# Le satellite TARANIS

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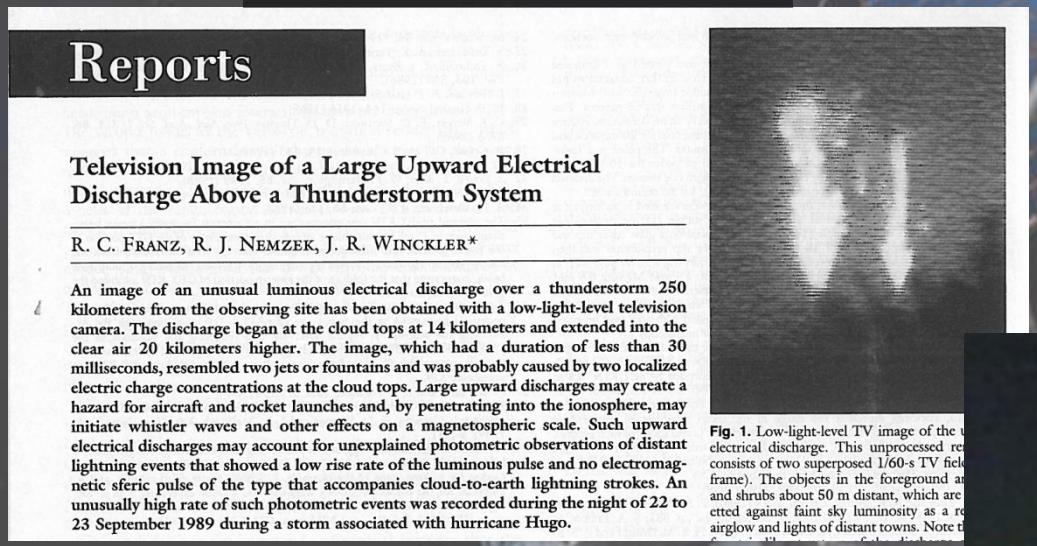
## Plan

- Les Transient Luminous Events (TLE)
- Les Terrestrial Gamma-ray Flashes (TGF)
- La mission TARANIS

# First evidence of a TLE

**Franz et al., Science 1990**



Reports

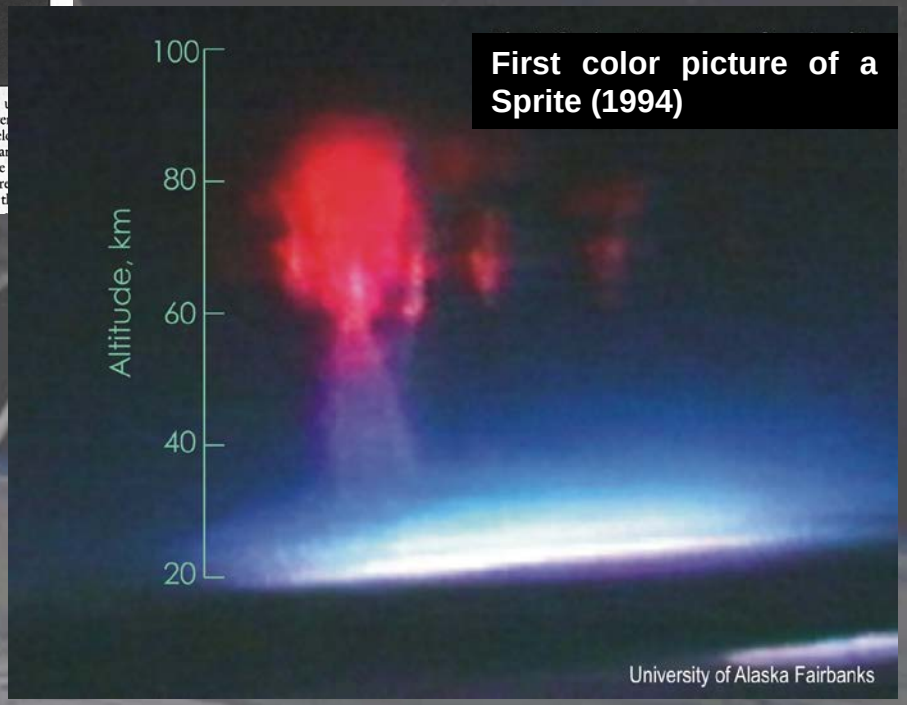
Television Image of a Large Upward Electrical Discharge Above a Thunderstorm System

R. C. Franz, R. J. Nemzek, J. R. Winckler*

An image of an unusual luminous electrical discharge over a thunderstorm 250 kilometers from the observing site has been obtained with a low-light-level television camera. The discharge began at the cloud tops at 14 kilometers and extended into the clear air 20 kilometers higher. The image, which had a duration of less than 30 milliseconds, resembled two jets or fountains and was probably caused by two localized electric charge concentrations at the cloud tops. Large upward discharges may create a hazard for aircraft and rocket launches and, by penetrating into the ionosphere, may initiate whistler waves and other effects on a magnetospheric scale. Such upward electrical discharges may account for unexplained photometric observations of distant lightning events that showed a low rise rate of the luminous pulse and no electromagnetic sferic pulse of the type that accompanies cloud-to-earth lightning strokes. An unusually high rate of such photometric events was recorded during the night of 22 to 23 September 1989 during a storm associated with hurricane Hugo.

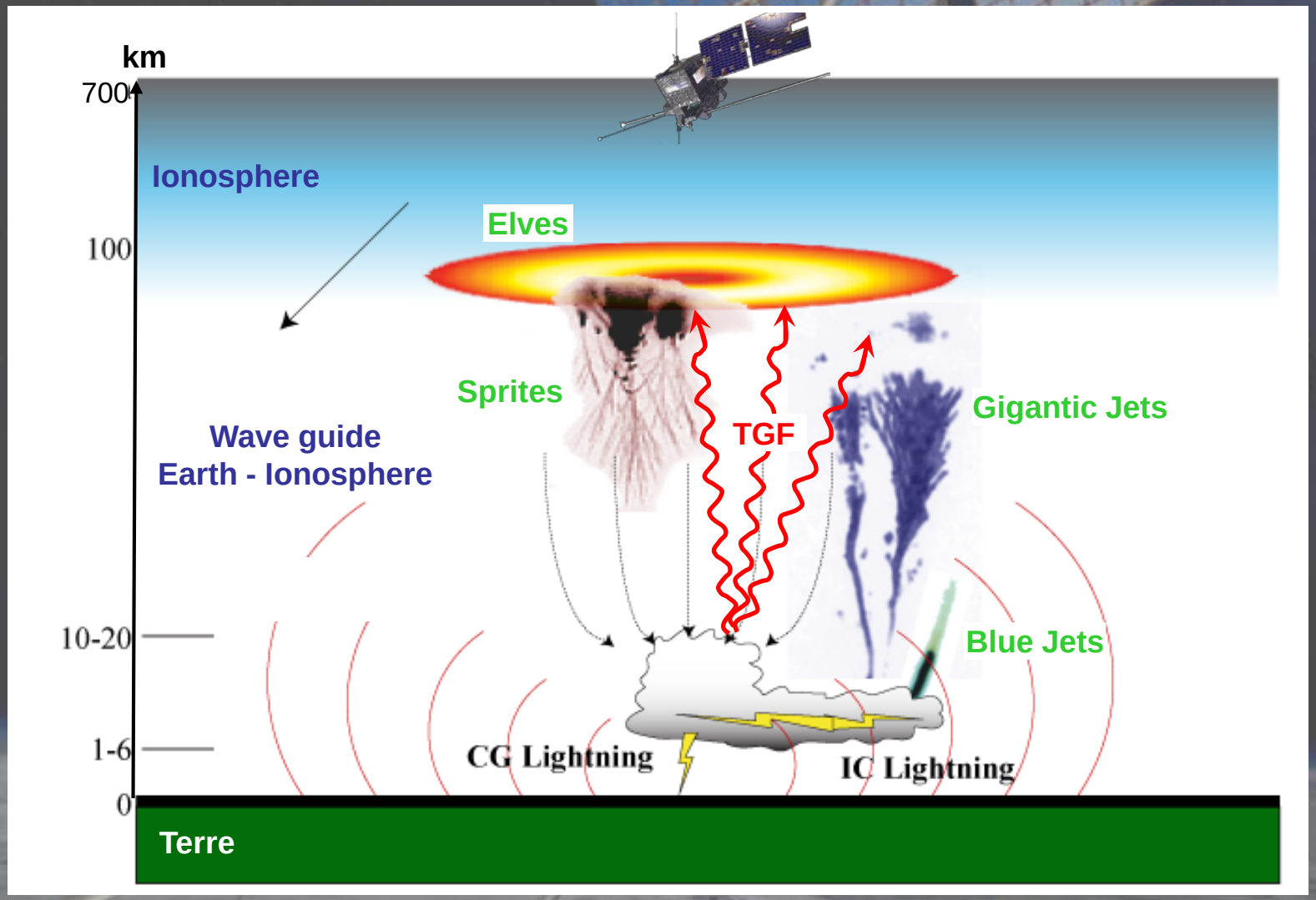
**Fig. 1.** Low-light-level TV image of the u
electrical discharge. This unprocessed re
consists of two superposed 1/60-s TV field
frame). The objects in the foreground ar
and shrubs about 50 m distant, which are
etted against faint sky luminosity as a re
airglow and lights of distant towns. Note t

1990 : First evidence of a sprite above a thunderstorm!!!!



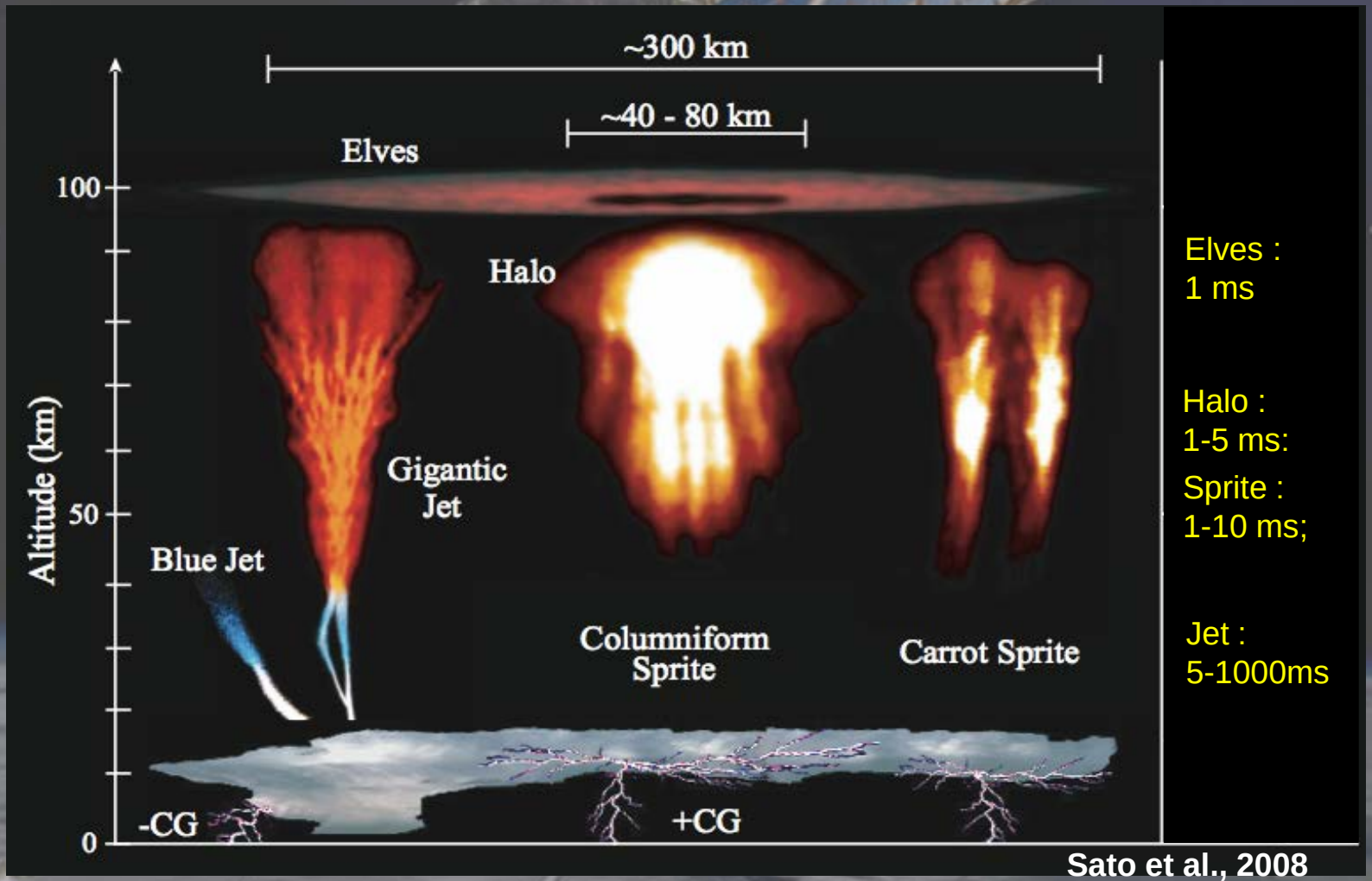

**First color picture of a Sprite (1994)**

# Discovery of TLEs and TGFs above thunderstorms



# Transient Luminous Events (TLEs)

- 1st TLE (Sprite) observation by Franz et al., 1990
- Correlation with lightning




Elves :
1 ms

Halo :
1-5 ms:

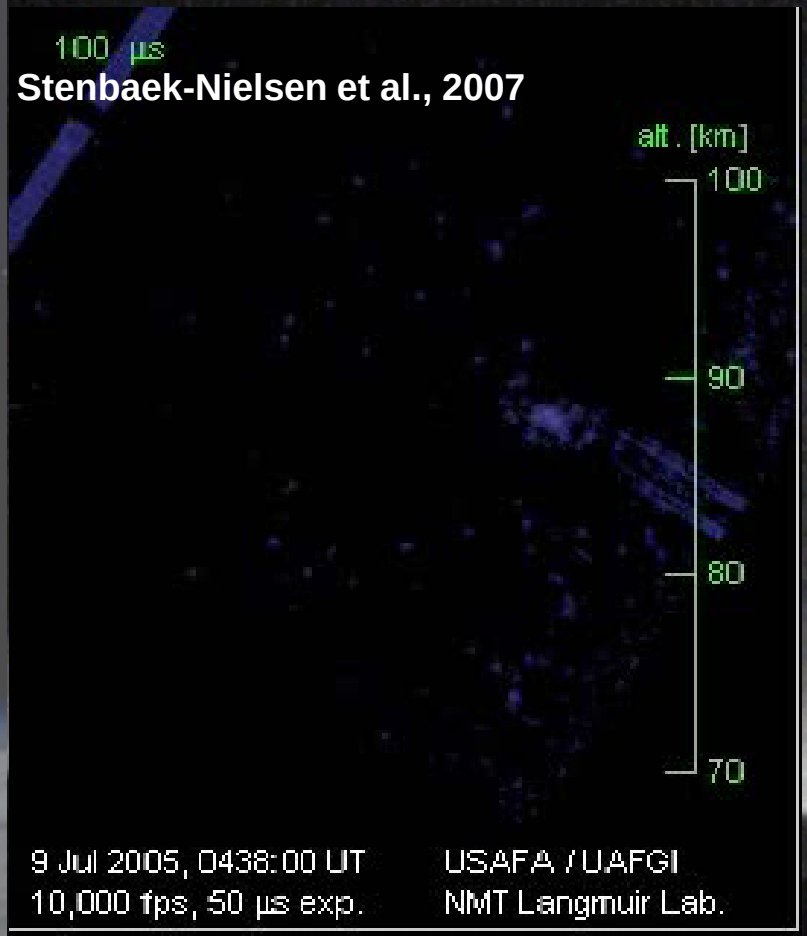
Sprite :
1-10 ms;

Jet :
5-1000ms

Sato et al., 2008

# Transient Luminous Events (TLEs)

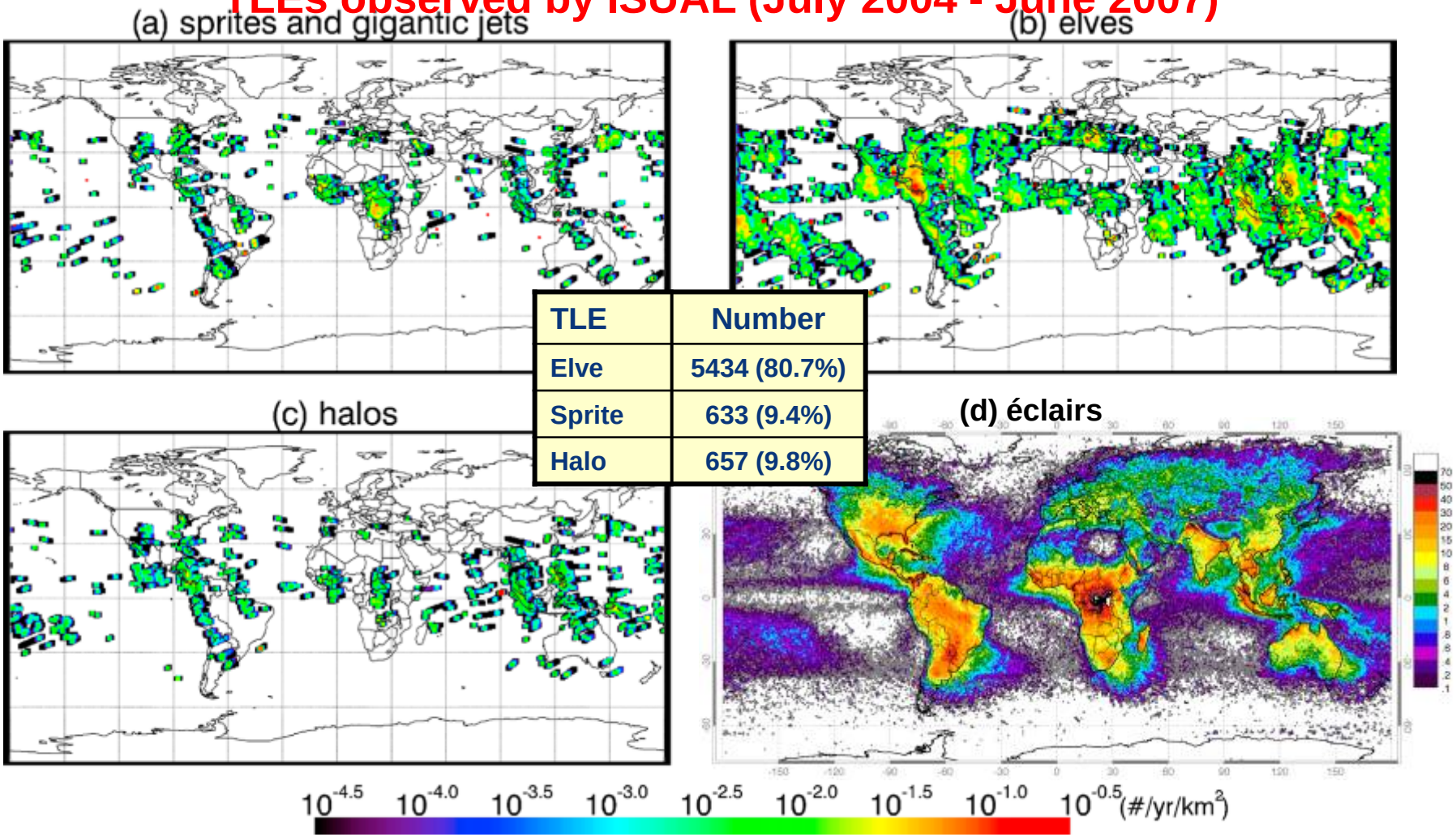
**Ultra-fast video of a Sprite**
**Total time = 9 ms**




**Giant Jet**
**Total time = 333 ms**

# Transient Luminous Events (TLEs)

## TLEs observed by ISUAL (July 2004 - June 2007)




| TLE | Number |
|---|---|
| Elve | 5434 (80.7%) |
| Sprite | 633 (9.4%) |
| Halo | 657 (9.8%) |

*a), b) c) from Chen et al. (2008). d) : from Christian et al., (2003).*

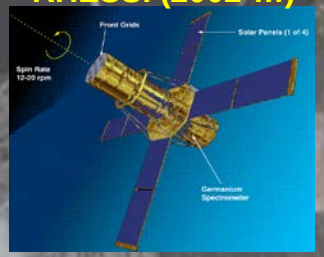
| | AB | Limb | CD |
|---|---|---|---|
| Distance (km) | 2310 | 3190 | 4130 |
| Size (km) | 912 | 1219 (*h* = 223) | 1590 |

# Terrestrial Gamma ray Flashes (TGFs)

- Discovery by Fishman et al., 1994
- Correlation with thunderstorm areas

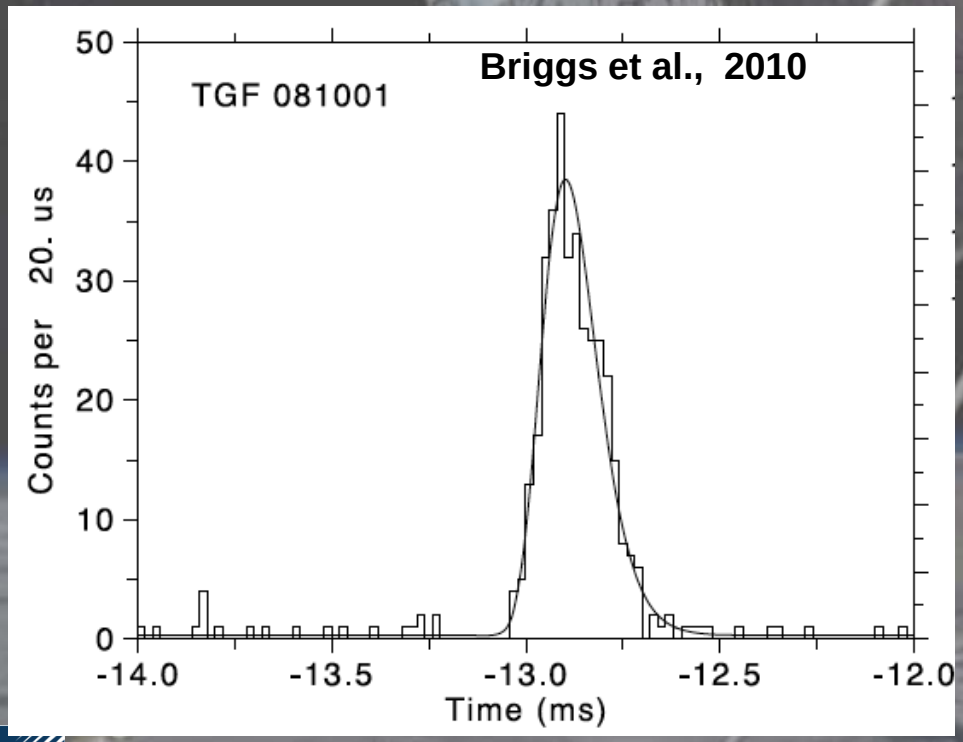
CGRO (1991-2000)

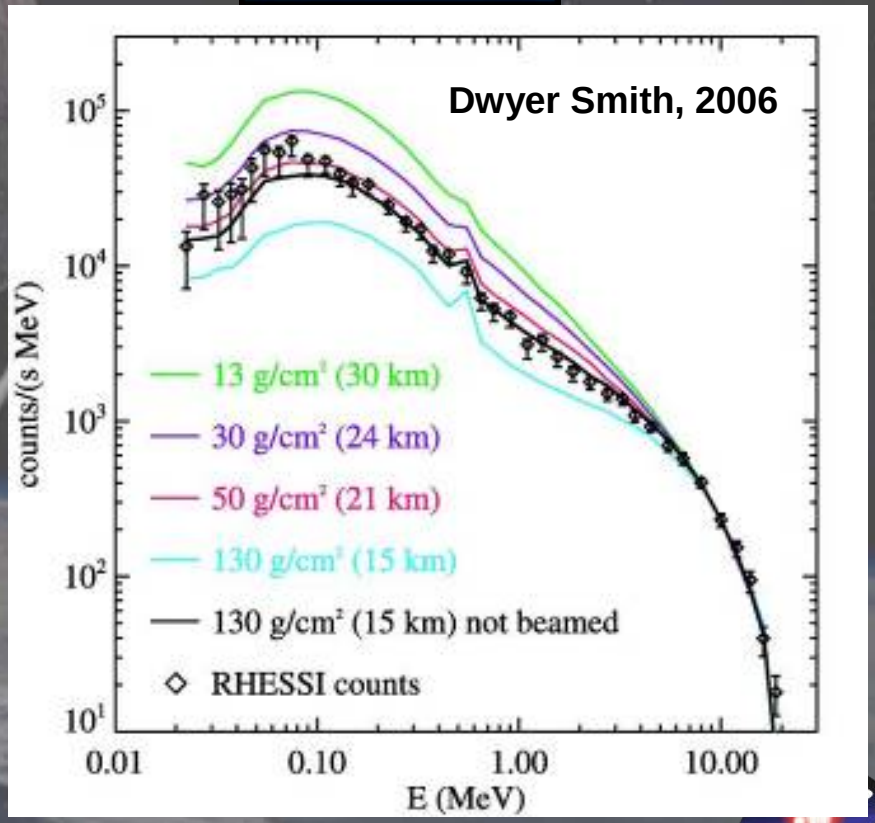
RHESSI (2002-…)



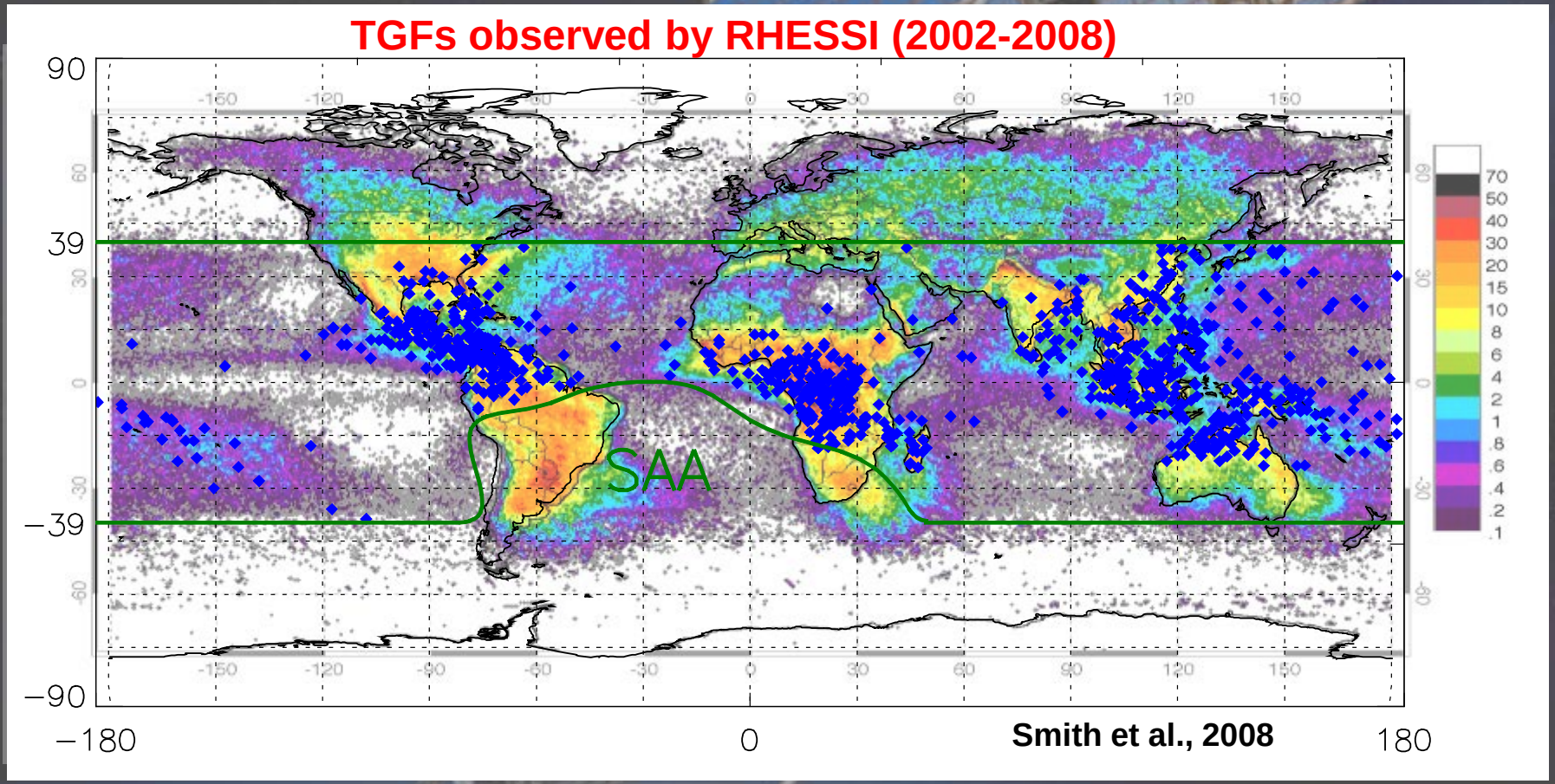
AGILE (2007- …)


Fermi (2008-…)



# Terrestrial Gamma ray Flashes (TGFs)




Smith et al., 2008

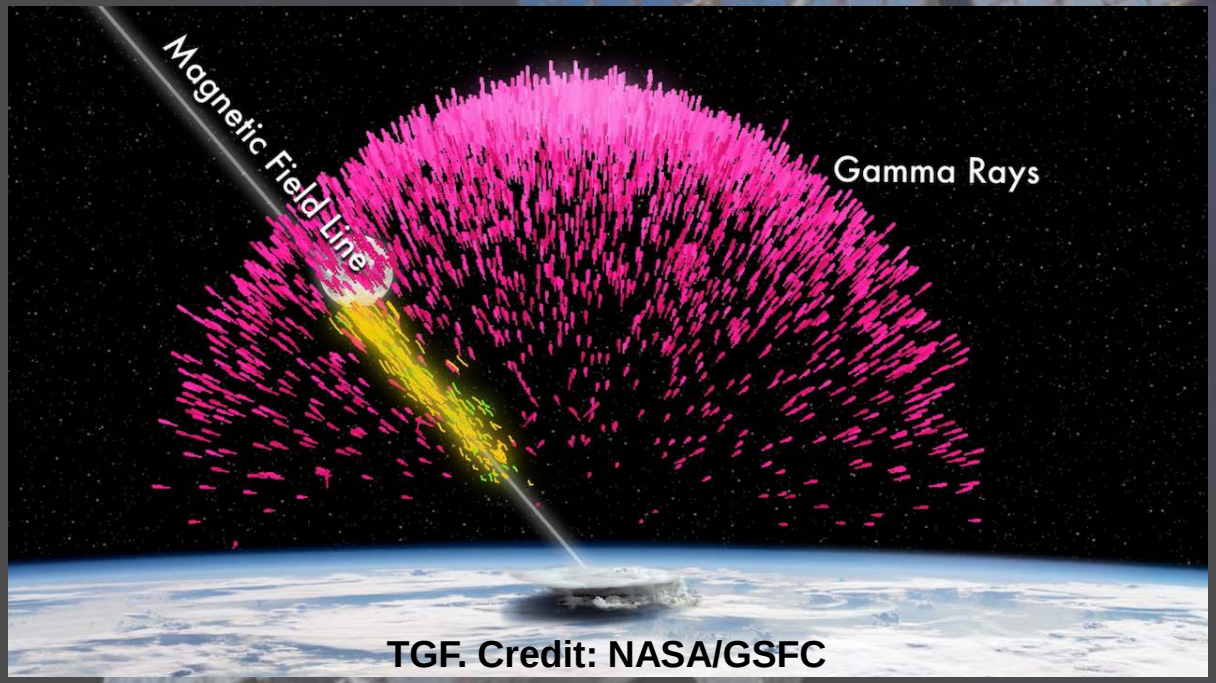

More than 800 TGF between 2002 and 2008:

3 TGF/week


Since 2010 a special TGF mode is used:

30 TGF/week!

# Terrestrial Gamma ray Flashes (TGFs)




TGF. Credit: NASA/GSFC

**Typical maximun Energie: 30 MeV.**
**Typical duration: fraction of ms.**
**Global occurrence rate: > 400 000/year (1/min).**
**Typical flux: 1 photon/cm$^2$ at low altitude orbit**

# TLEs and TGFs : the remaining questions

**TLEs:**
- Microphysics of TLEs?
- How to explain the various kind of sprites?
- Relationship between thunderstorms and the various TLEs?
- Correlation between Jets and lightning?

**TGFs:**
- Generation mechanisms?
- What are the real flux and spectra at S/C altitude?
- Are TGFs dangerous for flight passengers?
- Link with low altitude TLEs (jets)?
- Link with electron/positon beams?

**TLE et TGF :**
- Impact to high atmospheric chemistry?
- Impact to the Global Electric Circuit?

**Need of simultaneous observations of TLEs and TGFs from Nadir**

# Tool for the Analysis of RAdiation from lightNIng and Sprites

- Combined Nadir observations of TLEs and TGFs.
- High resolution measurement of energetic electrons.
- Wave field measurements over the frequency range [DC - 35 MHz].

- Dimension: ~ 1m$^3$
- Mass: ~ 200 kg

**Orbit:**
- Sun-synchronous
- Inclination: 98°
- Altitude: 700 km

**Subsystems:**
- Memory: 16 Gbits
- X band: 16.8 Mb/s

**Data: 4 GB/day**

**Time stamping accuracy: ±1 ms**

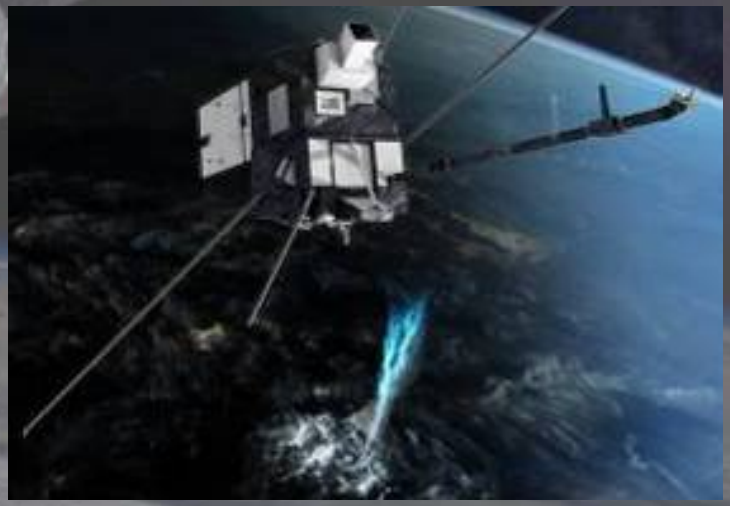
**Pointing accuracy**
- localization: 5 km

# Scientific objectives of TARANIS

- **To advance the physical understanding of the links between TLEs, TGFs and environmental conditions** *(lightning activity, geomagnetic activity, atmosphere/ionosphere coupling, occurrence of Extensive Atmospheric Showers, etc).*

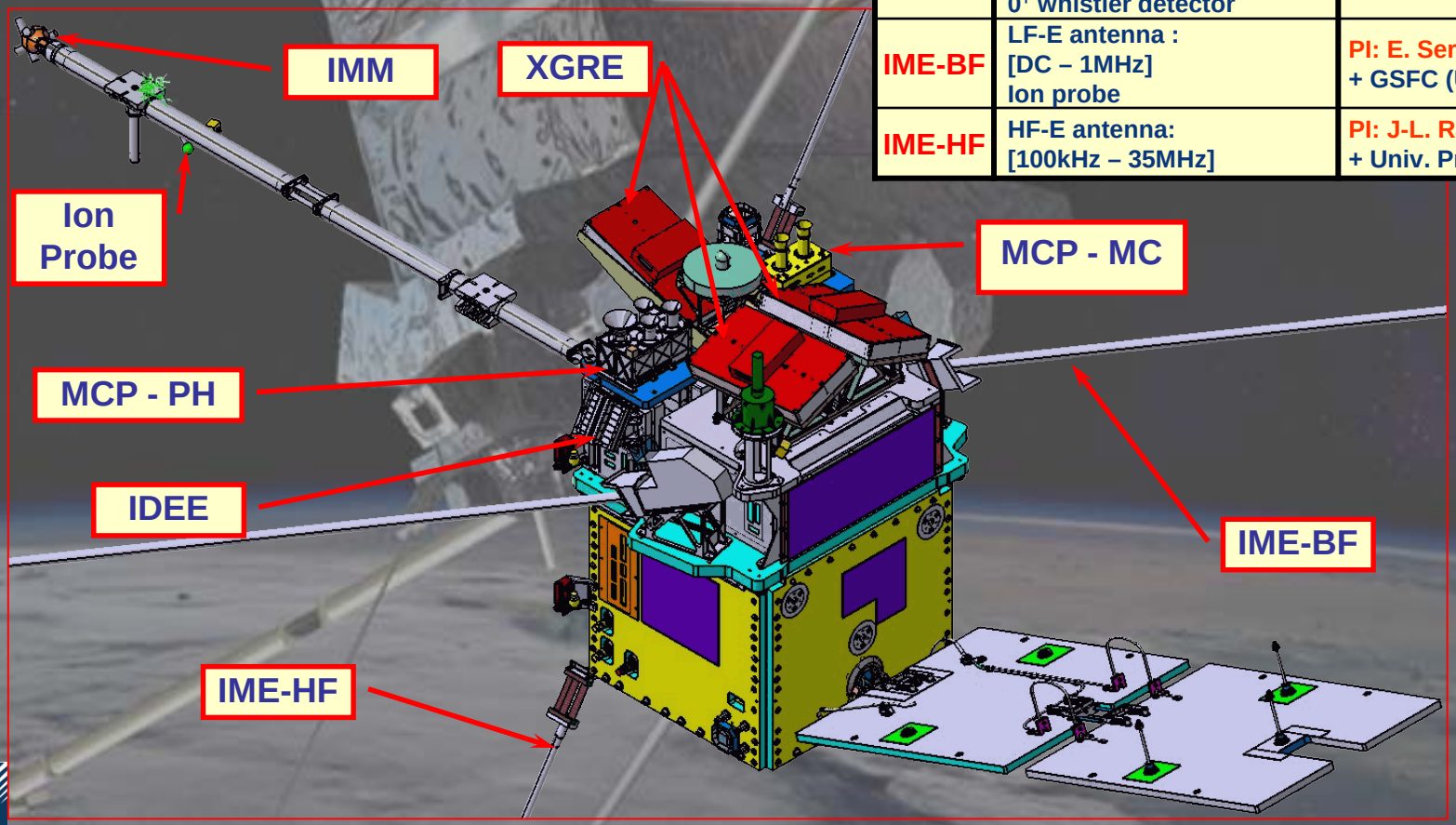
- **To identify the signatures associated with these phenomena** *(electron beams, associated electromagnetic or/and electrostatic fields)* **and to provide inputs to test generation mechanisms.**

- **To provide inputs for the modelling of the effects of TLEs, TGFs and bursts of precipitated and accelerated electrons** *(lightning induced electron precipitation, runaway electron beams)* **on the Earth's atmosphere.**



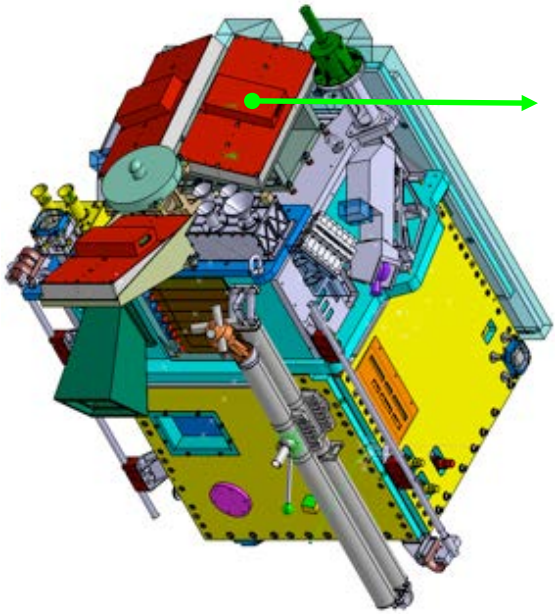
# Scientific payload accommodation

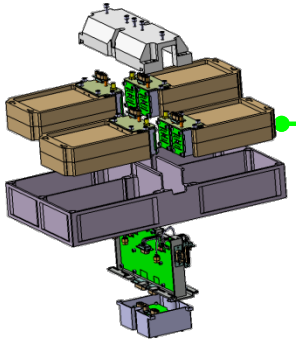
| | | |
|---|---|---|
| MCP | Lightning micro-camera<br>TLE micro-camera<br>Photometers | PI: E. Blanc, CEA (F) and Th. Farges (CEA) |
| XGRE | X and γ detectors:<br>Photons : [20keV – 10MeV]<br>$e^-$: [1 MeV – 10 MeV | PI: P-L. Blelly, IRAP (F) and F. Lebrun, APC (F) |
| IDEE | Two $e^-$ detectors:<br>[70keV – 4MeV] | PI: J-A. Sauvaud, IRA (F)<br>+ Univ. Prague (Cz) |
| IMM | Triaxial search coil :<br>[5Hz – 1MHz]<br>$0^+$ whistler detector | PI: J-L. Pinçon, LPC2E (F)<br>+ Univ. Stanford (USA) |
| IME-BF | LF-E antenna :<br>[DC – 1MHz]<br>Ion probe | PI: E. Seran, LATMOS (F)<br>+ GSFC (USA) |
| IME-HF | HF-E antenna:<br>[100kHz – 35MHz] | PI: J-L. Rauch, LPC2E (F)<br>+ Univ. Prague, IAP (Cz) |



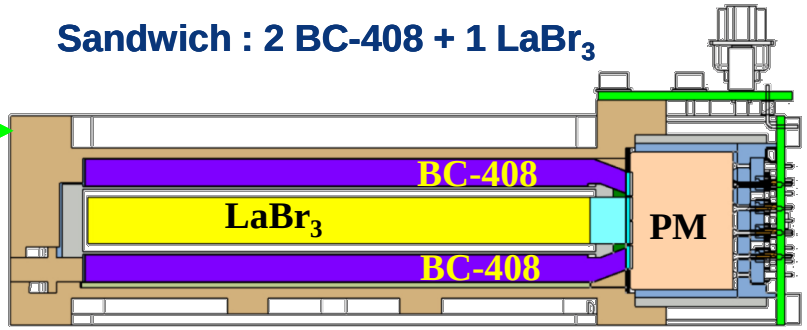
# XGRE (PIs : P-L Blelly (IRAP) et F. Lebrun (APC))

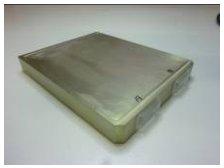
**Three sensors facing the Earth placed on TARANIS spacecraft with different orientations and one analyzer.**





**Sandwich : 2 BC-408 + 1 $LaBr_3$**



## XGRE experiment

- 3 sensors
- Total detection area
  ~ 900 $cm^2$

## XGRE Sensor

- 4 Detection Units
- ADC converters
  12 bits (LaBr3)
  10 bits (BC408)
- Fast electronics
  dead time = 300 ns

## $LaBr_3$ (photons)

- Fast (pulse pile up < 150 ns)
- Good linearity
- Good spectral resolution

## BC-408 (electrons)

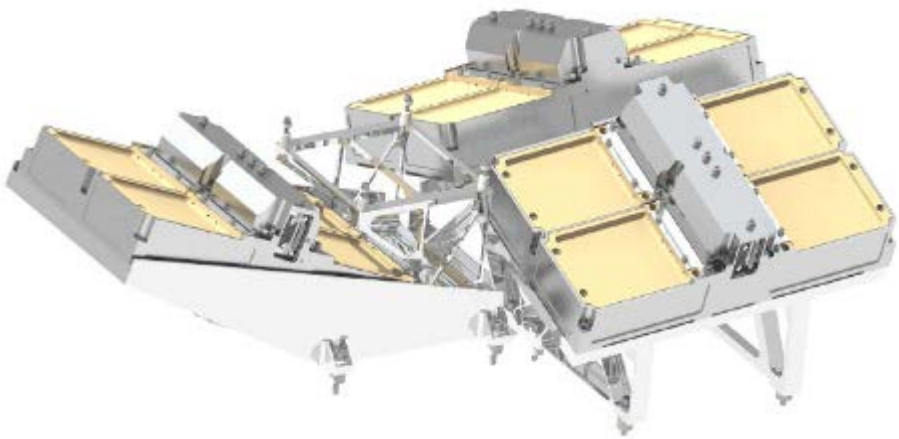
**Gamma-Rays:** energy range [20 keV – 10 MeV]
(accuracy: 30% at 20 keV ; 10% at 511 keV).

**Electrons:** energy range [1 MeV – 10 MeV]

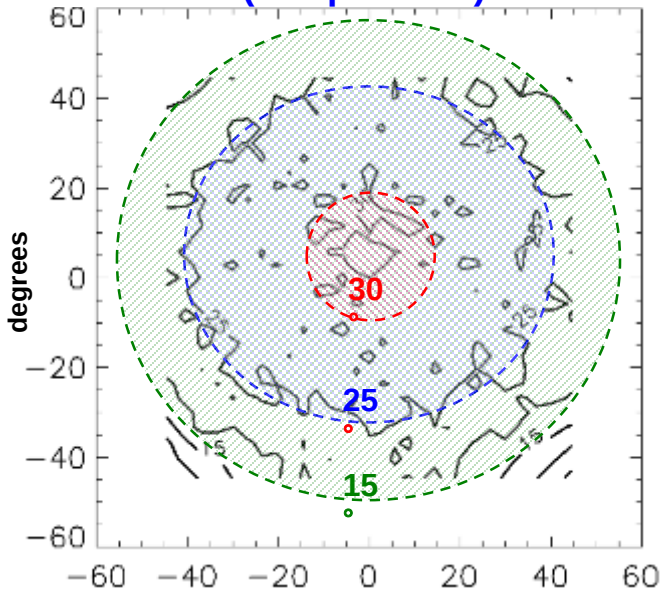
# XGRE (PIs : P-L Blelly (IRAP) and F. Lebrun (APC))

## Spatial localization

- Three planes (~20° inclination)

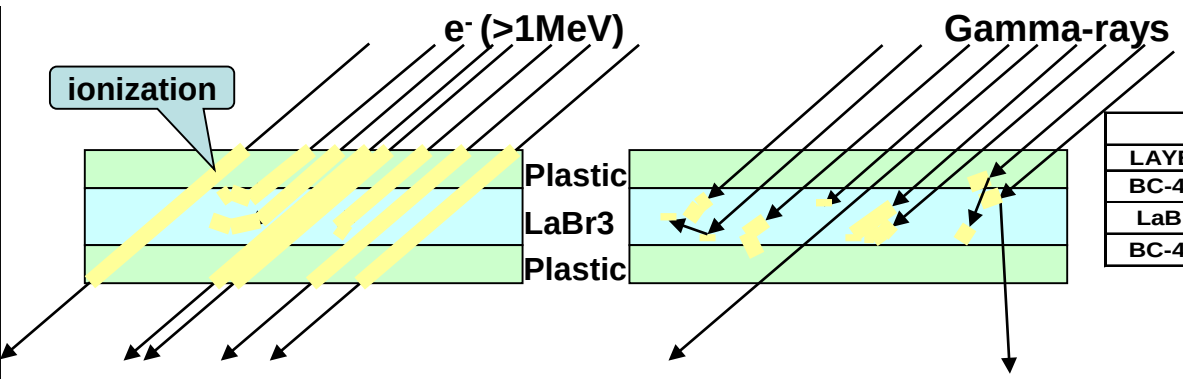


**Arrival direction accuracy (100 photons)**



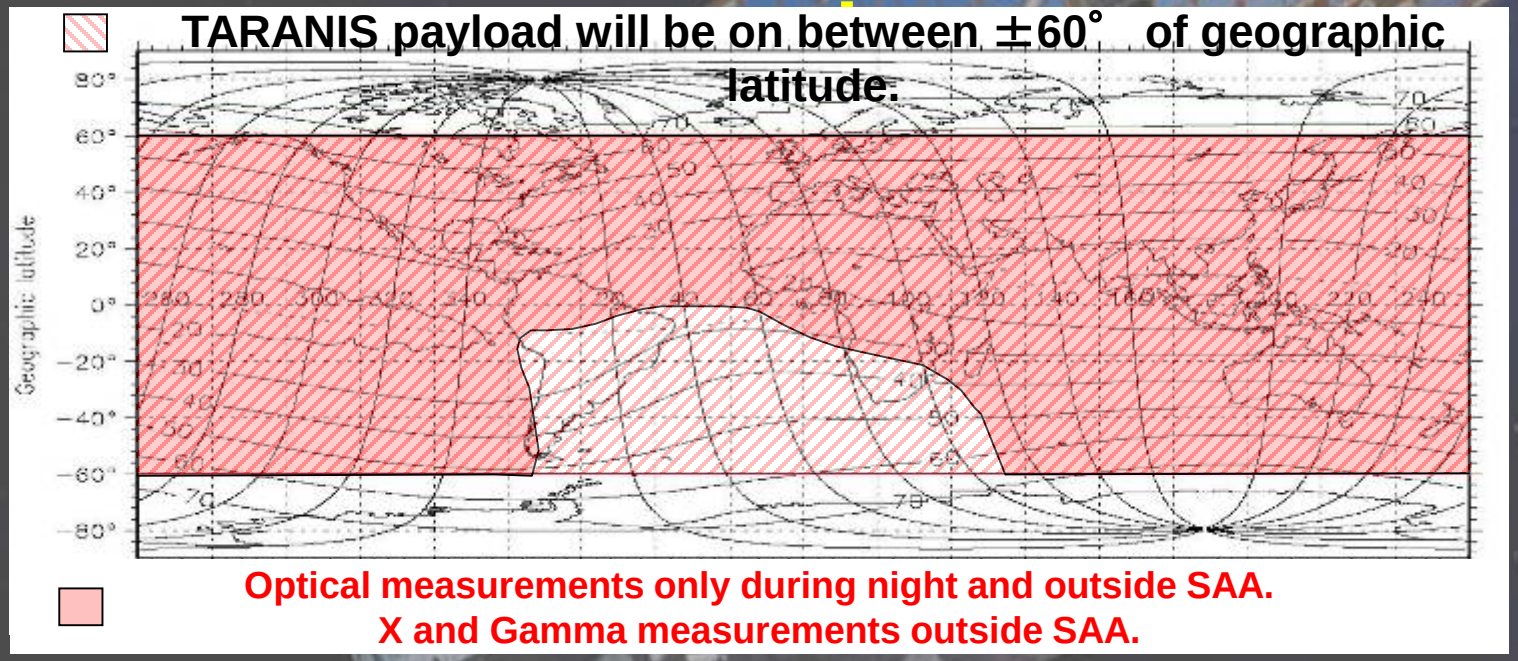

## Separation photons - electrons

- Coincidence/anti-coincidence between LaBr3 and BC408




| | electrons | | | photons | |
|---|---|---|---|---|---|
| LAYER | < 1 MeV | 1 - 8 MeV | > 8 MeV | <200 keV | >200 keV |
| BC-408 | E | ~ 0.7 MeV | ~ 0.7 MeV | 0 | 0 |
| LaBr3 | 0 | ~ E-0.7 MeV | ~ 7 MeV | E | ≤ E |
| BC-408 | 0 | 0 | ~ 0.7 MeV | 0 | 0 |

# TARANIS: Event and Survey




**Survey data:**

Continuous monitoring of the background conditions.

**2 GB of low resolution data per day!**

**Event data:**

Triggered when a priority event is detected (TLE, TGF, electron beam, burst of electromagnetic/electrostatic waves), then all instruments record and transmit high resolution data.

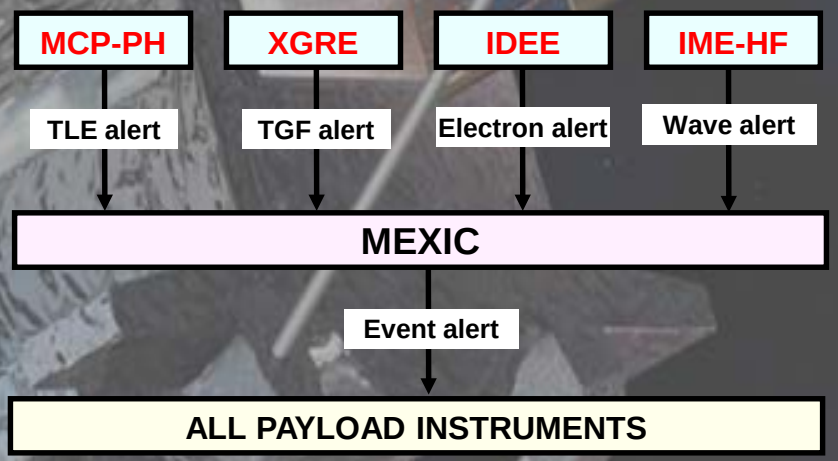
**2 GB of high resolution data per day!**

# TARANIS event data

**TARANIS**
**Mass memory: 16 Gbits**
**X-band telemetry: 16.8 Mbits/s**

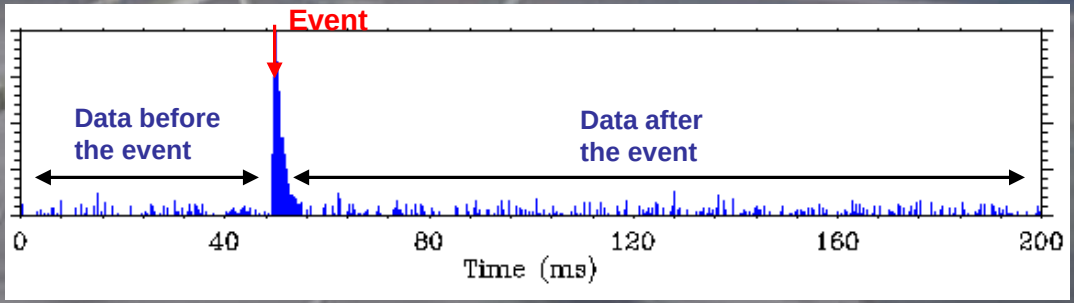
**2 GBytes of event data per day**
- On average 12 events per half-orbit (T=100mn)
- A maximum of 36 events per half-orbit

**4 triggering instruments**



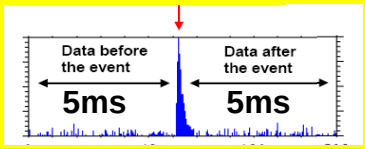
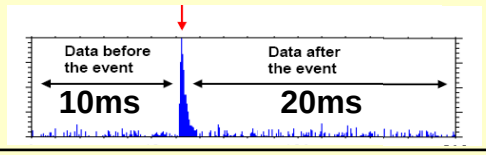
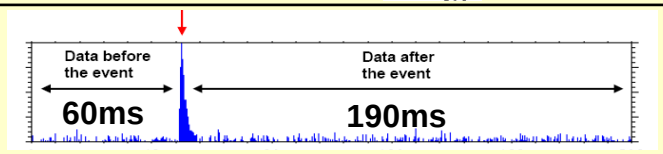
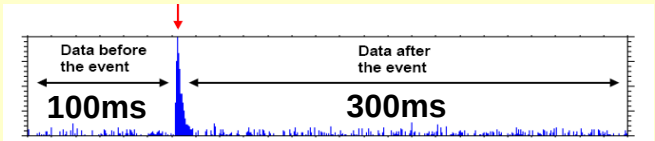
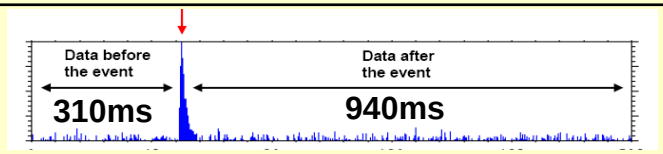
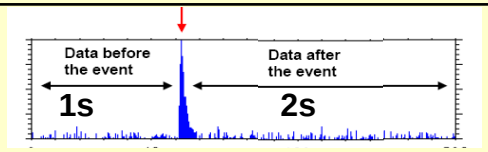

**Multi EXperiment Interface Controller to power and to manage the whole scientific payload.**

**On-board analyzers will include event buffer memory sized to record high resolution data both before and after the trigger**



# TARANIS event data (2/2)

TGF event triggering

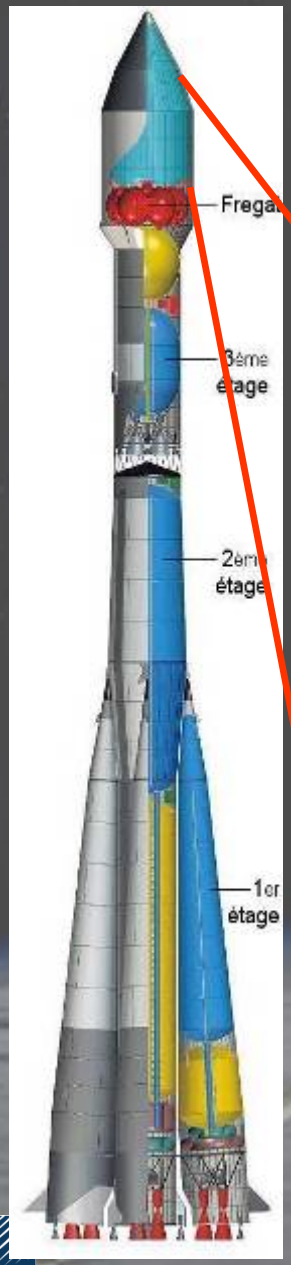
| | | |
|---|---|---|
| XGRE |  | photons |
| IME-HF (HF) |  | Fe = 80MHz |
| IME-IMM (LF-MF) |  | Fe = 2MHz |
| MCP-PH |  | Fe = 20kHz |
| MCP-MC | Nadir Image TLEs, lightning \| Nadir Image TLEs, lightning \| Nadir Image TLEs, lightning \| Nadir Image TLEs, lightning | 500x500<br>Δt ≈ 100ms |
| IME-IMM (ELF-VLF) |  | Fe = 50kHz |
| IDEE |  | electrons |

**Time stamping accuracy**

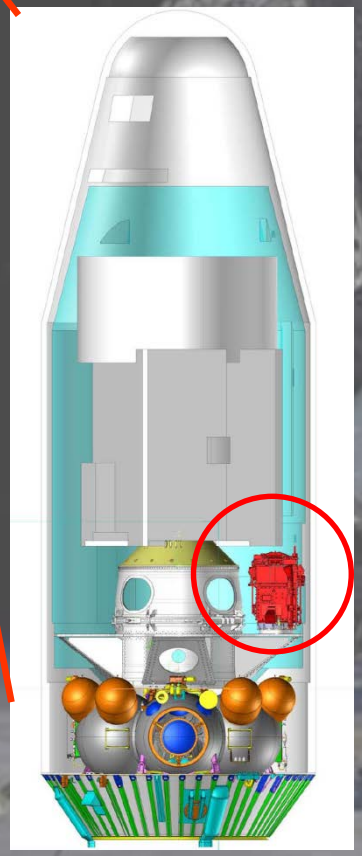
**Absolute accuracy:**
**1 ms** (comparison with ASIM, balloon, and ground based measurements).

**Relative accuracy:**
**10 µs** (comparison between TARANIS experiments).

# TARANIS LAUNCH




**SOYUZ**
**~4,8 tons**
**SSO orbit**



**KOUROU**
**2017**

# TARANIS Status

| 2011 | 2012 | 2013 | 2014 | 2015 | |
|---|---|---|---|---|---|
| Phase A & B | Phase C (EM) | | | Phase D (FM) | AIT |

# TARANIS Data

| | | Data access | | | | | |
|---|---|---|---|---|---|---|---|
| | | Mission PI | Instrument PI | Instrument Lead Co-I | Instrument Co-I | Guest Investigator | Public |
| Data & Products | Raw Survey data | Yes | instrument | instrument PI agreement required | No | No | No |
| | Raw Event data | Yes | instrument | instrument PI agreement required | No | No | No |
| | Calibrated Survey data | Yes | Yes | Yes | instrument | CST agreement required | No |
| | Calibrated Event data | Yes | Yes | Yes | instrument | CST agreement required | No |
| | Quickview Survey | Yes | Yes | Yes | Quicklook + instrument | CST agreement required | Quicklook only |
| | Quickview Event | Yes | Yes | Yes | Quicklook + instrument | CST agreement required | No |
| | Plot Survey data | Yes | Yes | Yes | instrument | CST agreement required | No |
| | Plot Event data | Yes | Yes | Yes | instrument | CST agreement required | No |
| | Auxiliary data | Yes | Yes | Yes | Yes | Yes | No |

# MERCI !