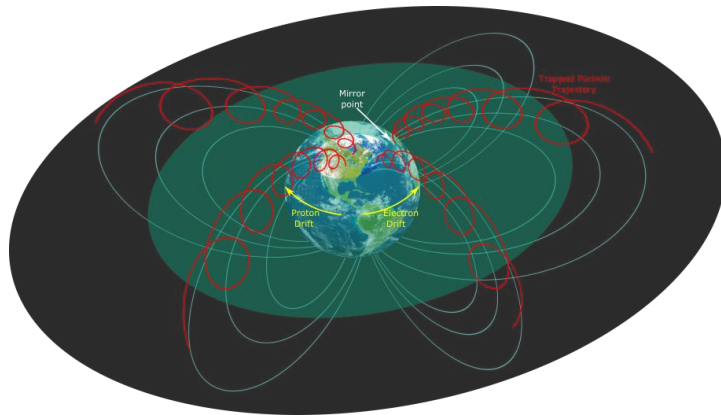


# Results of the radiation monitoring and the implications for the associated drift shells

John Jørgensen, Matija Herceg, Peter Siegbjørn Jørgensen

Technical University of Denmark

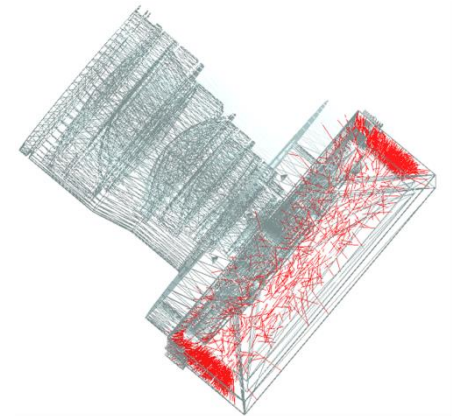
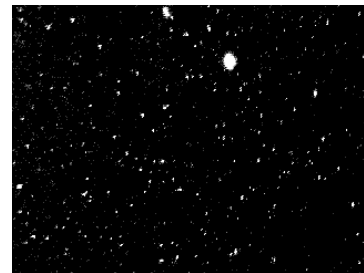
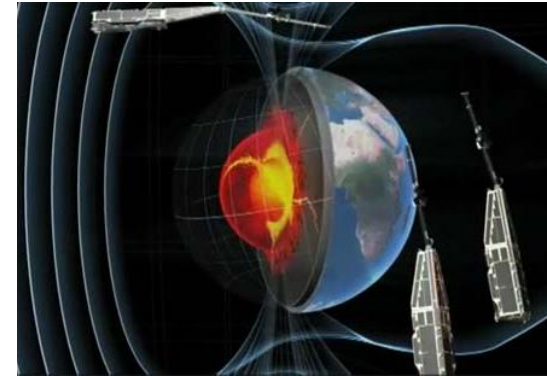


DTU Space  
National Space Institute

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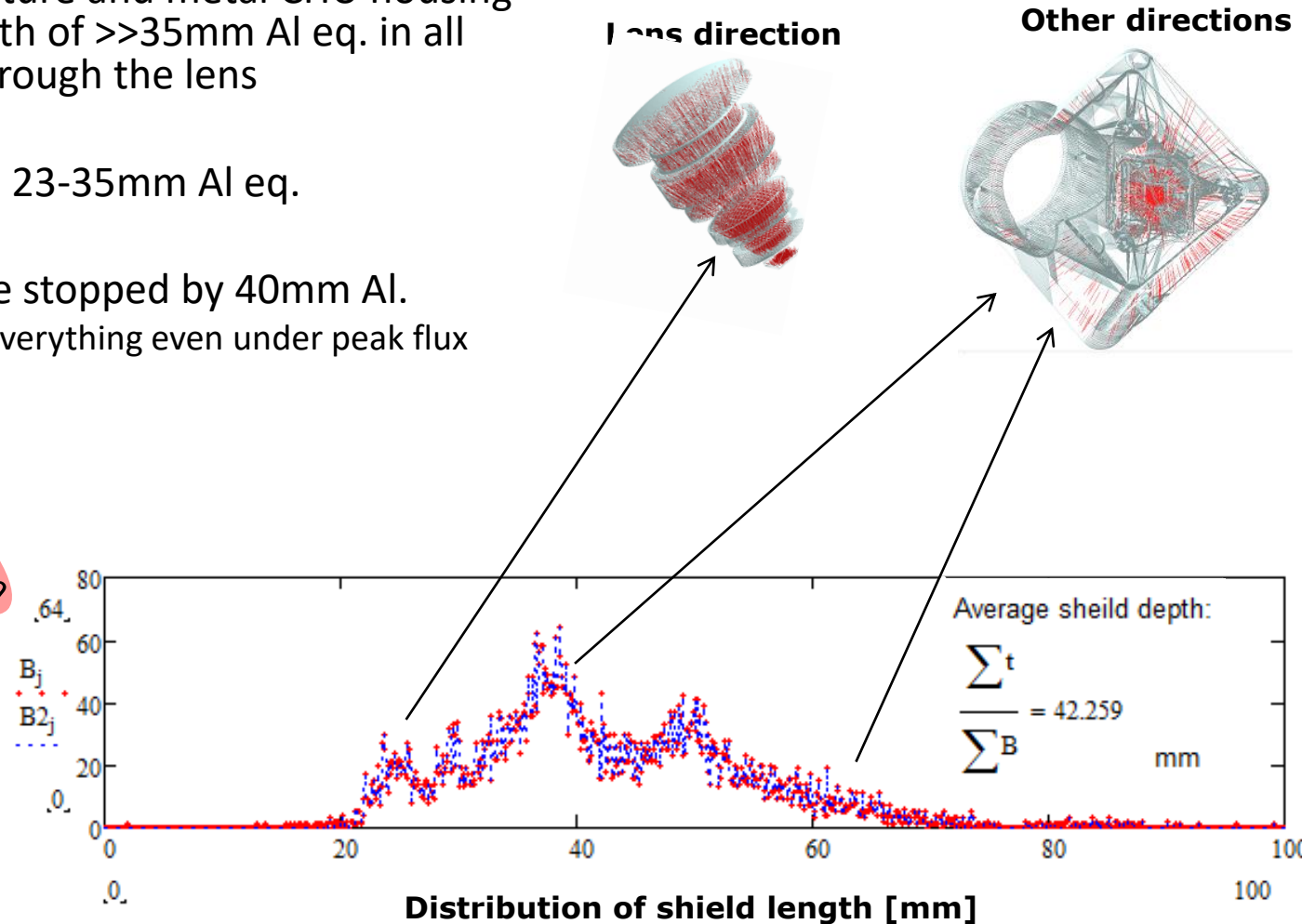
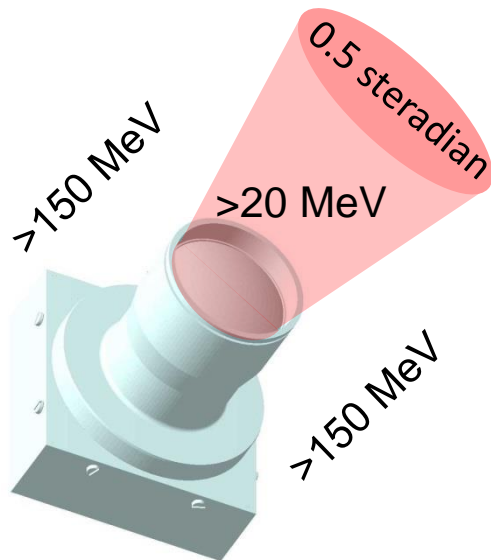
# Monitoring particles

- Star tracker flight software has been updated to enable particle count telemetry.
- additional product is generated during each attitude cycle (1Hz/2Hz) by counting the number of hotspots
- The product adds radiation environment monitoring to the instrument alongside with the attitude determination and is envisaged for auxiliary science investigation.
- The functionality has been uploaded to the primary STR electronics on all three spacecraft and is now fully commissioned.



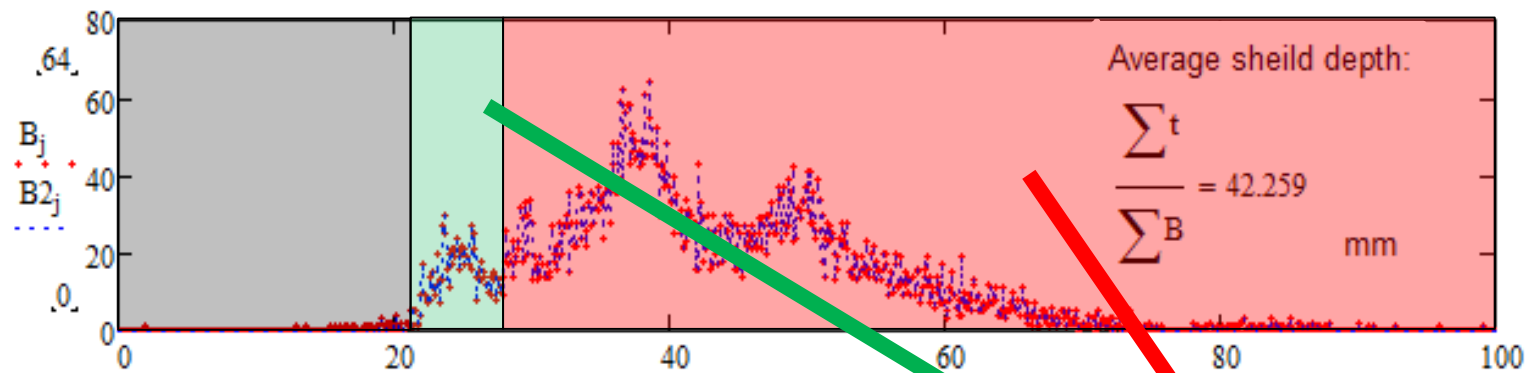
# Swarm CHU shield length

- Silicon carbide structure and metal CHU housing provides shield length of  $\gg 35$ mm Al eq. in all directions except through the lens
- Lens shield length is 23-35mm Al eq.
- 100MeV protons are stopped by 40mm Al.
  - that is practically everything even under peak flux conditions



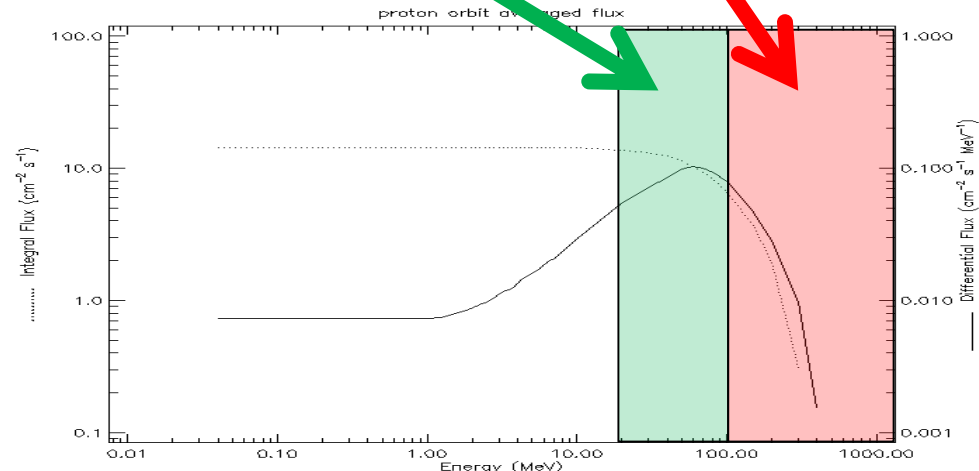
# Swarm CHU shield length

- Shield depth, the quartz only (lenses and CCD quarts), 19-32 mm eq. Al
  - blocks protons with  $E < 40$  MeV



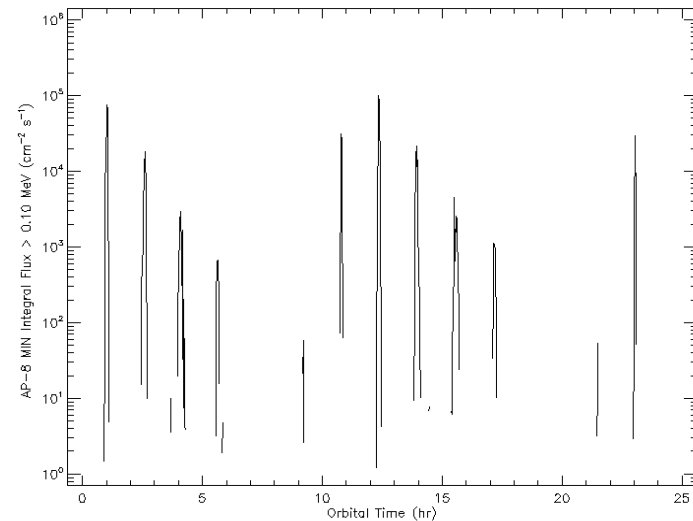
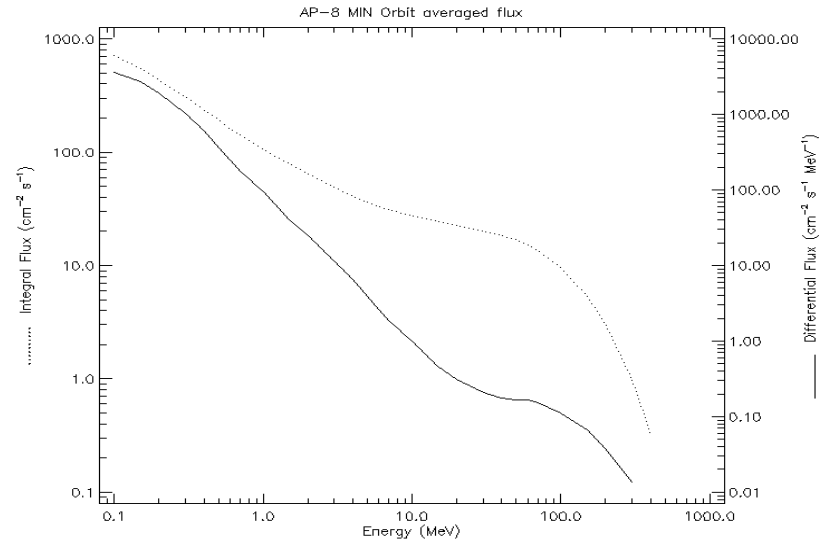
>40MeV may pass through the lens

>100MeV passes through from all directions



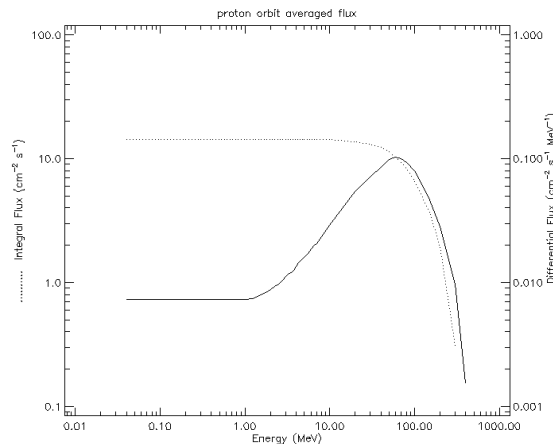
# Ionizing particles in the Swarm orbits

- Swarm mission profile: Two spacecraft at  $\sim 450\text{km}$  (A and C) and one at  $530\text{km}$  (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



# Swarm CHU shield length

- Shielded flux for 20 mm Al Shielding (from SPENVIS), incl. trapped and solar protons,  $\sim 10$   $p^+/cm^2/s$ .
- Field of view (in steradians) should be taken into account. Quiet time flux will result in a few  $p^+/cm^2/s$
- Peak flux conditions several thousand times higher



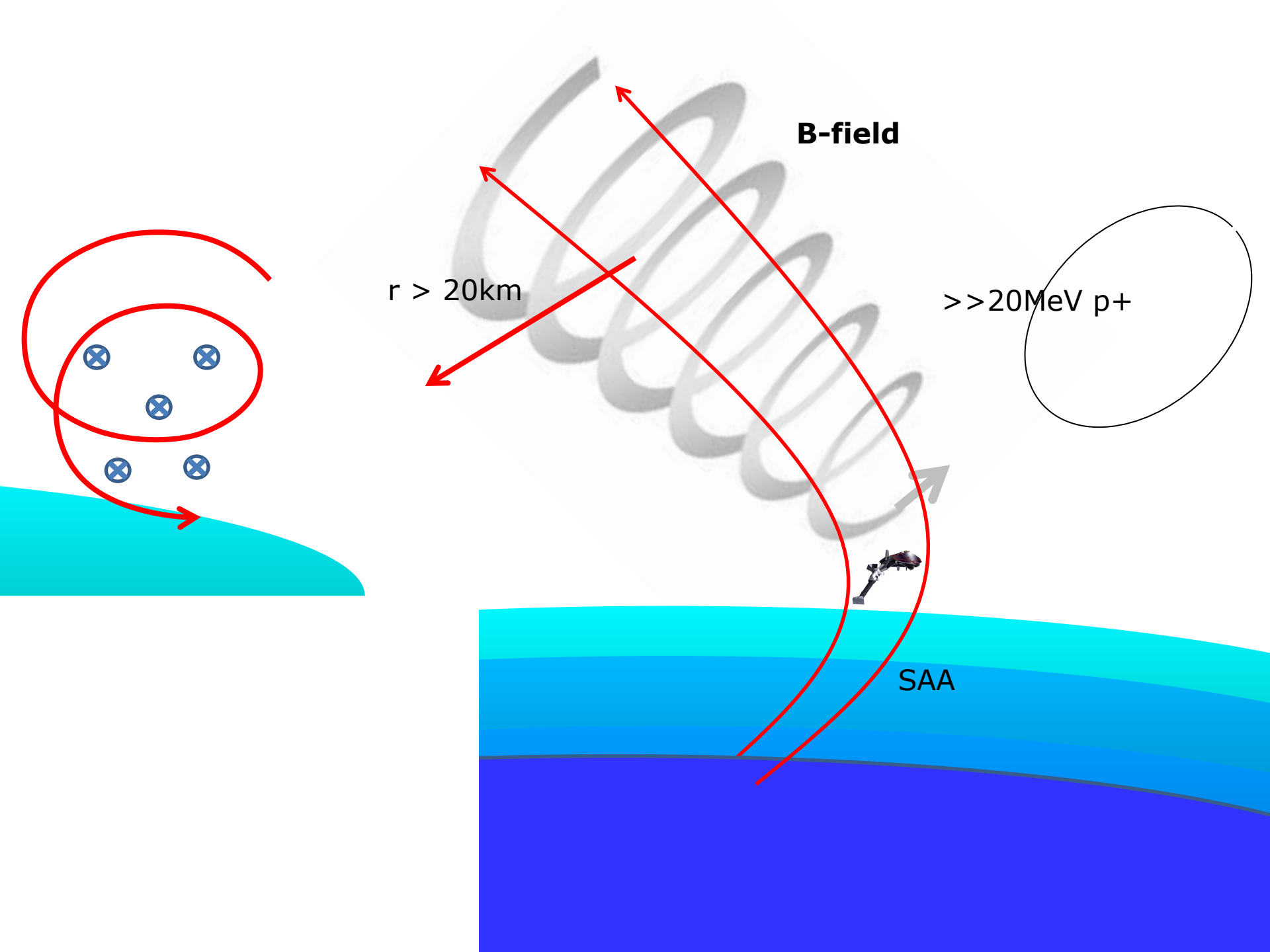
## Radiation sources and effects MFLUX: Parameters

Source		
<input checked="" type="checkbox"/> Trapped protons	<input type="checkbox"/> Trapped electrons	<input checked="" type="checkbox"/> Solar protons
Shielding		
Total thickness:	2.0	[g/cm <sup>2</sup> ]
Ta to Al mass ratio:	0	[%]
Shielding: 7.410 [mm] Al + 0.000 [mm] Ta		

Reset Run

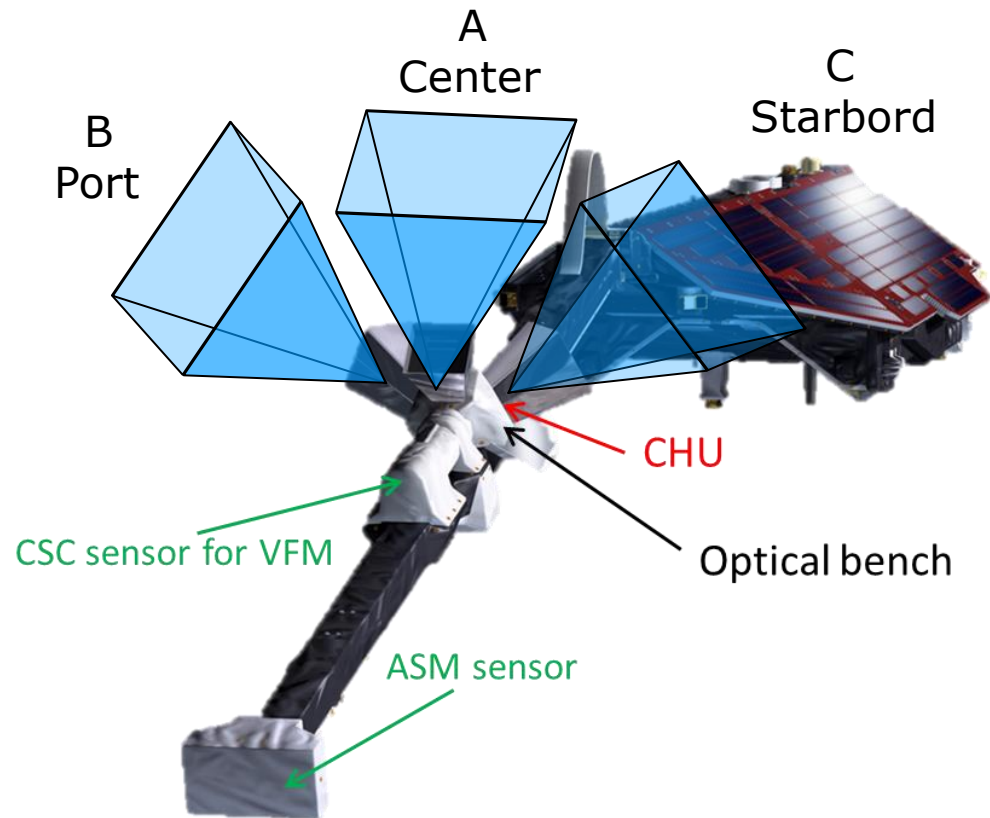
Model developed by





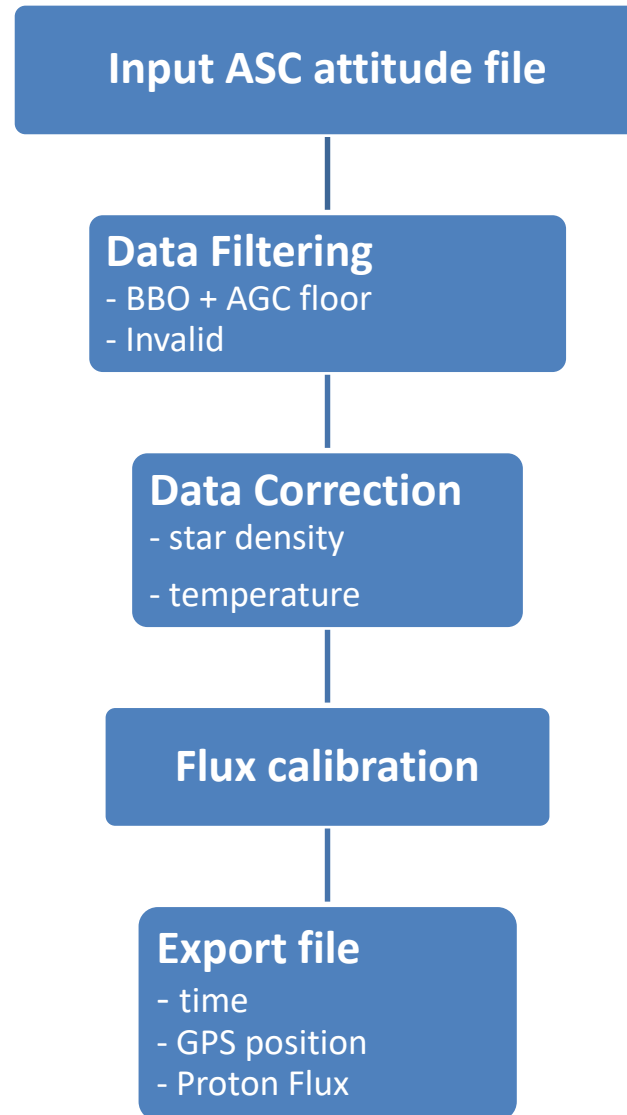
## CHU view directions (light and particles)

- $20\text{MeV} < p_+$ : The CHU shield stop all
- $20\text{MeV} < p_+ < 100\text{MeV}$   
Particle view-cone per CHU of  $\sim 0.5$  steradian centered on the lens boresight
- $p_+ < 100\text{MeV}$  omnidirectional sensitivity
- Particles  $> 150\text{MeV}$  penetrates omnidirectionally



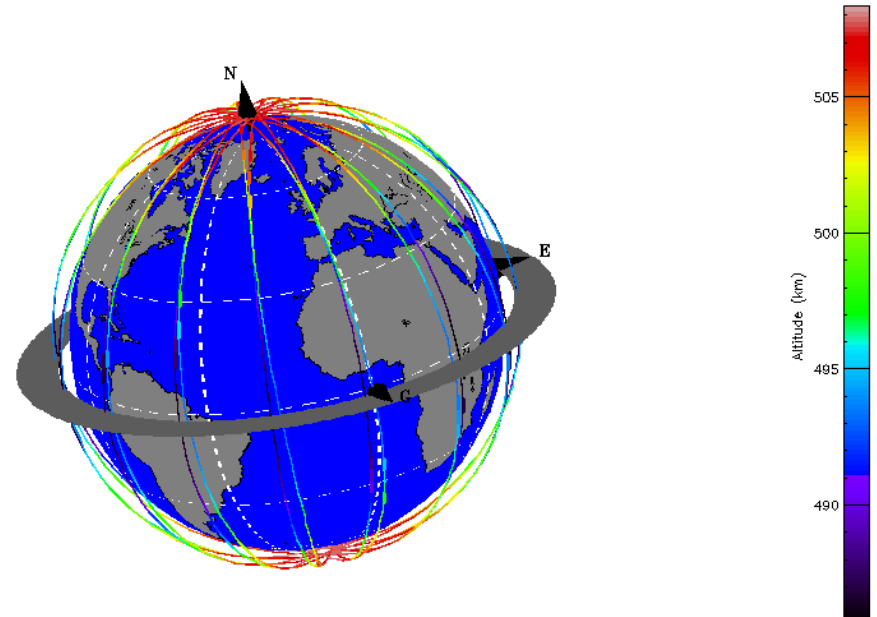


# Swarm radiation data processing

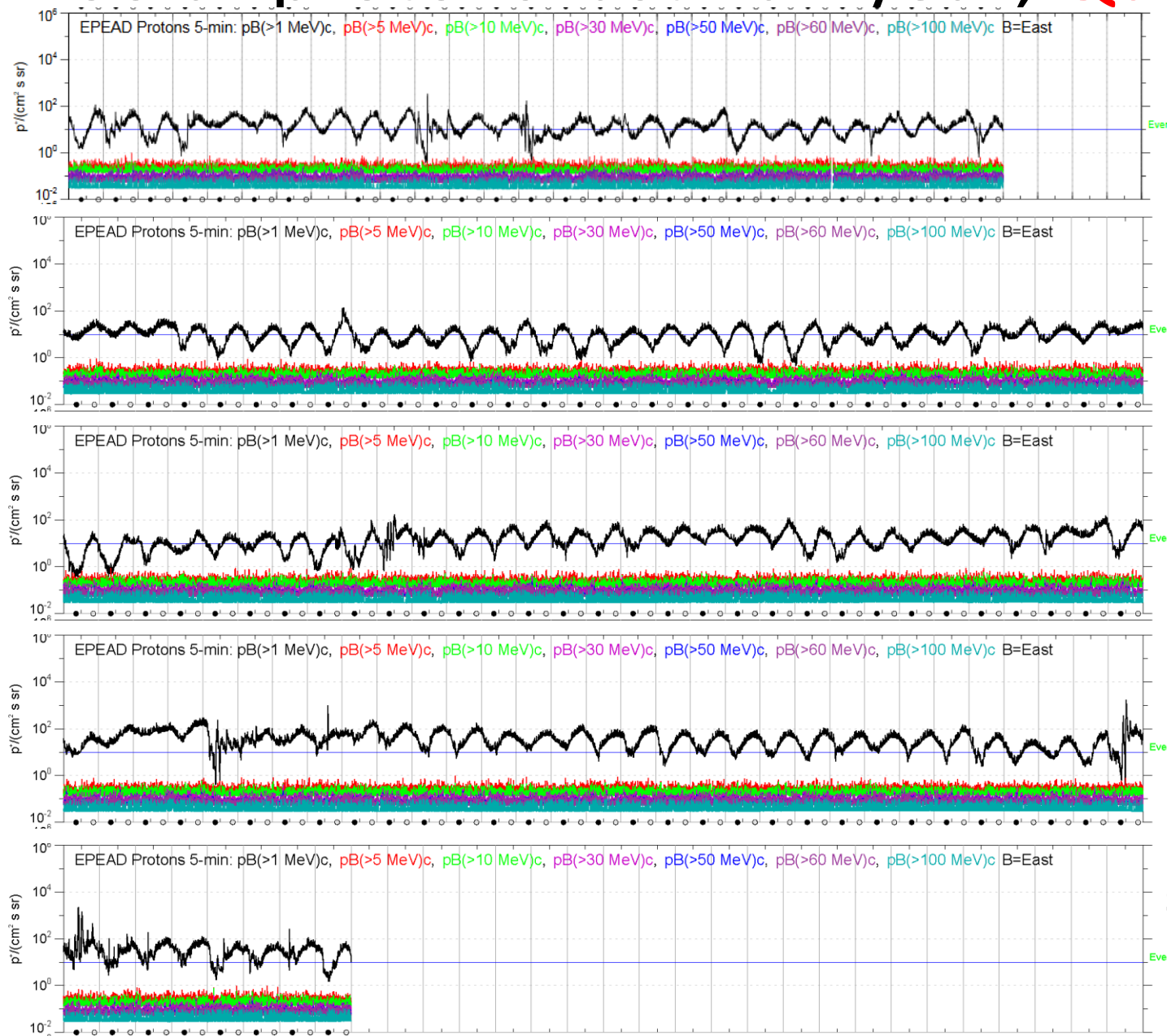


# Ionizing particles in the Swarm orbits

- Swarm mission profile: Two spacecraft at  $\sim 450\text{km}$  (A and C) and one at  $530\text{km}$  (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



# Solar protons last half year; Quiet



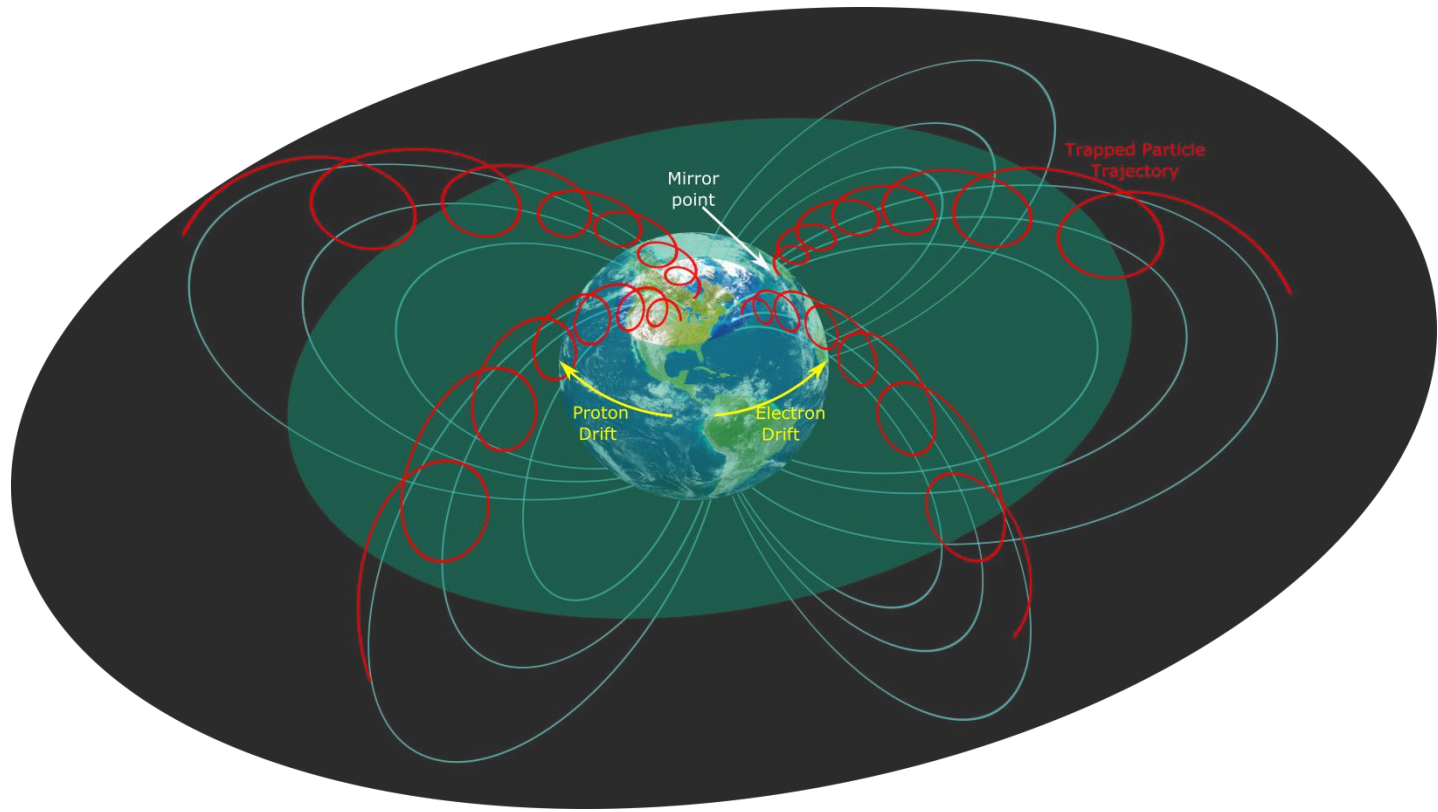
May2019

June 2019

July 2019

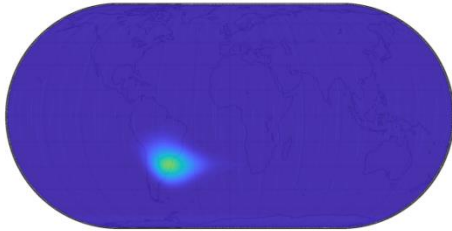
August 2019

September 2019

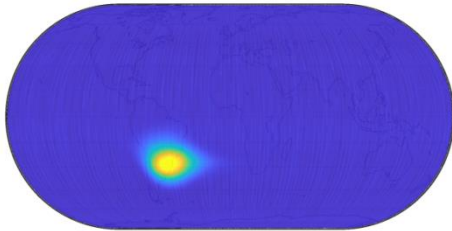


# Particles flux for Swarm spacecraft

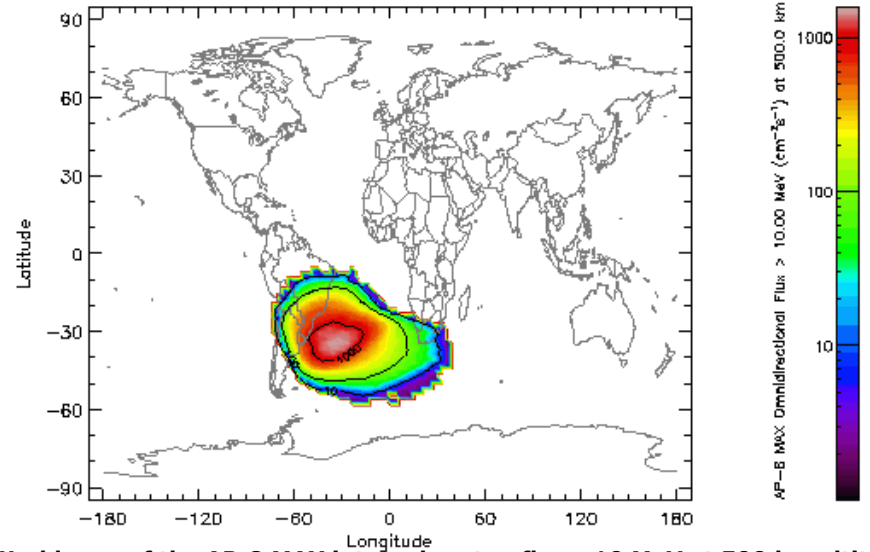
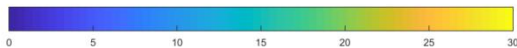
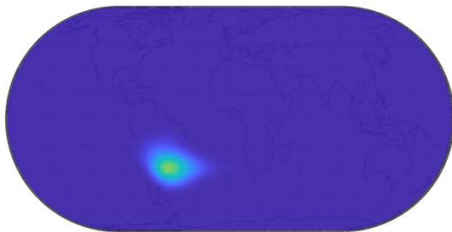
Swarm A, Integral proton flux



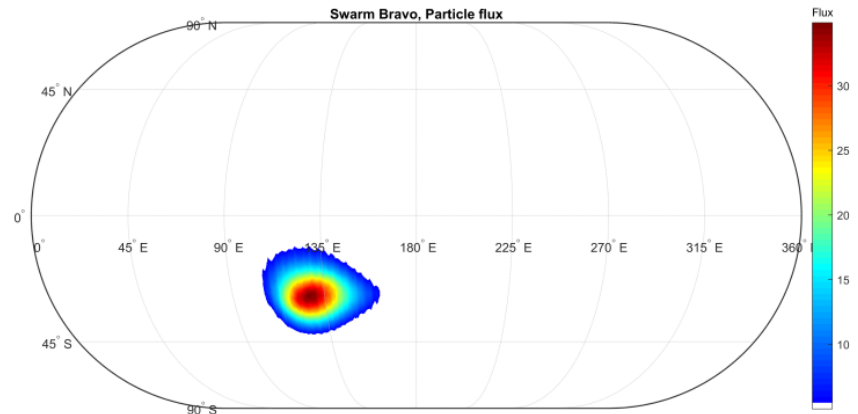
Swarm B, Integral proton flux



Swarm C, Integral proton flux

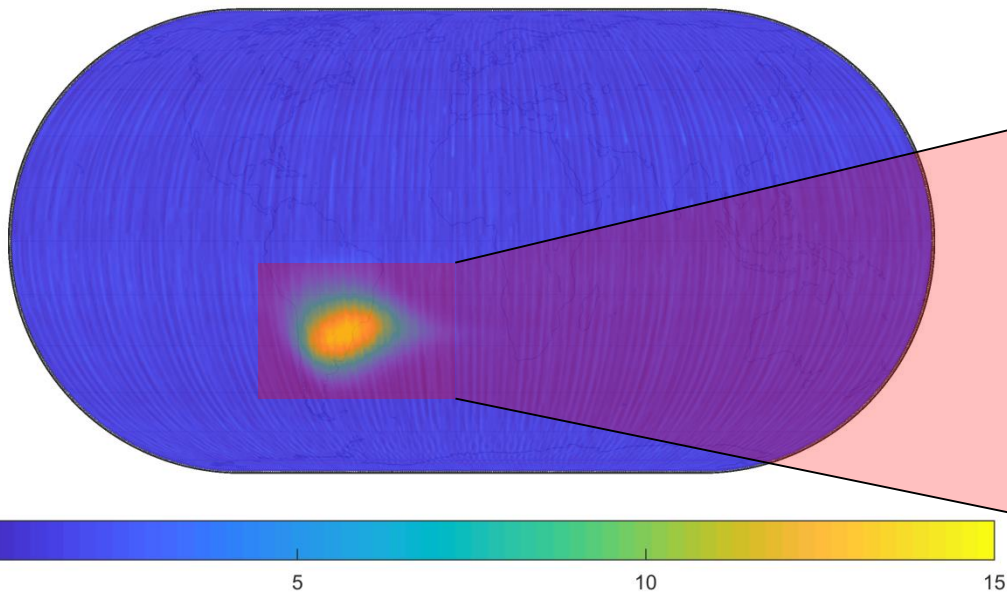


World map of the AP-8 MAX integral proton flux >10 MeV at 500 km altitude (Heynderickx, 1996)

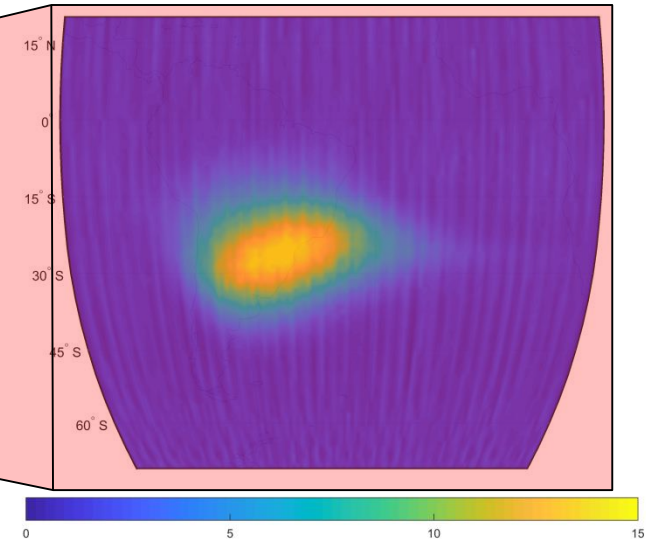


# Swarm Integral Proton Flux radial gradient

Swarm B-(A+C) Integral proton flux radial gradient

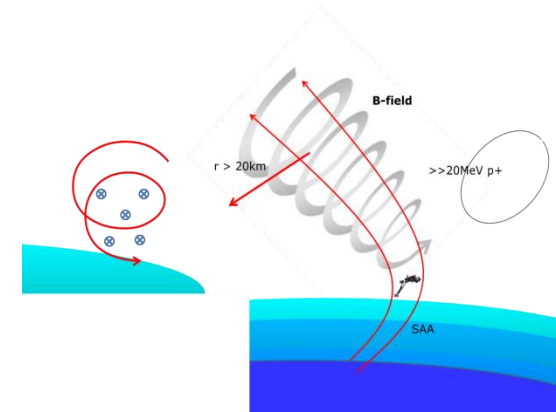


Swarm B-(A+C) Integral proton flux radial gradient

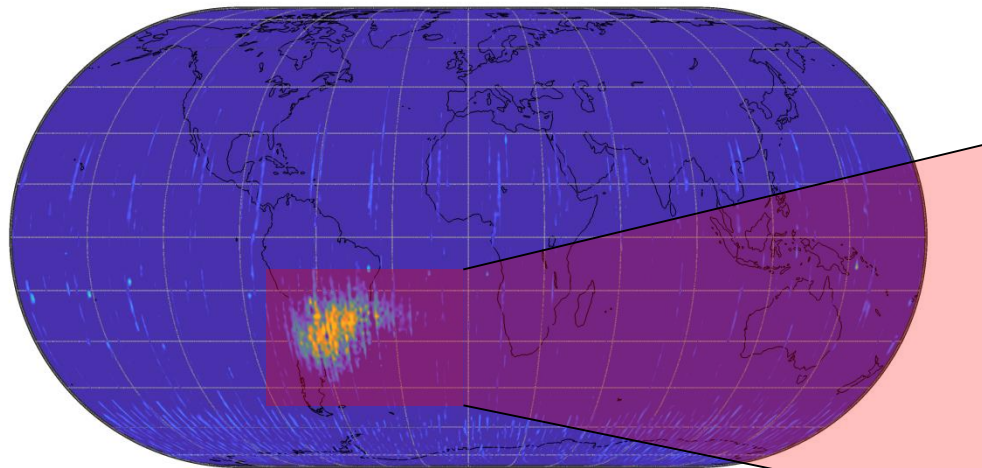




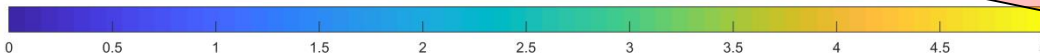
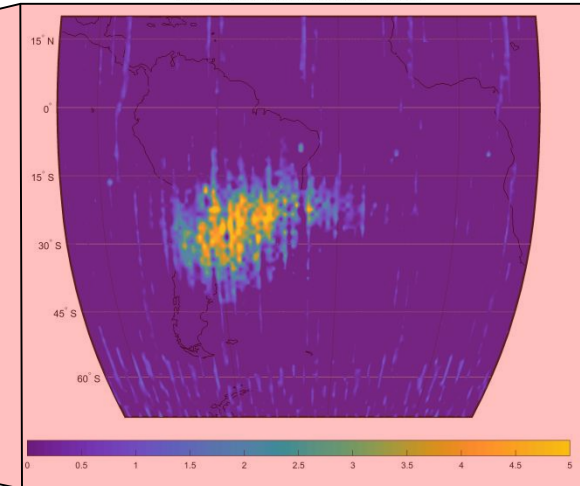
# Swarm Integral Proton Flux East-West gradient



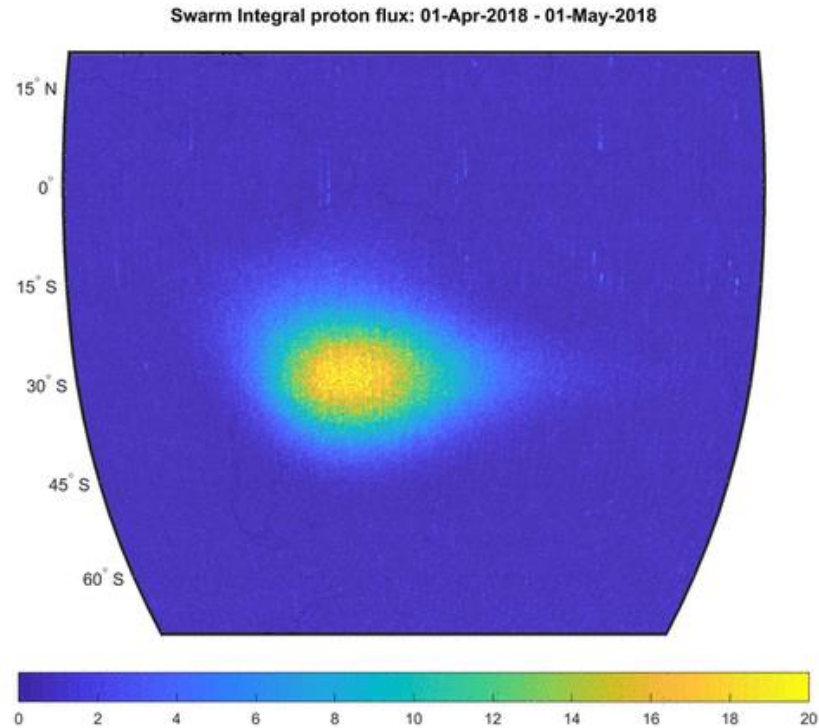
Swarm B Integral proton flux West-East gradient



Swarm B Integral proton flux West-East gradient



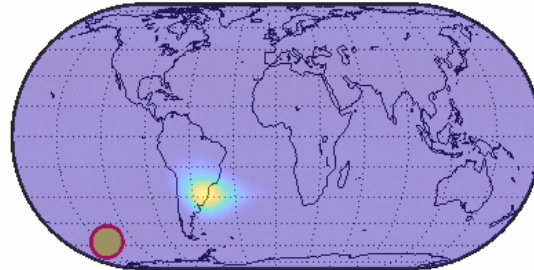
# Integral proton flux seasonal changes (Swarm Alpha and Charlie combined)





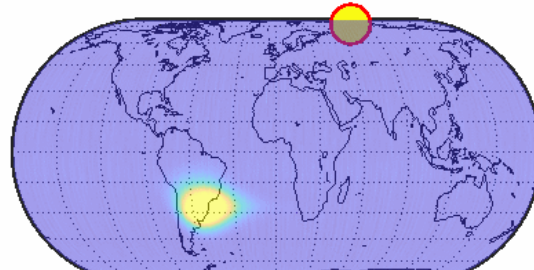
# Particles flux burst detection by Swarm

Swarm A, Integral proton flux



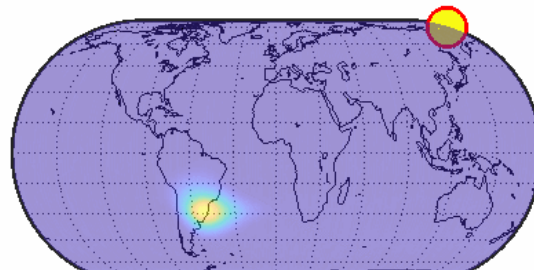
16-Mar-2018 02:30:29 [29.5556]

Swarm B, Integral proton flux

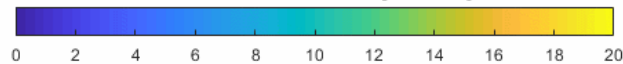


16-Mar-2018 18:51:47 [45.6159]

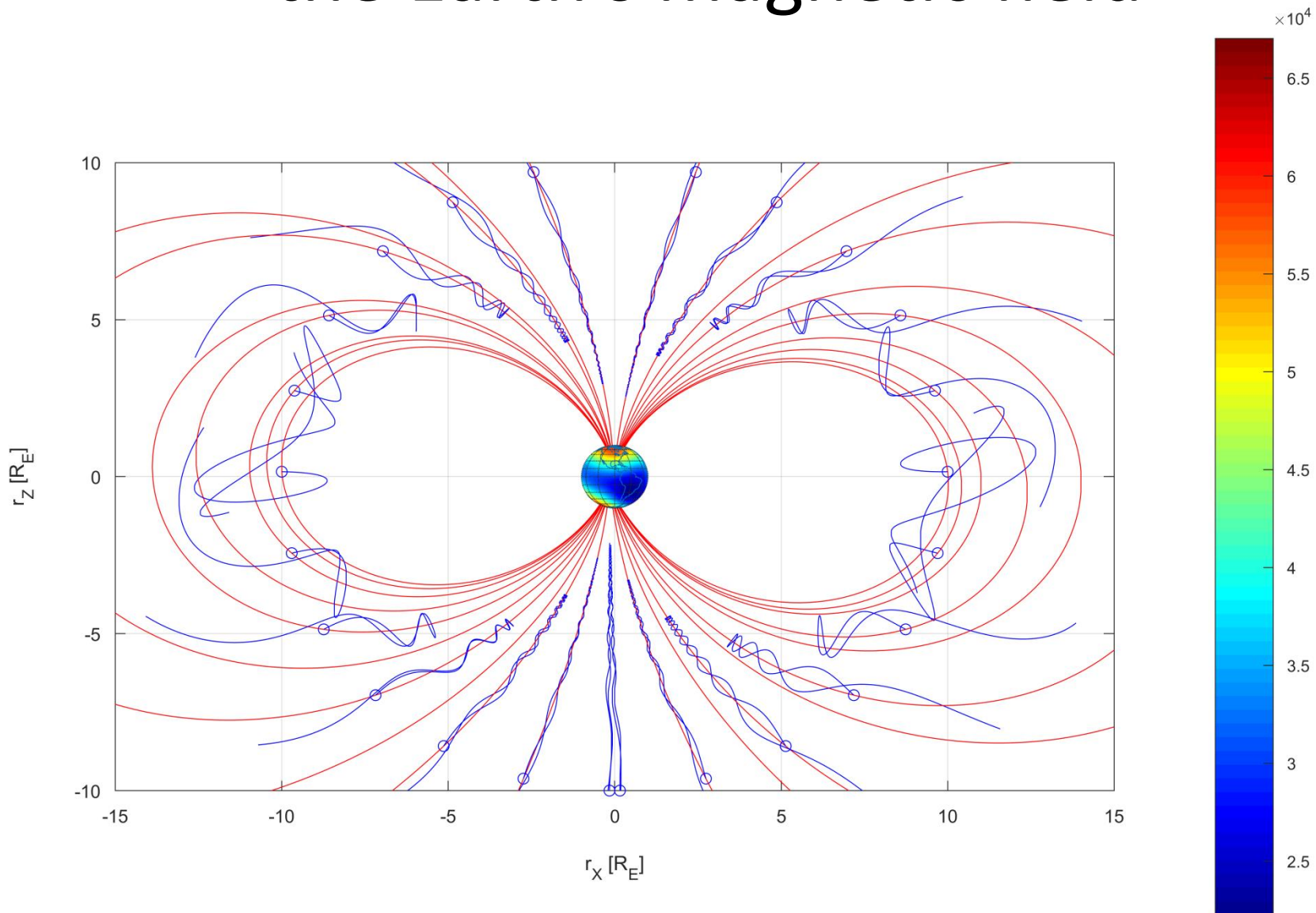
Swarm C, Integral proton flux



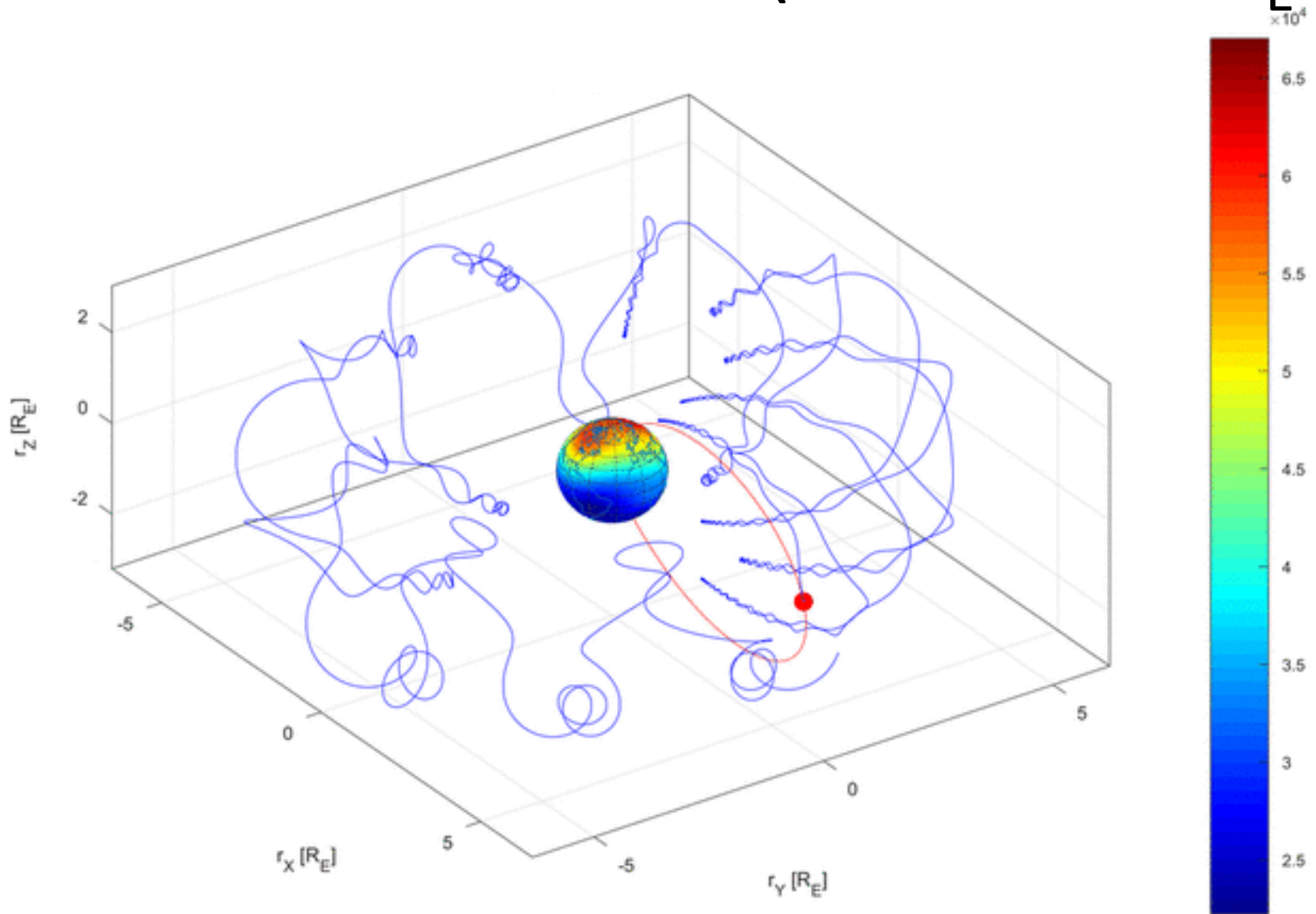
16-Mar-2018 06:11:25 [44.3971]



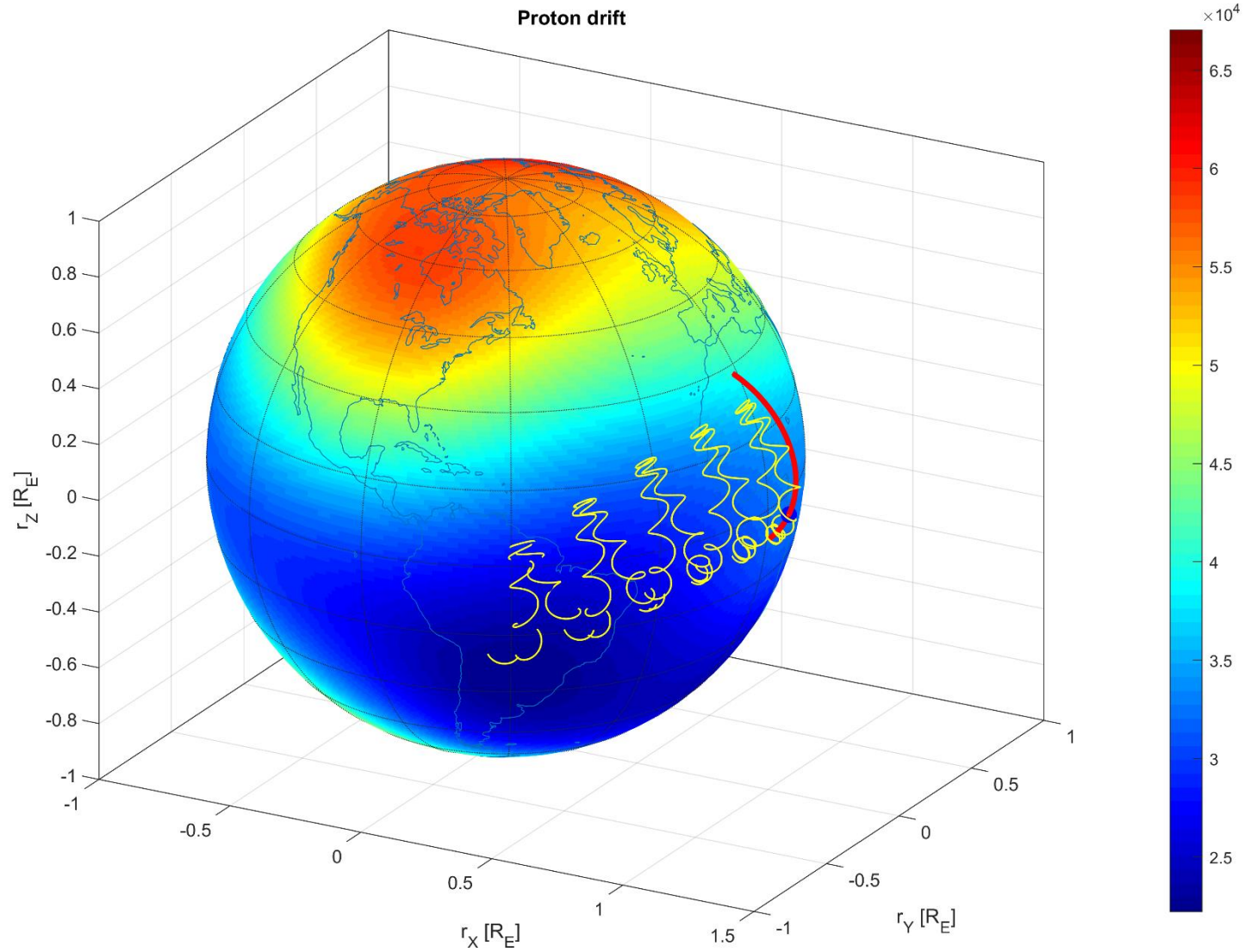
# Injected electron into the Earth's magnetic field



# Electron drift shell ( $\sim 3.2$ sec for $R_E$ 6)



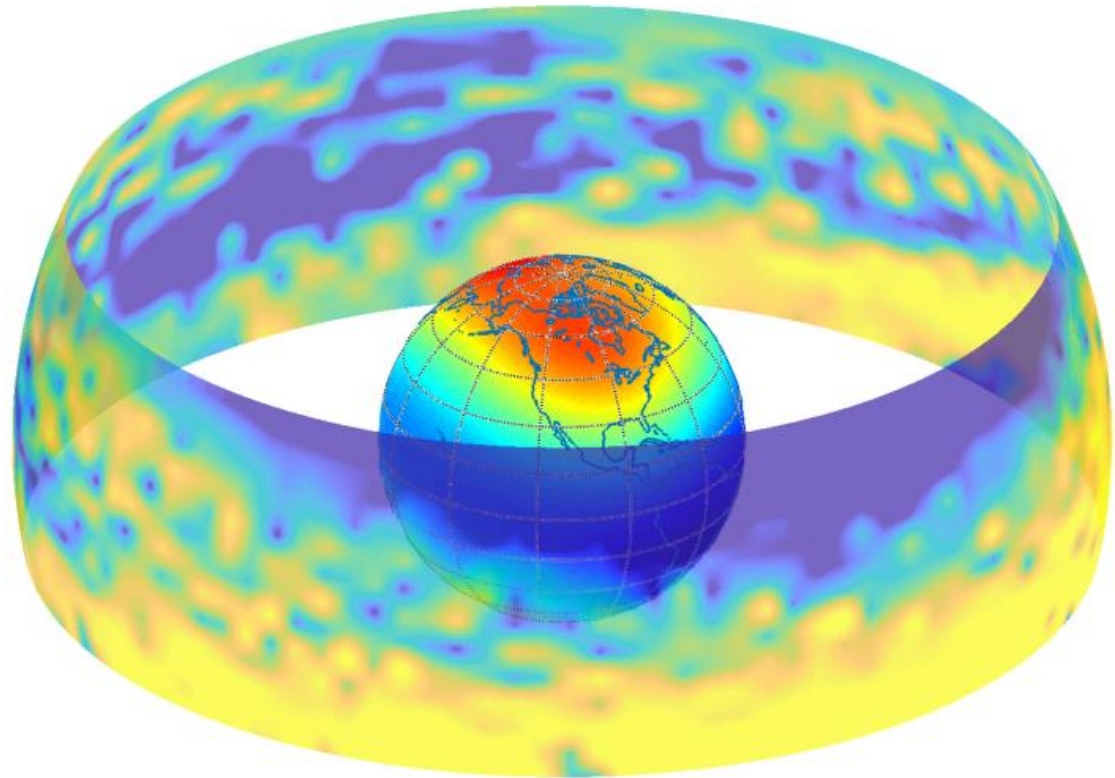
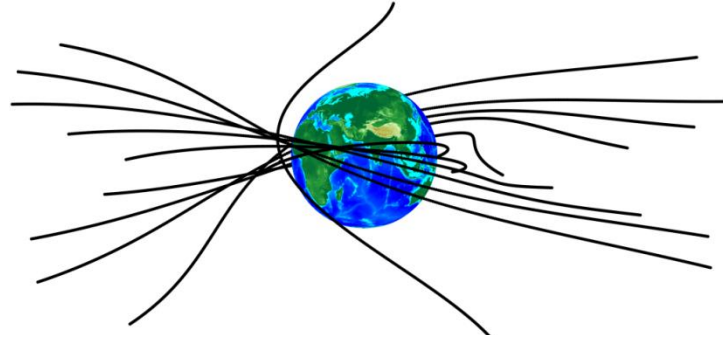
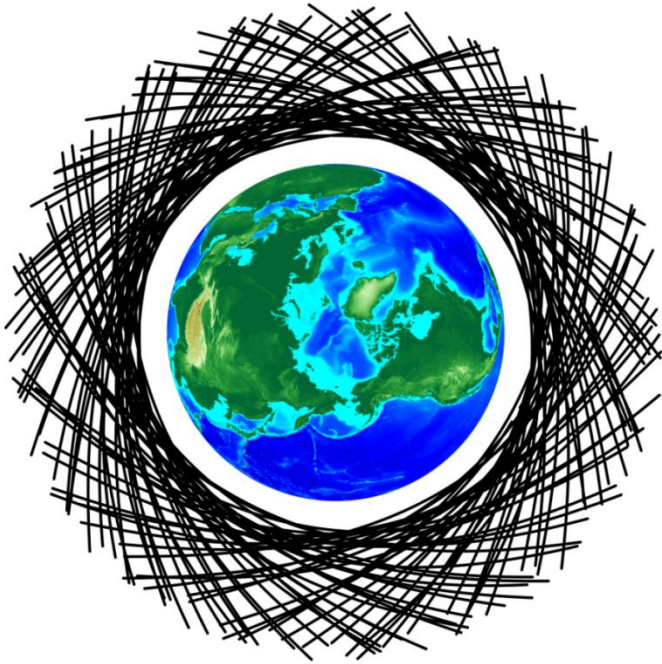
# Proton's drift shell ( $\sim 0.4$ sec for 500km)



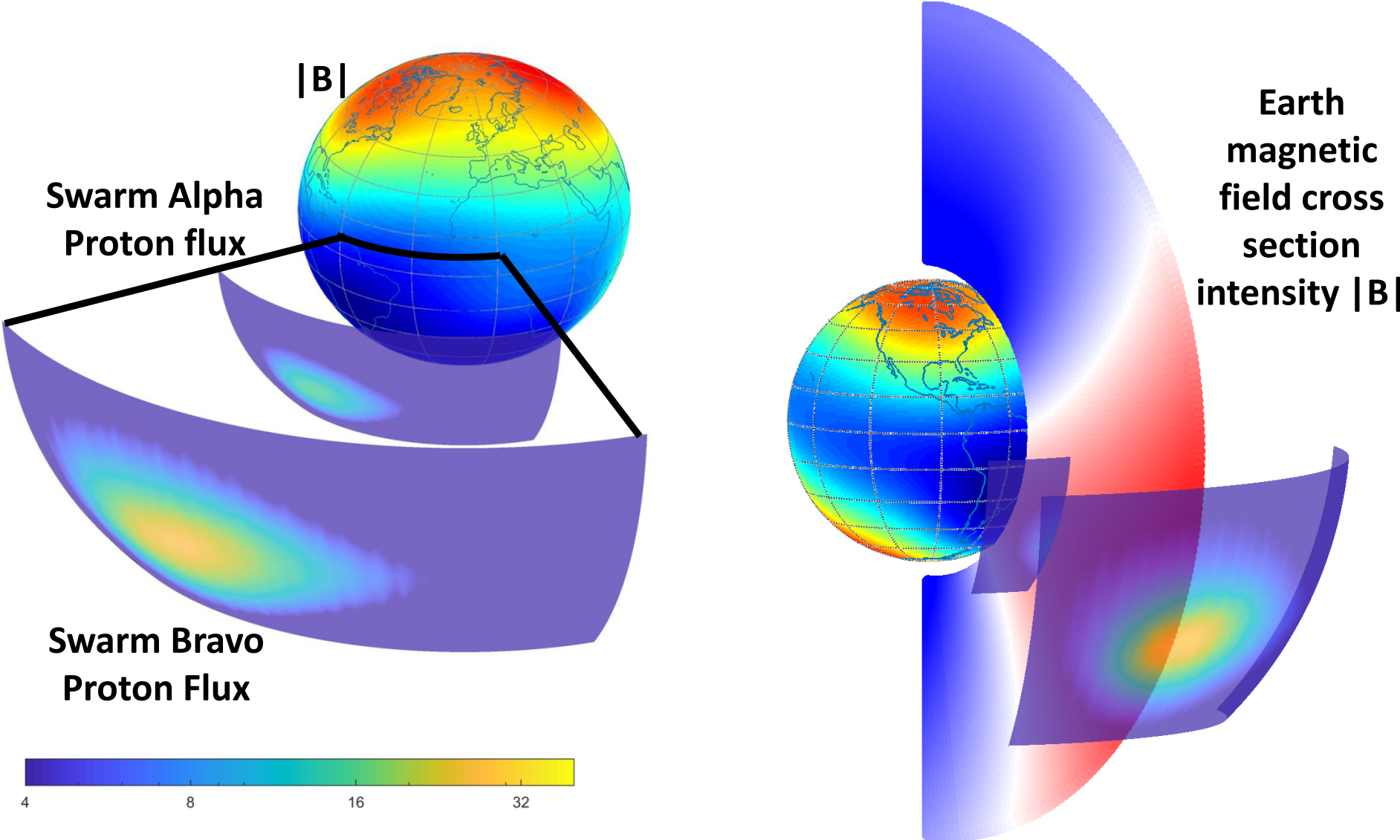


# Particles flux – Swarm vs. MMS

MMS1 data coverage (13-May-2017 06:39:08 - 09-Apr-2018 21:04:10)



# South Atlantic Anomaly Proton Flux radial gradient



# Conclusion

- The first half year of operations demonstrate expected performance resulting in:
  - Global map of  $p^+$  in 40MeV to 100MeV in three sectors
  - The vertical gradient of the SAA
  - Day/Night side flux differences
  - East/West flux differences
- Results to come
  - Seasonal variations in high energy flux
  - Detailed profiling of solar to trapped protons flux injections
  - Scatter times of protons migrating from trapped to SAA loss cone