Current hardware developments at IRAP and CNES for thermal plasma measurements

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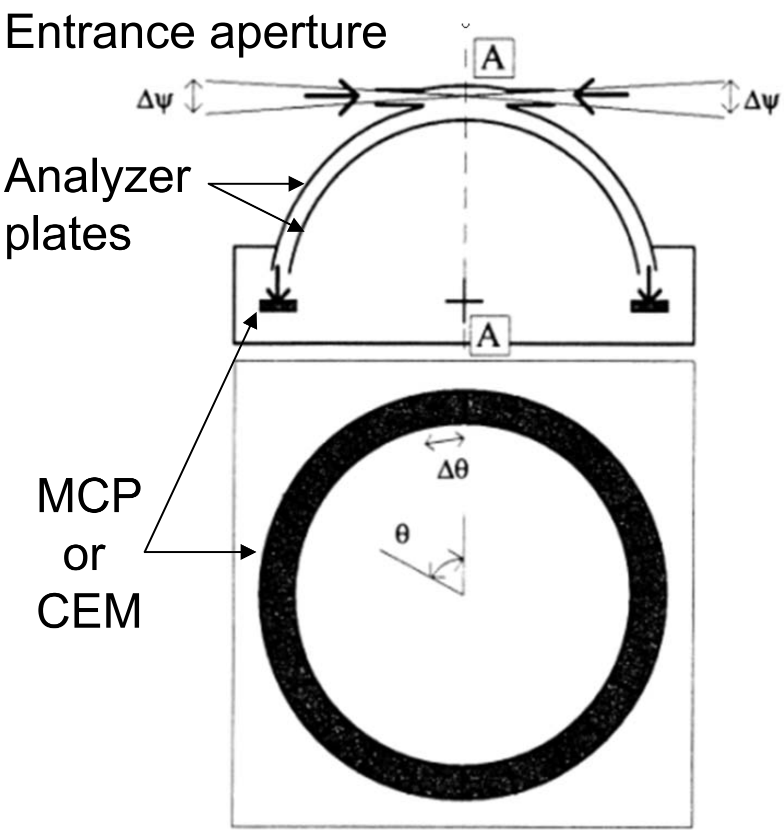
Outline

A review of current activities related to electrostatic analyzers:

- Deflection system
- Variable geometric factor
- Composition measurements
- Dual ion-electron detectors
- New low-resource design specific to geo. orbit (in response to ESA AO).

Intro: basics of thermal plasma electrostatic analyzers
(~0 to 40 keV)



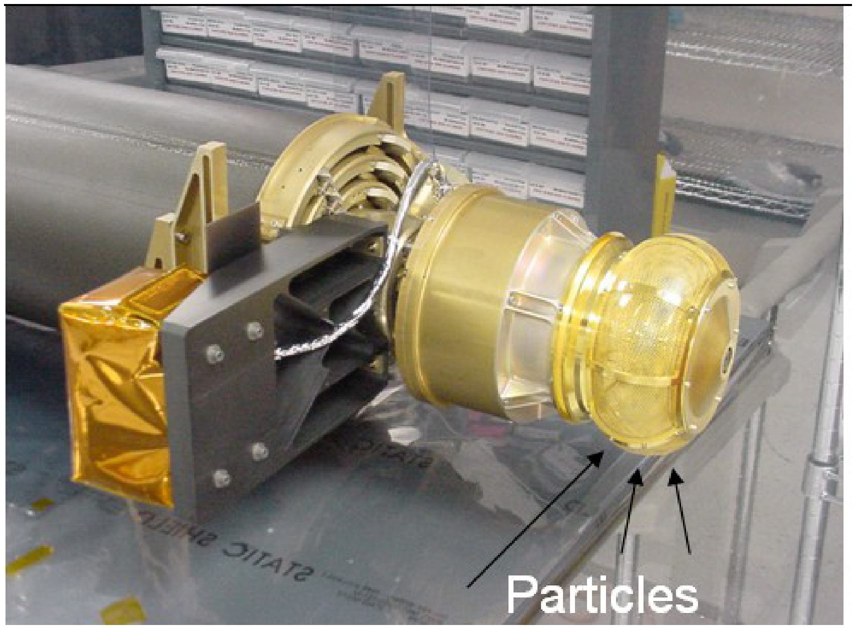
- Principle: selection of E/Q thanks to curved plates with differential voltages

- IRAP has built or contributed to such instruments for numerous missions:
  - Giotto
  - Interball
  - Cluster
  - Equator-S
  - Double Star
  - MEX - VEX
  - STEREO
  - Bepi-Colombo
  - Solar Orbiter, …

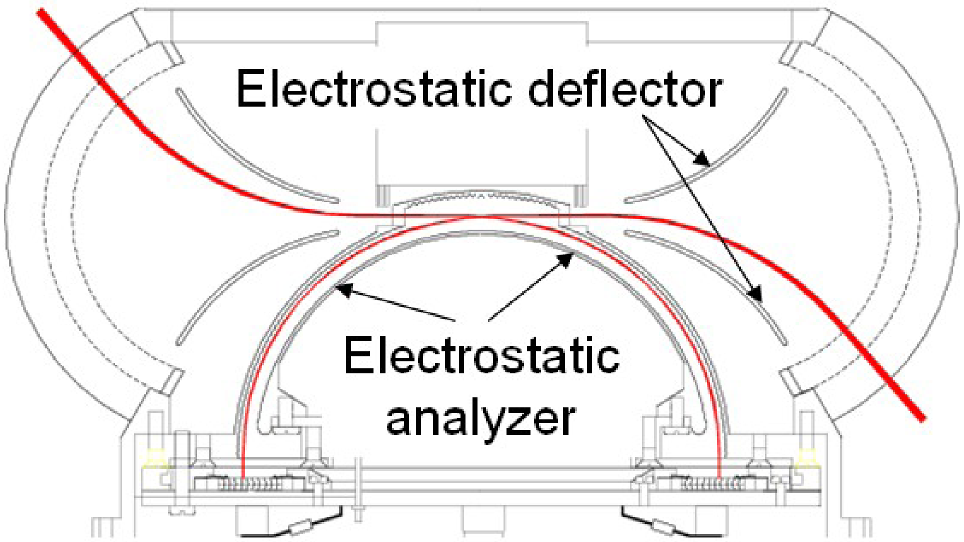
→ Prime advantage over solid-state detectors is to measure down to ~0 eV with high energy resolution

Entrance deflection system for non-spinning S/C

Exemple of the two STEREO Solar Wind Electron Analyzers (SWEA)
Sauvaud et al. (2008)



Requires large HV to go to high energies

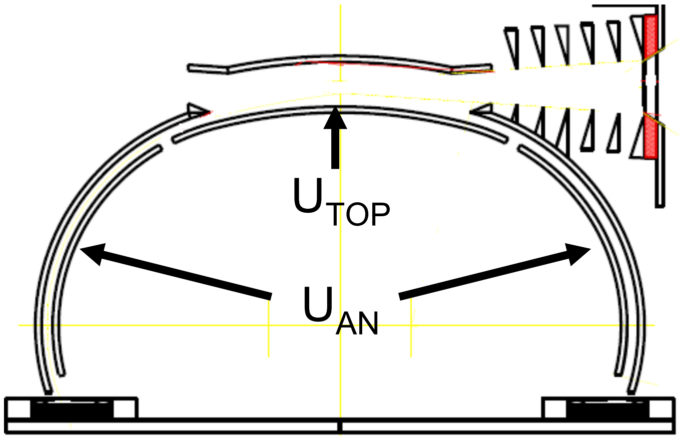


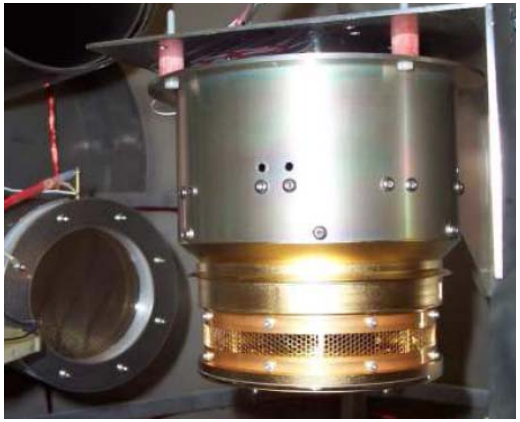
→ **Deflection system allows increased FOV for non-spinning spacecraft, but increases resources and limits E range**

Electrostatically variable geometric factor

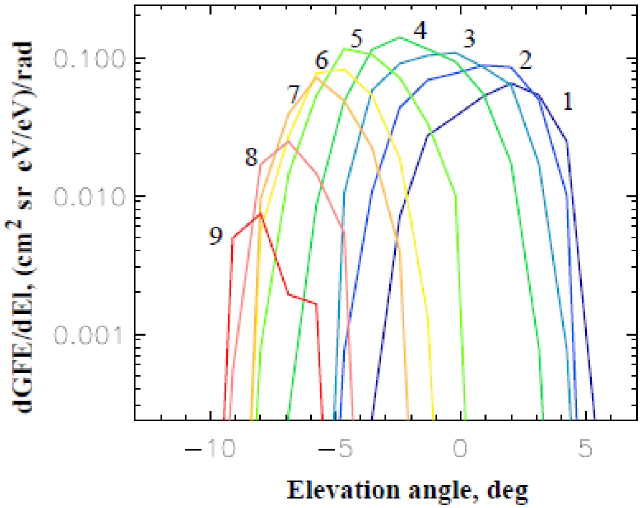
Exemple of Mercury Electron Analyser (MEA) on Bepi-Col.
Sauvaud et al. (2010)

- Design and picture





- Simulations of geometric factor as a function of voltages and elevation angle



→ Variable geometric factor useful to access large dynamic range of fluxes, but requires additional HV resources

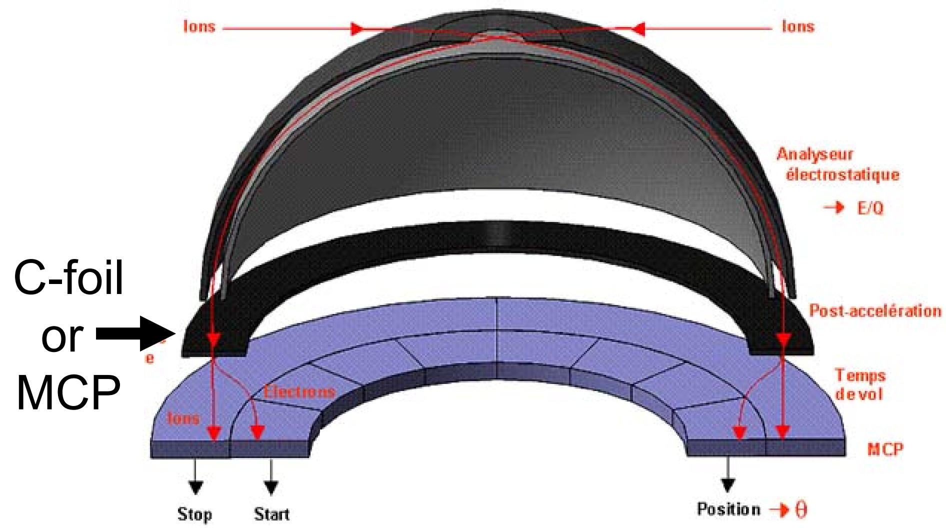
Composition measurement with MCP instead of C-Foil

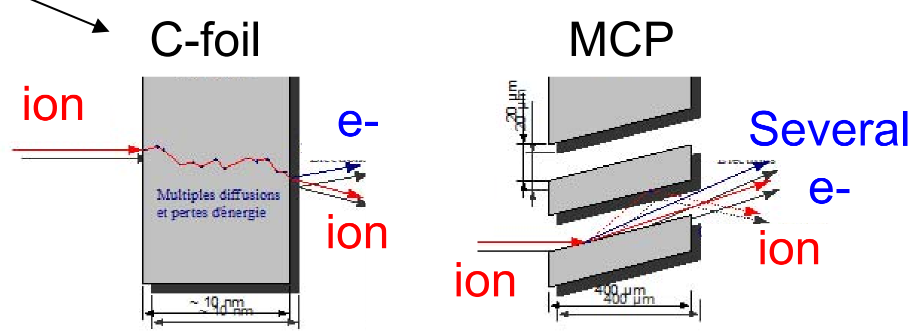
Prototype under development
Cadu et al. (2012)

Time-of-flight typically based on ion passage through C-foil, releasing secondary electron

→ Leads to significant energy straggling upon transmission

→ Tested design:
Use grazing incidence within thin MCP to create secondary electron



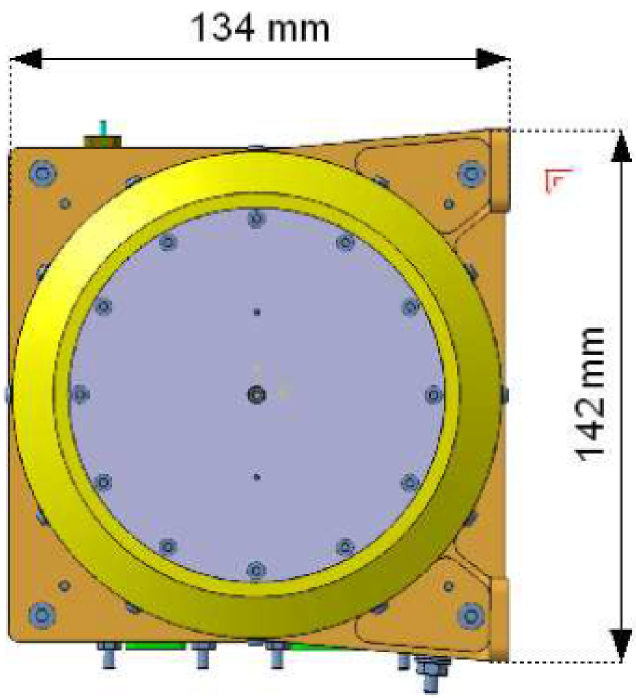


→ Promising idea for improved composition accuracy, but of course TOF requires significant resources

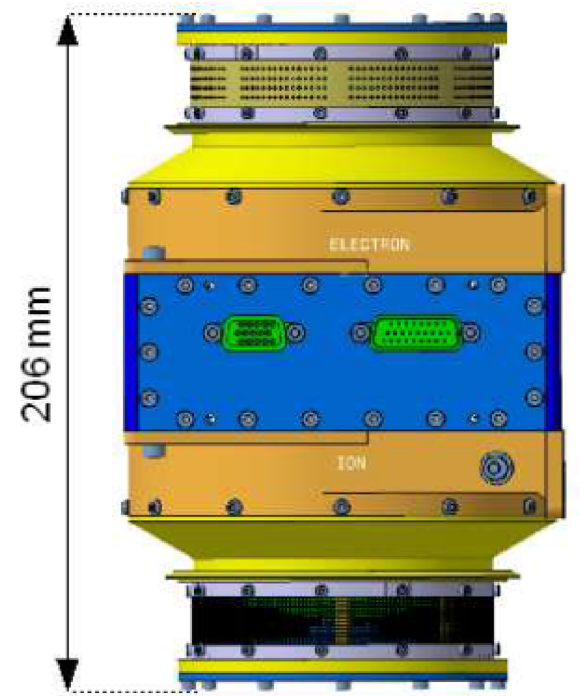
Dual-head ion-electron monitor for JASON-3

AMBER: Active Monitor Box of Electrostatic Risks

Robust design & electronics for simultaneous ion and electron measurements



View from top



Side view

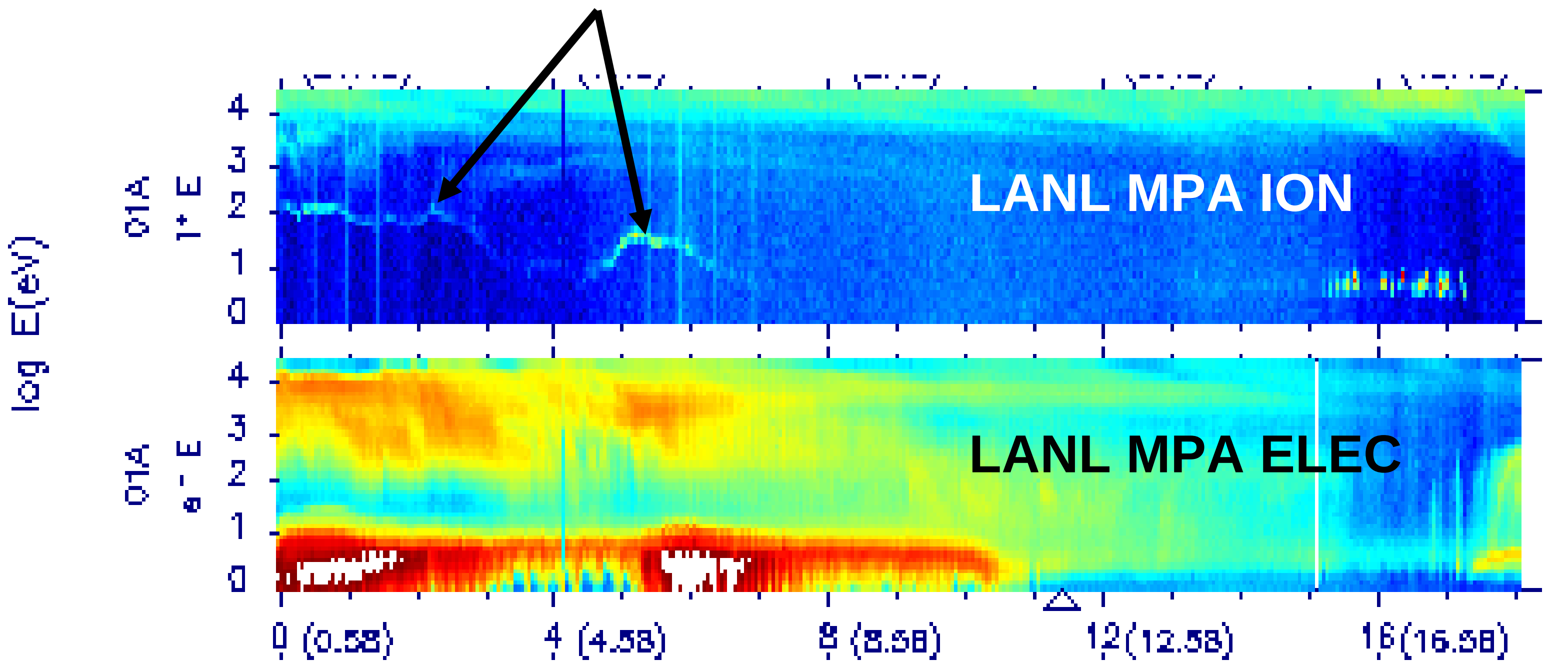
Payan et al. (2010)

→ Simple and robust design, but not particularly compact

Thermal ion measurement in geosynchronous orbit

Telecom sats typically are non-conducting and charge negatively:

Spacecraft charging line in Los Alamos geo. data



→ Hi-res ion measurements required to monitor charging

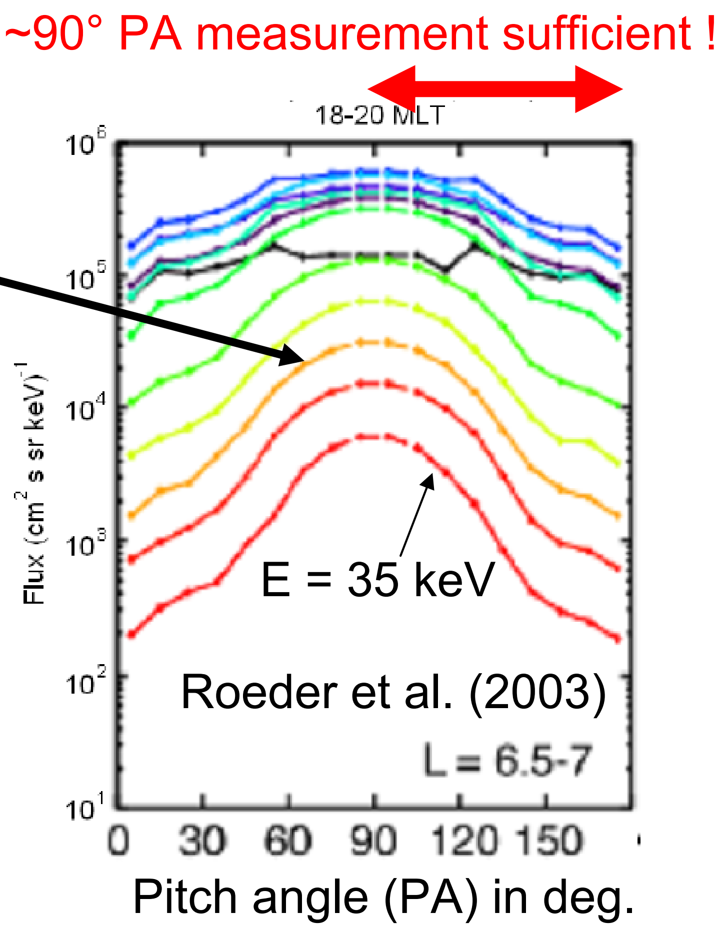
Thermal ion measurement in geosynchronous orbit

- Ion anisotropy is often large

- It is the source of Electro-magnetic Ion Cyclotron (EMIC) waves

→Leads to energetic particle losses

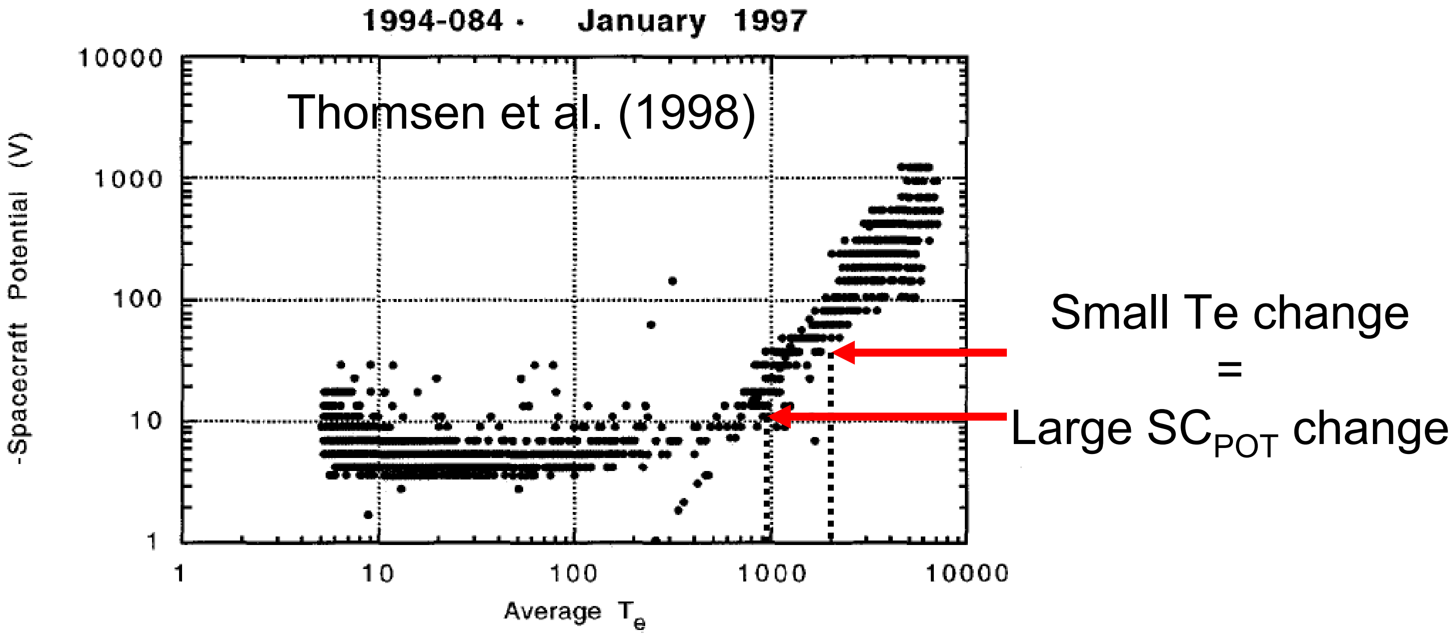
Note: Latitudinal B-field direction can be obtained from anisotropy PA data fitting!



→ Pitch angle data pivotal at geo. to study plasma access & ring current/radiation belt/wave-particle interaction modeling

Thermal electron measurement in geosynchronous orbit

- Knowledge of thermal electron distribution is a key:
→ Population responsible for charging



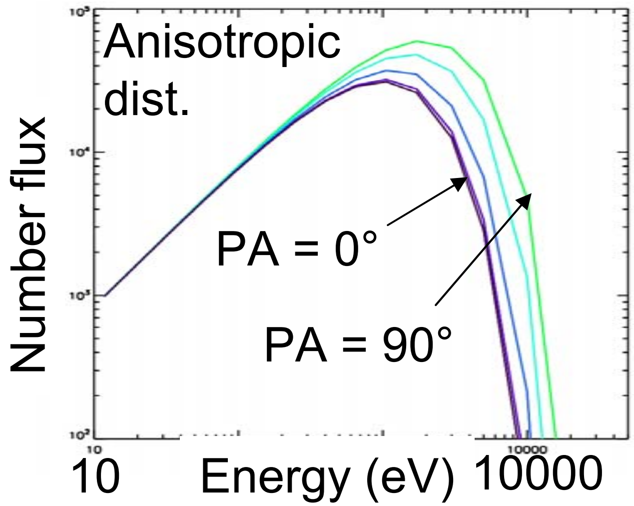
- Negative charge leads to loss of part of electron distribution:
→ Need accurate resolution at low energy to best recover it

→ Thermal electrons are key to all aspects of space weather: responsible for charging, thus needed for its modeling

Thermal electron measurement in geosynchronous orbit

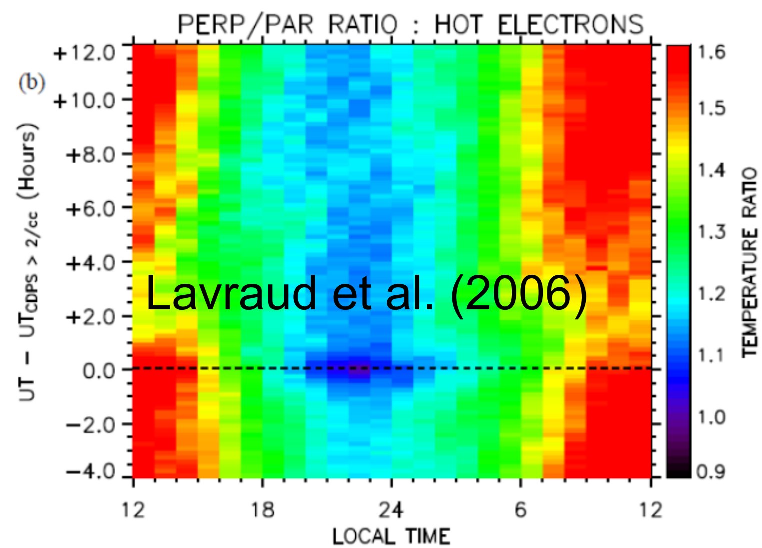
- Thermal electrons highly anisotropic:

→ Lack of pitch-angle data (PAD) leads **to order of magnitude errors** in fluxes: huge impact on charging modeling!



- Thermal electron anisotropy is the source of Chorus and Hiss waves

→ Pitch angles needed to study energetic electron loss & acceleration processes



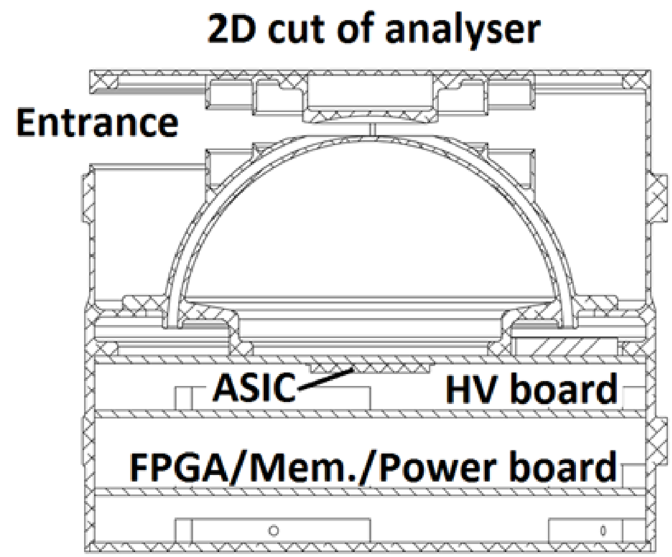
→ Thermal electrons are key to all aspects of space weather: PAD needed for modeling of charging and killer electrons

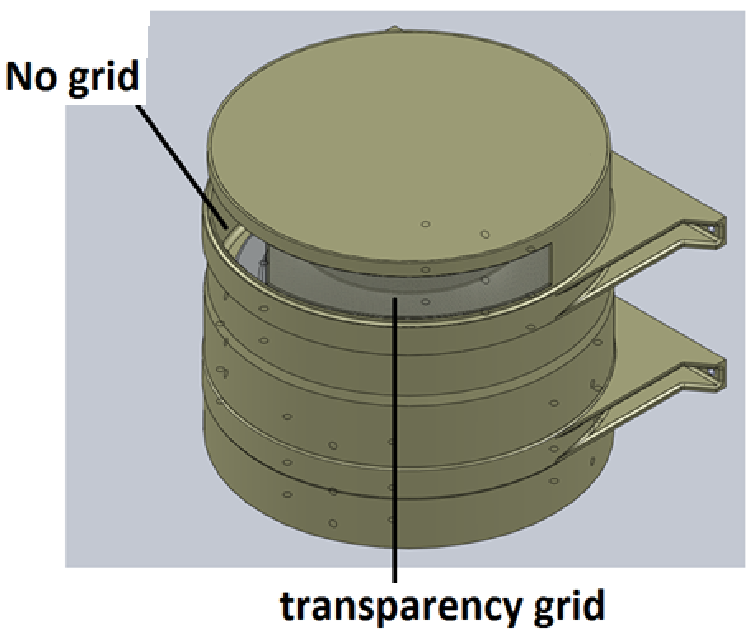
Compact design for geosynch. orbit: AMBER_GEO

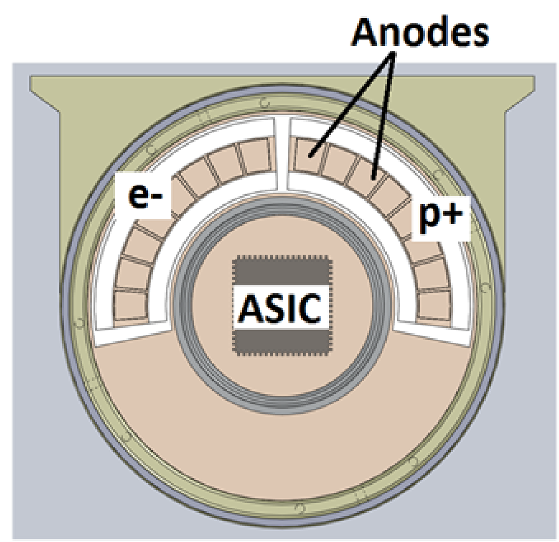
Main features of design:

- one head with alternative ion and electron measurements
- ASIC on anode board
- only 2 more boards for HV and DPU/power
- 90° FOV for each species

→ efficient for trapped, gyrotropic populations at geo. orbit







Compact design for geosynch. orbit: AMBER_NG

Measurements:

- Ion and electron energy spectra (0-35 keV)
- N, T_{PAR} & T_{PERP} moments
- Pitch-angle dist. at several E
- B field latitud. stretching angle (from anisotropy fitting)
- Time resolution 30s

Budgets:

- Los Alamos MPA	3.6 kg
- AMBER	2.5 kg
- MEA Bepi-C (e^- only)	1.2 kg

→ **AMBER_GEO**

Mass ~0.9 – 1.0 kg
Power ~ 1 W
Volume 103 x Ø125 mm

→ **Compact, low resource instrument <u>specific to geo. orbit</u>**

Conclusion

IRAP works on various key developments to enhance thermal plasma measurements capabilities

Each development is thoroughly studied in view of mission scientific/technical requirements, as well as environment

We believe the AMBER_GEO design proposed for geo. Telecom satellites (ESA ITT) is the best value in terms of usefulness of operational & scientific data versus resources

Small note: us Europeans, we should strive to do at least as good as what Americans do in geo. orbit since almost 40 years…