Star-Formation and Gas-Fuelling of Spiral Galaxies in the Group Environment

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Gas-Fuelling: Expectations

- Gas-fuelling is a function of environment (halo mass)

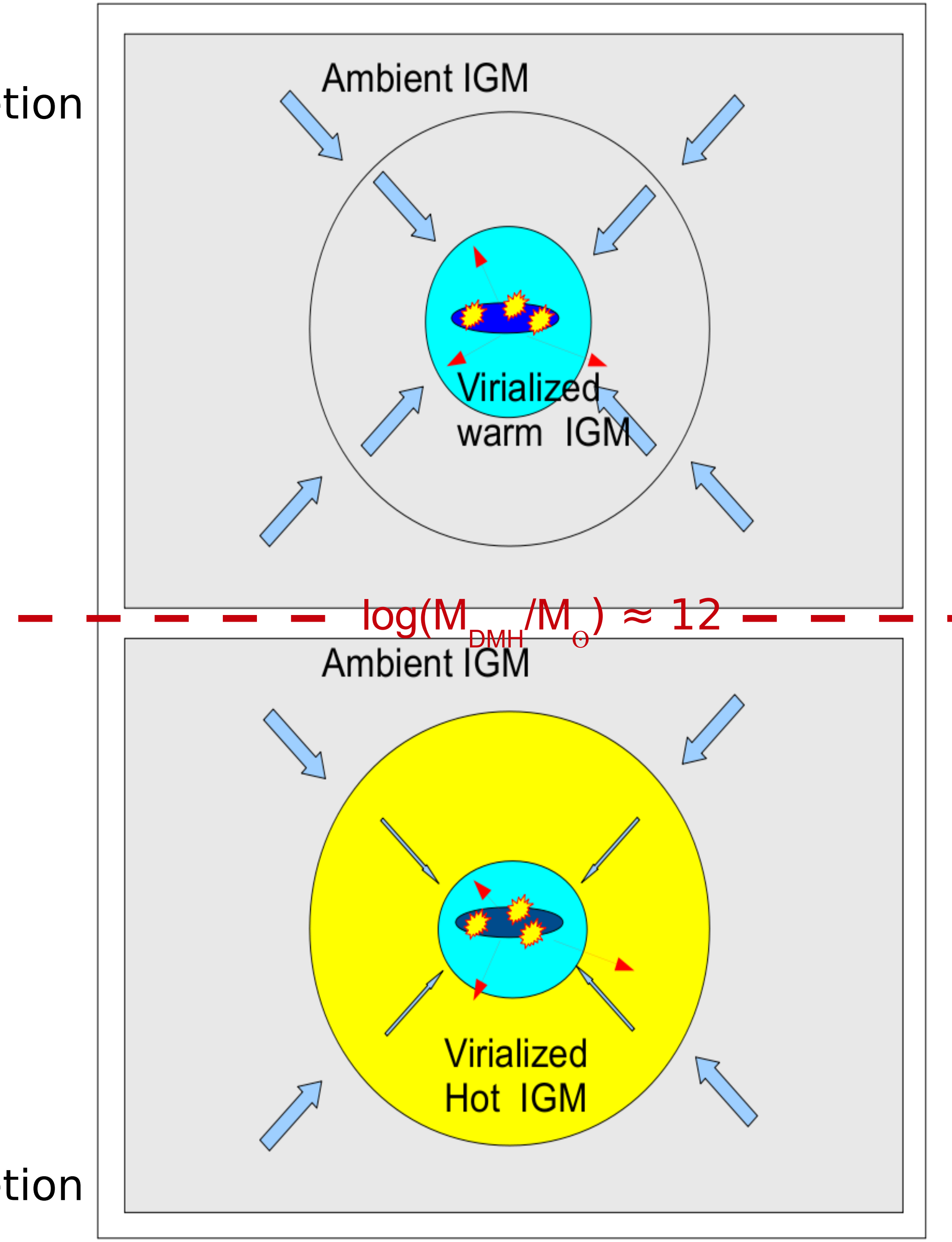
  Accretion mode

- Gas-fuelling is a function of galaxy properties (mass)

  Feedback (SF/AGN) with varying efficiency

→ Self-regulated balance

Cold Accretion



Hot Accretion

Gas-Fuelling: The Group Environment

≳40 % of galaxies reside in groups
(Eke+2004,Robotham+2011)

→ Central & Satellite Galaxies

Satellite galaxies:

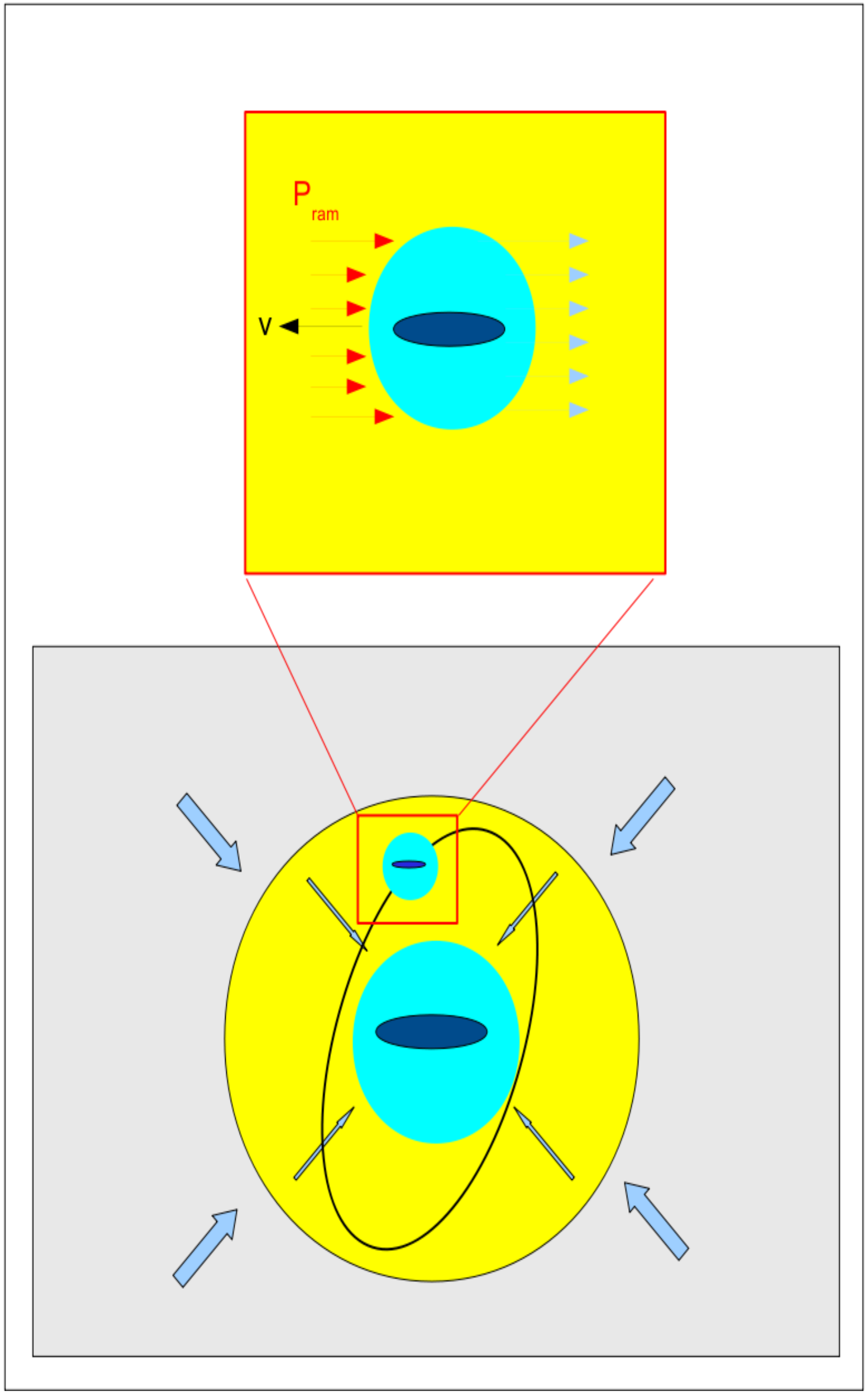
Ram-pressure stripping
(Gunn&Gott1978)

'Strangulation'
(Larson+1980,Kimm+2008)

⬇

No gas-fuelling

Quenching of SF



Observational Impediments

(I) Gas content of large samples in range of environments

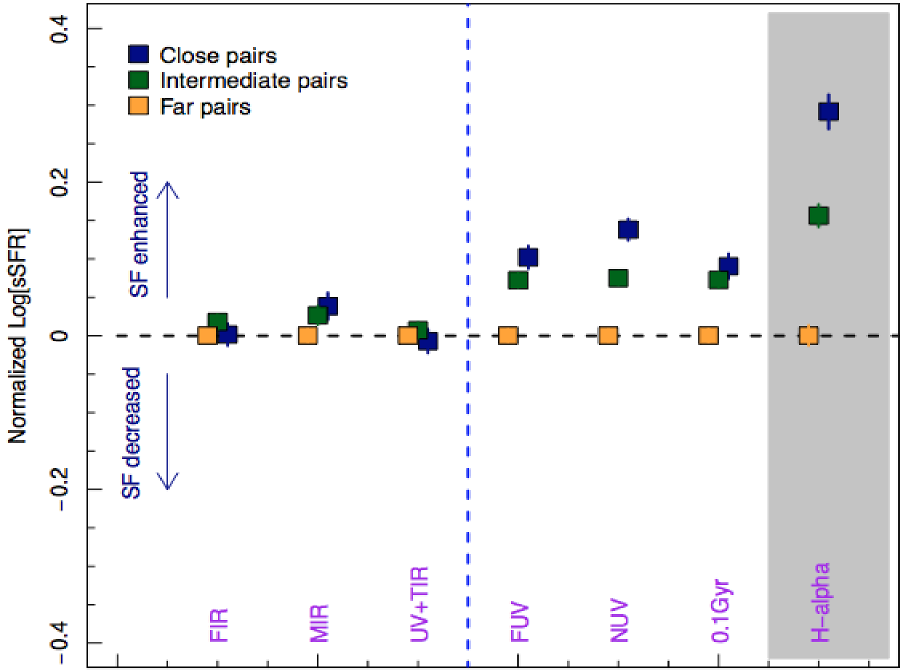
Invert (integrated) KS - relation

(II) Dichotomy in galaxy morphology

Different average colors/SSFR & different kinematics

Morphology – density relation

Q: What drives difference in sSFR ?



Davies+2015

Credit: Adam Block/NOAO/AURA/NSF

Credit: David A. Aguilar (CfA)

(III) Galaxy – Galaxy Interactions

Impact SFR/SFE

Add/remove stellar and gas mass (merger/tidal stripping)

Requirements on an Empirical Reference

- Large statistical sample of galaxies probing full HMF down to $\log(M_{halo}/M_{\odot}) \approx 12$
- Sensitive to changes in gas-content/total SFR on timescales $<< \tau_{dyn}$ (~1 Gyr)   (NUV & control morphology)
- Control for galaxy-galaxy interactions (control morphology & relative isolation)

GAMA is the perfect resource

The Galaxy And Mass Assembly Survey (GAMA)

Driver+2011, Liske+2015

300 k redshifts

r < 19.8 $_{AB}$mag

Quantitative spectroscopy

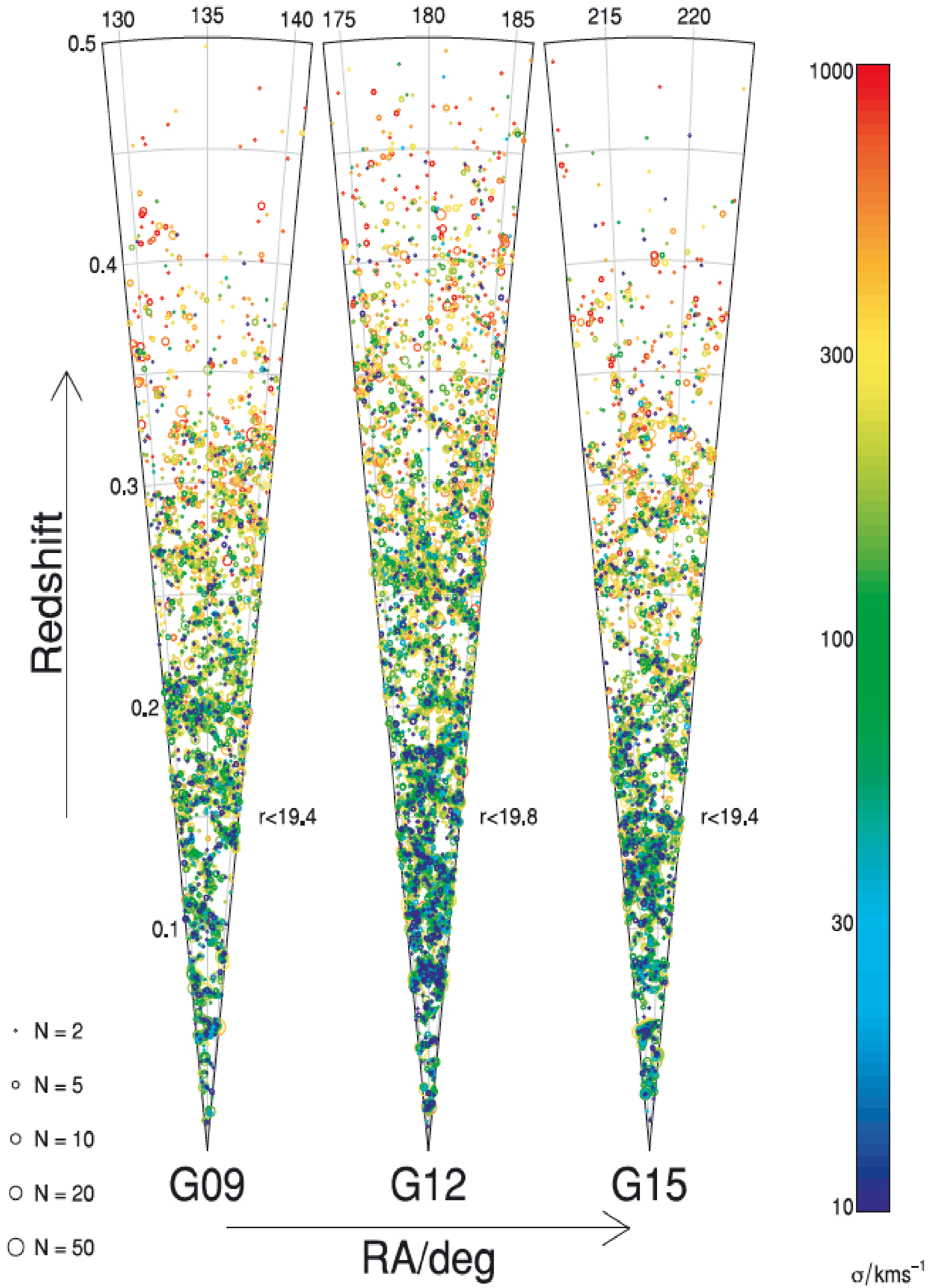
>98% target completeness,
even in crowded regions

HMF to ≲ 10^{12} $M_\odot$

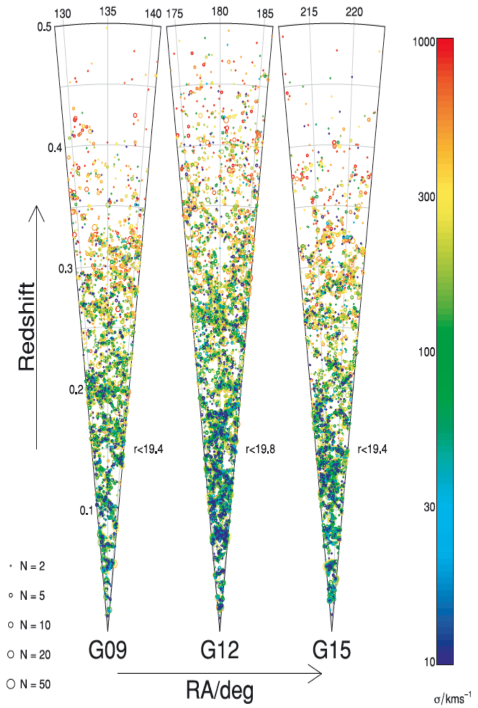
Unprecedented characterization
Of cosmic web and galaxy groups
Over z=0-0.5

Complementary coverage of full
UV – FIR/submm SED with uniform
broad-band photometry

DR2 availabale (www.gama-survey.org)
DR3 (full release) forth-coming

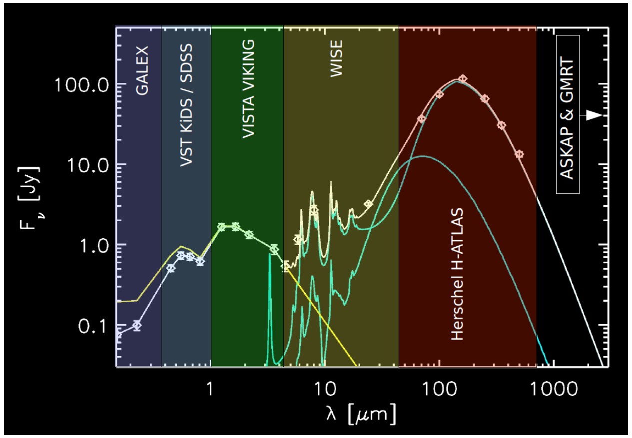


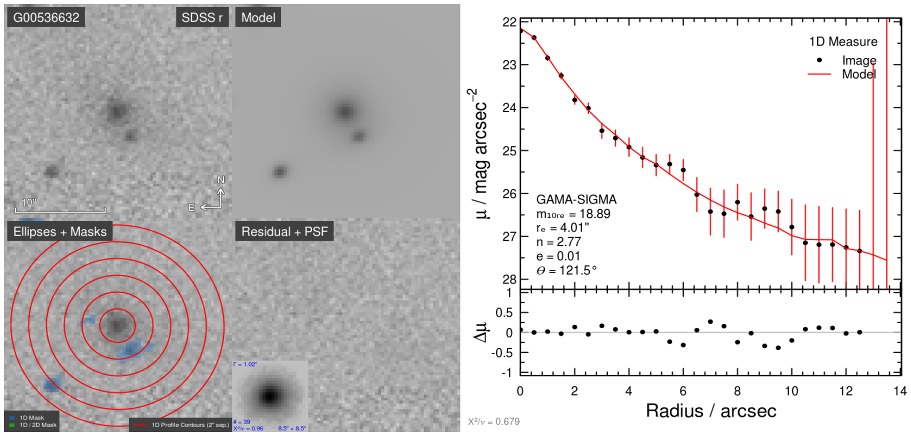
GAMA: Creating an empirical reference



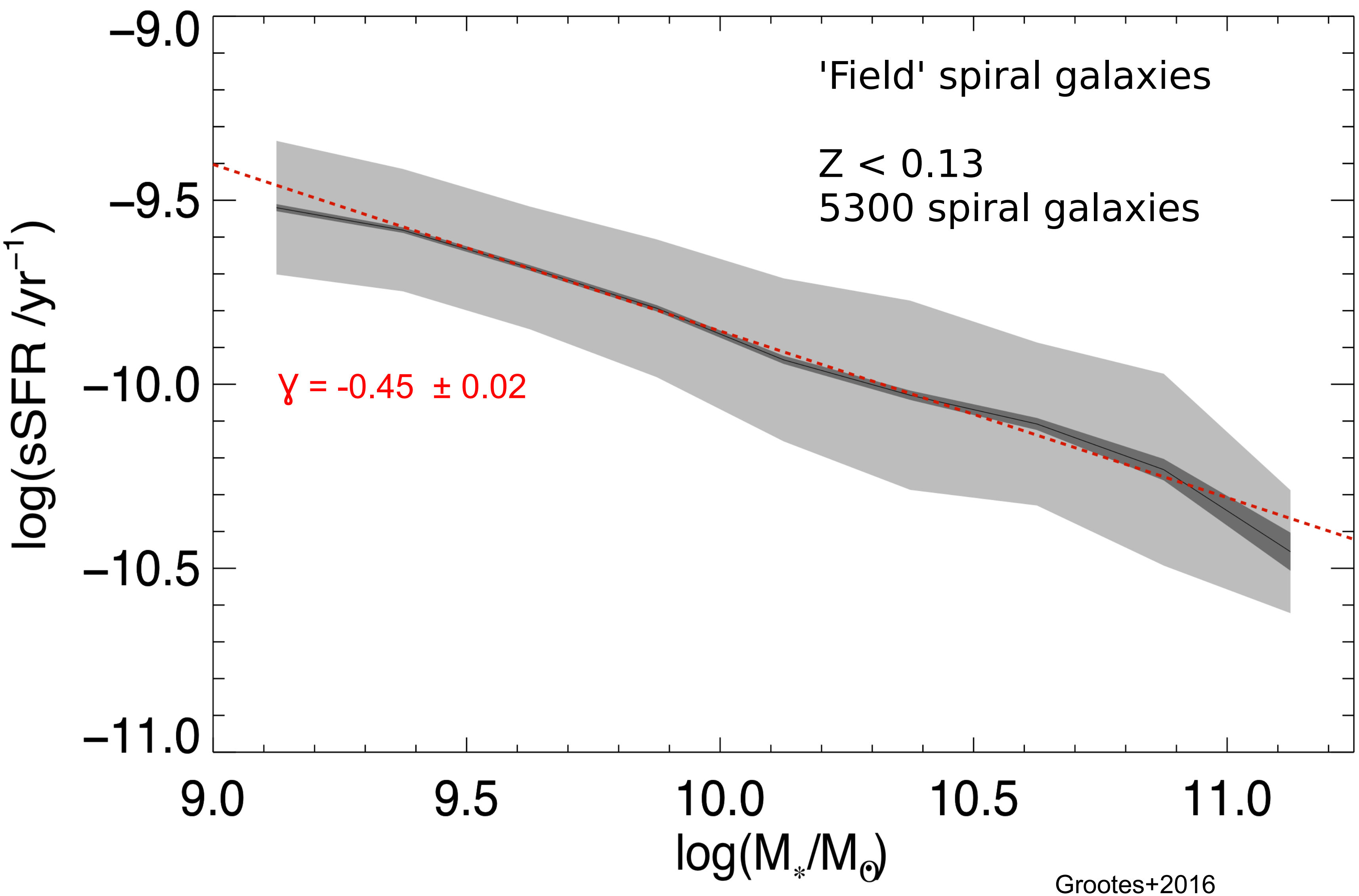
Construction of pure and complete morphologically selected sample of spiral galaxies using a new purpose built method
(Grootes+2014)

Determination of highly accurate star formation rates using radiative transfer modelling techniques applied to large samples
(Popescu+11, Grootes+13)



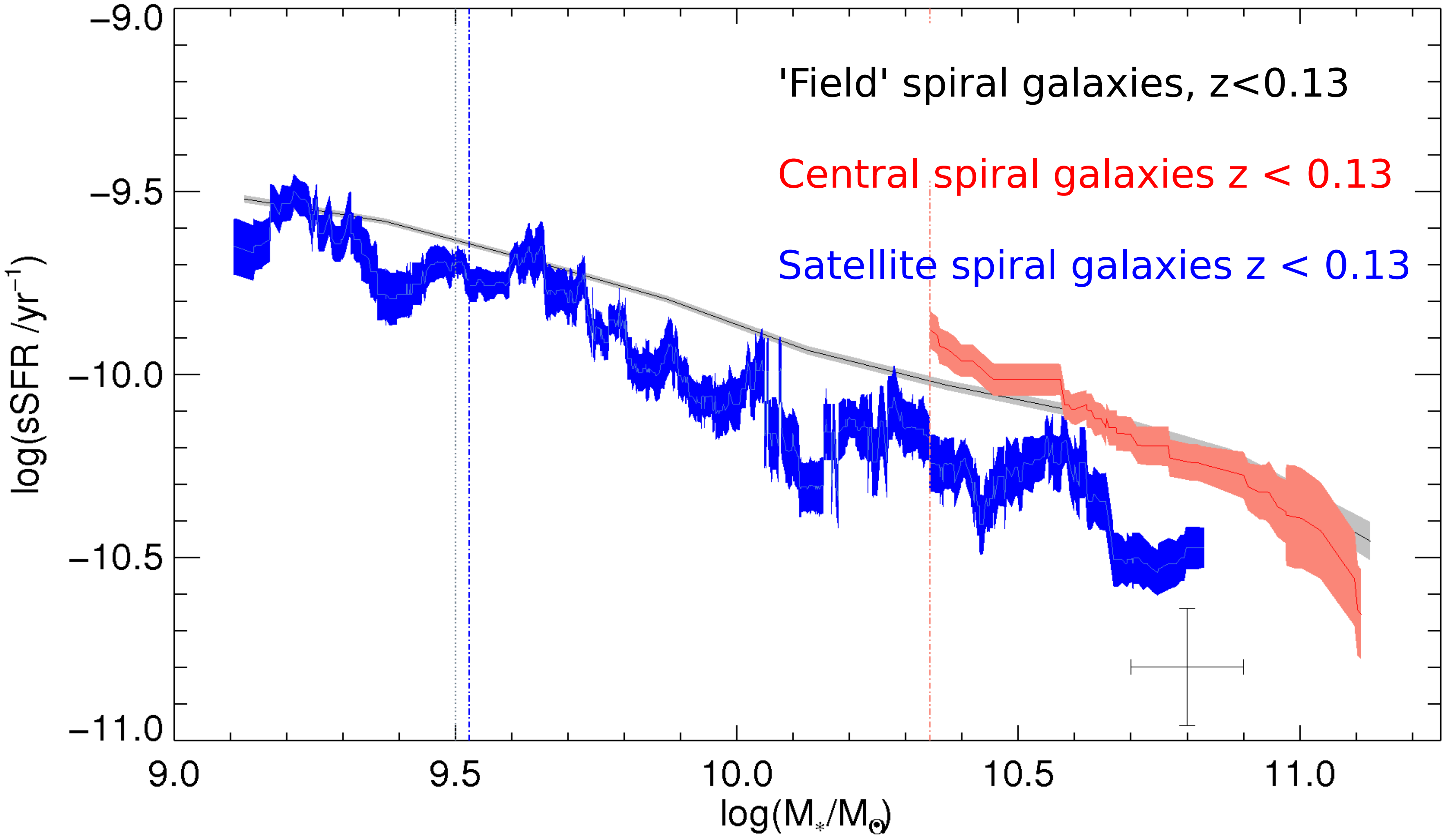


Main sequence of 'Field' spiral galaxies



Grootes+2016
(submitted)

Main sequence of group spiral galaxies:
Satellites & Centrals

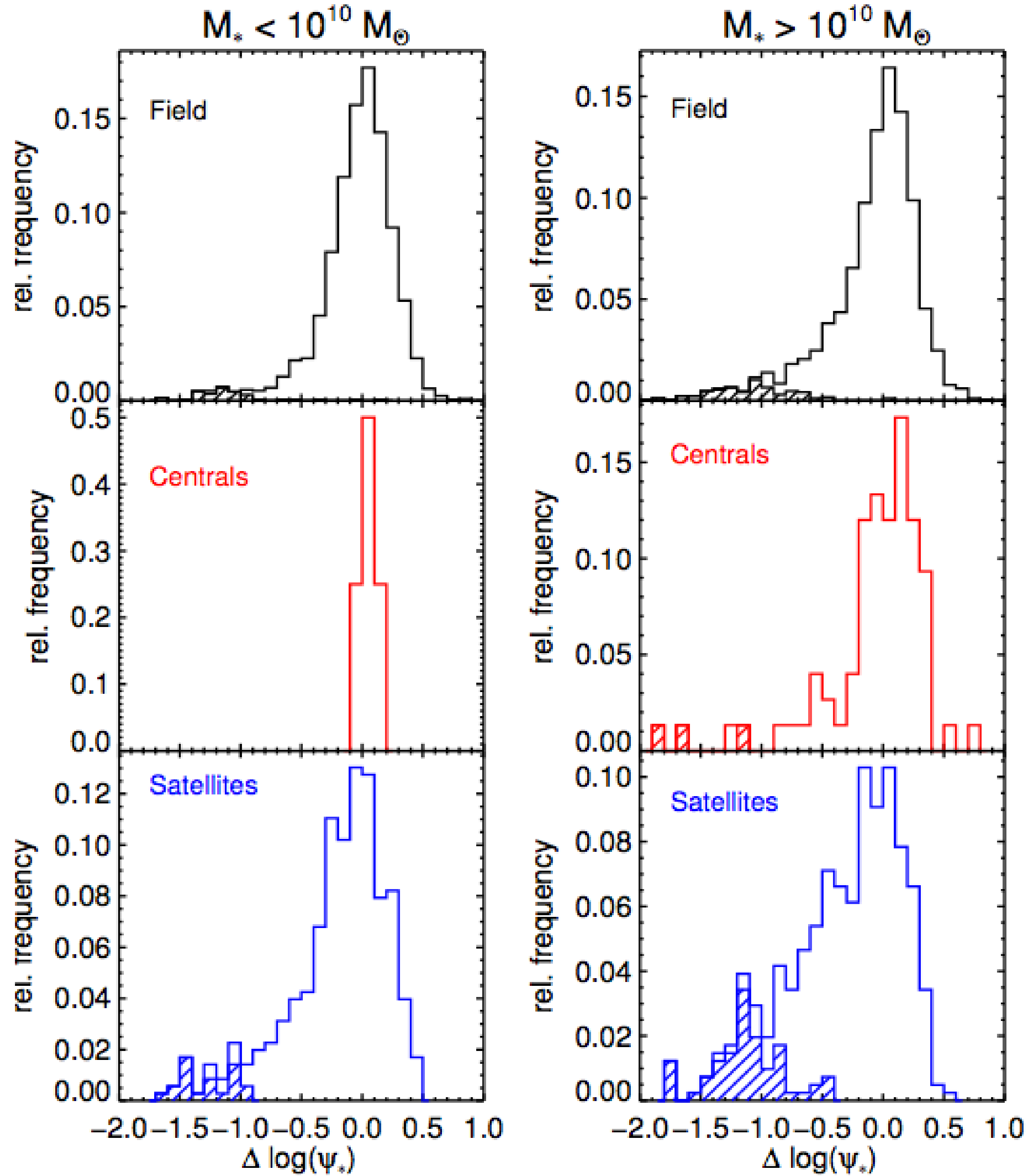


Grootes+2016

Main sequence of group spiral galaxies: Satellites & Centrals

Spiral fraction only decreases by 40% w.r.t field

Large fraction of galaxies have spent Gyrs as satellites



Grootes+2016

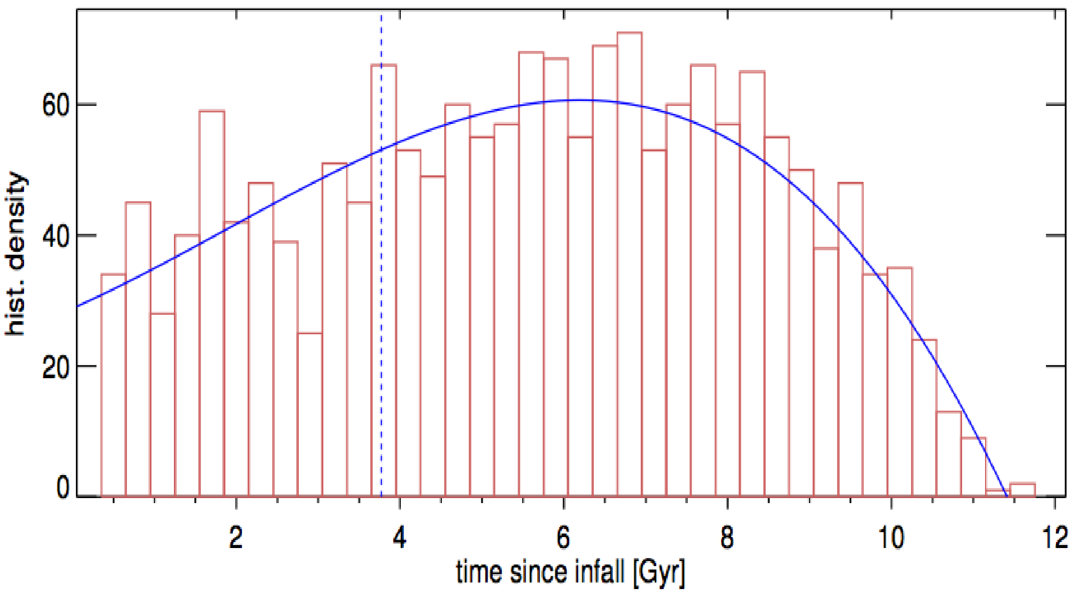
Modelling Spiral Satellites: Galaxy Populations at Infall

MC sample mass and appropriate SFR distribution of field sample at present

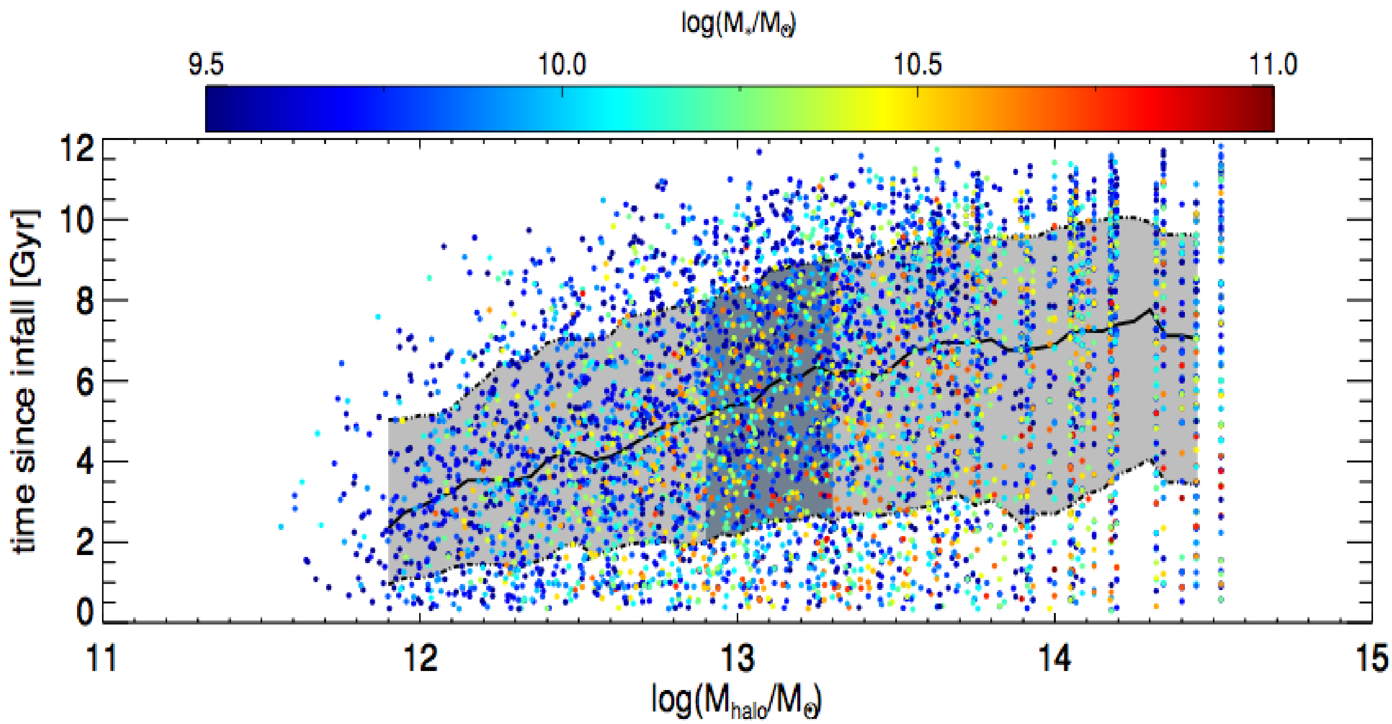
MC sample infall time (based on mocks) accounting for spiral fraction

Evolve backwards according to MS relation
of Speagle+2014

Evolve galaxies forward following parameterized SFH



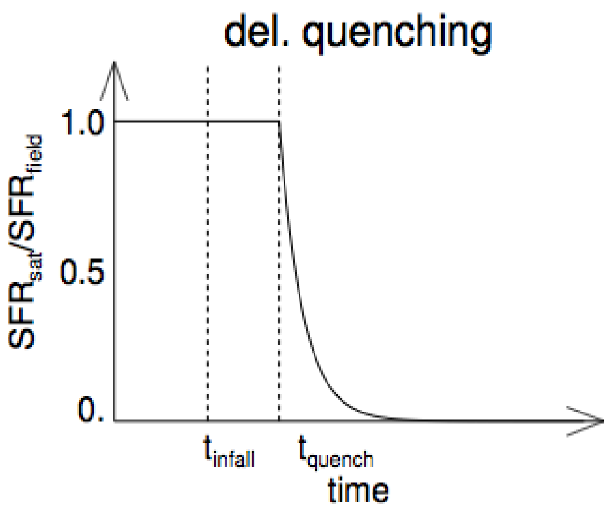
Grootes+2016



Grootes+2016

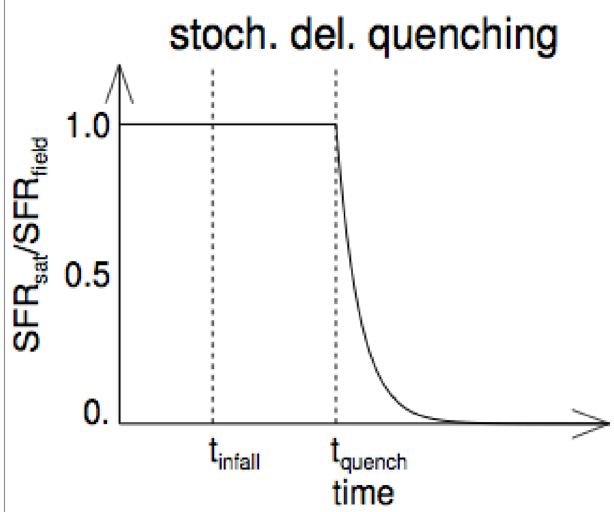
Modelling Spiral Satellites

Parametrized SFH



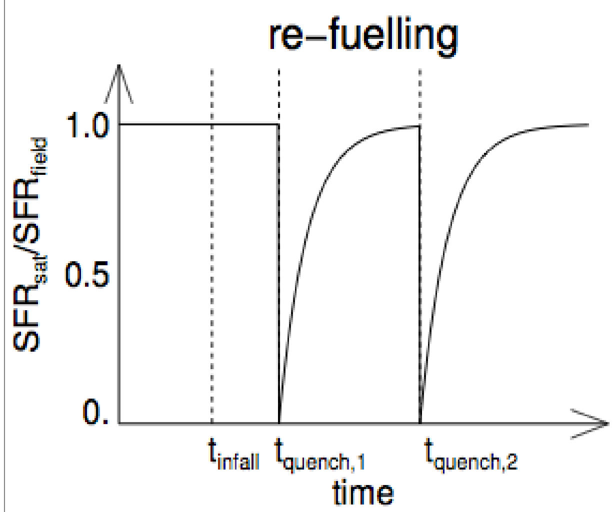
Fixed delay time

Exponential decay



Stochastic delay time

Exponential decay



Stochastic instantaneous quenching

Exponential resurrection

Repeated quenching

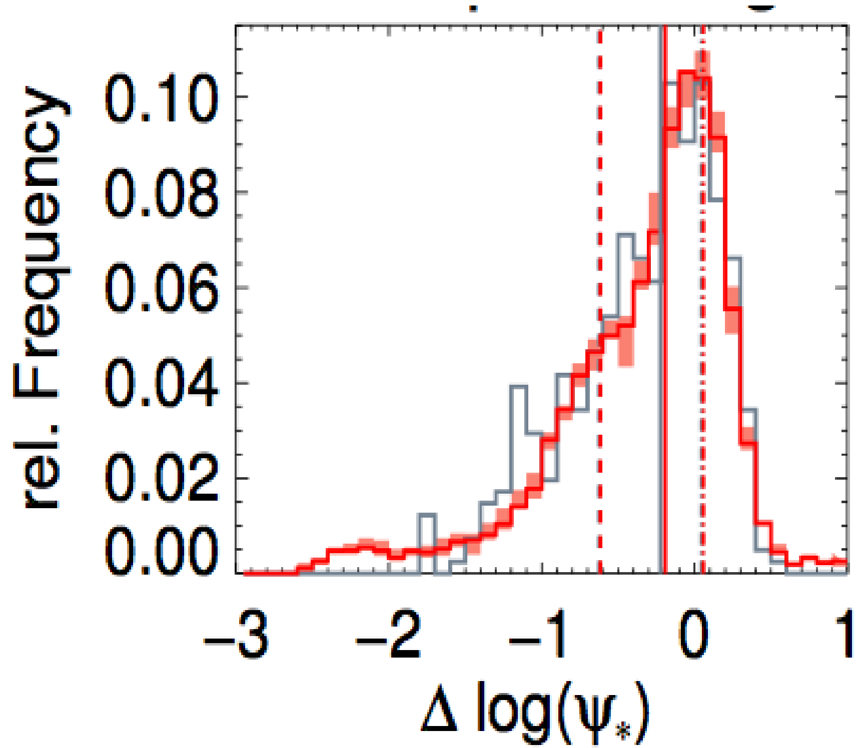
Grootes+2016

Comparison with Data

Compare 2 noisy distributions

FoM: recovery of characteristics (quartiles) of distribution

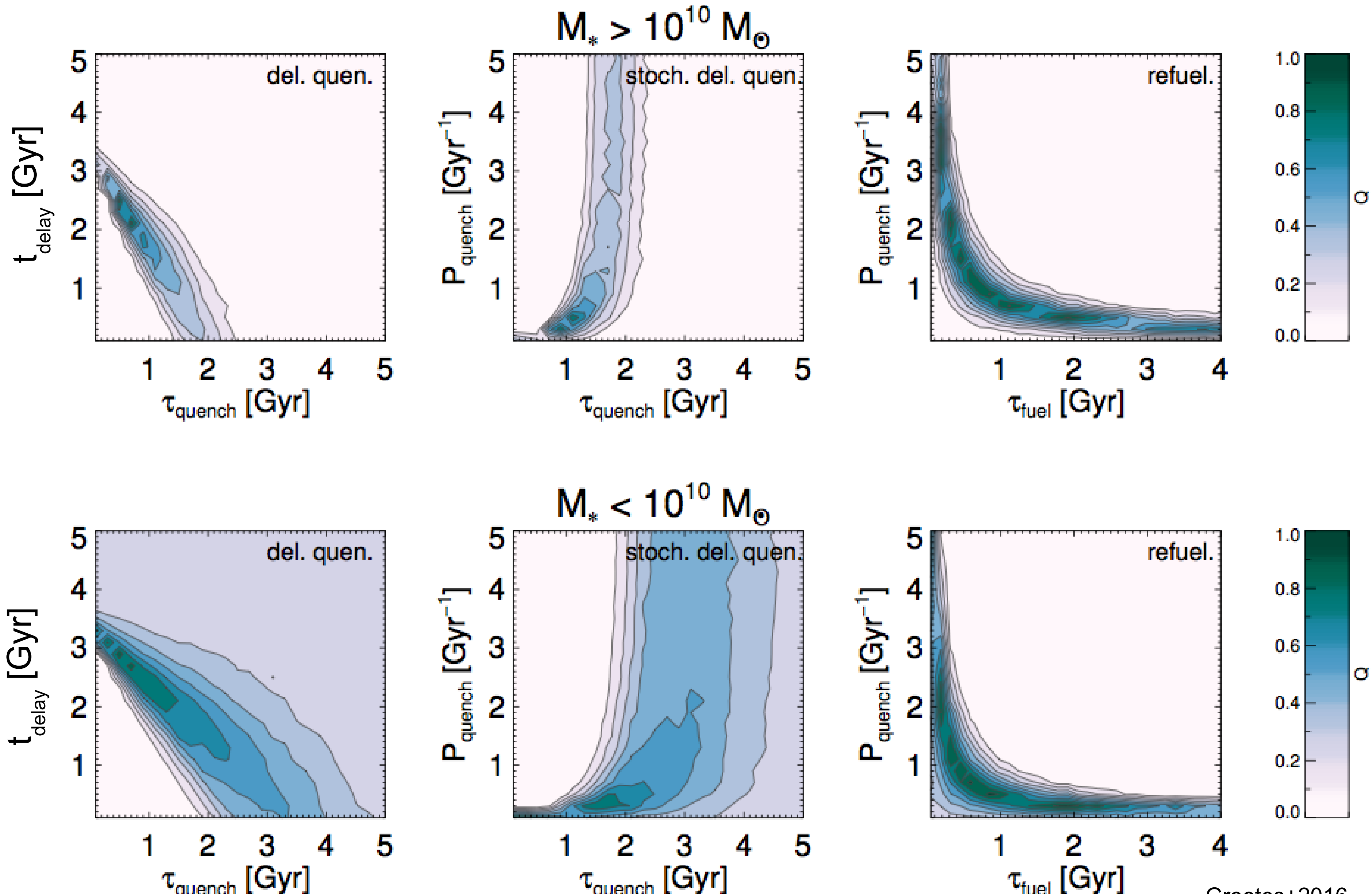
Grootes+2016 (submitted)



$$Q_i(p_1,p_2) = \begin{cases} [1-\Delta q_i(p_1,p_2)]\cdot 0.3^{-3} & \text{for } \Delta q_i(p_1,p_2) \leq 0.3 \\ 0 & \text{otherwise} \end{cases}$$

$$Q(p_1,p_2) = \prod_i Q_i(p_1,p_2)$$

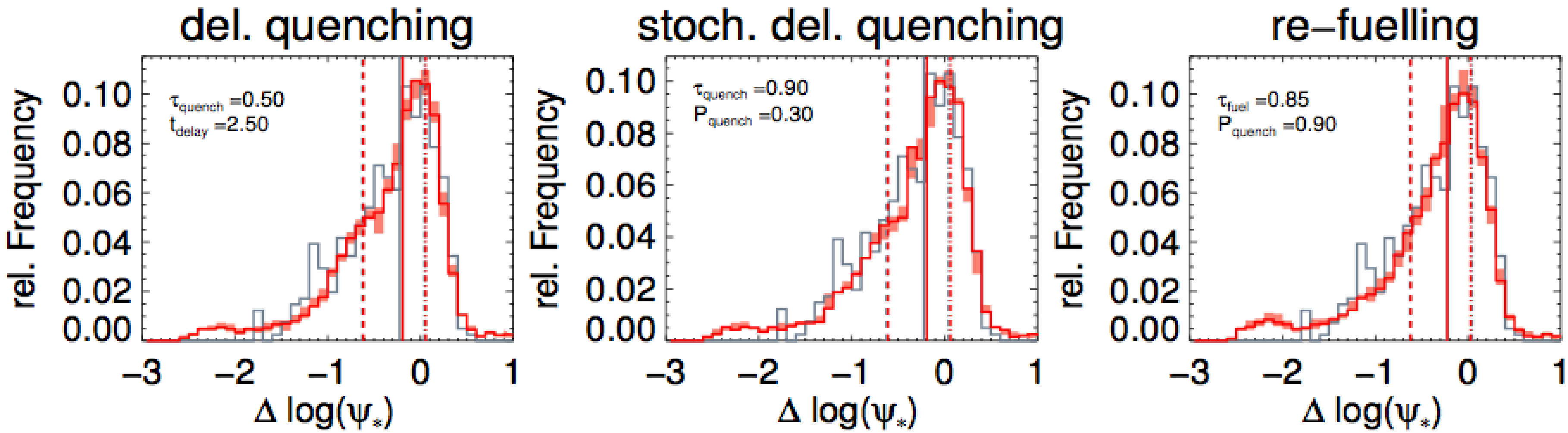
Comparison with Data



Grootes+2016
(submitted)

Comparison with Data

$M_* > 10^{10} M_\odot$



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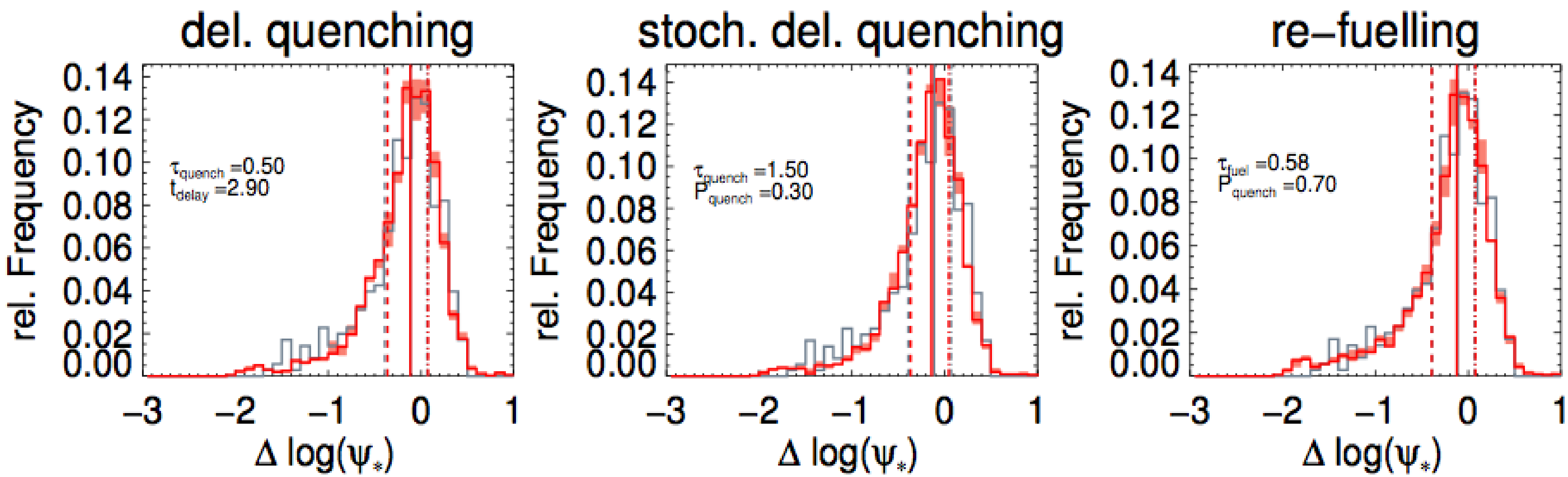


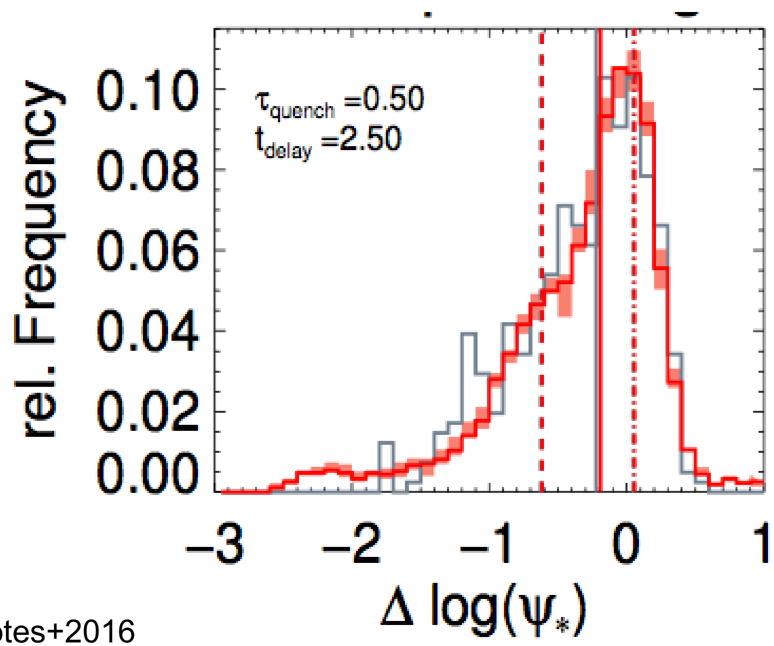
Grootes+2016
(submitted)

Interpretation

Rapid cycle of gas into/out of ISM ~ several times SFR

For all models gas associated with galaxy upon infall (ISM & CGM) insufficient to support sustained SF activity

Require (additional) fuelling of ISM from IGM of group at rate comparable to SFR (depends on retention of ISM & CGM)



Grootes+2016 (submitted)

$$\dot{M}_{\rm ISM} = \dot{M}_{\rm in} - \dot{M}_{\rm out} - \alpha\Phi_*$$

$$= \dot{M}_{\rm in} - \frac{M_{\rm ISM}}{\tau_{\rm res}} - \kappa M_{\rm ISM}$$

Identify SFH with solutions

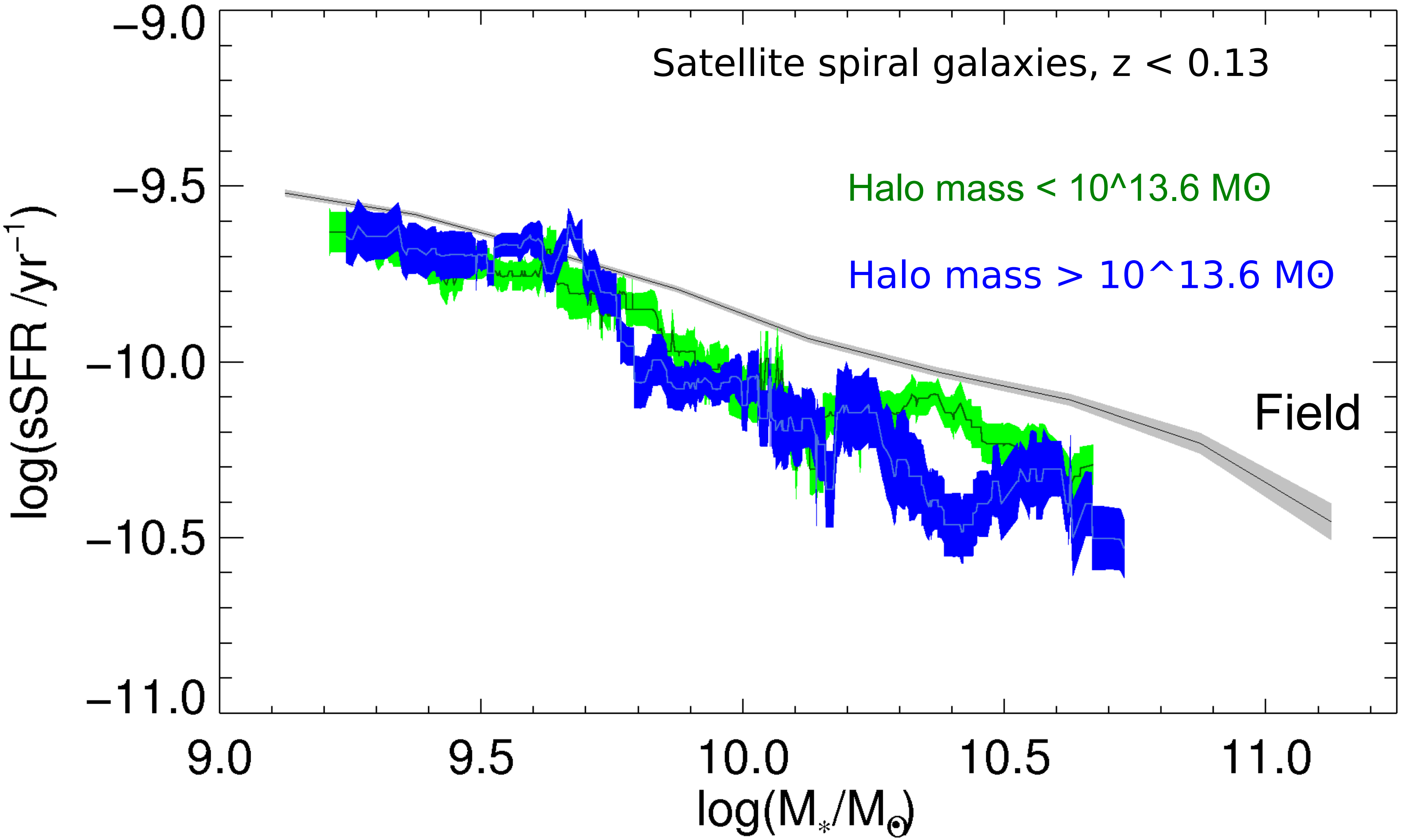
$$\frac{1}{\tau_{\rm quench}} = \frac{1}{\tau_{\rm res}} + \kappa$$

$$\frac{1}{\tau_{\rm fuel}} = \frac{1}{\tau_{\rm res}} + \kappa$$

steady-state

$$\dot{M}_{\rm in} = (\frac{1}{\tau_{\rm res}} + \kappa) M_{\rm ISM}$$

Probing Environmental Dependencies in Detail: Halo Mass



Grootes+2016, in prep

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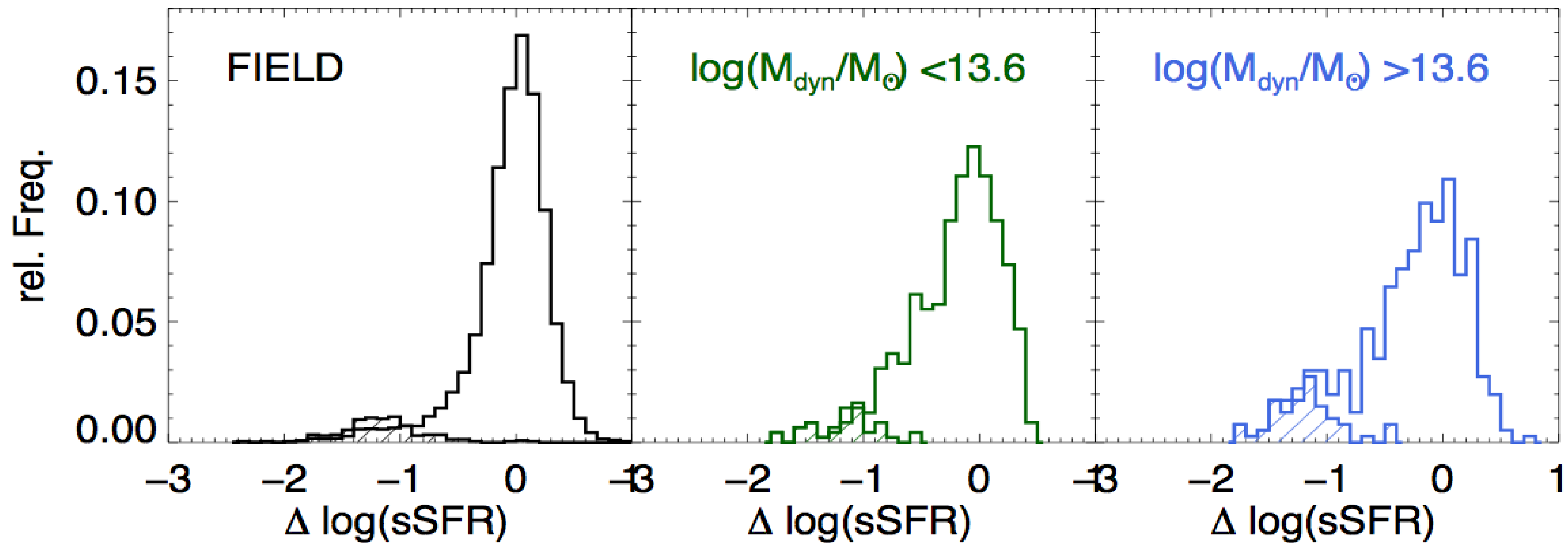
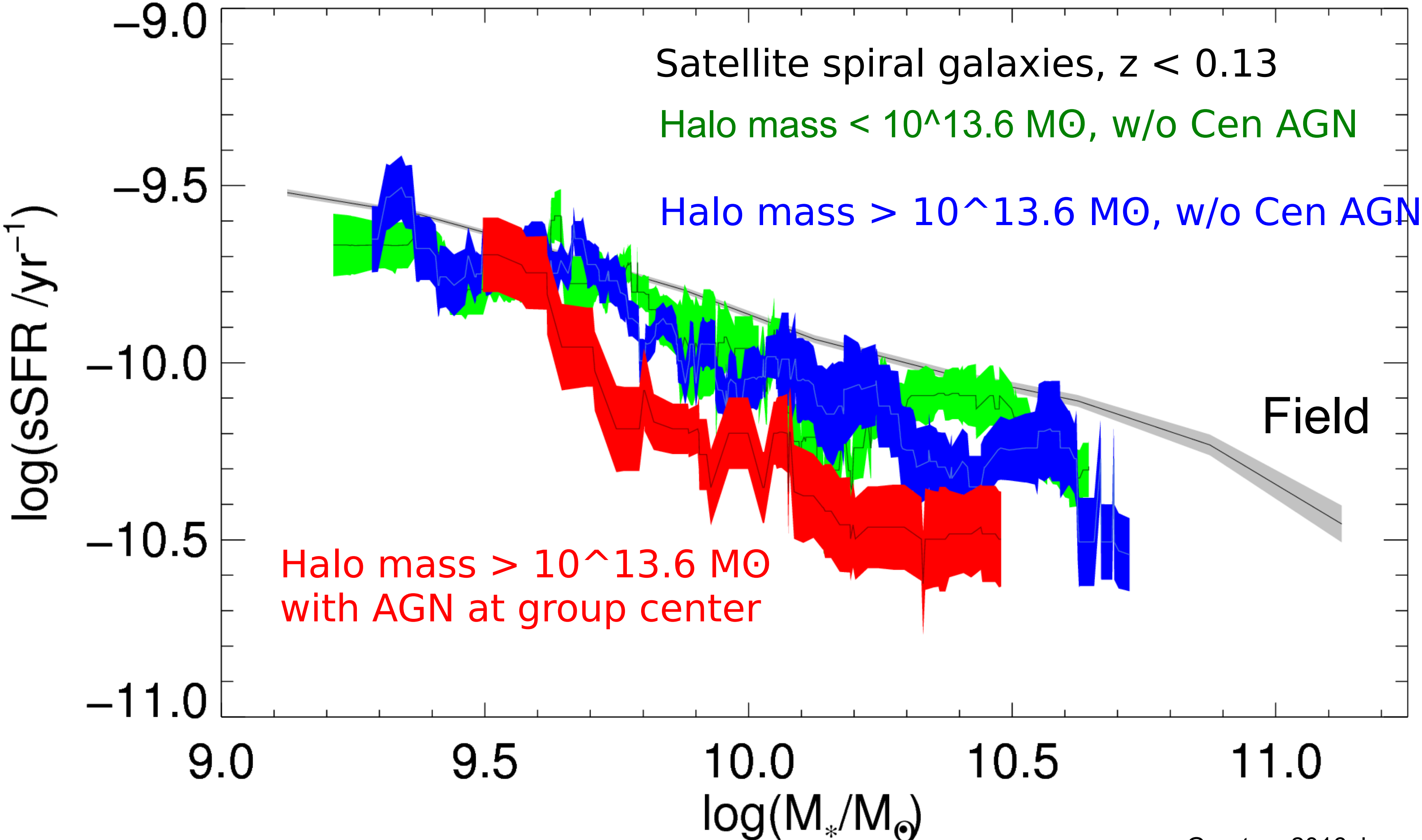


Grootes+2016, in prep

Satellite spiral galaxies, $z < 0.13$

Split at median dynamical halo mass

Probing Environmental Dependencies in Detail: Group Central AGN



Grootes+2016, in prep

Probing Environmental Dependencies in Detail:
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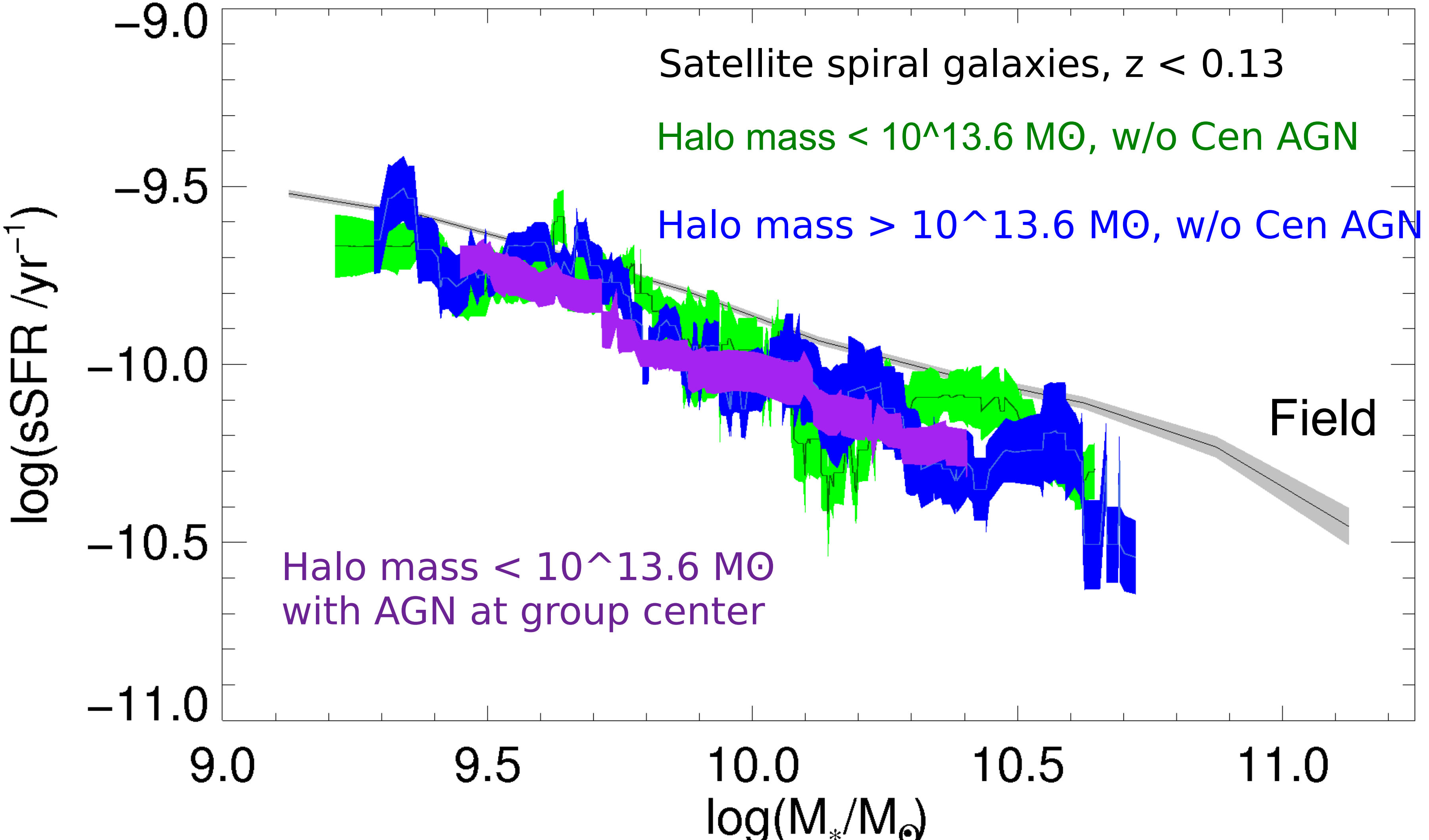
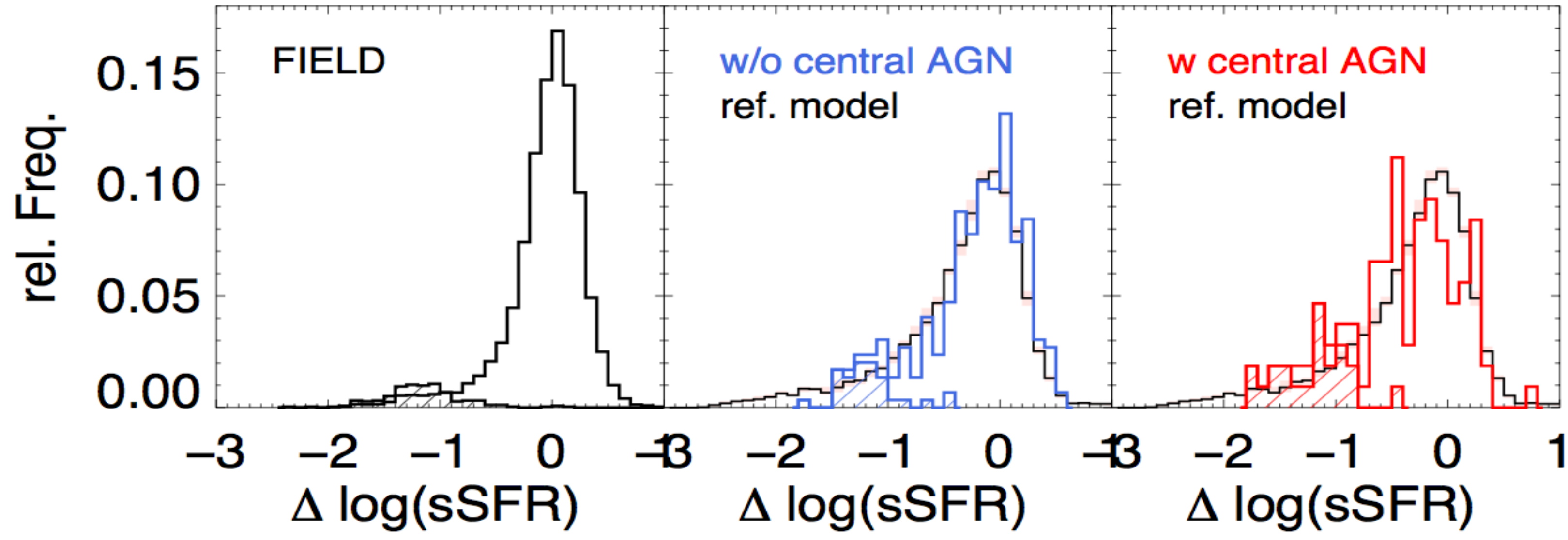


Grootes+2016, in prep

Probing Environmental Dependencies in Detail: Group Central AGN

Satellite spiral galaxies; Halo Mass > 10^13.6 M⊙



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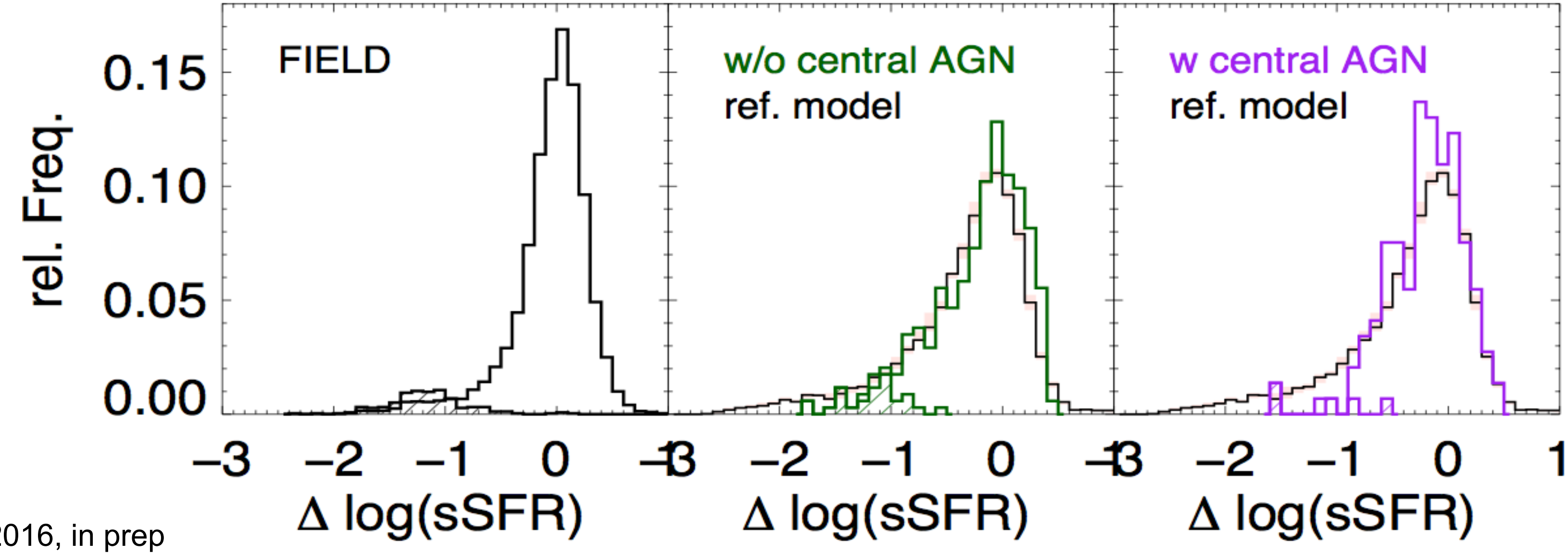


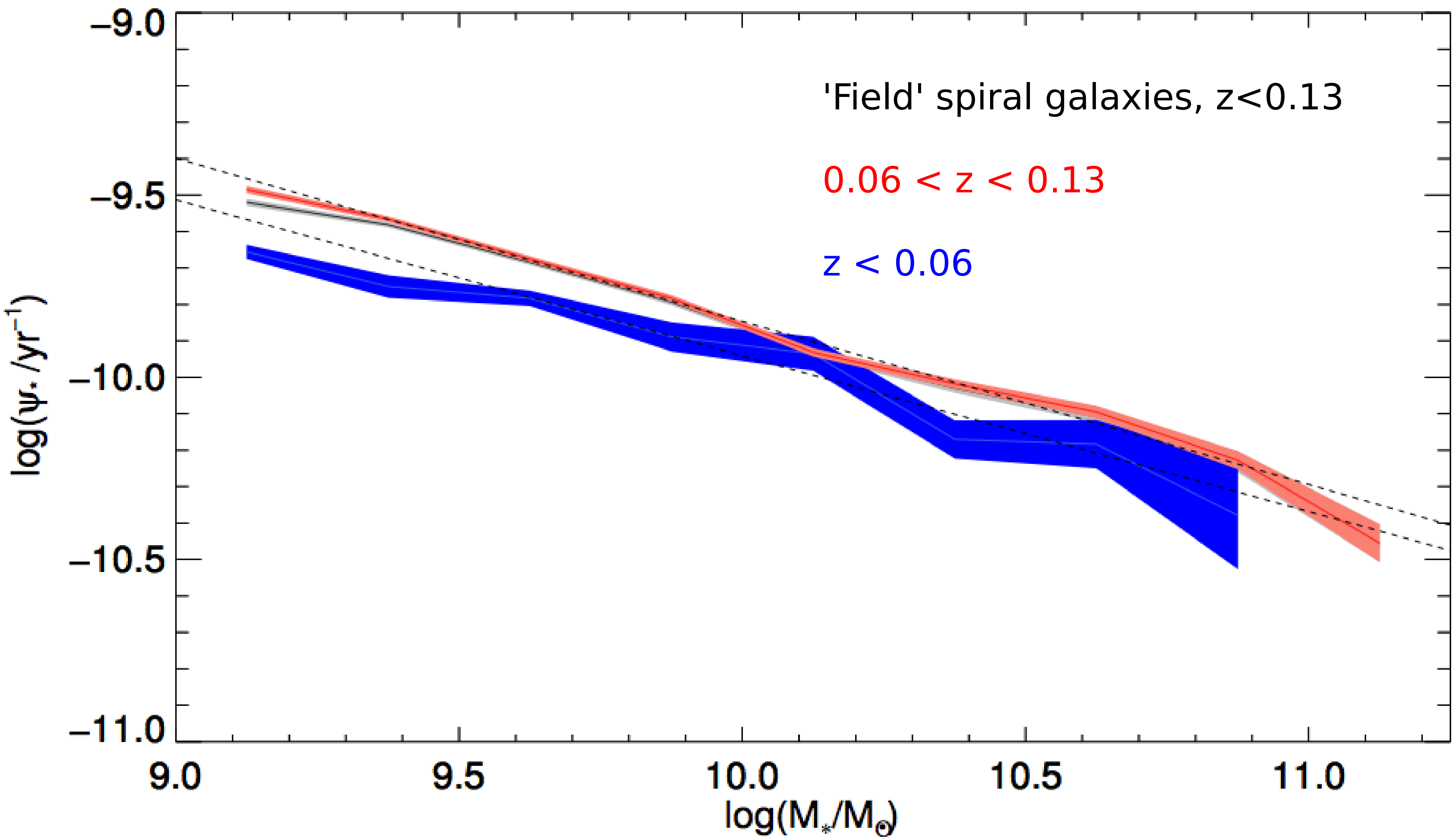
Grootes+2016, in prep

Conclusions

- Gas-fuelling is on-going in satellite spiral galaxies. Accretion from gas in group halo (IGM).
- Gas-fuelling largely independent of environment (halo mass) on scale of galaxy groups
- Independence only broken for massive groups with a central AGN.
- Our picture of how gas-fuelling works (and its importance) is incomplete.
- The color density relation for galaxies is determined by morphological mix rather than gas-fuelling

THANK YOU

Main sequence of 'Field' spiral galaxies:
Evolution over Δz = 0.05



Grootes+2016

Central Spiral Galaxies: A self-regulated balance?

'Field' Galaxies are centrals

Fit evolution of SFMS

Determined by self-regulation and inflow rate

But !

Field:

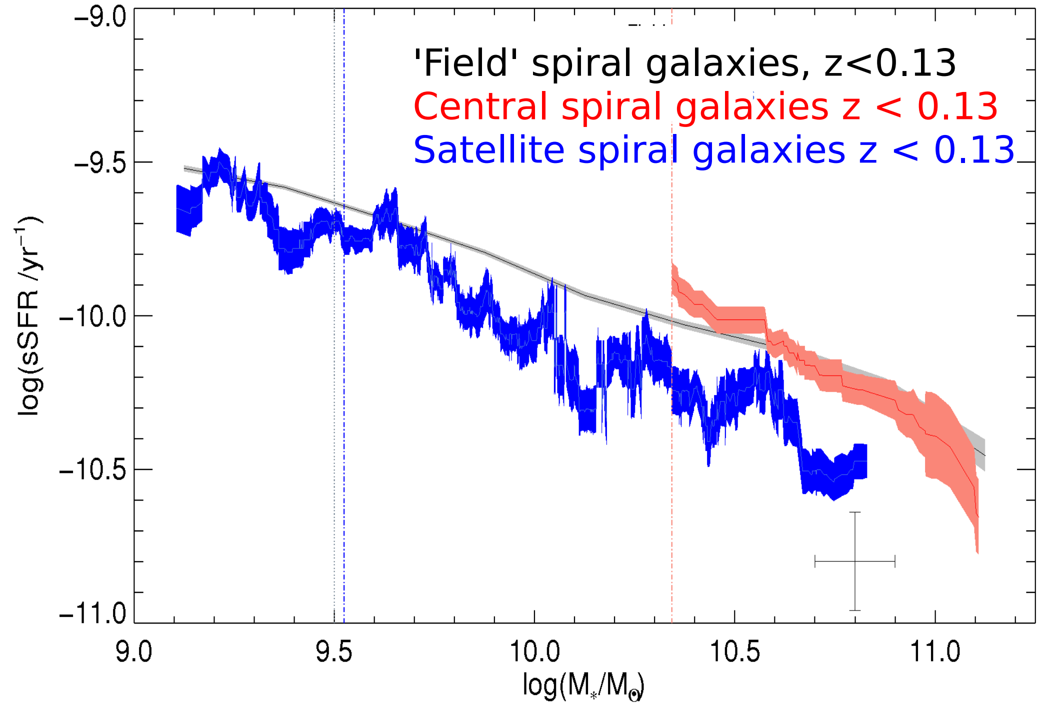
$<\log(M_*/M_{halo})> \approx -1.5$

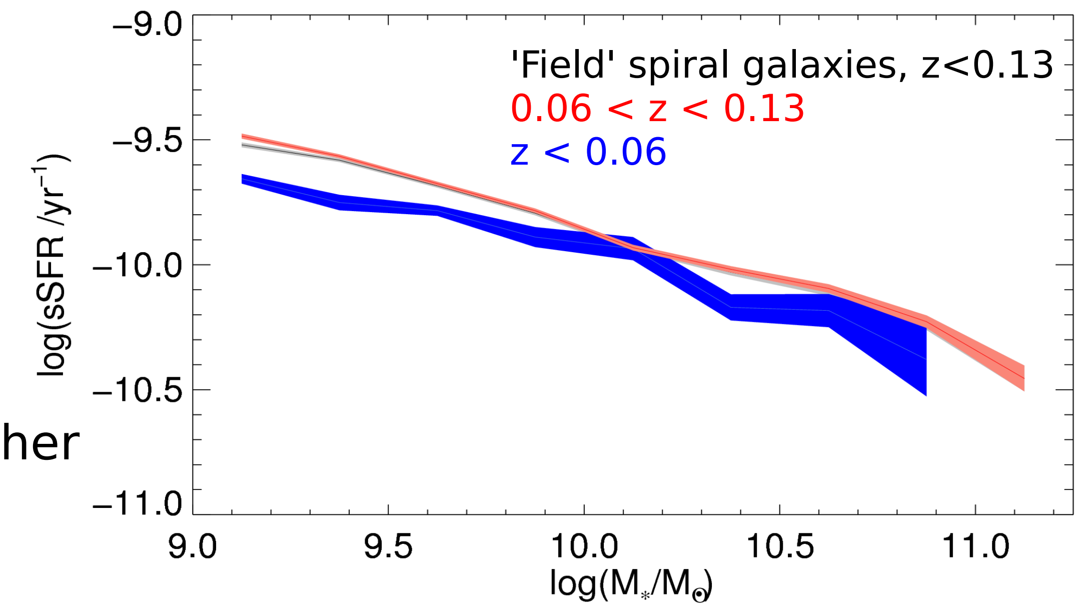
Group Central:

$<\log(M_*/M_{halo})> \approx -2.1$

More inflowing baryons, but same sSFR

→ Not self-regulated. Need further mechanism





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