Lazar et al. 2024 (a), MNRAS, 529, 499-518

Lazar et al. 2024 (b), MNRAS, 533, 3771-3783

The morphological mix of dwarf galaxies in the nearby Universe

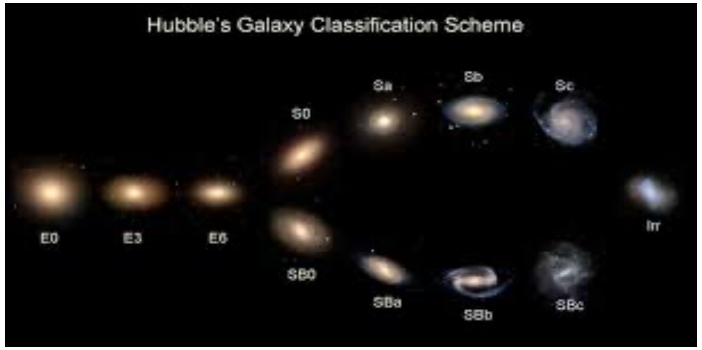
I. Lazar (Hertfordshire), S. Kaviraj (Hertfordshire), A. E. Watkins (Hertfordshire), B. Bichang’a (Hertfordshire), R. Jackson (private sector) and G. Martin (Nottingham)

Morphology – a key tracer of galaxy evolution

- The morphological properties of a galaxy are driven by the small and large-scale processes that act on it over its lifetime

- Two main types of processes:
    - Internal – e.g stellar and AGN feedback (e.g. Beckmann +17), stellar bar dynamics (Maiolino et al. 2012)
    - External – e.g minor or major merger (Kaviraj 2014), RAM pressure stripping, starvation, accretion events (e.g Cooper et al. 2006, Peng et al. 2010)

- Correlation exists between these processes and the formation of Hubble types (e.g Aumer et al. 2012, Nogueira-Cavalcante et al. 2017 Martin et al. 2018, Jackson et al. 2022).



Morphology – dwarf galaxies outside the Local Group

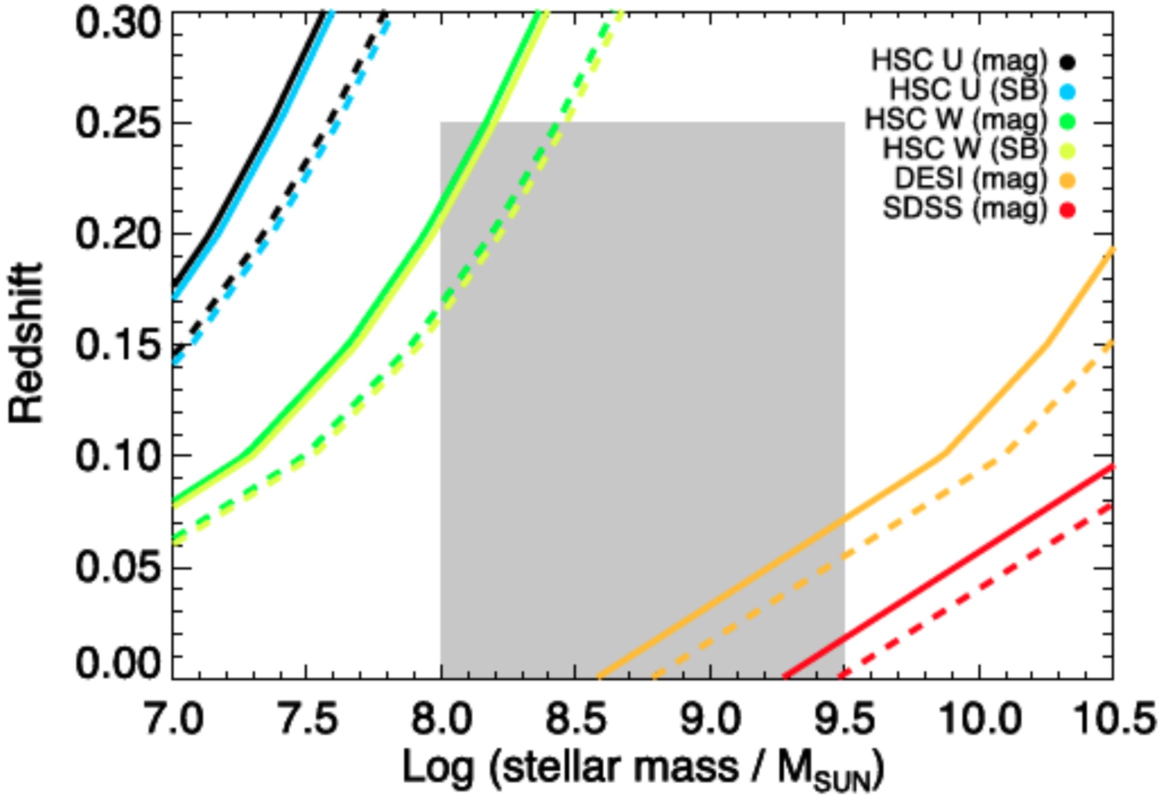
- There are various studies of dwarf galaxies in the Local Volume or very Local Universe ($z < 0.01$) (e.g. Thompson et al., 1993, Tolstoy et al., 2009, Sanjaya et al., 2023)

- Lack of statistical and unbiased studies

- Dwarfs – biased towards anomalously

high SFRs

- Difficult (impossible!) to obtain unbiased results when studying dwarfs morphologies in shallow surveys like SDSS – **need deep-wide surveys**

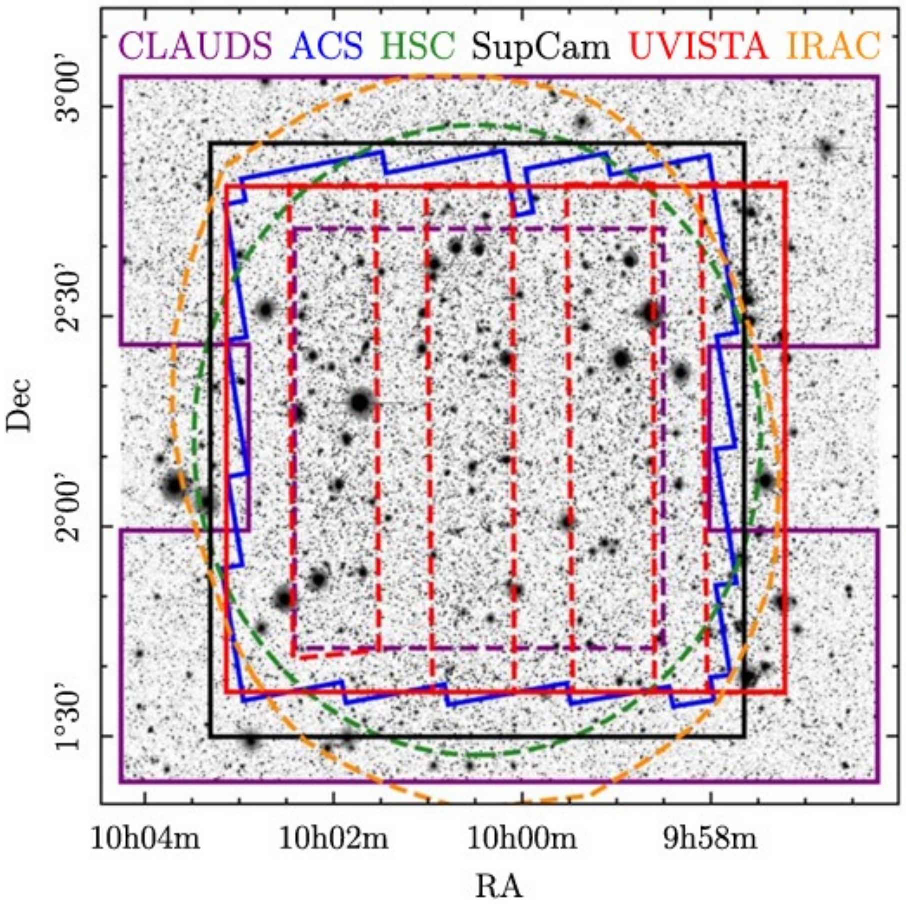


Completeness limits based on stellar population synthesis models from Bruzual et al. 2003. Credit: Kaviraj et al. (2025)

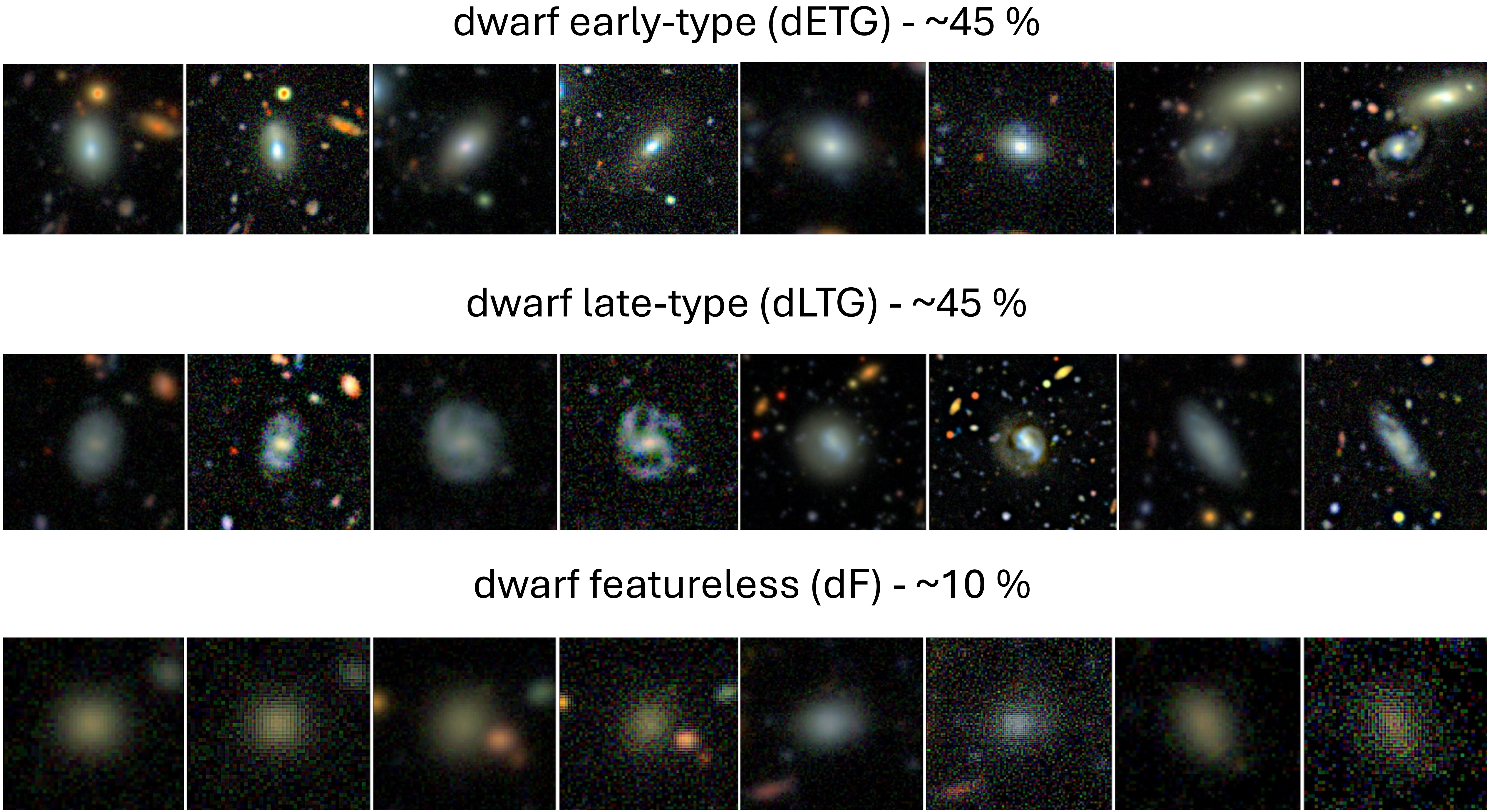
Lazar et al. 2024 (a and b)

Dwarf morphological pilot study - data

- Deep Hyper Suprime-Cam imaging (i<28 mag, PSF~0.6 arcsec) + COSMOS2020 catalog (Weaver et al. 2022)
- Pilot study for LSST 10 year data
- COSMOS field – average to low density environment for z<0.1
- $z < 0.08$; $10^8 < M_\star < 10^{9.5}\ M_\odot$
- Sample of ~250 dwarfs
- One of the first unbiased dwarf morphological studies in terms of colour (outside of the very Local Universe)



COSMOS2020 multiband sky footprints.
Credit: Weaver et al. 2022.


dwarf early-type (dETG) - ~45 %
dwarf late-type (dLTG) - ~45 %
dwarf featureless (dF) - ~10 %

Galaxy interactions

- Interactions in dLTGs – factor of 2 higher than in high mass regime (e.g. Kaviraj 2014)

- Interactions in dETG – **factor of 5 lower** than in high mass regime (van Dokkum 2005)

- Dust lanes as signposts for merger activity in massive ETGs (e.g. Kaviraj et al. 2012) – **only one dETG** has a dust lane

- Evolution of dETGs – less to do with interactions (Lazar et al. 2023, 2024)

- dFs – only 20 % show signs of interactions (not formed via interactions)

Interaction fractions in different morphological classes

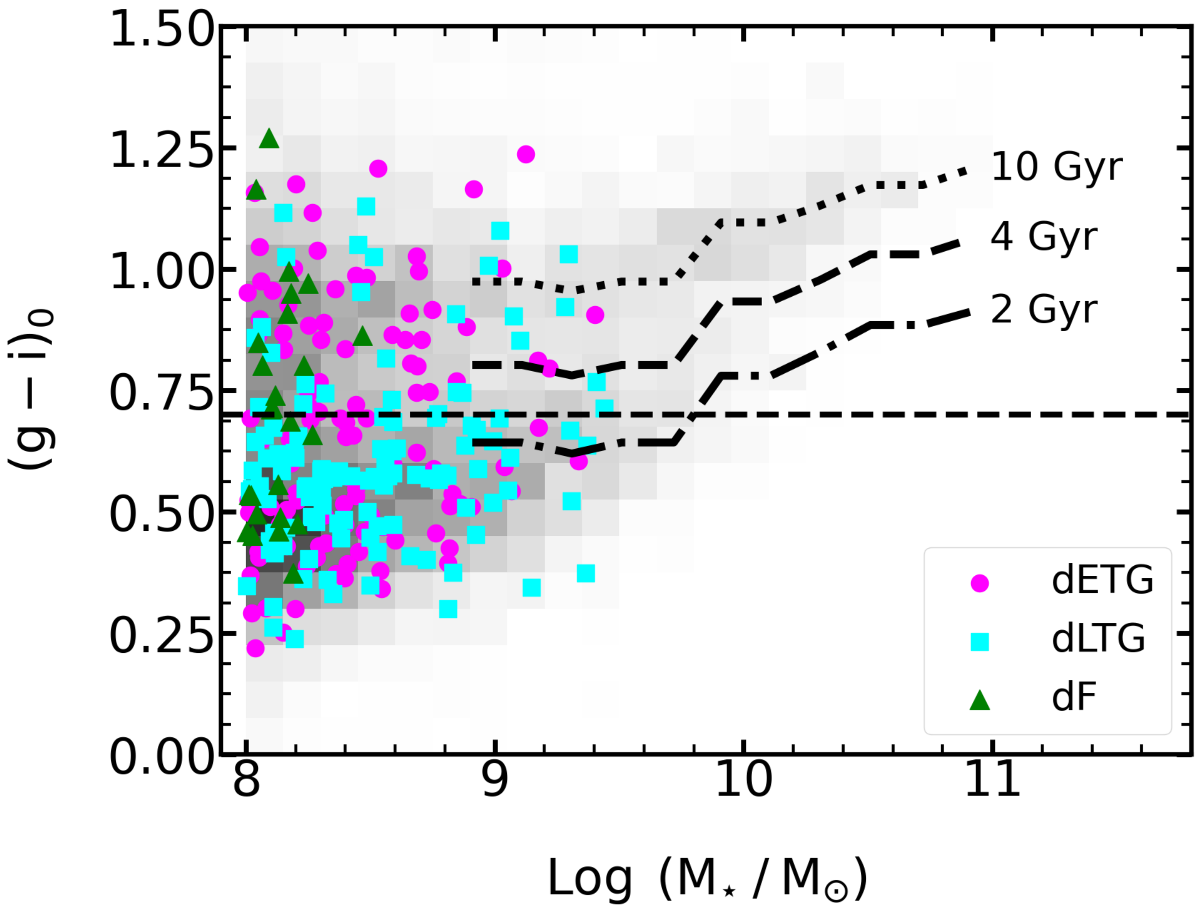
	$10^8\ \mathrm{M}_\odot < M_\star < 10^{9.5}\ \mathrm{M}_\odot$
dETG	$\mathbf{0.14^{0.03}}$
dLTG	$\mathbf{0.28^{0.04}}$
dF	$\mathbf{0.20^{0.07}}$

Rest frame colours

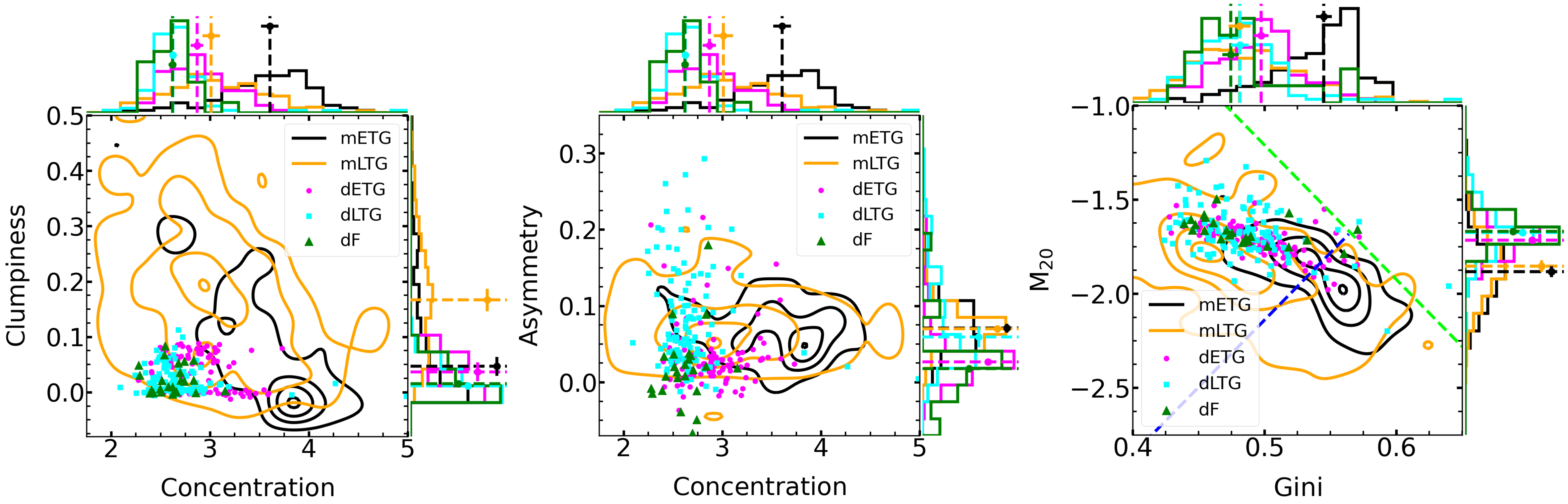
- dETGs:
    - **~60 % of dETGs are blue** (g – i < 0.7) – different from their massive counterparts
    - likely to have had SF activity in the last 4 Gyrs

- dFs:
    - $M_{med} \sim 10^{8.2}\ M_{\odot}$ + low incidence of tidal features + location in low density environments
    - Evolution – likely dominated by stellar feedback due to shallow potential wells

	Red fractions
dETG	$0.41^{0.04}$
dLTG	$0.23^{0.03}$
dF	$0.52^{0.09}$

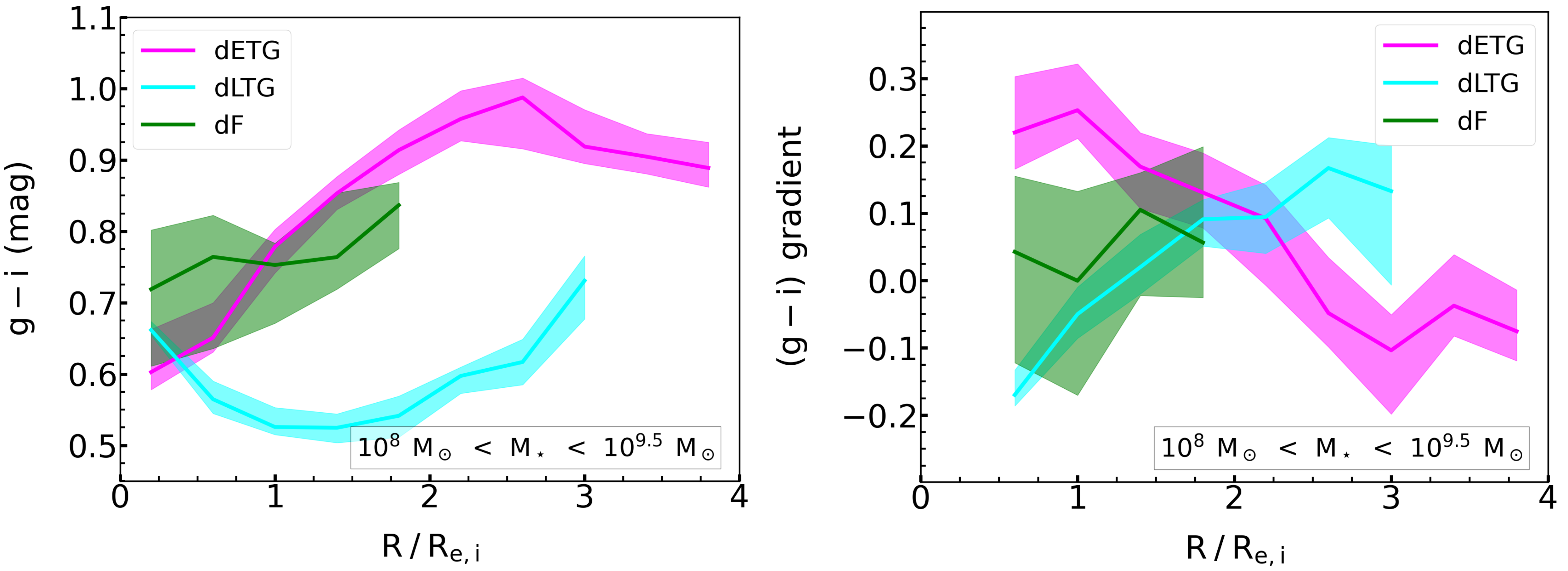


Dwarf morphologies – structural parameters



- Contrary to high mass regime it is challenging to separate dETG and dLTGs via traditional parameters e.g. CAS, Gini, M_{20}
- **dETGs – generally lower in concentration by factor of ~1.4 than massive ETGs** ⟶ divergence in main evolutionary channels dETGs VS massive ETGS

Colour profiles



- Colour profiles of dwarf and massive ETGs are significantly different
- Inside-out stellar growth in massive ETGs, outside in growth in dETGs

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Summary

- dETG, dLTG and dF fractions - ~45%, ~45%, 10%
- Evidence for differences in photometric and structural properties between dwarf and massive regimes
  - dLTG: possibly more susceptible to morphological transformation
  - dETG:
    - Tidal interactions – factor of 5 lower than in massive ETGs
    - 60% of dETGs are blue – likely to have had SF activity in the last 4 Gyr
    - Significantly less concentrated (factor of ~1.4) than massive ETGs
    - Dust lane signs – only one dwarf
    - Positive color gradients – inside-out mass assembly model not likely

dETG evolution is likely dominated by secular processes

- dF -- class inexistent in the high mass regime
  - Reside in average to low density environments (COSMOS field at $z < 0.08$)
  - Low interaction fraction (≈ 20 percent)
  - Have low gravitational potential wells (i.e. $\mathrm{Log}(M_\star) < 8.5\ M_\odot$)

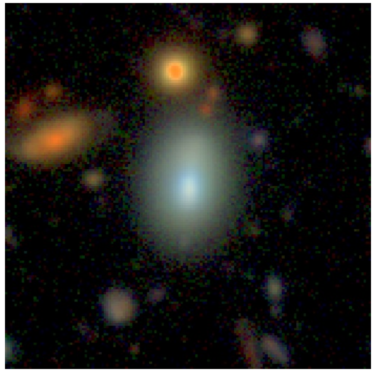
dFs are likely to evolve through feedback

Future plans – Spectroscopic observations

- Morpho-kinematic studies - Spectroscopic observations of dwarfs of stellar content and HI gas with an emphasis on dwarf ellipticals and featureless

- Featureless: are they pressure or rotation supported? What are their metallicities? Any evidence for AGN?

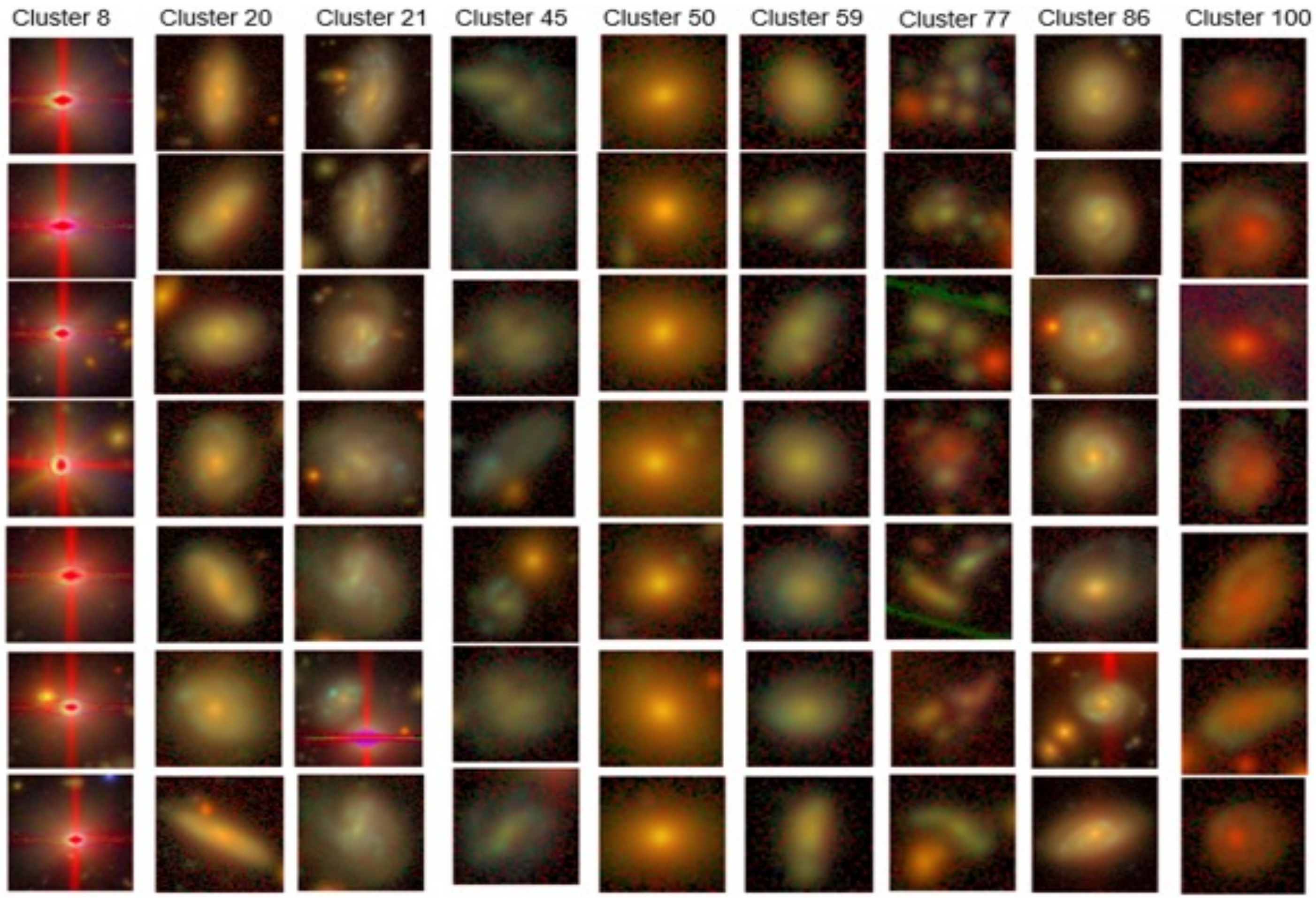
- dETG: what are the SFRs in the blue cores? Is the SFR driven by metal rich or metal poor gas?



Future plans – Unsupervised Machine Learning

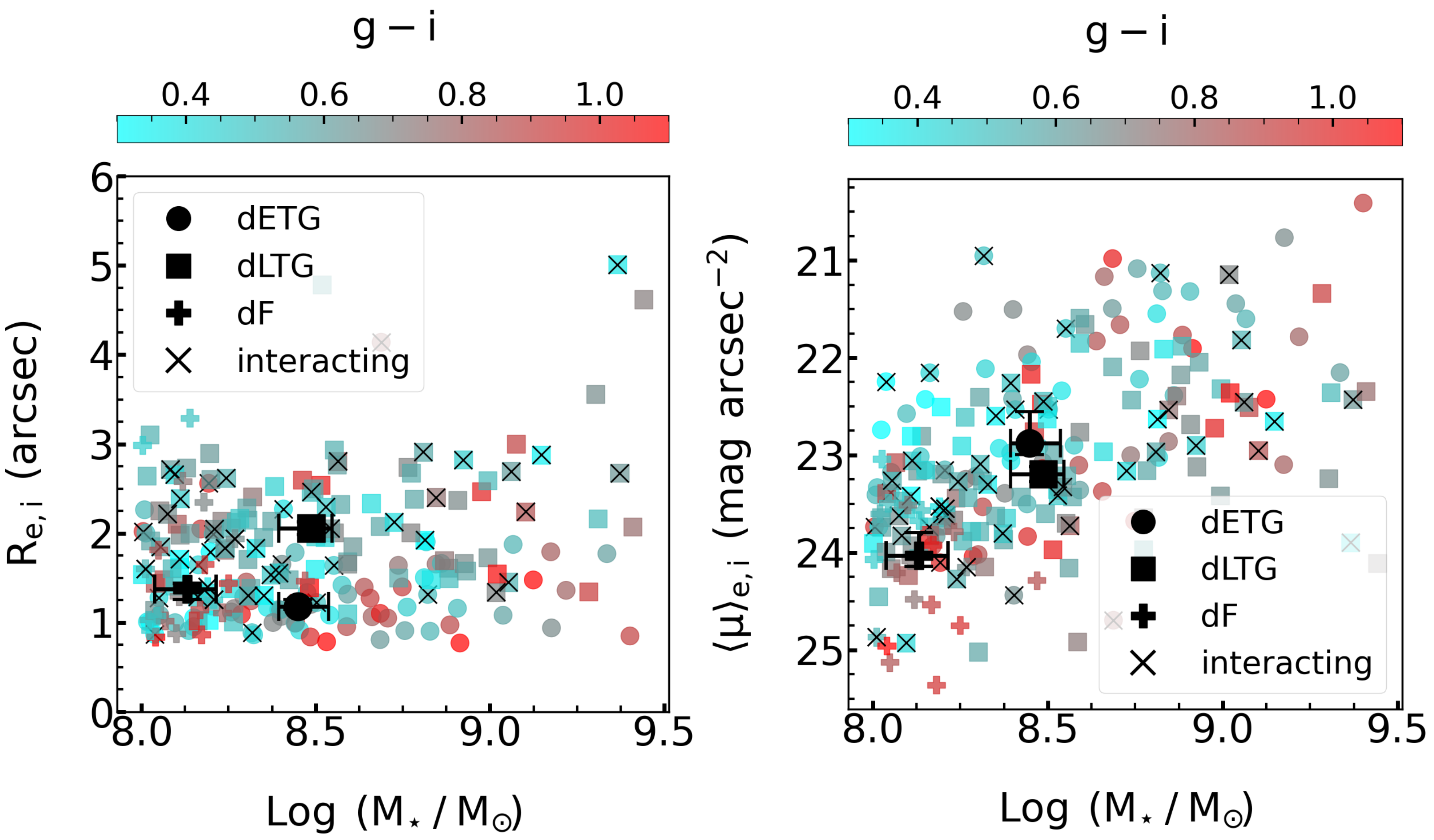
Hocking et al. 2018, Martin et al, 2020, Lazar et al. (in prep)

GitHub link:



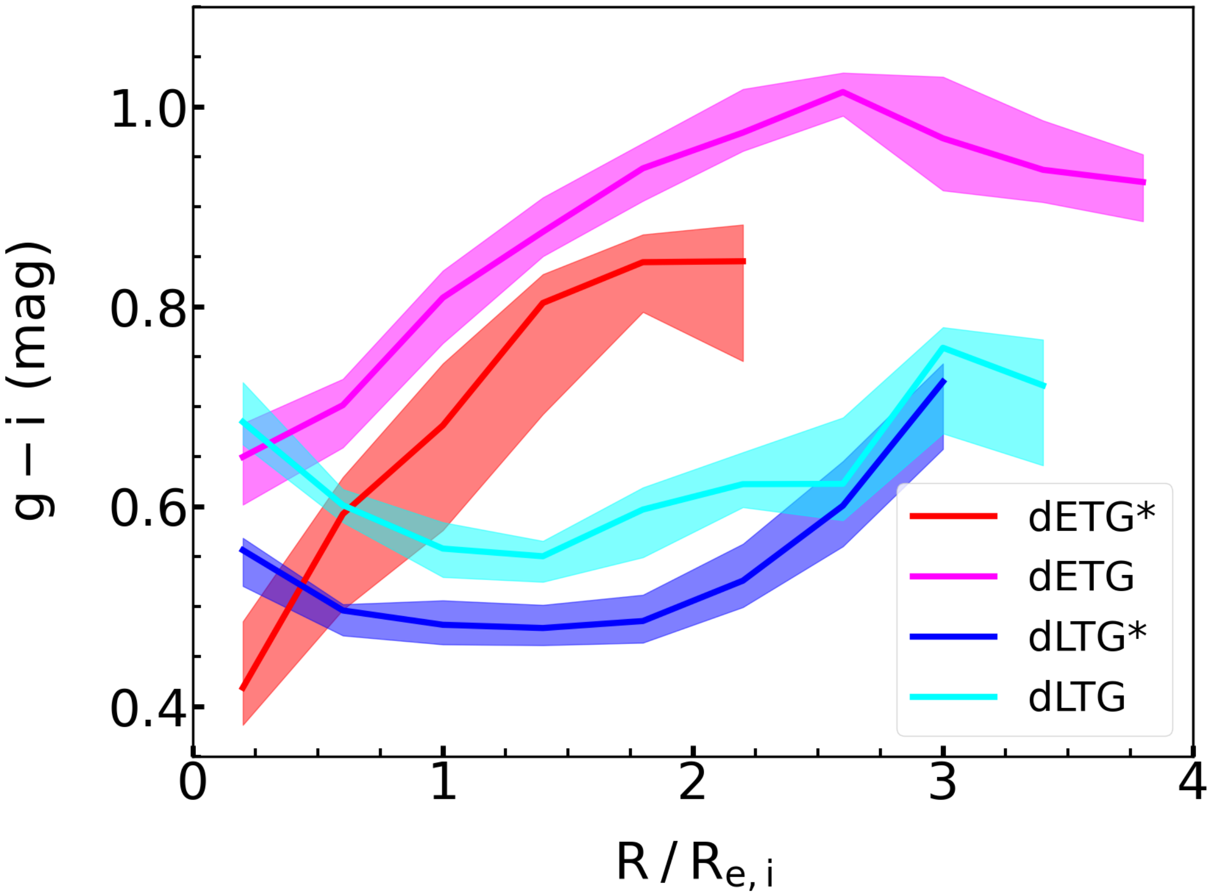
- Based on several clustering algorithms currently processing data at 1 deg^2/hr at LSST 20 yr depth
- Deployment of code on Euclid and LSST data – study the dwarf regime in unprecedented detail

Effective radii and surface brightness



- R_e (LTG)/R_e (ETG) ~ 2 - similar to high mass regime ($M_\star \sim 10^{10.5}$ $M_\odot$)
- μ_e (LTG)/μ_e (ETG) ~ 0.9 – marginal difference
- Featureless dwarfs differ from dETGs in μ_e – different formation channels

Colour profiles



- Galaxy interactions enhance star formation across the **whole** galaxy