DOI: 10.18727/0722-6691/5249

Report on the ESO/ESA Workshop

Detector Modelling Workshop 2021

held online, 14–16 June 2021

Elizabeth George [1]
Benoît Serra [1]
Thibaut Prod'homme [2]
Matej Arko [2]
Frédéric Lemmel [2]
Bradley Kelman [3]

[1] ESO
[2] European Space Agency, ESTEC, Noordwijk, the Netherlands
[3] Open University, Milton Keynes, UK

The Detector Modelling (DeMo) workshops aim to bring together a community of scientists and engineers who are interested in modelling detector effects and simulating detectors for astronomy. The first such workshop was held online over three afternoons from 14 to 16 June 2021. The three afternoons were organised around blocks of contributed talks from the community covering a wide range of detector topics such as detector effects like persistence and radiation damage, instruments covering a wide range of astronomical wavelengths from X-ray to the optical and infrared, and detectors used in other fields like particle physics. In addition to the scientific programme, the workshop featured a tutorial series on how to use the Pyxel detector simulation framework and how to contribute to Pyxel.

Introduction

As astronomical observations move ever further into the realm of precision astronomy, systematic effects in instruments, especially detectors, are beginning to dominate instrument error budgets. Understanding, modelling, and correcting for detector effects are now necessary to achieve science goals ranging from characterising exoplanet atmospheres, to measuring chemical abundances in high-redshift galaxies, to performing precision astrometry of stellar fields.

Engineers working on detectors at ESO and the European Space Agency (ESA) have been collaborating for several years, under the umbrella of the ESA–ESO collaboration, on a detector simulation tool named Pyxel[1]. The goal of Pyxel is to create an open-source simulation tool that allows astronomical instrument builders to simulate their detectors at the design and engineering stage as well as helping astronomers develop calibration or analysis strategies to address detector effects that may impact their science. The DeMo workshop was envisioned both as a way to share Pyxel with the community through hands-on tutorial sessions, and as a forum for the exchange of ideas around detector modelling for astronomy via a programme of contributed talks. Figure 1 is the workshop poster.

Scientific programme

The scientific programme was based on the contributions of the participants and consisted of 22 talks in seven thematic blocks. These were:
- optical and infrared instrument simulators (two blocks);
- detector measurements and models (three blocks);
- X-ray instrument simulators;
- particles and radiation modelling.

One of the most popular themes of the conference was instrument simulators. Speakers presented ScopeSIM (the simulator for the Multi-AO Imaging Camera for Deep Observations [MICADO] at ESO's Extremely Large Telescope), PLATOsim, the Euclid suite of instrument simulators, SIXTE (a generic X-ray instrument simulation) toolkit, xifusim (the Athena X-IFU instrument simulator), and PhoSim for Vera C. Rubin Observatory. These complete instrument simulators often include modules for generating astronomical scenes and transmission through the instrument optics, a simulation of detector effects, and in some cases also an analysis pipeline for the resulting data. The goal of these simulation tools is complete end-to-end modelling of an instrument, or even a complete simulation of a specific instrument science case including the analysis of synthetic data.

Following the full instrument simulators, detector-specific simulations were presented in several sessions covering simulation work for the China Space Station Telescope (CSST), the European Synchrotron Radiation Facility's X-DECIMO (a Python package for X-ray detector modelling), CERN's Allpix Squared (silicon detector Monte Carlo simulations for particle physics), and electron avalanche photodiode (e-APD) saphira modelling. In these sessions we had several presentations from fields outside astronomy (particle physics, for example) which provided a different perspective on detector characteristics and modelling.

The largest number of talks covered measurements, models, and/or simulations of individual detector effects. These tended to be very detailed models of single detector effects that astronomers and engineers had worked hard to understand in order to enable a specific science case. These included C3TM (radiation damage in CCDs), CosmiX (charged particles in detectors), and various models covering interference, non-linearity, inter-pixel capacitance effects, persistence, and luminescence effects in mercury cadmium telluride (MCT) hybridised arrays, as used in many ESO instruments. Some of the detector models presented are already integrated into Pyxel, and others will be added by the speakers in the coming months as the flexible nature of Pyxel allows users to add their own favourite models to the simulation framework. A highlight of these talks was the many cases where precision laboratory data were combined with physical knowledge of the detectors to create a model of detector behaviour.

The final theme covered by the scientific programme was the impact of detector effects on science instruments and the use of detector simulations in instrument design and systems engineering. Speakers presented Pandeia (the James Webb Space Telescope exposure time calculator), persistence correction in ESO's instruments, mitigation of tearing in the Vera C. Rubin Observatory CCDs, and NASA's Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer (SPHEREx) mission. These talks provided valuable context for why detector modelling is so important for precision astronomical instruments, as the impacts of the effects are clearly seen in the (synthetic) data.

Whilst the models and simulations presented at DeMo were all different, some of the challenges associated with simulating detectors and instruments are common, and all workshop participants were exposed to a huge range of instrument and detector simulation tools already in existence. We are confident that participants looking to simulate detector effects now have a buffet of options to choose from when getting started with their own modelling project.

Pyxel tutorials

This dense programme of scientific talks was complemented by two sessions dedicated to Pyxel, comprising close to four hours of live interactive tutorial. The goal of these tutorial sessions was to introduce Pyxel to the community and allow participants hands-on practice using the simulation tool. The tutorials were organised as a walkthrough using jupyter notebooks with the participants being able to follow, either by running the notebooks without any prior installation using binder in their web browser, or by installing Pyxel beforehand on their own computers. Installation instructions and support were provided in a dedicated channel under the workshop Discord server before, during and after the workshop.

The first tutorial session was dedicated to (i) introducing all the necessary information needed to start working with the tool, (ii) a simple demonstration of Pyxel focusing on single image mode, an explanation of the configuration file, and how to interact with Pyxel's outputs, and (iii) a guide on how to add new detector models to the framework. The second Pyxel tutorial session took a deeper look into the three advanced modes: (i) parametric mode, to run the pipeline multiple times looping over a range of parameters, (ii) dynamic mode, to simulate time-dependent effects, and (iii) calibration mode, to optimise models or detector parameters to fit target datasets. The tutorial notebooks are available online for anyone who would like to try them out[2].

Demographics

The Science Organising Committee was a small group made up of the Pyxel developers at ESO and ESA. It was decided early on that the workshop should be free, 100% online, and open to anyone to submit an abstract so as to ensure the broadest participation possible. All abstracts submitted to DeMo were excellent, so all submissions were scheduled in one of the scientific blocks, ensuring talks from a range of career levels from students onwards. We did not collect demographic data at workshop registration; however, we held a post-workshop survey that approximately one third of the 270 workshop participants completed.

The profiles of the participants who took part in the post-workshop survey were:
- 50% early career and 50% mid-late career;
- 77% male, 14% female, and 2% diverse (7% no response);
- 47% university and 44% research/government organisation, < 8% from industry.

Additionally, based on the affiliations given at registration, there were participants from five continents, with speakers from North America, Europe and Asia. The online format of the workshop allowed a much broader geographic participation than is usually seen at in-person detector conferences, with peak participation of 150 simultaneous talk viewers and 100 simultaneous instances of the Pyxel tutorial notebooks running. Three of the 22 talks were given by women, matching the participant demographics. Figure 2 is a conference "photo" of some attendees at one of the virtual talks.

We also collected data on the professional activities of the participants and found that around 80% are involved in detector simulation activities or detector characterisation, and the majority are involved in instrument development, with many detector engineers. The full list of participants with names and affiliations and all presentations are now openly available online on the event website[3].

Conclusions and way forward

Overall the DeMo2021 workshop was a success in terms of the number of participants, the quality of the presentations, and the engagement of the participants, but above all because it accomplished its main goal of building a community of scientists and engineers who are interested in modelling detector effects and simulating instruments for astronomy and beyond. At the end of the workshop, everyone (including the organisers!) had learned about a huge number of detector models and simulation tools that might be useful for their own work.

During the workshop we had good interaction between participants on the workshop Discord server, but the post-workshop survey indicated that only 67% of participants felt engaged with the other participants. Future versions of this workshop, whether online, hybrid, or in-person, will have more interactive sessions so that workshop participants can get to know each other outside of the strict format of plenary talks.

The vast majority (98%) of those who responded to the survey felt welcome at the workshop and are interested in participating in a future version of this workshop. The survey brought some interesting information which will guide the organisation of the next iteration of this workshop: for example, 66% would like an event every year and 33% every two years, 55% are interested in a hackathon component, and 89% would like tutorials for some of the other simulations tools presented at DeMo.

Acknowledgements

The organisers would like to thank the European Intergovernmental Research Organisation forum (EIROforum) and CERN in particular for providing hosting for the conference website.

Links

[1] Pyxel website: https://esa.gitlab.io/pyxel/
[2] Pyxel tutorials: https://gitlab.com/esa/pyxel-data
[3] DeMo workshop website: https://indico.cern.ch/event/1026001/