LEO Charging Environment Characterisation using AMBRE data

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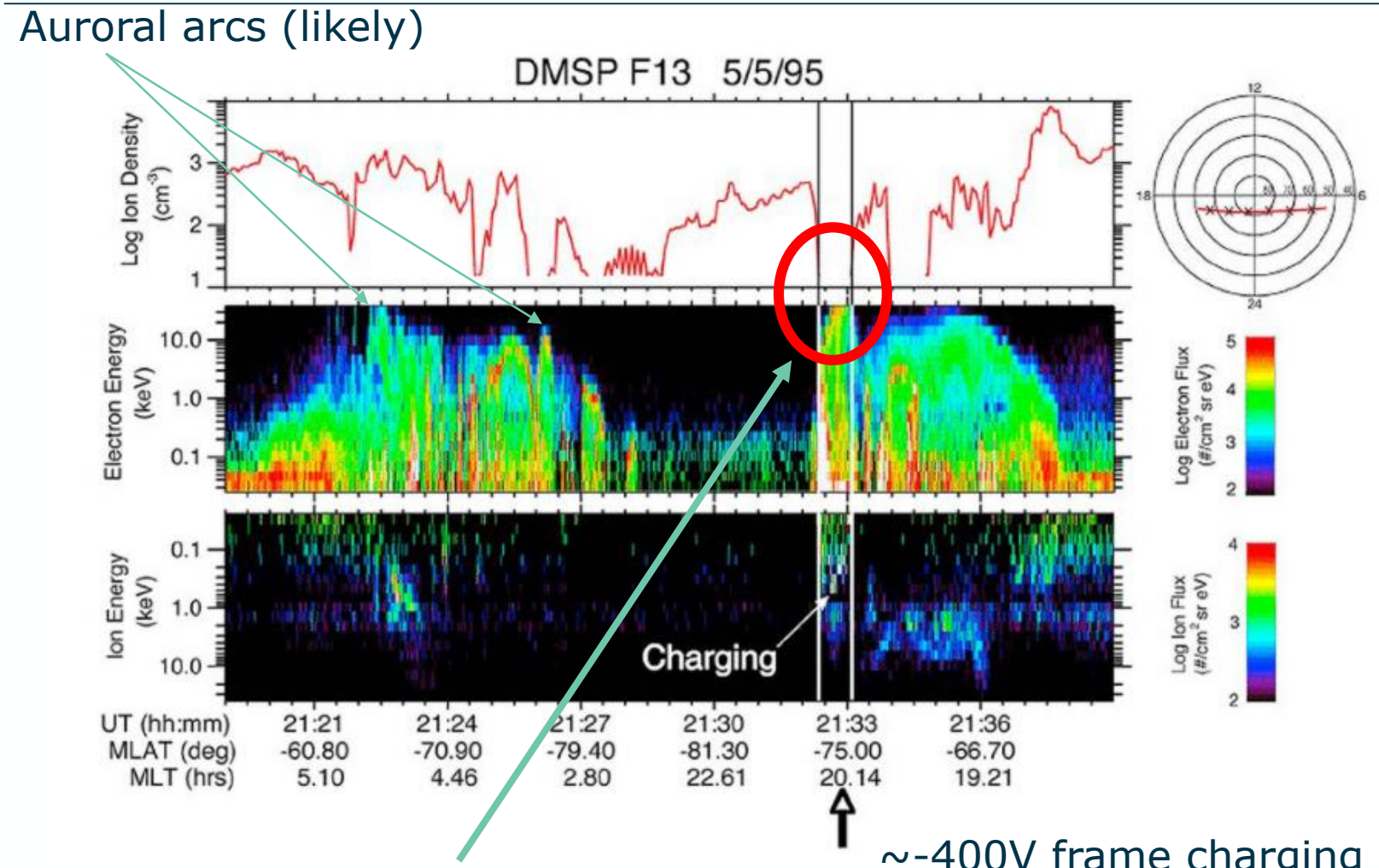
Motivation – LEO Environment and Charging



Darkness, low background density, and High electrons average energy

In LEO, thermal currents (electron) mostly dominate, wake effects , Vs/c ~-0.5V typically

Strong charging observed occasionally (below -2000V)

Defense Meteorological Satellite Program

Polar orbit ~ 99° , 101 min

840 km

Electrons spectrometer, Background Ions (LP, RPA, DM)

12 years of data, 7 satellites

Motivation - Heritage and ECSS

8.2.3 Auroral charging environment

a. For auroral charging assessment, the following worst-case electron distribution function shall be used.

1. For E ≤17,44 keV:

$$f(v) = 3{,}9 \times 10^{-18} \quad s^3m^{-6}$$

2. For E > 17,44:

$$f(v) = \frac{[N_0(m_e)^{3/2} \exp\{-(E - E_0)/kT_0\}]}{(2\pi kT_0)^{3/2}}$$

where

$f(v)$ is the distribution function in $sec^3\ m^{-6}$

N_0 is the density in m^{-3}

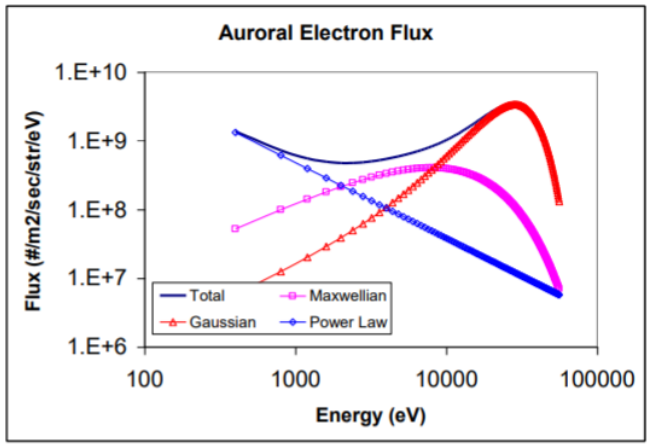
m_e is the electron mass in kg

kT_0 is the thermal energy in J

E_0 is in J

E is energy in J

- ✓ Single point model
- ✓ Inclination, altitude dependence (background density) ?
- ✓ Events duration (s/c dependence)?



DMSP F6 and F7
26th November 1983

and parameters of the worst case environment are:

N_0 = 1,13E6 m^{-3}

kT_0 = 3,96 keV

E_0 = 17,44 keV

NOTE This comes from [RD.7] and is based on work described in [RD.8]. Unfortunately, it is printed in [RD.7] with a typographical error.

or worst case auroral charging assessments, a thermal ion density of 25 cm^{-3} and temperature 0,2 eV shall be used.

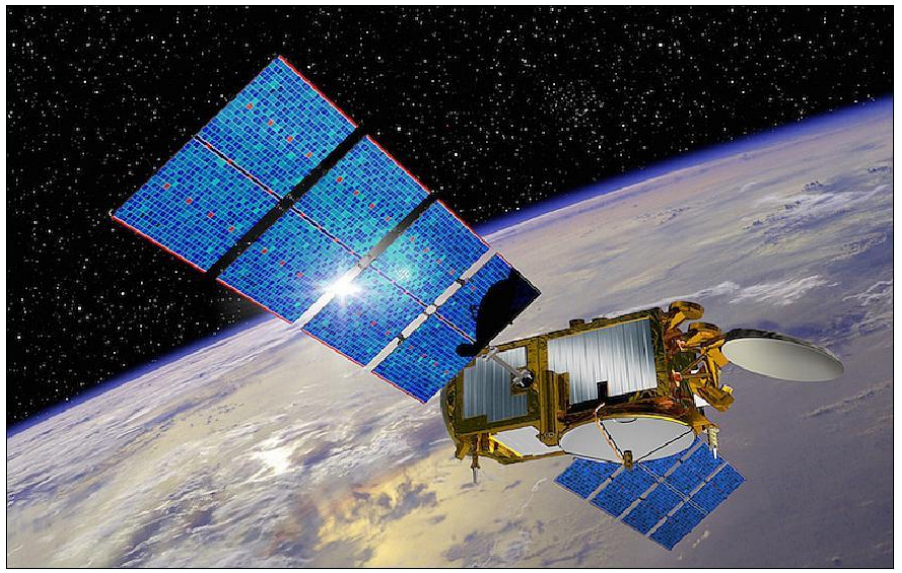
NOTE This low ion density comes from a severe charging case seen on the DMSP spacecraft by [RD.9]. Measuring ionospheric thermal ion density during a strong charging event is potentially prone to errors because of the way the charged satellite alters ion trajectories, so there is high a degree of uncertainty in this measurement but there is currently no better information..

c. A Maxwellian fit to the auroral electron distribution specified in 8.2.3a may be usedwith temperature 11keV and density 1.1e7m-3 [RD.168]

d. The worst case environments specified in 8.2.3a, 8.2.3b and 8.2.3c shall be applied for 10s.

JASON 3 / AMBER

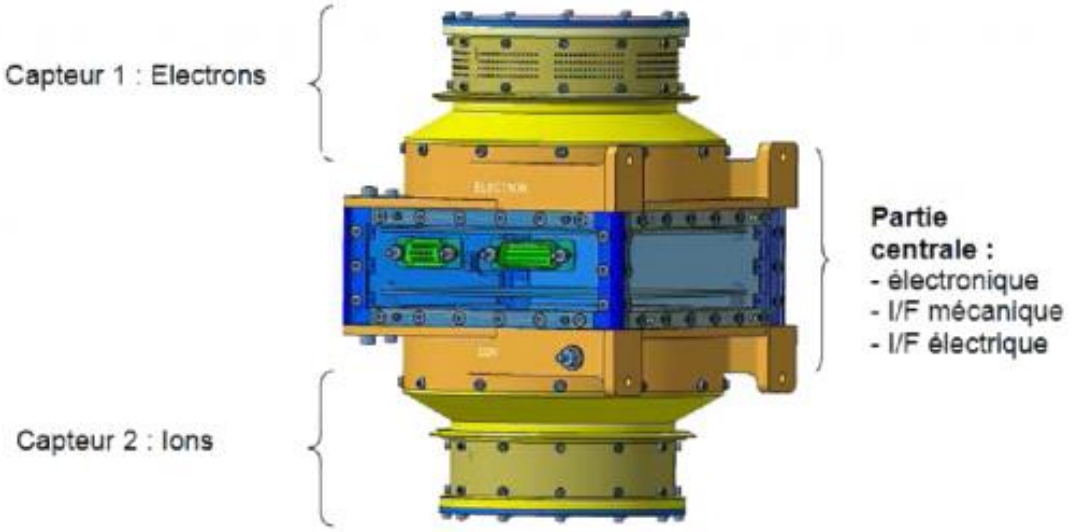
JASON-3



- Joint Altimetry Satellite Oceanography Network -3
- joint NOAA/EUMETSAT/CNES ocean topography mission
- satellite launched in January 2016
- circular orbit at 1336 to 1340 km altitude, inclination = 66.038º

AMBER

(image credit: CNES)



- Active Monitor Box of Electrostatic Risks
- double-head thermal electron and ion electrostatic analyzer
- energy range 0 – 30 keV

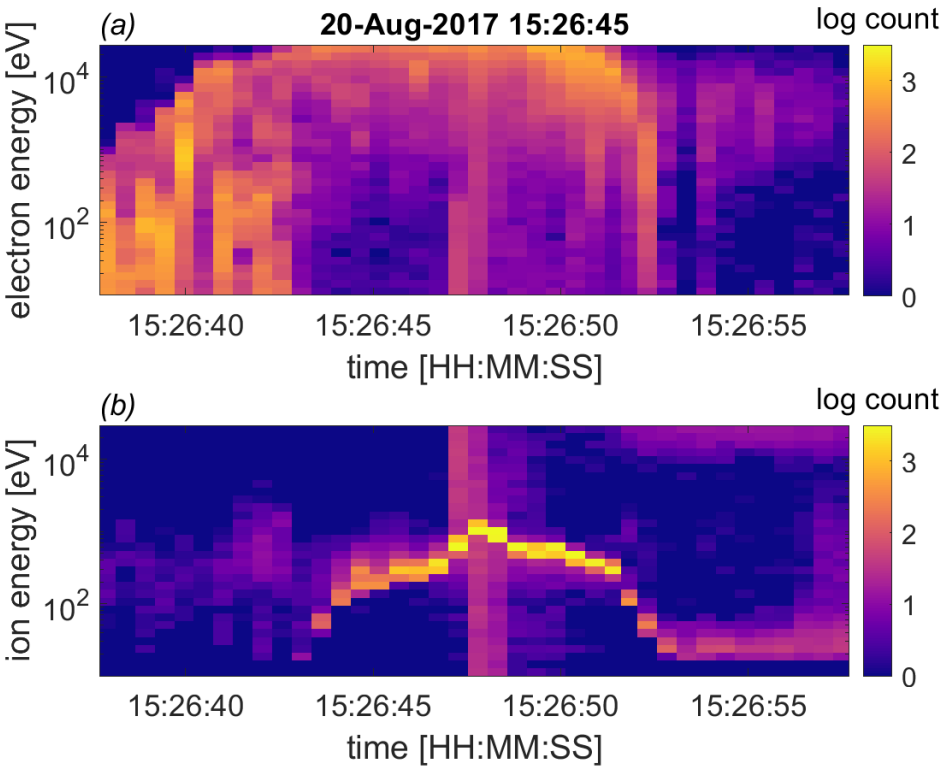
Table 1. Main properties of the new AMBER prototype.

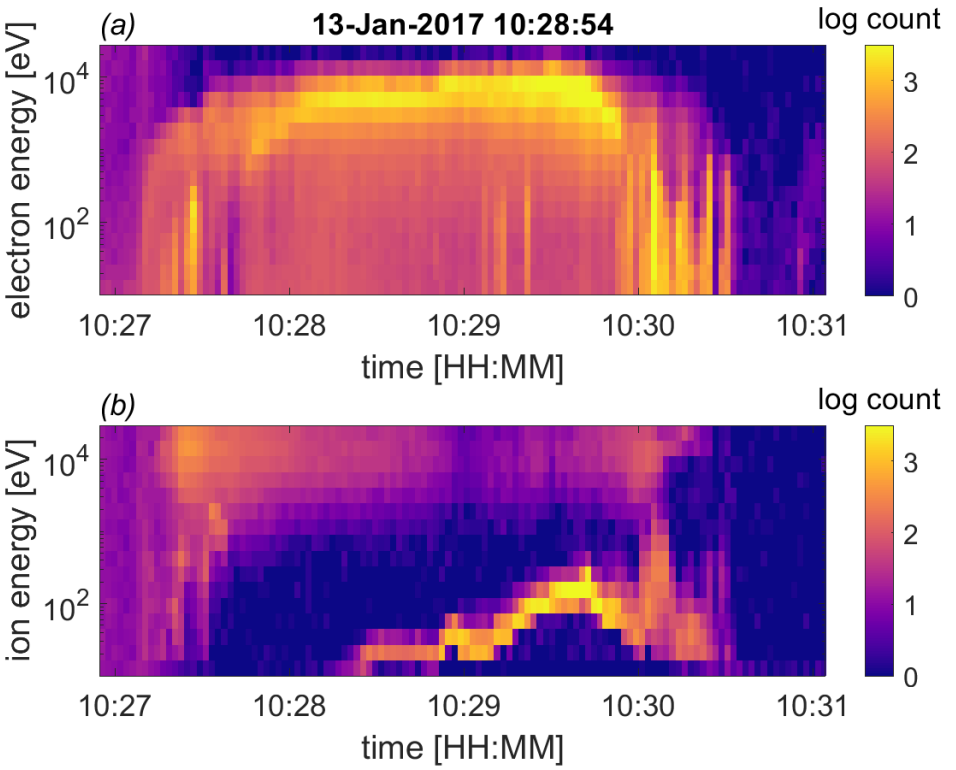
Parameter	*Value*
Sphere diameter	86 mm
Azimuthal resolution (anode)	22.5°
Azimuthal resolution (intrinsic)	6°
Elevation resolution	7.5°
Instantaneous FOV	7.5° × 360°
Energy resolution	14°
k-factor	9.1
Geometric factor (per anode)	0.75 × 10^{-3} cm².sr.eV/eV
Volume	130 × 130 × 140 mm
Mass*	~1 kg
Power*	~1.5 W

Source: Lavraud et al. (2014)

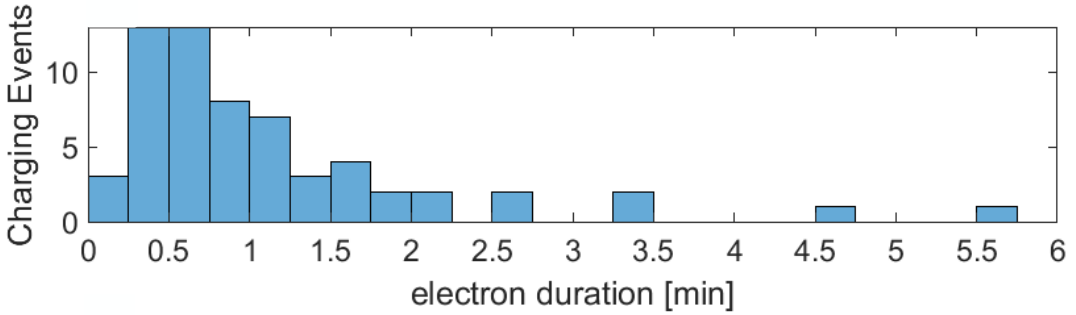
Data analysis – ion spectrograms

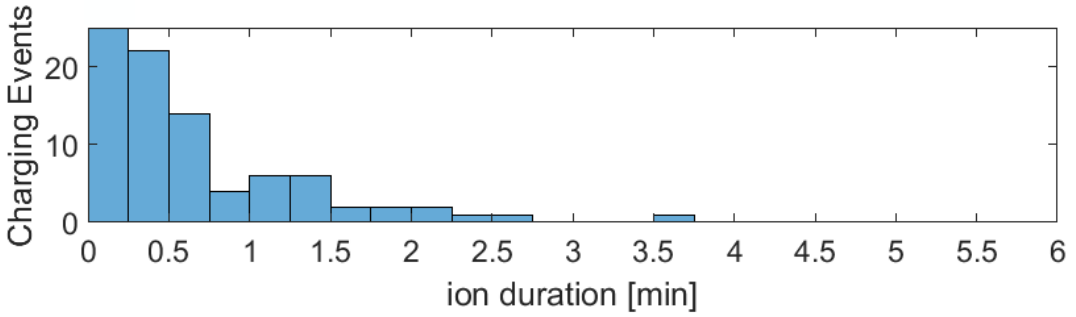
- search for 3 consecutive datapoints with counts over 10^2.9 in any of the ion energies
- from 2017 – March 2020: around 63 events in 2017, 26 events in 2018, 23 events in 2019, 9 events in 2020

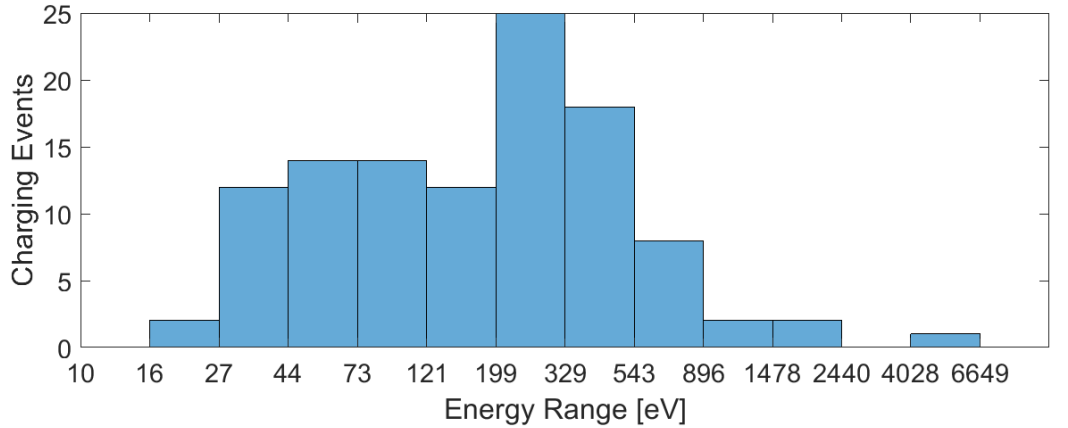


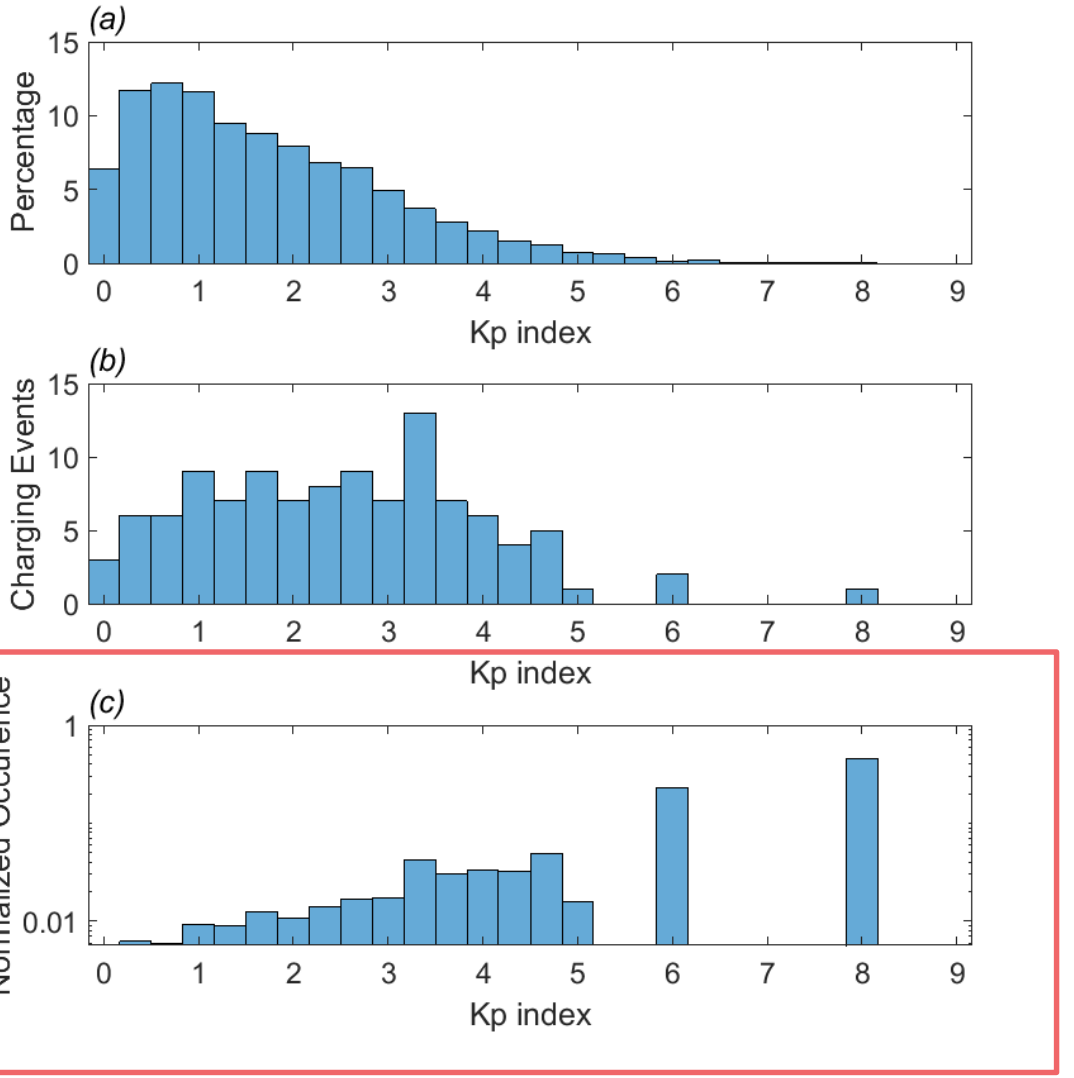


Charging events distributions



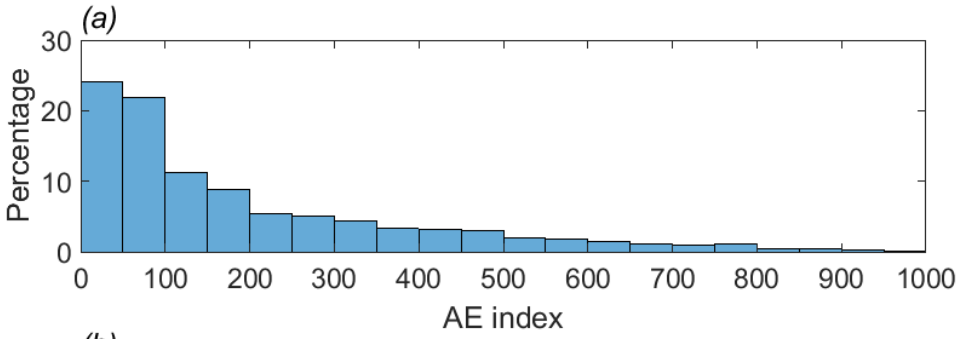


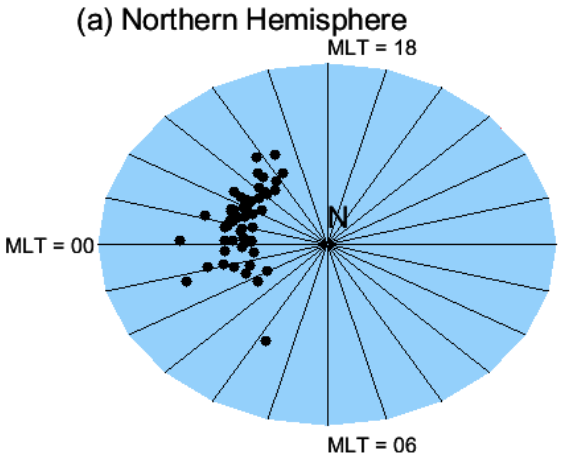


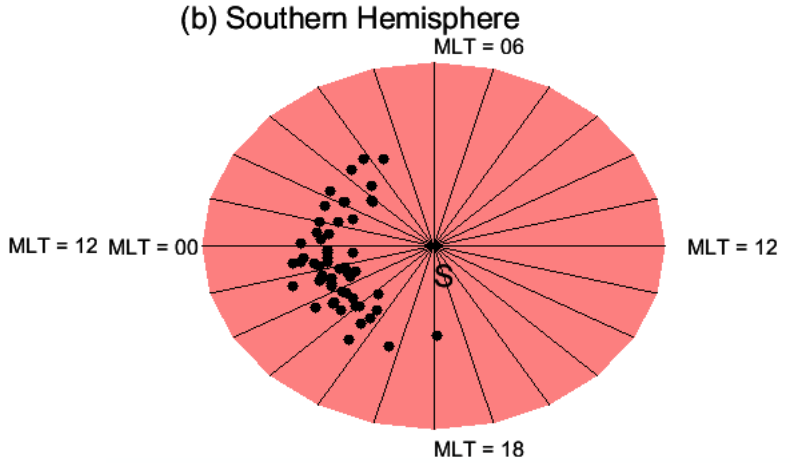


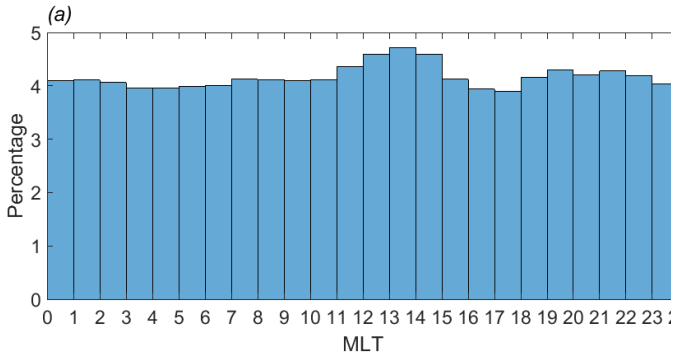
→ THE EUROPEAN SPACE AGENCY

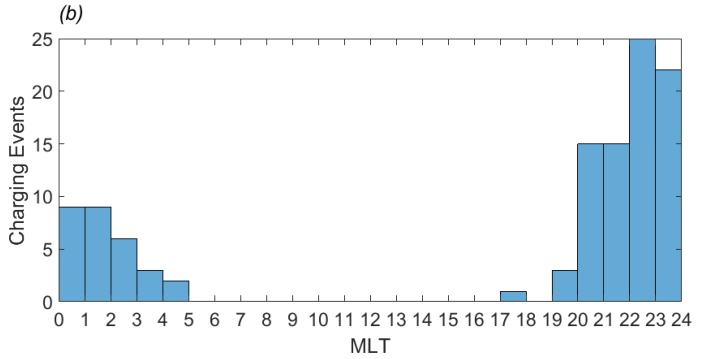
Charging events distributions

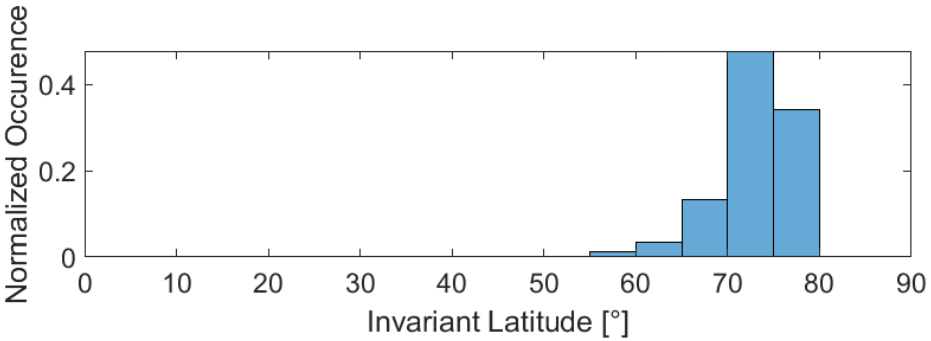




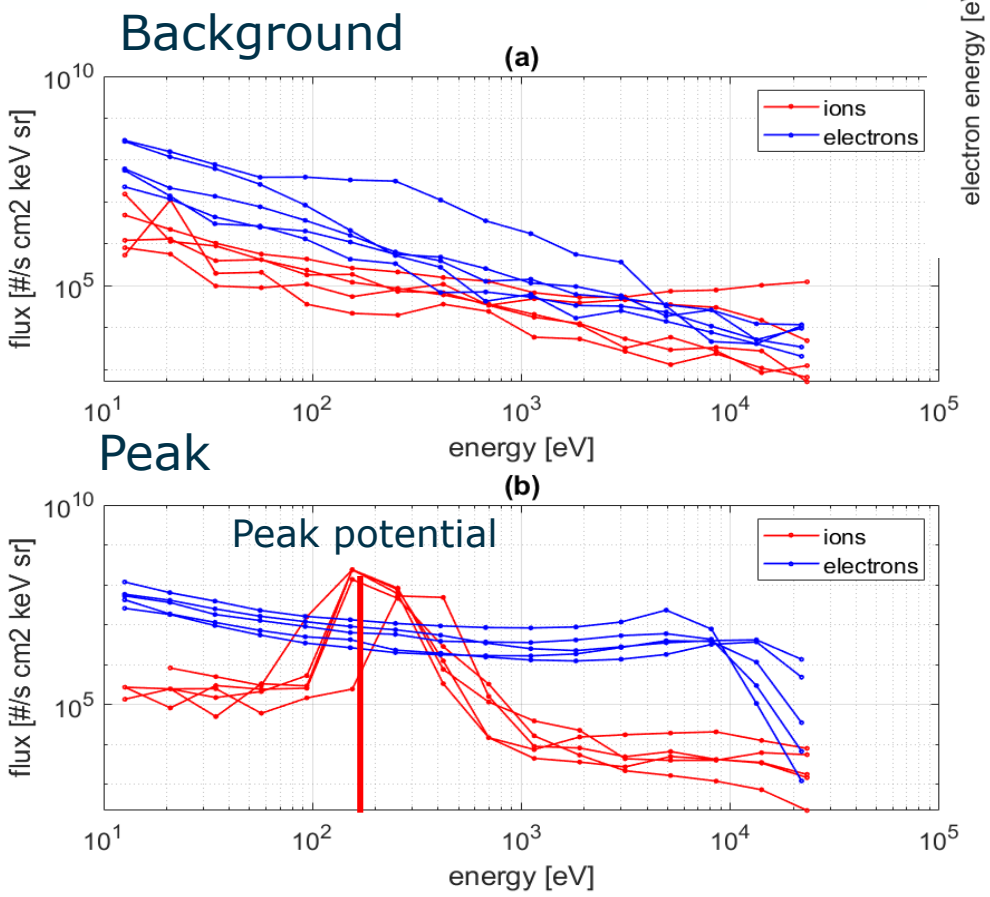


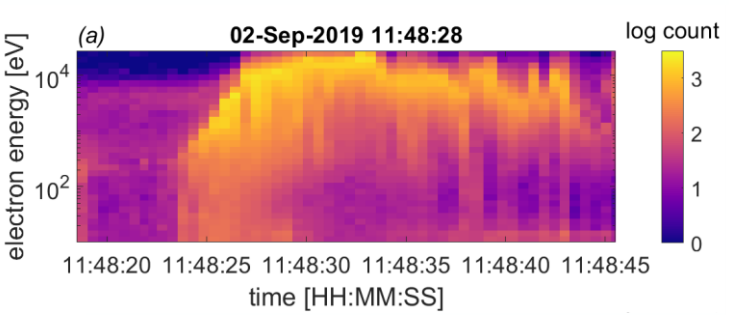


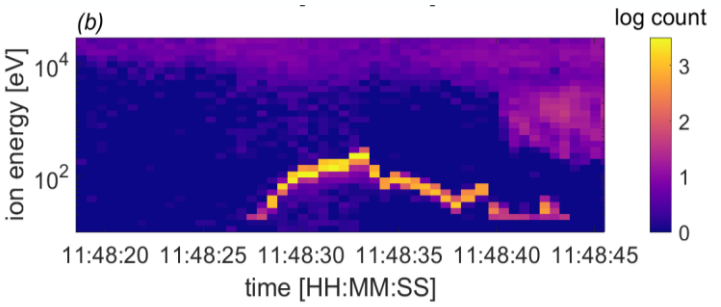


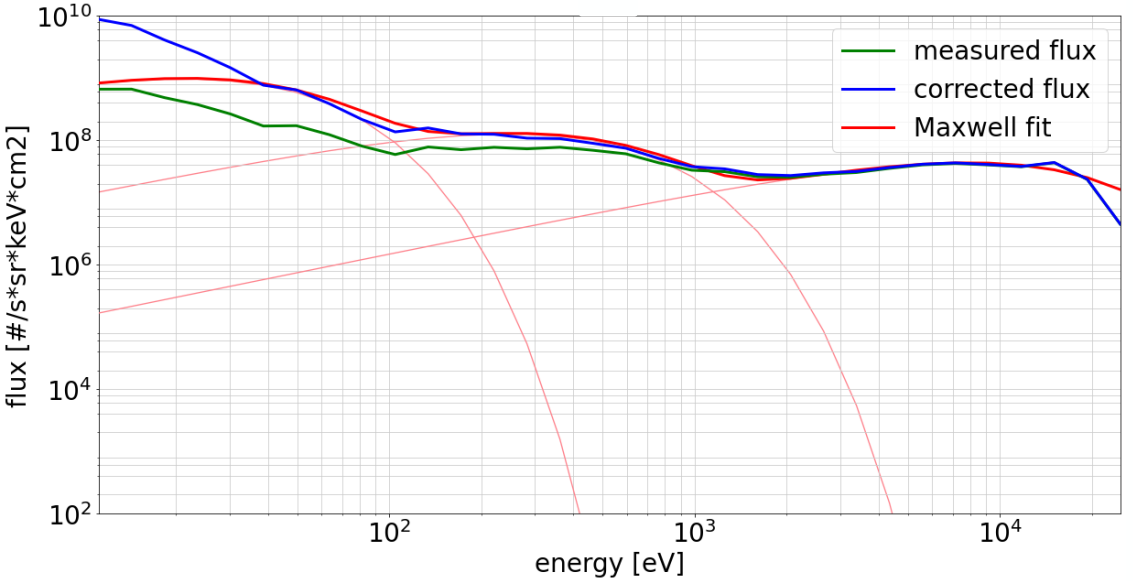


Typical particle fluxes spectra retrieval and and fitting









Conclusions and follow-up

- 110 charging events identified
- Duration between 30s and 1 minute
- Charging levels between ~x-10V and …to <-2000V
- good agreement with previous studies in terms of MLT/LAT distributions, Kp correlation
- In depth analysis as direct follow up of this first statistical survey for systematic evaluation / environment model parameters
- Retrieval of plasma conditions prior charging with 3D modelling (spis)
- Other datasets (when available) should be investigated to strengthen our environment models and especially WC analysis in LEO – revisit ECSS if need be
- More sensors needed !