ASIM – challenges and possibilities

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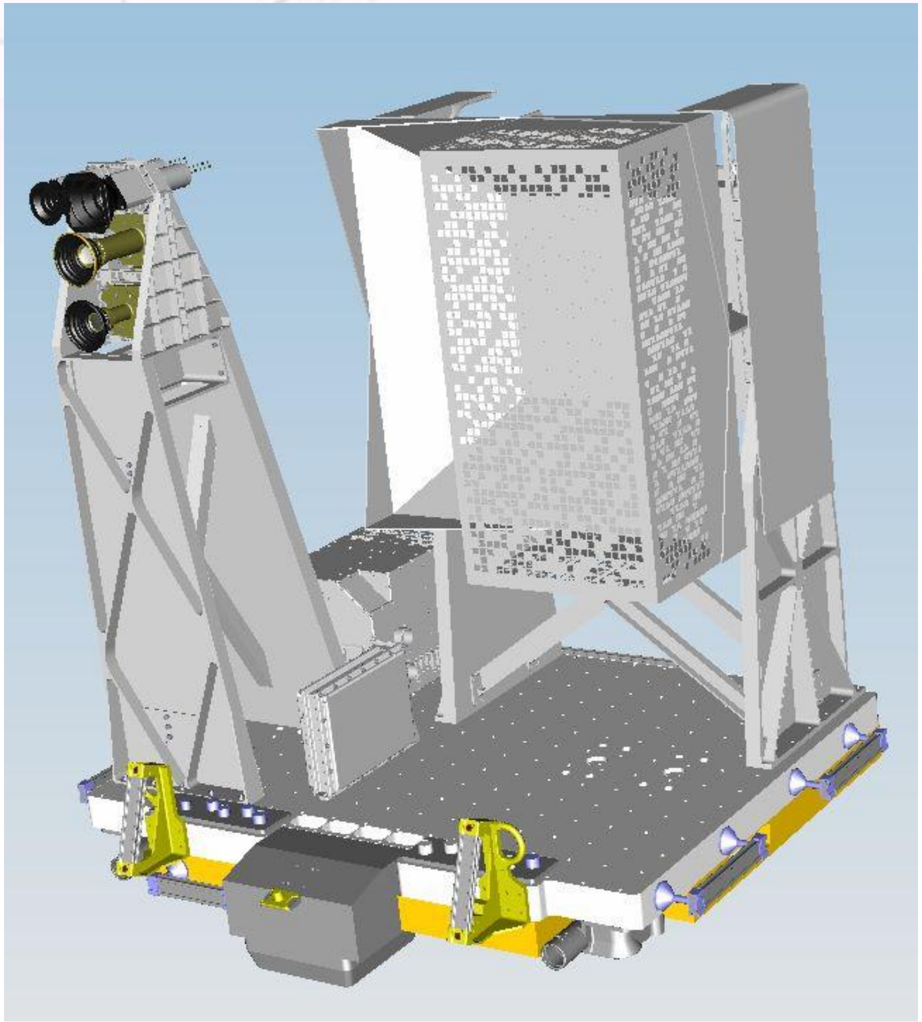
ASIM - payload



MXGS

Modular X- and Gamma-ray Sensor:

X- and gamma rays,

2 layers

Coded mask – full FOV

MMIA:

Modular Multi-spectral Imaging Array

Nadir - looking:

2 photometers

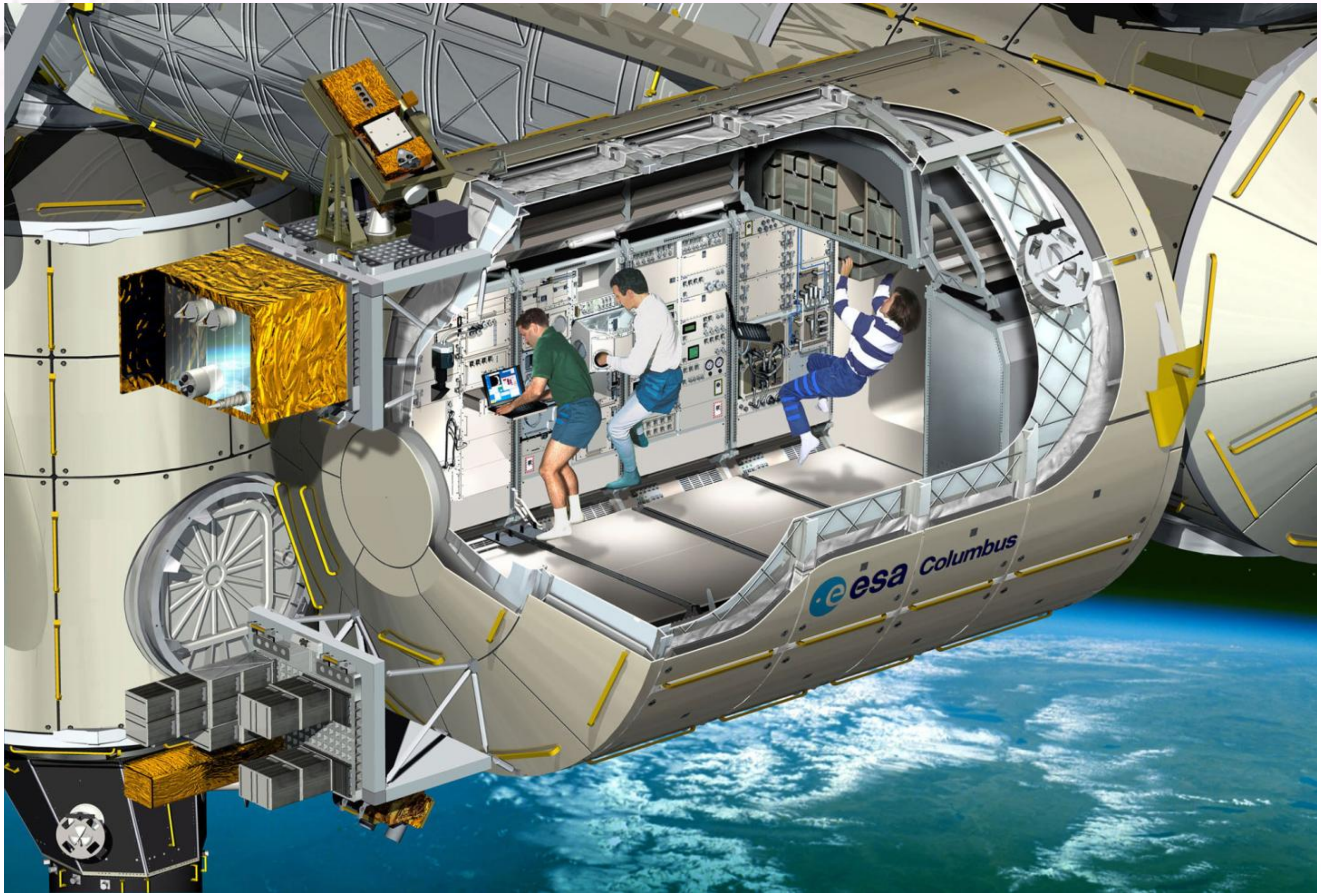
2 cameras

If funding available:

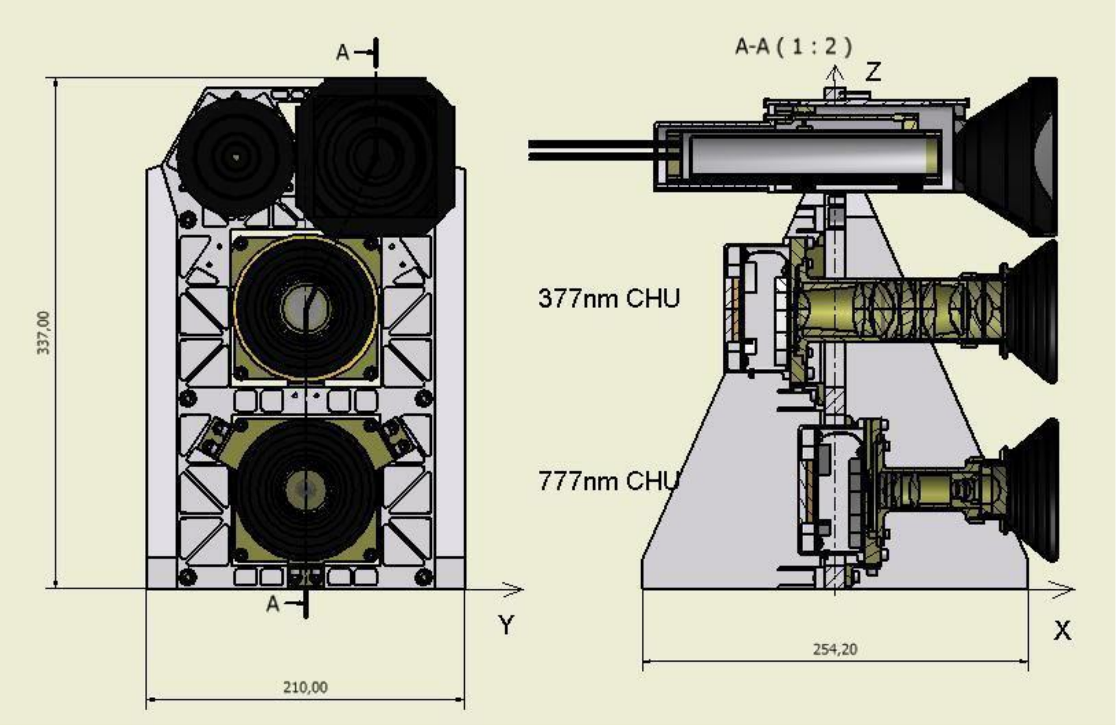
One more MMIA

Limb-looking

Columbus on ISS



MMIA



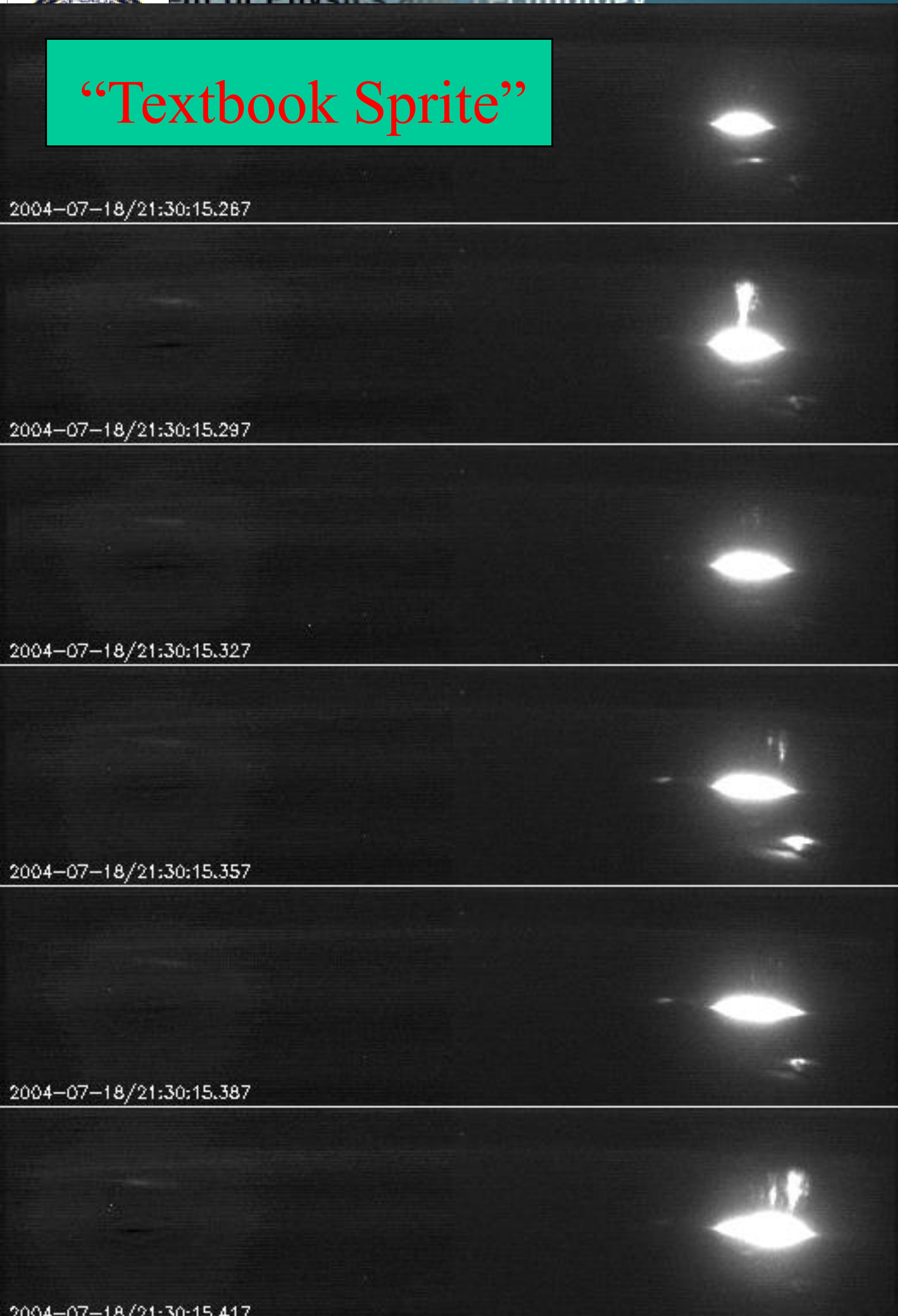
- Photometers – 10 microsec (10 kHz)
- Cameras – 40 ms

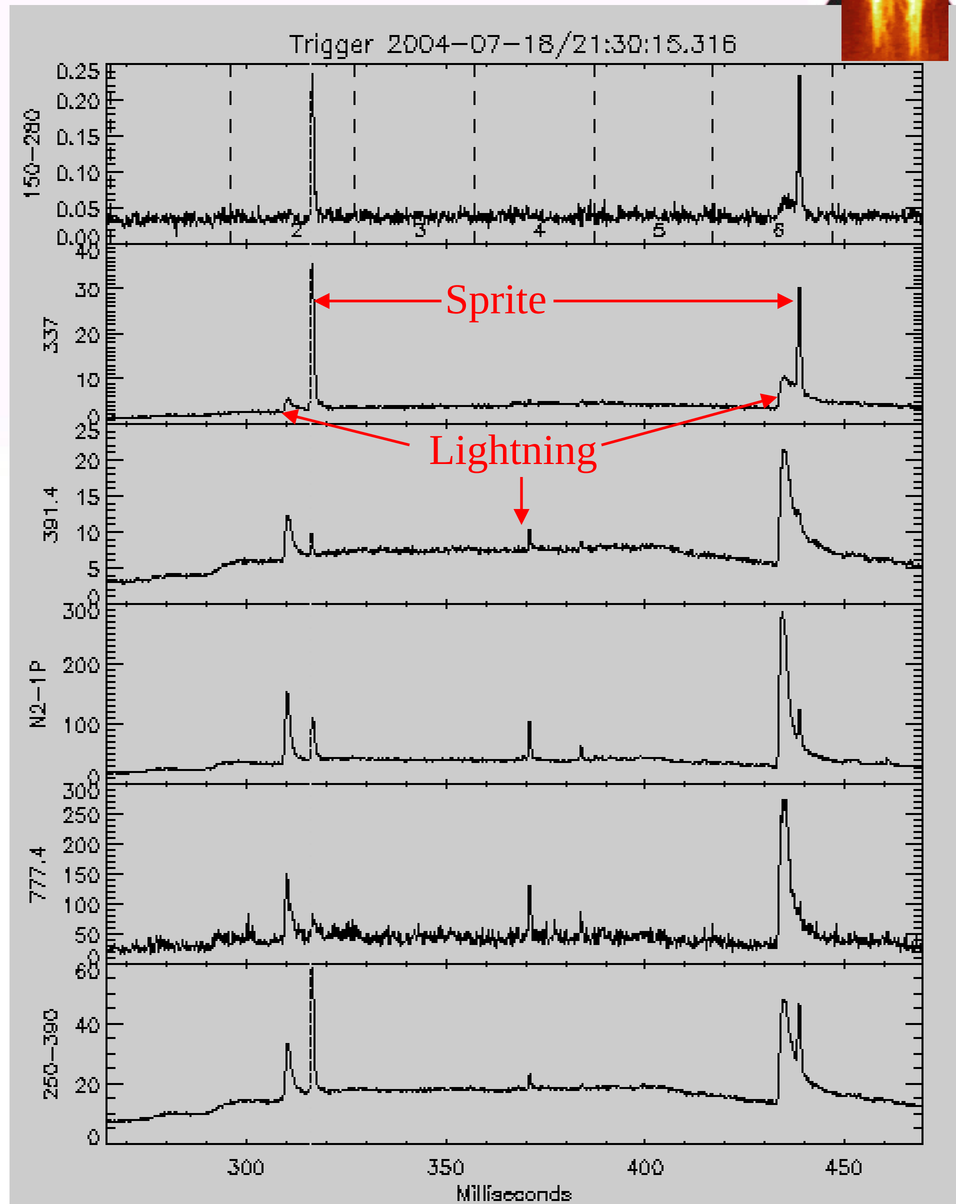
- 337.0 nm (N2 – 2PG)

Sprites (absorbed by O2)

- 777.4 nm (O1)

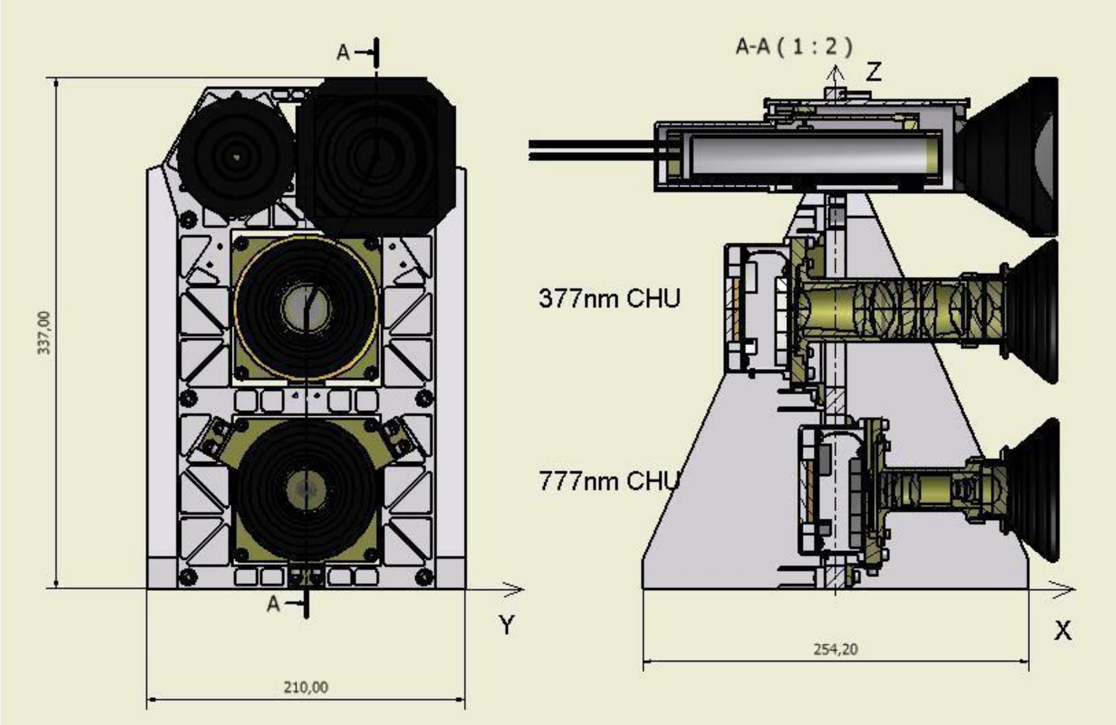
Lightning


"Textbook Sprite"
2004-07-18/21:30:15.267
2004-07-18/21:30:15.297
2004-07-18/21:30:15.327
2004-07-18/21:30:15.357
2004-07-18/21:30:15.387
2004-07-18/21:30:15.417

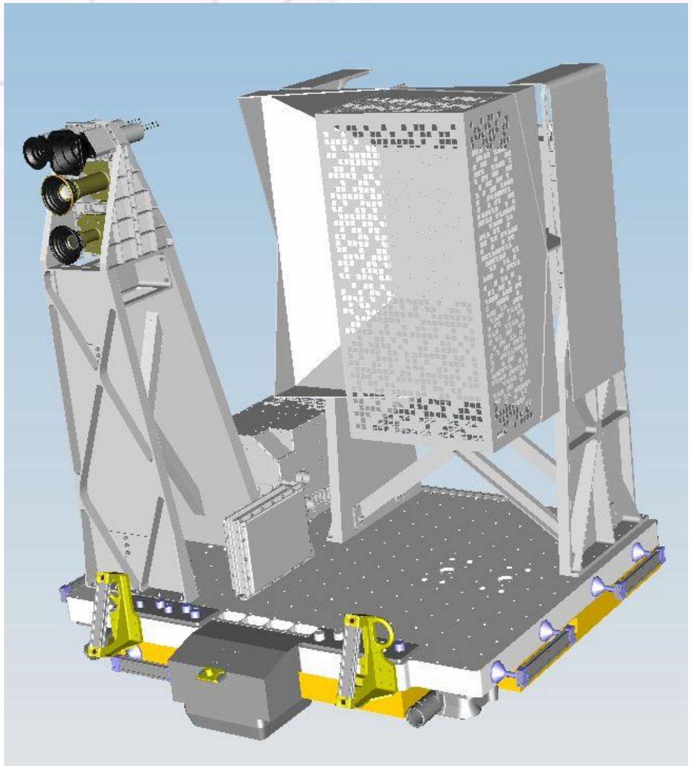

Trigger 2004-07-18/21:30:15.316
150-280
337
391.4
N2-1P
777.4
250-390
Sprite
Lightning
Milliseconds
300
350
400
450

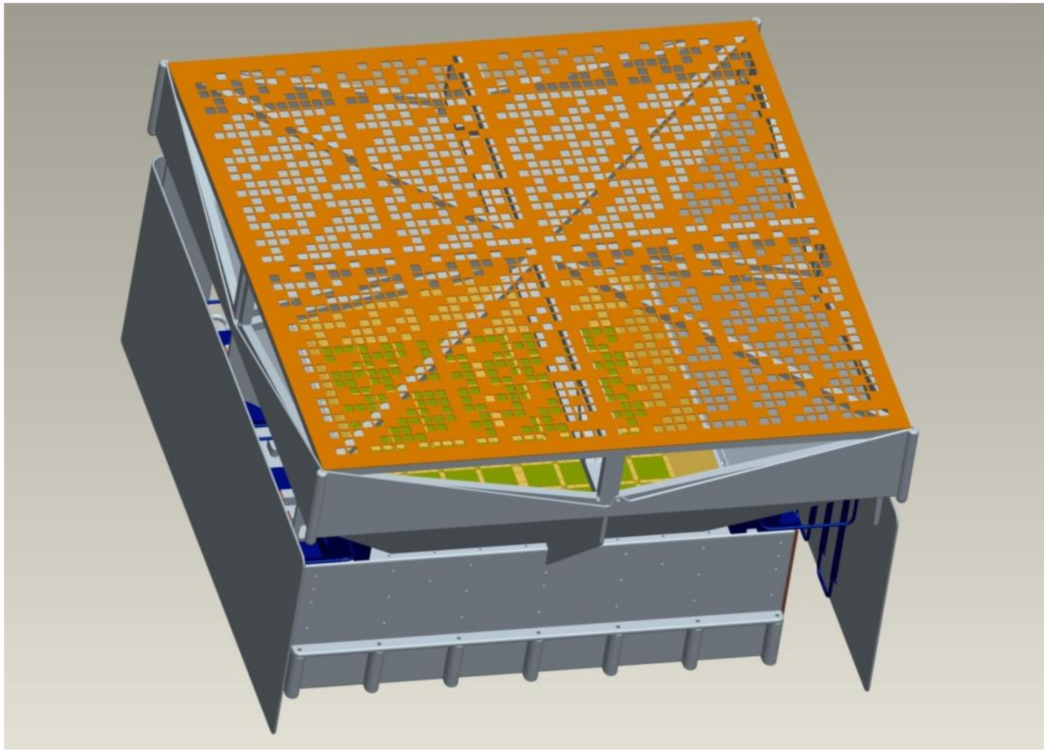
MMIA

- Camera – position of lightning/sprite
- Photometer – time at 10 microsec



ASIM - MXGS



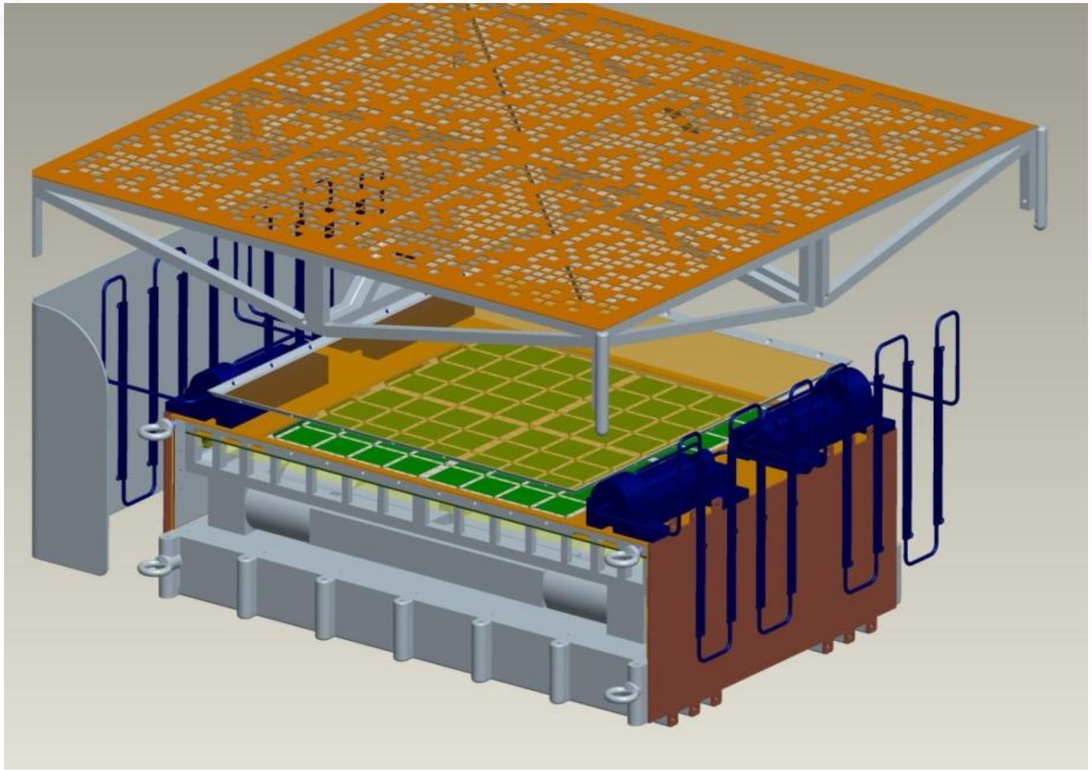


Coded mask – full FOV

1- Imaging (15-150 keV) – 1024 cm^2 - CZT

2. Spectral analysis (15 keV-20 MeV) CZT+BGO

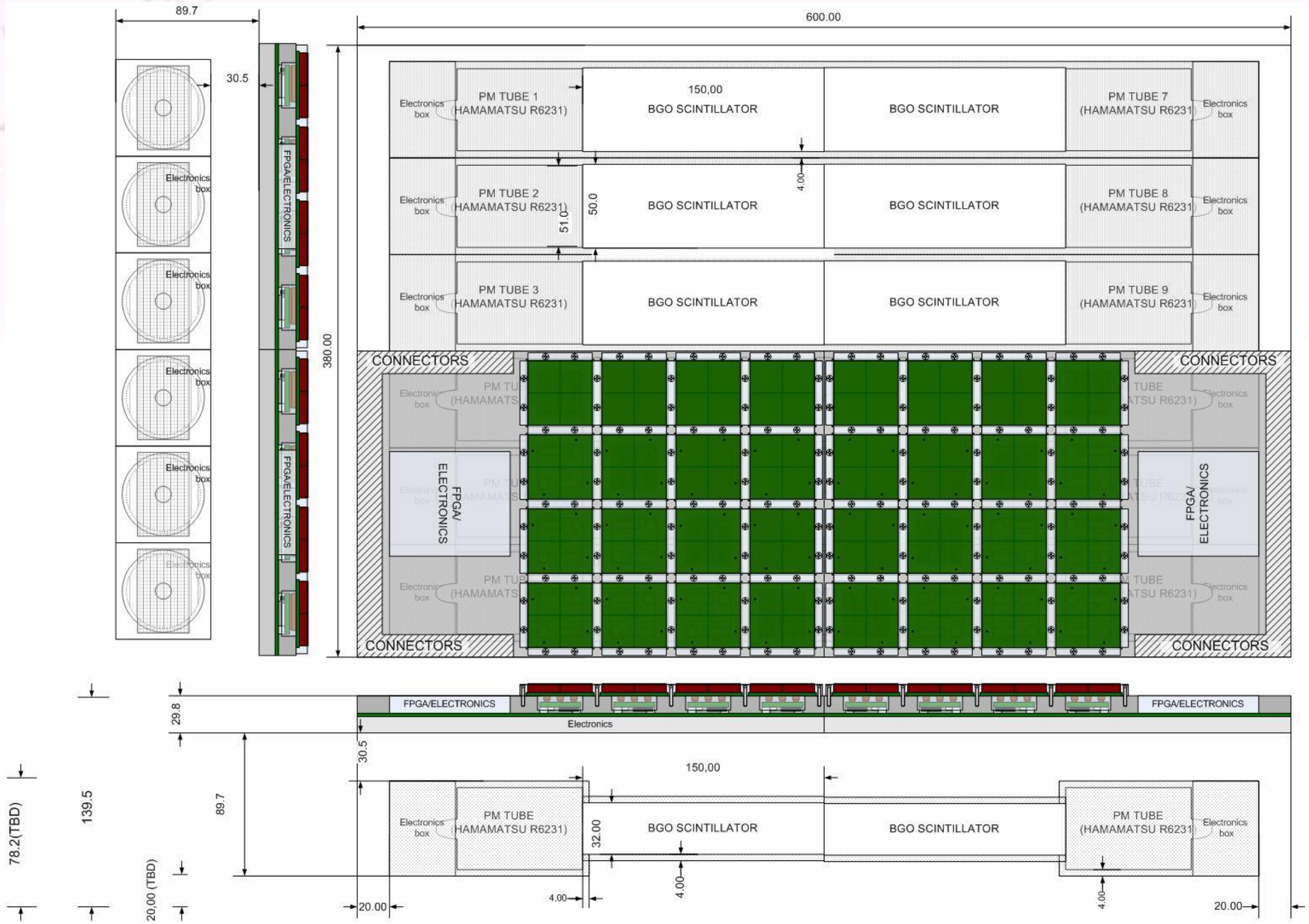
MXGS – exploded view



1024 cm^2 CZT – 5 mm thick – 16384 pixels

900 cm^2 BGO – 32 mm thick

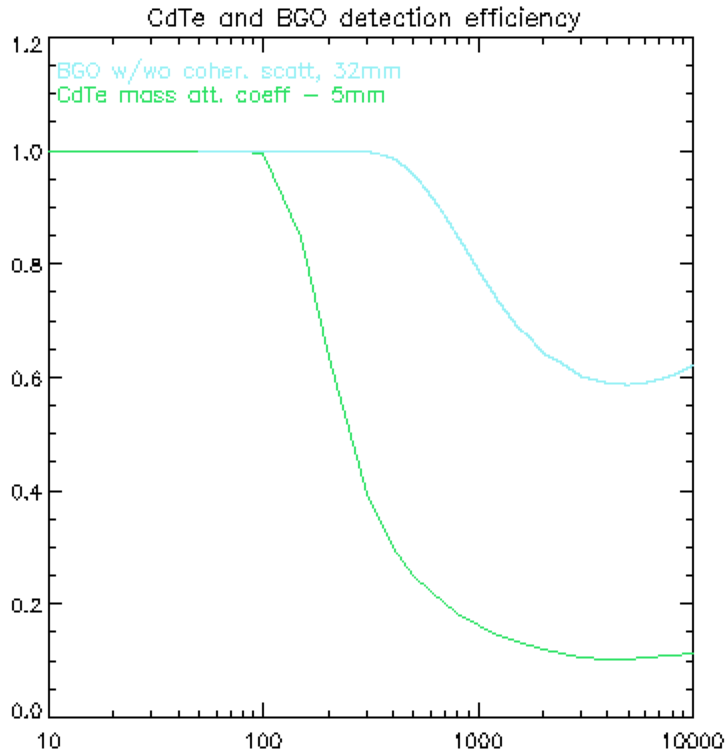
MXGS – two layers



1- Imaging (15-150 keV) – Pixelated CZT layer

2. Spectral analysis (15 keV-20 MeV) – CZT + BGO

RHESSI TGF if they were detected by ASIM



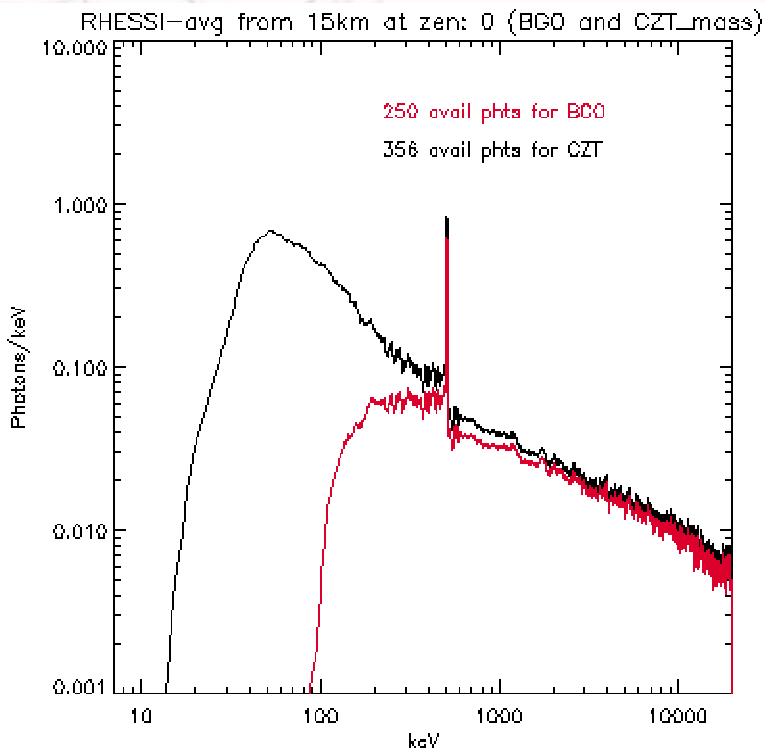
1/r2: ISS at 350 km

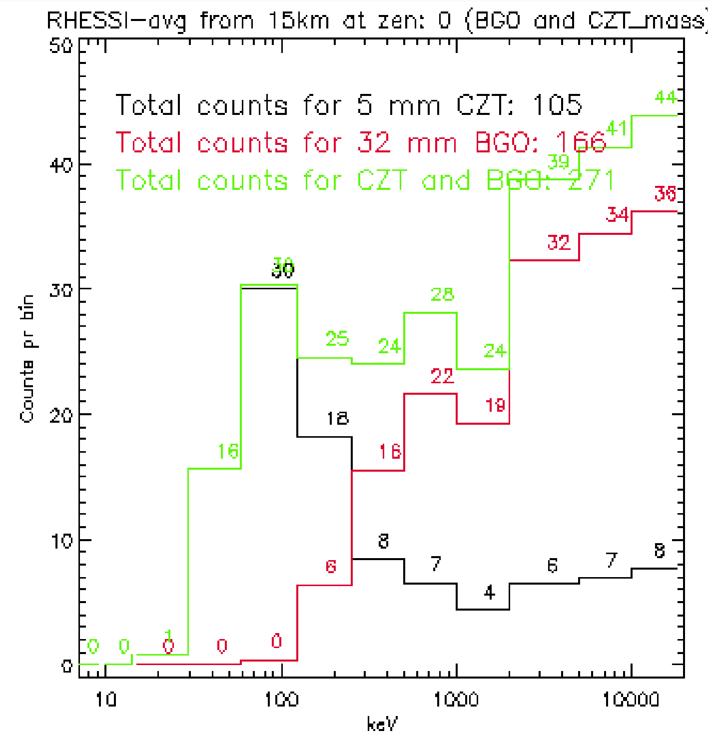
RHESSI at 600 km

RHESSI: 250 cm^2

ASIM: 1024 cm^2

RHESSI TGF if they were detected by ASIM





RHESSI: average 27 cnts
ASIM: average 270 cnts

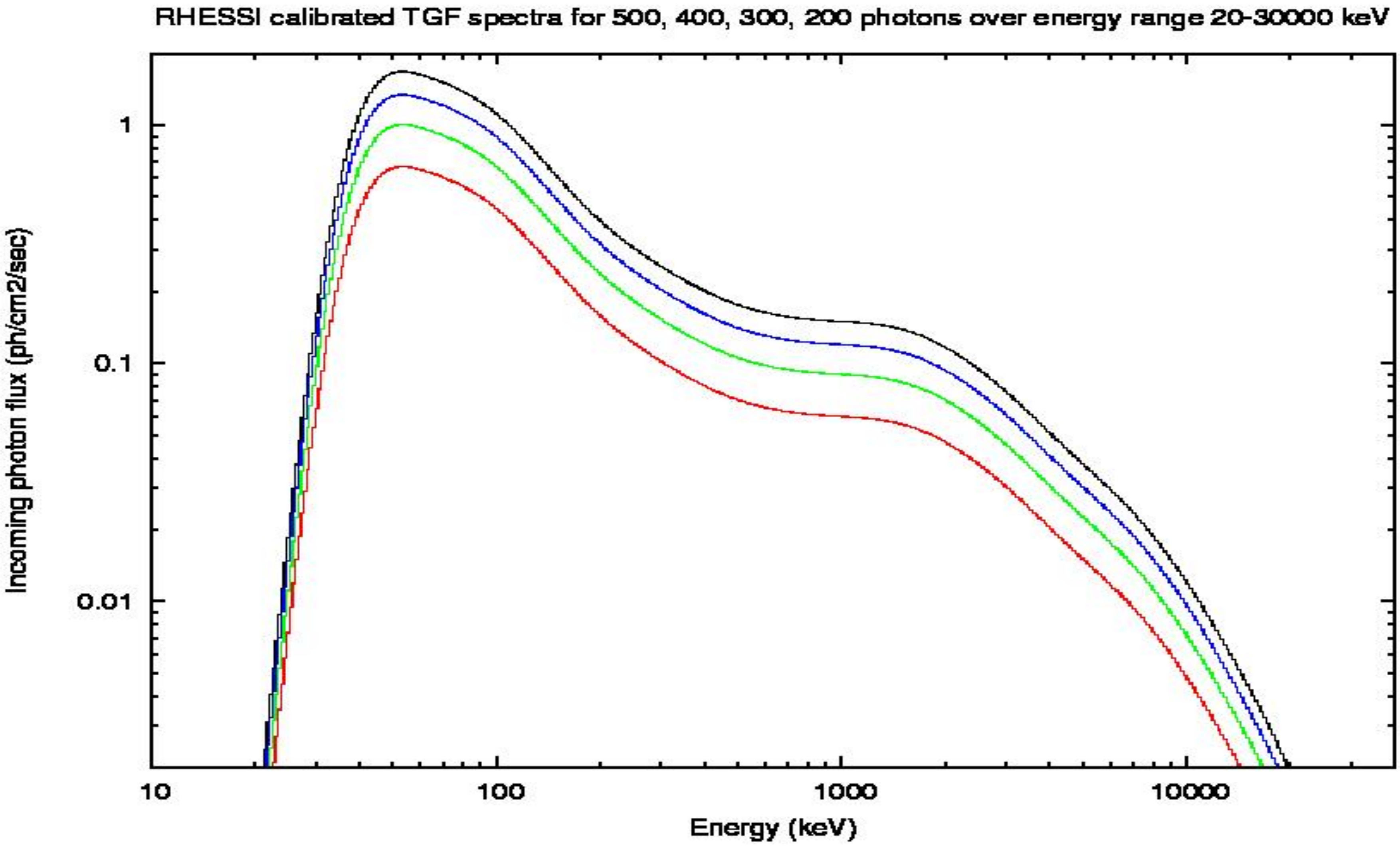
ASIM Q1: How common are TGFs?

BATSE: 10 TGF pr year
RHESSI: 100 TGF pr year - average 27 cnts
ASIM: 1000 TGF pr year – average 270 cnts

If TGF follow a power law distribution:
$F(n) \sim n^{-\lambda}$
$\lambda=2.0$: *4/24 hour:* 1000 TGFs
$\lambda=2.5$: *9/24 hour:* 2000 TGFs

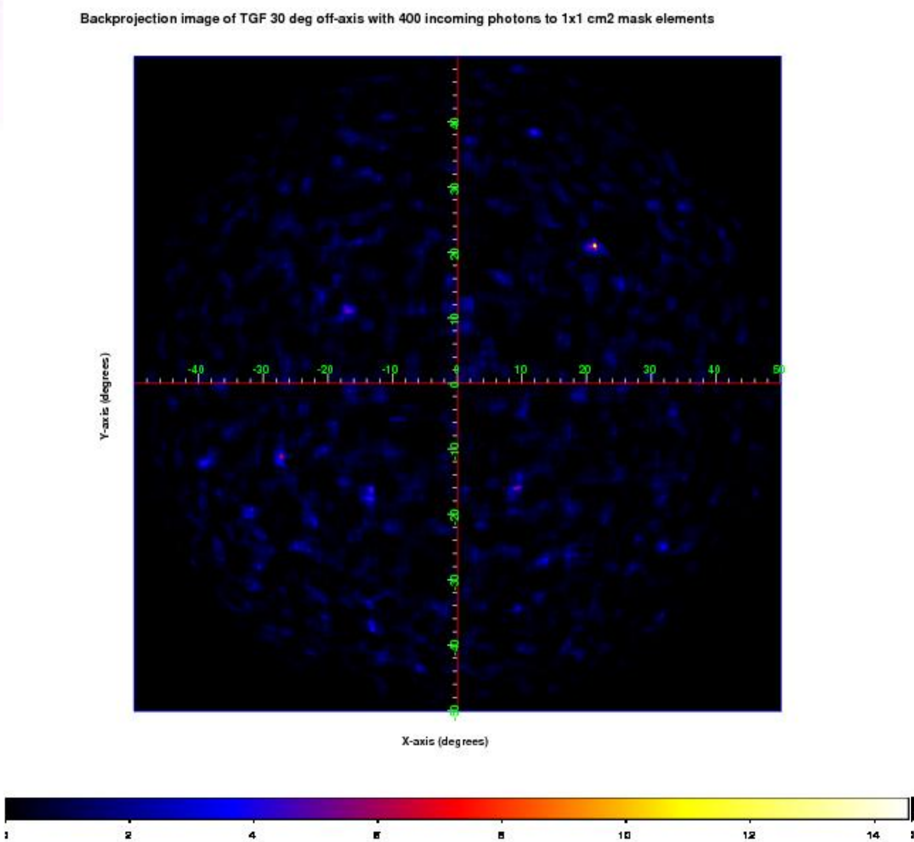
This is one of the main questions answered by ASIM.

IMAGING

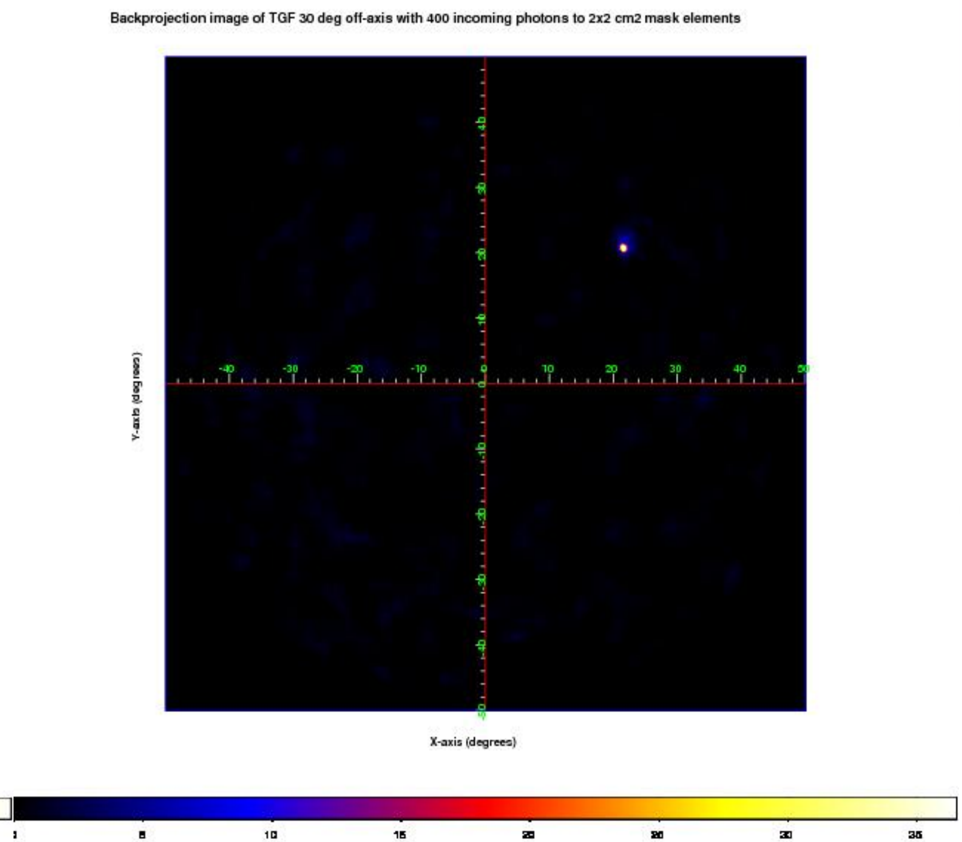

RHESSI calibrated TGF spectra for 500, 400, 300, 200 photons over energy range 20-30000 keV
Incoming photon flux (ph/cm2/sec)
1
0.1
0.01
10
100
1000
10000
Energy (keV)

Images for 400 incoming TGF photons on 1x1 and 2x2 cm² mask elements – 30 deg off-axis

1x1 cm

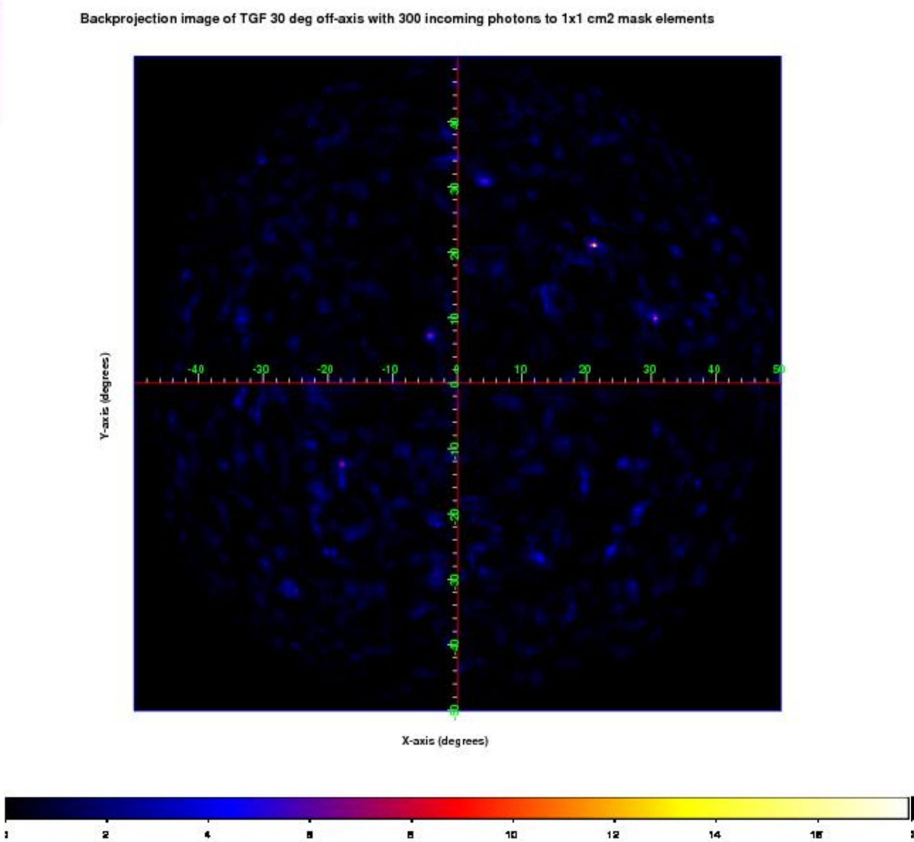


2x2 cm

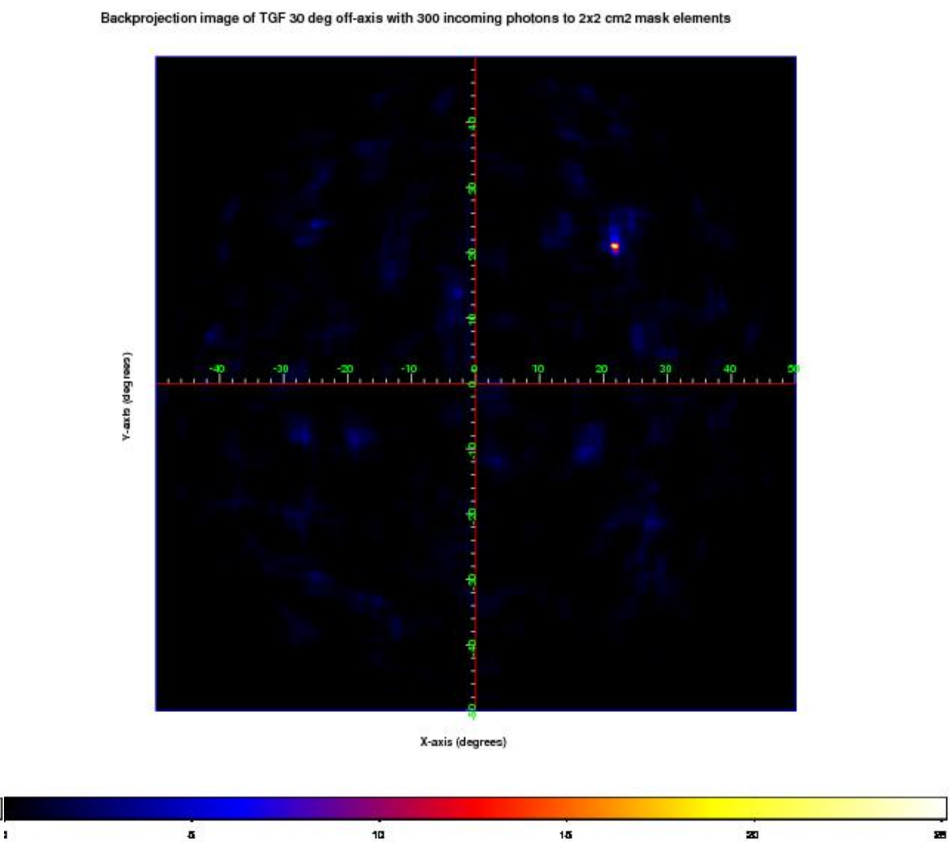


Images for 300 incoming TGF photons on 1x1 and $2x2\ cm^2$ mask elements – 30 deg off-axis

1x1 cm



2x2 cm



ASIM Q2: Are there TGFs without lightning

- ASIM first to image a TGF
- Streamers can form without subsequent return stroke.

ASIM Q3: What type of lightning?

Combined with other measurements (VLF-ELF) timing can give us information about type of lightning.

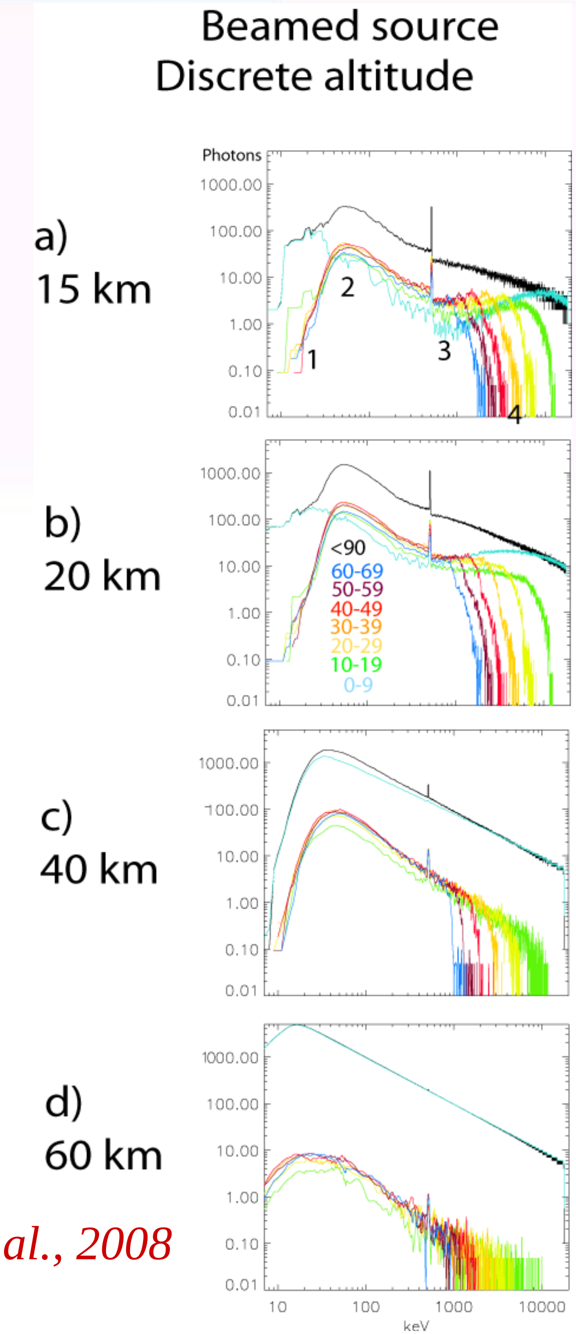
TGF spectral characteristics

1) High energy cut-off moves to lower energies as escaping angles increase

2) Low energy cut-off moves to lower energies as TGFs are produced higher

3) Peak moves to lower energies

4) Bump around 0.7-1 MeV or flattening at 500 keV for TGFs produced deep disappears higher up



Østgaard et al., 2008

ASIM Q4: Production altitude

Gjesteland et al., 2010

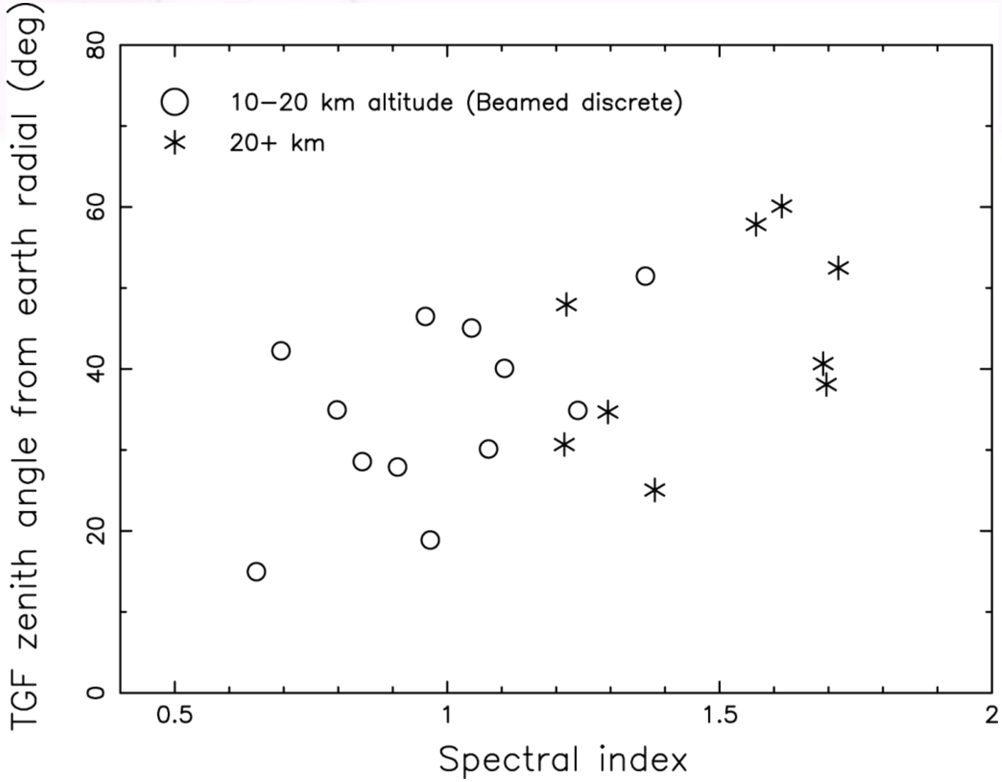
Table 1. Altitudes

BATSE		Beamed					Cone				
TGF	TD [μs]	Ø[km]	new[km]	TD[μs]	Flux	DL[%]	Ø[km]	new[km]	TD[μs]	Flux	DL[%]
2144	125 ± 22	39	17	148 ± 22	0.62	272	25	25	162 ± 22	0.62	352
2370	124 ± 18	40	16	117 ± 21	0.36	208	41	22	96 ± 12	0.36	230
2465	147 ± 19	26	21	137 ± 20	0.49	268	27	24	124 ± 17	0.49	338
2955	145 ± 40	39	23	118 ± 16	0.44	216	38	26	80 ± 21	0.51	277
5587	66 ± 34	14	12	52 ± 17	0.20	46	17	29	54 ± 17	0.28	111

Results for 5 TGFs where BATSE deadtime was corrected, converge with results from others: 15-20 km

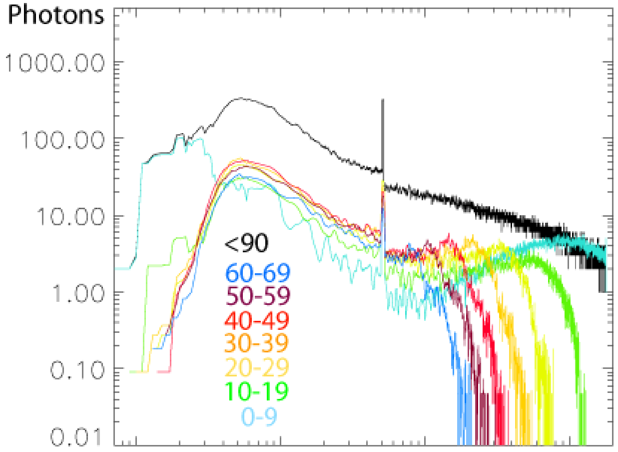
ASIM will give production altitudes for many single TGFs

ASIM Q5: Spatial distribution of produced photons



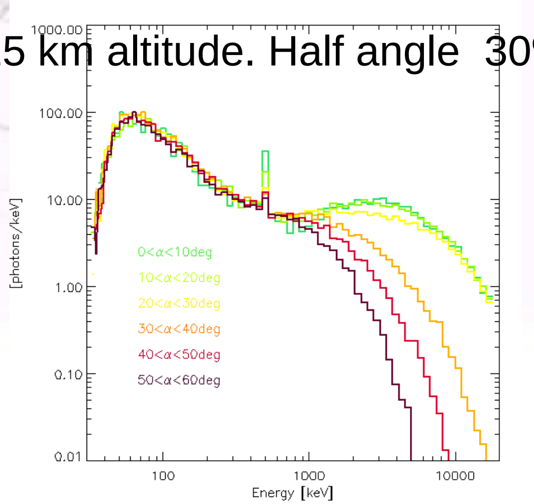
BATSE analysis indicated beamed distribution – but this is still an open question

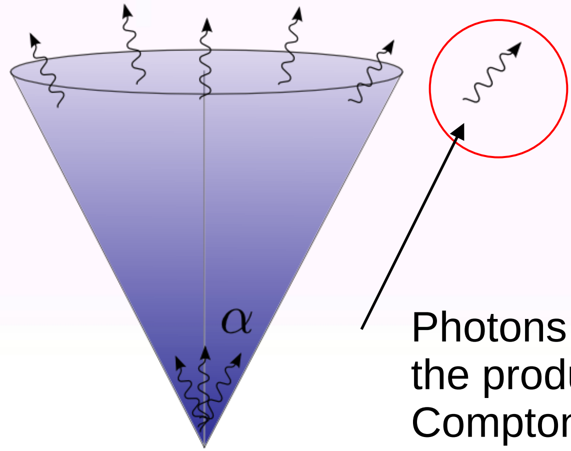
This is important for production mechanism.



More on Spatial distribution of produced photons

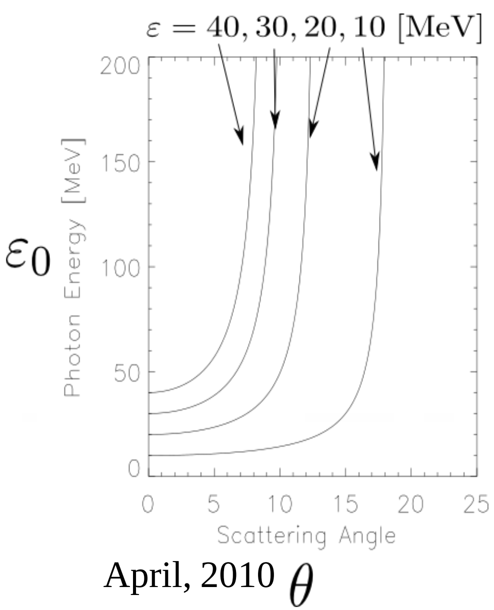
15 km altitude. Half angle 30º

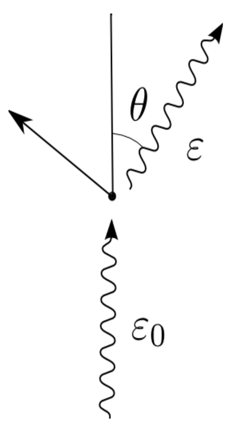




Photons measured outside the production cone are Compton scattered

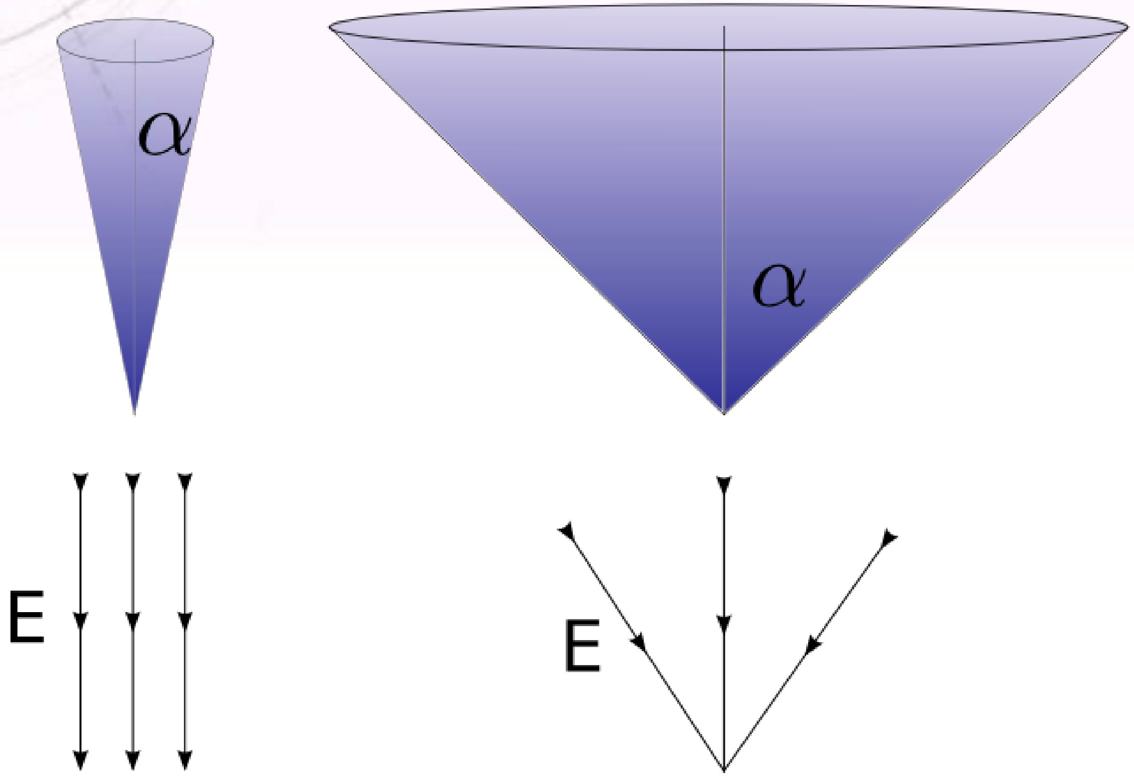
Energy loss in Compton scattering





- High energy photons (E>10 MeV) measured at satellite altitudes are scattered less than 10º.
- If satellite measurements finds:
  - High energy cut off at increasing angles.
    - indicates narrow TGF production cone.
  - High energy photons measured at large angles.
    - Indicates wide TGF production cone.

Spatial distribution of produced photons and E-field



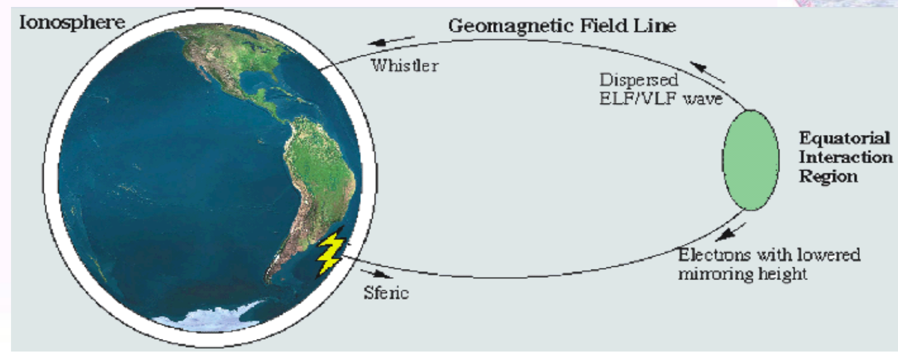
Electrons are accelerated in the direction of –E. The geometry of the E-field defines the production cone.
Superposition of TGFs cannot tell - it could be superposition of narrow beams in different directions

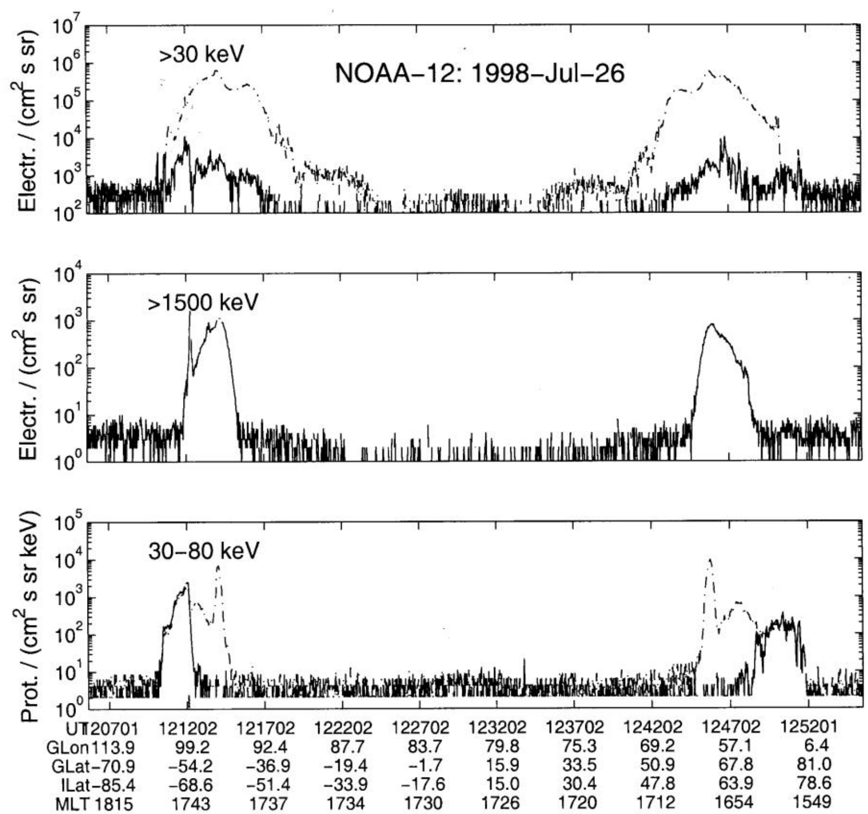
Questions - summary

1. How common are TGFs
   - Give hint towards type of lightning
2. Are there TGFs without lightning
   - Streamer??
3. What type of lightning
   - Combinde with other measurements
4. Production altitude
   - Another hint towards type of lightning
5. Spatial distribution of produced photons
   - Geometry of electric field generating bremsstrahlung

Secondary Science

- Whistler-induced electron precipitation
  - Lightning induced precipitation (LEP)– cyclotron resonance
  - MXGS will see the soft LEP
- Relativistic Electron Precipitation
  - Continuous and burst
  - MXGS will see the continuous (500 times more intense than TGFs)
- Aurora
  - MXGS will see this, of course.





Future plans

- Balloons – French COBRAT
- Aircraft – several options if money is found

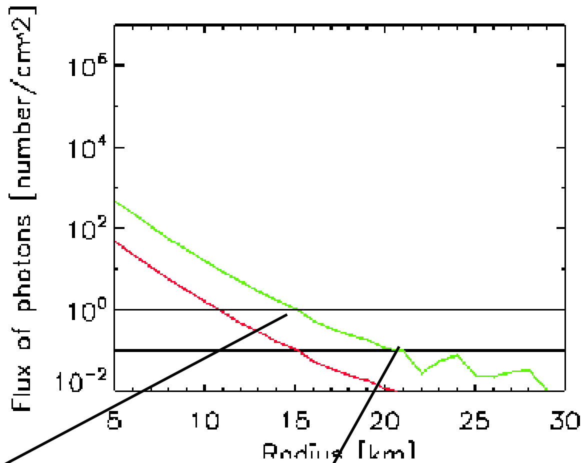
- X- and gammaray detector – 1 microsec res
- Electric Field measurement – 1 microsec res

- Want to see if TGF is before the discharge – return stroke, which would indicate streamer/leader tip generation
- TGF is after the discharge – favour the feed-back theory, where positrons and downgoing gamma rays contribute to avelanche process.

Aircraft - Balloon

- Flux of photons at production is 10^{17}
- modeling and analytic solution based on RHESSI.
- Here: 250 cm^2 detector

Production: 12 km, Observed:19 km

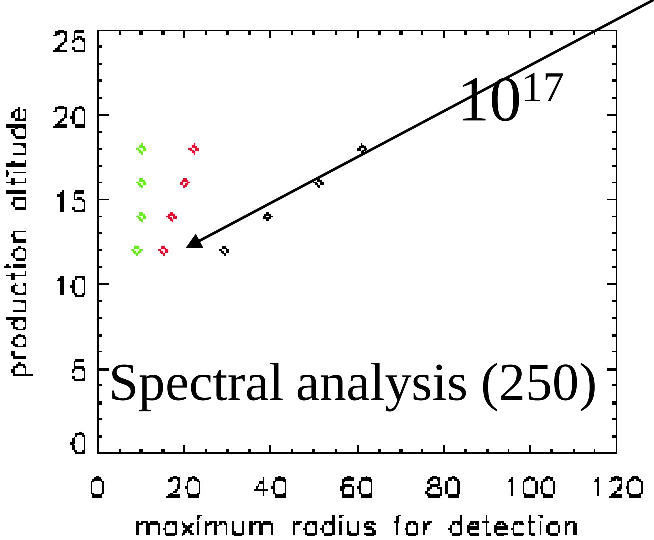


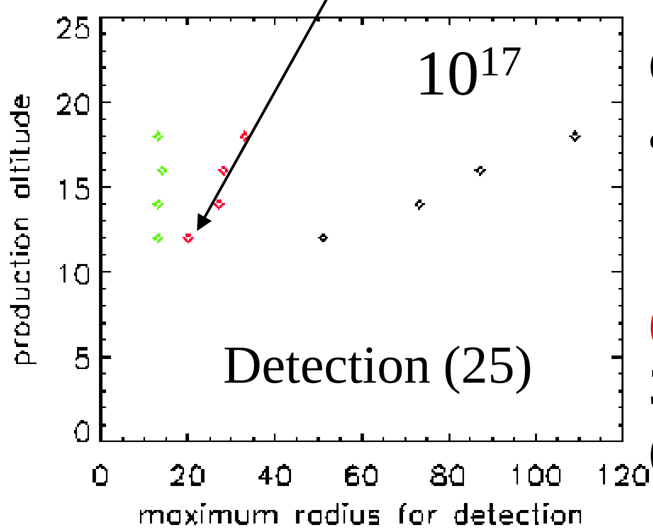
10^{17}

10^{16}

1 cm^{-2} - 250 phts

0.1 cm^{-2} - 25 phts





Observation altitude:

15 km

19 km –aircraft (radius: 15-20km)

35 km – balloon (radius: 30-50 km)

Thanks