
# Spatially resolved stellar populations of nearby galaxies:

## the overall age bimodality and the subtle nature of gradients in ETGs

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the European Union
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***SteMaGE***

# SPATIALLY RESOLVED STELLAR POPULATIONS

## WHAT FOR?

- Scaling relations exist involving global/average galaxy properties
- Bimodalities exist in global/average galaxy properties

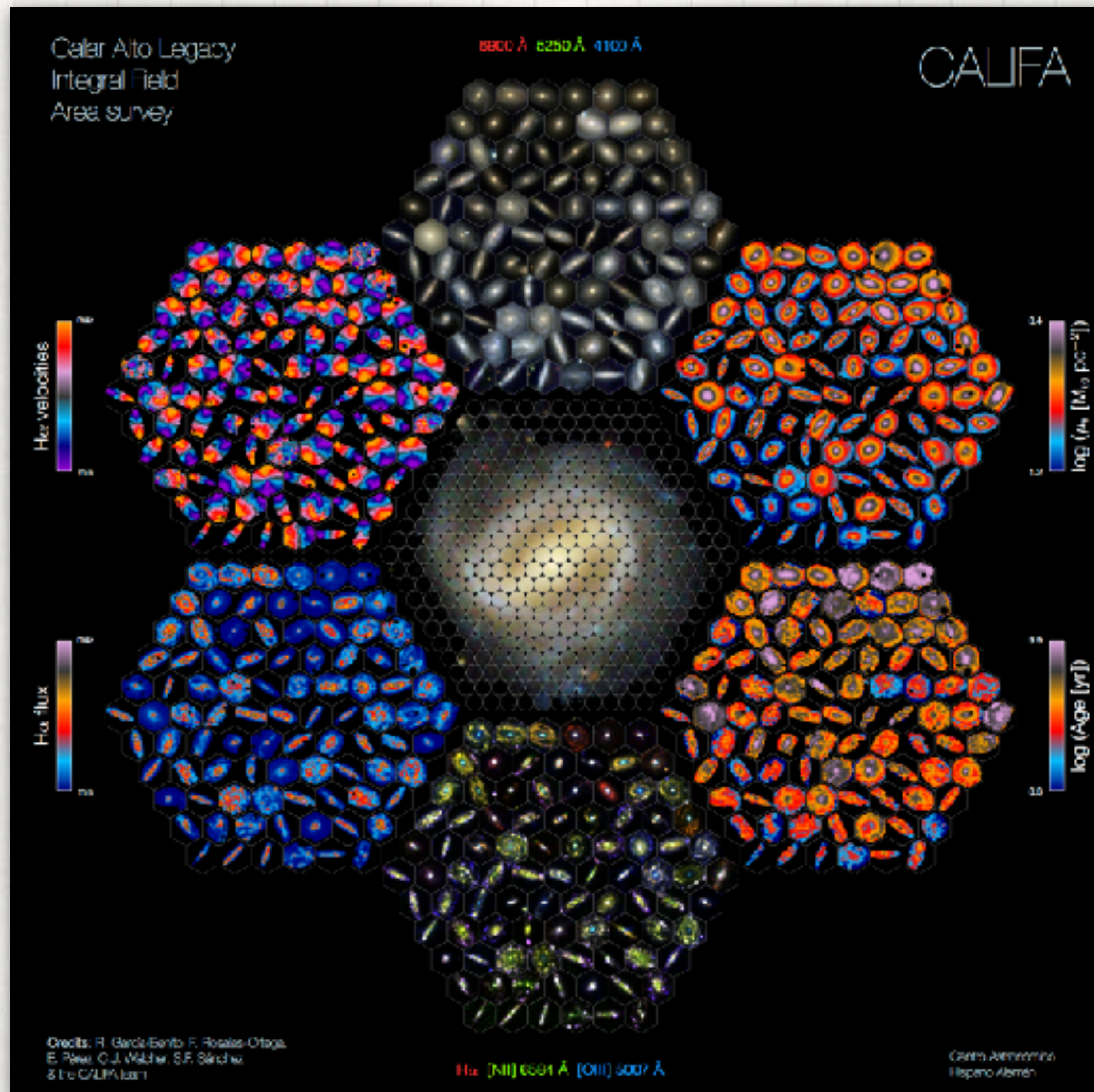
***however***

- Galaxies are hardly homogeneously mixed systems
  - gradients in various (stellar population) properties exist, which retain, to different extents, memory of the local physical conditions in which e.g. stars were born or accreted
  - the youngest populations don't even have time to "talk" to the entire galaxy!
- How are global and local properties related? What causes what? (i.e. "which came first: the chicken or the egg?") Through which physical mechanisms?

# CALIFA, the Calar Alto Legacy Integral Field Survey

Sanchez+2012,2016 (DR3), Walcher+2014 - HTTP://CALIFA.CAHA.ES

- Integral field spectroscopic optical survey at PMAS-PPAK on CAHA 3.5m:
  - two spectral setups:
    - V500 [4240-7140Å] 6Å FWHM
    - V1200 [3650-4620Å] 2.3Å FWHM
- Diameter selected sample of **~600 nearby galaxies** (0.005<z<0.03), **all morphologies**, full coverage of the color-mag plane
  - typical coverage out to **>~2 Reff**
  - resolution **~1 kpc**
- Stellar continuum, main optical emission line
- **Statistical representation of local Universe** at $\log(M^*/M_\odot)>9.7$ (Vmax volume correction) — representativeness drops at $\log(M^*/M_\odot)>11.4$
- Complemented by SDSS imaging (by selection)



# STELLAR POPULATION MAPS OF CALIFA GALAXIES

## A BAYESIAN SPECTRO-PHOTOMETRIC APPROACH

("BI-STAIN", evolution of Kauffmann+2003, ***Gallazzi+2005, Zibetti et al. 2017***)

- **PRIOR distribution of models, characterised by:**
  - **synthetic observables**
  - **physical quantities**

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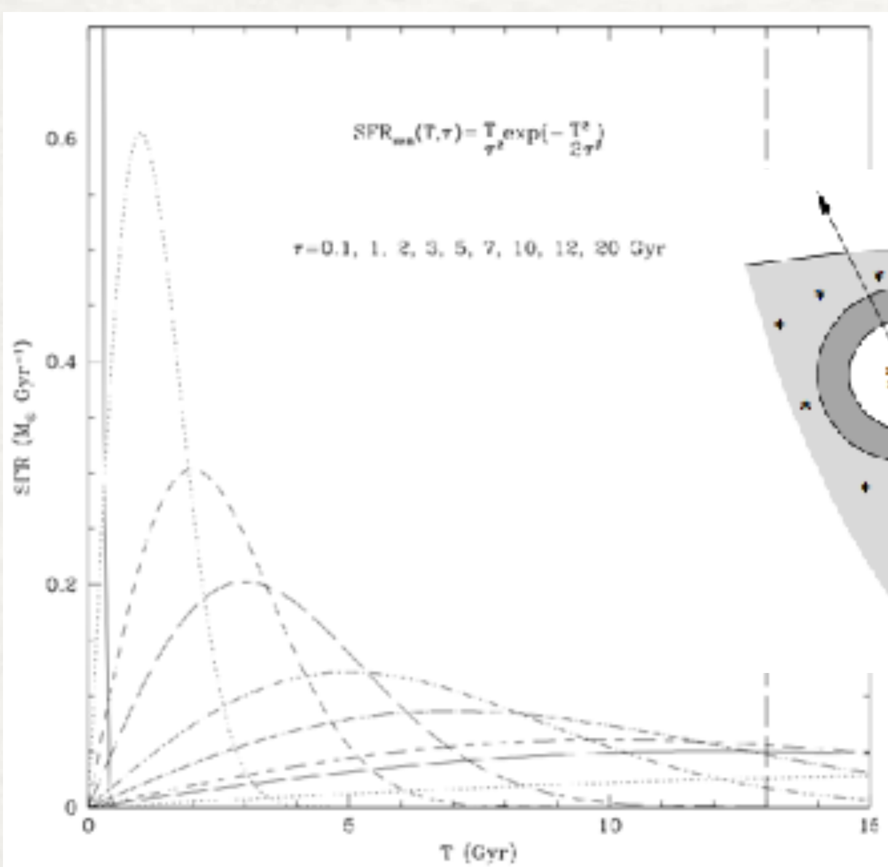


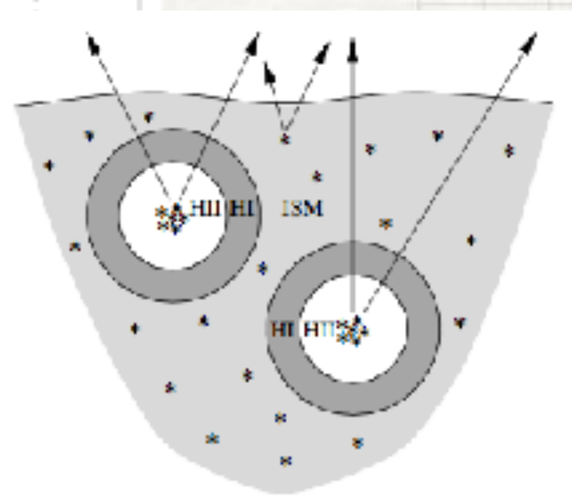


- 500,000 models, based on BC03 "evo"+MILES
- variable SFHs á la Sandage (1986, declining and rising) + stochastic bursts
- variable Chemical Enrichment Histories ("generalized" leaking box, Erb 2006)
- dust treatment á la Charlot & Fall (2000): differential attenuation from ISM and birthcloud — stochastic distribution
- Full coverage of age-metallicity plane, equalisation in observables plane

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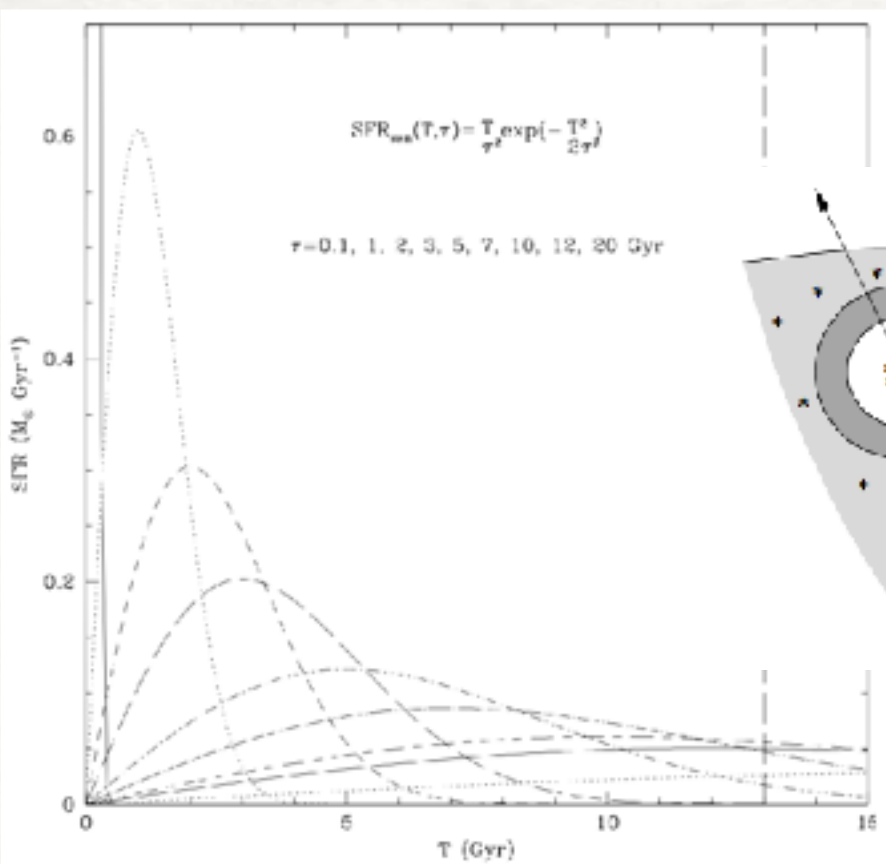


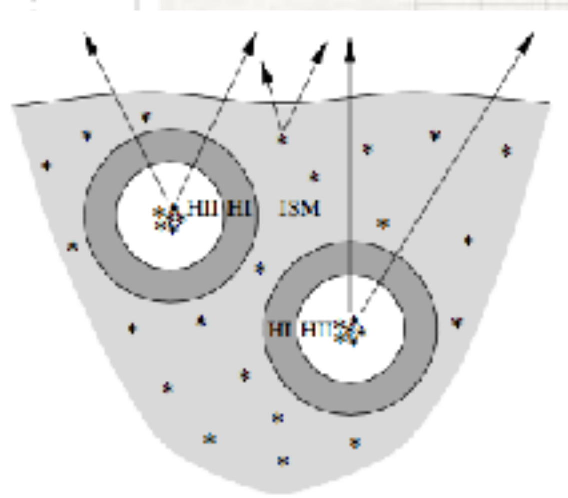


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Complexity

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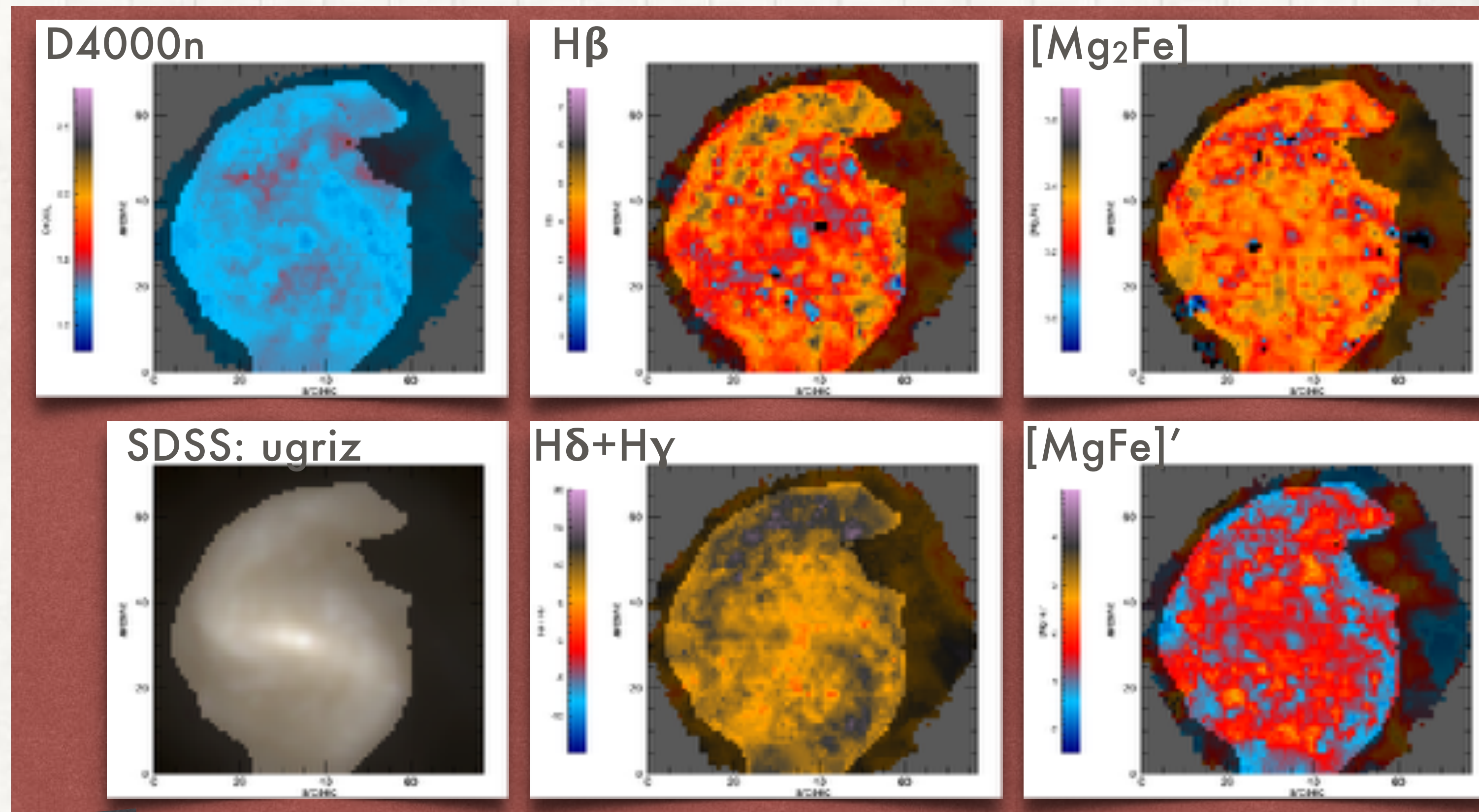



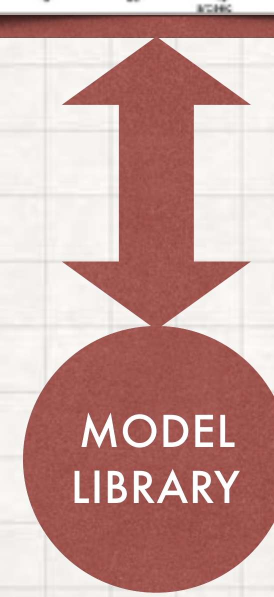

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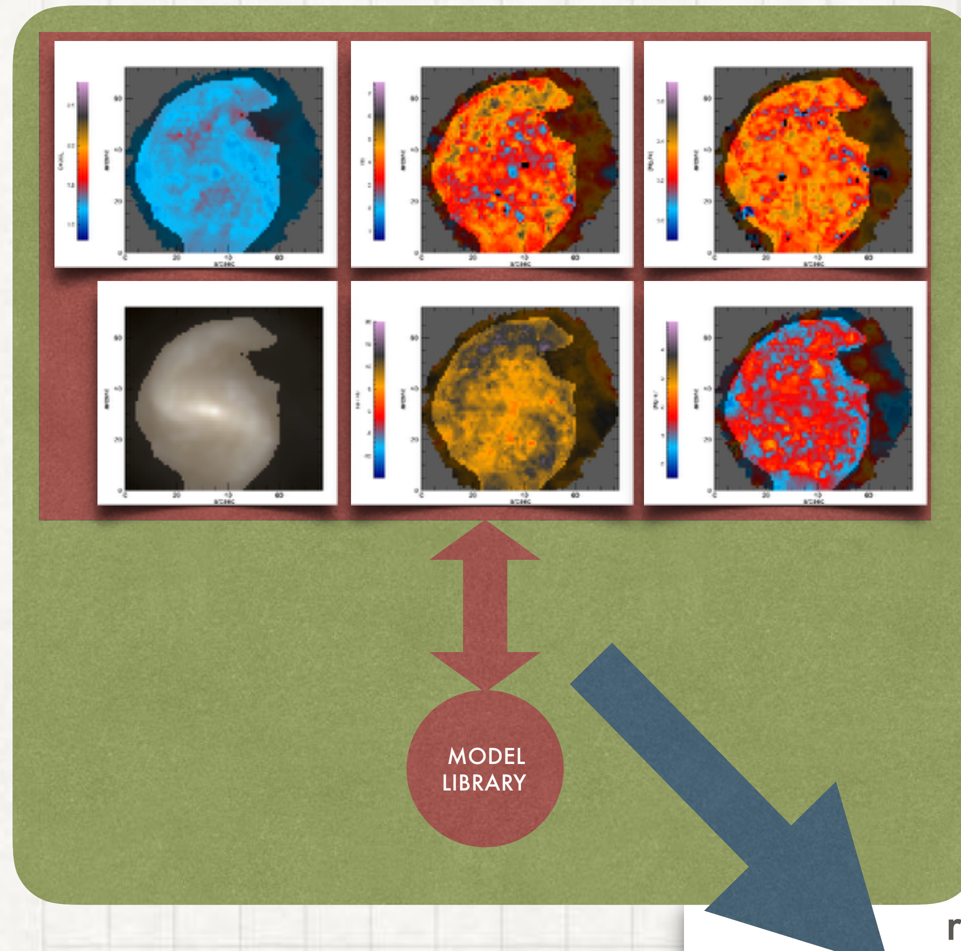
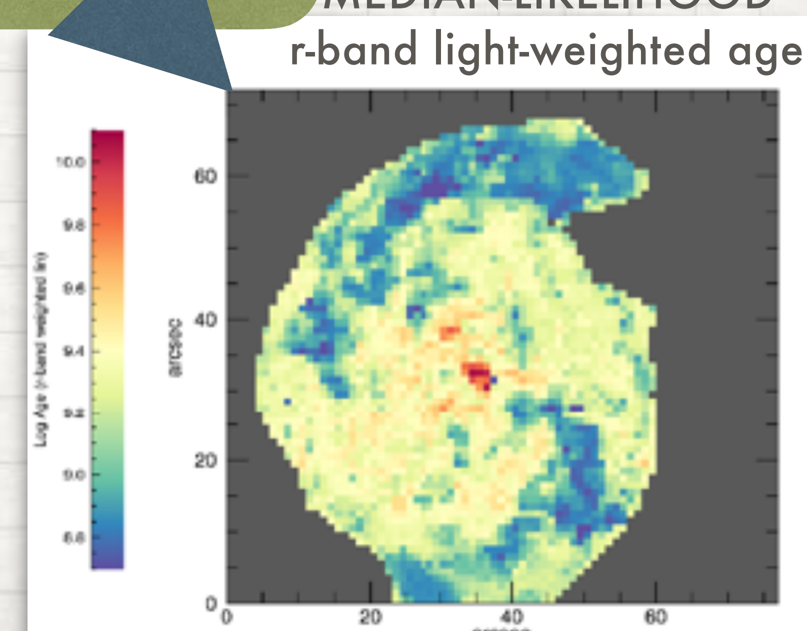
- **POSTERIOR probability distribution for the physical parameter(s) of interest, obtained via marginalisation over the entire library**




COMBINE SPECTRAL ABSORPTION INDICES AND 5-BAND PHOTOMETRY TO LIFT AGE-METALLICITY-DUST DEGENERACY

MEDIAN-LIKELIHOOD
r-band light-weighted age



# AGE MAPS EXAMPLES

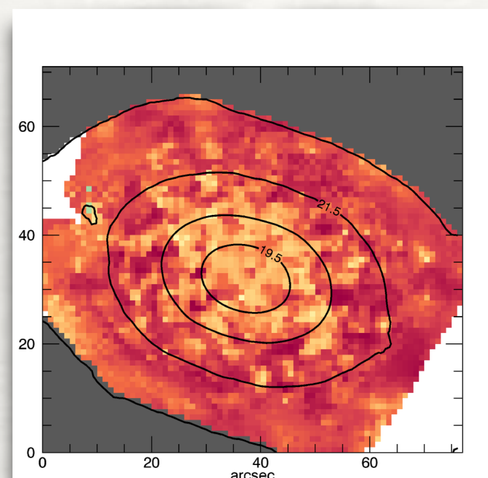
NGC6411 (E)

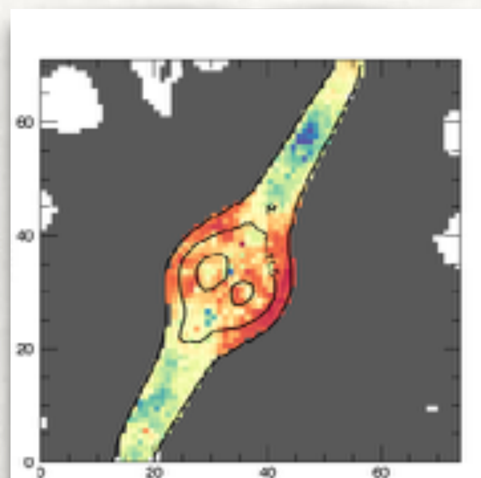
UGC10043(Sab)

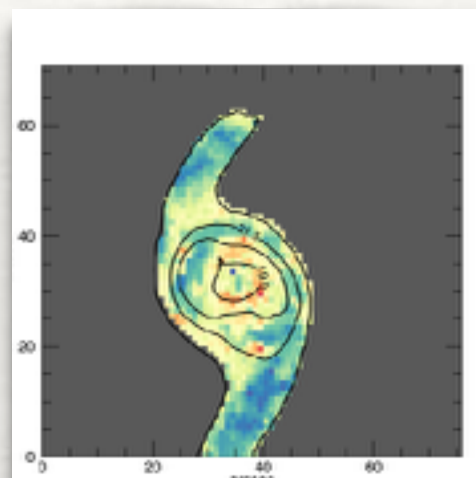
NGC5394 (Sbc)

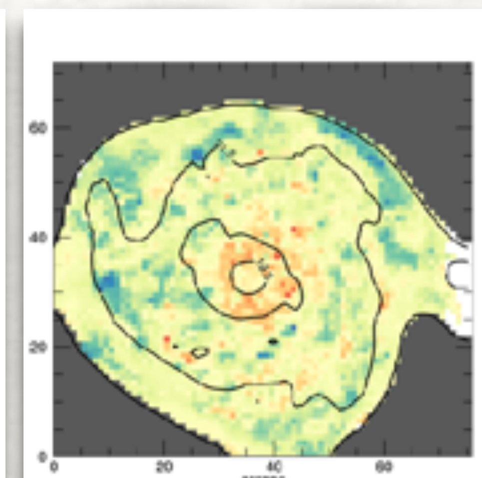
NGC0234 (Sc)

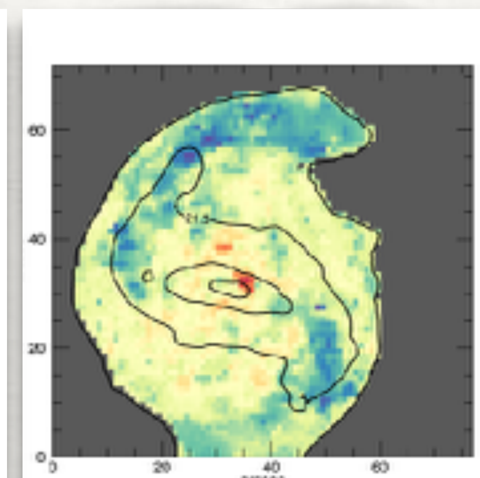
NGC3381 (Sd)

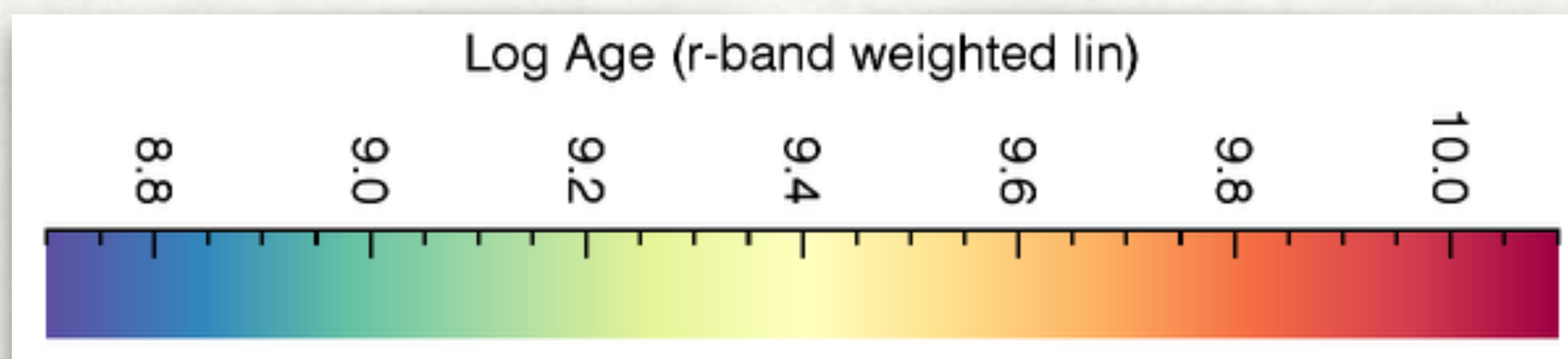


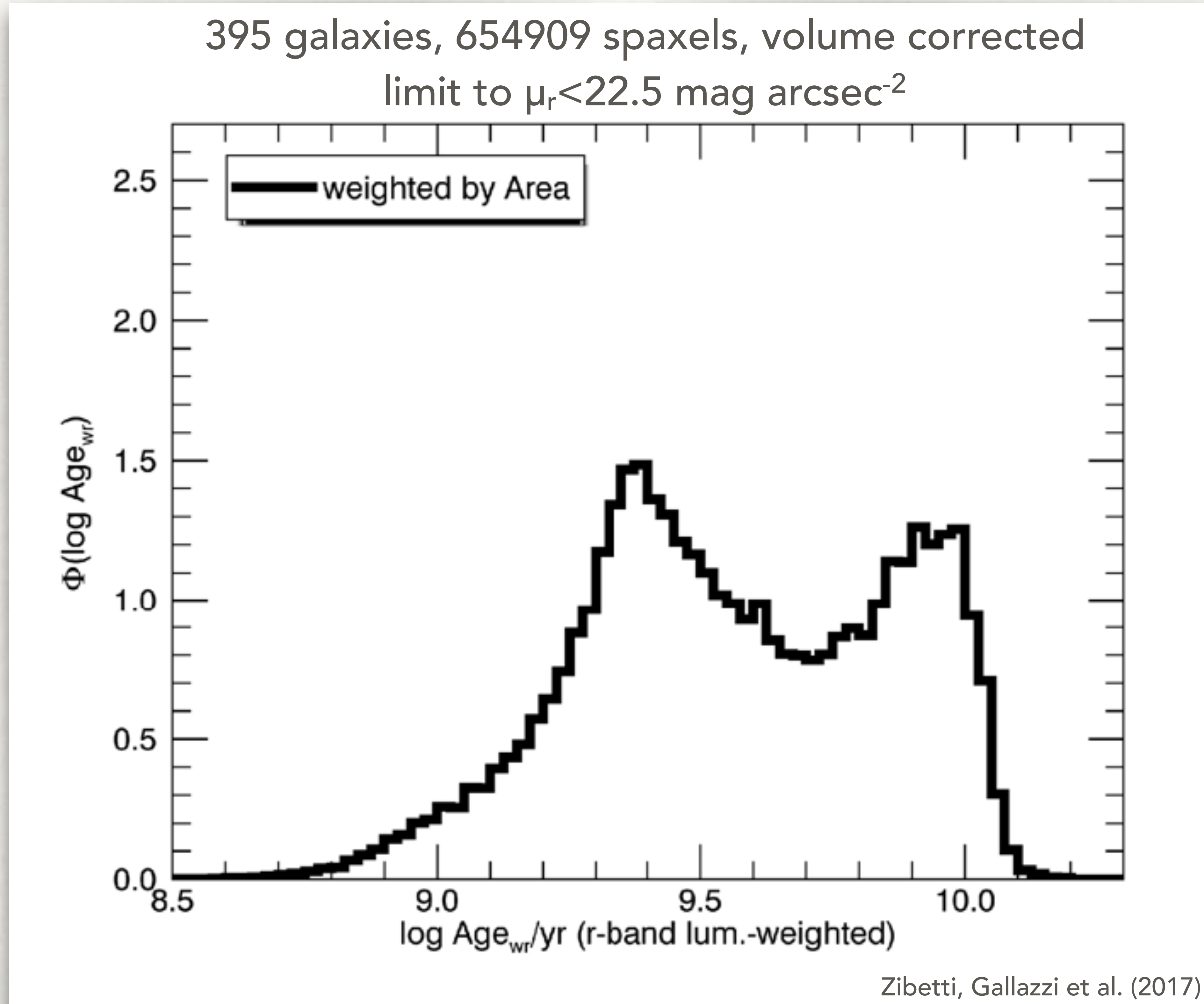



light-weighted!

# RESOLVED STELLAR ✓ AGE DISTRIBUTION



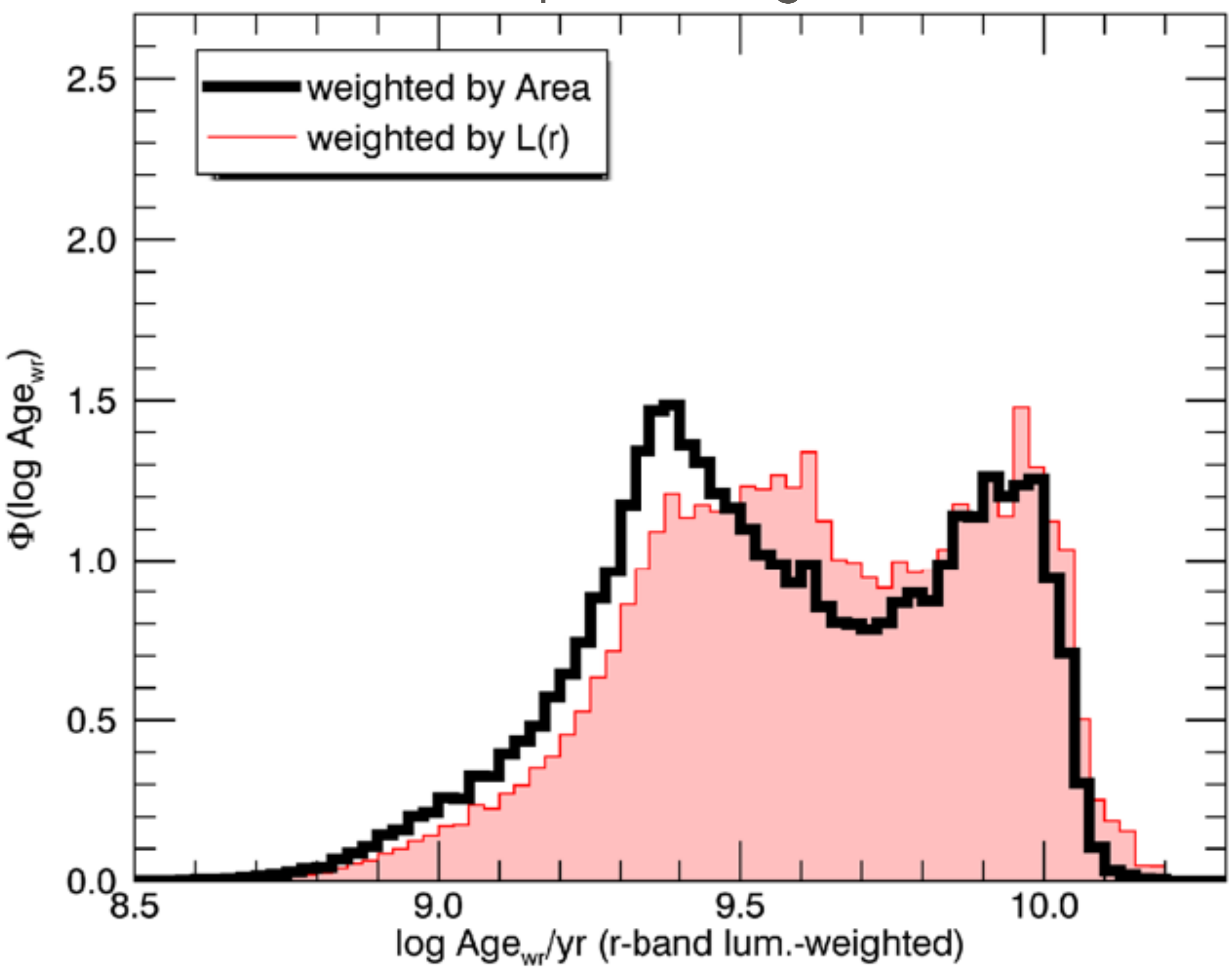

Zibetti, Gallazzi et al. (2017)

light-weighted!

# RESOLVED STELLAR ✓ AGE DISTRIBUTION

395 galaxies, 654909 spaxels, volume corrected

limit to $\mu_r$<22.5 mag arcsec$^{-2}$

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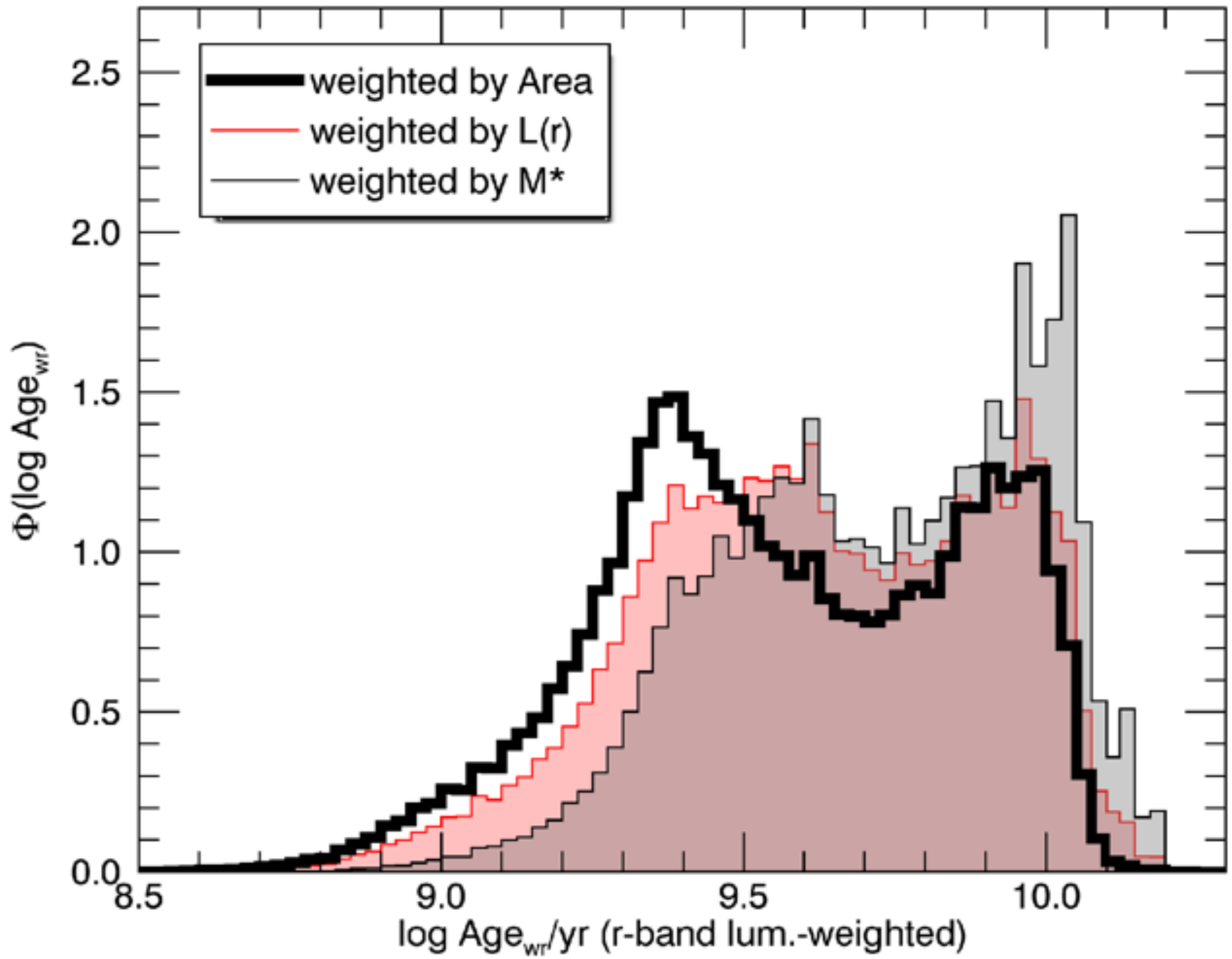


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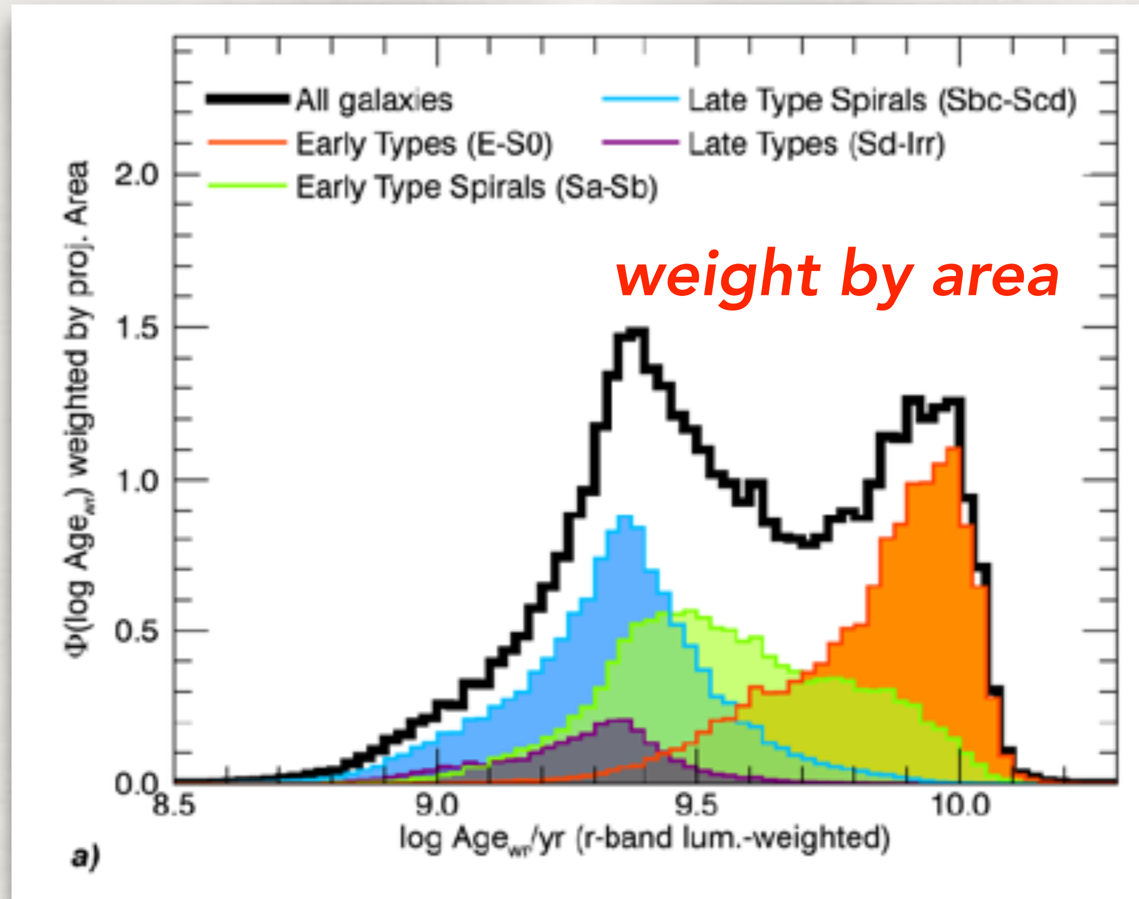


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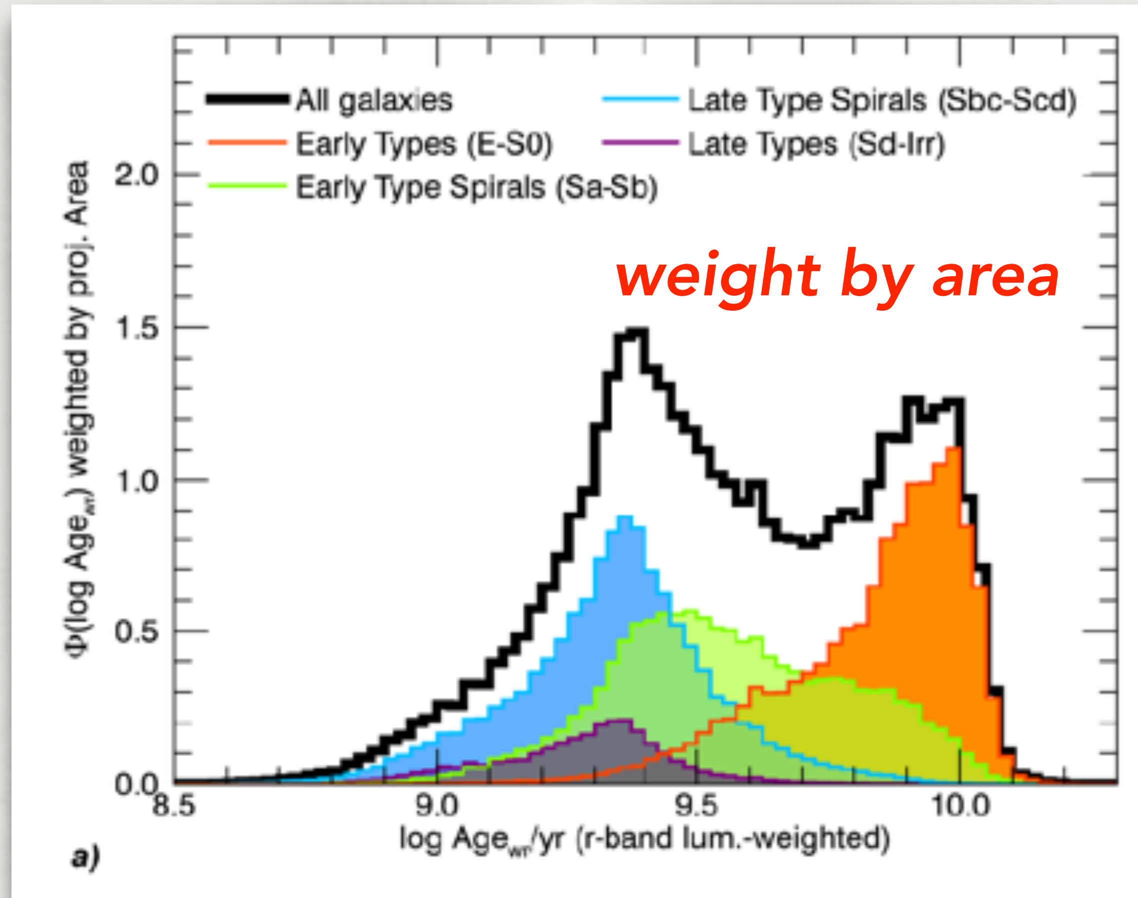
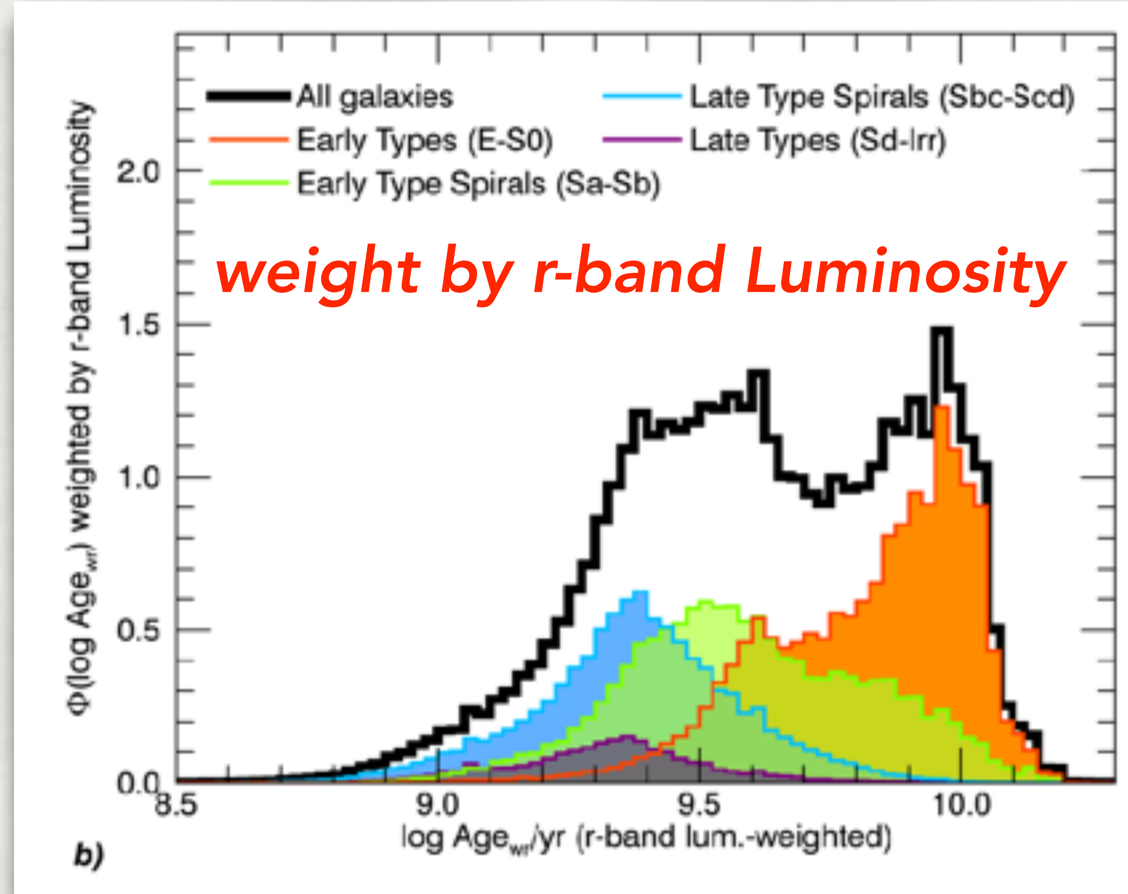
# AGE BIMODALITY SPLIT BY MORPHOLOGY

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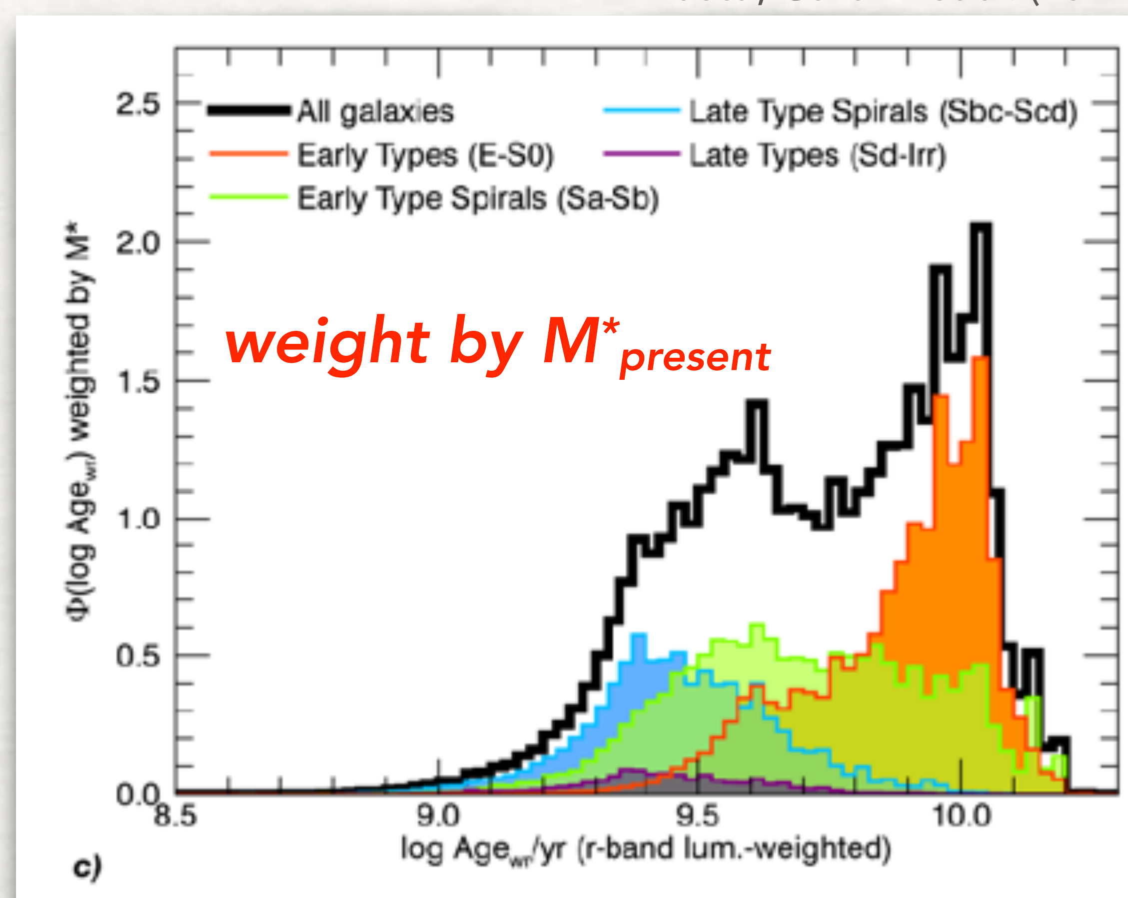

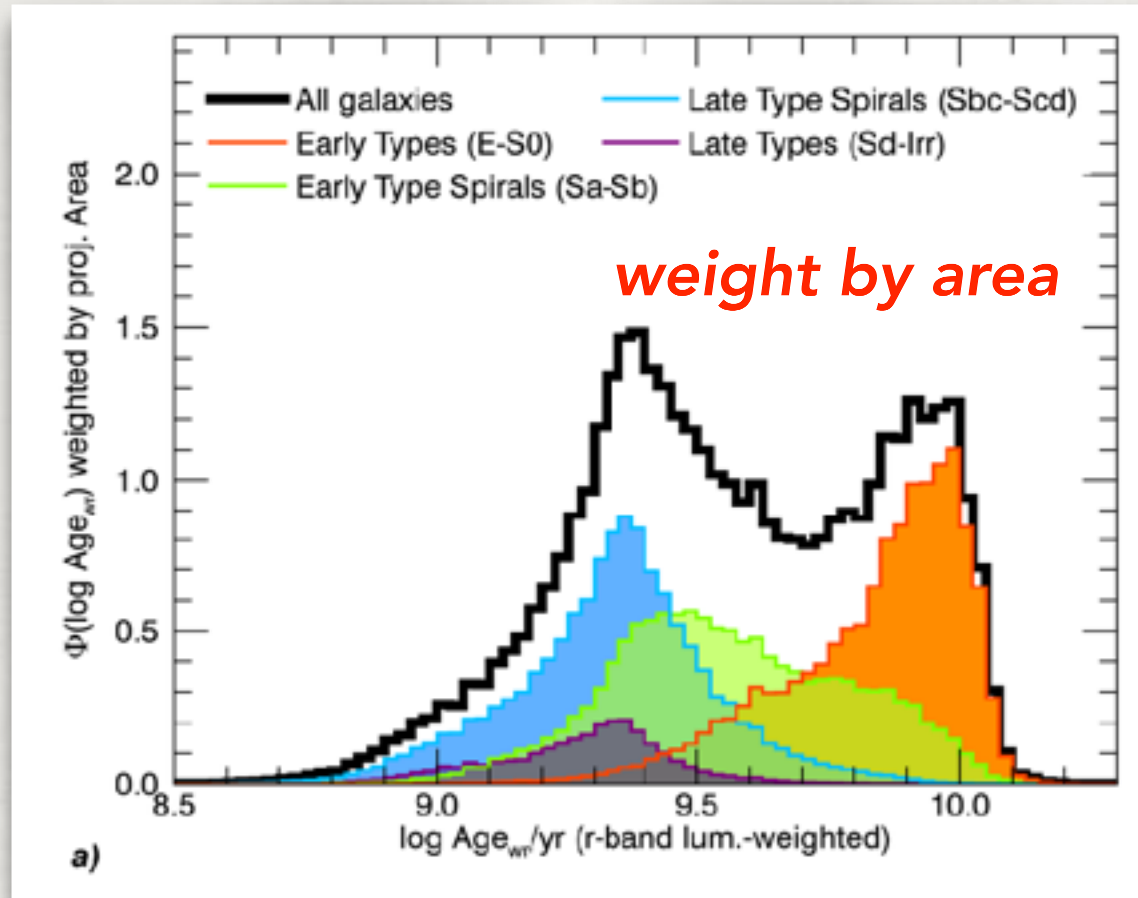


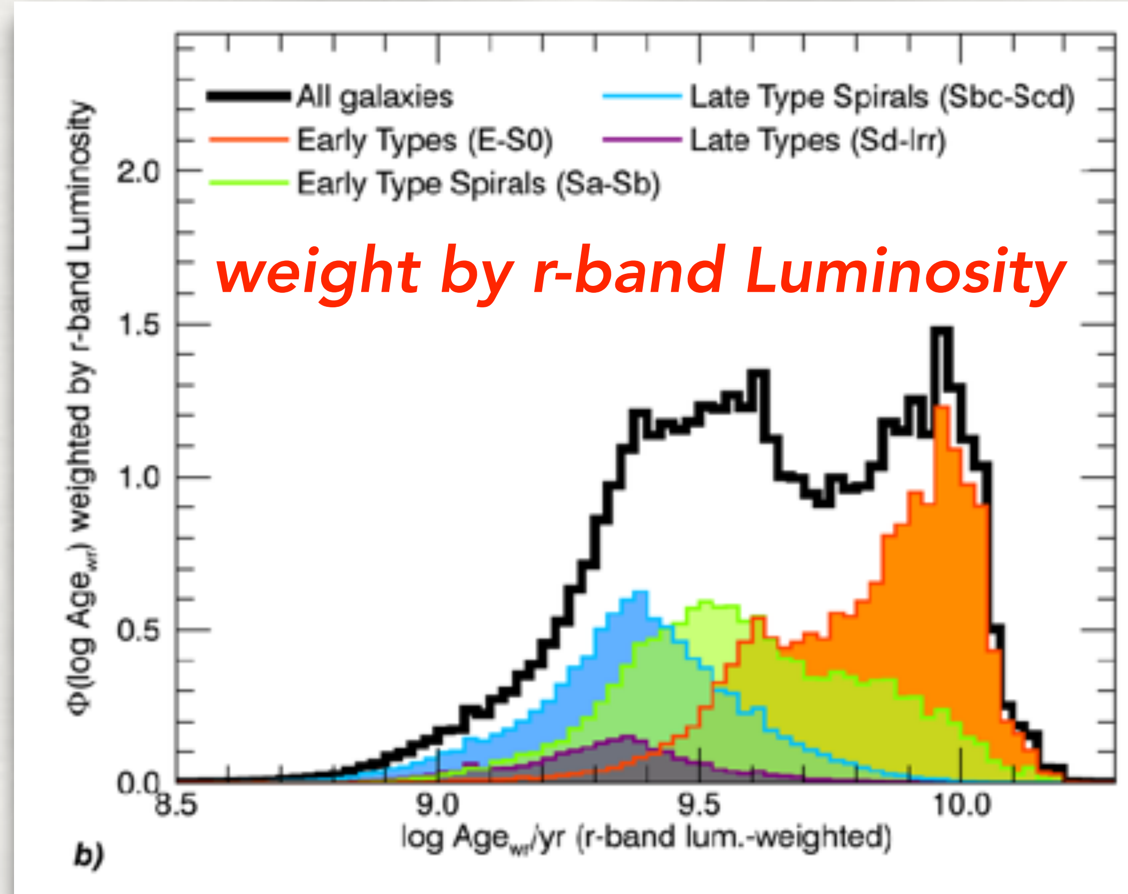


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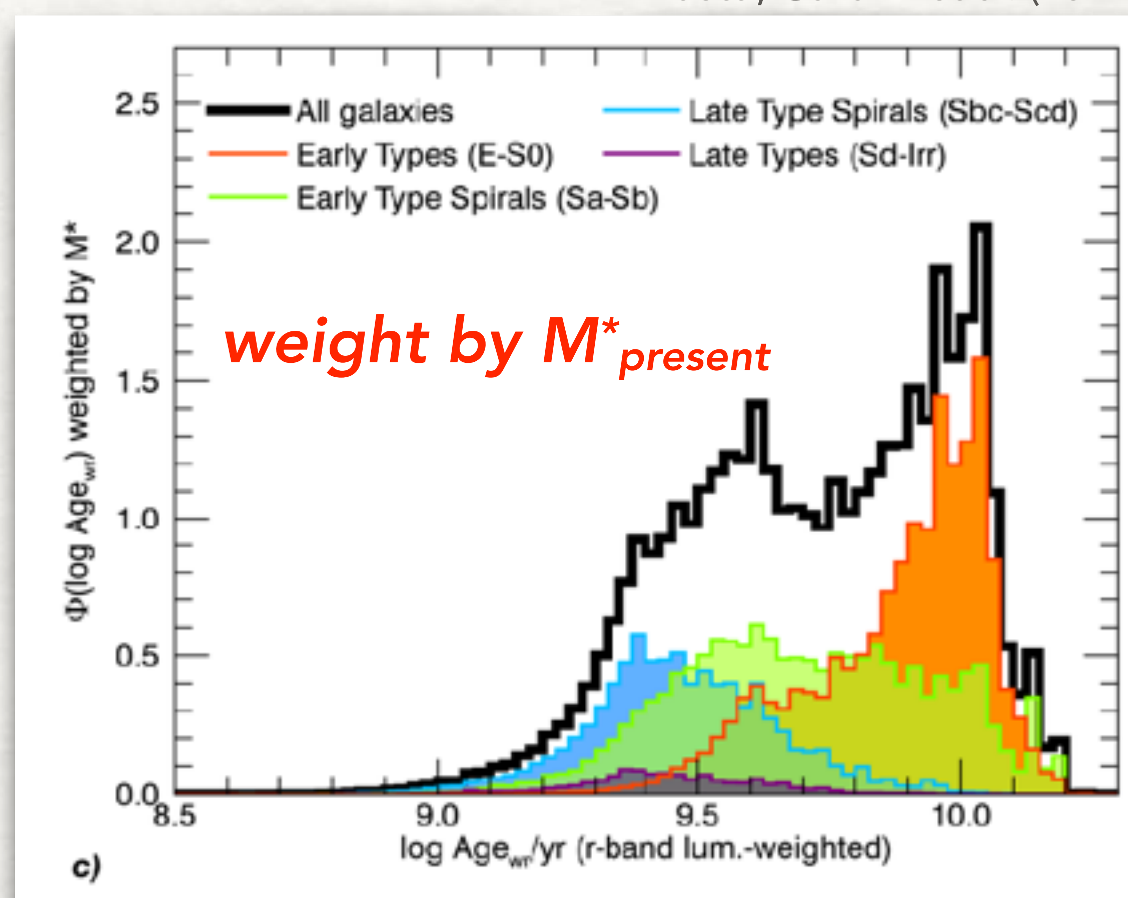
mainly a bulge vs disc bimodality



# IS SURFACE MASS DENSITY THE KEY?

## IS BIMODALITY GLOBAL OR LOCAL IN ITS ORIGIN?

Zibetti, Gallazzi et al. (2017)

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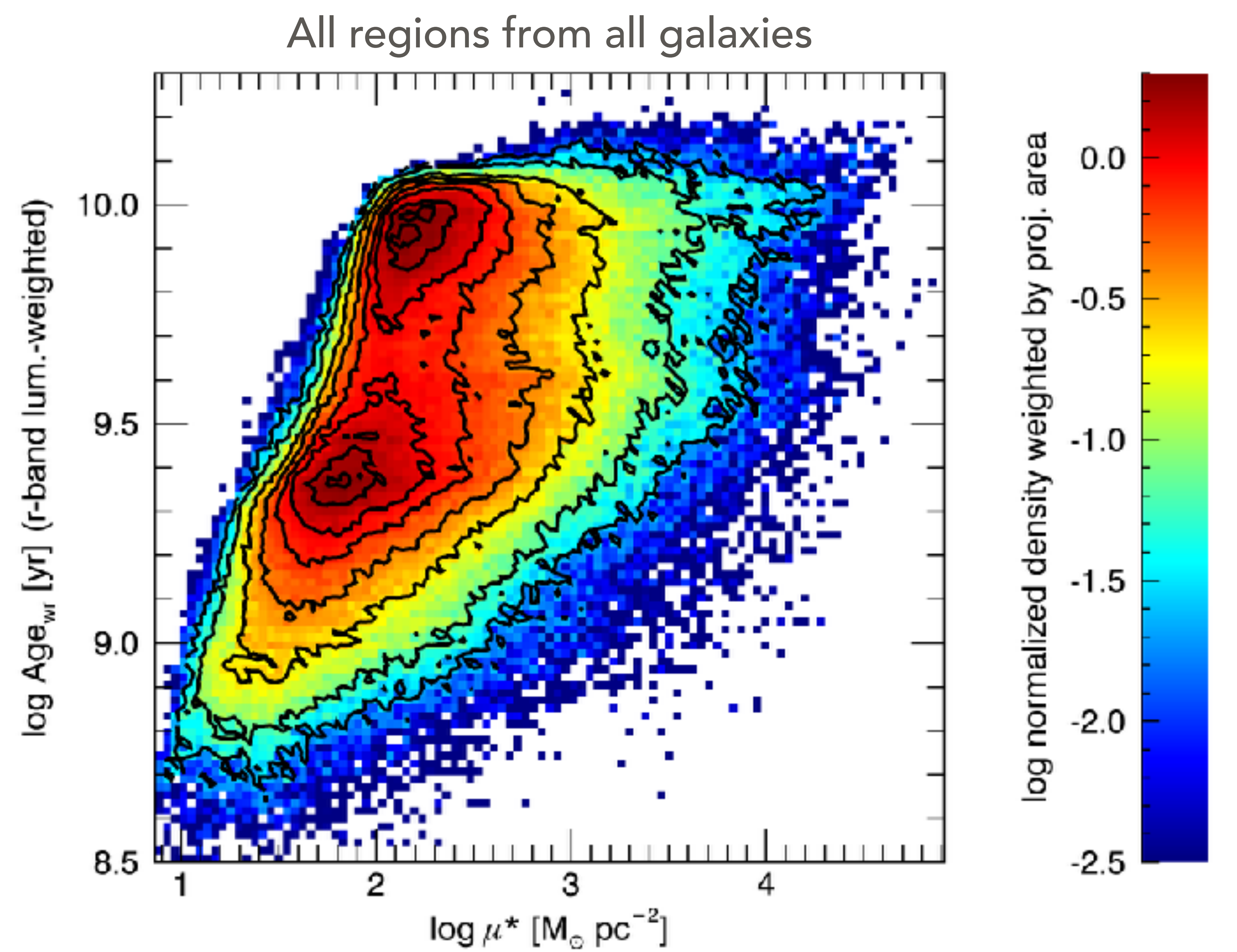


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cf. also Gonzalez-Delgado +2014

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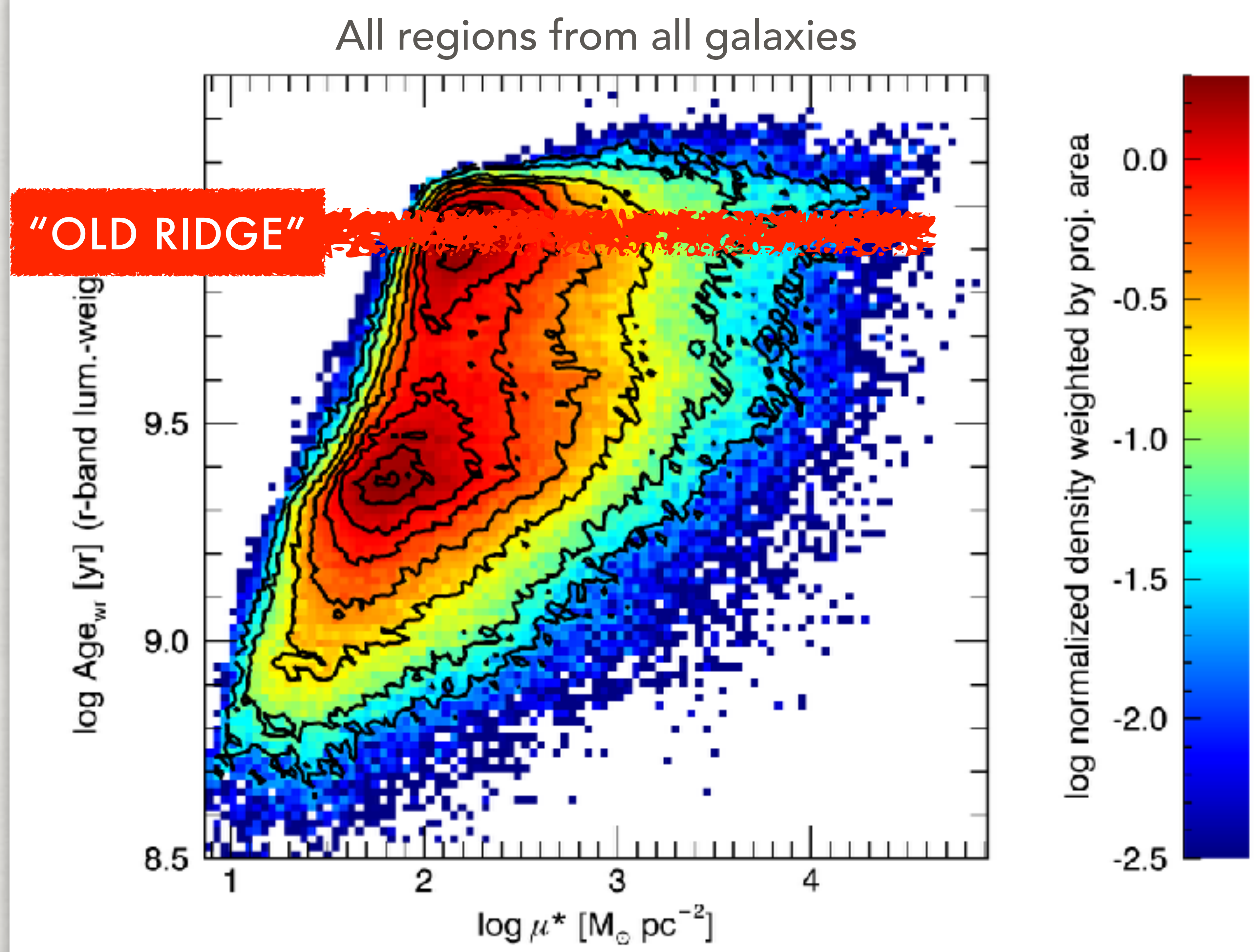


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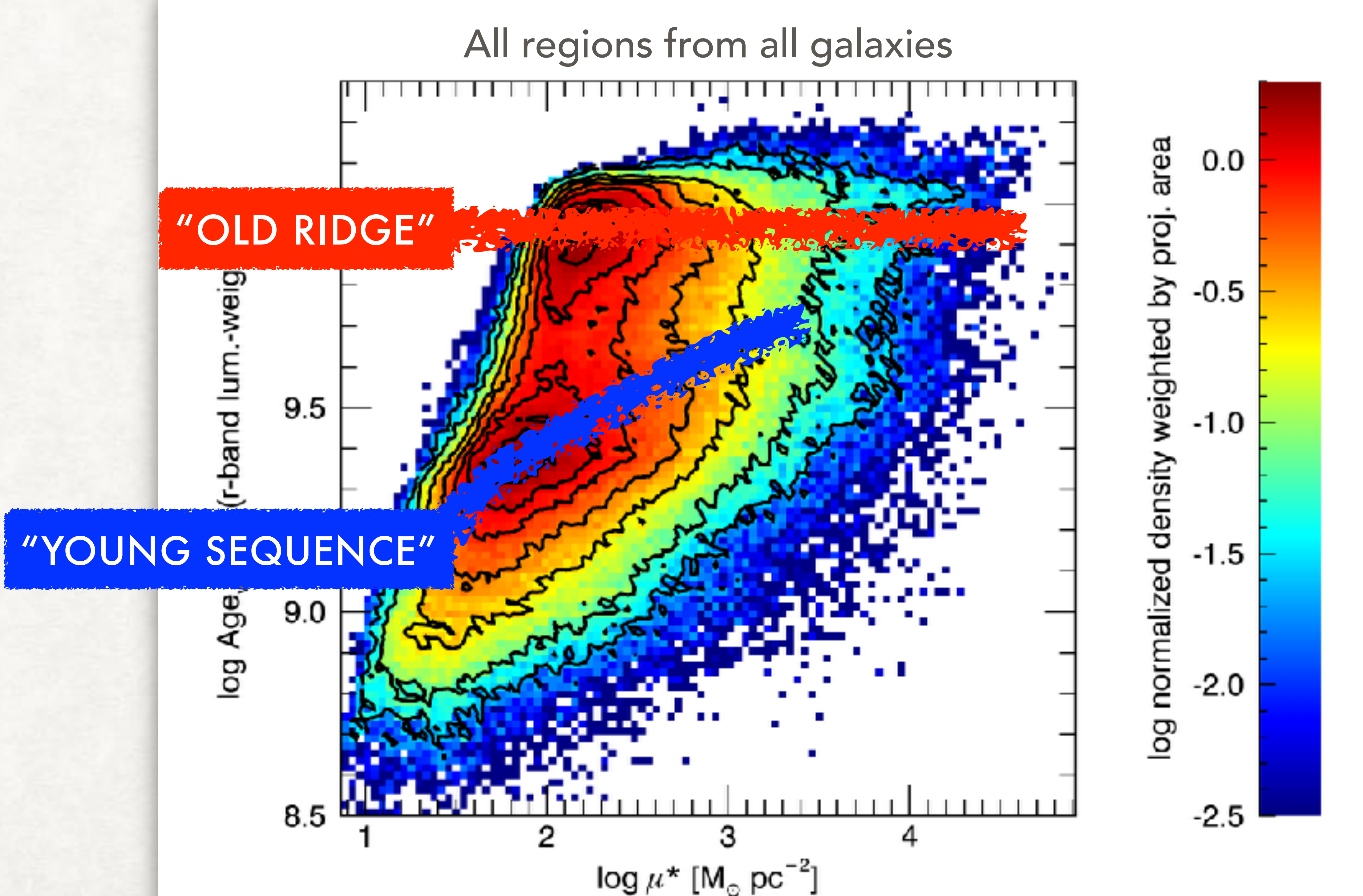


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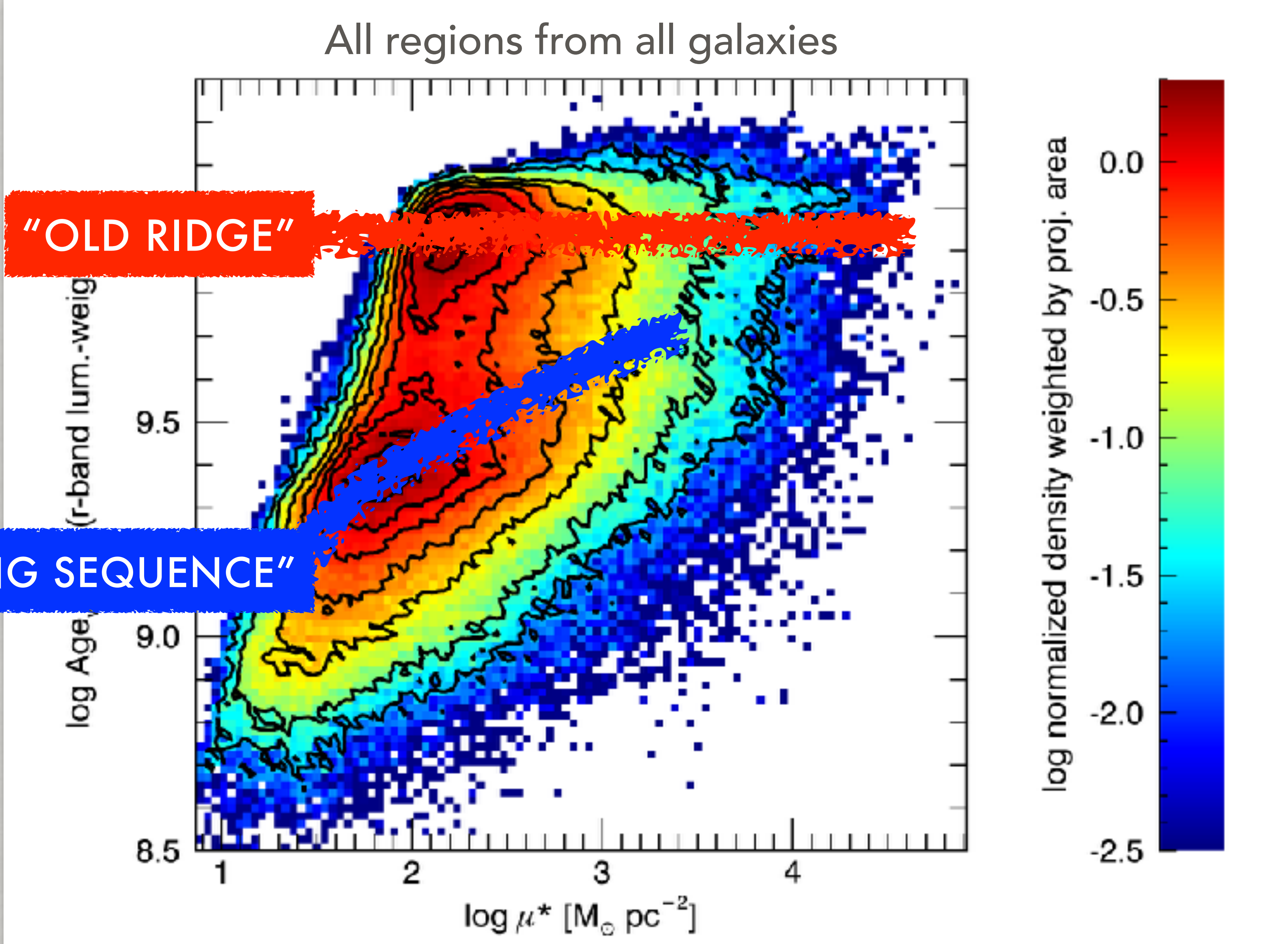


a signature of inside-out growth/ quenching? radial migration?

Zibetti, Gallazzi et al. (2017)

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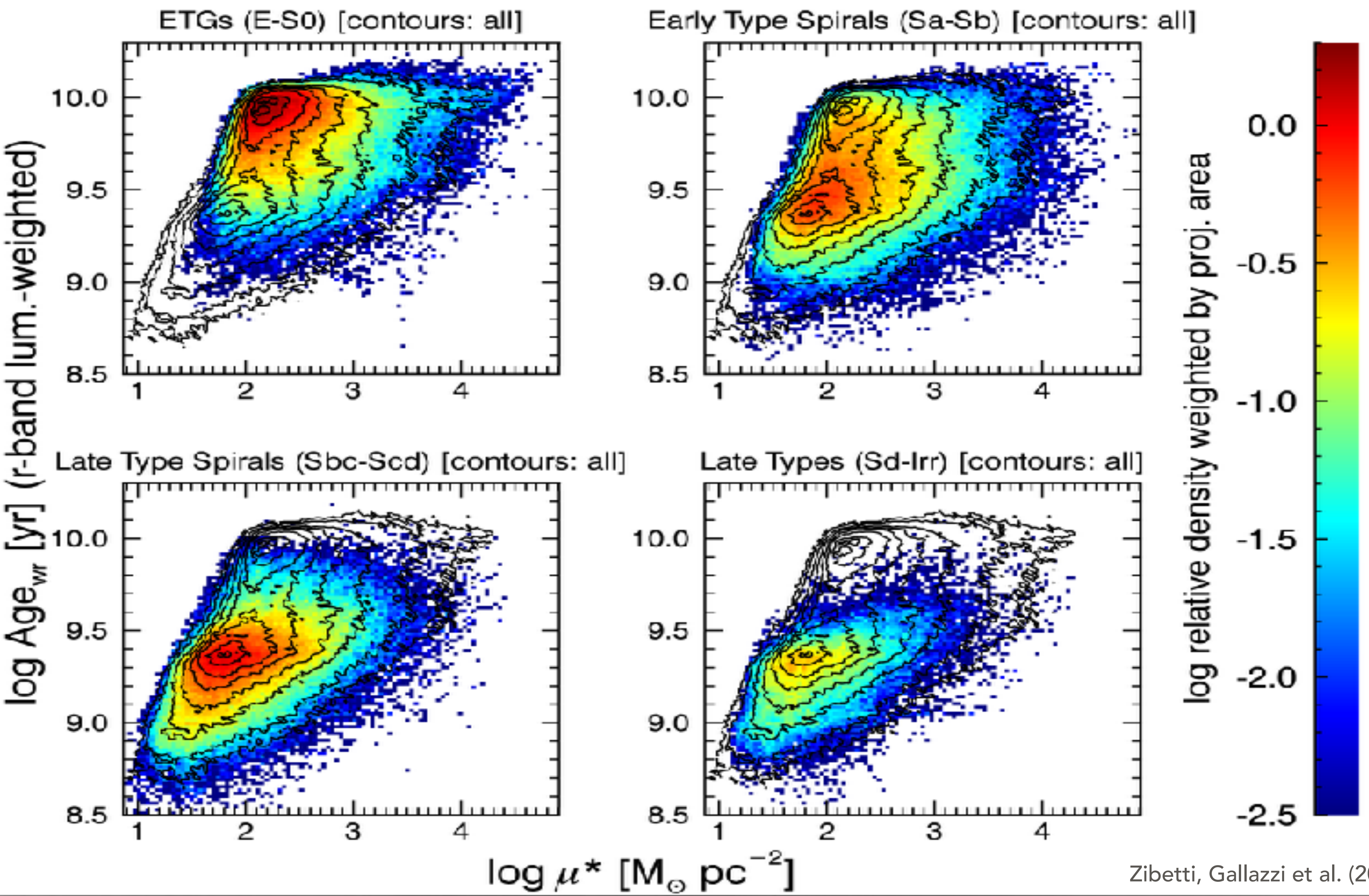
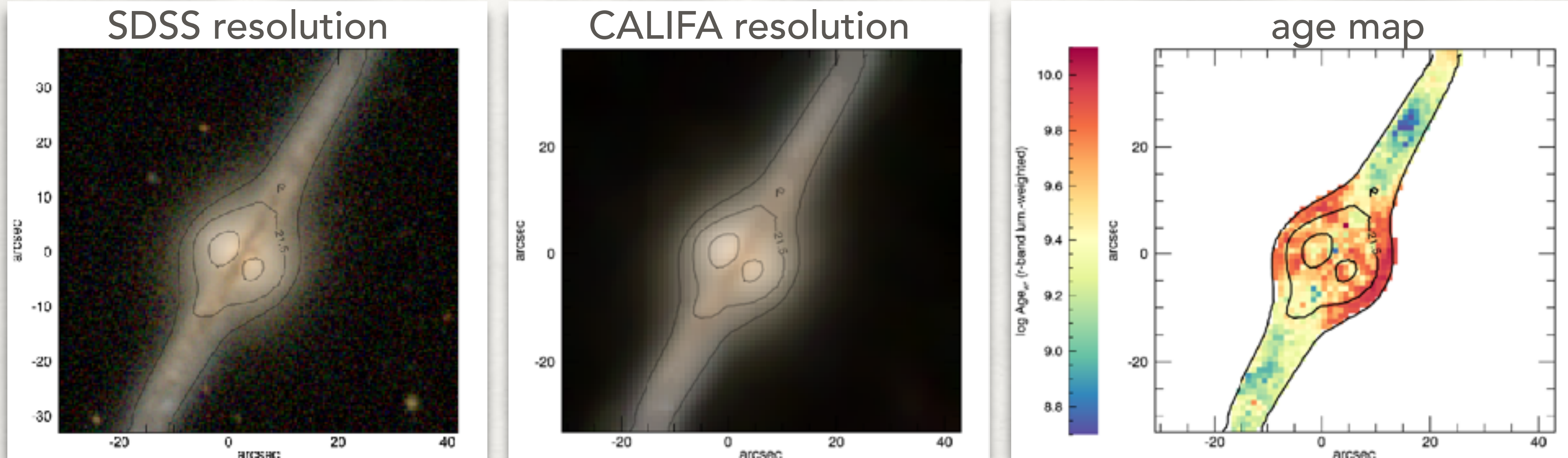



Zibetti, Gallazzi et al. (2017)

# NOT ONLY BULGE VS DISC...

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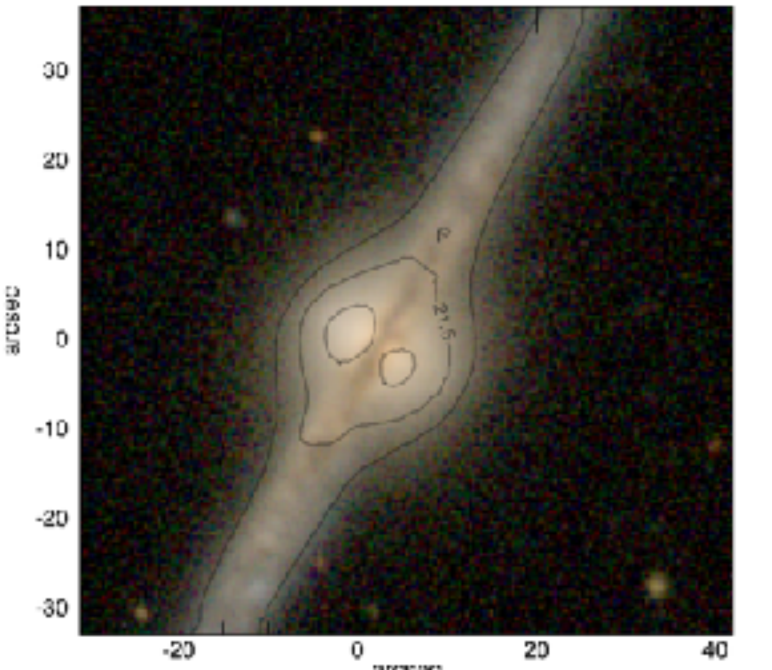
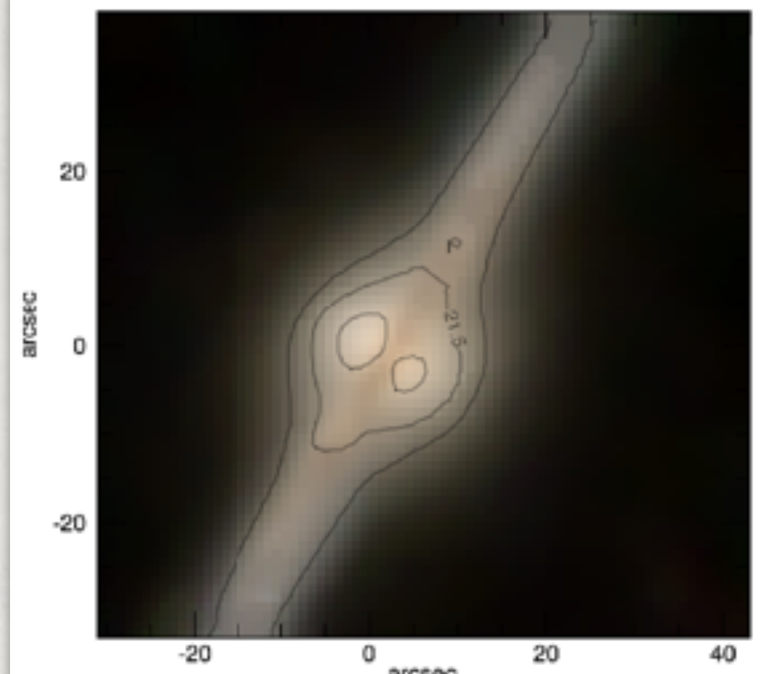
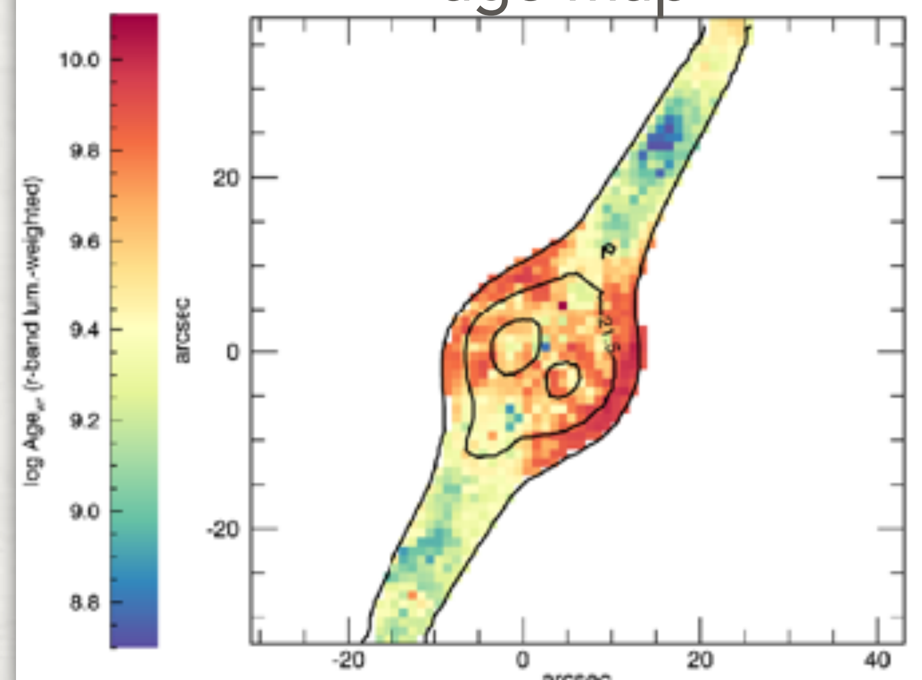
SDSS resolution




CALIFA resolution

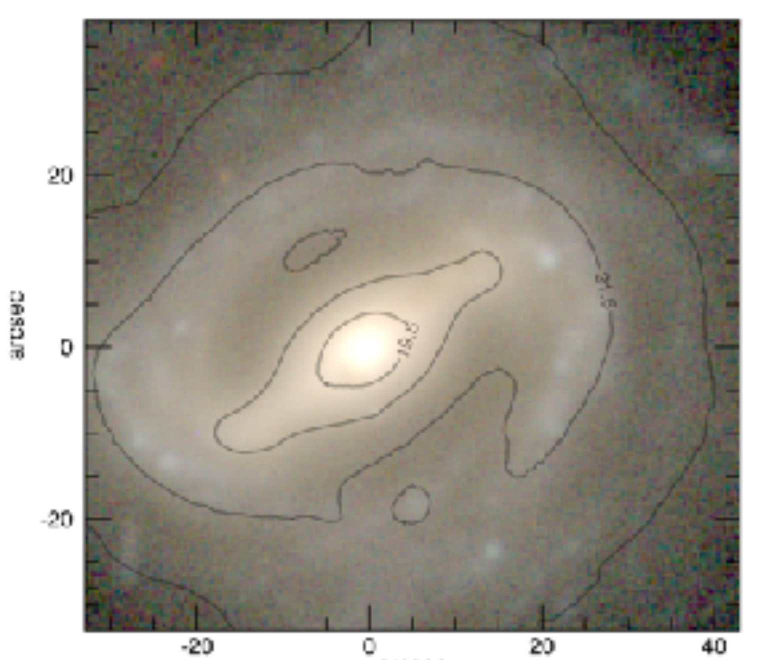



age map




# ...BUT ALSO ARM VS INTERARM

SDSS resolution

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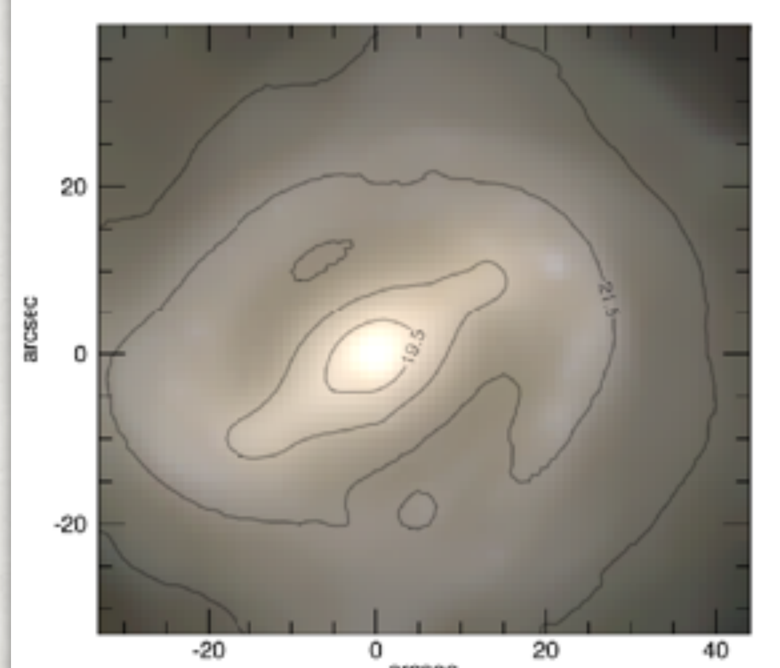


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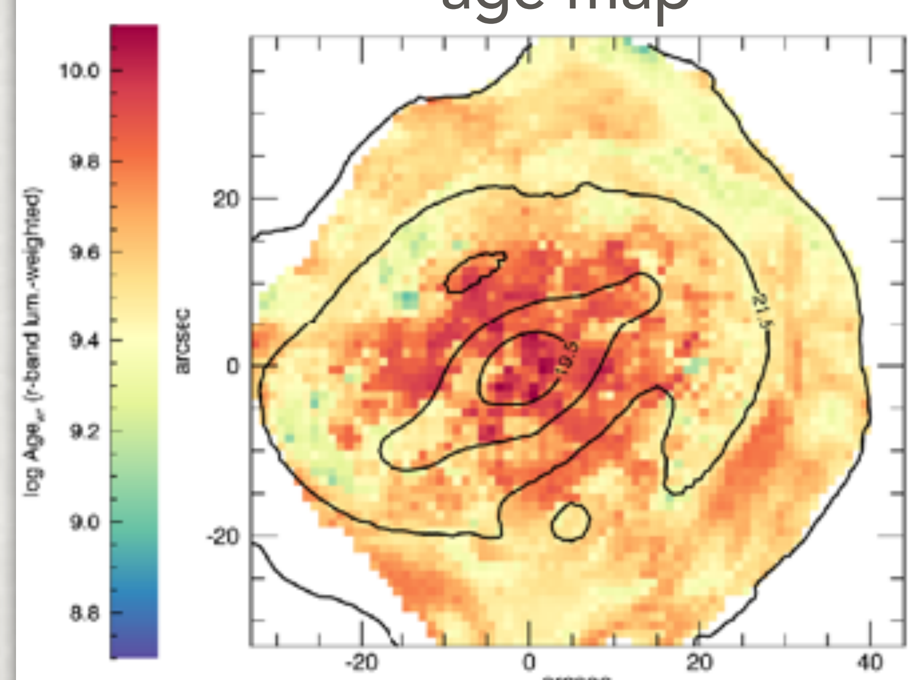




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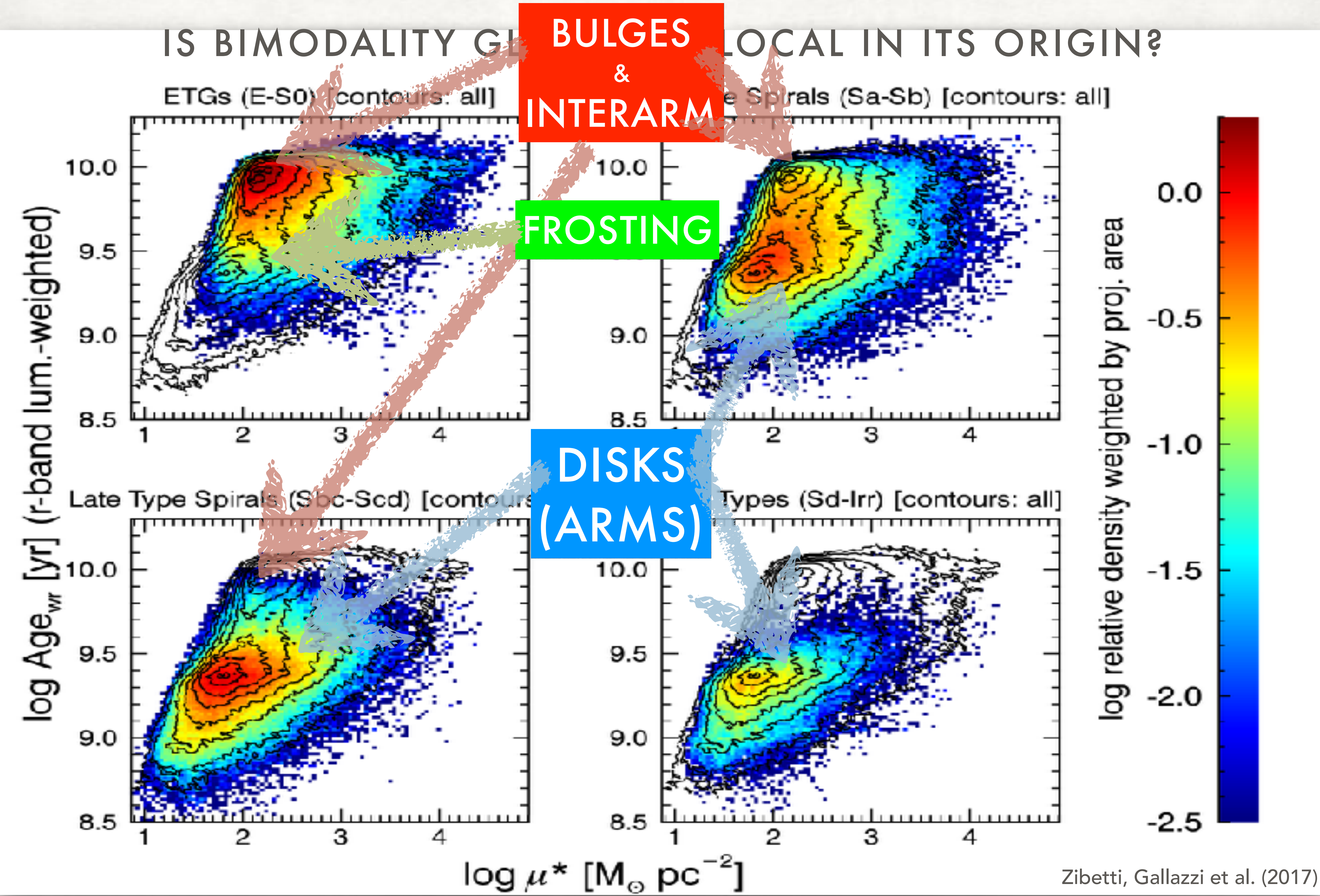
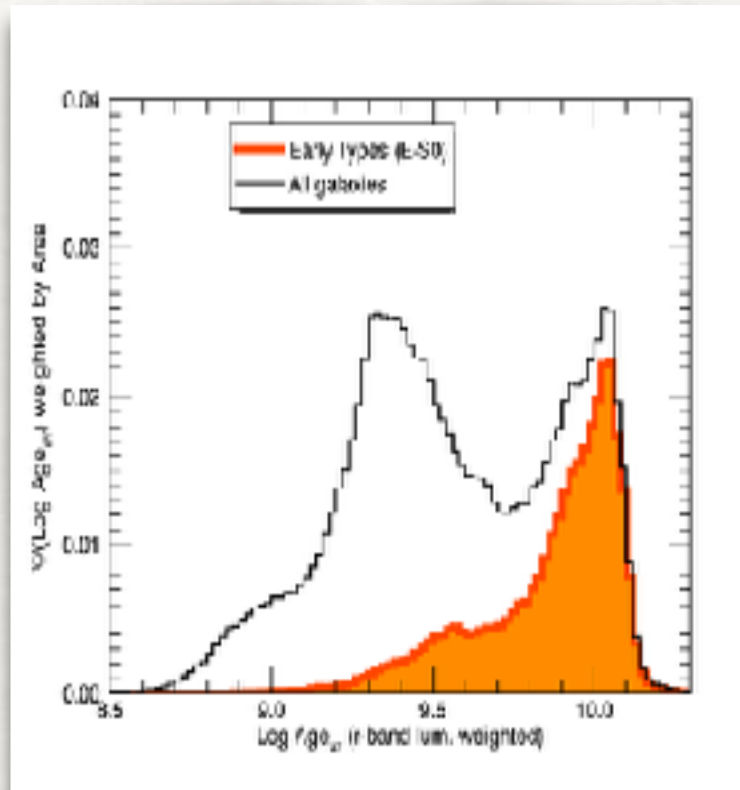
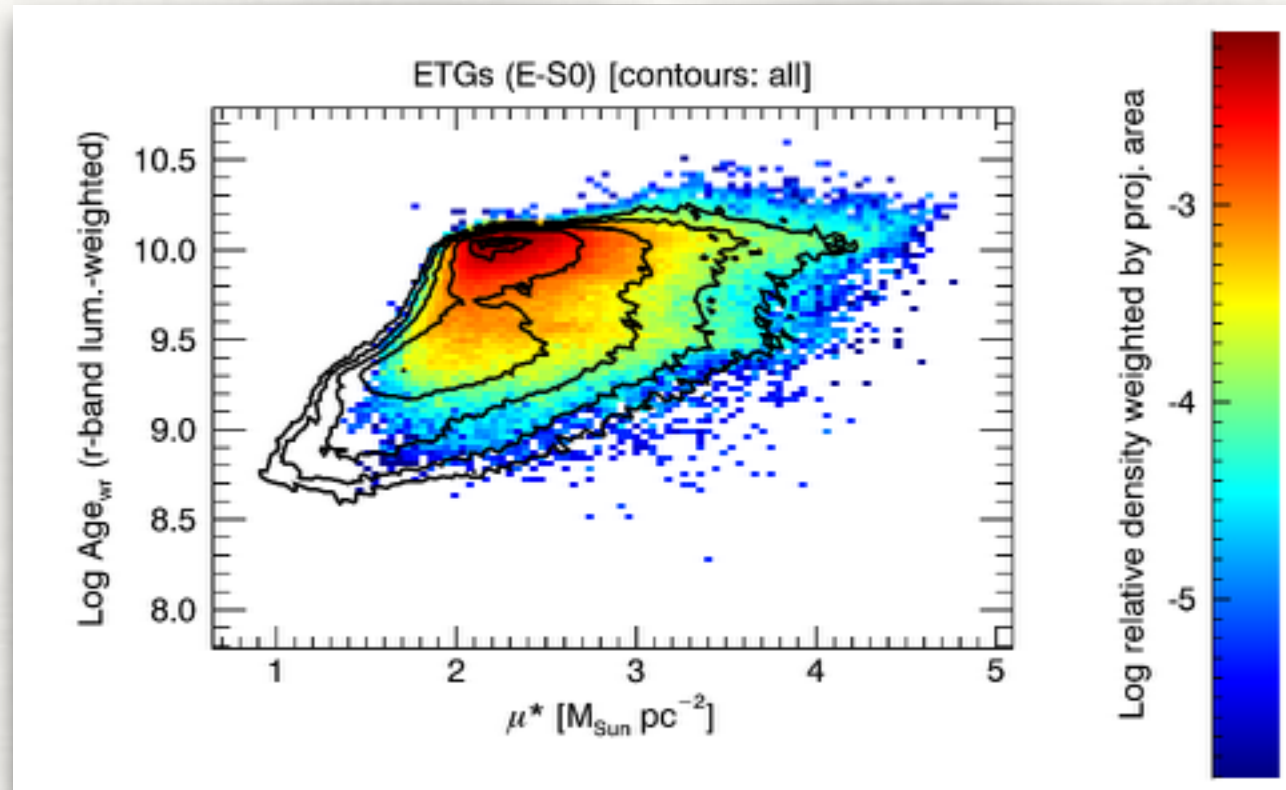



Zibetti, Gallazzi et al. (2017)

# EARLY-TYPE GALAXIES

## INTERNAL SCALING RELATIONS AND THEIR DRIVERS



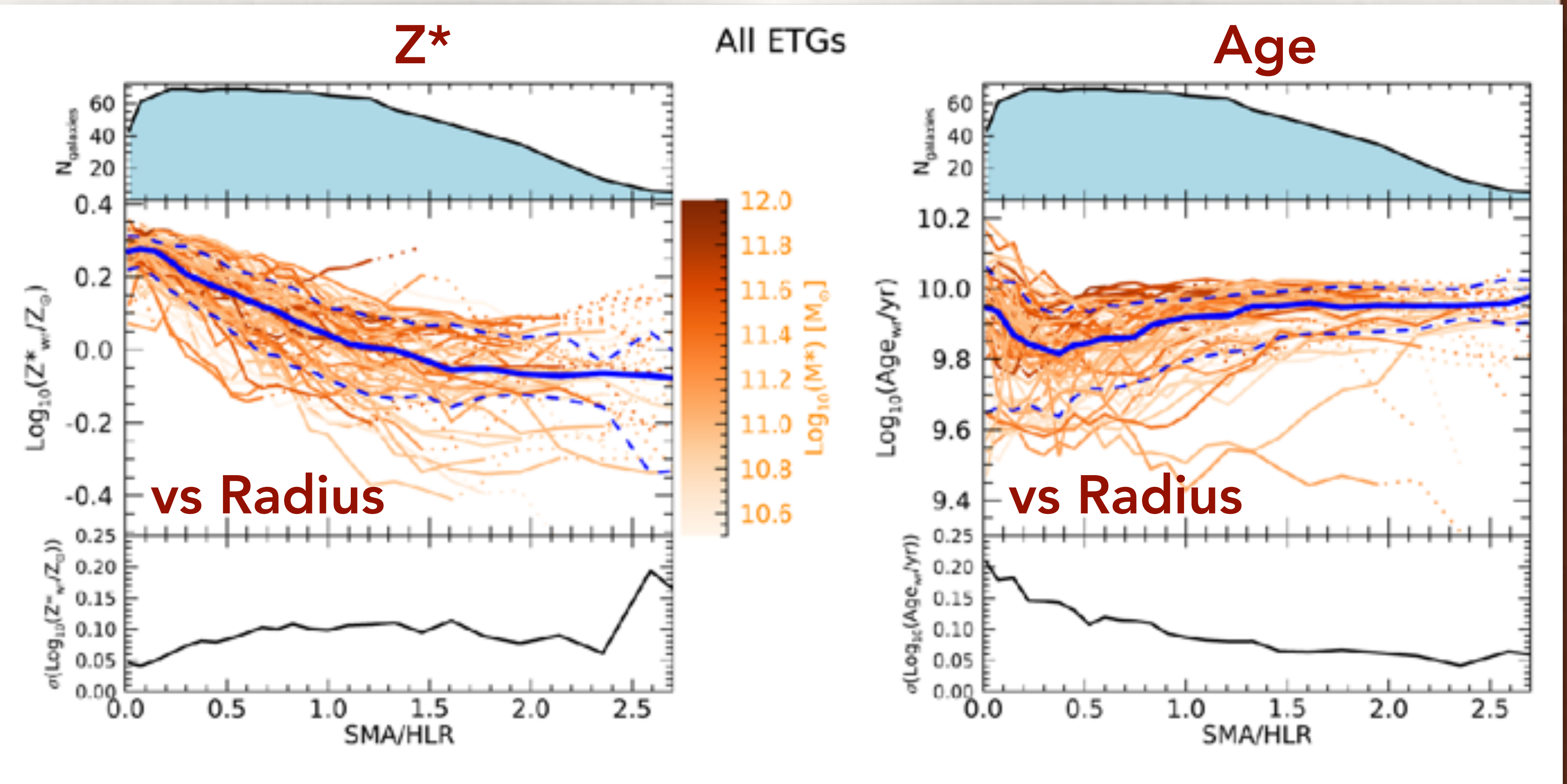




- Stellar population gradients:
  - radius
  - surface mass density
  - total (stellar) mass
- What do they tell us about physical mechanisms of galaxy evolution?
- Can they be used to constrain models?
- **Observations: 69 CALIFA ETGs, 48 E, 21 S0**, excluding obviously interacting/merging systems

# Stellar population gradients in ETGs

*Radius vs Surface Mass density*

- Ubiquitous negative metallicity gradients
- U-shaped age profiles: minimum at ~0.3-0.4 HLR
  - **inconsistent with simple inside-out growth/ quenching**
- Metallicity: much lower scatter with μ* than with radius
  - Scatter in mu* dominated by errors! **"universal" μ*-Z* relation**?
- Age: marginally less scatter with radius





Zibetti et al. (in prep.)

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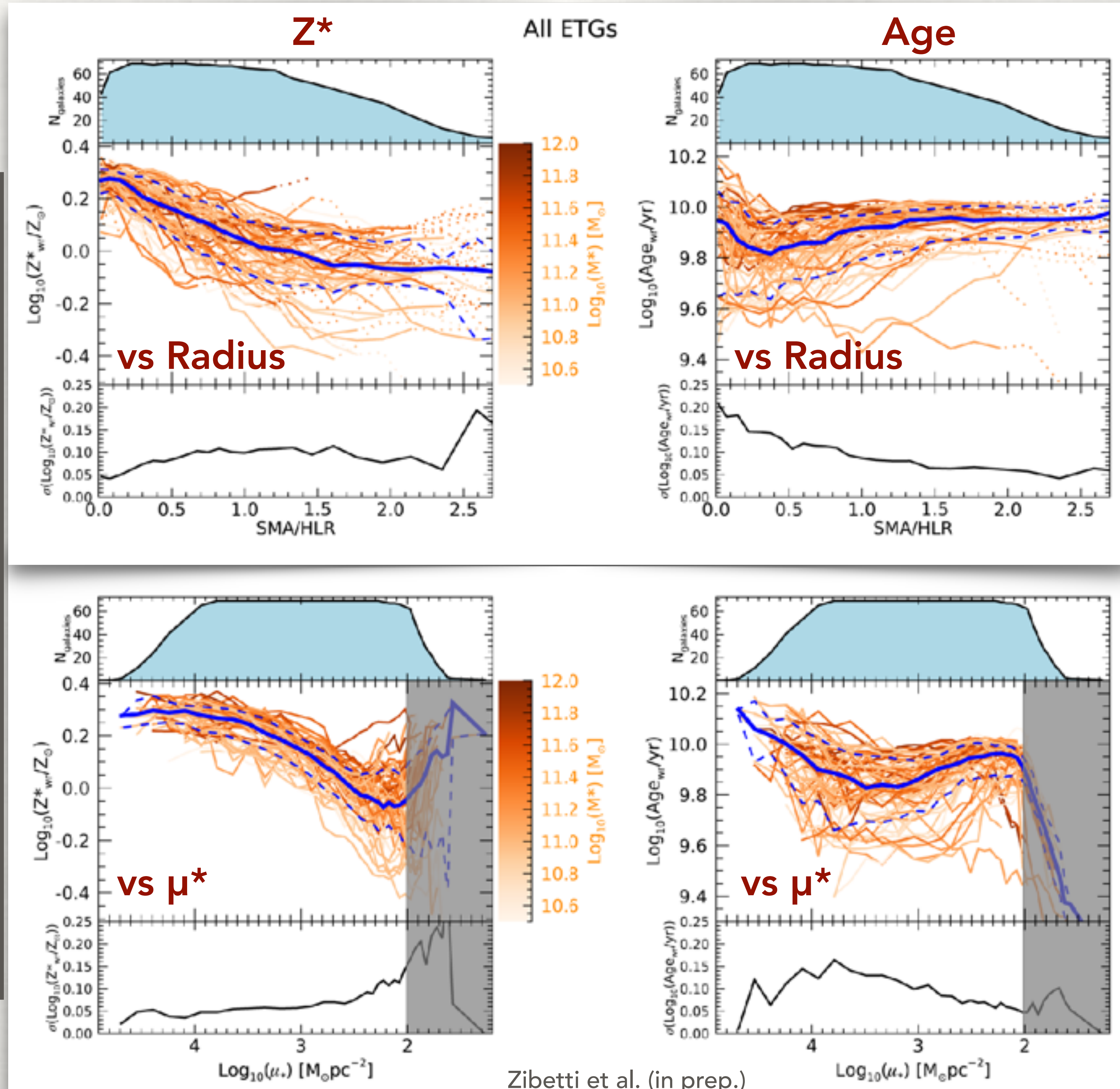
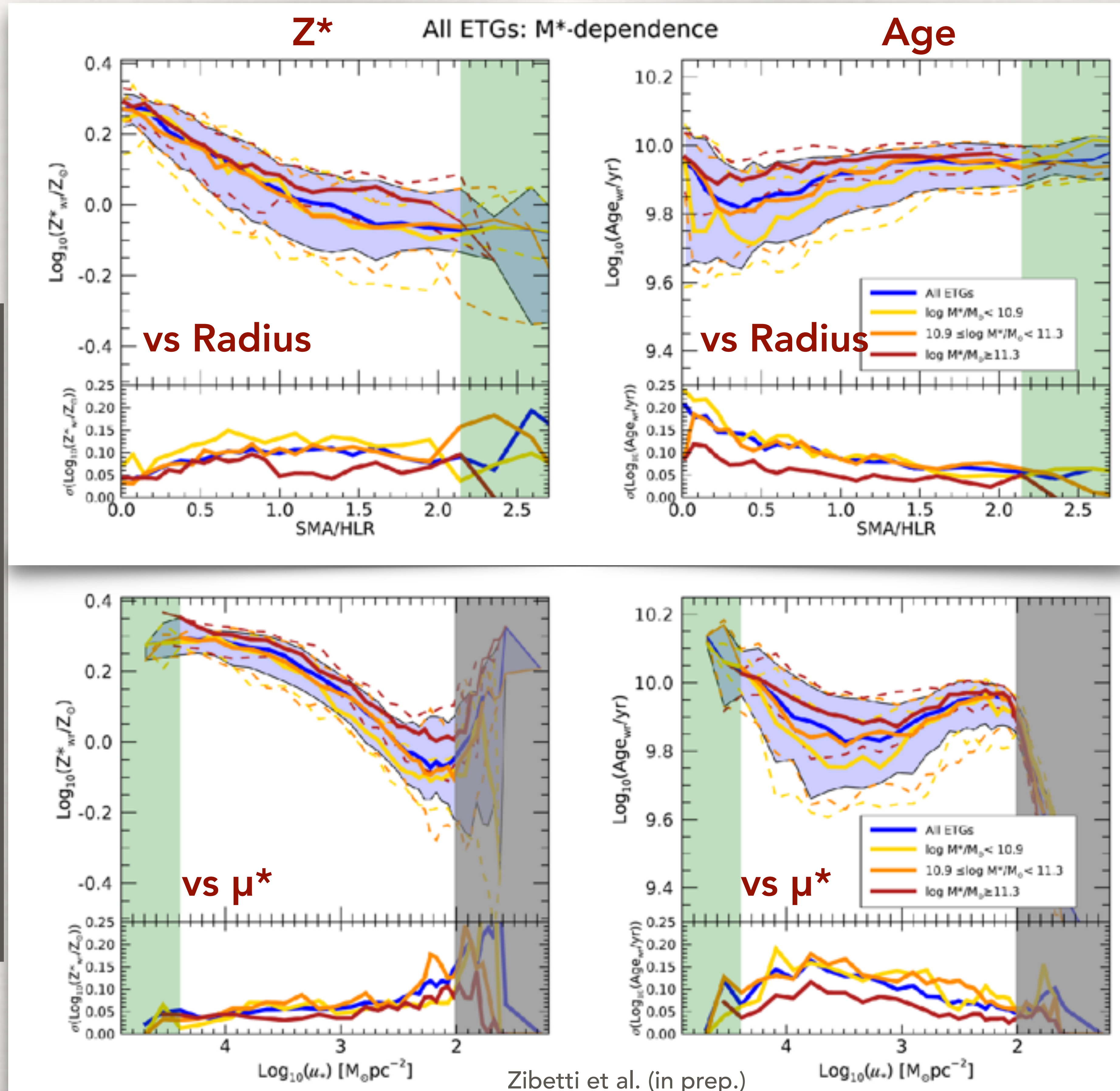


# Stellar population gradients in ETGs

*Radius vs Surface Mass density: total mass dependence*

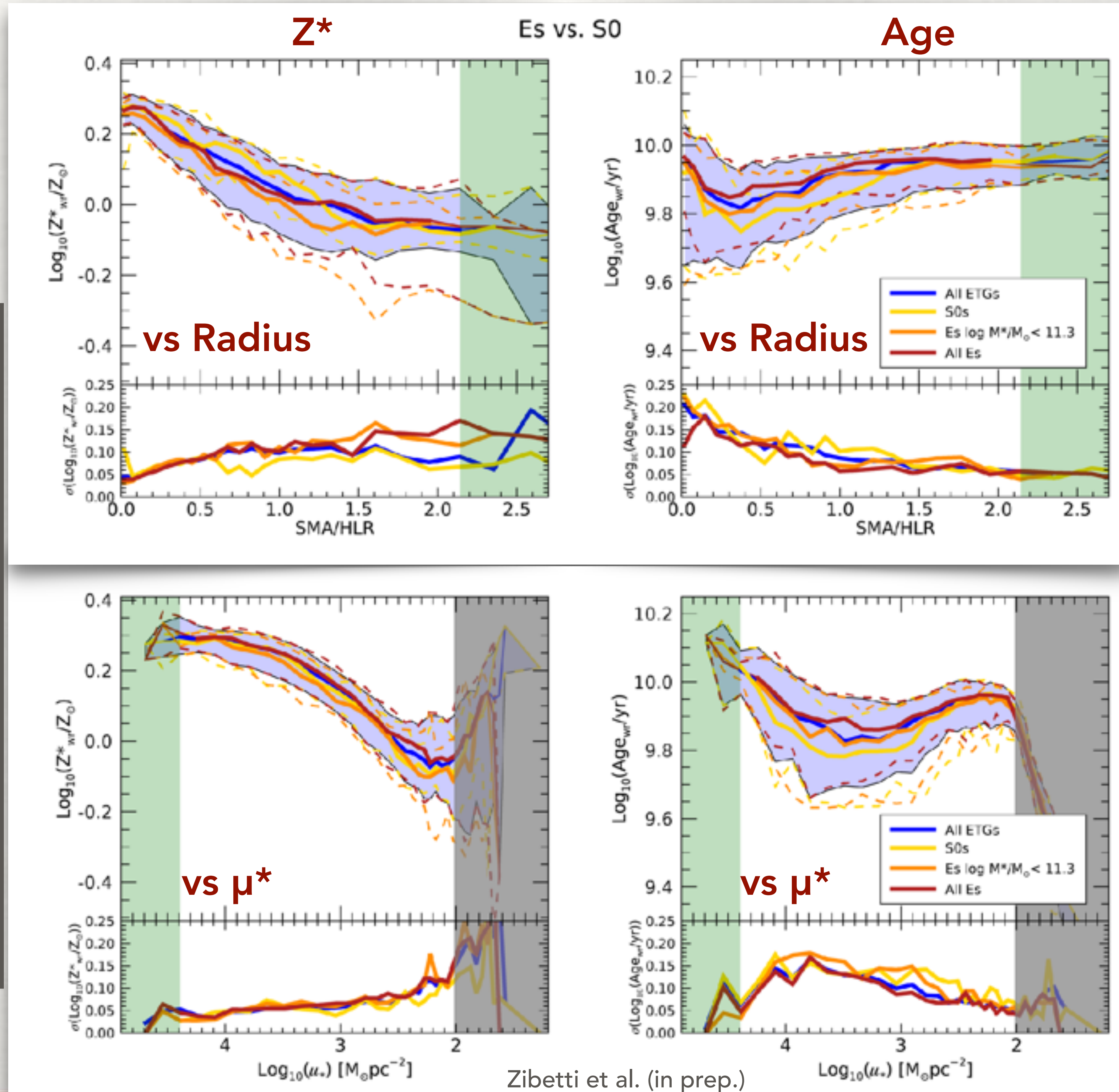
- Metallicity: almost universal μ*-Z* relation, residual dependence on M*, reminiscent of MZ relation
- Age: clear dependence of age minimum (hence gradient strength) on mass



# Stellar population gradients in ETGs

*Radius vs Surface Mass density: morphology (E-S0) dependence*

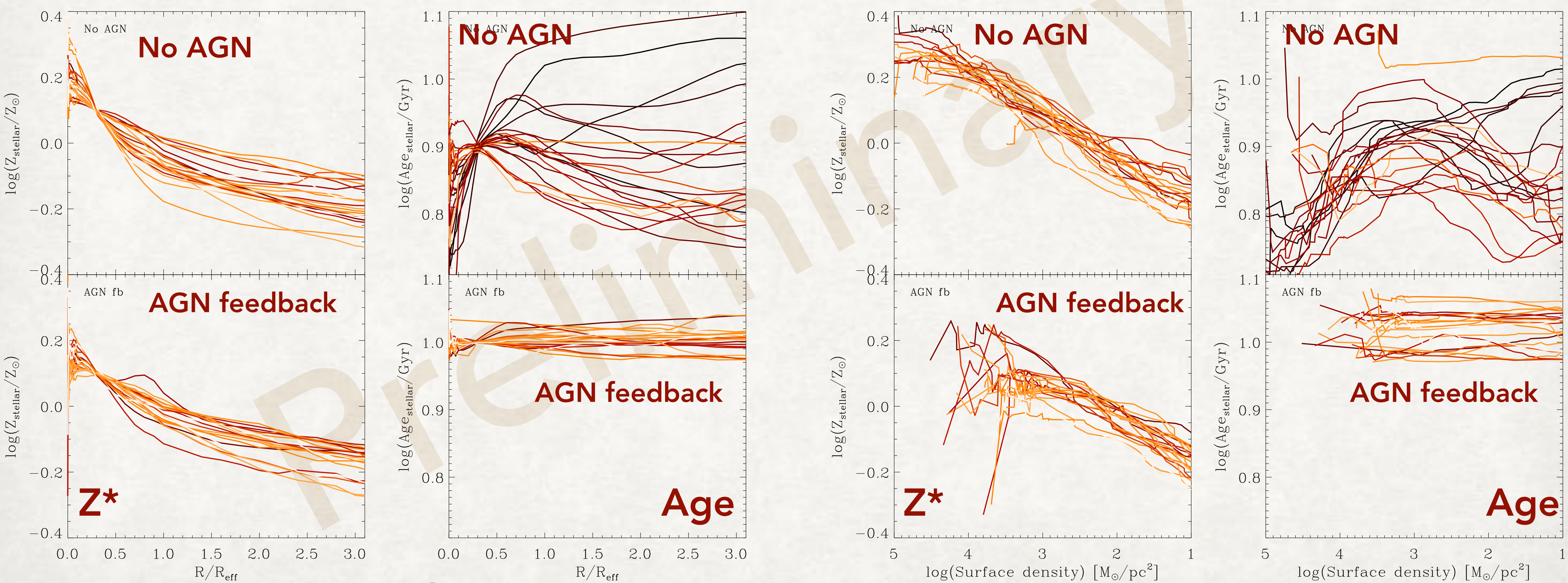
- Metallicity: no big differences, virtually identical universal μ*-Z* relation
- Age: S0 have lower minimum at ~0.4 HLR, hence stronger positive age gradient
  - Not only a mass effect!



# Stellar population gradients in ETGs

## what can we learn from / teach to **simulations?**

- Hard to reproduce the shapes of the stellar population profiles with "simple" AGN-feedback prescriptions even in state-of-the-art SPH simulations (zoom-in of cosmological N-body simulations)
  - Z gradients ~ok qualitatively, quantitatively better without AGN feedback
  - Age gradients are off, already qualitatively




vs Radius    Hirschmann et al. (in prep.)    vs μ*

# SUMMARY

- Overall "local" age bimodality, reflecting global structure/morphology but also driven by local mass density
  - "universal" old ridge and young sequence (consistent with inside-out)
- ETGs
  - ubiquitous negative Z* gradients
  - "universal" μ*-Z* relation (tiny 0.05 dex scatter!), with small residual dependence on total M*
  - U-shaped age profiles: minimum lower for lower M* and for S0 (at fixed M*) — inconsistent with inside-out scenarios; possibly hinting at mechanisms of gas inflow?
  - Hard time for models of AGN feedback… difficult to find a fit to everything