The triggering of AGN

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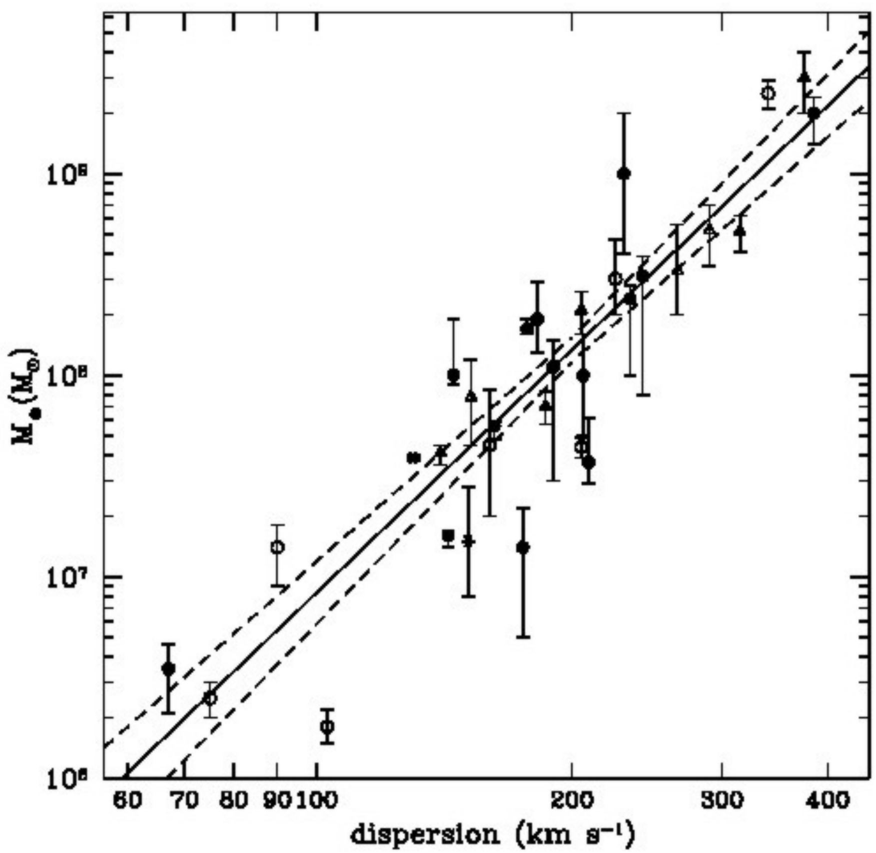
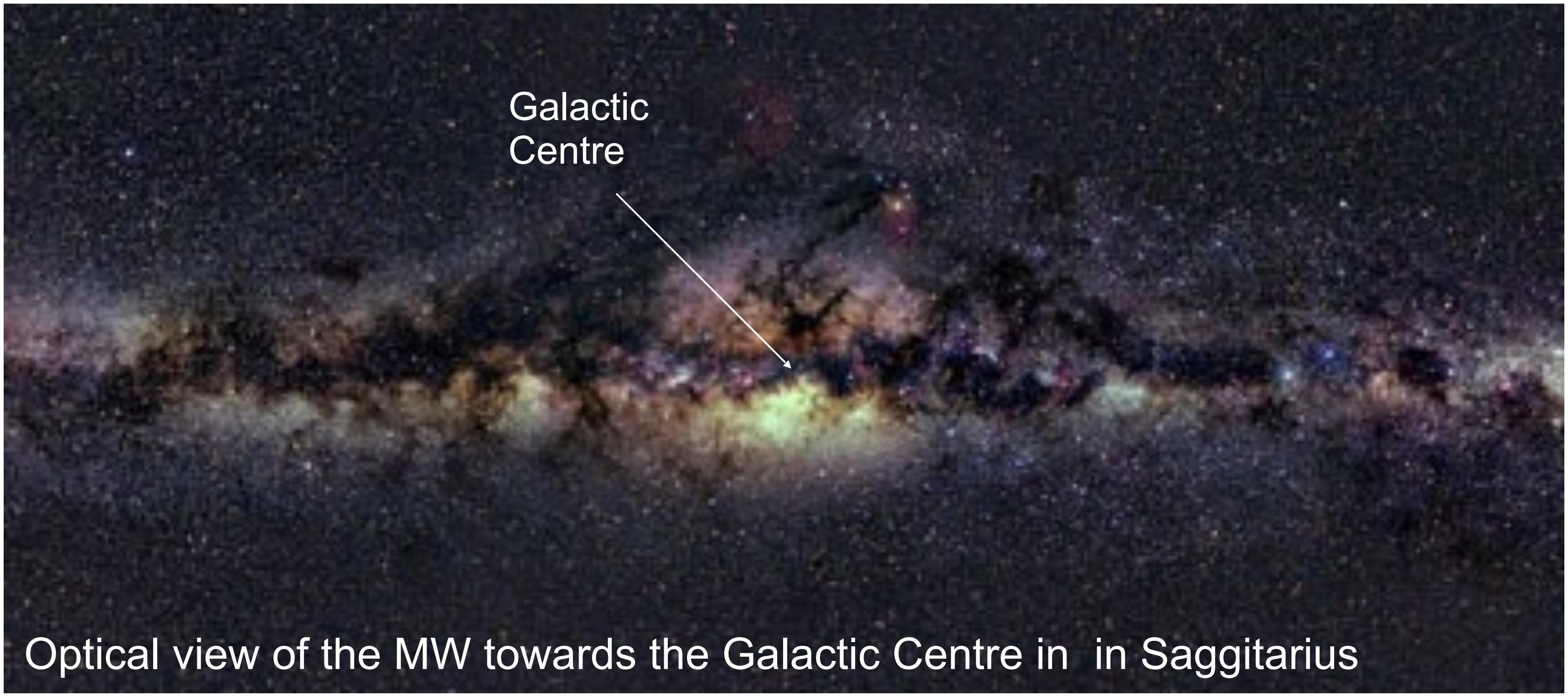
M_{bh} vs σ correlation for nearby galaxies



Tremaine et al. (2002)

Most of the points plotted on the M_{bh} vs s correlation are measured for normal, non-active galaxies

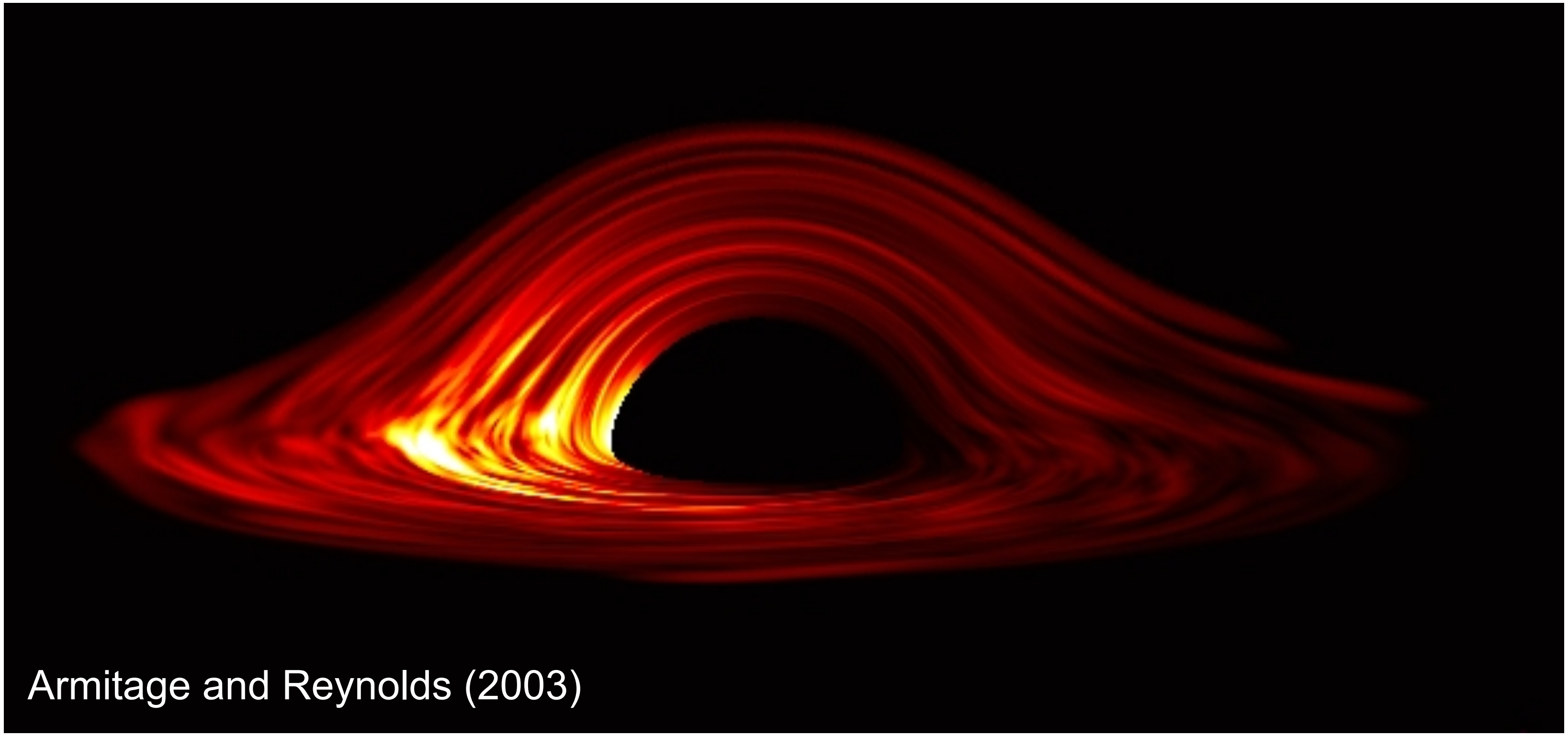
Why no AGN in the Milky Way?



Optical view of the MW towards the Galactic Centre in in Saggitarius

There is currently no quasar in the centre of the Milky Way because there is insufficient gas "fuel" being accreted by its super-massive black holes. But there may be minor flare-ups from time-to-time as as small gas clouds pass close to the centre…

Supermassive black holes: the energy source for active galactic nuclei



$$L_{BOL} = \eta \dot{M} c^2; \eta \sim 0.1 - 0.3$$

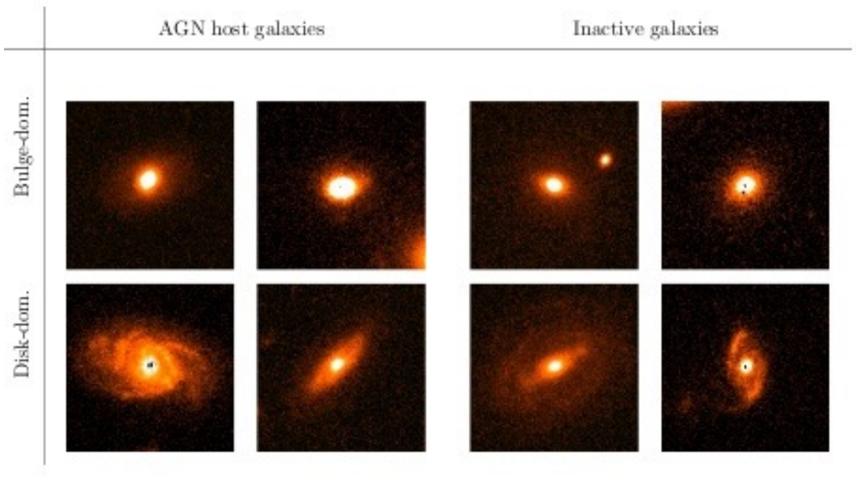
The scale of the accretion disk of a supermassive black hole is $<10^{-2}$ pc. Gas needs to lose a large fraction of its angular momentum to reach such scales… This is the triggering problem.

Triggering mechanisms for AGN

- Galaxy mergers and interactions (Heckman et al. 1986, Smith & Heckman 1989)
- Secular processes (e.g. bars, disk instabilities, slow cold gas accretion, satellite galaxy accretion)
- 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 structures (Keres 2005, Dekel et al. 2009)

Triggering of moderate luminosity AGN

Seyfert: $L_{bol} < 5 \times 10^{37}\, W;\ \dot{M} \leq 0.1\, M_{sun}\, yr^{-1}$



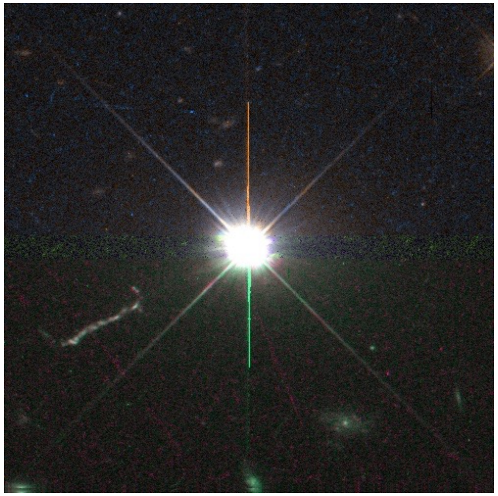
Cisternas et al. (2010)
(see also
Grogin et al. 2005)

- Deep field studies find no evidence for a higher rate of mergers or interactions in the hosts of moderate luminosity AGN compared with well-matched control samples
- This suggests that secular processes (e.g. bars, disk instabilities, slow cold gas accretion, satellite galaxy accretion) may trigger such AGN

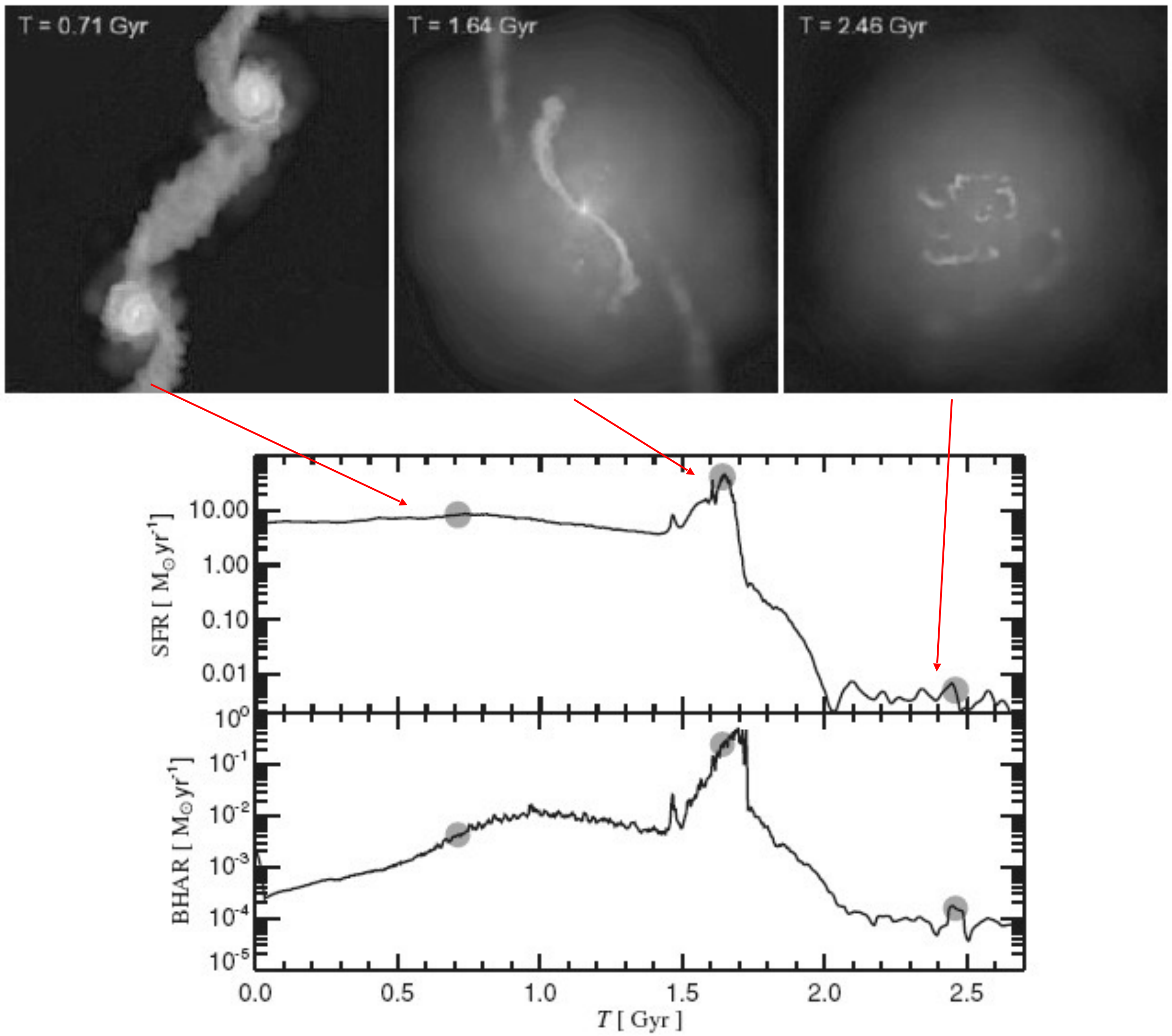
Are quasars triggered in galaxy mergers?

Quasar:

$$L_{bol} > 10^{38}\,W;\ \dot{M} \geq 0.2\,M_{sun}\,yr^{-1}$$
$$M_B < -23$$
$$L_{[OIII]} > 10^{35}\,W$$
$$t_{QSO} \sim 1 - 100\,Myr$$



AGN activity in major gas-rich mergers



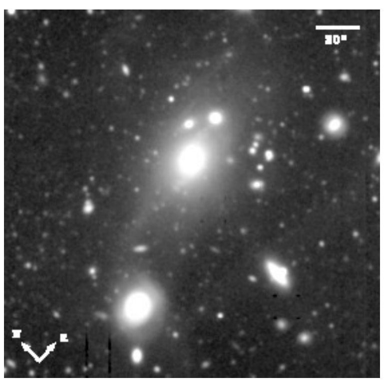
Springel et al. (2005)

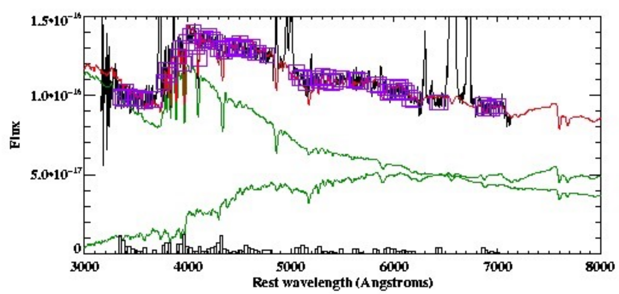
Investigating triggering mechanisms

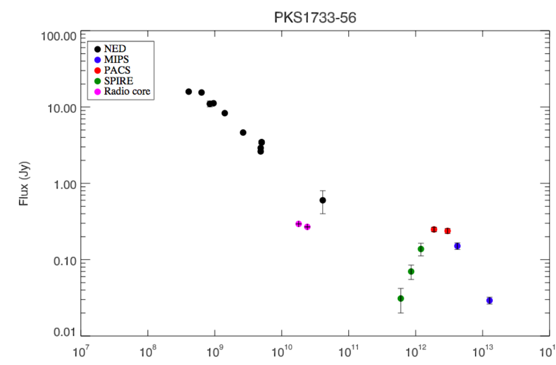
Galaxy morphologies and environments

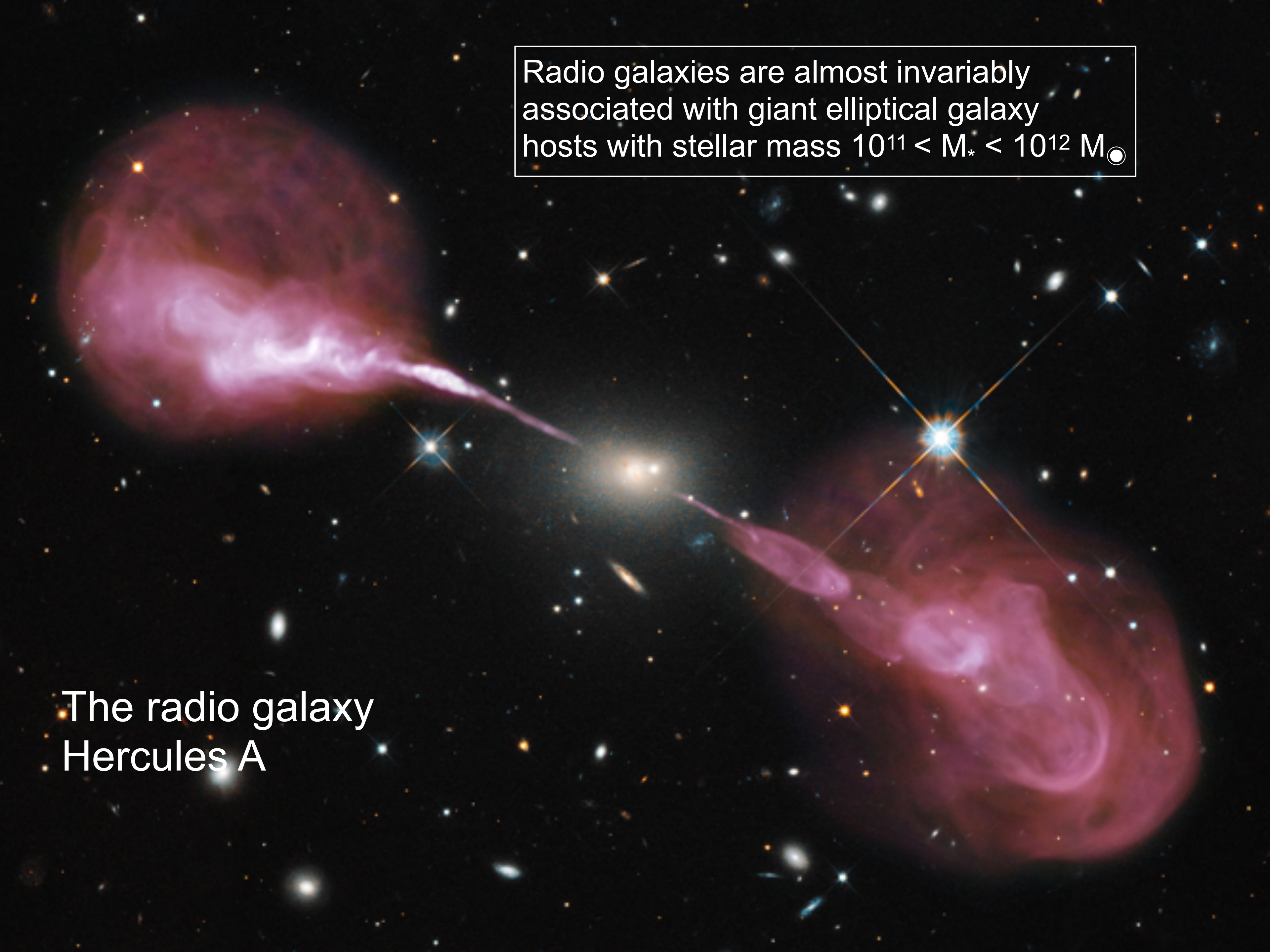
Star formation

Cool gas contents







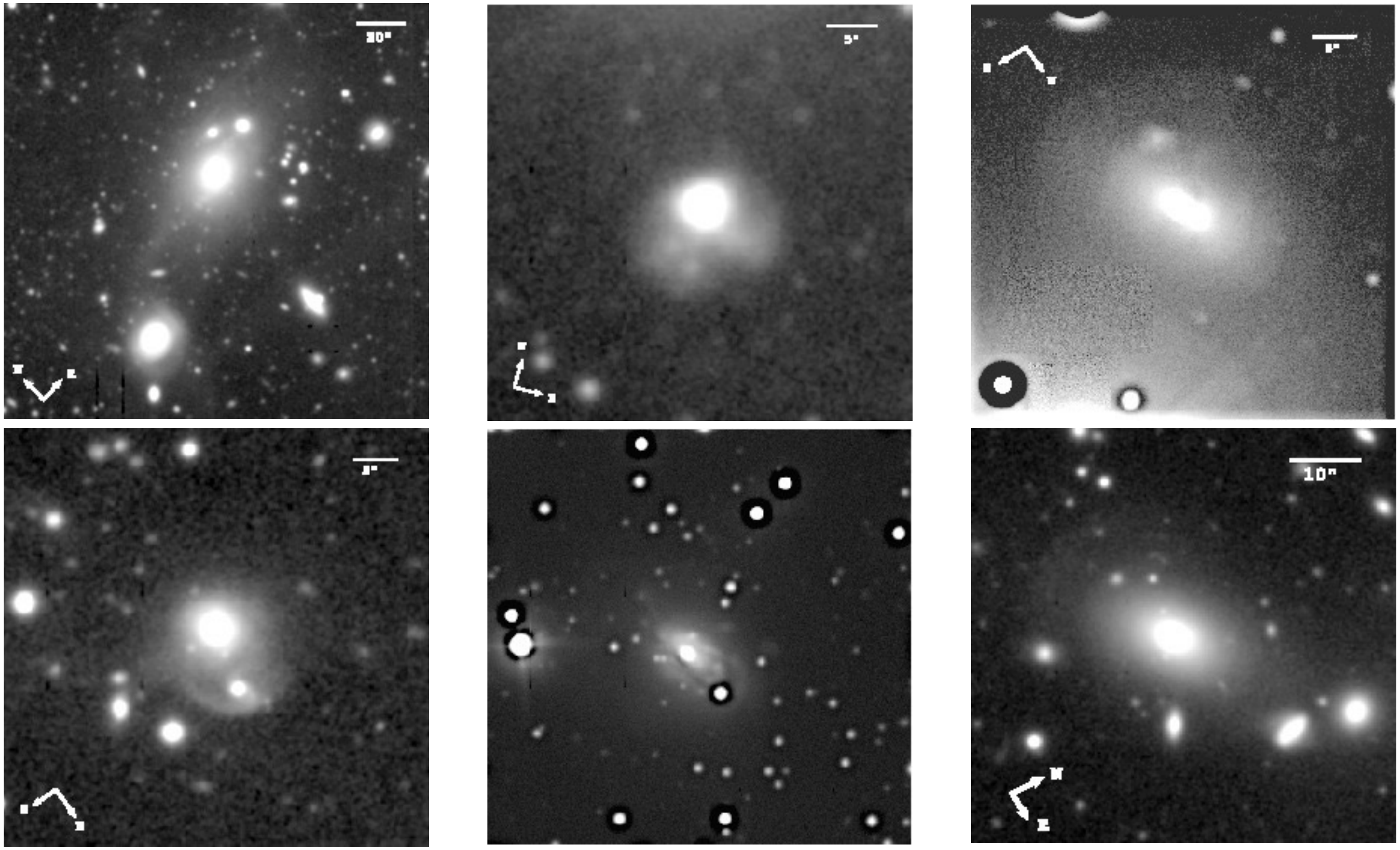

Radio galaxies are almost invariably associated with giant elliptical galaxy hosts with stellar mass $10^{11} < M_* < 10^{12}\ M_\odot$
The radio galaxy Hercules A

Deep Gemini, Spitzer & Herschel observations of the 2Jy sample

- Complete sample of 46 southern 2Jy radio sources with intermediate redshifts 0.05 < z < 0.7
- Best observed of all radio galaxy samples: deep X-ray (Chandra, XMM), optical (ESO3.6m/VLT/Gemini), mid-IR (Spitzer), far-IR (Herschel) and radio (VLA/ATCA) data…
- Optical classifications: 43% NLRG, 33% BLRG/QSO, 24% WLRG
- *Most sources are have nuclei of quasar-like luminosity (hidden from our direct view in the radio galaxies)*

Triggering I: galaxy morphologies

Deep Gemini imaging of the 2Jy sample



85% of the 2Jy sample show evidence for tidal features at relatively high surface brightness levels.

Ramos Almeida et al. (2011,2012)

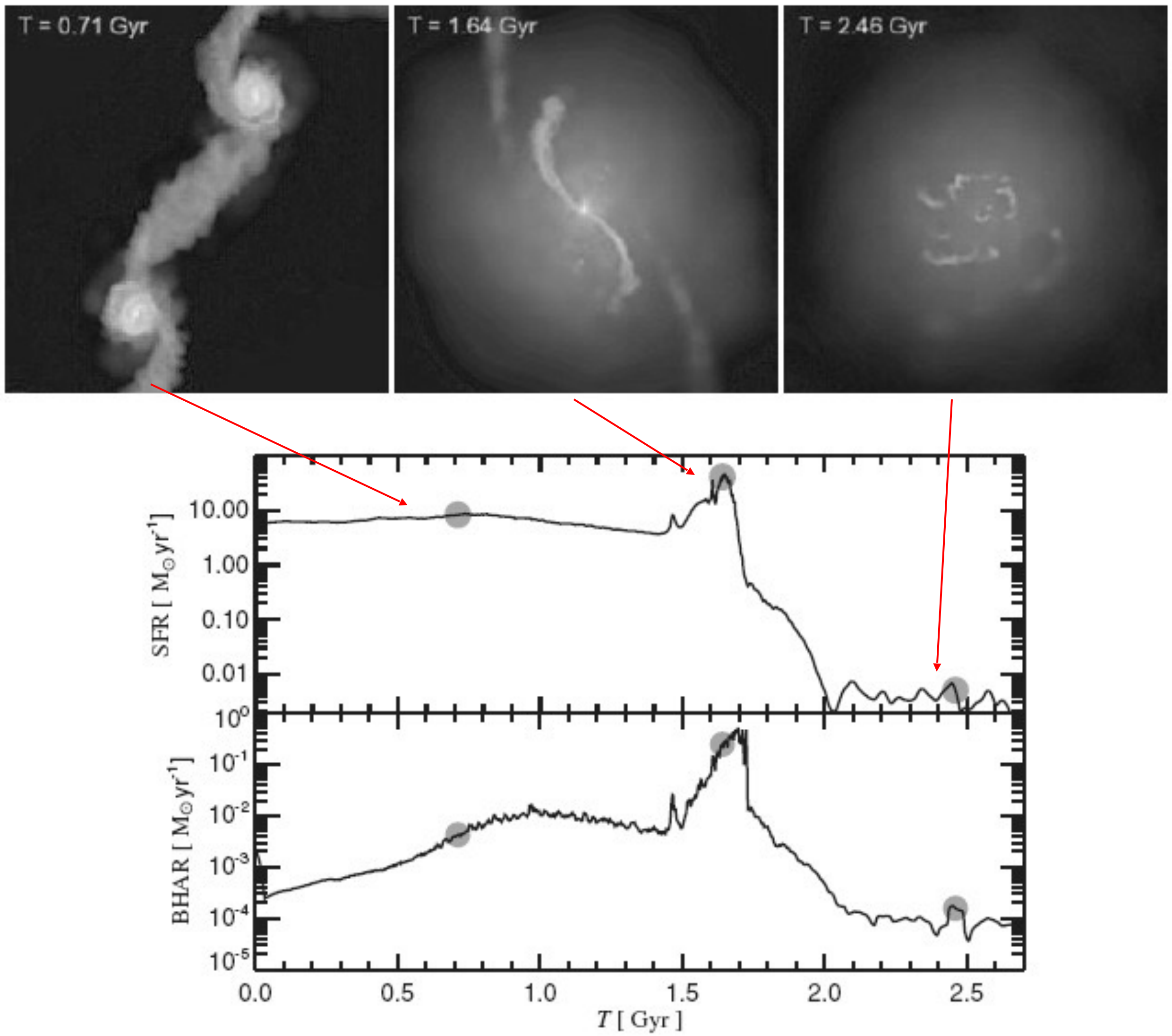
Gemini Imaging: summary

- 85% of the full 2Jy sample show morphological peculiarities at relatively high surface brightness levels:
  - 37% show tidal bridges, tidally distorted companion galaxies or double nuclei ($r < 10$kpc)
  - 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

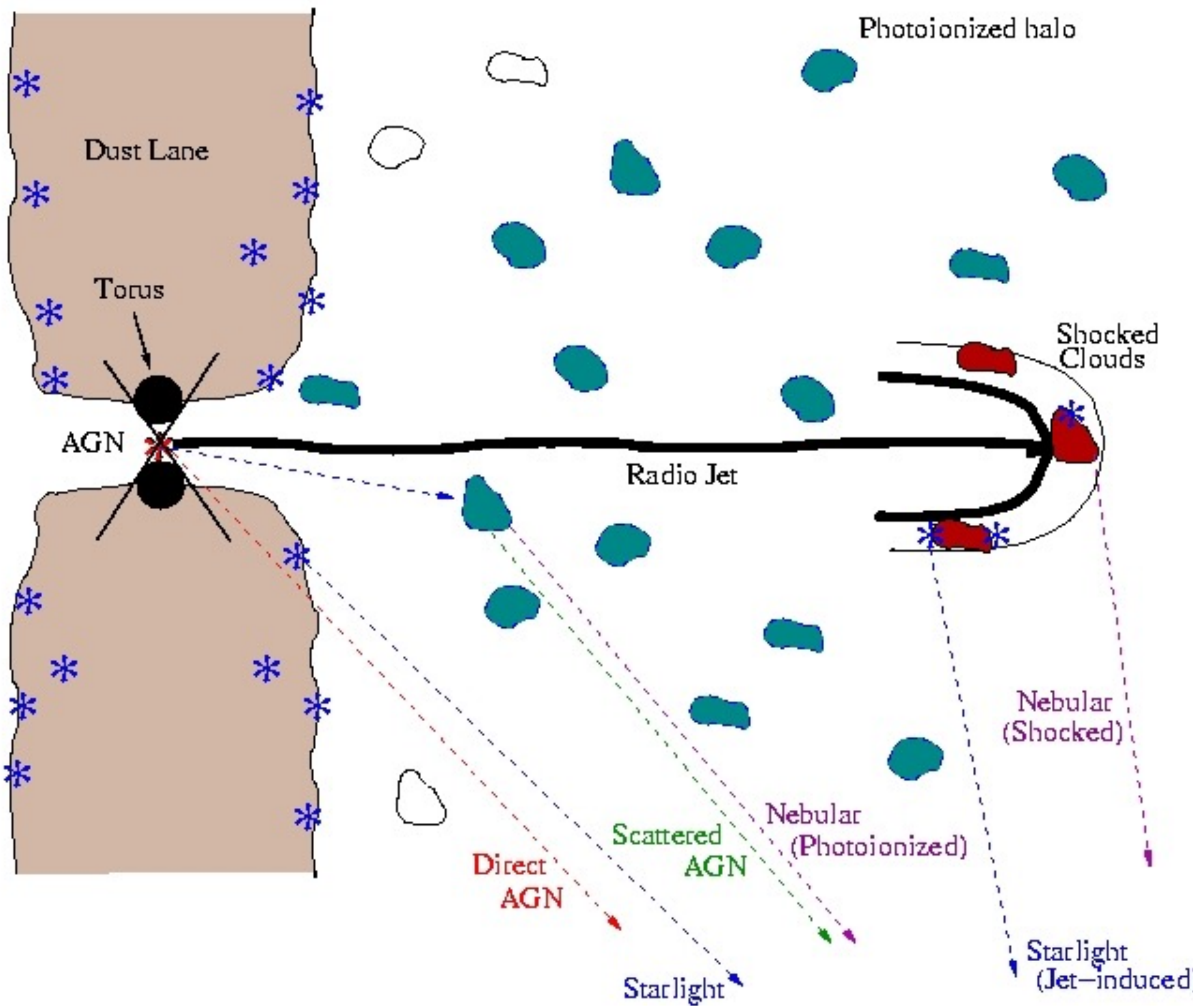
Triggering II: star formation

AGN activity in major gas-rich mergers



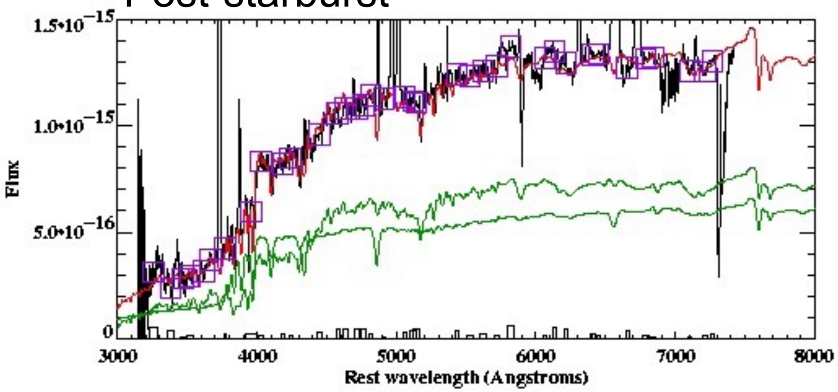
Springel et al. (2005)

Contributions to the UV excess in powerful radio galaxies

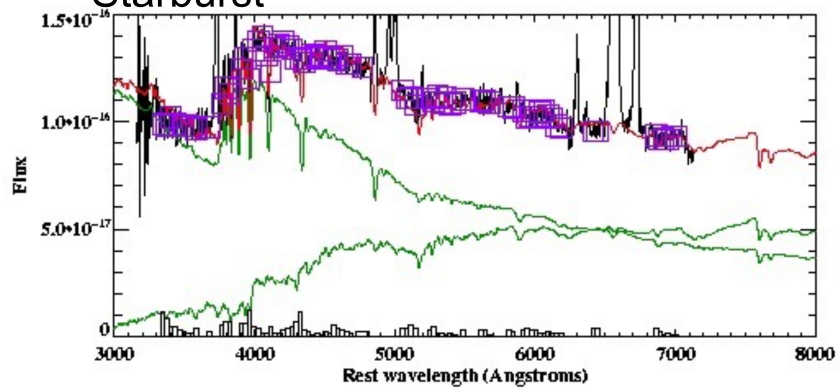


Optical evidence for star formation in radio galaxies

Post-starburst



Starburst



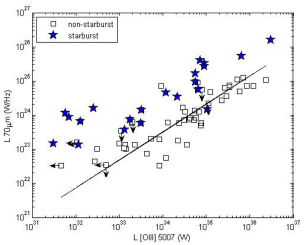
3C305 YSP Properties
Age: 0.4 - 0.6 Gyr
Mass:1.5+/-0.5x10^{10} M_{sun}
(16-40% of total stellar mass)
Post starburst

3C459 YSP Properties
Age: 0.05 Gyr
Mass:4x10^{9} M_{sun}
(>5% of total stellar mass)
Starburst (ULIRG)

The young stellar populations (YSP) in radio galaxies show a diversity of properties, but they are detected in only ~20-35% of objects…

Star formation indicators in radio galaxies (2Jy+3CRR samples)

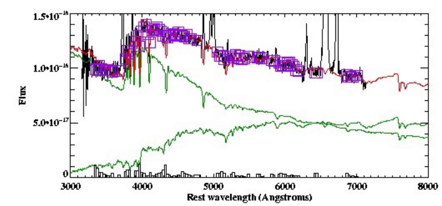
Far-IR Excess (22%)



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.

Optical Spectroscopy (21%)



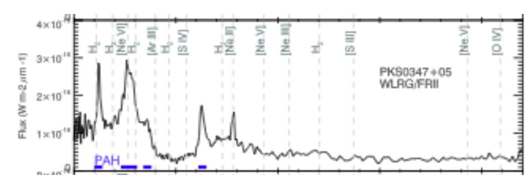
Tadhunter et al. (2002,2005), Holt et al. (2007)

3C326

P1934-63

P1733-56

PAH emission (22%)



Dicken et al. (2012)

Triggering III: cool ISM contents

How massive is the gas/dust reservoir?

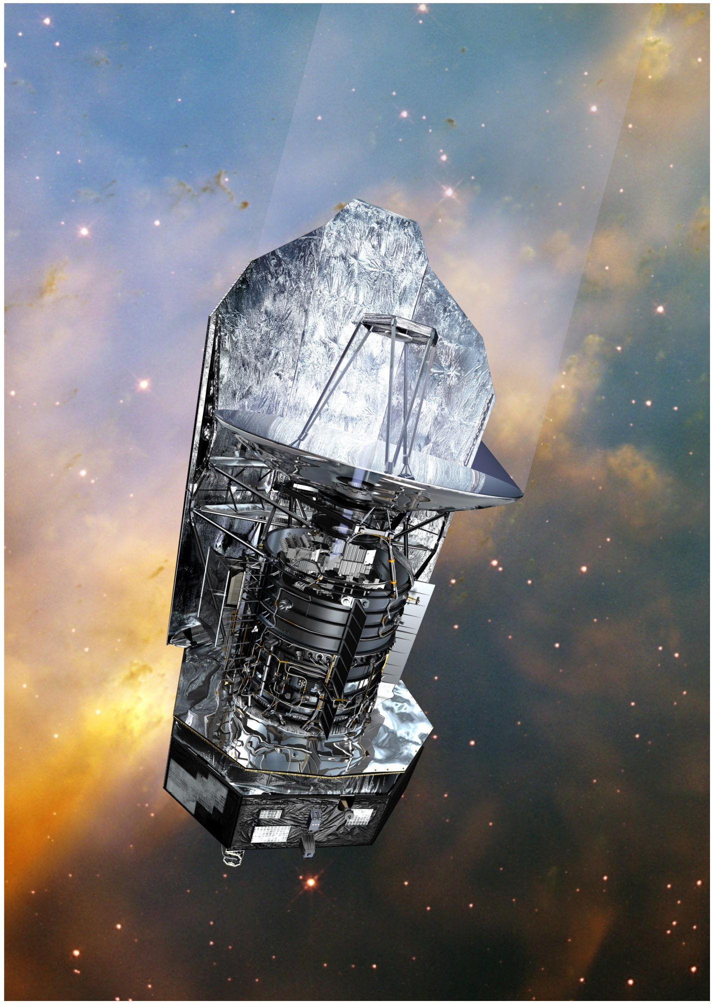
- Define quasar to have L_{bol}>10^{38} W (M_B < -23)
- Black hole must accrete >0.2 $M_\odot\ yr^{-1}$ to maintain activity
- Typical quasar lifetimes: ~10^6 - 10^8 yr

  ➔Mass accreted by SMBH over lifetime: ~$2x10^5$ - $2x10^7$ $M_\odot$
- But, on the basis of the black hole mass/host galaxy correlations, for every 1 $M_\odot$ accreted by the black hole, ~500 $M_\odot$ stars must be formed in the bulge of the host galaxy

➔The *total* gas reservoir for a particular quasar triggering event is ~10^8 - 10^{10} M_{sun}

➔For typical quasar lifetime of ~10^7yr predict dust mass ~10^7 $M_\odot$ for M_{gas}/M_d=100

The Herschel far-IR satellite

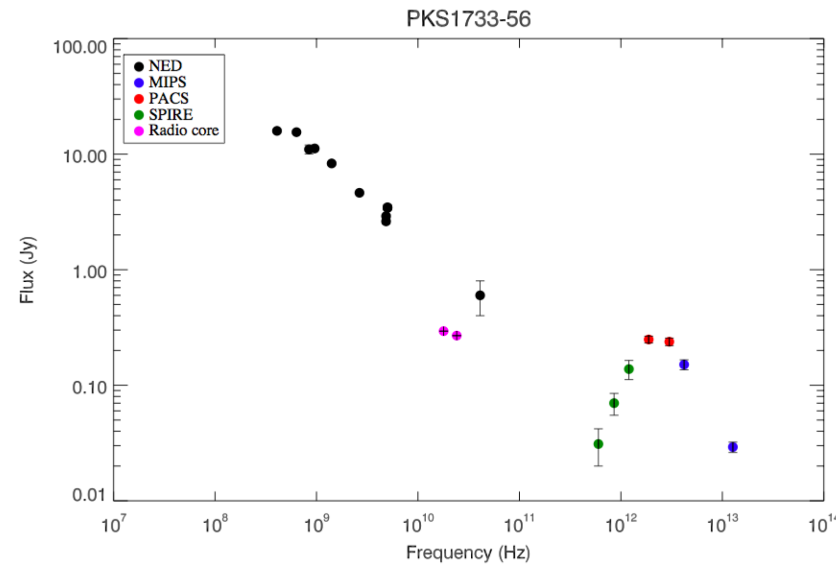


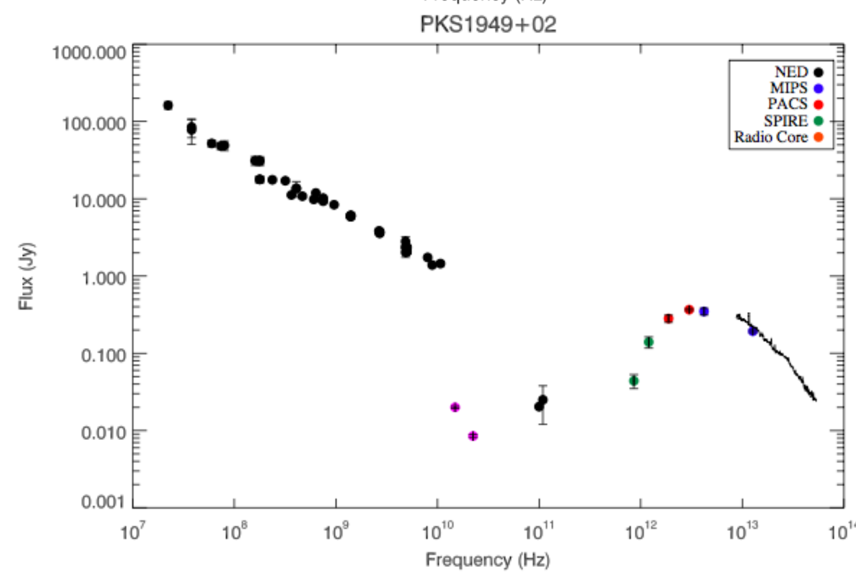
- Launched 2009
- Worked at wavelengths between 70 and 500μm
- Most sensitive far-IR satellite yet launched; largest primary mirror (~4m) for a space telescope

Determining dust masses using Herschel data for the 2Jy sample

- Initially assume a single temperature modified BB fit
- Preliminary fits to SEDs and colour-colour plots (objects with SPIRE data) ➔ $\beta \sim 1.2$
- Determine dust temperatures (T_d) for non-SPIRE objects from 160/100 colour and $\beta = 1.2$
- Dust masses follow from:

$$M_d = \frac{S_\nu D^2}{\kappa_\nu^m B(\nu, T_d)}$$





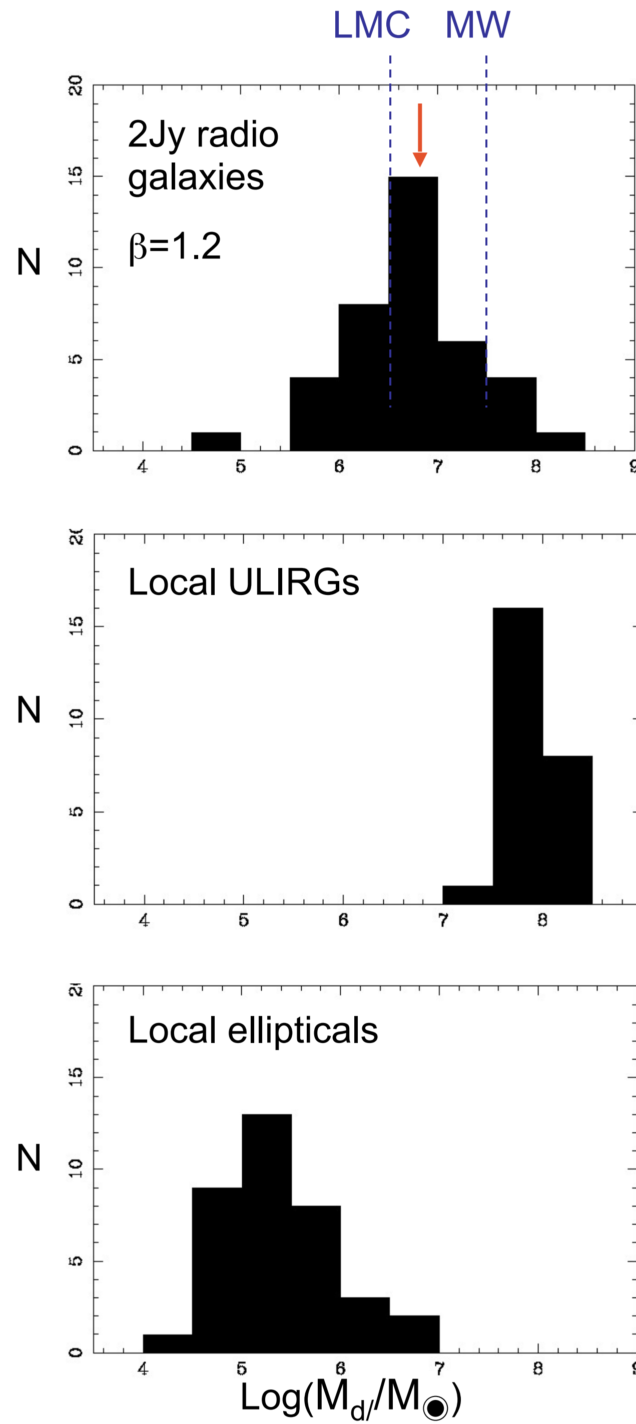
Dust mass results

Median dust masses

$\log_{10}(M_{d}/M_{\odot})$

Radio Galaxies: 6.8
Local ULIRGs: 7.8
Local Ellipticals: 5.2
Prediction: 6.8

A minor merger with a gas-rich companion galaxy (~2xLMC) would provide a sufficient reservoir of cool gas to sustain quasar-like activity in a radio galaxy for ~10^7 yr; such reservoirs detected in most SLRG.



Clements et al. (2010)

Martini et al. (2013)
Smith et al. (2012)

Triggering of powerful radio-loud AGN in the local Universe: summary

- Powerful radio-loud AGN are associated with massive elliptical galaxies ($2\times10^{11} < M_{star} < 2\times10^{12}\ M_{\odot}$)
- Local radio galaxies are diverse in terms of their detailed morphologies, star formation properties, and cool ISM contents
- A small but significant minority (<15%) are triggered in major, gas-rich mergers in which both the super-massive black holes and stellar masses of the host galaxies are growing rapidly
- But the majority of local radio galaxies represent the late time re-triggering of AGN activity via galaxy interactions and/or minor mergers (~2xLMC gas mass)

Lecture 15: learning outcomes

- Understanding of the main triggering mechanisms for AGN
- Understanding of the main methods used to investigate triggering mechanisms for AGN
- Knowledge of the recent results on AGN triggering from observations of samples of moderate and high luminosity AGN