IS THE *LOCAL* (STELLAR) MASS DENSITY THE DRIVER OF STELLAR POPULATION PROPERTIES?

insights from pixel-by-pixel spectro-photometric analysis of SDSS-CALIFA galaxies

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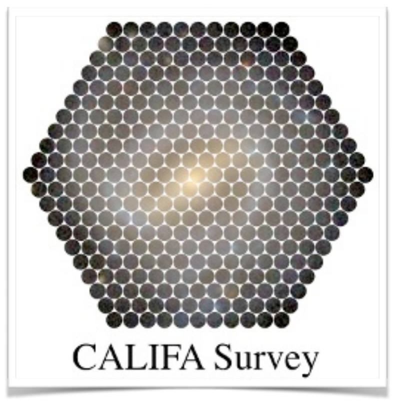
Main References:
Zibetti et al., 2017, MNRAS, 468, 1902
Zibetti et al., 2018, to be submitted
Zibetti, Charlot & Rix, 2009, MNRAS, 400, 1181

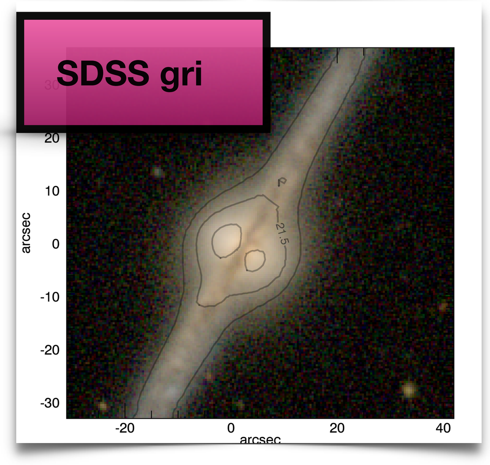


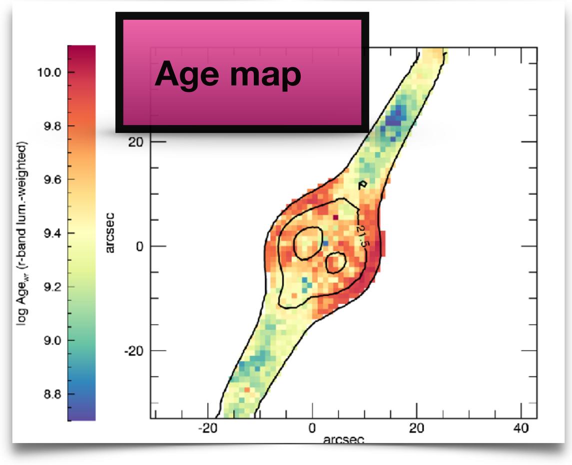
The CALIFA-SDSS sample

394 diameter-selected galaxies from the CALIFA DR3 (Sanchez et al. 2012, 2016, Walcher 2014) observed in integral field spectroscopy over the range 3700-7000 Å (6 Å FWHM), ~2.6” FWHM spatial resolution. Representative sample of the local Universe in the mass range $10^{9.7}$—$10^{11.4}$ M⊙. 5-band SDSS imaging matched to the IFS cubes. Effective spatial resolution ~1kpc

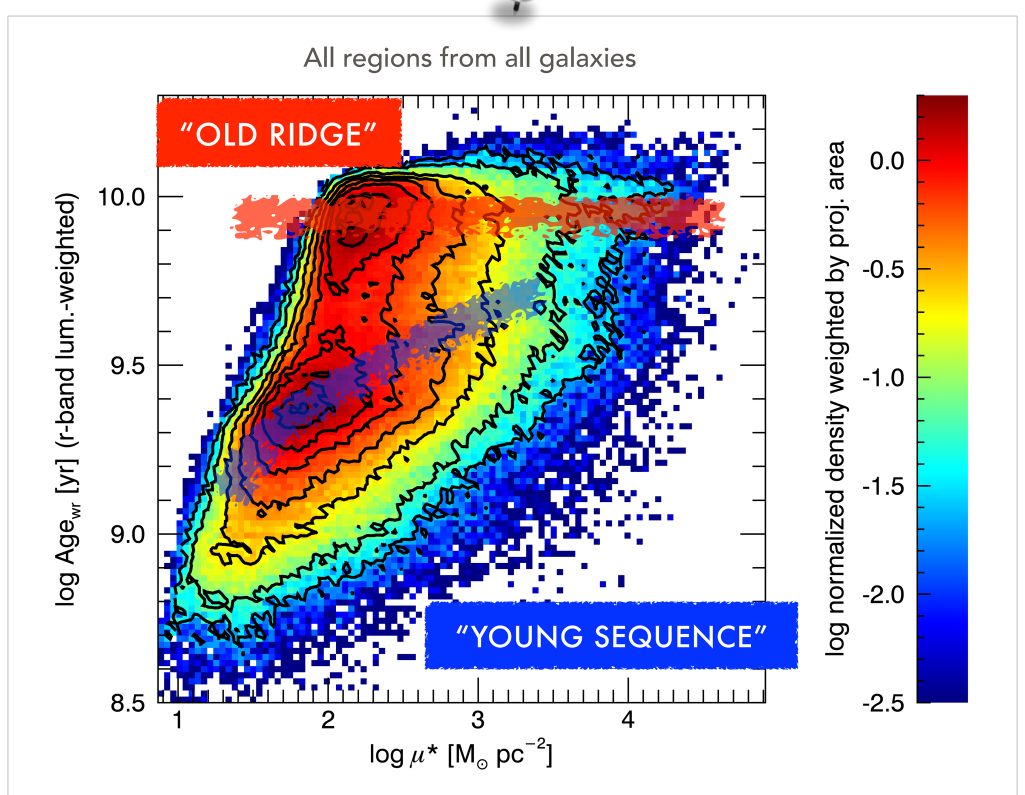
Stellar population analysis

Stellar population parameters, including present-day stellar mass, light-weighted age and metallicity, effective dust attenuation, are derived at each spaxel with a Bayesian approach (similar to Gallazzi et al. 2005). The observed fluxes in the 5 photometric SDSS bands and 5 absorption indices (D4000n, Hβ, Hγ+Hδ, Mg2Fe and [MgFe]') are compared with those measured on a comprehensive library of 500,000 synthetic spectra, built using a variety of star-formation histories, chemical enrichment histories and differential dust attenuation. A probability distribution function is obtained, from which median and percentiles are extracted as fiducial estimate and uncertainty range, which takes into account not only observational errors but also model degeneracies.
In regions of low-surface brightness, an adaptive smoothing is applied to enhance the signal-to-noise ratio (see Zibetti et al. 2009).



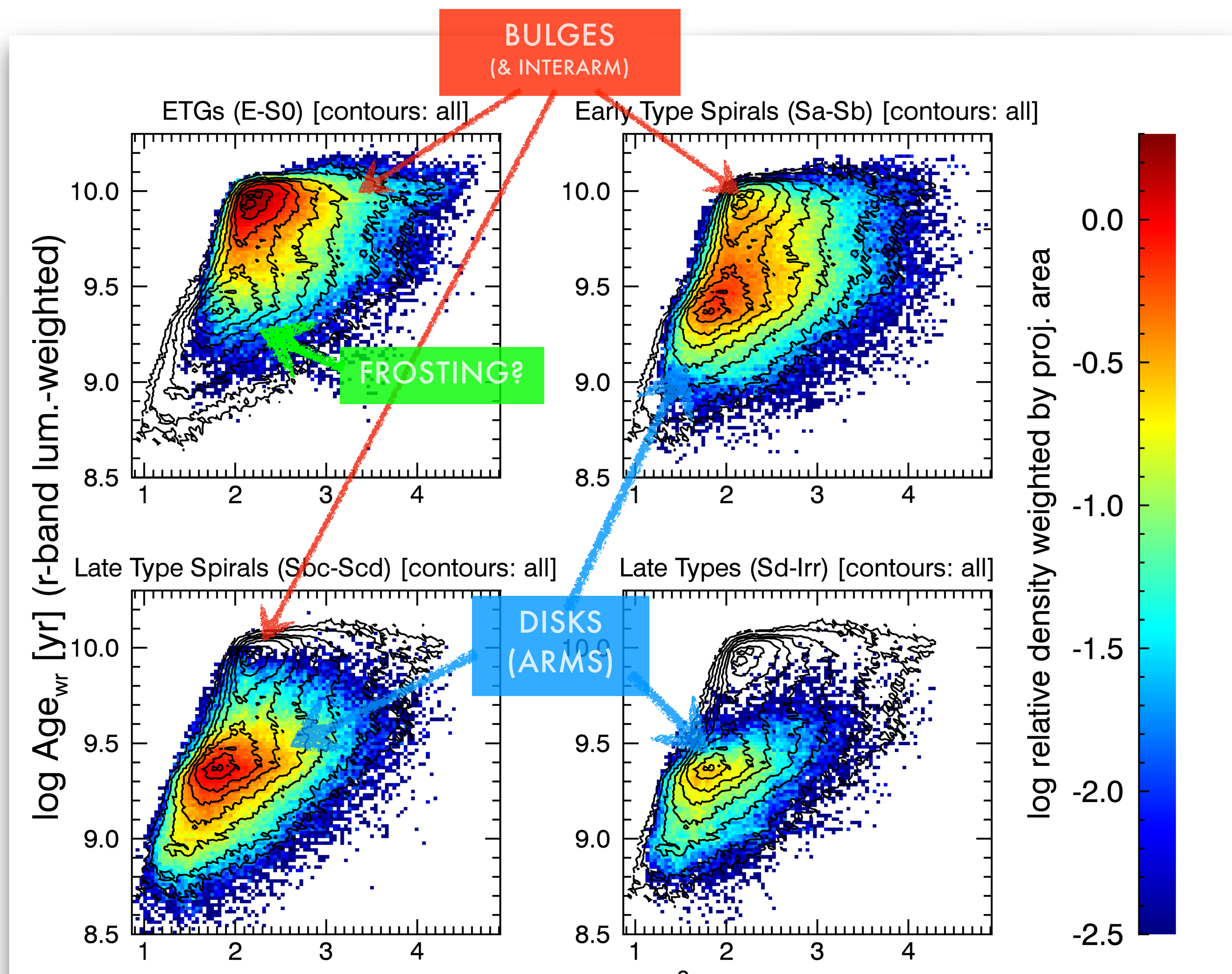


Local stellar age bimodality modulated by surface mass density



Zibetti, Gallazzi et al. (2017) cf. also Gonzalez-Delgado et al. (2014)

The distribution of ~650,000 regions, each covering ~1 kpc², from the 394 galaxies of all morphological types, is shown in the *light-weighted-age vs surface mass density (μ*) plane* (*left figure*). The distribution is *bimodal*, with two age peaks at any given μ*. We identify an “old ridge” of regions of age ~9 Gyr, independent of μ*, and a “young sequence” of regions with age increasing with μ* from 1–1.5 to 4–5 Gyr. We interpret the former as regions containing only old stars, and the latter as regions where the relative contamination of old stellar populations by young stars decreases as μ* increases.
By *splitting the regions according to the morphology of the galaxy they belong to* (*right figure*), we can identify early-type galaxies and bulges as the main contributors to the “old ridge”, and disks (spiral arms) as main contributors to the “young sequence”. Interarm regions also contribute to the young tail of the “old ridge”, while some “frosting” (little recent star-formation on the top of an old population) may be responsible for the “young sequence” tail in the ETGs.
The trend in the “young sequence” shows that higher stellar density in disks derives from star-formation histories that peaked more in the past and/or started earlier.

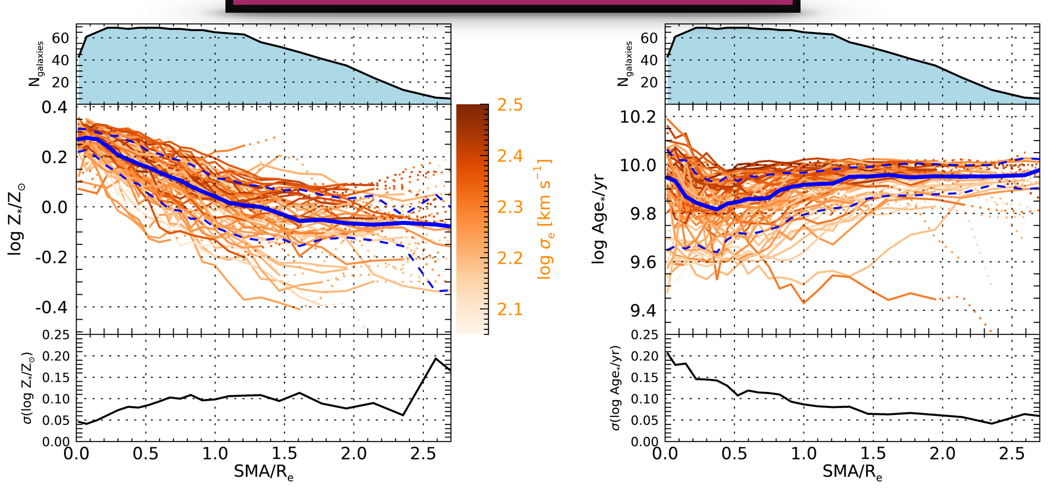


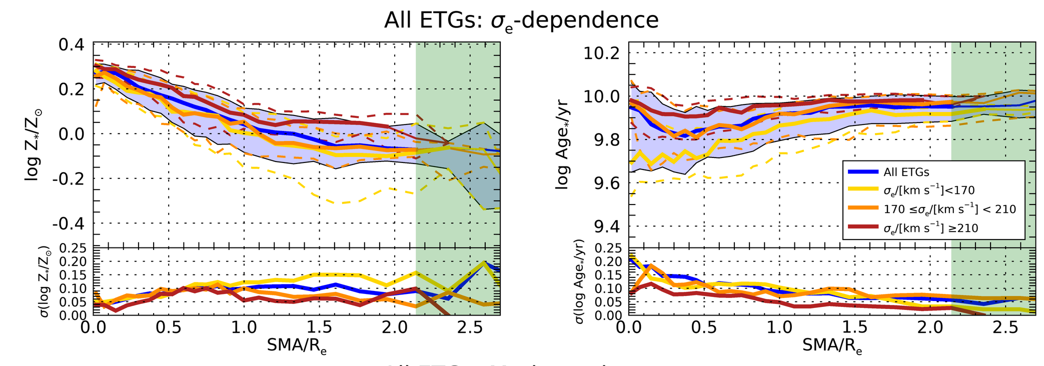
Zibetti, Gallazzi et al. (2017)

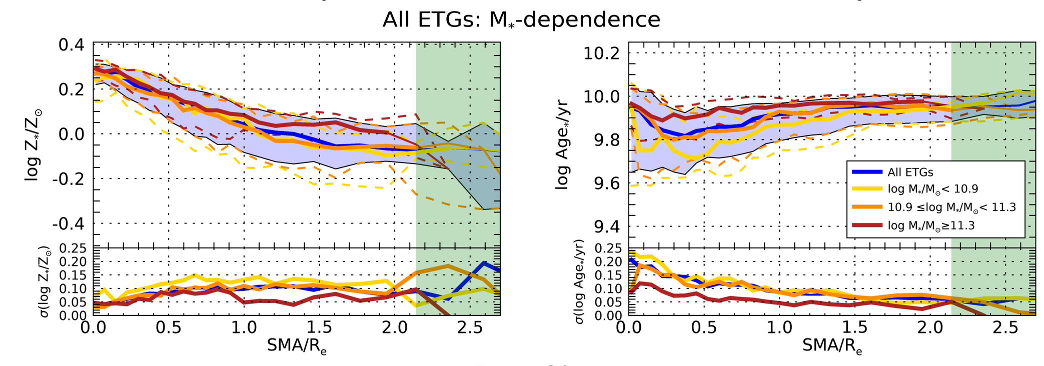
Stellar population profiles in Early-type galaxies

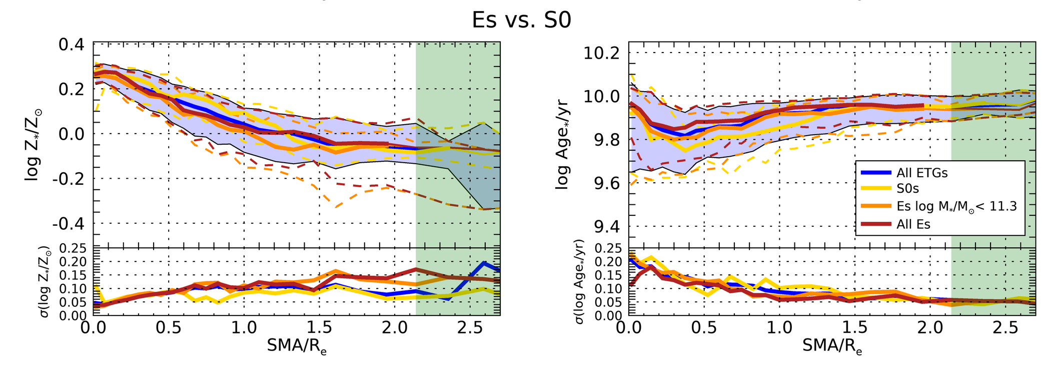
Dependence on surface mass density, global velocity dispersion, total stellar mass and morphology

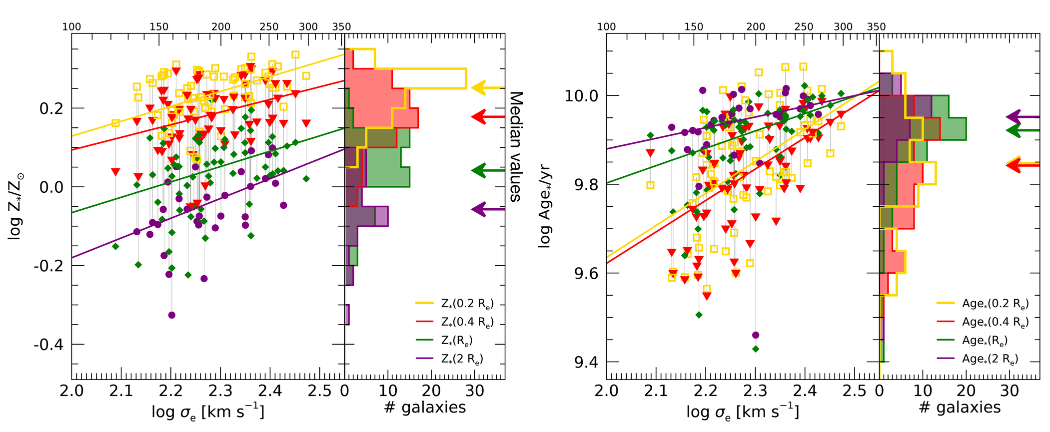
Radial profiles











Profiles of light-weighted metallicity (Z*) and age (Age*) as a function of radial distance (elliptical semi-major axis, normalized to the effective radius R_e, SMA, *left figures*) and of surface stellar mass density (μ*, *right figures*) are obtained for 69 Early-Type CALIFA Galaxies (48 Ellipticals and 21 S0's). The 2D maps are binned either radially or in μ* and the median values and percentiles of Z* and Age* are considered.
We cover up to 1 R_e for most galaxies, ~50% of the profiles extend to 2 R_e.
Individual galaxy profiles are color-coded by velocity dispersion within R_e, σ_e (Falcon-Barroso et al. 2017). The median and 16th-84th percentile range are shown by blue lines (solid and dashed, resp.).
The bottom panels display the scatter as defined by 1/2 of 16th-84th percentile range.
Note that there is indeed a close correspondence between radial (SMA) and mass density (μ*) profiles, with the former being more stretched beyond 0.5 R_e and the latter being more stretched at μ*>10^3 M$_\odot$ pc^{-2}.

- The whole ETG population unambiguously displays ***Z* profiles that decrease from the centre to the outer parts***, with typical slopes of -0.27 dlogZ*/dR/R_e within 1 R_e, -0.12 outside
- ***Age profiles peak in the center, display a minimum at ~0.3-0.4 R_e (3.2-3.3 in log μ*) and then increase very mildly in the outer parts*** (SMA>1 R_e). This is the first time that a ***systematic minimum in age*** is detected in ETGs
- The scatter in metallicity is tiny in the inner regions, reaching as small as <0.05 dex, and increases to ~0.10 dex in the outer regions
- The scatter in age is remarkably small beyond 1-1.5 Re reaching as small as <0.07 dex, and increases towards the inner regions up to ~0.15 dex
- By ***sorting galaxies in velocity dispersion σ_e***, we observe clear ***systematic offsets*** (see also plots at the bottom):
  - higher-σ_e galaxies have higher-metallicity profiles and flatter ones with respect to lower-σ_e galaxies
  - higher-σ_e galaxies have higher-age profiles, less deep minima and flatter profiles in the outskirts with respect to lower-σ_e galaxies; at the lowest σ_e, the median age-profile is overall increasing
- Similar trends are observed when sorting by total stellar mass, but trends are less clear and not statistically significant in some case
- Morphology (E vs S0) plays a marginal role: in the same mass range, S0 have a slightly deeper age minimum and marginally higher metallicity in the inner regions with respect to Es of similar mass

1. **Stellar velocity dispersion σ_e is the main parameter that correlates with the shape of the stellar population property profiles in ETGs**
2. **Total stellar mass determines similar trends, in that is strongly correlated with σ_e**
3. **A very tight local stellar-mass-density vs Z* relation exists, with a galaxy-to-galaxy scatter <0.1 dex overall (~0.05 in the inner parts). This relation is primarily modulated by σ_e *(plots on the right)***
4. **ETGs with higher σ_e (and higher mass) are:**
   1. **overall older and more metal-rich**
   2. **characterised by flatter profiles, both in age and in metallicity, i.e. they are overall more homogeneous/relaxed/evolved**

Profiles along μ*