# Simulating radiation effects of imaging detectors using Pyxel simulation framework

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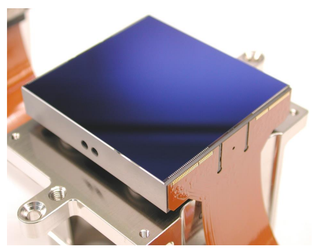
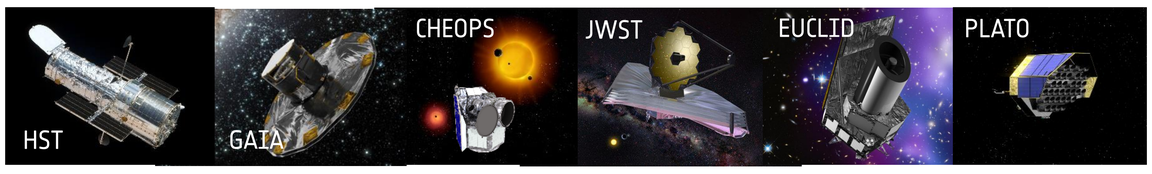
## ➔ Astronomy missions & Payload imaging detectors

- Charge-Coupled Devices (CCD)
- CMOS imaging sensors:
  - Hybrid (HgCdTe)
  - Monolithic (Si)






Visible & Near-Infrared astronomy missions of ESA

HST image with cosmic rays and CTI added by Pyxel

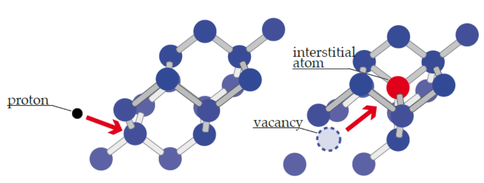
## ➔ Pyxel – the python detector simulation framework

- A novel, end-to-end detector electro-optical performance simulation framework hosting and pipelining a pool of detector effect models [2]
- Simulates both CCD and CMOS-based imaging detectors
- General, modular and scalable Python framework
- Easy-to-use plug-in mechanism for model functions, which could be analytical, numerical and statistical codes as well
- Using structured YAML configuration files as input
- Automatically generated web-based Graphical User Interface
- Model calibration & detector optimization with genetic, self-adaptive evolutionary and non-linear optim. algorithms [3]
- Will be released and maintained as an open-source software for the whole detector scientist and astronomer community
- Some detector effects:
  - Radiation effects: Cosmic ray tracks, Charge Transfer Inefficiency (CCD), Persistence (CMOS)
  - Optical effects: Tree rings, Internal reflections, Optical Point Spread Function, Pixel Response Non-Uniformity
  - Charge diffusion: Brighter-fatter, Blooming
  - Noises: Dark current, Shot & Readout noise, RTG, Digitization, Crosstalk

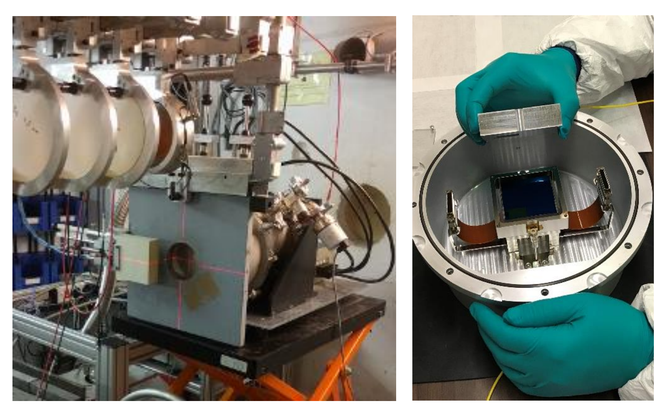
## ➔ CCD Charge Transfer Inefficiency & proton irradiation

- High energy particles cause displacement damages in the CCD silicon lattice which are trapping charges during their pixel-to-pixel transfer and releasing them later
- CTI distorts images (smear) and decreases the SNR
- Different trap species have different energy levels, charge capture cross-sections and release time constants
- Modelling CTI is critical to understand laboratory data, estimate end-of-life performance and also perform on-ground mitigation during the data processing
- The Charge Distortion Model (CDM) [1] is a physically realistic, and fast analytical CTI model. It was developed originally for the Gaia CCD operating mode.

Euclid CCD irrad. at UCL with 14 & 62 MeV protons




Si displacement damage



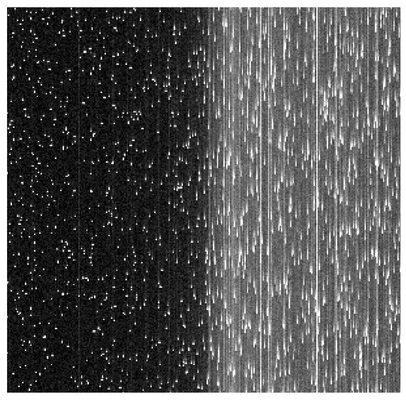
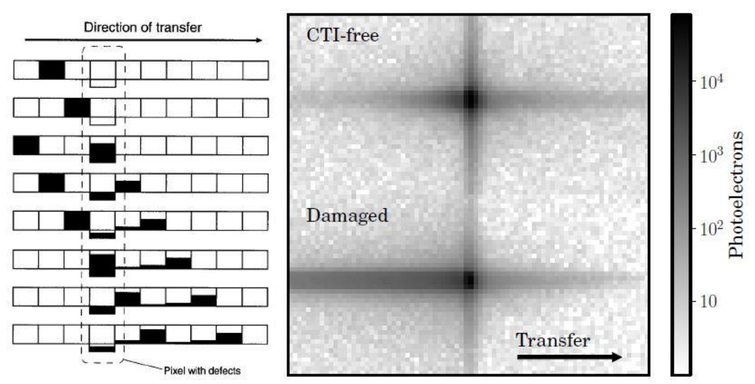
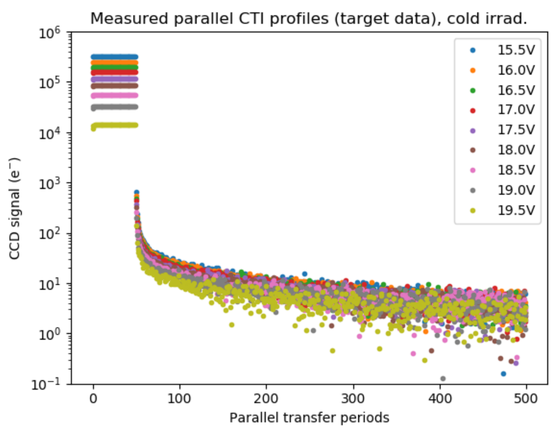


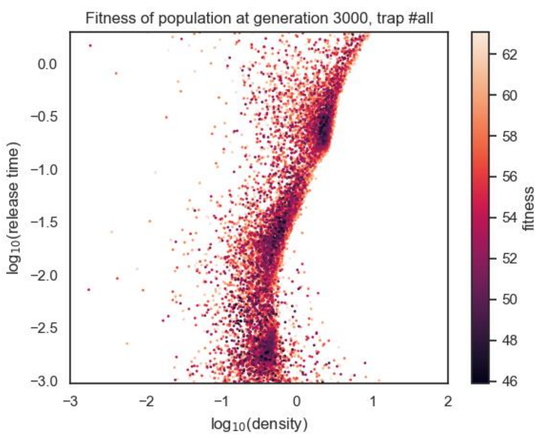
Image of irrad. CCD



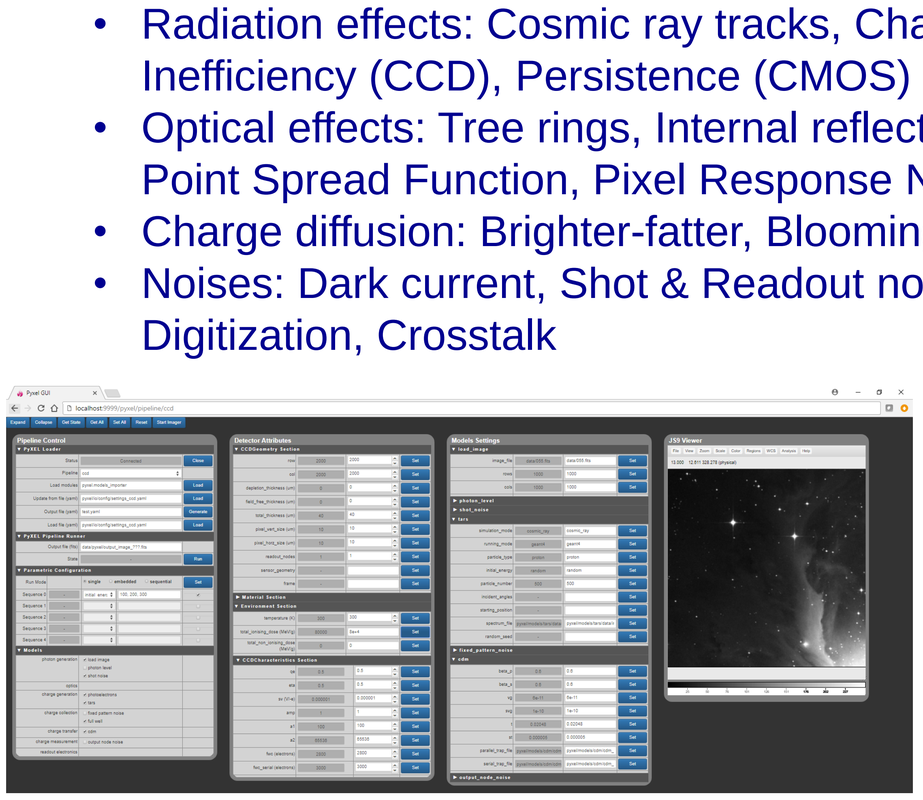

Simulated CTI effect in Gaia CCDs



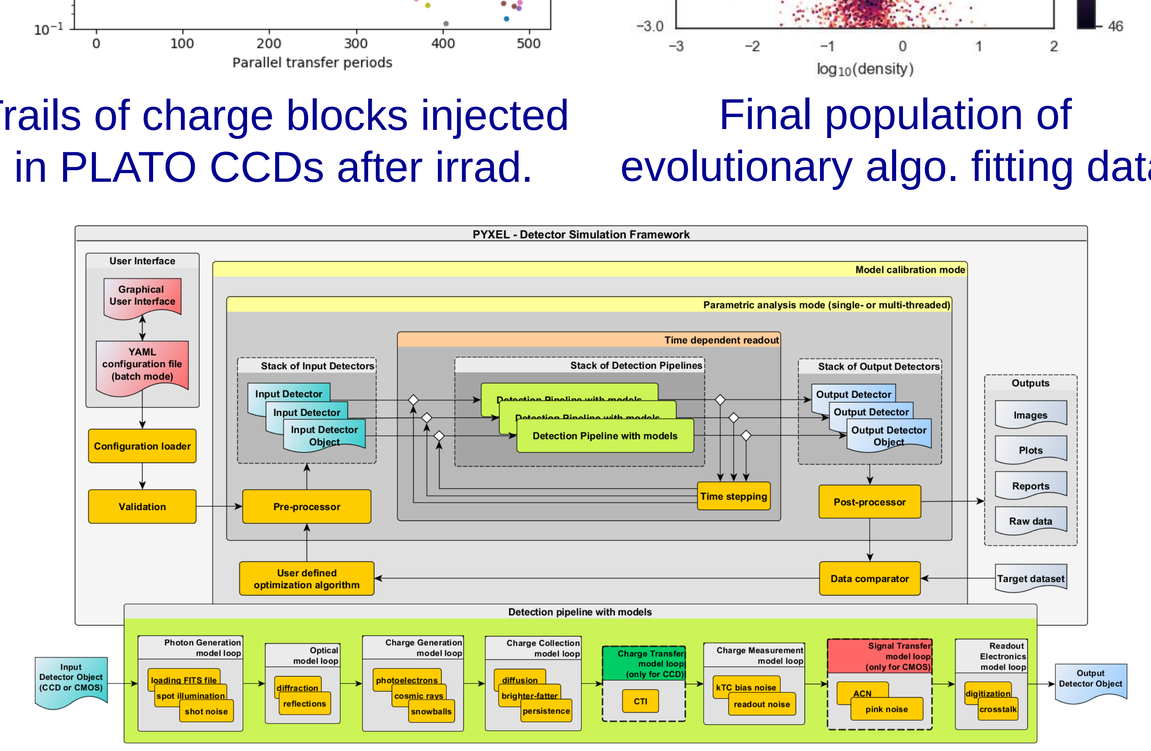

Trails of charge blocks injected in PLATO CCDs after irrad.




Final population of evolutionary algo. fitting data




The GUI and a YAML config file of Pyxel framework




The architecture of Pyxel and its pipeline

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**http://sci.esa.int/pyxel**

[1] A. Short et al., "An analytical model of radiation-induced Charge Transfer Inefficiency for CCD detectors", Monthly Notices of the Royal Astronomical Society 430(4), 2013.
[2] D. Lucsanyi et al., "Pyxel: a novel and multi-purpose Python-based framework for imaging detector simulation", Proc. SPIE 10709, 2018.
[3] F. Biscani & D. Izzo., Pagmo 2.9, DOI:10.5281/zenodo.1406840, 31. Aug. 2018.

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