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

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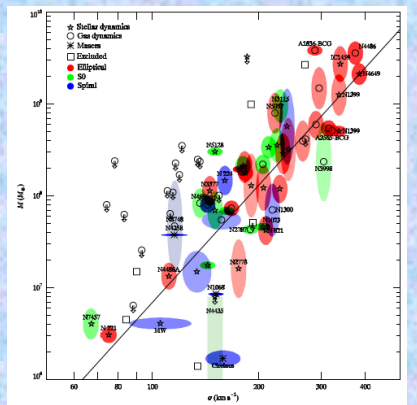
Galaxy Zoo citizen scientists

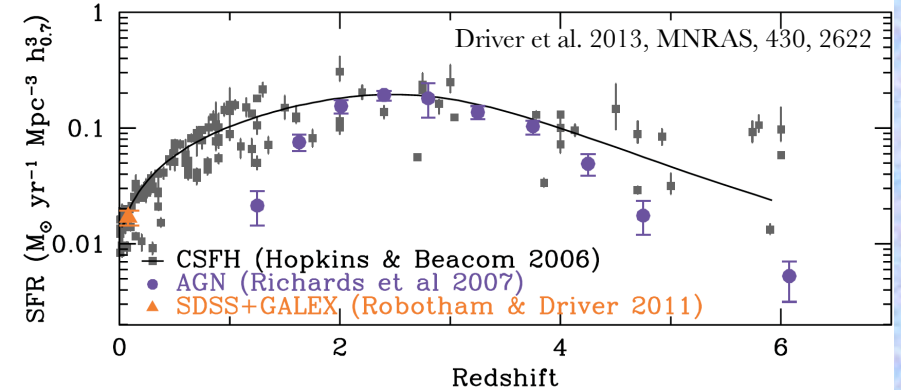
Black hole – galaxy relations

- **BH – galaxy relations**
  - $M_{BH} - M_{bulge}$
  - $M_{BH} - \sigma$ (Gebhardt+2000, Silk & Rees 1998)

Gultekin et al. 2009, ApJ, 698, 198

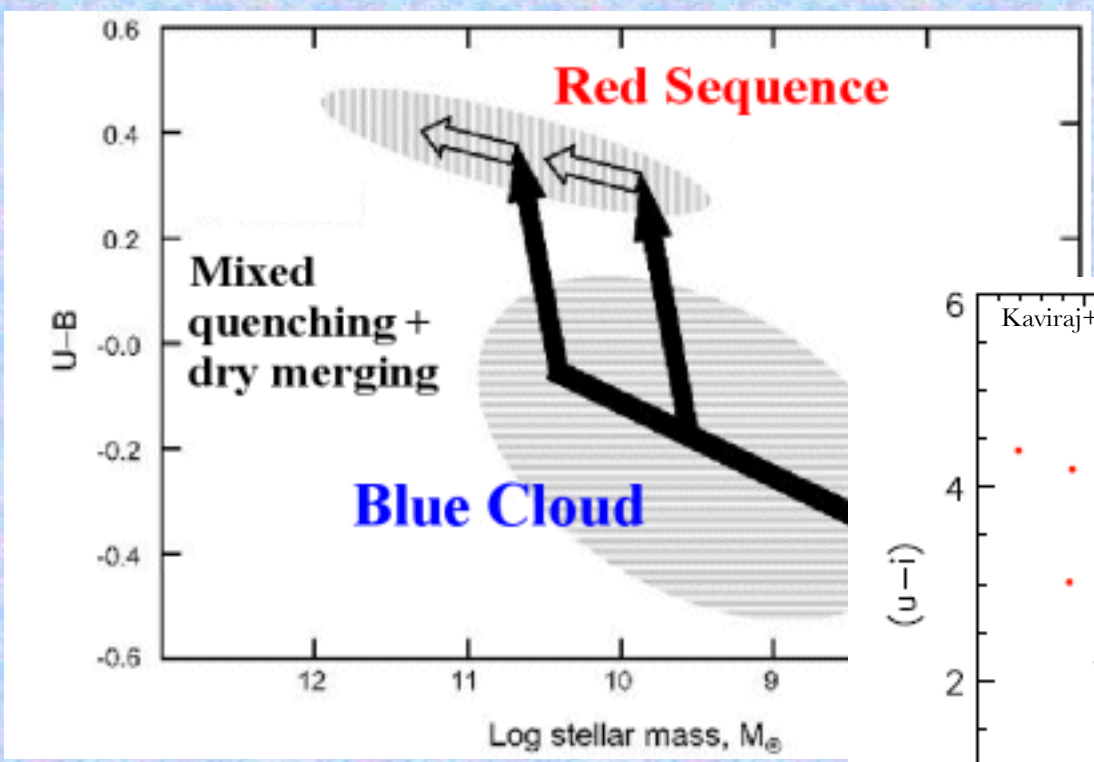


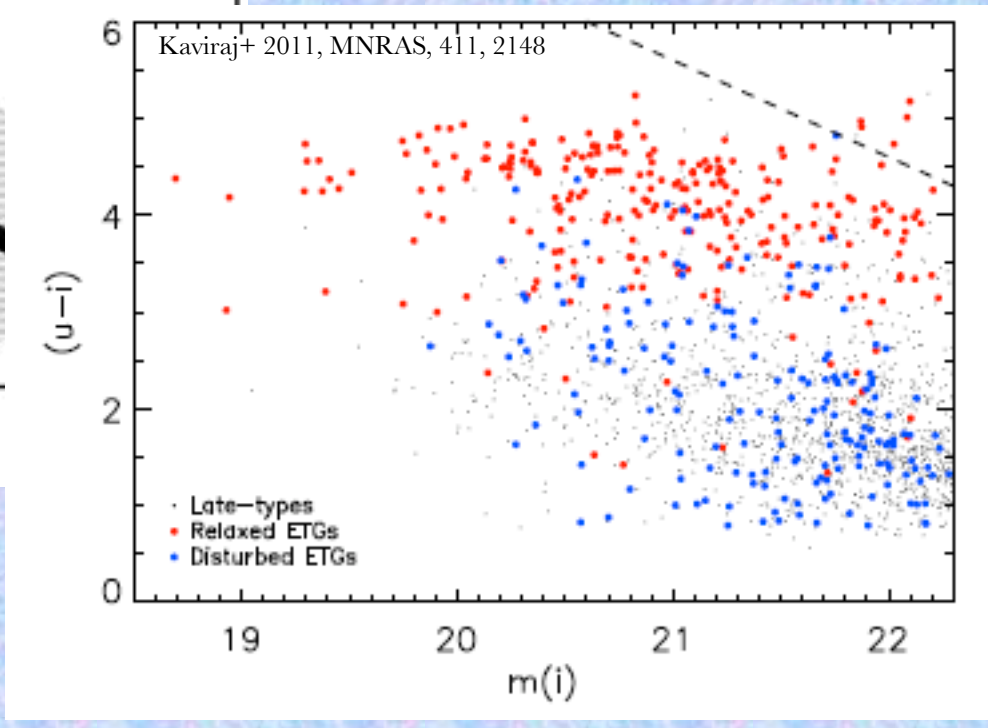
- **Cosmic co-evolution**
  - BH growth and SF tightly coupled
  - Feedback or common formation?



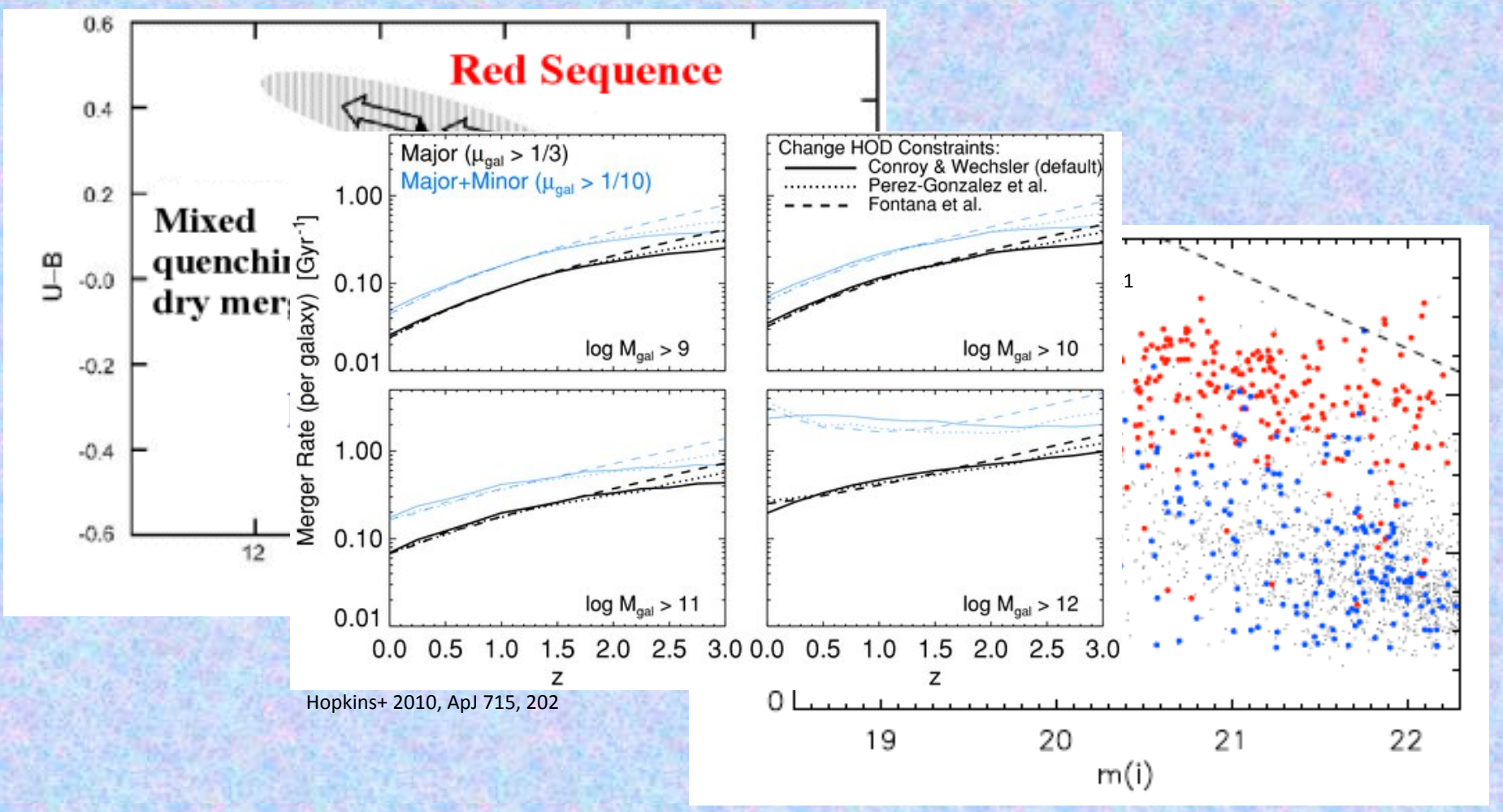
How are SF and AGN activity related in a hierarchical Universe?

Merger-driven star formation



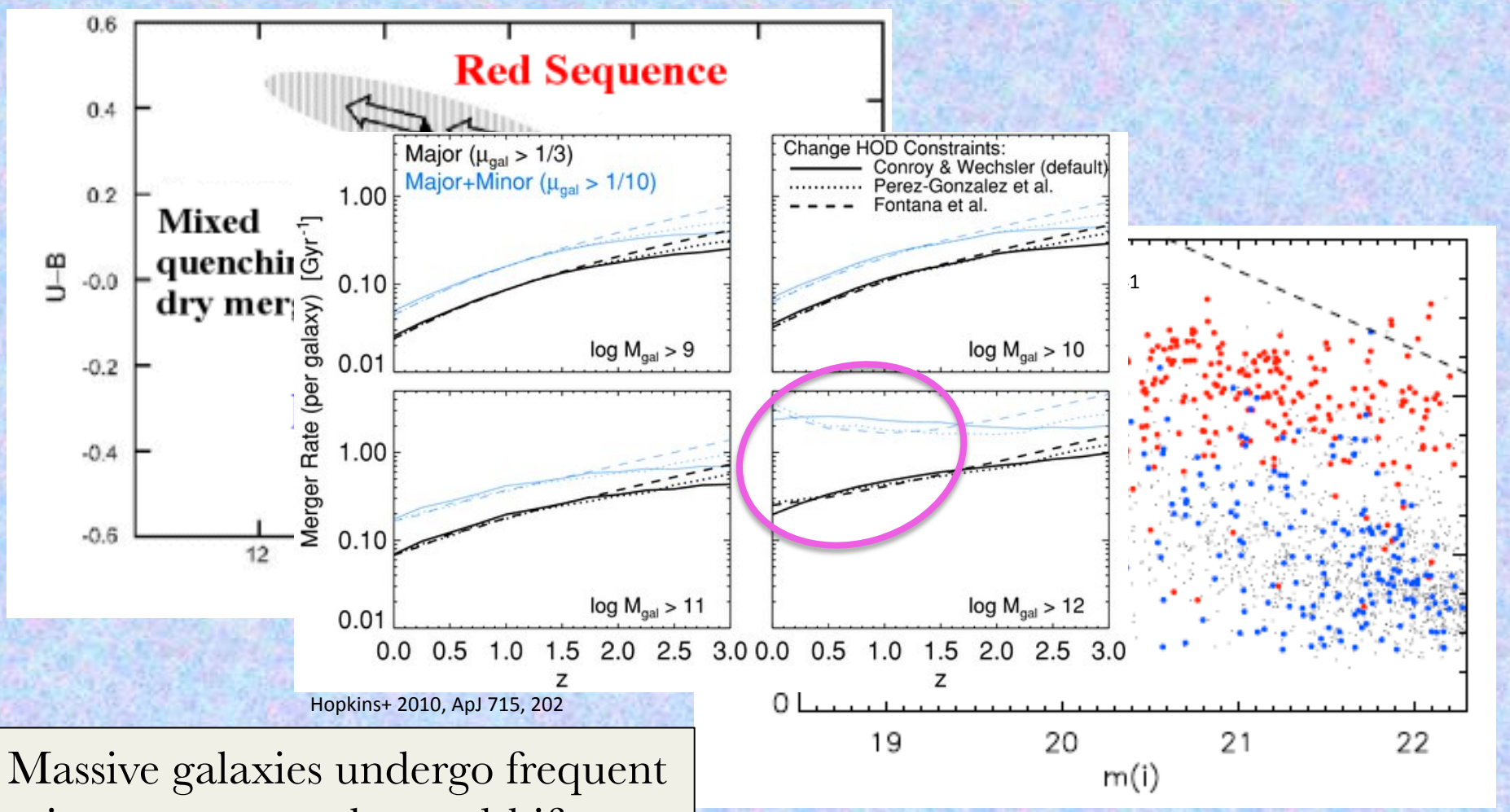


Merger-driven star formation



Hopkins+ 2010, ApJ 715, 202

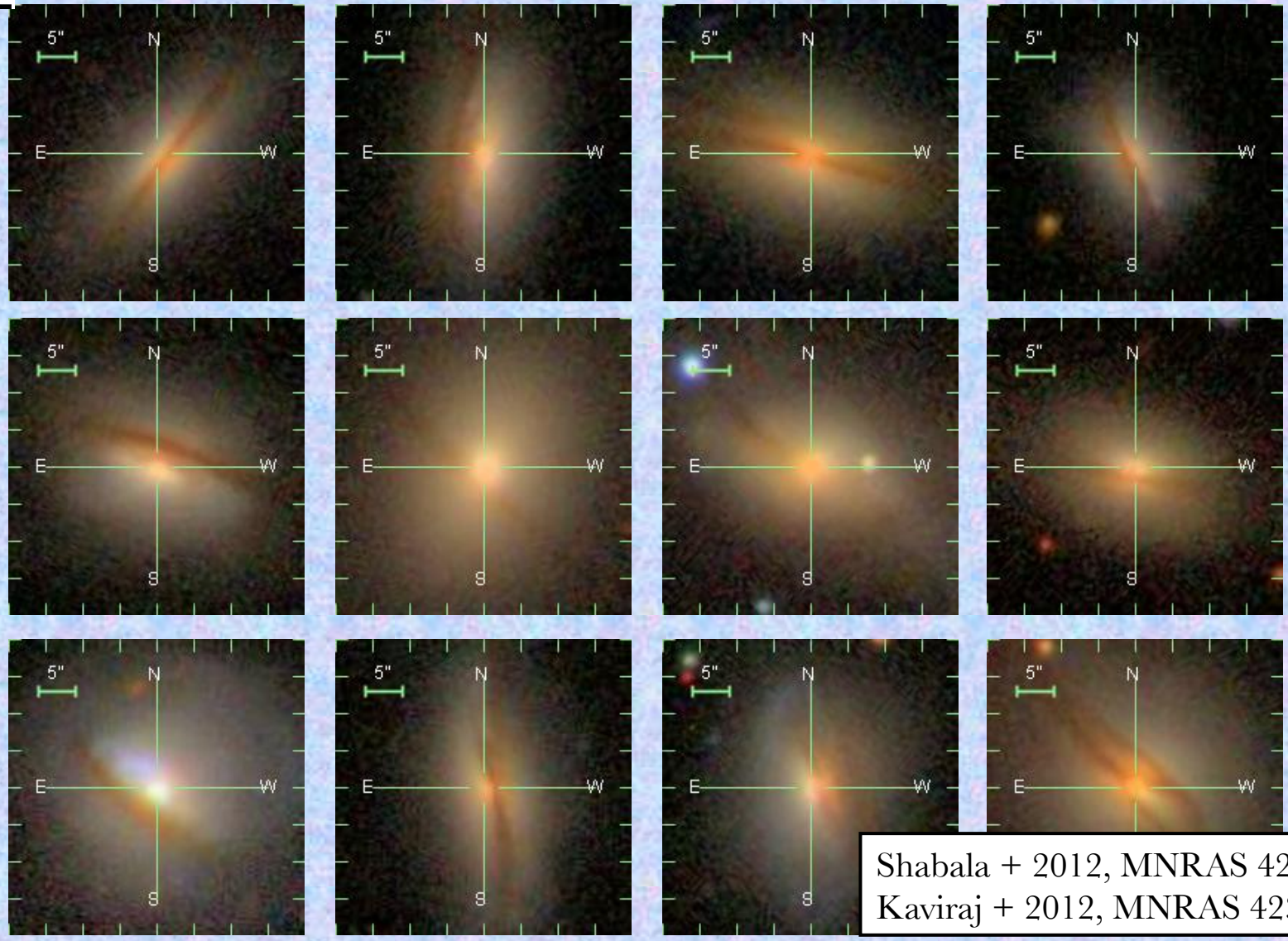
Merger-driven star formation



Hopkins+ 2010, ApJ 715, 202

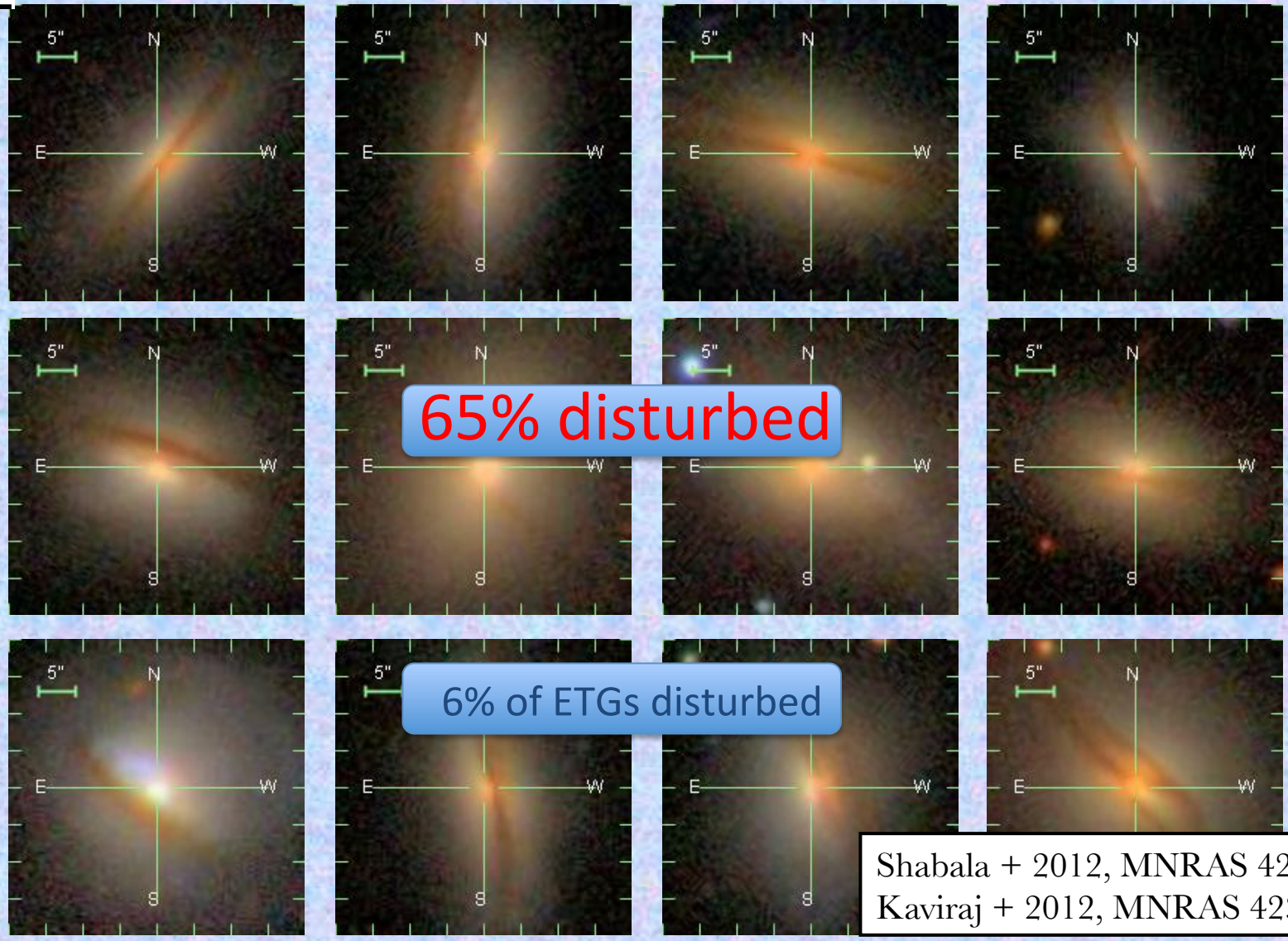
Massive galaxies undergo frequent minor mergers at low redshift

Dust lane early type galaxies



Shabala + 2012, MNRAS 423, 59
Kaviraj + 2012, MNRAS 423, 49

Dust lane early type galaxies



Shabala + 2012, MNRAS 423, 59
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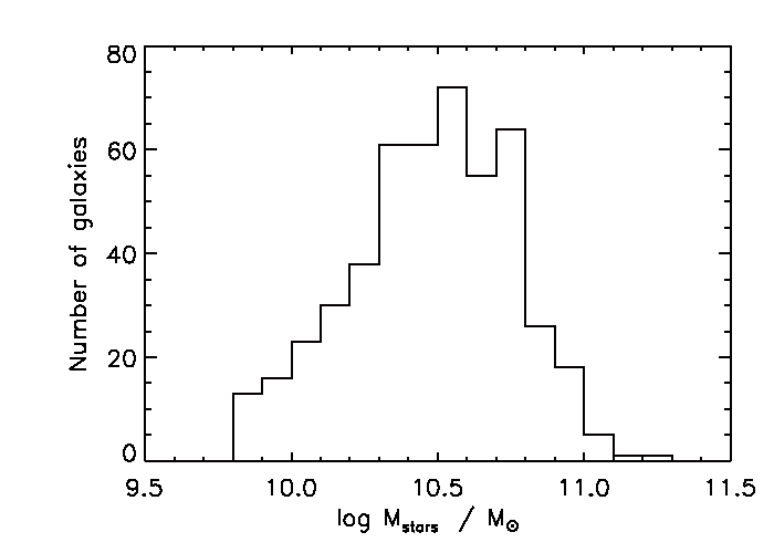
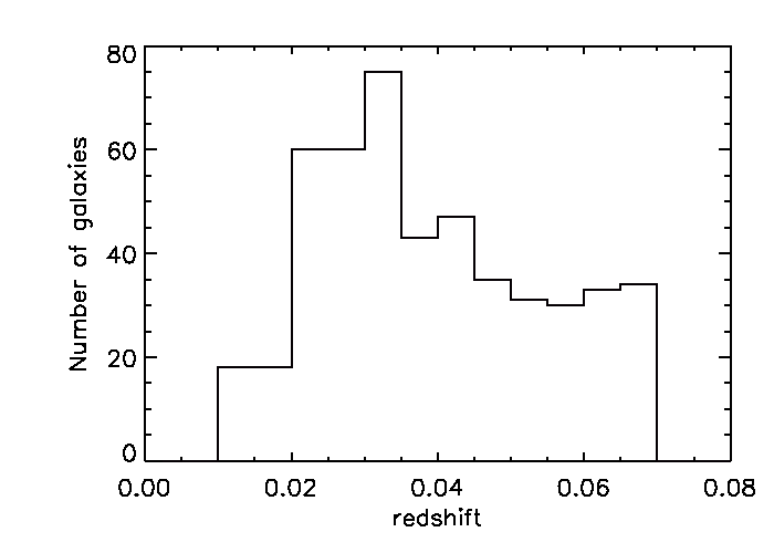
Are dust lane early types special ?

Control sample

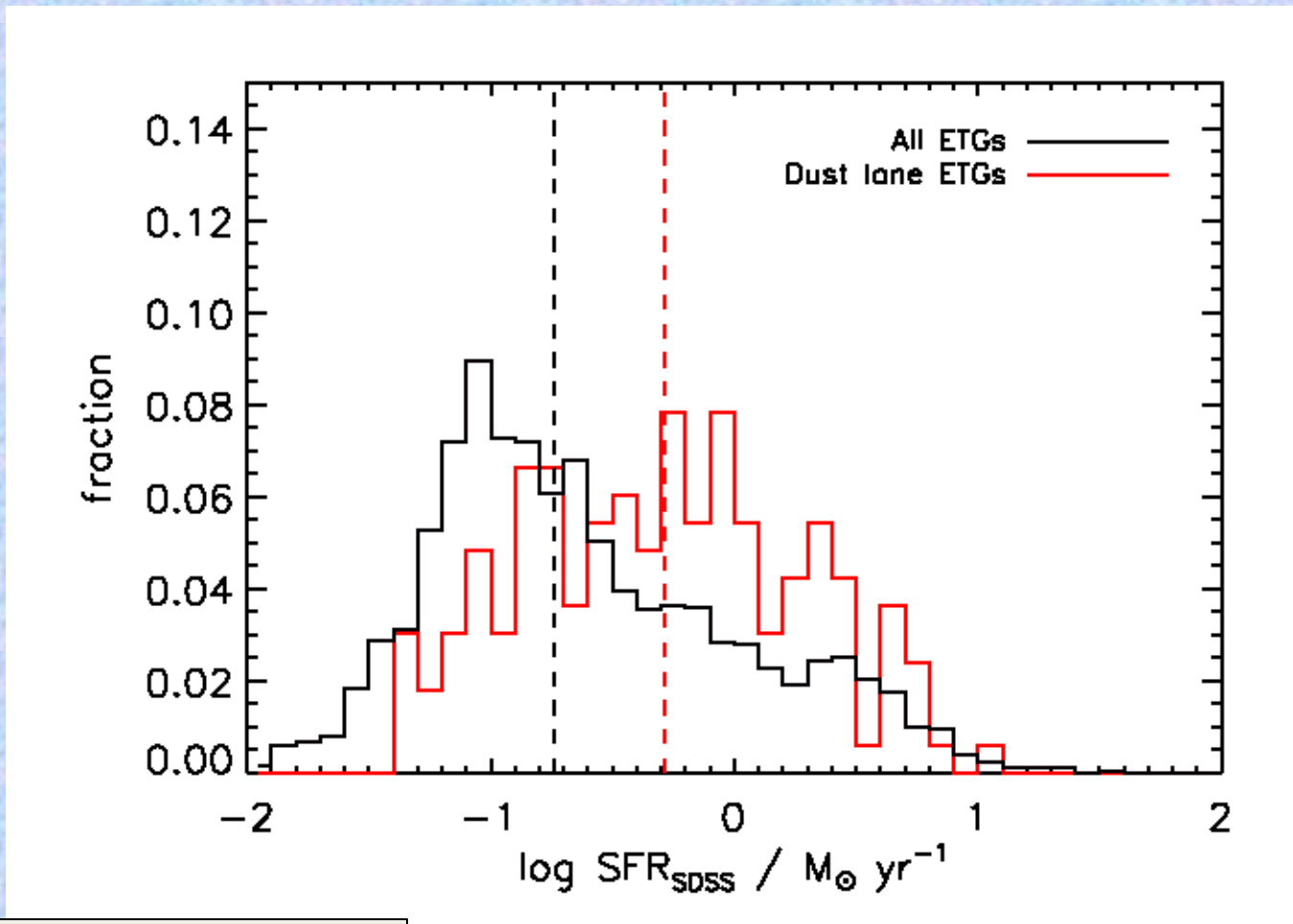




Matched in stellar mass and redshift

Shabala + 2012, MNRAS 423, 59
Kaviraj + 2012, MNRAS 423, 49

Star formation rates

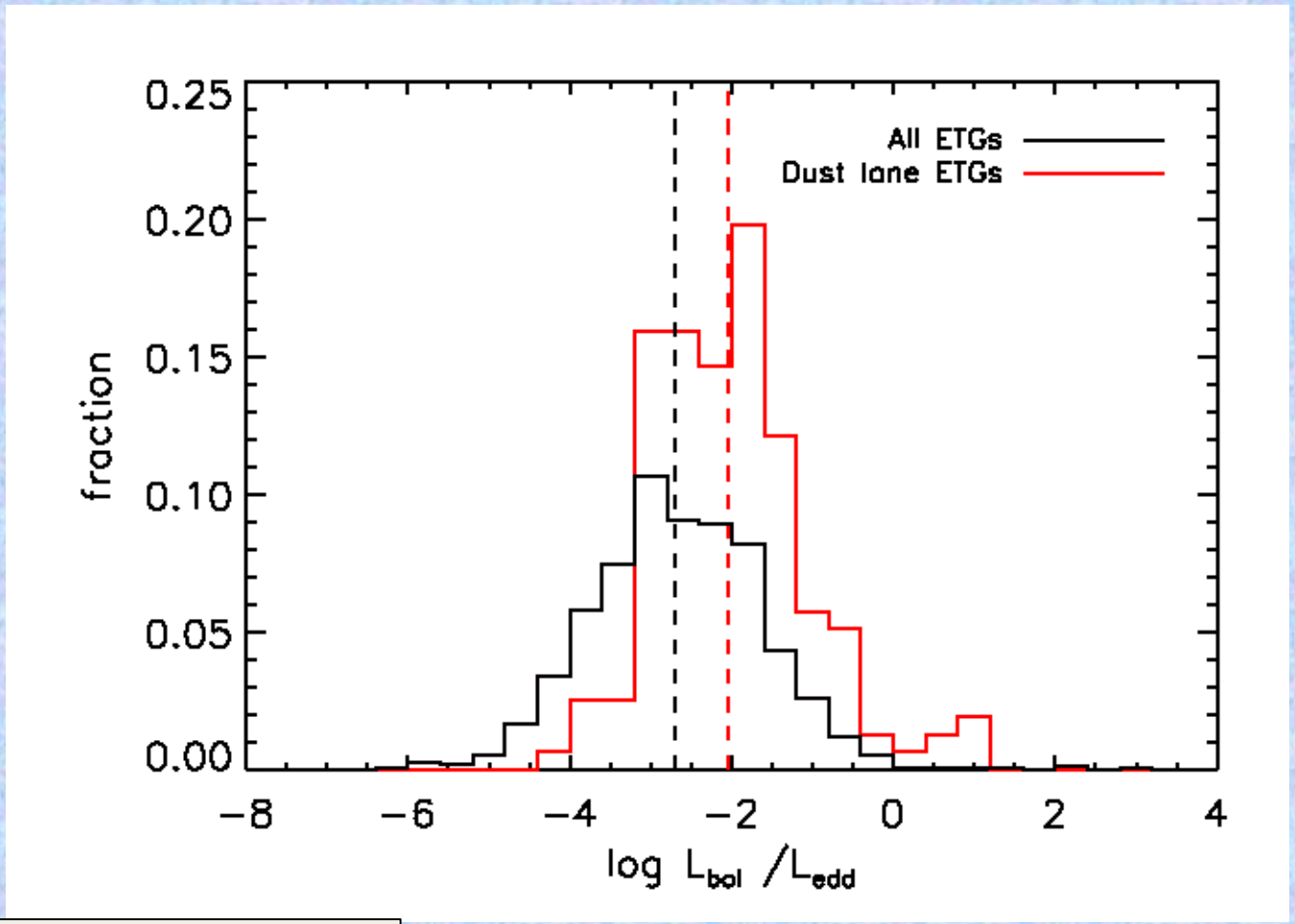


Matched in stellar mass, redshift *and starburst age*

Stanislav Shabala

Shabala + 2012, MNRAS 423, 59
Kaviraj + 2012, MNRAS 423, 49

AGN fuelling



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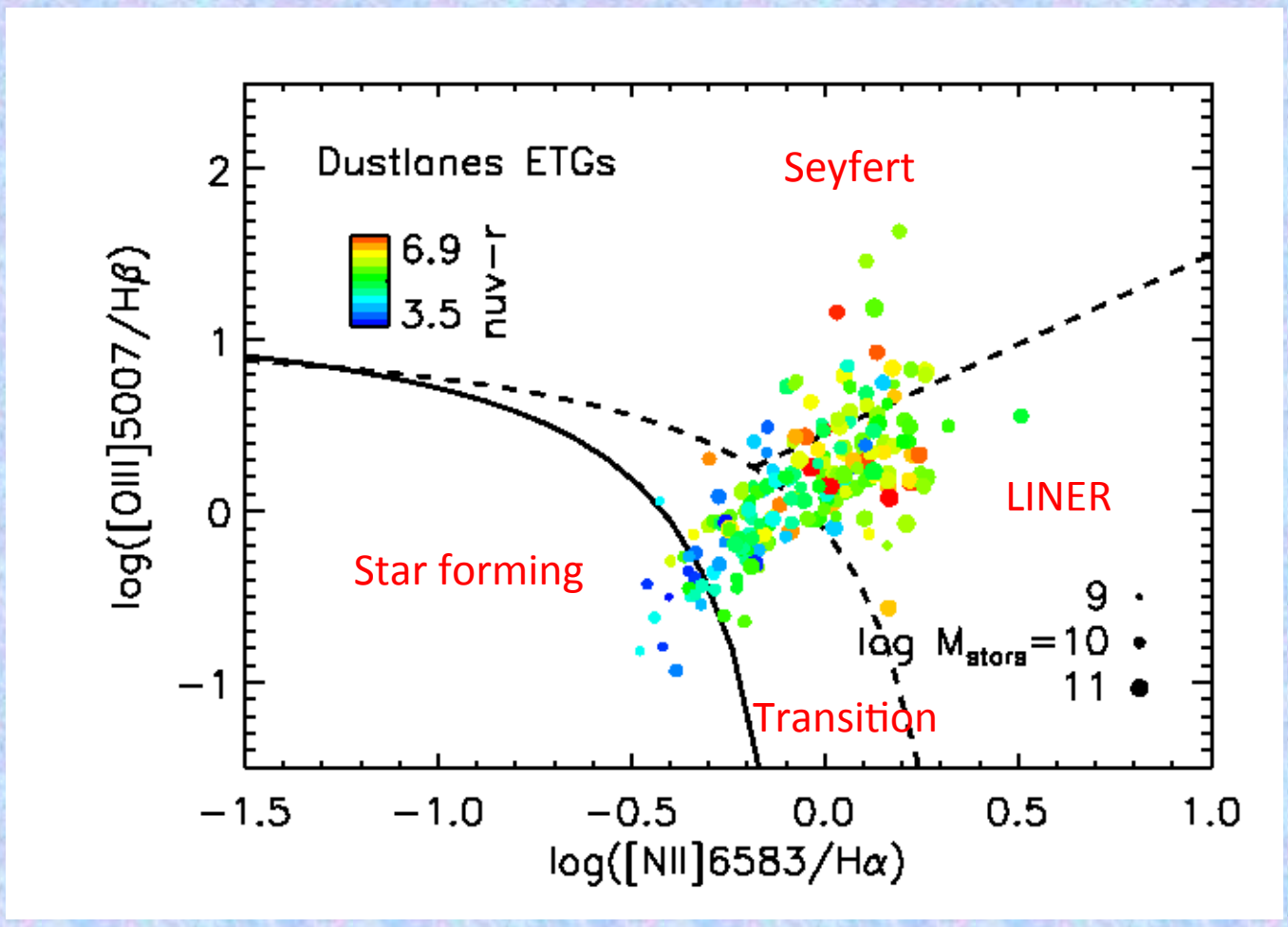
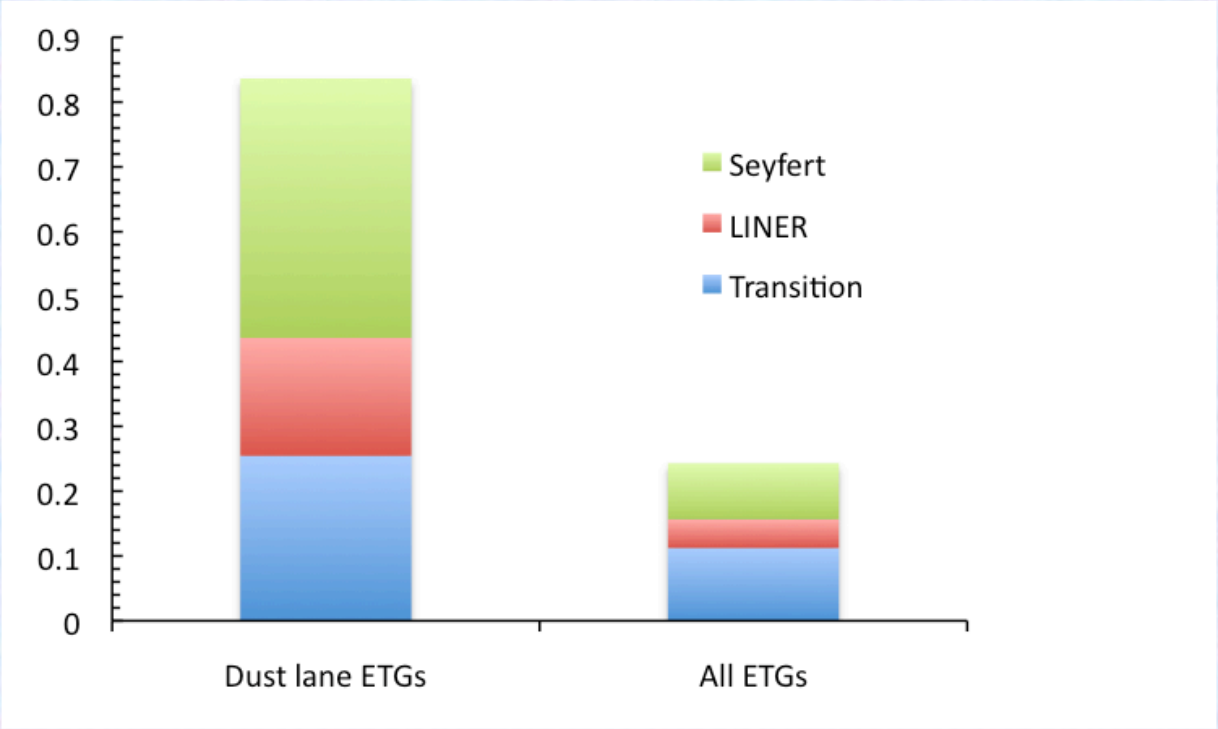
AGN diagnostics: optical



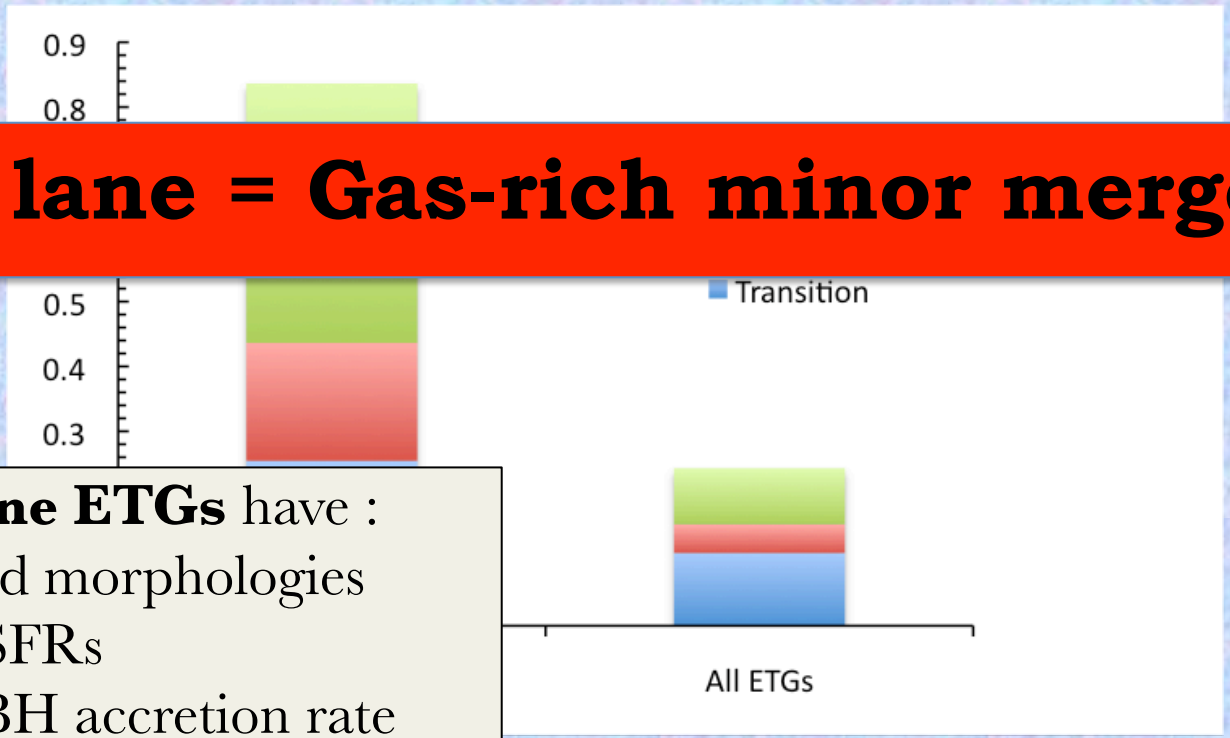
Optical AGN fraction



Shabala + 2012, MNRAS 423, 59

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

Shabala + 2012, MNRAS 423, 59

So what ?

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Disturbed morphologies
Higher SFRs
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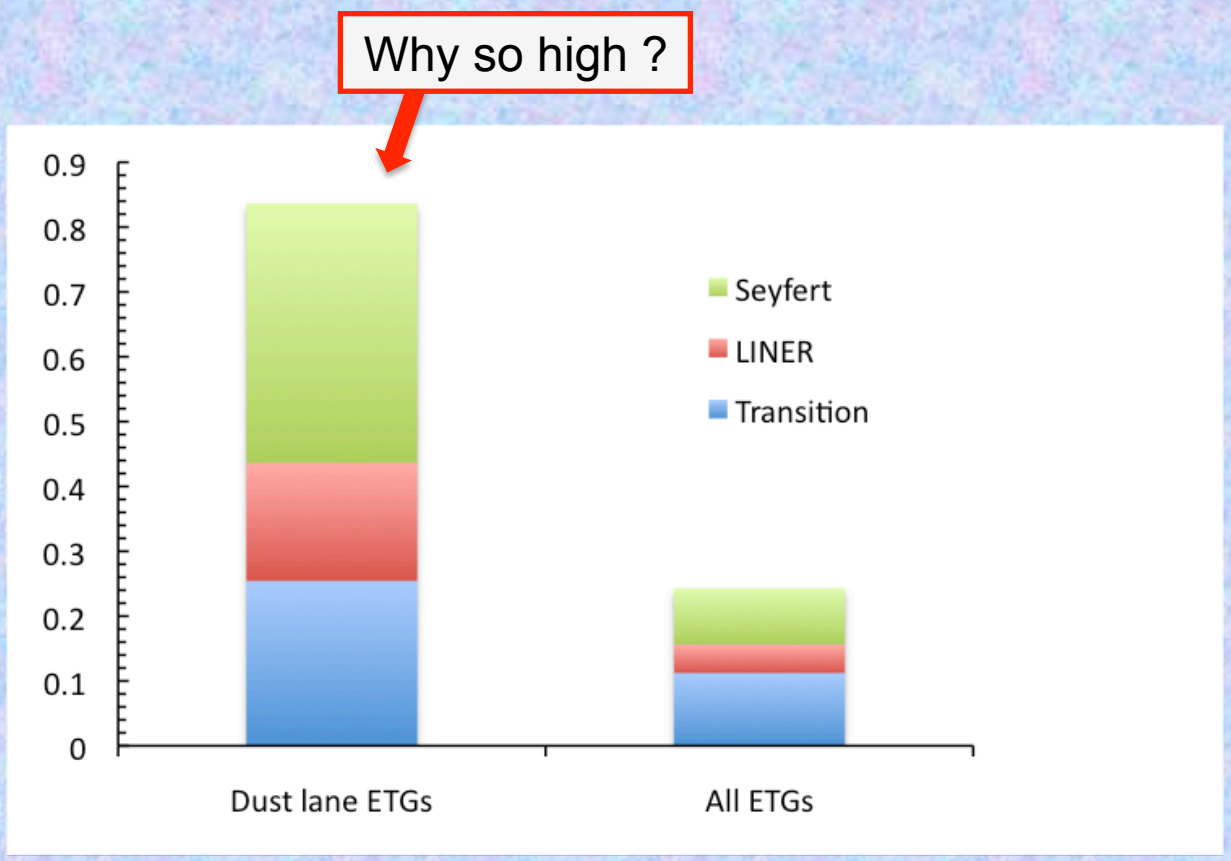
Optical AGN fraction



Shabala + 2012, MNRAS 423, 59

How are the AGN triggered ?

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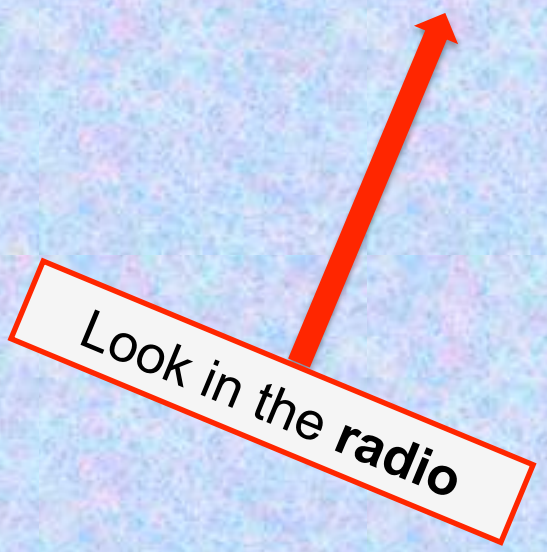


1. Triggering mechanisms

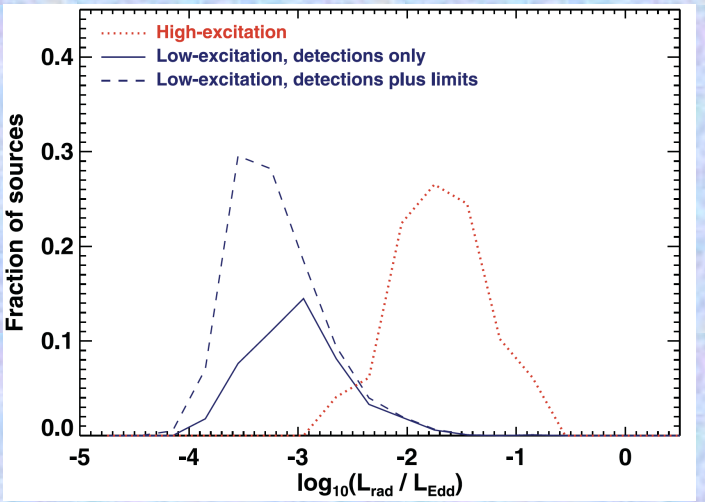
2. Chronology

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 (Pope+ 2012, MNRAS, 419, 50)



Best & Heckman 2012, MNRAS, 421, 1569

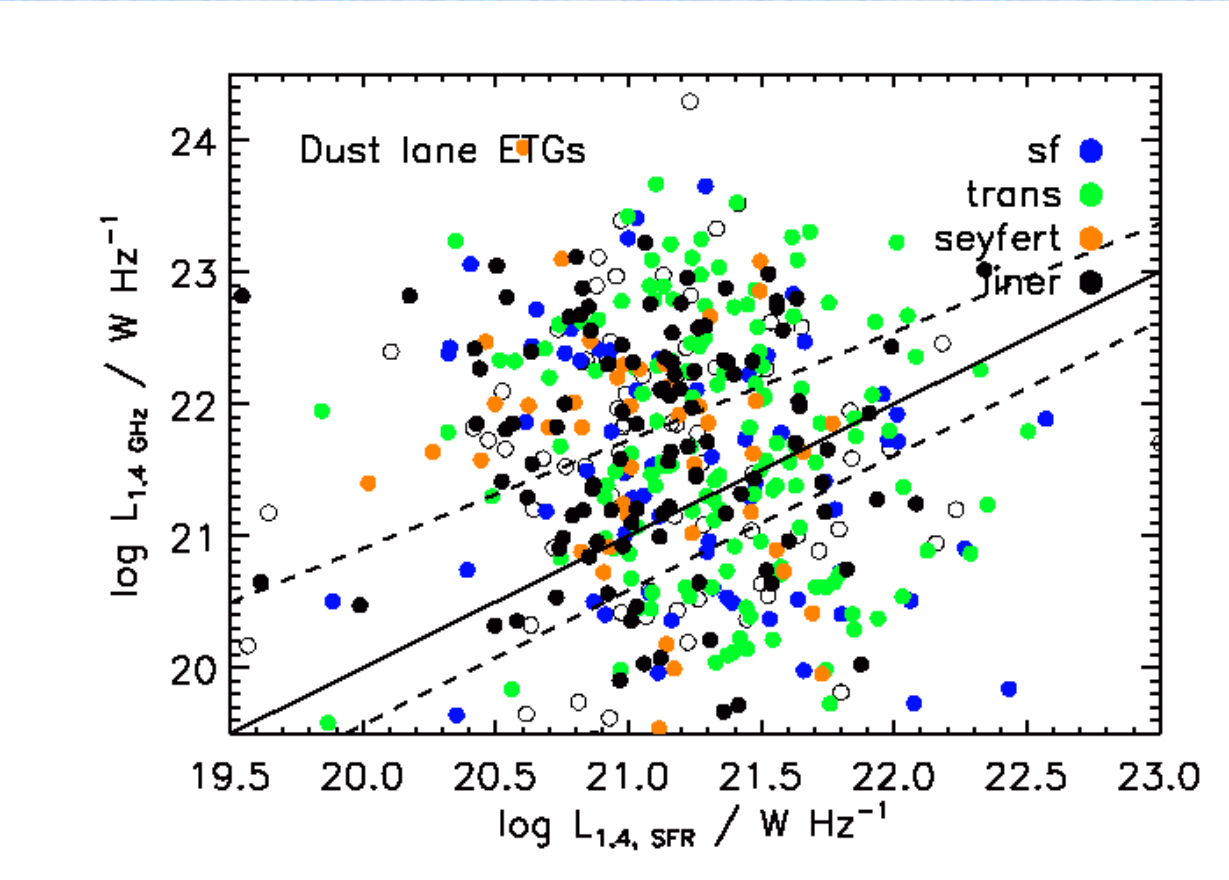
High Excitation Radio Galaxies

- 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**

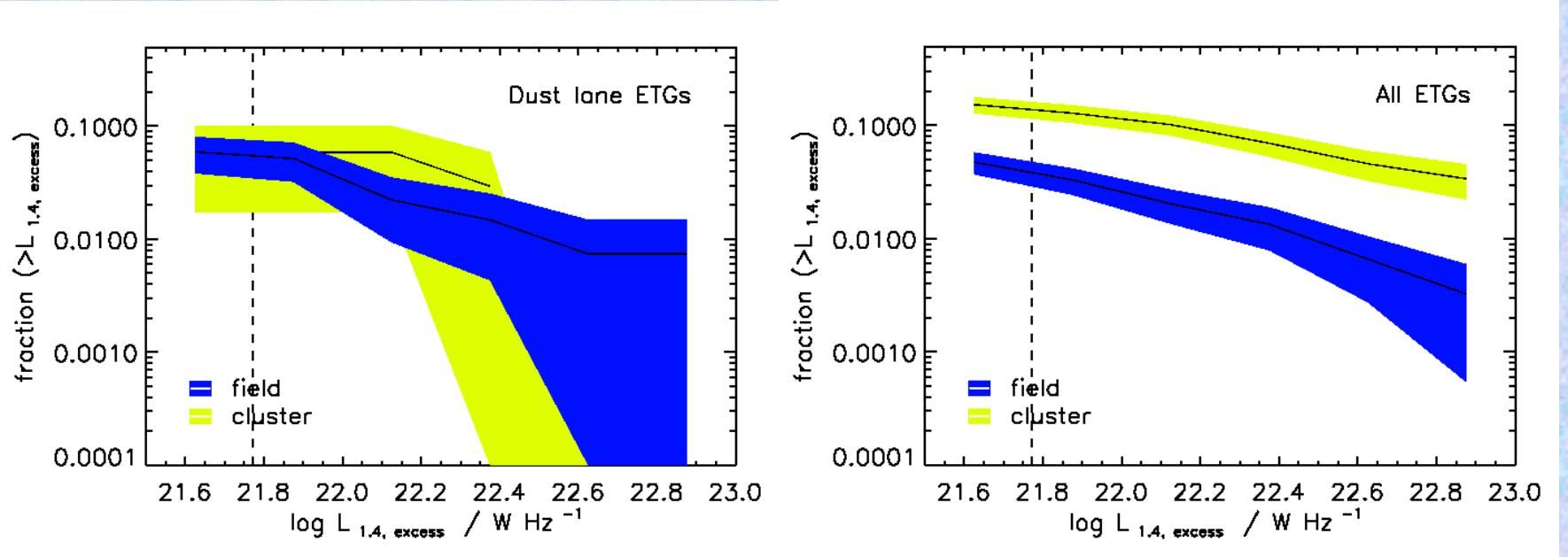
What are the **radio + optical** AGN properties of dust lane early types ?

AGN diagnostics: radio



Cross match SDSS with FIRST + NVSS
Excess radio emission relative to SFR ➔ AGN

Radio luminosity functions



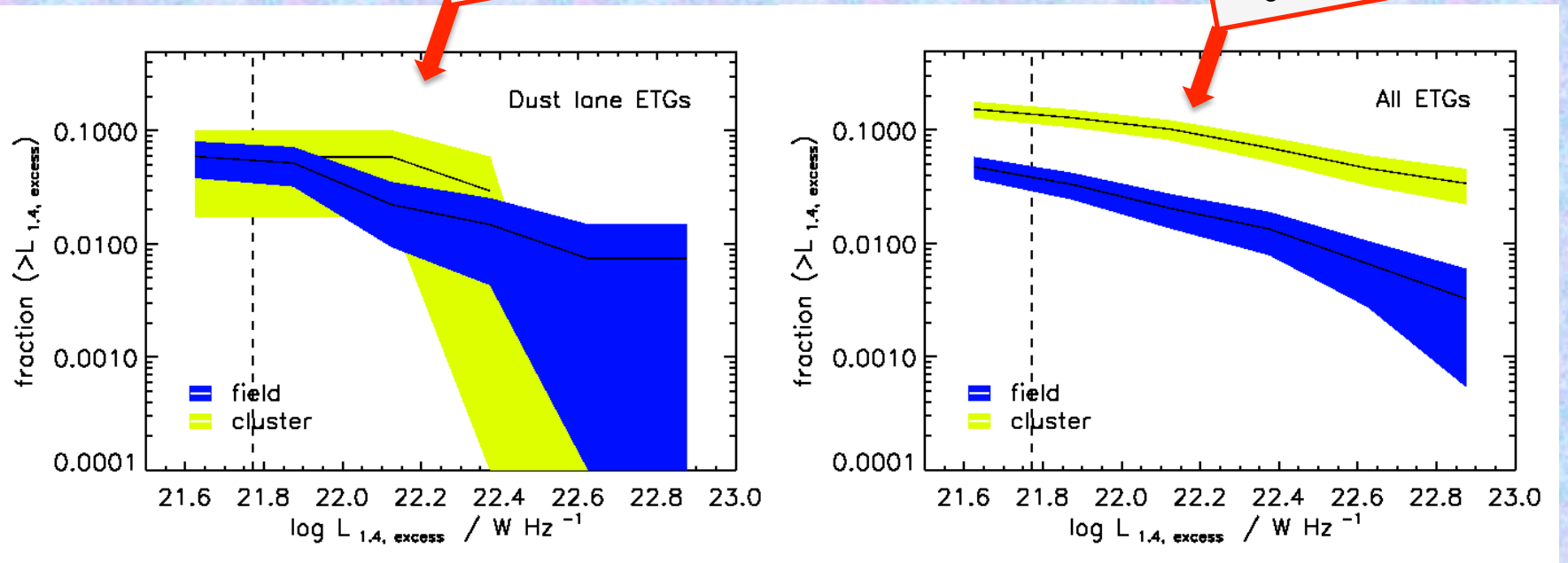
- Split up by environment
  (radio AGN trigger is environment-dependent)
- Matched control sample

Shabala + 2012, MNRAS 423, 59
Kaviraj + 2012, MNRAS 423, 49

Radio luminosity functions

No difference for DETGs

Higher AGN fraction in clusters for all ETGs



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

Shabala + 2012, MNRAS 423, 59
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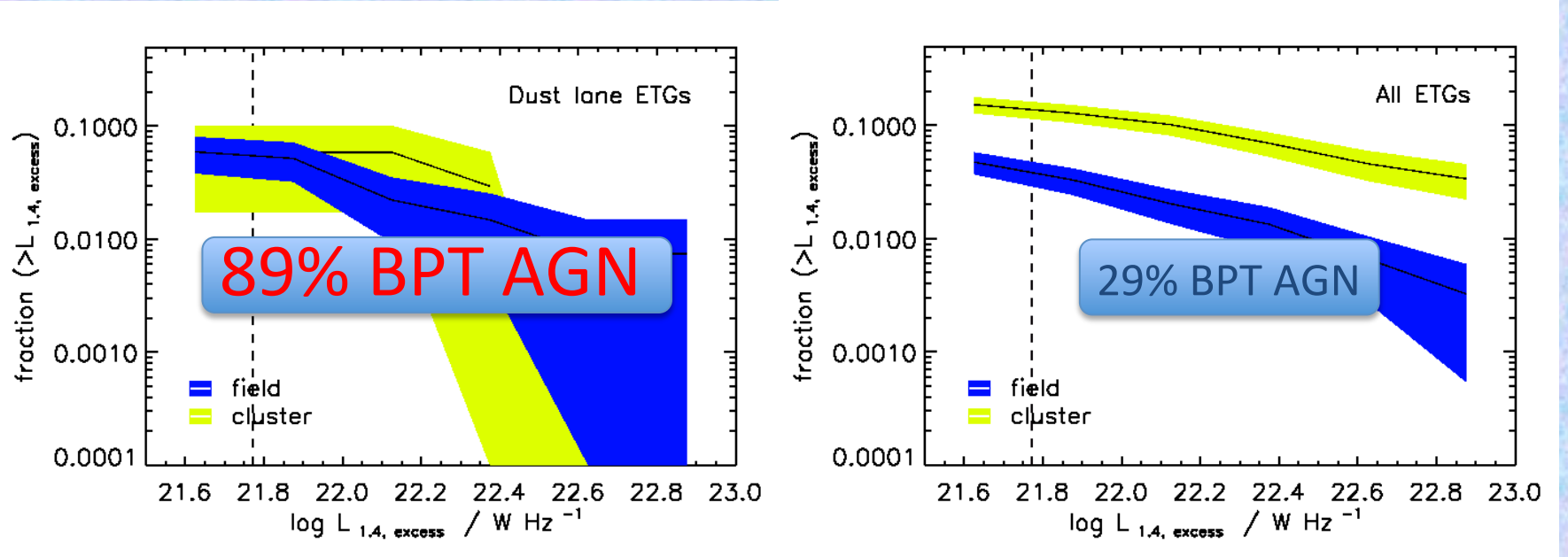

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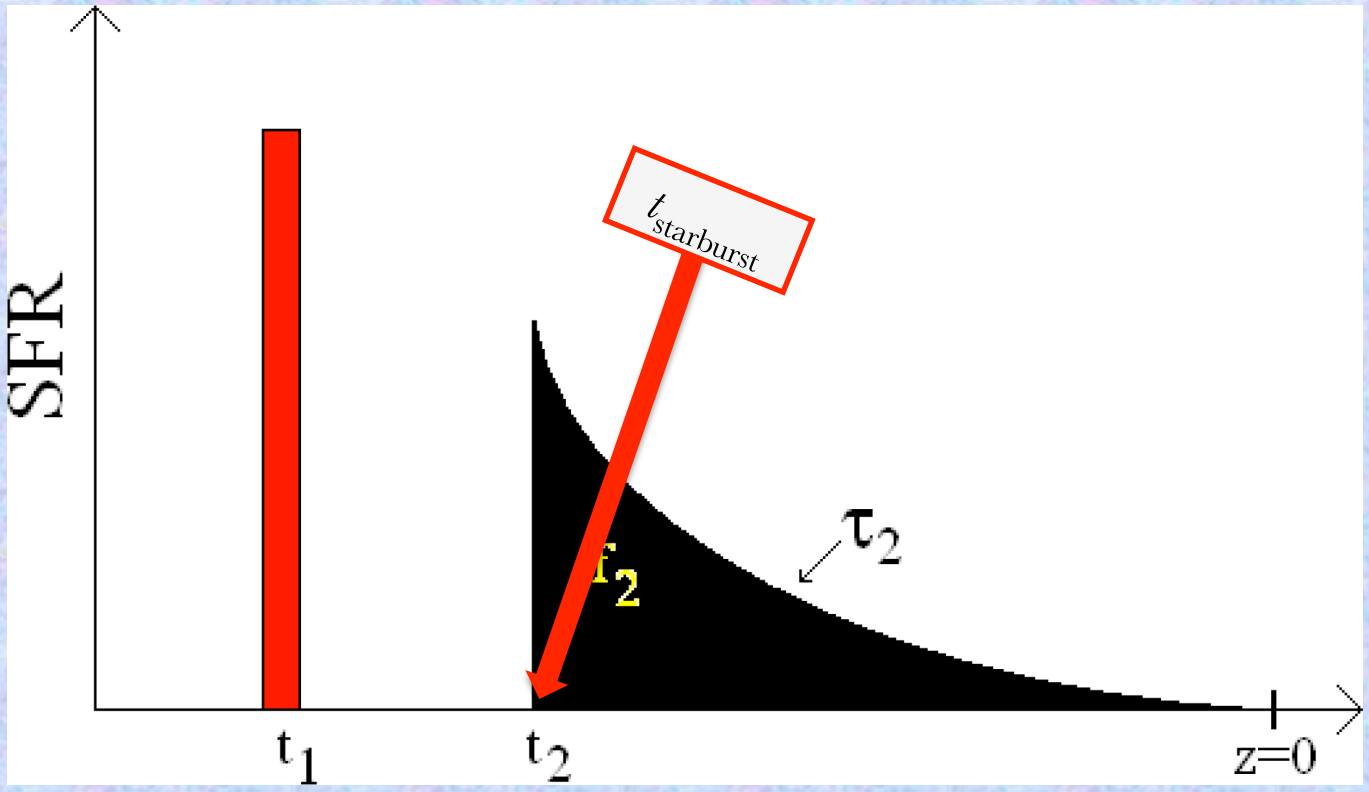
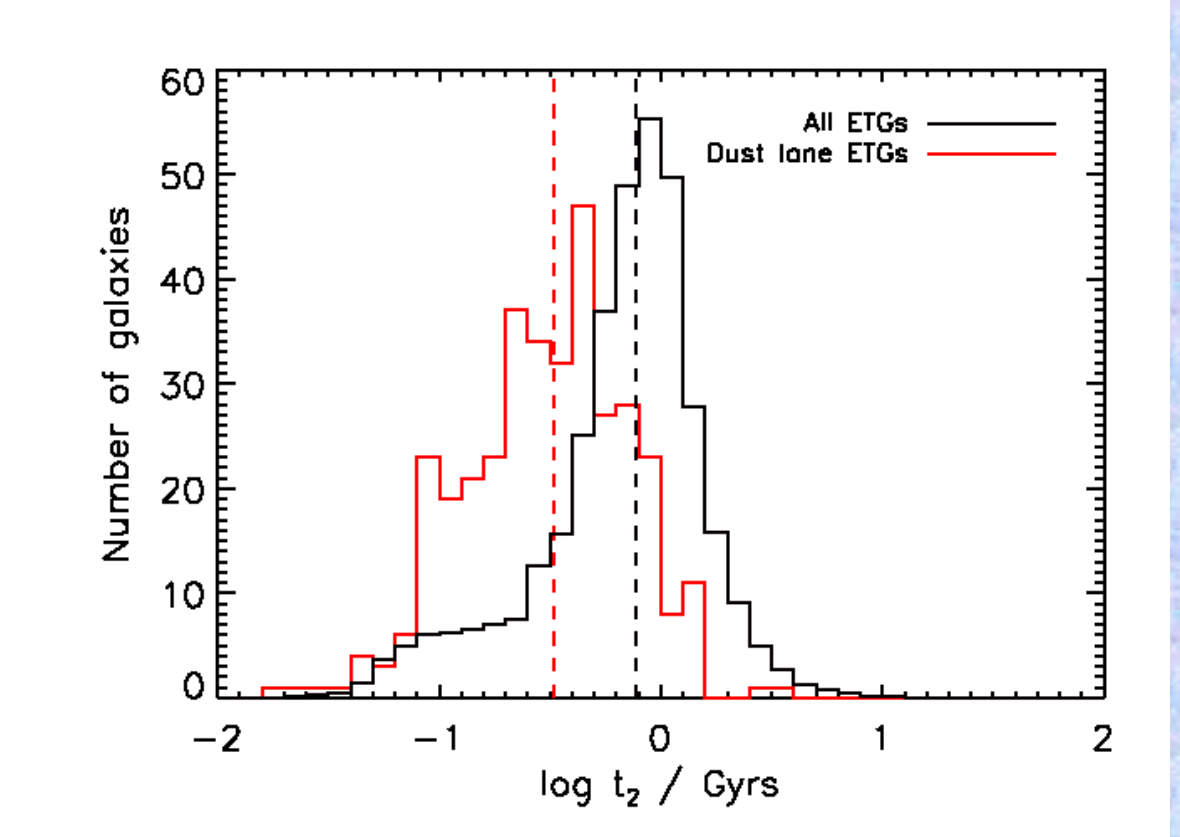
When do AGN switch on ?

Starburst ages



Photometric SFHs (SDSS + GALEX)

Starburst ages



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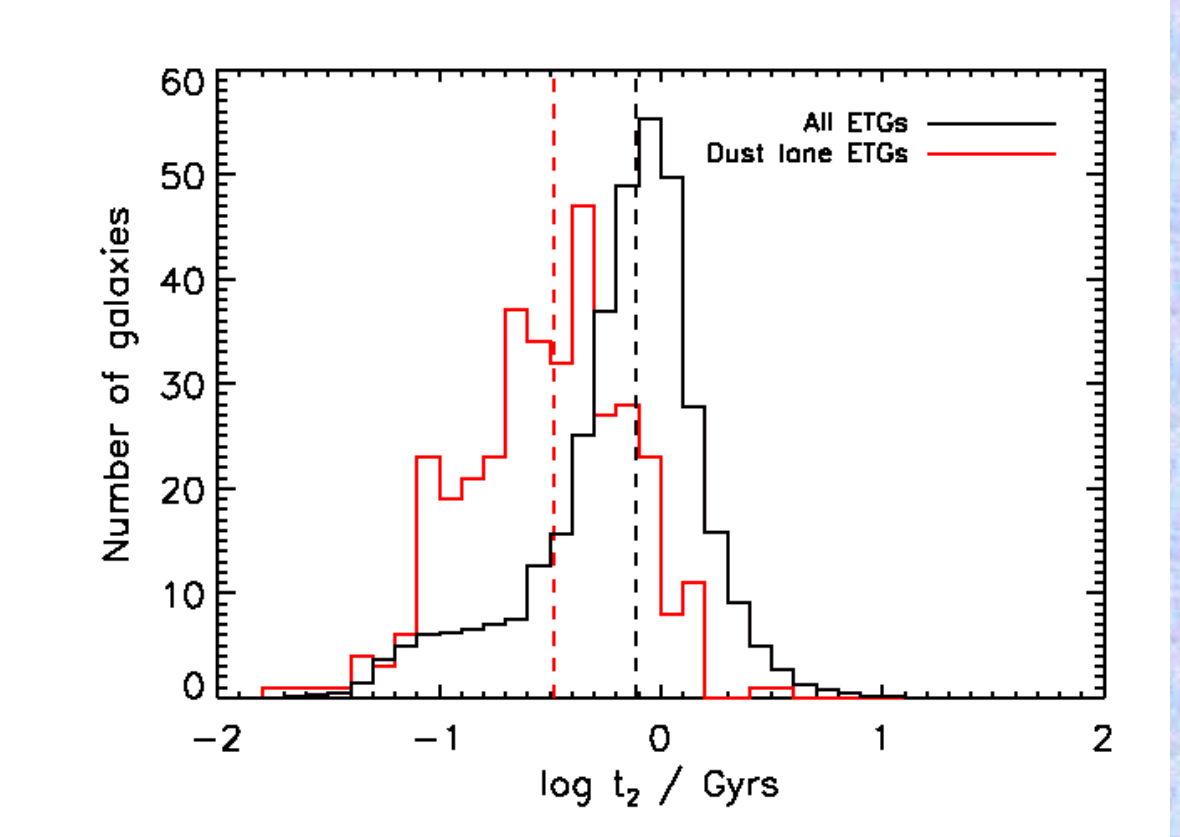
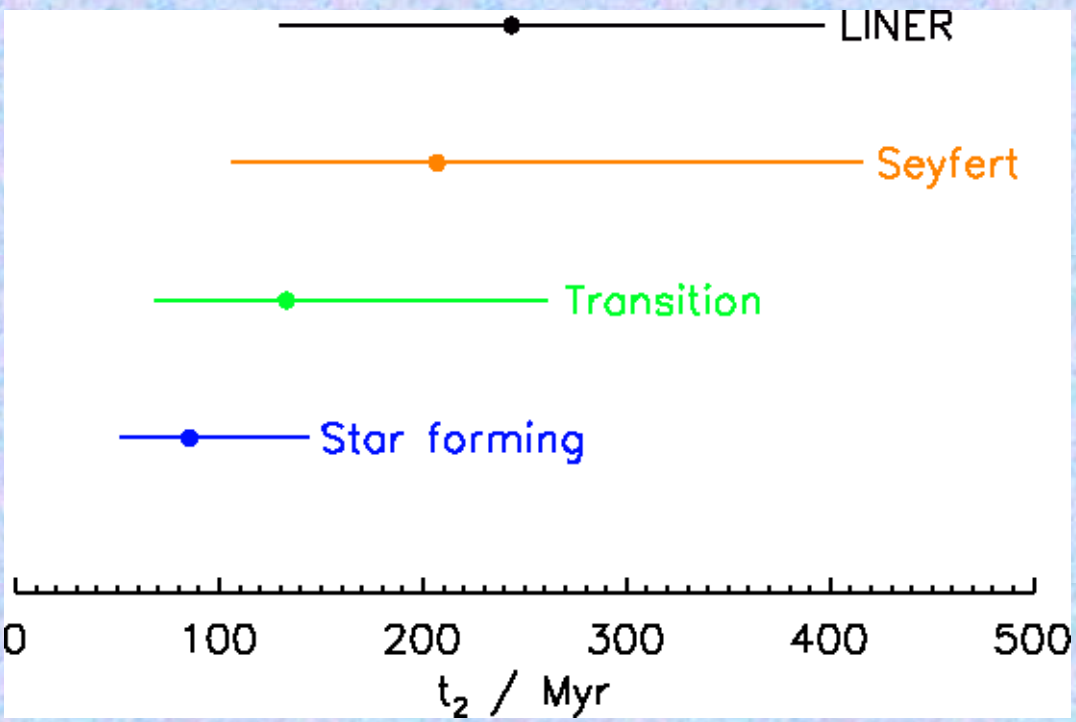
Starburst ages



Shabala + 2012, MNRAS 423, 59

How are the AGN and SF properties related ?

Evolutionary sequence



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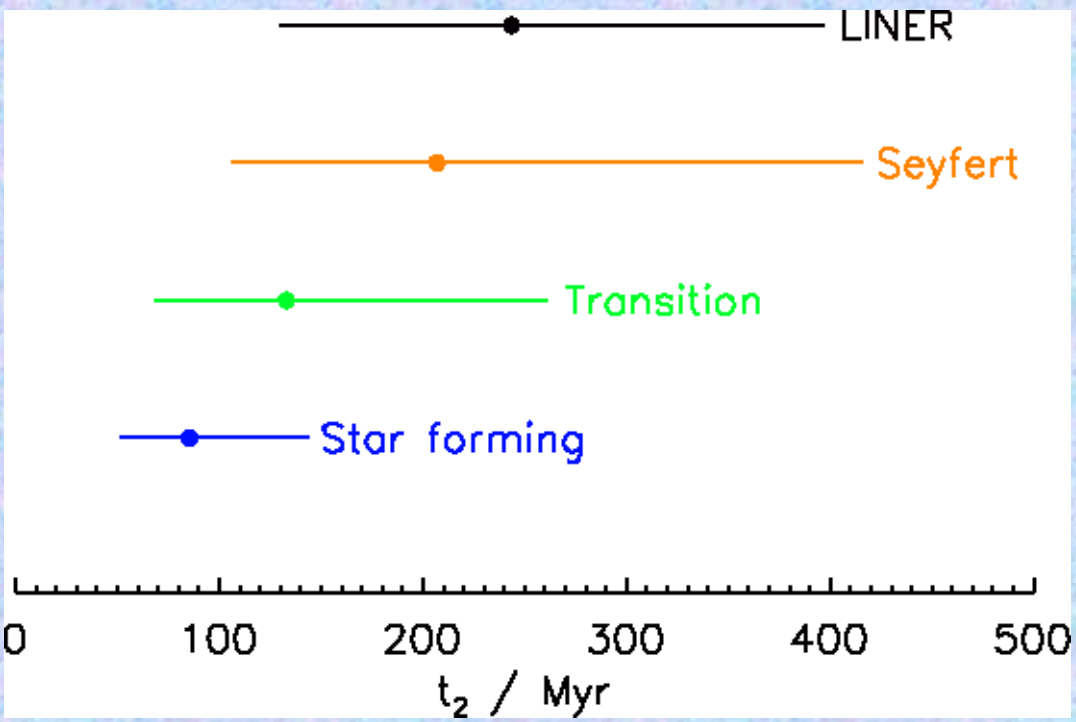
Evolutionary sequence

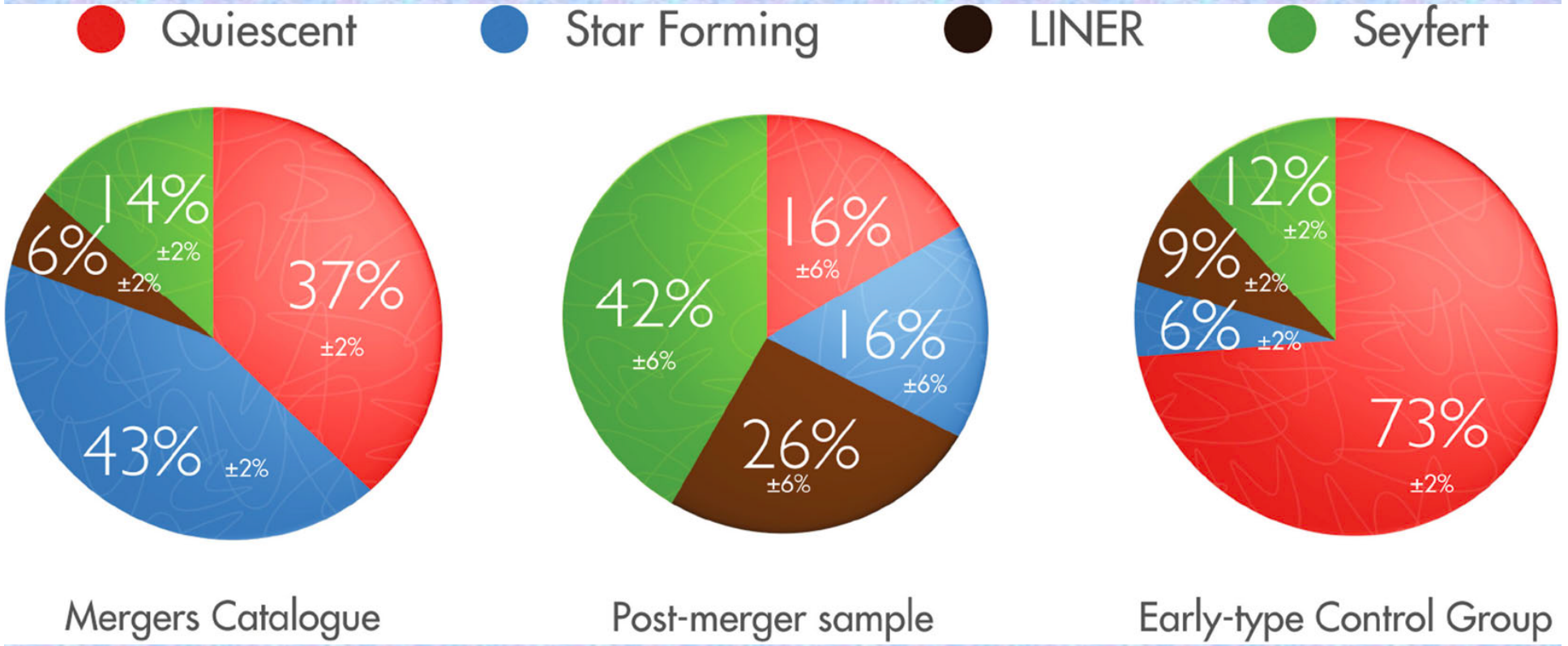


AGN switches on ~100 Myrs **after** SF

Shabala + 2012, MNRAS 423, 59

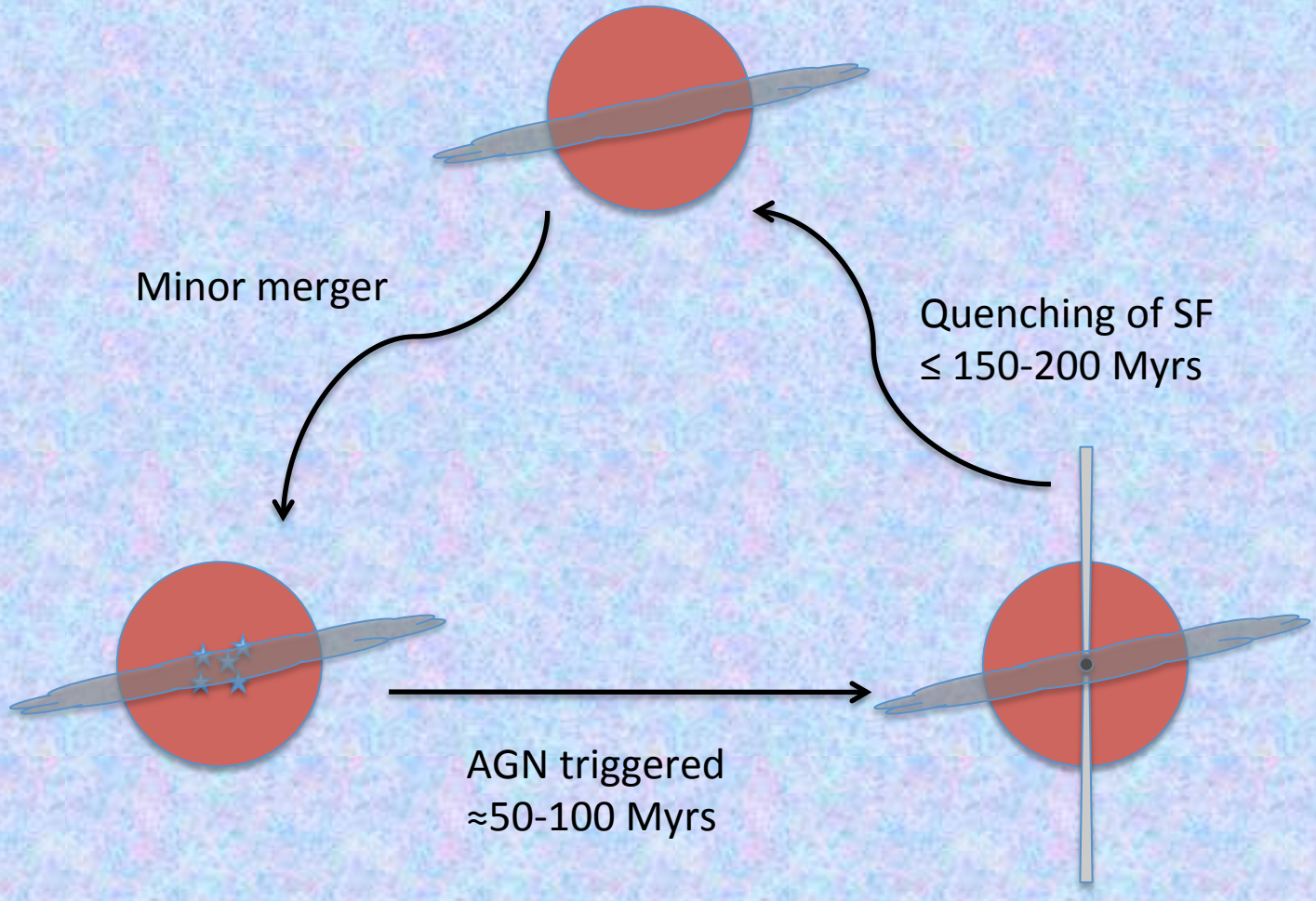
Merger sequence

Carpineti+ 2012, MNRAS, 420, 2139



Star formation peaks in mergers

AGN peak in **post**-mergers


Minor merger
Quenching of SF
≤ 150-200 Myrs
AGN triggered
≈50-100 Myrs

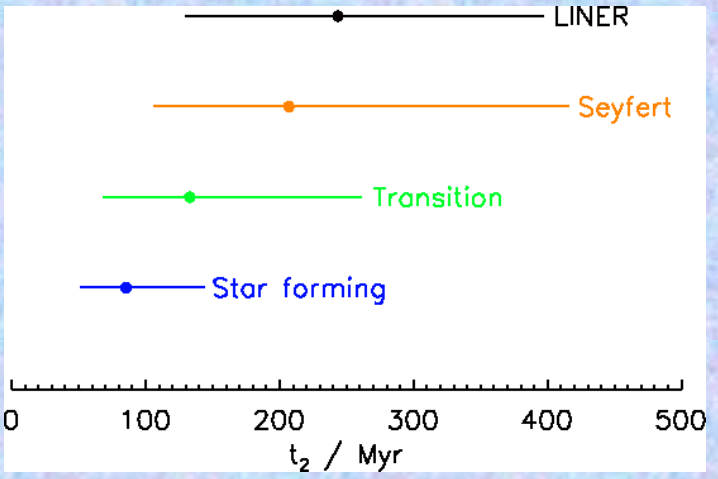
Implications for AGN feedback

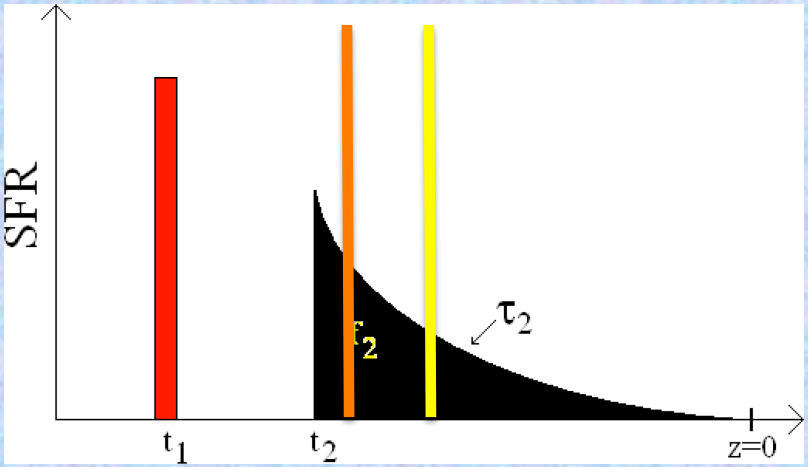
- Feedback efficiency depends on when AGN switches on

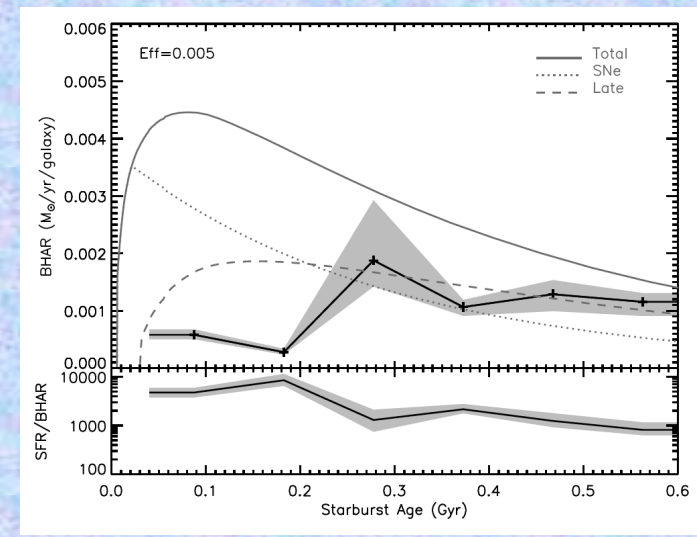
(e.g. Shabala+ 2011, MNRAS, 413, 2815)

- Interaction signatures wash out

(Pimbblet+ 2013, MNRAS, 429, 1827)







Stanislav Shabala

Wild+ 20010, MNRAS, 405, 933

VLBI follow-up

"The only sure way to identify an AGN is with VLBI"

- Enno Middelberg

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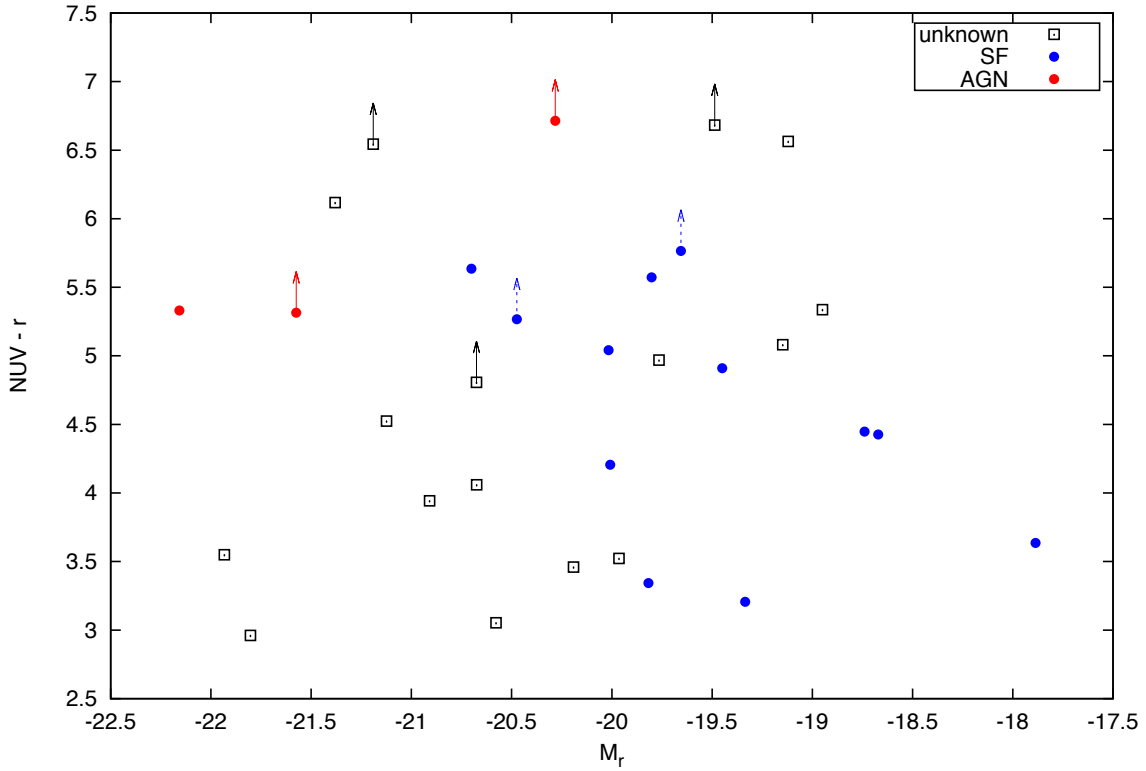

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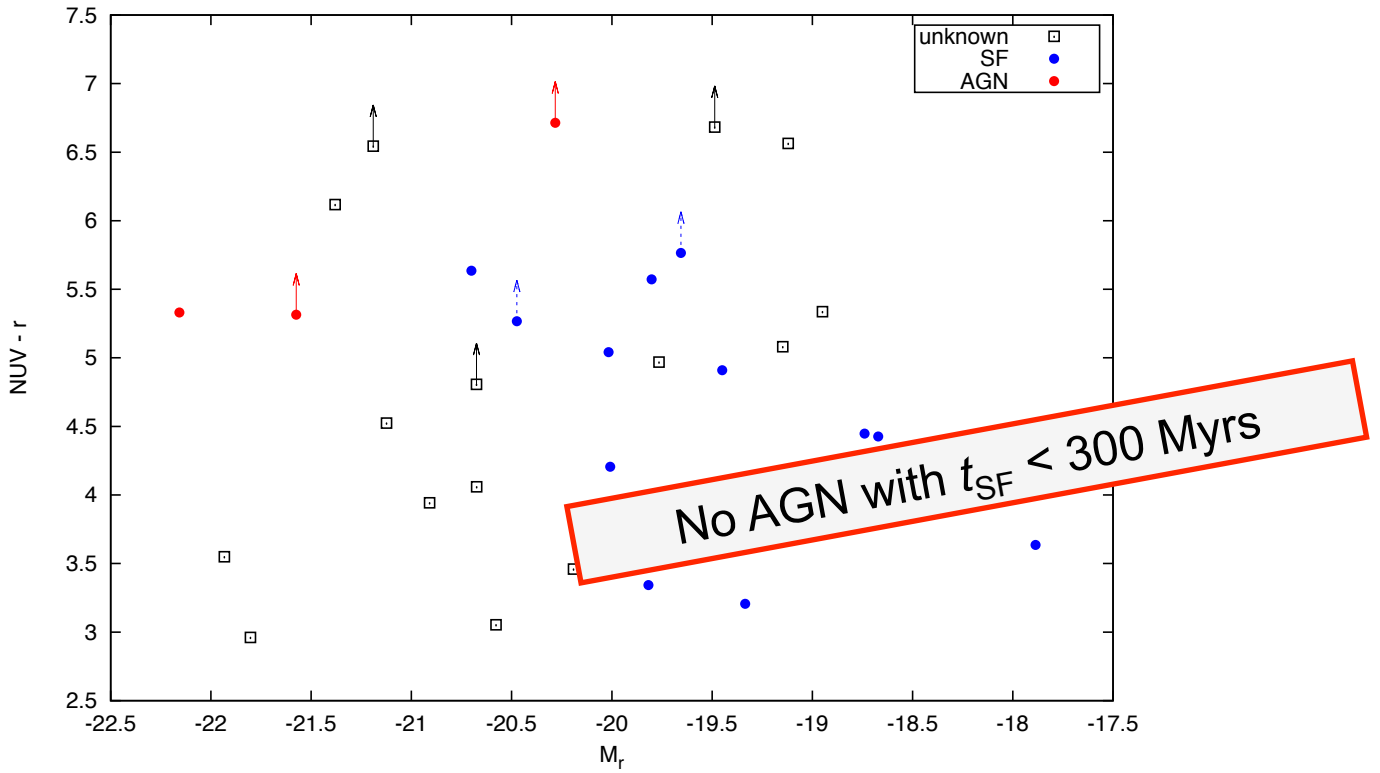
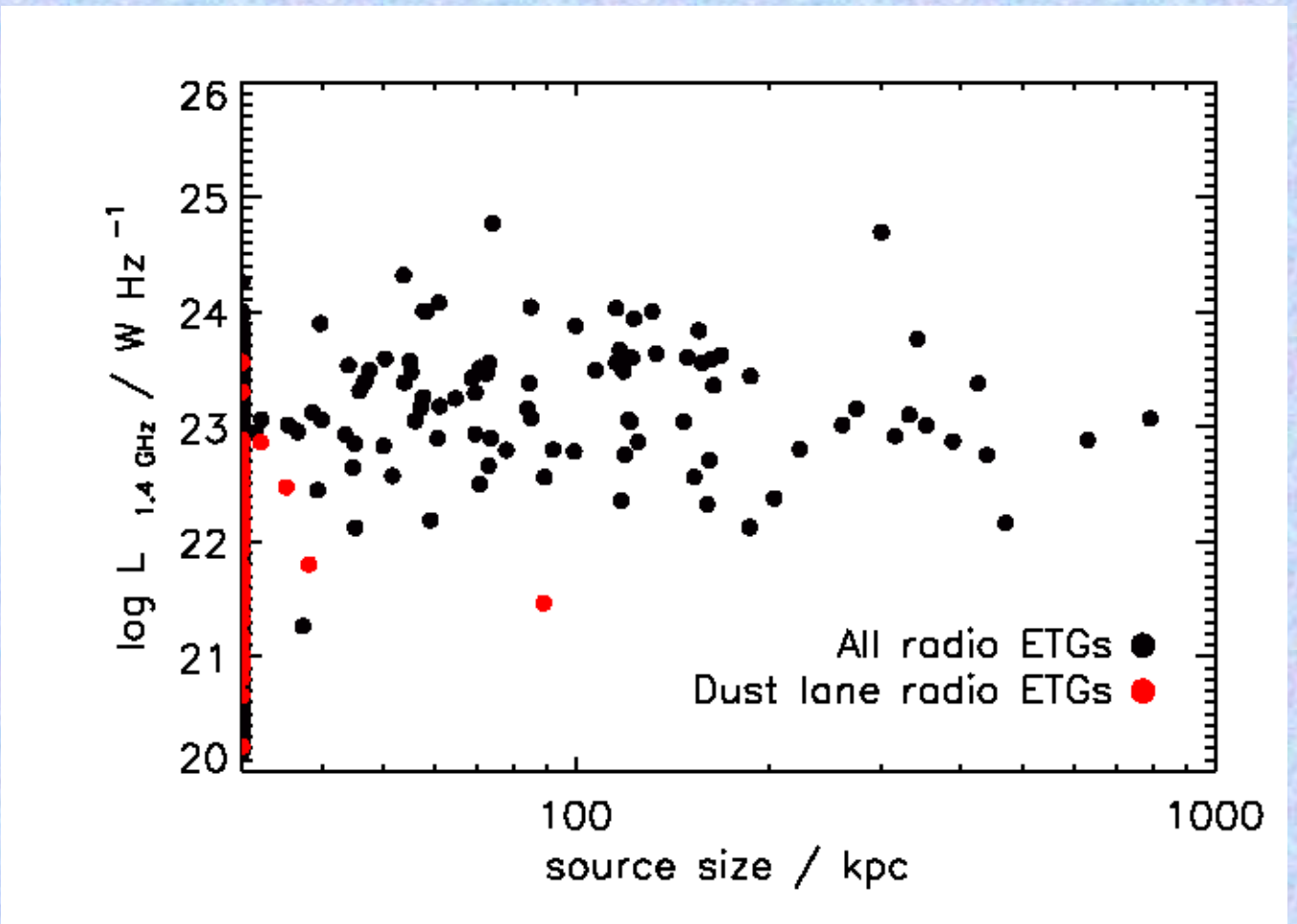


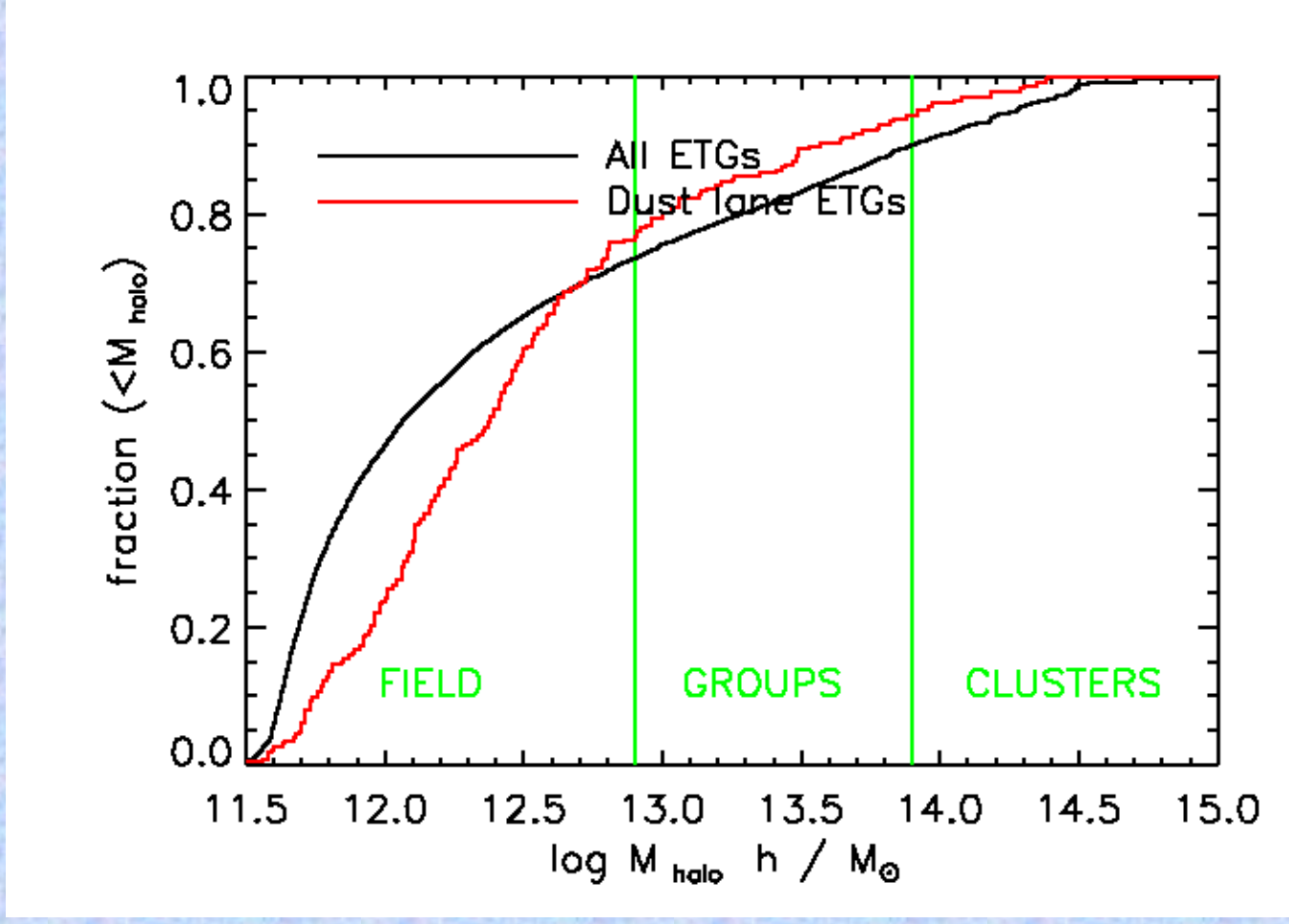
Summary

- Dust lane ETGs are a proxy for gas-rich minor mergers
  - Disturbed morphologies
  - Enhanced star formation and AGN activity
- AGN switches on ~100 Myrs after SF onset
- Star formation ➔ SF+AGN ➔ AGN
- Implications for feedback

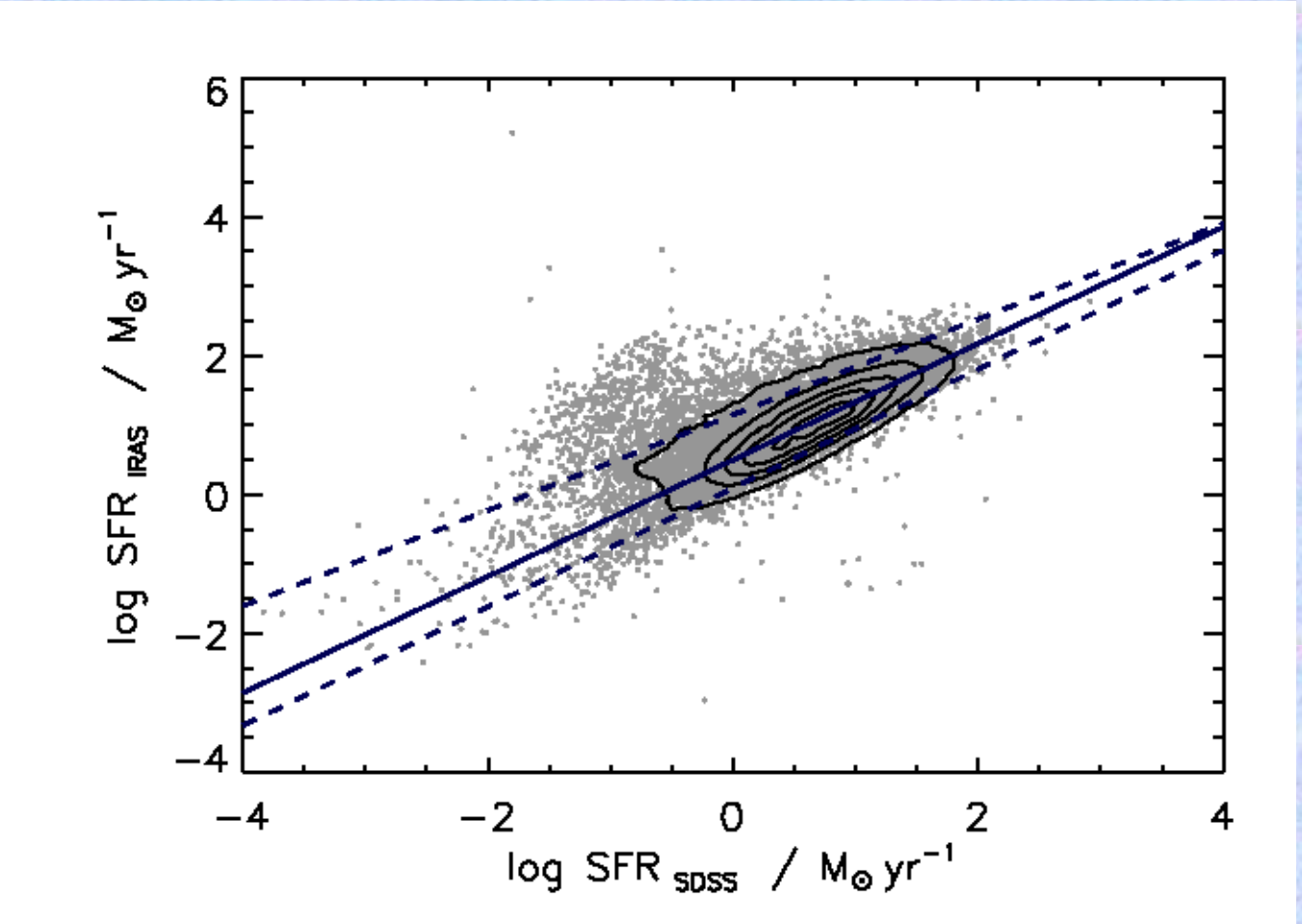
P-D distribution



Environments



Radio AGN identification



Dust fraction