MEGAMORPH

Investigating galaxy structure with multi-wavelength bulge-disc decompositions

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Why Bulge-Disk decomposition?

The bimodality of several galaxy properties, colour–magnitude, colour–concentration, and colour–morphology reflects their internal structure, red galaxies have a dominant bulge component while blue galaxies have a dominant disk component.

Strateva et al 2001, Baldry et al. 2004, Driver et al 2006, Drory & Fisher 2007, Bamford et al. 2009

Bulges

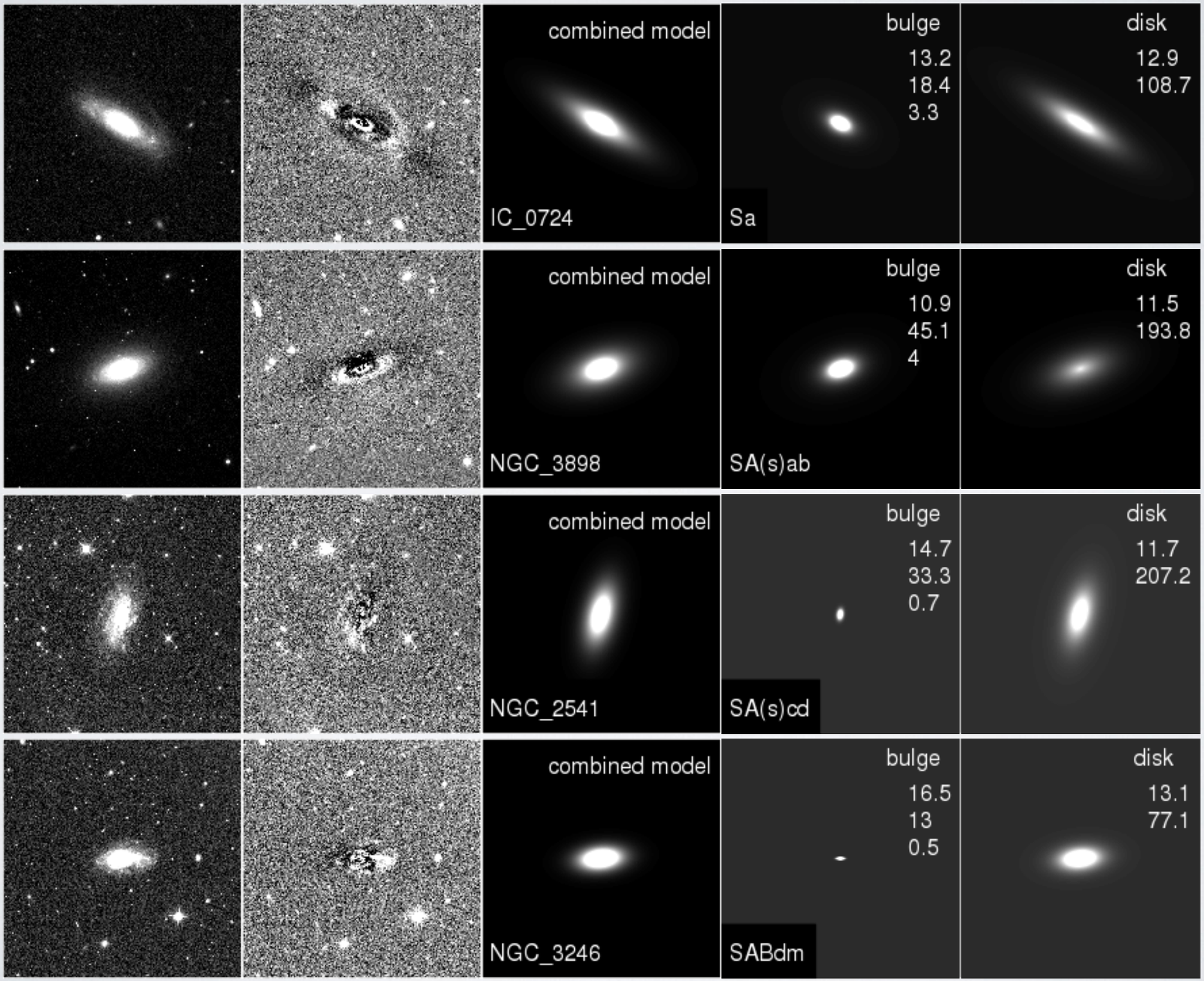
- old stellar populations
- low star formation rates
- pressure-dominated systems
- but we also have pseudo-bulges

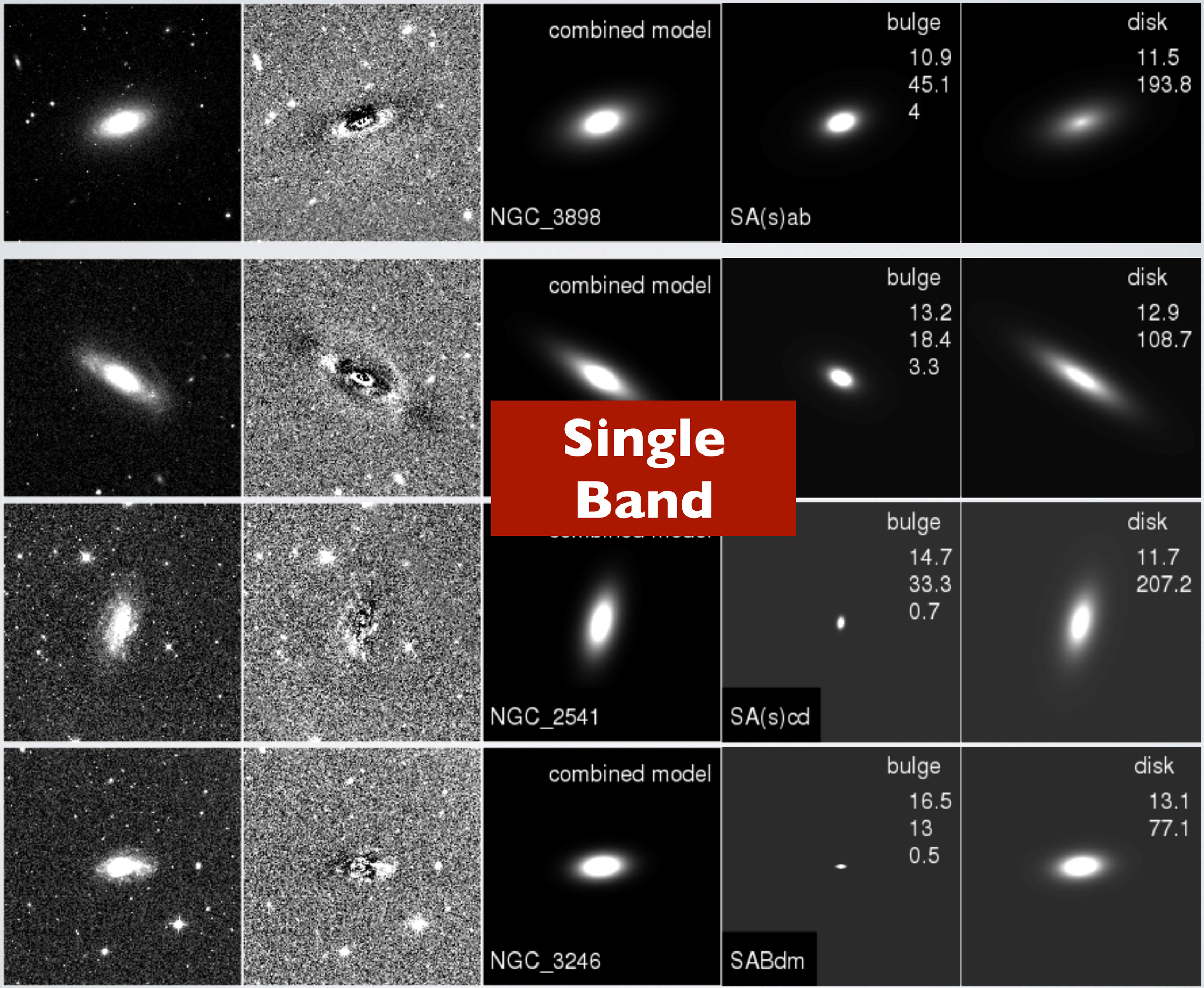
Disks

- younger stellar populations
- higher star formation rates
- rotationally supported systems

Various formation and evolutionary mechanisms have been proposed to explain the variety of properties observed in these two components: e.g. bulges formed by hierarchical mergers, their disks grow afterward from inside-out processes while pseudo-bulges form from secular processes inside discs.

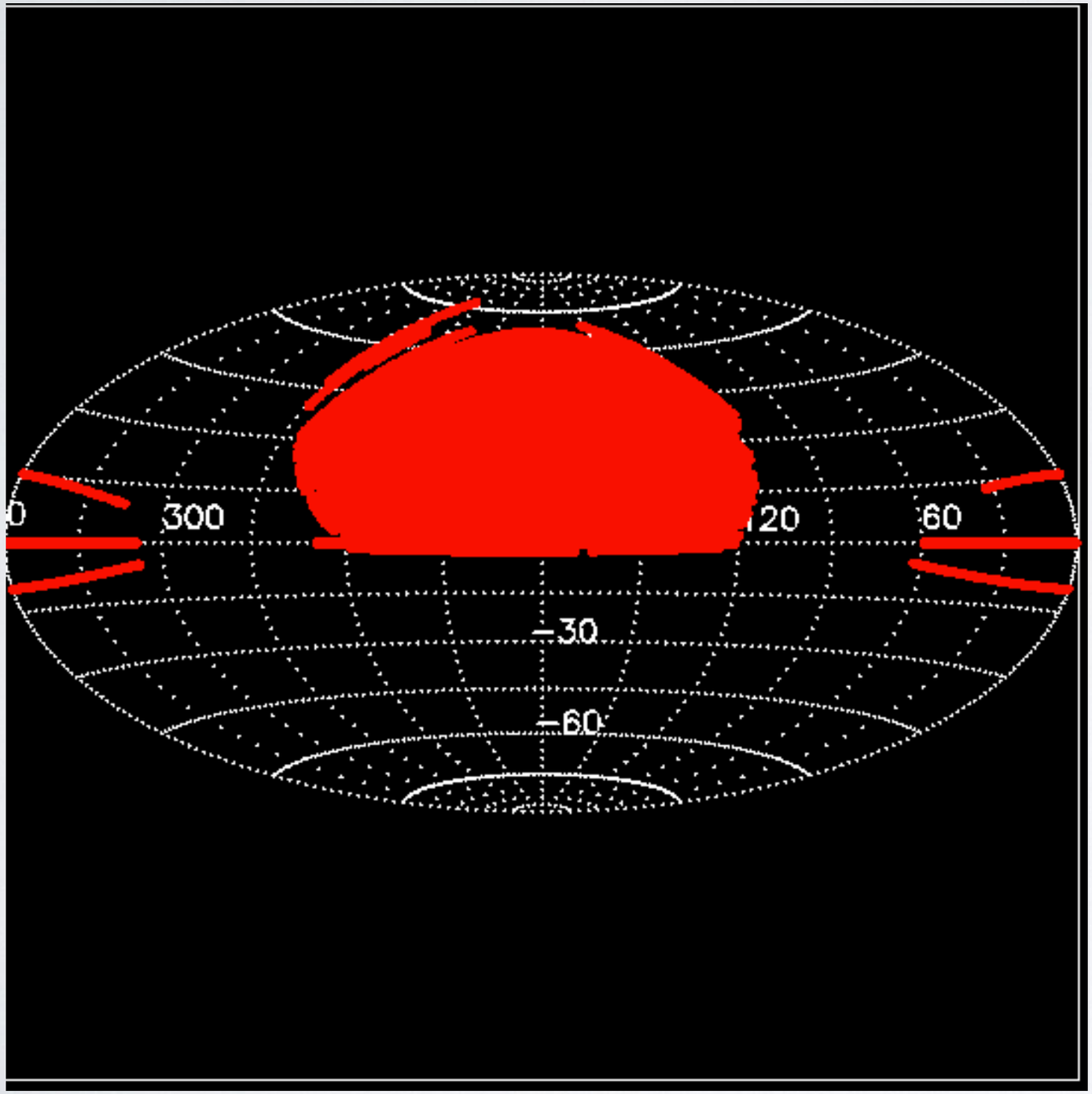
Quantitative measurements of bulge & disk properties




combined model
NGC_3898
bulge
10.9
45.1
4
SA(s)ab
disk
11.5
193.8
combined model
bulge
13.2
18.4
3.3
disk
12.9
108.7
Single Band
combined model
NGC_2541
bulge
14.7
33.3
0.7
SA(s)cd
disk
11.7
207.2
combined model
NGC_3246
bulge
16.5
13
0.5
SABdm
disk
13.1
77.1

SDSS

(Sloan Digital Sky Survey)



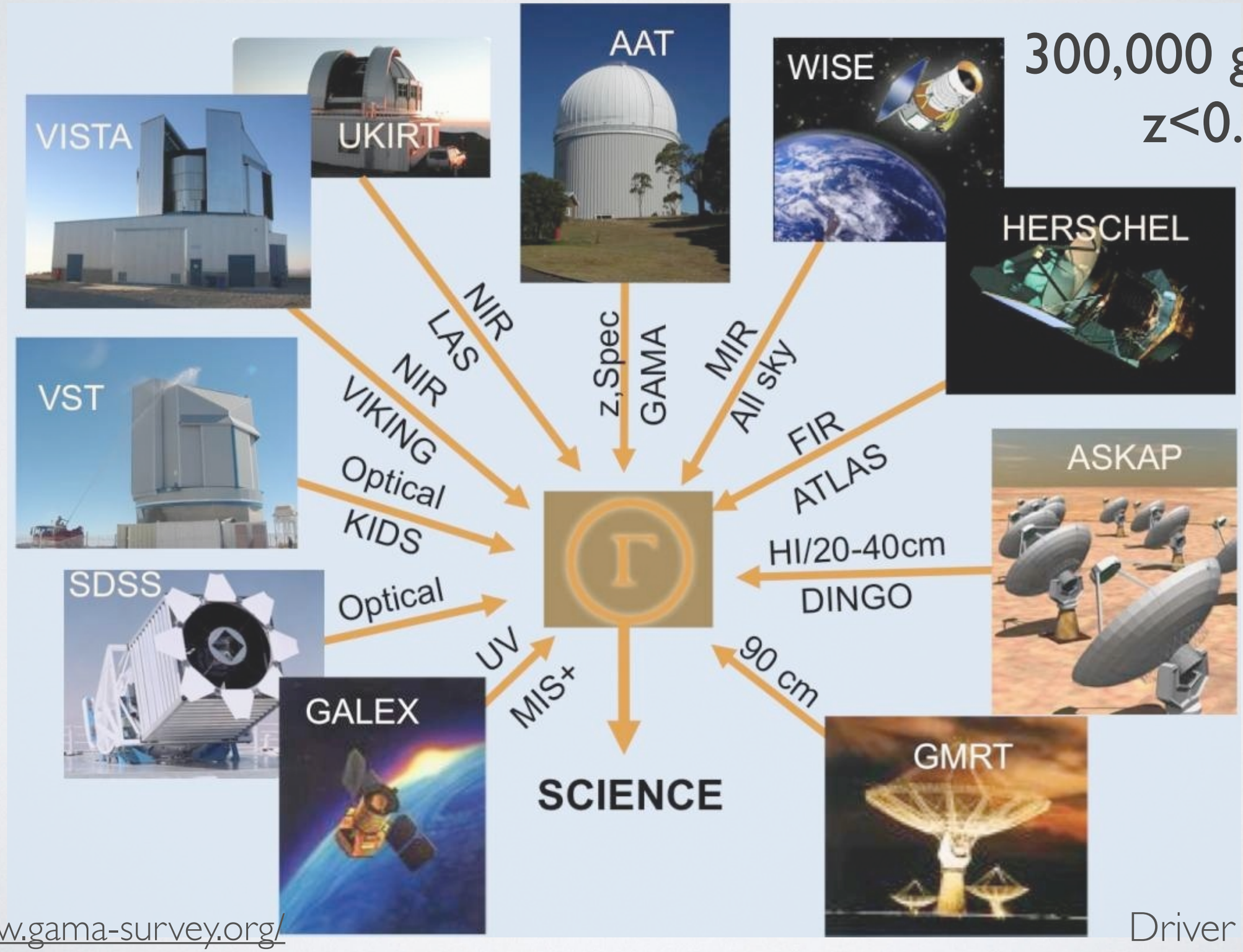
Multi wavelength (u,g,r,i,z) images covering more than a quarter (10,000 square degrees) of the sky containing more than 930,000 galaxies.

http://www.sdss.org/

Abazajian et al 2009

GAMA

(Galaxy And Mass Assembly)



300,000 galaxies
z<0.05

http://www.gama-survey.org/

Driver et al 2012

MEGAMORPH

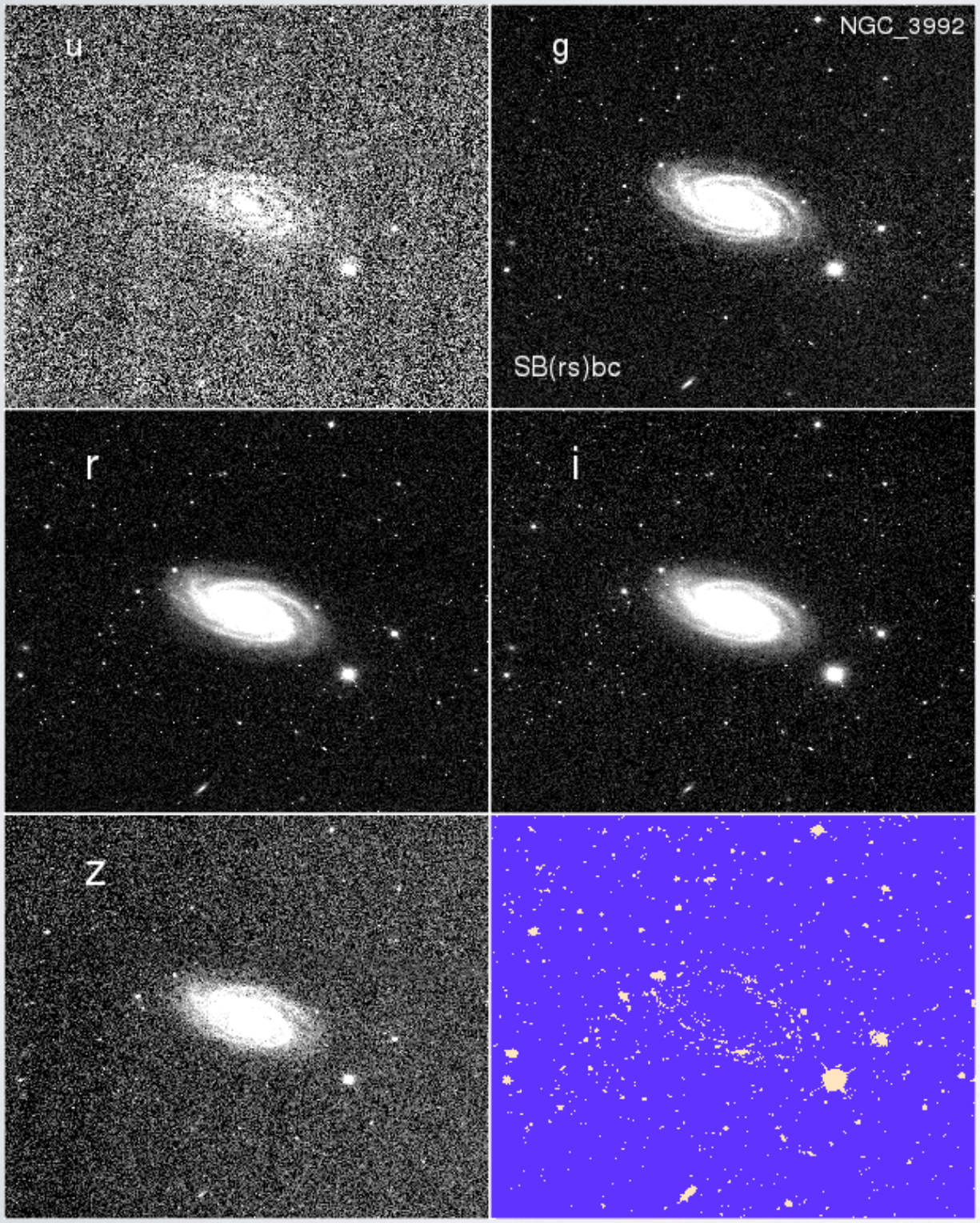
MULTI-WAVELENGTH MEASUREMENT OF GALAXY STRUCTURE

MegaMorph aims to improve our ability to separate galaxy components, particularly in large surveys.

MEGAMORPH

- Multi-band fitting (Bamford et al in prep. A)
- ~~Non parametric components~~ (Bamford et al in prep. B)
- ~~Explored parameter space (MultiNest)~~ (Bamford et al in prep. A)
- ~~Single Sérsic modelling~~ ~~(Vika et al 2013, 2015, Häußler 2013)~~
- Bulge-disk decomposition(Vika et al 2014, Häußler et al in prep., Kennedy et al B)
- ~~Wavelength dependent sizes and profiles of galaxies~~ (Vulcani et al 2014, Kennedy et al in prep. A)

Multi-Wavelength Sample

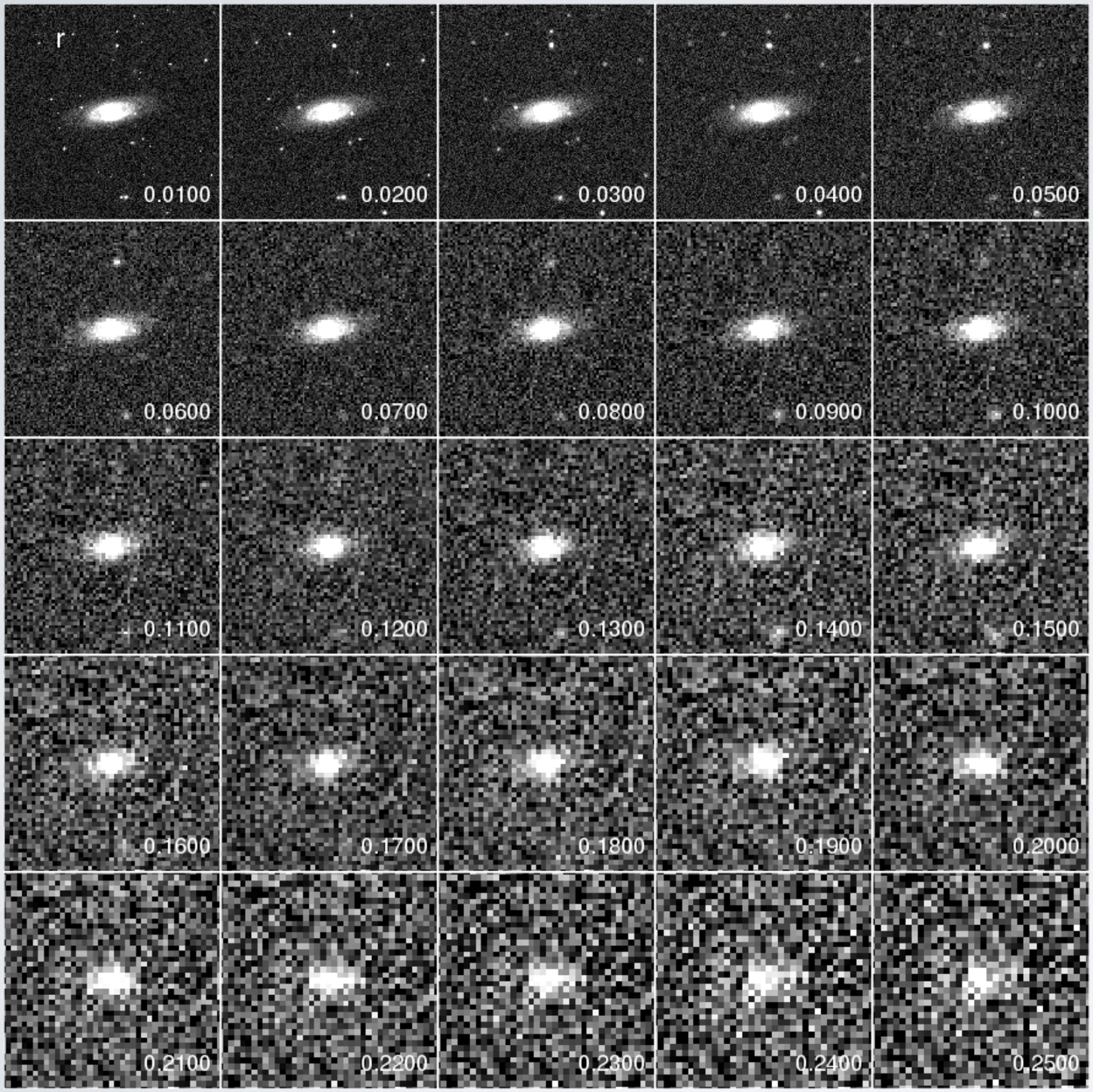


164 Galaxies
u,g,r,i,z bands
(SDSS)

- Mixed morphology
- Have been perviously studied in detail
- **Not** a complete sample

Vika et al 2013

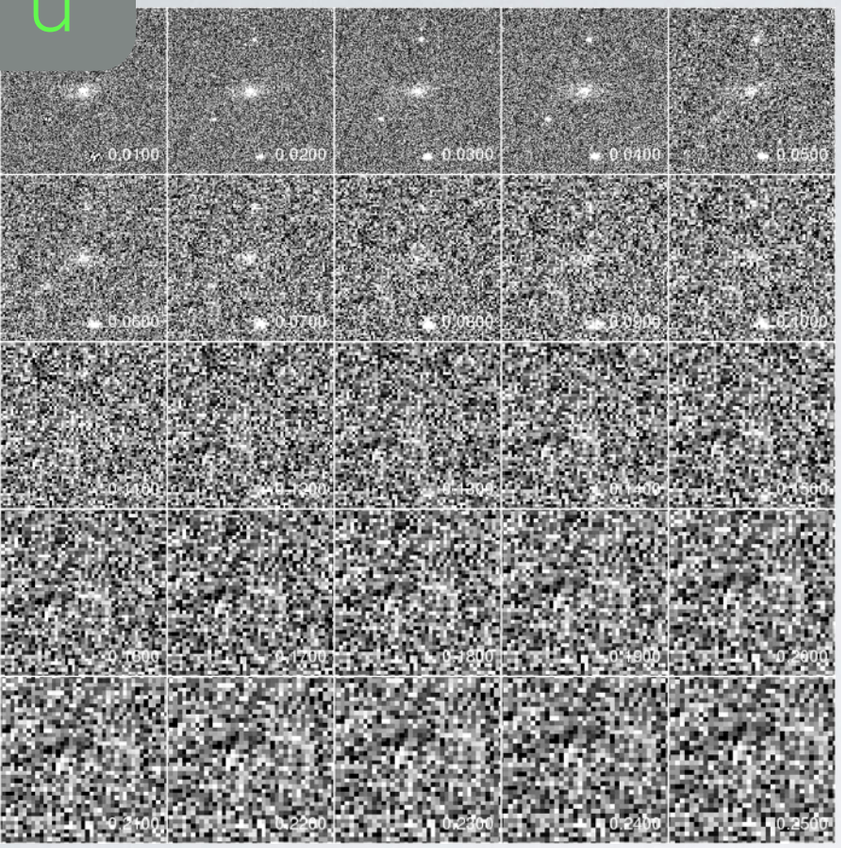
Artificially redshifted Sample



NGC 4274

We artificially redshift images using *FERENGI*

u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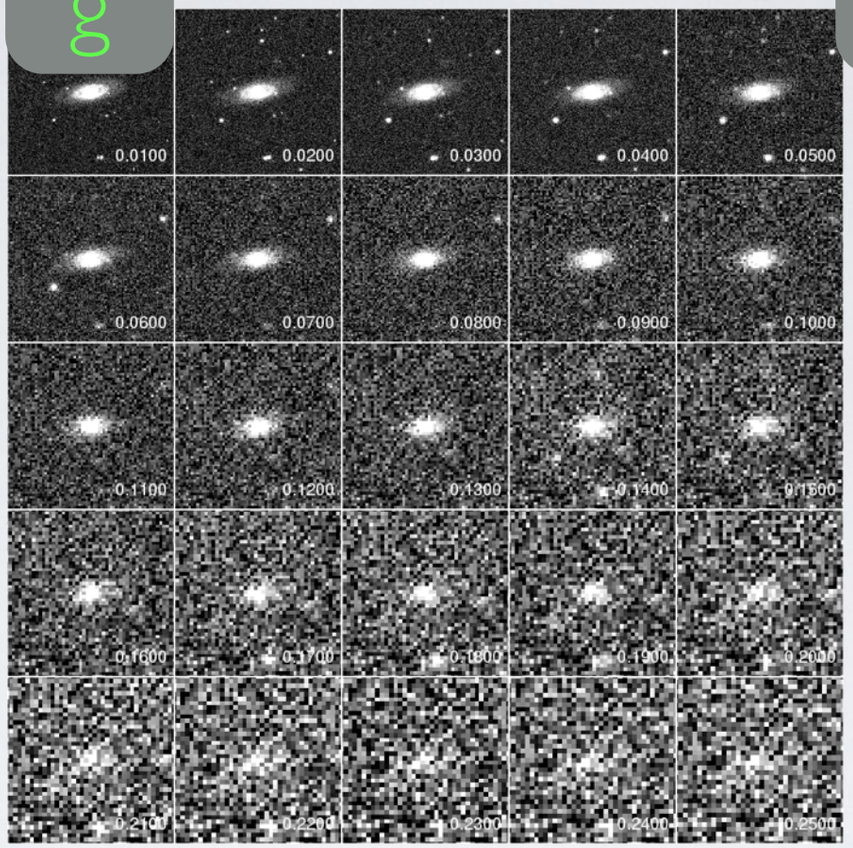
g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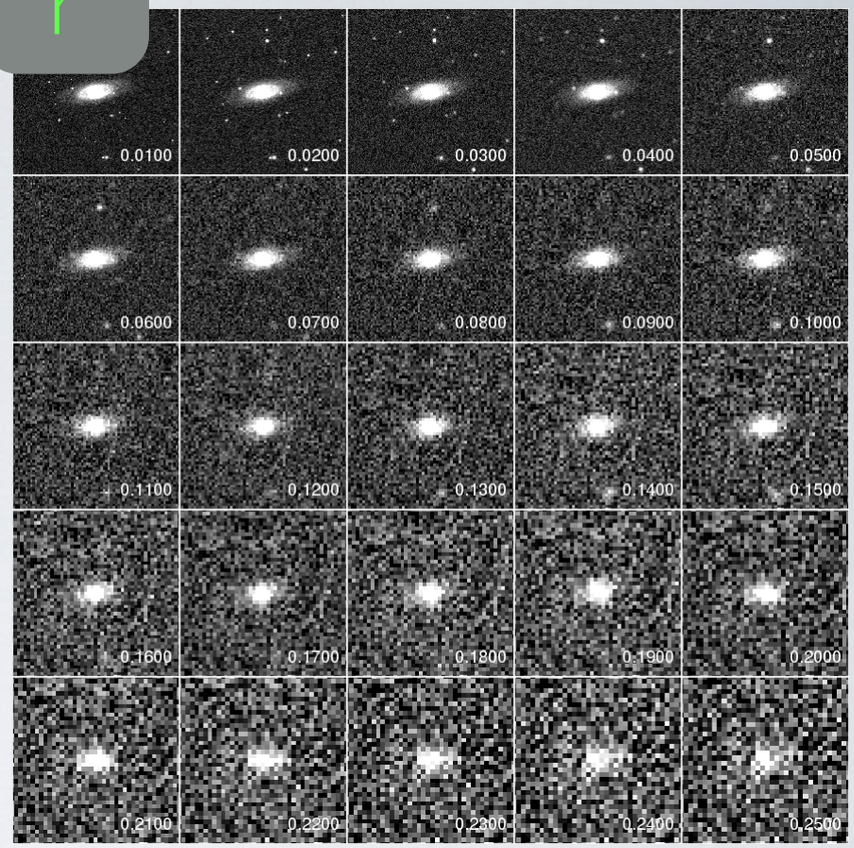
r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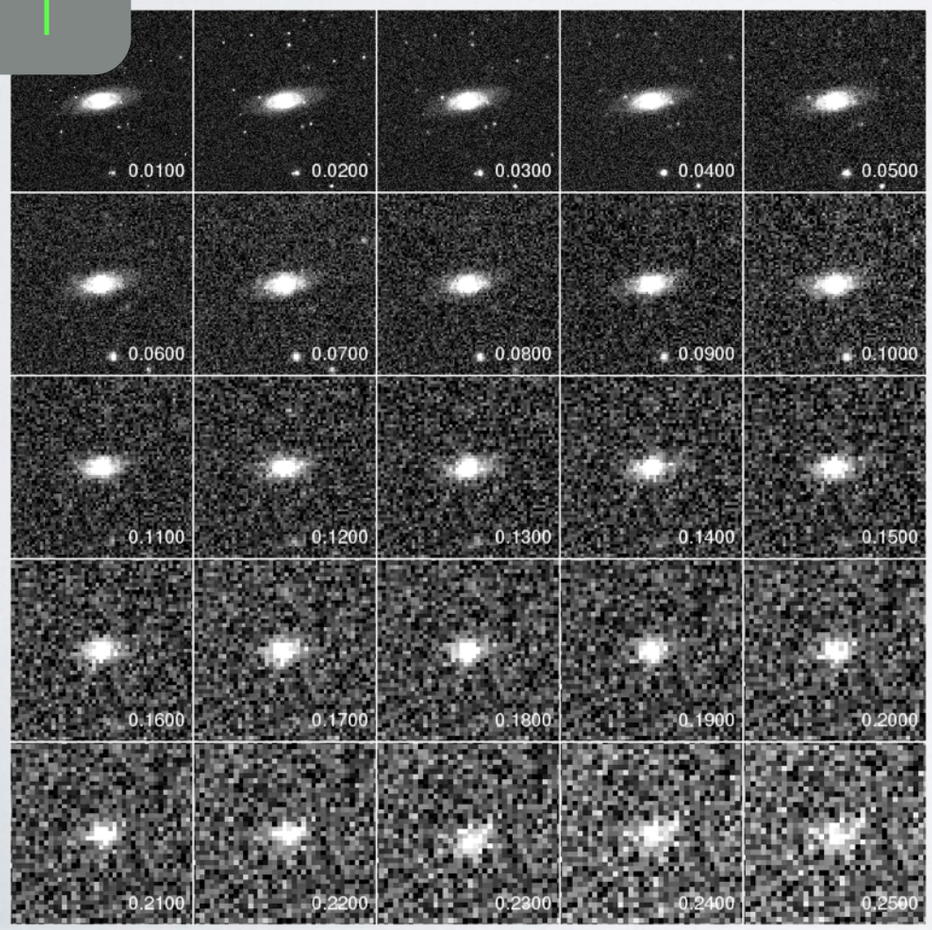
i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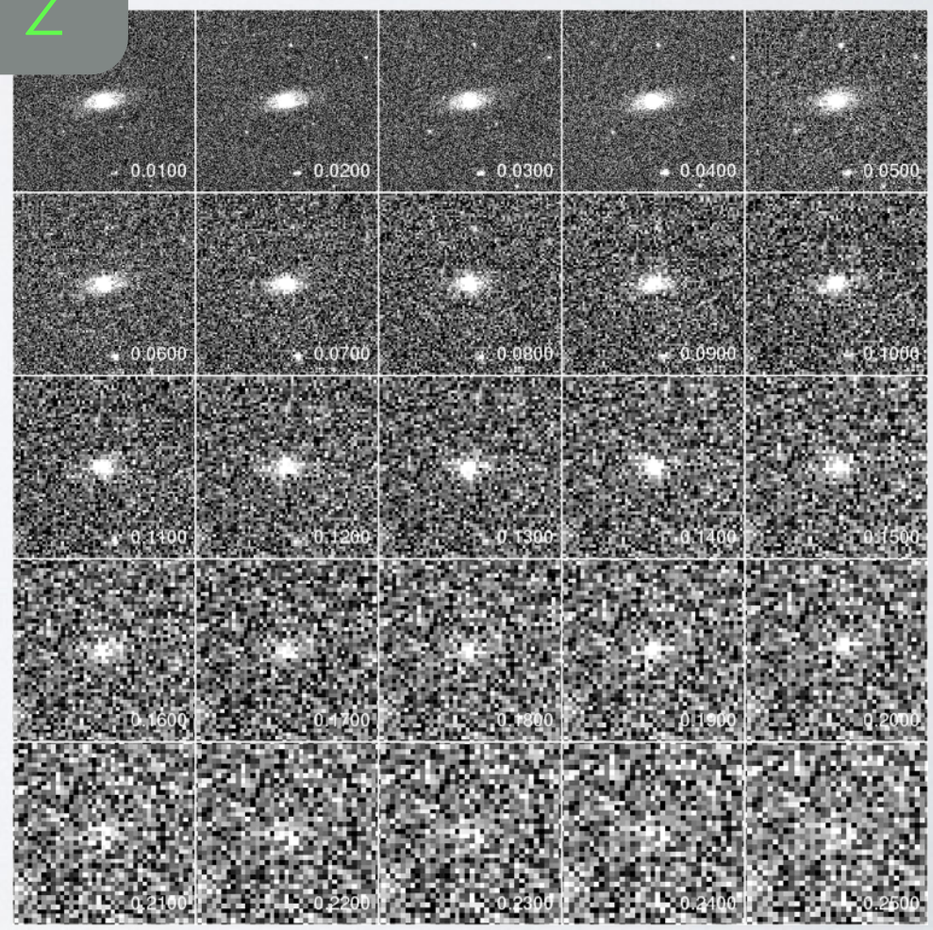
z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Fit polynomials instead of values

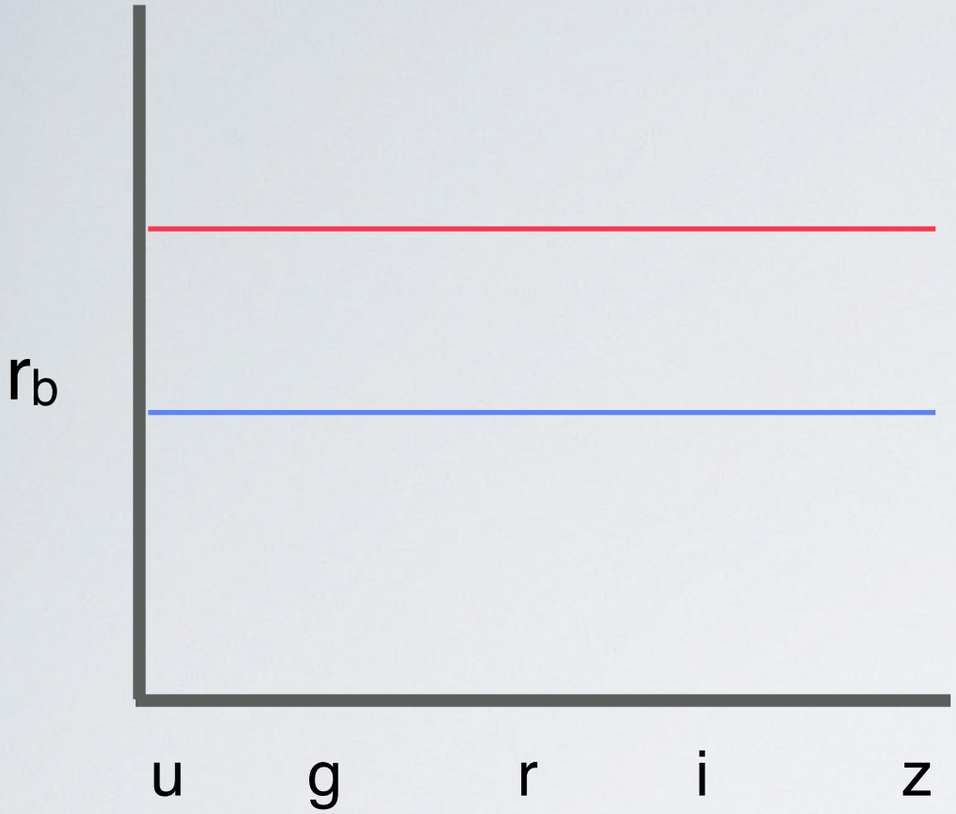
Chebyshev polynomials $$f(\lambda) = \sum_{i=0}^{m} c_i T_i(\lambda)$$

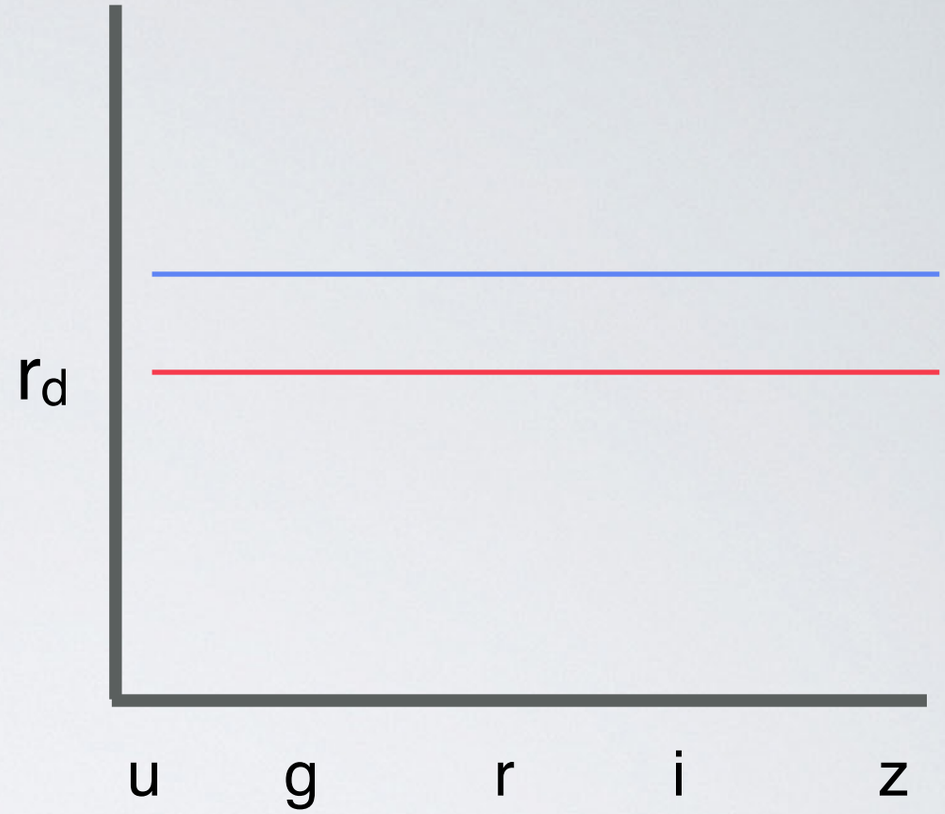
$$I(r) = I_e \exp\left(-b_n \left[(r/r_e)^{1/n} - 1)\right]\right)$$ Sérsic function

$I_e(\lambda)$ $r_e(\lambda)$ $n(\lambda)$

GALFIT → GALFITM

GALAPAGOS → GALAPAGOS-2


r_b
u
g
r
i
z


r_d
u
g
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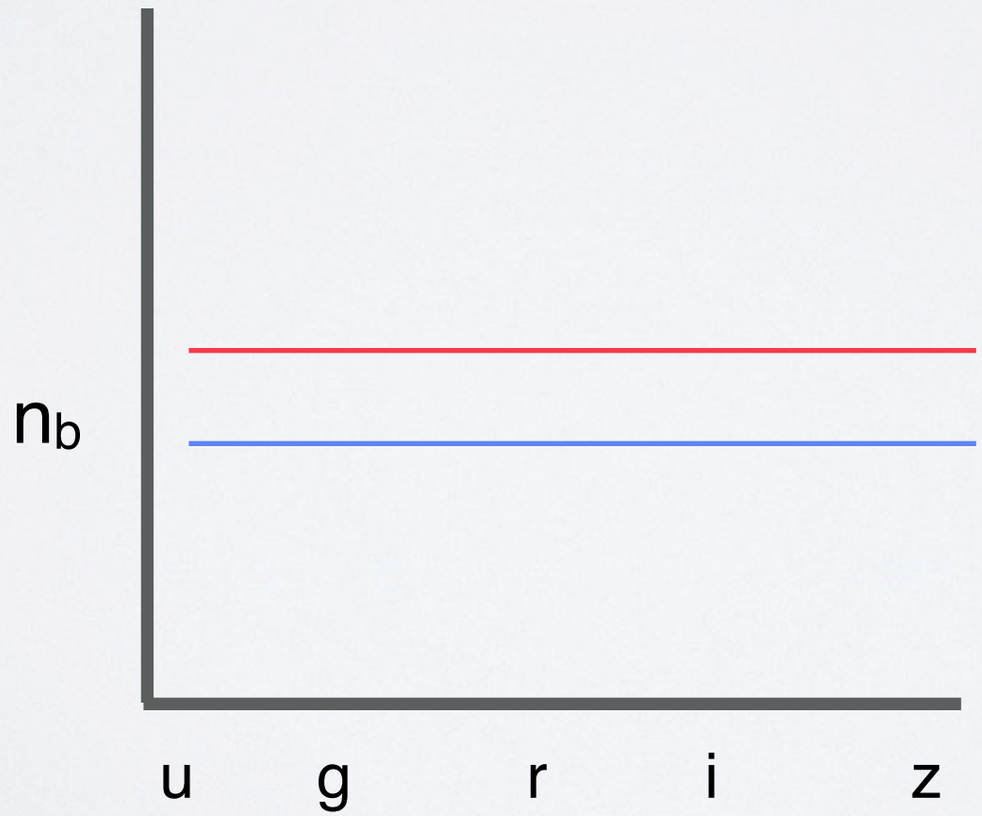
n_b
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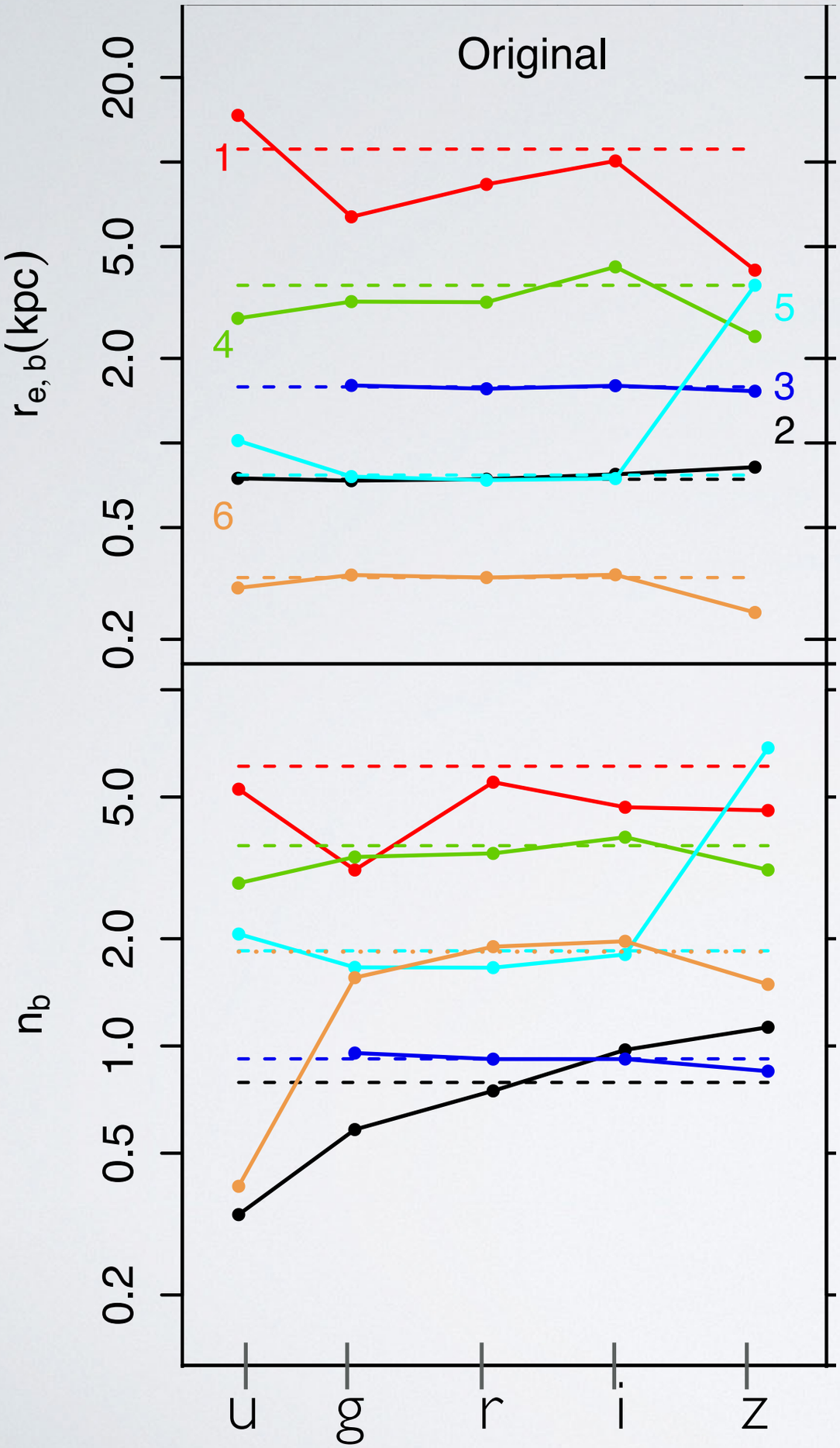
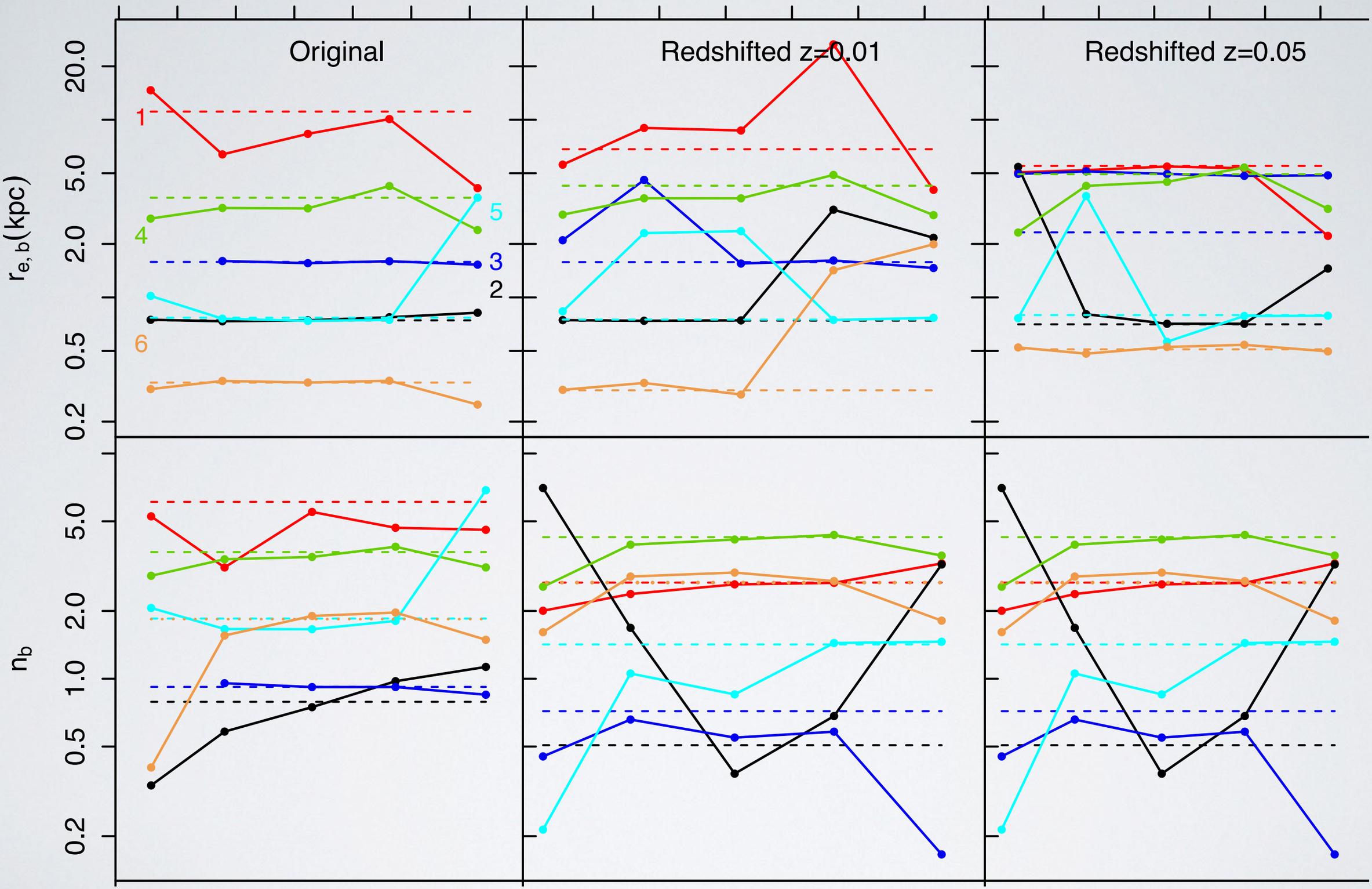


Effective radius of bulge($r_{e,b}$)
values for 6 galaxies

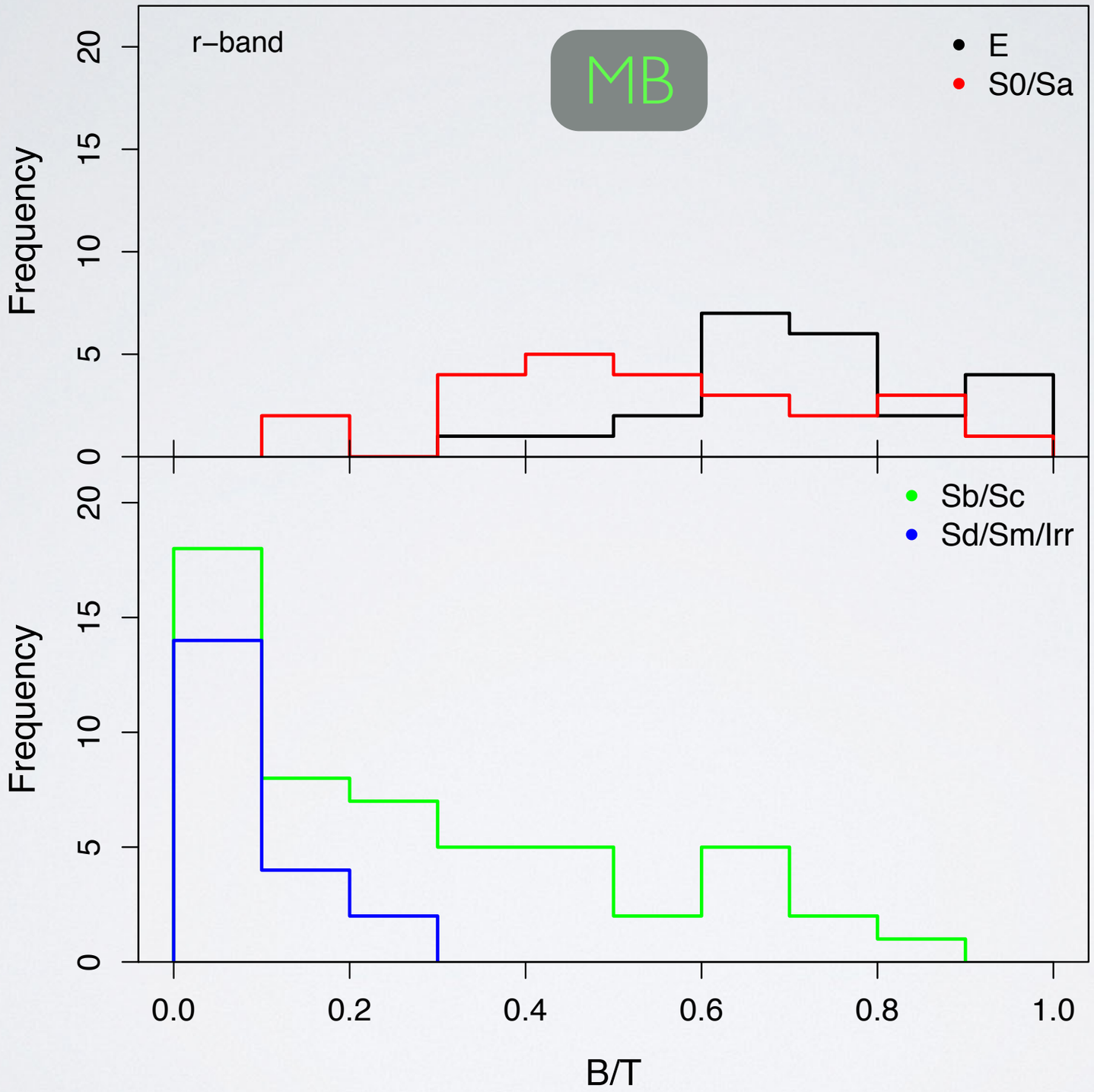
Bulge Sérsic index (n_b)
values for the same galaxies.

Vika et al 2014

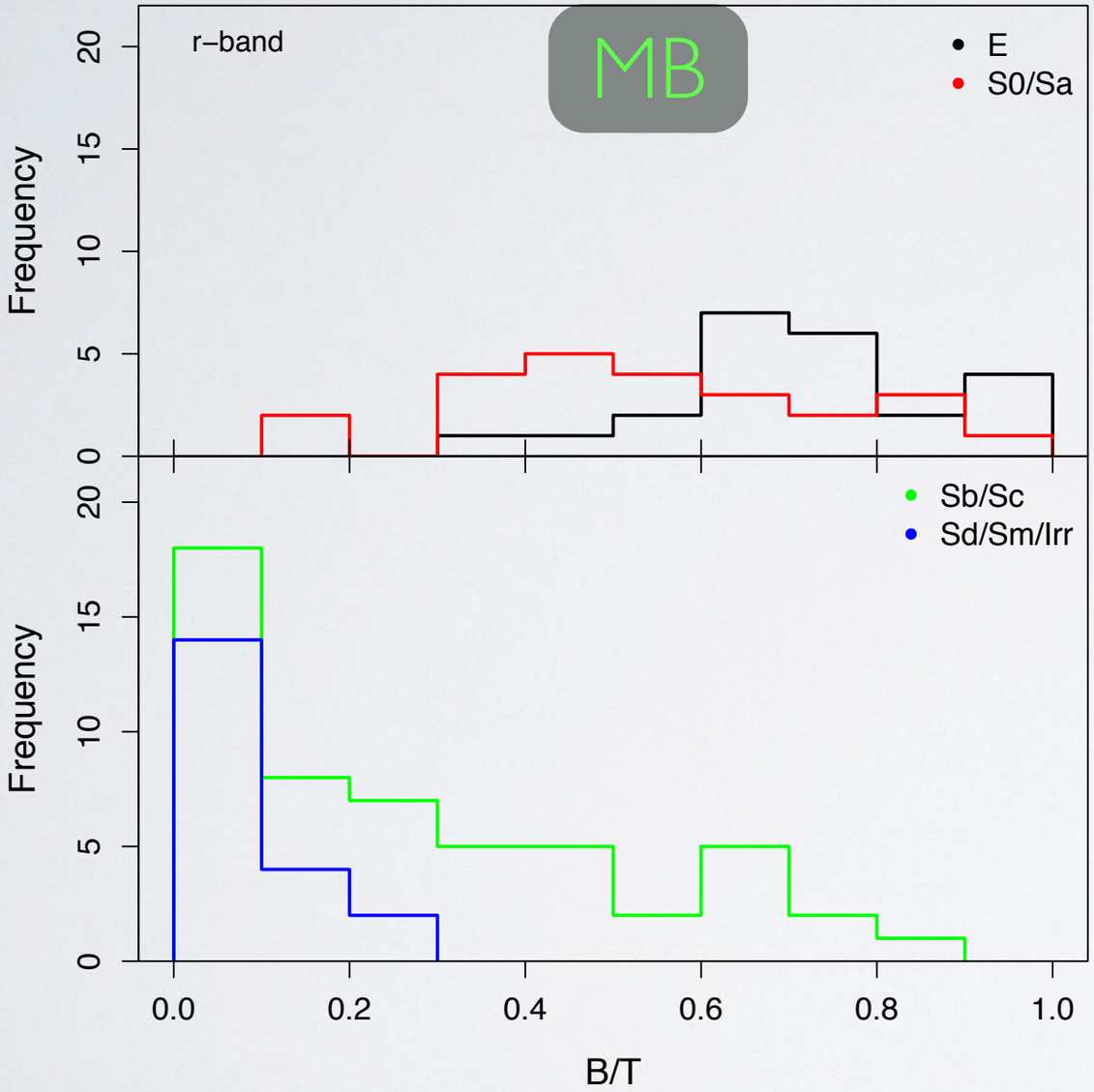


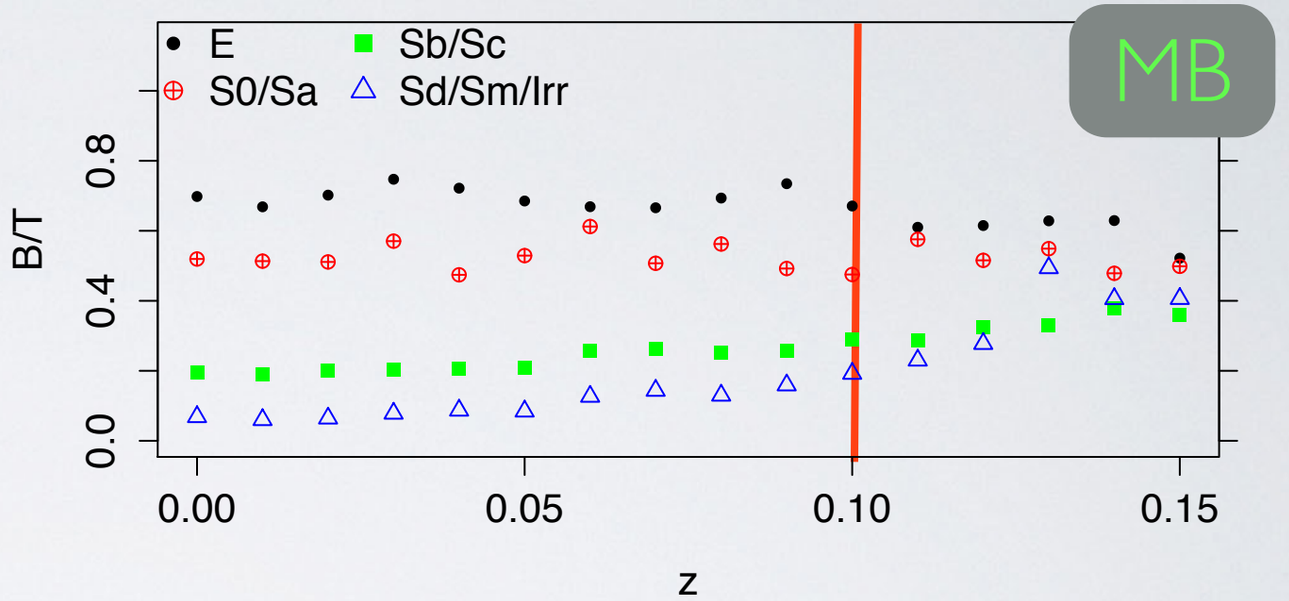
Vika et al 2014

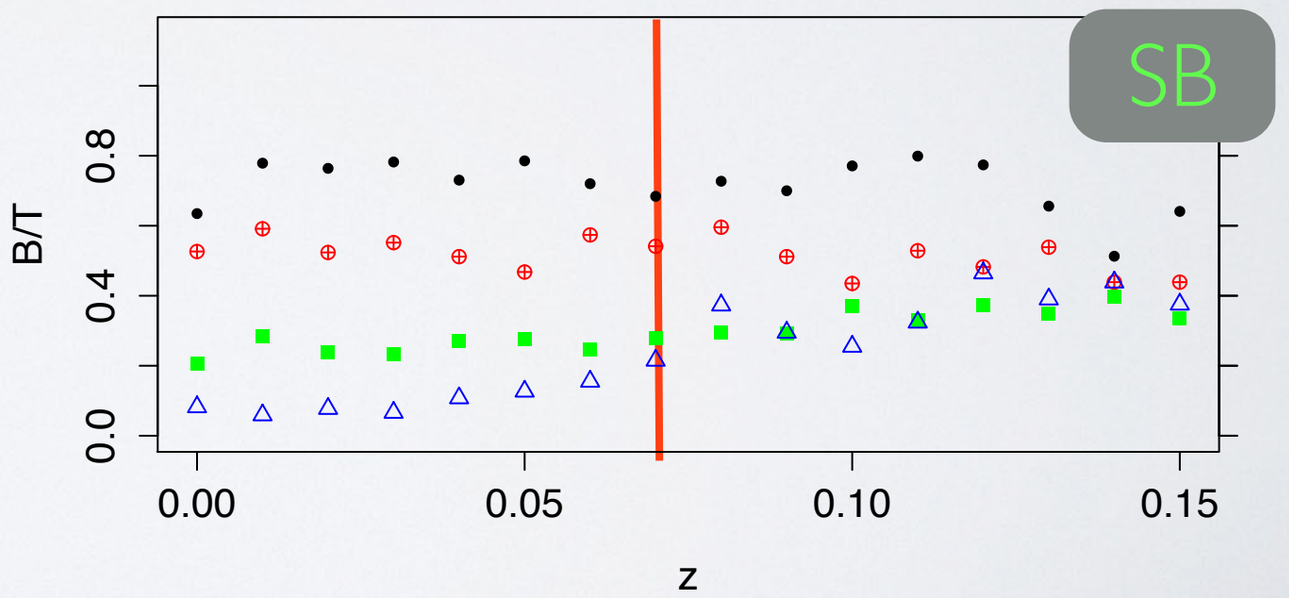
Bulge-to-total flux ratio (Original images)



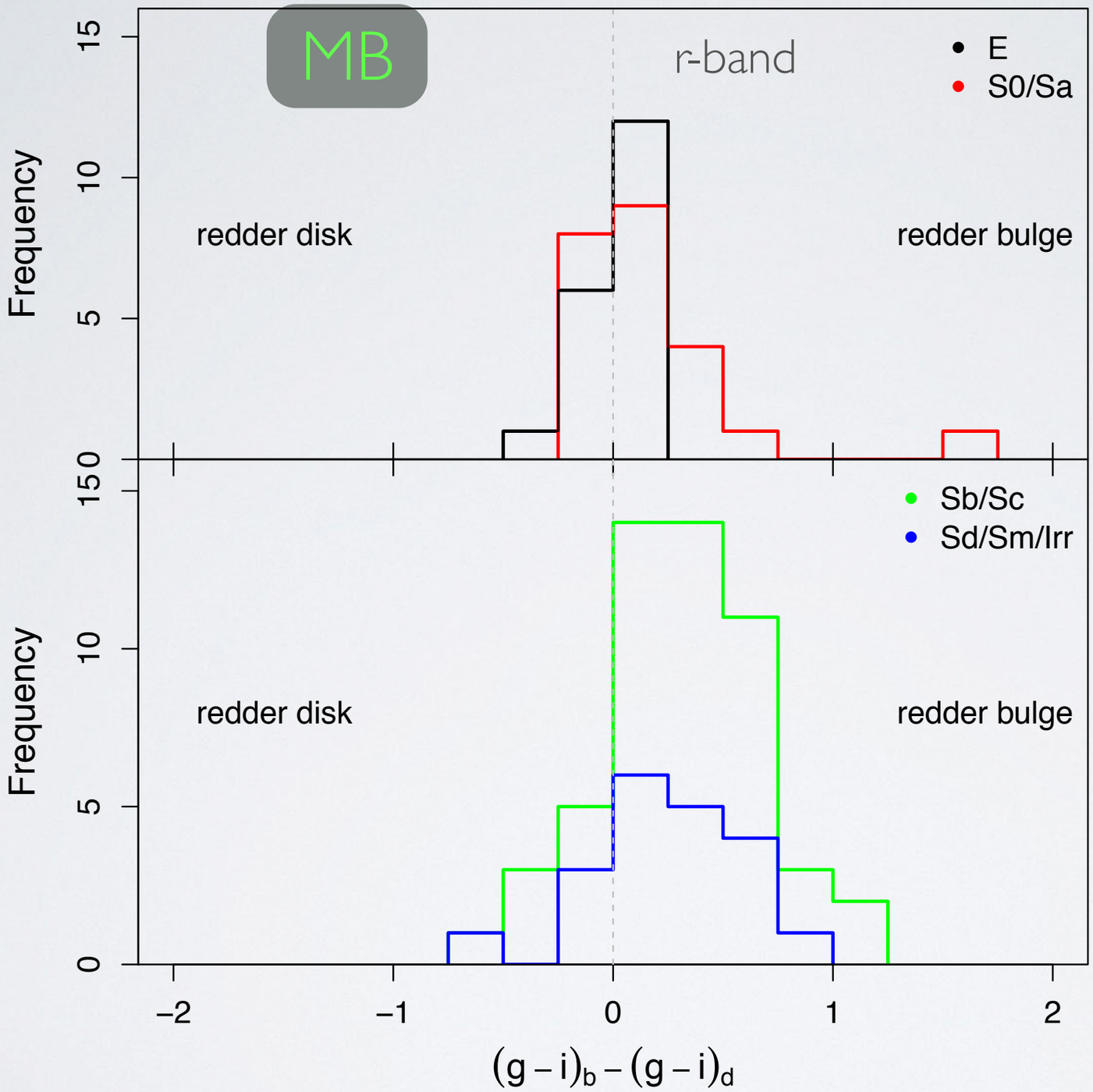
Bulge-to-total flux ratio (Original & Redshifted images)







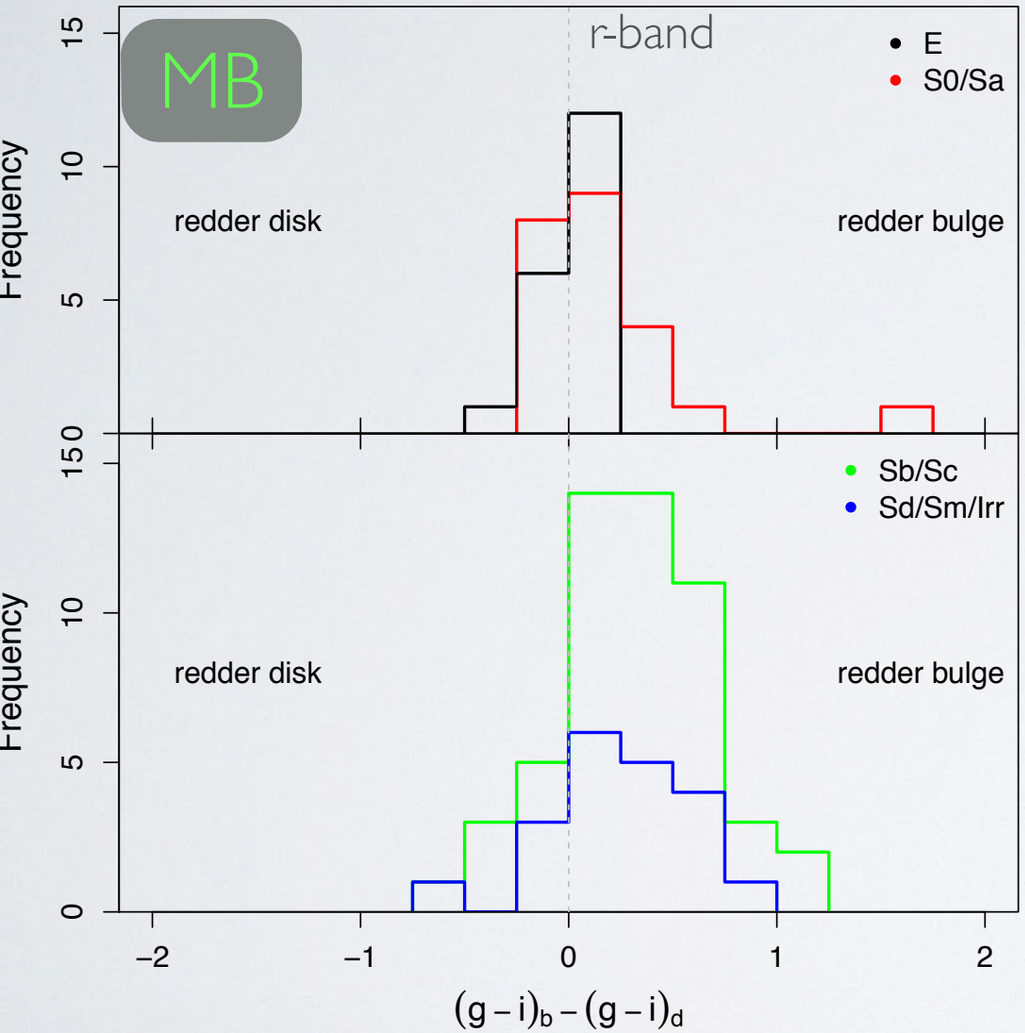
Bulge-Disk colour difference (Original images)

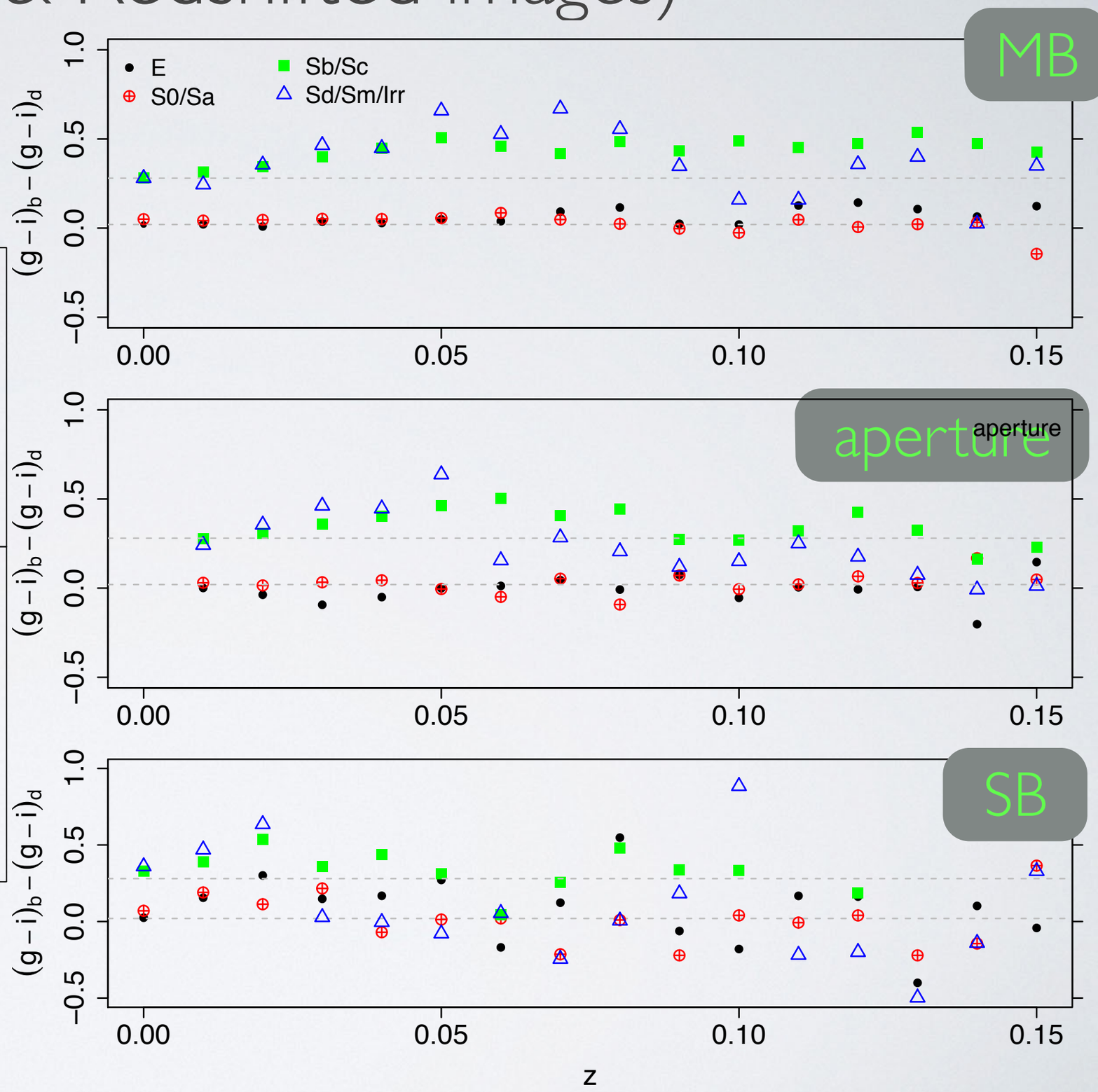


Average:
$(g\text{-}i)_b - (g\text{-}i)_d = 0.3 \pm 0.07$
in agreement with
previous studies

Vika et al 2014

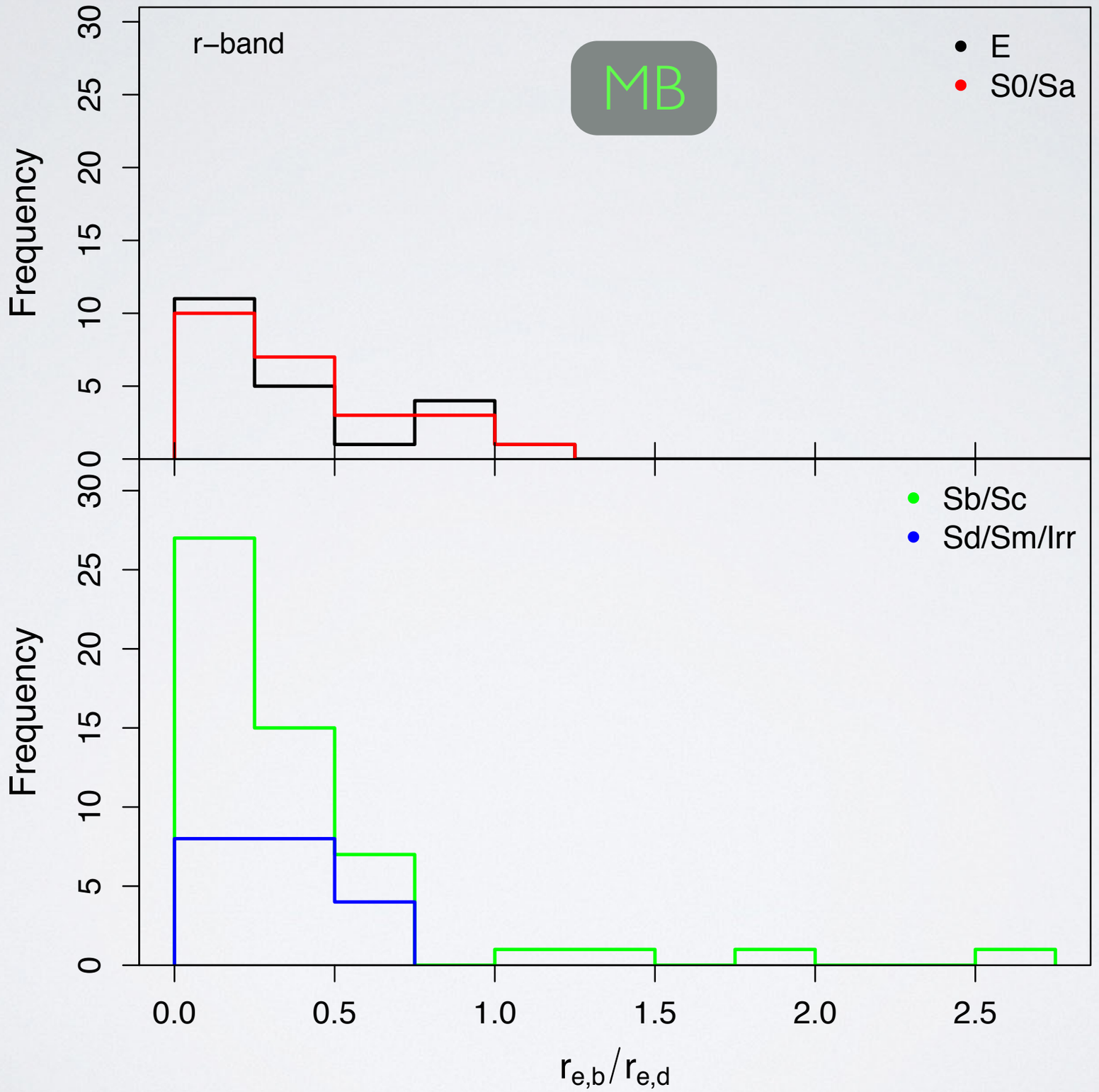
Bulge-Disk colour difference (Original & Redshifted images)



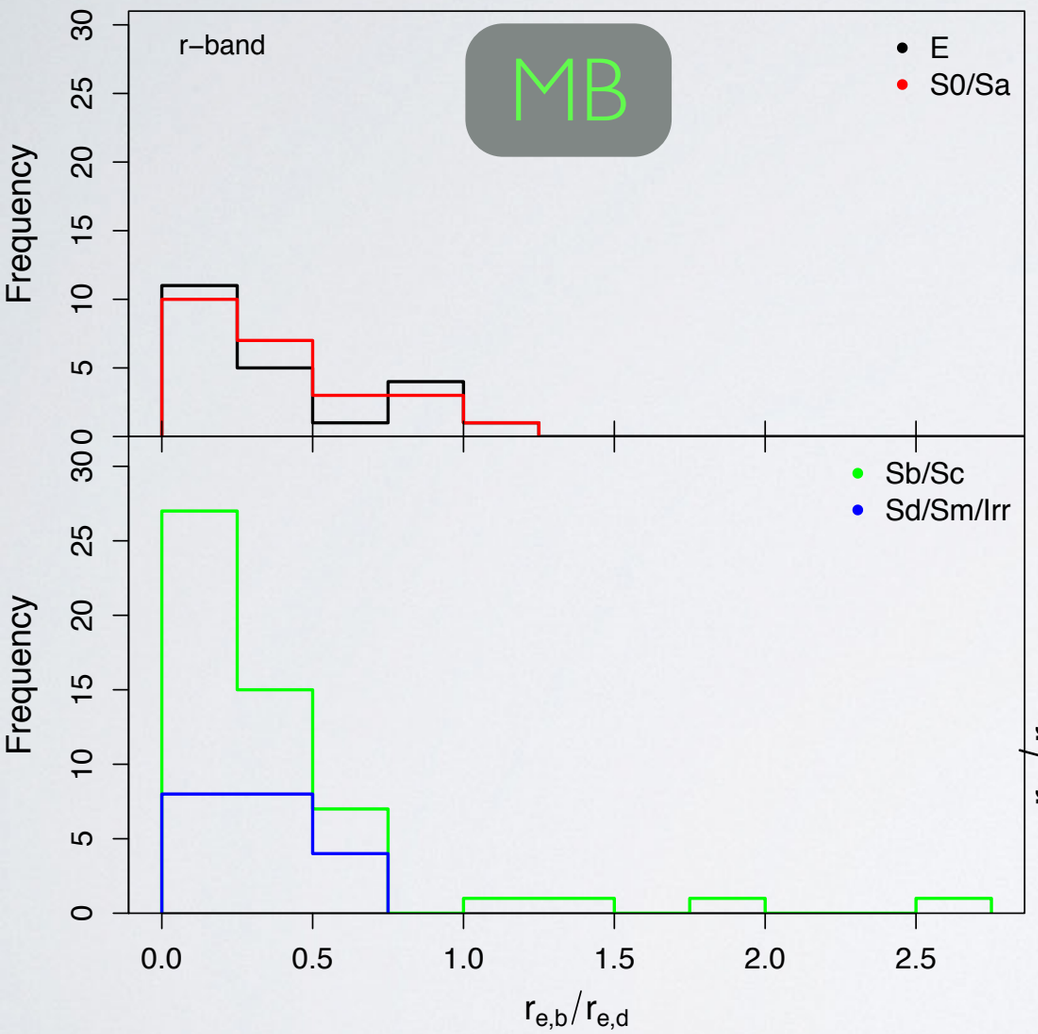


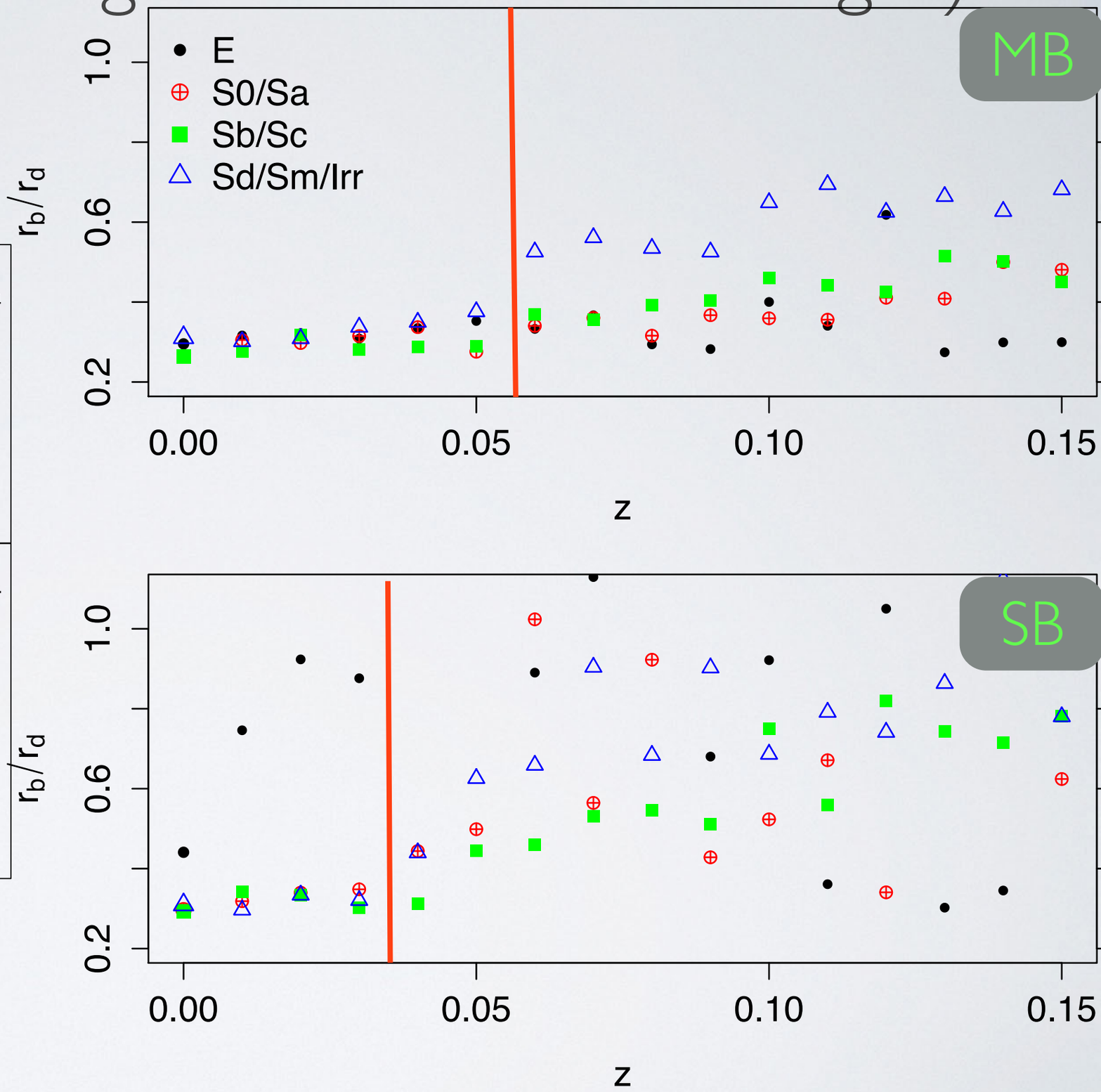
Vika et al 2014

Effective Radius (Original images)

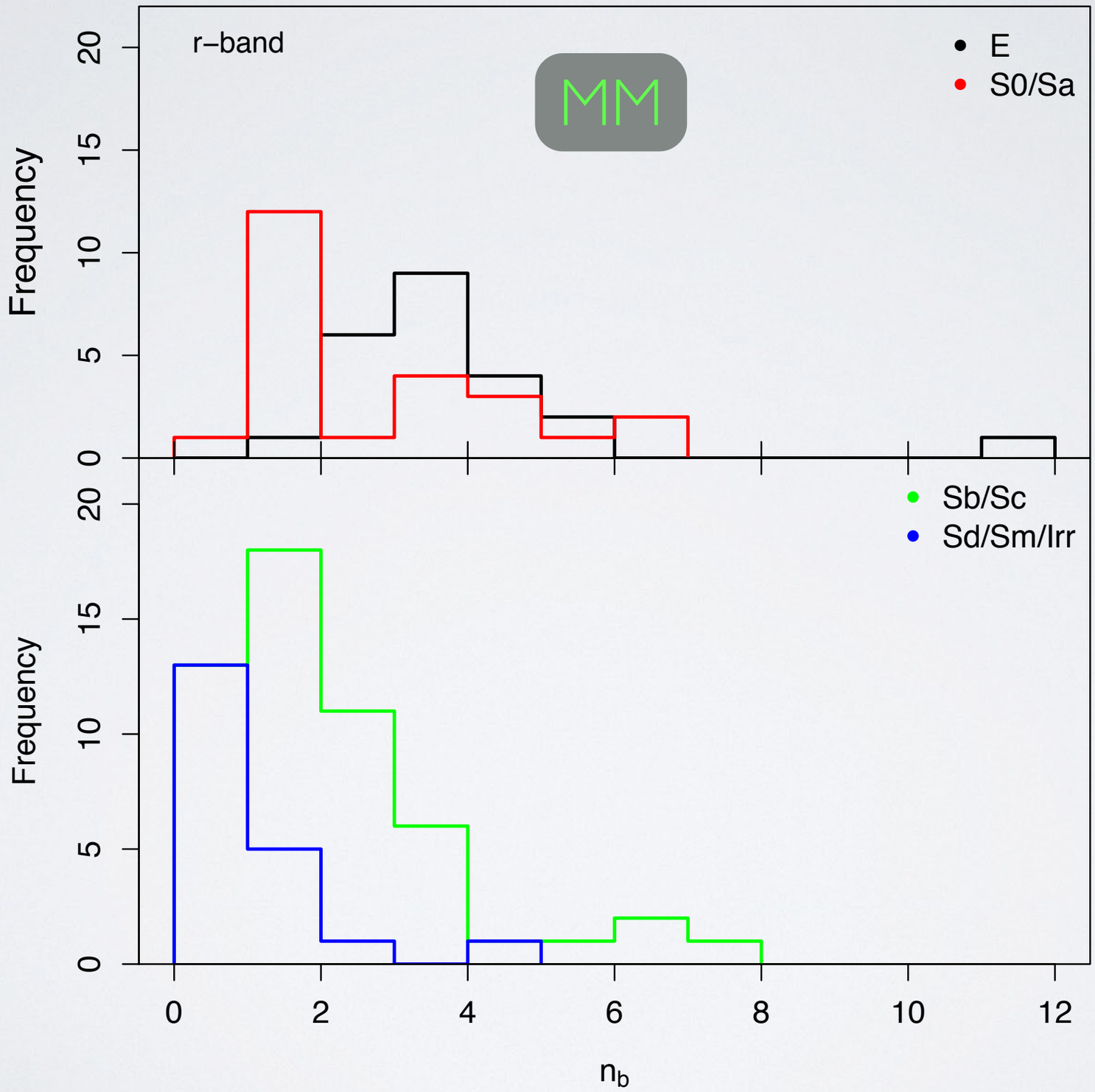


Effective Radius (Original & Redshifted images)

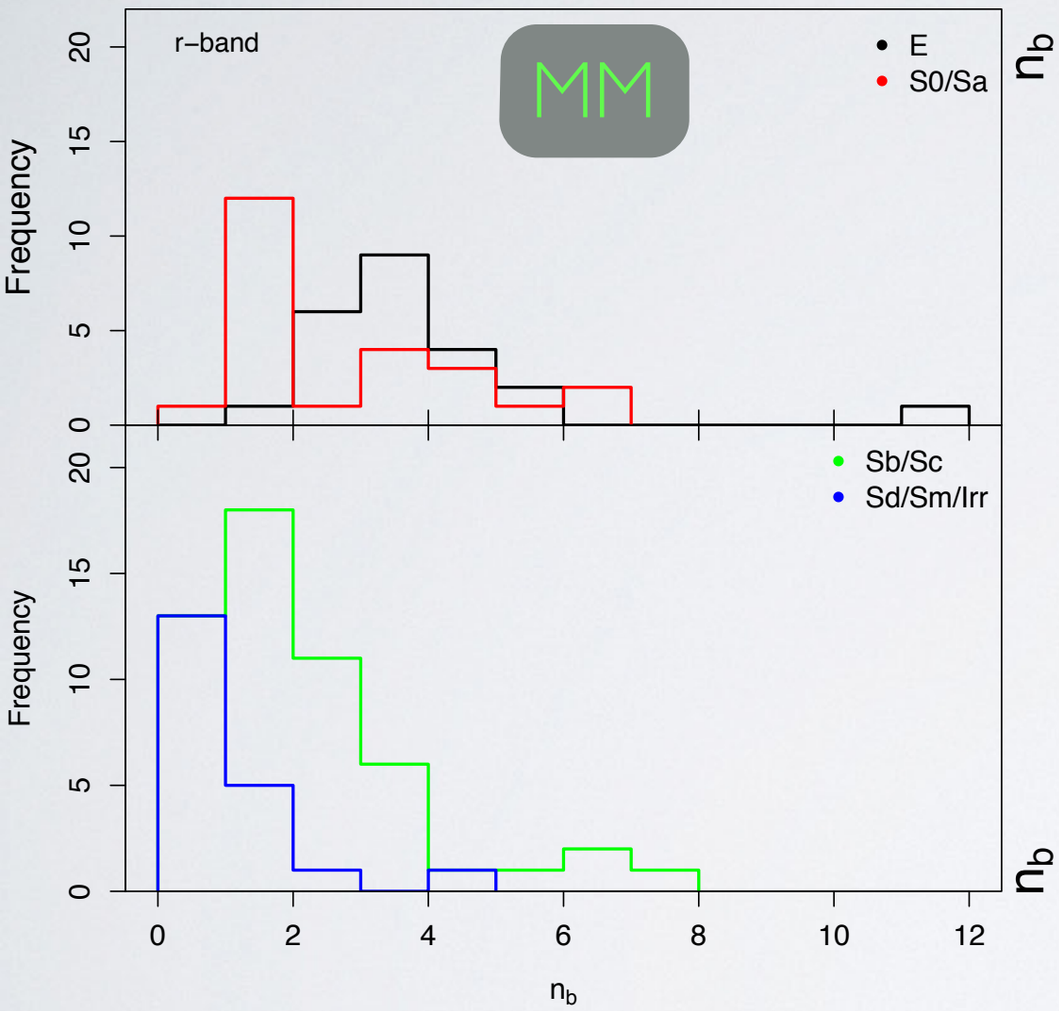


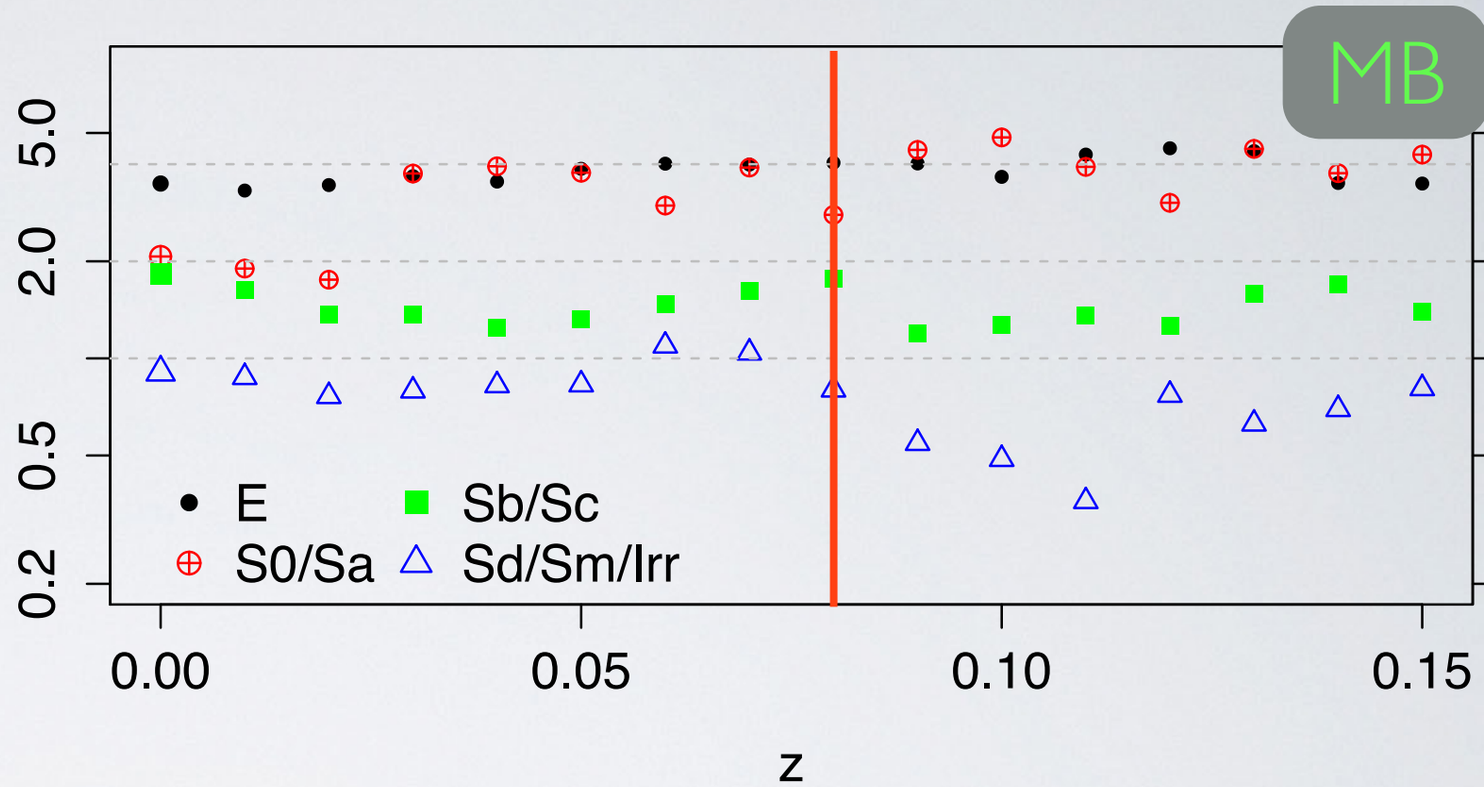


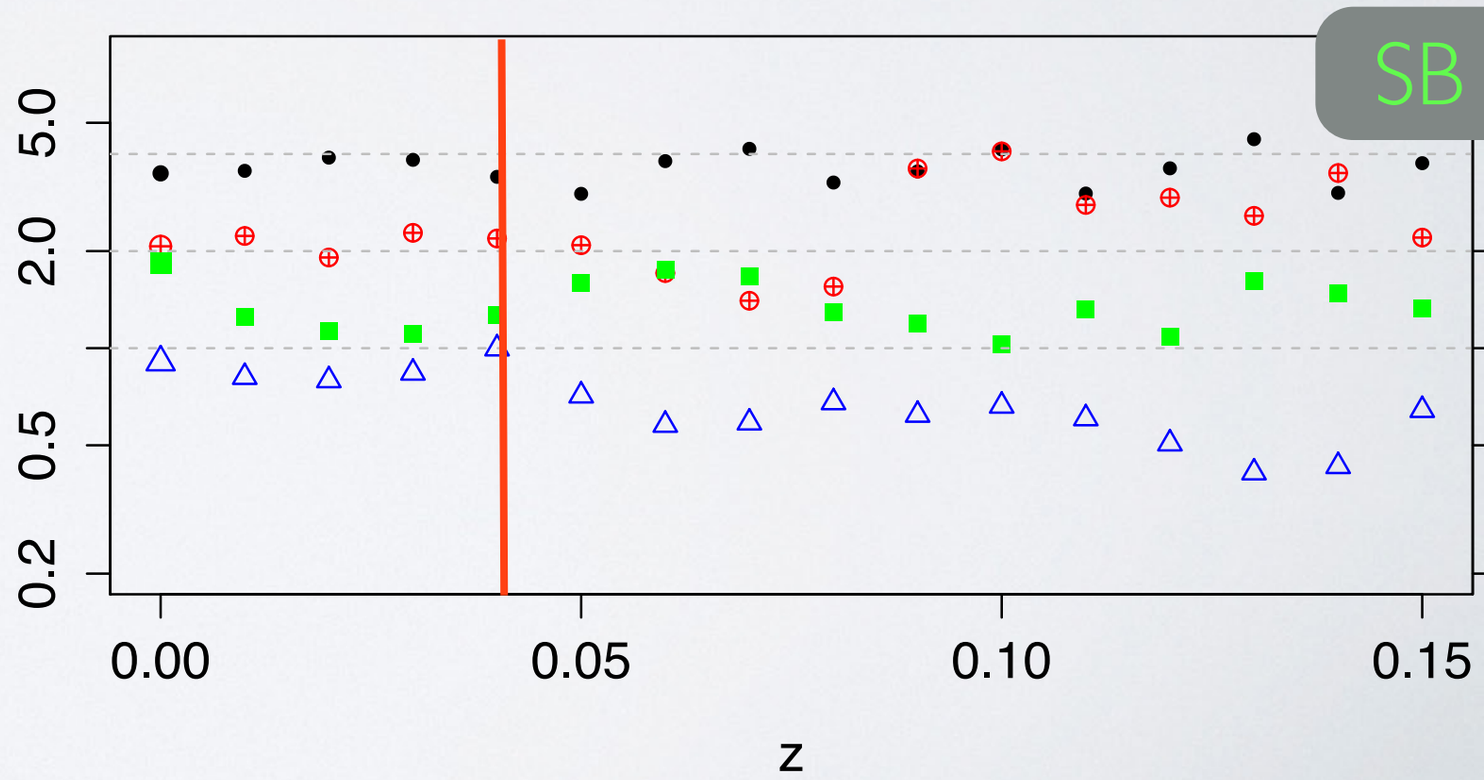
Bulge Sérsic index (Original images)

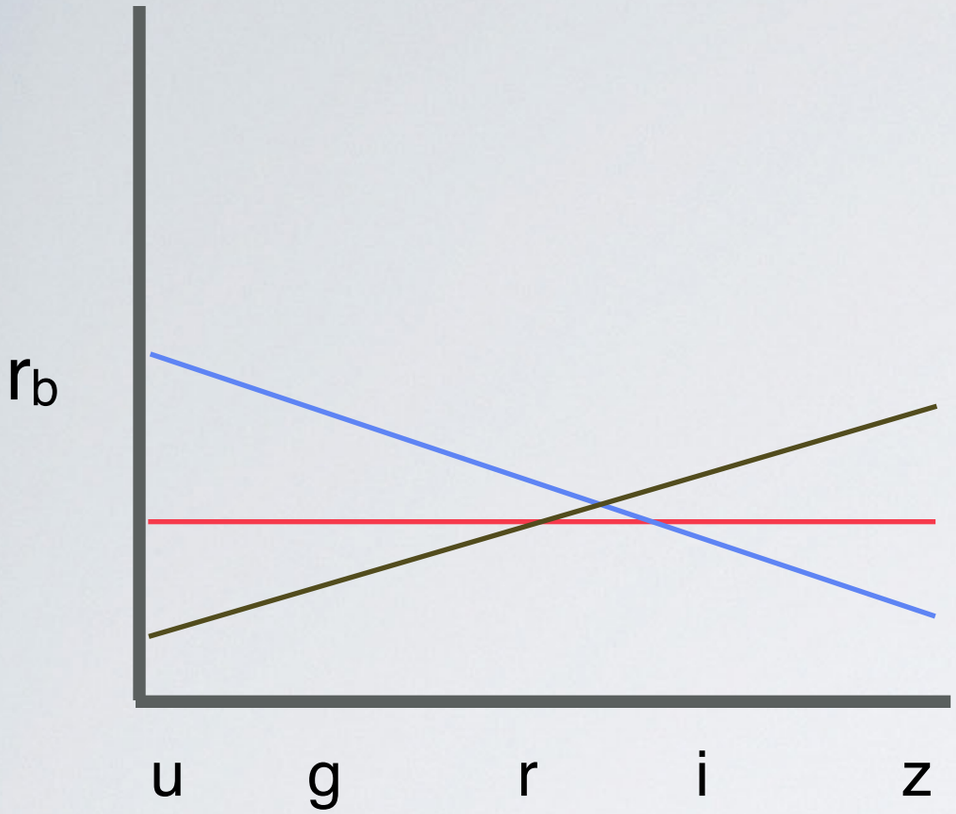


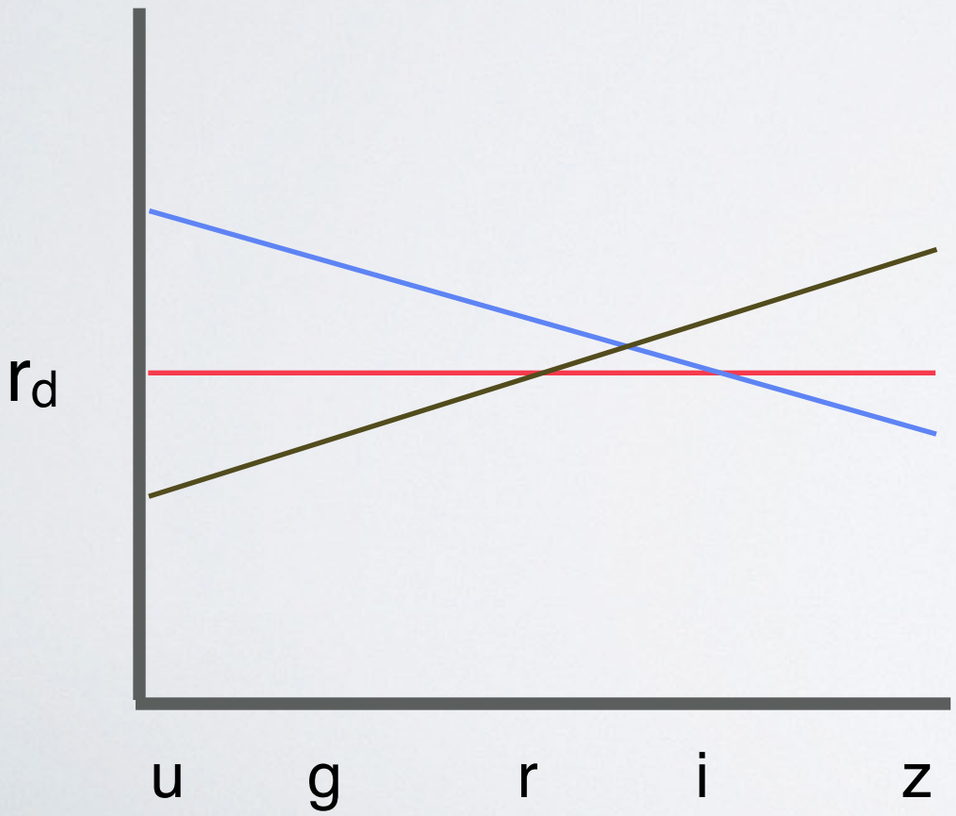
Bulge Sérsic index (Original & Redshifted images)





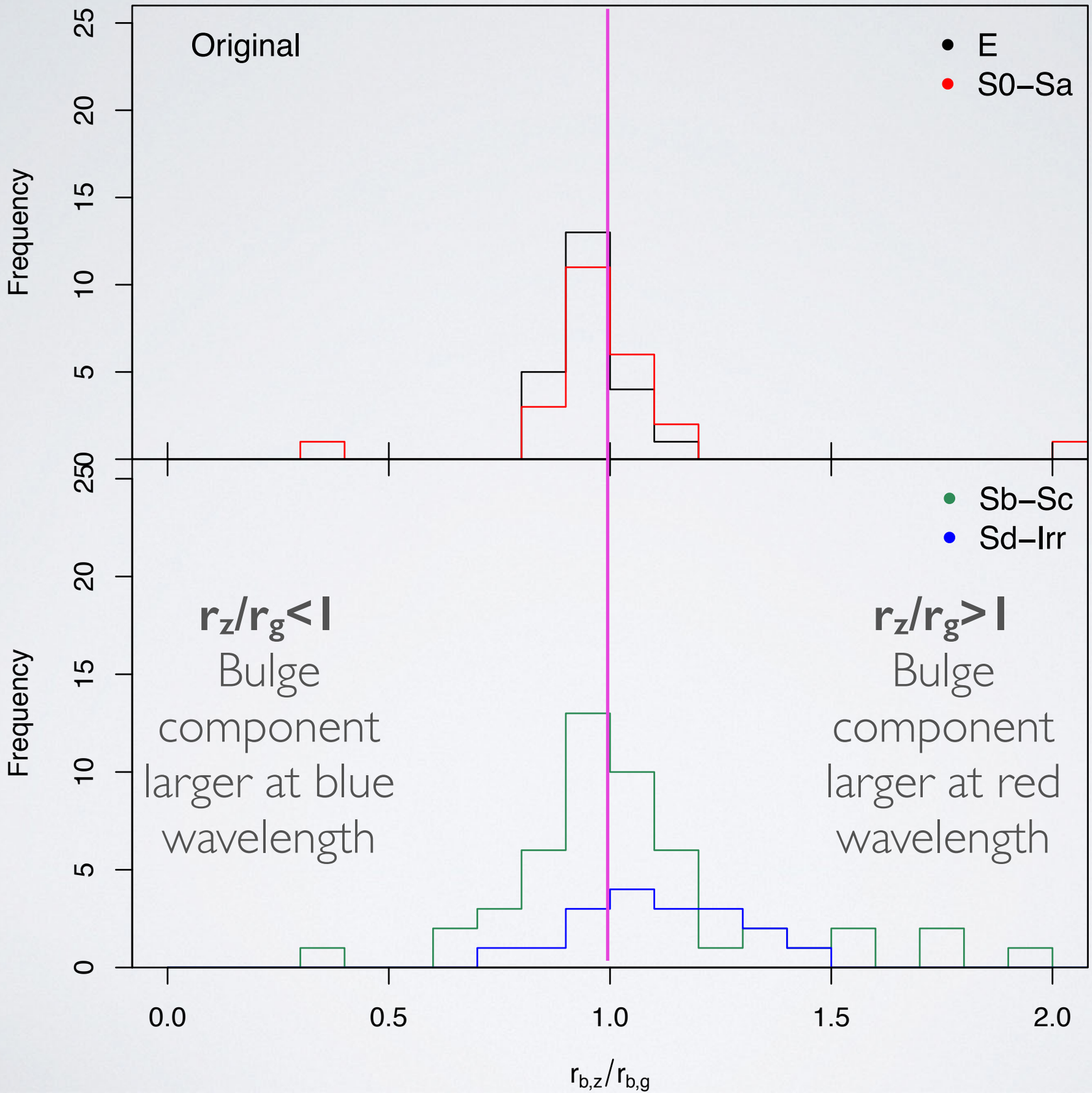




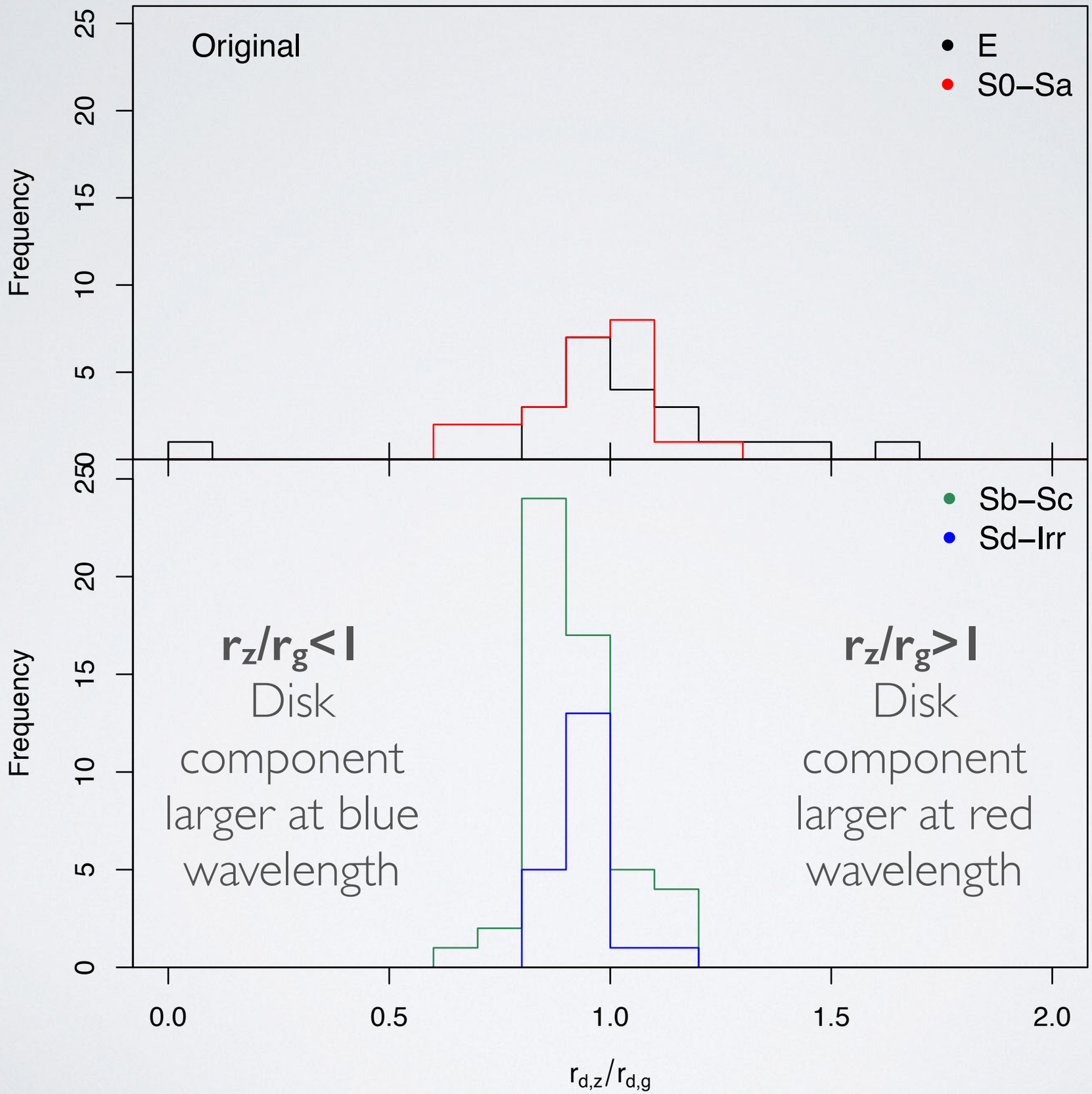


first degree polynomial

Bulge ($r_{b,z}/r_{b,g}$)

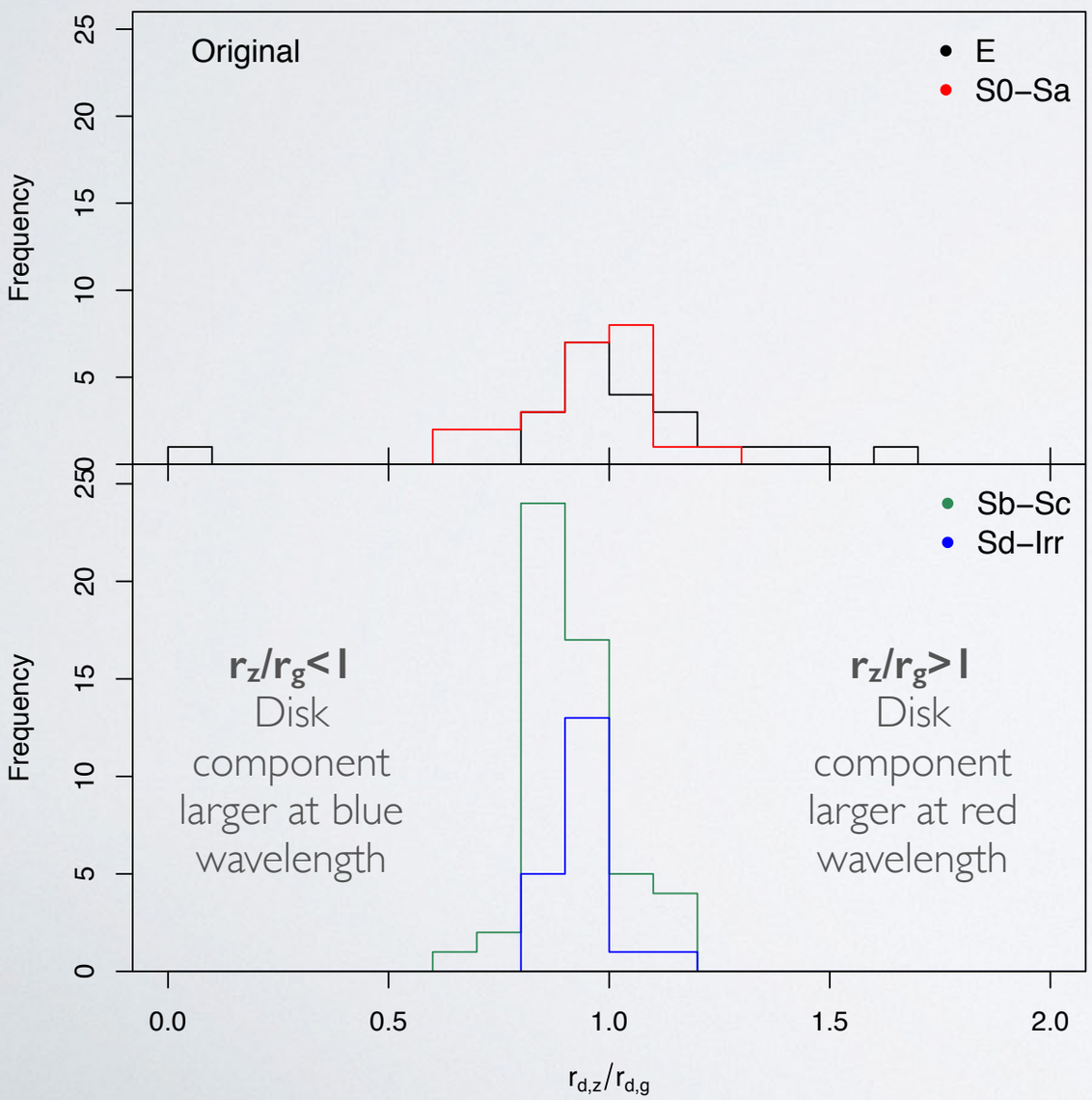


Disk ($r_{d,z}/r_{d,g}$)

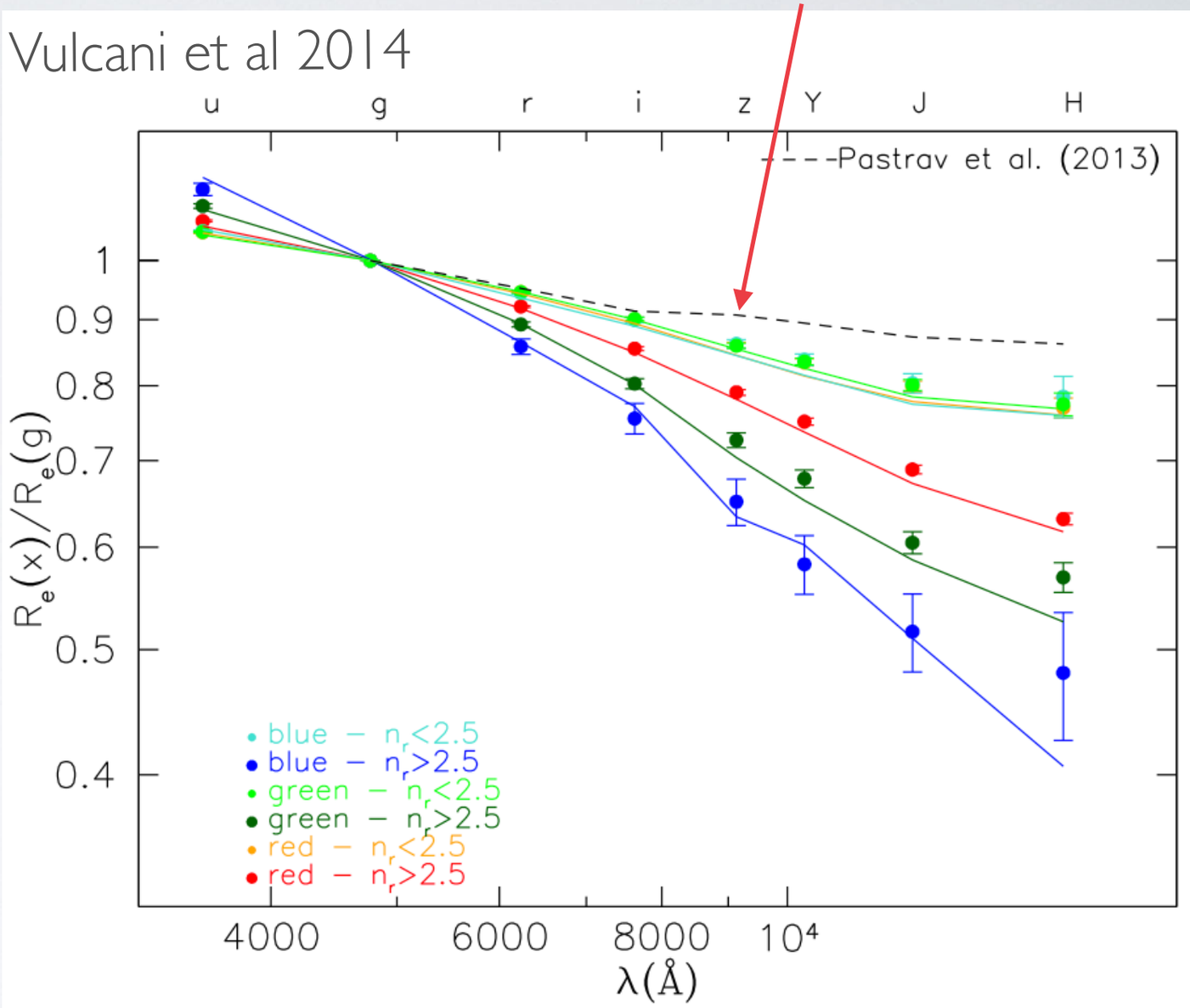

Original
E
S0–Sa
Sb–Sc
Sd–Irr
Frequency
0
5
10
15
20
25
250
$r_z/r_g<1$
Disk component larger at blue wavelength
$r_z/r_g>1$
Disk component larger at red wavelength
0.0
0.5
1.0
1.5
2.0
$r_{d,z}/r_{d,g}$

Disk Effective Radius

$R_{e,z}/R_{e,g}$ ~ 0.9 due to dust extinction



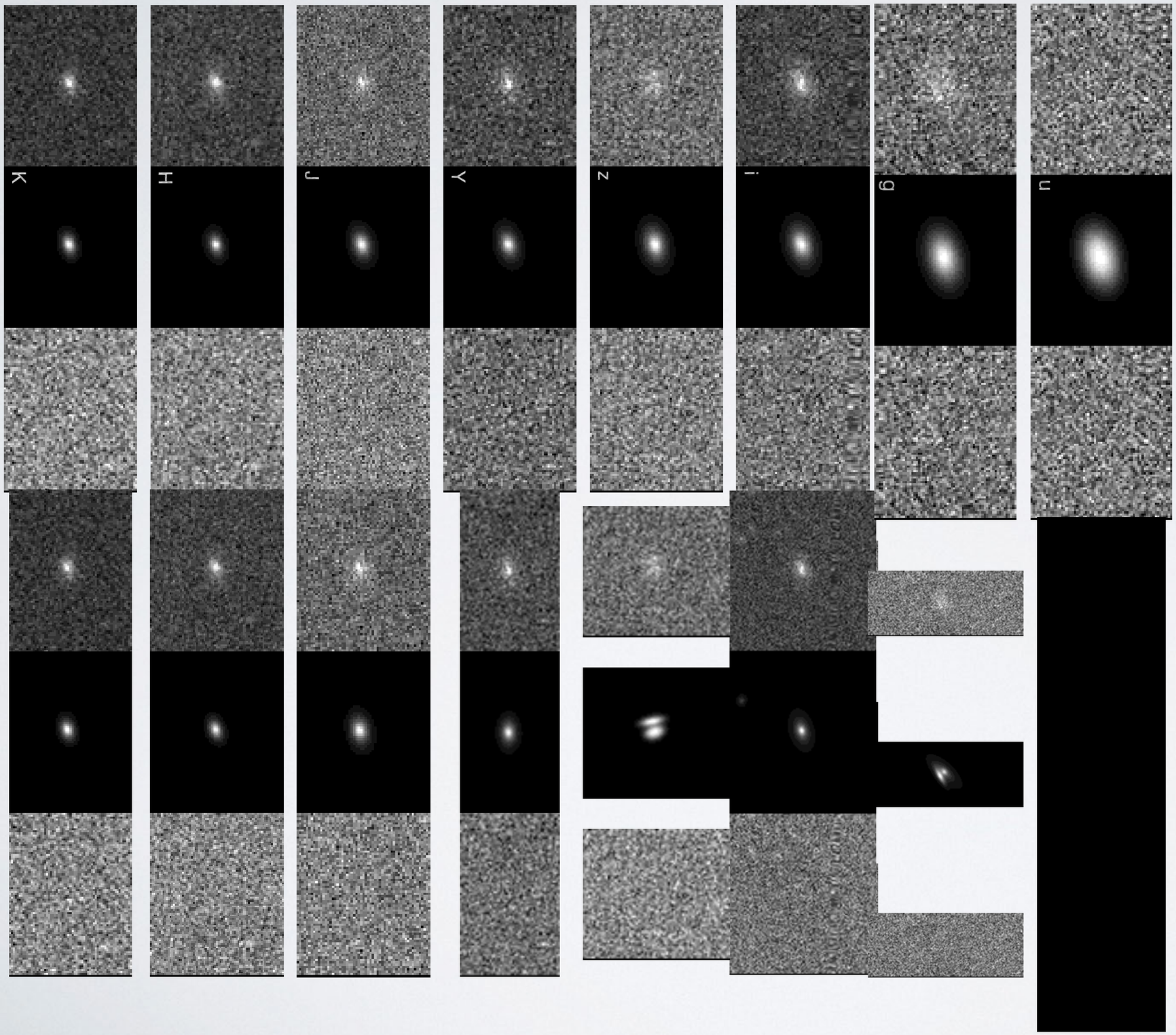
Vulcani et al 2014



MEGAMORPH

APPLICATION ON MULTI-WAVELENGTH SURVEYS

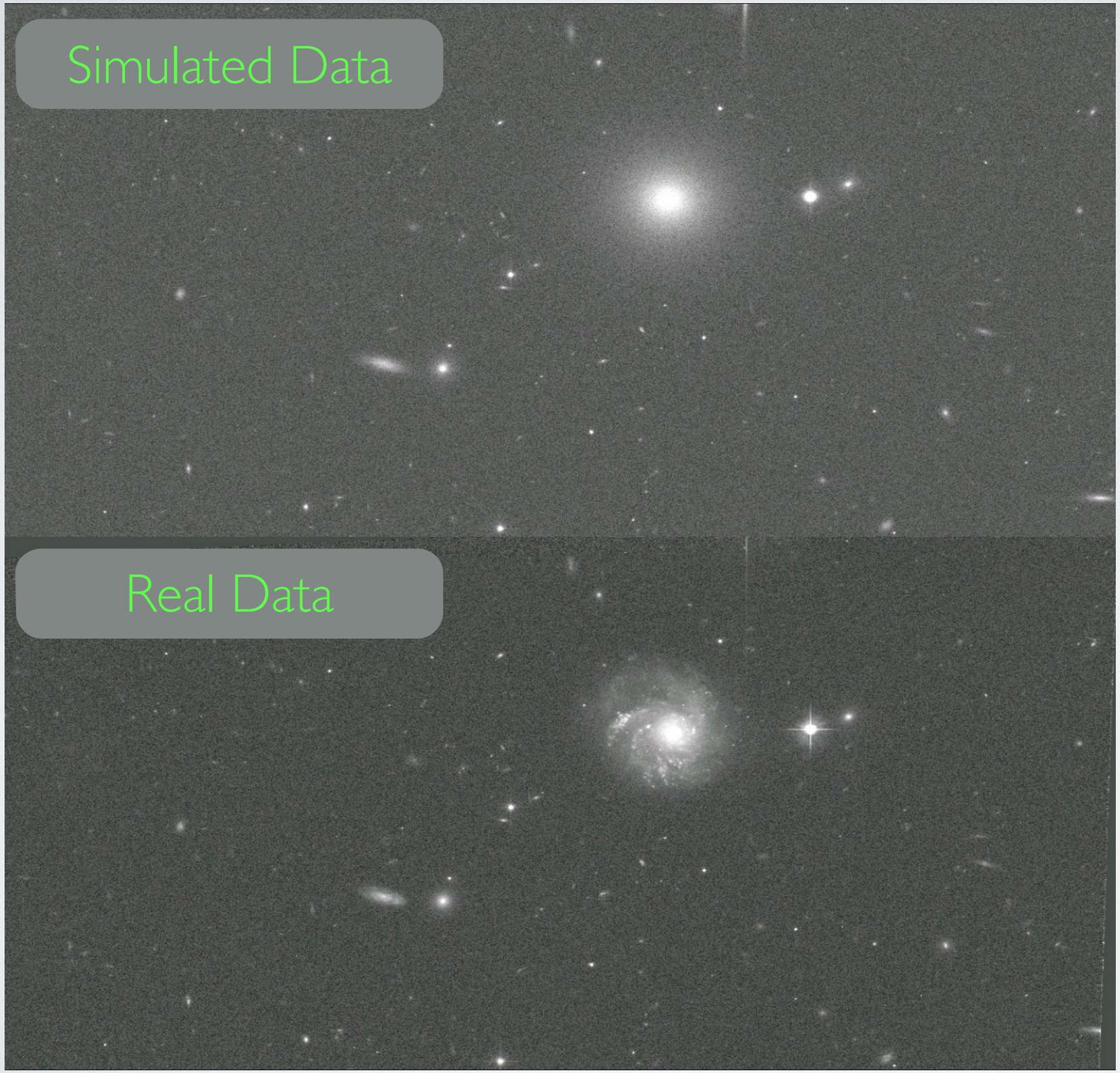
Multi-Wavelength Sample - Real Galaxies



20,000 Galaxies
u,g,r,i,z,Y,J,H,K
bands
(GAMA)

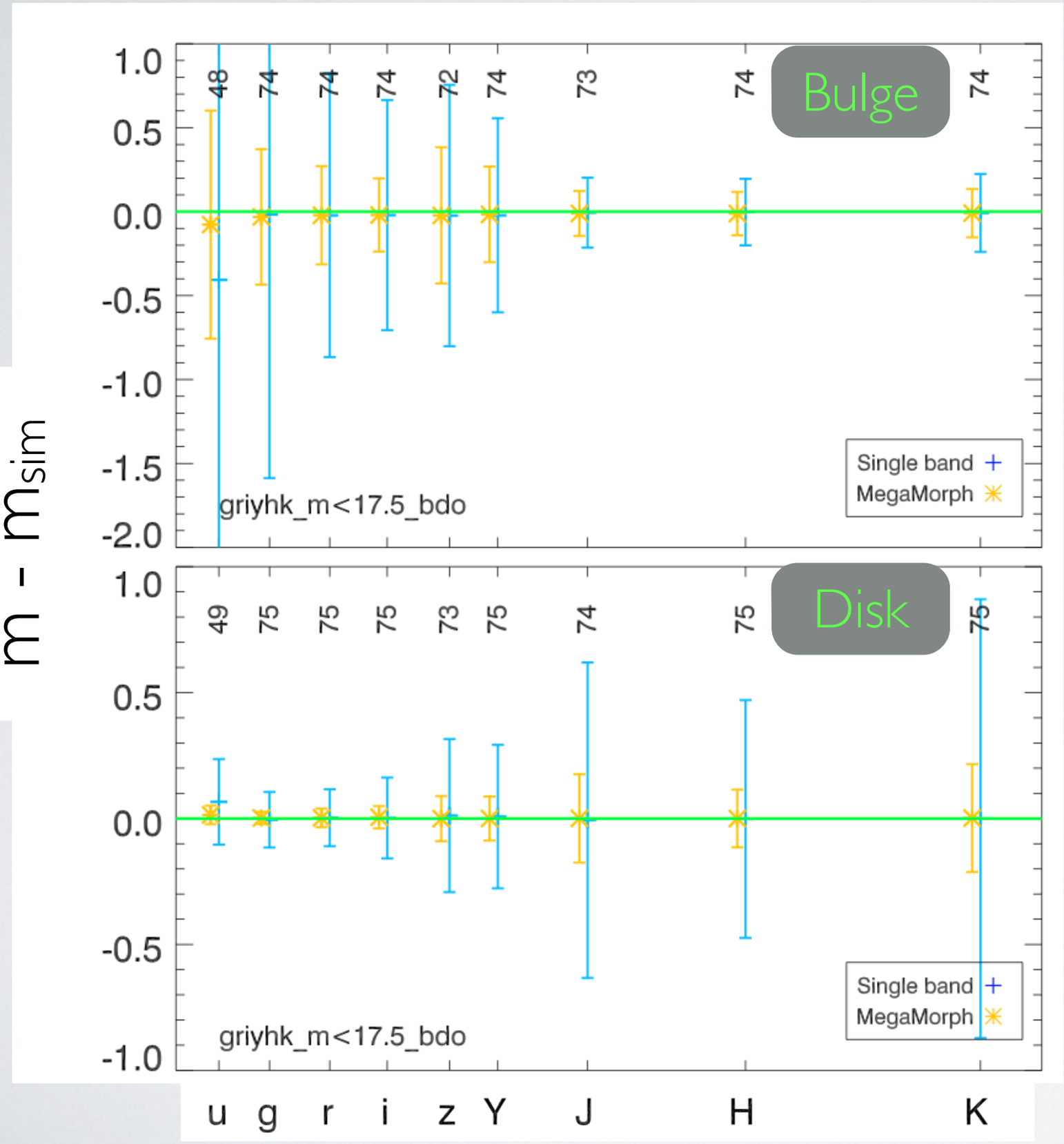
Häussler et al 2013

Multi-Wavelength Sample - Simulated Galaxies



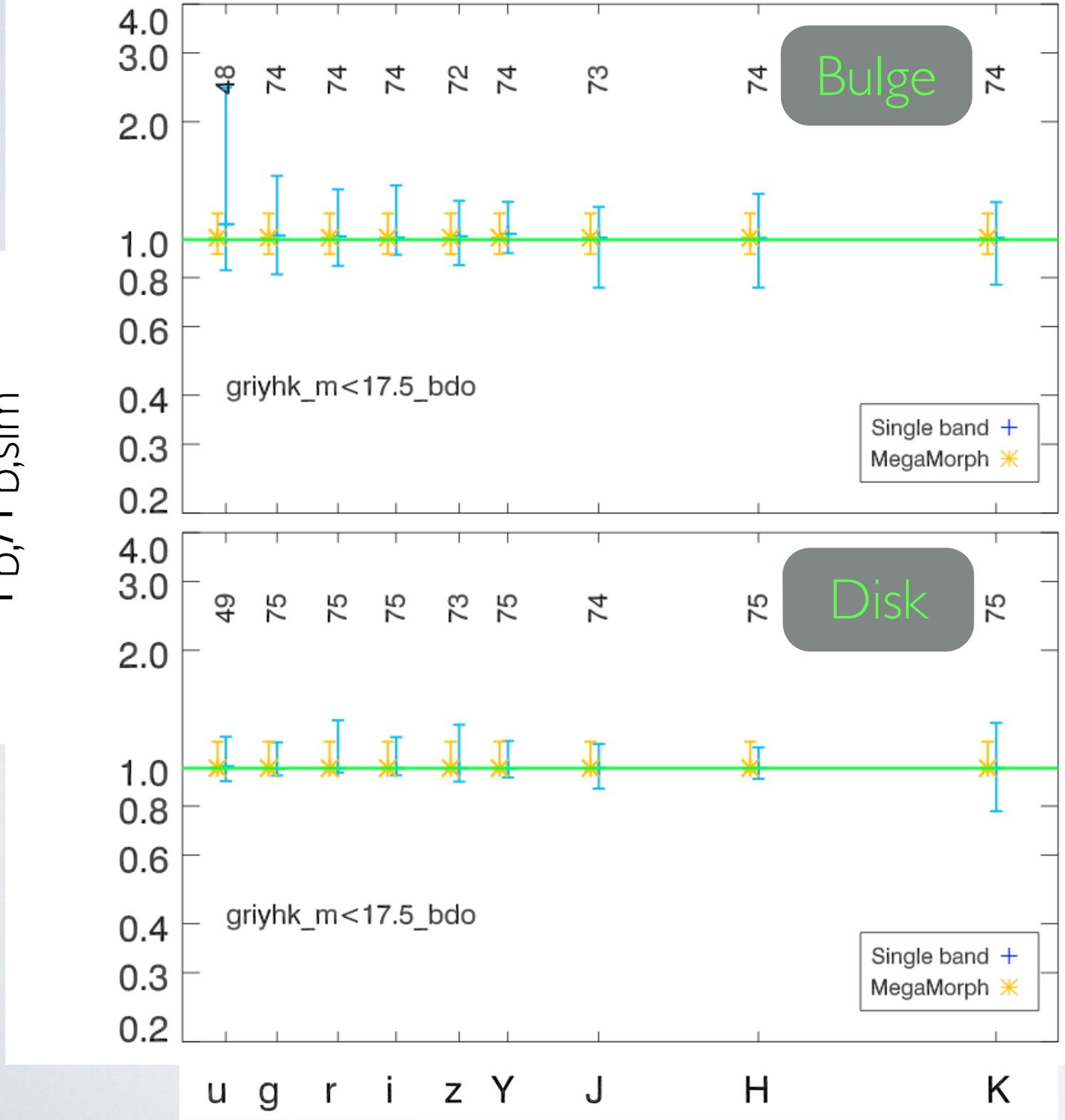
Methodology is described in Häußler et al. 2007

Bulge and Disk Magnitude



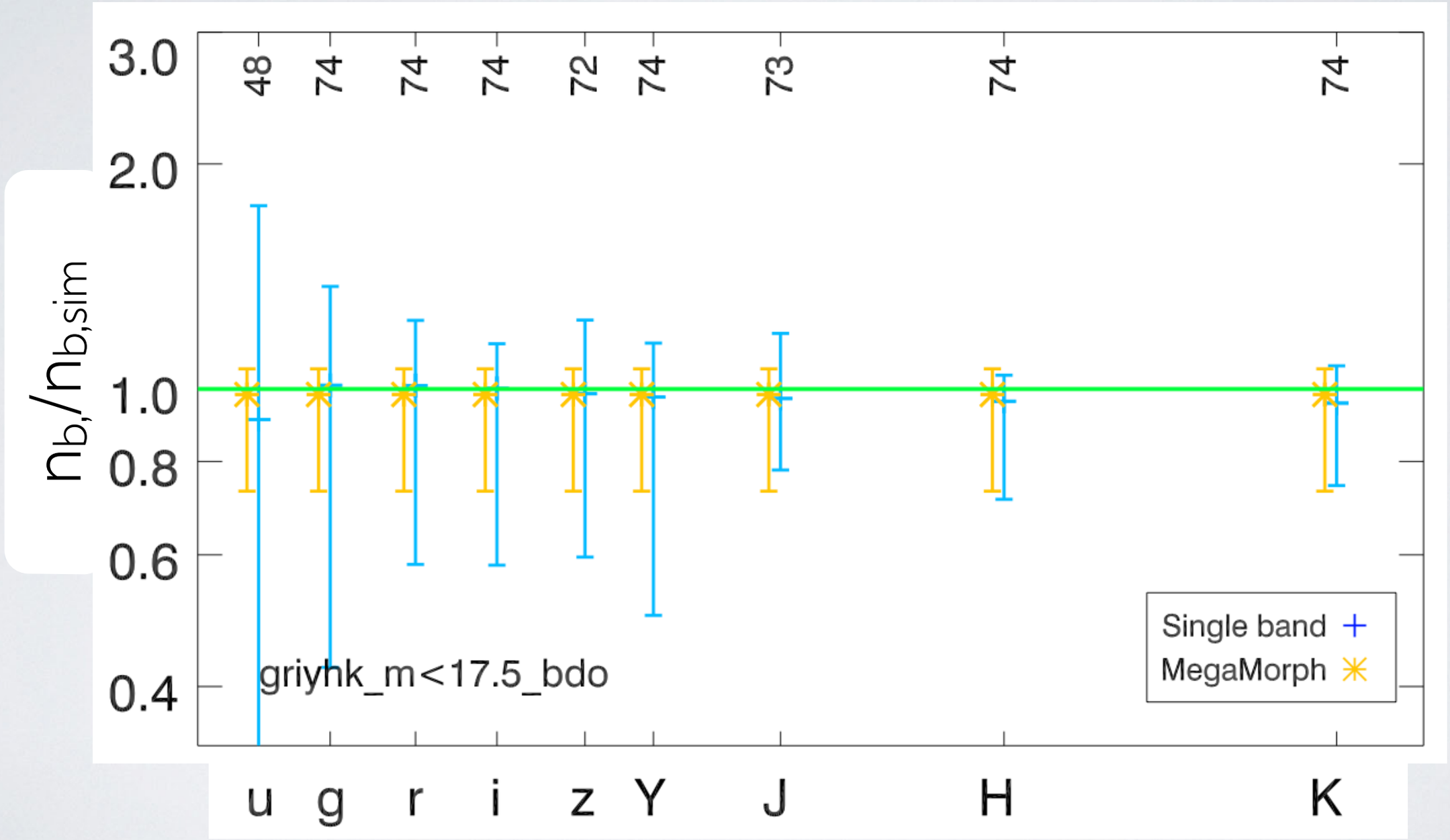
Häussler et al in prep.

Bulge and Disk Effective Radius



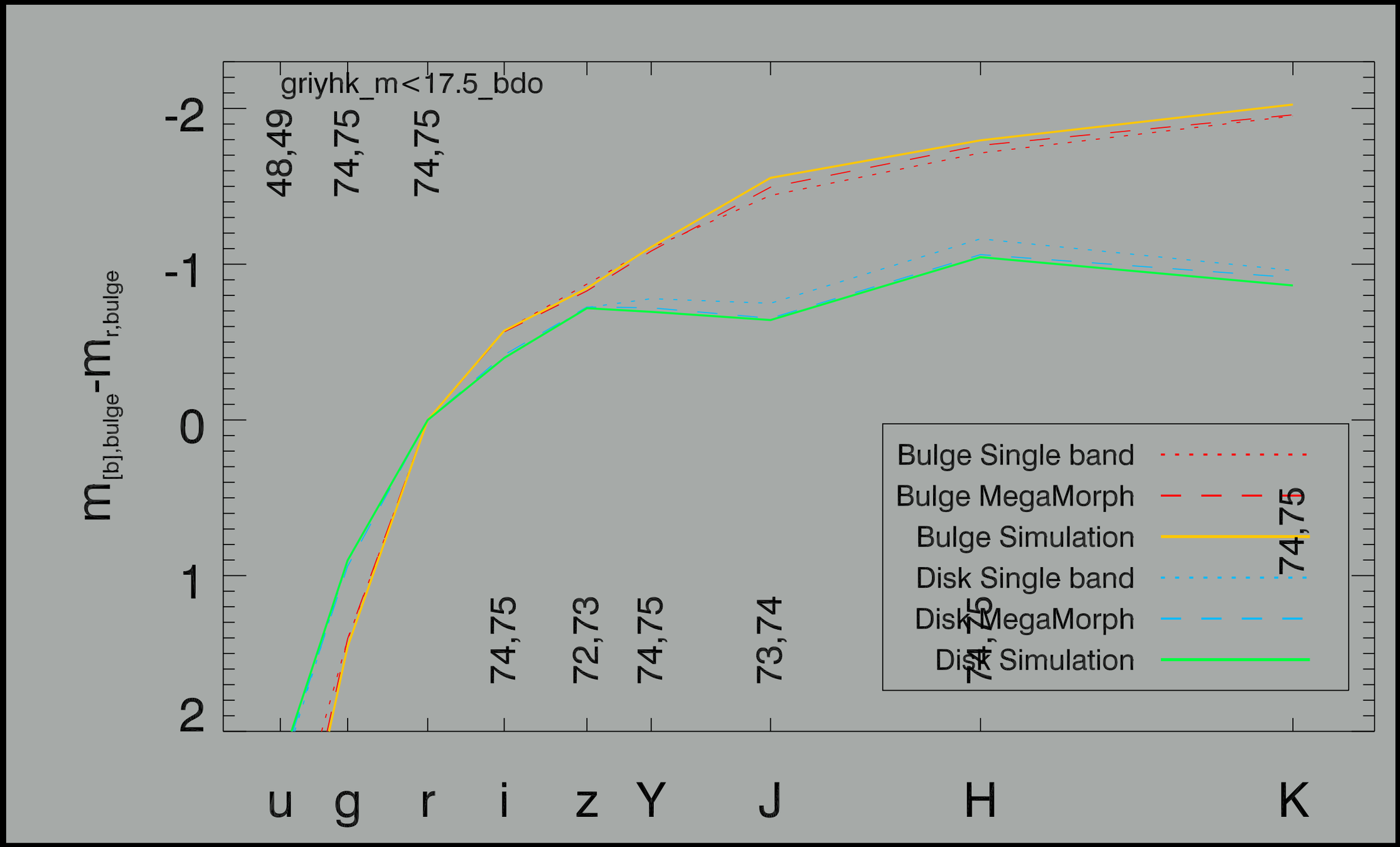
Häussler et al in prep.

Bulge Sérsic Index



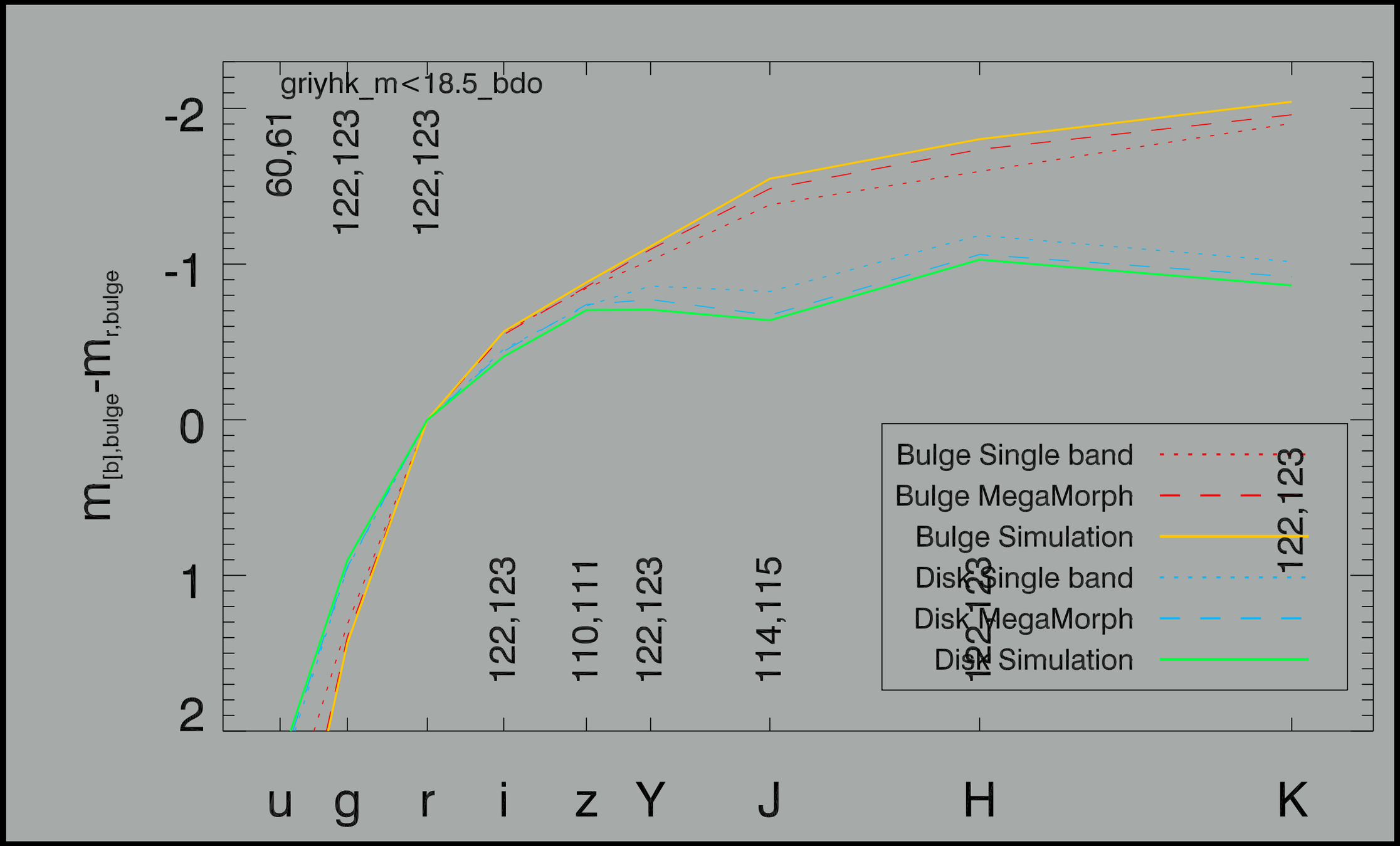
Häussler et al in prep.

SEDs for Simulations



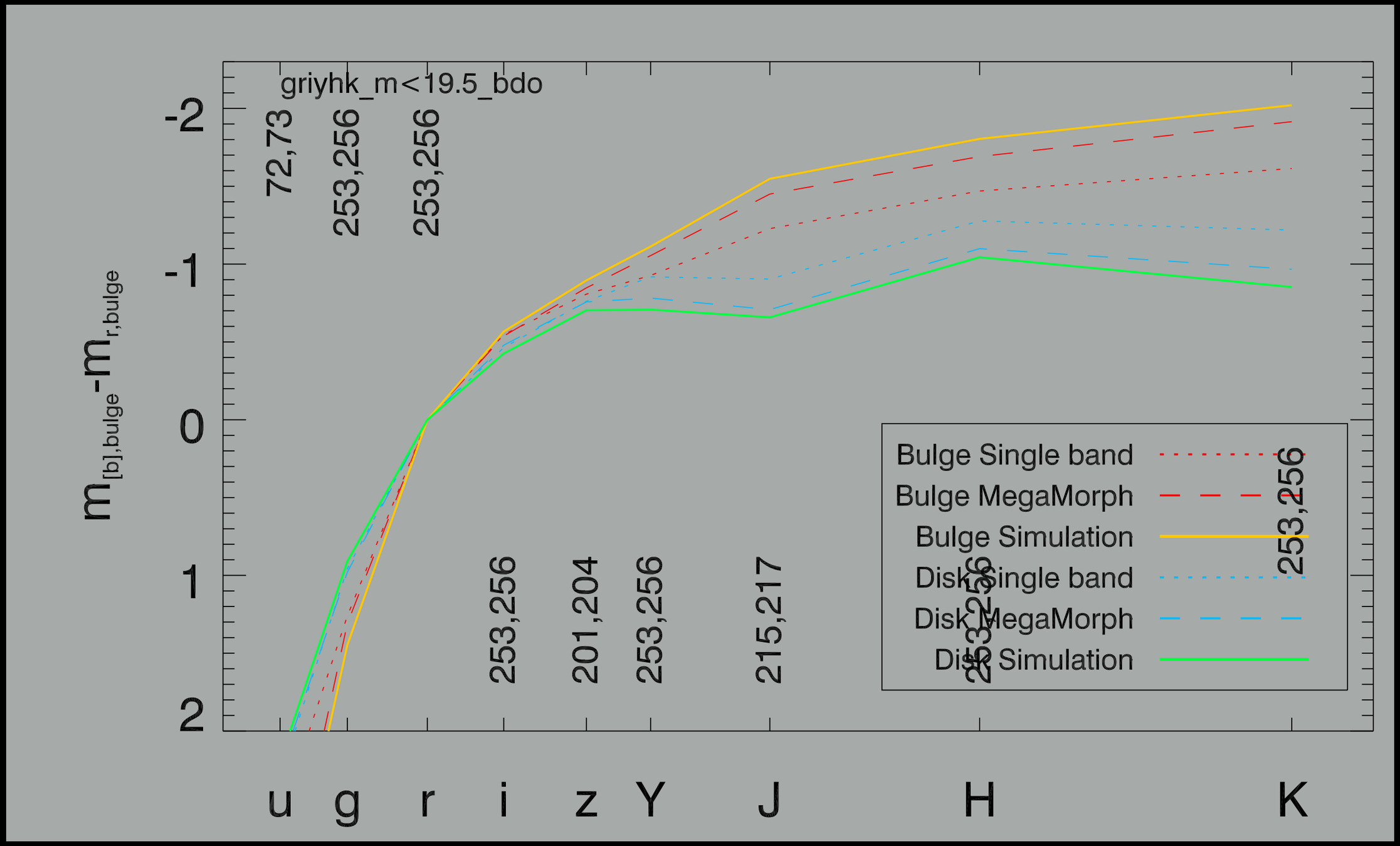
Häussler et al in prep.

SEDs for Simulations



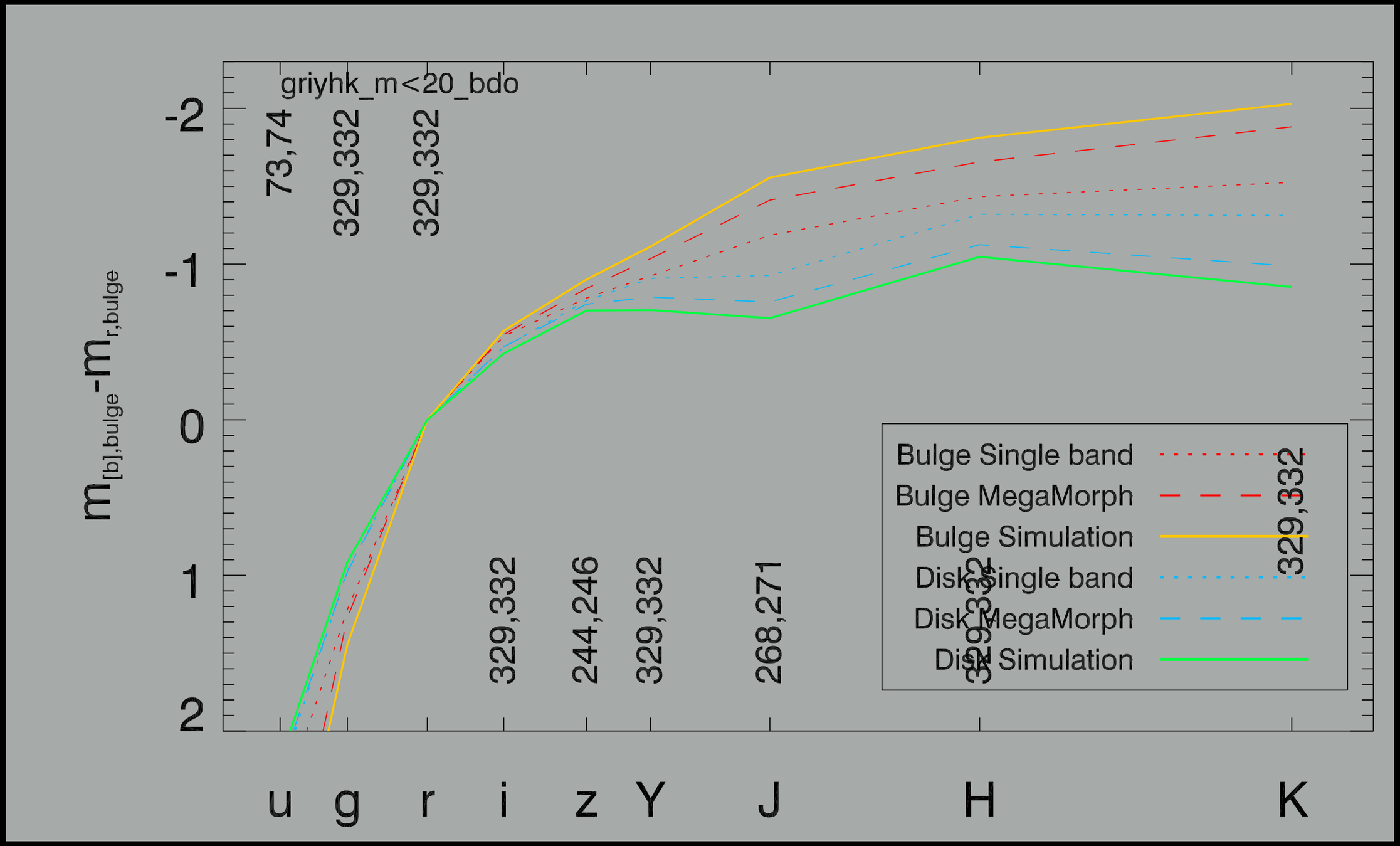
Häussler et al in prep.

SEDs for Simulations



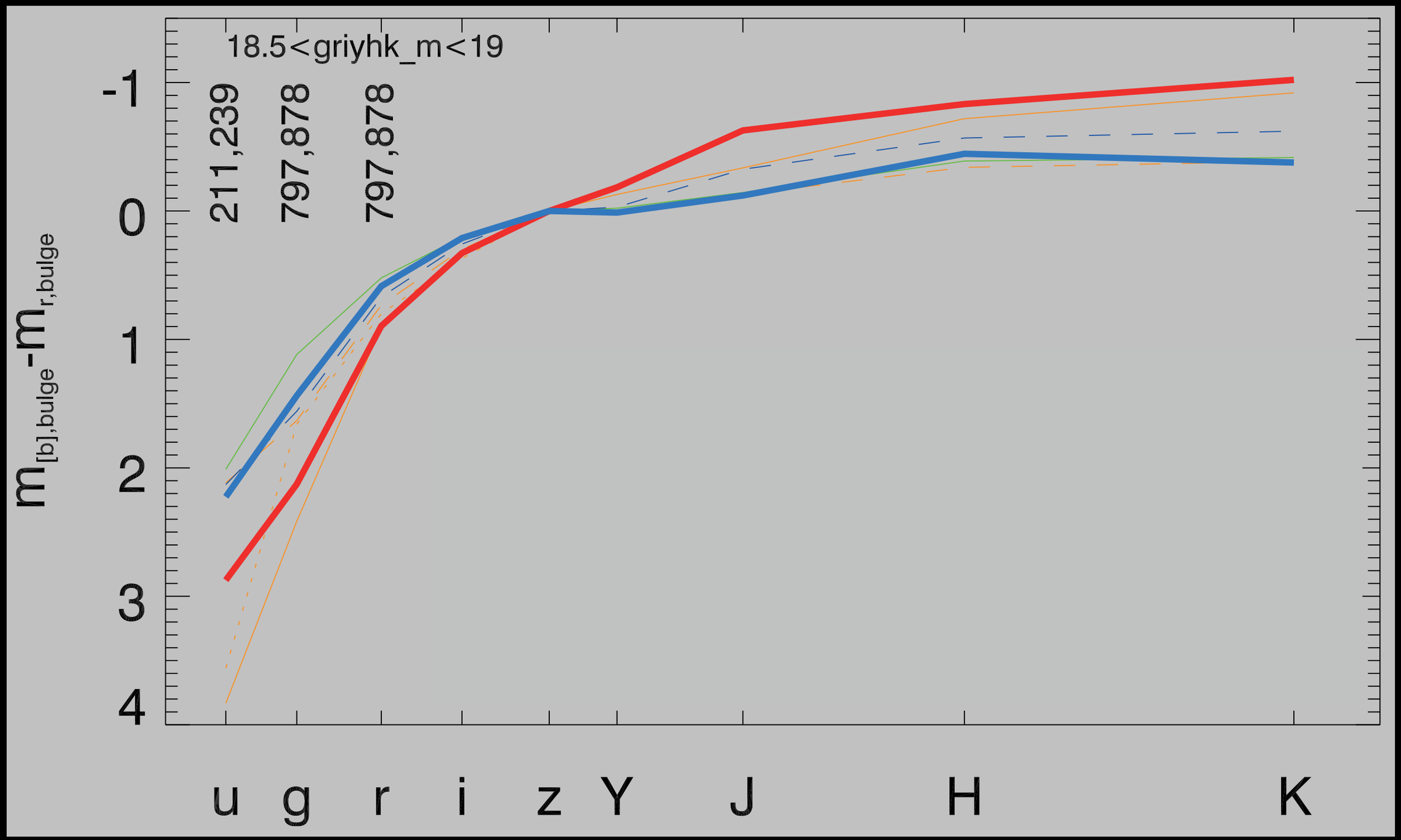
Häussler et al in prep.

SEDs for Simulations



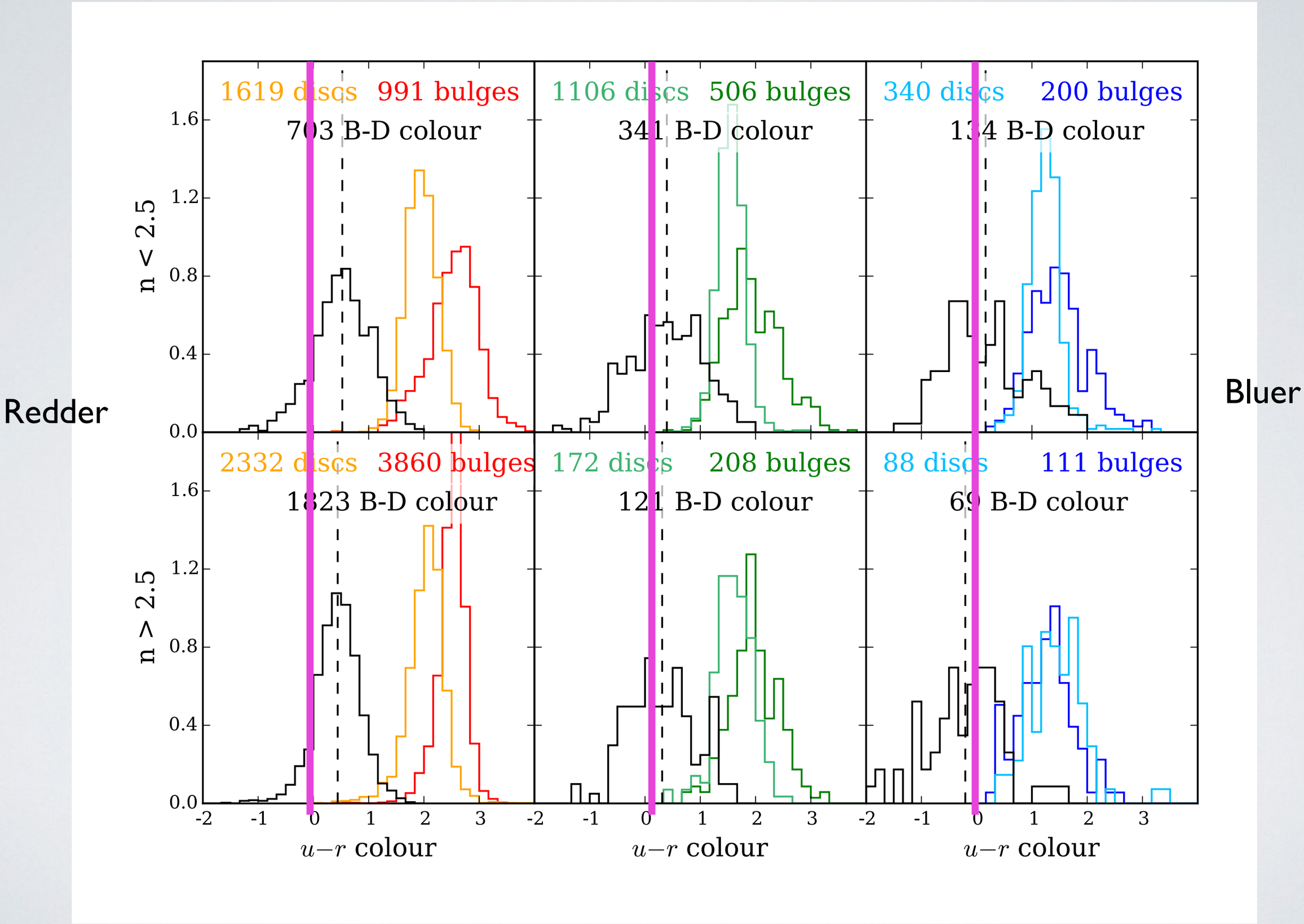
Häussler et al in prep.

SEDs for real data



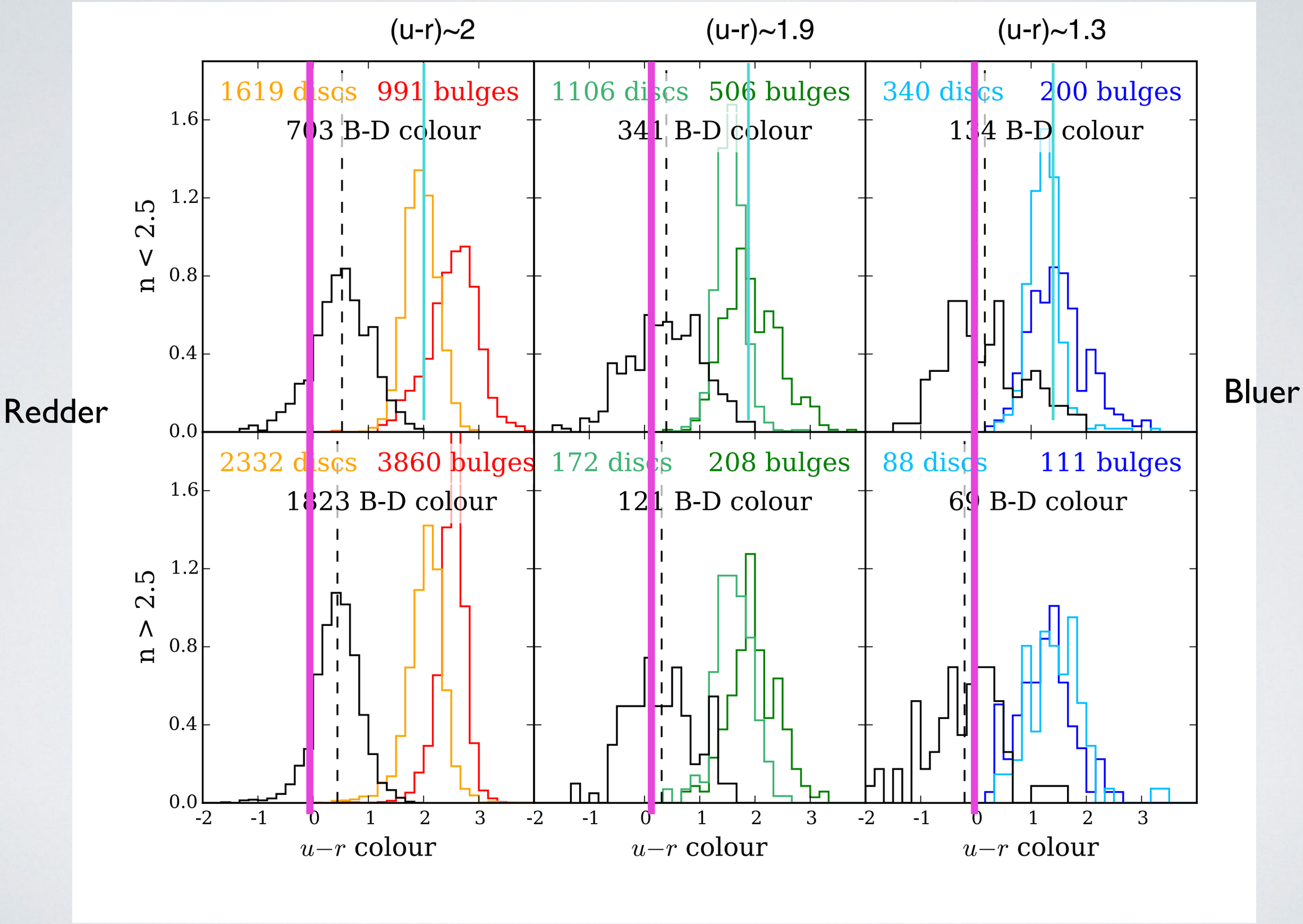
Häussler et al in prep.

Bulge-Disk colour difference



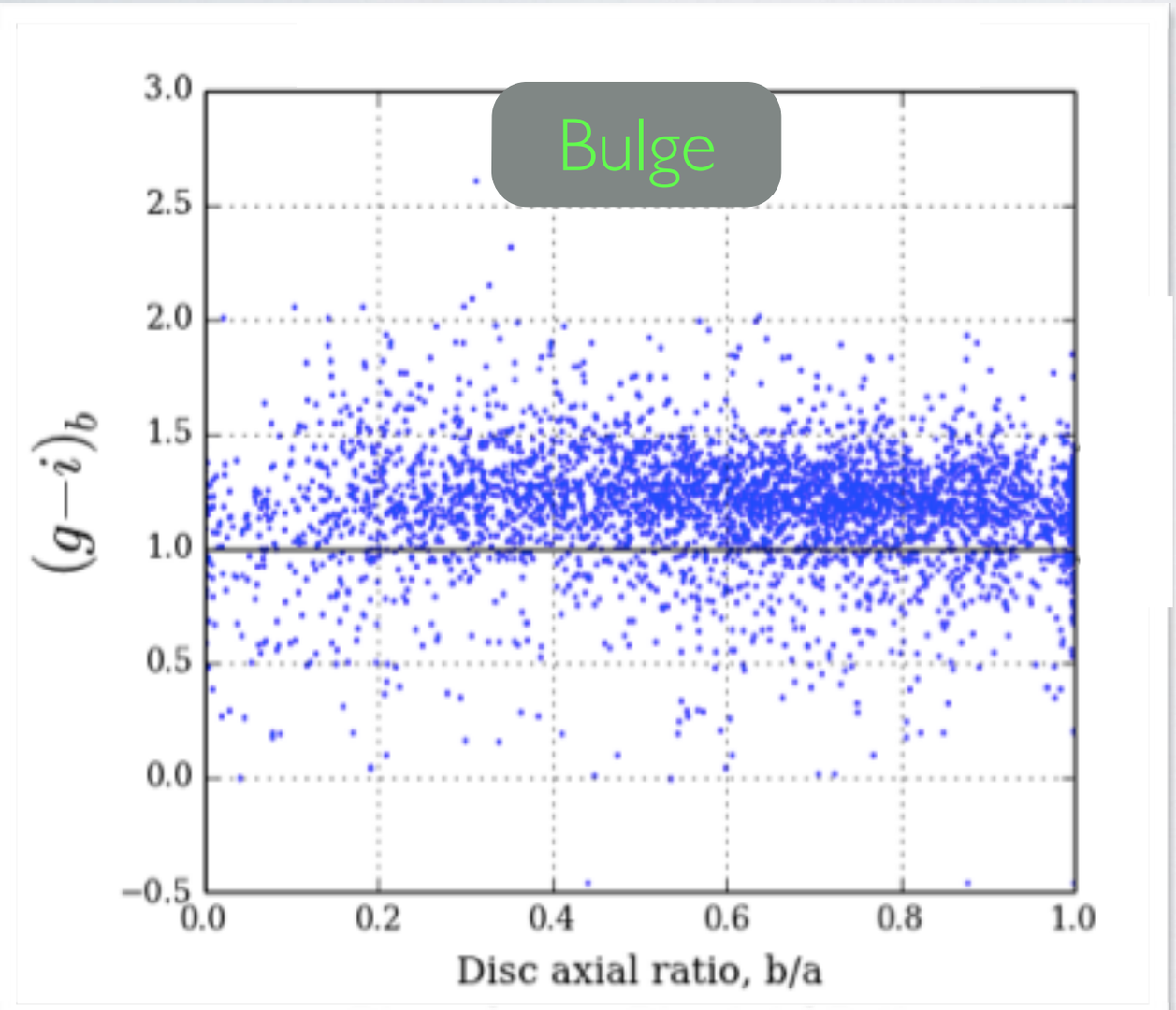
Kennedy et al in prep.

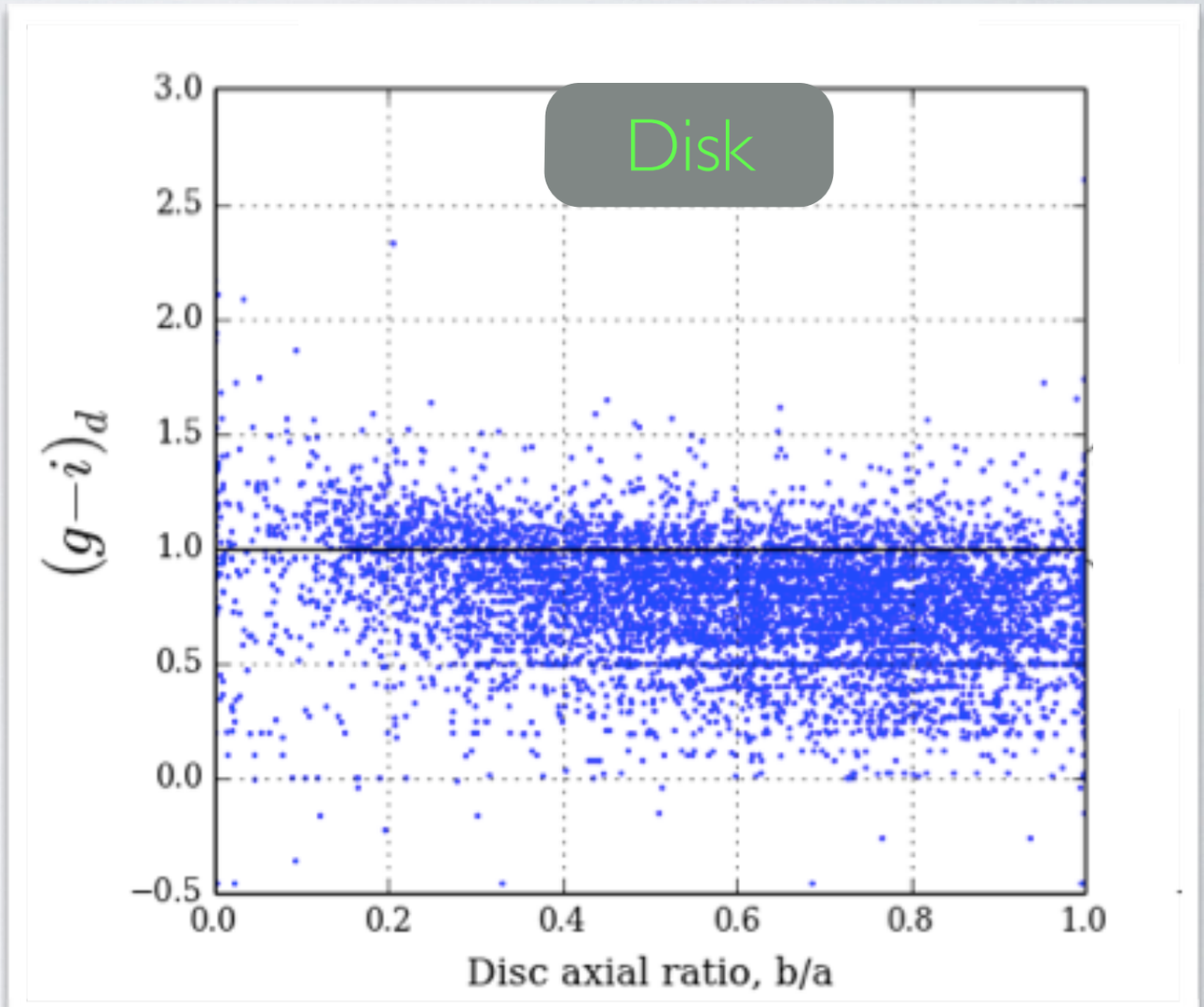
Bulge-Disk colour difference



Kennedy et al in prep.

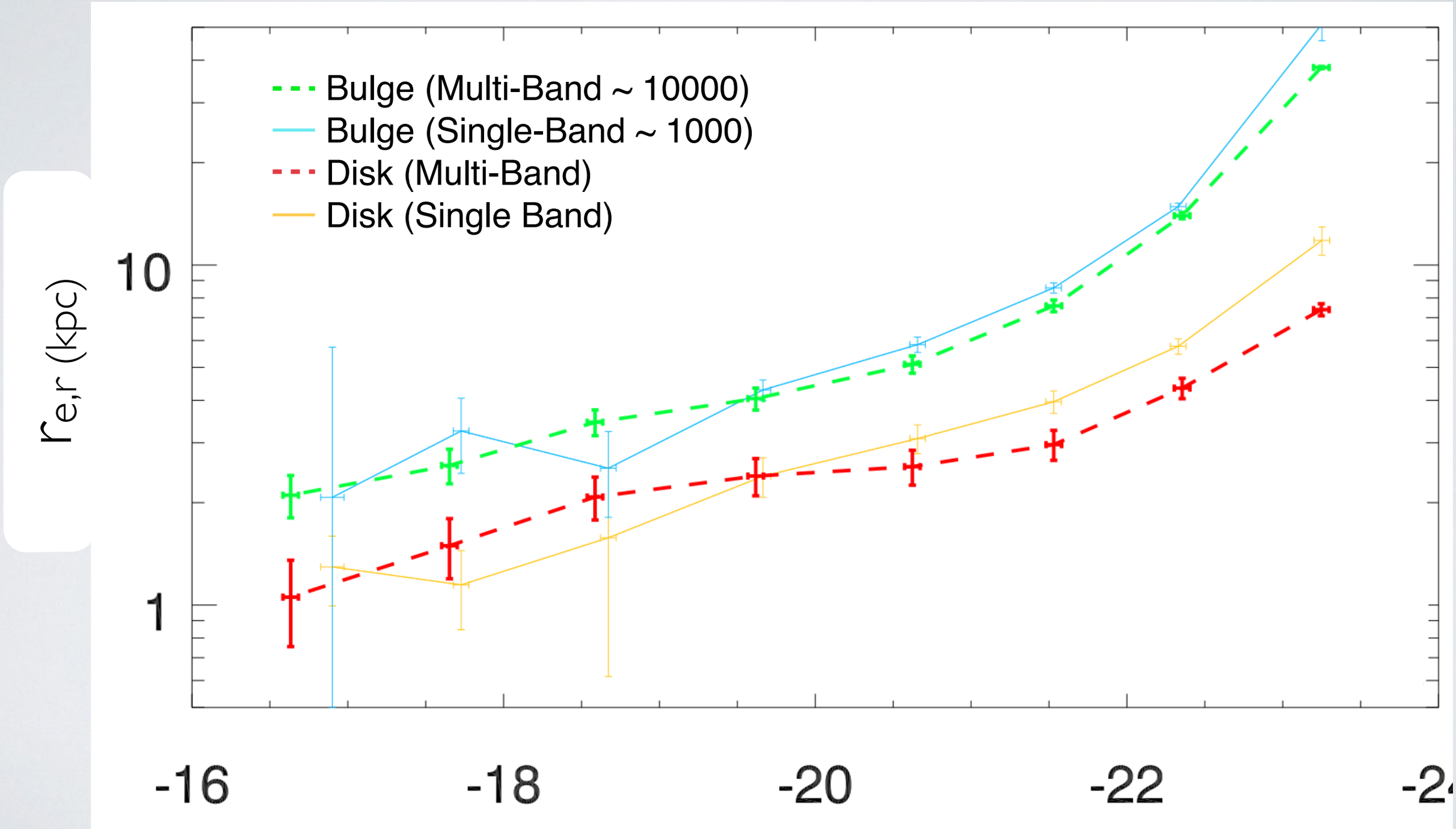
Colour vs Inclination





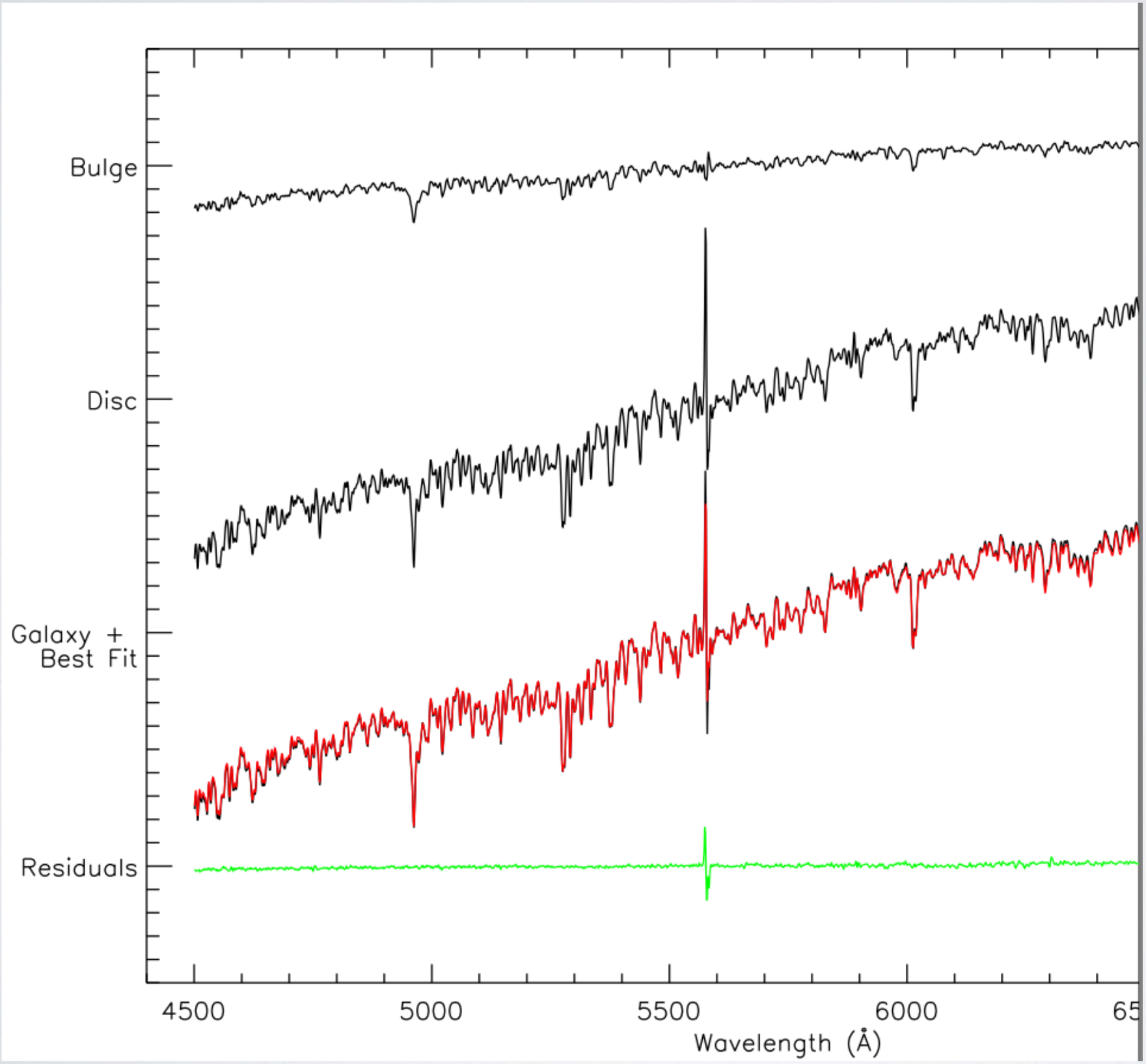
Kennedy et al in prep.

Bulge & Disk Size - Magnitude Relation



Häussler et al in prep.

Bulge & Disk Decomposition of IFU data



Johnston et al in prep.

Summary

- In this project we have developed a method that allows us to create wavelength-dependent models of the bulge and disk component. Our new multi-wavelength method expands and improves over single-band fitting for the extraction of structural parameters.

- We can recover the SED of the bulge and the disk.

- Disks in red galaxies can be redder than bulges in blue galaxies.

- Bulge colours appear unaffected by disc inclination

- A number of key conceptual **developments** have been made and implemented in well established software packages (GALFITM, GALAPAGOS-2). You can download the software from: **www.nottingham.ac.uk/astronomy/megamorph/**

    - What is the colour (or age) of each component and how does it change depending on the overall mass and enviroment of the galaxy?

    - Is there any size change with wavelength for bulges and disks and what does it tell us?

Thank you!