Usage of an End-to-End Simulator for Instrument Operations: Application to the Euclid Mission

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Abstact

End-to-End mission performance Simulators (E2ES) enable the generation of simulated output data for selected test scenarios to support the assessment of the mission performance. We here present the designed architecture of an E2ES aimed to support instrument operations and an implemented prototype, providing basic functionalities, with some preliminary results. The Euclid Mission has been selected as test case.

The Euclid Mission

Euclid is an **European Space Agency** (ESA) mission aimed to understand the nature of the dark Universe. Observations conducted on the **Cosmic Microwave Background** (CMB) Radiation proved the existence in our Universe of two dominant components whose nature is entirely unknown [1]:

- ▷ **Dark Matter** (26.8 %)
- ▷ **Dark Energy** (68.3 %)

Euclid will investigate the distance-redshift relationship and the evolution of cosmic structures by means of two instruments:

- ▷ **VIS**: high quality images to carry out the weak lensing galaxy shear measurements;
- ▷ **NISP**: redshift of galaxies measurements.

E2E Simulations

End-to-End Mission Performance Simulator (E2ES) tools are highly desirable during instrument design and before the earliest test campaigns.

An **E2ES** is a set of algorithms and computer programs that reproduce the expected mission performance in order to:

- ▷ Assess mission performance;
- ▷ Support the operation preparation and validation;
- ▷ Support the consolidation of technical requirements and design;
- ▷ Evaluate the fulfillment of requirements by the mission.

E2E Mission Performance Simulators have been widely used, especially for **Earth Observatory** (EO) missions.

The **modular design** of these simulators allows the evolution of the E2ES in future phases.

E2ES Architecture & Requirements

The high-level architecture, considering the Euclid mission as a test case, is designed considering two different versions of the simulator:

- ▷ proto-E2ES (reduced features, limited to NISP);
- ▷ full-E2ES

The resulting scheme of the E2E high level architecture and main components, complied for the Euclid case, is shown in **Figure 1**.

Top level requirements have been spread into the eight simulation modules and applied.

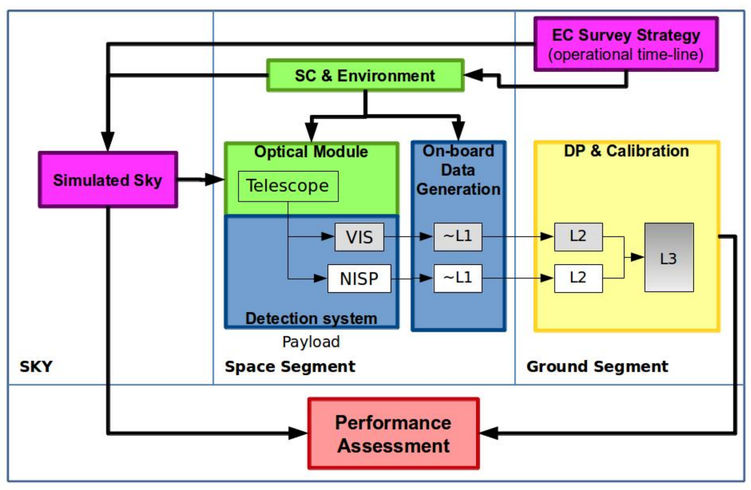


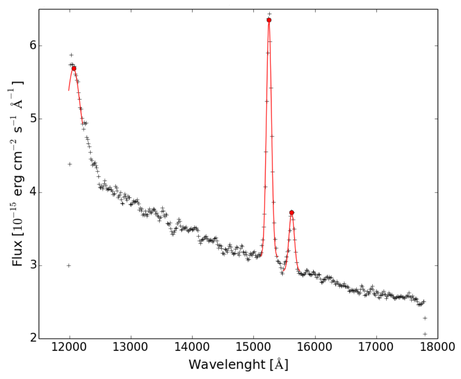
Figure 1: Proto-E2ES high level architecture scheme complied for the Euclid case.

First Implementation

Proto-E2ES has already been implemented and tested. This simplified version provides a basic but representative E2ES simulation focused on **IR spectroscopy** and in particular on **redshift measurements**.

The spectroscopic redshift parameter is the main observable needed to study one of the main Euclid cosmological probes: the **Baryonic Acoustic Oscillations** (BAO).

The line identification in version 1.0 was left to IRAF (*http://iraf.noao.edu/*). In version 2.0 a dedicated algorithm has been implemented for this task (**Figure 2**).



General information on the proto-E2ES:

- ▷ Current version: 2.0
- ▷ Language: Python
- ▷ Dependences: TIPS [3], aXe [4]
- ▷ To be integrated: ZEUS (See *M. Maris et al.*, ADASS XXVI poster session)

Figure 2:
Spectrum extracted by the aXe software from the TIPS output slit-less images. In red the Gaussian fit of the emission lines identified by the proto-E2ES v2.0 algorithm.

Preliminary results

The prototype has been tested on a **simplified catalog**, shown in **Figure 3**. The full test catalog is covered by four different pointings.

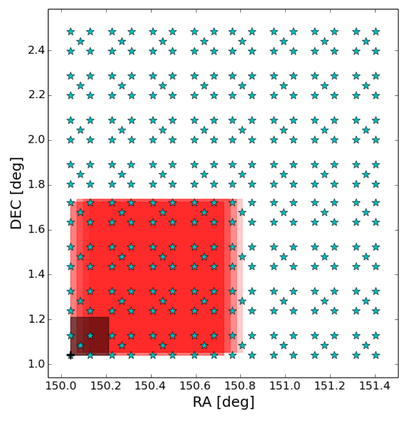


Figure 3:
The test catalog consists in 320 sources, distributed in a regular pattern, all at the same redshift, $z \simeq 1.324$, and at the same magnitude, $m = 15$.

Legenda:

- ▷ **Black cross**: pointing reference pixel (lower-left)
- ▷ **Dark box**: single detector FoV
- ▷ **Red boxes**: full detector array FoV (one for each dither)

The main output of the simulation is shown in **Figure 4**. Each identified line is treated as Hα emission line. A set of z is given for each source.

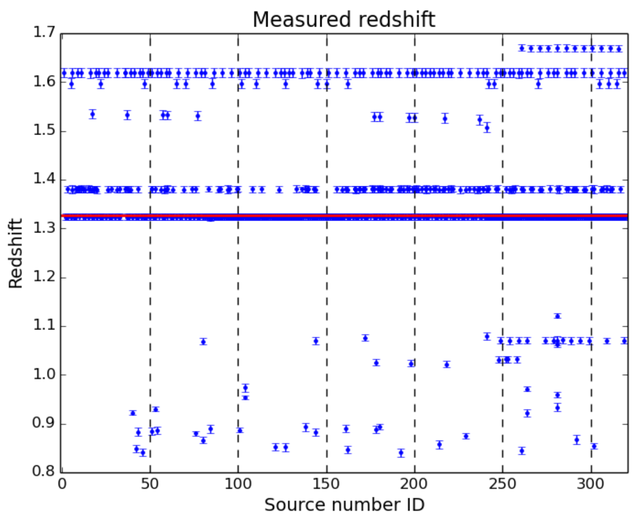


Figure 4: Redshift values measured for each source. The red line represent the reference redshift $z \simeq 1.324$. The correct value is measured in nearly every detected source.

Conclusions

E2E simulators enables the generation of simulated output data for selected test scenarios to support the assessment of instrument configuration changes on the mission performance.

We propose our E2ES as a tool for the **Instrument Operation Teams** (IOTs) to simulate test scenarios in order to assess the mission performance.

The implemented prototype provides a basic but representative end-to-end simulation.

Acknowledgments

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References

[1] Planck Collaboration. *Planck 2015 results. I. Overview of products and scientific results.* Astronomy & Astrophysics, arXiv:astro-ph/1502.01582

[2] Euclid Red Book Editorial Team. *Euclid Definition Study Report - revision 1.* January 2011

[3] Ealet A., Kermiche S. and Zoubian J., *TIPS: A prototype for pixel simulations of the Euclid NISP detector.* issue 2.3, C.P.P.M., Nov. 2012.

[4] Kümmel M. and collaborators, *The Slitless Spectroscopy Data Extraction Software aXe.* The Astronomical Society of the Pacific, Vol. 121, 2009, pp. 59–72.