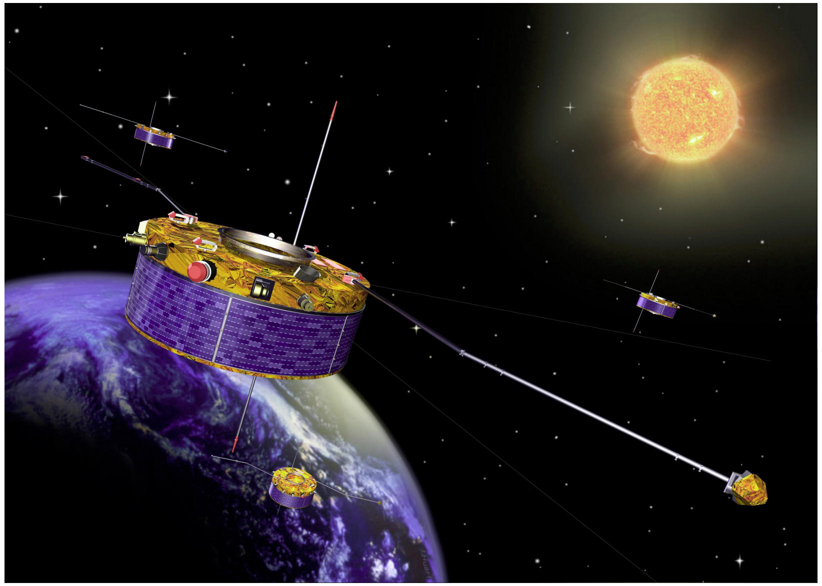

# Cold plasma: a previously hidden solar system particle population


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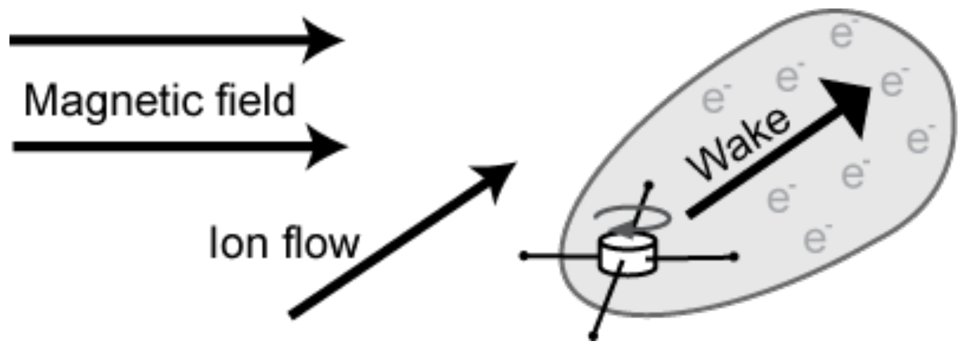
**The Cluster Science Team**

**The Cluster Active Archive**

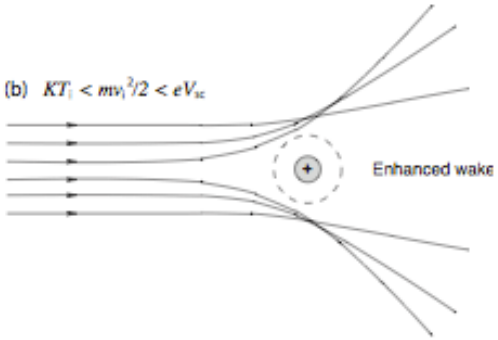

**André and Cully, GRL, 2012**

# Low-energy ions

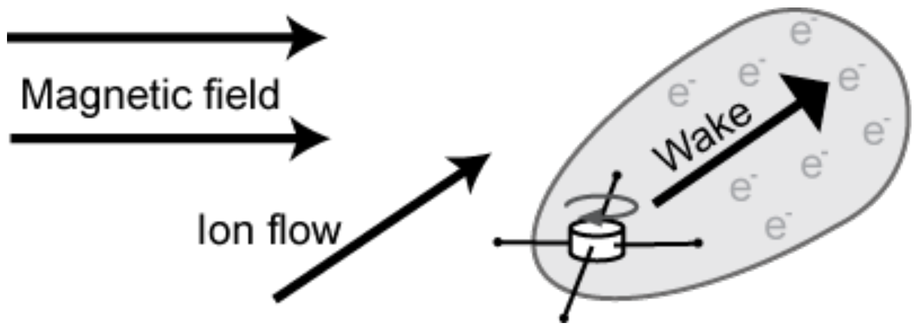
- **Low-energy: thermal energy, and drift energy, less than 10 eV (sometimes 100 eV).**
- **From the Terrestrial ionosphere, planets or moons.**
- **Low-energy *positive ions* hard to detect on *SC charged to a several Volts positive.***



# Cold flowing ions:
# Wake behind a charged SC



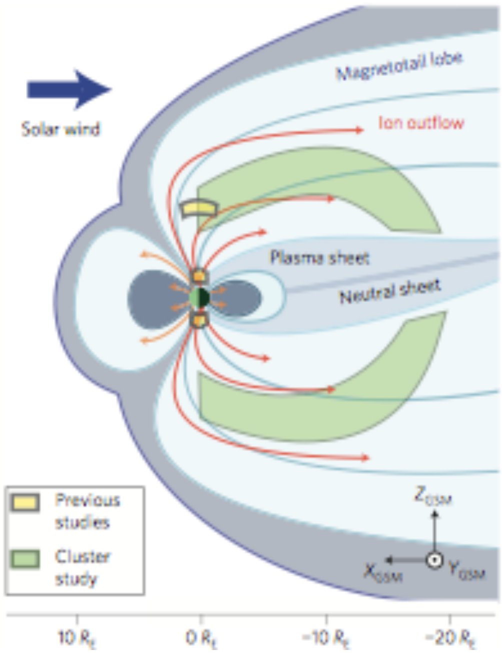

$KT < mv^2/2 < eV_{sc}$

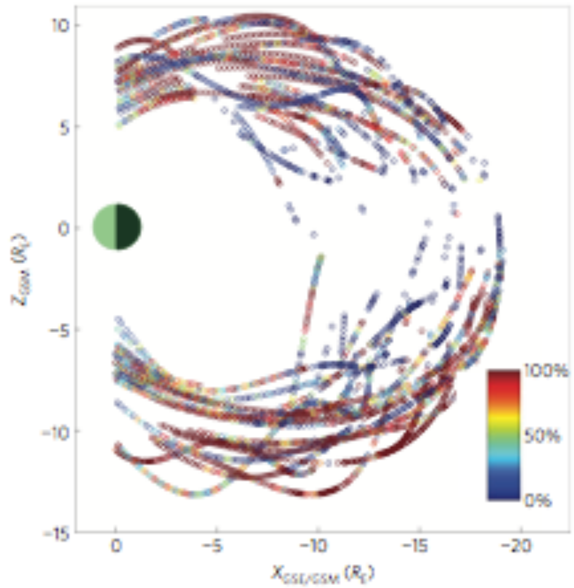



Cluster (Engwall et al., 2009)

Density from SC potential
(calibrated, Pedersen et al., 2008)

# Low-energy ions: Nightside



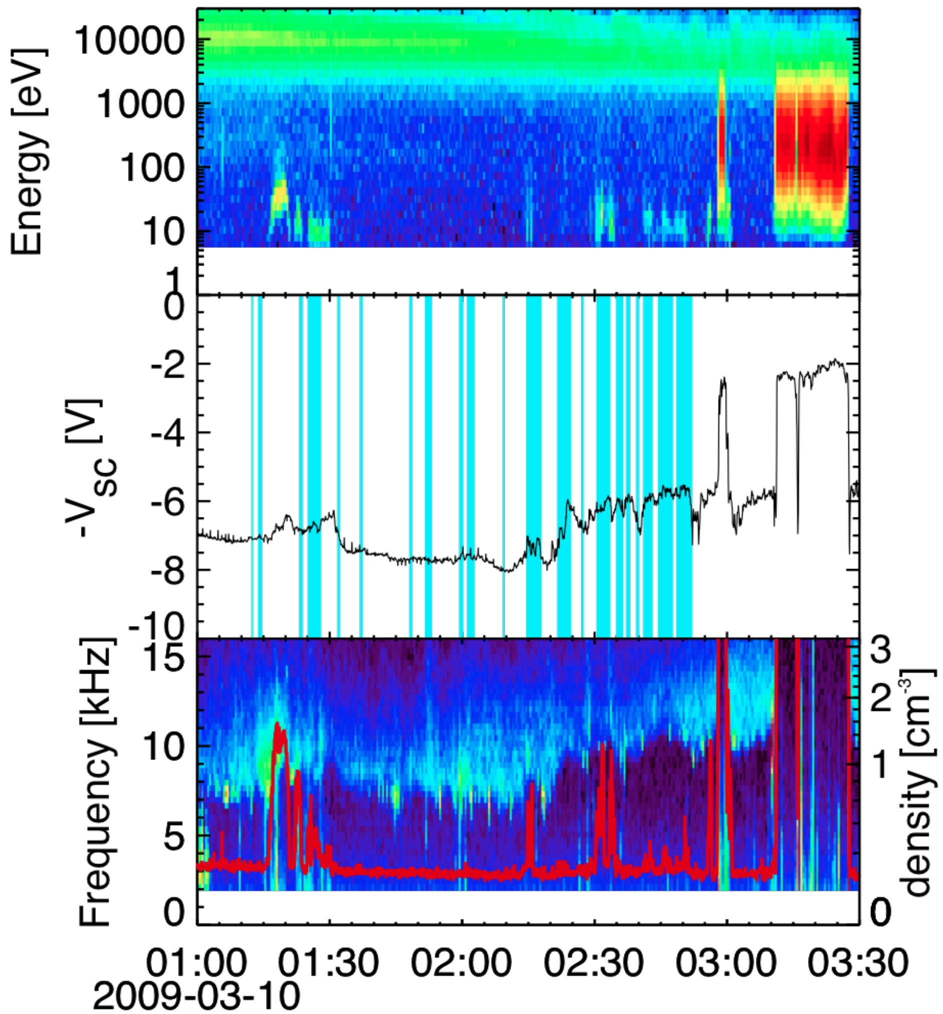

**Low-energy ions dominate 70% of the time**

**$H^+$ outflow about $10^{26}$ ions/s**

Cluster

(Engwall et al., 2009)

# Cluster at the Magnetopause

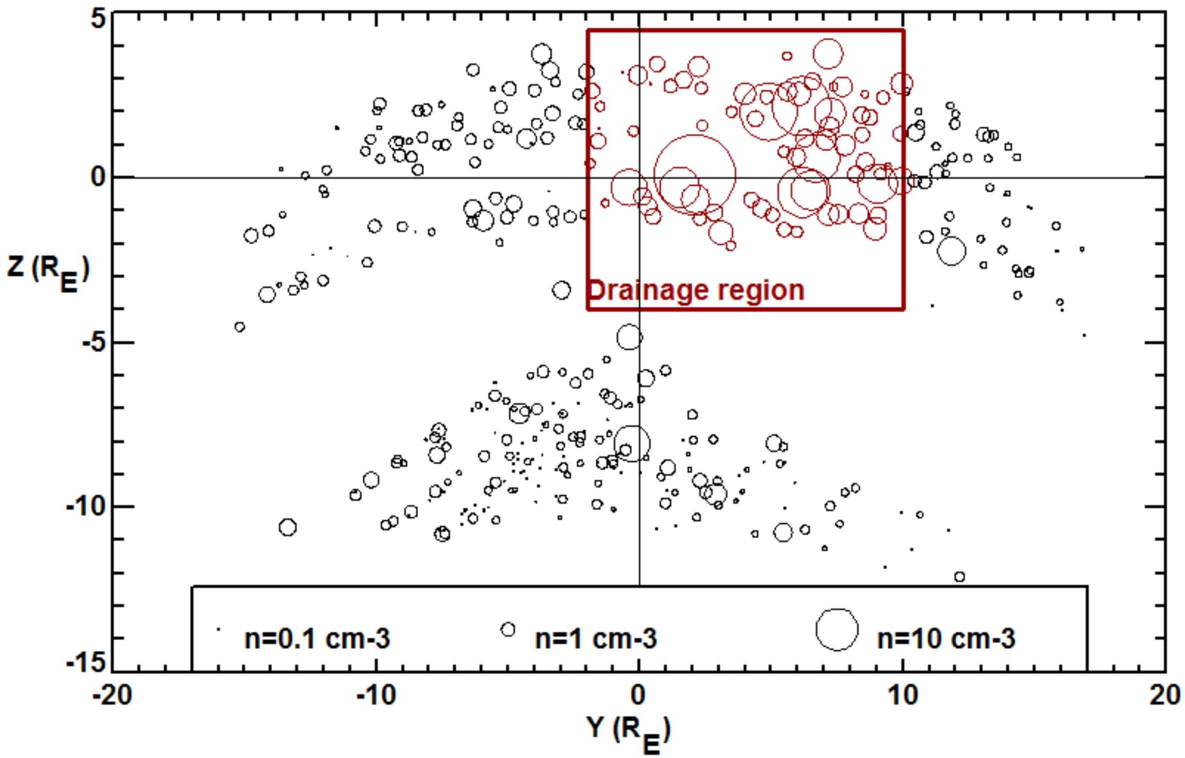



**Sporadically energized cold ions**

**Spacecraft wake from drifting cold ions**

**Difference total density ($f_{PL}$) vs. hot ions => cold ions**

# Magnetopause statistics I

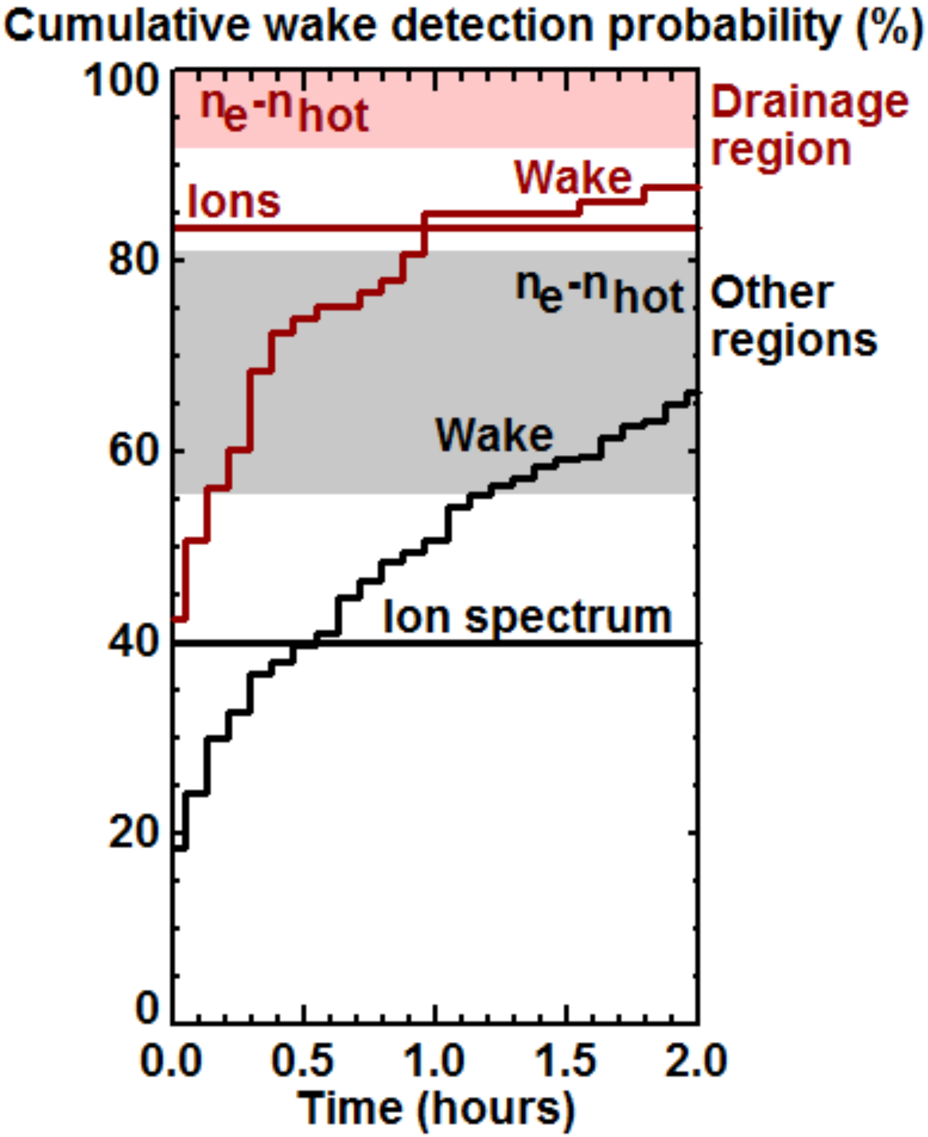



**Cluster 370 MP crossings 2006-2009**

***Drainage region:**
**0.5-40 $cm^{-3}$ (incl. plumes)**
***Other regions**
**0.05-1.0 $cm^{-3}$**

André et al., 2010
McFadden et al., 2008
Sauvaud et al., 2001

# Magnetopause statistics II

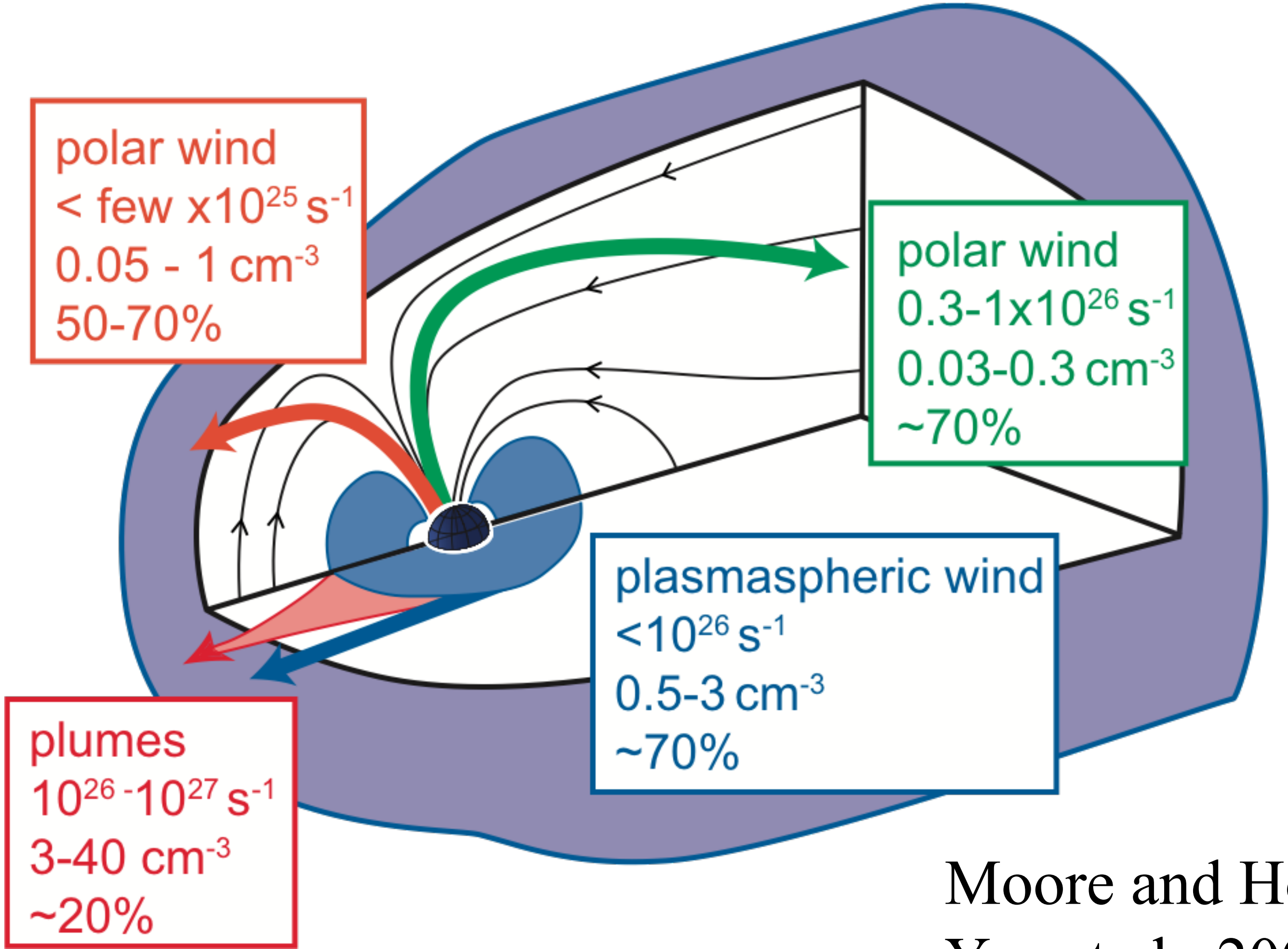



**Cold ions dominate (percent of time)**

***Drainage region: > 85%**
***Other regions: 50-70%**

Darrouzet et al., 2009
Borovsky and Denton, 2008
Chen and Moore, 2006
Matsui et al., 1999

# Low-energy ions: Summary




André and Cully, 2012

Moore and Horwitz, 2007
Yau et al., 2007
Peterson et al., 2006
Cully et al., 2003

# Ion Outflow: Dayside

Cross-polar cap potential; 60 kV

Cusp to cusp: 20 $R_E$

Magnetospheric B: 30 nT

Outside drainage region (2/3):

0.25 $cm^{-3}$ => **4x$10^{25}$ ions/s** 2x (Cully et al., 2003)

Inside drainage region (1/3):

No plume, 1 $cm^{-3}$ => **8x$10^{25}$ ions/s** 2x (Matsui et al., 1999)

Plume, up to 40 $cm^{-3}$ => **> $10^{27}$ ions/s** (Borovsky and Denton, 2008)

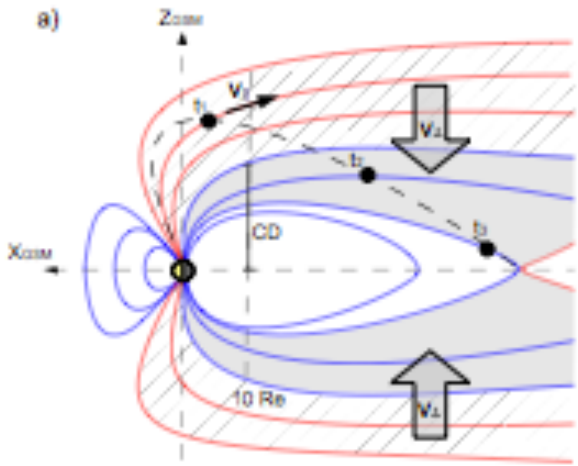
# Ion Outflow: Nightside

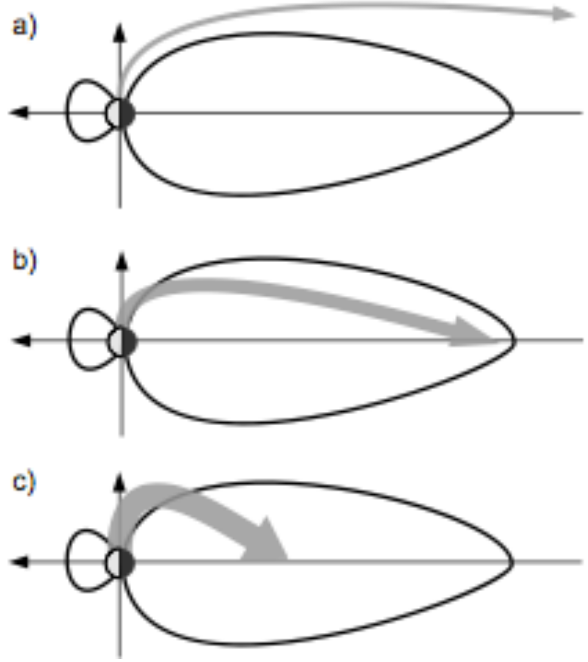
Outflow at 10-20 $R_E$: 0.3-1x$10^{26}$ ions/s

Escape: depends on v-perp, tail reconncetion (IMF $B_z$)

Positive Bz: most of outflow

Negative Bz: nothing direct, most indirect (plasmoid)?




Haaland et al., in preparation

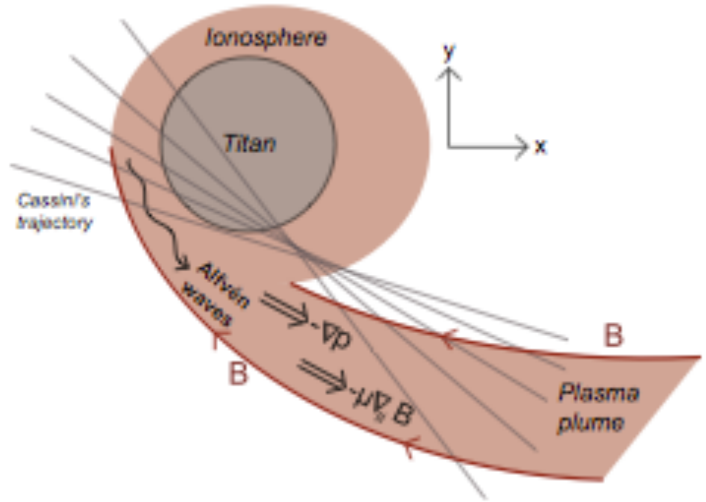
# Low-energy ions: Mars, Venus, Titan

**Mars**
Phobos-2 (Nairn et al., 1991)
MEX (Lundin et al., 2009; Nilsson et al., 2011)
MEX MARSIS radar (Dubinin et al., 2008)

**Venus(?)**
Pioneer Venus (Brace et al., 1987)
VEX (Barabash et al, 2007; Fedorov et al., 2011)

**Titan**
Cassini (Edberg et al., 2011)

**Total outflow, all** ≈$10^{25}$ ions/s

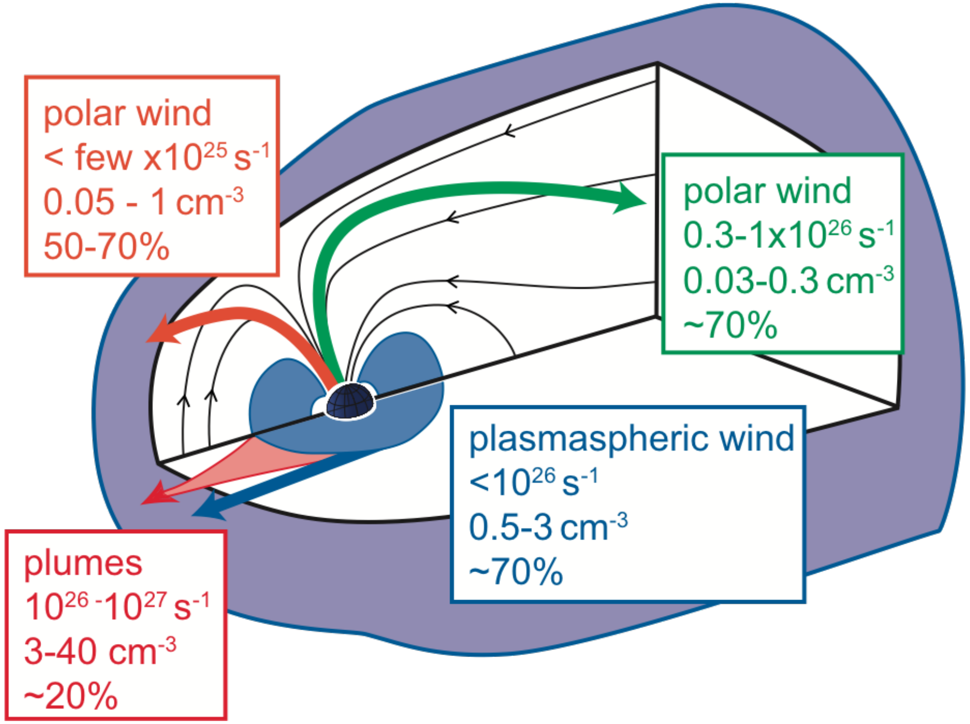



Cassini Langmuir probe
Edberg et al., 2011

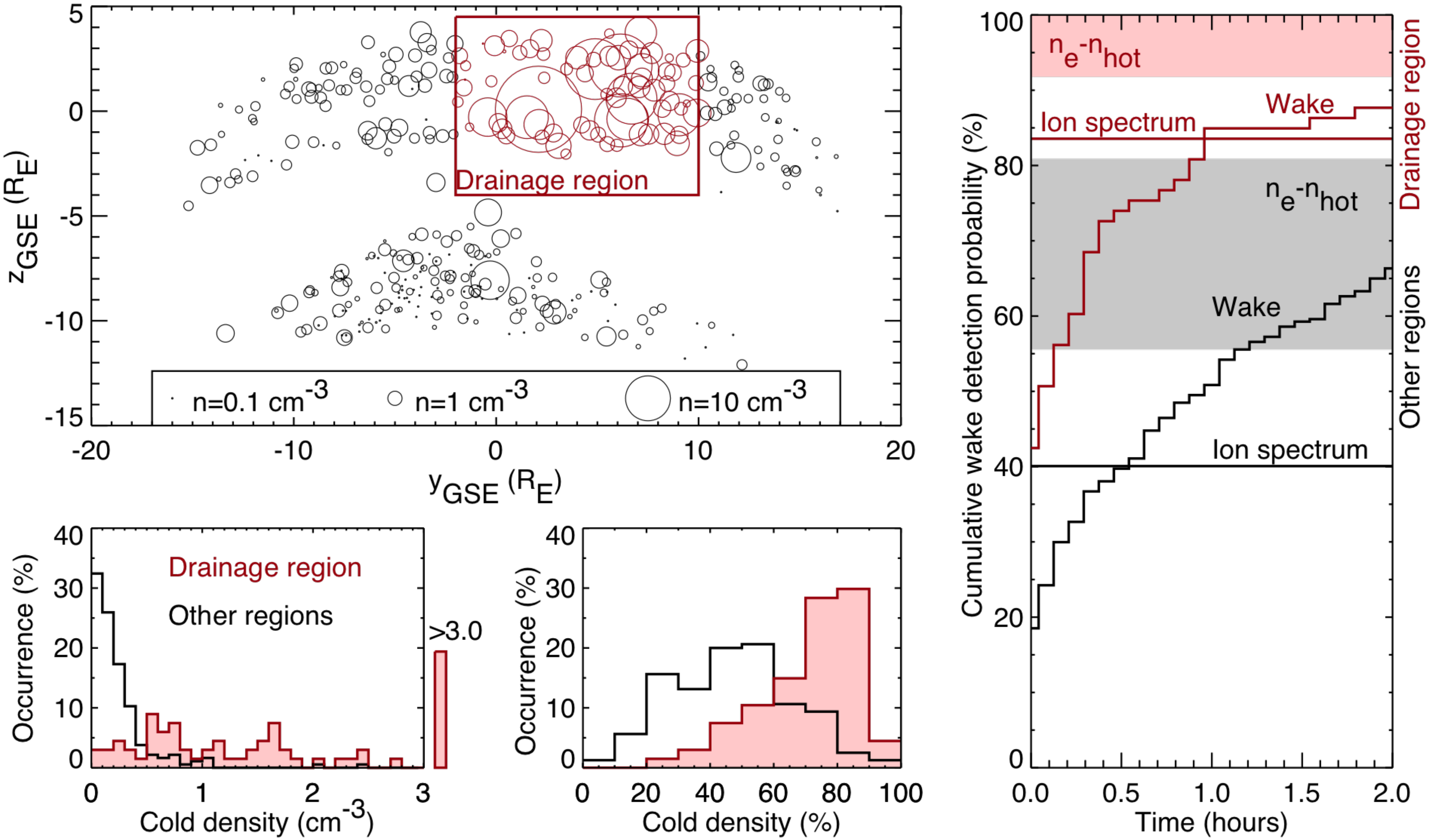
# Conclusions: low-energy ions

- Often dominating in large volumes: > 50% of time
- Important for energy transport (Alfvén velocity)
- Important for energy conversion (reconnection)
- Important for total outflow/escape

✓**Always stay tuned to find low-energy ions when anywhere near a planet, moon or comet!**



# Extra slide



Drainage region
n=0.1 cm-3
n=1 cm-3
n=10 cm-3
zGSE (RE)
yGSE (RE)
Drainage region
Other regions
>3.0
Occurrence (%)
Cold density (cm-3)
Occurrence (%)
Cold density (%)
ne-nhot
Wake
Ion spectrum
ne-nhot
Wake
Ion spectrum
Cumulative wake detection probability (%)
Drainage region
Other regions
Time (hours)