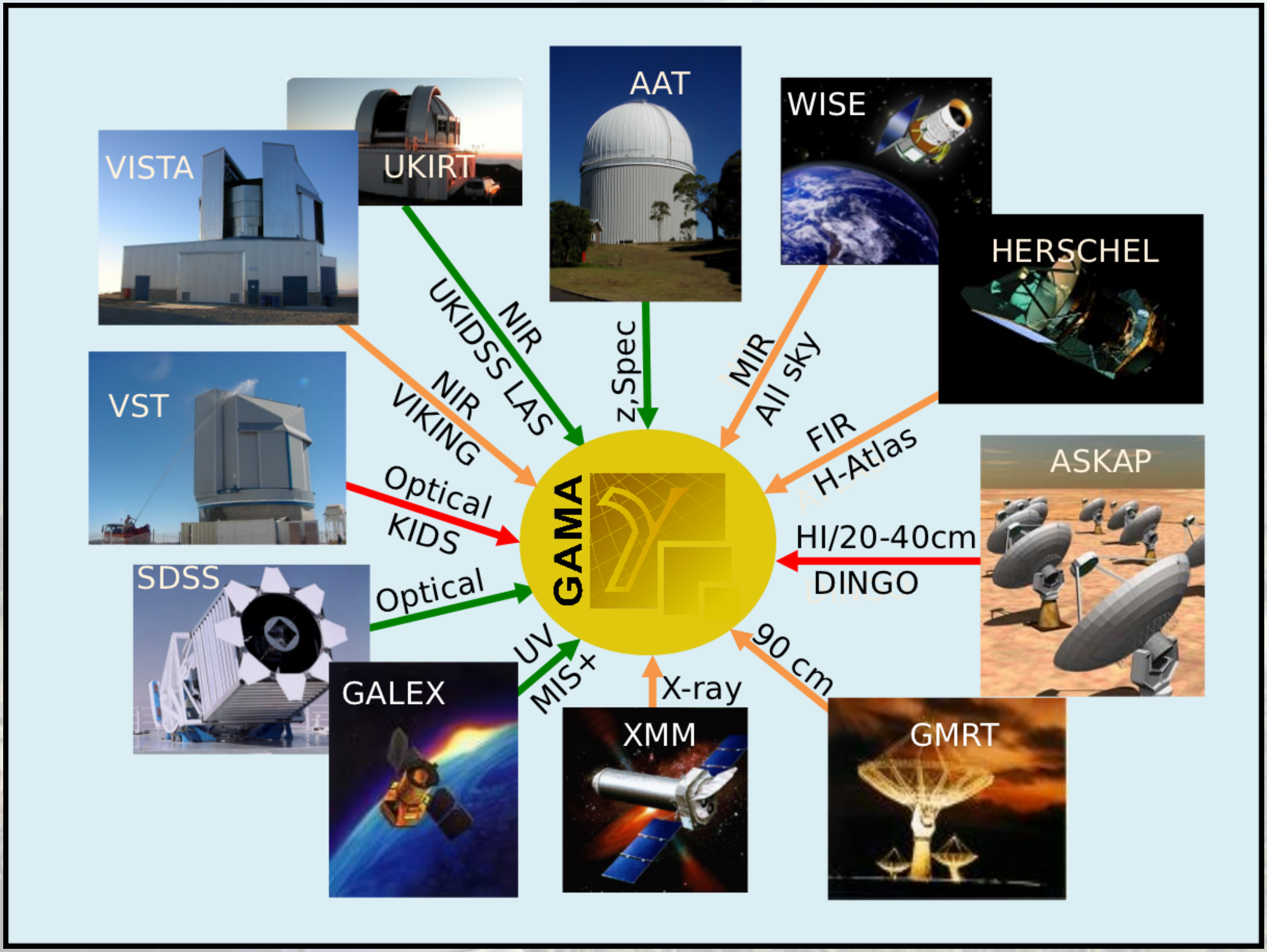
Dividing the Local Galaxy Stellar Mass Function by Morphology and Structure

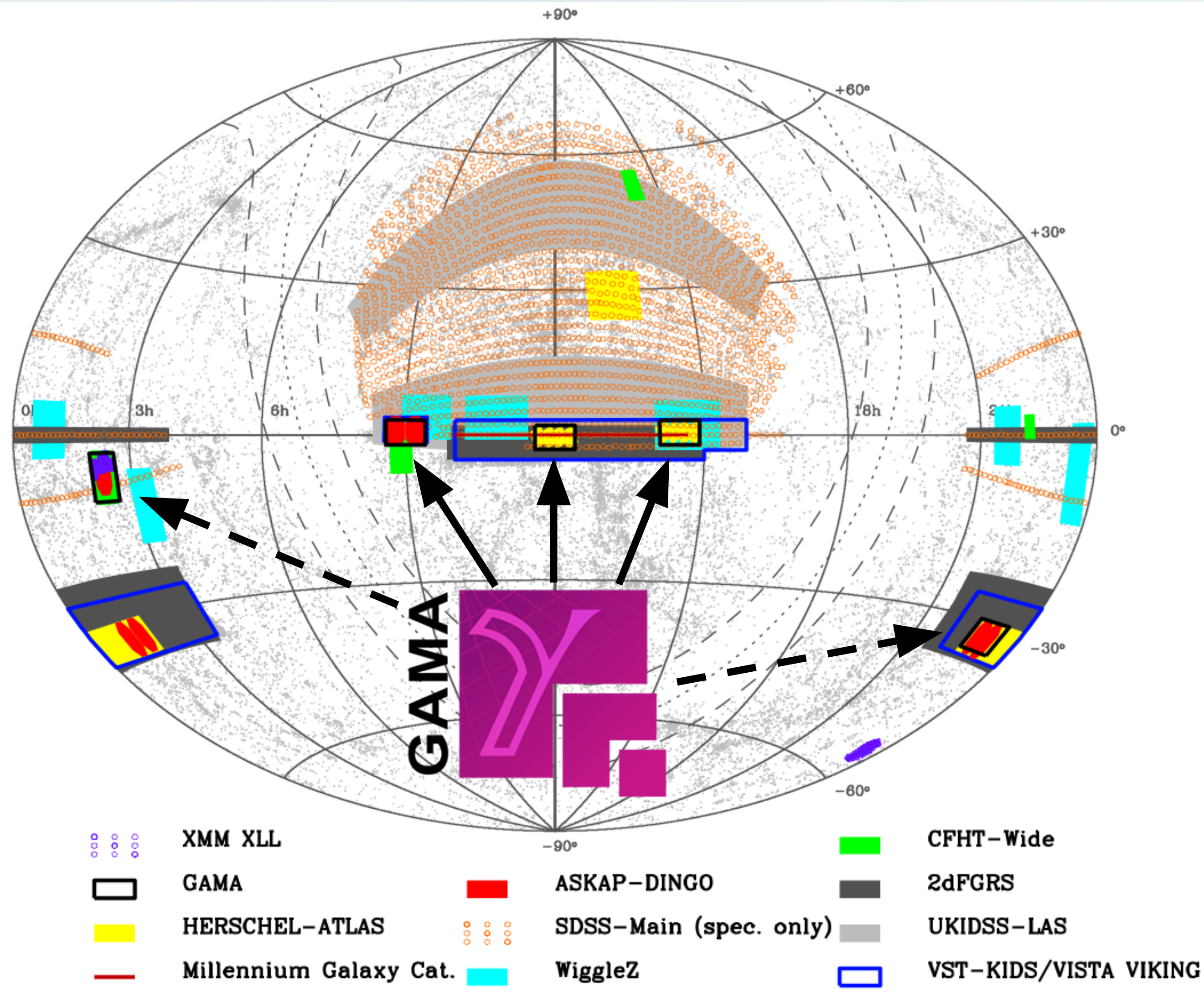
Lee Kelvin

University of Innsbruck

Galaxy and Mass Assembly



GAMA Regions



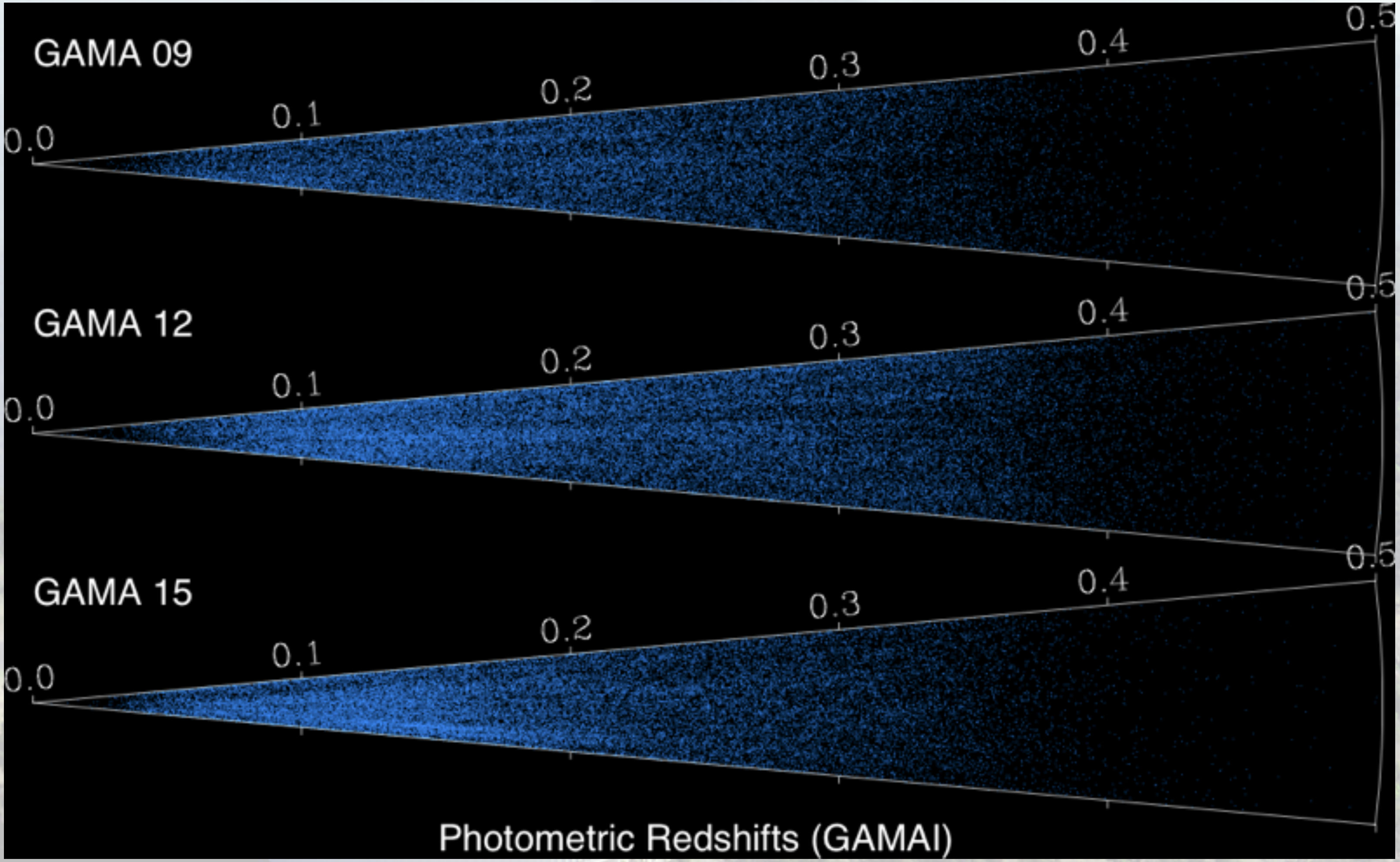
- ~340,000 gals
- r < 19.8 mag
- ~310 deg^2
- 27 passbands

"Study structure on scales of 1 kpc to 1 Mpc"

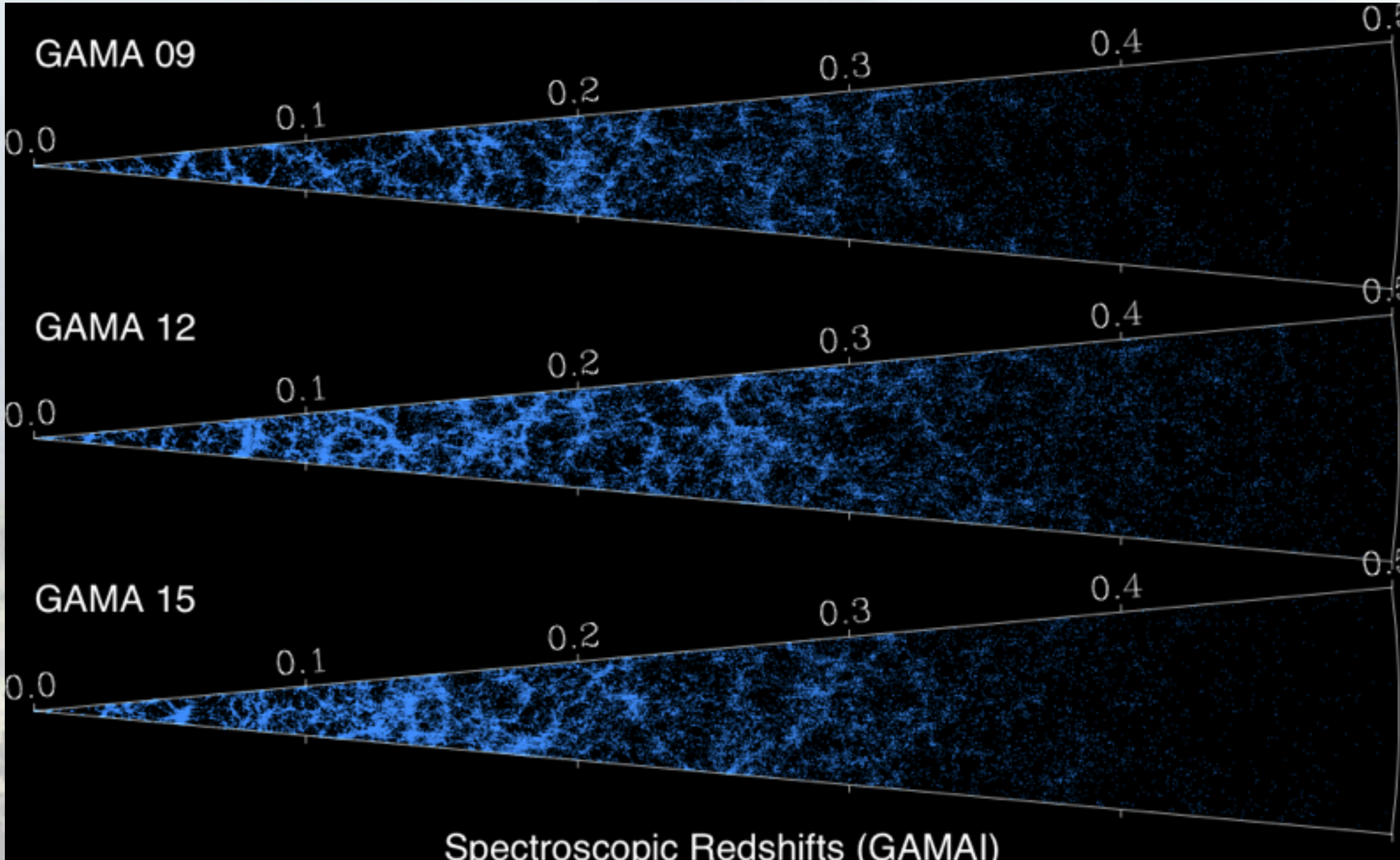
galaxy...

- clusters
- groups
- mergers
- structure

GAMA: Photo-Redshifts...



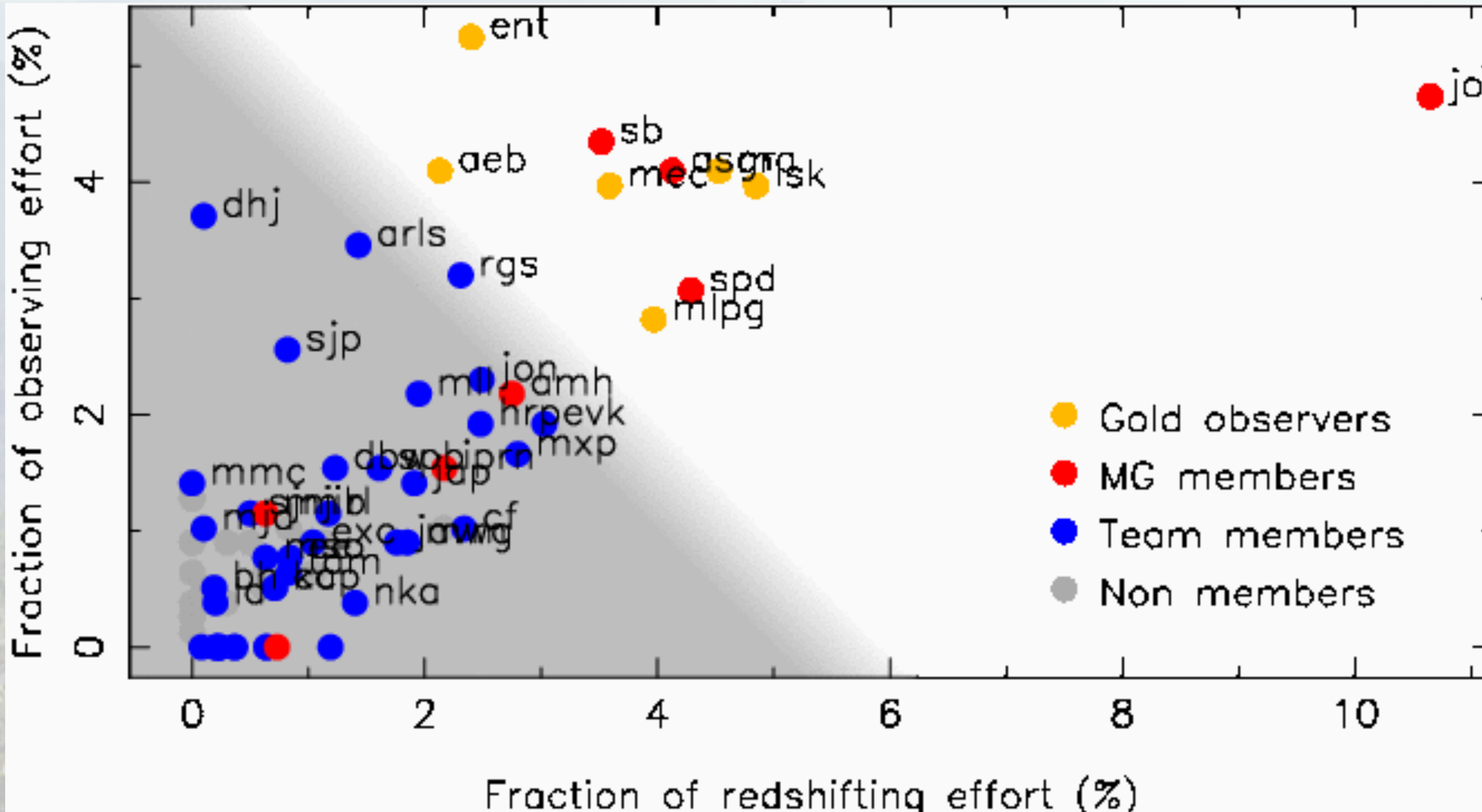
GAMA: Spectro-Redshifts



GAMA: People (2012)

GAMA: People (2013)

GAMA Redshifts

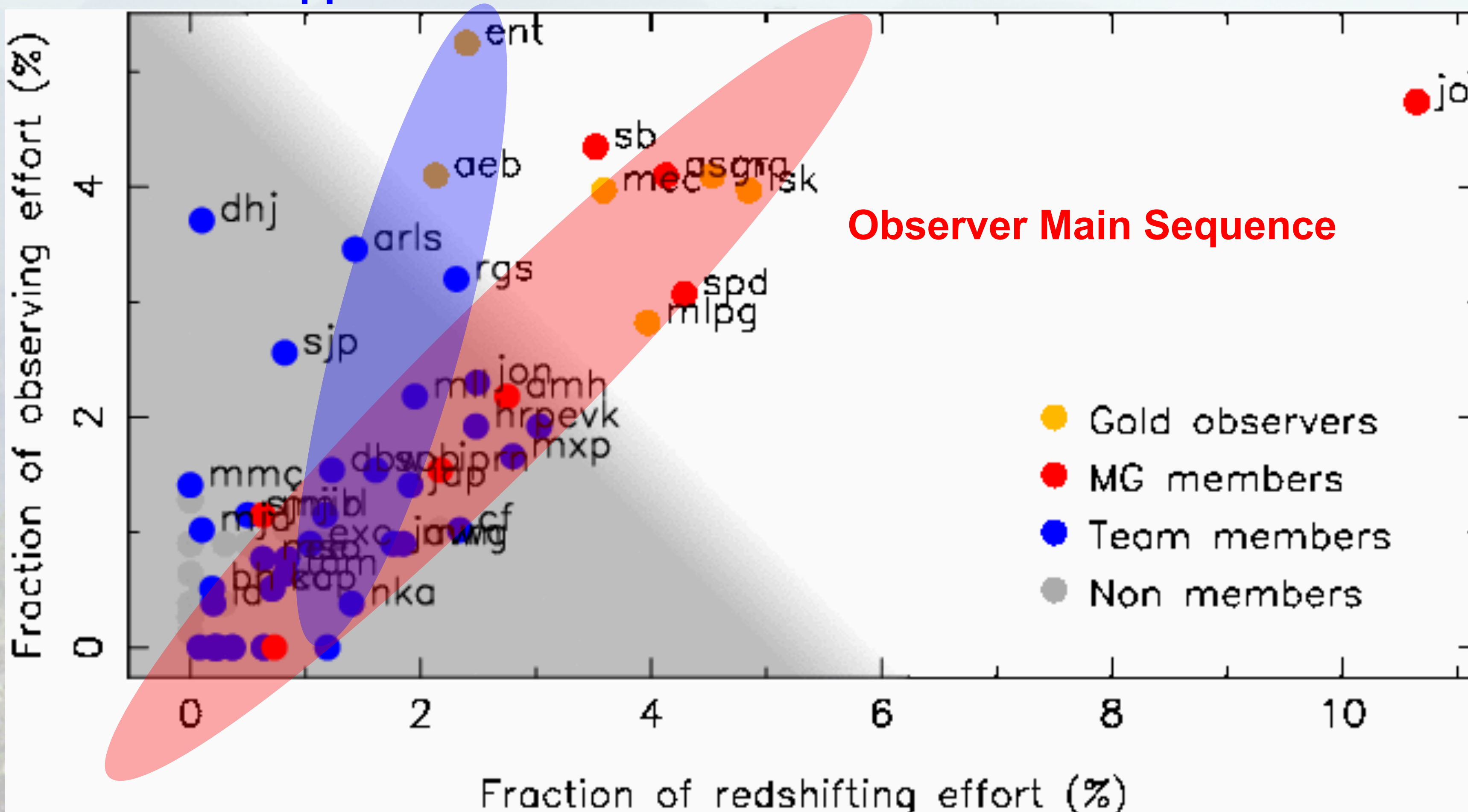


~250,000 spectroscopic redshifts

0 < z < 0.5

GAMA Redshifts

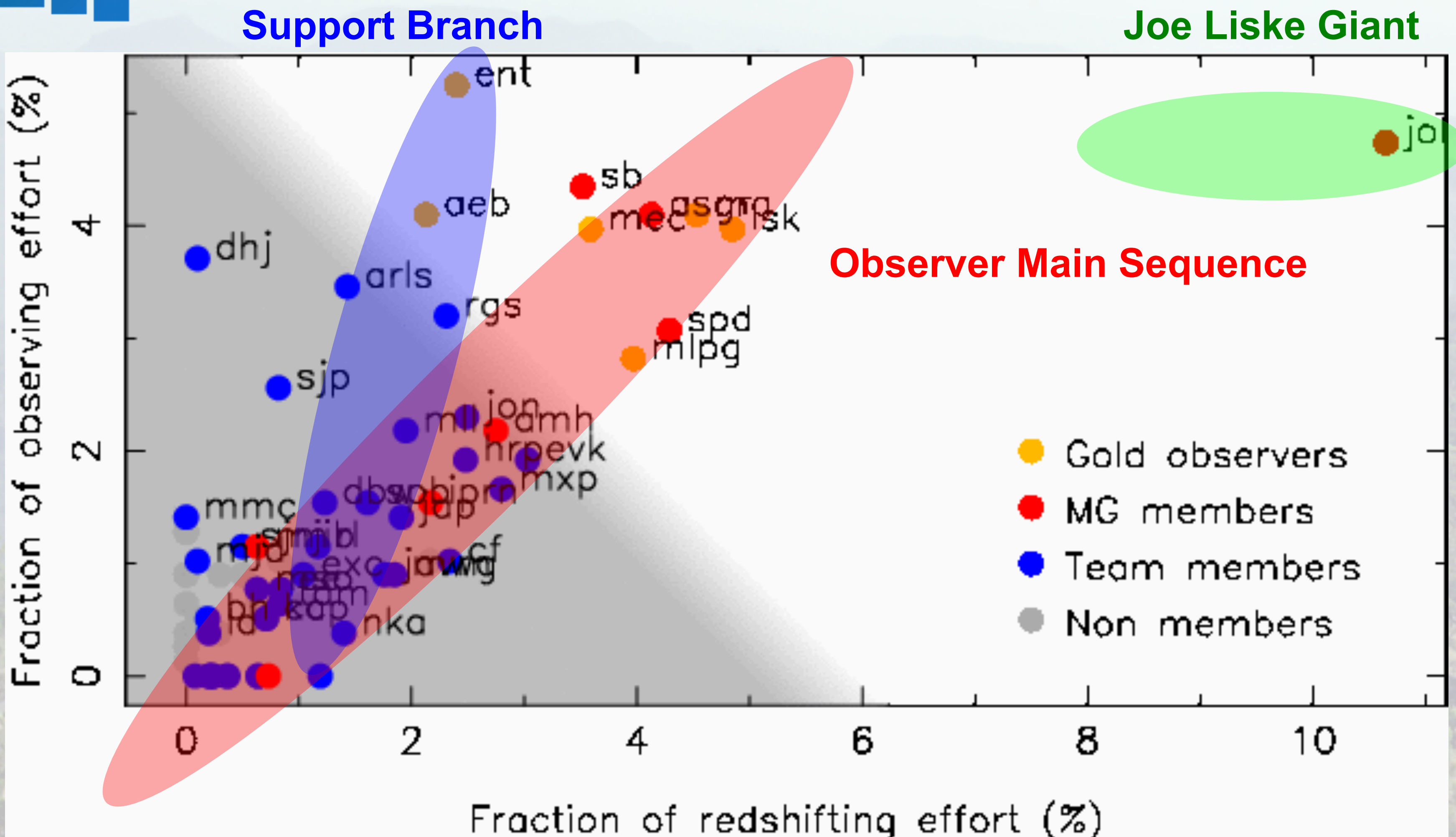
Support Branch



~250,000 spectroscopic redshifts

0 < z < 0.5

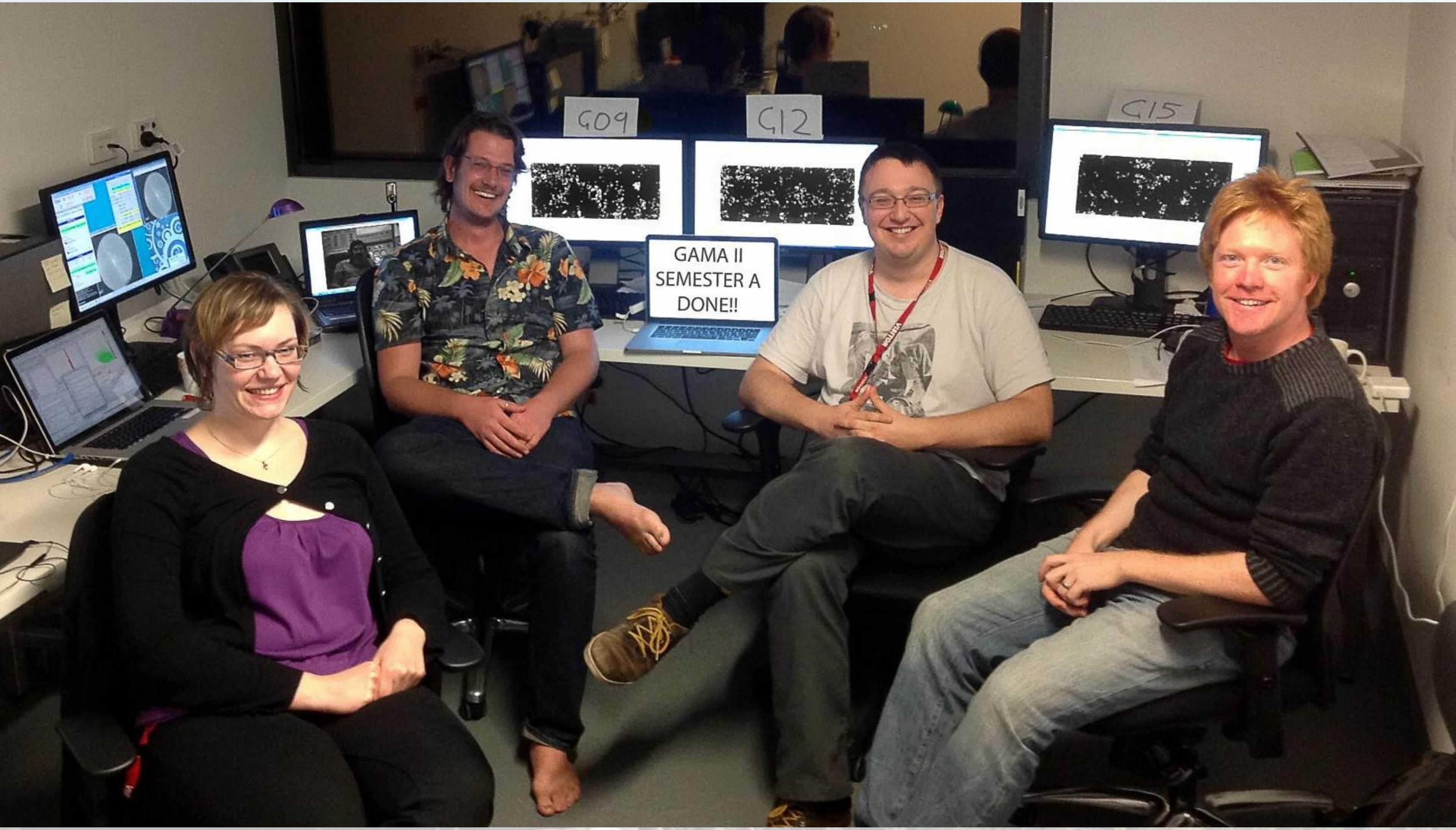
GAMA Redshifts

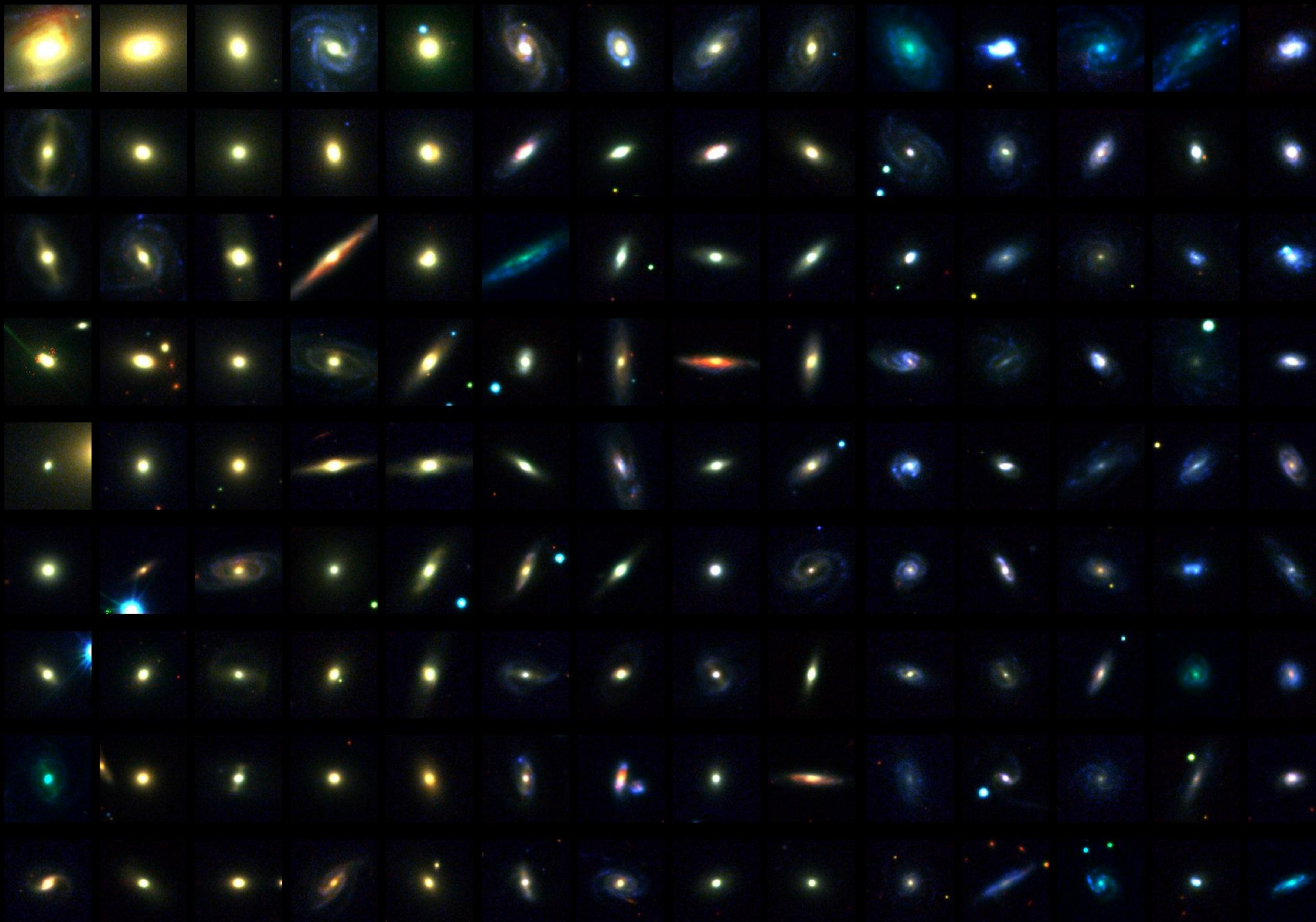


~250,000 spectroscopic redshifts

0 < z < 0.5

GAMA: Equatorial Regions Done!

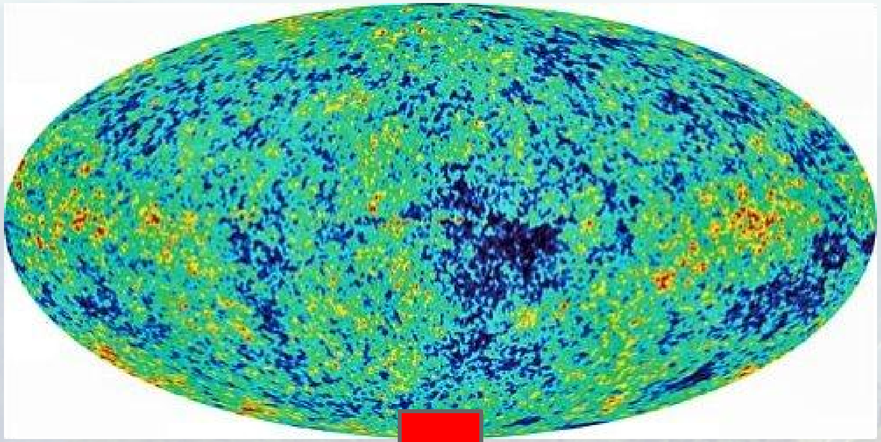


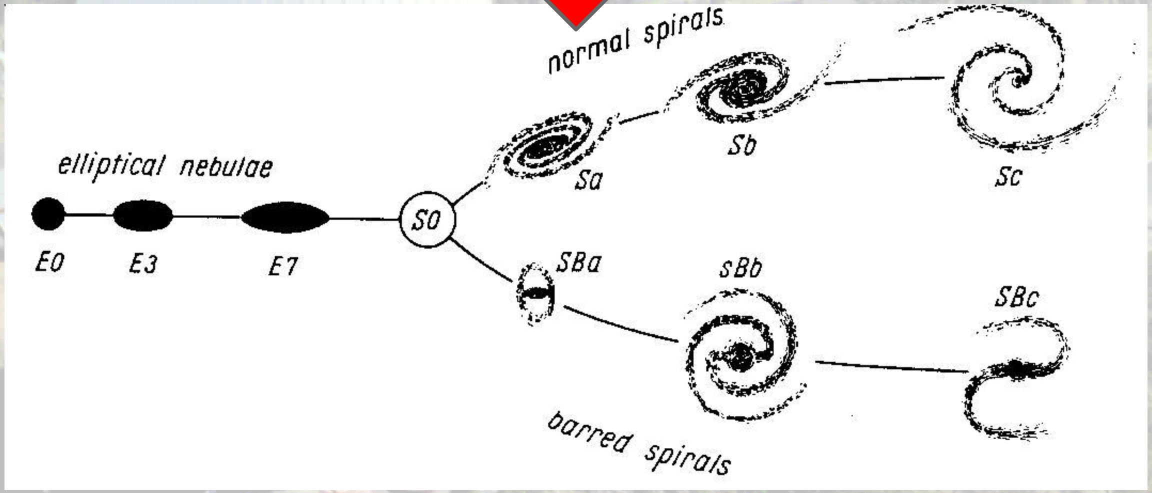



How do these galaxies
form and evolve?

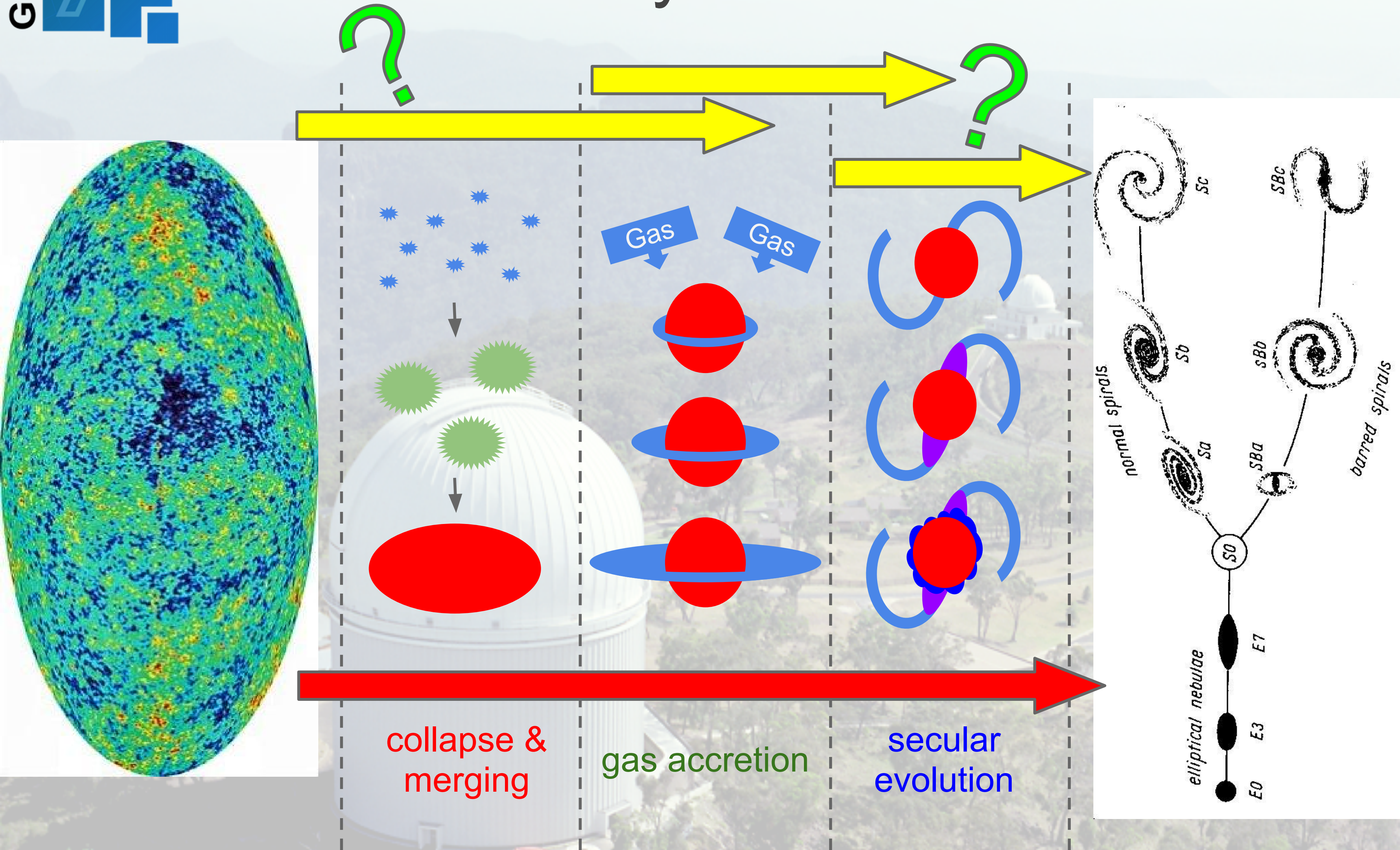
How do galaxies form and evolve?

Motivation

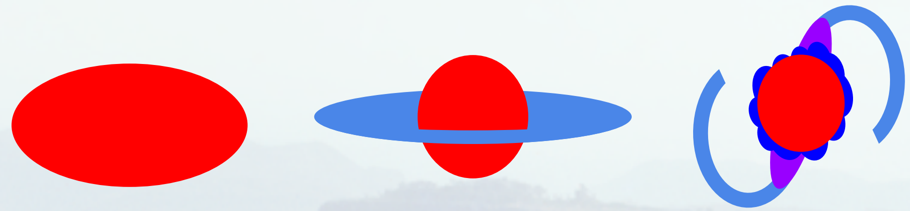


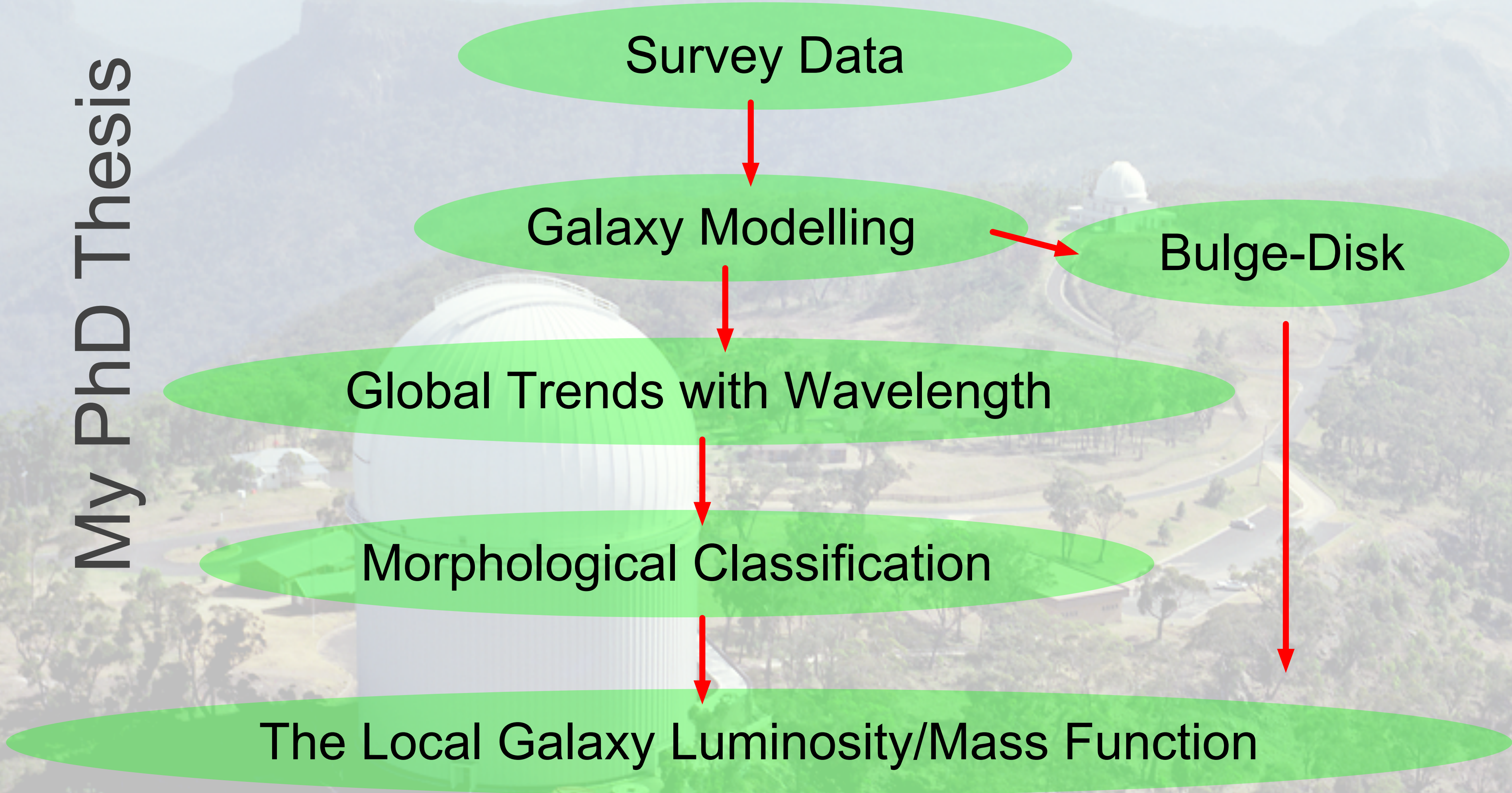


Evolutionary Mechanisms

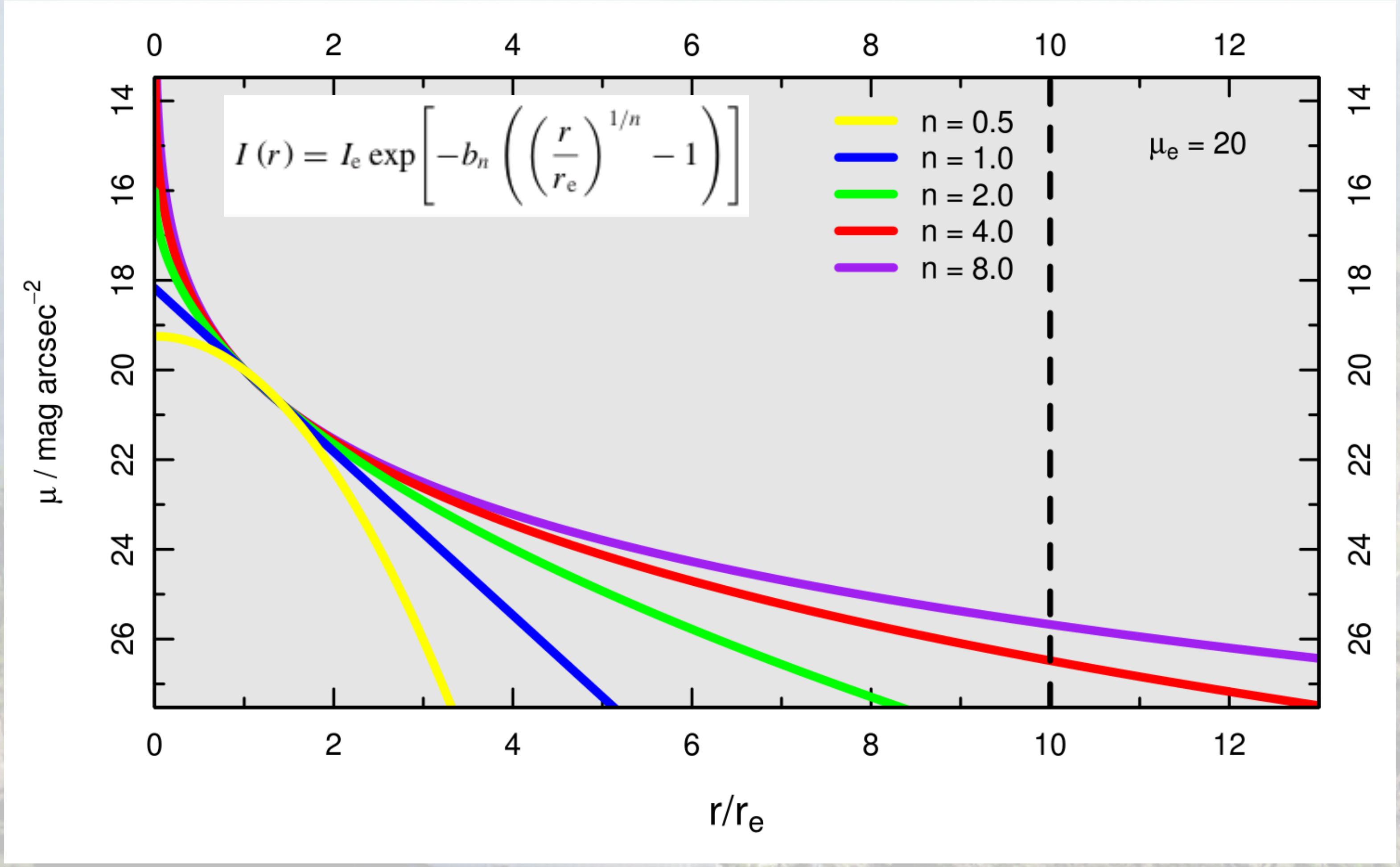


My PhD Thesis





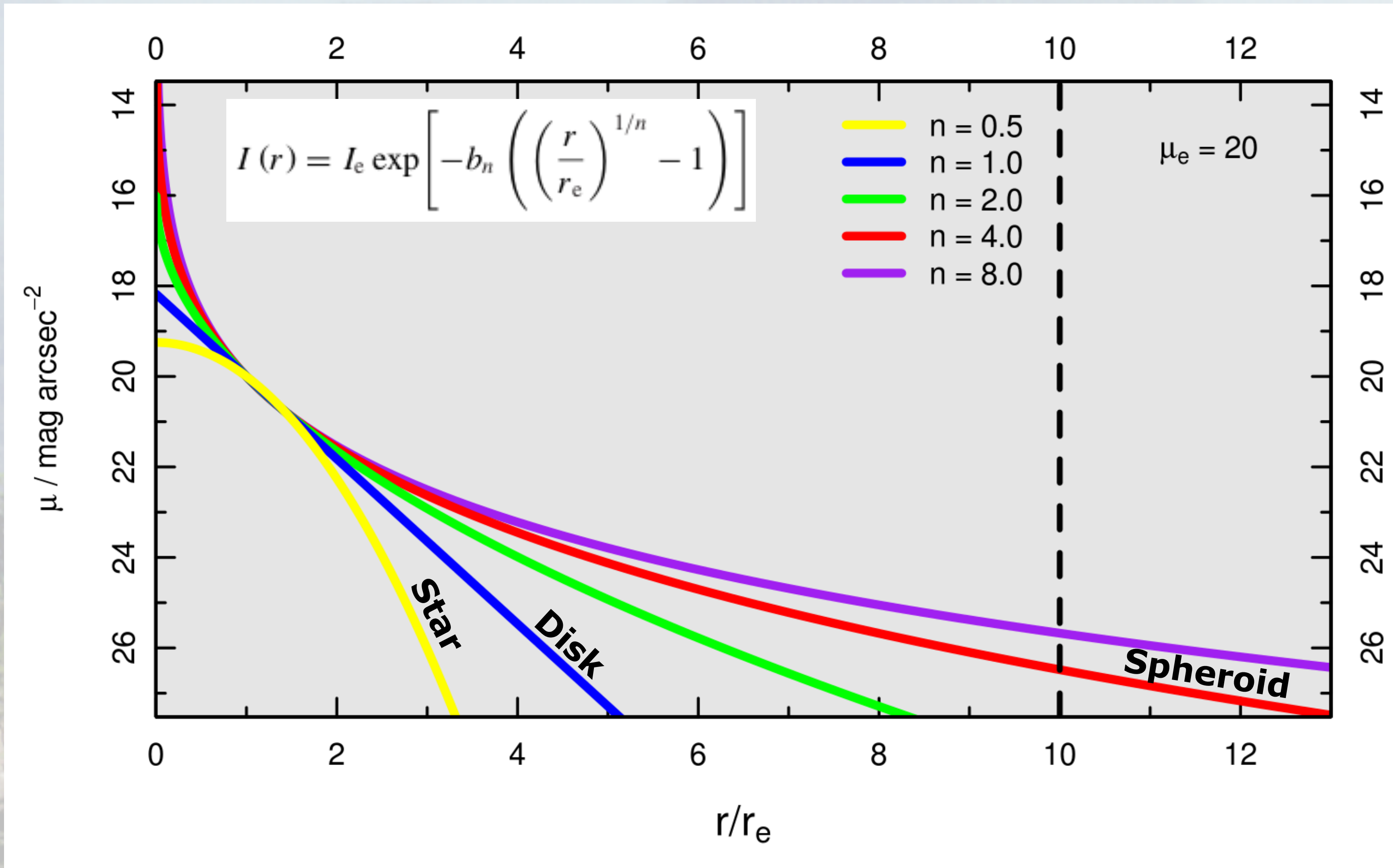
Sérsic Profile



José Luis Sérsic

Models many different galaxy profile shapes

Sérsic Profile

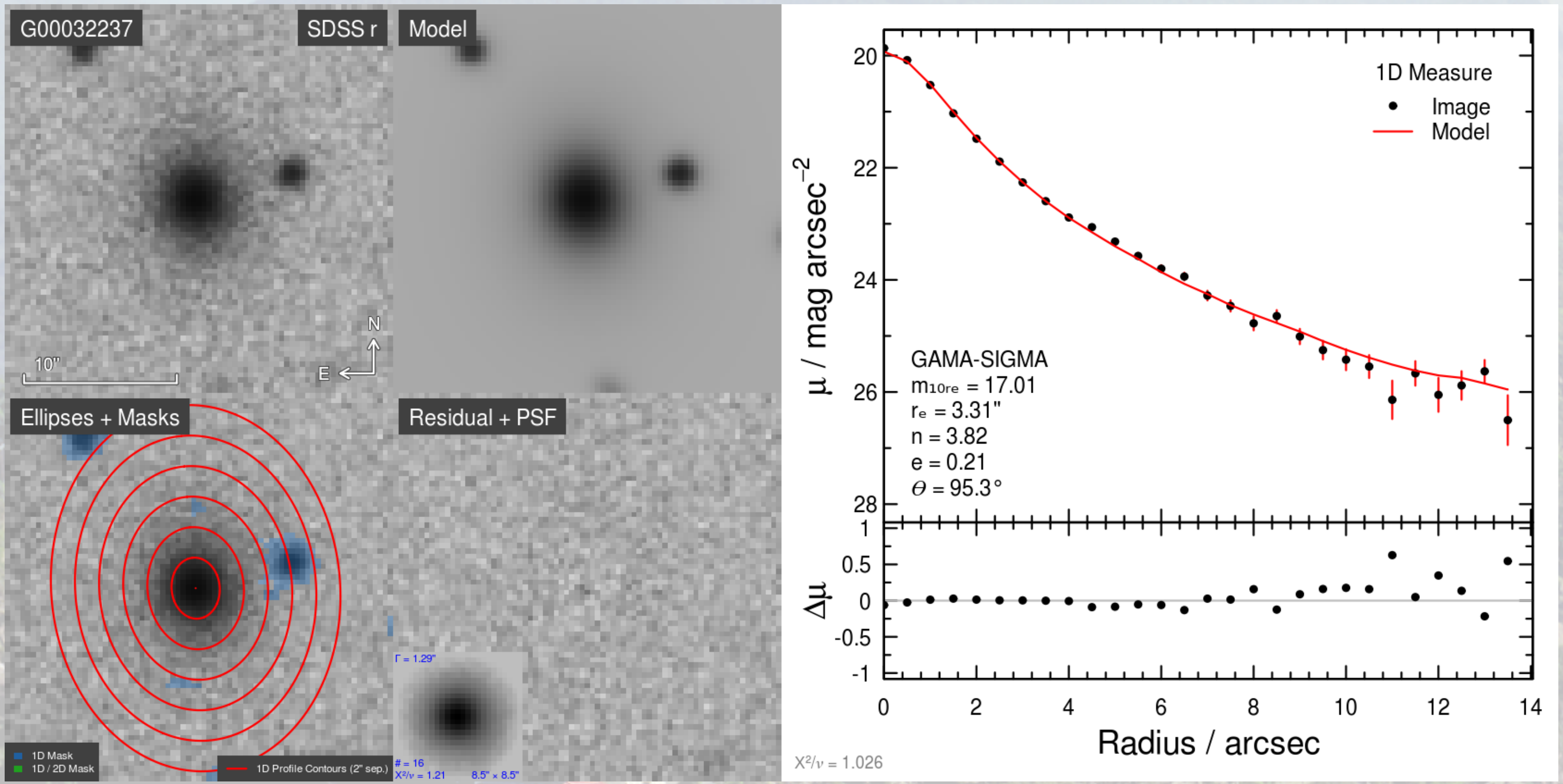


José Luis Sérsic

Models many different galaxy profile shapes

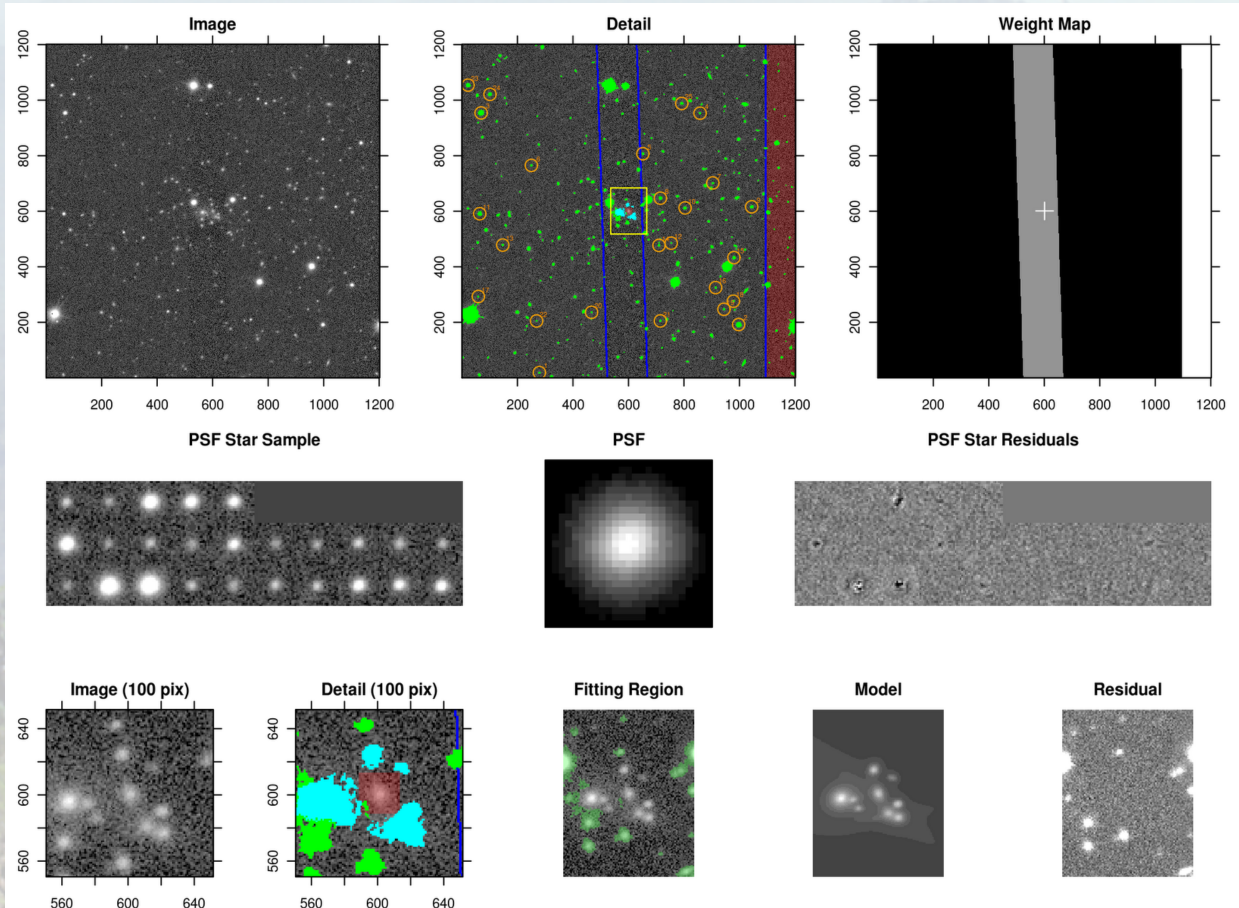
Sérsic Modelling

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



SIGMA

Structural Investigation of Galaxies via Model Analysis



Imaging & Pointing Data

- 400" x 400" cutout
- Star identification
- Empirical PSF
- Galaxy detection
- Sérsic modelling
- Model self-check
- Value added results

Model Fit Parameters

SExtractor Bertin+ 1996

PSFEx Bertin 2011

GALFIT3 Peng+ 2010

astro-staff.uibk.ac.at/~lee

SIGMA

Structural Investigation of Galaxies via Model Analysis

Achtung! The model does not always accurately represent the underlying image!

Mass-Limited Sample

Limits:

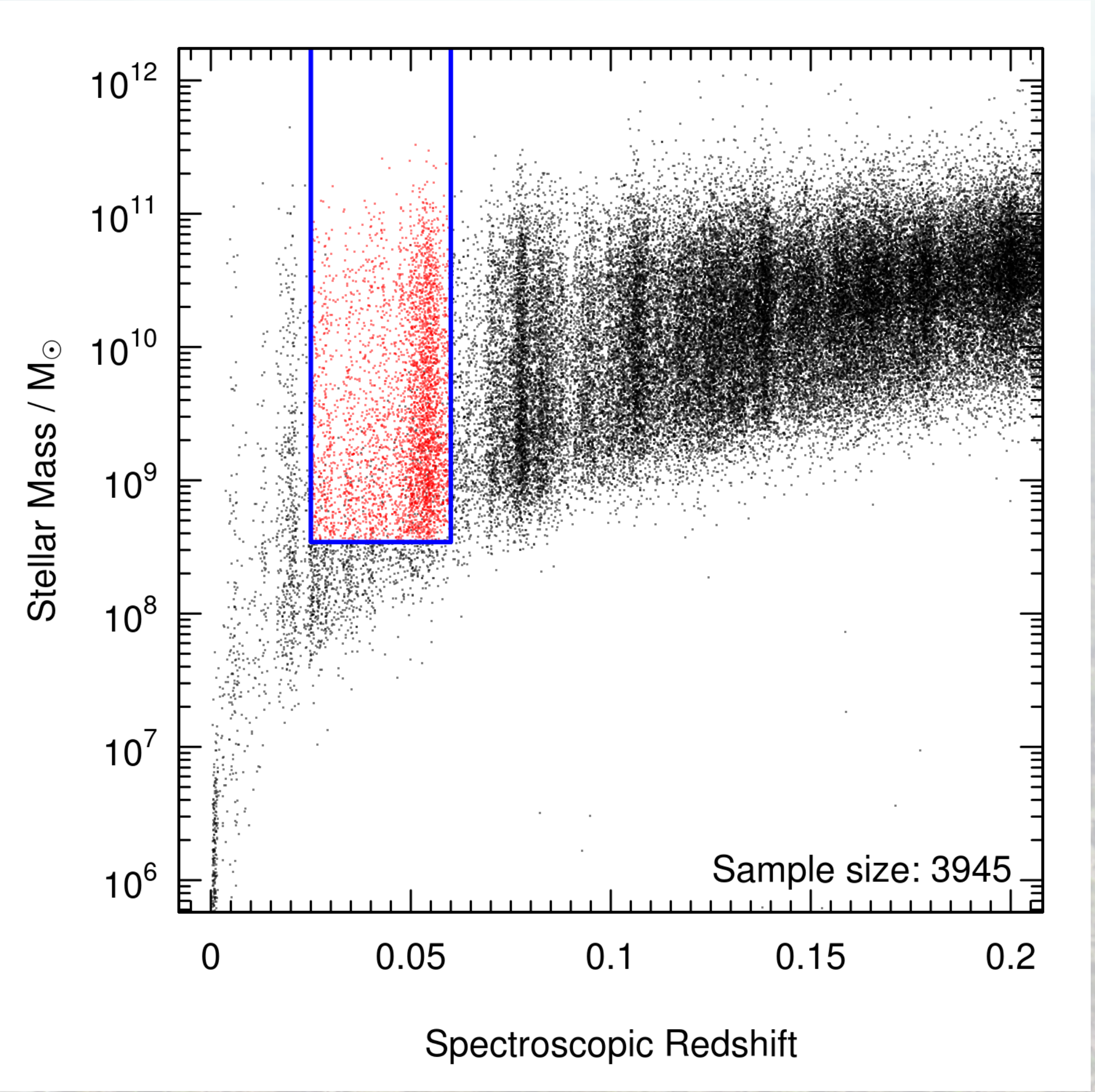
$0.025 < z < 0.06$

$\log_{10}M > 8.537$

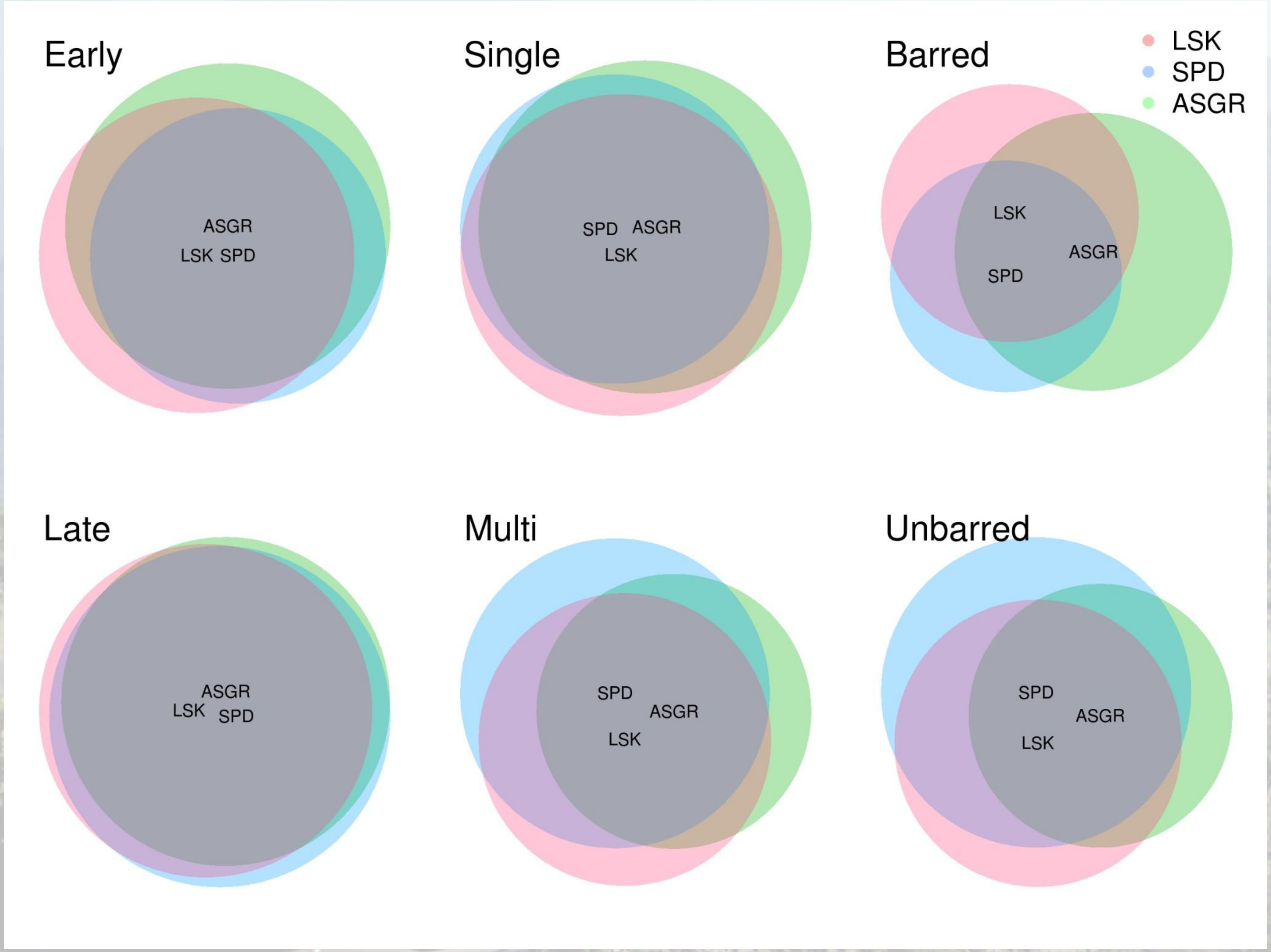
(Taylor et al., 2011)

Structural Decomposition:

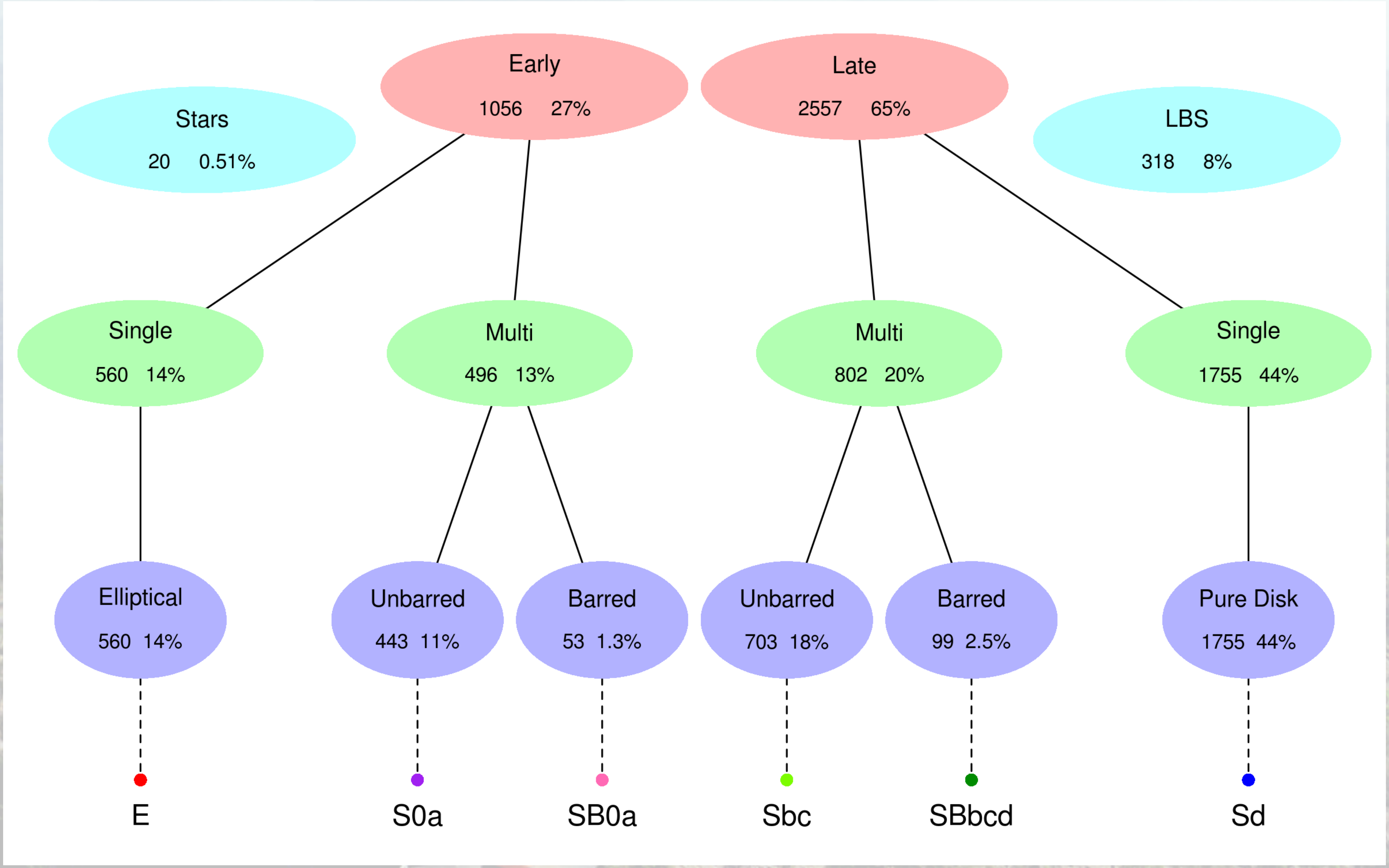
1. Morphological classification
2. Bulge-Disk decomposition



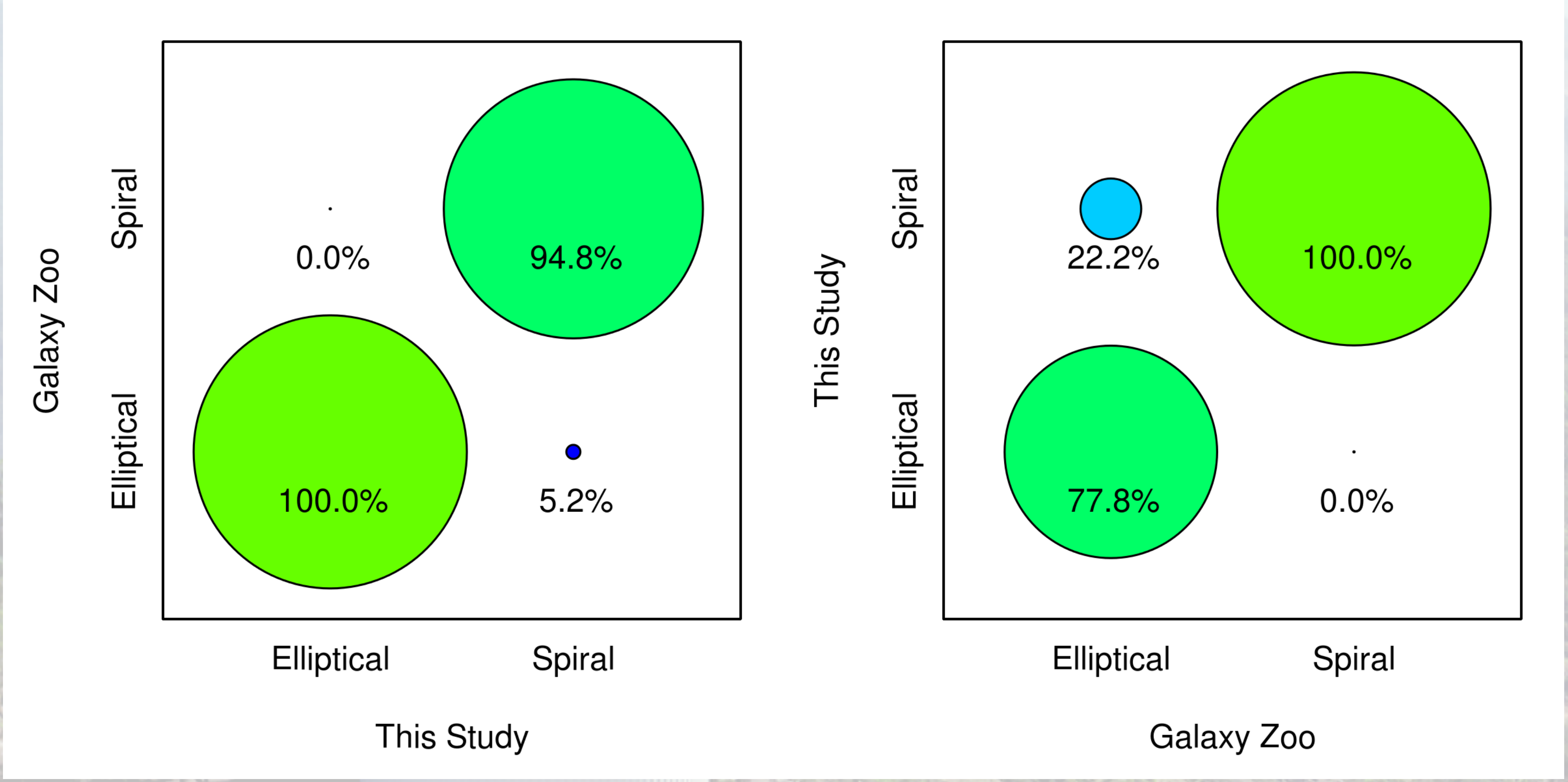
Visual Classification



Visual Classification



Visual Classification



(Lintott et al., 2010)

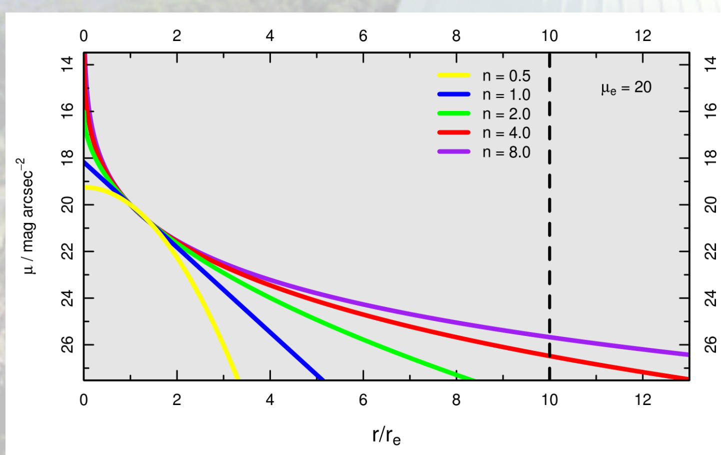
Multi-Component Models

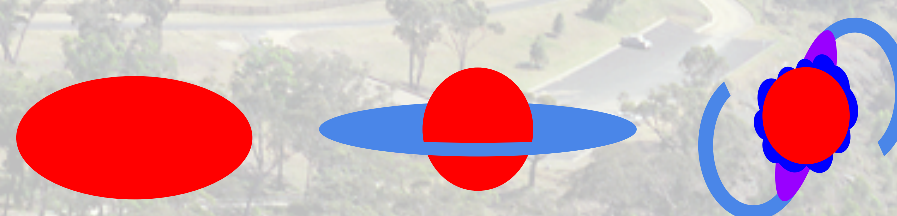
M01: Single-Sérsic

M02: De Vaucouleurs bulge + exponential disk

M03: Sérsic bulge + exponential disk

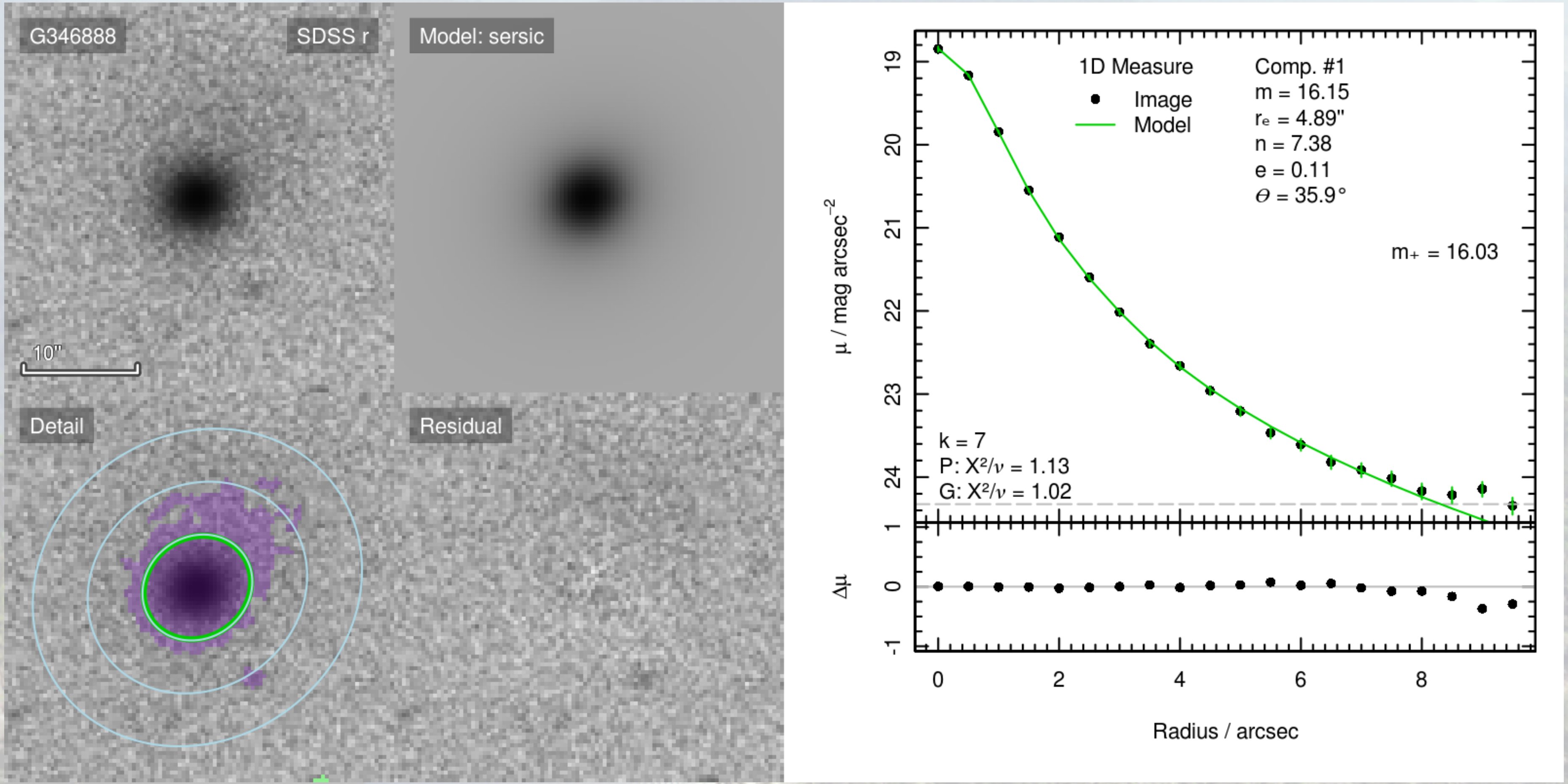
M04: Sérsic bulge + Sérsic disk





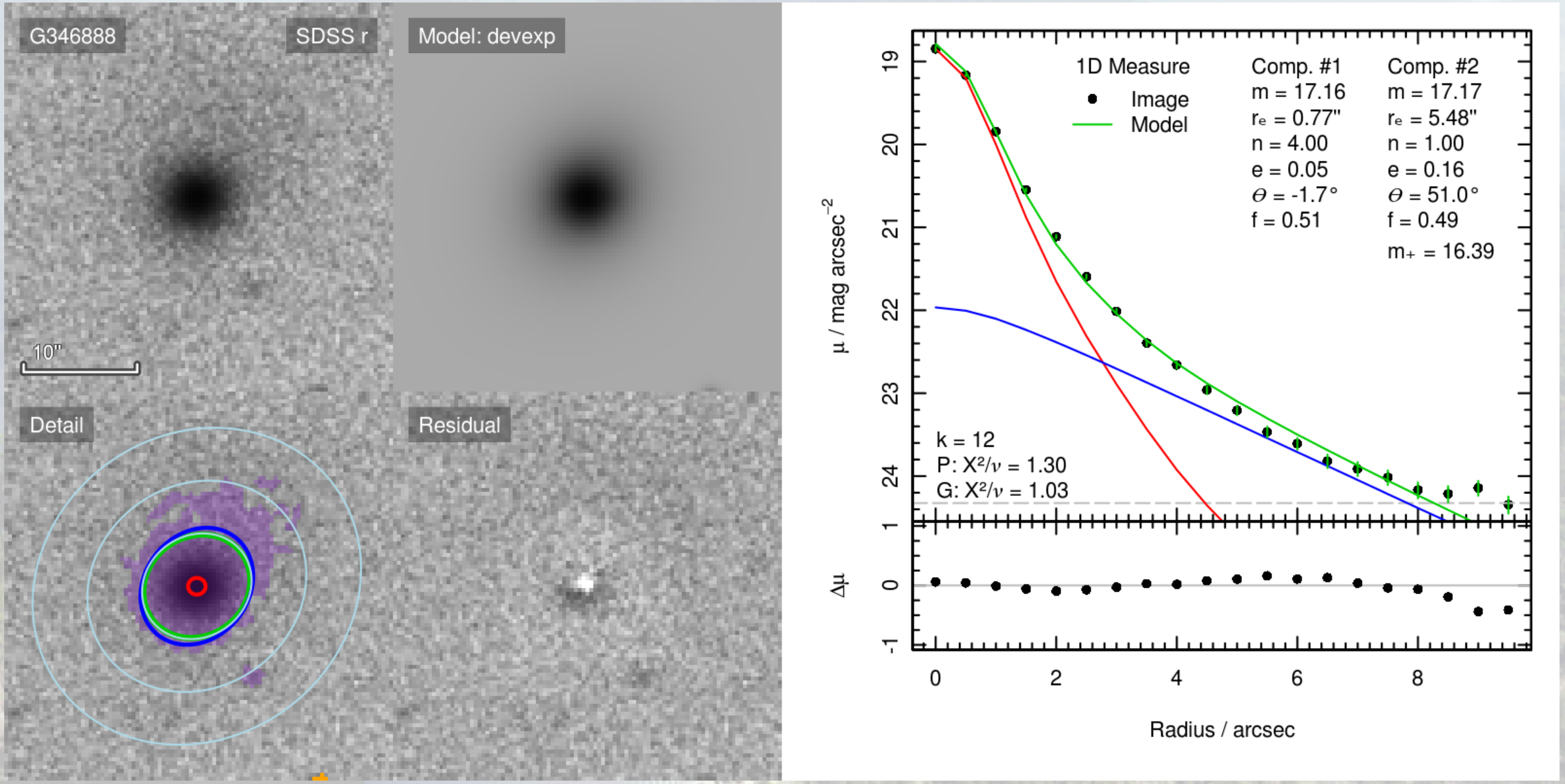
Elliptical: G346888

M01: Single-Sérsic



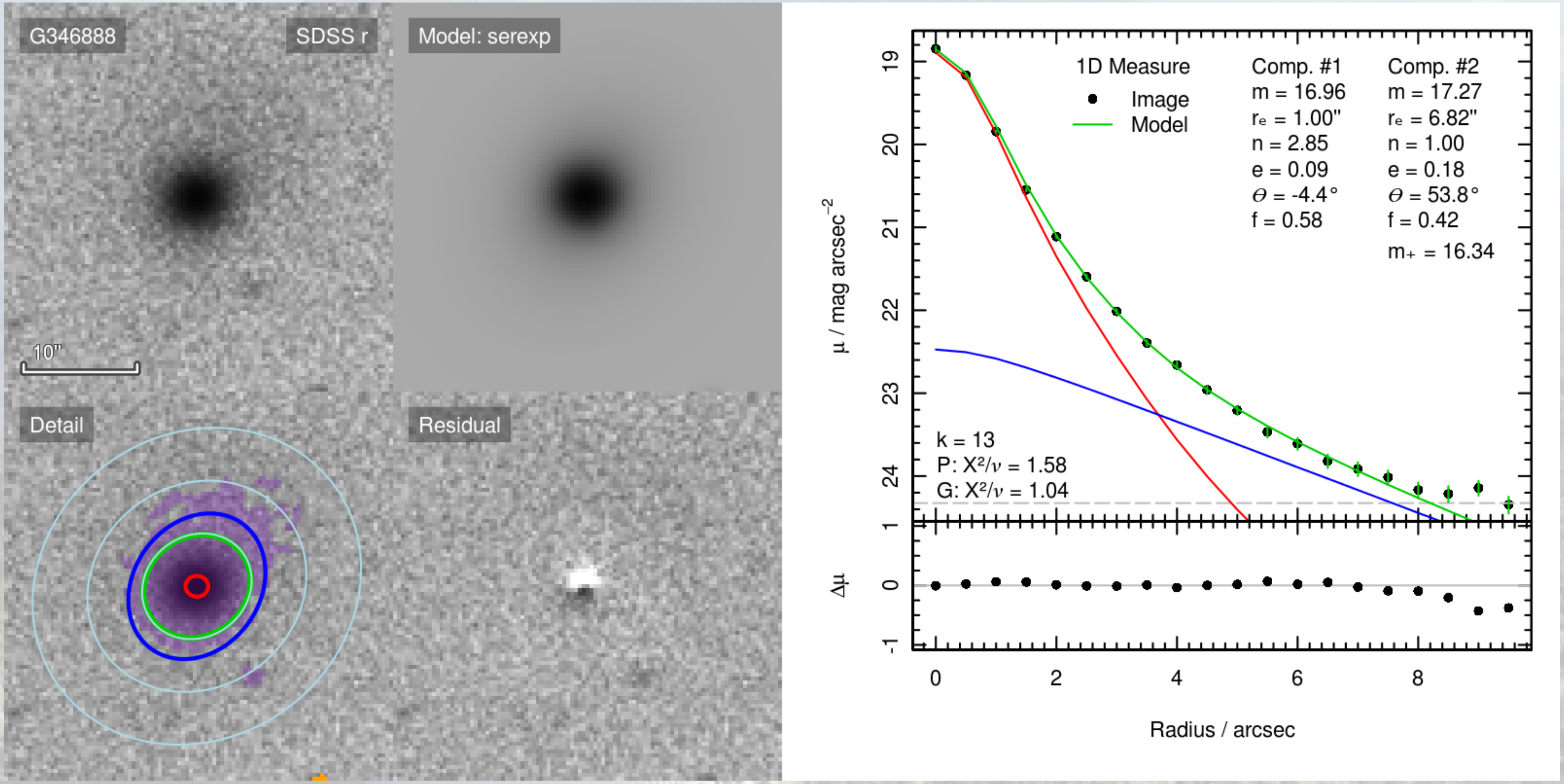
Elliptical: G346888

M02: De Vaucouleurs bulge + exponential disk



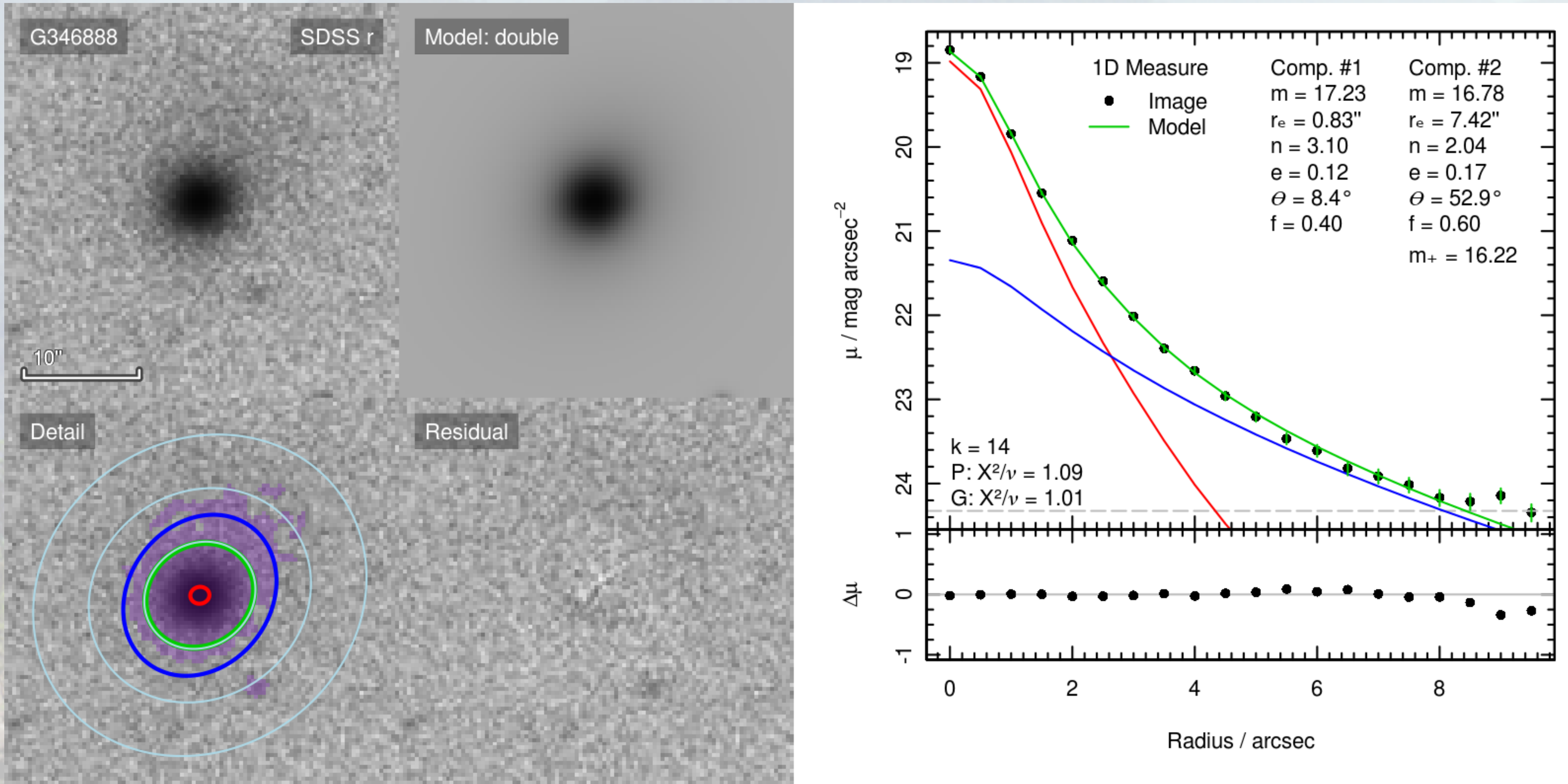
Elliptical: G346888

M03: Sérsic bulge + exponential disk



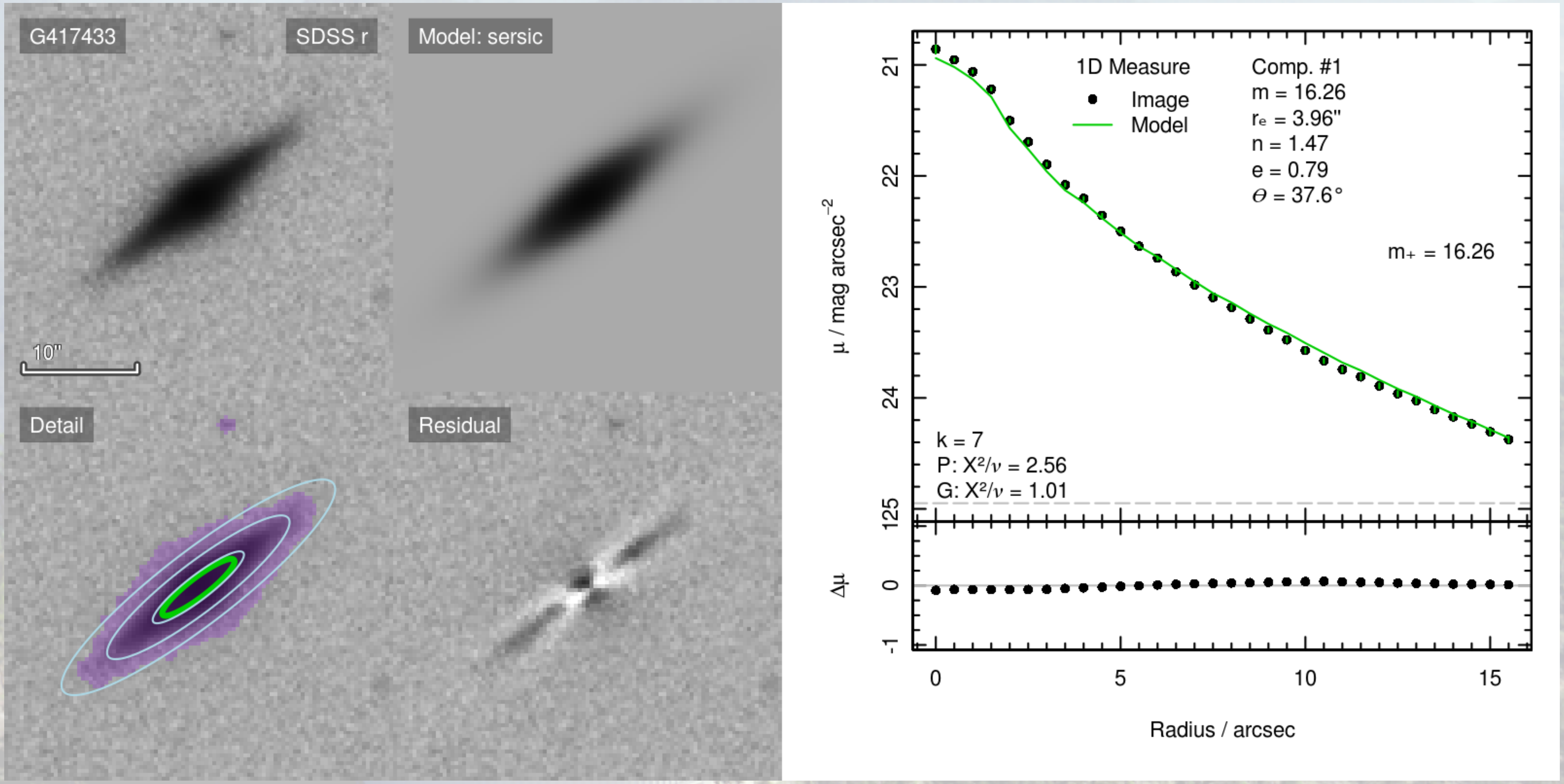
Elliptical: G346888

M04: Sérsic bulge + Sérsic disk



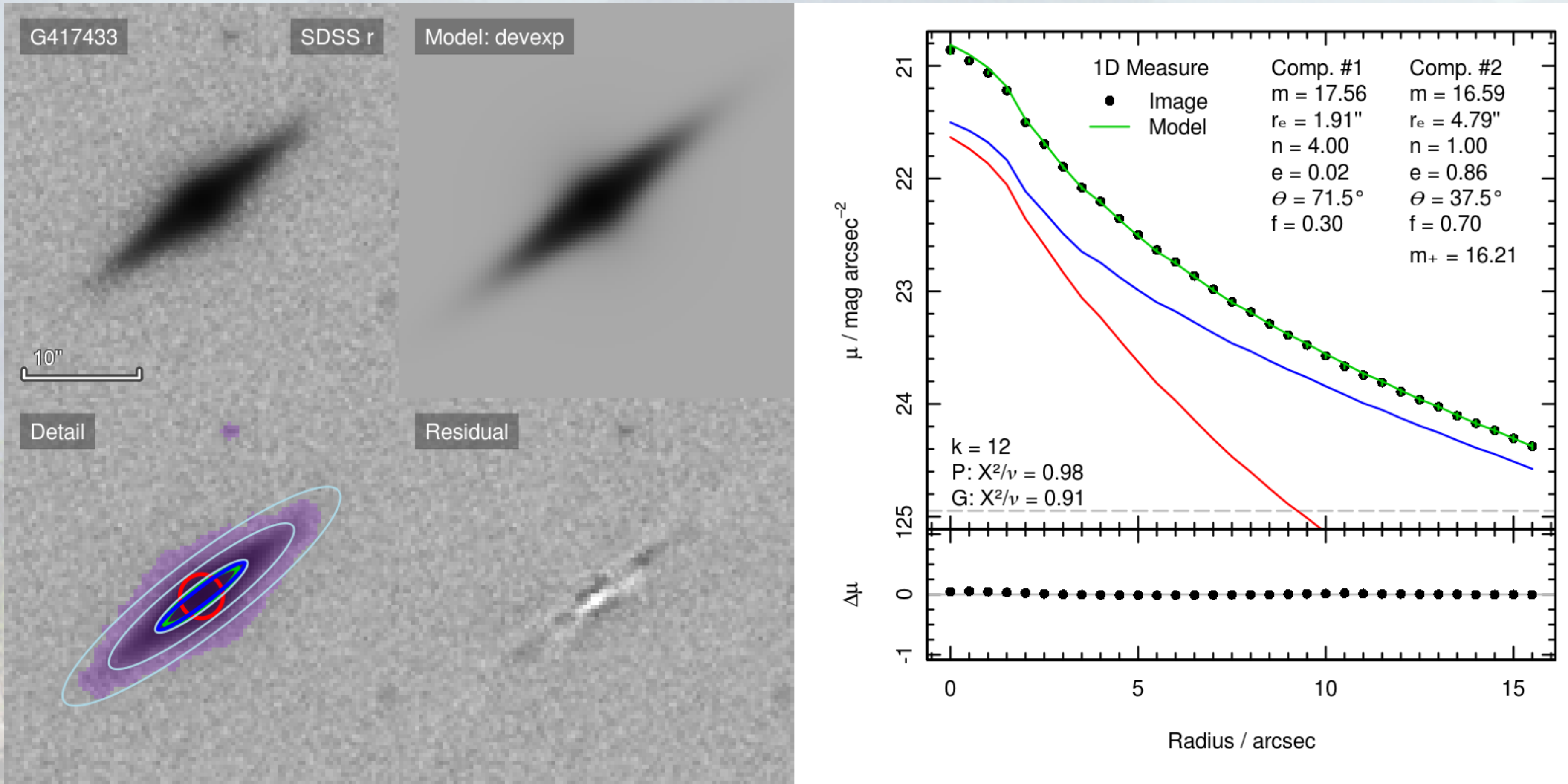
S0a: G417433

M01: Single-Sérsic



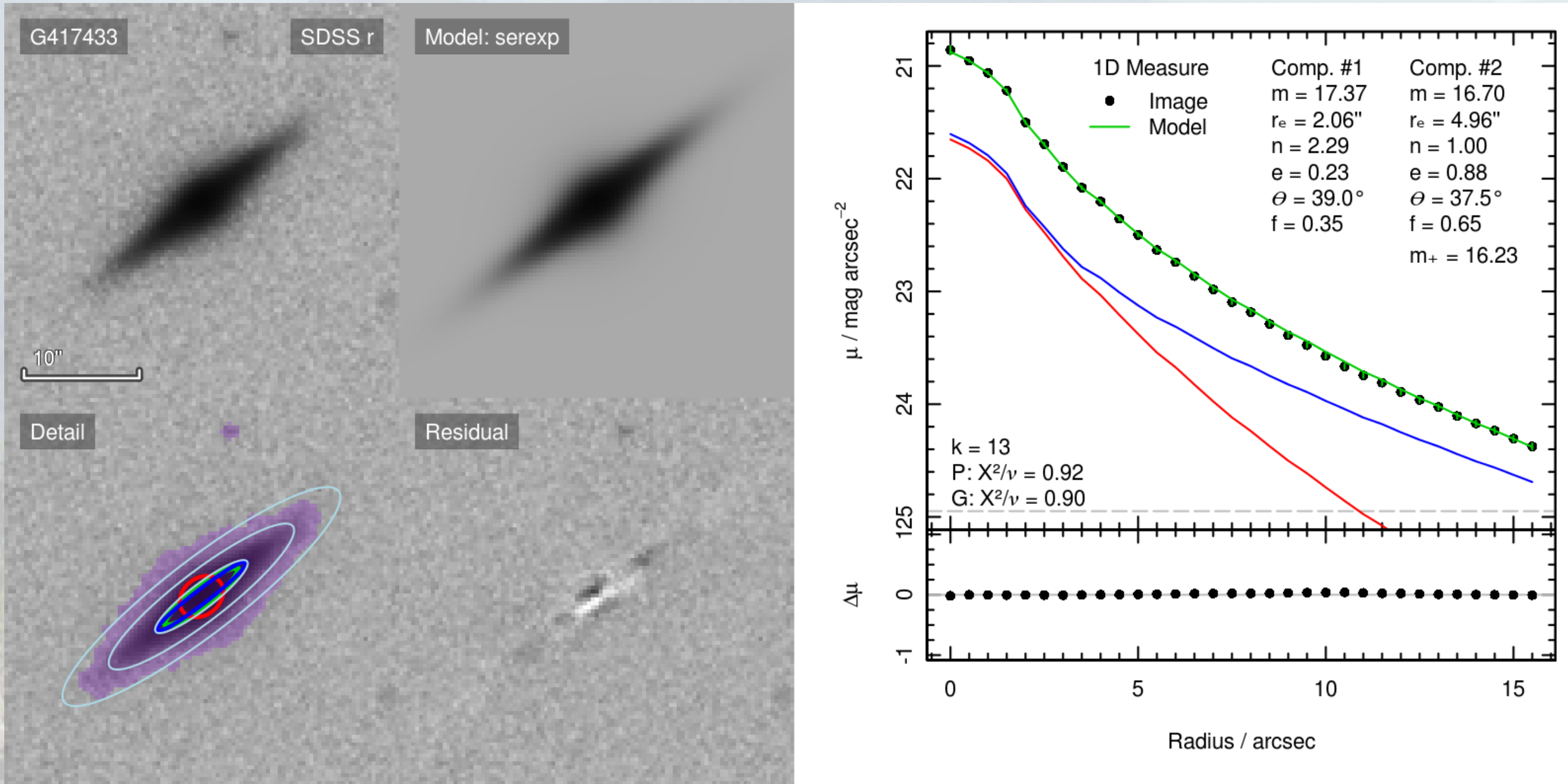
S0a: G417433

M02: De Vaucouleurs bulge + exponential disk



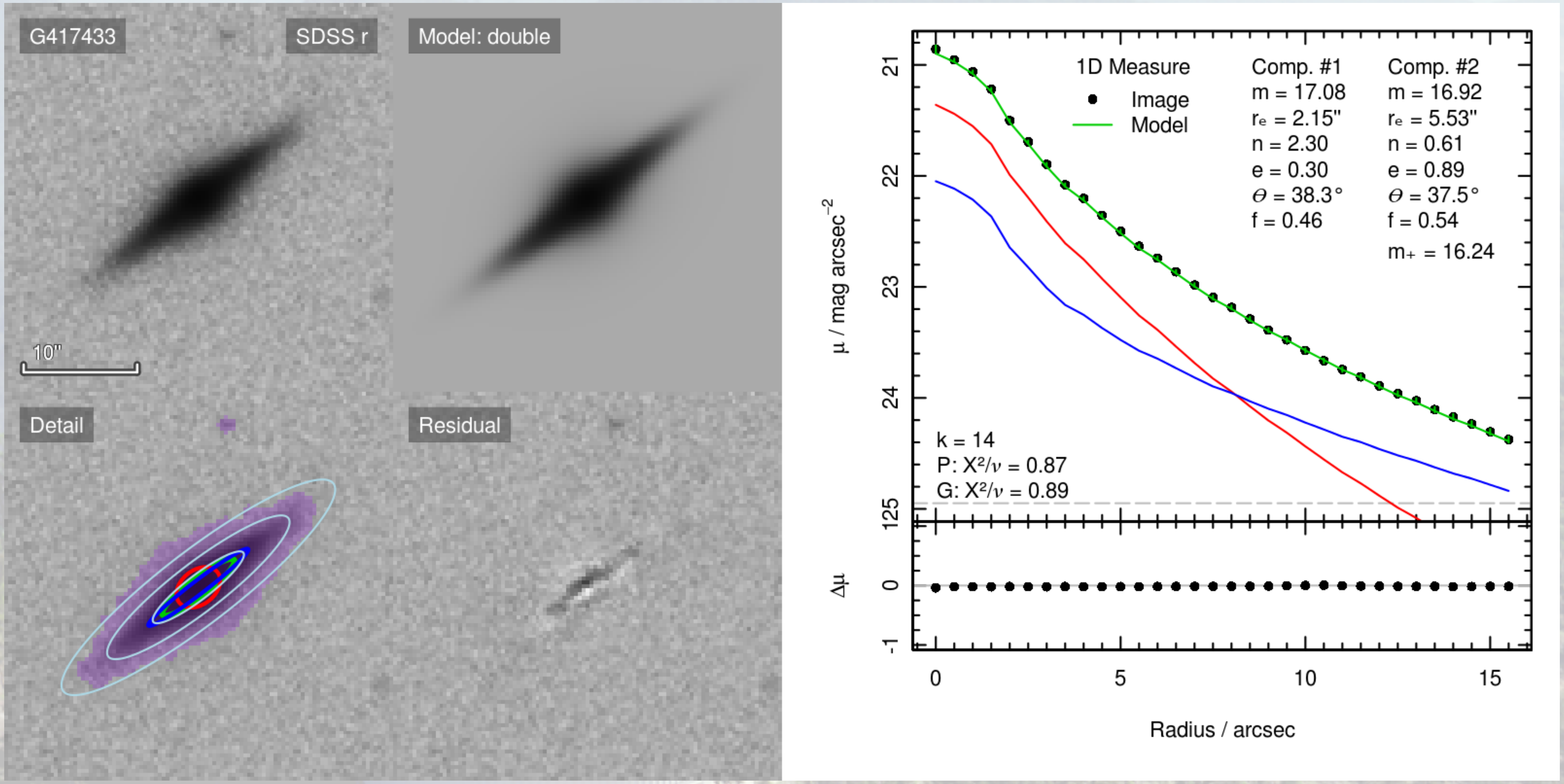
S0a: G417433

M03: Sérsic bulge + exponential disk



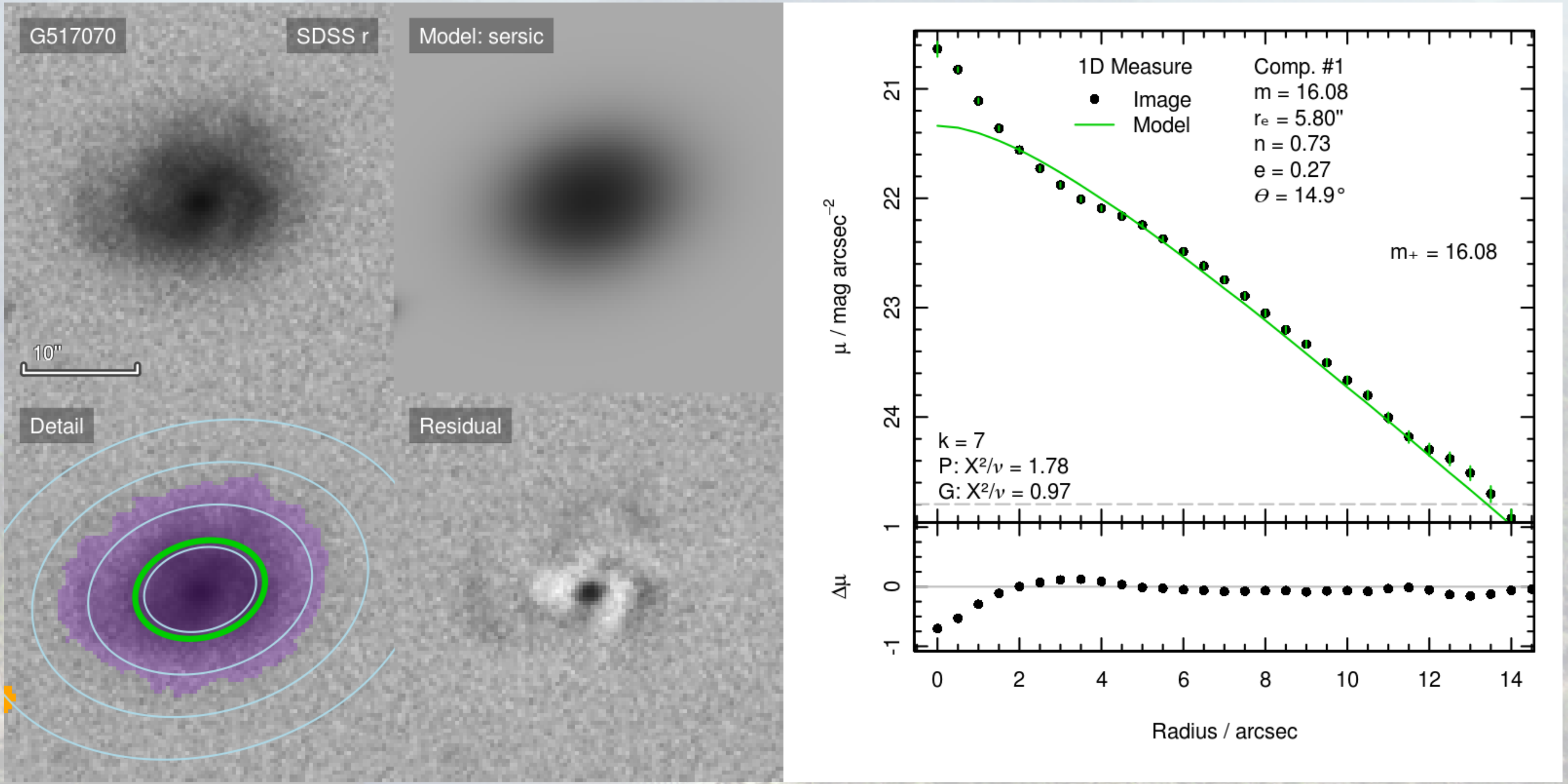
S0a: G417433

M04: Sérsic bulge + Sérsic disk



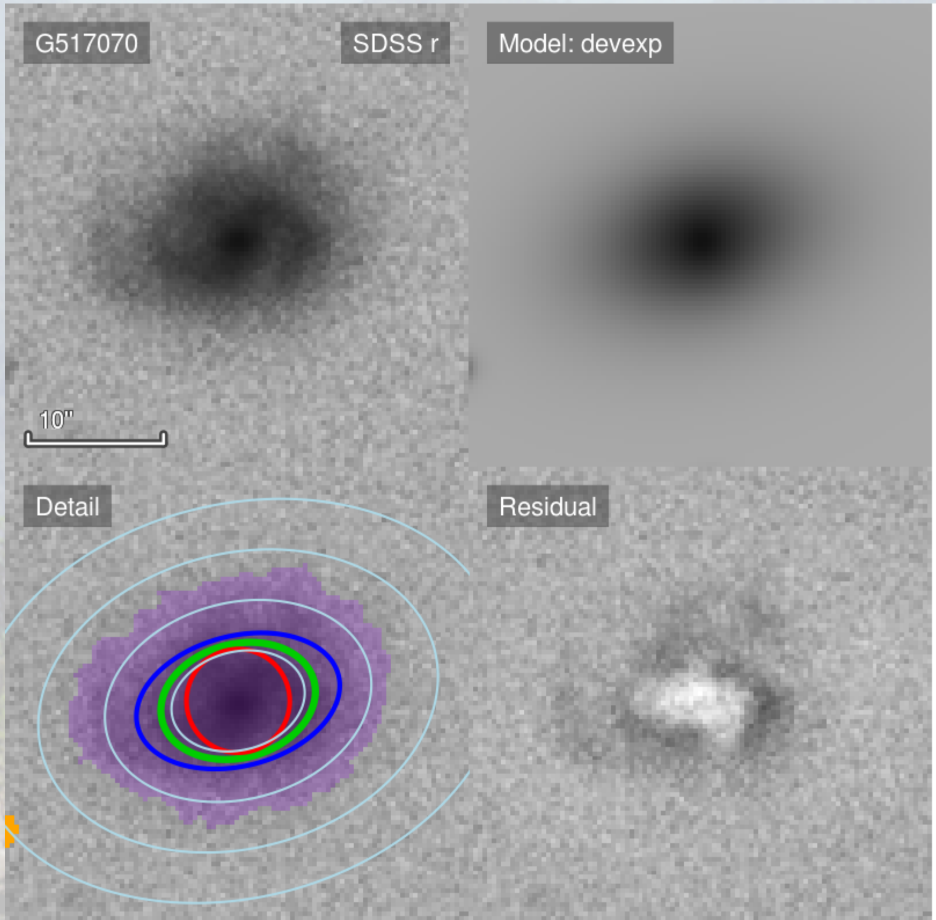
SBbc: G517070

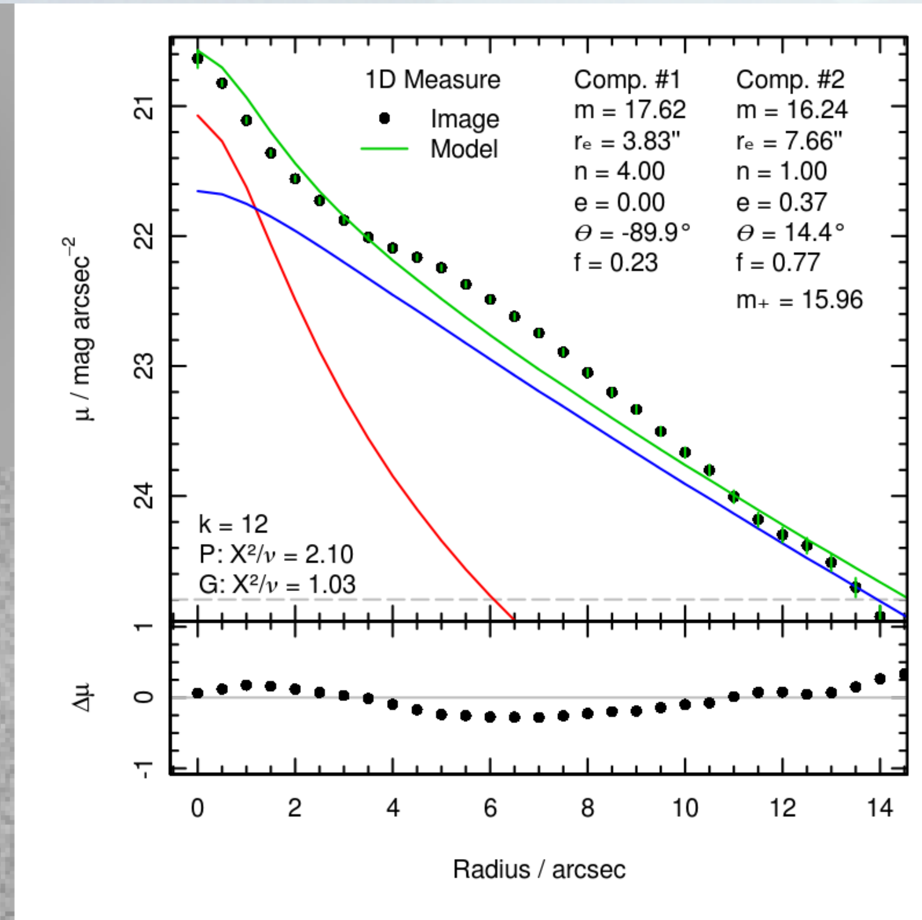
M01: Single-Sérsic



SBbc: G517070

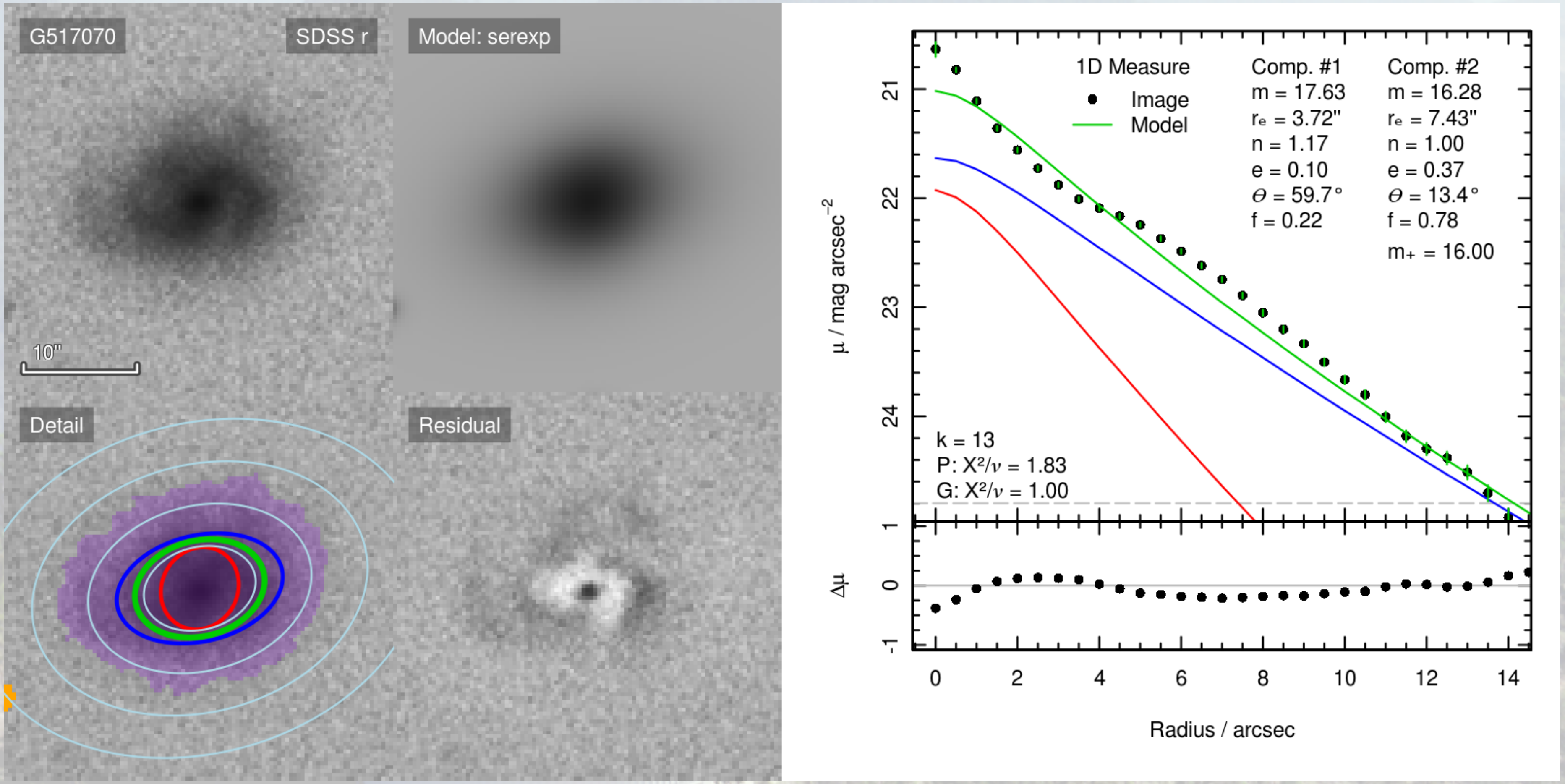
M02: De Vaucouleurs bulge + exponential disk





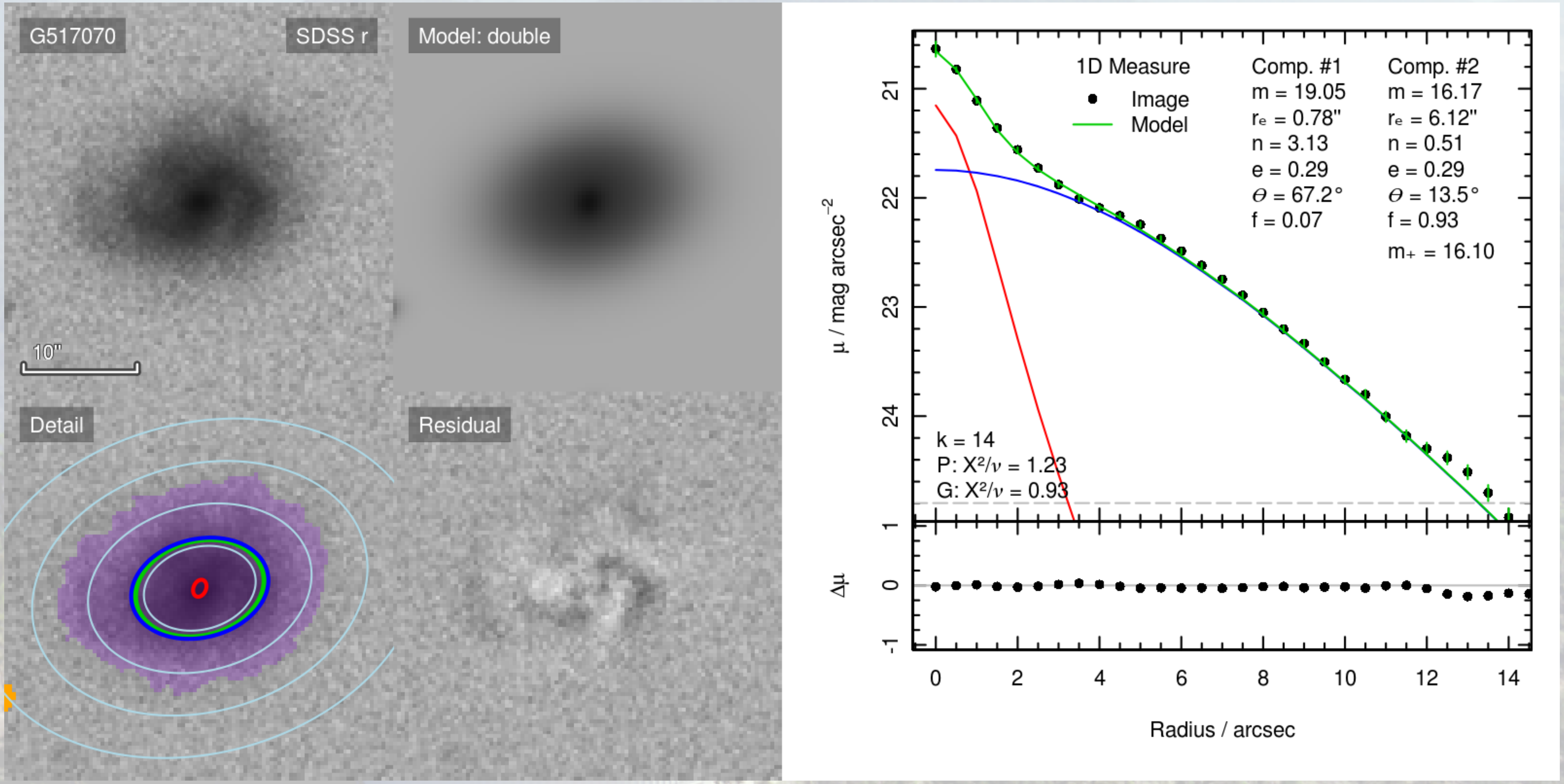
SBbc: G517070

M03: Sérsic bulge + exponential disk



SBbc: G517070

M04: Sérsic bulge + Sérsic disk



Model Choice

How do we select the 'best' model?

Model Choice

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Bayesian Information Criterion:

$$\mathrm{BIC} = \chi^2 + k \cdot \ln(n)$$

x^2	total goodness of fit
k	number of free parameters
n	number of contributing pixels

Model Choice

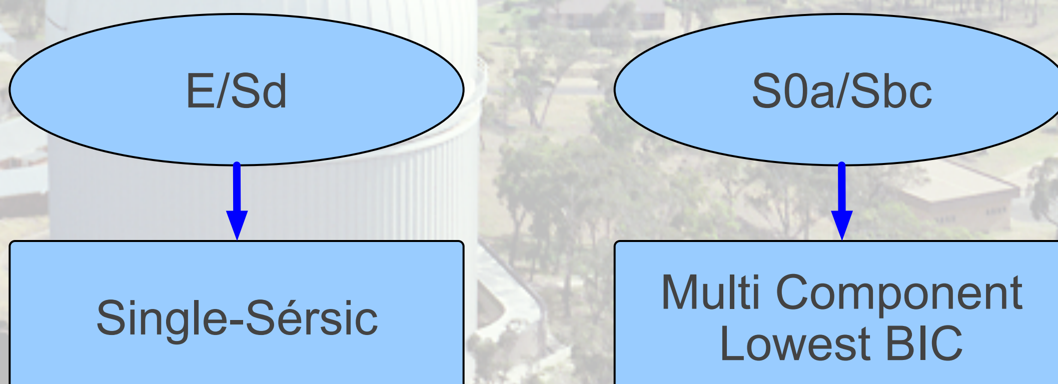
How do we select the 'best' model?

Bayesian Information Criterion:

$$\mathrm{BIC} = \chi^2 + k \cdot \ln(n)$$

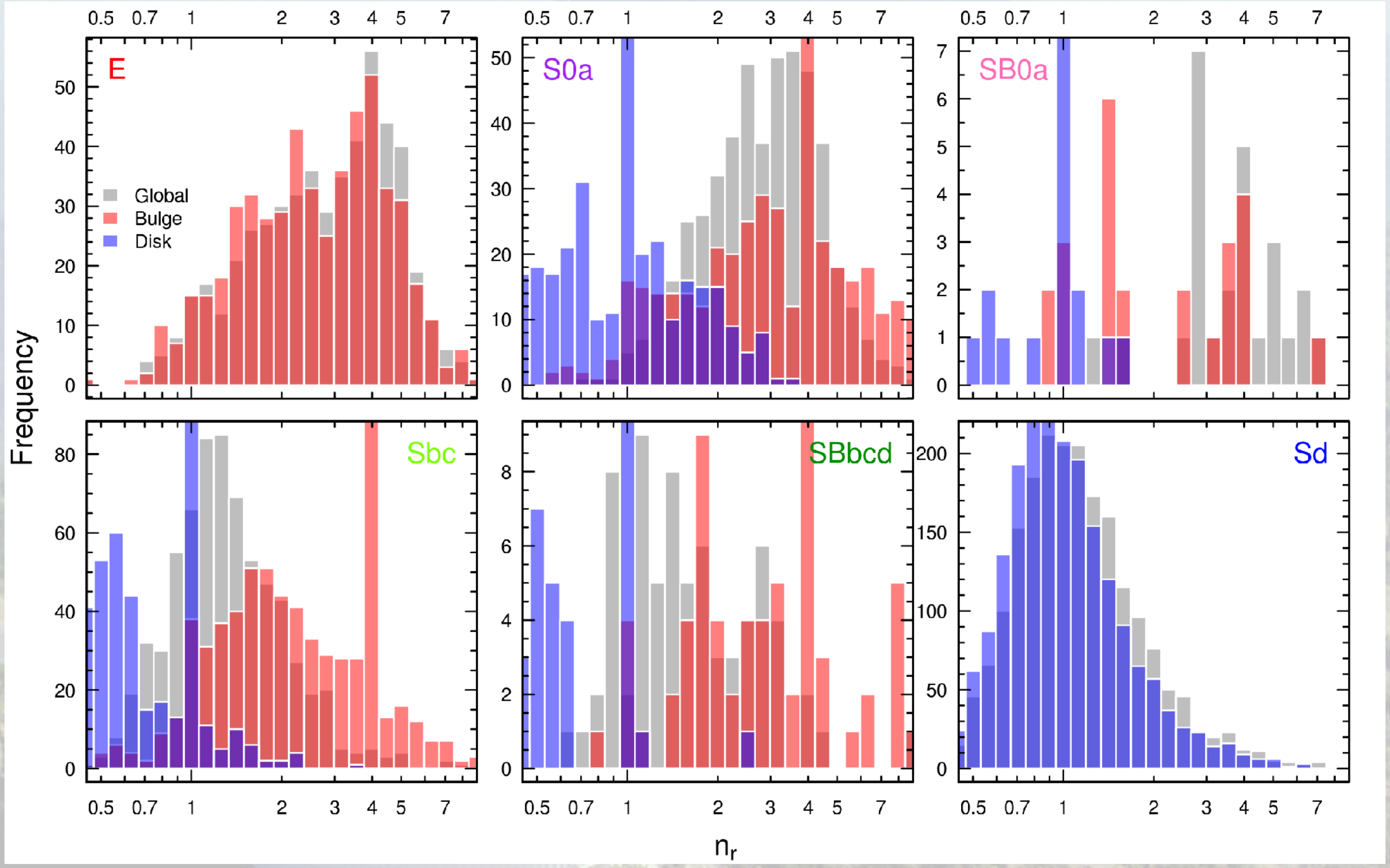
x^2	total goodness of fit
k	number of free parameters
n	number of contributing pixels

Use visual classifications as a guide:



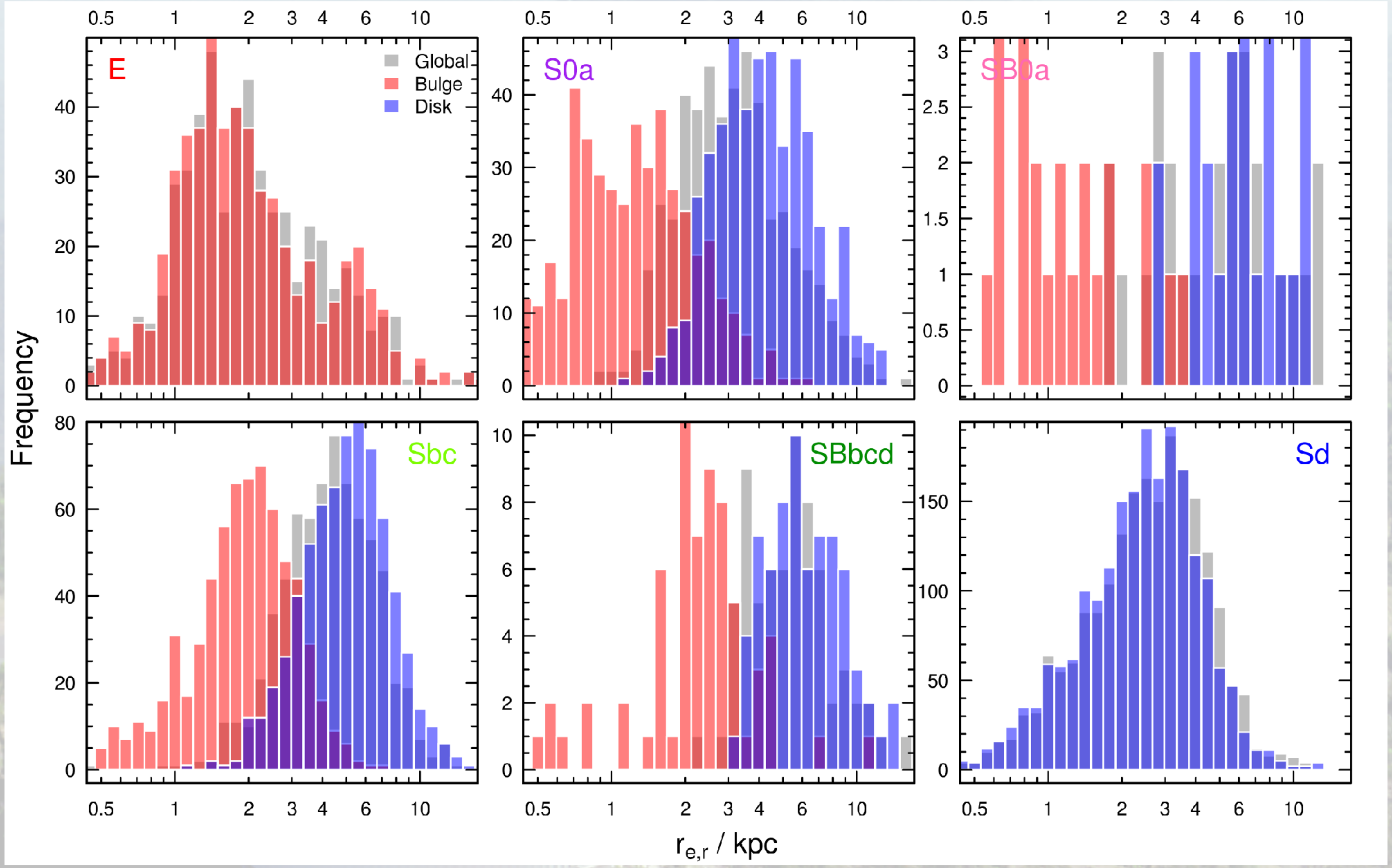
Structural Results

Sérsic Index



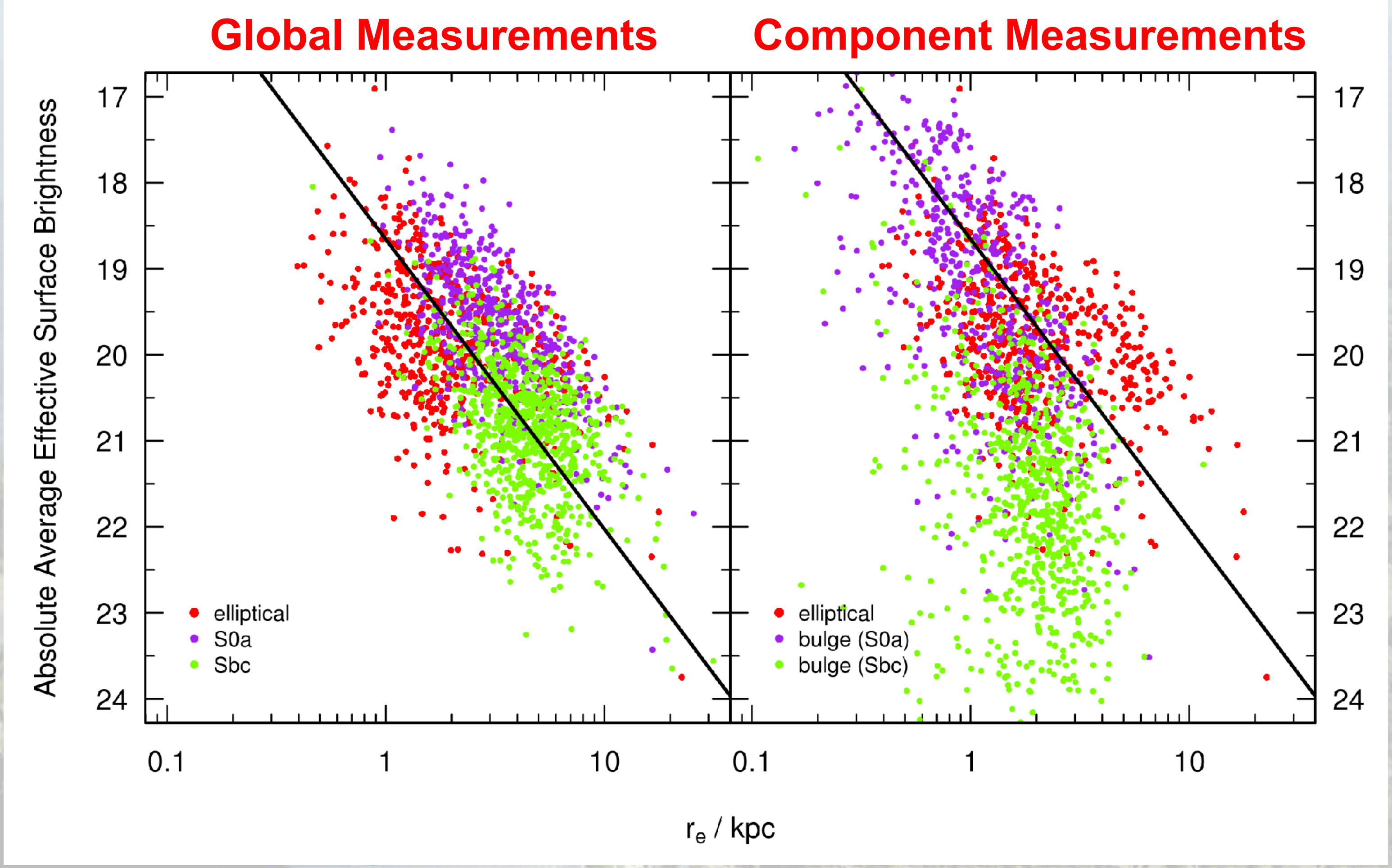
Structural Results

Half-Light Radius



Early/Late Type Bulges

Kormendy Relation



Quick Recap

3945 galaxies: $0.025 < z < 0.06$; $\log_{10}M > 8.537$

Morphological Classification

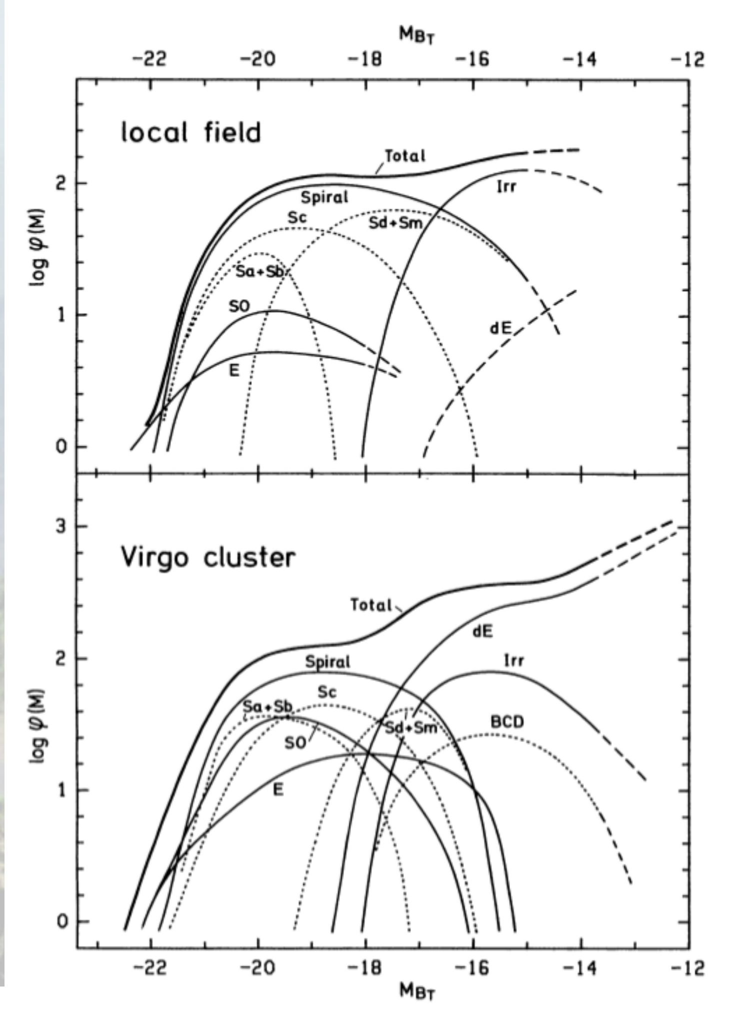
Elliptical
S0a
Sbc
Sd

Bulge-Disk Decomposition

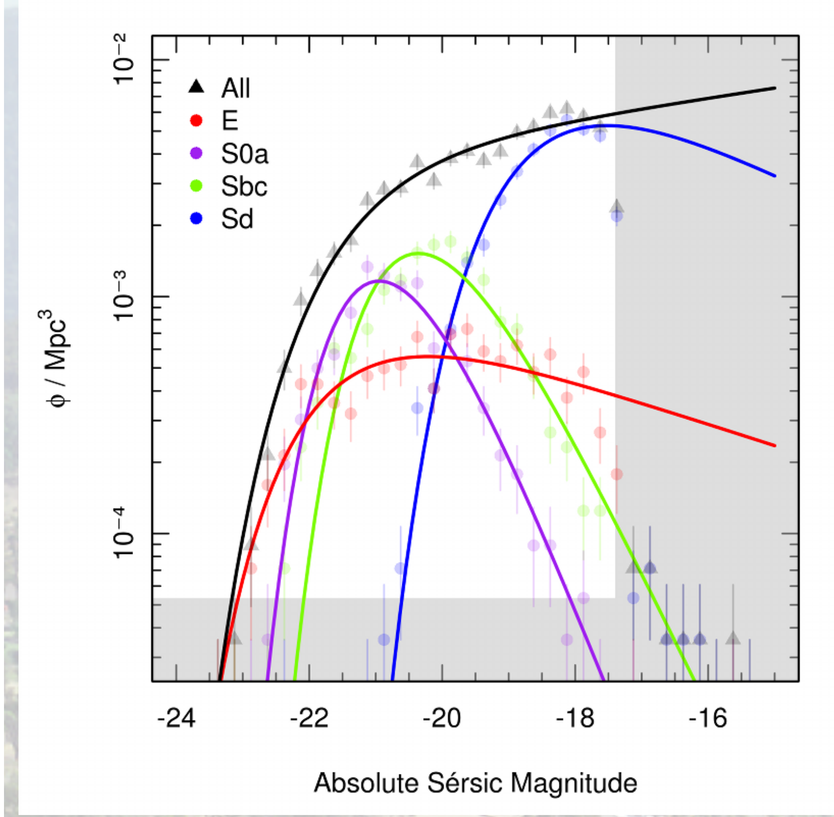
Elliptical
Classical Bulge
Pseudo-Bulge
Disk

redshifts, stellar masses, aperture-matched photometry, photometric corrections, sturctural information (size, inclination, position angle), environmental measures and group information

Sérsic Luminosity Functions

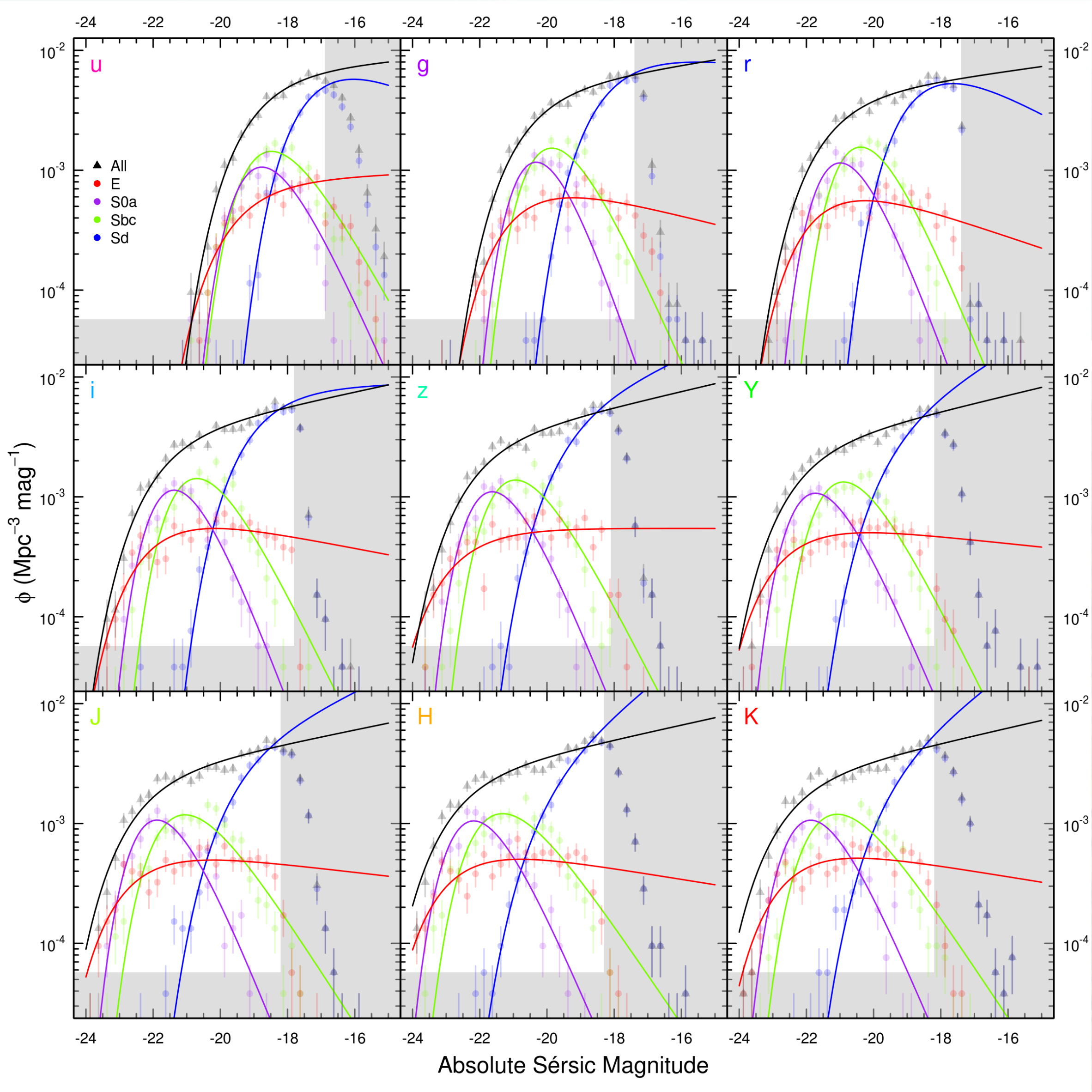


Binggeli et al., 1988



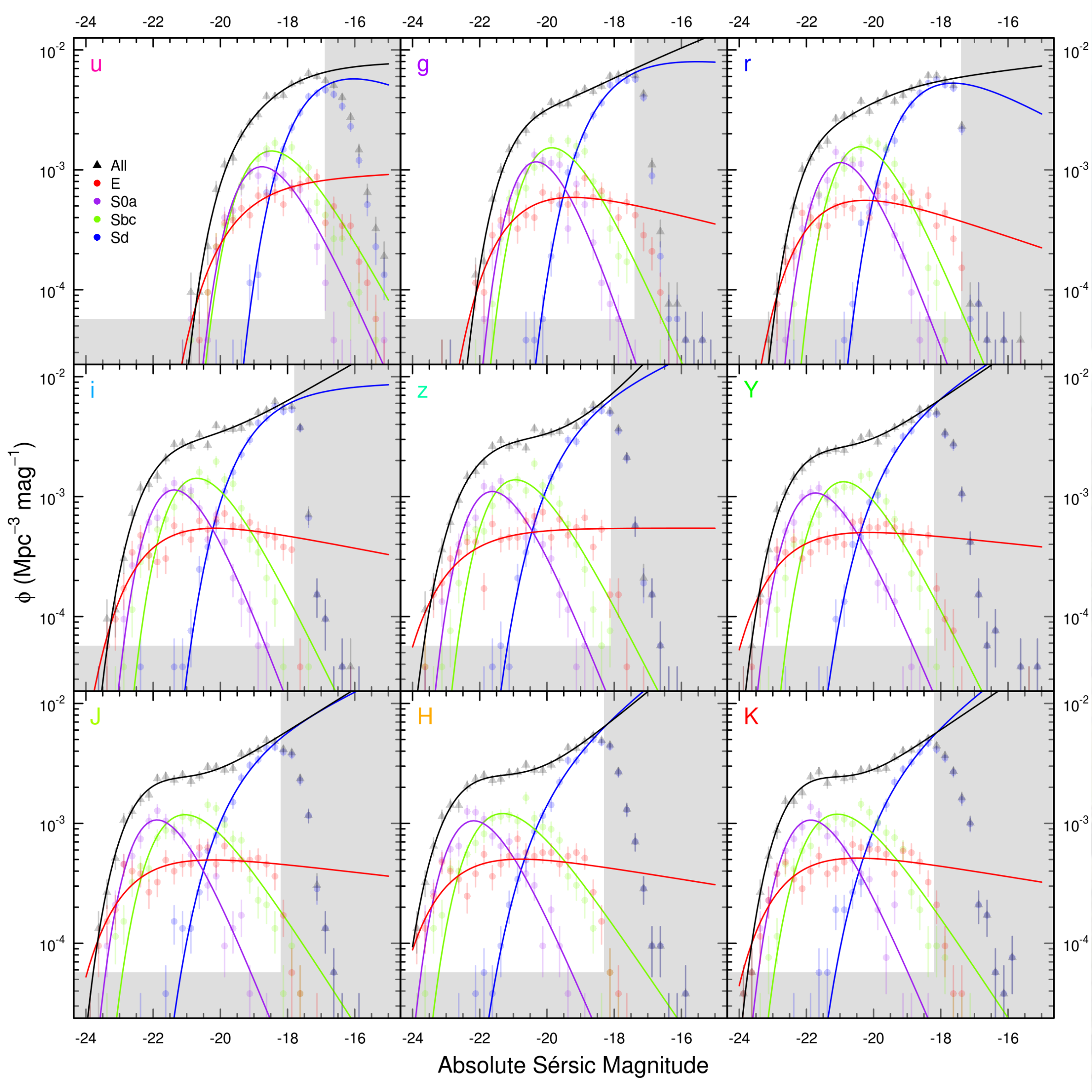
$$\phi(L)\,\mathrm{d}L = \phi^{*}\left(\frac{L}{L^{*}}\right)^{\alpha} \exp\left(-\frac{L}{L^{*}}\right) \mathrm{d}\left(\frac{L}{L^{*}}\right)$$

Sérsic Luminosity Functions



Single-Schechter

Sérsic Luminosity Functions

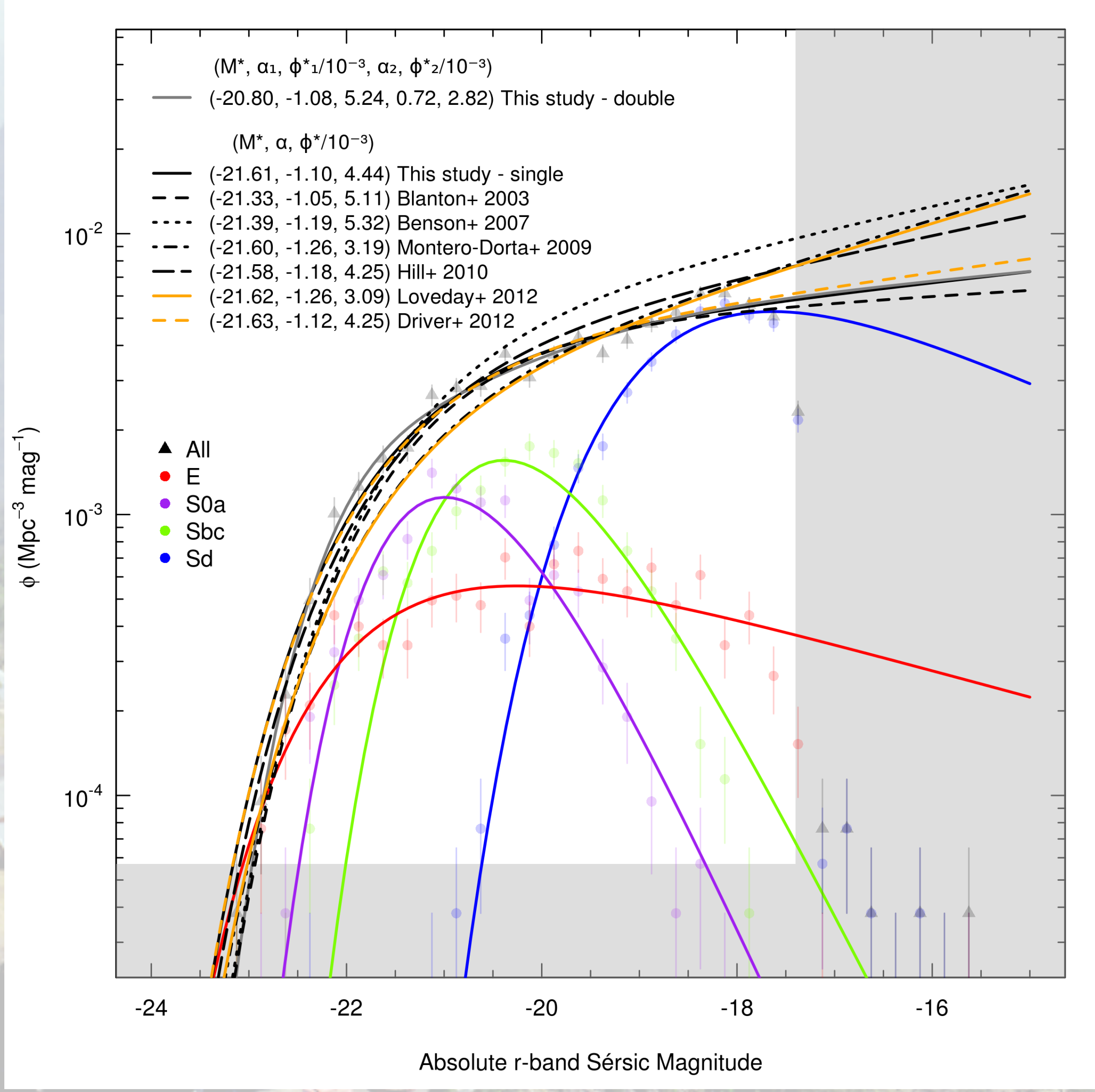


Double-Schechter

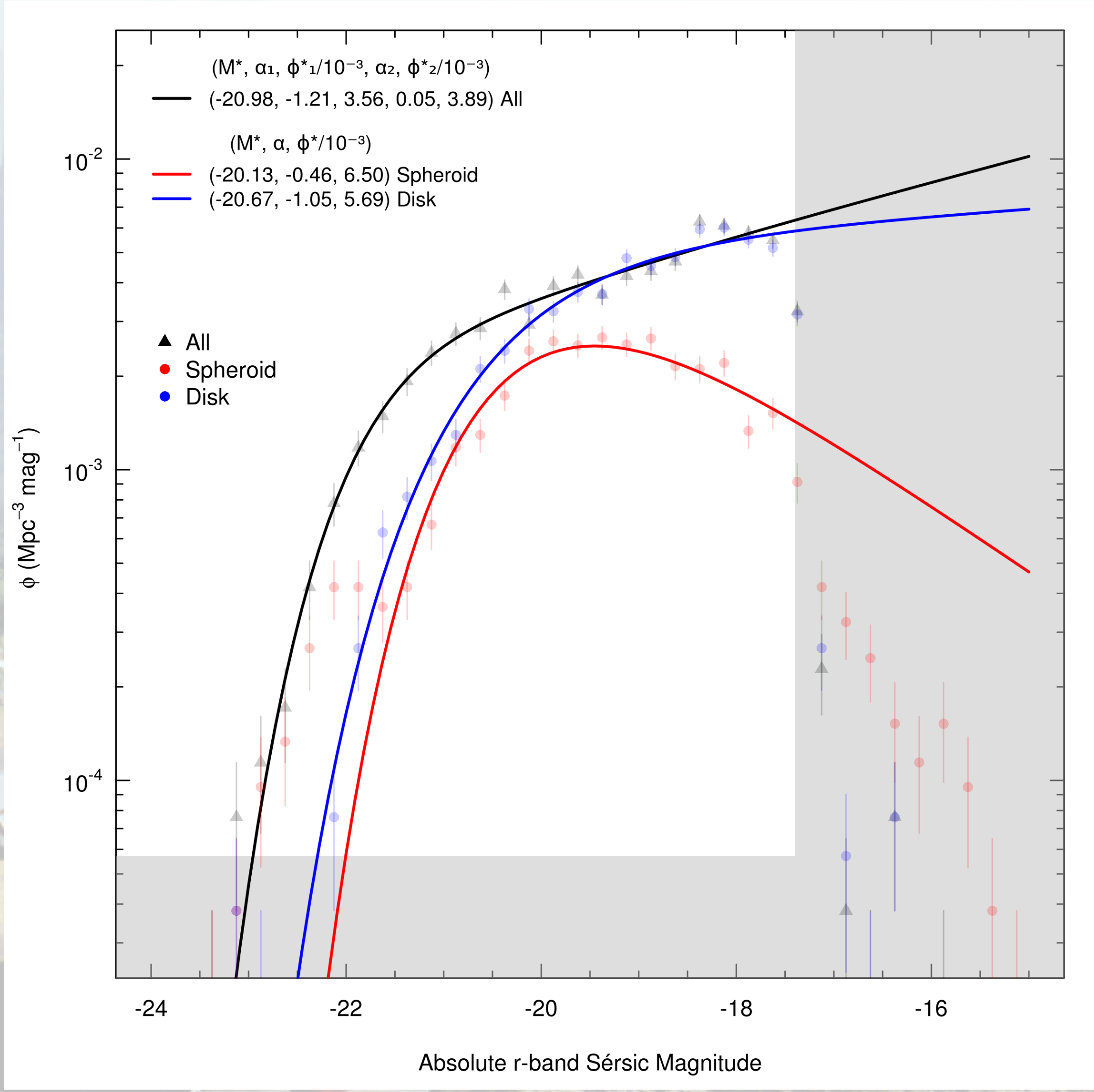
Test, e.g.: quenching of SF in galaxies

(Baldry et al., 2012)

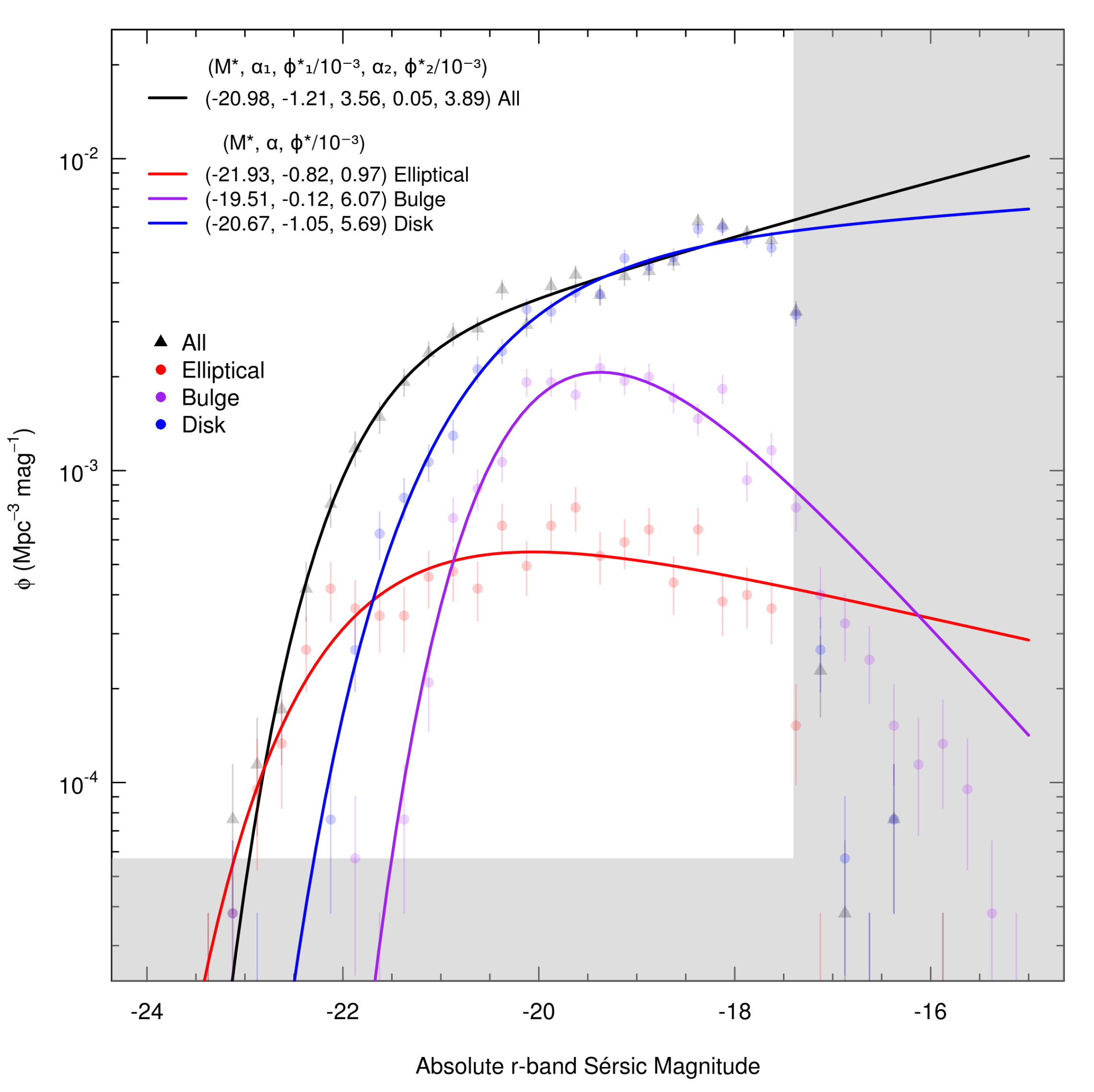
Sérsic Luminosity Functions



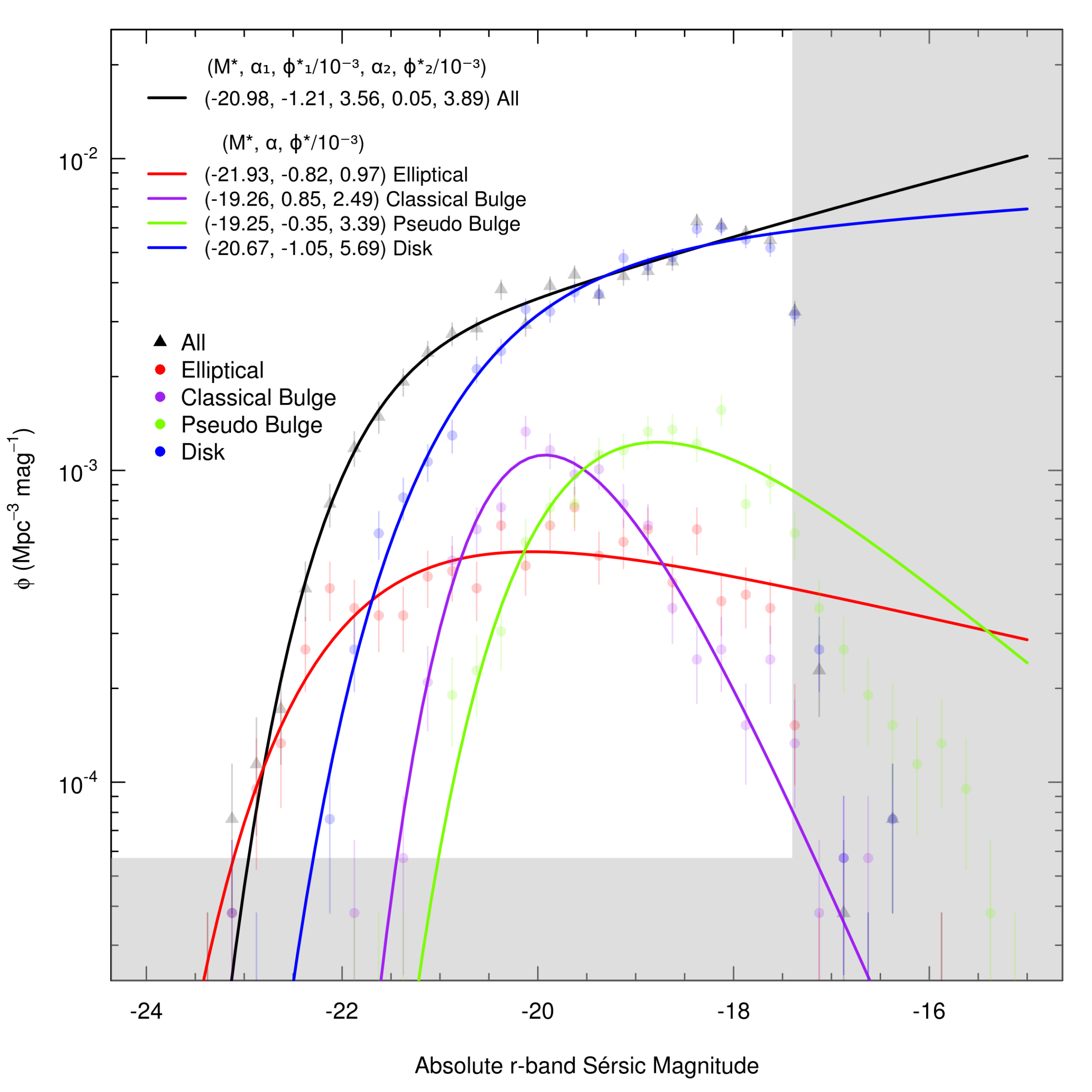
Sérsic LF by Structure



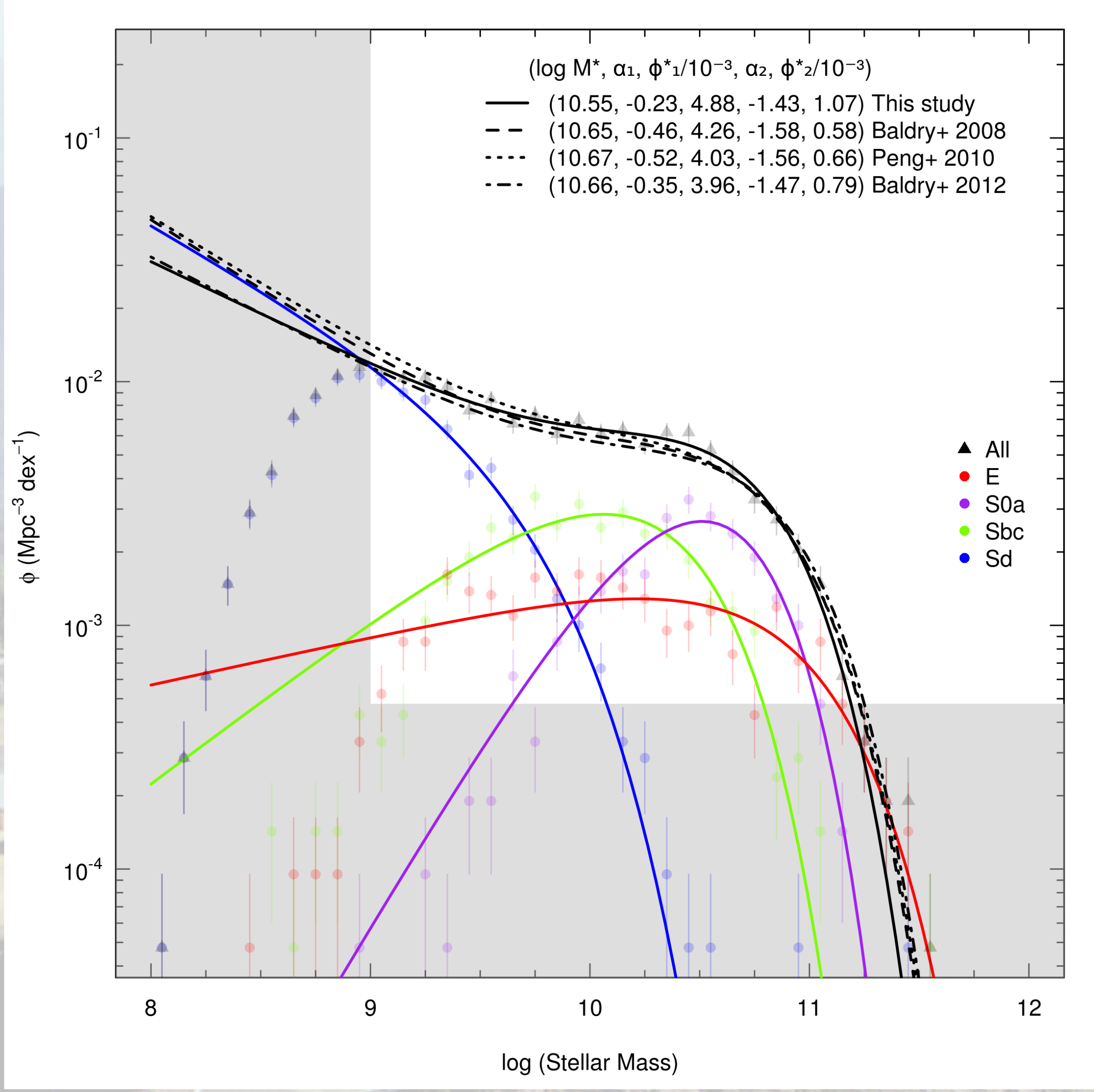
Sérsic LF by Structure



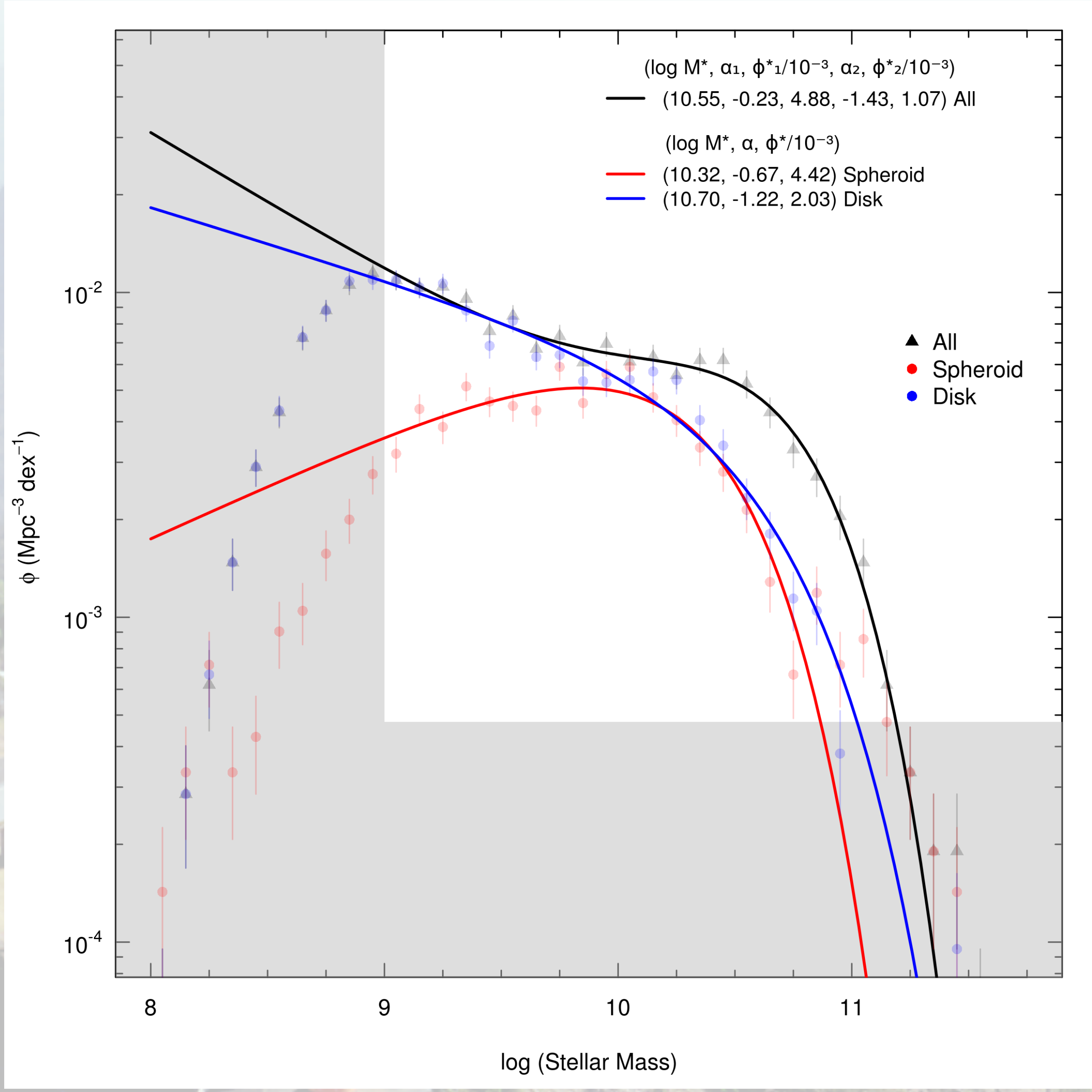
Sérsic LF by Structure



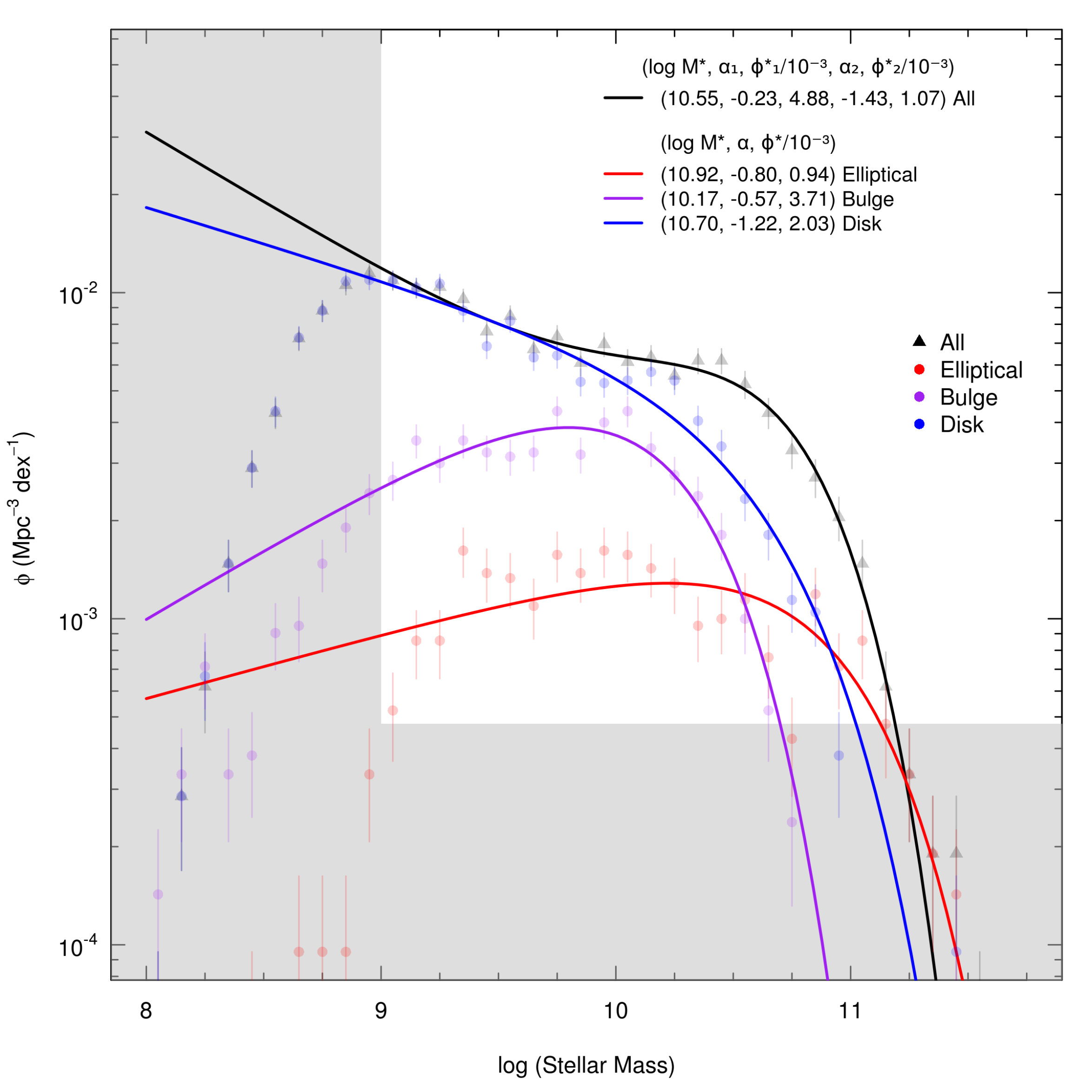
Morphology Mass Function



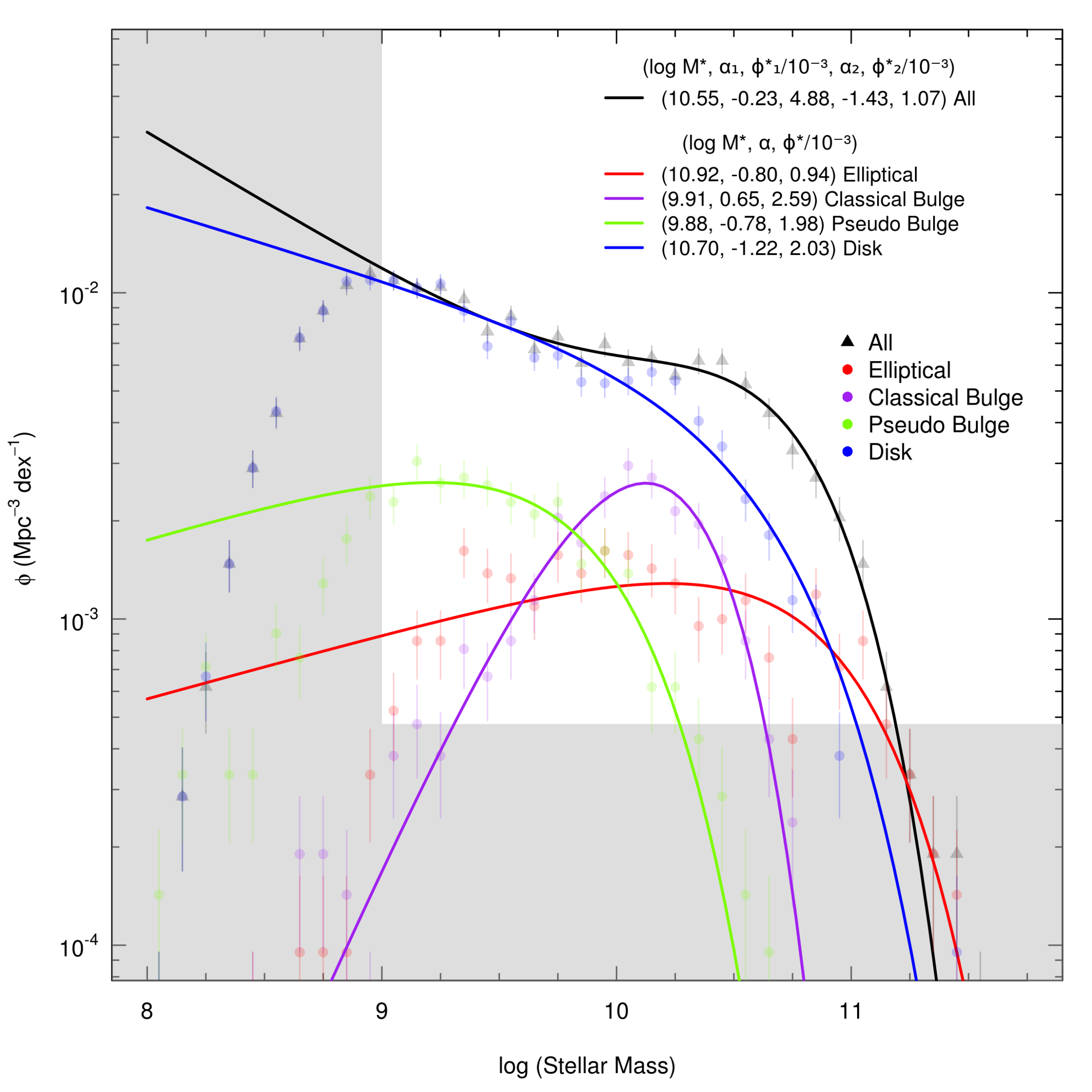
Structural Mass Function



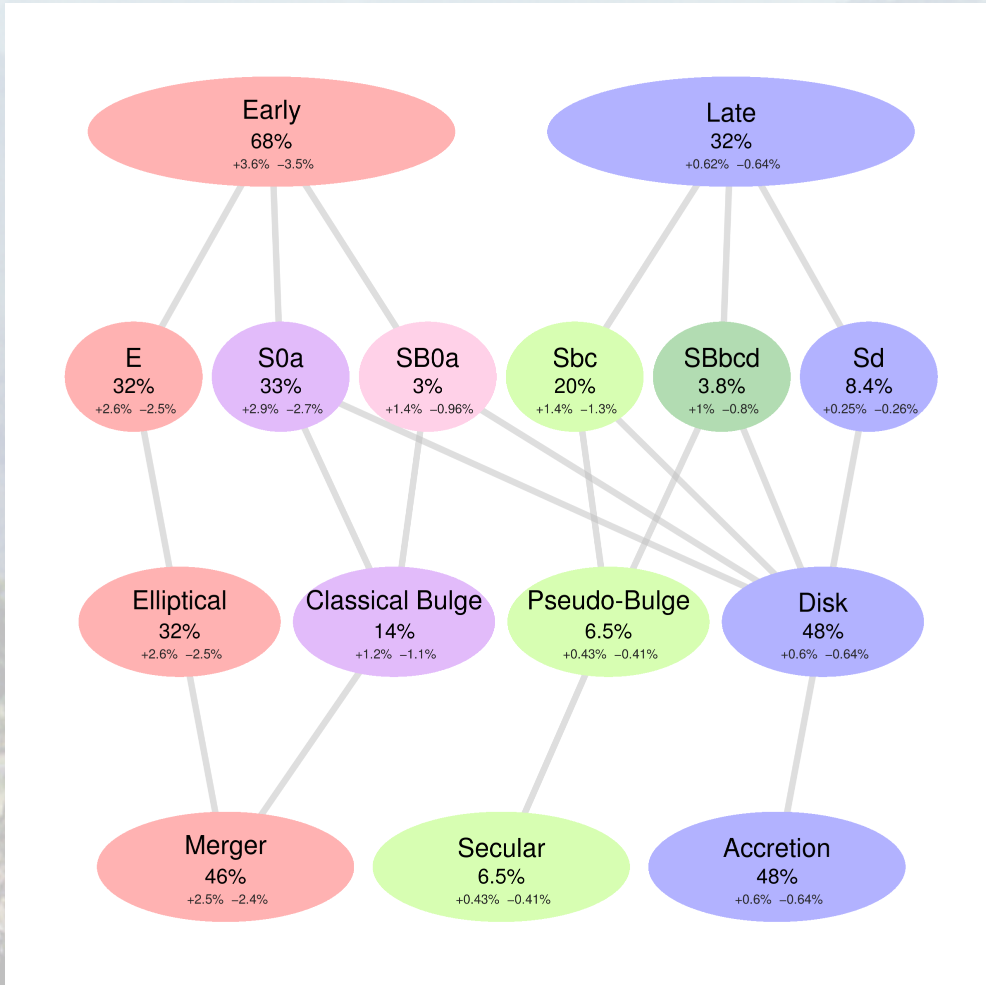
Structural Mass Function



Structural Mass Function



Stellar Mass Breakdown



Mass in the local Universe:

Hierarchical merging ~45.8%
Gas accretion ~47.7%
Secular evolution ~6.5%

Stellar Mass Breakdown

Mass in the local Universe:

Hierarchical merging	~45.8%
Gas accretion	~47.7%
Secular evolution	~6.5%

Summary

Automated, fast and robust structural decomposition is essential in order to model increasingly large galaxy datasets to a high level of accuracy.

NIR wavelengths are preferred, as they avoid the effects of dust attenuation and hence are able to 'see' more of the galaxy (but multi-λ cannot be ignored).

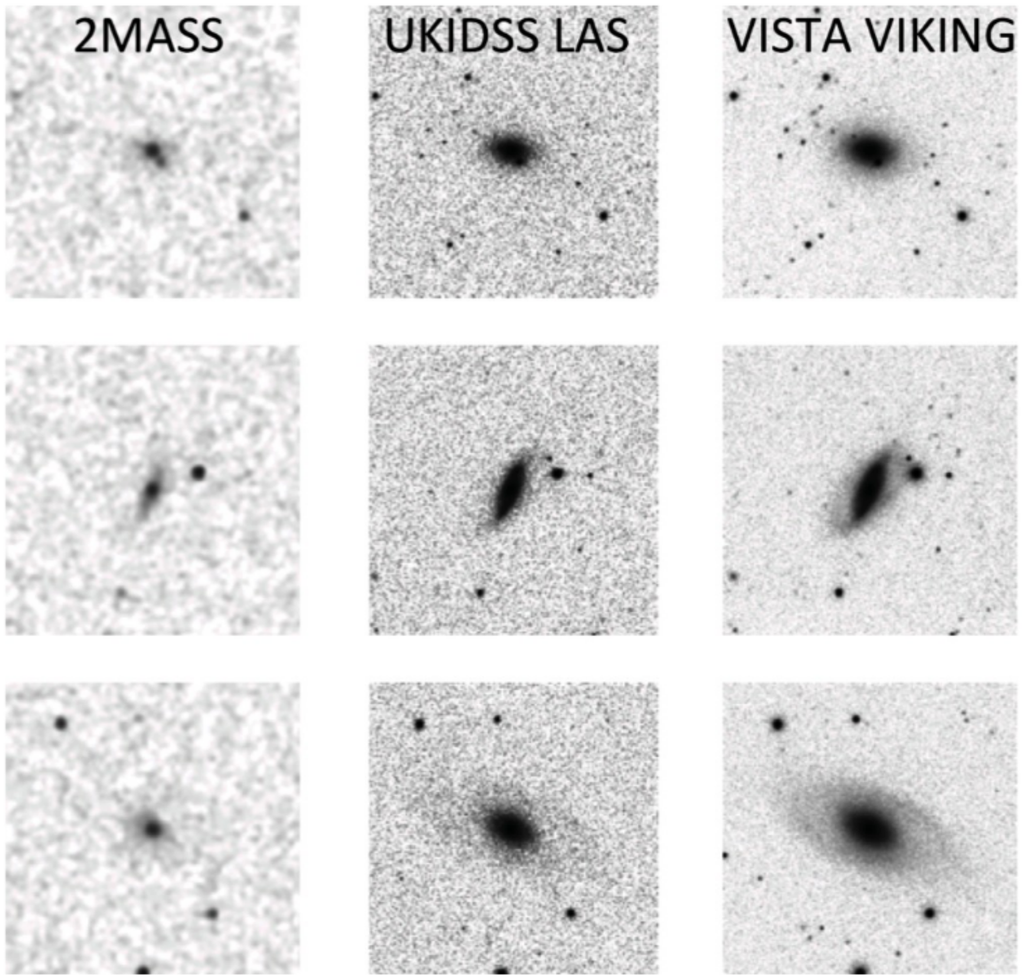
Early-type bulges are well described by the Kormendy relation, whereas late-type bulges do not follow this relation
→ early-type bulges ~ classical bulge, late-type bulges ~ pseudo-bulge

The evolutionary processes of monolithic collapse/merging and gas accretion contribute roughly equal measures of stellar mass in the local universe.

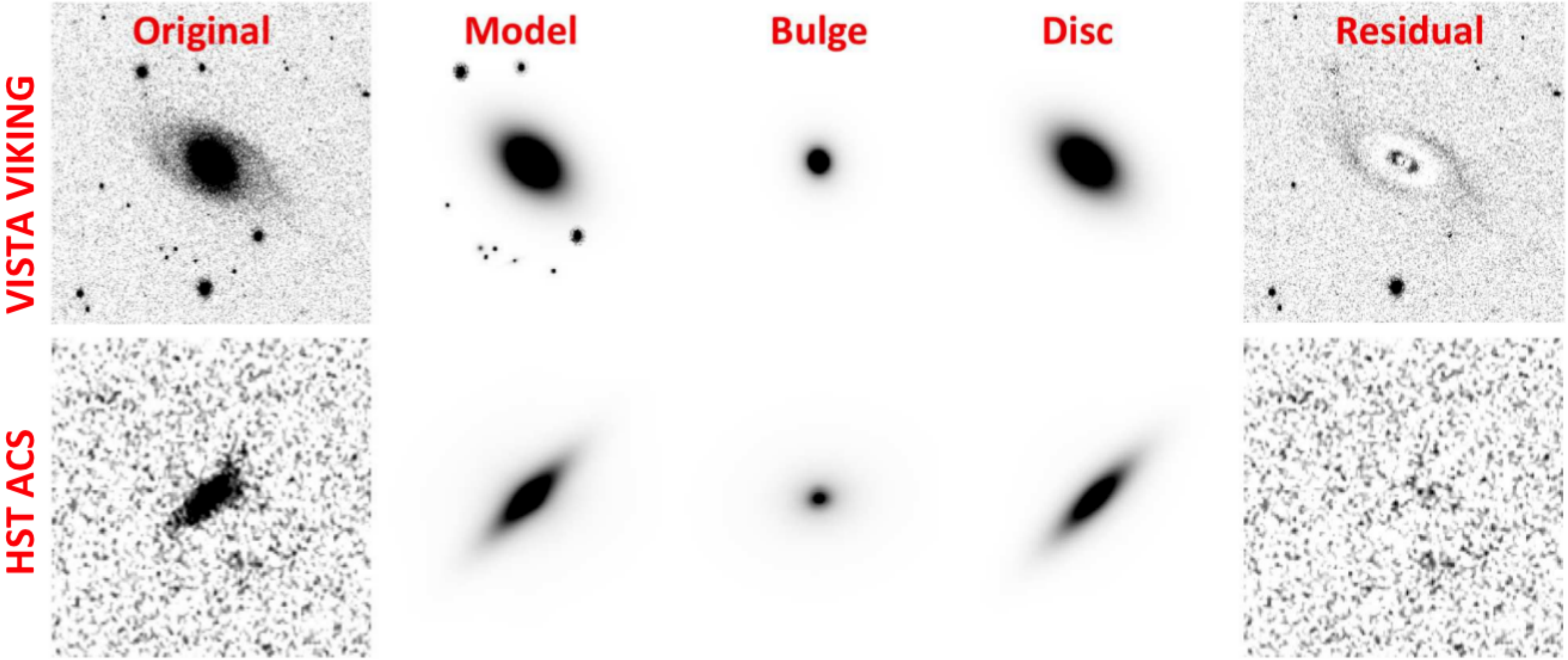
Secular evolutionary processes contribute ~6.5% of the total stellar mass at $z < 0.06$ through the creation of pseudo-bulges.

2MASS - UKIDSS - VIKING

Significant improvements in structural measurements when moving from **previous-generation** to **current-generation** to **next-generation** survey data

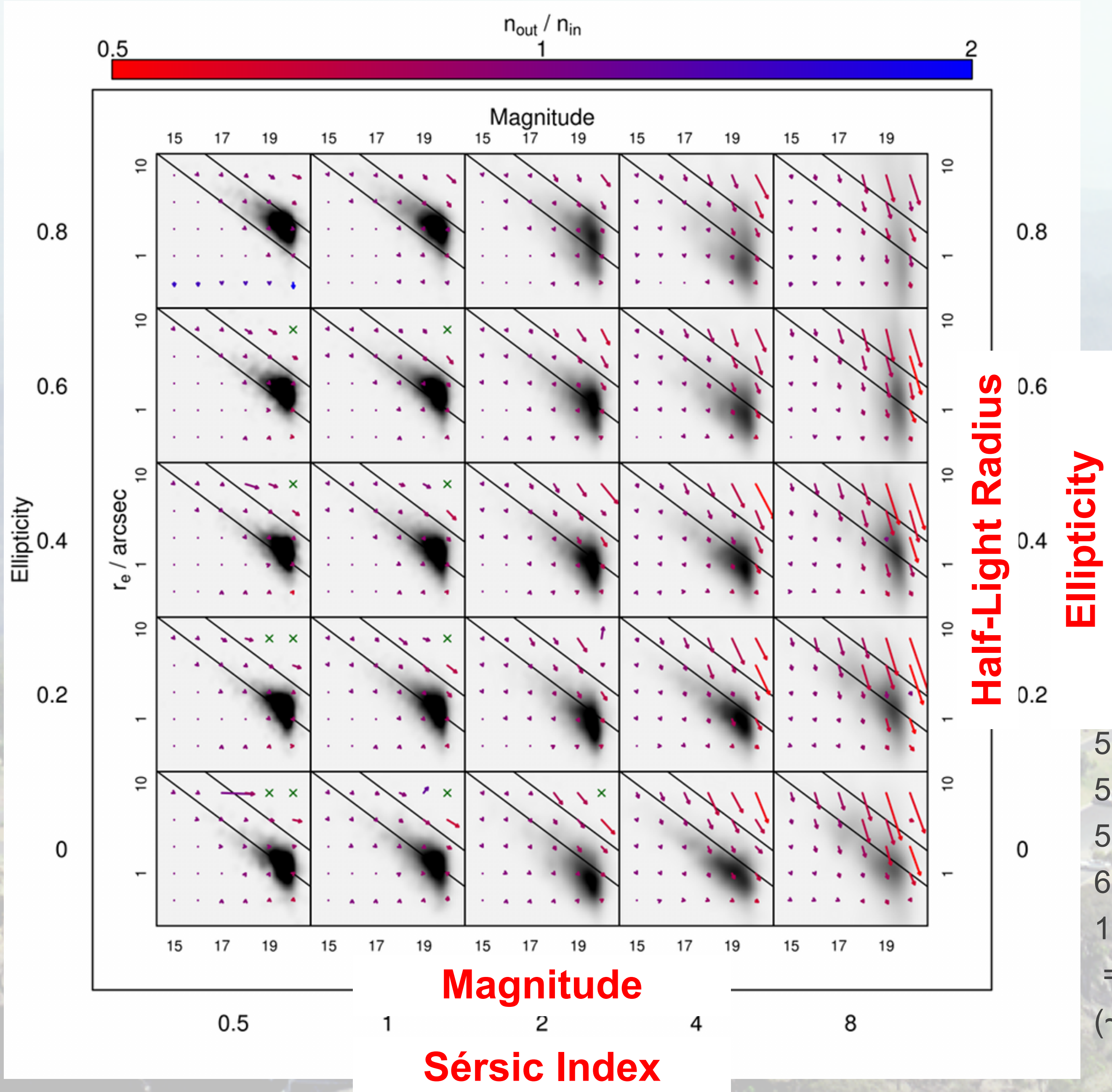


High-Redshift Modelling



Bulge-Disk decomposition essential for a full understanding of galaxy structure and mass breakdown

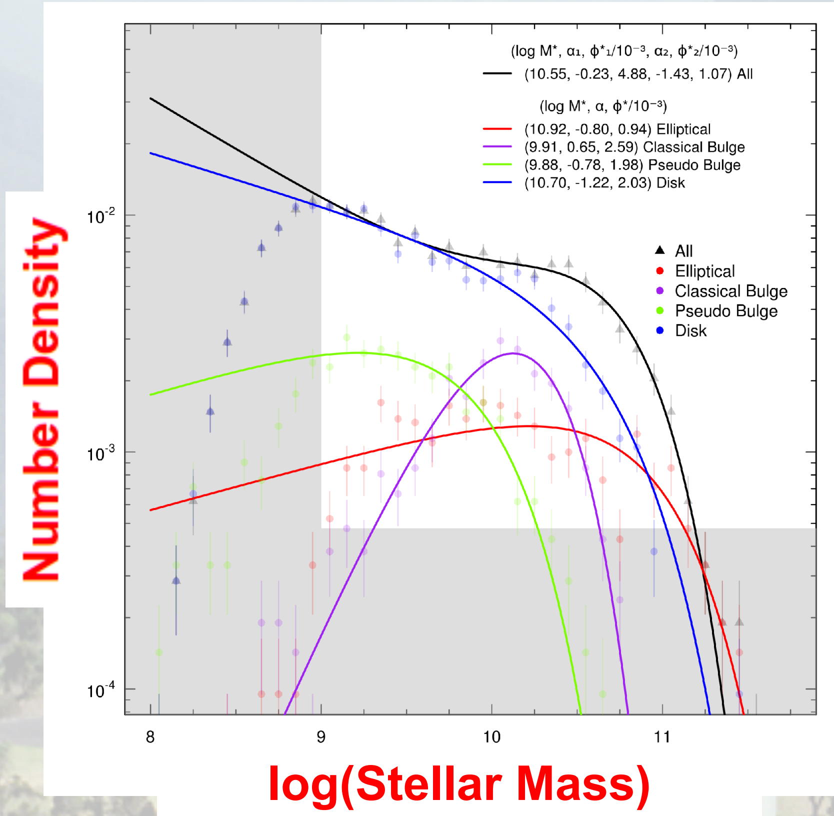
Does SIGMA work?

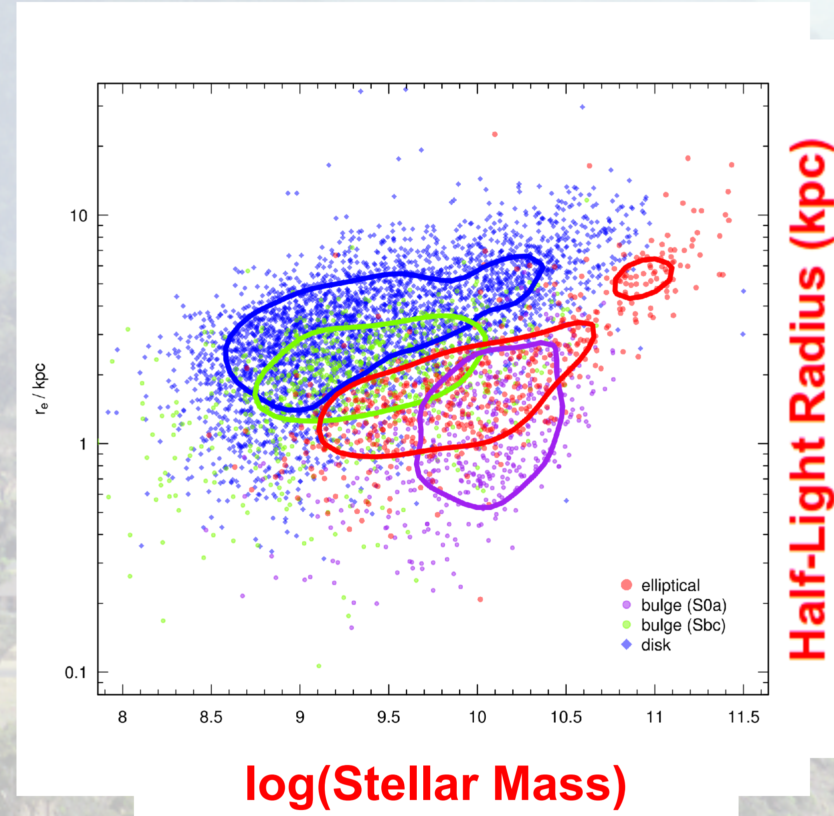


5 × Sérsic index
5 × Half-light rad
5 × Ellipticity
6 × Magnitude
100 × iterations
= 75,000 models
(~24h; 16 procs)

Component Mass

Stellar Masses: Taylor 2011+





Ellipticals dominate at high-mass, disks at low-mass

Late-type bulges share more in common with disks than early-type bulges