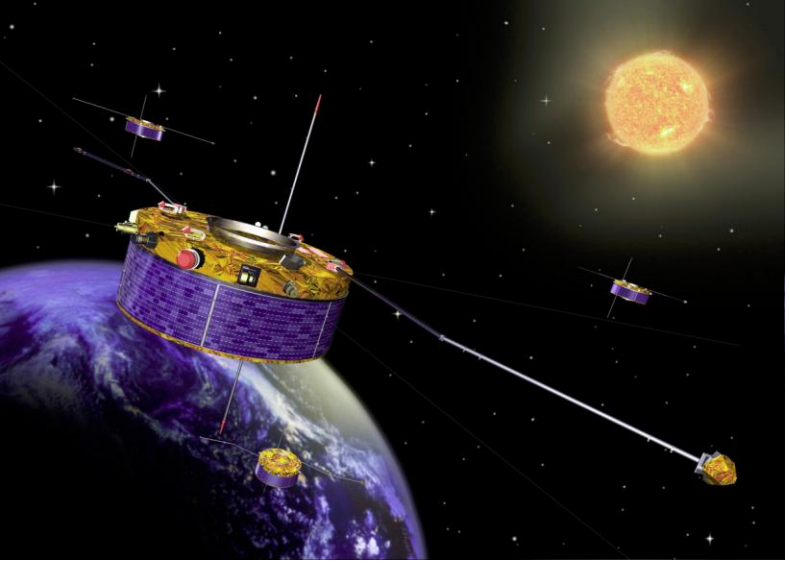


Outflow of low-energy ions and the solar cycle (Or: The new map of the magnetosphere)

M. André, K. Li, A. I. E. Eriksson,

H. Nilsson and S. Haaland

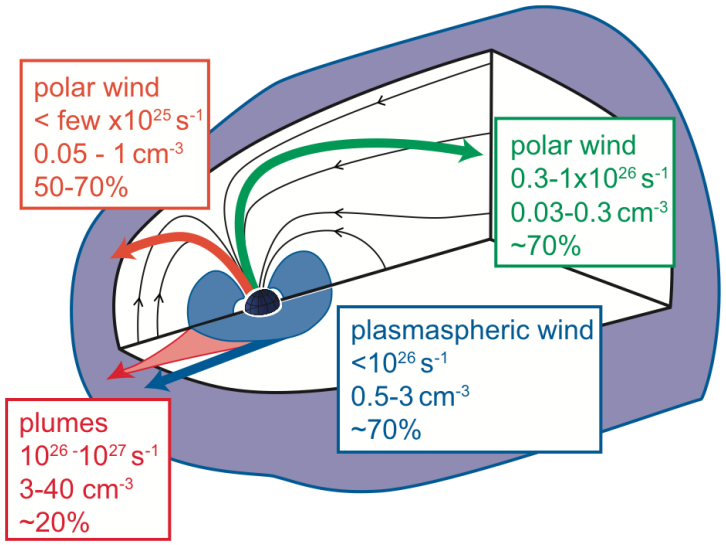
The Cluster EFW, EDI and FGM teams

The new map

Low-energy (eV) ions dominate

- **Most of the Terrestrial magnetosphere**
- **Most of the time**
- **All of the solar cycle**

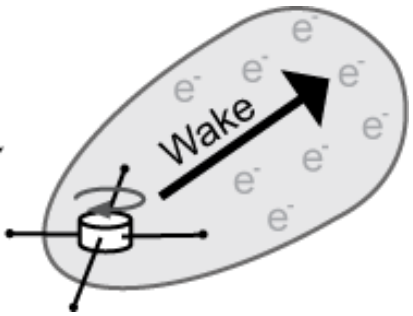
Can often not be observed with particle detectors



André and Cully, GRL, 2012

Low-energy ions

- **Low-energy: thermal energy, and drift energy, less than 10 eV (sometimes 100 eV).**
- **From the ionosphere.**
- **Low-energy *positive ions* hard to detect on *SC charged to a several Volts positive.***



Low-energy ions: An old idea

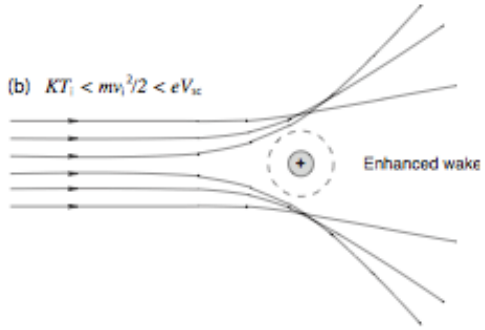
Some previous studies

- Chappell+ 1980; 1987
- Olsen 1982; Olsen+ 1985
- Moore 1984, Moore and Horwitz 2007
- Horwitz 1987
- Su+ 1998
- Sauvaud + 2001
- Seki+ 2003
- Yau+ 2007

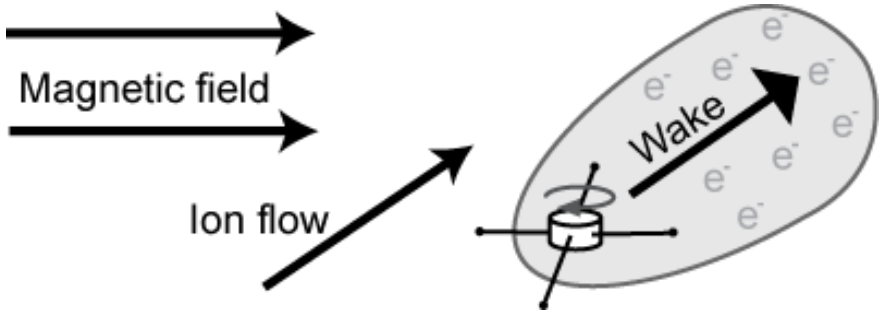
Some new studies

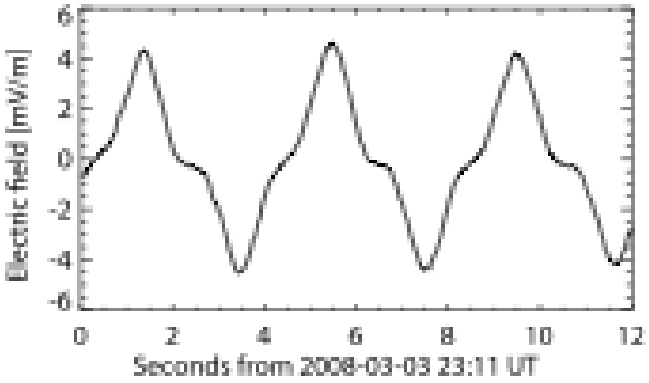
- Engwall+ Nature Geoscience, 2009
- Engwall+ Ann Geophys, 2009
- André and Cully, GRL, 2012

Cold flowing ions: Wake behind a charged SC



$KT < mv^2/2 < eV_{sc}$

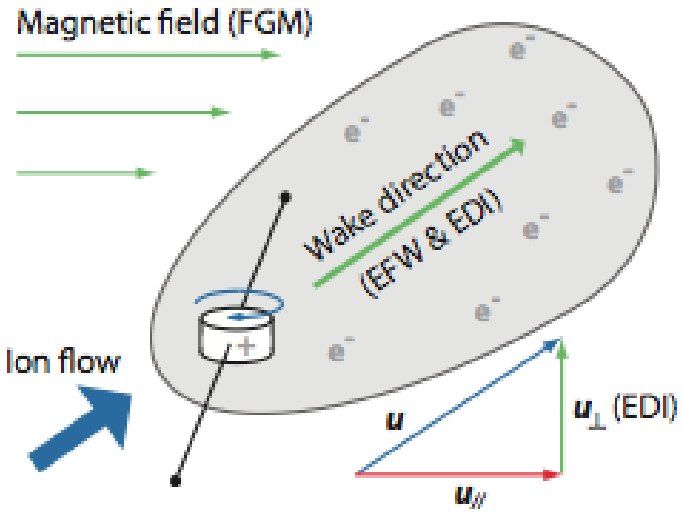




Cluster

Theory, simulations (Engwall+ 2006)

Cold flowing ions: Flux



Velocity

Wake direction (EFW, EDI)

B direction (FGM)

u_{perp} (EDI, FGM)

Density

SC potential: Lybekk+ (2012)

Haaland+ (2012)

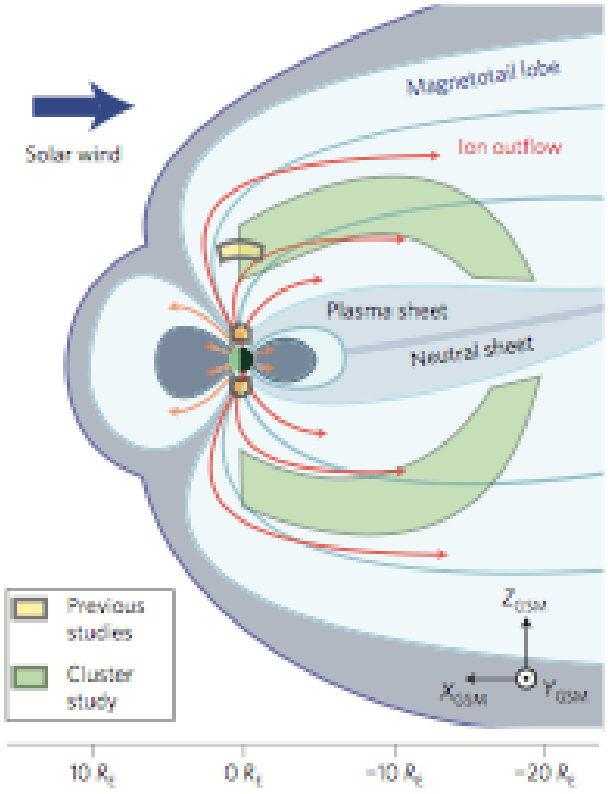
Eriksson and Winkler (2008)

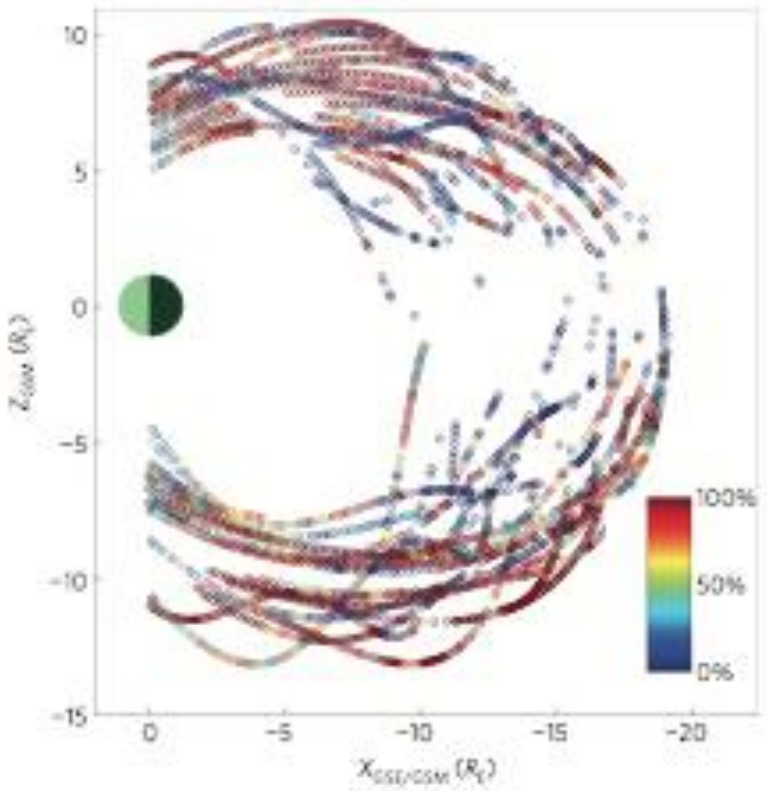
Compare with ion observations

CIS RPA, ASPOC on (one event)

Engwall+ 2006

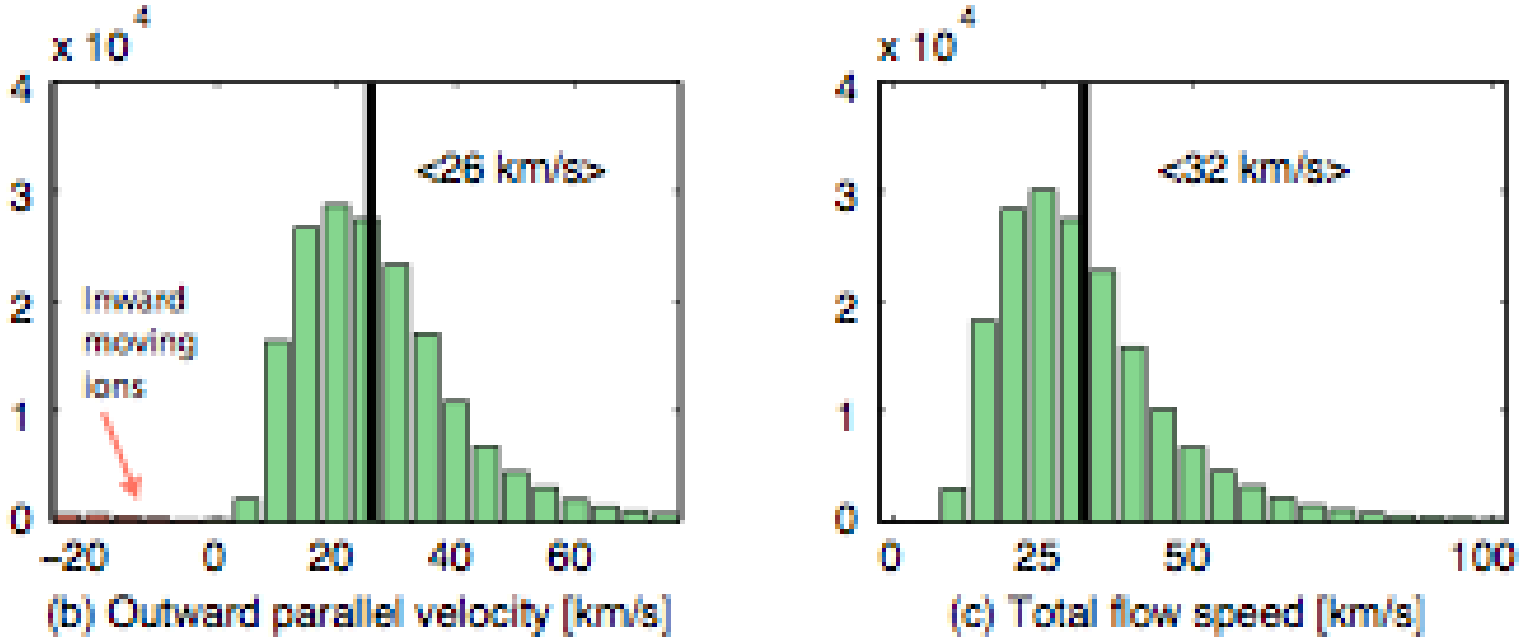
Magnetotail lobes I





Engwall+ 2009

Magnetotail lobes II

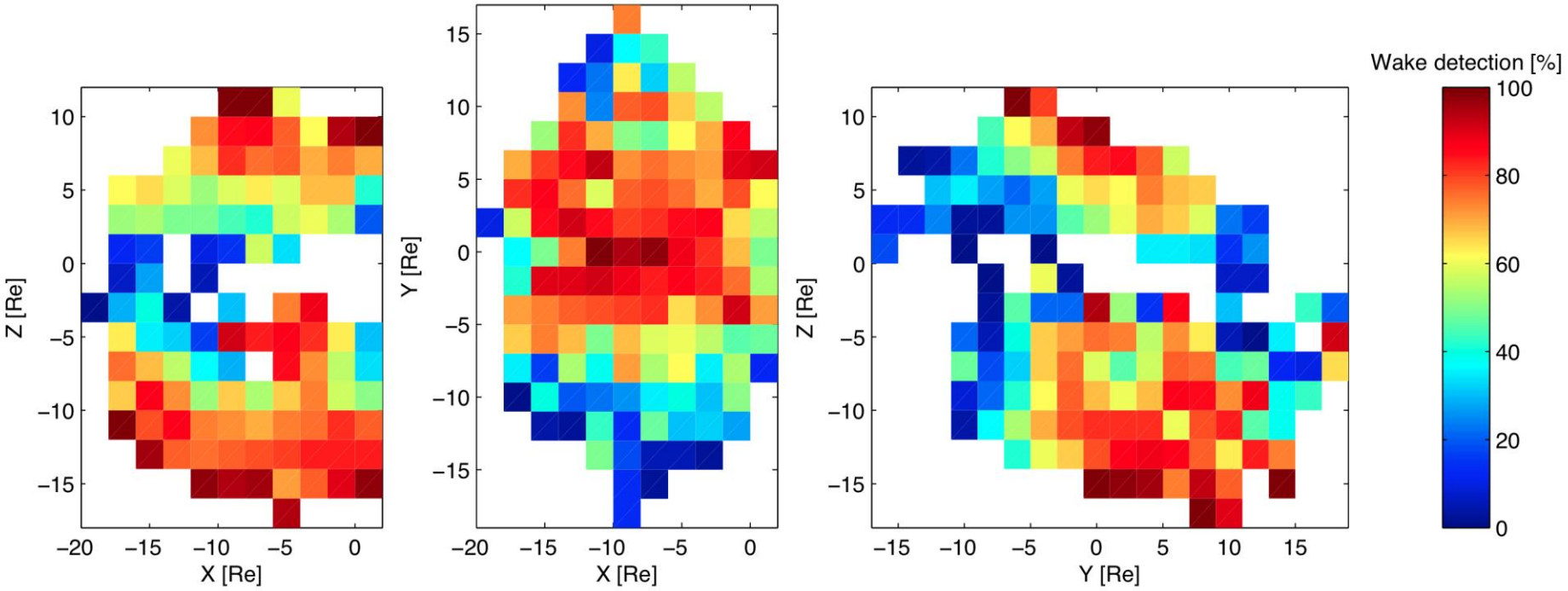


+2 V SC potential => ≈ 20 km/s H^+ cut-off

Engwall+ 2009

First you see only the tail…

Magnetotail lobes III

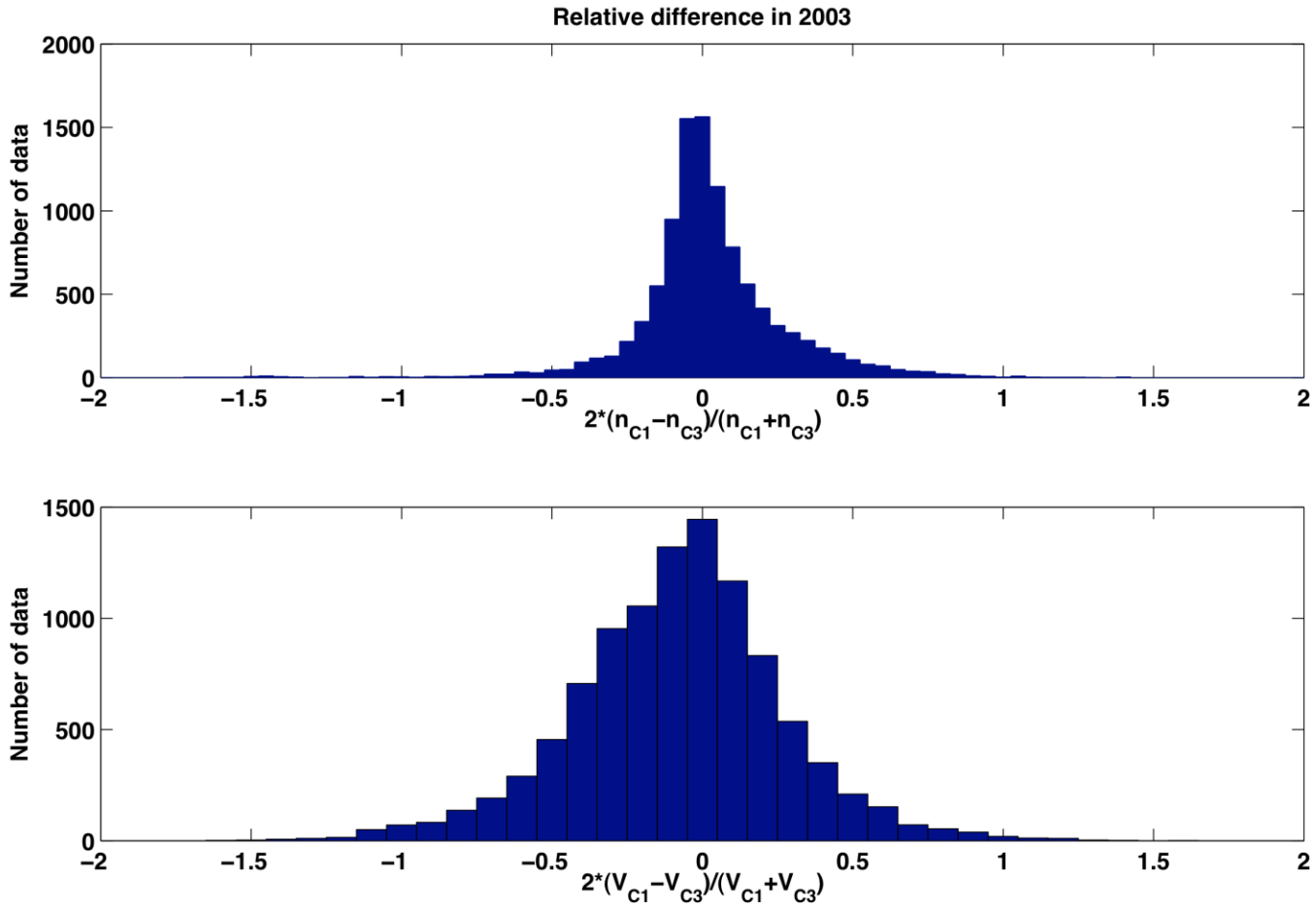


NEW C1 2001-2009

NEW C3 2001-2010 Total 1,680,000 data points

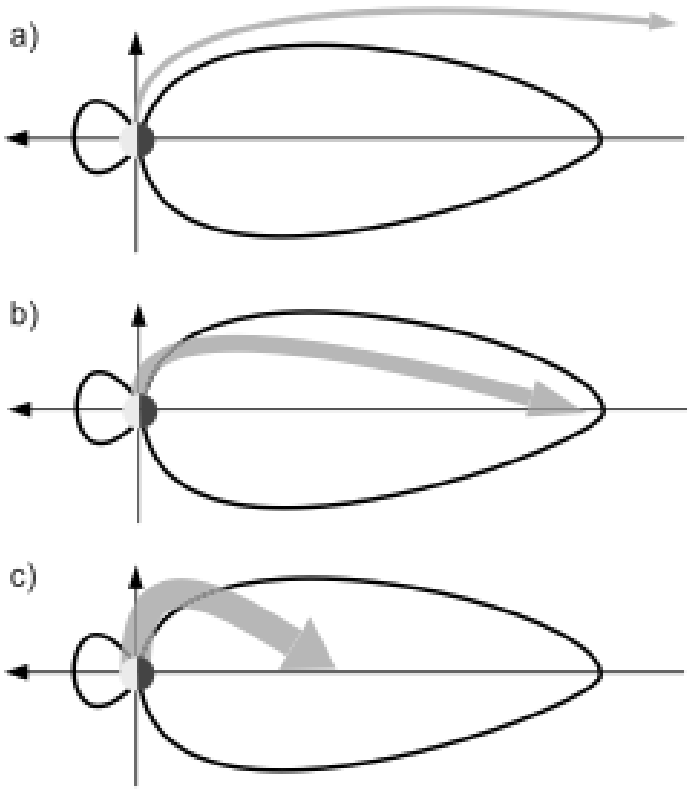
=> **low-energy ions (wake) 64% of the time**

Two spacecraft

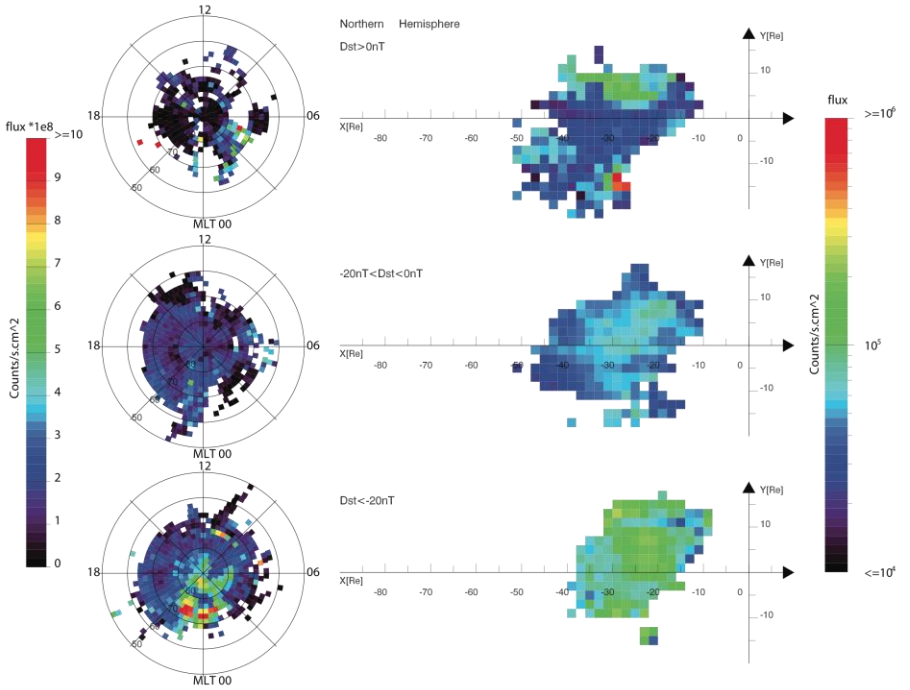


C1 and C3 at few 100 km separation

Final destination?



Haaland+ 2012

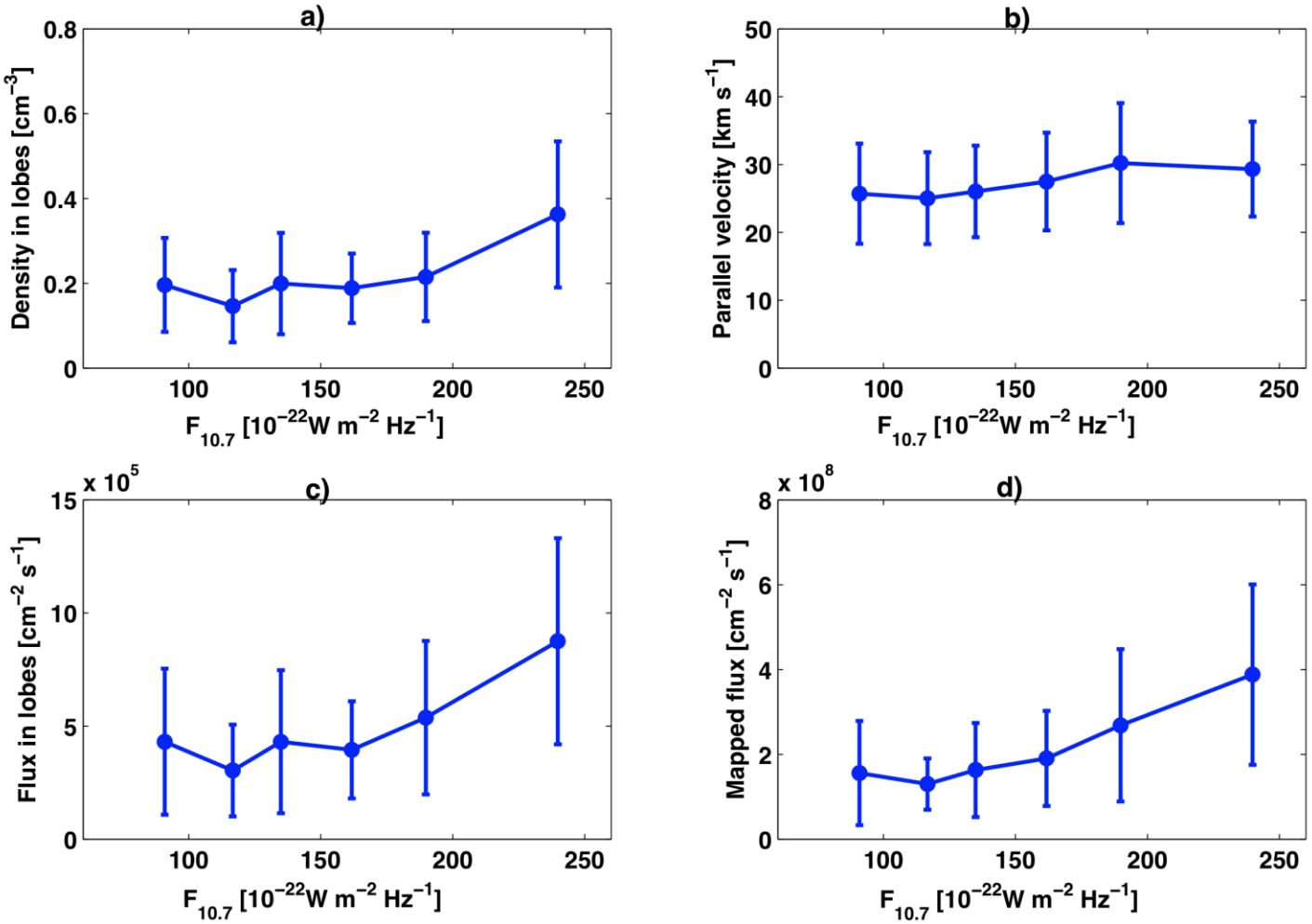


Li+ 2012, 2013

Polar cap => Plasma sheet =>

not much precipitating (Newell+ 2009) => **escaping**

Solar variation I

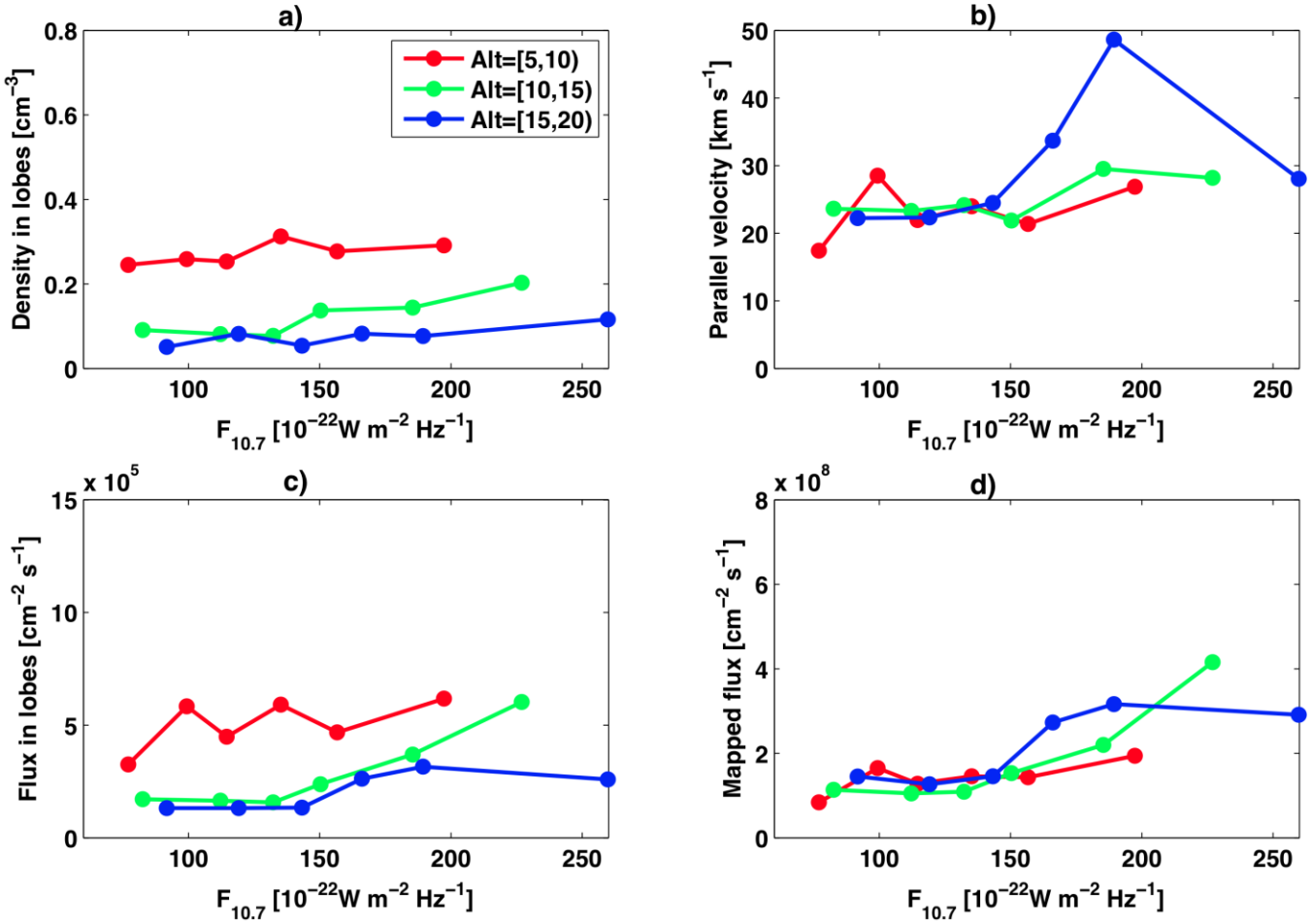


C 1 and C3 (year 2001-2010): total 330,000 data points

=> **total outflow ≈ 10^{26} ions/s**

Solar variation II

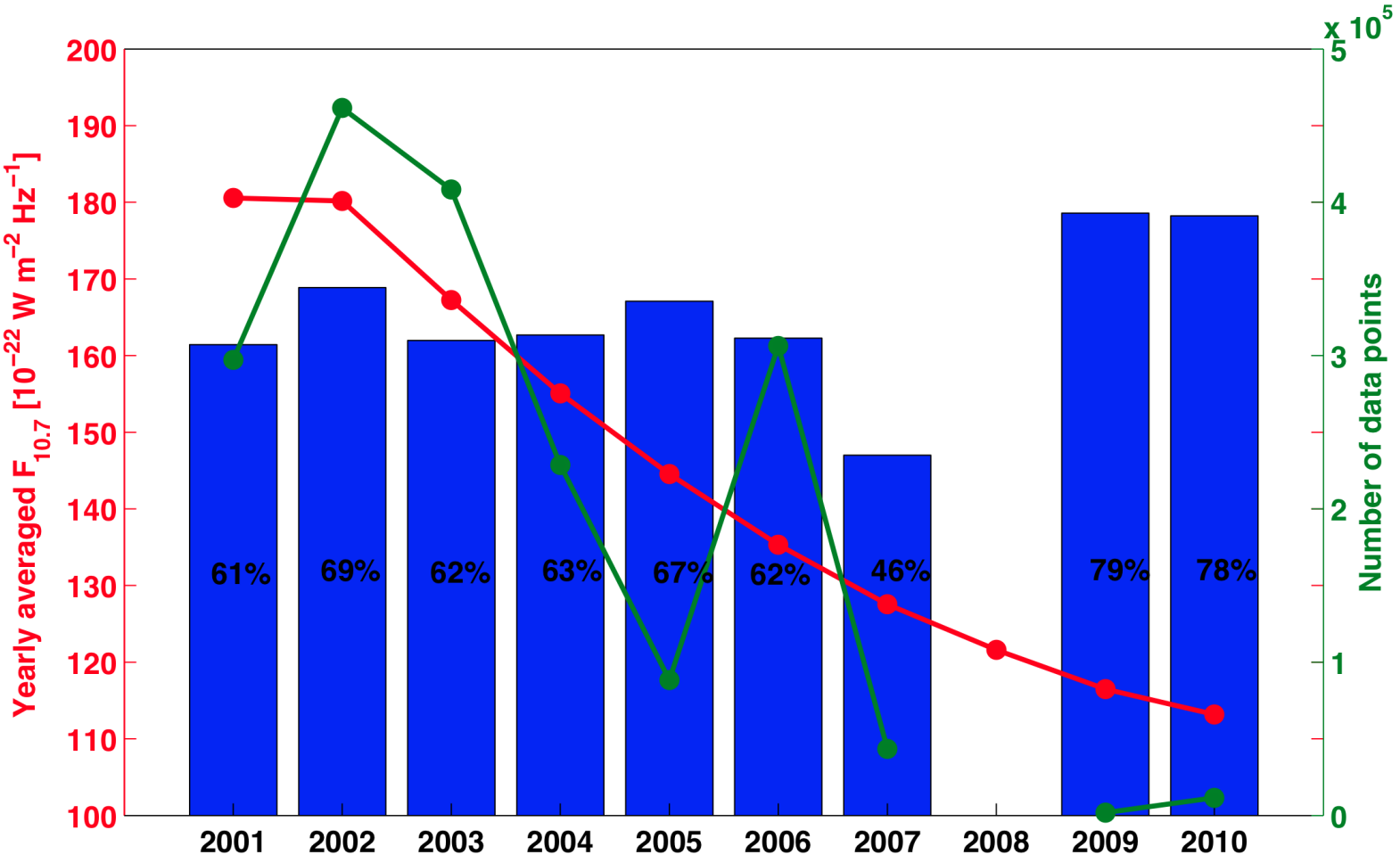
Kp < 3



Increased flux due to increased density

Factor 2. (Another factor 2 from polar cap expansion)

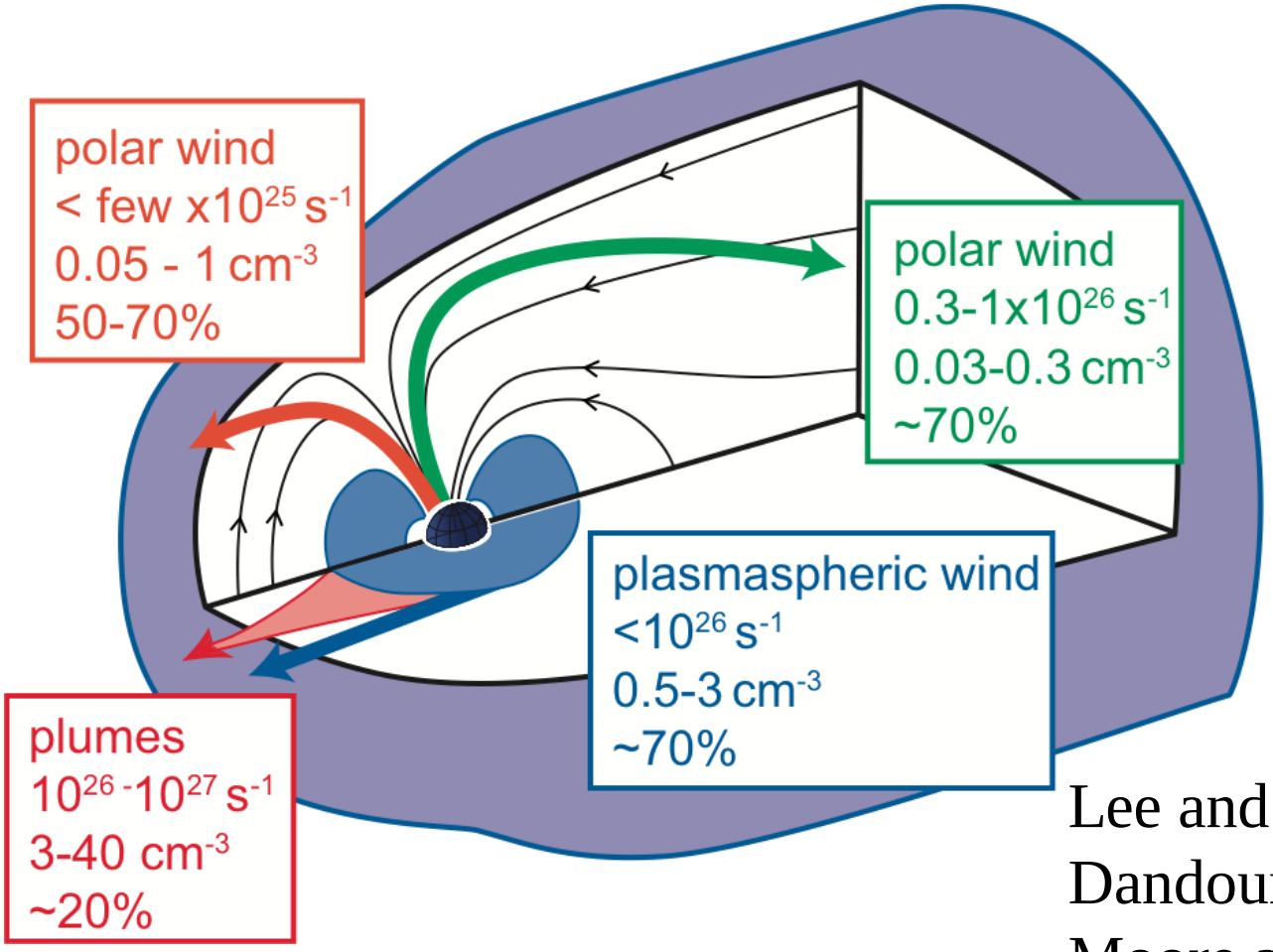
Solar variation III



Low-energy ions (wake) for all solar conditions (60-70%).

(1,680,000 data points)

Low-energy ions



André and Cully, GRL, 2012

Lee and Angelopoulos, 2014
Dandouras, 2013
Moore and Horwitz, 2007
Yau+, 2007
Peterson+ 2006

So what?

- **Total mass**
- **Alfvén velocity:** Wave propagation, reconnection rate
- **Microphysics:** New scale,

  between electrons and hot ions (Toledo-Redondo)
- **Cold (eV) and hot (keV) ions**:

  Regions and times (Nilsson; Li)

Conclusions

- Low-energy ions dominate the magnetotail lobes (60-70% of the time). And the outflow. For all solar EUV.
- Two Cluster SC agree.
- Outflow ≈ 10^{26} ions/s.
- Outflow increases with solar EUV (mainly density increase).