In Honor of Kristian Birkeland (1867-1917)
- Predicted field-aligned currents
- Studied lightening in laboratory
How is Earth coupled to space?

• 4 main questions – 4 science groups
• 2 instrumentation groups
• Education and Public outreach group
• UiB – UNIS – NTNU
• ~50 people + 20 Master students
Q1: When and why is the aurora in the two hemispheres asymmetric?

Q2: How do we get beyond the large-scale static picture of the ionosphere?

Q3: What are the effects of particle precipitation on the atmospheric system?
What is the role of relativistic electrons and antimatter from thunderstorms in geospace?
Elves

Red Sprites

Blue jets

Terrestrial Gamma-ray Flashes

C. T. R. Wilson
Nobel prize physics 1927

“The electric field of a thundercloud and some of its effects” 1925:

Something has to happen above thunderstorms!
Discovered by a case of Serendipity

Vela satellites '70-'80
Looked at the Earth...

Galactic gamma

BATSE on CGRO 1991 – 2000
Looked to space…

Terrestrial gamma flashes

6/19
2010: Gammas, relativistic electrons, positrons

Relativistic particles through the atmosphere and into space

An unknown source of particles from Earth to space
Terrestrial gamma-ray flashes - discovered in 1991

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

BATSE
Compton Gamma Ray Observatory
How common are TGFs?

New analysis of RHESSI gave twice as many 200-300 observed per year – global production rate of 50 000 per day \( (Gjesteland \textit{et al}, 2012) \)

BATSE: 78 TGF - 9 year

RHESSI: 820 TGF - 6 year

Tip of an iceberg?

Do all lightning produce TGFs
A million per day?
\( (\textit{Østgaard \textit{et al.}, 2012}) \)
What if all lightning produce TGFs

45 lightning pr second – 4 million pr day
Are TGFs also common? (Østgaard et al., 2012)
Project by master student Kjetil Albrechtsen
Use WWLLN time tags of lightning occurring within 800km of RHESSI footpoint. Superimpose continuous (~0.1s string) RHESSI data and check for an emerging signal.
760,000 lightning from the 2006 and the 2012 WWLLN dataset.

Peak of 5 sigma (Poisson) relative to the background.
A new set of approx 100 TGFs!
Lightning – many processes

Charging the cloud

Leader forms from the negative charge layer

Leader short-cuts the negative and positive poles

Bright visible lightning

Thunder

When and how is gamma produced?
• Lightning Lake Maracaibo, Venezuela
• Two satellites < 300 km apart
• Terrestrial gammaray flash 70 μs
• Two radio measurements
• Sequence: Initiation(duke), VLF(duke - TGF), Optical/VLF (LIS/duke – return stroke)
What are the production mechanisms?
RREA and Feedback?

[Broberg Skeltved, et Al. 2014]

Vertical extension of electric field at 15 km (km)

Electric field strength (kV/m)

- 48.5 MV
- 2500 kV/m

[Dwyer et al., 2003]

LBE

300 MV
390 kV/m

Scaled electric field to 15 km (kV/m)

Electric potential (MV)
Thermal acceleration in streamer/leader fields.

![Diagram](image.png)
• Birkeland Centre for Space Science – a healthy 2 year old centre

• A very large community that participates in a wide range of projects:
  • ASIM,
  • Detailed analysis of satellite and ground measurements (radiowave - ULF,VLF,VHF..), Particle/gamma,
  • Computer modeling,
  • Laboratory experiments,
  • Aircraft – in-flight measurements