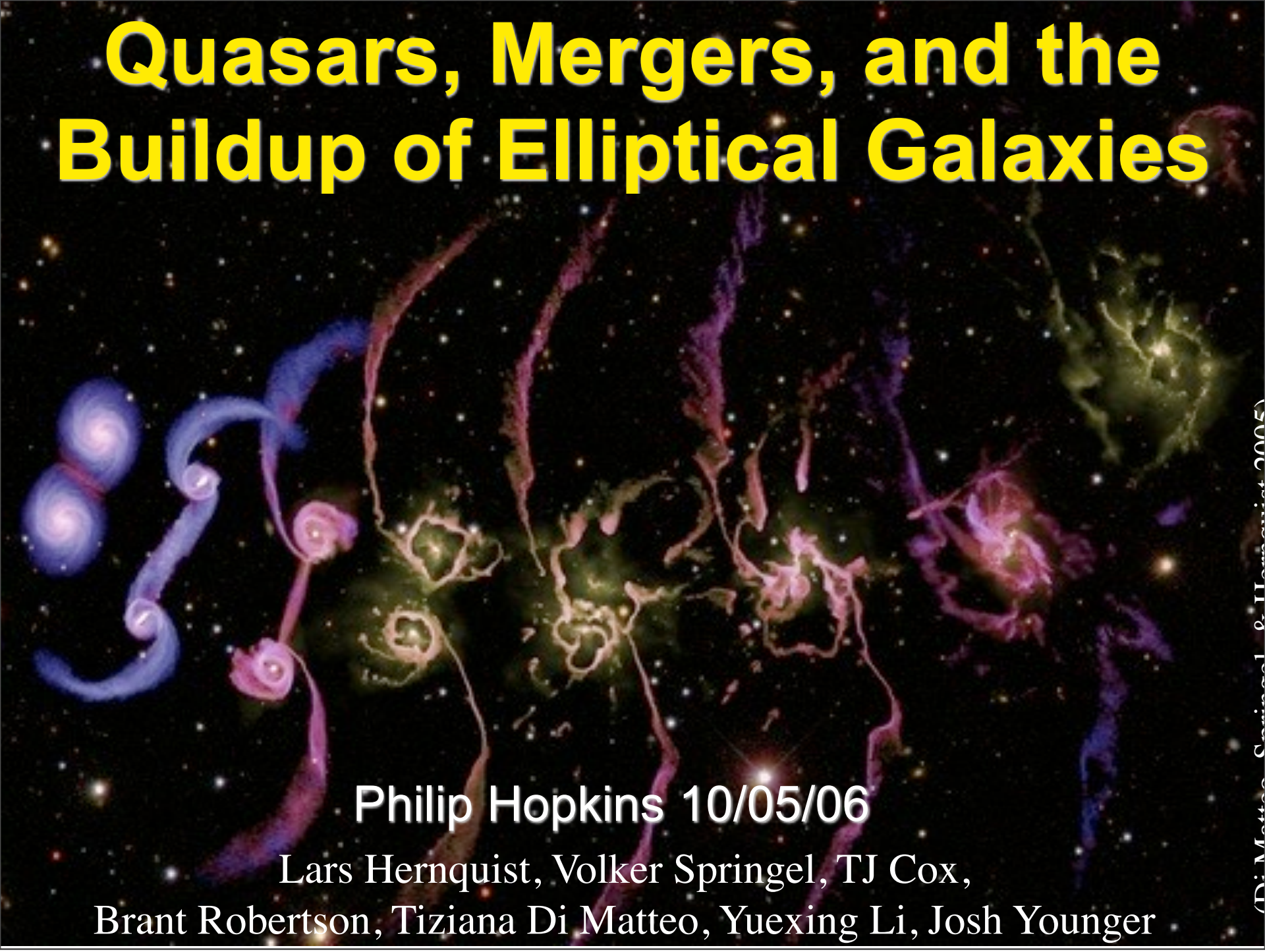
Quasars, Mergers, and the Buildup of Elliptical Galaxies



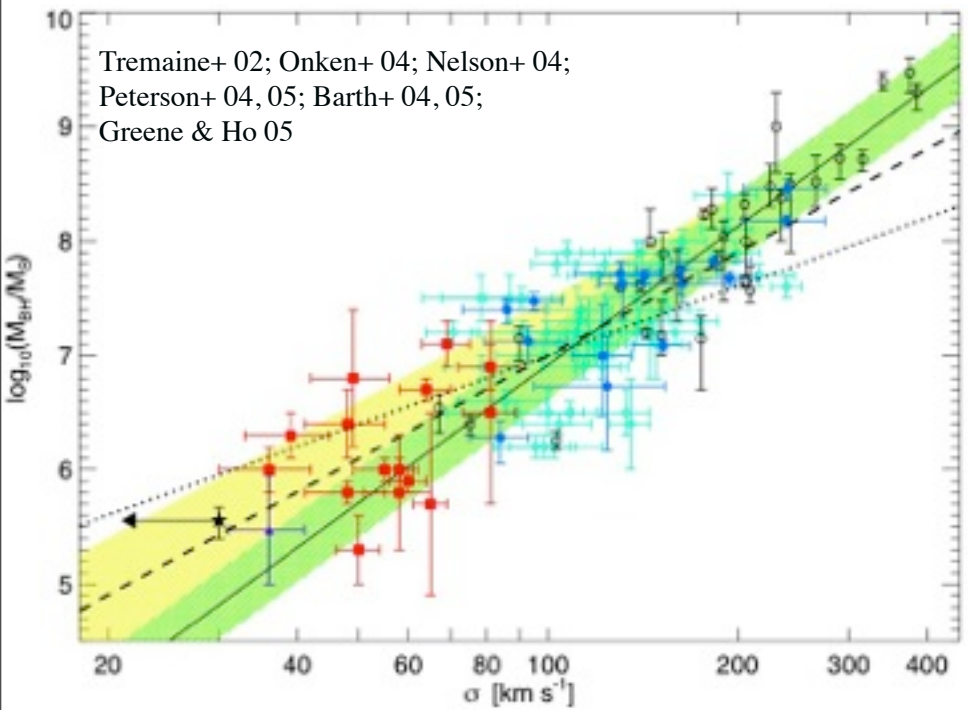
Philip Hopkins 10/05/06

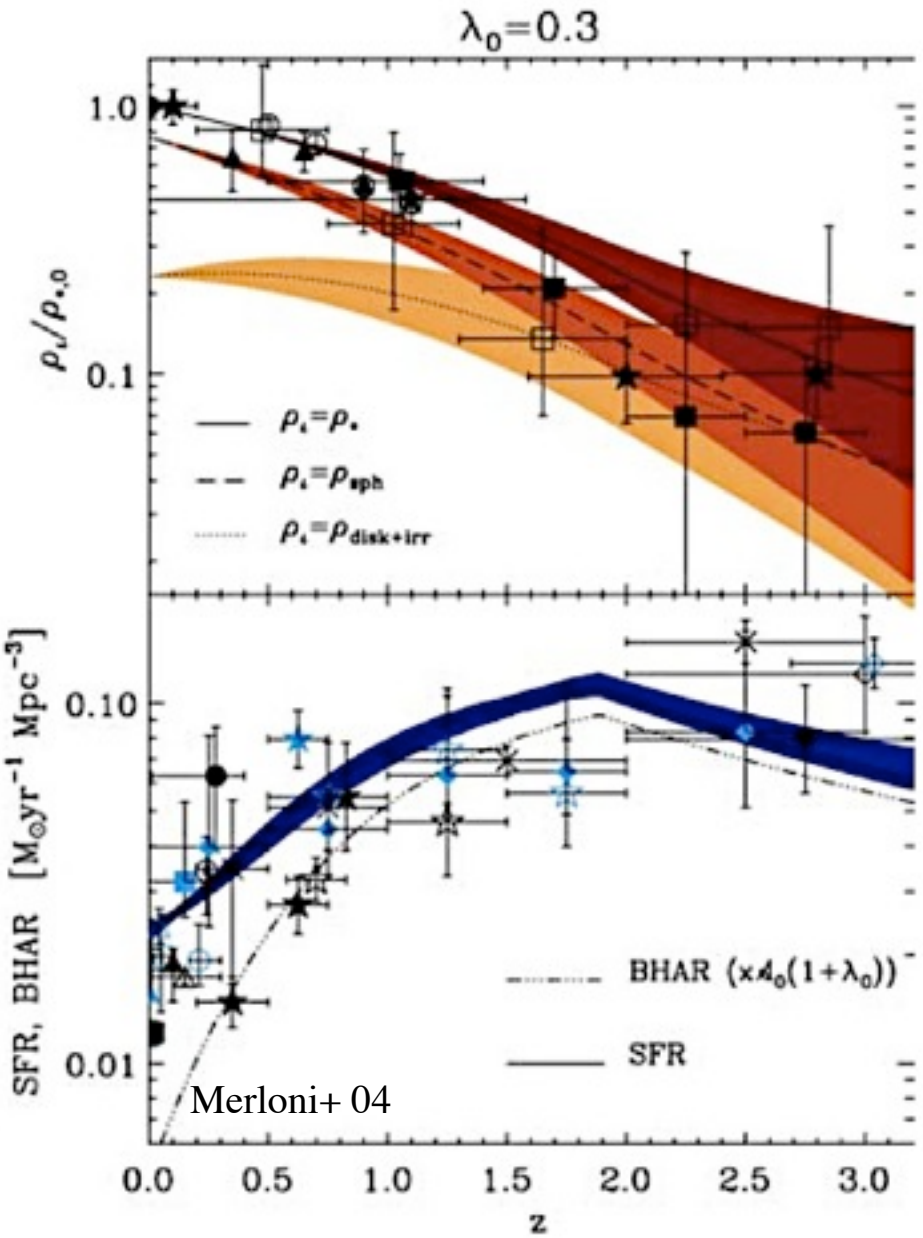
Lars Hernquist, Volker Springel, TJ Cox,
Brant Robertson, Tiziana Di Matteo, Yuexing Li, Josh Younger

(Di Matteo, Springel, & Hernquist 2005)

Motivation

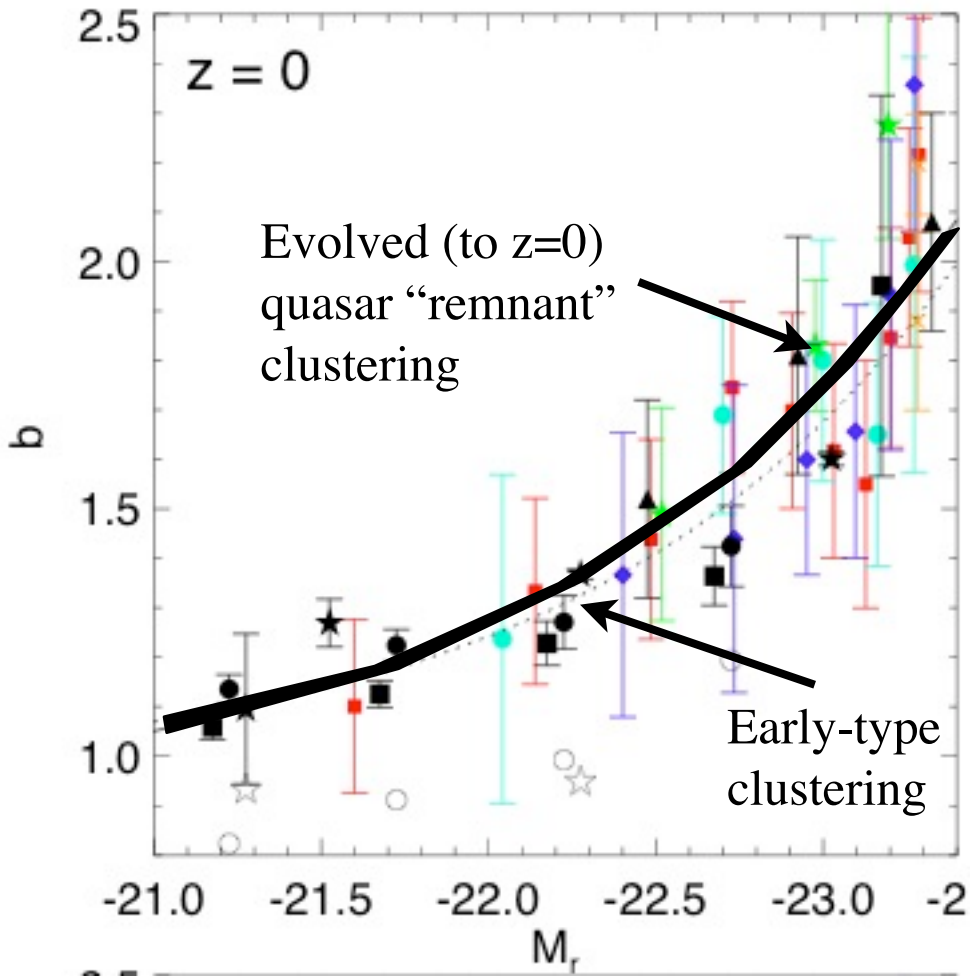
QUASARS AND SPHEROID FORMATION





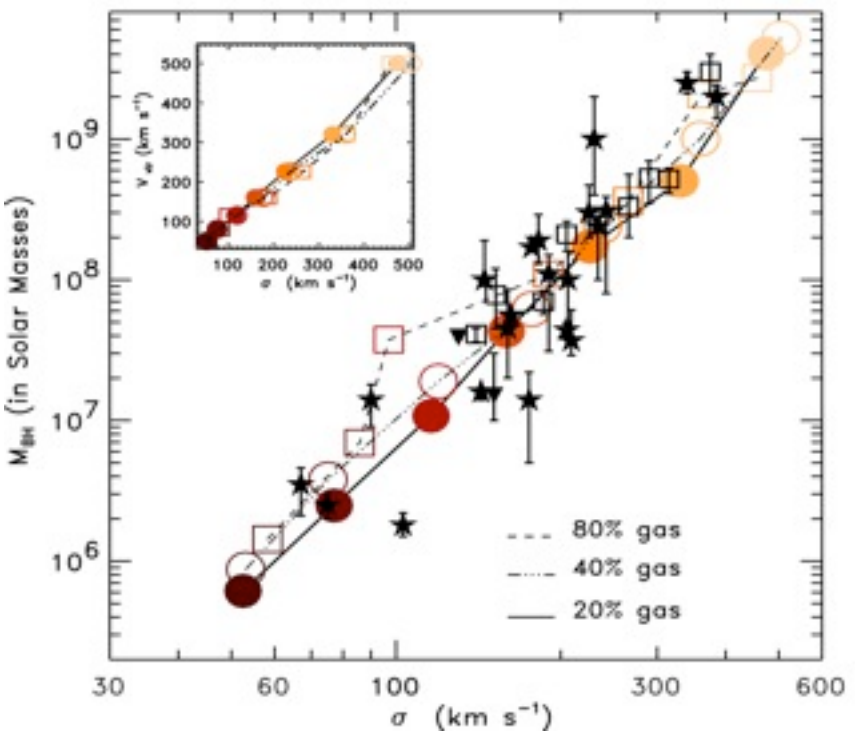
Motivation

QUASARS *ARE* LOCAL ELLIPTICAL PROGENITORS



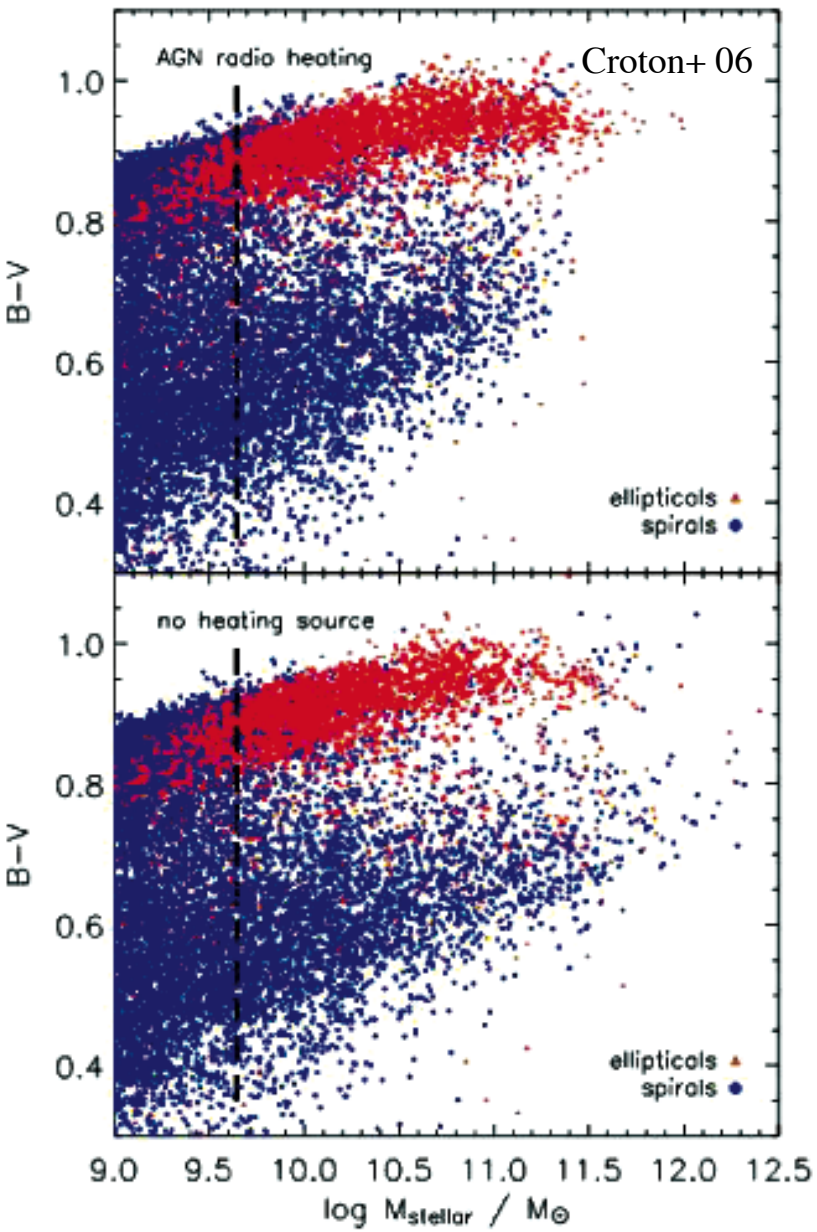
Hopkins et al. (in prep)

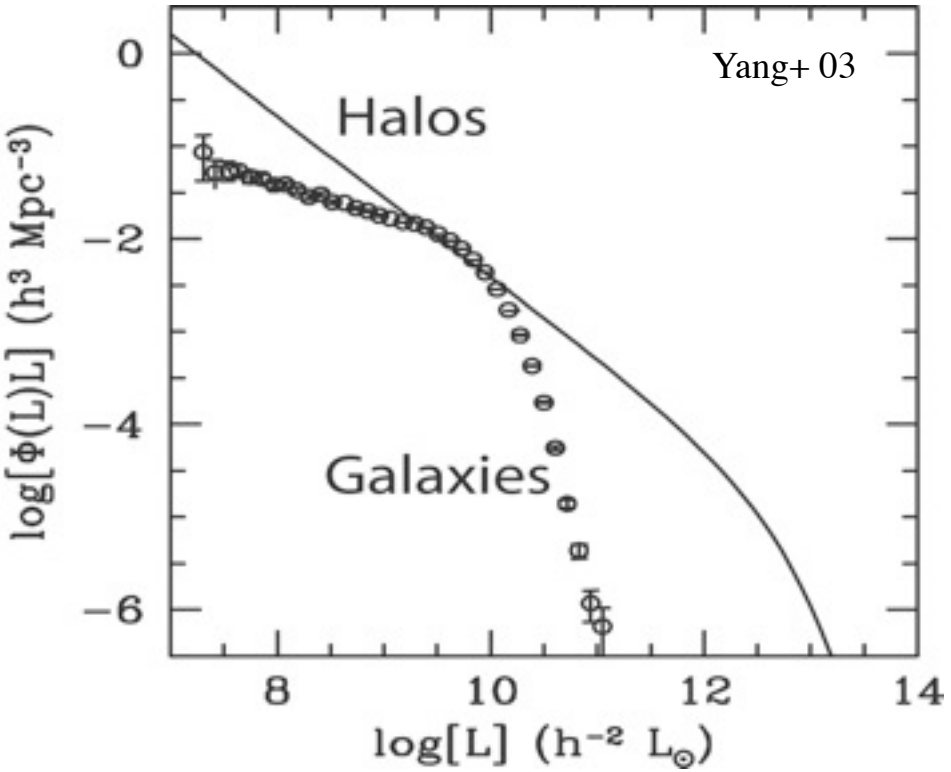
di Matteo+ 05

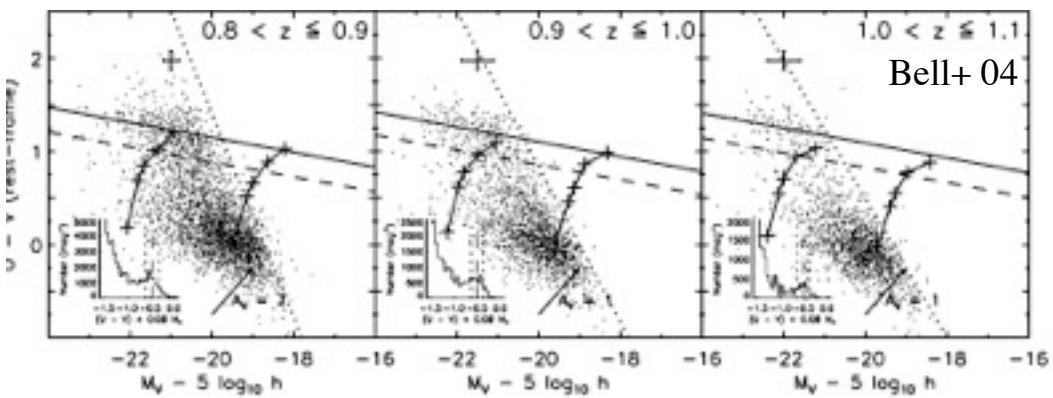


Motivation

QUASARS AND SPHEROID FORMATION

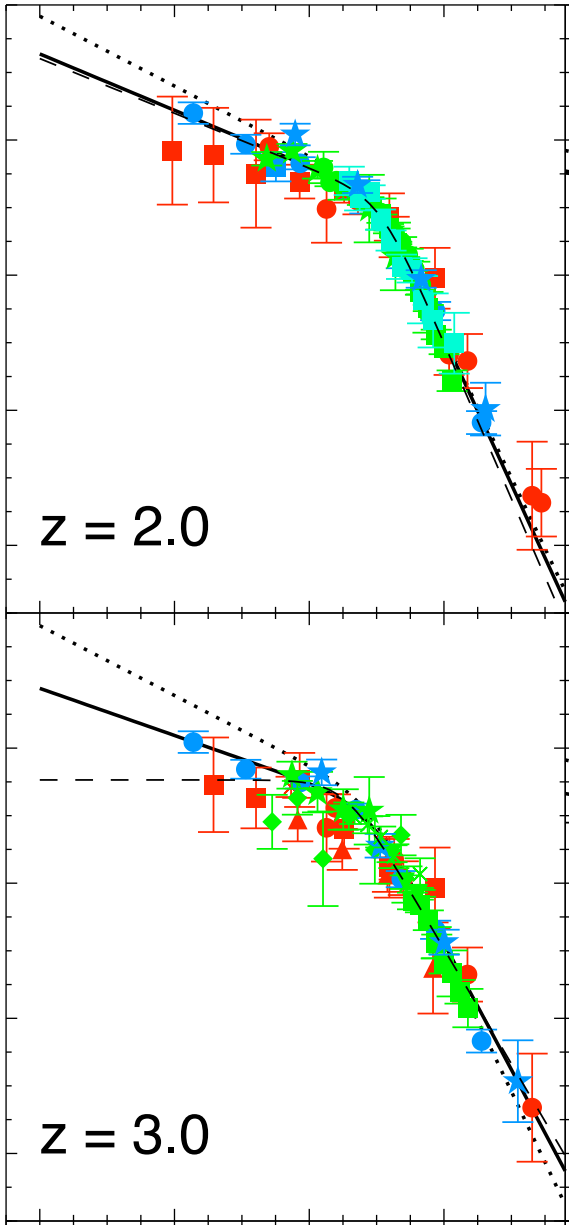


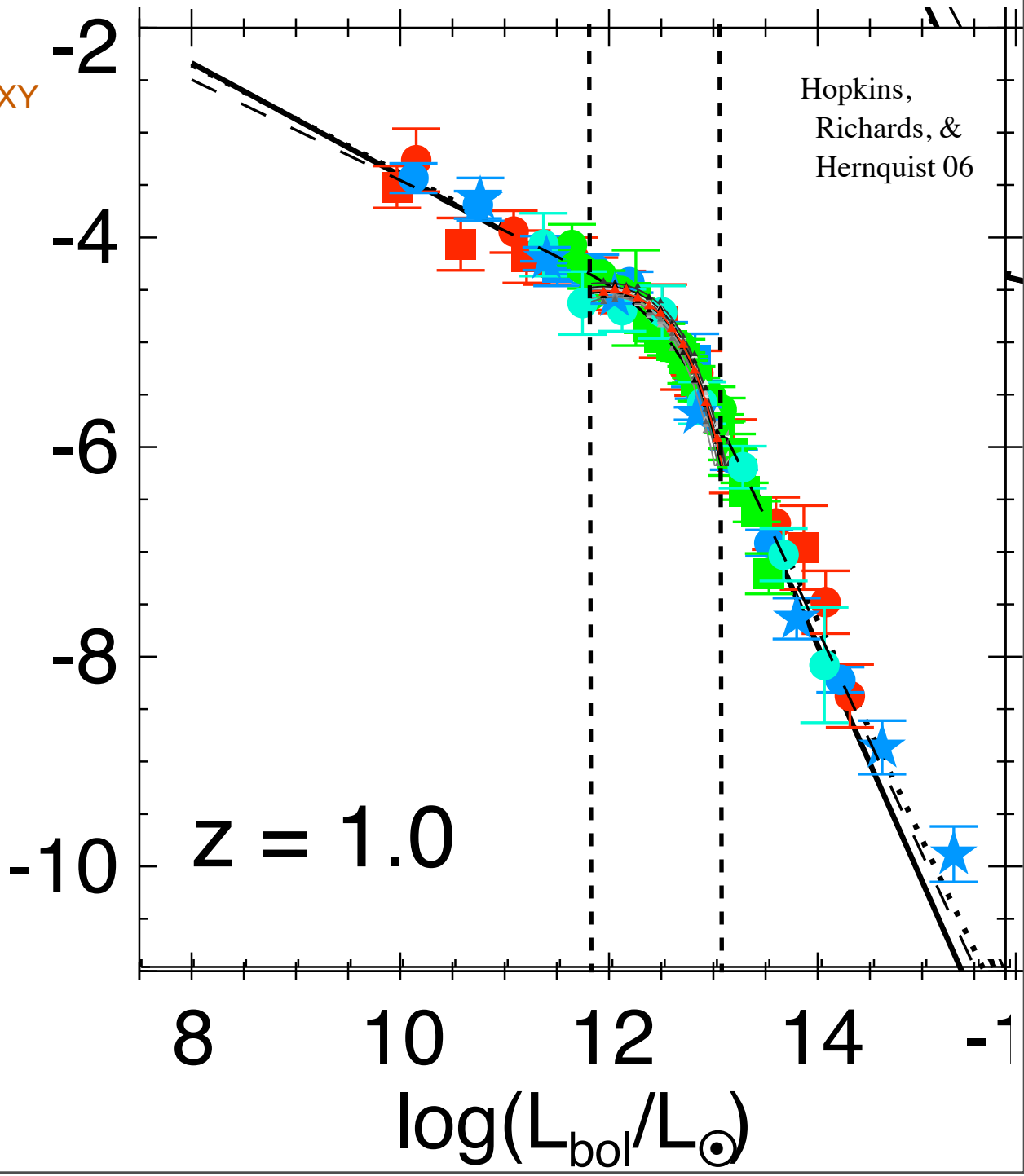




Motivation

QUASARS AS PROBES OF GALAXY FORMATION?



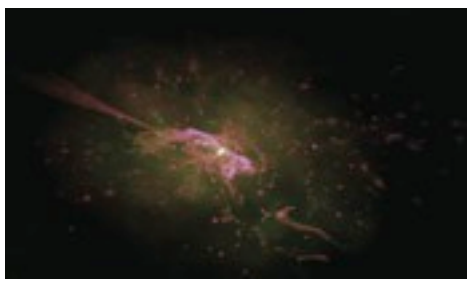


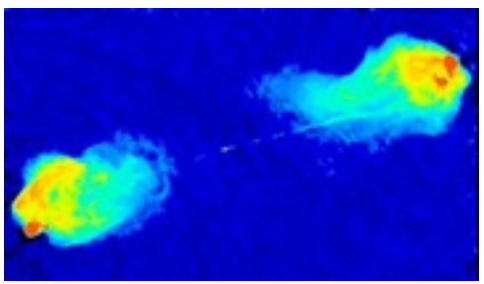
First, A Caveat...

"Transition" vs. "Maintenance"

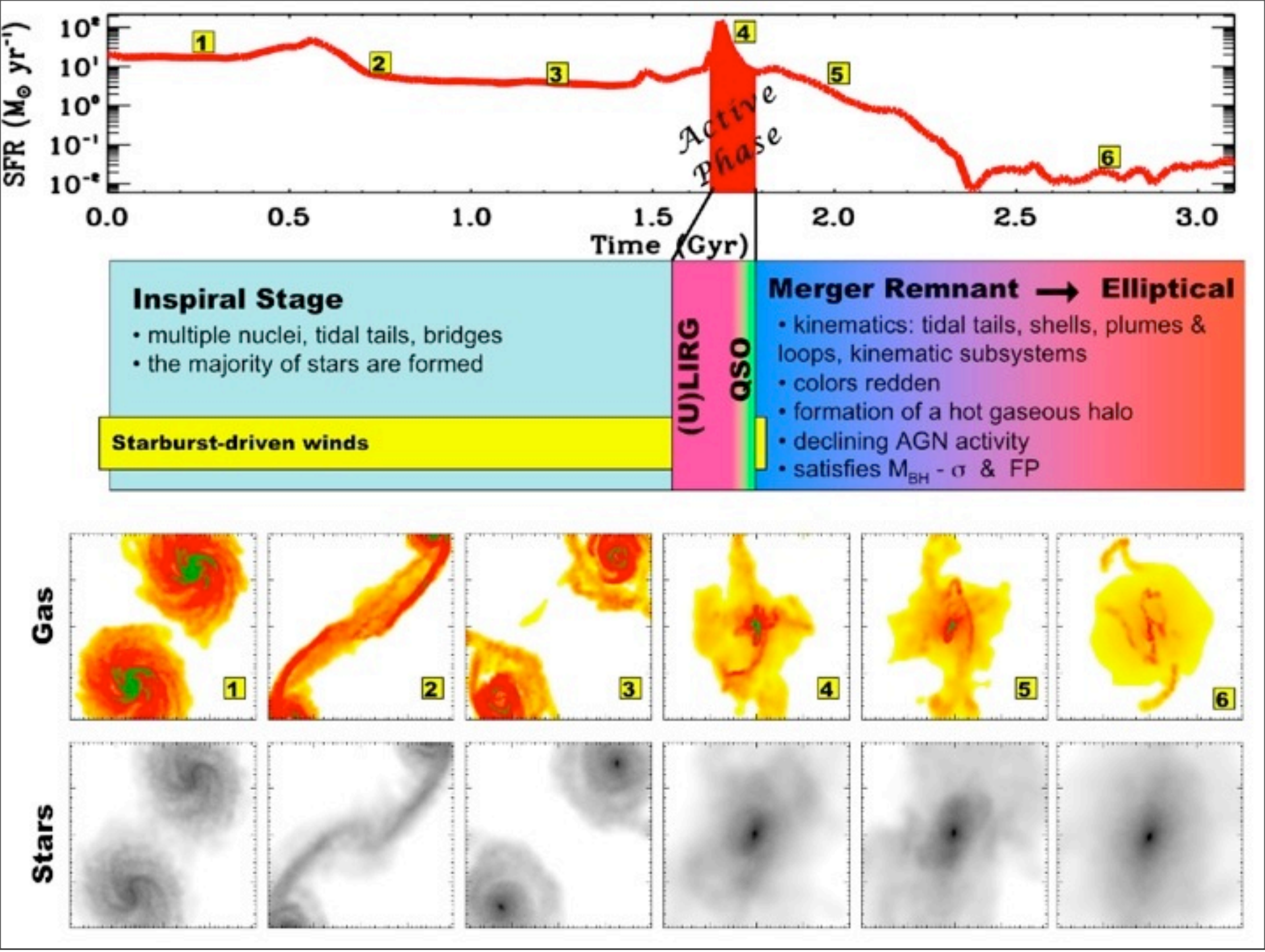
- Move mass from Blue to Red
- Rapid
- Small scales
- "Quasar" mode (high mdot)
- Morphological Transformation
- Gas-rich/Dissipational Mergers

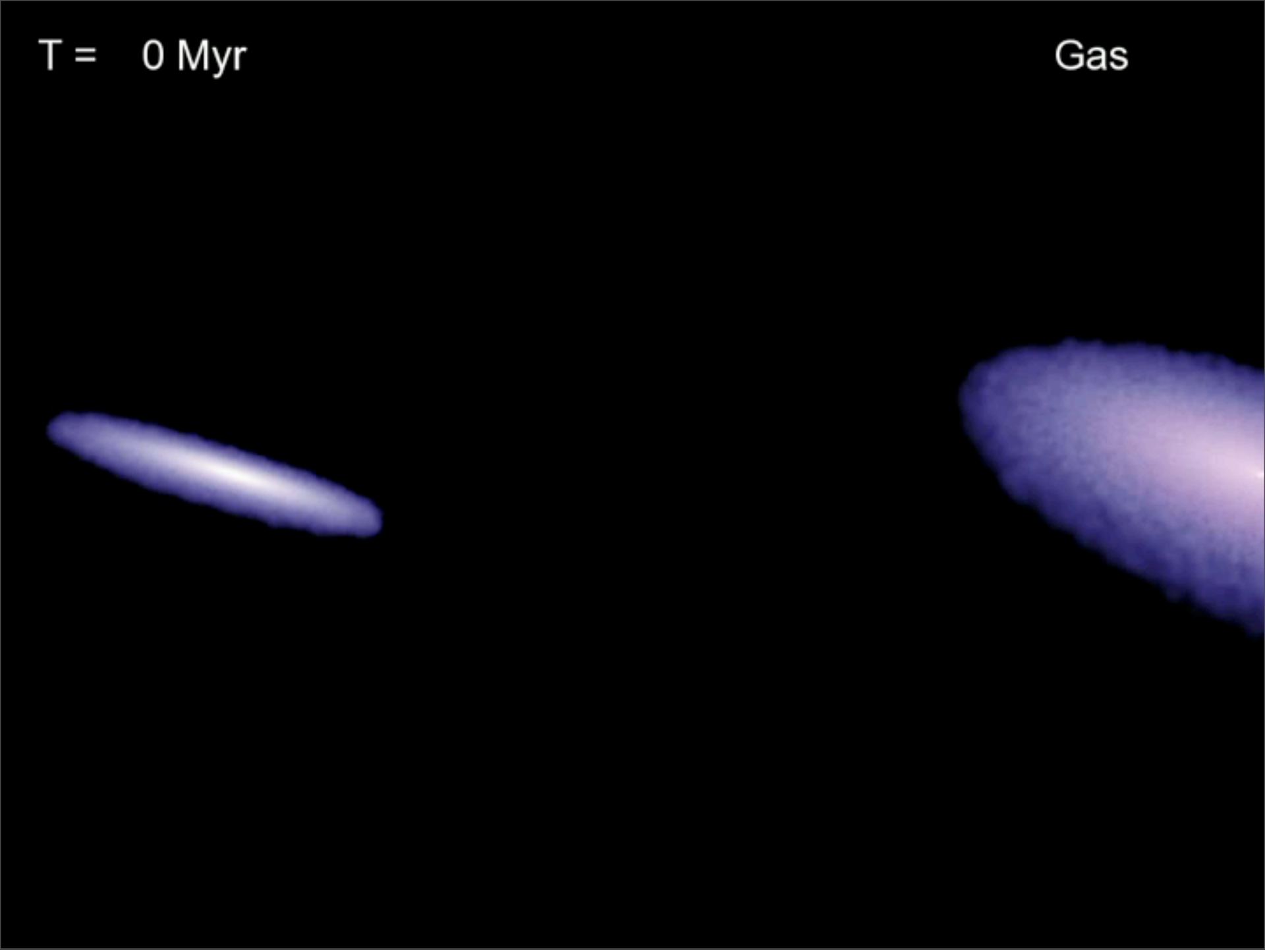
- Keep it Red
- Long-lived (~Hubble time)
- Large (~halo) scales
- "Radio" mode (low mdot)
- Subtle morphological change
- "Dry"/Dissipationless Mergers





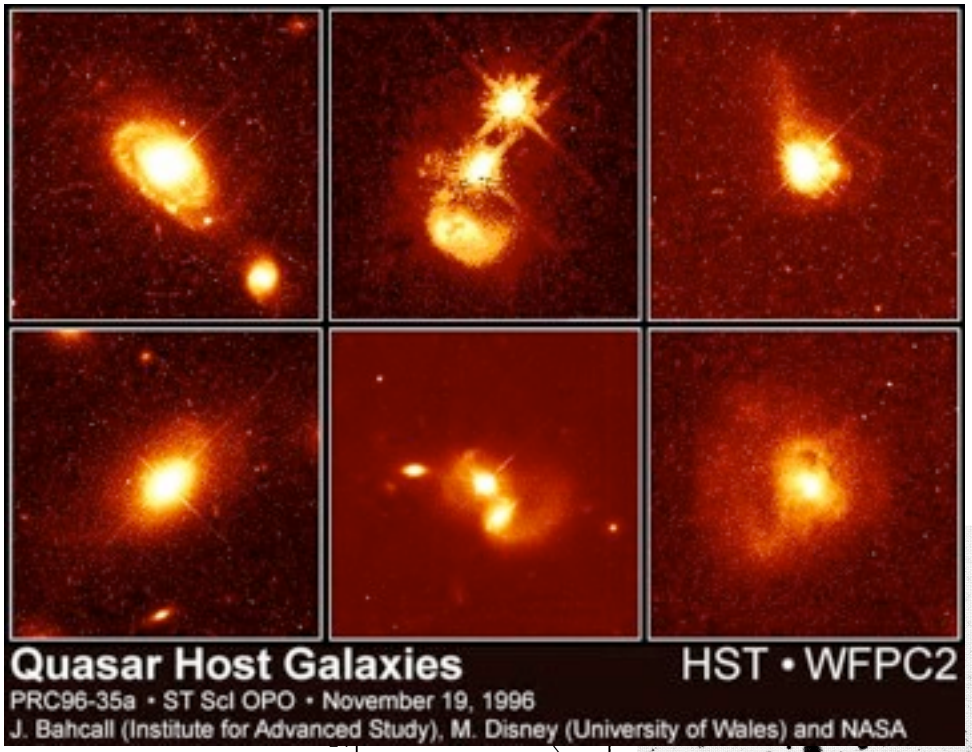
NO reason these should be the same mechanisms


SFR ($M_\odot$ yr^{-1})
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
1
2
3
4
5
6
Active Phase
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Time (Gyr)
Inspiral Stage
• multiple nuclei, tidal tails, bridges
• the majority of stars are formed
Starburst-driven winds
(U)LIRG
QSO
Merger Remnant → Elliptical
• kinematics: tidal tails, shells, plumes & loops, kinematic subsystems
• colors redden
• formation of a hot gaseous halo
• declining AGN activity
• satisfies M_{BH} - σ & FP
Gas
Stars


T = 0 Myr
Gas

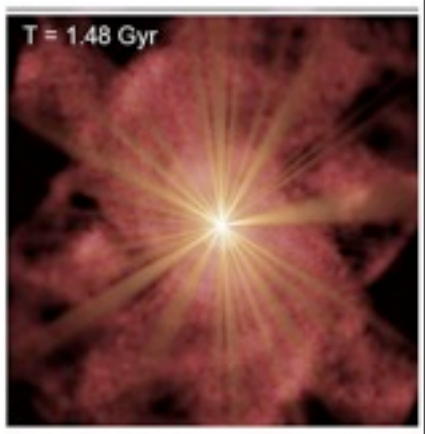
Feedback Reveals the Brightest Quasars

GAS IS HEATED AND EXPELLED IN BLOWOUT, REVEALING A BRIEF, BRIGHT QUASAR

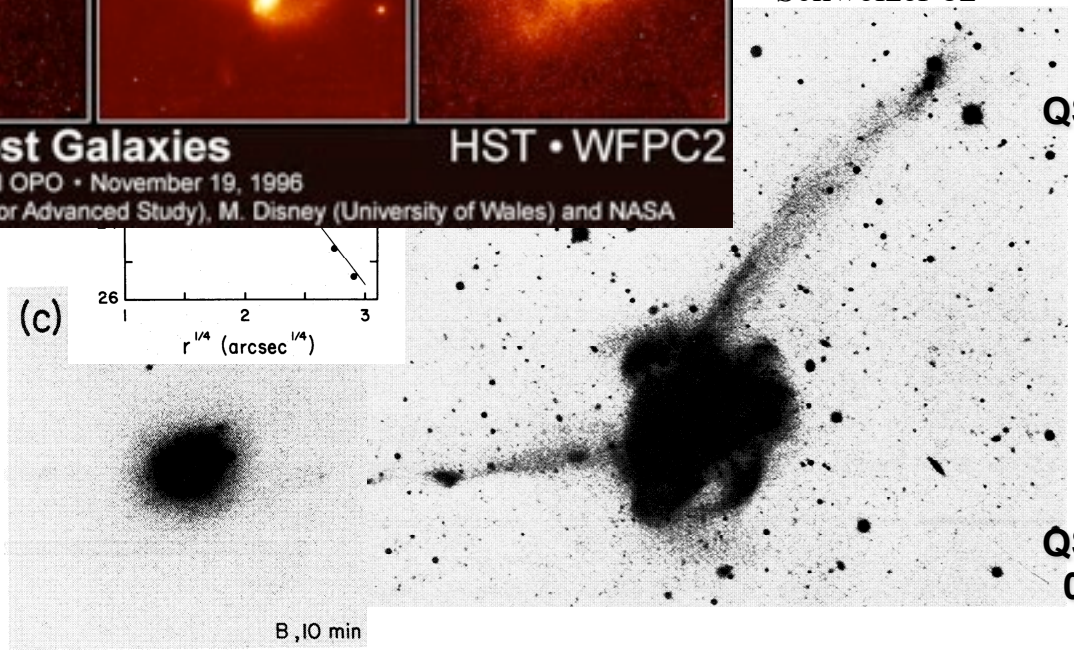


Bahcall+ 97

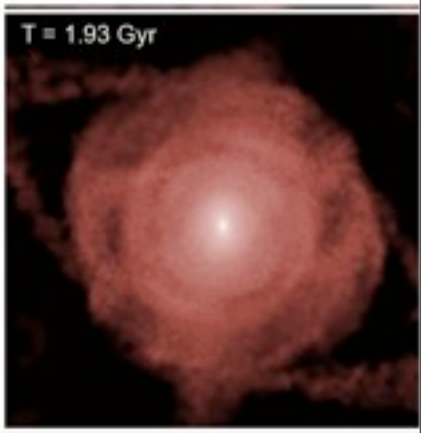
QSO = 1000xHost



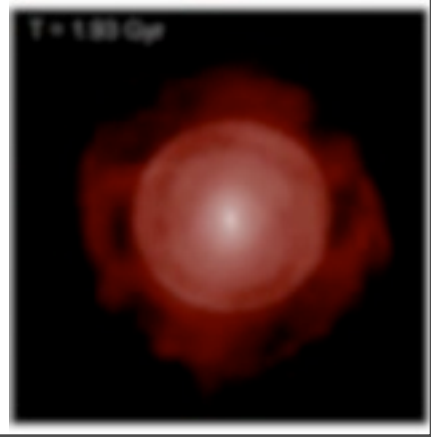
Schweizer 82



QSO = Host



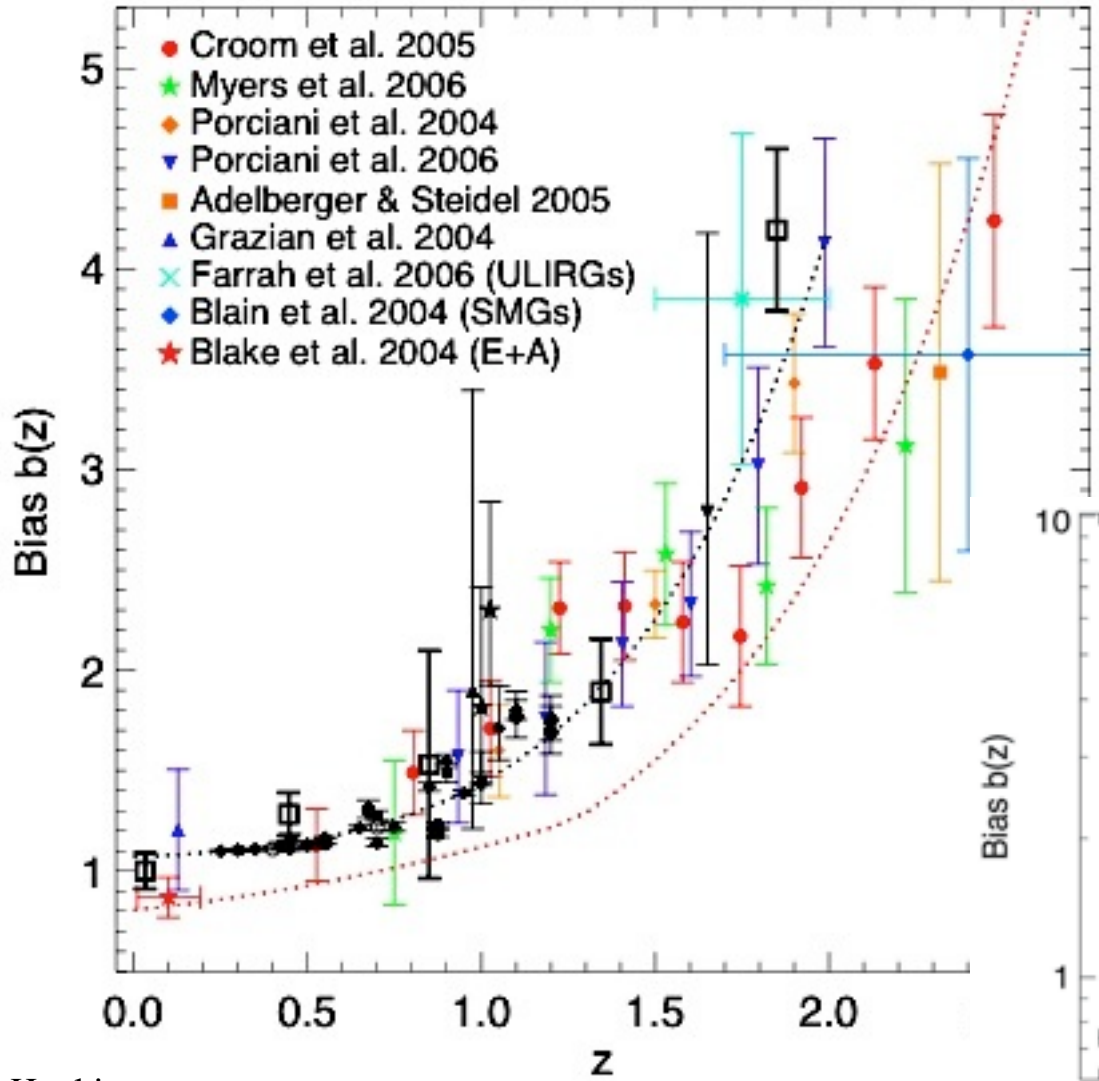
QSO = 0.1xHost



- Why can't we just look for the mergers? (see Jennifer Lotz's talk also!)

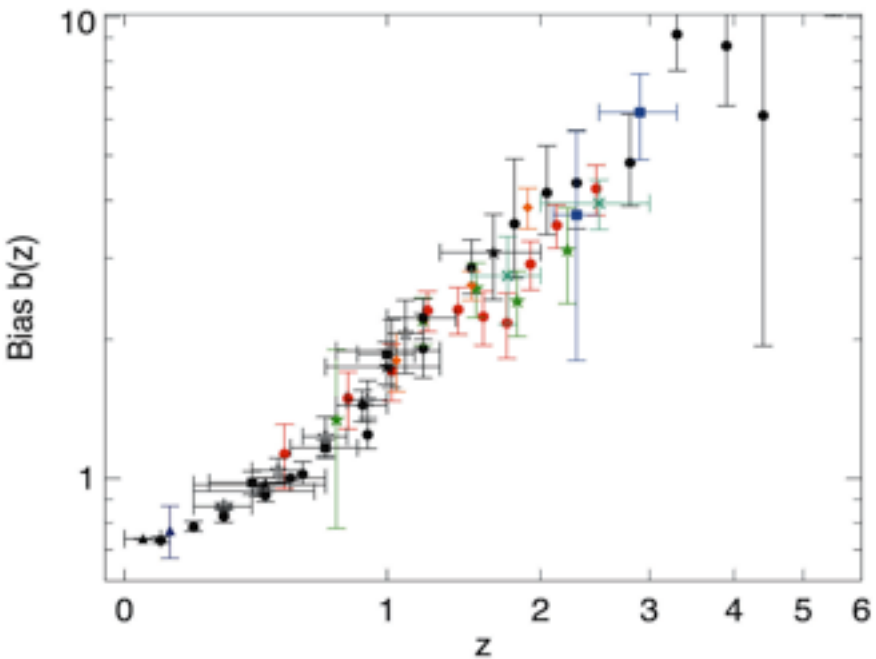
Empirical Tests of the Merger-Quasar Link

MERGER DRIVING WHEN YOU CAN'T SEE THE MERGER



Hopkins,
Bundy+ 06

Quasar Clustering =
Merger Clustering

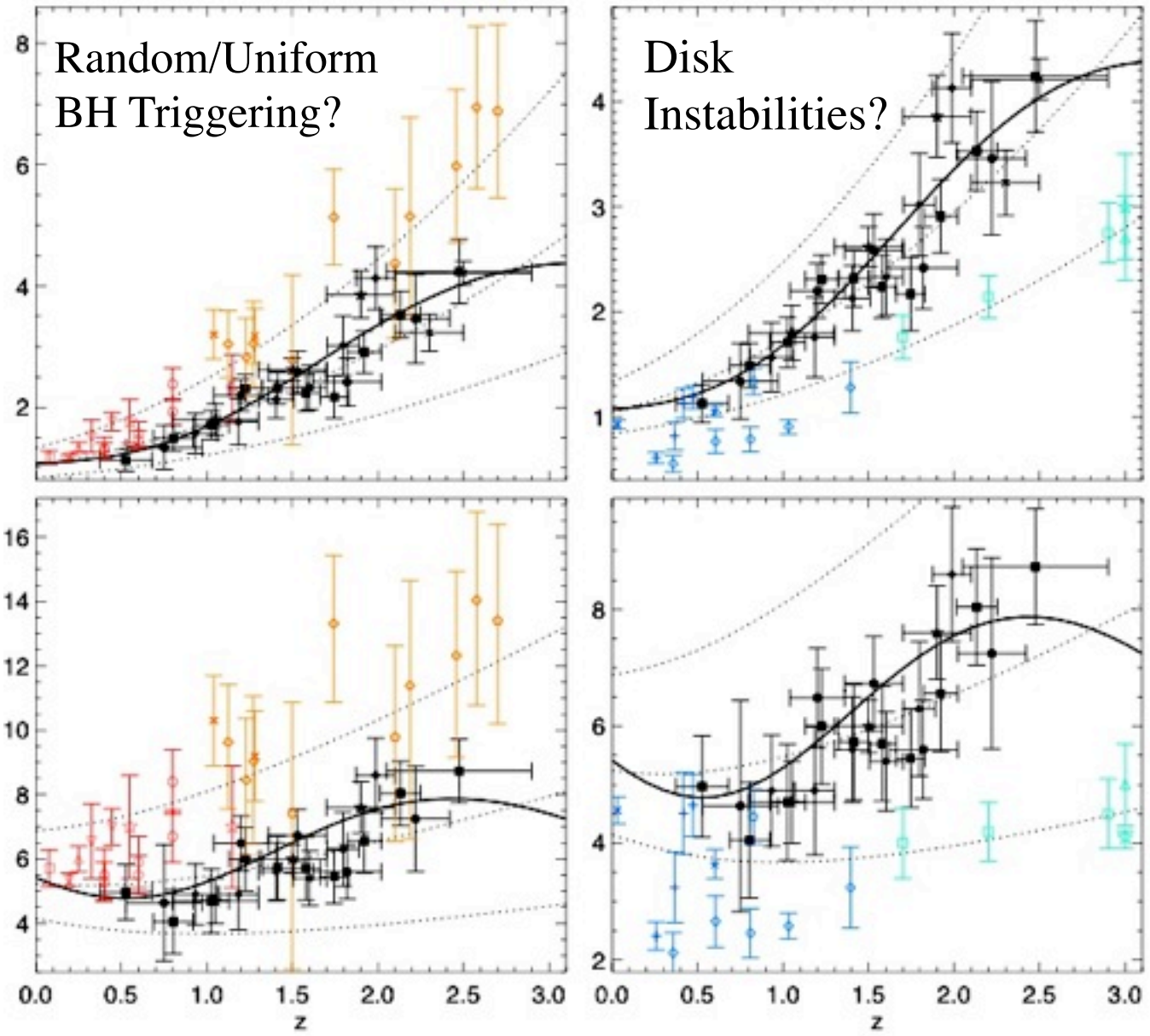


Empirical Tests of the Merger-Quasar Link

MERGER DRIVING WHEN YOU CAN'T SEE THE MERGER

b(z)

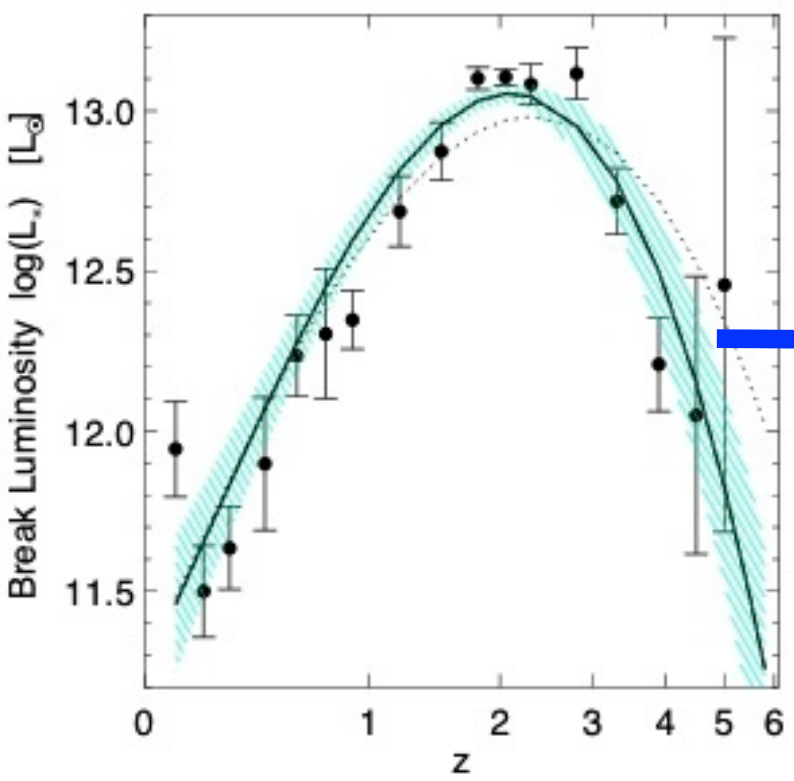
r_0(z)

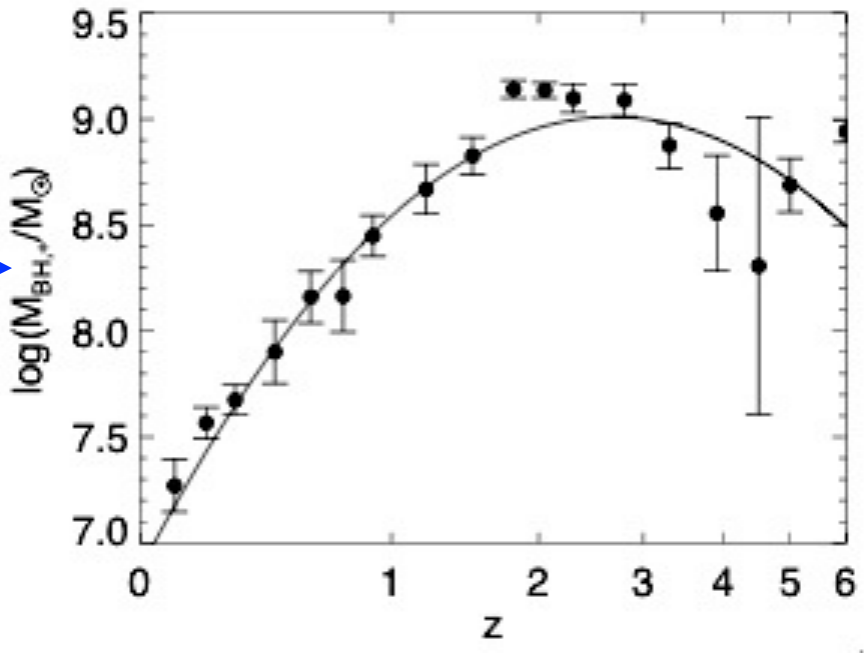


Quasar Luminosity Function Defines a Characteristic “Forming” Mass(z)

- Little ambiguity in interpretation at z < 2
  - High-z can’t get bigger
    - Observed mdot
    - Observed clustering
    - Local BHMF

Hopkins, Richards, & Hernquist 06





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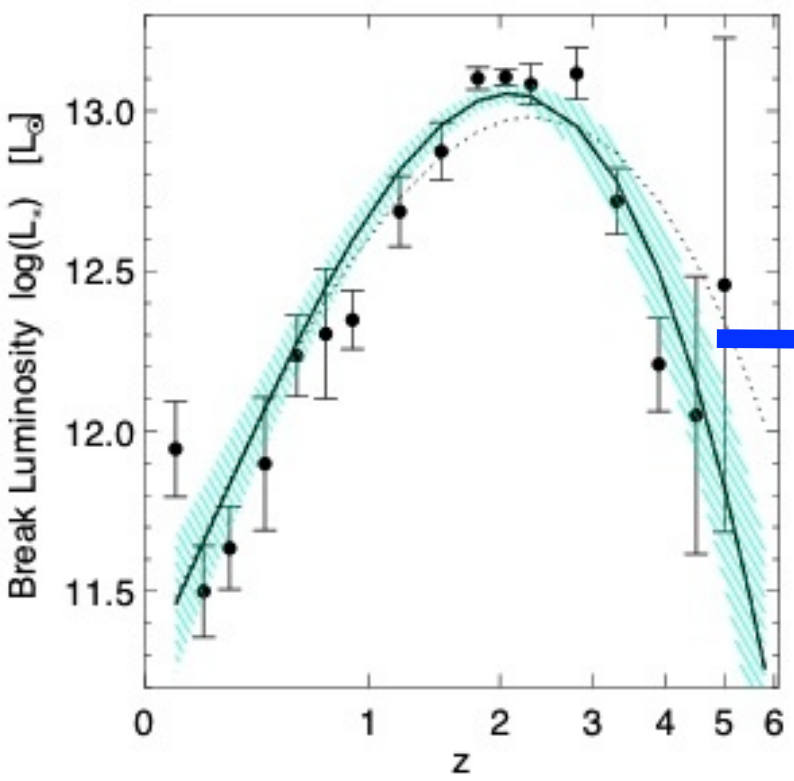
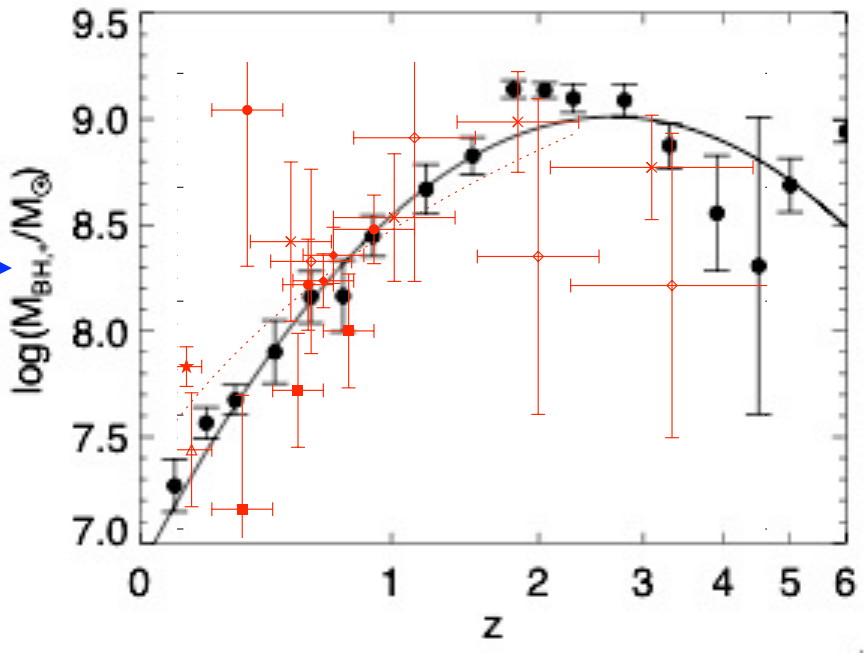
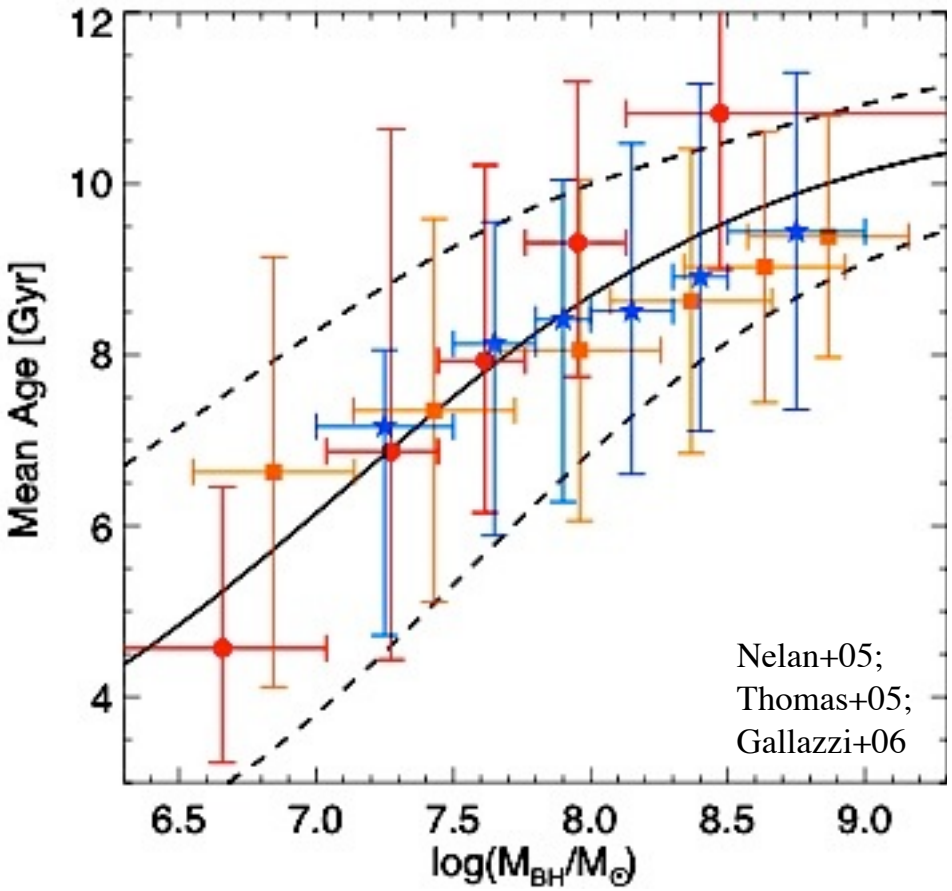
Hopkins, Richards, & Hernquist 06

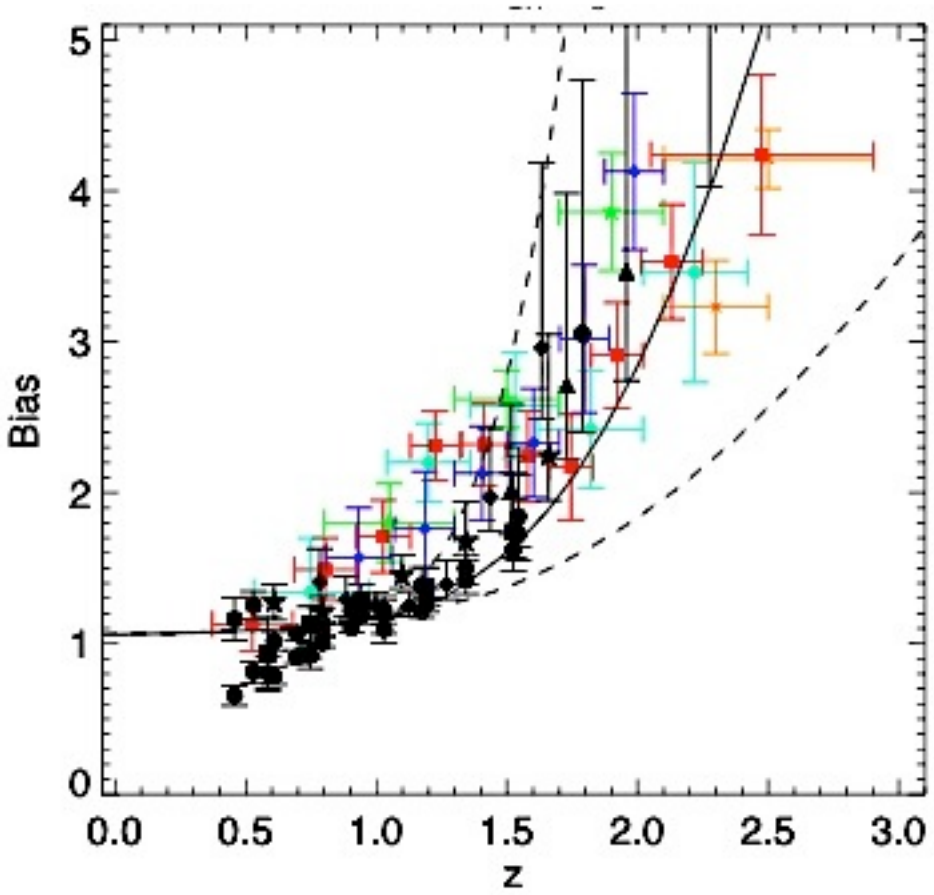




Quasar Luminosity Function Defines a Characteristic “Forming” Mass(z)

- Compare that M_BH(z) with the z=0 hosts’ formation times



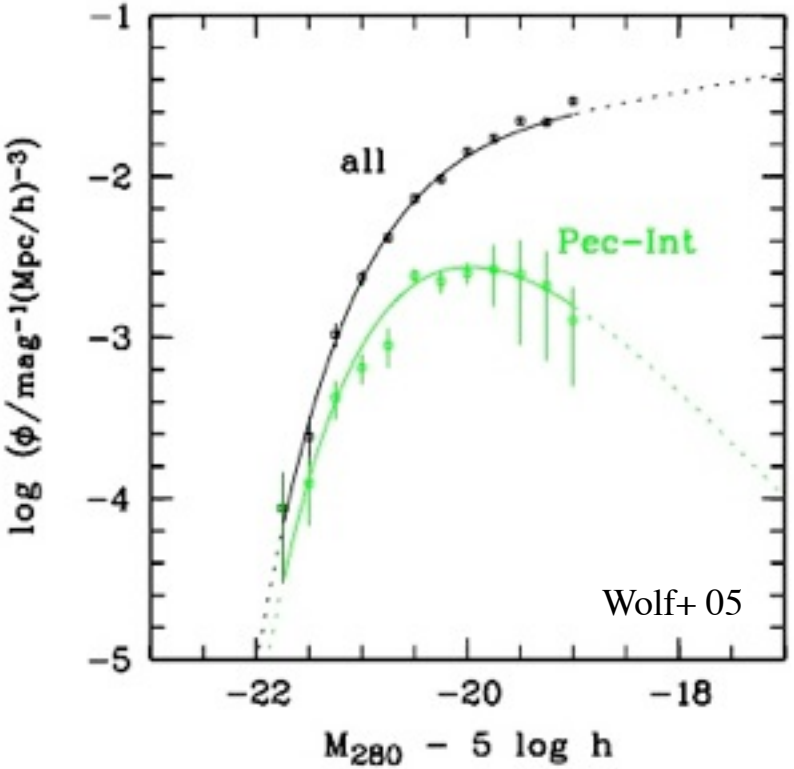


(in prep)

More Detailed Comparison

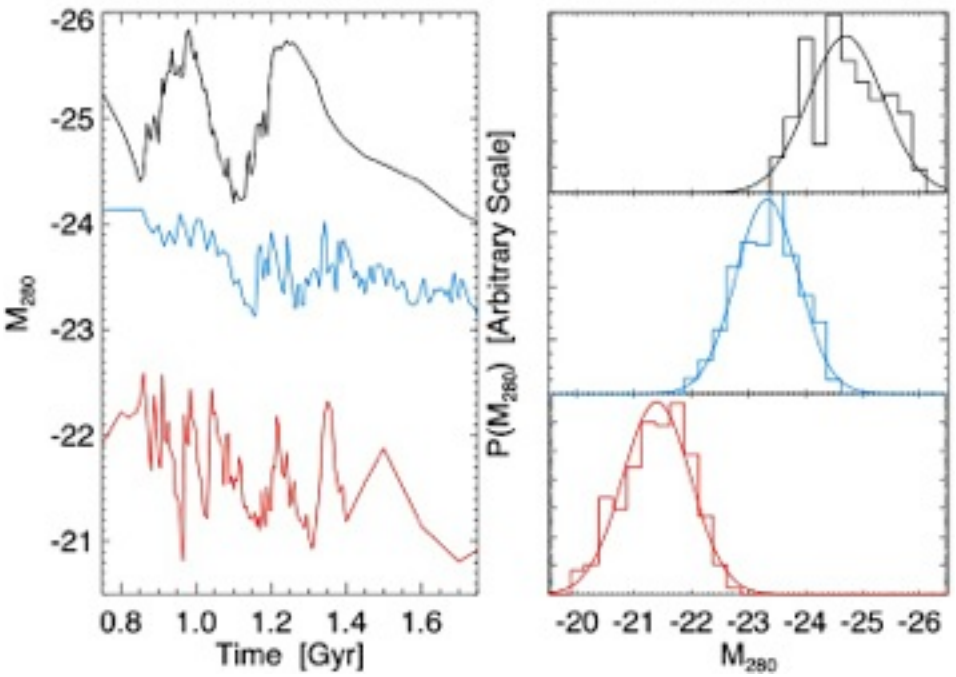
USING SIMULATIONS TO MAP QUASARS <> SPHEROIDS

Observed "Merger" MF



+

~500 Merger Simulations



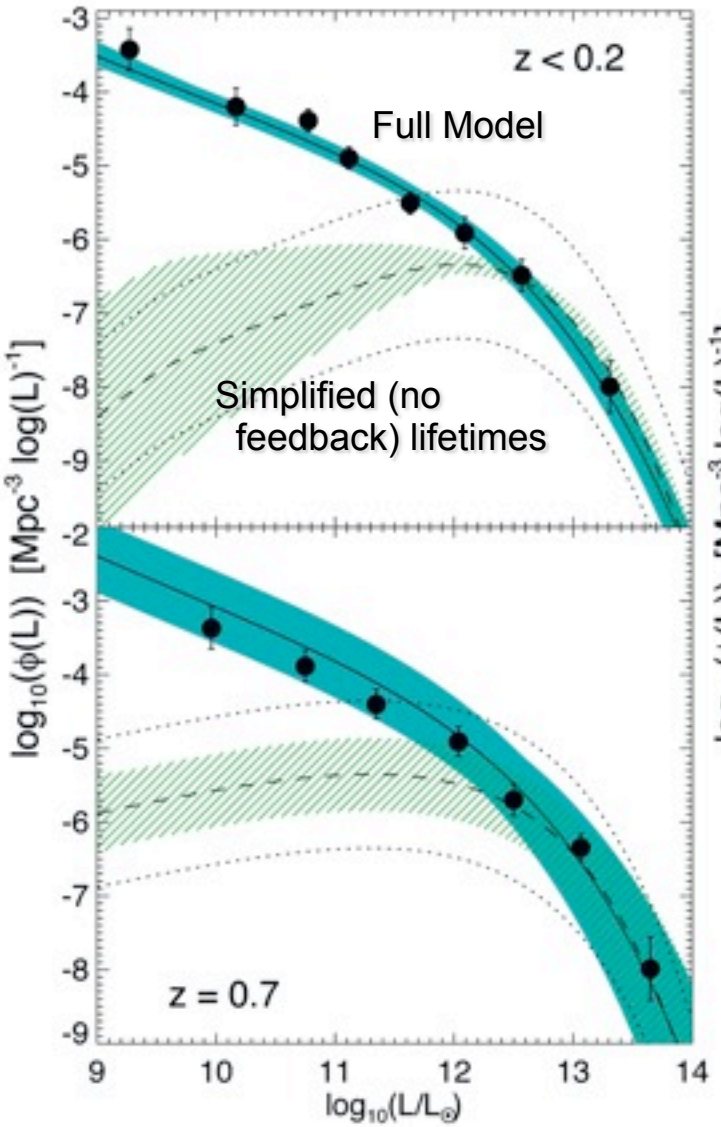
Hopkins, Somerville, Hernquist+ 06

More Detailed Comparison

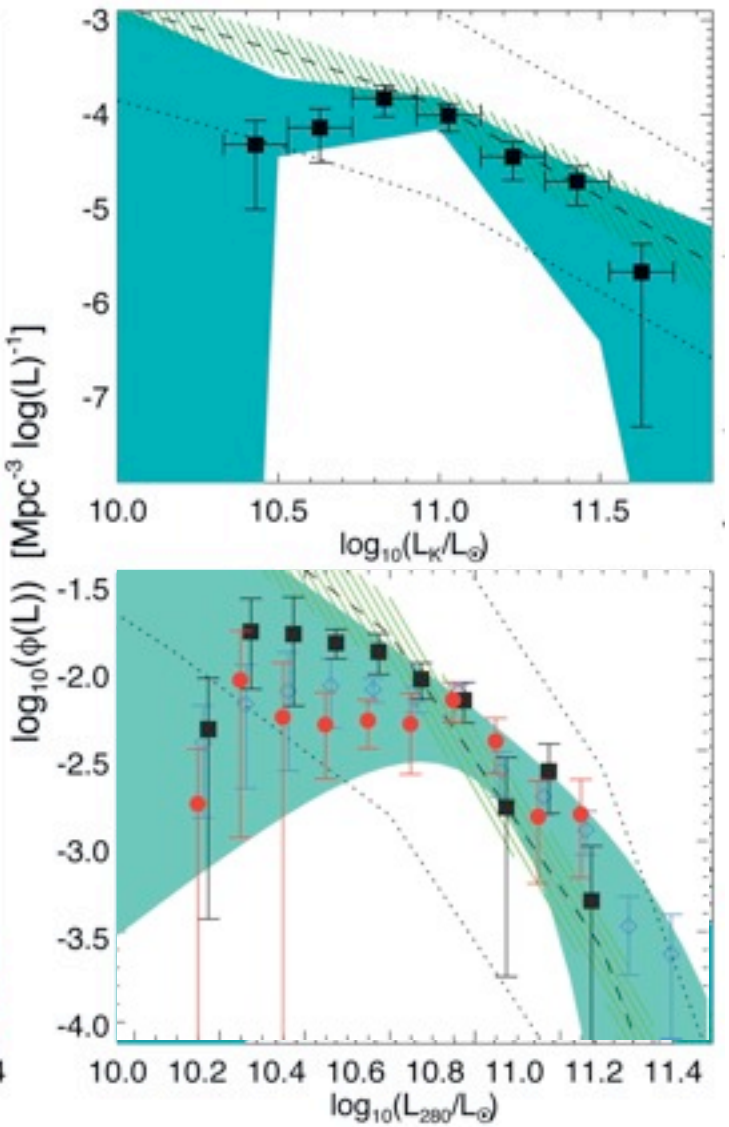
TEST STATISTICS OF QUASAR, RED GALAXY, & MERGER POPULATIONS

(see also Fontanot et al. 2006, Malbon et al. 2006, Volonteri et al. 2006)

Merger LF → Quasar LF



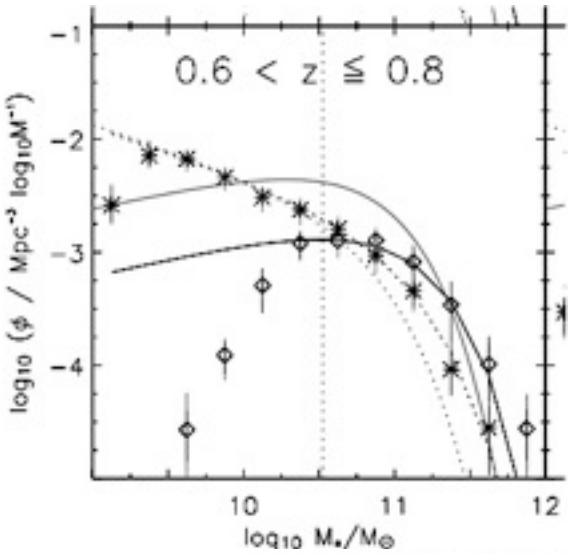
Quasar LF → Merger LF

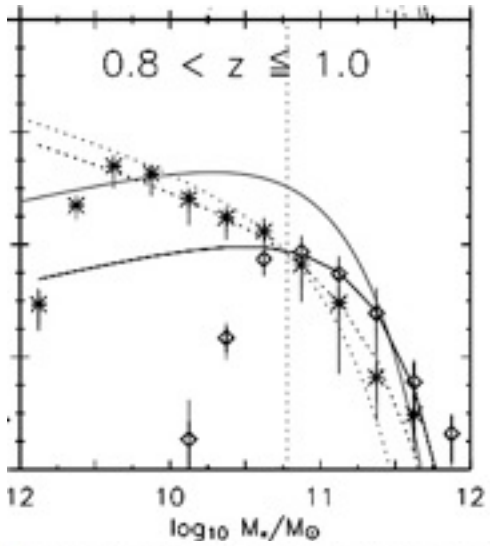


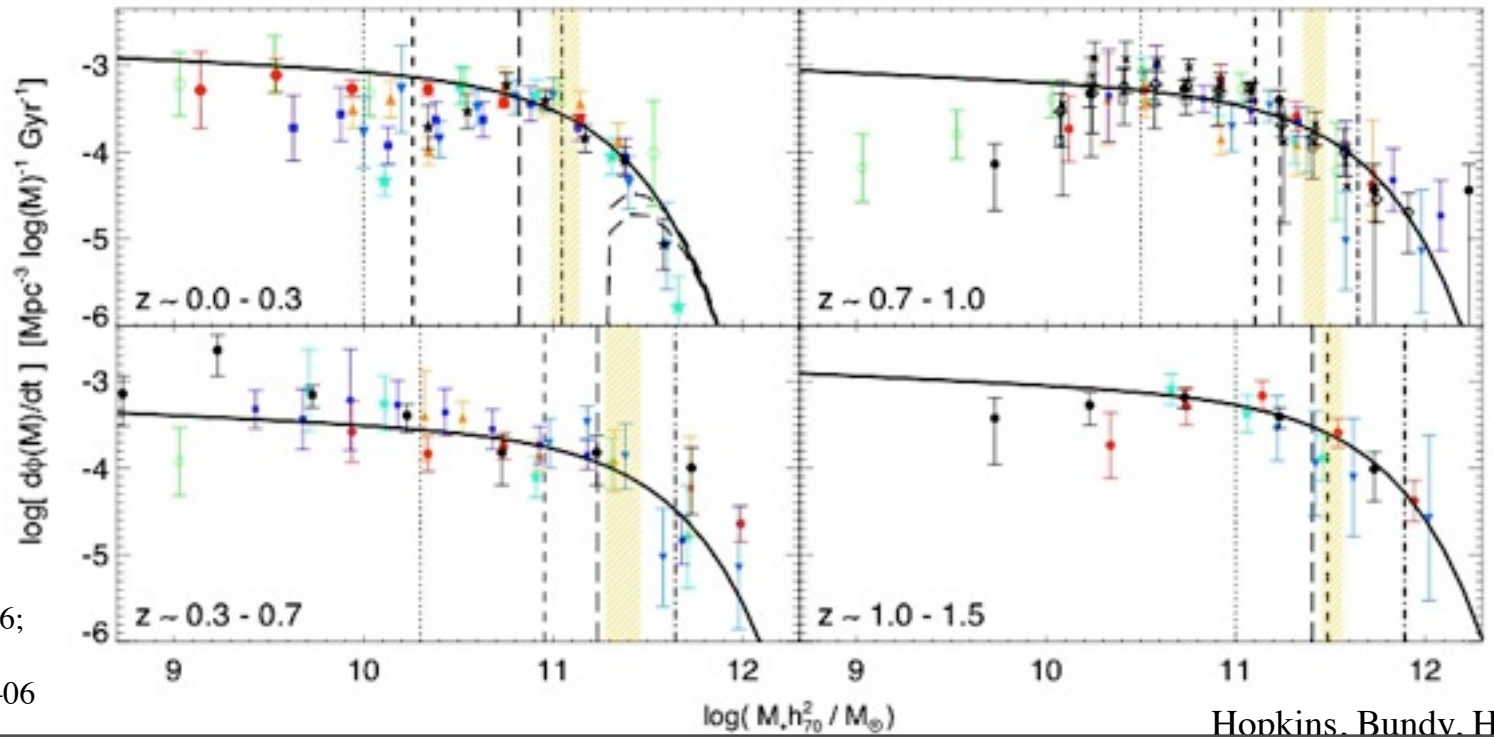
Xu+;Wolf+; Ueda+

More Detailed Comparison

TEST STATISTICS OF QUASAR, RED GALAXY, & MERGER POPULATIONS







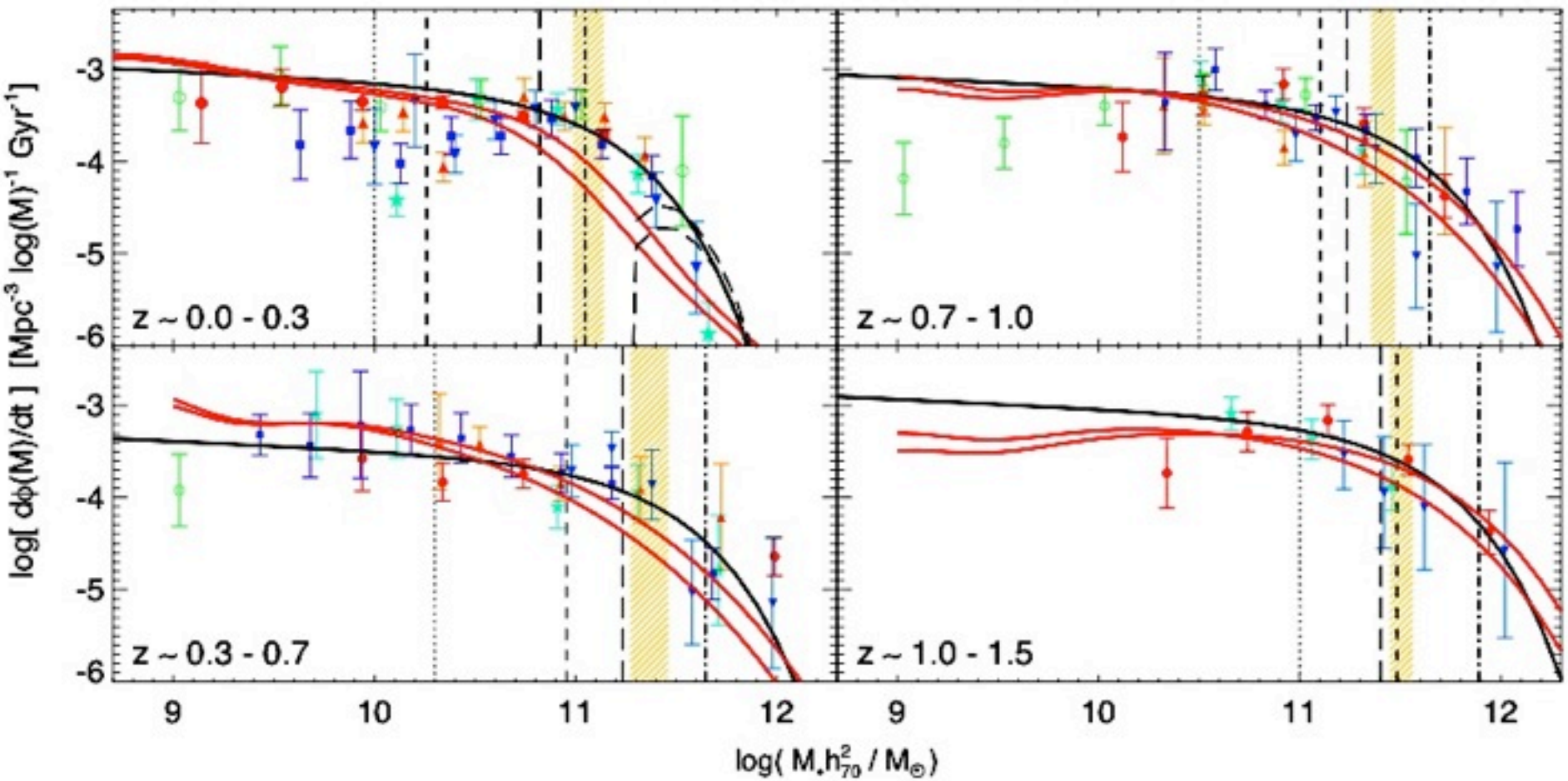
Borch+06;
Bundy+06;
Fontana+04,06;
Pannella+06;
Franceschini+06

Hopkins, Bundy, Hernquist+ 06

More Detailed Comparison

TEST STATISTICS OF QUASAR, RED GALAXY, & MERGER POPULATIONS

- Observed RS Buildup to z>~1 = Expectation if *all* new mass to the RS "transitions" in a quasar-producing merger



Hopkins, Bundy, Hernquist+ 06

More Detailed Comparison

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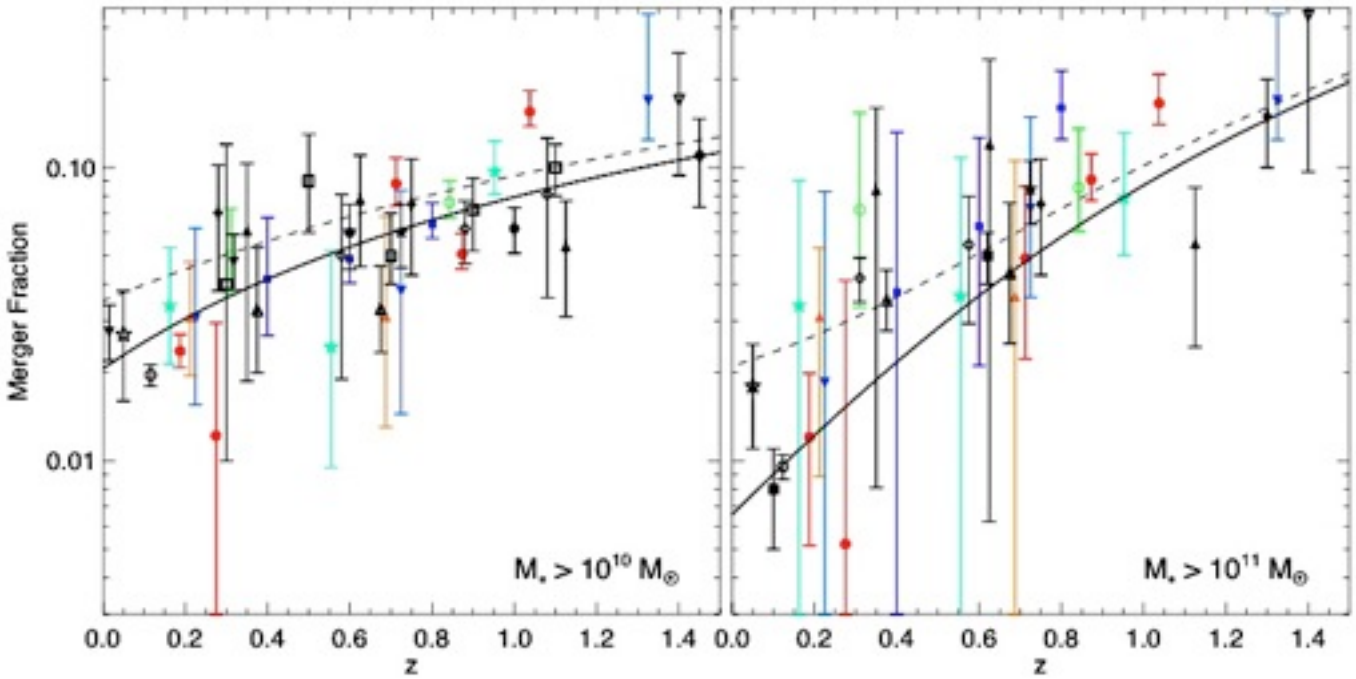
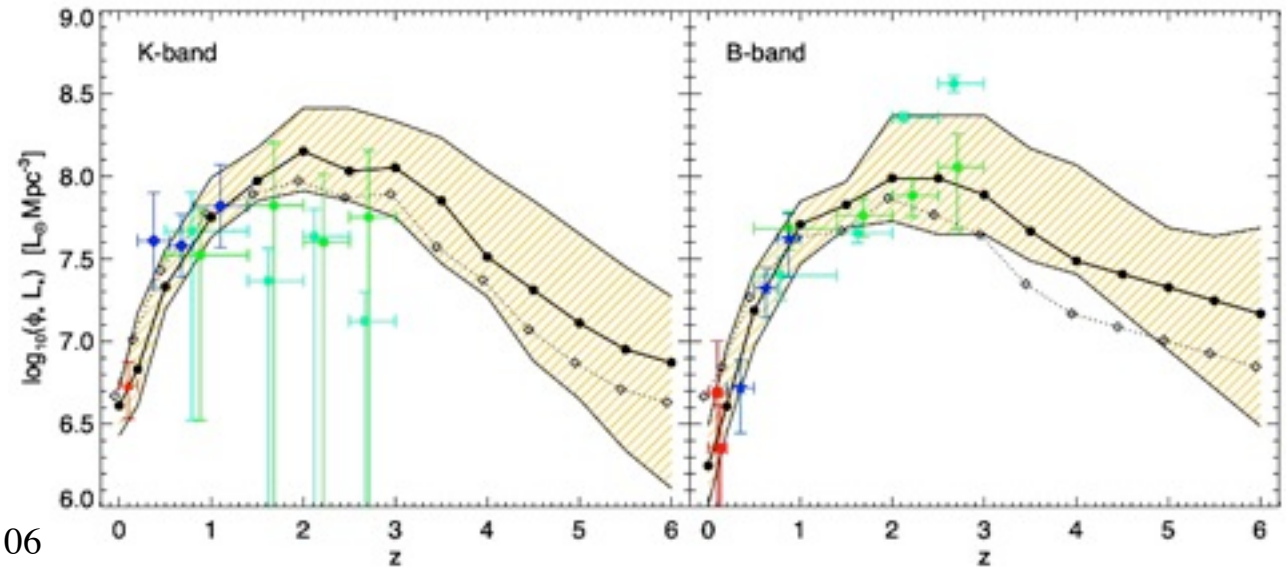


Bell+06; Lotz+06; Lin+04; Patton+02; Conselice+03

Xu+;Wolf+;Brinchmann & Ellis; Conselice+; Hamilton+; Bundy+

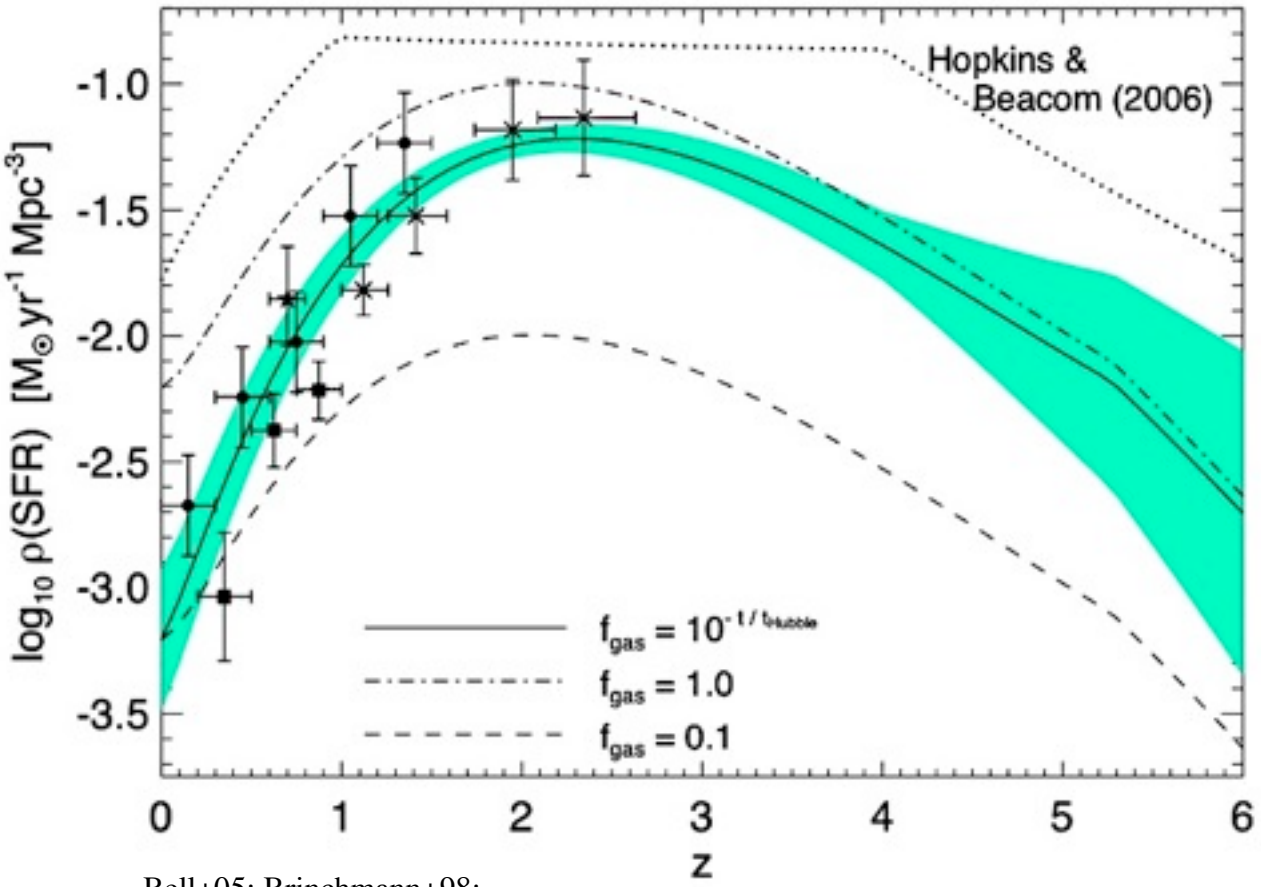
Hopkins, Bundy+ 06



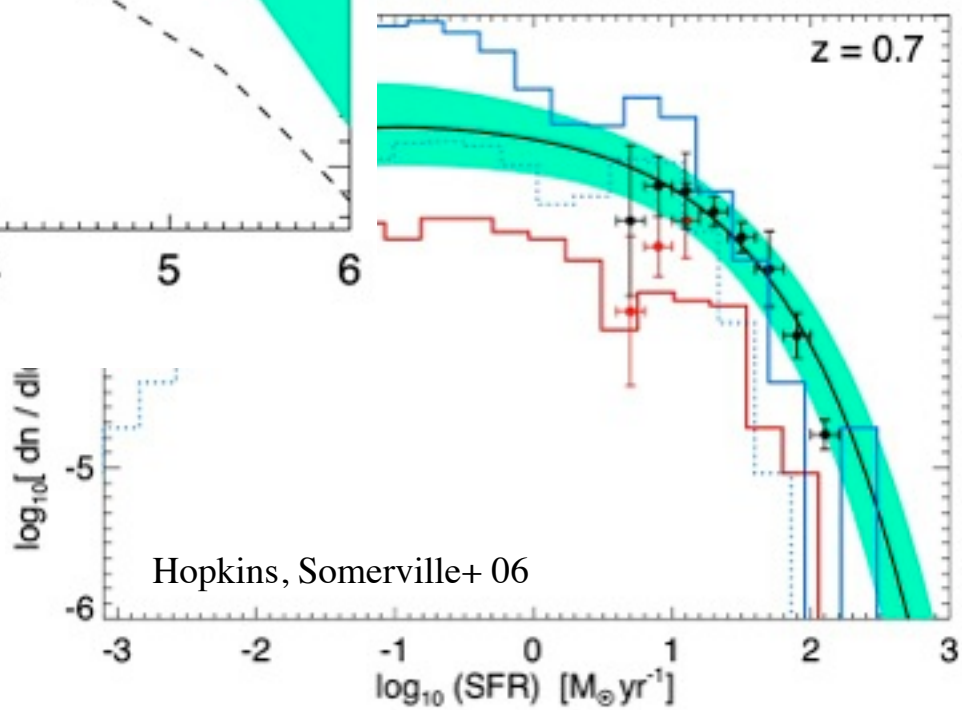
Hopkins, Somerville+ 06

What Else Can We Learn From These Comparisons?

THE MERGER CONTRIBUTION TO THE STAR FORMATION RATE



Bell+05; Brinchmann+98;
Perez-Gonzalez+05



Hopkins, Somerville+ 06

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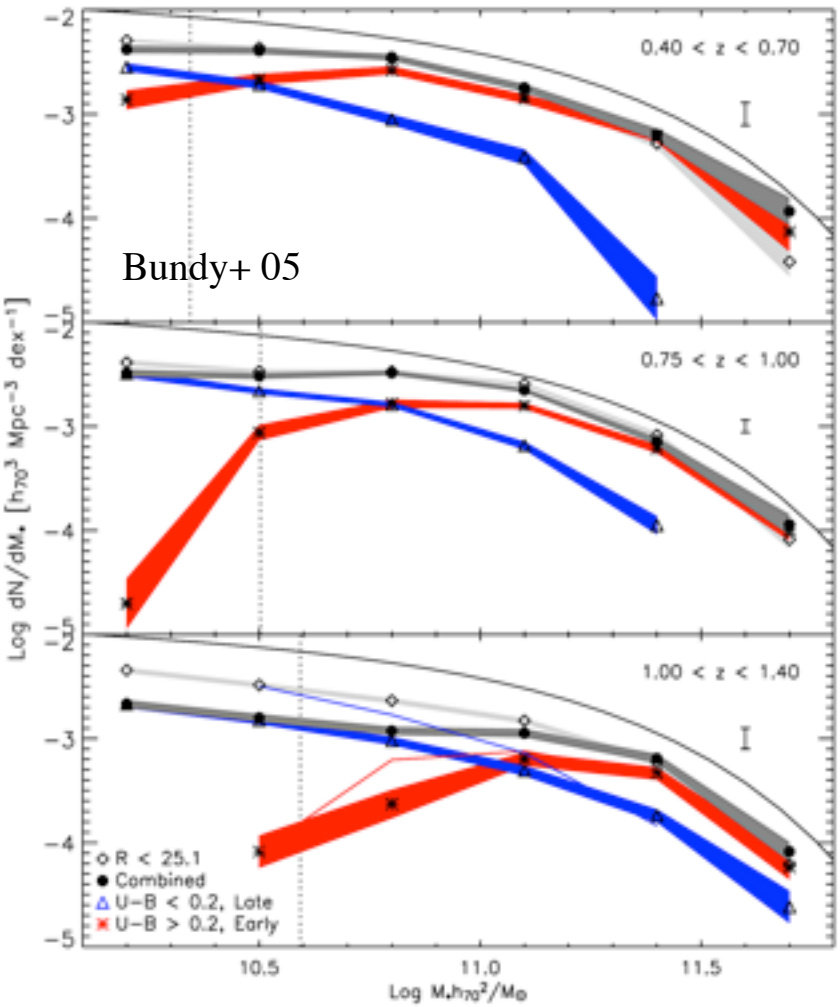
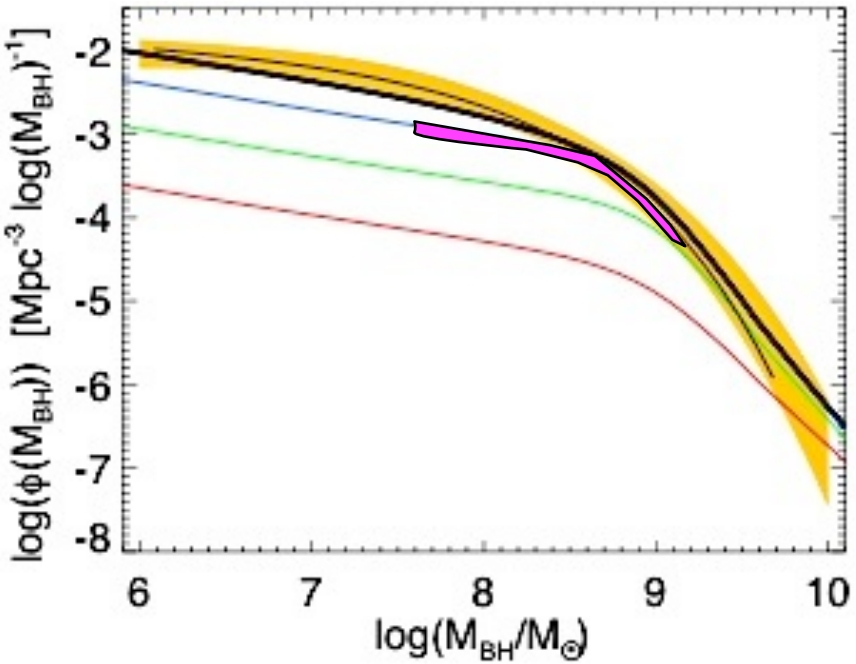
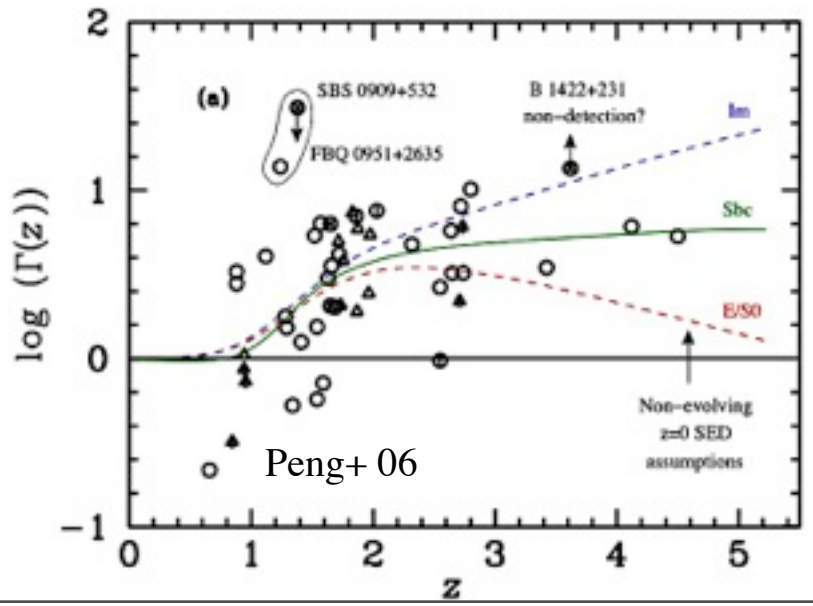


Bundy+ 05

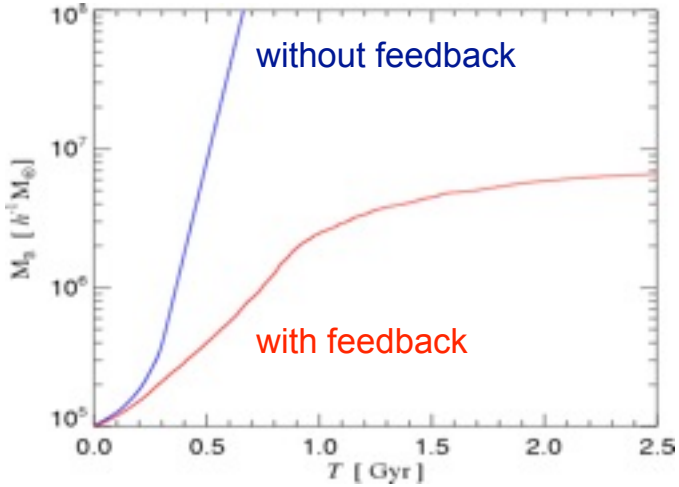




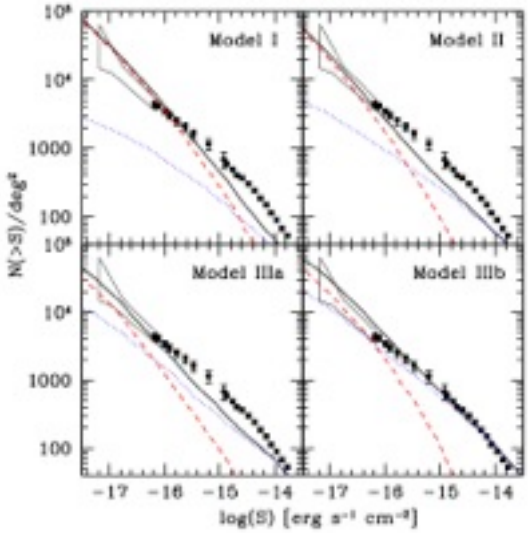
Peng+ 06

The Role of "Quasar" Feedback

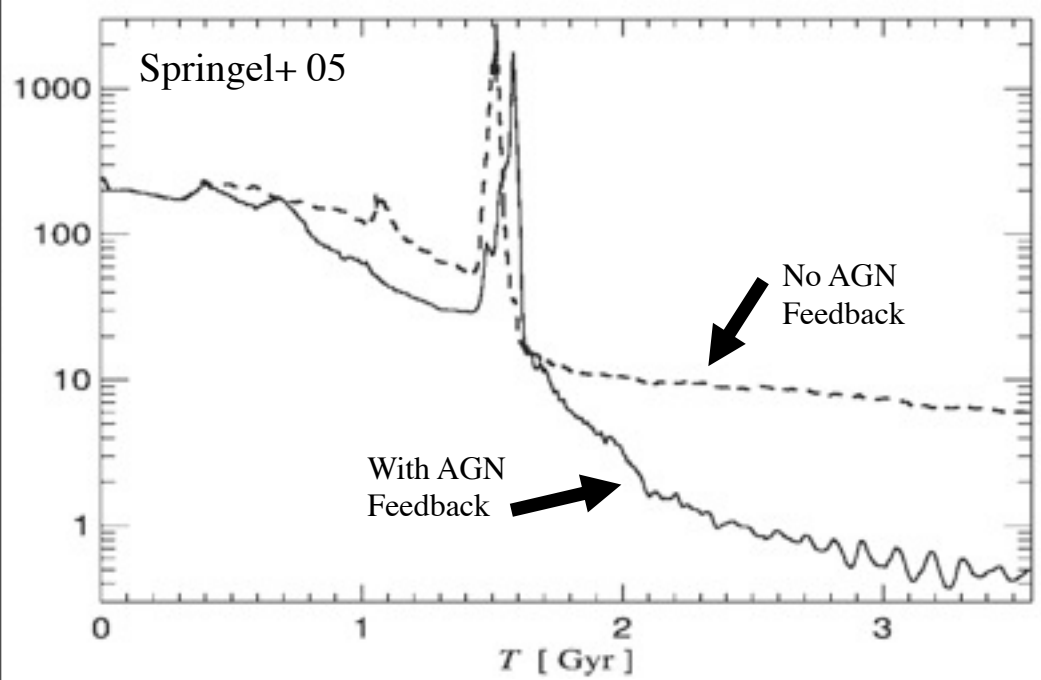
CORRELATION VS. CAUSALITY?

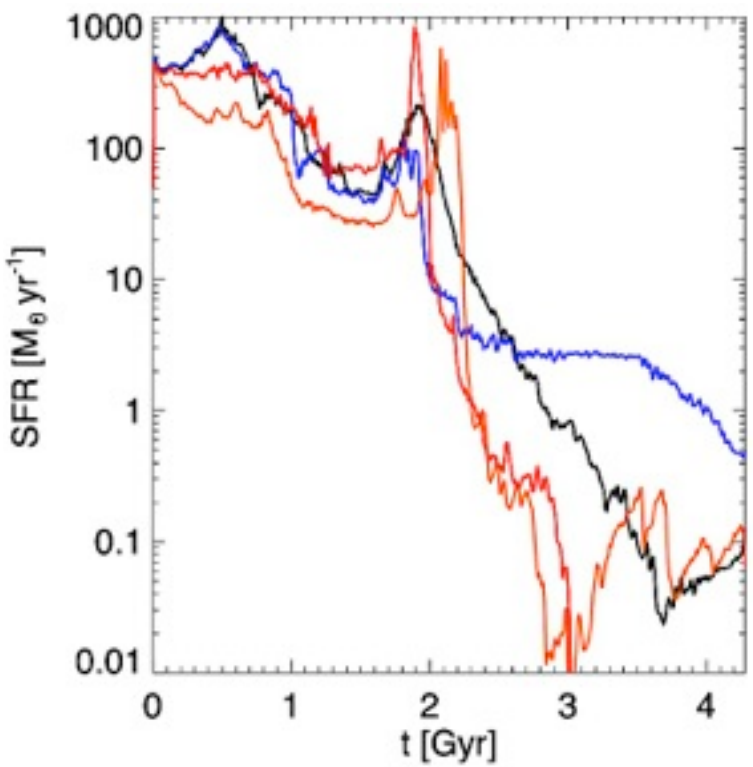


(see also Fontanot+ 06; Volonteri+ 06)



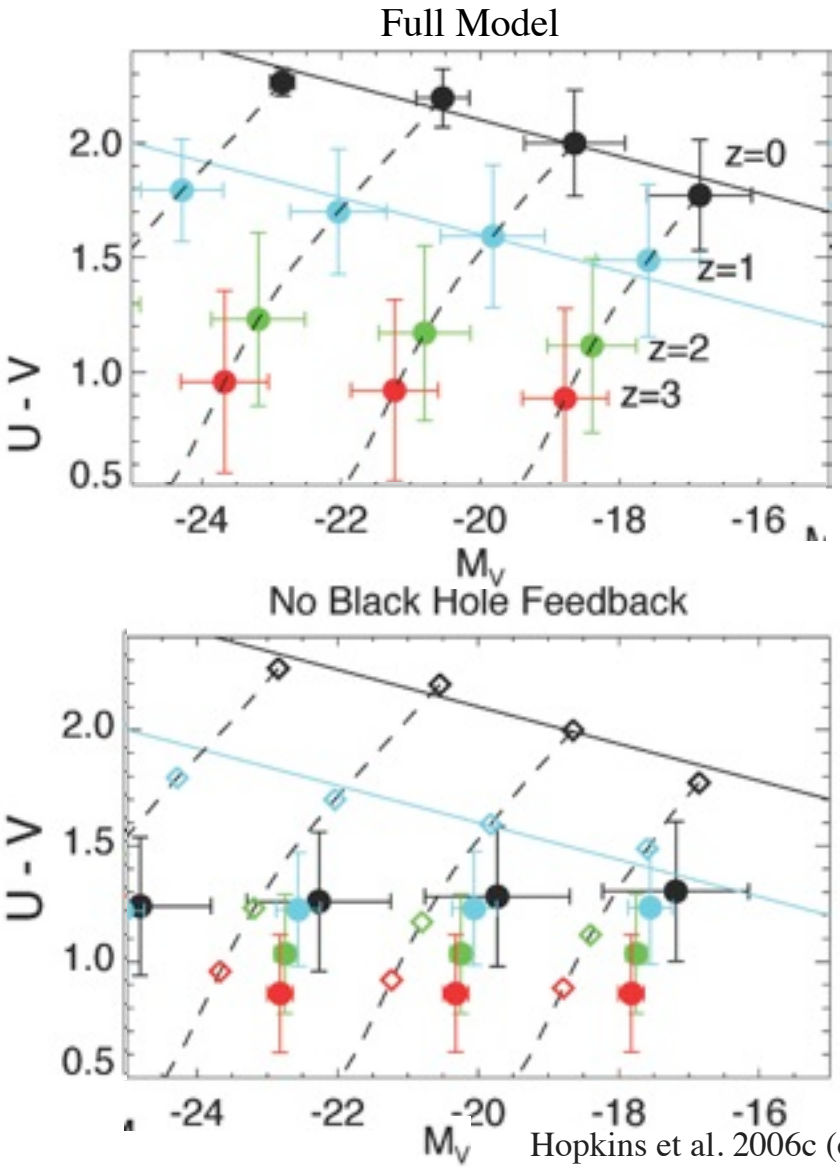
but...



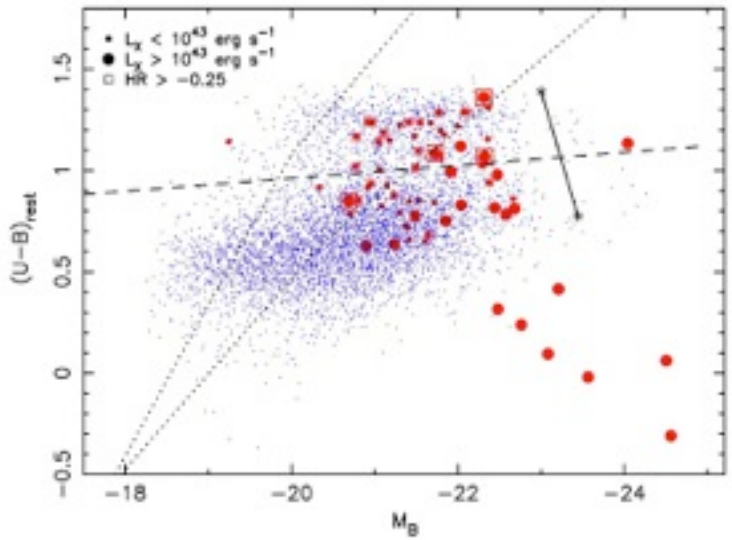


The Role of "Quasar" Feedback
CORRELATION VS. CAUSALITY?

- On average, probably important for CMR

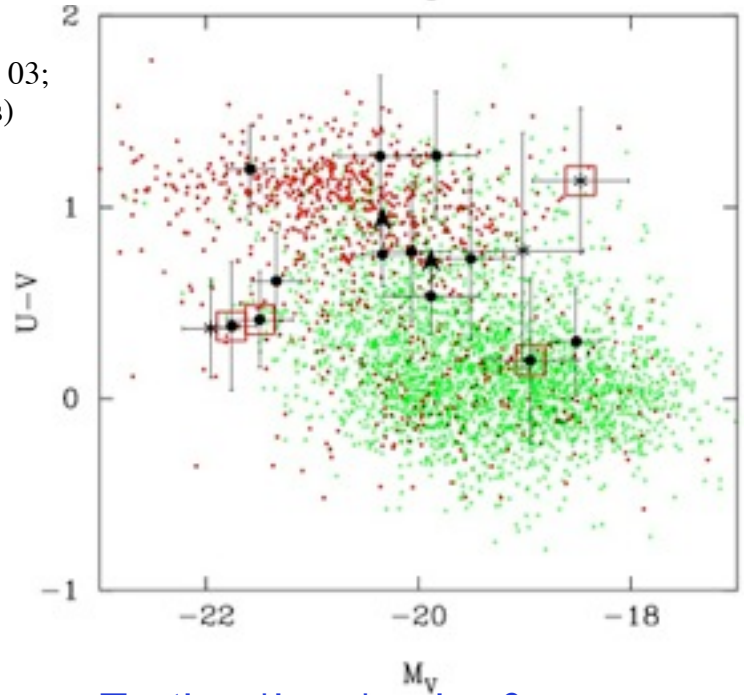


Hopkins et al. 2006c (obs: Bell+; Faber+)



Sanchez+ '0:
GEMS
0.5 < z < 1.
Optical QS(

(also, Kauffmann+ 03; local SDSS hosts)

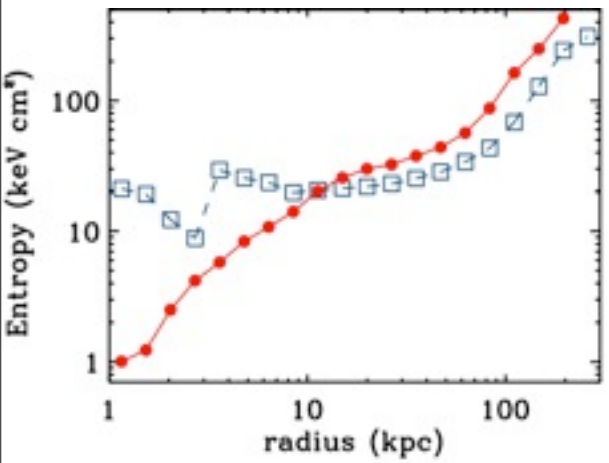


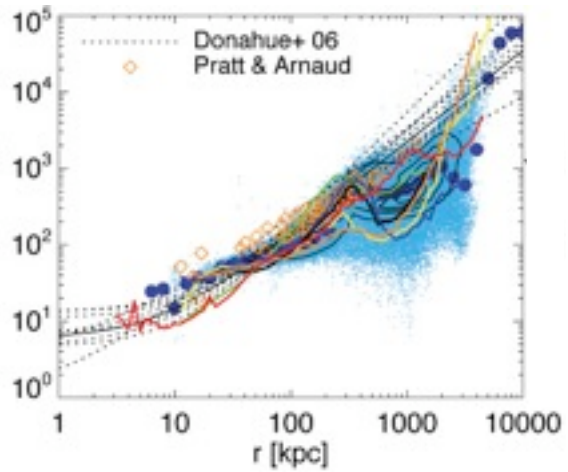
Nandra+ '06
DEEP2
0.7 < z < 1.4
X-ray QSOs

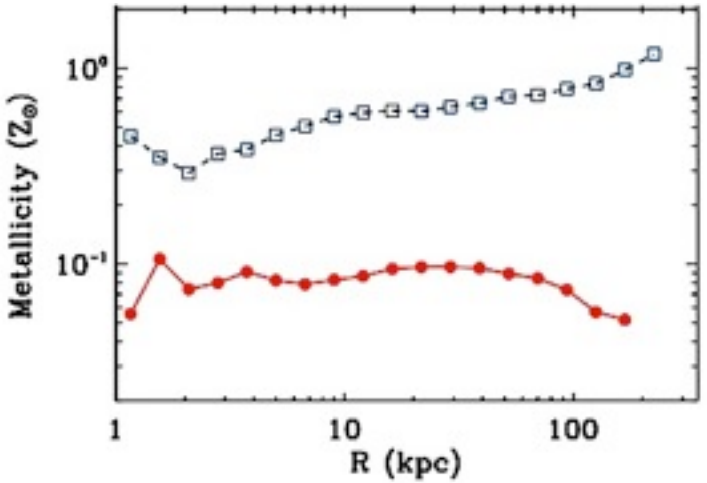
- Testing *how* color & accretion rate co-evolve breaks model degeneracies

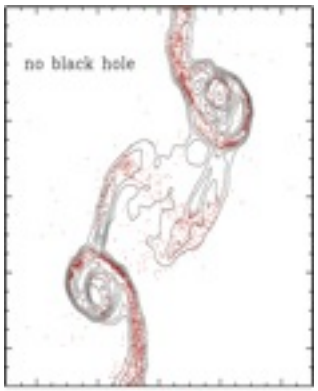
The Role of "Quasar" Feedback

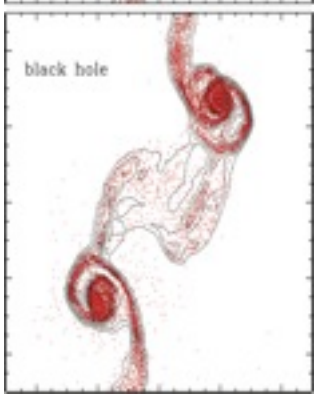
CORRELATION VS. CAUSALITY?

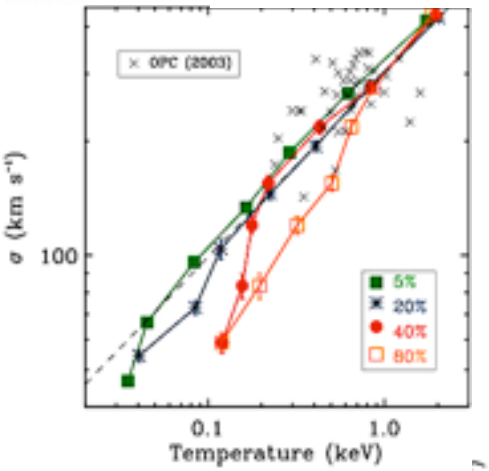


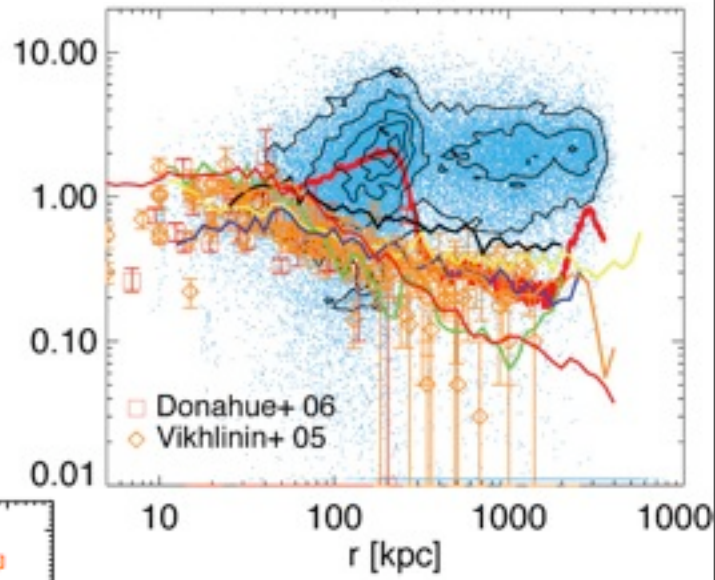


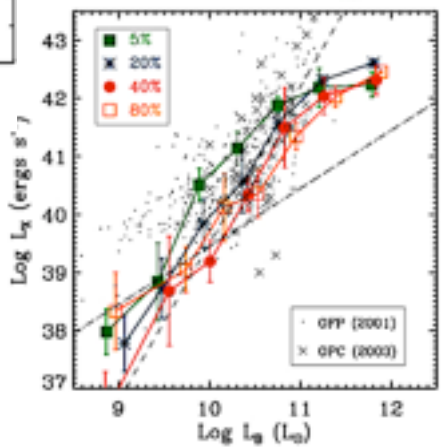


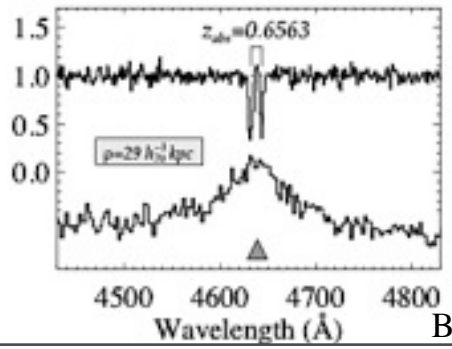












Cox+ 06

Hopkins+ 06 (in prep)

Bowen+ 06

Summary

- There really does appear to be a strong association between quasars, mergers, and the buildup of the red sequence
  - Non-merger driven models (while almost certainly dominant at low L & low z) just don't work

- It is possible to "map" between populations
  - Quasars have a lot to tell us about spheroid formation:
    - Where stars formed? When?
    - Downsizing?
    - When is formation gas rich / gas poor?

- Open questions:
  - "Maintenance" : smooth mapping from quasar to "radio" modes?
  - How much work does the *quasar* do?