CHEMICAL ABUNDANCES AND COSMOLOGICAL SIMULATIONS: HOW FAR FROM THE TRUTH?

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- To understand how galaxies form, one needs to study stellar populations
- The Milky Way is the best laboratory
- Galactic chemical evolution is a fruitful tool to probe:
  - SF timescales
  - Ages of the stellar populations
  - Gas accretion/outflow histories

Important diagnostics are:

- Metallicity distribution function (MDF)

(FC et al., 2012, MNRAS, arXiv:1204.1051)

- Metallicity Gradients

 (Pilington et al., 2012, A&A, 540, 56)

- Abundance ratios

 (e.g. [α /Fe]-[Fe/H], Few et al., 2012, MNRAS, in press, arXiv:1202.6400)

Standard Cosmology

- ΛCDM, i.e.:

$$\Omega_m \sim 0.3$$

$$\Omega_\Lambda \sim 0.7$$

$$H_0 \sim 70\, km\, s^{-1}\, Mpc^{-1}$$

$$\Omega_b = 0.04$$

Our Instruments:
1. The MUGS simulations

- N-Body + SPH code GASOLINE (Wadsley+04)
- Star formation occurs in a particle with density > 1 cm^{-3} and T<15000 K (SF threshold)
- SF : $$\frac{dM_*}{dt} = c_* \frac{M_{gas}}{t_{dyn}} \; ; \qquad t_{dyn} \sim \frac{1}{\sqrt{G\rho}} \qquad c_* = 0.05$$
- Kroupa+93 IMF
- Two chem. Elements studied: O (produced mostly by massive stars) and Fe (both by MS(~33% in a SSP) and type Ia Supernovae (~67%, Matteucci & Greggio 1986)

→ Z=O+Fe underestimated (w/ some effects rgd. Cooling, but non-linear)

Our Instruments: 2. The RADES simulations

- AMR code RAMSES (Teyssier 02)
- Star formation occurs in gas cells with density > 0.1 cm^{-3} (SF threshold), (Duboys & Teyssier 08)
- SF : $$\frac{dM_*}{dt} = \frac{\rho}{t_*} \quad ;$$

$$t_* \propto t_0 \sqrt{\rho/\rho_0}$$
$$t_0 = 8Gyr$$
$$\rho_0 = 0.1cm^{-3}$$

- Kroupa+01 IMF
- Several chem. Elements (H, He, C, N, O, Ne, Mg, Si, Fe)

  =>Better description of global metallicity Z

Our Instruments: 3. Classical Chemical Evolution Models

- Chiappini+01; Molla & Diaz 05; Cescutti + 07
- Analytical infall (exponential, with τ growing ~ linearly with radius, τ~7 Gyr in the S. N.)
- Star formation occurs if $\sigma_{gas}(R,t) > 7 M_{\odot} pc^{-2}$

  (SF threshold, Kennicutt 1998)

- SF : $\dot{\sigma}_{*} \propto \nu \sigma^{k}_{gas}(R,t)$; $\nu = 1/Gyr$ $k = 1.5$

  (Schmidt-Kennicutt law)

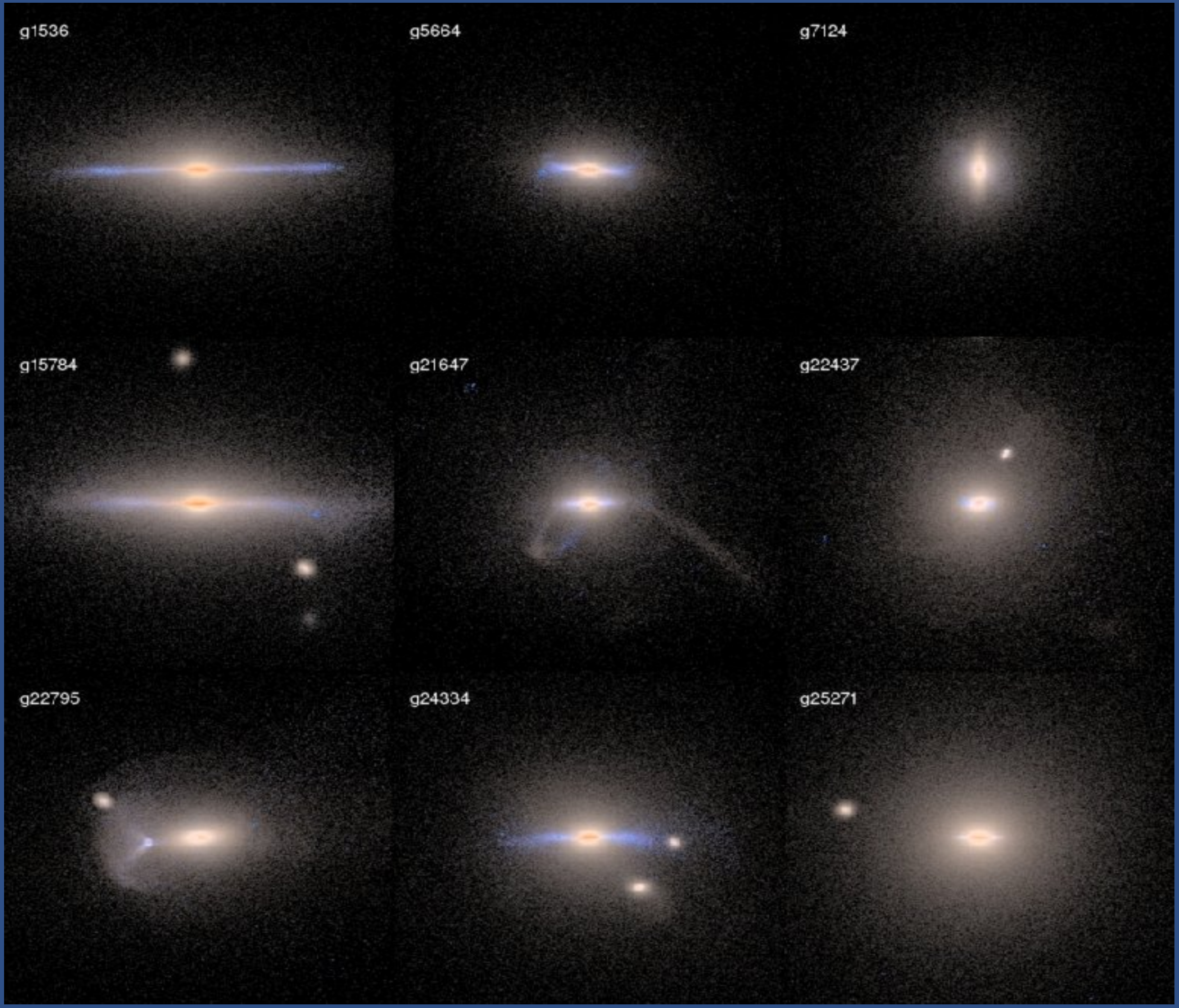
- Scalo (1986) IMF

Simulations: Modus Operandi

(a) Low resolution simulation in a large box (size : 20- 50 h^{-1} Mpc)

(b) MW-like halo re-run with higher resolution

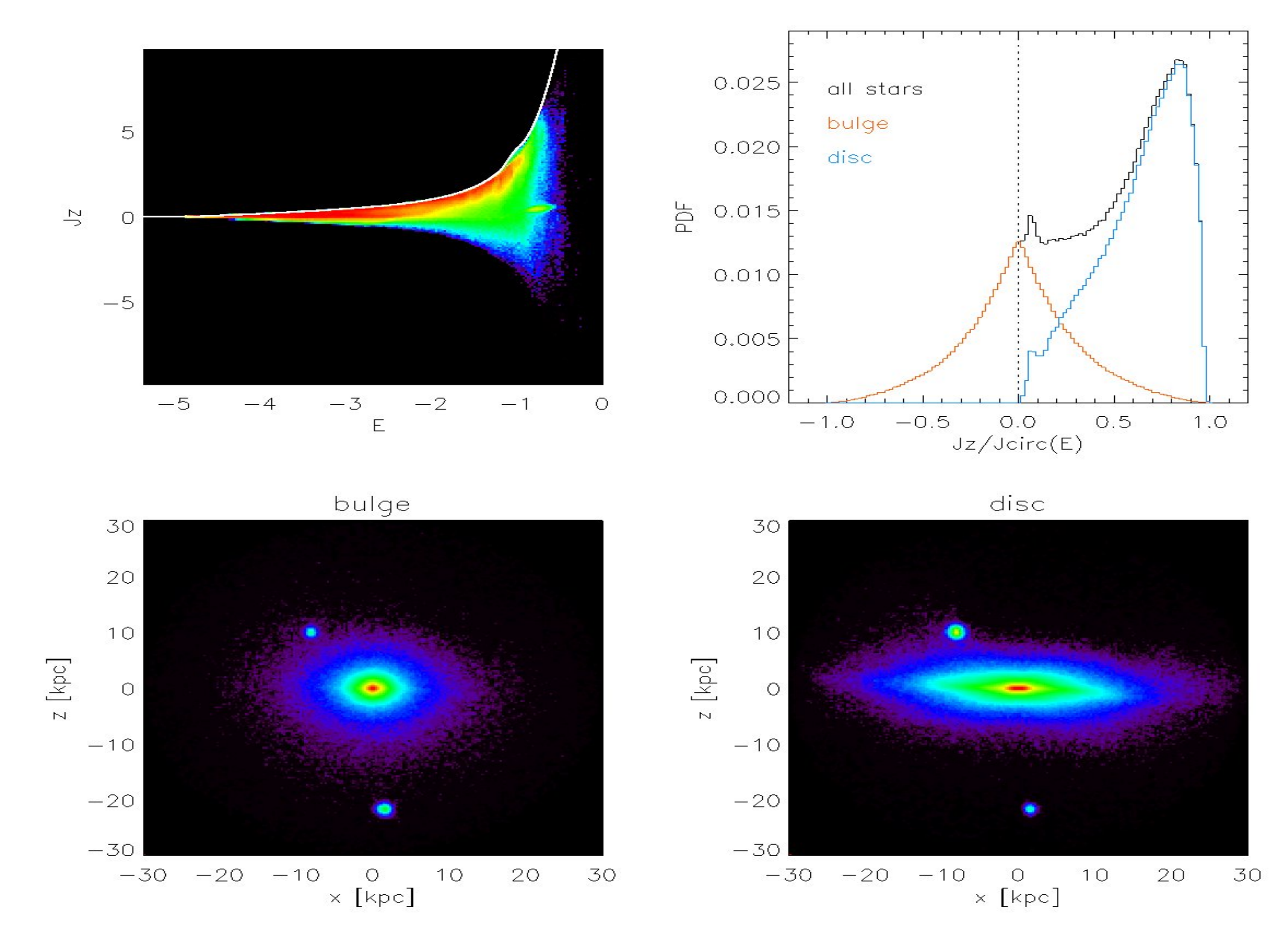
The MUGS galaxies: how they look like



Stinson et al. (2010)

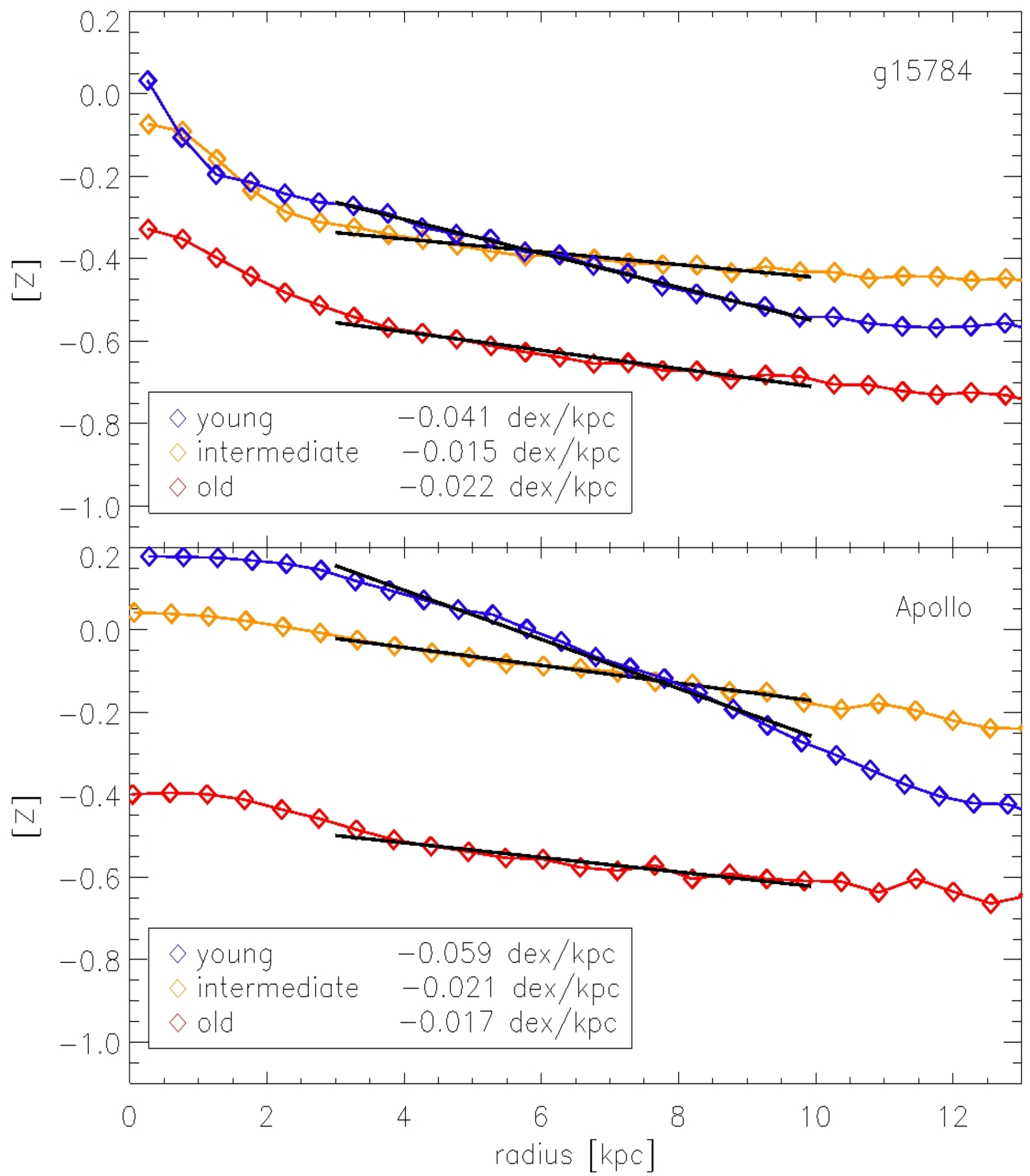
Kinematical decomposition: Bulge vs Disc

Abadi+03



+ further spatial cut (innermost regions+vertical cut to exclude satellites)

Stellar Z Gradients

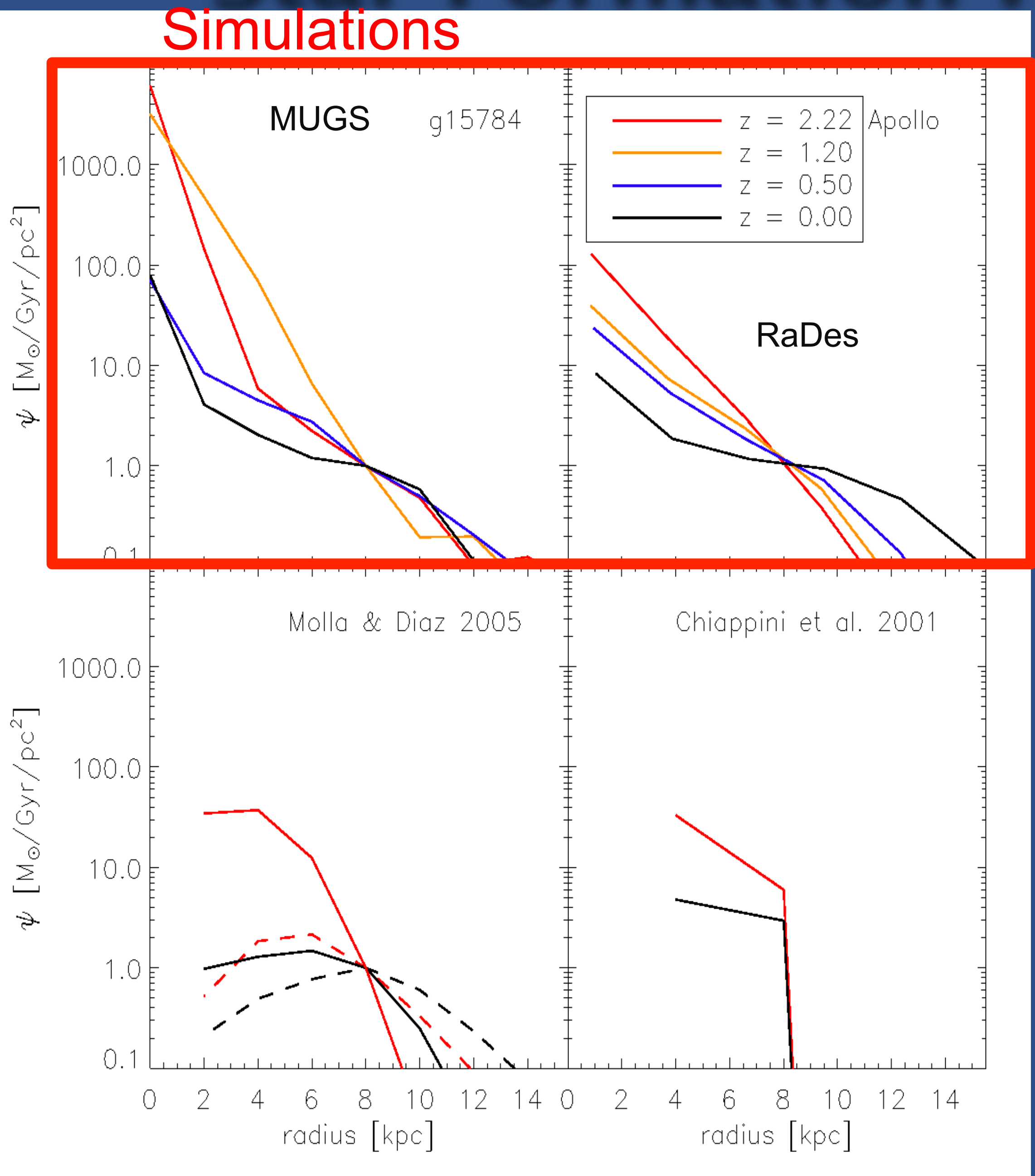


Pilkington, Few et al. 2012

- This is counter to observations in MW Pne (Maciel+03)
- Possible causes:
  1. kinematically "hot" discs (House+2011)
  2. mixing/migration, more pronounced for older stars

➔ A diagnostic to constrain migration?

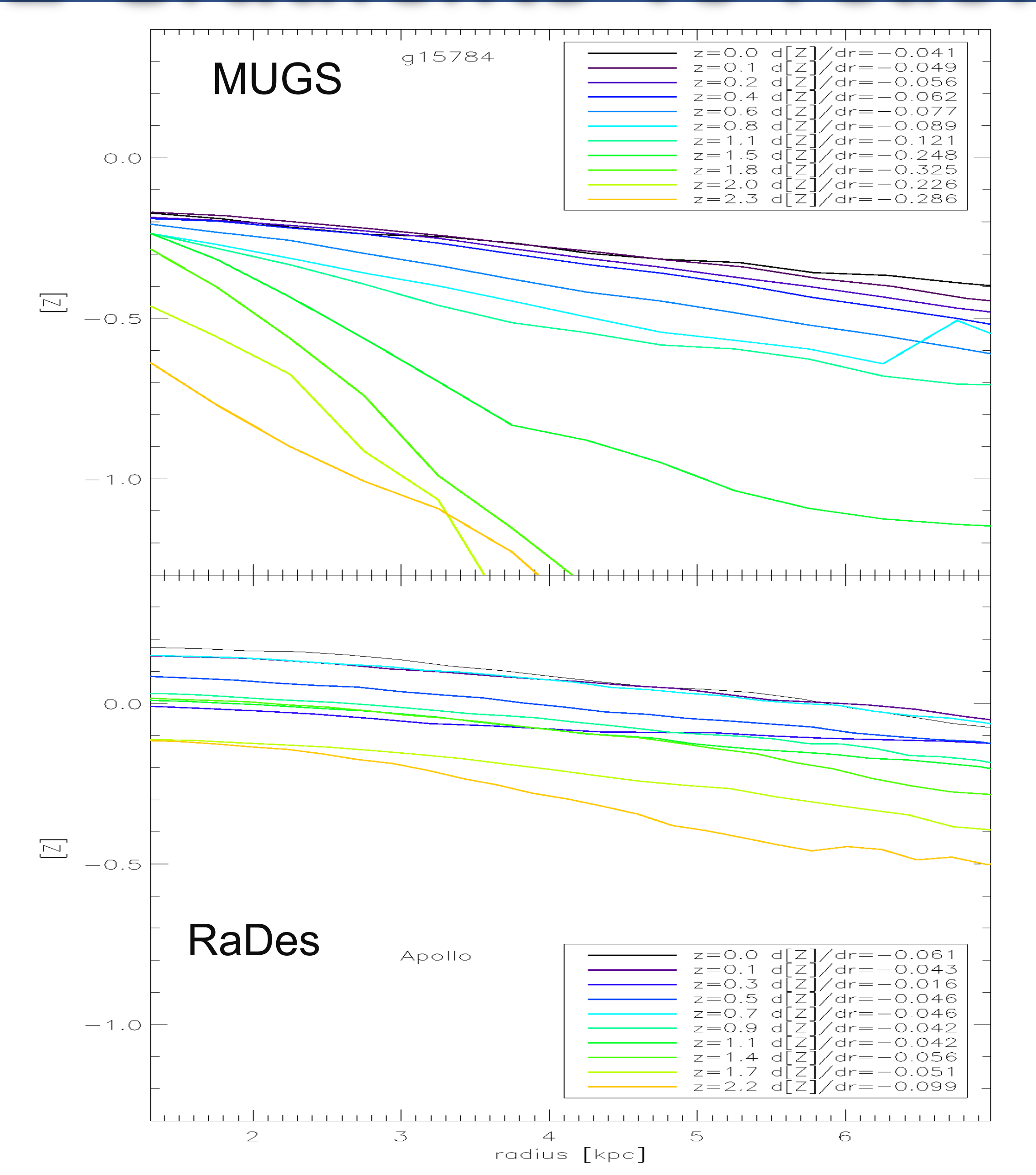
Star Formation Profile vs z



- All approaches show similar trends
- "Inside – out" formation (longer SF-timescales at larger radii, Matteucci & Francois 1989)
- Threshold plays a dominat role (MUGS more centrally-concentrated)

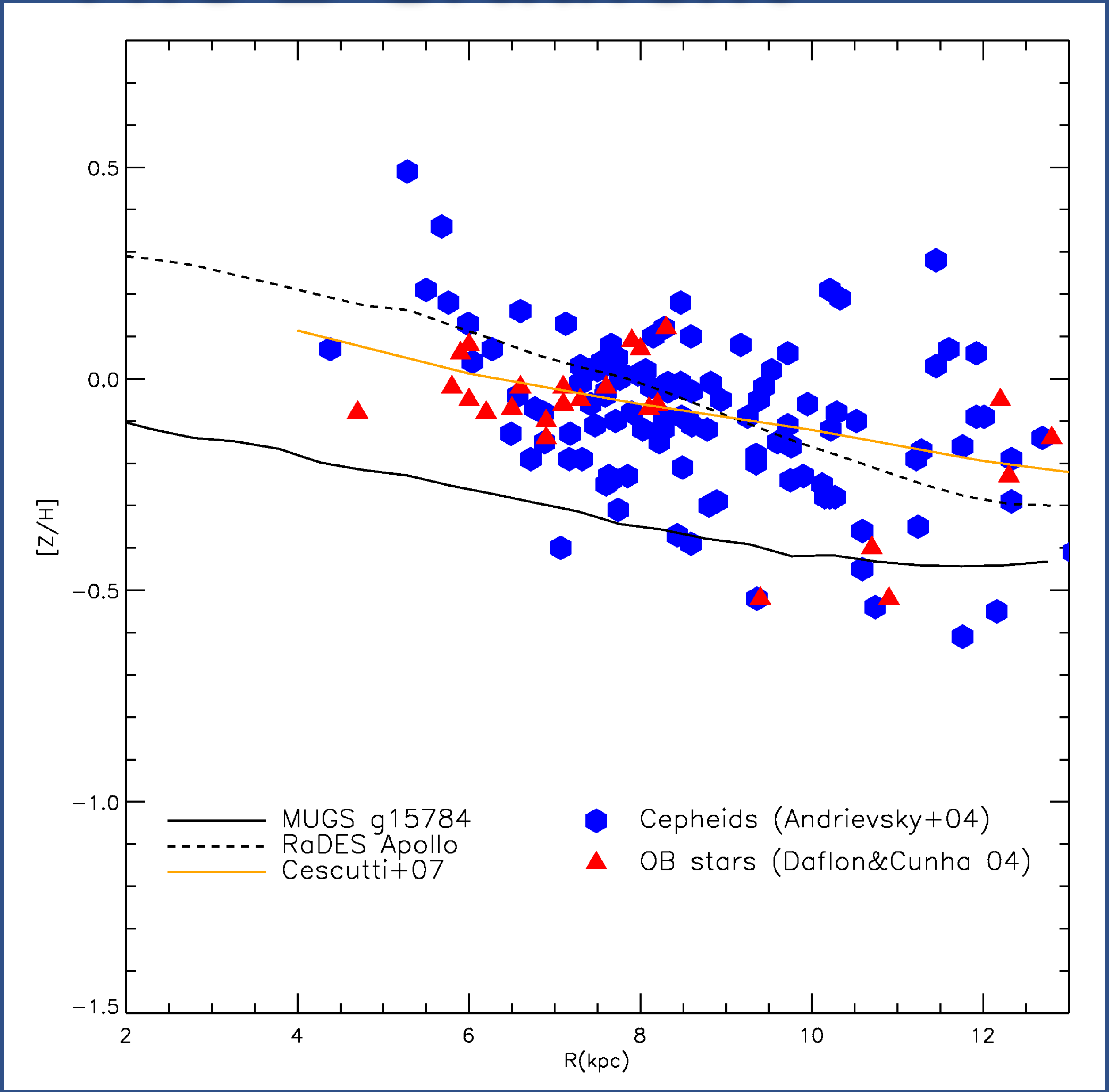
Pilkington, Few et al. 2012

Z Gradients vs redshift



Pilkington, Few et al. 2012

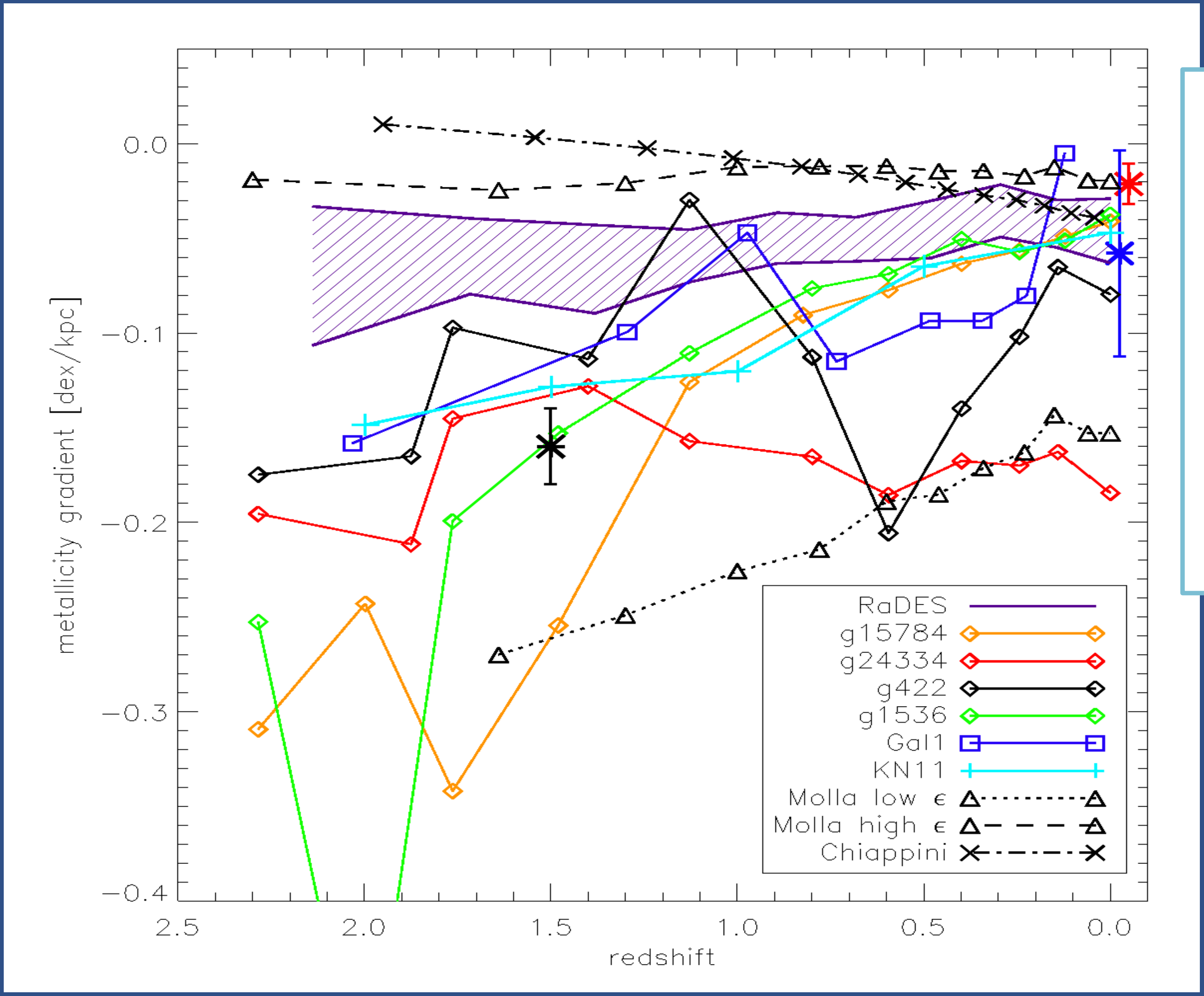
The Z Gradient



The Z Gradient

Where	d[Z]/dr	Ref.
	Observations	
Milky Way (O)	**−0.07 dex/kpc**	Shaver+03
Local Spirals, Av. value	**−0.058 dex/kpc**	Zaritsky+94
Local Spirals, Av. value	**−0.053 dex/kpc**	Van Zee+98
	Simulations	
MUGS g15784	**−0.04 dex/kpc**	Pilkington, Few +12
RaDes Apollo	**−0.04 dex/kpc**	Pilkington, Few +12

D[Z]/dr vs redshift

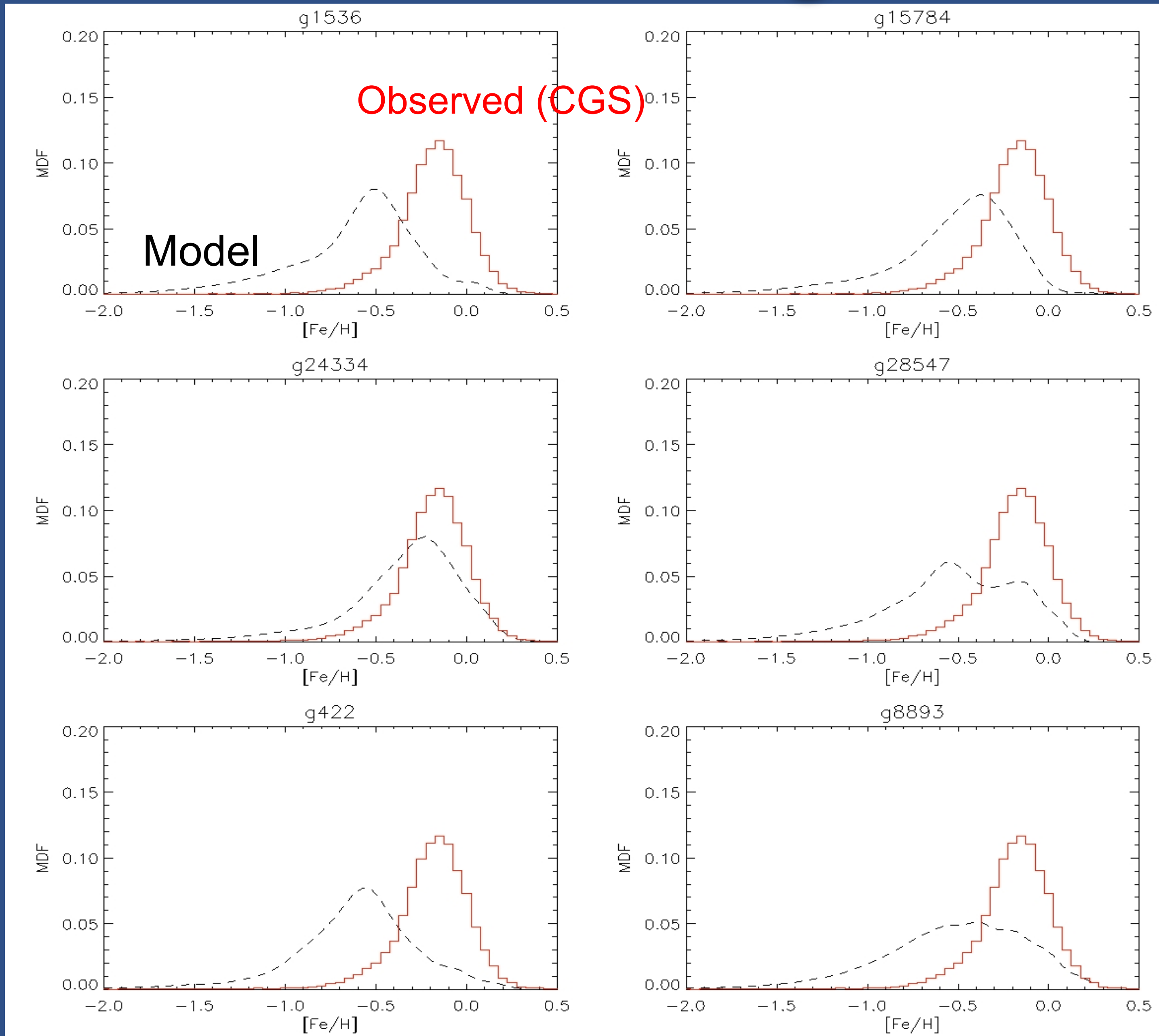


*:Yuan+11

*:Zaritsky +94

*:Kewley +10 (in pairs)

MDF in the solar neighbouhood



For us S.N is made of stars at 2Reff<R<3 Reff
+
Gaussian convol.

FC et al, 2012

Conclusions

- Inside-out formation even in simulations
- SF threshold and sub-grid physics play a fundamental role in the evolution of the gradient
- Classical CEM: gradient steepens; Simulations: gradient flattens w/ redshift
- In sims, gradients in local old & young stars may be useful to constrain migration

Conclusions

- Close to the truth

  - Z Gradients: locally  

  - Z Gradients: redshift evolution? (if Yuan+11 confirmed)

Conclusions

- Far from the truth

- Z Gradients in old stars steeper than Z gradients in your stars

- Metallicity distribution functions