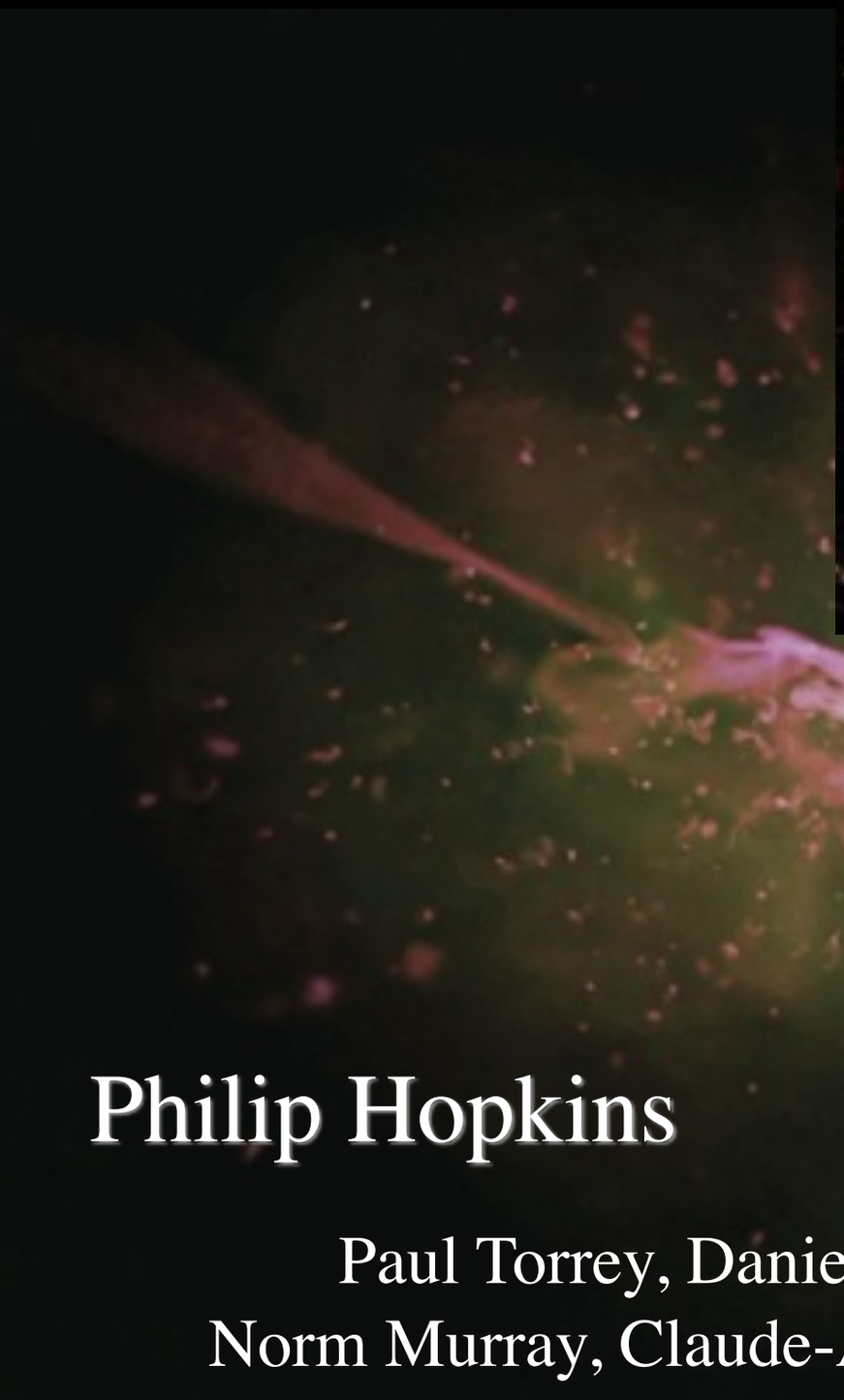
How Does Gas Get to Black Holes?



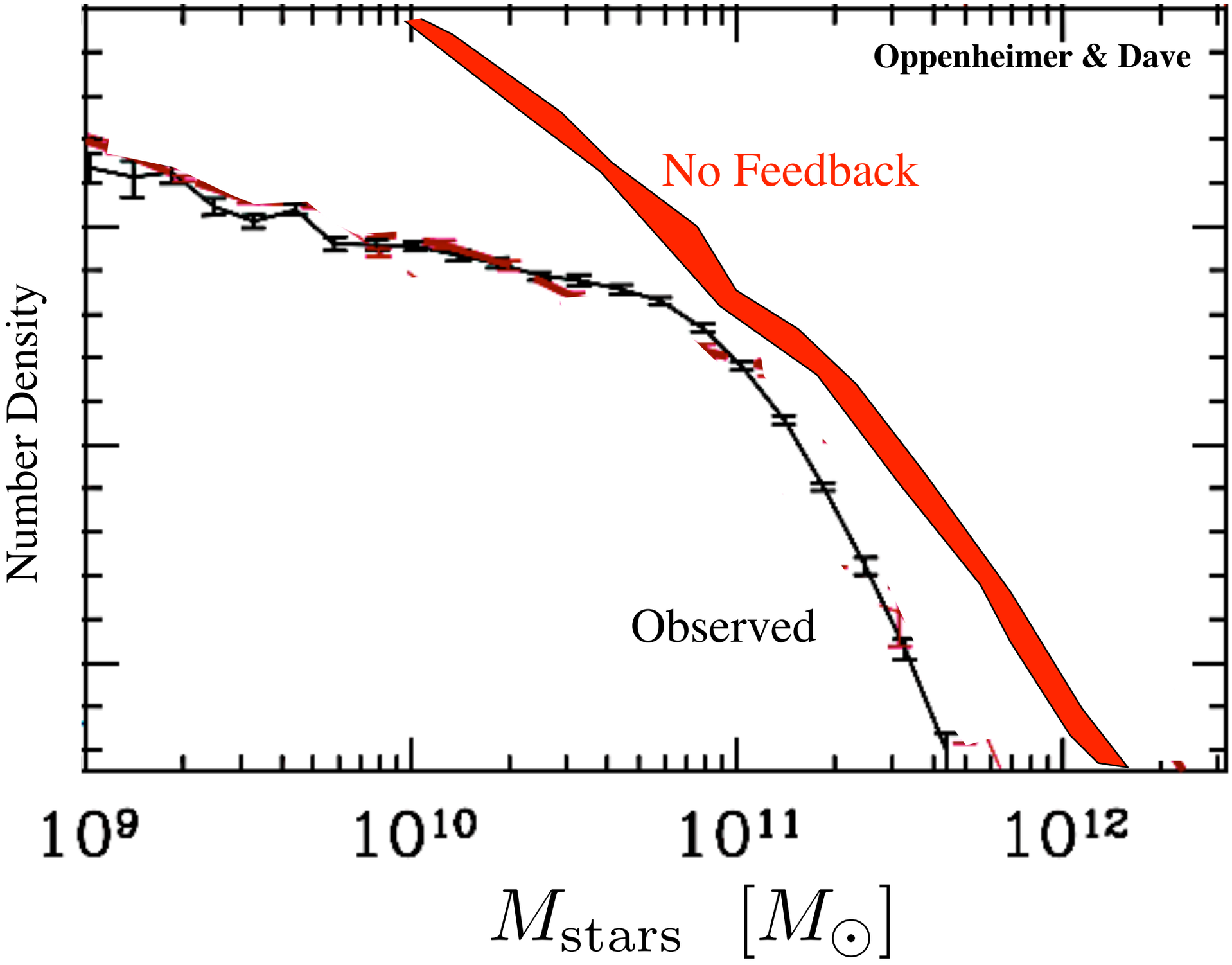
Philip Hopkins

Caltech

Paul Torrey, Daniel Angles-Alcazar, Dale Kocevski, Kevin Bundy,
Norm Murray, Claude-Andre Faucher-Giguere, Dusan Keres, Eliot Quataert

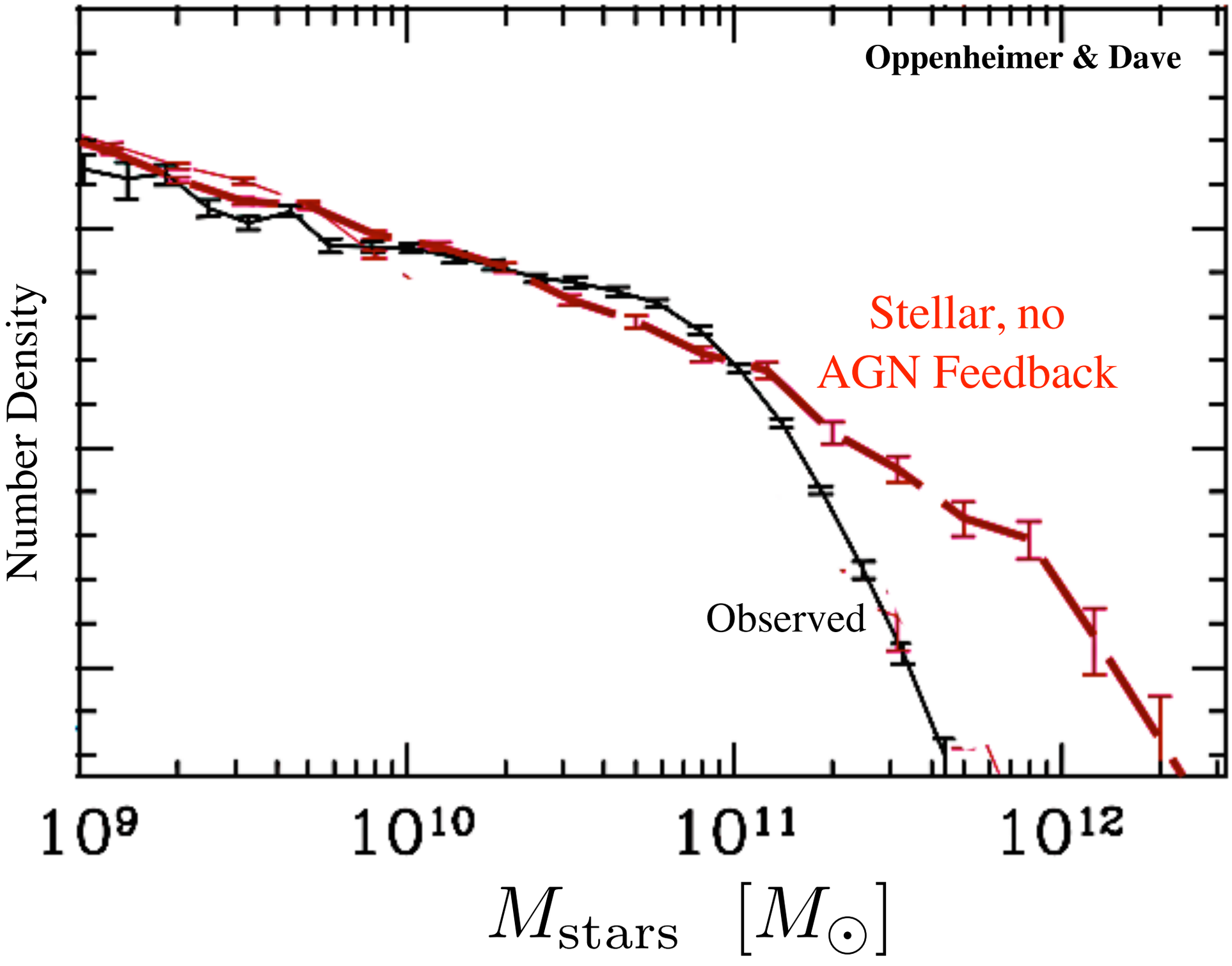
The Need for AGN Feedback

NEED TO SUPPRESS STAR FORMATION IN MASSIVE GALAXIES



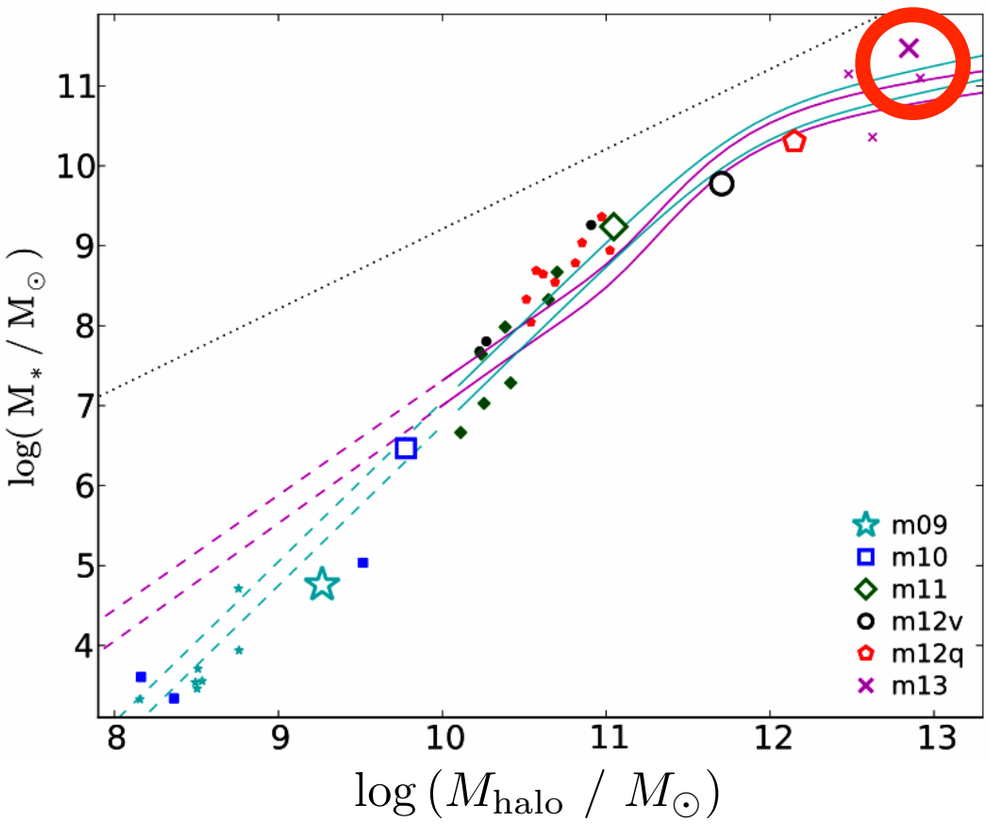
The Need for AGN Feedback

FEEDBACK FROM STARS IS NOT ENOUGH



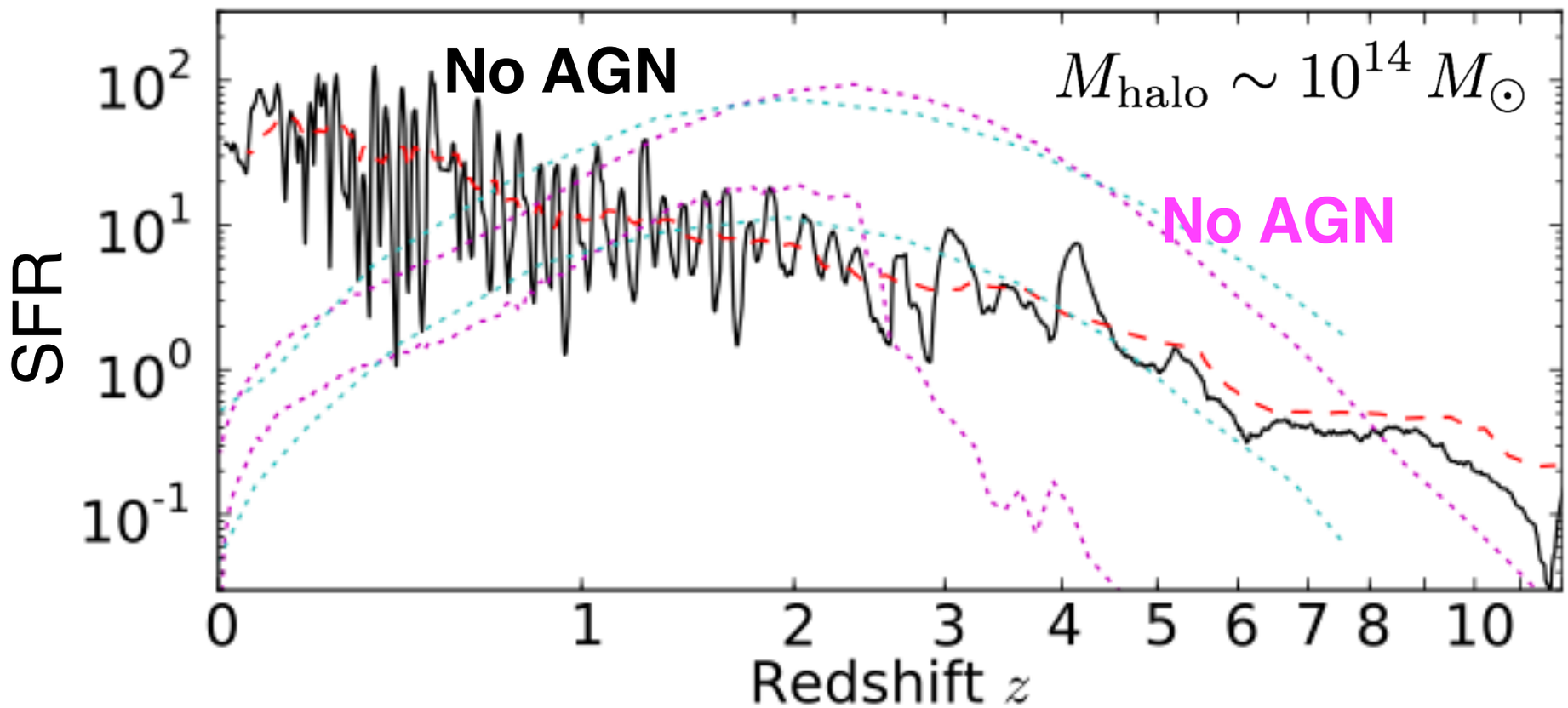
The Need for AGN Feedback

FEEDBACK FROM STARS IS NOT ENOUGH



- **Include:**
  - Stellar feedback (including AGBs & Ia's)
  - "Gravitational" heating (clumps, shocks)
  - MHD & conduction

Still no quenching!



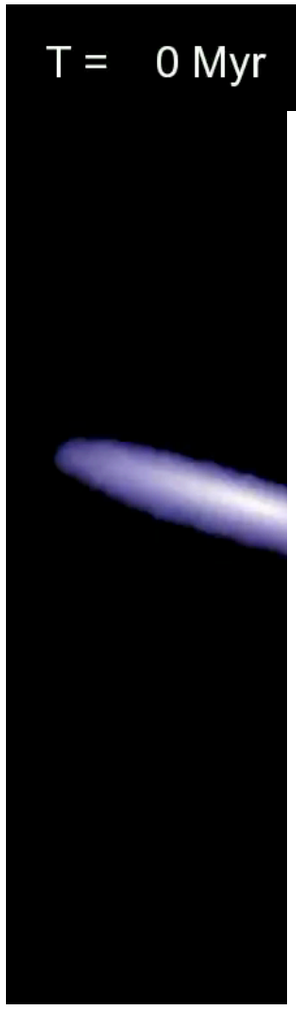
Robert Feldmann

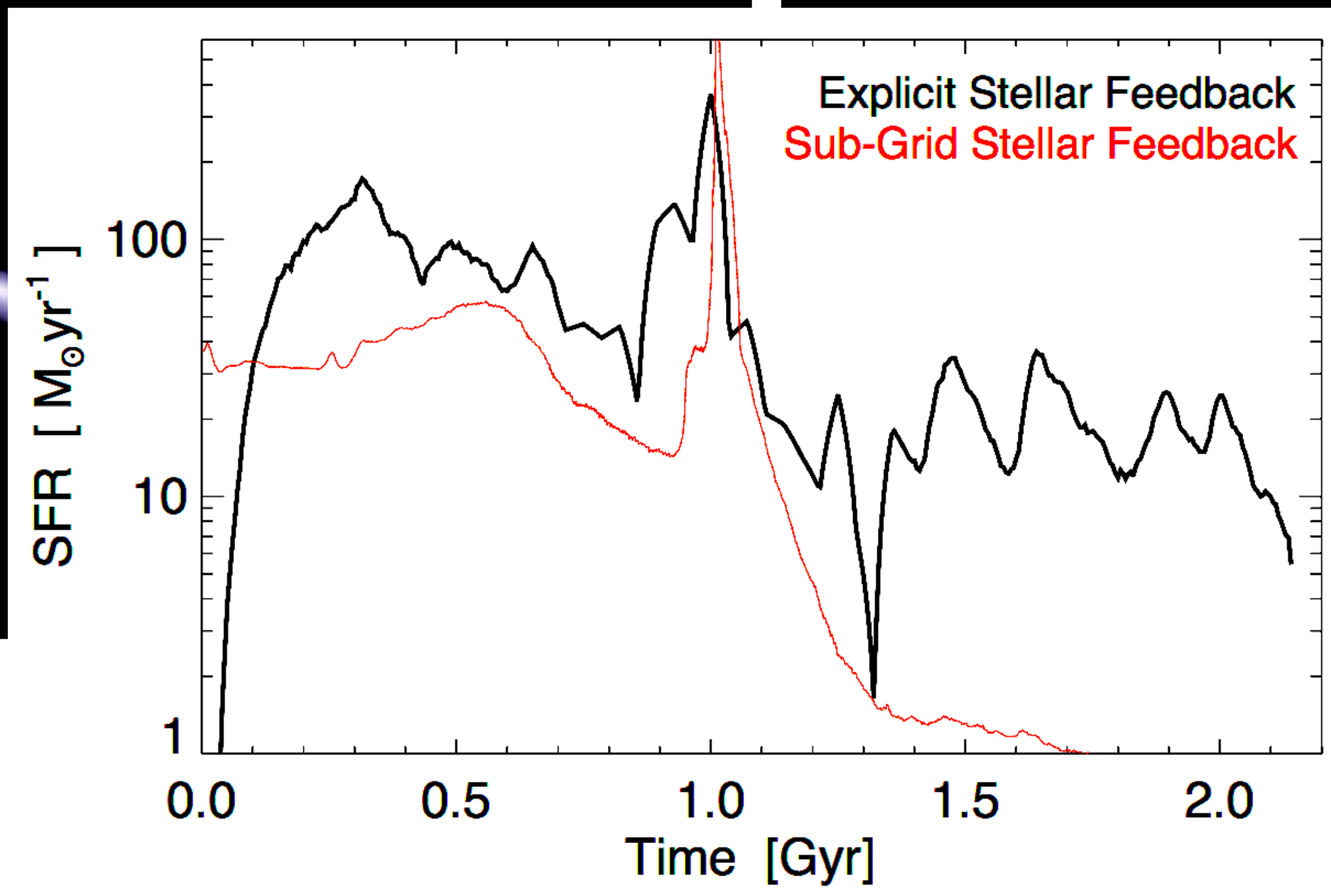
Quenching: Don't Trust Models that Don't Do Stars Right

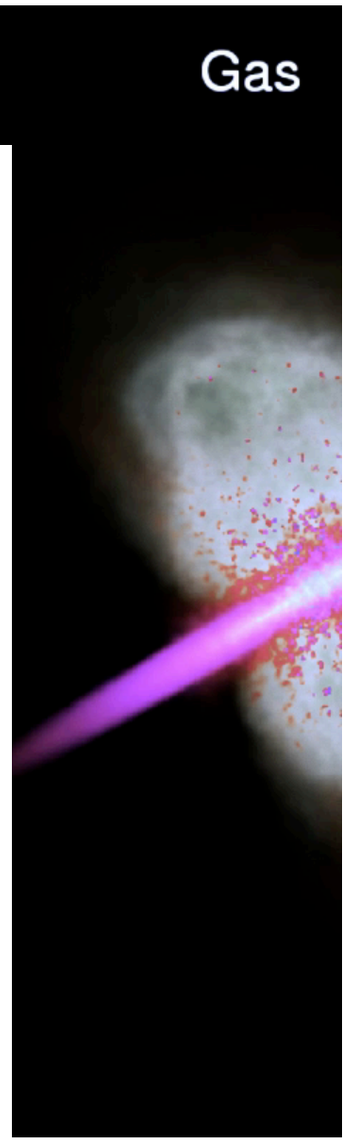
SMALL GALAXIES BECOME BIG GALAXIES

"Decoupled Winds" (Sub-Grid)

Following Explicit Feedback





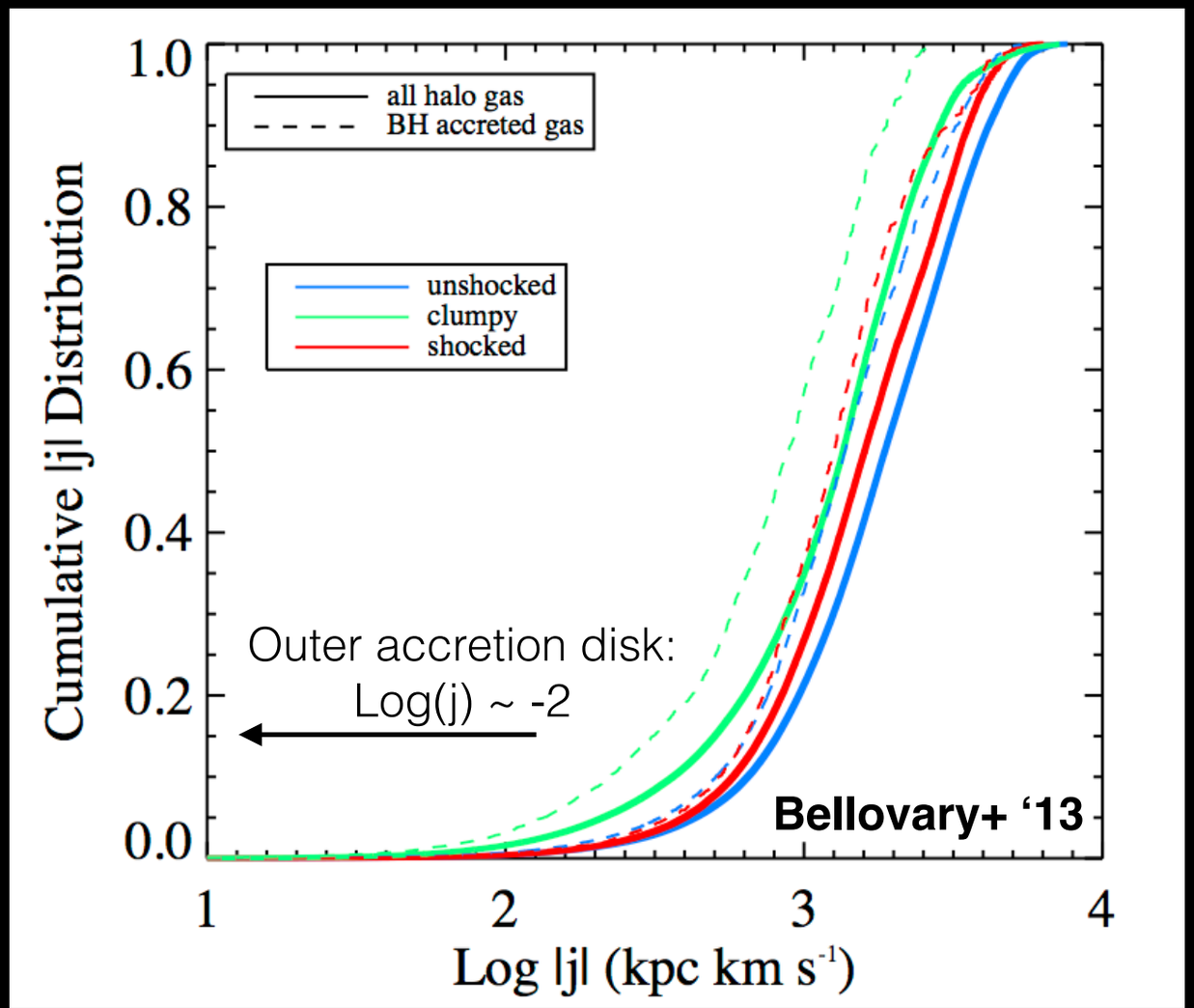


Do Cold Flows Fuel BHs?

NO!

Inflow from Cosmological Scales To Galaxies

z=30.0



z=30.0

50 kpc

Do Mergers Fuel BHs?

NO!

Do Disk Instabilities Fuel BHs?

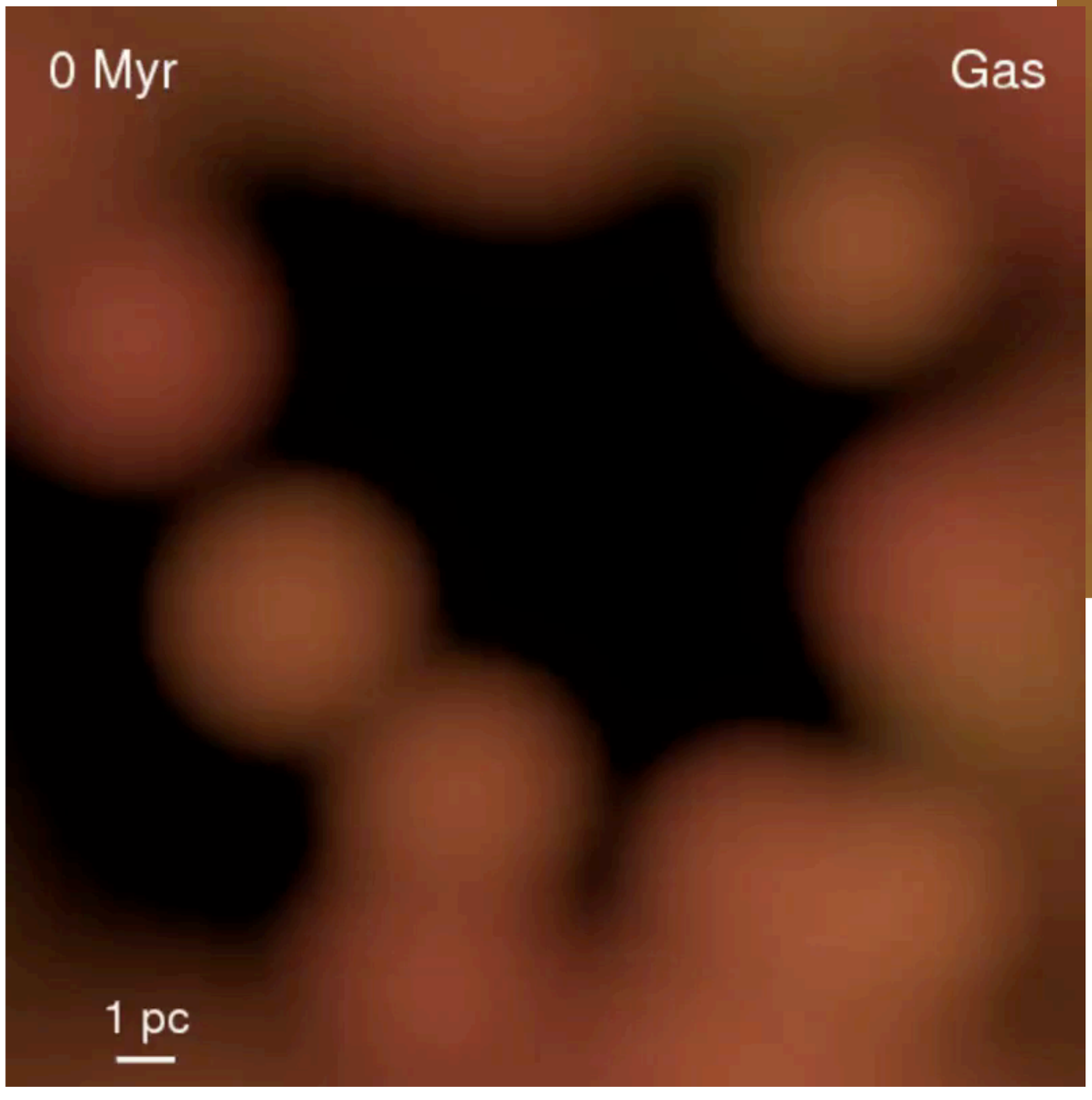
NO!

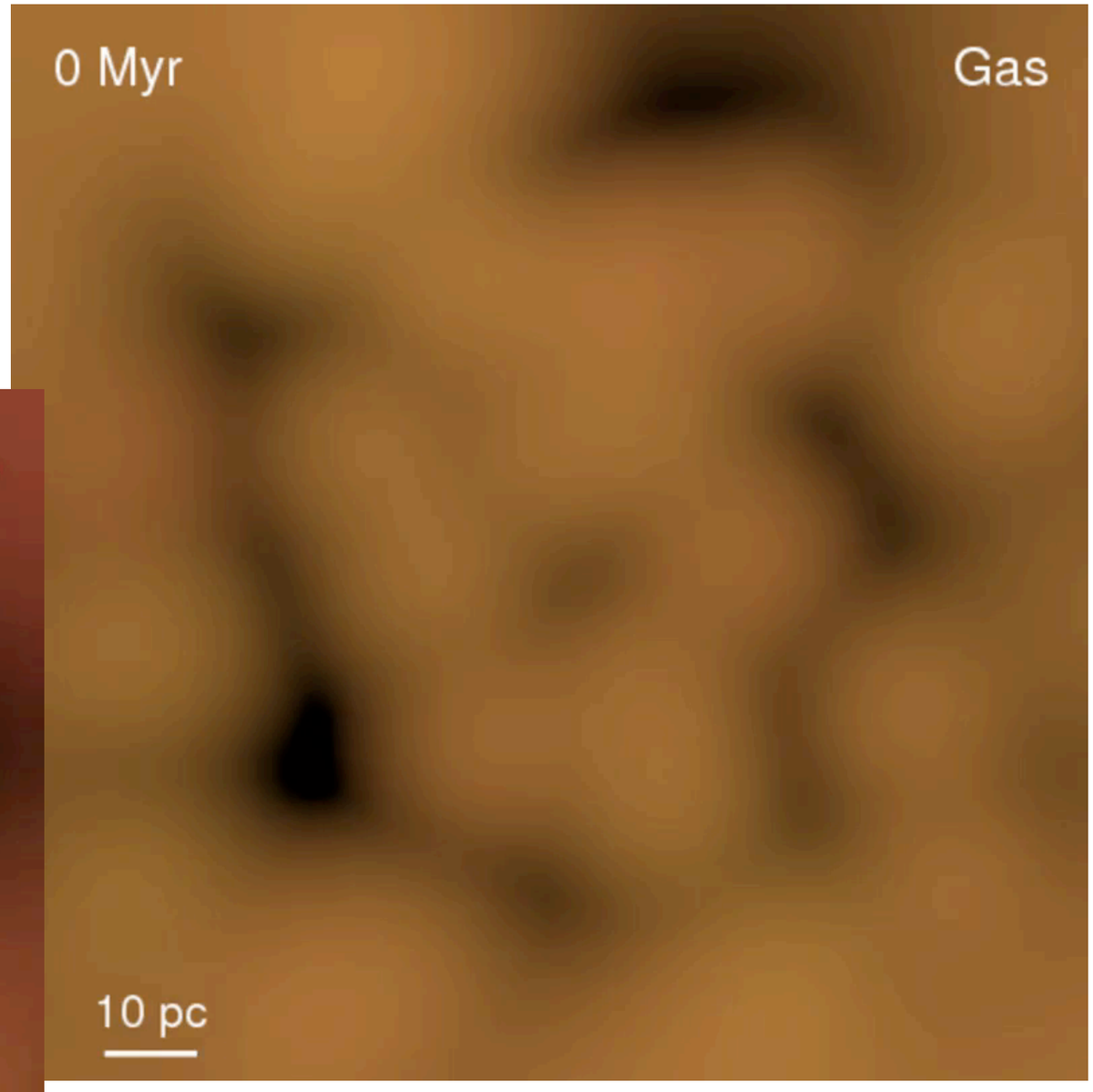
F. Summers

- Galaxy merger: good way to get lots of gas to small scales!

- *If* BHs trace spheroids, then *most* mass added in violent events that also build bulges

- BUT, disk instabilities/random nuclear gas motions are *really* common

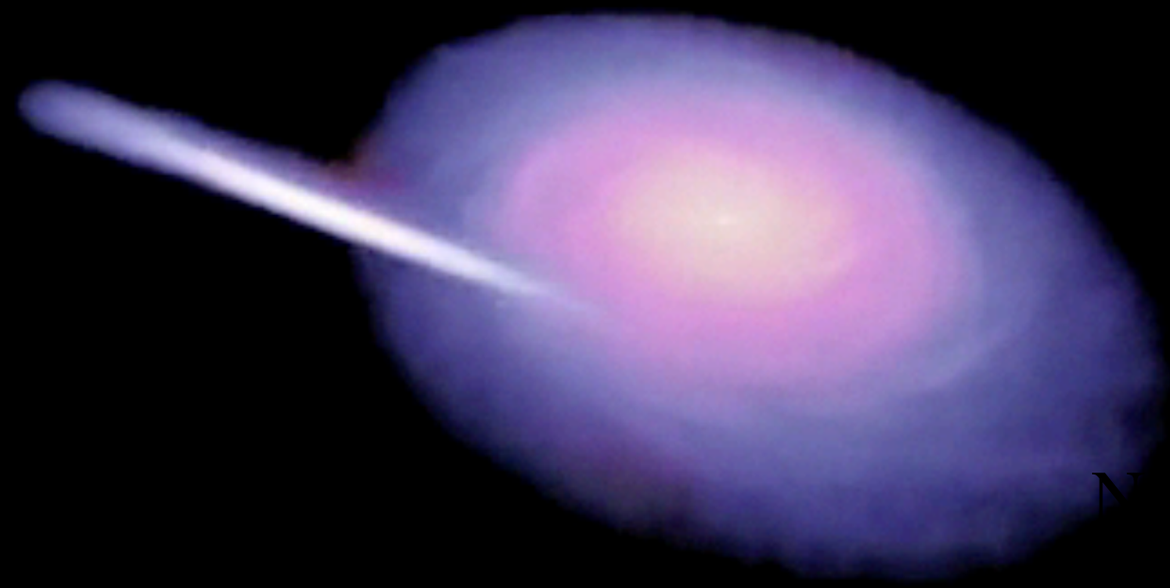




- Extrapolate from ~10 pc to BH accretion rates

T = 250 Myr

Gas



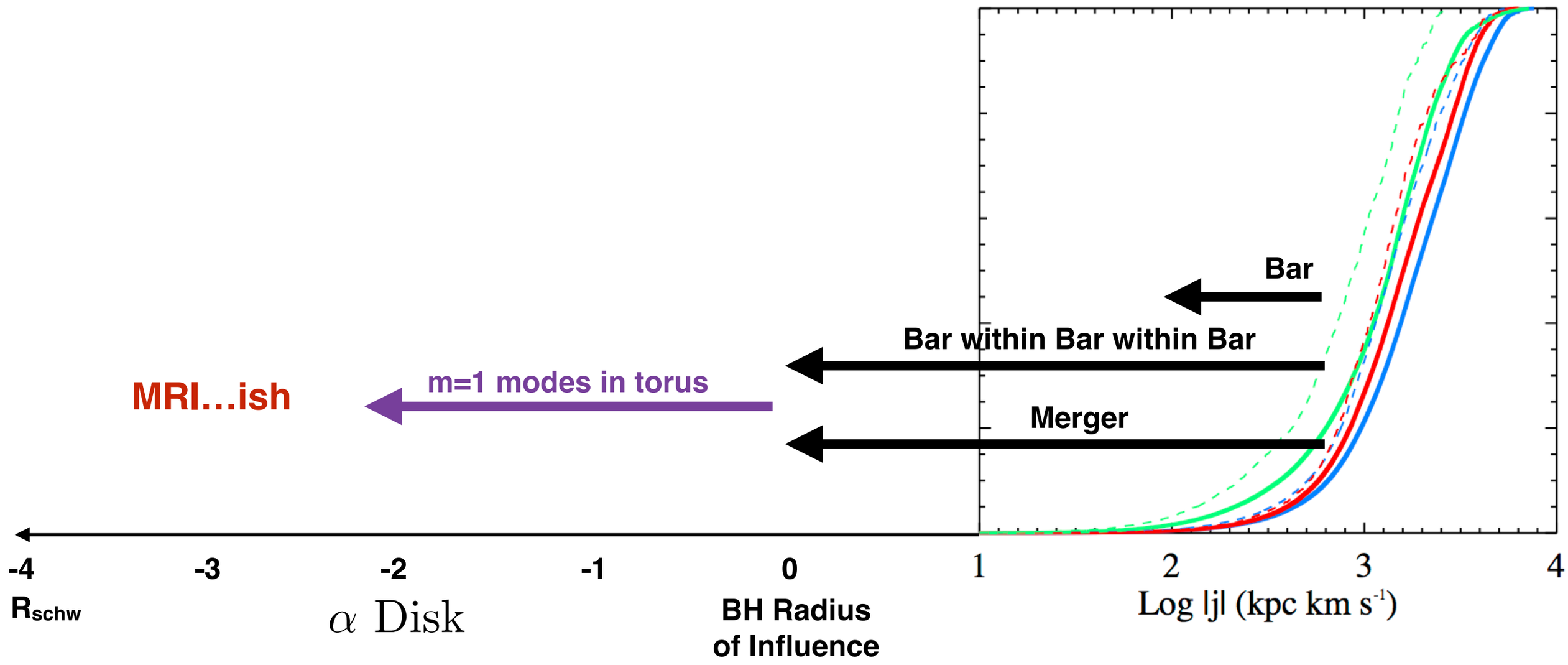
Large Scale Simulation:

Fueling Rapid BH Growth:

(Triggering Quasar Activity: Hopkins & Hernquist 2005)

(Triggering Quasar Activity: Barnes & Hernquist 1991)

But we're still a long way from the BH!



(PFH & Quataert 2010)

Bars w/in Bars

(Shlosman et al. 1989)

"It's Bars all the Way Down ..."

More accurately ...

"It's Non-axisymmetric Features all the Way Down ..."

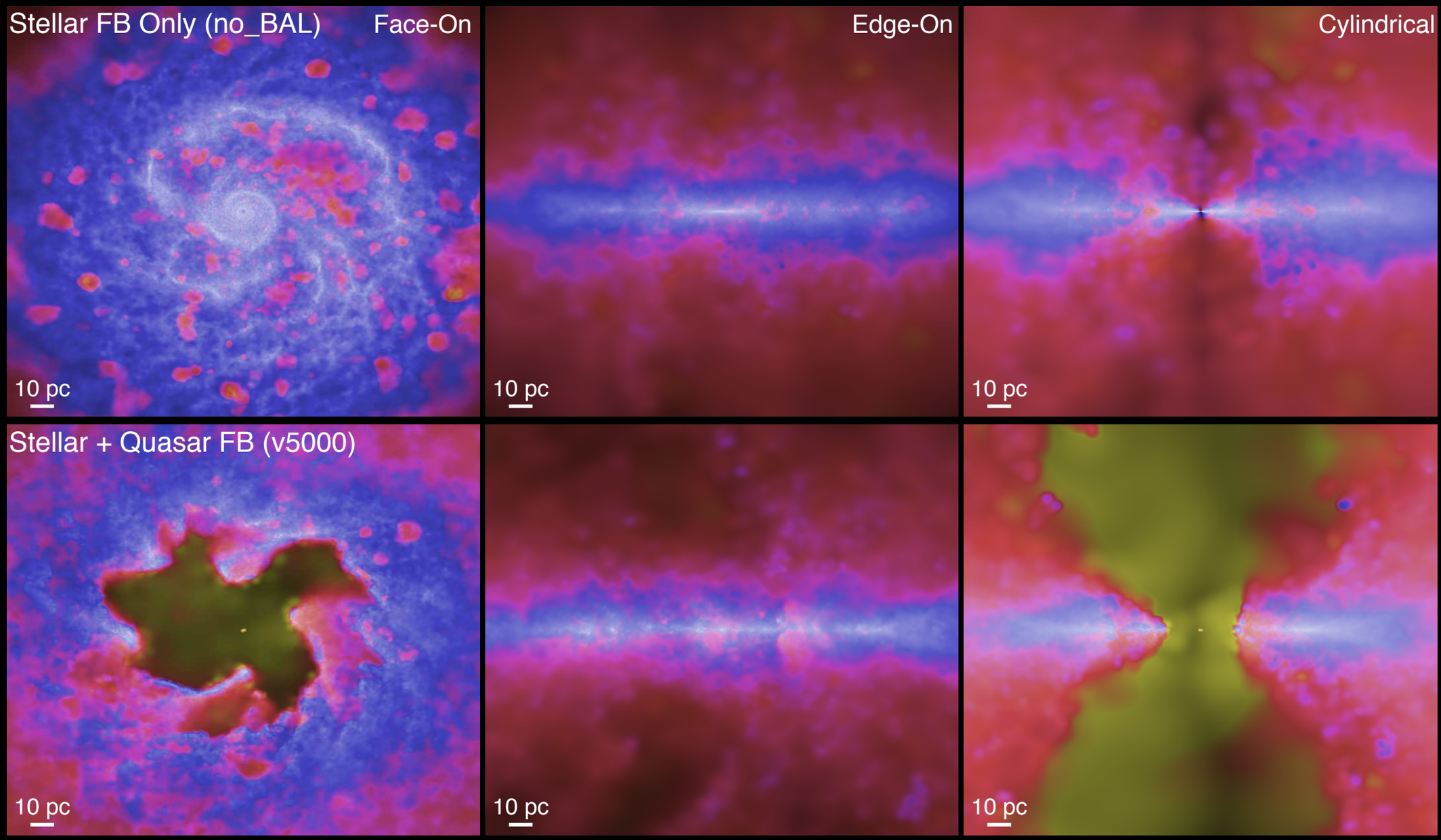
Revisiting Accretion

INCLUDING:

- *RESOLUTION = 0.01 pc, 10 Msun*
- *STELLAR FEEDBACK*
- *COOLING (10K - 1e10 K)*
- *COMPTON HEATING*
- *PHOTOIONIZATION FROM BH+STARS*
- *RADIATION PRESSURE*
- *ACCRETION DISK WINDS*

Stars

Gas



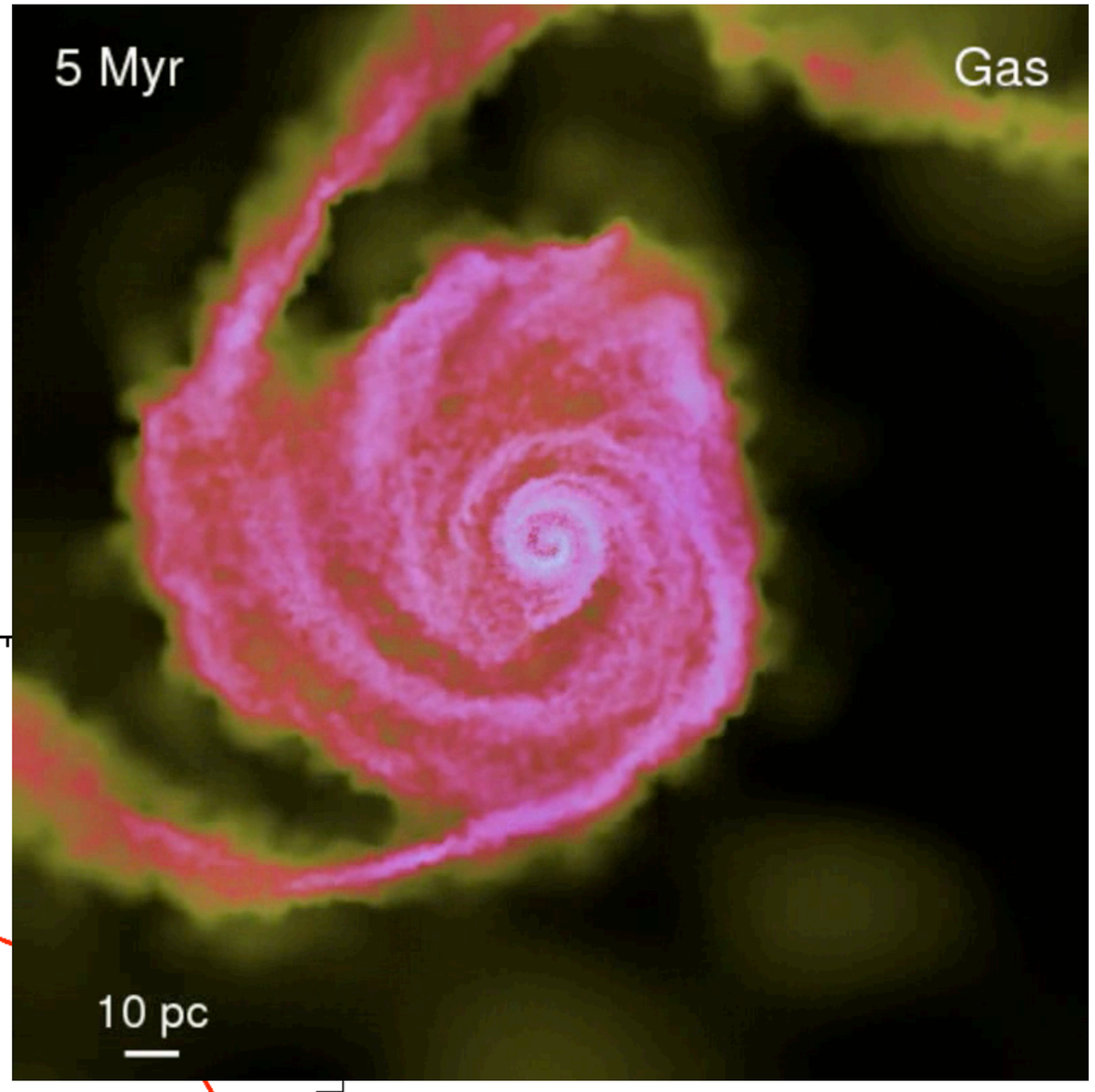
Stars

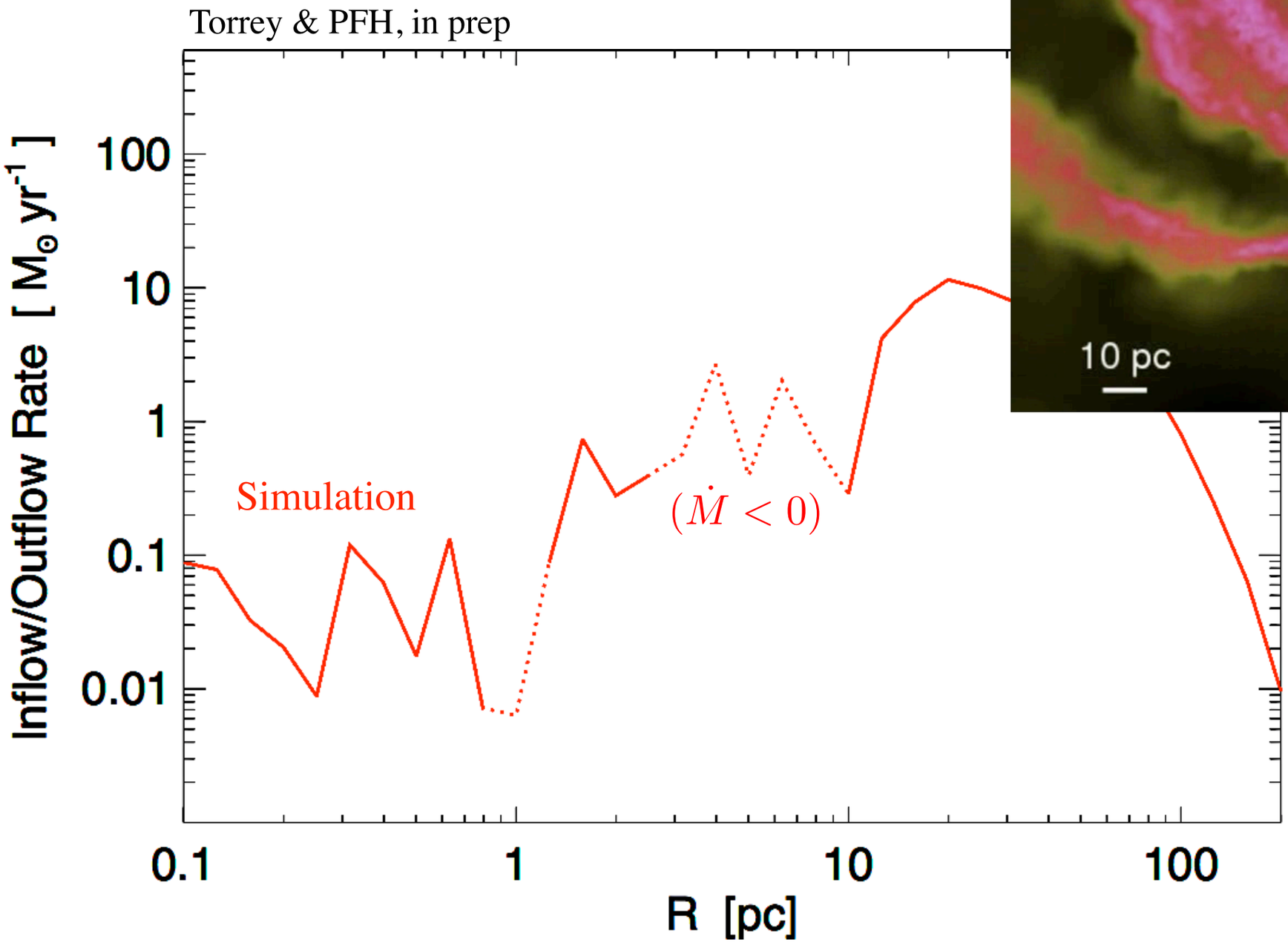
Gas

Large-scale inflows

HOW DO WE APPROXIMATE IT?

- Do we understand inflow to sub-pc scales?





PFH & Quataert 2009,10,11
Levine, Gnedin, Kravtsov 09,10
Mayer, Callegari, 09,10

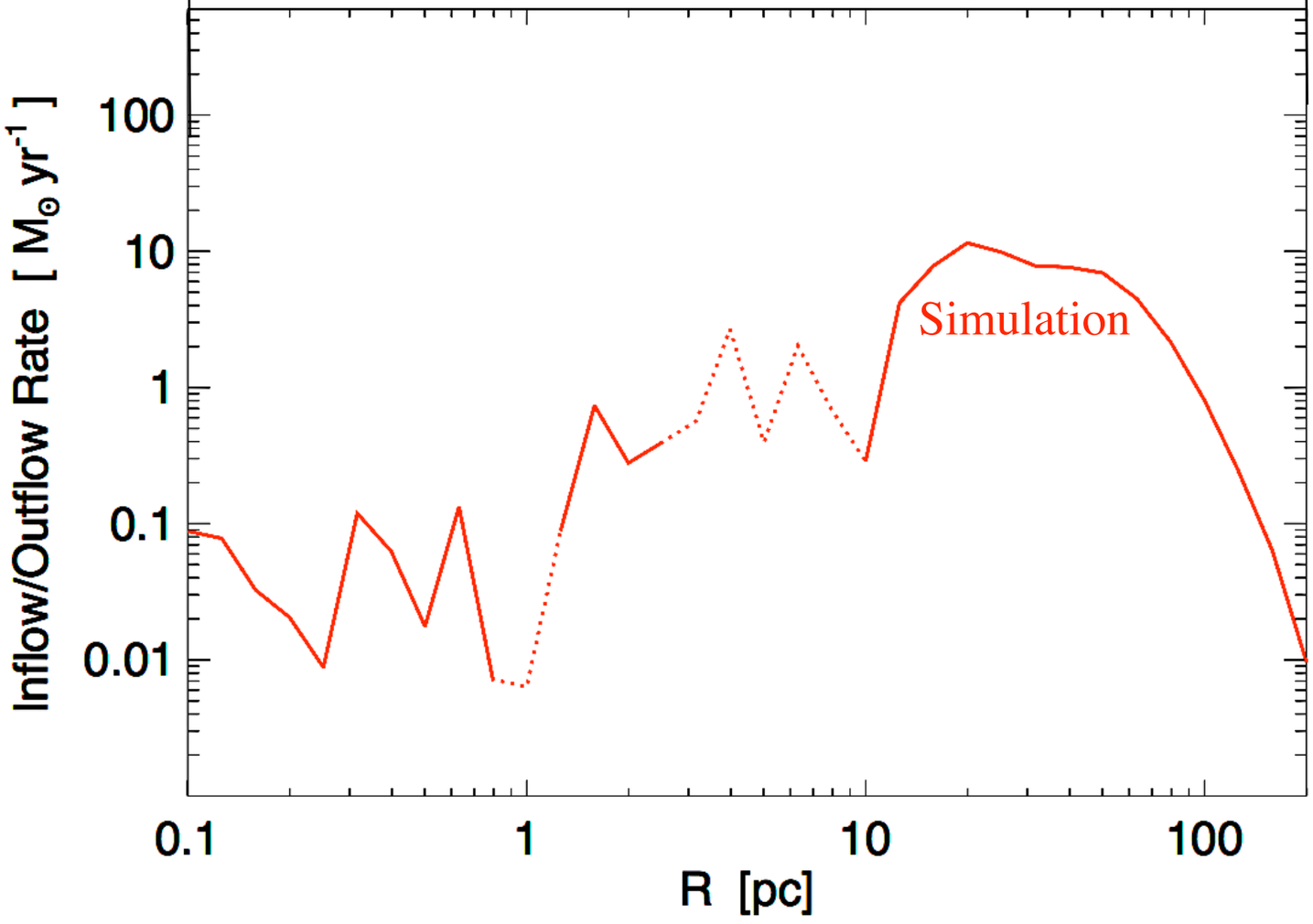
Large-scale inflows

HOW DO WE APPROXIMATE IT?

Torrey & PFH, in prep

"classical" Bondi rate

$$\dot{M} = \frac{4\pi\, G^2\, M_{\rm BH}^2\, \rho}{c_s^3}$$



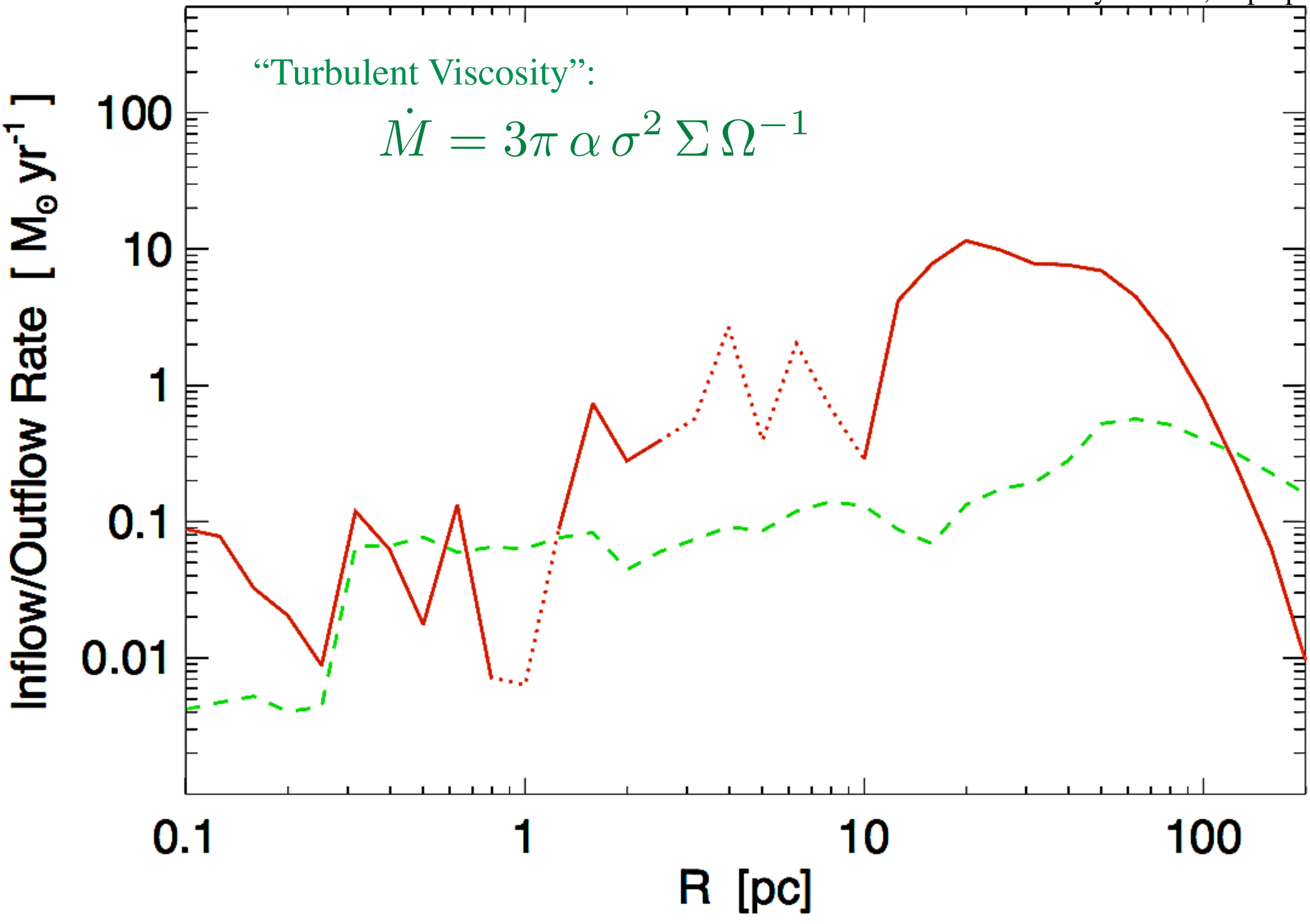
Large-scale inflows

HOW DO WE APPROXIMATE IT?

Torrey & PFH, in prep

"Turbulent Viscosity":

$$\dot{M} = 3\pi\,\alpha\,\sigma^2\,\Sigma\,\Omega^{-1}$$



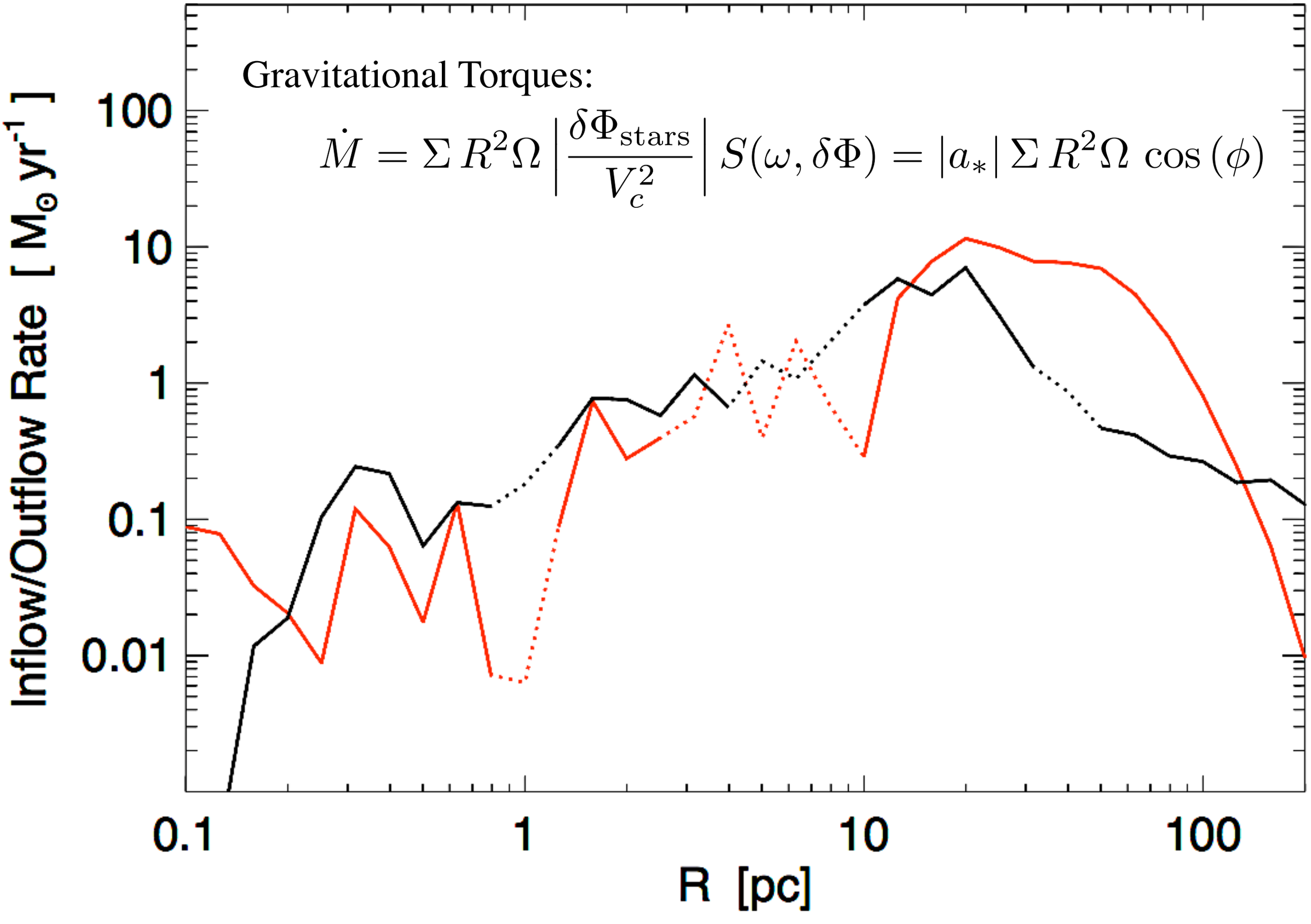
Large-scale inflows

HOW DO WE APPROXIMATE IT?

Torrey & PFH, in prep

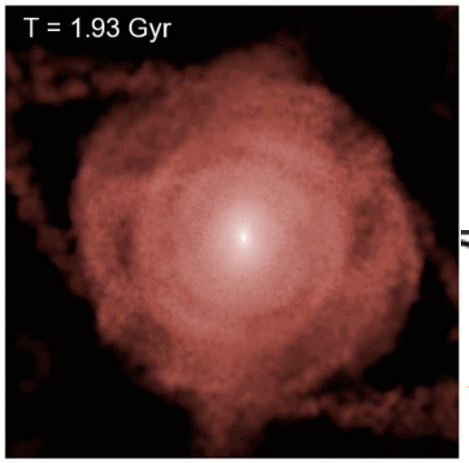
Gravitational Torques:

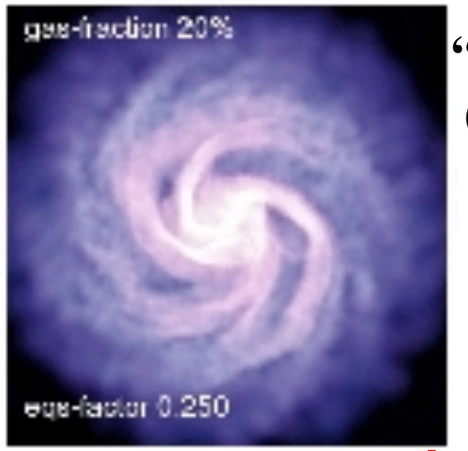
$$\dot{M} = \Sigma\, R^2 \Omega \left| \frac{\delta\Phi_{\rm stars}}{V_c^2} \right| S(\omega, \delta\Phi) = |a_*|\, \Sigma\, R^2 \Omega\, \cos(\phi)$$



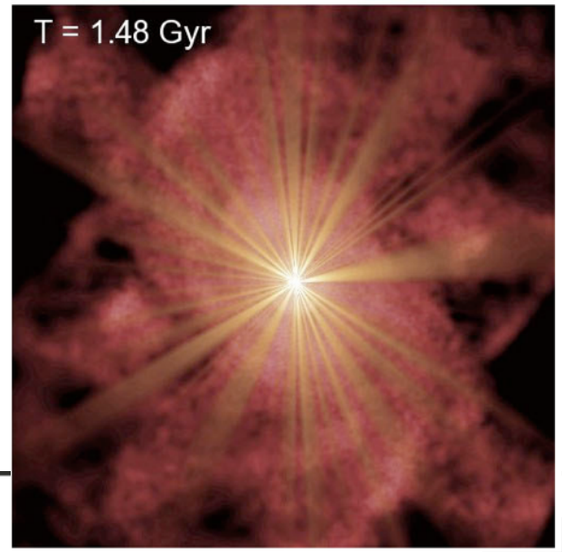
What Does This Lead To?

"Dead" Bulges (stellar wind/hot gas halo accretion)

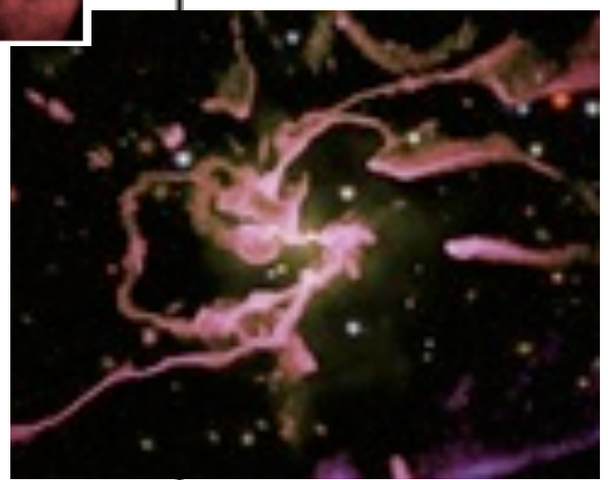




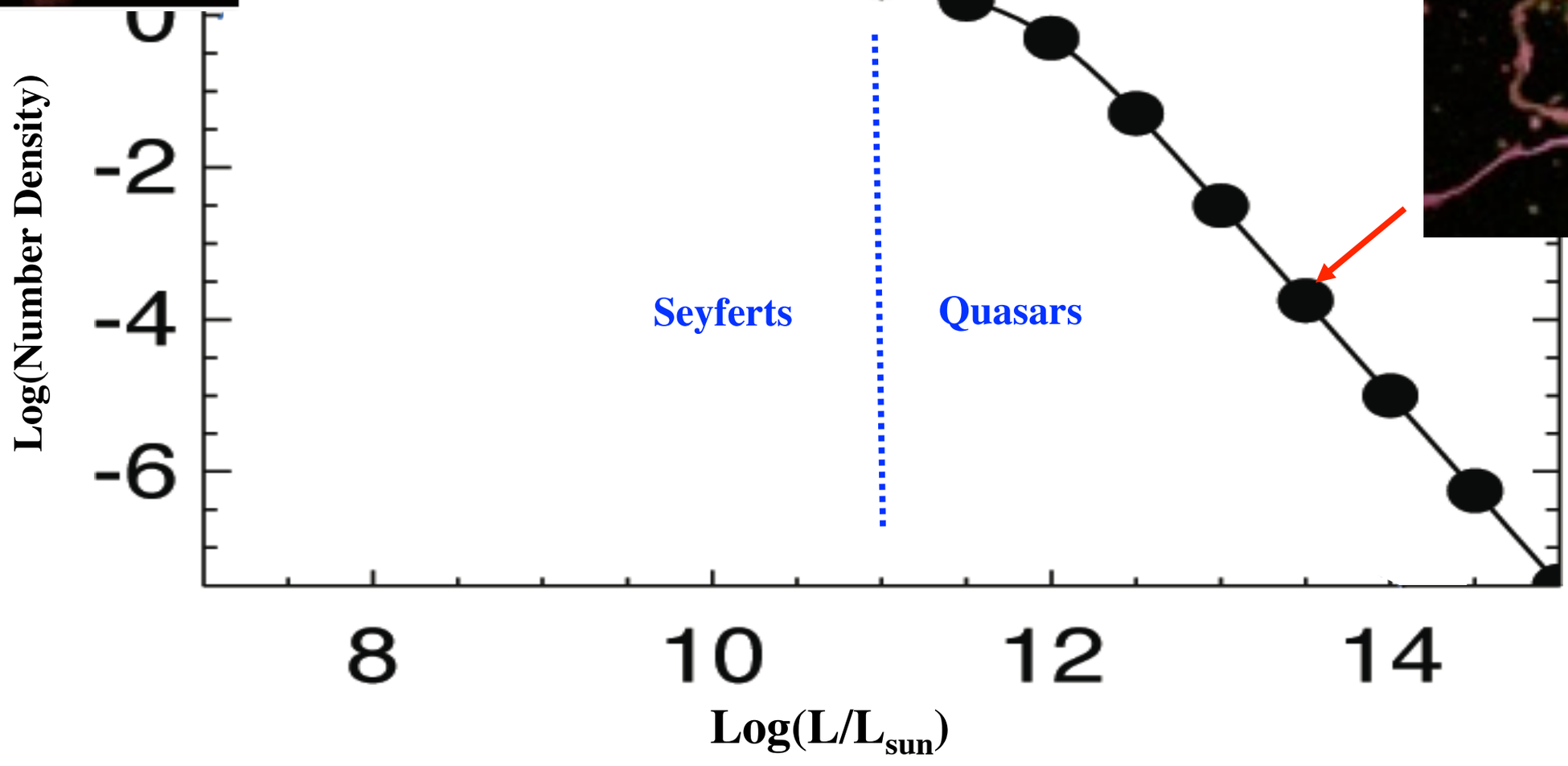
"Seyferts" (disk-dominated, secular/minor mergers)



"Fading" Mergers (post-starburst spheroids)

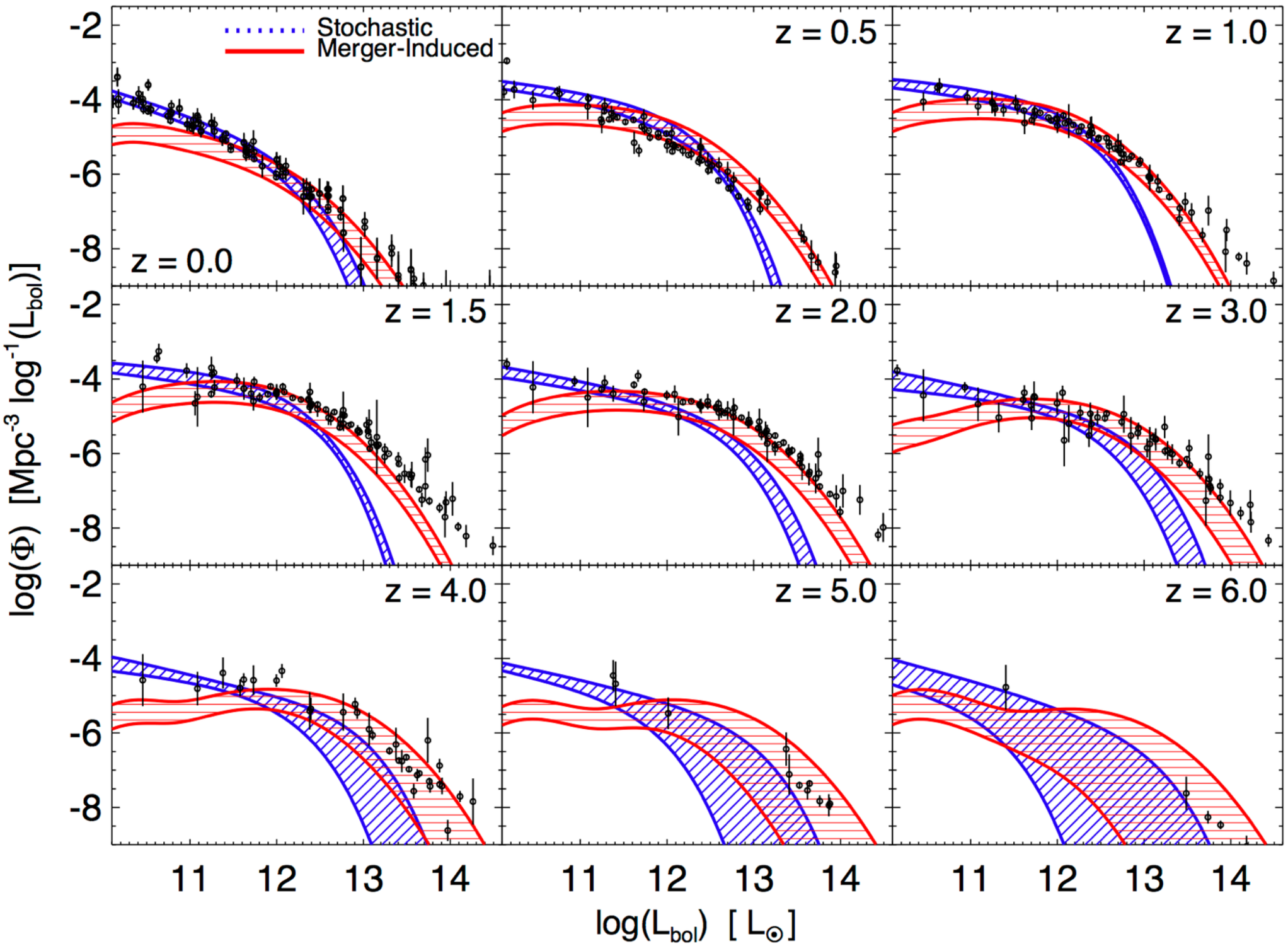


"Blowout" (Bright Mergers)



- Observed luminosity function: mix of populations with different triggering, evolution

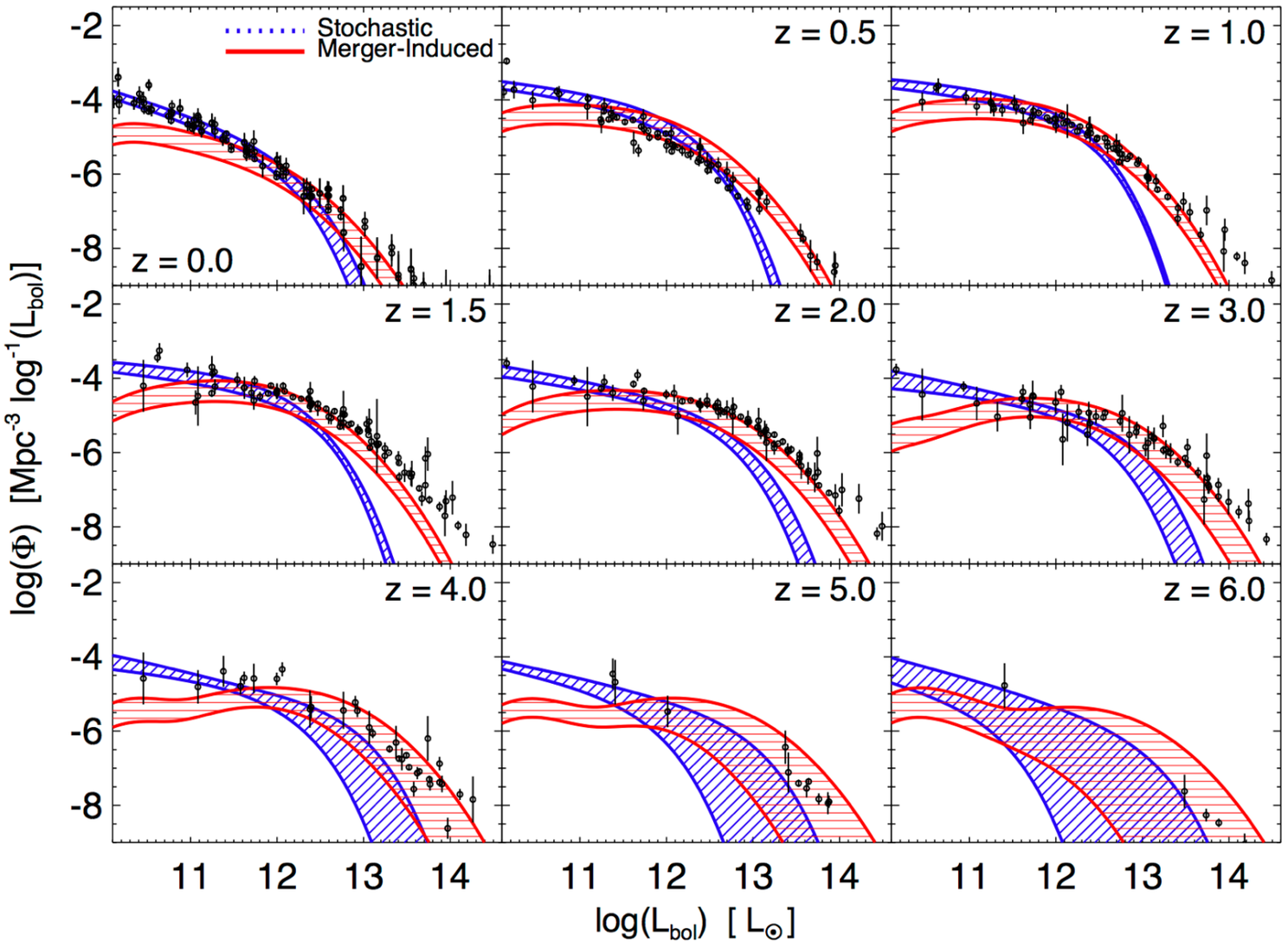
Statistical “association” between accretion & host dynamics

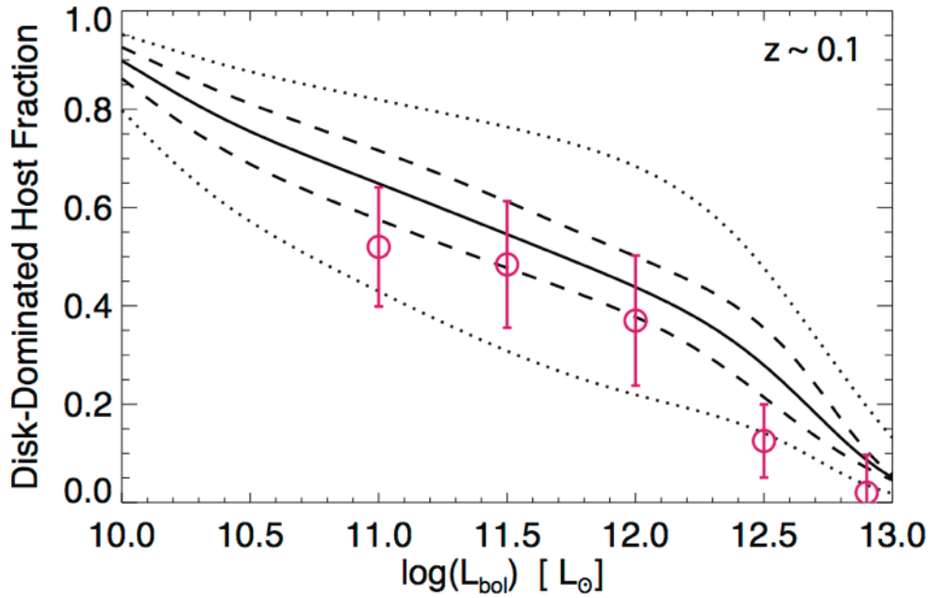


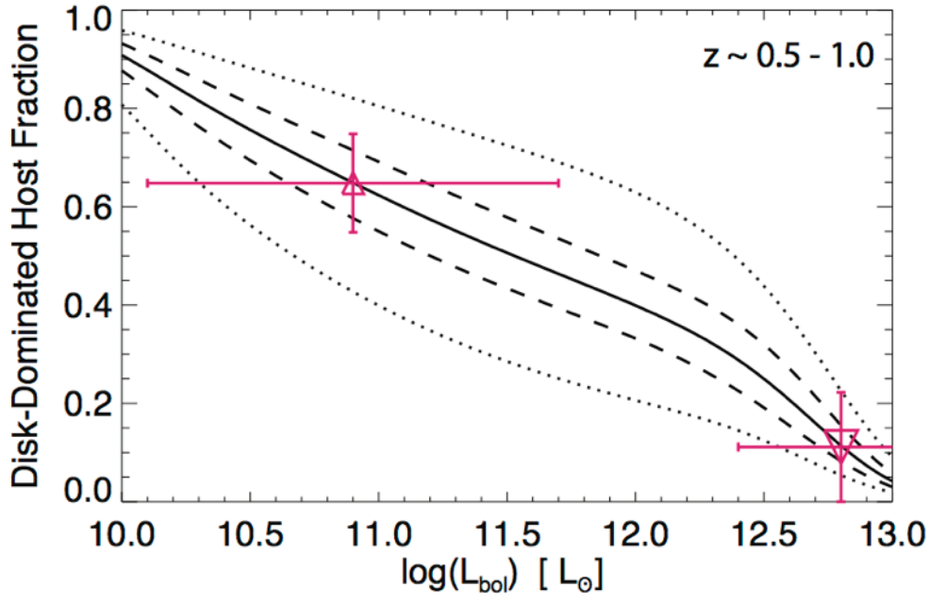
Hopkins, Kocevski, & Bundy ‘13

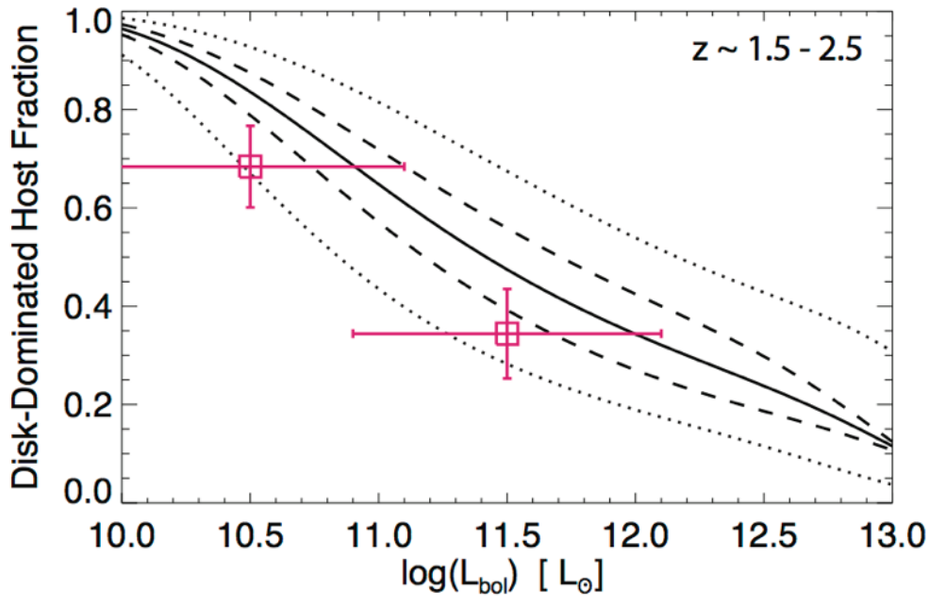
Statistical "association" between accretion & host dynamics

Hopkins, Kocevski, & Bundy '13



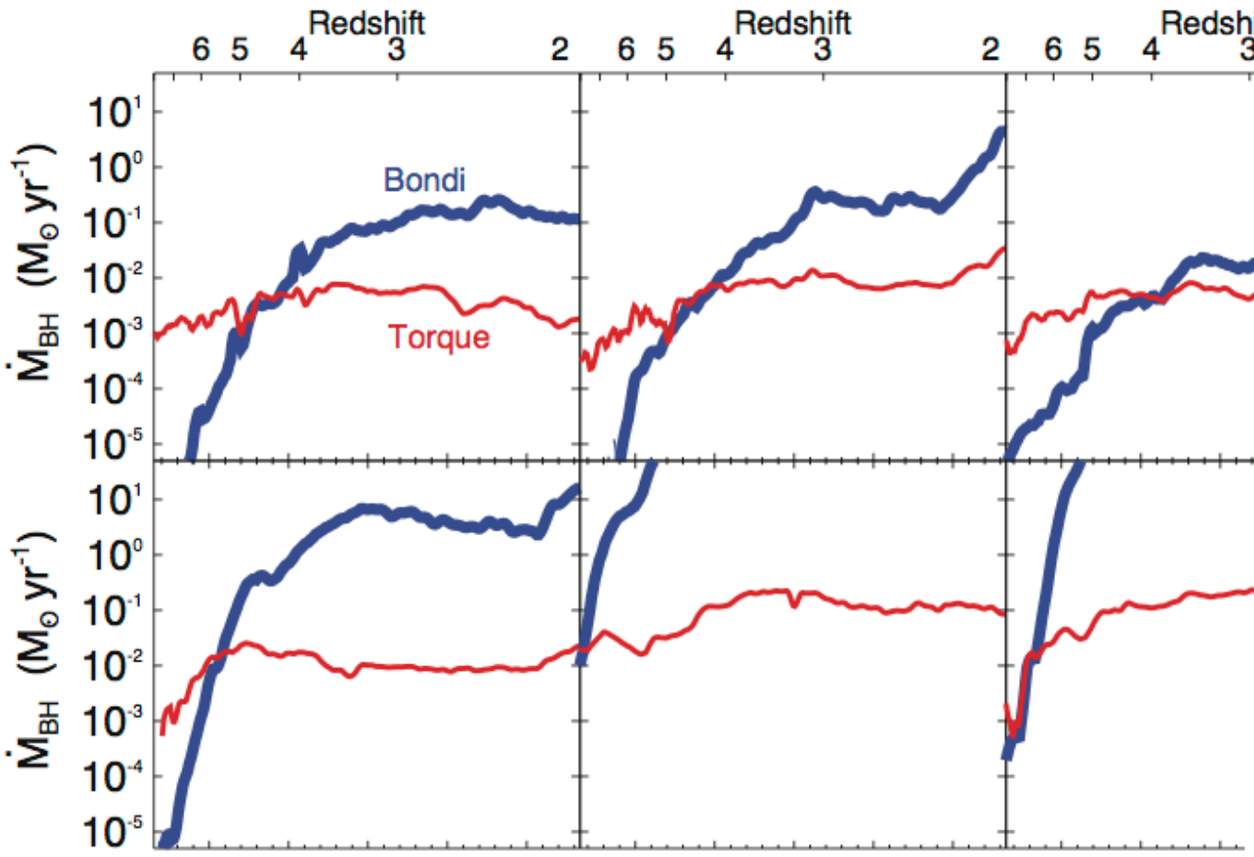


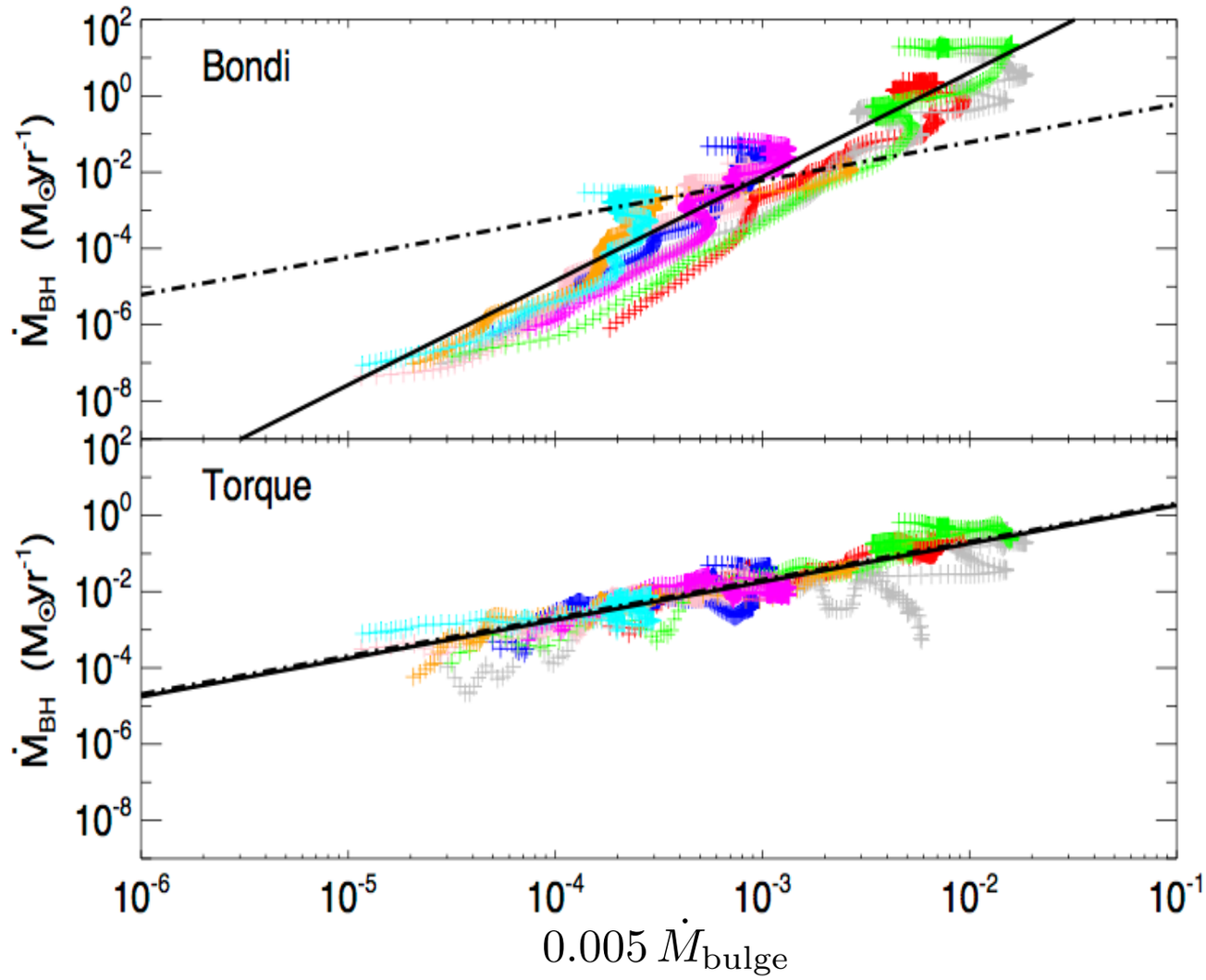


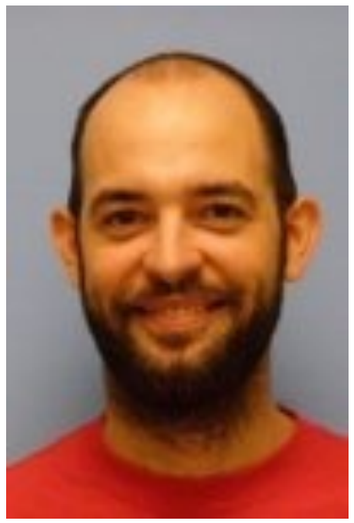


Does This Matter on Large Scales?

GRAVITATIONAL TORQUES VS. BONDI IN COSMOLOGICAL SIMS







Angles-Alcazar et al. 2013

Summary

- Gravitational instabilities CAN power luminous BHs (~10 M_{sun}/yr)! Really!
  - New accretion rate estimator: neither viscous nor Bondi

- "Stuff within Stuff": Cascade of instabilities with diverse morphology
  - > 10 kpc :: Cold flows
  - ~ 0.1 - 10 kpc :: Mergers (high-L_{BH})
    "Stochastic" disk-fueling (low-L_{BH})
  - ~ 10 - 100 pc :: Nuclear "Messiness" (bars, spirals, clumps, feedback)
  - ~ 0.1 - 10 pc :: Lopsided Disks (star-gas exchange)
  - < 0.1 pc :: alpha-disk (?)

- Does accretion or feedback set BH-host relations?
  - Feedback may only need to 'kick out' material