PROCEEDINGS OF SCIENCE

Selection of the optimal pointing pattern for the Self-Calibration field of the Euclid mission

I. Risso [a,*], S. Caprioli [a], M. Schirmer [c], and S. Davini [b]on behalf of the Euclid Consortium

[a] *Università degli studi di Genova, Via Dodecaneso 33, Genova, Italy*
[b] *INFN sezione di Genova, Via Dodecaneso 33, Genova, Italy*
[c] *Max Planck Institute for Astronomy, Königstuhl 17, Heidelberg, Germany*
E-mail: ilaria.risso@ge.infn.it, silvia.caprioli@ge.infn.it, schirmer@mpia.de, stefano.davini@ge.infn.it

The *Euclid* mission of the European Space Agency (ESA), scheduled for launch in 2023, is designed to investigate the nature of Dark Matter and Dark Energy. From the privileged position of the L2 Lagrange point, *Euclid* will cover about 15 000 deg^2 out to a redshift $z \sim 2$, making it the largest redshift survey ever performed [1]. *Euclid* will use two main probes to constrain the cosmological parameters: weak gravitational lensing and galaxy clustering, which require the measurement of the shapes and of the three-dimensional distribution of galaxies, respectively. The precision required for these scientific goals dramatically depends on a complete calibration of the scientific instruments, both on the ground and in flight. In this work, we describe our procedure to determine the optimal set of pointings for *Euclid*'s in-flight Self-Calibration procedure.

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*Speaker

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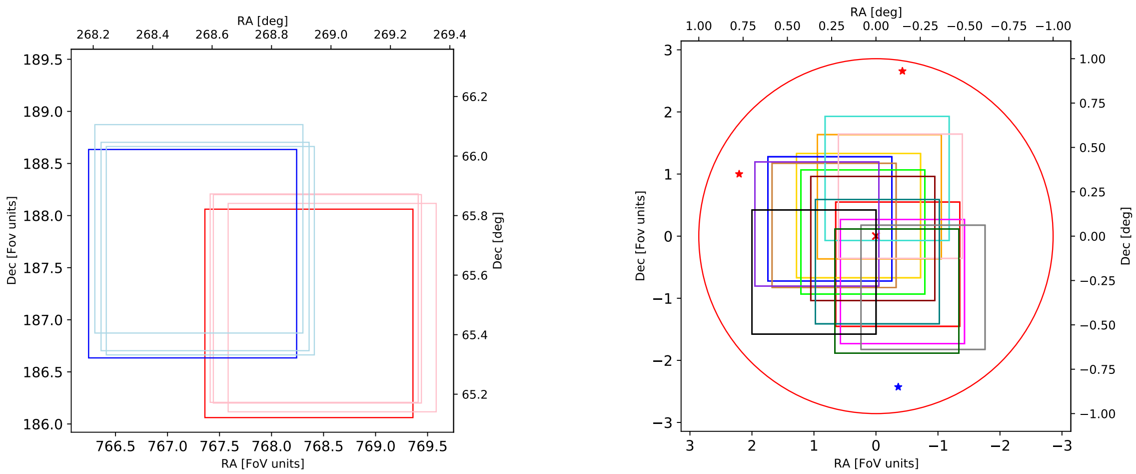

Figure 1: *Left panel*: Example of two main pointings (bold lines) in the sky and their related dithers (lighter lines). *Right panel*: The 15 main pointings of the best pointing sequence for the Self-Calibration (dithers are omitted for sake of clarity). Each square represents an Euclid FoV. The encircled area represents the Self-Calibration field. The three asterisks refer to spectrophotometric calibrators in the area.

1. The Self-Calibration

The core science objectives of the *Euclid* mission require a very accurate and precise calibration of the scientific payload, both on ground and in flight. The work presented in this paper is concerned about the accuracy of *Euclid*'s spectro-photometric measurements. The illumination of the focal plane (FP) is in general not perfectly uniform, and it may change over time due to molecular contamination from outgassing. Using monthly observations of the Self-Calibration field, the large-scale illumination of the FP and its temporal evolution are monitored by measuring a large number of stellar fluxes.

The procedure exploits multiple observations of the same astrophysical sources in different positions on the focal plane, constraining the illumination variation on different spatial scales. The goal of this study is to select the optimal pointing pattern for these Self-Calibration observations. During the scientific survey each pointing will be made up of four, slightly offset ("dithered") frames [2]. This allows us to compensate for inter-detector gaps, to reject cosmic rays, and to decontaminate the overlapping 1st spectral orders in the dispersed images. The Self-Calibration must properly sample all spatial scales between the dither scale ($10''$) and the size of the field-of-view (FoV = $0.7°$). To this end, the Self-Calibration field is observed with 60 dithered pointings, covering a 3.1 deg^2 circular field in a pseudo-random fashion. In this work, we test different random pointing sequences, and select the one that most uniformly samples the Self-Calibration field.

2. Selection of pointings: simulation and metrics

We summarise the selection procedure among a statistical sample of surveys as follows:

- generate 1000 Self-Calibration-like random surveys;
- select the 20 surveys that most uniformly cover the spatial scales of interest on sky;

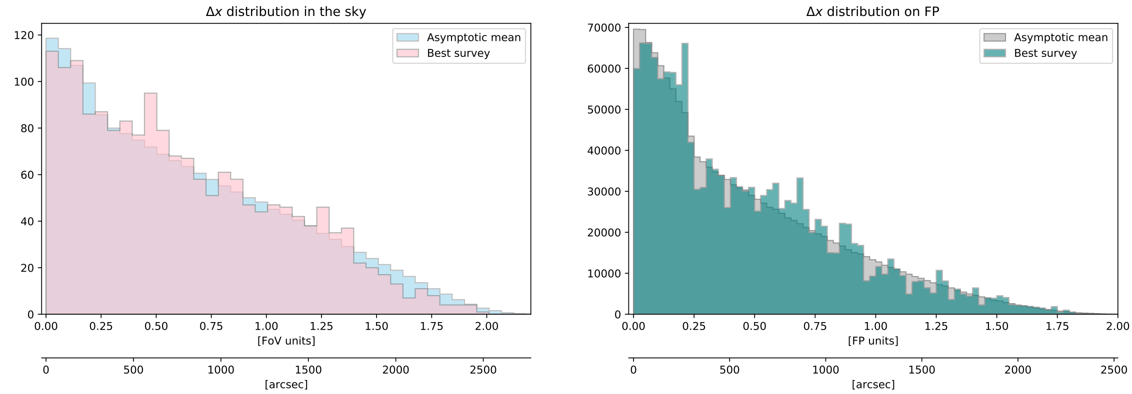

Figure 2: *Left Panel:* best-survey distribution of the x component of all pointings pair distances in the sky. The bump below $300''$ is due to the dithers. *Right panel:* best-survey distribution of the x component of all pair distances between repeated records of the same sources on the FP. The bump below $300''$ is due to the dithers.

- among these, select the survey that samples the FP in the best manner.

The 60 pointings of each survey can be grouped into 15 main pointings having four dithers each (*left panel* in Fig. 1). The main pointings are uniformly extracted around the centre of the Self-Calibration field within one FoV ($\Delta x,\ \Delta y \in [-\mathrm{FoV}, +\mathrm{FoV}]$); the corresponding three dithers are uniformly extracted around their main pointing, within a smaller range of angular scales ($\Delta x,\ \Delta y \in [10'', 300'']$).

In order to evaluate the goodness of a survey, we define two metrics:

- **Sampling of all spatial scales in the sky:** The set of pointings should properly cover the relevant angular scales, that is from the smallest dither offset to the full FoV. We compute the pair distances between the centres of the various pointings.
- **Sampling of all spatial scales on the Focal Plane:** The FP must be sampled on all relevant scales. During the calibration survey, each source is observed many times in different positions on the focal plane. We compute the pair distances between the repeated observations of the same sources.

We exploit both metrics in the best-survey selection procedure. First, we compute the distribution of the pair distances $(\mathrm{d}x, \mathrm{d}y)$ between the pointing centres in the sky for each realization. We choose the 20 surveys that have the smallest discrepancy from the ideal case. Then, we compute the distribution of the pair distances $(\mathrm{d}x, \mathrm{d}y)$ between different records of the same source on the FP, for all observed sources. Among the 20 surveys selected before, we choose the one that deviates least from the ideal case.

3. The best pointing pattern

In the *right panel* of Fig. 1 we present the main pointings of the best pointing sequence, identified as explained above. It is evident that they are distributed over the full range of angular scales as required, from the smallest dither scale to the entire FoV. Fig. 2 shows the distribution of the metrics for the selected pointing sequence. This "*best*" pointing set means that this is the survey with the smallest discrepancy with respect to the asymptotic case, in which the Self-Calibration field was observed thousands of times by thousands of Self-Calibration-like surveys.

The best pointing sequence was also tested through realistic simulations of the Self-Calibration, to ensure an accurate reconstruction of the illumination variation over the entire FP.

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