Chemical enrichment in semi-analytic models

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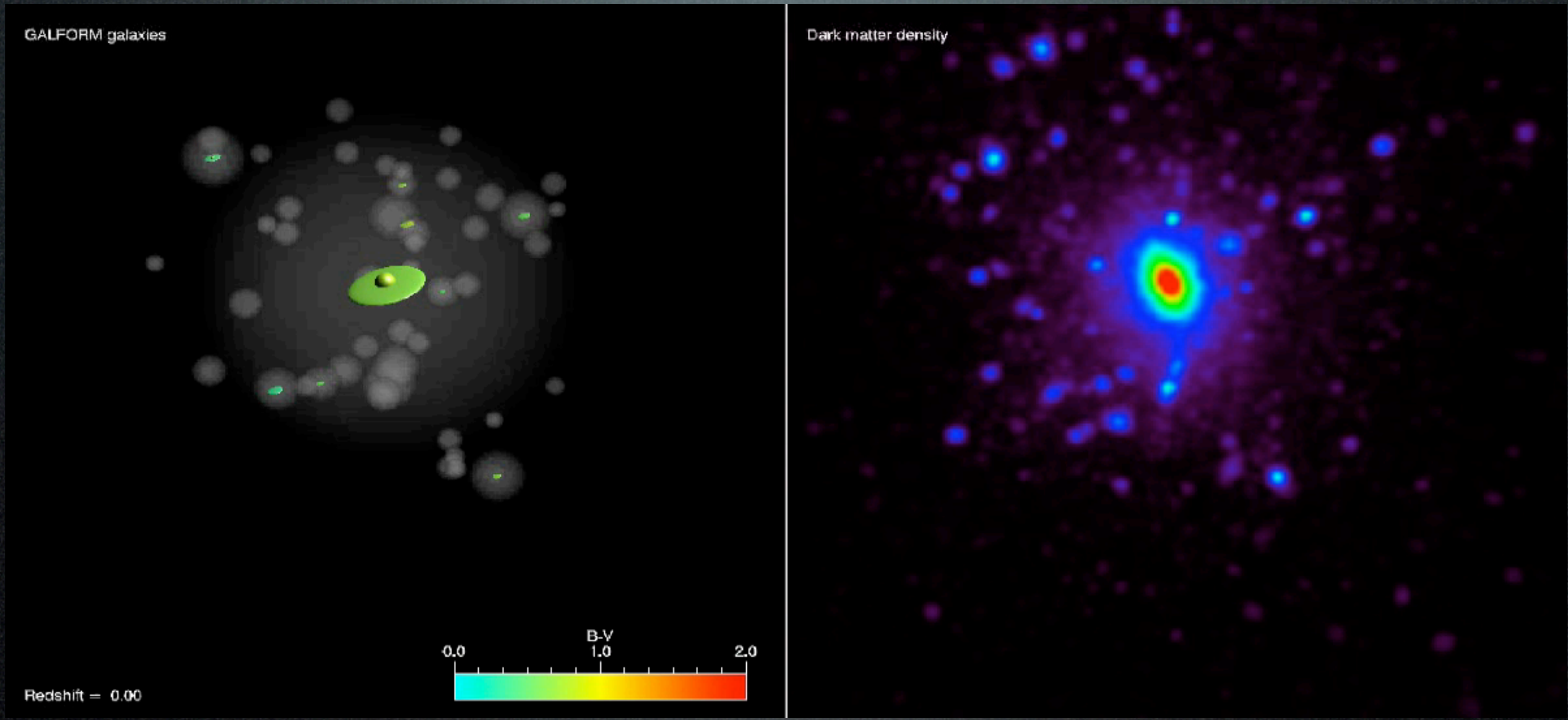
We ARE kidding...



Credit: John Helley

Semi-analytics represent CDM + baryon physics

Why chemical evolution

Chemical evolution is more than just metallicity

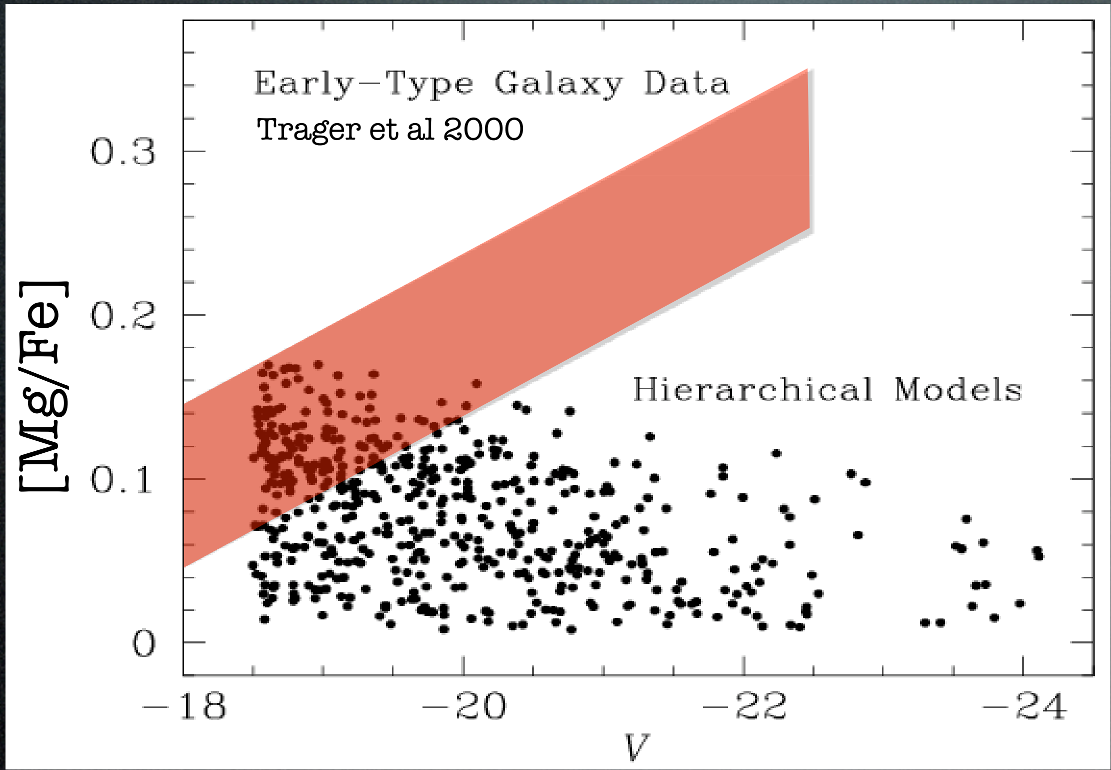
Why add even more parameters?

- IMF dependent
- Stellar nucleosynthesis uncertain
- Element abundances difficult to measure
- Progenitor and rate of Type Ia supernovae controversial
- ...

Because

- Fossil record of element ratios does not evolve
- Provides direct probe of physics at formation epoch
- Element ratios constrain (star) formation histories

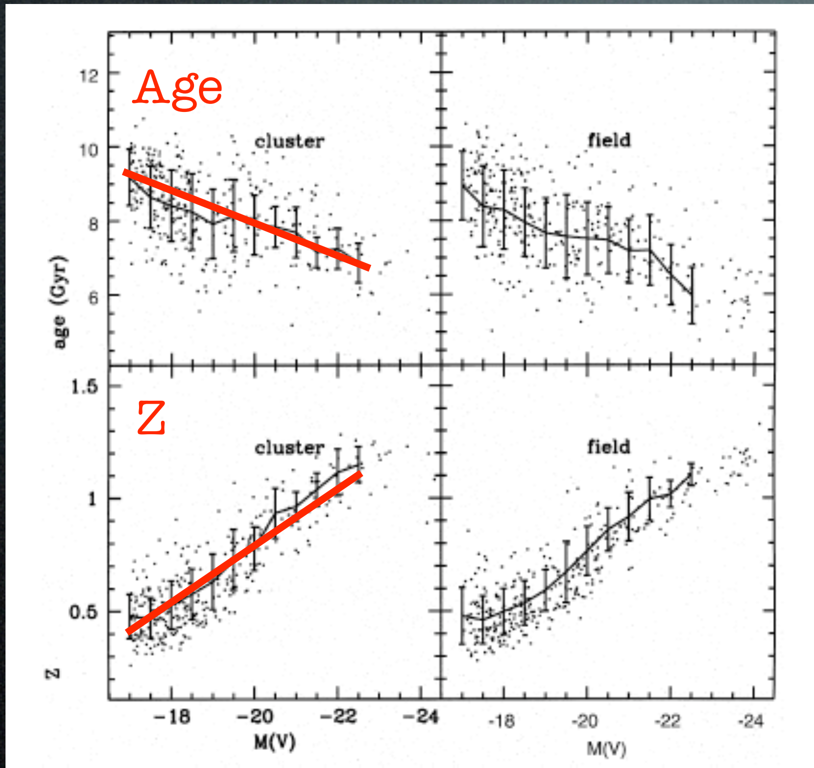
Clues from Mg/Fe

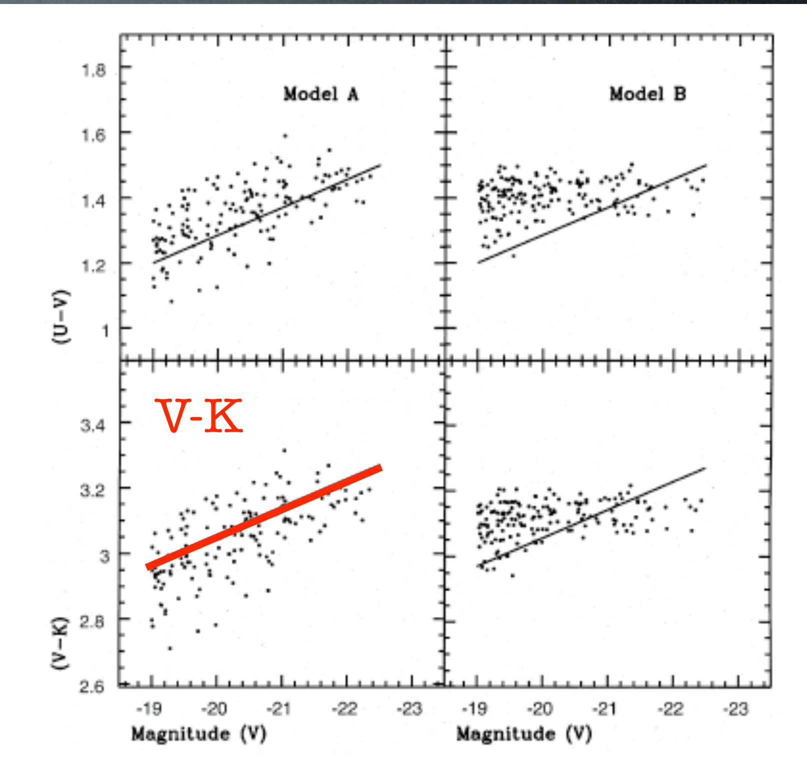


Thomas 1999
Thomas & Kauffmann1999

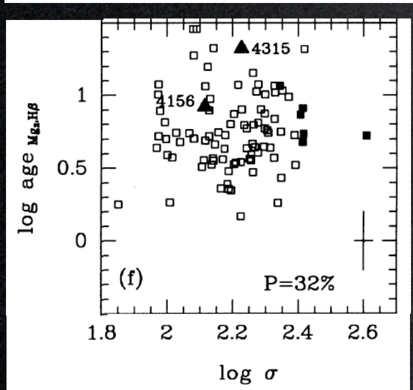
problem with star formation histories
introduce top-heavy IMF in bursts... ...Cedric could have predicted sub-mm galaxies!

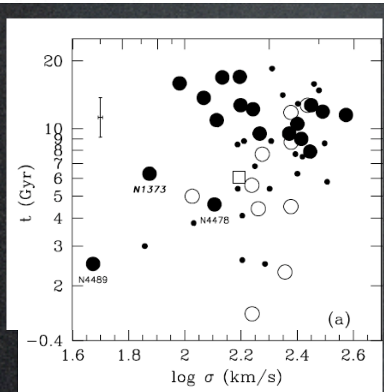
Upsizing in 1998





Kauffmann & Charlot 1998





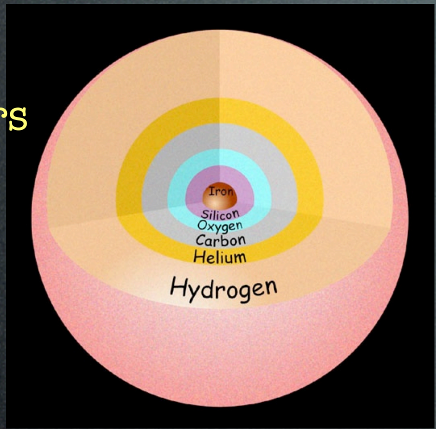
Jorgensen 1999

Trager et al 2000

Chemical enrichment

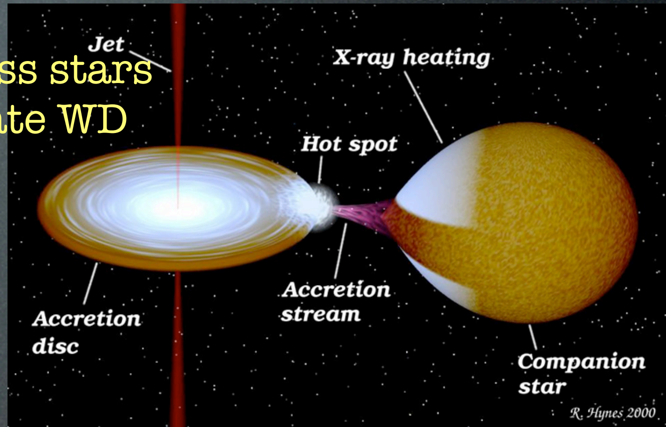
Type II supernovae

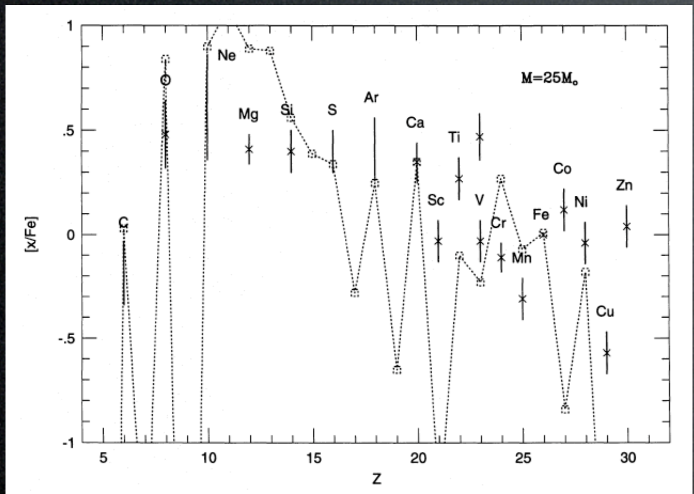
- Massive stars
- O,Mg,Si,Ti
- Fe,Ni
- Eu,Th



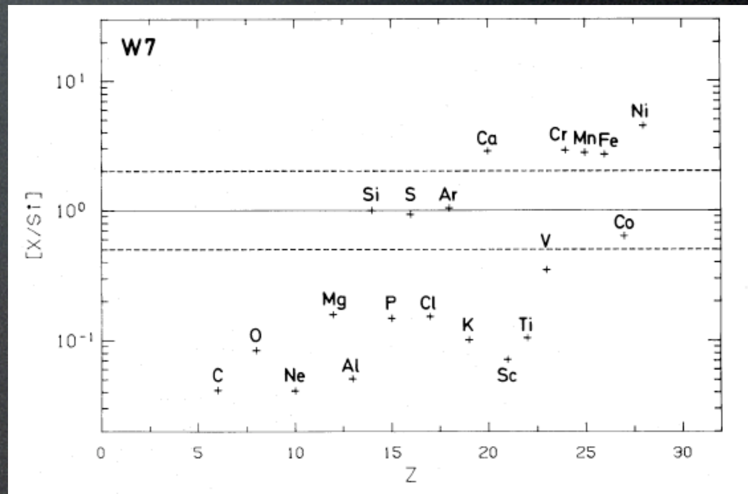
Type Ia supernovae

- Low-mass stars
- Degenrate WD
- Fe,Ni





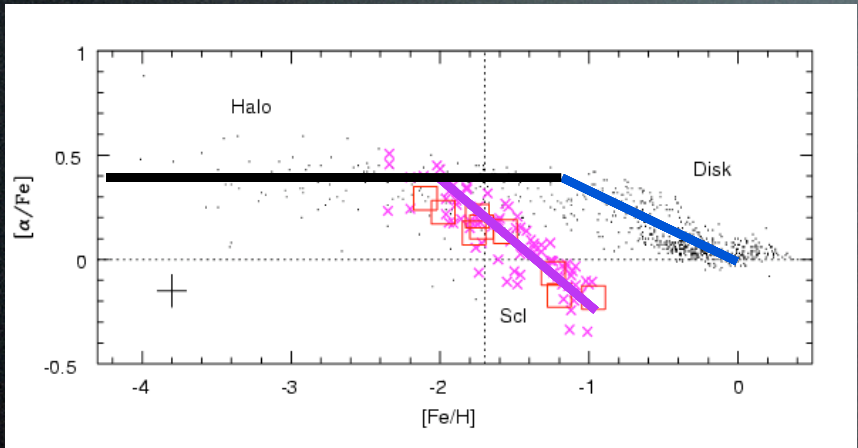
Thielemann et al 1996



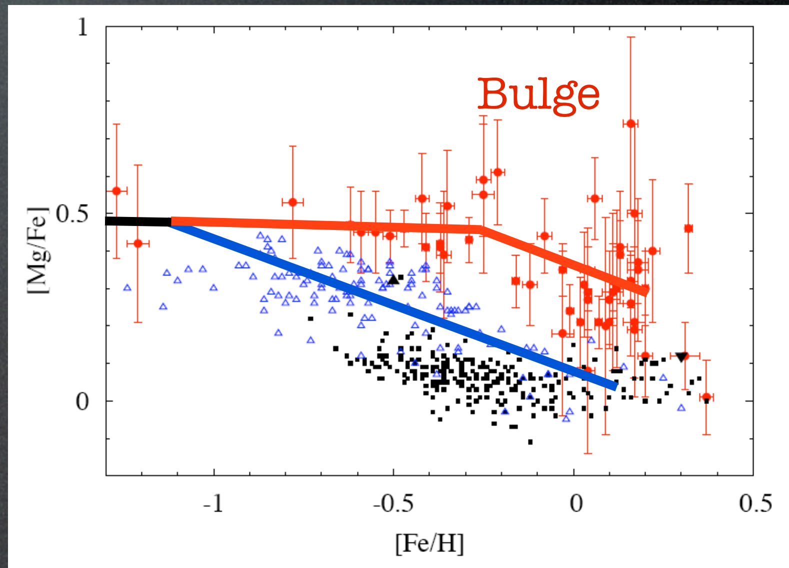
Nomoto et al 1984

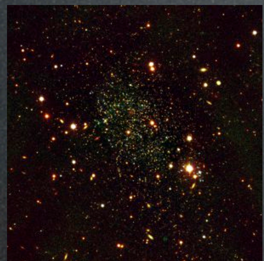
Enrichment of the Milky Way

Tolstoy et al 2006

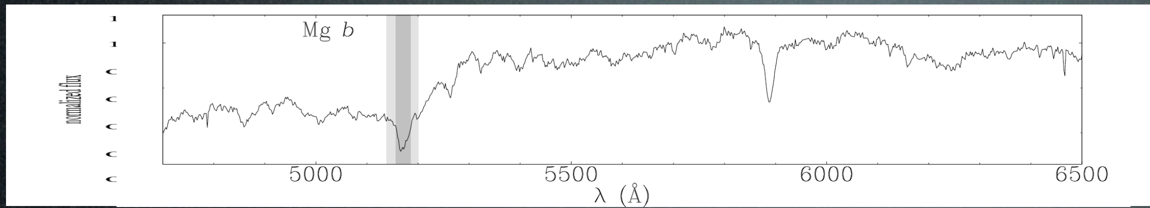


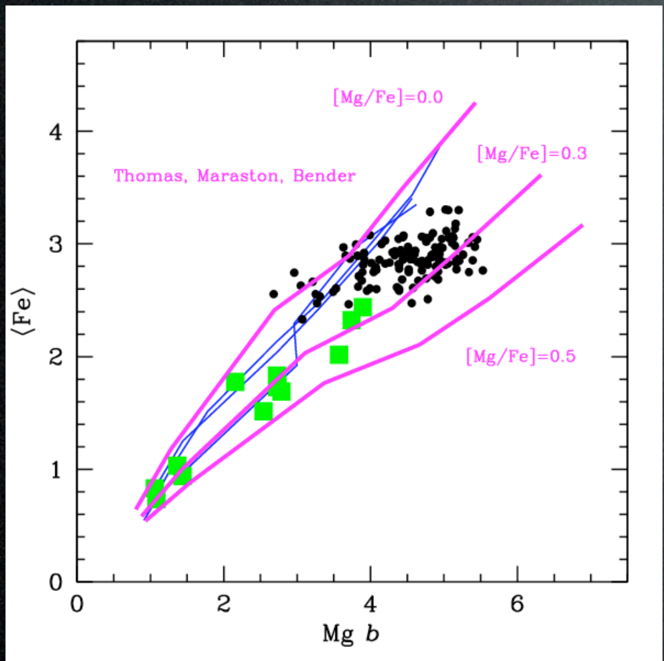
Lecreur et al 2006



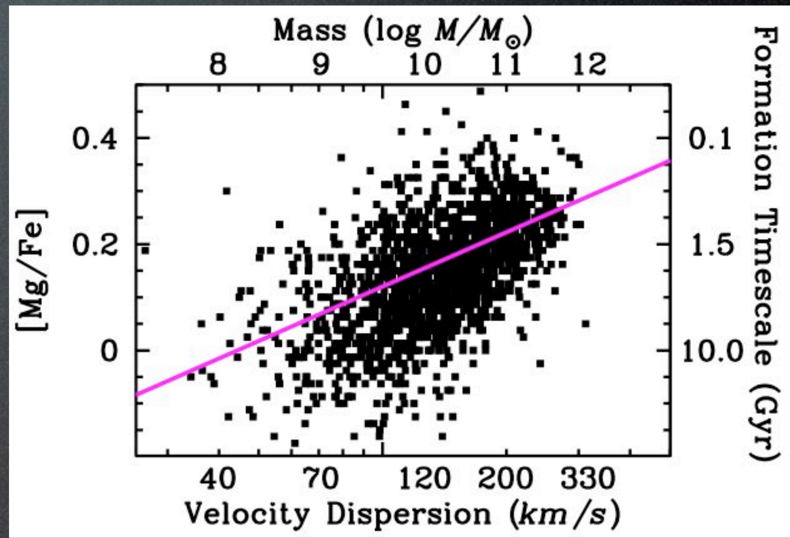


Element ratios in ellipticals



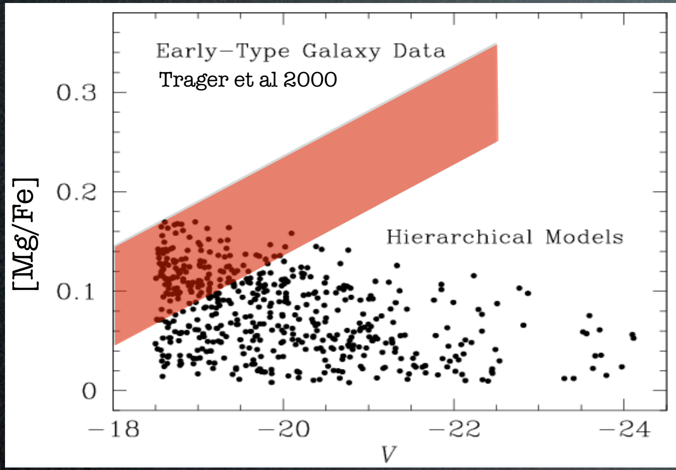


Thomas et al 2003



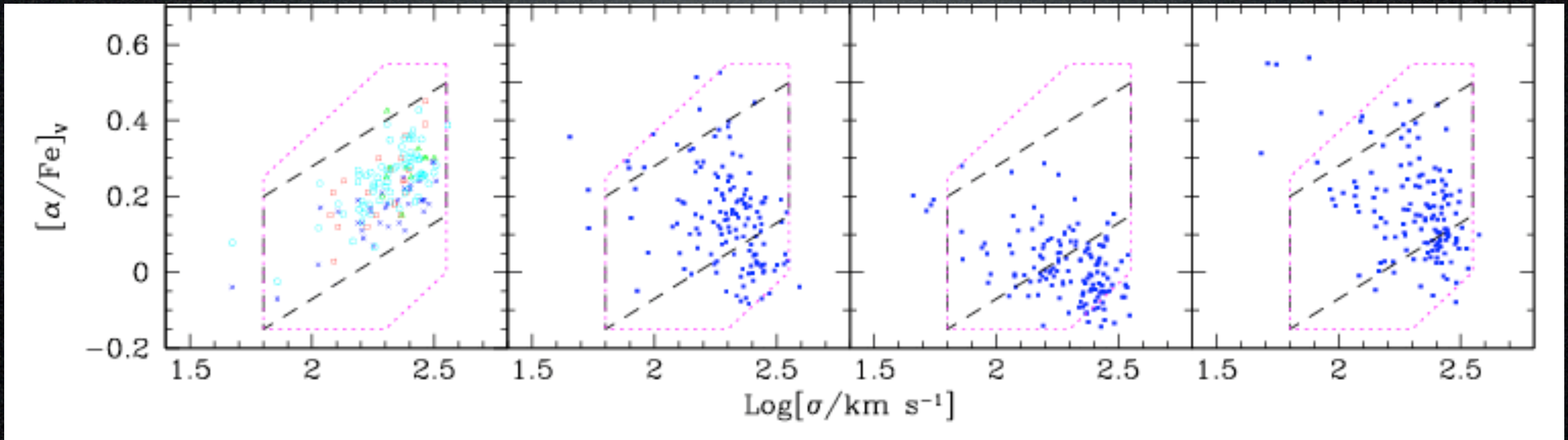
Thomas et al 2005, 2008

Simple but true



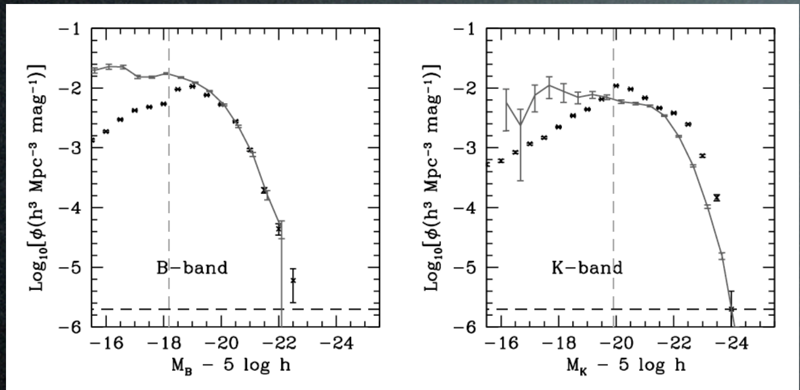
Thomas & Kauffmann 1999

Nagashima et al 2005

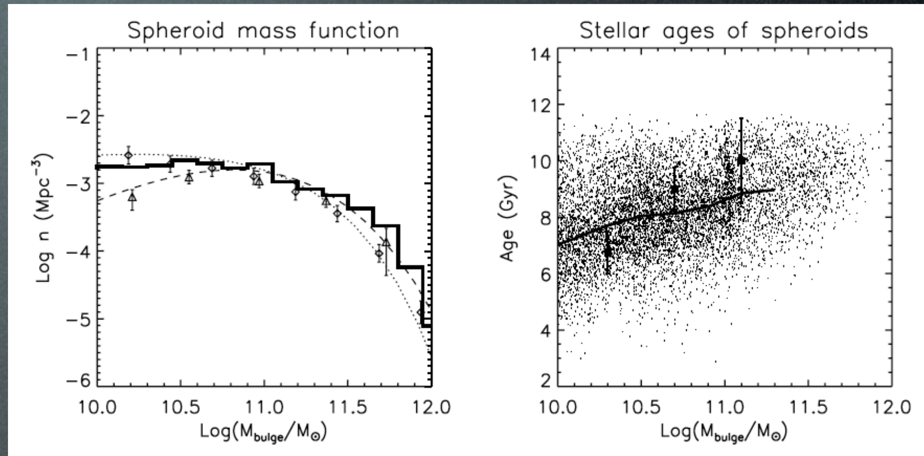


GALICS - well calibrated

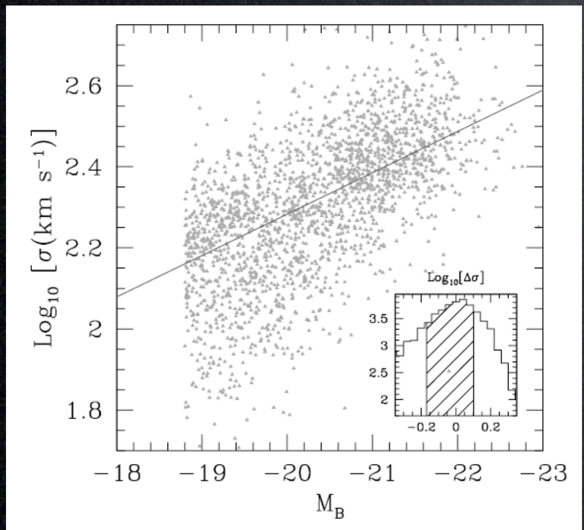
Luminosity functions



Ages

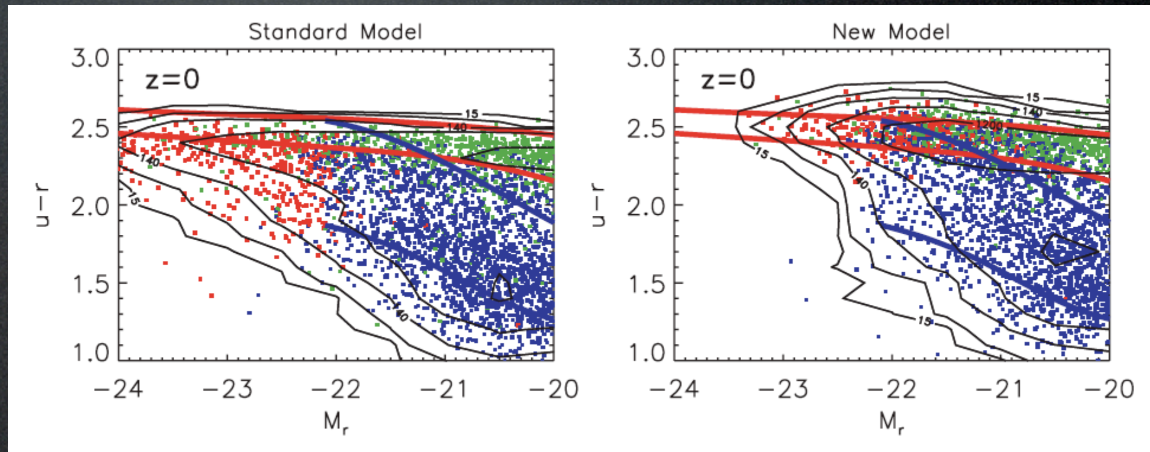


Faber-Jackson



Hatton et al 2003

Colour



Cattaneo et al 2005

Chemical enrichment in GALICS

- Self-consistent treatment of chemical evolution
- H, He, O (→ Mg, α), Fe
- Salpeter initial mass function
- Inclusion of delayed Type Ia supernovae (Matteucci & Recchi 2001; Greggio 2005)

$$R_{Ia}(t) = k_\alpha \int_{\tau_i}^{min(t,\tau_x)} A(t-\tau)\psi(t-\tau)DTD(\tau)d\tau$$

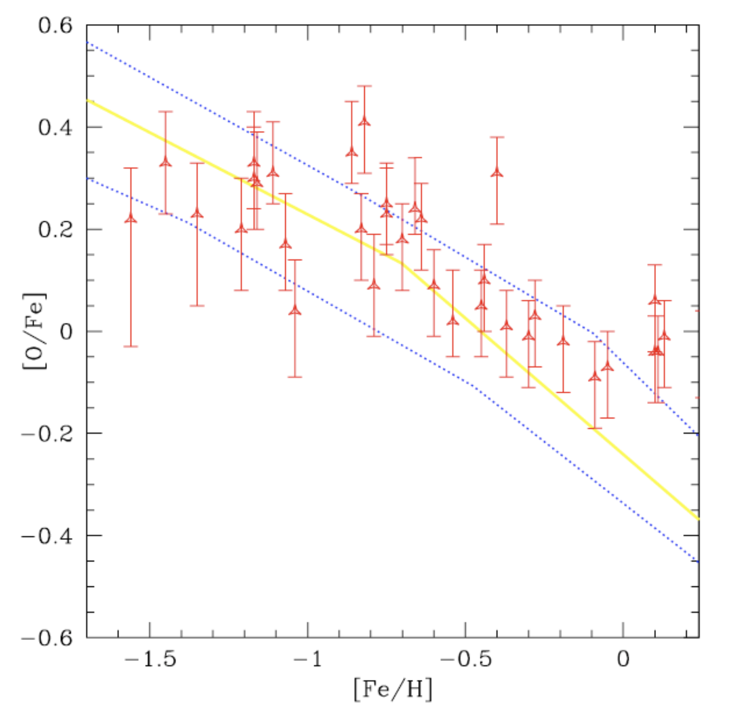
- Stellar yields from Iwamoto et al 1999
- Time resolution <1 Myr
- Ejecta

$$\mathcal{E}_i(t) = \int_{m(t)}^{\infty} \psi(t-t_m)([m-w(m)]Z_{\mathrm{i,cold}}(t-t_m) + mY_i(m))\phi(m)dm$$

- Instantaneous mixing with cold gas + SN heating
- Cooling cut-off in haloes above 10^{11} $M_\odot$ ("AGN feedback")

Calibration

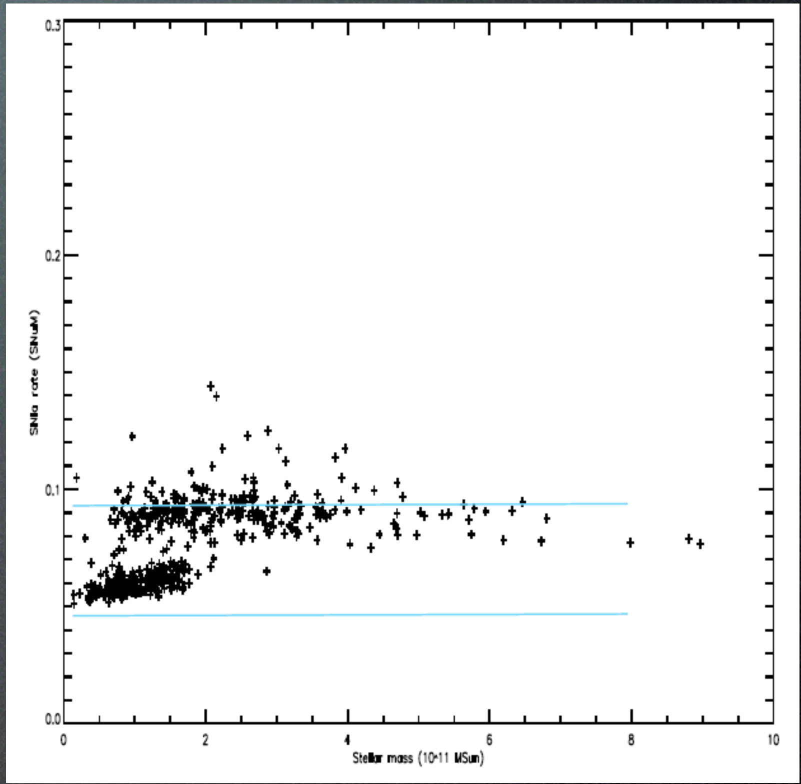
Element ratios in MW galaxies



Data: Francois et al 2004

Galaxies selected by gas fraction, luminosity, circular velocity, and B/D ratio

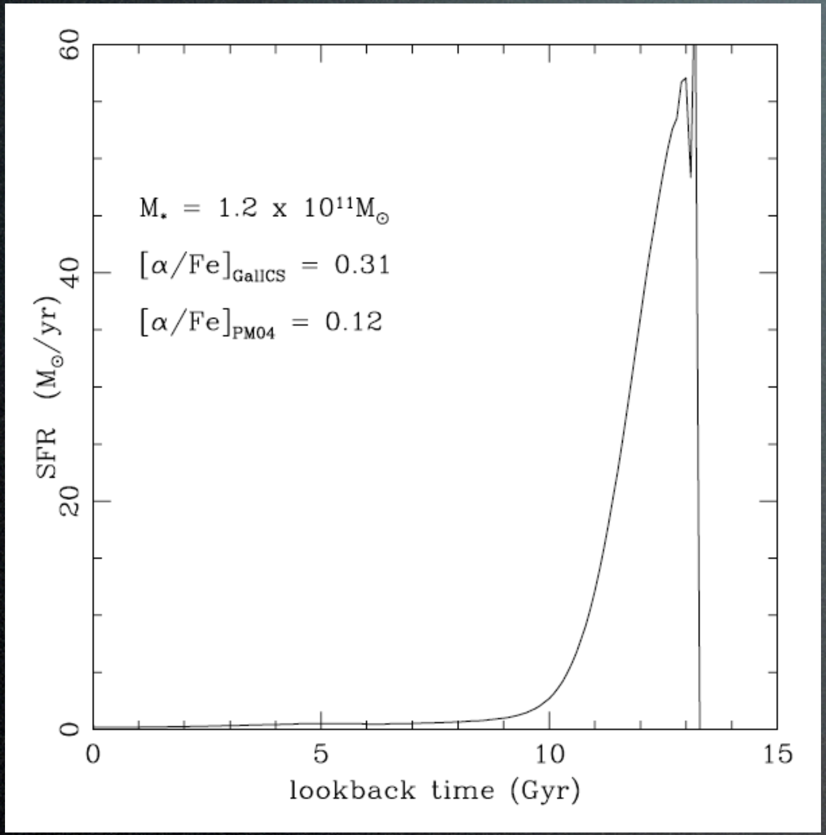
Supernova rates

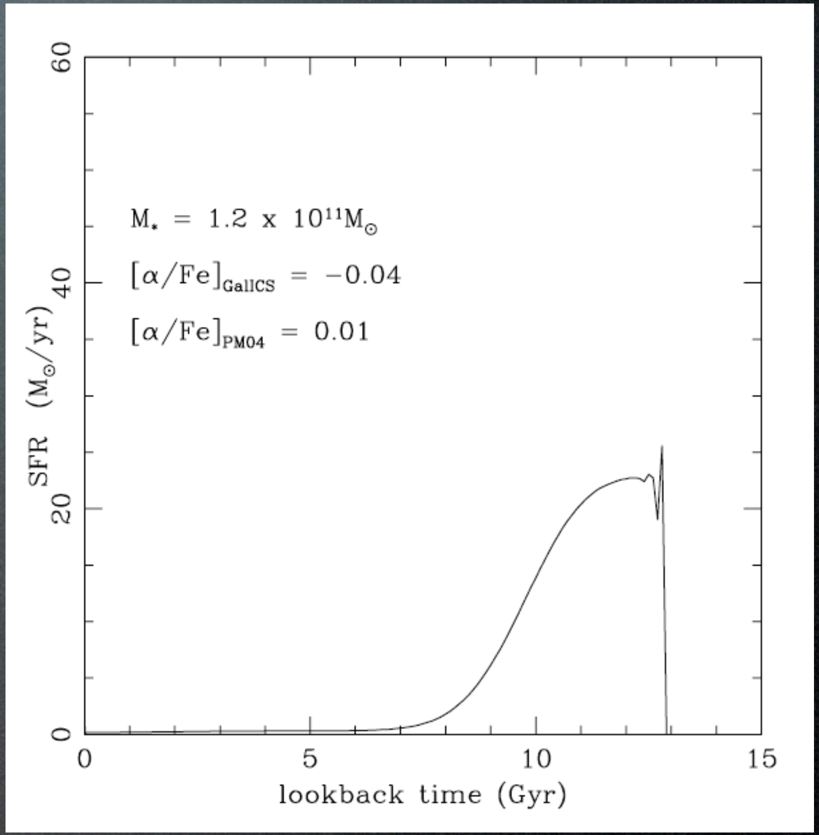


Data: Mannucci et al 2008

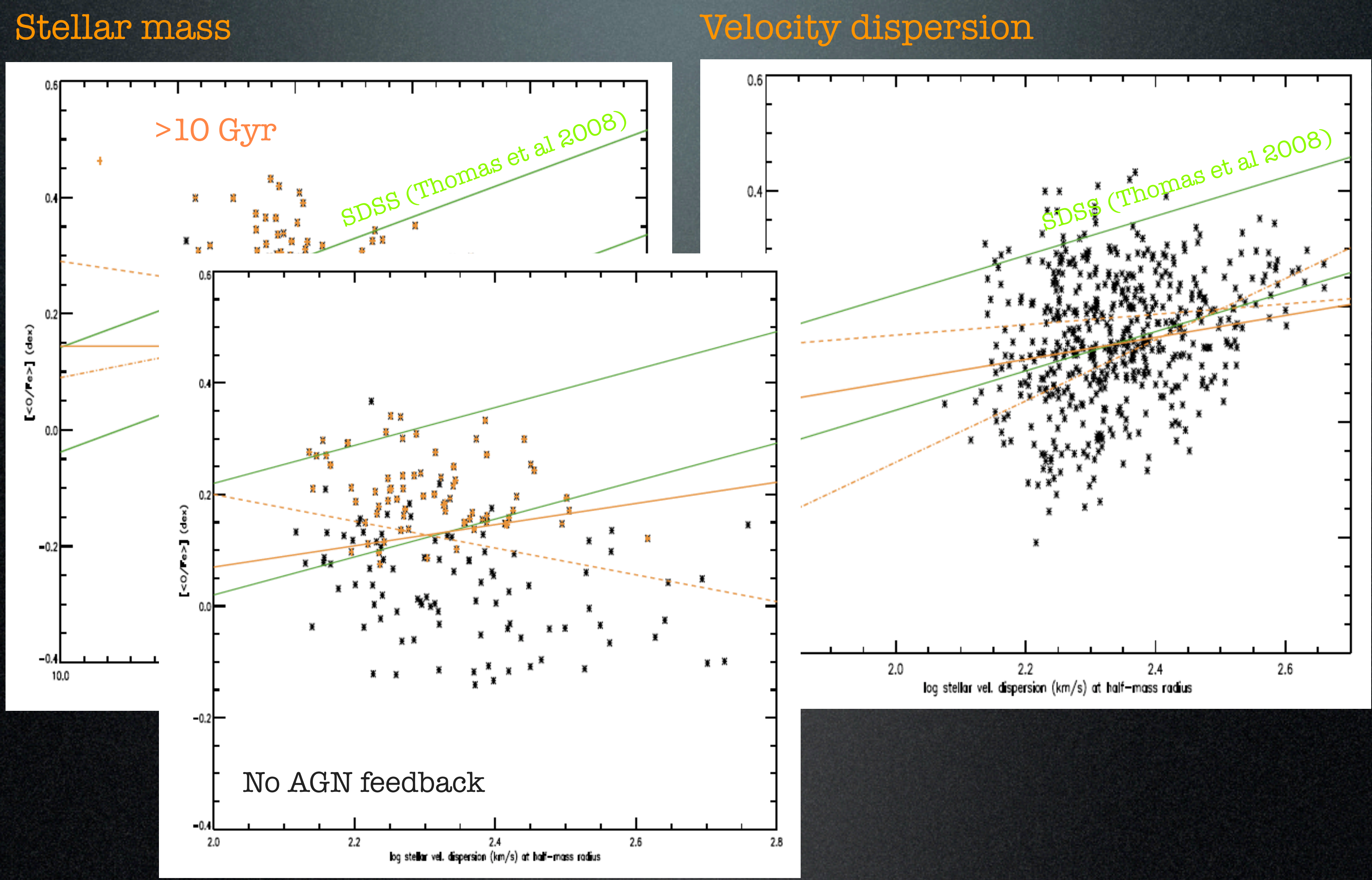
Rates measured in SnuM (mass weighted)

Merger tree vs closed box

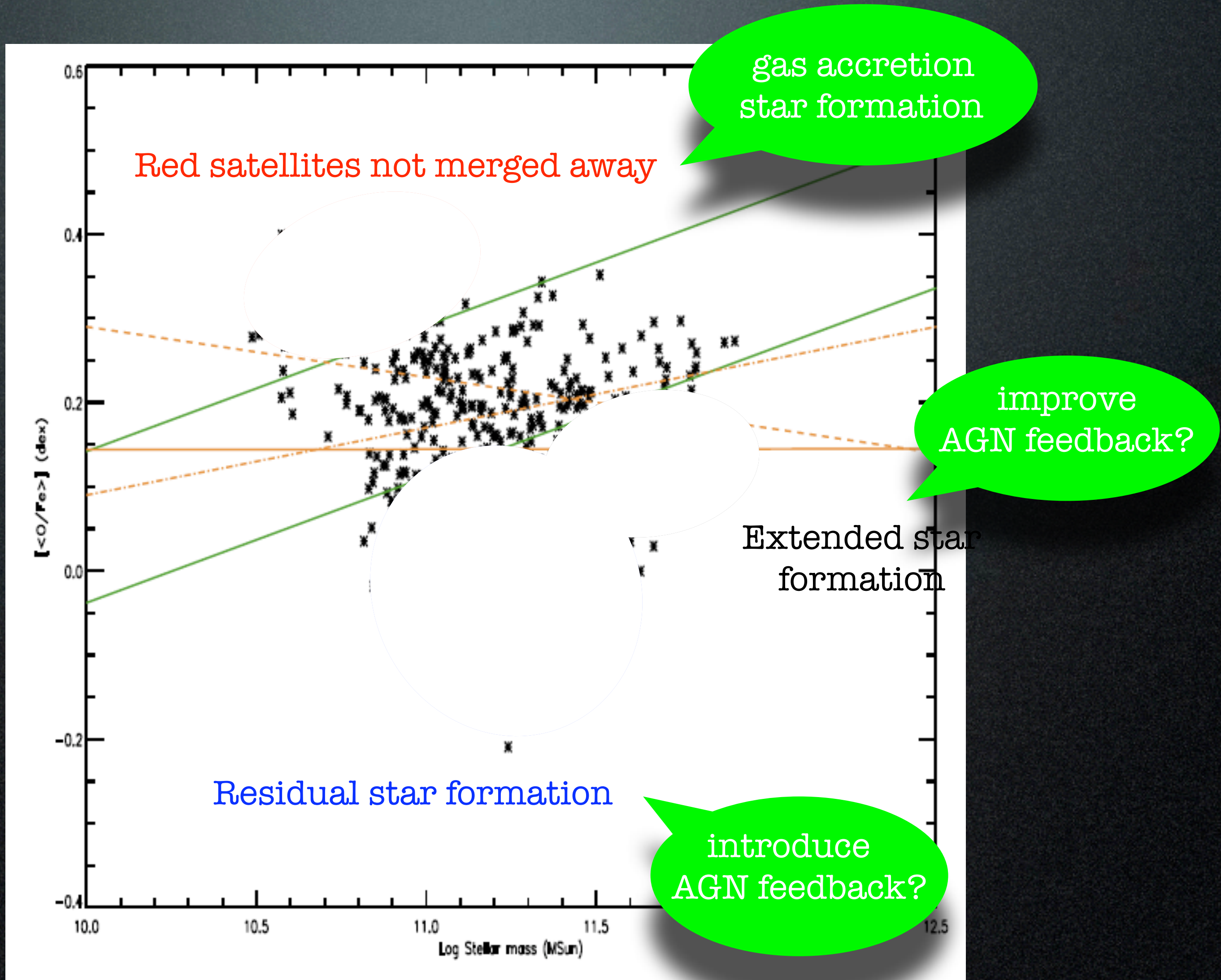




Result


Stellar mass
Velocity dispersion
>10 Gyr
SDSS (Thomas et al 2008)
SDSS (Thomas et al 2008)
No AGN feedback
[<O/Fe>] (dex)
log stellar vel. dispersion (km/s) at half-mass radius
log stellar vel. dispersion (km/s) at half-mass radius

What do we learn



ICG Portsmouth

Summary

- Chemical evolution → enrichment of H, He, O, Mg, Fe
- Key 'observable' → Mg/Fe-mass relationship of ellipticals
- Type Ia supernova enrichment
- Implement chemical enrichment in GALICS
- Well calibrated in LF, colour-magnitude, Faber-Jackson, ages
- Semi-analytic model fails to reproduce Mg/Fe-mass relation
  - ☑ Allow gas accretion on satellites
  - ☑ Extend AGN feedback at intermediate and high masses