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

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The Euclid mission

The **Euclid mission** of the European Space Agency (ESA), scheduled for launch by the end of 2023, is designed to investigate the nature of **Dark Matter** and **Dark Energy**.

From the privileged position of the L2 Lagrangian point, Euclid will cover about **15000 deg^2** (about 36% of the Sky) up to a redshift **z ~ 2**, making it **the largest redshift survey ever performed**.

Euclid will use two main probes to constrain the cosmological parameters: **Weak gravitational Lensing** and **Galaxy Clustering**, which respectively requires the measurement of the shapes and of the three-dimensional distribution of galaxies.

For achieving these tasks, **two instruments** are mounted on board:

- **VIS**: a **visible imager** that will measure the shape deformations of 1.5 billion galaxies.
- **NISP**: a **near-infrared** (900 − 2000 nm) **photometer and spectrometer**. In photometric mode, it will estimate the photometric redshifts of the galaxies imaged by VIS; in spectroscopic mode it will be used to observe the spectra of 50 million galaxies.

Fig.1 A view of the Euclid flight module at Thales Alenia Space, Torino (IT). *Photos copyrights: ©Thales Alenia Space, Esa/ATG Medialab, Euclid Consortium*

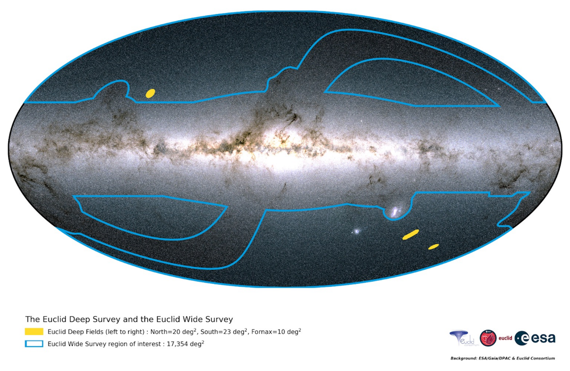


Fig.2 Graphic representation of the Euclid scientific survey. Copyright: ESA/Gaia/DPAC; Euclid Consortium. Acknowledgment: Euclid Consortium Survey Group.

The Self-Calibration

The precision required for the scientific goals of Euclid dramatically depends on **a complete calibration of the scientific instruments**, both on the ground and in flight.

The **detector illumination** on the Focal Plane may not be uniform and **can change with time** during the mission (e.g. because of ice deposition and in general non-uniform transmission of light introduced by the telescope optics).
A monthly in-flight self-calibration procedure is required in order to monitor in time the large-scale illumination variation on the FP.

Each month, the same sky area (i.e. the self-calibration field) is observed. Its position provides both a sufficient number of galactic stars and a low background level from the galactic disk.

The self-calibration procedure exploits the **multiple observations of the same astrophysical sources in different positions on the focal plane**, in order to constrain the illumination variation on the corresponding spatial scales.

During the scientific survey each pointing will be made up of **four close frames** (i.e. **dithers**, Fig.4). This allows to compensate for the dead regions between the FP detectors, to discriminate cosmic rays signal and to help disentangle overlapping spectra during the spectroscopic measurement.

The self-calibration should provide a **proper sampling of all spatial scales** between 10" and the **Field of View size** (~ 0.7°). This is achieved by observing the Self-cal field through **60 dithered pointings**, covering a 3.1 square degrees circular field in a pseudo-random fashion.

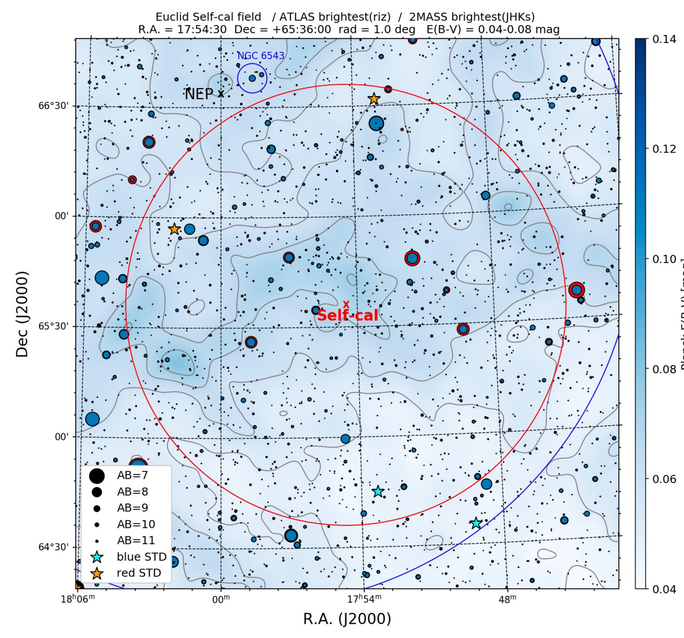
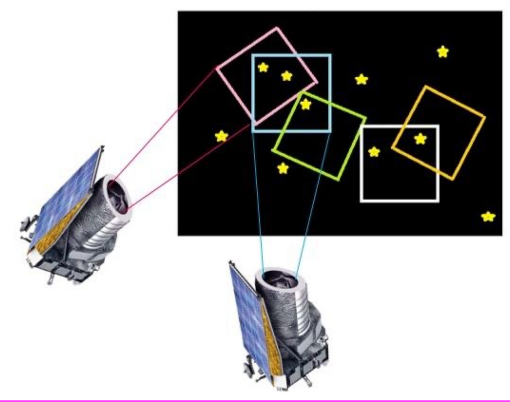


Fig.3 *Top* - The Self-Calibration field. *Bottom* – Scheme of the different overlapping poitings performed in order to spot the same source in different position on the FP.



Simulations for the pointings selection

In this work, we test different random pointing sequences and we select the best one based on the uniformity of the spatial sampling.

We can sum up the selection procedure as follows:

- generate 1000 self-calibration-like random surveys
- select the 20 surveys that most uniformly cover the spatial scales of interest **in the Sky**
- among them, select the best pointing sequence according to the goodness of the sampling **of the Focal Plane**

The 60 pointings of each survey can be grouped into **15 main pointings x 4 dithers**:

- the main pointing is uniformly extracted around the centre of the Self-Cal field: Δx, Δy ∈ [-FoV, FoV]
- the other three dithers are uniformly extracted around the corresponding main pointing: Δx, Δy ∈ [10", 300"]

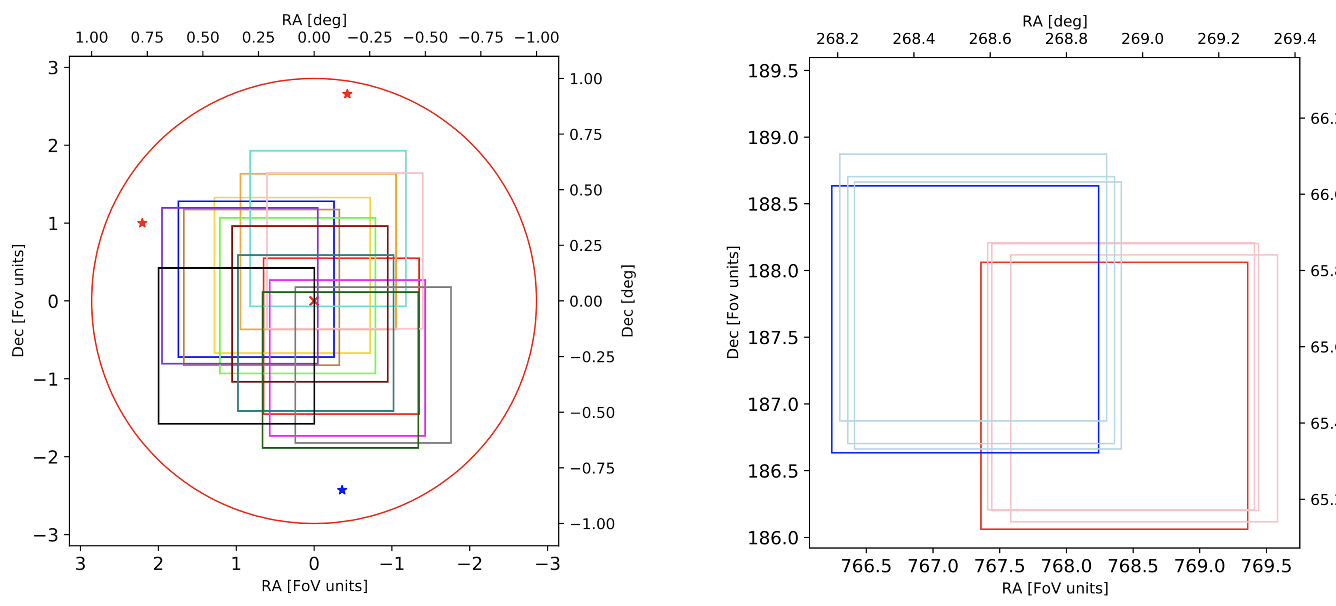


Fig.4 *Left* – Representation of 15 main pointings extracted within the Self-Cal field area. *Right*– Example of two main pointings with their corresponding dithered frames.

Definition of the metrics for the selection

In order to evaluate the goodness of each pointing realization 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 [dither scale - FoV scale].
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.**

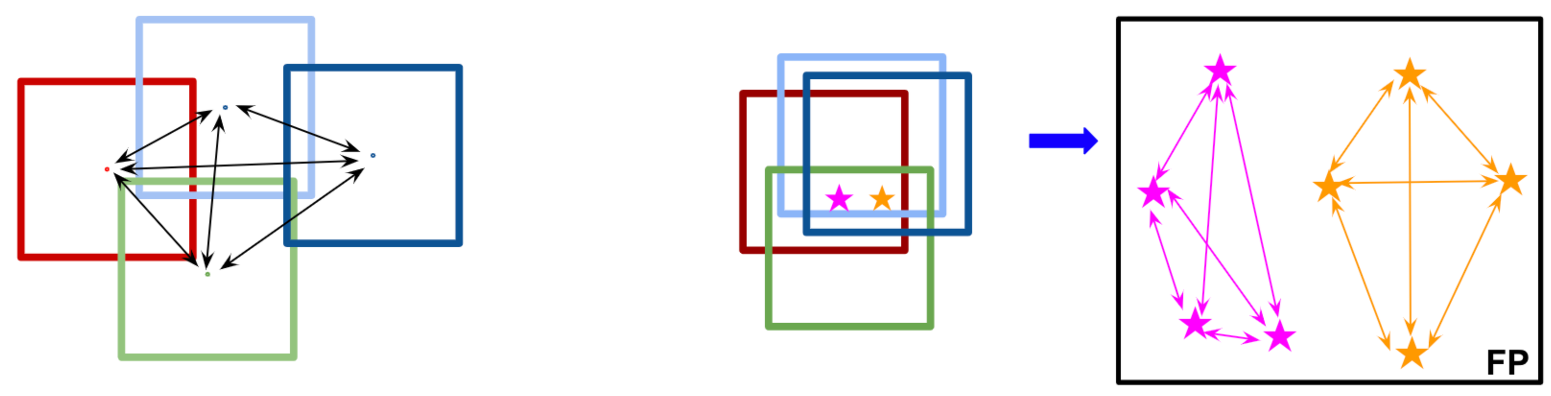


Fig.5 *Left* – Example of pair distances between the centres of different pointings. *Right*– Example of pair distances between reapeted observations of the same two sources on the FP.

The selection protocol

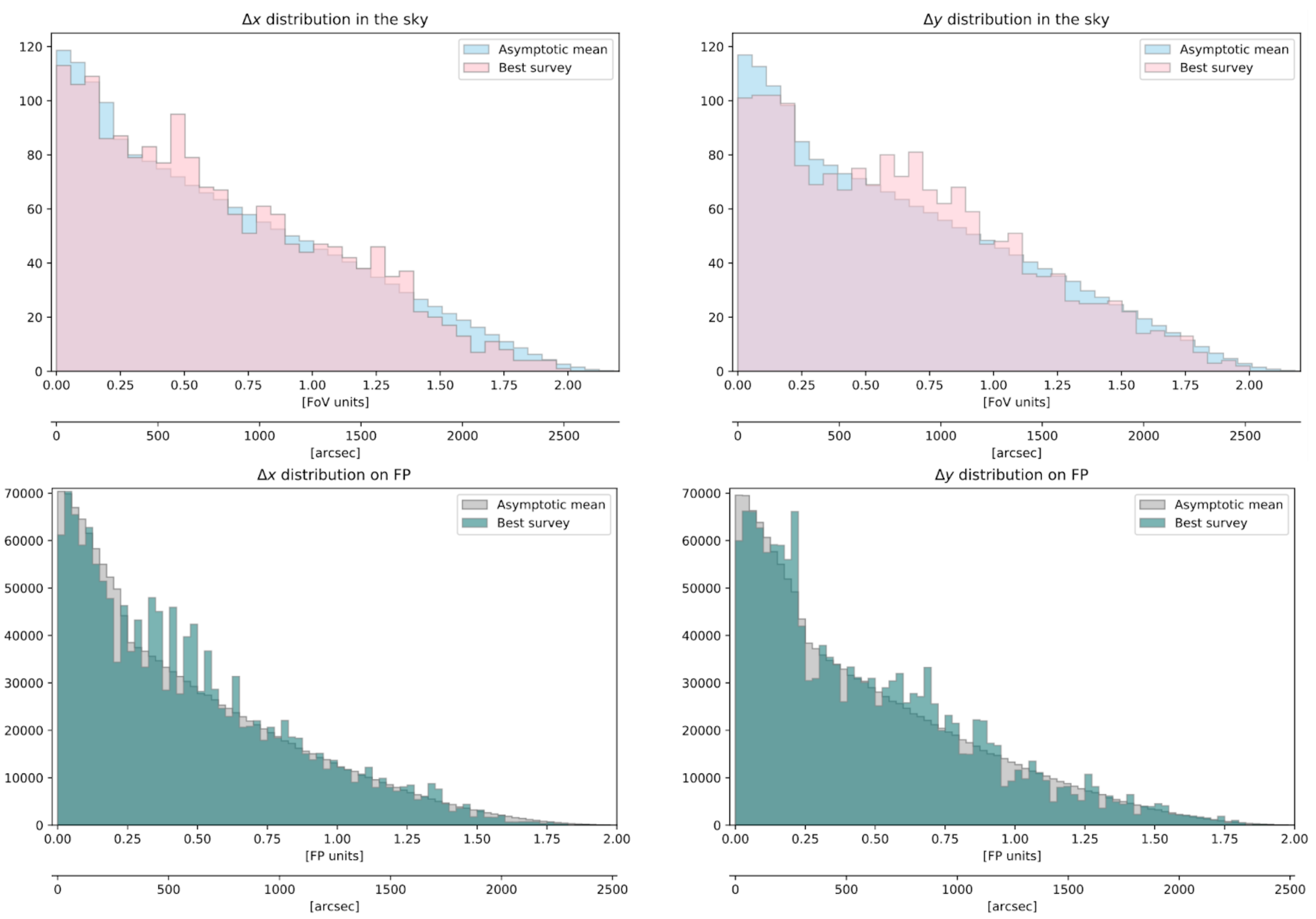
1) First, we compute the distribution of the pair distances (dx,dy) between the pointing centres **in the Sky** for each realization.

We choose the 20 surveys that show less discrepancy with the ideal case.

2) Then, we compute the distribution of the pair distances (dx,dy) between different records of the same source **on the Focal Plane** (for all observed sources).

Among the 20 surveys selected before, we choose the one that shows less discrepancy with the ideal case.

The Best Pattern



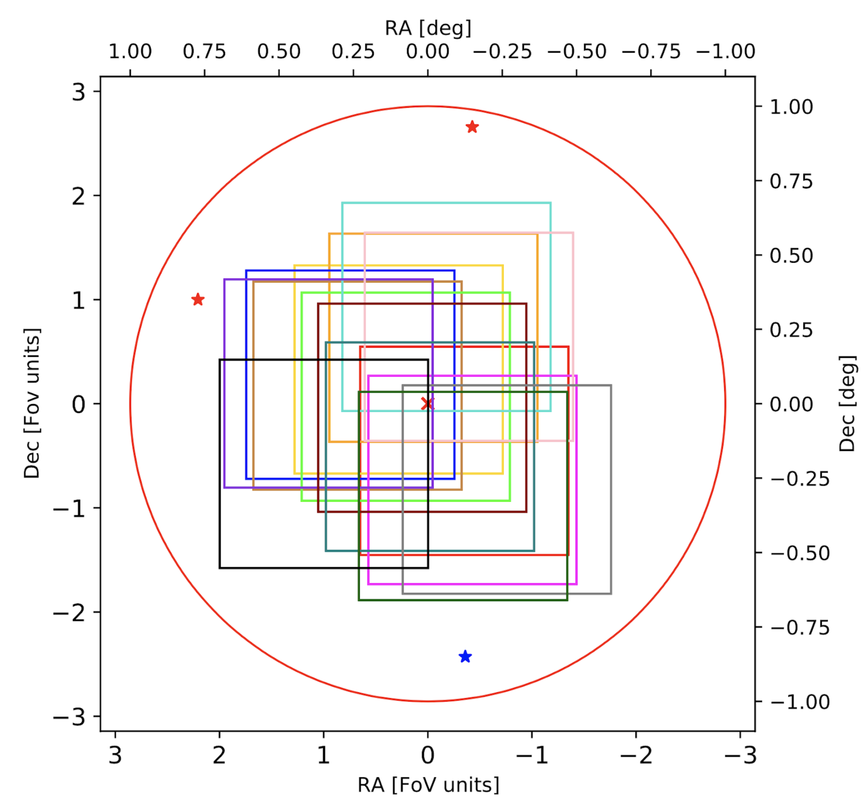


Fig.5 The plots refer to the Best Survey, that is the one that was chosen after the selection procedure. *Left-Up:* distribution of the pair distances between the pointing centres in the Sky. Both the large scales and the small ones related to the dithers are sampled. *Right*– distribution of the pair distances between different records of the same source on the Focal Plane (for all observed sources). Both the large scales and the small ones related to the dithers are sampled.

References

[1] Euclid Definition Study Report, arXiv:1110.3193

[2] "Euclid Near Infrared Spectrometer and Photometer instrument concept and first test results obtained for different breadboards models at the end of phase C", Proc. SPIE 9904, Space Telescopes and Instrumentation 2016: Optical, Infrared, and Millimeter Wave, 99040T (29 July 2016); https://doi.org/10.1117/12.2232941

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