The structure of galactic discs in the STAGES survey: probing the drivers of galaxy evolution

David Maltby, Alfonso Aragón-Salamanca, Meghan Gray

EWASS 2015, Tenerife

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

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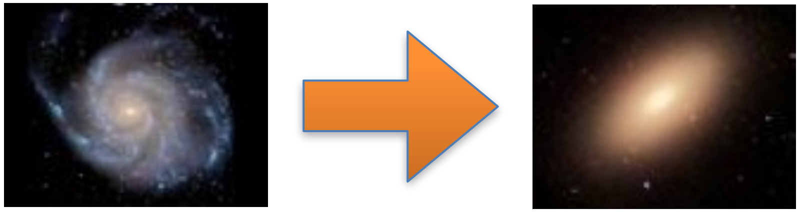
Overview

1. ***The effect of the galaxy environment on the structure of galactic discs***
   - Implications for galaxy evolution in different environments
2. ***The structure of galactic discs in spiral and S0 galaxies***
   - Implications for morphological evolution (***Spiral → S0***)



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The galaxy environment

- Environmental correlations:

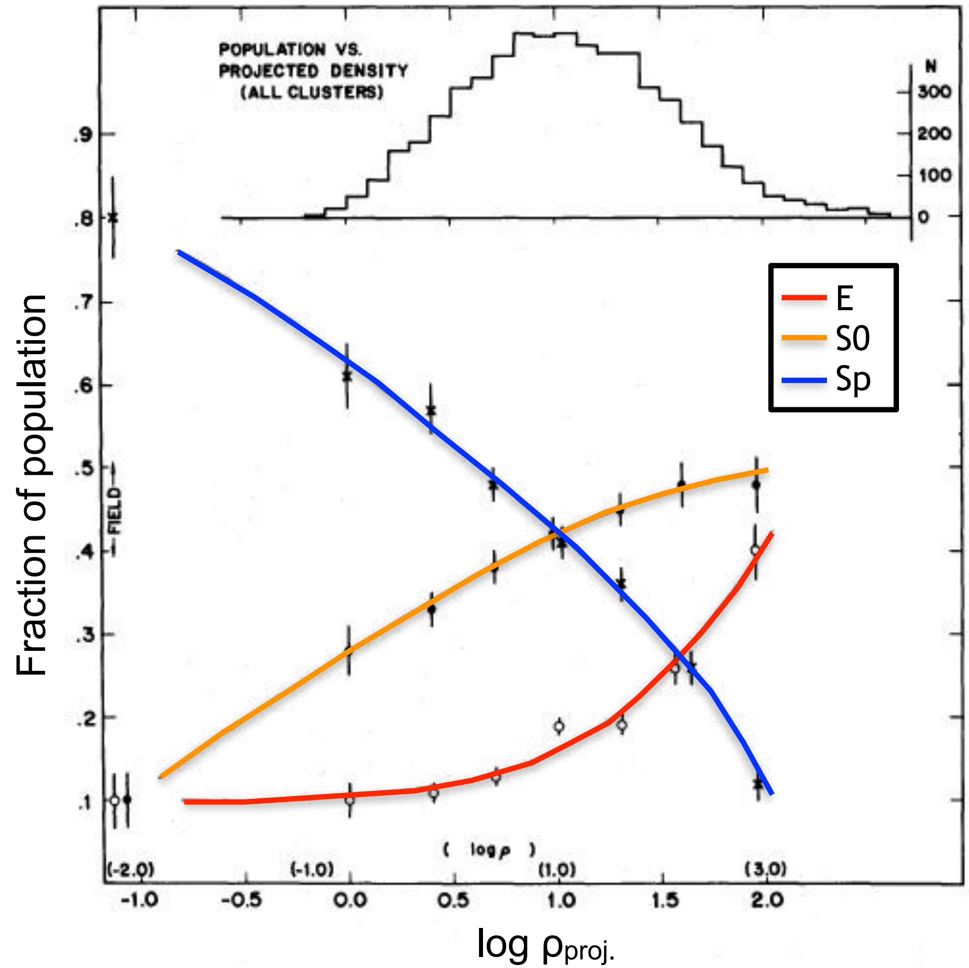
Environment	*Galaxy property*		
	Colour	*Star formation*	*Morphology*
High-density	**Red**	**Passive**	**Early-type**
Low-density	**Blue**	**Star-forming**	**Late-type**

- However, '*correlations*' do not necessarily imply causality.

  → ***Nature vs. Nurture Hypothesis***

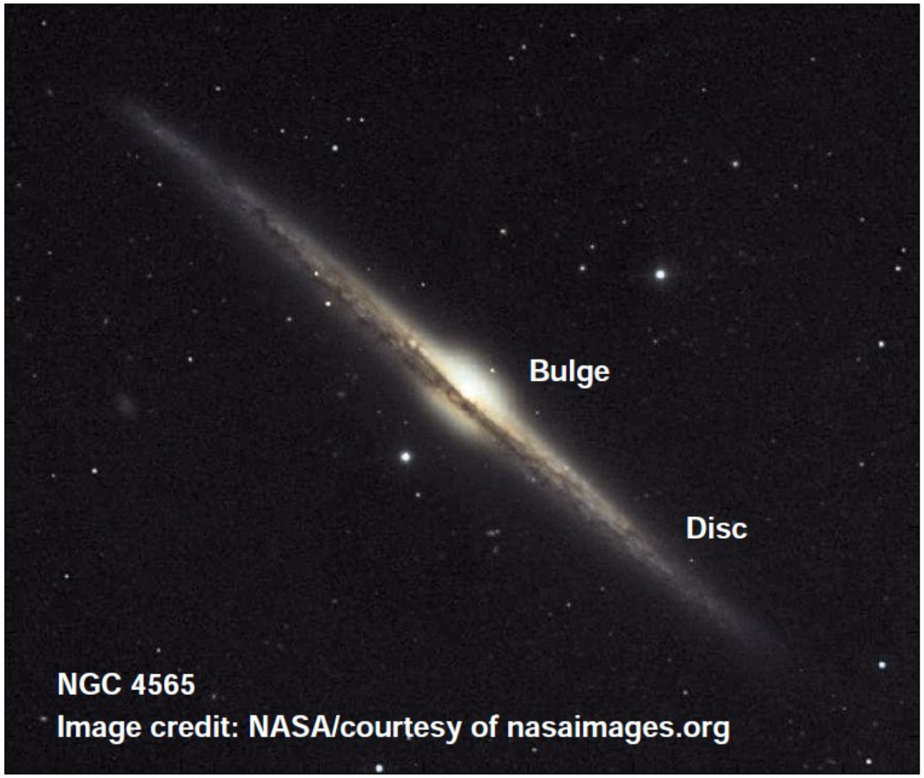
- ***Disc structure and environment***
  - ***'fragile' outer stellar disc*** *may show signatures of '****strong****' environmental processes – those that can disrupt the stellar distribution.*

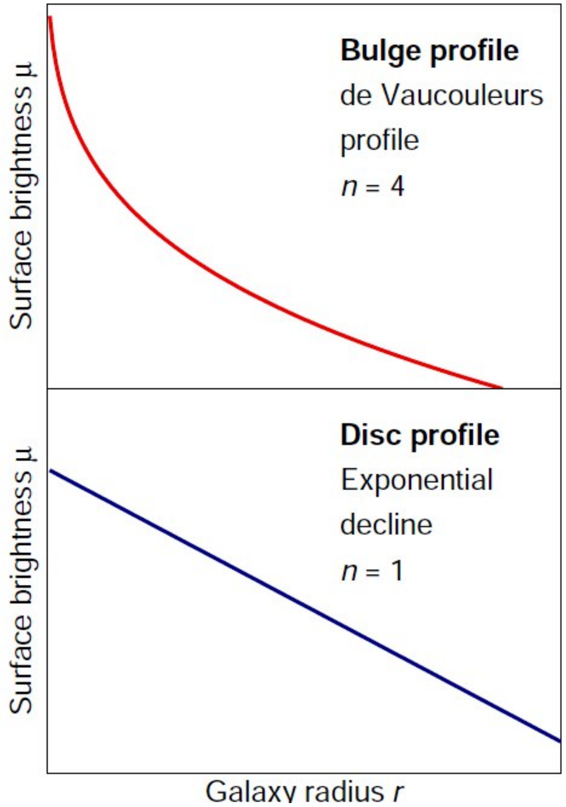
Morphology–density relation (Dressler 1980)



Structure of galactic discs

- Disc galaxies are comprised of ***two*** main structural components:



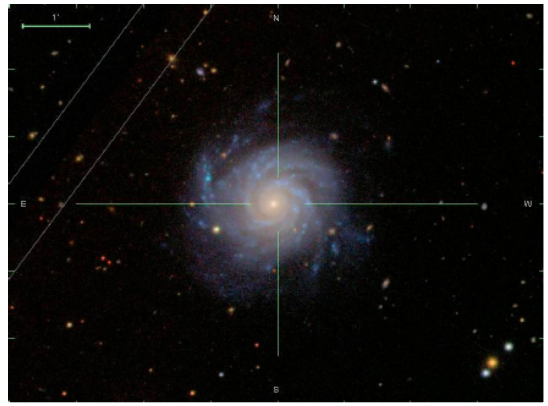


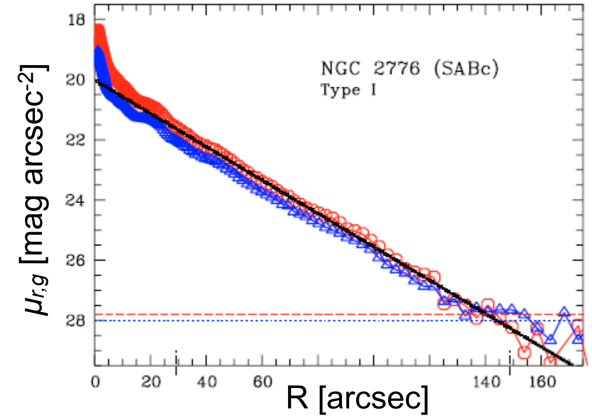
- However, this simple picture ***does not*** hold for most disc galaxies in the universe.
- Exponential component often ***broken*** and best described by a two slope model (*Pohlen et al. 2002*).

Structure of galactic discs

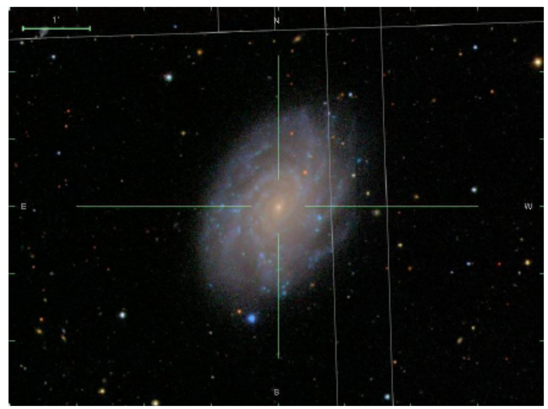
SDSS: Pohlen &Trujillo 2006

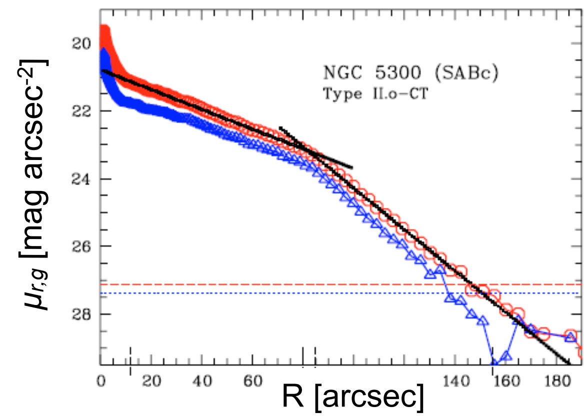
- **Type I**
  No break or simple exponential
  Pure exponential



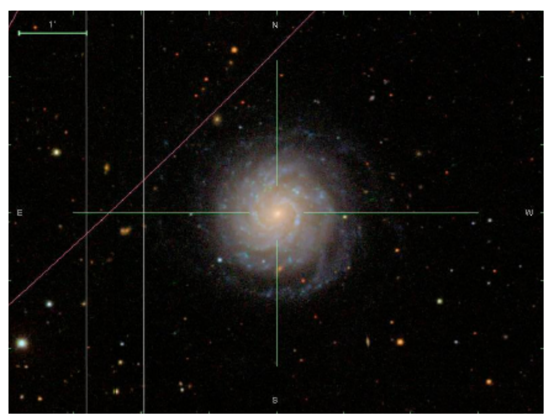


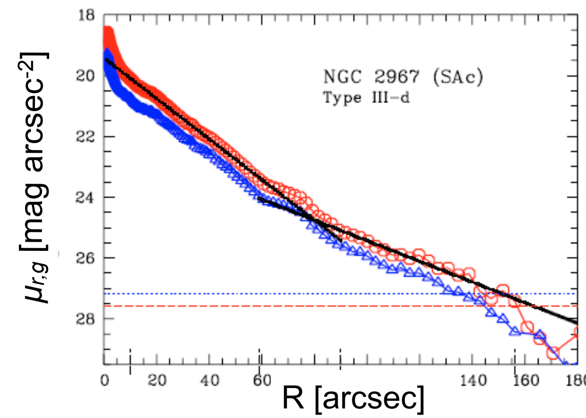
- **Type II**
  Down-bending break in exponential region
  Truncation





- **Type III**
  Up-bending break in exponential region
  Anti-truncation

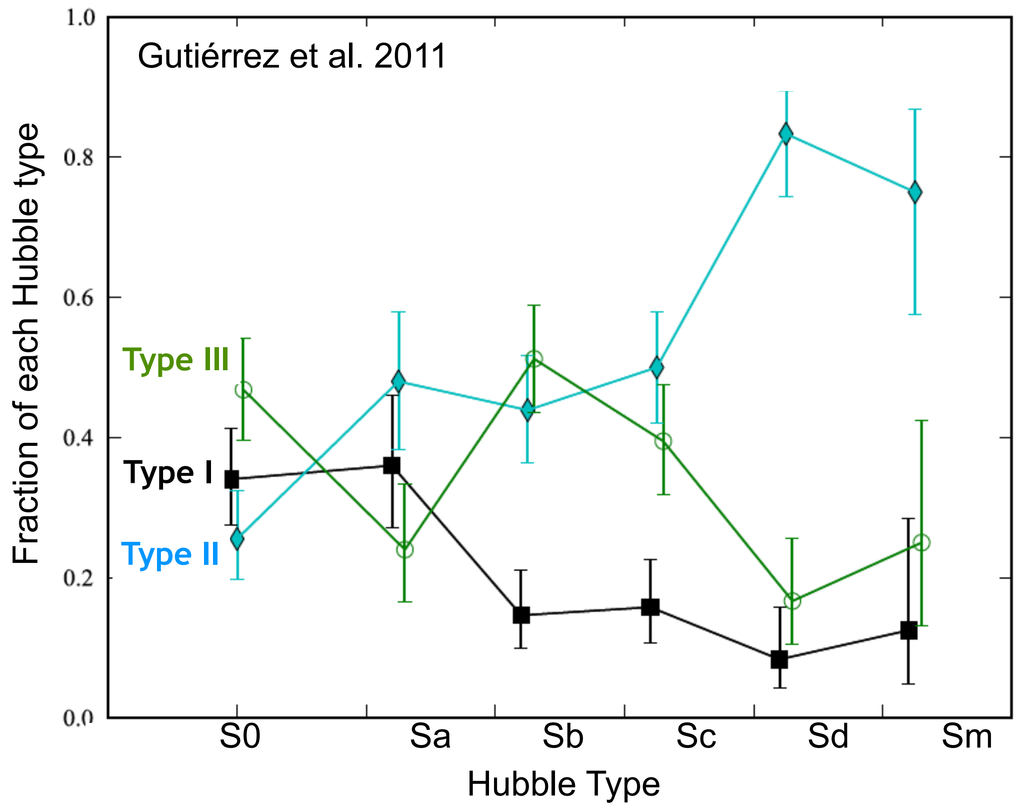




Structure of galactic discs

- **The abundance of profile types:**
  for ***local field galaxies* (S0-Sdm)**

  (Pohlen & Trujillo 2006; Erwin et al. 2008; Gutiérrez et al. 2011)



- Shows a ***strong*** dependence on morphology:

  Type I: more frequent in ***early*-types**

  Type II: more frequent in ***late*-types**

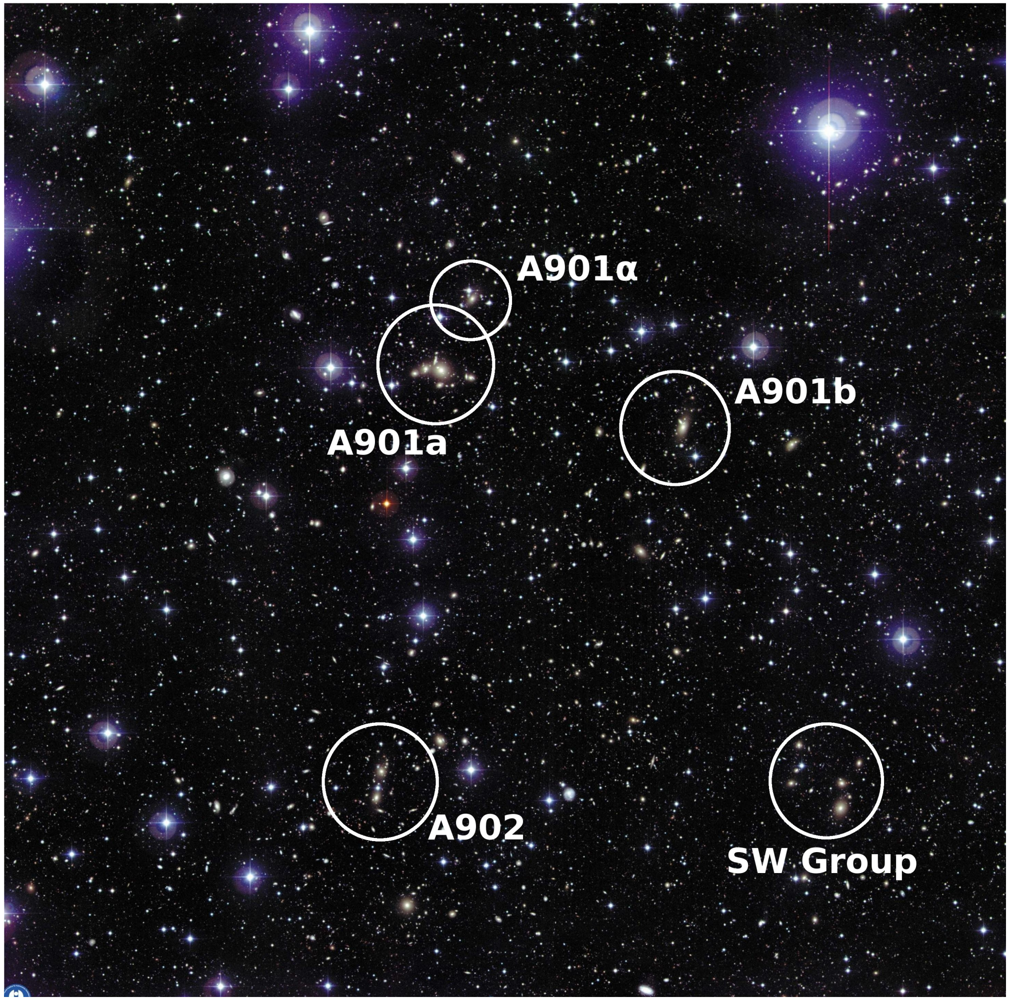
  Type III: more frequent in ***early*-types**

- **The effect of environment on disc structure?**

The STAGES Survey

STAGES

Space Telescope A901/2 Galaxy Evolution Survey



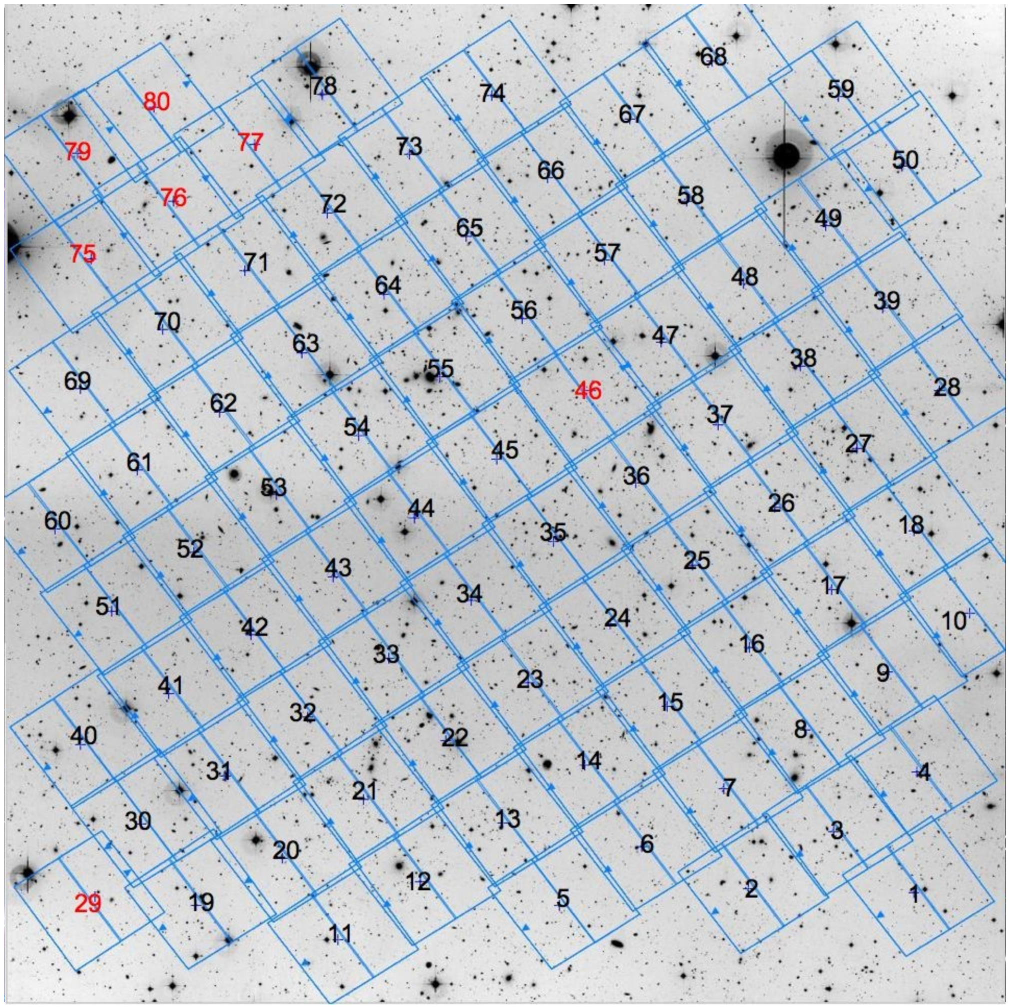
- A multi-wavelength survey spanning a wide range of galaxy environments.
- Contains the **Abell 901/2** multi-cluster system at $z \sim 0.167$.
- *V*-band *HST*/ACS imaging
  - ➡ ***Surface brightness μ(r) profiles for ~600 galaxies***
- Photometric redshifts (**COMBO-17**) + visual Hubble-type morphologies

Environment

- ***Cluster galaxies:*** photo-z selection based on the likelihood of cluster membership ($z_{cl} = 0.167$)
- ***Field galaxies:*** photo-z selected to avoid the cluster (**Note:** will include poor galaxy groups)

STAGES

Space **T**elescope **A**901/2 **G**alaxy **E**volution **S**urvey



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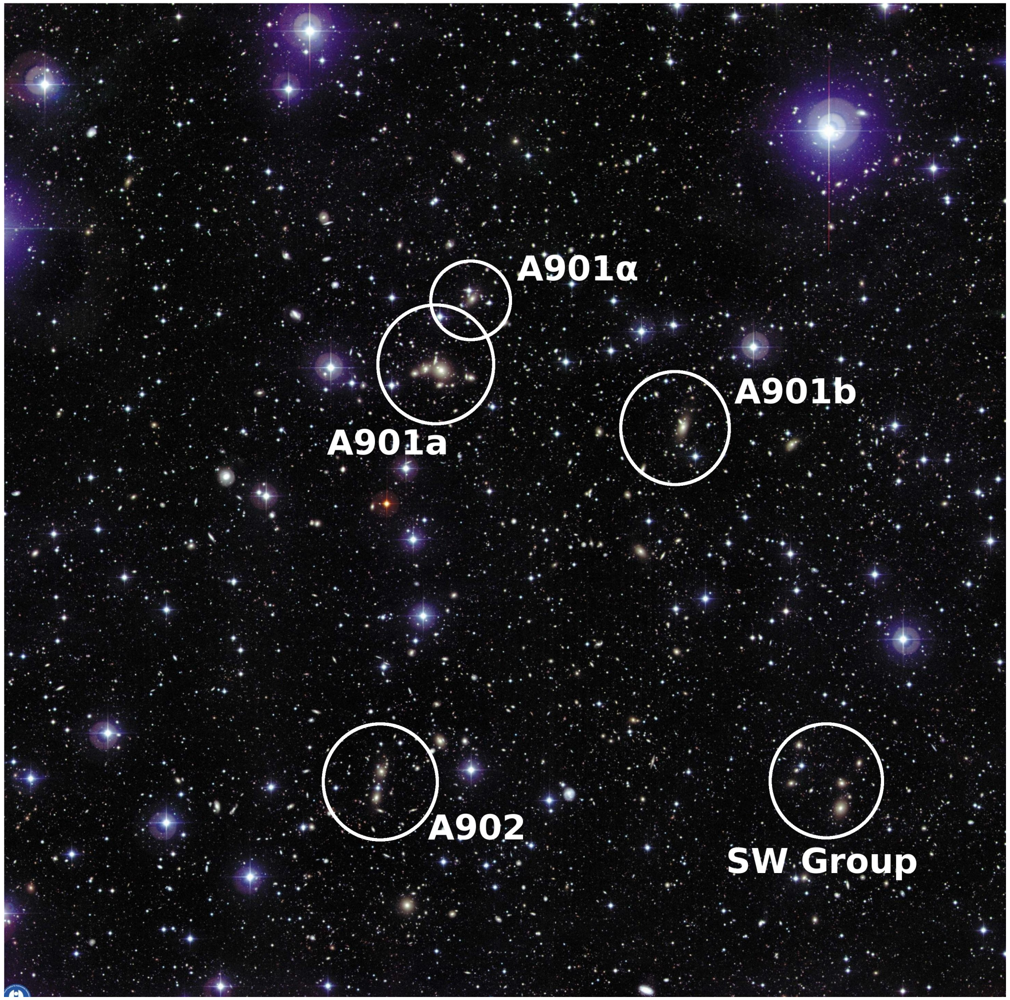

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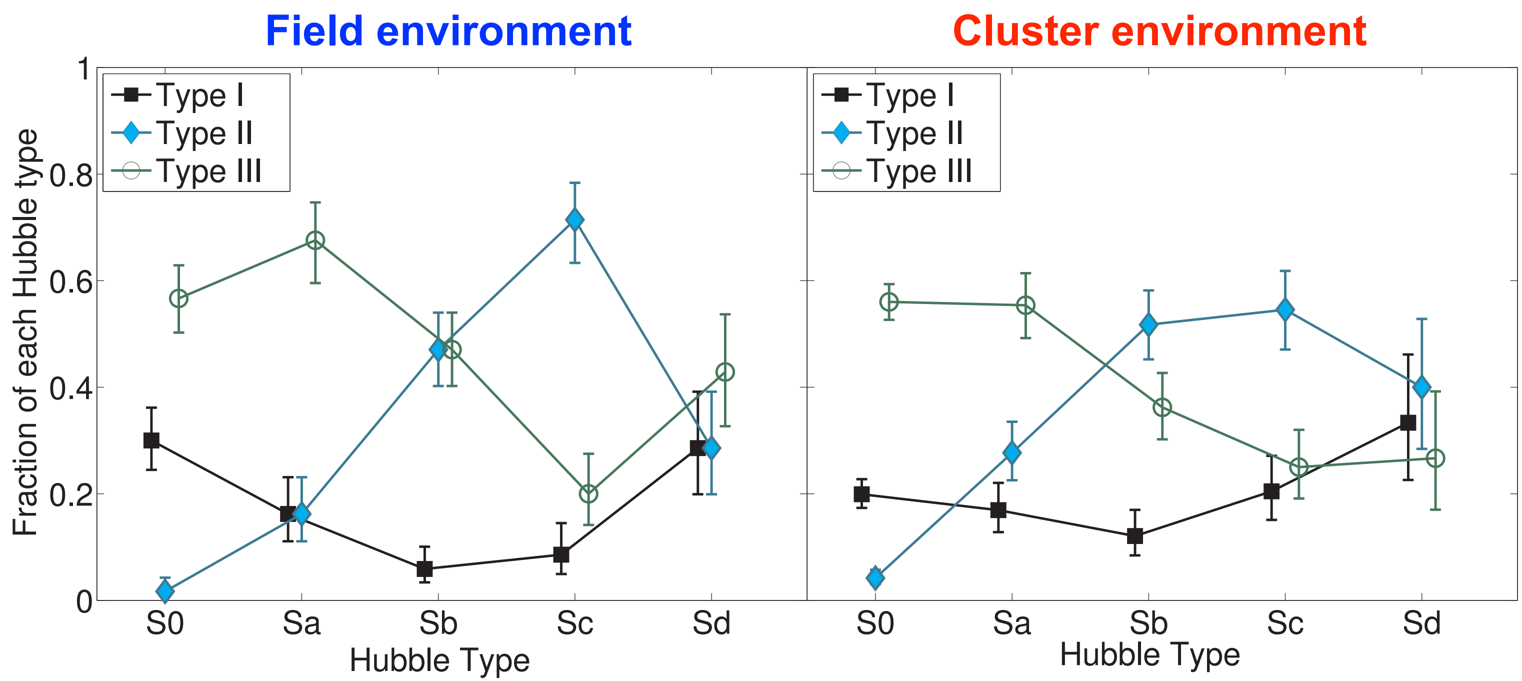
Disc structure & environment

The abundance of profile types

- Within **STAGES**, for all disc morphologies (**S0-Sd**) the frequency of profile types are the ***same*** in both the field and cluster environments.

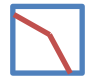


- In ***both*** the field and cluster environments.

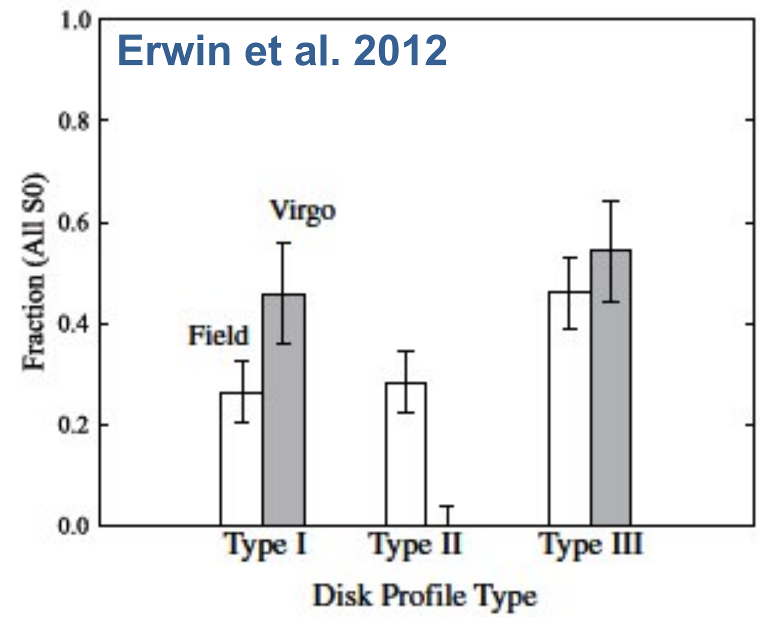
Morphology		***Type I***	***Type II***	***Type III***
	***Spiral***	*~20%*	*~40%*	*~40%*
	***S0***	*~25%*	***< 5%***	*~50%*

Disc structure & environment

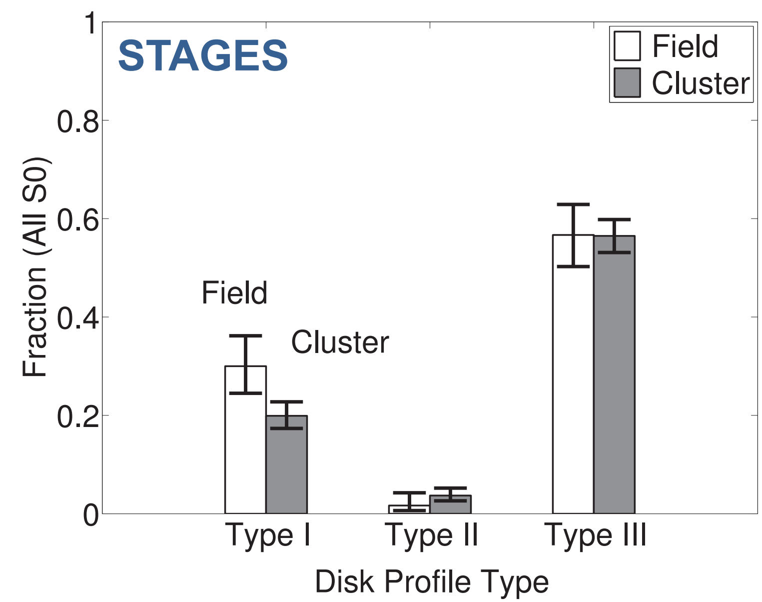
The abundance of profile types

- *An intriguing discrepancy for Type II*  *S0s!*

- *Erwin et al. (2012)*: an absence of Type II S0s in the cluster ***ONLY!***



- **STAGES:** an absence of Type II S0s in ***both*** the field and cluster.



- ***A possible explanation:***
  - In **STAGES**, the S0 bar fraction is much lower than in *Erwin et al. (2012).*
  - Bar related truncations (**Type II-OLR**) largely absent from **STAGES** S0s.

Could S0 Type II-OLR survive in the field but not the cluster environment?

Disc structure & environment

Disc properties

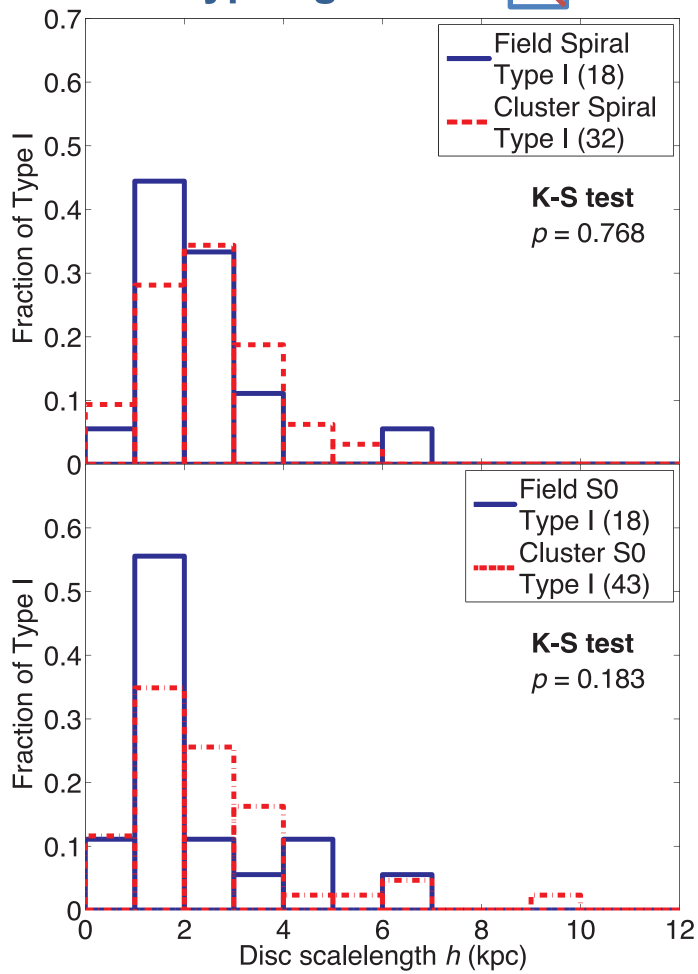
- Comparing ***disc structure*** [scalelength h; break strength T (log10 h_{out} / h_{in})] in the field and cluster environments.

No indication of an environmental effect!

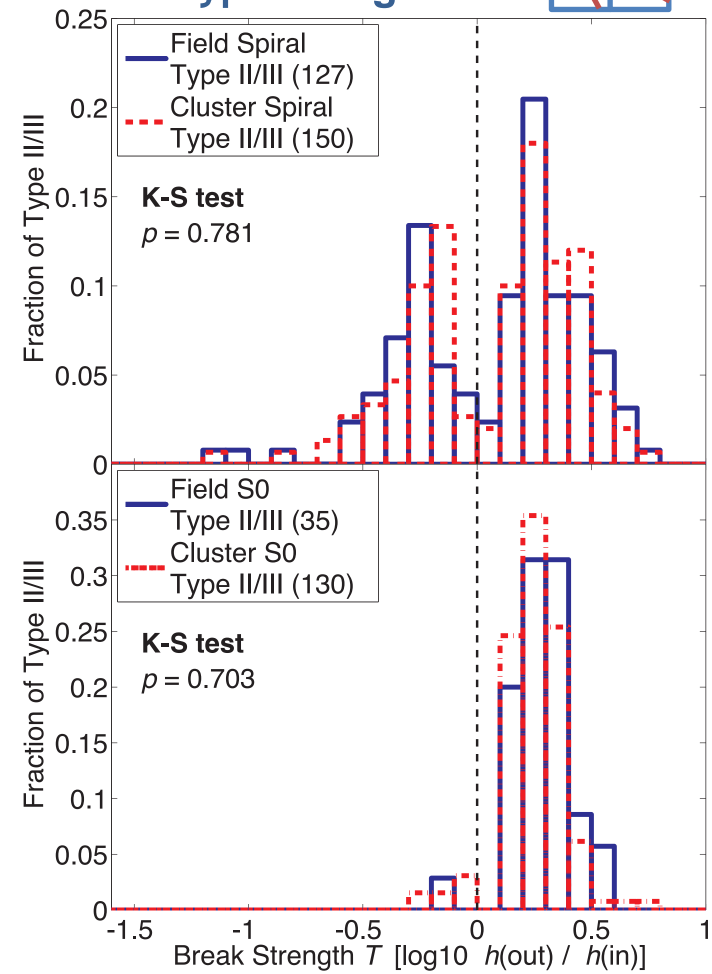
Spiral galaxies

S0 galaxies

Type I galaxies



Type II/III galaxies



So does environment influence the structure of galactic discs?

Does environment influence the structure of galactic discs?

In **STAGES,** we find:

- ***No evidence*** to suggest that the structure of galactic discs:

  - *frequency of profile type,*
  - *scalelength or break strength;*

  is dependent on the environment for either spirals or S0s.

- ***Suggests:***

  i. Galaxy environment has ***little direct effect*** *on the structure of a galaxy's stellar distribution over the environments probed by* ***STAGES***

  ii. Environmental processes that directly affect the structure of the stellar distribution ***are not*** *driving the observed morphology—density relation*

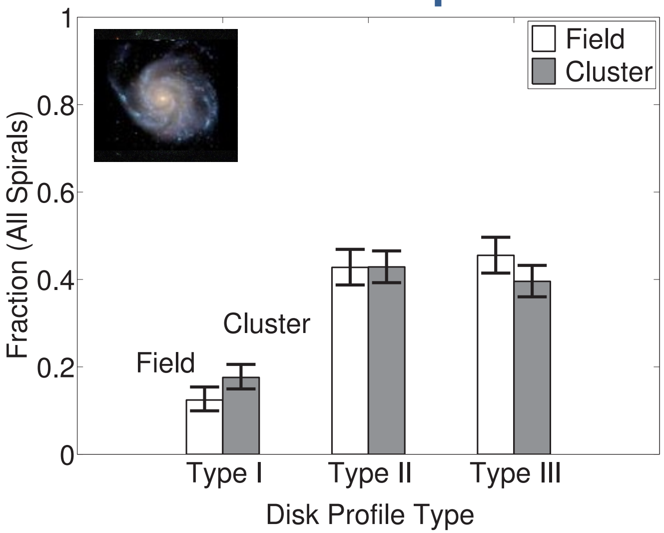
  ➔ more subtle (gas) processes likely to play an important role.

Disc structure in spirals/S0s

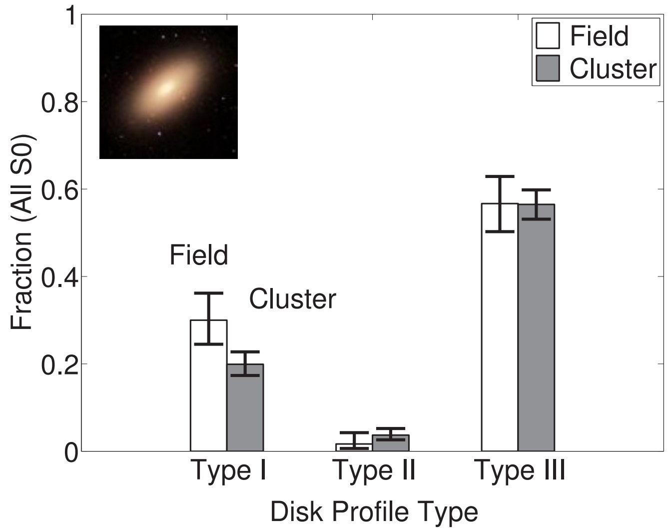
- The disc structure of ***spiral*** and ***S0*** galaxies exhibit some ***key differences:***

  i) **Profile Types:** a distinct ***lack of type II profiles in S0s*** compared to their abundance in spirals.

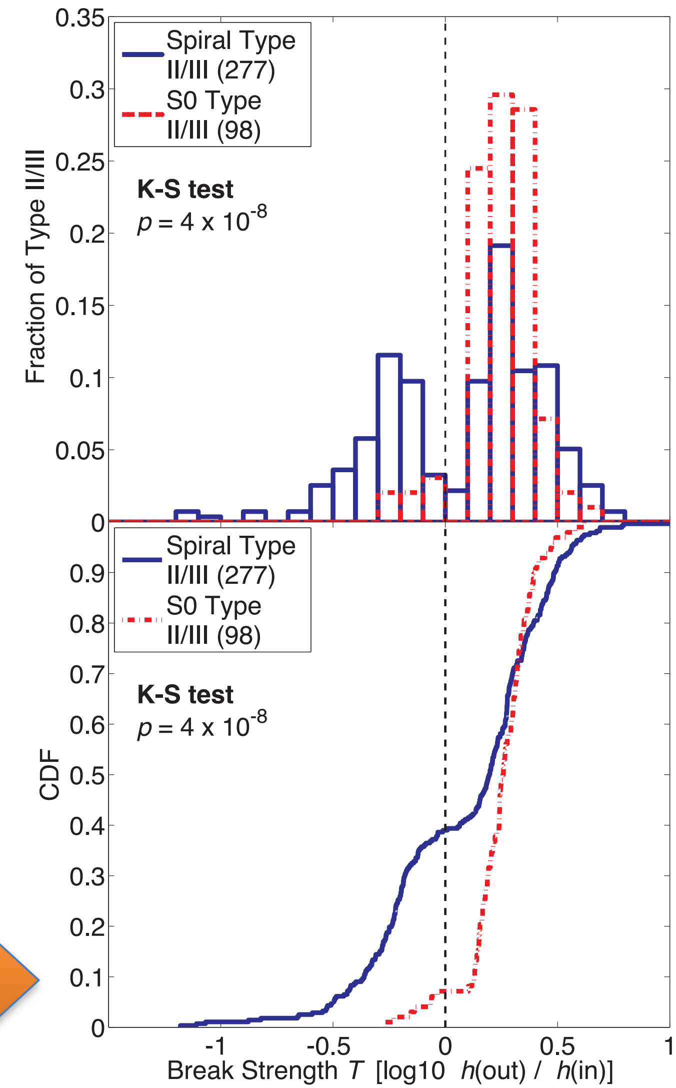
STAGES: Spirals



STAGES: S0s

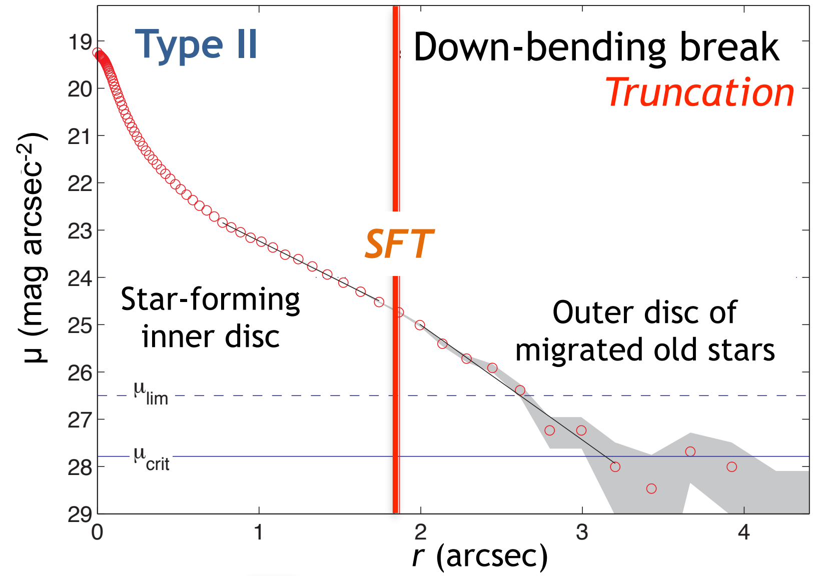


  ii) **Break Strength:** both truncations (; ***type II)*** and anti-truncations (; ***type III***) appear ***weaker in S0s*** compared to spirals

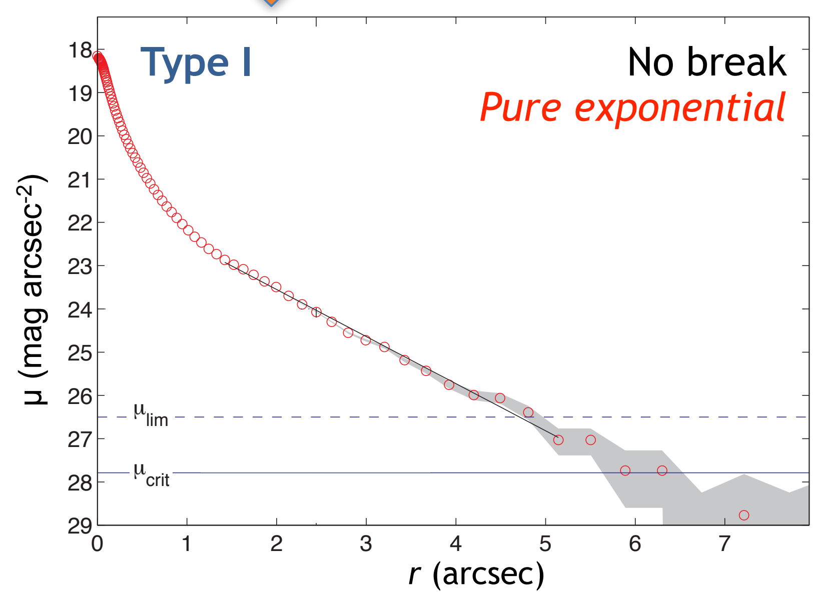


The absence of Type II S0s

- Whatever mechanism transforms ***spirals → S0s*** seems to erase stellar disc truncations



Suppression of star formation



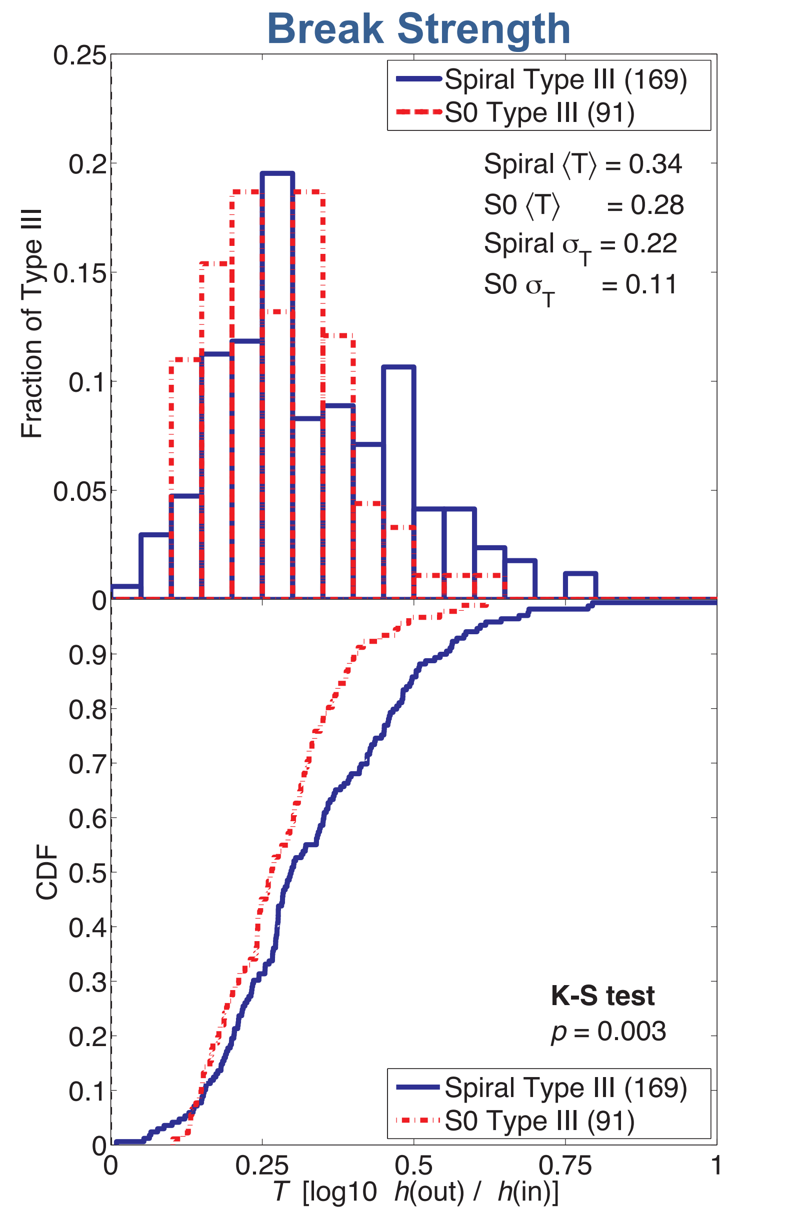
- ***A possible explanation:***
  - 'Classical' truncations (**Type II-CT**)

    → break related to a radial change in ***age*** of stellar population *(Bakos 2008; Roediger 2012)*
  - When star formation ceases, stars in the break region would eventually ***fade***

    → break ***weakens*** and maybe even ***disappears!***

Anti-truncated spirals/S0s

- Comparing ***disc structure*** between anti-truncated ( ; ***type III***) spirals and S0s:
  - anti-truncations ***weaker*** in S0s than in spirals



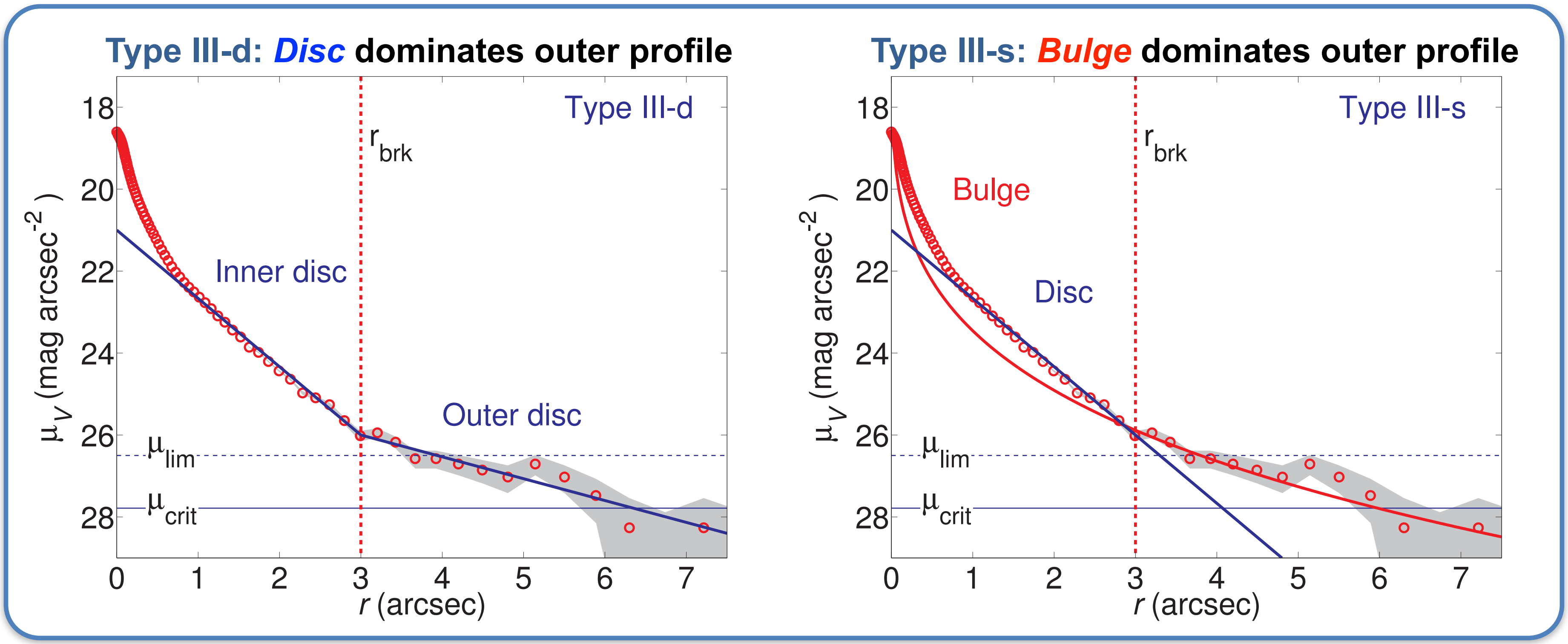
- ***A possible explanation:***
  - Formation probably due to an interaction (e.g. minor merger; *Younger et al. 2007*)
  - Stellar migrations could weaken break as ***Spirals → S0s***

- ***Complication: are some cases actually related to an extended bulge?***

Anti-truncated μ(r) profiles

Bulge or disc related?

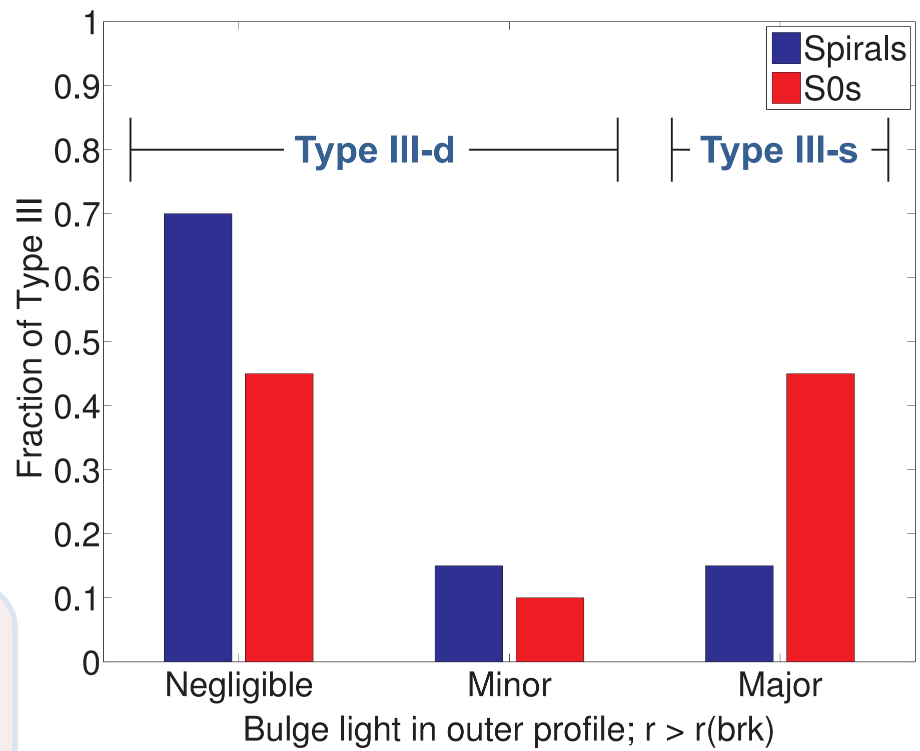
- **Type III profiles:** exhibit an up-bending break ( ; anti-truncation)
  - Probably relate to an interaction event (e.g. ***minor merger***) displacing stars into an ***extended outer disc*** → **Type III-d**
  - However, could equally be associated with an ***extended spheroidal*** (bulge) component (*initially proposed by Erwin et al. 2005)* → **Type III-s**



Anti-truncated $\mu(r)$ profiles

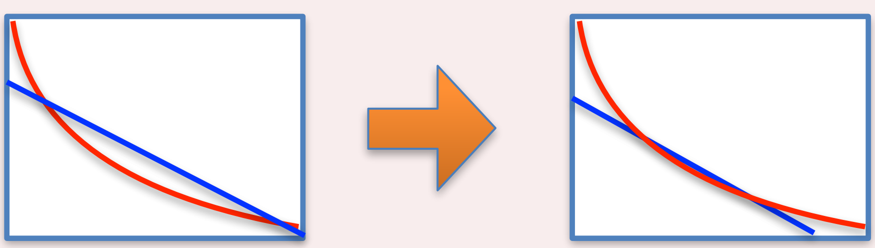
Bulge or disc related?

- **STAGES** Type III galaxies 
  - use ***bulge-disc decomposition*** to determine contribution of bulge light to outer profile ($r > r_{brk}$)



- A clear ***dependence on morphology***

- ***Conclusion:*** extended bulge light is far more prevalent in S0s than in spirals
  - suggests an ***evolving bulge-disc ratio*** and/or ***fading stellar disc*** as spirals transform into S0s



Morphology		Type III-d	Type III-s
	Spiral	~85%	~15%
	S0	~50%	~50%

Conclusions

- **STAGES:** *'The structure of galactic discs with environment'*

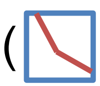
  i. Environment seems to have **little direct effect** on the structure of galactic discs

  ➡ ***suggests 'strong' environmental processes are not driving the observed morphology—density relation.***

  ➡ ***more subtle (gas) processes likely to play an important role.***

  ii. Truncated discs (; type II) are common in spirals but very rare in S0s.

  ➡ ***the termination of star-formation may erase any type II feature as spirals evolve into S0s.***

  iii. In spirals, anti-truncated light profiles (; type III) are primarily a disc phenomenon; but may be frequently caused by bulge light in S0s

  ➡ ***suggests an evolving bulge-disc ratio and maybe a fading stellar disc as spirals transform into S0s***

For further details see **Maltby et al. (2012a,b, 2015)**
[MNRAS 402, 282; MNRAS 419, 669; MNRAS 447, 1506]