

Euclid Quick Data Release (Q1)

From images to multiwavelength catalogues: the *Euclid* MERge Processing Function[★]

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ABSTRACT

The *Euclid* satellite is an ESA mission that was launched in July 2023. *Euclid* is working in its regular observing mode with the target of observing an area of 14 000 deg² with two instruments, the Visible Camera (VIS) and the Near IR Spectrometer and Photometer (NISP) down to $I_E = 24.5$ mag (10σ) in the Euclid Wide Survey. Ground-based imaging data in the *ugriz* bands complement the *Euclid* data to enable photo- z determination and VIS PSF modeling for weak lensing analysis. *Euclid* investigates the distance-redshift relation and the evolution of cosmic structures by measuring shapes and redshifts of galaxies and clusters of galaxies out to $z \sim 2$. Generating the multi-wavelength catalogues from *Euclid* and ground-based data is an essential part of the *Euclid* data processing system. In the framework of the *Euclid* Science Ground Segment (SGS), the aim of the MER Processing Function (PF) pipeline is to detect objects in the *Euclid* imaging data, measure their properties, and MERge them into a single multi-wavelength catalogue. The MER PF pipeline performs source detection on both visible (VIS) and near-infrared (NIR) images and offers four different photometric measurements: Kron total flux, aperture photometry on PSF-matched images, template fitting photometry, and Sérsic fitting photometry. Furthermore, the MER PF pipeline measures a set of ancillary quantities, spanning from morphology to quality flags, to better characterise all detected sources. In this paper, we show how the MER PF pipeline is designed, detailing its main steps, and we show that the pipeline products meet the tight requirements that *Euclid* aims to achieve on photometric accuracy. We also present the other measurements (e.g. morphology) that are included in the OU-MER output catalogues and we list all output products coming out of the MER PF pipeline.

Key words. Galaxies:photometry, Galaxies:morphology, Catalogues, Methods:data analysis

1. Introduction

The European Space Agency’s *Euclid* mission (Euclid Collaboration: Mellier et al. 2024) is dedicated to studying the dark Universe through a photometric and spectroscopic survey of the extragalactic sky at visible and near-infrared wavelengths. Successfully launched from Cape Canaveral on July 1 2023, the *Euclid* satellite aims to gather data for the Euclid Wide Survey (EWS) and the Euclid Deep Survey (EDS), both described in details in Euclid Collaboration: Scaramella et al. (2022), by means of two instruments, the Visible Camera (VIS, Euclid Collaboration: Cropper et al. 2024) and the Near-Infrared Spectrometer and Photometer (NISP, Euclid Collaboration: Jahnke et al. 2024).

To efficiently manage and process the immense volume of data generated by *Euclid*, the Euclid Consortium (EC) has developed a suite of software Processing Functions (PFs) forming the *Euclid* Science Ground Segment (SGS). Organizational Units (OUs) are responsible for developing, maintaining and validating the PFs. A detailed description on how the SGS processing is organized and how the OUs interact with each other is found in Euclid Collaboration: Aussel et al. (2025).

The MER PF realises the merging of photometric information from VIS and NISP, together with information from external photometric surveys: DES (Abbott et al. 2021), CFIS (Ibata et al. 2017), Pan-STARRS (Magnier et al. 2020), WHIGS and WHISHES (see Aihara et al. 2017), Rubin-LSST (Ivezić et al. 2019). The main objective of the MER PF is to provide source catalogues containing object information relevant for *Euclid*’s science goals.

The primary requirement for which the MER PF has been designed is the production of a image mosaics, and a photometric catalogue of sources. To provide this, it starts from VIS and NISP calibrated frames, processed by OU-VIS (Euclid Collaboration: McCracken et al. 2025) and OU-NIR (Euclid Collaboration: Polenta et al. 2025) respectively, and external surveys’ stacked frames, processed by OU-EXT (Euclid Collaboration: Aussel et al. 2025), together with related ancillary data and PSF models. Separate object detections are performed on both the photometric VIS and NIR (stacking the three NISP bands J_E , H_E , and Y_E) mosaics. A multi-wavelength flux determination is performed on detected objects with suitable photometric techniques. The final product of the MER processing function is a catalogue of sources with unique identification number, multi-wavelength photometric measurements, and ancillary information (morphological estimates, star/galaxy separation, etc.).

The MER PF also provides the required input, as additional information integrated in the final *Euclid* catalogue, for photometric redshift computation and for spectra extraction for which respectively OU-PHZ (Euclid Collaboration: Tucci et al. 2025) and OU-SIR (Euclid Collaboration: Copin et al. 2025) are in charge as customer OUs of OU-MER. The MER PF catalogues represent also a primary input for shear estimation, which is performed by OU-SHE. The MER products are among the core products delivered in the first *Euclid* data release, Q1 (Euclid Quick Release Q1 2025; Euclid Collaboration: Aussel et al. 2025), and are used in many science papers.

2. The *Euclid* MER software pipeline overview

The MER PF is designed around the concept of pipeline as a chain of Processing Elements (PEs). Each PE represents an atomic block that cannot be split further from a functional point of view. The tasks related to each PE are implemented by one or

* We wish to remember our colleagues Mario Nonino and Stefano Pilo, who played an important role in OU-MER, and, more importantly, in our lives.

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more software components. Source codes are in the official *Euclid* GitHub repository and are available throughout the EC via the Common DEvelopment ENvironment (CODEEN).

The pipeline is in charge of running PEs on the *Euclid* SGS infrastructure and controlling the parallelization scheme. The orchestration is performed via the *Euclid* Infrastructure Abstraction Layer (IAL), which is also in charge of managing the input/output data stream from and to the *Euclid* Archive System (EAS). A simplified MER PF pipeline workflow is shown in Fig. 1.

A standard run of the MER PF pipeline is performed on sky regions called MER tiles, described in Sect. 3.1, fed with the following input:

- the definition of the MER tile to be processed (see Sect. 3.1);
- the list of VIS calibrated frames (both nominal and short exposures, see [Euclid Collaboration: McCracken et al. 2025](#)) intersecting the tile;
- the list of NIR calibrated frames intersecting the tile;
- the list of EXT stacked frames covering the tile;
- a cutout of the Gaia Data Release 3 catalogue ([Gaia Collaboration et al. 2023](#)) with the sources that fall inside the tile;
- a set of configuration files, specifying the parameterisation of the pipeline PEs;
- a set of ancillary files, stored in the Mission Data Base (MDB) data container;
- the trained machine-learning models to be used for source classification;
- a list of quality parameter ranges used to flag invalid output data products.

The MER PF outputs the following products:

- the list of background-subtracted mosaiced images, one for each band, used to measure the source photometry;
- the VIS and NIR background-subtracted mosaiced images used to obtain the list of detected sources;
- the segmentation map containing the spatial pixels associated to each individual source;
- a set of catalogues, storing all the source information measured by the pipeline.

After a first initialisation step, aimed at decompressing and sorting the input images, the MER PF pipeline produces the mosaiced images. The mosaicing step (Sect. 3.2) coadds the VIS and NIR calibrated frames. VIS and NIR stacked images, together with the EXT stacks, are then rebinned so that all the mosaiced images share the same dimensions, image centre and pixel size ($0''.1$). On each mosaic, a background subtraction algorithm (Sect. 3.3) evaluates the background of an input mosaic, subtracts it from the original mosaic, and stores the background-subtracted image in a FITS file. The goal of this step is to remove any remaining residual background, because a flat background is fundamental to obtain precise photometry measurements.

The list of source candidates is extracted from the VIS mosaic and from a stack of the three NIR bands independently (Sect. 4.1). This preliminary segmentation of the image is then refined by an optimal deblending algorithm (Sect. 4.3) in order to obtain the list of sources detected in the VIS mosaic and the one detected on the NIR stack. The two lists are then merged into one single list, taking care of source duplicates (Sect. 4.4); this represents the formal list of sources detected by the OU-MER pipeline.

At this point, the input point spread functions (PSFs) are propagated for each mosaiced image and evaluated at the detected source positions, together with the PSF convolution kernels required by the subsequent photometry steps (Sect. 5).

The list of VIS+NIR detected sources is used as a baseline to force the photometry measurements in the detected loci (Sect. 6). For each source, the MER PF pipeline measures:

- the Kron total flux, measured on the detection mosaics;
- PSF-matched aperture photometry on all the input bands;
- template fitting photometry on all the input bands.

For all the sources detected in the I_E band, the MER PF pipeline provides a measure of the Concentration, Asymmetry, and Smoothness (CAS) parameters (Sect. 7.1), a list of morphological features measured via a machine-learning approach (Sect. 7.3) as well as a point-like probability (that can be used for star/galaxy separation, see Sect. 7.4).

A cataloguing unit then carries out the merging of all the information provided by the previous steps (Sect. 8). The main output of this step is the OU-MER final catalogue of sources with unique identification number, containing object information relevant in the *Euclid* project, in particular to OU-MER's customer OUs, namely OU-PHZ, OU-SIR, and OU-SHE.

Before releasing the output products to the Euclid Archive System (EAS), a final step runs on all the mosaiced images and the final source catalogue, performing a Sérsic fit and adding further photometry and morphology information (Sect. 7.2).

Initially designed as a separate pipeline to be run on the output products of the nominal pipeline, the Sérsic fit module has been integrated rather late into the MER PF processing workflow, after extensive testing and optimization.

With the current Q1 release configuration, taking into account that many PEs run in parallel and some of them make use of more than one processing cores, the total execution time is equivalent to approximately 140 core hours. The mosaicing, background-subtraction, and PSF calculation PEs account for 13% of the processing time. On average, 10% of the time is spent on the detection and deblending PEs. The large majority (75%) of the processing time is spent running the different photometry methods and on the calculation of the PSF transformation kernels.

3. Imaging input and mosaic creation

3.1. *Euclid* tiling

The MER PF pipeline runs on chunks of data called ‘tiles’, with each tile covering a predefined area on the sky. In every OU-MER PF run, all the available *Euclid* data covering the tile region are included in the processing. The *Euclid* tiling solution ([Kümmel et al. 2022b](#)) has a tile placement that is independent of the pattern of the *Euclid* observations and covers the entire sky $-88^\circ 0 < \text{Dec} < +88^\circ 0$ to become independent of the *Euclid* survey plan ([Euclid Collaboration: Scaramella et al. 2022](#)). The tiling solution associates each sky position with exactly one tile. The catalogues resulting from the processing of a set of adjacent tiles do not contain the same object in more than one tile. The *Euclid* tiling assures a certain overlap between two adjacent tiles to guarantee that the tile boundaries do not interfere with computation of the objects’ properties.

In the *Euclid* tiling solution each tile is defined by its central position in (RA, Dec) and size (width, height), and identified by a unique tile identifier. Every tile has an extended area and a core area. While the extended areas of adjacent tiles have an overlap to avoid border problems in the measurements, the core areas of any two tiles do not overlap. The extended areas and the core areas of all tiles cover the entire sky, with the limits mentioned above. The imaging output of OU-MER covers

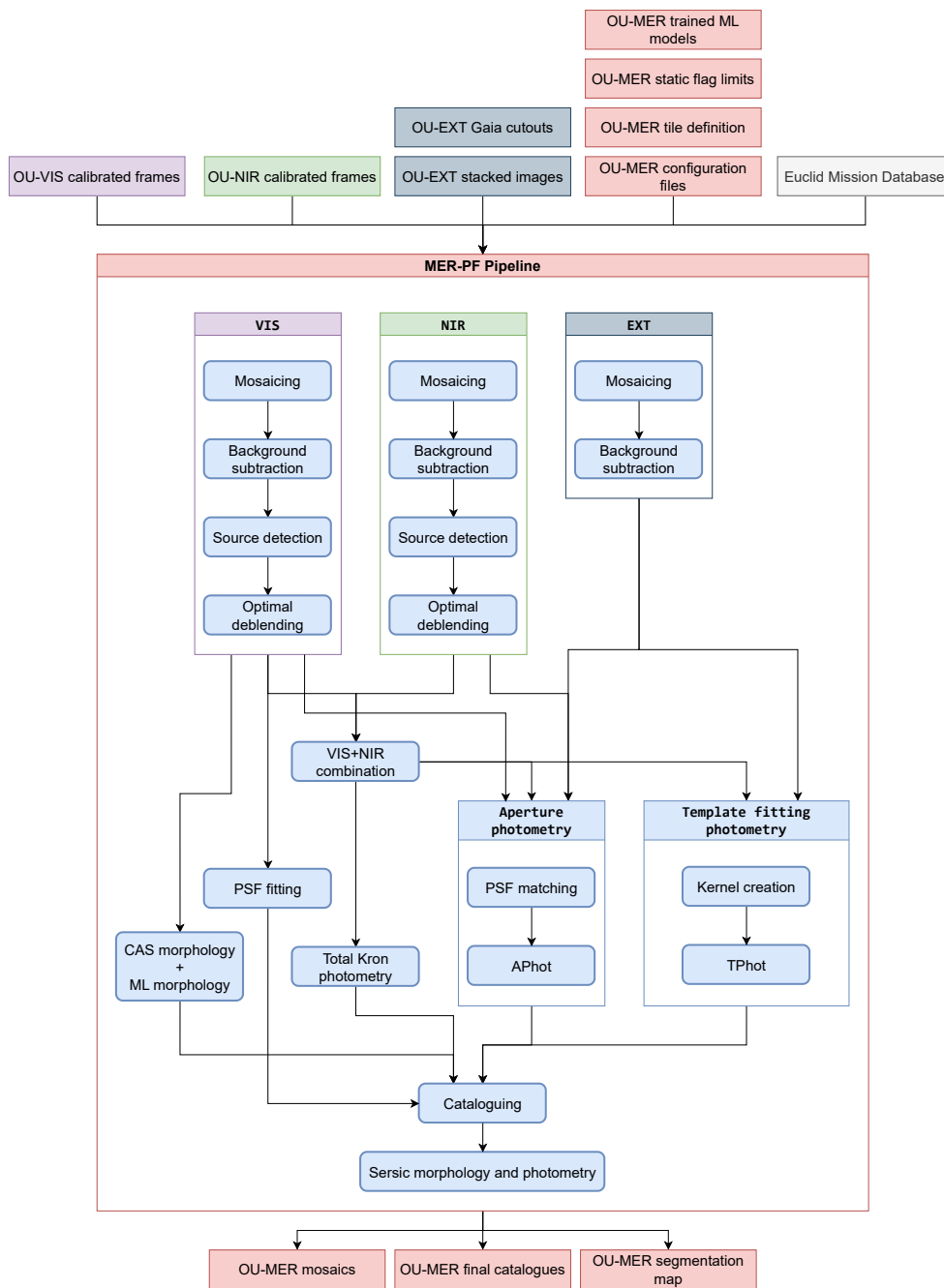


Fig. 1. Simplified workflow of the OU-MER pipeline. The pipeline is fed with a list of input products coming from OU-VIS, OU-NIR and OU-EXT, together with a set of configuration files and auxiliary products. The pipeline performs a mosaicing of input images before generating the source list after a combination of detection and optimal deblending procedures. The pipeline computes photometry and morphology measurements and collects all this information in a set of output catalogues. Those catalogues, together with the reference images, represent the output of the pipeline.

the extended tile area and object detection and property measurements are done on the extended tile area, however, the catalogue output is delivered only for the core area, thus avoiding multiple outputs of the same object. The core areas of the tiles are defined as HEALPix indices (Górski et al. 2005). Figure 2 shows tile 10215949 in Euclid Deep Field North (EDF-N),

with (RA, Dec) = (272°9038602, 66°5) and its centre (green), extended area (blue), and the HEALPix pixels (magenta) defining the core area.

The *Euclid* tiling solution:

- has an extended tile area of $32' \times 32'$ in tangential projection;

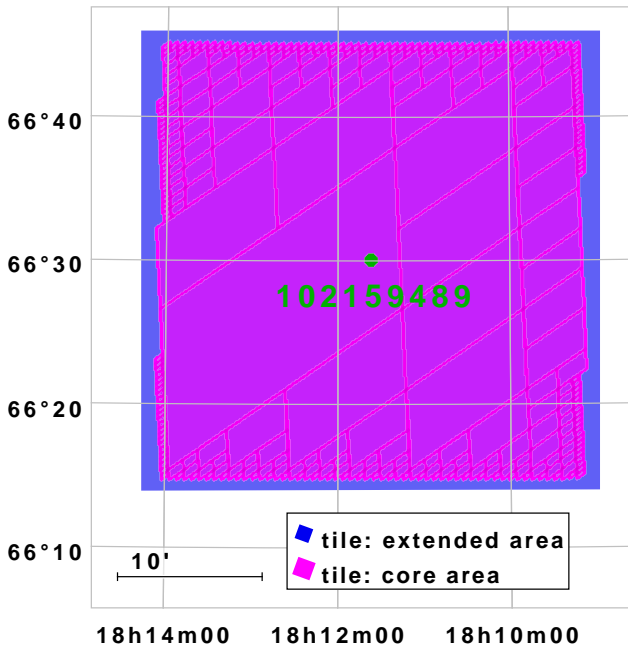


Fig. 2. Example of tile geometry, specifically for EDF-N tile 10215949: centre (green), core area (magenta) and extended area (blue).

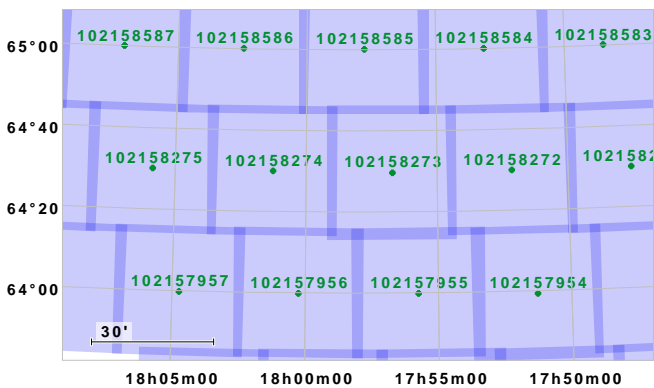


Fig. 3. Example tiling pattern. Notice that, the height of tile 102158273 in the EDF-N is enlarged to fully cover a larger galaxy.

- increments the tile centers by $30'$, which leads to an overlap of $2'$ for adjacent tiles;
- starts the central tile positions at (RA, Dec) = $(0^{\circ}0', 0^{\circ}0')$ and places them in strips of constant Dec;
- adjusts the tile width when closing a strip at the Meridian;
- defines the core area using HEALPix indices with $N_{\text{side}} = 13$;

To define the core areas we first start, for each tile, with the HEALPix indices that are inside of the extended area. Then we identify the indices located in the overlap of extended areas, which appear in more than one tile. For those, we measure the minimum distance to the border of each tile in which they appear; then each index is attached to the tile which maximizes this distance and removed from all others. This procedure avoids duplicated HEALPix indices in several tile and assures a contiguous coverage of the core areas.

With a strict tiling as outlined so far, some of the galaxies with sizes larger than the overlap size will inevitably extend beyond the tile that its centre is located on. To solve these cases, we identified, from publicly available catalogues, all large galaxies (size $> 2'$) located in the Q1 area and store their position and

size. We identify the critical cases where a large galaxy extends between more than one tile. We allow the tile with the galaxy centre to ‘breathe’, which means to enlarge its size until it contains the entire galaxy. This procedure covered all large galaxies in Q1. Figure 3 shows the tiling in the lower part of the EDF-N. In this particular case, the height of tile 102158273 was enlarged to $33'$ in order to fully cover the galaxy PGC61126.

3.2. Mosaicing

For the later measurement steps, specifically the photometry with A-PHOT and T-PHOT (see Sect. 6), we need a multi-band set of co-aligned images, where each pixel represent the same position on the sky. The layout of these co-aligned images is given by setting a pixel scale of $0''.1 \text{ pixel}^{-1}$ (to properly sample the VIS data) and the dimensions of the *Euclid* tiles presented in Sect. 3.1.

EXT imaging data is already provided per tile as stacked frames in the native scale of the respective camera, e.g. $0''.264 \text{ pixel}^{-1}$ for the DES data. These data are rebinned to the common pixel scale using a BILINEAR interpolation kernel.

VIS and NIR input data are the set of fully calibrated frames covering a tile in their native pixel scale of $0''.1 \text{ pixel}^{-1}$ and $0''.3 \text{ pixel}^{-1}$, respectively. After subtracting the background estimate provided with the input data (see Euclid Collaboration: McCracken et al. 2025; Euclid Collaboration: Polenta et al. 2025), these calibrated frames are rebinned and stacked to deep co-added images with a BILINEAR interpolation kernel and the combine type MEDIAN. For the stacking we apply the RMS data provided with the VIS and NIR data as weights. The different zero points for the VIS and NIR data are translated to global weighting values which are used in the co-add process. In addition, we scale these global weights such that the zero point of the resulting co-added images corresponds to the median value of the input zero points, rounded to one decimal place.

For all rebinning and co-adding operations we use the software CT_SWarp, which is a version of the SWarp (Bertin et al. 2002) software that is fully integrated into the *Euclid* processing environment.

In CT_SWarp we also implemented the interpolation kernel BILINEAR_FLAGS, which allows to combine the flagging information for the VIS and NIR data with the bitwise XOR operation. The resulting flag image shows, for every pixel, the flag values that were associated to the corresponding input pixels, which usually resulted in the exclusion of the flagged pixels.

The result of this processing step is, for every filter band, the set of co-added image plus the corresponding RMS and flag images. The astrometric validation of the co-added images shows that the non-linear astrometric solutions provided with the VIS and NIR data fulfill the requirements (see Sect. 9.1).

3.3. Background subtraction

We run the background subtraction step to remove possible residual background from the mosaic images. To avoid contamination from bright extended sources in the input mosaic, we apply a segmentation mask generated by source detection run using SourceExtractor++ (SE++, Bertin et al. 2020; Kümmel et al. 2022a) which is a re-designed and extended version of the SExtractor2 (SE2, Bertin & Arnouts 1996) software. The masked mosaic is divided into a grid, for each cell of which we estimate the background as a combination of k-sigma clipping and median filtering. In each cell, the local background pixel dis-

tribution is clipped iteratively until convergence at 2σ around its mean. If after convergence the mean and the median background differ by more than 3σ (e.g., in crowded fields), the background on that cell is defined to be the mean of the clipped histogram. If the mean and the median differ by less than 3σ , the background on that cell is estimated as the mode of the distribution,

$$B = 2.5 M - 1.5 \mu, \quad (1)$$

where M and μ are the median and mean of the clipped histogram, respectively.

Eventual gaps (cells lacking unflagged pixels to estimate the background) are filled with the distance-weighted average of the background values of the cells at the edges of the gap. Once the background is computed in each cell of the grid, we apply a median filter to suppress possible local overestimations due to residuals from bright stars. The background model at the original resolution of the mosaic is determined by a spline-interpolation of the cell values, and is subtracted from the mosaic image. Two main parameters control the background generation: the grid size, which we set to 256×256 pixels, and the size of the filter box, which we set to 3 cells.

4. Assembly of the source list

4.1. General considerations for source detection and deblending

The strategy for detecting objects in the available imaging data is dictated by the *Euclid* project requirements:

- Objects shall only be detected in the photometric bands coming directly from the *Euclid* instruments, which are I_E , Y_E , J_E , and H_E . VIS and NIR imaging data for a specific tile are observed over a short time (around 1 h) and give consistent basis for object detection. EXT data can span a large range of epochs, even within the bands available for one tile. Due to the epoch differences this would result in astrometric offsets within the data and pose problems for the photometry.
- We need to detect all objects in the *Euclid* VIS band (I_E). The weak lensing measurements by OU-SHE require an object sample with a simple selection function. Deriving the weak lensing sample from objects detected outside of VIS, such as co-added or χ^2 images in $I_E + Y_E/J_E/H_E$ would result in biases and systematic effects that cannot be recovered in the shear analysis.
- We need to detect all objects in the *Euclid* NIR data (Y_E , J_E , H_E). The catalogues from the MER PF are used as input to the slitless spectroscopy analysis. This requires a deep and complete detection process to find the direct image counterparts of all objects that possibly have spectral traces or emission lines in the slitless spectroscopic NISP data and hence must include a detection in the NIR bands.
- The detection shall record whether a source was detected in VIS or in NIR.

Since we need to separate sources detected in VIS and in NIR we cannot work with a single, deep detection image such as VIS+NIR or a χ^2 image as described in Szalay et al. (1999). Instead, as outlined in Fig. 1, we take the following the approach:

- perform a source detection and deblending in VIS.
- perform an independent source detection and deblending in NIR.

Table 1. Important SE++ parameters used for the VIS and NIR detections.

Parameter	VIS	NIR
segmentation-filter (Gaussian FWHM [pix])	2.4	5.0
detection-threshold	0.9	0.4
detection-minimum-area	10	10
core-threshold-value	1.3	0.55
core-minimum-area	10	10

- Combine the VIS sources and the NIR sources to a common object list and segmentation map.
- The computation of object properties, such as photometry and morphology, is then performed on the combined object lists.

4.2. Source detection

The source detection is done using SE++. The typical procedure for detecting objects in astronomical images is to:

- convolve the data and the rms images with the segmentation filter in order to enhance the signal-to-noise ratio (S/N);
- register all pixels with a $S/N > \text{detection-threshold}$;
- mark as an object the set of connected pixels with $N_{\text{pixel}} > \text{detection-minimum-area}$.

With this method there are usually some false detections around large, extended galaxies. Using reasonable values for the parameters `detection-threshold` and `detection-minimum-area`, which are tailored to avoid false detections from noise peaks in the background, the detection cannot follow the extended objects far out into the sky background. The algorithm then picks up ‘objects’ in the extended parts of large galaxies as individual sources.

To avoid these false positive detections, we have implemented an improved detection scheme in SE++ that reduces the number of false detections around bright galaxies. In this detection scheme there is in addition to the `detection-threshold` and `detection-minimum-area` discussed above a second threshold with:

- `core-threshold-value`: the SNR threshold value;
- `core-minimum-area`: the number of pixels above the `core-threshold-value` an objects needs to have to validate the object;

With these two detection thresholds it is possible to have a rather low value for the `detection-threshold` parameter. Then the detection areas of large galaxies extend into the region of the fake objects. The second, higher threshold `core-threshold-value` then eliminates the false detections that result from the low value `detection-threshold` at noise peaks in the sky background. The lower value of the `detection-threshold` in the ‘deep detection’ leads to a larger detection area (around) of the objects.

The VIS detection image is the background-subtracted mosaiced image described in Sects. 3.2 and 3.3. For the detection in NIR we produce a deep NIR detection image from the Y_E , J_E , and H_E background-subtracted mosaiced images using weighted summation. The different zero points of the input images are taken into account in the weighted summation to yield a common zero point for the resulting deep NIR detection image. Table 1 lists the most important parameters used in the VIS and NIR detection. The segmentation filters are chosen to have a width

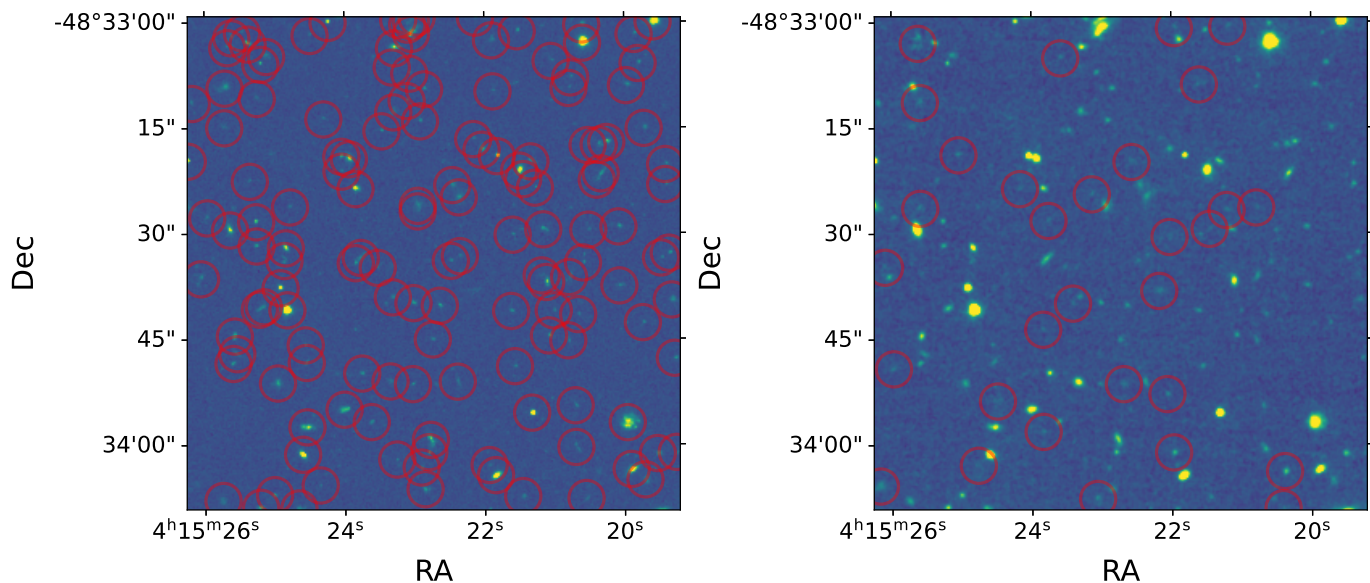


Fig. 4. Small cutouts of the detection images I_E (left) and NIR ($Y_E + J_E + H_E$, right) in tile 102021017. The VIS and NIR detected sources are marked in the left and right panels, respectively

similar to the target population, which are faint galaxies. The other parameters have been ‘calibrated’ using simulated images to produce a rate of false detections $< 1\%$, which is a typical value for large-scale surveys.

4.3. Deblending

Deblending is an essential procedure for separating overlapping sources in astronomical images. With its unprecedented sensitivity and resolution, *Euclid* captures densely packed fields and intricate morphologies, making source disentanglement one of the key challenges in its data analysis.

Following the independent image segmentation in the VIS mosaic and the NIR stack, resulting from detection, deblending is executed in a parallel manner for both groups of source clusters. The aim is to put together a refined list of individual sources in the merging stage described in the next section.

The deblending process is carried out using a dedicated software component based on ASTERIS (Tramacere et al. 2016). ASTERIS is a Python package designed for automatic source detection and classification, leveraging two topometric clustering algorithms: DBSCAN (Ester et al. 1996) for identifying sources and DENCLUE (Hinneburg et al. 1998; Hinneburg & Gabriel 2007) for deblending overlapping sources and identifying galaxy morphological features such as spiral arms. Our internal processing element, with a specific set of configuration parameters for VIS mosaic and NIR stack, inherits the operation of ASTERIS as a deblender, which is based on the execution of a modified version of the DENCLUE density-based clustering algorithm, where the kernel-density estimation is substituted with a convolution of the image using a given kernel. This algorithm processes, as a function of the configuration parameters, a downsampled version of the segmentation clusters in terms of a distinct spatial scale. The adaptive approach allows for a robust separation of the overlapping sources within each cluster.

The two sets of parameters selected in the MER pipeline for deblending the clusters of sources detected in the VIS mosaic and the NIR stack have been validated using the images and catalogues from the True Universe (TU) simulation (Euclid Collaboration: Serrano et al. 2024). This was done by exploring a discrete sampling of the parameter space to single out the values for which the total number of over- and under-deblendings is minimised in reference to a ground-truth segmentation map built from the TU catalogue. Two parameters were considered in this process due to their significant influence on the operation of the DENCLUE algorithm, one of them defines the typical scale of the sources blended within a cluster, while the other one establishes the converge criterion that identifies the local maximum corresponding to the centre of a deblended source.

4.4. Merging the VIS and NIR detections

The results of the independent detection and deblending in VIS and NIR are one catalogue and one segmentation image in each of the VIS and NIR bands. These two data sets need to be combined to a single output catalogue and the corresponding segmentation image for the subsequent determination of object properties (photometry, morphology, etc.).

The VIS data have higher resolution ($0''.1$) than NIR ($0''.3$) and a better sampling. This leads to much better results for the detection and deblending. As a consequence, we combine the VIS and NIR datasets such that the merged catalogue and segmentation image contain all VIS objects plus the so-called NIR-only objects, which are the objects that are detected in NIR but not in VIS.

To identify the NIR-only objects we project the coordinates of all NIR detected objects into the VIS segmentation image. NIR objects that are already detected in VIS are identified by evaluating the VIS segmentation image, which marks the pixels of all VIS detected sources. VIS segmentation values > 0 at the projected central NIR position are considered to be already de-

tected in VIS, since they are already part of a VIS object. NIR objects with value 0 in the VIS segmentation image are not detected in VIS and thus form the subset of NIR-only sources. The final output catalogue is then the combined VIS and NIR-only catalogue.

To derive the combined VIS+NIR segmentation image we copy the VIS segmentation image and add the detected pixels of the NIR-only sources from the NIR segmentation image to the now combined segmentation image. In this operation we do not overwrite any VIS-detected pixels. Preserving all VIS-detected pixels changes and reduces the detection area of few NIR-only objects, and we recompute their properties (position and shape). Also we discard NIR-only objects that would end up having fewer than `detection-minimum-area` pixels (see Tab. 1) after the combination of the segmentation maps.

Figure 4 shows in the left and right panel a small cutout from the VIS and NIR detection images, respectively. The red circles mark all sources detected on these cutouts. The brighter objects are all detected in VIS and the NIR detected sources constitute the faint and rather red sources. There are 141 and 31 sources detected on the VIS and NIR cutout, respectively. As in this small cutout about 20% of all sources are detected in NIR.

It can sometimes happen in the combined VIS+NIR segmentation map that VIS and NIR-only sources are located side-by-side without any empty sky pixels in between. These artificial VIS-NIR blends are identified and marked by assigning a unique number to the corresponding objects in the final catalogue column `PARENT_VISNIR`.

We are aware that current merging procedure may dis-favor very interesting sources such as red objects that are very close to VIS objects. Some of those sources should be discovered in dedicated pipelines such as The Strong Lensing Discovery Engine (see [Euclid Collaboration: Walmsley et al. 2025a](#)), but we are also planning to refine the merging procedure in the future.

5. Mapping of the point spread functions and convolution kernels

MER receives the PSFs measured by the VIS, NIR, and EXT PFs and propagates them to the MER mosaic grid to calculate a different PSF stamp for each individual source and band. VIS PSFs are measured for each VIS quadrant on a dedicated calibration processing run using the PSFEx software ([Bertin 2011](#)) and are assumed to remain constant for each VIS calibrated frame observation ([Euclid Collaboration: McCracken et al. 2025](#)). NIR PSFs are calculated for each NISP detector and each calibrated frame ([Euclid Collaboration: Polenta et al. 2025](#)) using PSFEx.

MER propagates the VIS and NIR PSFs following a similar approach as described in Sect. 3.2, with the following differences:

- the pixel values of the mosaicing step input images are set to zero, but the zero points, WCS information, flags, and RMS are left untouched.
- PSF stamps are then added to the empty images at the de-blended source positions, taking into account the VIS and NIR PSF spatial variations and the image zero points.
- the Swarp resampling and co-adding software ([Bertin et al. 2002](#)) is run on the modified images and a mosaic with the averaged stamp PSFs is produced.
- the averaged PSF stamps are extracted for each source and stored in a FITS file, which contains a grid with the PSF stamps and a table with their associated sky and pixel coordinates.

Source separations in the MER catalogue can be smaller than the input VIS and NIR PSF stamp sizes (less than $3''$). To avoid any overlap between the PSF stamps of nearby sources the whole process is repeated three times. Each run uses a different subset of sources whose separations are large enough to avoid PSF stamp overlaps. This generally produces a PSF stamp for more than 80% of the sources. For the remaining sources, the closest PSF stamp is used, which by design is at a distance smaller than the PSF stamp size.

In its current state, the MER pipeline assumes that the PSF of a given band does not change with the source intrinsic color. The propagation of wavelength-dependent PSFs could be introduced in the future if the VIS and NIR PFs are able to deliver their input PSFs with this information.

The EXT stage-2 PF calculates their stacked frames PSFs using a similar approach as described above. MER rebins the EXT PSFs from the EXT stacked frame pixel size to the reference $0''.1$ mosaic pixel size. The PSF stamp positions are based on the EXT stacked frame catalogue, which is generally not as deep as the MER catalogue, and as a result contains fewer sources. We select the closest PSF stamp for each source in the MER catalogue.

Table 2 compares the typical Full Width at Half Maximum (FWHM) values measured on the propagated PSF stamps and the detected *Gaia* stars in the MER mosaics. The agreement between the median values is better than 1%, with the exception of the NISP bands. The propagated PSFs for these bands are between 1.75% and 3.5% more compact than the *Gaia* star profiles. Future versions of the NIR PF pipeline should improve the quality of the PSFs that MER receives as input. We expect that this will reduce the FWHM discrepancies that we currently find in the Q1 processing.

The FWHM values reported for the propagated VIS and NIR PSFs in Table 2 are 30% to 35% larger than the corresponding input PSFs measured on the VIS and NIR calibrated frames ([Euclid Collaboration: McCracken et al. 2025](#); [Euclid Collaboration: Polenta et al. 2025](#)). This is a result of the stacking procedure described in Sect. 3.2. In particular, the use of a BILINEAR interpolation kernel instead of a LANCZOS3 kernel introduces an extra 15% broadening of the PSFs.

The multi-band photometry (described in Sect. 6) needs convolution kernels to homogenise the PSFs from the different bands. The algorithm we use to create the convolution kernels is based on Wiener filtering with a tunable regularization parameter. For each detected object, we compute convolution kernels from higher- to lower-resolution bands using the object PSF stamps generated in the previous step. A complete description of the kernel creation algorithm can be found in [Boucaud et al. \(2016\)](#).

6. Multi-band photometry

OU-MER must provide photometric measurements for all the detected sources. The pipeline has been designed to produce photometric estimates using various techniques, which can be combined in different ways to obtain the desired scientific information. Namely, the output catalogue contains: (i) aperture photometry, obtained using a customized version of the software A-PHOT ([Merlin et al. 2019](#)); (ii) template-fitting photometry, obtained using a customized version of the code T-PHOT ([Merlin et al. 2015, 2016](#)); and (iii) model-fitting photometry, obtained using SE++.

Concerning aperture photometry, the total flux of each object is estimated as the flux within a [Kron \(1980\)](#) elliptical aper-

Table 2. Full width half maximum (FWHM) values measured using two-dimensional Gaussian fits on the MER propagated PSFs and the *Gaia* star stamps extracted from the MER mosaics. The different statistics are calculated combining the median FWHM values measured for each tile in the Q1 data release. Tiles with less than 20% coverage in one of the *Euclid* bands, as well as tiles associated to the Dark Cloud region, have not been considered.

Survey	Band	PSF FWHM			Gaia stars FWHM		
		Median ($''$)	Min ($''$)	Max ($''$)	Median ($''$)	Min ($''$)	Max ($''$)
EWS	I_E	0.203	0.197	0.212	0.204	0.199	0.213
EWS	Y_E	0.475	0.456	0.484	0.492	0.474	0.502
EWS	J_E	0.504	0.494	0.517	0.513	0.505	0.524
EWS	H_E	0.542	0.536	0.547	0.552	0.539	0.570
UNIONS CFIS	u	1.00	0.84	1.16	0.99	0.84	1.17
UNIONS WHIGS	g	0.79	0.57	1.47	0.79	0.58	1.48
UNIONS CFIS	r	0.85	0.69	1.00	0.85	0.70	0.99
UNIONS Pan-STARRS	i	1.27	1.18	1.37	1.26	1.17	1.36
UNIONS WISHES	z	0.63	0.51	0.83	0.63	0.51	0.83
DES	g	1.28	1.02	1.40	1.28	1.01	1.43
DES	r	1.12	0.95	1.23	1.12	0.95	1.26
DES	i	1.07	1.00	1.47	1.07	0.99	1.47
DES	z	1.05	0.95	1.27	1.06	0.95	1.27

ture on the detection image, which is the I_E mosaic for most of the sources, and the NIR stack for the additional NIR-detected sources (see Sect. 3.2). This corresponds to the FLUX_AUTO in SE2; here the Kron radius is computed as

$$R_{\text{Kron}} = \max\left(7a, \frac{\sum_{ij} r_{ij} f(i, j)}{\sum_{ij} f(i, j)}\right), \quad (2)$$

where a is the semi-major axis provided by the deblending algorithm during the deblending step, r_{ij} is the distance of each pixel to the centroid of the object, $f(i, j)$ is its flux, and the summation is extended over a circular region typically of radius $6a$. The final Kron area for which the flux is computed is an elliptical area of semi-major axis $2.5R_{\text{Kron}}$ and ellipticity, again provided by the deblending step. A-PHOT sub-divides the pixels crossed by the limit of the elliptical aperture into 10 subpixels, to provide a more precise estimate.

Aperture photometry is then measured for all bands on PSF-matched images, within a set of circular apertures with diameters fixed individually source by source as integer multiples of the FWHM of the worst resolution band (typically an EXT band, with FWHM around $1''$). In this way, the same physical region of the sources is always sampled, providing a robust colour estimate. The smoothing is performed using convolution kernels obtained from the PSFs estimated as described in Sect. 5. To determine the total flux in each band, one must combine the value obtained on the detection band with these aperture fluxes, as follows (e.g. Merlin et al. 2022):

$$f_{\text{tot,band}} = f_{\text{ap,band}} \frac{f_{\text{tot,det}}}{f_{\text{ap,det}}}. \quad (3)$$

The uncertainty budget can be computed with an analogous formula, where it is safe to assume that the ratio $f_{\text{tot,det}}/f_{\text{ap,det}}$ is a constant and there is no need to propagate their errors. The uncertainty $e_{\text{ap,band}}$ is computed by A-PHOT as the square root of the quadratic sum of the pixels in the PSF-matched RMS map, within the considered aperture. All the measurements are done without performing a further local background subtraction, since two background subtraction steps have already been performed on the images.

Template-fitting photometry is a well-established technique used to exploit spatial and morphological information from high-resolution images to estimate fluxes on lower-resolution images of the same FoV, using cut-outs of sources from the former (smoothed with a convolution kernel) as priors for the latter, to mitigate the effect of blending of sources. While it was initially designed to fit infrared data (from e.g., *Spitzer*) with HST priors, it has proven to be useful in the *Euclid* context as well. The crispness and depth of the I_E data can provide exquisite priors for EXT data, and can be used for NIR data as well, although in that case the difference in resolution is not dramatic. Fluxes are obtained by solving a χ^2 minimisation problem,

$$\chi^2 = \sum_{m,n} \left[\frac{I(m, n) - \sum_i^N F_i(m, n) P_i(m, n)}{\sigma(m, n)} \right]^2, \quad (4)$$

where m and n are pixel indexes, N is the number of sources being fitted, P are the values of the pixels of the normalised high-resolution cutouts convolved to the measurement image resolution, I are the values of the pixels in the measurement image, and σ are the values of the pixels of its RMS map (see Merlin et al. 2015, for details). The error budget of the fitting process is obtained from the covariance matrix of the problem, as the square root of the diagonal element relative to that source (i.e. its variance). In principle, one could fit the full image at once, but in practice this would be too computationally demanding given the large spatial dimensions of the OU-MER tiles. The pipeline therefore exploits a feature of T-PHOT which allows to perform individual fits looping on the sources, building a cell around each one including its contaminants, and removing it after it has been fitted. This algorithm has proven to yield a significant saving of computational time, while keeping optimal accuracy.

The pipeline provides the direct output of the template-fitting runs, which can be taken as a proxy for the total flux of the objects. Additionally, fluxes measured in the detection band smoothed to the resolution of each other band are also provided; they can be used to obtain an estimate of colours complementary to that obtained with aperture photometry, and used to scale the detection Kron flux to get another total flux value in each band. Typically, one expects $f_{\text{templ,band}} \leq f_{\text{tot,band}}$, where the latter is the total flux from aperture photometry as described above;

this is because the contamination from nearby sources, when present, should be drastically decreased. Figure 5 shows the situation for a random OU-MER tile, and the case of one discrepant galaxy. However, the colors obtained with the two techniques should obviously be reasonably consistent. Figure 6 shows the compared $g - H_E$ colors (g is from DECam) obtained from aperture and template fitting photometry in the same tile, for stars (blue crosses, $\text{POINT_LIKE_PROB} > 0.7$) and galaxies (red dots, $\text{POINT_LIKE_PROB} \leq 0.7$; see Sect. 7.4), ensuring this is indeed the case. It should be stressed that for Q1 we found that for point-like sources (bright stars in particular), contrary to what was just discussed for extended sources, the total fluxes computed using aperture photometry were found to be more accurate than template-fitting fluxes in NIR bands, most likely due to their higher sensitivity to PSF related issues (see Sect. 9.5). Currently, OU-PHZ uses aperture colors to compute photometric redshifts (see [Euclid Collaboration: Tucci et al. 2025](#)).

We point out that template-fitting, where real cut-outs of high-resolution images are used to infer the expected shape of low-resolution images, is different from model-fitting, where galaxy profiles are fitted using analytical models. Indeed, the pipeline also provides photometric values derived by fitting a parameterized model to the multi-band imaging data. For Q1 we have chosen to fit Sérsic models (Sérsic 1963) to all detected objects. This is done with SE++ in an iterative procedure that involves VIS and NIR data to fix the Sérsic parameters and then EXT data for photometry only. Further details are given in Sect. 7.2.

It is worth recalling that, as it is custom practice, the provided error budgets are a measure of the uncertainty due to the observational noise level, as encoded in the RMS map. In other words, it does not include an estimate of any systematic deviation to which a measurement might be prone (e.g. because of contamination from nearby sources), and might therefore be an underestimation of the actual uncertainty on the real flux of the sources.

The flux within the segmented area of each source is also provided (corresponding to FLUX_ISO in SE2). Finally, a PSF-fitting estimate is provided for the VIS band only, again using T-PHOT.

All the photometric measurements are stored in the MER photometric catalogues (Sect. 8), a column-by-column description of which is referenced in Appendix A. It is not always trivial, though, to handle the amount of information stored in such a huge container. In order to help the user to become familiar with our products and to handle the photometric information measured by OU-MER, we provide a Photometry Cookbook¹, explaining the basic operations that need to be performed in order to correctly use MER data.

7. Morphological characterization

For each galaxy used in the weak lensing analysis up to the limiting magnitude the following information is provided: (i) the classification star/galaxy (ii) at least one size measurement. An object radius is provided via the detection and photometry pipelines. Three kinds of morphological estimators are included in the MER catalogue:

- Non-parametric parameters. Those are Concentration, Asymmetry, and Smoothness (CAS, [Conselice 2014](#); [Tohill](#)

¹ <http://st-dm.pages.euclid-sgs.uk/-/data-product-doc/-/jobs/162527/artifacts/build/merdpd/merphotometrycookbook.html>

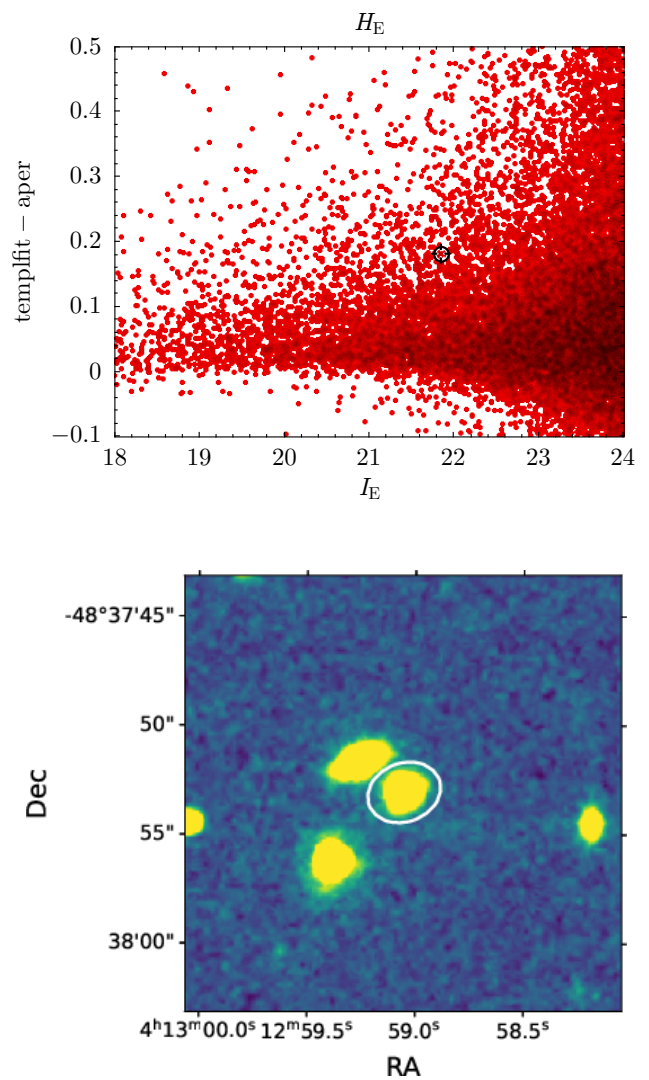


Fig. 5. Upper panel: difference in H_E total magnitudes as obtained with template-fitting and aperture photometry as a function of I_E detection magnitude, for extended objects ($\text{POINT_LIKE_PROB} < 0.7$, see Sect. 7.4) in a random OU-MER tile. Template-fitting magnitudes are typically fainter, because the contaminating light from blended sources is removed in the fitting process. Lower panel: as an example, the source selected with the black circle in the upper panel is shown in the corresponding H_E OU-MER mosaic. The AB magnitude of the pixels within the white aperture (which is certainly still contaminated by the nearby objects), as given by the SAO ds9 software, is 19.96; the OU-MER catalog values are 19.81 ± 0.02 (total from color in 2FWHM aperture) and 19.99 ± 0.01 (template-fitting).

[et al. 2021](#)), the Gini index ([Lotz et al. 2004](#)), and the second order moment at 20% flux, i.e the M20 index;

- Parametric parameters computed through model fitting ([Euclid Collaboration: Bretonnière et al. 2022, 2023](#));
- Deep learning based morphologies calibrated on visual classifications.

As per the photometric catalogue, we provide a Morphology Cookbook² aimed at better understanding how to correctly use the information stored in the MER morphology catalogue.

² <http://st-dm.pages.euclid-sgs.uk/-/data-product-doc/-/jobs/162527/artifacts/build/merdpd/mermorphologycookbook.html>

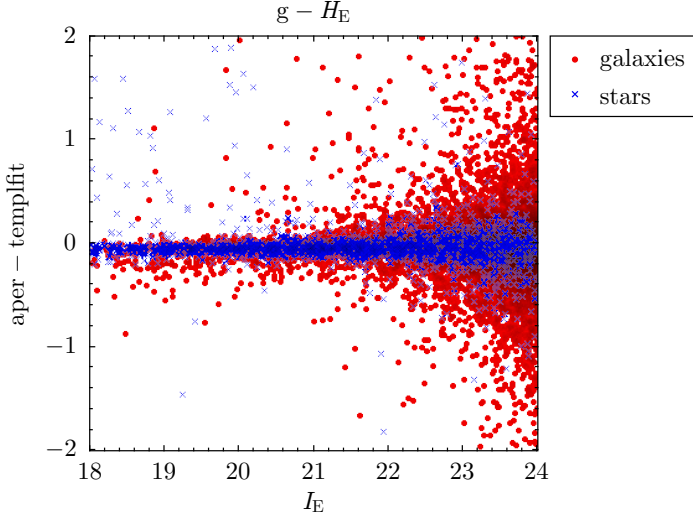


Fig. 6. Difference in $g-H_E$ colors obtained from aperture and template fitting photometry for a random OU-MER tile, as a function of I_E magnitude.

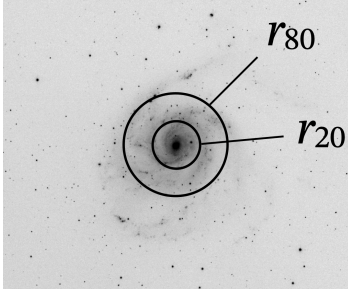


Fig. 7. Concentration calculation schematics, here r_{80} and r_{20} are circular radii encompassing 80% and 20% of the galaxy flux (cf text and Eq. 5).

7.1. Non-parametric indices for object morphology

The original implementation of CAS, Gini, and M20 parameters as *Euclid* processing element was coded from ASTERISM, a code for deblending objects and morphological measurements (Tramacere et al. 2016). The CAS parameters are non-parametric parameters carrying morphological characteristic in a three-dimensional space that segregate main morphological features. They are computed on *Euclid* I_E images covering the segmentation map of each object.

7.1.1. Concentration index C

The concentration of light index C (Conselice 2014) is used as a method for quantifying how much light is in the centre of a galaxy as opposed to its outer parts. It correlates strongly with Sérsic n values,

$$C := 5 \log_{10} \frac{r_{80}}{r_{20}}, \quad (5)$$

where r_{80}, r_{20} are the circular apertures enclosing 80% and 20% of the total galaxy flux. The associated error is defined:

$$C_{\text{err}} := 5 \log_{10} \frac{r_{80}}{r_{20}} - 5 \log_{10} \frac{r_{80} - 0.5}{r_{20} + 0.5}. \quad (6)$$

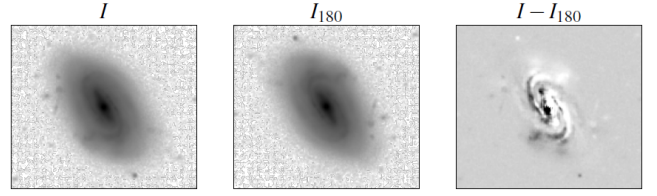


Fig. 8. Asymmetry calculation schematics. The original image (I) is rotated by 180° (R), the asymmetry index A is computed from a combination of the two (cf text and Eq. 7).

7.1.2. Asymmetry A

The asymmetry index A (Conselice 2014) measures how asymmetric a galaxy is after rotating along the line of sight centre axis of the galaxy by 180° (Fig. 8). The analytic definition calculating A is given by

$$A := \min \left(\frac{\sum |I_0 - I_{180}|}{\sum |I_0|} \right) - \min \left(\frac{\sum |B_0 - B_{180}|}{\sum |B_0|} \right), \quad (7)$$

where I_0 is the original galaxy image, I_{180} is the image after rotating it from its centre by 180° . The measurement of the asymmetry parameter includes a careful treatment of the background noise in the same way that the galaxy itself is analysed by using a blank background area (B_0), and finding the location for the centre of rotation. The area B_0 is a blank part of the sky near the galaxy. The centre of rotation is not defined a priori, but tweaked iteratively around the starting value to yield the minimum value of A . The error on A is

$$A_{\text{err}} := \frac{\sigma[B(x, y)]}{f + \sqrt{|f|}}. \quad (8)$$

7.1.3. Clumpiness/Smoothness index S

The clumpiness (or smoothness) index S (Conselice 2014) is used to describe the fraction of light in a galaxy that is contained in clumps. The smoothness can be computed as

$$S := \frac{f_s - f_b}{f}, \quad (9)$$

with

$$f_s := \sum I(x, y) - I(x, y)_{\text{blurr}}, \quad (10)$$

$$f_b := \sum B(x, y) - B(x, y)_{\text{blurr}}, \quad (11)$$

$$f := \sum I(x, y), \quad (12)$$

where $I(x, y)$ are the image pixels chopped within $r_{\text{inner}} = 0.1\eta$ of the object flux peak, η is the petrosian radius (Petrosian, 1976), $I(x, y)_{\text{blurr}}$ is the chopped image convolved with a gaussian kernel of $\sigma = 0.1\eta$, $B(x, y)$, and $B(x, y)_{\text{blurr}}$ are the noise maps treated identically. Finally, the associated error is

$$S_{\text{err}} := \frac{10 \sqrt{|n f_s|}}{n(f + \sqrt{|f|})}, \quad (13)$$

where n is the number of unmasked pixels.

7.1.4. Gini index

The Gini index (Lotz et al. 2004) originates from the world of economics, where it has been defined originally to evaluate inequalities of incomes in a population. If everyone earns the same income, Gini = 0, if one person concentrate all incomes Gini = 1. Applied on an astronomical image, the calculation is done on pixels covered by the segmentation map of objects. A galaxy in this case is considered a system with n pixels each with a flux f_i , where i ranges from 1 to n . The Gini index is then measured by

$$\text{Gini} := \frac{1}{|\bar{f}|n(n-1)} \sum_i^n (2i - n - 1)|f_i|, \quad (14)$$

where \bar{f} is the average pixel flux value.

7.1.5. Moment-20 index M20

The mathematical definition of the M20 index is

$$\text{M20} := \log_{10} \left(\frac{\sum_i M_i}{M_{\text{tot}}} \right) \quad \text{while} \quad \sum_i^n i f_i < 0.2 f_{\text{tot}}. \quad (15)$$

The value of M_{tot} is

$$M_{\text{tot}} = \sum_i^n M_i = \sum_i^n f_i [(x_i - x_c)^2 + (y_i - y_c)^2], \quad (16)$$

where (x_c, y_c) is the flux-weighted mean position of the galaxy. In the case of M20, this center is defined as the location where the value of M_{tot} is minimal.

7.2. Parametric morphology

To derive some parametric morphology, we have decided to fit two-dimensional Sérsic profiles (Sérsic 1963) in all photometric bands to all objects. As a function of the angular radial r , the Sérsic function defines the variation of the light intensity as:

$$I(r) = I_e \exp \left\{ -b_n \left[\left(\frac{r}{R_e} \right)^{1/n} - 1 \right] \right\}, \quad (17)$$

with R_e the major-axis of the elliptical profile that encloses half of the total light, $I_e = I(R_e)$ the light intensity at R_e , n the Sérsic index characterizing the steepness of the profile, and b_n a normalisation parameter which depends solely on n . Fitting 2D elliptical light profiles to the *Euclid* imaging data adds the position angle and the axis ratio.

The Sérsic fitting is performed using SE++ (Kümmel et al. 2022a), which, from version 0.21³ on, includes model fitting as an isolated process without the preceding object detection process. All necessary parameters such as objects centres, the fitting area, and initial values for the model parameters are provided in an input table to the model fitting process.

The model fitting in the OU-MER PF has a dual purpose and provides, in addition to the Sérsic parameters, also the Sérsic flux in all photometric bands as an independent photometry in addition the ones introduced in Sect. 6. We do this in an iterative process:

- The first model fitting operation on VIS and NIR data computes all structural Sérsic parameters and the VIS and NIR fluxes:

- We fit to the VIS (I_E) data the corresponding Sérsic radius (R_{VIS}), ellipticity (e_{VIS}), and index (n_{VIS});
- We also fit to the NIR ($Y_E/J_E/H_E$) data the independent Sérsic radius (R_{NIR}), ellipticity (e_{NIR}), and index (n_{NIR}) for the NIR bands.
- The VIS and NIR Sérsic models share the same angle $\alpha_{\text{VIS,NIR}}$
- In addition the integrated Sérsic flux in the VIS and NIR bands ($f_{\text{Sérsic,I}_E}$, $f_{\text{Sérsic,Y}_E}$, $f_{\text{Sérsic,J}_E}$ and $f_{\text{Sérsic,H}_E}$) are computed as well.
- The second model fitting operation runs on the EXT data g, r, i, z . It uses the Sérsic parameters R_{VIS} , e_{VIS} , n_{VIS} and $\alpha_{\text{VIS,NIR}}$ as constant values to compute the integrated Sérsic flux in those EXT bands.
- In both fitting operations we use the object centres provided as an input as the fixed centres for the Sérsic models.

For all fitted quantities we provide the error obtained from the square root of the diagonal element of the covariance matrix. The approach of using an iterative approach for VIS plus NIR for the morphology and then EXT for photometry is rather unusual, and configuration for deriving two independent set of Sérsic parameters with a common orientation angle is complex. As an example for this setup we share a multi-band data set⁴. As imaging data we provide cutouts from a Q1 tile. There are also the various configuration files for both model fitting operations described above and the SE++ commands to run the SE++ model fitting on the data. A scientific evaluation of the parametric morphology provided in the OU-MER catalogues is given in [Euclid Collaboration: Quilley et al. \(2025\)](#).

7.3. Machine learning based morphology - Zoobot

The MER catalogue contains visual morphologies following the GalaxyZoo (GZ) classification tree. This includes broad morphological classes, such as ‘featured’ or ‘smooth’, as well as more detailed features such as the count and tightness of spiral arms or the strength of stellar bars. For the Q1 data release, the MER catalogue includes visual morphologies for galaxies brighter than $I_E < 20.5$ or with a segmentation area larger than 1 200 pixels, which represent around 1% of galaxies in the photometric catalogue. This conservative selection is performed to guarantee that the structure is unambiguously detected but could be extended to fainter and smaller sources in future releases.

Galaxies are classified with the deep foundation model Zoobot (Walmsley et al. 2023). For this work, we use the pre-trained ConvNext Nano model (22.5 million parameters) available on HuggingFace⁵. This is pretrained on the GZ Evo dataset (Walmsley et al. 2022b; Walmsley et al. 2024), which includes 820 000 images and over 100 million volunteer votes drawn from every major Galaxy Zoo campaign: GZ2 (Willett et al. 2013), GZ UKIDSS (Masters et al. 2024), GZ Hubble (Willett et al. 2017), GZ CANDELS (Simmons et al. 2017), GZ DECaLS/DESI (Walmsley et al. 2022a, 2023), and GZ Cosmic Dawn (in prep).

To optimise the classifications for *Euclid*, we fine-tune Zoobot with an additional 1.56 million labels obtained on *Euclid* stamps through a dedicated GZ campaign carried out during August 2024. Specific details about the methodology and reli-

⁴ <https://cloud.physik.lmu.de/index.php/s/3K4KemBsw5y9yqd>

⁵ https://huggingface.co/mwalmsley/zoobot-encoder-convnext_nano

³ <https://github.com/astrorama/SourceXtractorPlusPlus>

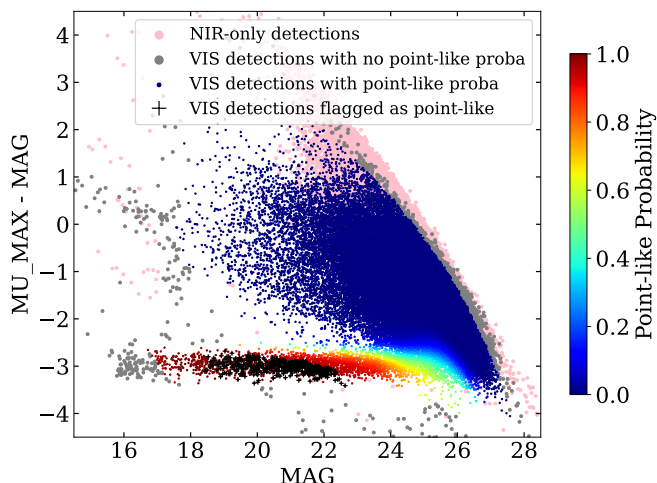


Fig. 9. VIS and NIR detections in the $MU_MAX - MAG_AUTO$ plane for real data from tile 102021495. Stars are prominently present in the bottom horizontal branch. Black crosses are sources identified as stars and the colours code the probability of being a point source.

bility of the classifications are presented in [Euclid Collaboration: Walmsley et al. \(2025b\)](#).

7.4. Star-galaxy separation

A simple star-galaxy (S/G) classifier has been historically implemented in the MER pipeline in order to identify the point-like detected objects on which the PSF characterization could be performed by SHE. In addition to the `POINT_LIKE_FLAG`, a point-like probability (`POINT_LIKE_PROB`) was also requested in the output catalogue. Note that this classifier is heavily biased towards a high purity, and thus has a low completeness.

The method is inspired by the `SPREAD_MODEL` method provided by SE2 which is used in [Desai et al. \(2012\)](#) and [Sevilla-Noarbe et al. \(2018\)](#).

Our method uses $MU_MAX - MAG_AUTO$ as a proxy for `SPREAD_MODEL`; MU_MAX being the peak surface brightness above the background. Thus, our estimator $MU_MAX - MAG_AUTO$ is related to the concentration of light at the peak versus the total magnitude. This parameter has been used in [Jauzac et al. \(2012\)](#), [Sharon et al. \(2022\)](#), and [Estrada et al. \(2023\)](#) as input for the S/G classification.

Before flight, the point-like probability has been estimated in the plane of Fig. 9 ($x_m = MAG$, $y_m = MU_MAX - MAG$) using official simulated data by merely counting the number of galaxies and stars in each bin of this 2D space. Afterwards, the point-like probability of any real observation is computed by interpolating in this 2D array at the (x_m, y_m) position of the observation.

As shown in Fig. 9, the S/G separation is only performed in VIS-detected objects. The current rule-of-thumb to select stars in the MER catalogue is: (a) select very bright (even saturated) sources at VIS magnitudes $I_e < 17$; and (b) select `POINT_LIKE_PROB` > 0.96 . Note that the `POINT_LIKE_FLAG` is defined as `POINT_LIKE_PROB` > 0.96 and `DET_QUALITY_FLAG` = 0 so this flag can also be used. A more refined object classification, differentiating between star, galaxies and QSO, is performed by PHZ ([Euclid Collaboration: Tucci et al. 2025](#)).

8. The MER catalogue

The last step of the MER pipeline merges all the measurements performed in the previous steps and creating the output catalogues. The format of the MER PF output catalogues comply with the *Euclid* SGS standard. The main output of the cataloguing PE is the following:

- `EUC_MER_FINAL-CAT`: a FITS table, storing the official *Euclid* source ID, i.e., the `OBJECT_ID`, the source coordinates, the quality flags, and all the information related to the photometry measurements. Some DEEP regions could contain imaging data from additional EXT filters. In those cases the additional EXT photometry measurements are stored in a separated FITS table, namely the `EUC_MER_FINAL-DEEP-CAT`.
- `EUC_MER_FINAL-MORPH-CAT`: a FITS table storing all the morphological measurements performed in the MER pipeline. Each source in this table shares the `OBJECT_ID` information with all the other catalogues produced within this step.
- `EUC_MER_FINAL-CUTOUPS-CAT`: a FITS table containing information on the corners of the source cutouts. As for the `EUC_MER_FINAL-MORPHO-CAT`, all the sources share the `OBJECT_ID` information with the rest of the output catalogues.
- `EUC_MER_FINAL-SEGMAP`: a FITS binary image representing the map showing the connected pixels of the objects detected on the corresponding detection mosaics (VIS and NIR).

Appendix A gives a the detailed description of the content of the MER PF output catalogues.

External data coverage is heterogeneous across the different sky regions observed by *Euclid*. In particular, the Q1 release focuses on the processing of the EWS, including data from the DES (South) and UNIONS (North, Gwyn et al. in preparation) surveys, namely WHIGS, CFIS, Pan-STARRS, and WHISHES. Table 3 shows the list of bands available in the Q1 release.

8.1. $E(B-V)$ estimates

The distribution of galaxies on large scales probed by the *Euclid* satellite is affected by Galactic absorption and therefore the study of the galaxy clustering has to be corrected by the different survey depths, which could induce artefacts in the analysis. Moreover, the errors in this correction should be taken into account in the covariance matrix.

OU-MER provides the extinction $E(B - V)$ as estimated by the R1.20 *Planck* data release and estimates an error in the $E(B - V)$. This is done via the `LE3_GALEXT_ED` PF, a Python program that imports the public `healpy`⁶ in order to read the extinction map described in [Planck Collaboration \(2014\)](#). The map provides values for $E(B - V)$ and τ , the optical depth of dust as measured at 353 GHz, together with its associated error τ_{err} . The error associated with $E(B - V)$ can be calculated via the ratio between τ_{err} and τ ,

$$E(B - V)_{\text{err}} = E(B - V) \frac{\tau_{\text{err}}}{\tau}. \quad (18)$$

The algorithm takes a list of sky positions in a specified coordinate system and computes the dust extinction $E(B - V)$ based on the reference extinction map, assigning an $E(B - V)$ measurement and its associated error to each source in the catalogue.

⁶ <https://healpix.jpl.nasa.gov/>

Table 3. List of photometric bands available in the Q1 release. The ‘Filter label’ columns, shows how the filter is labeled in the MER catalogue data model.

Survey	Band	Filter label
EWS	I_E	VIS
EWS	J_E	J
EWS	H_E	H
EWS	Y_E	Y
EWS	Stack of J_E , H_E and Y_E	NIR_STACK
UNIONS CFIS	u	U_EXT_MEGACAM
UNIONS CFIS	r	R_EXT_MEGACAM
UNIONS Pan-STARRS	i	I_EXT_PANSTARRS
UNIONS WHIGS	g	G_EXT_HSC
UNIONS WISHES	z	Z_EXT_HSC
DES	g	G_EXT_DECAM
DES	r	R_EXT_DECAM
DES	i	I_EXT_DECAM
DES	z	Z_EXT_DECAM

8.2. Identification of spurious sources

We have developed a machine-learning tool to identify and remove spurious (i.e not real) sources in the photometric catalogues. This belongs to the general class of classification problems, since we need to assign a binary flag (1 for spurious objects, 0 otherwise) to each source. For this task, we adopt the Random Forest Classifier (RFC) algorithm (Breiman 2001). We trained the algorithm on a reference simulated catalogue of 430 000 sources, to which we already assign a spurious flag, matching the catalogue to the *Euclid* pre-launch True Universe (TU) simulation (Serrano et al. 2024). Sources that are matched to at least one TU source (either a star or a galaxy) within a radius of $0''.2$ are flagged as real (spurious flag set to 0), while sources that are not matched to any TU object within $0''.8$ are considered to be spurious (spurious flag set to 1). We exclude sources with matching radii between $0''.2$ and $0''.8$, to minimise the uncertainty of the label assignments. We kept 2% and 20% of the original sample, randomly selected, as validation and testing set, respectively, to check the performance of the classification algorithm. The RFC uses a set of N input features to determine whether a source is spurious or not, and the training allows us to find an optimal function from the input N -dimensional parameter space to the final binary flag. We selected, as input features, template fitting (TPhot) fluxes and S/N of photometric bands I_E , Y_E , J_E , and H_E from *Euclid*, and the g , r , i , and z subset from ground-based instruments. In addition, we adopted a set of discrete features: the quality flags estimated for each of the above-mentioned bands (FLAG_<band>), the detection quality flag (DET_QUALITY_FLAG) and a flag telling if the source comes from a blended parent (DEBLENDED_FLAG). In total these are 26 input features. RFC allows us to extract two types of information:

- the importance ranking of each input feature, which determines the most relevant properties in classifying the sources as spurious or real, resulting in the ground bands g , r , i , and z obtaining the highest ranking;
- the actual spurious probability (SPURIOUS_PROB) for each object in the photometric catalogue.

Given SPURIOUS_PROB, we identify a source to be spurious by adopting a probability threshold of 50%. With such a threshold, we identify up to 90% of the true spurious sources in our test sample, while only 0.13% of real galaxies or stars are wrongly

labelled as spurious. A more conservative threshold of 75% allows us to increase the purity (only 0.04% of real sources are lost), at the cost of a lower completeness of the spurious sample (only 80% of them are correctly identified and removed). We found 50% to be a good compromise between purity and completeness, and this represents our default choice.

8.3. Bright star masking

As a survey satellite, *Euclid* observes bright stars up to 8th magnitude brightness. The image of bright stars is characterised by a large and often saturated centre, together with diffraction spikes and possibly a blooming signature from the VIS detectors. These features are difficult to handle in the detection, deblending, and photometry. To mitigate this we map the contours of bright stars on the co-added VIS and NIR images as polygons.

Starting from positions provided by *Gaia* we map the imprint of stars on the individual VIS and NIR calibrated images using simple geometric forms:

- a central circle for the stellar disk;
- rectangles for the three diffraction spikes;
- a rectangle for the VIS blooming pattern.

The size of these simple forms scales with the brightness of the stars. For every *Gaia* star we build the union of the simple forms as a polygon and then project the polygon from each calibrated image to the co-added mosaic. The final polygon for each *Gaia* star is then set as the union of the polygons projected from the individual VIS and NIR calibrated images. As output we provide for all co-added measurement images a list of the combined polygons for the *Gaia* stars on that image as a JSON⁷ file.

Figure 10 shows with the red lines the bright star masks in two small cutouts of the I_E (left) and H_E (right) band image of tile 102021017. The different colour denote the brightness bracket of star, which scales the size of the geometric forms constituting the masks. All objects within the bright star masks in I_E or any of the bright star masks in Y_E , J_E or H_E are marked in the column DET_QUALITY_FLAG in two separate bits.

8.4. Matching of Gaia sources

We automatically match the *Euclid* objects with the *Gaia* DR3 sources (Gaia Collaboration et al. 2023). To optimise the match-

⁷ <https://www.json.org/json-en.html>

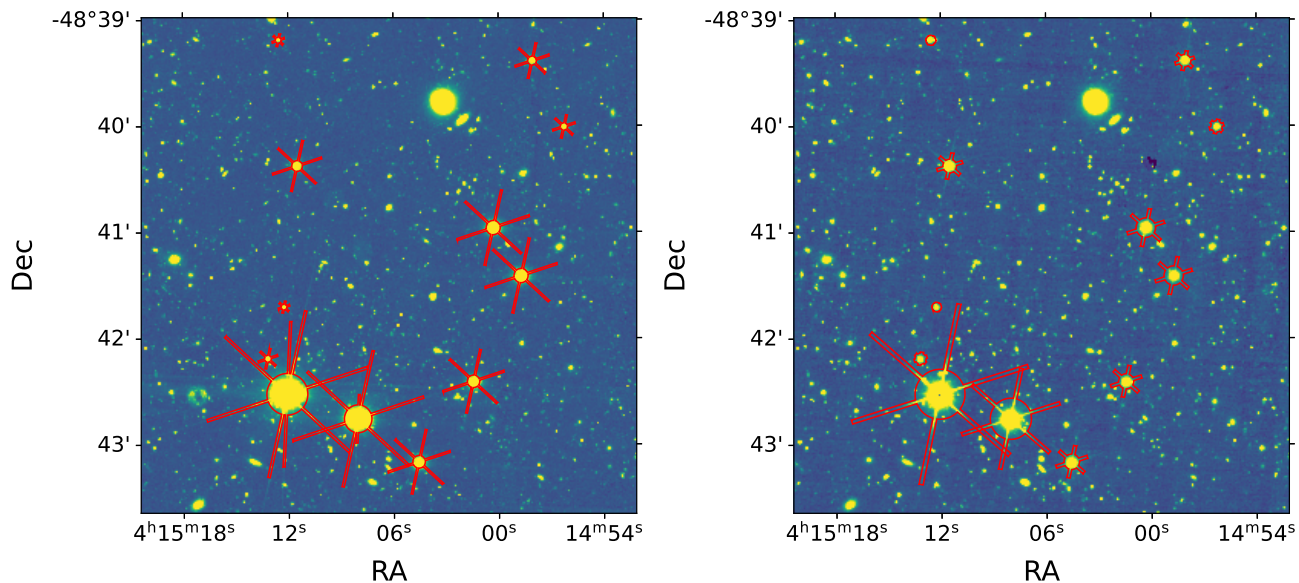


Fig. 10. The bright star masks (regions marked in red) in two small cutouts of the I_E (left) and H_E (right) band image of tile 102021017. The central ring and the length of the diffraction and blooming features scale with brightness of the star.

ing result, we propagate the positions of the *Gaia* objects from the DR3 epoch J2016.0 to the reference time of the MER catalogue, which is averaged from the VIS and NIR detection image reference times. The maximum allowed distance of $0''.3$, and the ID of the matched *Gaia* source is stored in the catalogue column `GAIA_ID`. The column `GAIA_MATCH_QUALITY` stores the matching quality as the squared distance between the *Gaia* and *Euclid* positions. Depending on Galactic latitude the number of *Gaia* matches is between 800 and 3000 objects in the final catalogues.

9. Validation pipeline

The ultimate purpose of the validation is to assure that output data of the MER pipeline are within the specification and requirements and contribute to reach the science goals of the *Euclid* project. Data validation helps also to identify processing issues or in general data quality problems. In the OU-MER validation we measure key properties of the MER outputs, such as object properties and image characteristics. If possible we compare and extrapolate the object properties with ground-truth information provided by the *Gaia* satellite.

The OU-MER validation is run automatically as a separate pipeline directly after the processing pipeline. The Q1 dataset is made up of three distinct fields, namely EDF-N, EDF-S, and EDF-F (Euclid Collaboration: Aussel et al. 2025), covered by several tiles each. We aggregate the information of all the tiles covering a given field, in order to analyse the statistical trend of the parameters computed in the validation pipeline. This aggregated information is an essential tool to monitor and improve the MER processing.

In the following Sections we present the most important validation results either for individual selected tiles or the aggregate numbers for a dataset such as EDF-S.

9.1. Astrometry

To assess the accuracy of the MER pipeline astrometry, we measure, for each tile, the mean positional offset with respect to *Gaia* (Fig. 11). Tiles with larger values of `FILLING_FACTOR` (Sect. 9.3), with a comparably large offset are located at the border of the field. This is expected since both these offsets originate from systematic residuals in the VIS astrometry (Euclid Collaboration: McCracken et al. 2025), which are not evenly sampled at the border.

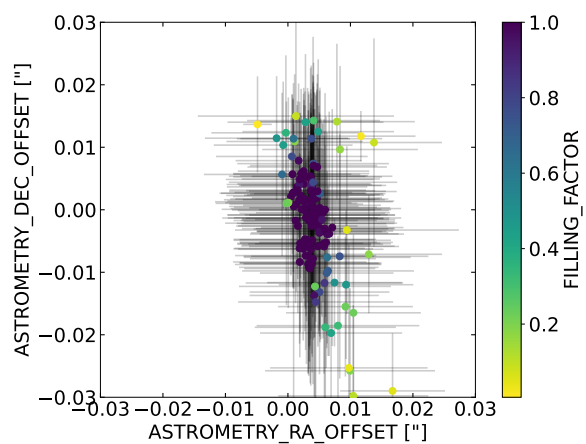


Fig. 11. Distribution of the astrometric offsets for all tiles in the EDF-S field.

9.2. Image Depth

We determine the depth of the imaging data by measuring the flux in several thousand randomly selected circular apertures. We restrict the measurements to background areas by skipping over apertures that have non-zero values in the segmentation image or

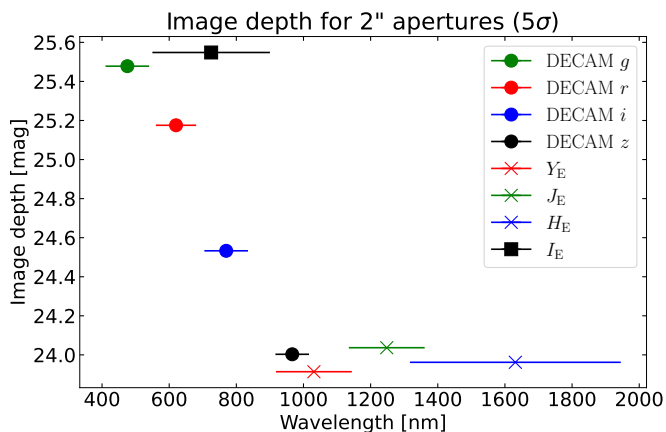


Fig. 12. The 5σ depth depth measured in all imaging data of tile 102021017 using flux measurement in $2''$ apertures in the sky background.

contain empty image areas. From the scatter of the flux values in these apertures we compute the image depth in the corresponding filter.

As an example Fig. 12 shows the 5σ depth in the multi-band data of tile 102021017 measured in apertures of $2''$ diameter. We have chosen a $2''$ diameter since corresponds to the typical 2 FWHM diameter in the worst resolution band (see Sect. 6). The depth estimates in other Q1 tiles are very similar to the ones shown in Fig. 12, especially for the data observed with the *Euclid* satellite I_E , Y_E , J_E , and H_E .

Note that these depth estimates are done on aligned images that are resampled from their original pixel scale, which certainly has an effect on these measurements. Also the variable exposure time within fully covered images and especially in the border tiles of Q1 may not fully be represented in a single depth value per band. Consequently we do not see these estimates as very accurate and absolute values. We use them as relative estimates for a set of tiles such as that released in Q1 to control the data quality.

9.3. Detection

In this part we collect for each tile all characteristic numbers associated to the object detection, cross-matching and object marking. We compute the object density in the `HealPix` pixels of the tile core area and determine the `FILLING_FACTOR` of the tile, which is the fraction of `HealPix` pixels containing at least one detected object. For interactive checks we illustrate these numbers in images such as Fig. 13, which shows the positions of the VIS and NIR detect numbers for tile 102021017 in EDF-S on the left and right panel, respectively. The bright star masked objects as well as the objects identified from *Gaia* are marked in both panels. The vertical “lines” of NIR detected objects in the right panel are caused by an insufficient masking of pixels affected by persistence (see *Euclid Collaboration: Polenta et al. 2025*). For an entire Q1 dataset the detection validation numbers help to identify border tiles with a small `FILLING_FACTOR` or data quality issues such as shallow or incomplete coverage in a detection band when comparing the number of VIS and NIR detected objects.

9.4. PSF

The PSF propagation method described in Sect. 5 is validated using *Gaia* stars with `CLASSPROB_DSC_COMBMOD_STAR` > 0.99. In addition, a magnitude cut of `MAG_G_GAIA` > 18 is applied to avoid possible saturation effects (see *Gaia DR3 Data Model* for details on the *Gaia* source catalogue definitions). For Q1, depending on the field, this results on a typical sample of 300 to 600 *Gaia* stars per MER tile.

We extract stamps in the MER mosaics around the *Gaia* star positions corrected for their proper motion. We use small stamps, $2''.1 \times 2''.1$ for the *Euclid* bands and $4''.5 \times 4''.5$ for the EXT mosaics, to minimise contamination from nearby sources. The star stamps are then fitted to a two-dimension Gaussian function and the fit FWHM values are compared with the propagated PSF stamps at the star positions. PSF stamps are fitted with exactly the same method. Ideally one would expect a 1 to 1 correlation between the two fitted values. Any systematic shift or large scatter in the correlation would imply that either the propagation method is not correct or that the input PSFs are not applicable to the input image data.

Figure 14 shows the propagated VIS PSF FWHM values for an example tile in the EDF-S field. The FWHM could change by more than 20%, depending on the source spatial position. Large-scale variations can be attributed to PSF changes in the VIS instrument field of view (*Euclid Collaboration: McCracken et al. 2025*). Figure 15 shows the comparison between the propagated PSF stamps and the *Gaia* stars extracted from the VIS mosaic. The agreement is very good with minimal excursions from the the $\pm 2\%$ offset lines. As discussed in Sect. 5, the results for the NIR bands are not as good, but they should improve in DR1 with newer NIR input PSFs. The agreement for the EXT bands is generally also very good. In these cases the PSF spatial variations can be attributed to varying seeing conditions in the images that were used to produce the mosaics.

9.5. Photometry

The photometric accuracy of the MER pipeline in each of the three Q1 datasets can be assessed by means of the magnitude offsets provided by the MER *Gaia* validation. The offsets are computed for each band (namely I_E , Y_E , J_E , and H_E along with the EXT-UNIONS filters for the case of EDF-N, and I_E , Y_E , J_E , and H_E plus the EXT-DECAM filters for the case of EDF-N and EDF-F) and for two different photometric approaches (APHOT and TPHOT), taking into account the non-saturated sources with a magnitude $I_E < 19.5$ that have been detected by the MER pipeline and that have been successfully cross-matched against the *Gaia* DR3 catalogue.

A photometric offset can be calculated for each source using a set of transformation functions generated to provide an expected analytic value for the magnitude difference between a given *Euclid* band and the total *g* magnitude in the *Gaia* system. Finally, the median magnitude offset of the all selected sources is computed, in order to have an aggregate quantity to describe the overall photometric accuracy per tile. For each of the three Q1 fields, this mean magnitude offset was computed after applying a 3σ -clipping over the per-tile values, a procedure that also allowed the identification of outlier tiles where the specific magnitude offset value was not aligned with the global trend of the field (this typically being a direct consequence of major distorting elements that affected the normal execution of the MER pipeline). We find overall reasonable agreement, with offsets at the percent level varying from band to band. For instance, as it can be ob-

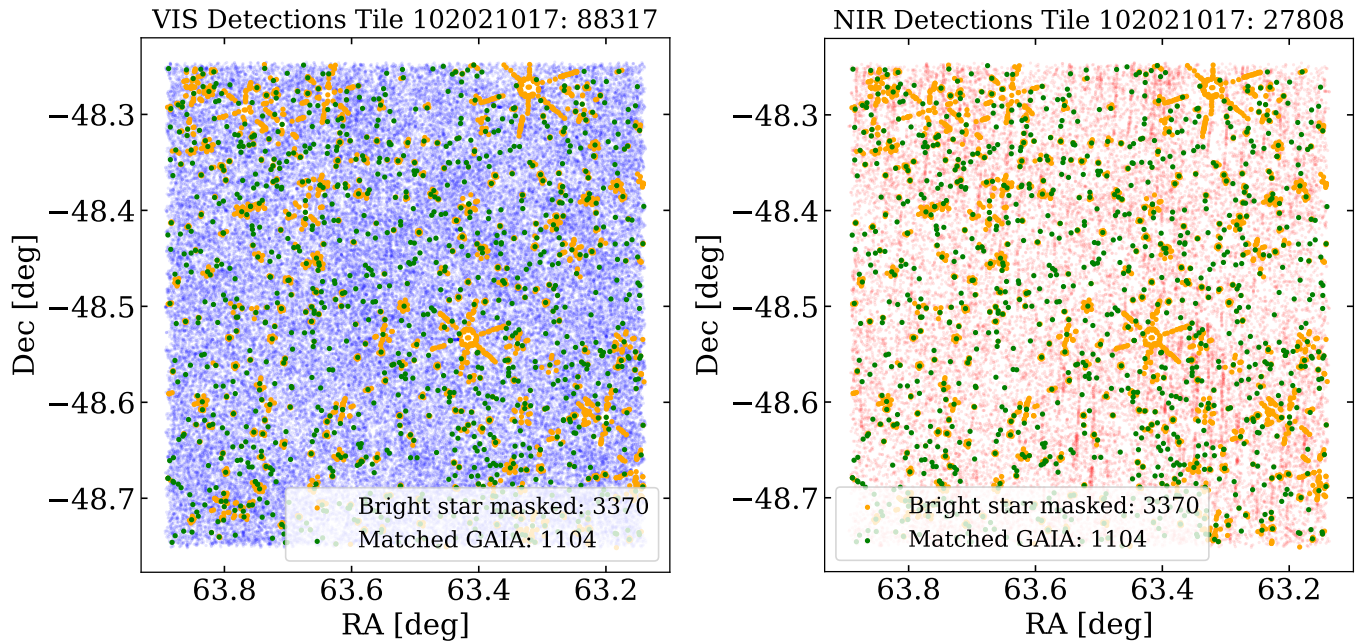


Fig. 13. The positions of all detected objects in tile 102021017. The color mark the various object categories as indicated on the right.

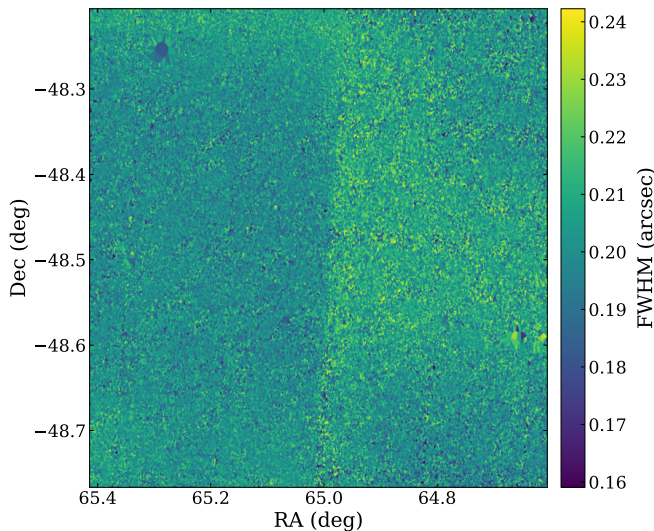


Fig. 14. Spatial variation of the MER catalogue-PSF for the VIS band on an example MER tile in the EDF-S field (tile index 102021019). FWHM values are measured fitting a two-dimensional Gaussian model to each propagated PSF stamp. Large-scale variations can be traced back to PSF changes along the VIS focal plane (see [Euclid Collaboration: McCracken et al. 2025](#), for more details). In this example, the sharp FWHM change at RA $\sim 65^\circ$ coincides with the transition between two different *Euclid* observation.

served in Fig. 16 for the case of EDF-S, we find mean magnitude offsets of -0.0688 ± 0.0029 mag in I_E , -0.0202 ± 0.0100 mag in Y_E , -0.0306 ± 0.0109 mag in J_E and -0.0078 ± 0.0128 mag in H_E , respectively in what concerns aperture photometry (APHOT), while, for the case of template fitting photometry (TPHOT), we report mean magnitude offsets of -0.0809 ± 0.0128 mag in Y_E , -0.0746 ± 0.0131 mag in J_E and -0.0426 ± 0.0124 mag in H_E , respectively. For the case of the EXT-DECAM bands included in EDF-S, we find mean magnitude offsets of -0.0285 ± 0.0142

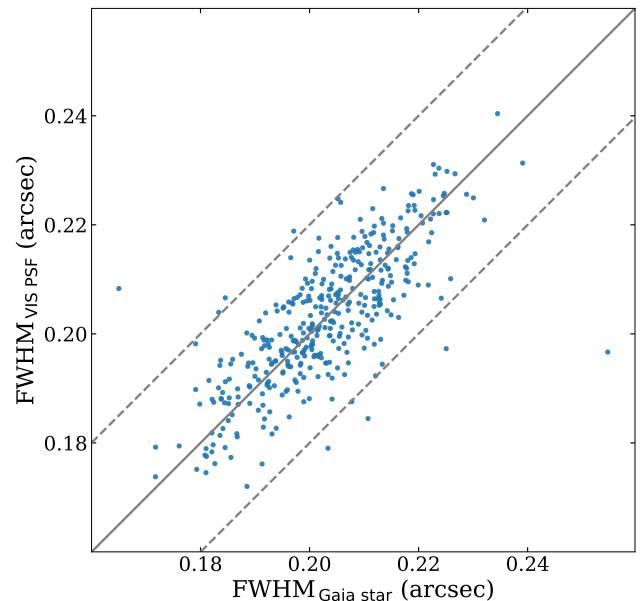


Fig. 15. Comparison between the *Gaia* star profiles extracted from the VIS mosaic in tile 102021019 and the propagated VIS PSFs stamps at the *Gaia* star positions. FWHM values are measured fitting a two-dimensional Gaussian model to the PSF stamps and the *Gaia* star profiles. The identity line (continuous) and $\pm 2\%$ FWHM difference lines (dashed) show that both measurements agree within 2% in most of the cases.

mag in g , -0.0086 ± 0.0054 mag in r , 0.0007 ± 0.0072 mag in i and -0.0018 ± 0.0102 mag in z , respectively in what concerns APHOT, while for the case of TPHOT, we report mean magnitude offsets of -0.0103 ± 0.0208 mag in g , 0.0188 ± 0.0059 mag in r , 0.0275 ± 0.0087 mag in i and 0.0246 ± 0.0126 mag in z , respectively. However, we point out that these offsets values have been continuously changing in the various phases of the observa-

tional campaign. Their causes are under investigation, with difference in photometric techniques, PSF, and calibration related issues being the most probable culprits. More detailed information, including data for other fields and bands, can be found in the Q1 release notes associated to this paper (see Sect 9.7).

It should be kept in mind that all of the validation involves bright stars only, which are not the main targets of the survey and therefore of the pipeline; checks against archival catalogues of galaxies have been performed, yielding reasonable agreement, but the uncertainties are too large to allow for a thorough evaluation of the accuracy. We have verified with random direct checks on the final mosaics that while for bright stars the aperture photometry estimate yields the best estimates, template fitting performs better for extended objects, not only helping to beat blending issues, but providing more accurate measurements in all cases for galaxies.

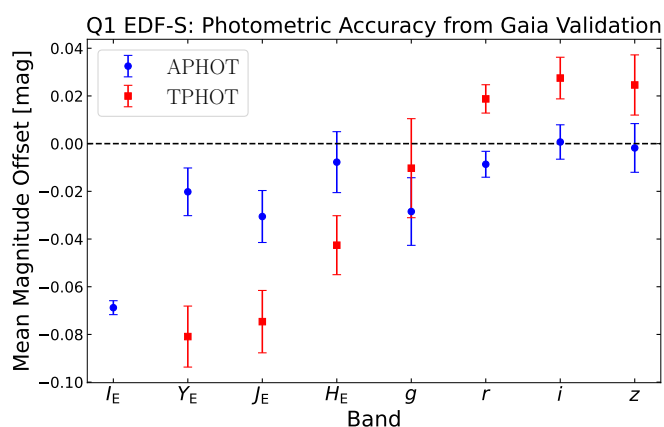


Fig. 16. Mean magnitude offsets for aperture (A-PHOT) and template fitting (T-PHOT) photometry in EDF-S derived from the results computed by the validation pipeline against cross-matched *Gaia* sources for the *Euclid* (I_E , Y_E , J_E and H_E) and EXT-DECAM bands (g , r , i and z). The error bars correspond to the specific standard deviation associated to each mean magnitude offset calculated.

9.6. Point-like probability

In order to identify possible errors in the identification of point-like objects, we compare for each tile the number of *Gaia* matches with the number of objects with `POINT_LIKE_PROB > 0.96`. As can be seen in Fig. 17, these two parameters are roughly equal. In EDF-N (the galactic latitude is $30^\circ 0'$), they can be both small if the tile is not fully observed, or both around 2000 if the filling factor is close to 1. Any strong deviation from the dashed gray line ($y = x$) indicates a tile that needs further analysis (it is often a good indicator that some solar X ray burst has hit the VIS detectors).

At the tile level we validate `POINT_LIKE_PROB` against *Gaia* matches identified in the MER final catalog (See Sect. 9.6) as shown in Fig. 18 for tile 102021017. There are 1104 objects with *Gaia* matches and 1070 with a high point-like probability (`POINT_LIKE_PROB > 0.96`). From these 1070 there are 744 with and 326 without *Gaia* matches. The not matched objects are concentrated beyond the limiting magnitude of *Gaia*.

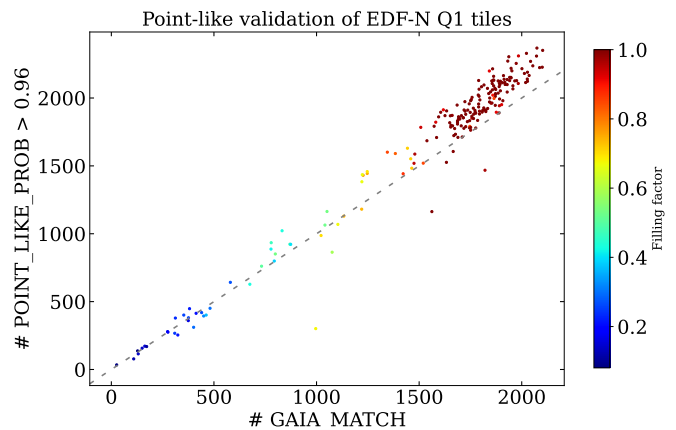


Fig. 17. Comparison for each EDF-N tile between the number of *Gaia* objects found and the number of objects with a high probability to be point-like (`POINT_LIKE_PROB > 0.96`).

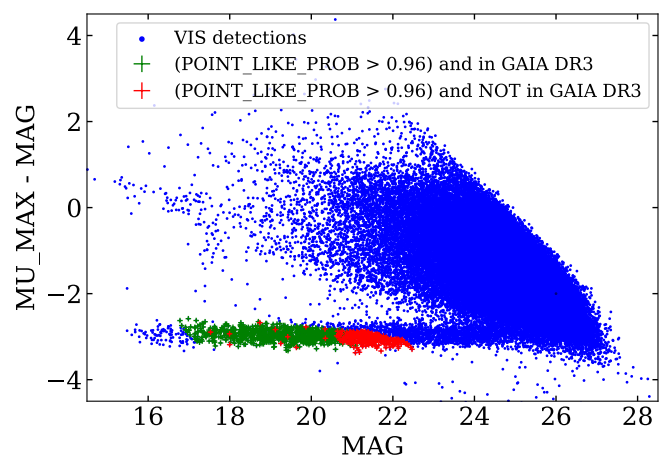


Fig. 18. Tile 102021017 : VIS detections with a high probability to be point-like (`POINT_LIKE_PROB > 0.96`) identified in *Gaia*. Most of them (in green) are found up to $MAG = 21$. Red points (MER point-like detections not found in *Gaia*) are mostly at fainter magnitudes, beyond the *Gaia* detection limit.

9.7. Q1 release notes and known issues

Q1 data come with a list of *caveats* and known issues identified also thanks to the effort of EC scientists outside the perimeter of OU-MER and, in general, the SGS. An exhaustive description of how to deal with OU-MER products in the Q1 dataset can be found in the Q1 Explanatory Supplement⁸.

10. Conclusions and outlook

In this paper we have presented a general overview of the OU-MER pipeline, with a particular focus on the work done for the data released as part of Q1. The Q1 exercise has allowed us to identify some areas in which to focus our work towards future, larger data releases such as DR1.

The main goal of OU-MER is to provide photometric and morphological measurements to both the customer OUs in the *Euclid* SGS (OU-PHZ, OU-SIR, OU-SHE) and the general scientific community. The main effort towards the upcoming Data

⁸ <https://euclid.esac.esa.int/dr/q1/expsup>

Release 1 (DR1) is to improve the consistency of our photometry. The validation pipeline has shown that the current results for photometry are reasonably good, although with some room for improvement. As part of the continuing pipeline development we are currently conducting various tests to reach a full understanding of some issues that are outlined in the Q1 release notes (details in the Q1 Explanatory Supplement linked in Sect. 9.7).

The most important assessment on the quality of the OUMER pipeline output products is going to come from the downstream units such as OU-PHZ, -SHE and -LE3 when using larger quantities of *Euclid* data in a cosmology analysis such as planned for DR1 and later releases.

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This work has made use of the *Euclid* Quick Release (Q1) data from the *Euclid* mission of the European Space Agency (ESA), 2025, <https://doi.org/10.57780/esa-2853f3b>.

Based on data from UNIONS, a scientific collaboration using three Hawaii-based telescopes: CFHT, Pan-STARRS, and Subaru www.skysurvey.cc. Correspondingly, please add “Based on data from the Dark Energy Camera (DECam) on the Blanco 4-m Telescope at CTIO in Chile <https://www.darkenergysurvey.org>.” if you use MER data from the southern hemisphere. If you use Gaia data, please acknowledge: “This work uses results from the ESA mission *Gaia*, whose data are being processed by the Gaia Data Processing and Analysis Consortium <https://www.cosmos.esa.int/gaia>”

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Appendix A: The OU MER Data Model

All *Euclid* data products must comply with the SGS Data Model (DM) and are documented in the MER Data Product Description Document⁹ (DPDD). The DPDD also states, for each product, if the product itself is ingested into the *Euclid* Science Archive System (SAS, [Euclid Collaboration: Aussel et al. 2025](#)). In this section we provide a brief summary of the OU-MER pipeline deliverables.

Appendix A.1: Output images and segmentation maps

Together with the photometric and morphological catalogues, the OU-MER pipeline outputs the set of images on which the photometric and morphological analysis is performed. Those images areas follows.

- The background-subtracted mosaics, one for each input band. The associated data product in the DPDD is `DpdMerBksMosaic`.
- The mosaics used to perform the object detection, one for VIS (VIS) and one for the stack of the three NIR bands (NIR_STACK). The associated data product in the DPDD is `DpdMerDetectionMosaic`.
- A map showing the connected pixels of the objects detected on the corresponding detection mosaics (VIS+NIR_STACK). The associated data product in the DPDD is `DpdMerSegmentationMap`.

Note that the segmentation map, together with the catalogue, refers to the inner region of a MER tile (see Sect. 3.1), while the mosaics cover the whole tile region. Figure A.1 shows the inner and outern tile region of a MER tile with respect to a reference mosaic.

Appendix A.2: Naming convention and data format

The names of the data files associated to the MER data products are formed using the following format:

`EUC_MER_[TYPE]_TILE[INDEX]-[RND]_[TIME].[EXT]`

where TYPE is one of the file types described below, INDEX is the associated MER tile index (e.g., 102022523), RND is a random string that it is used to avoid possible file name duplications (e.g., 15E4F0), TIME is the file creation timestamp (e.g., 20241121T114727.022303Z) and EXT is the file extension (`fits.gz` or `json`).

The following are the file types used in the MER PF (see Table 3 for a complete list of band label values):

- `BGSUB-MOSAIC-<band>`: Mosaic image data.
- `MOSAIC-<band>-RMS`: Mosaic rms data.
- `MOSAIC-<band>-FLAG`: Mosaic flag data.
- `BGMOD-<band>`: Mosaic subtracted background model.
- `FILTER-TRANSMISSION-<band>`: Mosaic average filter transmission wavelength.
- `DETECTOR-LAYERING-<band>`: Mosaic input layers information.
- `CATALOG-PSF-<band>`: Mosaic catalogue PSF.
- `GRID-PSF-<band>`: Mosaic grid PSF.
- `STAR-MASKS-<band>`: Mosaic bright star spatial masks.
- `FINAL-SEGMAP`: Detection segmentation map.

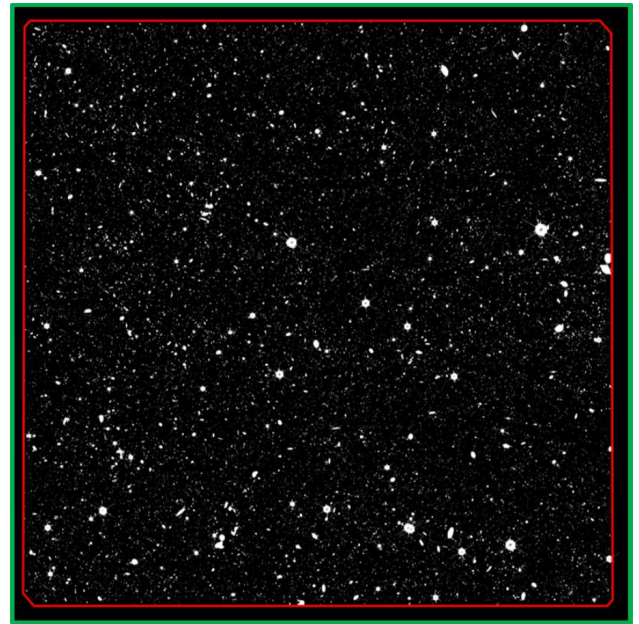


Fig. A.1. Outer and inner tile regions relative to an OU-MER mosaic. The green frame shows the MER tile outern region, while the red frame is the inner MER tile region. The segmentation map and the catalogue refer to the inner tile region; all the sources between the outer and inner regions are not catalogued. A value of -1 is assigned to pixels related to sources outside the inner region. A standard MER tile (outern region) covers an area of $32' \times 32'$. The border between the outern and inner region has a depth of $2'$.

- `FINAL-CAT`: Catalogue with the main photometry information.
- `FINAL-MORPH-CAT`: Catalogue with the morphology information.
- `FINAL-CUTOUTS-CAT`: Catalogue with the source cutout coordinates.
- `FINAL-DEEP-PHOTO`: Catalogue with extra photometry information available only on the Euclid DEEP fields.

The DPDD provides more details about the content of the different MER data files.

Appendix A.3: Column-by-column catalogue description

The catalogues produced by OU MER pipeline list more that 3200 columns. The structure of the photometry catalogues (`EUC_MER_FINAL-CAT` and `EUC_MER_FINAL-DEEP-CAT`) is summarised in sections [Main catalogue FITS file](#) and [DEEP field photometry catalogue FITS file](#) of the MER DPDD. Section [Morphology catalogue FITS file](#) describes the morphology catalogue (`EUC_MER_FINAL-MORPHO-CAT`), while section [Cutouts catalogue FITS file](#) lists the columns available in the cutout catalogue (`EUC_MER_FINAL-CUTOUTS-CAT`).

⁹ <https://euclid.esac.esa.int/dr/q1/dpdd>