OBSERVATION of
Long laboratory sparks and
lightning interaction with aircraft
by Pavlo Kochkin

Research school of Birkeland Centre for Space Science:
Atmospheric Electricity and Hard radiation from Thunderclouds
First X-rays from long spark

X-ray bursts produced by laboratory sparks in air


- Intensity and spectra are inconsistent with RREA
- Cold runaway breakdown

![Graph showing friction force in air vs. energy in MeV and electric field vs. voltage over time.](image)
On the possible origin of X-rays in long laboratory sparks

Vernon Cooray\textsuperscript{a,*}, Liliana Arevalo\textsuperscript{a}, Mahbubur Rahman\textsuperscript{a}, Joseph Dwyer\textsuperscript{b}, Hamid Rassoul\textsuperscript{b}

"... an encounter between two streamer heads in the mid gap region can push the electrons to energies in the range of 200 keV."

Time resolved photography in simultaneous measurement of X-rays would be able to confirm this prediction.
Experimental setup in Eindhoven, The Netherlands

1 MV over 1 meter spark
Experimental setup
HV-electrode

GND-electrode

Voltage

Anode current

Cathode current

X-rays [appearance]

GND-electrode
Positive discharge animation https://www.youtube.com/watch?v=1n96IHrKelw

Negative streamers is necessary condition to produce X-rays
Negative discharge animation https://www.youtube.com/watch?v=2vjElSVaiPo

Papers
Negative streamer

10 cm

50 ns
Negative streamer

10 cm

50 ns

Negative streamer
Pilot system development
Pilot system development in metre-scale laboratory discharge

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Questions?
• Lightning interaction with aircraft
• Gamma-Ray Glows and positron annihilation observed from aircraft
• 1 E-field sensor
  10 Hz to 500 kHz
• 8 window H-field sensors
  100 Hz to 10 MHz
• 2 X-ray detectors
  0-10 MeV

- Continuous (15 ms)
- Triggered (10 ns)
Aircraft-triggered discharge

REAL LIFE SCENARIO

- Positive leader initiation threshold
- Aircraft polarization
- Negative leader initiation threshold
- 10's MV (Million Volts)
Aircraft-triggered discharge

Ambient E-field

ILDAS Data

positive leader initiation

negative leader initiation

Bi-directional leader propagation
initiation

Recoil, RS

E field [kV/m], H field [A/m]

X-ray [MeV]

Time [ms]
Aircraft-triggered discharge

(c) Presented by Otowa Electric Co., Ltd.
Gamma-Ray Glows and positron annihilation
Observational campaigns

Airborn Lightning Observatory for FEGS and TGFs (ALOFT, 2017)

- NASA ER-2, 20 km altitude, Colorado, USA
- X-ray detectors: 3 BGO (15 x 5 x 3.2 cm each)
- Energy range: 0.3 - 40 MeV
- Lightning Mapping Array: COLMA (VHF)

In-flight Lightning Damage Assessment System (ILDAS, 2016)

- Airbus A340, 12 km altitude, Darwin, Australia
- X-ray detectors: 2 LaBr3 (4 x 4 cm cylinder)
- Energy range: 0.05 - 10 MeV
- Lightning data: GPATS (hybrid VLF-VHF)

Østgaard N. et al., 2019, Gamma-ray glow observations at 20 km altitude, submitted to JGR

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ALOFT observation

![Graph showing Gamma-rays (cps) over UTC time]

- **Glow 1**
- **Glow 2**

UTC time:
- 21:44 to 21:53

May 08, 2017
ALOFT

41° N

40° N

39° N

38° N

105° W

104° W

103° W

102° W

101° W

ER-2

230 m/s

100 km
A thunderstorm near Darwin
ILDAS observation

- Locations labeled A, B, and C
- 55 km distance
- X-ray [counts/15 ms] graph showing peaks at UTC time:
  - A: 07:15:00
  - B: 07:35:00
  - C: 07:55:00
ILDAS observation site

ILDAS animation
1. https://www.youtube.com/watch?v=Q7pMcu4OPj4
2. https://www.youtube.com/watch?v=u6IbpDh5Rwg

ILDAS papers
ILDAS observation

511 keV pulses
511 keV pulses
In-Flight Observation of Positron Annihilation by ILDAS

P. Kochkin, D. Sarria, C. Skeie, A. P. J. van Deursen, A. I. de Boer, M. Bardet, C. Allasia, F. Flourens, N. Østgaard

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It was a ferry flight to Farragut, ID. Enroute there were many scattered thunder showers. As we approached Billings, Montana, the build-up was becoming more and more noticeable. We had severe radio static. Communication was impossible with Billings. To reduce static somewhat I reduced RPM. That was when we were struck directly on the nose section. Second of just blank, then a hurried look at gauges, radios, instruments and personnel. The Radio Operator said a ball of flame passed down the isle through the door. The passenger said the ball of flame about the size of a basketball rolled down the isle even with the right wing, out through the fuselage, down the wing and off the tip. After landing at Billings the aircraft was checked completely for any skin damage. None was found, but there was 70 ft. of trailing antenna burned off the radio station spool.
LED light reflection