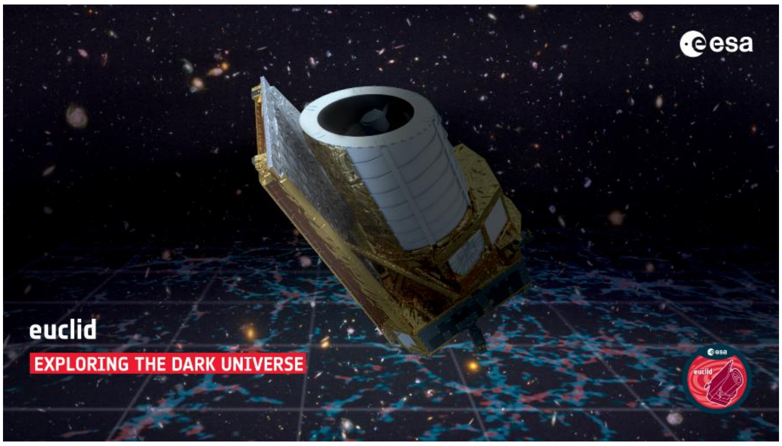
Radiation damage in detectors: what really happens to silicon imaging detectors in orbit?

Project highlights:

- Join our team of scientists and engineers to work with the latest detector technology as launched on the ESA Euclid mission in the VIS instrument.
- The radiation environment in space presents a challenge to all space missions, particularly when the radiation damages the cameras used to make the science observations.
- With a new analysis technique, for the first time it will be possible to observe the damage to individual atoms in the silicon lattice of the detectors in-orbit, opening the door to a step change in how radiation damage can be mitigated in future space missions.
- "Best of both worlds" approach to a PhD studentship through the STFC CASE scheme - undertaking a PhD that is sponsored by our long-running industrial partner Teledyne e2v Space Imaging, with a dedicated industrial supervisor and an extended placement with the company during your PhD.
- Hands-on experiments with space technologies, both in the laboratories at the Open University, Teledyne e2v, and at a wide range of science facilities across Europe.
- Opportunity to discuss your research with scientists across Europe and the space agencies, as well as present at international conferences.



An artist's impression of Euclid (ESA).

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Project description:

The Euclid mission, launched in July 2023, is an ESA space mission with the objective of mapping the geometry of the Universe and better understand dark matter and dark energy. While in space, Euclid is bombarded with highly energetic particles mainly from the Sun, which will slowly degrade the detectors and thus have a have a major impact on the scientific data unless corrected for.

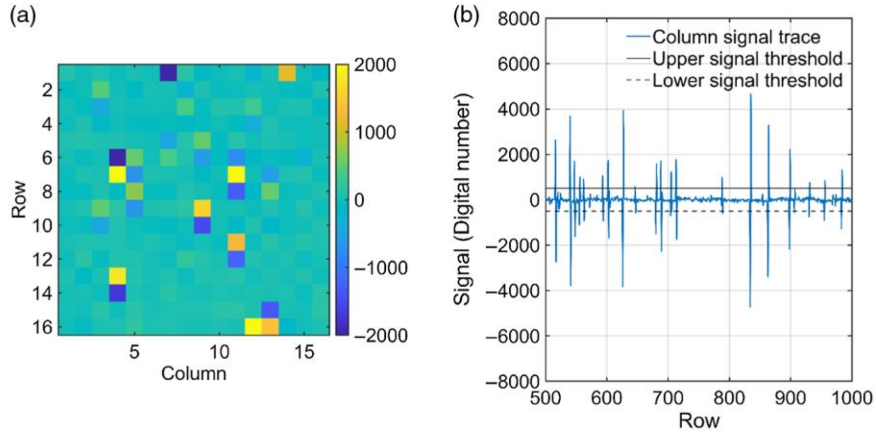
The Centre for Electronic Imaging (CEI) at the Open University has been involved in the Euclid mission since its conception as part of the Euclid VIS instrument development work, carrying out detector characterisation and leading the radiation damage testing of the imaging detectors in the Euclid VIS focal plane. As part of this work, the CEI has developed the *trap pumping* technique, which allows for the characterisation of single defects in the silicon lattice caused by the space radiation environment and leading to the degradation of the science images returned. This new technique, originally developed by the CEI a decade ago, allows for a much deeper understanding of the actual damage the devices are subject to when in space and will be performed on a daily basis as part of the in-orbit calibrations. This will be the first that the technique has been used in space, opening up a new era in the understanding of radiation damage to detectors in-orbit.

As part of the data processing and calibration routines for the Euclid VIS instrument, the data from trap pumping will be analysed to provide parameters for the image correction algorithms. However, the data are able to tell us much more about the space radiation environment, radiation damage processes, and how accurately our current ground-based testing can replicate the conditions in-orbit. Through a deeper analysis of the in-orbit data, coupled through targeted ground-based experiments in the laboratory, we will for the first time be able to directly analyse the radiation damage processes in space.

For the Gaia mission, a previous CEI PhD student investigated the differences between pre-launch predictions of radiation damage and what happened in-orbit using simple calibration data. Their findings have shown interesting correlations with device batches, as well as fine-tuned the calibration process used in the RVS instrument. A first proper investigation of radiation damage while in-orbit will help our fundamental understanding, not just for CCDs but also for future CMOS missions.

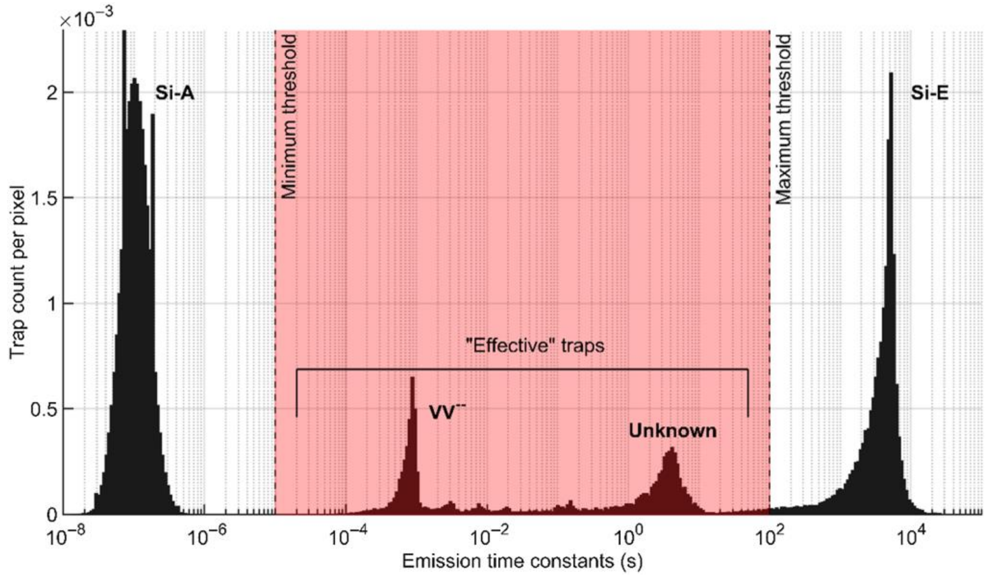
For Euclid, we have access to a highly accurate and much deeper analysis technique in trap pumping, giving the power to analyse the performance in great detail and investigate many open questions that can't be answered from ground testing, important to all future space missions, whether CCD or CMOS:

- How does a 5 minute on-ground irradiation compare to a steady rate of increase over 5 years in-orbit?
- How does a NIEL scaled 200MeV dose compare to a full spectra of particle energies?
- How does annealing compete with new trap production?



<u>Above:</u> Each pair of bright and dark pixels in the image give the location of a single silicon atom being out of place in the lattice. How these "dipoles" in the images vary with frequency and temperature allows us to determine what other atom may be present at the lattice defect site.

<u>Below:</u> We can use this information from the Euclid VIS in-orbit calibration data to build a spectrum of defect types, allowing us to predict the impact of this radiation damage on the science data and better correct the observations [3].



References:

1. https://doi.org/10.1109/TNS.2013.2295941
2. https://doi.org/10.1088/1748-0221/12/12/C12033
3. https://doi.org/10.1117/1.JATIS.8.2.028003