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The Assembly Histories of Quiescent Galaxies Since z = 0.7 from Absorption Line Spectroscopy

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Motivations

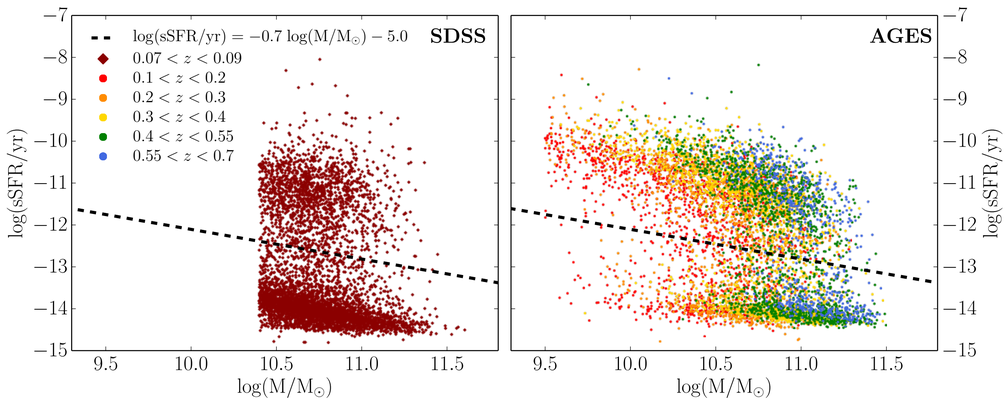
Galactic archaeology: where one infers the past evolution of galaxies through detailed analysis of the present-day galaxies and their stellar populations.
Stellar population synthesis technique: the extraction of fundamental properties of stellar populations—such as the ages and detailed abundance patterns—that are encoded in the spectral energy distributions.

Objectives: Use full-spectrum modeling to measure accurate ages and abundances for a large mass-complete sample of quiescent galaxies from z ~ 0.7 to z ~ 0.1 using the SDSS and AGES data. Examine how their stellar population properties evolve over time as a function of $M_\star$.

Powerful constraints can be placed on the assembly histories of galaxies from the evolution of their stellar population properties.

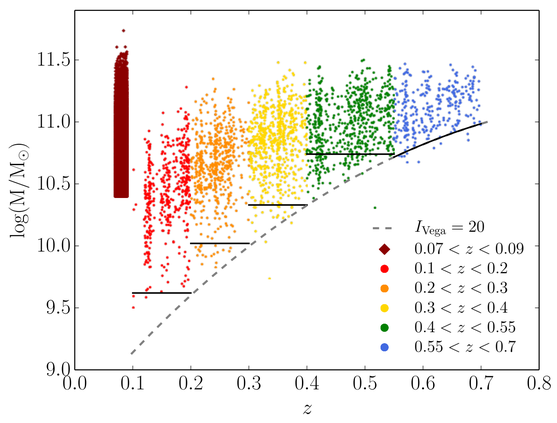
Selecting a Mass-Complete Quiescent Sample

- Low redshift: SDSS (York et al. 2000), with 14.5 < r < 17.6.
- Intermediate redshift: AGES (Kochanek et al. 2012), with 15 < I_{Vega} < 20.
- Estimate the $M_\star$ and SFR for the galaxies in the sample using `iSEDfit` (Moustakas et al. 2013).
- Select quiescent galaxies based on their specific SFR.
- Apply mass-completeness cuts in each redshift bin.
- Stack the quiescent galaxy spectra in bins of redshift and $M_\star$.



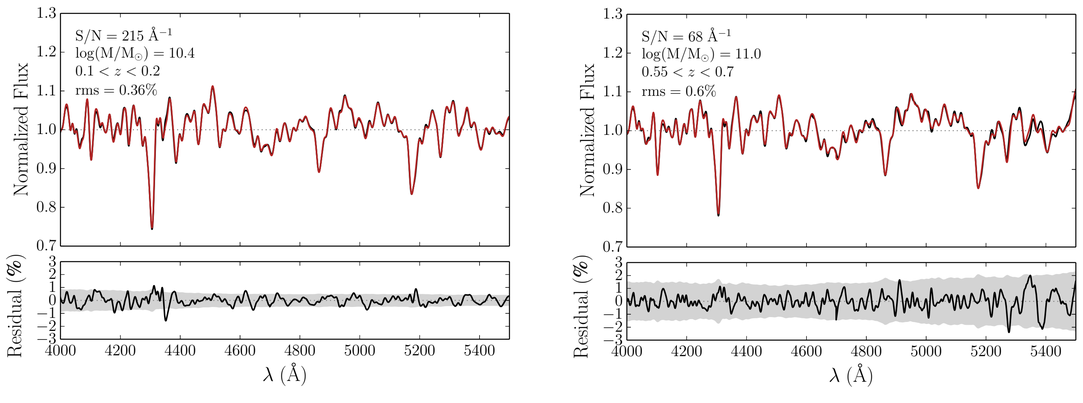
Specific SFR vs. $M_\star$ for the SDSS and AGES sample. The bimodality of SDSS galaxies is used to derive the quiescence cut, shown here as a dashed black line. Only those that fall below the specific SFR threshold are included in the quiescent sample.

$M_\star$ vs. redshift for the quiescent sample. The black lines are the completeness cuts applied to each color-coded redshift bin and the dashed grey line corresponds to I_{Vega}=20 estimated from a photo-z sample (Brodwin et al. 2006, 2013).



Full-Spectrum Model Fitting

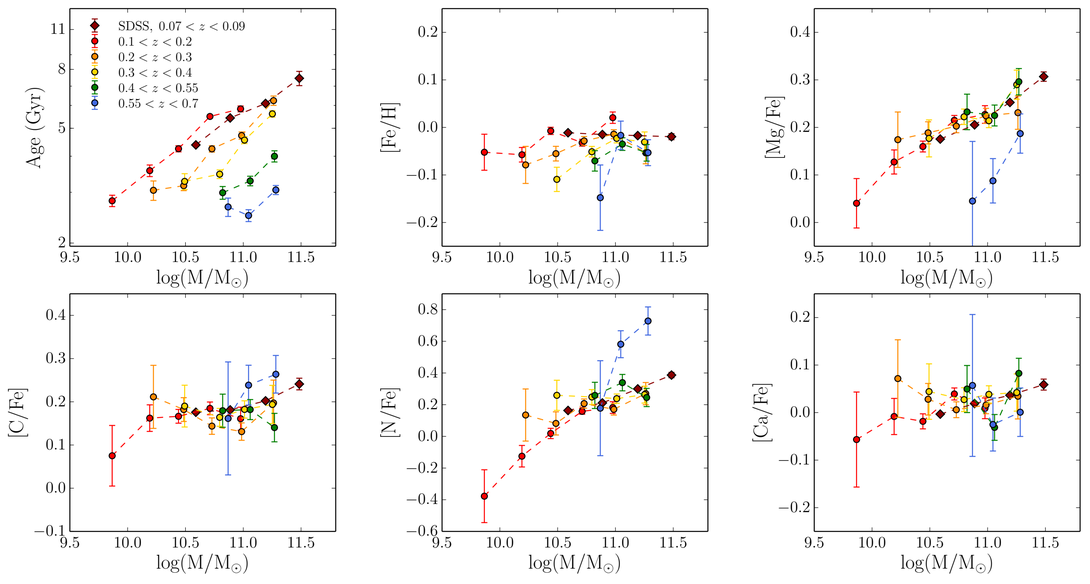
- Full-spectrum modeling code of Conroy & van Dokkum 2012.
- Makes use of response functions to model variable abundance patterns.
- Measured age and abundance ratios over 4000 – 5500 Å.
- Best-fit parameters obtained using an affine-invariant ensemble sampler for MCMC, `emcee` (Foreman-Mackey et al. 2013).



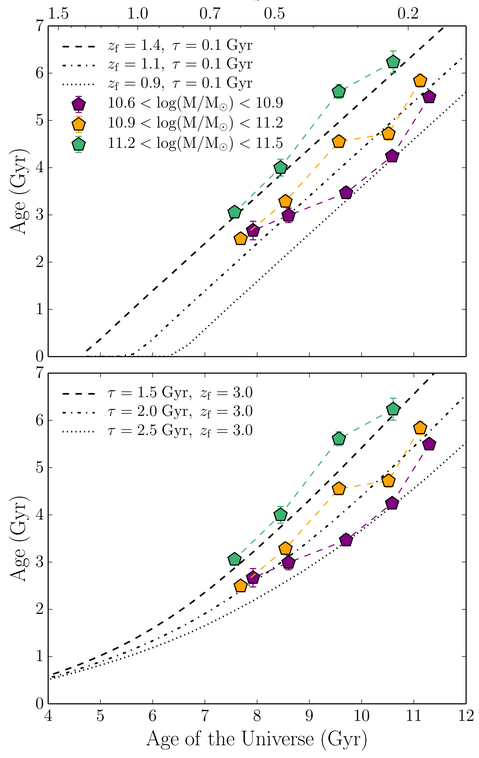
Representative AGES stacked spectra and the corresponding best-fit models, displayed in black and red, respectively. The bottom panel shows the fractional residuals in the models in black and the flux uncertainties as the grey shaded region.

No Evidence for Evolution of Stellar Population Properties Since z = 0.7

- There is ≲0.1 dex variation in the abundance ratios at fixed $M_\star$.
- The increase in stellar ages with time for massive galaxies is consistent with passive evolution for the last 7 Gyr of cosmic time.
- The stellar ages are younger than the age of the Universe at all epochs, consistent with an effective single-burst star formation epoch of z ~ 1.5.

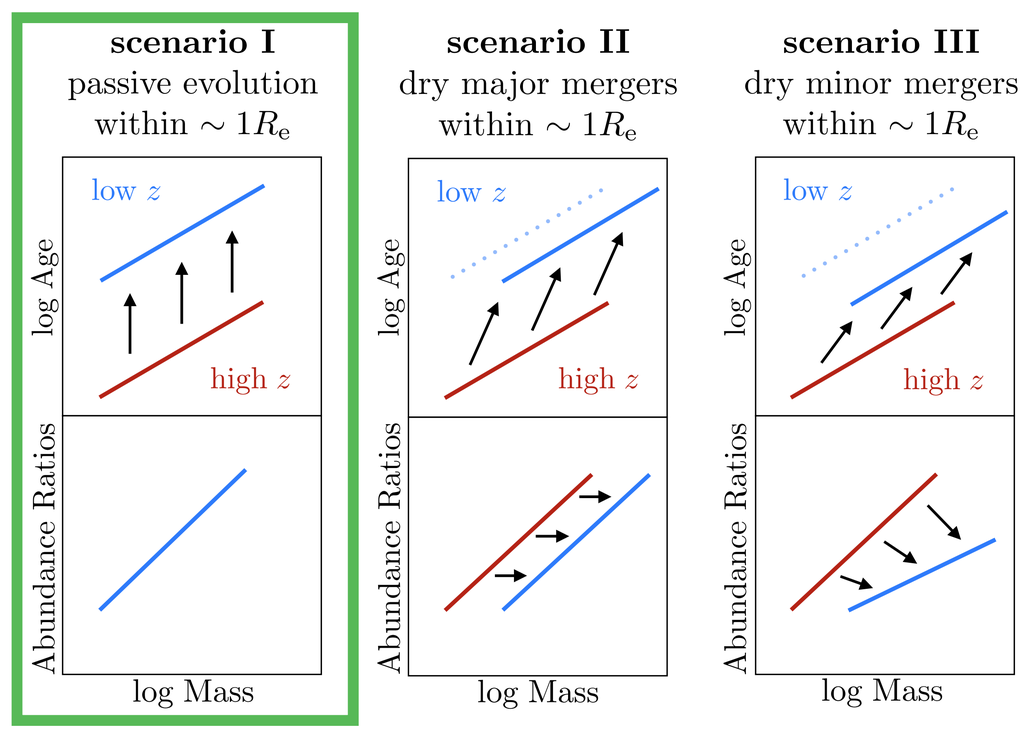


Best-fit stellar population parameters shown as a function of $M_\star$ for the SDSS and AGES data. The mass values correspond to the median $M_\star$ of the samples within each bin. The error estimates are statistical only and come directly from the MCMC spectrum-fitting algorithm.



Age evolution of AGES galaxies for the three highest mass bins. The black curves represent the evolution of different light-weighted age of models with SFR(t) ∝ exp(−t/τ). The top panel shows passive evolution tracks following a burst (τ = 0.1 Gyr) at different formation redshifts, z_f. The bottom panel shows passive evolution tracks with the same formation redshift, z_f = 3.0, and varying τ. The age evolution of the most massive galaxies is consistent with passive evolution while there is evidence for a shallower age evolution for the lower mass galaxies shown in this figure.

Implications



Schematic diagrams for the time evolution of age and abundance ratios of quiescent galaxies as a function of their $M_\star$ for three scenarios. Ages and abundance ratios are assumed to be measured within a spectroscopic fiber which has an extent of ~ 1 R_e unless noted otherwise.

The inner regions of massive quiescent galaxies appear to be passively evolving since z~0.7.

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