Momentum Driven AGN Feedback In Galaxy Merger Simulations

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Introduction

- Observations suggest BH-Galaxy evolution link
- Feedback invoked as explanation
- Previous work uses largely similar models
  - Springel et al. 2005
  - Kazantzidis et al. 2005
  - Johannson et al. 2009
  - Booth & Schaye 2009
- Can simulation constrain AGN feedback physics?

Method

- Perform major mergers implementing new feedback model
  - Accretion via angular momentum transport
  - Feedback via radiation pressure
- Tree-SPH Gadget-3
  - Includes star formation model of Springel & Hernquist 2003
  - Added BH growth and feedback

DeBuhr, Quataert, Ma, Hopkins 2010, MNRAS, 406, L55
DeBuhr, Quataert, Ma 2010, arXiv:1006.3312

Model: Accretion

$$\dot{M} = 3\pi\alpha\Sigma\frac{c_s^2}{\Omega}$$

- Accretion via angular momentum transport
  - Bondi rate physically inappropriate
- Accretion radius R_{acc} ~ 188pc
  - Volume average of SPH particle properties
- α ~ 0.05

Model: Feedback

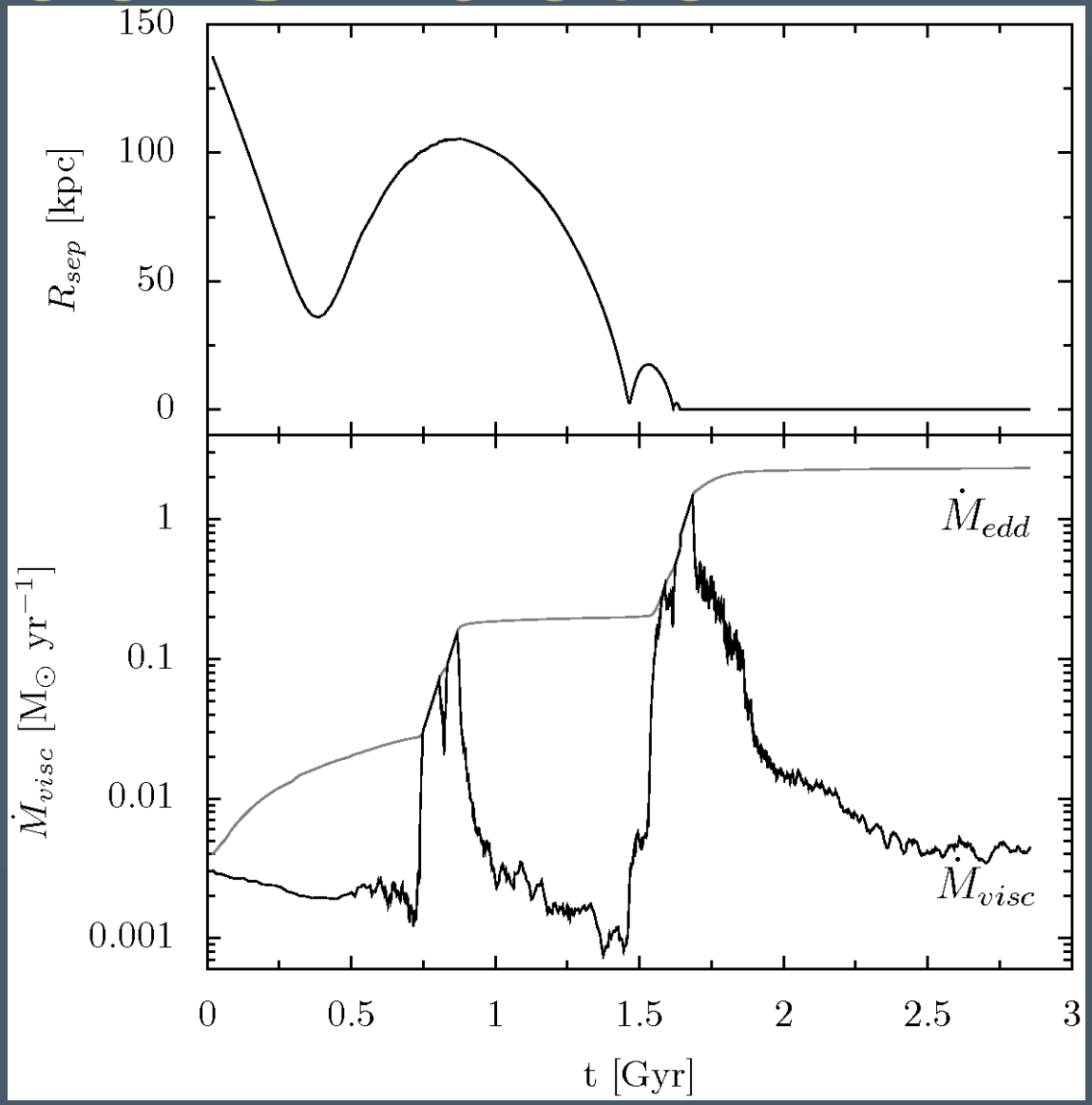
$$\dot{p} = \frac{\tau}{c} \min\left(L_{edd}, \eta \dot{M} c^2\right)$$

- Feedback via radiation pressure
- Applied inside R_{acc}
- Directed radially outward
- $\tau \sim 10$, IR optical depth

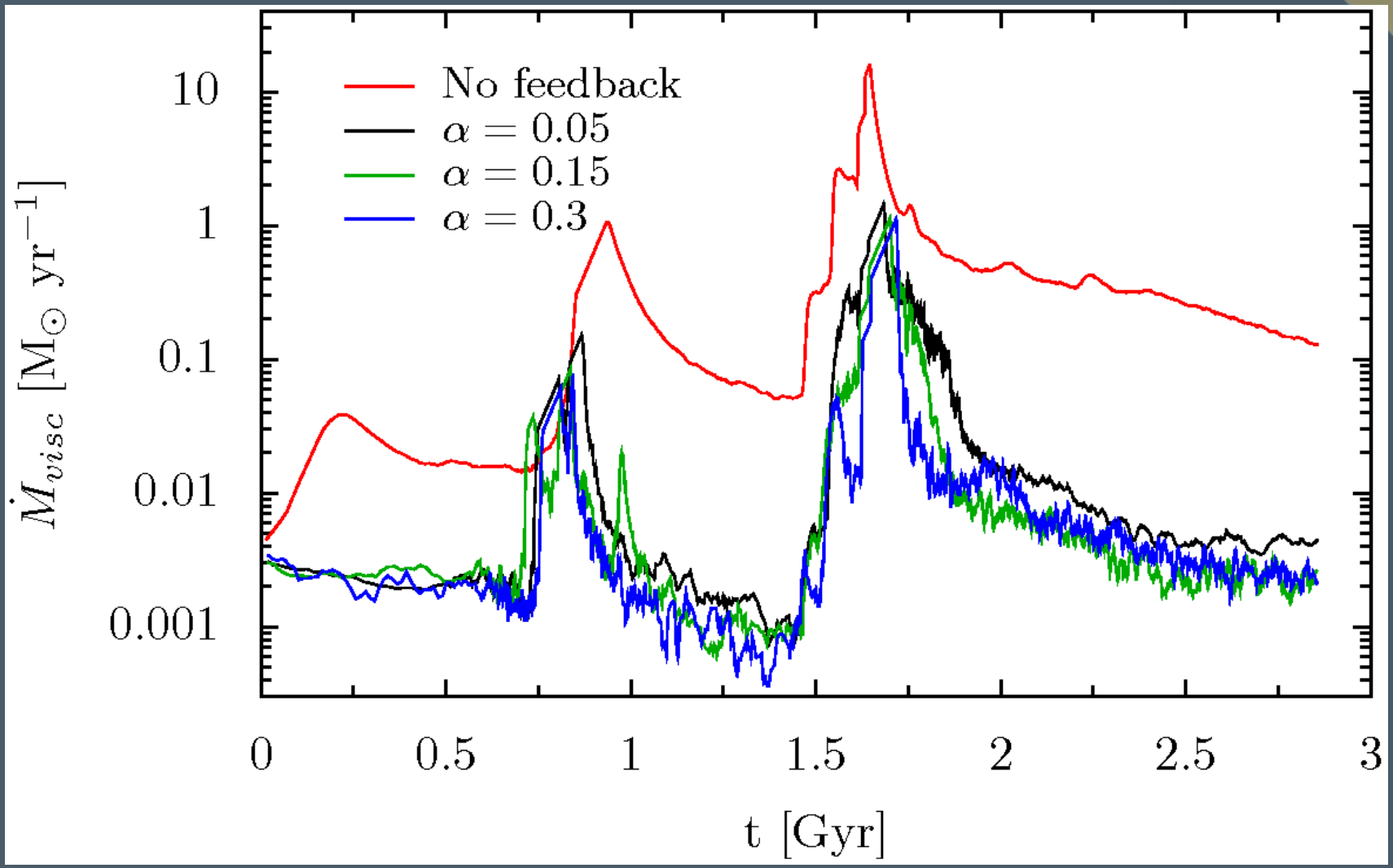
Simulations

- Fiducial Galaxy
  - $M_{gal} = 5x10^{10}\ M_{\odot}$, $f_g = 0.1$
  - R_d=3.5kpc, Z_0 = 0.71kpc
- Orbit
  - Parabolic, prograde
  - r_i = 142 kpc, r_{peri} = 14.2 kpc
- Model parameters
  - $\alpha = 0.05$, $\tau = 10$, R_{acc} = 188 pc
- Varied model and galaxies

Fiducial Simulation



Self-Regulation



Self-Regulation

- Balance gravity and feedback

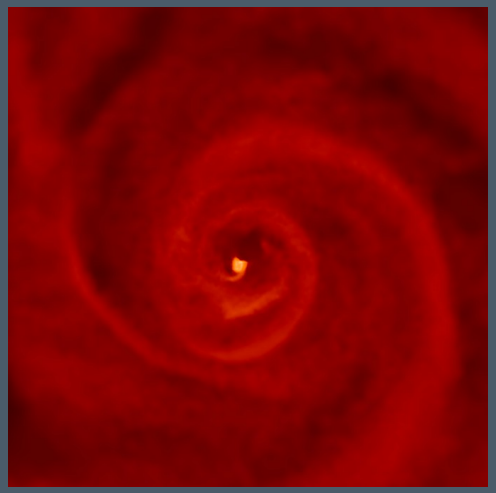
$$\tau \frac{L}{c} = \frac{GMM_g}{R^2}$$

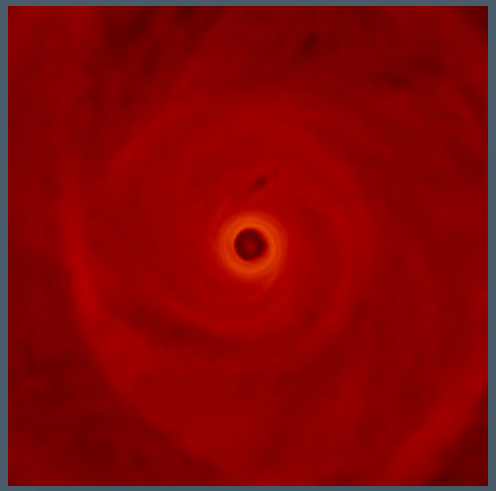
with $$\sigma^2 = \frac{GM}{2R}$$

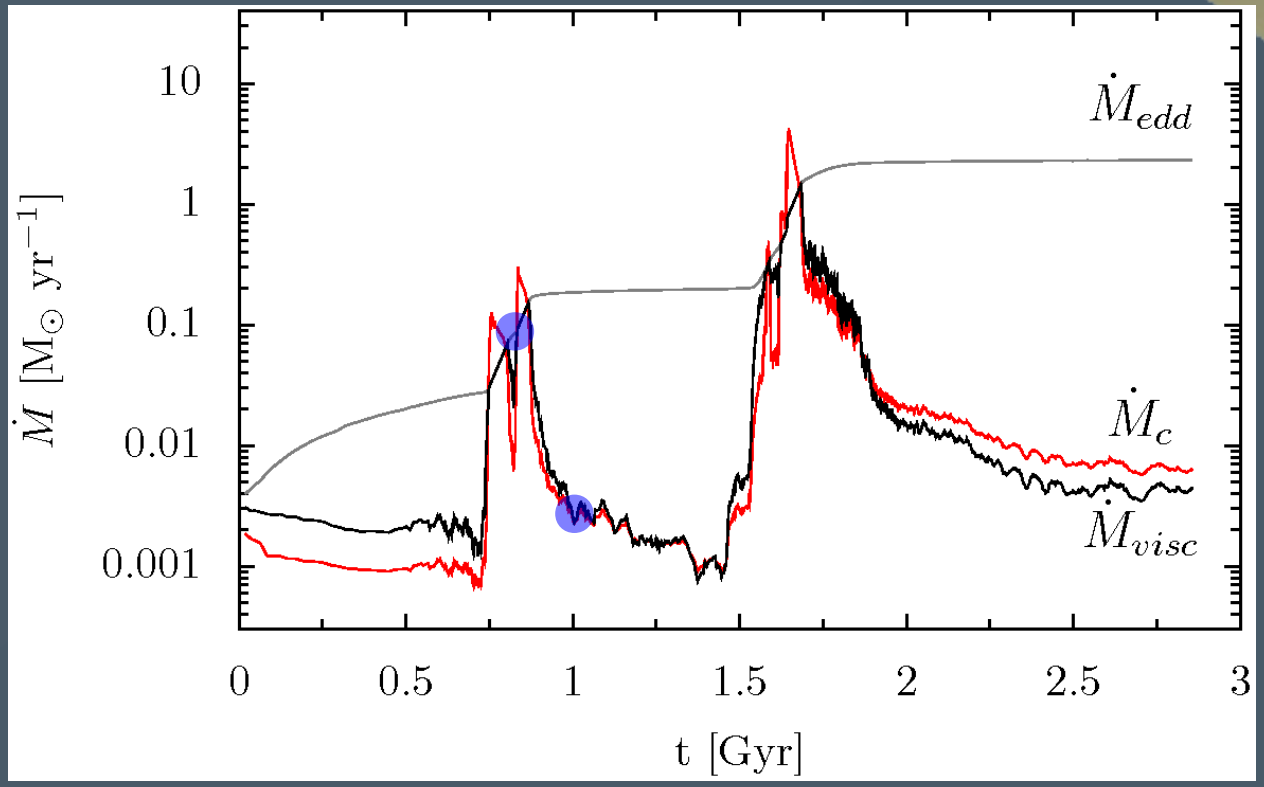
$$\dot{M}_{crit} = \frac{4 f_g}{\tau \eta c G} \sigma^4$$

- Independent of α

Self-Regulation



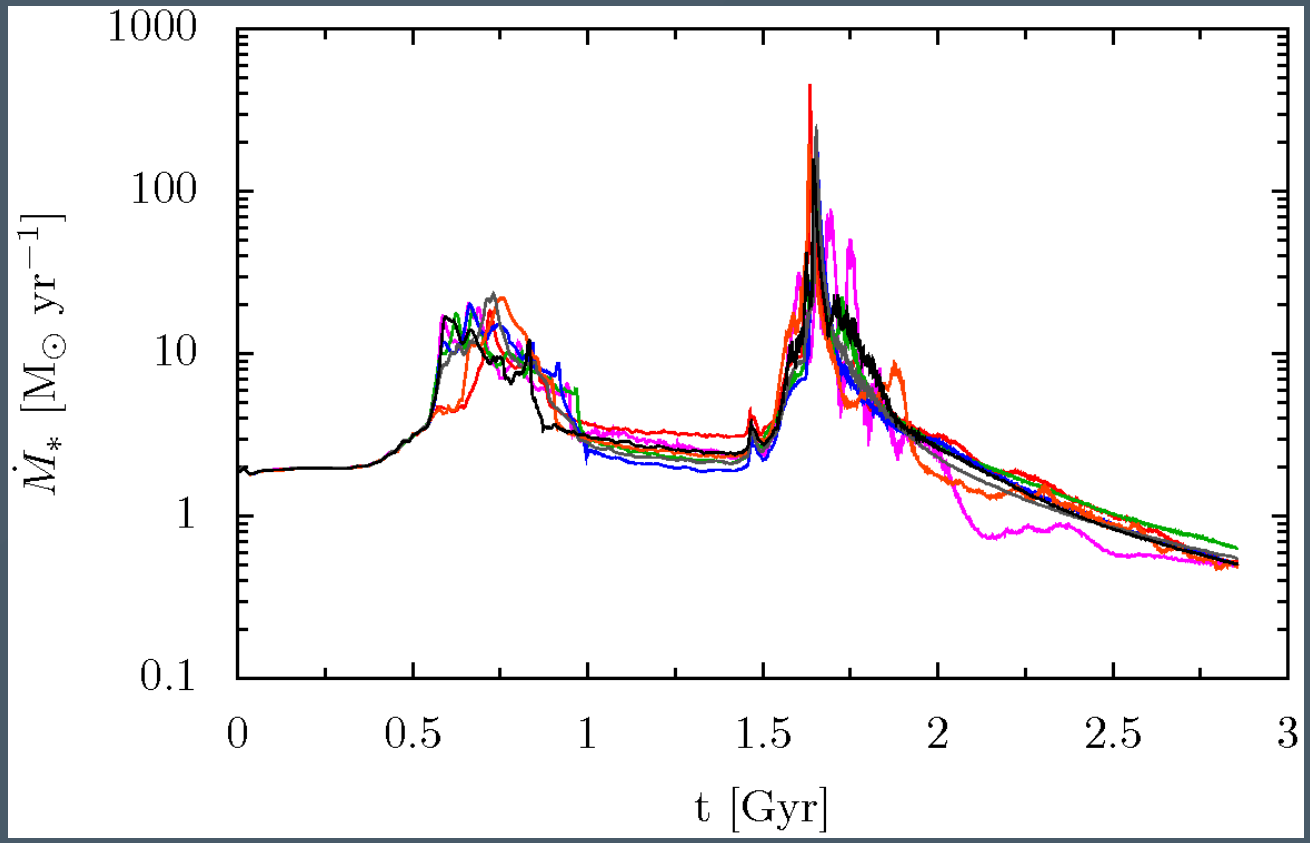




- Feedback clears R_{acc}
- $\dot{M}$ approaches $\dot{M}_{crit}$

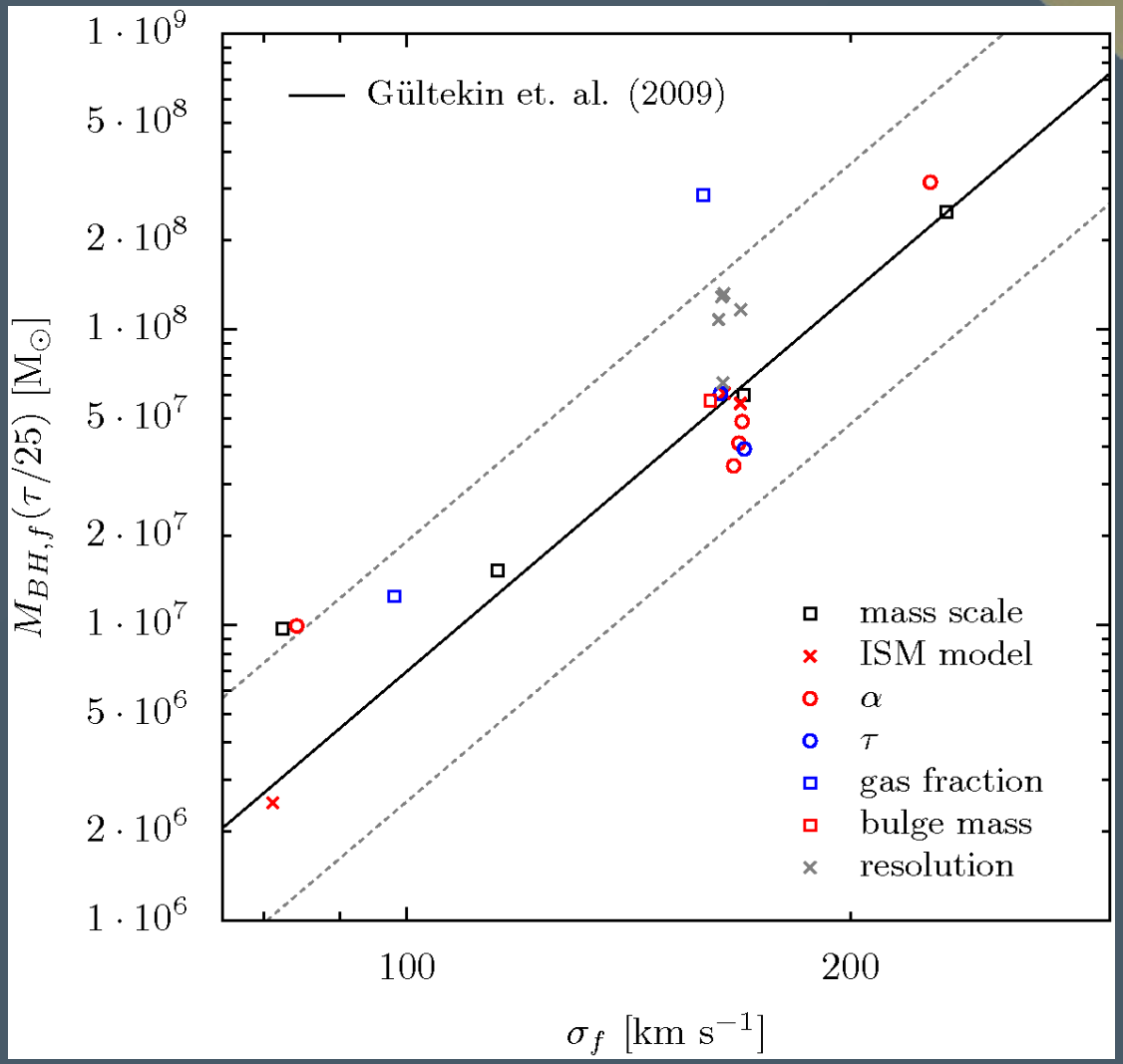
Other Results

- Robust SF and M_{BH} with parameter variation
- Little gas blow-out



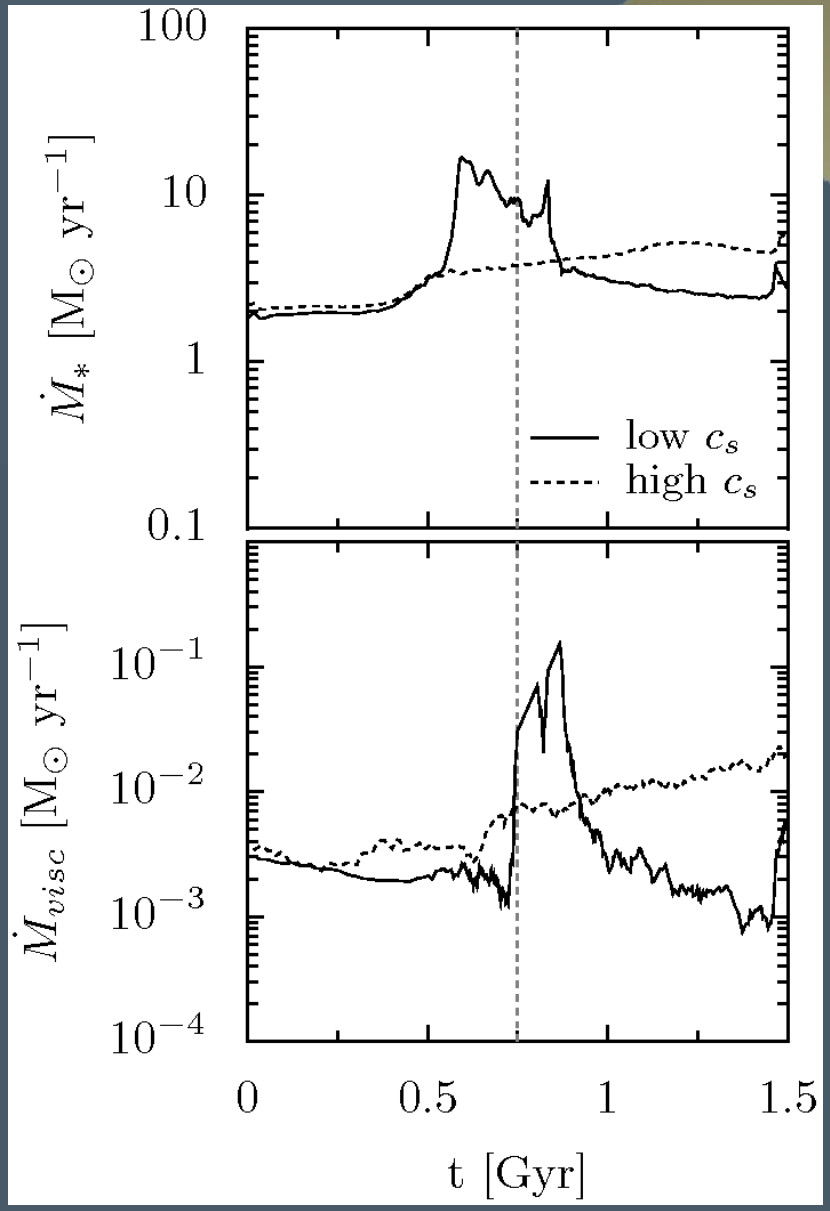
M-σ Relation

- σ_{LOS}
- Median of 1000 sight lines
- Scaled to τ=25
- Flattening at low mass (tentative)



ISM Modeling

- SH03 c_s too high
  - Reduce P by ~ 10
- After first passage
  - Lower c_s gas fragments
  - Dense SF knots spiral into center
- Highlights importance of ISM modeling
  - See also Teyssier et al. 2010



Summary

- Robust integrated quantities
  - M_*, M_{BH}
- Model can match observed M_{BH}-σ
  - Requires high optical depth
  - Suggests additional feedback modes required
- Next steps
  - Use improved fueling model
  - Improve radiation transport
  - Connect with detailed simulations of central region