

Energetic particle observations on-board CubeSats

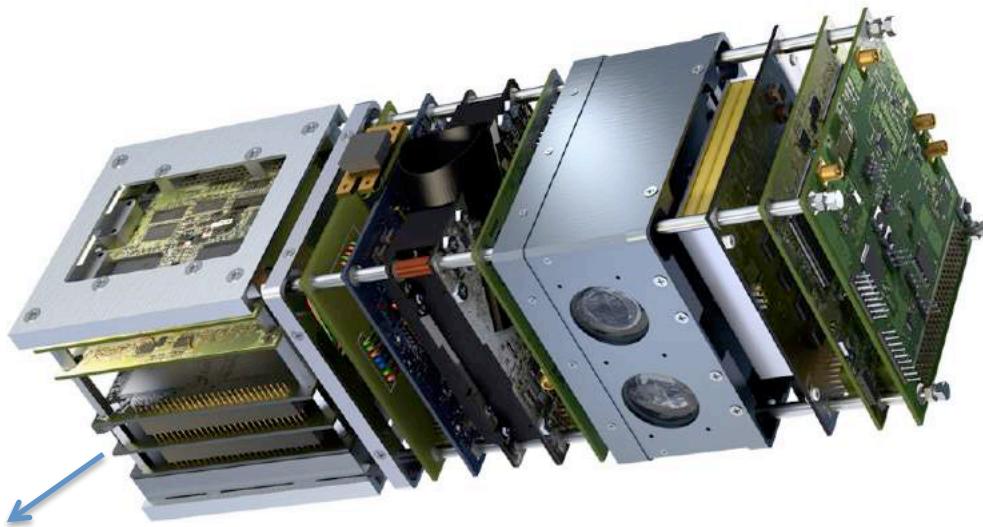
Rami Vainio

With special thanks to
Artu Punkkinen and the rest of the
RADMON and Aalto-1 teams

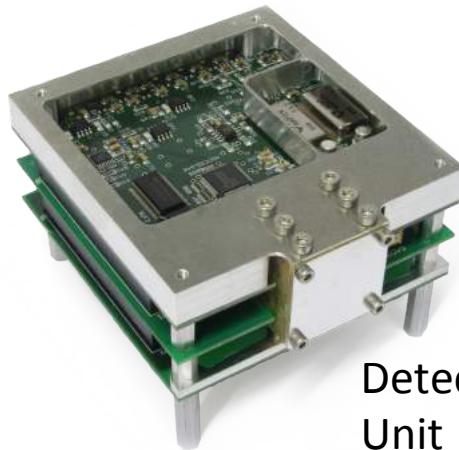
Energetic particles @ LEO by Aalto-1

RADMON

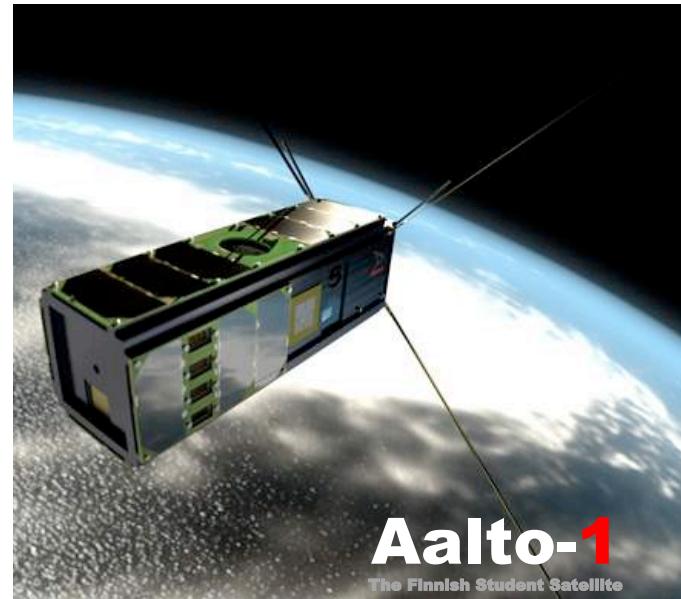
Mass: 0.4 kg
Power: 1 W
Volume: 0.4 U



Analog Board
Digital Board
PSU Board



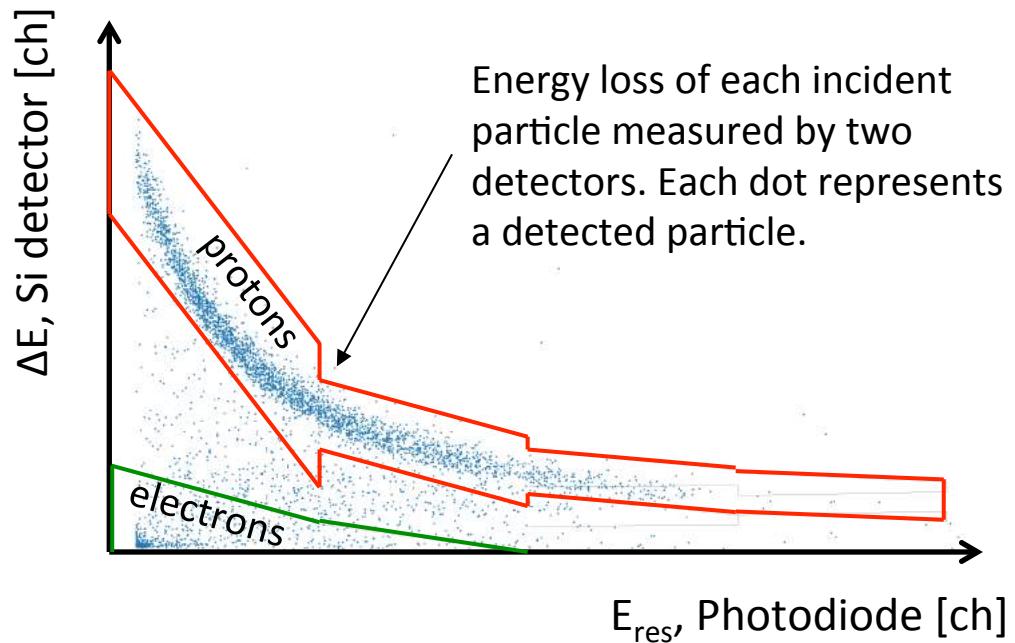
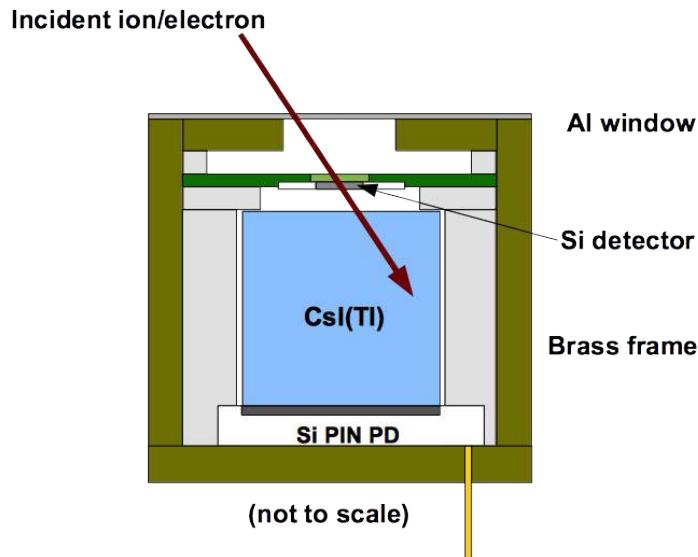
Detector
Unit



RADMON measurement principle: ΔE vs E_{res} method

ΔE @ constant E_{res} gives the species

$\Delta E + E_{\text{res}}$ gives the energy

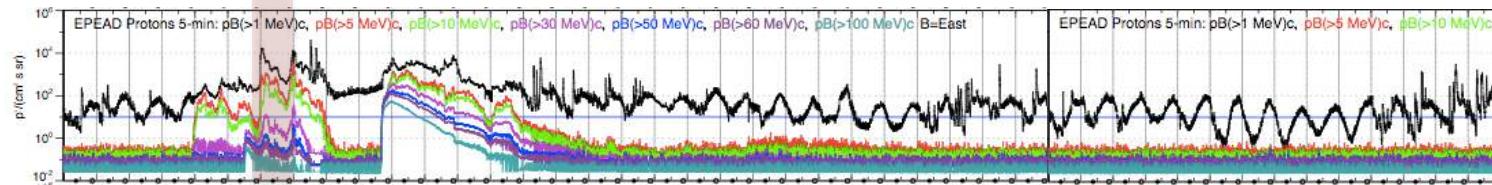
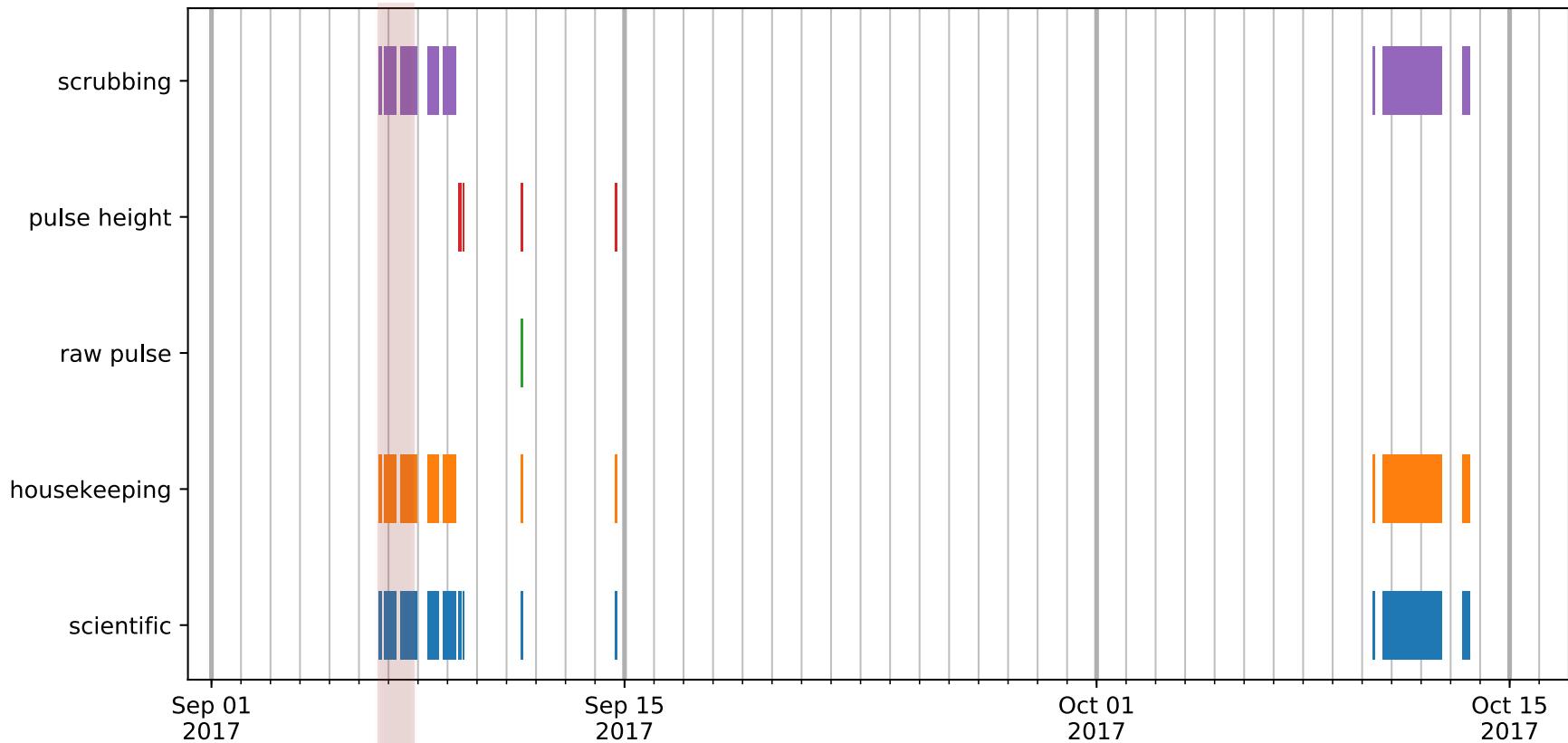


RADMON Mass: 0.4 kg
RADMON Power: 1 W
RADMON Volume: 0.4 U



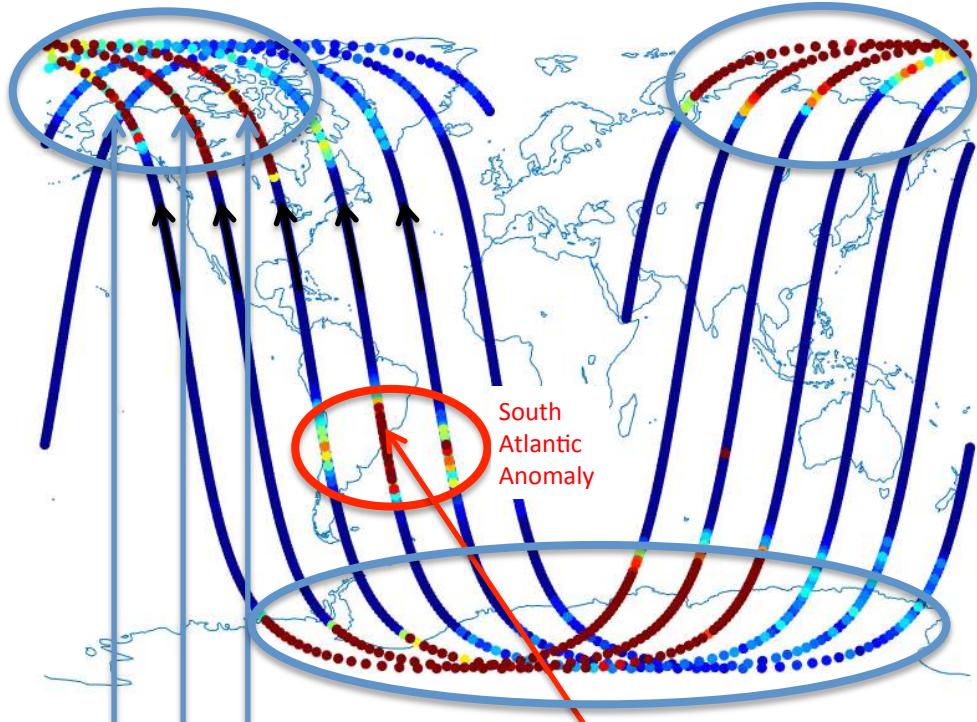


RADMON early data coverage

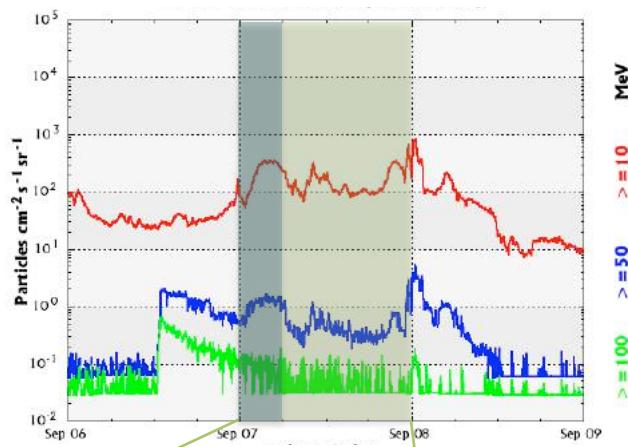


Credit for GOES flux plot: NOAA

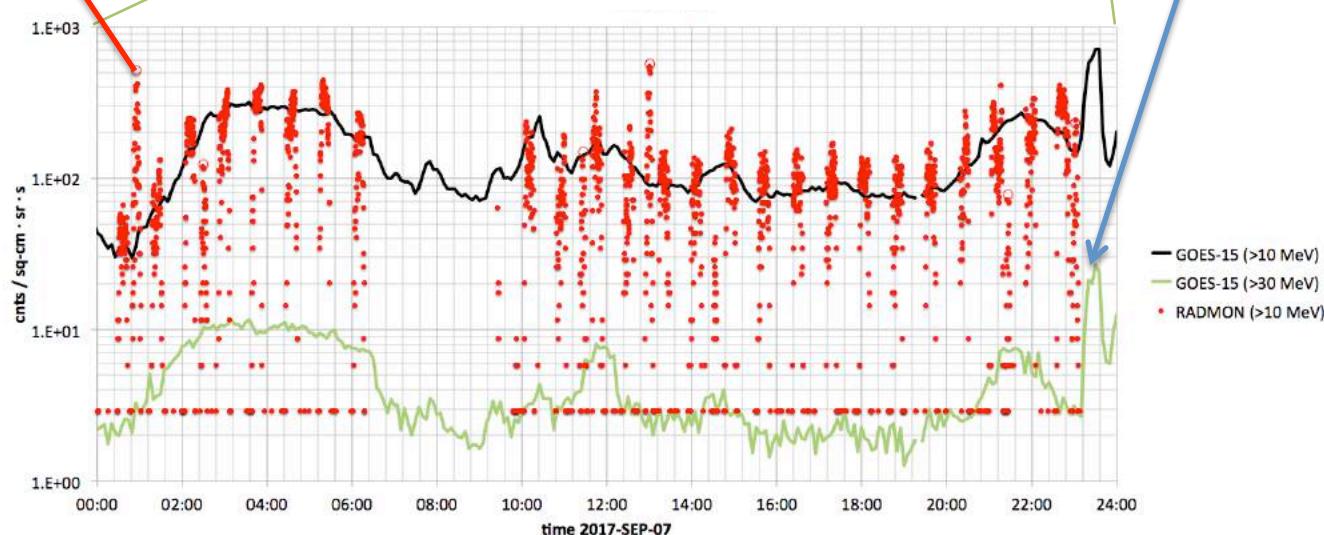
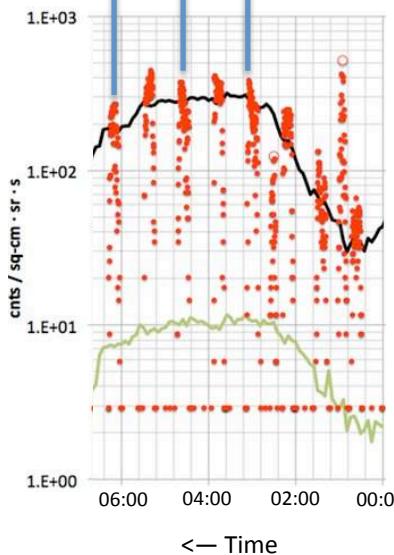
Proton storm



Radiation storm 6-8/9/2017

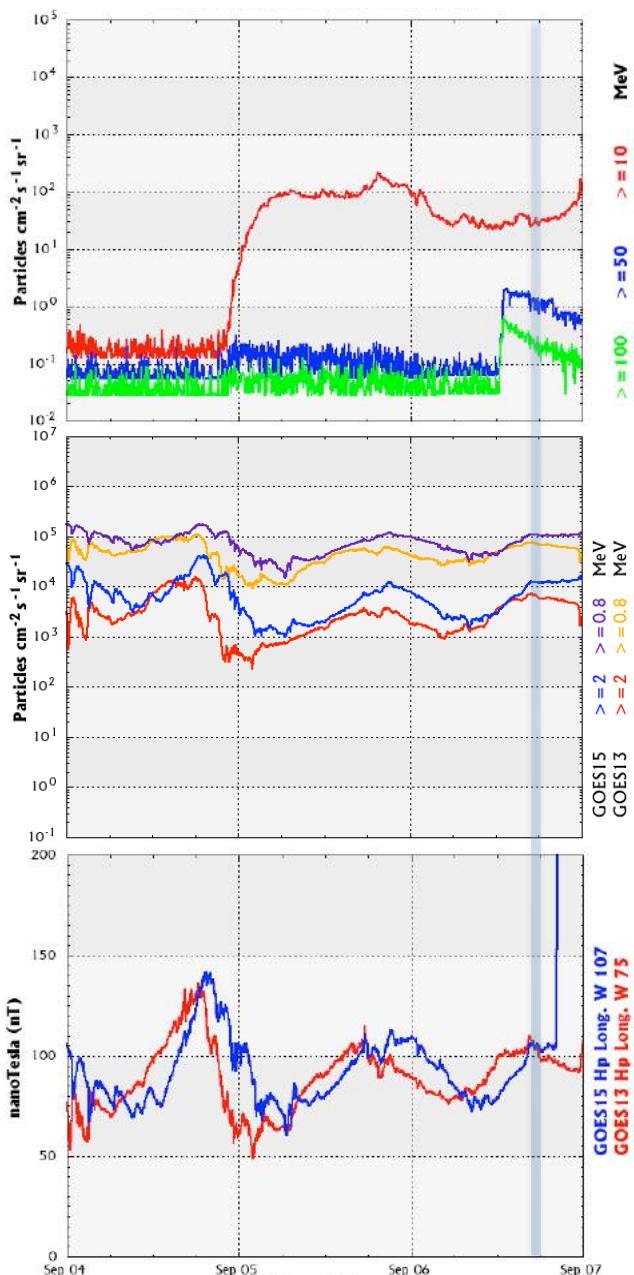
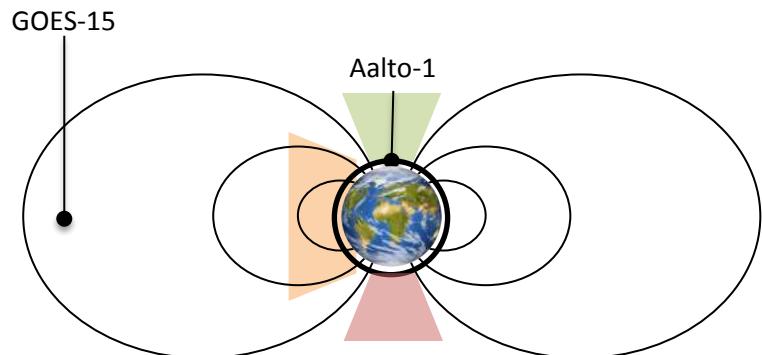
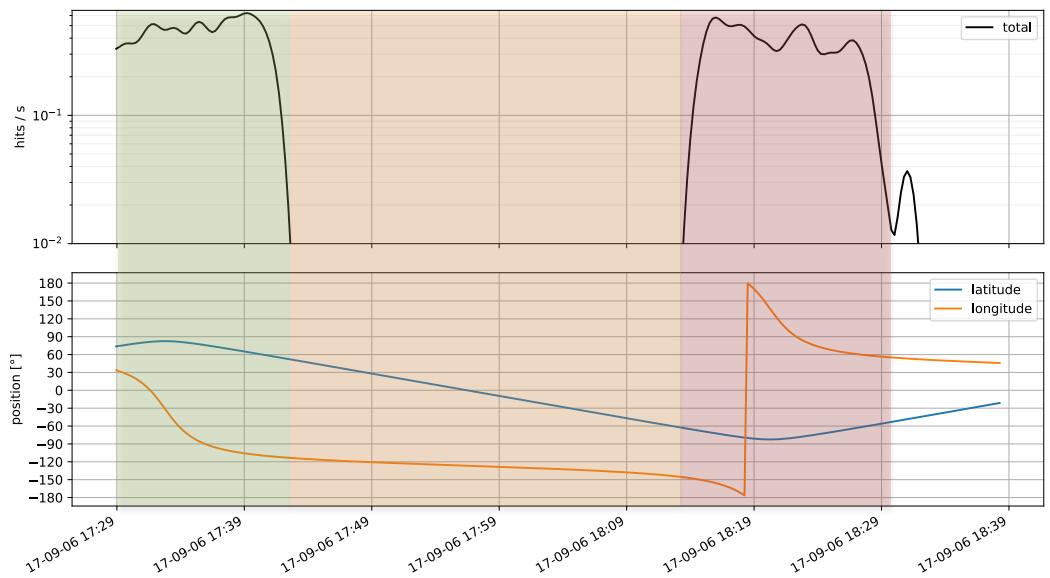


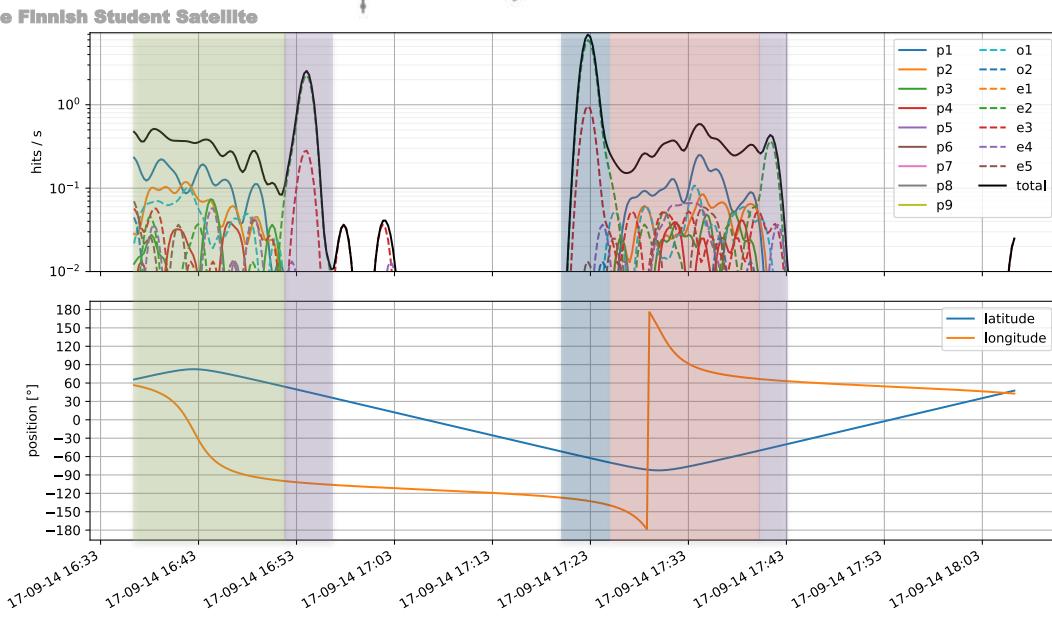
OBC
reboots



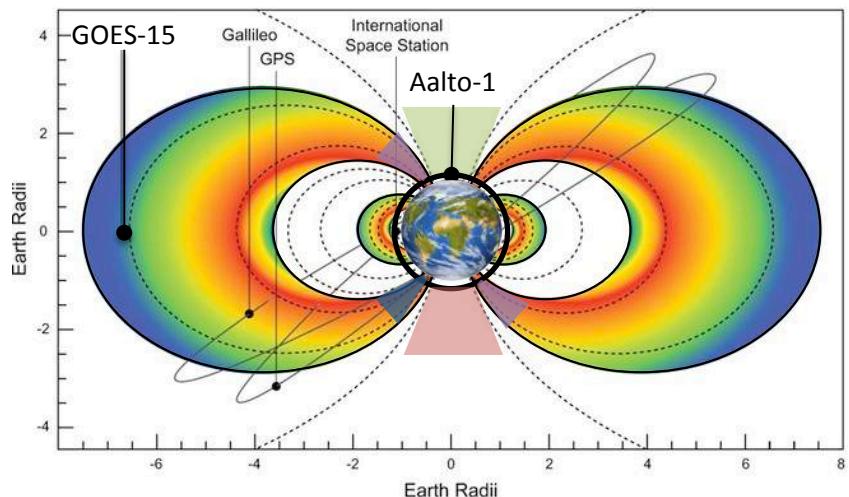
Credit for GOES flux plot: NOAA & KSWC

Radiation storm 4-6/9/2017



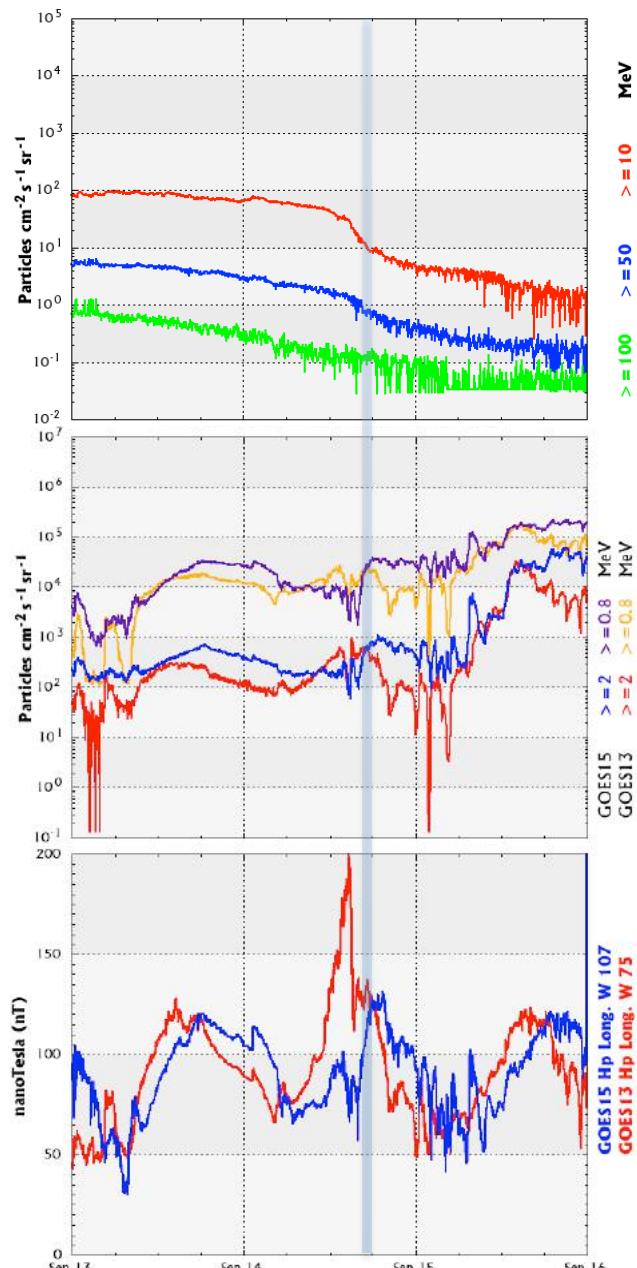


The Earth's Electron Radiation Belts

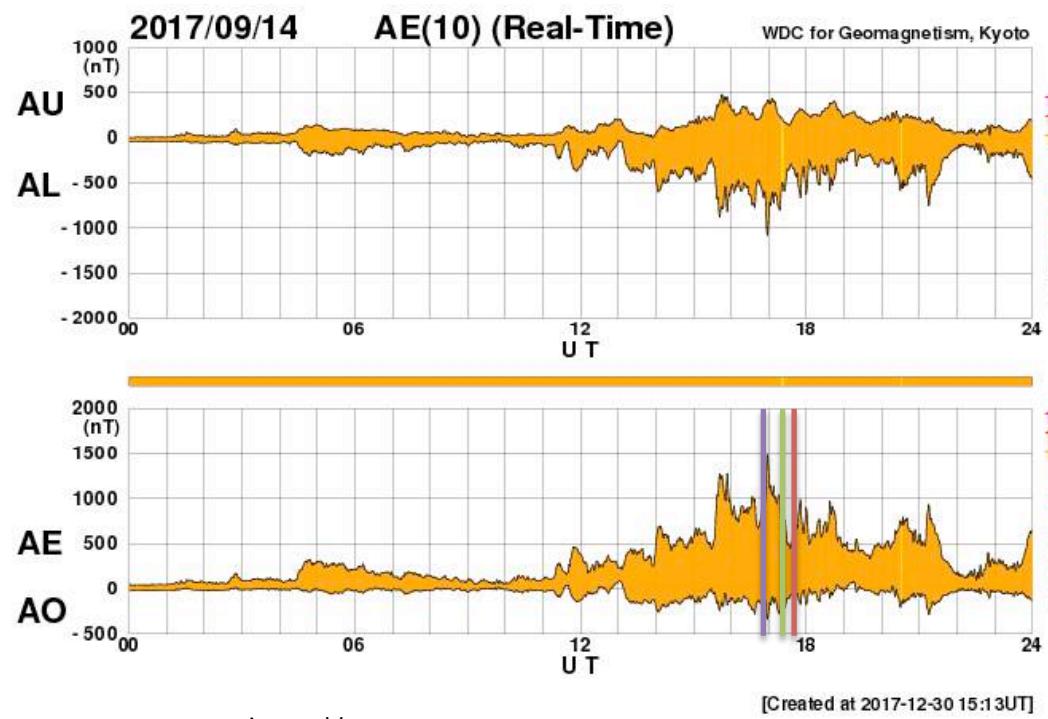


Highly perturbed magnetic field makes electrons rain down from radiation belts to Aalto-1 orbit and atmosphere?

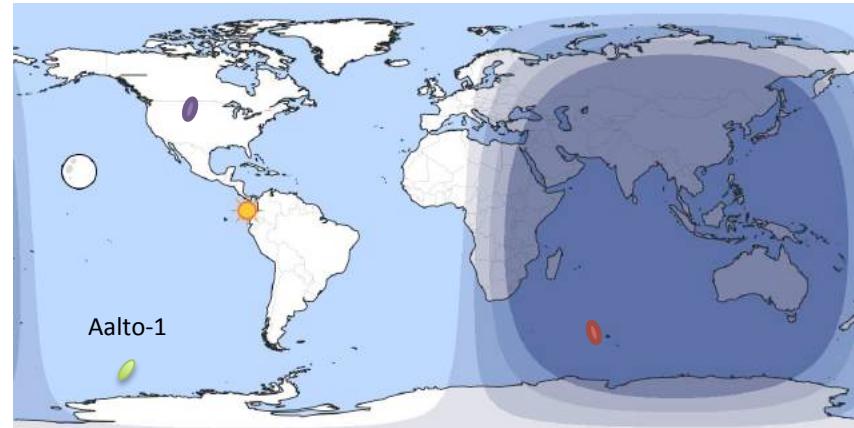
Radiation storm 13-15/9/2017



Credit for GOES plots: NOAA & KSWC



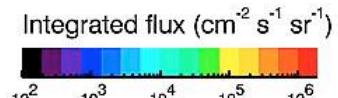
www.timeanddate.com



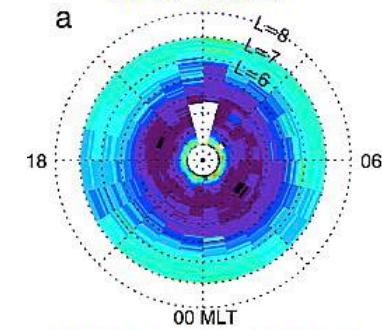
UTC time = Thursday, 14 September 2017, 17:22:00.

Sun is at 80° West; Aalto-1 is at 130° West, i.e., LT 08–09

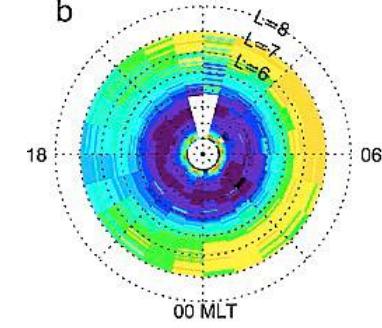
>30 keV e⁻ precipitation



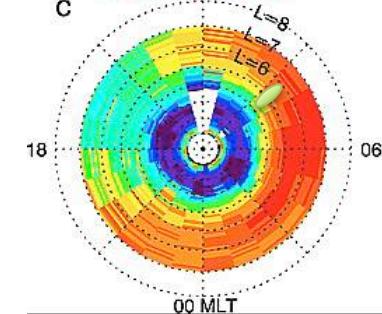
AE < 100 nT

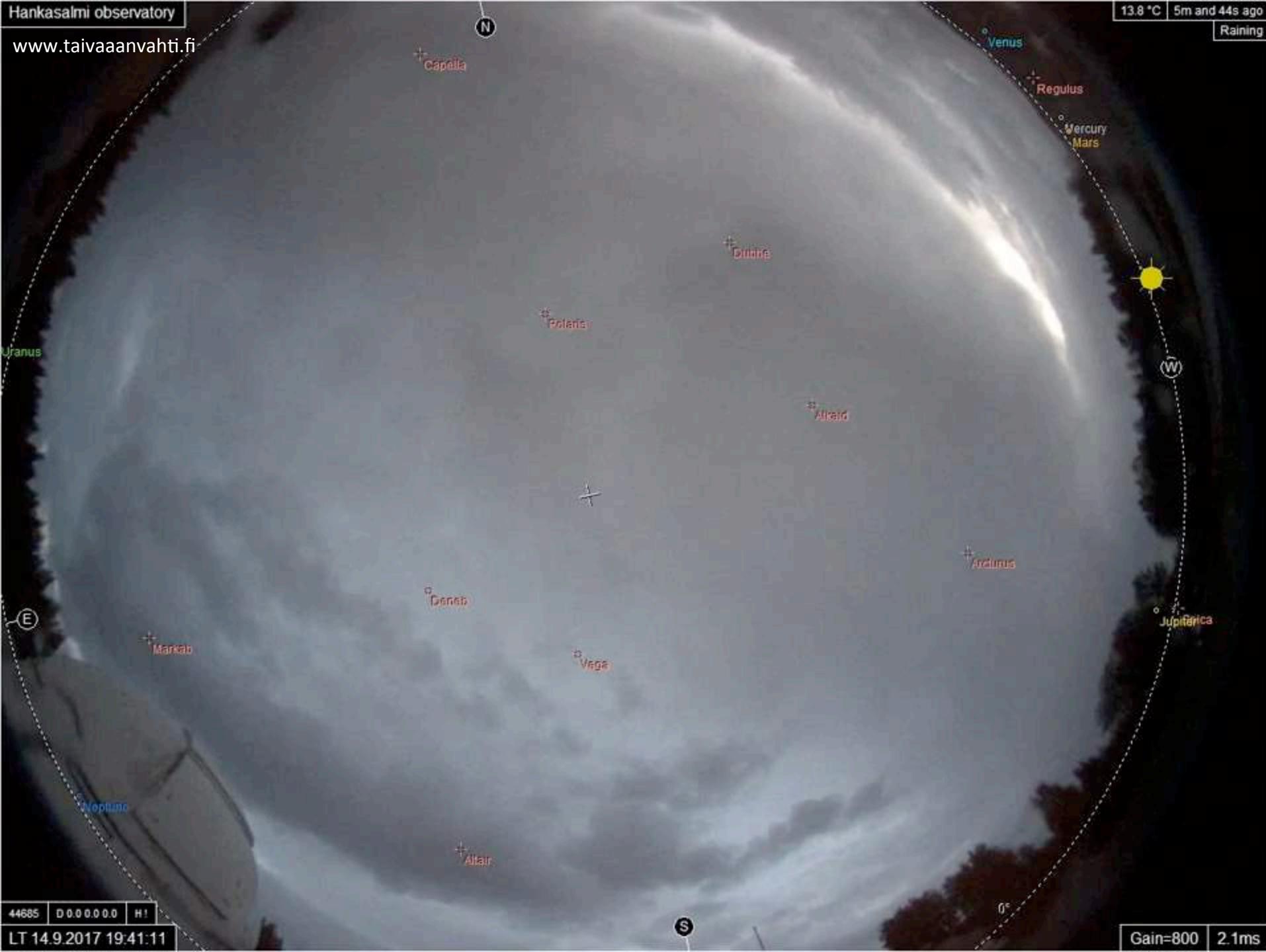


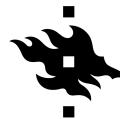
100 nT < AE < 300 nT



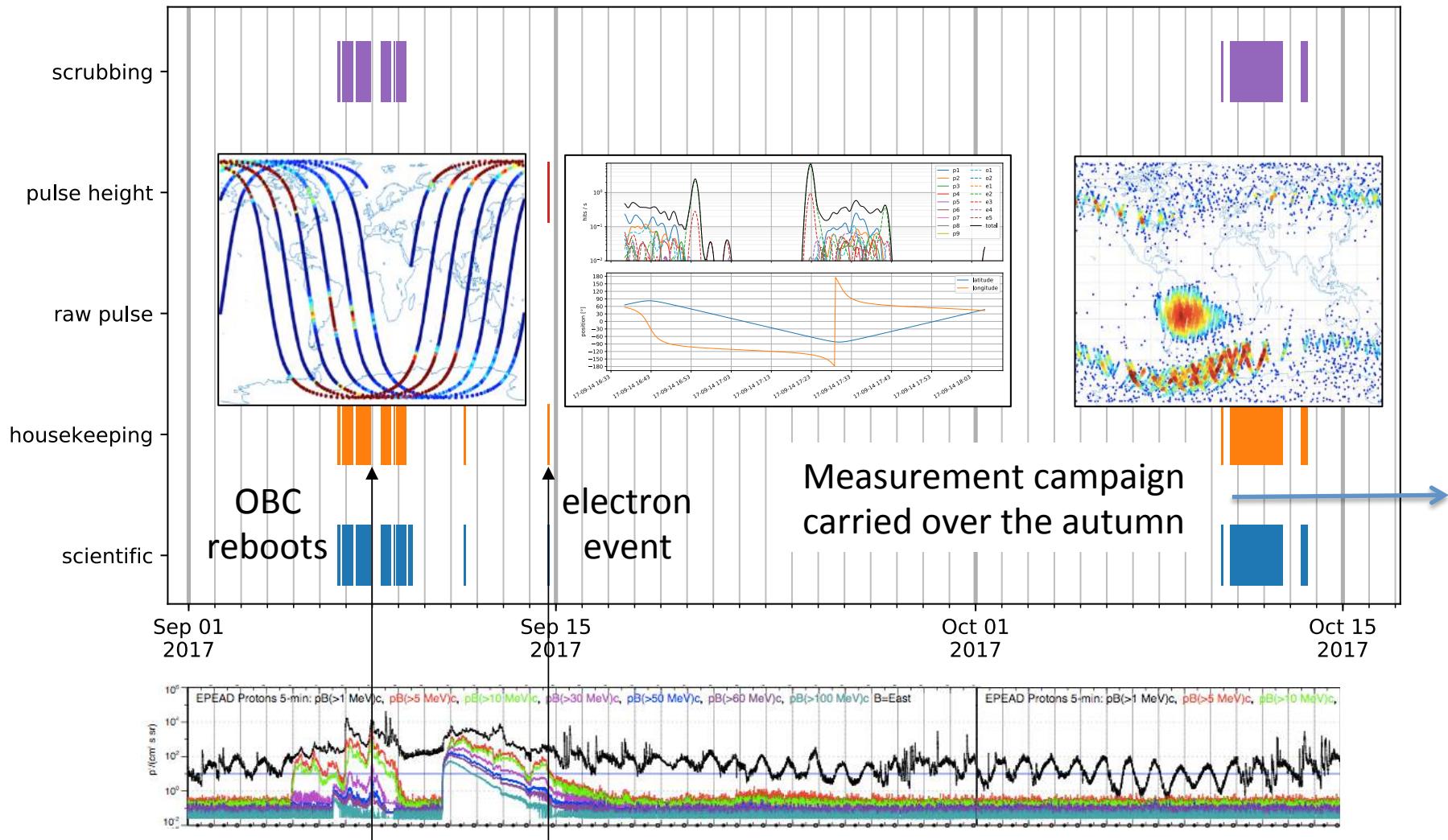
AE > 300 nT

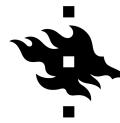




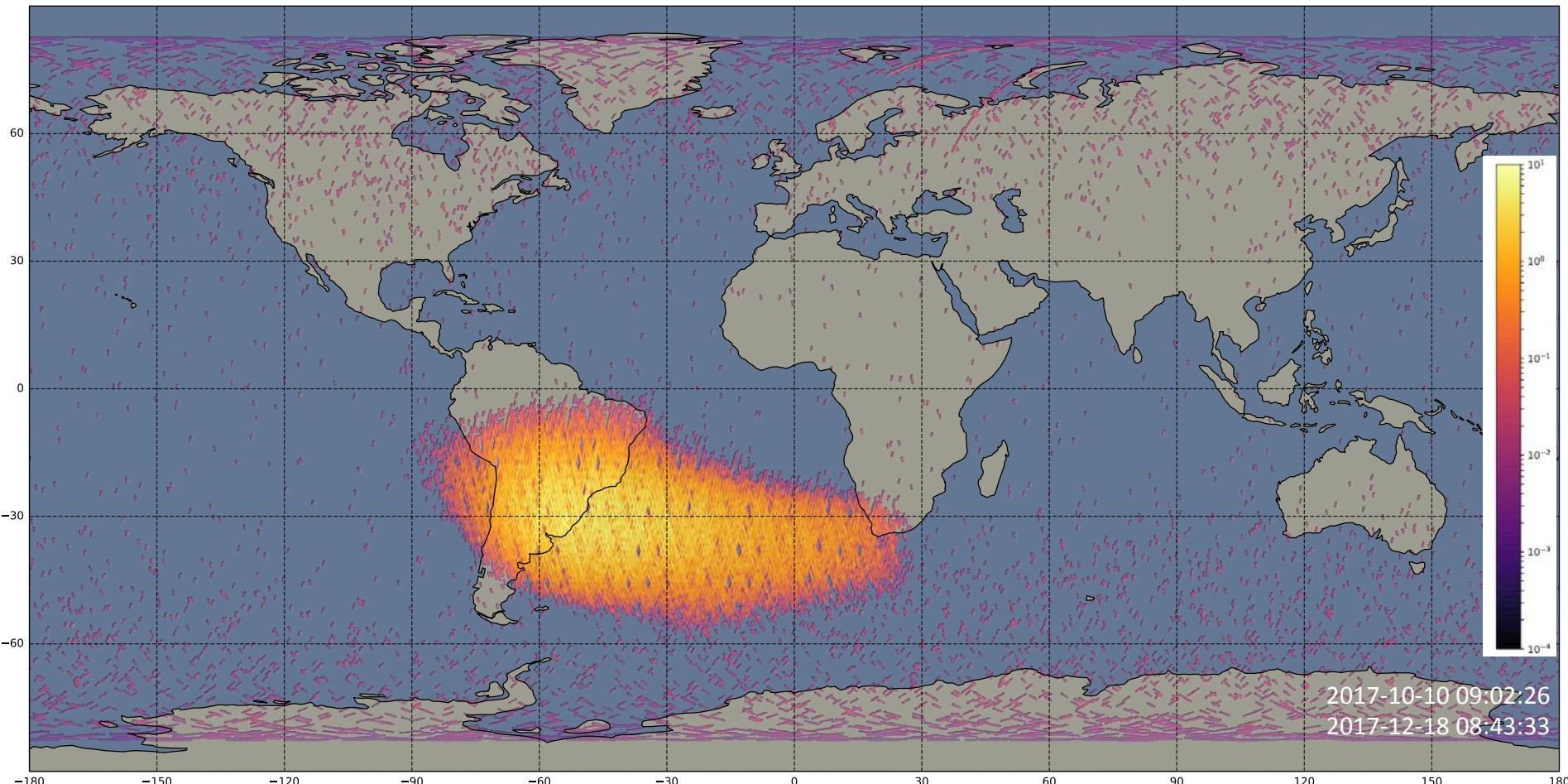


RADMON early data coverage

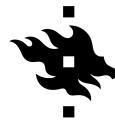




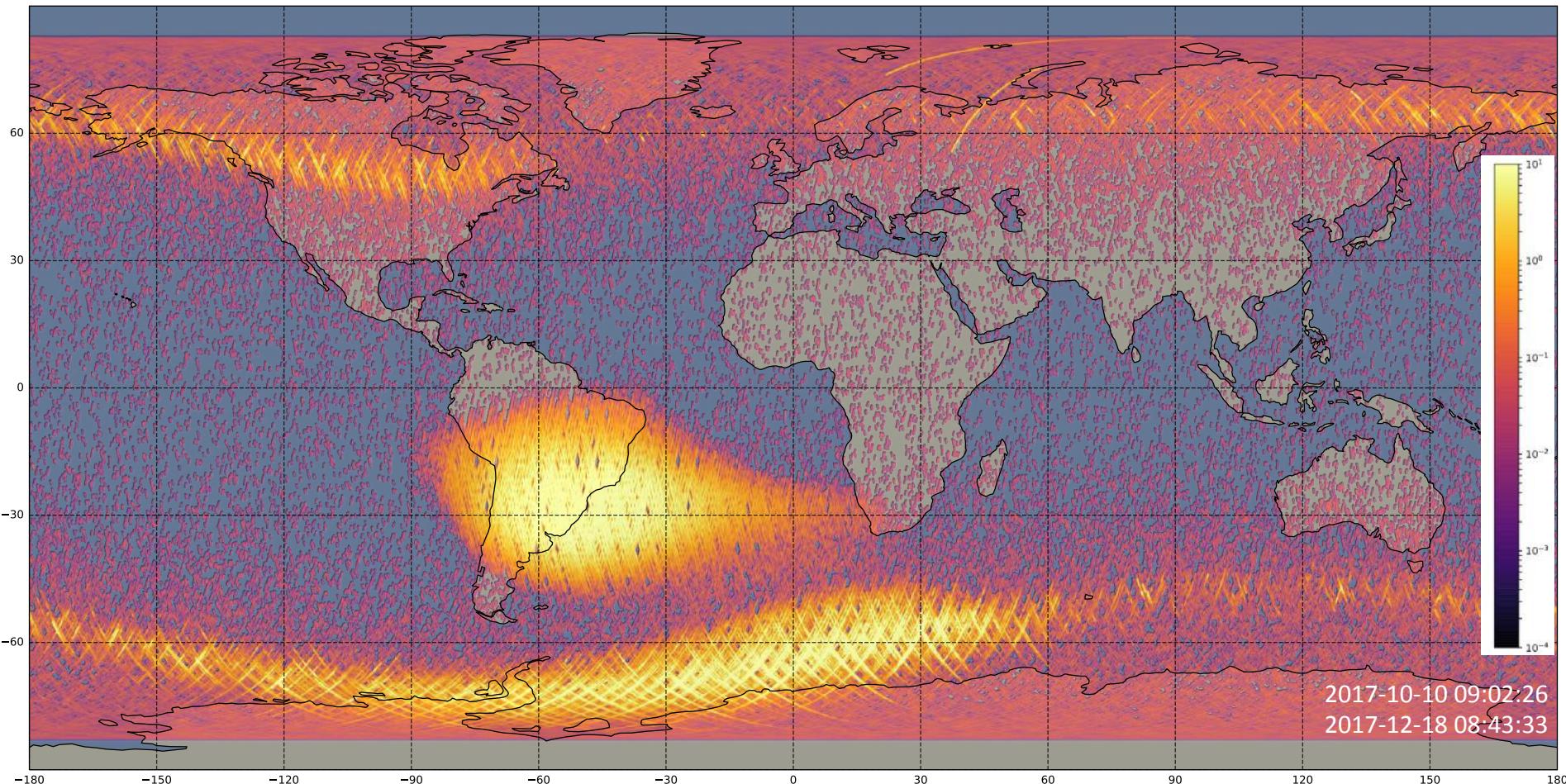
Energetic (>10 MeV) protons



Inner-belt protons observed in SAA at a stable rate [not much orbit-to-orbit variations]



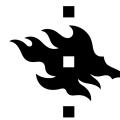
Relativistic (>1 MeV) electrons



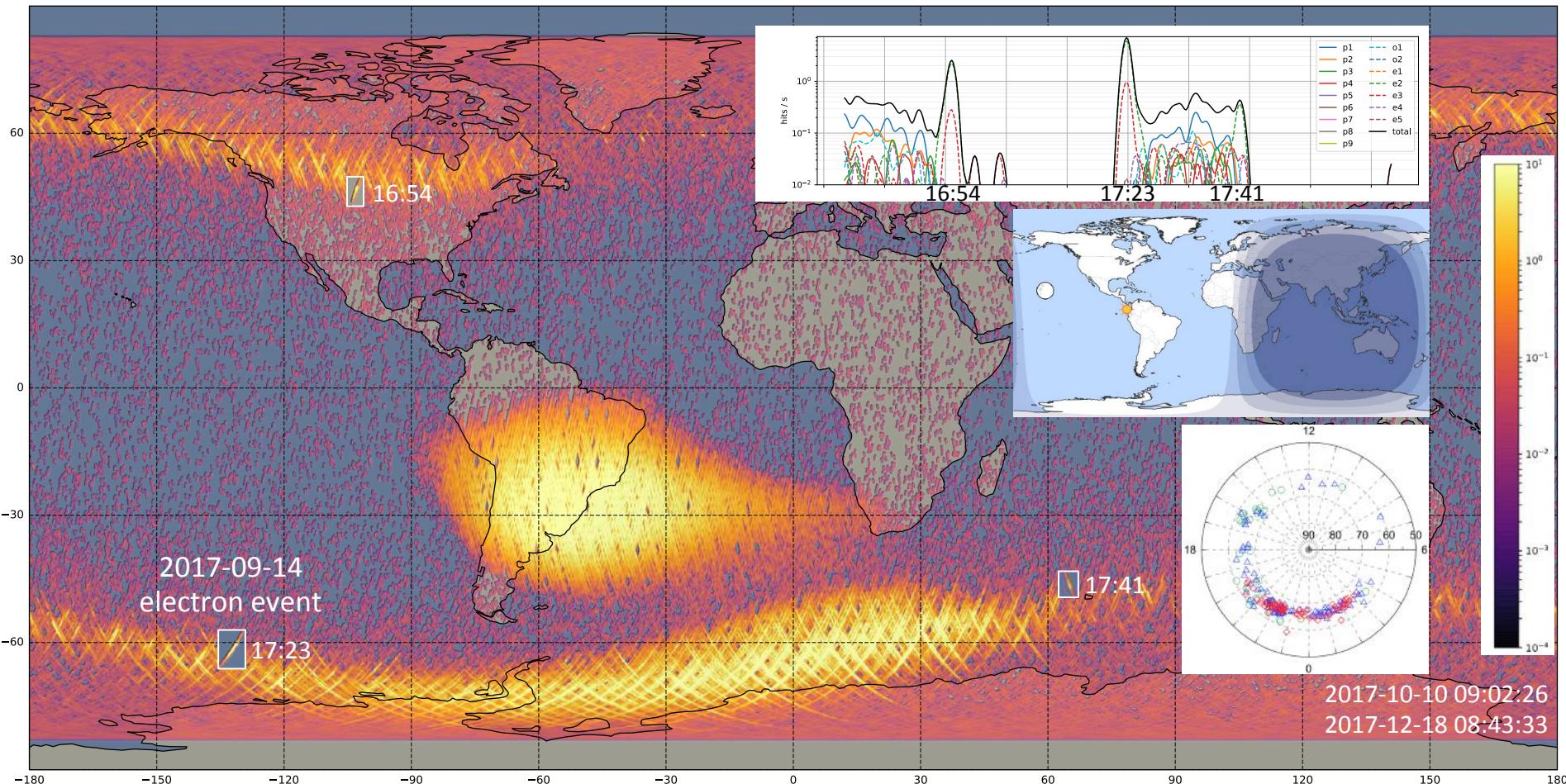
Inner-belt electrons observed in SAA at a stable rate

Outer-belt electrons observed at higher latitudes more variable

Quasi-trapped electron flux increases with longitude from trapped region



Relativistic (>1 MeV) electrons



RADMON electron event on 2017-09-14 is observed at inner edge of average outer belt
 Local times correspond (roughly) to 08, 09 and 21. While typical for lower energies,
 the morning sector is atypical for REP events (Yahnin et al. 2016)?

Fig. A. Punkkinen

Summary of RADMON/Aalto-1

- A simple, low-power low-mass radiation monitor for CubeSat observations was constructed, launched and operated
 - Mass 0.4 kg; Volume 0.4U; Power 1 W; Geometric factor 0.023 cm² sr
- Measures >10 MeV protons and >1 MeV electrons
- Observational campaign has so far produced
 - LEO measurements of a large SEP event, which can be correlated with GEO measurements and local effects
 - LEO measurements of a magnetospheric electron event which can be correlated with auroral and geomagnetic activity
 - Maps of >10 MeV protons and >1 MeV electrons from a two-month campaign from Oct-Dec 2017
- Challenges
 - Electron sensitivity with the scintillator is not optimal
⇒ energy and flux calibration challenging, not yet completed
 - Tumbling state of S/C does not allow assessing measurement directions
⇒ no understanding of pitch-angle distributions (trapped/precipitating)

