The life-cycle of galaxies:
feedbacks in galaxy evolution

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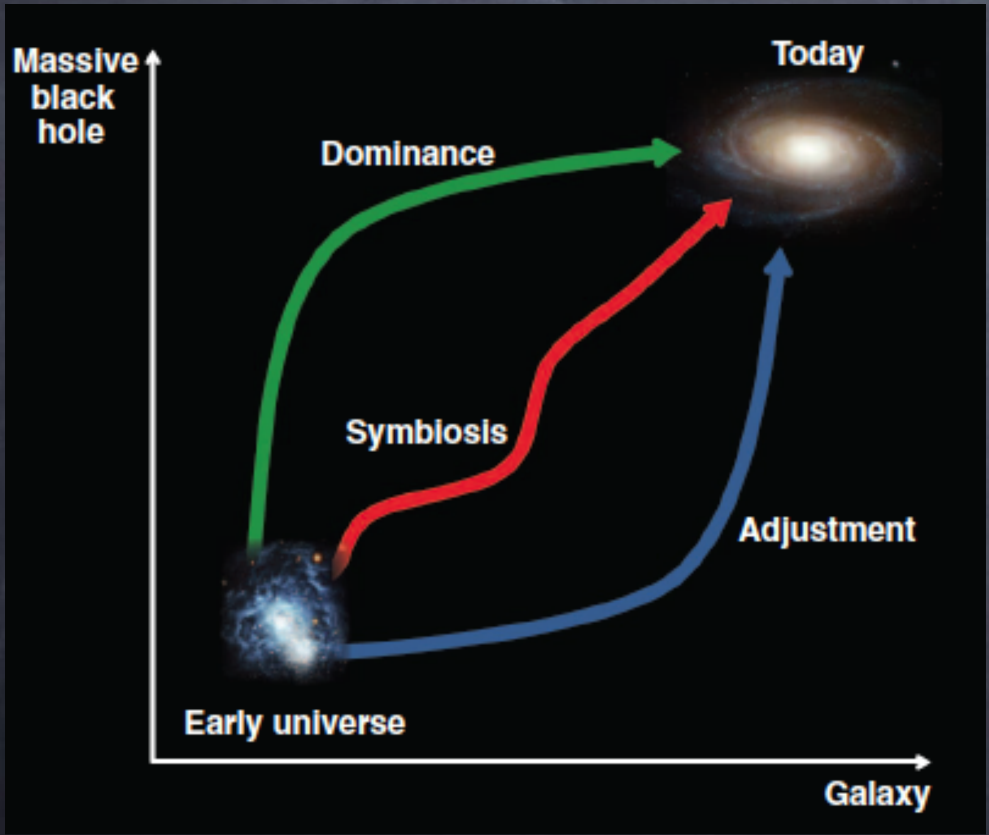
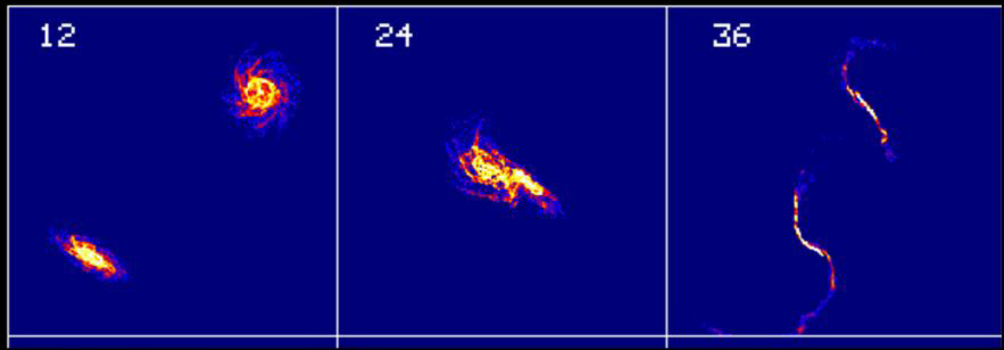
The AGN/galaxy coevolution



- Collapse
  - Galaxy Formation
  - MBH Formation
  - Accretion
- Merging
  - Galaxy
  - MBH
- Feedback
  - Stellar / SN
  - AGN

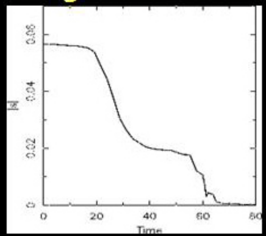
Galaxy encounters



"'tidal forces during encounters cause otherwise stable disks to develop bars, and the gas in such barred disks, subjected to strong gravitational torques, flows toward the central regions "

Mihos & Hernquist 1996
See also Noguchi 1987
Barnes & Hernquist 1991

Gas Angular Momentum



Part of the available galactic cold gas is detabilized and funnelled toward the centre

$$f(v,V) = \frac{1}{2}\left|\frac{\Delta j}{j}\right| \approx \frac{1}{2}\left\langle \frac{m' r_d v_d}{mbV} \right\rangle$$

Cavaliere Vittorini 2000

(Sanders & Mirabel 96)

This occurs at a rate:

$$\tau^{-1}_{FlyBy} \propto n(\pi r^2_{tidal}) V_{rel}$$

It is averaged over all merging partners (m') in the same group/cluster (with relat. velocity V) at inpact param. b. These quantities + the cold available gas mcold are obtained from the SAM (NM et al. 2002)

1/4 feeds the central BH

QSO Properties

$$\dot{m}_{acc}(v,t) = \frac{1}{4}\left\langle \frac{f\, m_{cold}}{\tau_r} \right\rangle$$

$$L(v,t) = \frac{\eta c^2 \Delta m_{acc}}{\tau}$$

$$m_{BH} = (1-\eta)\int_0^t \dot{m}_{acc}(v,t')\, dt'$$

3/4 feeds circumnuclear starbursts

Starbursts Properties

$$\Delta\dot{m}_*(v,t) = \frac{3}{4}\left\langle \frac{f\, m_{cold}}{\tau_r} \right\rangle$$

$$\Delta S_\lambda = \int_0^t \Delta\dot{m}_*(t-t')\,\Phi_\lambda(t')\, dt'$$

Galaxy dinamycs

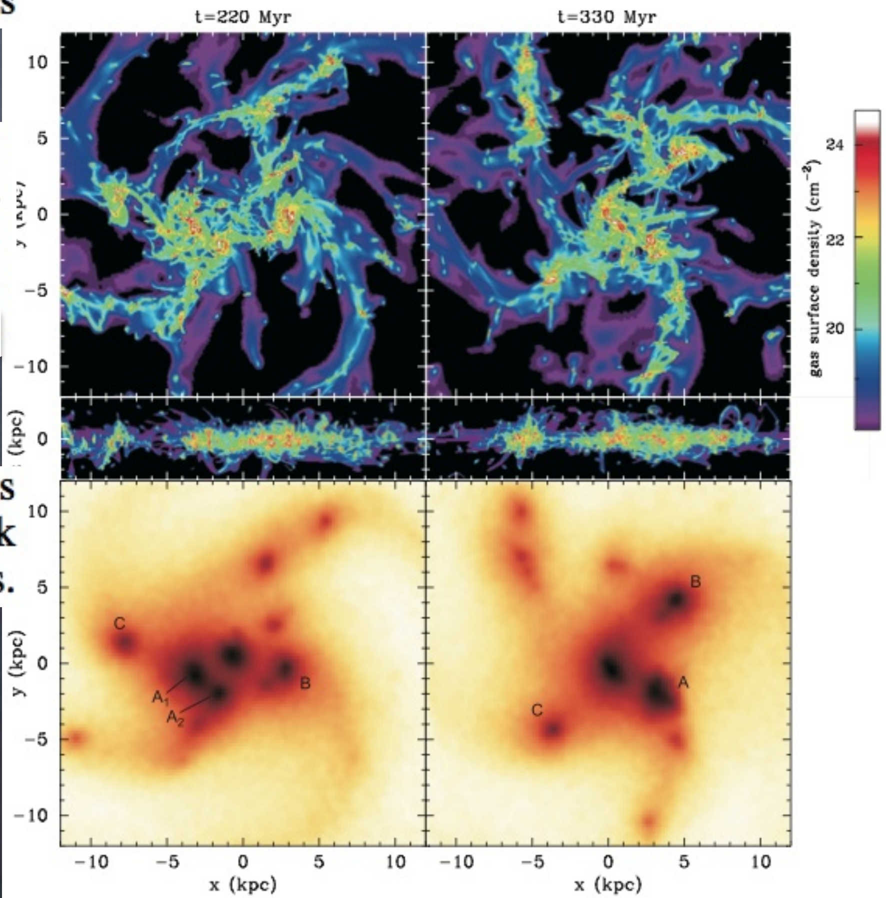
The corresponding bolometric luminosity is 2×10^{44} erg s^{-1}. With typically 1%–5% in X-rays, we estimate on average $L_X \sim 10^{42}$–10^{43} erg s^{-1}, scaling with galaxy mass and with $(1+z)^{2.5}$. While the average luminosity would be modest, short episodes of higher accretion rate, possibly up to the Eddington level, occur during the central coalescence of migrating giant clumps—which could also bring with them seed BHs

Disk instability at $z \sim 2$ can thus funnel half of the disk gas toward the center in 2 Gyr. This is similar to the mass inflow in a major merger (Hopkins et al. 2006), but spread over a 10 times longer period, resulting in a lower average AGN luminosity, with higher duty cycle, and high obscuration.

The main prediction is thus that many high-z AGNs should be hosted by star-forming disk galaxies, composed of clumpy disks and growing spheroids.

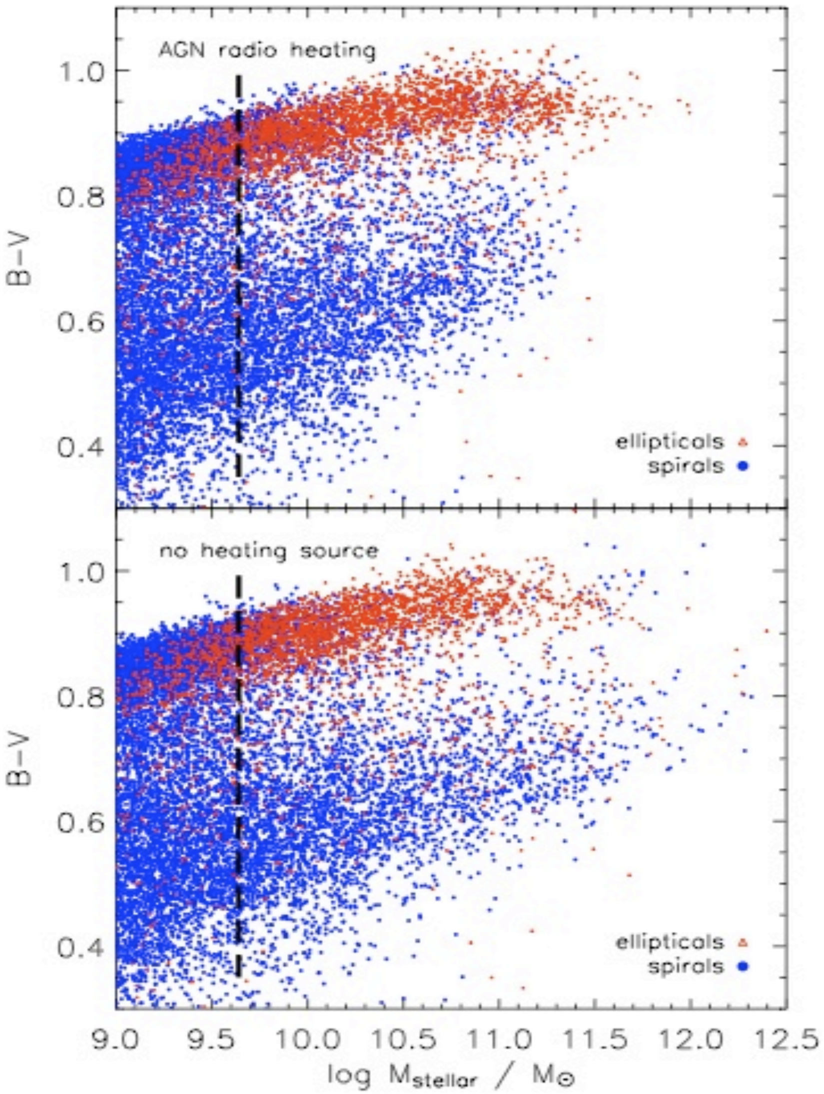
Cold flows (similar to minor mergers)

Dekel+ 2009, Bournaud+ 2011

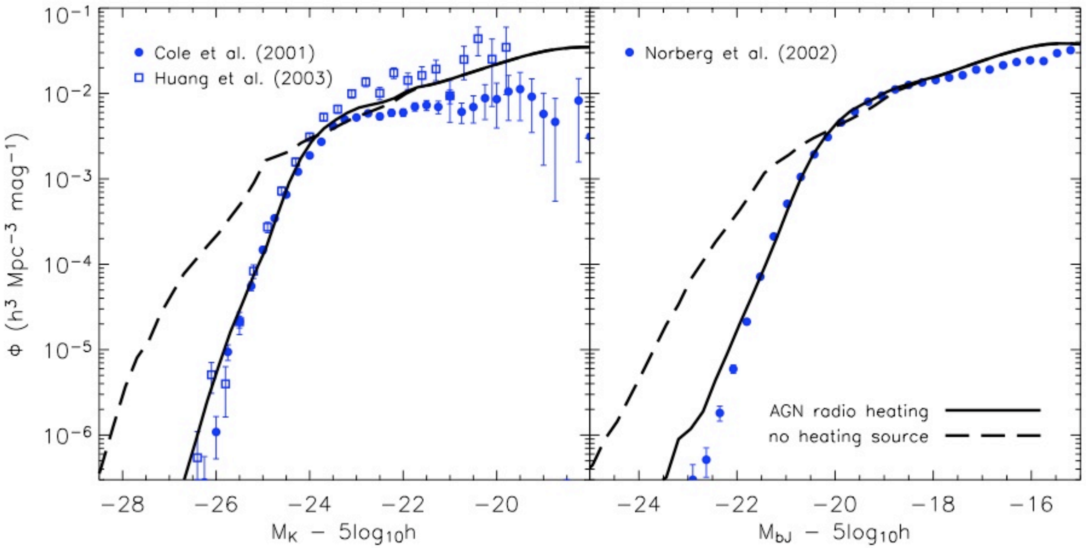


Massive galaxy density and colors: AGN feedback!

Menci+ 2006



Croton+2006



Without AGN heating SAMs:

1. overpredict luminosities of massive galaxies by ~2 mags

and/or

2. predict a number of massive blue galaxies higher than observed

AGN Feedback & AGN accretion mode

- Quasar mode
  - Major mergers
  - Minor mergers
  - Galaxy encounters
  - Activity periods are strong, short and recurrent
- AGN density decrease at z<2 is due to:
  - decrease with time of galaxy merging rate
  - Decrease with time of encounters rate
  - Decrease with time of galactic cold gas left available for accretion
- Feedback is driven by AGN radiation

Menci+ 2003,2004,2006,2008

- Radio mode
- Low accretion-rate systems tend to be radiatively inefficient and jet-dominated
- Feedback from low luminosity AGN dominated by kinetic energy
- Low level activity can be ~continuous

Croton+ 2006

AGN feedback & AGN obscuration

Lapi Cavaliere & Menci 2005 ***Blast wave model:*** a way to solve the problem of the transport of energy: central highly supersonic outflows compress the gas into a blast wave terminated by a shock front, which moves outwards at supersonic speed and sweeps out the surrounding medium

Recipe plugged in the Menci et al. SAMs

$$R_S(t) \propto Mach\ t \propto \left(\frac{\Delta E}{E}\right)^{1/2} t$$

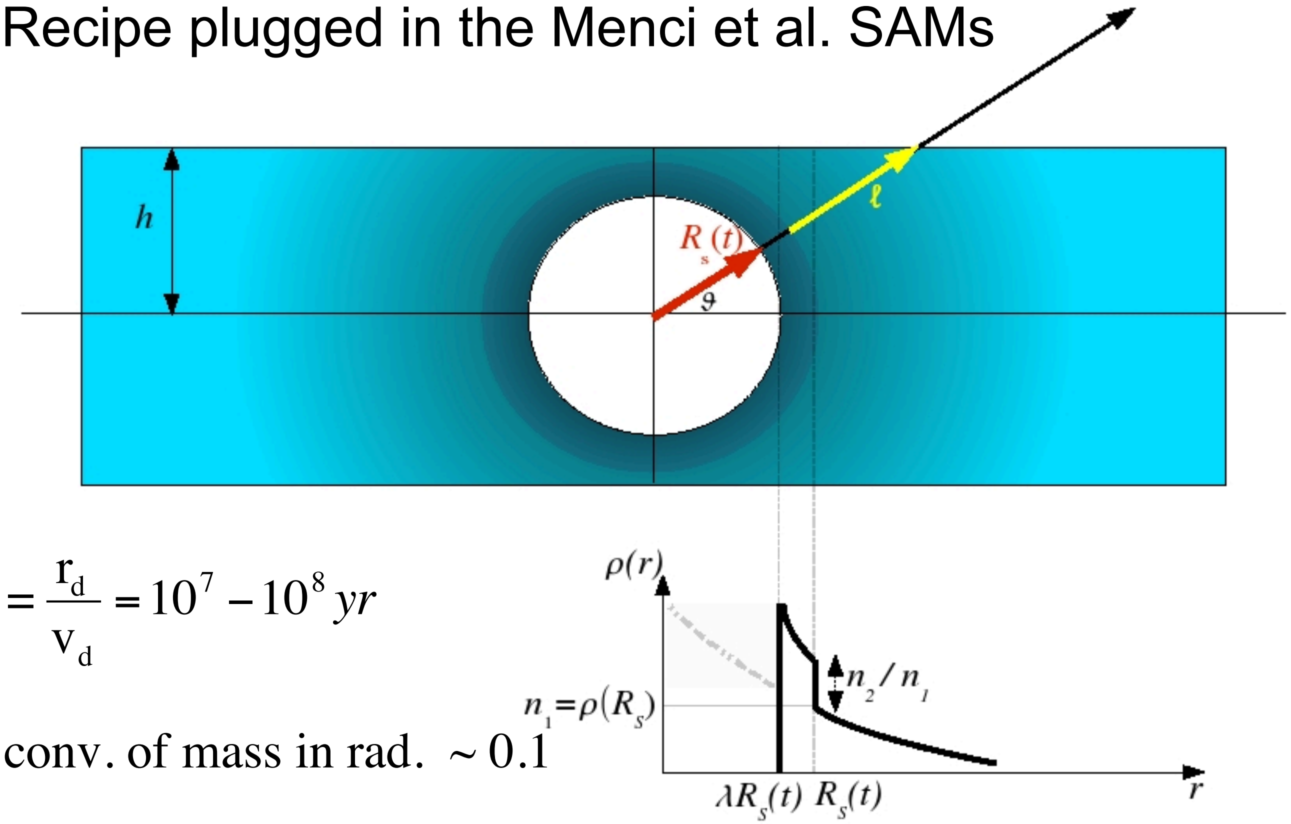
$$Mach \sim \left(\frac{\Delta E}{E}\right)^{1/2} \sim 40$$

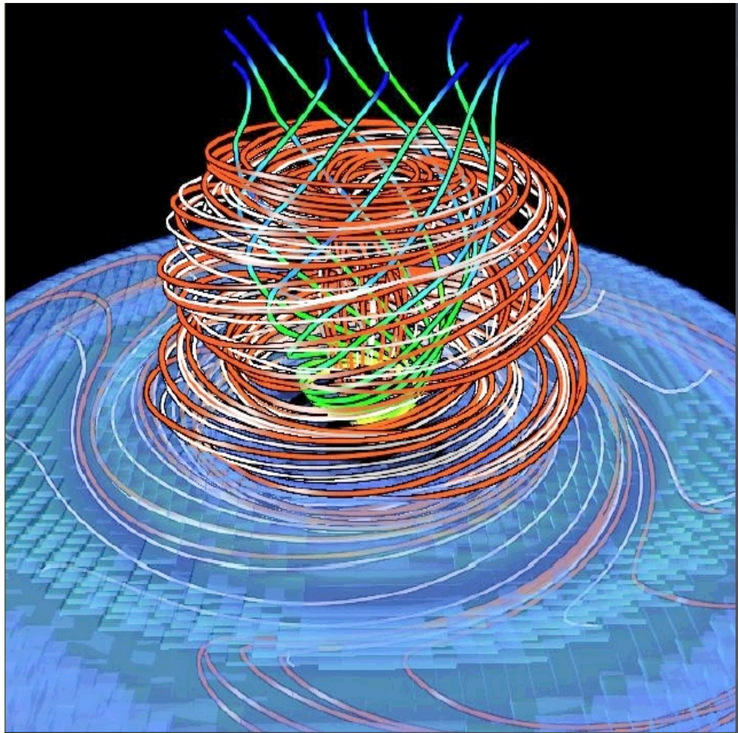
$$\Delta E = \varepsilon L \tau$$

$$\varepsilon \sim \frac{v_w}{2c} \sim 0.05 \text{ if } v_w \sim 0.1$$

$$\tau = \text{ timescale of AGN activity } = \frac{r_d}{v_d} = 10^7 - 10^8\,yr$$

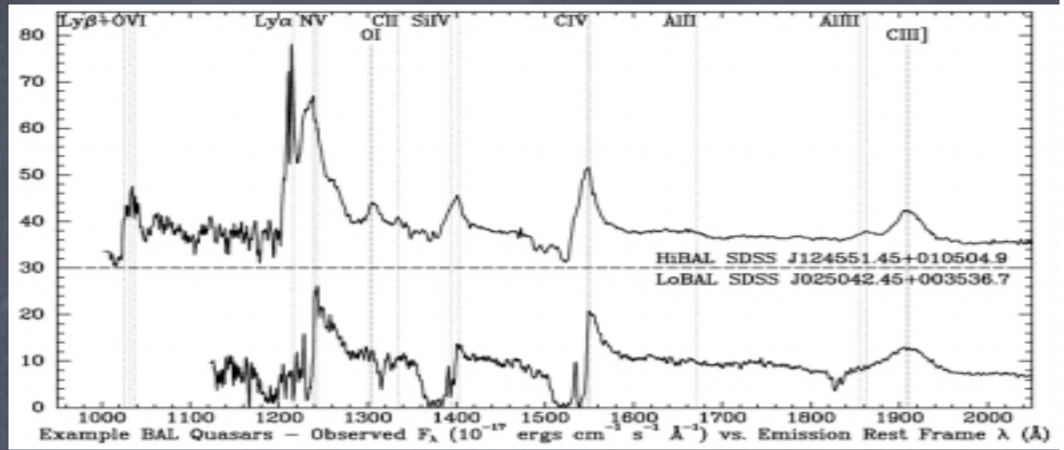
$$L = \frac{\eta c^2 \Delta m_{acc}}{\tau} \quad \eta = \text{efficiency of conv. of mass in rad. } \sim 0.1$$





AGN winds and outflows

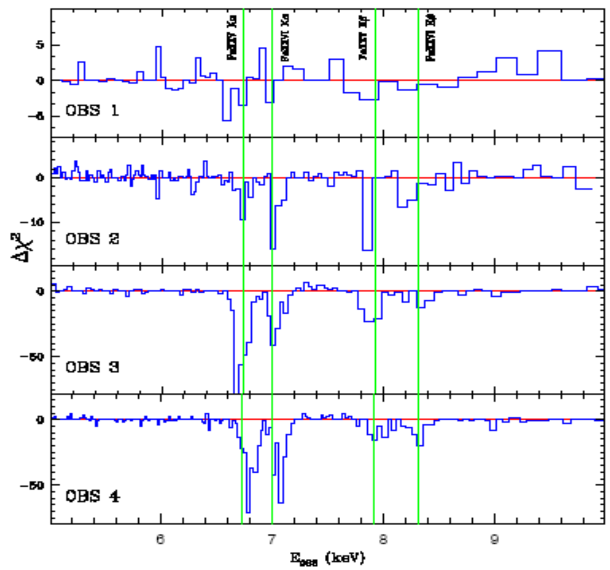
BAL QSOs (10-40% of all QSOs)



Fast winds with velocity up to a fraction of c are observed in the central regions of AGNs; they likely originate from the acceleration of disk outflows by the AGN radiation field.

Crenshaw+03, Pounds+03, Reeves+09, Moe+09

NGC1365 Risaliti+ 2005



BAL sequence Lipari+ 2006