Jeremiah Horrocks Institute

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Using Galactic Archaeology to Uncover the Formation History of S0 Galaxies

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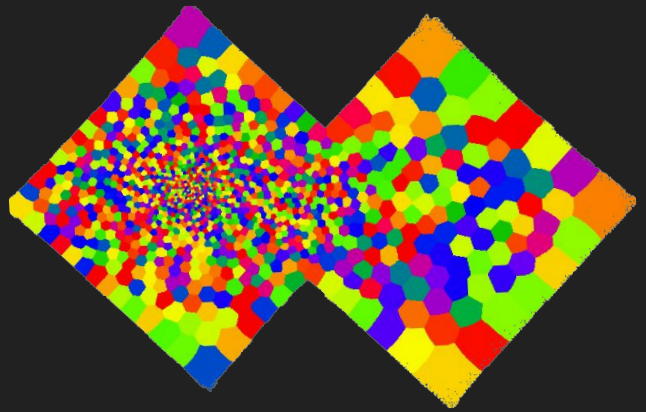


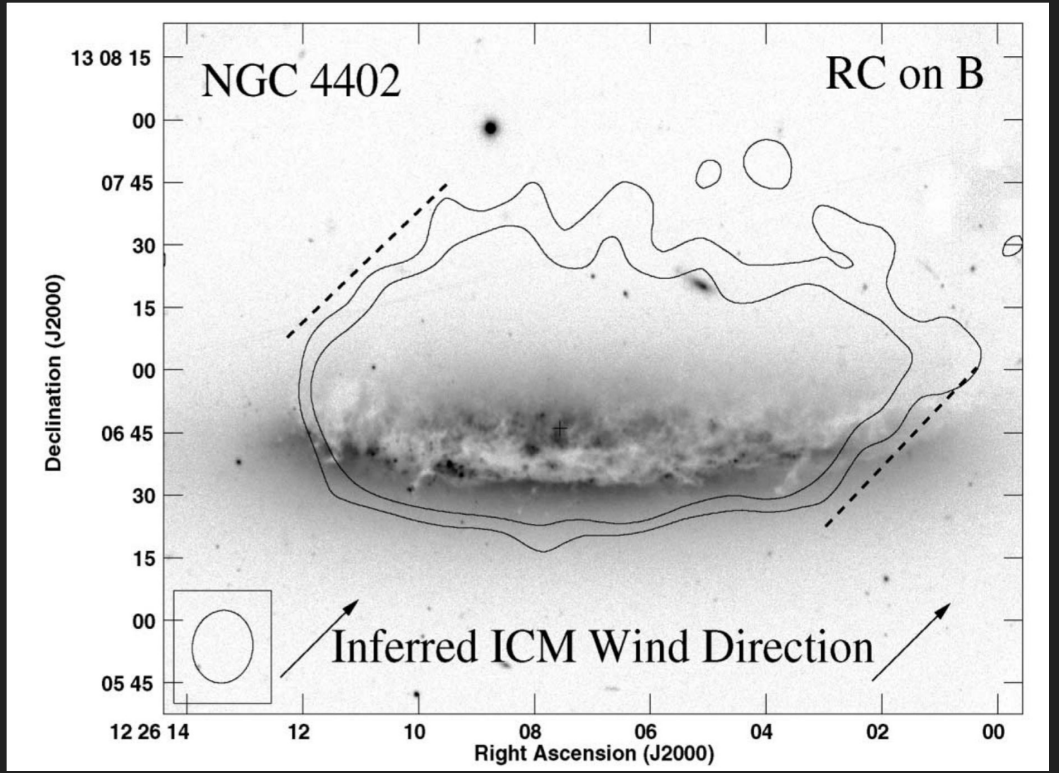
The mystery of S0’s

- Red and dead
- Spiral → Elliptical transition?
- Dispersion supported bulge
- Rotationally supported disk

By NASA, ESA, and The Hubble Heritage Team (STScI/AURA)

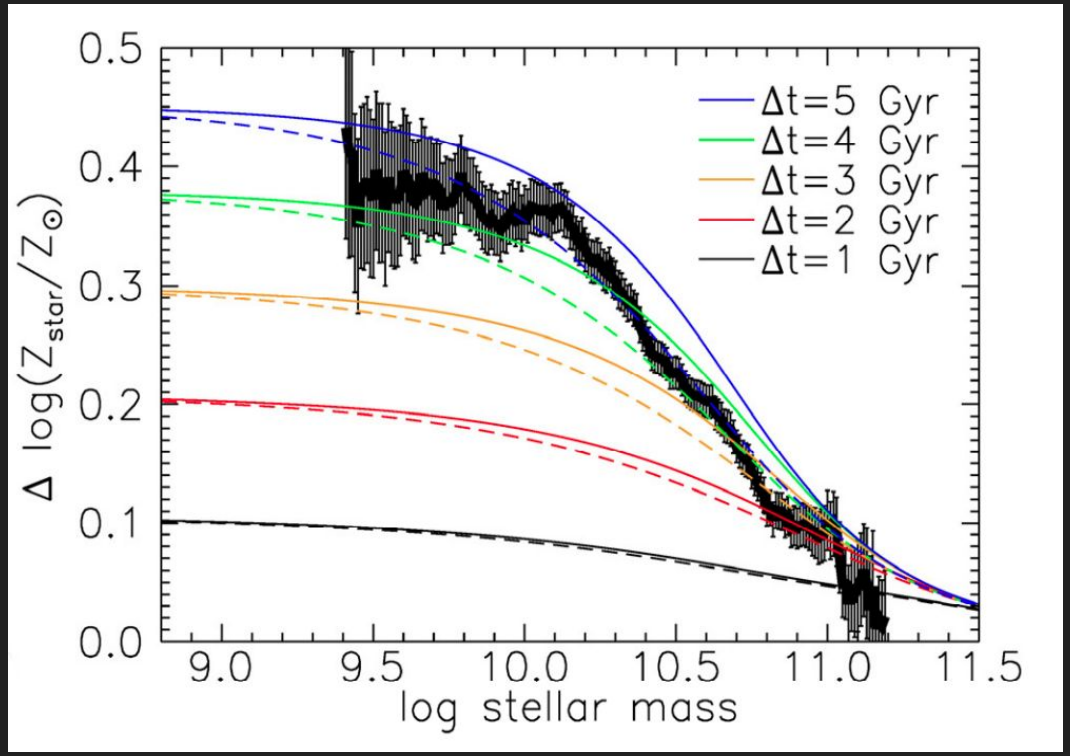
Possible formation mechanisms

1) Ram Pressure Stripping
   - Hot halo gas removed
   - Obliteration of cold gas disk
   - Evidence in NGC4402 (Crowl et al., 2005)
   - Fast SFR shutdown (<1Gyr)



Possible formation mechanisms

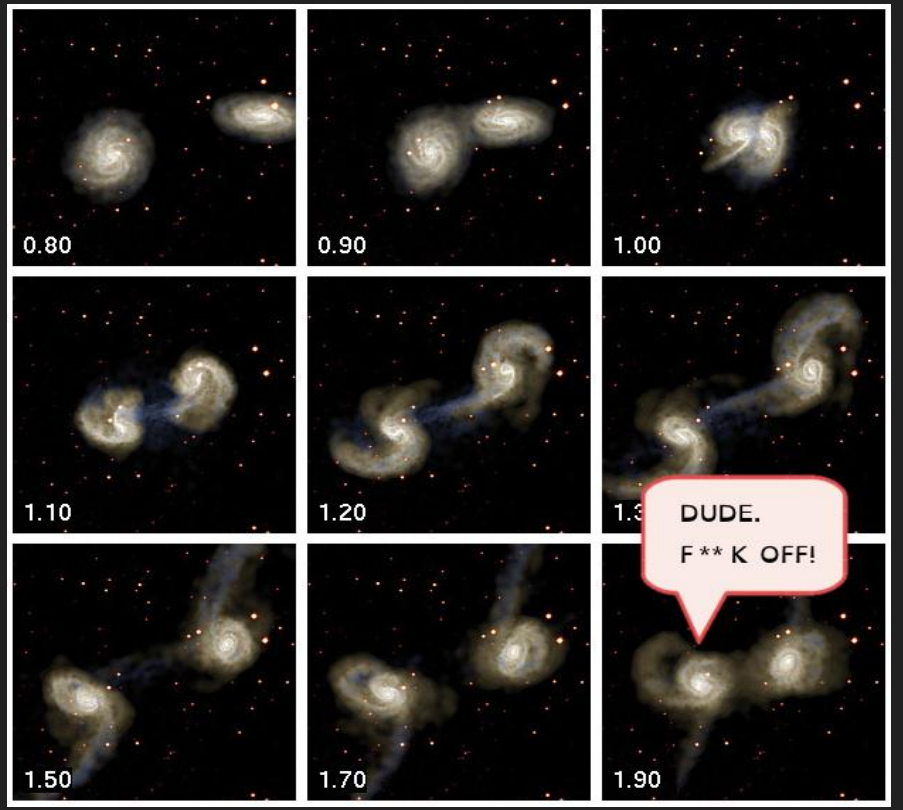
2) Strangulation
   - Subject to strong tidal forces
   - Loss of gas replenishment
   - Continues SF, raising metallicity
   - Gradual SFR shutdown



Peng et al., 2015

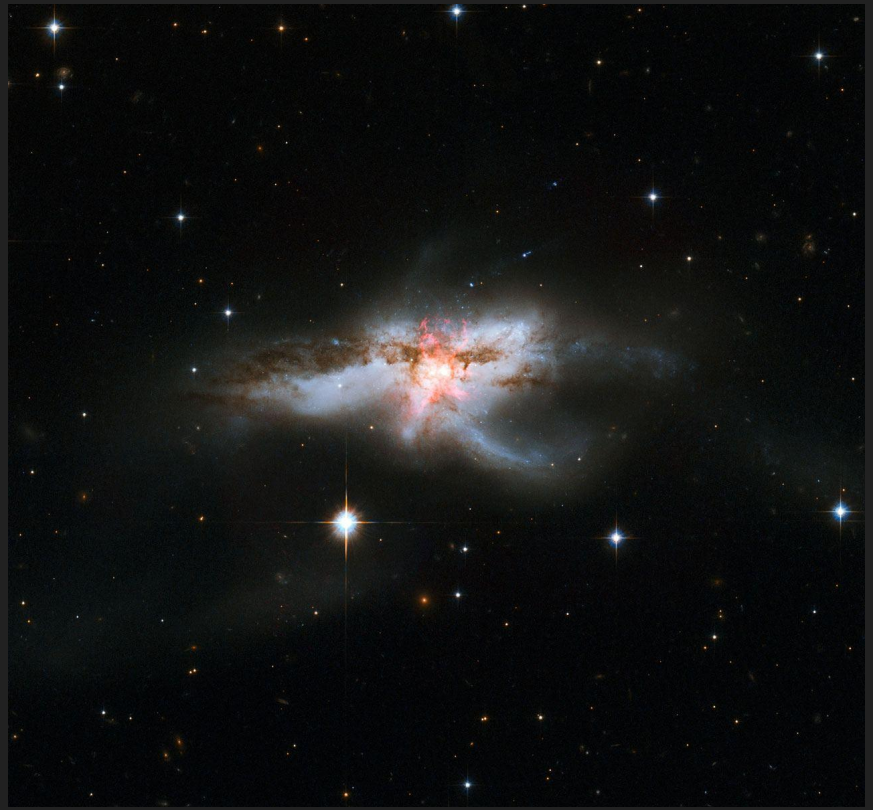
Possible formation mechanisms

3) Harassment
   - Dense cluster environment
   - Fly-bys transport gas to core
   - Stochastic rapid SFR increase, then shutdown



Possible formation mechanisms

4) Major mergers
   - Massive gas relocation
   - Destruction of coherent disk
   - Huge SFR spike, then shutdown

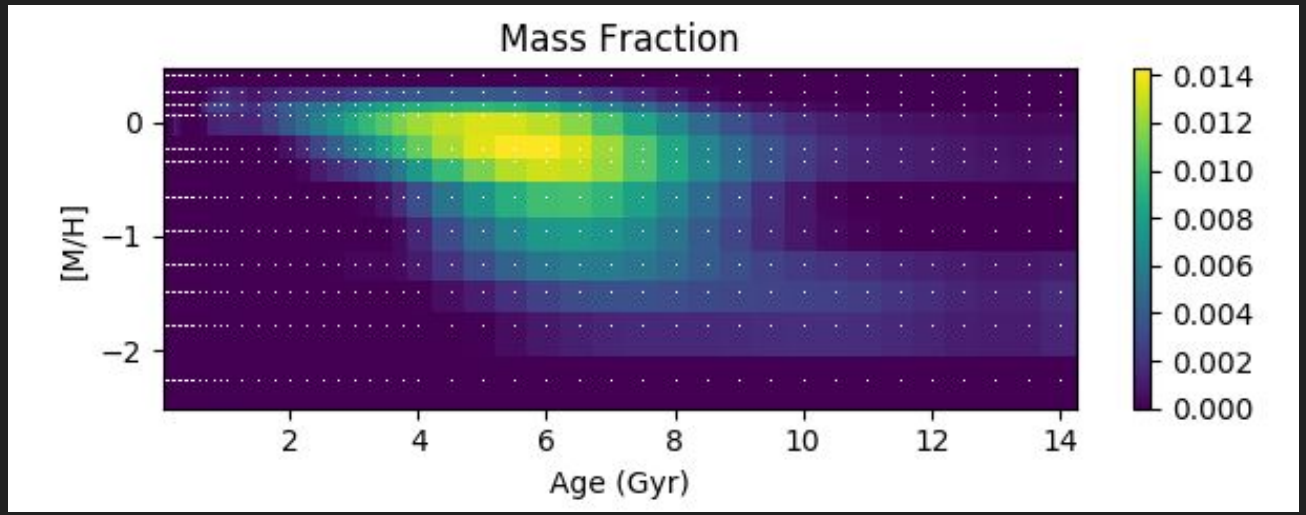


P Weilbacher (AIP), NASA, ESA, the Hubble Heritage

Possible formation mechanisms

- Signatures for all formation mechanisms
- Polluted by merger history

- Has to be disentangled from SHF

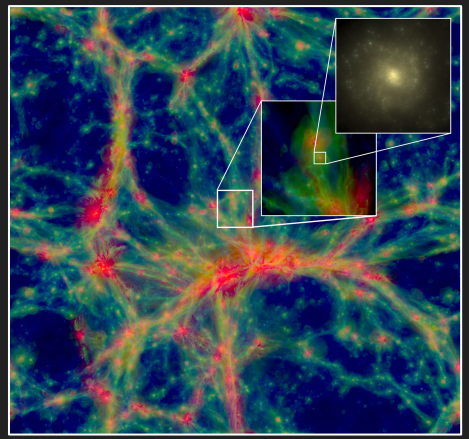


Three phase project

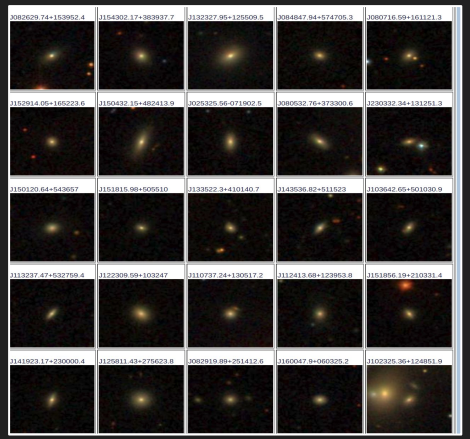
Phase 1: EAGLE Cosmological simulations

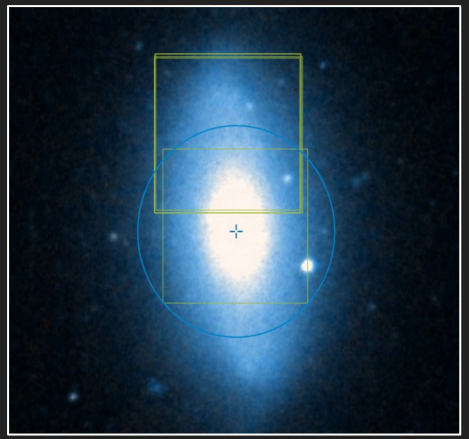
Phase 2: SDSS pipeline for SFH and ex-situ population extraction

Phase 3: Ex-situ population maps of resolved galaxies using MUSE



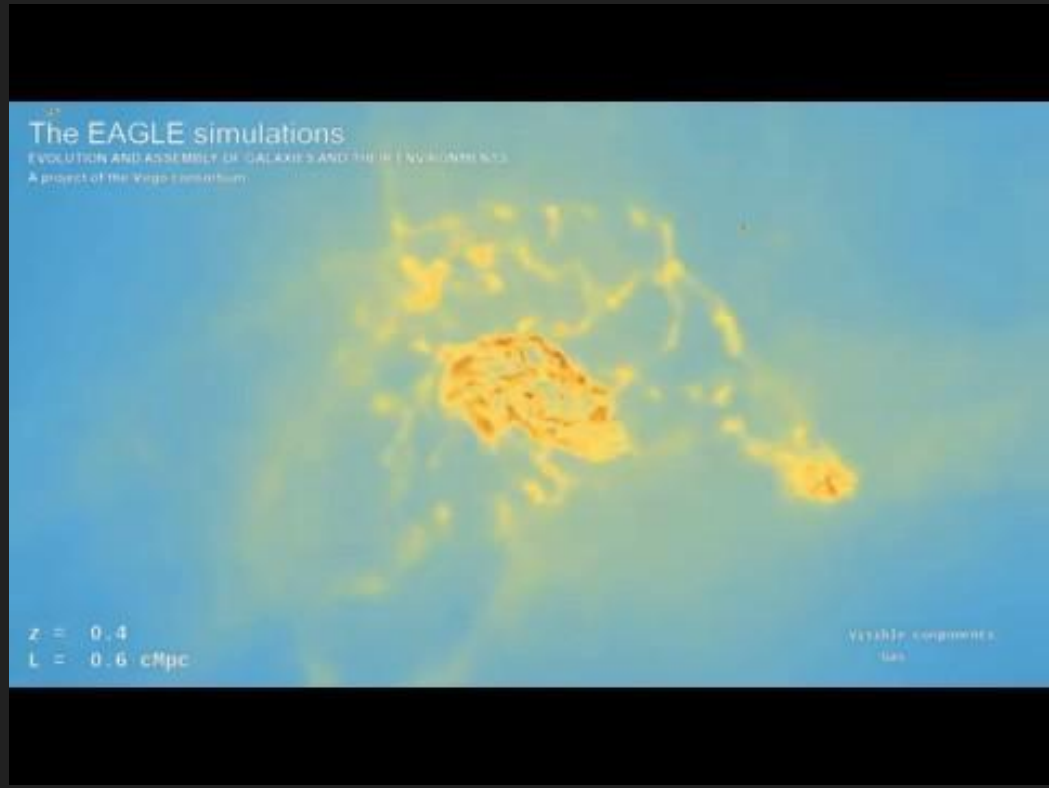
Schaye et al. 2014





Phase 1 - The EAGLE simulations Schaye et al. (2015); Crain et al. (2015).

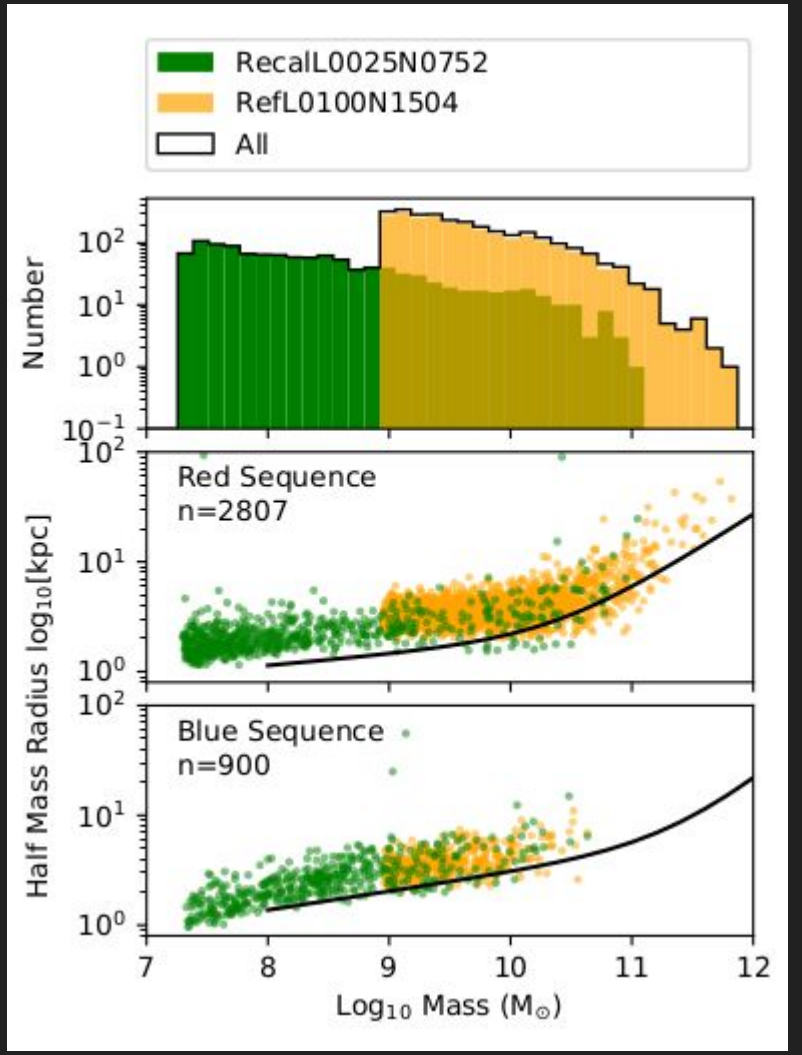
- 100cMpc^3 volume, 2x1504^3 particles
- 25cMpc^3 reference volume, 2x752^3 particles
- Origin of stellar particles traced through merger tree
- Final z=0 snapshot considered
- More than 160’000 galaxies of M>10^{9}M$_\odot$



Building a sample

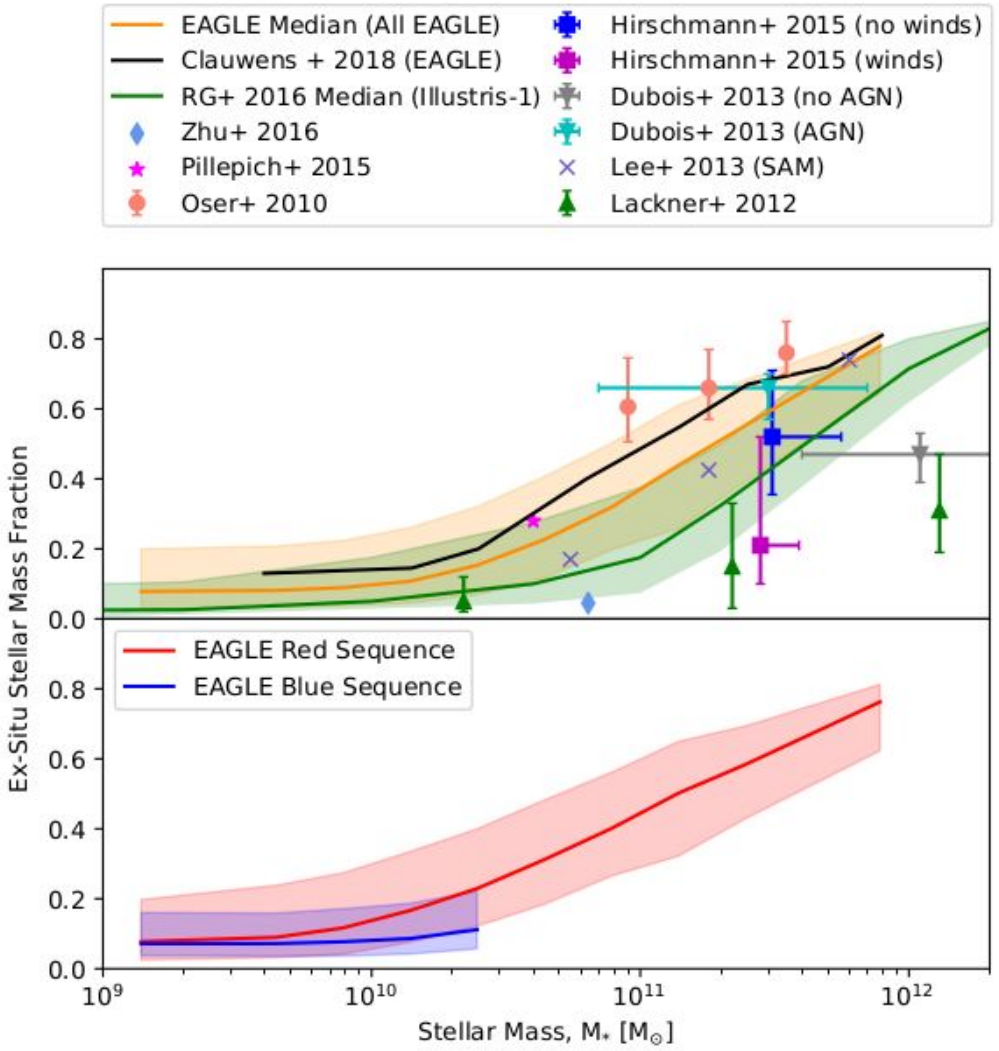
- Minimum 500 stellar particles
- Galaxies divided red and blue sequence using κ_{co}
- Shown to be effective in Correa et al. (2017)
- κ_{co} > 0.4 = Blue Sequence
- κ_{co} < 0.4 = Red Sequence

$$\kappa_{co} = \frac{K_{co}^{rot}}{K} = \frac{1}{K} \sum_{i, L_{z,i}>0} \frac{1}{2} m_i \left(\frac{L_{z,i}}{m_i R_i} \right)^2$$



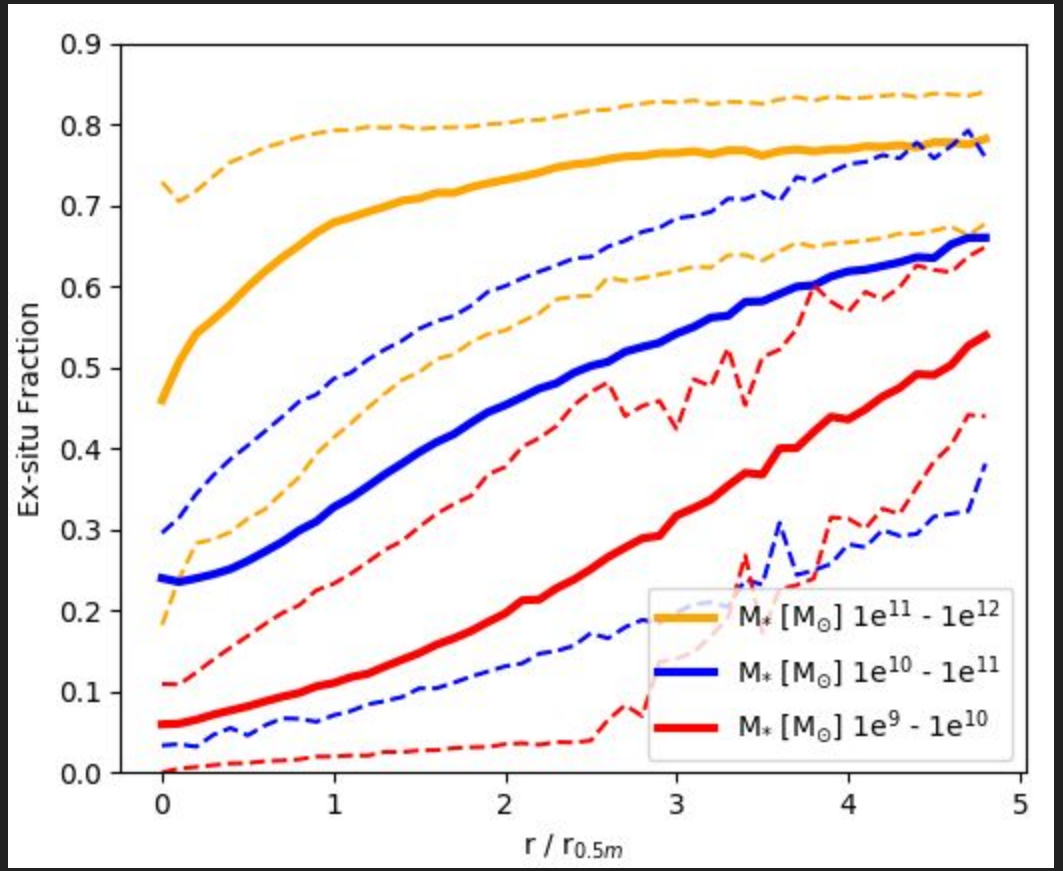
Ex-situ fractions

- At M>$10^{12}M_{\odot}$ ex-situ fraction > 80% for red sequence
- Improved situ tracing gives lower ex-situ fraction at all masses
- 30 pkpc limited (EAGLE standard aperture)



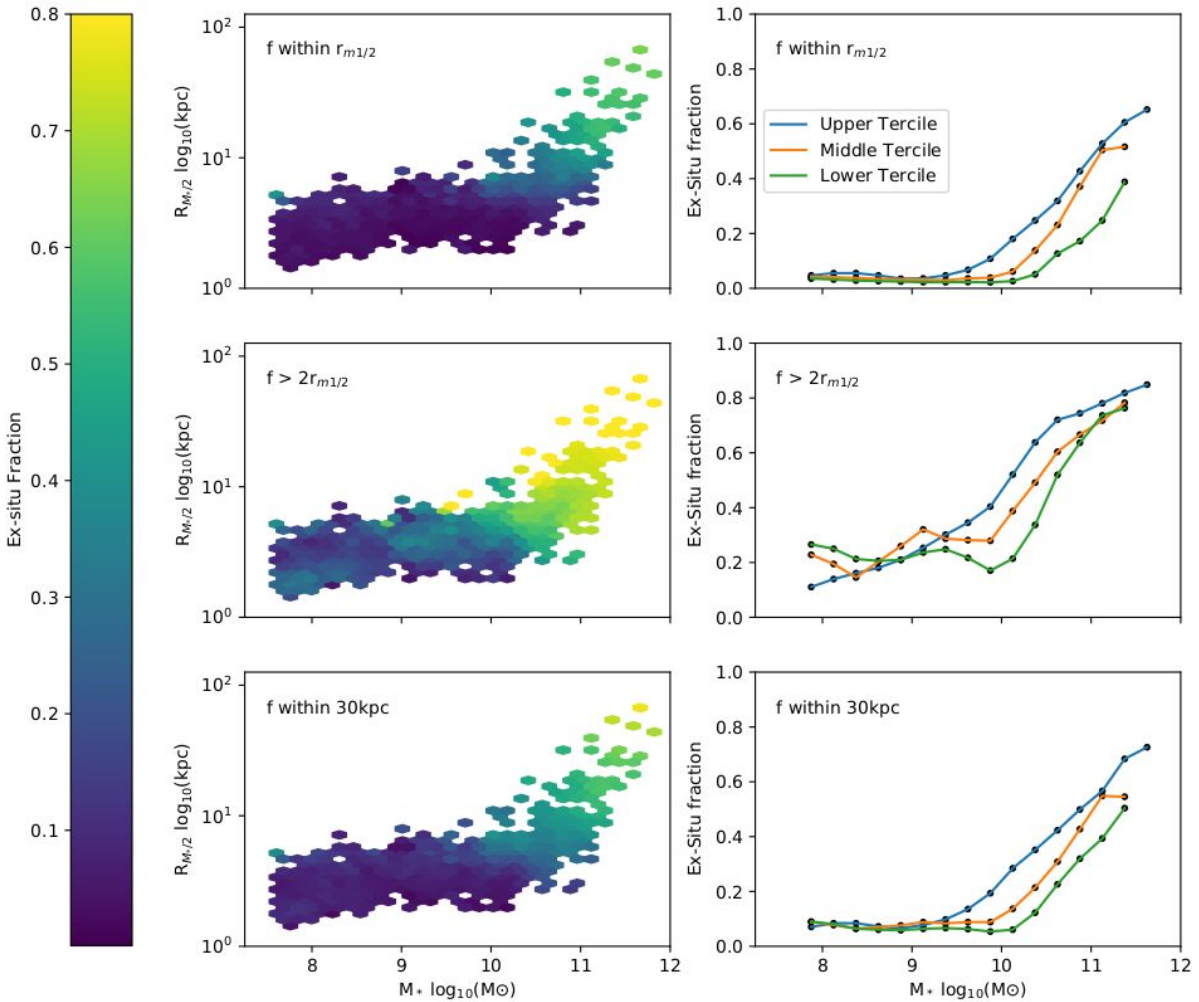
Ex-situ fractions

- At all masses, ex-situ fraction increases with radius
- Constant increase for low-mass sample
- Plateau after half-mass radius for massive sample
- Clear example of two-phase assembly



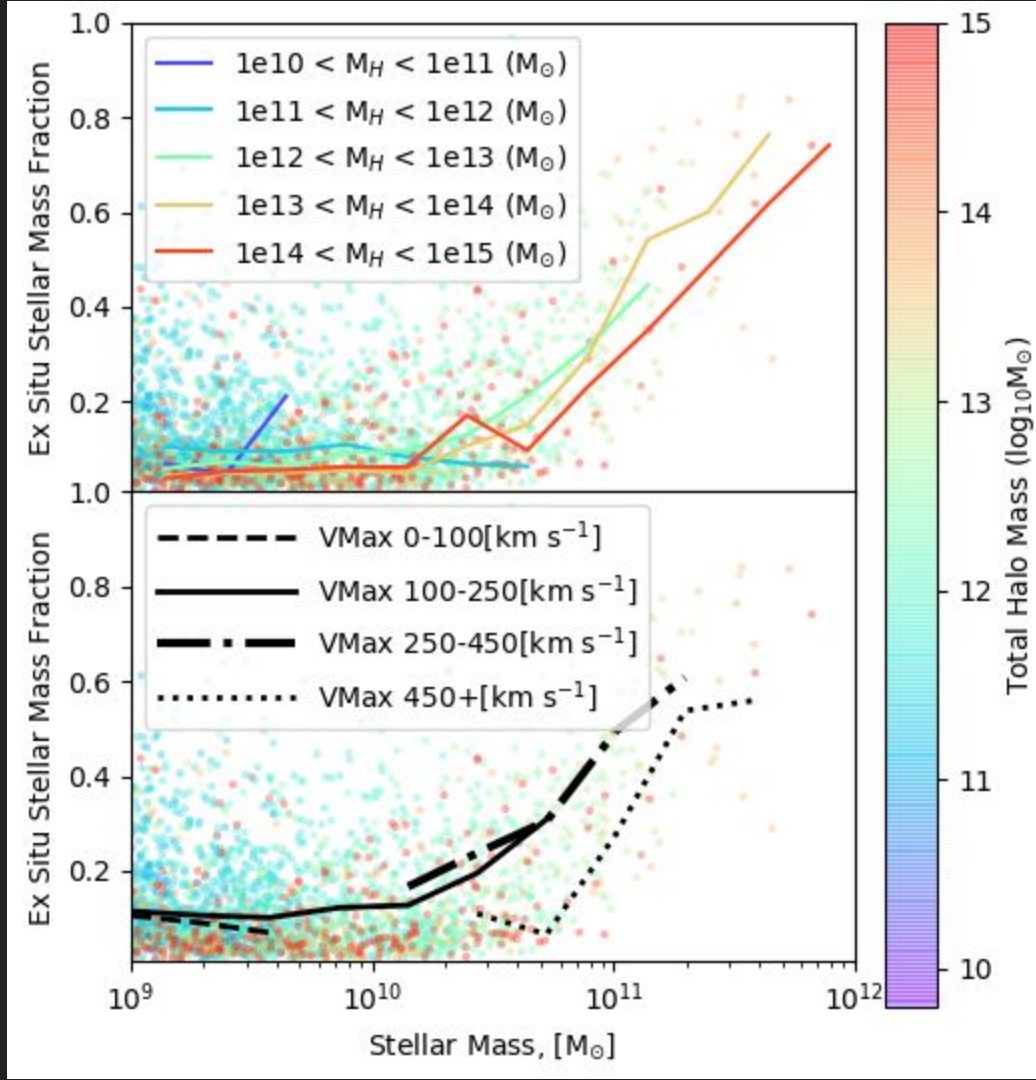
Ex-situ fractions

- Trends with density
- More diffuse galaxies have higher ex-situ fractions
- Separation appears after $M>2x10^9M_\odot$



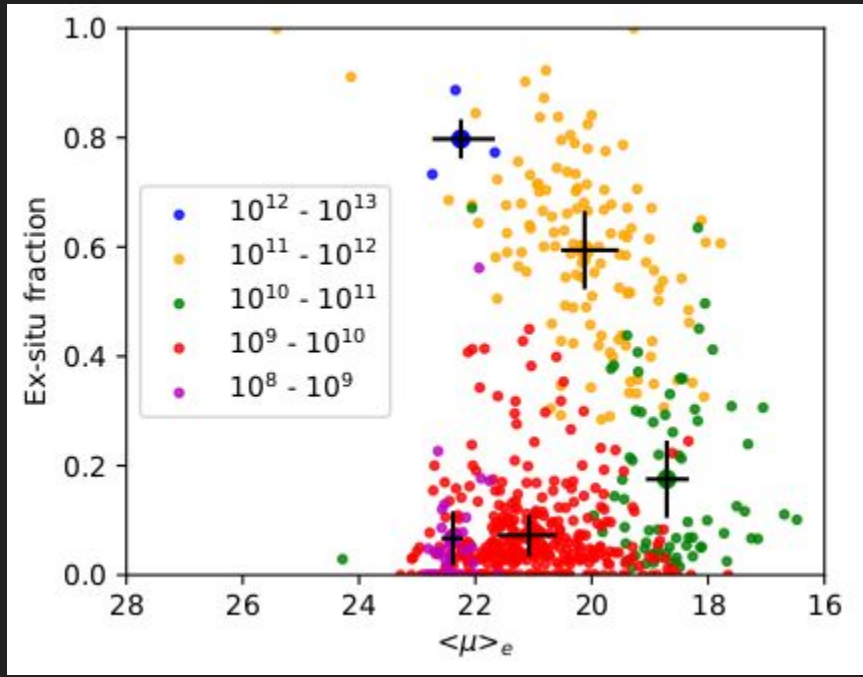
Ex-situ fraction

- More massive halos contain galaxies with lower ex-situ fractions
- Possible result of high pasing velocities, e.g. model fitting of ISM in Gu et al. 2018
- Alternatively result of survivor bias, massive clusters form efficiently, thus contain less subhalos

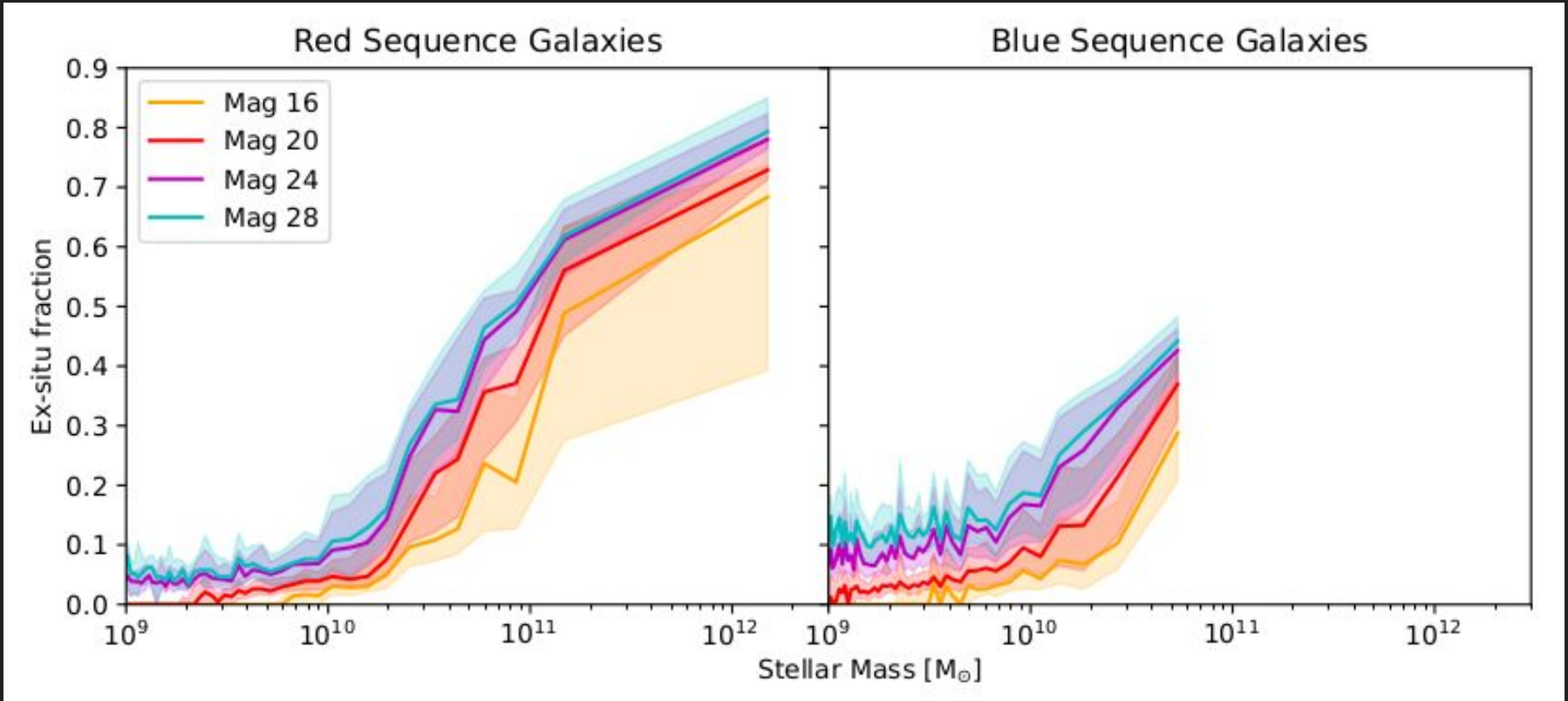


Two phase build-up

- Clear evidence of two-phase formation history
- After $M>10^{10}M_{\odot}$ accreted material extends galaxy, reducing surface brightness



Predictions for observers

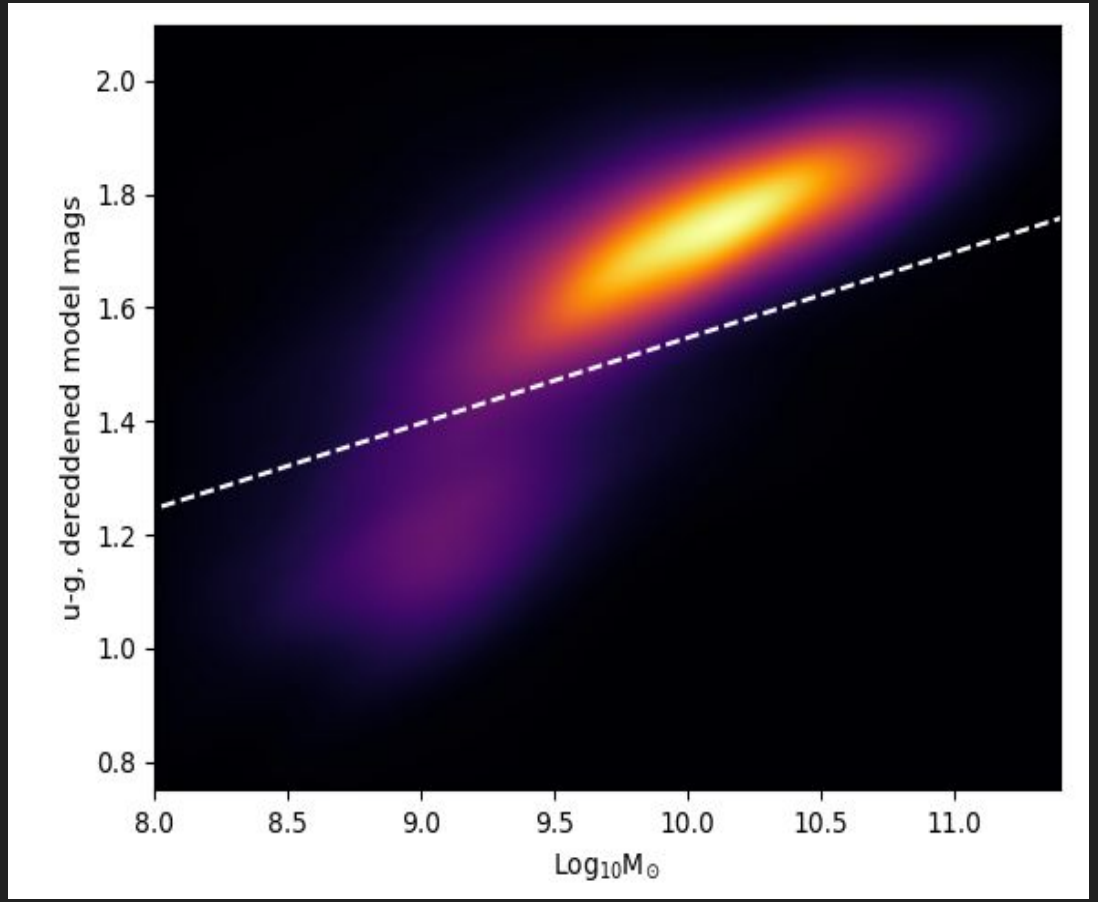


Phase 2 - SDSS galaxies

- Extracting ex-situ fractions and SFH of real galaxies
- Building and testing pipeline for extraction of parameters
- Implementing new regularisation technique for full spectral fitting

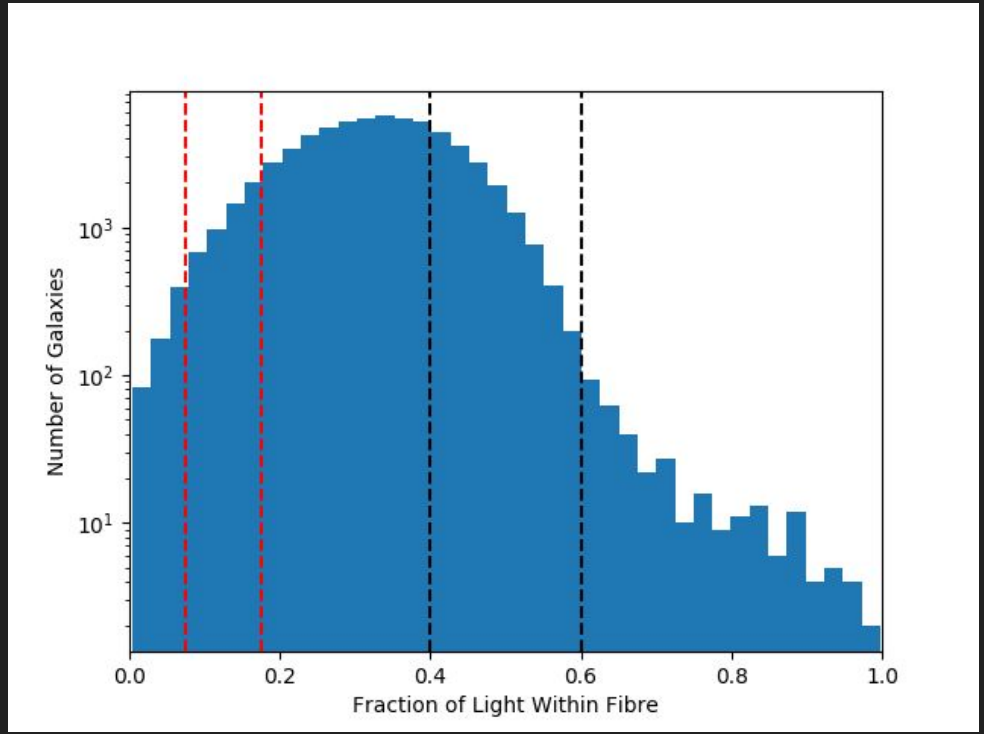
Building a sample

- Query to SDSS removes high Hα flux sources
- Cut on green valley
- 63’937 targets remaining



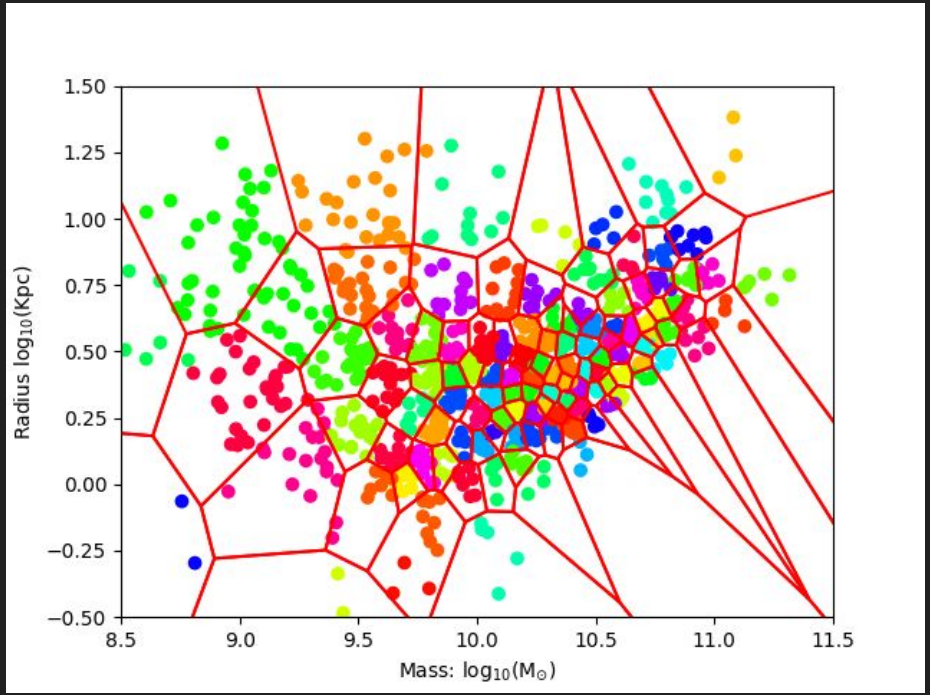
Limiting by light-fraction

- Light fraction limited to 12.5% and 50%
- Gives radial information on galaxies
- 1’925 and 825 galaxies in each sample respectively



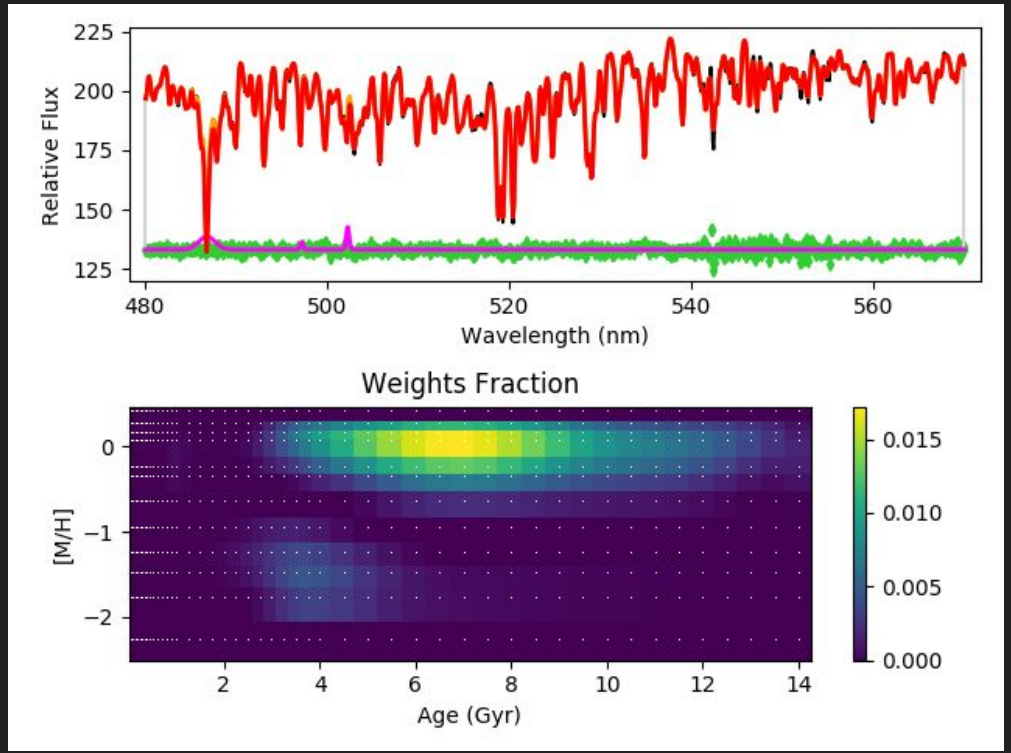
Voronoi binning

- Bin to required signal to noise
- SN > 200
- Average single target SN, ~11
- Treat spaxel as single object
- Sum spectra



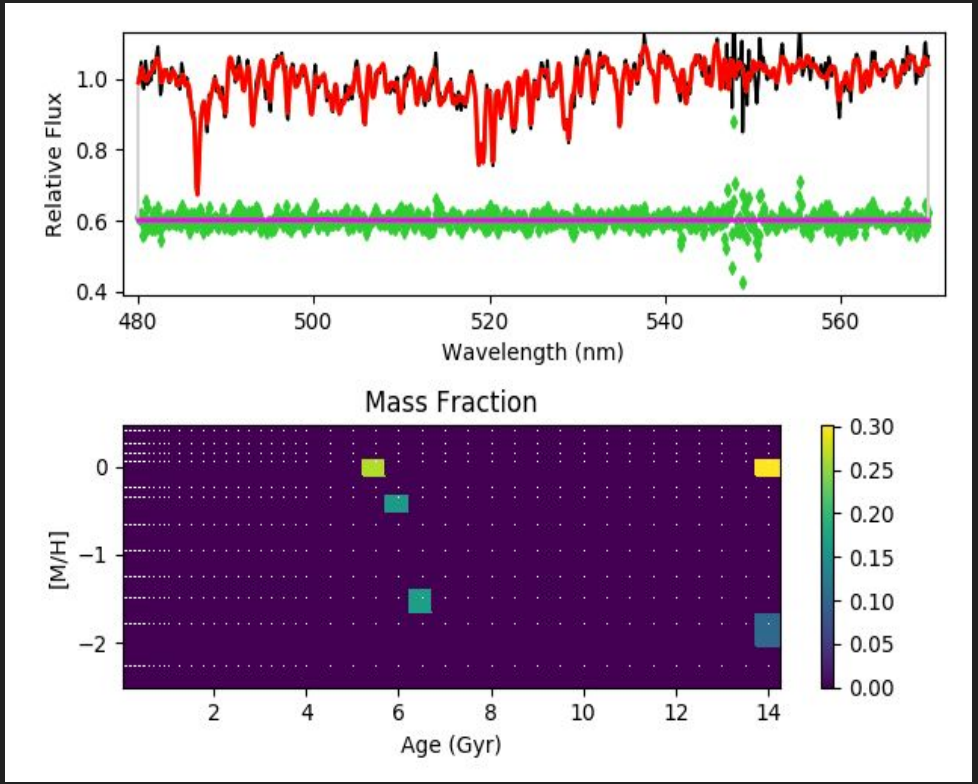
Full spectral fitting - PPXF (Cappellari & Emsellem, 2004. Cappellari, 2016)

- Combination of single stellar population models fit to spectrum
- Age-metallicity of models mapped
- Gives SFH
- Infers ex-situ population mass



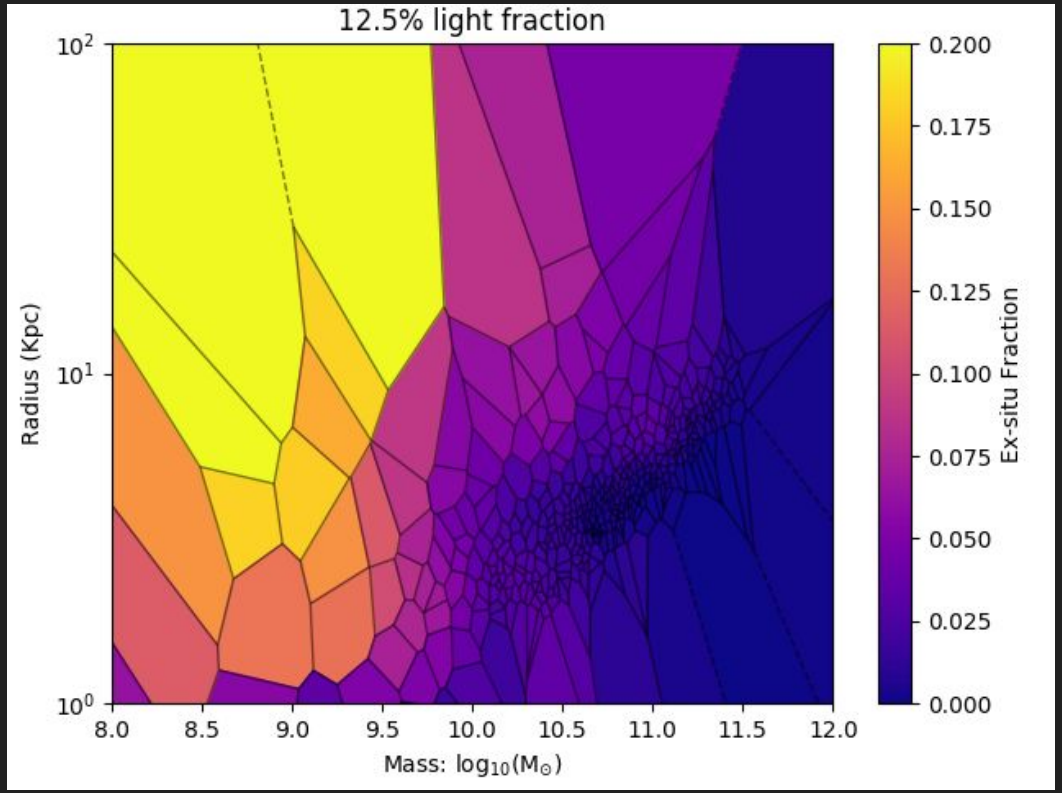
Regularisation

- Optimal regularisation gives most accurate weight distributions
- Monte-Carlo used for optimisation
- Implementation of third order regularisation (Böker et al, 2019)



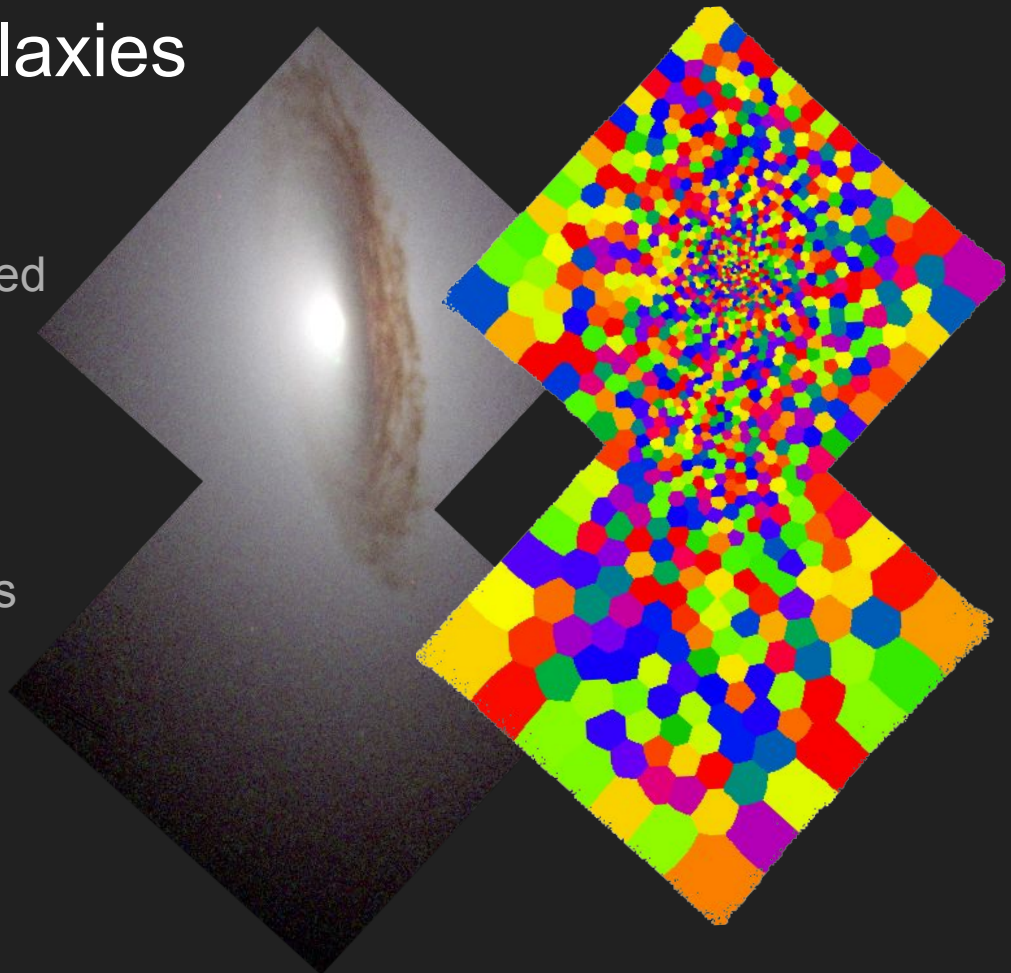
Voronoi with weights

- Highlights trends across mass-size plane
- Vertical trends for ex-situ fraction
- Similar to trends in galaxy extent seen in EAGLE



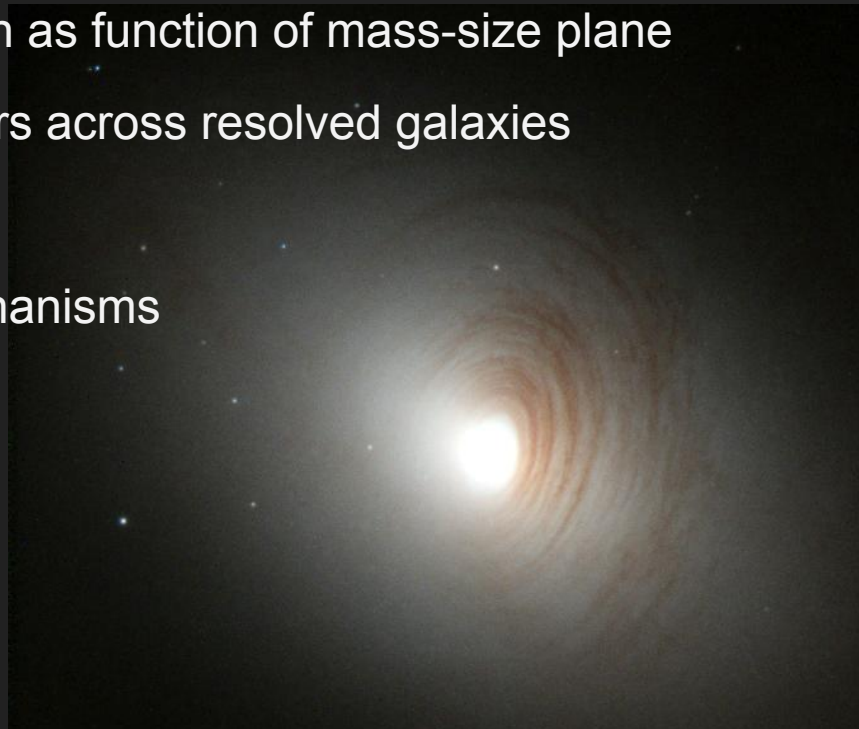
Phase 3 - Resolved galaxies

- Ongoing work
- Application of method to resolved objects with MUSE
- Same binning and extraction methods
- Infers SFH and ex-situ locations
- Can be used to map ex-situ population across galaxies



End of project expectations

- Predictions of ex-situ fractions from EAGLE
- Observations of ex-situ population fraction as function of mass-size plane
- Pipeline to map populations of ex-situ stars across resolved galaxies
- Extraction of accurate SFH of galaxies
- Identification of S0 galaxy formation mechanisms

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