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3D mapping of the Earth's trapped radiation particles using µASC: from the inner zone to the magnetosphere

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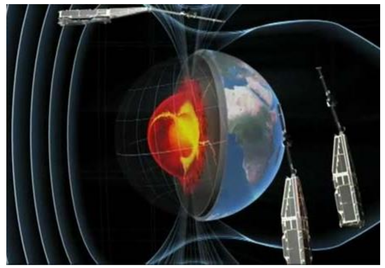
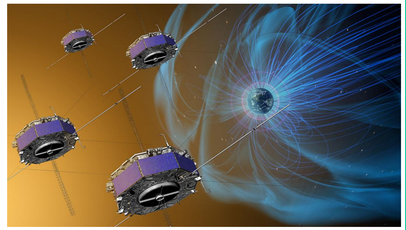
Introduction

As a pioneer of the fully autonomous star trackers, the micro Advanced Stellar Compass (DTU Space) has been operating successfully on numerous satellite missions ranging from Low Earth Orbiters (e.g. ESA's Swarm) to Deep Space missions (e.g. NASA's Juno), accurately providing absolute attitude reference. Besides its primary function of attitude determination, the µASC is also capable of detecting and monitoring the population of the Earth's high energy particles.

The particles with energies high enough (>20MeV) to pass the heavy shielded optics, will leave a temporary trace on the CCD sensor. The signature of these high energy particles is eliminated in flight by the instrument software ensuring full performance even during the most intense CMEs.



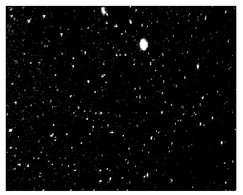


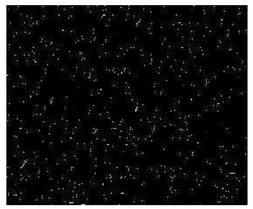
Mapping the rate of the penetrating particles on the CCD sensor enables the monitoring of the high energy particle flux. We present compilation of detected particle flux, its global maps and radial variation from 400 to 10000 km altitude. We further present a view of the dynamic part of the flux, from injection sources such as CMEs, which gives a detailed profiling of the direction, injection time scales and relaxation times.

micro Advanced Stellar Compass µASC

- Designed and produced by the Measurement and Instrumentation (DTU)
- One of the most successful star tracker worldwide
- Autonomously calculates attitude based on all bright stars in the CHUs
- Absolute accuracy of < 1 arc second
- Operating on many satellite missions without a single failure

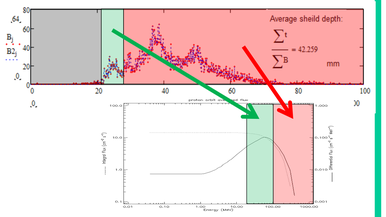
DTU Space µASC

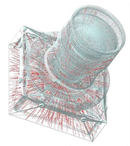




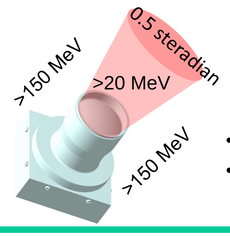
Ionizing particles spectrum shield depth analysis

- Silicon carbide structure and metal CHU housing provides shield length of >>35mm Al eq. in all directions except through the lens
- Lens shield depth is 23-35mm Al eq.



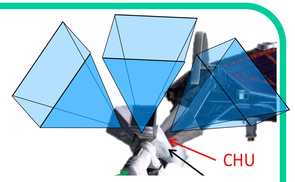


CHU shielding stops charged particles <20 MeV

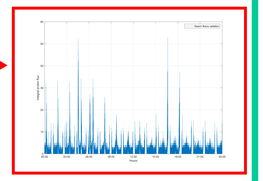


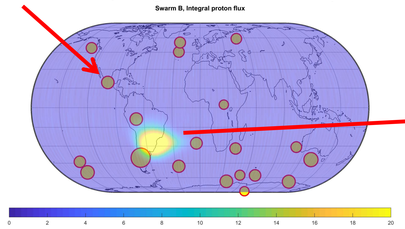
- P+ < 100MeV omnidirectional sensitivity
- Particles > 150MeV penetrates omnidirectionally

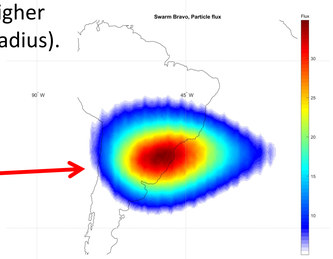
Trapped particles detection



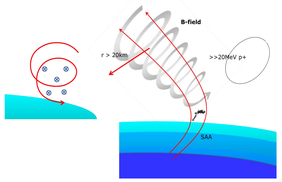
- Swarm mission profile: Two spacecraft at ~450km (A and C) and one at 530km (B) to provide lateral and radial gradients
- Solar quiet times flux: Few protons and no electrons fluxes with penetrating energies, except from over the South Atlantic Anomaly
- Shielded flux for 20 mm Al Shielding (from SPENVIS), incl. trapped and solar protons, ~10 $p^+/cm^2/s$.
- Field of view solid angle should be taken into account. Quiet time flux will result in a few $p^+/cm^2/s$
- **Peak flux** conditions several hundreds times higher (yellow circles , magnitude is shown by circle radius).

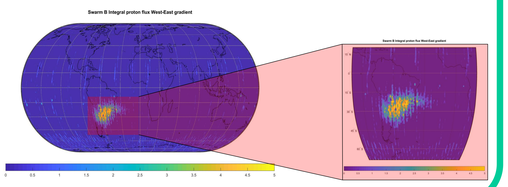






Swarm Integral Proton Flux East-West gradient

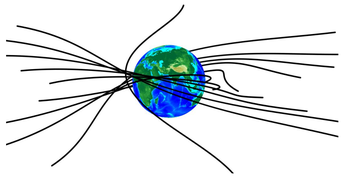




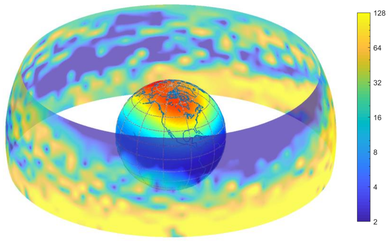
Magnetosphere particles population

MMS (NASA's Magnetospheric MultiScale mission) investigates how the Sun's and Earth's magnetic fields connect and disconnect, explosively transferring energy from one to the other, regulating the geospace weather. It consist of the four identically instrumented spacecraft measure plasmas, fields, and particles . Each spacecraft is equipped with four µASC CHU's which continuously precisely monitor spacecraft attitudes and tracks population of the energetic particles.

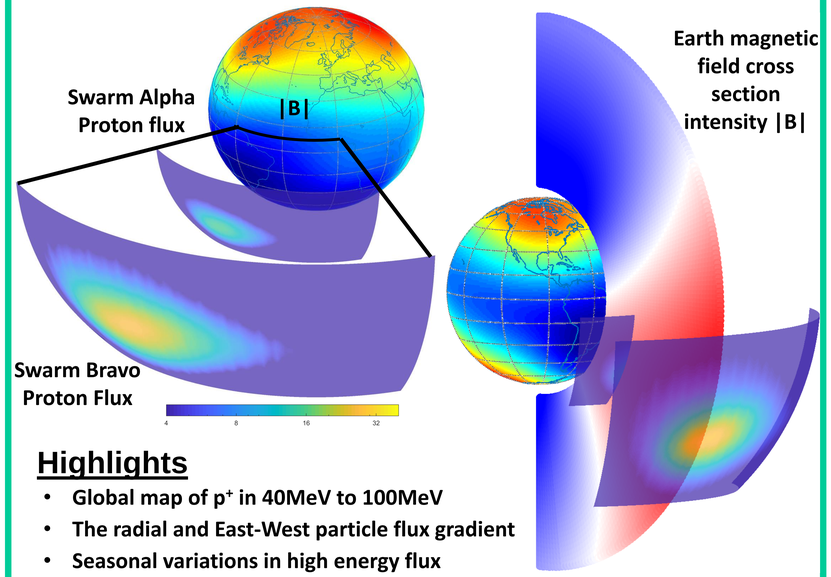
Highly elliptical MMS orbits



MMS particle population (~8000km)



South Atlantic Anomaly Proton Flux radial gradient



Highlights

- **Global map of p^+ in 40MeV to 100MeV**
- **The radial and East-West particle flux gradient**
- **Seasonal variations in high energy flux**
- **Scatter times of protons migrating from trapped to SAA loss cone**
- **Magnetosphere particle population**

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