Preparing for LSB science with the Rubin Observatory

Characterisation of LSB tidal features from mock images

Garreth Martin (KASI, Arizona)
with
LSST Galaxies LSB Working Group*

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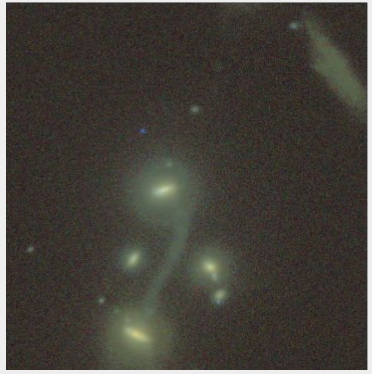
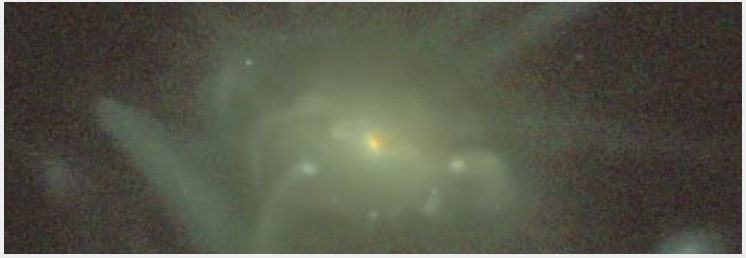
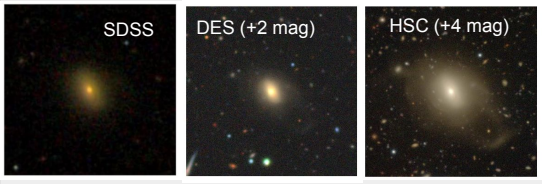
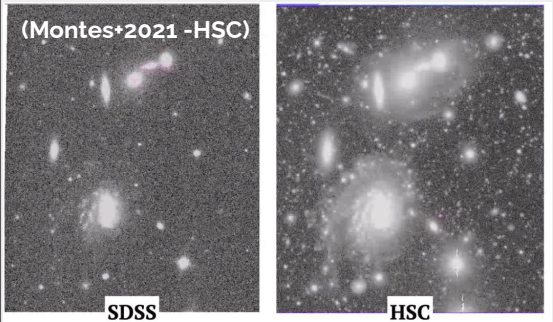
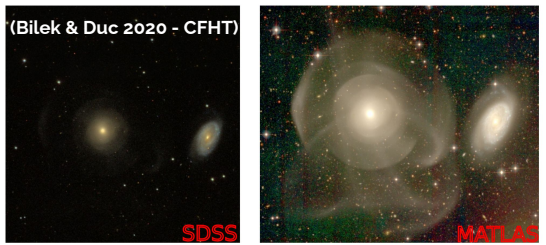
* *full list in final slide*





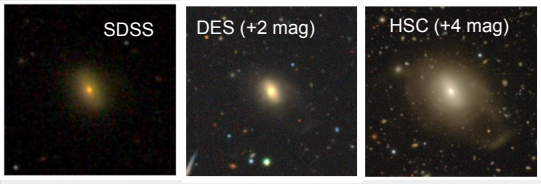


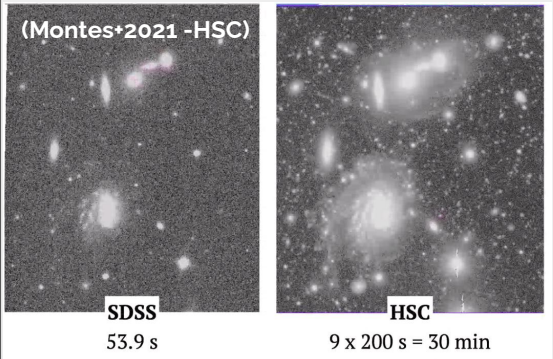


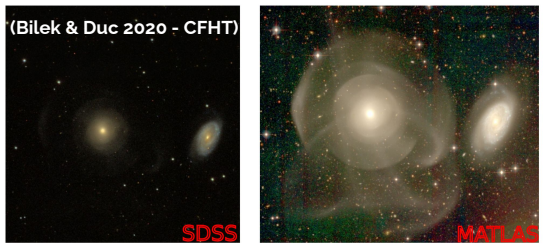


Deep imaging in the era of the Rubin Observatory/LSST

- Hyper Suprime-Cam ($\mu^{lim}_{r}(3\sigma,10''\times10'') > 30.5$ mag arcsec^{-2}) and other pathfinder instruments give us an idea of what Rubin Observatory will be capable of
    - Such instruments recover many more LSB features around galaxies compared with SDSS ($\mu^{lim}_{r}(3\sigma,10''\times10'') \sim 24$ mag arcsec^{-2}) and therefore a more complete record of past low mass accretion events







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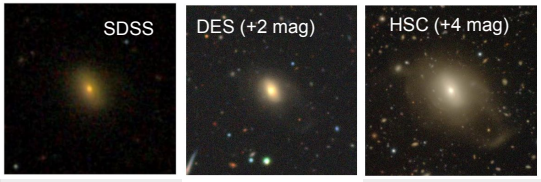

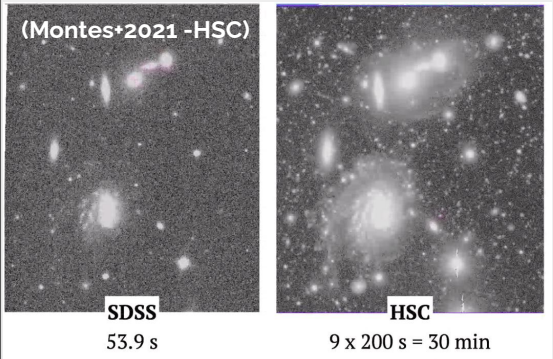

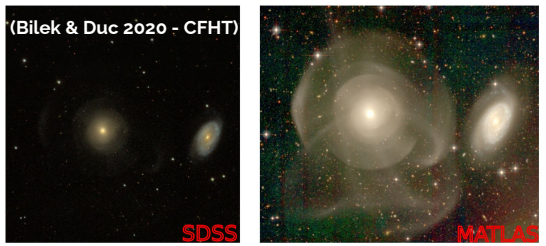

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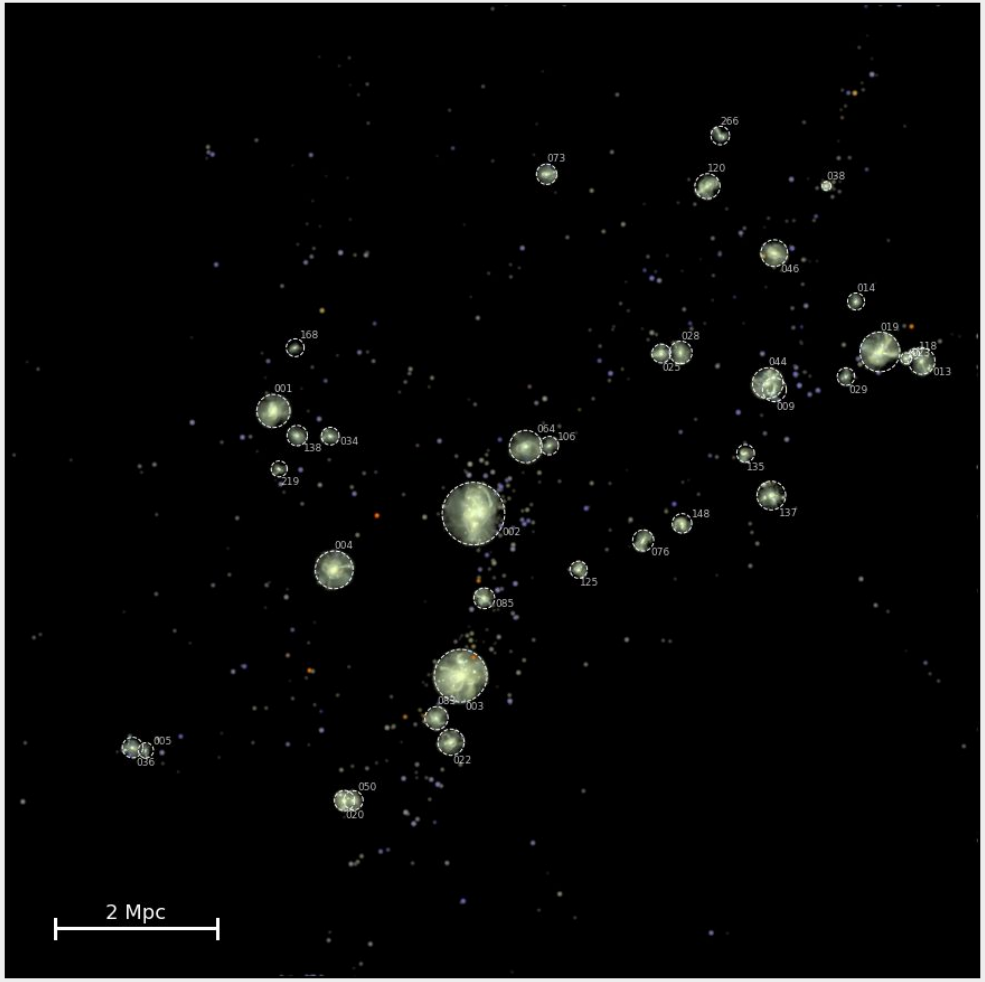
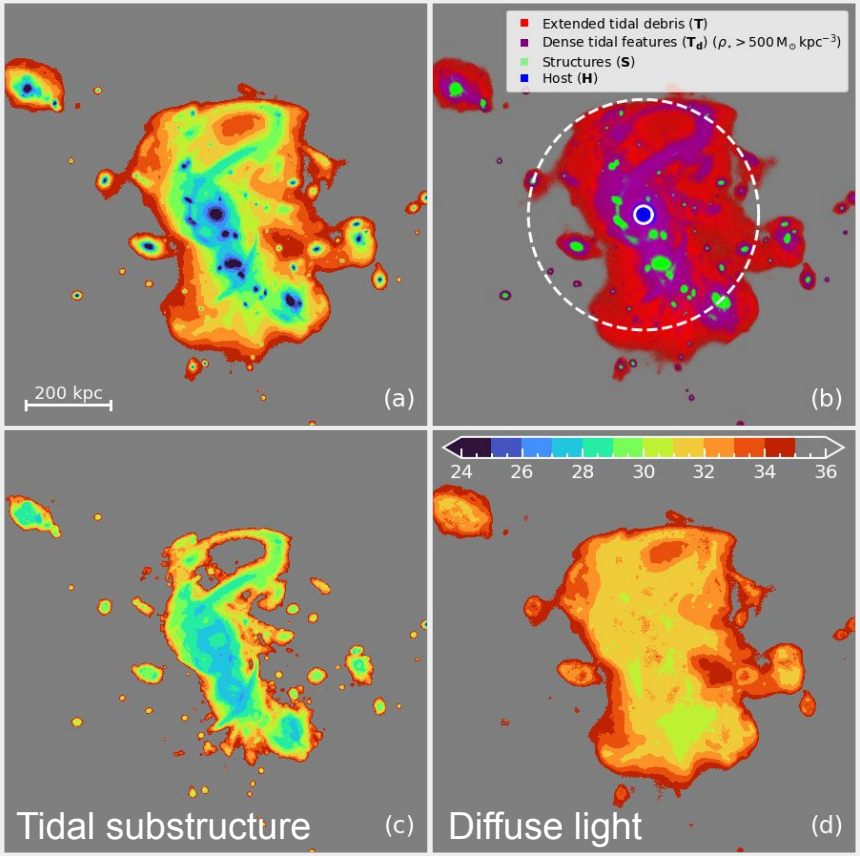
- Rubin Observatory will greatly increase the sample size of galaxies with very deep observations
  - Detailed ΛCDM predictions will allow us to understand the capabilities of this new dataset and make predictions for
    - Frequency and distribution of tidal features as a function of halo mass
    - Biases from orientation, redshift, etc.
    - Surface brightness distribution of tidal features



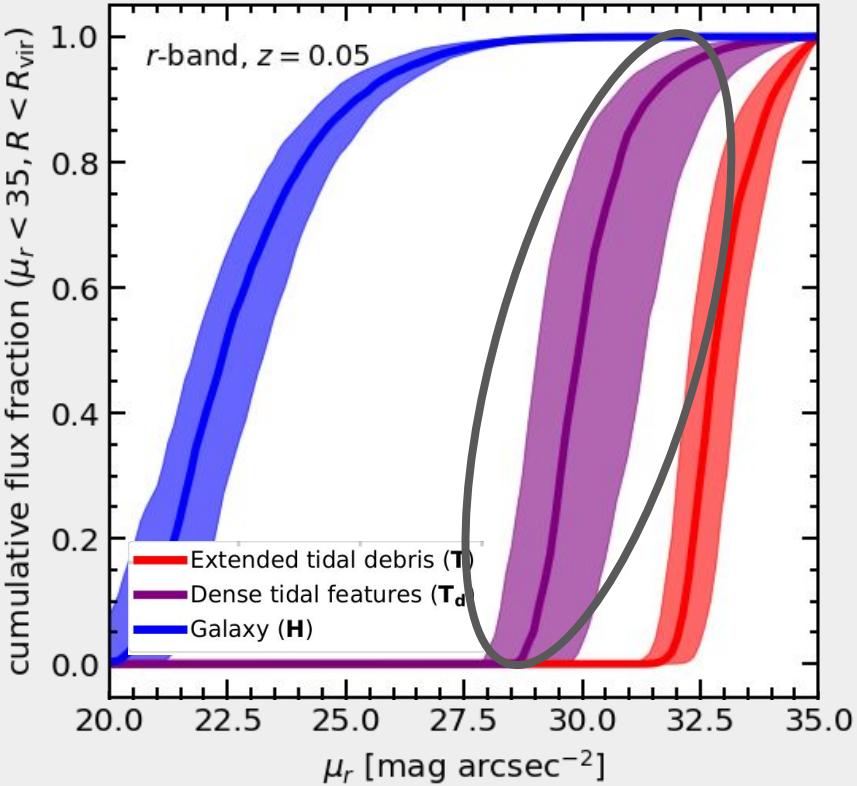
The New Horizon Simulation (Dubois+21)

- **New Horizon is a high resolution cosmological simulation**
  - Contiguous volume of $(16\ \mathrm{Mpc})^3$
  - High spatial and stellar mass resolution of **34 pc** / **$10^4\ M_\odot$**
  - Sufficient mass resolution to resolve the stellar halo around <MW mass galaxies

Measuring flux distributions in the stellar halo

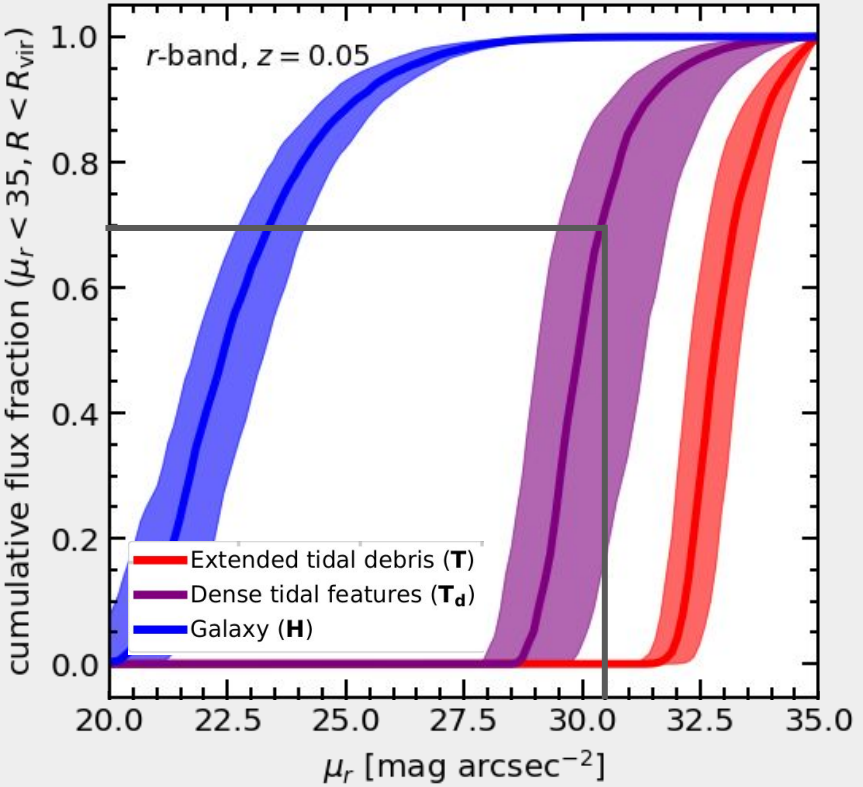


- Decompose galaxy stellar haloes into:
  1) Dense tidal substructures
  2) Diffuse light / debris



Measuring flux distributions in the stellar halo

- Defined substructures like streams are typically brighter



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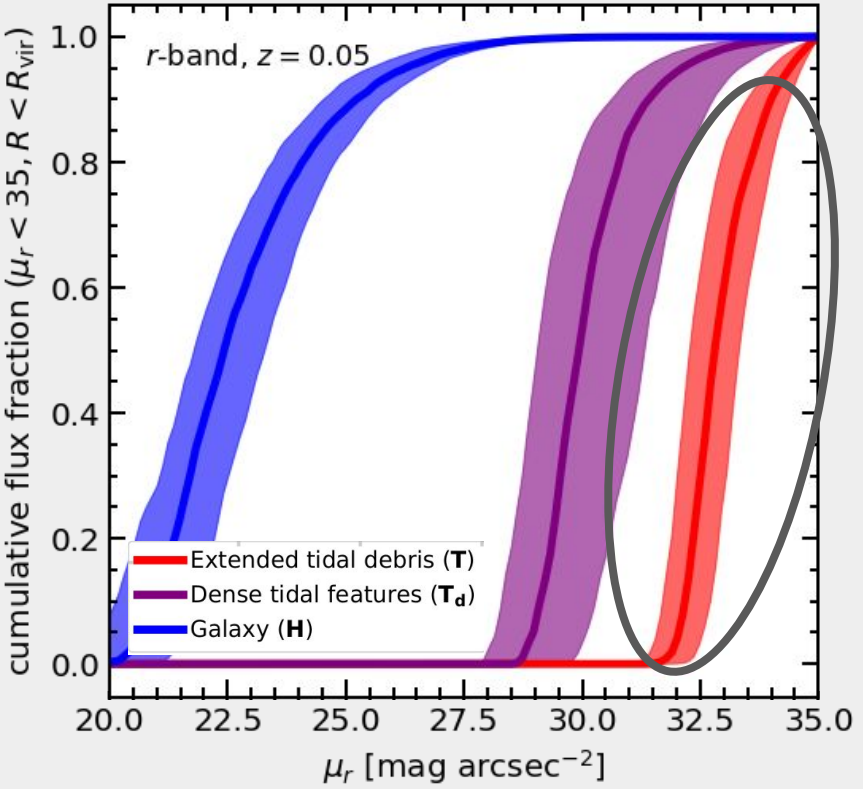

Measuring flux distributions in the stellar halo

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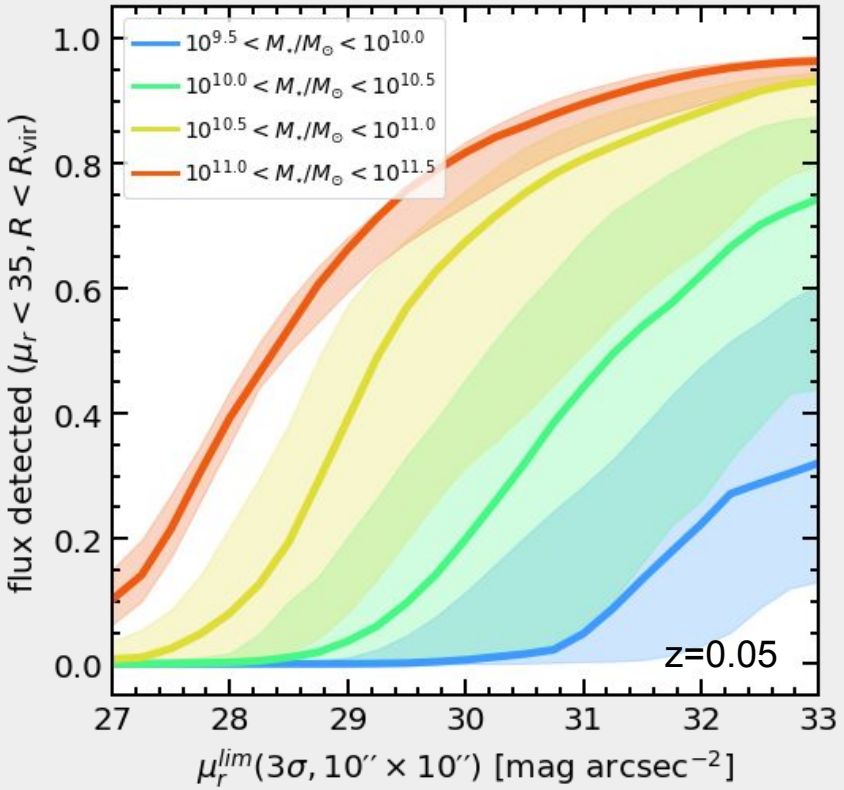
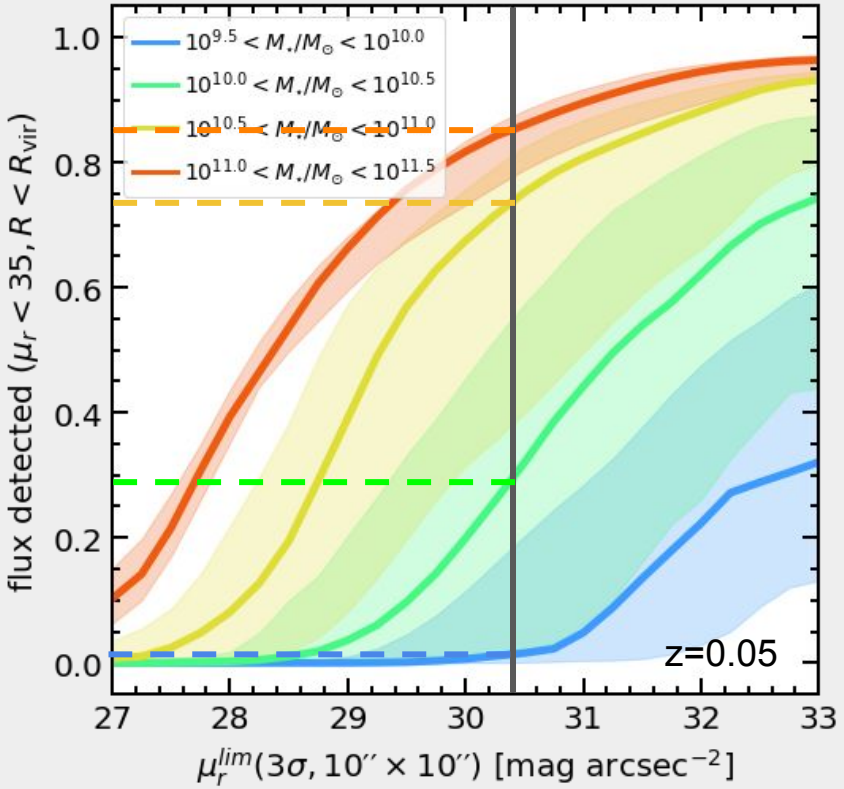
- Very diffuse light in the stellar halo is inaccessible at expected LSST SB limits
  - It accounts for 25% of the total halo light on average



Measuring flux distributions in the stellar halo

- Lower mass galaxies ($M_*/M_\odot < 10^{10}$) are unlikely to have detectable tidal features at LSST SB limits.



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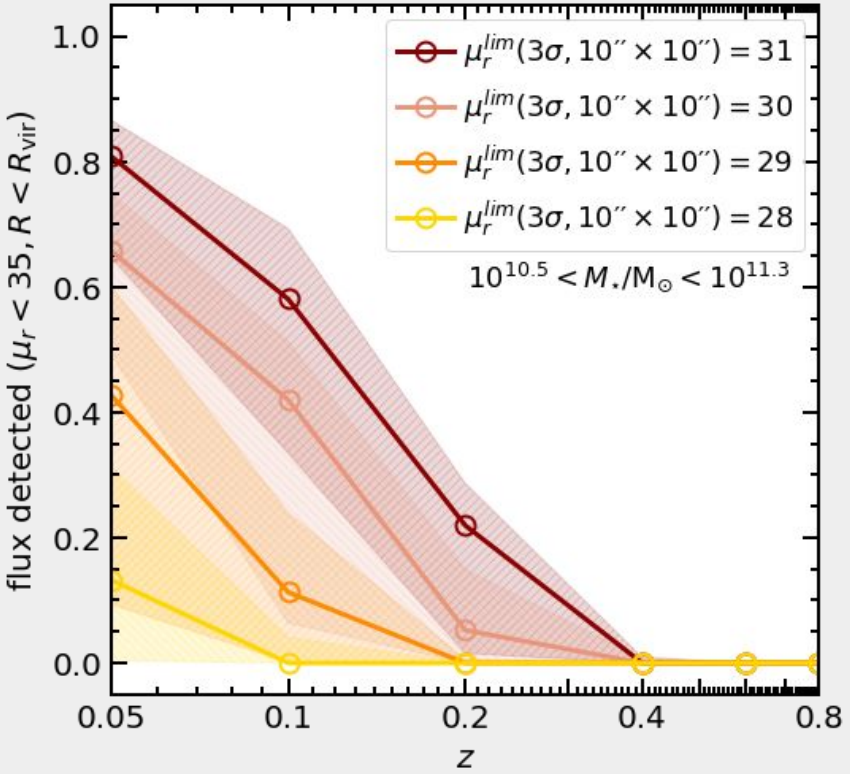
- Lower mass galaxies ($M_*/M_\odot < 10^{10}$) are unlikely to have detectable tidal features at LSST SB limits.
- A large fraction of flux in more massive galaxies is likely to be detected



Measuring flux distributions in the stellar halo

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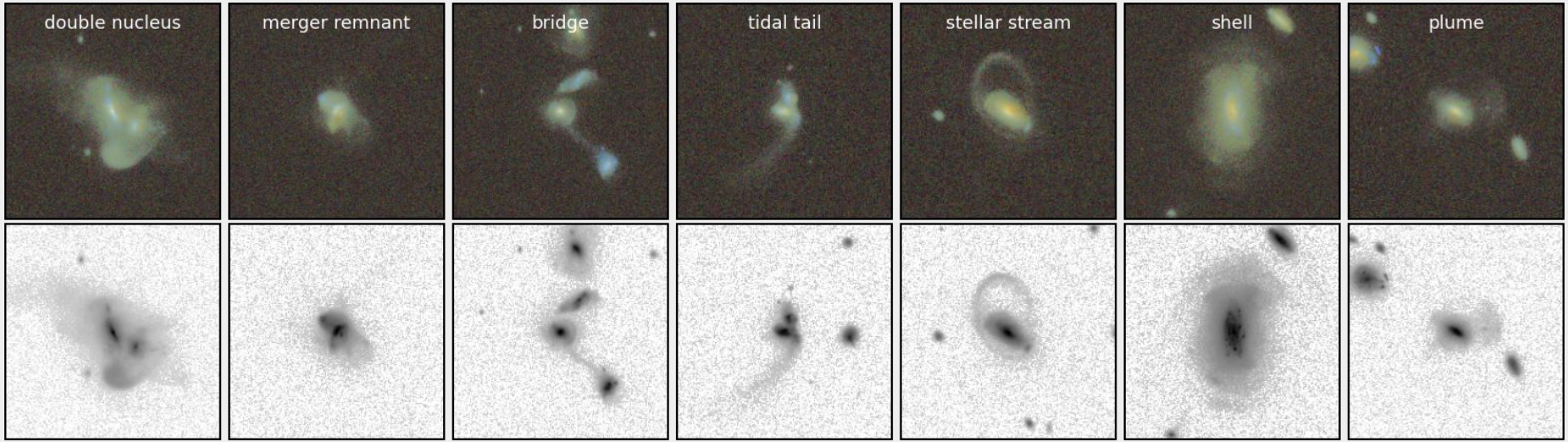
- A large fraction of flux in more massive galaxies is likely to be detected
- The number of galaxies with detectable tidal features also falls with redshift so that <10% flux in the stellar haloes of MW mass galaxies is detected by z=0.2
    - The low mass / high redshift Universe will remain inaccessible

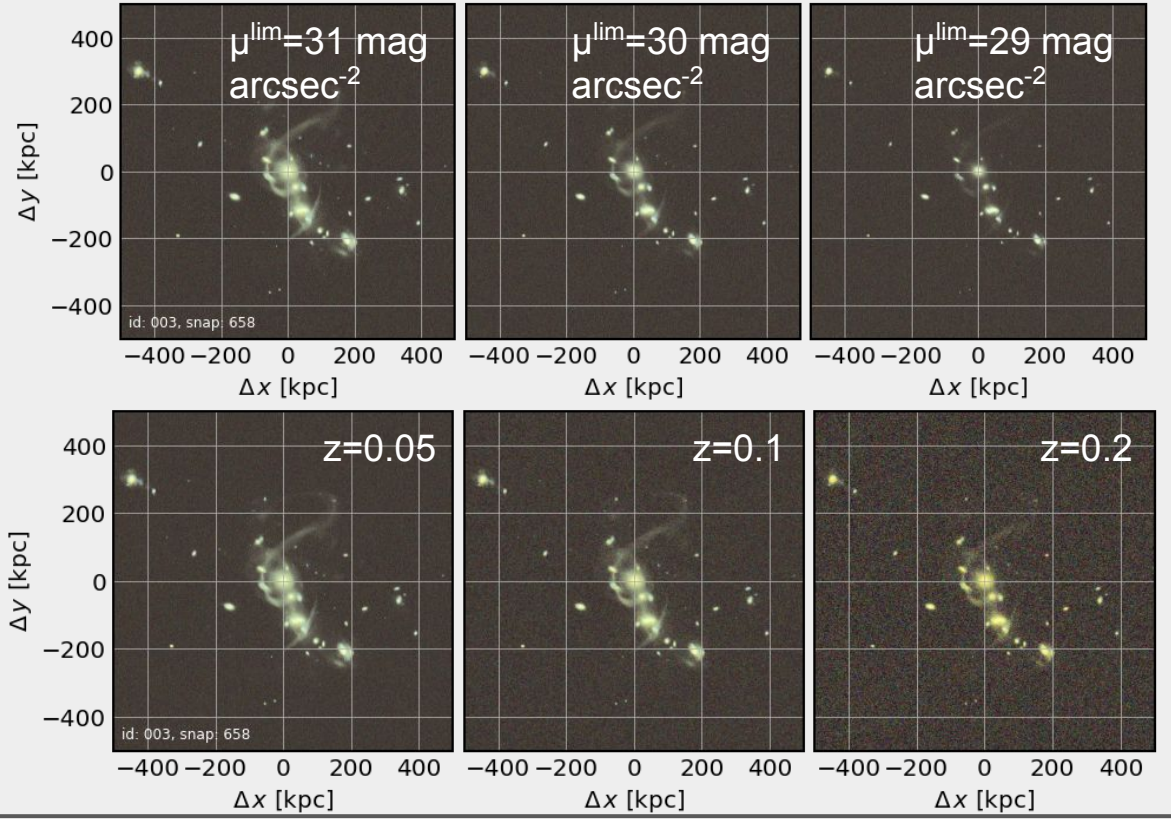
Visually classifying LSB features in the stellar halo

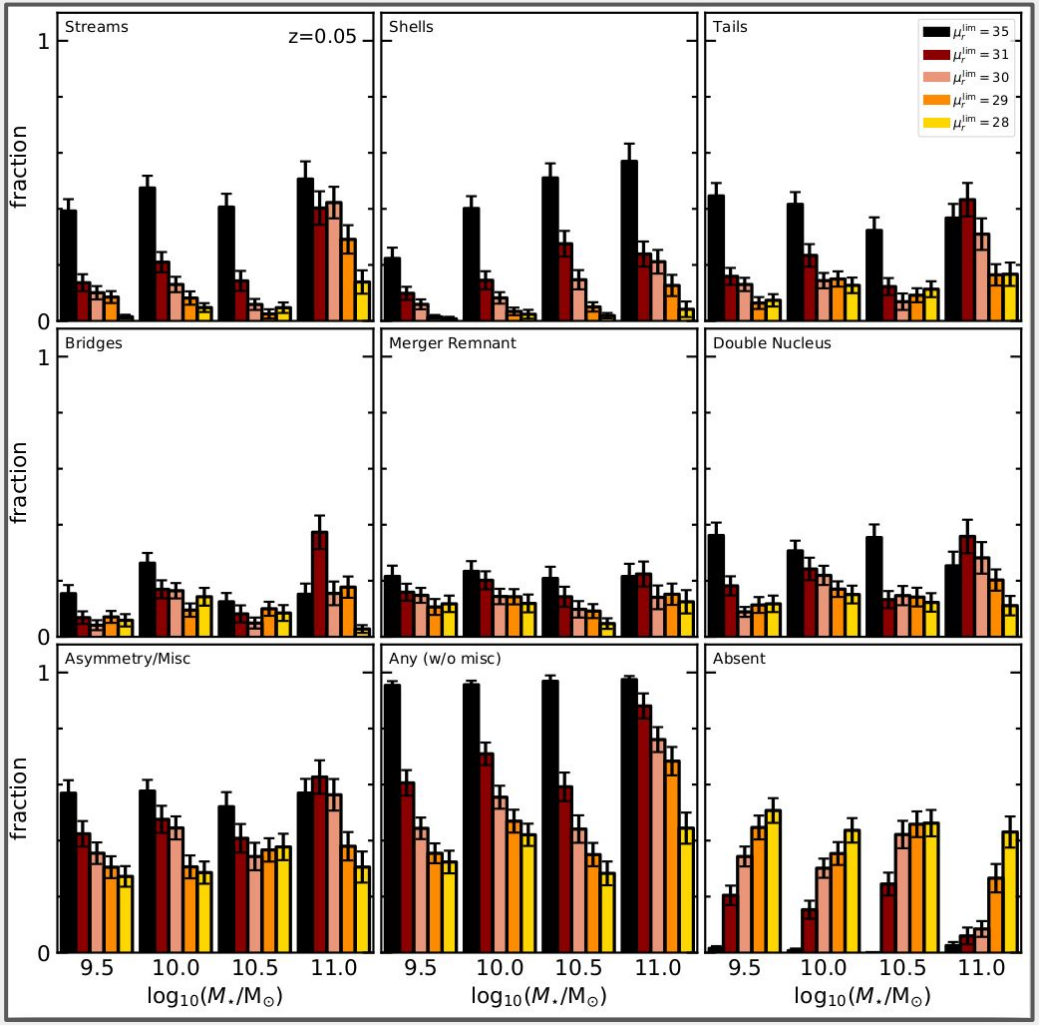
- ~50 volunteers visually classified tidal features mock Rubin Observatory images
  - Classified for a range of:
    - Limiting surface brightness (single visit → 10 year depth + 35 mag arcsec^{-2} to probe beyond the limits of LSST)
    - Redshift (z = 0.05 → 0.8)
    - Orientations (projected along xy, xz, yz)



Visually classifying LSB features in the stellar halo

- Sources of uncertainty
  - Limiting surface brightness and surface brightness dimming

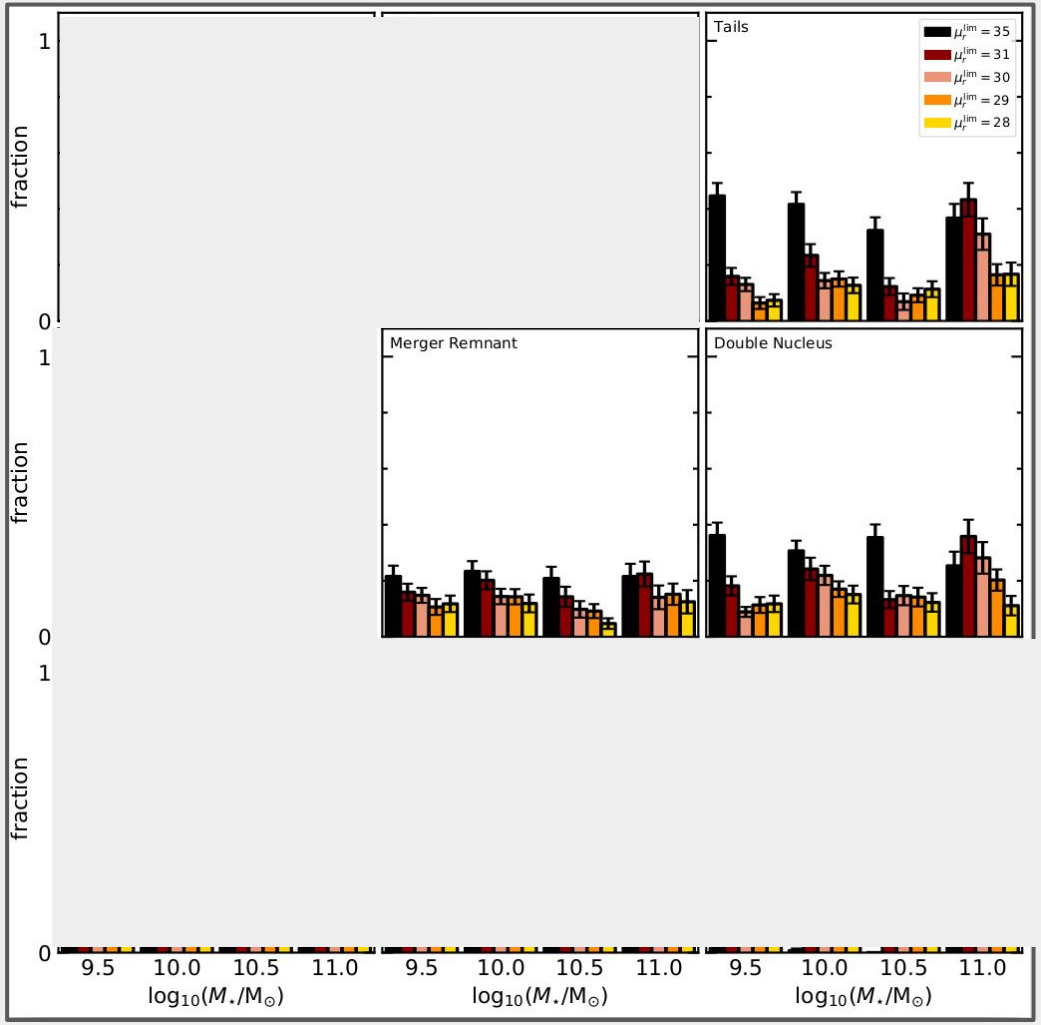




Visually classifying LSB features in the stellar halo

- At sufficient depth, almost 100% of objects were found to have some kind of tidal feature
  - Even at low masses, most galaxies undergo frequent interactions, but not necessarily mergers (**Martin+2021**)

- Many MW mass galaxies are expected to have visible tidal features at LSST 10 year depth



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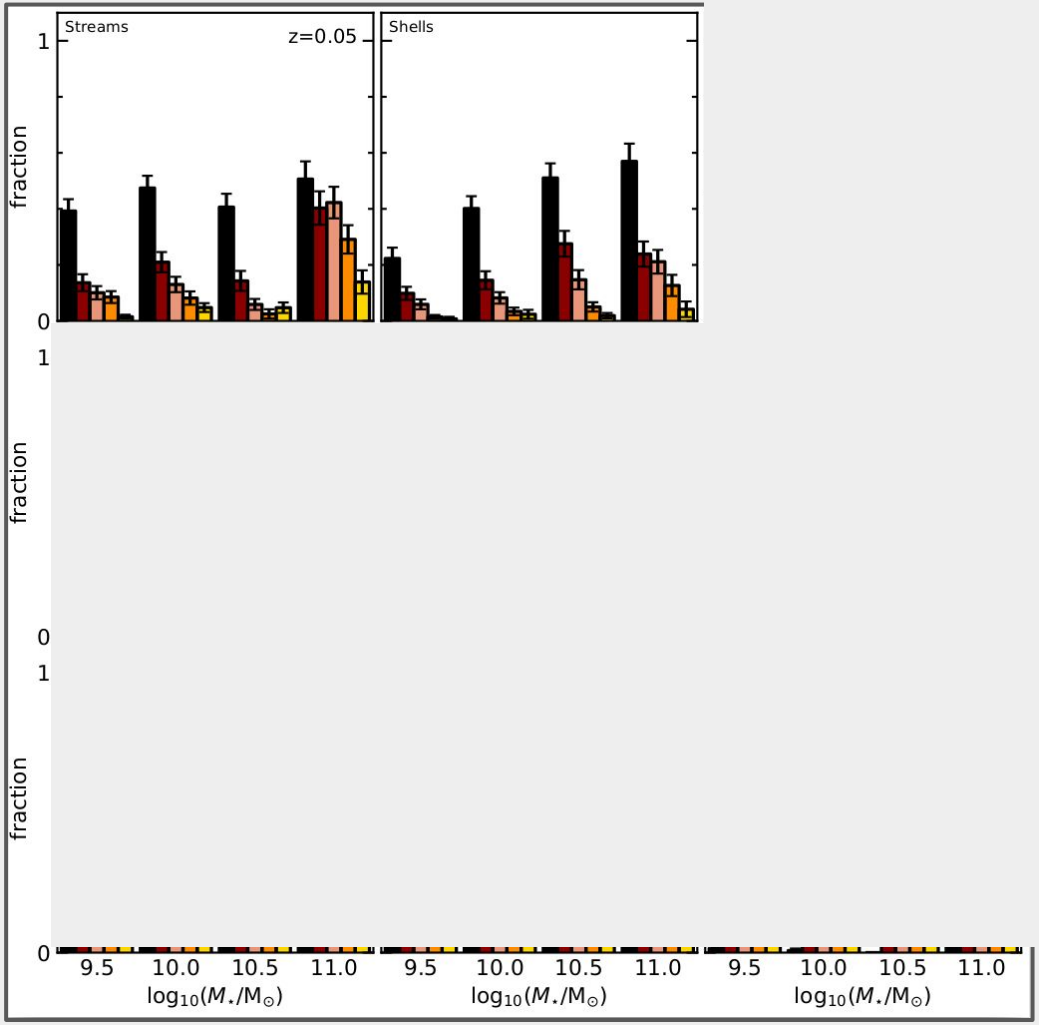
- The prominence of different classes of tidal feature vary with mass and image depth
  - Mergers and tails are more robustly detected



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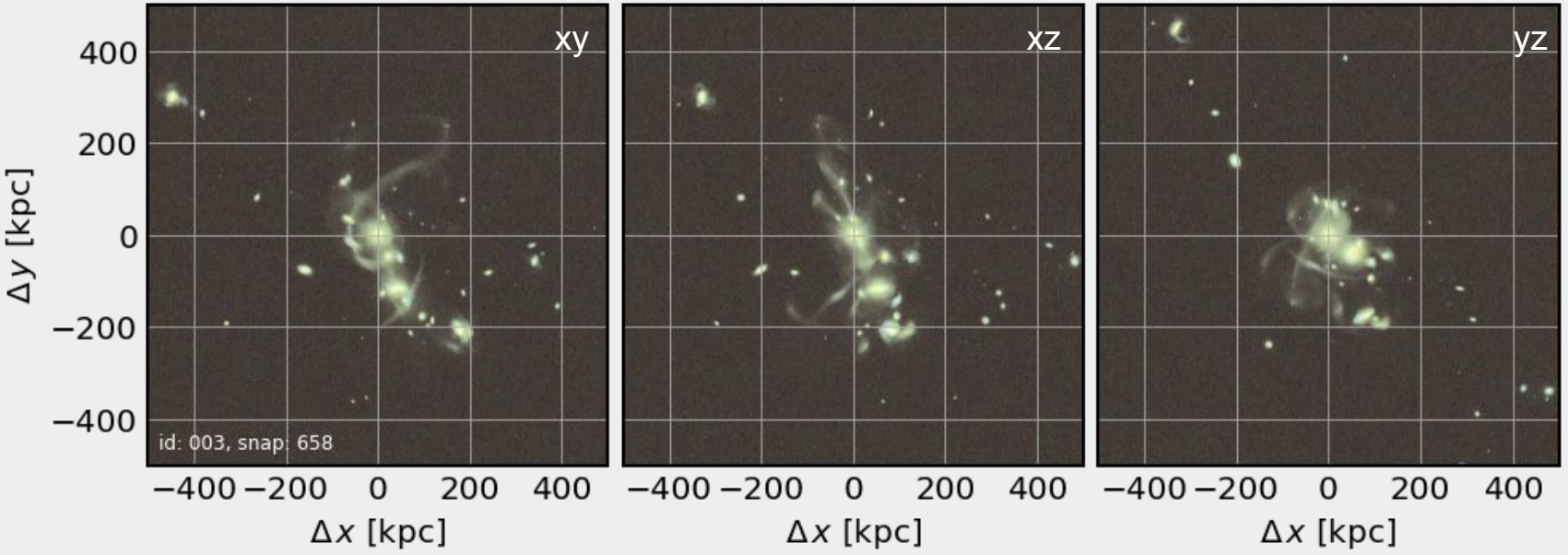
- The prominence of different classes of tidal feature vary with mass and image depth
  - Mergers and tails are more robustly detected
  - The detection of streams and shells depends more on mass and depth

Visually classifying LSB features in the stellar halo

- Tidal streams and shells are less common in but also weaker in less massive galaxies.
  - his reflects a possible observational bias since the tidal features present in galaxies with a smaller number of tidal features are also likely to be weaker and are therefore more likely to go undetected.

Visually classifying LSB features in the stellar halo

- More sources of uncertainty
  - Orientation
  - Inherent ambiguity in tidal feature classification



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- We explore how the scatter in visual classifications changes with image depth
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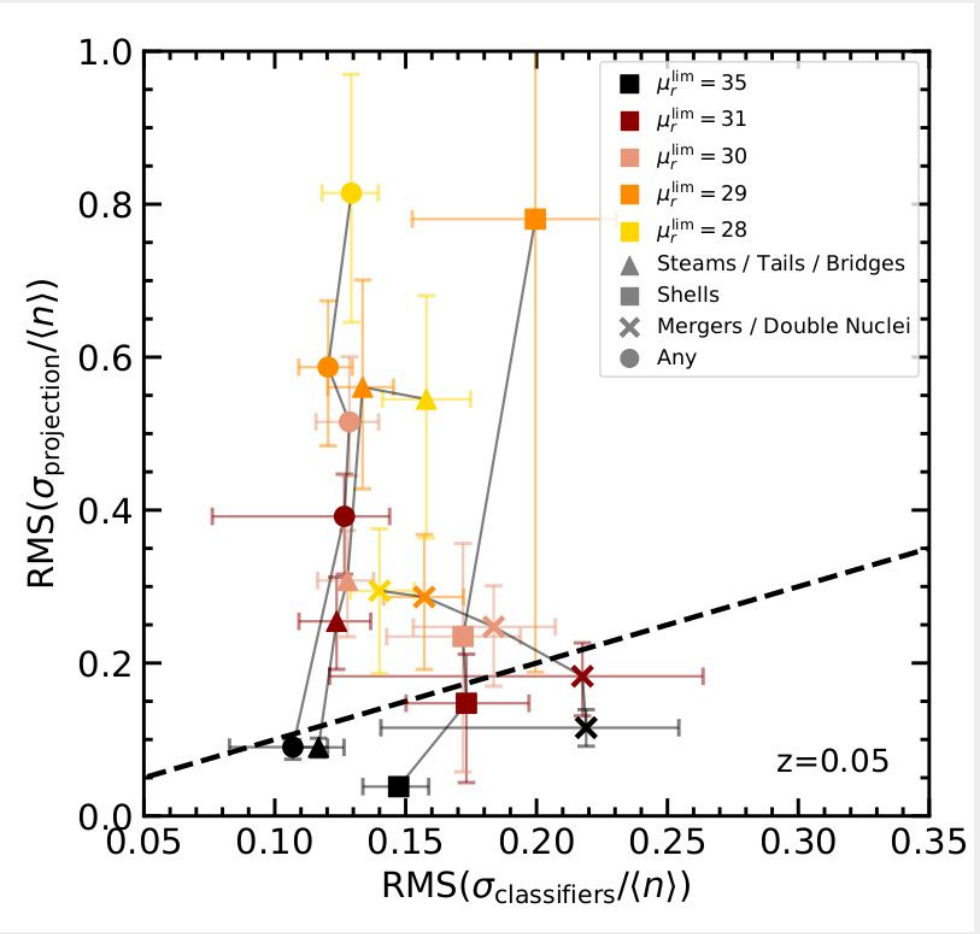

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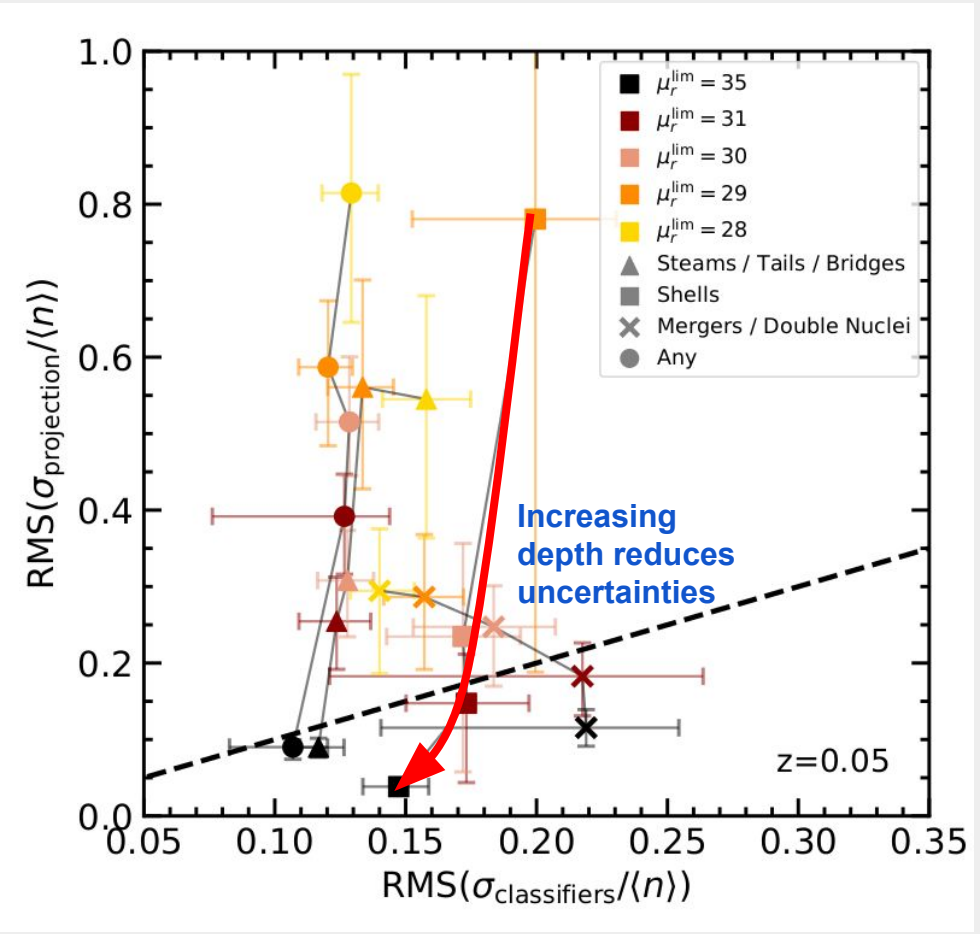

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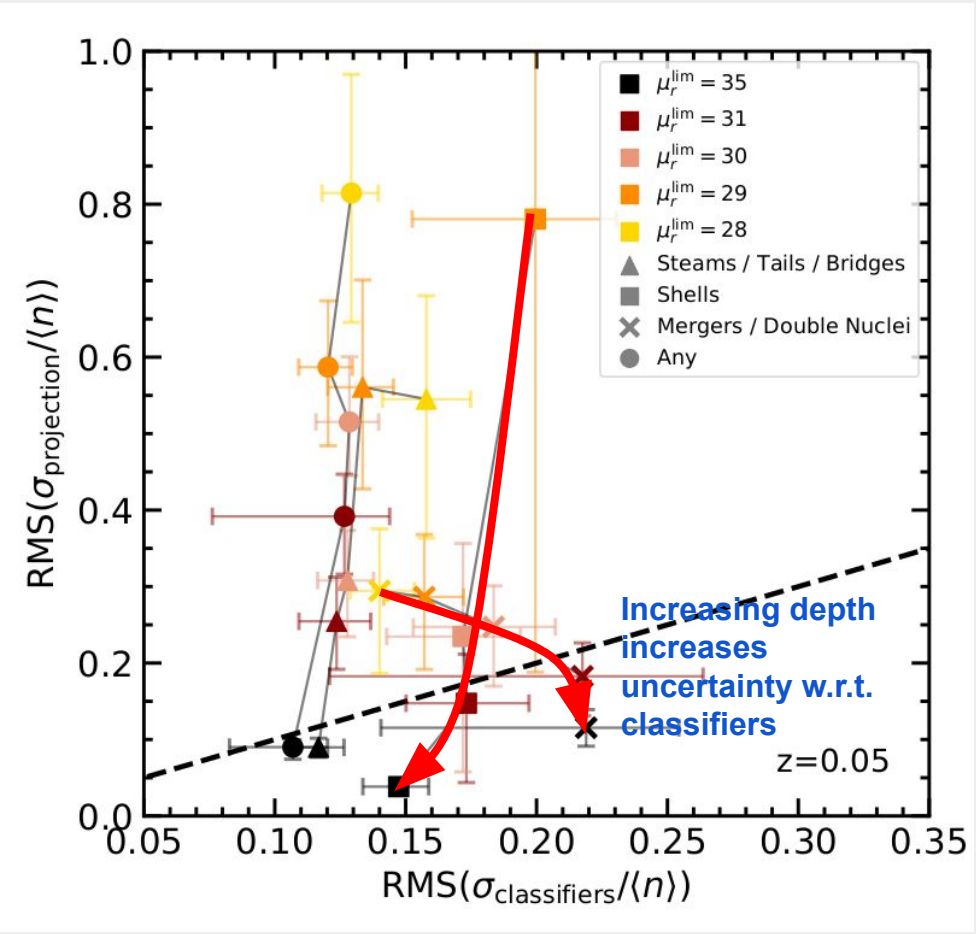
- In most cases, deeper imaging means classifiers and more likely to agree with each other and agree across projections
- However, for some categories, increasing the depth makes classification ambiguous
  - As depth improves, morphologies can become more complex, introducing uncertainty in precise characterisation



Conclusions

- After its 10 year survey, LSST will have sufficient depth to resolve a significant fraction of the flux found in tidal substructures of MW galaxy stellar haloes
- Around 75% of flux lies in these denser tidal features rather than more diffuse tidal debris which lie beyond the surface brightness limits accessible to LSST
- At sufficient depth, almost 100% of galaxies ($M_*/M_\odot < 10^{9.5}$) possess tidal features
  - But most detectable tidal features are hosted by high mass galaxies at relatively low redshift
- Surface brightness limits, galaxy orientation, redshift, etc. have a clear effect on the ability of expert classifiers to visually identify and characterise tidal features
- Concurrence between classifiers generally improves with deeper imaging but morphologies can become more complex, introducing uncertainty in precise characterisation

Please look out for out paper coming soon...

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