AGN Fueling and Feedback in Massive Galaxies: Discussion Topics
Two-way communication

- How are supermassive black holes fed?
- How is their growth regulated ("local feedback")
- How do supermassive black holes affect their surroundings on galactic scales ("global feedback")
Points to provoke discussion

- Mergers are not a **major** driver of black hole growth
- Black hole growth is due to stellar mass loss in bulges
- “Local” feedback from supernovae is important
- Radiation-pressure-driven outflows **alone** do not explain starburst winds
- There is direct evidence for “global” feedback that is **generic** in starbursts and radio-loud AGN (but not in typical radio-quiet AGN)
Mergers probed by “lopsidedness”

The primary correlations are between:
1) lopsidedness and star-formation
2) star formation and black hole growth

> The there is no physical correlation between lopsidedness and black hole growth

> Reichard et al.
Close Companions: Same Result

- Excess of close companions clear for starbursts
- No excess for AGN (Li et al. 2007)
Stellar mass loss: Test in Starbursts

• Black hole growth is suppressed until the supernova rate drops
• Accretion rate then tracks mass loss from intermediate mass stars
• Roughly 0.5% accreted by black hole
• 1000:1 ratio of new stars to black hole mass growth over the event
  
Wild et al
Similar results at later stages

- The age-dependence of the black hole growth rate for older systems is also consistent with the capture of about 0.5% of the mass lost by evolved stars in the bulge
- Kauffmann & Heckman
The growth rate distribution

Universal log-normal shape for “living” bulges. SNe LOCAL feedback causes growth rate to saturate.

Age-dependent power-law for “dead” ones. Higher stellar mass loss rate leads to higher accretion rate.

Kauffmann & Heckman
Supernovae vs. Radiation Pressure

- Both radiation pressure and the ram-pressure of a supernova-driven outflow carry a comparable outward momentum flux
- Both could explain outflow of cold clouds
- The supernova-driven model also explains the observed multiphase nature of winds
The Very Hot Phase

- Diffuse hard X-ray emission ($T \sim 60$ million K)
- Carries most of the new metals and energy
- Requires near-unit conversion efficiency of SNe KE
- Strickland & Heckman
The Hot & Warm Phases

• Close correspondence of hot and warm gas
• Wind-cloud collisions
• Cloud outflow due to wind momentum
The Relativistic Phase

- Radio synchrotron emission from advected cosmic ray electrons and magnetic field
- NGC 4631 (Wang; Dahlem)
Wind ram pressure can be measured on galactic-scales

- Lehnert & Heckman
GLOBAL Feedback

> Benchmark: Need to see hydrodynamical consequences of galactic scale and beyond
> Blue-shifted absorption-lines are not enough (mass flow rate ~ N v r)
Must know sizes
Global Feedback in Starbursts

- Do see the hydrodynamical effects of feedback on a galactic scale in starbursts
- Star formation accompanies BH growth
See feedback from radio sources on scales ranging from a galaxy (~10 kpc) to a cluster core (~200 kpc)

Finoguenev et al.; McNamara & Nulsen