

Euclid Quick Data Release (Q1)

X. A census of dwarf galaxies across a range of distances and environments

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ABSTRACT

The *Euclid* Q1 fields were selected for calibration purposes in cosmology and are therefore relatively devoid of nearby galaxies. However, this is precisely what makes them interesting fields in which to search for dwarf galaxies in local density environments. We took advantage of the unprecedented depth, spatial resolution, and field of view of the *Euclid* Quick Release (Q1) to build a census of dwarf galaxies in these regions. We have identified dwarf galaxies in a representative sample of 25 contiguous tiles in the Euclid Deep Field North (EDF-N) covering an area of 14.25 deg². The dwarf galaxy candidates were identified using a semi-automatic detection method based on properties measured by the *Euclid* pipeline and released as part of the catalogue produced by the MERge Processing Function (MER PF) pipeline. A selection cut in surface brightness and magnitude was used to produce an initial dwarf candidate catalogue, and this was followed by a cut in morphology (removing background spirals) and $I_E - H_E$ colour (removing red ellipticals). This catalogue was then visually classified to produce a final sample of dwarf candidates, including their morphology, number of nuclei, globular cluster (GC) richness, and presence of a blue compact centre. We identified 2674 dwarf candidates, corresponding to 188 dwarfs per square degree. The visual classification of the dwarfs reveals a slightly uneven morphological mix of 58% ellipticals and 42% irregulars, with very few potentially GC-rich (1.0%) and nucleated (4.0%) candidates but a noticeable fraction (6.9%) of dwarfs with blue compact centres. The distance distribution of 388 (15%) of the dwarf candidates with spectroscopic redshifts peaks at about 400 Mpc. Their stellar mass distribution confirms that our selection effectively identifies dwarfs while minimising contamination. The most prominent dwarf overdensities are dominated by dwarf ellipticals, while dwarf irregulars are more evenly distributed across the field of view. This work highlights *Euclid*'s remarkable ability to detect and characterise dwarf galaxies across diverse masses, distances, and environments.

Key words. galaxies: dwarf – galaxies: evolution – galaxies: fundamental parameters – galaxies: general – galaxies: nuclei – galaxies: star clusters: general

1. Introduction

Dwarf galaxies are characterised by their small size and low luminosity, and their stellar masses are generally smaller than about $10^9 M_\odot$ (Hodge 1971). This sets the Large Magellanic Cloud, with a stellar mass of $2.7 \times 10^9 M_\odot$ (van der Marel 2006), at the threshold of the dwarf galaxy regime. Dwarf galaxies are the most abundant type of galaxies (Binggeli et al. 1988), and in the hierarchical model of structure formation, they are thought to be the building blocks of the Universe (White & Rees 1978). They are distinct from other low-mass objects, such as star clusters, due to their larger radii (Kim et al. 2016a; Simon 2019) and, most importantly, their dark matter content (Mateo 1998; Collins et al. 2013; Kim et al. 2016b).

Dwarf galaxies come in several morphological classes. Late-type dwarf galaxies are star-forming galaxies that are split into dwarf irregular (dI or dIrr) and blue compact dwarf (BCD) galaxies, where the main difference between the two is the star-formation rate. Early-type dwarf galaxies are typically quenched, meaning they have ceased star formation. They are classified into dwarf spheroidal (dSph), dwarf elliptical (dE), ultra-diffuse galaxies (UDGs), ultra-compact dwarfs (UCDs), and ultra-faint dwarf (UFD) galaxies, and they can either be nucleated or non-nucleated. Some UDGs, especially those in the field, are star-forming late-type objects. The distinction between dEs and dSphs is historical in nature, with the early-type dwarf galaxies in our own Local Group referred to as dSphs (e.g. Mateo et al. 1991; Ibata et al. 1994), while

outside of it, such as in the Virgo cluster, they are usually referred to as dEs (e.g. Binggeli 1994; Lisker et al. 2006). The dSphs are also usually considered to be less massive than the dEs. In this paper the term ‘dE’ refers to all quenched dwarf galaxies.

The morphology of dwarf galaxies appears to be driven by their environments. Early-type dwarf galaxies are found mostly in group and cluster environments (Binggeli et al. 1987; Geha et al. 2012), while late-type dwarfs are also found in the field (Papastergis et al. 2015; Prole et al. 2021; Heesters et al. 2023). In dense environments, various mechanisms can quench a dwarf galaxy (Boselli et al. 2008, 2022; Kormendy et al. 2009), such as ram-pressure stripping, tidal harassment, and starvation. In ram-pressure stripping, the interaction between the hot intra-cluster gas and the infalling dwarf galaxy removes its star-forming gas reservoir (Gunn & Gott 1972). In tidal harassment (or tidal stripping), the gas is removed via tidal deformations, usually forming two arms (Moore et al. 1996; Mayer et al. 2001; Smith et al. 2010). Starvation describes the mechanism where a galaxy is depleted of its star-forming gas in a cluster environment (Larson et al. 1980). Although these mechanisms are dominant in cluster environments, a recent survey of dwarf galaxies has identified dEs in large numbers in the low- to medium-density environments of groups of galaxies (e.g. Habas et al. 2020), which suggests that there is likely more than one pathway to their formation.

The detection of faint dwarf galaxies is no trivial task due to their low surface brightness and relatively small

sizes. Surveys focused on the detection of such objects have been heavily based on the visual inspection of astronomical images (e.g. Karachentsev et al. 2015; Ordenes-Briceño et al. 2016; Wittmann et al. 2017; Park et al. 2017; Müller et al. 2017; Paudel et al. 2023; Crosby et al. 2024; Montes et al. 2024), thus limiting the area of the night sky that can effectively be covered by this type of a census. Semi-automated approaches using detection tools such as SourceExtractor (Bertin & Arnouts 1996), NoiseChisel (Akhlaghi & Ichikawa 2015), or MTOBjects (Teeninga et al. 2015), have yielded catalogues of potential dwarfs (e.g. Merritt et al. 2016; Venhola et al. 2017; Carlsten et al. 2020; Habas et al. 2020; Tanoglidis et al. 2021); however, the detected sources still need to be inspected by eye to eliminate false positives, and these detection tools often miss obvious dwarf galaxies located near bright sources such as stars or galaxies (Müller & Jerjen 2020). Currently, no fully automated process exists that yields both a pure and complete dwarf galaxy catalogue without visual inspection. This is a problem for wide-field surveys such as *Euclid*, which cover large fractions of the entire night sky.

The *Euclid* space mission (Laureijs et al. 2011; Euclid Collaboration: Mellier et al. 2025) is set to observe nearly one-third of the sky across four photometric bands, extending from the red optical to the near-infrared (NIR). The *Euclid* telescope has two key instruments mounted: the visible instrument (VIS; Euclid Collaboration: Cropper et al. 2025), which has a single broad-band filter, I_E , devoted to imaging at red optical wavelengths, and the Near Infrared Spectrometer and Photometer (NISP; Euclid Collaboration: Schirmer et al. 2022; Euclid Collaboration: Jahnke et al. 2025), which provides both imaging in the NIR through three filters (Y_E , J_E , and H_E), and low-resolution NIR spectroscopy. In addition to providing images with superb spatial resolution (VIS: $0''.20$, NISP: $\approx 0''.48$; see Sect. 2.1) and covering a large part of the sky ($14\,000\text{ deg}^2$; Euclid Collaboration: Scaramella et al. 2022), *Euclid* is poised to reach unprecedented surface brightness sensitivity in the different surveys: $29.8\text{ mag arcsec}^{-2}$ for the Euclid Wide Survey (EWS; Euclid Collaboration: Scaramella et al. 2022) and $31.8\text{ mag arcsec}^{-2}$ for the Deep Survey.

Thanks to all this, *Euclid* is expected to detect and characterise roughly a million new dwarf galaxies, including tens of thousands of new UCDs and UDGs over a range of distances and environments. UDGs are particularly interesting given the ongoing debate on their nature, formation mechanisms, and variety of globular cluster (GC) populations compared to the general population of dwarf galaxies (Lim et al. 2018; Forbes et al. 2020; Marleau et al. 2021, 2024; Gannon et al. 2022; Saifollahi et al. 2022, 2025a; Ferré-Mateu et al. 2023).

This new era of wide-field imaging surveys (e.g. EWS) is set to be transformational in the way galaxy formation and evolution is understood, particularly at the low-mass end of the galaxy mass function. Already with the large number of Early Release Observations (EROs; Euclid Early Release Observations 2024) papers, *Euclid* has proven its outstanding performance on all the scientific topics involved. Notably, it has shown its outstanding capability to detect new dwarfs and reveal their GC systems (Marleau et al. 2025; Cuillandre et al. 2025; Saifollahi et al. 2025a,b). Examples of these exquisite capabilities are shown in the ERO (Euclid Early Release Observations 2024) papers describing the observation and characterisation of the dwarf galaxies in the Perseus galaxy cluster (Marleau et al. 2025; Saifollahi et al. 2025a), the GCs in the Fornax cluster (Saifollahi et al. 2025b; Euclid Collaboration: Voggel et al. 2025), the diffuse stellar structures and GCs in the Dorado group

(Urbano et al. 2025), and the ERO project on nearby galaxies (Hunt et al. 2025).

In this paper, we present the detection and characterisation of the dwarf galaxy population in a representative sample of the Euclid Quick Release Q1 (2025). The Q1 data are outlined in Sect. 2. Sections 2.2, 2.3, and 2.4 detail the data preparation procedure and the catalogue used for source detection and photometric analysis. Section 3 describes the methodology for processing the data and identifying the dwarf galaxy candidates. Section 4 presents the results of the visual classification; photometric and structural properties; spectroscopic redshift; and spatial distribution of the dwarf candidates. Finally, in Sect. 6 we summarise the findings on the dwarf population in the Q1 tiles.

2. Data

2.1. Euclid observations

The Q1 data span 63.1 deg^2 (Euclid Collaboration: Aussel et al. 2026) and cover three Euclid Deep Fields (EDFs; 53 deg^2), with a single visit depth equivalent to one Reference Observation Sequence (ROS), similar to EWS (Euclid Collaboration: Scaramella et al. 2022). These three fields are known as EDF North (EDF-N), EDF South (EDF-S), and EDF Fornax (EDF-F). A detailed description of the EDFs can be found in Euclid Collaboration: Mellier et al. (2025). The Q1 data also include observations of the Lynds Dark Nebula LDN1641; the seven ROSs of this field were obtained as part of the commissioning of the Fine Guidance Sensor (FGS).

The field of view of each Q1 tile is of size 0.28 deg^2 ($32' \times 32'$; Euclid Collaboration: Romelli et al. 2026). The data were obtained in a dithered observation sequence where an image in I_E is taken simultaneously with slit-less grism spectra in the NIR, followed by NIR images taken through J_E , H_E , and then Y_E . The telescope is then dithered and the sequence is repeated four times. This observation sequence is similar to the ROS that is being used to observe the EWS. The integration time per dither position is 549.6 s in the I_E filter and 87.2 s in each of the Y_E , J_E , and H_E filters (Euclid Collaboration: Mellier et al. 2025).

The pixel sizes for the VIS and NISP instruments are $0''.1$ and $0''.3$, respectively, which means that for both instruments the point-spread function (PSF) is slightly undersampled. In the final Q1 stacked frames produced by the MERge Processing Function (MER PF) pipeline, VIS and NISP images are re-sampled to a similar pixel size of $0''.1$. The final Q1 data have a median PSF full width at half maximum (FWHM) of $0''.20$, $0''.48$, $0''.50$, and $0''.54$ in I_E , Y_E , J_E , and H_E , respectively (Euclid Collaboration: Romelli et al. 2026). The zero point (ZP) in all filters is $ZP = 23.9\text{ AB mag}$. The details of the data reduction are described in Euclid Collaboration: McCracken et al. (2026) and Euclid Collaboration: Polenta et al. (2026). Hereafter, we refer to AB magnitudes as simply magnitudes.

In total, the Q1 data release contains 351 tiles. However, the seven tiles pertaining to LDN1641 display a large amount of foreground Galactic extinction that leads to fewer sources being detected and a larger extinction correction for the photometric measurements. Therefore, we excluded these seven tiles from our analysis, leaving 344 Q1 tiles. Overall, a total of 57 tiles have bad quality (e.g. extreme edge, no colour information, and dark nebula) and 91 tiles have partial coverage. This leaves a number of $351 - 57 - 91 = 203$ tiles with good quality data and full coverage.

In this paper, we present the detection and characterisation of the dwarf galaxies in a representative region of the Q1 data

release, consisting of a contiguous set of 25 Q1 tiles in the EDF-N. One of the reason that led us to select the tiles in the EDF-N field is that the EDF-N has very good spectroscopic redshift coverage. The analysis of the remainder of the Q1 tiles will be presented in a separate future paper.

2.2. Background restoration

The *Euclid* standard pipeline includes background-removal steps that are optimised for its cosmological science, which requires the shape measurement for weak lensing analysis of millions of small ($1''$ – $2''$) distant galaxies. Structures larger than the mesh size used for the background determination are erased by the standard pipeline. The larger the source, the higher the effect of the background subtraction.

For the background-subtracted image by the MER processing pipeline (BGSUB MER product; [Euclid Collaboration: Romelli et al. 2026](#)), even at scales of a few $10''$, i.e. the scale of dwarf galaxies, the local background subtraction is detrimental. Therefore, the final MER background subtraction step was reversed by adding back the background measured by the MER processing pipeline (BGMOD MER product) to the BGSUB MER product, hence providing the image before the final MER background removal. As a result, these MER-background restored images are stacks of VIS images that have had their background subtracted by the VIS processing pipeline, which provides good background subtraction up to about $1'$ scale. This is not the case for the Q1 NIR images, which have a background subtraction that has not been optimised for analysis of low surface brightness features at this scale. The rendering of the colour images shown in this paper is affected by this for the most extended objects.

It is important to note, however, that the MER catalogue ([Euclid Collaboration: Romelli et al. 2026](#)), discussed in more detail in Sect 2.4, was generated from the standard pipeline produced background subtracted image. This means that the photometric parameters (e.g. magnitudes, surface brightness) will likely be impacted. However, for the small dwarfs, we do not expect this impact to be significant (the effect becomes more important for the bright extended galaxies).

2.3. Colour images

Colour images at the VIS spatial resolution were generated for all 344 tiles using the AstrOmatic software program STIFF, a program that converts scientific FITS images to the more popular TIFF format for illustration purposes ([Bertin 2012](#)). This was done using the I_E , Y_E , and H_E images, since the J_E image is the most affected by persistence effects because it is taken right after the NISP spectroscopic data. An example colour image of a zoomed-in region of tile 102158889 is shown in Fig. 1. This image illustrates that dwarf galaxy candidates are easily identifiable in the Q1 data set.

The VIS-NISP colour images were then generated in the HiPS format ([Fernique et al. 2015](#)), for visualisation and classification of the dwarf galaxy candidates, using the I_E band in blue, the Y_E band in green, and the H_E band in red. The colour image has the same spatial resolution as the high-resolution I_E band image. To produce these images, the luminance channel was taken from the I_E band image, while the I_E , Y_E , and H_E images were used for the three colour channels (corresponding to blue, green, and red, respectively). As the NIR images are simply resampled at the VIS resolution, this means that the colour images are limited by the NIR resolution.

2.4. Source catalogue

The source catalogue was taken directly from the MER catalogue. This product is an output from the MER Catalogue Assembly Processing Element ([Euclid Collaboration: Romelli et al. 2026](#)). The MER catalogue is the final merged catalogue, with photometric and morphological information. It contains object positions, total fluxes, colours and some object characterisation parameters.

For all sources in the MER catalogues, the magnitudes of the objects were derived by taking the fluxes reported in the MER catalogues and applying the zeropoint given above. The extinction correction was applied using the following formula: $m_0 = m - R_\lambda \times \text{GAL_EBV}$, where ‘GAL_EBV’ is the estimated Galactic $E(B - V)$ at the source centroid according to the reference *Planck* map provided in the MER catalogue and R_λ is taken from the Milky Way extinction law ($R_V = 3.1$; [Fitzpatrick 1999](#)).

Comparison of the MER catalogue with our own run of SourceExtractor on one of the tiles showed the MER catalogue to be very complete, and hence we decided to rely on the MER catalogue for our analysis. Using a methodology for detecting dwarf galaxies based on the source catalogue generated by the pipeline has two main advantages: firstly, it makes the analysis more easily reproducible since the catalogues are publicly available; and secondly, it avoids unnecessary computing time, which will become even more important when we are dealing with the large number of tiles in the *Euclid* Data Release 1 (DR1). It is important to note that the MER catalogue associated with each tile does not contain sources from the edge region ($60''$ in size) in order to avoid the duplication of sources between adjacent tiles in the overlap regions.

We also investigated the completeness of the MER detection to determine whether the most nearby and extended dwarf galaxies are adequately detected and included in the final source catalogue. Given the lack of such nearby dwarf galaxies within 50 Mpc in the EDF-N, we focused our assessment on the dwarf galaxies found in EDF-S. We searched the SIMBAD database ([Wenger et al. 2000](#)) for such nearby objects and found six dwarf galaxies within the EDF-S with radial velocities between 700 and 3500 km s^{-1} , corresponding to redshift distances of 10–50 Mpc, respectively. All six of these objects have been detected and included in the MER catalogue.

3. Dwarf identification and classification

To efficiently identify dwarf candidates in the Q1 tiles, we adopted a semi-automated methodology. The procedure we followed consisted firstly of selecting a representative tile, namely a ‘reference’ tile, for which we performed a full visual detection and classification analysis. The results obtained for the reference tile were then used to calibrate our automatic selection method for all Q1 tiles.

The general steps of our methodology were divided into two main parts. First, our analysis of the reference tile consisted of (i) visually inspecting the colour image and annotating the dwarf candidates; (ii) comparing and merging the catalogues of the different human classifiers (hereafter, referred to simply as ‘classifiers’); (iii) visually classifying objects in the merged catalogue (16 classifiers per object); and (iv) creating the final catalogue from the average score selection cut. This reference sample of dwarf galaxies was then used to define the selection cut for all of the Q1 tiles. The second part of our analysis therefore consisted of (i) applying the selection cut to all of the tiles and automatically generating the candidate list; (ii) visually classifying the

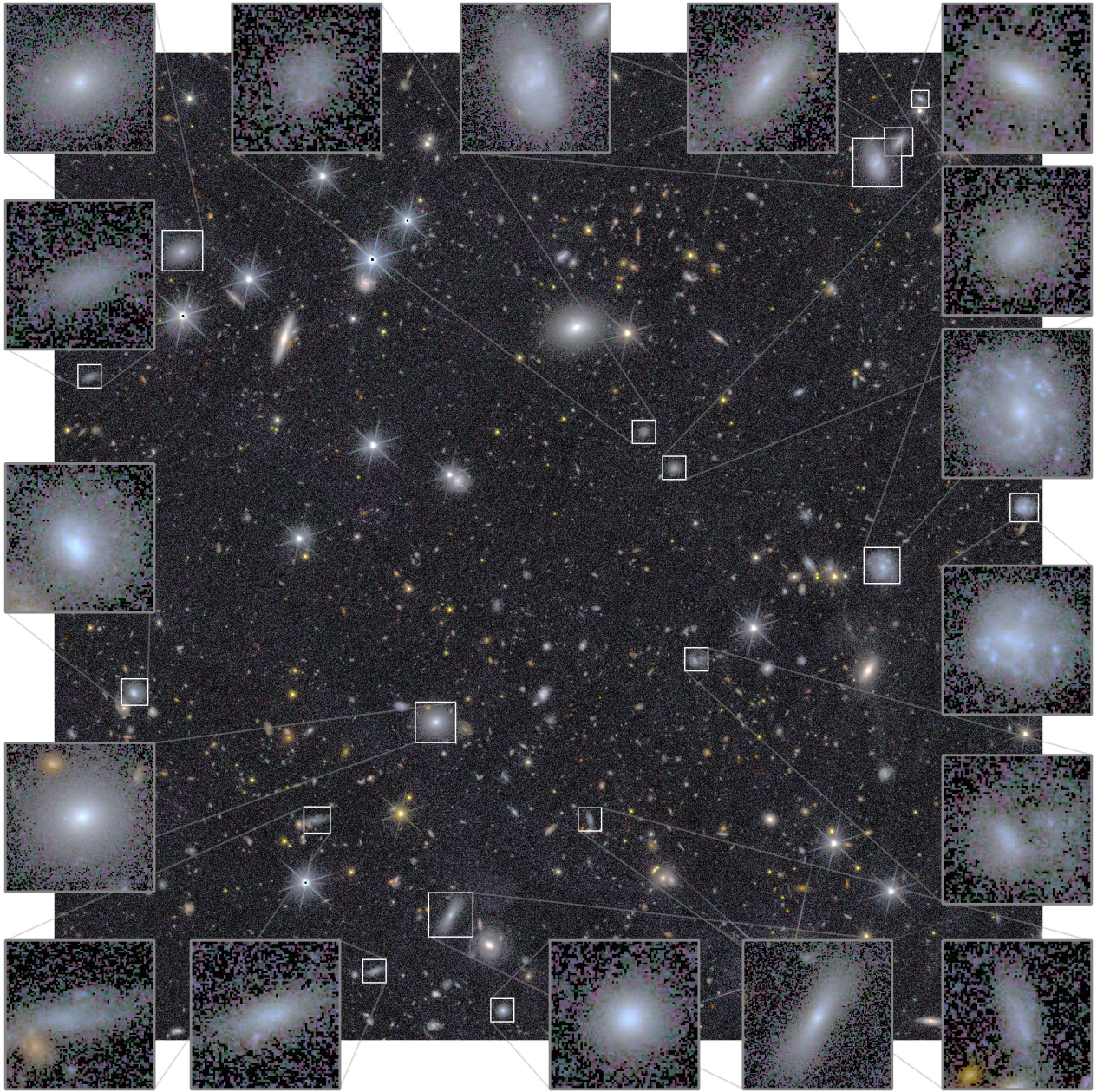


Fig. 1. VIS-NISP colour image of a zoomed-in region of the EDF-N tile 102158889, $5\frac{1}{2} \times 5\frac{1}{2}$ in size, created using the I_E band in blue, the Y_E band in green, and the H_E band in red. The colour image has the same spatial resolution as the high-resolution I_E band image. Examples of seventeen dwarf galaxy candidates with score ≥ 0.67 and area $\geq 700 \text{ pixel}^2$ (see the text for details) are shown in the individual cutouts of sizes between $5'' \times 5''$ and $15'' \times 15''$. In all images, north is up and east is to the left.

dwarf candidates (three classifiers per object); (iii) comparing and merging the catalogues of the different classifiers; (iv) creating the catalogue of the dwarfs in all the tiles from the average score selection cut; and (v) visually inspecting the tiles and catalogued dwarfs and creating the final catalogue. These two main parts of our analysis are described in more detail in the following sections.

3.1. Reference tile: Visual identification

To ensure the robustness of our selection criteria, we first created a visual catalogue of dwarf galaxies that could be used as a reference sample. We used the Jafar annotation tool (Sola et al. 2022) to identify and validate the dwarf candidates

in tile 102158889, carefully selected as representative of the Q1 data set. Jafar relies on the Aladin tool (Baumann et al. 2022) and allows one to navigate across images, zoom in and out, and precisely delineate the contours of any objects of interest, while also attaching a corresponding label. The coordinates, labels, and geometrical properties of the annotated shapes are stored in a centralised database. This identification and annotation process is similar to the one used in Marleau et al. (2025) to determine the catalogue of dwarf galaxy candidates in the ERO data for the Perseus galaxy cluster, and is divided into several steps.

First, 16 classifiers were presented with an inpainted coloured version of the tile 102158889 with the I_E pixel scale, as described in Sect. 2.3. The combined information from colour and high spatial resolution enabled the distinction between back-

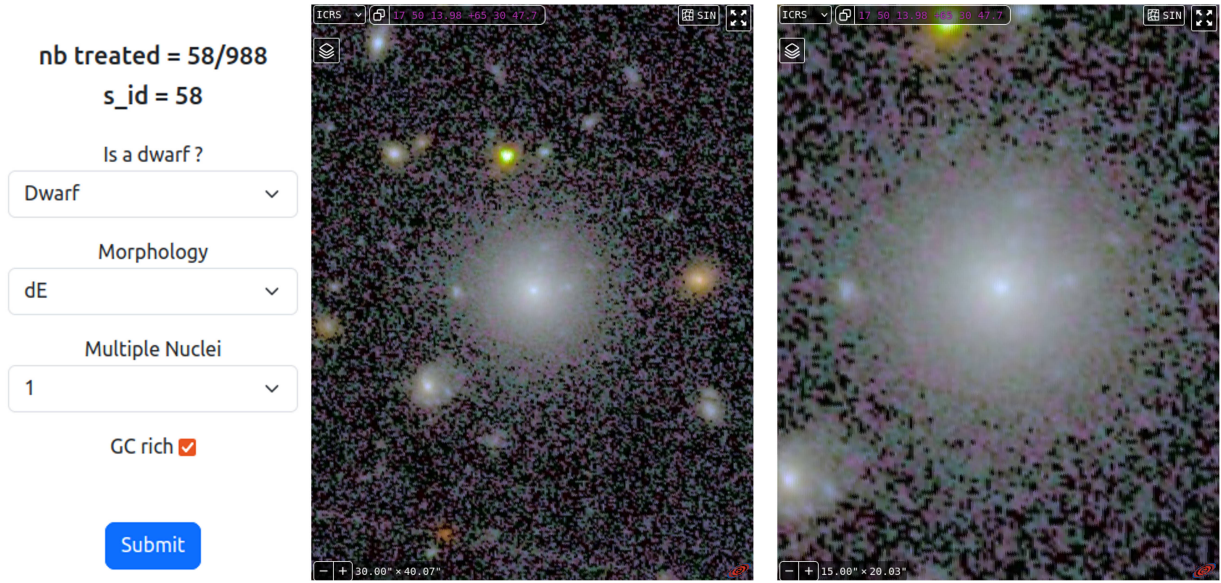


Fig. 2. Online tool (JaFar) used to validate and visually classify the dwarf galaxy candidates showing an example of a nucleated and potentially GC-rich dwarf galaxy candidate.

ground objects, artefacts, and dwarf galaxy candidates. Each classifier independently inspected the full tile, annotating potential dwarf galaxies. These candidates were delineated using ellipses, while internal substructures such as nuclei were annotated using circles.

The sixteen individual catalogues contained a total of 2759 annotations. These classifications were gathered into a single table by removing duplicate objects; each catalogue was first cross-matched against itself in order to identify and remove mislabelled structures (e.g. nuclei that were erroneously flagged as galaxies), then we identified duplicates within a search radius that was scaled by the square root of the annotated area of each galaxy. This allows for larger tolerances around more extended galaxies, yet should ensure that small neighbouring dwarf candidates are not falsely merged into a single object. This generated a list of 989 objects of interest that had been annotated by at least one individual, 463 had been flagged by at least two people, and 146 galaxies had been flagged by a majority of the classifiers at this early stage.

For galaxies that were flagged more than once, we adopt the average RA and Dec as the final coordinates of the object. To test how accurate this value is, we performed a final cross-match between the catalogue containing the objects of interest and the original annotations, using the square root of the averaged area as the new search radius. The separation between the averaged coordinates and the original annotated coordinates peaks at $0''.2$ and drops to almost zero at about $1''.5$, with a nearly negligible tail extending to larger radii. In general, we find very good agreement between the annotations.

3.2. Reference tile: Visual classification

The next step was to validate the annotated objects, i.e. to visually re-inspect all objects of interest to confirm a sample of dwarf candidates and reject any interlopers among the 989 flagged galaxies. This task was also performed in JaFar, but with a different interface. Instead of navigating around the full image, the 16 classifiers were now presented with two panels: one displaying a $I_E Y_E H_E$ coloured image centred on the object with a fixed field-of-view of $30''.0 \times 24''.5$, and the other displaying a zoomed-

in version of the image (see Fig. 2). These displays show a subset of the full image, which could still be manipulated in all the ways the images could be adjusted during the earlier annotation stage, but also allowed classifiers to display data from other surveys (e.g. Pan-STARRS DR1) if more information was needed. However, the initial displays were chosen to facilitate quick decisions for nearly all of the candidates. The classifiers were asked if the object was considered a dwarf galaxy and to assess the morphology ('dE', early-type galaxy; 'dI', star-forming irregular galaxy; 'disturbed', tidally disrupted or interacting galaxy), GC-richness, and number of nuclei. It is important to note that the galaxies classified as disturbed were explicitly dEs; hence, there is no disturbed dI.

Users were given a set of guidelines for training and consistency, similar to the 'Field Guide' provided to users as part of a Zooniverse project¹. An important distinction however from the Zooniverse project is that in our case, only professional astronomers with a priori knowledge of dwarf galaxies were involved. This guide includes *Euclid* Q1 example images and identifies key features to distinguish the classes described above. In addition, classifiers were advised to reject (classify as "not a dwarf") any galaxy with a bright red bulge (more likely to be a background massive elliptical), segments of extended galaxies, background spirals, edge-on disks, stars, or artefacts. The "unsure dwarf" category was intended for objects that are inherently more difficult to classify, such as very small dwarfs, galaxies on the cusp between dIs and background clumpy spirals, objects with bright, extended nuclei – which can be confused with background S0 galaxies, and objects with high ellipticities. Such conditions may inadvertently introduce bias against certain types of dwarf galaxies, such as dwarf spirals (not a classification option in this survey) and those with bright, extended central 'nuclei'. For these latter types of galaxies, which are likely situated near the boundary between normal and dwarf galaxies, spectroscopic information is required to obtain an accurate estimate of their stellar mass and hence confirm their dwarf nature.

¹ <https://www.zooniverse.org/projects/zookeeper/galaxy-zoo/classify>

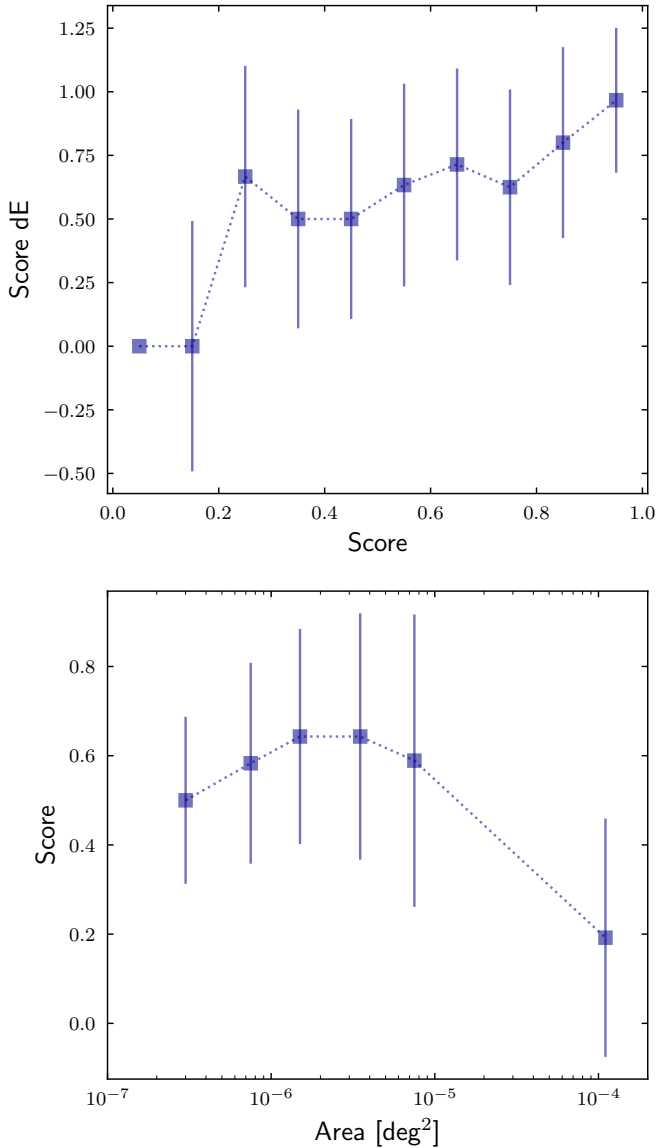


Fig. 3. *Top:* Score that the dwarf is classified as a dE as a function of the score that the candidate is a real dwarf. *Bottom:* Median score as a function of the source area from the annotation tool. The error bars represent the standard deviation in each bin. This plot provides the range of object sizes that we could more securely consider for the dwarf validation. It shows that early-type dwarfs get a better consensus and that too small or large objects tend to be excluded as dwarfs.

When visually classifying dwarf candidates, one open question was the nature of diffuse galaxies with extended bulges. It can be unclear if these are dwarf galaxies with atypically bright centres, background S0s, or another class of objects. To ensure we did not bias our sample by erroneously including or excluding these galaxies, we further inspected these objects, as described below.

In the reference tile, we detected 81 (8.2%) dwarf galaxies with morphology similar to dEs but with a bright central blue or white core. Similar objects have been identified in recent works as ‘blue-cored’ dwarf elliptical galaxies (e.g. Lisker et al. 2006; Urich et al. 2017; Paudel & Yoon 2020; Chung et al. 2023). However, the lack of spatial resolution from ground-based data means that many of the central blue clumps appear as unresolved cores in these images.

Early-type galaxies with a large bright core component in the inner regions were introduced by Sandage & Binggeli (1984) and Binggeli & Cameron (1991) as dwarf lenticular galaxies (dS0s). The surface brightness profile of these dwarfs can be well fit with exponential or King profiles, with an excess of light in the central region (Binggeli & Cameron 1991, 1993). However, these galaxies exhibit a variety of disc morphologies, and there is an ongoing debate regarding whether they can be considered a subclass of dEs, due to their similarity in surface brightness, or if they represent a distinct class of dwarf galaxy (Ryden et al. 1999). In the Q1 images, the early-type dwarfs with large cores clearly exhibit a recent or on-going star formation in these regions, and they may be considered transitional dwarf galaxies, an intermediate product of the transformation from gas-rich late-type dwarf galaxies into gas-poor early-type dwarfs. For the rest of the paper, we therefore refer to these dwarf galaxies as ‘transitional dwarf galaxies’.

In order to determine if the classifiers should identify the transitional galaxies as dwarf candidates, we examined those found in the reference tile with spectroscopic redshifts from which we could compute their absolute magnitudes. In the reference tile, we cross-matched the 81 transitional dwarf galaxies with the spectroscopic redshift catalogue of Dark Energy Spectroscopic Instrument (DESI) spectra (DESI Collaboration 2024) and found 30 (37%) matches. Aperture photometry was performed for all these candidates using the Python package Photutils (Bradley et al. 2024) and good agreement was found with the MER pipeline magnitudes, in particular with the values determined from the FLUX_DETECTION_TOTAL parameter. The early-type dwarfs with bright cores and spectroscopic redshifts were found to have absolute magnitudes in the range $-19 < M(I_E) < -16$. Therefore, we concluded that they all qualify as dwarfs.

A score was computed for each source with the following weights: 1 = dwarf is validated, 0 = dwarf is not validated, and 0.5 = unsure. The total score for each object is the sum of all votes, normalised by the number of classifiers. We obtained similar scores for the morphology, nucleated status, and GC-richness, although these did not have an option for ‘unsure’. To test our confidence at classifying various types of galaxies, we show the total score as a function of the probability that the dwarf is classified as a dE in Fig. 3 (top panel), and as a function of the annotated area in Fig. 3 (bottom panel). The error bars represent the standard deviation in each bin. From these plots, it can be seen that we are more confident in classifying dE-type dwarfs, while the smallest and largest galaxies were more likely to be rejected.

In Marleau et al. (2025), a score threshold could be clearly selected to define the final sample of dwarf candidates, due to the uniformity in terms of morphology and distance of the dwarf population in the ERO Perseus images. The selection cut was not as straightforward for the dwarf classification in the Q1 reference tile (and all Q1 tiles), since the dwarf population consists of galaxies located at a range of distances and is made up of a higher fraction of dIs. As our final robust dwarf candidate galaxy sample, we therefore chose a total validation score ≥ 0.8 to conservatively select our most robust dwarf galaxy candidates.

3.3. Reference tile: Comparison of visual and MER catalogue

As discussed earlier, the MER catalogue uses background-subtracted images, so there was some question if it would be appropriate for identifying LSB dwarf candidates. We compared the visual catalogue with the MER catalogue of the reference

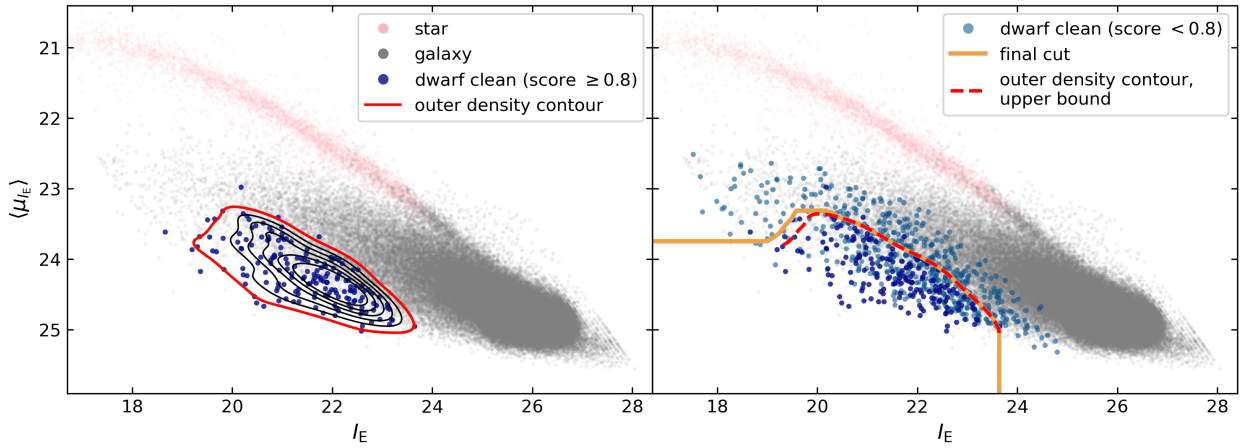


Fig. 4. *Left:* Isodensity contour plot in average surface brightness versus apparent magnitude space for the visually identified dwarf galaxy candidates in the reference tile 102158889 with a score ≥ 0.8 . The dwarf candidate sample was manually cleaned to ensure good MER photometry of the sources. The upper portion of the outermost contour is used as basis for the subsequent automated selection cut (*right*). The non-dwarf galaxies (POINT_LIKE_PROB < 0.8 ; grey points) and stars (POINT_LIKE_PROB ≥ 0.8 ; pink points) are also included for reference. *Right:* Example of the automatic selection cut in the reference tile. We slightly extended the upper portion of the outer density contour (red) to select the few bright dwarf candidates with score ≥ 0.8 that would otherwise have been missed. The final selection cut is shown in orange. Many of the less confident dwarfs (score < 0.8) are also selected by this line.

tile and found a good agreement in the galaxies detected. Using the area measured from the visual annotation of users and the MER catalogue parameter SEGMENTATION_AREA, we also compared their measured sizes and also found, in general, a good agreement. Moreover, we identified only a few situations where the MER catalogue was inconsistent with the visual identification. These were either when the dwarf galaxy candidate was a dI with star-forming clumps and these clumps had been detected as separate sources in the MER catalogue, or when the dwarf galaxy candidate was near a bright galaxy/star and missing from the MER catalogue.

3.4. All Q1 tiles: Automatic selection

We used the dwarf candidate sample of reference tile 102158889 to determine the selection cut and to calibrate the photometry of the other tiles. We followed the general methodology outlined in Habas et al. (2020) to determine the best parameters to select potential dwarf candidates. For the MATLAS data set, the cleanest separation between the visually identified dwarfs and background galaxies was found in plots of average surface brightness, $\langle \mu_g \rangle$, versus apparent magnitude, g . In particular, they found less scatter using average surface brightnesses instead of the more common central surface brightness, $\mu_{g,0}$. Therefore, for each galaxy in the Q1 MER catalogues, the magnitude, I_E , was computed using the FLUX_SEGMENTATION parameter and the average surface brightness, $\langle \mu_E \rangle$, was computed using both the FLUX_SEGMENTATION and SEGMENTATION_AREA parameters. We did not attempt to convert I_E to absolute magnitudes, since there is no preferential distance to assume in the Q1 tiles.

It should be noted, however, that the placement of the dwarf candidates in the *Euclid* diagnostic plot relative to the background galaxies is different from the relative positions observed in the equivalent MATLAS diagnostic diagram. The MATLAS dwarfs follow a slightly shallower slope than the background galaxies, whereas the visually identified *Euclid* dwarf candidates follow a sequence parallel to the main locus of points. A possible explanation for this difference may be the data reduction pipeline, since the MATLAS images were processed with the

EXLIXIR-LSB pipeline which was specifically designed to preserve low surface brightness signals. Thus, the rest of the dwarf selection procedure in this work was modified for the Q1 data set.

Although the $\langle \mu_E \rangle - I_E$ selection criterion is among the best at separating dwarf candidates from massive galaxies, it still identifies a high fraction of contaminants. Many of these are background S0 galaxies, spirals with diffuse halos, diffraction spikes, and spurious detections. We imposed a series of cuts based on the following MER parameters to further clean the candidate catalogue and remove badly formatted entries:

- VIS_DET = 1;
- FLAG_Y = 0 or = 2;
- FLUX_SEGMENTATION > 0;
- SEGMENTATION_AREA > 0;
- RIGHT_ASCENSION > 0;
- DECLINATION > -100.

We intentionally did not impose any conditions on the quantity POINT_LIKE_PROB. In principle, this can be used to distinguish galaxies from stars, similar to the CLASS_STAR parameter in SourceExtractor, but applying a cut here removed a handful of visually identified objects of interest from the sample. Thus, there are a few stars remaining in the candidate list.

We identified two issues while looking at the photometric parameters from the MER catalogues of all Q1 tiles. Firstly, there is a small shift in the photometry in some of the tiles; this was fixed by fitting the narrow locus of stars (POINT_LIKE_PROB ≥ 0.8 ; pink points in Fig. 4) in the reference tile and using this as the photometric calibration point for all other tiles. The magnitude of the surface brightness shift across all 25 tiles ranges from -0.198 to 0.364, with a median of -0.008. Secondly, some tiles that are at the border of the Q1 footprint have only partial coverage, which reduces the number of detected sources in the tile. For the ten tiles with very few sources (102018211, 102102020053, 102020542, 102022971, 102041033, 102047412, 102158579, 102159781) or no stars (102021021, 102160873), no shift was applied, and the photometry was assumed to match that of the reference tile.

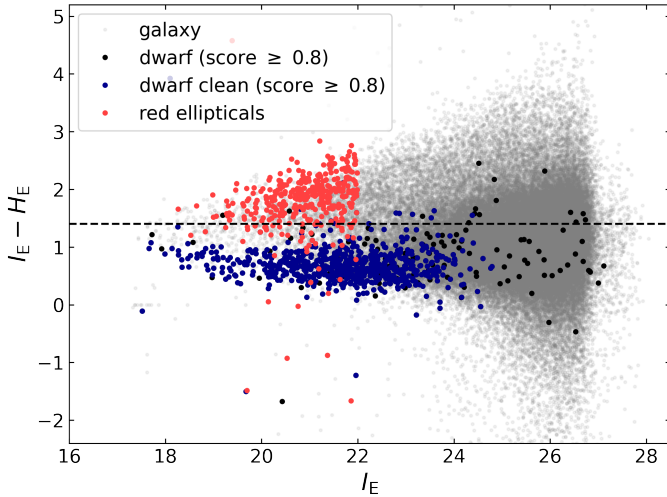


Fig. 5. Colour-magnitude diagram showing the colour cut of $I_E - H_E \leq 1.4$ used to remove the red elliptical galaxies from our automatically selected dwarf sample. The MER detections in the reference tile are in grey, and the objects in the visual catalogue for score ≥ 0.8 are in black. The manually cleaned visual dwarfs for score ≥ 0.8 , as described in Fig. 4, are in blue-violet, and the visually identified red elliptical galaxies are in red.

To determine an optimal selection cut, we matched the visual catalogue with the MER catalogue for the reference tile using a matching radius of $2''$. Since the MER catalogue does not include detections within approximately $1'$ of the tile edge – these galaxies are, however, extracted from overlapping observations in neighbouring tiles – we first removed these galaxies from our visual sample so that they would not register as missed detections. We then cleaned the visual-MER matched catalogue of problematic matches, such as: when the matching picked a nearby star or bright galaxy instead of the dwarf (which was not detected in the MER catalogue due to the proximity of the bright source); when the visual source was split into clumps in the MER catalogue; when the full extent of the diffuse dwarf was only detected in the MER catalogue as a very small source (MER_SEGMENTATION_AREA is too small compared to the visual extent of the dwarf leading to a wrong calculation of the surface brightness); when the source is an artefact; and when the source is near a stellar spike (and therefore the photometry may be incorrect). After this cleaning, we obtained a total of 682 dwarf candidates with MER photometry, making no distinction between different classification scores. We then used the most secure dwarf candidates with scores ≥ 0.8 to produce isodensity contours in the surface brightness vs. magnitude plot for these robust 174 dwarf candidates (see Fig. 4).

The outer contour of the isodensity plot was used to define an upper demarcation line between dwarf galaxies and likely background galaxies (see Fig. 4). Given the low statistics of dwarf candidates at the bright end of the contour, we manually extended the curve enough to capture the brightest candidates that would otherwise have been excluded by the line. With this adjustment, the selection cut recovers 97% of the score ≥ 0.8 dwarf candidates, 73% of the score ≥ 0.5 candidates, or 66% of the cleaned candidates with no score cut. The position of this line was fixed and then applied to all Q1 tiles, producing a catalogue of 373 745 sources.

Although the region of the selection plot that is populated by the cleaned sample is not as dense as the main locus of background galaxies, small shifts in the selection cut can

sharply increase the number of sources that are extracted for visual inspection. For example, if we apply a vertical offset of $-0.1 \text{ mag arcsec}^{-2}$ to the original selection cut, we would add an additional 778 galaxies from the reference tile alone. Such a shift would allow us to also retain a further 61 dwarf candidates (no score cut applied) from the cleaned sample, but this is a very low return rate for the amount of time it would take to classify the additional galaxies. Alternately, one could consider a selection cut where the turnover at the bright end of the outer density contour is ignored and the slope of the contour is simply extended to the bright end; this would select an additional 521 objects from the reference tile, but with zero additional dwarf candidates.

Our selected objects were then matched with a morphological classification produced by Zoobot and based on the *Euclid* Zooniverse project (Euclid Collaboration: Walmsley et al. 2026) in order to clean the catalogue of as many background spiral galaxies as possible. The catalogue contains predictions for galaxies with an area $\geq 700 \text{ pixel}^2$ and of any magnitude. To identify the (background) spiral galaxies to remove from our sample, we selected the keywords (with format: {QUESTION}_{ANSWER}_FRACTION): SMOOTH-OR-FEATURED_FEATURED-OR-DISK_FRACTION > 0.5 and DISK-EDGE-ON_NO_FRACTION > 0.5 and HAS-SPIRAL-ARMS_YES_FRACTION > 0.5 . We visually checked some of the sources that were identified as spirals in the reference tile and confirmed their spiral nature. This step removed 51 810 (14%) background spiral galaxies, leaving a catalogue of 321 934 sources.

We then examined the colours of the galaxies in the reference tile to remove any red ellipticals, a major source of contamination. We visually identified a sample of 353 red elliptical galaxies, computed their $I_E - H_E$ colours, and compared these values against the colours of the visually identified dwarf candidates. These colours were calculated using the MER parameters FLUX_VIS_2FWHM_APER and FLUX_H_2FWHM_APER, and corrected for Galactic extinction (as described in Sect. 2.4). The colour distributions of these populations are shown in Fig. 5. We adopted a colour cut of $I_E - H_E < 1.4$, hence removing 155 101 (48%) red elliptical contaminant sources and leaving 166 834 candidates for all Q1 tiles. For the 25 tiles analysed in this paper, the catalogue after the automatic selection and cleaning contains a total of 14 369 sources.

3.5. All Q1 tiles: Visual classification

The 14 369 dwarf galaxy candidates in the automatically produced catalogue for the 25 tiles were validated using the same online interface as described in Sect. 3.2. The classes were the same as for the reference tile, although we added two additional flags: ‘blue nucleus’; and ‘object of interest’. Both of these options could be selected independently of any other inputs.

To most efficiently classify the sample, we split the catalogue of dwarf candidates into four groups, with each group being examined by a subset of three classifiers. The classifiers for each group were selected after examining classification trends between individuals in the reference tile (e.g. who was more conservative or more liberal in the galaxies they classified as dwarfs), and we avoided grouping those on either end of the spectrum who classified too similarly, to avoid unbalanced voting between groups. The catalogue of dwarf candidates was first sorted by tile, then magnitude – ideally, to increase our consistency with similar objects viewed one after another – then evenly split between each of the four groups. The summed scores for objects within each group are shown in Fig. 6. There are still

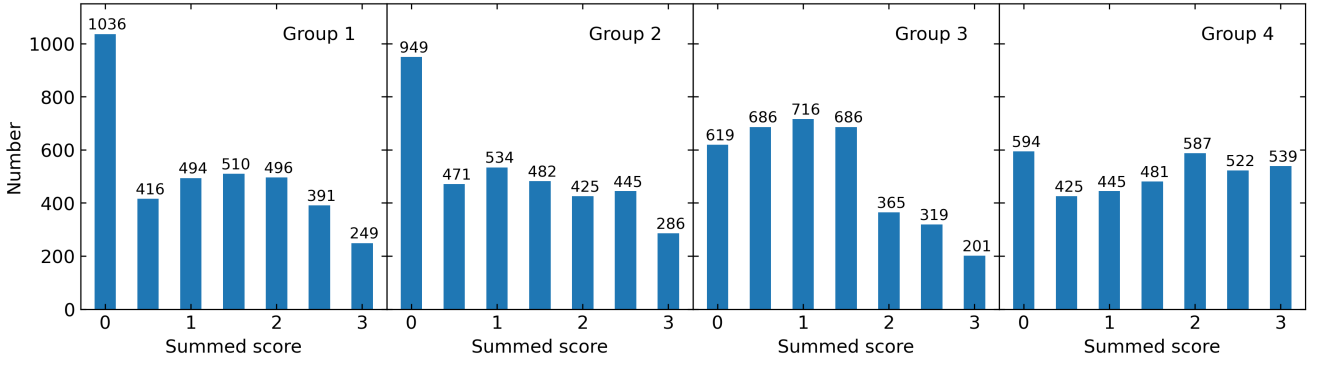


Fig. 6. Summed scores (‘dwarf’ = 1, ‘unsure dwarf’ = 0.5, ‘not dwarf’ = 0) for the three classifiers in each of the four groups of classifiers. The groups were arranged to avoid combinations of classifiers that were consistently more conservative (or more liberal) in the reference tile. Some differences still remain between the groups, but these are not severe for the more confident dwarf candidates, and this may reflect a degree of cosmic variance between regions on the sky.

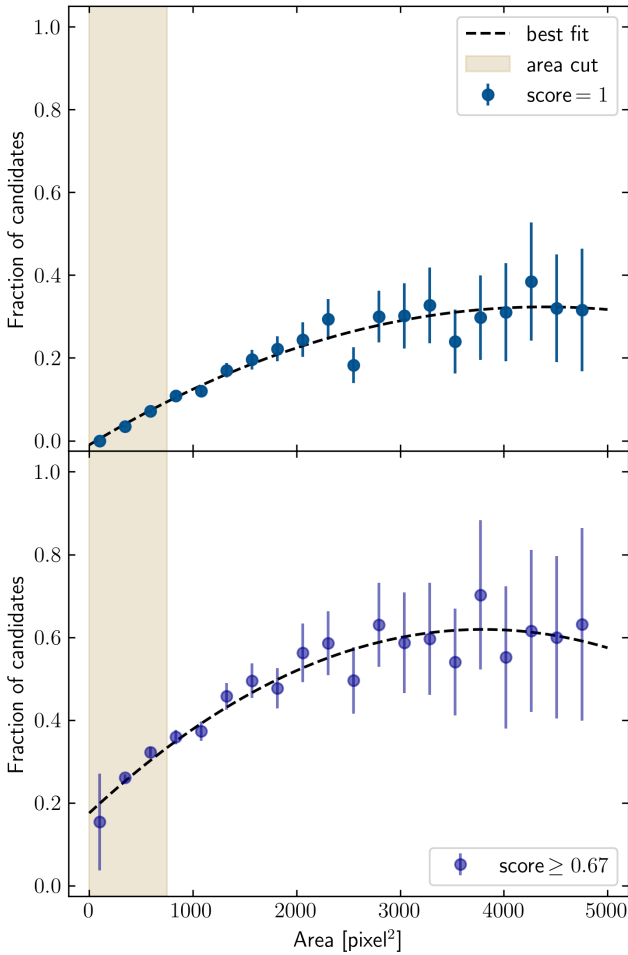


Fig. 7. *Top:* Fraction of all dwarf candidates from all groups with a score of 1 per area bin. A quadratic function was fit to the data to create the best-fit line. For this paper, we dropped candidates with areas < 700 pixel², as highlighted by the tan region. The errors were propagated assuming Poisson statistics and that the number of dwarf candidates and the total number of galaxies per bin are independent. *Bottom:* Same as top but for all dwarfs in the final sample (score ≥ 0.67).

some inconsistencies between groups, particularly in the use of the ‘unsure dwarf’ classifications (this is most prominent in the summed scores < 1.5), but the distribution of votes above the

median score seems reasonable. It should also be noted that the on-sky regions covered by groups three and four contain fewer massive galaxies (see Sect. 4) – and presumably fewer dEs – which could naturally have led to more ‘unsure’ votes.

For the remainder of this paper, the dwarf catalogue consists of the dwarf candidates with summed scores ≥ 2, i.e. normalised scores ≥ 0.67. These are galaxies with at least (a) 1 ‘dwarf’ and 2 ‘unsure dwarf’ votes or (b) 2 ‘dwarf’ votes. This returns 1136, 1156, 885, and 1648 dwarfs from each of the four groups, respectively. The apparent discrepancy between Group 4 and the other three occurs amongst the smallest candidates, which Group 4 tended to more confidently classify as dwarfs. To further balance systematics between the groups, we applied an area cut, as described below. We note that, by chance, this is also the size below which Euclid Collaboration: Walmsley et al. (2026) deemed the galaxy modelling to be unreliable.

To explore the impact of area on our classifications, we examined the fraction of dwarf candidates per area bin in Fig. 7. For clarity, we merged the four groups into a single sample, but we note that the fraction of dwarf galaxies in the smallest area bins are largely driven by a single group. Regardless if we consider our most secure candidates (score = 1) or a more relaxed sample (score ≥ 0.67), the shape of the distributions are similar; we voted to keep a smaller fraction of candidates in the smallest area bins and higher fractions in the larger area bins (but there is significant contamination in every bin). For the most secure candidates in the sample, the fraction of dwarf candidates drops below 10% at roughly 700 pixel². In Fig. 8, it can be seen that there are legitimate dwarf candidates even at these small sizes, but it is increasingly difficult to identify structures in the smallest candidates that would distinguish dwarfs from background galaxies. Given the high levels of contamination at small sizes, the difficulty in consistently classifying the smallest dwarf candidates, and the need to normalise classifications between the groups, we adopted the 700 pixel² size cut.

After this size cut was applied, the final catalogue was then produced by applying a final score cut of 0.67 (2/3). The candidate list was subsequently inspected using Jafar to remove duplicates. The nine dwarf candidates with colours bluer than the main distribution, i.e. $I_E - H_E < -1.4$ were also visually inspected; four were background contaminants and were removed, while five were kept as they appear to be genuine dwarf candidates. However, of these five, three have colour image defects, making their colour measurements (and photometry) unreliable. These are flagged in Tables A.2 and A.3. The

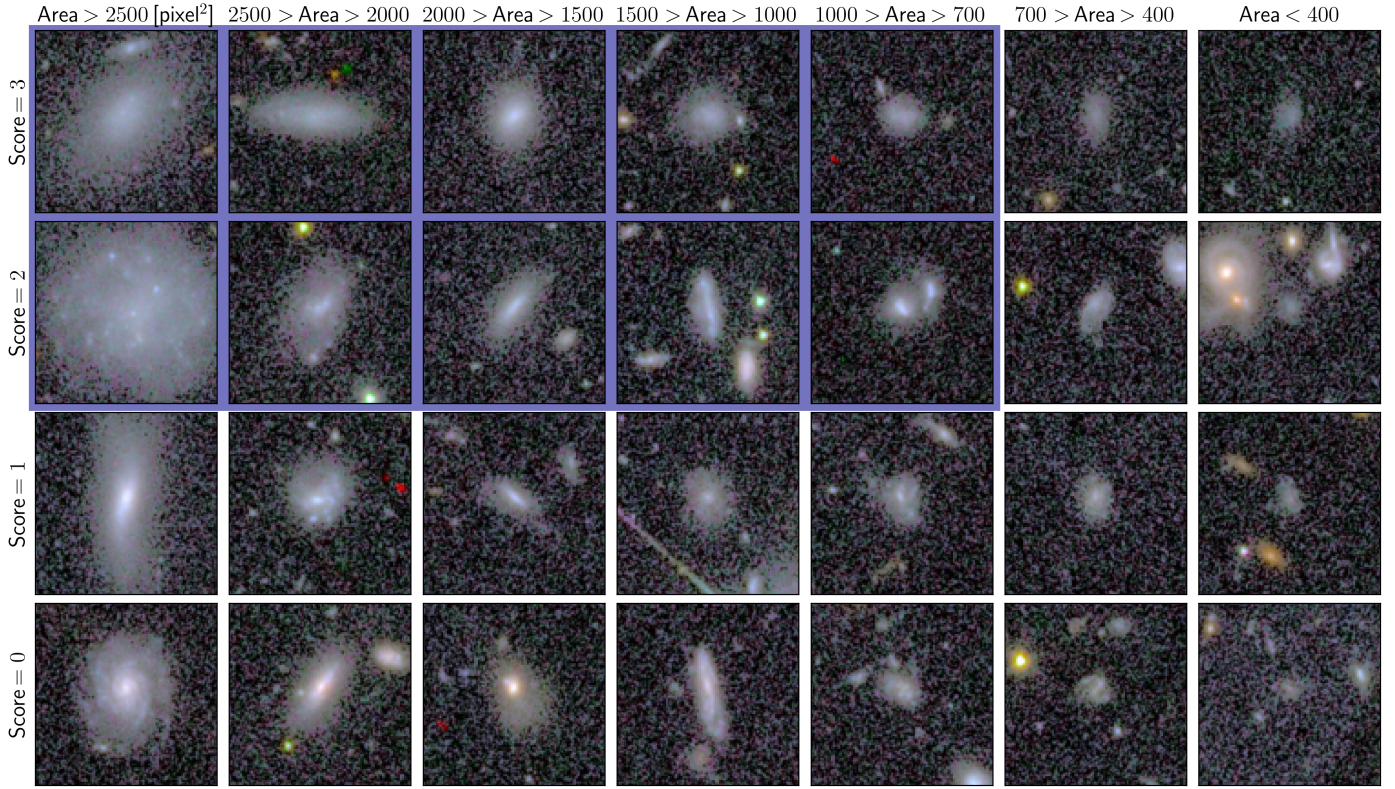


Fig. 8. Examples of galaxies returned by the selection cut, as a function of area and visual classification score. The rows and columns with blue-violet background are part of our final sample. The two right-most columns were dropped due to their small sizes and the bottom two rows were dropped for their low classification scores; see Sect. 3.5 for details. To better sample the range of areas in the sample, we note that the area bins do not have a fixed width. The images are approximately $15'' \times 15''$ in size with north up and east to the left.

remaining two have colours $I_E - H_E = -1.8$ and -1.4 . The final catalogue contains a total of 2674 dwarf galaxy candidates.

4. Results

In total, 2674 dwarf candidates were identified in these 25 tiles, encompassing 14.25 deg^2 of the sky, which translates to 188 dwarfs per deg^2 . Assuming these 25 tiles are representative of the full region imaged by the Q1 EDFs and the EWS, we can extrapolate this number to estimate the presence of approximately 9900, 360 000 and 2.6 million dwarf candidates in the Q1 EDFs (53 deg^2), DR1 (1900 deg^2), and the EWS ($14\,000 \text{ deg}^2$), respectively.

4.1. Morphological classification

We examine the results of the visual classification of our dwarf candidates for the following classes: morphology; GC richness; presence of one or multiple nuclei; and presence of one or more blue central clumps.

The breakdown in the number of dwarf candidates in each of the morphological classes is given in Fig. 9 and listed in Table A.1. A total of 57.9% were classified as dE, of which a small fraction (4.4%) were identified as being a dE with disturbed morphology (possibly the result of tidal interaction, tidal tail formation or dwarf-dwarf merger). Very few (1.0%) dwarfs were found to have two or more GC candidates. As presented in Sect. 4.3 below, our dwarf candidates span larger distances, and therefore it is not surprising that this fraction is much lower than what was found for the more nearby dwarfs in the Perseus

cluster (at a distance of 72 Mpc), where 26% of the dwarfs were visually classified as GC-rich (see a more detailed discussion in Sect. 4.5). Likewise, there are few (4.0%) nucleated dwarfs, and a small fraction (6.9%) of candidates show a blue core. It should be noted that if a dwarf was classified as having both a blue core and a nucleus, it was not considered as having a nucleus. The blue core dwarfs show a wide range of visual structural properties, including unresolved blue cores, extended blue central clumps, complex and S-shape substructures, and finally double nuclei and multiple clumps. Examples of dwarf candidates in each of the visual morphological classes are shown in Fig. 10.

4.2. Photometric properties of the candidates

Because our dwarf candidates were originally identified based on the sources detected and listed in the MER catalogue, we examined the range of some of the most important properties measured by the MER pipeline (e.g. ISO_MAG, SEGMENTATION_AREA, SEMIMAJOR_AXIS, ELLIPTICITY, POSITION_ANGLE) and compared them to both our automatically selected catalogue for all Q1 tiles (hence prior to visual classification) and all galaxies in the MER catalogue. The distribution of some of these properties are shown in Fig. 11. The MER properties for the 2674 dwarf candidates can be found in Tables A.2 and A.3.

As can be seen in Fig. 11, the dwarf candidates in the final sample are rounder than the automatically selected dwarf candidates. All other parameters appear to be consistent with our expectations. Compared to the *Euclid* ERO Perseus dwarfs (Marleau et al. 2025), the Q1 dwarfs have the same range of

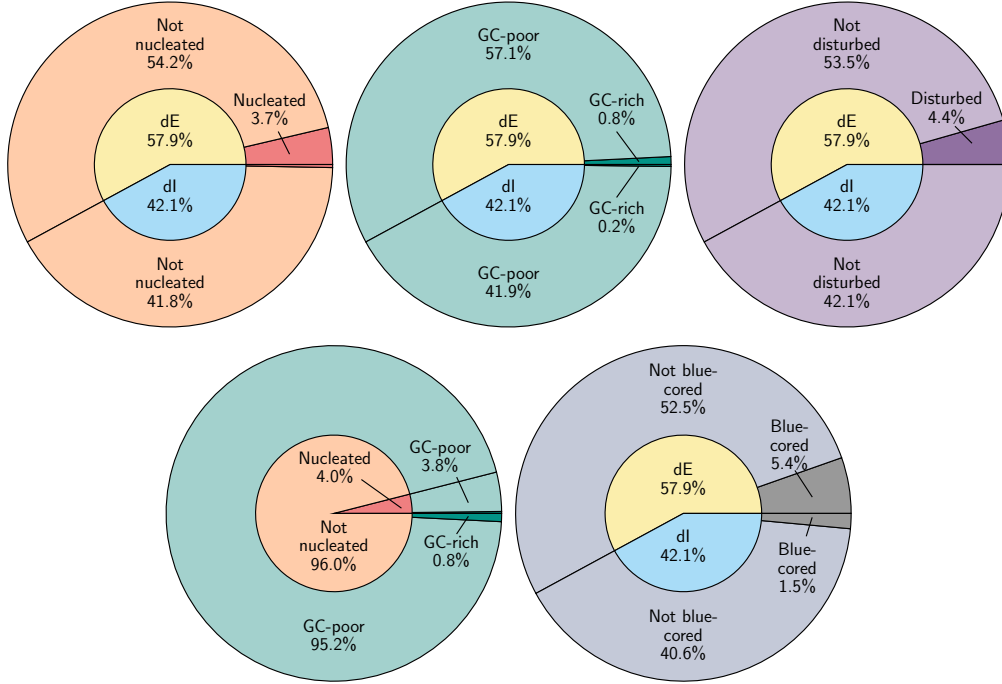


Fig. 9. Morphological classification of the 2674 dwarf galaxy candidates. Darker shades on the outer circle correspond to the presence of the feature of interest. *Top left:* Nucleated fraction (outer circle) as a function of morphology (inner circle). *Top middle:* GC richness (outer circle) as a function of morphology (inner circle). *Top right:* Signs of disturbed morphology (outer circle) as a function of morphology (inner circle). *Bottom left:* GC richness (outer circle) as a function of the nucleated fraction (inner circle). *Bottom right:* Blue-cored fraction (outer circle) as a function of the morphology fraction (inner circle). A total of 1548 (57.9%) dwarf galaxy candidates are classified as dE (dI: 1125 or 42.1%), 106 (4.0%) are nucleated, 26 (1.0%) are potentially GC-rich, 118 (4.4%) have a disturbed morphology, and 183 (6.9%) are blue-cored. It is important to note that the galaxies classified as disturbed were explicitly dEs; hence, there is no disturbed dI.

colours and ellipticity, but tend to have smaller angular sizes and a wider range of surface brightnesses.

To highlight the diversity of the galaxies found in the Q1 fields, we show special examples of dwarf candidates in Fig. 12. This includes: (i) a nucleated dE with an elongated substructure connecting to the nucleus, likely a signature of a GC migration and merging with the NSC (Poulain et al. 2025); (ii) a traditional nucleated dE, similar to the nucleated dEs found in the Perseus cluster; (iii) a dI with clumps of star formation extending beyond the diffuse component, possibly triggered by an interaction; (iv) a pair of interacting dwarfs; (v) a dI with a diffuse blue centre; (vi) a dI in superposition with a more distant spiral galaxy (having a spectroscopic redshift of $z = 0.388$); (vii) a blue-cored dE; (viii) a dE with a spectroscopic redshift of $z = 0.0272$ (or a distance of about 120 Mpc) showing a double nucleus with inner “S-shape” features, likely associated with a NSC-NSC merger event (Poulain et al. 2025); and (ix) a group of three dwarfs situated within a 30'' radius.

We also show in Fig. 13 some examples of the dwarf candidates with the very low surface brightness that were visually identified in the Q1 images. Of these four examples, it is interesting to note that three have a MER detection, but are not retained by our automatic selection cut. As described in Sect. 3.4, for this paper, we restricted ourselves to a conservative selection cut in magnitude and surface brightness. In a future paper, lower surface brightness sources will be explored.

4.3. Candidates with spectroscopic redshifts

We can test the accuracy of our dwarf candidate classifications for the subsample of galaxies with pre-existing spec-

troscopic redshifts. The full *Euclid* Q1 source catalogue has been matched against an external spectroscopic redshift catalogue (Saulder et al., in prep.). This external spectroscopic catalogue contains redshifts obtained from many surveys, including the DESI Stellar Mass and Emission Line Catalogue². We cross-matched our list of dwarf candidates with this catalogue. Using a 2'' match radius, a total of 388 candidates (15% of the total sample) were found to have a match, all from the DESI catalogue.

The properties of the Q1 dwarf candidates with spectroscopic redshift are shown in Fig. 14 and compared to those of all galaxies in the MER catalogue and the automatically selected dwarf candidates with spectroscopic redshifts in the 25 Q1 tiles. The MER catalogue, automatically selected dwarf candidates, and final dwarf candidates have a median distance of 5448, 3848, and 404 Mpc, respectively. The dwarf candidates with a spectroscopic redshift have the following properties: $I_E = 17.8\text{--}22.5$, $I_E - H_E = -1.05\text{--}1.18$, $\langle\mu_{I_E}\rangle = 23.15\text{--}24.66$, SEGMENTATION_AREA = 5.24–168.66 arcsec², and SEMIMAJOR_AXIS = 0'67–2'92.

As can be seen in the top middle panel of Fig. 14, the distribution of absolute magnitudes for the Q1 dwarfs is shifted towards brighter values with respect to the ERO Perseus dwarfs. This difference is most likely due to the fact that the Perseus dwarfs are closer than the majority of the dwarf candidates in the Q1 data and therefore are detected to fainter absolute magnitudes. However, the difference could also be caused by spectroscopic redshifts that are incorrectly associated with the dwarf

² <https://data.desi.lbl.gov/doc/releases/dr1/vac/stellar-mass-emline/>

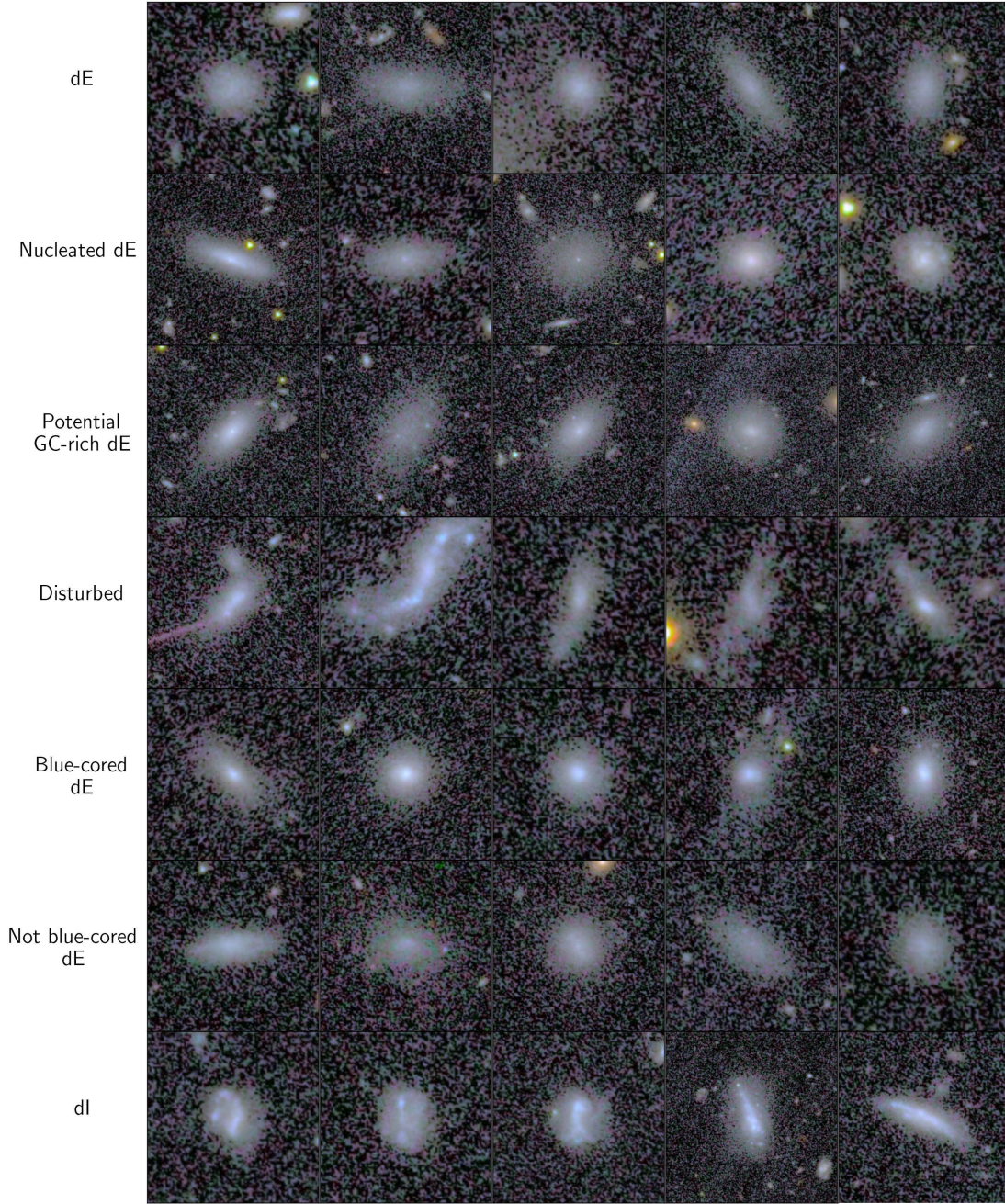


Fig. 10. Cutouts of some dwarf candidates taken from the VIS-NISP colour image created using the I_E band in blue, the Y_E band in green, and the H_E band in red. The colours are projected onto the high-resolution I_E band to best reflect their appearance as detected. *From top to bottom:* dE, nucleated dE, potential GC-rich dE, disturbed morphologies, blue-cored dE, not blue-cored dE, and dI. The sizes of the cutouts are proportional to twice the area determined from the annotation of classifiers; north is up and east is to the left.

candidates, when the redshift really belongs to a small background galaxy near or on top of the diffuse dwarf galaxy; this most likely explains the dwarf candidates with distances larger than about 500 Mpc (Fig. 14, top left panel). Another reason could be that the faintest dwarf galaxies are missed due to our automatic selection cut, since the MER catalogue contains some sources at these faint magnitudes. It is also worth noting that the galaxies likely to have a spectroscopic redshift are presumably star-forming emission line objects that could have been detected at larger distances.

In terms of physical sizes, as shown in the bottom right panel of Fig. 14, the Q1 and Perseus dwarf candidates cover a similar range; this comparison however relies on the assumption that

the Perseus dwarfs have a semimajor axis approximately equal to twice their effective radius ($2R_e$).

4.4. Comparison with DESI Extragalactic Dwarf Catalogue

The DESI collaboration has also produced their own catalogue of extragalactic dwarf galaxies identified in DESI DR1³, based on a mass cut $\log_{10}(M_*/M_\odot) \leq 9.0$ in the full value-added catalogue. As described in Siudek et al. (2024), the stellar mass estimates were obtained from spectral energy distribution (SED)

³ <https://data.desi.lbl.gov/doc/releases/dr1/vac/extragalactic-dwarfs/>

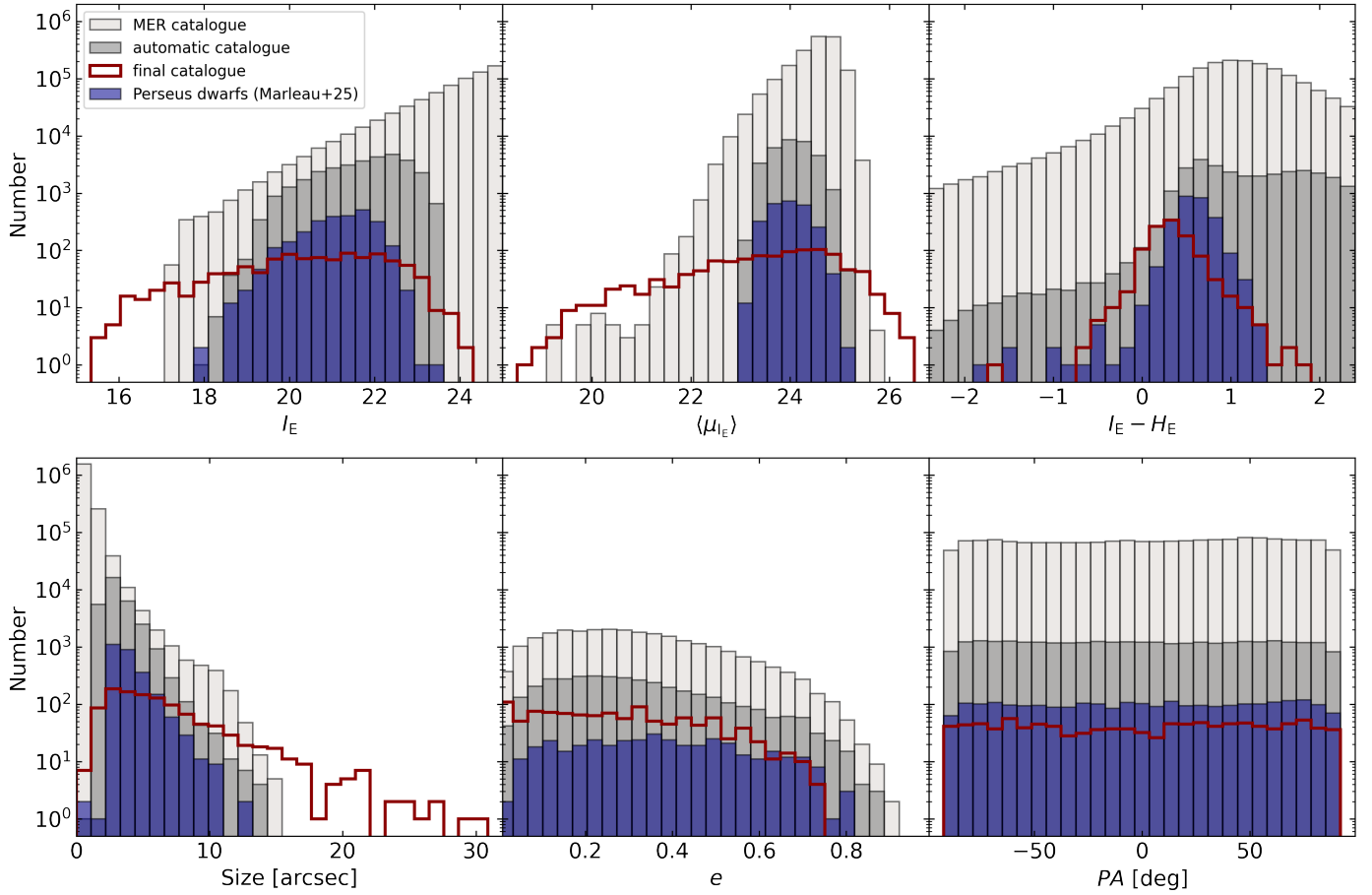


Fig. 11. Distribution of the properties of our final dwarf candidates (blue-violet) overlaid on the properties of all galaxies in the MER catalogue (pale brown) and the automatically selected dwarf candidates in all 25 Q1 tiles (dark grey). The properties of the *Euclid* ERO Perseus dwarfs from Marleau et al. (2025) are shown for comparison (dark red). The Perseus dwarfs have colours and ellipticities similar to those of the Q1 dwarfs but tend to be more spatially extended and with a wider range of surface brightness.

modelling using CIGALE (Boquien et al. 2019), based on photometry from the ninth data release of the Legacy imaging surveys (Dey et al. 2019). For galaxies in the north, this includes g and r band imaging from the Beijing-Arizona Sky Survey (BASS; Zou et al. 2017), z -band imaging from the Mayall z -band Legacy Survey (MzLS), and the unWISE MIR catalogues (Meisner et al. 2019, 2021). To model the stellar component, they assumed Bruzual & Charlot (2003) SSP models, a Chabrier (2003) initial mass function, solar metallicities, and a two-component star formation model that incorporates a delayed star formation history and an optional exponential burst to better model both star forming and passive galaxies (Ciesla et al. 2015). CIGALE also accounts for nebular emission, dust attenuation and emission, and allows for an AGN component. After obtaining the stellar masses and selecting the dwarf candidates, the DESI dwarf catalogue was further cleaned of spurious sources, including shreds of larger galaxies. In the latter case, the photometry was redone. A total of 230 DESI dwarf candidates fall in the footprint of our study.

We cross-matched our list of dwarf candidates with the DESI extragalactic dwarf galaxy catalogue using a $2''$ match radius, resulting in a total of 29 matches. The spatial distribution of the two catalogues is illustrated in the left panel of Fig. B.1. The visual inspection of the sources indicates that the DESI dwarfs are not distributed uniformly across the field; in particular, there is a region extending north-south midway across the footprint

and another around the Cat’s Eye nebula that are devoid of DESI low mass galaxies. Furthermore, unlike our dwarf sample, the DESI dwarfs do not show any prominent dwarf overdensities around bright (massive) galaxies (see Sect. 4.7 for more detail).

We find that only 1% (29 out of 2674) of the dwarf candidates in our final catalogue have a match in the DESI dwarf catalogue. The majority of the dwarfs in our sample without a DESI dwarf match are classified as dEs in our catalogue (1542 out of 2645, or 58%). The DESI dwarfs that are not in our sample typically fall in the categories that we excluded in our selection process, as described in Sect. 3.2 and displayed in Fig. B.2, namely: (i) galaxies with bright extended centres, (ii) edge-on galaxies, (iii) galaxies showing internal spiral structures, and (iv) galaxies with multiple star forming regions. We find that some of the DESI dwarf candidates are likely misclassified, as they exhibit features more consistent with other galaxy types. For example, some display spiral structures with red centres, or have catalogue coordinates located in the outskirts of a bright (massive) galaxy (see Fig. B.3). The galaxy displayed in the left panel of Fig. B.3 has a nearby companion galaxy of similar appearance that is not in the DESI dwarf catalogue. Using the DESI redshift of $z = 0.107$ and the methodology described below in Sect. 4.6, we compute a stellar mass for this galaxy of $\log_{10}(M_*/M_\odot) = 9.55$, i.e. above the dwarf galaxy mass cut of 9.0. Based on our visual classification, the 13% (29 out of 230) of the DESI dwarf candidates that have a match in our final dwarf catalogue are mostly



Fig. 12. Examples of dwarf galaxy candidates of different types. *From top left to bottom right*: Nucleated dE with an elongated substructure connecting to the nucleus, possibly a signature of a GC migration and merging with the NSC; a traditional nucleated dE; a dI with clumps of star formation extending beyond the diffuse component; a pair of interacting dwarfs; a dI with a diffuse blue centre; a dI in superposition with a more distant spiral galaxy (having a spectroscopic redshift of $z = 0.388$); a blue-cored dE; a dE with a spectroscopic redshift of $z = 0.0272$ (or a distance of about 120 Mpc) showing a double nucleus with inner ‘S-shape’ features, likely associated with a NSC-NSC merger event; and a group of three dwarfs situated within a $30''$ radius. The images are approximately $11'' \times 11''$ in size, except the image in the middle which is $2' \times 2'$, and north is up and east to the left.

dIs (22 out of 29, or 76%). The 7 matched dEs typically display a bright blue/white extended core.

From this comparison, we conclude that our dwarf catalogue demonstrates greater completeness compared to the DESI dwarf sample, owing to the unique capability of *Euclid* to detect low surface brightness (quiescent) galaxies across the images, even in regions near bright sources. Additionally, we recommend exercising caution when interpreting certain entries in the DESI catalogue, as they may include some misidentifications.

Within the footprint of our study, we are also able to compare the non-dwarf sample in the DESI Stellar Mass and Emission Line Catalogue and the MER catalogue, containing 24 765 and 1 885 533 sources, respectively. We find that 24 657 out of the 1 885 533 (1%) have a match; the percentage of matched sources from the DESI catalogue is 90% (22 346 out of 24 765). This means that, although the MER catalogue is quite comprehensive in detecting DESI sources, the reverse is not true. The vast majority of sources in the MER catalogue are simply not part of the DESI sample.

4.5. Potential GC-rich dwarf candidates

With the spatial resolution and depth of the Q1 data, for dwarf galaxies we expect to detect GCs only out to about 100 Mpc (Euclid Collaboration: Voggel et al. 2025). At this distance threshold, we are only able to detect the brightest GCs. Considering that most dwarf galaxies in the EDF-N are at dis-

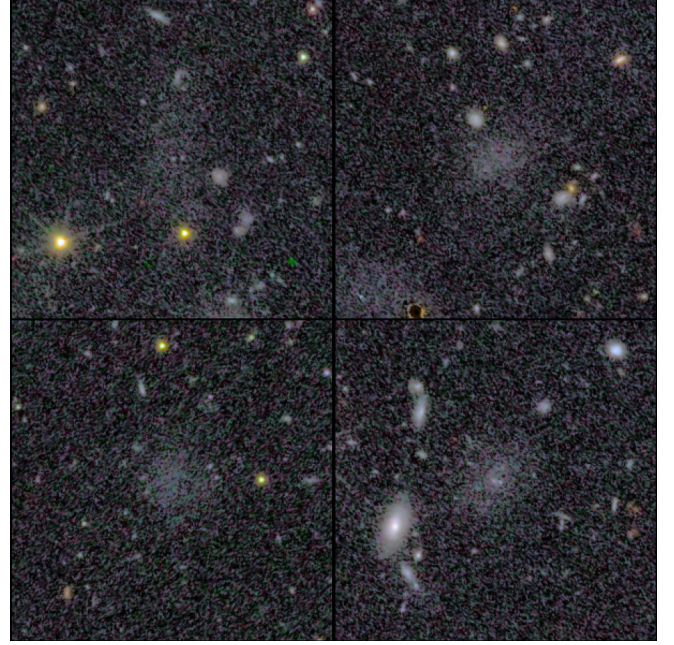


Fig. 13. Examples of dwarf galaxy candidates with a very low surface brightness identified during the visual inspection of the Q1 tiles. Three of these galaxies (top left, top right, and bottom right) have a MER detection within a $2''$ matching radius but are not retained by our automatic selection cut. The images are $1' \times 1'$ in size; north is up and east to the left.

tances larger than 100 Mpc, for typical dwarf galaxies with only a few GCs, we expect to see no GCs. However, in the case that some dwarf galaxies are indeed rich in GCs (more than 20), we expect that, given the shape of the GC luminosity function, a few GCs would be detected around those GC-rich dwarf galaxies. Therefore, in this work, the presence of two or more point-like sources (GC candidates) around dwarf galaxies are considered as a hint that the dwarf galaxy is potentially GC-rich. On the other hand, the lack of detection of GC candidates does not necessarily imply that the galaxy is GC-poor. In addition, since the majority of field dwarf galaxies are star-forming, any point-like source detections could instead be star-forming clumps within the galaxy, rather than GCs. In this work, we cautiously call dwarf galaxies with two or more apparent GC candidates ‘potential GC-rich’ galaxies.

4.6. Stellar mass calculation

To further characterise the dwarf sample and infer physically meaning interpretations, as well as constrain the stellar masses, we ran the software LePhare (Arnouts et al. 1999; Ilbert et al. 2006), which performs a simple χ^2 fitting between the stellar population synthesis theoretical models and the data. The multi-wavelength photometry was fitted using the models of Bruzual & Charlot (2003), assuming: (i) a Chabrier (2001) initial mass function, (ii) the Calzetti et al. (2000) extinction curve, and (iii) an exponentially declining star-formation rate. The models allowed variations in star formation duration ($\tau \leq 30$ Gyr), metallicity ($0.2 \leq Z/Z_\odot \leq 1$), age (age ≤ 14 Gyr), and internal extinction ($E(B - V) \leq 0.5$). This library favours high metallicity values and does not include metal-poor models that would better represent the stellar populations of certain dwarf galaxy types. To address this, we also performed SED fitting using single-burst models including metal-poorer metallicities in

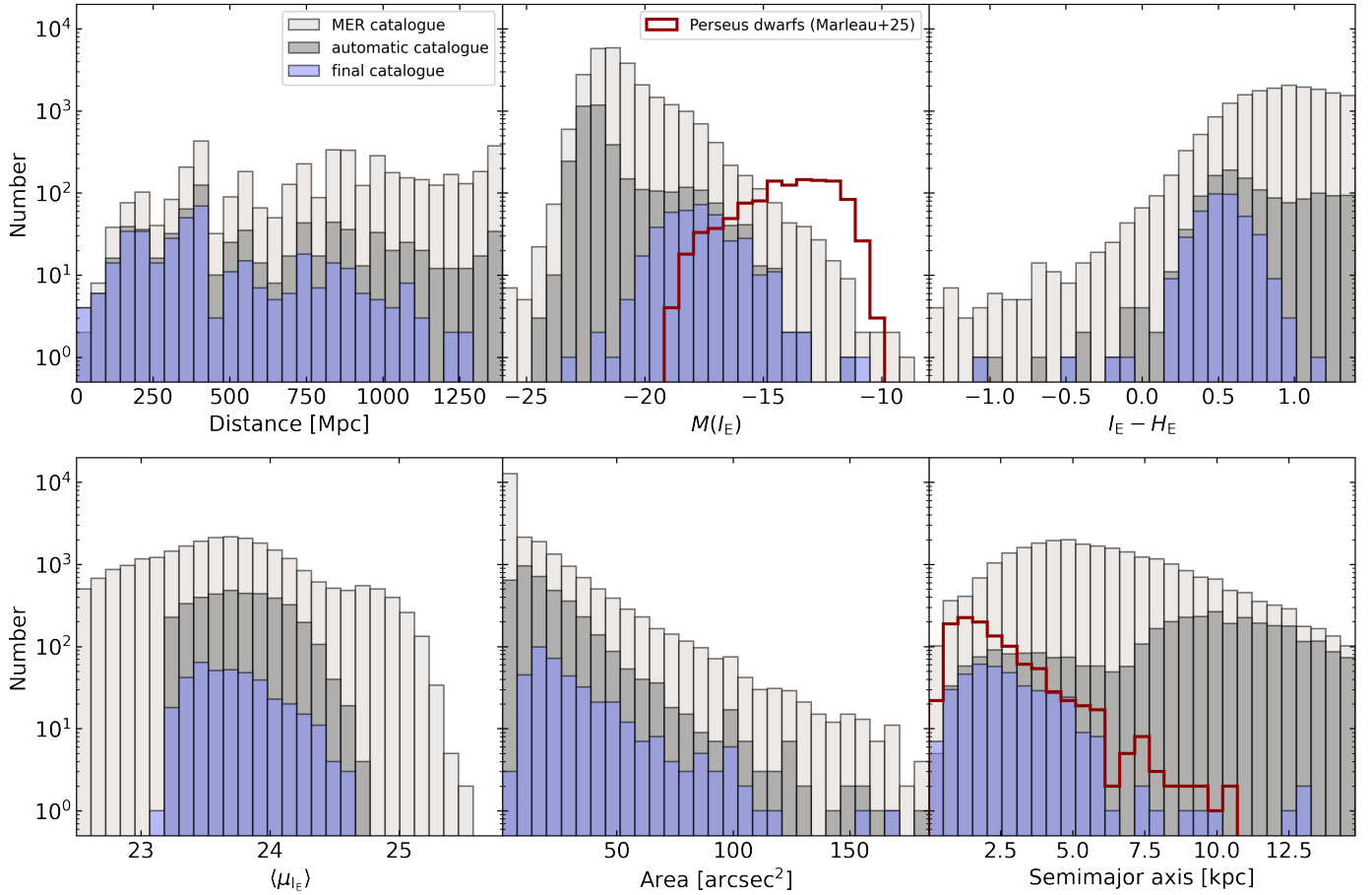


Fig. 14. Distribution of the properties of the Q1 dwarf candidates with spectroscopic redshift (pale blue-violet) overlaid on the properties of all galaxies in the MER catalogue (pale brown) and the automatically selected dwarf candidates with spectroscopic redshift in all 25 Q1 tiles (dark grey). The absolute magnitudes of the *Euclid* ERO Perseus dwarfs from Marleau et al. (2025), at a distance of 72 Mpc, are shown for comparison (dark red). The Perseus dwarfs are closer than the majority of the dwarf candidates in the Q1 data and therefore are detected to fainter absolute magnitudes. The physical sizes of the Q1 and Perseus dwarf candidates (dark red) cover a similar range, assuming that the Perseus dwarfs have a semimajor axis approximately equal to twice their effective radius ($2R_e$).

the range $0.005 \leq Z/Z_\odot \leq 2.5$, age ≤ 14 Gyr and $E(B-V) \leq 0.5$. The spectrum was redshifted using a reference value for redshift (see below), or the spectroscopic value when available. Using the redshift, the distance is calculated to rescale the total luminosity and, therefore, properly scale the stellar mass.

We used magnitudes within an aperture of $2 \times \text{FWHM}$, $m_{2\text{FWHM}}$, and adopted two sets of magnitudes: *Euclid* bands only; and *Euclid* bands plus the ground-based optical bands, CFHT u , HSC g , CFHT r , Pan-STARRS i (and related 1σ uncertainties). The photometry was corrected for Galactic extinction, as explained in Sect. 2.4. In order to correct the stellar mass M_* estimates from LePhare for any missing flux, we used the total magnitudes, m_S , derived from the Sérsic fitting in the I_E band using

$$\log_{10}(M_*/M_\odot) = \log_{10}(M_*/M_\odot)^{\text{LePhare}} + 0.4 \times (m_{2\text{FWHM}} - m_S), \quad (1)$$

where $\log_{10}(M_*/M_\odot)^{\text{LePhare}}$ is the best-fit stellar mass estimate returned by LePhare.

The spectroscopic redshift is available for only a fraction of the dwarf candidates; hence the distance is unknown for the rest of the sample. For the former, we obtained a stellar mass estimate using the spectroscopic redshifts. We also derived stellar mass estimates for the whole sample by adopting a redshift of

$z = 0.05$ and $z = 0.1$ (corresponding to a distance of approximately 200 and 400 Mpc, respectively), as representative values for the true redshift distribution of the dwarf candidate sample. After removing objects with missing photometry and extinction corrections, we obtained stellar mass estimates for 2636 out of 2674 dwarfs. A total of 388 dwarf galaxies have a stellar mass estimate that was derived using their spectroscopic redshift. The average 1σ error on the stellar mass of the whole and spectroscopic sample are 0.15 and 0.05 dex, respectively.

The results are shown in Fig. 15 and listed in Tables A.4 and A.5. In the top panel, we observe that the stellar mass distribution for the entire sample, obtained using the reference SED fitting setup and assuming $z = 0.1$, closely overlaps with that of the spectroscopic sample. Lowering the redshift assumption to $z = 0.05$ has a minor effect on the stellar mass-to-light ratio, but significantly impacts the distance estimation, leading to a systematic shift in stellar mass normalisation of about 0.6 dex compared to the $z = 0.1$ case. Focusing on the spectroscopic sample, we investigated the impact of using only *Euclid* bands and adopting a different spectral library with single-burst models. We find that the resulting stellar masses remain robust against these changes, with negligible variations.

The median, 5th, and 95th percentiles of the stellar mass distribution for the spectroscopic sample are $\log_{10}(M_*/M_\odot) \approx 8.6$, 7.3, and 9.4 dex, with only a few galaxies in the 9.4–9.9 dex

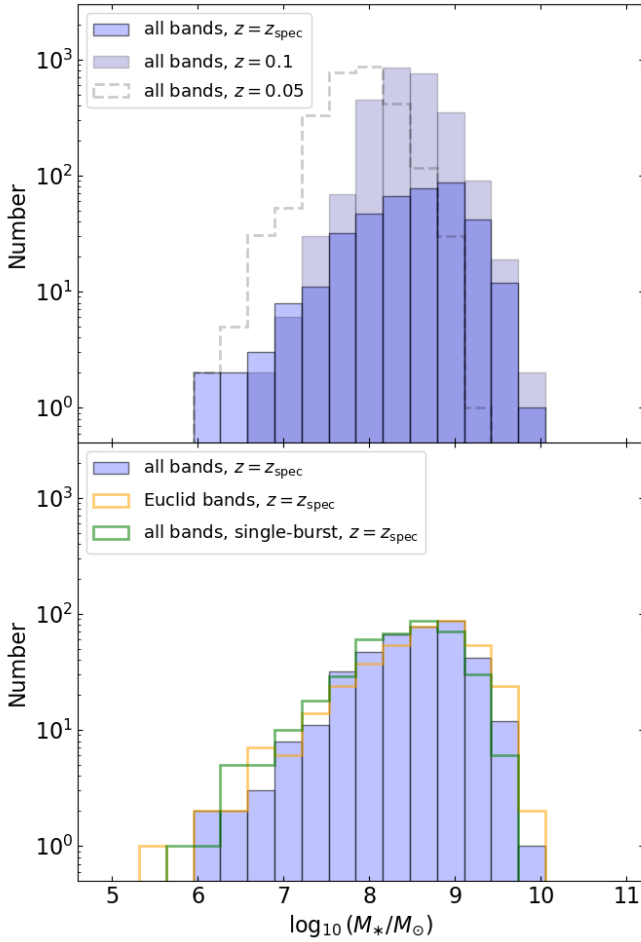


Fig. 15. Distribution of stellar masses for the Q1 dwarf candidates. *Top:* Stellar mass distribution obtained using the reference SED fitting setup and all available bands for all dwarf galaxies, assuming $z = 0.1$ (pale blue-violet) and $z = 0.05$ (dashed blue-violet), as well as for those with spectroscopic redshifts z_{spec} (opaque blue-violet). *Bottom:* Only dwarf galaxies with spectroscopic redshifts z_{spec} , comparing the reference SED fitting results with those obtained using *Euclid* bands alone (orange). Additionally, it includes results from an alternative SED fitting approach that employs single-burst models with a broader range of metallicities (green).

range and the least massive ones at 6–6.5 dex. Similar values are obtained when fitting the full sample assuming $z = 0.1$. The stellar mass distribution of the dwarf candidates aligns with expectations and therefore confirms that our selection criteria were successful at identifying dwarf galaxies while minimising contamination from non-dwarfs.

We compared the stellar masses of our dwarf sample, as shown in Fig. 15, to those reported in the DESI catalogues discussed in Sects. 4.3 and 4.4. For consistency with the stellar mass cut of the DESI dwarf catalogue, we first apply a stellar mass cut of $\log_{10}(M_*/M_\odot) \leq 9.0$ to our catalogue and the DESI Stellar Mass and Emission Line Catalogue, which reduces our sample to 303 and 2037 (out of 25 719 sources in the footprint of our study) galaxies, respectively. After applying the stellar mass cut and matching our dwarf catalogue to the DESI dwarf catalogue using a radius of $2''$, we find a total of 20 matches, with a morphological mix of 15 dIs and 5 dEs, based on the visual classification in our final dwarf catalogue. The comparison of the two stellar mass catalogues is shown in the right panel of Fig. B.1. We find that 93% (282 out of 303) of our spectroscopic dwarfs

do not have a match in the DESI dwarf catalogue. The dwarf candidates missing in the DESI dwarf catalogue are typically small or near a bright source (a galaxy or a star) and have the following properties: (i) dEs with blue cores, (ii) nucleated dEs, (iii) interacting dwarfs, and (iv) dIs with clumps of star formation. Figure B.4 highlights a selection of typical examples.

We additionally compared our estimated stellar masses with those reported in the DESI Stellar Mass and Emission Line Catalogue and the DESI Extragalactic Dwarf Galaxy Catalogue, without applying any stellar mass cut. The result of the comparison is shown in Fig. B.5. We find matches with 388 sources in the DESI Stellar Mass and Emission Line Catalogue and 22 in the DESI Extragalactic Dwarf Catalogue. We find a stellar mass median offset of -0.15 dex and -0.04 dex between our estimates and the DESI Stellar Mass and Emission Line Catalogue and DESI Extragalactic Dwarf Catalogue, respectively. As Fig. B.5 shows, there are hundreds of dwarfs from our catalogue that have a stellar mass $\log_{10}(M_*/M_\odot) \leq 9.0$ in the DESI Stellar Mass and Emission Line Catalogue but are not found in the DESI Extragalactic Dwarf Catalogue.

4.7. Two-dimensional spatial distribution

Mapping the spatial distribution of the identified dwarf galaxy candidates is essential for determining whether they are associated with specific host galaxies or exist as isolated objects. We selected adjacent tiles for this purpose. The spatial distribution of the 2674 identified dwarf candidates in the Q1 tiles is shown in Fig. 16. There are no large discontinuities in the number of dwarf candidates near the boundaries between groups.

To investigate their clustering with respect to possible host galaxies, we selected galaxies from The Heraklion Extragalactic Catalogue⁴ (HECATE, Kovlakas et al. 2021), which is a value-added catalogue of nearby galaxies, featuring robust distance measurements out to about 200 Mpc. The black circles in Fig. 16 correspond to the positions of HECATE galaxies, which are overlapping with the 25 tiles analysed in this paper. It can be seen that several of these positions have corresponding overdensities in the distribution of the host galaxies and the automatically selected dwarf candidates.

To better quantify the distribution of the dwarf galaxies, Fig. 17 displays a colour map, where yellow regions correspond to high dwarf overdensities and blue regions to lower overdensities. Additionally, dwarf galaxies with spectroscopic redshifts and HECATE galaxies, with distances, D , falling within two specific ranges, $90 \leq D/\text{Mpc} < 150$ and $150 \leq D/\text{Mpc} < 210$, are overplotted in the left and right panels, respectively⁵.

In particular, we observe in the right panel of Fig. 17 that the three HECATE galaxies located at (RA, Dec) = (267°9, 65°6) – NGC 6505, PGC 2678657, and 2MASX J17503135+6538075 – at a distance of around 180–185 Mpc, are not only overlapping with a clear overdensity in the dwarf sample, but are also associated with dozens of dwarfs with spectroscopic redshift and comparable distances. This confirms the presence of a clear overdensity of dwarf galaxies surrounding these three galaxies. The second most pronounced overdensity is found at (RA, Dec) = (269°0, 65°2), corresponding to the position of six host galaxies (PGC 061115, PGC 061122, PGC 061140, PGC 061148, PGC 061160, NGC 6536) with distances $D < 150$ Mpc (Fig. 17, left panel). However, we observe

⁴ <https://hecate.ia.forth.gr/index.php>

⁵ Distances for dwarfs with spectroscopic redshifts are calculated using a Hubble constant value of $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$.

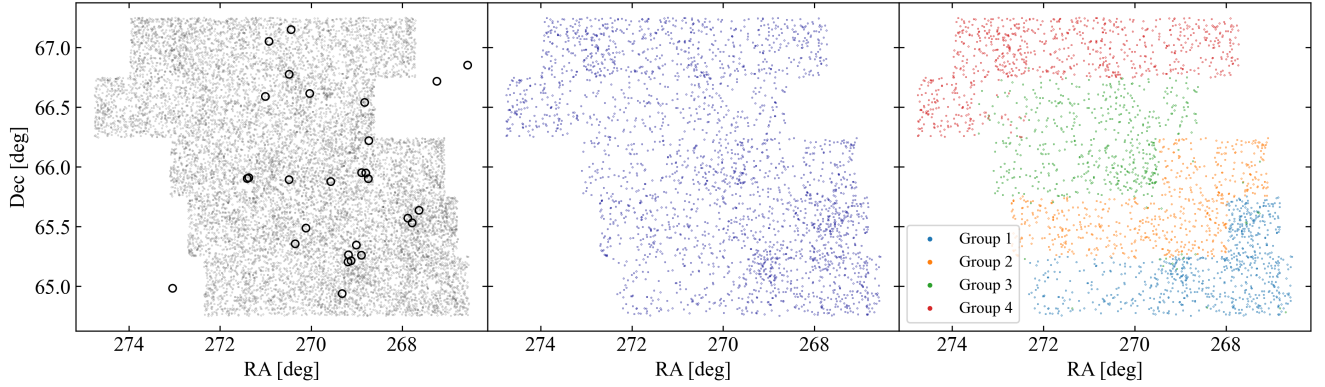


Fig. 16. *Left:* Spatial distribution of all candidates in the 25 tiles. The open black circles correspond to the positions of galaxies within a distance of about 200 Mpc from the HECATE sample. It can be seen that several of these positions have corresponding overdensities in the distribution of the automatically selected dwarf candidates as well. *Middle:* Spatial distribution of the final dwarf candidates where it can be seen that some of the overdensities around the massive galaxies shown in the left plot remain present in the final dwarf sample. *Right:* Spatial distribution of the final dwarf candidates, colour-coded by group. There are no large discontinuities in the number of dwarf candidates near the boundaries between groups.

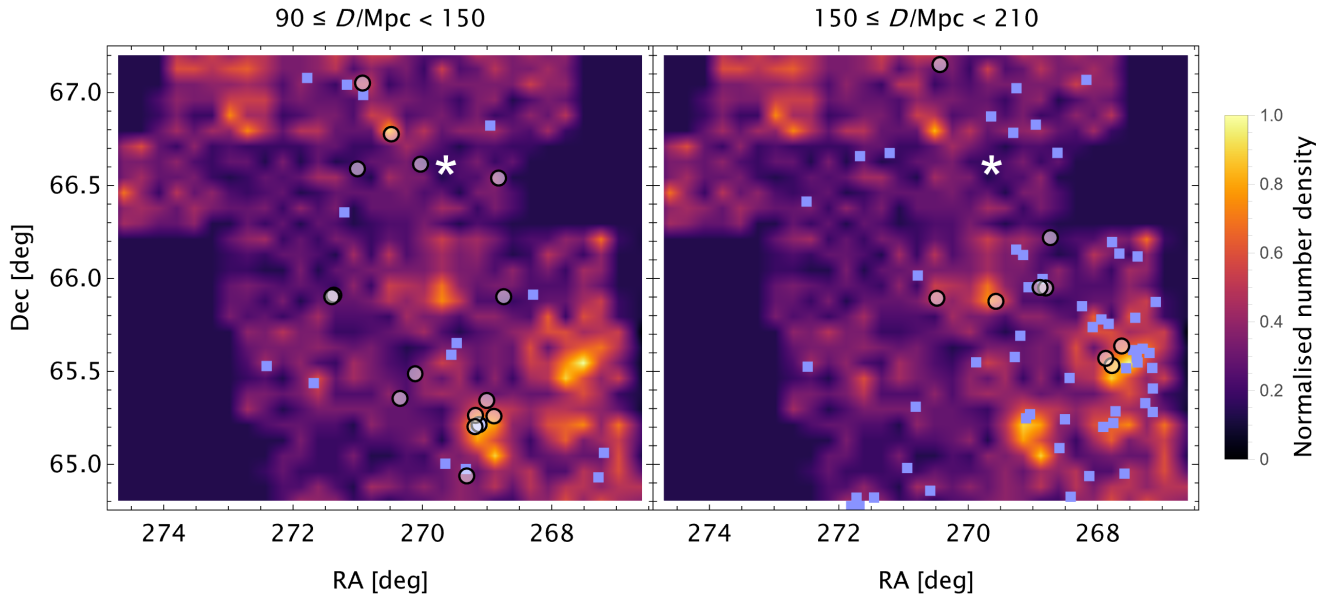


Fig. 17. Spatial distribution of the final dwarf candidates is shown alongside the HECATE galaxies within the 25 tiles (marked as open black circles) and dwarf galaxies with measured spectroscopic redshifts and different distance intervals (pale blue-violet filled squares). The colour map is based on the number of dwarfs within bins of RA and Dec, with this count normalised to a value of 1. According to the colour bar, orange-yellow colours indicate regions with dwarf galaxy overdensities. HECATE host galaxies and dwarfs with spectroscopic redshifts are displayed in the left and right panels, representing distances, D , in the ranges of $90 \leq D/\text{Mpc} < 150$ and $150 \leq D/\text{Mpc} < 210$, respectively. The white star indicates the location of the Cat's Eye nebula where a lack of dwarfs is expected.

that no significant overdensity of dwarfs with similar distances is detected in this specific region. For the rest of the sky area, while some dwarf overdensities are found near potential host galaxies, there are not enough dwarf galaxies with spectroscopic redshifts to confirm a definitive association. No potential host galaxy from the HECATE sample is found at the location of the dwarf overdensity detected at $(\text{RA}, \text{Dec}) = (273^\circ 0, 66^\circ 9)$. However, a visual inspection of the region reveals some extended galaxies that are not included in the HECATE sample and are therefore likely at larger distances.

Finally, it is interesting to explore how dwarf galaxies are distributed in terms of types and colour. Therefore, in Fig. 18 we show the colour map of the spatial distributions of dEs and dIs, and dwarfs divided in red and blue, defined using a threshold of

$I_E - H_E = 0.6$. In particular we notice that the most prominent dwarf overdensities are dominated by dEs, while dwarfs identified as dIs are distributed more uniformly spread the field of view. In particular, dEs are predominant in the two dwarf overdensities in the bottom-right side of our field of view, where we have also seen that a large number of host galaxies are identified. Similarly the reddest dwarfs are on average more clustered than bluer dwarfs, the latter being, similarly to dIs, distributed more homogeneously. However, in this last case, we also observed a clustering of bluer dwarfs around the overdensities in the bottom-right of our field of view. A more in-depth analysis of the field, which is beyond the scope of this paper, would be required to characterise the clustering of the sample and its variation with each single host.

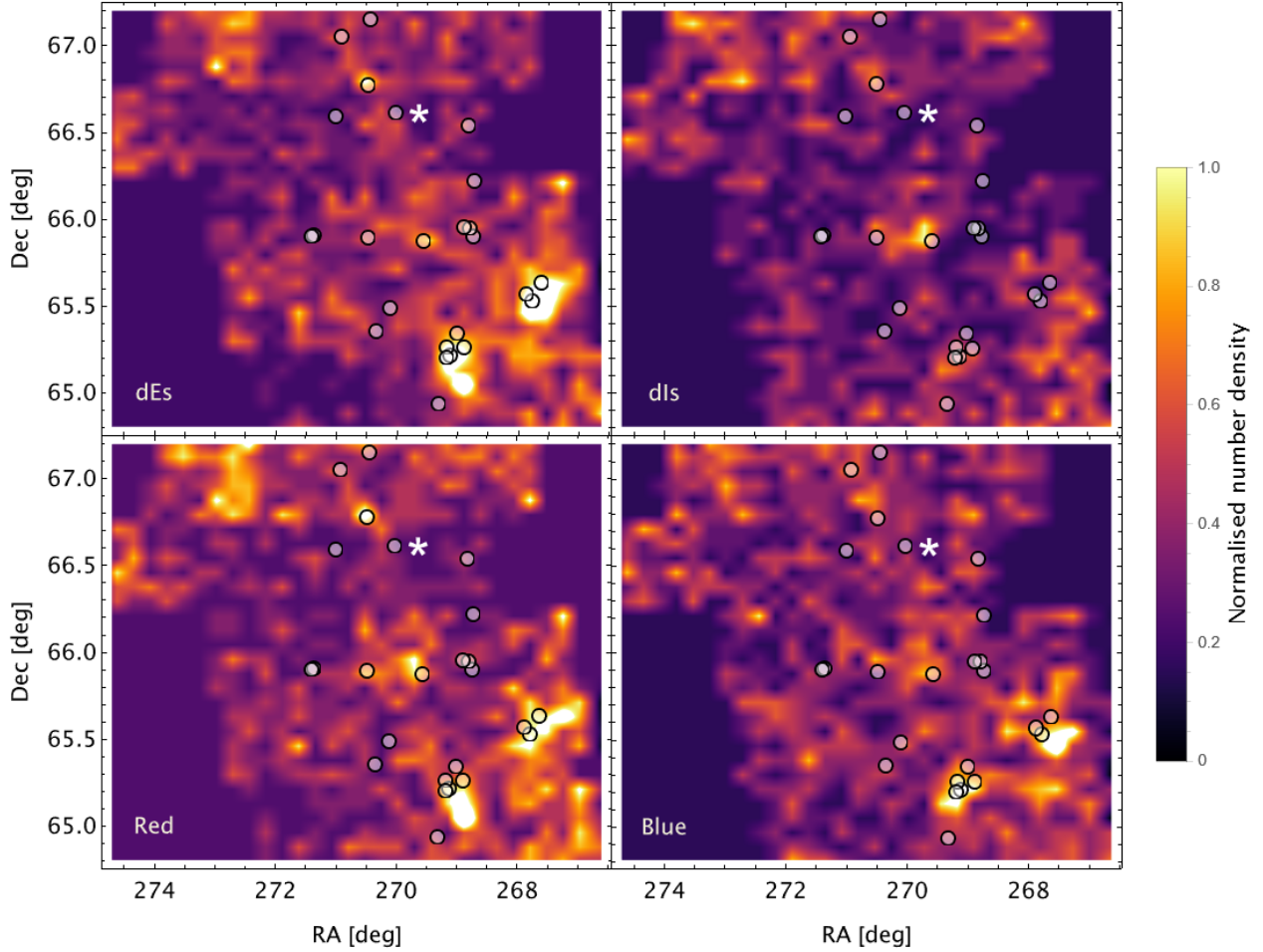


Fig. 18. *Top:* Spatial distributions of the final dwarf candidates, divided into the dEs and dIs, shown alongside the HECATE galaxies within the 25 tiles (marked as open black circles). *Bottom:* Same as top but divided into the red ($I_E - H_E > 0.6$) and blue ($I_E - H_E \leq 0.6$) dwarf galaxies. The white star indicates the location of the Cat's Eye nebula, where a lack of dwarfs is expected.

5. Dwarf formation pathways

Our analysis of the 25 tiles in the EDF-N has revealed different morphological classes of dwarf galaxies with a range of clustering properties. As discussed in Sect. 4.7, the dwarf candidates appear to be in some cases clustered around massive host galaxies, while in other parts of the sky, they are either clustered in regions empty of massive galaxies or found in isolation (or with one or two other dwarf companions).

A significant number of dEs exhibit a compact white or blue central nucleus, but only a very small number of them are GC-rich (0.8%). In contrast, in the Perseus galaxy cluster we found that 24.5% of the dEs are GC-rich (Marleau et al. 2025). This large discrepancy could be due to the ERO fields having a higher signal-to-noise ratio, better accuracy compared to the standard observing sequence used in the Q1 observations, or simply to the fact that more GC-rich dwarfs are found in denser environments (Cuillandre et al. 2025; Marleau et al. 2024). Moreover, dwarf galaxies in the Perseus cluster are located at a distance of 72 Mpc, which is below *Euclid*'s GC detection distance (about 100 Mpc; Euclid Collaboration: Voggel et al. 2025; see also discussion in Sect. 4.5). Figure 19 shows examples of dEs with a blue compact core (top left), dEs with an extended blue central clump (top right), and dwarf galaxies with a large central bright core (bottom left and right).

The central nuclei in dEs have typical sizes of a few to a few tens of parsecs with a mass of nearly 1% of their hosts (Côté et al. 2006; Rossa et al. 2006), and data from the *Hubble* Space Telescope have revealed that dE nuclei are slightly bluer than the rest of their host galaxies (Lotz et al. 2004; Côté et al. 2006). Moreover, detailed stellar population studies from integrated light spectroscopy have shown that they are, on average, younger than the host galaxies' stellar halos (Chilingarian 2009; Paudel et al. 2011; Guérou et al. 2015; Kacharov et al. 2018). While typical dEs with a compact white central core have old nuclei and no star formation, the blue-cored ones exhibit a central region with active star formation. This suggests that they may be early-type dwarf galaxies in the process of forming a central nucleus (Paudel & Yoon 2020).

The formation channels of the central core in dEs are under debate. It is not clear whether the dEs formed with central nuclei that co-evolved together or formed later during the host galaxy evolution. Three formation channels have been envisaged: (1) nuclear clusters form via mergers of multiple GCs accreted through dynamical friction (Tremaine et al. 1975; Oh & Lin 2000; McLaughlin et al. 2006; Böker 2010; Poulain et al. 2025); (2) nuclear clusters form in situ from gas channelled into the centres of galaxies (Milosavljević 2004; Bekki & Chiba 2007); and (3) a significant merger event triggering a starburst in which an NSC forms and which self-

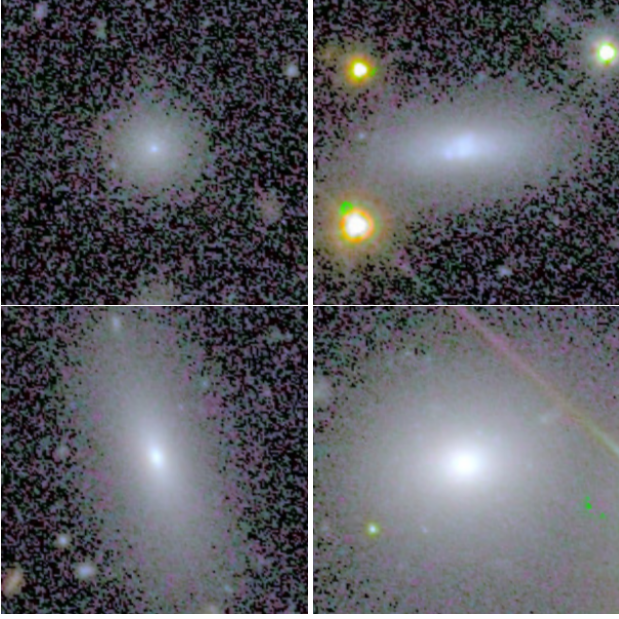


Fig. 19. Cutouts of some dwarf candidates taken from the VIS-NISP colour image created using the I_E band in blue, the Y_E band in green, and the H_E band in red. The colours are projected onto the high-resolution I_E band to best reflect their appearance as detected. *Top left:* Example of a compact blue-cored dE. *Top right:* Dwarf with extended blue central clump. *Bottom left and bottom right:* Candidate transitional dwarfs, one of which exhibits an elongated central clump. The sizes of the cutouts are proportional to twice the area determined from the annotation of classifiers; north is up and east is to the left.

quenches the galaxy (Gray et al. 2025). The first formation scenario is motivated by the fact that there are similarities between massive GCs and NSCs in terms of stellar mass and luminosity (McLaughlin 1999; Côté et al. 2006; den Brok et al. 2014; Poulain et al. 2021; Marleau et al. 2025). Paudel & Yoon (2020) presented a study of a sample of dEs located on the outskirts of the Virgo cluster that possess star-forming blobs near the isophotal centre of the galaxy. The top panels of their Figure 1 show some of the dEs found in their analysis with SDSS spatial resolution ($1''.5$). In Fig. 19, we show similar objects but with a *Euclid* spatial resolution (I_E , $0''.20$), where the central blue cores look more like extended blobs. Inspection of the figure shows that the central blue regions appear large and, in some cases, exhibit elongated shapes. In Sect. 3.2, we referred to these galaxies as transitional dwarf galaxies.

As discussed in Paudel & Yoon (2020), star formation in these galaxies is concentrated within the nuclei region and presents high emission line metallicity ($12 + \log_{10}(\text{O}/\text{H}) > 8.4$ dex), with a median of 8.59. In contrast, the stellar population of the halo is old and has a mean metallicity of $\log_{10}(Z/Z_\odot) \approx -0.8$ (5 times more metal-poor), consistent with a typical dE. One of the key points to fully understand the nature of these galaxies is the origin of the gas supply that fuels star formation in the central regions. In the case of dEs with a blue core and residing in the outskirts of a galaxy cluster, they could have acquired their gas during a migration process from the inner regions to the outskirts; however, the metallicity of the star-forming regions would be lower than that observed in the galaxies from Paudel & Yoon (2020), which reside in the outskirts of the Virgo cluster. An alternative scenario would be recycled gas flowing into the galaxy centre and re-igniting star formation (Boselli et al. 2008).

The formation pathway of the dwarfs and their NSC likely depends on the density of their local environment. In the satellites of the MATLAS galaxies (Poulain et al. 2025) and in the dwarf galaxies detected by *Euclid* in the Perseus galaxy cluster (Marleau et al. 2025), there is evidence of the GC-inspiral scenario supported by the complex structure in the nuclei of the dwarf galaxies. This formation scenario is also supported by the presence of a large percentage (24.5%) of GC-rich dEs in the Perseus cluster. In our visual inspection of the 25 Q1 tiles, we also find evidence of such nucleus substructure, as seen in Fig. 12 (top left) and discussed in Sect. 4.2.

One important aspect to consider is the fact that some of the dEs with a large central blue or white core detected in Q1 are isolated dwarfs, and therefore alternative formation mechanisms of a central star-forming region in these galaxies must be envisaged. Gray et al. (2025) used a suite of cosmological high resolution zoom simulations named EDGE (Agertz et al. 2020) to study an isolated dwarf galaxy with virial mass of around $5 \times 10^9 M_\odot$ at redshift $z = 0$. The simulations show that dwarfs are quenched by reionisation, but retain a significant reservoir of gas that is unable to cool and form stars. Sometime after reionisation, the dwarfs then undergo a major merger that triggers rapid gas cooling, leading to a significant starburst. An NSC forms in this starburst that then quenches star formation thereafter. Two possibilities are predicted: (1) formation of a dense NSC in the dwarf that started its assembly history at later epochs; and (2) no formation of a central core in dwarfs that had an earlier assembly history. This means that isolated galaxies can form a dense central core via merging events, and it is likely that the dEs with star-forming blue or white cores found in the Q1 data are going through a process of NSC formation, while evolving in nucleated quenched dEs.

Other scenarios for the origin of dEs with large white or blue core involve: (1) the conversion of gas-rich disc galaxies into gas-poor early-type dwarfs; and (2) a primordial origin. The first involves gas removal, with subsequent tidal heating, harassment, and ram-pressure stripping (Gunn & Gott 1972; Moore et al. 1996; Lake et al. 1998). The process of ram pressure stripping alone is envisaged by Boselli et al. (2008) and Steyrleithner et al. (2020), while Chilingarian (2009) suggested a process involving major/minor mergers. It is worth noting that the transformation of gas-rich late-type galaxies to early-type dwarfs would be more likely in crowded environments like galaxy groups or clusters, where a significant portion of these transitional dwarf galaxies is found (Makarov et al. 2011). However, some of the galaxies detected in Q1 exist in isolation, as shown in this analysis, and the scenario of a primordial formation would be more plausible. As shown in Ann & Seo (2024), such a scenario is challenged by the fact that the star formation histories (SFHs) of transitional dwarf galaxies exhibit an active period of more recent star formation, similar to the SFHs observed in dEs. The SFHs of the isolated dwarfs reveal two distinct periods of active star formation. The first period ended about 6 Gyr ago and witnessed the formation of predominantly old, metal-poor stars ($Z = 0.0004$), while the second period, which ended around 1 Gyr ago, contributed to the formation of moderately old stellar populations with intermediate metallicity. Moreover, the SFHs of transitional dwarf galaxies show a clear dependence on stellar mass, with more massive dwarfs forming stars at earlier epochs. From these findings, it seems that the scenario of primordial formation is unlikely.

As shown in the top panel of Fig. 18, early-type dwarfs tend to cluster around massive galaxies, and therefore, the formation of a central star-forming region, and the NSC, is likely affected

by the high-density environment. In the case of dEs with no obvious massive galaxy host, the more plausible scenario would be an in situ formation, where the central core formed from the gas channelled into the centre of the dwarf, in certain instances possibly triggered by a dwarf-dwarf merger event. Future in-depth investigations of the stellar populations in these galaxies are already planned and will help shed light on the formation and evolution of dEs in different environments.

6. Conclusions

We have taken advantage of the unprecedented depth, spatial resolution, and field of view of the [Euclid Quick Release Q1 \(2025\)](#), consisting of a total of 351 tiles located in EDF-N, EDF-S, and EDF-F and the Lynds Dark Nebula LDN1641 to build a census of dwarf galaxies in the 203 tiles with good quality data and full coverage. A representative sample of 25 contiguous tiles in the EDF-N were selected covering a total area of 14.25 deg^2 for a first exploration of the Q1 data set. The analysis of the remaining tiles will be presented in a future paper.

The dwarf galaxy candidates were identified using a semi-automatic detection method based on properties measured by the *Euclid* pipeline and released as part of the MER catalogue. A detailed visual analysis of a reference tile was used to calibrate the automatic selection method for all Q1 fields. A selection cut in surface brightness and magnitude was used to produce an initial dwarf candidate catalogue, which was followed by a cut in morphology (removing background spiral galaxies) and $I_E - H_E$ colour (removing red ellipticals). This catalogue was then visually classified to produce a final sample of dwarf candidates as well as to determine the morphology (dE, dI, disturbed), number of nuclei, potential GC richness, and the presence of a blue core. The distribution of the most relevant photometric and morphological parameters contained in the MER catalogue for each of the dwarf candidates was then obtained for this first sample of Q1 dwarfs. We highlight some of our key findings below:

- After applying a score and size cut, a total of 2674 dwarf candidates were identified over a region of 25 tiles, therefore covering 14.25 deg^2 . In terms of number per sky area, this corresponds to 188 dwarfs per deg^2 . Extrapolating this number to all Q1 EDF regions (53 deg^2), the sky area covered by DR1 (1900 deg^2), and EWS ($14\,000 \text{ deg}^2$), we calculated approximately 9900, 360 000, and 2.6 million dwarf candidate galaxies, respectively.
- In the final dwarf sample, 57.9% were classified as dE, of which a small fraction (4.4%) were identified as being a dE with disturbed morphology (possibly the result of tidal interaction, tidal tail formation, or dwarf-dwarf merger). Very few (1.0%) dwarfs were found to have two or more GC candidates, compared to 26% for the dwarfs in the Perseus cluster. This is possibly due to the fact that the Q1 dwarfs span a larger range of distances and probe different large-scale environments. Likewise, there are few (4.0%) nucleated dwarfs, and a small fraction (6.9%) of candidates show a blue core. These show a wide range of visual structural properties, including unresolved blue cores, extended blue central clumps, complex and S-shape substructures, and finally double nuclei and multiple clumps.
- The properties of the final dwarf candidates, as compared to the automatically selected dwarf candidate catalogue, appear to be rounder. Compared to the *Euclid* ERO Perseus dwarfs, the Q1 dwarfs have the same range of colours and ellipticities

but tend to have smaller angular sizes and a wider range of surface brightnesses.

- We have cross-matched our list of dwarf candidates with a spectroscopic catalogue from DESI ([DESI Collaboration 2024](#)) using a $2''$ match radius. A total of 388 candidates (15% of the total sample) were found to have a match. Based on this spectroscopic sample, we find the median of the distance distribution for the dwarf candidates to be around 400 Mpc.
- The Q1 dwarfs with matched spectroscopic redshifts have a brighter range of absolute magnitudes than the Perseus dwarfs, most likely due to the fact that the majority of the Q1 dwarfs are found at greater distances. The physical sizes of the Q1 and Perseus dwarfs cover a similar range, assuming that the Perseus dwarfs have a semimajor axis approximately equal to twice their effective radius.
- Based on SED fitting, the stellar mass range for the spectroscopic sample is $\log_{10} M_*/M_\odot \sim 7.3\text{--}9.4$, with only a few galaxies with larger masses. This implies that our selection criteria are successful at identifying dwarf galaxies while minimising contamination by other sources.
- Several of the positions of the bright (massive) galaxies have corresponding overdensities in the final dwarf sample. The most prominent dwarf overdensities are dominated by dEs, while dwarfs identified as dIs are distributed more homogeneously across the field of view.
- A significant number of Q1 dEs exhibit a compact white or blue central nucleus. Since early-type dwarfs tend to cluster around massive galaxies, the formation of a central star-forming region, and the NSC, is likely affected by the high density environment. In the case of dEs with no obvious massive galaxy host, the more plausible scenario would be an in situ formation, where the central core formed from the gas channelled into the centre of the dwarf.

The Q1 images have demonstrated the capability of *Euclid* to detect and characterise dwarf galaxies across a range of distances, stellar masses, and environments. Due to the large range of distances probed by the Q1 data, contamination by background galaxies remains a major challenge. Future work will make use of the results presented in this paper to study the properties of these dwarfs in more detail and optimise their detectability.

Data availability

The full versions of Tables [A.1–A.5](#) are available at the CDS via <https://cdsarc.cds.unistra.fr/viz-bin/cat/J/A+A/711/A10>

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Appendix A: Properties of the dwarf galaxy candidates

The dwarf galaxy candidates are classified by visual inspection with the methodology described in Sect. 3. Table A.1 contains the visual classification of the dwarf candidates, ordered by increasing RA. The column definitions are as follows: a unique identifier (ID) based on the OBJECT_ID parameter in the MER catalogue; RA in degrees; Dec in degrees; morphology (either dE or dI); GC-rich flag (dwarfs with $N_{GC} \geq 2$ GCs are defined as GC-rich); a flag for the presence of a nucleus (Nucleated); a disturbed morphology flag (Disturbed); and a blue-cored flag (Blue-cored). Table A.2 lists the photometric and structural parameters of the dwarf candidates (ordered by increasing RA) obtained from the MER catalogue. The column definitions are as follows: a unique identifier (ID) based on the OBJECT_ID parameter; RA in degrees; Dec in degrees; apparent magnitude in the I_E filter (I_E , computed using the FLUX_SEGMENTATION parameter, see Sect. 3.4); area in arcsec² (area, see Sect. 3.4); ellipticity (e); position angle in degrees (PA); and average surface brightness in mag arcsec⁻² ($\langle\mu_{I_E}\rangle$, see Sect. 3.4). The uncertainties are calculated based on the propagation of error formulae using the uncertainties reported in the MER catalogue. The area is based on the SEGMENTATION_AREA parameter which has no associated uncertainty in the catalogue. The ellipticity and position angle are based on the POSITION_ANGLE and ELLIPTICITY parameters, respectively, which have the associated uncertainty parameters POSITION_ANGLE_ERR and ELLIPTICITY_ERR; however, the respective column entries are empty. Table A.3 lists the aperture magnitudes and extinction corrections (EC) (ordered by increasing RA) described in Sect. 2.4. The column definitions are a unique identifier (ID) based on the OBJECT_ID parameter in the MER catalogue; the apparent magnitude in the I_E filter ($I_{E,2FWHM}$, computed using the FLUX_VIS_2FWHM_APER parameter); the extinction correction in I_E ; the apparent magnitude in the Y_E filter ($Y_{E,2FWHM}$, computed using the FLUX_Y_2FWHM_APER parameter); the extinction correction in Y_E ; apparent magnitude in the J_E filter ($J_{E,2FWHM}$, computed using the FLUX_J_2FWHM_APER parameter); the extinction correction in J_E ; the apparent magnitude in the H_E filter ($H_{E,2FWHM}$, computed using the FLUX_H_2FWHM_APER parameter); and the extinction in H_E .

Table A.1. Visual properties of the dwarf galaxy candidates.[†]

ID	RA [deg]	Dec [deg]	Morphology	GC-rich	Nucleated	Disturbed	Blue-cored
2665542189652466511	266.554219	65.246651	dI	No	No	No	No
2665815442648786462	266.581544	64.878646	dE	No	No	No	No
2665837571652492797	266.583757	65.249280	dE	No	No	No	Yes
2665847551651610342	266.584755	65.161034	dI	No	No	No	Yes
2665914298650060584	266.591430	65.006058	dE	No	No	No	Yes
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2747385300663221364	274.738530	66.322136	dI	No	No	No	No
2747397180663791709	274.739718	66.379171	dE	No	No	No	Yes
2747513424663839120	274.751342	66.383912	dE	No	Yes	No	No
2747532158662611810	274.753216	66.261181	dE	No	No	No	No
2747550219666016765	274.755022	66.601677	dI	No	No	No	No

Notes. ^(†) Table A.1 is only available in electronic form at the CDS.

Table A.2. Photometric and structural properties of the dwarf galaxy candidates.[†]

ID	RA [deg]	Dec [deg]	I_E [mag]	Area [arcsec ²]	e	PA [deg]	$\langle\mu_{I_E}\rangle$ [mag arcsec ⁻²]
2665542189652466511	266.554219	65.246651	21.00 ± 0.07	15.96	0.34	56.25	23.96 ± 0.07
2665815442648786462	266.581544	64.878646	21.95 ± 0.07	10.82	0.17	55.90	24.48 ± 0.07
2665837571652492797	266.583757	65.249280	21.54 ± 0.06	7.93	0.73	-80.01	23.74 ± 0.06
2665847551651610342	266.584755	65.161034	19.83 ± 0.07	33.10	0.36	71.22	23.58 ± 0.07
2665914298650060584	266.591430	65.006058	21.08 ± 0.08	14.92	0.23	61.73	23.97 ± 0.08
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2747385300663221364	274.738530	66.322136	22.27 ± 0.07	8.44	0.26	-72.74	24.59 ± 0.07
2747397180663791709	274.739718	66.379171	19.59 ± 0.06	41.67	0.14	-52.62	23.63 ± 0.06
2747513424663839120	274.751342	66.383912	20.81 ± 0.06	13.17	0.05	67.14	23.60 ± 0.06
2747532158662611810	274.753216	66.261181	21.87 ± 0.06	10.24	0.22	84.88	24.39 ± 0.06
2747550219666016765	274.755022	66.601677	22.08 ± 0.06	7.13	0.27	26.87	24.21 ± 0.06

Notes. ^(†) Table A.2 is only available in electronic form at the CDS.

Table A.3. Aperture magnitudes and extinction corrections (EC) in the *Euclid* I_E , Y_E , J_E , and H_E bands for each dwarf galaxy candidate.[†]

ID	$I_{E,2FWHM}$ [mag]	EC (I_E) [mag]	$Y_{E,2FWHM}$ [mag]	EC (Y_E) [mag]	$J_{E,2FWHM}$ [mag]	EC (J_E) [mag]	$H_{E,2FWHM}$ [mag]	EC (H_E) [mag]
2665542189652466511	21.88 ± 0.07	0.116 ± 0.003	21.45 ± 0.06	0.058 ± 0.001	21.36 ± 0.05	0.0398 ± 0.0009	21.27 ± 0.04	0.0258 ± 0.0006
2665815442648786462	22.67 ± 0.07	0.103 ± 0.002	22.08 ± 0.06	0.052 ± 0.001	22.00 ± 0.05	0.0352 ± 0.0007	21.84 ± 0.04	0.0228 ± 0.0005
2665837571652492797	22.13 ± 0.06	0.117 ± 0.002	21.69 ± 0.06	0.059 ± 0.001	21.59 ± 0.05	0.0399 ± 0.0007	21.50 ± 0.04	0.0258 ± 0.0004
2665847551651610342	20.69 ± 0.07	0.112 ± 0.002	20.32 ± 0.05	0.056 ± 0.001	20.20 ± 0.04	0.0384 ± 0.0007	20.11 ± 0.03	0.0248 ± 0.0005
2665914298650060584	21.75 ± 0.08	0.110 ± 0.003	21.33 ± 0.06	0.055 ± 0.001	21.18 ± 0.07	0.0380 ± 0.0010	21.07 ± 0.04	0.0243 ± 0.0006
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2747385300663221364	22.80 ± 0.07	0.125 ± 0.002	22.42 ± 0.08	0.063 ± 0.001	22.24 ± 0.06	0.0426 ± 0.0007	22.27 ± 0.06	0.0276 ± 0.0005
2747397180663791709	20.42 ± 0.06	0.122 ± 0.002	19.79 ± 0.04	0.0614 ± 0.0009	19.72 ± 0.04	0.0418 ± 0.0006	19.63 ± 0.03	0.0271 ± 0.0004
2747513424663839120	21.41 ± 0.06	0.122 ± 0.002	20.93 ± 0.05	0.0614 ± 0.0009	20.82 ± 0.04	0.0418 ± 0.0006	20.68 ± 0.03	0.0271 ± 0.0004
2747532158662611810	22.49 ± 0.06	0.125 ± 0.002	22.18 ± 0.07	0.0627 ± 0.0009	22.08 ± 0.06	0.0427 ± 0.0006	22.11 ± 0.06	0.0276 ± 0.0004
2747550219666016765	22.51 ± 0.06	0.125 ± 0.002	22.16 ± 0.07	0.0627 ± 0.0009	22.01 ± 0.05	0.0427 ± 0.0006	21.90 ± 0.04	0.0276 ± 0.0004

Notes. ^(*) Denotes dwarf candidates for which the colour information is affected by image defects.^(†) Table A.3 is only available in electronic form at the CDS.

Table A.4 and Table A.5 list stellar mass estimates for the dwarf galaxy candidates as described in Sect. 4.6 and shown in Fig. 15. Table A.5 only lists dwarf galaxy candidates for which spectroscopic redshifts are available. The column definitions for Table A.4 are a unique identifier (ID) based on the OBJECT_ID parameter in the MER catalogue; RA in degrees; Dec in degrees; the stellar mass estimate obtained via the reference SED fitting setup and all available photometric bands assuming $z = 0.1$ ($M_{*,z=0.1}$); and the stellar mass estimate using all bands assuming $z = 0.5$ ($M_{*,z=0.05}$). The column definitions for Table A.5 are the unique identifier (ID); RA in degrees; Dec in degrees; the stellar mass estimate obtained via the reference SED fitting setup and all available photometric bands assuming $z = z_{\text{spec}}$ ($M_{*,z=z_{\text{spec}}}$); the stellar mass estimate obtained using *Euclid* bands alone ($M_{*,z=z_{\text{spec}}}(\text{Euclid bands})$); and the stellar mass estimate obtained by employing a single-burst model in the SED fitting approach ($M_{*,z=z_{\text{spec}}}(\text{single-burst})$). The uncertainties given in both tables were estimated by using the 16th, 50th and 84th quantiles of the fitting routine and calculating the upper limit as (84th-quantile–50th-quantile) and the lower limit as (50th-quantile–16th-quantile).

Table A.4. Stellar mass estimates of the dwarf galaxy candidates.[†]

ID	RA [deg]	Dec [deg]	$M_{*,z=0.1}$ [$\log_{10} M_*/M_\odot$]	$M_{*,z=0.05}$ [$\log_{10} M_*/M_\odot$]
2665542189652466511	266.554219	65.246651	$8.49^{+0.15}_{-0.08}$	$7.83^{+0.41}_{-0.14}$
2665815442648786462	266.581544	64.878646	$8.51^{+0.20}_{-0.16}$	$7.90^{+0.20}_{-0.18}$
2665837571652492797	266.583757	65.249280	$8.27^{+0.10}_{-0.10}$	$7.61^{+0.08}_{-0.17}$
2665847551651610342	266.584755	65.161034	$8.87^{+0.03}_{-0.03}$	$8.30^{+0.04}_{-0.04}$
2665914298650060584	266.591430	65.006058	$8.51^{+0.22}_{-0.05}$	$7.97^{+0.22}_{-0.18}$
⋮	⋮	⋮	⋮	⋮
2747385300663221364	274.738530	66.322136	$7.96^{+0.16}_{-0.13}$	$7.33^{+0.15}_{-0.17}$
2747397180663791709	274.739718	66.379171	$9.21^{+0.04}_{-0.04}$	$8.65^{+0.05}_{-0.18}$
2747513424663839120	274.751342	66.383912	$8.71^{+0.07}_{-0.10}$	$7.93^{+0.13}_{-0.16}$
2747532158662611810	274.753216	66.261181	$7.97^{+0.11}_{-0.17}$	$6.72^{+0.12}_{-0.13}$
2747550219666016765	274.755022	66.601677	$7.98^{+0.16}_{-0.18}$	$7.52^{+0.18}_{-0.19}$

Notes. ^(†) Table A.4 is only available in electronic form at the CDS.

Table A.5. Stellar mass estimates of the dwarf galaxy candidates calculated with different models.[†]

ID	RA [deg]	Dec [deg]	$M_{*,z=z_{\text{spec}}}$ [$\log_{10} M_*/M_\odot$]	$M_{*,z=z_{\text{spec}}}(\text{Euclid bands})$ [$\log_{10} M_*/M_\odot$]	$M_{*,z=z_{\text{spec}}}(\text{single-burst})$ [$\log_{10} M_*/M_\odot$]
2668226817651115008	266.822682	65.111501	$8.61^{+0.06}_{-0.11}$	$8.92^{+0.09}_{-0.13}$	$8.63^{+0.04}_{-0.04}$
2668228983656635904	266.822898	65.663601	$8.44^{+0.08}_{-0.09}$	$8.62^{+0.17}_{-0.21}$	$8.19^{+0.05}_{-0.05}$
2668283271656967168	266.828327	65.696713	$8.56^{+0.05}_{-0.07}$	$8.00^{+0.31}_{-0.36}$	$8.52^{+0.04}_{-0.04}$
2668500153654553088	266.850015	65.455303	$7.97^{+0.03}_{-0.03}$	$8.04^{+0.15}_{-0.17}$	$7.86^{+0.03}_{-0.03}$
2668644262651000320	266.864426	65.100031	$8.89^{+0.11}_{-0.08}$	$9.35^{+0.14}_{-0.22}$	$8.91^{+0.03}_{-0.03}$
⋮	⋮	⋮	⋮	⋮	⋮
2730261537666017792	273.026154	66.601767	$6.96^{+0.05}_{-0.05}$	$9.53^{+0.18}_{-0.13}$	$8.25^{+0.03}_{-0.03}$
2732068271664329216	273.206827	66.432926	$8.56^{+0.03}_{-0.04}$	$8.64^{+0.15}_{-0.13}$	$8.57^{+0.03}_{-0.03}$
2732101421668001280	273.210142	66.800147	$8.48^{+0.04}_{-0.04}$	$8.03^{+0.20}_{-0.50}$	$8.50^{+0.03}_{-0.03}$
2733911470664385024	273.391147	66.438544	$8.13^{+0.06}_{-0.13}$	$8.65^{+0.10}_{-0.20}$	$8.01^{+0.06}_{-0.06}$
2735409222663873024	273.540922	66.387278	$8.86^{+0.04}_{-0.04}$	$9.17^{+0.11}_{-0.17}$	$8.87^{+0.03}_{-0.03}$

Notes. ^(†) Table A.5 is only available in electronic form at the CDS.

Appendix B: Comparison with the DESI catalogues

In Sect. 4.4, we discussed how our *Euclid* dwarf galaxy candidate sample compares to the one identified in the DESI Extragalactic Dwarf Catalogue. In this appendix, we illustrate the key differences between the two catalogues. Figure B.1 displays our dwarf galaxy candidates at their respective positions in the sky together with information about their morphological type, stellar mass estimate and if they contain an identifiable nucleus. Additionally, we mark the positions of dwarf candidates from the DESI Extragalactic Dwarf Catalogue and emphasise matches between them. The left panel of Fig. B.1 includes dwarf candidates with photometric as well as spectroscopic redshift estimates, whereas the right panel of Fig. B.1 only includes candidates with spectroscopic redshift estimates. The two figures clearly show the dwarf candidate density variation across the investigated region of the sky. The morphological type, stellar mass and nucleated dwarf candidates seem to be distributed evenly and have no especially strong effect on whether a dwarf candidate is found in both catalogues.

Most of the potentially missed dwarf galaxies in our catalogue can be assigned to one of the following groups: dEs with bright and extended centres, edge-on galaxies, galaxies with clear spiral structures, and galaxies with multiple star forming regions. Galaxies belonging to these categories were intentionally excluded due to the difficulty of properly characterising such galaxies using a visual scheme. We show a few examples of such intentionally excluded galaxies in Fig. B.2. With Fig. B.3, we show examples of DESI dwarf galaxy candidates which have likely been misclassified as such. In particular, the left image displays two similar spiral galaxies, one of which is classified as a dwarf galaxy in the DESI catalogue, while the other is not. Additionally, we show examples of galaxies included in our catalogue but missing in the DESI Extragalactic Dwarf Catalogue in Fig. B.4.

When we compare the stellar mass estimates of our SED fitting approach to the one used by DESI in Fig. B.5, we find that the resulting stellar mass estimates are mostly consistent with each other. However, some outliers are clearly visible, and there also seems to be a small systematic offset of the results of the two compared approaches.

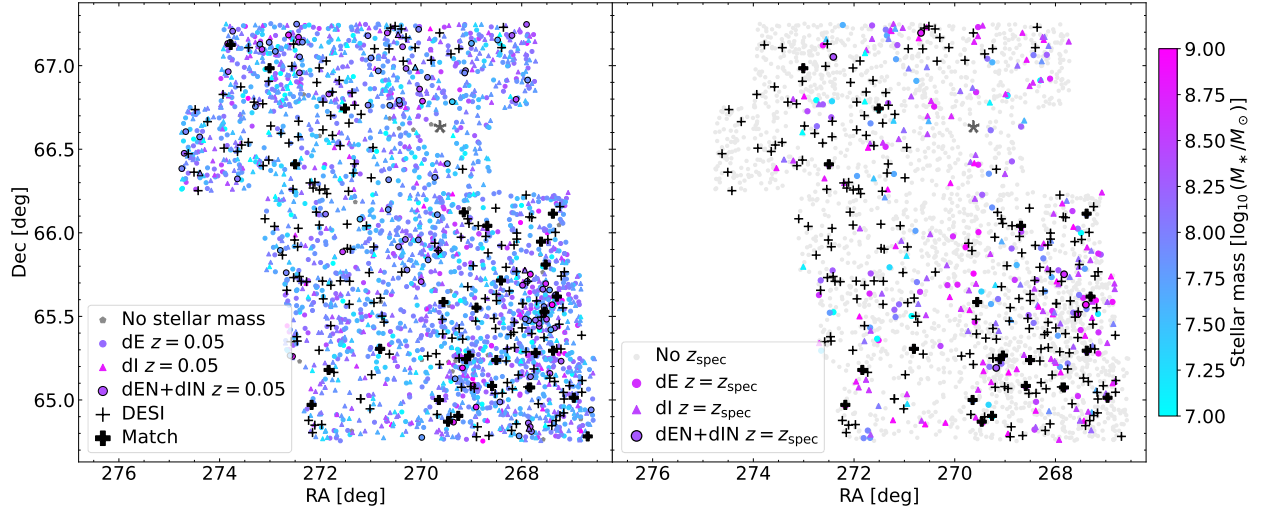


Fig. B.1. *Left:* Comparison between our final dwarf catalogue (filled circle coloured by stellar mass) and the DESI Extragalactic Dwarf Catalogue (black plus). We find a total of 29 matches (filled black plus). These matches have a visual morphological mix of 22 dIs and 7 dEs. *Right:* Comparison between the 303 dwarf candidates with spectroscopic redshifts and $\log_{10}(M_*/M_\odot) \leq 9.0$ (filled circle coloured by stellar mass), and the DESI Extragalactic Dwarf Catalogue (black plus). The 20 matches (filled black plus) have a visual morphological mix of 15 dIs and 5 dEs. In both plots, the dark grey star indicates the location of the Cat’s Eye nebula where a lack of dwarfs is expected.



Fig. B.2. Cutouts of some DESI dwarf candidates that are not in our final dwarf catalogue due to our visual selection criteria (see Sect. 3.2 for more detail), taken from the VIS-NISP colour image created using the I_E band in blue, the Y_E band in green, and the H_E band in red. The colours are projected onto the high-resolution I_E band to best reflect their appearance as detected. *From left to right:* dE with bright extended centres; edge-on galaxy; and galaxy with spiral structure. The sizes of the cutouts are proportional to twice the area determined from the annotation of classifiers; north is up and east is to the left.



Fig. B.3. Cutouts of some DESI dwarf candidates that have likely been misidentified as dwarf galaxies, taken from the VIS-NISP colour image created using the I_E band in blue, the Y_E band in green, and the H_E band in red. The colours are projected onto the high-resolution I_E band to best reflect their appearance as detected. *From left to right:* a DESI dwarf galaxy (red cross) that was excluded during our dwarf selection as it shows a red centre and spiral structures – the nearby companion, with a strikingly similar appearance, is not in the DESI Extragalactic Dwarf Catalogue –, a DESI dwarf galaxy with coordinates (red cross) located in the outer part of this bright galaxy that was excluded during our dwarf selection as it is a bright (massive) galaxy. The sizes of the cutouts are proportional to twice the area determined from the annotation of classifiers; north is up and east is to the left.

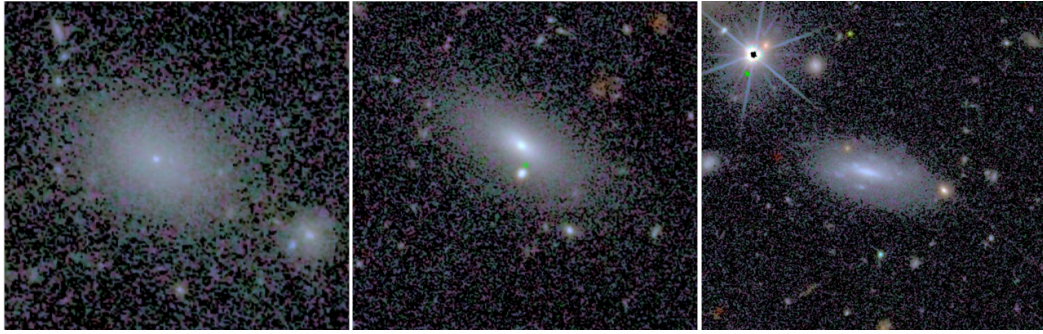


Fig. B.4. Cutouts of some dwarf candidates in our final catalogue that are not in the DESI Extragalactic Dwarf Catalogue, taken from the VIS-NISP colour image created using the I_E band in blue, the Y_E band in green, and the H_E band in red. The colours are projected onto the high-resolution I_E band to best reflect their appearance as detected. *From left to right:* nucleated dE, dE with bright nucleus, dI with star-forming regions near a bright star. The sizes of the cutouts are proportional to twice the area determined from the annotation of classifiers; north is up and east is to the left.

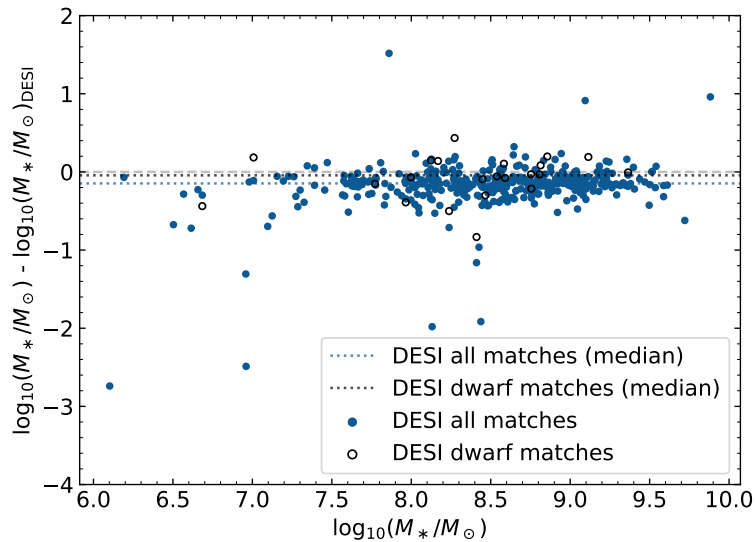


Fig. B.5. Comparison between the stellar mass computed for our dwarf sample and the stellar mass found in the DESI catalogues. The blue filled circles identify the matches with the 388 DESI Stellar Mass and Emission Line Catalogue (‘DESI dwarf’) and the black empty circles show the matches with the 22 DESI Extragalactic Dwarf Catalogue (‘DESI dwarf’). The stellar mass median offset of -0.15 dex and -0.04 dex between our estimates and each of the DESI catalogue values are shown as a blue dotted line (DESI all) and black dotted line (DESI dwarf), respectively.