The ESPERIA Project: a Mission to Investigate the near-Earth Space

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Summary. ESPERIA is an equatorial space mission mainly concerned with detecting any tectonic and preseismic related signals. More in general, it has been proposed for defining the near-Earth electromagnetic, plasma, and particle environment, and for studying perturbations and instabilities in the ionosphere-magnetosphere transition region. The same multi-instrument payload also allows anthropogenic electromagnetic emissions to be investigated. To study earthquake preparation processes and anthropogenic impacts in the Earth's surface, a phase A study has been realized for the Italian Space Agency. Within this framework also the ARINA particle experiment is in progress.

Key words: geomagnetic field, earthquakes, magnetosphere, plasma, radiation belts.

1 Introduction

Earthquake prediction is a very fascinating tool in geophysics but the possibility to determine the space and time occurrence, and the magnitude of a forthcoming earthquake is still a good way from a solution. Also relevant is the possibility to investigate lithosphere-atmosphere-ionosphere-magnetosphere coupling mechanisms in the near-Earth space. In recent years it has been observed that both earthquakes and near-Earth space phenomena have a privileged and sensitive zone of investigation constituted by the ionosphere-magnetosphere transition region at altitudes ranging around 600÷1000 km. Sun and cosmic rays as well as Earth's interior processes, anthropogenic electromagnetic emissions and thunderstorm activity, influence the structure and dynamical behavior of the zone. These external and internal contributions play an important role in defining the particle and electromagnetic (EM) field character of the region, both in steady-state and perturbedstate conditions. A suitable monitoring of the ionosphere-magnetosphere transition zone may also give an help mapping the geomagnetic field and studying many important physical phenomena as earthquakes, anthropogenic EM emissions (EME), solar wind and flares, etc.

ESPERIA is an equatorial mission planned with a *Low-Earth-Orbit* (LEO) small-satellite and a multi-instrument payload ideally conceived to define the steady-state near-Earth EM, plasma, and particle environment, and to investigate perturbations and instabilities in the ionosphere-magnetosphere transition region. The ESPERIA *Phase A* study has been performed by an International Consortium lead by the University Roma Tre (Sgrigna, 2001), within the Earth observation program for small scientific missions of the Italian Space Agency (ASI). The ARINA particle experiment, has been realized within the PAMELA mission (Picozza, 2003). Specific ASI constrains restricted the above mentioned original scientific objectives of the ESPERIA project, but contacts with other missions and science teams give indications to reconcile the project to its original aims.

2 The ESPERIA mission

The scientific objectives of the mission are to detect tectonic, anthropogenic, and preseismic related EM signals. The scientific program is planned with strong emphasis on coordinated, continuous, and simultaneous space and ground-based observations, as well as on mutual data comparison with other missions of similar quality.

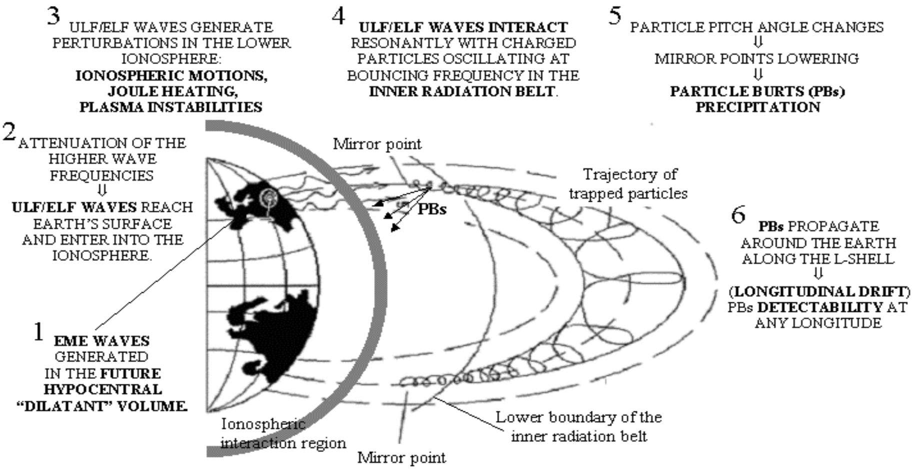

Fig. 1. Seismic EME-waves generation, propagation and interaction with ionospheric plasma and magnetospheric trapped particles.

Science background

Preseismic ground mechanical, electric and electromagnetic fields have been observed as well as ULF-HF EME-waves in the ionosphere and magnetosphere over seismic regions. At present it doesn't exist an exhaustive physical model to justify these seismo-associated phenomena. For a review on the subject see Hayakawa (1999); Sgrigna and Malvezzi (2003); Aleksandrin et al., (2003). A qualitative representation of the phenomenology, as suggested by several authors, is shown in figure 1. Observation of EME-waves generated by anthropogenic activities at the Earth's surface revealed that sources of these waves are power line harmonic radiation, VLF and HF transmitters (Parrot and Zaslavski, 1996).

ESPERIA main features

1. ORBIT CHARACTERISTICS
- Ground track repetition with accuracy of 10 km
- Revisit time ≤ 24 h; geosynchronous orbit: 14 orbits / day
- Altitude=813km; inclination=11°.5, eccentricity=0; Orbit period:110'
- Orbit knowledge and time resolution ≈ 100 m and 1s, respectively
- Field of view: ± 38.5°
- Maximum oscillation around the magnetic equator: ± 23°

2. SPACECRAFT
- Platform MITA with Nadir pointing
- FEEP thrusters applied to the platform (constant altitude)

3. MISSION DURATION ≥ 2 years

4. 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&RPA)**
  LP : electron temperature: 300÷15000K and density: $10^{2}÷10^{7}$ cm^{-3}
  RPA: ionic temperature: 300÷10000K and density: $10^{2}÷10^{7}$ cm^{-3}
- **Particle Detector Analyser (PDA)**
  - Energy range: 300 KeV ÷ 2GeV
  - Pitch angle precision < 4° with particle identification
  - Geometry: 5 silicon strip telescope + 1 calorimeter
    1 silicon strip telescope + 1 calorimeter

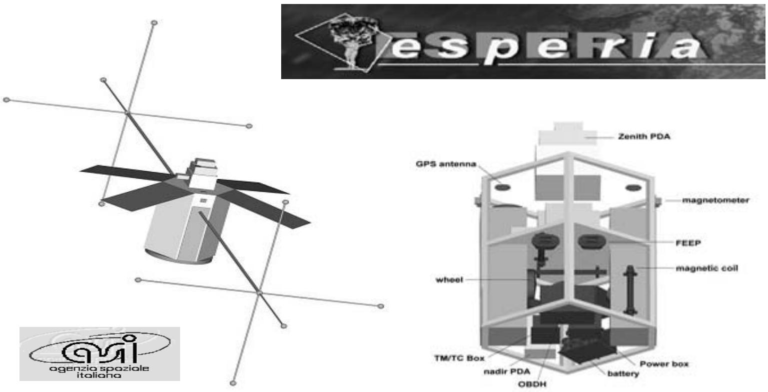

Fig. 2. Overview of the ESPERIA equatorial satellite.

An overview of the satellite is given in figure 2. At the topside of the satellite are located PDA, LP, and RPA instruments. Each MAFA sensor system is at one different end of the two primary expanding booms (of ≈5m), so that search-coils are separated by about 10m from flux-gate sensors and each sensor system is at a distance of about 5m from the satellite body. Electric probes with preamplifiers inside are located at the end of secondary booms (of ≈2m), so that each electric sensor system is about 2m from the nearest magnetic sensor system. Instead of magnetic torques, the attitude control is implemented by 3 reactions wheels (of known EM spectra). In this way, magnetic disturbances are less than 2pT at a distance of 5m (deployed booms/magnetic probes accommodation), that is magnetic disturbances are less than instrumental sensitivity.

All probes will be switched off during the desaturation of reaction wheels or when (for short periods) FEEP will be active. To build a "quiet" spacecraft we also planned a surface plating and a special solar panels design in order to ensure the equipotentiality of external satellite surfaces. This requires uniform electrical and optical characteristics of the external surfaces of the satellite and equal to that of areas of electric EFA probes. The velocity vector of the satellite is perpendicular to the direction of primary booms.

The ARINA Experiment

The ARINA experiment consists of a proton-electron telescope to be installed on board the polar *LEO* Russian satellite RESURS-DK1, which launch is scheduled for mid-2004. The orbit will be elliptic with altitude ranging from 300 km to 600 km and inclination 70.4°. The duration of the mission will be ≥ 3 years. The scientific objective of the experiment is to detect fluxes of high-energy charged particles (3÷100 MeV), from the inner radiation belt and correlate them with seismic activity. So, ARINA may be considered as a preliminary test of the ESPERIA project.

Relation with other missions and science teams

ARINA and DEMETER (Parrot, 2002) are two simultaneous polar missions which allow comparisons of particle data. ESPERIA may be considered as a second generation of the DEMETER concept and can profit by the information from previous missions. But the equatorial character of the ESPERIA mission and some augmentation or changes in its payload allow to extend the original scientific objectives of this mission for geo-electric and magnetic field mapping, for studying sun activity and cosmic rays, and investigating structure and dynamics of the magnetospheric cavity. In this sense, four proposals for adding experiments to be carried out on board of ESPERIA have been suggested by the scientific community. They are listed below:

1. Atmospheric and ionospheric structure and dynamics (pressure and temperature profile, ionospheric electron density profile, TEC). A blackjack limbsounding and reflections GPS receiver for occultation measurement is requested[1].
2. Geomagnetic equatorial measurements. ESPERIA may be considered as an equatorial complement to polar missions as SWARM. A scalar magnetometer and an attitude star imager are requested[2].
3. Luminous emissions (Sprites, Blue Jets, etc.) during thunderstorm activity. An Imaging Camera is requested[3].
4. Equatorial electrojet[4].

3 Conclusions and Outlook

The ESPERIA space mission has been proposed and the ARINA experiment is in progress for defining the near-Earth electromagnetic, plasma, and particle environment, and for investigating perturbations and instabilities caused by seismicity and anthropogenic EME in the ionosphere-magnetosphere transition region. There is a fruitful collaboration between ESPERIA, ARINA, and DEMETER science teams. The ESPERIA equatorial mission could also be used as a complement to polar Earth's magnetic field mapping missions, like SWARM, and to study relevant phenomena caused by external sources (sun and cosmic rays) or generated inside the magnetospheric cavity.

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