A RELATIONSHIP BETWEEN STELLAR METALLICITY GRADIENTS AND GALAXY AGE IN DWARF GALAXIES

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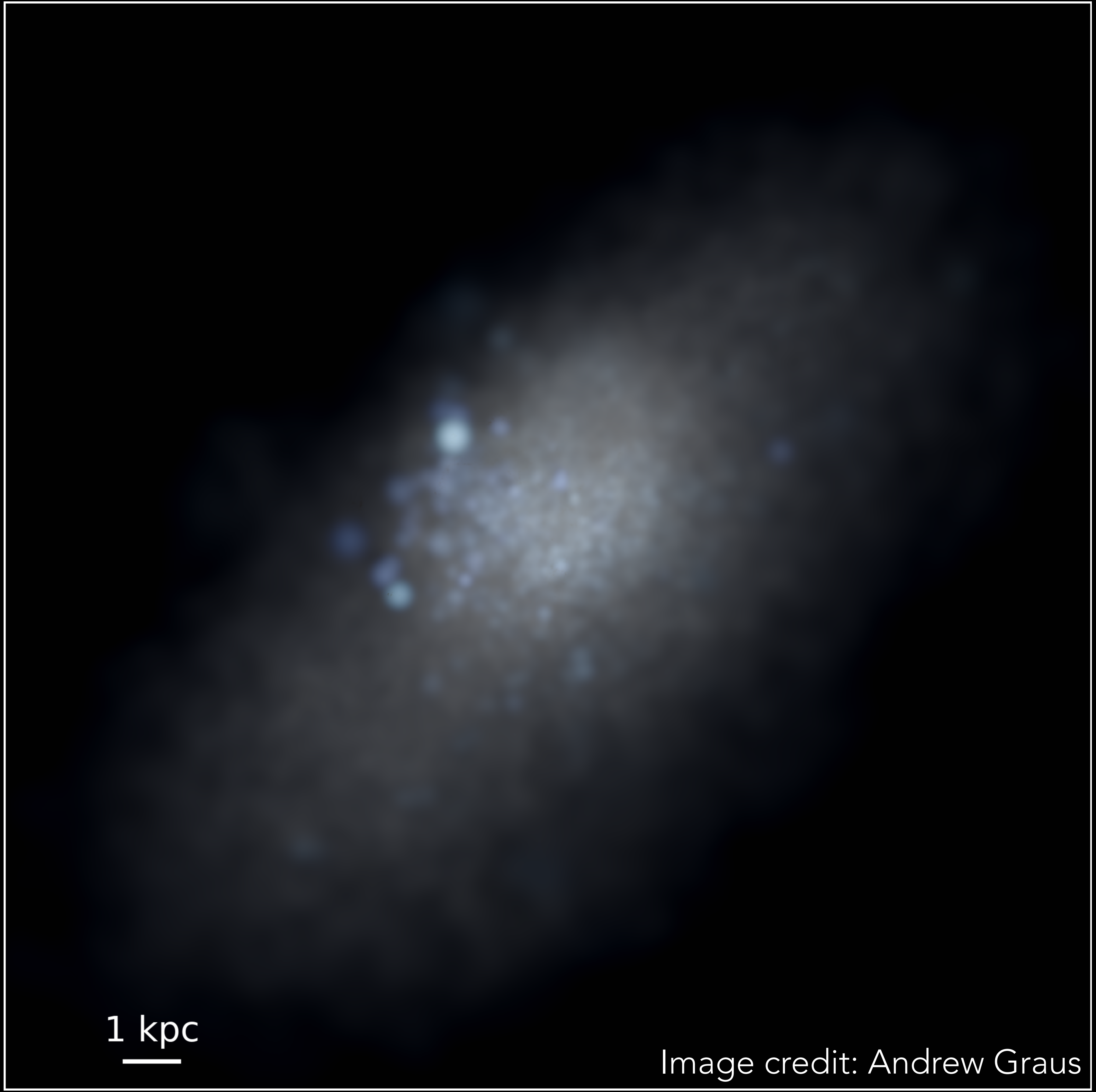
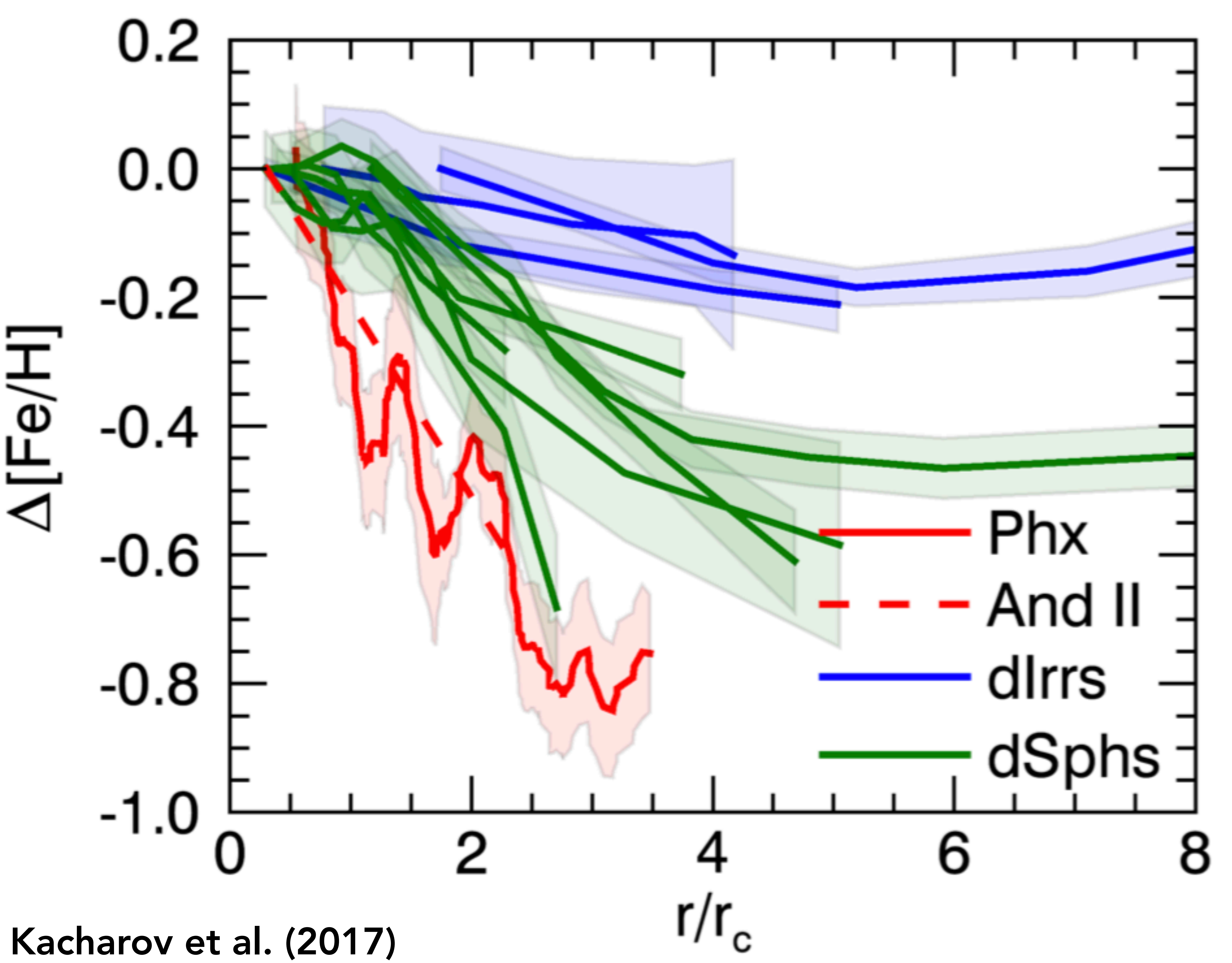


Image credit: Andrew Graus

METALLICITY GRADIENTS IN LG DWARF GALAXIES



Kacharov et al. (2017)

- Metal rich (poor) stars inhabit the central (outer) regions of the galaxy
- Recent studies point to a slight dichotomy in gradient strength
- Identifying systematic trends underlying differences in gradient strength can provide insight into their origin

MECHANISMS THAT MAY AFFECT METALLICITY GRADIENT STRENGTH

- *Internal:* Enriched gas in high angular momentum galaxies can form less radially clustered stellar populations resulting in a weaker gradient (Schroyen et al. 2011)

- *Internal:* Star formation feedback can redistribute material within a galaxy and thus weakening or strengthening the gradient (De Young & Heckman 1994; El-Badry et al. 2016)

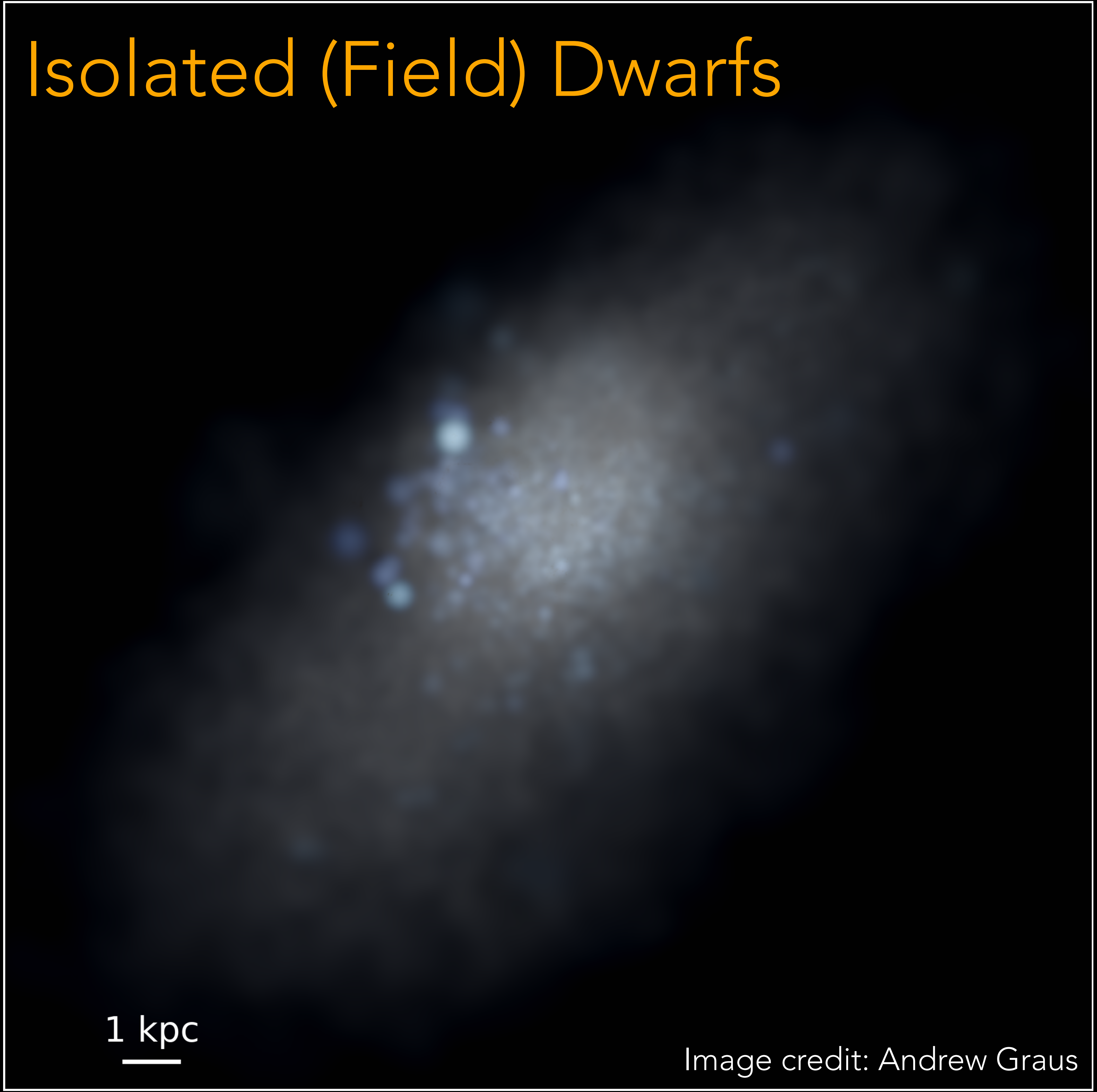
- *External:* Ram-pressure stripping of inflating satellites can shrink the star formation region of a galaxy leading to a stronger gradient (Mayer et al. 2001, 2007)

FIRE-2 simulations of dwarf galaxies

Feedback In Realistic Environments

- 9 from Fitts et al. 2017
  - $M_{vir} \sim 10^{10}\, M_\odot$
  - $M_\star \sim 10^{5\text{-}7}\, M_\odot$
  - $m_{dm} = 2500\, M_\odot$
  - $m_g = m_\star = 500\, M_\odot$

- 17 from Graus et al. 2019
  - $M_{vir} \sim 10^{10\text{-}11}\, M_\odot$
  - $M_\star \sim 10^{7\text{-}9}\, M_\odot$
  - $m_{dm} = 20000\, M_\odot$
  - $m_g = m_\star = 4000\, M_\odot$



FIRE-2 simulations of dwarf galaxies

- Star formation in **dense self-gravitating molecular** clouds
  - n_{SF} > 1000 atoms / cm^3

- Mass and Metallicity inherited from progenitor gas particle

- Total metallicity along with 11 chemical species tracked for each star particle (H, He, C, N, O, Ne, Mg, Si, S, Ca, Fe)

Model for stellar feedback:

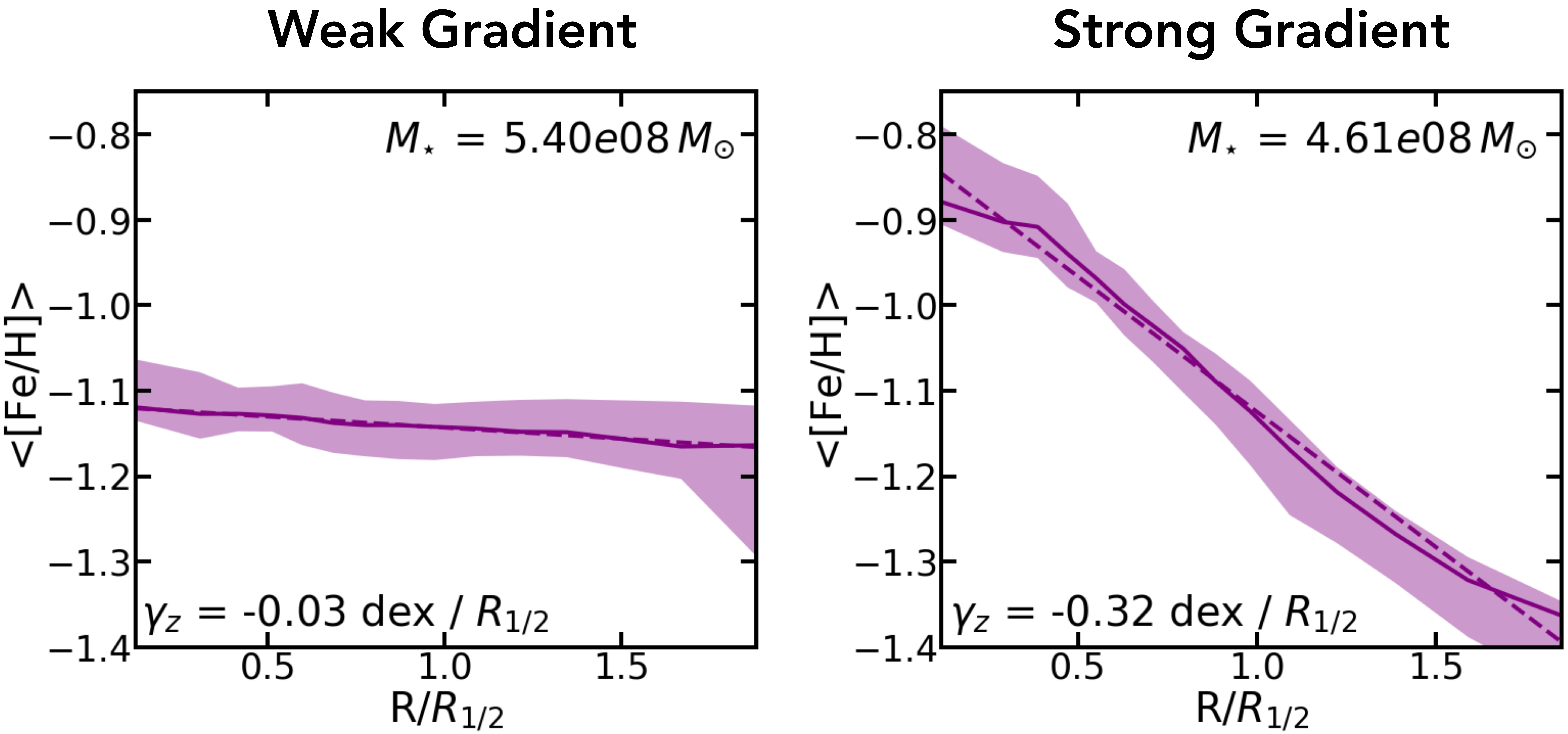
See Hopkins, Wetzel, Keres et al 2018

- Supernovae
  - core-collapse
  - type Ia

- Stellar radiation
  - radiation pressure
  - photoionization heating (HII regions)
  - photoelectric heating (via dust)

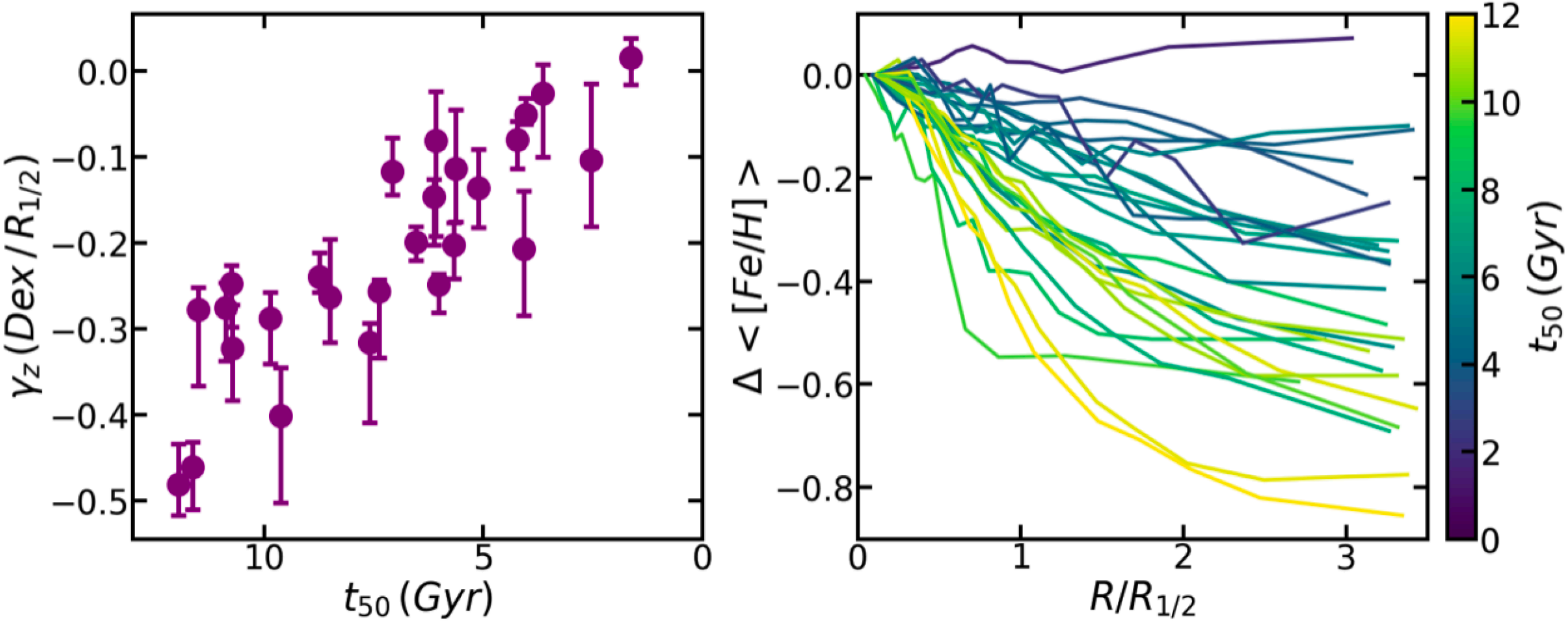
- Stellar winds
  - massive O & B stars
  - AGB stars

NEGATIVE METALLICITY GRADIENTS COMMON IN OUR SIM SAMPLE



THE GRADIENT-STRENGTH-GALAXY-AGE RELATIONSHIP

Older Galaxies —> Stronger Gradients



t_{50}: The median stellar age in a given galaxy

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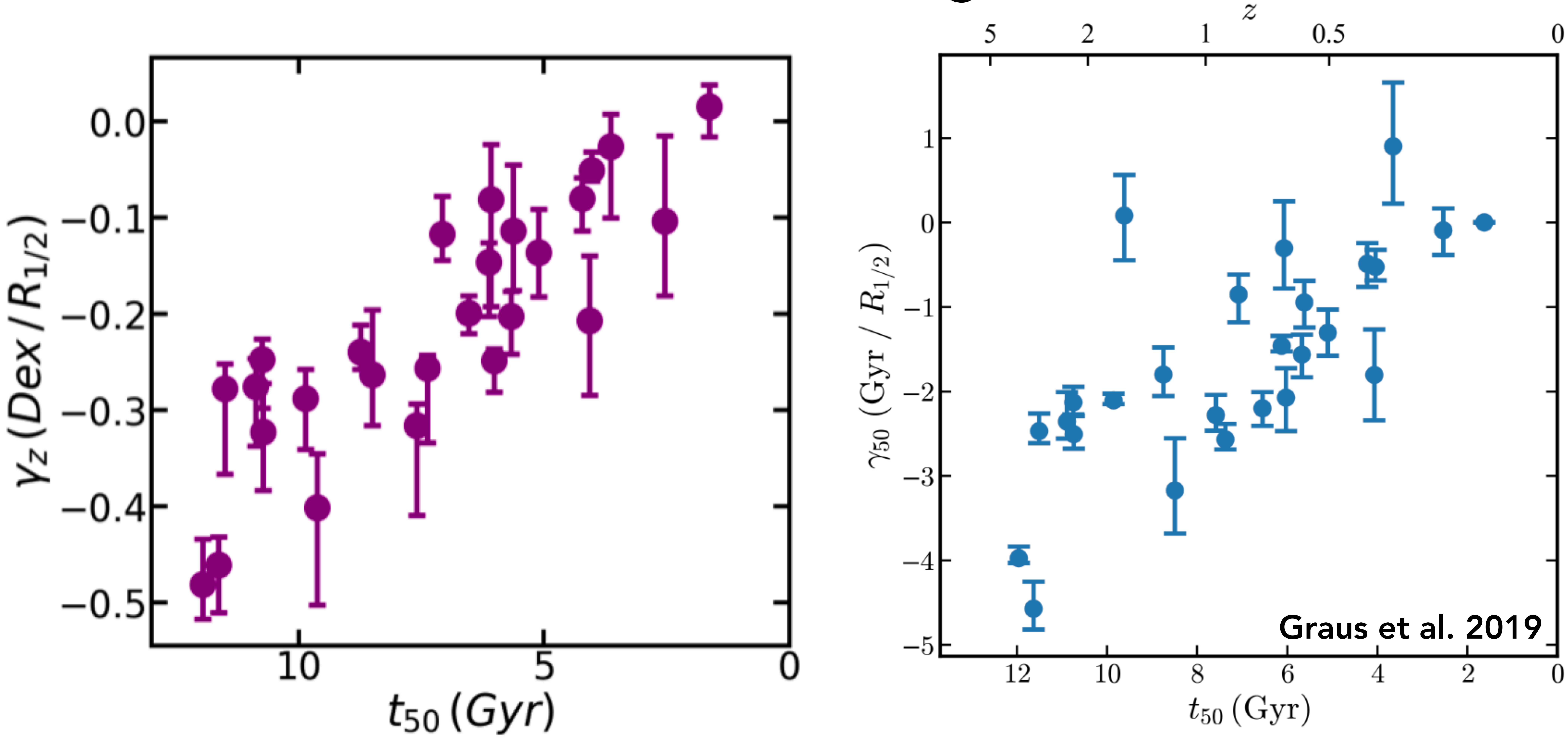
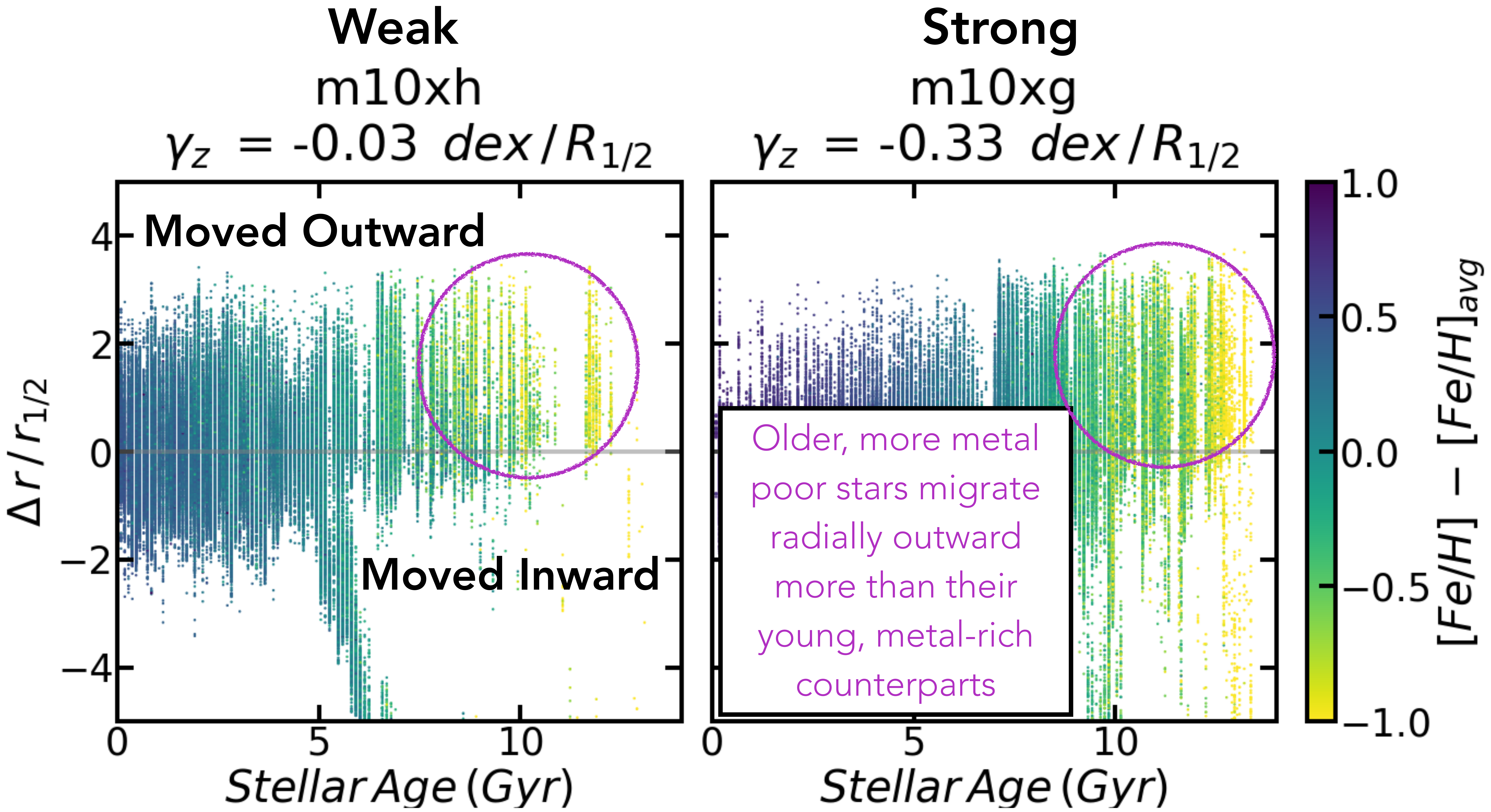
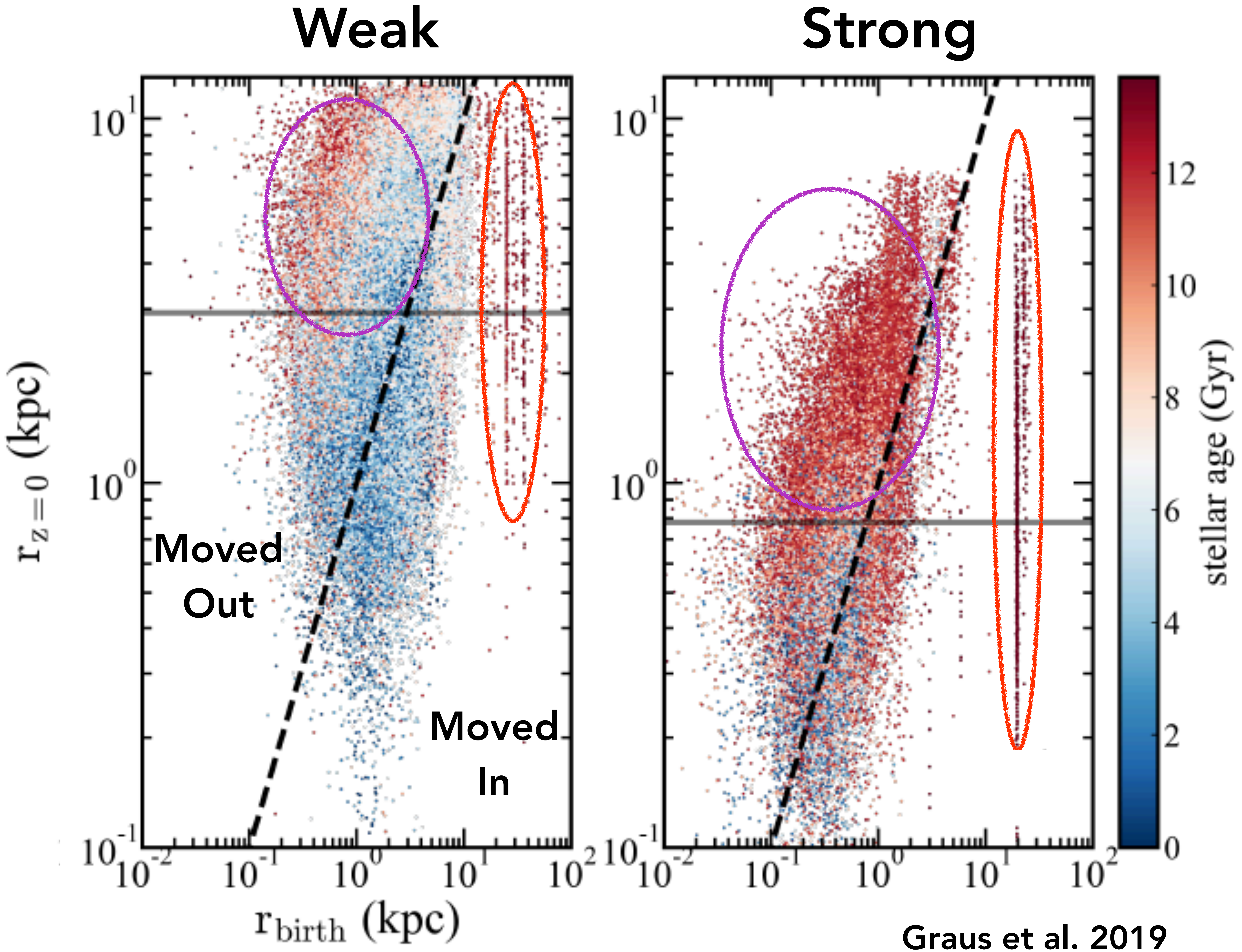


t_{50}: The median stellar age in a given galaxy

THE ORIGIN STORY: RADIAL STELLAR MIGRATION



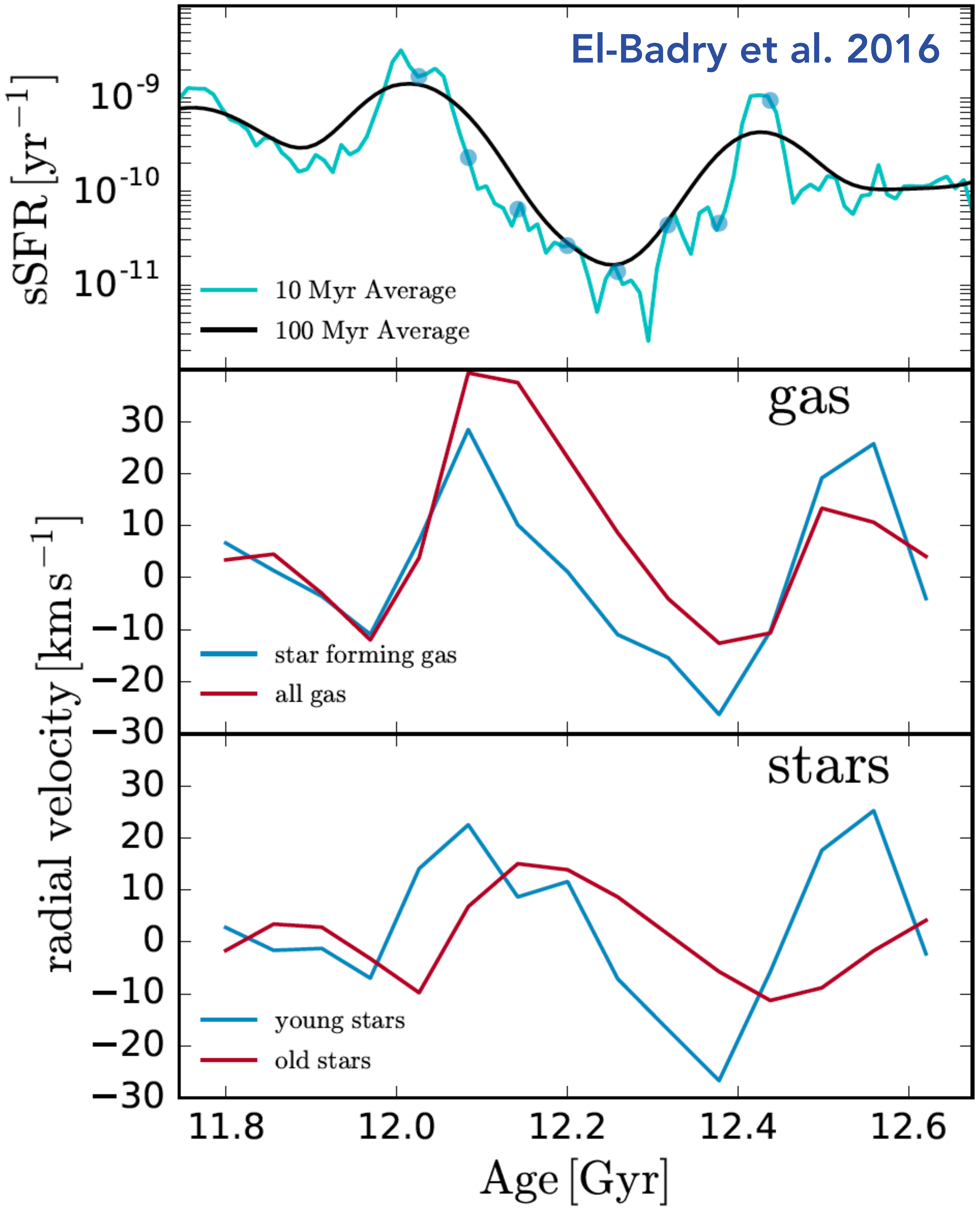
THE ORIGIN STORY: RADIAL STELLAR MIGRATION



Accreted stars being distributed throughout the whole galaxy rules out the possibility of mergers significantly affecting gradients

Graus et al. 2019

THE ORIGIN STORY: RADIAL STELLAR MIGRATION



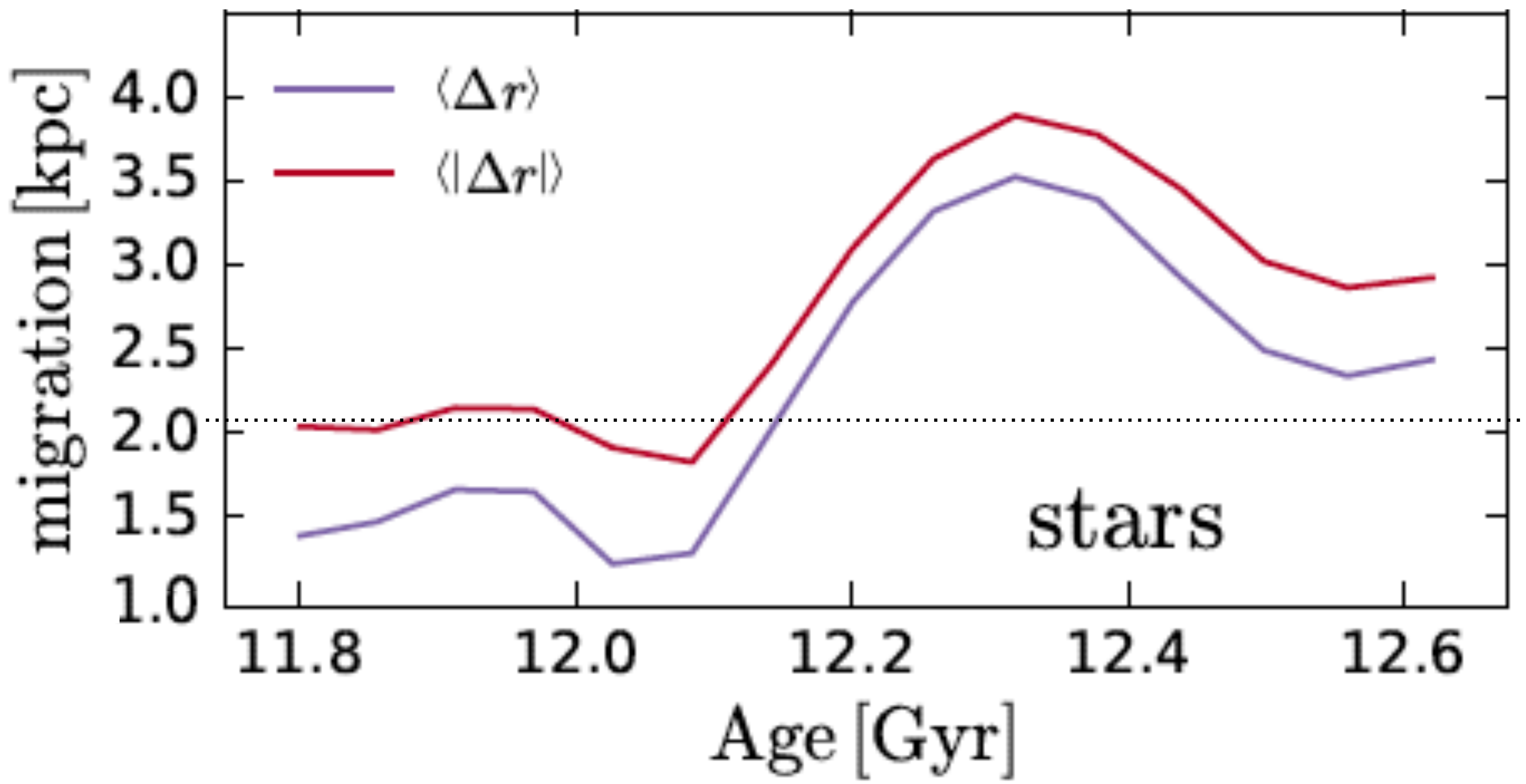
Use FIRE-2 galaxies to study what causes radial migration

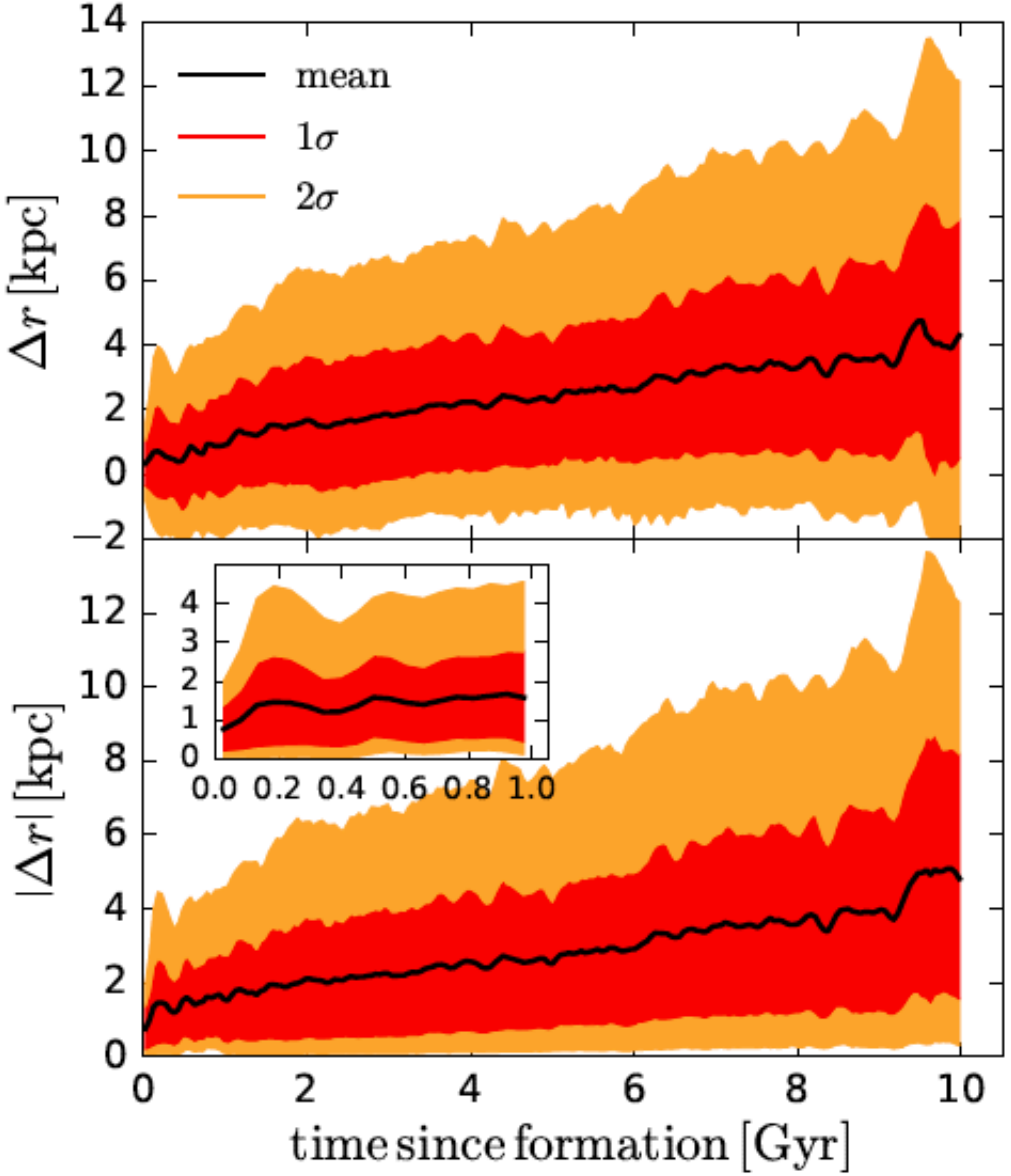
Gas responds to star formation events

Stars responds to change in potential well

THE ORIGIN STORY: RADIAL STELLAR MIGRATION

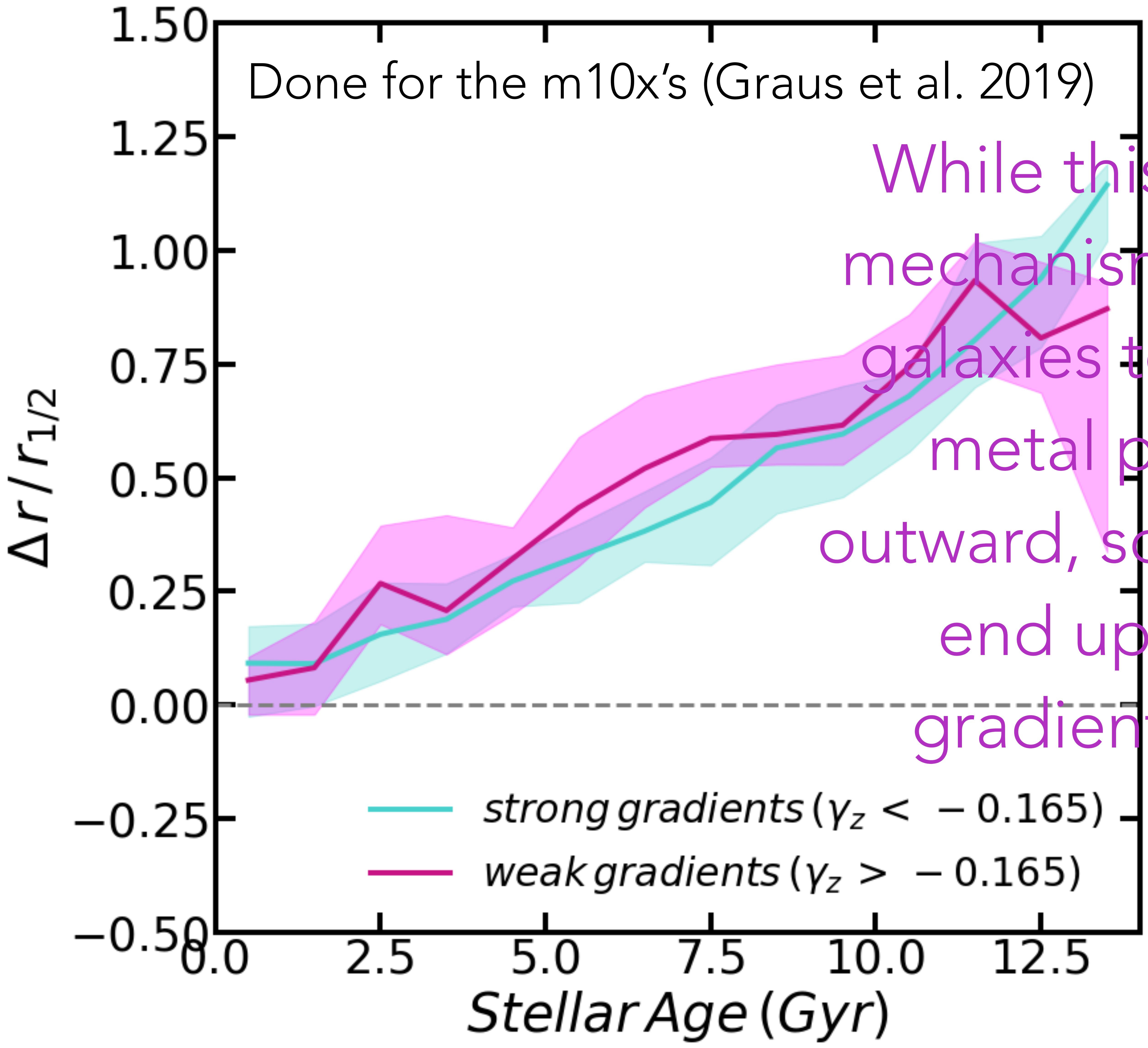
El-Badry et al. 2016





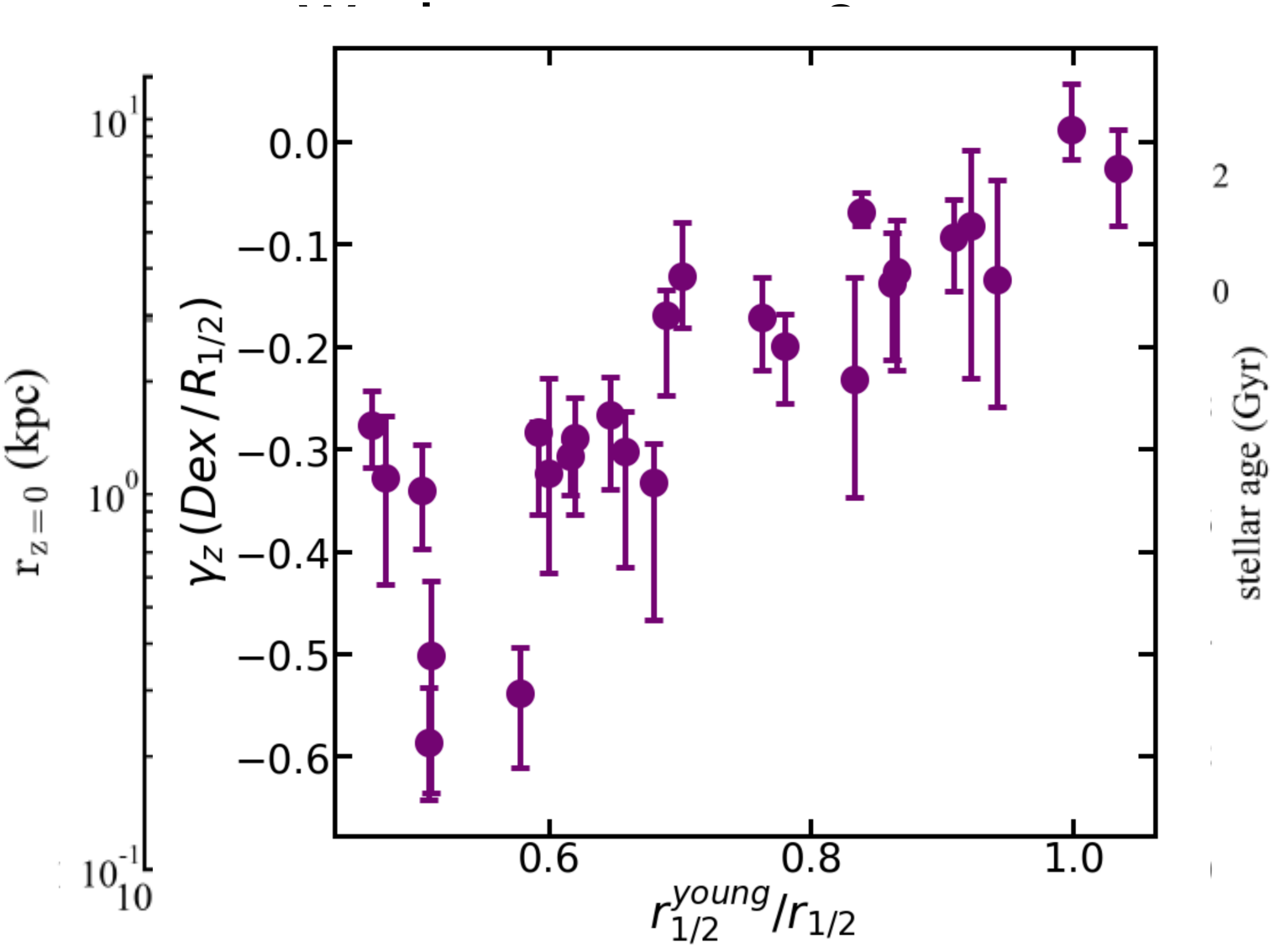
Stars that live through more "puffing cycles" will have migrated more than younger stars that lived through fewer

THE ORIGIN STORY: RADIAL STELLAR MIGRATION

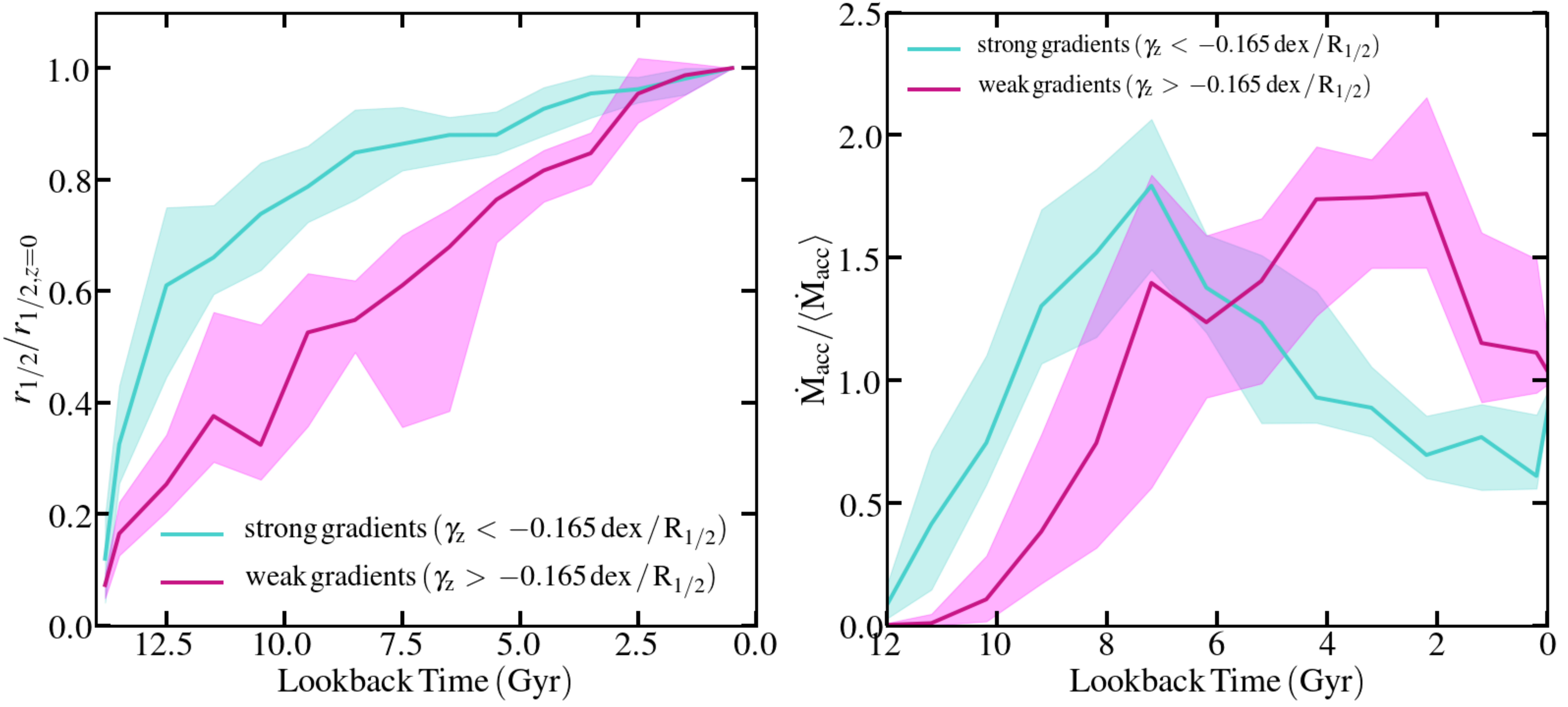


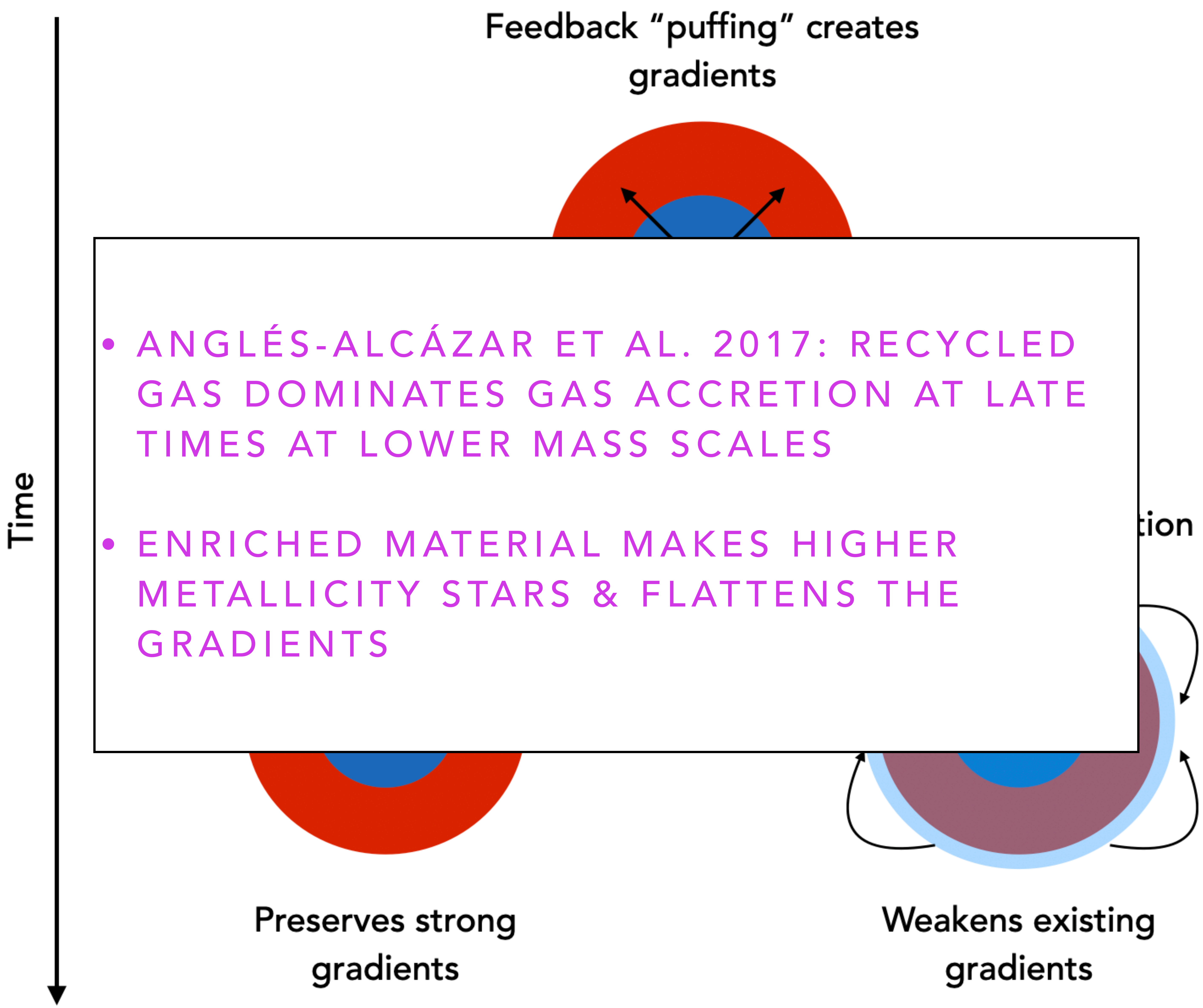
While this "puffing" mechanism acts on all galaxies to drive old, metal poor stars outward, some galaxies end up with flat gradients anyway

SETTING THE GRADIENT STRENGTH



SETTING THE GRADIENT STRENGTH





- ANGLÉS-ALCÁZAR ET AL. 2017: RECYCLED GAS DOMINATES GAS ACCRETION AT LATE TIMES AT LOWER MASS SCALES
- ENRICHED MATERIAL MAKES HIGHER METALLICITY STARS & FLATTENS THE GRADIENTS

THE OBSERVED GRADIENT-STRENGTH-GALAXY-AGE RELATIONSHIP

- t_{50} values taken from SFHs presented in Weisz et al. (2014a,b) and Bettinelli et al. (2018)
- R_e values taken from McConnachie (2012), Muñoz et al. (2018), and Simon (2019)
- Metallicity profiles presented in Leaman et al. (2013) and Kacharov et al. (2017)

Galaxy Name	t_{50} [Gyr]	γ_z $[dex/R_{1/2}]$	R_e [kpc]
MW Dwarfs	(1)	(2)	(3)
WLM	2.28	-0.11 ± 0.12	2.111
SMC	3.21	-0.13 ± 0.07	1.106
LMC	4.68	-0.15 ± 0.04	2.697
Carina	4.99	-0.16 ± 0.05	0.311
Leo I	5.22	-0.15 ± 0.02	0.270
Fornax	7.40	-0.21 ± 0.03	0.792
Leo II	8.54	-0.18 ± 0.06	0.171
Phoenix	10.48	-0.30 ± 0.02	0.454
Sculptor	11.95	-0.33 ± 0.06	0.279
Sextans	12.64	-0.16 ± 0.07	0.456

γ_z and errors determined by bootstrapped sampling the observed profile data

THE OBSERVED GRADIENT-STRENGTH-GALAXY-AGE RELATIONSHIP

SUMMARY

- In observed galaxies negative metallicity gradients are common such that more **metal rich** stars populate the **central regions** while more **metal poor** stars inhabit the **outer regions**
- In FIRE-2 galaxies we see such gradients and also predict a **Gradient-Strengeth-Galaxy-Age Relationship**
- Galaxies with **older** stellar populations tend to have **stronger gradients**
- **Gradients are formed by steady "puffing"** from feedback effects that drive the oldest, more metal poor stars outward over time (El-Badry et al. 2016)

SUMMARY: CONTINUED

- We predict that **late time, radially extended star formation** acts to **flatten out gradients**
- These **stars form from recycled gas** that fell back onto the galaxy after being ejected by feedback processes
- We use data from **10 observed LG dwarfs** to show that they **also follow a Gradient-Strength-Galaxy-Age Relationship**, similar to that of the simulated sample
- **These results suggest that metallicity gradients in real galaxies may be governed by feedback puffing and late-time accretion of recycled gas**