The TARANIS mission

J-L. Pinçon[1]; E. Blanc[2]; P-L. Blelly[3]; F. Lebrun[5]; M. Parrot[1]; J-L. Rauch[1]; J-A. Sauvaud[4]; E. Seran[4]

1. LPC2E, CNRS/University of Orléans, France - 2. DASE/LDG, CEA, France - 4. LATMOS, CNRS, France
3. IRAP, CNRS/University of Toulouse, France - 5. APC, CNRS/University of Paris 7, France

Tool for the Analysis of RAdiation from lightNIng and Sprites

Motivation: Atmosphere-ionosphere-magnetosphere couplings

- Dimension: ~ 1m^3
- Mass of the Scientific Payload: ~ 35 Kg

TARANIS is a satellite dedicated to the study of impulsive energy transfers between the atmosphere of the Earth and the space environment.

Orbit:
- Sun-synchronous

local time 22:30 → 02:00
- Inclination: 98°
- Altitude: 700 km

Time stamping accuracy: ±1 ms

Pointing accuracy
- localization: 5 km

Subsystems:
- mass memory: 16 Gbits
- X band telemetry: 16.8 Mbits/s

Data: 4 GB/day

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

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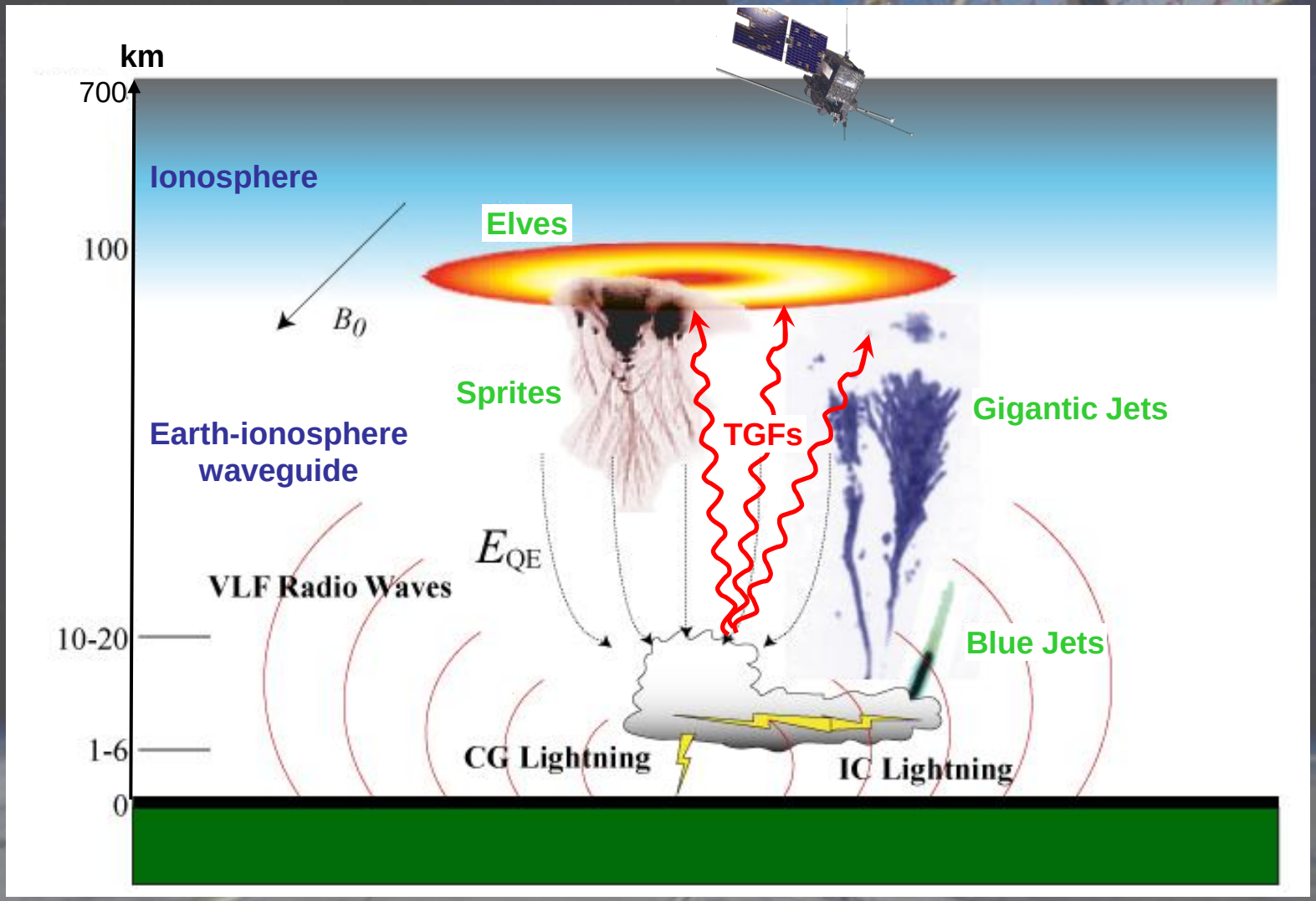
TLEs and TGFs above thunderclouds



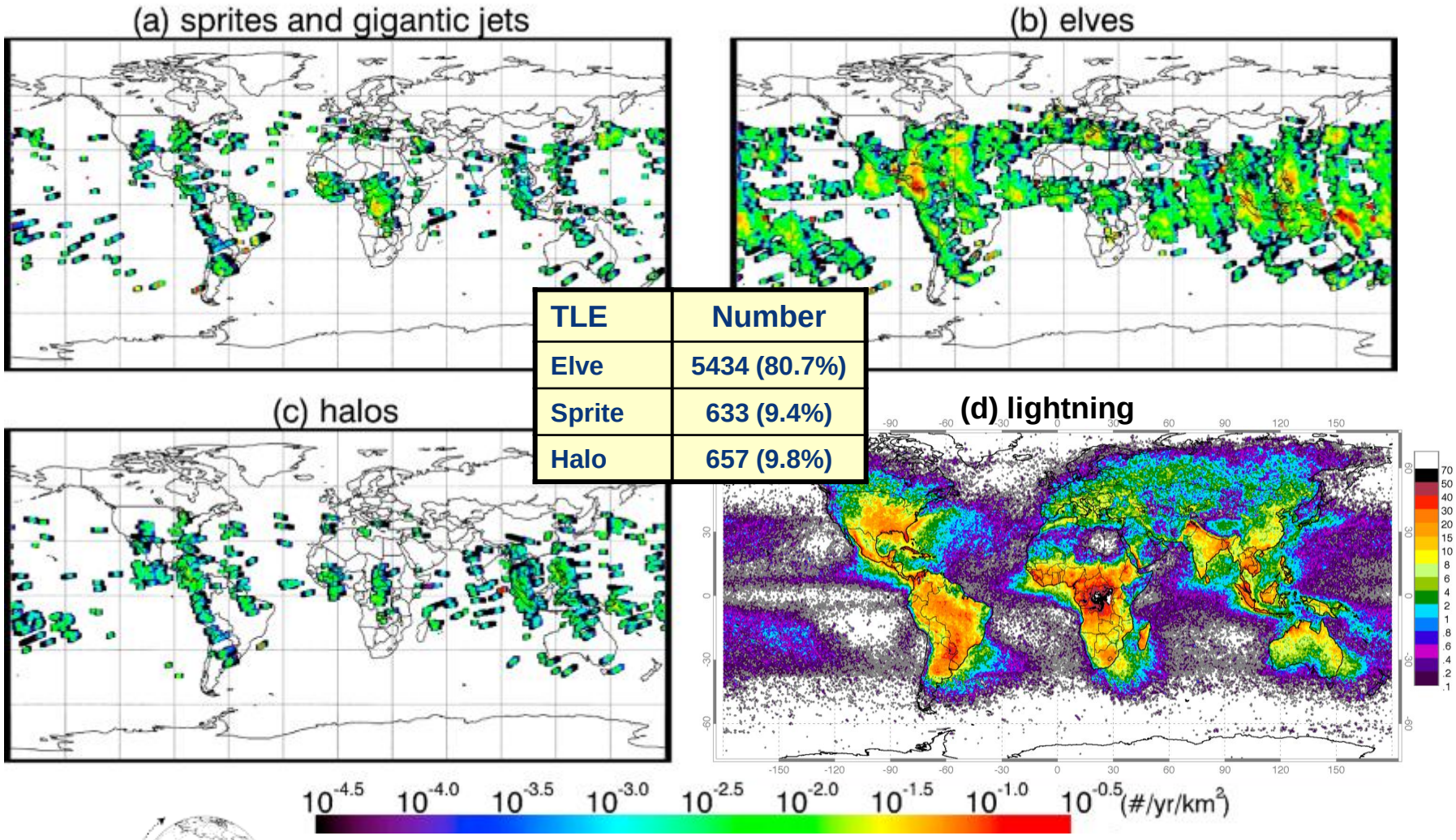
Elves: 1 ms E&M pulse

Halo: 1-5 ms: glow discharge

Sprite: 1-10 ms; streamer discharge

Blue jets: 5-1000ms process ?

Transient Luminous Events (TLEs)

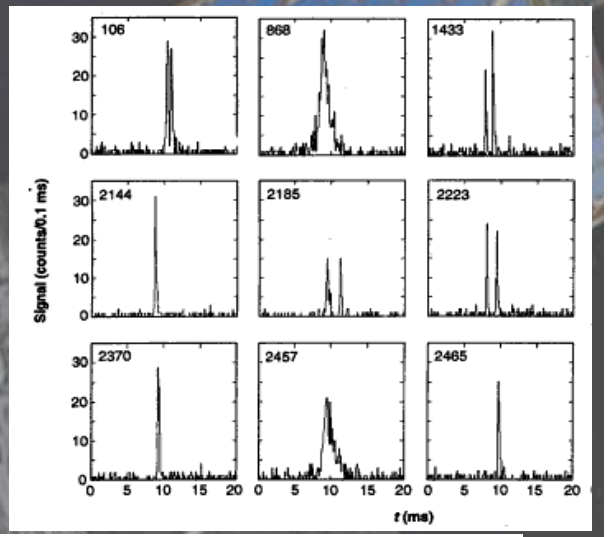


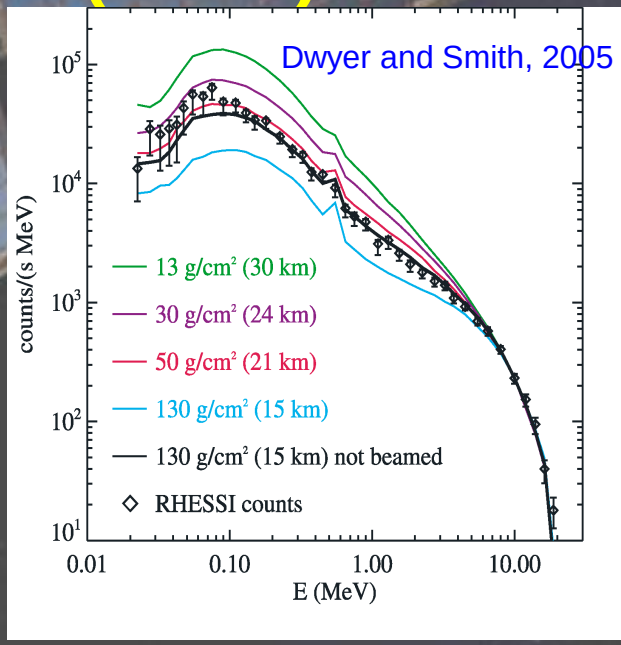
TLE	Number
Elve	5434 (80.7%)
Sprite	633 (9.4%)
Halo	657 (9.8%)

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

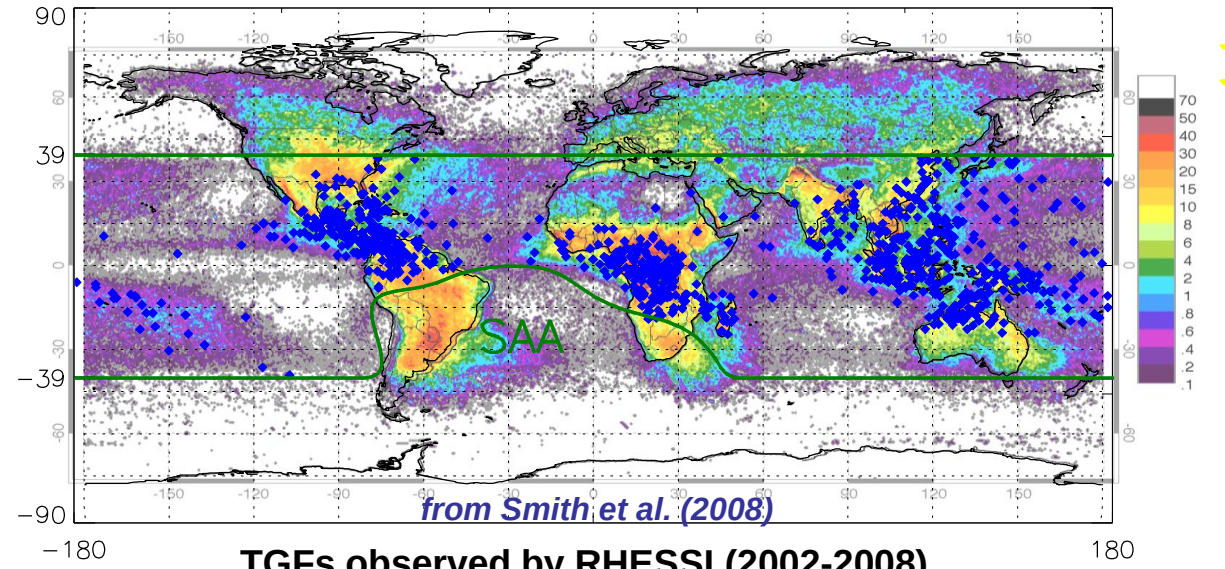
TLEs observed by ISUAL (July 2004- June 2007)

Terrestrial Gamma ray Flashes (TGFs)

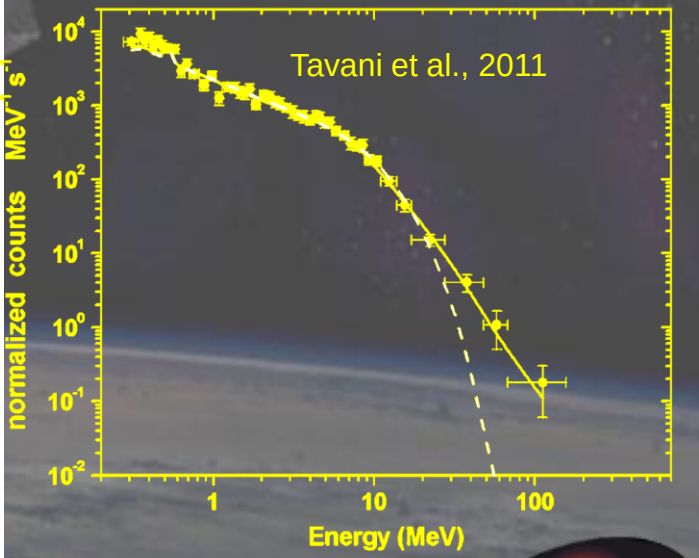




On average 27 events/week expected on board TARANIS

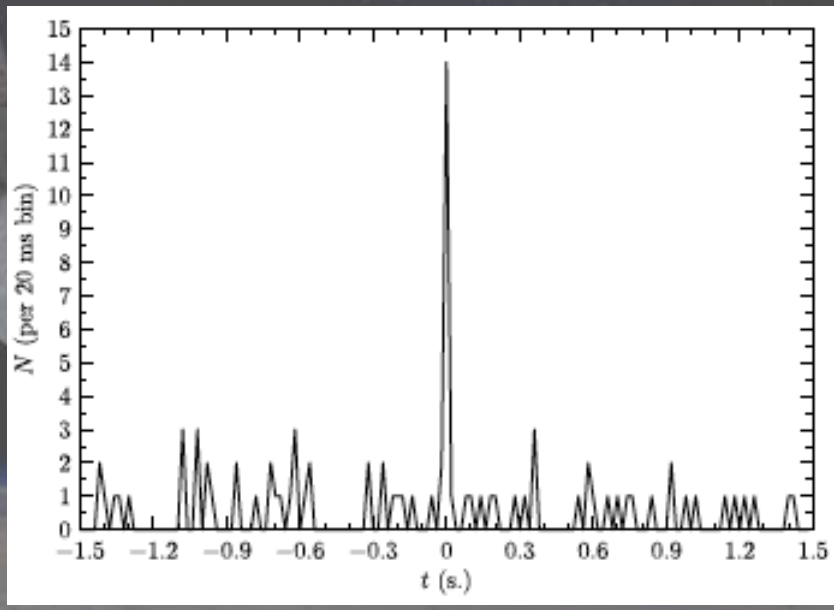


TGFs observed by RHESSI (2002-2008)



TGF electrons

- Brief electron pulses: 2-10 ms
- About 1 e^-/cm^2 spread over 50 km wide
- +/- along the magnetic field, coming from the Earth, and possibly reflected from the conjugate hemisphere
- Only 1 spacecraft with adequate performances
  - SAMPEX: 60 cm^2.ster, 20 ms



- Expected counts during 10 ms: 50 max
- High energy limit, at least 4 MeV (10 MeV)

November 22, 2002
Lat/Long:-2.65 N/166.95, L=1.1

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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.**

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TARANIS scientific payload

- MEXIC **(Multi Experiment Interface Controller)**
  - electronics equipment to power and to manage the whole scientific payload
  - Alert management
- MCP **including MC (MicroCameras)**
  - a set of two cameras (a sprite camera and a lightning camera), and their associated analyzer, and PH (Photometers);
  - a set of four photometers and their associated analyzer;
- XGRE **(X-ray, Gamma-ray and Relativistic Electron experiment)**
  - a set of three X and γ detectors and their associated analyzer;
- IDEE **(Instrument Détecteurs d'Electrons Energétiques)**
  - two electron detectors with one analyzer per detector;
- IMM **(Instrument de Mesure du champ Magnétique)**
  - a compound triaxial system of search-coil magnetometers to measure the alternative magnetic field in the low and medium frequency ranges and the medium frequency wave analyzer (electric and magnetic);
  - IMM also includes a Sferics Detector (SD) to make on-board characterization of whistlers;
- IME-BF **(Instrument de Mesure du champ Electrique Basse Fréquence)**
  - a sensor to measure the electric field in the low frequency range and the low frequency wave analyzer (electric and magnetic);
  - IME-BF also includes an Ion Probe (SI) to determine fluctuations of thermal plasma;
- IME-HF **(Instrument de Mesure du champ Electrique Haute Fréquence)**
  - a sensor to measure the electric field in the high frequency range and the associated high frequency wave analyzer;

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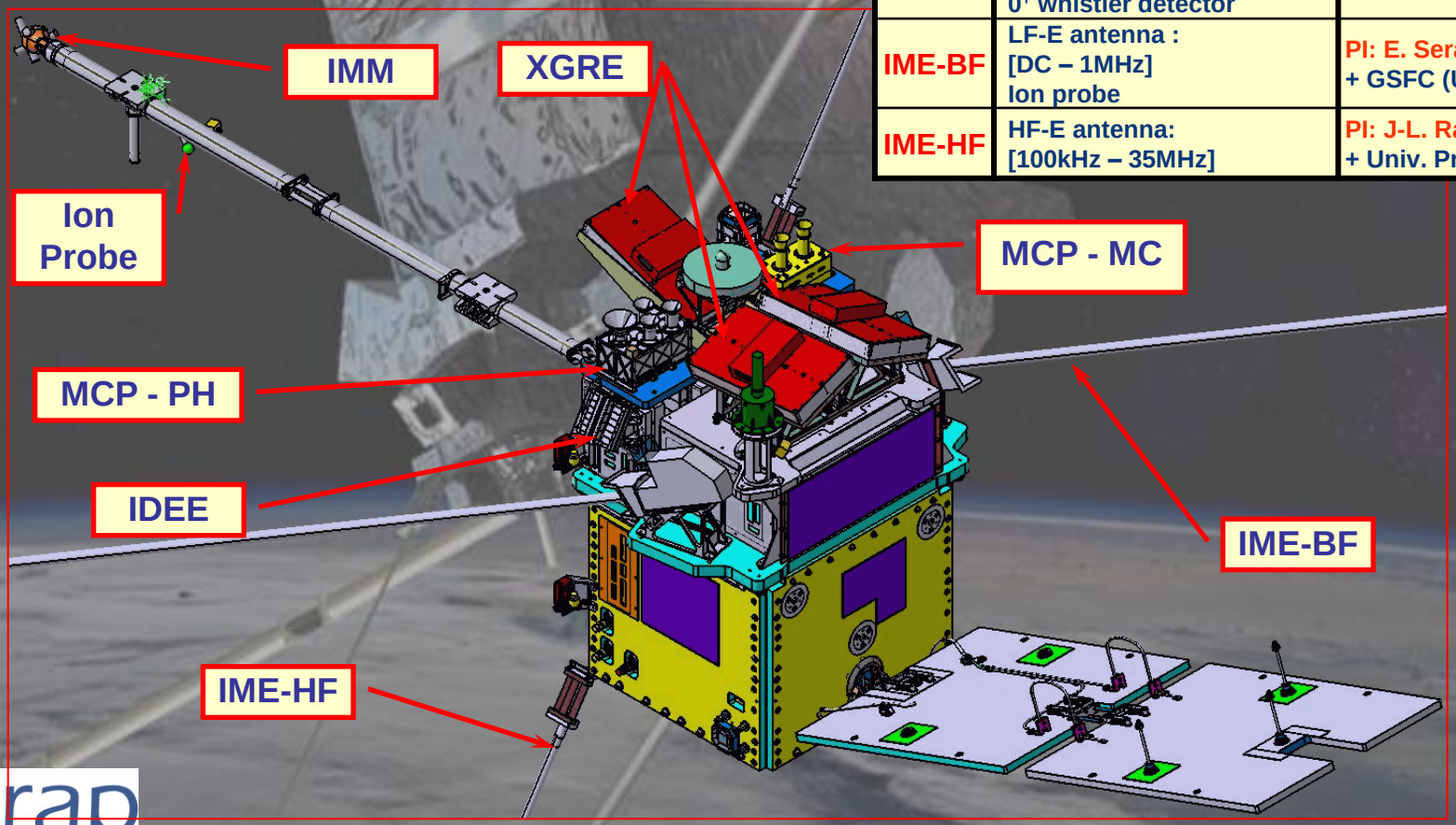
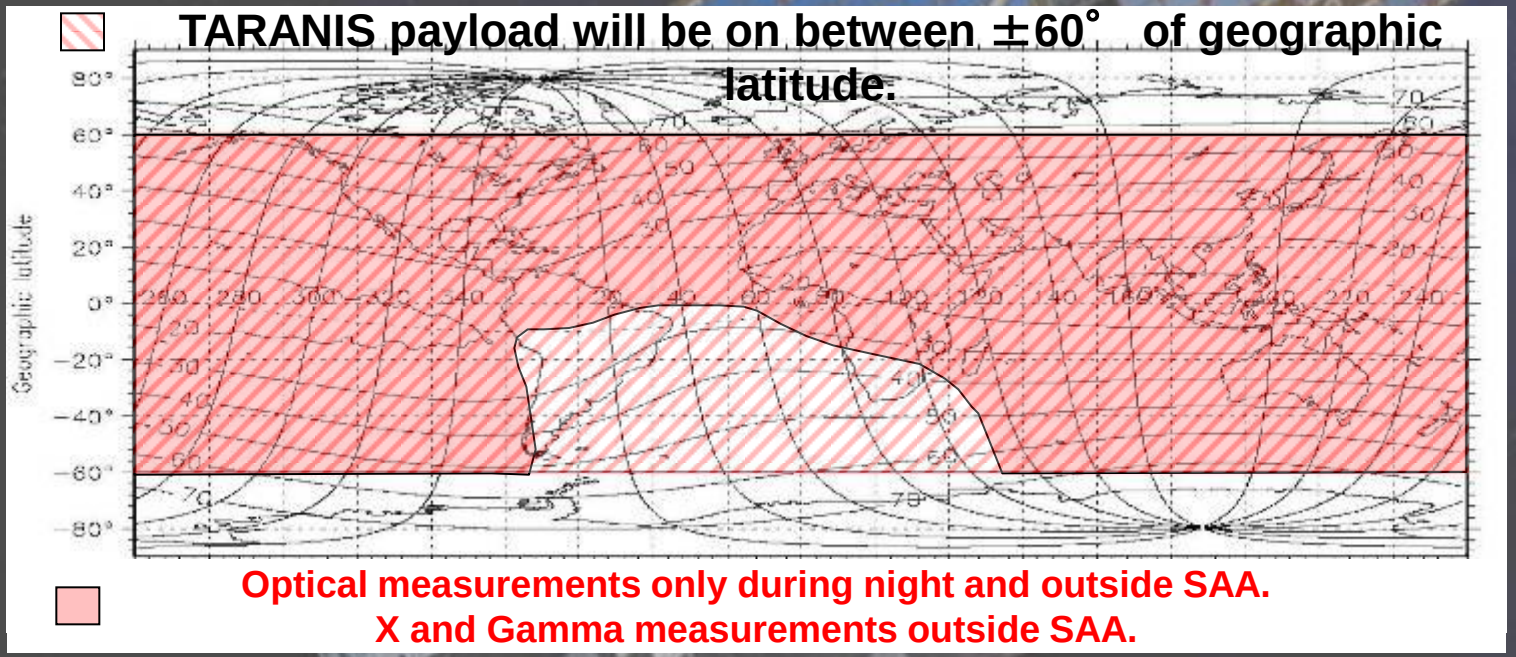
Scientific payload accommodation

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



TARANIS: Event and Survey modes



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!

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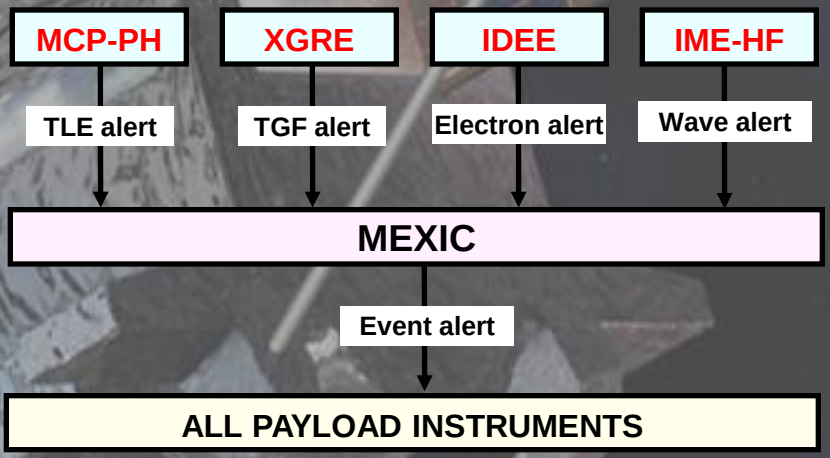
TARANIS event data (1/2)

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

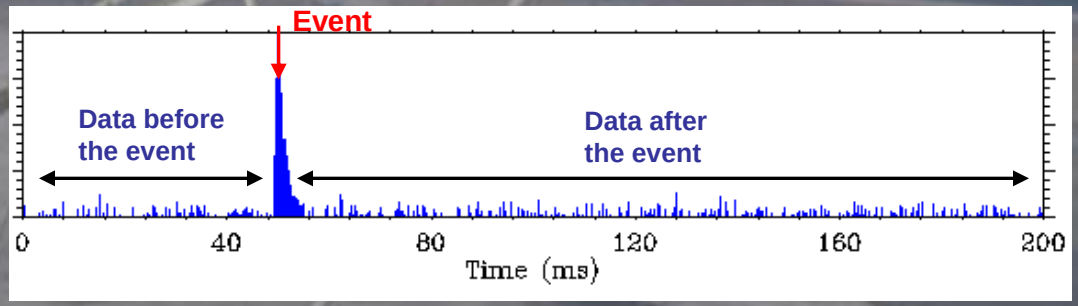
2 GBytes of event data per day
- On average 12 events per half-orbit (T=100mn)
- A maximum of 36 events per half-orbit

4 triggering instruments



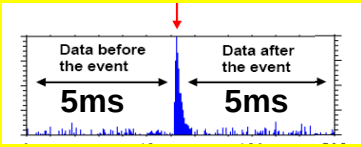
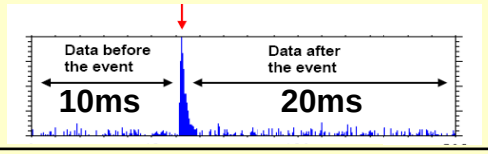
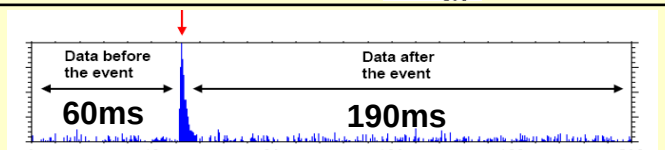
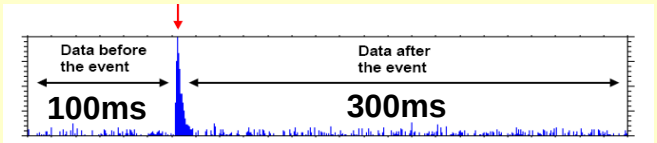
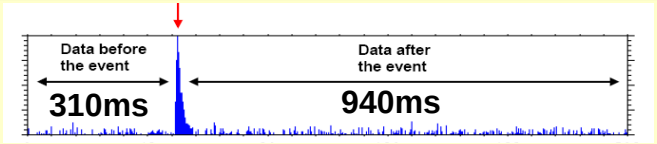
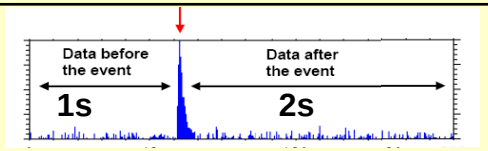
Multi EXperiment Interface Controller to power and to manage the whole scientific payload.

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 Δt ≈ 100ms
IME-IMM (ELF-VLF)		Fe = 50kHz
IDEE		electrons

Time stamping accuracy

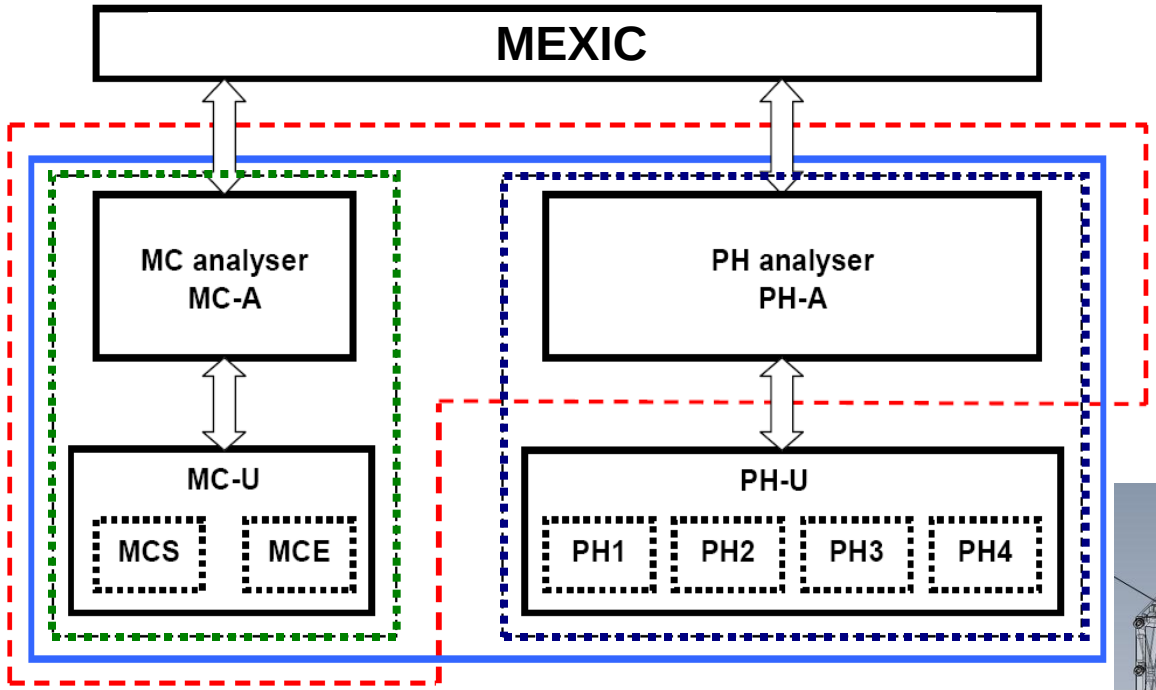
Absolute accuracy:
1 ms for comparison with ASIM, balloon, and ground based measurements.

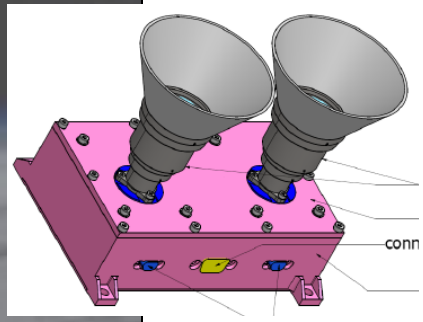
Relative accuracy:
10 µs for comparison between TARANIS experiments.

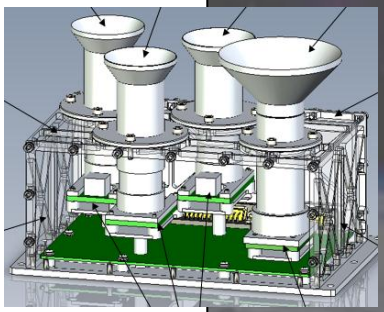
MCP: Instrument and team

MCP: PI E. Blanc (CEA)
MCP-MC: E. Blanc and Th. Farges (CEA)
MCP-PH: Lead Co-I M. Sato (Hokkaïdo Univ.)

CNES industrial contract



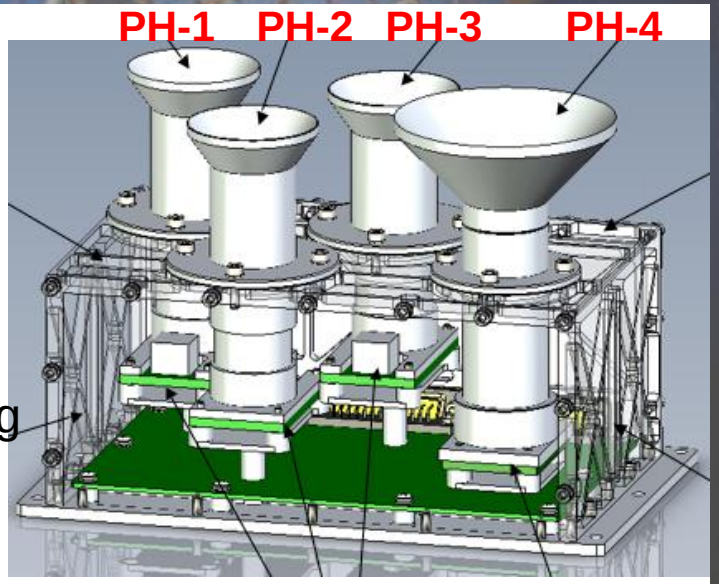




MCP-MC
Localization

MCP-PH
Detection, radiance, duration

MCP- PH Units



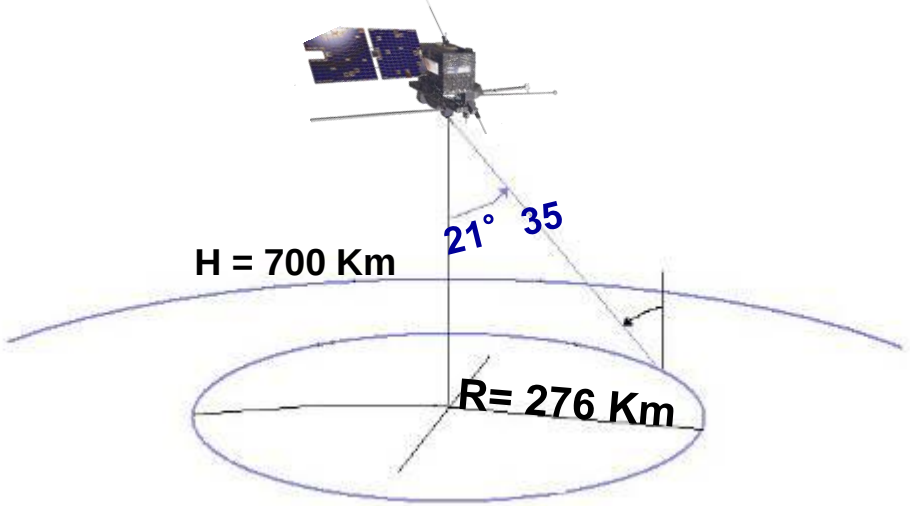
➢ **Spectral bands**

• PH1: UV-C	150 - 280 nm	Sprite
• PH2: UV-A	337 ± 5 nm	Sprite
• PH3: NIR	761 ± 5 nm	Sprite
• PH4: Red - NIR	600 – 900 nm	Lightning

➢ **Field Of View (FOV):**

PH1 – PH2 – PH3: "small" FOV (+/- 21° 35 ⇨ R= 276 Km)

PH4 : "large" FOV (+/- 43° 4 ⇨ R= 700 Km)



XGRE instrument requirements

- **Speed**
  - **High count rate per cm^2 (10^4 – 10^5 cm^{-2} s^{-1})**
    - Dead time < 300 ns (10^6 s^{-1})
  - **Datation**
    - triggers with 300 ns relative time accuracy
    - events (TGFs) with 1 µs relative time accuracy
- **Detection**
  - **Separation between γ-rays and electrons**
  - **γ-rays**
    - Energy range
      - 20 keV-12 MeV
    - 30 % accuracy at 20 keV
    - 9 % accuracy at 511 keV
  - **Electrons**
    - Energy range
      - <1 MeV – >10 MeV
  - **minimize risk of missing TGF**
    - Storage capacity of 200 000 photons
    - burst and survey algorithms
- **Localization**
  - **Ascending or descending particle motion**
  - **Zenithal and azimuthal direction (~30° resolution)**

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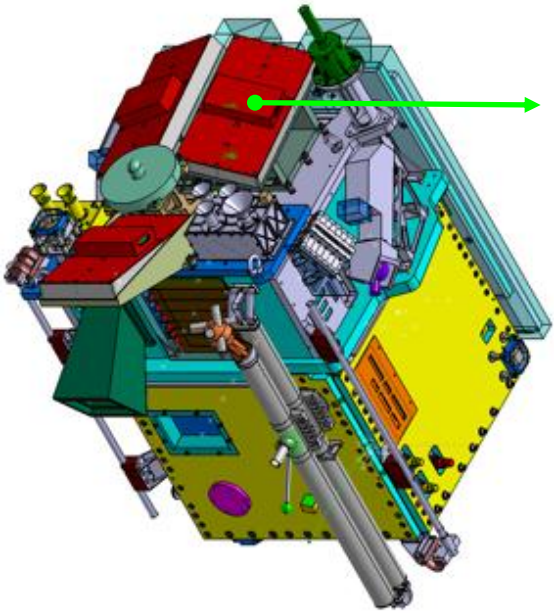
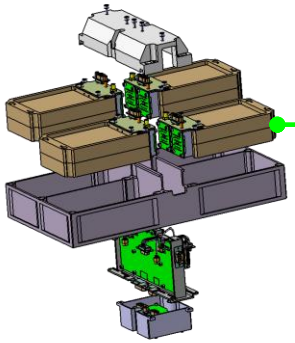
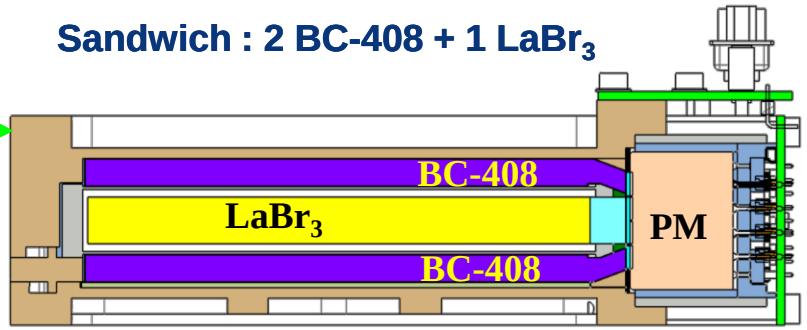
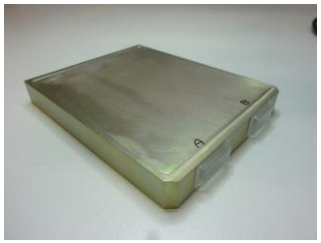
XGRE (PIs : P-L Blelly (IRAP) et F. Lebrun (APC))

Three sensors on the platform oriented towards Earth + 1 toward space.









XGRE Instrument

- 3 sensors
- total detection surface ~ 900 cm^2

XGRE Sensor

- 4 detection units
- AD converters
  - 12 bits (LaBr3)
  - 10 bits (BC408)

$LaBr_3$ (photons)

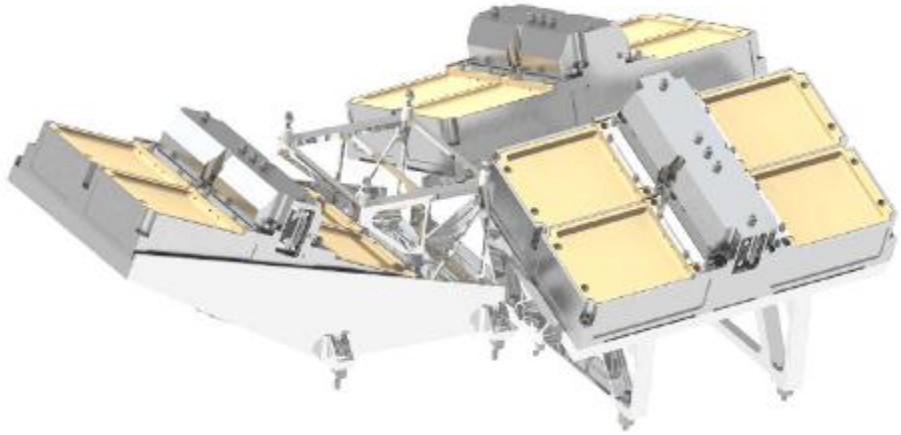
- Rapid (dead time < 300 ns)
- good linarity
- spectral resolution

BC-408 (electrons)

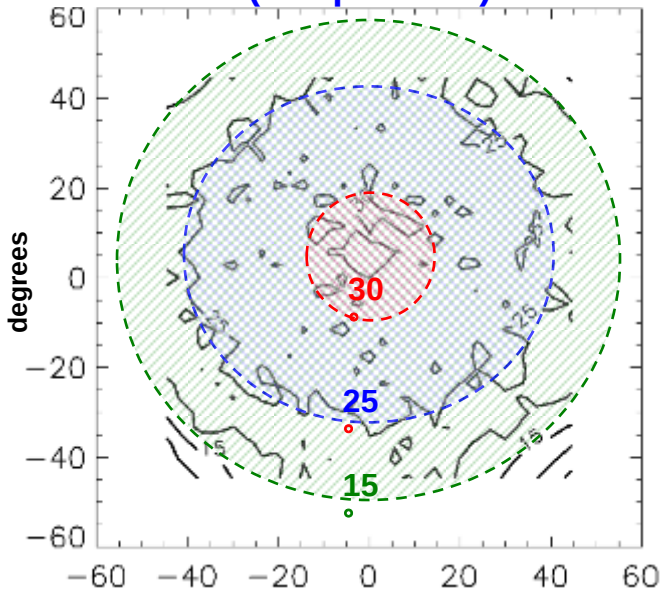
XGRE (PIs : P-L Blelly (IRAP) et F. Lebrun (APC))

TGF localization

- three planes (~20° inclination)

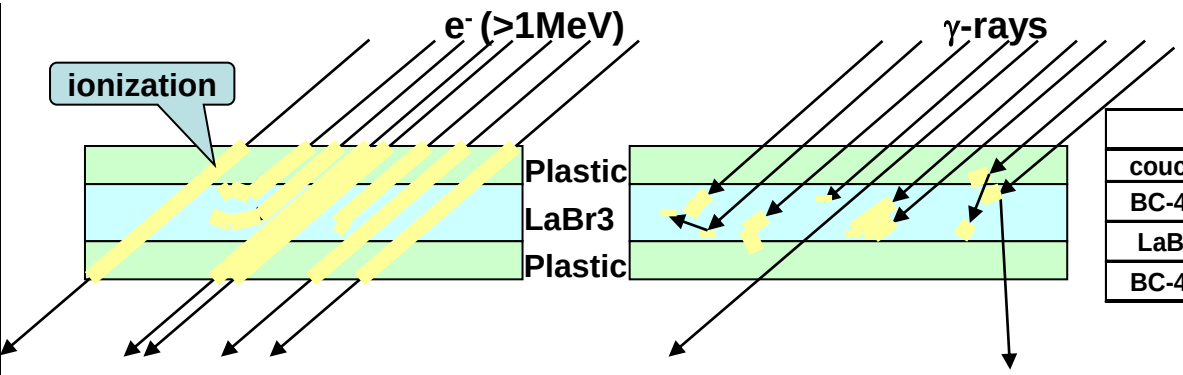


accuracy on the arrival direction (100 photons)



Separation between electrons and photons

- Coïncidence/anti-coïncidence entre LaBr3 et BC408



	électrons			photons	
couche	< 1 MeV	1 - 8 MeV	> 8 MeV	<200 keV	>200 keV
BC-408	E	~ 1 MeV	~ 1 MeV	0	0
LaBr3	0	~ E-1 MeV	~ 8 MeV	E	≤ E
BC-408	0	0	~ E-9 MeV	0	0

IDEE (PI : J-A Sauvaud (IRAP))

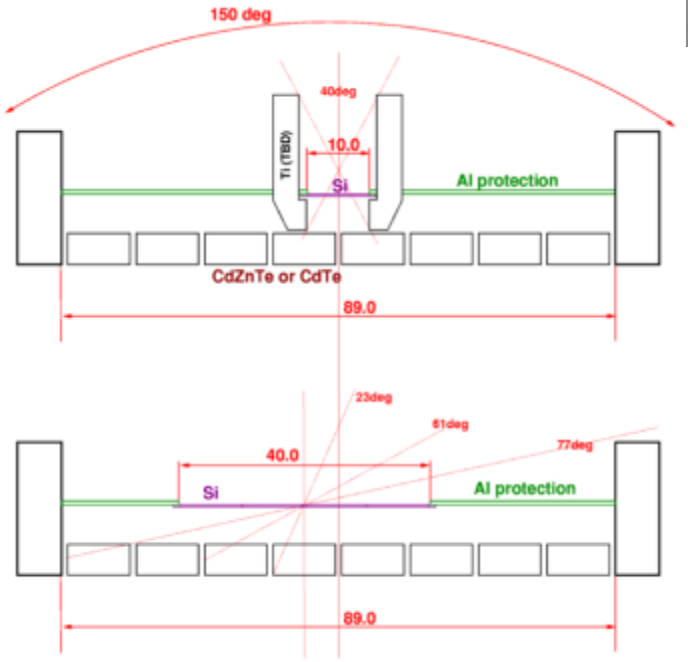
- 2 spectrometers
  - nadir
  - zenith
- Energy range
  - 60 keV – 5 MeV

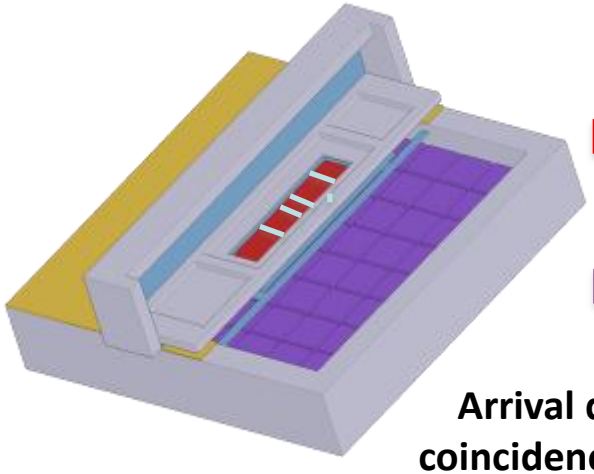
  ΔE = 16 keV [60 keV – 500 keV]

  ΔE = 60 keV [500 keV – 5 MeV]
- 8 angles

  Field of view = 150x40° [60 keV – 500 keV]

  Field of view = 150x150° [500 keV – 5 MeV]





Silicium, 5 cells

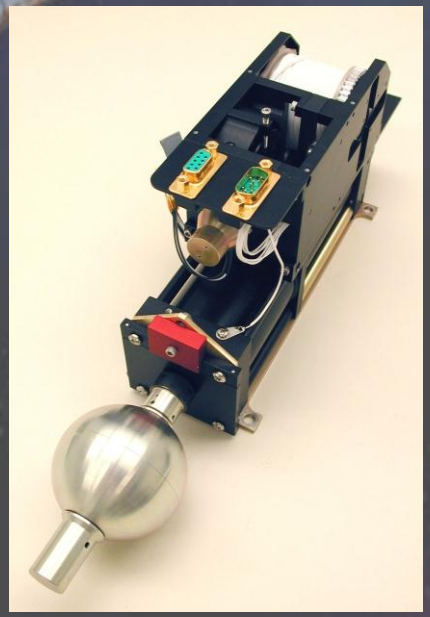
CdTe, 64 cells

Arrival direction derived from the coincidence between Si and CdTe cells

IMM (PI : J-L PINCON (LPC2E))

- Triaxial search coil magnetometer
- 2 mono band antennas
  - 10Hz-20kHz frequency range
- 1 double-band antenna
  - 10Hz-20kHz and 10kHz-1MHz frequency range

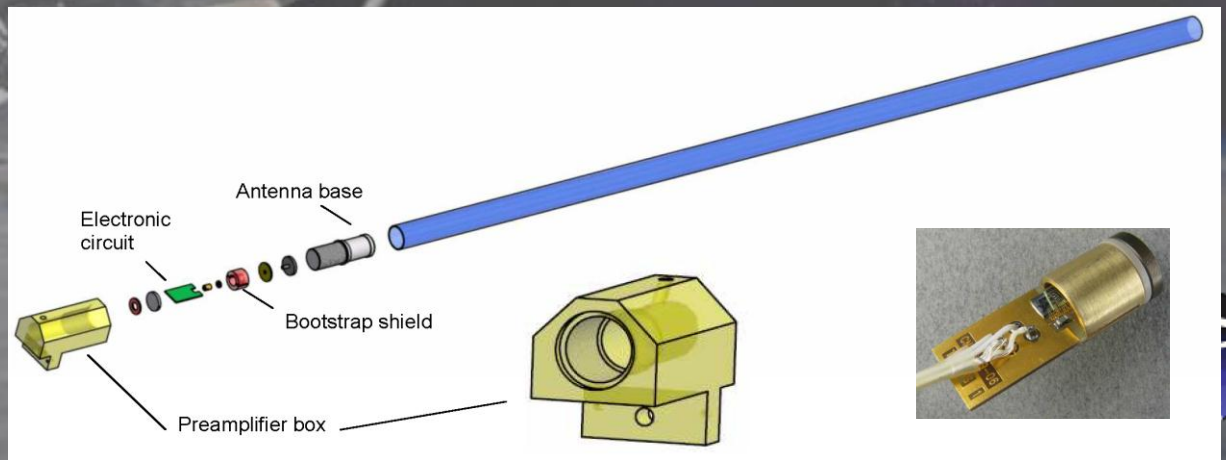
IME-BF (PI : E. SERAN (LATMOS))



- **Two sphere sensors on booms**
  - **1 component of the electric field**
  - **from DC to 3.3 MHz**
  - **ULF frequency range: 0 – 64 Hz**
  - **VLF frequency range from few Hz to 20 kHz,**
    - frequency resolution: 94 Hz
- **Langmuir probe**
  - **Current due to the ion/electron thermal plasma**
  - **Plasma density range: 10^2-10^7 cm-3**
  - **frequency: 128 Hz**

IME-HF (PI : J-L Rauch (LPC2E))

- **Double-wire Hertz dipole**
  - aligned with a satellite diagonal
  - on the opposite side of the solar panel
- **1 component of the electric field**
  - from 100kHz to 30MHz



TARANIS STATUS

		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

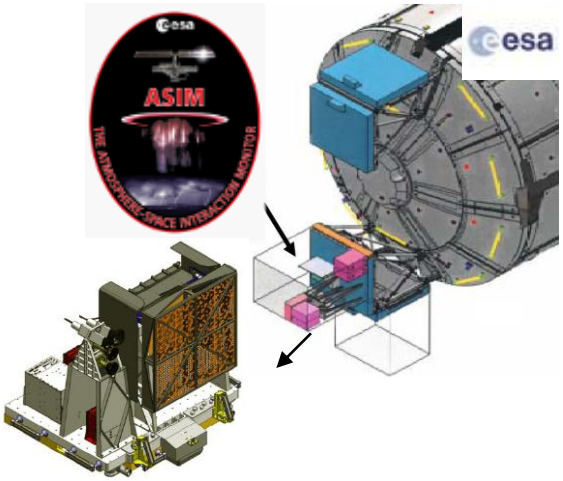
TARANIS Planning

2011	2012	2013	2014	2015
Phase A &B	Phase C (Engineering model)	Phase D (Flight model)	AIT	

Context: TARANIS – ASIM – GLIMS – COBRAT and Chibis-M

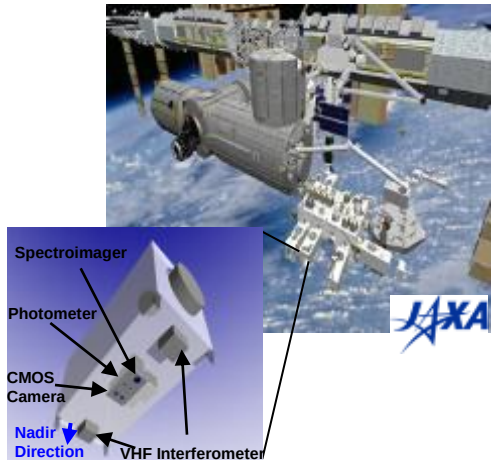
Tool for the **A**nalysis of **RA**diation from light**NI**ng and **S**prites

Launch: 2015
Polar orbit, altitude 700 km
Optical - gamma-ray – energetic e^- & electromagnetic detectors
Nadir Obs.



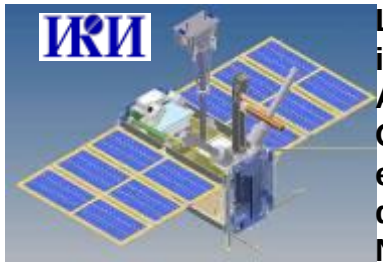
Atmosphere-**S**pace **I**nteraction **M**onitor

Launch: 2014
ISS orbit, inclination = 51°
Optical & gamma-ray detectors
Nadir Obs.



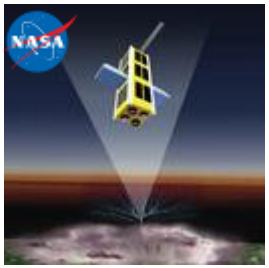
Global **L**ightning and spr**I**te **M**easurement**S**

Launch: end of 2012
ISS orbit, inclination = 51°
Optical detectors
Nadir Obs.



Launch: 2012
inclination = 51.6°
Altitude = 500 km
Optical - gamma-ray - energetic e^- & EM detectors
Nadir Obs

Chibis-M



Firefly ?

COBRAT

Coupled **O**bservation from **B**alloons **R**elated to **A**SIM and **T**ARANIS

Long duration balloon flights for the study of high energy phenomena observed in the atmosphere above thunderstorms and their consequences for stratospheric chemistry