GALAXY ZOO

insights into galaxy evolution from a million morphologies

Steven Bamford

University of Nottingham

Chris Lintott, Kevin Schawinski, Kate Land, Anze Slosar, Daniel Thomas, Bob Nichol, Ramin Skibba, Jim Cresswell, Will Percival, Ivan Baldry, Mehri Torki, Chris Miller, Alex Slazay, Jordan Raddick, Edd Edmondson, Jan van den Berg, Phil Murray, Daniel Andreescu

Classifications by: Luke Hughes, Marek Pietrzak, P. Taylor, Joona Mononen, Mike Moore, Kaluzny Olivier, Alice-Amanda Kay, Anna Trela, Randall Buck, Joe D. Reed, Jr, Oscar van de Leur, Sansha Johnson, Mark Watts and many more…

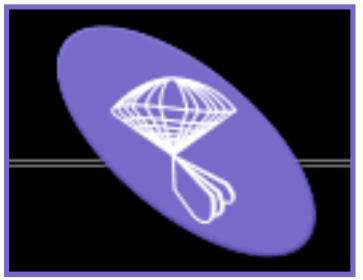

astro-ph/0903.5377

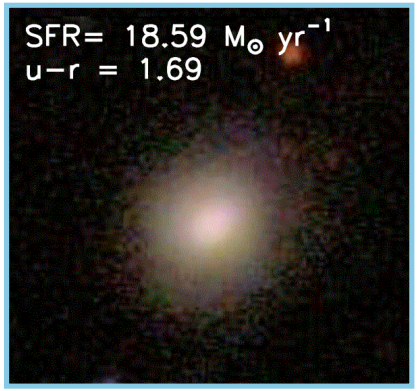
Outline

- Brief overview of the Galaxy Zoo project
- Morphology bias corrections and reliability
- Morphology versus environment
  - Stellar mass dependence
  - Comparison with colour
  - Red spirals and blue early-types
  - Why are red spirals red?
- Future directions

Aims of Galaxy Zoo

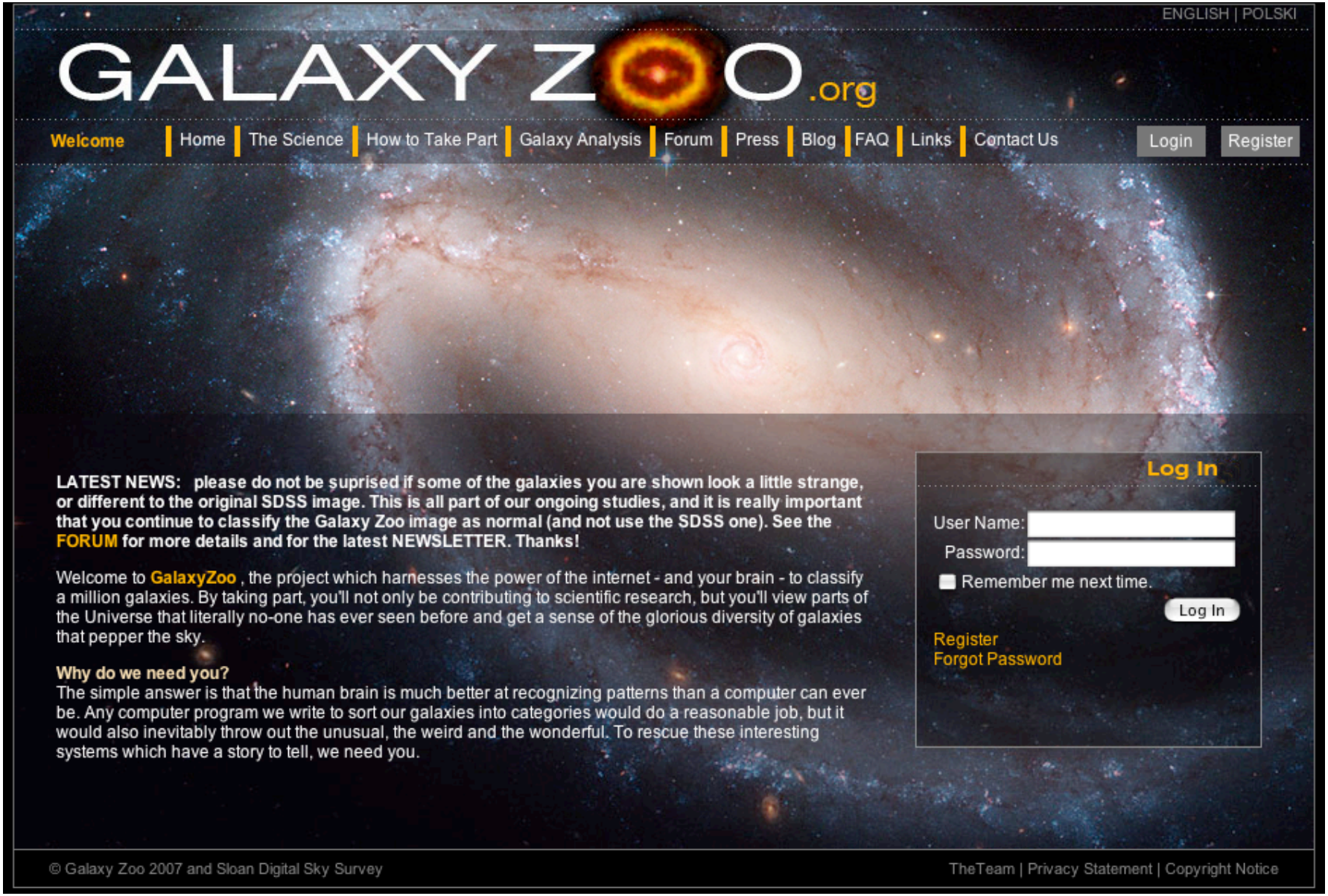
- Visually classify as many objects as possible from SDSS
- Find rare objects
- Cosmology with spiral spins
- Test morphology proxies
- Statistical studies with traditional morphology
- Public outreach





GALAXY ZOO .org

Website


ENGLISH | POLSKI
GALAXY ZOO .org
Welcome
Home
The Science
How to Take Part
Galaxy Analysis
Forum
Press
Blog
FAQ
Links
Contact Us
Login
Register
LATEST NEWS: please do not be suprised if some of the galaxies you are shown look a little strange, or different to the original SDSS image. This is all part of our ongoing studies, and it is really important that you continue to classify the Galaxy Zoo image as normal (and not use the SDSS one). See the FORUM for more details and for the latest NEWSLETTER. Thanks!
Welcome to GalaxyZoo , the project which harnesses the power of the internet - and your brain - to classify a million galaxies. By taking part, you'll not only be contributing to scientific research, but you'll view parts of the Universe that literally no-one has ever seen before and get a sense of the glorious diversity of galaxies that pepper the sky.
Why do we need you?
The simple answer is that the human brain is much better at recognizing patterns than a computer can ever be. Any computer program we write to sort our galaxies into categories would do a reasonable job, but it would also inevitably throw out the unusual, the weird and the wonderful. To rescue these interesting systems which have a story to tell, we need you.
Log In
User Name:
Password:
Remember me next time.
Log In
Register
Forgot Password
© Galaxy Zoo 2007 and Sloan Digital Sky Survey
TheTeam | Privacy Statement | Copyright Notice

Tutorial

Part 1B ... More Tricky Spiral or Elliptical Galaxies

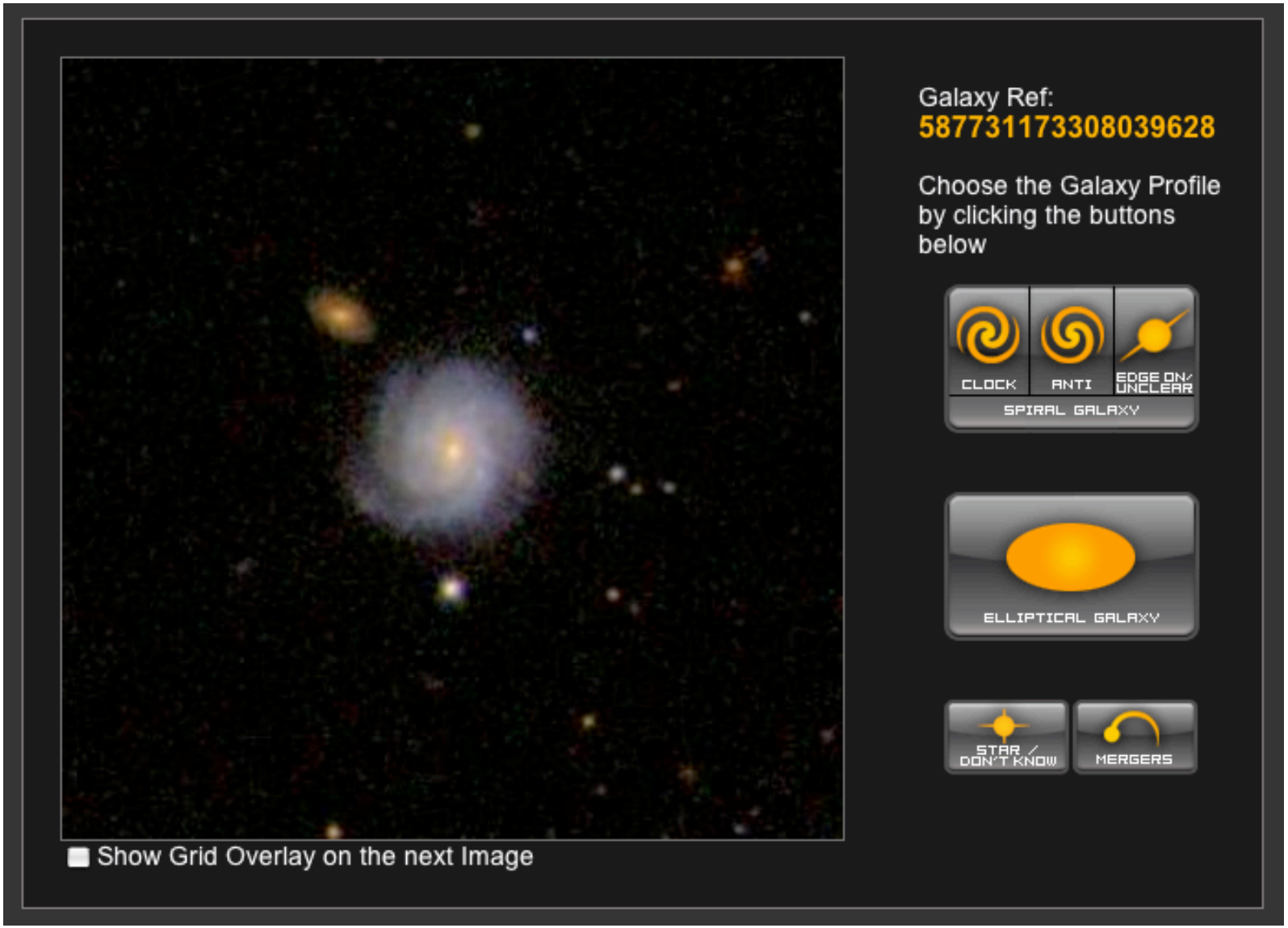
Some galaxies are a bit more tricky. As you noticed in the previous section, some spiral galaxies can look like ellipticals when viewed edge-on. Also, in some faint spiral galaxies, you have to look hard to see the spiral arms. Now, see if you can separate the genuine ellipticals from the spirals.

Try your hands at some!
Click the image to see if you're right.

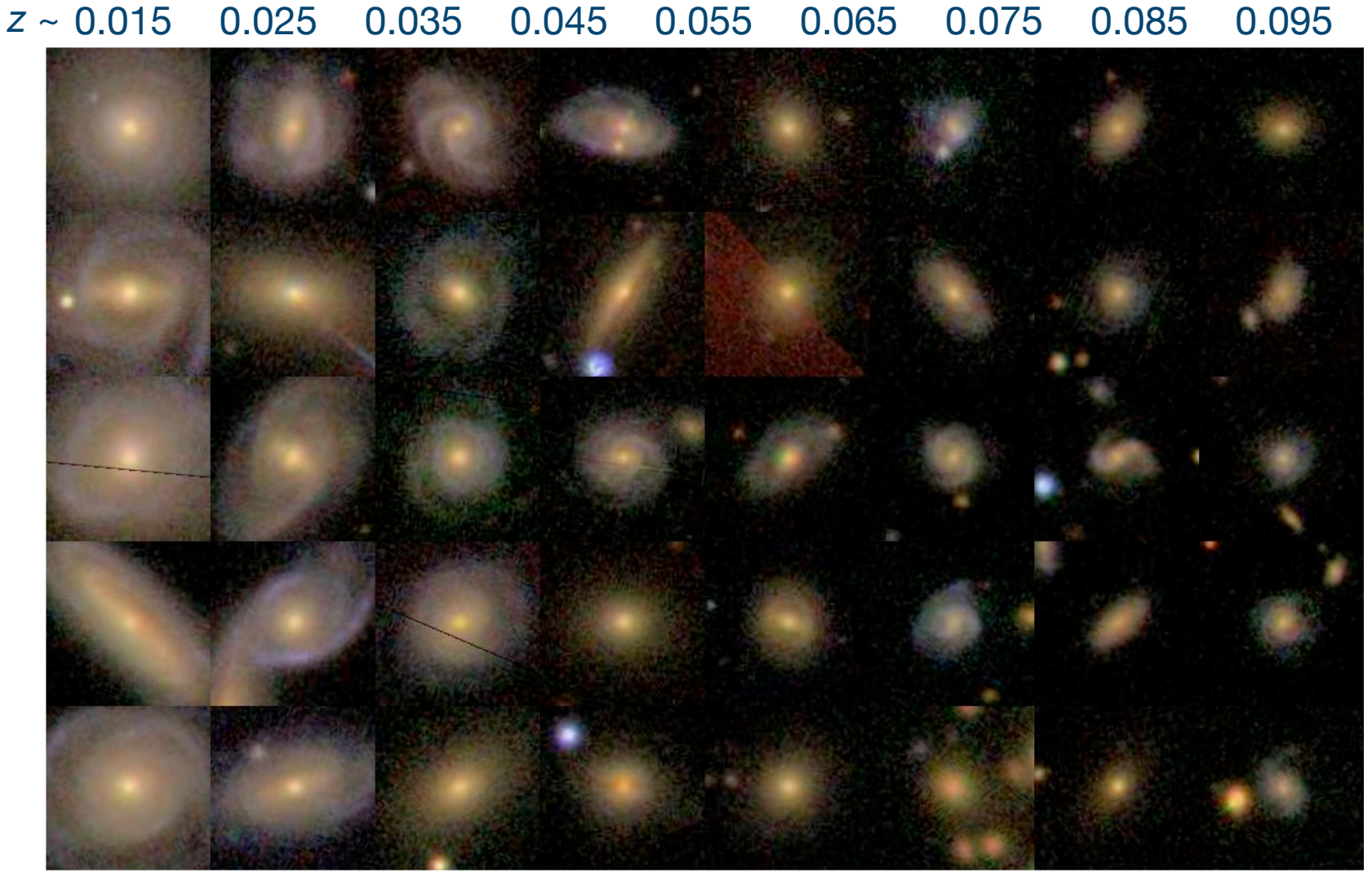
Part 1C ... Merging Galaxies

Sometimes, galaxies crash into each other, or come close. These are called merging galaxies. Merging galaxies are very interesting to astronomers because we think that large galaxies are built from mergers of small galaxies – if we see merging galaxies, we can see a snapshot of how that process happens. When you look for mergers, look for places where two galaxies appear to be merging into one. The galaxies should be close together, and you should be able to see some connection between them. In the trial or in your galaxy analysis, whenever you see this, click the button that says "Mergers".

Analysis

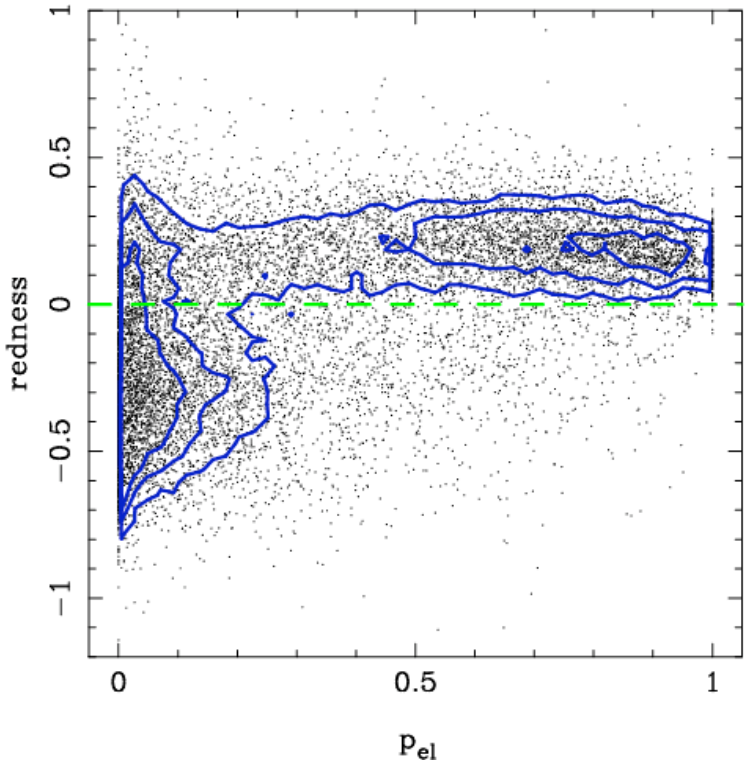

Galaxy Ref:
5877311733080396 28
Choose the Galaxy Profile by clicking the buttons below
CLOCK
ANTI
EDGE ON/ UNCLEAR
SPIRAL GALAXY
ELLIPTICAL GALAXY
STAR / DON'T KNOW
MERGERS
Show Grid Overlay on the next Image

Feasibility



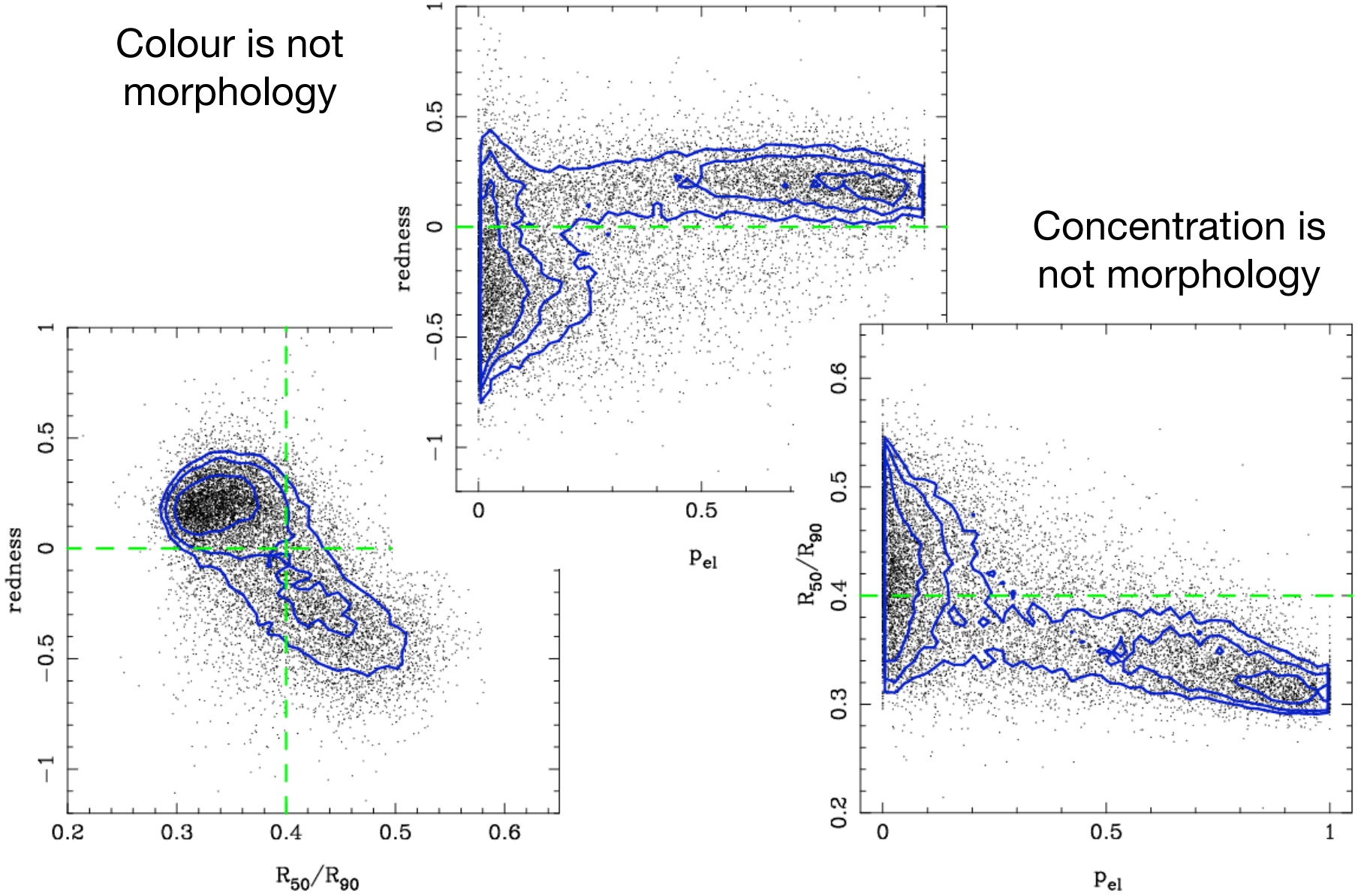
Why bother with visual inspection?

Colour is not morphology



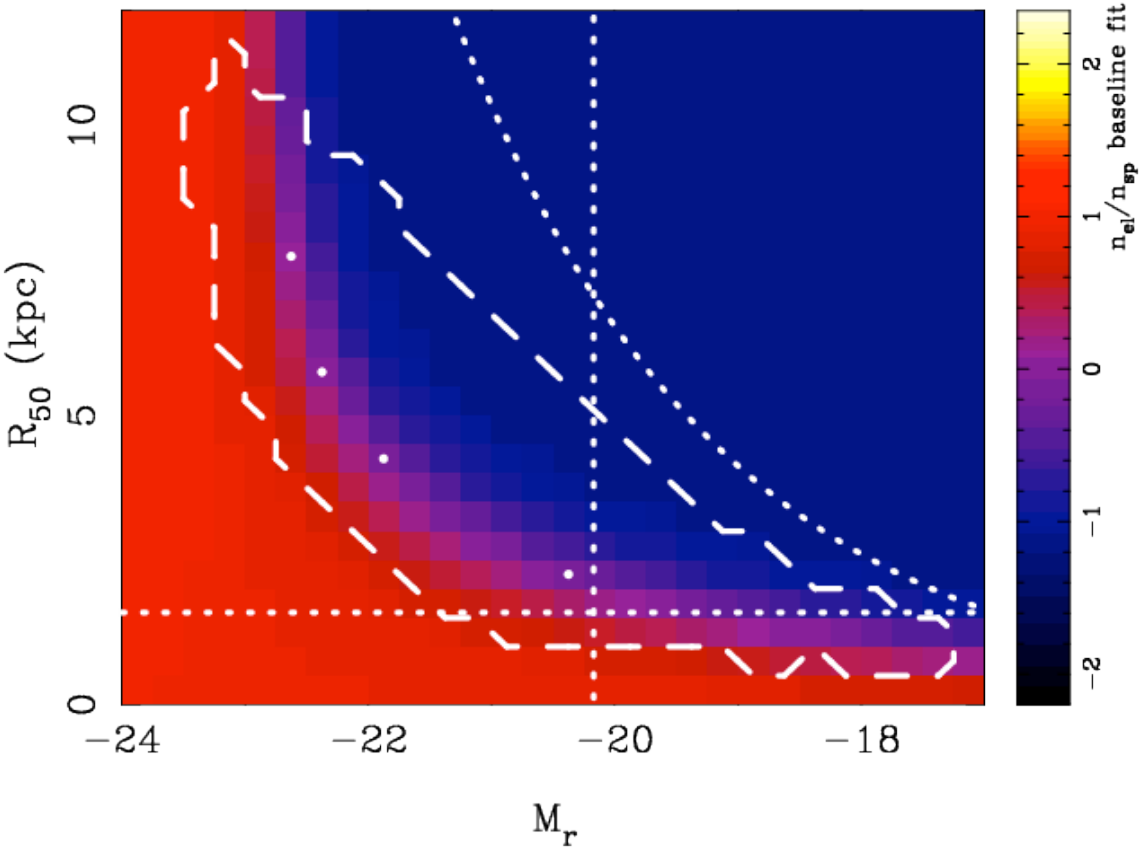
Why bother with visual inspection?

Colour is not morphology

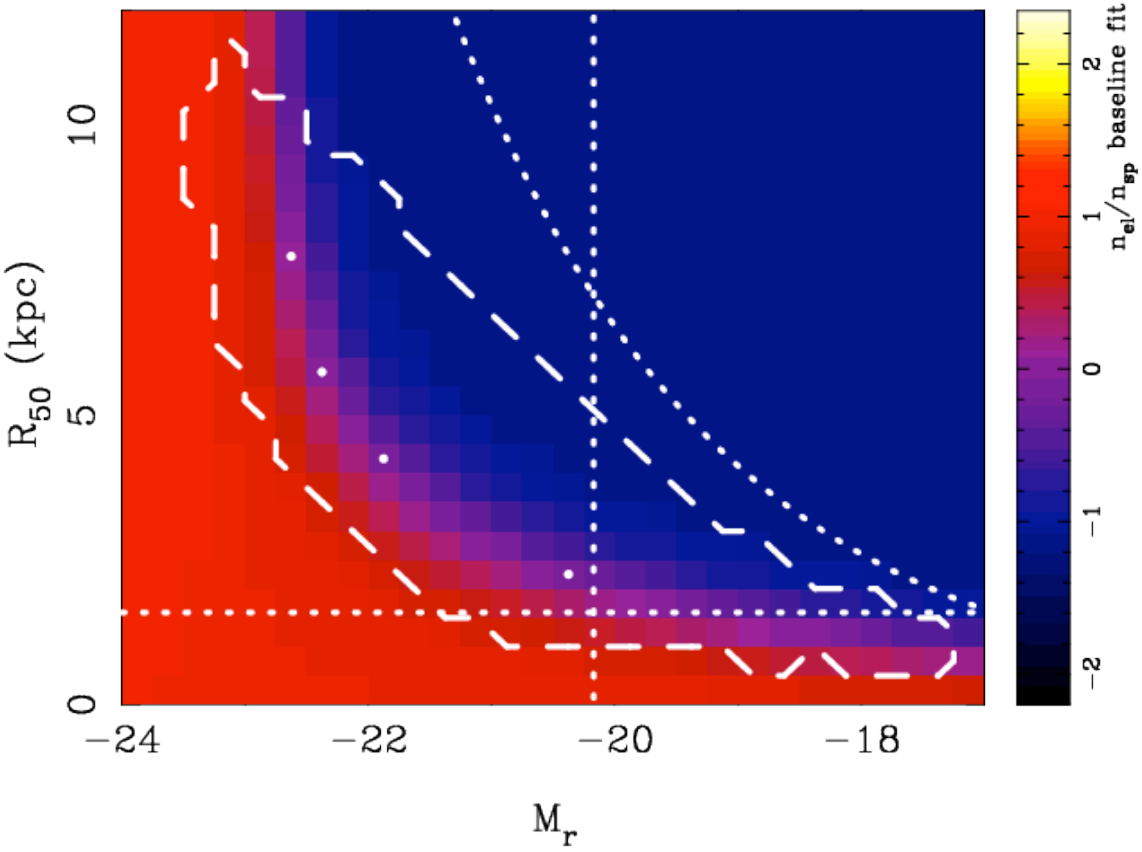


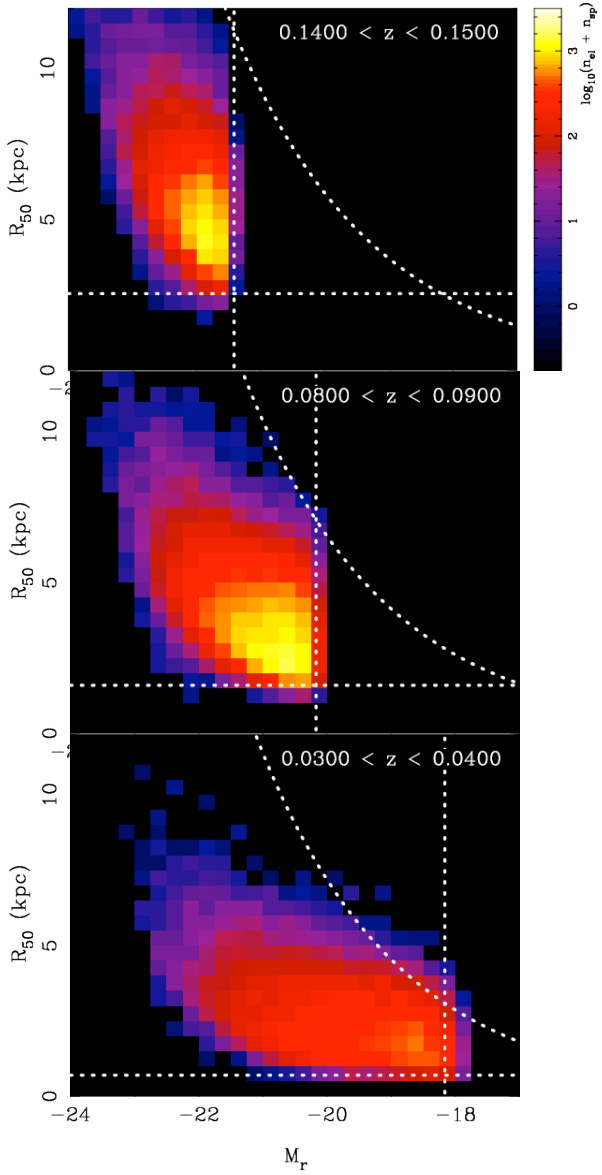
Concentration is not morphology

Morphology versus luminosity and size

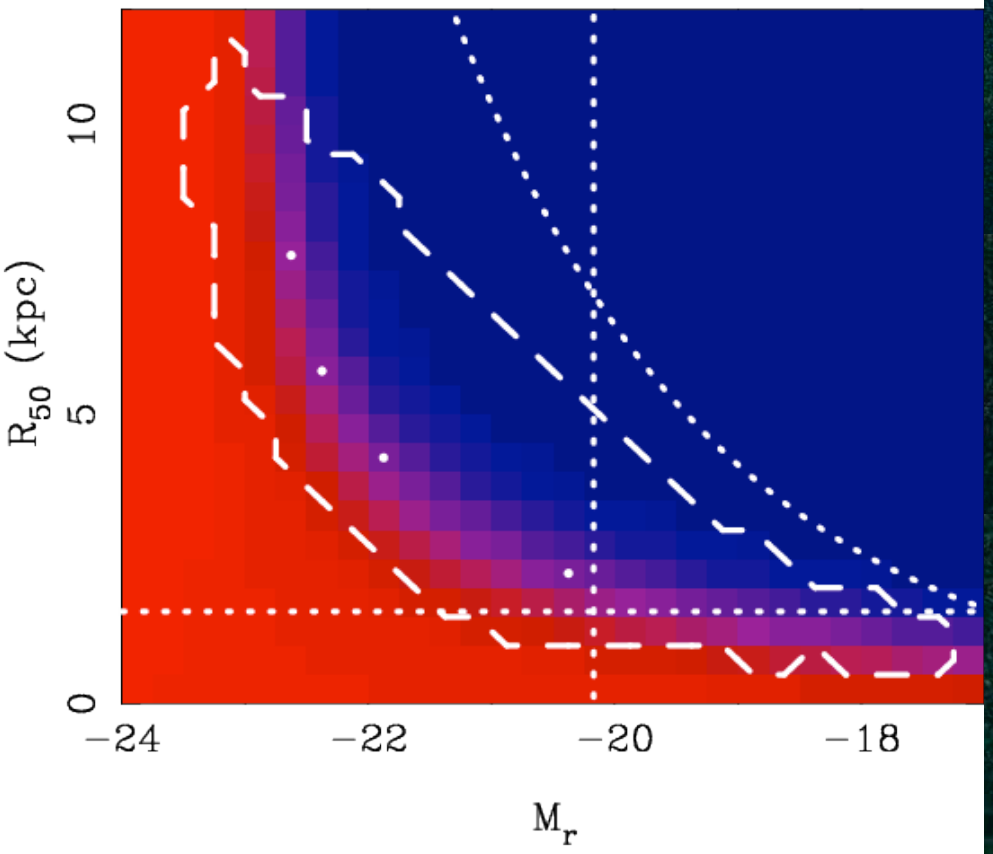


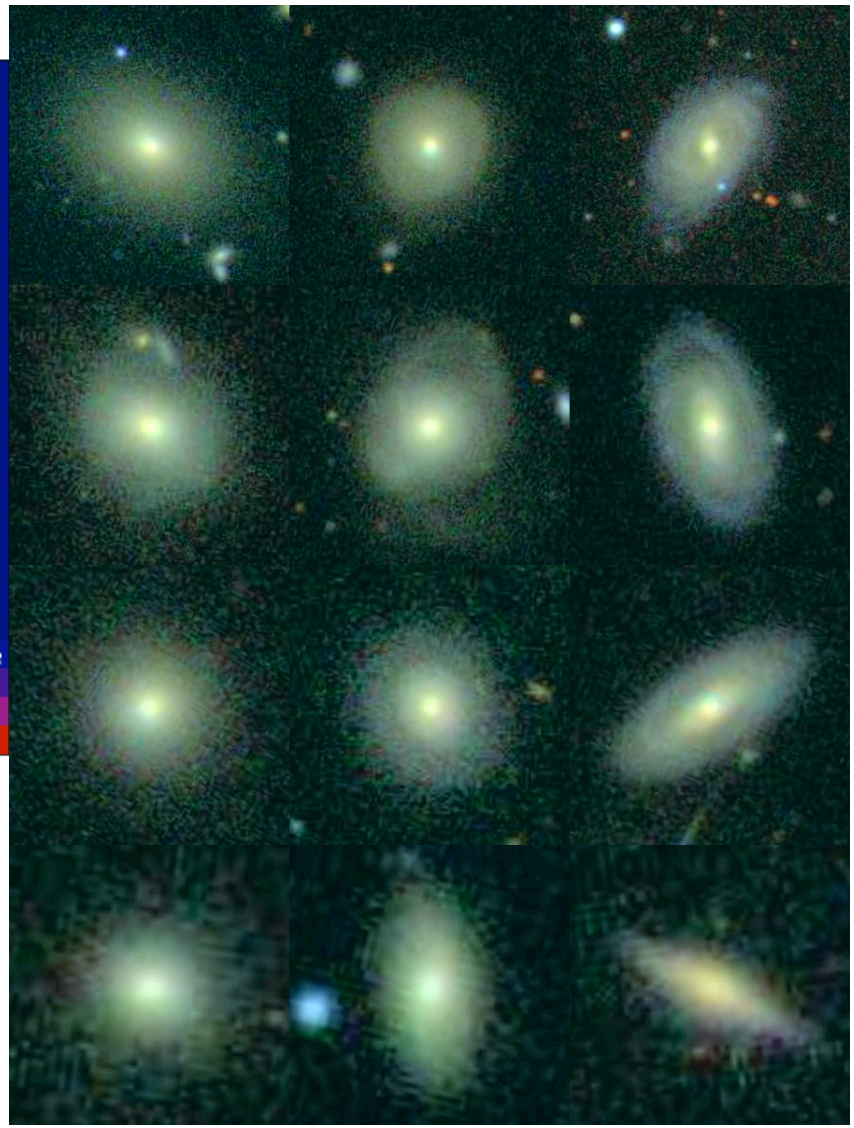
Morphology versus luminosity and size





Why bother with visual inspection?



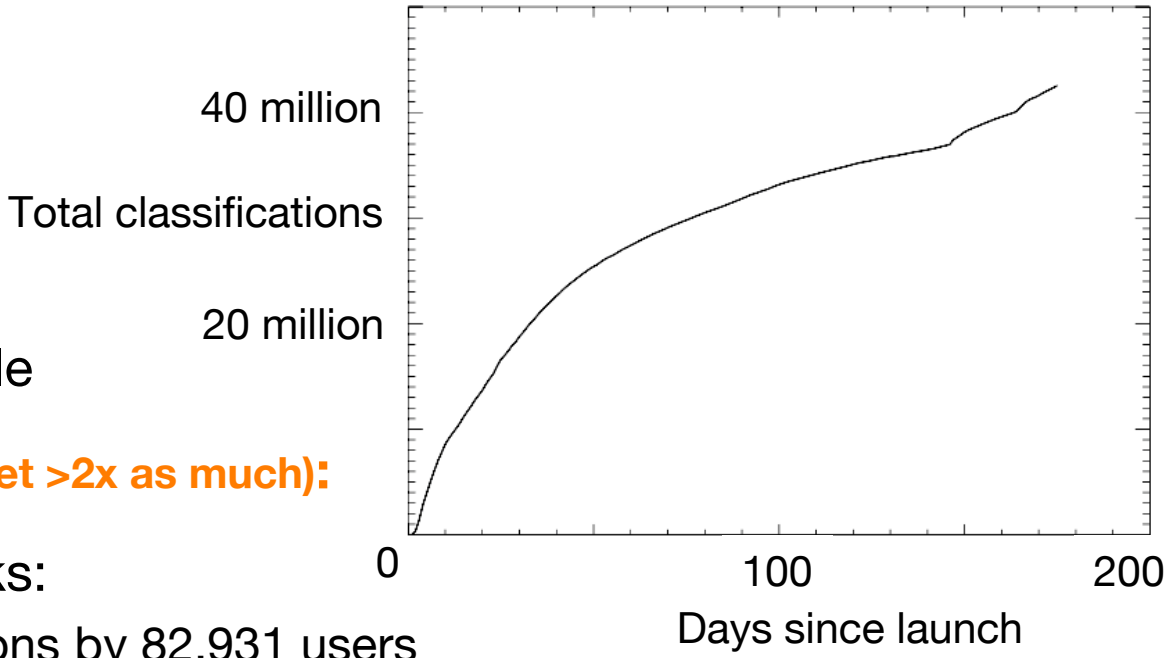


z ~ 0.05

p_{sp}~0.1 p_{sp}~0.5 p_{sp}~0.9

Classification database

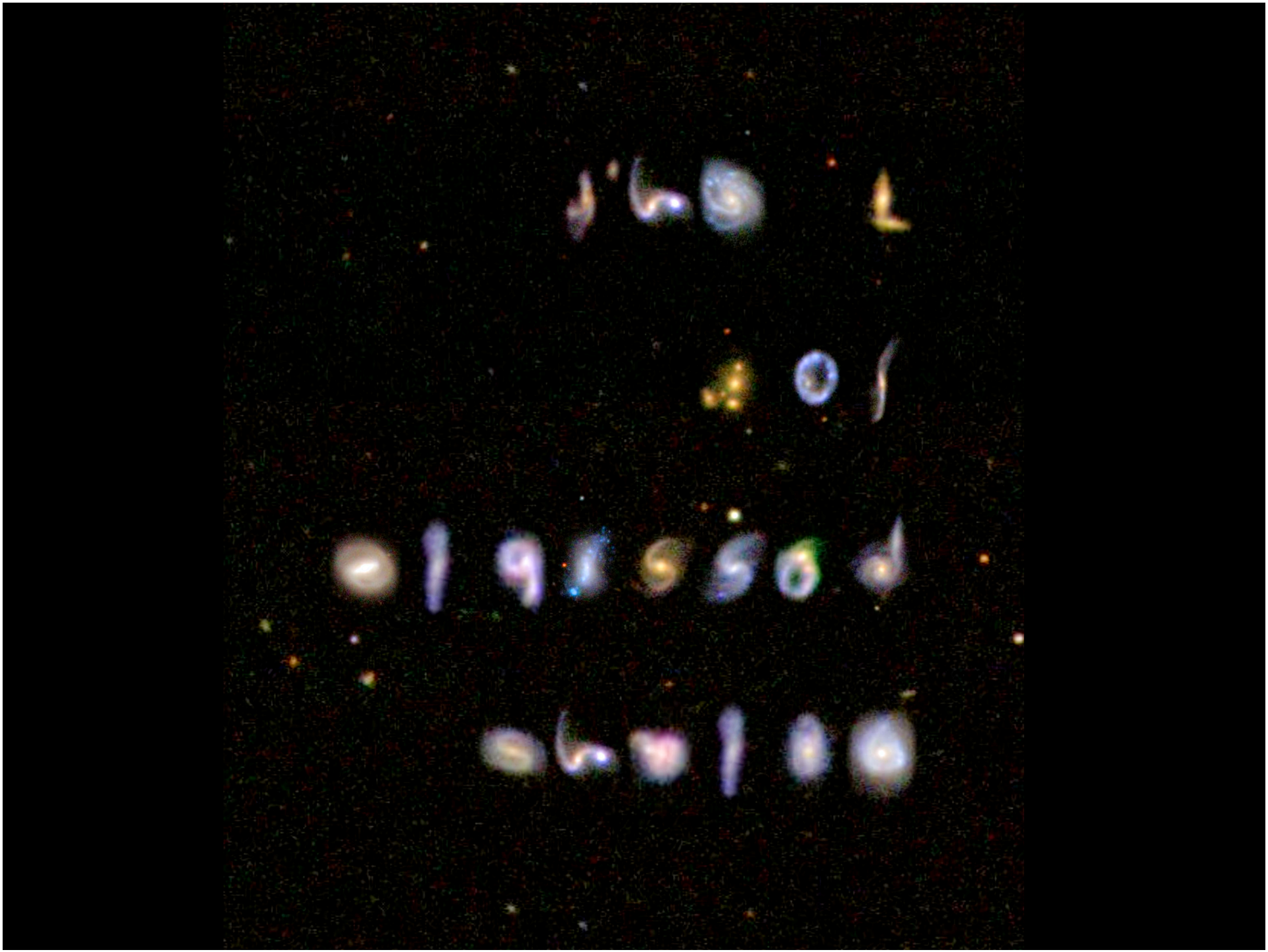
Overview paper:
Lintott et al.
MNRAS, 389, 1179



- 893212 objects in sample

First six months (final dataset >2x as much):

- After ‘cleaning’ raw clicks:
  - 34,617,406 classifications by 82,931 users
  - median of 33 classifications per object
  - >20 classifications per object for 98% of sample
- Roughly 3.3 continuous person-years!
- Most classifications are done by ~1/3 users who do 100 - 10,000 each
  - ~ few hours effort each
- Catalogue public soon



Clicks to morphologies

- Raw morphological type ‘likelihoods’ p_{el}, p_{sp}, p_{mg}, p_{dk}
  - average classifications for each galaxy
    - all users equal (with cleaning), or
    - weight ‘better’ users
- Assigning types
  - work with likelihoods
  - threshold likelihoods
    - definite types
    - many uncertain
- Classification bias - quantified and corrected

Clicks to morphologies

- Raw morphological type ‘likelihoods’ p_{el}, p_{sp}, p_{mg}, p_{dk}
  - average classifications for each galaxy
    - all users equal (with cleaning), or
    - weight ‘better’ users
- Assigning types
  - work with likelihoods
  - threshold likelihoods
    - definite types
    - many uncertain
- Classification bias - quantified and corrected

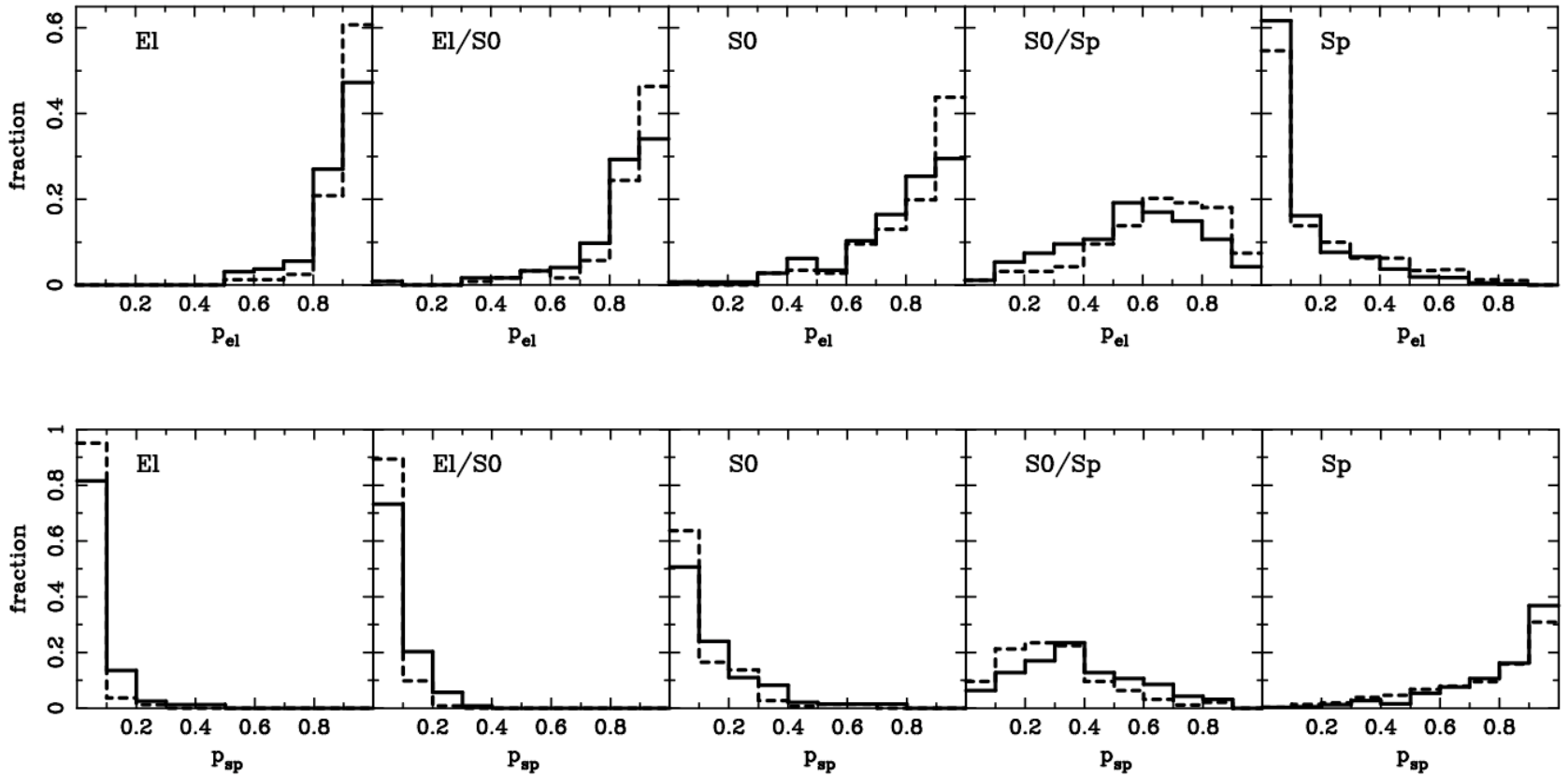
Clicks to morphologies

- Raw morphological type ‘likelihoods’ p_{el}, p_{sp}, p_{mg}, p_{dk}
  - average classifications for each galaxy
    - all users equal (with cleaning), or
    - weight ‘better’ users
- Assigning types
  - work with likelihoods
  - threshold likelihoods
    - definite types
    - many uncertain
- Classification bias - quantified and corrected

Comparison to other morphologies

Fukugita et al. 2007

S0 galaxies mostly classed as elliptical



Current projects

- Completed:
  - Spiral galaxy spins distribution
    Land et al., 2008, MNRAS, 388, 1686
  - Blue ellipticals
    Schawinski et al., MNRAS, in press (arXiv:0903.3415)
  - Morphology versus environment
    Bamford et al., 2009, MNRAS, 393, 1324
  - 2-point correlation function of spiral spins
    Slosar et al., 2009, MNRAS, 392, 1225
  - Mark correlation functions
    Skibba et al., MNRAS, in press (arXiv:0811.3970)
  - Merger fraction and merger properties
    Darg et al., MNRAS, submitted (arXiv:0903.4937 & arXiv:0903.5057)
- Projects underway:
  - Spectroscopic properties of red spirals
  - More morphology versus environment
  - Transition rates
  - Morphology-dependent colour-magnitude sequences
  - Morphology-dependent luminosity functions and galaxy bias
  - SFR and AGN fraction as a function of morphology and environment
  - Structural parameters of blue ellipticals

- Serendipitous projects:
  - Hanny's Voorwerp
    Lintott et al., MNRAS submitted
  - Overlapping galaxies - dust
  - Lenses
  - Ring galaxies

- Non-astronomy projects:
  - Zooites motivation study
  - The Zoo in a brain scanner

Current projects

- Completed:
  - Spiral galaxy spins distribution
    Land et al., 2008, MNRAS, 388, 1686
  - Blue ellipticals
    Schawinski et al., MNRAS, in press (arXiv:0903.3415)
  - Morphology versus environment
    Bamford et al., 2009, MNRAS, 393, 1324
  - 2-point correlation function of spiral spins
    Slosar et al., 2009, MNRAS, 392, 1225
  - Mark correlation functions
    Skibba et al., MNRAS, in press (arXiv:0811.3970)
  - Merger fraction and merger properties
    Darg et al., MNRAS, submitted (arXiv:0903.4937 & arXiv:0903.5057)
- Projects underway:
  - Spectroscopic properties of red spirals
  - More morphology versus environment
  - Transition rates
  - Morphology-dependent colour-magnitude sequences
  - Morphology-dependent luminosity functions and galaxy bias
  - SFR and AGN fraction as a function of morphology and environment
  - Structural parameters of blue ellipticals
- Serendipitous projects:
  - Hanny's Voorwerp
    Lintott et al., MNRAS submitted
  - Overlapping galaxies - dust
  - Lenses
  - Ring galaxies
- Non-astronomy projects:
  - Zooites motivation study
  - The Zoo in a brain scanner

Current projects

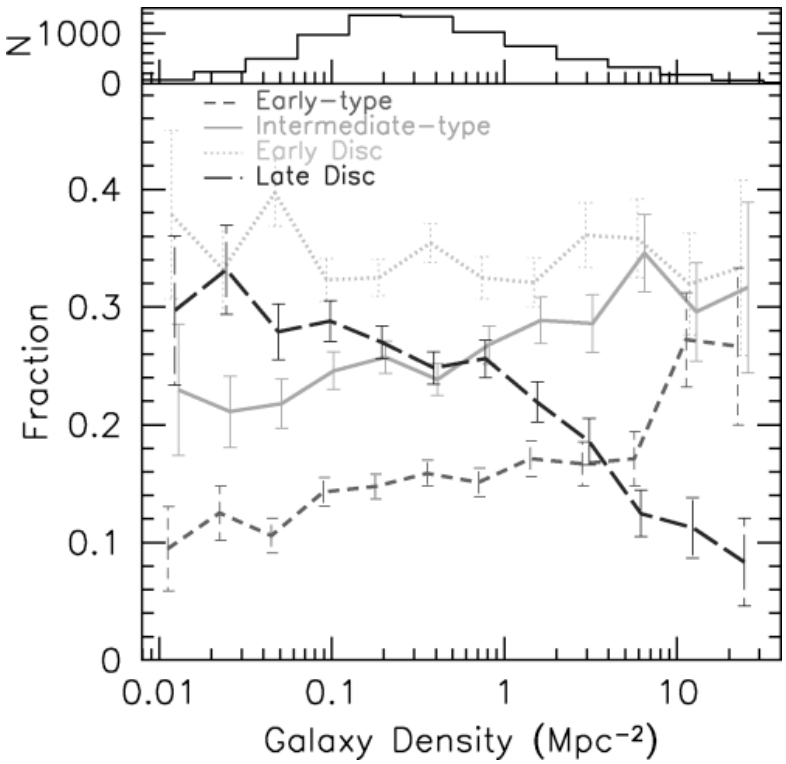
- Completed:
  - Spiral galaxy spins distribution
    Land et al., 2008, MNRAS, 388, 1686
  - Blue ellipticals
    Schawinski et al., MNRAS, in press (arXiv:0903.3415)
  - Morphology versus environment
    Bamford et al., 2009, MNRAS, 393, 1324
  - 2-point correlation function of spiral spins
    Slosar et al., 2009, MNRAS, 392, 1225
  - Mark correlation functions
    Skibba et al., MNRAS, in press (arXiv:0811.3970)
  - Merger fraction and merger properties
    Darg et al., MNRAS, submitted (arXiv:0903.4937 & arXiv:0903.5057)
- Projects underway:
  - Spectroscopic properties of red spirals
  - More morphology versus environment
  - Transition rates
  - Morphology-dependent colour-magnitude sequences
  - Morphology-dependent luminosity functions and galaxy bias
  - SFR and AGN fraction as a function of morphology and environment
  - Structural parameters of blue ellipticals

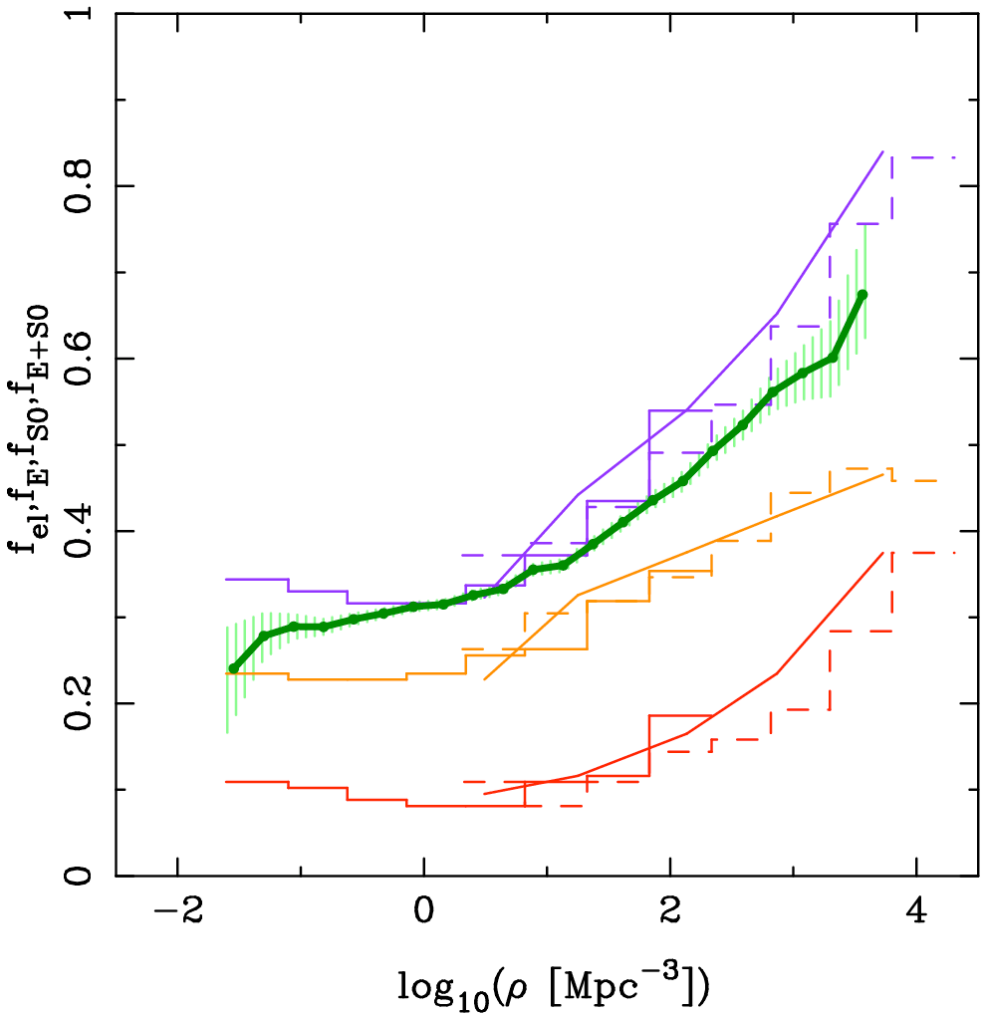
- Serendipitous projects:
  - Hanny's Voorwerp
    Lintott et al., MNRAS submitted
  - Overlapping galaxies - dust
  - Lenses
  - Ring galaxies

- Non-astronomy projects:
  - Zooites motivation study
  - The Zoo in a brain scanner

Morphology versus environment

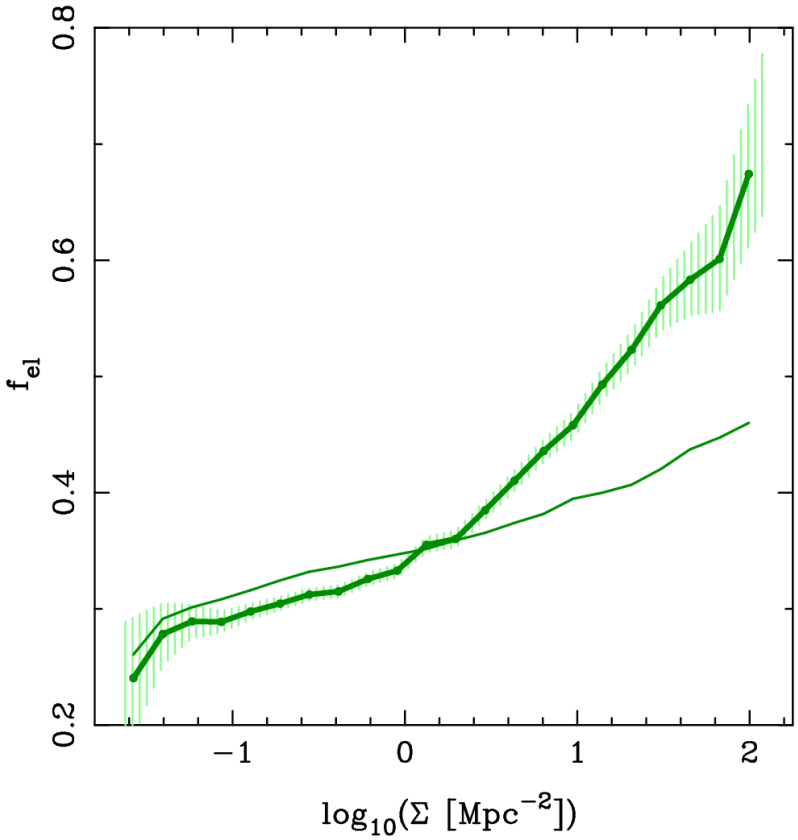
- Previous local work:
  - Dressler 1980
  - Postman & Geller 1984
  - Goto et al 2003





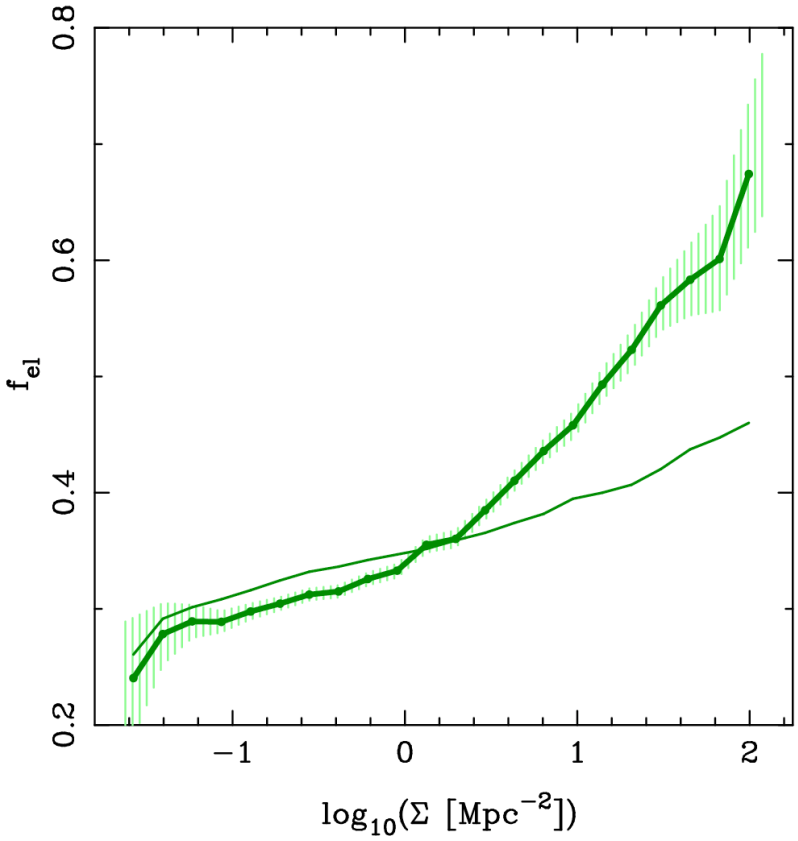
Morphology versus environment

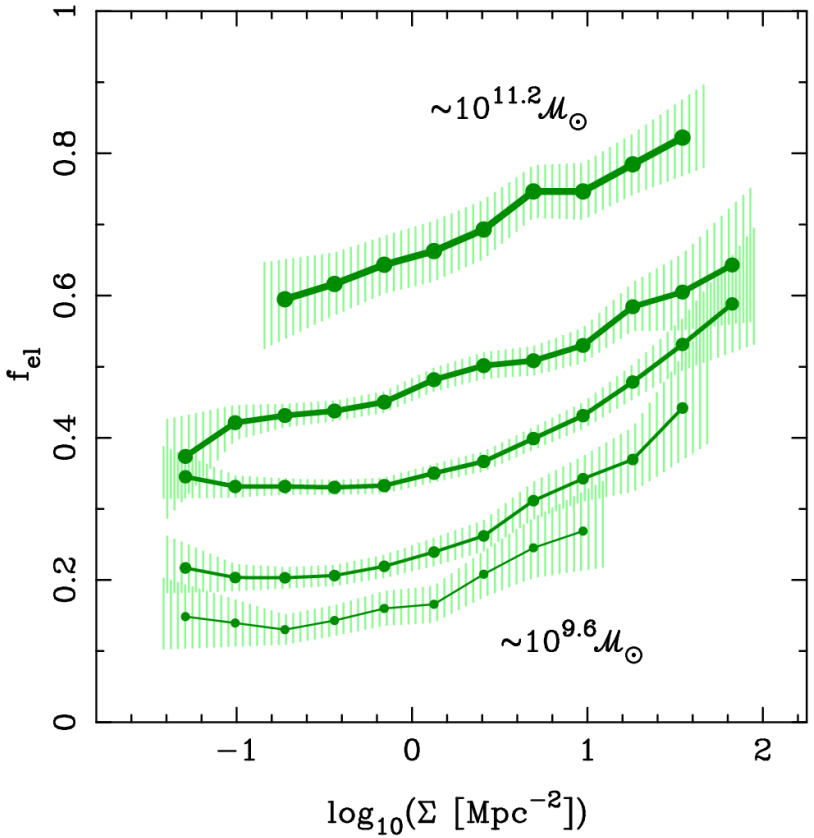
- Early-type fraction versus local galaxy density and stellar mass



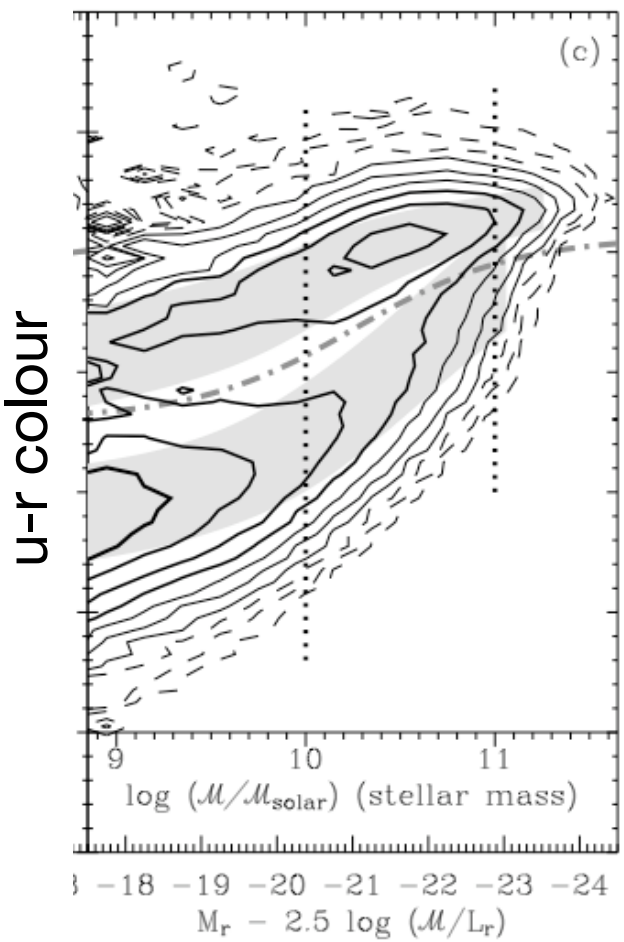
Morphology versus environment

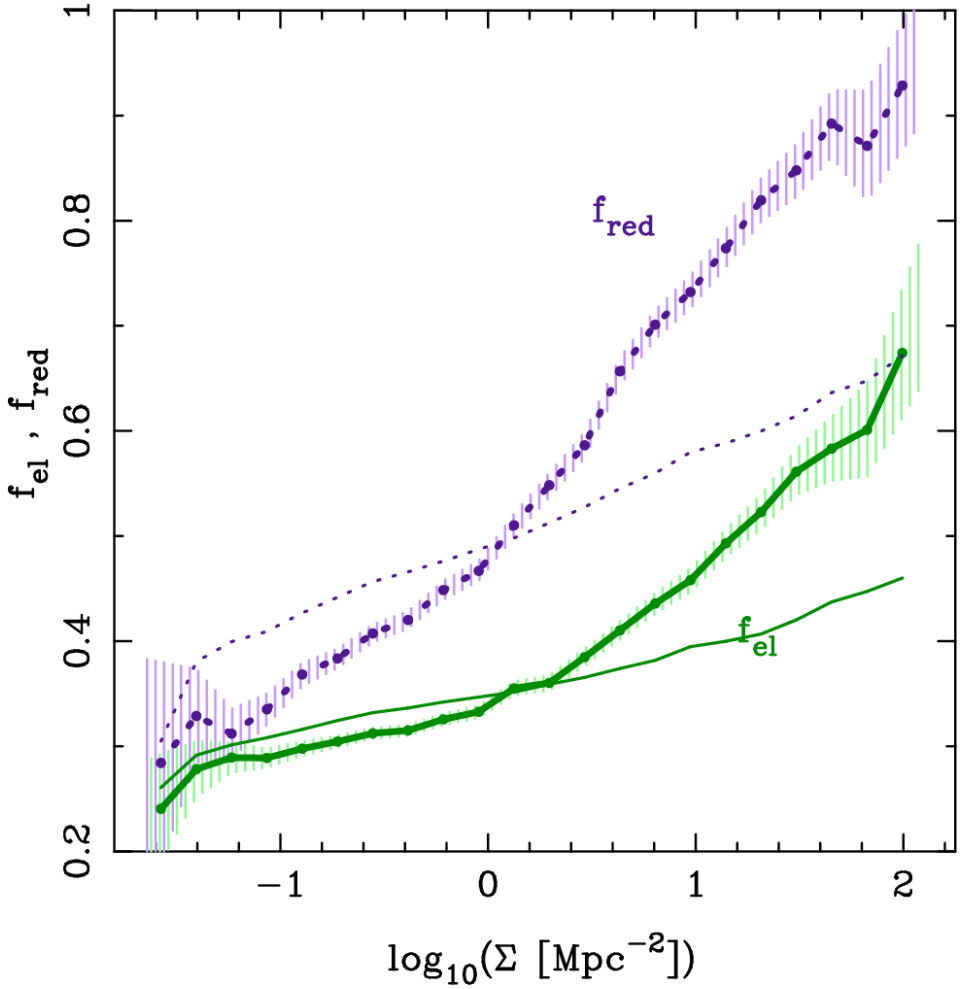
- Elliptical fraction versus local galaxy density and stellar mass





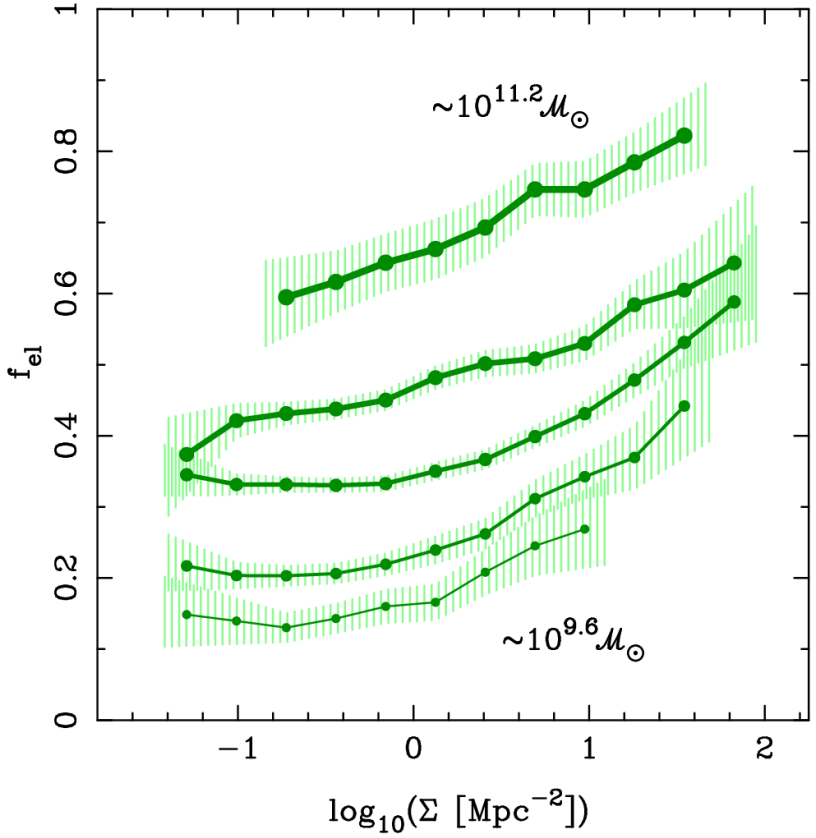
Morphology versus colour bimodality

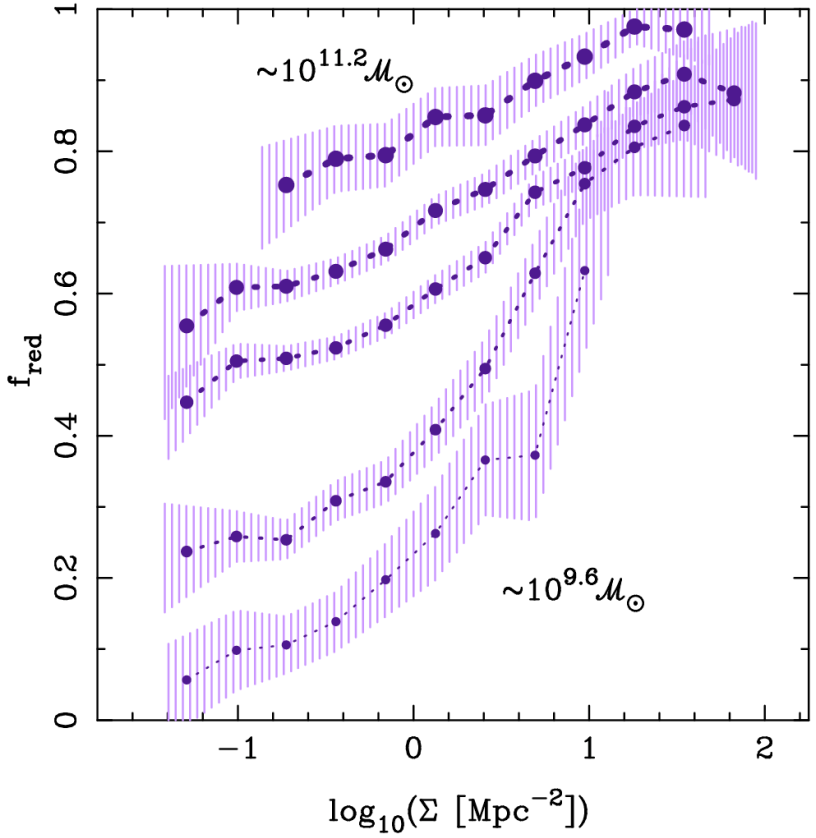




Morphology versus colour bimodality

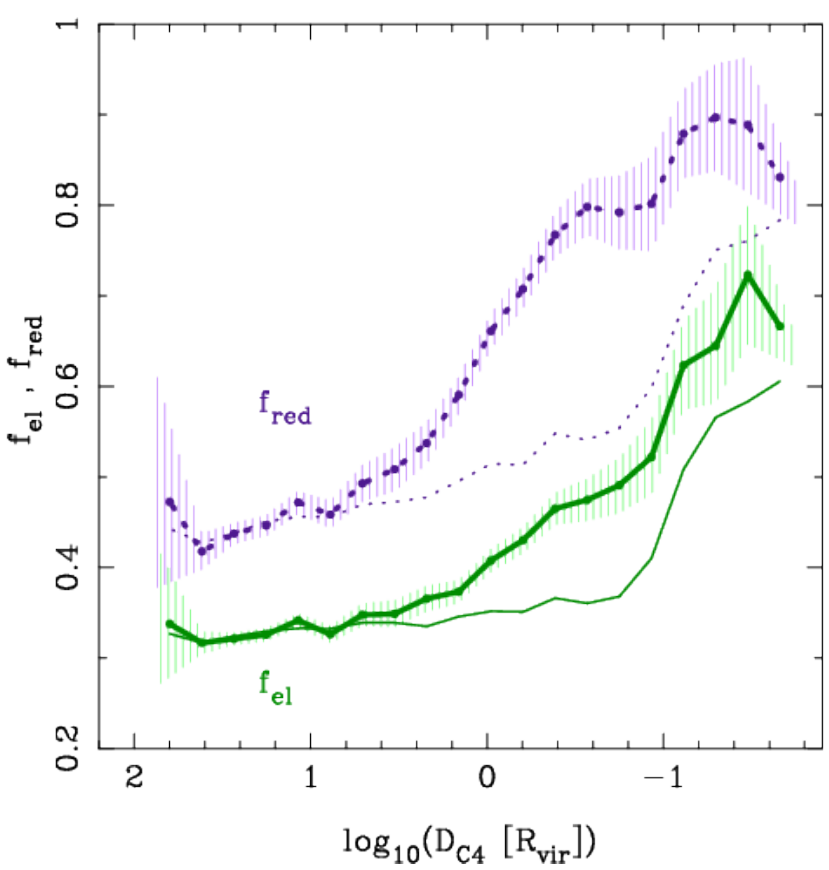
- Comparison with colour

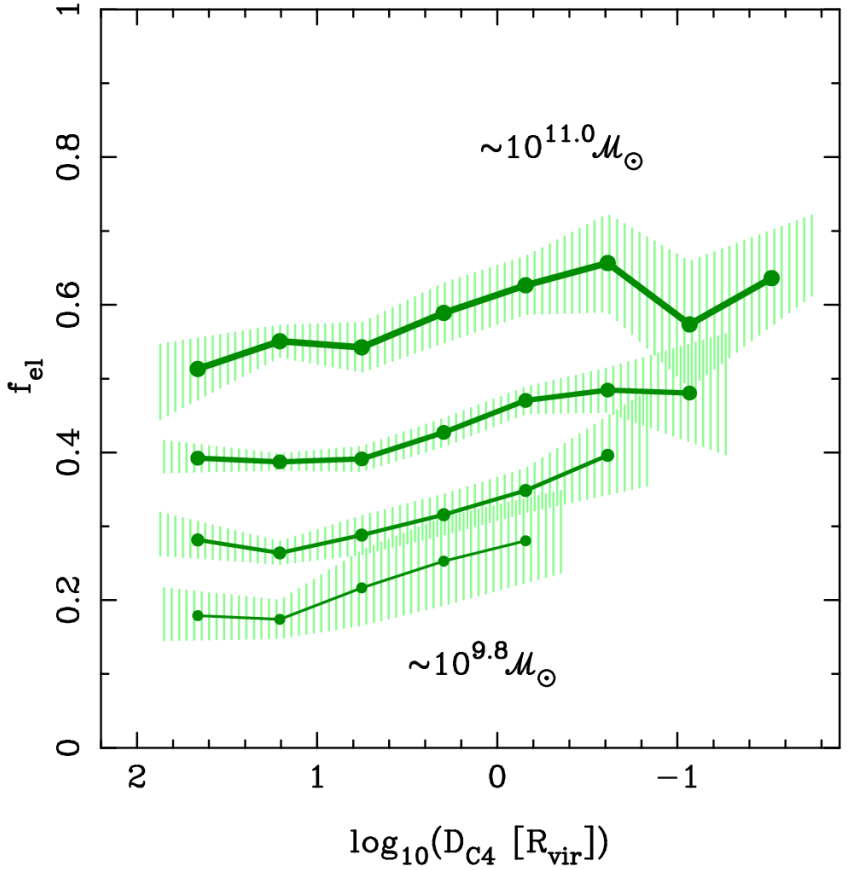




Morphology and colour in groups

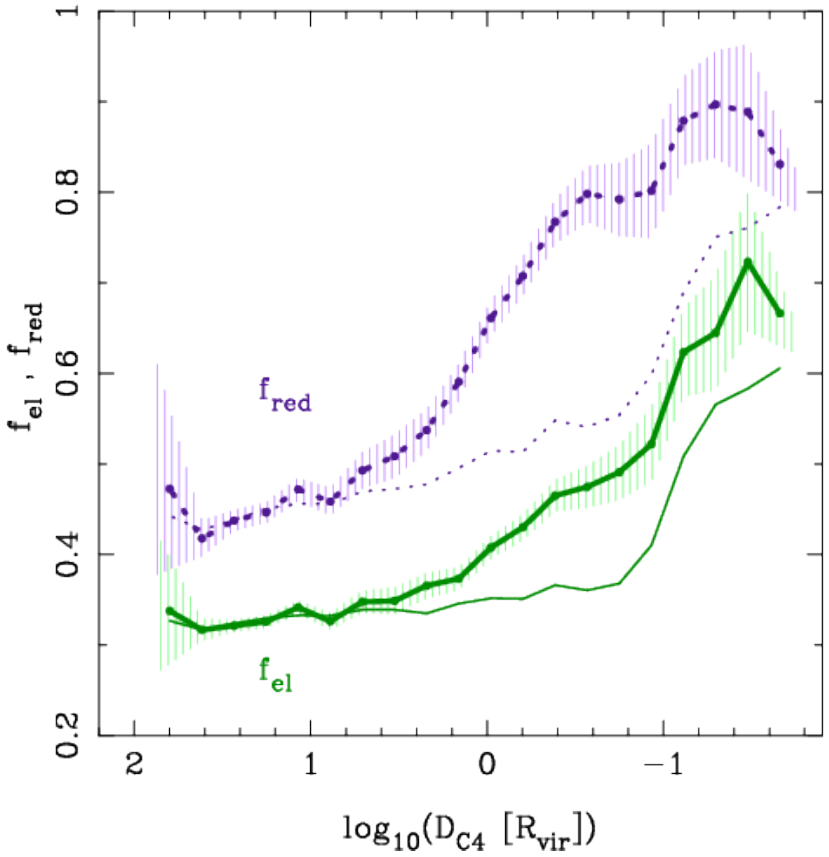
- Early-type fraction versus distance to a group (>10^{13} M_{sun}) and stellar mass

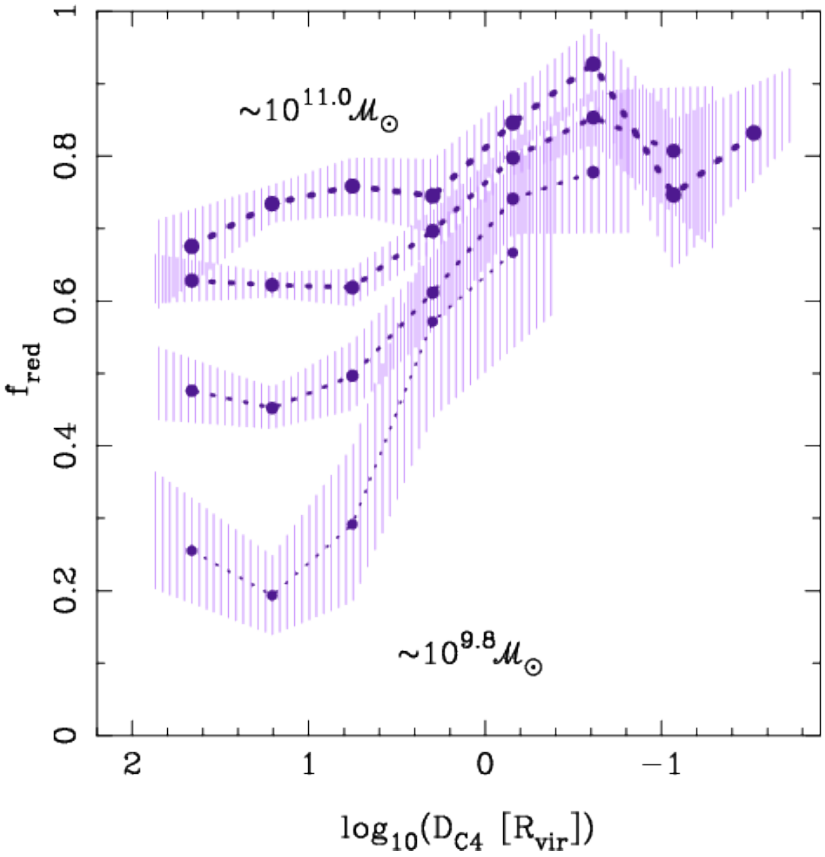




Morphology and colour in groups

- Early-type fraction versus distance to a group (>10^{13} M_{sun}) and stellar mass

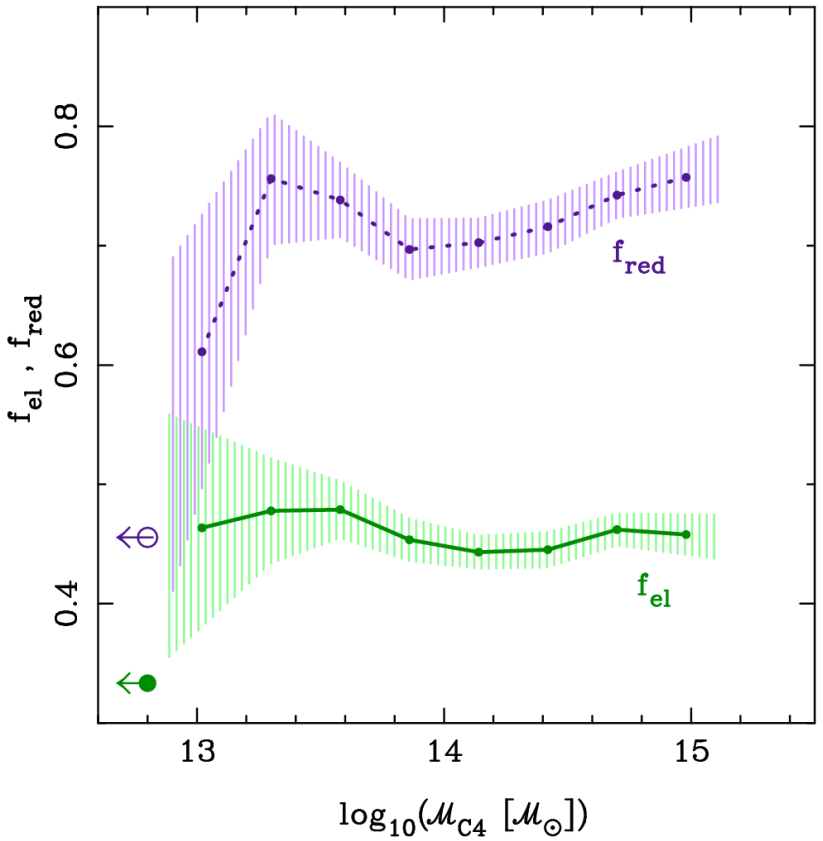




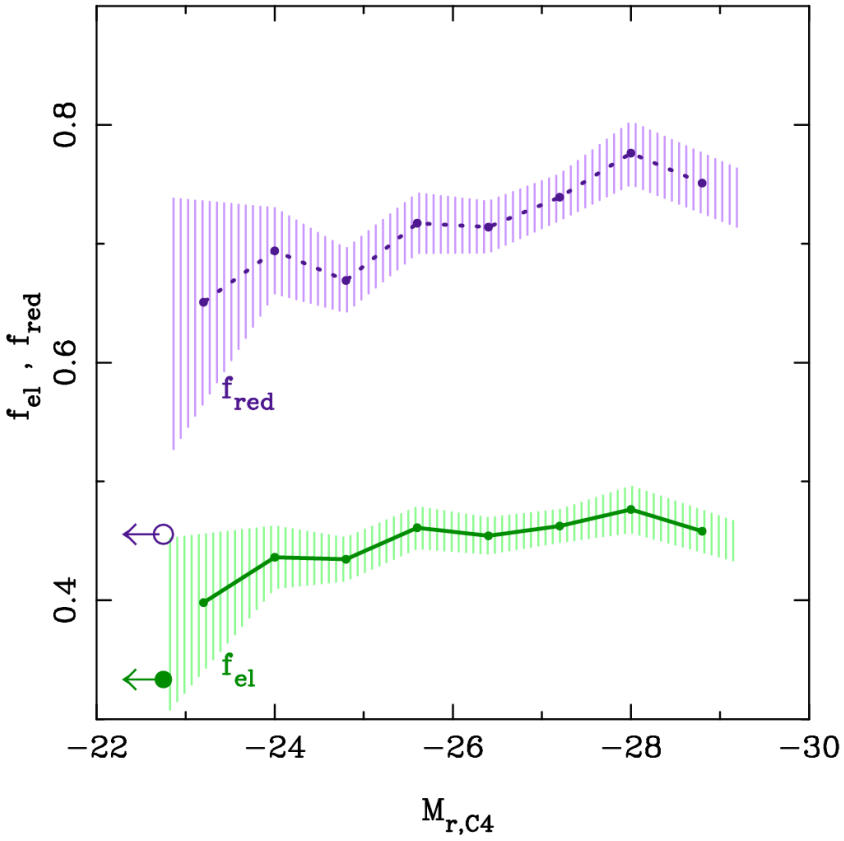
Morphology and colour in groups

- Little dependence of fractions on group mass (>10^{13} M_{sun})

total mass (from velocity dispersion)

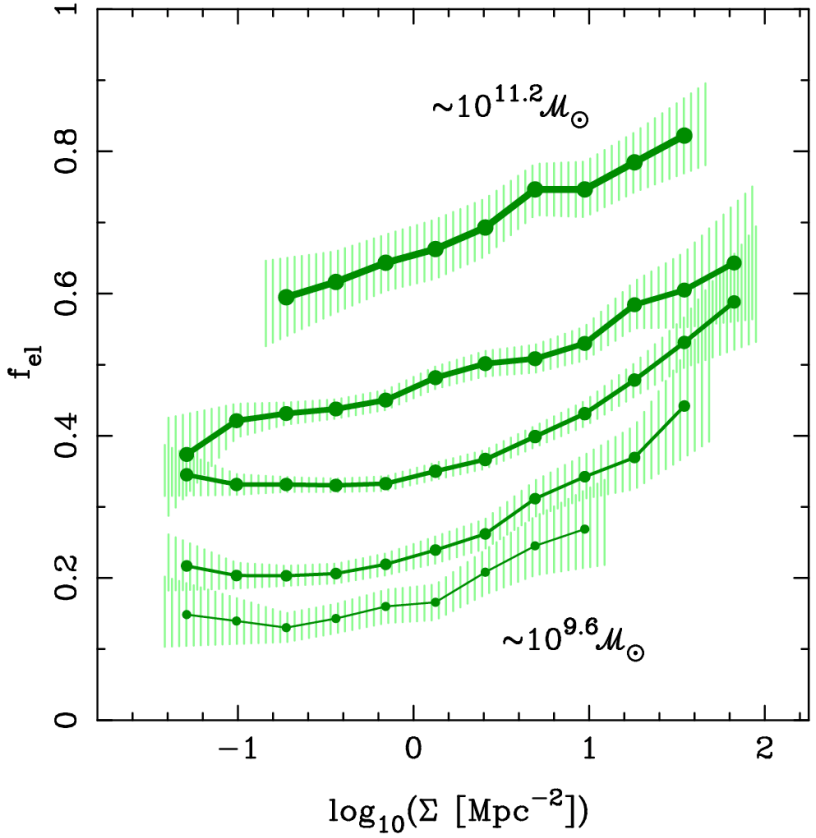


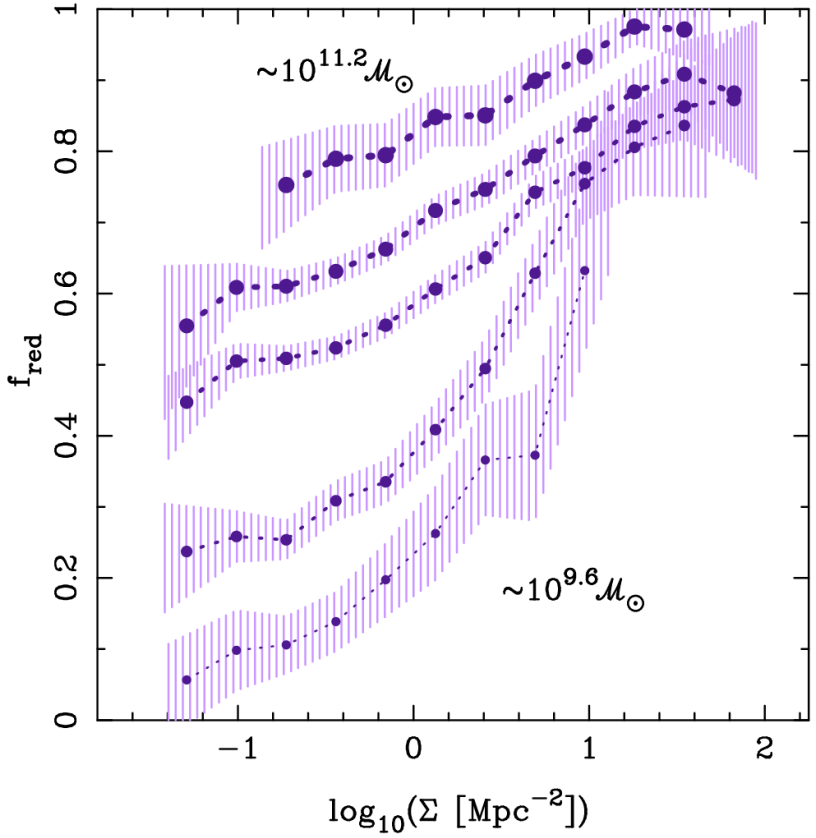
integrated luminosity



Morphology versus colour bimodality

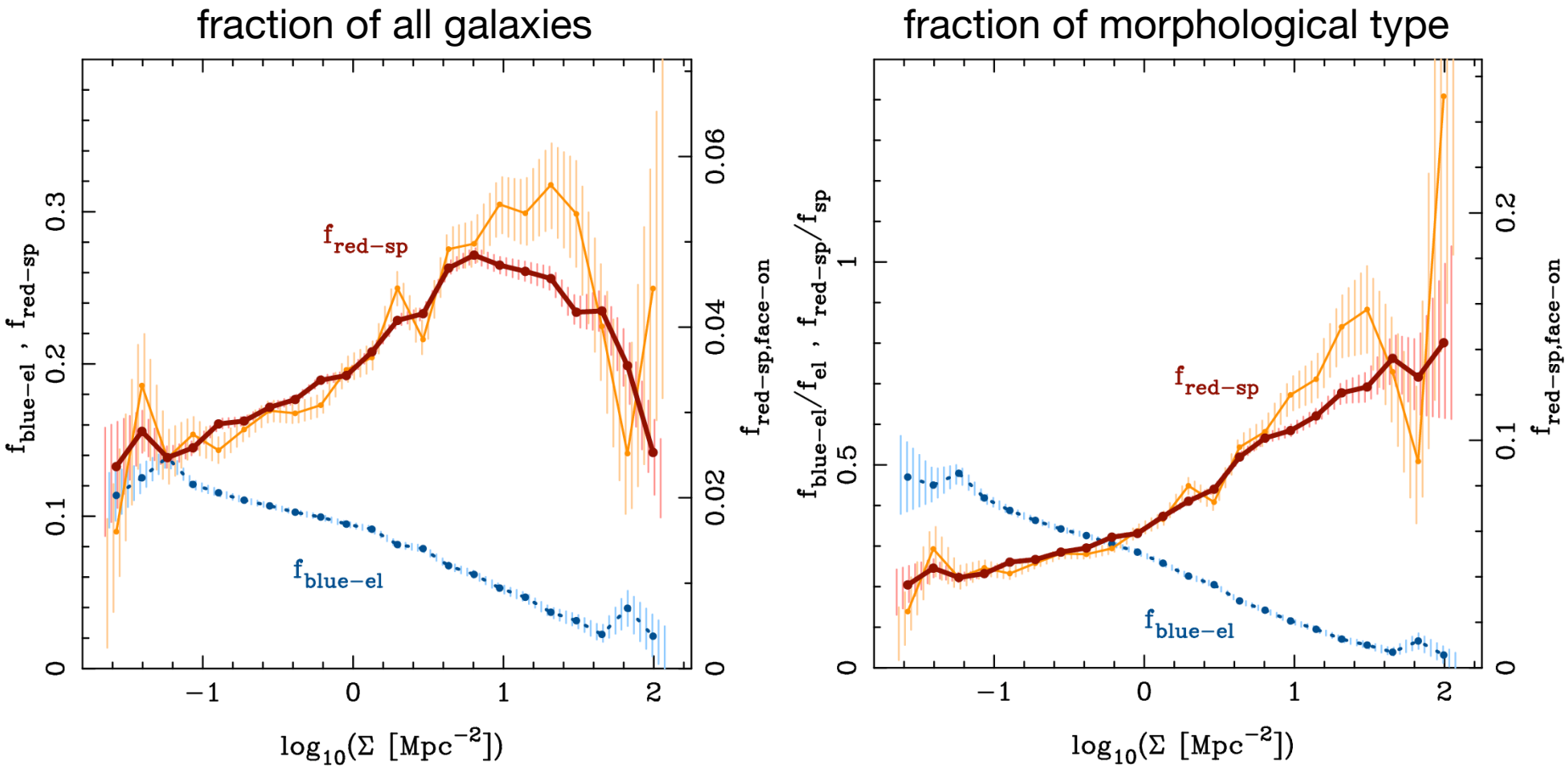
- Comparison with colour





Red spirals and blue early-types

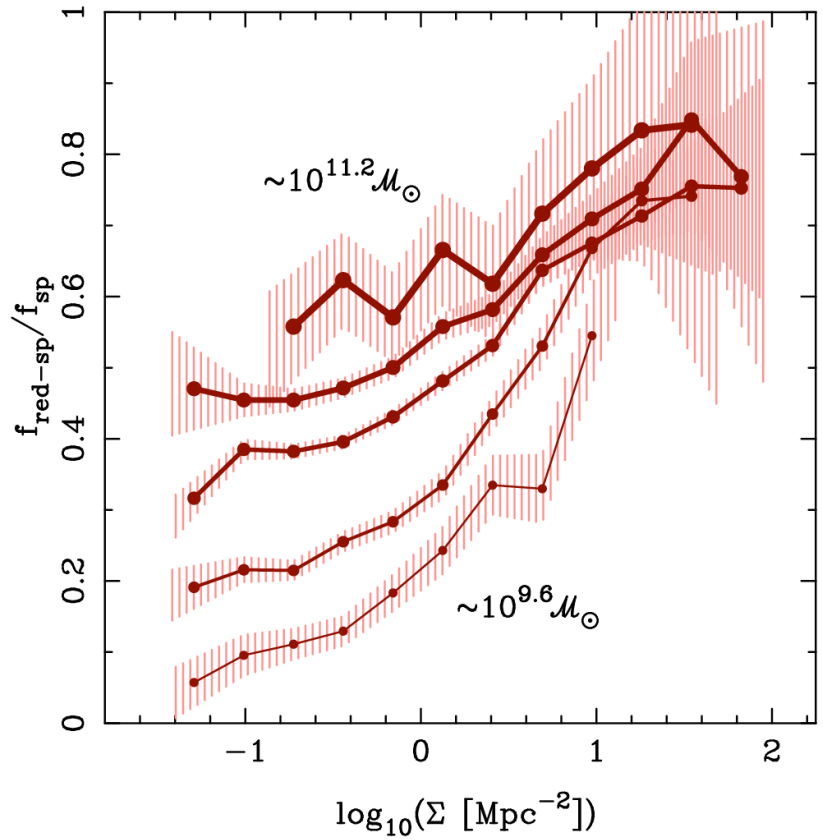
- Objects on opposite sides of morphology/colour bimodalities

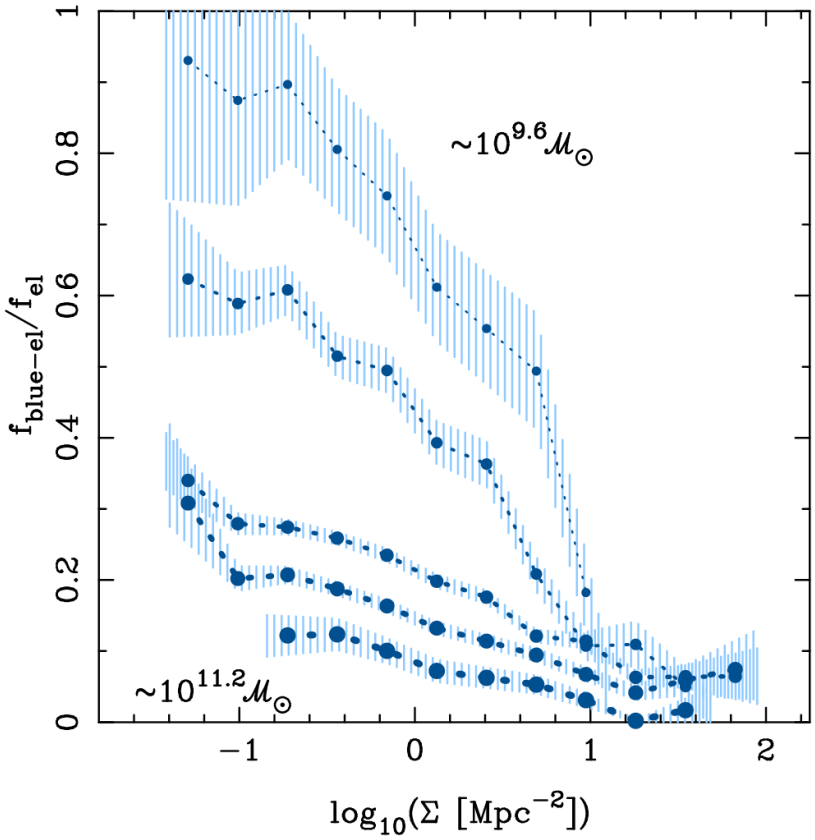


orange = face on only, must have visible spiral arms

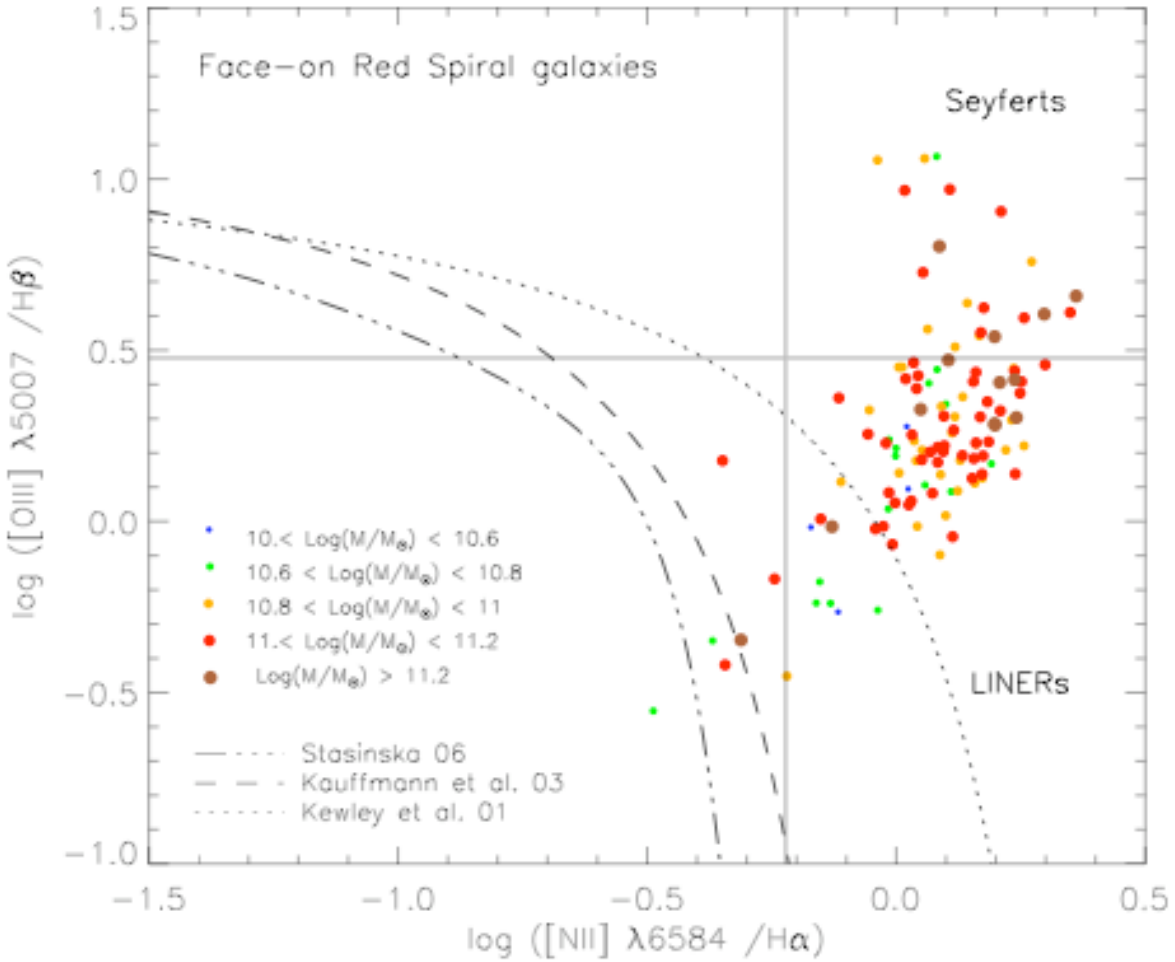
Red spirals and blue early-types

- Stellar mass dependence



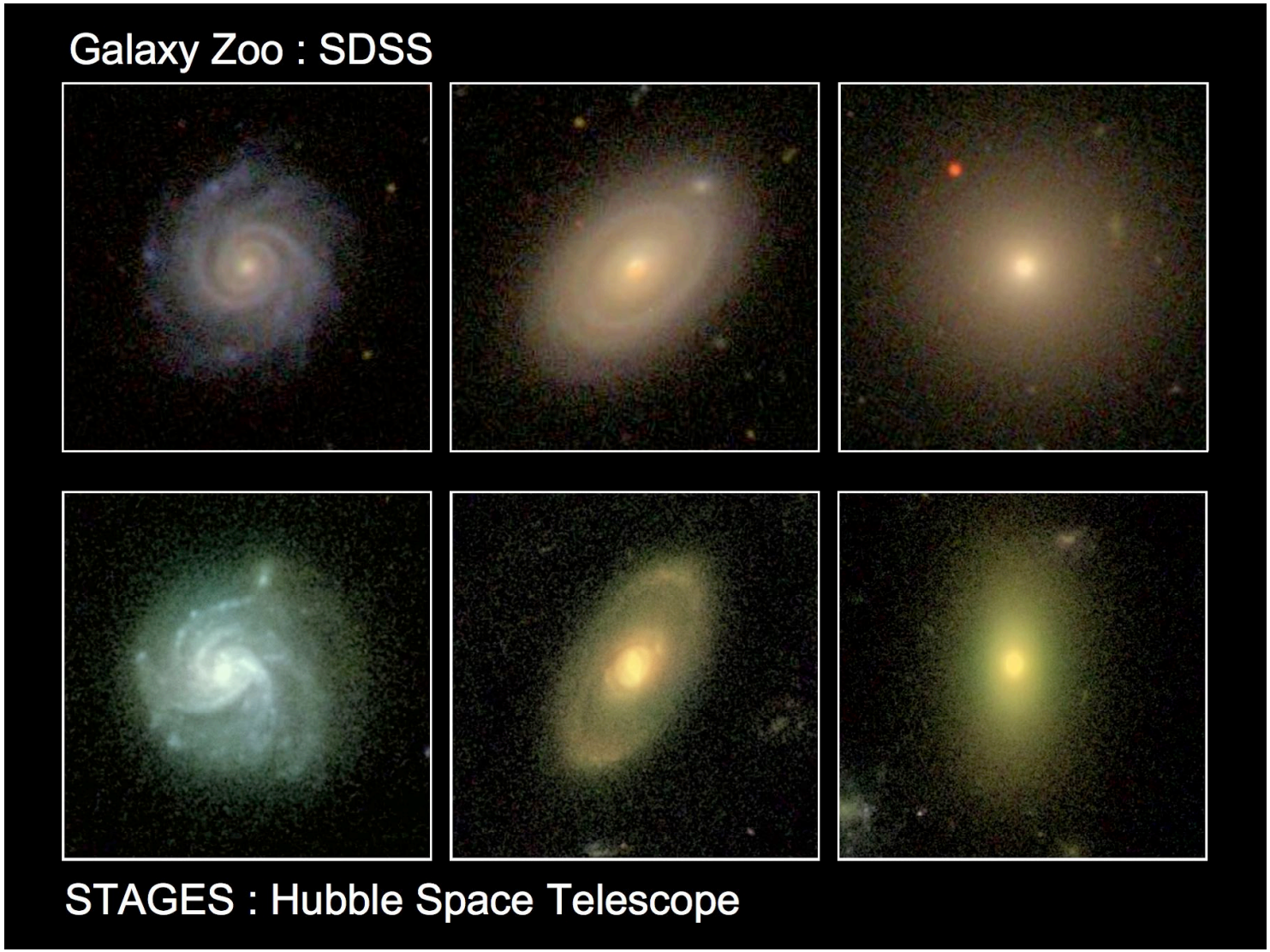


Red spirals optically passive



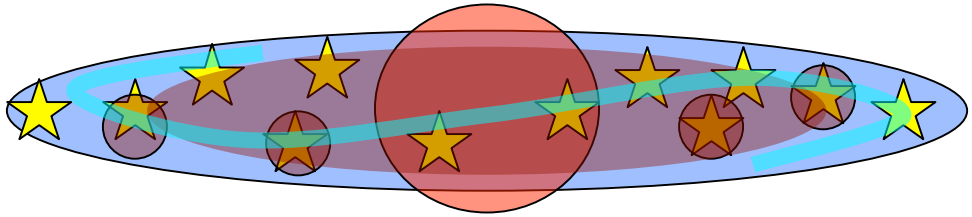
Retired galaxies? Stasinska et al., 2008, MNRAS, 391, L29

Compliments STAGES results

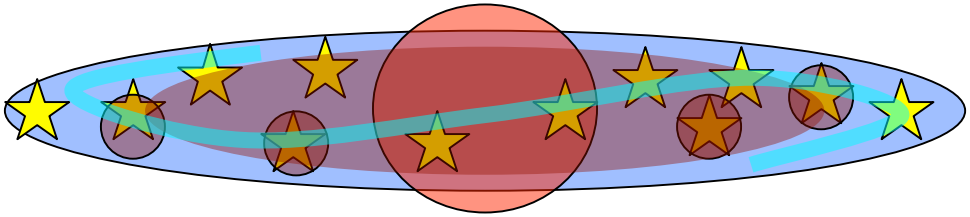


Wolf, et al., 2009, MNRAS, 393, 1302

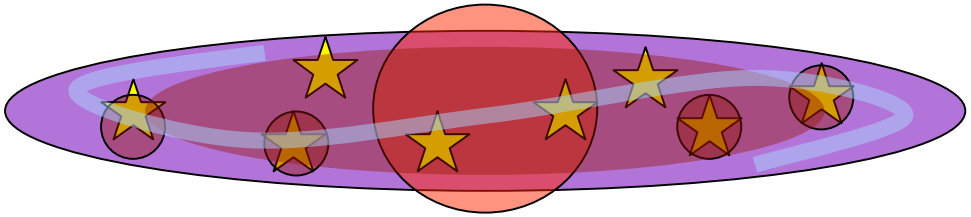
Possible scenario



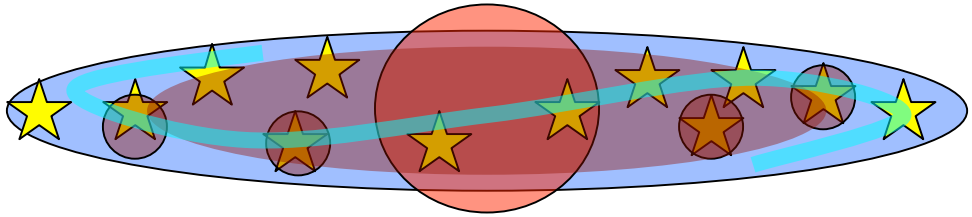
Possible scenario



environmental effect
(strangulation?)



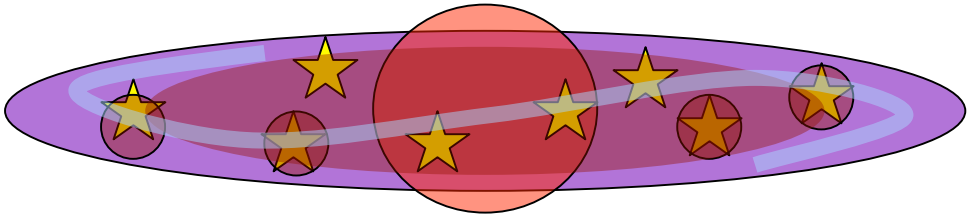
Possible scenario



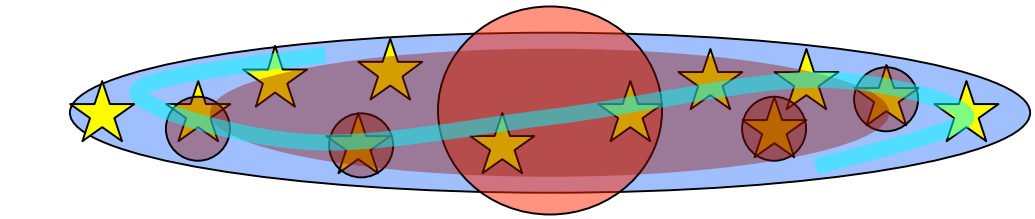
slow change in star-formation

rapid change in optical signatures

environmental effect
(strangulation?)



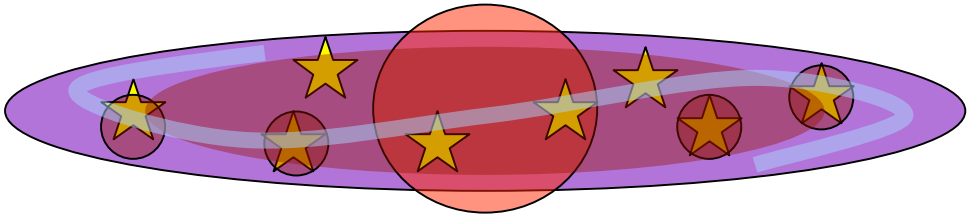
Possible scenario

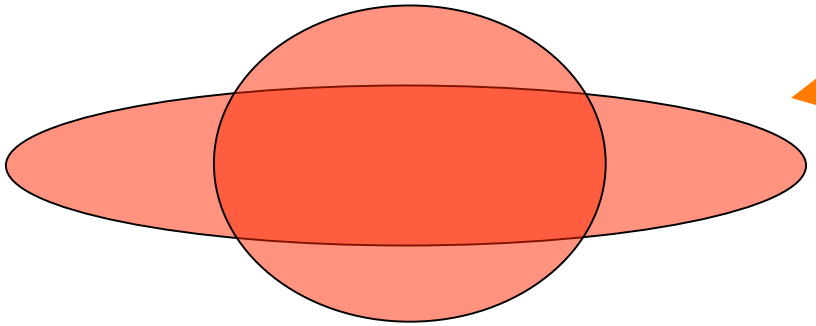


slow change in star-formation

rapid change in optical signatures

environmental effect
(strangulation?)





fading and later dynamical interaction?

Morphology versus environment

Conclusions

- Morphology - density relation does exist at fixed stellar mass, but is weak
- Colour - density relation stronger, especially at fixed mass
- Morphology vs density and group distance show very similar behaviour
- Little dependence of group members on group mass
- Colour trends with environment are much stronger for lower mass galaxies
  - low mass ellipticals and spirals almost all blue at low densities, red at high densities
- Red spirals most common in outskirts of clusters / intermediate densities - combination of two competing environmental effects
- Trends of morphology and colour vs environment **not** due to same processes
- Colour versus environment driven by occurrence of red spirals
  - Not just usual S0 population
  - Retain morphology, some remaining SF? --> gentle transformation mechanism
  - Later dynamical transformation closer to group core