The LSST Galaxies Science Collaboration

Sugata Kaviraj

LSST@LATAM 3
3 Nov 2026



LSST Galaxies Science Collaboration

Scientific goals



Core goal: perform extra-galactic science using the LSST over of cosmic time

- **Revolutionary statistics** across full spectrum of extra-galactic studies
- **Vast discovery space in the 'low-surface-brightness' regime** (e.g. dwarfs outside local group, intra-cluster light, faint galaxy outskirts, tidal features)
- **Statistical studies of rare and/or extreme objects** (e.g. starbursts, massive high-z systems)
- **Intersection with computer science** will drive new technologies (e.g. machine learning) for big data astrophysics

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Roadmap

arXiv:1708.01617v1 [astro-ph.GA] 4 Aug 2017

Large Synoptic Survey Telescope
Galaxies Science Roadmap

Robertson, Brant E.[1], Banerji, Manda[2], Cooper, Michael C.[3], Davies, Roger[4], Driver, Simon P.[5], Ferguson, Annette M. N.[6], Ferguson, Henry C.[7], Gawiser, Eric[8], Kaviraj, Sugata[9], Knapen, Johan H.[10,11], Lintott, Chris[4], Lotz, Jennifer[7], Newman, Jeffrey A.[12], Norman, Dara J.[13], Padilla, Nelson[14], Schmidt, Samuel J.[15], Smith, Graham P.,[16], Tyson, J. Anthony[15], Verma, Aprajita[4], Zehavi, Idit[17], Armus, Lee[18], Avestruz, Camille[19], Barrientos, L. Felipe[14], Bowler, Rebecca A. A.[4], Bremer, Malcolm N.[20], Conselice, Christopher J.[21], Davies, Jonathan[22], Demarco, Ricardo[23], Dickinson, Mark E.[13], Galaz, Gaspar[14], Grazian, Andrea[24], Holwerda, Benne W.[25], Jarvis, Matt J.[4,26], Kasliwal, Vishal[27,28,29], Lacerna, Ivan[30,14], Loveday, Jon[31], Marshall, Phil[32], Merlin, Emiliano[24], Napolitano, Nicola R.[33], Puzia, Thomas H.[14], Robotham, Aaron[5], Salim, Samir[34], Sereno, Mauro[35], Snyder, Gregory F.[7], Stott, John P.[36], Tissera, Patricia B.[37], Werner, Norbert[38,39,40], Yoachim, Peter[41], Borne, Kirk D.[42], and Members of the LSST Galaxies Science Collaboration

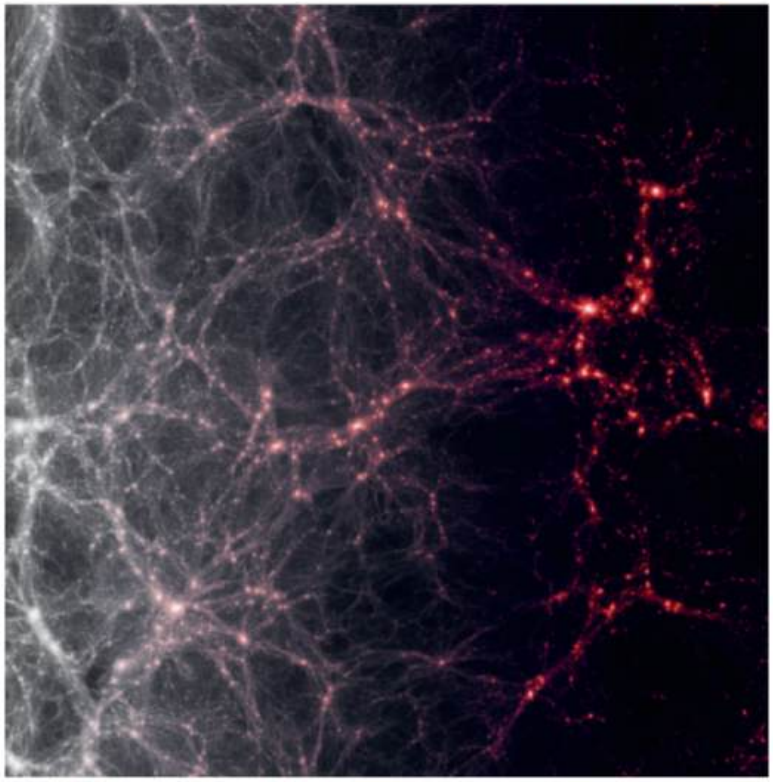
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Robertson +17, ArXiv:1708.01617

nature REVIEWS

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PHYSICS



Robertson +19, Nature Rev. Phys, 1, 450

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Organizational structure



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Active infrastructure work – key themes

- **Low-surface-brightness science**
  - Preserving LSB flux in LSST images + detection and deblending in LSB-friendly images
  - Subtraction of bright stars to large radii
  - Automated detection of faint/dwarf galaxies
  - Detection and characterisation of faint LSB structures

- **Galaxy structure and morphology**
  - Structure/morphology using parameters and ML
  - Spatially resolved properties of galaxies

- **Estimation of physical properties and distance parameters**
  - Photo-zs (e.g. using methods like DEmP)
  - Physical properties from broadband SED fitting using CIGALE, BAGPIPES and PROSPECTOR
  - Distance estimation using SBF

- **Star cluster detection and characterisation**

- **Cross-matching Rubin with ancillary datasets (e.g. MeerKAT, VISTA)**

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LSB-optimised LSST pipeline

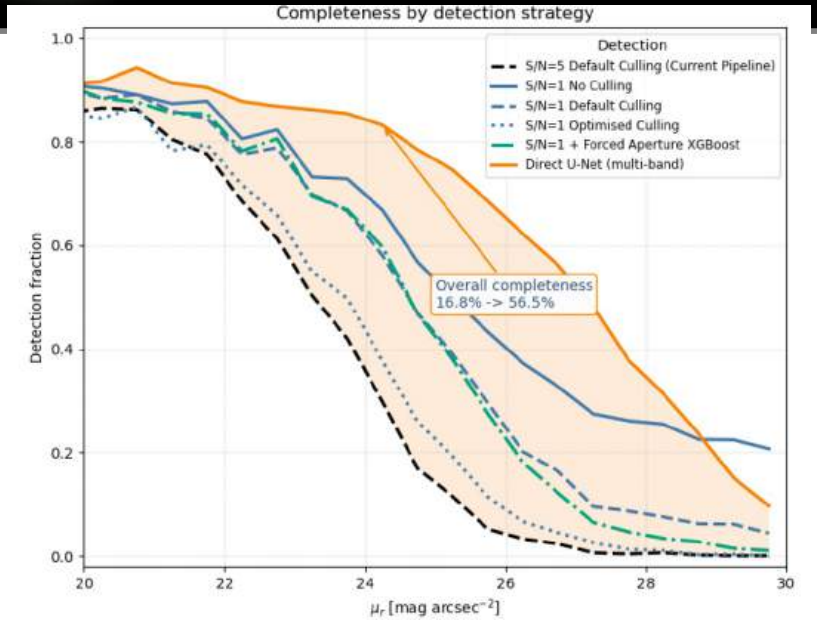


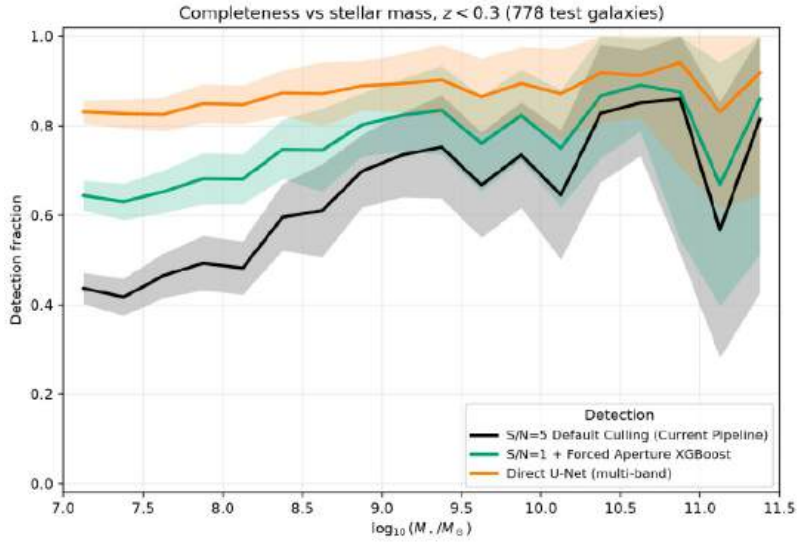
A. Watkins, A. Bazkiaei, S. Brough and the Rubin DM team

- Much of LSST's discovery space is in the low-surface-brightness (LSB) regime
- Theoretical 10-year SB depth is ~30 mag arcsec^{-2} but achieving this requires pipeline optimisation
- Several potentially significant issues e.g.:
  - Sky over-subtraction
  - Shredding of large objects
  - Incomplete source detection
  - Ghosts and scattered light due to bright stars

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Source detection and deblending





- Faint, low-surface-brightness (LSB) galaxies can be missed
- Structures within galaxies identified as separate sources (shredding)
- ML-based methods trained on realistic simulated LSST images can improve source detection
- Better detection improves galaxy photometry and deblending and enables more reliable studies of faint galaxies

T. Sedgwick and the Rubin DM team

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Detection of LSB galaxies

DES

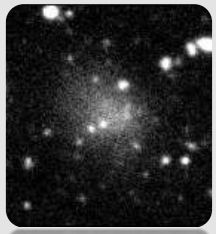


Thuruthipilly+24

Trained on DES imaging

+4,083 new LSBGs from DES

HSC: Deep data



Thuruthipilly+25

DES-trained model on deeper HSC data with no fine-tuning

93% recall

KiDS



Thuruthipilly+26

DES-trained model on KiDS with no fine-tuning

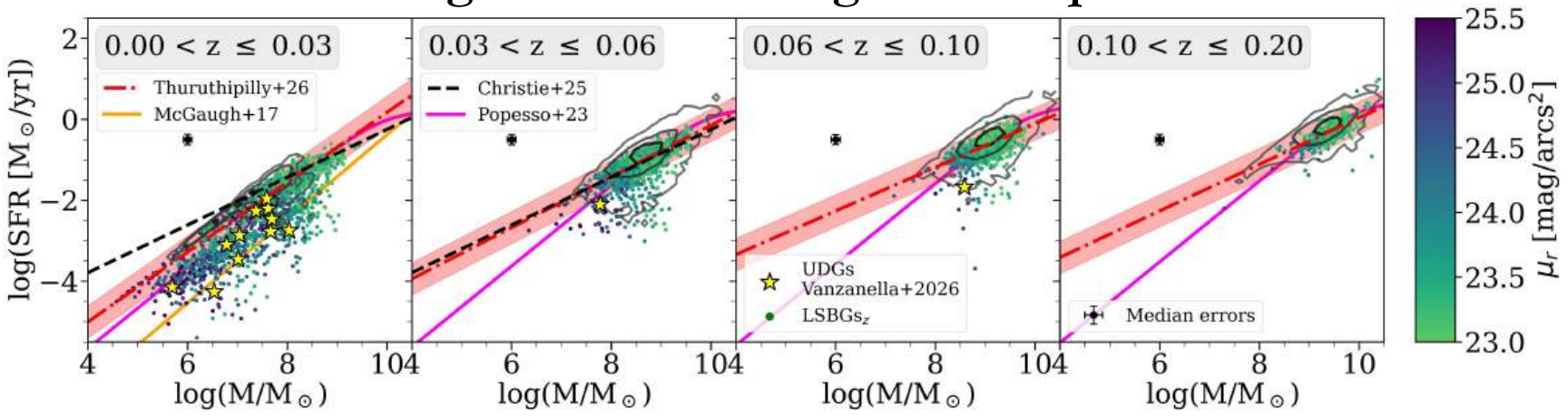
20,180 LSBGs +434 UDGs

LSST

LSST-ready framework



Extending the star-forming main sequence to LSBGs

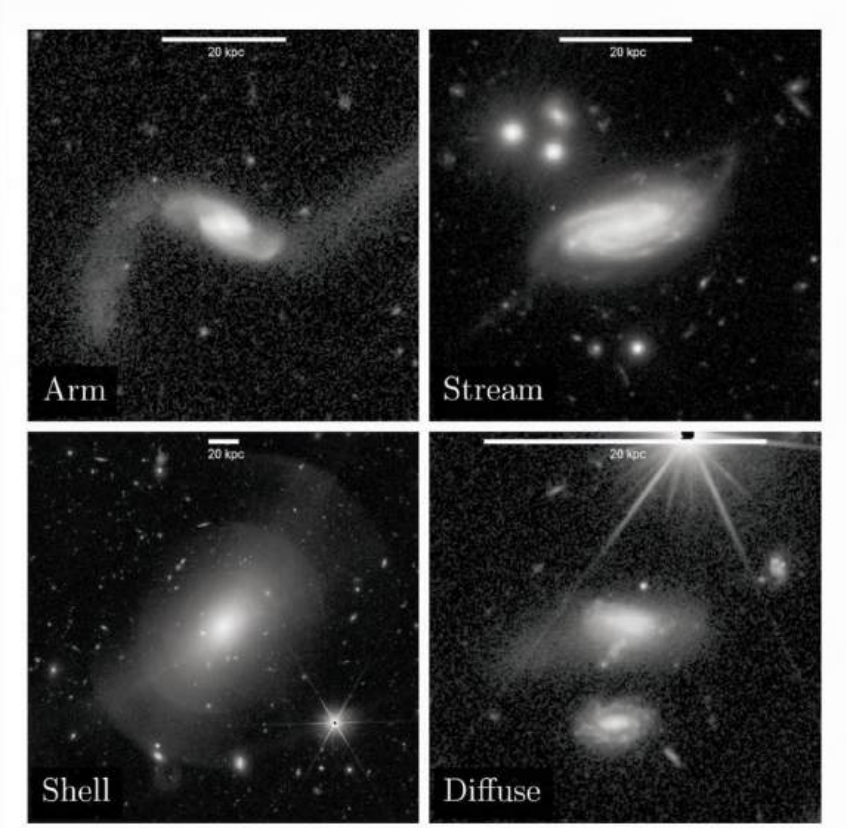


H. Thuruthipilly et al.

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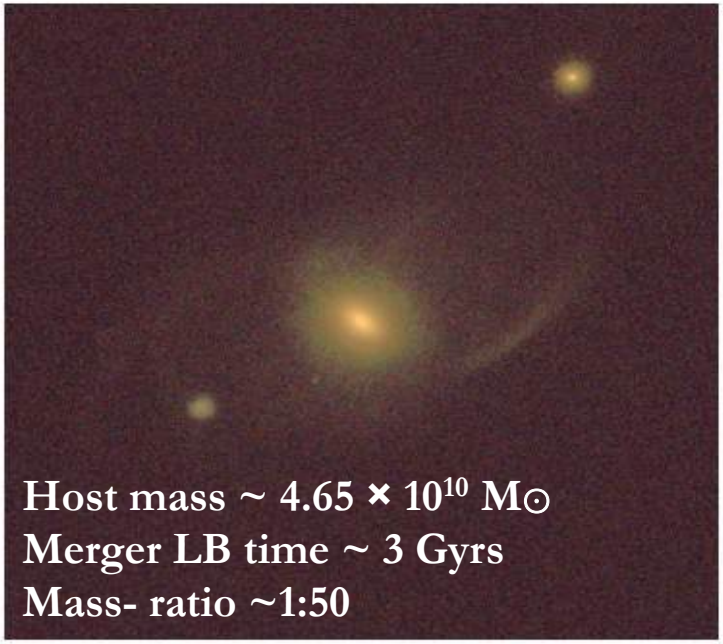
Detection and characterisation of tidal features

- Trained CNN to classify DECaLS galaxies into four categories of tidal features
- Currently adapting network to run on millions of Euclid and LSST galaxies



A. Gordon et al.

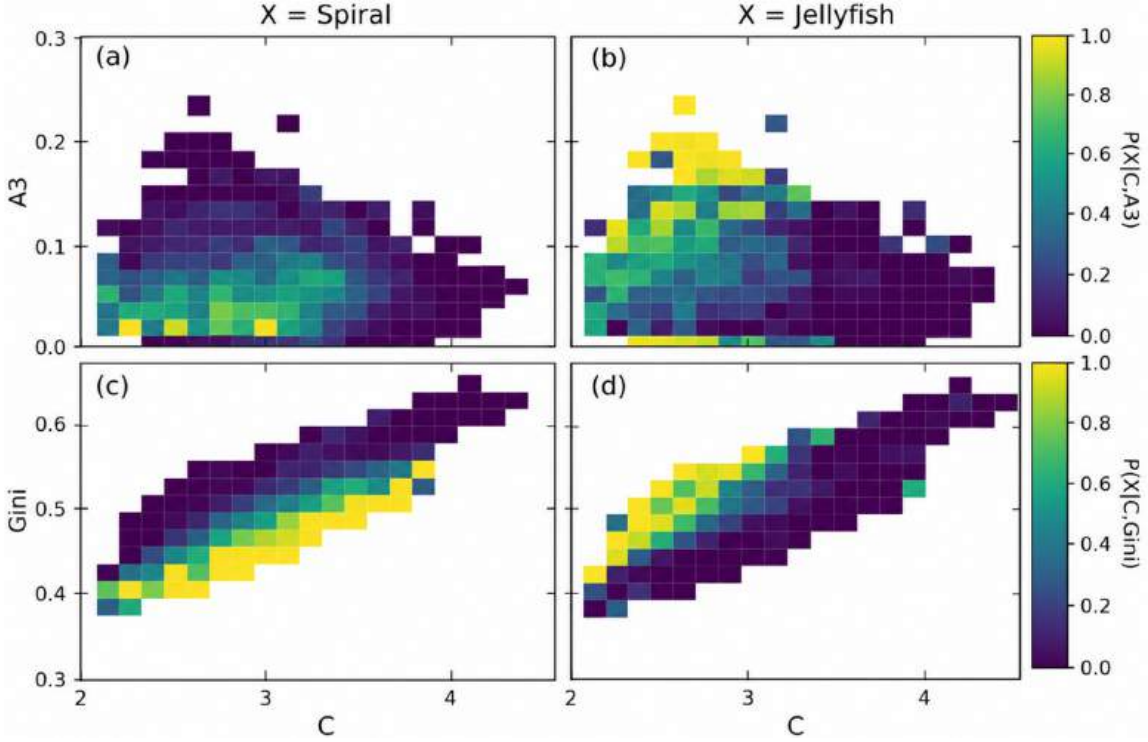
A. Khalid et al.



- Interpret observed tidal features using high resolution cosmological simulations

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Galaxy morphologies using morphological parameters



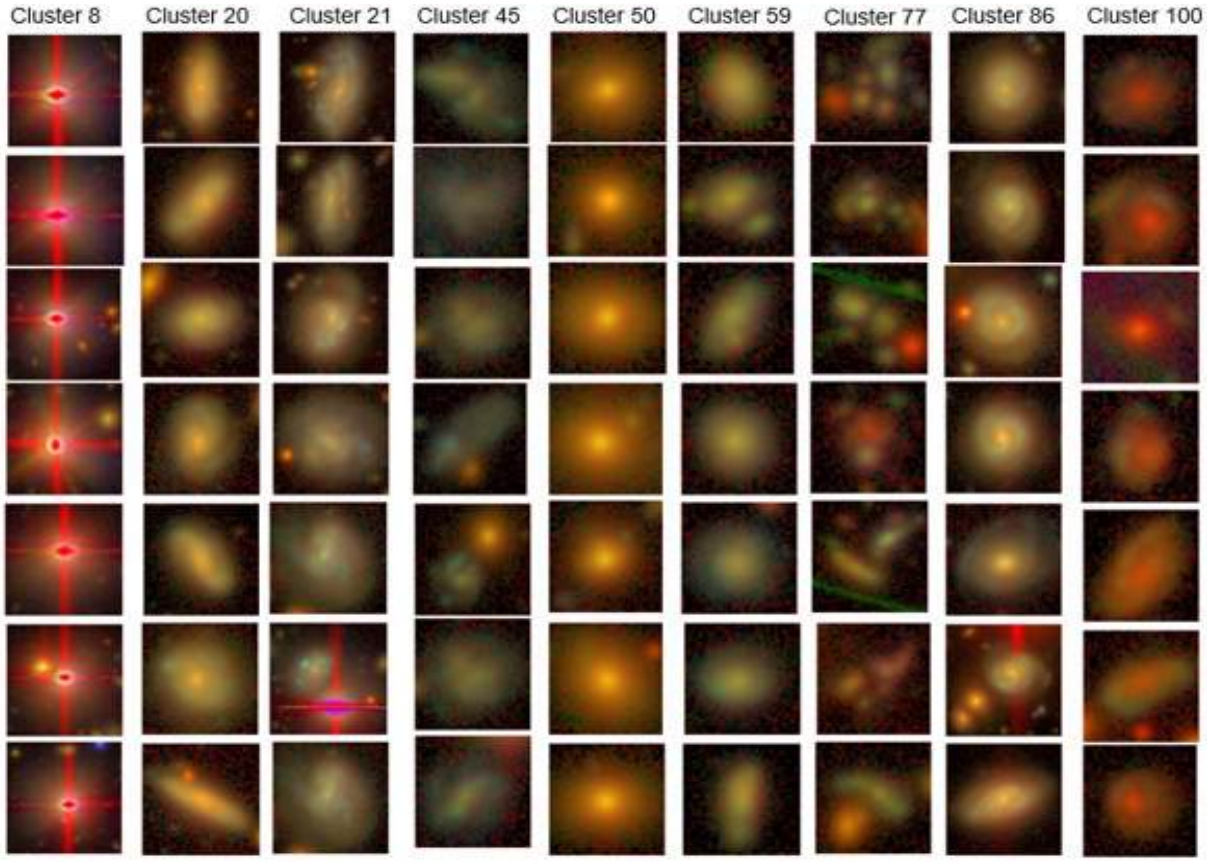
A3: Shape asymmetry (Pawlik et al. 2016)
Gini: Gini index (Lotz et al. 2004)
C: Concentration index (Conselice et al. 2003)

V. M. Sampaio, Y. Jaffé, et al.

- Scalable morphology: *galmex* homogeneous, non-parametric measurements and probabilistic classifications for ~1.7M DECaLS galaxies.
- Beyond Hubble types: identify disturbed and rare systems, including mergers and jellyfish/RPS candidates.
- Towards Rubin/LSST: recalibrate *galmex* for LSST imaging and build survey-scale morphology catalogs.

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Unsupervised ML for galaxy morphologies

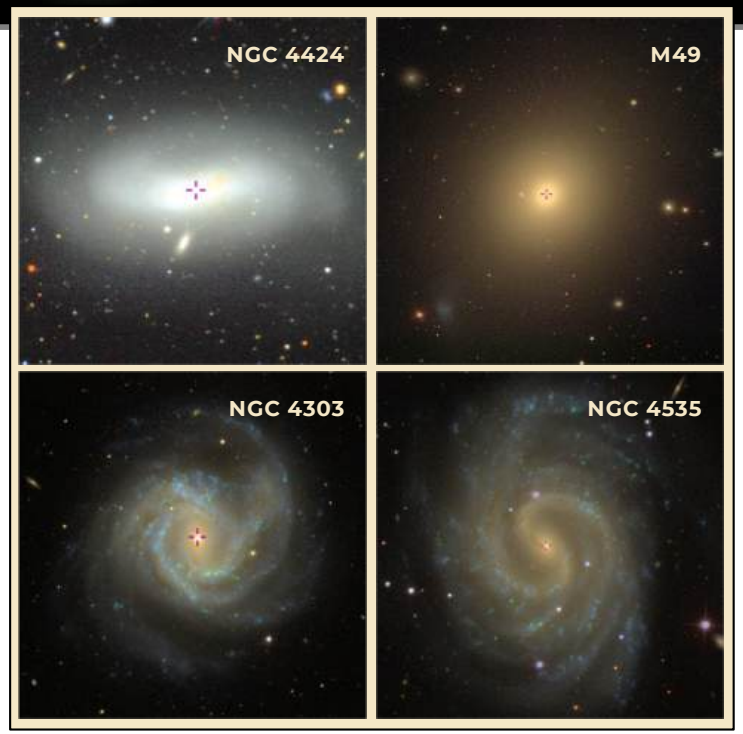


I. Lazar, G. Martin et al.

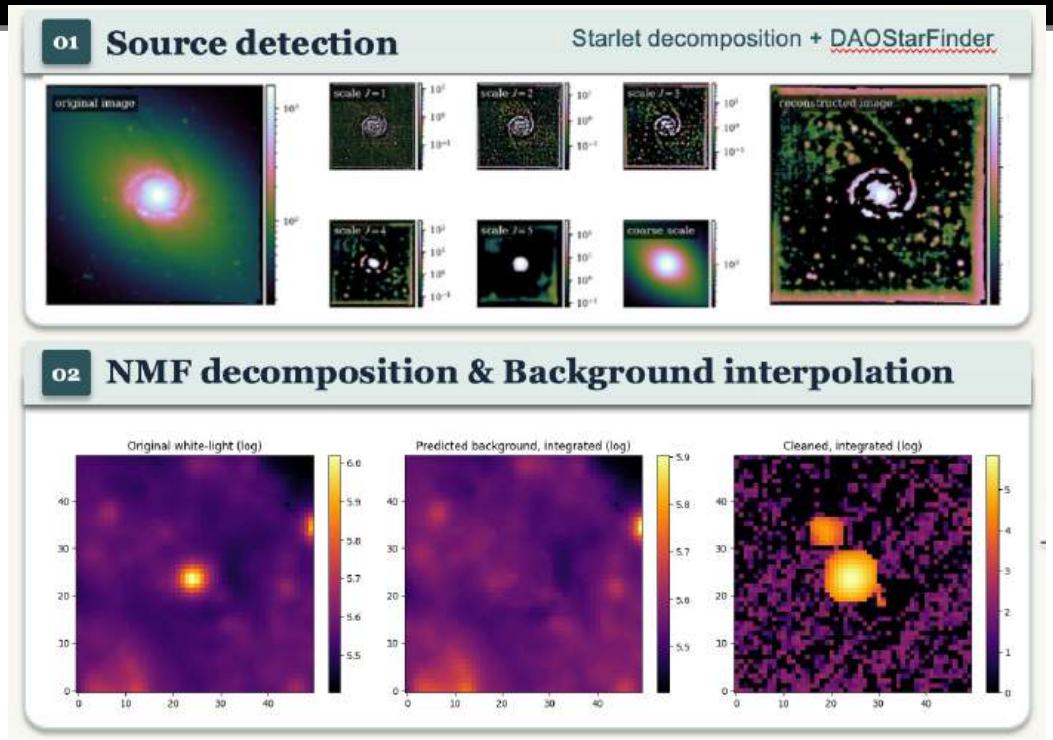
- Unprecedented data volumes mean that traditional methods (e.g. visual inspection) will need augmentation using ML
- Unsupervised ML is a useful tool for galaxy morphological classification
- Prototype validated on HSC images
- Currently being optimized for scaling up to LSST and Euclid data volumes

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Star clusters



Credit: SDSS

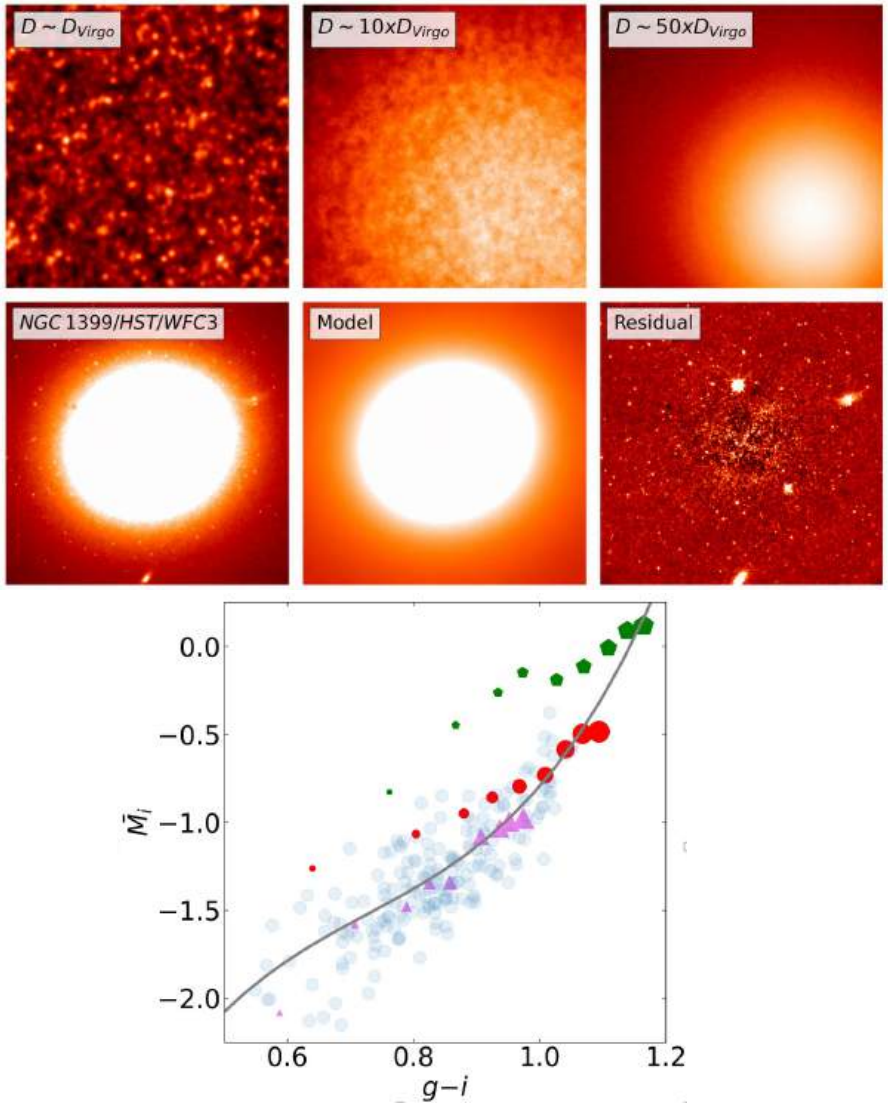


- Star clusters trace their host galaxy's formation histories
- Use photometric and spectroscopic data to identify and characterise SCs
- Insights into star formation and chemical enrichment histories of galaxies detected by LSST

Niranjana P., P. dos Santos-Lopes, A. L. Chies-Santos, R. S. de Souza et al.

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Galaxy distances via surface brightness fluctuations



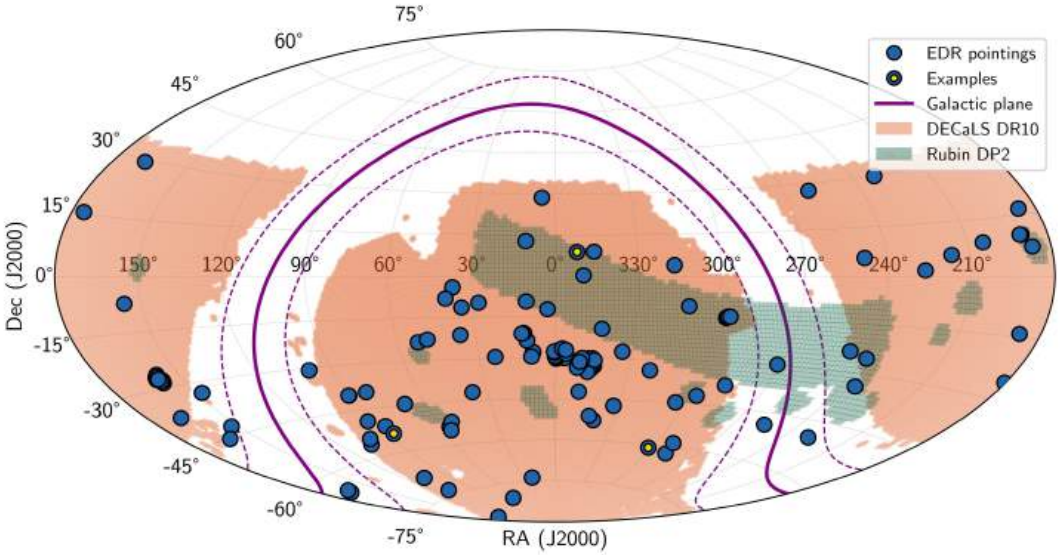
- Observed "mottling" is directly related to the target distance
- *FAST-SBF* uses this technique to produce rapid estimation of galaxy distances, ~ few minutes per galaxy
- Phase 1: Development and validation complete
- Phase 2: Ready for distance and stellar population studies of tens of thousands of LSST galaxies

G. Riccio, M. Cantiello et al.

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Cross-matching LSST with ancillary surveys

- In-kind contribution to Rubin from South Africa within the GSC.
- Early Data Release (EDR) - 111K MeerKAT sources crossmatched with DECaLS.
- Statistical measurements such as radio source counts and radio luminosity functions.
- On-going effort to integrate within Rubin science platform.



Sky distribution of the 141 EDR pointings

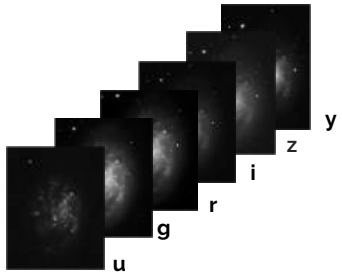
U. Sureshkumar, M. Hilton et al.

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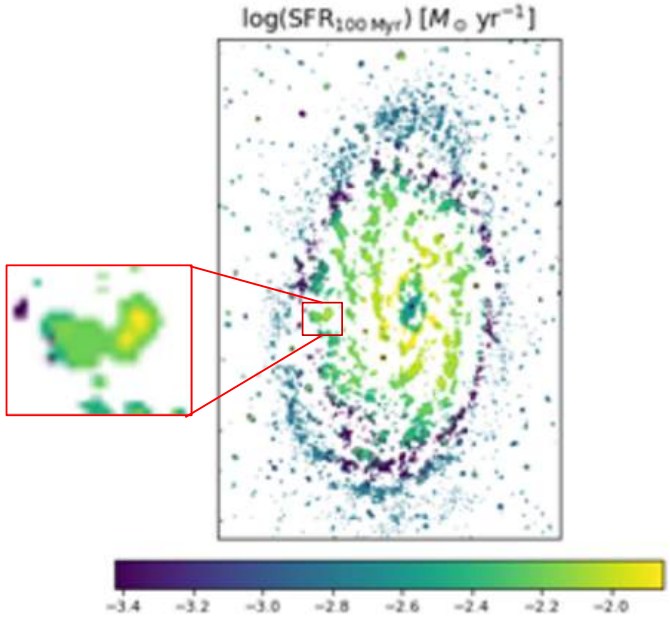
DP1 results - spatially resolved galaxy structure

NGC 1494 in DP1





Spatially resolved maps of physical properties, after SAGUI segmentation



Work in progress

- SAGUI segments galaxies by hierarchically clustering regions with similar SED profiles.
- After segmentation, perform spatially resolved analysis of properties for each structure.
- To be expanded to other galaxies in the LSST DRs.

A. Wille, A. L. Chies-Santos, R. S. de Souza

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DP2 results – NGC 4261 dissected



Piecing together the

NGC 4261 Group

01 **Segment** the galaxies of the NGC 4261 group into regions with similar spectral energy distributions using deep optical imaging from Rubin DP2, recovering their internal structure and faint, low-surface-brightness features.

02 **Map** the stellar populations of each region to reveal how ages, metallicities and dust vary within the galaxies and across the group, tracing the imprint of interactions.

03 **Detect** and build a census of the globular cluster systems of the group, exploring their spatial and color distributions as tracers of how the group was assembled.

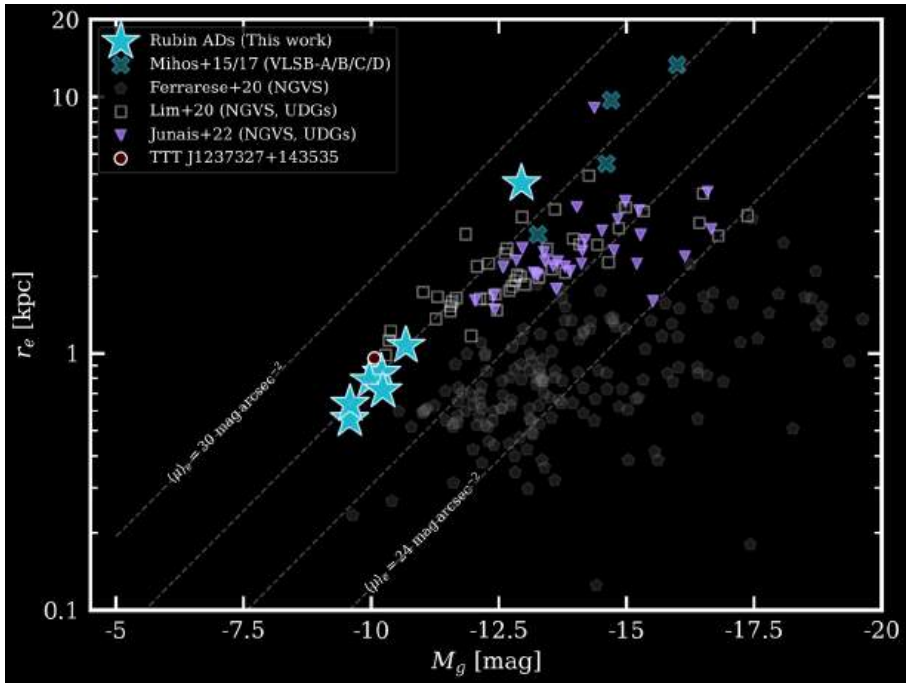
04 **Carry out** spectroscopic follow-up of the detected globular cluster candidates to confirm their membership and measure their radial velocities, ages and metallicities.

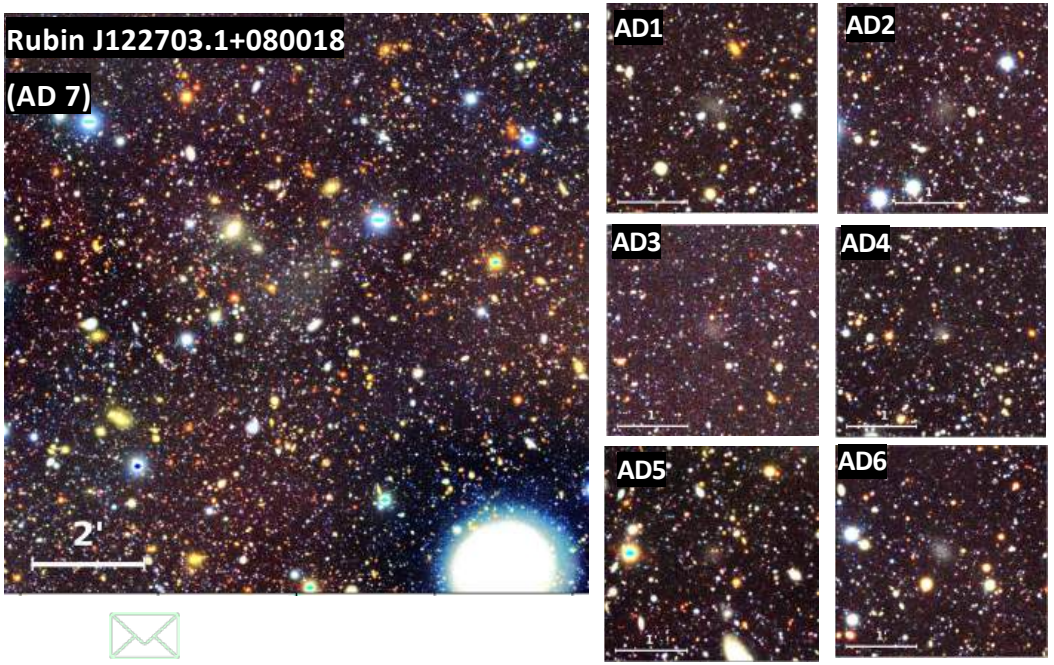
M. Santamaría, A. L. Chies-Santos et al.

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DP2 results – 'almost dark' galaxies

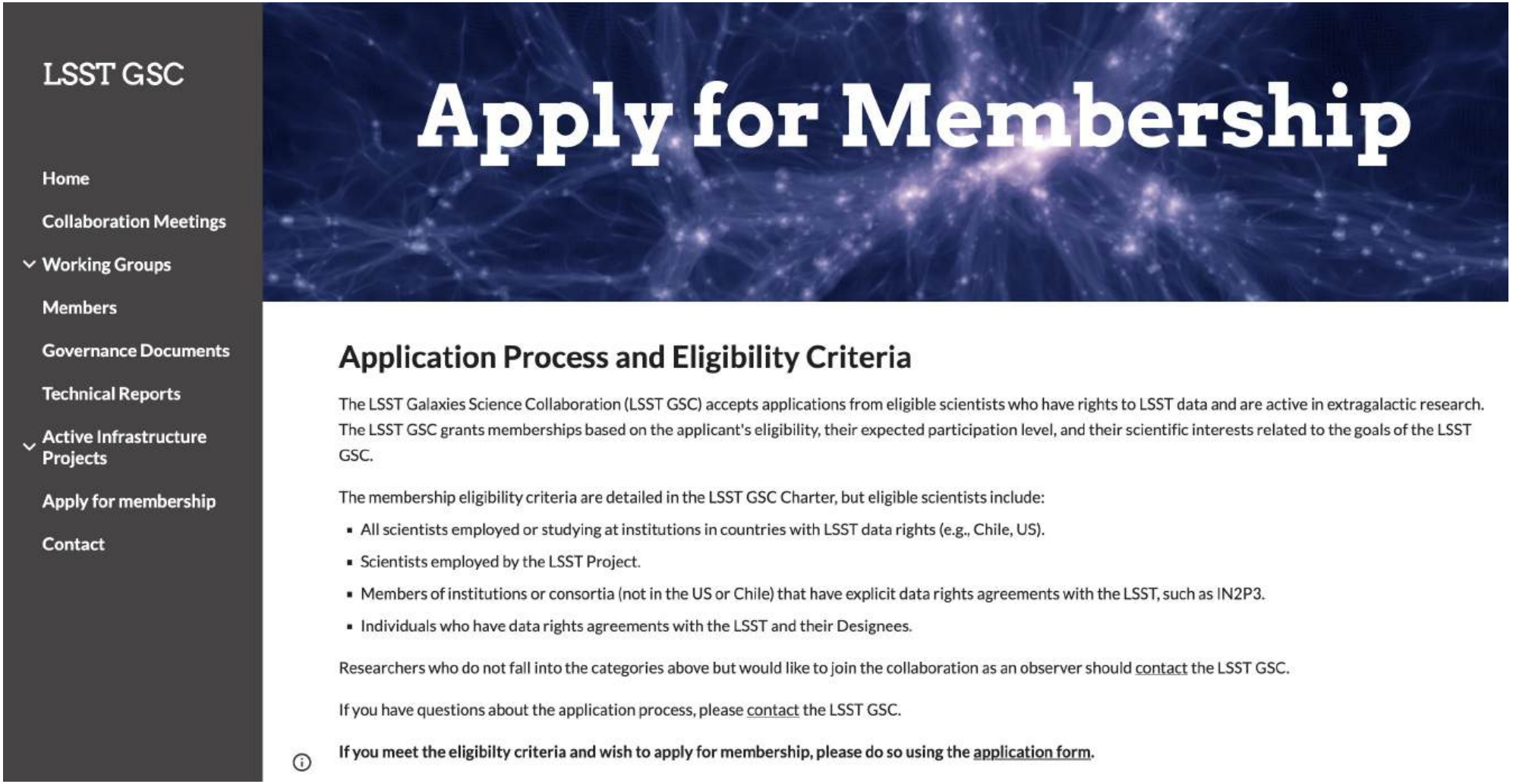
- 7 almost-dark galaxies (ADs) found around M49 in Rubin DP2
- Extremely faint (central surface brightness 27-28.5 mag/arcsec^{-2}, r_eff ~ 0.6-4.6 kpc)
- More ADs are expected to be found in DP2 & future LSST DRs





Minh Ngoc Le et al., Mitra et al.

Join us (LSST data rights not required)



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