Galaxies in Statistical Equilibrium

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UCSC Galaxy Workshop
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Forbes, Krumholz, Burkert, and Dekel (2014b)
MNRAS 443 168

Krumholz

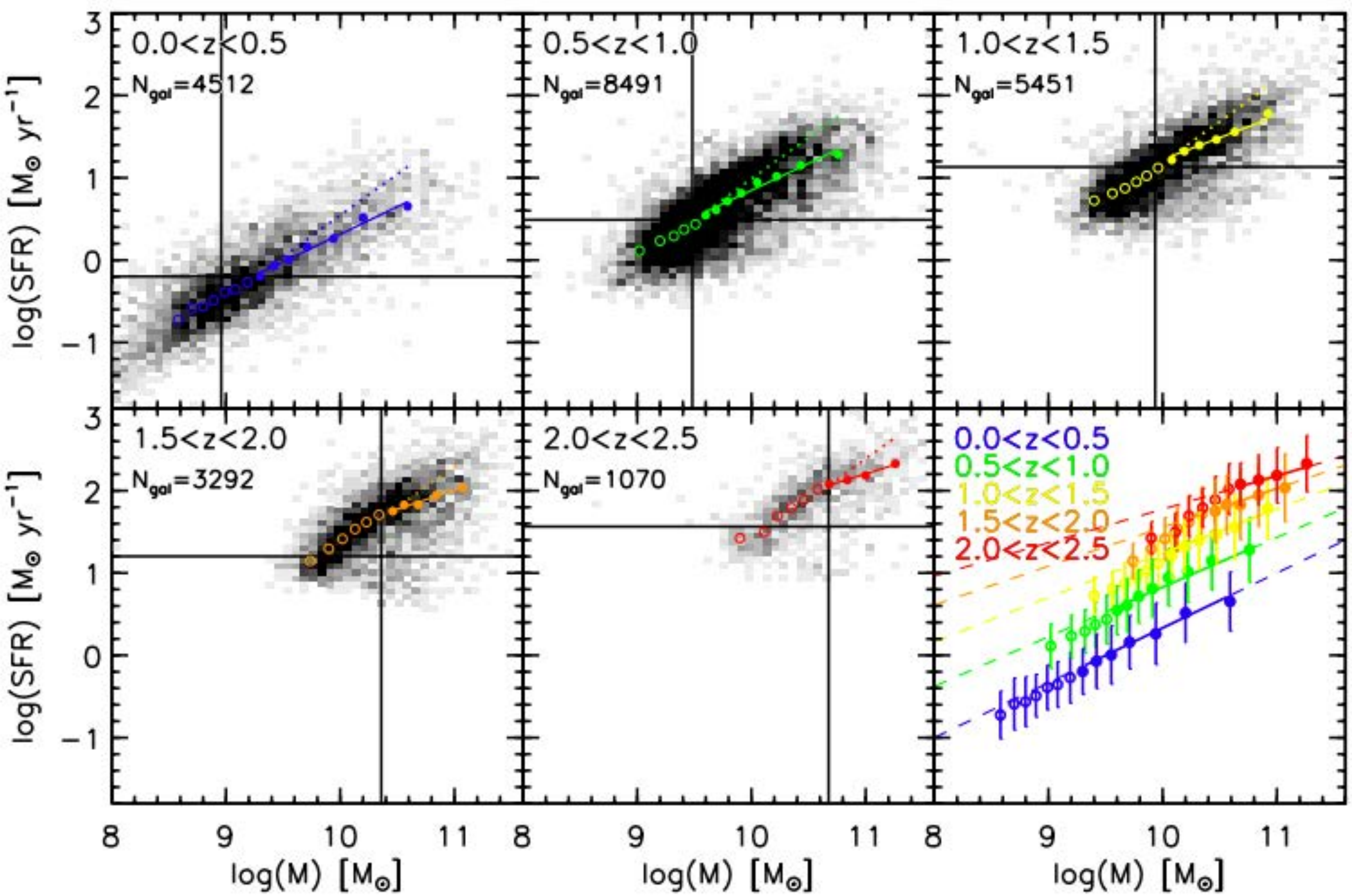
Burkert

Dekel

Original question:

What sets the *intrinsic* scatter in the SFR main sequence?

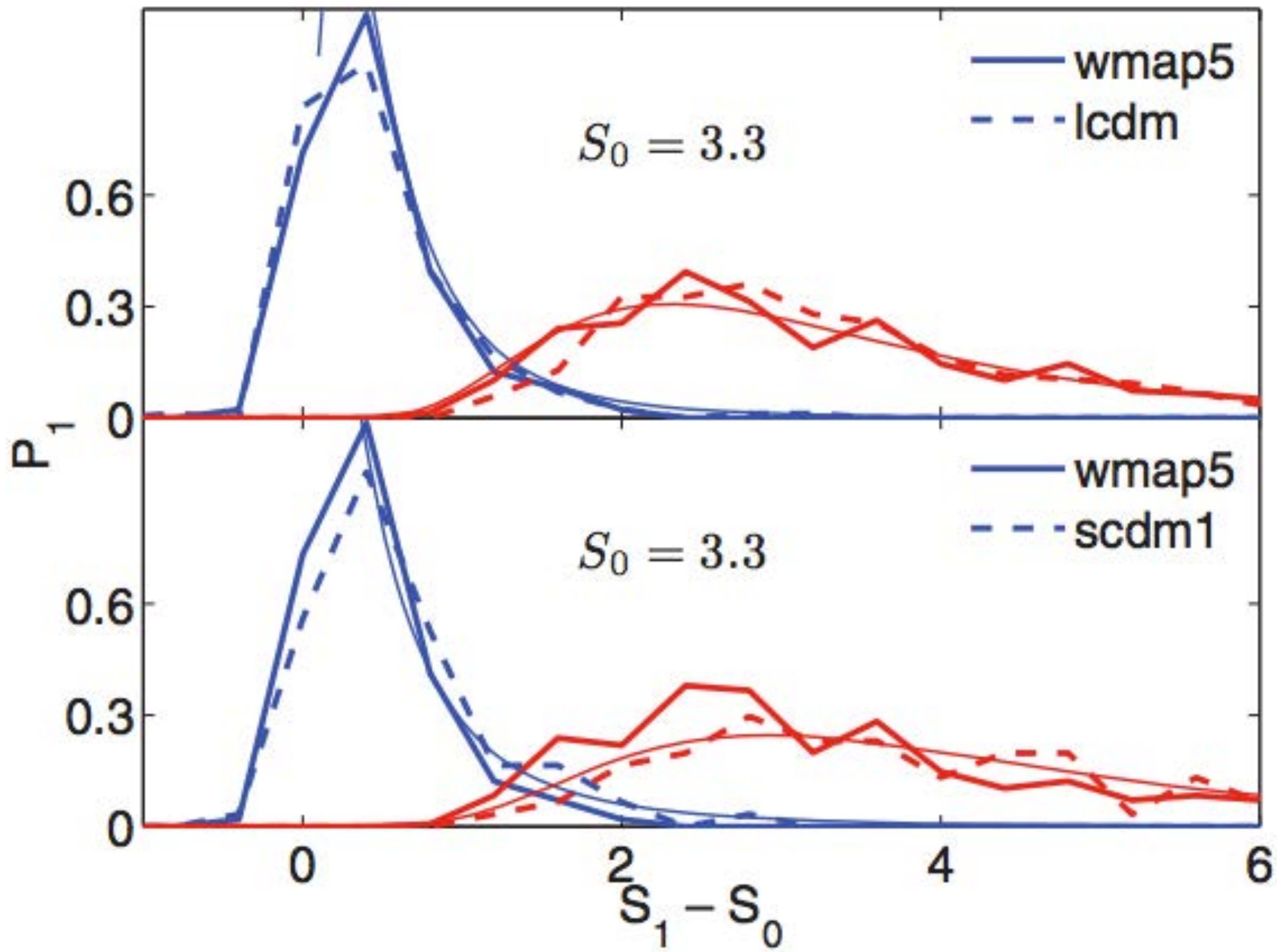
Original question:



Why do galaxies at **fixed mass** have a **variety of SFRs**?

Whitaker+ 2012

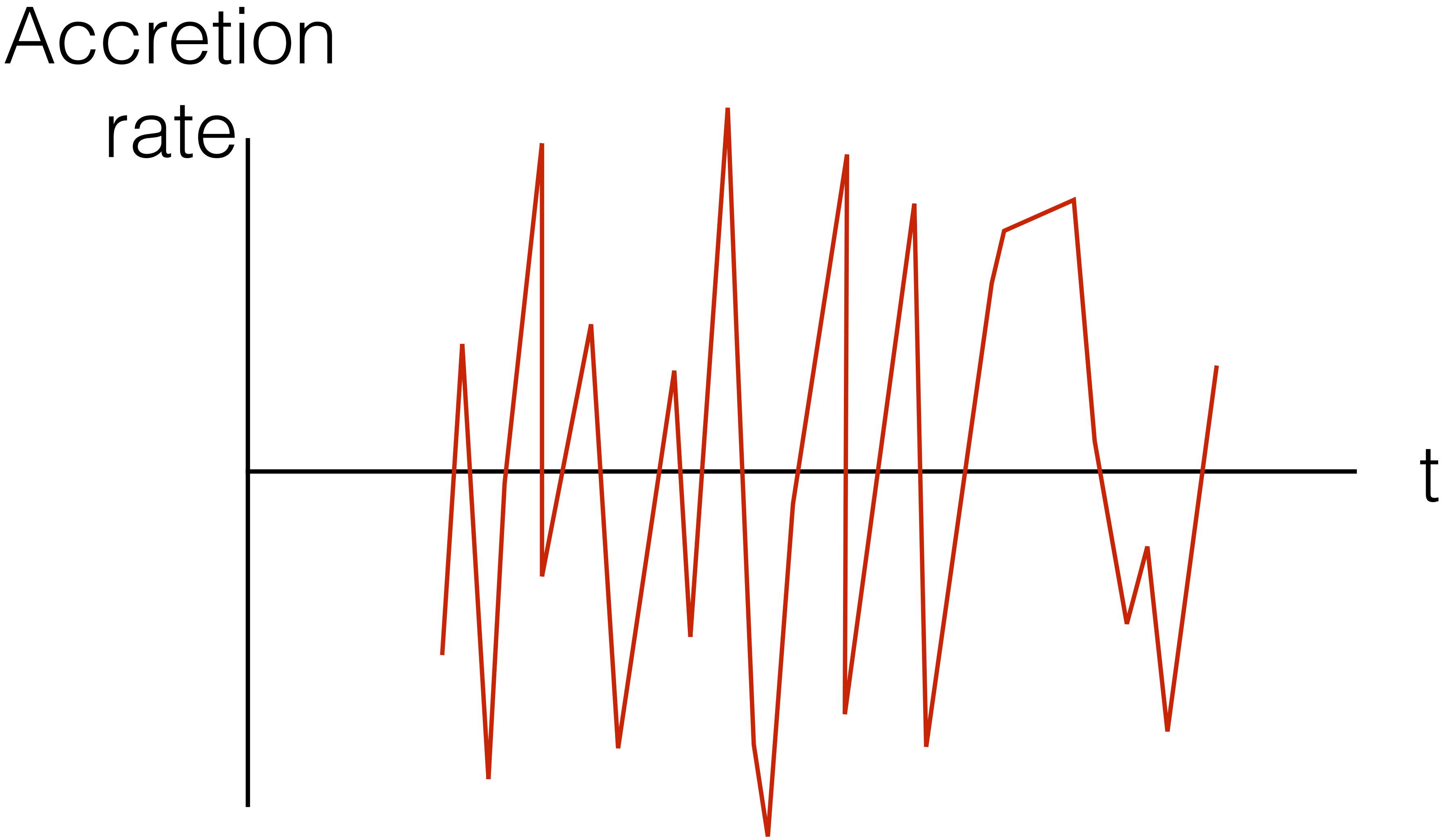
DM halos have substantial scatter in their accretion rate



Neistein, Macciò, & Dekel (2010)

$$P_1(\Delta S_1|S_0, \Delta\omega) = \frac{1}{\sigma_p \Delta S_1 \sqrt{2\pi}} \exp\left[-\frac{(\ln \Delta S_1 - \mu_p)^2}{2\sigma_p^2}\right]$$

… but timescales are also important



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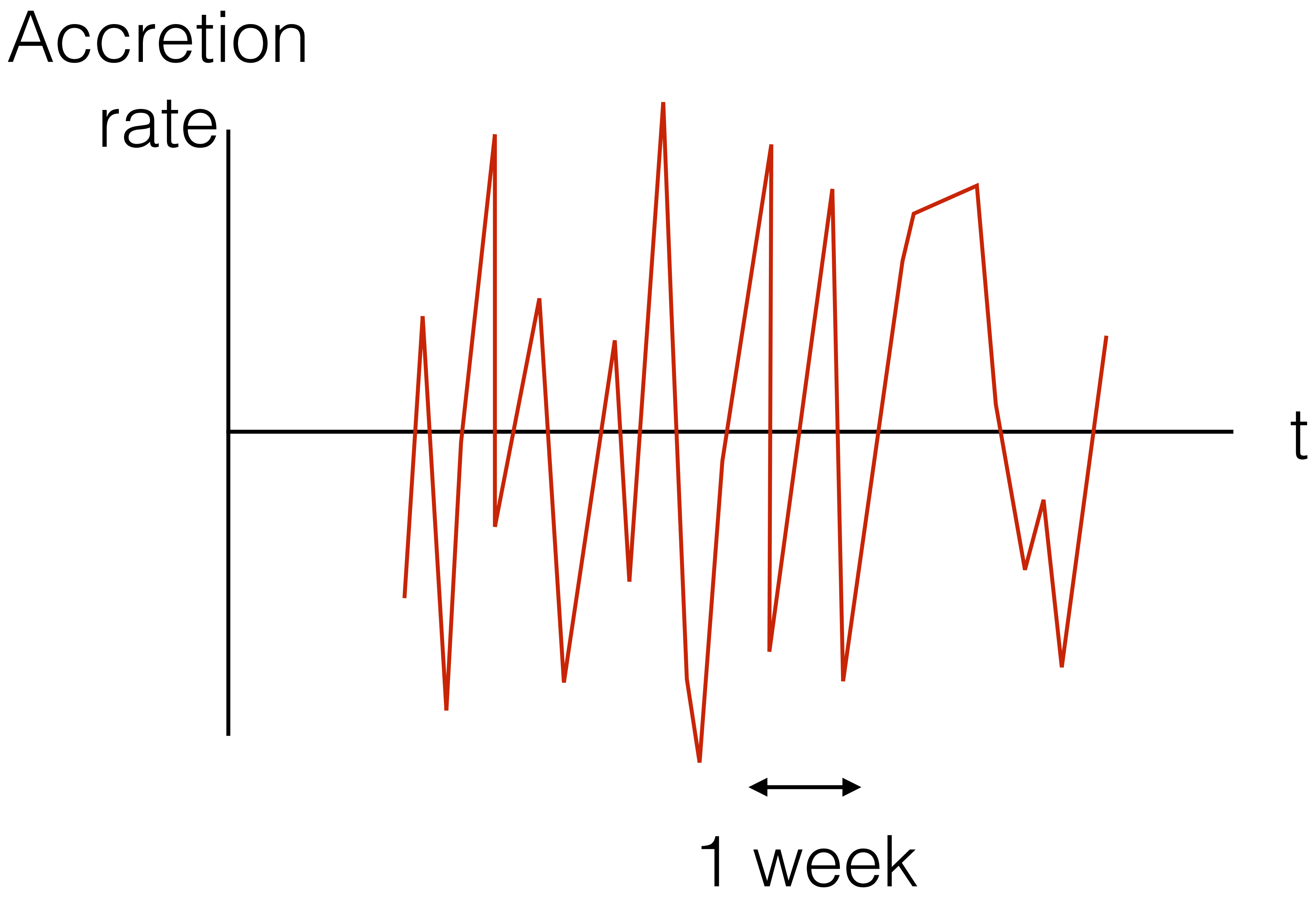

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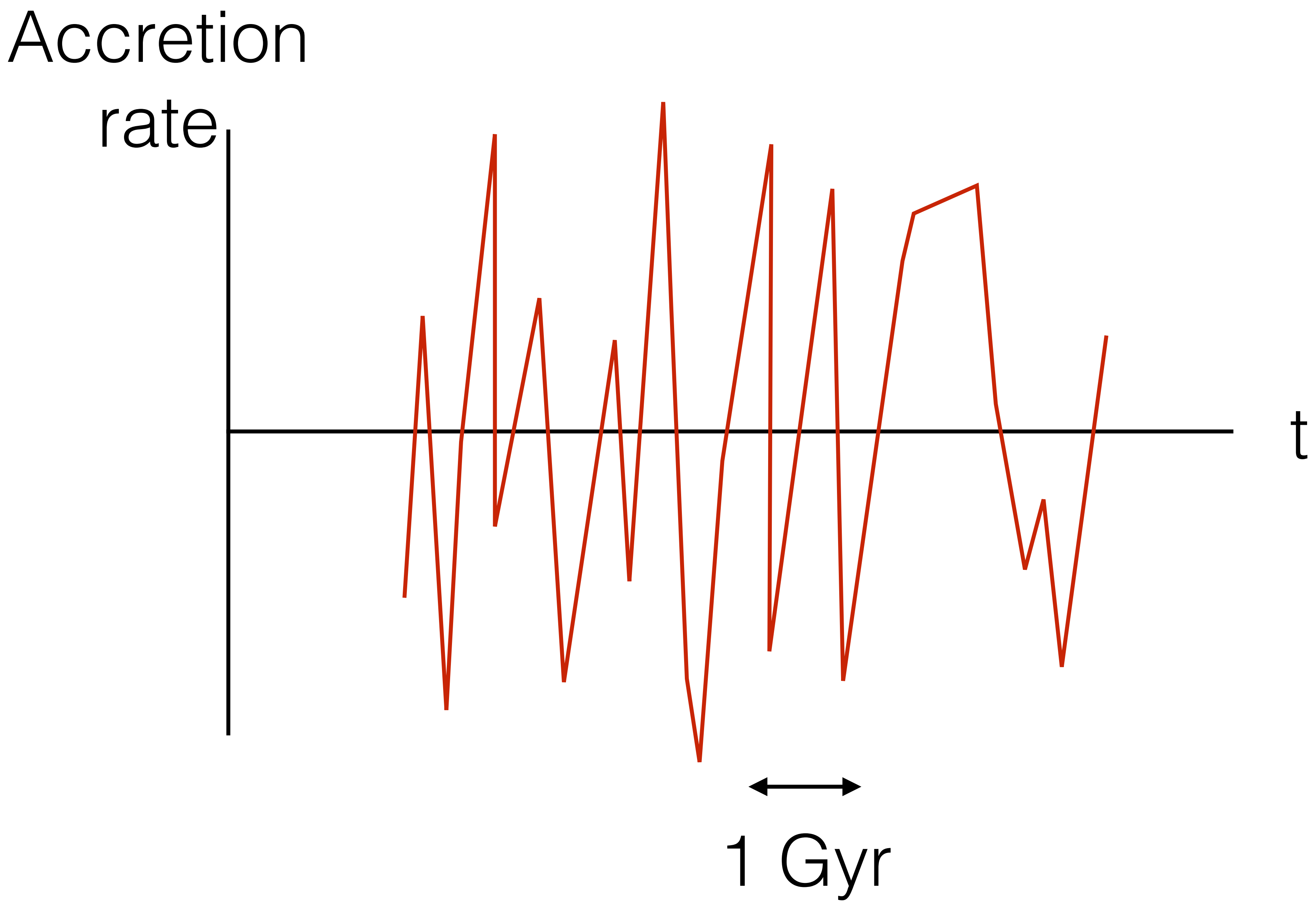
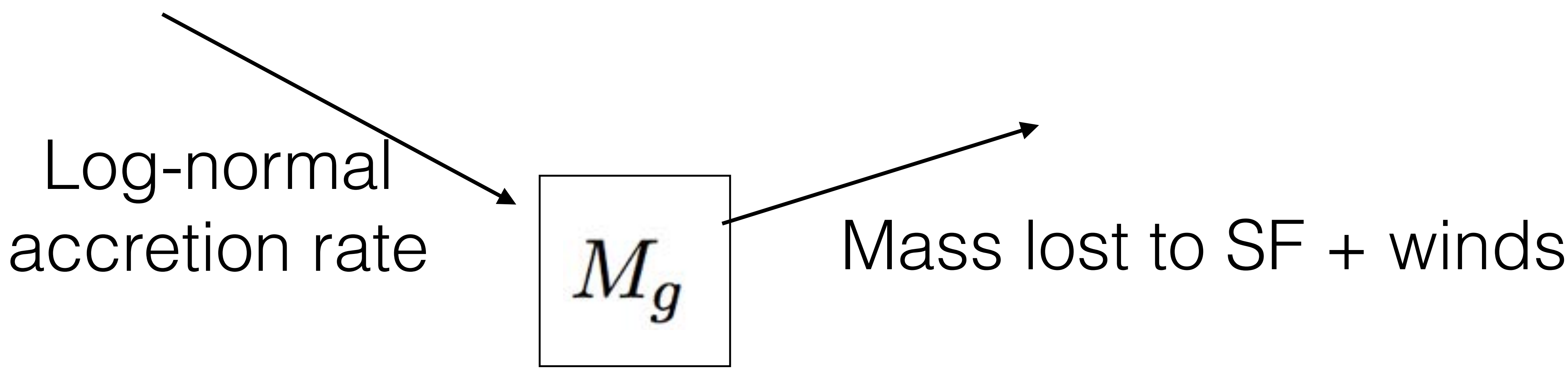
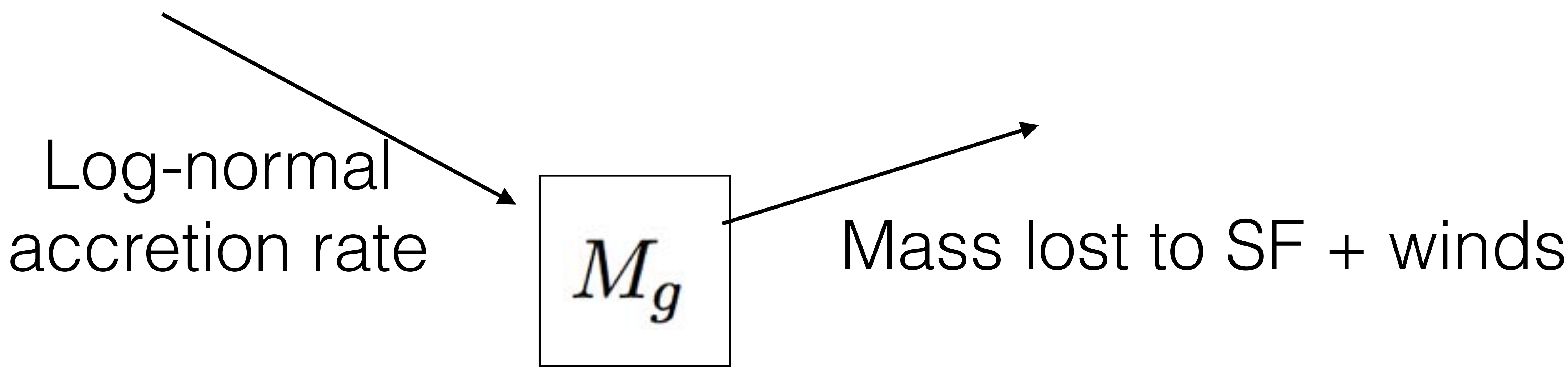


A very simple model



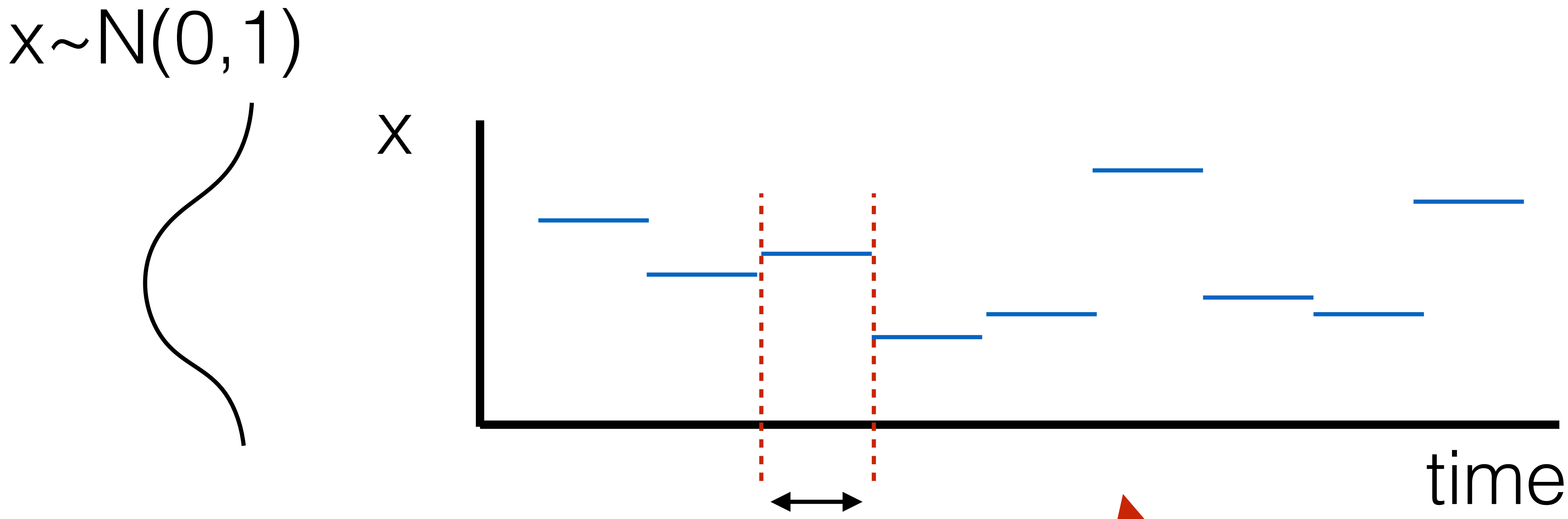
$$\dot{M}_g = \dot{M}_{\rm ext} - \frac{M_g}{t_{\rm loss}}$$

A very simple model



$$\dot{M}_g = \dot{M}_{\mathrm{ext,med}}\ e^{\sigma \boxed{x(t)}} - \frac{M_g}{t_{\mathrm{loss}}}$$

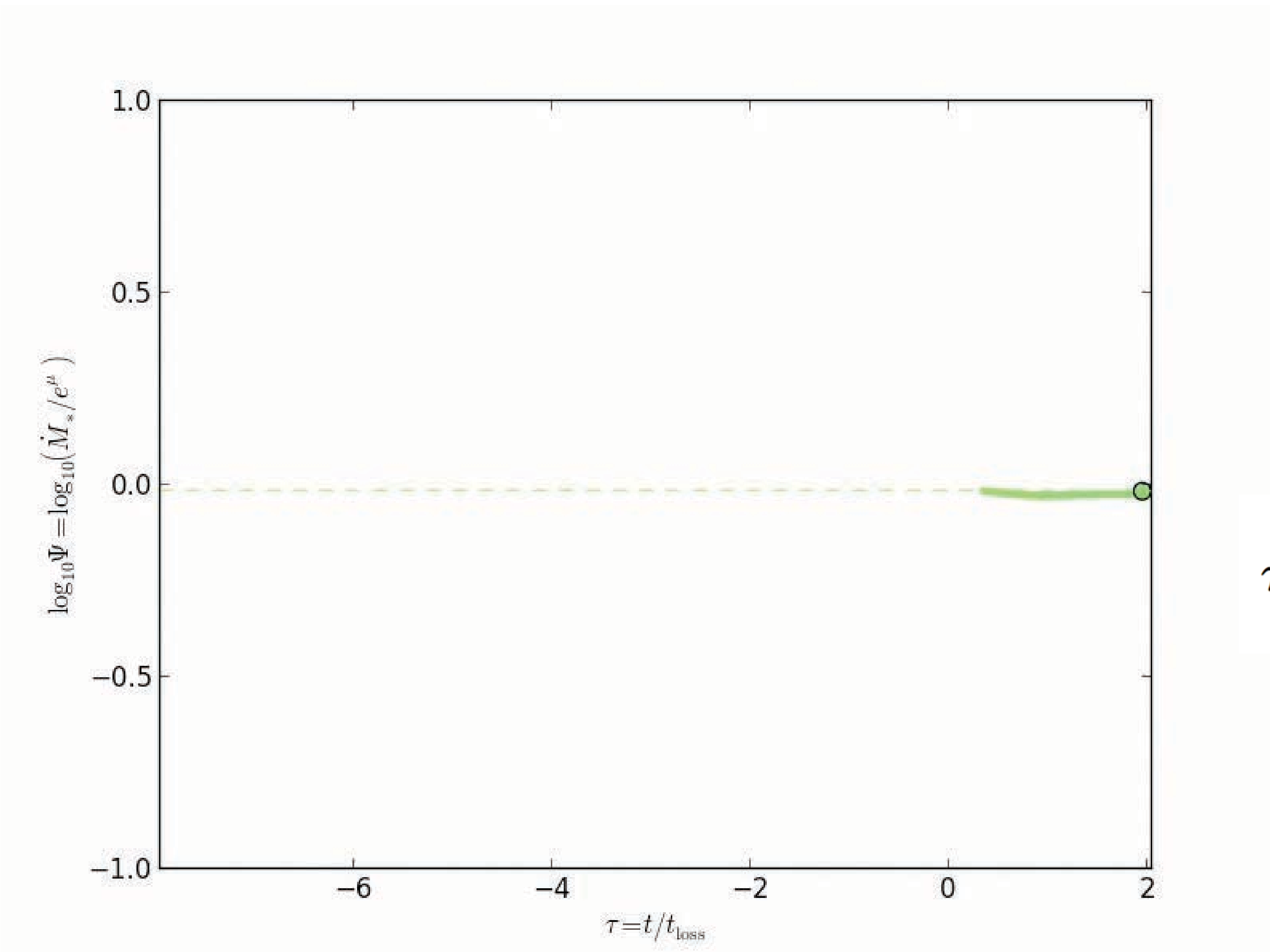
A very simple model



$t_{\text{coherence}}$

$$\dot{M}_g = \dot{M}_{\text{ext,med}}\, e^{\sigma x(t)} - \frac{M_g}{t_{\text{loss}}}$$

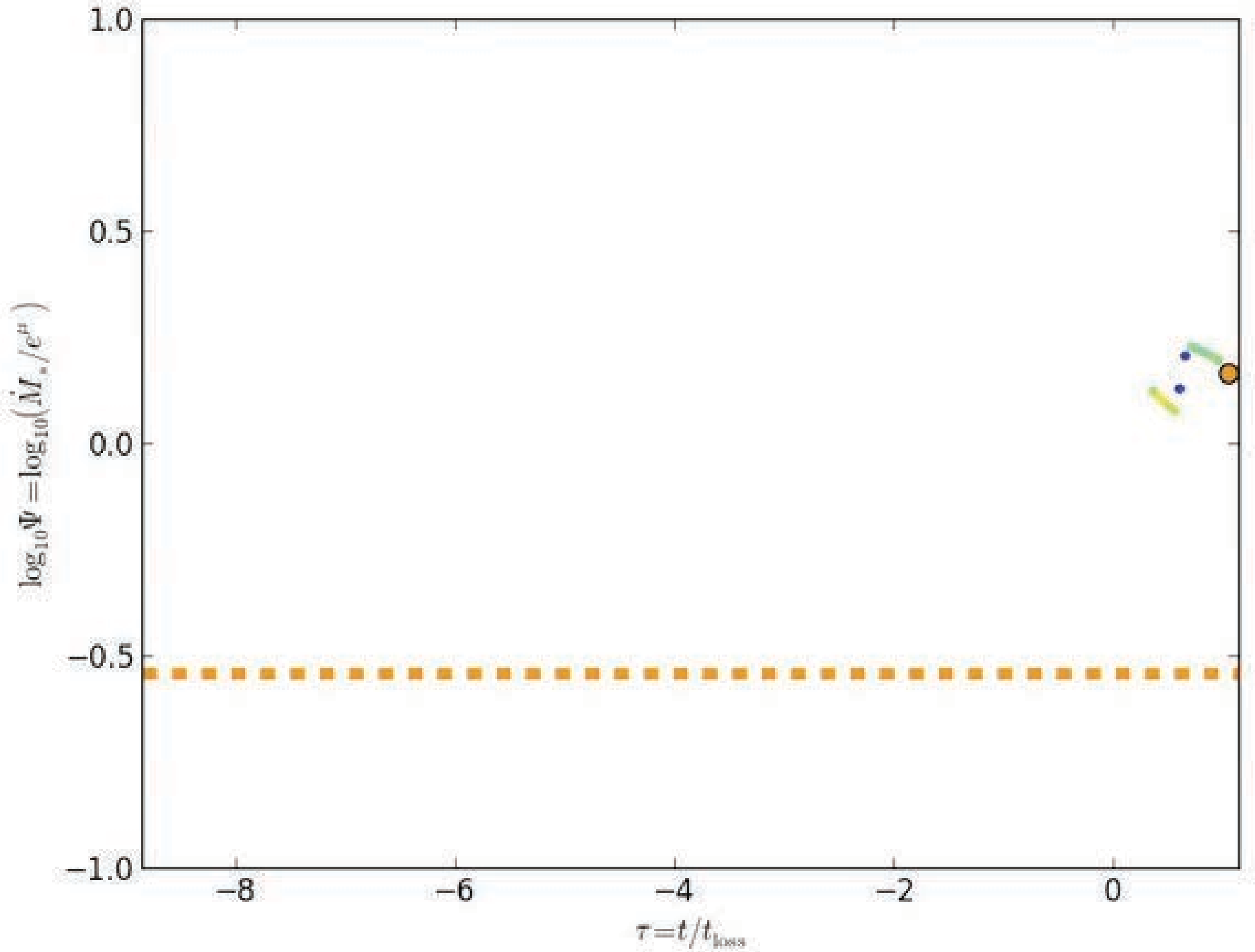
Can derive solution analytically



$\sigma = 1$

$$\tau_c = \frac{t_{\rm coherence}}{t_{\rm loss}} = 1$$

Quick variations

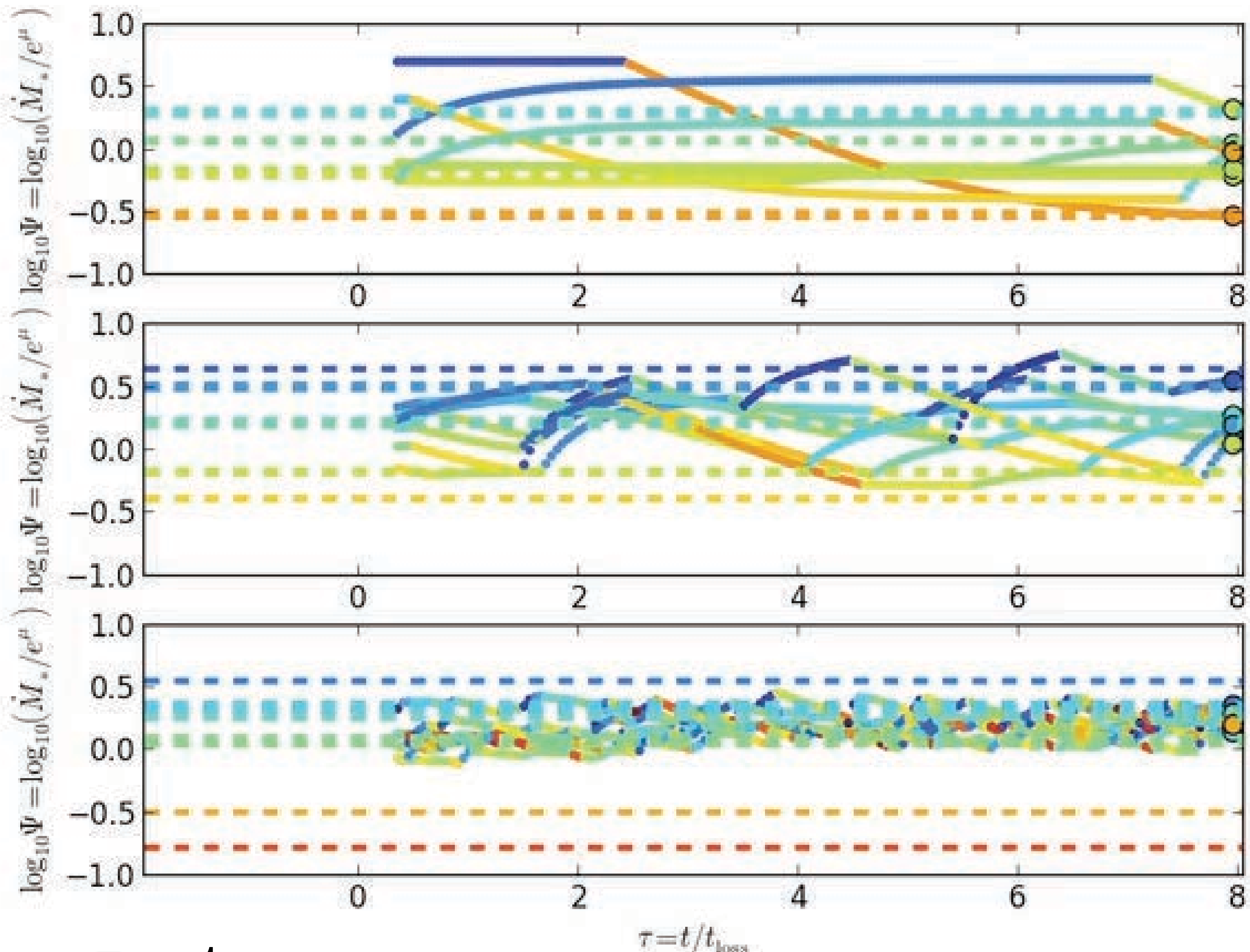


$\sigma = 1$

$$\tau_c = \frac{t_{\rm coherence}}{t_{\rm loss}} = .1$$

An ensemble

$$\tau_c = \frac{t_{\text{coherence}}}{t_{\text{loss}}}$$



7

1.0

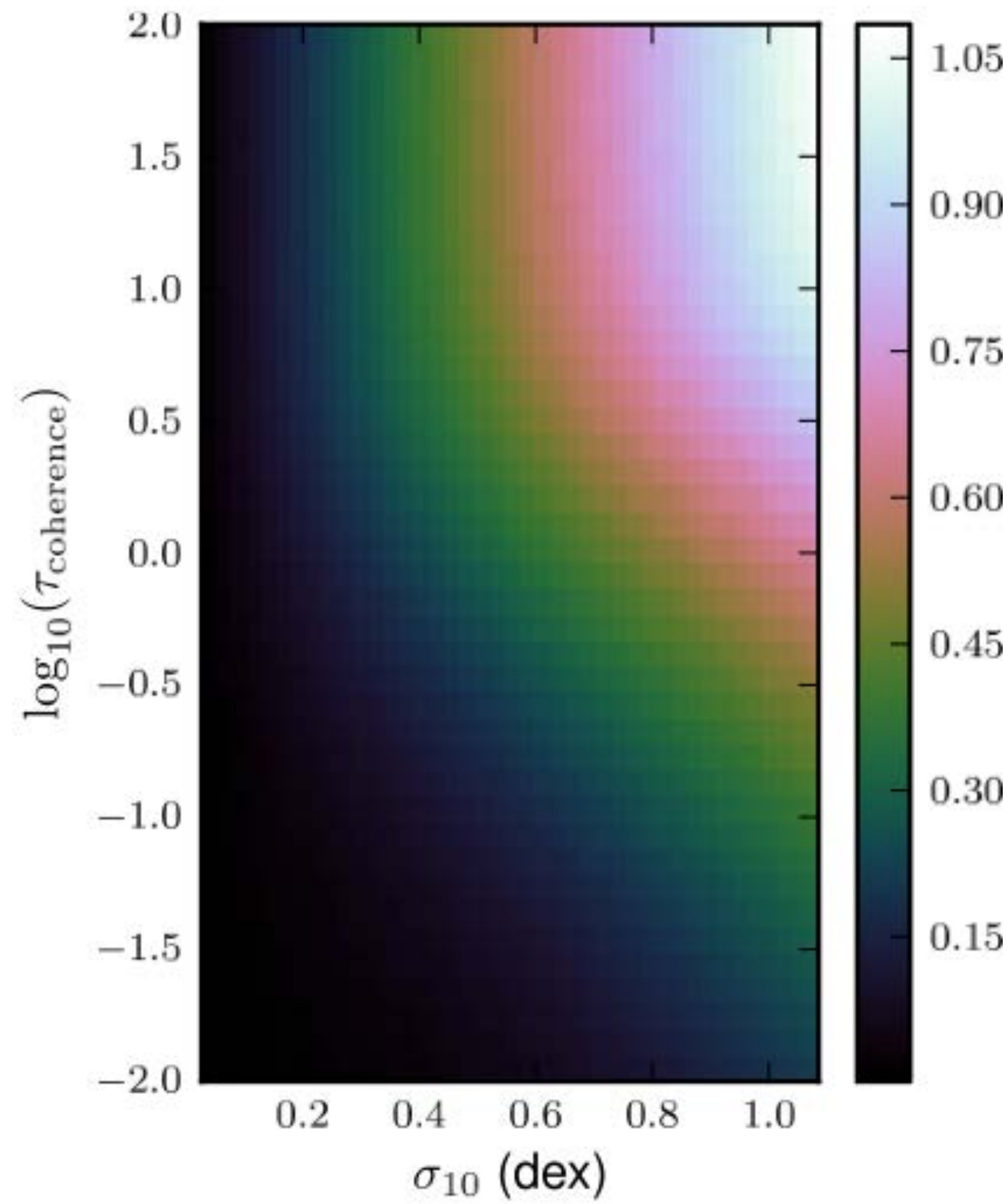
0.1

σ =1

Scatter in the SFR at fixed mass

Slow variation

Fast variation



scatter in the SFR (dex)

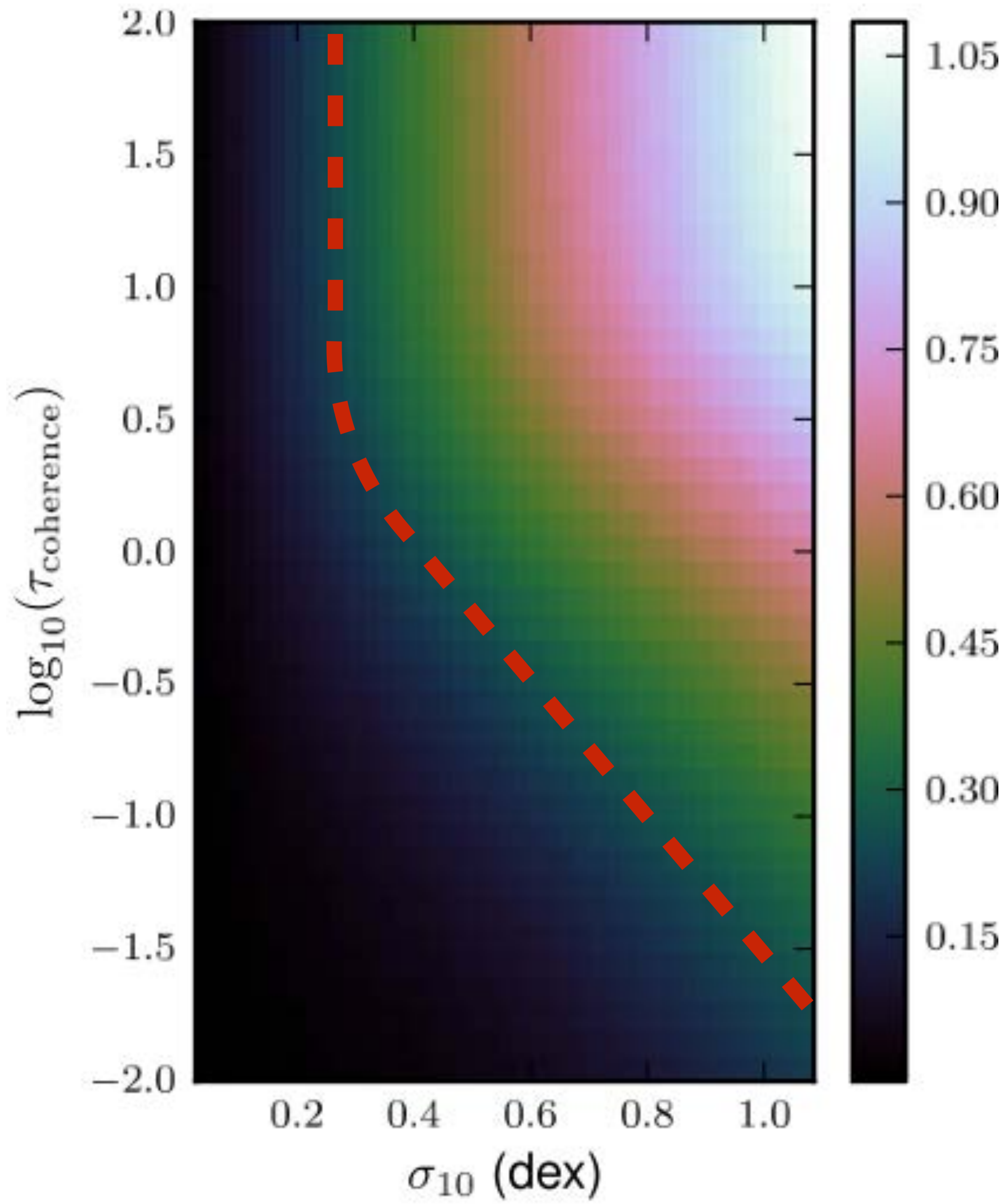
small intrinsic scatter

large intrinsic scatter

Scatter in the SFR at fixed mass

Slow variation

Fast variation

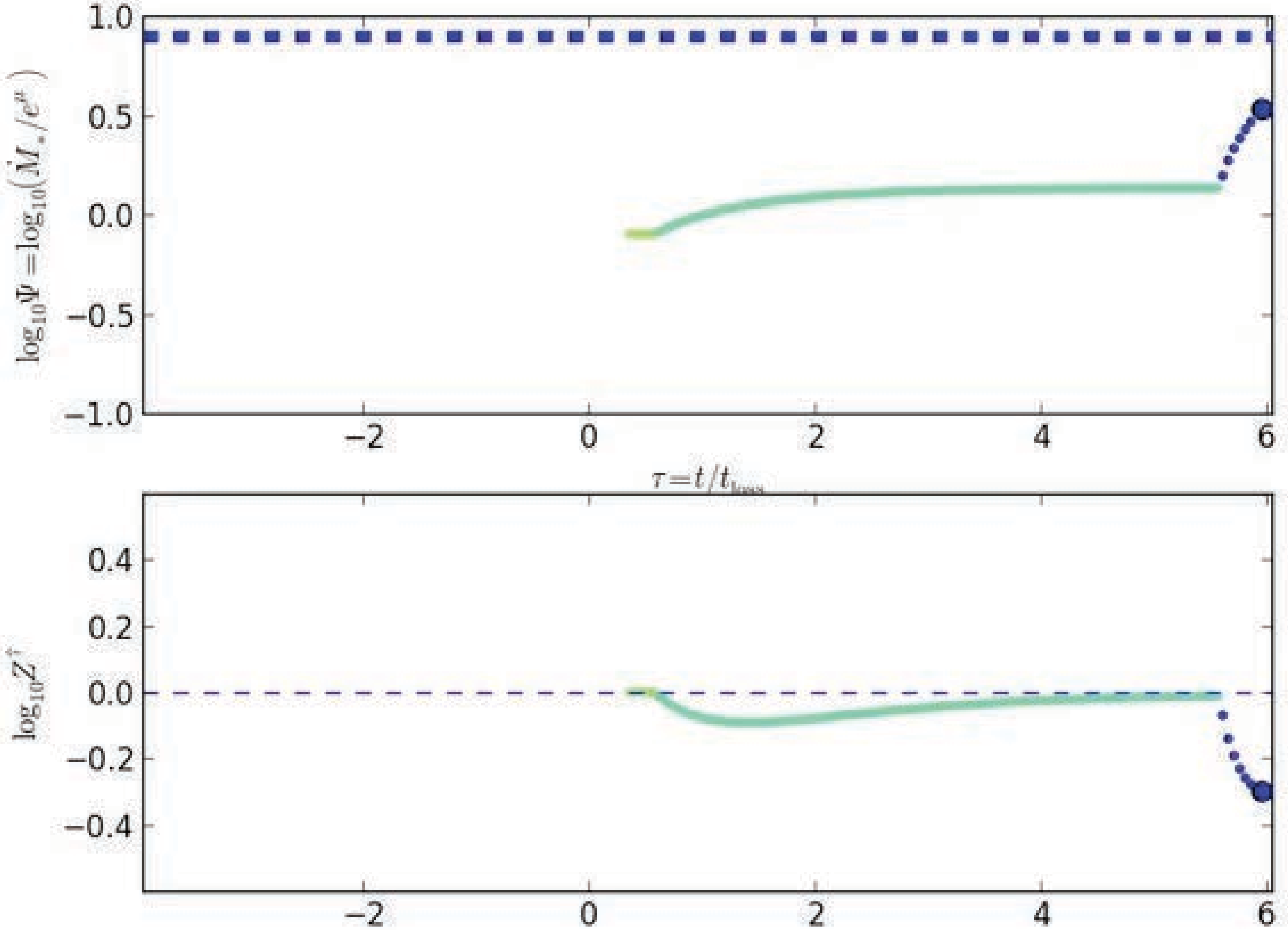


scatter in the SFR (dex)

small intrinsic scatter

large intrinsic scatter

Add in metallicity

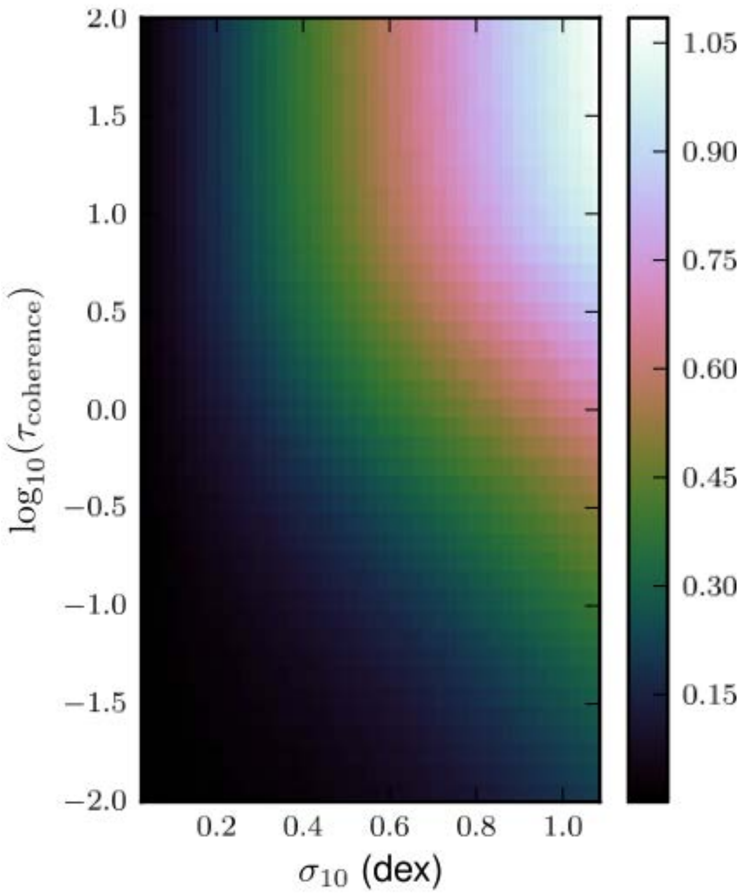


$\sigma = 1$

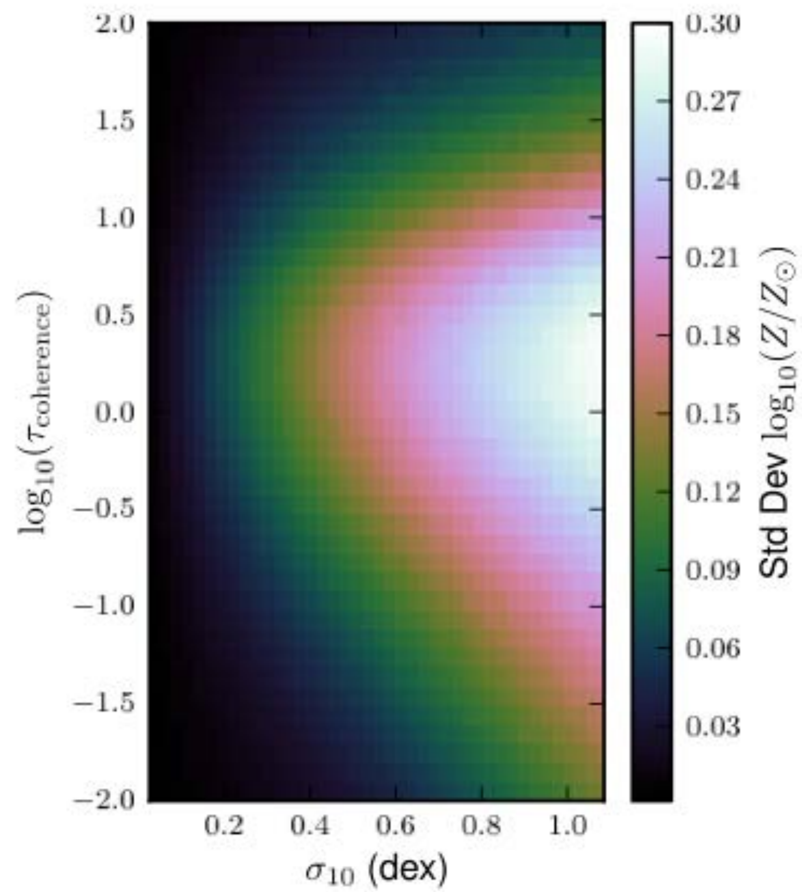
$$\tau_c = \frac{t_{\text{coherence}}}{t_{\text{loss}}} = 5$$

$$Z_{eq} = Z_{IGM} + q = Z_{IGM} + \frac{y f_R}{f_R + \eta}$$

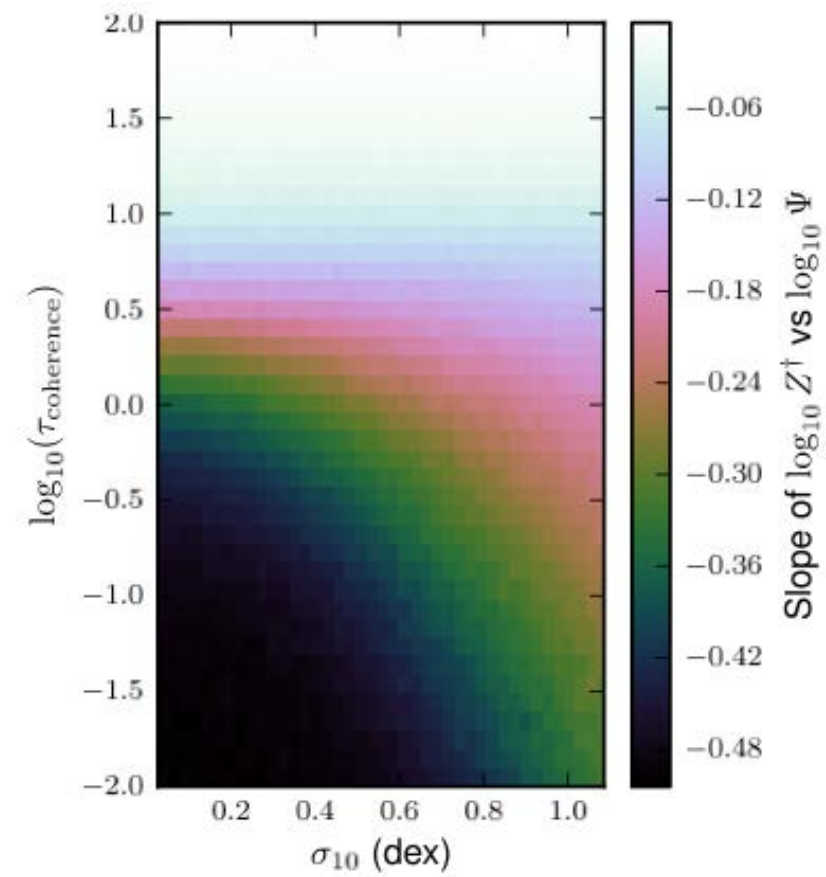
Now we have three complementary constraints



SFR

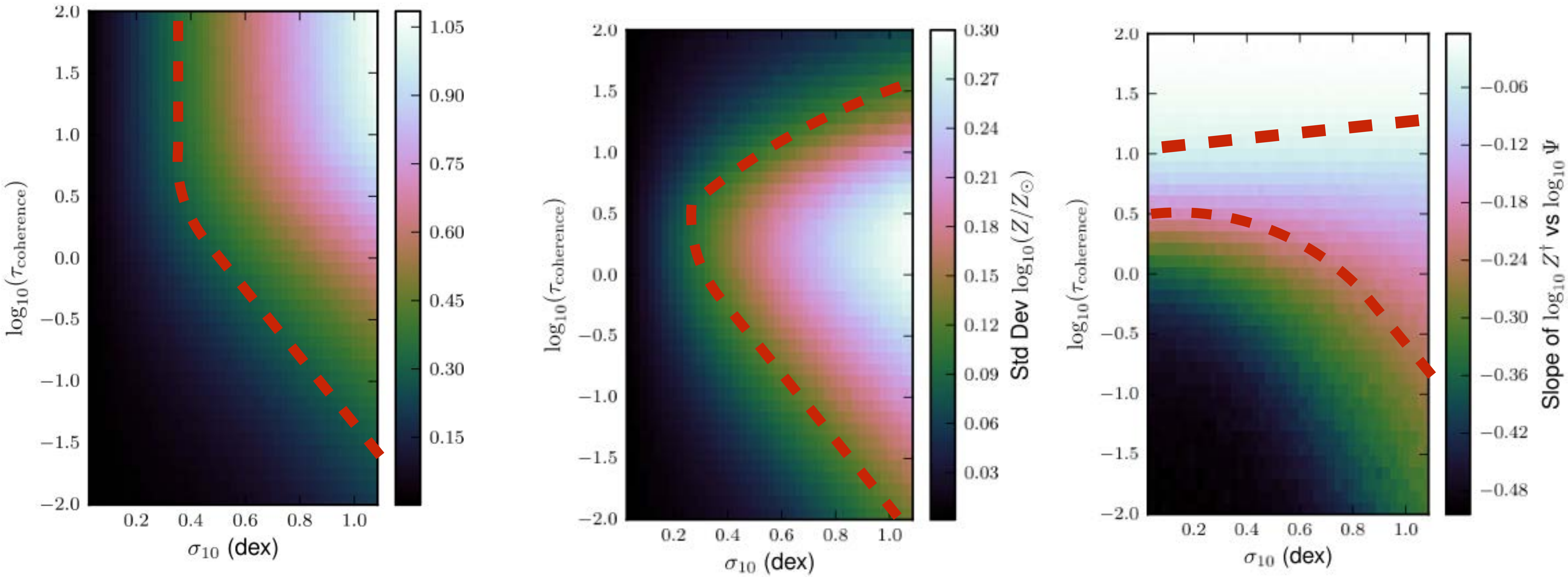


Z



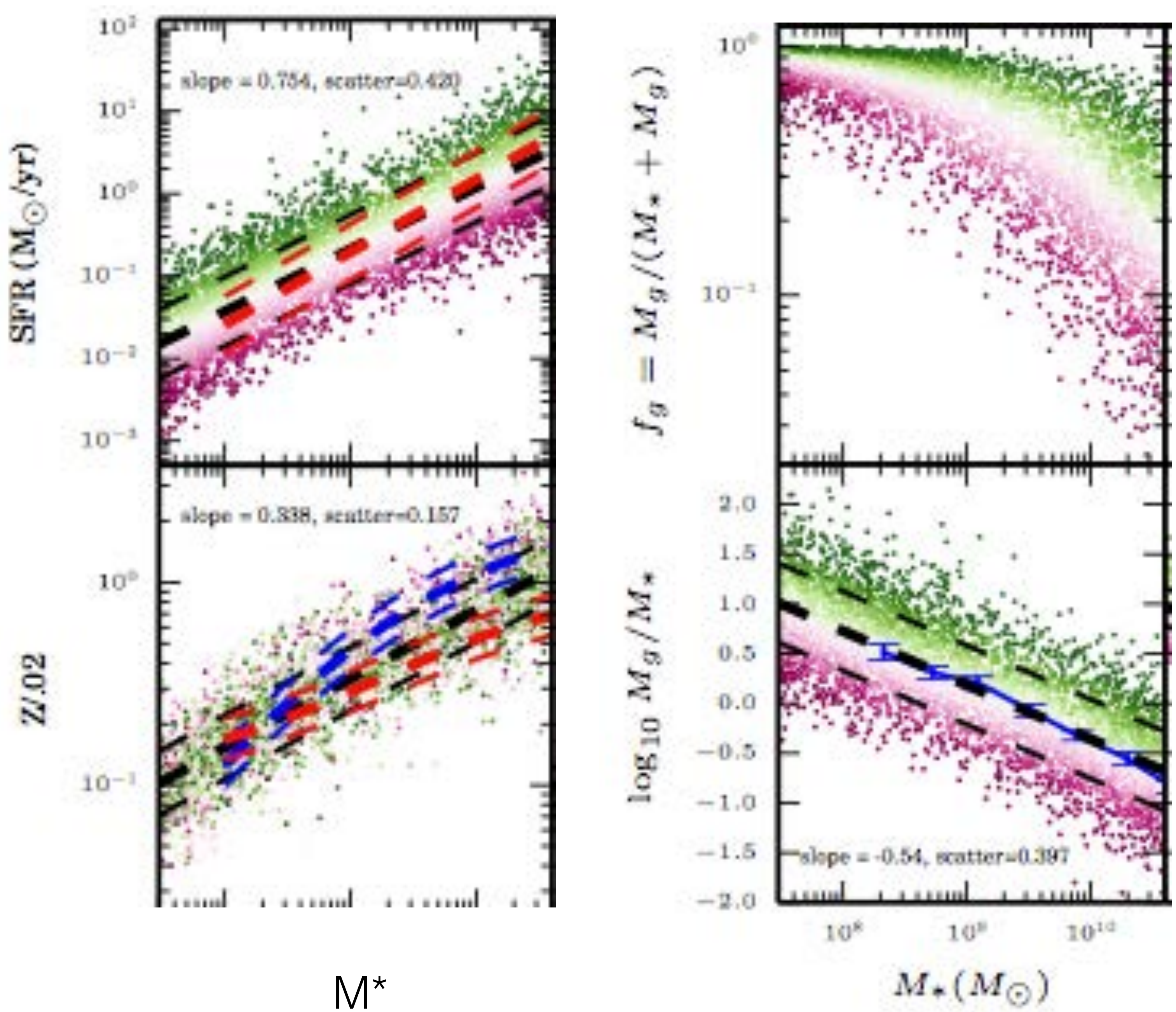
FMR slope

Now we have three complementary constraints



SFR Z FMR slope

Example synthetic scaling relations



Powerlaw fit to synthetic relation

Fits to the real-world observations

The constraints

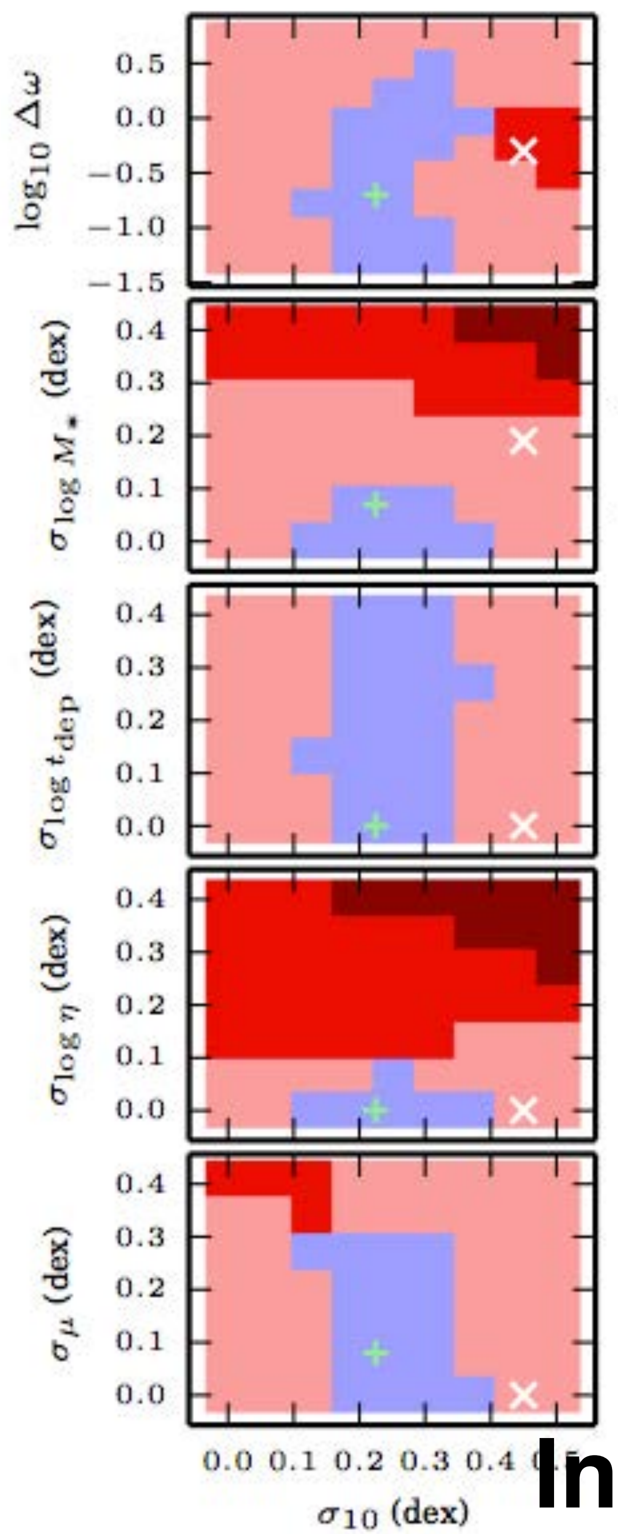
Coherence

M*

Depletion

Mass loading

Median Accretion



Intrinsic Scatter

Allowed

1 constraint violated

2 constraints violated

3 constraints violated

The constraints

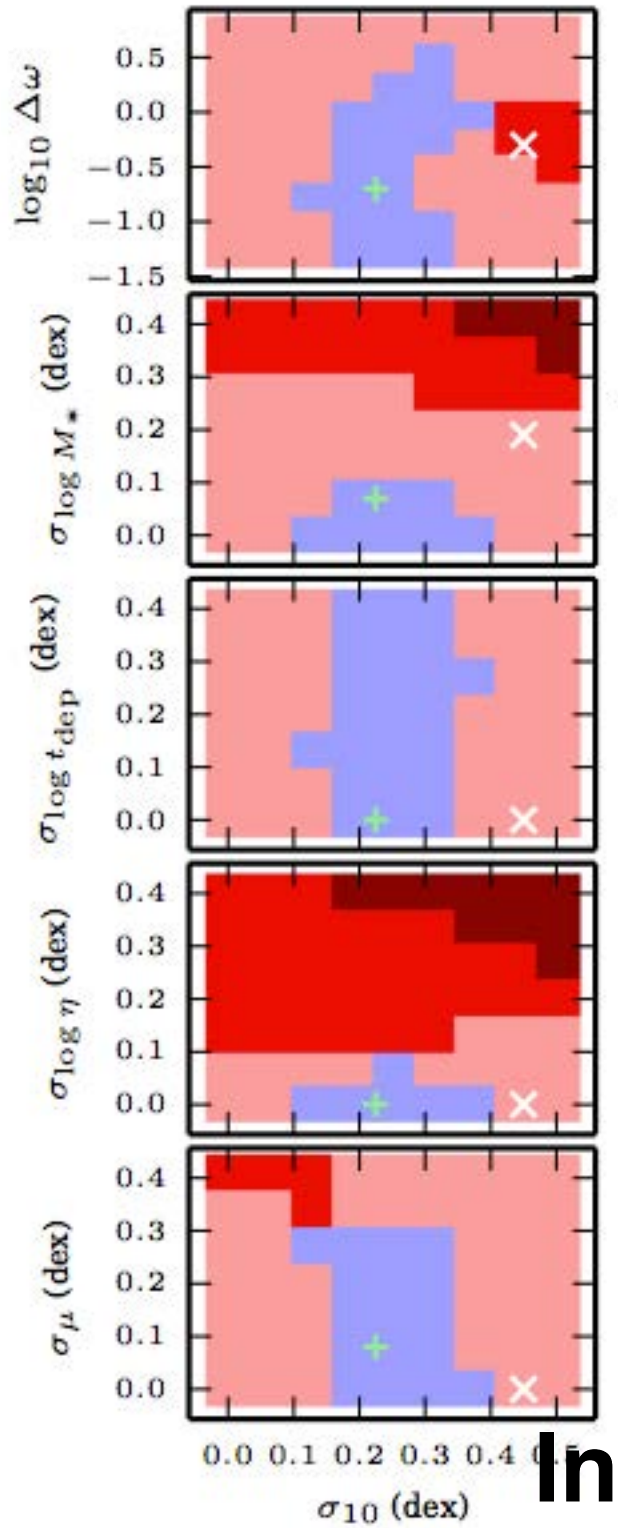
Coherence

M*

Depletion

Mass loading

Median Accretion



Intrinsic Scatter

$$Z_{eq} = Z_{IGM} + q = Z_{IGM} + \frac{y f_R}{f_R + \boxed{\eta}}$$

$$\dot{M}_{\rm SF,\mathit{eq}} = \dot{M}_{\rm ext}/(\boxed{\eta} + f_R)$$

The constraints

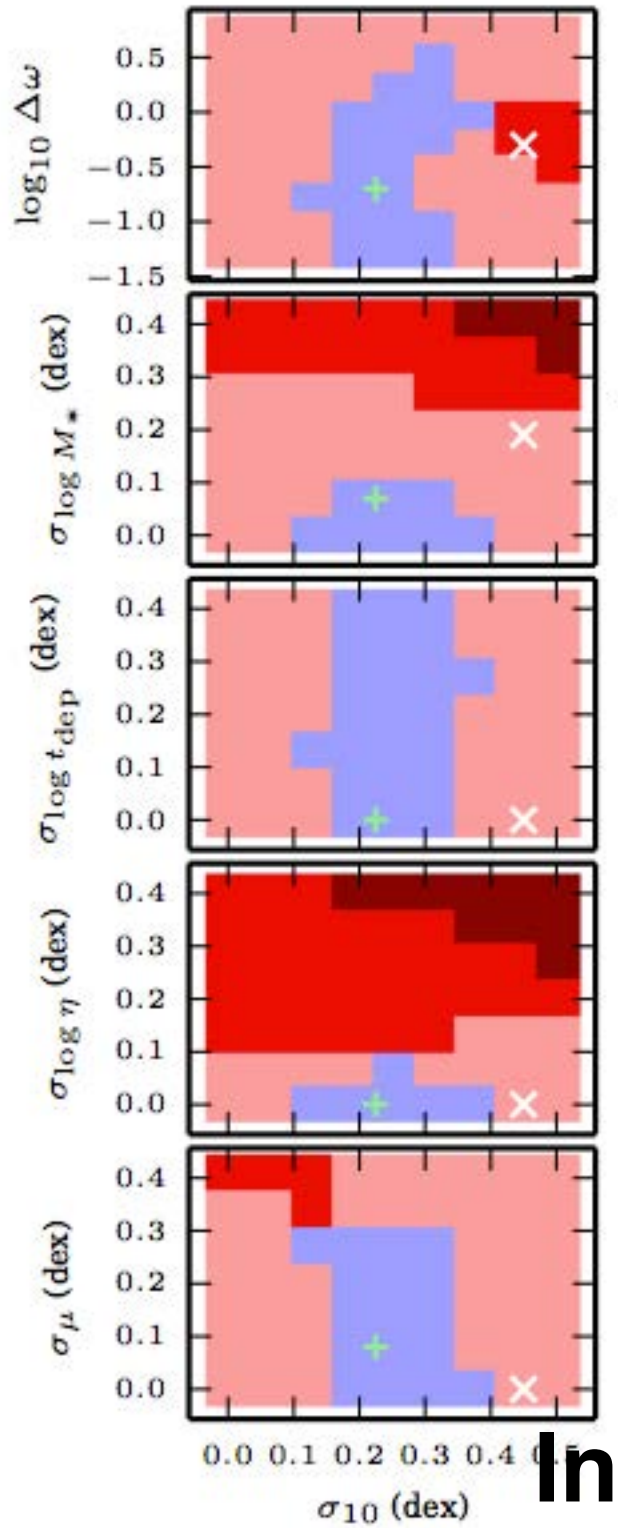
Coherence

M*

Depletion

Mass loading

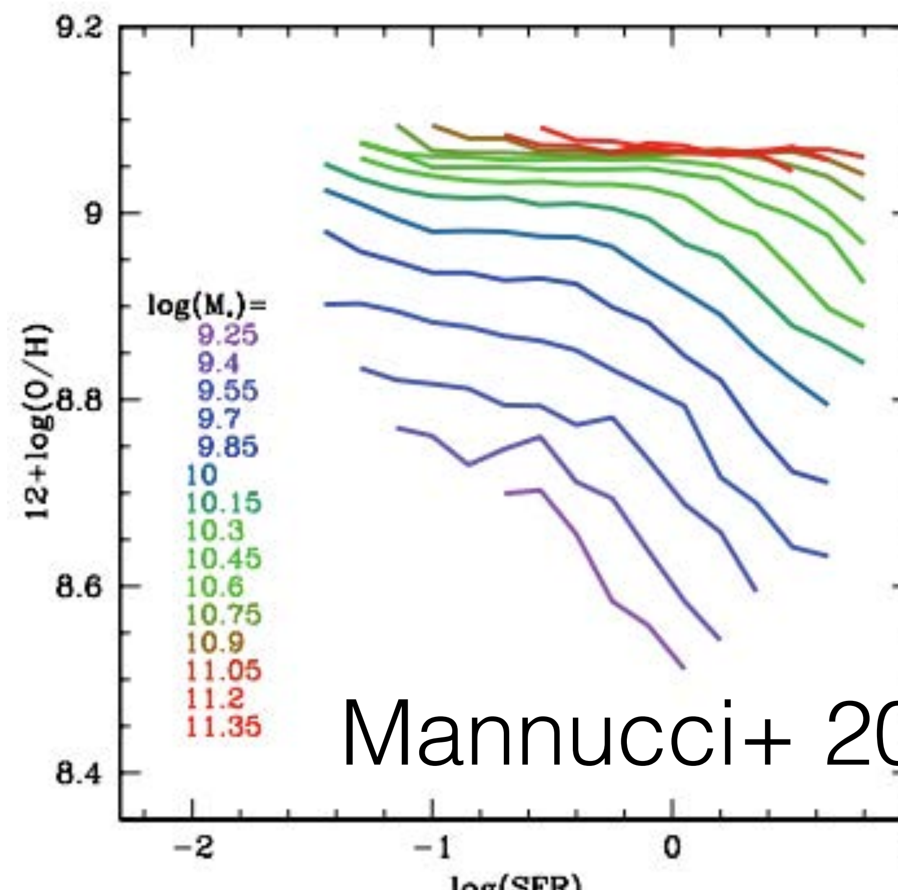
Median Accretion



Intrinsic Scatter

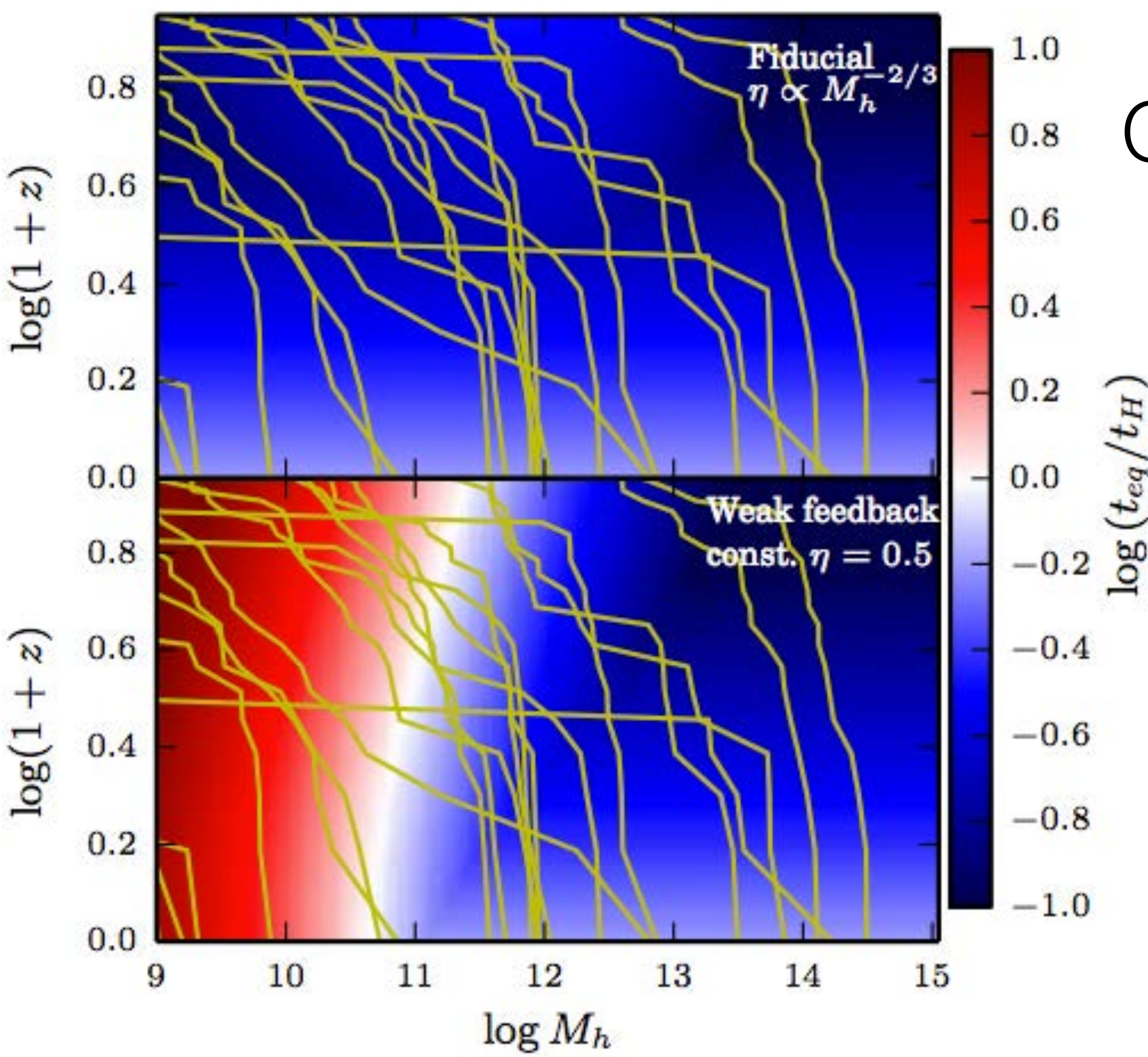
$$Z_{eq} = Z_{IGM} + q = Z_{IGM} + \frac{y f_R}{f_R + \eta}$$

$$\dot{M}_{\mathrm{SF},eq} = \dot{M}_{\mathrm{ext}} / (\eta + f_R)$$



Mannucci+ 2010

Where is this model a reasonable approximation?



Out of equilibrium

In equilibrium

$$t_{\rm loss} = \frac{t_{\rm dep}}{f_R + \eta}$$

Summary

- Including a realistic scatter in the accretion rate produces substantial, even too much, scatter in the scaling relations.
- The scatter in mass loading factor at fixed mass must be small.
- The scatter in the accretion rate of baryons may be smaller than that of the DM.
- Measuring/predicting the MLF is fundamental for understanding the nature of galaxies.