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PROBING DWARF GALAXIES AND TIDAL DEBRIS IN THE LOCAL UNIVERSE WITH EUCLID EARLY RELEASE OBSERVATIONS

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Abstract. The *Euclid* design will make its Wide Survey a pioneer in terms of low surface brightness (LSB) studies over large areas. We showcase its potential with its Early Release Observations of Local Universe objects. We provide a brief overview of the initial work on these images. The data have made it possible to successfully characterise 1100 dwarf galaxies within 0.7 square degree of the Perseus cluster, and to study their internal substructures, including nuclei and their substructures. We have also studied tidal features in the Dorado group galaxies NGC 1549, NGC 1553 and NGC 1546, and their globular cluster population. These data are shedding a light on the past merging history of these galaxies as well as the limits of LSB object detection with *Euclid*.

Keywords: Galaxies: dwarf, Galaxies: elliptical and lenticular, cD, Galaxies: evolution, Galaxies: groups: individual: Dorado, Galaxies: interactions, Galaxies: clusters: individual: Perseus, Galaxies: structure

1 Introduction

The core science of the *Euclid* mission is to probe the two biggest mysteries of cosmology: the nature of dark matter and dark energy. To meet the requirements of these studies, it was designed to have well-controlled PSF, high resolution, depth, and large coverage in visible and infrared bands (Euclid Collaboration: Scaramella et al. 2022). The *Euclid*'s Early Release Observations (ERO, Cuillandre et al. 2024a) investigative work has highlighted that this unique combination of characteristics also makes it an exceptionally versatile tool for legacy science, and especially for low surface brightness (LSB) science. In particular, provided the extended sources signal is preserved by processing pipelines, the Euclid Wide Survey (EWS) could extend the study of LSB objects to a huge part of the extra-galactic sky (14 000 deg^2, Euclid Collaboration: Mellier et al. (2024)).

The first science images delivered by *Euclid* during the ERO program were partly dedicated to the observation of Local Universe targets. In particular, *Euclid*'s view of the Perseus cluster (four times deeper than the EWS, Cuillandre et al. 2024b) has confirmed its potential for detecting LSB features, from intra-cluster light (Kluge et al. 2024) to dwarf and ultra-diffuse galaxies (Marleau et al. 2024).

2 Detecting dwarf galaxies in ERO Perseus

In Marleau et al. (2024), seven experts performed independent visual dwarf galaxy classification of dwarf galaxies throughout the whole ERO Perseus field of view (FoV). They used the online tool `Jafar` (Sola et al. 2022),

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which allows the marking and classification of tidal features directly on the image (Fig. 1) and their properties can be exported (in particular, the location of the dwarfs and an estimate of their shape and size). Based on the initial catalogues, any object that was flagged by two classifiers was retained for a secondary review by all seven experts. This process allowed the construction of a catalogue of 1100 dwarfs detected, of which 606 were not previously reported in the literature. During this work, we found that:

- The *Euclid* high resolution images and near-infrared data offers a unique advantage for efficiently identifying background galaxies from the cluster member dwarfs, until reaching small radius or faint objects. If this capability is confirmed across the EWS and in non-cluster environment, it suggests that we will obtain statistical sample of dwarfs with very small contamination out to distances of the order of 100 Mpc.
- With its ability to probe globular clusters (GCs) and nuclei inside dwarf galaxies (Euclid Collaboration: Voggel et al. 2024; Saifollahi et al. 2024), *Euclid* can unlock aspects of their formation and evolution. In particular, the nuclear substructures visible in the Perseus dwarfs suggest ongoing interactions at the centre of the galaxies.

Fig. 1. View of the Jafar annotation tool on a cutout of the *Euclid* ERO Perseus colour image (using the I_E, Y_E and H_E bands), annotated with the help of the `Jafar` tool. Dwarf galaxies are encompassed by red filled ellipses, and ghost reflections (a contamination source identifiable by their unnaturally blue colour) in red empty circles.

With the help of the exported characteristics from `Jafar`, we produced cutouts centred on each dwarf galaxy and scaled to its size. Then, an automatic masking procedure was applied. This process is summarised in Fig. 2. Finally, we made use of fitting algorithms (Sérsic fitting with `Galfit`: Peng et al. 2002, ellipse fitting with `AutoProf`: Stone et al. 2021) to obtain the structural parameters of the dwarfs. The results of this study agree with scaling relations in the literature (e.g., Poulain et al. 2021). Moreover, those `Jafar` identification and dwarf analysis procedures have been extended to other ERO fields (Duc et al. in prep).

3 Euclid's view on galaxies of the Dorado group: a combined study of tidal features and GCs

Another ERO dataset is focused on galaxies of the Dorado group (see Fig. 3). It was acquired in the same way as the future EWS. In particular, the ERO Dorado image has the same depth than the EWS, allowing to gauge its potential for detecting LSB features (such as tidal tails, stellar streams and shells). The ongoing work Urbano et al. 2024 (in prep) is addressing the question of the merger history of the three main galaxies of this field of view: NGC 1549, NGC 1553, and NGC 1546.

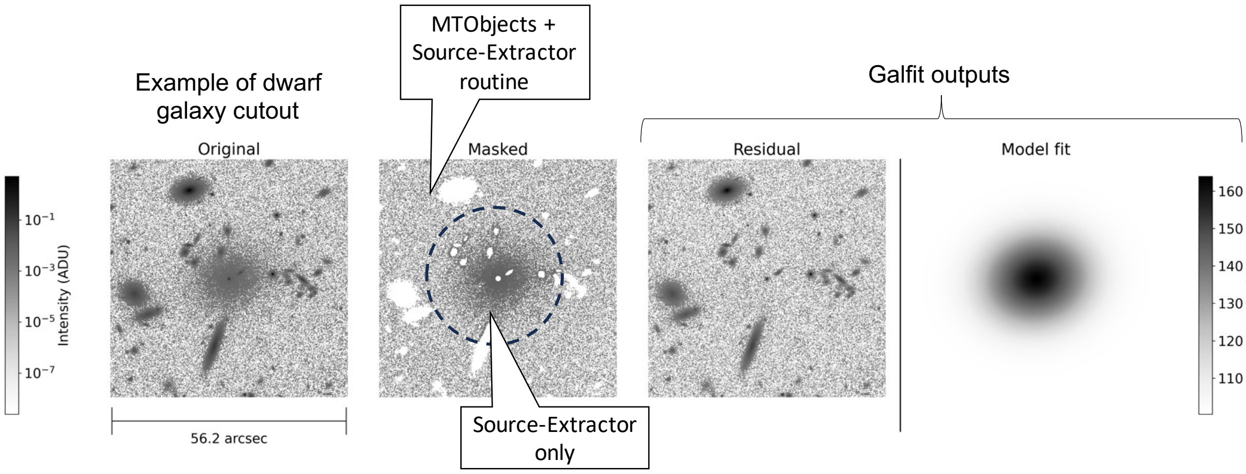

Fig. 2. Summary of the procedure of source masking for the ERO Perseus dwarf galaxy cutouts. We made use of `MTObjects` (Teeninga et al. 2015) and `Source-Extractor` (Bertin & Arnouts 1996) in order to mask every source in each cutout (except the galaxy of interest) before applying a galaxy fitting program (here, `Galfit`). The efficiency of the method can be checked by analysing the residual image.

This ongoing work includes the study of tidal features and internal substructures. To detect them, our strategy is to subtract the light from the galaxy by subtracting either a model (ellipse fitting) or a blurred version of the initial image (unsharp masking). Once this is done, the annotation tool can be used to delineate the features. The ERO Dorado image allowed to detect all the tidal feature which were already known, and to discover new ones, even if the presence of contaminants specific to the ERO data forces us to restrict our detection to tidal features brighter than an average surface brightness of 28 mag arcsec^2. It therefore sets a lower limit for the EWS detection capabilities. A GC study is also being performed on this FoV, with the aim of addressing the question of whether or not clustering is observed at the level of the tidal features.

The masks from the annotation tool can then be used for comparison purpose with color maps and GC distribution, or for performing precise photometry by measuring the total flux of each feature, allowing us to derive their colours and giving us indications about their metallicity (Kluge et al. 2024; Hunt et al. 2024). This combined study of tidal features and GCs, allowed by the depth and resolution of ERO images, is the first of its kind on such a large FoV. With the EWS, it will be extended to other galactic systems.

4 Conclusions & prospects

The unique combination of *Euclid*'s characteristics (depth, visible and infrared photometric bands, coverage, and sharp PSF) makes it a groundbreaking tool for LSB science in the Local Universe. ERO data demonstrate the potential of the future EWS. The ERO dataset has more than doubled the number of known dwarf galaxies in this FoV of the Perseus cluster. *Euclid* images are ideal for probing the populations of dwarf galaxies and their GCs and nuclei, including their substructures.

An effort to characterise the tidal features of the Dorado ERO field is currently underway. These data allow us, on the one hand, to propose a past merger scenario for the galaxies they contain, and on the other hand, to show that the EWS will detect tidal features at least down to an average surface brightness of 28 mag arcsec^2. The next step is to cover a larger area of the sky and allow proper statistics of dwarf galaxy and tidal feature abundances. With the data from the EWS coming over the next six years, we will be able to perform such studies and compare our results to predictions from large hydro-dynamical simulations for galaxy formation. This will allow to constrain the mass assembly history of local Universe galaxies.

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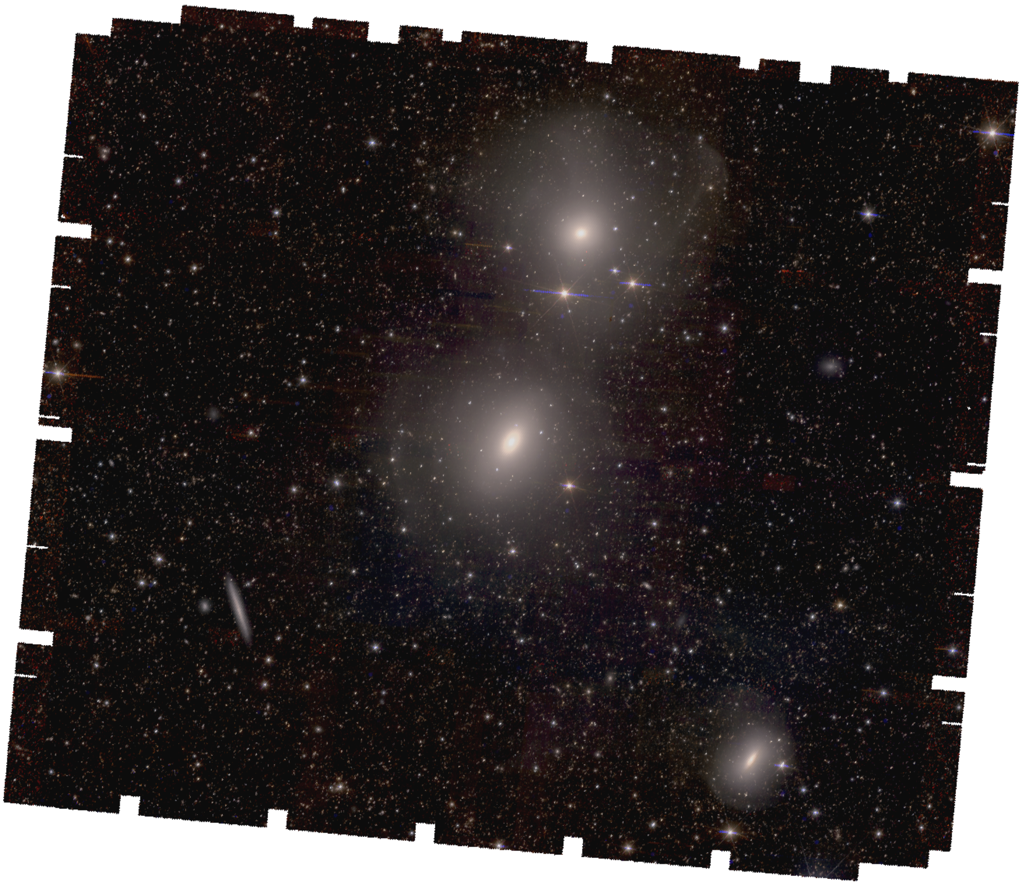

Fig. 3. *Euclid* ERO Dorado colour image made by addition of the $I_{\rm E}$, the $Y_{\rm E}$ and the $H_{\rm E}$ bands.

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