BIRKELAND CENTRE FOR SPACE SCIENCE

UV and X-ray imaging of aurora and other atmospheric phenomena

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Norway

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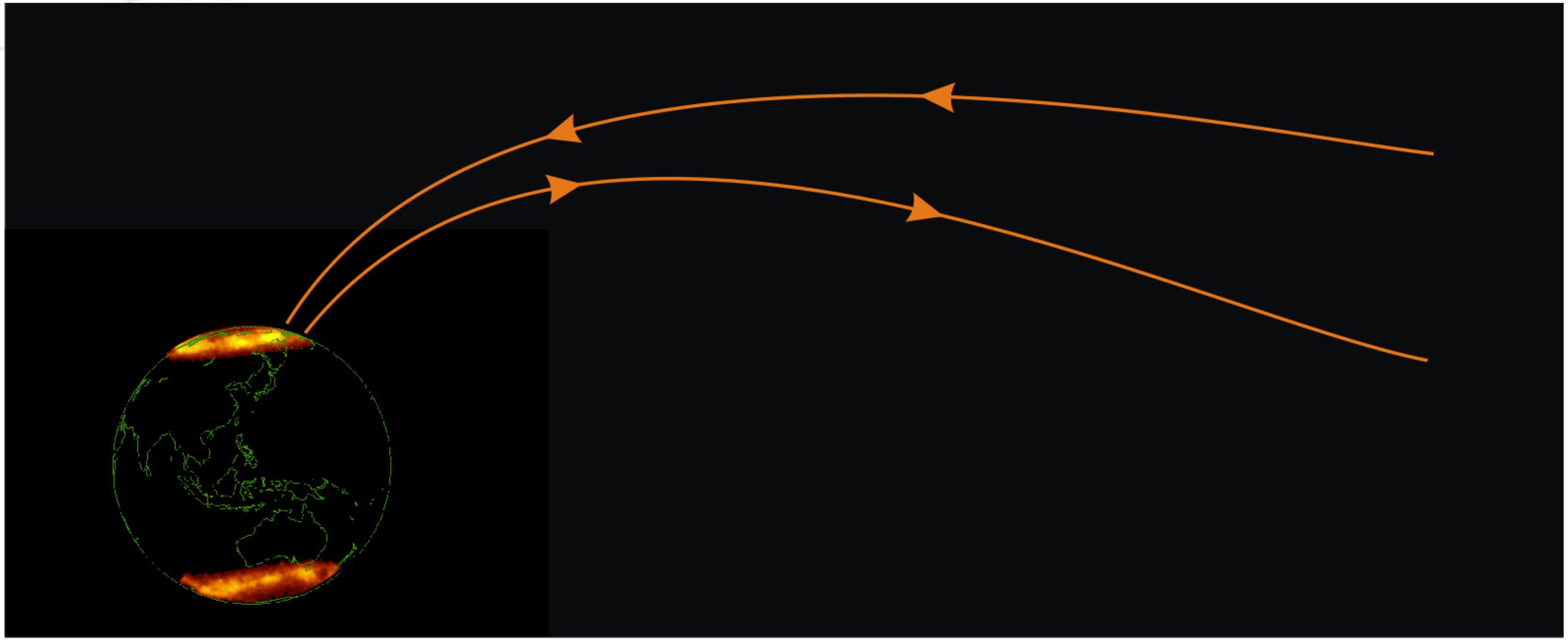
Global imaging:
Footprint of processes in magnetosphere and acceleration regions.



Derive electron energies

Emissions	Technique	Electron energies
X-rays (Polar)	Known production	3-100 keV
UV (Polar/IMAGE)	Absorption by O2	0.1- 20 keV

X-ray imaging by Polar PIXIE

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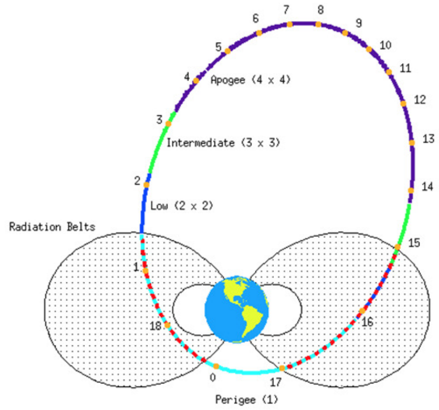

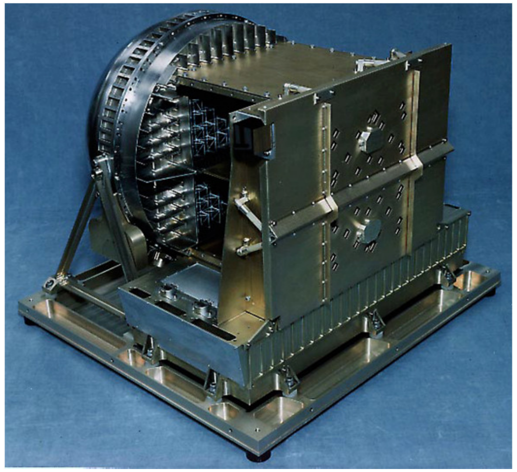

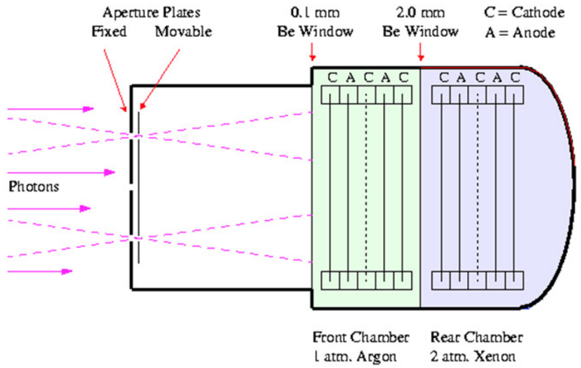

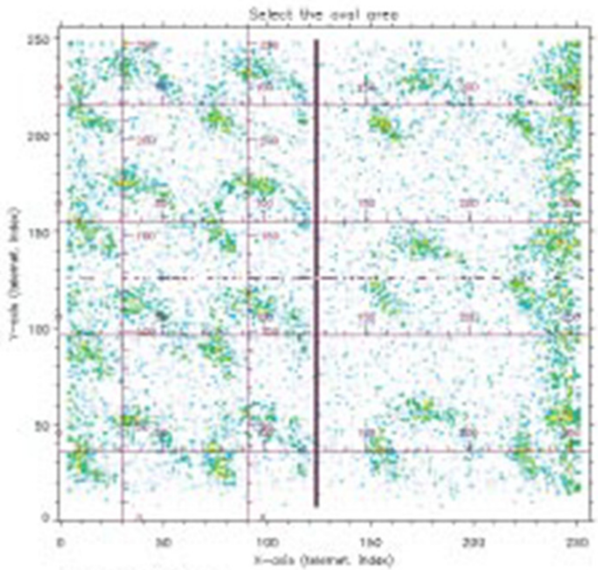

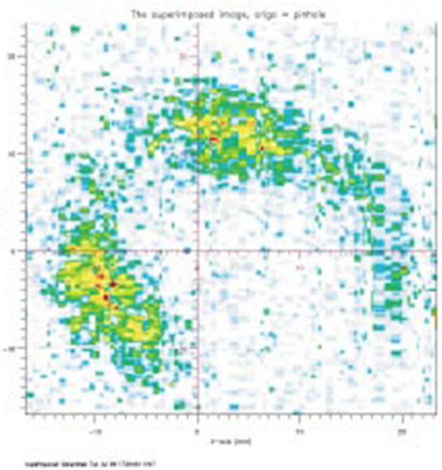

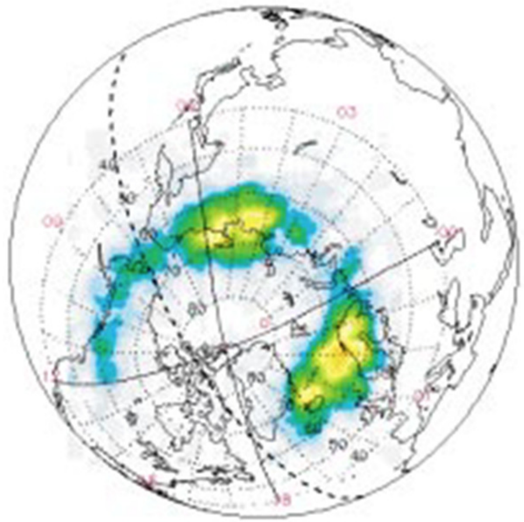

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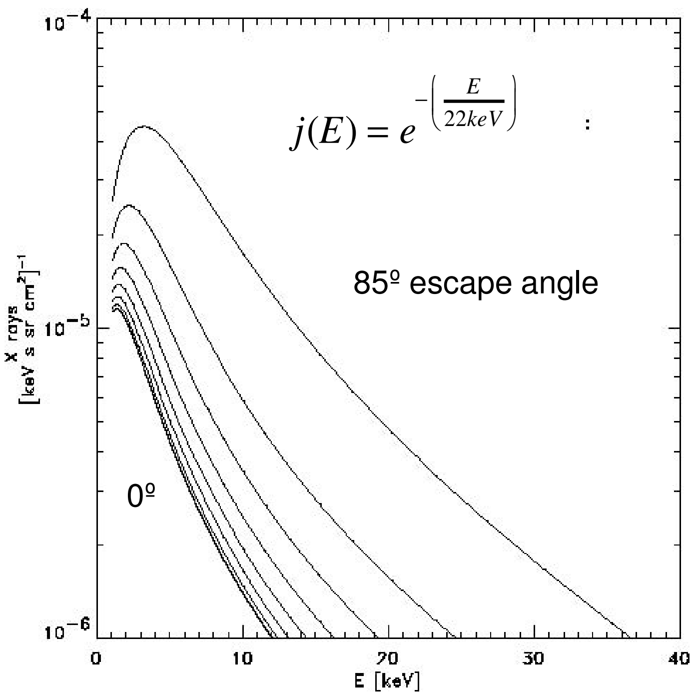
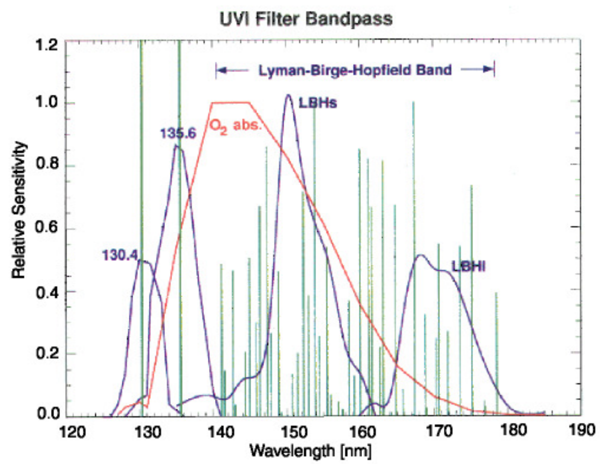
Inversion techniques:

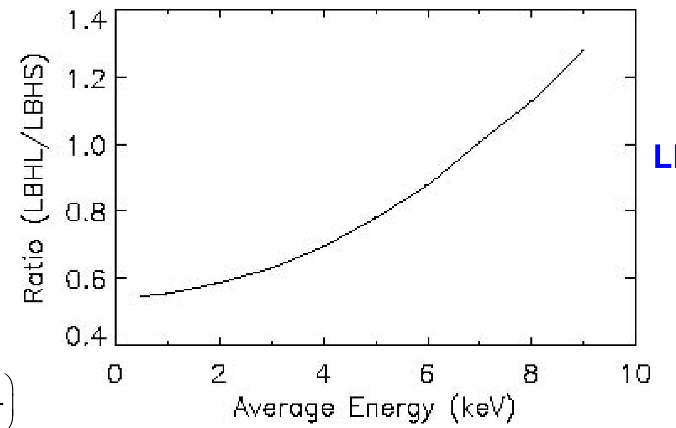
X-rays:
A library of X-ray spectra from electron exponential spectra



exponential: $j(E) = A_1 e^{-\left(\frac{E}{E_{01}}\right)} + A_2 e^{-\left(\frac{E}{E_{02}}\right)}$

UV: LBH long and short - O2 absorption





exponential: $j(e) = A_{oe} e^{-\left(\frac{E}{E_{0e}}\right)}$

Maxwellian: $j(e) = EA_{0m} e^{-\left(\frac{E}{E_{0m}}\right)}$

Ratio gives E_0

LBHL gives total energy -> A_0

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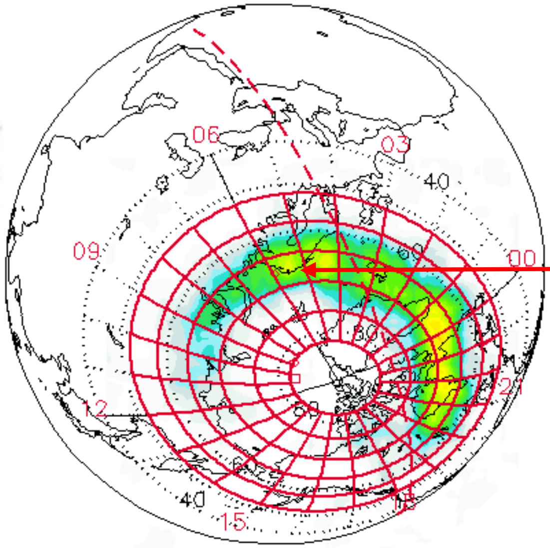
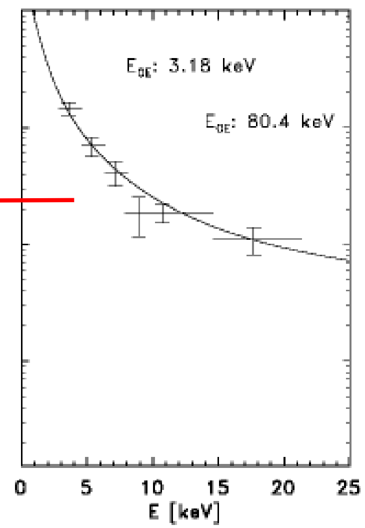
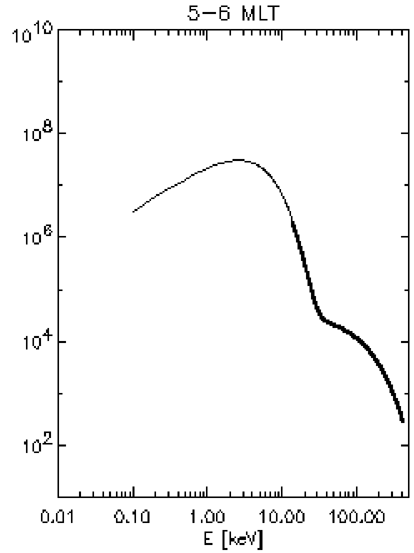
UVI and PIXIE

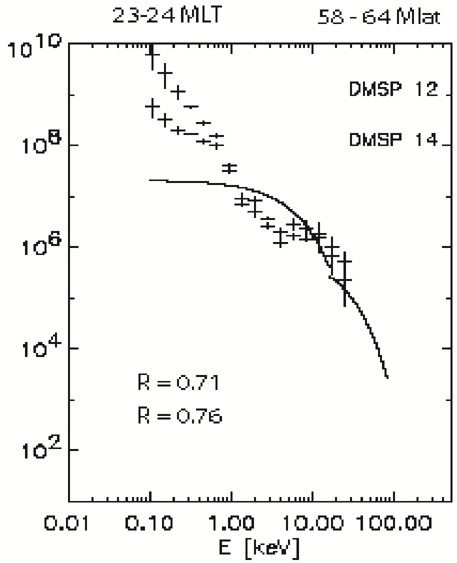


Best fit to X-ray spectra





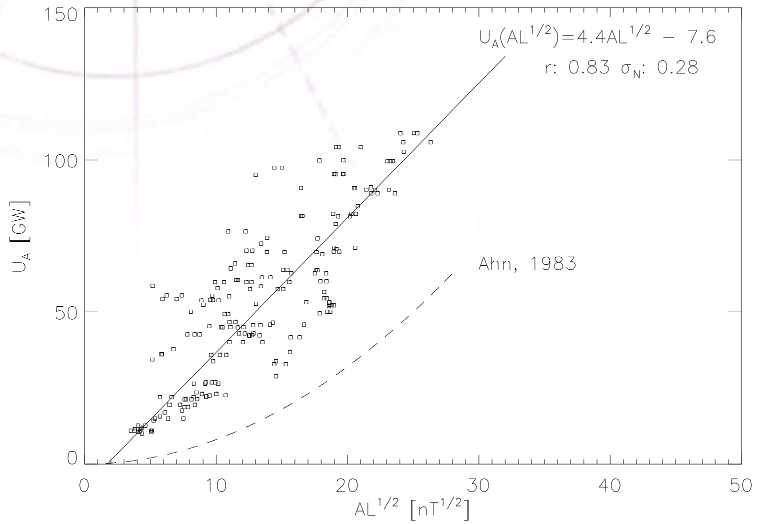
Electron spectra (0.1-100 keV)
from UV and X rays



Validated by DMSP passes

Østgaard et al., JGR, 2001

The linear relation with $AL^{1/2}$



Østgaard et al., JGR, 2002

$$U_A = 4.4AL^{1/2} - 7.6$$

Two other energy sinks:

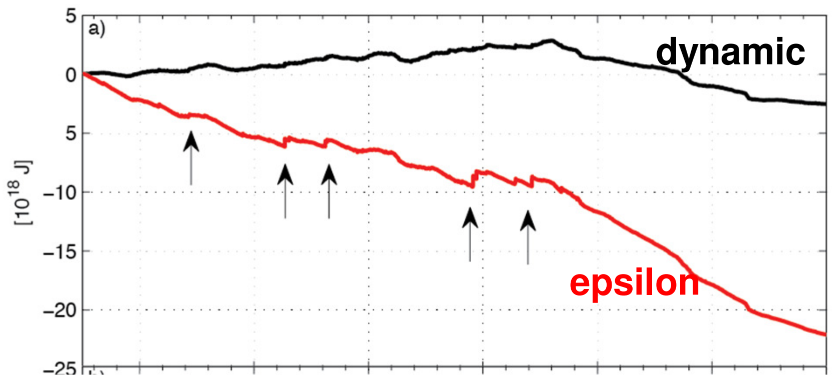
$$U_R = 4\times10^4\left(\frac{dDst^*}{dt}+\frac{Dst^*}{\tau}\right)$$

$$U_J = 0.54AE + 1.8$$

This has been used to derive an improved energy coupling function

$$P_{input} = \frac{B_T^2 V_x}{\mu_0} M_A \sin^4(\theta/2)\frac{167}{5\times10^{-5}|B_z|^3+1}\cdot R_E^2$$

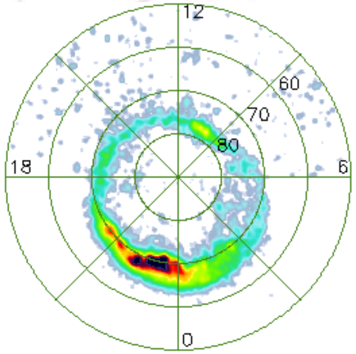
$$\text{where } B_T = \sqrt{B_y^2 + B_z^2} \text{ and } M_A = \frac{\sqrt{\mu_0 P_f}}{B_T}$$



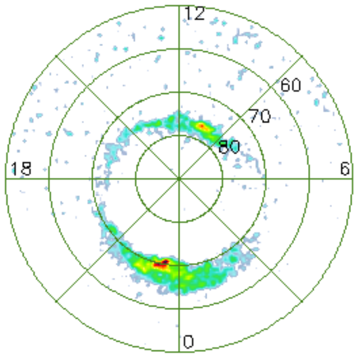
Tenfjord and Østgaard, JGR, 2013, in press

IMAGE: Electron spectra derived from UV emissions

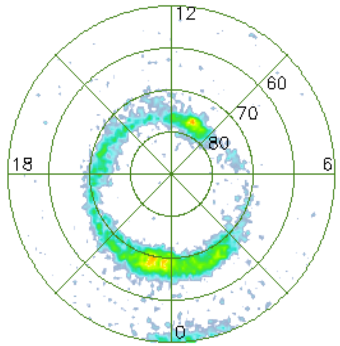
WIC
N_2-LBH:
140-190 nm



SI-13
OI: 135.6nm



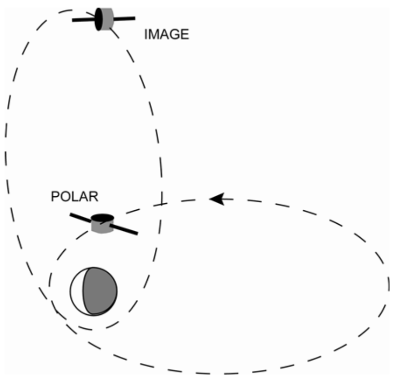
SI-12
Doppler shifted Ly-a 121.8 nm

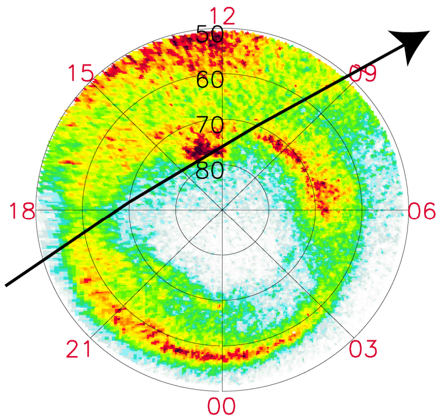


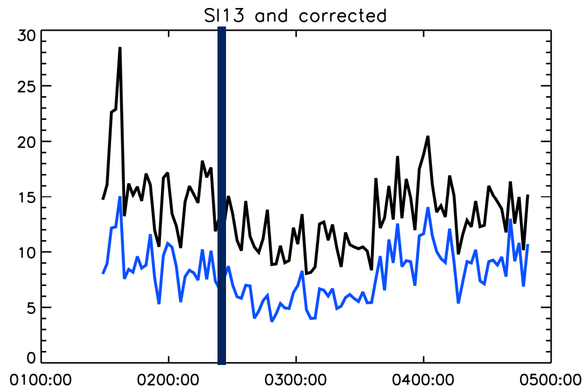
Electron energy flux (after removing effects of protons): WIC/SI-13

Proton energy flux

Protons usually 15%, Cusp with high solar wind pressure could be 60%







Østgaard et al., GRL, 2005

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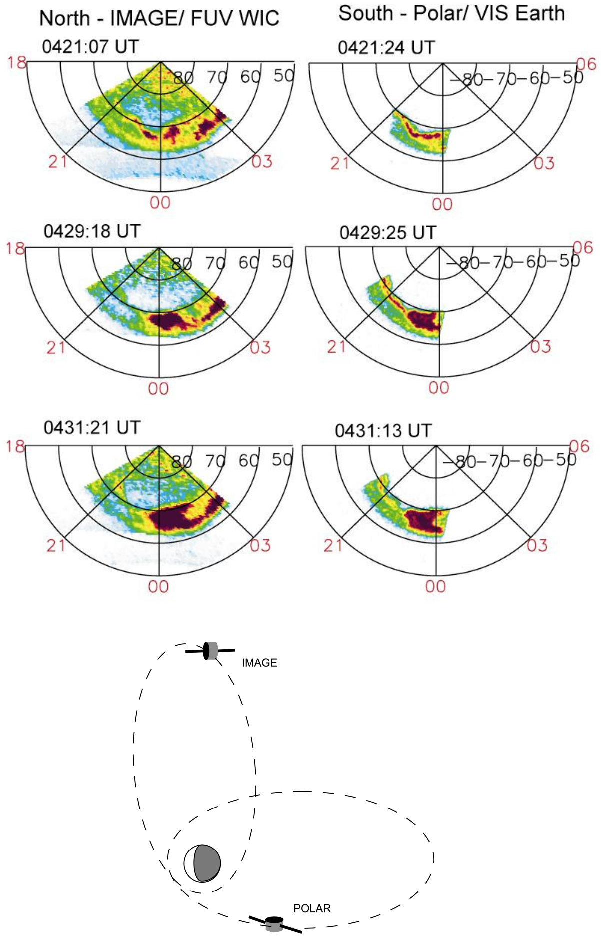
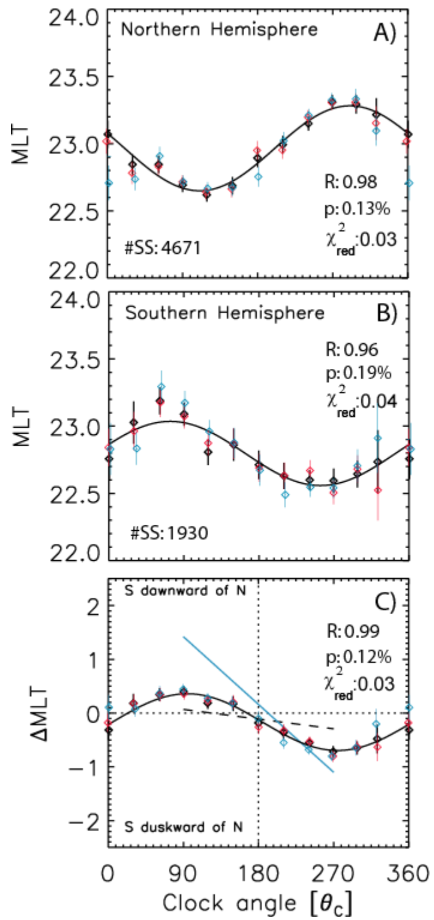
Conjugate imaging: Asymmetric substorm onset location

IMAGE and Polar VIS Earth



Østgaard et al., JGR, 2005



Statistical 6700 substorms by IMAGE and Polar

$$\Delta MLT(south - north) = 0.53 \times \sin(\theta_C - 4.8^\circ) - 0.17$$

Østgaard et al., GRL, 2013

Conjugate imaging: complete asymmetric aurora

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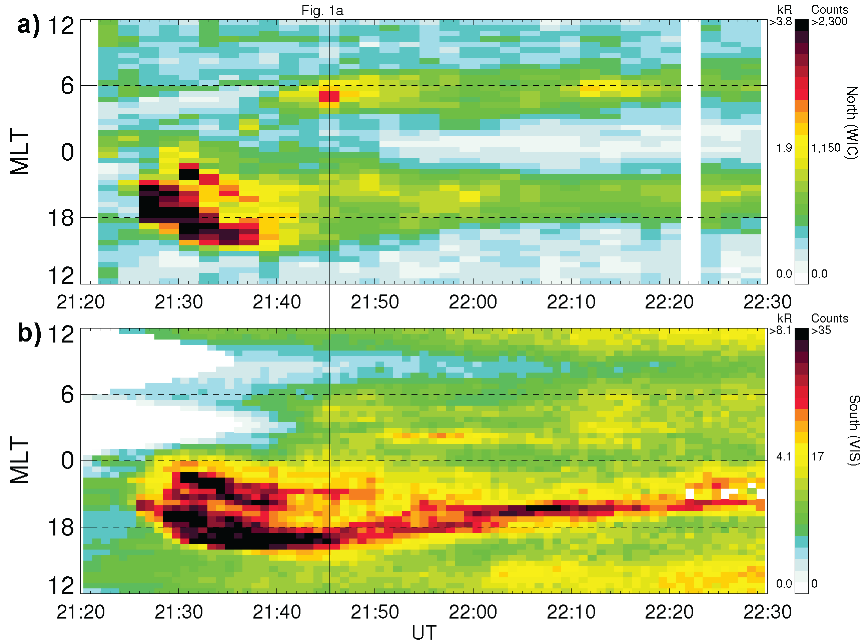


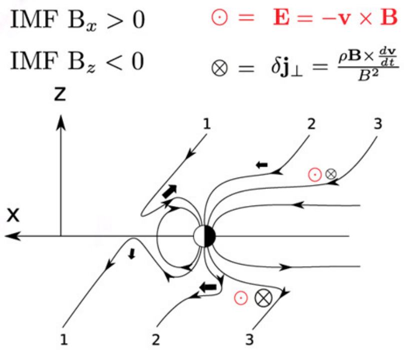
Persistent dusk aurora in the south

Transient dawn aurora in the north

Laundal and Østgaard, Nature, 2009

Asymmetric aurora – three candidates

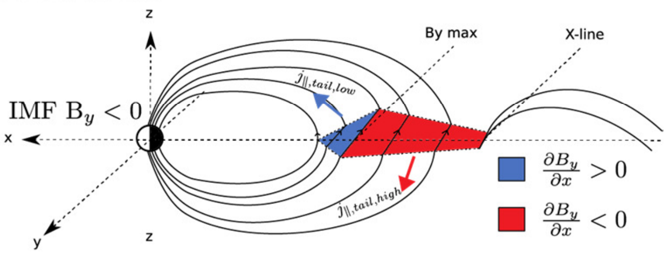
SOLAR WIND DYNAMO



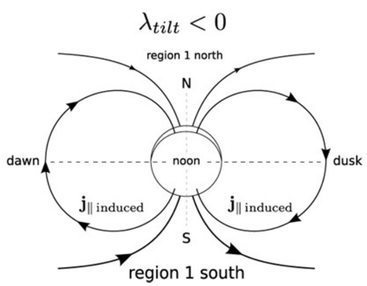
Østgaard and Laundal, 2012, AGU monograph:

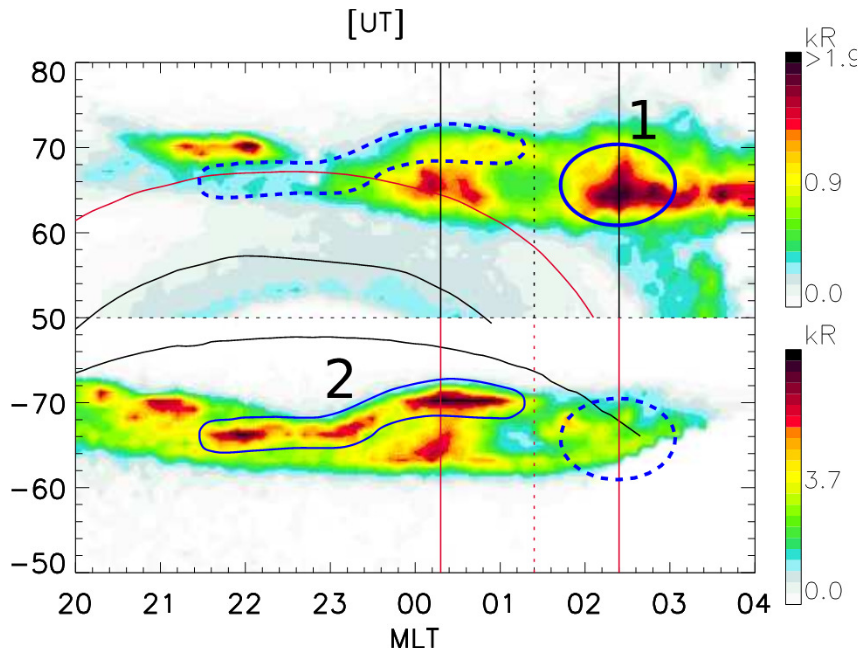
Reistad et al., 2013 – JGR

IMF By PENETRATION

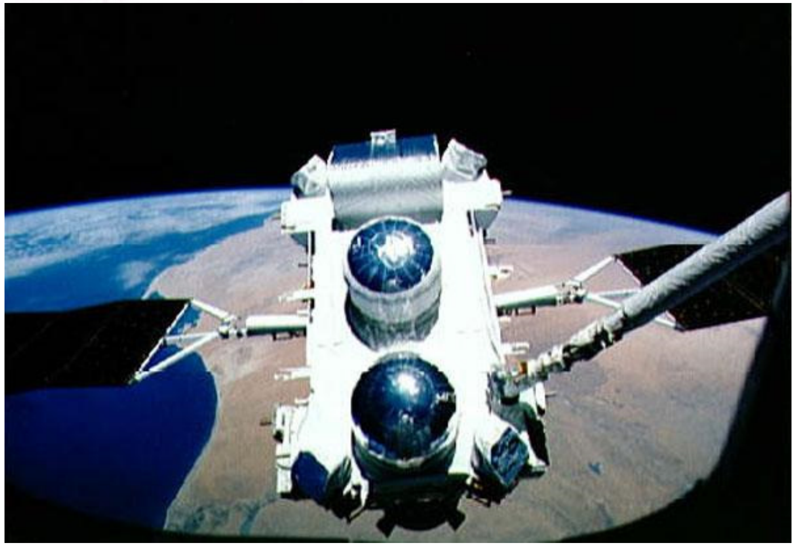


CONDUCTIVITY

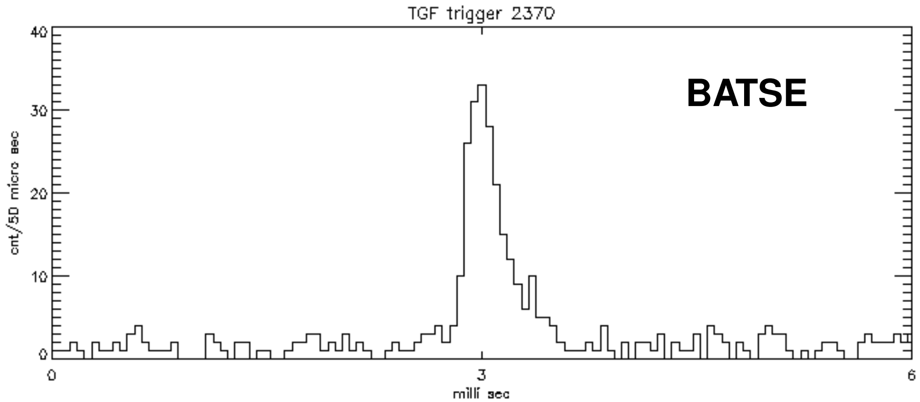




1991: Terrestrial gamma-ray flashes discovered

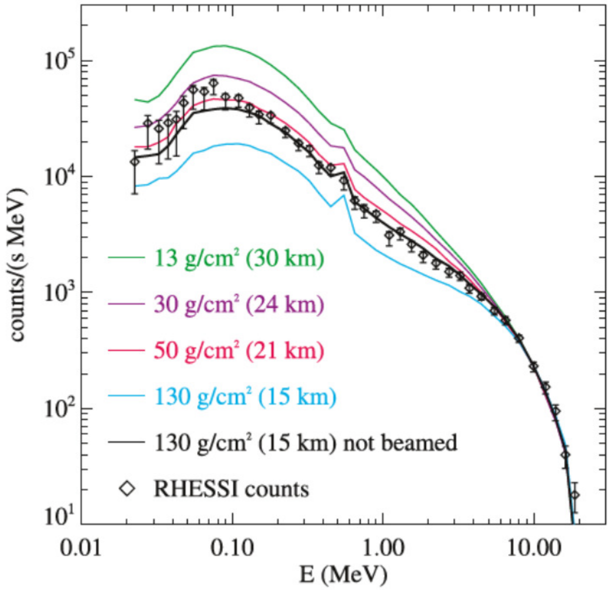


BATSE
Compton Gamma Ray Observatory



- Typical: < 1 ms
- Energies >40 MeV
- produced < 20 km

RHESSI



2010: Gammas, relativistic electrons, positrons

Relativistic particles through the atmosphere and into space

An unknown source of particles from Earth to space

How common are TGFs?

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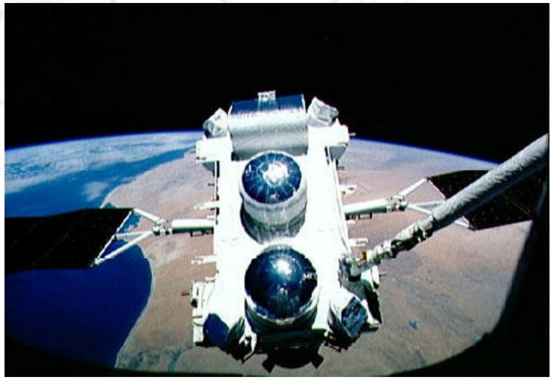
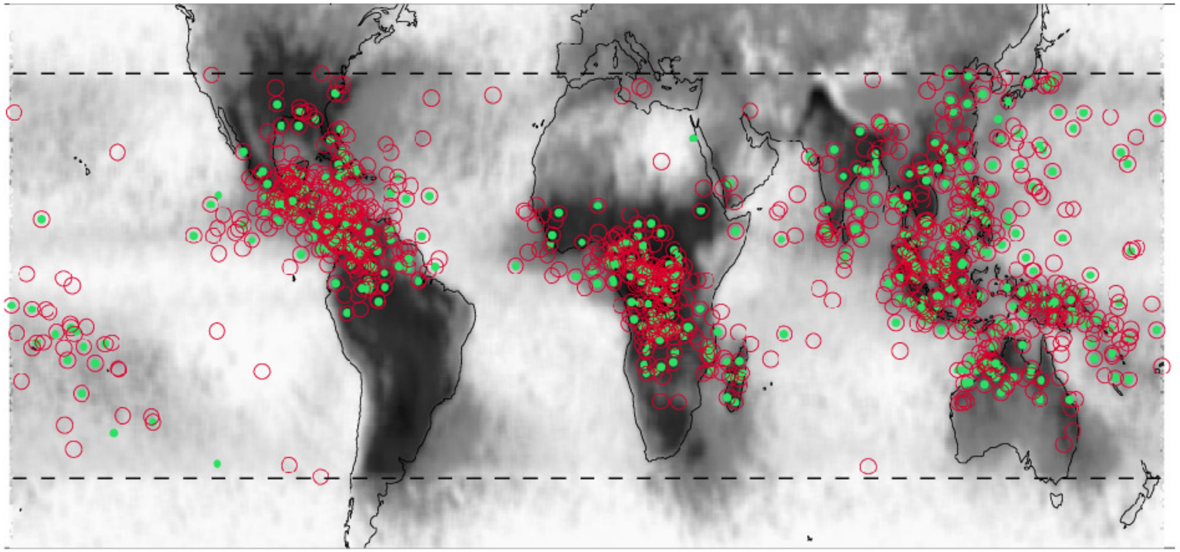
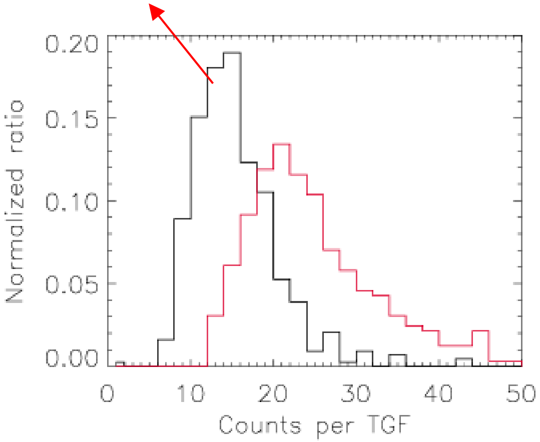
New analysis of RHESSI gives twice as many
200-300 observed pr year – global production rate of
50 000 per day *(Gjesteland et al, 2012)*



BATSE: 78 TGF - 9 year



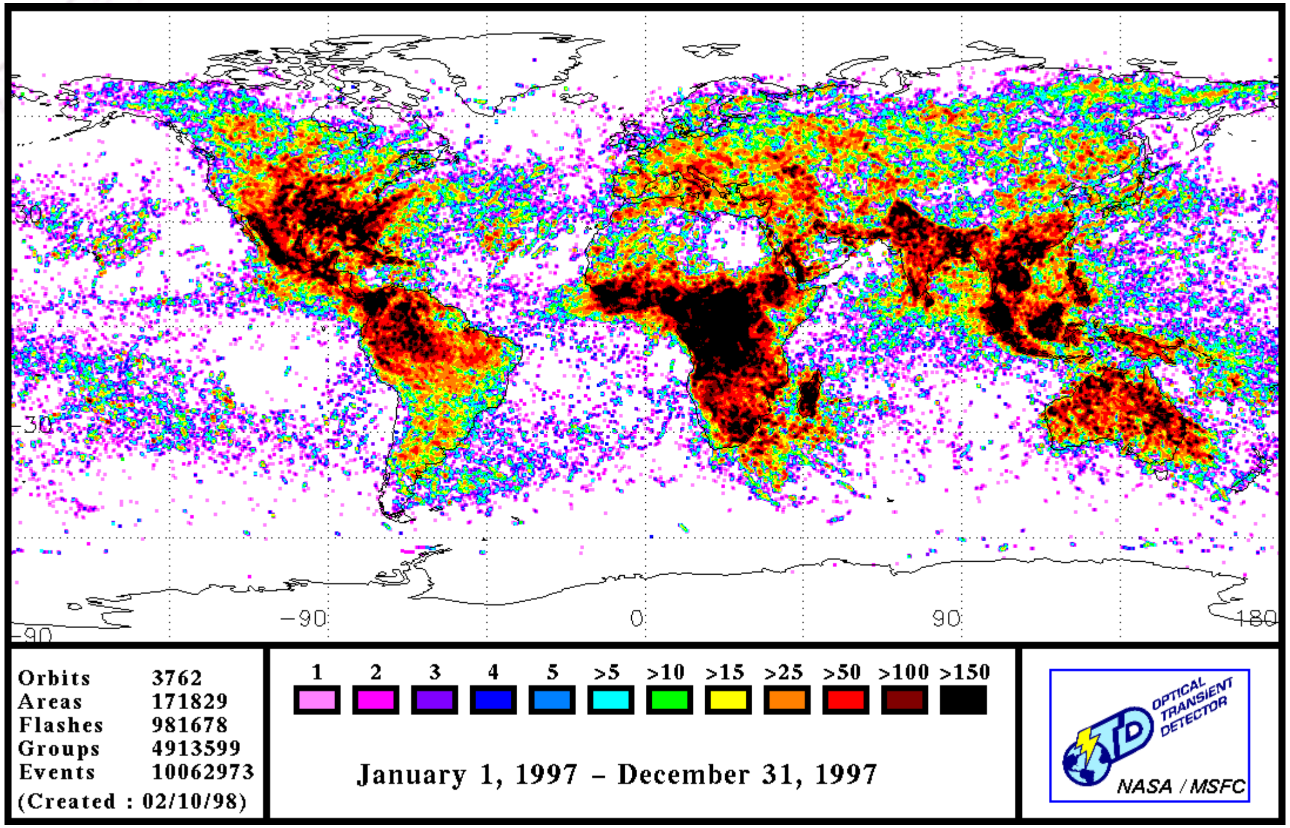
RHESSI: 820 TGF - 6 year



Tip of an iceberg?

Do all lightning produce TGFs
A million per day?
(Østgaard et al., 2012)

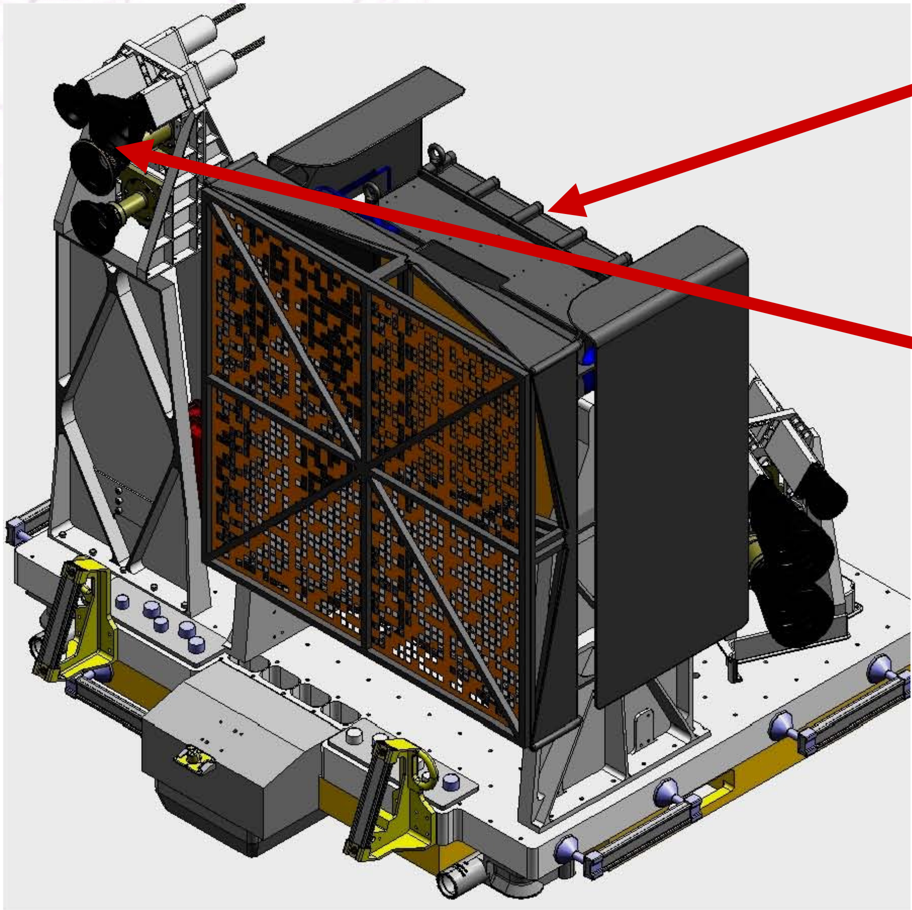
What if all lightning produce TGFs



45 lightning pr second – 4 million pr day

Are TGFs also common? *(Østgaard et al., 2012)*

ASIM – instruments



70cm x 70cm x 40cm – 140 kg

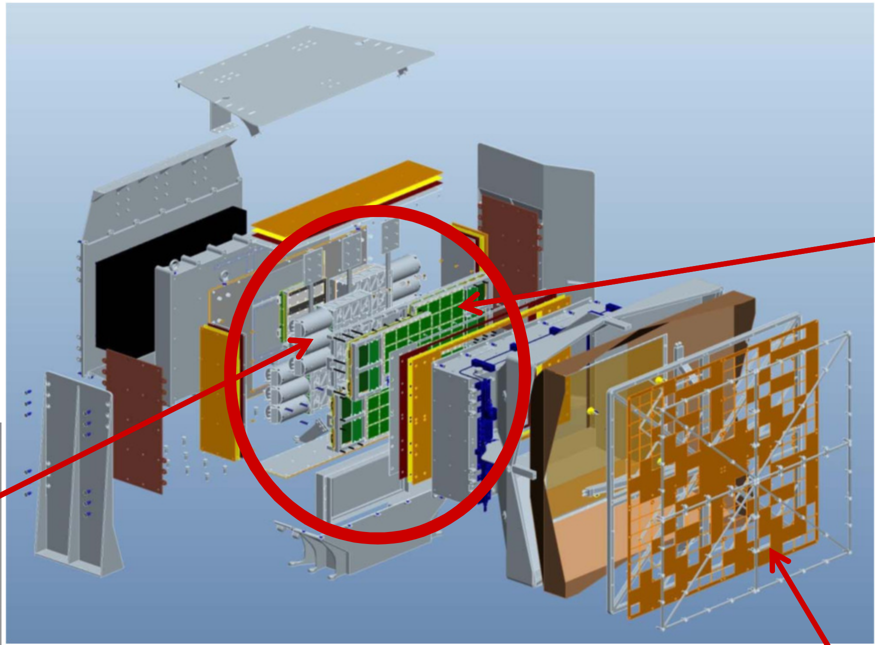
MXGS:
X-rays and gamma:
20keV – 40 MeV
Imaging TGFs

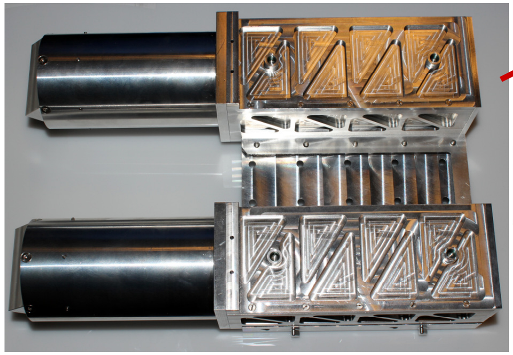
MMIA:
3 photometer
2 camera
Lightning, elves, red sprites, blue jets

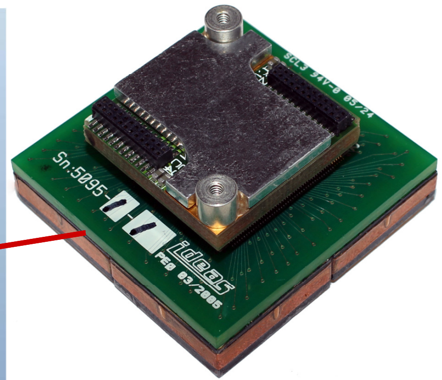
ASIM is the first to image lightning and TGFs simultaneously with relevant temporal resolution ~1 μs

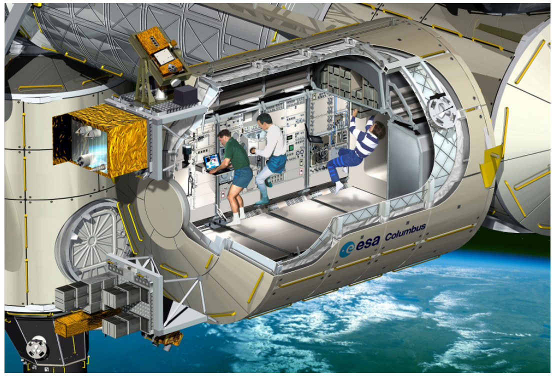
Sensitivity 10 times better than previous instruments

The X- and gamma-ray detector on ISS









4x3 BGO bars
200 keV – 20 MeV

64 CZT modules : 16384 pixels 20-400 keV

Imaging through coded mask

Summary:

Global imaging of aurora:

- different wavelengths give electron energy distribution

- two satellites give new perspective on how two polar caps respond

We tried KuaFu – will try again

X- and gamma rays from thunderstorms:

- Resolve newly discovered phenomenon: terrestrial gammaray flashes

ASIM, TARANIS, COBRAT, aircraft

Thank you

Production of photons: UV and X-rays (UVI and PIXIE)

	LBHL	PIXIE	LBHL/PIXIE
Å	1650-1800	0.5-4 (3-25 keV)	
Electron energies	0.1-20 keV (50 keV)	3-100 keV	
Photons from a 5 keV electron	0.8	$3\ 10^{-5}$	>25 000
Photons from a 50 keV electron	8	$5\ 10^{-3}$	>1000

Sensitivity: PIXIE >> UVI