There and back again: pathways to and from the red-sequence for ISM rich ETGs

Timothy A. Davis
Ernest Rutherford Fellow & Lecturer, Cardiff University
with the ATLAS3D, HeViCS/HeFoCS/AlFoCS/H-ATLAS and MASSIVE teams

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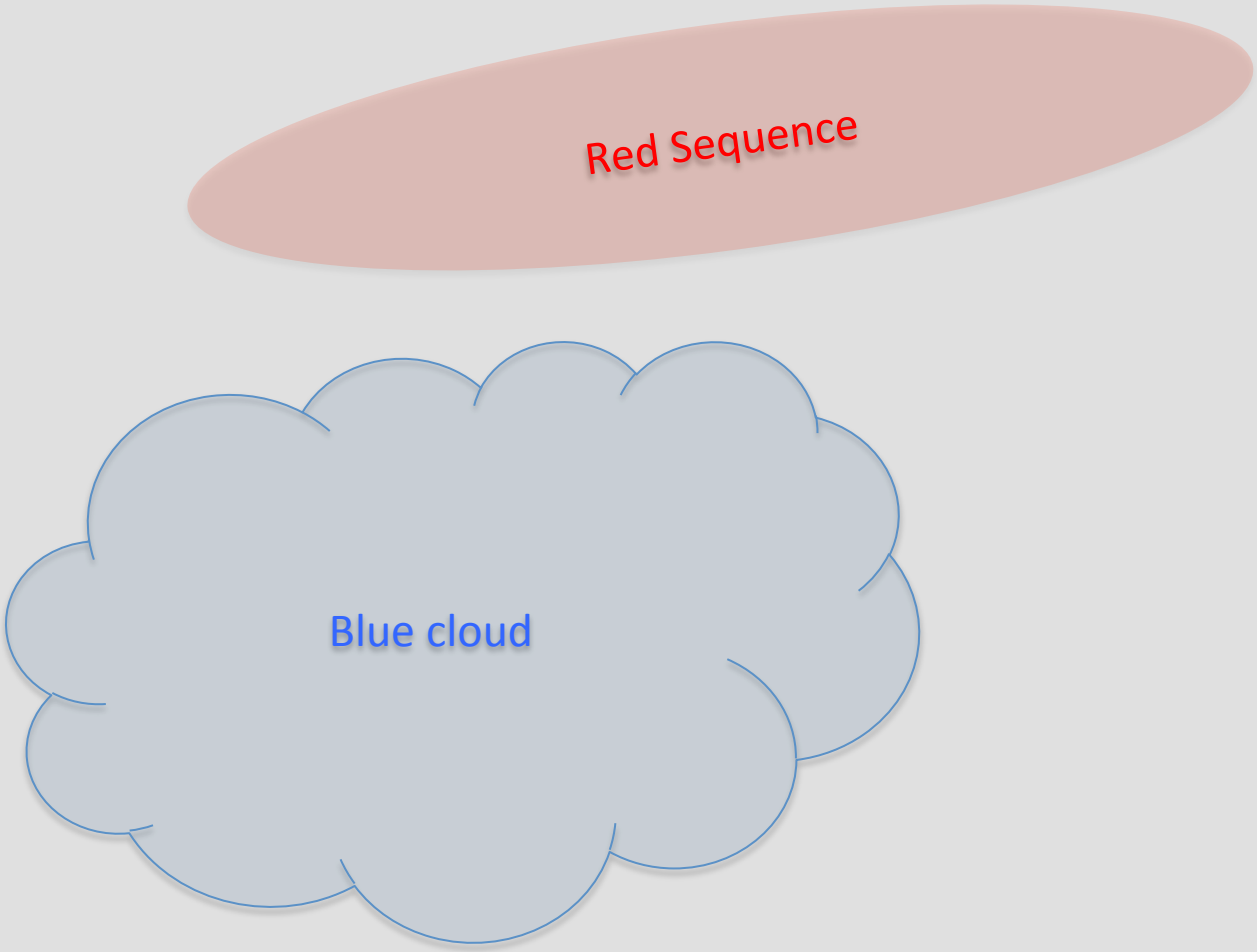
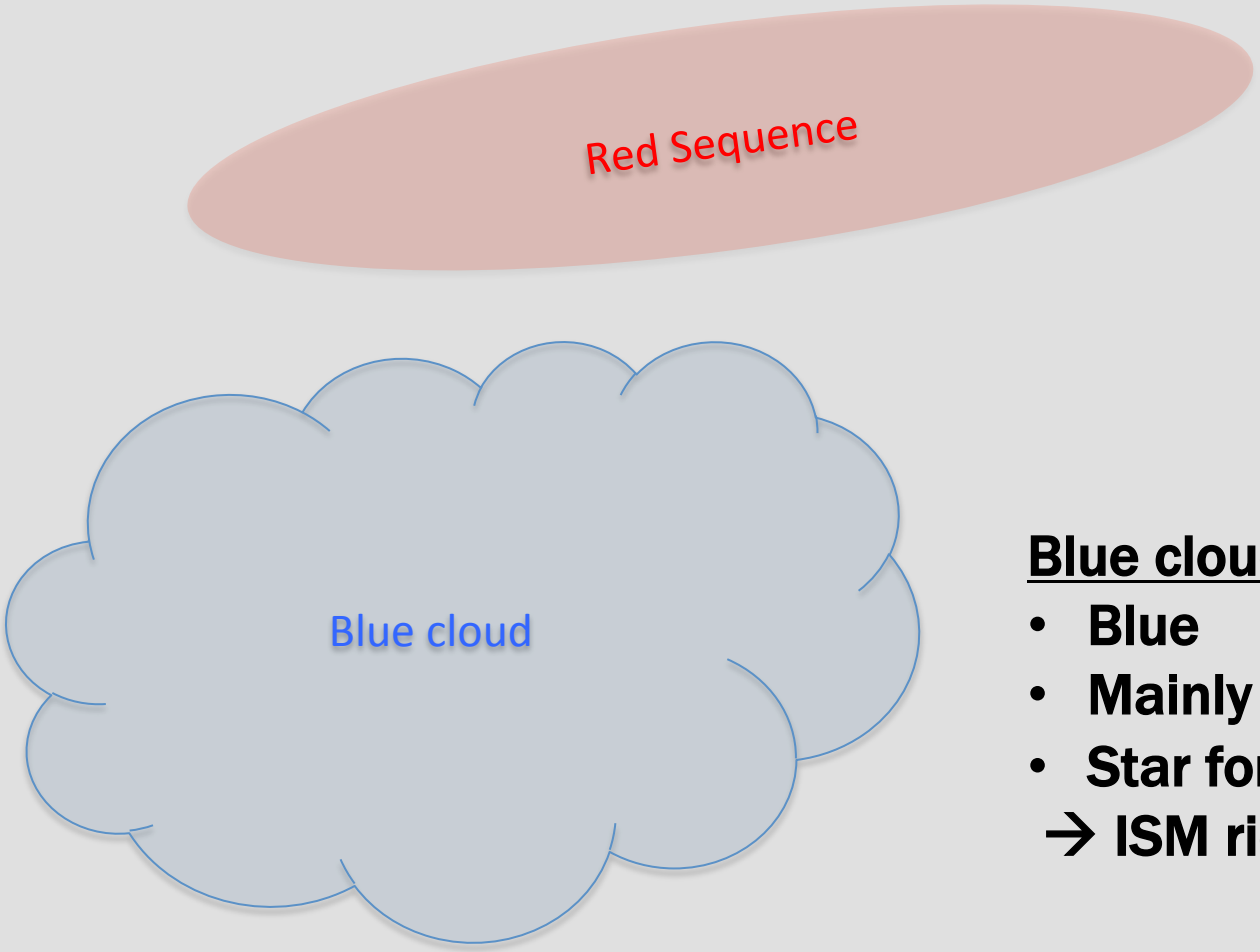
Pathways to and from the red-sequence



Pathways to and from the red-sequence



Blue cloud

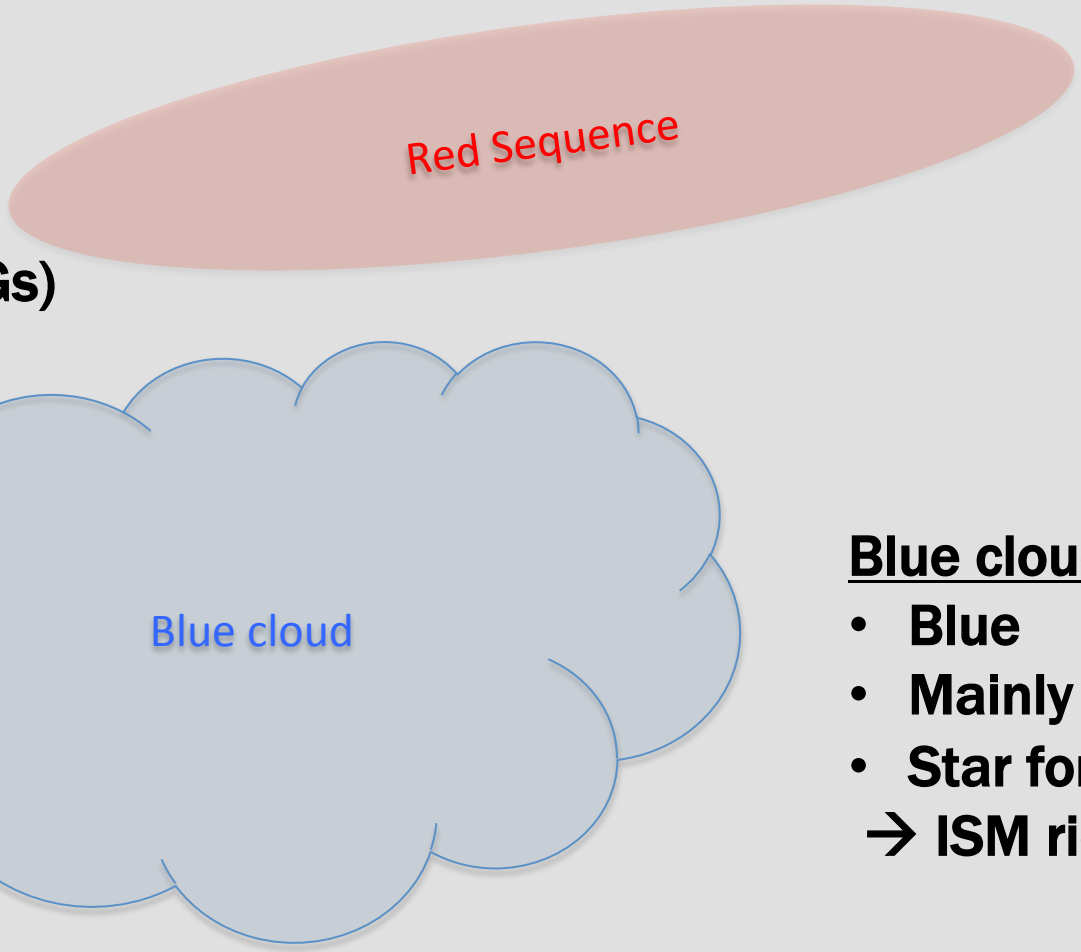
- **Blue**
- **Mainly S/Ir (LTGs)**
- **Star forming**

→ **ISM rich**

Pathways to and from the red-sequence

Red Sequence
- **Red**
- **Mainly E/S0 (ETGs)**
- **Little SF**

→ **ISM poor**



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→ ISM depletion and morphological change are *key*

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S/Ir (LTGs)
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Morphological change?

- or -

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- or -

ISM depletion/removal?

Search for ETGs with an ISM! Are they transitioning?

→ ISM depletion and morphological change are *key*

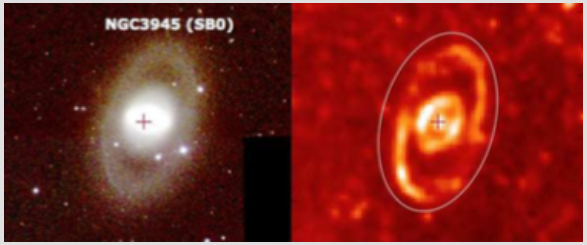
Pathways to and from the red-sequence

More than 40% of early-type galaxies have a cold ISM

Pathways to and from the red-sequence

Dust (abs and emission)
(>40% of ETGS. Upto 10^7 M_{sun})

(e.g. Goudfrooij et al. 1994, Smith et al., 2012, Rowlands et al., 2012…)



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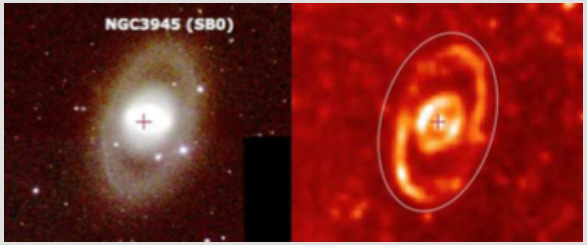
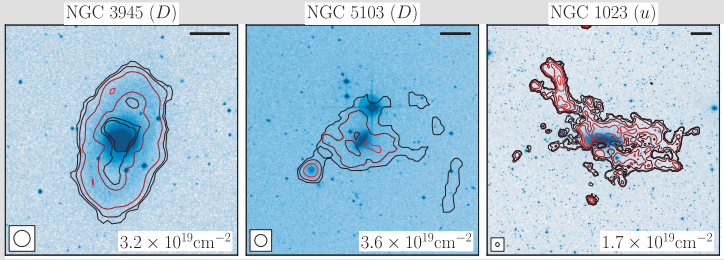


More than 40% of early-type galaxies have a cold ISM

Atomic gas (>40% in the field. Upto 10^{10} M_{sun})



(e.g. Morganti et al., 06, Oosterloo et al., 10, Serra et al., 12...)

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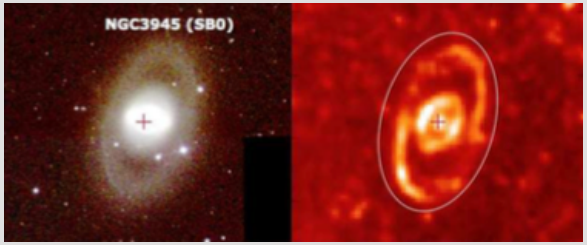

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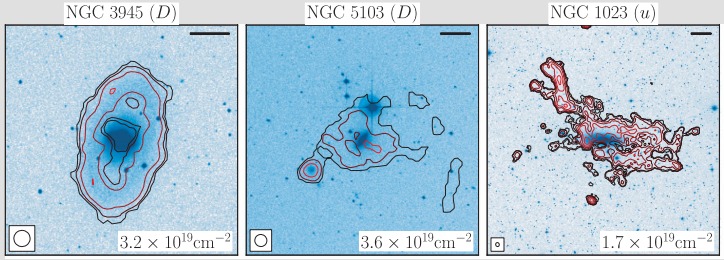
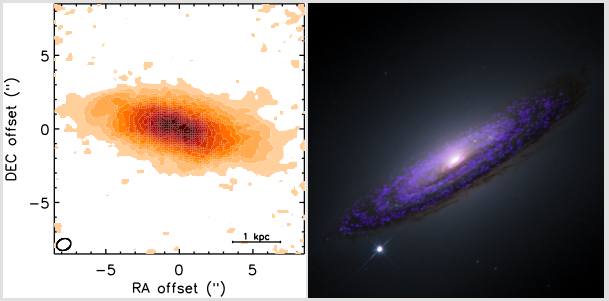


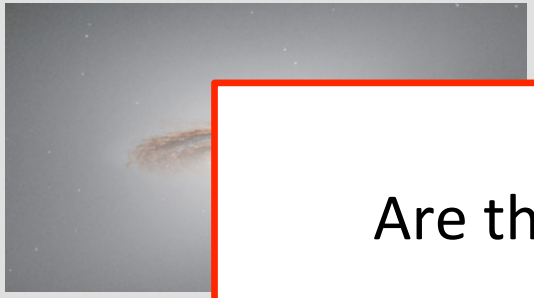
(e.g. Morganti et al., 06, Oosterloo et al., 10, Serra et al., 12...)

Molecular gas (>23% of ETGs. Upto 10^9 M_{sun})

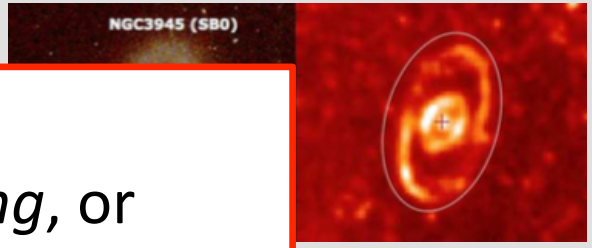


(e.g. Welch & Sage 2003; Young+ 2011, Alatalo+ 2014, Davis+ 2016)

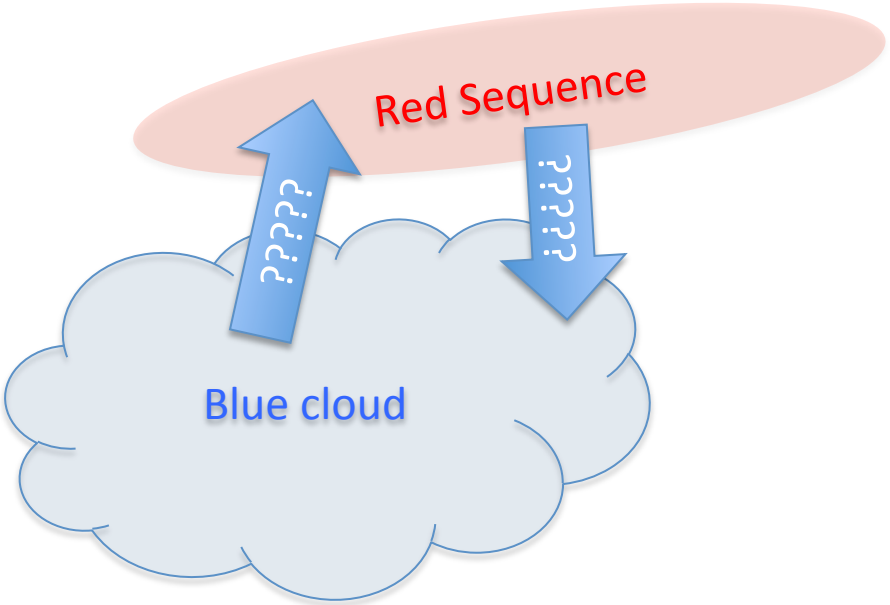
Pathways to and from the red-sequence



Dust (abs and emission)

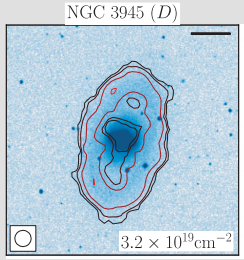


Are these objects *transitioning*, or *regenerating*?



Atomic gas (>40

Gs Upto 10^9 M_{sun})



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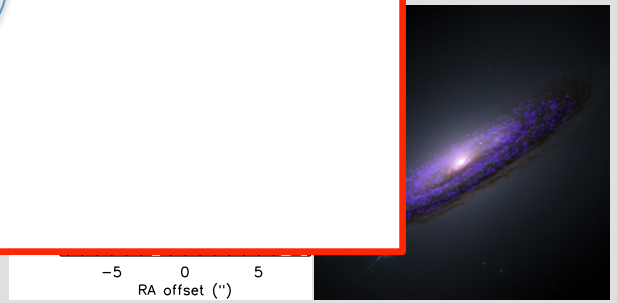
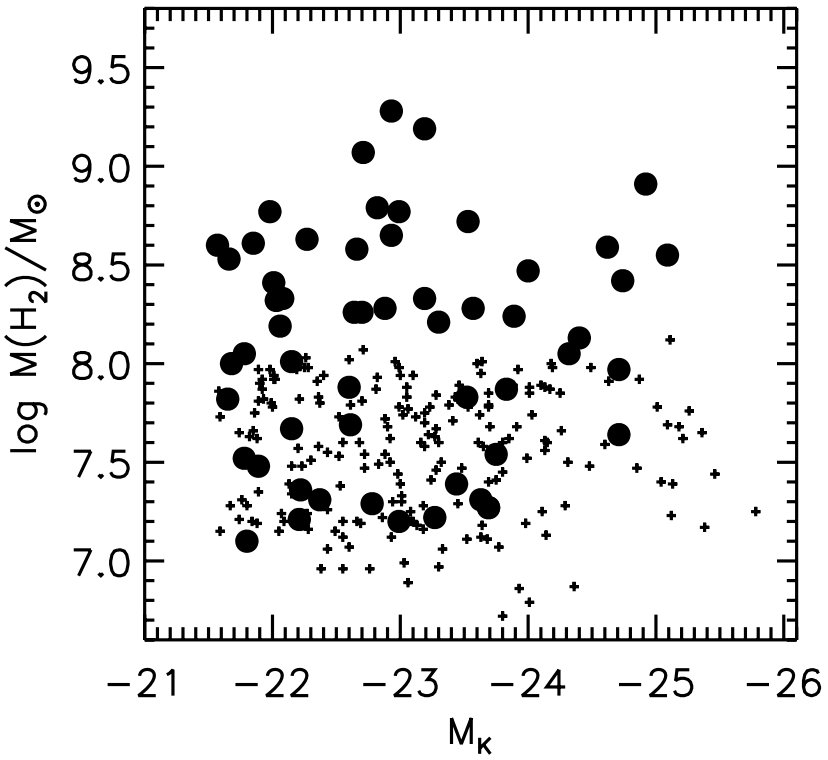


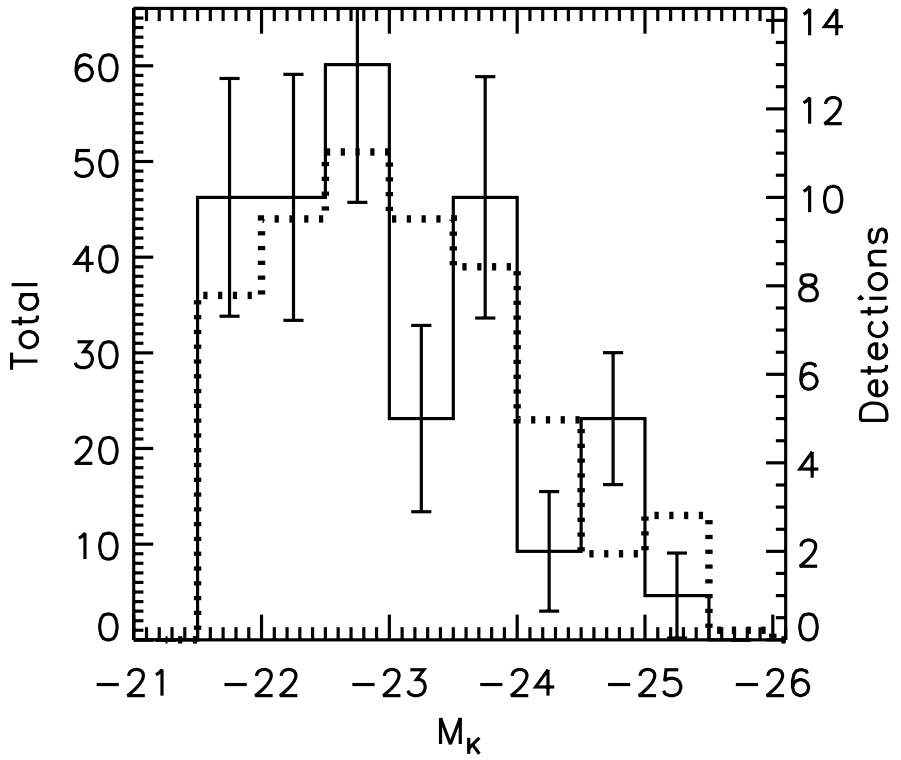
(e.g. Welch & Sage 2003; Young+ 2011, Alatalo+ 2014, Davis+ 2016)

Pathways to and from the red-sequence

First clue: detection fractions

Young et al., 2011



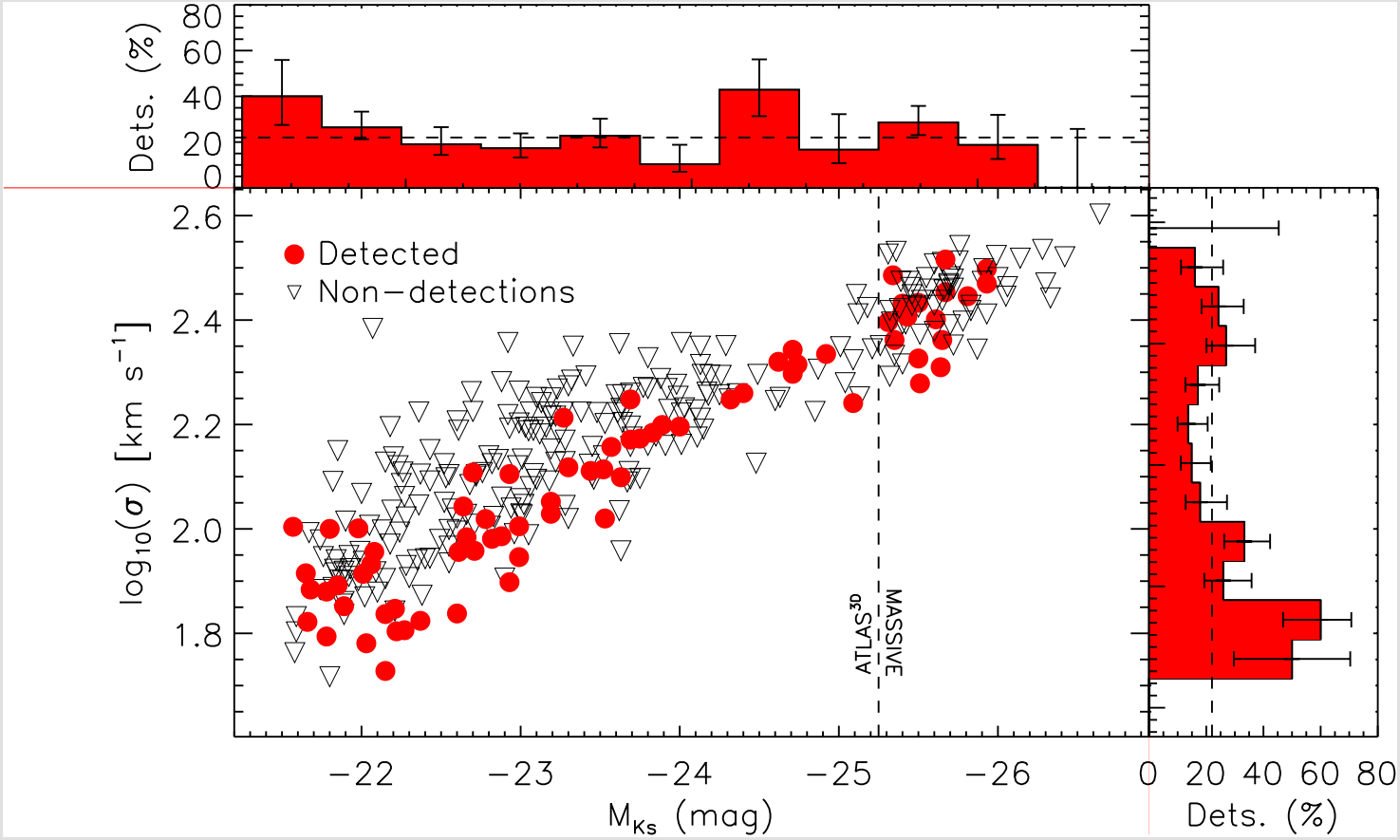


A flat detection rate as a function of mass

Pathways to and from the red-sequence

First clue: detection fractions

MASSIVE survey:
Davis et al., in prep

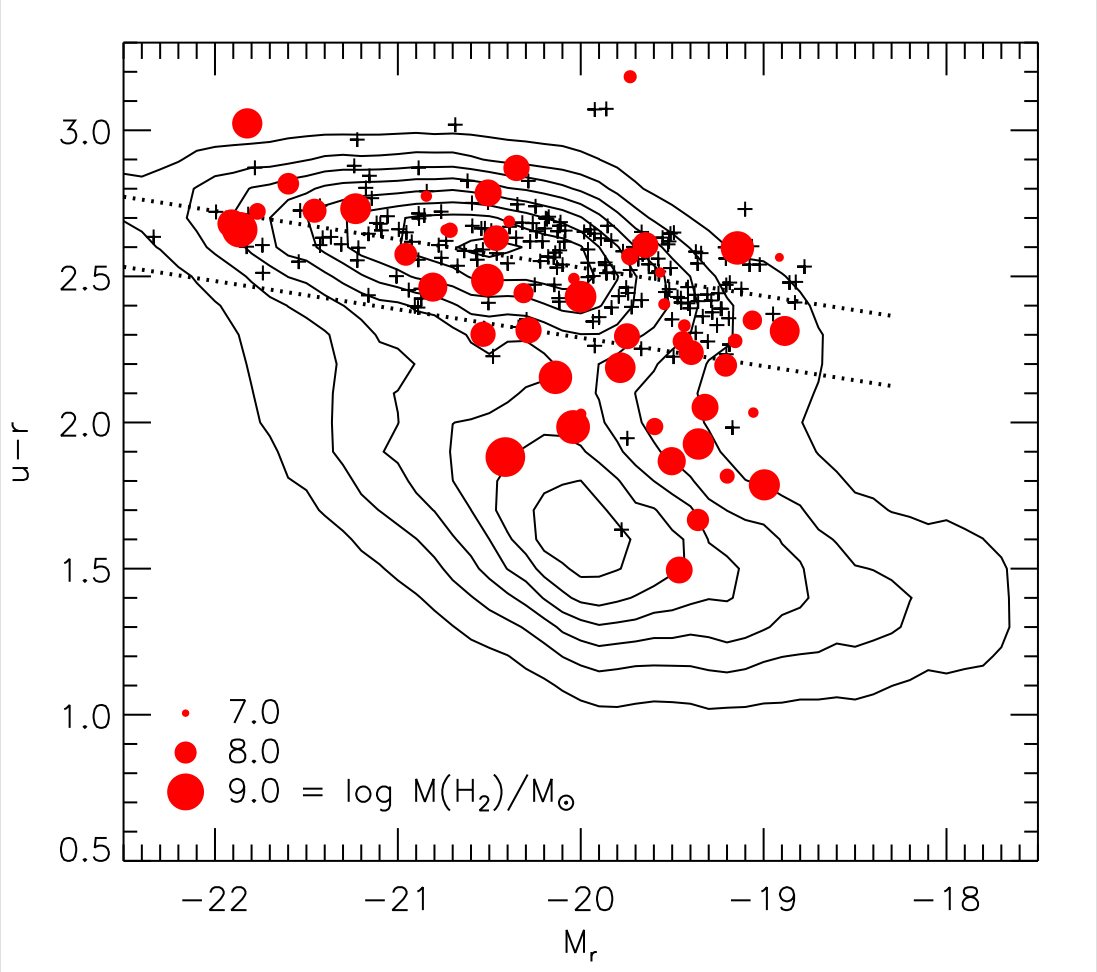


Even at the very highest masses...

Pathways to and from the red-sequence

Even clearer on the CMD:

- Detections lie throughout the red sequence
- Mass fractions also appear randomly distributed
- Not what you would expect for galaxies in transition

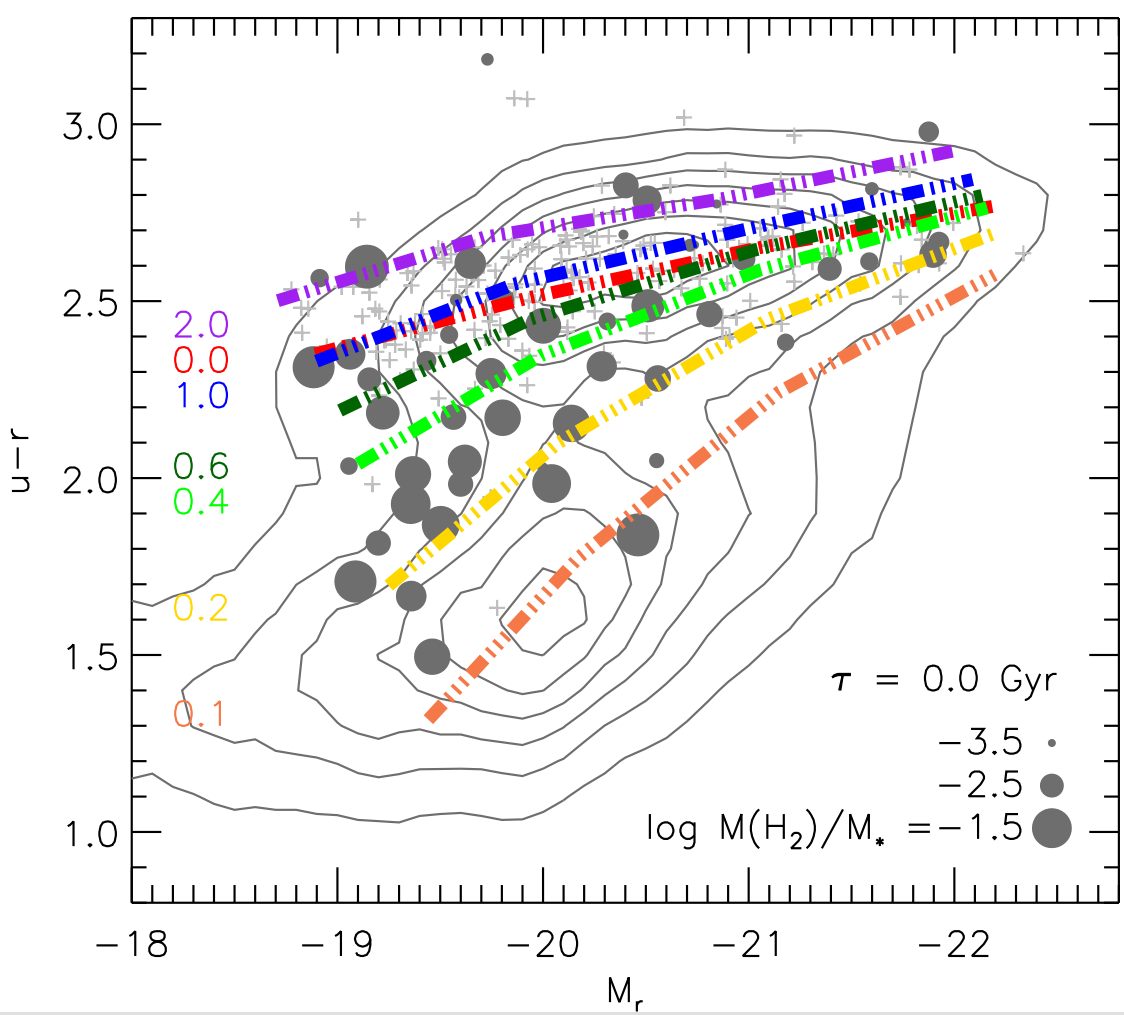


Pathways to and from the red-sequence

What about the blue tail? Are they transition objects?

- Colour distribution entirely consistent with galaxies from the red sequence that have been ***regenerated***

→ Whatever mechanism keeps galaxies quiescent has *failed* in up to 40% of cases…



Young et al., 2014

Pathways to and from the red-sequence

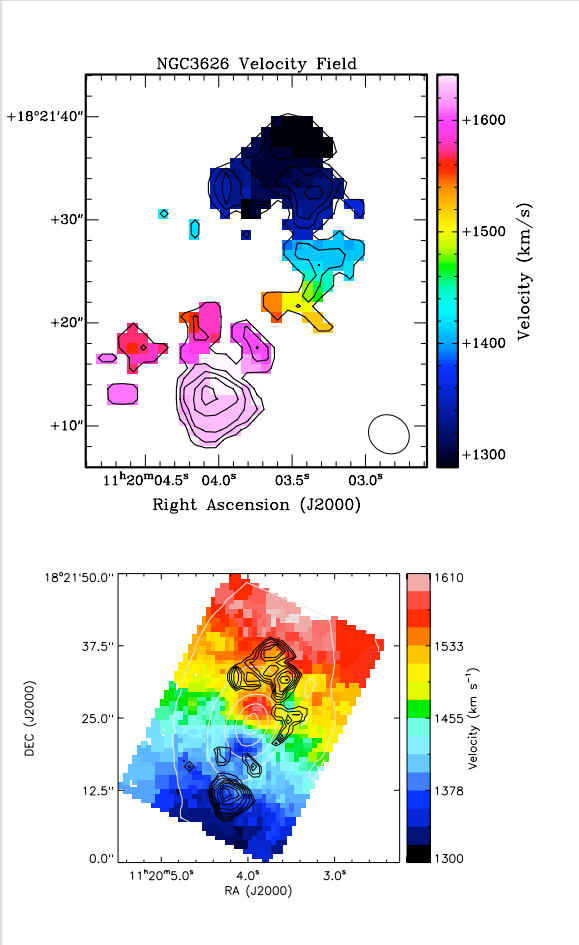
Colours are not the only evidence of regeneration...

Observationally:

- Gas accretion dominates in field environments

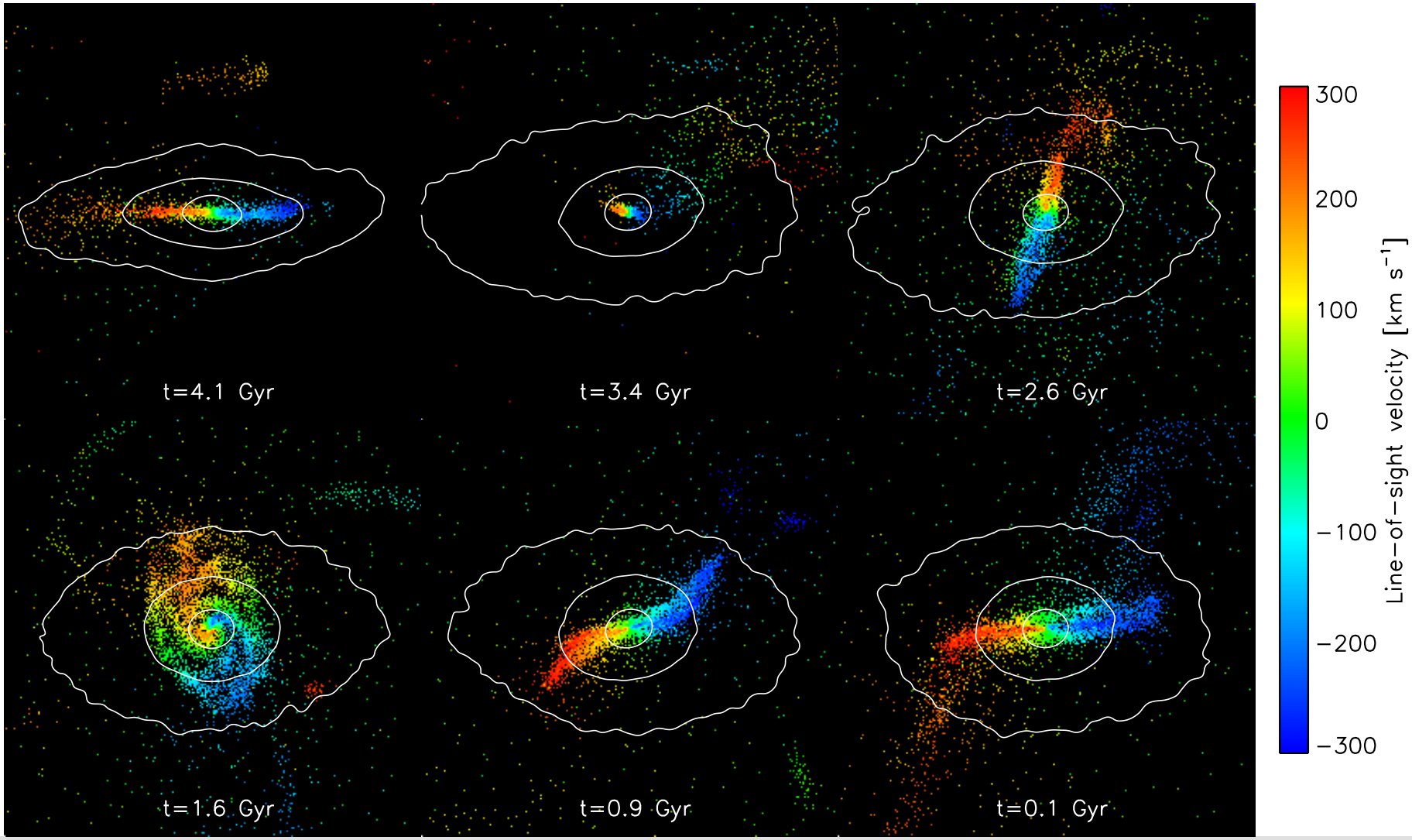
  → Misaligned gas kinematics

  (Davis+11b, van de Voort et al., 15, Davis & Bureau 16)



Davis+11b

Pathways to and from the red-sequence



van de Voort et al., 15

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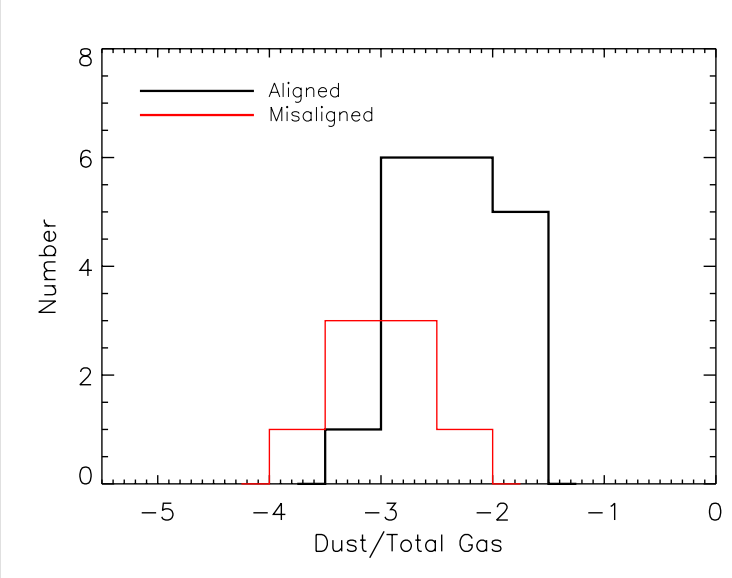

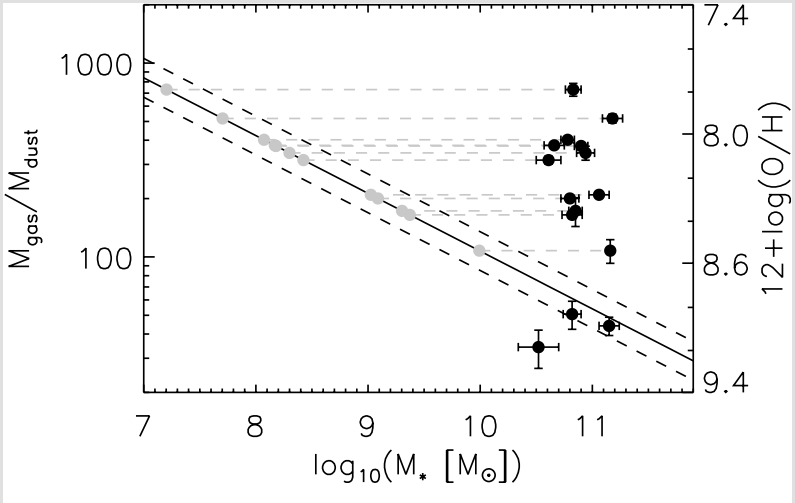

Davis+15

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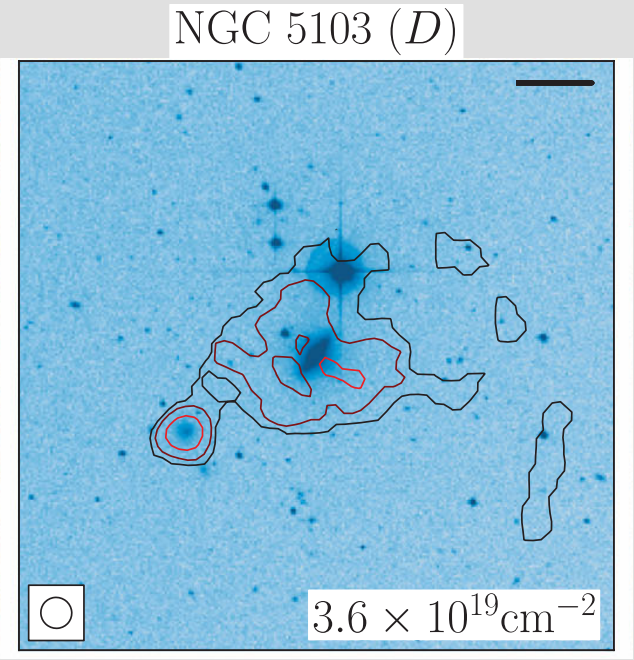
  - → HI accretion from environment visible
    (e.g. Oosterloo et al., 10)



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  → HI accretion from environment visible
  (e.g. Oosterloo et al., 10)

  → Shells, tidal streams etc on deep images
  (e.g. Duc et al., 2012, 2014)

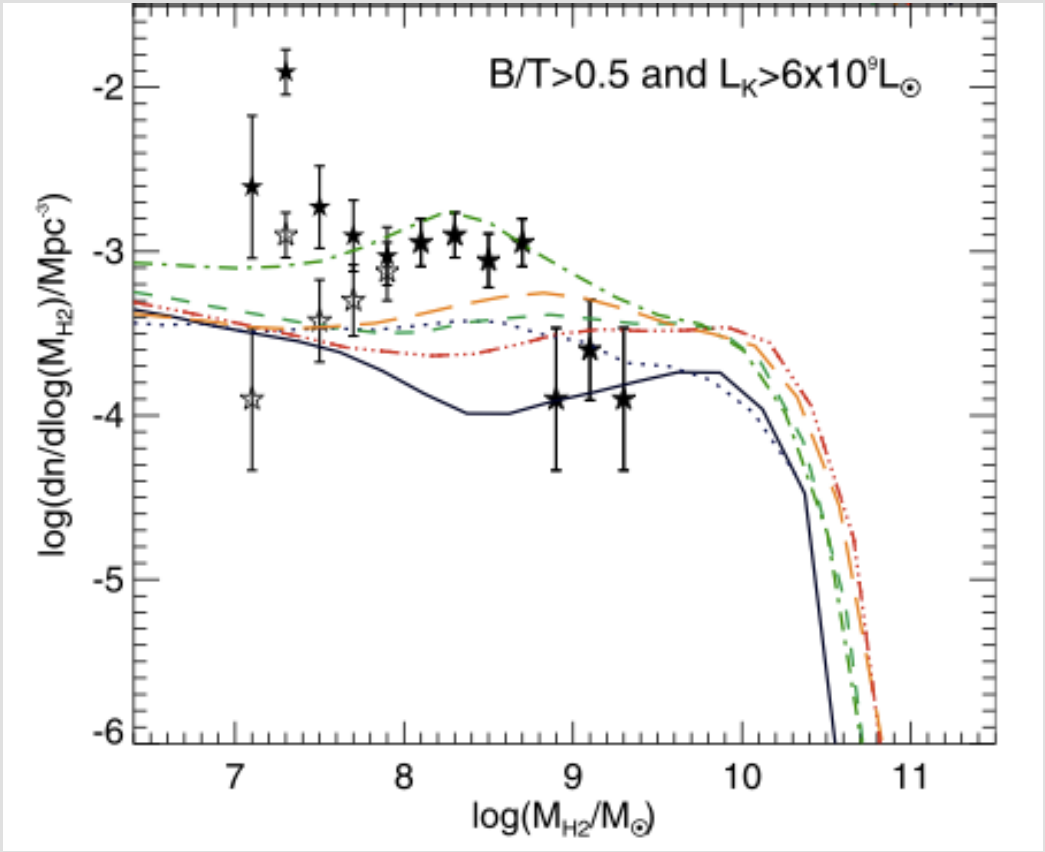
Pathways to and from the red-sequence

Colours are not the only evidence of regeneration...

Theoretically:

- Semi Analytic models can match well the HI/H2 mass function and gas mass fractions of ETGs

→ Tracing back in time show the majority of these objects are regenerated



(Lagos, Davis et al., 14a,b)

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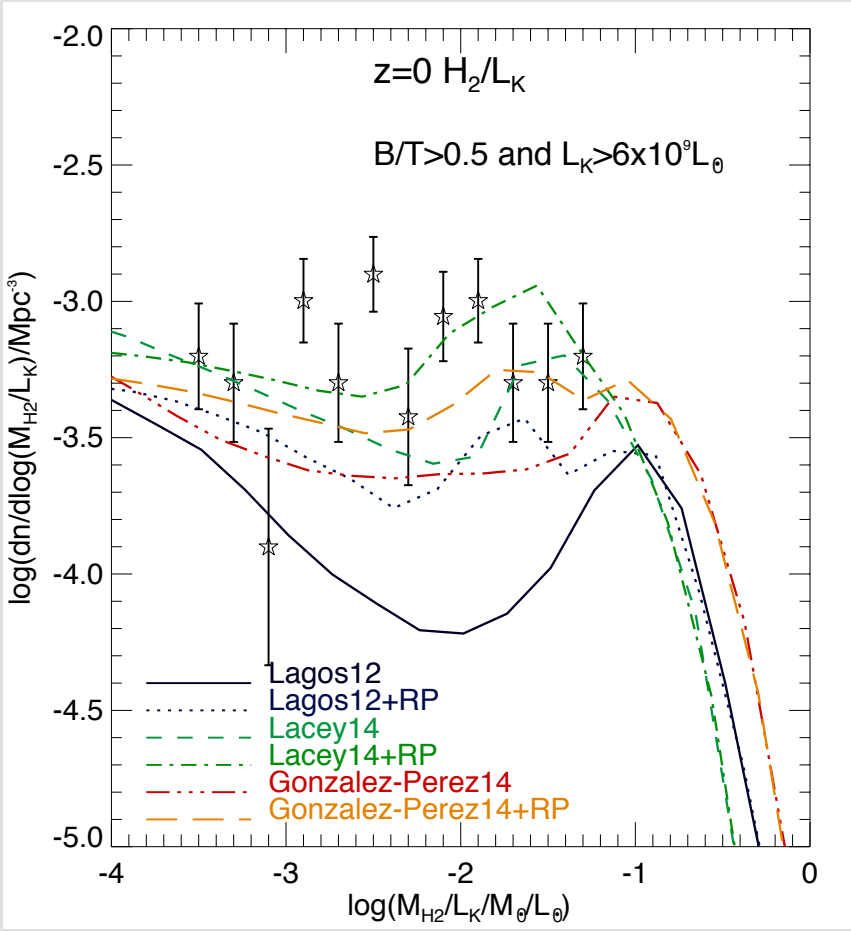

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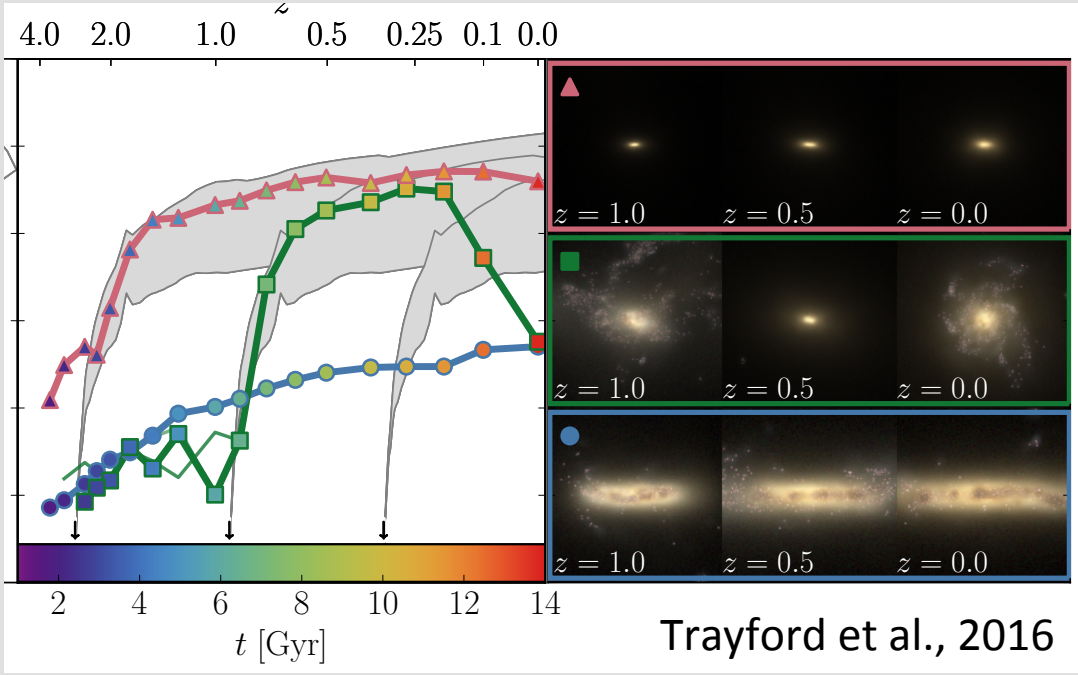
Hydro: EAGLE shows >15% of galaxies transforming in colour are regenerating



Trayford et al., 2016

Pathways to and from the red-sequence

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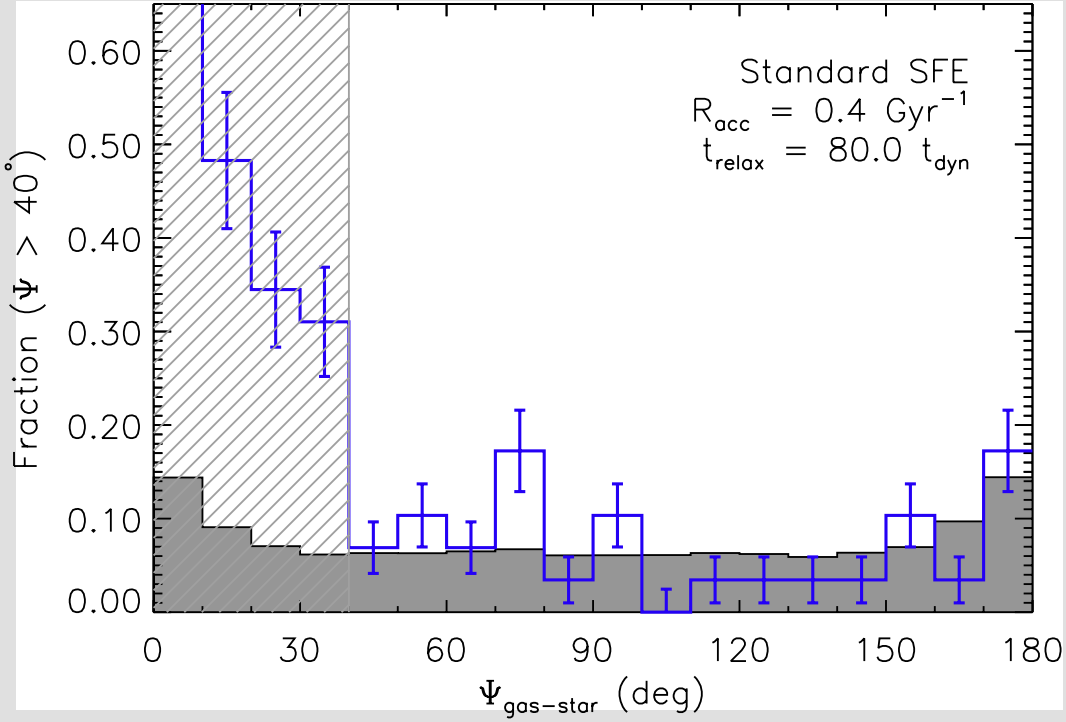
Analytically: rates of gas detection and misalignments consistent with expectation from LCDM *minor* merger rates (Davis & Bureau 2016)



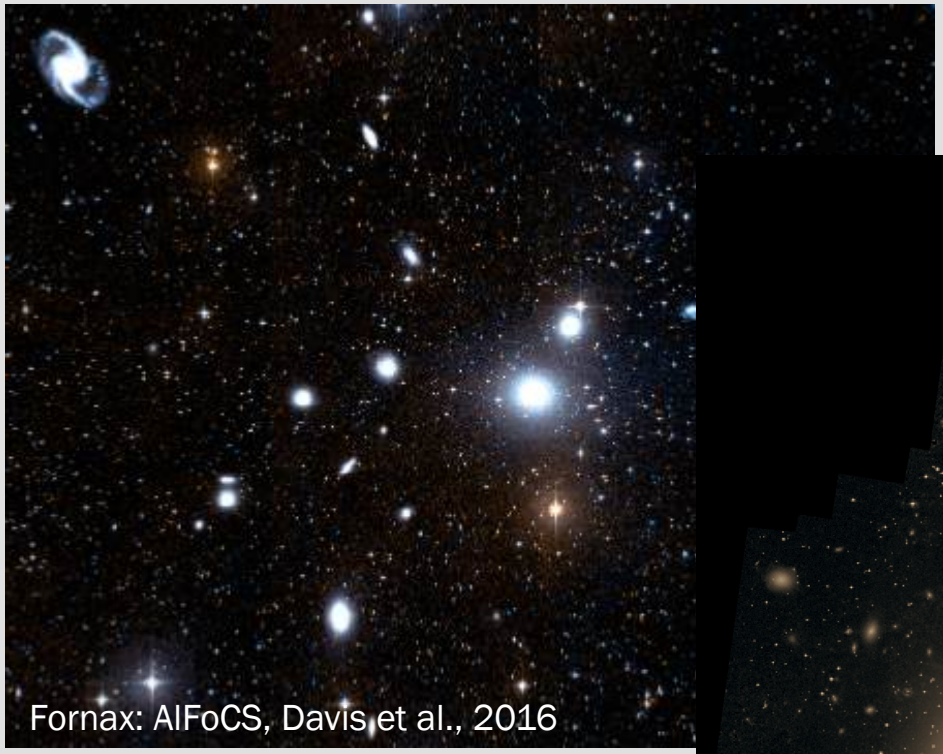
Pathways to and from the red-sequence

So are gas rich ETGs a write off?

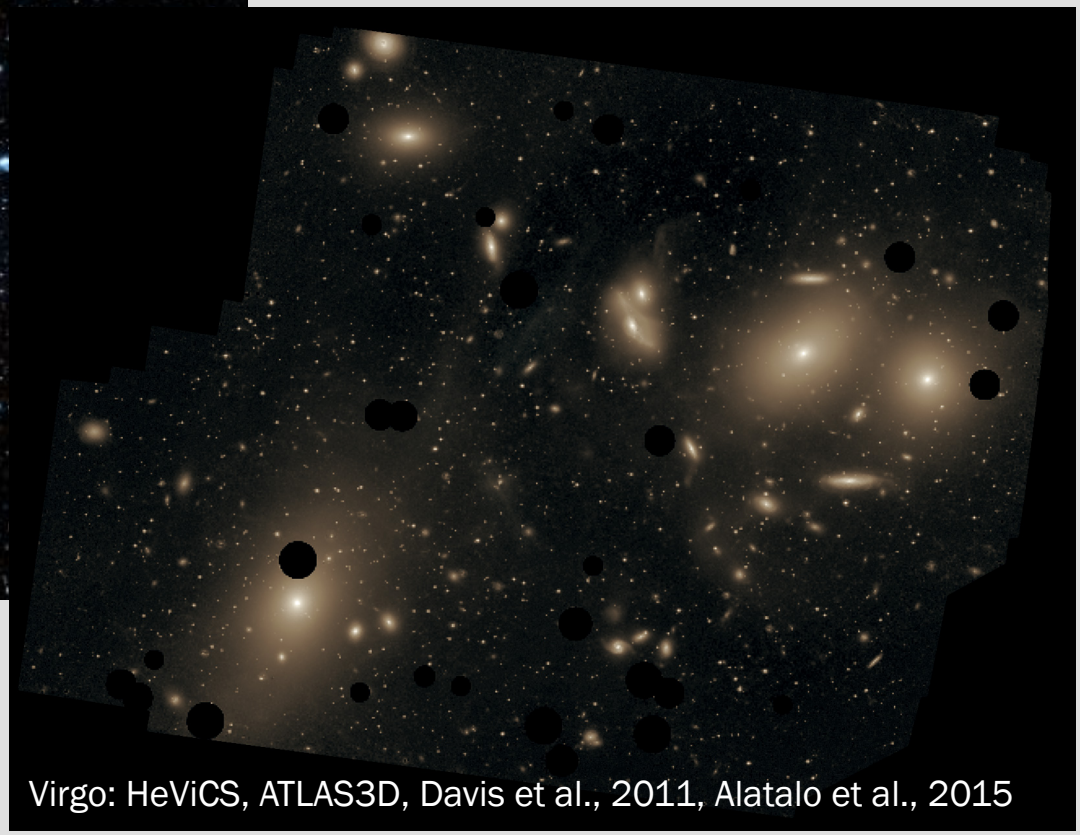
(e.g. does ISM depletion always seem to happen before morphology transformation?)

Pathways to and from the red-sequence

Not so fast: Clusters may be the place to look!



Fornax: AIFoCS, Davis et al., 2016



Virgo: HeViCS, ATLAS3D, Davis et al., 2011, Alatalo et al., 2015

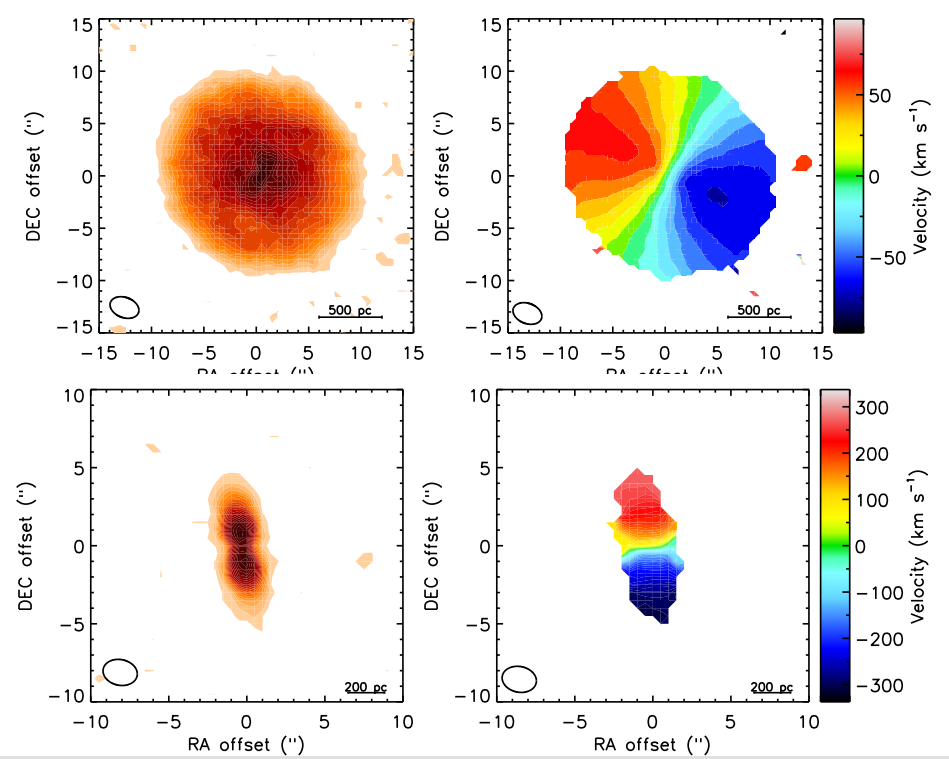
Pathways to and from the red-sequence

Not so fast: Clusters may be the place to look!

Gas rich cluster ETGs all have:

- Relaxed, aligned gas kinematics
- High gas metallicites
- No easy way to accrete gas and merge…

→ Environment perhaps can change morphology before removing all molecular gas?



The ALMA Fornax Cluster Survey (AlFoCS – Davis et al., in prep)

Pathways to and from the red-sequence

1. Gas rich early-type galaxies in field environments: are mostly regenerated objects, on a short term trip there and back again...

2. Suggests that usually gas depletion is first, before morphological change

3. Clusters are our best bet for finding remnant transitioning galaxies with early-type morphologies