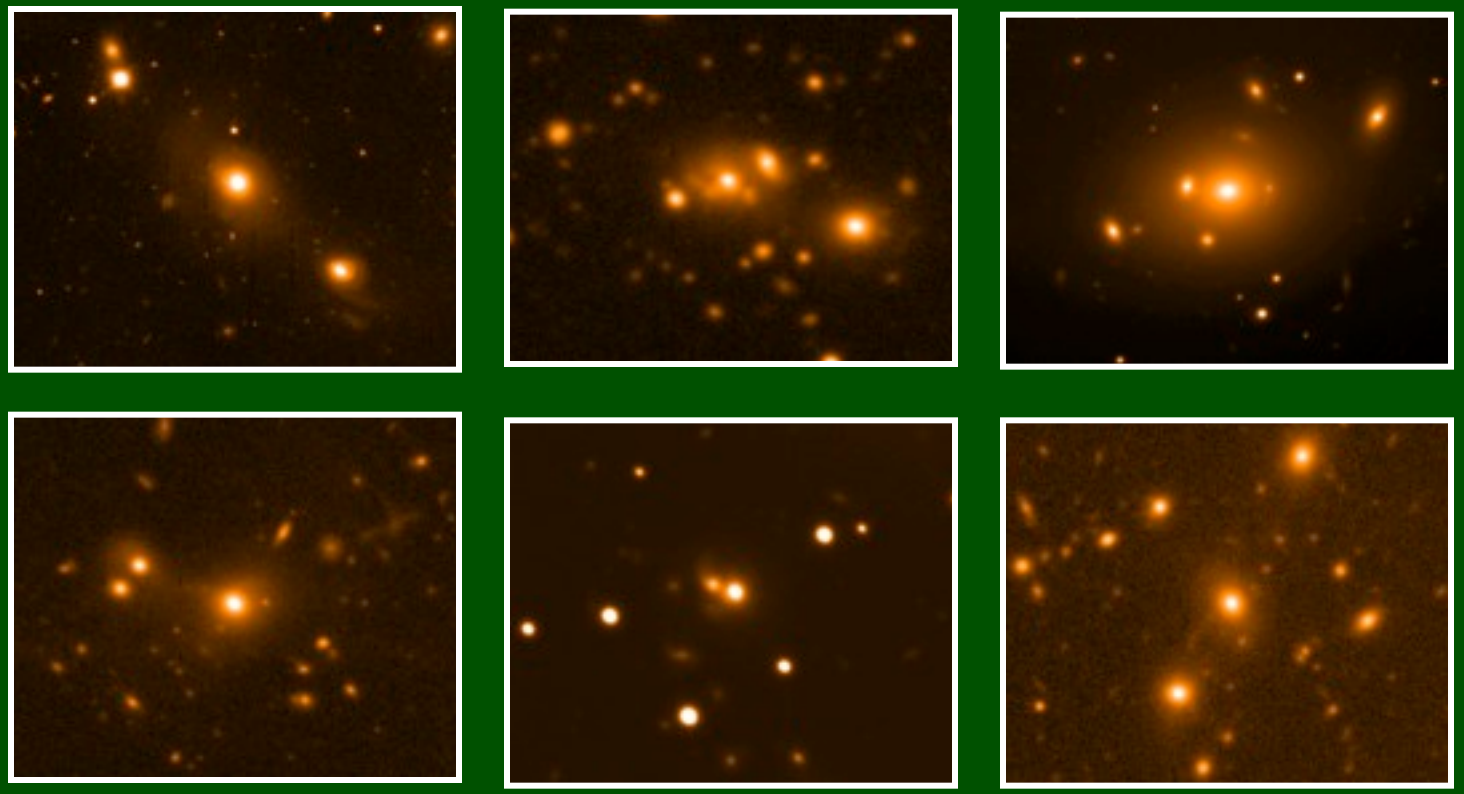
C. Ramos Almeida

The triggering mechanisms of powerful radio galaxies: mergers and interactions

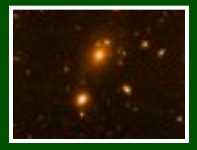
Despite speculation that both starburst and nuclear activity in galaxies may be intimately linked via the common triggering mechanism of mergers and interactions, very little is known about the true nature of the link. Thus, the role of AGN in the formation and evolution of galaxies is still not well established.

I will present deep Gemini/GMOS imaging observations which are used to investigate the triggering mechanism(s) in a complete sample of radio-loud AGN for which, uniquely, we have quantified the level of both the AGN and star formation activity. I will show results on the proportion of powerful radio galaxies triggered in galaxy mergers and also on the link between the degree of star formation/AGN activity and the interaction status of the host galaxies.

The Optical Morphologies of the 2Jy of Radio Galaxies: evidence for Galaxy Interactions



Cristina Ramos Almeida, Clive Tadhunter
University of Sheffield
K. Inskip, R. Morganti, J. Holt & D. Dicken



Introduction

Nuclear Activity – Star Formation

- Triggering of AGN in gas-rich mergers → accompanied by major starburst (e.g., Kauffmann et al. 2000, Di Matteo et al. 2005, Springel et al. 2005, Hopkins et al. 2008, Somerville et al. 2008).
- Moment and conditions in which a galaxy triggers its star formation likely related with triggering of nuclear activity (timescales uncertain).

Radio galaxies = associated with ealy-type hosts → cleaner searches for signs of morphological disturbance and recent star formation activity.

Introduction

Mergers in Powerful Radio Galaxies (PRGs)

- Ground-based 4m telescopes $z < 0.3$ PRG
  (Heckman et al. 1986, Smith & Heckman 1989)

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

  "…in contrast to conventional wisdom, very PRG are not always normal ellipticals."

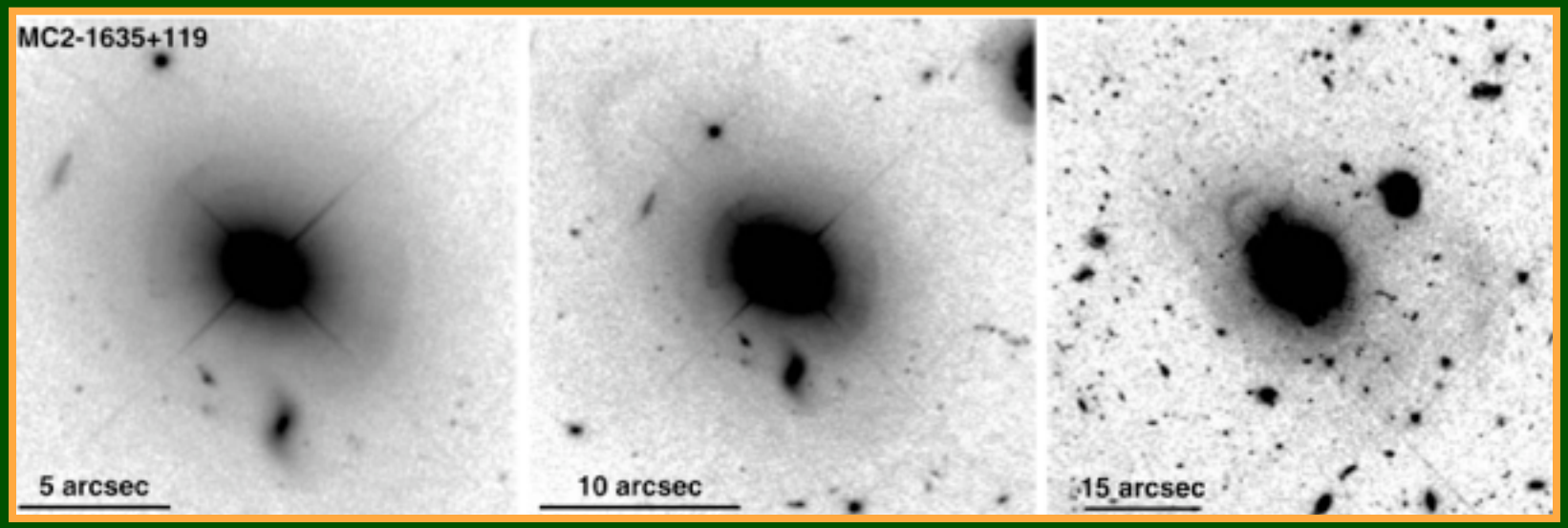
- HST + WFPC2 (1 orbit) $0.1 < z < 0.25$ RG, RQQ, RLQ
  (Dunlop et al. 2003)

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

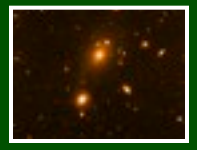
Surface brightness effects

Evidence for galaxy interactions in QSOs

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



• 4/5 low-z QSO host galaxies taken from Dunlop et al. (2003) -- classified as ellipticals -- reveal shells and tails → QSO hosts suffered mergers with accompanying starbursts that likely triggered the QSO activity.



Observations

Our Work

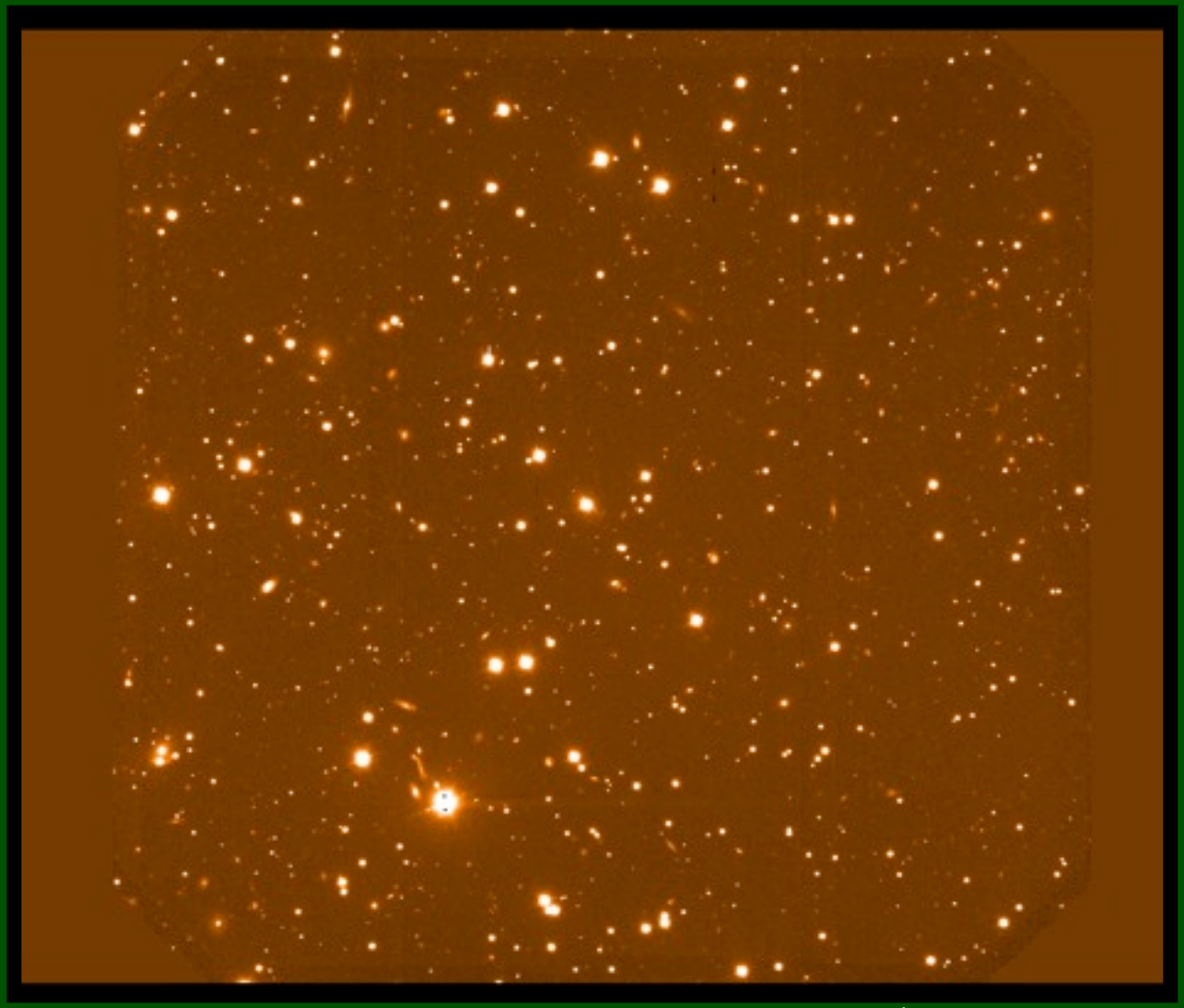
- Try to shed some light about importance of mergers/interactions in the triggering of PRG activity by solving previous problems: completeness, environment, control samples & surface brightness.

- Deep GMOS-S / Gemini optical broad-band observations of a complete sample of PRGs (BLRG/QSO: 33%, NLRG: 43%, WLRG; 24%).

Complete sample	Wide range of redshift	Deep observations	Big sky area covered
46 PRG	$0.05 < z < 0.7$	$\mu_V \leq 26$ mag/arcsec^2	~0.8□

Observations

GMOS-S data



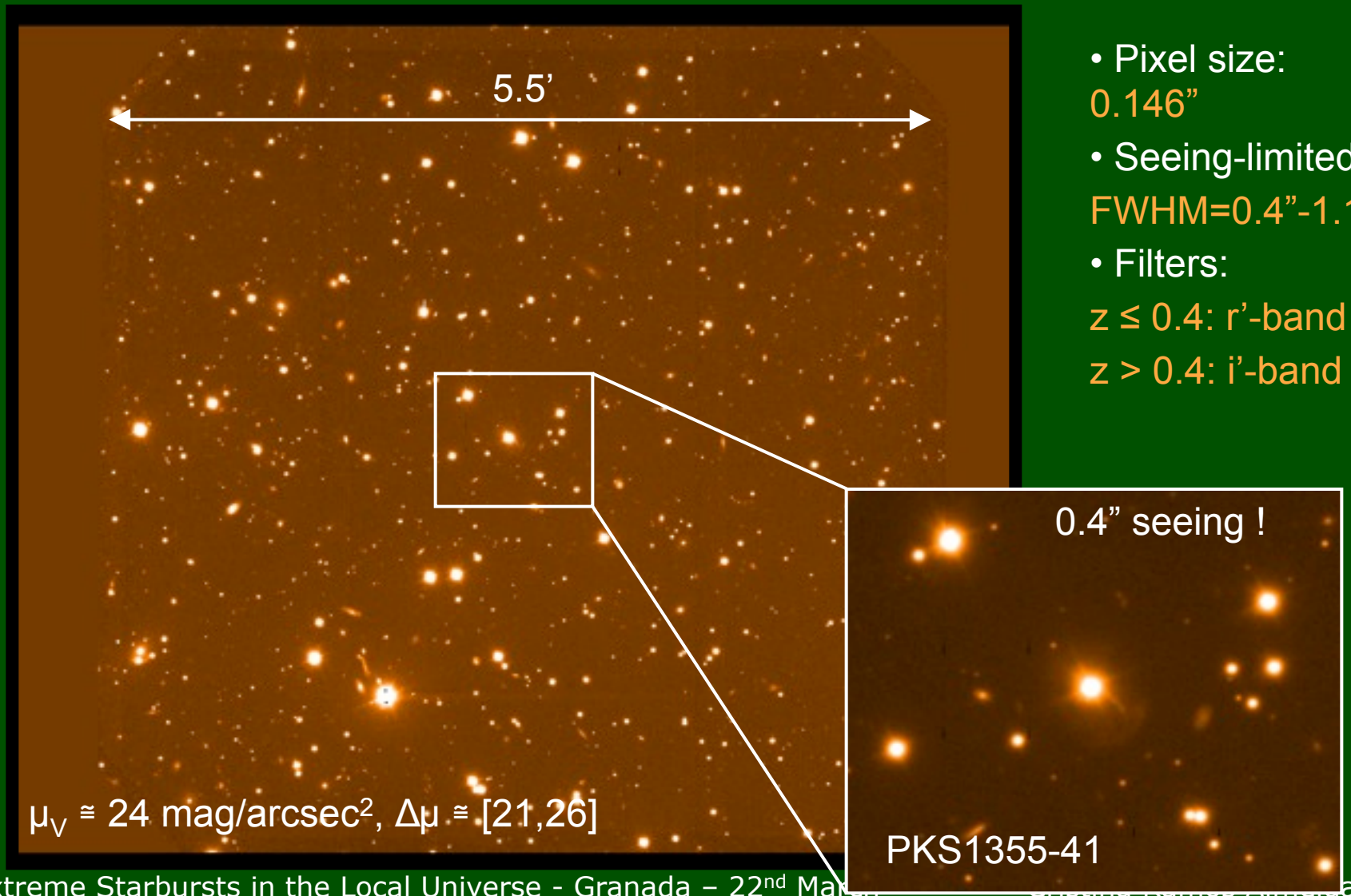
- Pixel size: 0.146”
- Seeing-limited: FWHM=0.4”-1.1”
- Filters:

z ≤ 0.4: r’-band

z > 0.4: i’-band

Observations

GMOS-S data



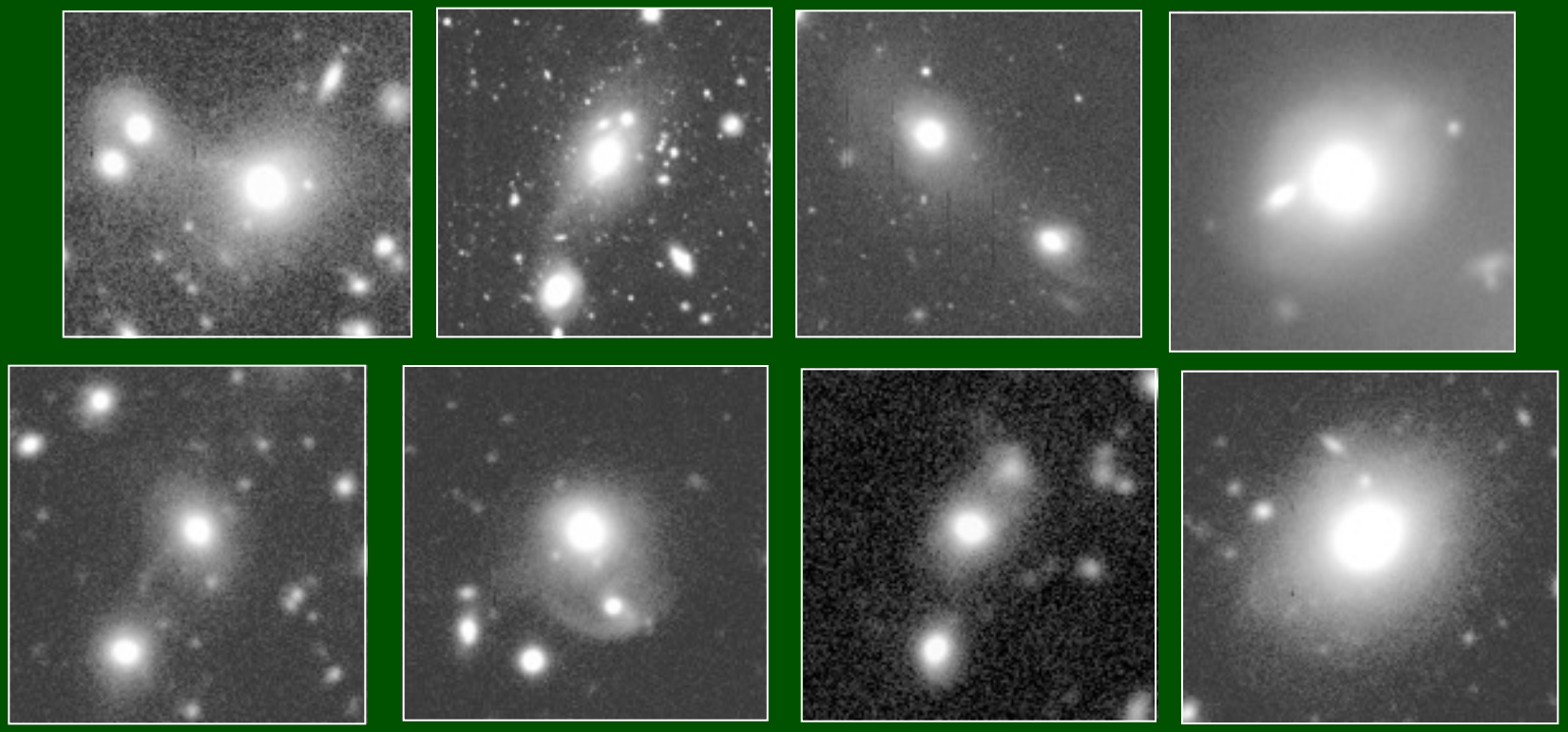
- Pixel size: 0.146”
- Seeing-limited: FWHM=0.4”-1.1”
- Filters:

$z \leq 0.4$: r’-band

$z > 0.4$: i’-band

Results

Evidence for galaxy interactions in PRGs

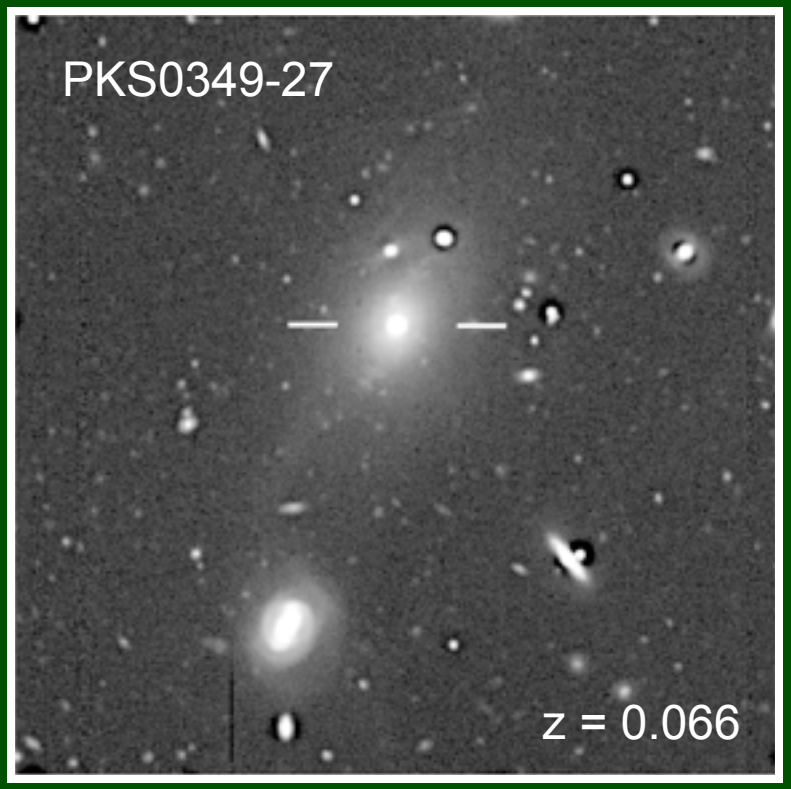


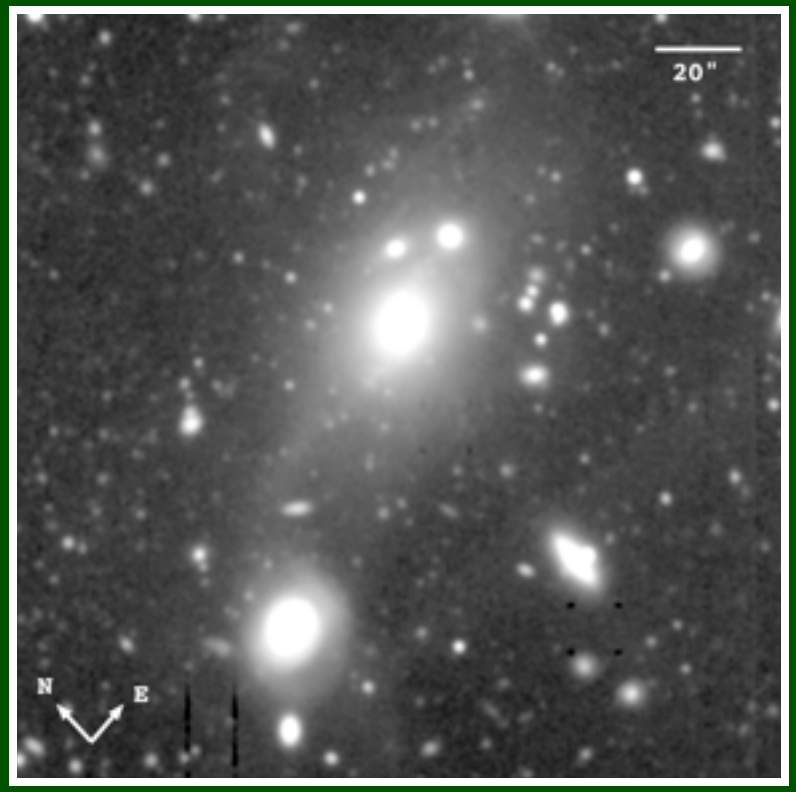
• 85% of the total sample of PRGs show signs of morphological disturbance (Ramos Almeida et al., submitted to MNRAS).

Results

Evidence for galaxy interactions in PRGs

- Morphological peculiarities: remnants of a merger event.
  - Bridges, Tails, Fans, Shells, Dust, Amorphous haloes, Irregular features, Double or multiple nuclei.

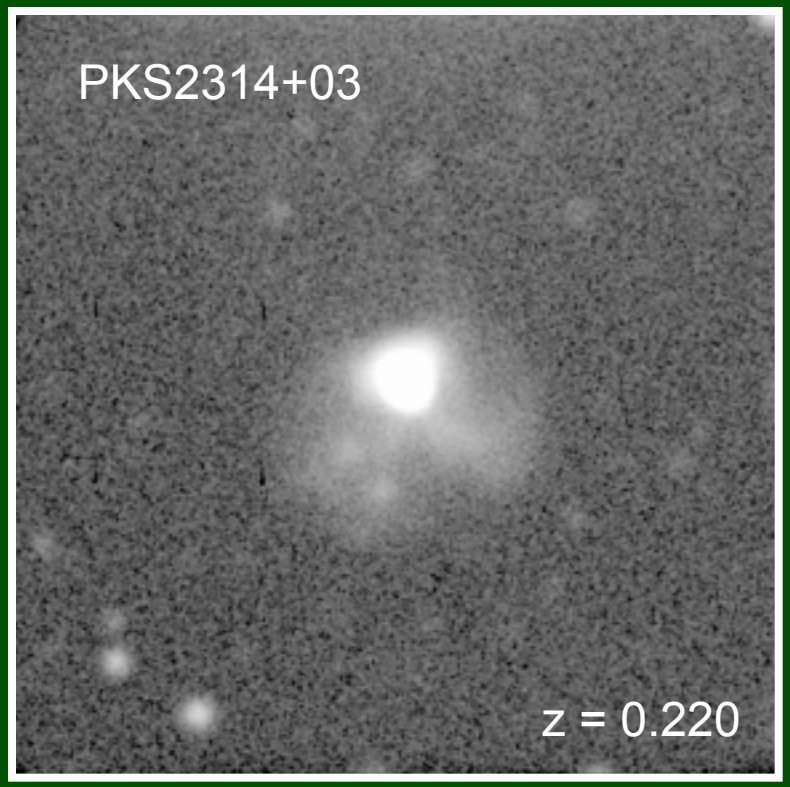


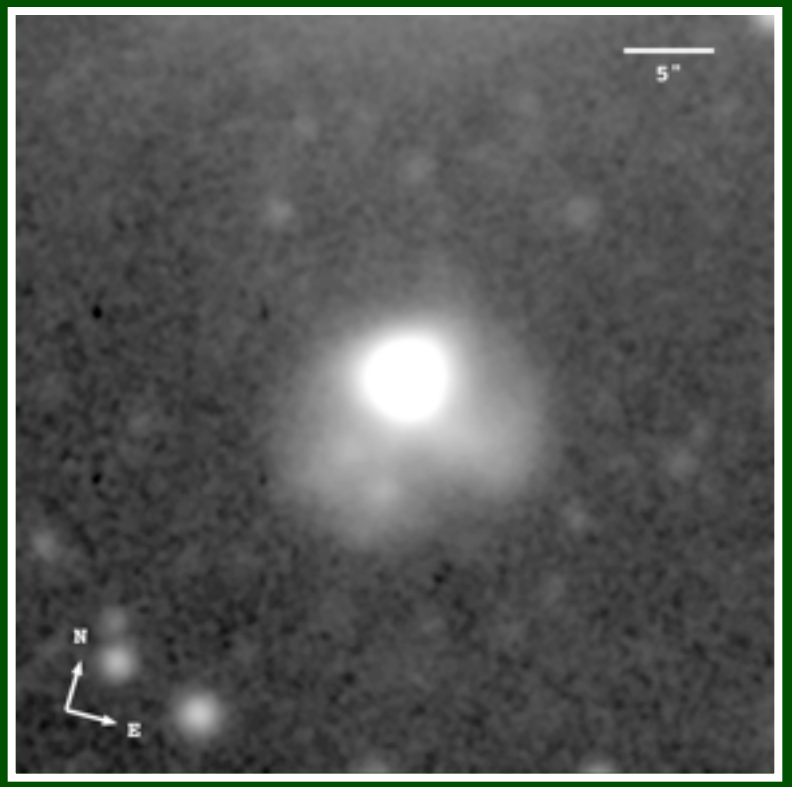


Results

Evidence for galaxy interactions in PRGs

- Morphological peculiarities: remnants of a merger event.
  - Bridges, Tails, Fans, Shells, Dust, Amorphous haloes, Irregular features, Double or multiple nuclei.

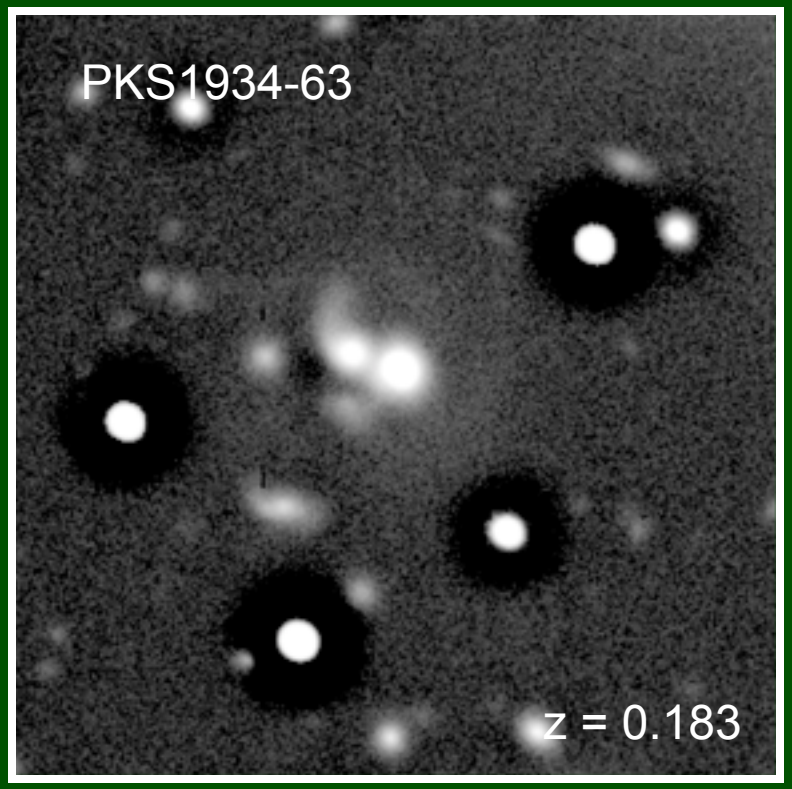


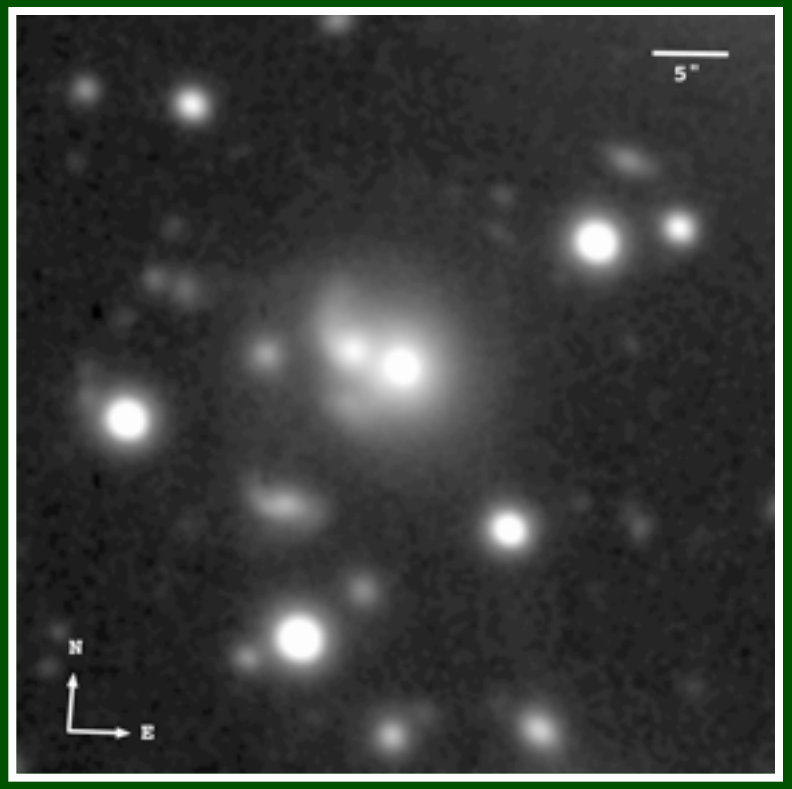


Results

Evidence for galaxy interactions in PRGs

- Morphological peculiarities: remnants of a merger event.
  - Bridges, Tails, Fans, Shells, Dust, Amorphous haloes, Irregular features, Double or multiple nuclei.

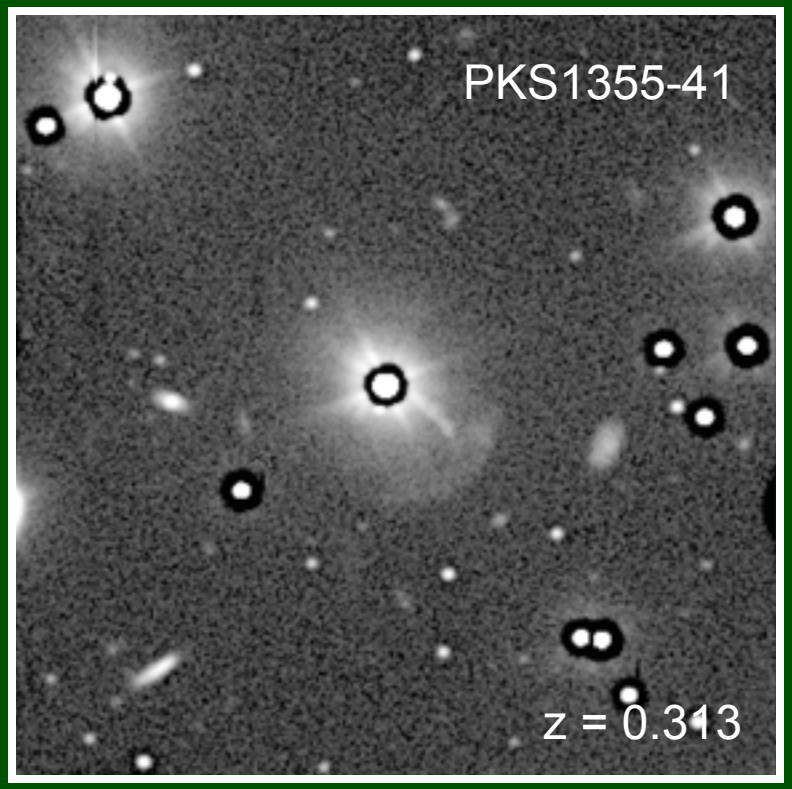


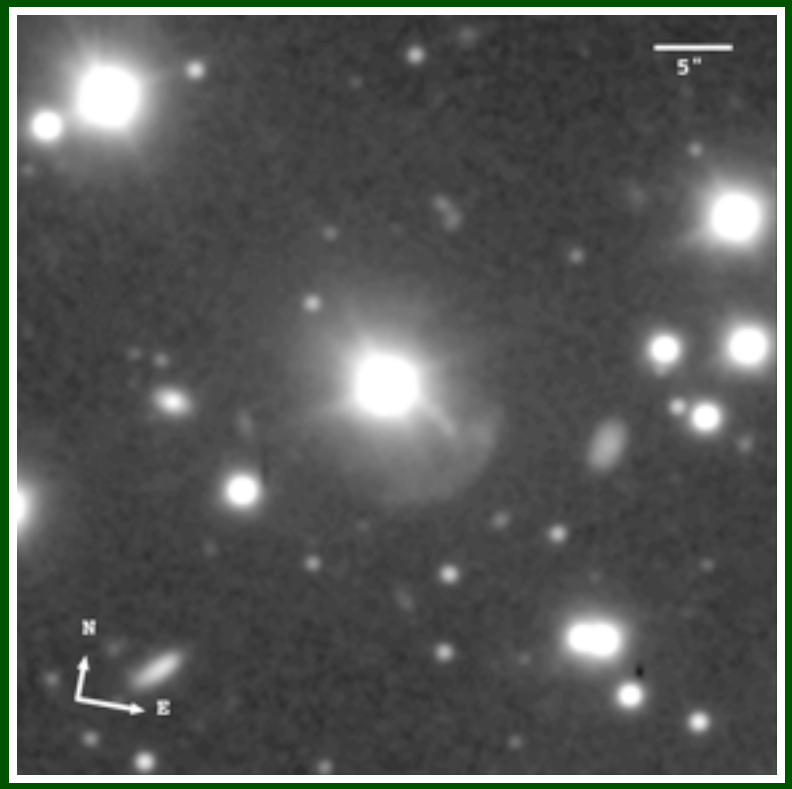


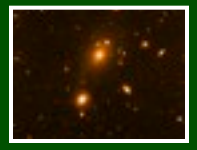
Results

Evidence for galaxy interactions in PRGs

- Morphological peculiarities: remnants of a merger event.
  - Bridges, Tails, Fans, Shells, Dust, Amorphous haloes, Irregular features, Double or multiple nuclei.







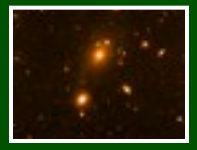
Results

Evidence for galaxy interactions in PRGs

- Division of sample attending to different morphologies:

1. Galaxy pair or group in clear tidal interaction (e.g., bridges) – **20%**
2. Galaxies presenting morphological disturbance (tails, fans, shells, dust, amorphous haloes, irregular features) – **56%**
3. Galaxies with double or multiple nuclei inside 10 kpc – **17%**
4. Galaxies with no sign of interaction – **15%**

85% of the total sample of PRGs show signs of morphological disturbance (78% if we do not consider dust as a sign of interactions)



Results

Evidence for galaxy interactions in PRGs

- Division of sample attending to different morphologies:

1. Galaxy pair or group in clear tidal interaction (e.g., bridges) – **20%**
2. Galaxies presenting morphological disturbance (tails, fans, shells, dust, amorphous haloes, irregular features) – **56%**
3. Galaxies with double or multiple nuclei inside 10 kpc – **17%**
4. Galaxies with no sign of interaction – **15%**

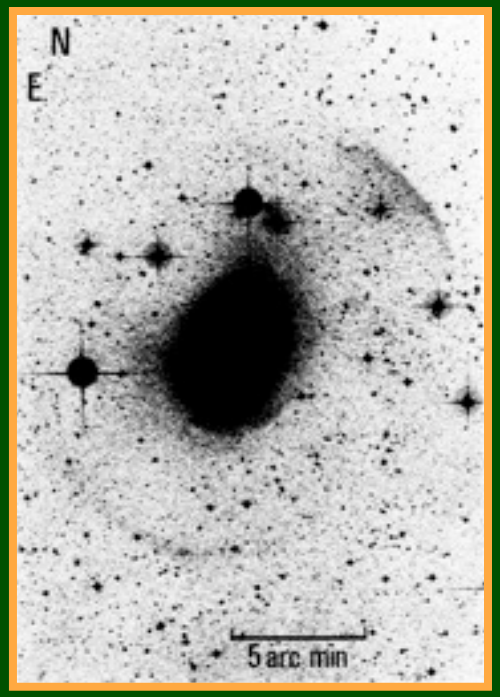
35% included in 1 & 3: close encounter of gas-rich galaxies or around the time of first pass of nuclei in a merger.

Gas-rich interaction signatures = 0.5-1.5 Gyr (e.g., Conselice et al. 2003)
PRG activity = 0.1 Gyr (Leahy et al. 1989)

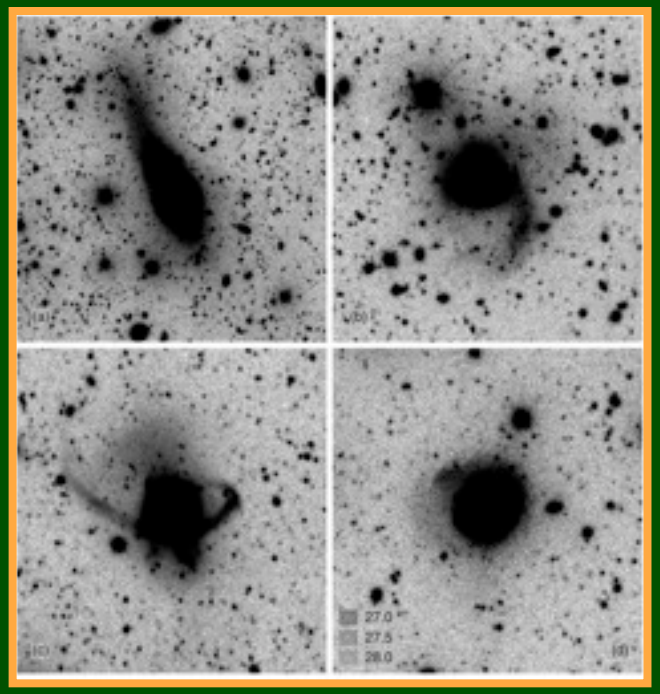
Results

Evidence for galaxy interactions in quiescent galaxies

- Tidal features in quiescent elliptical galaxies at faint surface brightness levels
  - ~10% of bright and nearby ellipticals show shells – Malin & Carter (1983)
  - ~70% of red galaxies at z=0.1 show signs of interaction – van Dokkum (2005)



Malin & Carter (1983)
$\mu_V \leq 26$ mag/arcsec^2

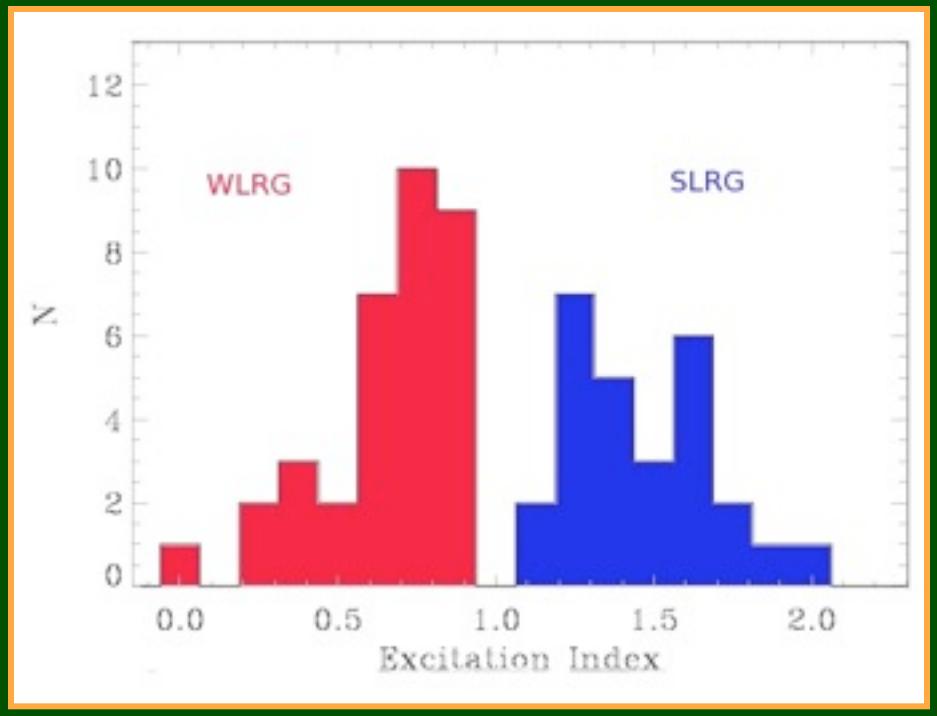


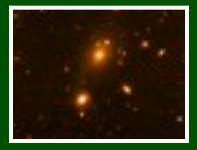
van Dokkum et al. (2005)
$\mu_V \leq 29.5$ mag/arcsec^2

Results

Evidence for galaxy interactions in WLRGs

- WLRGs & SLRGs (NLRGs, BLRGs, QSOs) → defined according to optical spectral lines intensities (e.g., Buttiglione et al. 2010).





Results

Evidence for galaxy interactions in WLRGs

- AGN powered by cold gas accretion - e.g., provided by gas-rich mergers (Heckman et al. 1986, Smith & Heckman 1989)
  - Cold gas approaching the AGN forms BLR, torus and NLR.
- AGN powered by hot gas accretion - Bondi accretion (Allen et al. 2006, Best et al. 2006, Balmaverde et al. 2008, Hardcastle et al. 2009, Buttiglione et al. 2010)
  - Gas temperature prevents formation of “cold” structures.

Importance of mergers in triggering WLRG activity ?

Results

Evidence for galaxy interactions and in WLRGs

- Sample division:

  Weak-line Radio Galaxies (WLRGs) - 11 objects

  Strong-line Radio Galaxies (SLRGs) - 35 objects

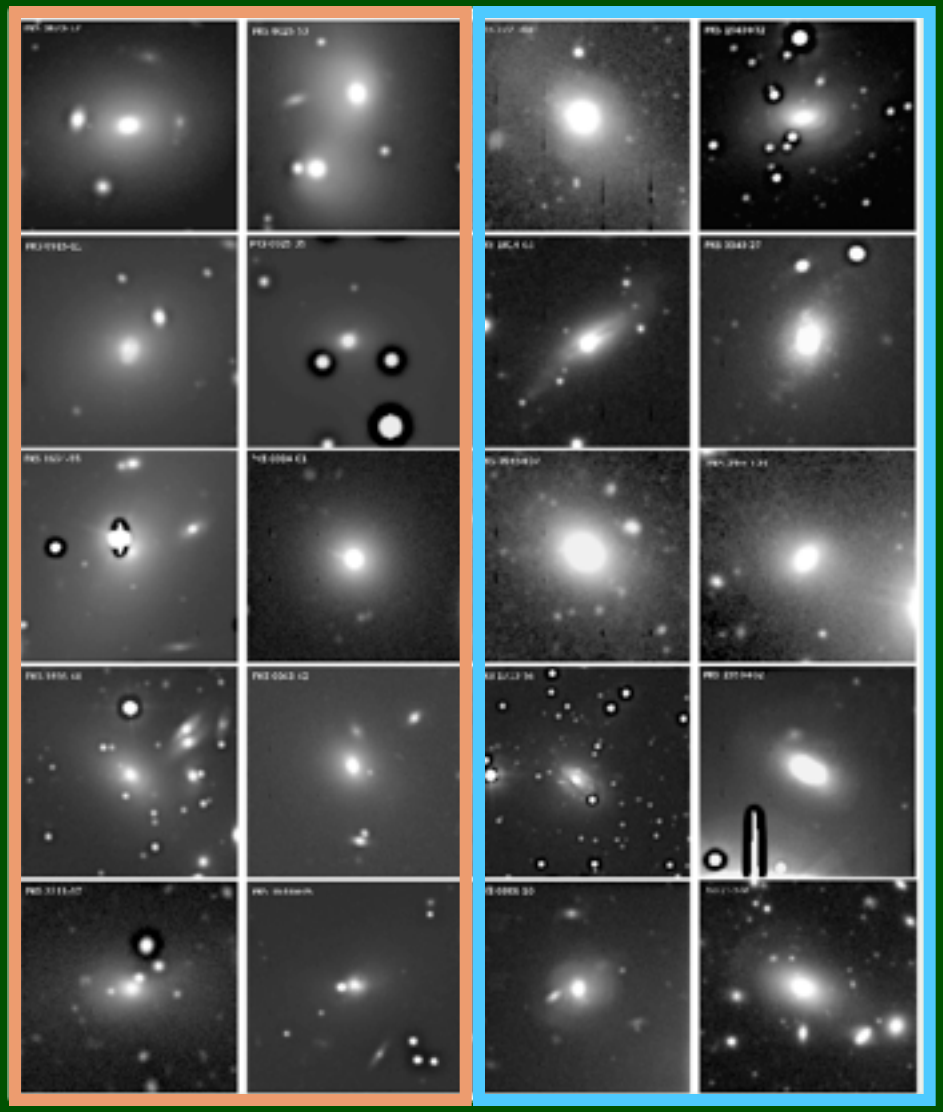
- 55% (27% if we do not consider dust as evidence for interactions) of WLRGs show peculiar optical morphologies versus 94% of the SLRGs (this work).

- 7% of WLRGs exhibit peculiar optical morphologies versus 50% of the SLRGs – same trend (Smith & Heckman 1989).

Results

Evidence for galaxy interactions in WLRGs

WLRG



SLRG

Results

Evidence for galaxy interactions in starburst PRGs

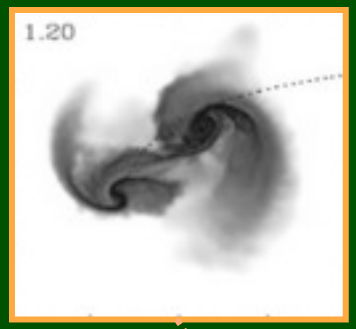
- Only 28% of sample show evidence for significant starburst activity (Dicken et al. 2008; 2009) → less than expected considering evidence for galaxy interactions?

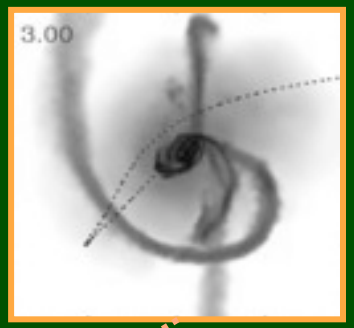
- 92% of starburst sample present peculiar morphologies = same trend as total and SLRG samples.

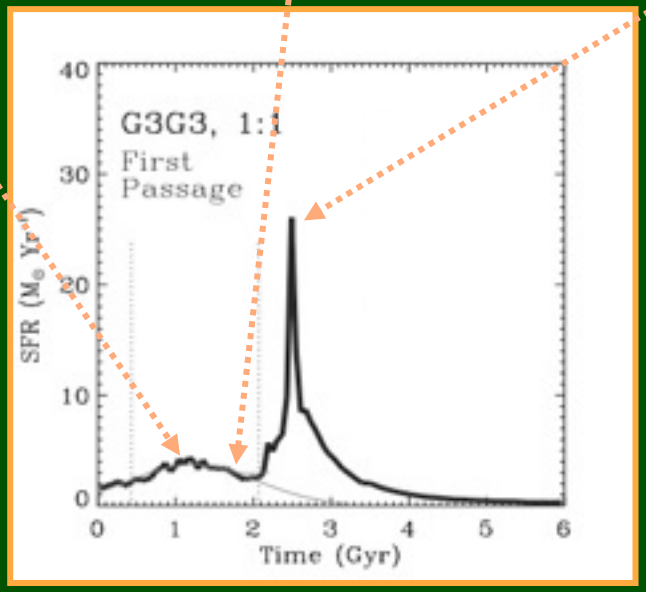
No significant differences between the morphologies of starburst and non-starburst PRGs

Results

Triggering starbursts in major galaxy mergers







Cox et al. (2008)

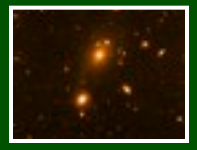
Results

Triggering starbursts in major galaxy mergers

- According to age of young stellar populations (ysp):
  - LIRG/ULIRG-like systems (t_{ysp} < 0.1Gyr) → radio source triggered quasi-simultaneously with starburst
  - Post-starburst systems (t_{ysp} > 0.2 Gyr) → radio source triggered (or retriggered) a significant period after starburst episode
- Unless AGN/radio activity lasts longer than 0.1 Gyr (Leahy et al. 1989) must be a time lag between main starburst and AGN triggering.

  Tadhunter et al., submitted.

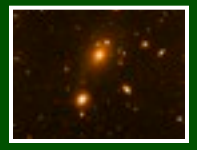
See Clive's talk!



Future Work

Ramos Almeida et al., in preparation

- Development of a control sample of quiescent elliptical galaxies using the GMOS-S fields.
- Study of the environment properties of our galaxies, relating it with their morphologies.
- Multiwavelength analysis of the 2Jy sample using the GMOS-S imaging data + mid- and far-IR data (Dicken et al. 2008, 2009, 2010) + near-IR data (Inskip et al. 2010) + radio data (Morganti et al. 1999) + optical spectroscopy data (Tadhunter et al. 1993, 1998, 2002).



Conclusions

Evidence for galaxy interactions and mergers in PRGs

- 85% of the total sample of PRGs show peculiar optical morphologies at relatively high levels of surface brightness ($\mu_V \leq 26.2$ mag/arcsec^2).
- Peculiarities include fans, tails, bridges, shells, etc = result of galaxy interactions.
- 35% of the sample consistent with the galaxies observed after the first peri-center passage but before the final coalescence of the merging nuclei.
- If interactions play a role in the triggering of PRG, that can happen at different stages of the interaction.
- Only 27% of WLRGs show evidence for clear interactions versus 94% of the SLRGs.