The Need for AGN Feedback

NEED TO SUPPRESS STAR FORMATION IN MASSIVE GALAXIES

Oppenheimer & Dave

**Observed**

**No Feedback**

**Observed**

Number Density vs. $M_{\text{stars}}$ [$M_\odot$]
The Need for AGN Feedback

FEEDBACK FROM STARS IS NOT ENOUGH

Oppenheimer & Dave

Stellar, no AGN Feedback

Observed

\[ M_{\text{stars}} \quad [M_\odot] \]
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!
Quenching: Don’t Trust Models that Don’t Do Stars Right
SMALL GALAXIES BECOME BIG GALAXIES

“Decoupled Winds” (Sub-Grid)

Following Explicit Feedback

Explicit Stellar Feedback
Sub-Grid Stellar Feedback
Do Cold Flows Fuel BHs?

NO!
Inflow from Cosmological Scales To Galaxies

$z=30.0$

Outer accretion disk: $\log(j) \sim -2$
Do Mergers Fuel BHs?

NO!
Do Disk Instabilities Fuel BHs?

**NO!**
• 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
Tidal torques ⇒ large, rapid gas inflows (e.g. Barnes & Hernquist 1991) Triggers Starbursts (e.g. Mihos & Hernquist 1996)

Fuels Rapid BH Growth? (e.g. Di Matteo et al., PFH et al. 2005)

Large-scale simulation: follow gas to sub-kpc scales

Now: Re-simulate central kpc at high-res Follow gas to ~10 pc Continue, re-simulate central regions, down to 0.1 pc resolution
But we’re still a long way from the BH!

MRI...ish

$m=1$ modes in torus

Bar within Bar within Bar

Merger

$\alpha$ Disk

BH Radius of Influence

Log $|l|$ (kpc km s$^{-1}$)
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

Stellar FB Only (no_BAL)  Face-On
Edge-On  Cylindrical

Stellar + Quasar FB (v5000)

Stars
Gas
Large-scale inflows
HOW DO WE APPROXIMATE IT?

Do we understand inflow to sub-pc scales?

Torrey & PFH, in prep

PFH & Quataert 2009,10,11
Levine, Gnedin, Kravtsov 09,10
Mayer, Callegari, 09,10
Large-scale inflows
HOW DO WE APPROXIMATE IT?

“classical” Bondi rate

\[ \dot{M} = \frac{4\pi G^2 M_{\text{BH}}^2 \rho}{c_s^3} \]
Large-scale inflows

HOW DO WE APPROXIMATE IT?

“Turbulent Viscosity”:

\[ \dot{M} = 3\pi \alpha \sigma^2 \Sigma \Omega^{-1} \]
Gravitational Torques:

\[ \dot{M} = \sum R^2 \Omega \left| \frac{\delta \Phi_{\text{stars}}}{V_c^2} \right| S(\omega, \delta \Phi) = |a_*| \sum R^2 \Omega \cos (\phi) \]
What Does This Lead To?
"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 $M_{\odot}$/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-$L_{\text{BH}}$)
    - "Stochastic" disk-fueling (low-$L_{\text{BH}}$)
  - ~ 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