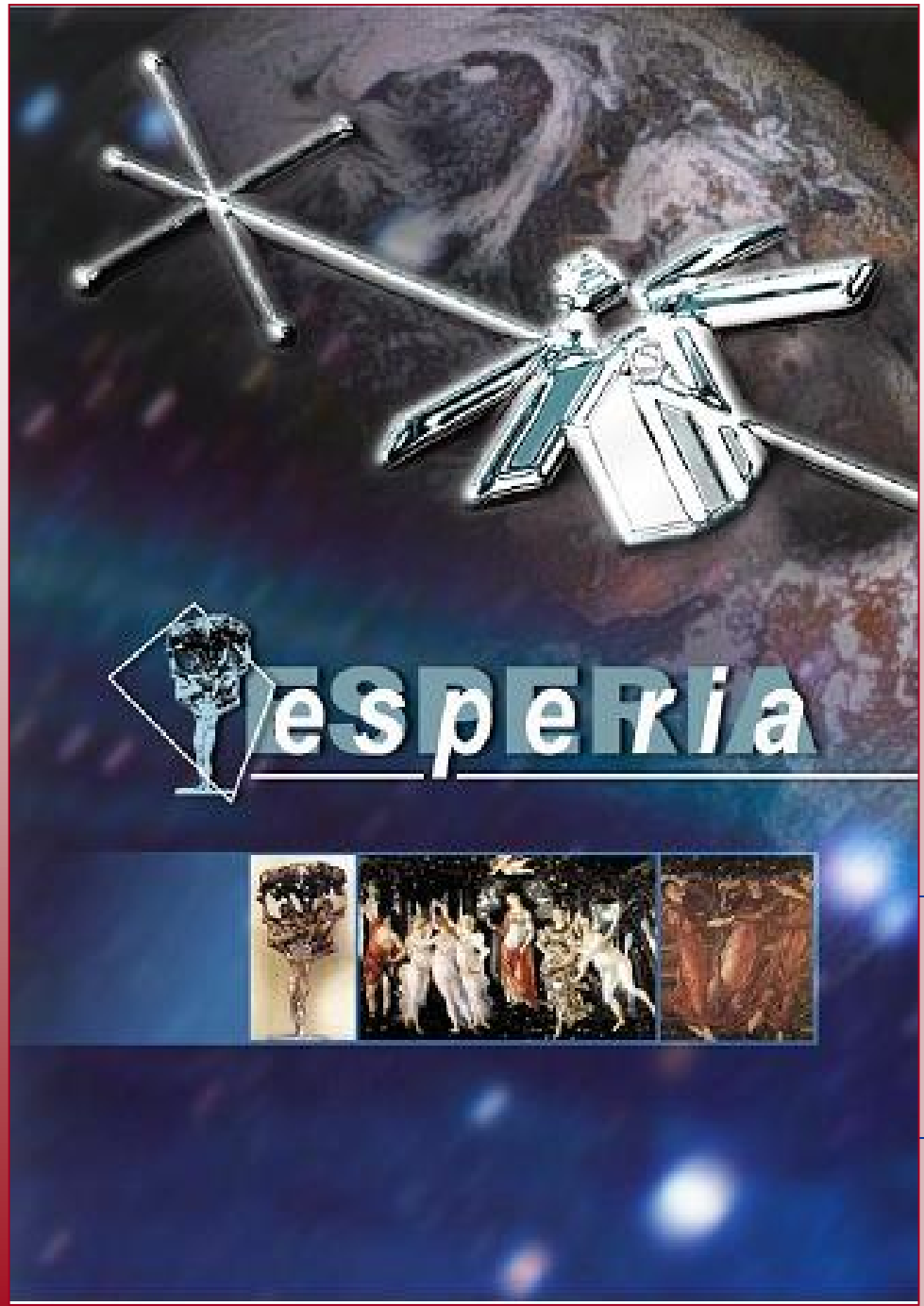

ESPERIA

Un progetto di missione spaziale
per lo studio di perturbazioni
nella zona di transizione
ionosfera-magnetosfera

Vittorio Sgrigna (*P.I.*)

Universita' e Sez. INFN

Roma Tre

Gruppo Esperia

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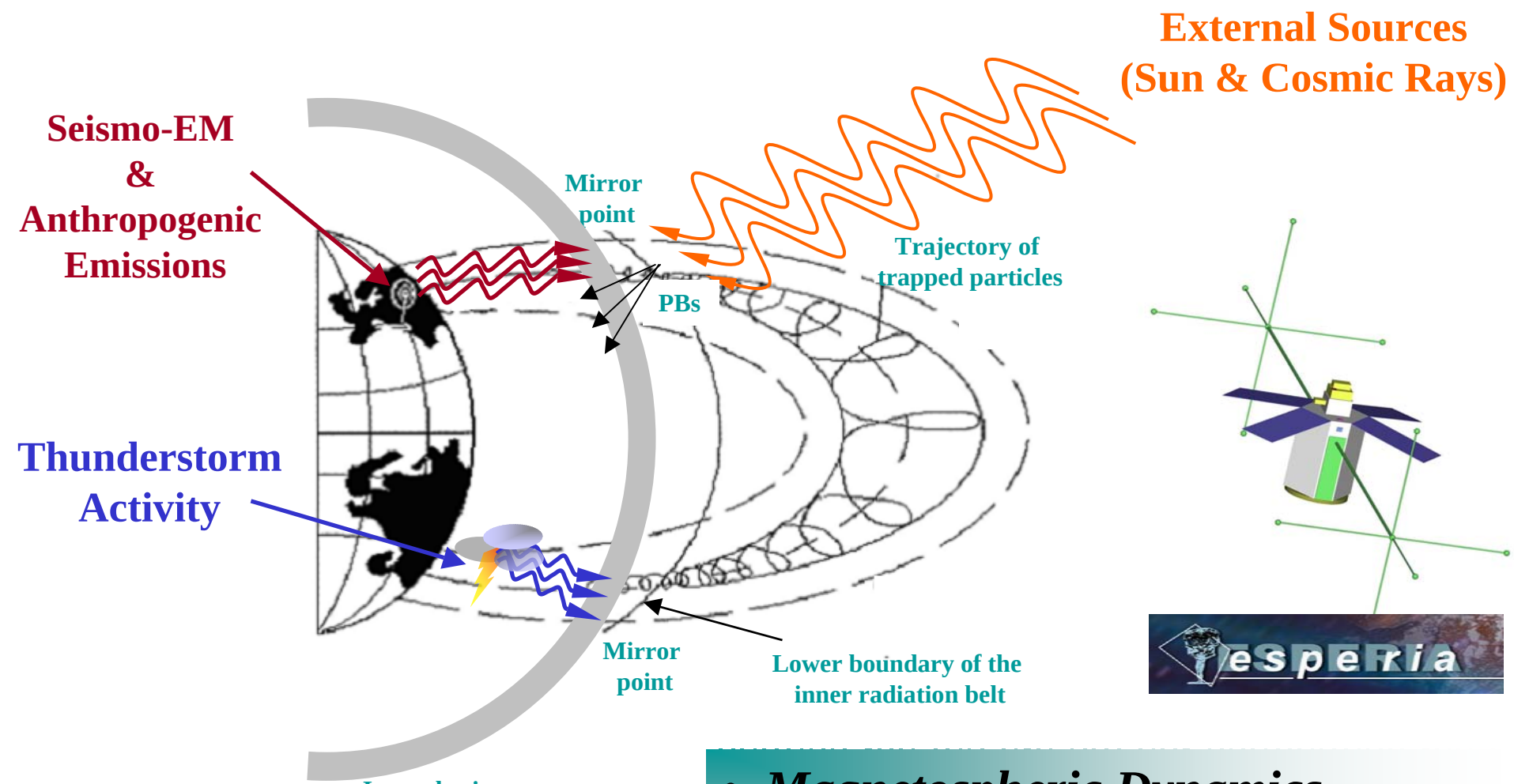
ESPERIA:
Earthquake investigations by **S**atellite and **P**hysics of the **E**nvironment **R**elated to the **I**onosphere and **A**tmosphere

ESPERIA (Earthquake investigations by Satellite and Physics of the Environment Related to the Ionosphere and Atmosphere) is a scientific proposal (Principal Investigator: Vittorio Sgrigna) for the investigation of ionospheric perturbations due to the seismic activity and to the Earth electromagnetic environment. The participants to the ESPERIA project are scientists involved in geophysics, seismology, cosmic physics, radio physics, and particle physics.

The proposal includes both on board satellite observations and ground-based measurements. On board the satellite ULF, ELF, VLF, HF electromagnetic fields, charged particle fluxes, and ionospheric plasma parameters will be measured. Ground based measurements of mechanical (tilt and strain) and electromagnetic (ULF, ELF, VLF, HF) fields will be carried out. The project also includes the monitoring of ionospheric perturbations due to the anthropogenic electromagnetic emission (power line harmonic radiation, VLF transmitters, HF broadcasting stations).

The proposal has been developed within the framework of a call for a mission of the Italian Space Agency (ASI) for a micro-satellite dedicated to Earth Sciences. First satellite observations concerning the precipitation of charged particle fluxes from the lower boundary of the Van Allen radiation belt were made in 1985 during the MARIA experiment carried out on board the SALYUT-7 orbital station. Most of these events were detected near the South Atlantic Anomaly (SAA). Further investigations, carried out by other orbital stations and satellites (Maria 2, Meteor 3A, ELECTRON and GAMMA 1), confirmed previous observations. The main observations and theoretical explanations can be found in the references listed below. On board the satellite we plan to install a particle detector, a Langmuir probe and a retarding potential analyzer for plasma investigations, electric and magnetic analyzers. Local and global seismic networks together with Zollner pendulum tiltmeters (TELLUS network), differential electromagnetic strainmeters, and electric and magnetic analyzer instrumental networks will be used in ground-based measurements.

Main Issues of the ESPERIA Space Mission Project



- *Magnetospheric Dynamics*
- *Ionospheric Perturbations*
- *Geomagnetic Field Fluctuations*
- *Seismic Precursors*

The ESPERIA general project

Designed to

Study of **near-Earth** EM, plasma, and particle environment in *steady-state* and *perturbed-state* conditions.

Planned with

- **Magnetic equatorial** mission
- LEO satellite
- Multi-instrument payload

Privileged region of investigation

Ionosphere-magnetosphere transition zone

Detectable phenomena

- Earth’s interior processes & Anthropogenic emissions
- Atmosphere-Ionosphere-Magnetosphere couplings
- Sun activity & Cosmic rays

ESPERIA Phase A Study *(Italian Space Agency)*

Scientific objectives

Primary:

- **seismo-electromagnetic emissions**

Secondary:

- **man-made EM emissions**

Scientific program & observations

Coordinated, simultaneous, and continuous

ground-based and **space** observations

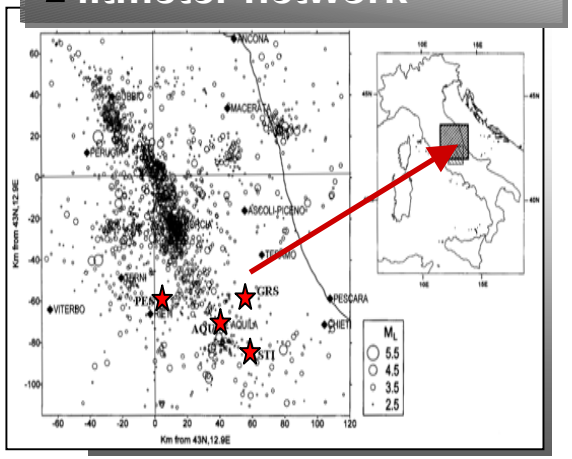
Ground-based Mechanical Observations

TELLUS
Ground deformations and their effects in the near Earth Space

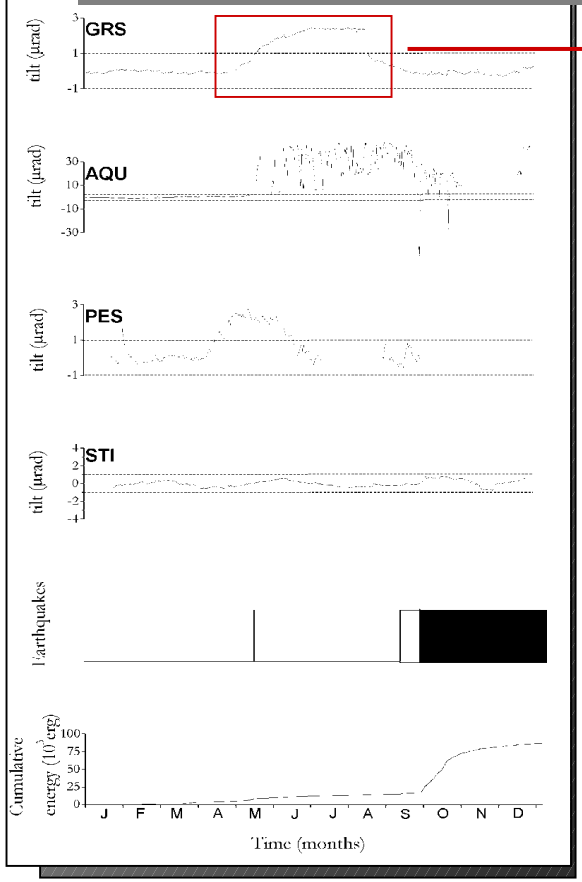
Intermediate-term tilt precursors (≈ weeks÷months)

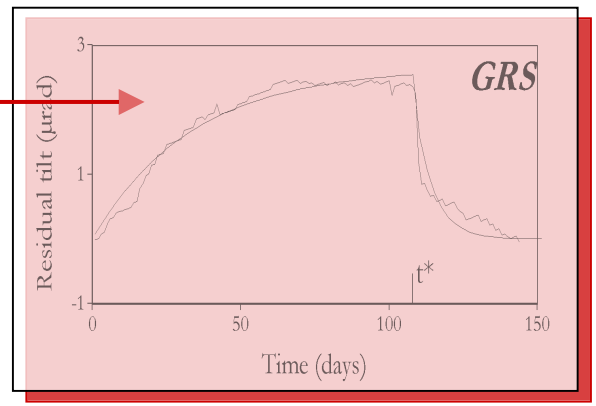
Preseismic fault creep events: 1997 Umbria-Marche seismic sequence

Tiltmeter network

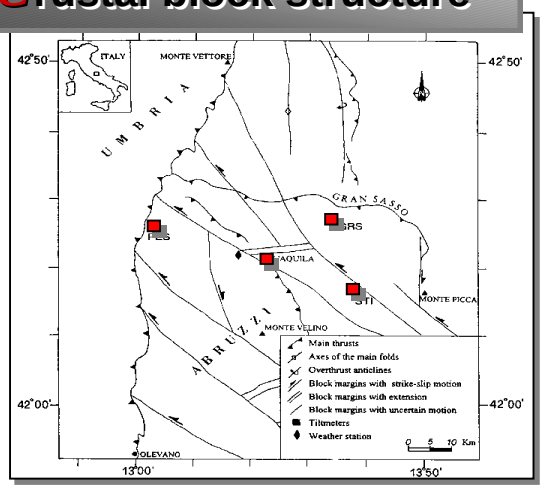


Tilt Data

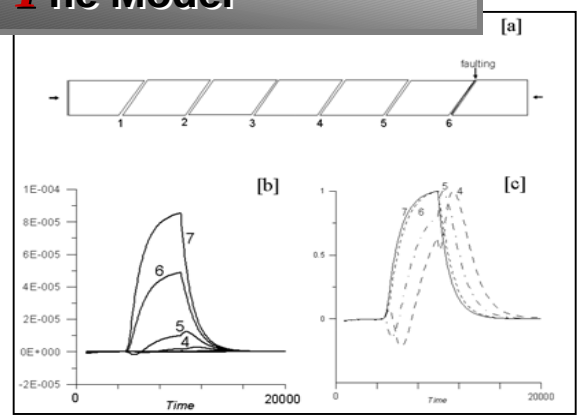




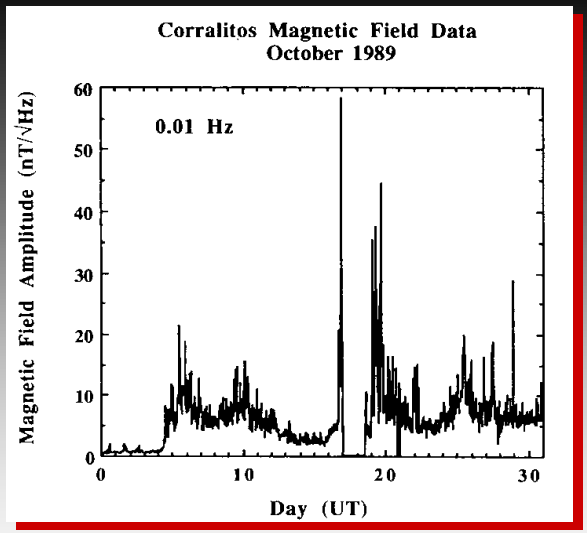
Crustal block structure



The Model

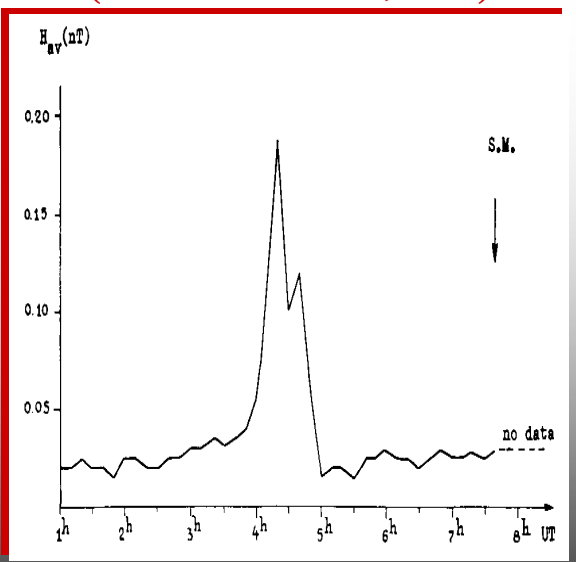


Ground-based EME observations



Loma Prieta earthquake, October 18, 1989, M=7.1

(*Fraser-Smith et al., 1990*)

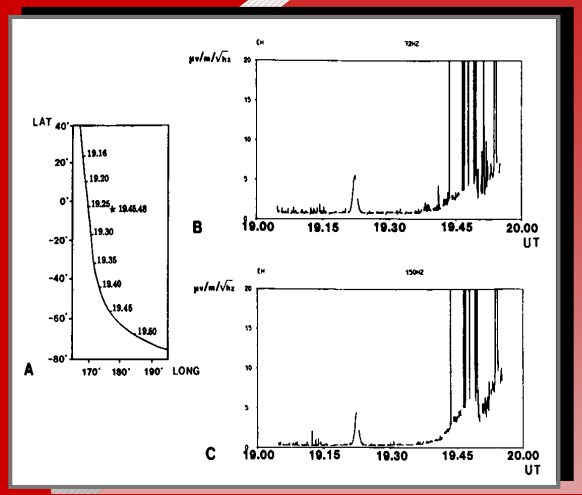


Spitak earthquake, December 7, 1988, M = 6.9

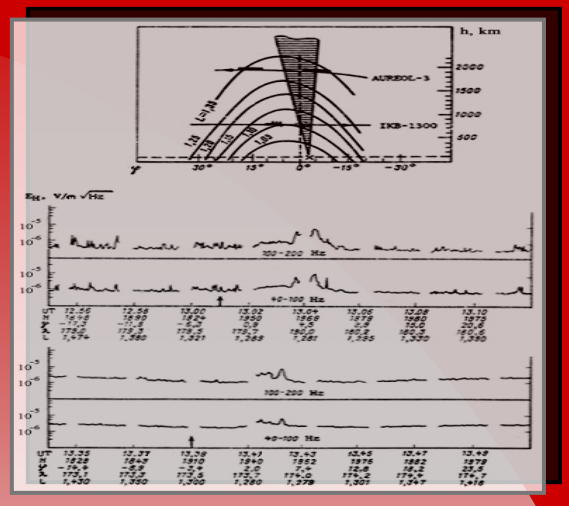
(*Kopytenko et al., 1993*)

Earthquake	M	Date	Type of emission	Pre/ co/ post seismic	Freq. range (Hz)	Amplitude	Back-ground	Distance of the epicenter	Instrument	Reference
Loma Prieta, CA	7.1 Ms	18/10/1989	ELF/VLF EM	Pre(3h), co	0.01	5 - 60 nT Hz-1/2	~1 nT Hz-1/2	52 km	ground-based magnetometers	Fraser-Smith, A.C., et al 1990
Loma Prieta, CA	7.1 Ms	18/10/1989	ULF magnetic	Post	0.01 - 10	≈ 1 nT	-	7.3 km	proton magnetometers	Mueller, R.J., and M.J.S. Johnston 1990
Loma Prieta, CA	7.1 Ms	18/10/1989	ULF magnetic	Pre (3h), post	0.01	4-5 nT	-	7 km	-	Molchanov, O.A., et al 1992
Armenia, Spitak	6.9 Ms	7/12/1988	ULF magnetic	Pre (4h), post	0.01 - 1	0.2 nT	0.02 nT	128 km	3-axis high-sensitivity magnetometers	Molchanov, O.A., et al 1992
Armenia, Spitak	6.9 Ms	7/12/1988	ULF magnetic	Pre (4h), post	0.005 - 1	0.1 - 0.2 nT	0.03 nT	120 km and 200 km	-	Kopytenko, Y.A.,et al 1993
Upland, CA	4.7	17/4/1990	ULF-ELF magnetic	Pre (1 day)	3.0 - 4.0	- 40 dB	- 46.8 dB	160 km	vertical magnetic sensor	Dea, J.Y et al 1993
Watsonville CA	4.3	23/3/1991	ULF-ELF magnetic	Pre (2 days)	3.0 - 4.0	- 43 dB	- 47.6 dB	600 km	north-south magnetic sensor	Dea, J.Y et al 1993
Watsonville CA	4.3	23/3/1991	ULF-ELF Magnetic	Pre (2 days)	3.0 - 4.0	- 44 dB	- 46.8 dB	600 km	vertical magnetic sensor	Dea, J.Y et al 1993
Guam	7.1 Ms	8/8/1993	ULF magnetic	Pre (1 mounth)	0.02 - 0.05	≈ 0.1 nT	-	65 km	3-axis ring-core-type fluxgate magnetometer	Hayakawa, M., et al.1996
Chi - Chi	7.6	21/09/1999	ULF-ELF	Pre(4-5h)	0.001 – 50 Hz	5 – 10 dB	-	-	3-mutually orthogonal induction coils	Otha et al., 2001

EME space observations



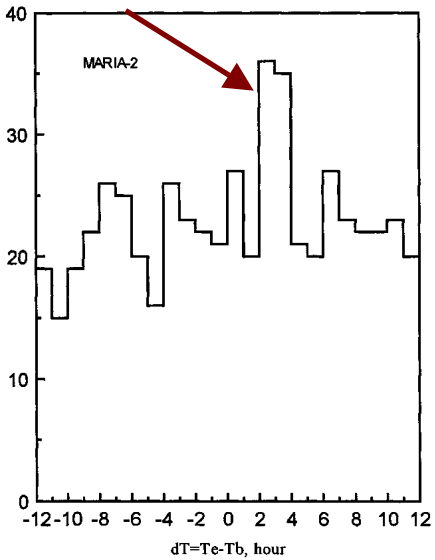
Electric field anomalies in the ULF-ELF range detected by AUREOL-3 satellite in coincidence of an earthquake of M=5.1, 17/3/1982 (*Parrot & Mogilevsky, 1989*).



EME ULF/ELF anomalies recorded contemporarily by AUREOL-3 and IKB-1300 satellites 4h before the Spitak's aftershock of M=5.2. [Galperin et al 1992].

Type of disturbance	Frequency Range	Amplitude Range	T_EQ-T_SEM	Earthquake Magnitude	Reference
E	0.1÷74 kHz	≈ 10 μV/m $\sqrt{Hz}$	0-6 hours	>4.9	Parrot et al. 1989
B	≈ 100 Hz	≈ 10 nT	≈ 1 hour		
E	0.1÷15 kHz	≈ 10 μV/m$\sqrt{Hz}$	1– 8 hours	> 5.5	Larkina et al. 1989
B	0.1÷15 kHz	≈ 1 pT /$\sqrt{Hz}$	1 – 8 hours		
E	0.1 ÷ 8 Hz	≈ 5 μV/m	≈ 15 min	4.8	Chmyrev et al. 1989
B	0.1 ÷ 8 Hz	≈ 3 nT	≈ 15 min		
E	40 ÷ 200 Hz	≈ 10 mV/m	≈ 4 hours	4.6	Galperin et al. 1992
E	8 ÷ 20000 Hz	≈ 10 μV/m $\sqrt{Hz}$	0-24 hours	>5.0	Molchanov et al. 1993
B	140 ÷ 450 Hz	≈ 10 pT	0-3 hours	>5.0	Buchachenko et al. 1996

Correlations between Earthquakes & Particle Bursts: ΔT_{EQ-PB} distributions

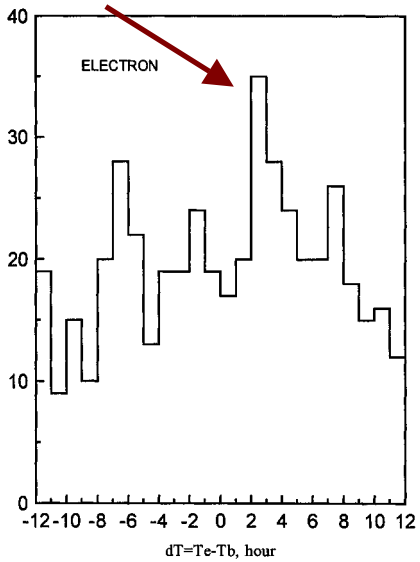


MIR mission
1985-2000

Altitude: 400 km

Inclination: 51°

E_e: 20 ÷ 200 MeV
E_p: 20 ÷ 200 MeV

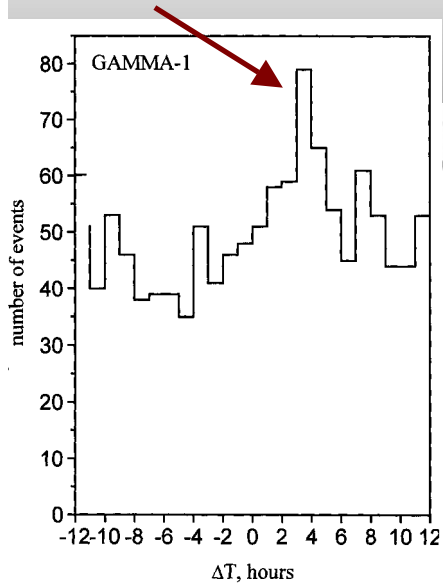


METEOR-3 mission
1985-1986

Altitude: 1250 km

Inclination: 82°

E_e: ≤ 30 MeV

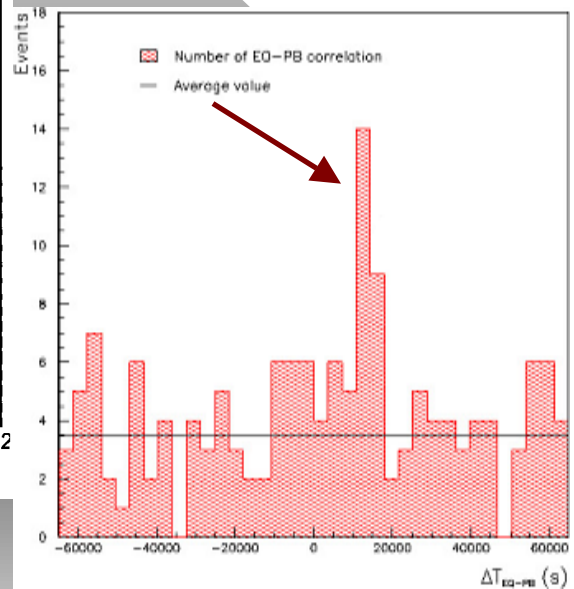


GAMMA mission
1990-1992

Altitude: 350 km

Inclination: 51°

E_e: > 50 MeV



ORR(Orbit Rate Rotation;
July 1992 - May 1994)

SAMPEX/PET mission
1992-1999

Altitude: 520 ÷ 740 km

Inclination: 82°

$4 \leq E_e \leq 15$ MeV

Payload Instruments:

Electric Field Analyser (EFA)

- frequency range: ~DC ÷ 10 MHz
- accuracy: 300 nV/m
- dynamic range: 120 dB

Magnetic Field Analyser (MAFA)

FLUX – GATE:
- frequency range: ~DC ÷ 10 Hz
- accuracy: a few (6-8) pT
- resolution: 24 bit

SEARCH – COIL:
- frequency range: ~10 Hz ÷ 100 kHz
- sensitivity: 10^{-2} pT /(Hz)½ (at 1 kHz)

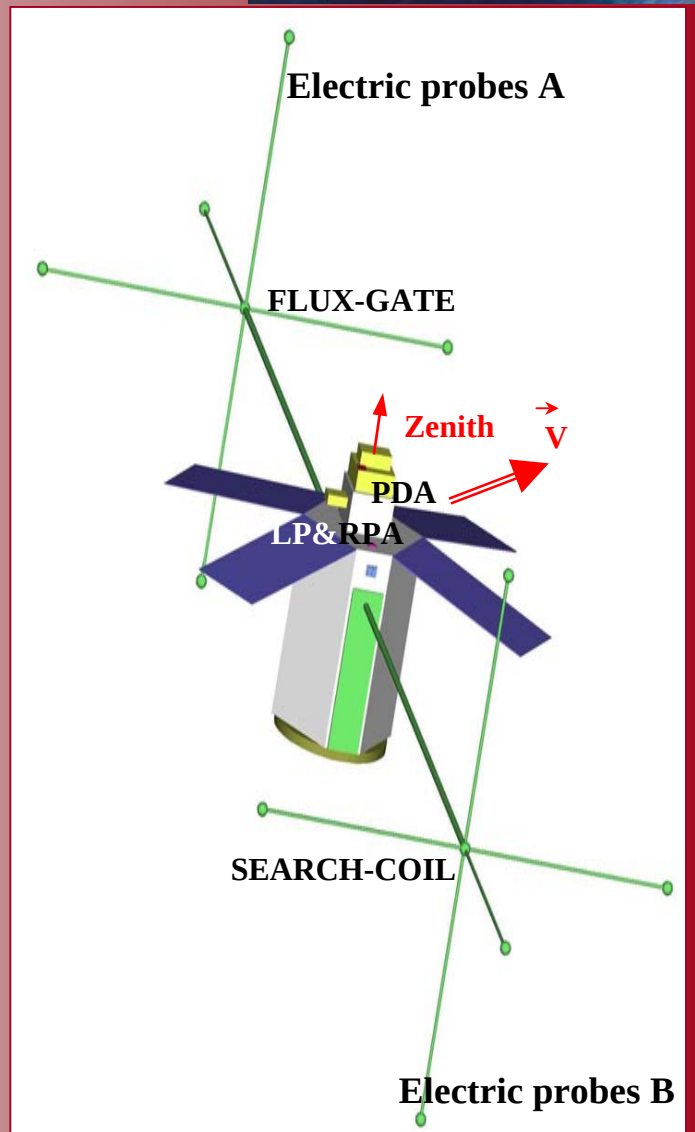
Langmuir Probe & Retarding Potential Analyser

LP:
- electron temperature: 300 ÷ 15000 K
- electron density: $10^2 \div 10^7$ cm^{-3}

RPA:
- ionic temperature: 300 ÷ 10000 K
- ionic density: $10^2 \div 10^7$ cm^{-3}

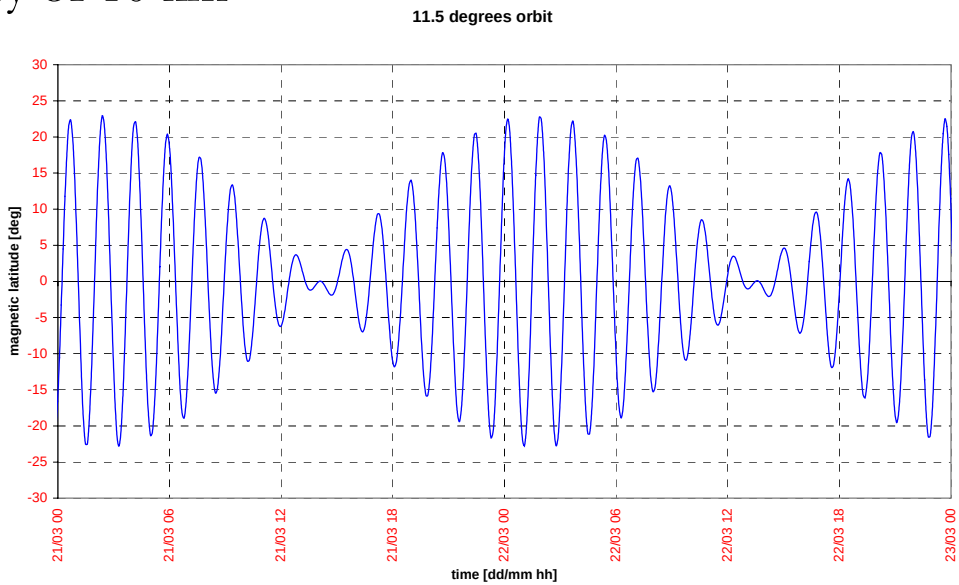
Particle Detector Analyser (PDA).

- Energy range: 300keV÷2GeV
- Pitch angle accuracy < 4° with particle identification
- Geometry: 5 silicon strip telescopes + 1 calorimeter & 1 silicon strip telescope + 1 calorimeter



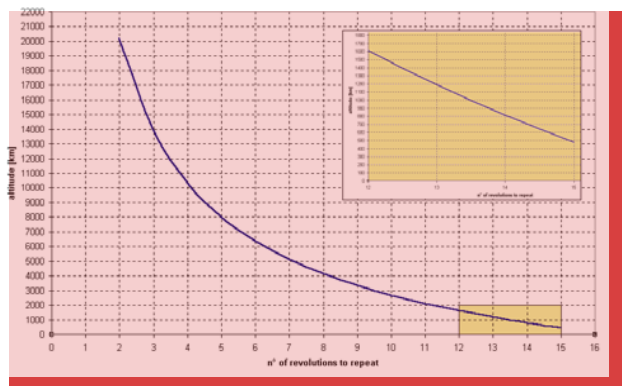
Orbit Characteristics

- **Ground track repetition** with an accuracy of 10 km (high-accuracy Earth' surface monitoring)
- Revisit time: **≤ 24 h**
- Geosynchronous orbit: 14 orbits / day
- Altitude: **813 km**
- Inclination: **11°.5**
- Eccentricity: 0
- Orbit period: **110 min**
- Maximum oscillation around the magnetic equator: ± 23°
- Field of view: **± 39°**
- Orbit knowledge and time resolution ≈ 100 m and 1s, respectively



Spacecraft

- Platform MITA
- Nadir pointing
- FEEP thrusters applied to the platform (constant altitude)



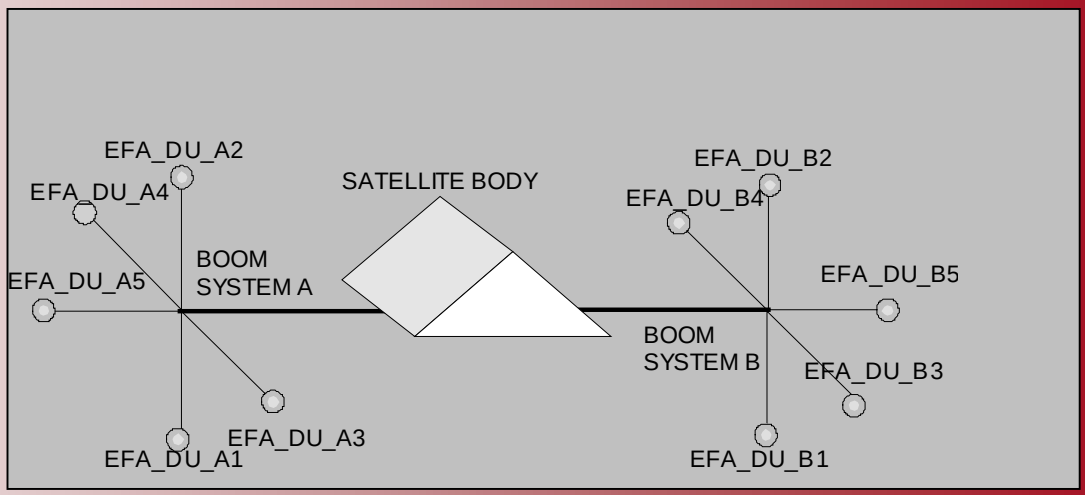
Mission duration ≥ 2 years

EFA sensors

- 10 spherical probes mounted on two booms system

Features:

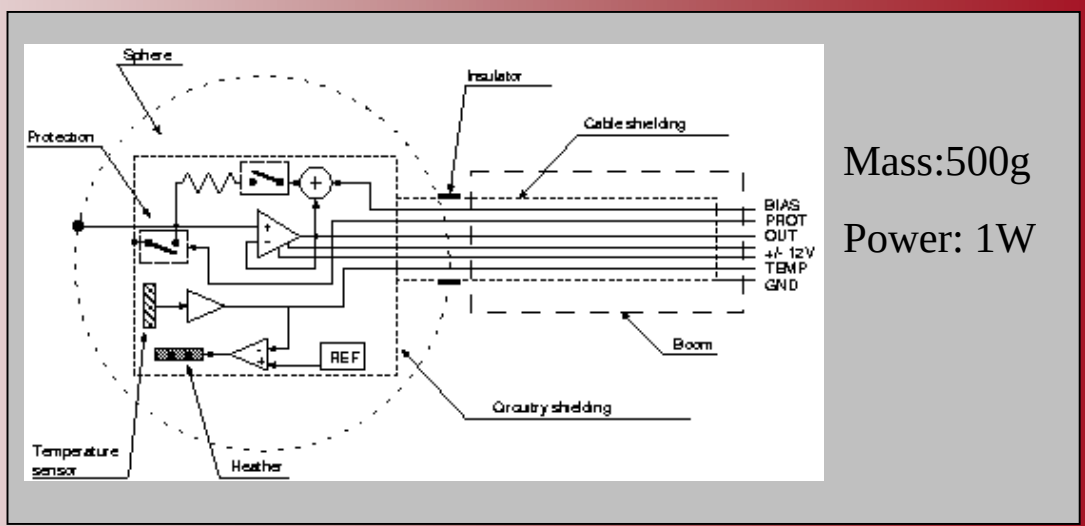
- Two booms system;
- primary boom : 5 meters
- secondary boom: 2 meters



- Single Probe schematic

Features:

- Spheres with pre-amp. inside
- Thermal control
- DC Current Bias



Mass:500g

Power: 1W

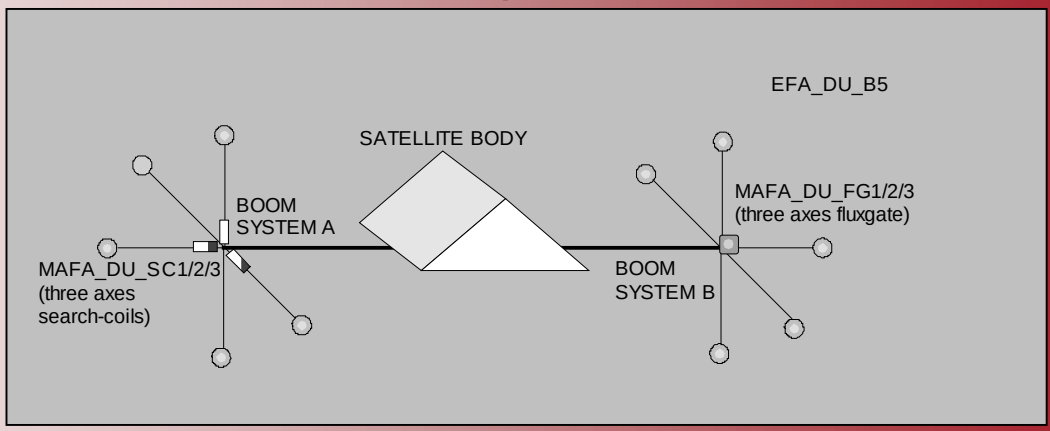
sphere sensor

MAFA sensors

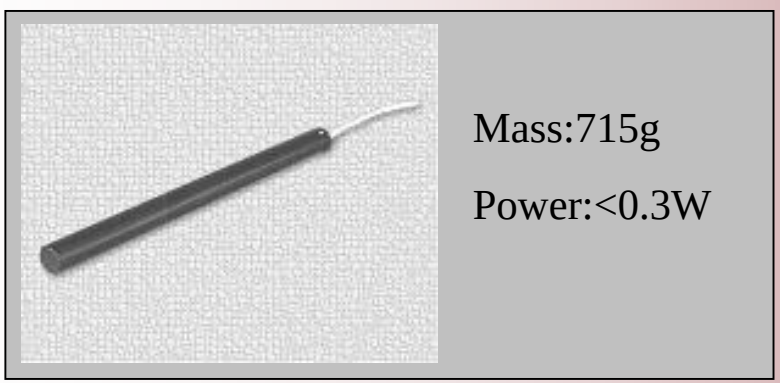
- Vectorial instruments: **search coils and fluxgates**

Features:

- Two MAFA sensors
- Fluxgate (DC-10Hz)
- Search Coils (10Hz-100KHz)

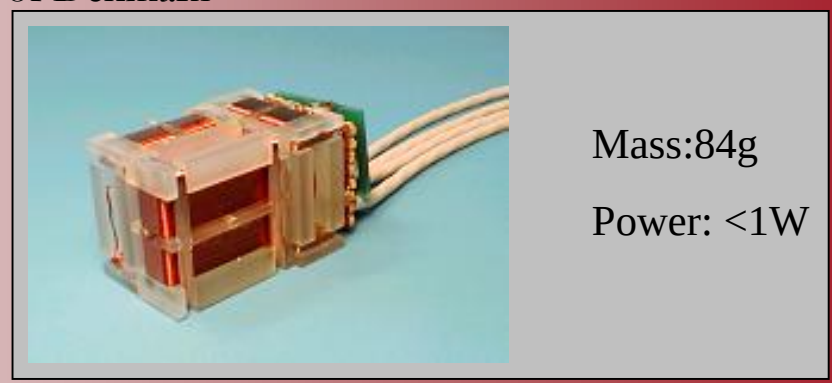


Search Coils possible supplier :MEDA inc., 22611 Market Court Suite 114 Dulles, VA 20166



Search coil sensor

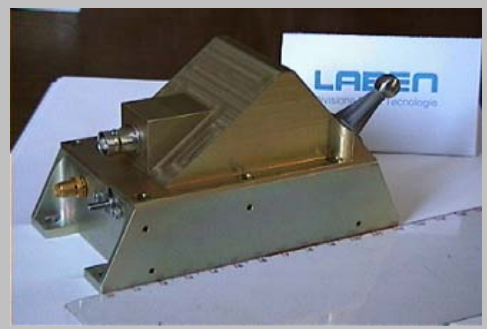
Fluxgate possible supplier :
Space Magnetometry Group of the Danish Space Research Institute and of Measurement Sci. & Instrum. Syst., Oersted-DTU, Technical University of Denmark



fluxgate sensor

LP&RPA sensors

- LP sensor for plasma density, electron temperature, plasma potential, floating potential analysis.
- RPA sensor for ion energy spectrum



LP&RPA box

Mass:400gr

Power: 4.7W

LP& RPA Boxes developed at LABEN/Proel Tecnologie Division for SMART-1 & Stentor satellite

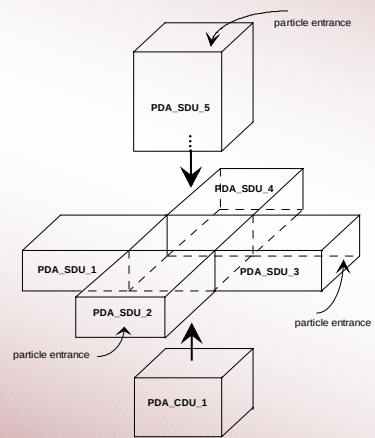
Particle Detector Analyzer

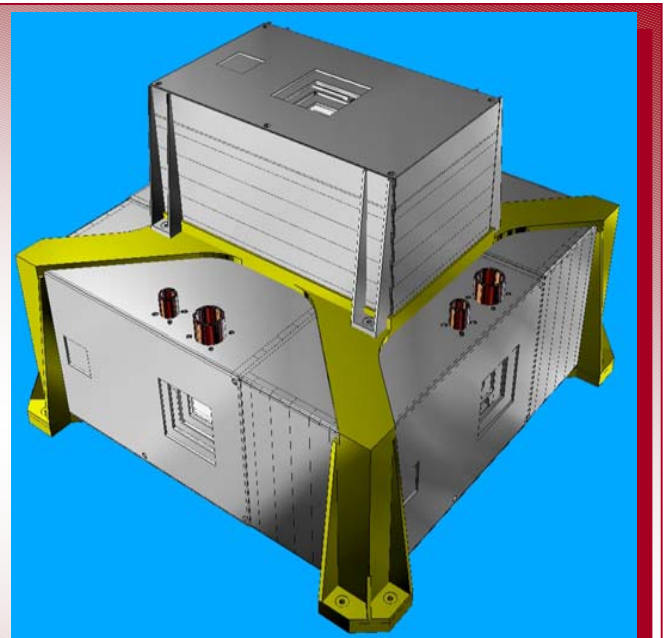
6 High Energy Detectors:

20 MeV ÷ 2 GeV

6 Medium Energy Detectors:

300 keV ÷ 30 MeV





Participants

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University of Rome "La Sapienza" (Italy)	M. Caputo, P. Dominici
University of Florence & INFN Section (Italy)	P.Spillantini
University of L'Aquila & INFN Section (Italy)	R. Scrimaglio, N. Finetti, L. Carota
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University and Polytechnic of Milan (Italy)	V. Piuri
LABEN S.p.A. (Italy) (payload)	
CARLO GAVAZZI SPACE S.p.A. (Italy) (satellite)	
TELESPAZIO S.p.A. (ground segment)	

OUTLINE of the Project

The ESPERIA general project

The ESPERIA Phase A Study

Construction of the ESPERIA payload

Particle observations:

– ARINA detector

– LAZIO detector

Plasma measurements:
LP&RPA *Alenia* instruments

Magnetic measurements:
EGLE search-coil instrument

Relation with other Missions and Science Teams

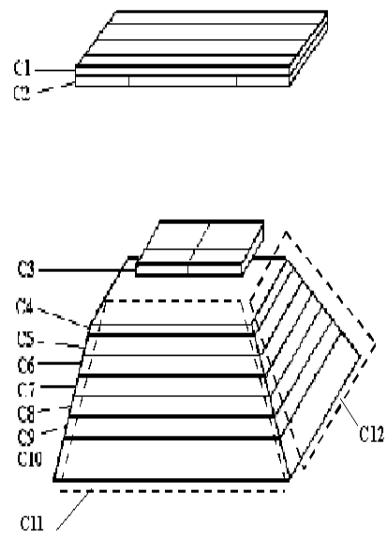
The *ARINA* experiment

- Detection of **preseismic particle** bursts (PBs)
- ***ARINA*** particle detector will be installed on board the Russian RESURS-DK1 satellite

  Orbit: elliptic *Altitude : 300÷600 km* *Inclination: 70.4°*
- Launch scheduled: **September 2005** (within the *PAMELA* mission)
- Duration of the Mission : > **3 years**

***ARINA* physical & technical parameters**

Geometric factor, cm2 sr	10
Aperture, degrees	±25
Energy of Electrons (MeV) Energy of Protons (MeV)	(3 ÷ 30) (30 ÷ 100)
Energy resolution	10 %
Trigger time resolution, ns	50
Angular resolution, degrees	6
Mass, kg	6.5
Dimensions, mm	300 × 200 × 200
Power consumption, W	9.5
Mass memory volume, Mbytes	8
Orientation of instrument axis	perpendicular to the plane of orbit



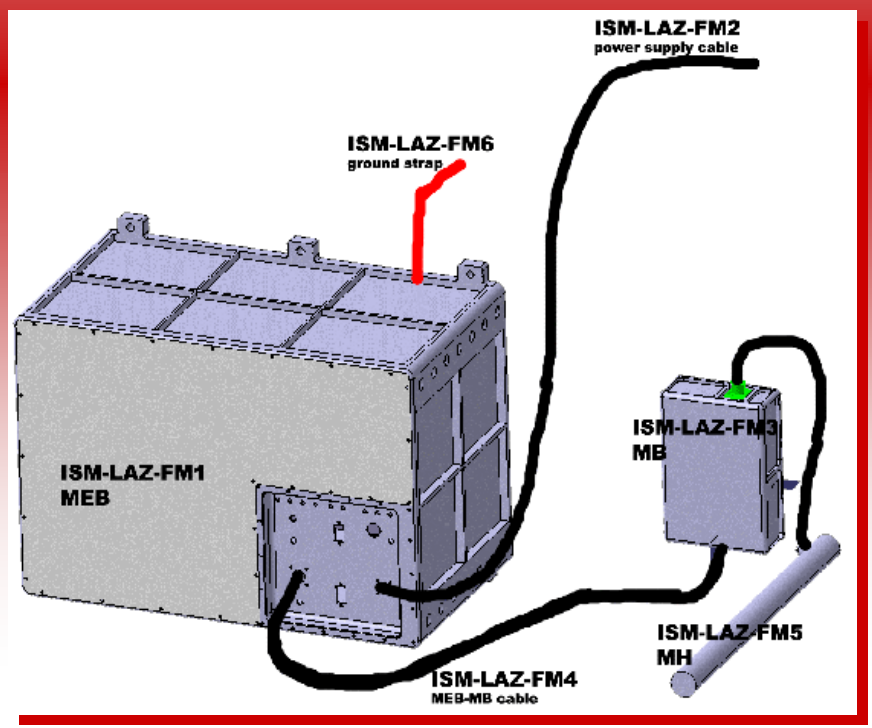
C1 – C3 trigger coincidence scintillation telescope
C4 – C10 scintillation calorimeter
C11 – C12 scintillation anticoincidence detectors

The LAZIO / EGLE experiment

- ✓The experiment aims at performing measurements of
  - the radiation environment ⇒LAZIO
  - the magnetic environment inside the ISS ⇒ EGLE

- EGLE (Esperia's Geo-magnetometer for a Low frequency wave Experiment) is an high-precision low-frequency search-coil magnetometer.

- Magnetic field data will be recorded by PCMCIA cards.



EGLE

Esperia's
Geo-magnetometer
for a Low-frequency
wave Experiment

ROMA TRE
UNIVERSITA' DEGLI STUDI

EGLE magnetic sensor

Basic technical specifications of the EGLE probe MH	
Frequency band of receiver signals	0.5 ÷ 50000 Hz
Shape of transfer function	linear – flat
Type of output	Symmetrical
Transformation factor at both output terminals:	
▪ at linear part (0.5 – 5 Hz)	f*4 mV/(nT*Hz)
▪ at flat part (5 – 50000 Hz)	20 mV/nT
Transformation factor error:	
▪ at flat part of band pass without edges	≤ ±0.25 dB
▪ at flat part band pass edges	≤ 3 dB
Magnetic noise level, $pT*Hz^{-1/2}$:	
▪ at 5 Hz	≤ 0.4
▪ at 100 Hz	≤ 0.02
▪ at 5 kHz	≤ 0.004
▪ at 50 kHz	≤ 0.02
Nominal output load	≤ 200 pF ≥ 50 kΩ
Power supply voltage	± (15 ± 0.2) V
Power consumption	300 mW
Temperature range of operation	$-30^{\circ}C \div +50^{\circ}C$
Outer dimensions (without prominent parts)	l = 400 mm d = 32 mm
Length of the output cable	0.7 m
Weight	≤ 320 g

Work in progress:

- ARINA & LAZIO (tests of the ***ESPERIA*** particle detector)
- EGLE (test of the ***ESPERIA*** magnetometers)
- DEMETER data analysis (Guest investigation program)
- Theoretical modeling

Proposals for other experiments on board of *ESPERIA*

1. **Atmospheric & ionospheric structure and dynamics** NASA/SENH (*J. LaBrecque*)

Blackjack limbsounding & reflections GPS receiver for occultation measurement

2. **Geomagnetic field mapping : *ESPERIA* *as an equatorial complement to polar missions***

DSRI/DTU (*E.Christensen* & *F.Primdhal*), NASA/SENH/GSFC/JPL (*J. LaBrecque* & *P. Taylor*)

Scalar magnetometer (or Polatomic self-calibrating vector/scalar magnetometer) & star imager

3. **Luminous emissions (sprites, blue jets,...) during thunderstorm activity**

DSRI (*E. Christensen*) & LPCE/CNRS (*M. Parrot*) ⇒ **Imaging Camera**

4. **Equatorial electrojets**

Indian Institute of Technology, Kanpur, IITK. (*R. Singh*)

Conclusions & Outlook

✓ ***ESPERIA*** Phase A study has been made for ASI

✓ Instrumental and theoretical activities are in progress :

- Two experiments (***ARINA*** & ***LAZIO/EGLE***) are going to be carried out on board a LEO satellite & the ISS
- LP&RPA intruments have been built by Alenia

✓ There is a fruitful collaboration between ***ESPERIA***, ***ARINA***, and ***DEMETER***

ARINA & ***DEMETER***: simultaneous polar missions ⇒ data comparisons

✓ ***ESPERIA*** payload features and orbit characteristics allow many investigations of lithospheric-atmospheric-ionospheric-magnetospheric phenomena