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The Swarm mission high energy particle flux investigation

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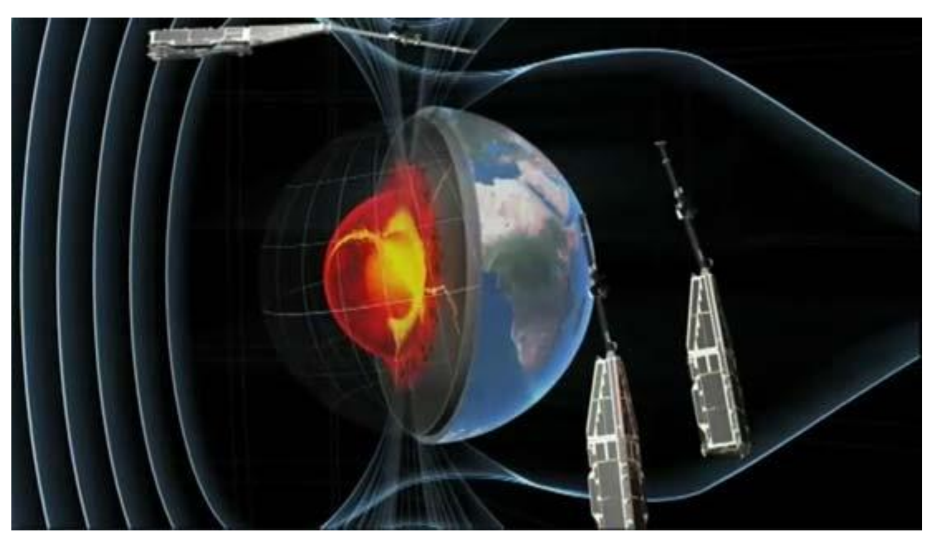
Introduction

Swarm mission constellation, launched into orbit on November 22, 2013, consists of three satellites that precisely measure magnetic signal of the Earth using the ASM and VFM, integrated with three Advanced Stellar Compass star trackers cameras. By using a minimum of magnetic material close to the magnetometer sensors (optimal for the magnetic measurements), the resulting shielding is insufficient to stop the more energetic part of the particle flux encountered in the Swarm constellation orbit, where protons above 60MeV and electrons above 10MeV may penetrate to the focal plane detectors.

To eliminate the ASC cameras sensitivity to passing energetic particles, the ASC employ a suite of morphological filters removing the effects from such particles before the stars observed are matched to the onboard catalogue. The efficacy of these filters is high enough to ensure full performance even during the most intense CMEs, moreover, the measured rate of these penetrating particles, effectively monitors the high energy particle flux. Since May 2018, the spacecraft thus have sent the measured fluxes to ground, enabling very precise map of this part of the energetic flux.

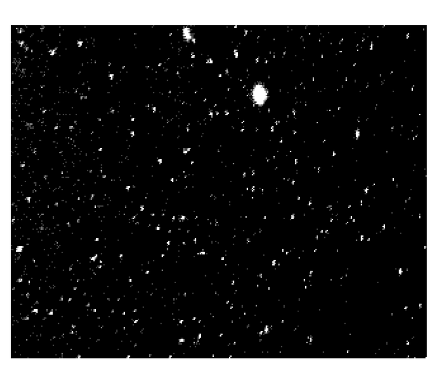


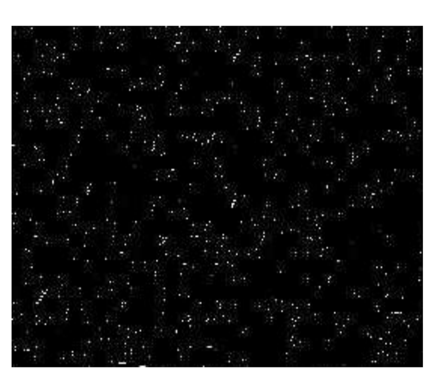
We present world maps of the energetic particle flux, its variation with altitude, local time, direction and seasonal variations. We further present a view of the dynamic part of the flux, from injection sources such as CMEs, which gives a detailed profiling of the direction, injection time scales and relaxation times.

micro Advanced Stellar Compass µASC

- Designed and produced by the Measurement and Instrumentation (DTU)
- to date one of the most successful star tracker worldwide
- autonomously calculates attitude based on all bright stars in the CHUs
- Running a single CHU, µASC can provide 22 true solutions per second
- absolute accuracy of < 1 arc second
- operating on many satellite missions without a single hardware or functional failure

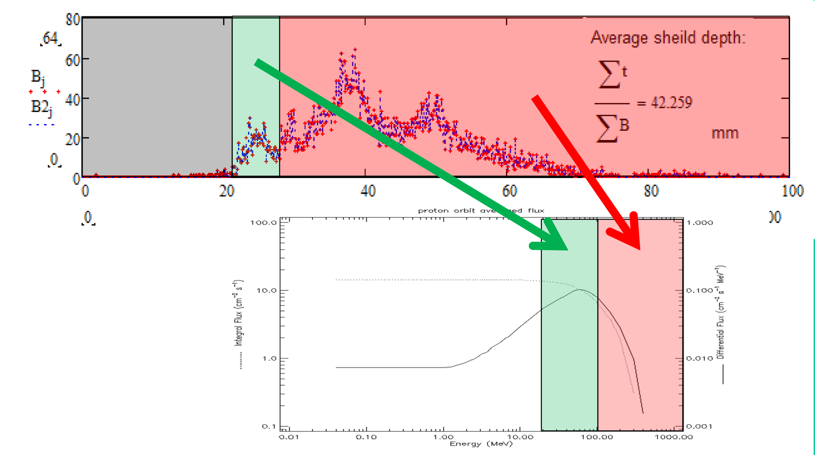
DTU Space µASC





Ionizing particles in the Swarm orbits

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

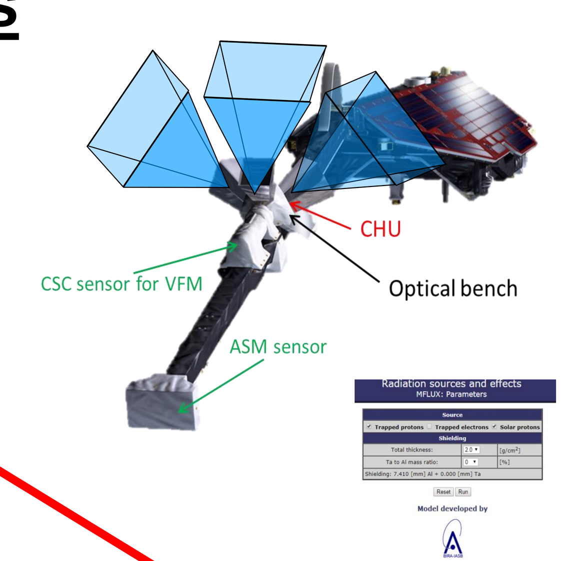


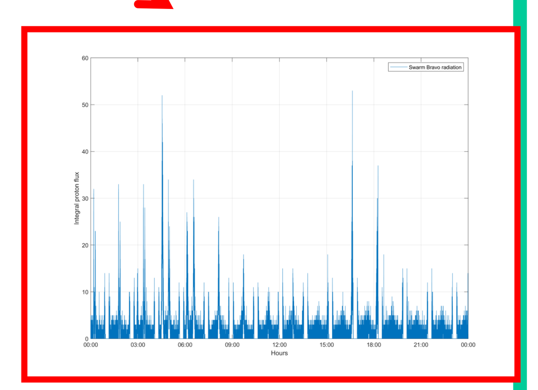
CHU shielding stops everything <20 MeV

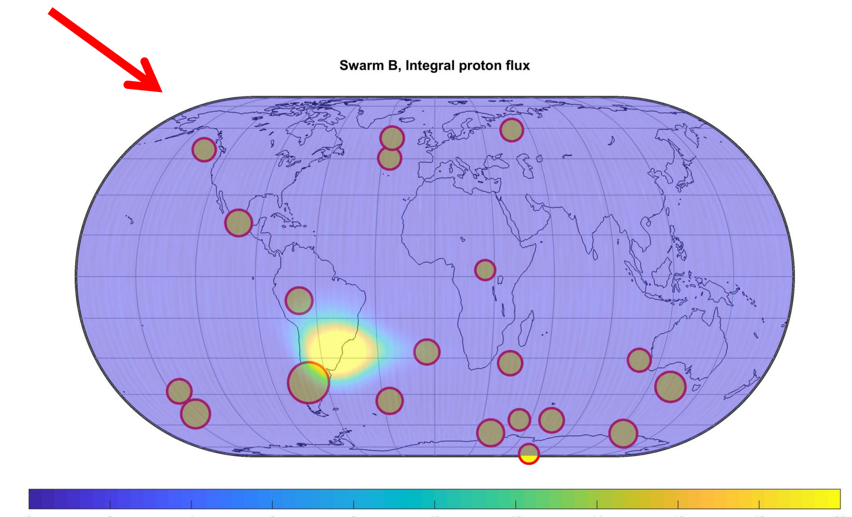
- P+ < 100MeV omnidirectional sensitivity
- Particles > 150MeV penetrates omnidirectionally

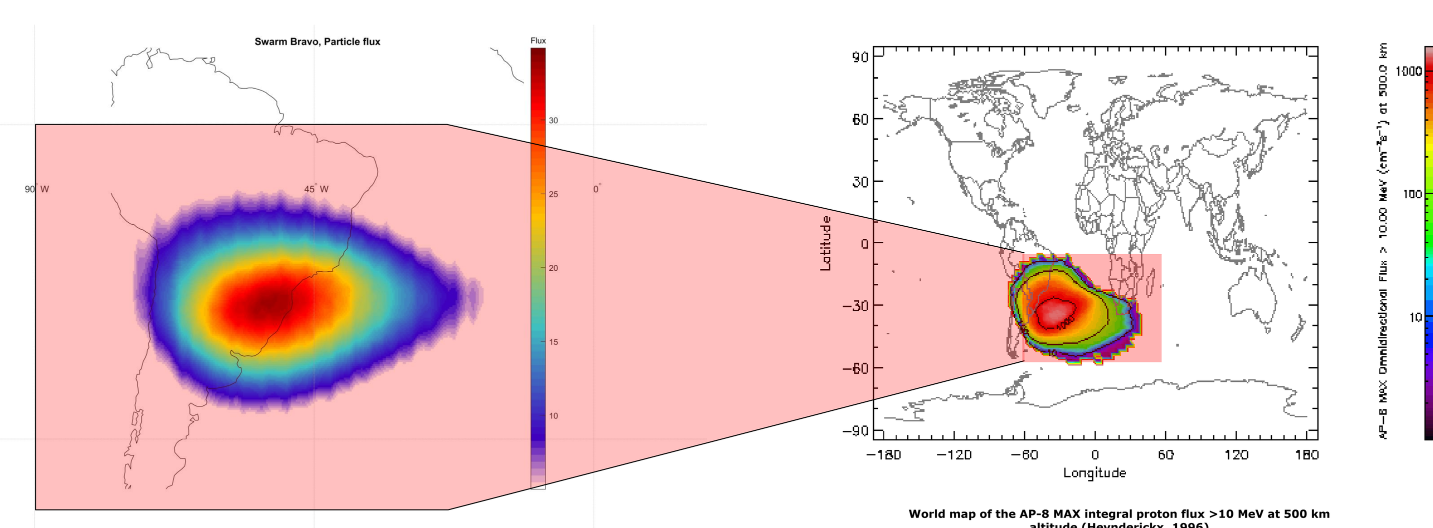
Particles flux for Swarm spacecrafts

- 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+/cm²/s.
- Field of view (in steradians) should be taken into account. Quiet time flux will result in a few p+/cm²/s
- **Peak flux** conditions several thousand times higher

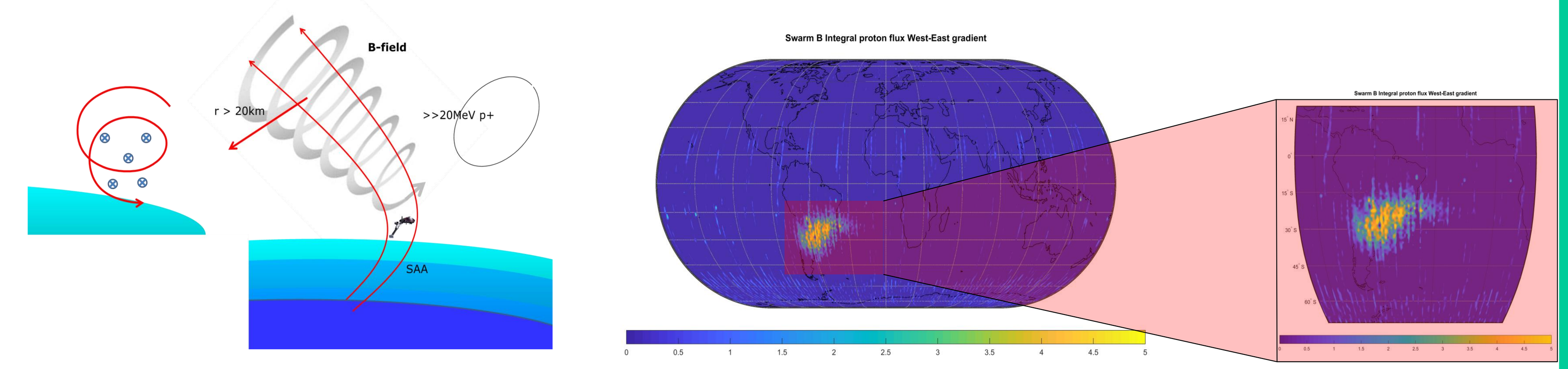




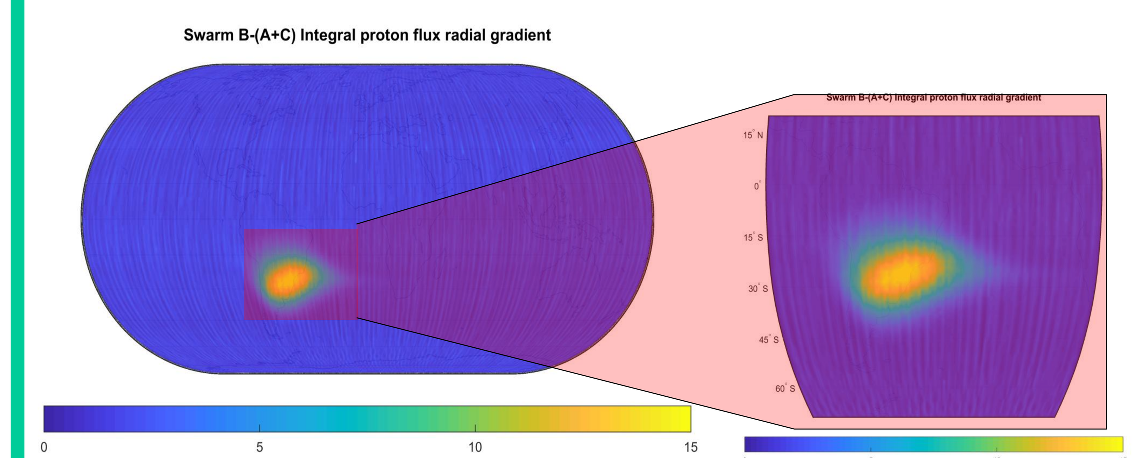


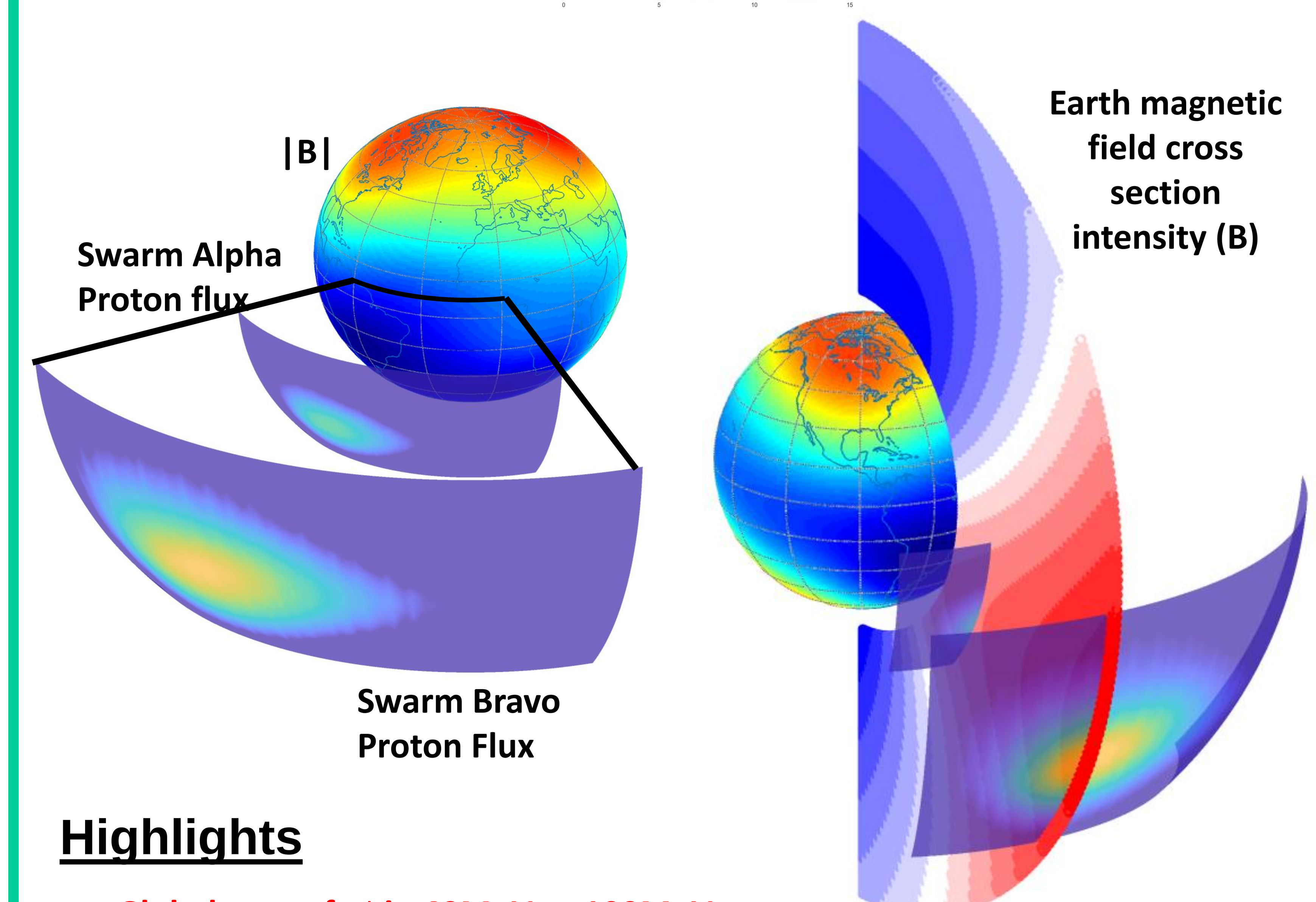


Swarm Integral Proton Flux East-West gradient



Swarm Integral Proton Flux radial gradient





Highlights

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

References

Jørgensen, P. S., Jørgensen, J. L., & Denver, T, 2004. *µAsc: a miniature star tracker*, Proceedings of The 4S Symposium: Small Satellites, Systems and Services (ESA SP-571). 20 - 24 September 2004, La Rochelle, France. Editor: B. Warmbein. Published on CDROM., id.55.1, 2004ESASP.571E..55J***Haagmans, R.**, 2005. Swarm: The Earth's. Magnetic Field* and. *Environment Explorers. Mission. Requirements. Document* for. *Phases B*, C/D, E1

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