

## ***Euclid*: Early Release Observations – The star cluster systems of the Local Group dwarf galaxies IC 10 and NGC 6822<sup>★</sup>**

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### **ABSTRACT**

Star clusters are valuable indicators of galaxy evolution, offering insights into the buildup of stellar populations across cosmic time. Understanding the intrinsic star cluster populations of dwarf galaxies is particularly important given these systems' role in the hierarchical growth of larger systems. We use data from *Euclid*'s Early Release Observation programme to study star clusters in two star-forming dwarf irregular galaxies in the Local Group, NGC 6822 and IC 10 ( $M_* \sim (1-4) \times 10^8 M_\odot$ ). With *Euclid*, star clusters are resolved into individual stars across the main bodies and haloes of both galaxies. Through visual inspection of the  $I_E$  images, we uncover 30 new star cluster candidates in NGC 6822 and 16 in IC 10, ranging from compact to diffuse extended clusters. We compile and re-evaluate previously identified literature candidates, resulting in final combined catalogues of 52 (NGC 6822) and 71 (IC 10) cluster candidates with confidence-based classifications. We present homogeneous photometry in  $I_E$ ,  $Y_E$ ,  $J_E$ , and  $H_E$ , and in archival *UBVRI* data, alongside size measurements and properties derived from the spectral energy distribution fitting code BAGPIPES. Through synthetic cluster injection, we conclude our sample is  $\sim 50\%$  complete to  $M \lesssim 10^3 M_\odot$  for ages  $\lesssim 100$  Myr, and to  $M \lesssim 2 \times 10^4 M_\odot$  for ages of  $\sim 10$  Gyr. We find that IC 10 has more young clusters than NGC 6822, and its young clusters extend to higher masses, consistent with its starburst nature. We find several old massive ( $\gtrsim 10^5 M_\odot$ ) clusters in both dwarfs, including an exceptional cluster in NGC 6822's outskirts with a mass of  $1.3 \times 10^6 M_\odot$ , nearly twice as massive as any other old cluster in either galaxy. In NGC 6822, we also identify a previously undetected, old, and extended cluster ( $R_h = 12.4 \pm 0.11$  pc). Using well-defined criteria, we identify 11 candidate GCs in NGC 6822 and nine in IC 10. Both galaxies have high specific frequencies ( $S_N$ ) for their luminosities but remain consistent with the known GC scaling relationships in the low-luminosity regime.

**Key words.** galaxies: dwarf – galaxies: individual: NGC 6822 – galaxies: individual: IC 10 – Local Group – galaxies: star clusters: general

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## 1. Introduction

Star clusters are present in nearly all galaxies and can be observed across most of cosmic time (e.g. [Forbes et al. 2018a](#); [Adamo et al. 2024](#)). They are likely the sites of most, if not all, star formation in the Universe, even if they do not always survive for long as coherent or bound groupings of stars. In the Local Volume, star clusters are observed with a remarkable range of properties, from massive and young clusters (e.g. [Portegies Zwart et al. 2010](#)) to ancient, faint, and extended ones (e.g. [Huxor et al. 2005](#); [Crnojević et al. 2016](#)). The origin of this diversity is not fully understood but likely reflects the complex interplay between birth conditions, stellar feedback, and dynamical evolution (e.g. [Krumholz et al. 2019](#); [Lahén et al. 2025](#)). Nearby galaxies offer key advantages for studying star clusters, as their proximity allows resolution into individual stars, facilitating both identification and characterisation (e.g. [Huxor et al. 2014](#); [Johnson et al. 2017](#); [Jang et al. 2012](#)). Furthermore, using resolved stars, star clusters can be observed to lower luminosities and surface densities than is possible in more distant systems, yielding insight into small-scale star-formation events and the bottom end of the cluster mass function.

Comprehensive views of star cluster populations in nearby galaxies are still relatively rare. Historically, many extragalactic star cluster studies have been conducted with the *Hubble* Space Telescope (HST), which captures only a small field of view (FoV) in a single pointing. Studies often choose to focus on the bright inner regions of galaxies where recent star formation is concentrated and hence the number of young clusters is highest (e.g. [Adamo et al. 2017](#)). Even large HST imaging campaigns, such as the PHAT and PHATTER surveys of M31 and M33, capture star clusters only in the main disc ([Johnson et al. 2015, 2022](#)). This biased view may have important consequences for our overall understanding of cluster populations, since old-aged objects, including ancient globular clusters (GCs), are often more widely distributed in and around galaxies than young and intermediate-age ones (e.g. [Rhode & Zepf 2004](#); [Huxor et al. 2014](#); [Veljanoski et al. 2015](#)).

While young to intermediate-age star clusters are of great interest for understanding star-formation processes and calibrating stellar evolution and population models (e.g. [Grasha et al. 2019](#); [Renzini & Fusi Pecci 1988](#); [Dotter et al. 2007](#)), old clusters provide probes of galaxy assembly histories (e.g. [Brodie & Strader 2006](#)). Evidence suggests many GCs are accreted through mergers, and their identification and analysis offer insights into the timeline and nature of hierarchical galaxy growth (e.g. [Côté et al. 1998](#); [Mackey et al. 2010](#)). In the Milky Way (MW), searches for accreted GCs focus on cluster kinematics, chemistry and ages (e.g. [Massari et al. 2019](#); [Monty et al. 2024](#)). In contrast, outside the MW, accreted GCs can often be recognised more directly through their association to tidal streams (e.g. [Foster et al. 2014](#); [Mackey et al. 2019](#)). The GC populations of dwarf galaxies ( $M_{\star} \lesssim 10^9 M_{\odot}$ ) are of particular interest not only for understanding how they might contribute to the build-up of more massive galaxy GC systems via accretion events, but also for understanding whether these small systems have acquired GCs from merger and accretion events themselves ([Deason et al. 2014](#)).

In this paper, we use state-of-the-art data from the *Euclid* satellite ([Euclid Collaboration: Mellier et al. 2025](#)) to conduct an in-depth study of the star cluster populations in two Local Group (LG) dwarf irregular (dIrr) galaxies, NGC 6822 and IC 10. Aside from the Magellanic Clouds, these are the closest gas-rich dwarf galaxies to us and, with stellar masses of  $\sim(1-4) \times 10^8 M_{\odot}$

**Table 1.** Galaxy properties.

Galaxy	$D^a$ kpc	$E(B - V)^b$ ...	$M_{\check{V}}^c$ ...	$b^d$ deg	$R_h^e$ arcmin	$SFR^f$ $M_{\odot} \text{ yr}^{-1}$
IC 10	$720^{+90}_{-70}$	$\sim 0.7-1.15$	-15.1	-3.3	2.7	0.3
NGC 6822	$510 \pm 12$	0.24–0.45	-15.2	-18.4	12.0	0.02

**Notes.** <sup>a</sup> Distances from [Gerbrandt et al. \(2015\)](#) and [Fusco et al. \(2012\)](#). <sup>b</sup> Total line-of-sight reddening measurements, as detailed in text. <sup>c</sup> Absolute magnitudes taken from [McConnachie \(2012\)](#) and [Sanna et al. \(2010\)](#). <sup>d</sup> Galactic latitudes from NASA/IPAC Extragalactic Database (NED). <sup>e</sup> Half-light radii ([McConnachie 2012](#); [Higgs et al. 2021](#)). <sup>f</sup> SFRs determined from SED fitting through CIGALE, and adjusted to our adopted distances ([Nersesian et al. 2019](#); [Hunt et al. 2025](#)).

([Pace 2024](#)), they serve as valuable analogues to the star cluster-forming low-mass galaxies that are now being identified at high redshift (e.g. [Mowla et al. 2024](#)). *Euclid*'s spectacular capabilities allow us to conduct a comprehensive and systematic survey of star clusters in these systems that is unprecedented in its combination of depth, areal coverage, and spatial resolution. In particular, the pixel scale of *Euclid* corresponds to sub-parsec scales at the distances of these galaxies, while the FoV captures  $>6$  kpc on a side. Additionally, *Euclid* extends star cluster studies in these systems to near-infrared (NIR) wavelengths. We summarise the properties of the two galaxies in Table 1 and briefly review their properties below.

## 2. Overview of the two galaxies

### 2.1. NGC 6822

First identified by [Barnard \(1884\)](#), NGC 6822 is the third nearest dIrr galaxy after the Large and Small Magellanic Clouds and has a distance of 510 kpc determined from the tip of the red giant branch (RGB, [Fusco et al. 2012](#)). It has many luminous H II regions (e.g. [Hodge et al. 1988](#); [Efremova et al. 2011](#)) and studies suggest it has experienced an increase in its global star-formation rate (SFR) over the last few hundred Myr ([Hodge 1980](#); [Gallart et al. 1996](#); [Fusco et al. 2014](#); [Khatamsaz et al. 2024](#)). NGC 6822's young stellar component is predominantly concentrated within a central bar structure, aligned along the north-south direction ([Hodge 1977](#)). In contrast, the older and intermediate-age populations exhibit elliptical distributions and extend to larger radii (e.g. [Letarte et al. 2002](#); [Battinelli et al. 2006](#); [Tantalo et al. 2022](#)). In addition, NGC 6822 contains a significant quantity of H I gas which lies in a disc that is misaligned to both the inner bar structure and the extended spheroid ([de Blok & Walter 2000](#); [Weldrake et al. 2003](#)). Notably, this H I disc rotates perpendicular to the older stellar component and hence constitutes a dynamically decoupled structure ([Demers et al. 2006](#)). In spite of the complex stellar structure of NGC 6822, there is no compelling evidence for a recent merger or interaction ([Zhang et al. 2021](#)). In fact, most studies suggest that the galaxy is not even bound to the MW at the present epoch, although it may have entered within its virial radius in the past (e.g. [Battaglia et al. 2022](#); [Bennet et al. 2024](#)).

Previous estimates of reddening towards and internal to NGC 6822 have been fairly consistent. [Massey et al. \(1995\)](#) determined a colour excess of  $E(B - V) = 0.26$  near the edges of the galaxy through spectroscopic samples of hot, luminous stars. Similarly, [Gallart et al. \(1996\)](#) found  $E(B - V) = 0.24 \pm 0.03$ , using a multiwavelength fit to the  $B$ ,  $V$ ,  $R$ , and  $I$  magnitudes of

Cepheids, and through observations obtained with HST, Fusco et al. (2012) estimated a value of  $0.30 \pm 0.032$ . These values are consistent with the dust maps of Schlegel et al. (1998), which return foreground values between  $E(B - V) = 0.18$  and  $0.26$ . Some studies suggest the reddening varies between the galaxy's centre and edges. Massey et al. (1995) estimated central reddening at  $E(B - V) = 0.45$ , while others reported slightly lower values of  $0.35$ – $0.37$  (Rich et al. 2014; Fusco et al. 2012; Gieren et al. 2006). However, Massey et al. (2007) noted that the Massey et al. (1995) sample likely had above-average reddening, potentially inflating the estimate.

The metallicity of NGC 6822's young population is roughly similar to that of the Small Magellanic Cloud (hereafter SMC;  $Z \approx 0.2$ – $0.3 Z_{\odot}$ ). Venn et al. (2001) found a mean iron abundance of  $[\text{Fe}/\text{H}] = -0.49 \pm 0.22$  using two A-type supergiant spectra. Similarly, Lee et al. (2006) obtained an oxygen abundance of  $[\text{O}/\text{H}] = -0.55$  from H II region spectra. More recently, Patrick et al. (2015) found a mean metallicity of  $[\text{Fe}/\text{H}] = -0.52 \pm 0.21$  by using NIR spectra of 11 red supergiants. The metallicity of NGC 6822's older population was found to be  $[\text{Fe}/\text{H}] = -1.29 \pm 0.07$  using asymptotic giant branch stars (Sibbons et al. 2012; Hirschauer et al. 2020) and  $[\text{Fe}/\text{H}] = -1.05 \pm 0.49$  from the spectra of RGB stars (Kirby et al. 2013). In contrast, Swan et al. (2016) reported a higher mean metallicity of  $[\text{Fe}/\text{H}] = -0.84 \pm 0.04$  from Ca II spectroscopy of RGB stars, with dispersion  $\sigma = 0.31$  dex.

NGC 6822's star cluster system has been well-studied, dating back to a century ago, although studies have been carried out in a somewhat piecemeal fashion. Using photographic plates, Hubble (1925) identified five potential clusters, and Hodge (1977) later confirmed four (Hubble-IV, VI, VII, and VIII) of these as genuine clusters, and identified 26 additional potential clusters in the main body. Follow-up studies of the Hubble (1925) clusters using HST and ground-based spectroscopy (Wyder et al. 2000; Chandar et al. 2000; Larsen et al. 2022; Hwang et al. 2014) confirmed Hubble-VII as a GC, Hubble-VI and VIII as likely young or intermediate-age clusters, and Hubble-IV to be associated with an H II region. Krienke & Hodge (2004) further identified nine new cluster candidates in the central regions using HST imaging. In the remote halo, Hwang et al. (2011) identified four GCs using Canada–France–Hawaii telescope (CFHT) MegaCam data ( $3^{\circ} \times 3^{\circ}$ ), and Huxor et al. (2013) later discovered three more GCs from an independent analysis of the same data, plus additional coverage. Veljanoski et al. (2015) presented a homogeneous photometric and spectroscopic analysis of NGC 6288's GC system and used it to infer a dynamical mass of  $(3\text{--}4) \times 10^9 M_{\odot}$  within 11 kpc, implying the system is very dark-matter dominated. Particularly striking is the linear alignment of the outermost GCs in NGC 6822, which extends over  $\sim 17$  kpc at the distance of the galaxy.

## 2.2. IC 10

Housing a substantial population of Wolf–Rayet stars, IC 10 is presently undergoing a strong burst of star formation and is arguably the closest example of a starburst galaxy (Richer et al. 2001). IC 10's low Galactic latitude and formidable foreground extinction have hindered detailed study in the past and it has received comparatively less attention than other dwarf galaxies in the LG. Similar to NGC 6822, IC 10's youngest populations are the most centrally concentrated and the older stars are distributed much more broadly (Demers et al. 2004; Sanna et al. 2010; Gerbrandt et al. 2015). It has been suggested that the geometric centre of IC 10's younger populations is offset by a

few hundred parsecs from its oldest population (Gerbrandt et al. 2015). Nidever et al. (2013) argue that a recent interaction might have occurred based on the existence of an extended H I feature, but there are no clear signs of stellar tidal features or distortions in the outer regions of the galaxy (Demers et al. 2004; Sanna et al. 2010). IC 10 is a remote satellite of M31 that likely underwent a moderately close pericentric passage ( $\sim 130$  kpc) roughly 1–2 Gyr ago (Bennet et al. 2024).

There is considerable uncertainty in the total reddening towards IC 10. Massey et al. (2007) measured the total reddening value to be  $E(B - V) = 0.81$  using the location of the plume of blue supergiants from *UBVRI* wide-field imaging ( $37' \times 37'$ ). This aligns with the values of  $0.78 \pm 0.06$  and  $0.77 \pm 0.07$  reported by Sanna et al. (2008) and Richer et al. (2001), based on deep HST imaging of field stars and optical spectroscopy, respectively. It also agrees well with the average reddening value of  $0.79$  from Demers et al. (2004), measured using Carbon stars over a  $42' \times 28'$  field. However, their values vary across the field by as much as  $0.30$  magnitudes. A few higher values have also been reported, such as Kim et al. (2009), who found the total reddening to be  $E(B - V) = 0.98 \pm 0.06$  through deep *JHK* photometry of the central  $4' \times 7'$  field and more recently, using NIR and mid-IR data, Dell'Agli et al. (2018) found a value of  $E(B - V) = 1.14$ , also restricted to a FoV that excludes the halo. The low Galactic latitude of IC 10 places it in the regime in which the foreground reddening maps of Schlegel et al. (1998) are known to be inaccurate. With the Schlafly & Finkbeiner (2011) recalibration, the dust maps return foreground values between  $0.77$  and  $1.58$ , considerably larger than some of the total line-of-sight estimates in the literature.

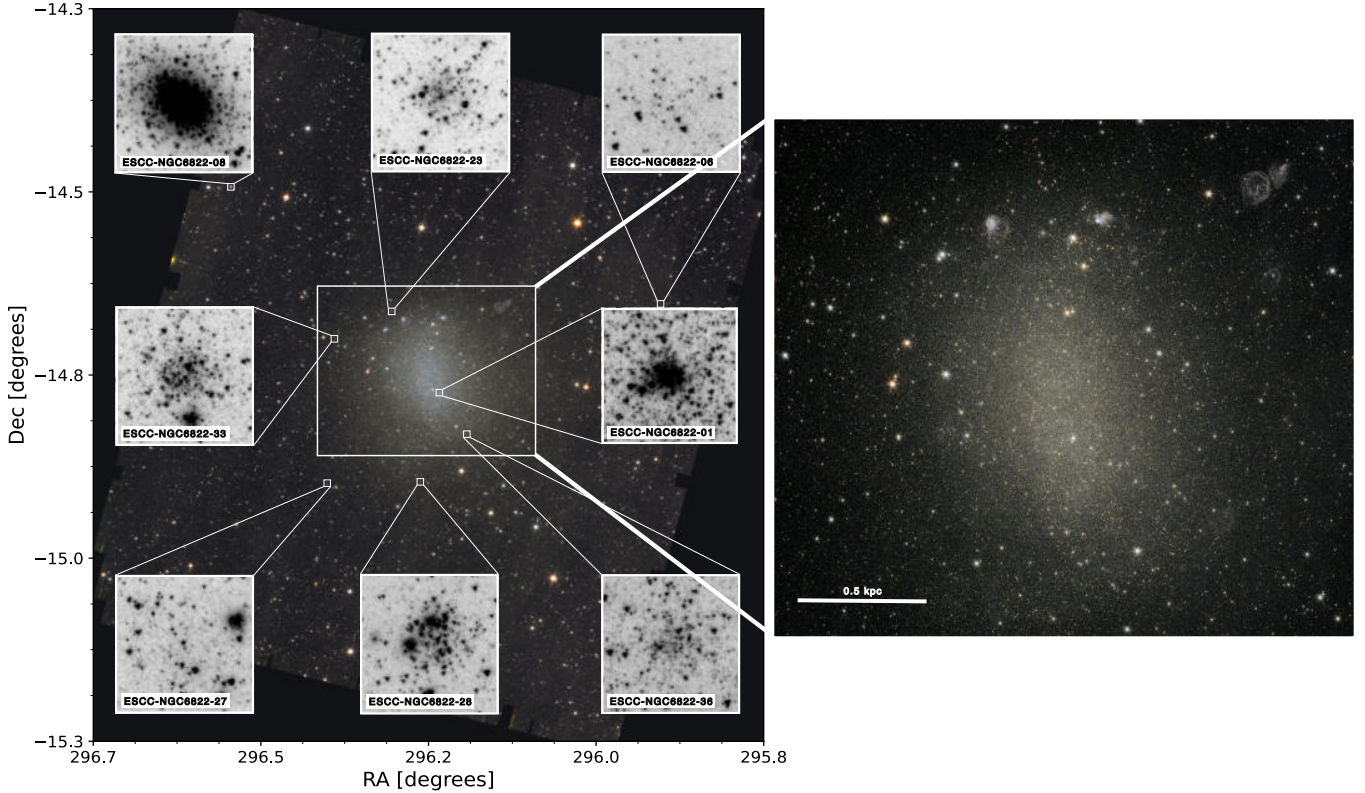
Similar to NGC 6822, IC 10's metallicity has been estimated to be  $Z \approx 0.2$ – $0.3 Z_{\odot}$ , based on its H II regions (Skillman et al. 1989; Garnett 1990; Lee et al. 2003). IC 10's older population has received less attention but using RGB stars, Tikhonov & Galazutdinova (2009) measured a photometric metallicity of  $[\text{Fe}/\text{H}] = -1.28$ .

Karachentsev & Tikhonov (1993) first identified seven star cluster candidates in IC 10 from ground-based *B*- and *V*-band images. Hunter (2001) later found additional candidates using HST imaging, focused on the central and eastern parts of the galaxy. Tikhonov & Galazutdinova (2009) conducted a more extensive search across the central body and parts of the halo using a combination of HST data and ground-based observations from the 6m BTA and 1m Zeiss telescopes, compiling a list of 57 candidates, subsuming those from Karachentsev & Tikhonov (1993) and some from Hunter (2001). Sharina et al. (2010) identified 17 new objects in archival HST data, while Lim & Lee (2015), hereafter L15, found five additional cluster candidates in the remote halo using Subaru *R*-band imaging with  $0''.7$  seeing. As with NGC 6822, the previous cluster work has involved an amalgamation of patchy high-resolution HST coverage, wide-field low-resolution coverage, and varying search sensitivities across the galaxy.

## 3. Data

We combined the Euclid Early Release Observations (ERO, Cuillandre et al. 2025)<sup>1</sup> with the NOAO Local Group Galaxy Survey (LGGs, Massey et al. 2007) to provide broad wavelength coverage from *U* to  $H_{\text{E}}$ , which we used for both star cluster identification and detailed characterisation of their properties.

<sup>1</sup> Euclid Early Release Observations (2024).



**Fig. 1.** Examples of old and young clusters across NGC 6822, both previously found and new from this study, showcased alongside an RGB image of the *Euclid* data displaying its full FoV.  $I_E$ ,  $Y_E$ , and  $H_E$  are the blue, green, and red channels, respectively. Each cutout is  $\sim 44$  pc on the side in the  $I_E$  band, displayed in log scale. The zoom-in region is roughly  $16'.5 \times 13'.5$  ( $2.5$  kpc  $\times$   $2$  kpc). The top row includes the GCs SC7 (ESCC-NGC6822-08) and SC5 (ESCC-NGC6822-06), the middle row shows the cluster Hubble-VI (ESCC-NGC6822-01), and the bottom row features a newly identified extended cluster candidate, ESCC-NGC6822-27.

### 3.1. *Euclid* Early Release Observations

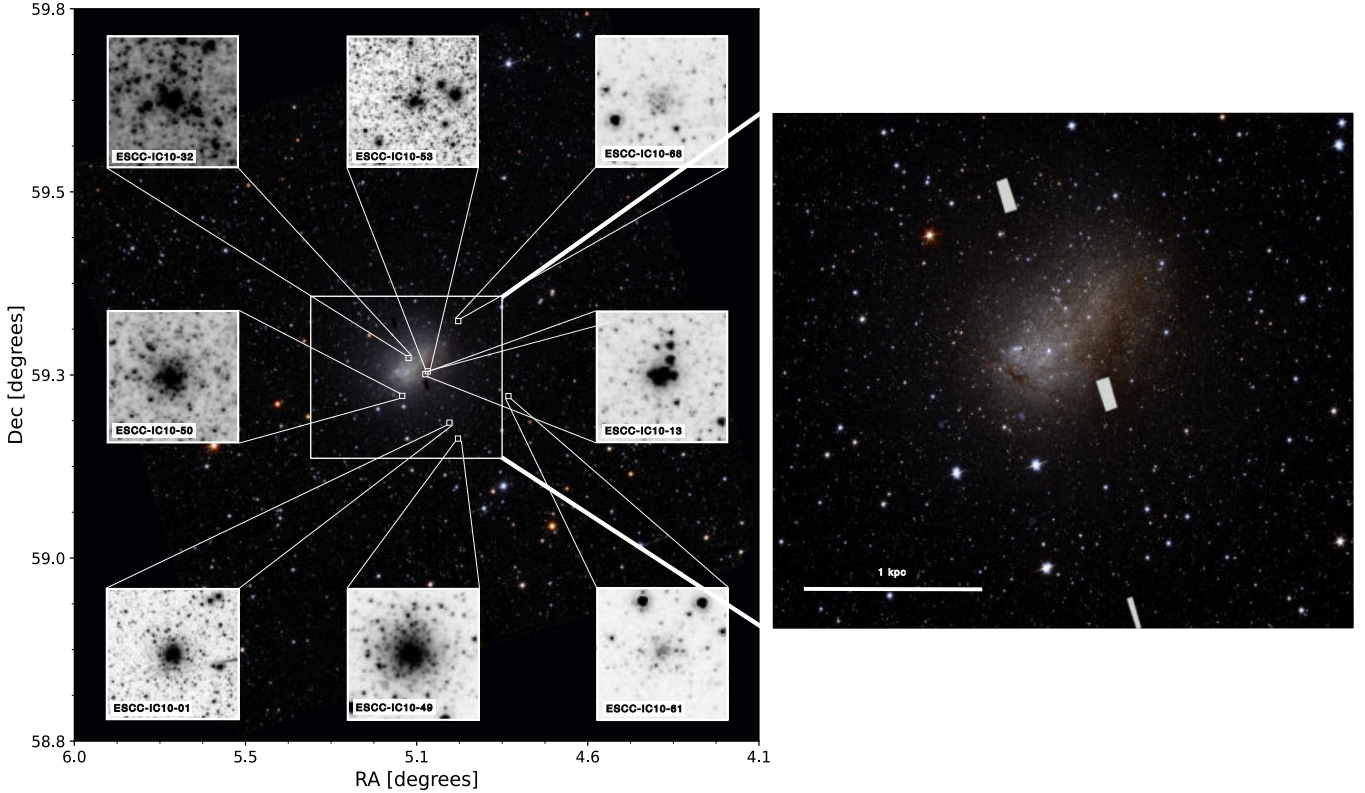
As described in [Hunt et al. \(2025\)](#), *Euclid* observed NGC 6822 and IC 10 with one and two Reference Observation Sequences respectively (ROS, see [Euclid Collaboration: Scaramella et al. 2022](#)) using the Visible and Near Infrared Spectrometer (VIS and NISP) instruments ([Euclid Collaboration: Cropper et al. 2025](#); [Euclid Collaboration: Jahnke et al. 2025](#)). One ROS consists of four dithered images per band (4 repetitions of 566 s for  $I_E$  and 87.2 s for  $Y_E$ ,  $J_E$ , and  $H_E$ ). The *Euclid* images cover a  $\sim 0.67$  deg<sup>2</sup> area centred on each galaxy, with the  $I_E$  band providing a  $0'.1$  pixel scale, while the  $Y_E$ ,  $J_E$ , and  $H_E$  bands each have a  $0'.3$  pixel scale. Additionally, the point-spread function (PSF) full width at half maximum (FWHM) in the stacked images is  $\sim 1.6$  pixels in each band ([Cuillandre et al. 2025](#)).

All the images have been processed using a bespoke ERO reduction pipeline, as detailed in [Cuillandre et al. \(2025\)](#). In brief, this involved the removal of instrumental signatures, astrometric calibration, image stacking, photometric calibration onto the AB magnitude system, and the production of science-ready catalogues. Two versions of the image stacks are available: a stack that is optimised for studying diffuse extended emission, in which the background is preserved, and a stack that is optimised for detection and analysis of compact sources, in which the background has been modelled and subtracted. After some experimentation, we opted to use the extended-emission images for cluster identification and the compact-sources images for photometry and size measurements. Figures 1 and 2 show full and zoom-in RGB images of NGC 6822 and IC 10, respectively,

together with cutouts of some known and new clusters (see Sect. 4).

### 3.2. Local Group Galaxy Survey

The LGGS imaged NGC 6822 and IC 10 using the CTIO Blanco and Kitt Peak Mayall 4m telescopes, respectively, in each of the  $UBVRI$  and  $H\alpha$  filters ([Massey et al. 2007](#)). The two cameras are nearly identical, consisting of a  $2 \times 4$  array of  $2048 \times 4096$  SITE CCDs, yielding images that cover  $37' \times 37'$  per pointing with a pixel scale of  $0'.27$ . The seeing was measured to be  $\approx 0'.9$  in each case. A single pointing was obtained for each galaxy, with NGC 6822 centred in the FoV but IC 10 offset somewhat to avoid a ghost image from the prime focus corrector. As a result, while the *Euclid* and LGGS images cover much of the same area in NGC 6822, the *Euclid* IC 10 images extend slightly more toward the north-east and LGGS images extend more to the south-west. Nonetheless, the combined fields of view cover all previously identified clusters in IC 10 and all except for four in NGC 6822, three of which lie outside both the LGGS and *Euclid* footprints, and one outside only the LGGS footprint (see Sect. 4.2). From Table 14 of [Massey et al. \(2007\)](#), the median magnitude uncertainties in the LGGS survey reach  $\sigma_V \approx 0.20$ , corresponding to a  $5\sigma$  point-source detection, at  $V \approx 25.0$  in IC 10 and  $V \approx 24.5$  in NGC 6822. In comparison, [Cuillandre et al. \(2025\)](#) report a  $5\sigma$  point-source detection limit in  $I_E$  of  $\sim 27.0$ . While *Euclid* reaches fainter sources, the LGGS photometry is sufficiently deep and precise for the clusters in our sample, enabling a reliable combination of the two datasets.



**Fig. 2.** Same as Fig. 1 for IC 10. Each cutout is 63 pc on the side in the  $I_E$  band, displayed in asinh scale. The zoom-in region is roughly  $15'.5 \times 12'.9$  ( $3.25 \text{ kpc} \times 2.7 \text{ kpc}$ ). The sample includes some clusters identified in the halo by Lim & Lee (2015), specifically ESCC-IC10-49 and ESCC-IC10-50.

To ensure that the LGGS images had a consistent astrometric solution to those from *Euclid*, we ran them through *Astrometry.net* (Lang et al. 2010). With the improved astrometric calibration, the positions of bright stars showed a median offset of  $0''.006$  in RA and  $0''.05$  in Dec between the  $Y_E$  and  $V$  images for IC 10, and  $0''.006$  in RA and  $0''.08$  in Dec for NGC 6822.

## 4. Cluster identification

### 4.1. Blind cluster search

At the distances of IC 10 and NGC 6822, luminous young and evolved stars are resolved in *Euclid* images (Hunt et al. 2025, Annibali et al., in prep). Compact star clusters appear as central diffuse light concentrations with resolved stellar outskirts, while faint and/or extended star clusters are fully resolved, albeit with irregular shapes. While either type can be readily detected in the sparse outer regions of galaxies, they can be very hard to distinguish against the field populations in the more crowded regions. Figures 1 and 2 show examples of the diverse morphologies and brightnesses of the star cluster candidates as seen by *Euclid*. Their complex appearance, ranging from partially to fully resolved, and projecting on top of widely varying stellar fields, has previously been recognised as a significant challenge for automated or semi-automated methods of star cluster detection in LG galaxies (e.g. Huxor et al. 2008, 2014; Johnson et al. 2015). As advocated by previous work, we decided that visually inspecting the full survey area was the most efficient and least biased star cluster detection method.

The initial search was conducted by one of us (JH) on the  $I_E$  images as these offer the highest spatial resolution compared to

the NIR filters, and a greater sensitivity to various cluster ages due to the broad filter bandwidth. The extended-emission images were preferred as they help to highlight instances where there is significant coincident nebular emission. We excluded cases where an object is so heavily embedded in nebular emission that it becomes difficult to discern whether it is a distinct star cluster or a sparser OB association. We also note that very red clusters (heavily dust reddened or embedded) may be more clearly distinguished in the NIR and therefore underrepresented by our search. The search was conducted blindly, without prior knowledge of existing cluster locations, though we inspected cutouts of a few already confirmed clusters before starting, to familiarise ourselves with the likely range of morphologies. This was helpful for learning how to identify faint clusters and for calibrating our expectations for the appearance of star clusters at these distances, and with *Euclid* resolution. Once the cluster candidates were identified in  $I_E$ , they were inspected across the other eight bands:  $U$ ,  $B$ ,  $V$ ,  $R$ , and  $I$ , as well as  $Y_E$ ,  $J_E$ ,  $H_E$ . This aided in distinguishing between clusters and background galaxies, as the galaxies tend to drop out in the shorter-wavelength passbands. Objects exhibiting this behaviour, or showing other indications of a not being a star cluster, were immediately discarded. Remaining candidates were labelled as either ‘likely’ or ‘maybe’ and were passed for further classification by two additional team members (AF and SL). By the end of this process, each object initially classed as maybe or likely also had two further (independent) classification attempts into the categories of likely, maybe, and ‘unlikely’. The final classification of a given star cluster candidate was arrived at as follows:

- Three likely classifications == 1;
- Two likely and one maybe == 2;
- One likely and two maybe == 3;

**Table 2.** NGC 6822 cluster candidate list.

Euclid ID	RA (deg)	Dec (deg)	Class	Recovered?	Previous ID	Ref
ESCC-NGC6822-01	296.223235	-14.819755	1	Yes	Hubble-VI	H25
ESCC-NGC6822-02	296.231932	-14.815552	1	Yes	Hubble-VII	H25
ESCC-NGC6822-03	296.242518	-14.720538	1	Yes	Hubble-VIII	H25

**Notes.** Full list of NGC 6822 clusters identified in our blind search (classifications 1–5), alongside previously reported candidates (classifications 1–6), both those we recover and those we do not. Previous IDs take the form: Hubble-*n* (Hubble 1925, H25), SCn (Hwang et al. 2011; Huxor et al. 2013), Cn (Hodge 1977) and KHn (Krienke & Hodge 2004). Previously reported candidates are listed first, and new clusters are labelled from ESCC-NGC6822-21 onwards. We provide only the first three rows here; the complete table is provided in electronic form at the CDS.

**Table 3.** IC 10 cluster candidate list.

Euclid ID	RA (deg)	Dec (deg)	Class	Recovered?	Previous ID	Ref
ESCC-IC10-01	4.974880	59.224041	1	Yes	TG1	TG09
ESCC-IC10-02	4.990859	59.331172	3	Yes	TG2	TG09
...	4.997314	59.326613	4	No	TG3	TG09

**Notes.** Same as Table 2 but for IC 10. Previous IDs take the form TG-*n* (Tikhonov & Galazutdinova 2009; Karachentsev & Tikhonov 1993), Ln (Lim & Lee 2015), dn or Sn (Sharina et al. 2010) and Hn-*n* (Hunter 2001). Previously reported candidates are listed first and new clusters are from ESCC-IC10-58 onwards. Literature candidates that were not recovered in our blind search do not have a *Euclid* ID; only their previously assigned IDs are listed. The full table is available at the CDS.

- Three maybe == 4;
- Any combination with unlikely == 5.

Tables 2 and 3 contain the results of our blind star cluster search, detailing the positions and classifications of all cluster candidates with final classifications 1–5, and indicating whether or not the candidate was previously known (see Sect. 4.2). Candidates are labelled Euclid Star Cluster Candidate (ESCC) – galaxy – *n*.

#### 4.2. Literature sample compilation

As mentioned before, previous studies have searched for star clusters in NGC 6822 and IC 10 and we sought to identify which of the candidates uncovered in our *Euclid* blind search were already known. To this end, we undertook a thorough literature source compilation. The process was mostly straightforward for IC 10, due to the list of 66 cluster candidates already compiled from various sources (Karachentsev & Tikhonov 1993; Hunter 2001; Sharina et al. 2010) by L15. However, we discovered that 21 previously identified cluster candidates were missing from the list by L15 (four from Hunter 2001 and 17 from Sharina et al. 2010), which we included in our compilation.

In the case of NGC 6822, we did not have the benefit of a recent compilation and hence had to tabulate directly the cluster candidates presented in multiple works spanning several decades (Hubble 1925; Hodge 1977; Krienke & Hodge 2004; Hwang et al. 2011; Huxor et al. 2013)<sup>2</sup>. In older studies, cluster candidates generally lacked published coordinates (Hodge 1977) or

had coordinates that did not always correspond to a visible overdensity in the *Euclid* images (Krienke & Hodge 2004). In such cases, positions were determined on a best-effort basis, either by updating the coordinates to match the nearest cluster candidate to the provided coordinates or, for Hodge (1977), the closest cluster candidate to the position highlighted in their finding chart.

In total, we compiled a list of 87 previously identified cluster candidates within IC 10 and 43 within NGC 6822 (noting an additional three NGC 6822 clusters outside of the *Euclid* footprint). Cross-matching the list of candidates from our blind search with those from the literature, we found that we recovered many but not all of the sources identified in earlier studies, as well as adding many new sources not previously known. For completeness, all three inspectors examined the positions of the literature candidates and classified them using the same system described above. Reassuringly, all the literature candidates within the IC 10 and NGC 6822 footprints that we classified as classes 1 and 2 already appeared in our blind search list. On the other hand, several literature candidates were missed. In some cases, the reported positions did not correspond to any obvious stellar overdensity in the *Euclid*  $I_e$  images. In other cases, the reported positions clearly corresponded to single stars, nebulae, or background galaxies; such objects were assigned to class 6, indicating sources that are definitely not star clusters. In NGC 6822, our blind search missed 23 out of 43 literature candidates. Of these, one was classified as class 3 and one as class 4, while 14 were assigned to class 5 and four to class 6. As a result, the majority were deemed unconvincing as cluster candidates. In IC 10, we missed 30 out of 87 previous candidates. Of these, one was classified as class 3, six as class 4, 18 as class 5, and five as class 6. Notably, of the five candidate clusters in the remote halo of IC 10 found by L15 using Subaru *R*-band imaging, three were recovered in our blind search and are confirmed as genuine clusters (ESCC-IC10-49, 51 and 52; 49 and

associations. We therefore exclude the Gouliermis et al. (2010) candidates from our final lists and do not aim for completeness in very low-mass young clusters.

<sup>2</sup> We note that Gouliermis et al. (2010) studied hierarchical clustering of blue stars in NGC 6822 using ground-based imaging. Using a nearest-neighbour density method, they defined clusters as overdensities of point sources that are  $3\sigma$  above the average stellar density. However, apart from C24 from Hodge (1977), these clusters are not visually apparent in the *Euclid* image. Their clusters span a large range of sizes (10–120 pc), with most of them having half-light radii  $>30$  pc, which is considerably larger than the objects we identify as star cluster candidates in this paper. Indeed, combined with their stellar masses of  $10^3$ – $10^4 M_\odot$ , these objects are more akin to low-mass unbound stellar

51 are displayed in Fig. 2), while the remaining two (L64 and L65) are clearly background galaxies and have been assigned to class 6. While it is unlikely that many class 5 sources are genuine clusters, we note that objects previously identified as faint clusters at UV wavelengths may appear less convincing in the  $I_E$  filter due to its longer wavelength. Similarly, it is possible that some faint sources previously identified at HST resolution may be less obvious at the slightly lower resolution of *Euclid*. However, since class 5 sources do not appear cluster-like in the *Euclid* data, we do not analyse them further in this work. For completeness and to facilitate future studies of these cluster systems, we include all literature candidates, whether recovered or not, and regardless of our classification, in Tables 2 and 3, retaining their original identifiers (based on the earliest published ID). These objects can be identified as having an entry in the column ‘Recovered?’. Thumbnails of the previously-identified candidates that we reclassify as class 5 and 6 are included in the Appendix (Figs. C.1 and C.2), alongside all other previously identified and newly discovered clusters.

The outcome of our combined *Euclid* blind and literature searches can be summarised as follows:

- Class 1: 30 in NGC 6822 (15 previously reported), 29 in IC 10 (23 previously reported).
- Class 2: 10 in NGC 6822 (five previously reported), 24 in IC 10 (23 previously reported).
- Class 3: seven in NGC 6822 (one previously reported), seven in IC 10 (three previously reported).
- Class 4: five in NGC 6822 (one previously reported), 11 in IC 10 (six previously reported)
- Class 5: 22 in NGC 6822 (17 previously reported), 37 in IC 10 (27 previously reported).
- Class 6: four in NGC 6822 (all previously reported), five in IC 10 (all previously reported).

In summary, our blind search identified 30 new star cluster candidates of classes 1–4 in NGC 6822 and 16 in IC 10. Incorporating the 22 and 55 previously reported literature candidates with classifications 1–4 (of which 20 and 48 were independently recovered in our blind search), the total number of candidates in these classes increases to 52 in NGC 6822 and 71 in IC 10. For clarity, we refer to our final list of class 1–4 cluster candidates simply as ‘clusters’ throughout the remainder of the paper.

## 5. Analysis

### 5.1. Cluster photometry

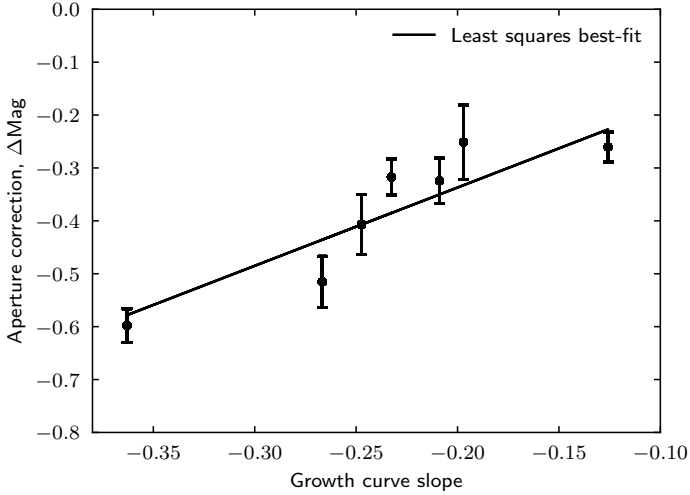
Some preliminary steps were taken before performing photometry. Firstly, we needed to determine the photometric zeropoints for the LGGS images. These were derived through the 1000 brightest and unsaturated stars (with photometric errors less than 0.05 in all bands) from Massey et al. (2007), who provided measurements on the Vega system. The aperture size for measuring total instrumental magnitudes was determined using the average flattening point of the growth curves of the 20 brightest stars (approximately 5.5 pixels for IC 10, and 7 pixels for NGC 6822). The zeropoints were then calculated by taking the median of the sigma-clipped differences between the Massey et al. (2007) published magnitudes and our derived instrumental aperture values. The standard deviations of the zero points (ranging from 0.01 to 0.06 magnitudes) were combined with our photometric uncertainties. It should be noted that while the LGGS photometry is on the Vega system, the *Euclid* photometry is on the AB system (Cuillandre et al. 2025).

The next stage was to mask bright stars and contaminating objects in the vicinity of the clusters. As the clusters themselves are largely resolved into individual stars, and given that they lie within highly resolved regions of galaxies, deciding how much to mask was not straightforward. In the end, we took a conservative approach and decided to mask only the most obvious contaminants. Cluster centres were determined on the *Euclid*  $I_E$  images, as these are the deepest and have the highest spatial resolution. For centrally concentrated objects, the centres were derived using a centre-of-mass algorithm within a  $2''$  box, starting from a best-guess point based on visual inspection. For more diffuse objects, or for those which were impacted by masking, we determined the centres manually. Since the astrometric calibration was consistent across all *Euclid* and LGGS images, the  $I_E$  centres could be adopted universally.

We determined the magnitudes of the clusters via aperture photometry across the nine photometric bands:  $U$ ,  $B$ ,  $V$ ,  $R$ ,  $I$ ,  $Y_E$ ,  $J_E$ ,  $H_E$ , and  $I_E$ . The measurements were made using PhotUtils, an Astropy package for the detection and photometry of astronomical sources (Bradley et al. 2023). We largely followed the methodology outlined in L15, who also conducted photometry for a sample of IC 10 clusters using the LGGS images. Specifically, we adopted their aperture radii of 6 pixels (corresponding to  $\sim 1''.6$ , or 5.6 parsecs at the distance of IC 10) to derive the instrumental aperture magnitudes in the *UBVRI* images. This radius was found to be a good compromise between capturing sufficient flux and minimising the influence of contaminating objects. For background subtraction, we used annuli spanning the radial range 20–30 pixels (corresponding to  $\sim 5''.4$ – $8''.1$  or 18.8–28.3 parsec) with three  $\sigma$  sigma-clipping. In NGC 6822, we adopted the same physical-sized apertures, with the 5.6 pc aperture corresponding to  $\sim 2''.3$  (8 pixels), and background annuli spanning 28–42 pixels. Apertures and background annuli corresponding to the same physical size were used for extracting photometry from the *Euclid*  $I_E$   $Y_E$   $J_E$   $H_E$  images. Colours were derived by subtracting the small-aperture magnitudes from each other ( $1''.6$  and  $2''.3$  apertures in IC 10 and NGC 6822, respectively).

To go from aperture magnitudes to total magnitudes, aperture corrections are required. For point sources, the correction can be determined in a straightforward manner from the instrumental PSF, while for extended sources, we must also consider the intrinsic radial profile. Unfortunately, this represents a major source of uncertainty in star cluster studies (e.g. Chandar et al. 2010) and methods to deal with this have been widely discussed in the literature (e.g. Cook et al. 2019; Adamo et al. 2015; Deger et al. 2022). A common approach is to derive a relationship between the slope of the enclosed flux growth curve at a given radius and the aperture correction, which can be calibrated using either isolated real clusters or injected synthetic ones. We again followed the approach of L15, who sampled the slope of the growth curve at radii where it is typically at its steepest, and calibrated the relationship using a small sample of relatively bright and isolated star clusters in each galaxy (clusters ESCC-IC10-01, -03, -17, -45, -49, -50, and -52, and ESCC-NGC6822-05, -07, -08, -15, and -28).

Given the uncertainties introduced by applying aperture corrections, we opted to calculate these only for the  $V$  and  $Y_E$  filters. Total magnitudes in other passbands were then obtained by combining the small-aperture colours with the aperture-corrected  $V$  or  $Y_E$  magnitudes, a valid approach considering that star clusters should not exhibit strong colour gradients. In this way, all bands are placed on the same total-magnitude scale without requiring uncertain, band-by-band aperture corrections. For the IC 10



**Fig. 3.**  $V$ -band aperture correction relationship for clusters in IC 10, derived using bright and isolated clusters.

$V$ -band photometry, the slope of the growth curves was calculated using the difference between the magnitudes calculated within  $1''.6$  and  $2''.7$  aperture radii, and the aperture corrections were calculated from the magnitude difference between  $1''.6$  and  $5''.4$  aperture radii. Figure 3 illustrates a linear least squares fit to the data. For NGC 6822, we used apertures of  $2''.3$  and  $3''.8$  for the slope of the growth curves and  $2''.3$  and  $7''.5$  for the aperture corrections, corresponding to the same physical radii as in IC 10. The same-sized physical apertures were used for calculating the *Euclid*  $Y_E$  aperture corrections. To prevent over-correction, we limited the maximum aperture correction to be the largest one observed in the isolated clusters, which avoided extrapolating beyond the linear relationship shown in Fig. 3. Thus, the maximum aperture corrections applied were  $V = -1.2$  and  $-0.6$ , and  $Y_E = -1.4$  and  $-0.8$  for NGC 6822 and IC 10, respectively. The mean corrections were somewhat smaller,  $V = -0.76$  and  $-0.44$ , and  $Y_E = -0.78$  and  $-0.33$  for NGC 6822 and IC 10, respectively. Mean aperture correction uncertainties, derived from the slope and intercept uncertainties of the relationship, were approximately  $0.02$ – $0.05$  magnitudes and were combined in quadrature with photometric errors from Poisson noise, sky background uncertainty, and zeropoint uncertainties.

Tables B.1 and B.2 present the photometric measurements for all candidates with classes 1–4 and are available at the CDS. In NGC 6822, the resulting median photometric uncertainties in the  $V$ - and  $Y_E$ -bands are  $0.02$  and  $0.04$  for the brightest 50% of clusters, increasing to  $0.08$  and  $0.13$  among the faintest half. In IC 10, the corresponding photometric uncertainties are  $0.05$  and  $0.06$  for the brighter clusters, rising to  $0.08$  and  $0.22$  in the fainter population. Some clusters were particularly faint in some photometric bands or partially obscured by nearby bright stars, resulting in large photometric errors. These clusters are excluded from our analysis and flagged in our photometry tables with an asterisk.

## 5.2. SED fitting

To derive the physical properties (e.g. ages, masses, metallicities) as well as the line-of-sight extinction values of the clusters, we compared our photometric  $UBVRI + Y_E J_E H_E$  measurements to spectral energy distributions (SEDs) predicted by the 2016 version of Bruzual & Charlot (2003) models, which are updated using the stellar evolutionary tracks of Bressan et al. (2012)

**Table 4.** BAGPIPES priors.

Free parameter	NGC 6822	IC 10
$\log_{10}(M/M_{\odot})^a$	(0.1,7)	(0.1,7)
Age [Gyr]	(0.001,14)	(0.001,14)
$Z/Z_{\odot}$	(0.02,0.3)	(0.05,0.5)
$E(B - V)^b$	(0.2,0.45)	(0.65,1.2)

**Notes.** Uniform priors used within the BAGPIPES SED-fitting routine. <sup>a</sup> Mass priors are set in initial mass formed. <sup>b</sup>Maximum and minimum allowed line-of-sight reddening values. Note that inner and outer galaxy regions have slightly different priors, as detailed in the main text; these represent the overall limits. Metallicity priors are on a scale where  $Z_{\odot} = 0.02$ , consistent with BAGPIPES.

and Marigo et al. (2013). We did not include  $I_E$  in SED fitting, as it offers no additional information compared to the optical bands. The stellar population models were constructed and fit using the BAGPIPES code (Carnall et al. 2018). Prior to fitting, *Euclid* AB magnitudes and *UBVRI* Vega magnitudes were converted to flux using the zero points provided by the SVO filter profile service. The BAGPIPES code assumes a fully sampled initial mass function from Kroupa (2001) and we assumed a single burst of star formation can approximate all clusters. BAGPIPES uses Bayesian inference to derive the properties of the clusters, constructing a probability distribution based upon the  $\chi^2$  value for each model fit (the likelihood), assuming uncertainties are Gaussian and independent. Priors for each parameter can also be set, which we discuss below and detail in Table 4. The posterior distribution was sampled using the MULTINEST nested sampling algorithm (Skilling 2006; Feroz & Hobson 2008; Feroz et al. 2009) via the PYMULTINEST interface (Buchner et al. 2014). The median of the posterior distribution (50<sup>th</sup> percentile) was used to determine the best estimate of each cluster property, with the 16<sup>th</sup> and 84<sup>th</sup> percentiles defining the uncertainties. To deal with dust, we adopted a Cardelli et al. (1989) extinction law, an  $R_V$  value of 3.1 and allowed the total line-of-sight extinction in the  $V$ -band,  $A_V$ , to vary according to the range of  $E(B - V)$  values in the literature (detailed in Sects. 2.1 and 2.2). We did not correct for foreground extinction before fitting, as BAGPIPES assumes a foreground screen approximation, and applying a single extinction law consistently avoids introducing additional assumptions about the foreground  $A_V$  and the intrinsic source spectrum used to compute  $A_{\lambda}$  values. Although the internal extinction law in dwarf galaxies may differ from that of the MW, the uncertainties involved in estimating foreground extinction and correcting for it separately are significant enough that we opt to model the total extinction with a single component. Within a central  $3'$  radius of IC 10, we imposed an  $E(B - V)$  prior with a minimum of  $0.8$ , reflecting the higher extinction values reported in the literature. Beyond this radius, the prior was allowed to extend down to  $0.65$ . For NGC 6822, the  $E(B - V)$  prior ranged from  $0.2$  to  $0.45$  in the central regions (approximately within a radius of  $6'.5$ ), and was capped at  $0.35$  beyond this, consistent with previous studies. Additionally, we applied high-metallicity, low-age priors to five clusters in NGC 6822 and seven in IC 10 that appeared as prominent  $H\alpha$  sources in continuum-subtracted images that were constructed from the LGGs images. Specifically, for these clusters we limited the fits to metallicity values of  $0.2$ – $0.3 Z_{\odot}$  for NGC 6822 and  $0.2$ – $0.5 Z_{\odot}$  for IC 10, and ages of  $0$ – $10$  Myr. We note that since most of the clusters to be fit did not have strong coincident  $H\alpha$  emission, we did not include a nebular component

in the fits. Tables B.3 and B.4 present the BAGPIPES SED-fitting results (including ages, initial mass formed, living stellar masses,  $Z/Z_{\odot}$  and  $A_V$ ) for all candidates with classes 1–4 and are available at the CDS. While BAGPIPES provides both the mass formed and the living stellar mass, it does not have an option for including remnants. However, using FSPS models (Conroy et al. 2009; Conroy & Gunn 2010), we approximate that the inclusion of the latter contributes an additional  $\sim 1\text{--}5\%$  in present-day mass.

### 5.3. Half-light radii

We empirically calculated the cluster half-light radii,  $R_h$ , from the growth curves of  $I_E$  magnitude versus radius by identifying the radius where the magnitude is 0.75 fainter than the plateau value. To do this, we first smooth the growth curve using a Savitzky–Golay filter and obtain the derivative to find the flattening point. The growth curves for isolated clusters flatten out at the cluster’s boundary. However, in crowded fields, nearby stars contaminate the growth curves, an effect that is especially apparent for low-mass clusters. For these objects, we apply additional masking and identify the local minimum of the derivative in the region where the overall shape of the growth curve plateaus, intentionally disregarding other minima that may appear farther out. Alternative methods for determining cluster sizes involve fitting profiles to the data. However, in the study by L15, many half-light radii remained undetermined via this method due to the irregular profiles of the clusters. Consequently, we opted for this empirical approach for a more complete analysis. Our measured half-light radii are also included in Tables B.1 and B.2.

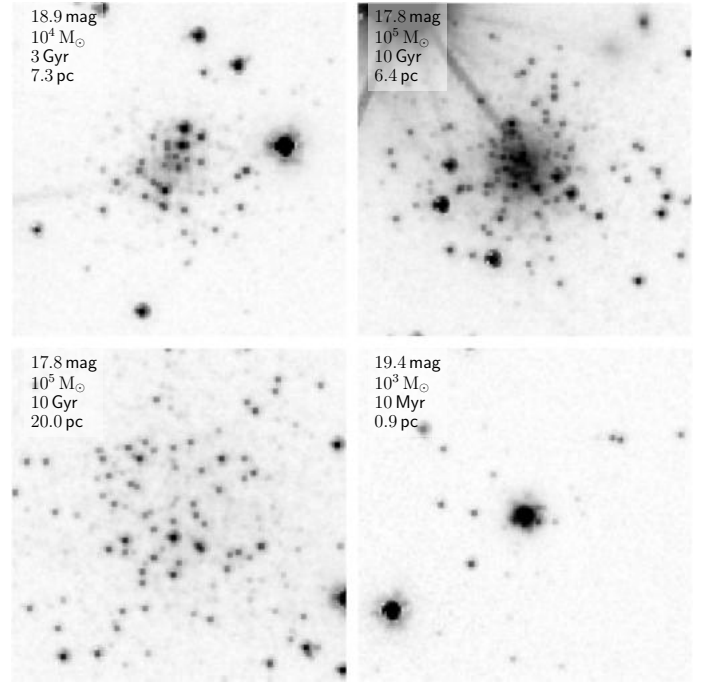
## 6. Validation and completeness

Before proceeding to present our results, we discuss the artificial cluster tests we conducted to assess the completeness of our sample and the accuracy of our measurements. These tests involved creating synthetic clusters using the Padova stellar isochrones (Bressan et al. 2012; Chen et al. 2015; Pastorelli et al. 2020) and the assumption of a Moffat profile (Elson et al. 1987). Moffat profiles are generally used to describe young clusters, while King profiles (King 1966) are typical for GCs. However, for the purposes of visual detection, we found that a Moffat distribution could adequately represent the various clusters visible in our images, most of which are not particularly old (see Sect. 7.2).

The following steps were taken to build a sample of synthetic clusters.

1. Clusters were generated across a grid of ages (10 Myr to 10 Gyr) and stellar masses (10 to  $10^6 M_{\odot}$ ). Metallicity was fixed at  $Z = 0.004$ , and a Kroupa initial mass function (IMF) was assumed (Kroupa 2001).
2. Moffat profile parameters, core width (0.1–15 pc) and power index (1.25–1.75), were drawn from uniform distributions, corresponding to half-light radii ranging from 0.1 to 58 pc. Stars were spatially distributed within a cluster based on the weighting of the Moffat profile and convolved with the  $I_E$  PSF.
3. Stellar magnitudes were adjusted by the distance modulus of each galaxy and reddened using Schlegel et al. (1998) dust maps, re-calibrated via Schlafly & Finkbeiner (2011), using the dustmaps package (Green 2018).

Example synthetic clusters, spanning a range of physical properties, are demonstrated in Fig. 4. To make the analysis more tractable, we focused on inserting clusters into a representative inner and an outer region of each galaxy, selected from



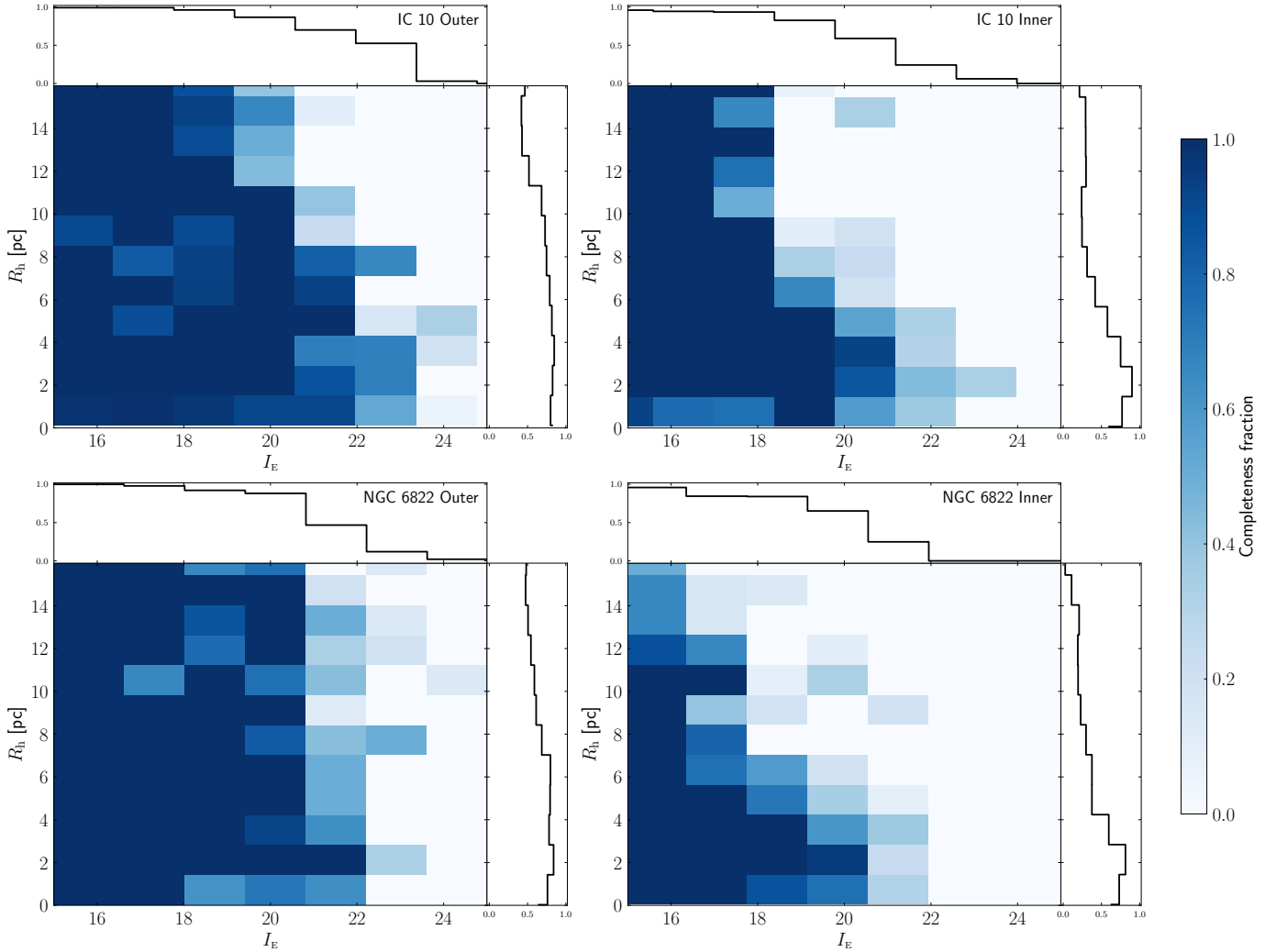
**Fig. 4.** Synthetic clusters displayed in asinh scale, placed within the outermost regions of the IC 10  $I_E$  image. Each cutout is 12 arcseconds on the side with apparent  $I_E$  magnitude, age, and half-light radii displayed.

the full *Euclid* FoV. The inner regions cover the dense central areas of the galaxies, defined approximately by a box of width  $15'$  centred on NGC 6822 and  $12'$  in IC 10. The outer regions, located beyond these boxes, probe the sparser halo environments. In all,  $\sim 1500$  clusters were inserted at random positions in each region (around 6000 clusters in total). We then performed a search for the synthetic clusters and recorded which ones were successfully recovered.

Figure 5 shows the completeness fraction, defined as the recovery rate, versus the magnitude and half-light radius for each region and galaxy. The full two-dimensional map is shown alongside the projected completeness fractions shown as histograms along each axis. The projected histograms in the top panels display the expected behaviour of high completeness at bright magnitudes, falling to lower values for fainter clusters. We estimate the 50% and 90% completeness limits by fitting a logistic function to the decay using a non-linear least squares method; the resulting limits are listed in Table 5. These magnitude limits are assumed to be constant with age. When translating these magnitude limits into mass limits (see Sect. 7.2), we find that, overall, we are  $\sim 50\%$  complete to  $M \lesssim 10^3 M_{\odot}$  for ages  $\lesssim 100$  Myr, and to  $M \lesssim 2 \times 10^4 M_{\odot}$  for ages of  $\sim 10$  Gyr, in both galaxies. We note, however, that the assumption of constant magnitude completeness limits is a simplification, as completeness may vary somewhat with age due to differences in cluster appearance.

We also examine how the completeness depends on half-light radius, as shown in the vertically-oriented projected histograms in Fig. 5. Our results indicate that the completeness generally decreases with half-light radius across both regions and galaxies, following a maximum at half-light radii of  $\sim 2\text{--}3$  pc. Recovery rates in the inner regions decline steeply beyond this maximum, whereas those in the outer regions decline more shallowly.

The synthetic clusters were also used to test the accuracy of our photometry method. Adopting the IC 10  $Y_E$  image as



**Fig. 5.** Cluster completeness derived from artificial cluster tests for inner and outer regions of each galaxy, as a function of  $I_E$  magnitude and half-light radius.

**Table 5.** Completeness limits.

Region	50% limit	90% limit
NGC 6822 inner	19.9	18.2
NGC 6822 outer	21.4	19.8
IC 10 inner	20.9	18.8
IC 10 outer	21.9	19.7

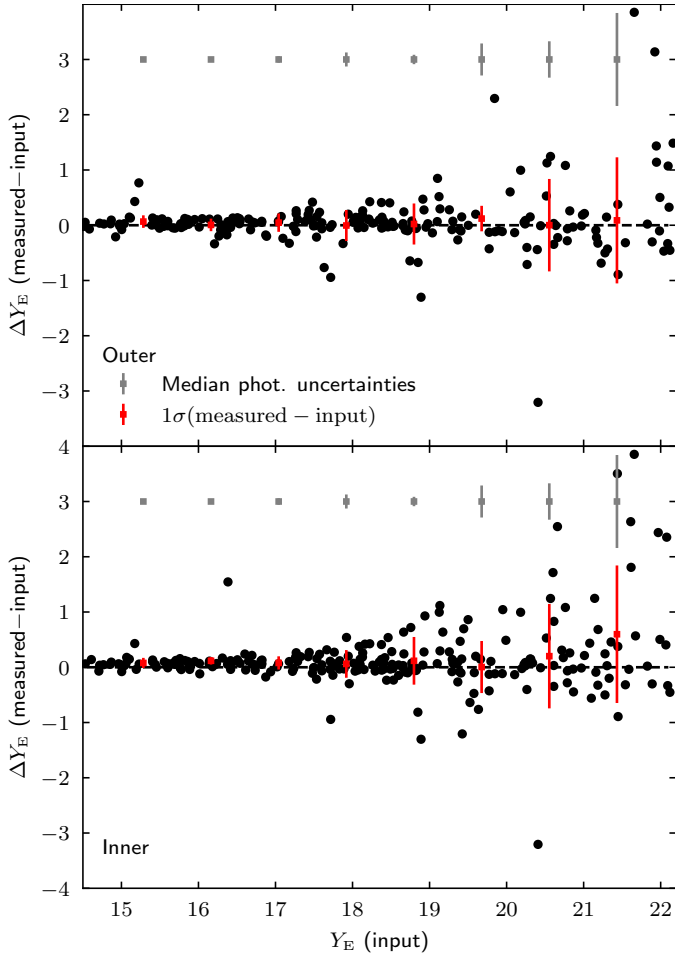
**Notes.** Cluster magnitude completeness limits for the galaxies, separated by inner and outer regions.

a representative case, we performed photometry in the same way as described in Sect. 5.1, using the same aperture correction relationship and aperture sizes. In Fig. 6, we plot the input vs. measured minus input  $Y_E$  magnitudes for the separate regions. For sources brighter than  $Y_E = 19$ , the mean offset is very small, 0.01 magnitudes in the outer region and 0.06 in the inner region, indicating excellent agreement, albeit with a slight bias towards fainter recovered magnitudes. For fainter clusters, the mean offset increases to 0.42 and 0.69 magnitudes in the outer and inner regions, respectively. Translating this magnitude offset to stellar mass (see Sect. 7.2), it corresponds to offsets

of  $\log_{10}(M/M_{\odot}) \sim 0.2$  and  $\sim 0.3$ , in the outer and inner regions, respectively, across both young and old clusters.

At magnitudes brighter than  $Y_E = 19$ – $20$ , the standard deviation in each bin remains below  $\sim 0.3$  magnitudes. However, at fainter magnitudes, the scatter increases substantially, with standard deviations reaching up to one magnitude in the faintest bin. It is evident that the cluster photometric uncertainties are 1–5 times smaller than the observed scatter, indicating that the formal errors underestimate the true uncertainties, as is expected. To further validate our measurements, we compare our  $UBVRI$  IC 10 photometry to that of L15 in Fig. 7. We find excellent agreement with their values, with the weighted mean offset being  $\leq 0.03$  in each colour and 0.03 in the  $V$ -band, with corresponding standard deviations  $\leq 0.07$  and 0.28, respectively. Furthermore, there is generally very good agreement among the  $V - I$  colours of NGC 6822 clusters Hubble-VI, Hubble-VII, Hubble-VIII, SC3, SC6 and SC7 (ESCC-NGC6822-01, -02, -03, -05, -07 and -08) with those published in previous studies, as demonstrated in Table 6.

Figure 8 shows how well we can recover the sizes of the synthetic clusters, using the methodology described in Sect. 5.3. Clusters with half-light radii in the 0–5 pc range are recovered well, but with increasing scatter, whereas for clusters with sizes greater than about 7 pc, we increasingly underestimate the



**Fig. 6.** Input versus measured minus input  $Y_E$ -band magnitudes in the outer (top) and inner (bottom) regions of IC 10 using synthetic clusters produced with a Moffat profile and PARSEC isochrones. The dashed line indicates an offset of zero. Also plotted, for each magnitude bin, are the mean offsets with associated standard deviations (red) and, for comparison, the median cluster sample photometric uncertainties placed above at a  $\Delta Y_E$  value of 3 (grey).

half-light radius. This is also true when we compare our results to those of L15, shown in the right-hand panel of Fig. 9. While our validation tests indicate an underestimation at larger radii, the discrepancy with L15 appears across all sizes. This may reflect a systematic offset between their profile-fitting methodology and our empirical one.

Finally, to benchmark the performance of BAGPIPES, we compared the metallicity outputs to spectroscopic literature values, available only for NGC 6822 (Chandar et al. 2000; Hwang et al. 2014; Larsen et al. 2022). The outputs from BAGPIPES have the format  $Z/Z_\odot$ , with  $Z_\odot = 0.02$  (Carnall et al. 2018). For clusters from Larsen et al. (2022), we transformed their reported  $[\text{Fe}/\text{H}]$  values into total metallicities ( $Z/Z_\odot$ ) using the corresponding  $\alpha$ -element abundances and the empirical relation from Salaris et al. (1993). In contrast, Hwang et al. (2014) and Chandar et al. (2000) reported their metallicities directly in terms of  $[Z/\text{H}]$ , allowing for a more straightforward comparison. Since Hwang et al. (2014) provided results based on multiple fitting methods, we adopted the mean of the published values for each cluster. The final values used for comparison are listed in Table 7. Our metallicity estimates are consistent within errors with the spectroscopic values for Hubble-VI, Hubble-VII,

Hubble-VIII, and SC6. However, we find a higher metallicity for SC3 and a lower metallicity for SC7 relative to the literature. Although the comparison sample was limited, the metallicity offsets did not demonstrate a correlation with cluster magnitude, as we might expect if stochastic effects were contributing to these discrepancies (stochastic effects are discussed further in Appendix A).

A detailed comparison of our derived masses and ages with those from L15 is provided in Fig. 9. Both studies utilise the Bruzual & Charlot (2003) models but differences stem from the version used, variations in SED-fitting techniques, prior selections, and the inclusion of NIR bands in our analysis. Although we observe fairly good agreement in mass, discrepancies are noted in age estimates. Notably, a number of clusters for which L15 finds old ages are found to be considerably younger in our work. We checked if removing the most dust-extended sources would eliminate this discrepancy, but they persisted, although the overall scatter slightly decreased.

## 7. Results and discussion

In this section, we present the results of our photometric measurements alongside our SED-fitting results, tabulated in Appendix B. Unless otherwise specified, we restrict our analyses to clusters with class 1–4 and with photometric errors less than one magnitude in all bands. Our catalogues and results should facilitate a variety of future in-depth studies of the cluster populations in NGC 6822 and IC 10 and we focus only on a few specific science results in this work.

### 7.1. Photometric properties

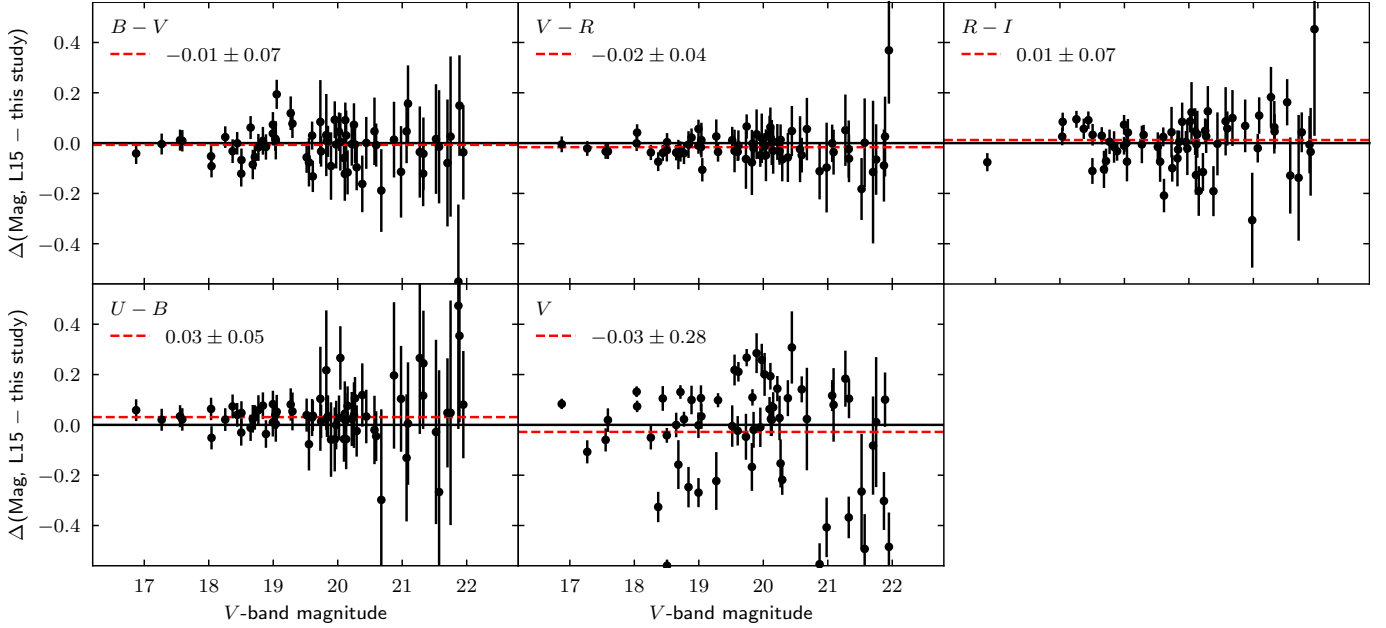
In Fig. 10, we plot the  $B - V$  vs.  $Y_E - H_E$  colours, alongside PARSEC SSP models (Bressan et al. 2012; Chen et al. 2015; Pastorelli et al. 2020) calculated for two metallicities,  $[\text{M}/\text{H}] = -2$  and 0. Constant ages are indicated by the connected dashed lines, with increasing age from left to right. It can be seen that while  $B - V$  is mostly sensitive to age,  $Y_E - H_E$  is mostly sensitive to metallicity. We note that the PARSEC SSP models are expected to be consistent with the BAGPIPES output due to their common usage of the Bressan et al. (2012) stellar evolutionary tracks.

For this initial comparison, we simply correct our photometry for reddening using the total  $E(B - V)$  towards each galaxy taken from the literature; we use  $E(B - V) = 0.81$  for IC 10 (Massey et al. 2007) and  $E(B - V) = 0.30$  for NGC 6822 (Fusco et al. 2012).

We see that the clusters largely span the expected range of colour-colour space, suggesting the presence of both young and old clusters, in addition to high and low metallicities. That said, we also observe some clusters which have dereddened  $Y_E - H_E$  colours bluer than what is expected for  $[\text{M}/\text{H}] = -2$ , irrespective of age. The origin of this offset is not clear, but could potentially be due to one or more of stochastic effects, nebular emission, alpha-enhancement, small-scale reddening variations and photometric uncertainties. We highlight in red the known GCs within our sample. They fall in the low-metallicity and high-age region, as would be expected and broadly agreeing with their literature values (Hwang et al. 2014; Veljanoski et al. 2015; Huxor et al. 2013; Larsen et al. 2022).

### 7.2. Ages and masses of the star clusters

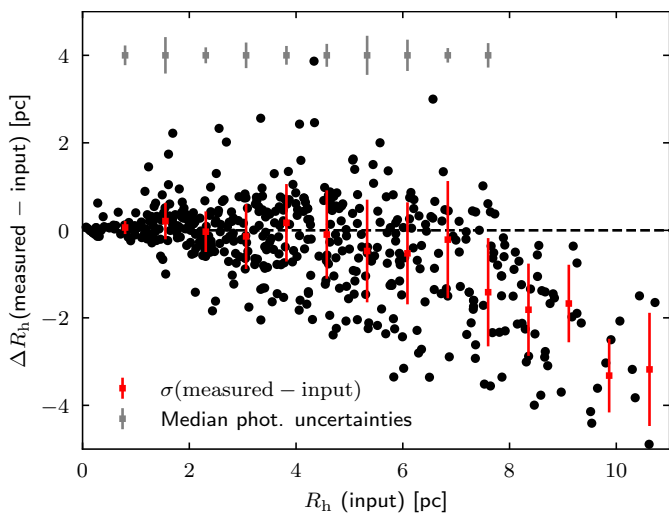
We use the outputs of BAGPIPES to separate our cluster sample into young, intermediate, and old sub-populations. We adopt the following age cuts:



**Fig. 7.** Comparison of our *UBVR* photometry to that of [L15](#), using their catalogue of 66 clusters in IC 10. No extinction corrections have been applied. Error bars reflect the combination of [L15](#) and our photometry uncertainties. The red dashed line is the weighted mean offset (indicated in the top left alongside the associated standard deviation), while the black line indicates an offset of zero.

**Table 6.** Comparison of  $(V - I)_0$  (extinction-corrected  $V - I$  colour) in NGC 6822 to values from previous studies.

ID	$(V - I)_0$ This study	$(V - I)_0$ <a href="#">Veljanoski et al. (2015)</a>	$(V - I)_0$ <a href="#">Hwang et al. (2011)</a>	$(V - I)_0$ <a href="#">Huxor et al. (2013)</a>	$(V - I)_0$ <a href="#">Krienke &amp; Hodge (2004)</a>
Hubble-VI	$0.53 \pm 0.03$	...	...	...	0.32
Hubble-VII	$0.94 \pm 0.03$	$0.87 \pm 0.04$	1.05	...	0.89
Hubble-VIII	$0.62 \pm 0.04$	...	0.93	...	0.65
SC3	$0.87 \pm 0.03$	$0.87 \pm 0.05$	1.31	...	...
SC6	$0.91 \pm 0.03$	$0.87 \pm 0.03$	...	$0.84 \pm 0.03$	...
SC7	$1.18 \pm 0.03$	$1.02 \pm 0.03$	...	$1.05 \pm 0.03$	...



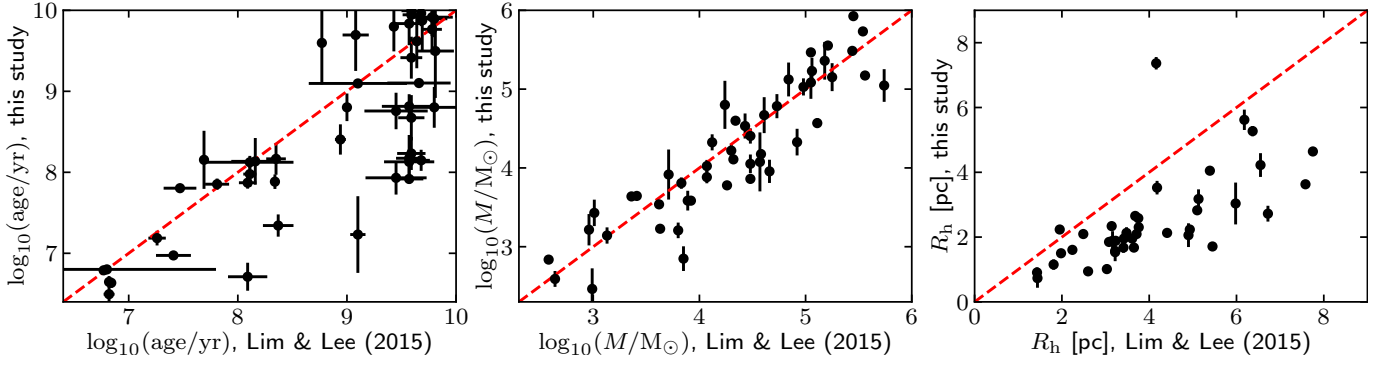
**Fig. 8.** Input versus measured minus input half-light radii (in pc units) derived in the  $I_E$ -band for artificial clusters in IC 10. The dashed line presents an offset of zero. Also plotted, for each magnitude bin, are the mean offsets with associated standard deviations (red) and, for comparison, the median cluster sample photometric uncertainties placed above at a  $\Delta R_h$  value of 4 (grey).

- $\log_{10}(\text{age}/\text{yr}) \leq 7.3$  for young clusters;
- $7.3 \leq \log_{10}(\text{age}/\text{yr}) \leq 9.3$  for intermediate-age clusters;
- $\log_{10}(\text{age}/\text{yr}) \geq 9.3$  for old clusters.

Based on these classifications, we identify eight and 12 young clusters (classes 1–4) in NGC 6822 and IC 10, respectively. We also identify 28 and 32 intermediate-age clusters, and 16 and 27 old clusters in these galaxies.

Figure 11 shows the cluster mass (initial mass formed) versus age for both galaxies, along with the 50% completeness limit calculated for the inner regions of each galaxy. This has been derived by converting the magnitude thresholds in Table 5 into corresponding age and mass limits using the models from [Bruzual & Charlot \(2003\)](#). For this, we assume a representative metallicity of  $0.1 Z_{\odot}$  along with reddening values of  $E(B - V) = 0.81$  for IC 10 ([Massey et al. 2007](#)) and  $E(B - V) = 0.3$  for NGC 6822 ([Fusco et al. 2012](#)). Figure 11 also presents masses and ages for a sample of 134 SMC<sup>3</sup> clusters, taken from the study by [Gatto et al. \(2021\)](#). These clusters, primarily situated within the central regions of the SMC (approximately  $\sim 2^{\circ}$ – $3^{\circ}$  from the centre), represent only a fraction of the  $\sim 850$  cluster

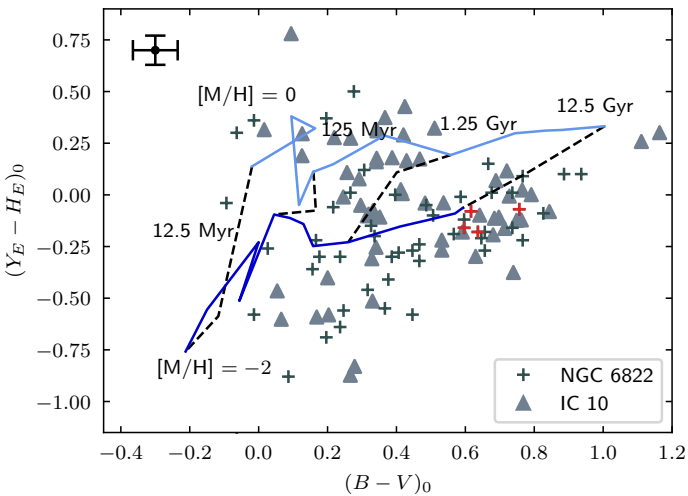
<sup>3</sup> As a dIrr with a stellar mass of  $\sim 9 \times 10^8 M_{\odot}$  ([Pace 2024](#)), the SMC provides a good analog to the systems we study in this paper, although it is a few times more massive.



**Fig. 9.** Left and middle: comparison of our SED-fit masses and ages with those of L15. The 1:1 line is shown in red. Right: comparison of our half-light radii estimates with their sample.

**Table 7.** Comparison of  $Z/Z_{\odot}$  in NGC 6822 to spectroscopic values from previous studies (assuming  $Z_{\odot} = 0.02$ , consistent with BAGPIPES).

ID	$Z/Z_{\odot}$ This study	$Z/Z_{\odot}$ Larsen et al. (2022)	$Z/Z_{\odot}$ Chandar et al. (2000)	$Z/Z_{\odot}$ Hwang et al. (2014)
Hubble-VI	$0.027 \pm 0.010$	...	$0.036 \pm 0.022$	...
Hubble-VII	$0.037 \pm 0.011$	$0.027 \pm 0.010$	$\sim 0.013$	$0.012 \pm 0.004$
Hubble-VIII	$0.244 \pm 0.052$	...	...	$0.293 \pm 0.129$
SC3	$0.191 \pm 0.02$	...	...	$0.052 \pm 0.029$
SC6	$0.026 \pm 0.005$	$0.028 \pm 0.001$	...	...
SC7	$0.022 \pm 0.001$	$0.066 \pm 0.002$	...	...



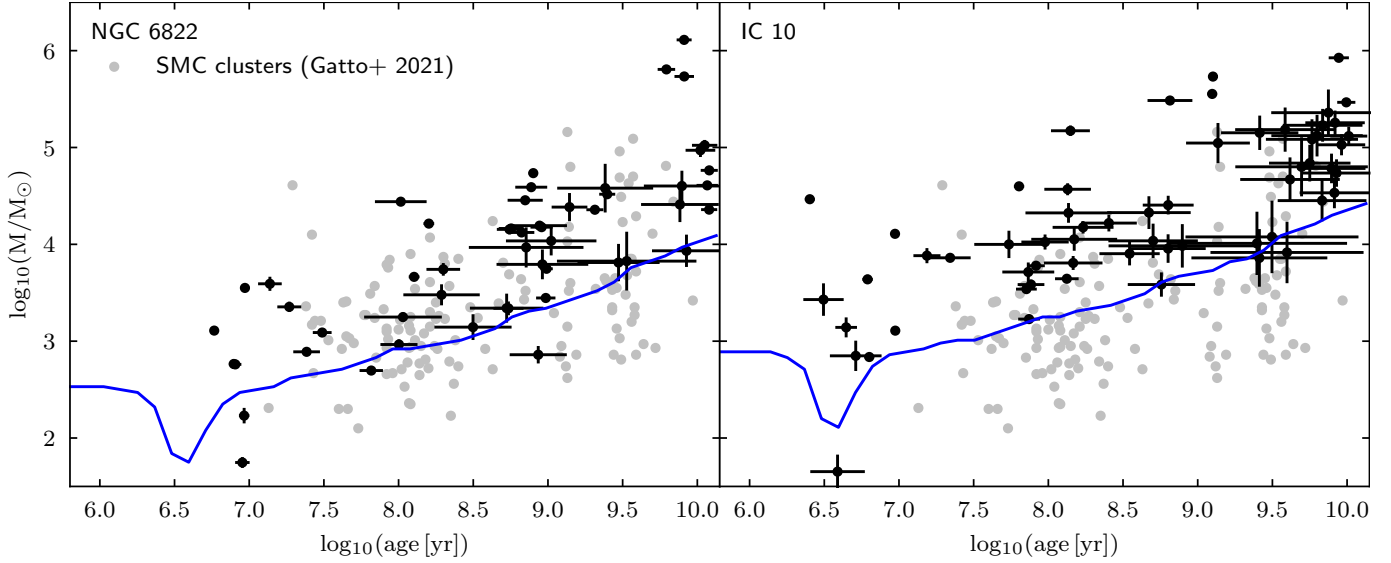
**Fig. 10.** Reddening-corrected  $(B - V)_0$  vs.  $(Y_E - H_E)_0$  colour-colour diagram of our cluster sample. PARSEC simple stellar populations with  $[M/H] = -2$  and  $0$  are overplotted (blue lines) with connecting lines of constant age (dashed lines). A subset of the GCs within NGC 6822 for which we have data coverage are indicated in red. Median errors are displayed in the top left-hand corner.

candidates in the SMC and Magellanic Bridge compiled by Bica et al. (2020). Gatto et al. (2021) use data from the STEP survey to uniformly derive ages and masses for this sample via colour-magnitude diagram (CMD) fitting, and this homogeneous nature makes it ideal for comparison. That said, it is important to keep in mind that the Gatto et al. (2021) sample is biased in terms of its central location (for example, it does not include NGC 121, which is the only old GC in the SMC). Furthermore, as it is based on clusters that were uncovered in a variety of earlier studies, it

is likely to have varying (unquantified) completeness. Nonetheless, due to the close proximity of the SMC, it is expected that it will reach to lower masses at any given age than our *Euclid* search, as indeed can be seen in Fig. 11. Both BAGPIPES and the AStECA (Perren et al. 2015) version used by Gatto et al. (2021) estimate the initial mass formed. While there may be systematic differences between the initial mass computations, these are expected to be small.

Both NGC 6822 and IC 10 host clusters that range in mass from  $\sim 10^2 M_{\odot}$  to  $\sim 10^6 M_{\odot}$ , and with ages from  $\sim 10$  Myr to  $\sim 10$  Gyr, generally consistent with the age range inferred from Fig. 10. We find that older clusters are typically more massive, which probably reflects the preferential disruption and fading of low-mass clusters over time (e.g. Fall & Zhang 2001), as well as a possible preference for the formation of more massive star clusters at early times (e.g. Elmegreen & Efremov 1997; Lahén et al. 2025). On the other hand, clusters younger than a few tens of Myr typically have masses below  $10^4 M_{\odot}$  in both systems. An exception is found in IC 10, which hosts two young, massive clusters: ESCC-IC10-40 (class 1) and ESCC-IC10-71 (class 4), with  $\log_{10}(M/M_{\odot}) = 4.1 \pm 0.01$  and  $4.5 \pm 0.01$ , and ages of  $9.4 \pm 0.3$  and  $2.5 \pm 0.2$  Myr, respectively<sup>4</sup>. Observational evidence suggests that the young cluster mass function follows a power law, with a truncation at the high-mass end that appears to correlate with the SFR surface density ( $\Sigma_{\text{SFR}}$ ) of the host galaxy (Larsen 2009; Adamo et al. 2015; Johnson et al. 2017). Converting the

<sup>4</sup> L15 discuss a potential Super Star Cluster (SSC) candidate in IC 10, first identified by Hunter (2001) but classified in that study as an OB association. L15 argue that, based on the stellar density in the HST image, this object could be an SSC. We identified this object in our cluster search (ESCC-IC10-44); however, after classification by our group, it was assigned class 5 so very unlikely to be a cluster, consistent with its original designation.

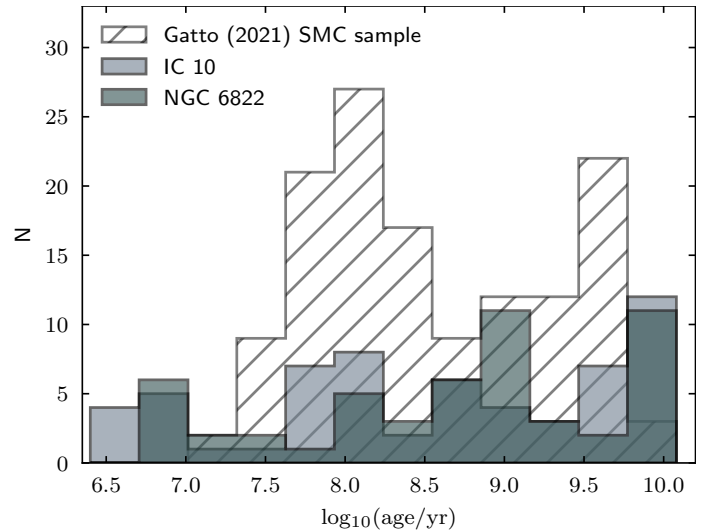


**Fig. 11.** Masses as a function of age as derived by BAGPIPES for the star clusters in NGC 6822 (left) and IC 10 (right). The blue line shows the 50% completeness limit in the inner regions. Also plotted in grey is the sample of SMC clusters from Gatto et al. (2021).

data listed in Table 1 to SFR surface densities within one half-light radius, we find values of  $\log_{10}(\Sigma_{\text{SFR}}/M_{\odot}\text{yr}^{-1}\text{kpc}^{-2}) = -8.7$  and  $-6.5$  for NGC 6822 and IC 10, respectively. While we do not have enough young clusters in our sample to construct meaningful mass functions, we note that the presence of more massive young star clusters in IC 10 is consistent with this expected dependence of the truncation mass on  $\Sigma_{\text{SFR}}$ .

The oldest clusters in the dwarfs reach masses well above  $10^5 M_{\odot}$ , with one exceptional GC in NGC 6822 (SC7=ESCC-NGC6822-08) above even  $10^6 M_{\odot}$ . With a derived initial mass formed of  $1.3 \times 10^6 M_{\odot}$ , this cluster is roughly twice as massive as any of the other old clusters in NGC 6822. Converting this mass to an estimate of the present-day mass (including both living stars and remnants) using FSPS models (Conroy et al. 2009; Conroy & Gunn 2010), we obtain a current mass of  $7.7 \times 10^5 M_{\odot}$ . This high mass is further supported by the cluster velocity dispersion reported by Larsen et al. (2022). Using their measurement of  $9.9 \text{ km s}^{-1}$ , we estimate the dynamical mass to be  $4.6 \times 10^5 M_{\odot}$  which is comparable, albeit slightly lower, to our estimated current mass. Our derived metallicity of  $Z/Z_{\odot} = 0.022 \pm 0.001$  is considerably lower than the one found by Larsen et al. 2022 (see Table 7), but in agreement with the metallicity from fitting a deep HST CMD (McGill et al., in prep). Aside from its high mass, other peculiarities of SC7 include an  $\alpha$ -abundance close to the solar value (Larsen et al. 2022) and a high ellipticity (see Fig. 1, and Huxor et al. 2013). The existence of this high ellipticity old massive star cluster in the outskirts of NGC 6822 is particularly intriguing, and it is tempting to speculate that it has been accreted. Indeed, SC7’s high mass and ellipticity are reminiscent of  $\omega$  Centauri, the most massive GC in the MW ( $2.5 \times 10^6 M_{\odot}$ ; van de Ven et al. 2006), which is suspected of being the stripped core of a disrupted dwarf galaxy (e.g. Bekki & Freeman 2003). A similar origin for SC7 may appear less compelling, as NGC 6822 shows no signs of recent tidal disturbance in its outskirts (Zhang et al. 2021). However, we note that the cluster may originate from a much earlier event, now fully phase-mixed and no longer evident in the galaxy’s present-day structure.

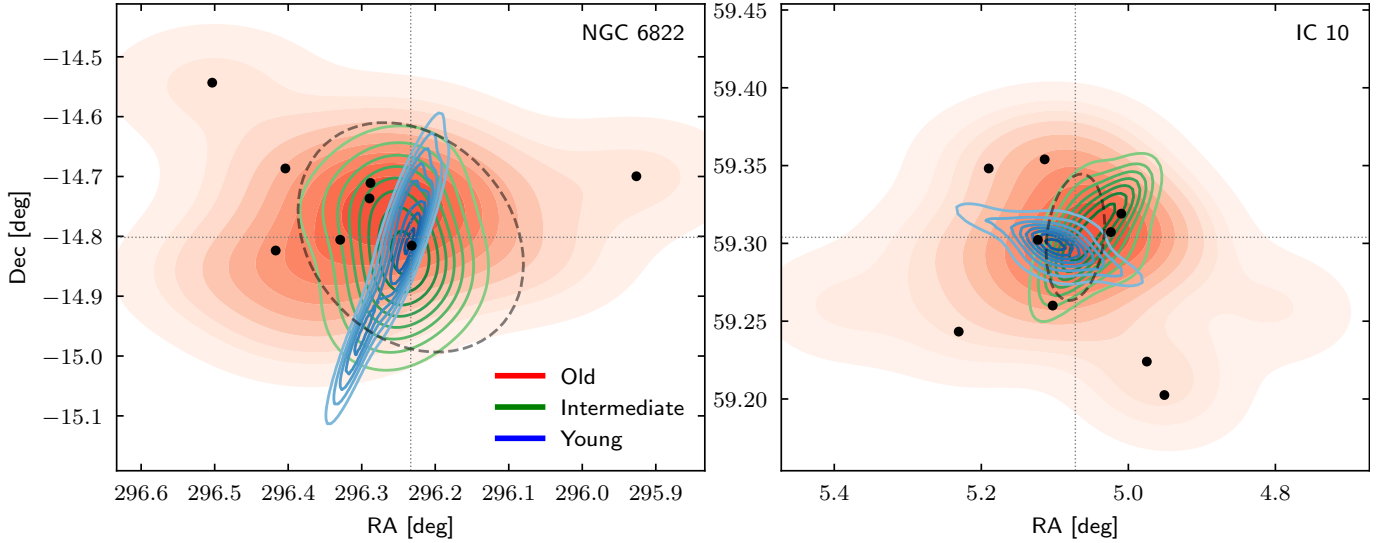
In Fig. 12, we examine more closely the relative distribution of cluster ages. All three systems show evidence of continuous cluster formation across time but the central part of the



**Fig. 12.** Age distributions of the clusters compared with the SMC clusters taken from Gatto et al. (2021).

SMC seems to have formed comparatively more intermediate-age clusters compared to the relatively flat distributions in both NGC 6822 and IC 10. While there is a hint of an enhanced proportion of ancient clusters [ $\log_{10}(\text{age}/\text{yr}) \geq 9.7$ ] in NGC 6822 and IC 10 compared to the SMC, it should be remembered that the Gatto et al. (2021) sample is biased in terms of areal coverage and that there are potential systematic effects related to the different age determination methods used for the SMC clusters and in this study, as well as their different completeness levels.

At both young and old ages, IC 10’s cluster population outnumbers that of NGC 6822. Given IC 10’s higher current SFR, we may expect more young clusters [ $\log_{10}(\text{age}/\text{yr}) \leq 7.3$ ] relative to NGC 6822, which is indeed the case. However, given IC 10’s classification as a starburst dwarf, it is perhaps surprising that it has only 50 percent more young clusters. A possible reason for why this number is not larger is cluster disruption. Some studies suggest that starburst galaxies exhibit particularly



**Fig. 13.** Kernel density estimation contour plots showing the spatial distribution of clusters in NGC 6822 (left) and IC 10 (right). Clusters are grouped by age: old (red), intermediate (green) and young (blue). The contours represent the density of clusters at their location within each galaxy. Old clusters are displayed with filled contours to enhance contrast against the other populations, making them easier to distinguish. Also plotted are grid lines marking the nominal centre of each galaxy (Sibbons et al. 2012; Gerbrandt et al. 2015) and the positions of candidate GCs in black (see Sect. 7.6). Note that there are 3 GCs in NGC 6822 which lie outside the *Euclid* FOV and are not shown here. Grey dashed ellipses, representing each galaxy’s half-light radius with the appropriate ellipticity and position angle, are overlaid (McConnachie 2012; Higgs et al. 2021; Jarrett et al. 2003).

short disruption timescales, around 7–10 Myr, due to rapid gas expulsion. This is supported by observations of diffuse UV light in these galaxies, which is argued to result from the swift dispersal of young clusters (Chandar et al. 2005). Additionally, the high extinction toward IC 10 may be obscuring some young clusters, preventing their detection, or they may still be deeply embedded in their dusty natal environments.

### 7.2.1. Spatial distributions by age

Smoothed density contours of the cluster spatial distributions are displayed in Fig. 13. The entire *Euclid* FoV is not shown; instead, we have adjusted the RA and Dec ranges to focus on the cluster locations farthest from the galaxy centres, making it easier to highlight the features. The centres of the galaxies are also indicated, with NGC 6822’s centre defined as RA = 19<sup>h</sup>44<sup>m</sup>56<sup>s</sup>, Dec = −14<sup>d</sup>48<sup>m</sup>06<sup>s</sup> (Sibbons et al. 2012) and for IC 10, RA = 00<sup>h</sup>20<sup>m</sup>17.3<sup>s</sup>, Dec = 59<sup>d</sup>18<sup>m</sup>14<sup>s</sup>, taken from Gerbrandt et al. (2015). The distributions are centrally concentrated in both systems for all age bins, but especially so for the young clusters. In NGC 6822, the young clusters are roughly co-located with a couple of previously known star-forming regions; namely, *Spitzer* I and Hubble-V. The elongated distribution of young clusters, primarily in a north-south direction, but extending slightly toward the south-east, is also consistent with the young stellar distributions displayed in Hunt et al. (2025), as well as earlier works (Tantalo et al. 2022; Hirschauer et al. 2020), and with the position of the bar. The intermediate-age cluster spatial distribution is more circular, albeit with a slight extension in the NE–SW direction, while the old clusters are more symmetrically distributed yet again. These strong age-dependent variations in spatial distribution are also seen in IC 10. The young clusters are primarily elongated in an northeast–southwest direction, while the intermediate-age clusters are oriented nearly perpendicular to this. Small offsets can be seen between the centroids of the cluster distributions but these are not likely to be meaningful

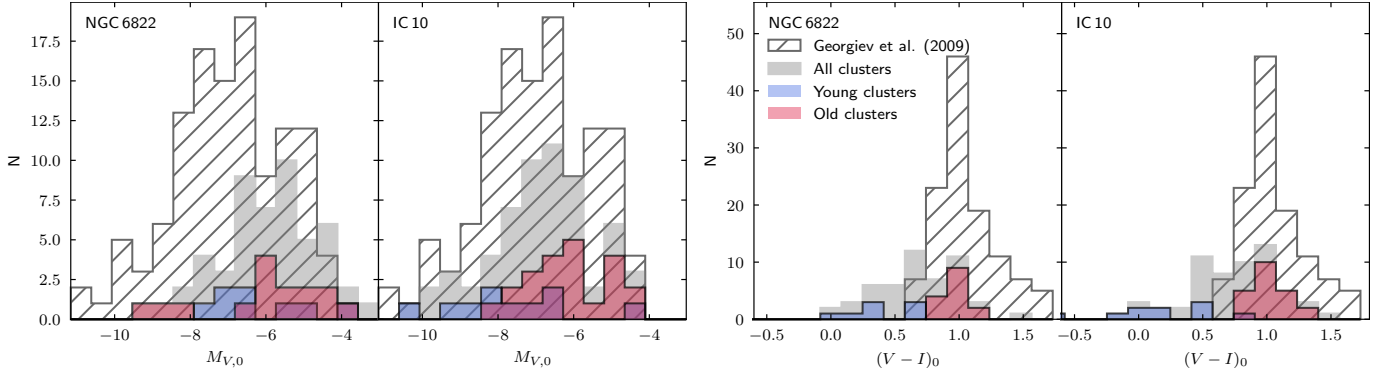
given the small numbers of clusters in each bin and the smoothing kernel used. An offset of a few hundred parsecs between the geometric centres of the old and young stellar populations in IC 10 was previously noted by Gerbrandt et al. (2015), but the sense of their offset is opposite to what we see for the star cluster populations. Consistent with the nature of dwarf starbursts, clusters of all ages are more centrally concentrated in IC 10 compared to those in NGC 6822 (also consistent with the star count maps shown in Hunt et al. 2025).

### 7.3. Luminosity and colour functions

The left panels of Fig. 14 show the star cluster luminosity functions (LFs), expressed in extinction-corrected absolute *V*-band magnitude calculated using the BAGPIPES outputs for  $A_V$  and the distances in Table 1. We show the overall LFs for each galaxy, as well as the LFs for the young and old clusters using the definitions introduced in Sect. 7.2. For completeness, we also add the NGC 6822 GCs SC1, SC2, and SC4, which lie outside the *Euclid* FoV, using the magnitudes and colours from Veljanoski et al. (2015).

The overall LFs for the two dwarfs are broadly similar. They exhibit approximately Gaussian shapes, with the peaks of a Gaussian fit in IC 10 ( $M_{V,0} \sim -6.7$ ) being slightly brighter than that in NGC 6822 ( $M_{V,0} \sim -5.9$ ). There is tentative evidence for a second peak in the IC 10 LF at  $M_{V,0} \sim -5$ , which is reminiscent of the fainter peak in the bimodal LF of M31 halo GCs (Huxor et al. 2014; Mackey et al. 2019), but the low numbers of clusters prevent any strong conclusions. The LF of IC 10 extends to  $M_{V,0} \sim -10$  and its most luminous clusters are of young to intermediate age. On the other hand, the most luminous clusters in NGC 6822 are old clusters, which are roughly one magnitude brighter than any of the old clusters found in IC 10.

We also show a comparison sample of 118 candidate GCs in 30 dIrr galaxies taken from Georgiev et al. (2009). These dIrrs have  $M_V > -16$  and reside in low-density, relatively nearby



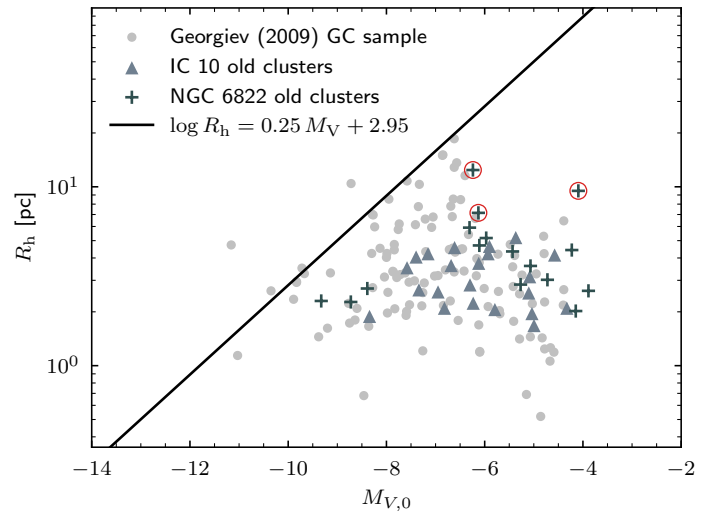
**Fig. 14.** Left panels: distributions of extinction-corrected absolute  $V$ -band magnitudes for our sample of clusters. The overall distribution is shown as well as the luminosity function split into young (blue) and old (red) age bins. We also show a sample of GCs in more distant dIrr galaxies, taken from [Georgiev et al. \(2009\)](#). Right panels: the same but for the  $(V - I)_0$  colour distributions.

( $D \lesssim 12$  Mpc) environments, similar to NGC 6822 and IC 10. Their candidate GCs have been identified through analysis of deep HST images, with 90% completeness estimated to be  $M_V \approx -4.5$ , however most have not been spectroscopically confirmed or age dated. Our old clusters fall within the magnitude range of the GCs in the [Georgiev et al. \(2009\)](#) sample but generally lie toward the fainter end of the distribution.

The right-hand panels of Fig. 14 show the  $(V - I)_0$  colour distributions. Our old clusters are found within the colour range spanned by the [Georgiev et al. \(2009\)](#) GC sample, while most of our young clusters are found blueward of our old clusters. The colours of the old clusters peak at a similar value compared to the GCs in the [Georgiev et al. \(2009\)](#) sample in both galaxies, with a peak around  $\sim 1.0$ . [Georgiev et al. \(2009\)](#) highlight an absence of faint ( $M_V \gtrsim -6$ ) blue GCs in their sample, defined as those with  $(V - I)_0 \leq 1.0$ . We have several old clusters that fit these criteria in both galaxies (with ages between 3 and 12 Gyr), but we note that the uncertain reddening may be impacting these colours.

#### 7.4. Half-light radii

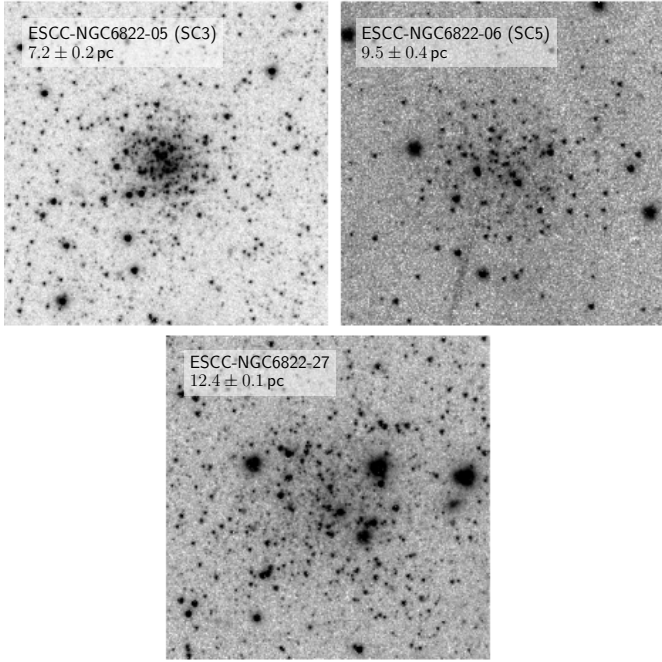
It is interesting to explore the correlation between the half-light radii of the old clusters and their luminosities. Since  $R_h$  changes very little over many relaxation times (e.g. [Meylan & Heggie 1997](#)), this can potentially provide insight into the formation process of the most massive, long-lived clusters. Figure 15 shows how the half-light radii of the old clusters depend on absolute  $V$ -band magnitude. In the MW, GCs show a clear trend in  $R_h$  with  $M_V$ , in the sense that more luminous clusters are more compact. Very few clusters exist above the empirical boundary  $\log_{10}(R_h/\text{pc}) = 0.25 M_V + 2.95$  ([Mackey & van den Bergh 2005](#)), which is reproduced in Fig. 15. For comparison, the [Georgiev et al. \(2009\)](#) sample is also plotted. Our old clusters lie below the empirical line and fall within the size range of the [Georgiev et al. \(2009\)](#) sample. Their half-light radii also peak at a similar value to ours (around  $\sim 2$  pc), as well as the old [ $\log_{10}(\text{age}/\text{yr}) \geq 9.3$ ] clusters in the [Gatto et al. \(2021\)](#) sample. The brighter old clusters ( $M_{V,0} \leq -6$ ) have half-light radii within the range  $\sim 1.5$ – $4.5$  pc, similar to what is seen in MW GCs ([Harris 1996](#)). However, toward fainter magnitudes, the spread increases considerably for NGC 6822, reaching up to 12 pc, and also extending beyond the half-light radii of the [Georgiev et al. \(2009\)](#) sample at these faint magnitudes. This increased scatter at faint magnitudes has also recently been observed in NGC 2403 and IC 342 using *Euclid* data ([Larsen et al. 2025](#)). On the other hand, the size distribution of old clusters in IC 10 is relatively flat



**Fig. 15.** Half-light radii as a function of absolute  $V$ -band magnitude for the old cluster sample, and for the sample of GCs from ([Georgiev et al. 2009](#)). The empirical relation  $\log_{10}(R_h/\text{pc}) = 0.25 M_V + 2.95$  ([Mackey & van den Bergh 2005](#)), which defines the upper envelope of MW GCs, is overplotted. Small red circles mark the three most extended clusters in NGC 6822.

as a function of magnitude. In both NGC 6822 and IC 10, there is a subtle trend where clusters located farther from the galaxy centre tend to have slightly larger half-light radii.

Figure 15 shows that NGC 6822 has three particularly extended old clusters (red circles), with  $R_h \gtrsim 7$  pc, which have no counterparts in IC 10. While a few examples of old extended clusters exist in the [Georgiev et al. \(2009\)](#) sample, they are all brighter than the ones highlighted here. Two of the extended clusters in NGC 6822, SC3 and SC5, were previously known from ground-based work ([Hwang et al. 2011](#); [Huxor et al. 2013](#)) while the other is newly identified in this work. With  $R_h = 12.4 \pm 0.1$  pc, ESCC-NGC6822-27 is the most extended old cluster within our sample, and it has an age of  $2.1 \pm 0.3$  Gyr, a mass of  $\log_{10}(M/M_\odot) = 4.4 \pm 0.04$  and a metallicity of  $Z/Z_\odot = 0.03 \pm 0.01$ . Thumbnails of the extended clusters within our FoV are shown in Fig. 16, where their very diffuse nature is readily apparent. Another three extended clusters are known in NGC 6822 which lie beyond the *Euclid* FoV ([Hwang et al. 2011](#); [Huxor et al. 2013](#)). A possible explanation for the origin of extended clusters is that they have been born extended and evolved in a weak



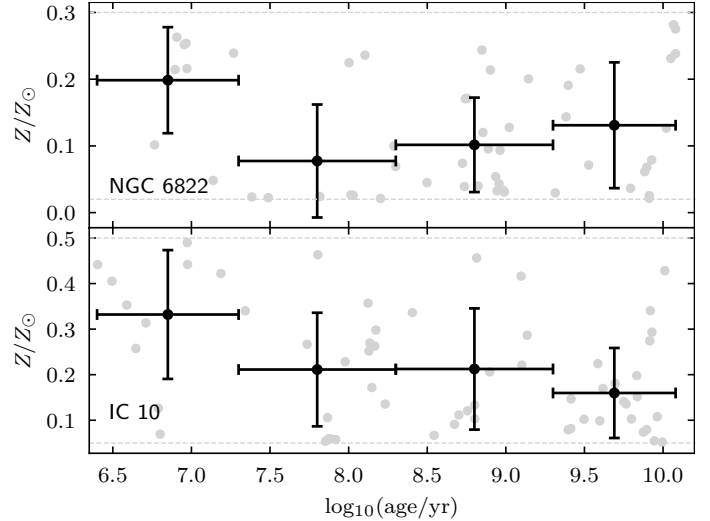
**Fig. 16.** Thumbnails in *Euclid*  $I_E$  of NGC 6822’s extended clusters. Each cutout is  $30''$  on a side, corresponding to 74 pc at the distance of NGC 6822.

tidal field (Hurley & Mackey 2010; Bianchini et al. 2014), consistent with their existence in the outskirts of a dwarf galaxy such as NGC 6822. The fact that extended clusters are also seen in the halos of massive galaxies (e.g. Huxor et al. 2005; Mouhcine et al. 2010; Jang et al. 2012) provides tantalising evidence that they have been donated via dwarf galaxy accretion events.

We have also searched for correlations between mass and size, and age and size within our sample. A modest but statistically significant correlation between cluster mass and size exists in NGC 6822, but not in IC 10. In contrast, no clear relationship is found between cluster age and size in either galaxy. While some studies have seen evidence for such trends (e.g. Lee et al. 2005; Chandar et al. 2016; Mackey & Gilmore 2003; Ryon et al. 2015; Bastian et al. 2012; Scheepmaker et al. 2007), others do not (e.g. Larsen 2004; Barmby et al. 2009). Overall, our findings suggest that while mass may influence cluster size to some extent, age does not appear to be a strong driver.

### 7.5. Cluster metallicities, extinctions, and ages

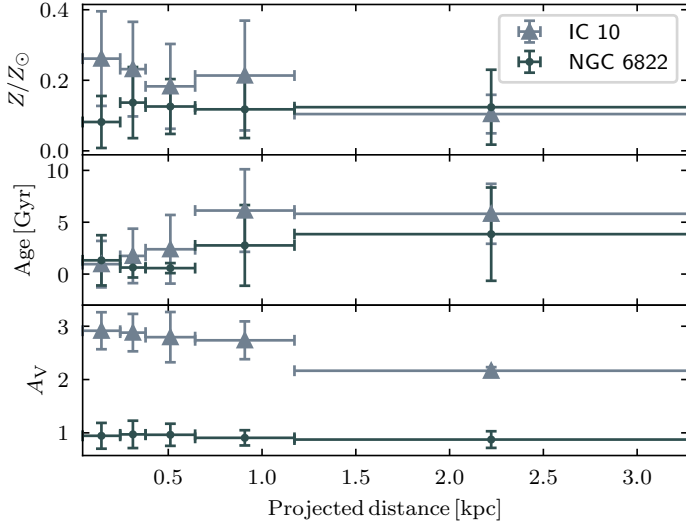
Figure 17 shows how the metallicity of the clusters varies as a function of age, using the BAGPIPES outputs. In addition to the individual cluster values (light grey), we also show the mean metallicity in specific age bins (black points), along with its standard deviation. The age bins correspond to our previous definitions of young, intermediate, and old populations, with the intermediate-age category further divided into two bins. Both galaxies show the expected behaviour, with the most recently formed clusters having the highest metallicities and older clusters having lower metallicities. Beyond the first age bin, the age-metallicity relation is flat to within the uncertainties in both systems, with metallicities at a given age being slightly higher in IC 10 than in NGC 6822. Within any age bin, there is significant scatter when examining individual clusters, only some of which is likely to be real. Indeed, the plots also hint at the existence of potential systematics: a preference for low-metallicity



**Fig. 17.** Age–metallicity relation based on BAGPIPES outputs for NGC 6822 (top) and IC 10 (bottom). Individual measurements are shown in light grey, with black points representing averages computed in bins of age. Horizontal bars represent bin widths, while vertical error bars show the standard deviation within each bin. Dashed grey lines mark the boundaries of the metallicity priors.

fits reaching the floor of the prior in the second age bin, as well as some unexpectedly high-metallicity fits in the oldest age bins. In the latter case, we checked that these clusters did not show a correlation with far-IR dust emission (by inspecting SPIRE 500  $\mu\text{m}$  and *Spitzer* 160  $\mu\text{m}$  images), or with strong  $H\alpha$  sources; this confirmed that their SEDs were not contaminated by non-stellar emission. One possible explanation for the high metallicities could be due to our extinction priors. These were set by considering the range of reddening values in the published literature; however, these may not capture the full range of reddening across the *Euclid* FoV. The Schlegel et al. (1998) dust maps, recalibrated by Schlafly & Finkbeiner (2011), suggest higher  $E(B - V)$  values in some places than our adopted limits. If the true extinction is higher than our allowed range, the SED fitting may only be able to reproduce the red colours by favouring older ages and higher metallicities. We explored this by assessing the impact of changing the dust prior in the BAGPIPES fitting process. First, we removed the upper limit on the dust prior and found the old, high-metallicity clusters still broadly occupied the same region. We then replaced the global dust prior for the entire galaxy with a local one specific to each cluster. For this, we exploited the high-resolution reddening map derived from resolved RGB stars (Annibali et al., in prep), who inferred  $E(B - V)$  by comparing the CMD positions of stars to a fiducial RGB sequence. Setting the prior for each cluster as a Gaussian of width 0.2 centered on the local  $E(B - V)$ , we redid the fits but found very little change to the results, with the old high-metallicity fits persisting. Alternatively, stochastic effects could be responsible for assigning old ages and high metallicities to these clusters (Appendix A). While Fig. 17 illustrates the qualitative trends in the metallicity evolution of the galaxies, a more detailed reconstruction of the age–metallicity relationship of the star clusters would require either CMD fitting or spectroscopy.

We also searched for radial gradients in age, metallicity, and extinction in the star cluster population of each system, binning the clusters by their projected radial distance from the centre of each galaxy and computing the mean of the quantity of interest. To facilitate comparison, the radial bins were constructed



**Fig. 18.** Top: average cluster metallicities (as output by BAGPIPES) computed in bins of projected distance from the centre of each galaxy. Horizontal bars represent bin widths, while vertical error bars show the standard deviation within each bin. Middle: the same as the top panel but for age. Bottom: The same but for  $A_V$ .

to have common edges and widths such that there was always a minimum of five clusters per bin. Figure 18 shows that there are clear negative radial gradients in metallicity and extinction within IC 10 but not NGC 6822. The variation in IC 10 confirms the presence of significant amounts of internal extinction in that system. Both systems show positive radial gradients with age, whereby the cluster population becomes increasingly older further out, as expected.

### 7.6. Globular cluster scaling relations

The GC populations of dwarf galaxies are of particular interest given their likely role in building up the halos of more massive systems. Furthermore, a remarkable diversity in the GC populations of low-mass galaxies has been uncovered in recent years (e.g. Eadie et al. 2022; Jones et al. 2023; Saifollahi et al. 2025) and it is interesting to explore how NGC 6822 and IC 10 compare.

Unfortunately, there is no universally accepted definition of what constitutes a GC (see Gratton et al. 2019). In the MW and its satellites, GCs are generally identified as ancient halo, bulge and disc star clusters. On the other hand, accurate age information is rarely available in extragalactic studies, where we also only have knowledge of projected positions. Instead, extragalactic GC candidates are generally identified on the basis of magnitude, colour, and size information, using stellar population models to select clusters older than a few gigayears (e.g. Carlsten et al. 2022; Floyd et al. 2024; Lim et al. 2025). To define a sample of GCs that bridges both the MW and extragalactic conventions, we use the results of our visual classification along with the output of BAGPIPES. Specifically, we adopt the following criteria:

- Class = 1 or 2;
- Age  $\geq 5$  Gyr;
- $Z/Z_{\odot} \leq 0.2$ .

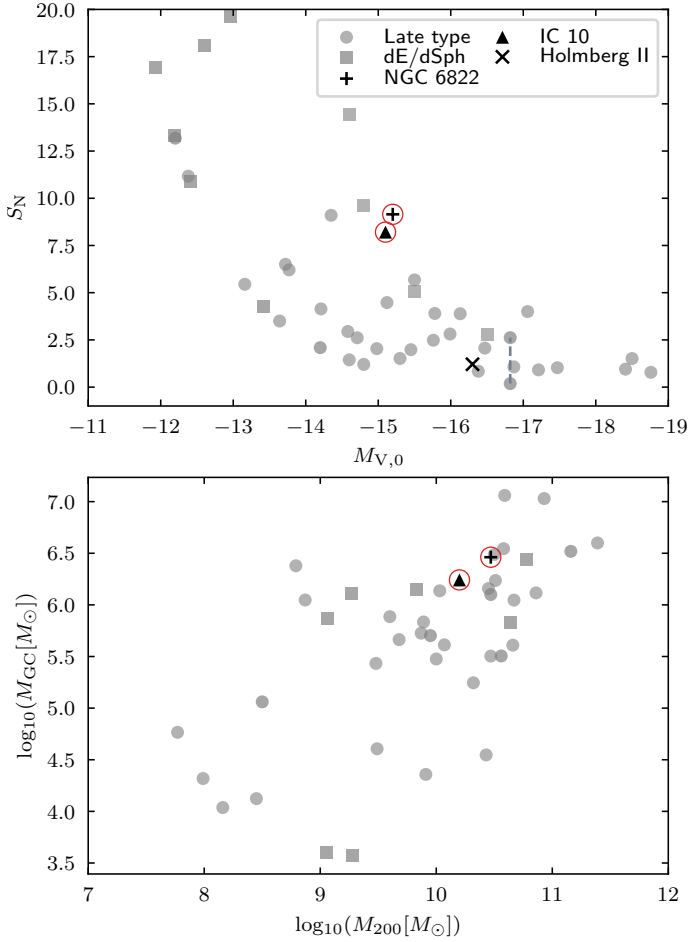
In dwarf galaxies, GCs are typically metal poor (e.g. Larsen et al. 2022), consistent with the mass-metallicity relation. For galaxies with stellar masses like NGC 6822 and IC 10, simulations suggest that star clusters formed 5 Gyr ago would be expected to have  $[\text{Fe}/\text{H}] \lesssim -1$  (Kruijssen 2019; Ma et al. 2016) and so we

apply a generous cut to exclude more metal-rich clusters. There is no well-established age criterion for a GC. In the MW, most GCs are  $\geq 10$  Gyr old, but there are also halo star clusters that are several gigayears younger (e.g. Weisz et al. 2016). Along with the metallicity cut, the age cut of 5 Gyr is designed to capture all long-lived metal-poor star clusters without being overly restrictive. We note that our selection criteria would retain all but one of the six GCs in the Fornax dSph galaxy. The excluded object would be Fornax 6, which has a spectroscopically derived metallicity of  $[\text{Fe}/\text{H}] = -0.71 \pm 0.05$  and an estimated age of  $\sim 2$  Gyr from Gaia photometry and MIST isochrone fitting (Pace et al. 2021). Given its young age and relatively high metallicity, Fornax 6 is arguably not what is typically considered to be a GC.

Figure 11 shows that the age cut adopted guarantees that all clusters are more massive than a few times  $10^4 M_{\odot}$ . With these criteria, we arrive at 6 GCs in NGC 6822, and 9 GCs in IC 10. Of the star clusters previously identified as NGC 6822 GCs, Hubble-VII, SC6, and 7 fall within our definition but SC3 does not. The SED-fitting routine assigns a rather young age (2.5 Gyr) and relatively high metallicity ( $Z/Z_{\odot} = 0.19$ ) to this cluster, which is the faintest of the known GCs in NGC 6822. Based on a previous spectroscopic analysis of this object (Hwang et al. 2014, see Table 7), as well as analysis of a deep HST CMD (McGill et al., in prep.), we believe the BAGPIPES fit is unreliable and that the cluster is older and more metal poor; we therefore include SC3 in the total number of NGC 6822 GCs. We further add in SC5, for which we could not perform SED-fitting due to lack of  $UBVRI$  coverage, as well as SC1, SC2, and SC4, all of which lie outside the *Euclid* FOV. This brings the total number of GCs in NGC 6822 to 11. The resulting GC candidates are flagged in the thumbnails shown in Appendix C and the spatial distribution of those that fall within the *Euclid* FoV are displayed as black points in Fig. 13. In both galaxies, the GCs exhibit extended distributions – in NGC 6822, 7 of the 11 GCs lie outside the galaxy half-light radius (indicated by dashed grey ellipse) while all 9 of the GCs in IC 10 lie outside of it. Interestingly, NGC 6822’s GCs appear to be preferentially located on the eastern side of the galaxy (this remains true even when considering the GCs outwith the *Euclid* footprint). The most obvious object for comparison is the SMC which, due to its proximity, has many cluster age and metallicity determinations from CMD fitting (e.g. Glatt et al. 2008). The SMC is generally considered to have only one old GC, NGC 121 (e.g. Forbes et al. 2018b)<sup>5</sup>. We use the Bica et al. (2020) catalogue to search for high-confidence star clusters (object class “C”) that satisfy our metallicity and age criteria. We find 14 SMC clusters fall within our definition of GC, which is slightly larger than the numbers found for NGC 6822 and IC 10.

The specific frequency of GCs, defined as the number of GCs per unit of galaxy luminosity, was introduced to measure the richness of GC systems in galaxies (Harris & van den Bergh 1981) and remains commonly used today. It is calculated as  $S_N = N_{\text{GC}} 10^{0.4(M_V+15)}$ , where  $M_V$  is the absolute  $V$ -band magnitude of the host galaxy and  $N_{\text{GC}}$  is the number of GCs. The  $S_N$  values are impacted by the galaxy’s recent star formation history, affecting its  $M_V$ , and the dynamical evolution history of its GCs, affecting its  $N_{\text{GC}}$ . Using the galaxy absolute magnitudes from Table 1, and  $N_{\text{GC}}$  of 11 and 9, we find that  $S_N$  is  $9.1 \pm 3.2$  and  $8.2 \pm 3.3$  in NGC 6822 and IC 10, respectively. The uncertainty in  $S_N$  reflects both Poisson noise in the GC counts and the reported uncertainty in  $M_V$ . These values are displayed in the top panel

<sup>5</sup> We note that two faint GC candidates have recently been discovered at large radius in the SMC but their true nature is not yet clear (Cerny et al. 2021; Cerny et al. 2023).



**Fig. 19.** Top: the GC specific frequency  $S_N$  versus absolute  $V$ -band magnitude  $M_V$  for nearby dwarf galaxies. NGC 6822 and IC 10 are shown by plus and triangle symbols enclosed in red circles. Each galaxy's  $N_{GC}$  is calculated from the number of clusters that are class 1 or 2 with ages larger than 5 Gyr and  $Z/Z_\odot \leq 0.2$ . The grey filled circles and squares represent a sample of LG and late-type galaxies taken from Forbes et al. (2018b). Bottom: the GC system mass-halo mass relation, where the halo mass is represented by  $M_{200}$ . The symbols are the same as in the top panel.

of Fig. 19, plotted against  $M_V$ . This plot also shows  $S_N$  and  $M_V$  values for the sample of LG and isolated late-type dwarf galaxies studied by Forbes et al. (2018b), which includes some of the systems originally presented in Georgiev et al. (2010). We add further datapoints from the recent studies by Karim et al. 2024 (IC 2574) and Larsen et al. 2025 (Holmberg II), and we include  $S_N$  values for the SMC calculated assuming both one and 14 GCs (connected via a dashed line). We see that NGC 6822 and IC 10 have high  $S_N$  values for their luminosity, and lie at the high end of the distribution when compared to the sample of dwarfs as a whole. This is particularly true when considering that this plot only shows dwarf galaxies that have at least one identified GC; many others show none at all. Of the three late-type galaxies with higher  $S_N$  values, one of them is the LG transition dwarf galaxy Pegasus (Cole et al. 2017) while the other two are more distant systems (Georgiev et al. 2010, KK 16 and UGC 685).

The bottom panel of Fig. 19 displays the GC system mass-halo mass relation. For NGC 6822 and IC 10, we calculate the total GC system mass by summing the individual cluster masses determined in this work. For clusters SC1, SC2, SC4, and SC5 in NGC 6822, which lie outside the data coverage for SED fitting,

we use luminosities from Veljanoski et al. (2015) and convert them to masses assuming a mass-to-light ratio of 1.88, consistent with the value adopted by Forbes et al. (2018b). We do the same for SC3, as the BAGPIPES fit returned a relatively young age for a globular cluster (2.5 Gyr). For IC 10, we adopt the total halo mass from Oh et al. (2015), while for NGC 6822 we use the halo mass reported by Forbes et al. (2018b). For the other galaxies shown, all values are taken directly from Forbes et al. (2018b). While there is much scatter in this scaling relationship at the low-mass end, the positions of NGC 6822 and IC 10 are consistent with expectations for galaxies of their halo mass.

## 8. Conclusions

We presented a detailed and homogeneous analysis of the star cluster systems in two LG dwarf galaxies, NGC 6822 and IC 10. We used images from the *Euclid* ERO programme to conduct a blind search for star clusters across the main bodies and into the remote halos of both systems. We classified star clusters into various confidence classes according to their appearance in  $I_E$  images, the highest spatial resolution imagery provided by *Euclid*. We undertook an extensive literature search to compile all previously identified star cluster candidates in these galaxies, and assigned classifications to them, too, based on  $I_E$  appearance. Each newly discovered or literature cluster was assigned to class 1, 2, 3, or 4, going from most likely to least likely. Two additional categories are used for literature candidates: class 5 indicates a source that does not resemble a cluster on *Euclid*  $I_E$  images, while class 6 denotes objects that are definitely not clusters in *Euclid*  $I_E$  images. Using archival LGGS  $UBVRI$  imagery in combination with *Euclid*  $I_E$ ,  $Y_E$ ,  $J_E$ , and  $H_E$  data, we derive homogeneous 9-band integrated photometry for our cluster sample, as well as size measurements. Furthermore, we used the BAGPIPES SED-fitting code to determine the age, mass, metallicity, and line-of-sight extinction to each cluster. Through injecting a range of artificial star clusters into the *Euclid*  $I_E$  images, we conclude that our sample is  $\sim 50\%$  complete to  $M \lesssim 10^3 M_\odot$  for ages  $\lesssim 100$  Myr, and to  $M \lesssim 2 \times 10^4 M_\odot$  for ages of  $\sim 10$  Gyr, in both galaxies.

Our star cluster study is unique in terms of its fidelity (with clusters being largely resolved and hence of high confidence), its probing nearly the full spatial extents of the two dwarfs, it being sensitive to both low- and high-mass clusters with a large variety of ages, and its systematic approach to deriving quantities of interest. It demonstrates how the high spatial resolution and NIR capabilities of *Euclid* can be effectively combined with ground-based optical photometry to enable comprehensive local volume star cluster studies – studies of this type will be increasingly common in the near future when *Euclid* Wide Survey data can be combined with the data from the Legacy Survey of Space and Time (Guy et al. 2022; Usher et al. 2023). The catalogues we release are intended to support a wide range of future investigations, including comparisons with resolved star CMD analyses. In this work, we focus on just a few specific topics.

Our primary results are listed below.

1. We identified 30 new clusters (classes one to four) in NGC 6822 and 16 in IC 10, taking the total candidates in these systems within our FoV to 52 and 71, respectively, when including those previously reported. An additional three previously known clusters in NGC 6822 lie outside our field of view. Additionally, we reclassified 21 and 32 previously identified candidates as either class 5 or 6.

2. The clusters identified have masses spanning from  $10^{1.7}$  to  $10^{6.1} M_{\odot}$ , and span ages from 10 Myr to 10 Gyr. IC 10 has more young clusters than NGC 6822, and its young clusters also reach higher masses ( $\geq 10^4 M_{\odot}$ ), consistent with this galaxy having a higher truncation mass on account of its higher SFR surface density. We found several examples of old massive ( $\geq 10^5 M_{\odot}$ ) clusters in both dwarfs that could be the descendants of the young star clusters recently uncovered in low-mass galaxies at high redshift (e.g. Mowla et al. 2024; Adamo et al. 2024). We highlighted the existence of a particularly exceptional object in the outskirts of NGC 6822, SC7, for which we made the first mass determination of  $10^{6.1} M_{\odot}$ , rivalling the most massive GC in the MW. Combined with its high ellipticity and moderately high metallicity, this object bears many hallmarks of being the accreted core of a now-defunct smaller system.
3. We examined the spatial distribution of the star clusters as a function of age in each system. In NGC 6822, the young clusters trace out an elongated N-S structure aligned with the bar, whereas the intermediate-age and old clusters have increasingly circular distributions. These strongly age-dependent spatial distributions are also seen in IC 10, with its young clusters primarily elongated in a northeast–southwest direction.
4. The size-magnitude distribution of the old star clusters is broadly consistent with that of the MW as well as that of GCs in nearby late-type galaxies. In NGC 6822, we observed an increase in the spread of half-light radii at faint magnitudes that is not seen in IC 10. Previous work has demonstrated that NGC 6822 hosts a population of extended GCs, and we identified a new example in this work, ESCC-NGC6822-27, which has  $R_h = 12.4 \pm 0.11$  pc, an age of  $2.1 \pm 0.3$  Gyr, a mass of  $\log_{10}(M/M_{\odot}) = 4.4 \pm 0.04$ , and a metallicity of  $Z/Z_{\odot} = 0.03 \pm 0.01$ .
5. We constructed age-metallicity relationships for both systems and observed the expected behaviour of the most recently formed clusters having the highest metallicities and the older clusters having lower metallicities. Beyond  $\sim 10^8$  yr, the age-metallicity relation is essentially flat to within the uncertainties in both systems, with metallicities at a given age being higher in IC 10 than in NGC 6822. The age-metallicity relationships revealed a few hints of systematics in the SED-fitting outputs, and a more detailed examination will require either CMD fitting or spectroscopy. The IC 10 cluster population exhibits clear negative radial gradients in metallicity and extinction but NGC 6822’s does not. Both systems show positive radial gradients with age, whereby the cluster population becomes increasingly older further out, as expected.
6. Lastly, we used well-defined criteria to select a subsample of clusters as candidate GCs; this yields 11 objects in NGC 6822 (folding in objects from previous studies) and 9 in IC 10. The GCs are more broadly distributed than other star clusters, with 7 of the 11 GCs lying outside the galaxy half-light radius in NGC 6822 and all 9 of the GCs in IC 10 lying outside of it. We placed the systems on the well-known GC scaling relations and found that both galaxies have high  $S_N$  values for their luminosity, and lie at the high end of the distribution when compared to the population of dwarfs as a whole. We note that although the new star clusters uncovered in this work have increased the GC count in both galaxies, more GCs may still await detection. Indeed, the *Euclid* ERO images do not cover the entire halos of these systems, where

more GCs may reside (including 3 previously known GCs in NGC 6822). This highlights the need for systematic, high-sensitivity, wide-field surveys of dwarf galaxies to obtain an accurate census of their GC populations.

## Data availability

Tables 2, 3, B.1, B.2, B.3 and B.4 are available at the CDS via <https://cdsarc.cds.unistra.fr/viz-bin/cat/J/A+A/706/A185>.

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## Appendix A: The effects of stochasticity

Stochastic sampling of the IMF can affect the integrated colours of lower-mass clusters. Fouesneau & Lançon (2010) showed that using continuous population models to analyse low-mass clusters (around  $10^4 M_\odot$  and below) often leads to age underestimation. This bias also affects mass estimates, as younger models are more luminous per unit mass than older ones. While underestimation was more common, some ages were overestimated, as clusters with an excess of luminous stars above the average predicted by continuous models tend to be very red. Additionally, Popescu & Hanson (2010) demonstrated that, at these low masses, clusters may appear much redder and older than they would if their IMF was fully sampled, primarily affecting clusters with ages less than  $\sim 10$  Myr but still evident at all ages in clusters below  $10^3 M_\odot$ . Offsets to bluer colours exist too, but their amplitudes are less significant.

To explore the contribution of stochasticity to our photometric uncertainties, we divided the circular aperture used for colour determination into halves, slicing it at five different angles. We then calculated the  $B - V$  and  $Y_E - H_E$  colours in each half (ten measurements in total for each cluster) and computed the standard deviation of these colour estimates for each cluster as a measure of internal colour variation. If stochastic fluctuations were dominant, we would expect to see significant variation in colour across a given aperture. In IC 10, the variation in the  $B - V$  colours increased significantly at  $I_E$ -band magnitudes below  $\sim 20.5$ , indicative of stochastic effects, but no correlation was apparent in  $Y_E - H_E$  or in NGC 6822 at all. Furthermore, the median and interquartile ranges of our measured colour variations closely match the corresponding median photometric uncertainties and interquartile ranges in both NGC 6822 and IC 10. Taken together, this suggests that measurement uncertainties unassociated with stochastic sampling of the LF are the dominant source of the observed colour variations.

We next proceeded to examine the impact of the colour variations measured above on the inferred masses and ages. We adopt fiducial colour intervals of  $B - V = 0.7 \pm 0.1$  and  $Y_E - H_E = 0.0 \pm 0.1$ , where the widths reflect the maximum uncertainties typically seen in our measurements described above. We explore the properties of low-mass clusters ( $\leq 10^4 M_\odot$ ) computed using stochastic population models with pypégase (Fouesneau & Lançon 2010), focusing on those that fall within our adopted colour intervals. By extracting the ages of all synthetic clusters within these colour ranges, we find that the age distributions remain largely independent of  $I_E$ -band magnitude, despite the stochastic effects. Furthermore, the spread in age estimates is comparable to the typical uncertainties from SED fitting.

To test the robustness of BAGPIPES in producing cluster property uncertainties commensurate with the photometric uncertainties, we drew 100 synthetic photometric realisations from the observed magnitudes and photometric uncertainties of each cluster in IC 10, and re-fit each realisation with BAGPIPES. We found agreement between the standard deviation of the resulting fits for each cluster and the single-fit posterior uncertainties. Additionally, we investigated whether the discrepancies between our age measurements and those reported in L15 (shown in Fig. 9) could arise from stochastic effects. To do this, we examined whether the age offsets between our results and those of L15 correlate with the standard deviations derived from the above 100 realisations per cluster. No correlations were apparent.

While we have not found strong evidence for stochasticity influencing our results, it will nevertheless be present. The tests that we have performed are quite limited and a more detailed exploration, including sampling across the full colour space, examining the effects of varying metallicity and invoking cluster luminosity as an additional age constraint, should be pursued in future work. Given their proximity, NGC 6822 and IC 10 provide excellent laboratories for testing and refining stochastic models at low metallicity, since many of the younger clusters can be resolved into individual stars with HST and hence also studied via CMD fitting. As demonstrated by Johnson et al. (2022), comparison of CMD-derived parameters with SED-fitted ones provides a valuable assessment of the performance of stochastic modelling of star clusters in the low-mass regime.

## Appendix B: Tables of photometry and properties of star clusters

In these tables, we list the results of our photometry and SED-fitting analysis of the clusters (classifications 1–4). The tables include IDs,  $UBVRI$  photometry, *Euclid*  $I_E Y_E J_E H_E$  photometry,  $R_h$  in pc, ages in Gyrs,  $\log_{10}(M/M_\odot)$  for both initial mass formed and living stellar mass, metallicities (expressed in terms of  $Z/Z_\odot$ , where  $Z_\odot = 0.02$ ) and  $A_V$  values for each cluster. Total apparent magnitudes for  $V$  band and  $Y_E$  band are provided alongside colours to convert to the remaining bands. We provide only the first six rows here; full tables are available at the CDS.

**Table B.1.** NGC 6822 magnitudes, colours and half-light radii. The full table is available at the CDS.

ID	Vmag	e_Vmag	B-V	e_B-V	U-B	e_U-B	V-R	e_V-R	R-I	e_R-I	YEmag	e_YEmag	YE-HE	e_YE-HE	JE-HE	e_JE-HE	IE-HE	e_IE-HE	Rh	e_Rh
ESCC-NGC6822-01	16.09	0.02	0.42	0.04	-0.16	0.07	0.36	0.03	0.45	0.04	15.95	0.03	-0.04	0.01	0.05	0.06	0.07	0.05	3.09	0.14
ESCC-NGC6822-02	15.57	0.02	0.87	0.01	0.1	0.01	0.61	0.01	0.63	0.01	14.57	0.01	0.1	0.01	0.0	0.01	0.66	0.01	2.27	0.37
ESCC-NGC6822-03	17.43	0.02	0.72	0.01	0.25	0.02	0.49	0.01	0.52	0.01	16.34	0.07	-0.06	0.03	-0.05	0.03	0.4	0.03	5.69	0.77
ESCC-NGC6822-04	17.91	0.03	0.63	0.01	0.23	0.01	0.44	0.01	0.47	0.02	17.01	0.14	-0.23	0.08	-0.14	0.08	0.07	0.06	3.09	0.54
ESCC-NGC6822-05	18.06	0.02	0.89	0.01	0.27	0.02	0.57	0.01	0.55	0.01	16.91	0.03	0.0	0.01	-0.03	0.01	0.54	0.01	7.15	0.17
ESCC-NGC6822-06	20.48	0.06	0.99	0.09	0.37	0.19	0.61	0.07	0.47	0.07	18.66	0.02	0.02	0.03	0.0	0.03	0.65	0.02	9.49	0.37

**Table B.2.** IC 10 magnitudes, colours and half-light radii. The full table is available at the CDS.

ID	Vmag	e_Vmag	B-V	e_B-V	U-B	e_U-B	V-R	e_V-R	R-I	e_R-I	YEmag	e_YEmag	YE-HE	e_YE-HE	JE-HE	e_JE-HE	IE-HE	e_IE-HE	Rh	e_Rh
ESCC-IC10-01	19.0	0.05	1.27	0.04	0.48	0.05	0.86	0.03	0.88	0.03	17.0	0.03	0.31	0.01	0.12	0.01	1.35	0.01	2.65	0.07
ESCC-IC10-02*	21.28	0.08	0.94	0.12	0.22	0.11	0.61	0.12	0.76	0.12	20.76	0.33	-0.38	0.86	-0.32	0.92	0.21	0.8	1.89	0.3
TG3	21.69	0.07	1.02	0.1	-0.1	0.1	0.76	0.09	1.12	0.09	19.29	0.04	0.8	0.05	0.42	0.05	2.2	0.04	1.05	0.31
ESCC-IC10-03	19.87	0.07	1.16	0.05	0.61	0.07	0.85	0.04	0.9	0.04	18.12	0.13	0.45	0.05	0.25	0.05	1.53	0.04	2.58	0.11
ESCC-IC10-04	20.42	0.09	1.01	0.06	0.19	0.07	0.67	0.05	0.8	0.06	19.86	0.45	-0.02	0.27	-0.02	0.3	0.74	0.25	2.13	0.12
TG6	20.46	0.04	0.94	0.07	0.25	0.08	0.82	0.06	0.87	0.06	18.91	0.42	0.77	0.13	0.4	0.13	1.92	0.09	1.15	0.16

**Table B.3.** NGC 6822 SED-fitting results. The full table is available at the CDS.

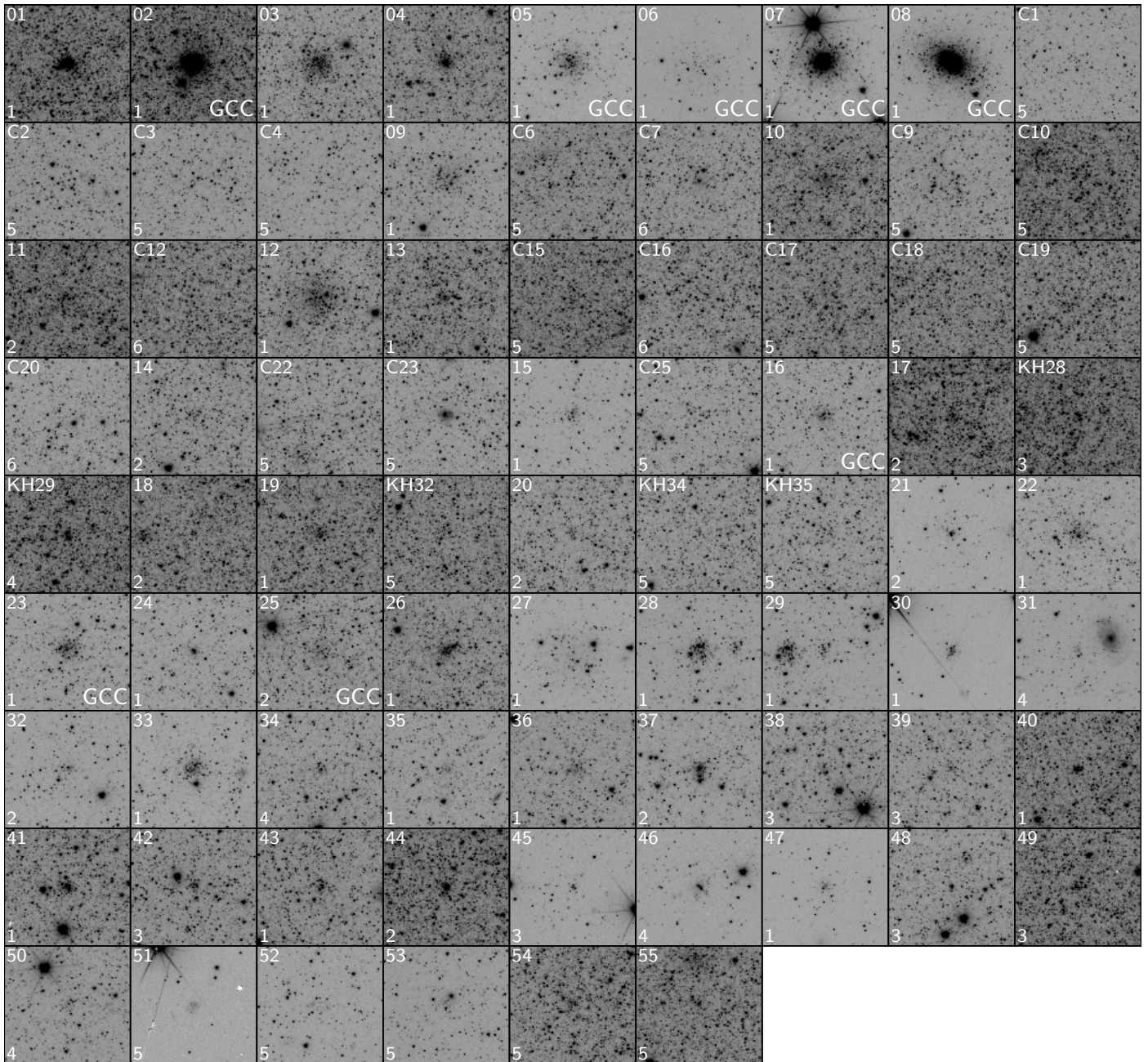
ID	Age	e_Age	Mass	e_Mass	Living Mass	e_Living Mass	Z/Z_0	e_Z/Z_0	AV	e_AV
ESCC-NGC6822-01	0.1	0.05	4.44	0.03	4.30	0.02	0.03	0.01	0.73	0.09
ESCC-NGC6822-02	6.21	0.82	5.81	0.04	5.45	0.03	0.04	0.01	0.78	0.03
ESCC-NGC6822-03	0.7	0.18	4.46	0.03	4.24	0.02	0.24	0.05	1.02	0.15
ESCC-NGC6822-04	0.55	0.11	4.15	0.05	3.95	0.04	0.17	0.09	0.96	0.18
ESCC-NGC6822-05	2.49	0.31	4.52	0.03	4.23	0.04	0.19	0.02	0.67	0.06
ESCC-NGC6822-07	8.17	1.29	5.73	0.04	5.37	0.03	0.03	0.01	0.64	0.02

**Table B.4.** IC 10 SED-fitting results. The full table is available at the CDS.

ID	Age	e_Age	Mass	e_Mass	Living Mass	e_Living Mass	Z/Z_0	e_Z/Z_0	AV	e_AV
ESCC-IC10-01	7.5	4.54	5.36	0.24	4.85	0.22	0.07	0.02	2.12	0.14
ESCC-IC10-02	0.07	0.01	3.23	0.04	3.05	0.02	0.06	0.01	3.61	0.08
TG3	0.13	0.03	3.64	0.04	3.39	0.02	0.36	0.12	2.53	0.06
ESCC-IC10-03	0.63	0.25	4.41	0.1	4.08	0.04	0.1	0.01	2.65	0.15
ESCC-IC10-04	0.08	0.02	3.58	0.05	3.42	0.02	0.06	0.01	2.51	0.05
TG6	0.15	0.07	3.81	0.07	3.58	0.04	0.26	0.16	2.72	0.16

### Appendix C: Cutouts of clusters

Here we present cutouts of all objects in the final catalogues (class 1–6), including newly-identified clusters, previously-known candidates and previously-identified candidates that do not appear as clusters in the *Euclid*  $I_E$  images.



**Fig. C.1.** Thumbnails of all clusters and candidate clusters in NGC 6822 shown in asinh scaling. New and recovered candidates display their *Euclid* ID in the top left corner and candidates that were not recovered in this work display their previous literature IDs. New clusters from this study start from *Euclid* ID 21 onwards. Classifications are indicated in the bottom left of each subplot. Clusters satisfying our definition of GC are indicated by a ‘GCC’ label in the bottom right of each subplot. Thumbnails are  $28''0$  on the side, corresponding to  $\sim 70$  pc at the distance of NGC 6822.

