Report on the

# ESO Data Simulation Workshop

held at ESO Headquarters, Garching, Germany, 14–15 April 2016

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**The role of simulated data is increasing rapidly across all phases of instrumentation projects, from design to scientific exploitation. The many commonalities among ESO instruments, their reduction software and archival products, makes it especially worthwhile to exchange knowledge between their instrument teams. The data simulation workshop was the first of its kind to bring together the ESO instrument simulator community and a brief overview of the workshop is presented. The participants expressed strong interest in continuing to exchange knowledge in this area.**

End-to-end detector array simulations of observation and calibration data are applied in many phases of instrument projects, from the assessment of instrument performance, optimisation of instrument design, validation of science cases, preparation of the exposure-time calculators and observing tools to evaluation and testing of data reduction algorithms, optimisation of observing and calibration strategies, as well as for the design of physical-model driven calibrations.

The purpose of the data simulation workshop was to provide a forum for specialists from the instrument consortia and from ESO engineering departments, to exchange information, methods, and experience about their respective simulation approaches and results. Around 50 participants from about ten different institutes and ESO attended, and a videoconference connection allowed participants at four other institutes, in Marseilles, Oxford, Groningen and Innsbruck, to contribute to the workshop The workshop was structured over two half days, with 11 talks and two lively discussion sessions. On Thursday evening, dinner at an Indian restaurant in Garching provided a relaxed setting for continuing discussions.

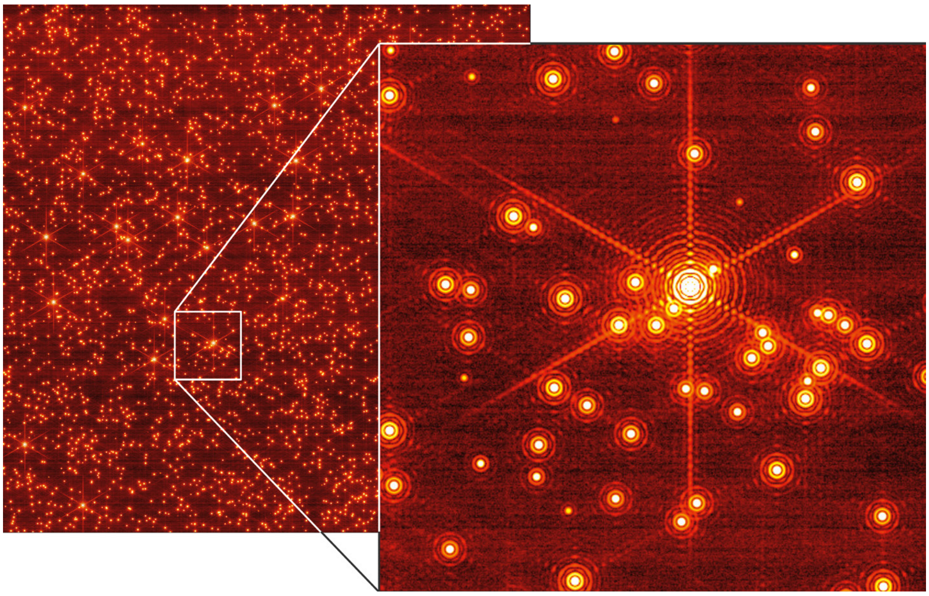


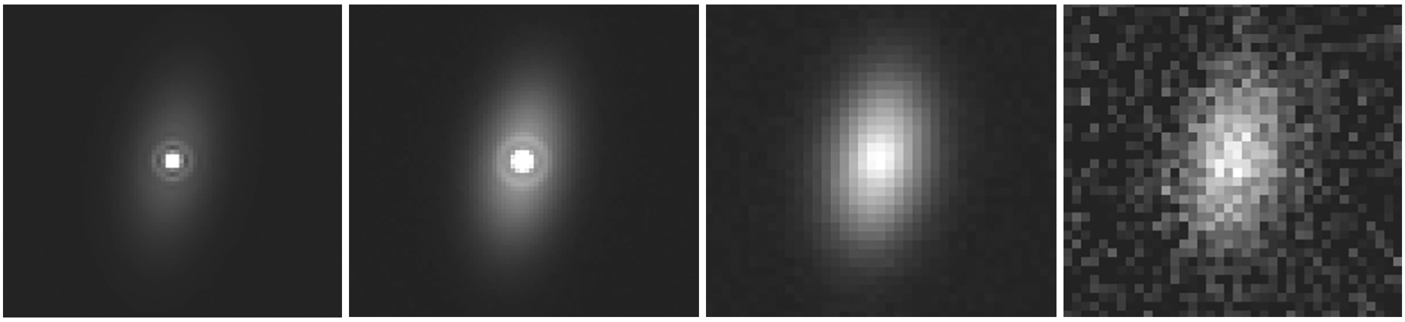

Figure 1. A simulated MICADO observation of a ~ 2000 $M_\odot$ open cluster in the Large Magellanic Cloud produced with SimCADO. The left image shows the raw readout from the central H4RG infrared detector chip in the MICADO detector array. The SimCADO package simulates all aspects of the optical train including the atmosphere, telescope optics, various adaptive optics correction modes and the MICADO optical design as well as the detector characteristics.

## Workshop themes

The first half-day included talks by the instrument consortia, presenting the intended usage, status and current results of their simulation projects. The projects represented included the European Extremely Large Telescope (E-ELT) instruments HARMONI (first light integral field spectrograph), MICADO (first light adaptive optics imager) and METIS (first light mid-infrared imager and spectrograph), as well as the spectroscopy survey facilities 4MOST (4-metre Multi-Object Spectroscopic Telescope) and MOONS (Multi-Object Optical and Near-infrared Spectrograph). While some projects are already completed, like the Virtual MOONS simulation (Li Causi et al., 2014), a number of first results were shown for the MICADO (Leschinski et al., 2016) and METIS (Schmalz et al., 2012) instruments; see Figures 1 and 2 respectively. Many teams are building upon the experience acquired in previous simulation projects: for instance the Multi-Unit Spectroscopic Explorer (MUSE) instrument numerical model (Jarno, 2012) is being used in the development of HARMONI.

Time was also reserved for discussion sessions. During the first day, the topics of discussion covered configuration control of the projects, sharing of common models and data, and the validation of models. The first topic of discussion was the integration of simulations within and between the projects, in terms of change and configuration control. Shared repositories of simulation results for the common parts, such as telescope wavefront errors or adaptive optics simulations, were also discussed. Since all the simulation projects presented make use of sky radiance and transmission data from the Austrian in-kind sky radiance model (Noll et al., 2012), a programmatic interface to the model, as a complement to the web application[1] *Skycalc*, was addressed. The validation of the simulations was also a topic of interest. Different approaches like cross-instrument modelling were proposed. The respective advantages of faster, but simpler simulations versus advanced models based on Fourier optics were also discussed.

During the second day, presentations were provided by ESO engineers on aspects of E-ELT modelling, including telescope wavefront errors, telescope vibrations, and adaptive optics modelling



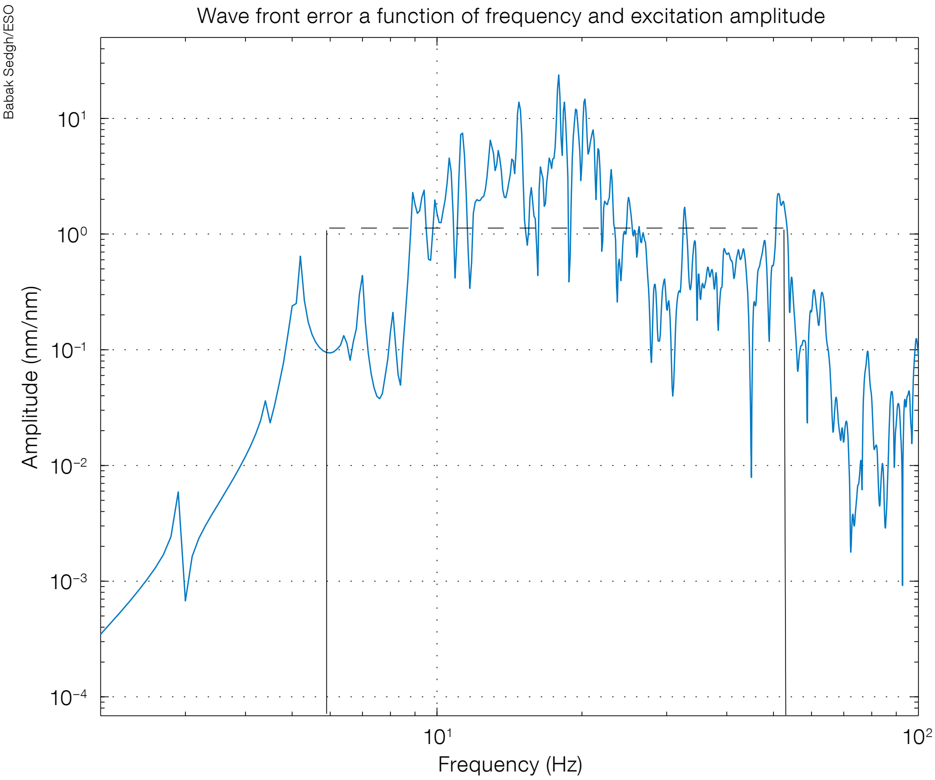
Jeff Meisner/Leiden Observatory

Figure 2. Using a model of a star surrounded by cooler circumstellar material, the METIS simulator predicts detector images using four different camera filters (from left to right) *L'*-band (3.8 μm), *M*-band (5 μm), *N*-band (10.7 μm), and *Q*-band (17.7 μm). At shorter wavelengths the hotter star dominates; at longer wavelengths the nebulous component is brighter and the instrument sensitivity decreases.

and point spread function simulation. The main philosophy for modelling and simulation of the E-ELT was discussed and presented. The project deliberately avoids complex end-to-end modelling. Instead, aspects of the temporal and spatial frequencies for the dynamics and control loops and the perturbations acting on the telescope are explored. The analysis and simulation environments are split into three different simulation toolkits: 1) active optics and phasing toolkit; 2) telescope dynamical and control toolkit; 3) adaptive optics toolkit (Octopus). This approach provides more flexibility to adjust the models to dedicated purposes and also reduces the computational effort. A model-based vibration sensitivity analysis and budgeting using the dynamical and control toolkit was presented (Figure 3).

Figure 3. Sensitivity response of the amplitude of the wavefront error (WFE) with the vibration frequency from the telescope pier.

Babak Sedgh/ESO




A session on physical-model driven calibration presented results obtained in the area of data quality control and science reduction for the CRyogenic Infra-Red Echelle Spectrometer (CRIRES), the Ultra-violet Visible Echelle Spectrograph (UVES) and the X-shooter instruments (Bristow, 2010). The Austrian in-kind sky radiance model, used by all ongoing instrument simulation projects, was also presented, and a specific discussion on modelling of infrared detectors concluded the workshop.

The slides of all talks are provided on the workshop web page[2]. The workshop was a very fertile platform for the exchange of practical and theoretical information among the participants. The participants expressed their interest in a continuation of this type of meeting and further sharing of paper references, methods and tools useful for data simulations.


## Acknowledgements

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## References


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## Links

[1] Skycalc web interface to the Austrian in-kind sky radiance model: https://www.eso.org/observing/etc/skycalc/
[2] Workshop programme, list of participants and presentations: http://www.eso.org/sci/meetings/2016/simu2016.html