Central quenching of galaxies via shutoff of gravitational instability

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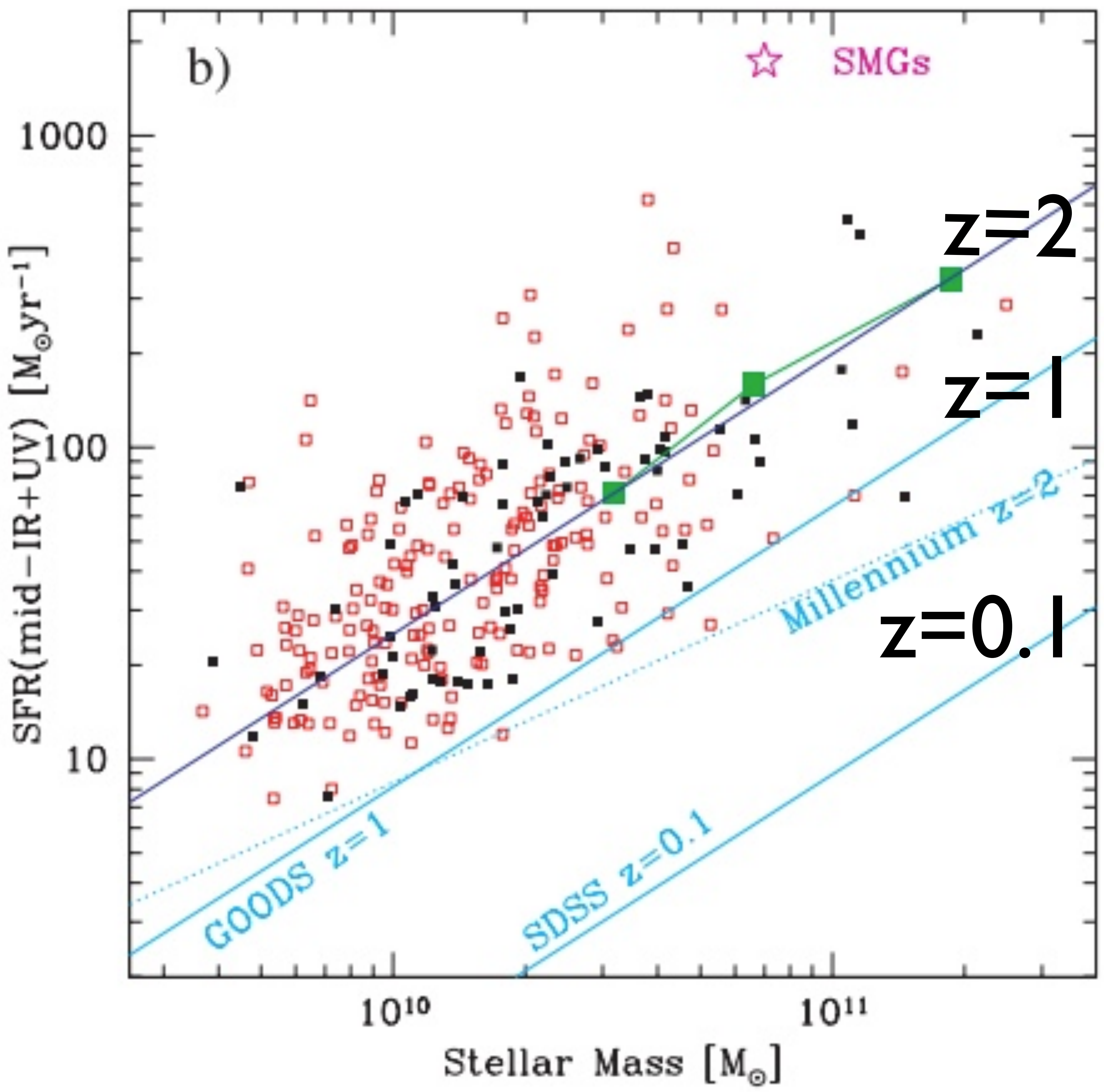
UCSC Galaxy Workshop - August 13, 2013

with Mark Krumholz, Andreas Burkert, Avishai Dekel

The more galaxies change the more they stay the same

- SFR 20x higher
- Giant clumps
- Large gas fractions
- Velocity dispersion 5-10x larger



Daddi+ '07

Some simple questions

- How do galaxies make the transition?
- What physical processes are important where?

A 1-D Disk Model

$$\frac{\partial \Sigma}{\partial t} = \frac{1}{2\pi r}\frac{\partial}{\partial r}\dot{M} - (f_R + \mu)\dot{\Sigma}_*^{SF} + \dot{\Sigma}_{cos}$$

Mass

$$\frac{\partial \sigma}{\partial t} = \frac{\mathcal{G} - \mathcal{L}}{3\sigma\Sigma} + \frac{\sigma}{6\pi r\Sigma}\frac{\partial}{\partial r}\dot{M} + \frac{5(\partial\sigma/\partial r)}{6\pi r\Sigma}\dot{M} + \frac{(\beta - 1)v_\phi}{6\pi r^3\Sigma\sigma}\mathcal{T}$$

Energy

$$\dot{\Sigma}_*^{SF} = \max\left(\epsilon_{\mathrm{ff}} f_{\mathrm{H}_2}\Sigma\kappa\frac{\sqrt{32/3}}{Q_g\pi}\left(1 + \frac{\sigma\Sigma_*}{\sigma_{zz}\Sigma}\right)^{1/2},\ f_{\mathrm{H}_2}\frac{\Sigma}{t_{SC}}\right)$$

Star formation

$$\frac{\partial M_Z}{\partial t} = \Delta r\frac{\partial \dot{M}Z}{\partial r} + (yf_R - f_R Z - \mu Z_w)\dot{M}_*^{SF} + \dot{M}_{acc}Z_{IGM} + \frac{\partial}{\partial r}\kappa_Z\frac{\partial}{\partial r}M_Z.$$

Metals

Radiative Dissipation

$$\mathcal{L} = \eta\Sigma\sigma^2\kappa Q_g^{-1}\left(1 + \frac{\sigma\Sigma_*}{\sigma_{zz}\Sigma}\right)\left(1 - \frac{\sigma_{th}^2}{\sigma^2}\right)^{3/2}$$

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Viscous Terms:

Set by gravitational instability

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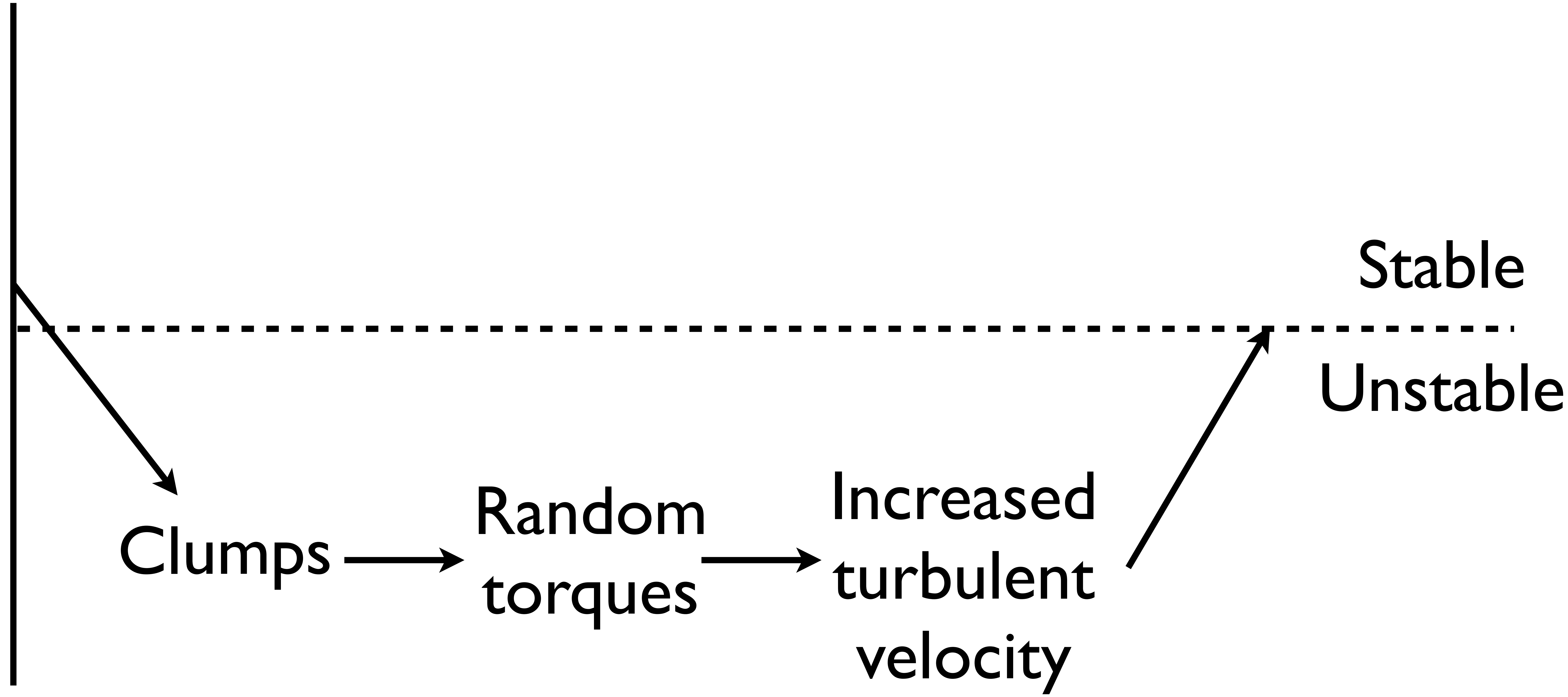
The viscous terms are set by

$$Q \sim \frac{\Omega\sigma}{\pi G \Sigma}$$



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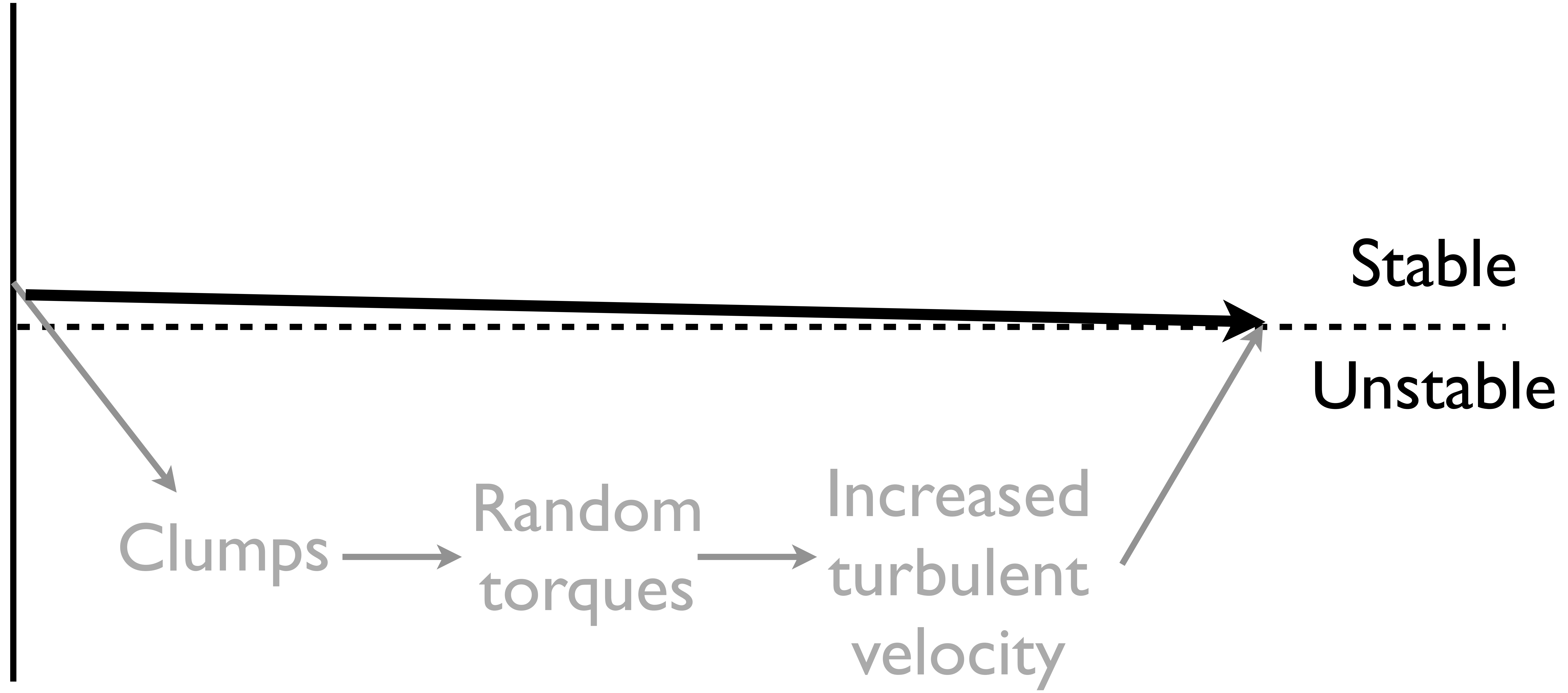
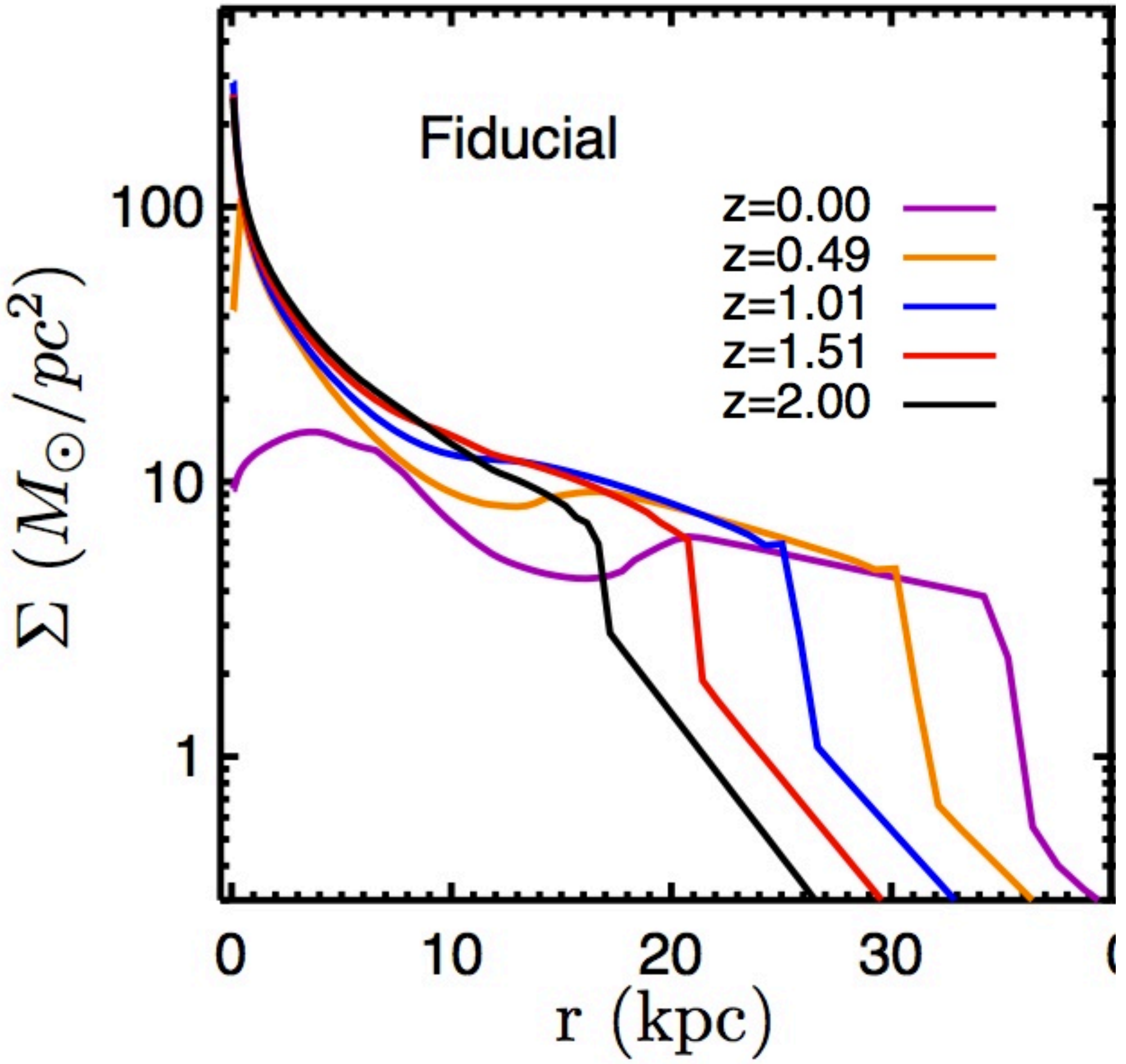


Here's the fiducial model



What sets the surface density?

$$\frac{\partial \Sigma}{\partial t} = \frac{1}{2\pi r}\frac{\partial}{\partial r}\dot{M} - (f_R + \mu)\dot{\Sigma}_*^{SF} + \dot{\Sigma}_{cos}$$

Transport SF+wind Cos. Accr.

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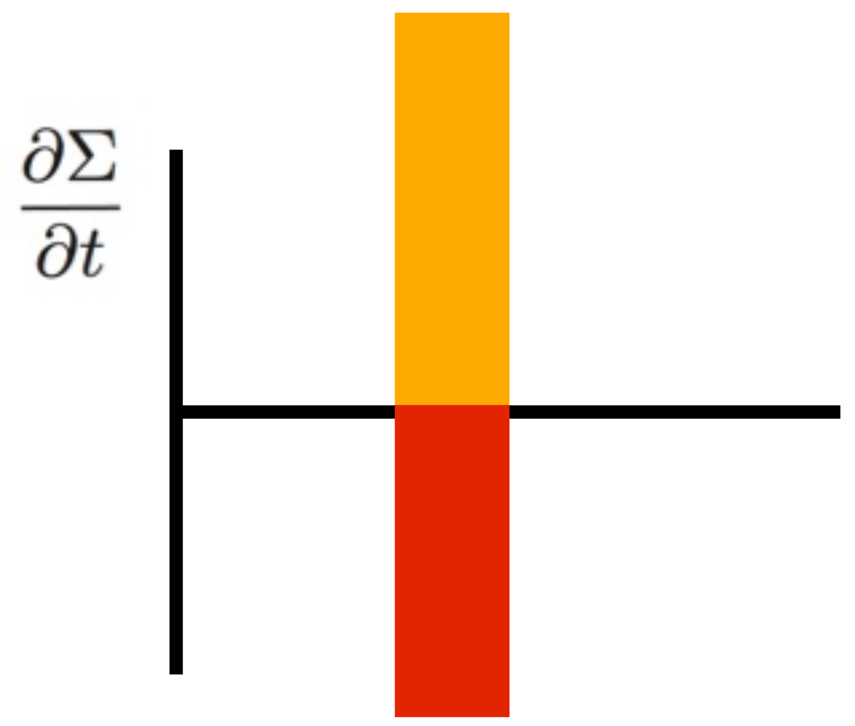

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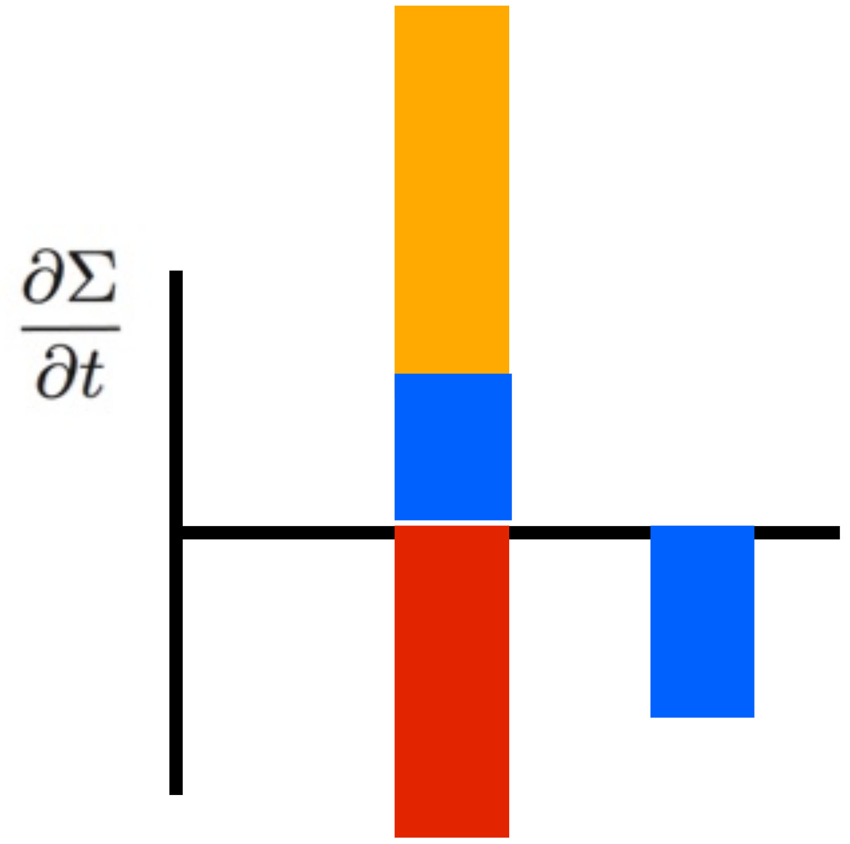
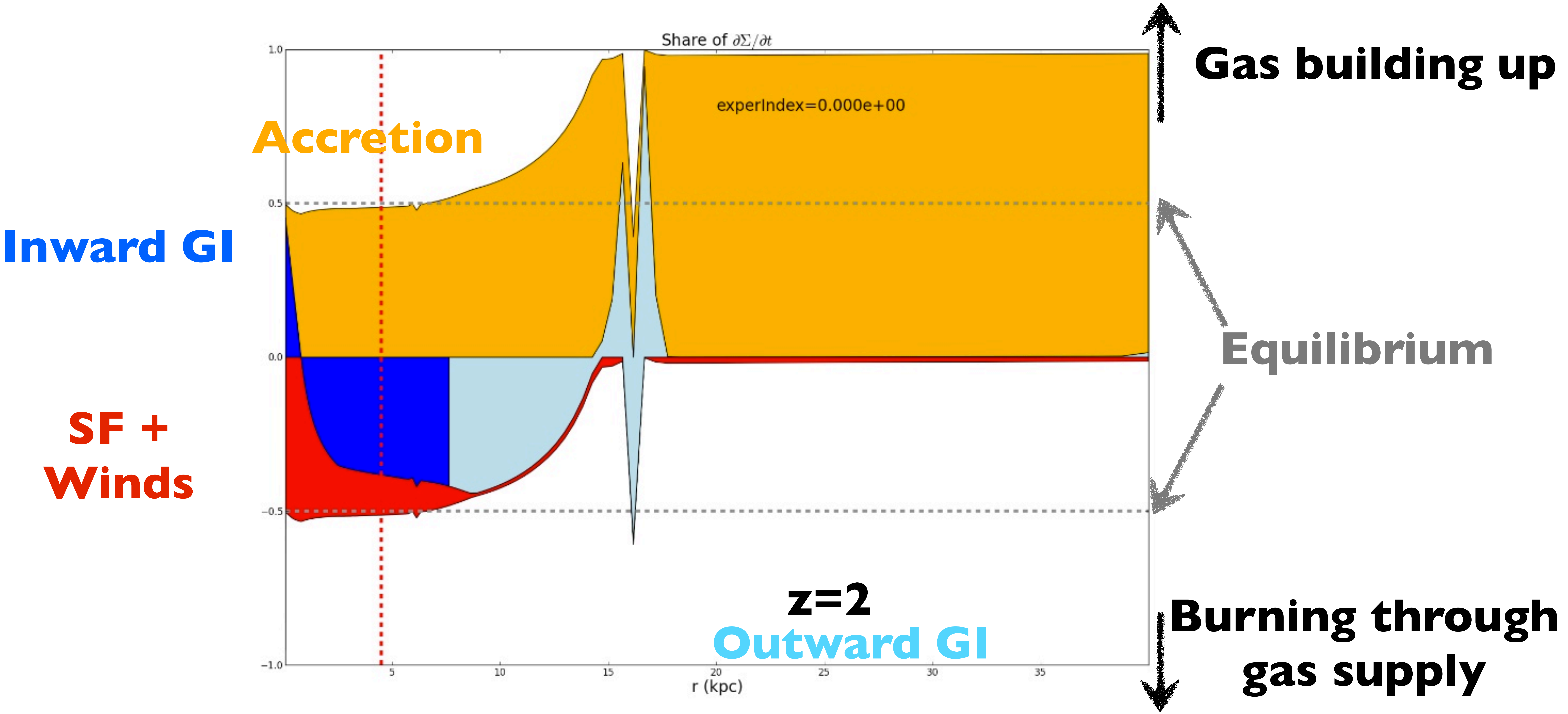


Evolving equilibrium among the terms in continuity eqn.



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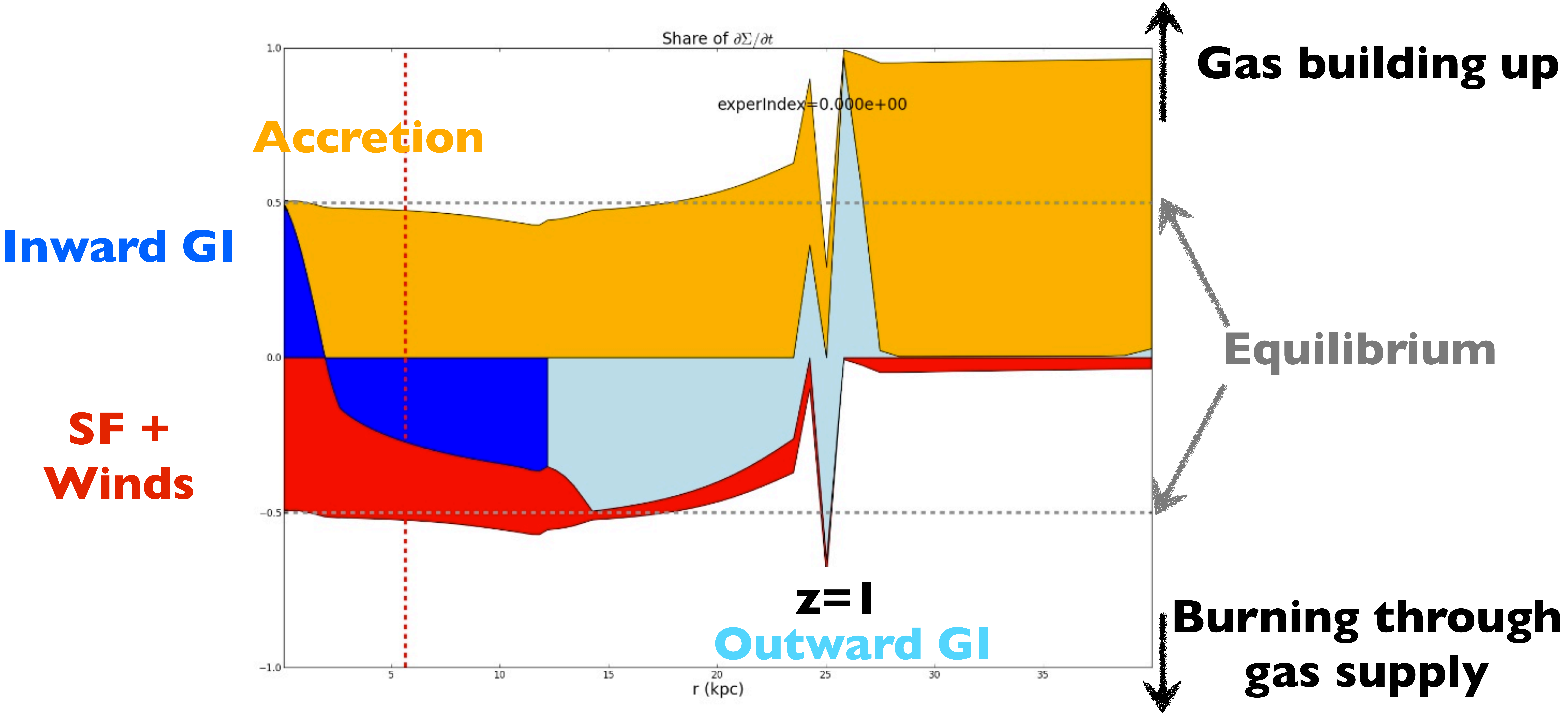

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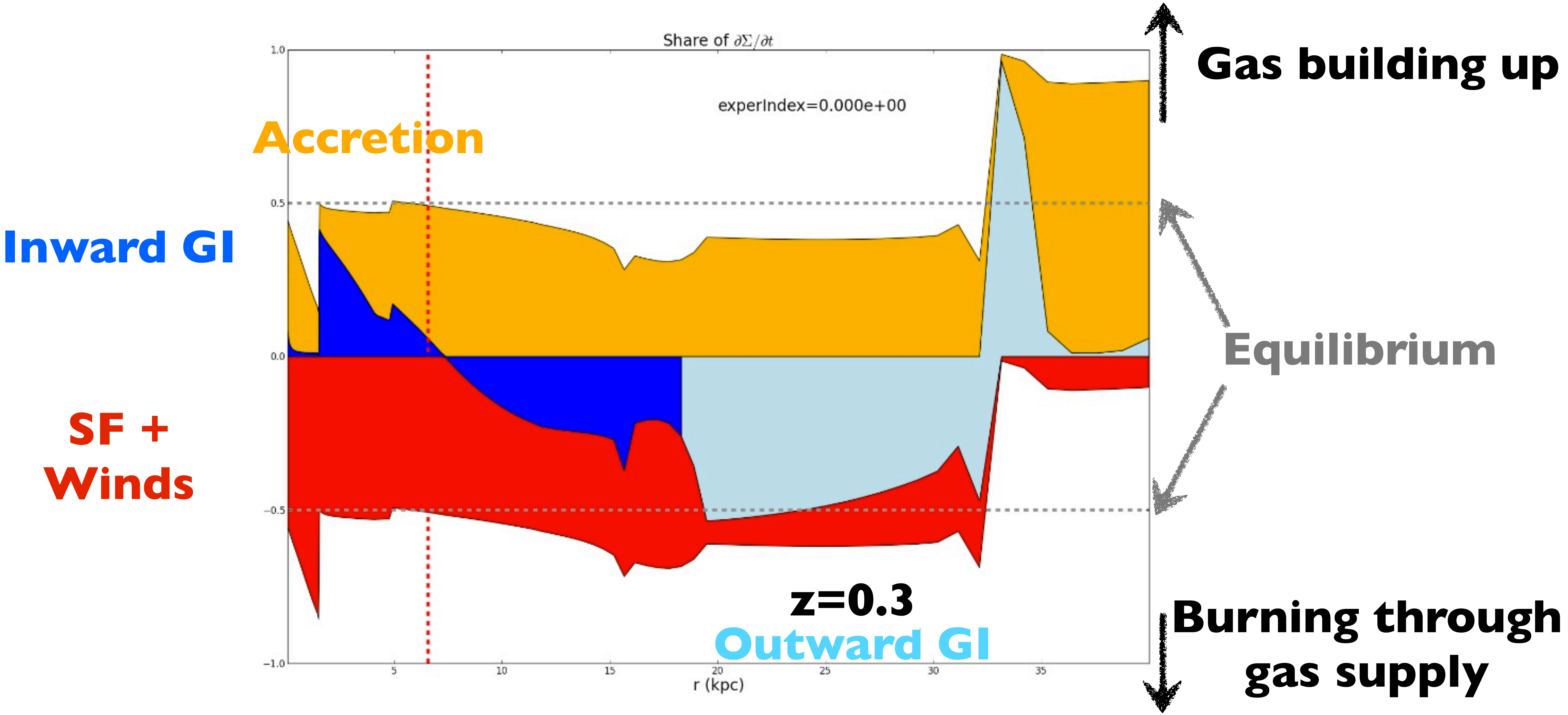

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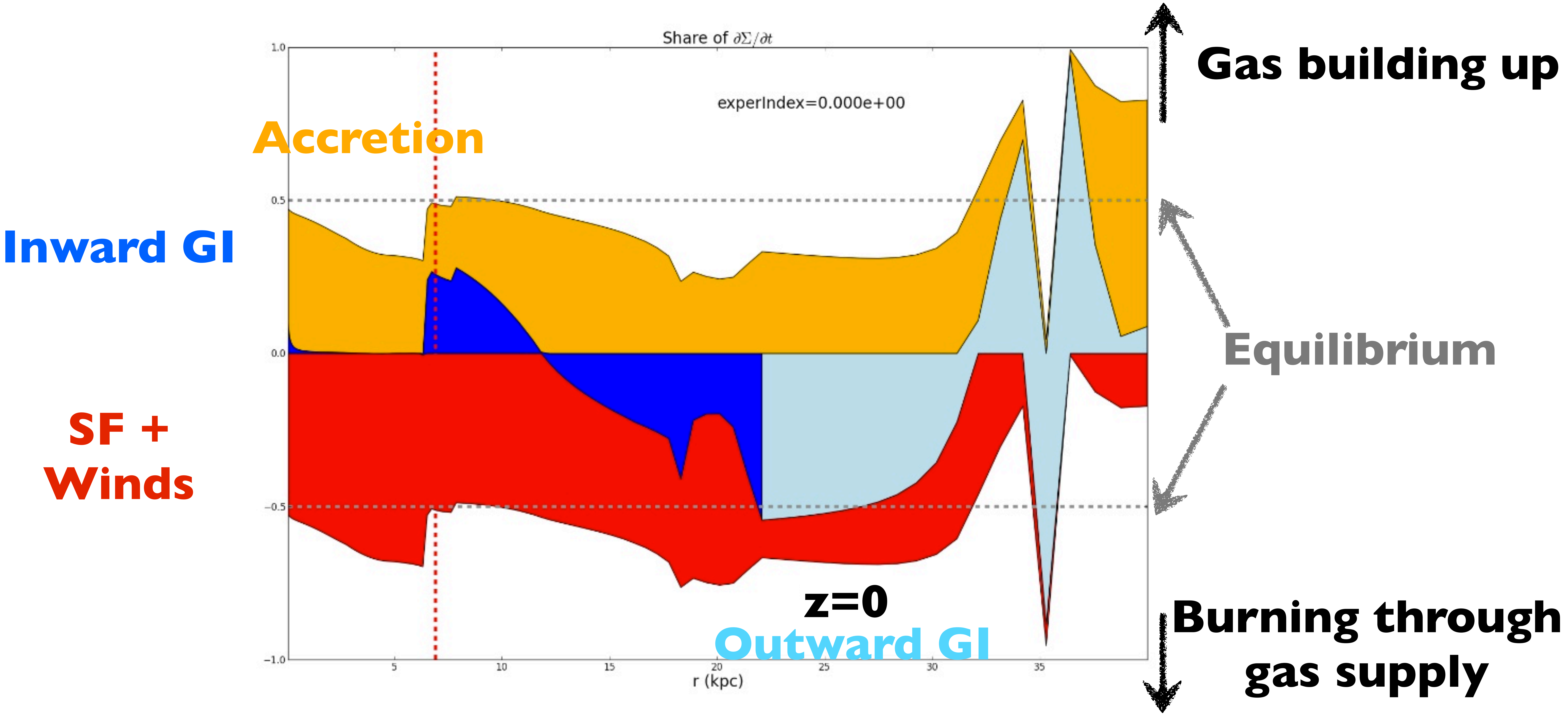
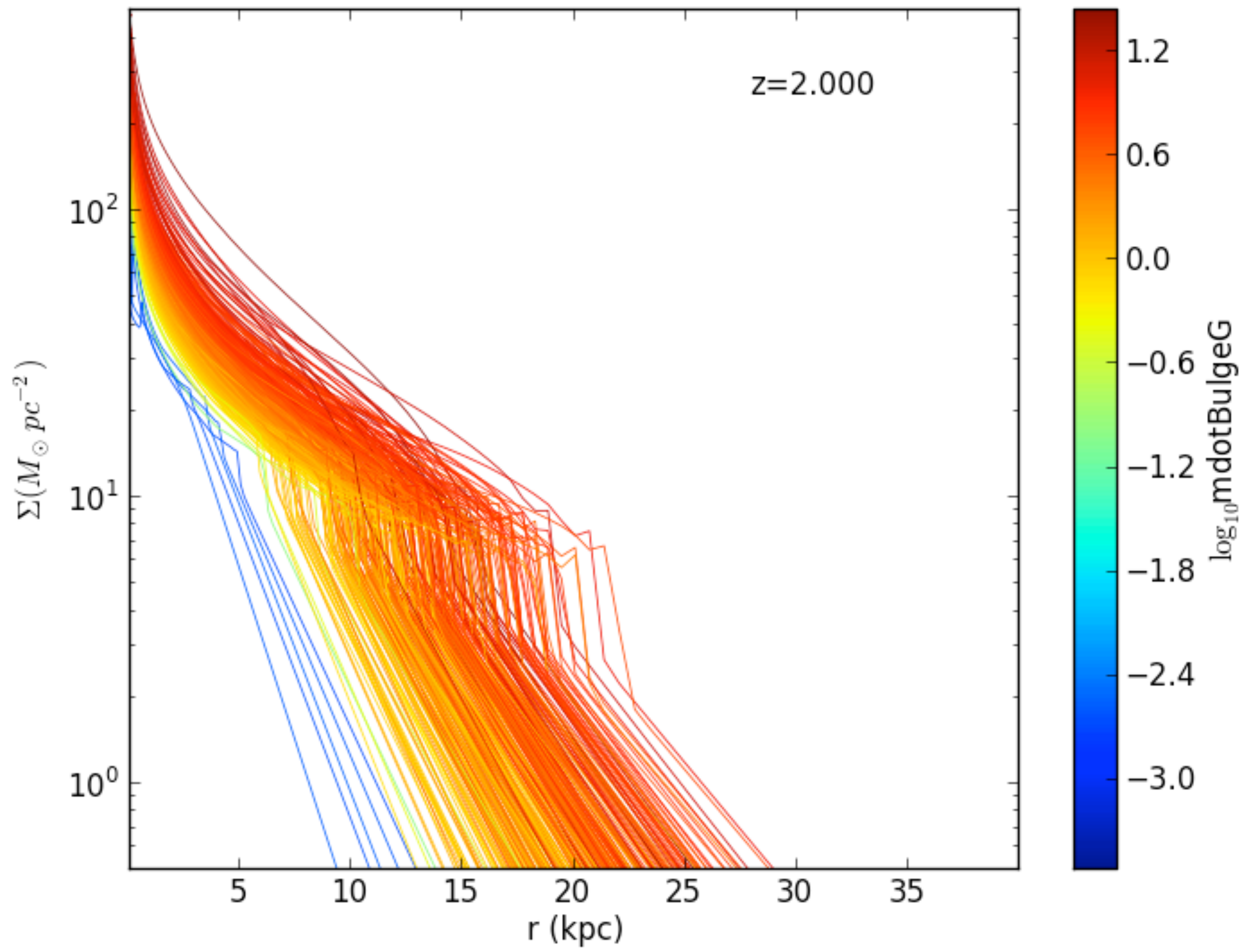
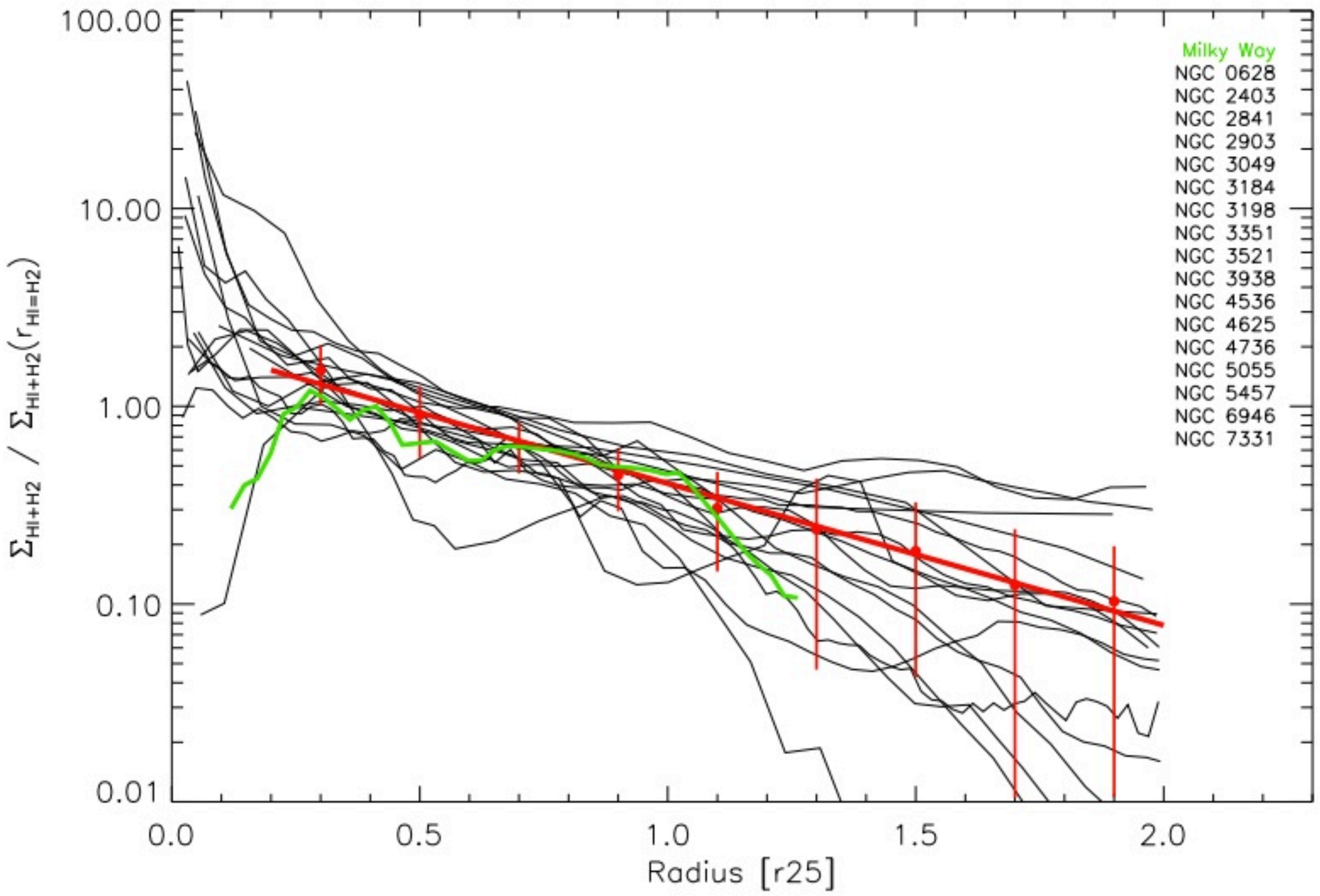


Including stochastic accretion





Bigiel and Blitz (2012)

GI Quenching vs MQ

All inflowing gas consumed by SF → Inner gas reservoir no longer supplied → Inner gas reservoir depleted by SF → Q increases / SFR falls

GI Quenching (Forbes+ 2013)

Morphological Quenching (Martig+ 2009)

Merger → Bulge forms → Q increases → Fewer bound star-forming clumps → SFR falls

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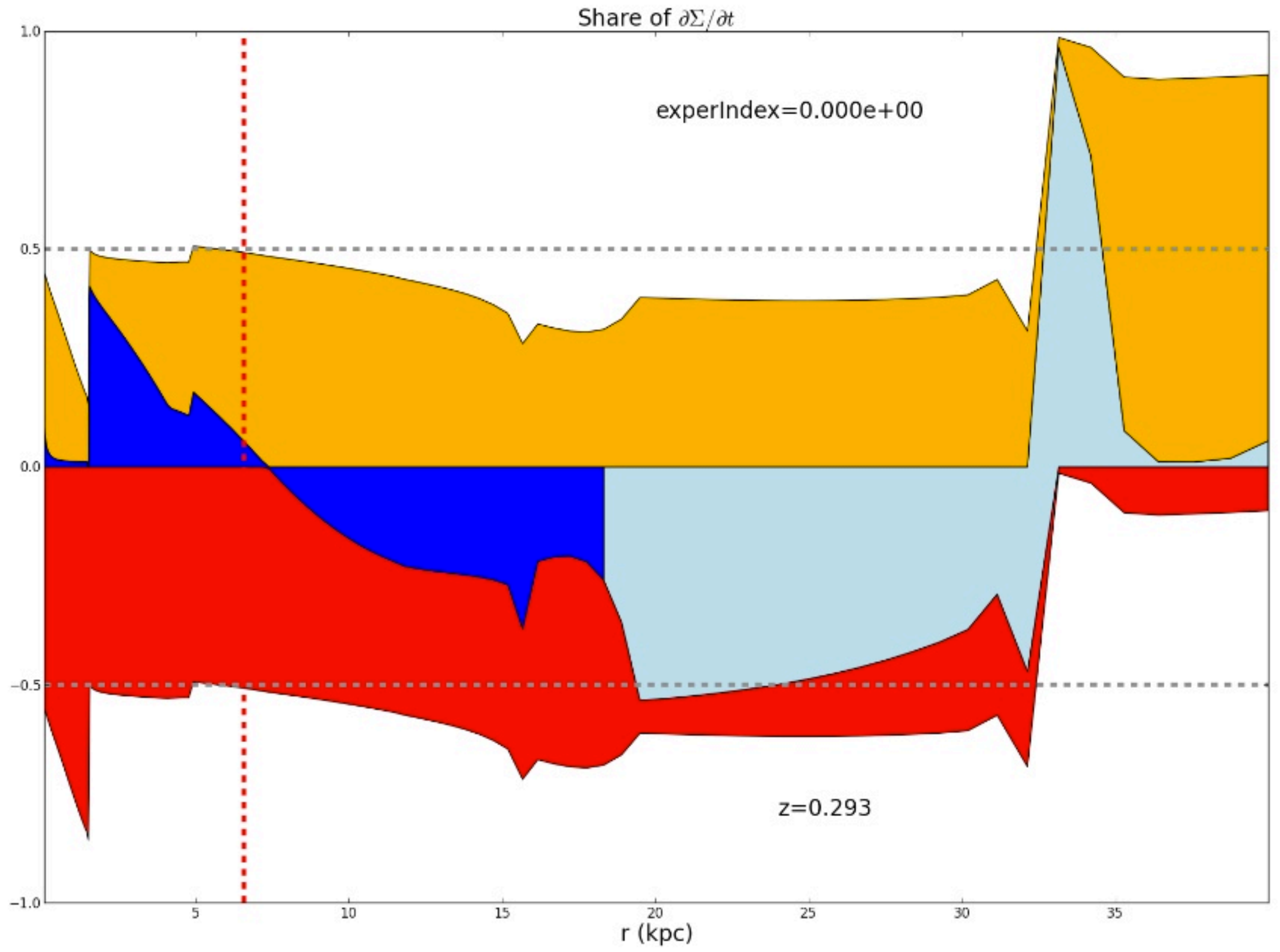
Summary

- Galaxies tend toward equilibrium, not only globally, but locally.
- The inner regions of galaxies can be
    - Supplied by gravitational instability
    - Quenched when it shuts off



- For more, see Forbes et al (2013) -- arXiv:1305.2925