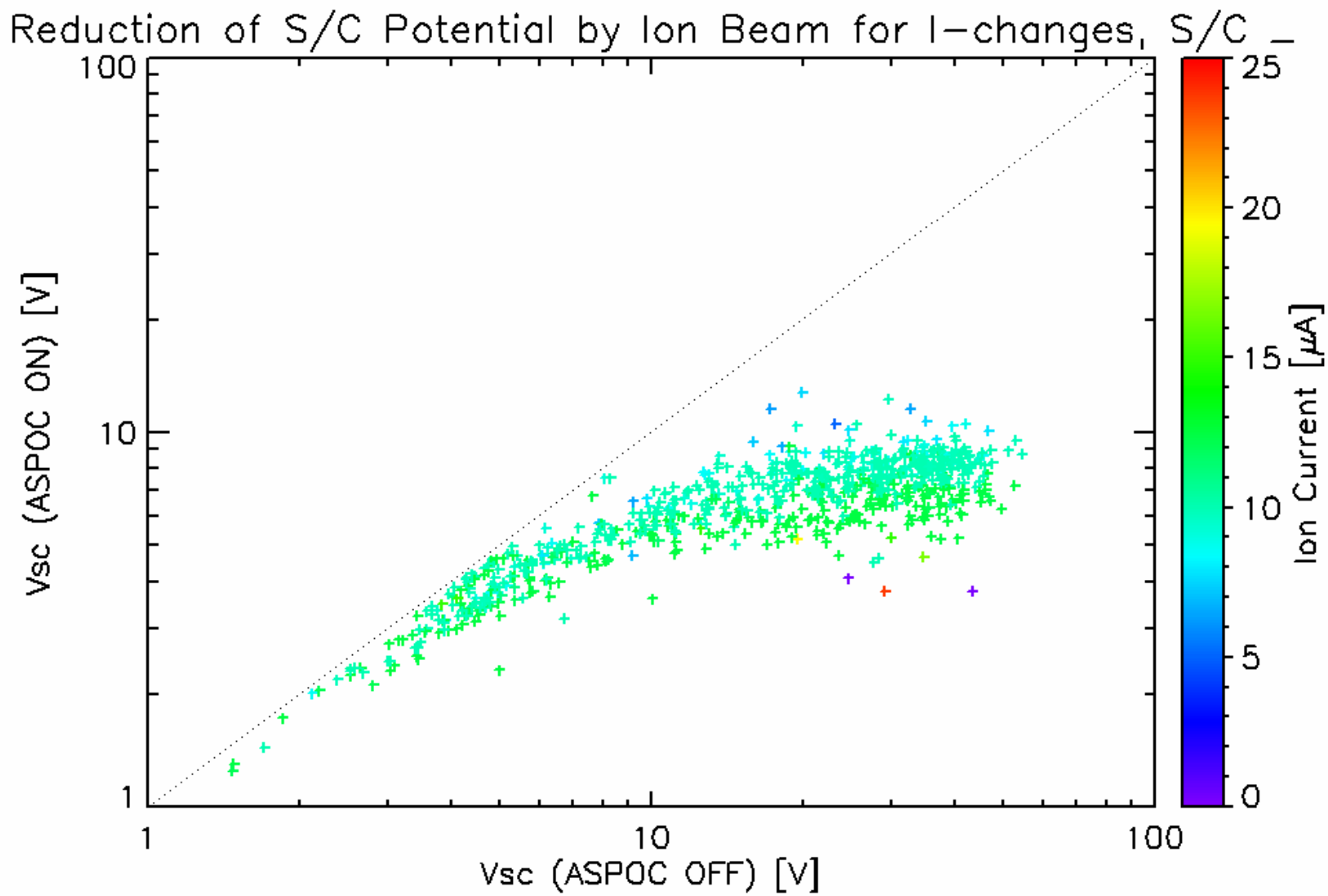
# Spacecraft Potential on Cluster 2,3,4 in Comparison with Cluster 1 During Active Periods of ASPOC on Cluster 2,3,4



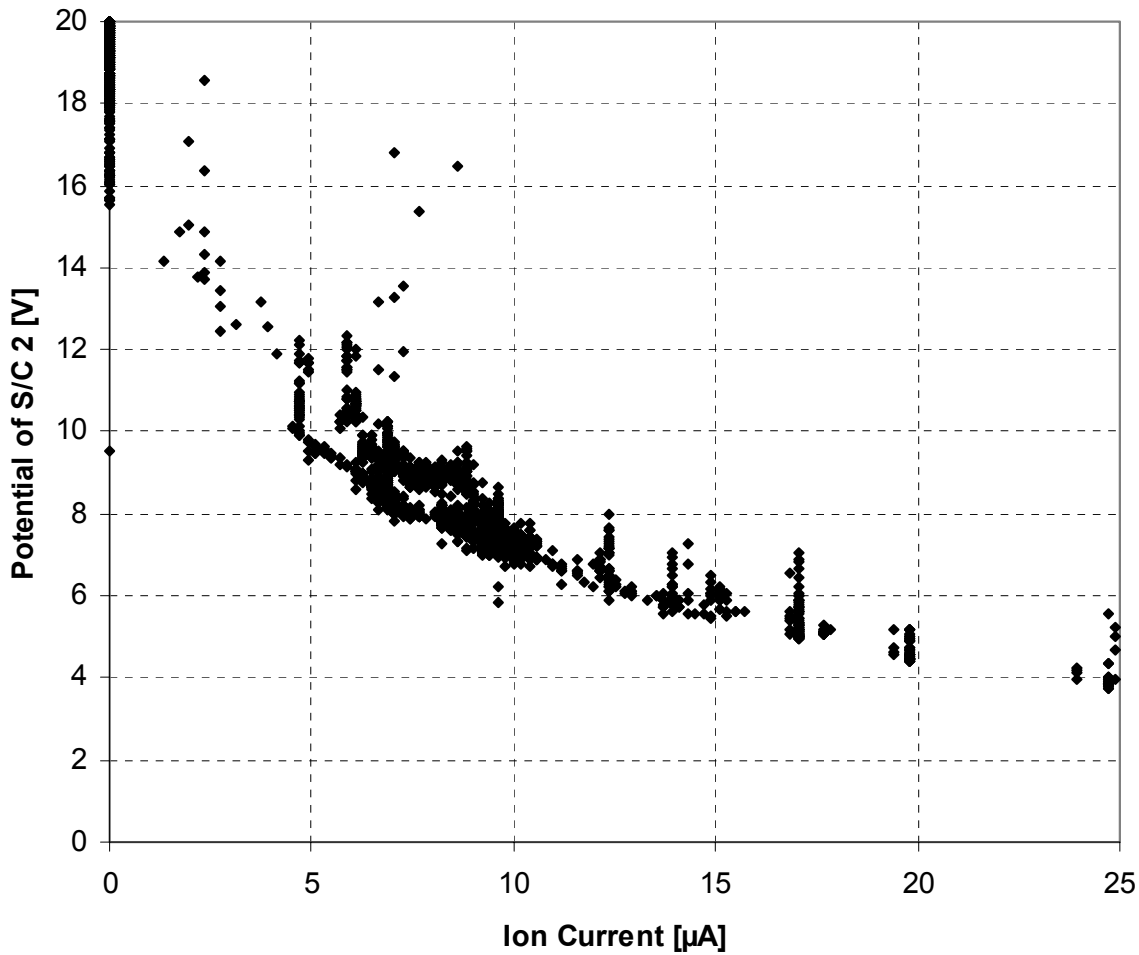



# Comparison of Spacecraft Potential Before and After Beam Turn-on

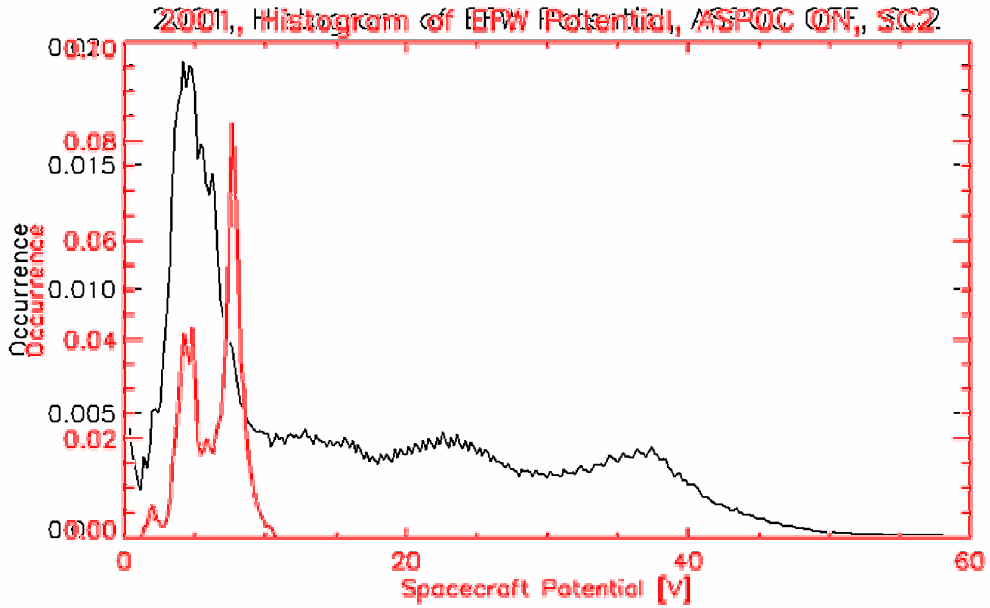


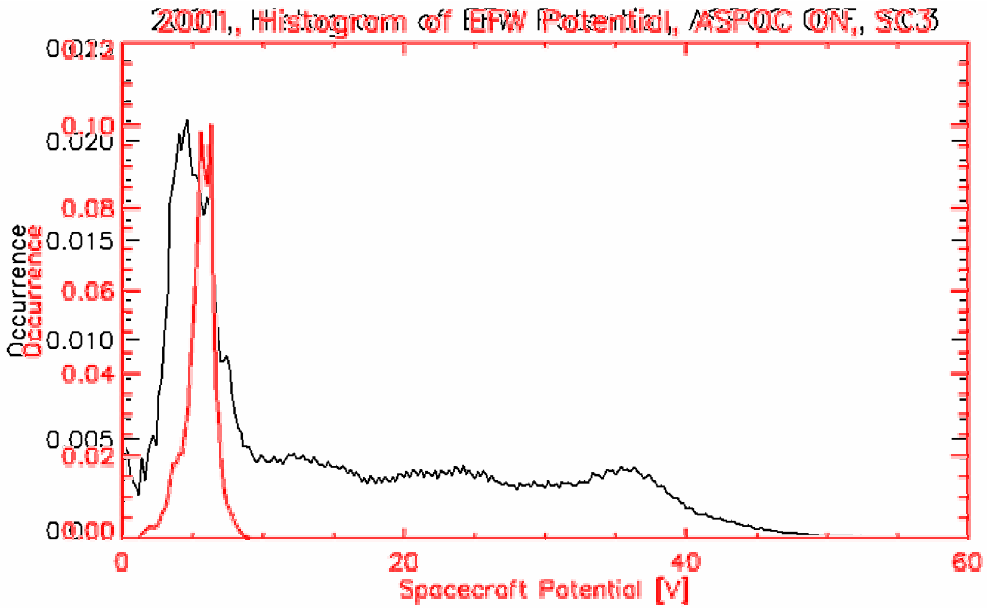
# Example of current-voltage characteristics, Spacecraft potential (EFW), Cluster 2

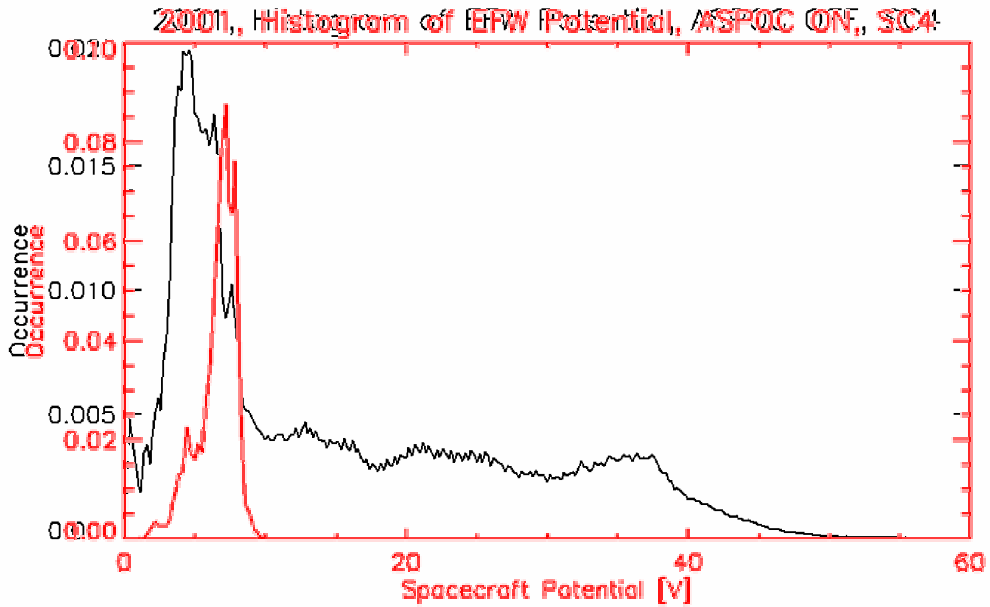


# Histograms of Spacecraft Potential

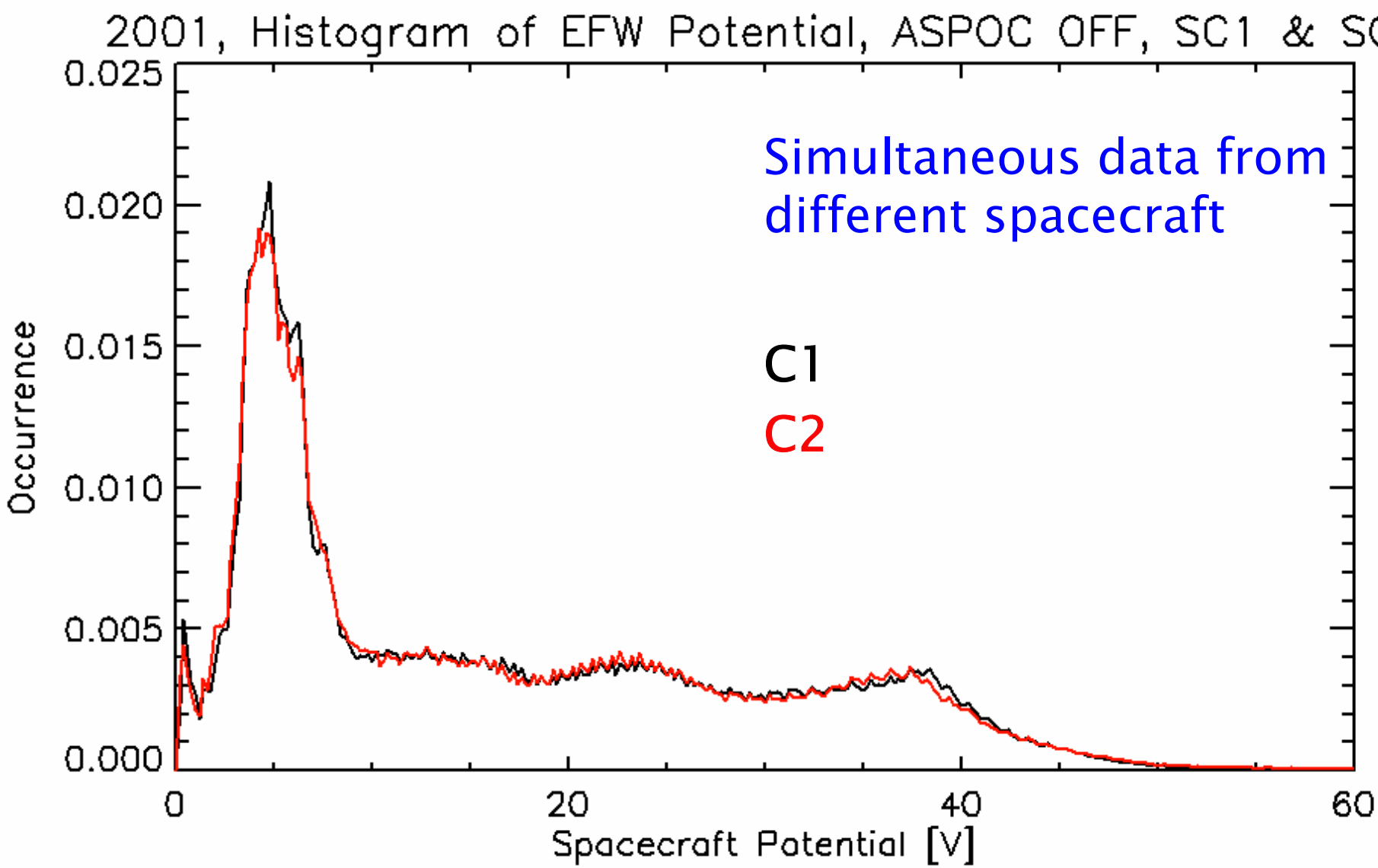
- Prime Parameter data of s/c potential measured by EFW
- Covering year 2001
- Data from the same s/c for different times



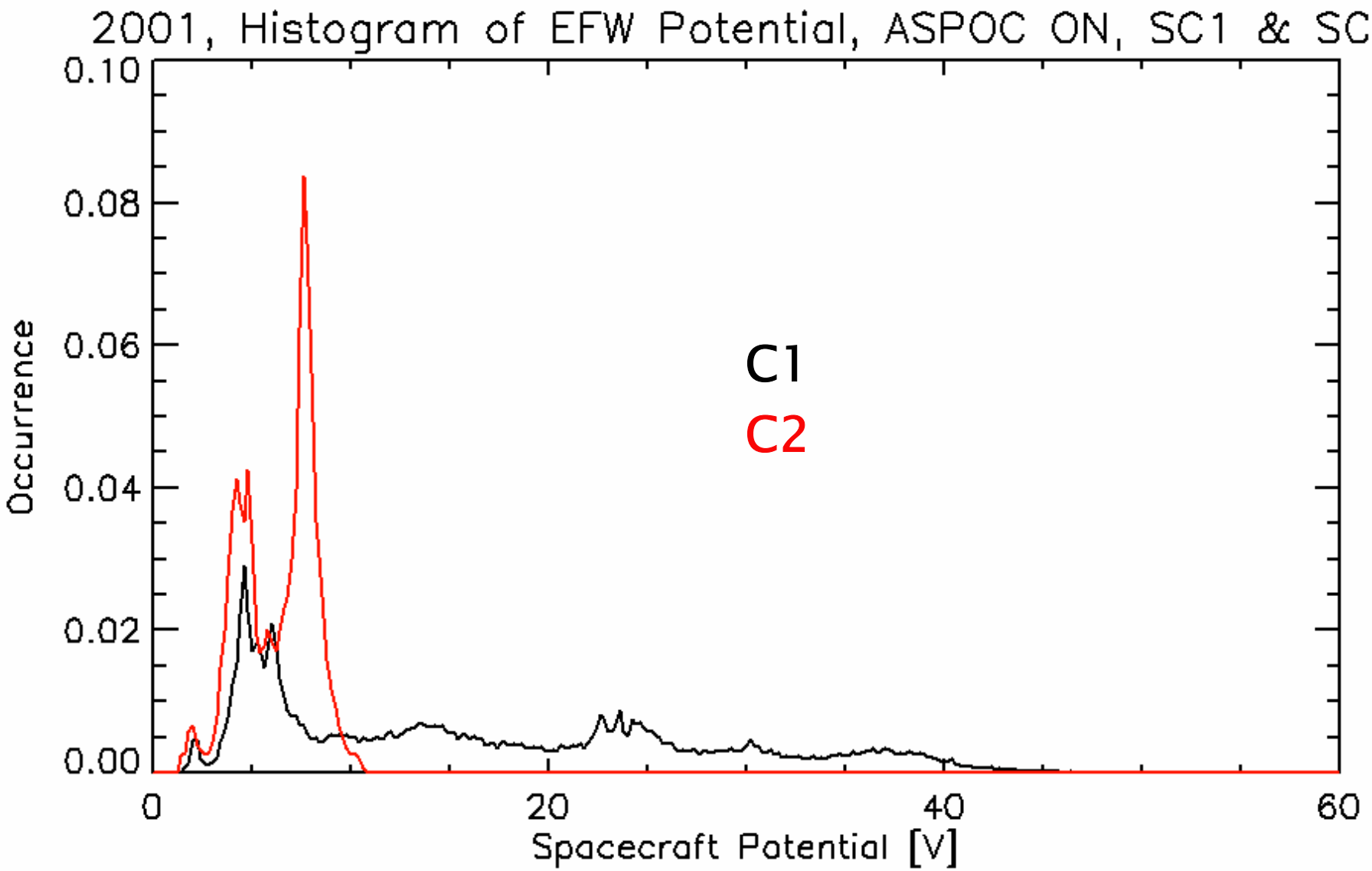



# Comparison of Spacecraft Potential Between Cluster 1 and 2, ASPOC OFF



# Comparison of Spacecraft Potential Between C1 and 2, ASPOC ON for C2



# Effect on PEACE electron measurements

- The following pages show the effect of ion beam operation on PEACE electron measurements, in various regions of the magnetosphere (polar cap, magnetotail, high-altitude cusp)

- Electron measurements not only benefit from the improvement of the data, but also from the increased lifetime of micro-channel plates, when photo-electron count rates stay low

# Polar Cap

ASPOC ON
I = 10 μA

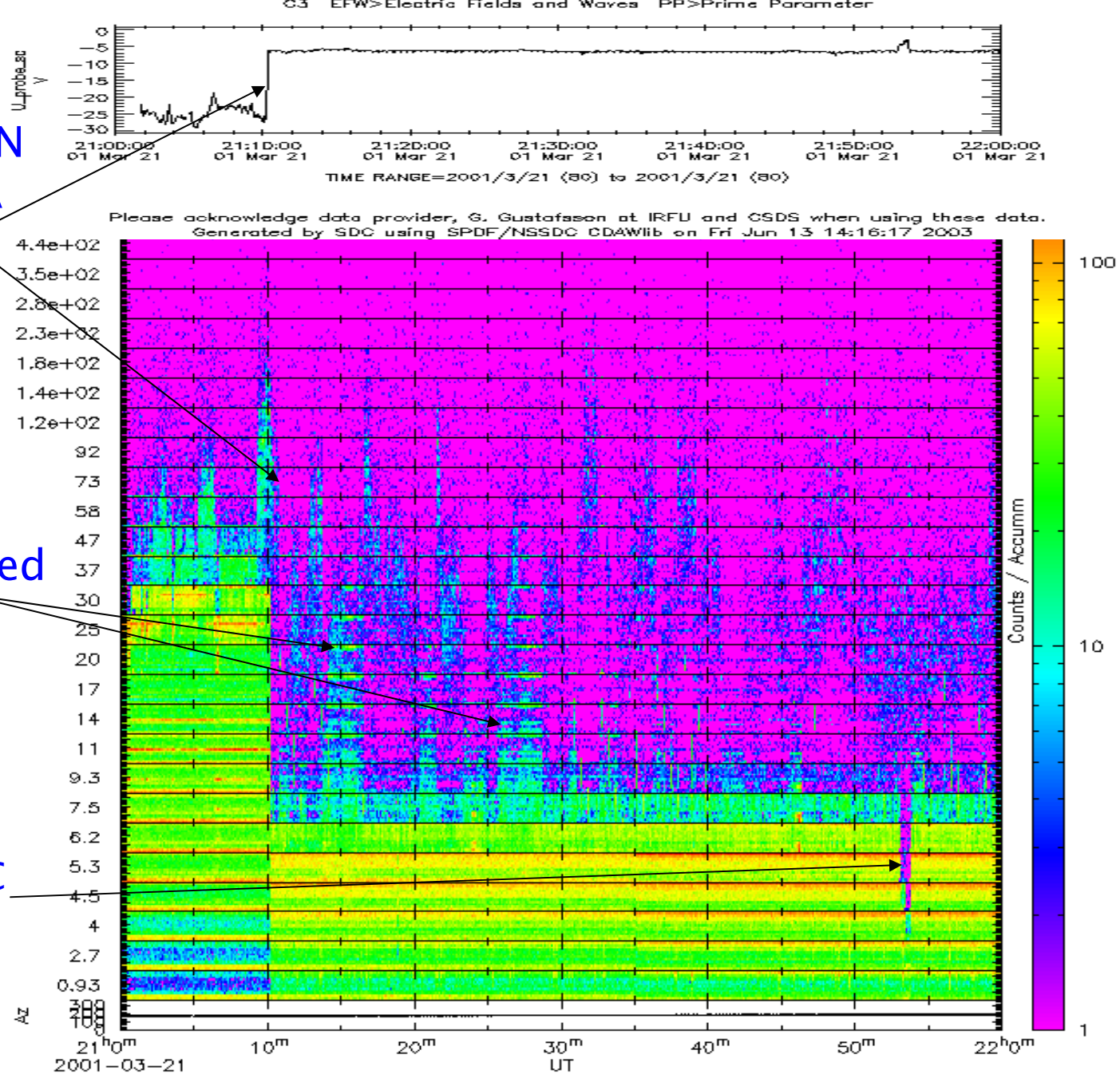
Mar. 21, 2001
AE< 50 nT
Kp=1-

Field-aligned
electrons

Location:
X = -1Re,
Y = 2.6 Re,
Z = 5 Re,
19-20 LT,
L > 50
(Vs/c=25V -
Vaspoc=7V)

ASPOC
30 μA

Svenes et al., 2003




ksv 16-Aug-2002 17:37

# Magnetotail

10 Sept. 2001
Sep. dist. 2000 km

Plasma sheet:
ne=0.1-0.2 $cm^{-3}$
Vs/c=20V

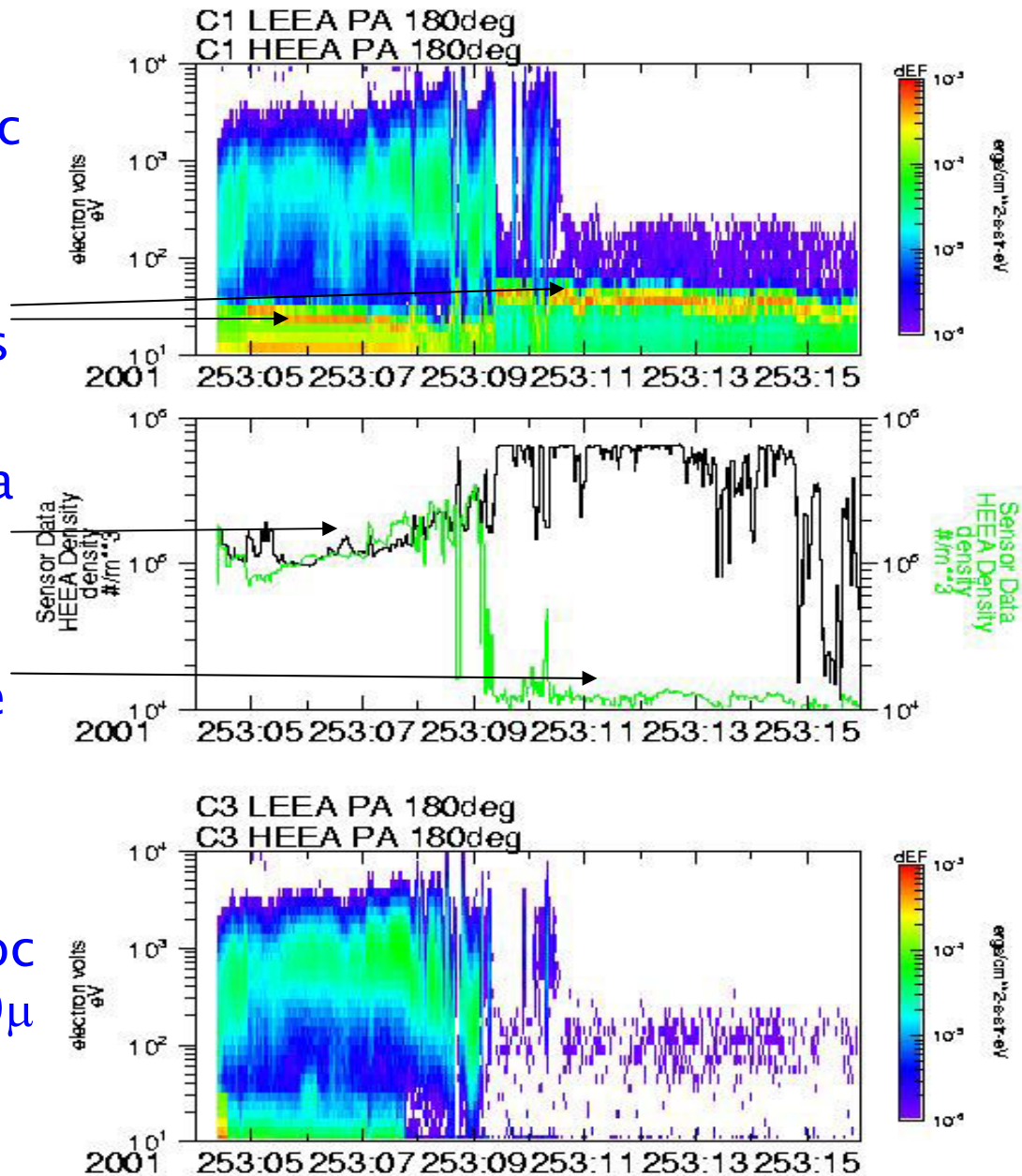
Tail lobe:
ne=0.01 $cm^{-3}$
Vs/c=45V

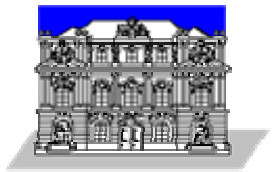
Vaspoc=9V

AE<50nT, Kp=1

23 MLT, close to apogee, near XY-plane

Svenes et al., 2003





# Effect on CIS ion measurements


- Changes of the spacecraft potential between <10 V and >20 V clearly influence the measurements of cold ions by the Cluster Ion Spectrometer (CIS)
- Effects can be seen in $H^+$, $He^+$, $O^+$ and total ion density data.
- This is demonstrated by examples on the following pages

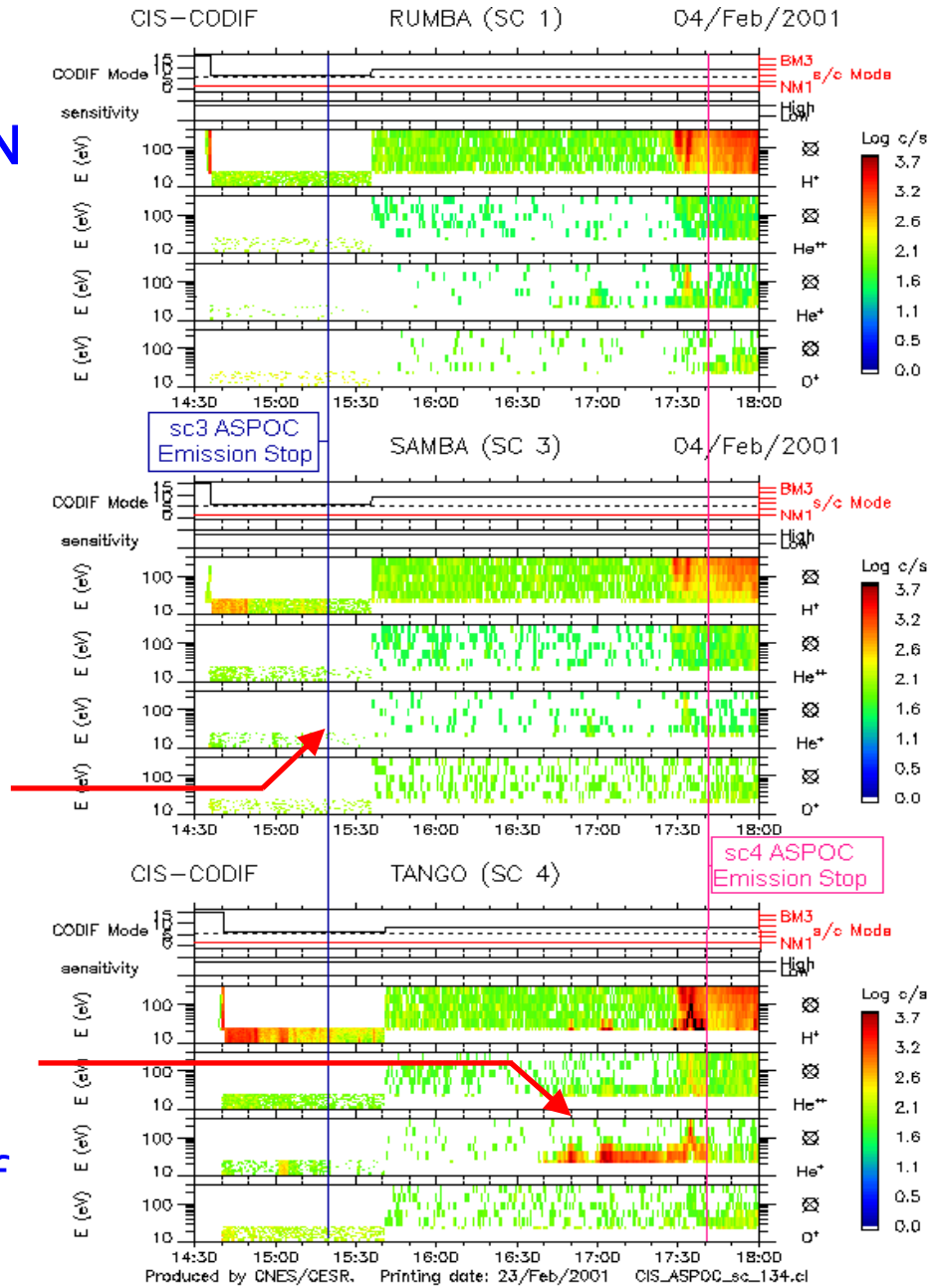
# ASPOC SUPPORTS DETECTION OF LOW-ENERGY $He^+$ AND $He^+$ IONS IN LOW DENSITY REGIONS

The Cluster Ion Spectrometer (CIS) measures significantly higher flux of low-energy $H^+$ and $He^+$ in low density regions when the ASPOC is active

The switch-off of ASPOC is clearly visible

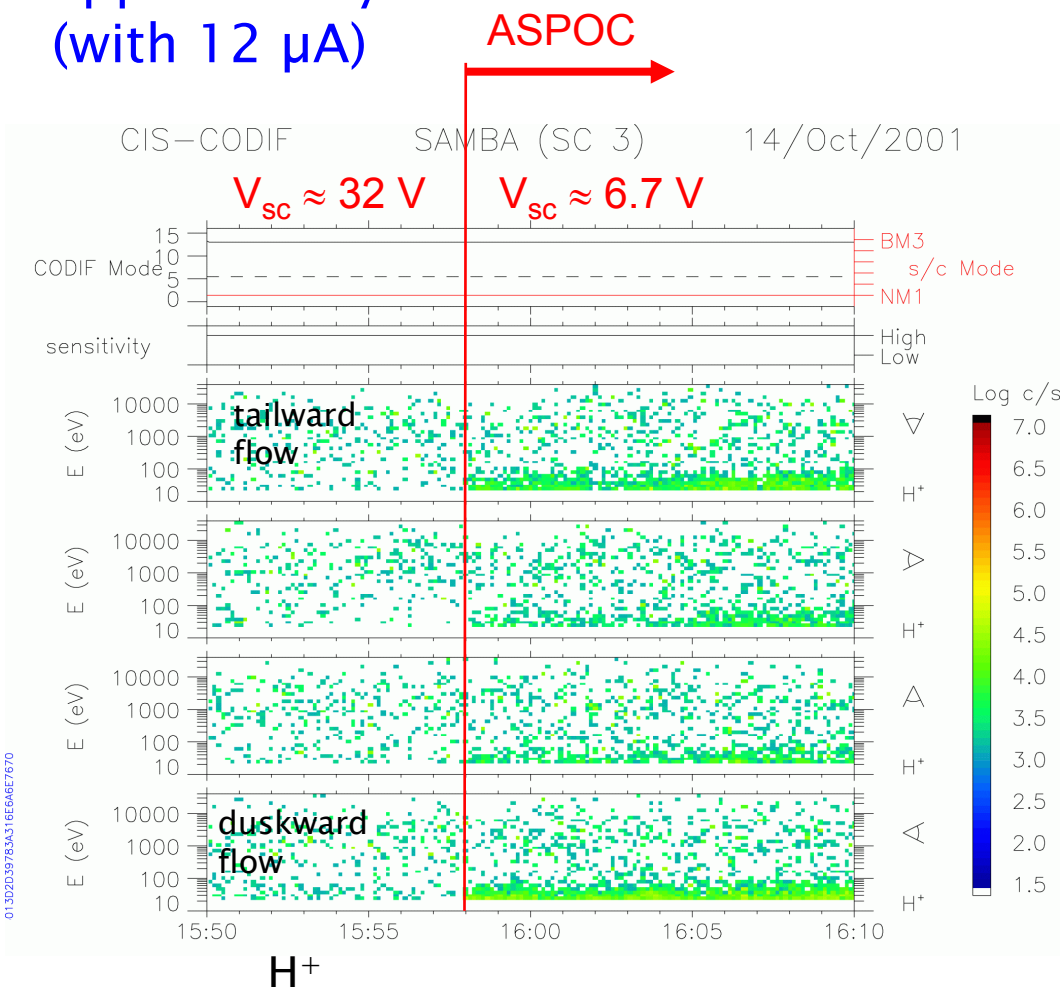
On S/C3 CIS stops to observe low-energy $H^+$ and $He^+$ after 15:19:57.

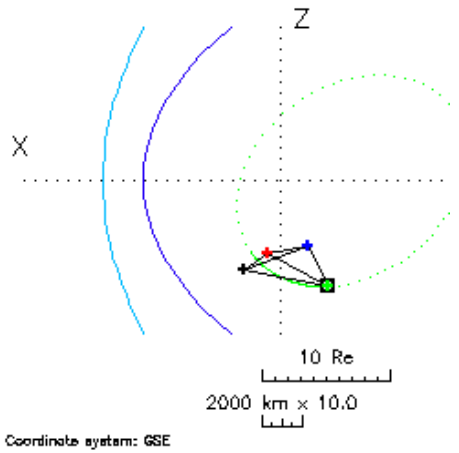
Effect is particularly clear on the He+ population (20 to 70 eV) on S/C4 from ≈16:40, and which was never observed on the other spacecraft on which ASPOC was off during that interval

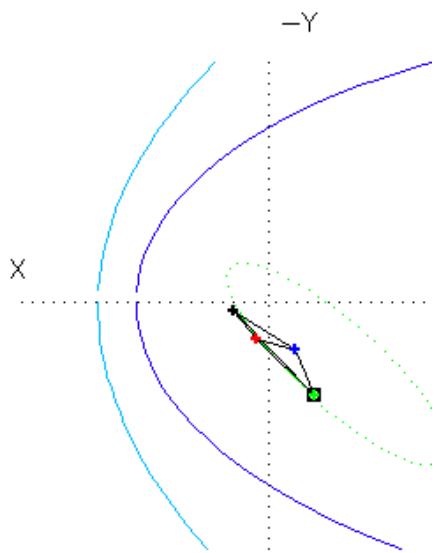


# Cold Ion Beam
# SC 3; 14 Oct 2001

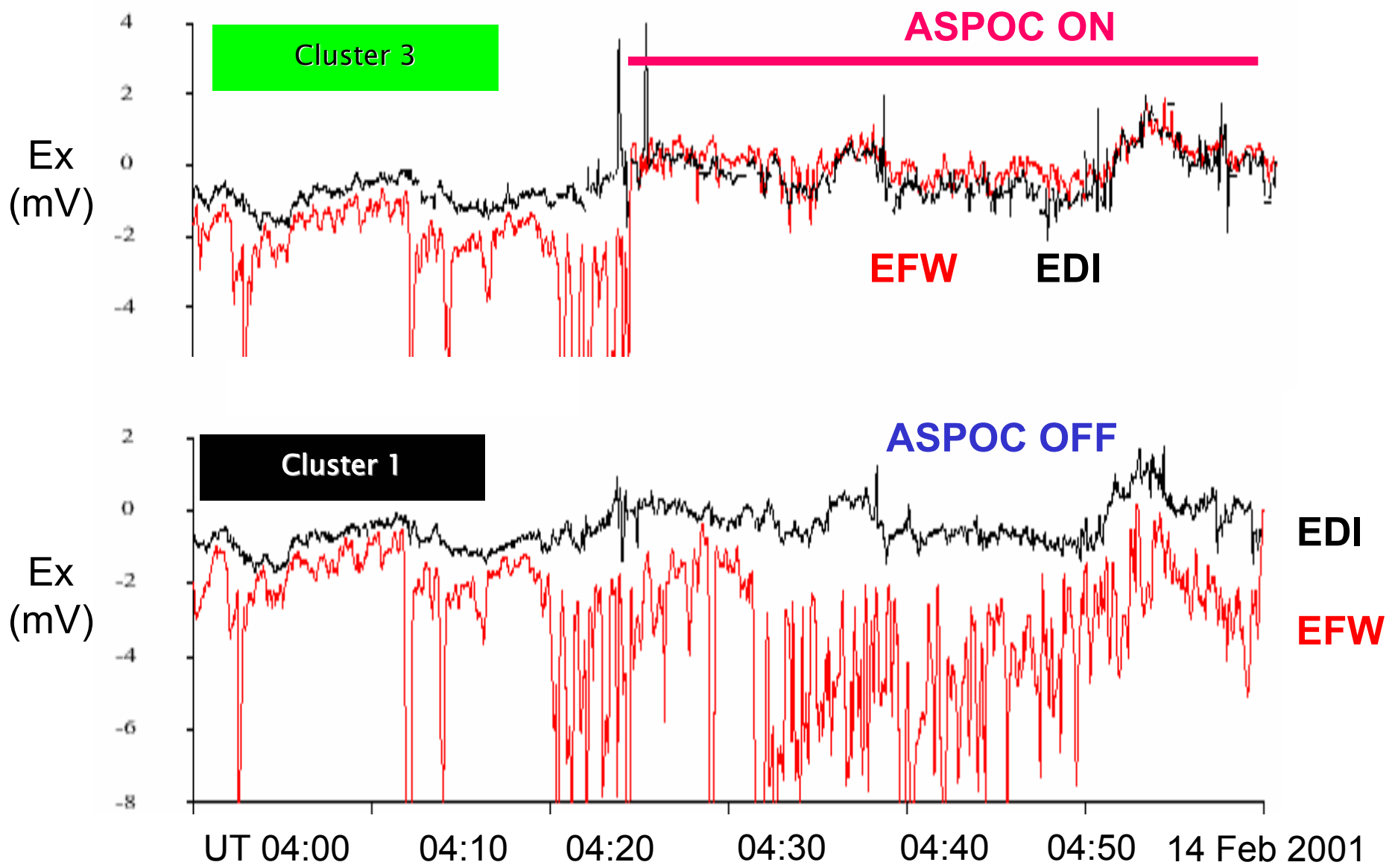
- Duskward/tailward streaming cold $H^+$ appears only after ASPOC turn-on at 15:58 (with 12 µA)

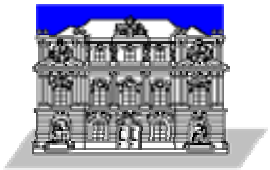


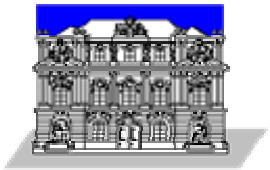
# ASPOC Support for EFW Electric Field Measurements





# Conclusions – 1

- While ASPOC is emitting 10 μA ion current, the spacecraft potential does not exceed 8 to 9 V
- With 12 to 15 μA => 6 to 7 V
- Histograms peak at ≈7 V when ASPOC is active
- Significant improvement of low energy electron measurements, without compromising wave and electric field measurements
- At times when the ion beam turns on while the plasma environment remains constant one can nicely study the effect of spacecraft potential control
- The reduction of photo-electron counts in the measurements and the improvement of the effective energy resolution is most obvious in any low density environment



# Conclusions – 2

- In spite of the low ambient density the ion beam does not appear to have a measurable effect on the incoming electrons at the present state of analysis; further work is to be done, including simulation
- Changes of the spacecraft potential between $<10$ V and $>20$ V clearly influence the measurements of cold ions; effects can be seen in $H^+$, $He^+$, $O^+$ and total ion density data, and on both spacecraft 3 and 4 $\Rightarrow$ observations are not specific to a single instrument or spacecraft.
- Electric field measurements by double probes may benefit in certain environments