Dust lane early-type galaxies: Connecting BH activity and star formation

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Black hole – galaxy relations

- $M_{\text{BH}} - M_{\text{bulge}}$
- $M_{\text{BH}} - \sigma$ (Gebhardt et al. 2000, Silk & Rees 1998)

Cosmic co-evolution

- BH growth and SF tightly coupled
- Feedback or common formation?

How are SF and AGN activity related in a hierarchical Universe?

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Merger-driven star formation


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Merger-driven star formation


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Massive galaxies undergo frequent minor mergers at low redshift.
Dust lane early type galaxies

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Dust lane early type galaxies

65% disturbed

6% of ETGs disturbed

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Are dust lane early types special?
Control sample

Matched in stellar mass and redshift

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Star formation rates

Matched in stellar mass, redshift and starburst age

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AGN fuelling

Matched in stellar mass, redshift and starburst age

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AGN diagnostics: optical

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Optical AGN fraction

Optical AGN fraction

Dust lane = Gas-rich minor merger

Dust lane ETGs have:
- Disturbed morphologies
- Higher SFRs
- Higher BH accretion rate
- Higher optical AGN fraction

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Disturbed morphologies
Higher SFRs
Higher BH accretion rate
Higher optical AGN fraction

So what?
Optical AGN fraction

Why so high?

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How are the AGN triggered?
How are the AGN triggered?

1. Triggering mechanisms
2. Chronology
Two types of radio AGN

Low Excitation Radio Galaxies
- Accretion rate $< 0.01$ Eddington
- Radio-only AGN
- Hosted by massive galaxies in rich environments
- Dominant at $z \sim 0$
- No evolution to $z = 0.3$

Fuelled by cooling of hot halo gas

High Excitation Radio Galaxies
- Accretion rate $> 0.01$ Eddington
- Optical (+ radio) AGN
- Low-mass hosts in poor environments
- Scarce at $z \sim 0$
- Number density increases with $z$

Fuelled by interactions

What are the radio + optical AGN properties of dust lane early types?

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AGN diagnostics: radio

Cross match SDSS with FIRST + NVSS
Excess radio emission relative to SFR \( \rightarrow \) AGN
Radio luminosity functions

- Split up by environment (radio AGN trigger is environment-dependent)
- Matched control sample

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**Hypothesis**: mergers trigger AGN in dust lane ETGs
- Environment-independent
- *Cf* cooling of hot halo gas dominating control sample
- Prevalent in clusters

**Prediction**: *radio* AGN in dust lane ETGs should also be *optical* AGN

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No difference for DETGs
Higher AGN fraction in clusters for all ETGs
Radio luminosity functions

89% BPT AGN

29% BPT AGN

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When do AGN switch on?
Starburst ages

Photometric SFHs (SDSS + GALEX)
Starburst ages


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Starburst ages

How are the AGN and SF properties related?

Evolutionary sequence

Evolutionary sequence

AGN switches on \( \sim 100 \) Myrs after SF

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Merger sequence

Star formation peaks in mergers
AGN peak in post-mergers

Minor merger

Quenching of SF ≤ 150-200 Myrs

AGN triggered ≈ 50-100 Myrs

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Implications for AGN feedback

- Feedback efficiency depends on when AGN switches on (e.g. Shabala+ 2011, MNRAS, 413, 2815)

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“The only sure way to identify an AGN is with VLBI”

- Enno Middelberg
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No AGN with $t_{\text{SF}} < 300$ Myrs
Summary

• Dust lane ETGs are a proxy for gas-rich minor mergers
  – Disturbed morphologies
  – Enhanced star formation and AGN activity

• AGN switches on \( \sim 100 \) Myrs after SF onset

• Star formation \( \Rightarrow \) SF+AGN \( \Rightarrow \) AGN

• Implications for feedback
$P-D$ distribution

![Graph showing the relation between log $L_{1.4 \text{ GHz}}$ / W Hz$^{-1}$ and source size / kpc.]

*All radio ETGs* - black circles
*Dust lane radio ETGs* - red circles
Environments

![Graph showing the fraction of ETGs in different environments](image-url)
Radio AGN identification