Triggering luminous AGN

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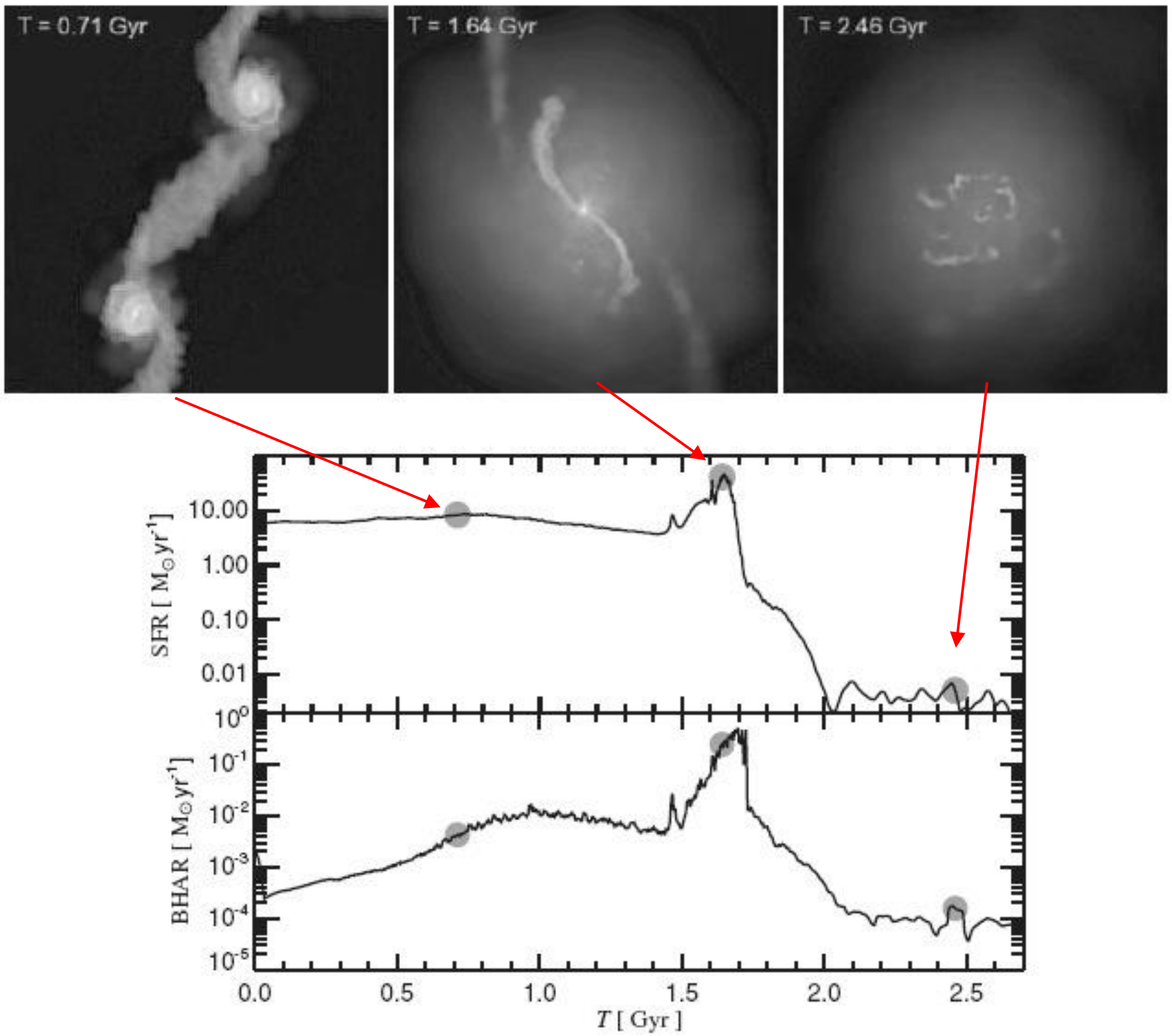
Triggering mechanisms for luminous AGN

Quasar: $L_{bol} > 10^{45}\, erg\, s^{-1};\ \dot{M} \geq 0.2\, M_{sun}\, yr^{-1}$

- Galaxy mergers and interactions (Heckman et al. 1986, Smith & Heckman 1989)
- Accretion of gas from hot X-ray haloes
  - Bondi accretion of hot gas (Allen et al. 1985, Best et al. 2006, Hardcastle et al. 2007, Buttiglione et al. 2009)
  - Accretion of cool gas from cooling flow (e.g. Bremer et al. 1997)
- Cold accretion from large-scale filamentary (Keres 2005, Dekel et al. 2009)

Star formation in major gas-rich mergers



Springel et al. (2005)

Uncertainties with hydrodynamical simulations

- Sub-element microphysics (feedback, star formation, eqn. of state etc.)
- Resolution: the resolutions of most of the simulations relatively poor (~100pc); they do not cover key aspects of AGN physics
- The proportion of the available accretion energy that goes into the quasar ouflows (the “coupling efficiency”: ~0.005 -- 0.1P_{acc})

Are luminous AGN triggered in mergers?

- Ground-based 4m telescopes, PRG, z <0.3 (Heckman et al. 1985, Smith & Heckman 1989): 50% of PRG with strong emission lines are morphologically disturbed

  "…galaxy interactions/mergers play an important role in the PRG phenomenon."

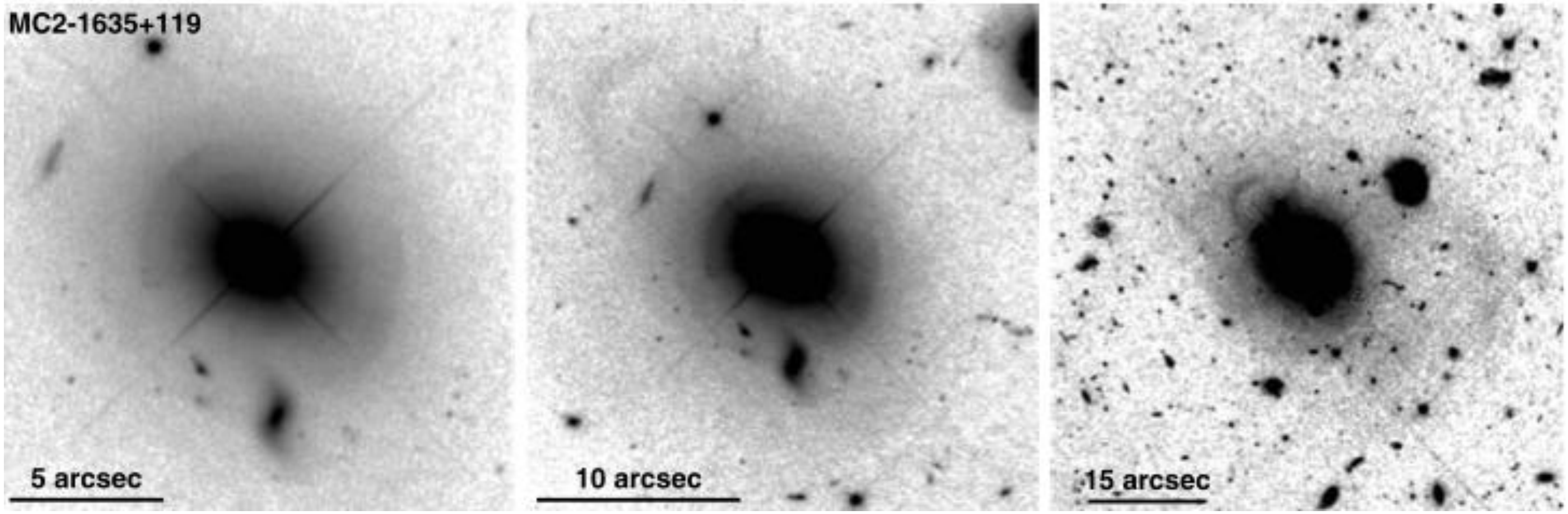
  "…in contrast to conventional wisdom, very powerful radio galaxies are now always ellipticals."

- HST+WFPC2 (1 orbit), 0.1 < z < 0.25, RLQ/RQQ/PRG (Dunlop et al. 2003)

  "…we demonstrate that the basic properties of these hosts are indistinguishable from those of quiescent, evolved, low-redshift elliptical galaxies of comparable mass."

Deep HST/ACS images of quasar hosts

- HST+ACS (5 orbits) observations of quasar hosts (Canalizo et al. 2007, Bennert et al. 2008)



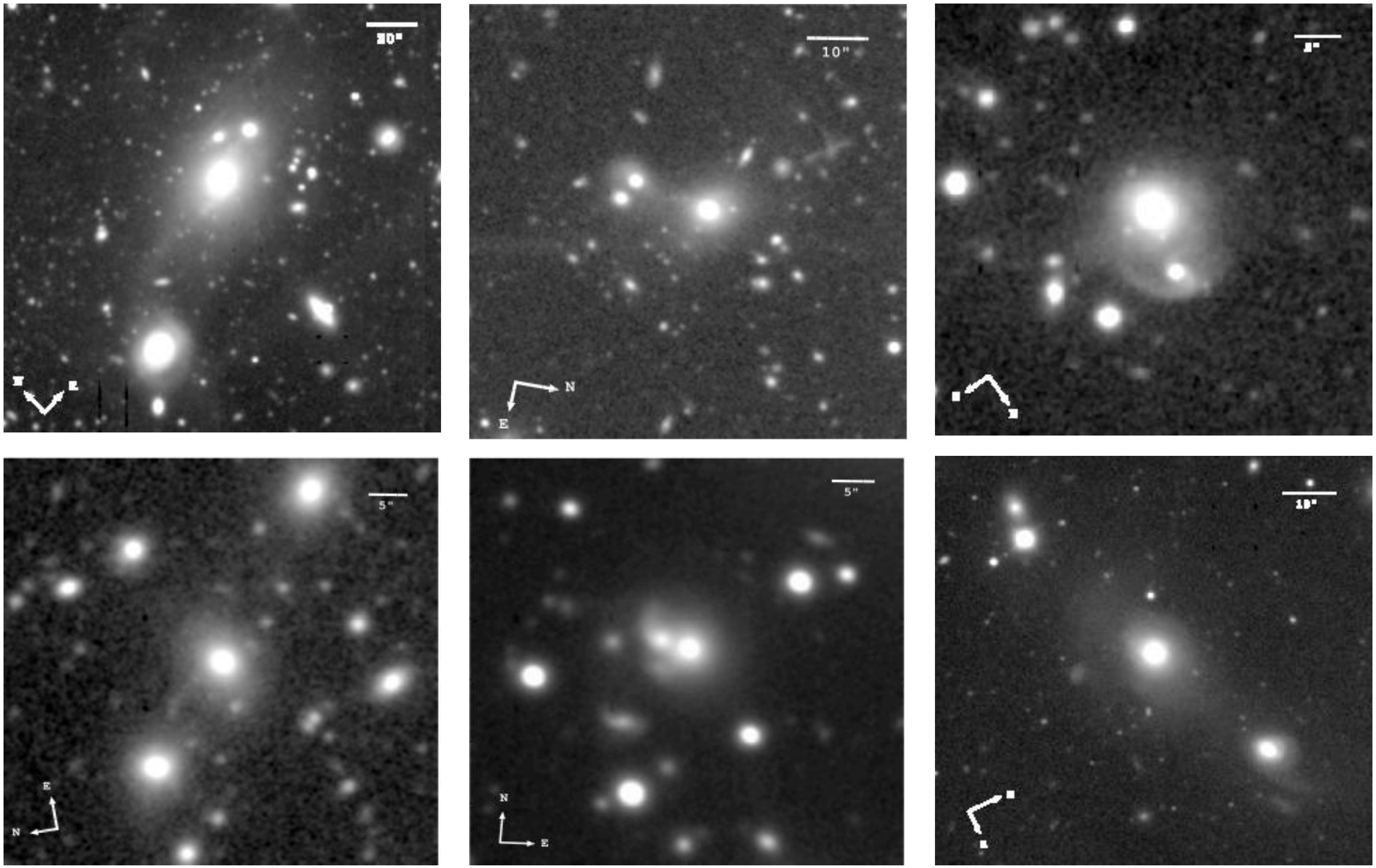
- 4/5 of low-z QSO host galaxies taken from Dunlop et al. (2003) -- classified as elliptical galaxies -- reveal shells and tails ➔ QSO hosts suffered mergers that likely triggered the the QSO

Deep Gemini observations of the 2Jy sample

Ramos Almeida et al. (2010)

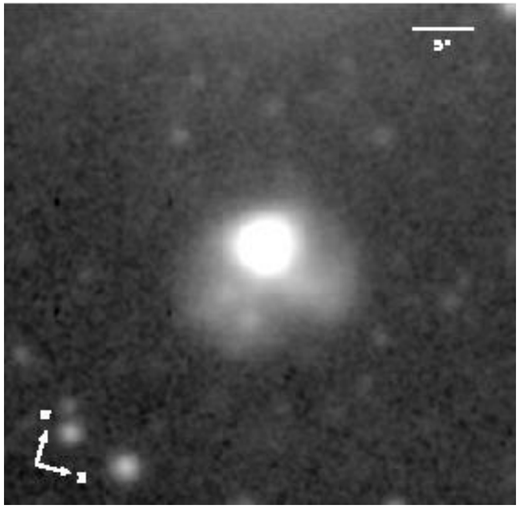
- Complete sample of 46 southern 2Jy radio sources with redshifts $0.05 < z < 0.7$ and steep radio spectra ($\alpha > 0.5$)
- Sample comprises: 43% NLRG, 33% BLRG/QSO, 24% WLRG
- Gemini-S/GMOS r’ imaging reaching an effective surface brightness of $\mu_{r'} \leq 27.3$ mag/arcsec^2

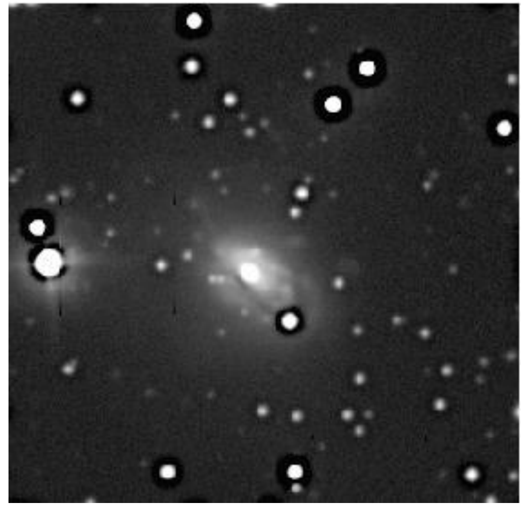
Interactions/mergers: pre-coalescence

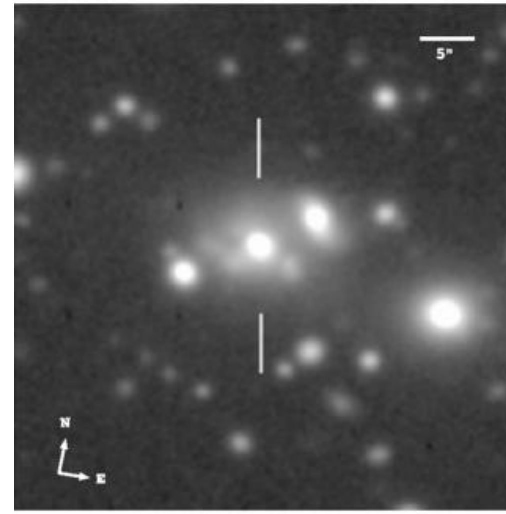


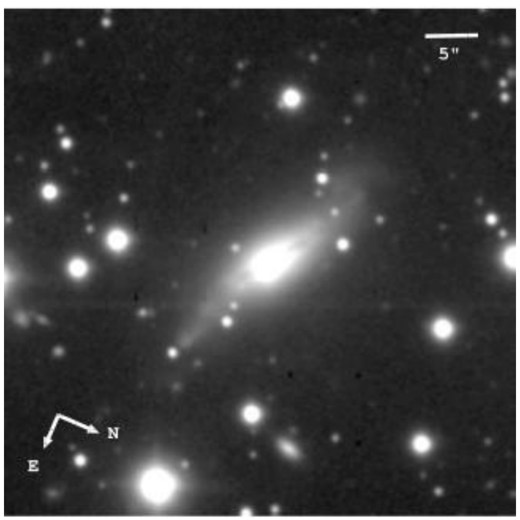
37% of the 2Jy sample show tidal bridges, double nuclei (r < 5kpc) or tidally distorted companion galaxies ➔ pre mergers.

Mergers: coalescence





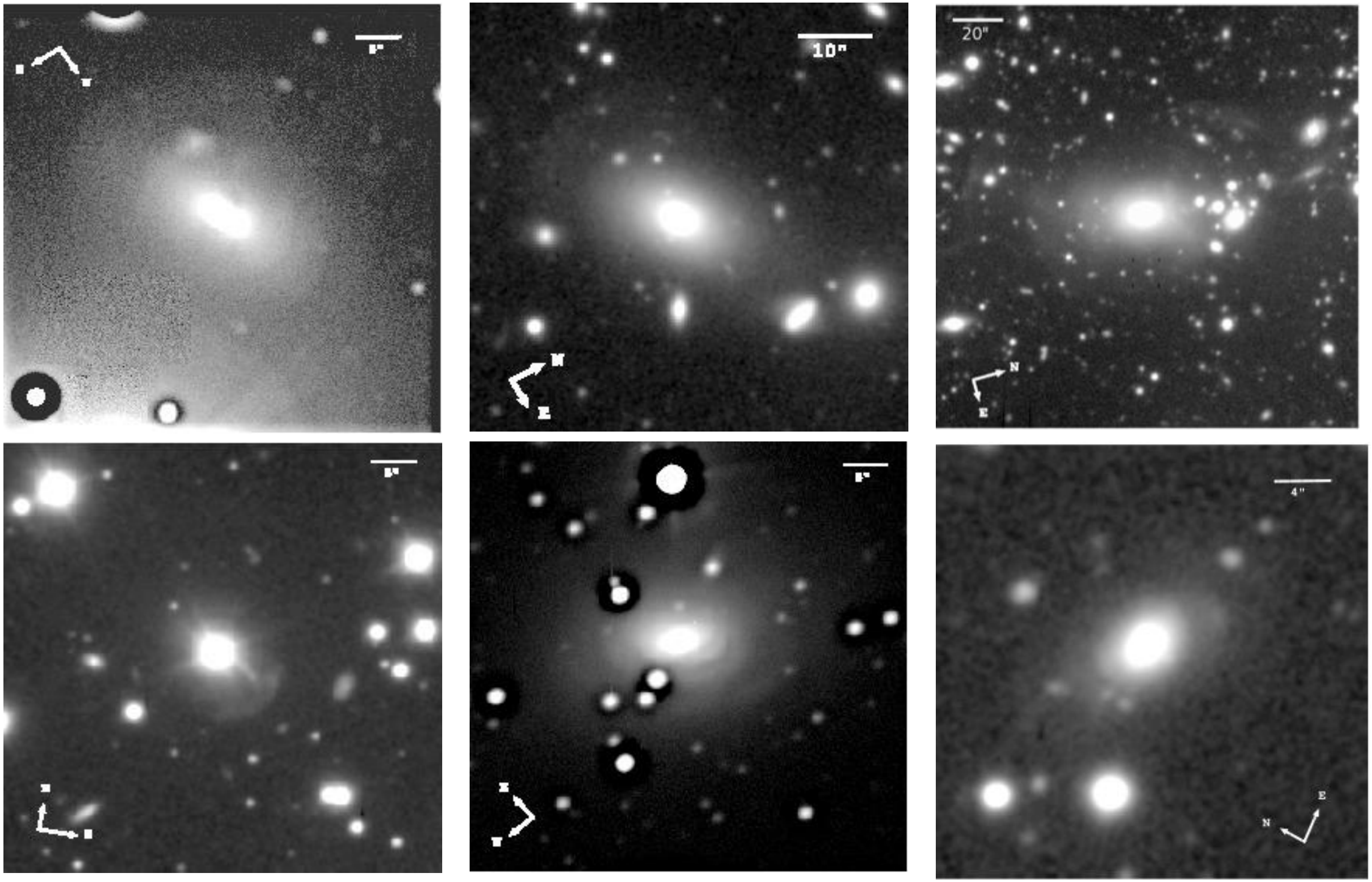




Some radio galaxies show highly disturbed morphologies suggesting that they are viewed close to the time of coalescence of the nuclei in a major galaxy merger

Ramos Almeida et al. (2010)

Mergers: post coalescence



Many radio galaxies are relatively settled, but show faint shell structures suggesting tht they have undergone a merger in the past.

Gemini Imaging: summary

- 85% of the 2Jy sample show morphological peculiarities:

  - 37% show tidal bridges, tidally distorted companion galaxies or double nuclei (r < 10kpc)

  - 56% show tidal tails, fans, shells or dust lanes

  - 15% show no sign of morphological disturbance

→ Consistent with the idea that powerful radio galaxies are triggered in galaxy interactions, but the triggering isn't solely associated with a particular stage of a merger

WLRG vs. SLRG in the 2Jy sample

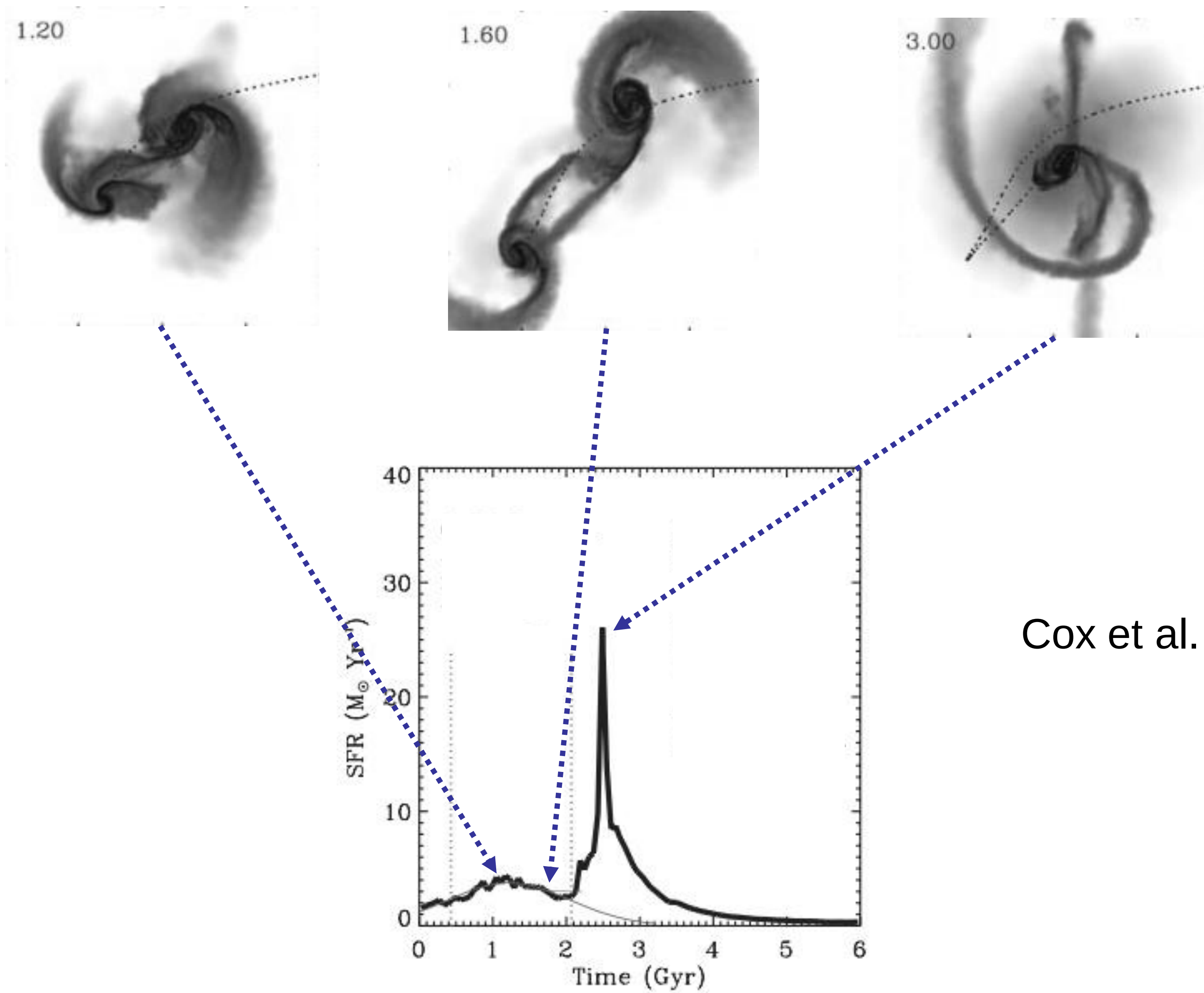
- 94% of strong line radio galaxies (NLRG, BLRG, RLQ) are morphologically disturbed, showing signs of recent interactions/mergers
- 27% of weak line radio galaxies are morphologically disturbed (excluding dust lanes)

➔ Results support the idea that, whereas the strong line sources are fuelled by cold gas accretion (e.g. from merger), the weak line sources are predominantly fuelled by Bondi accretion of the hot ISM

Comparison with normal E galaxies

Study	Redshift	SB (mag/arcsec^{-2})	% Disturbed
2Jy radio galaxies Ramos Almeida et al. (2003)	0.05 < z < 0.7	$21.3 < \mu_V < 26.2$ $(\bar{\mu}_V = 23.6)$	85%
Nearby E-galaxies Malin & Carter (1983)	z < 0.01	$\mu_V < 26$	10%
z~0.1 E-galaxies Van Dokkum (2005)	z~0.1	$\mu_V < 28.7$	71%
Nearby E-galaxies Tal et al. (2009)	z < 0.01	$\mu_V < 27.7$	73%

Triggering starbursts in major galaxy mergers



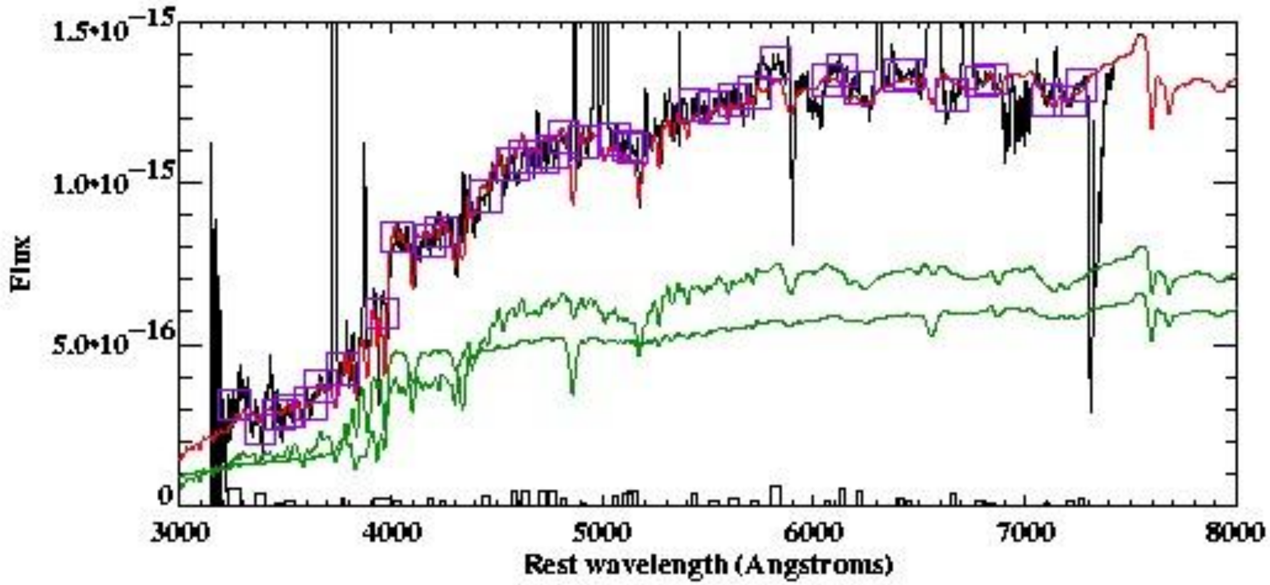
Cox et al. (2008)

Starbursts in radio galaxies: occurrence

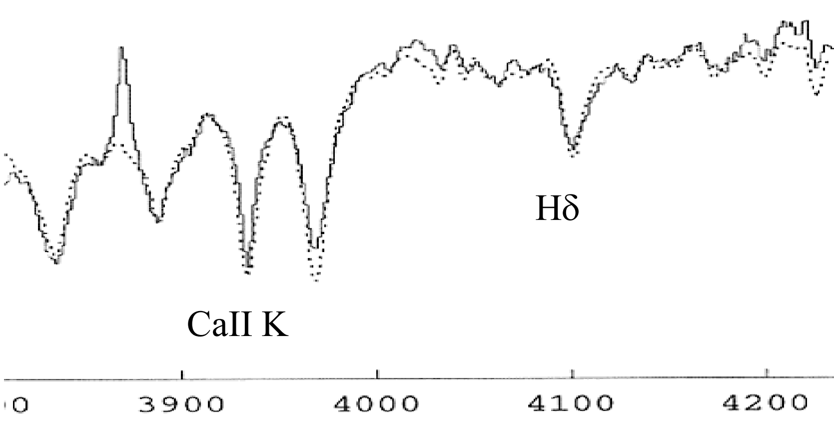
- Starburst rate from optical spectroscopy:
  - 2Jy($0.15 < z < 0.7$): <u>20 -- 35%</u> (22 objects)
    Tadhunter et al. (2002)
  - 3CR($z<0.2$): <u>33%</u> (14 objects)
    Aretxaga et al. (2001), Wills et al. (2002)
  - 2Jy ($z<0.08$, FRIs): <u>25%</u> (12 objects)
    Wills et al. (2004)
- Far-IR continuum excess+MFIR colours+PAH:
  - 2Jy($0.05 < z < 0.7$): <u>15--35%</u>
    Dicken et al. (2009,2010)

The lack of major starburst components in the majority of powerful radio galaxies (> 65%) demonstrates that, while the activity may be triggered in galaxy interactions, in most cases it is not triggered at the peaks of major, gas-rich mergers.

The post-starburst radio galaxy 3C305



WHT/ISIS



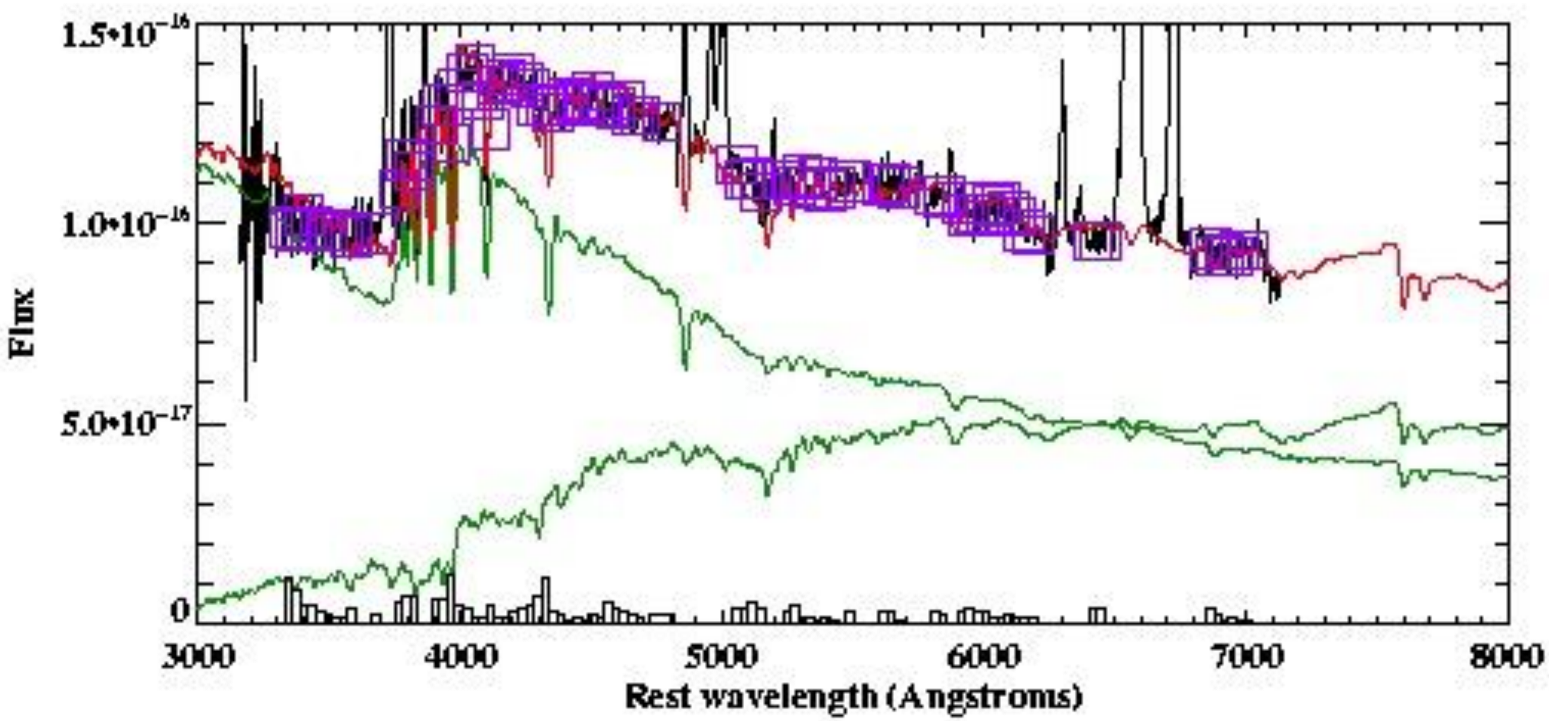
Starburst Properties
Age: 0.4 - 0.9 Gyr
E(B-V)=0.4 - 0.8 mag
Mass:1.5+/-0.5x10^{10} M_{sun}
(16 - 40% of total stellar mass)

Bruzual & Charlot(1996) models
Salpeter IMF (0.1-125 M_{sun})

3C305 (z=0.042) Heckman et al. 1986

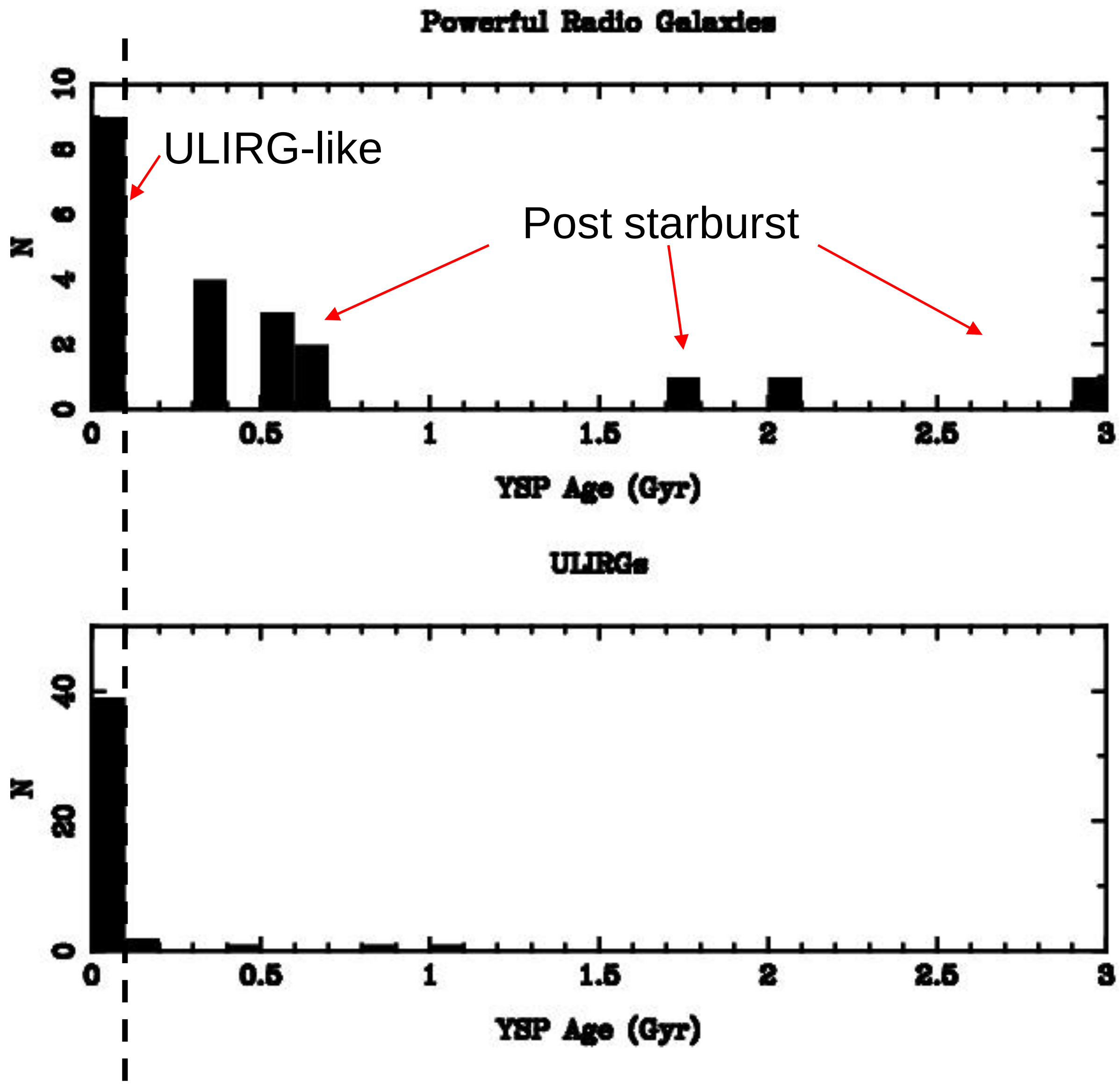
Starburst dominated objects: the ULIRG 3C459

3C459 (z=0.22) NTT+EMMI



YSP Properties
Age: 0.05 Gyr
Mass:$4x10^9$ M_{sun}
(>5% of total stellar mass in slit)

The Ages of the YSP in ULIRG and PRG

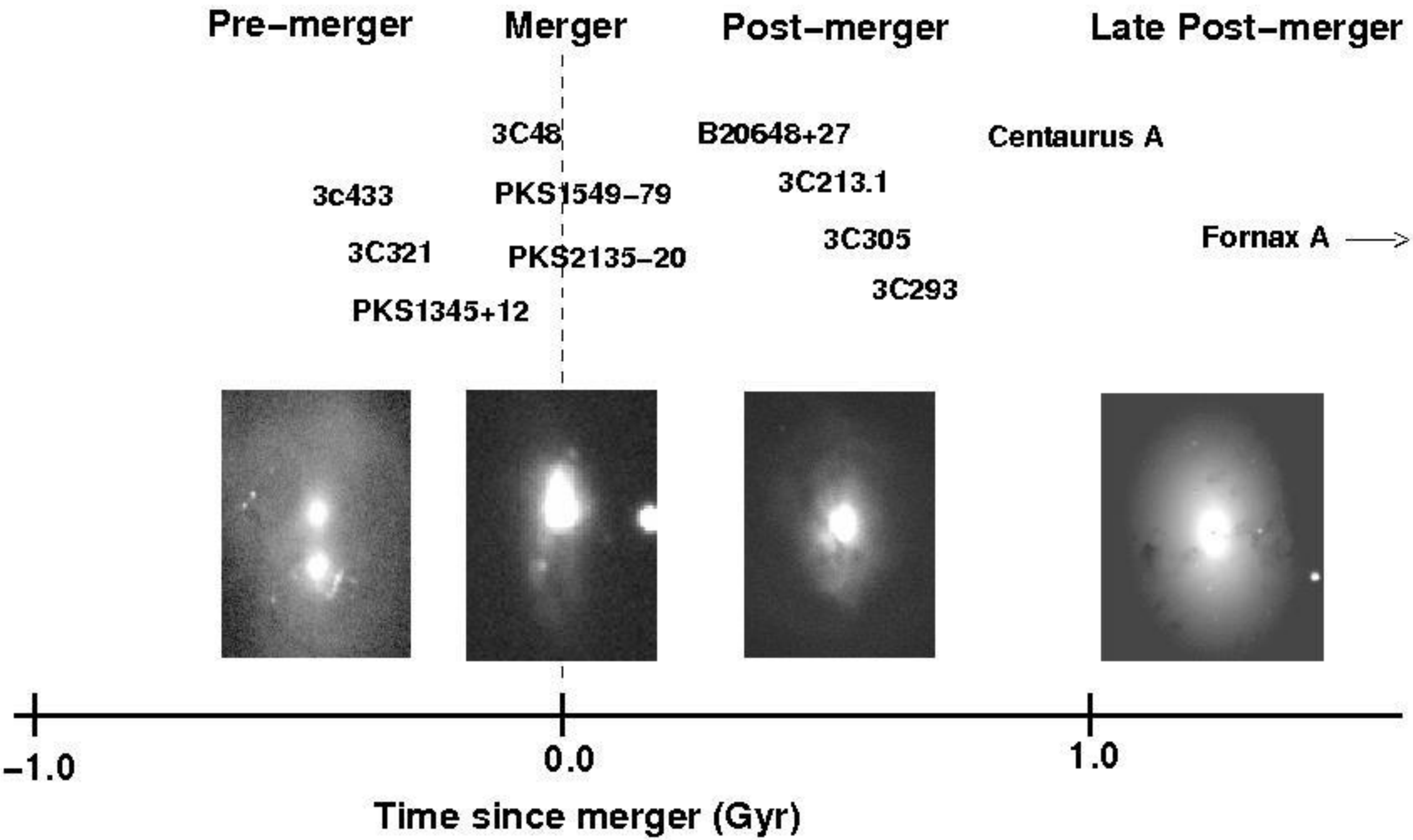


Tadhunter et al. (2005)
Holt et al. (2006,2007)
Wills et al. (2008)
Tadhunter et al. (2010)

Rodriguez-Zaurin et al. (2007,2008,2009,2010)

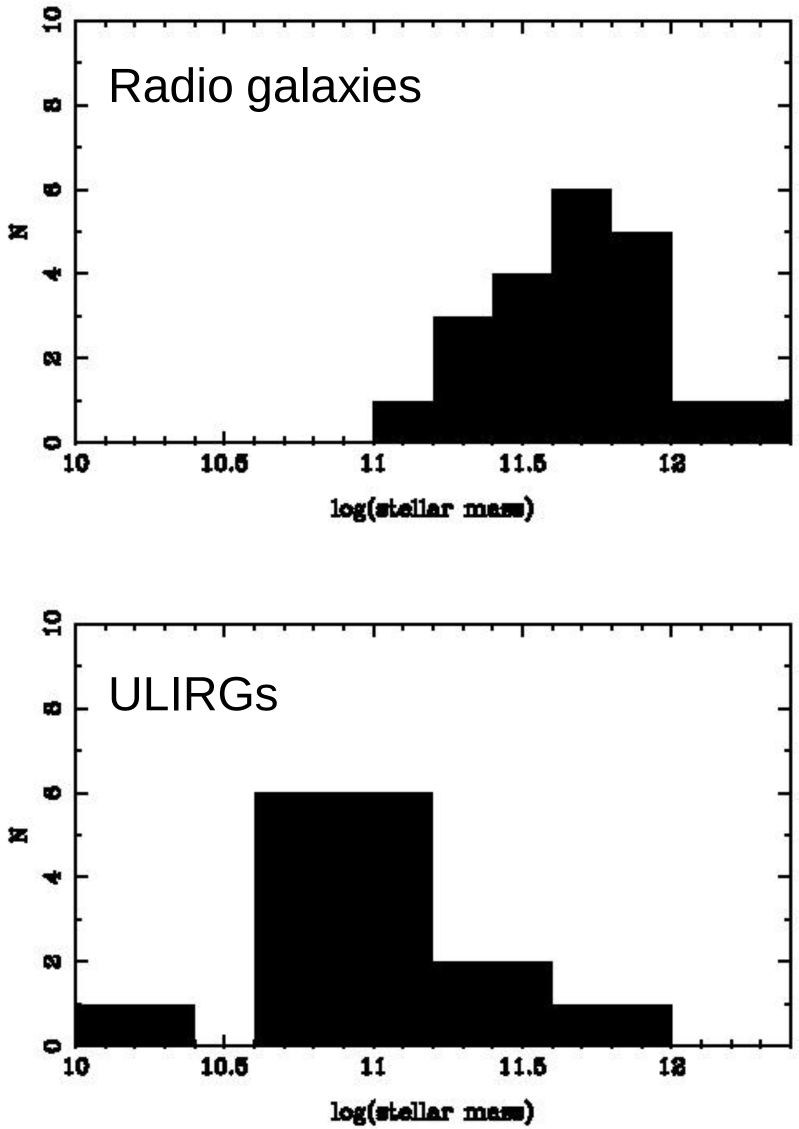
Typical maximum age of radio source

Merger sequence for starburst radio galaxies



Stellar masses of starburst radio galaxies

Comparison of their stellar masses suggests that only the most massive ULIRGs are capable of becoming radio galaxies



Starburst radio galaxies: summary

- Only a minority of PRG (<35%) show evidence for energetically significant SB activity
- Some SB radio galaxies show similar properties to ULIRGs: $t_{ysp}< 0.1$ Gyr, high degree of morphological disturbance ➔ AGN likely to be triggered close to peaks of major gas-rich mergers
- A significant subset of SB radio galaxies (generally of lower far-IR luminosity) are post-starburst systems ($0.2 < t_{ysp} < 2$ Gyr) ➔ AGN likely triggered after the merger-induced starburst

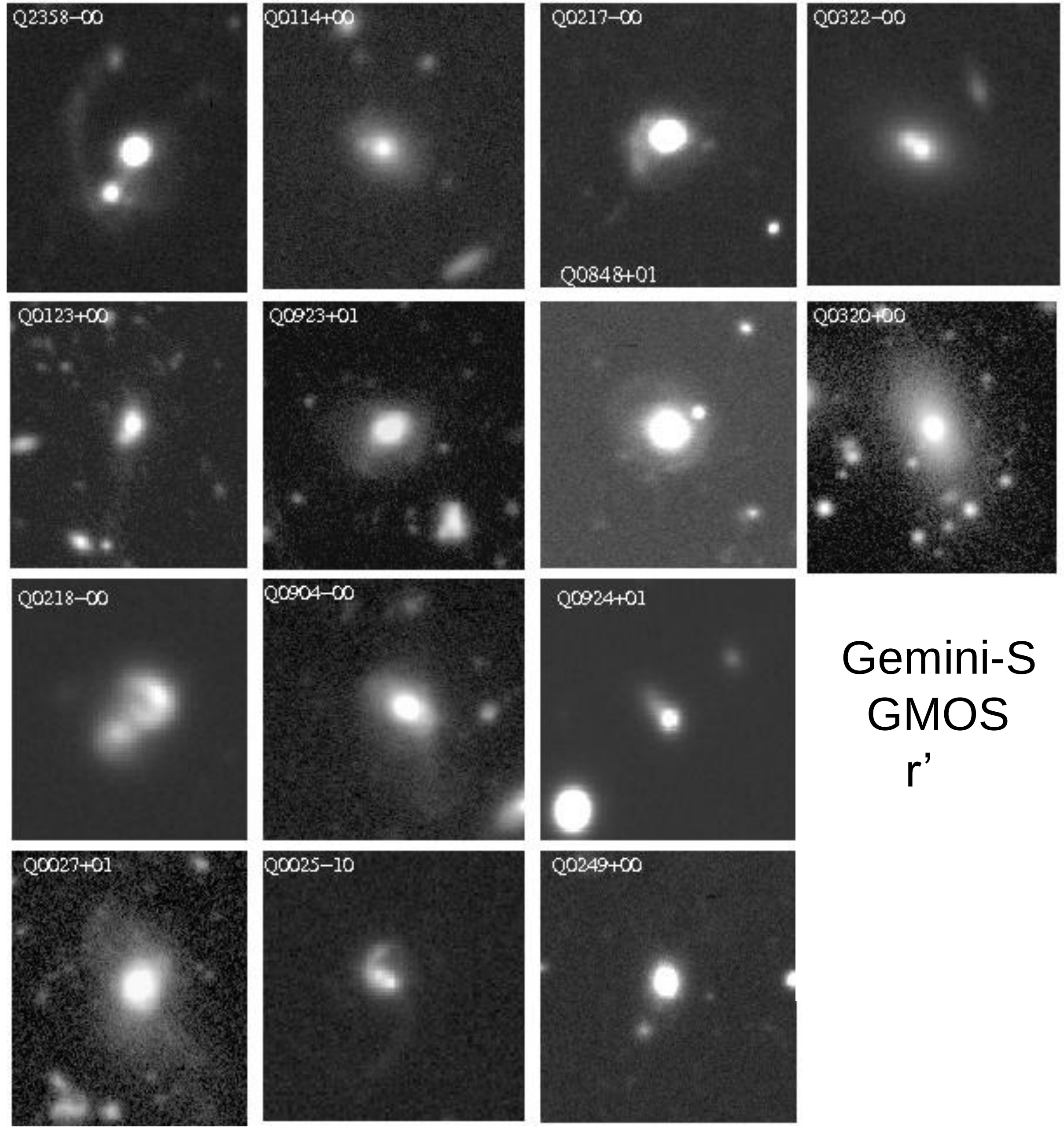
Results suggest that radio jets/AGN are not solely triggered at a particular phase of a particular type of galaxy merger

Gemini imaging of SDSS quasar 2 objects

- 19 quasar 2s
- 0.3 < z < 0.41
- $L_{[OIII]} > 3 \times 10^{8} L_{sun}$

(Zakamska et al. 2003)

75% of quasar 2s show evidence for tidal interactions



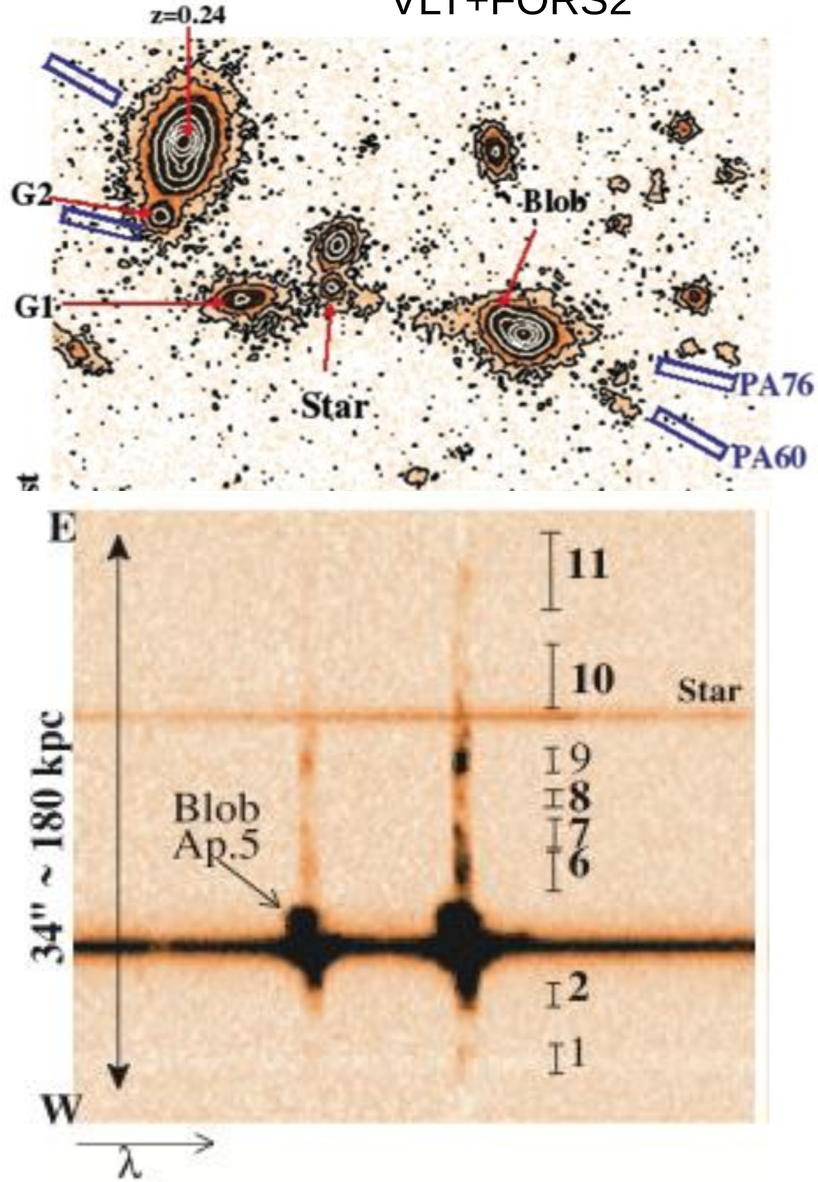
Gemini-S
GMOS
r’

Q0123+00: a quasar triggered in a galaxy encounter?

-SDSS quasar 2 at
 z=0.399

Q0123+00 is linked to
a companion galaxy
~100kpc to the east
by a gaseous tidal
bridge.
➔Suggests that
activity has been
triggered in a galaxy
encounter.

VLT+FORS2

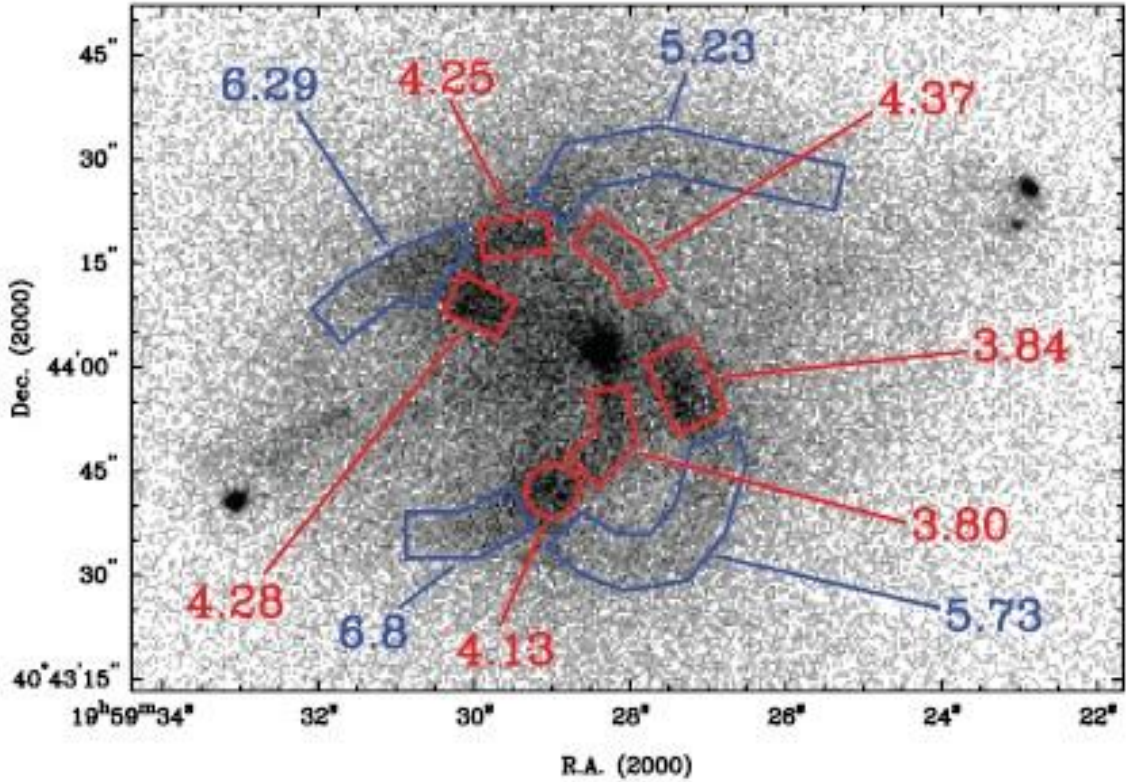


Villar-Martin et al. (2010)

Conclusions

- Clear evidence that luminous, quasar-like AGN of all types are triggered in galaxy interactions
- But the triggering not solely associated with a particular phase of a particular type of interaction
- Triggering occurs in a variety of pre-coalescence, coalescence and post-coalescence phases of mergers
- No strong like between star formtion and AGN activity for powerful radio galaxies

Cygnus A: impact of jets on hot ICM

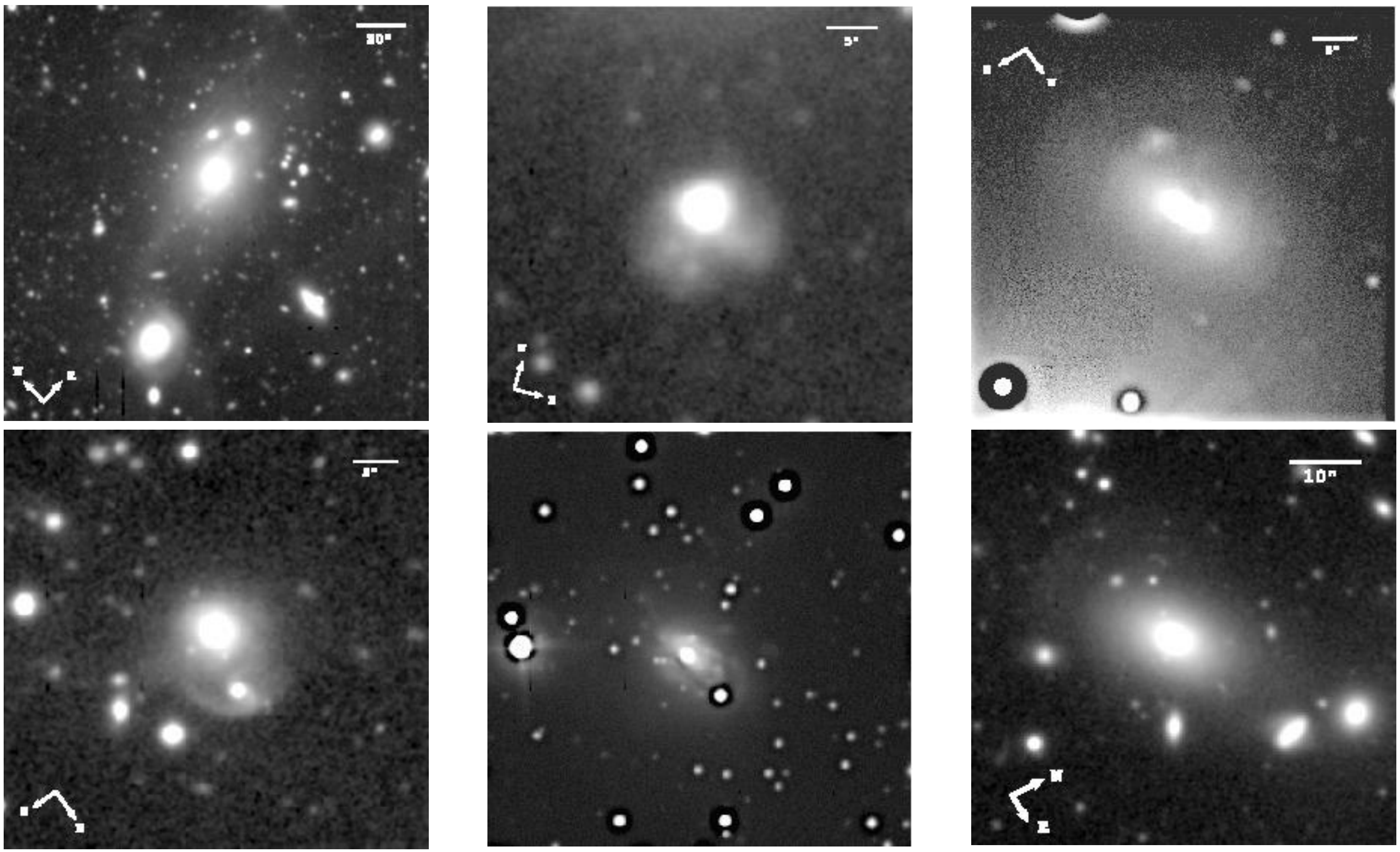


Chandra X-ray image (Wilson et al. 2006)

$$\dot{M} \sim 10^4 M_{sun} yr^{-1} \quad \dot{E} \sim 4 \times 10^{45} erg/s$$

$$\dot{E}/L_{edd} \sim 10^{-2}$$

Deep Gemini imaging of the 2Jy sample



The diversity of morphologies observed in powerful radio galaxies suggests that AGN can be triggered at a variety of stages in galaxy interactions (Ramos Almeida et al. 2010).