Incoherent Scatter Radar versus In-Situ Measurements

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Acknowlegement:
Johnathan Burchill
Bill Archer

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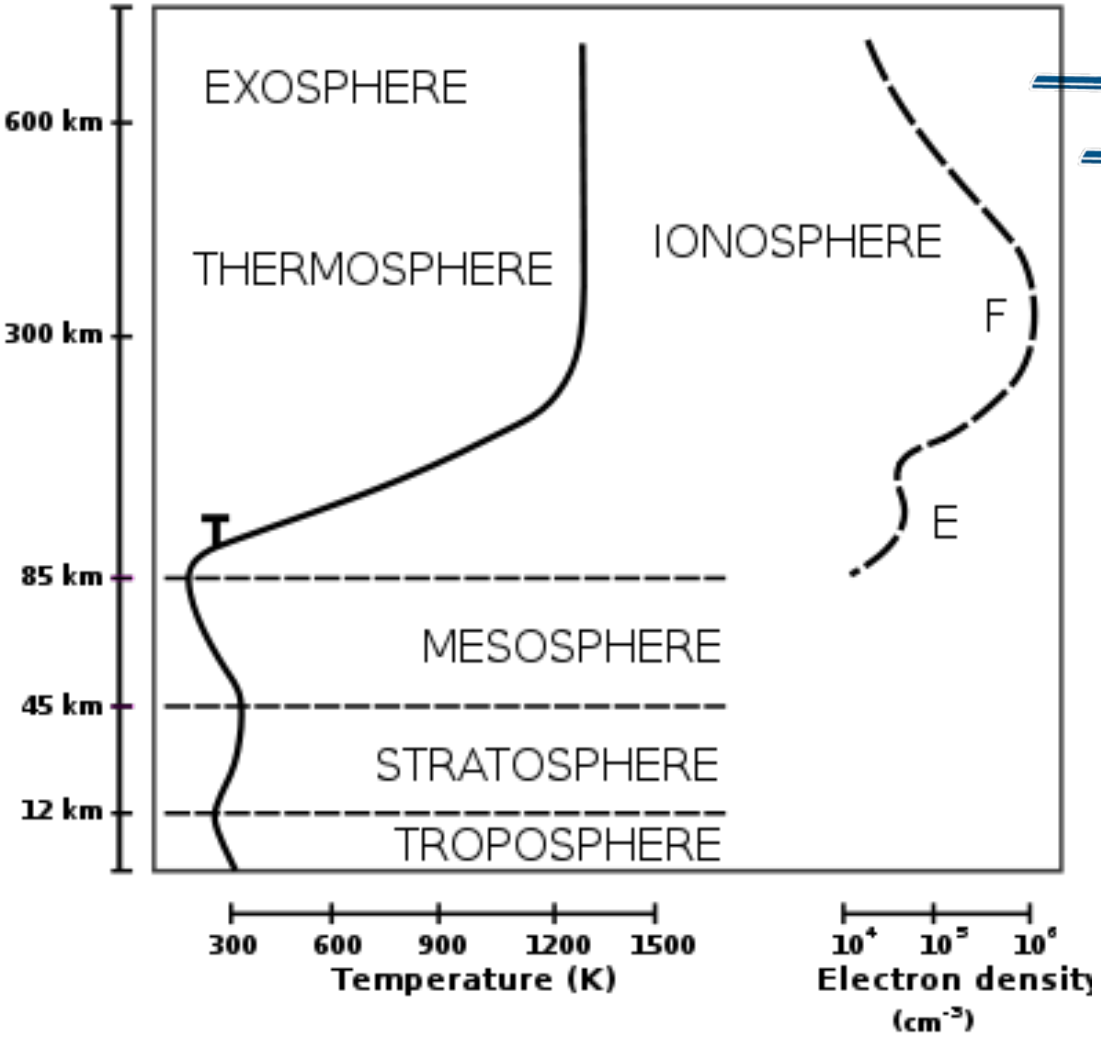
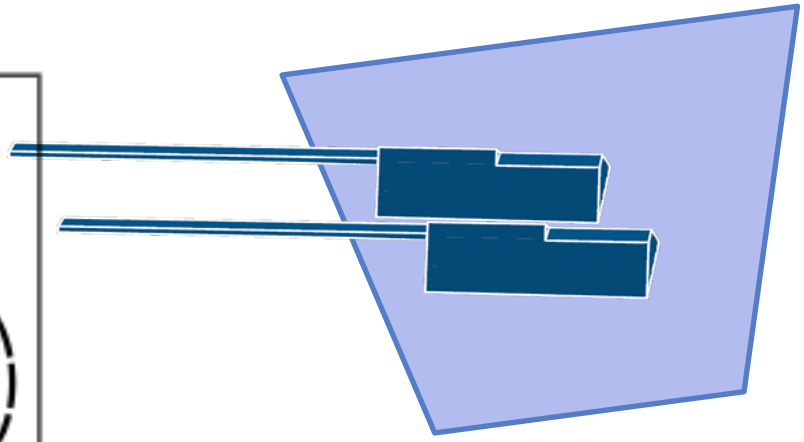
Natural Resources Canada
www.nrcan.gc.ca

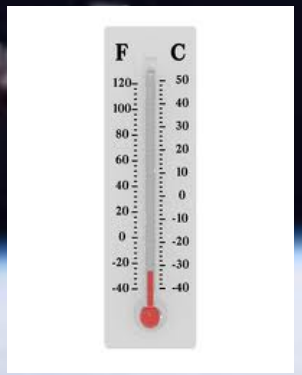
esa

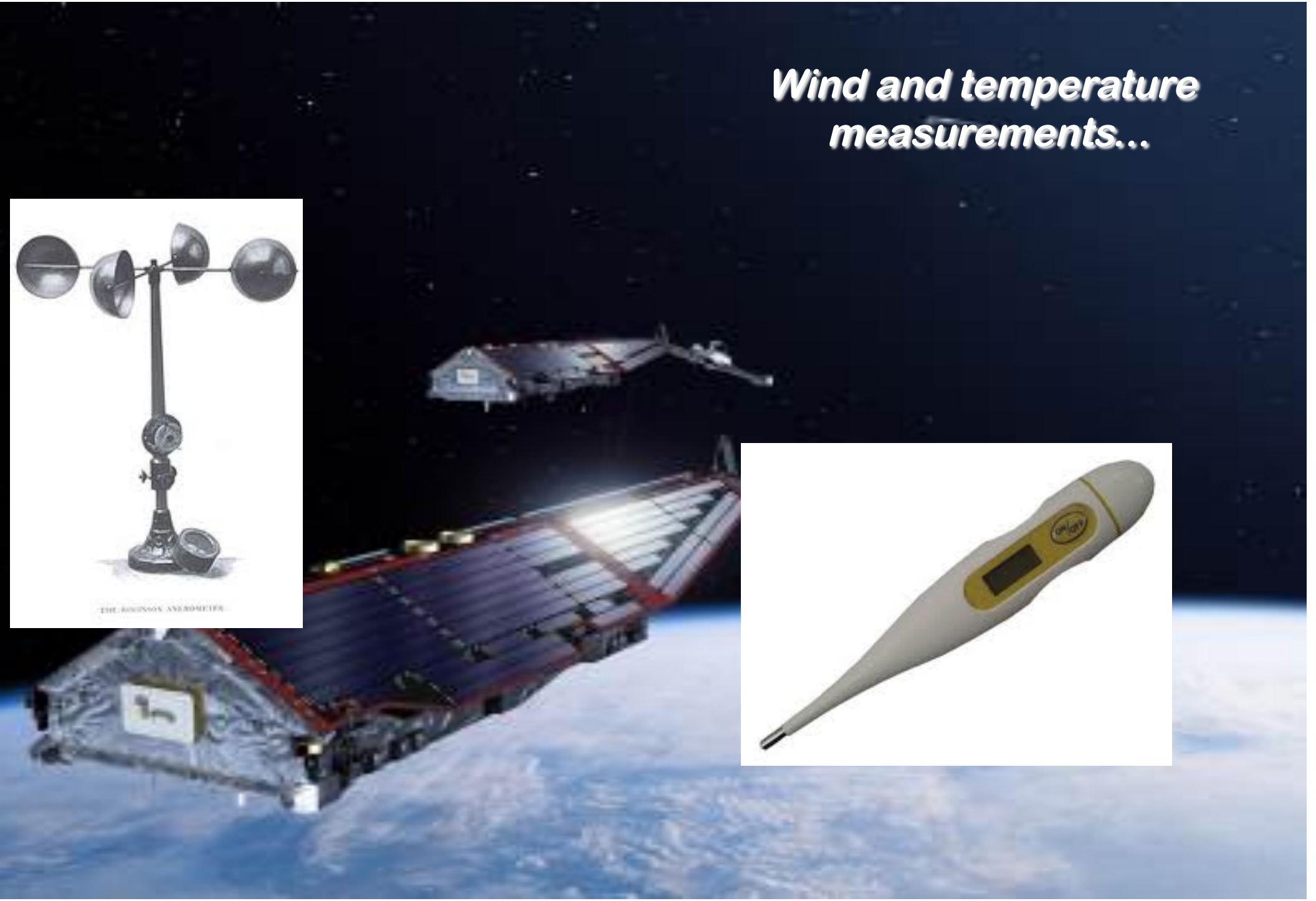




Why bother with ground-based remote sensing in the space age?

Wind and temperature measurements…




Wind and temperature measurements…

In-situ versus ISR: Pros and cons

	ISR	Satellite
1. Spatial resolution	1-10 km	< 1 km (or meters for E-fields)
2. Spatial coverage	100's by 100's km, but fixed	global, but 1-D
3. Time resolution	10's-100's seconds	<10 ms – 1 s
4. Steerability	Yes	No
5. Dwell time	Indefinite	none

In-situ versus ISR: Pros and cons

	ISR	Satellite
5. Basic parameters	n_e, v_i, T_i, T_e	n_e, v_i, T_i, T_e
6. Ion composition	derived or assumed	direct*
7. Electric fields	derived from v_i x B	direct or derived from v_i x B
8. Magnetic fields	N/A	✔
9. Electric currents	Σqnv	Σqnv or curl x B
10. Cost per year	several M$	50+ M$

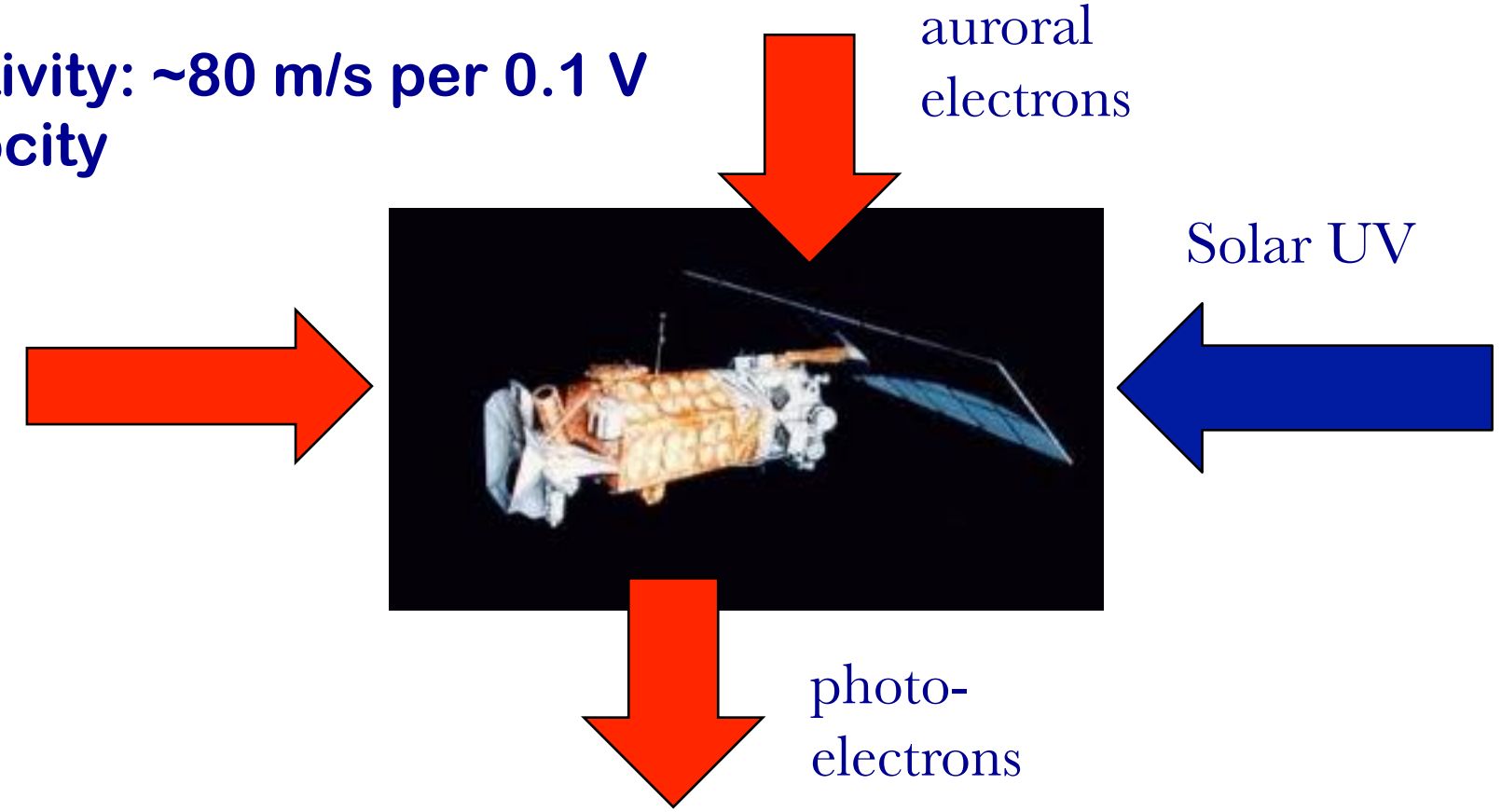
In-situ versus ISR: Pros and cons

	ISR	Satellite
11. Errors	Noisy but with low bias (e.g.: Doppler vel., plasma line-derived density)	Susceptible to large systematic errors

Major error sources:

1) Uncertain spacecraft floating potential

Error sensitivity: ~80 m/s per 0.1 V for ram velocity



Major error sources:

2) Space attitude uncertainty

Sensitivity: 130 m/s per degree for cross-track velocity.

3) Ion composition uncertainty (e.g. N+ vs. O+)

Error sensitivity: ~250m/s per a.m.u. (ram component)

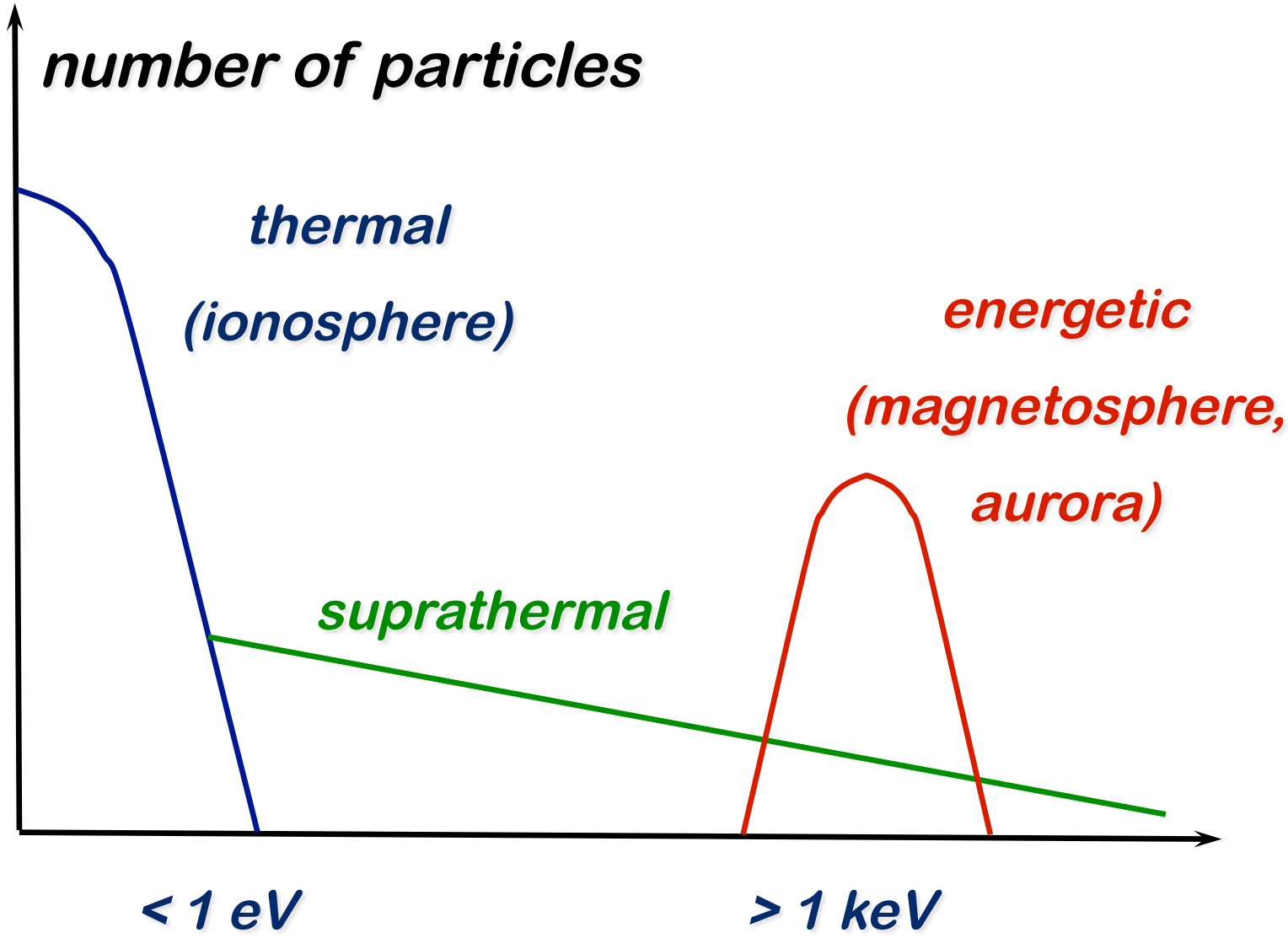
4) Spacecraft sheaths and wakes

5) and many others…

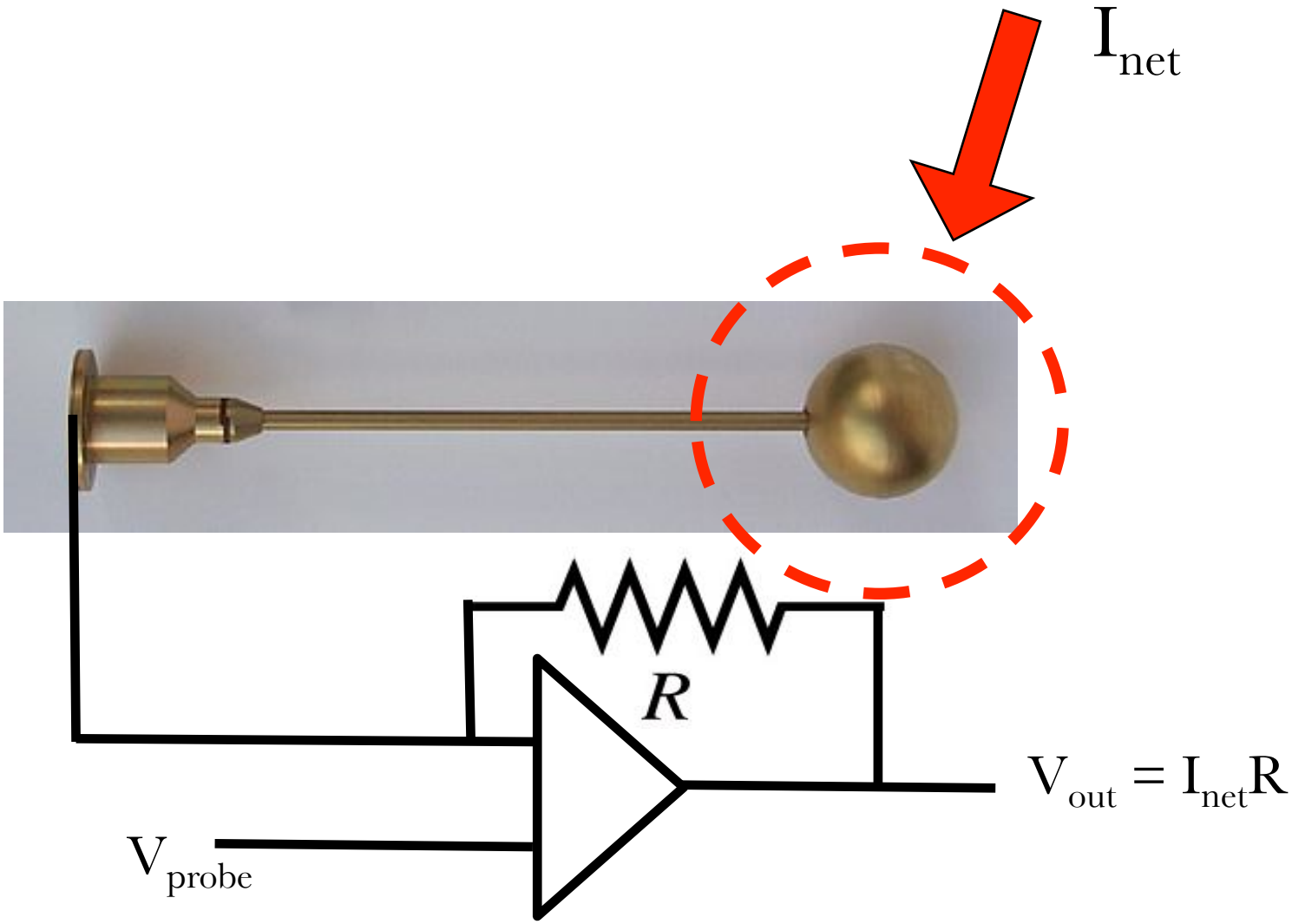
In-situ Techniques for ionospheric plasma

- **Langmuir probe**
- **Ion drift meter (IDM) and retarding potential analyzer (RPA):**
  ➔ used on DE 1&2DMSP, ROCSAT, C/NOFS, others
- **Thermal ion imaging** 

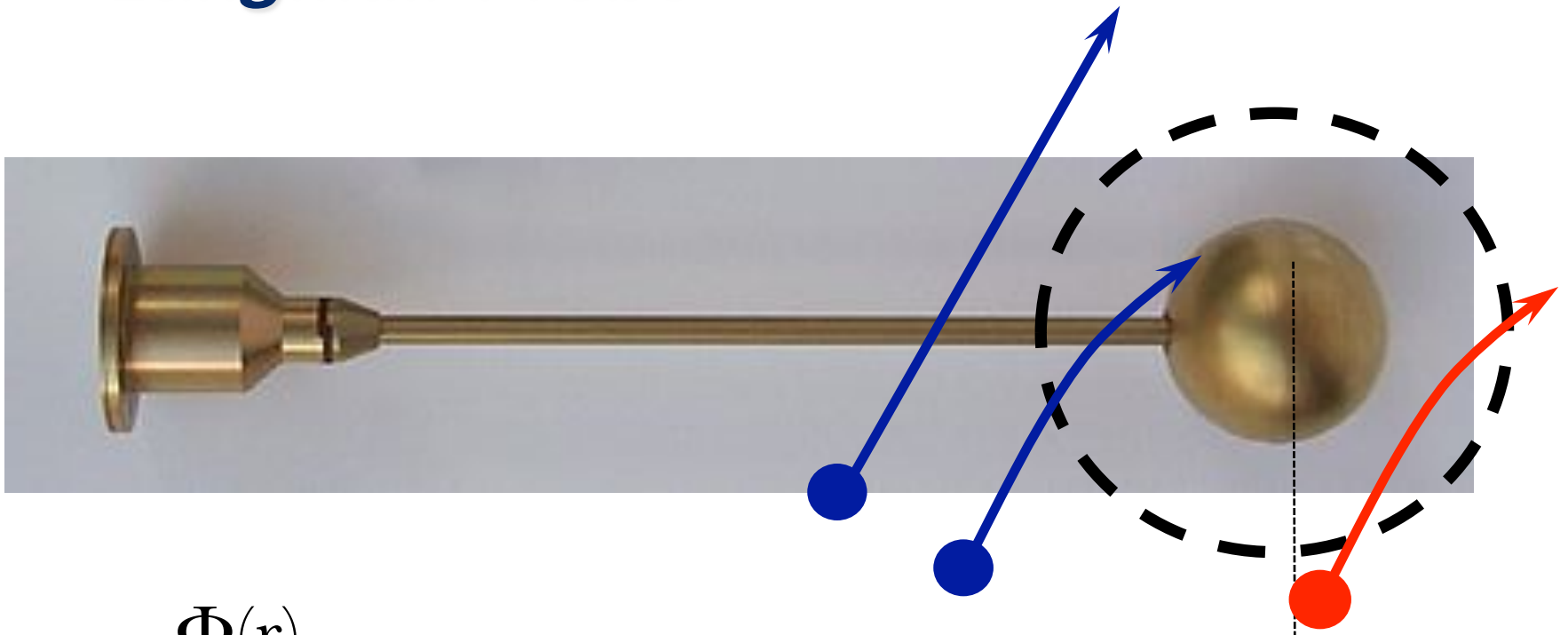
Charged particle populations in near-earth space

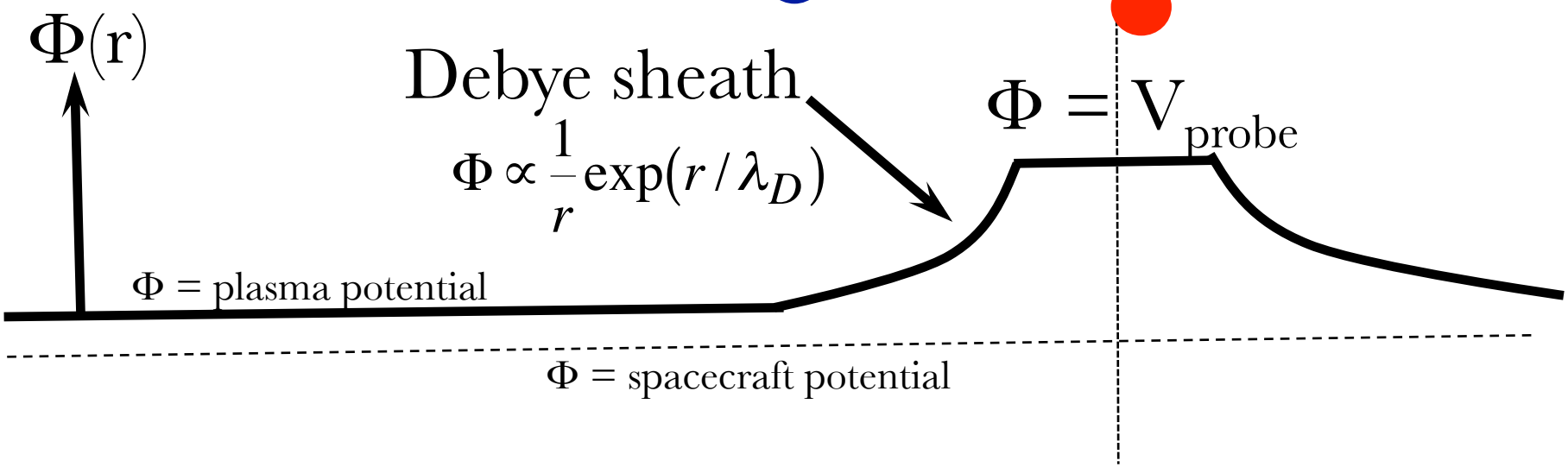


Langmuir Probe



Langmuir Probe





Langmuir Probe Current

$$I \propto \sum_{j} N_j \iiint_{A,E,\Omega} E^2 \hat{n} \cdot \hat{\Omega} f_j(E) dA dE d\vec{\Omega}$$

density of species "j"

"capture" surface

surface normal

distribution function *f*, species "j"

energy *E*

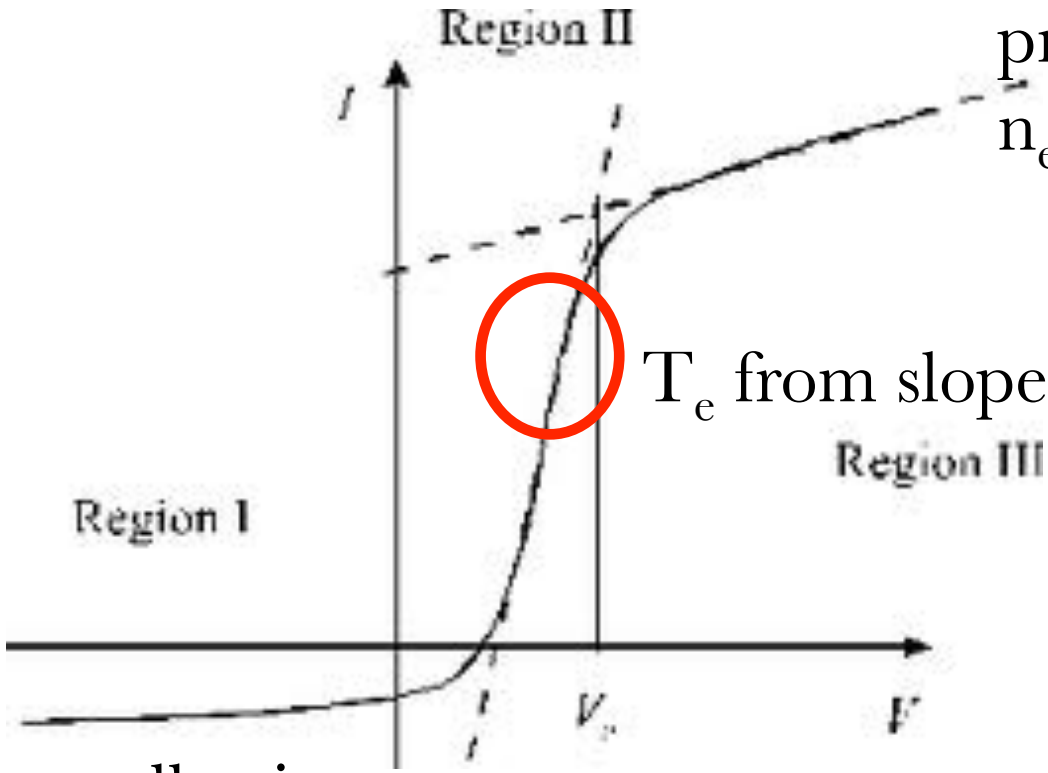
solid angle

➔ Integrate over all accessible energies and trajectories...

Langmuir I-V curve

chm.bris.ac.uk

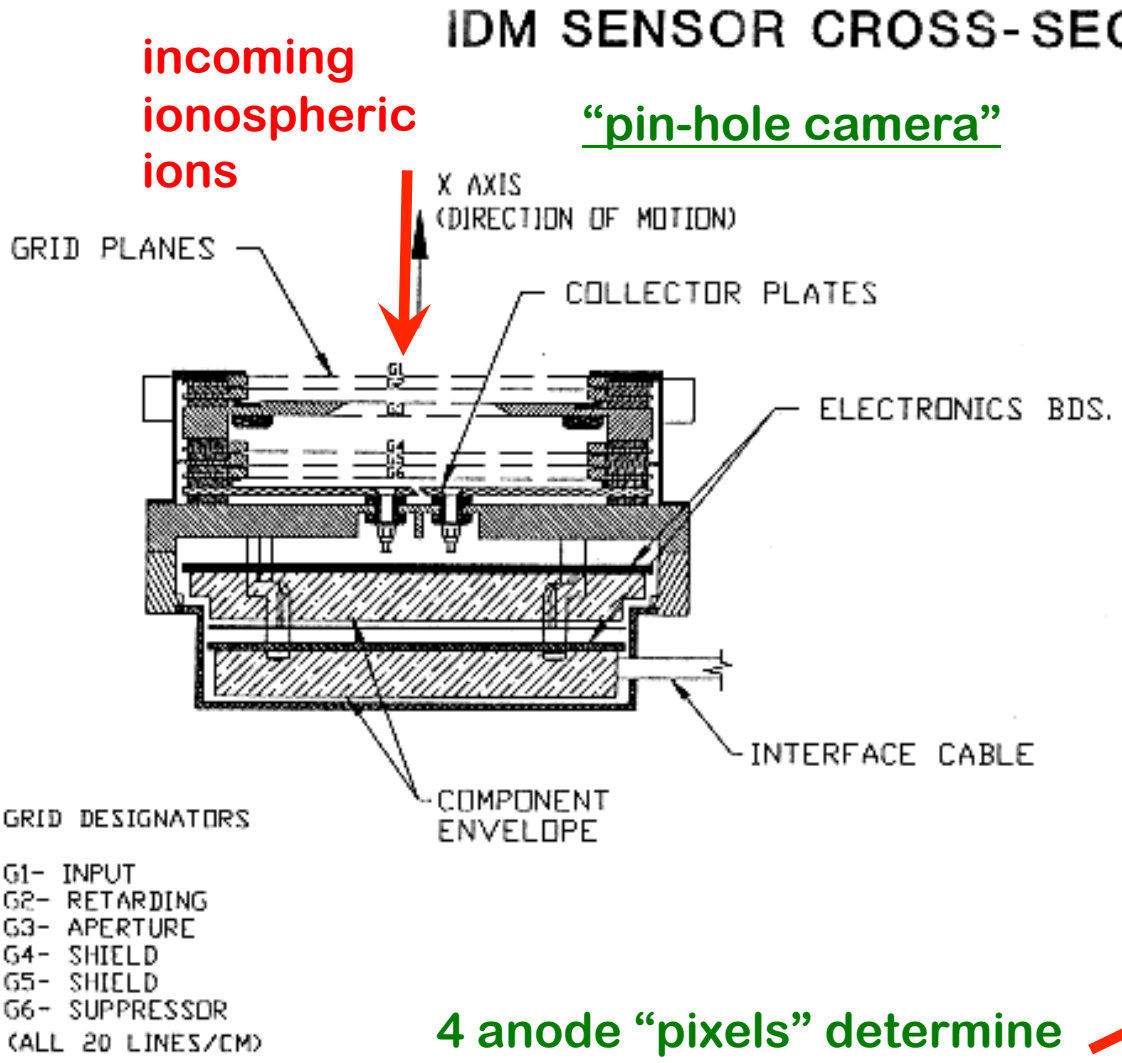
electron collection proportional to $n_e v_{e,th}$

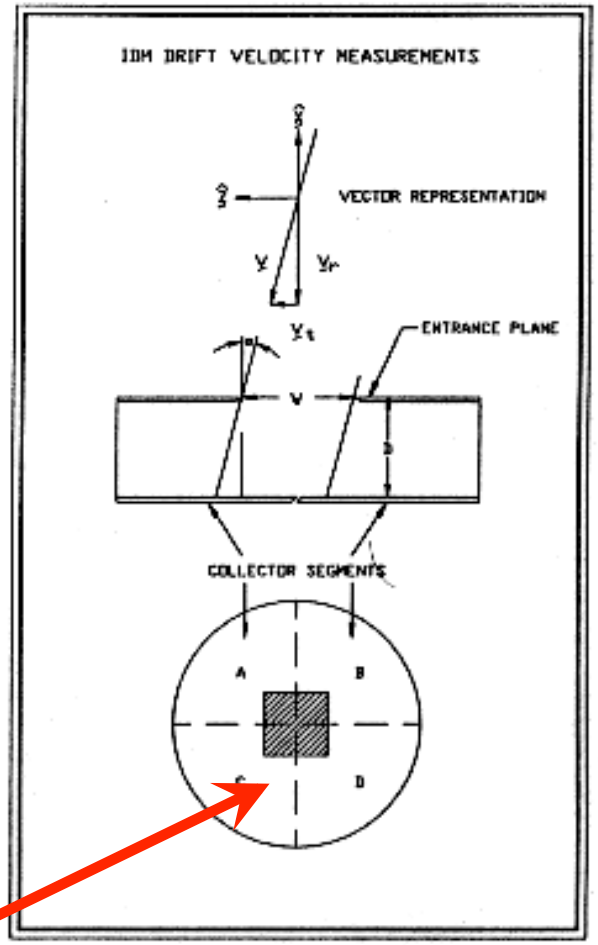


T_e from slope

ion collection prop. to n_i

State of the art, 1960's to 1990's

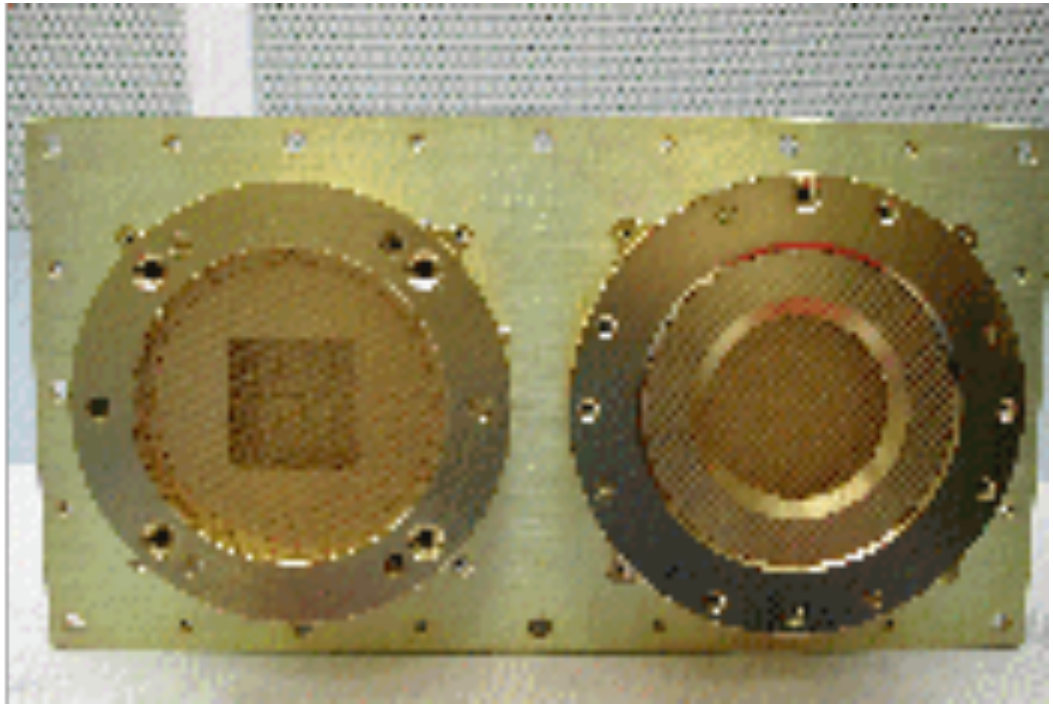




4 anode "pixels" determine arrival angle of incoming ions

W. Hanson, R. Heelis, Univ. Texas at Dallas

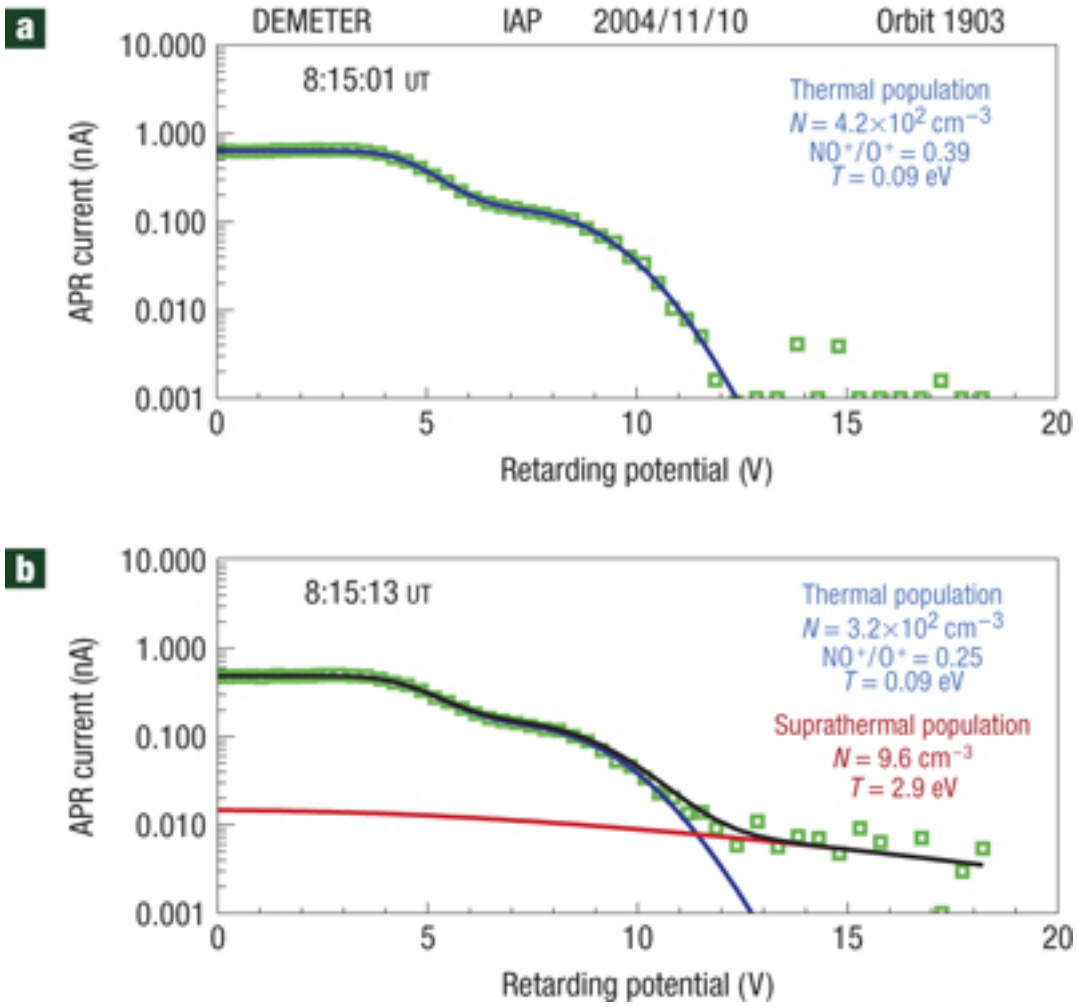
Retarding potential analyzer



Vary screen potential to measure energy to stop rammed ions.

$$q[V_{\text{screen}} + V_{\text{spacecraft}} = (m_i/2)[v_{\text{spacecraft}} + v_{\text{wind, ram}}]^2$$

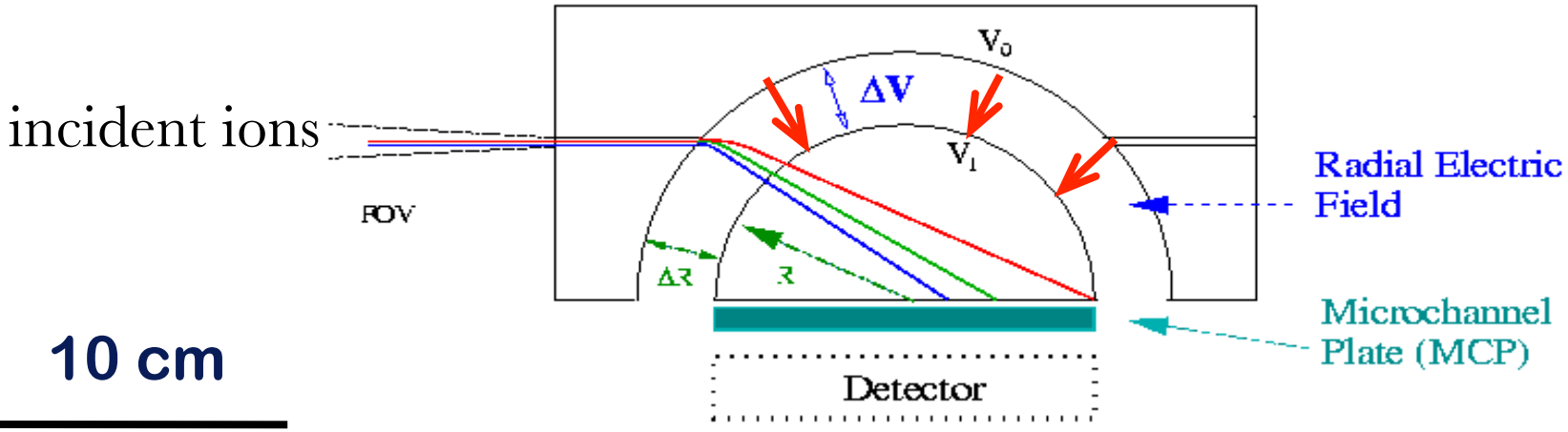
RPA example



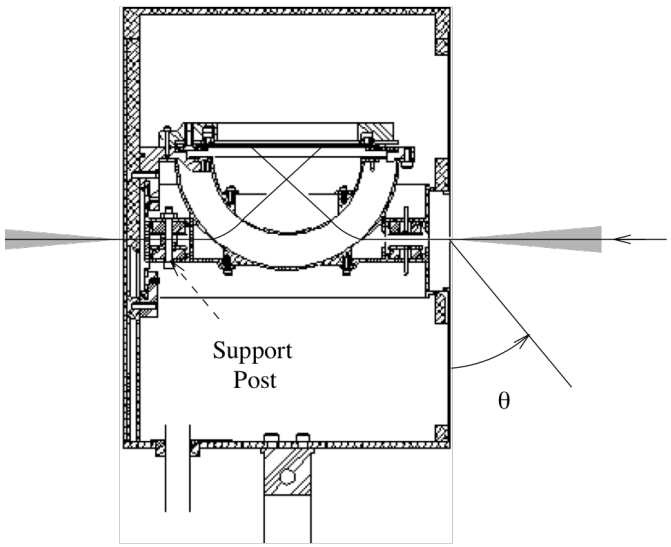
Disadvantage: Sweep time (~1 s) limits resolution

Berthelier et al., Nature Geoscience, 2008

Distribution Function Imaging

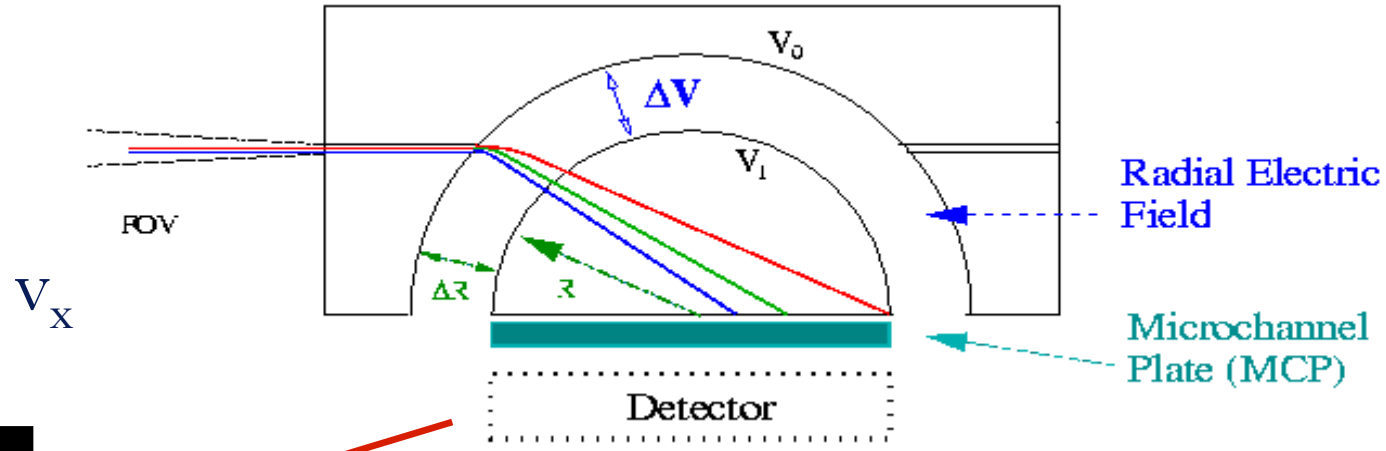


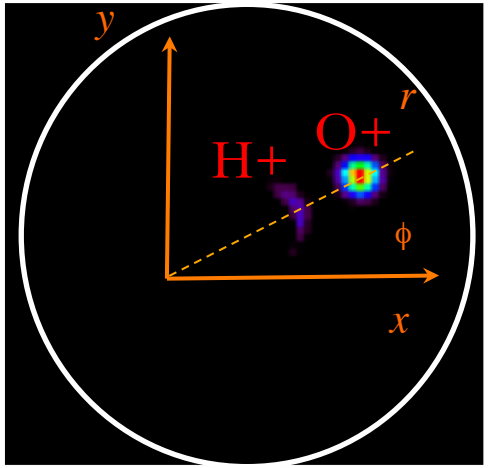
10 cm



Whalen et al, Sp. Sci. Rev., 1994

Ion Distribution Imaging

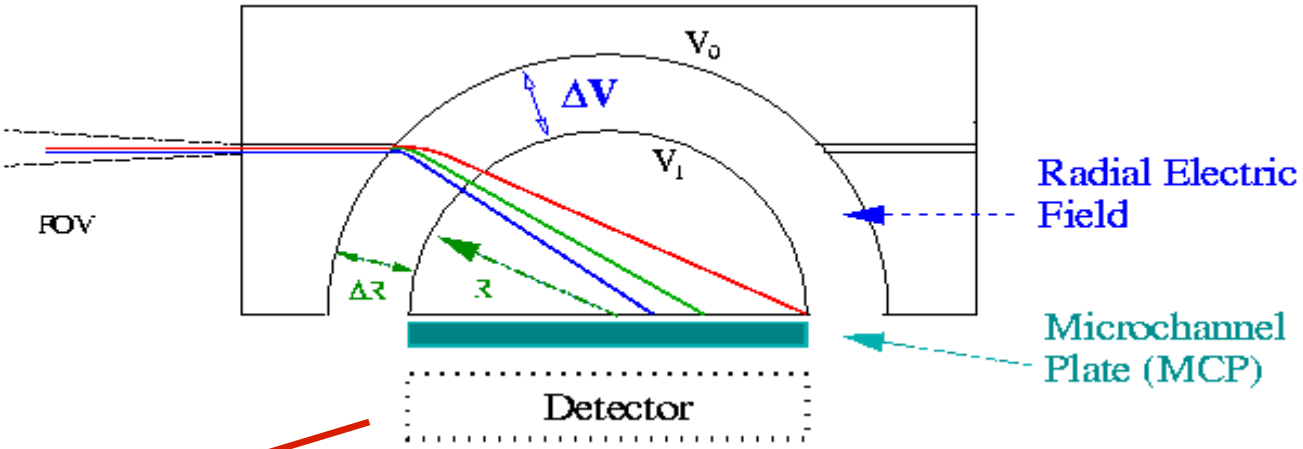


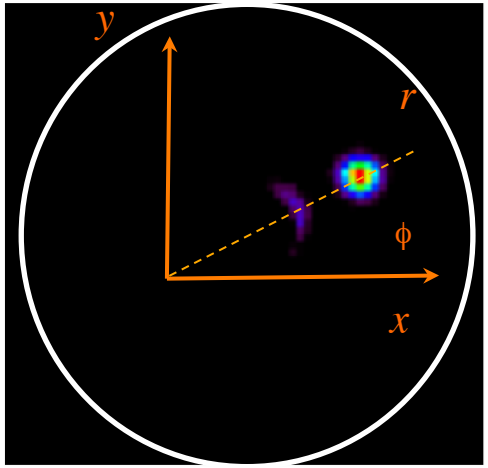


(simulation)

Whalen et al, Sp. Sci. Rev., 1994

Ion Distribution Imaging

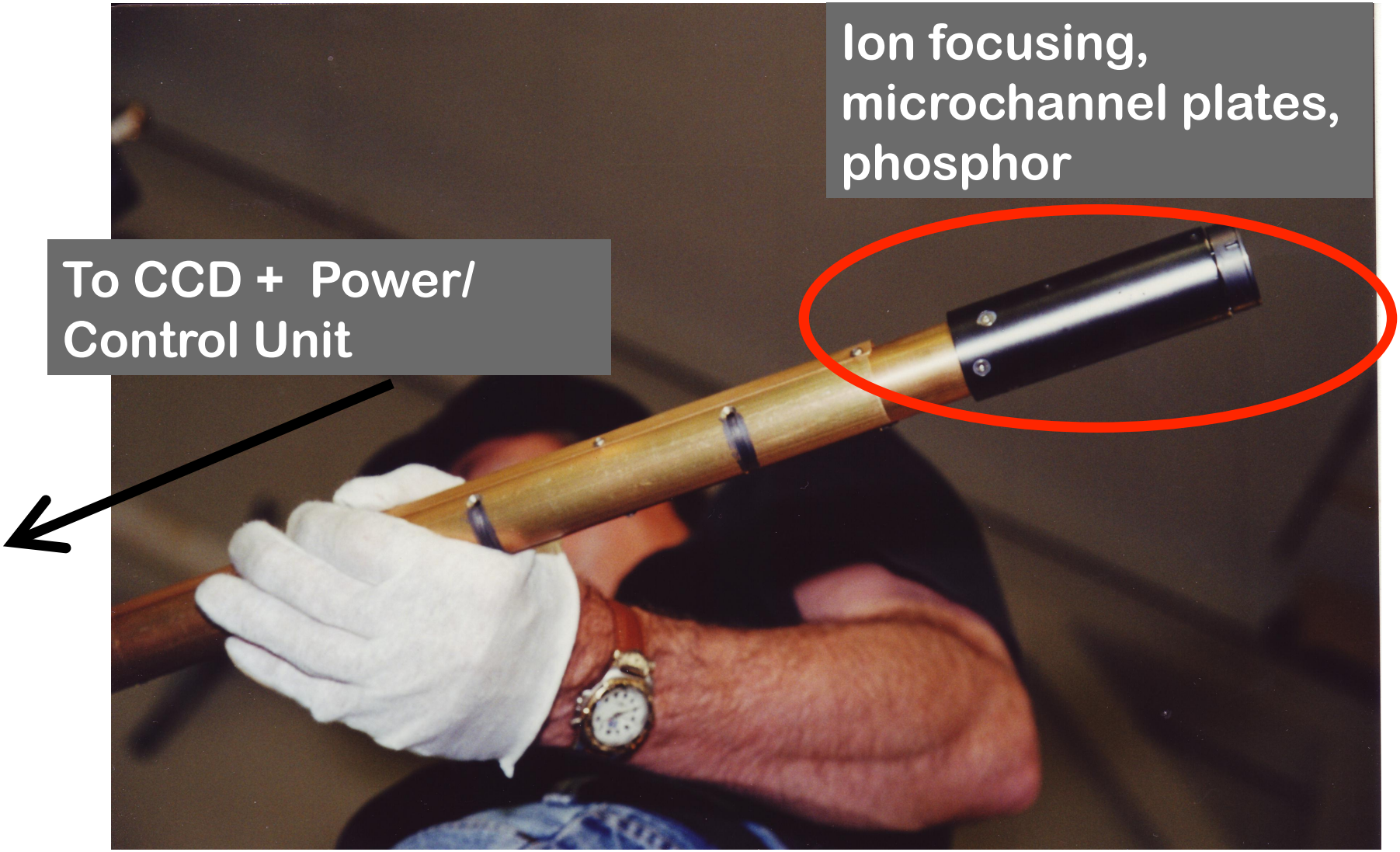




(simulation)

- velocity (2-D)
  - E = -vxB
- temperature
- anisotropies

The GEODESIC Suprathermal Ion Imager (2000)



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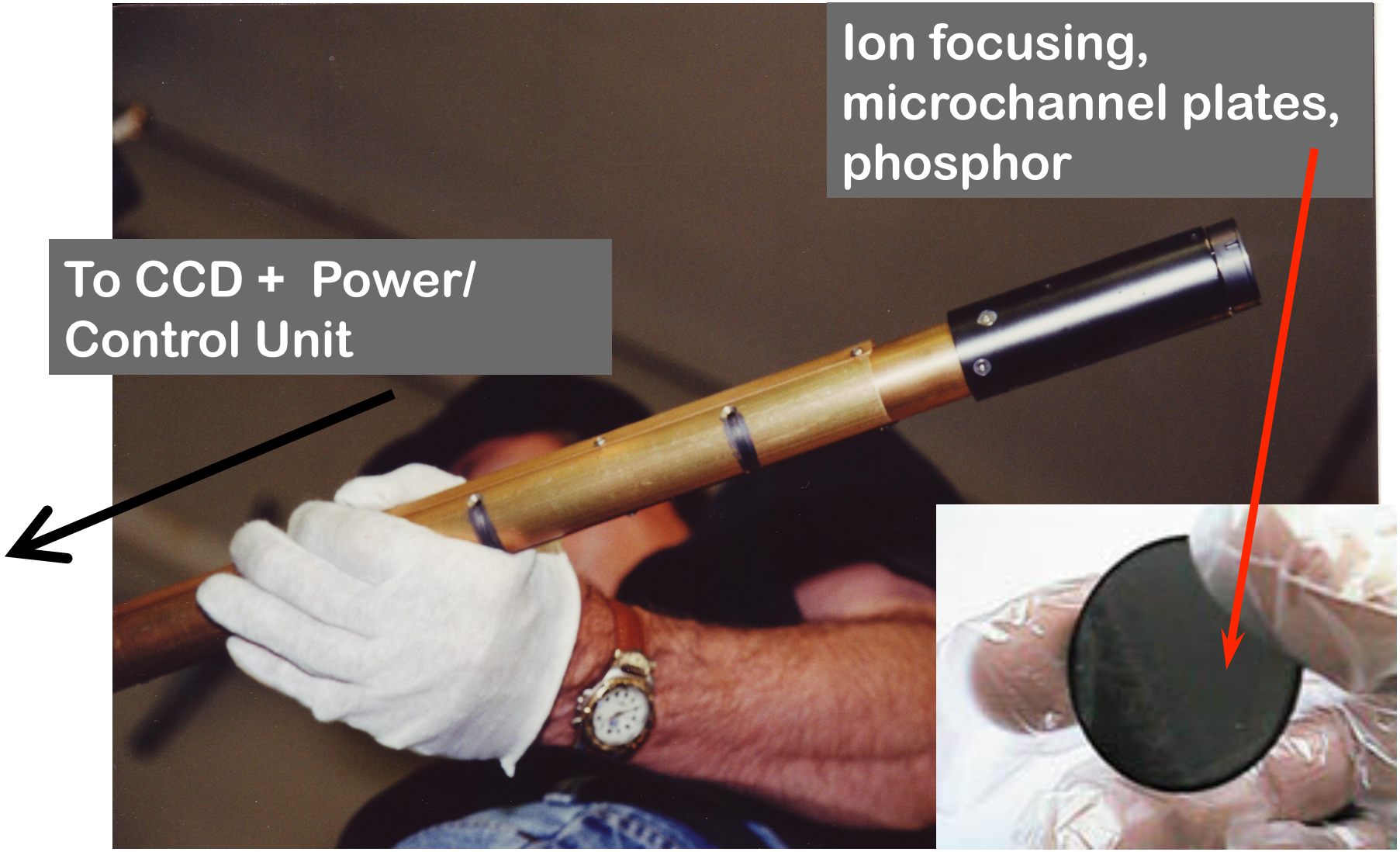
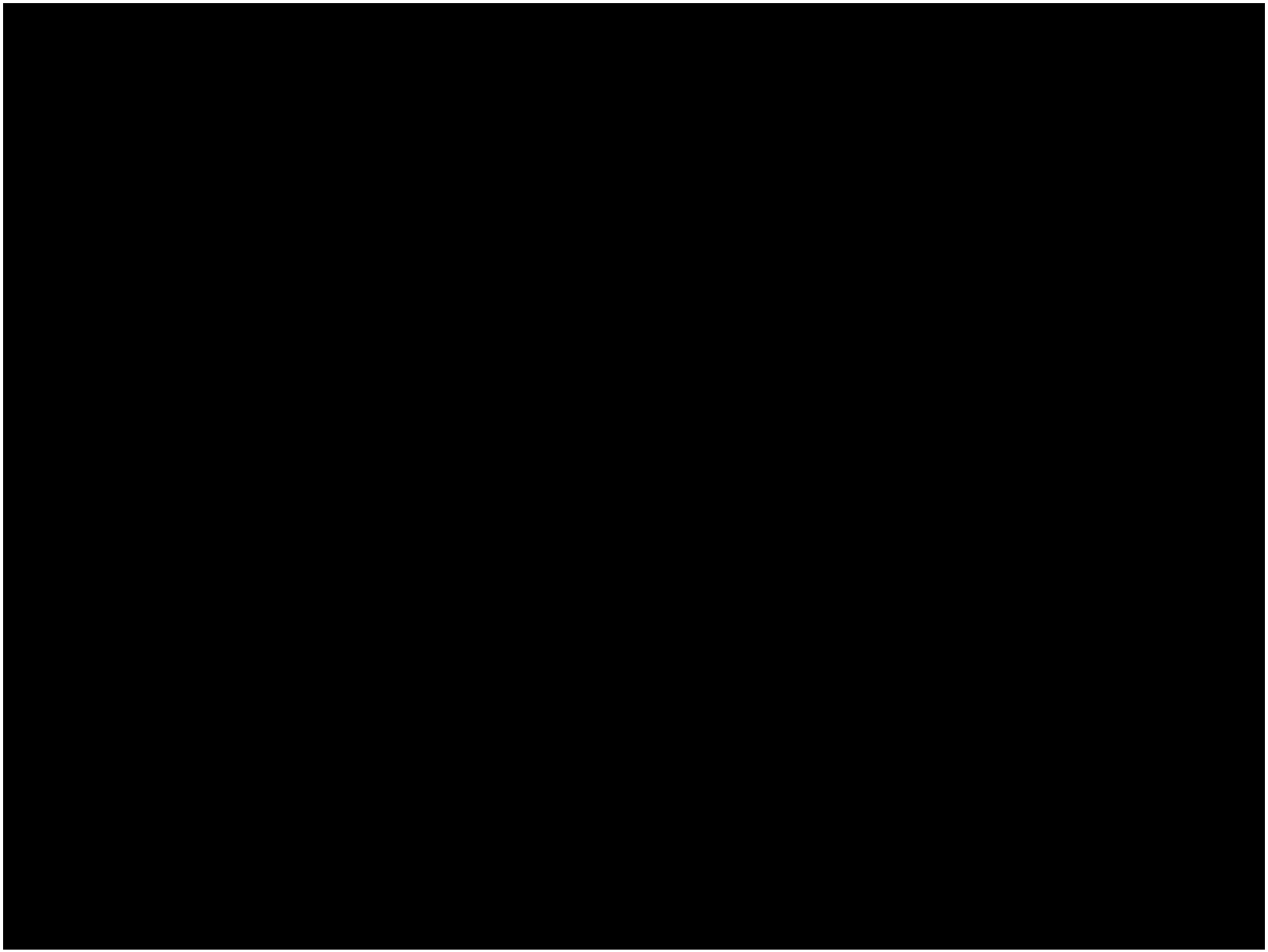


GEODESIC – 93 images/s – 990 km altitude:



JOULE II – 19 January 2007

CLEMSON

NASA

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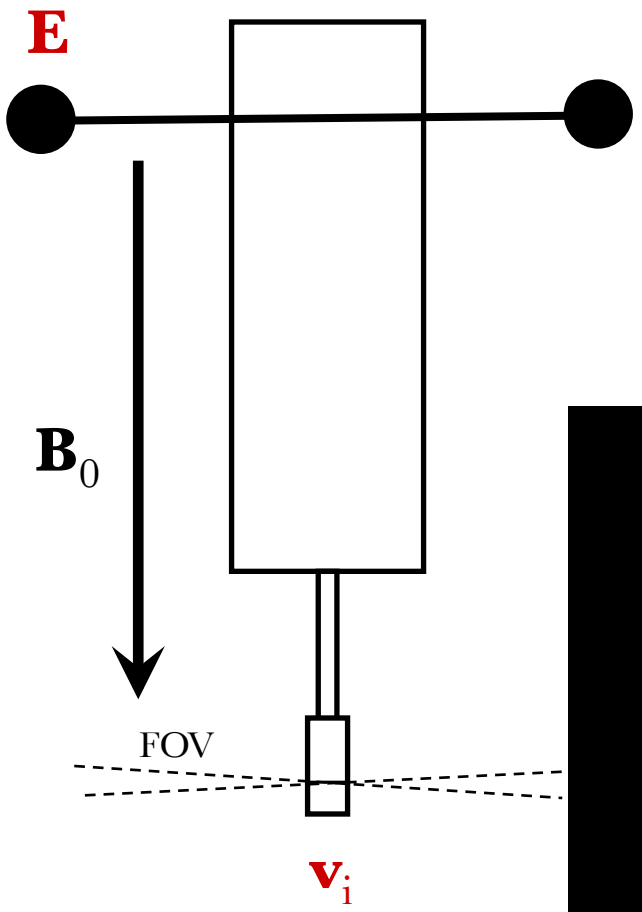
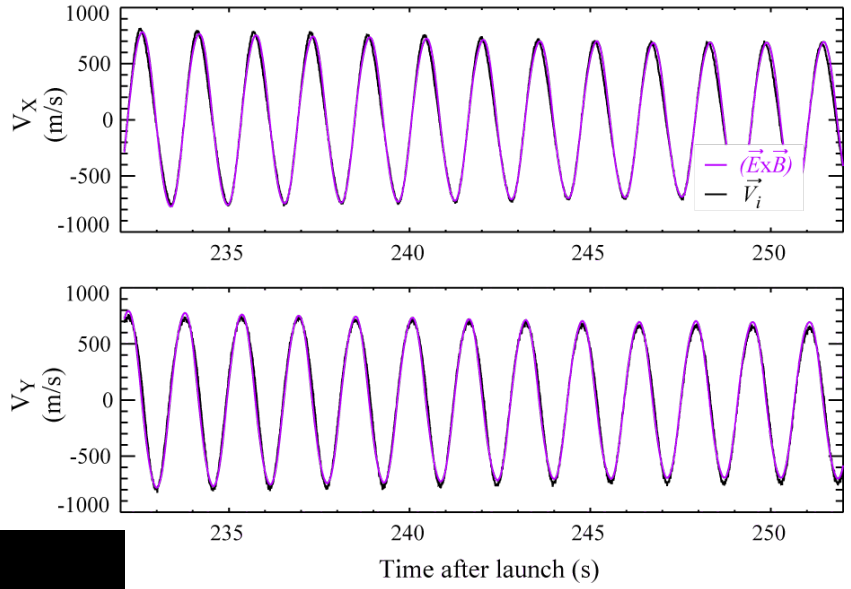
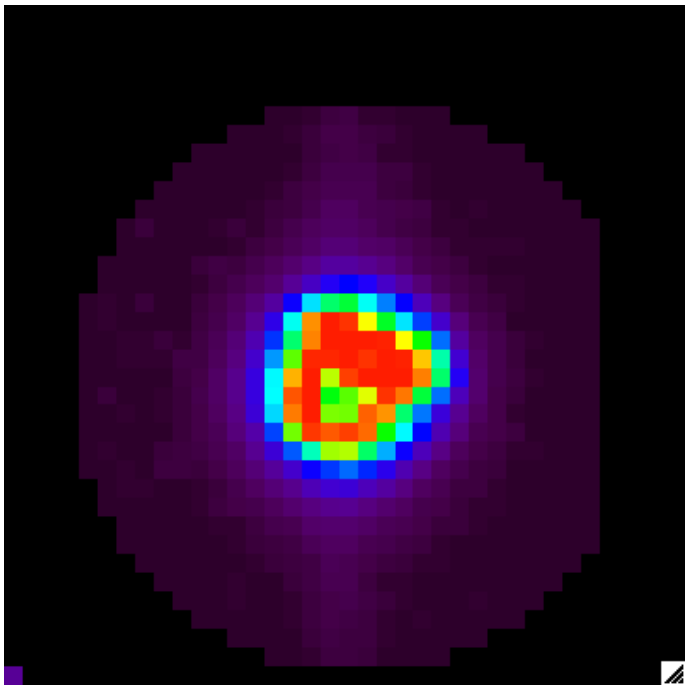
Case II – Sensor Deployed Parallel to Spin Axis



JOULE-II
21.138
Downleg



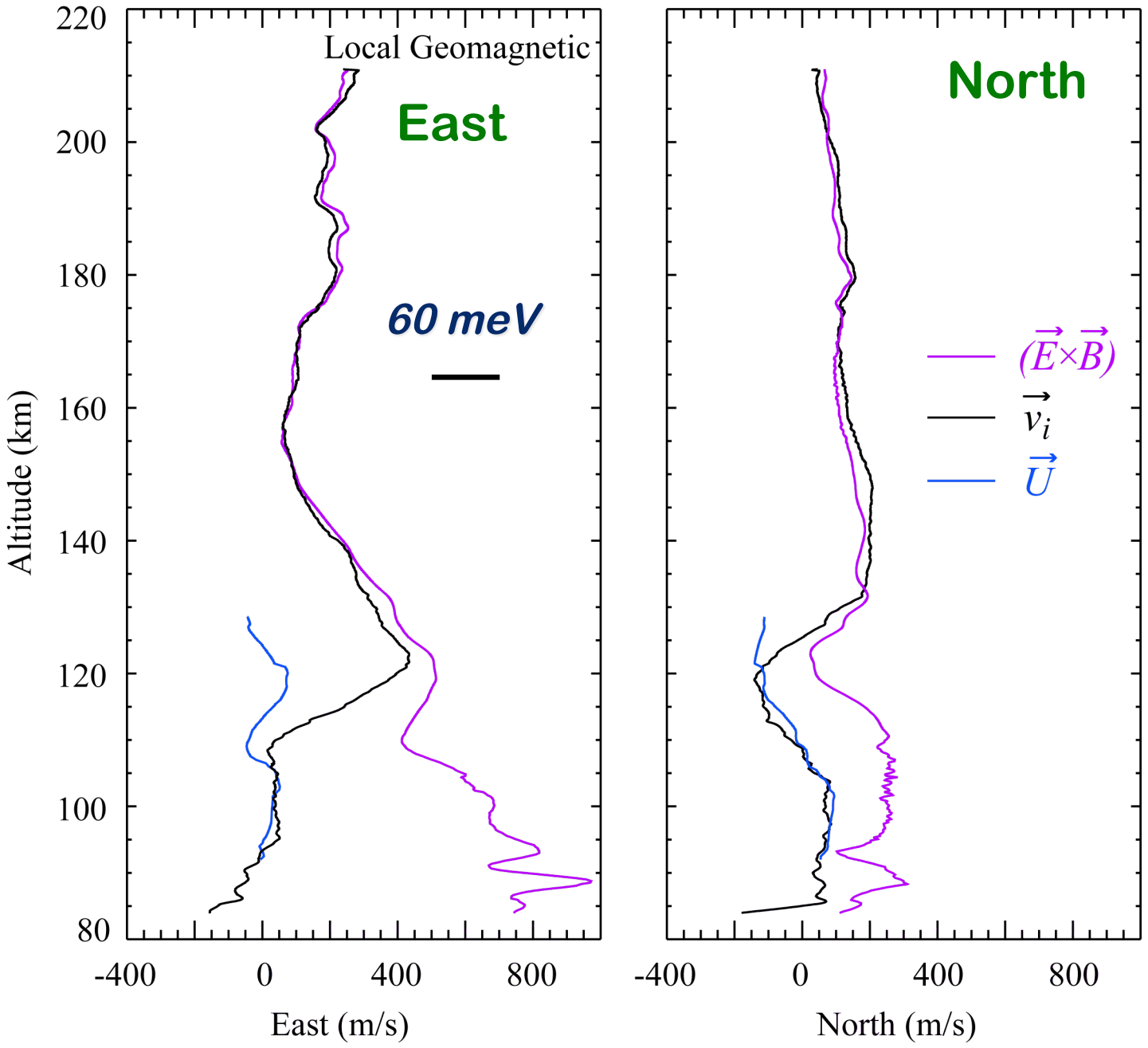


Electric field data: Robert Pfaff and Doug Rowland, NASA GSFC

Sangalli et al,

J. Geophys. Res. [2009]

0-9 eV ions



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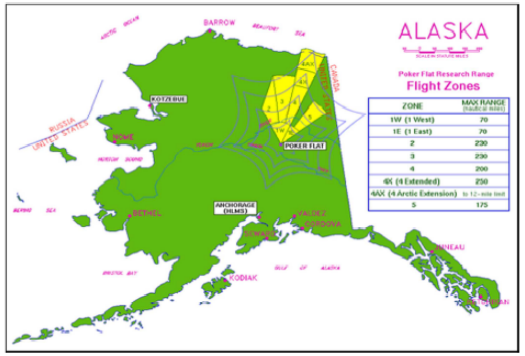
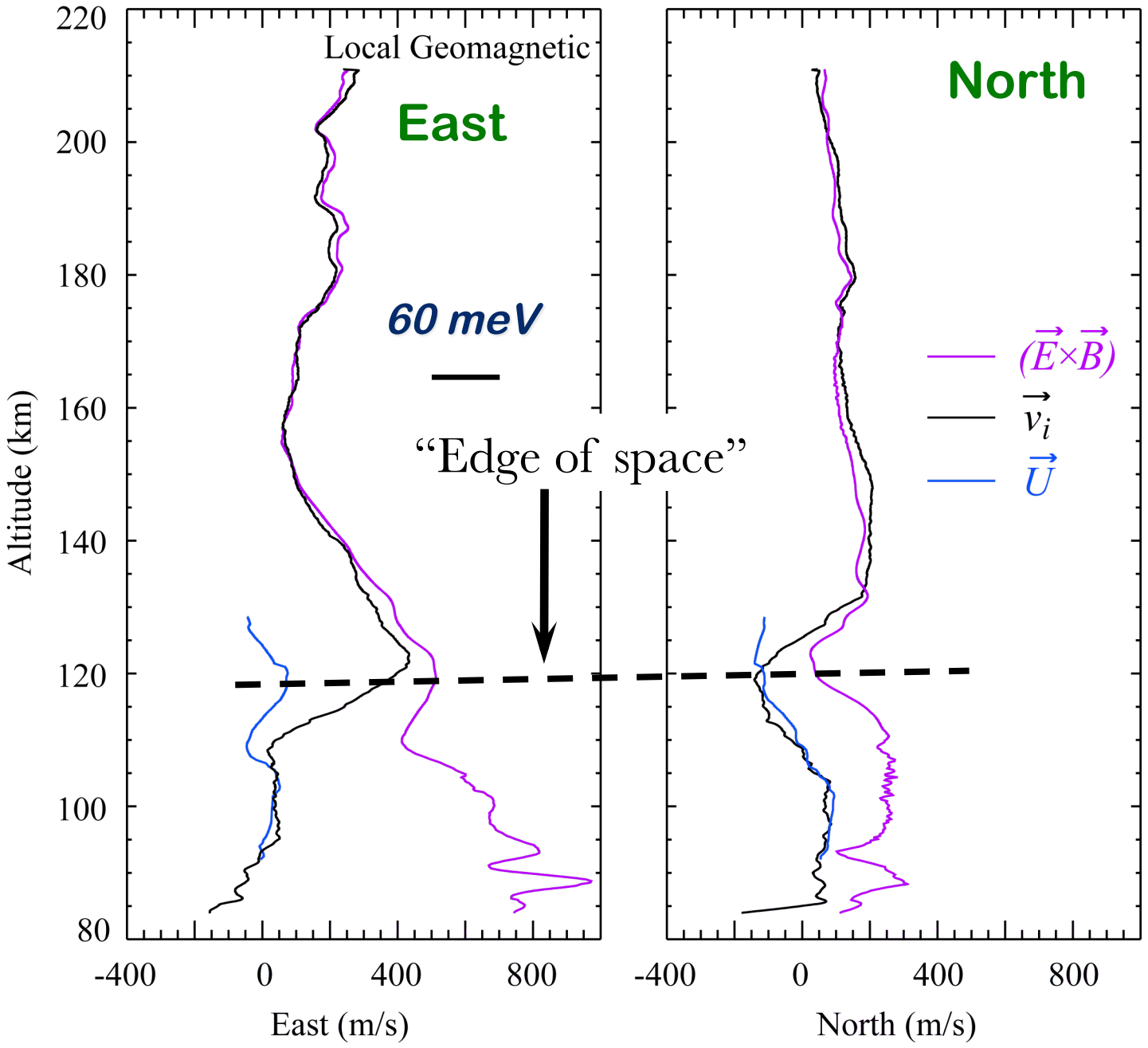


Sangalli et al,

J. Geophys. Res. [2009]



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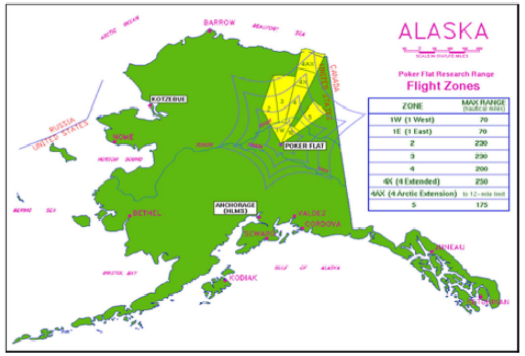

Sangalli et al,

J. Geophys. Res. [2009]

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Wisdom Quarterly: American Buddhist Journal: Edge of Space Found

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Scientists Find the Edge

Friday, April 10, 2009

SPACE.com

Hold on to your hats, or in this case, your he called edge of space — the boundary betwee

With data from a new instrument developed by confirmed that space begins 73 miles (118 kilo

A lot remains very fuzzy, however, as the bound confusing, conflicting definitions.

For starters, astronauts can say they've been t kilometer) mark.

Meanwhile the boundary recognized by many in miles (100 kilometers). Scientist Theodore von atmosphere is so thin that it's negligible, and co they can't go fast enough to get any kind of aer the Federation Aeronautique Internationale (FAI

maneuvering with air surfaces, NASA states. Ot should be posted way out at 13 million miles (2 where Earth's gravity is no longer dominant.

(While astronauts experience weightlessness in it's due to the balance of forces acting on them

In the new study, an instrument called the Supra tracking the relatively gentle winds of Earth's at particles in space, which can reach speeds well

The ability to gather data in that area is significa measurements in this region, which is too high f

"It's only the second time that direct measureme this region, and the first time all the ingredients been included," says project scientist David Knu

The instrument was carried by the JOULE-II roc about 124 miles (200 kilometers) above sea lev moving through the "edge of space."

The finding, detailed in the Journal of Geophysi space weather and its impacts on Earth.

The data "allows us to calculate energy flows in able to help us understand the interaction betwe "That could mean a greater understanding of th cooling of the Earth's climate as well as how spa navigation, and power systems."

http://www.foxnews.com/story/0,2933,513837,00.html

Scientists Pinpoint The 'Edge Of Space' 2

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Scientists Pinpoint The 'Edge Of Space'

29/03/11 8:07 AM

ScienceDaily (Apr. 10, 2009) — Where does space begin? Scientists at the University of Calgary have created a new instrument that is able to track the

enlarge

Where does Earth stop and space begin? 118-kilometers above the ground, according to scientists who created an new instrument that is able to pinpoint the so-called "edge of space."

10/04/09 5:06 PM

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FEBRUARY 2007 2008

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WISDOM QUARTERLY: AMERICAN BUDDHIST JOURNAL

DHARMA, SUTRAS, NEWS ARTICLES, AND SP
BUDDHISTS OF ALL TRADITIONS WITH AN E
DEVELOPMENT, NONHARMIN

FRIDAY, APRIL 10, 2009

Edge of Space Found

Earth in background, space station spacewalk above atmosphere (NASA)

"Scientists have finally pinpointed the so-called edge
April 9, 2009 story below.

ELPAIS.com el periódico global en español

Viernes, 10 de abril de 2009 - 19:53 h
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URGENTE Detenido en París Ekaitz Sirvent, supuesto jefe del aparato de falsificación de ETA - 19:24 h:

Jornada de luto nacional en Italia
El cardenal Bertone oficia el funeral de Estado por las 289 víctimas mortales del terremoto del lunes en Los Abruzos
El consulado busca a una española desaparecida
Imágenes de la tragedia | anterior | siguiente

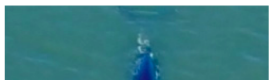
Detenido en París el responsable del aparato de falsificación de ETA
La gendarmería ha arrestado a Ekaitz Sirvent Auzmendi en la estación de Montparnasse al bajar de un tren que tomó en Burdeos

Un camión bomba mata a cinco soldados de EE UU y tres policías iraquíes
Estalla un camión bomba cargado con 1.000 kilos de explosivos cerca de una base militar conjunta en Mosul.- Hay unos 70 heridos

Mercosur crece pero no madura
JAVIER LAFUENTE
El bloque comercial suramericano cumple 18 años sin colmar las expectativas

Un huerto en la Casa Blanca
Michelle Obama utiliza 100 metros cuadrados de los jardines para plantar lechugas, espinacas y guisantes

Los piratas piden dos millones de dólares por el capitán de EE UU
El rehén trata de escapar a nado pero lo vuelven a capturar.- Francia rescata un yate secuestrado, pero muere uno de sus tripulantes
Francia rescata un yate secuestrado por los piratas



¿La frontera del espacio? A 118 km
MALEN RUIZ DE ELVIRA
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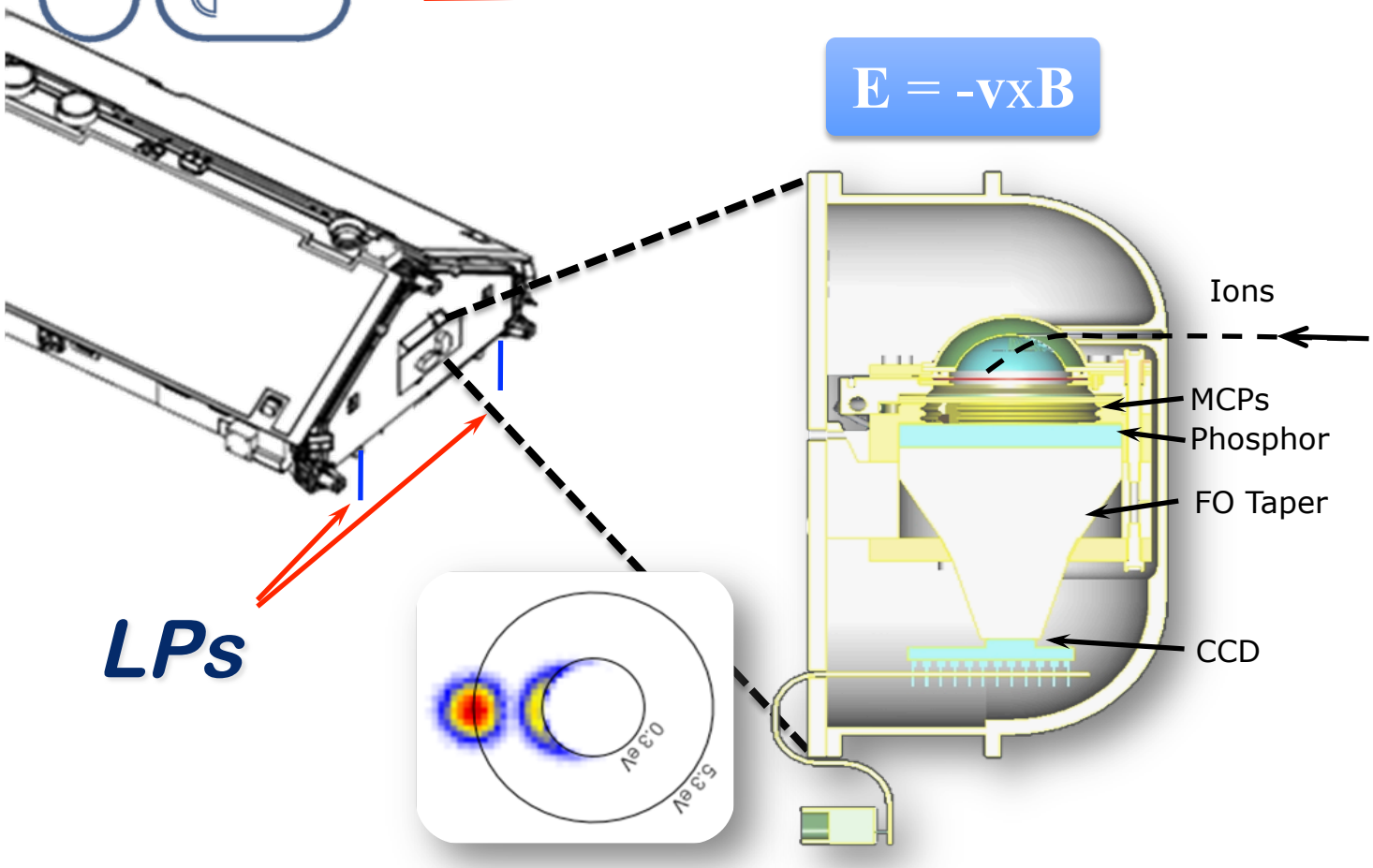
Swarm Thermal Ion Imager

$E = -vxB$



Imaging electrostatic analyzer, electro-optical detection

Langmuir probe

x 2 per satellite

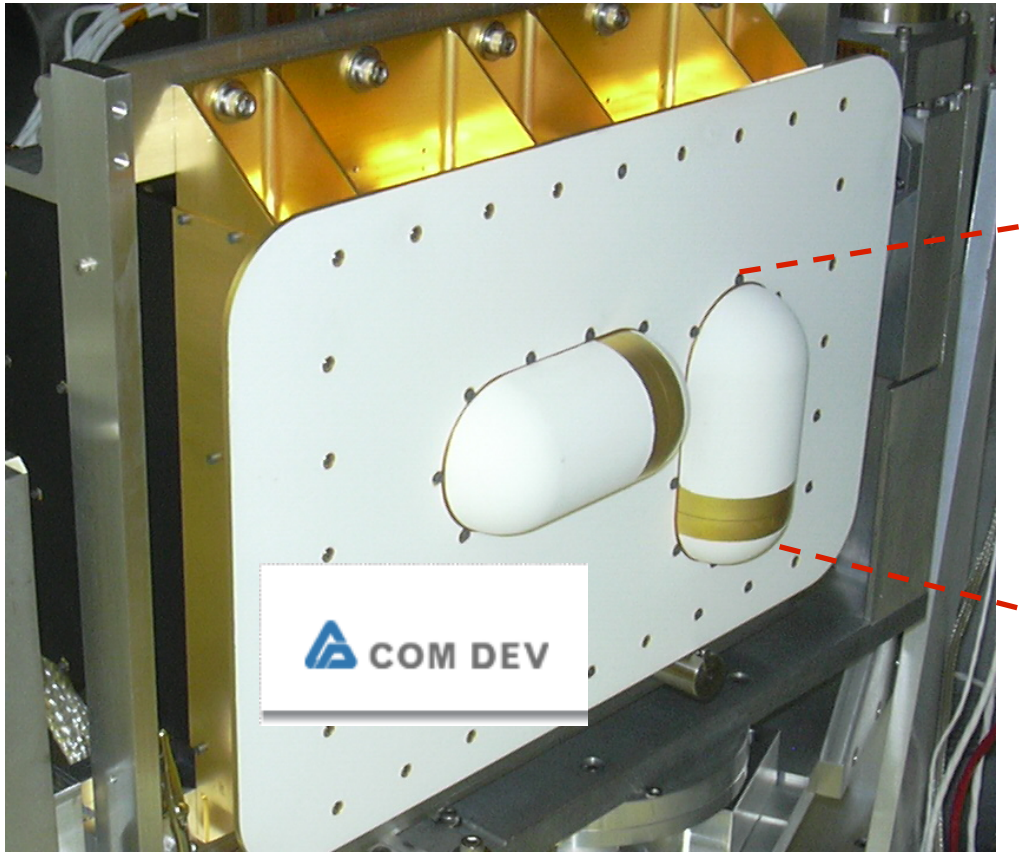
3D velocity from orthogonal analyzers

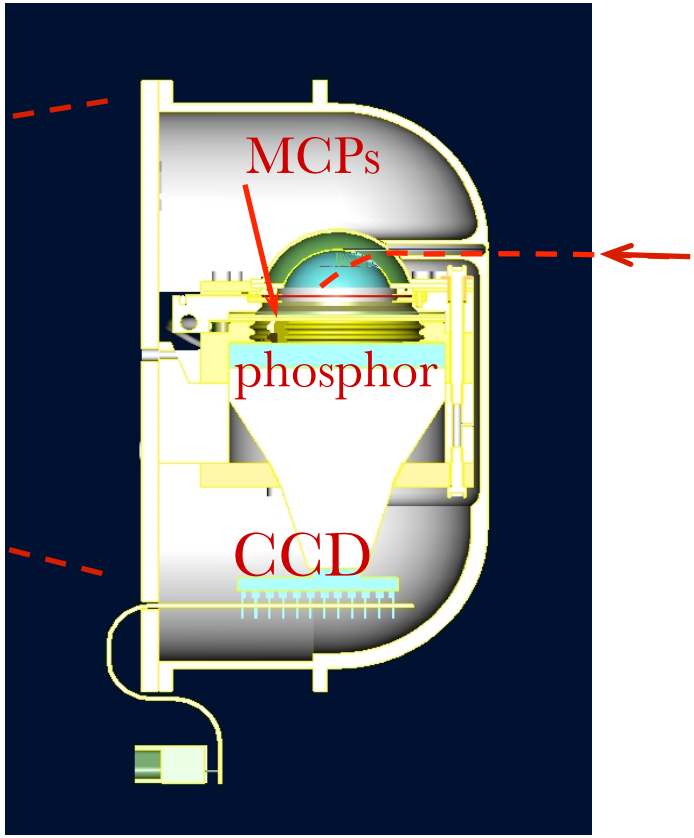
Coarse ion moments @16Hz

Calibrated products @ 2Hz

675 Full images/day

The Swarm CEFI





esa

CSA ASC

IRF
Uppsala

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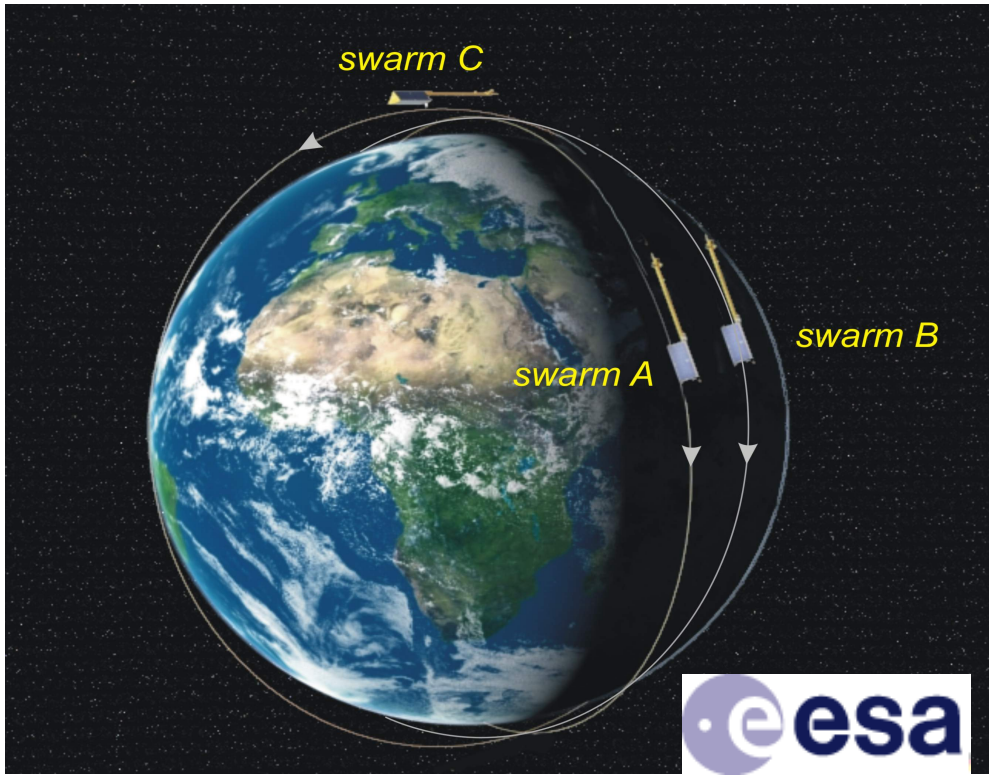
Swarm

- Precision B (vector and scalar)
- E from $-v_i \times B$ (2 & 16 Hz)
- T_i, T_e, n_e
- Data validation via ISR's



- ~85-88° inclination
- 2 satellites at ~450 km, laterally separated by 10's km
- 1 satellite at ~530 km, displaced several hours in local time
- Nominal science mission 2013-2016