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Radiation testing for the Jovian environment: in the laboratory and on CubeSats

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Abstract

The harsh Jovian radiation environment is one of the main drivers for the design of instruments to be flown to Jupiter. Radiation testing of the instruments in the relevant environment is crucial, but challenging. We introduce RATEX-J, a radiation test setup dedicated for the JUICE mission that focuses on active radiation mitigation approaches and employs ground based and spaceborne testing platforms.

1. Introduction

ESA's JUICE (Jupiter Icy Moons Explorer) mission will be launched in 2022 and will experience the harsh radiation environment within the Jovian magnetosphere. This is dominated by high fluxes of energetic electrons in the MeV range that are not easily possible to shield against. Instruments of the Particle Environment Package (PEP) onboard JUICE commonly use microchannel plates (MCPs) and channel electron multipliers (CEMs) for particle detection. One example is the Jovian plasma Dynamics and Composition analyzer (JDC), one of six sensors within PEP. JDC measures 3D distribution functions of positive and negative ions. Penetrating electrons will disturb the measurements, decrease the signal-to-noise ratio and can partially even prevent any useful measurement.

Therefore radiation mitigation techniques need to be employed. This includes obviously passive shielding, but also active approaches.

Simulating Jupiter's radiation environment in order to verify the performance of the radiation mitigation techniques, is a complex experimental task due to the combination of electron energy and particle flux.

2. Radiation mitigation

2.1. Anti-coincidence system

For JDC an anti-coincidence system based on a semiconductor detector will be used. This system protects the stop signal of the time-of-flight chamber in the instrument. Particles selected by JDC's ion optics will hit a conversion surface and produce low energetic electrons that are detected as stop signal by an MCP. Energetic electrons will however as well produce a false stop signal as they penetrate the surface. As in this case the anti-coincidence shield will also show a signal, it can be discarded.

2.2. Characterization of MCP and CEM response to penetrating radiation

The second approach focuses on the characterization of the pulse height distribution of MCP and CEM outputs. As it is a semi-Gaussian for low energetic electrons, these detectors are usually run in counting mode. The pulse height distribution for penetrating particles is however expected to look different.

Furthermore efficiencies of MCPs and CEMs to penetrating radiation will be investigated, as little to nothing is known about the efficiencies to electrons with energies above 100 keV.

3. Experiment setup

The Radiation Test Experiment for JUICE (RATEX-J) uses three different particle detectors: one MCP, one CEM and two semiconductor detectors, which serve as the respective anti-coincidence shields, arranged in two detector stacks. The experiments setup houses the two detector stacks, front-end electronics, pulse height analysis, high voltage supply and a simple data processing unit. The setup's volume takes less than half a CubeSat and allows flexibility and mobility of the unit.

4. Radiation testing

Complementary ground based and spaceborne radiation tests are foreseen.

4.1. Accelerator

RATEX-J will be irradiated with energetic electrons in the MeV range at the microtron facility at Stockholm university. As drastic flux reduction and beam scattering are required to reach an adequate radiation environment, supporting Monte Carlo simulations are performed. We will show first results of these experiments.

4.2. CubeSats

CubeSats in Earth orbits provide a relatively easy-to-access platform to test small payloads in the natural radiation belt environment, in case of sun synchronous orbits. They are considered valuable for future instrument and subsystem testing to be employed on planetary missions, even for radiation environments as harsh as Jovian.

RATEX-J is selected payload on the 3-unit CubeSat MIST by Stockholm University, which will be launched in 2017. Also a dedicated 1-unit CubeSat mission is investigated.