Background components at LEO and GRBAlpha status

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MUNI
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Background simulations for a large FoV gamma-ray detector at LEO

- Full Monte Carlo simulation in Geant4 including optical photon tracking, satellite structure and expected X-ray/particle background.
- Code at GitHub (github.com/ggalgoczi/szimulacio/tree/master/Bck_4.10.6)
- Outside SAA and for latitude < 50°, i.e. in the regions favorable for GRB detection

Simulations of expected signal and background of gamma-ray sources by large field-of-view detectors aboard CubeSats

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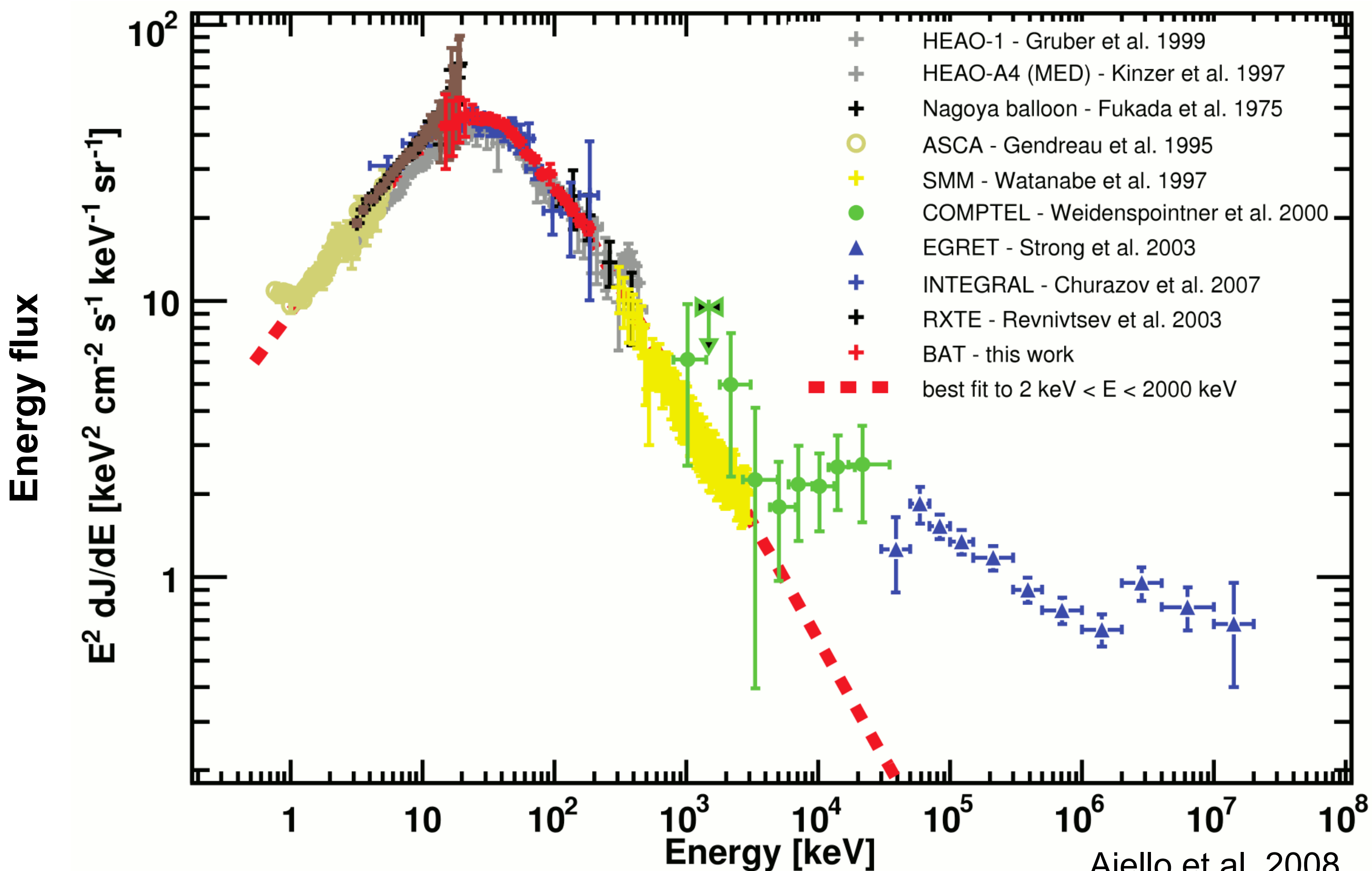
JATIS, in press

Cosmic X-ray Background (CXB)

- X-ray / gamma-rays
- Coming from all directions
- CXB is due to summation of emission from extragalactic unresolved point sources (AGNs, SNe Ia, galaxy clusters), also due to hot inter-galactic gas (diffuse part)

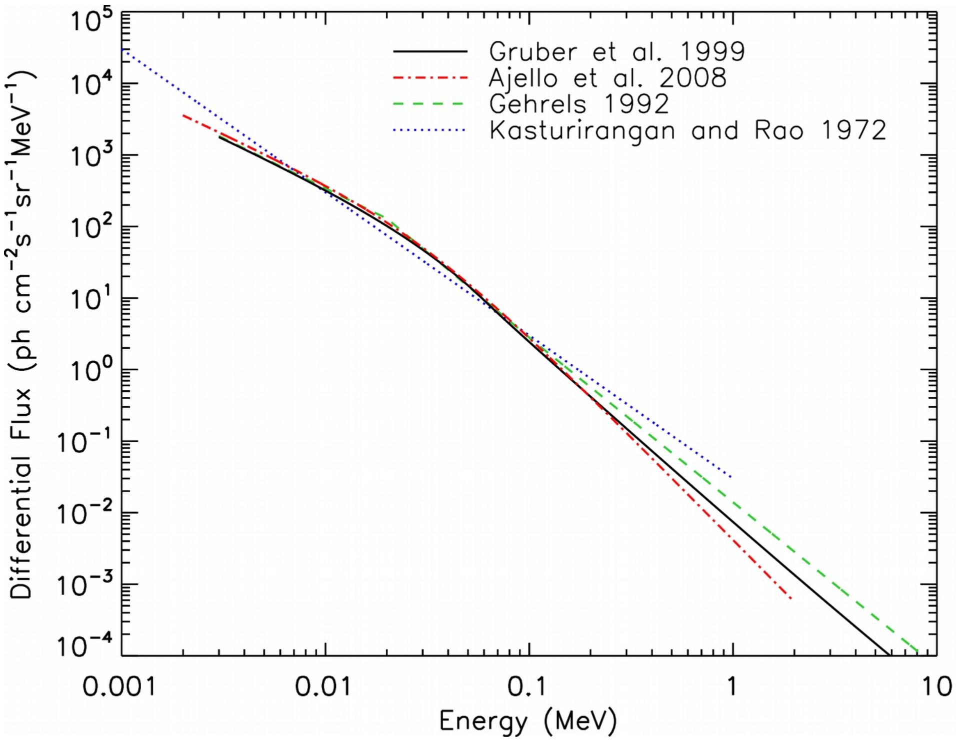


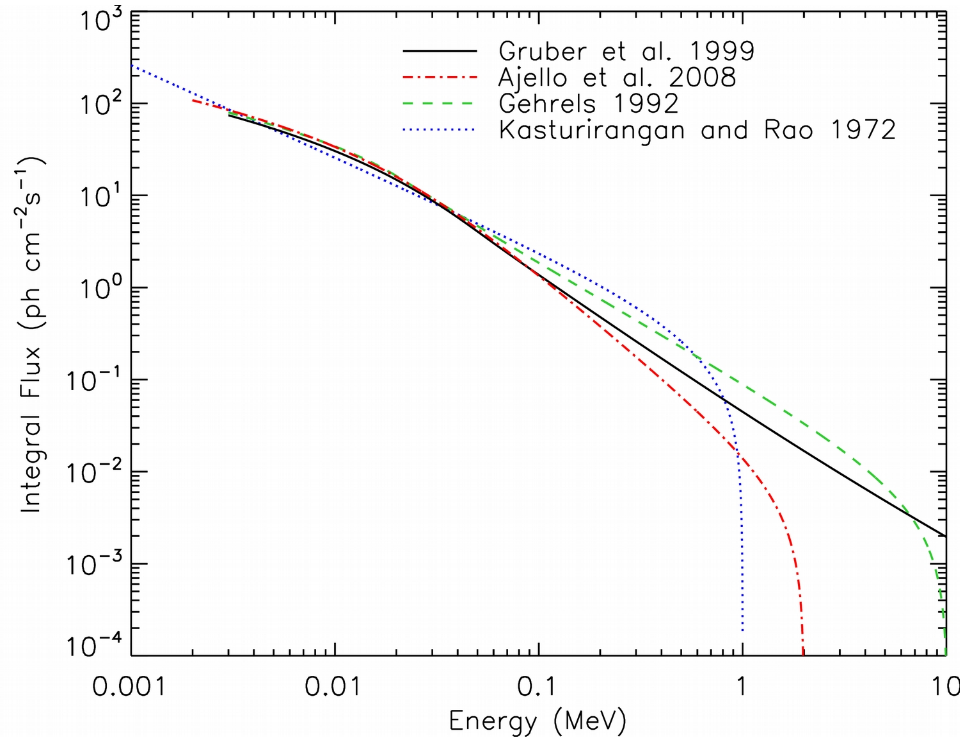
Ajello et al. 2008

Cosmic X-ray Background (CXB)

- Incident flux from solid angle Ω = 8.6 sr for 500 km
- For MC simulations we used models from:

  Ajello+ 2008 (2 keV - 2 MeV) and Gruber+ 1999 (3 keV - 100 GeV)

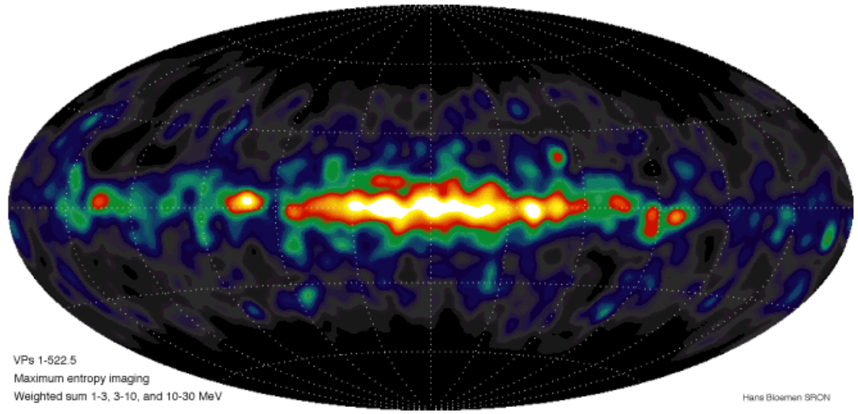




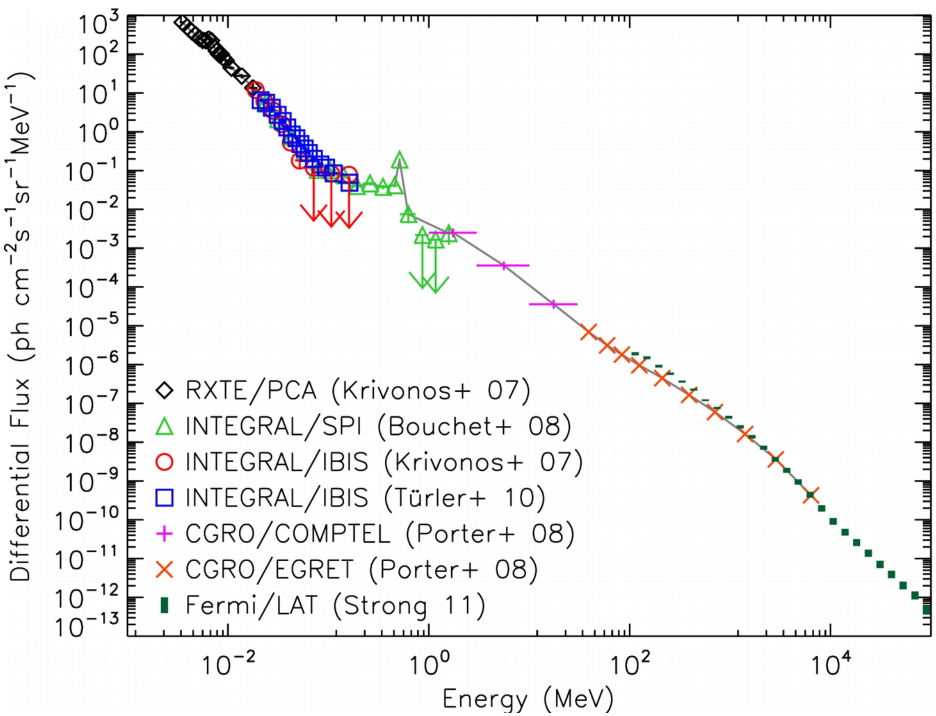
- Integral flux for E ≥ 10 keV and Ω = 8.6 sr from Ajello+ 2008 model is **33.7 ph cm^{-2} s^{-1}**

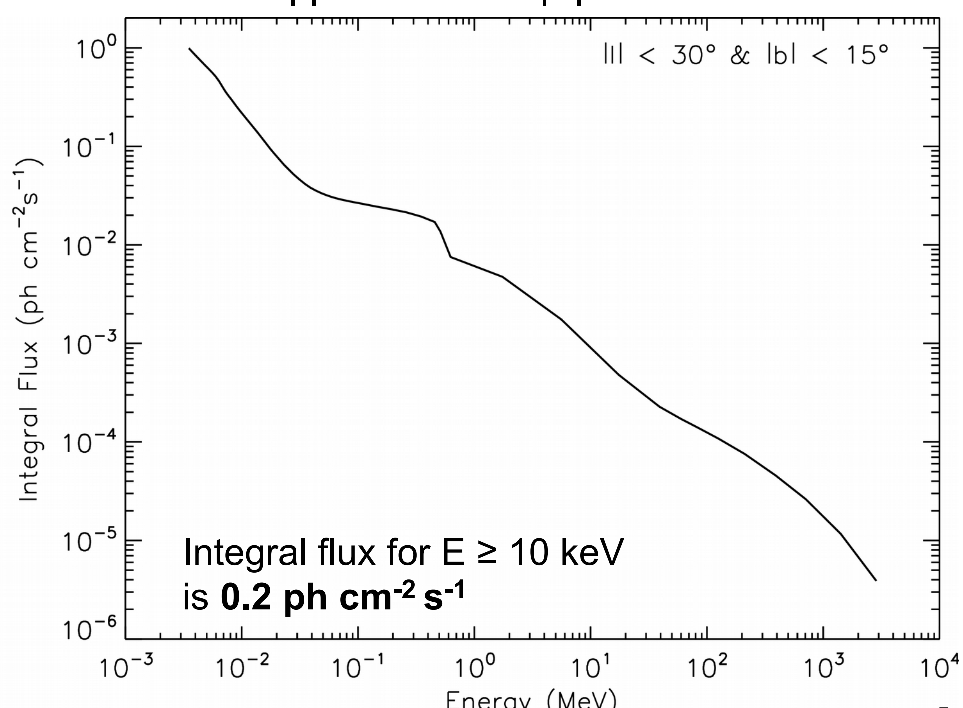
Galactic X-ray / gamma-ray emission

COMPTEL 1-30 MeV



Spectrum of the inner Galaxy emission from |l| < 30° and |b| < 15°



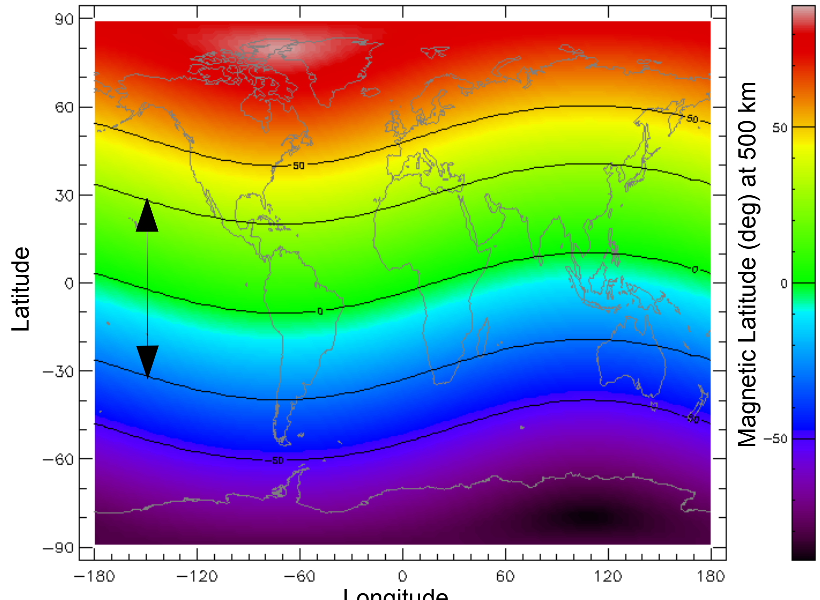


Primary CR particles

- Originate from SN explosions and AGNs
- Measured by many experiments: AMS, BESS, CREAM, Fermi/LAT, HESS, PAMELA
- Flux depends on latitude, Earth's magnetic shielding
- Incident flux from solid angle Ω = 8.6 sr for h=500 km
- Two models checked:

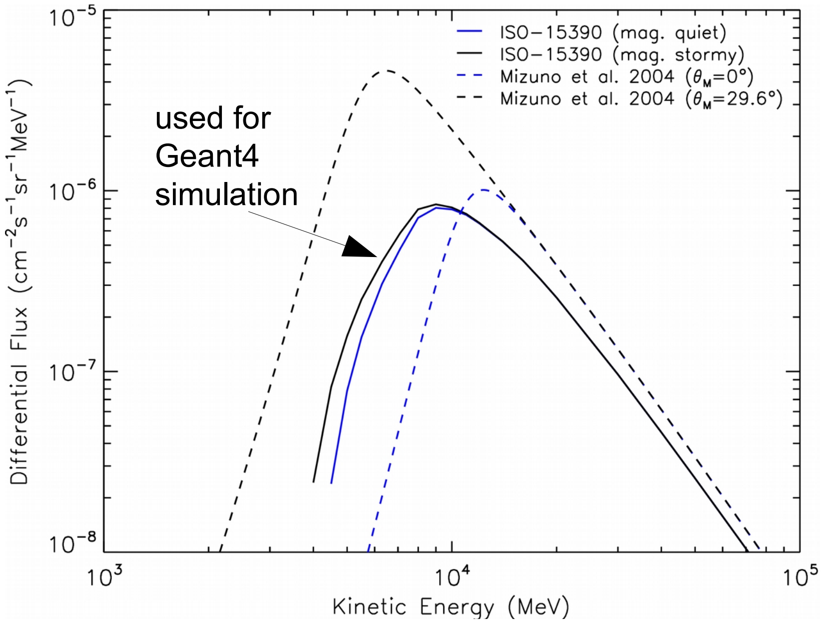
ISO-15390: international standard, we used SPENVIS tool, i=20°, magnetosphere quiet and stormy

Mizuno+ 2004: based on BESS and AMS data, solar minimum, checked two geomagnetic latitudes Θ_M=0° and $|\Theta_M|$= 29.6° = 20° (orbital inclination) + 9.6° (tilt between geomagnetic dipole axis and Earth's rotational axis)

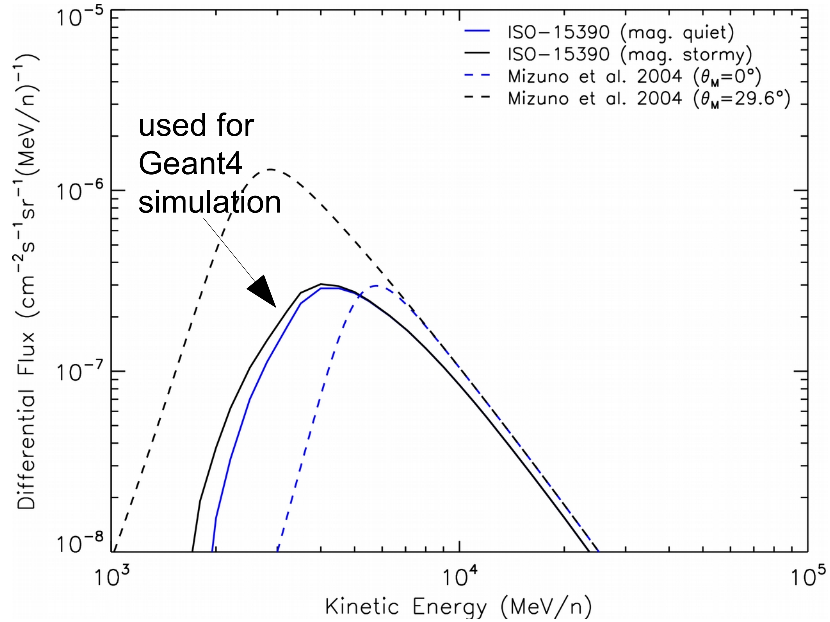


Primary CR particles

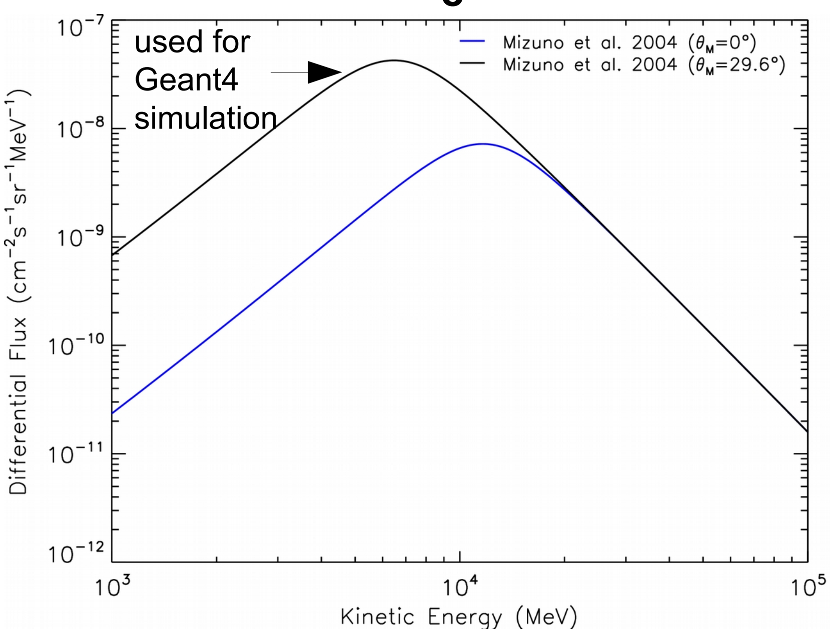
p^+



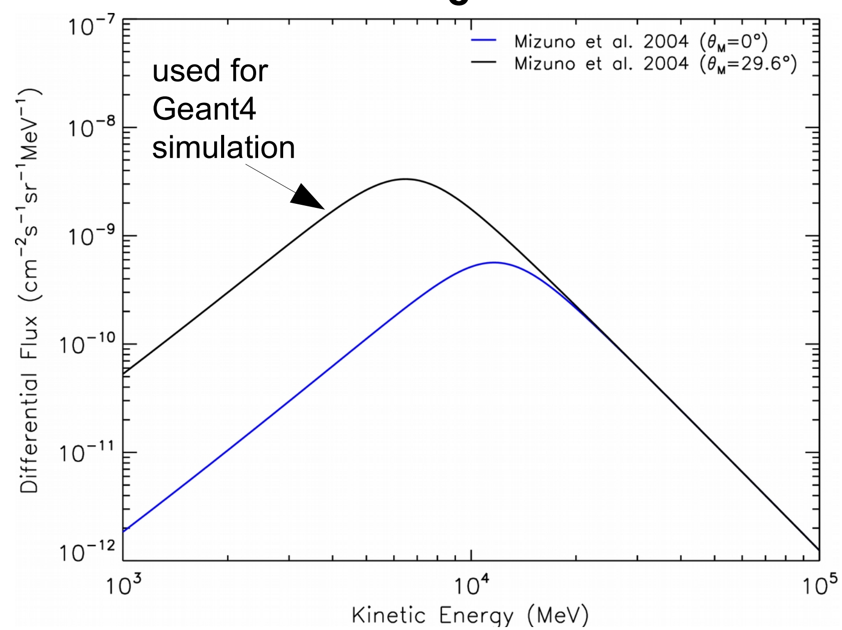
alpha



e^-

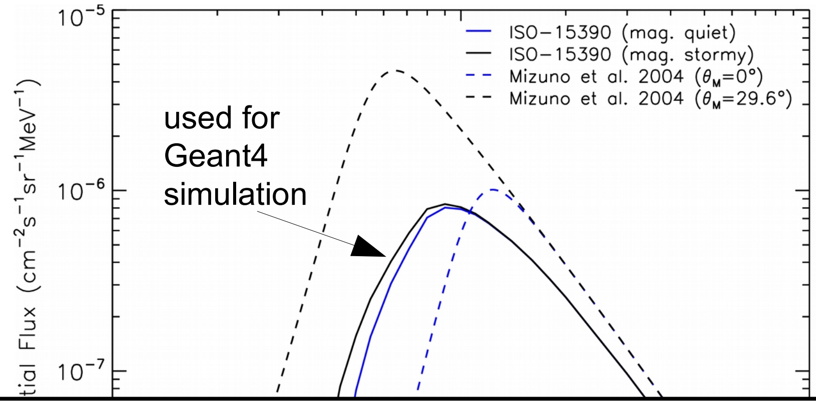


e^+

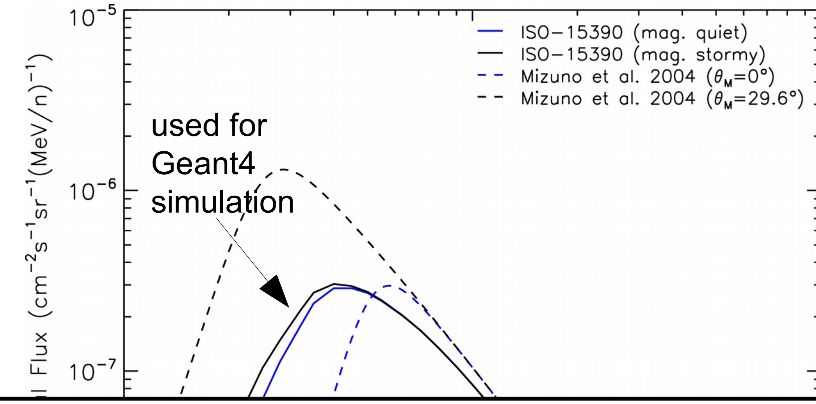


Primary CR particles

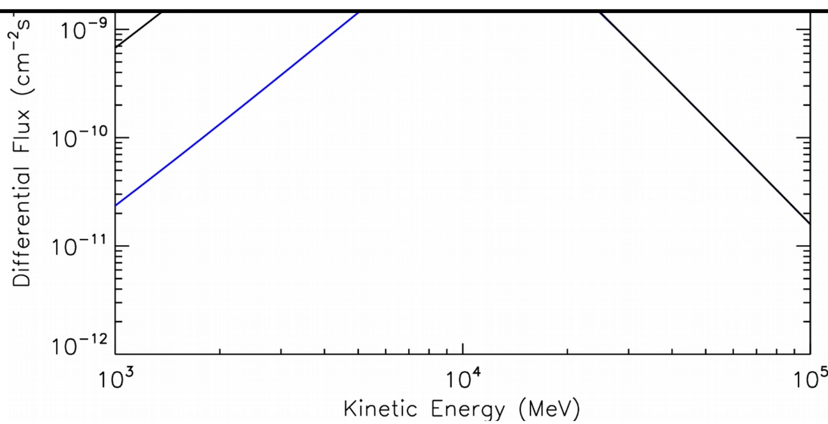
p^+

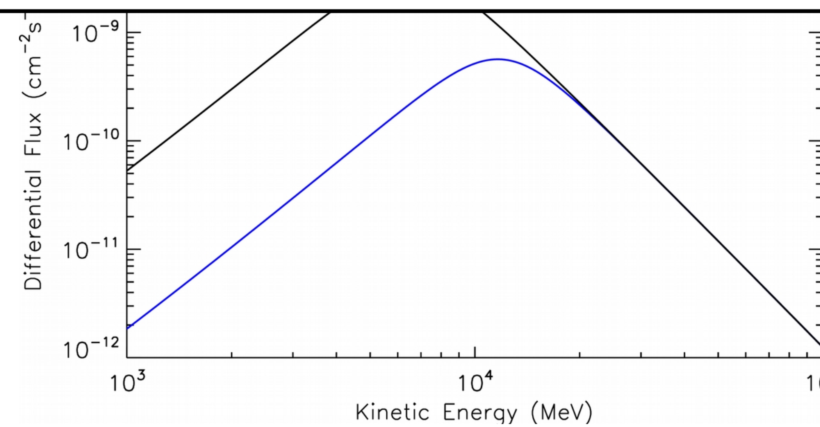


alpha



- Integral flux for ISO-15390 model w/ stormy mag., h=500km, i=20°(crossing Θ_M≈-30° to 30°), Ω=8.6sr is:
  - **p+ 0.1 $cm^{-2}s^{-1}$** (E>1GeV)
  - **alpha 0.02 $cm^{-2}s^{-1}$** (E>1GeV/n)
- Integral flux for Mizuno+ 2004 model, solar minimum, h=500km, Θ_M=29.6°, Ω=8.6sr is:
  - **e- $3x10^{-3}$ $cm^{-2}s^{-1}$** (E>1GeV)
  - **e+ $2.3x10^{-4}$ $cm^{-2}s^{-1}$** (E>1GeV)





Secondary particles and γ-rays due to GCR

- Created in Earth's atmosphere by interaction of CR with atoms --> showers
- Downward and upward components

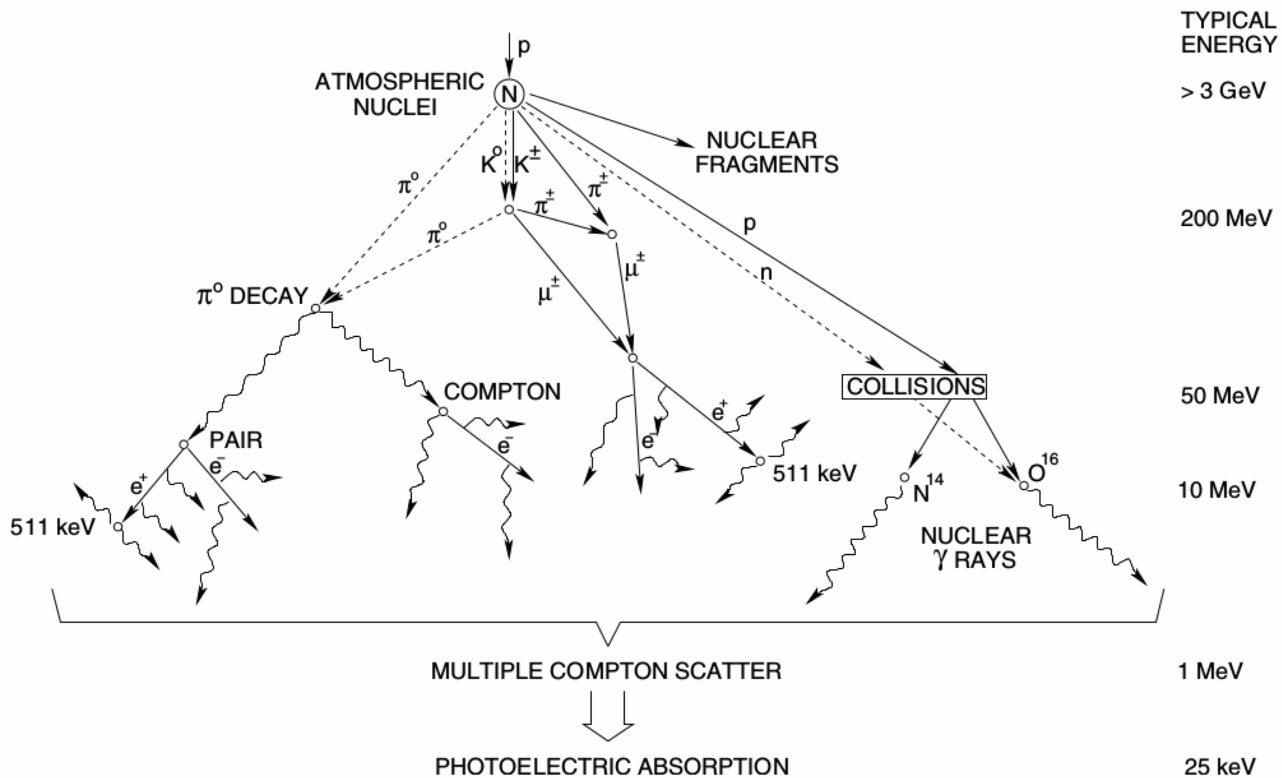
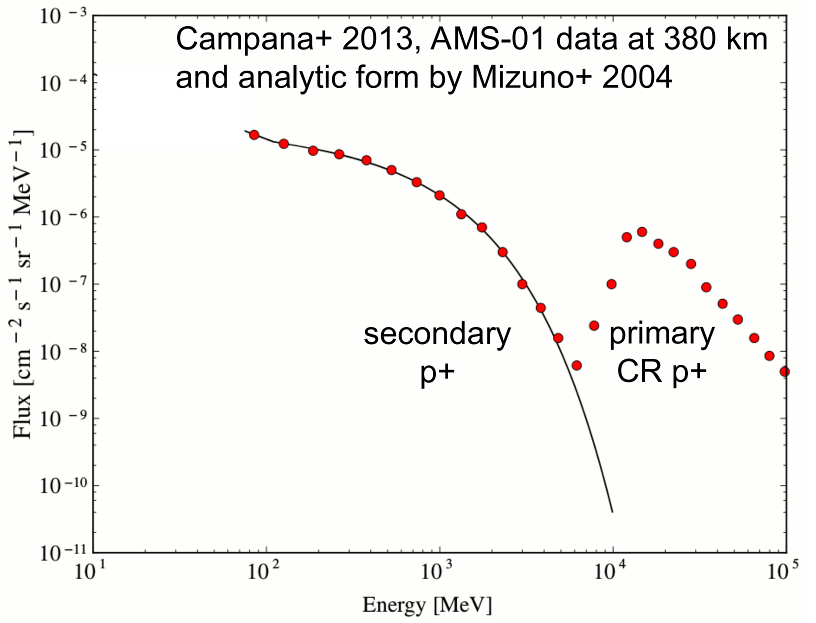


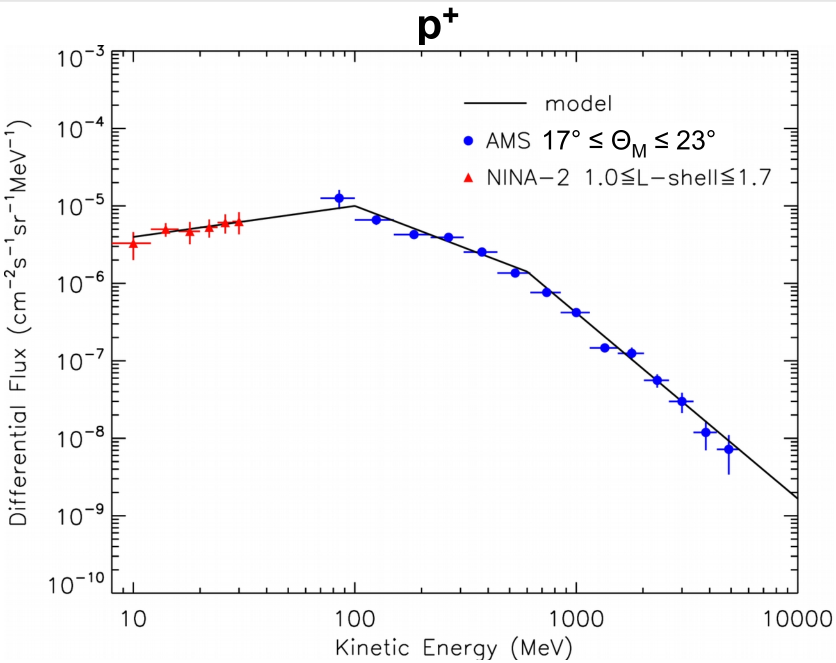
Figure 12. The γ-ray production mechanisms of cosmic ray interactions with the Earth's atmosphere. Adapted from Zombeck (1990).

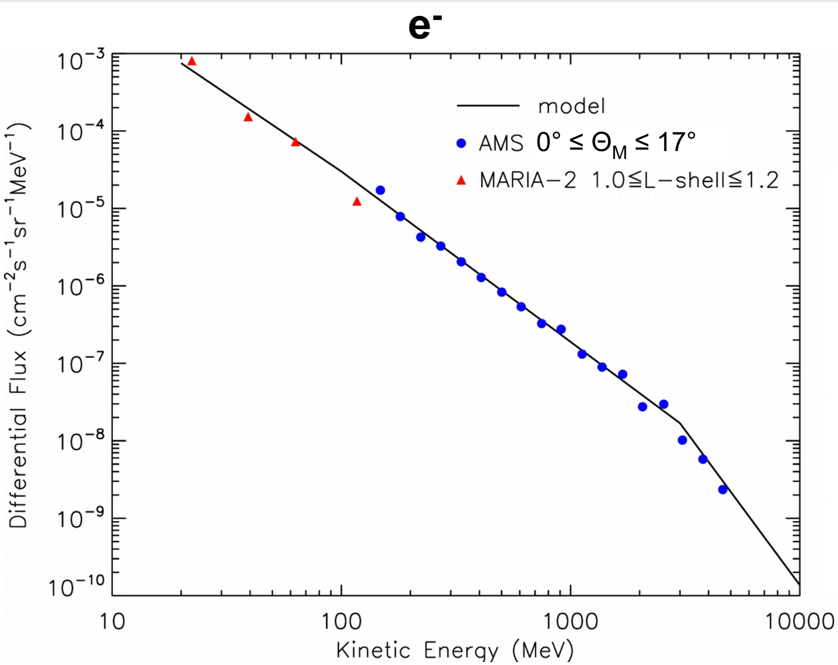
Secondary particles due to CR

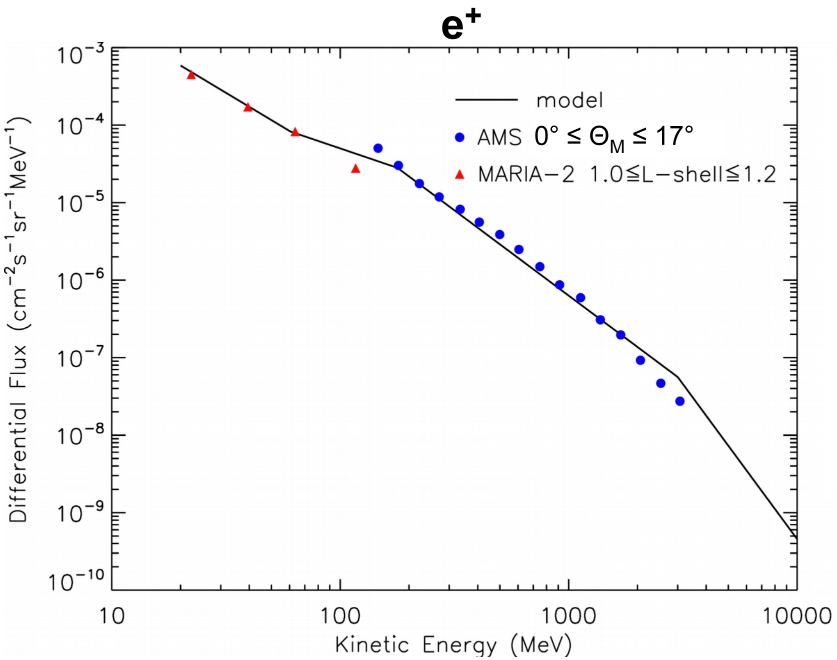
- Flux depends on latitude
- **for p+**
  - Model by Mizuno+ 2004 based on AMS data (380 km) for geomag. latitude 17° < Θ_M < 23° and fit to NINA-2 data (450 km) below 100 MeV for 1.0 ≤ L-shell ≤ 1.7 (Bidoli+ 2002 ; LAT Tech. Note LAT-TD-08316-01).
  - Same flux model for upward and downward component
  - Small dependence on altitude in range 200 km - 850 km (Zuccon+ 2003; Bidoli+ 2002)
- **for e- and e+**
  - Mizuno+ 2004 based on AMS for 0° < Θ_M < 17° and fit to Mir/MARIA-2 data (400 km) below 100 MeV for 1.0 ≤ L-shell ≤ 1.2 (Voronov+ 1999; LAT-TD-08316-01).
  - Same flux model for upward and downward component
- **for n**
  - QinetiQ Atmospheric Radiation Model (QARM), based on Monte Carlo radiation transport code, as reported in the ESA document ECSS-E-ST-10-04C.
  - Incident flux from solid angle Ω = 3.9 sr for 500 km
  - Checked two cutoff rigidities: 16.6 GV (geomagnetic equator at south-east Asia) and 5 GV (Θ_M = 37°)

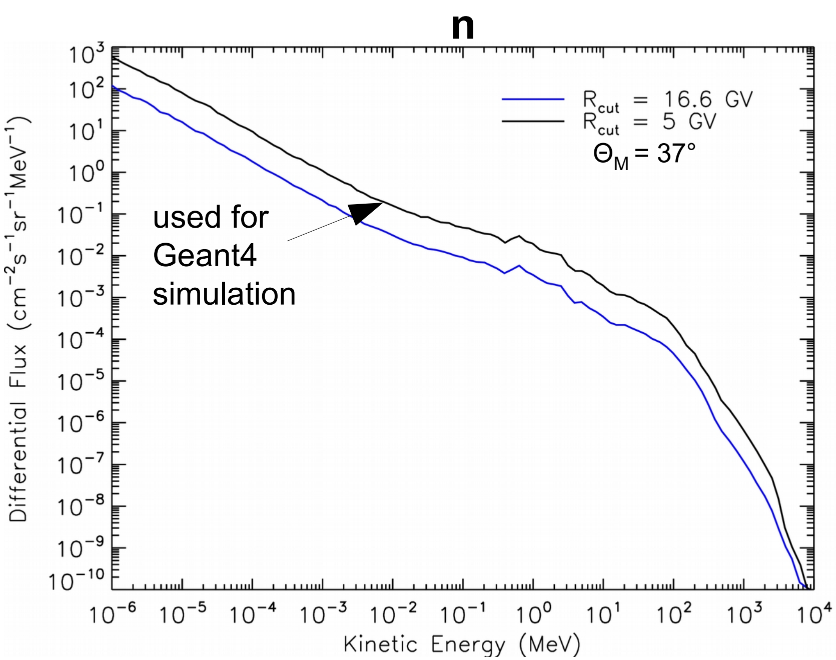


Secondary particles due to CR

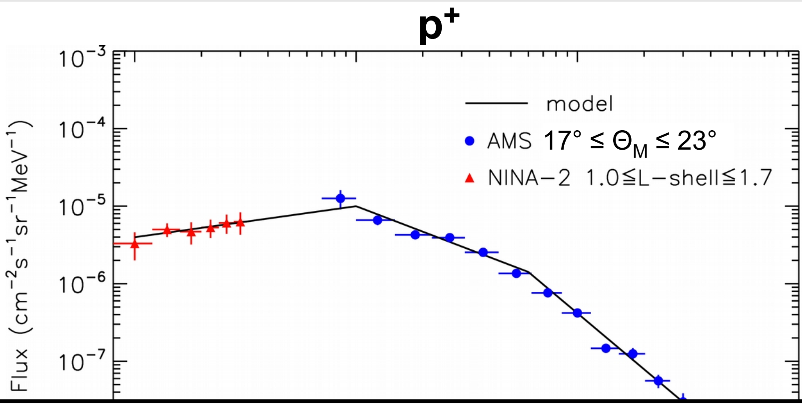


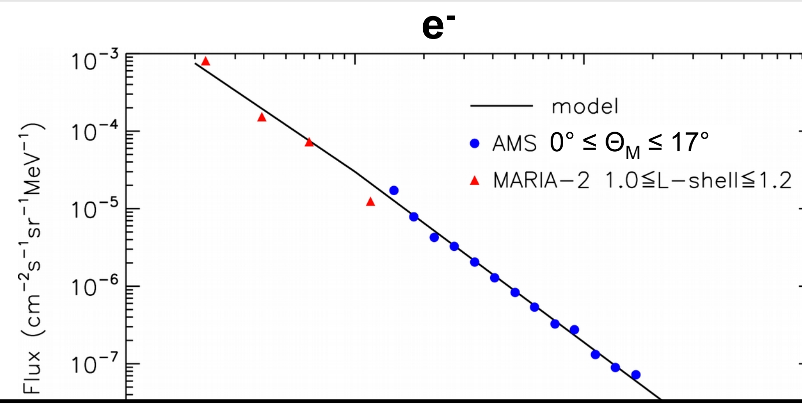






Secondary particles due to CR

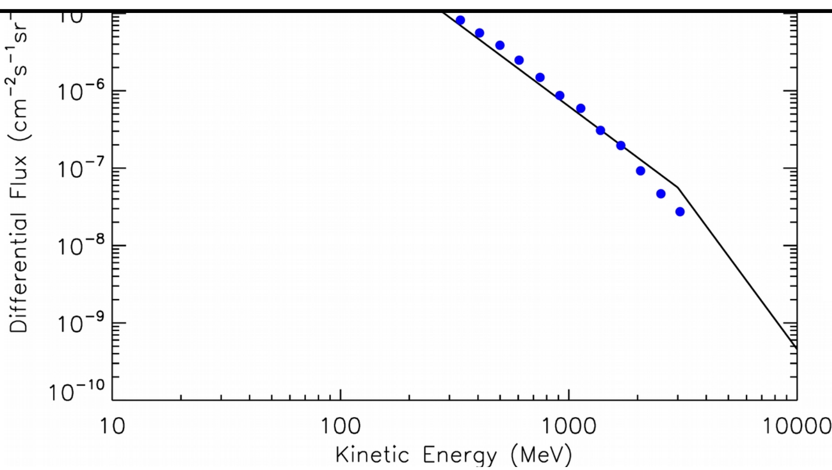


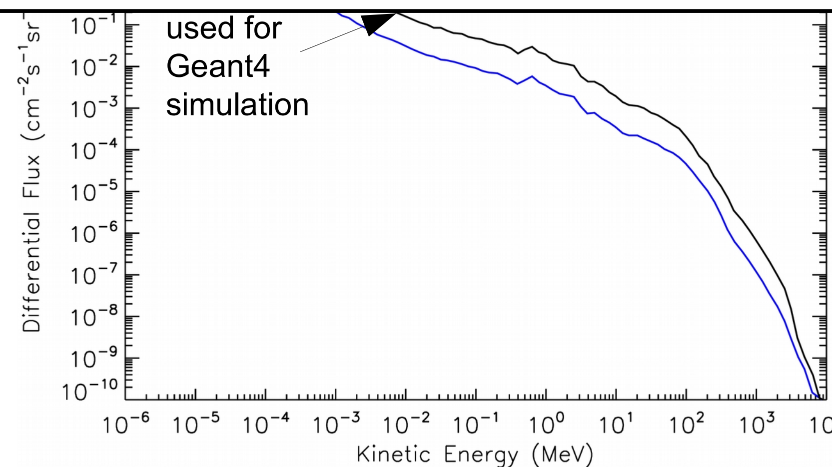


- Integral flux for sec. p+ for E ≥ 10 MeV, Ω = 4π sr - same model for upward and downward components:
  - **p+ 0.037 $cm^{-2}s^{-1}$**

- Integral flux for sec. e- and e+ for E ≥ 20 MeV, Ω = 4π sr - same model for upward and downward components:
  - **e- 0.18 $cm^{-2}s^{-1}$**
  - **e+ 0.23 $cm^{-2}s^{-1}$**

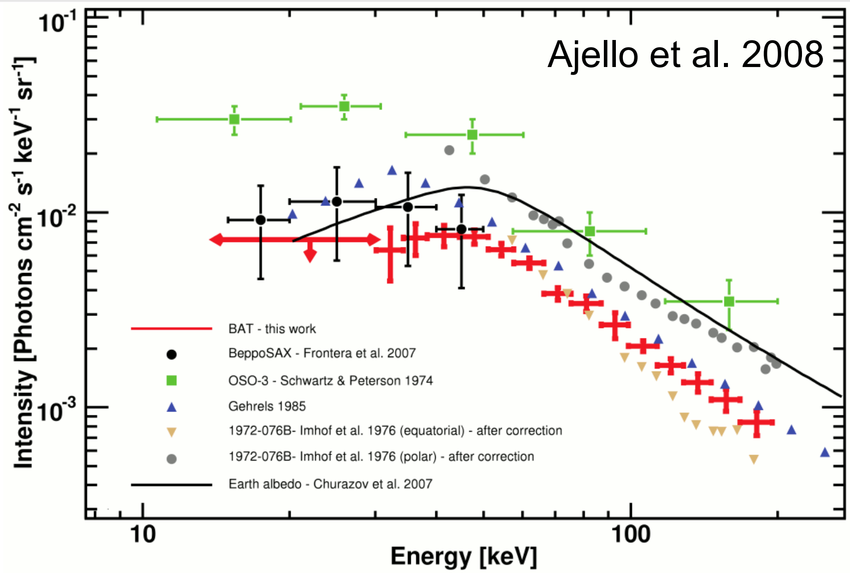
- Integral flux for sec. n for E ≥ 1 eV, Ω = 3.9 sr, h=500 km, cutoff rigidity R_{cut} = 5 GV (Θ_M = 37°):
  - **n 0.61 $cm^{-2}s^{-1}$**

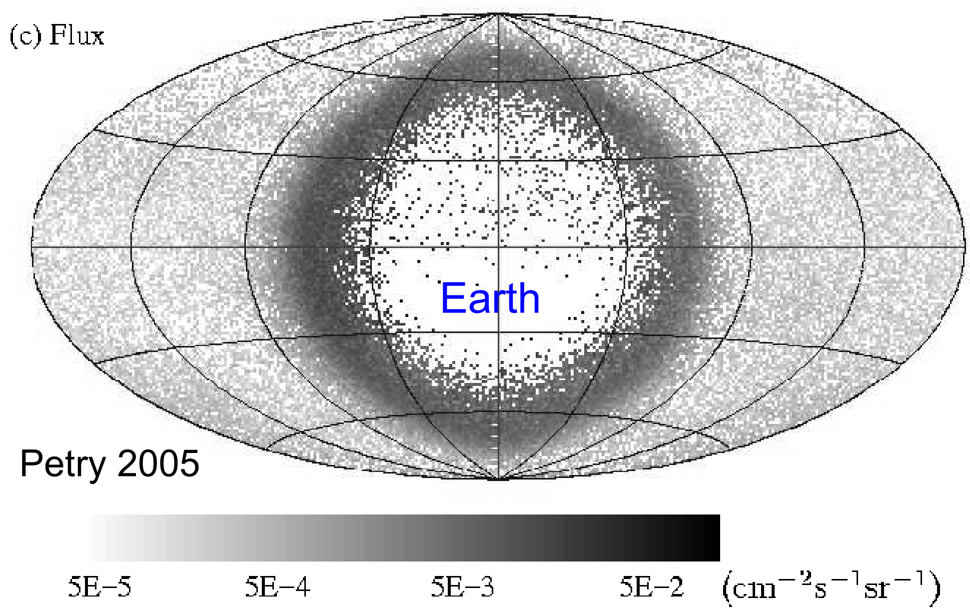




Albedo X-rays / gamma-rays

- Produced by decay of π^0 pions (>50 MeV), by bremsstrahlung from primary and secondary electrons (<50 MeV), and by reflection of CXB
- Incident flux from solid angle Ω = 3.9 sr for 500 km
- A zenith angle dependence for energies > 1 MeV has been measured
- For low energies 25 − 300 keV MC simulations (Sazonov+ 2007) suggest that there is no zenith angle dependence

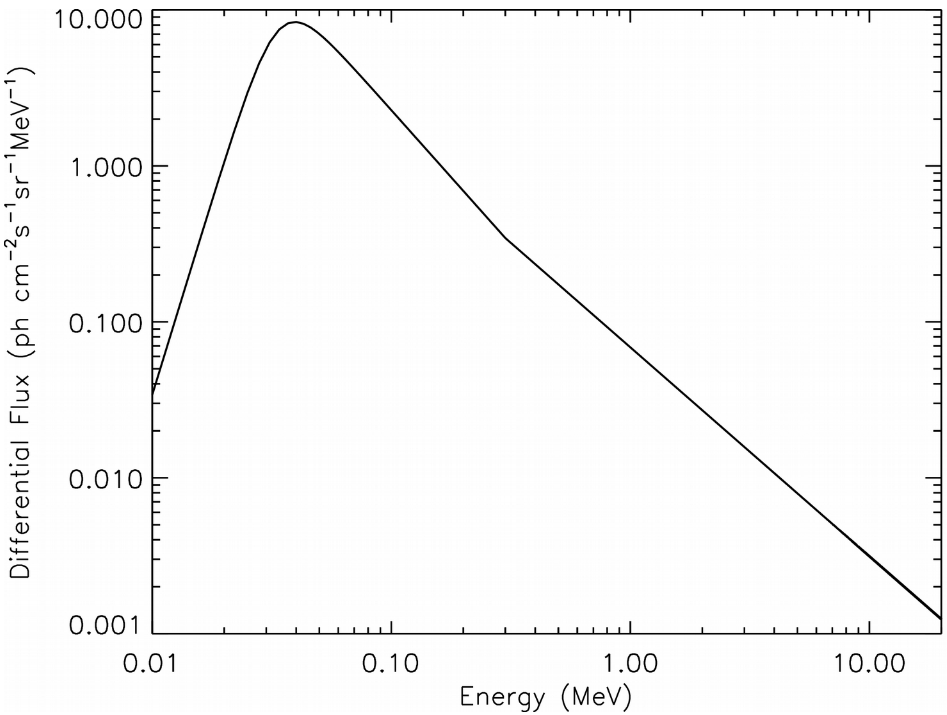


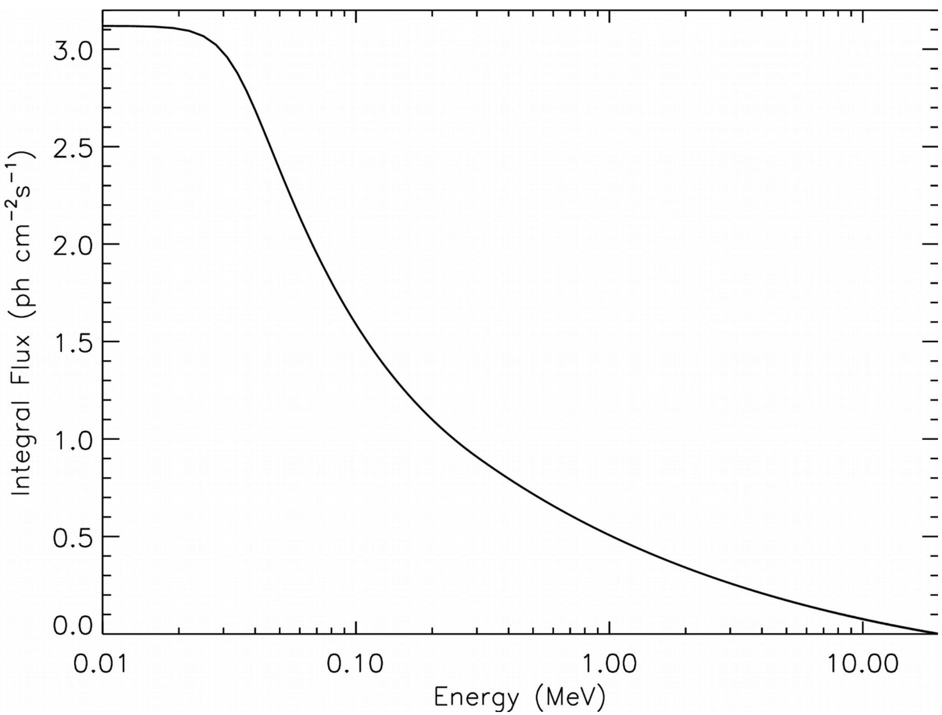


Earth view in 100 MeV - 300 MeV as seen by CGRO/EGRET

Albedo X-rays / gamma-rays

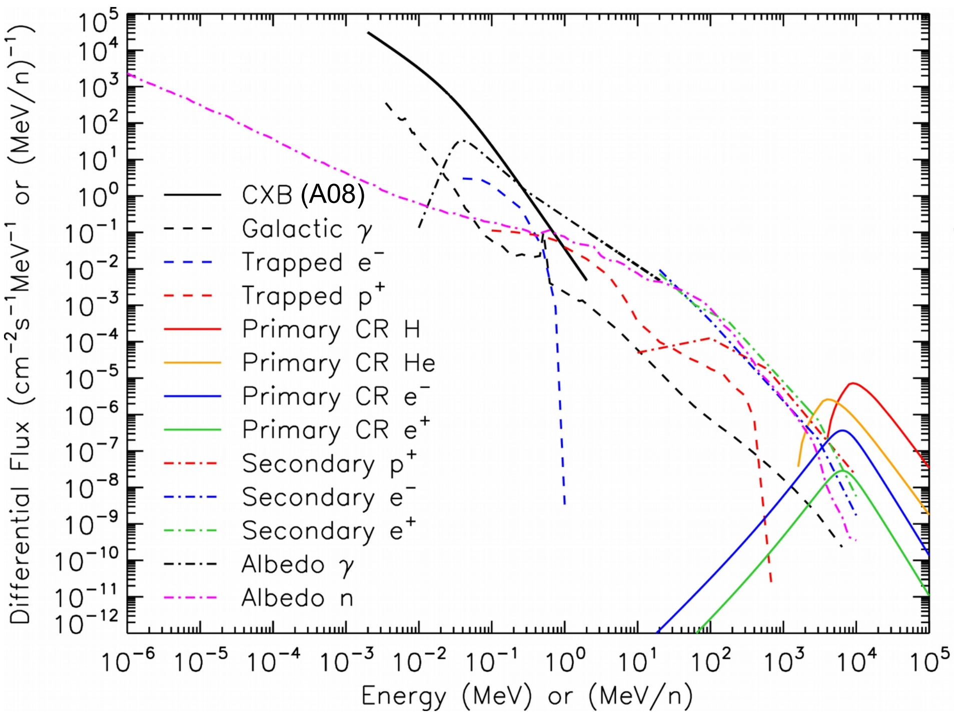
- We used flux based on Swift/BAT measurements (Ajello et al. 2008) in range 10−300 keV, for altitude ~550 km and i=20.6°
- For higher energies 0.3 − 20 MeV we used a model (Mizuno+ 2004) based on measurements by 1972-076B and Kosmos 461 satellites and by balloon flights

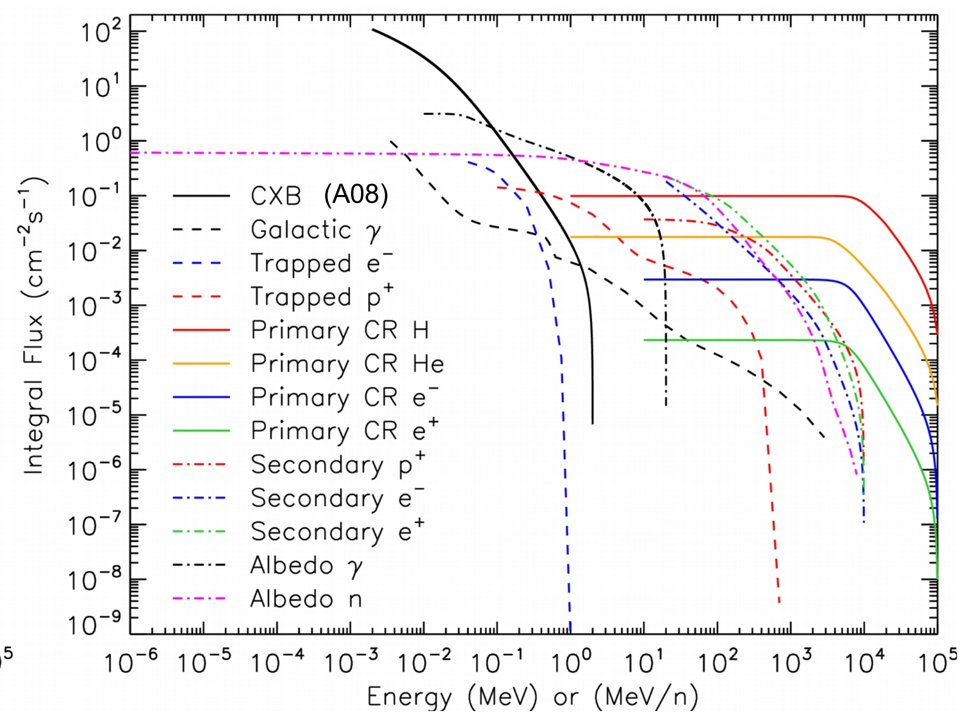




- Integral flux for E ≥ 10 keV and Ω = 3.9 sr is **3.1 ph cm^{-2} s^{-1}**

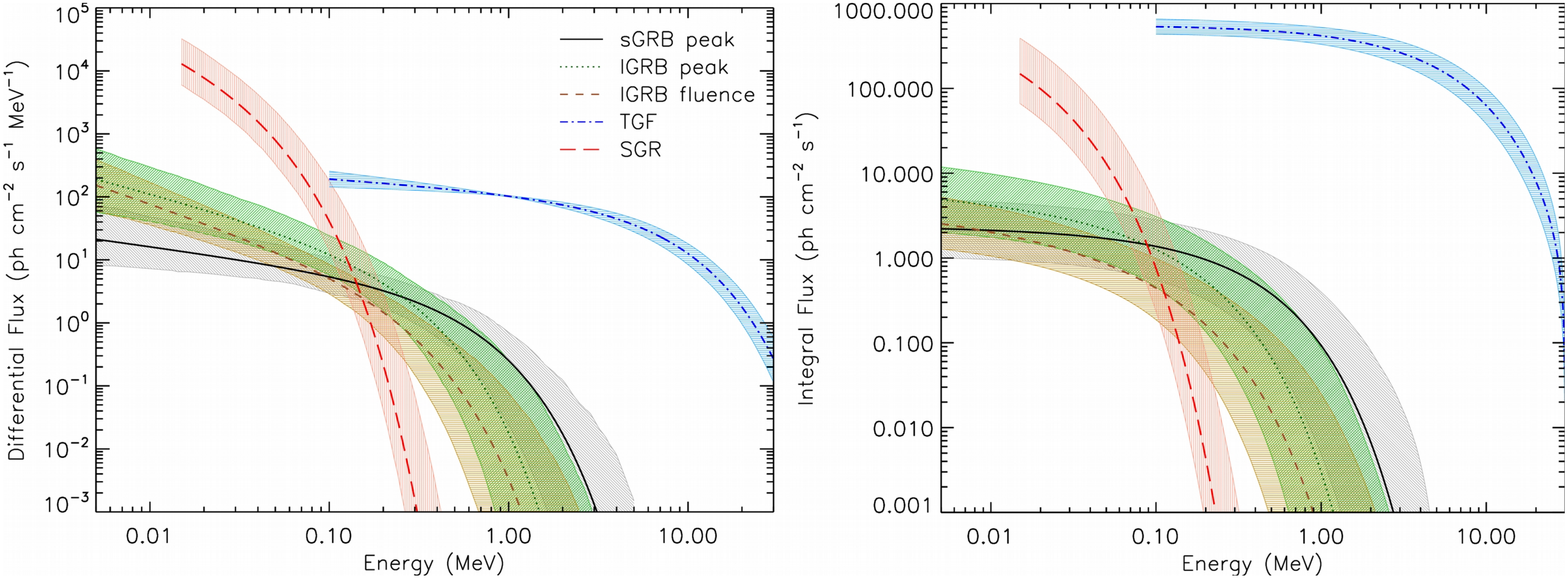
Various background components at 500 km, inclination ≲ 50°, outside SAA





- Highest components of integral flux outside SAA and polar regions are:
  - CXB: 33.7 cm^{-2} s^{-1} (Ajello+ 2008, E ≥ 10 keV)
  - Albedo γ-ray: 3.1 cm^{-2} s^{-1} (E ≥ 10 keV)
  - Sec. n: 0.61 cm^{-2} s^{-1} (E ≥ 1 eV)
  - Sec. e+: 0.23 cm^{-2}s^{-1} (E ≥ 20 MeV)

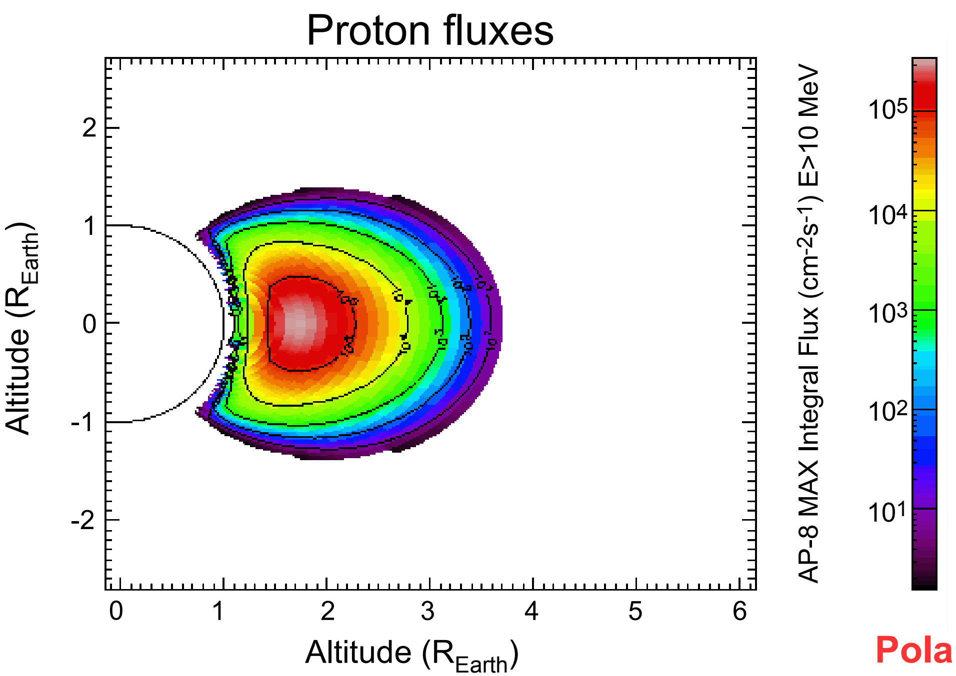
Spectra of typical GRBs, SGR and TGFs used in the simulation

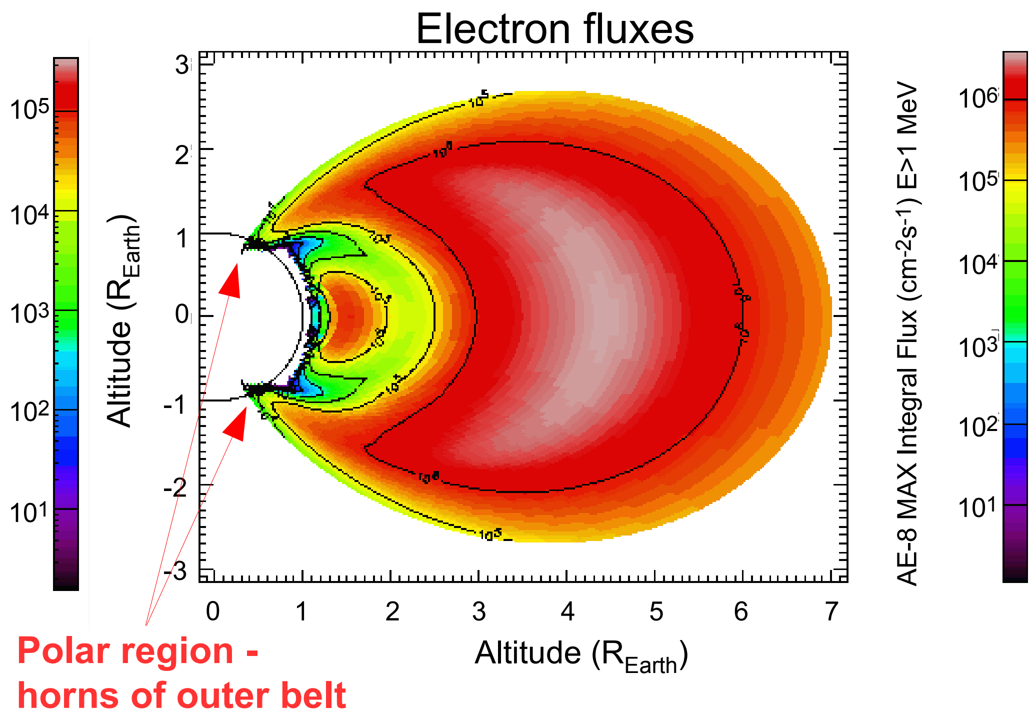


- Median peak and fluence spectra of short and long GRBs were obtained from the distribution of spectral parameters and fluxes in the Fermi/GBM GRB catalog (FERMIGRBST).
- A typical spectrum of a burst from a soft gamma repeater (SGR) is based on measured spectra with Konus in the SGR catalog by Aptekar+ 2001.
- Average spectrum of a terrestrial gamma-ray flash (TGF) is based on measurements by AGILE (Marisaldi+ 2014). Normalization corresponds to the AGILE's threshold level.

Van Allen radiation belts of magnetically trapped electrons and protons

- magnetically trapped electrons and protons - magnetic mirrors of Earth's dipole where $\vec{B} \| \vec{\nabla} B$
- most of trapped charged particles originate from solar wind and cosmic rays
- two belts now, inner (mostly p+ and e-) and outer (mostly e-)
- solar cycle variation

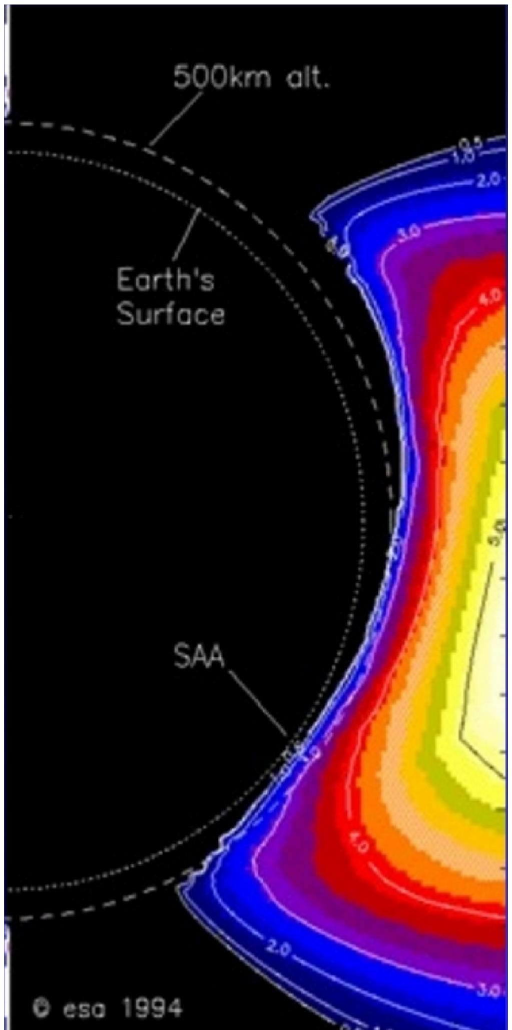


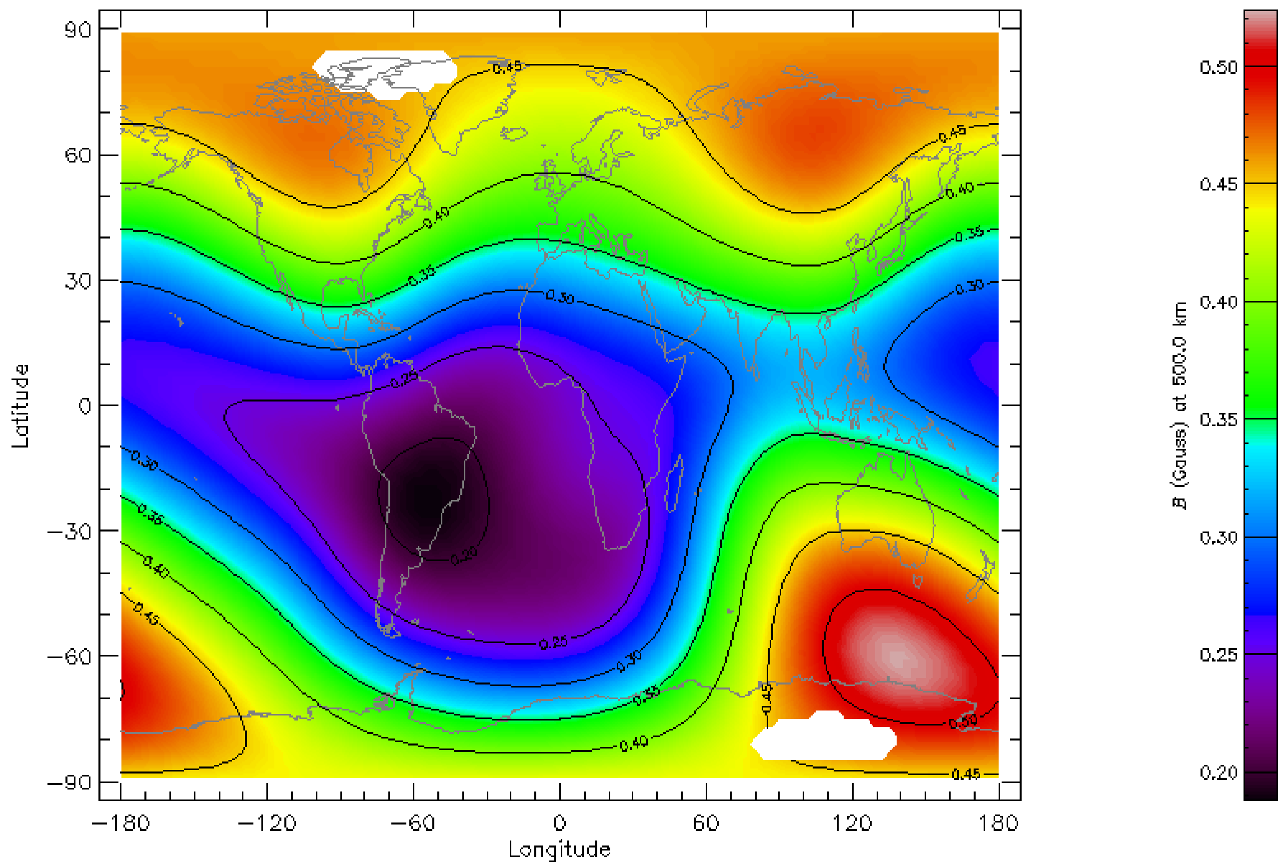


- For example AE8 & AP8 NASA models of electron (AE) and proton (AP) fluxes based on data from 60’s and 70’s or more recent AE9 & AP9 models based on data from 1976 to 2011.

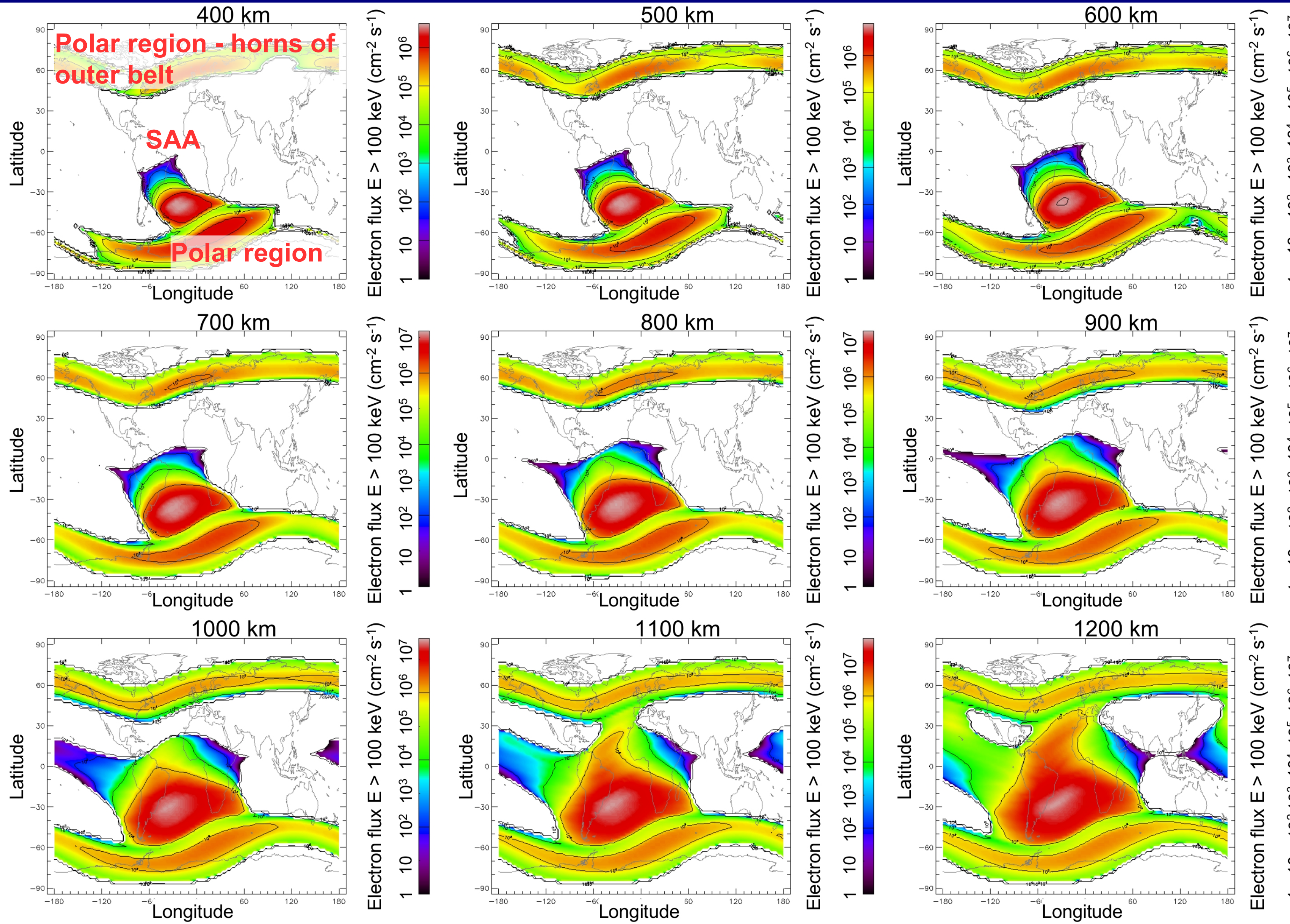
South Atlantic Anomaly (SAA)

- Low altitude part of radiation belts
- Tilt and shift of geomagnetic field
- Interaction with atmosphere

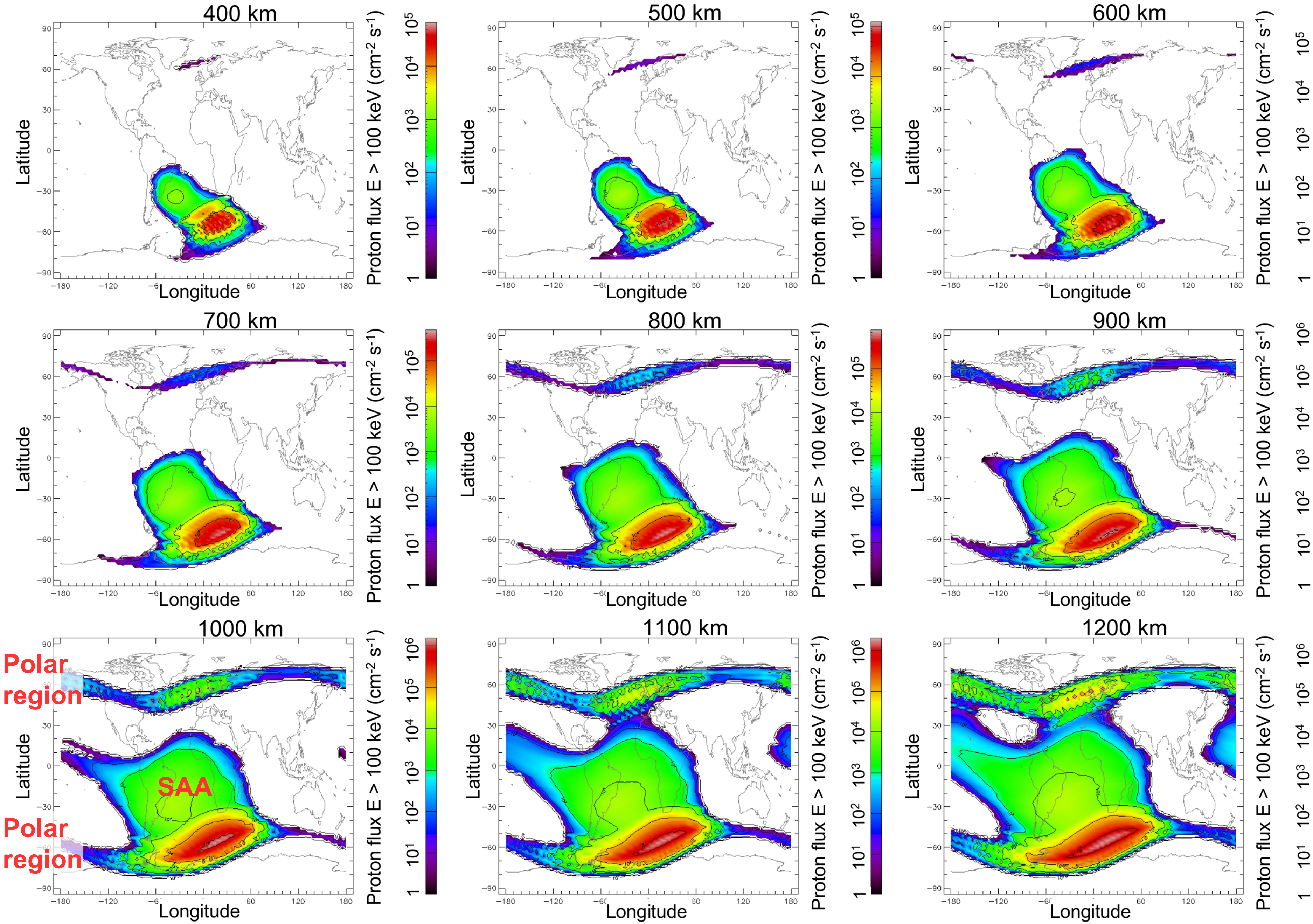




Trapped e^- (E>40keV) integral fluxes - AE-8 solar MAX, diff. altitudes



Trapped p⁺ (E>0.1MeV) integral fluxes - AP-8 solar MIN, diff. alt.



Trapped e⁻ integral fluxes - AE-8 solar MAX and AE-9 (50% CL), diff. E

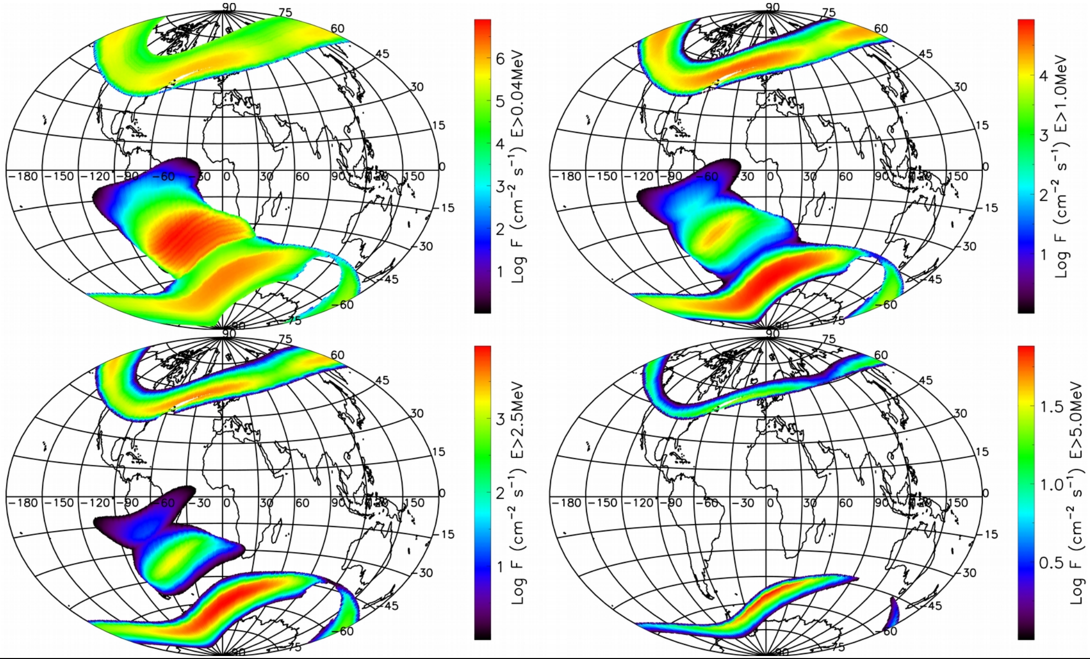
AE-8 MAX
550 km

E > 40 keV

E > 1 MeV

E > 2.5 MeV

E > 5 MeV



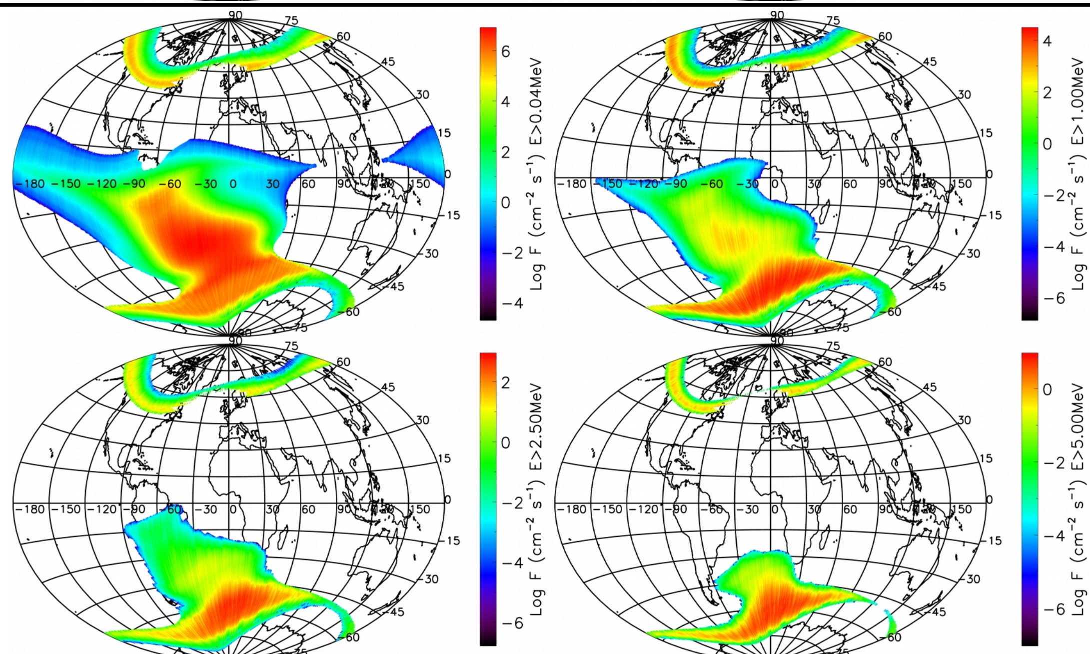
AE-9 (50% CL)
550 km

E > 40 keV

E > 1 MeV

E > 2.5 MeV

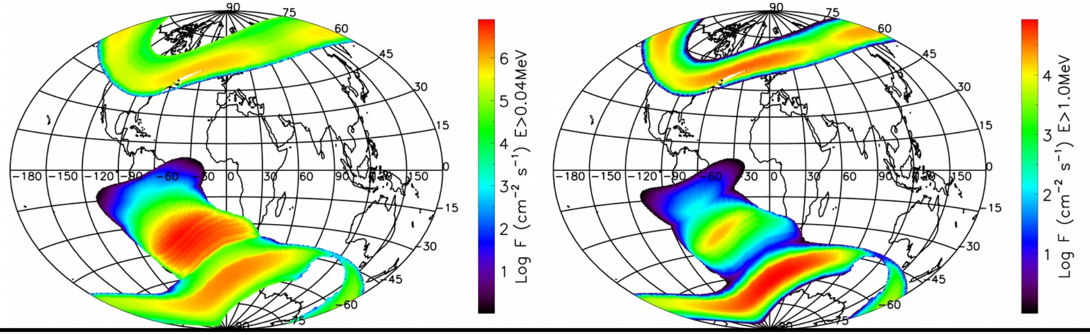
E > 5 MeV



Trapped e⁻ integral fluxes - AE-8 solar MAX and AE-9 (50% CL), diff. E

AE-8 MAX
550 km

E > 40 keV

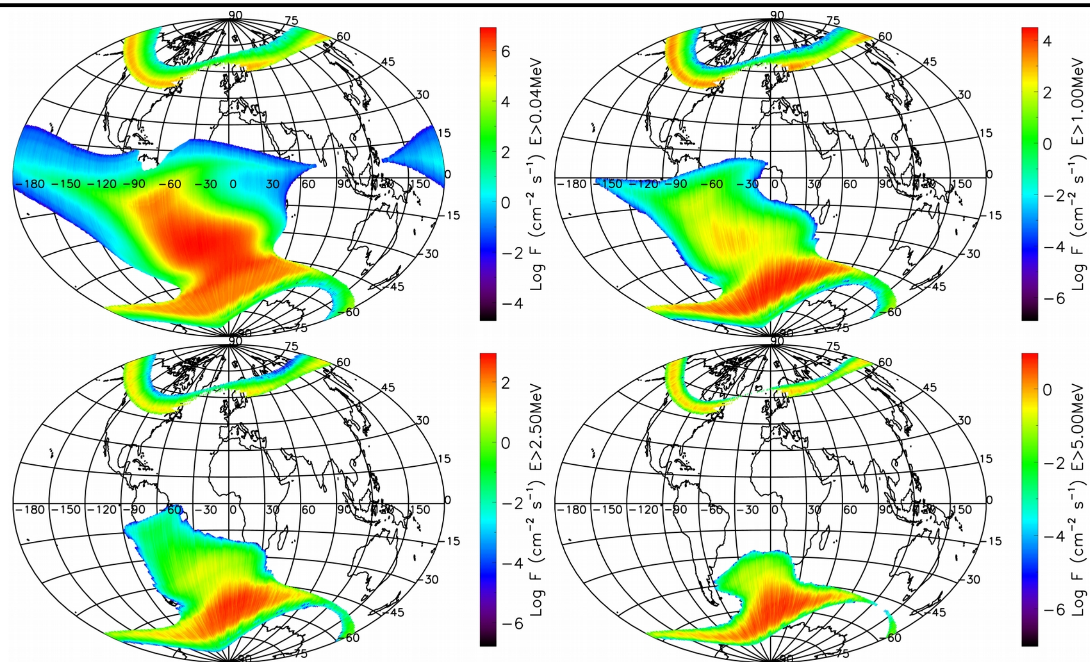


E > 1 MeV

- AE9 model has excess of low-energy, low-flux e⁻ near equator compared to AE8 model

AE-9 (50% CL)
550 km

E > 40 keV

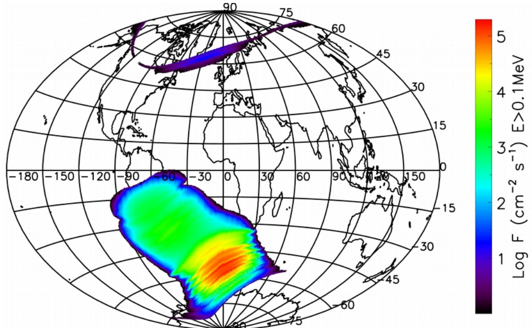


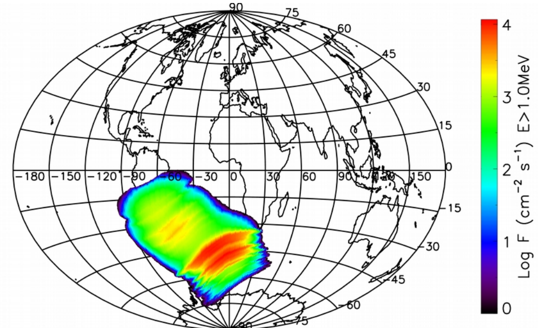
E > 1 MeV

Trapped e⁻ integral fluxes - AP-8 solar MIN and AP-9 (50% CL), diff. E

AP-8 MIN
550 km

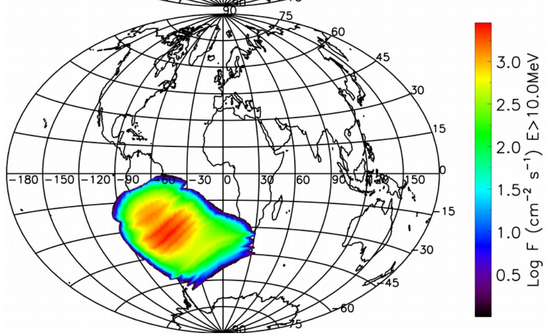
E > 0.1 keV

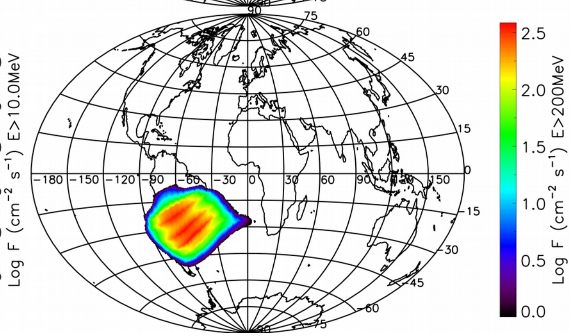




E > 1 MeV

E > 10 MeV

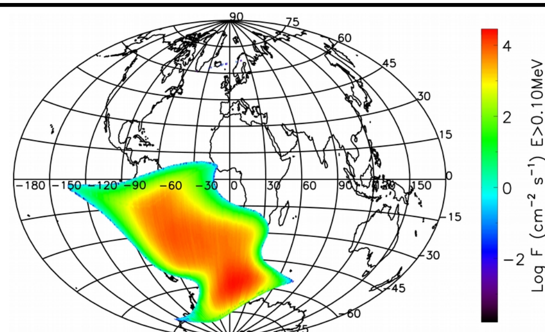


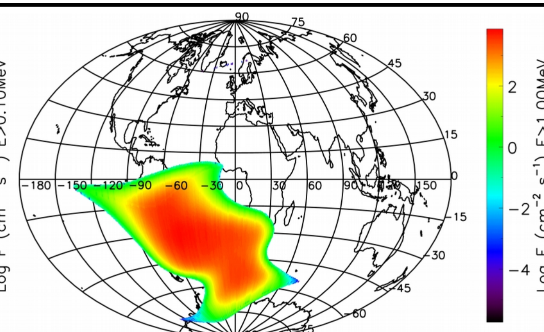


E > 200 MeV

AP-9 (50% CL)
550 km

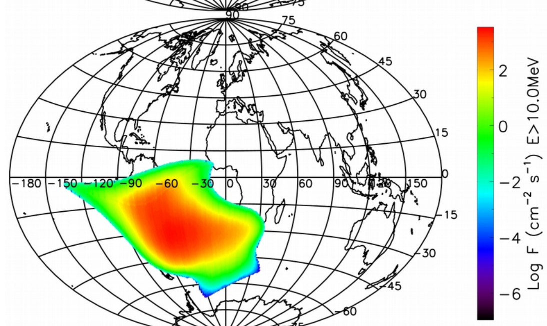
E > 0.1 keV

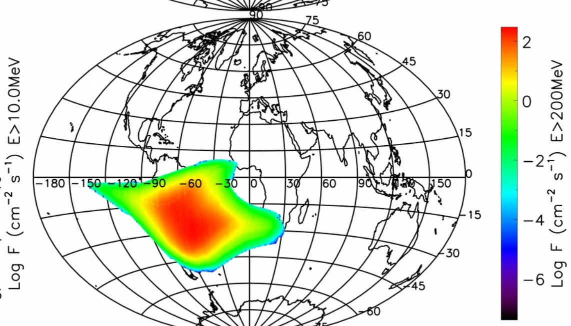




E > 1 MeV

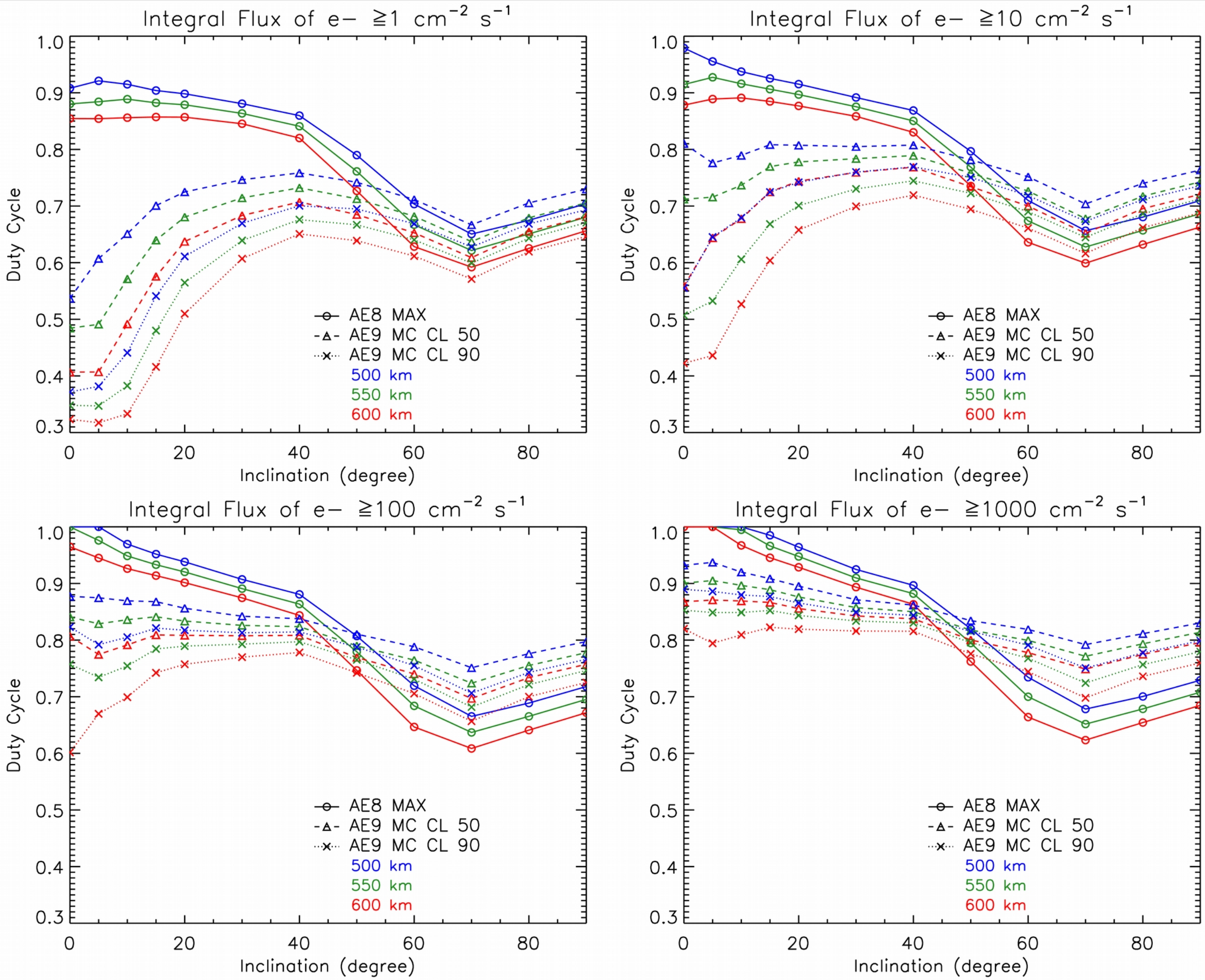
E > 10 MeV





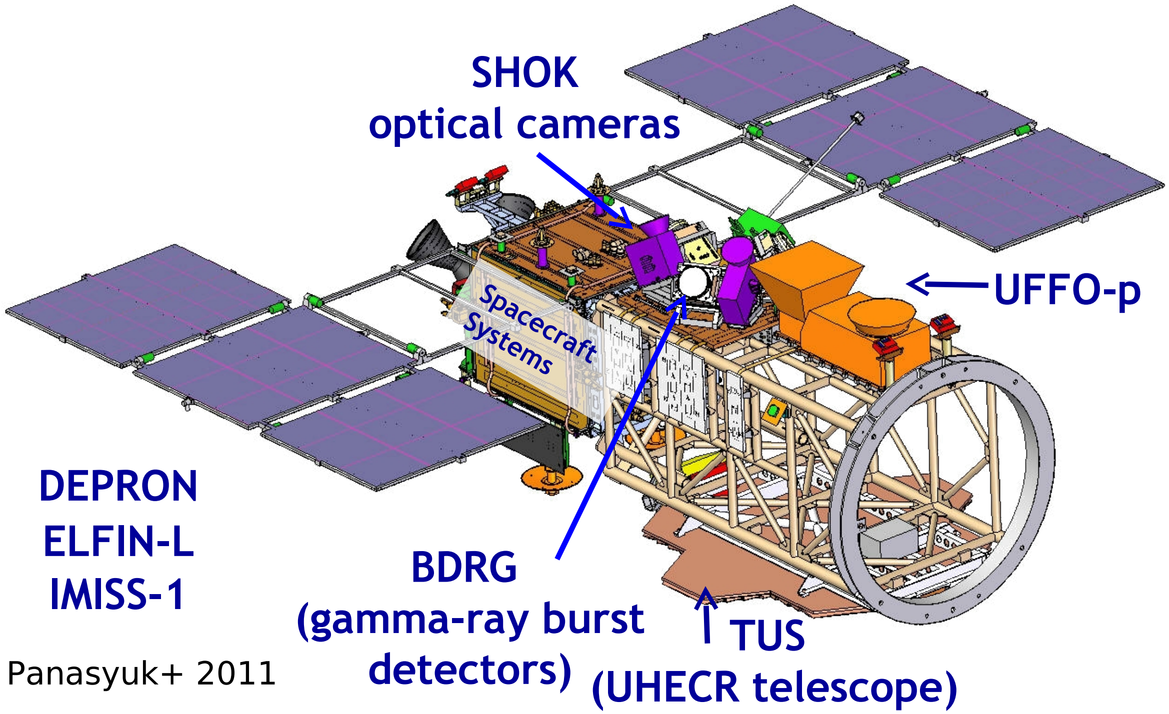
E > 200 MeV

Duty cycle for for AE8 MAX, AE9 (50%, 90% CL) models

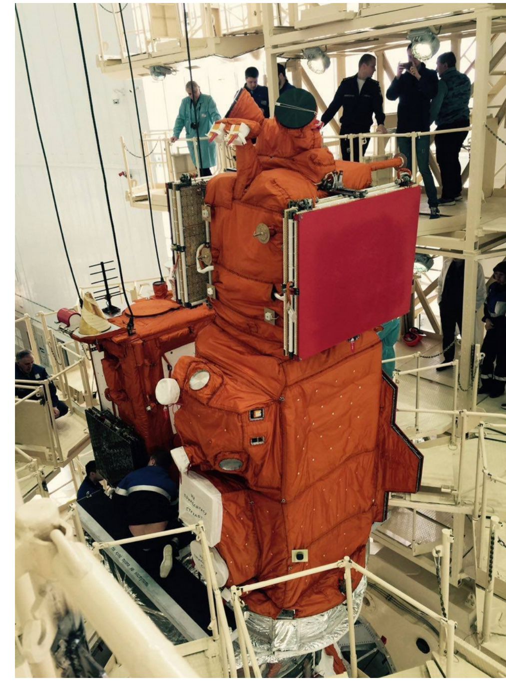


- Duty cycle was calculated as the fraction of time a satellite spends in the area with an integral flux of particles < a given flux threshold.
- For different models: AE8 MAX, AE9 (50%, 90% CL)
- For low-energy threshold of 0.04 MeV and for different flux thresholds and altitudes

Measured background at SSO: Lomonosov / BDRG Gamma-ray detector

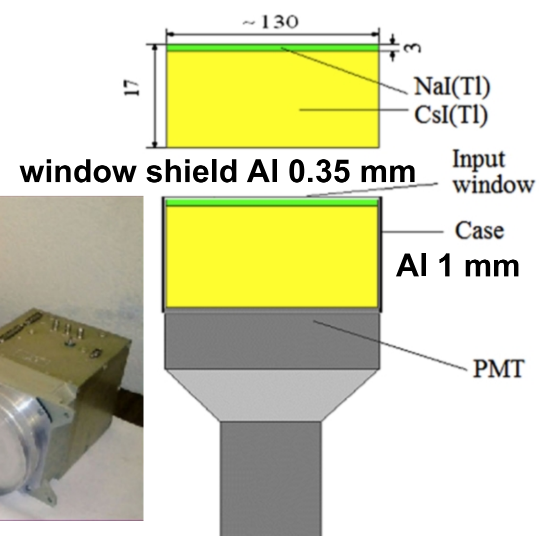


Panasyuk+ 2011



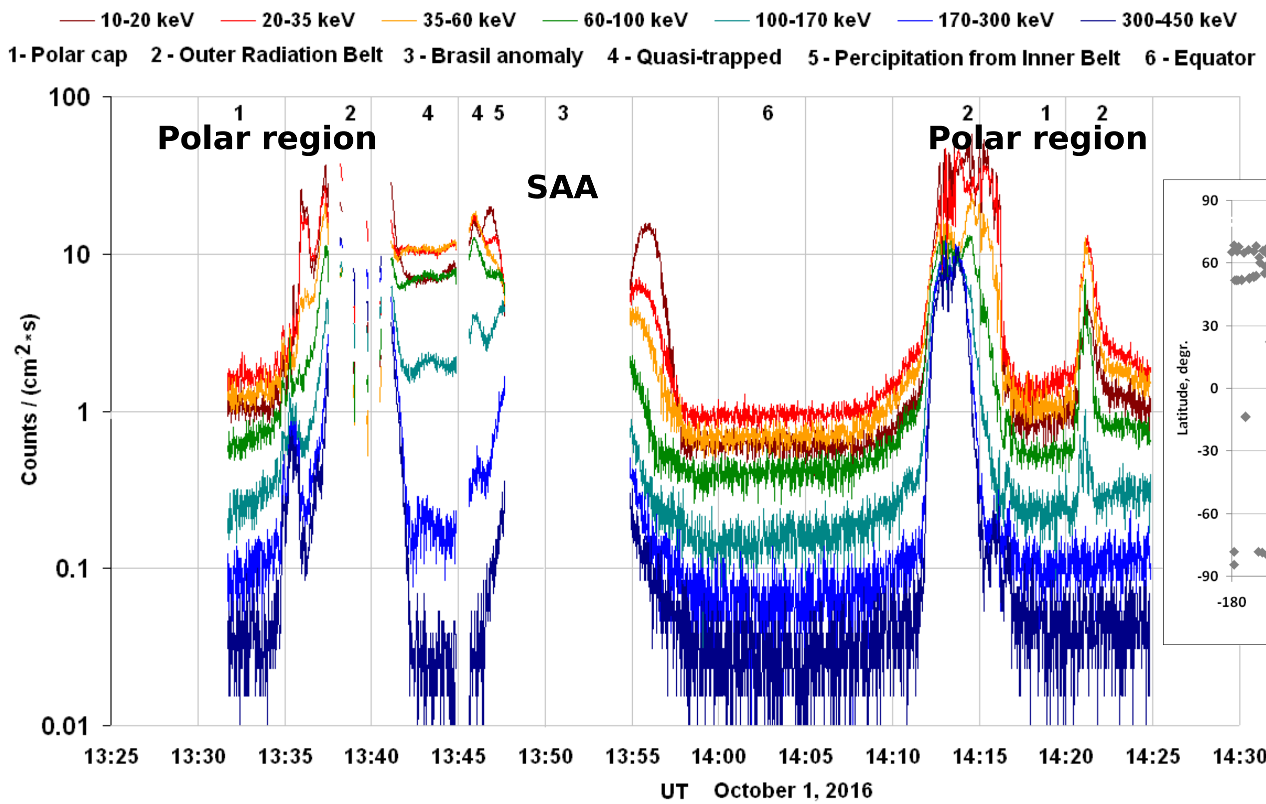
Spacecraft:	Lomonosov satellite (Russia)
Launcher:	Sojuz 2.1a, Vostochny
Launch:	Apr. 2016
Orbit & Altitude:	Sun-synchronous orbit ~500 km
Total/Payload Mass:	450 kg / 150 kg
BDRG E. Range:	5 keV - 3 MeV
BDRG Eff. Area:	3x120 cm^2
BDRG FoV:	2 sr

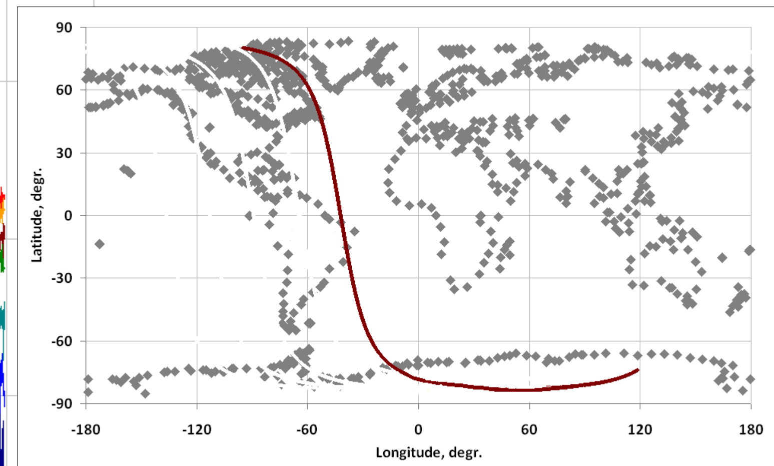
Svertilov+ 2018

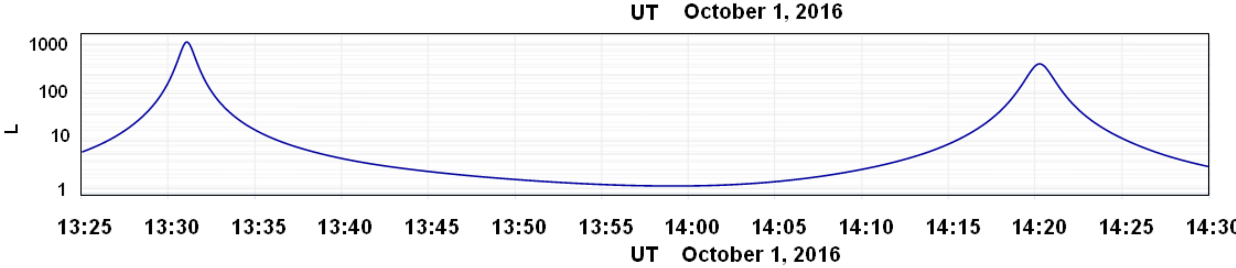


BDRG count rate

- Electrons with E>~300 keV can penetrate directly through the window shield.
- The counts in energy ranges less than several hundreds keV are caused mainly by bremsstrahlung (S. Svertilov).





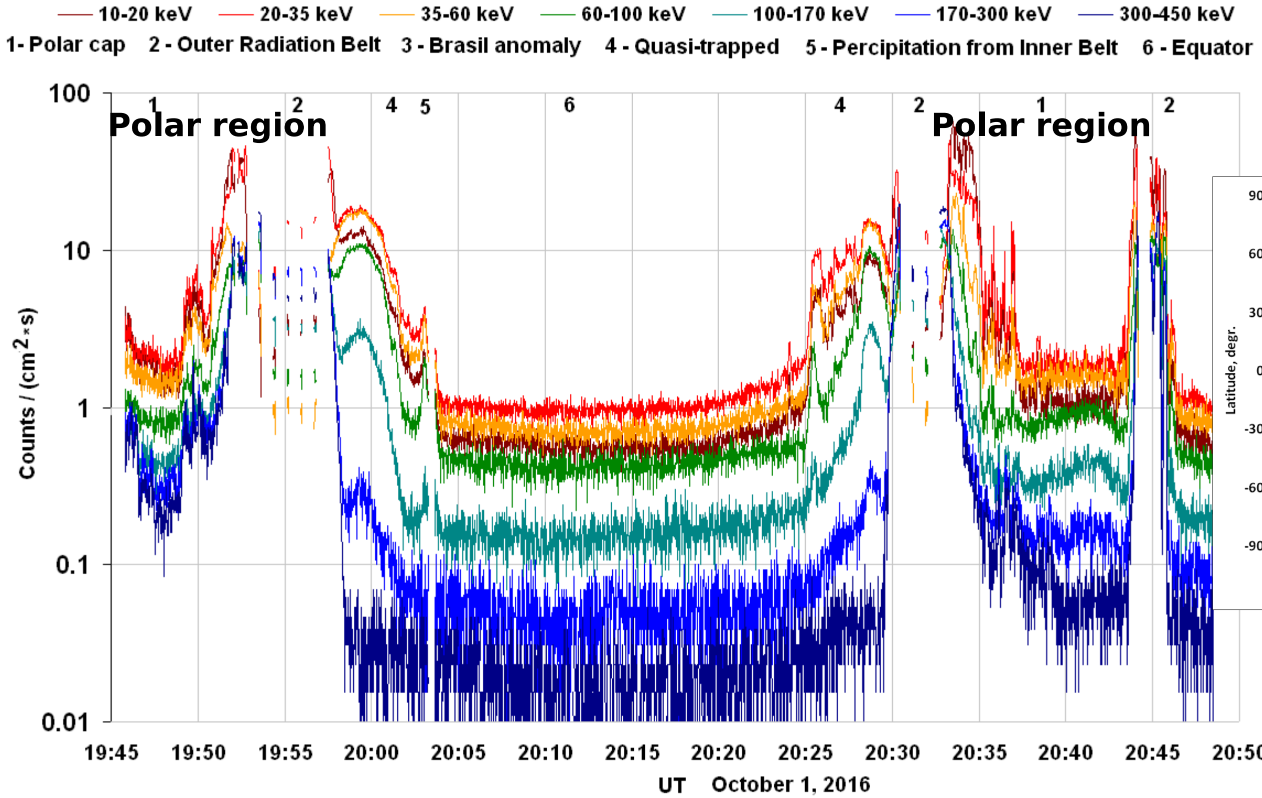


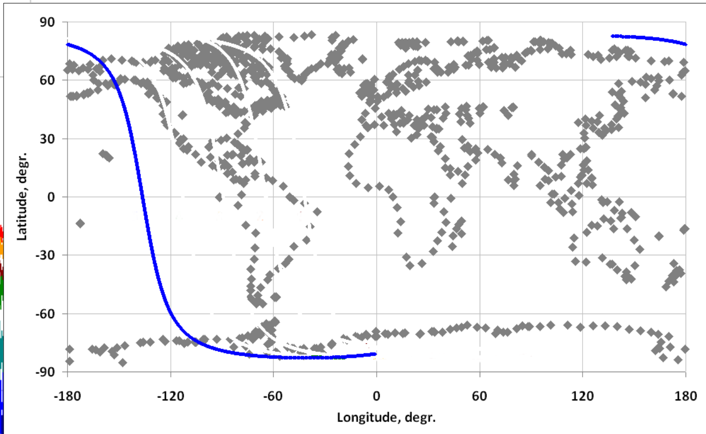
L-Shell parameter

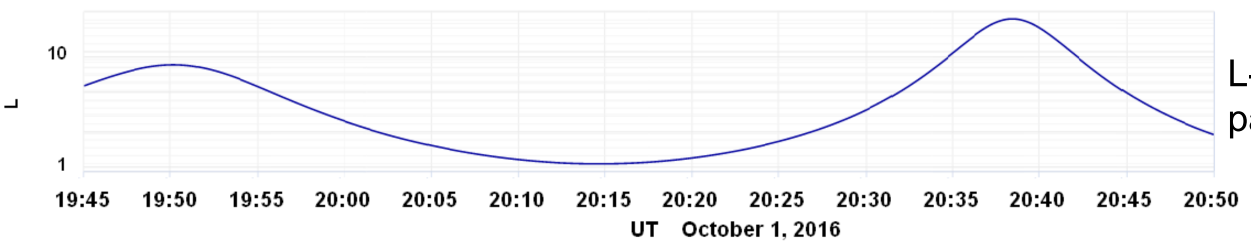
Credit: Svertilov, S. I. (Lomonosov team) - private communication

BDRG count rate

- Count rate at 10-450 keV is about 60x higher at polar region than at equator
- For polar orbit,duty cycle can be around 60% if we exclude high level and rapidly changing background regions.



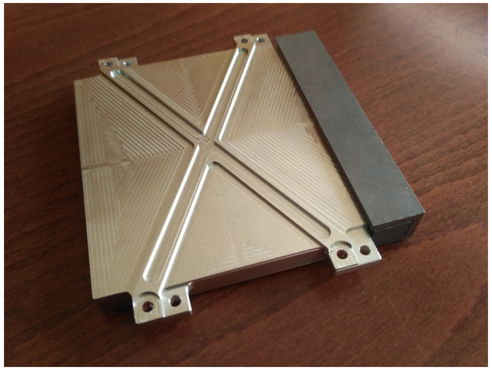


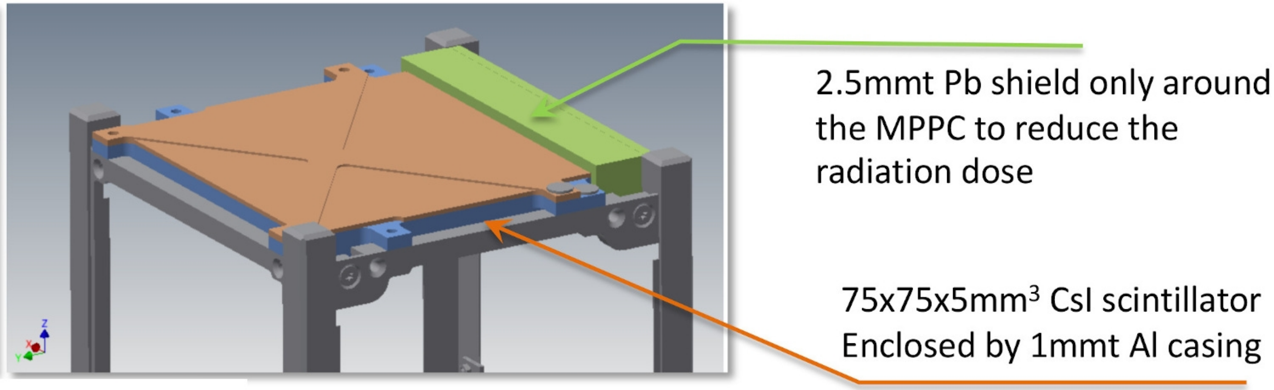


L-Shell parameter

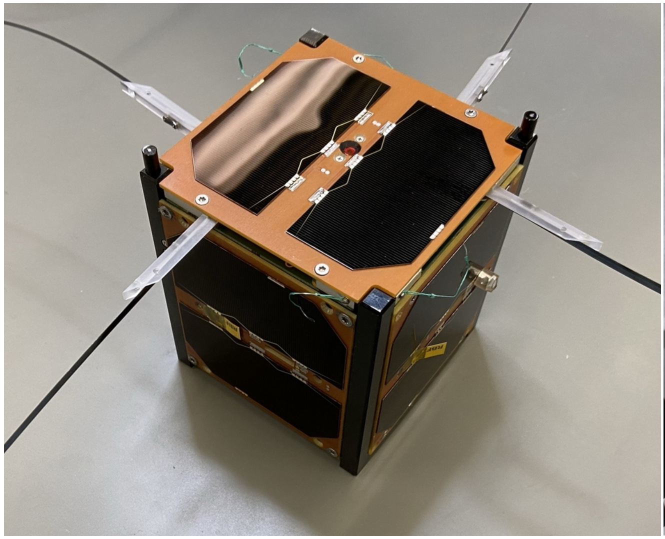
Credit: Svertilov, S. I. (Lomonosov team) - private communication

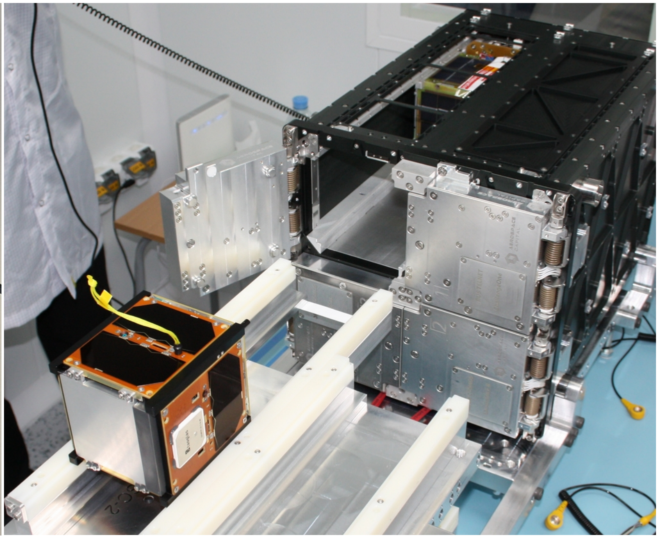
GRBAlpha status





- Small size of scintillator (75x75x5mm^3), readout by 8 MPPCs, for 1-U platform but the same basic concept to CAMELOT
- Assembled and shipped to Russia
- Launched from Baikonur by Soyuz-2 to 550 km SSO, yesterday!
- https://grbalpha.konkoly.hu/

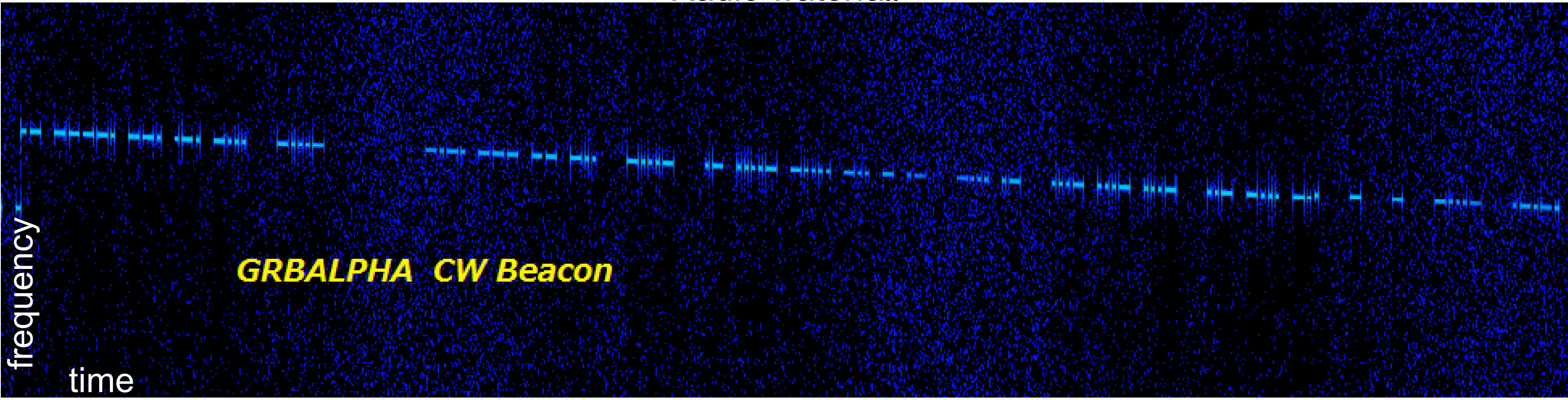




GRBAlpha status

- Detections by radio amateurs: https://network.satnogs.org/observations/?norad=99722&page=4
- At 437.025 Mhz

Radio waterfall



Credit: Satou Tetsurou (JA0CAW)

- Contact using ground station in Slovakia
- First ping to satellite
- OBC is responding, we got packets with sat. HK: CPU temp.; CPU, Bat. voltages; information from sun-sensors etc.
- Detector responded to commands