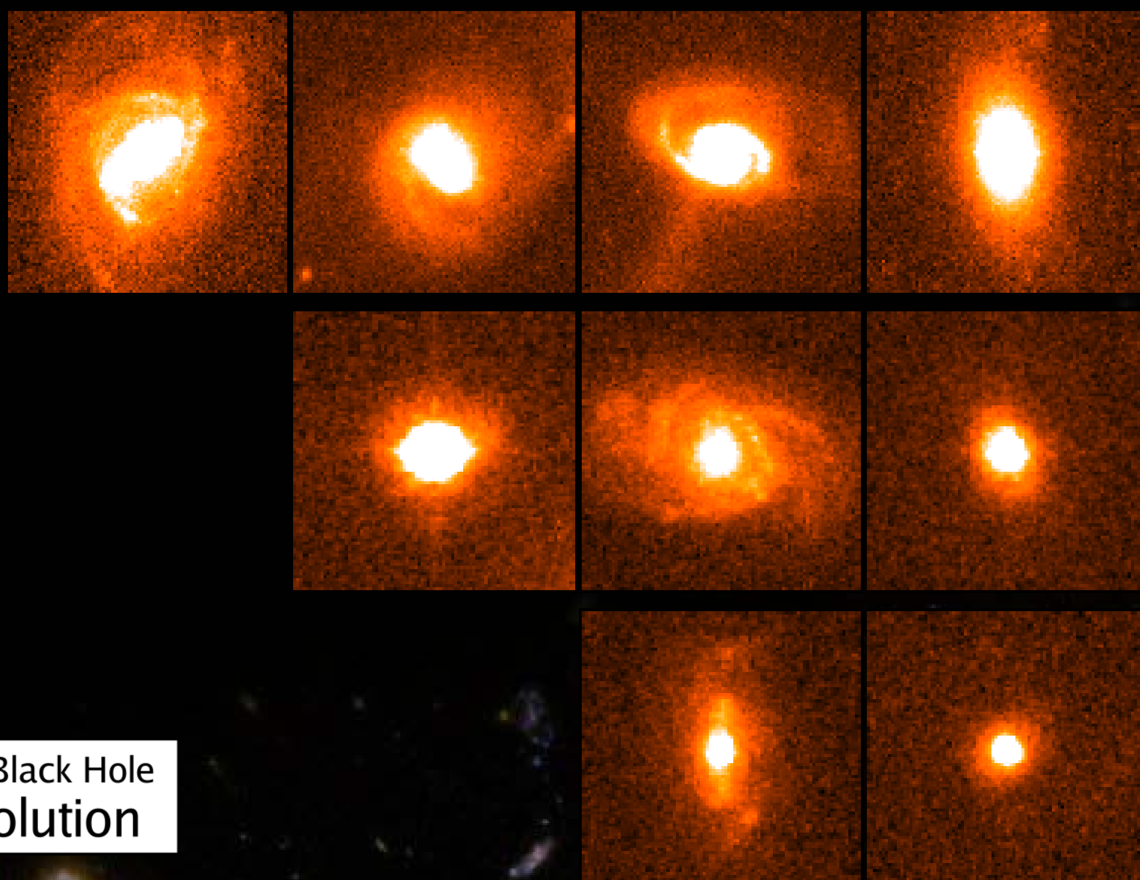
Co-evolution of galaxies and black holes?

Knud Jahnke

Max-Planck-Institut für Astronomie



Katherine Inskip, Dading Nugroho, Mauricio Cisternas, Hans-Walter Rix, Chien Y. Peng, COSMOS (Mara Salvato, Jonathan Trump, et al.), Lutz Wisotzki, Bernd Husemann

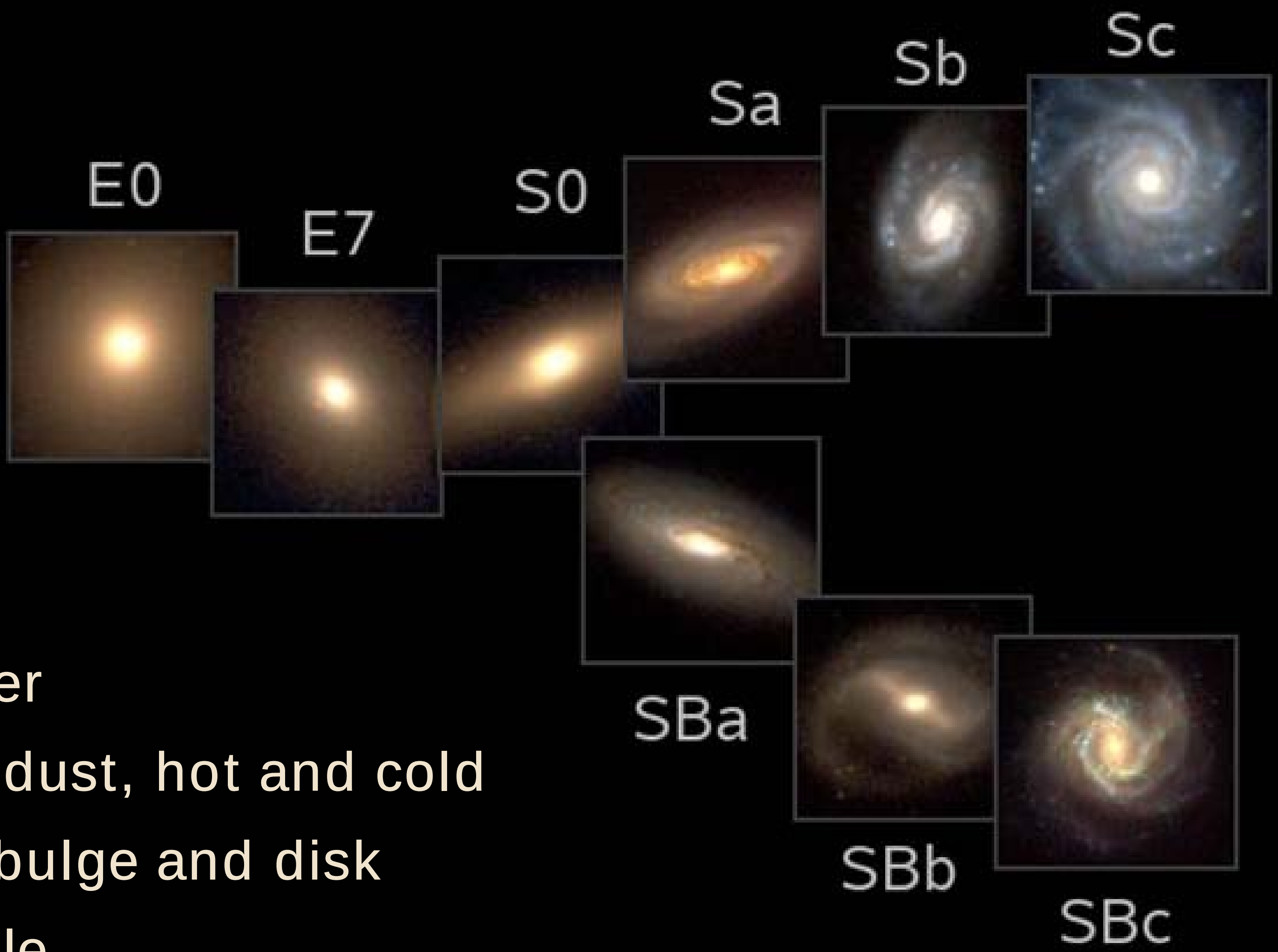
Galaxy–Black Hole Coevolution

www.mpia.de/coevolution

Overview

- Intro: galaxies – light and darkness
- Co-evolution & AGN feedback
- AGN and their host galaxies at earlier times
- Co-evolution, coupled evolution, coeval evolution?
- An incomplete summary

Galaxies – light and darkness



Galaxy =

dark matter

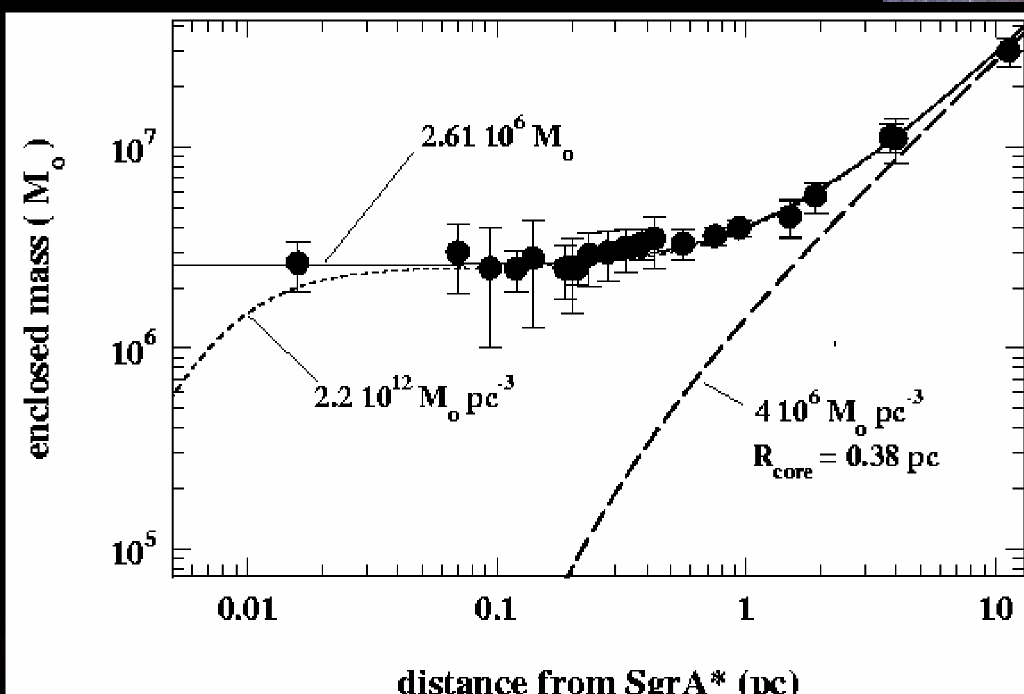
+gas and dust, hot and cold

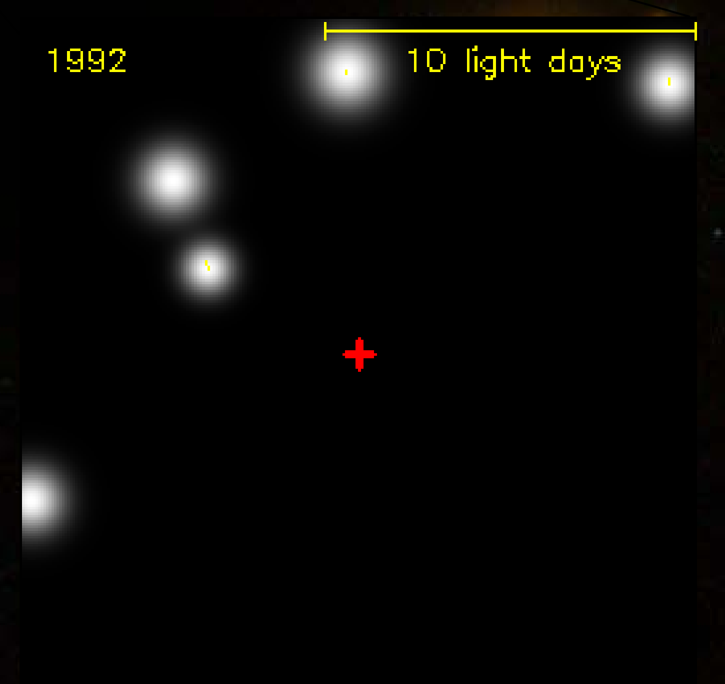
+stars in bulge and disk

+black hole

Galaxies – light and darkness

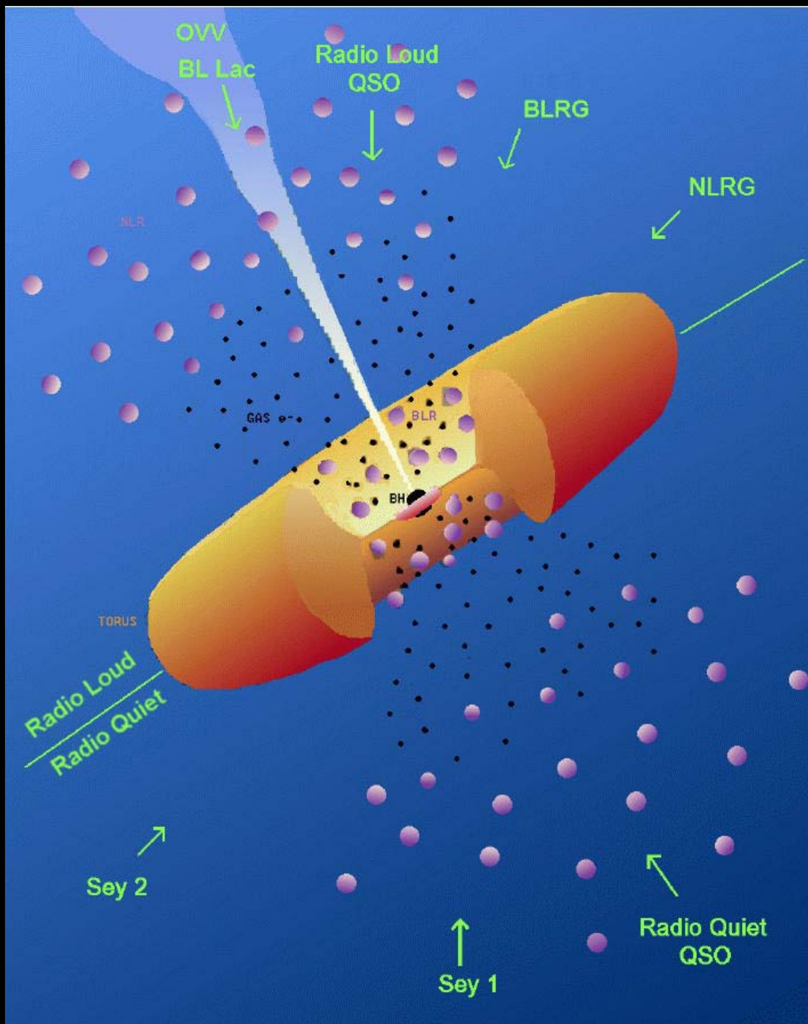
Black Hole in our Milky Way: $3 \cdot 10^6\ M_{sun}$



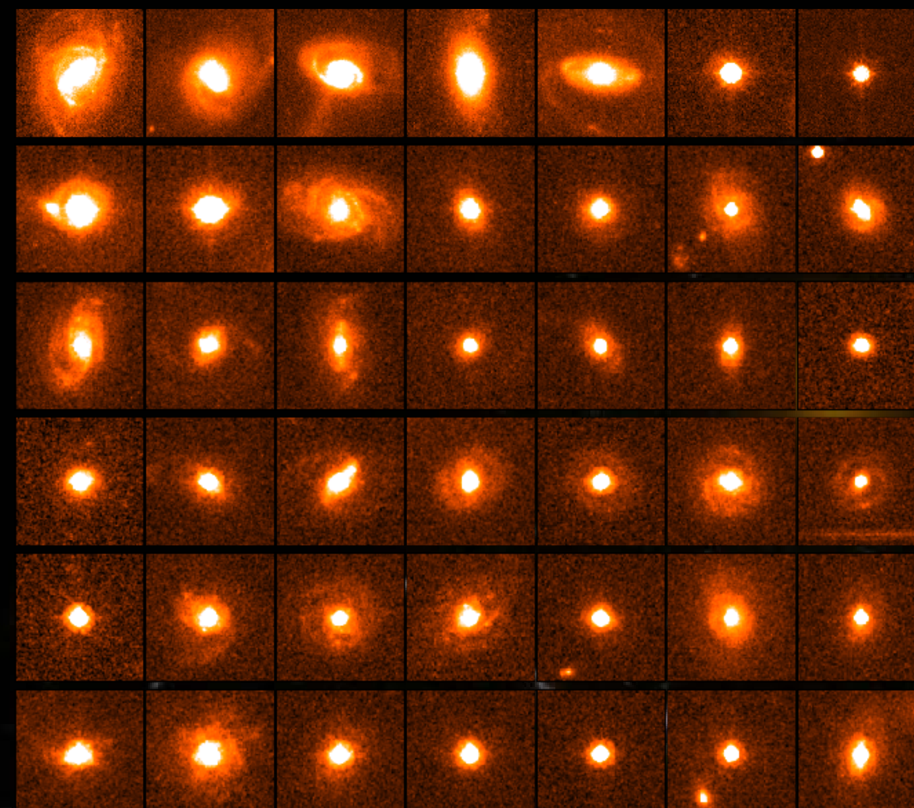


Genzel et al. 1998...2005, and others

Galaxies – light and darkness



In galaxy centers: BHs, active or dormant



Urry & Padovani 1995

COSMOS, KJ 2008

Galaxies – light and darkness

Galaxy growth:

- Growth by star formation → (cold) gas needed
- Growth by assembly → galaxy mergers needed

- Gas supply/feeding: minor mergers and instabilities?

Black hole growth:

- Growth by gas accretion → (cold) gas needed
- Growth by assembly → galaxy mergers needed

- Gas supply/feeding: minor mergers and instabilities?

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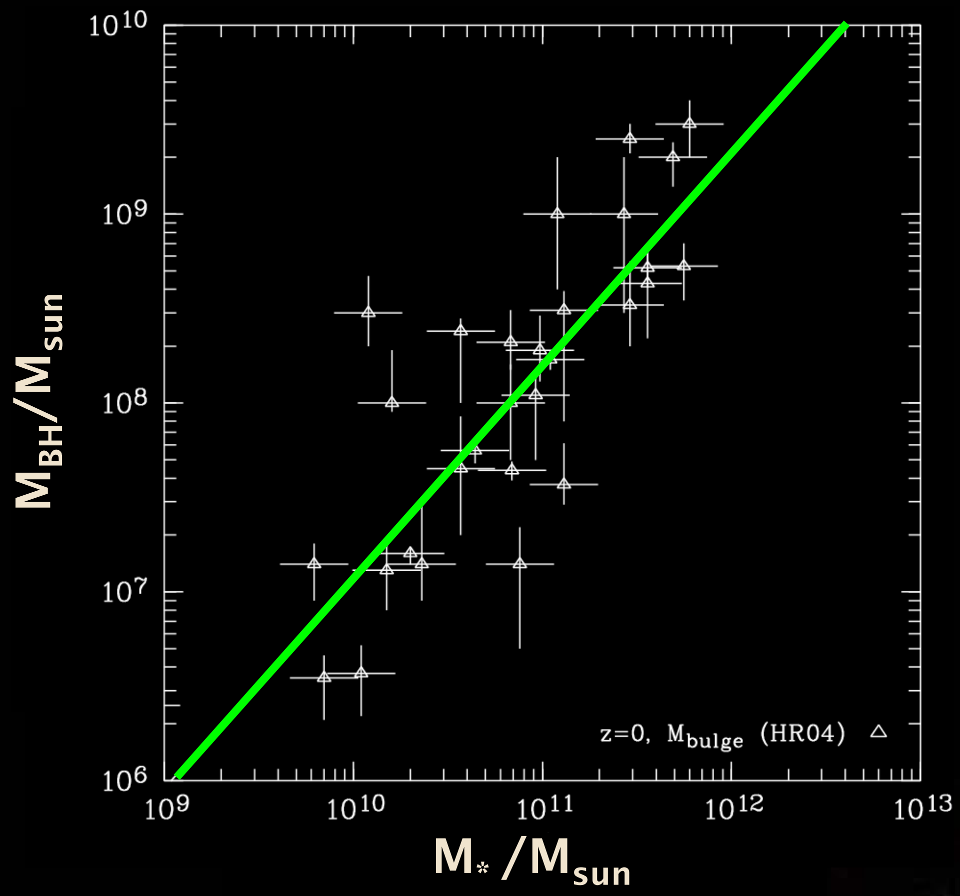
Co-evolution & AGN feedback



z=0: Häring&Rix 2004

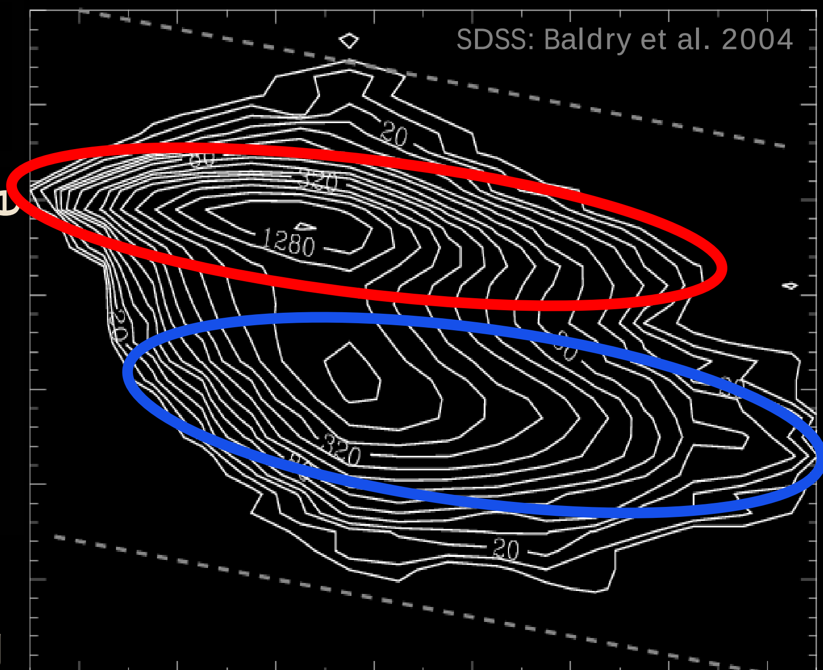
Co-evolution of Black Holes and galactic bulges:

- Tight correlation of M_{BH} and M_{bulge} (0.3dex scatter)
- Also with L_{gal} or sigma
- Linear scales differ by ~1,000,000,000

→ Which is physical mechanism?

Co-evolution & AGN feedback

observed (20.000 galaxies)



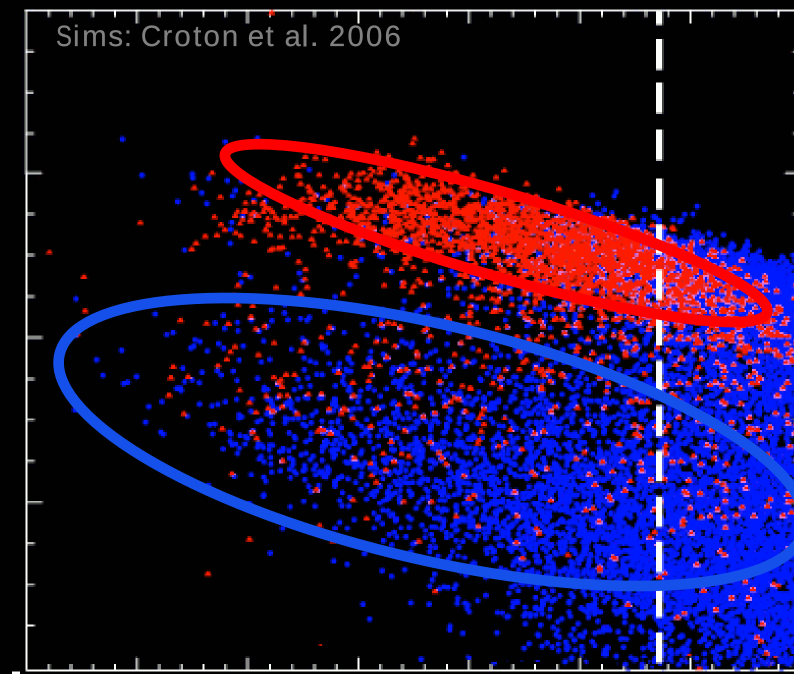
red/
old

Colour/age

blue/
young

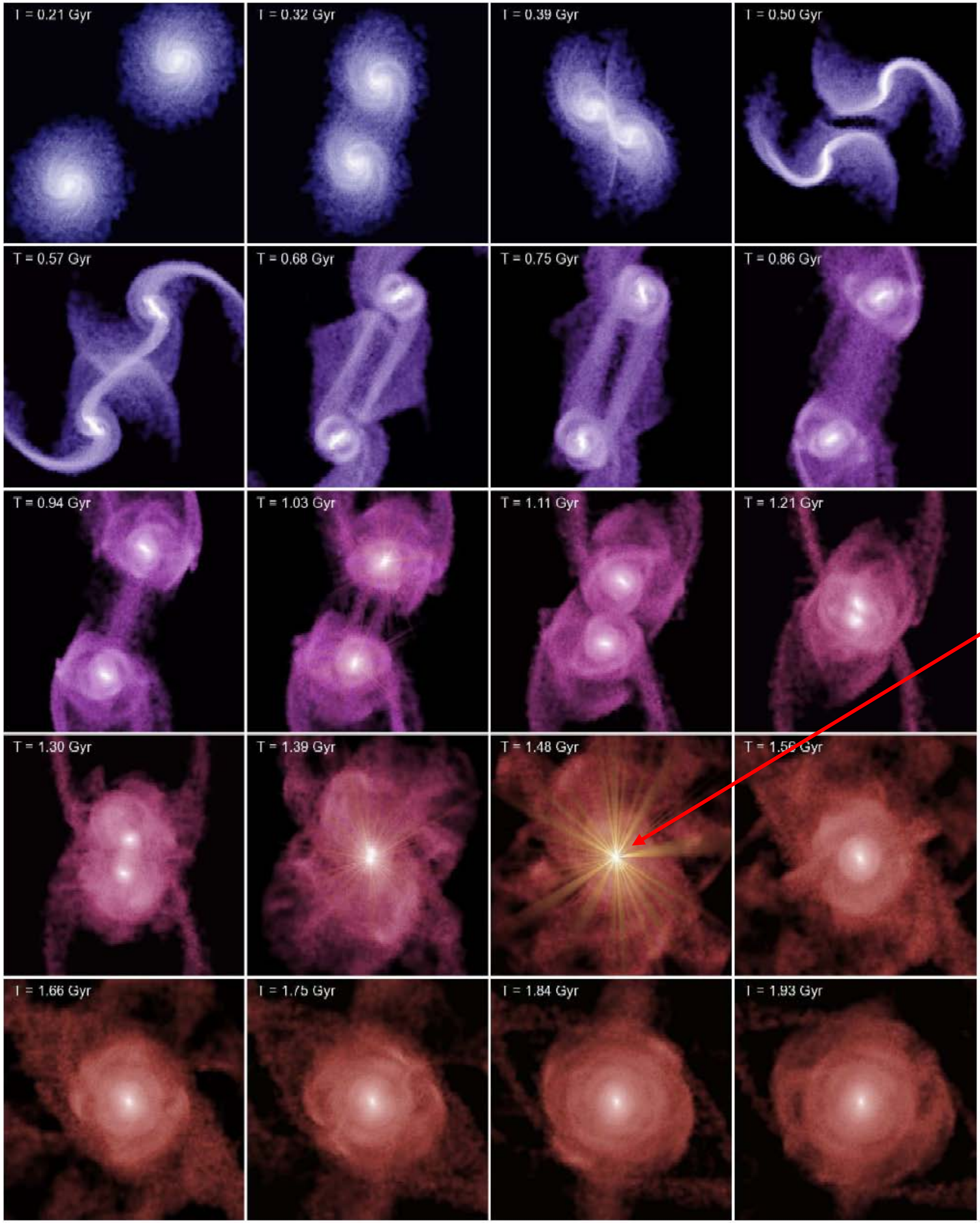
high Luminosity/mass low

theoretical prediction



„AGN feedback can solve it all“

Many people say



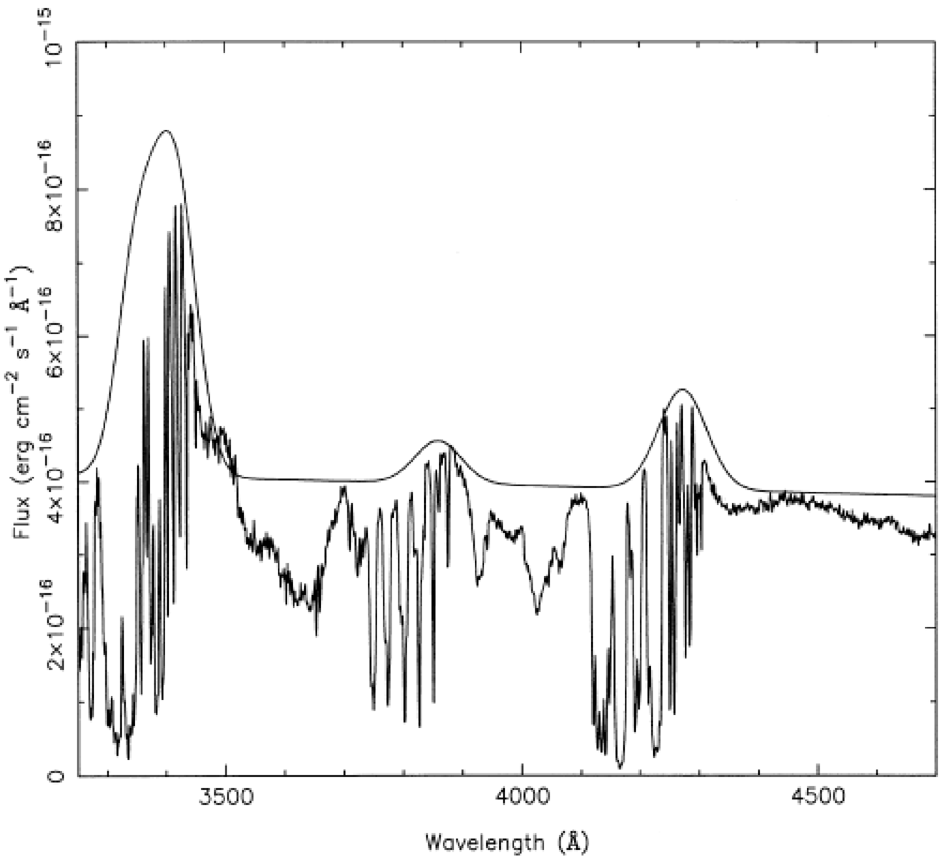
Simulations, not from first principles:

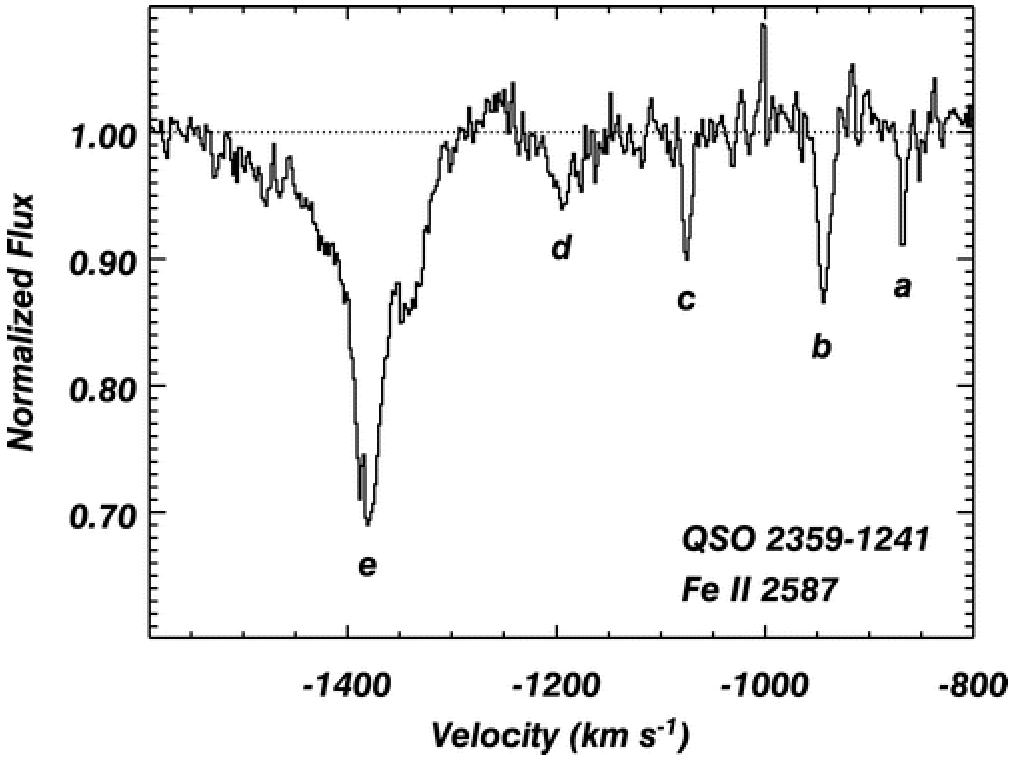
QSO/AGN phases as shortlived stages in a galaxy merger

Di Matteo, Springel & Hernquist

Co-evolution & AGN feedback

Quasar-mode feed-back?





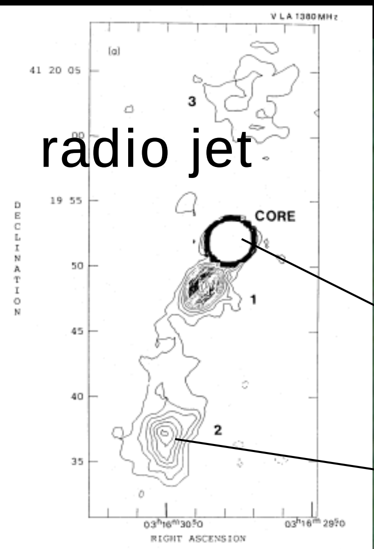
Broad Absorption Line QSOs (10%)

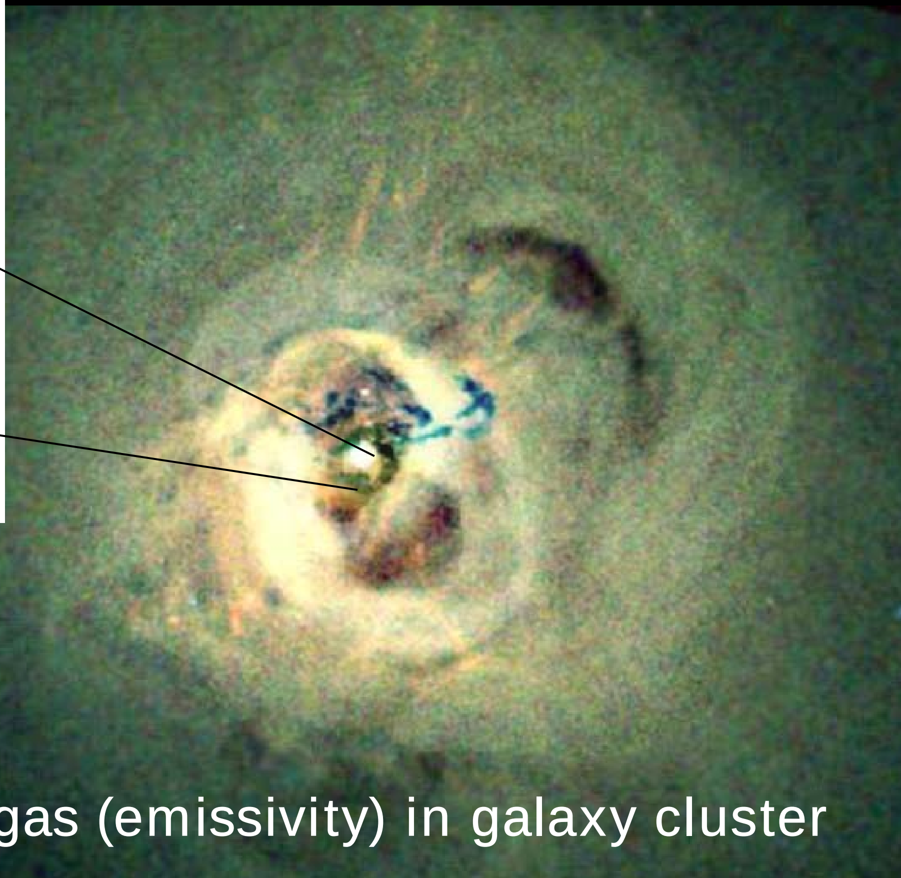
(Vilkoviskij et al. 2001)

Kinetic outflows

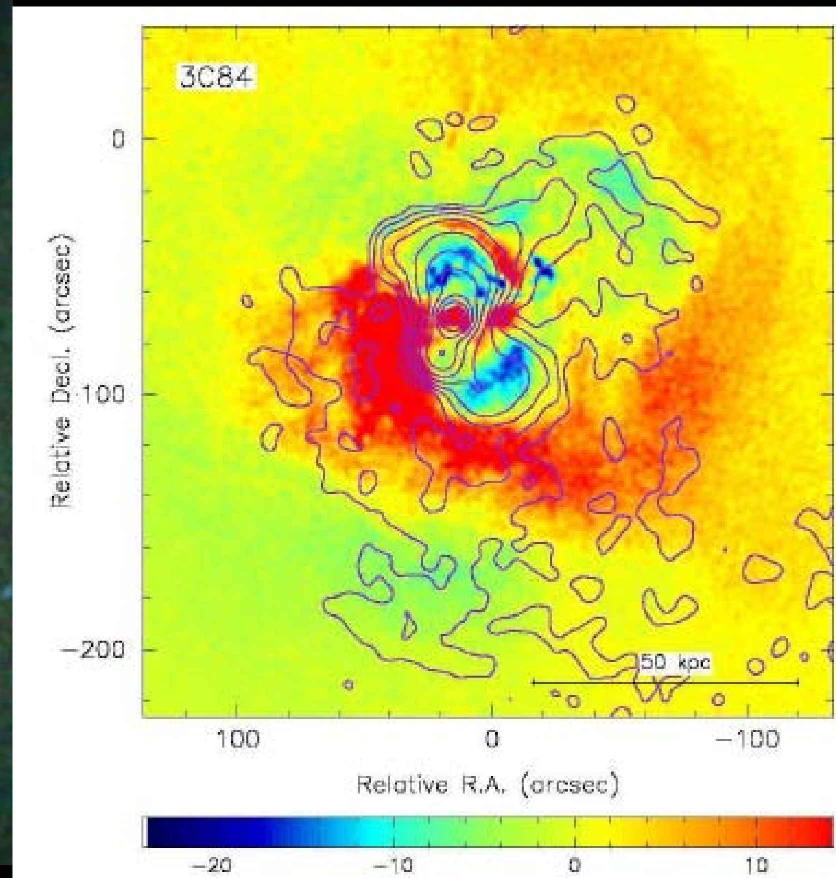
(Arav et al. 2008)

Co-evolution & AGN feedback





radio emission (relativistic particles) → X-ray (=gas) holes



Radio-mode feed-back (e.g. Croton et al. 2006)

→ effective in (massive) halos with ‘hot’ X-ray atmosphere

→ explanation of why massive galaxies no longer form stars?

(Fabian et al. 2003 and others)

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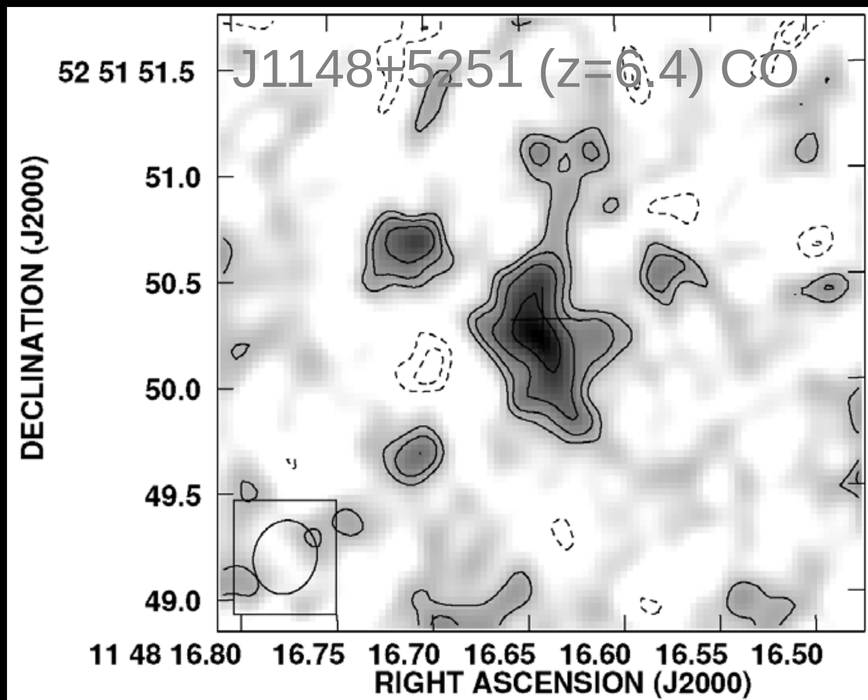
AGN and their host galaxies at earlier times

Highest-z quasar: J1148+5251 at z=6.42



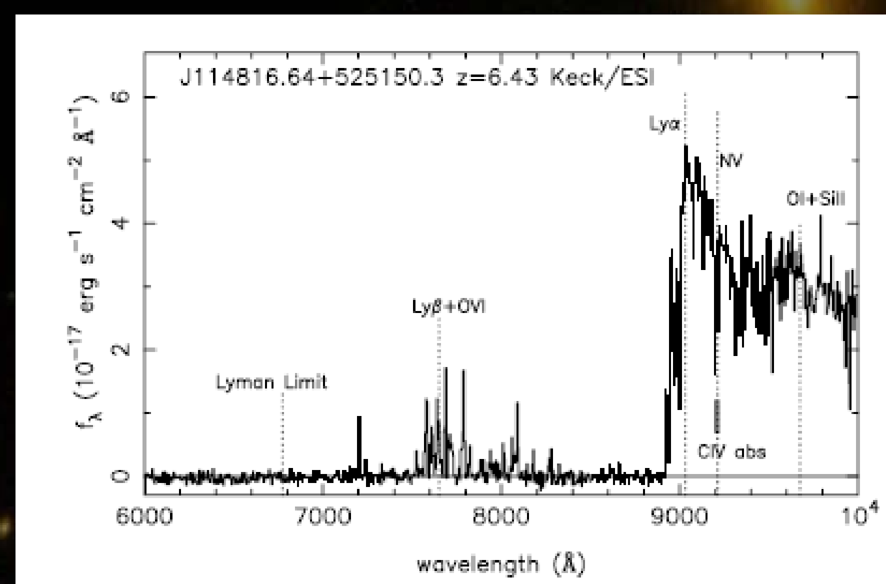
- $M_{gas} = 2 \times 10^{10}\ M_{sun}$
- $M_{dyn} \sim 6 \times 10^{10}\ M_{sun}$
- $M_{BH} = 3 \times 10^{9}\ M_{sun}$

$M_{dyn} \sim 3\ M_{gas}$

$M_{dyn} = 20\ M_{BH}$

SFR ~ 1000 M/yr (?)

→ merger
→ star-burst
→ massive accreting BH!



Walter et al. 2004

AGN and their host galaxies at earlier times

VLT Yepun (UT4) with PARSEC laser

Can be used with NACO (imager) and SINFONI (IFU)

→ High AO resolution also for fainter targets (R~17) w/o extra guidestar

AGN and their host galaxies at earlier times

Need quasars:

- M_{BH} from broad emission lines
- access to host galaxy difficult

Lens: boost in

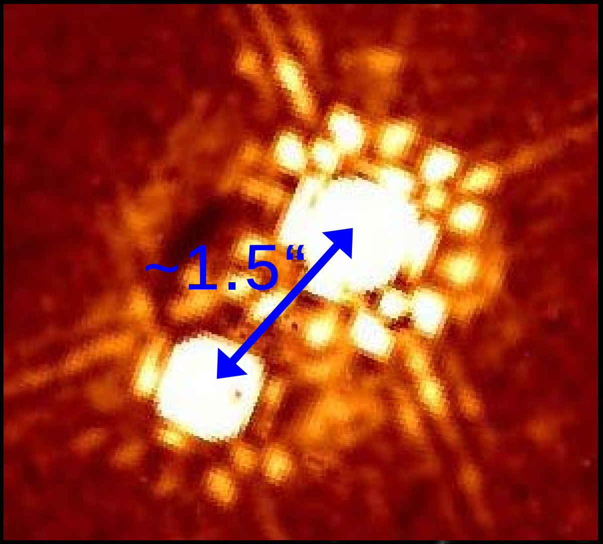
- Flux
- Angular scale

→ Host galaxy „easier“ analysis

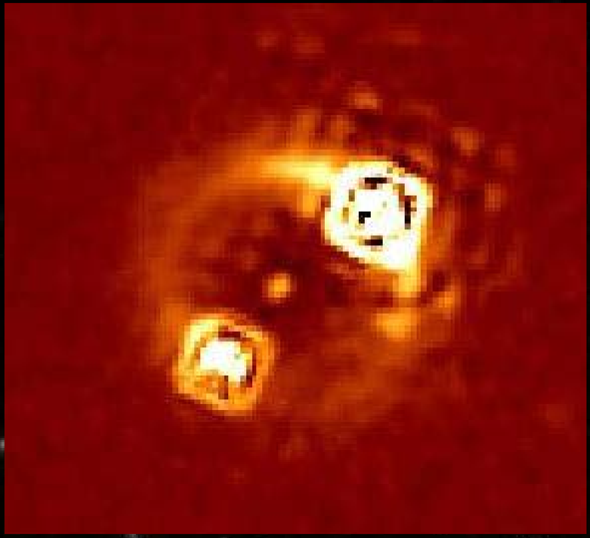
HE0047–1756, z=1.67

Double AGN, Einstein ring

HST NICMOS (H-band)

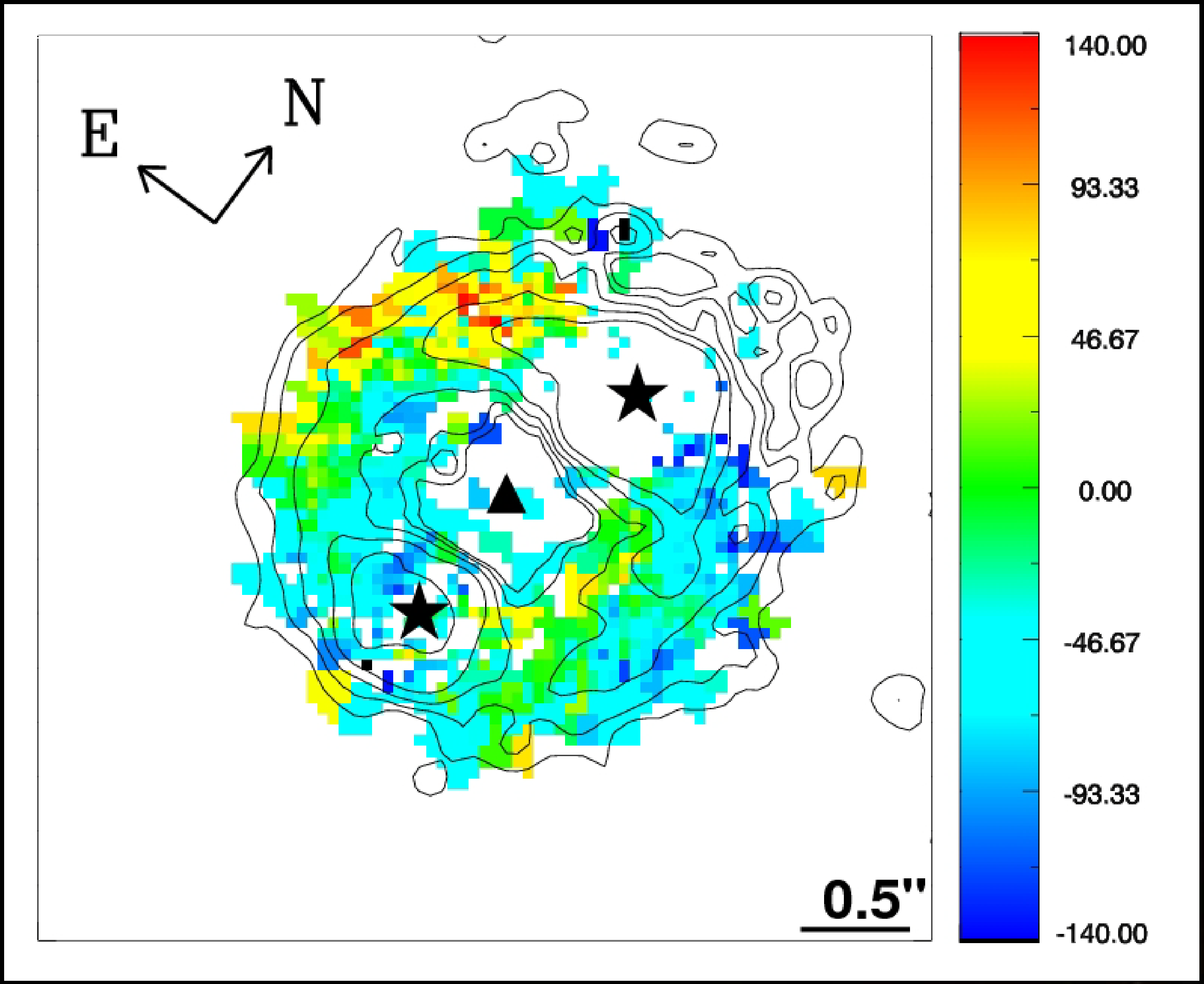


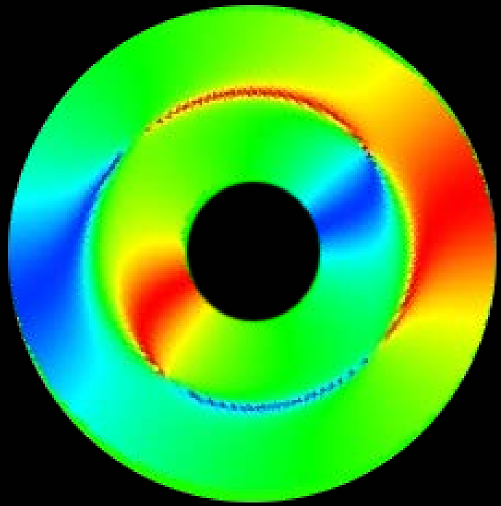
original



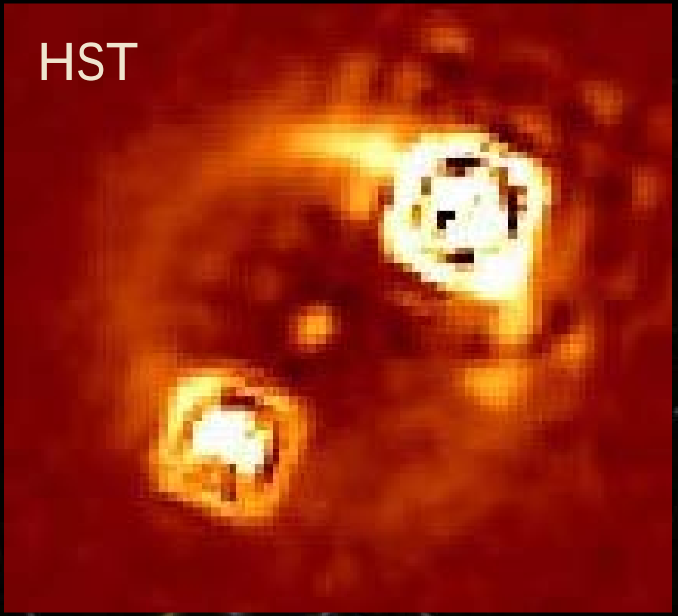
AGN subtracted

→ Try dynamical masses: Hα @1.75mu



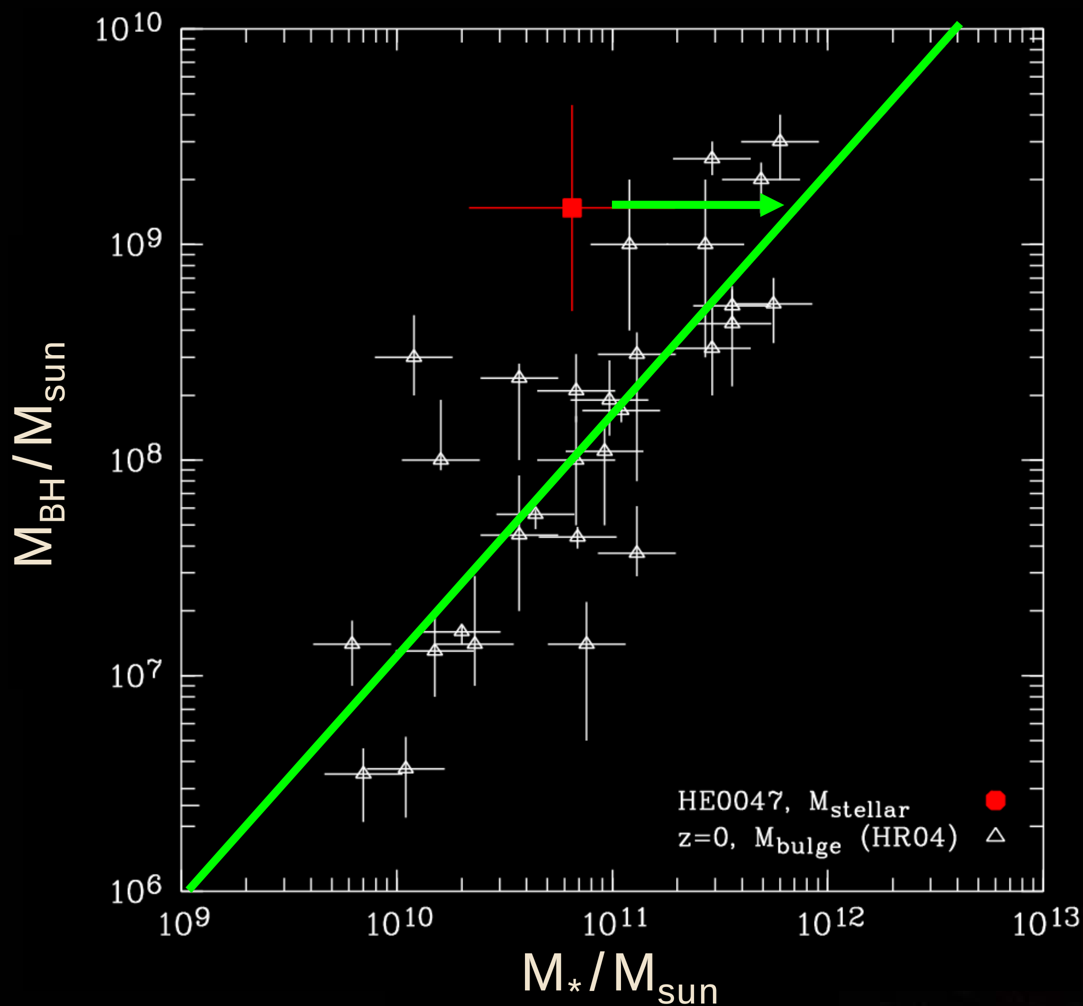


theor. vel. field sketch



HE0047–1746: enclosed M~6.5•10^{10} M_{sun} (assuming Kepler)

→ Inskip, Jahnke, Rix, Peng et al., in prep.



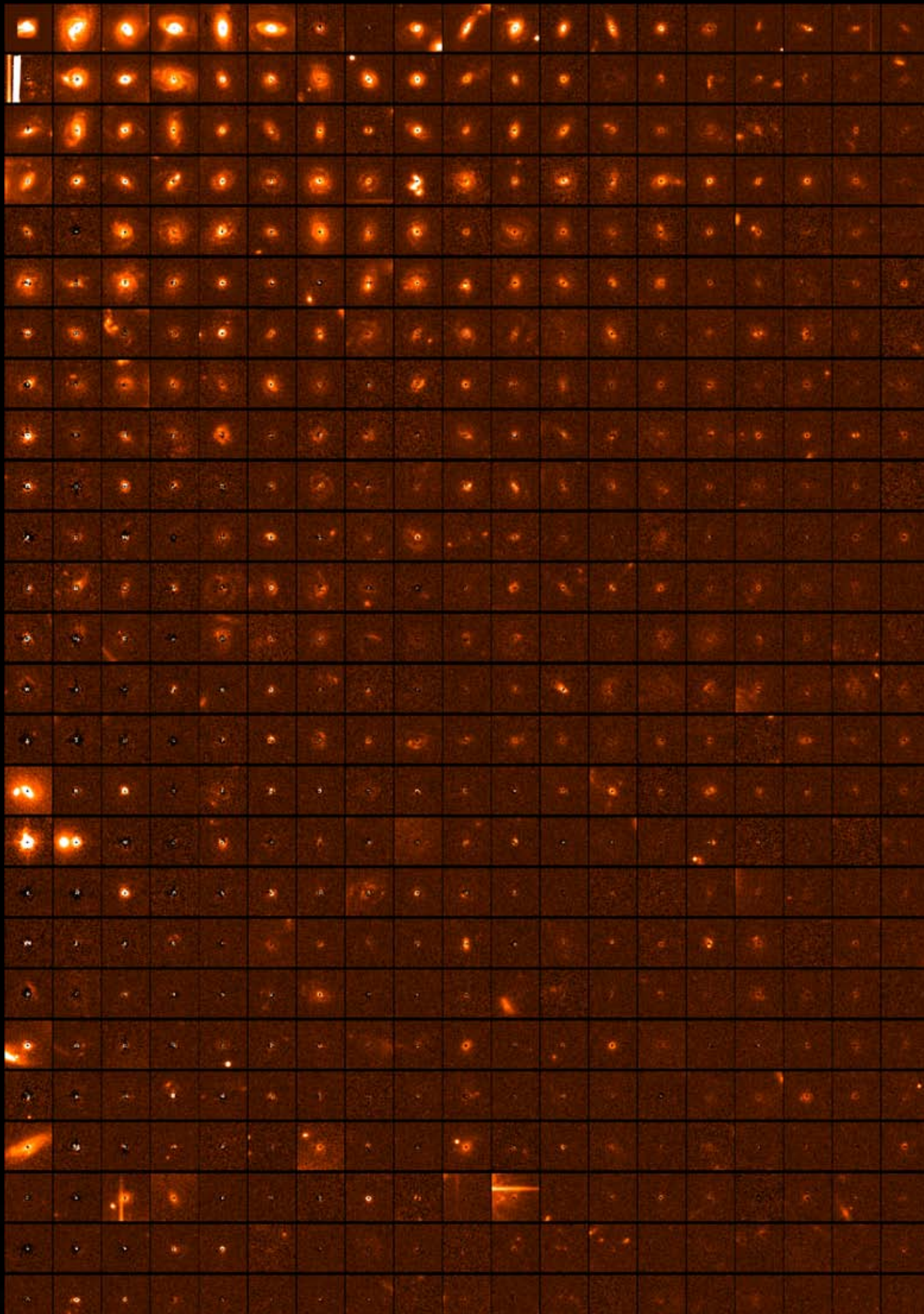
M_{BH}–M_{bulge}-relation

HE0047–1756 (z=1.67) lies off the local M–M-relation (x3–10 in M_{gal})

Consistent with Peng et al. 2006a+b and others: „mild evolution to z<1.7“

(Caveat: BH mass based on CIV emission line, need Hß to confirm this)

→ Velocity field + lens model fit pending



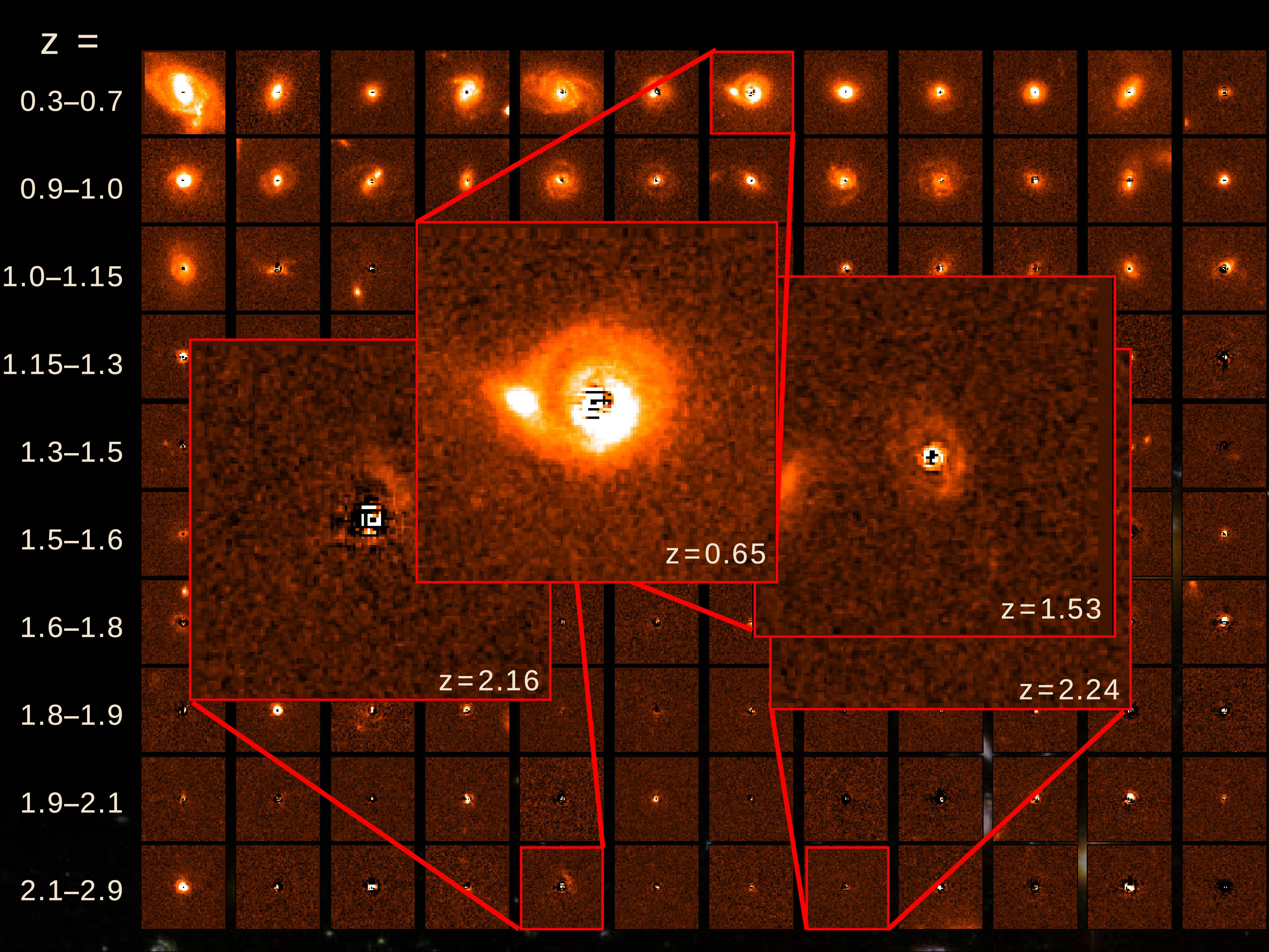
ACS, F814W

COSMOS: 1.8 deg^2 imaging with HST V-band (and many other data)

XMM-based type 1 AGN sample:

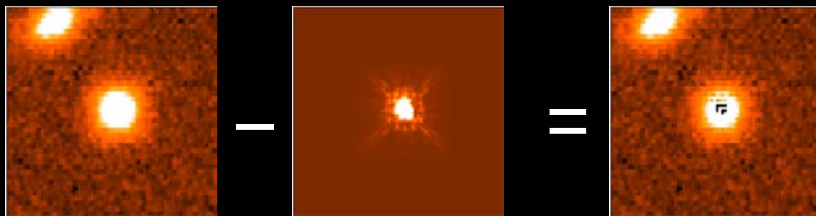
- Spec-z and/or phot-z existing
- Broad-line AGN class
- 494 type 1 AGN with I<24.5 and ACS images
- ~300 w/ resolved host galaxy
- ~300 w/ spectro-z's
- ~150 w/ BH masses

- Scaling relation study @z~1.4:
  - 10 with NIC3 parallel imaging and BH masses



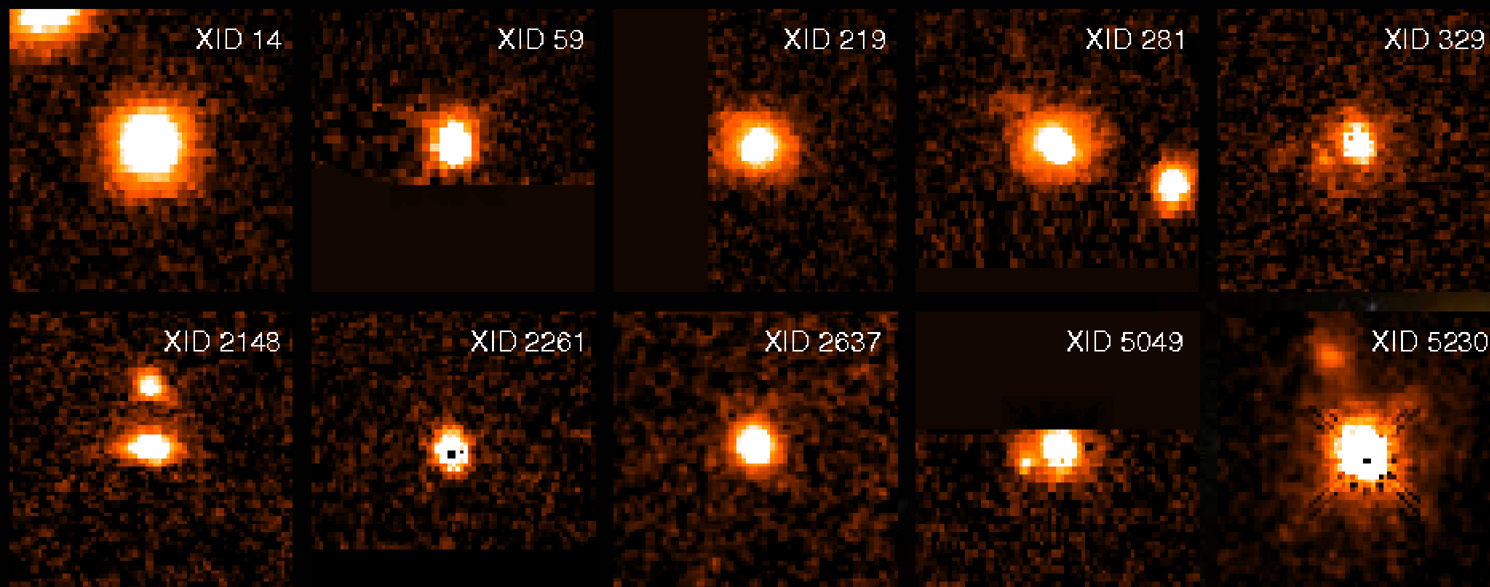
z =
0.3–0.7
0.9–1.0
1.0–1.15
1.15–1.3
1.3–1.5
1.5–1.6
1.6–1.8
1.8–1.9
1.9–2.1
2.1–2.9
z=0.65
z=1.53
z=2.16
z=2.24

ACS+NICMOS: M_{BH} vs. M_{gal} @ z~1.4



XID 14, z=1.06, I=20.7, H=19.4, $\log(M_{BH})=8.52$, $\log(M_{gal})=11.25$

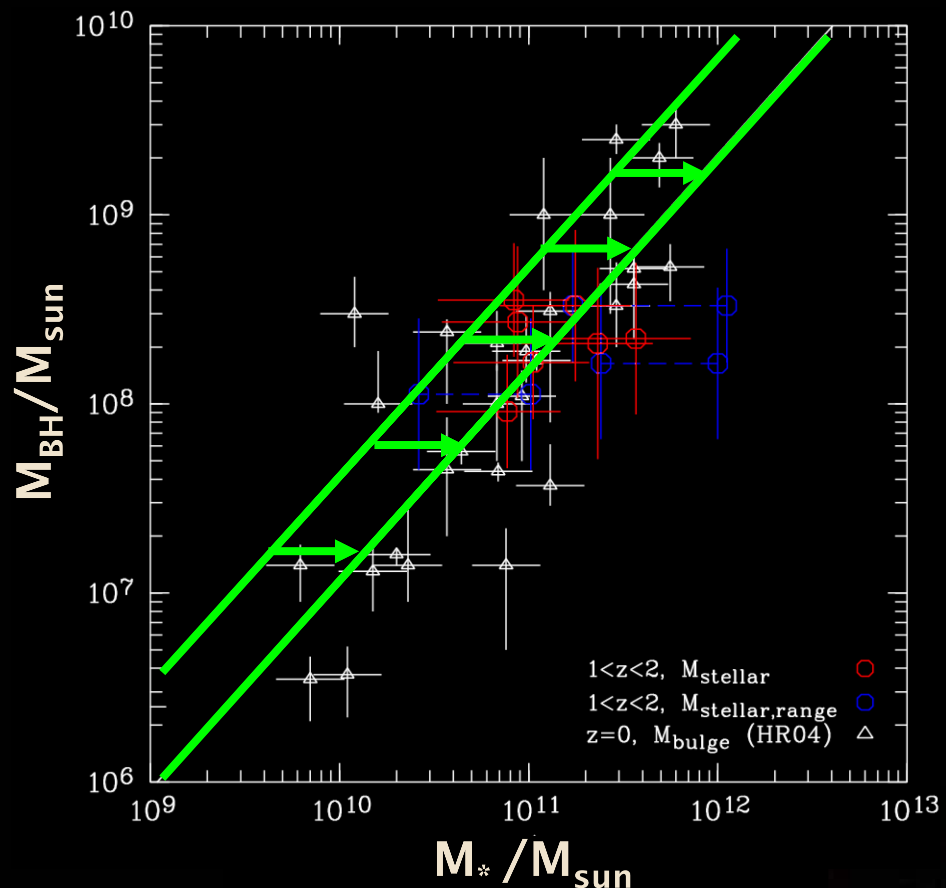
NIC3
F160W



- Coversion I+H to masses: inactive galaxy mass catalog and observed L and colors

Jahnke et al. 2009, ApJ in press

ACS+NICMOS: M_{BH} vs. M_{gal} @ z~1.4



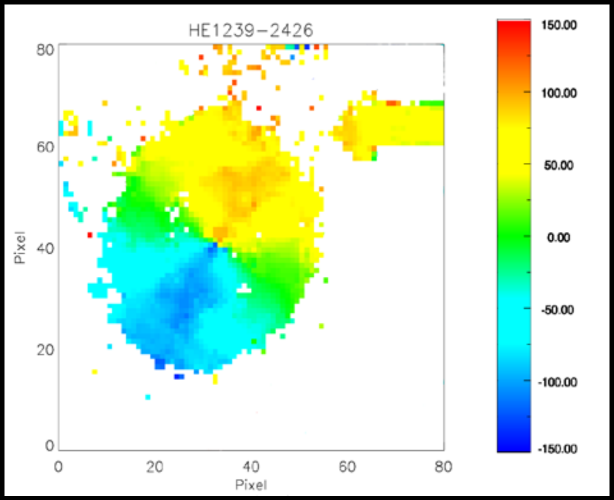
- Identical relations at z=1.4 and z=0
- at z=1.4: total stell. mass at z=0: bulge mass

1: If bulge dominated: no evolution (at $\log M_{*}=11.3$) over 9 Gyrs

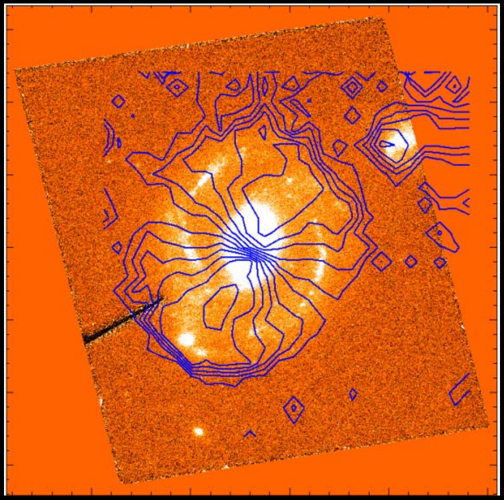
2: suspect substantial disks (Sérsic n, images, lower-z galaxies of same mass, SF/color mix at z>1): mass for z=0 bulges already in disk+bulge at z=1.4; conversion: merger

Jahnke et al. 2009, ApJ in press

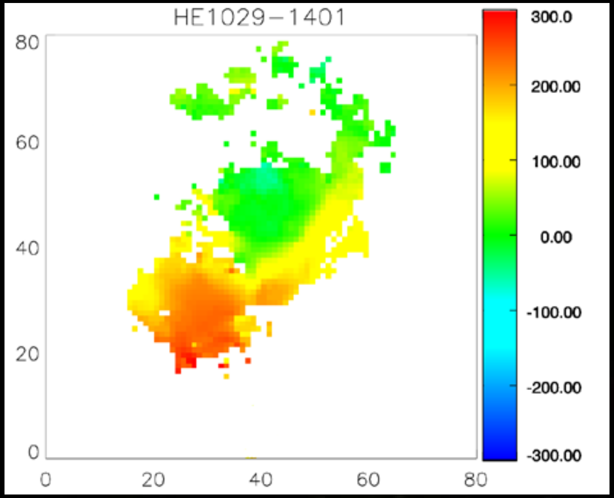
AGN and their host galaxies at earlier times

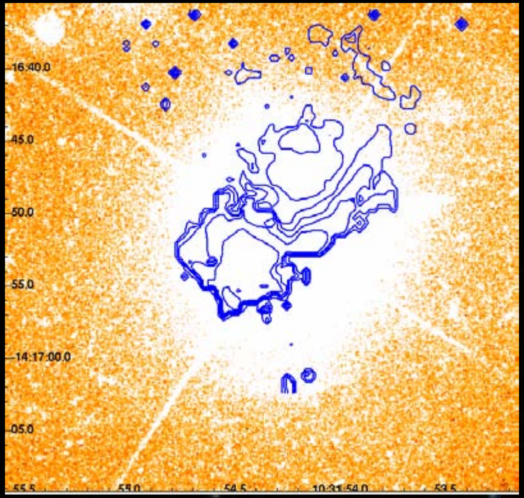


Hα rotation curve



HST image





- Luminous quasars at z~0.1: Kinematics, distortions, outflows (VLT/VIMOS IFU)

Full range:

→ smooth to distorted

→ bulge- or disk-dominated

→ some with potential outflows (Husemann, KJ, Nugroho et al. in prep)

Nugroho, KJ, Husemann, et al. in prep

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Co-evolution, coupled evolution, coeval evolution?

Zheng et al. 2009:

- SF mainly in disks
- BHAR density + SFR density offset by ~2000 @ all z

Cisternas et al. in prep:

- AGN not triggered by major merging

Robaina et al. 2009:

- SF through merging <10%

KJ et al. 2004ab, Sanchez et al. 2004, Silverman et al. 2009 and others:

- Mild increase of SF in AGN

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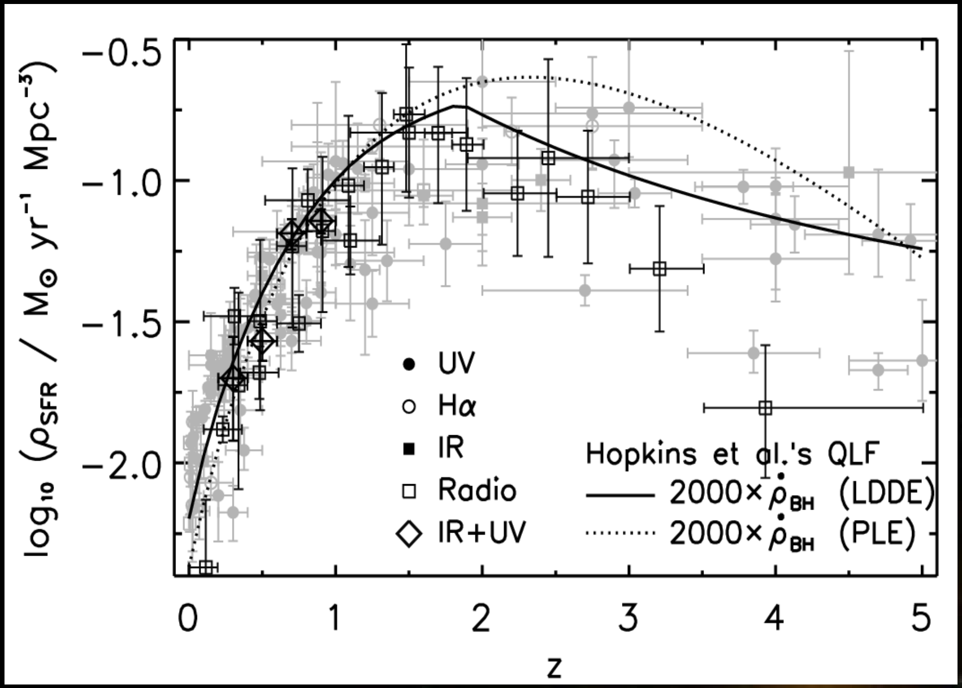

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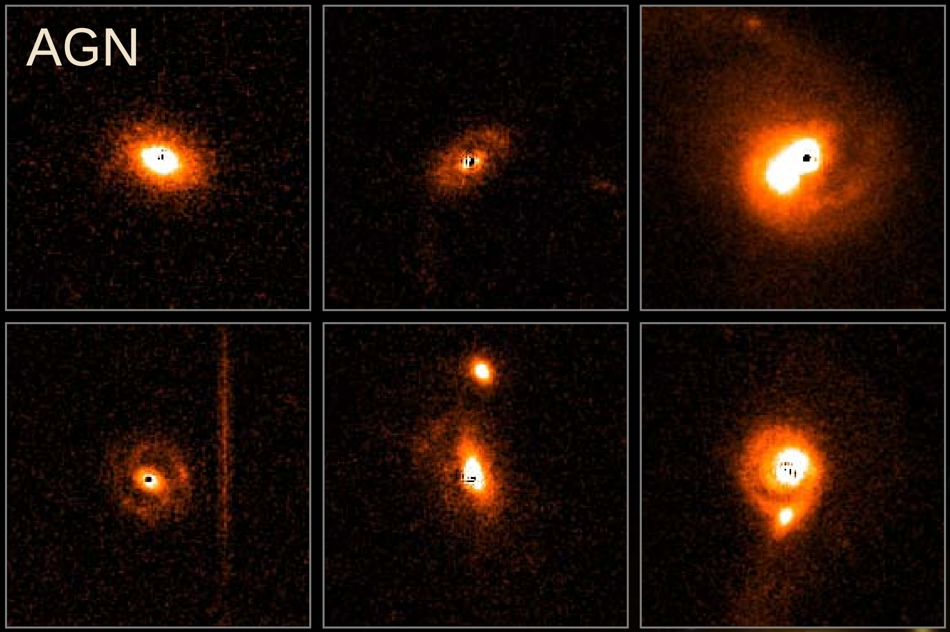

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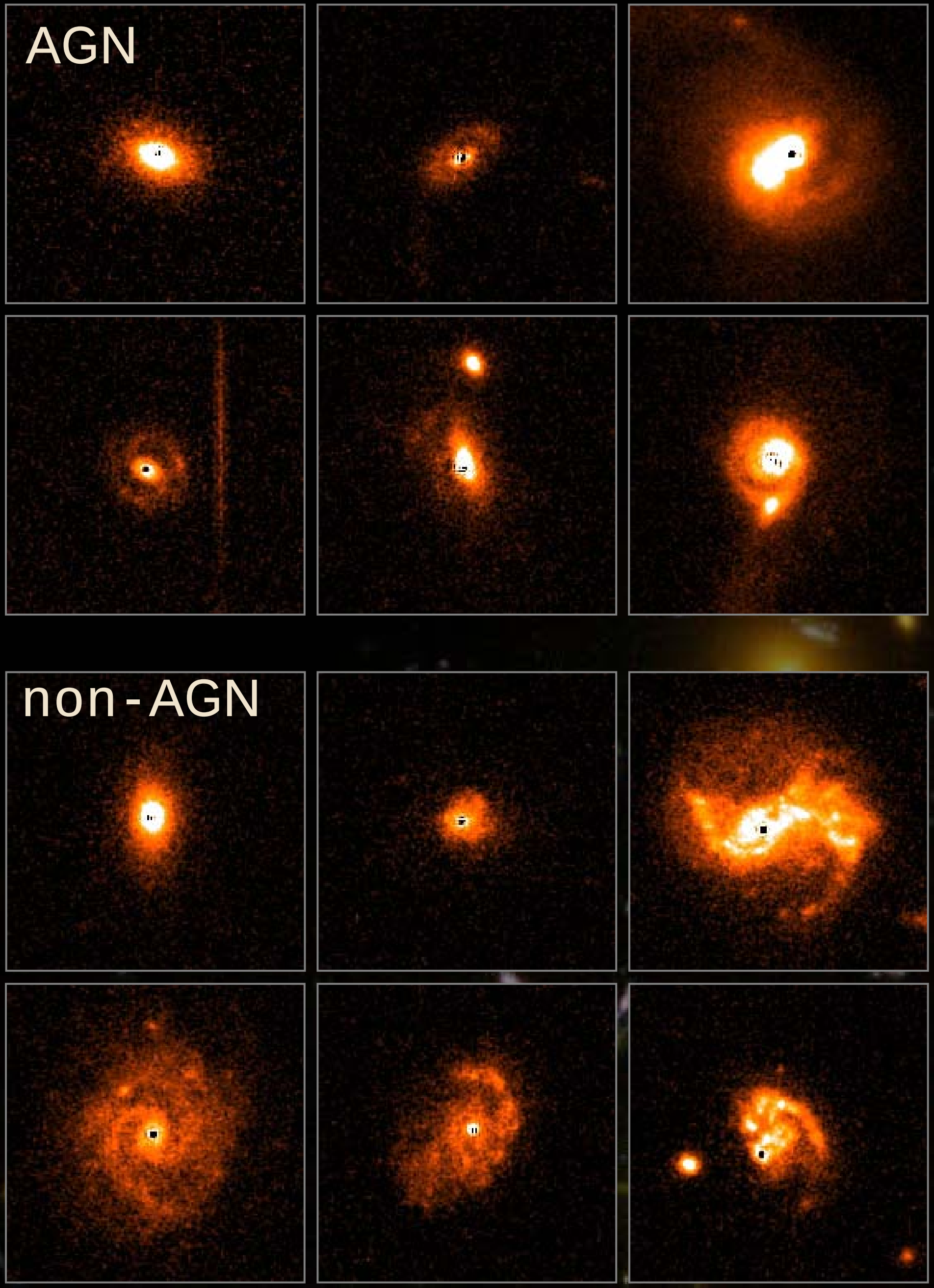

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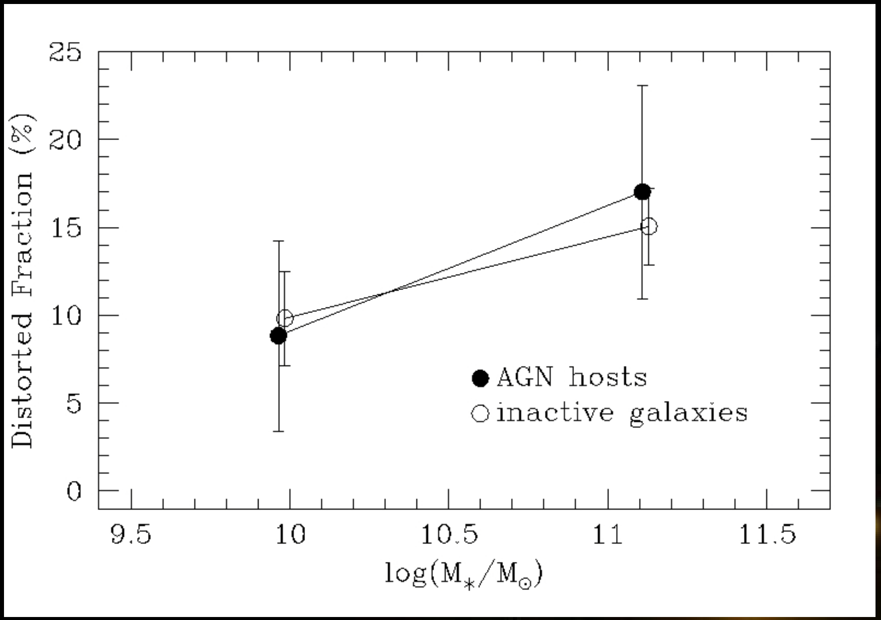

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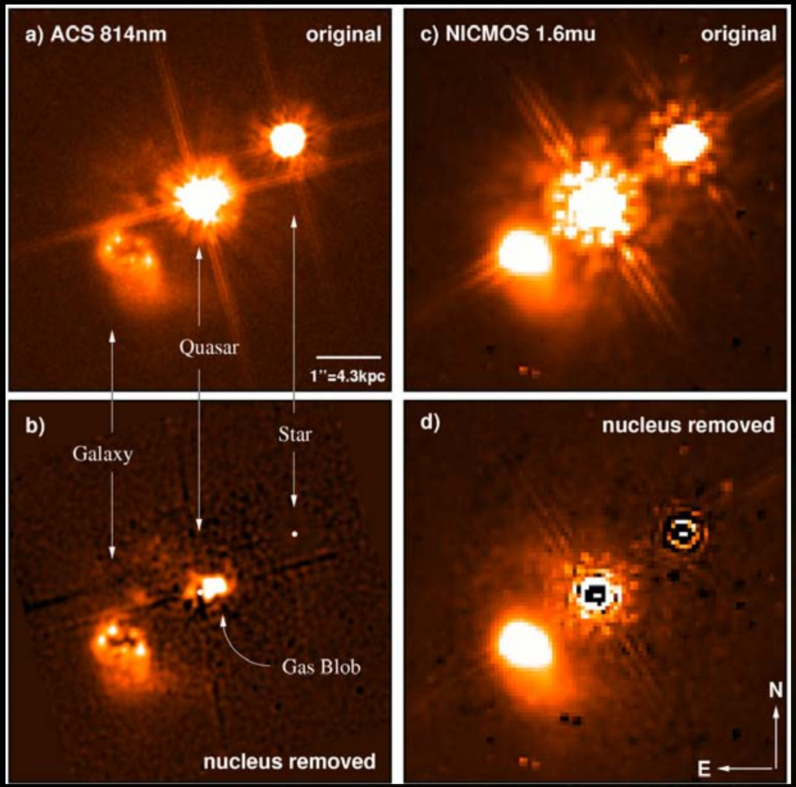
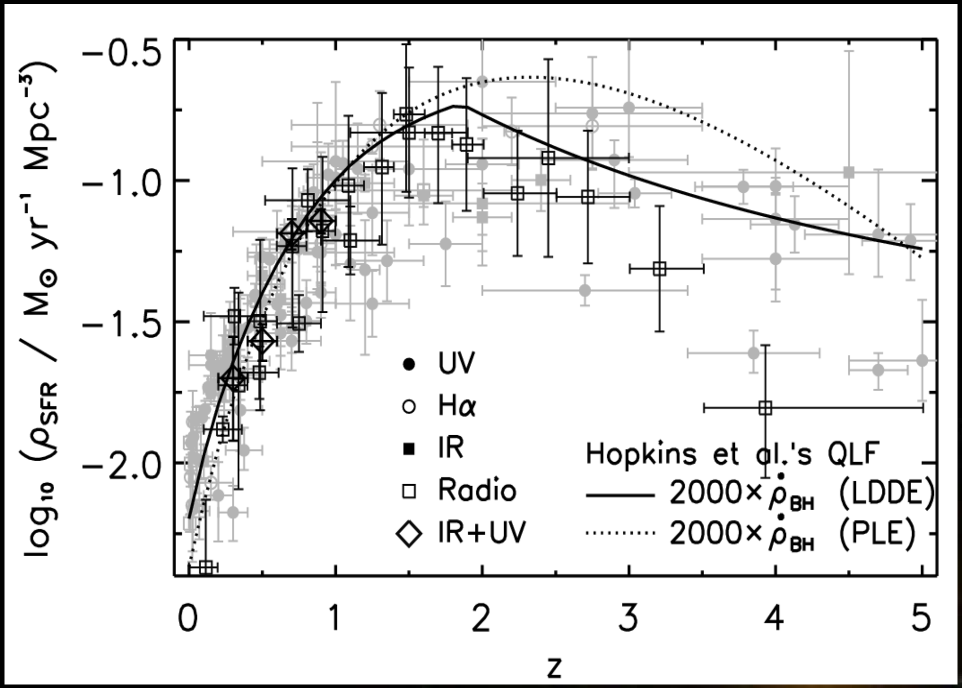


Co-evolution, coupled evolution, coeval evolution?

What co-evolution is not:

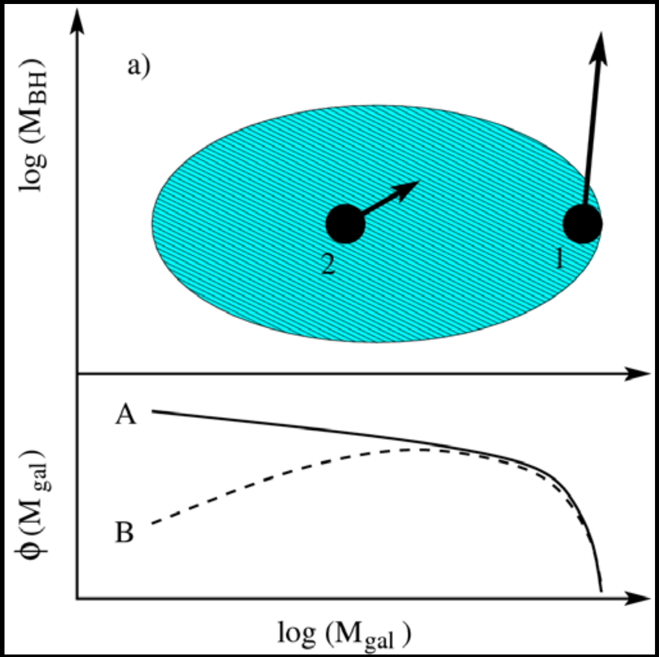
- „per unit M_*-increase M_{BH} grows by 1/700 units at any time" → wrong
- „bulge star formation and bulge assembly occur at the same time" → wrong
- „Major merger trigger AGN and form the bulge at the same time" → wrong

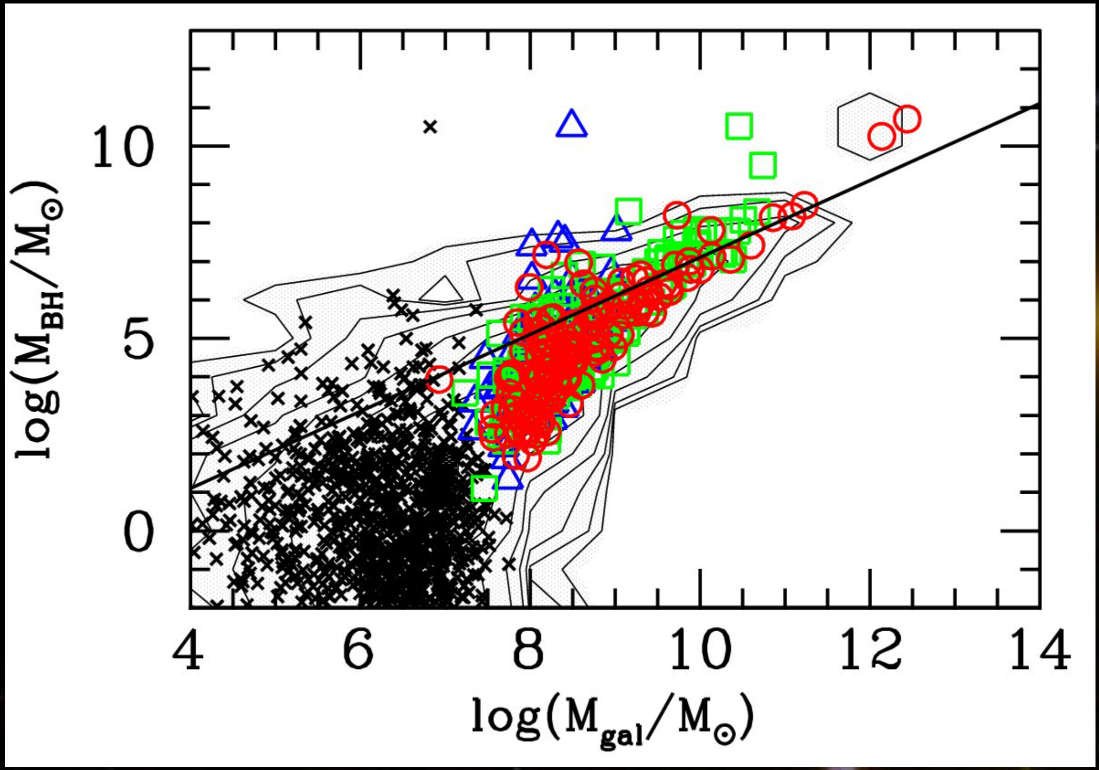


So what is co-evolution?

Co-evolution, coupled evolution, coeval evolution?

Peng 2007: Galaxy merging averages properties – is M_{BH}-M_* relation due to „central limit theorem“?

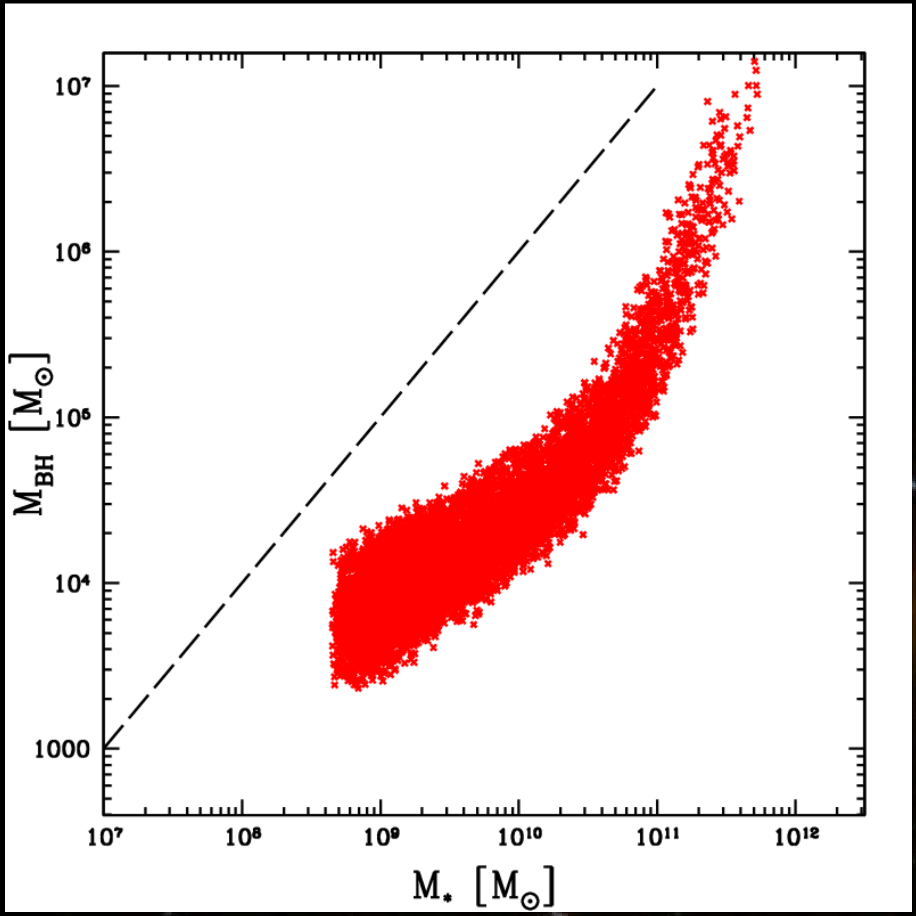


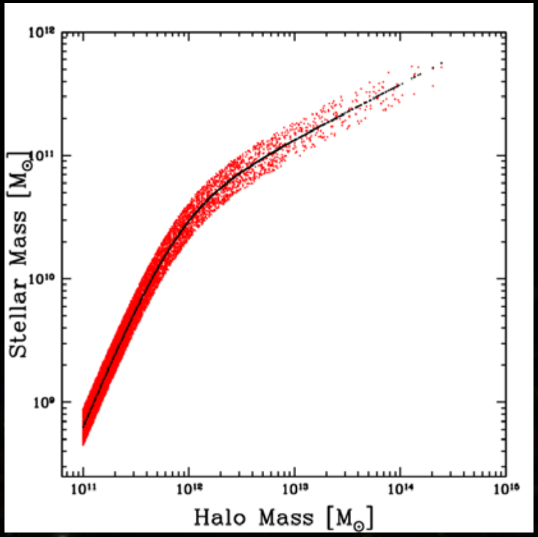


Co-evolution, coupled evolution, coeval evolution?

w/ Andrea Macciò:

- dark matter merger tree
- seeded with M_*, M_{BH}
- SF and dM_{BH} law
- Q: is AGN-feedback needed?





Co-evolution, coupled evolution, coeval evolution?

What does this mean?

Co-evolution is at maximum „indirect“

AGN feedback → yes, it exists, but no indications for global effect!

→ Possibly just a statistical process w/o physics? (work in progress)

→ Hierarchical structure formation at work?

An incomplete summary & outlook

- Massive galaxies have massive BHs
- Close relation of BH and bulge mass
- Evolution in M_{BH}/M_{bulge}
- Merging not dominating mechanism to trigger BH accretion (at $z<1$, $M_{*}<10^{11.5}$)
- Co-evolution = non-causal?
- AGN feedback needed? Possibly not!

~the end, for now~