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Abstract Book

HERMES Scientific Pathfinder

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- **Fabrizio Fiore,** INAF OATs

The HERMES-Technologic and Scientific Pathfinder

HERMES-TP/SP is a constellation of six 3U nano-satellites hosting simple but innovative X-ray detectors for the monitoring of Cosmic High Energy transients such as Gamma Ray Bursts and the electromagnetic counterparts of Gravitational Wave Events, and for the determination of their position. The projects are funded by the Italian Space Agency and by the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 821896.
HERMES-TP/SP is an in orbit demonstration, that should be tested in orbit by the beginning of 2022. It is intrinsically a modular experiment that can be naturally expanded to provide a global, sensitive all sky monitor for high energy transients.
On behalf of the HERMES-TP and HERMES-SP collaborations I will present the main scientific goals of HERMES-TP/SP, as well as a progress report on the payload, service module and ground segment developments.

- **Yuri Evangelista,** INAF IAPS

The scientific payload on-board the HERMES-TP and HERMES-SP CubeSat missions

HERMES (High Energy Rapid Modular Ensemble of Satellites) Technological and Scientific pathfinder is a space borne mission based on a LEO constellation of nano-satellites. The 3U CubeSat buses host new miniaturized detectors to probe the temporal emission of bright high-energy transients such as Gamma-Ray Bursts (GRBs).
Fast transient localization, in a field of view of several steradians and with arcmin-level accuracy, is gained by comparing time delays among the same event detection epochs occurred on at least 3 nano-satellites. With a launch date in 2022, HERMES transient monitoring represents a keystone capability to complement the next generation of gravitational wave experiments.
In this paper we will illustrate the HERMES payload design, highlighting the technical solutions adopted to allow a wide-energy-band and sensitive X-ray and gamma-ray detector to be accommodated in a Cubesat 1U volume together with its complete control electronics and data handling system.

- **Fabio Fuschino,** INAF OAS Bologna

An innovative architecture for wide band transient monitor on board HERMES nano-satellite constellations

The HERMES-TP/SP mission, based on nanosatellite constellation, has very stringent constraints of sensitivity and compactness, and requires an innovative wide energy range instrument. The instrument technology is based on the "Si-swich" concept, in which custom designed, low noise Silicon Drift Detectors are used to simultaneously detect soft X-rays and to readout the optical light produced by the interaction of higher energy photons in GAGG scintillators. To preserve the inherent excellent spectroscopic performances of SDDs, suitable readout electronics is necessary. The HERMES detector architecture concept will be described in detail as well as the specifically developed front-end ASICs (LYRA-FE and LYRA-BE) and integration solutions. The experimental performance of the integrated system composed by scintillator+SDD+LYRA ASIC will be discussed, demonstrating that the requirements of a wide energy range sensitivity, from 2 keV up to 2 MeV, are met in a compact instrument.

- **Riccardo Campana,** INAF OAS

The HERMES background and response simulations

HERMES (High Energy Rapid Modular Ensemble of Satellites) is an innovative mission aiming to observe transient high-energy events such as gamma-ray bursts (GRBs) through a constellation of CubeSats hosting a broadband X and gamma-ray detector. The detector is based on a solid-state Silicon Drift Detector (SDD) coupled to a scintillator crystal, and is sensitive in the 2 keV to 2 MeV band.
An accurate evaluation of the foreseen in-orbit instrumental background is essential to assess the scientific performance of the experiment. An outline of the Monte Carlo simulations of the HERMES payload will be provided, describing the various contributions on the total background and the optimization strategies followed in the instrument design. Moreover, the simulations were used in order to derive the effective area and response matrices of the instrument, also as a function of the source location with respect to the detector frame of reference.

- **Giuseppe Dilillo,** Universita' di Udine

Investigating GAGG:Ce afterglow and tolerance to space radiation through proton irradiation

GAGG:Ce (Cerium-doped Gadolinium Aluminium Gallium Garnet) is a promising new scintillator crystal. A wide array of enticing features - such as high light output, fast decay times, almost non-existent intrinsic background and robustness - make GAGG an interesting candidate as a component of new space-based gamma-ray detectors.
As a consequence of its novelty, literature on GAGG is still lacking on points crucial to its applicability in space missions such as tolerance to gamma and proton radiation. GAGG is also characterized by unusually high and long-lasting afterglow emission, which can be stimulated by interaction with trapped particles and could result in degradation of detector energy resolution.
We discuss the results of our irradiation campaign of GAGG crystals with protons, conducted in the framework of the HERMES-TP/SP (High Energy Rapid Modular Ensemble of Satellites - Technological and Scientific Pathfinder) mission. Samples from different manufacturers were irradiated with 70 MeV protons, at doses equivalent to those expected in equatorial and sun-synchronous Low-Earth orbits over orbital periods spanning 6 months to 10 years, representative of satellite lifetimes.
We report our findings on GAGG tolerance to proton irradiation in terms of degradation of light-output and modification of the afterglow emission signature. We introduce a new model for the afterglow emission resulting from relatively low-dose proton irradiations, such as those expected in repeated passages above LEO trapped particle regions. Results are applied to the HERMES-TP/SP scenario, aiming at a prediction of detector performance degradation resulting from the afterglow emission over the mission lifetime.

- **Jakub Ripa,** ELTE

A comparison of trapped particle models in Low Earth Orbit

Thanks to features such as compactness, light-weight, small power consumption and low cost, Silicon-based high-energy sensors are enabling miniaturized spacecrafts to pursue ambitious scientific objectives, once reachable only by larger missions.

However, space is an hazardous environment: the effect of space radiation lead to damage of solid-state sensors and to a consequent worsening of its performance. Space radiation models play a key role in the preventive assessment of the radiation damage and henceforth detector duty cycle, performance and lifetime.
In the context of High Energy Rapid Modular Ensemble of Satellites - Scientific Pathfinder (HERMES-SP) mission we present an investigation of the AE8/AP8 and AE9/AP9 models specifications of near-Earth trapped radiation environment. We consider 36 different circular Low-Earth Orbits (LEO) at three different altitudes (500, 550 and 600 km) and twelve inclinations (0°, 5°, 10°, 15°, 20°, 30°, 40°, 50°, 60°, 70°, 80° and 90°).
For each simulated orbit we obtain differential and integral trapped particles fluxes, from which we compute maps of the trapped particles region and estimate duty cycles at different flux thresholds.
Differences between AE8/AP8 and AE9/AP9 models are quantified. Trapped particles fluxes computed by AP9/AE9 models are found to be generally higher than its AP8/AE8 counterparts, especially at low inclinations. We compare the models with recently published results on in-situ measurements.

- **Alejandro Guzman**, Eberhard Karls Universität Tübingen

The Payload Data Handling Unit (PDHU) on-board the HERMES-TP and HERMES-SP CubeSat mission

The High Energy Rapid Modular Ensemble of Satellites (HERMES) Technological and Scientific pathfinder is a space borne mission based on a constellation of LEO nano-satellites. The payloads of these CubeSats consist of miniaturized detectors designed for bright high-energy transients such as Gamma-Ray Bursts (GRBs). This platform aims to impact Gamma Ray Burst (GRB) science and enhance the detection of Gravitational Wave (GW) electromagnetic counterparts. This goal will be achieved with a field of view of several steradians, armin precision and state of the art timing accuracy. The localisation performance for the whole constellation is proportional to the number of components and inversely proportional to the average baseline between them, and therefore is expected to increase as more.
In this paper we describe the Payload Data Handling Unit (PDHU) for the HERMES-TP and HERMES SP mission. The PDHU is the main interface between the payload and the satellite bus. The PDHU is also in charge of the on-board control and monitoring of the scintillating crystal detectors. We will explain the TM/TC design and the distinct modes of operation. We also discuss the on-board data processing carried out by the PDHU and its impact on the output data of the detector.

- **Gabor Galgoczi,** ELTE

A software toolkit to simulate activation background for high energy detectors onboard satellites

A software toolkit for the simulation of proton-induced activation and in general particle background on high energy detectors onboard satellites is presented on behalf of the HERMES-SP and CAMELOT collaborations. The Geant4 based toolkit consists of two modules. The first one quantifies the proton induced activation background from the irradiation profile provided as an input. The other module determines the signal produced by background particles, including cosmic, trapped and albedo particles. A CAD model of the satellites can be read into Geant4 directly using CADMesh.

A straightforward simulation of activation is not possible as it would require an extremely large computational time. In order to solve this problem a three-step simulation is implemented in one of the modules of the presented software toolkit. The first step is the simulation of radioactive isotope production. The second step consists of determining the relevant decay chains and calculating the activity of each element. The third step is the Geant4 simulation of the radioactive isotopes with the activity derived in step two. In this way it is possible to quantify the background signal in the detector induced by activation for arbitrary irradiation profiles and at every time scale.
As an example, the background of HERMES and the CAMELOT CubeSat missions is quantified for Low Earth Orbits. Besides the activation background, we investigated the contribution of protons, neutrons, electrons, alpha nuclei and positrons. Particles trapped in the magnetic field of Earth (e.g. the South Atlantic Anomaly), particles with cosmic origin and also albedo particles are considered.

- **Andrea Sanna**, UniCa

TIMING TECHNIQUES APPLIED TO DISTRIBUTED MODULAR HIGH-ENERGY ASTRONOMY: HERMES

The association of GW170817 with GRB170817A proved that electromagnetic counterparts of gravitational wave events are the key to deeply understand the physics of NS-NS merges. Upgrades of the existing GW antennas and the construction of new ones will allow to increase sensitivity down to several hundred Mpc vastly increasing the number of possible electromagnetic counterparts. Monitoring of the hard X-ray/soft gamma-ray sky with good localisation capabilities will help to effectively tackle this problem allowing to fully exploit multi-messenger astronomy. However, building a high energy all-sky monitor with large collective area might be particularly challenging due to the need to place the detectors onboard satellites of limited size. Distributed astronomy is a simple and cheap solution to overcome this difficulty. Here we discuss in detail dedicated timing techniques that allow to precisely locate an astronomical event in the sky taking advantage of the spatial distribution of a swarm of detectors orbiting Earth.

- **Luciano Burderi**, UniCa

GrailQuest & HERMES: Hunting for Gravitational Wave Electromagnetic Counterparts and Probing Space-Time Quantum Foam

GrailQuest (Gamma-ray Astronomy International Laboratory for Quantum Exploration of Space-Time) is an ambitious astrophysical mission concept that uses a fleet of small satellites, whose scientific objectives are discussed below.
Within Quantum Gravity theories, different models for space-time quantisation predict an energy dependent speed for photons. Although the predicted discrepancies are minuscule, Gamma-Ray Bursts, occurring at cosmological distances, could be used to detect this signature of space-time granularity with a new concept of modular observatory of huge overall collecting area consisting in a fleet of small satellites in low orbits, with sub-microsecond time resolution and wide energy band (keV-MeV). The enormous number of collected photons will allow to effectively search these energy dependent delays. Moreover, GrailQuest will allow to perform temporal triangulation of high signal-to-noise impulsive events with arc-second positional accuracies: an extraordinary sensitive X-ray/

Gamma all-sky monitor crucial for hunting the elusive electromagnetic counterparts of Gravitational Waves. A pathfinder of GrailQuest is already under development through the HERMES (High Energy Rapid Modular Ensemble of Satellites) project: a fleet of six 3U cube-sats to be launched by the end of 2021-beginning 2022.