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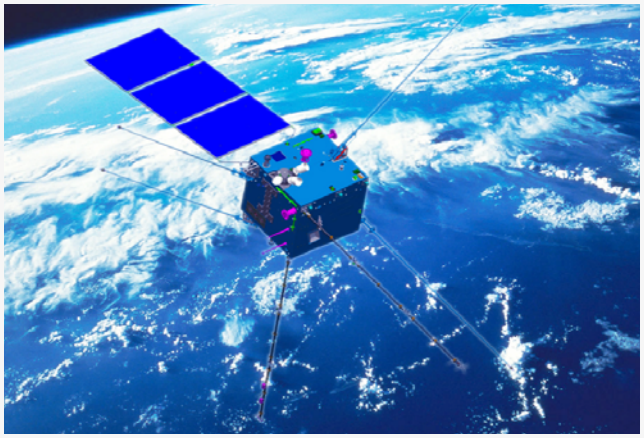

CSES-LIMADOU AND ITS FIRST THREE YEARS OF FLIGHT

Three years after its launch on 2 February 2018 from the Chinese Jiuquan Satellite Launch Center in the Gobi Desert in Inner Mongolia, the CSES (China Seismo-Electromagnetic Satellite)-Limadou satellite mission, dedicated to Earth observation, takes stock of its first scientific results.

Stemming from a collaboration between the Chinese Space Agency (CNSA) and the Italian Space Agency (ASI), with the important scientific contribution of INFN*, CSES-Limadou aims to develop new methods for the study of geophysical phenomena, such as earthquakes and volcanic eruptions, on a global scale. And, to accomplish its mission, it can count on as many as nine scientific instruments set up on board the satellite, practically all the main sensors needed to study the ionosphere, magnetosphere and their possible coupling with the lithosphere, including the made-in-Italy HEPD (High Energy Particle Detector), dedicated to the observation of high energy particles and nuclei.

In these three years of flight, HEPD and the set of instruments created for the study and characterisation of the plasma and the perturbations induced by solar activity, have transmitted a large amount of data that has been analysed by a highly interdisciplinary Italian collaboration**. The convergence in a single team with diverse scientific expertise, including seismology, particle physics and astrophysics, allowed important results to be obtained, presented at the most important international conferences and published in prestigious scientific journals.

In particular, in this first phase of the experiment, HEPD has also proven to be an excellent detector of space weather-related phenomena, recording one of the rare geomagnetic storms that has occurred in recent years, on 25 August 2018. For the first time in low orbit (approximately 500 km from Earth), the instrument also recorded low-energy cosmic protons in the period 2018-2020, measuring their flux with high precision. These measurements have provided an important contribution to our understanding of the interplanetary magnetic field. HEPD data on electrons and protons at energies in the order of the MeV

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or tens/hundreds of MeVs cover the most scientifically interesting range, and the capabilities of HEPD will be very useful to the international scientific community, especially in view of the completion of the Van Allen Probes mission that will study the Van Allen Radiation Belt.

Thanks to the high sampling rate of its instruments, the CSES-Limadou mission has also made it possible to identify high-frequency fluctuations in the electric field at the entrance to the auroral oval, where charged particles interact with the Earth's ionosphere. At low latitudes, the extraordinary sensitivity of the EFD (Electric Field Detector) and LP (Langmuir Probe) instruments have led to the identification and study of important phenomena associated with abrupt reductions in plasma density (plasma bubbles). In addition, the low-energy electron and electric field data, together with the information collected by the other instruments, have, for the first time, made it possible to highlight all the elements underlying the co-seismic coupling mechanism between the lithosphere and magnetosphere in the presence of an earthquake. During a seismic event, the movement of the Earth's surface (solid or liquid) activates a gravito-acoustic wave, observable by satellite, which, having reached the ionosphere, induces the emission of low frequency electromagnetic waves (hundreds of Hz) which alter the magnetic field, influencing the motion of particles trapped in the Van Allen belts. In order to describe this mechanism in a coherent manner, the MILC (Magnetospheric-Ionospheric-Lithospheric Coupling) model was developed. This model has been verified in all its components with measurements taken by CSES and other satellites during the Bayan earthquake (2018). The application of this model to the study of other earthquakes observed in the last two years is now being developed, expanding the study to the time interval adjacent to the time of the earthquake.

The CSES-Limadou mission, which is scheduled to continue to operate until 2023, therefore promises many interesting results and, in line with what has been produced in this first phase, will continue to provide us with valuable information to improve our knowledge of the geophysical phenomena that characterize our planet.

* INFN Divisions of Bologna, Perugia, Rome Tor Vergata, Naples, Trento TIFPA National Center and Frascati National Laboratories.

** The Italian data analysis collaboration, in addition to INFN, consists of INAF National Institute for Astrophysics-IAPS, INGV National Institute for Geophysics and Volcanology, CNR National Research Council-IFAC and of the Universities of Bologna, Trento, Rome Tor Vergata and Uninettuno International Telematic University (UTIU). ■