A study of the spacecraft potential of Cluster while in active control

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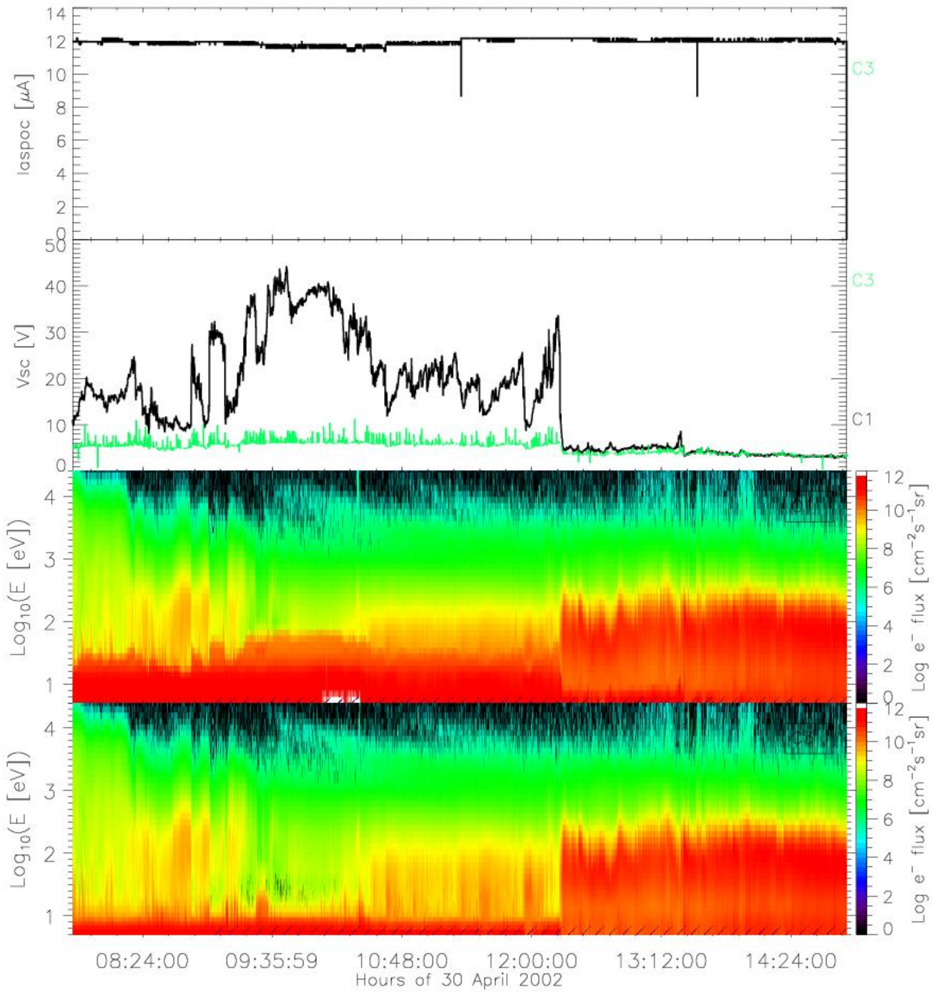
Active Spacecraft Potential Control

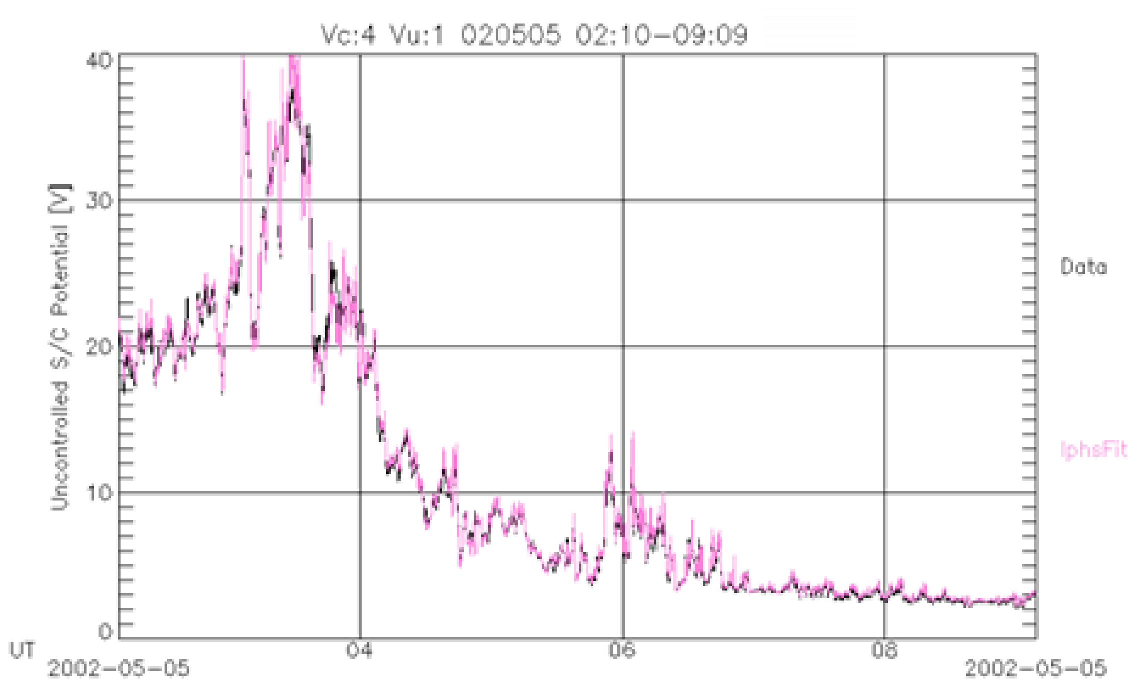
- Sunlit spacecraft → potentials up to 10's of V
- Ion emitters (ASPOC) → spacecraft potential control (≈8V: Cluster)
- More accurate electric field + low energy particle measurements
- However, spacecraft potential cannot be directly used for plasma density derivation with high resolution **(Pedersen et al. 2008)**
- How well can it be reconstructed ?



Reconstructing the uncontrolled from the controlled potential

- Successful efforts to reconstruct the uncontrolled potential for several single cases (combining controlled-uncontrolled potential data and ASPOC current properties)

- However reconstruction not yet successful in all cases...



(Torkar et al. 2014)

Motivation – ASPOC aboard MMS

- MMS: scheduled for launch in Spring 2015
- 2 ASPOC in each spacecraft → $V_{sc} \approx 4V$
- No WHISPER instrument aboard MMS → would have been useful to derive plasma density datasets also with ASPOC on
- Preparatory work → revisit all Cluster ASPOC data (beginning of mission – March 2005)

Goals

- Revisit all Cluster/ASPOC data
- Try reconstructing **uncontrolled** spacecraft potential from **controlled** one
- Derive a global photo-electron curve in different magnetospheric regions and use this for the reconstructions
- Investigate separately special cases that do not seem to fit at all the above regime
- Derive plasma density and respective errors

Initial studied period: August–October 2003

- Data from 27 case studies when ASPOC – on (V_{C4}) in the near midnight tail

  (C4: ASPOC On,   C1: ASPOC Off)

- "Good" period to study → – all spacecraft at small distances
  – similar orbits to MMS
  – comparison with previous curves (in limited energy range possible) (**Lybekk et al. 2012**)

- Data used for this analysis: – ASPOC (I_{aspoc})
  – EFW (V_{sc1}, V_{sc4})
  – PEACE (T_e, n_e) → **Ie**
  – CODIF (T_i, n_i) → **Ii**

Method

- Calculate I_e, I_i and estimate photo-electron current leaving the spacecraft with ASPOC off, I_{phot1} ($I_{phot1} = I_{e1} - I_{i1}$)

- Derive a fitting curve, using the (V_{sc1}, I_{phot1}) data of the whole interval

$$\boxed{I_{phot1} = f\,(V_{sc1})}$$

- Use the curve to reconstruct the controlled V_{sc4} data to the expected values we would get if ASPOC was OFF

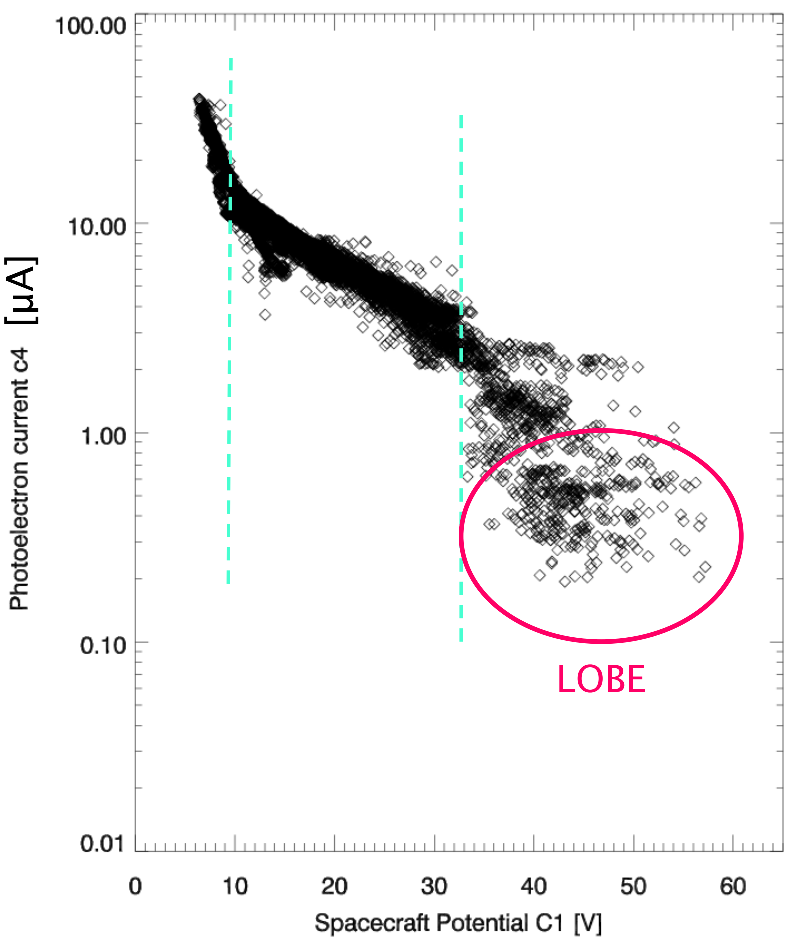
$$I_{phot4} = I_{e4} - I_{i4} + I_{aspoc} \rightarrow \boxed{I_{e4} - I_{i4} + I_{aspoc} = f\,(V_{sc4})}$$

- Derive plasma densities using this global curve (due to solar cycle, spacecraft effects, we would have to re-estimate the curve for the MMS case + different magnetospheric regions & time intervals)

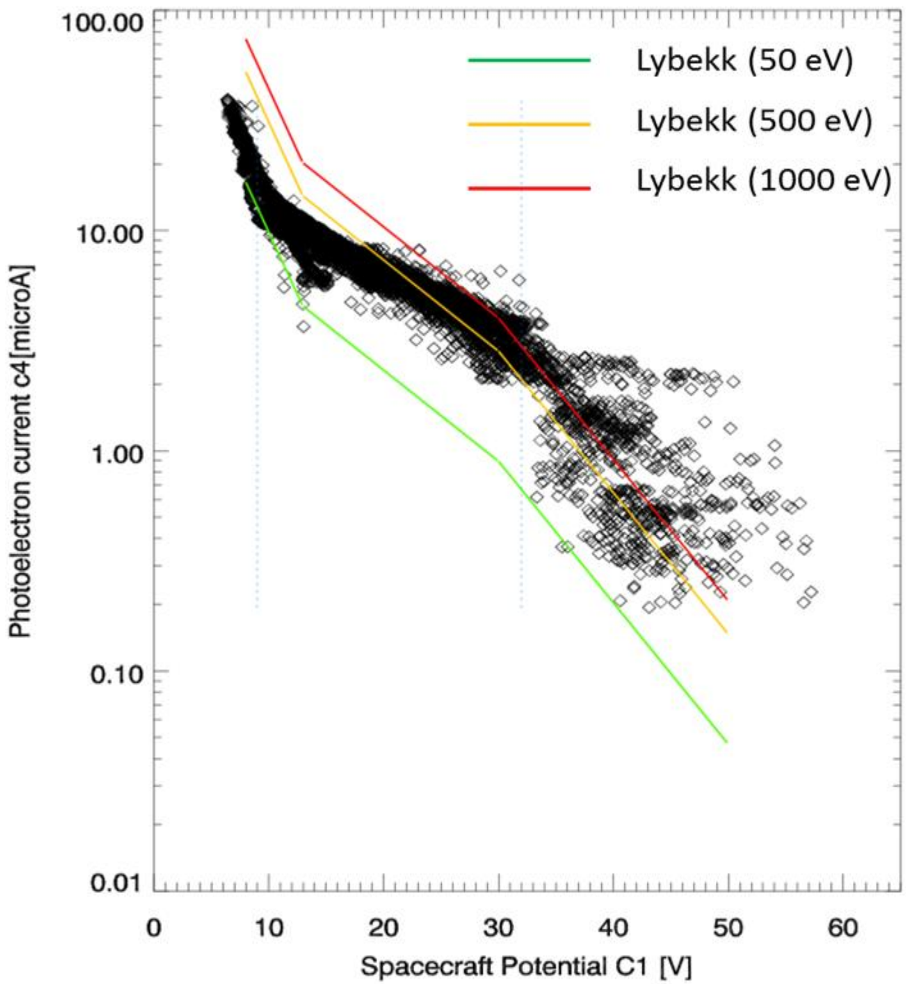
- Estimate accuracy of measurements

Results: photoelectron current

- $I_{e1} - I_{i1} = f\,(V_{sc1})$
- Underestimation of $I_{e1} - I_{i1}$ (ASPOC off) in low density regions → use $I_{e4} - I_{i4} = f\,(V_{sc1})$ instead
- 2 bends in the curve (at ~9V and ~32 V)



Comparing with the Lybekk curve



- Lybekk et al. 2012:

  2003–2004 (E:10–100 eV)

  $8<V<13 \quad N_e=30*e^{(-V/3.83)} \quad [1/cm^3]$

  $13<V<30 \quad N_e=3.5*e^{(-V/10.5)} \quad [1/cm^3]$

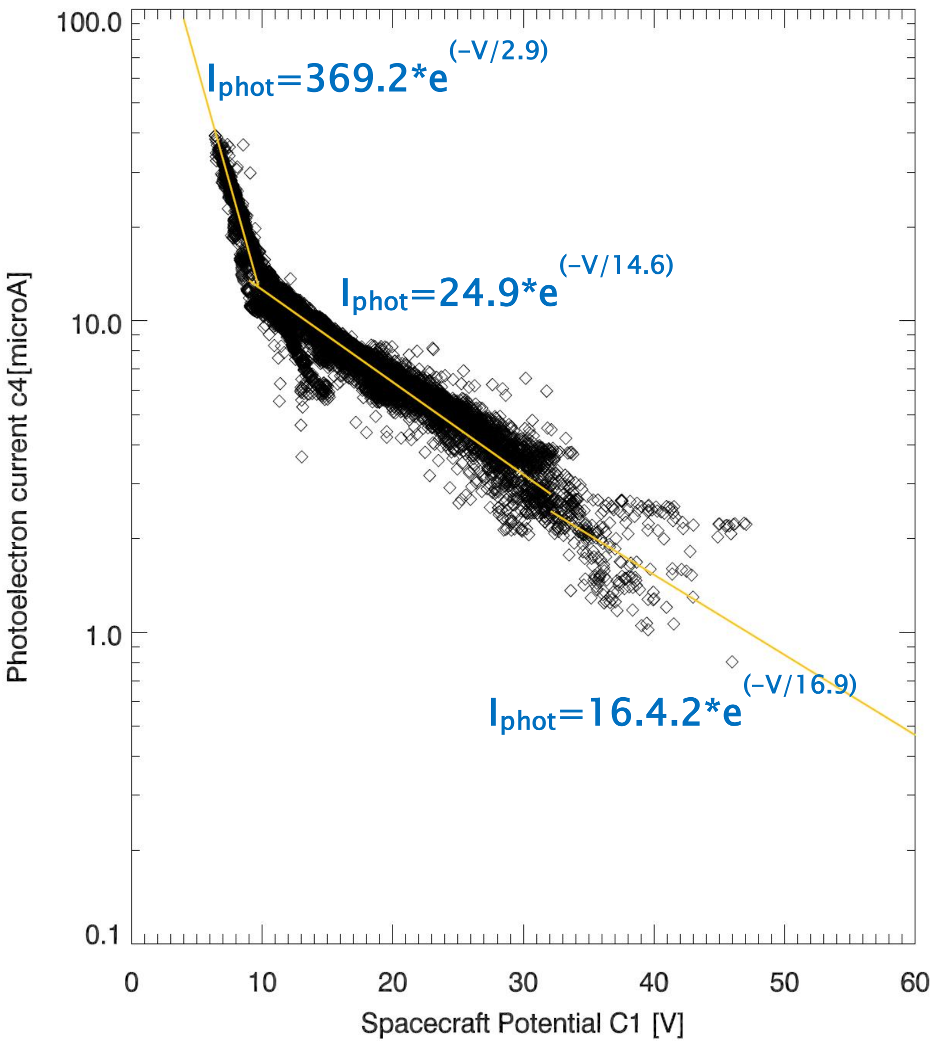
  $30<V<50 \quad N_e=17*e^{(-V/6.76)} \quad [1/cm^3]$

- Somehow agrees well in low energies, but these are not typical of the region

- Doesn't agree if we use it for higher energies

- Need to redo the fitting for our purposes

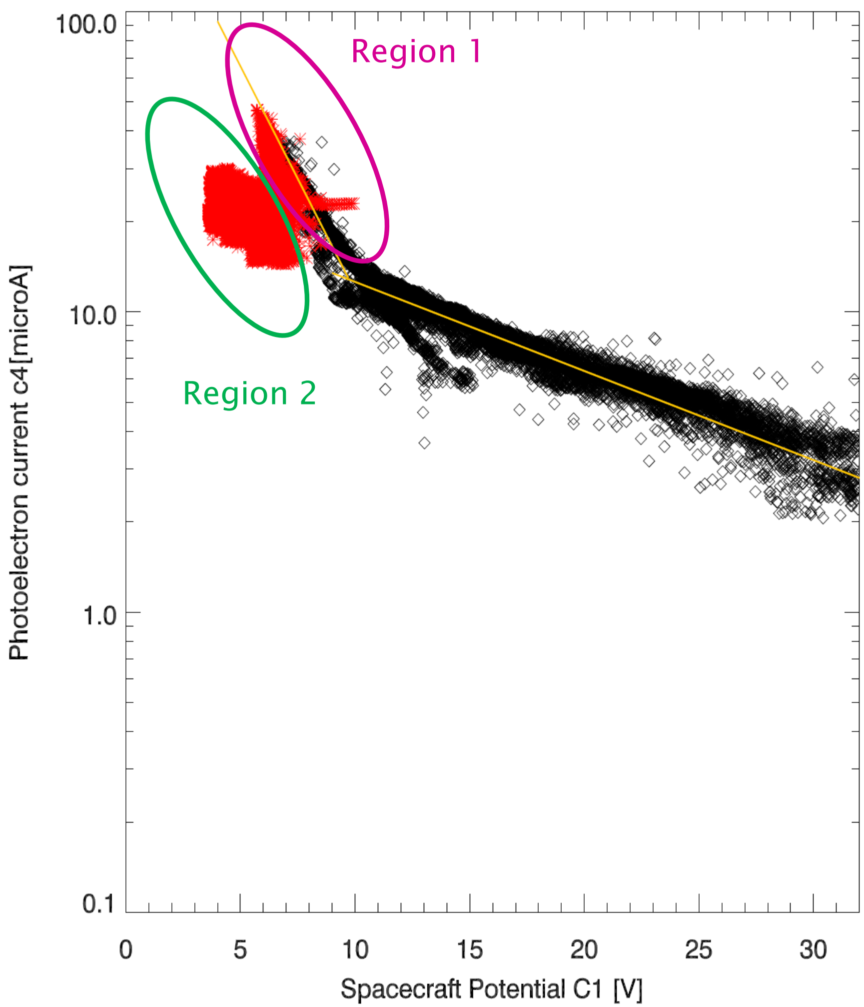
Fitting results (lobe data removed)



$V<9$	$I_{phot}=369.2*e^{(-V/2.9)}$	[μA]
$9<V<32$	$I_{phot}=24.9*e^{(-V/14.6)}$	[μA]
$V>32$	$I_{phot}=16.4*e^{(-V/16.9)}$	[μA]

- 3rd region needs revisiting
- Focus on the two first regions for now

Results: overplotting the controlled points to the uncontrolled ones



- Our method is expected to work when:

C1 (uncontrolled SC)

I_{ph1} = Ie –Ii (BLACK POINTS)

$= f(V_{sc1})$

C4 (controlled SC)

Ie –Ii + I_{aspoc} (RED POINTS)

$= I_{ph4} = f(V_{sc4})$

$= f(V_{sc1}) + I_{aspoc}$

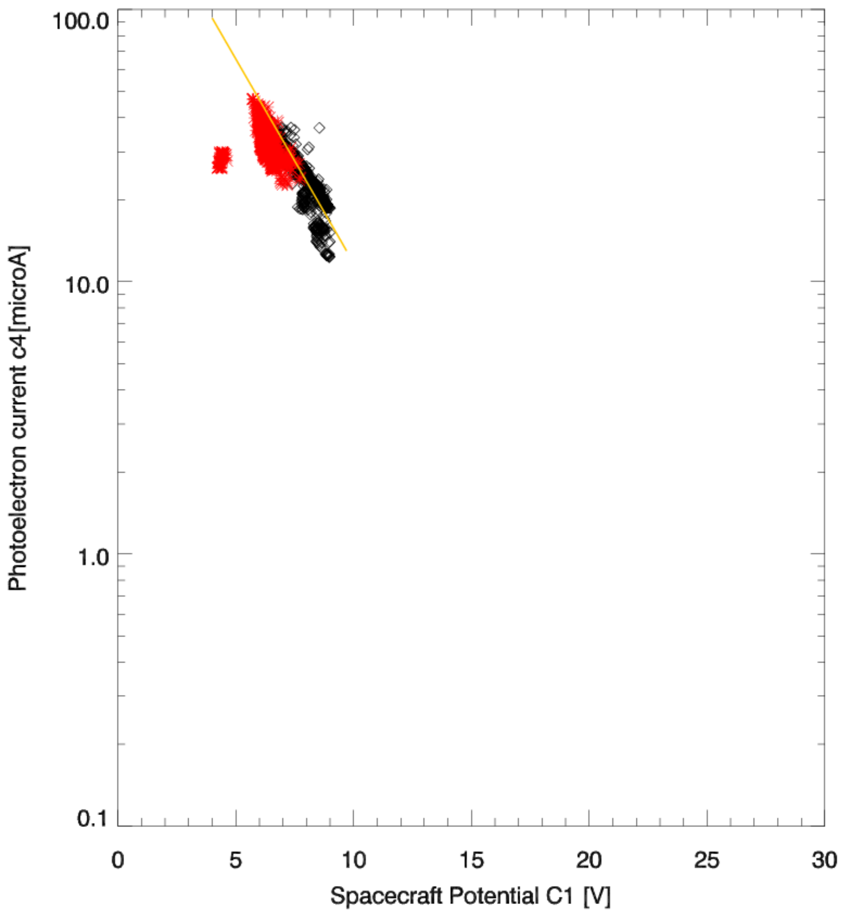
2 distinct regions for the C4 data points (RED POINTS):

Region 1: following the fitted curve

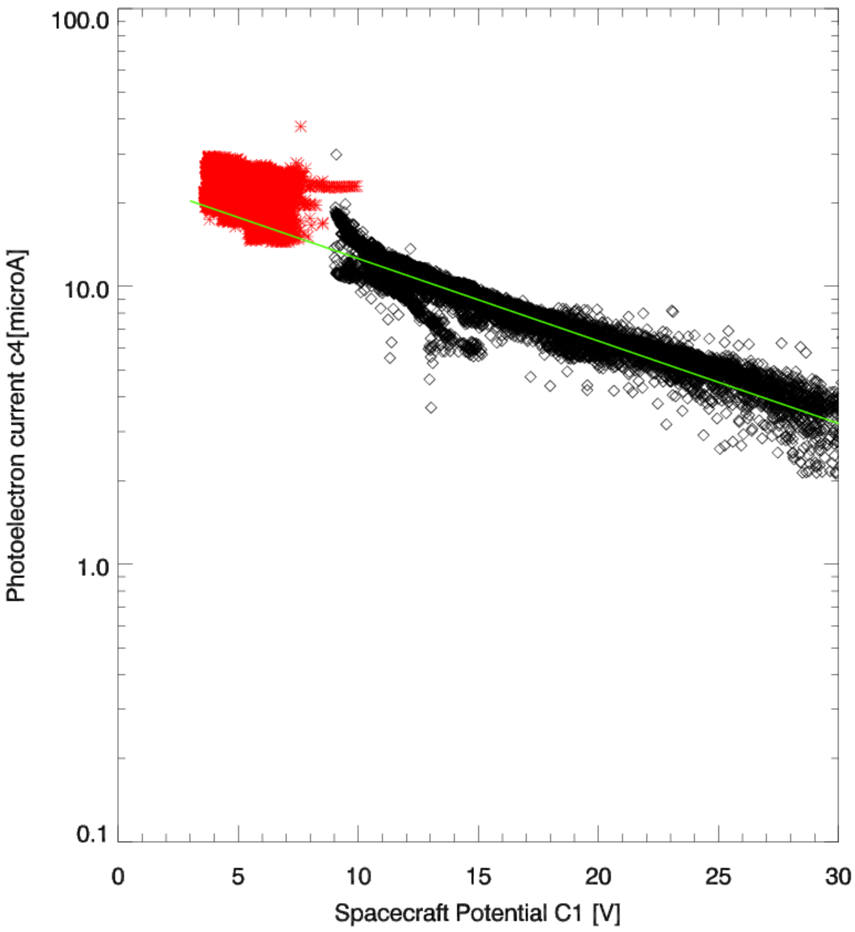
Region 2: below the fitted curve

Results: overplotting the controlled points to the uncontrolled ones

Region 1→ VC1 <9



Region 2→ 9 < VC1 < 32



- Different curves? Related to different magnetospheric regions? Temperatures ?

Discussion –Future work

- Understand why we have 2 different regions in the controlled potential curve (study single events, compare with other regions, time periods)
- Use the derived curve to fit “single” events (continuous time intervals when ASPOC is on)
- Redo the procedure by using the complete time interval for the uncontrolled case (careful data selection)
- Derive the curve considering other magnetospheric regions/time intervals and compare the results
- Estimation of errors

Summary

- Work on reconstructing the uncontrolled potential from the controlled one → plasma density estimation
- Studied period from August – October 2003 (near-midnight tail) → photo-electron curve and fitting for the uncontrolled points
- Use the controlled points and the derived function to reconstruct the uncontrolled potential
- Controlled points concentrated on 2 regions on the curve (similar to the fitted regions → under investigation