Galactic Girths:
(an attempt at)
a technical review

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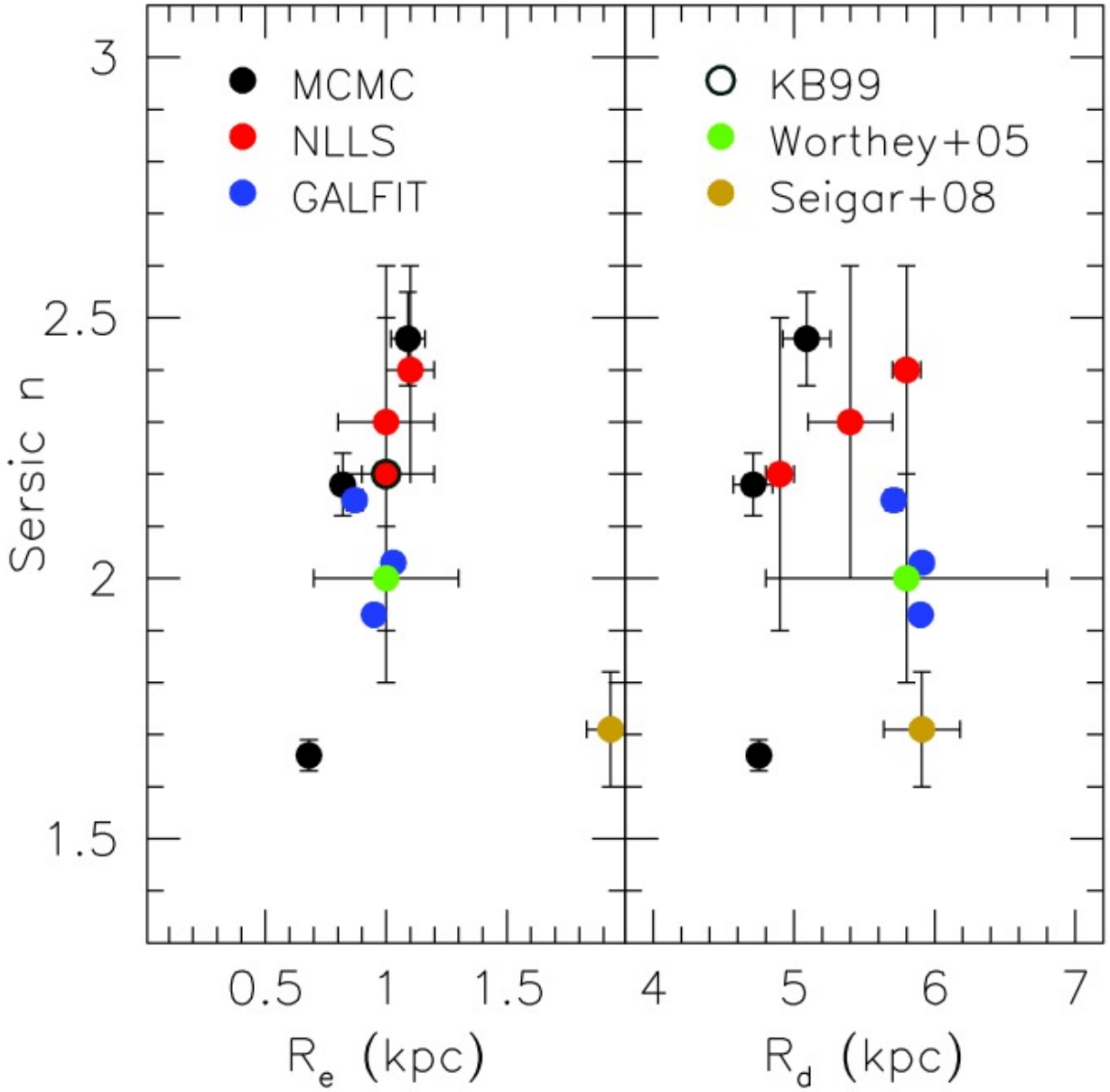
Remit

- Focus on sizes, but they aren't everything
- Fairly poor resolution and S/N
- Statistical studies, large samples

  - Measuring galaxy sizes
  - Sérsic complications
  - Separating by galaxy type
  - Beyond single-Sérsic fits
  - Multi-wavelength structure
  - Disastrous dust

Systematics-limited

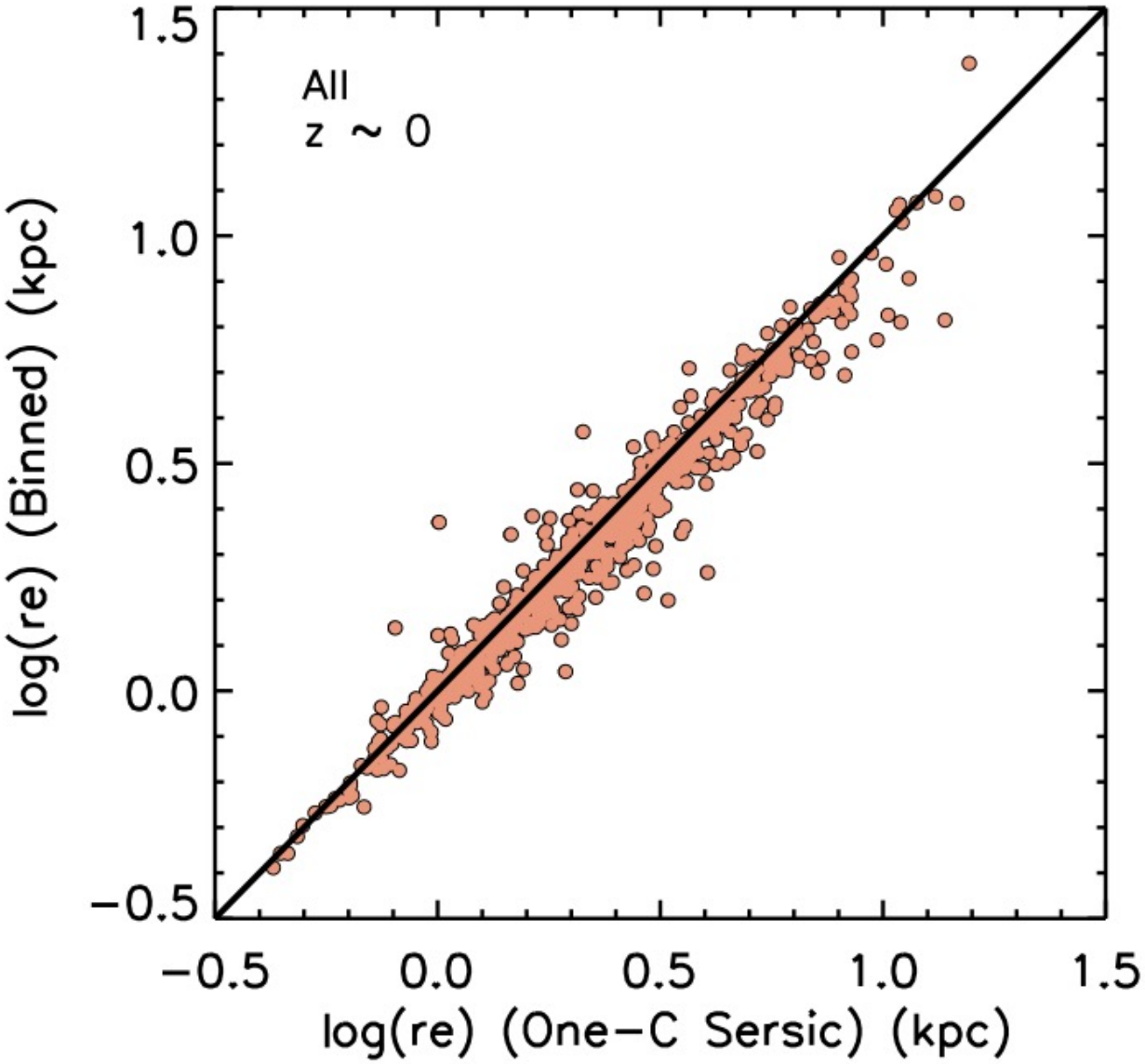
Courteau+2011:
"Nominal errors for the structural parameters of the M31 bulge, disk, and halo amount to 20%"



Can you have too much detail?

It seems to take more work to get a "meaningful" fit with high-quality data.

Is fitting simple models to low-quality data reducing random uncertainties at expense of increasing systematics?



Mosleh+13

What is a galaxy's size?

- Galaxy profiles are generally very peaky, but decline smoothly into the sky
- Tricky to define a size
  - isophotal, Petrosian/Kron, scalelength,…

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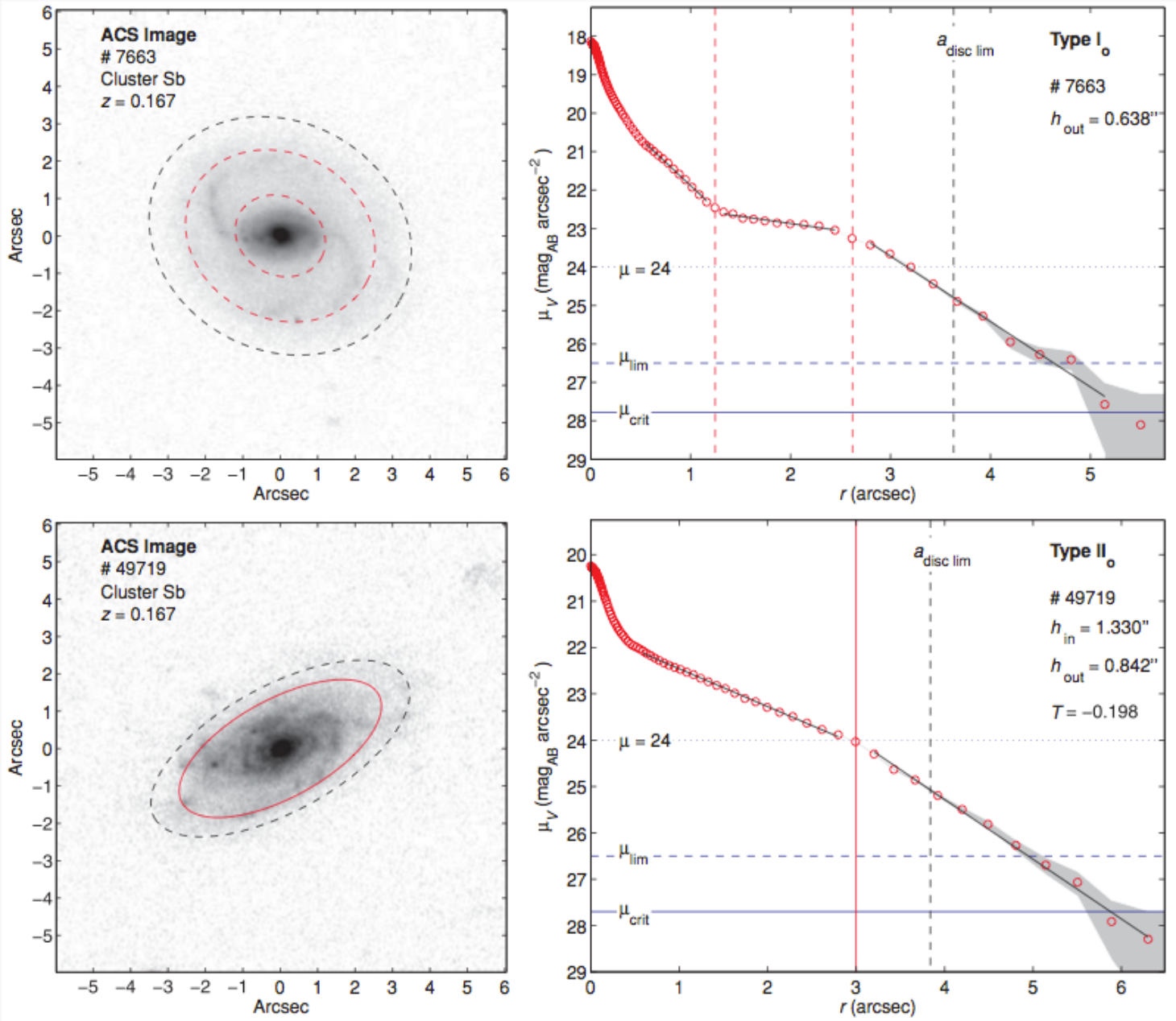
- Truncation


ACS Image
7663
Cluster Sb
z = 0.167
Arcsec
Arcsec
a disc lim
Type I o
7663
h out = 0.638"
μ = 24
μ lim
μ crit
μV (mag AB arcsec−2)
r (arcsec)
ACS Image
49719
Cluster Sb
z = 0.167
Arcsec
Arcsec
a disc lim
Type II o
49719
h in = 1.330"
h out = 0.842"
T = −0.198
μ = 24
μ lim
μ crit
μV (mag AB arcsec−2)
r (arcsec)

Maltby+12

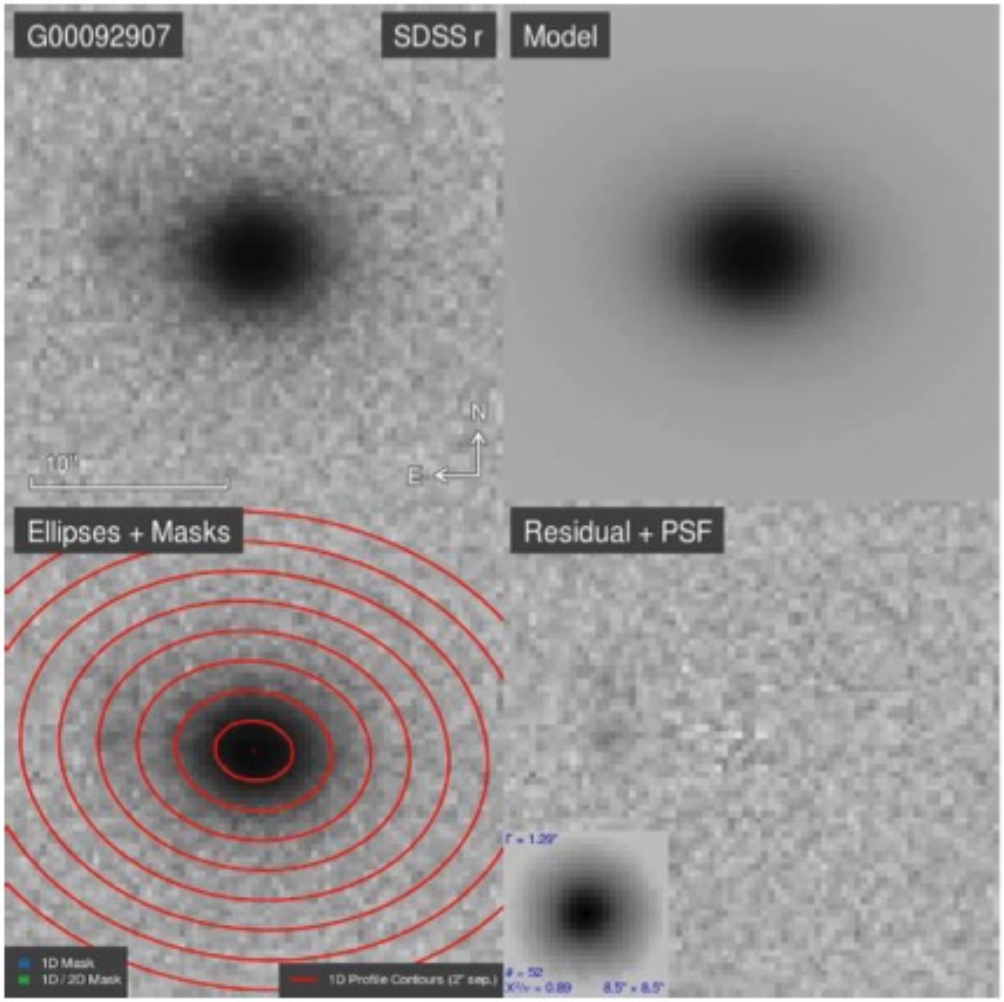
What is a galaxy's size?

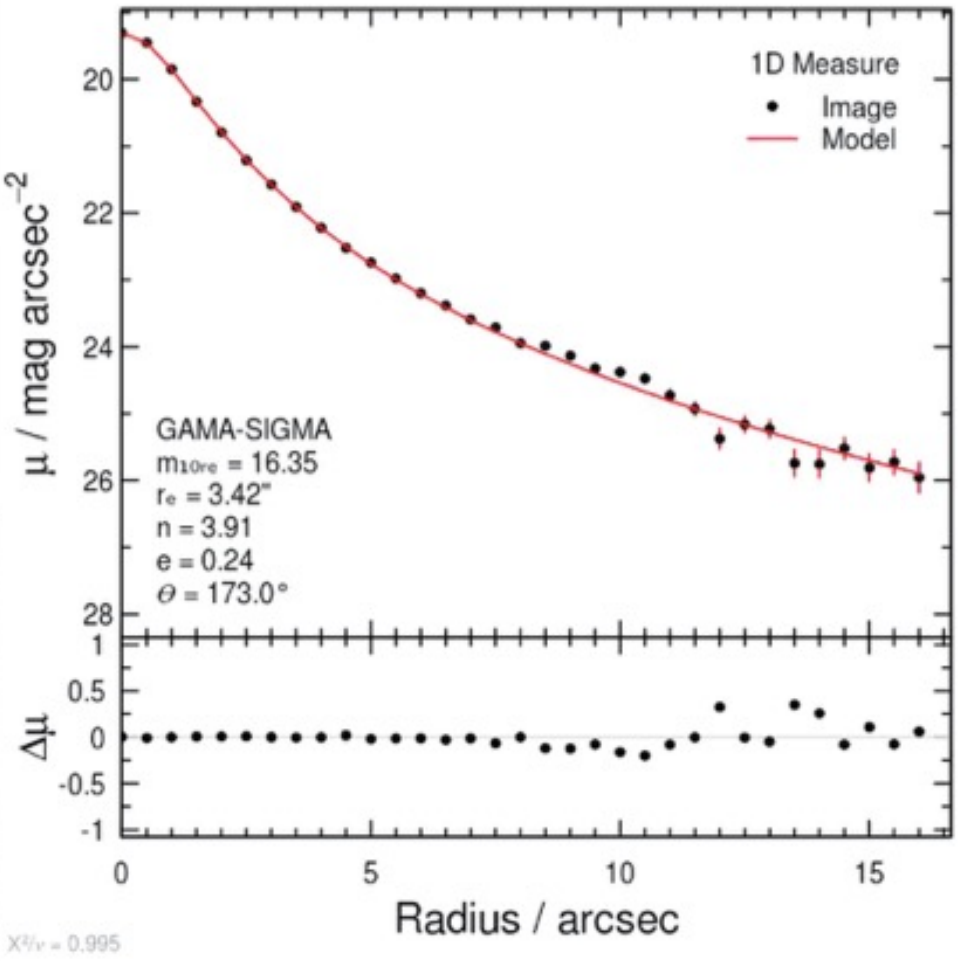
- Galaxy profiles are generally very peaky, but decline smoothly into the sky
- Tricky to define a size
  - isophotal, Petrosian/Kron, scalelength,...
- Truncation
- Half-light radius
  - most popular
  - but half of what light?

How to measure sizes (etc.)

- Non-parametric methods
  - 1D profiles (major/minor axes)
  - Ellipse fitting
  - Curve of growth
  - PSF issues / depth dependent
- Parametric fits
  - Sérsic and other profiles
  - Multiple components
- Software
  - GALFIT, GIM2D, BUDDA, IMFIT, …
  - GALAPAGOS, SIGMA, PYMORPH, …

The Sérsic profile

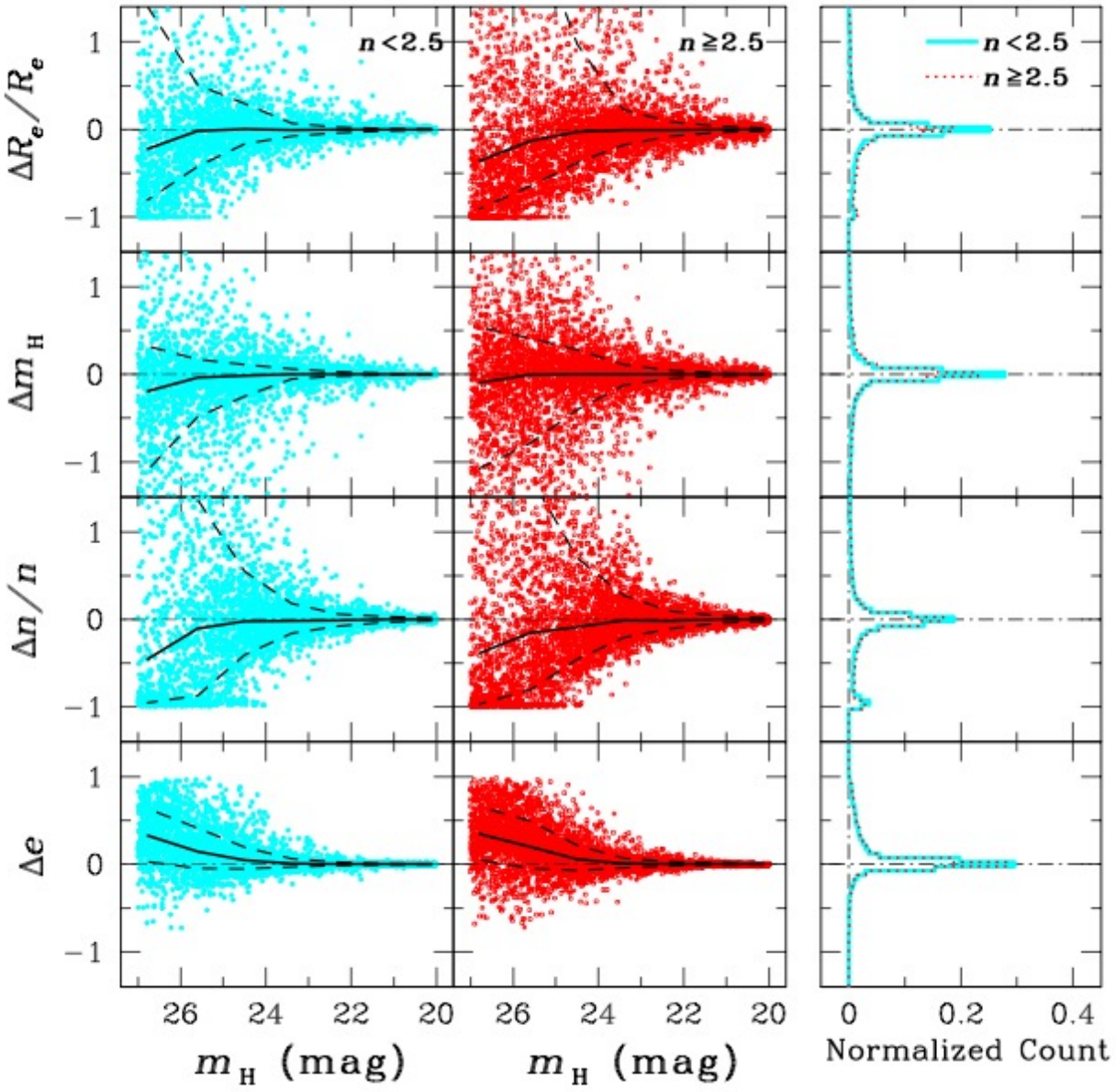




Kelvin+12 – GAMA survey

Good news

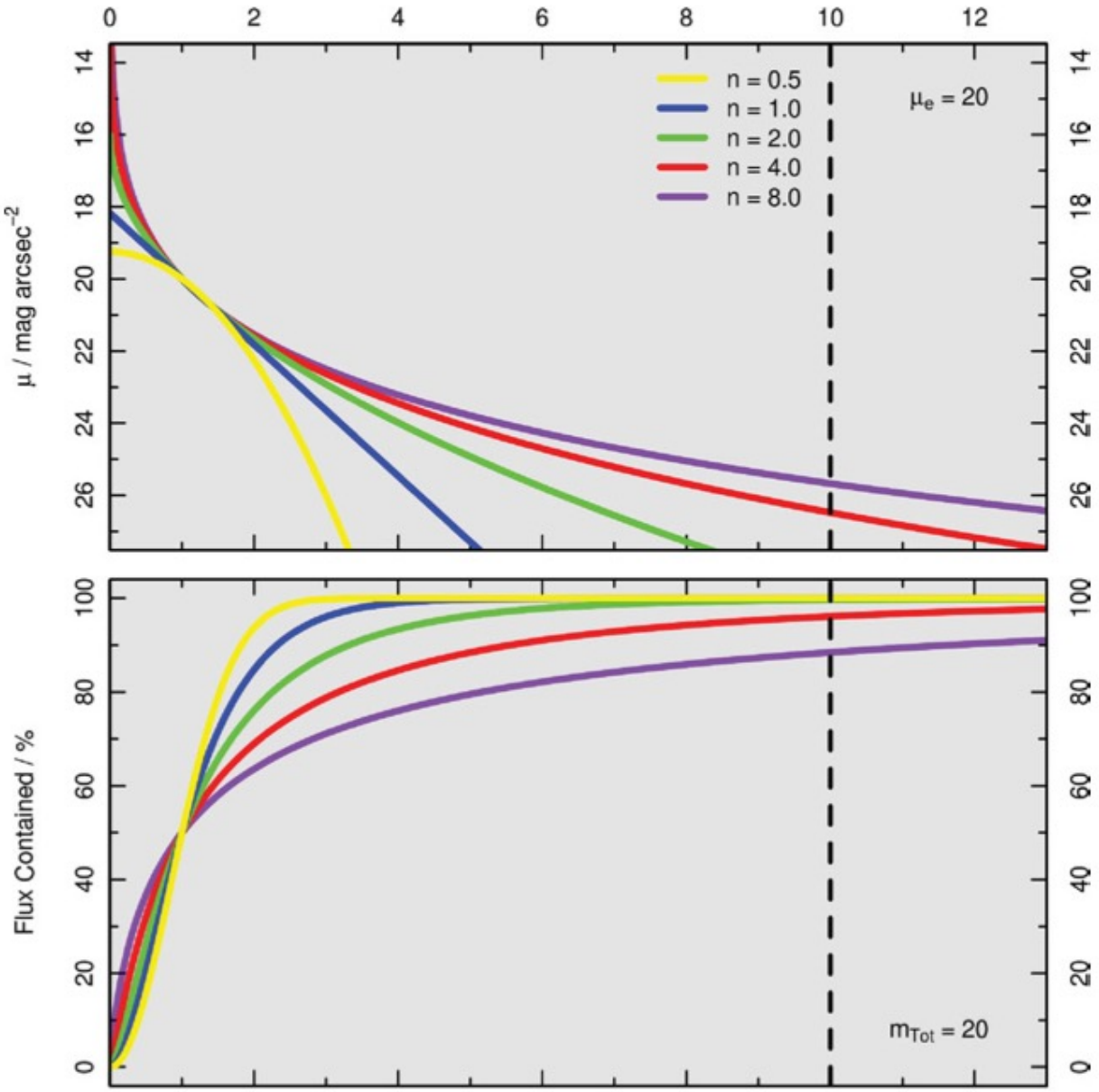
- We are pretty good at measuring sizes
- Appreciation of systematics
- Everyone tests their sizes now



Davari+14 – single-Sérsic fit with single-Sérsic

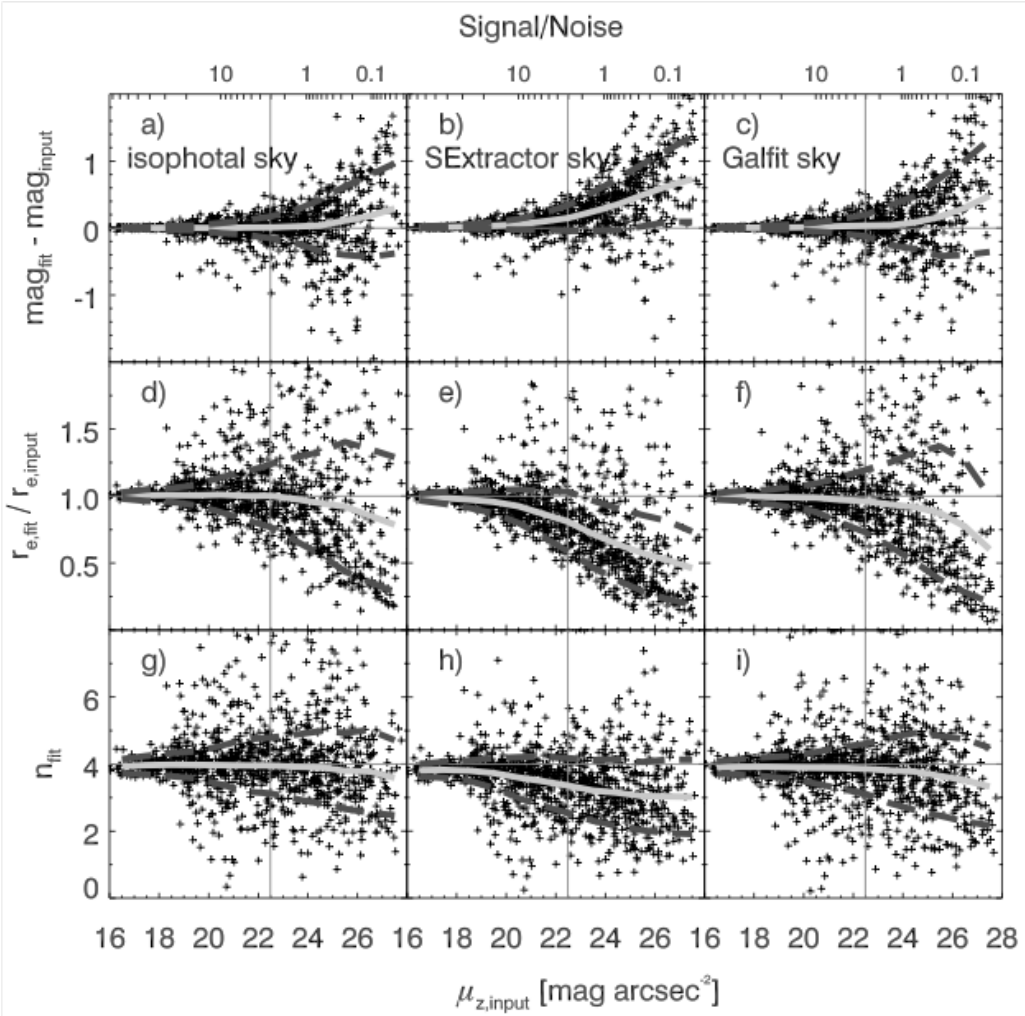
Problems with Sérsic fits

- Total magnitude involves an extrapolation
- Heavy wings: must be careful about the sky
- Tight relationship between inner and outer profile

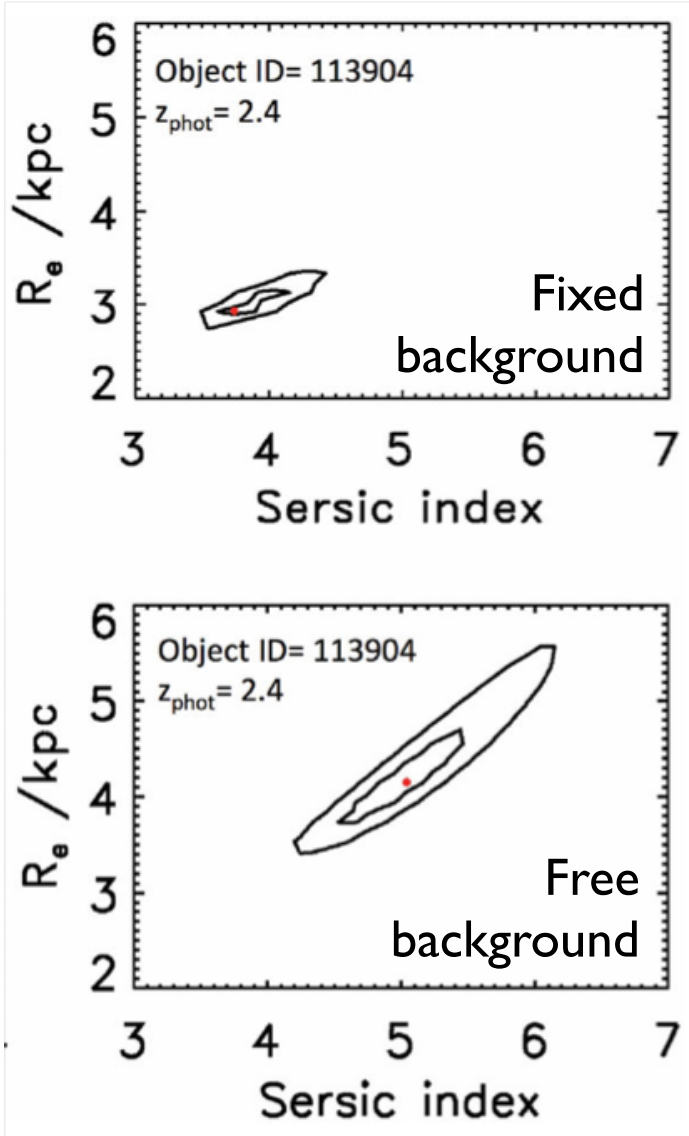


Kelvin+12

Look to the sky

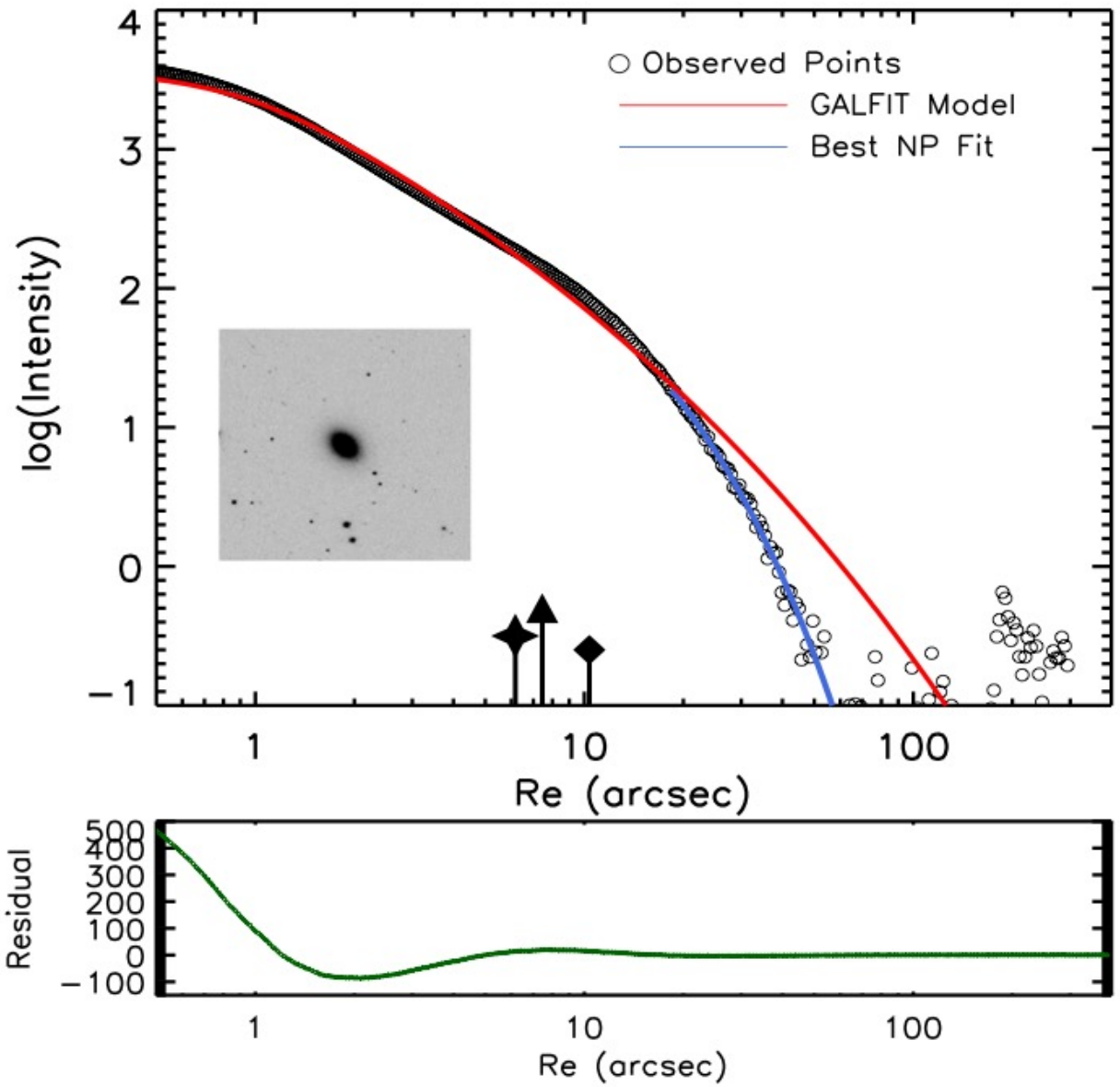


Haeussler+07



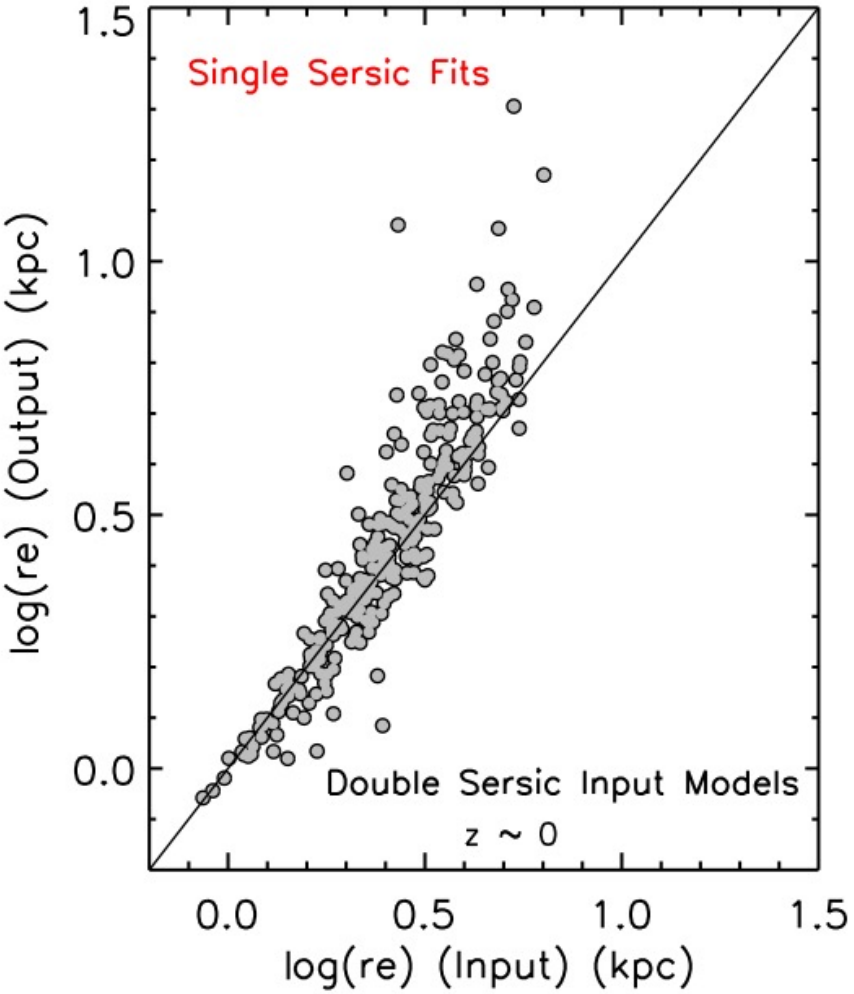
Bruce+14

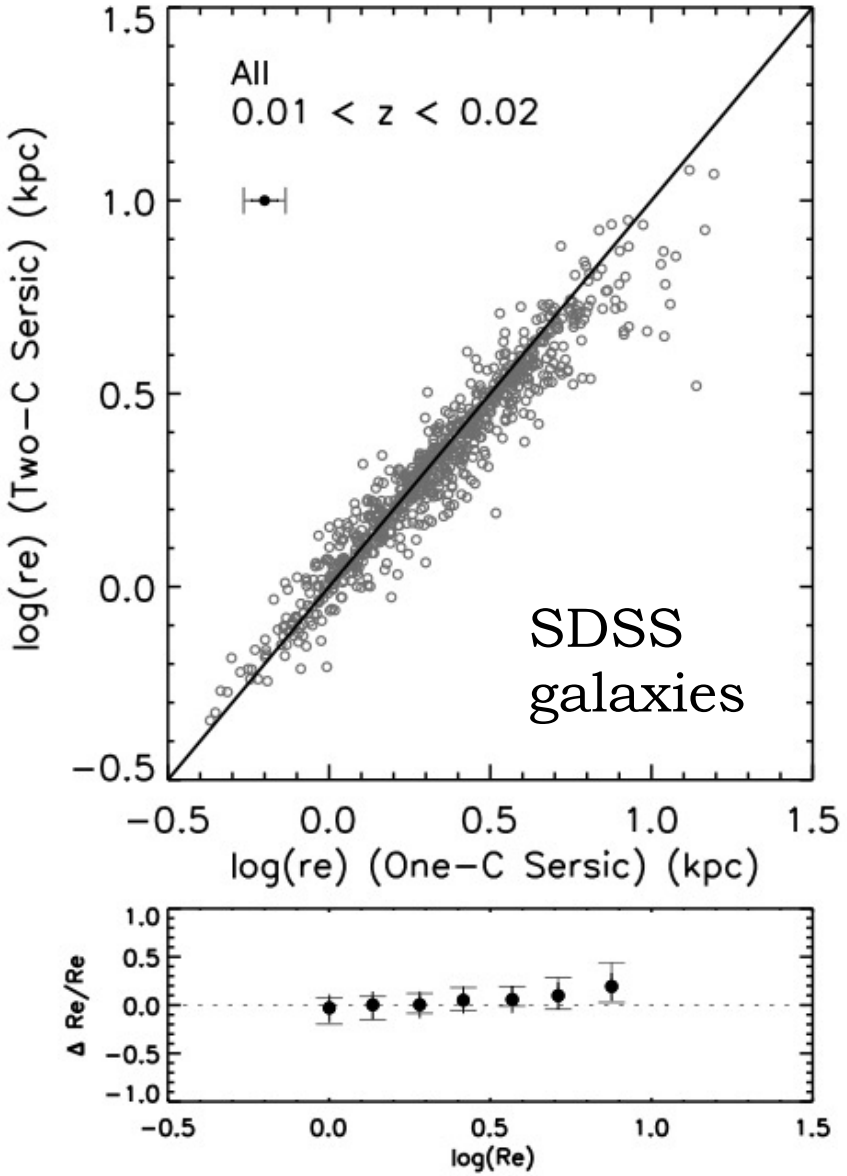
Profile mismatch



Mosleh+13

Profile mismatch





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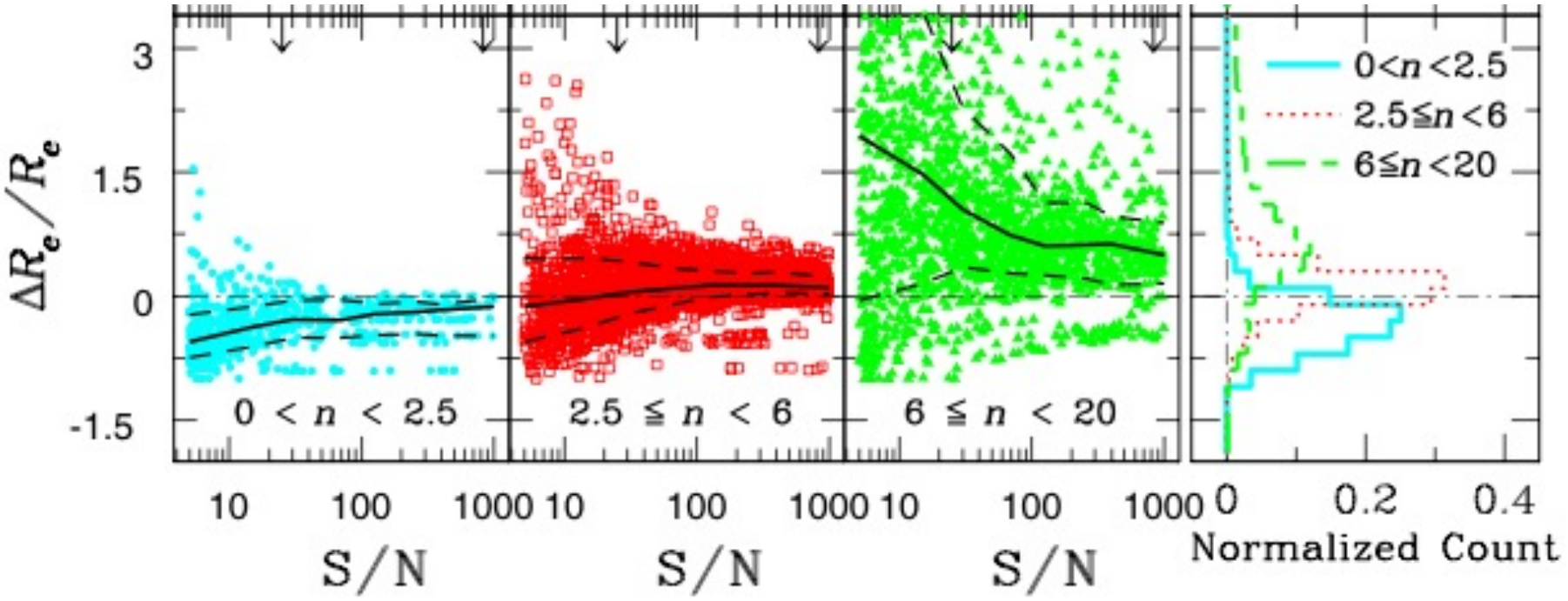
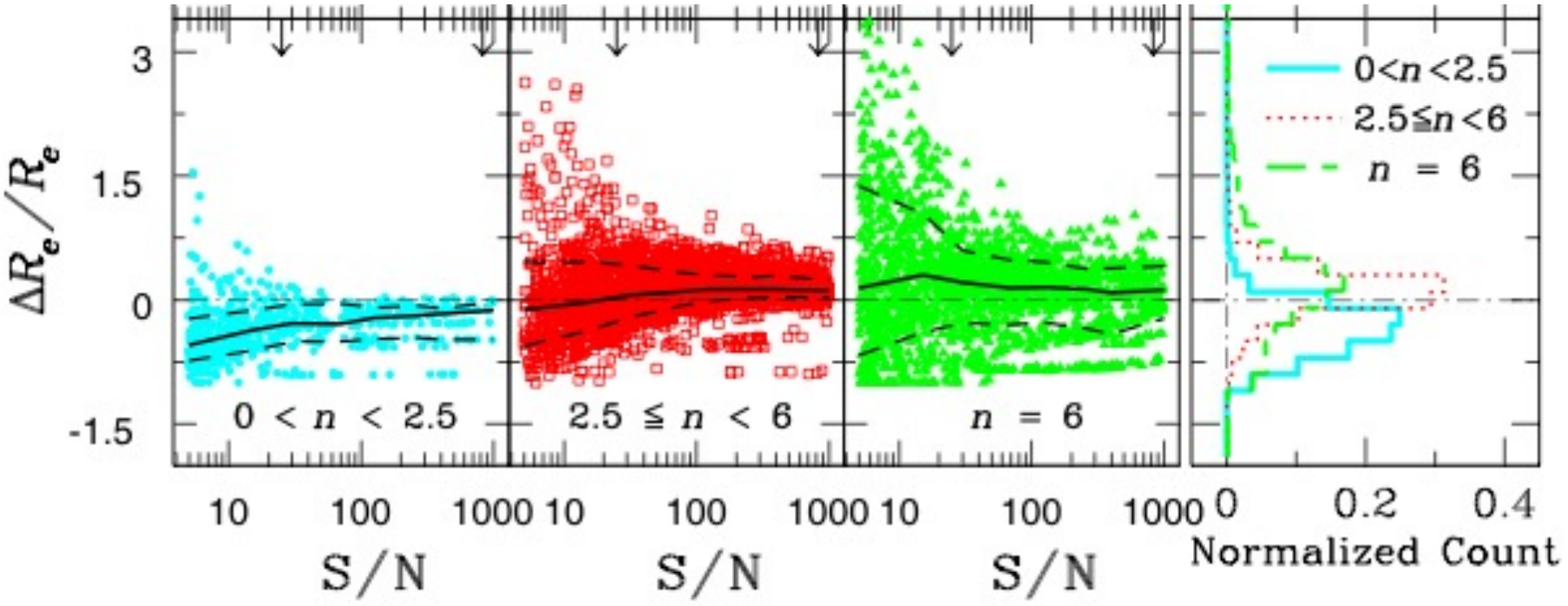


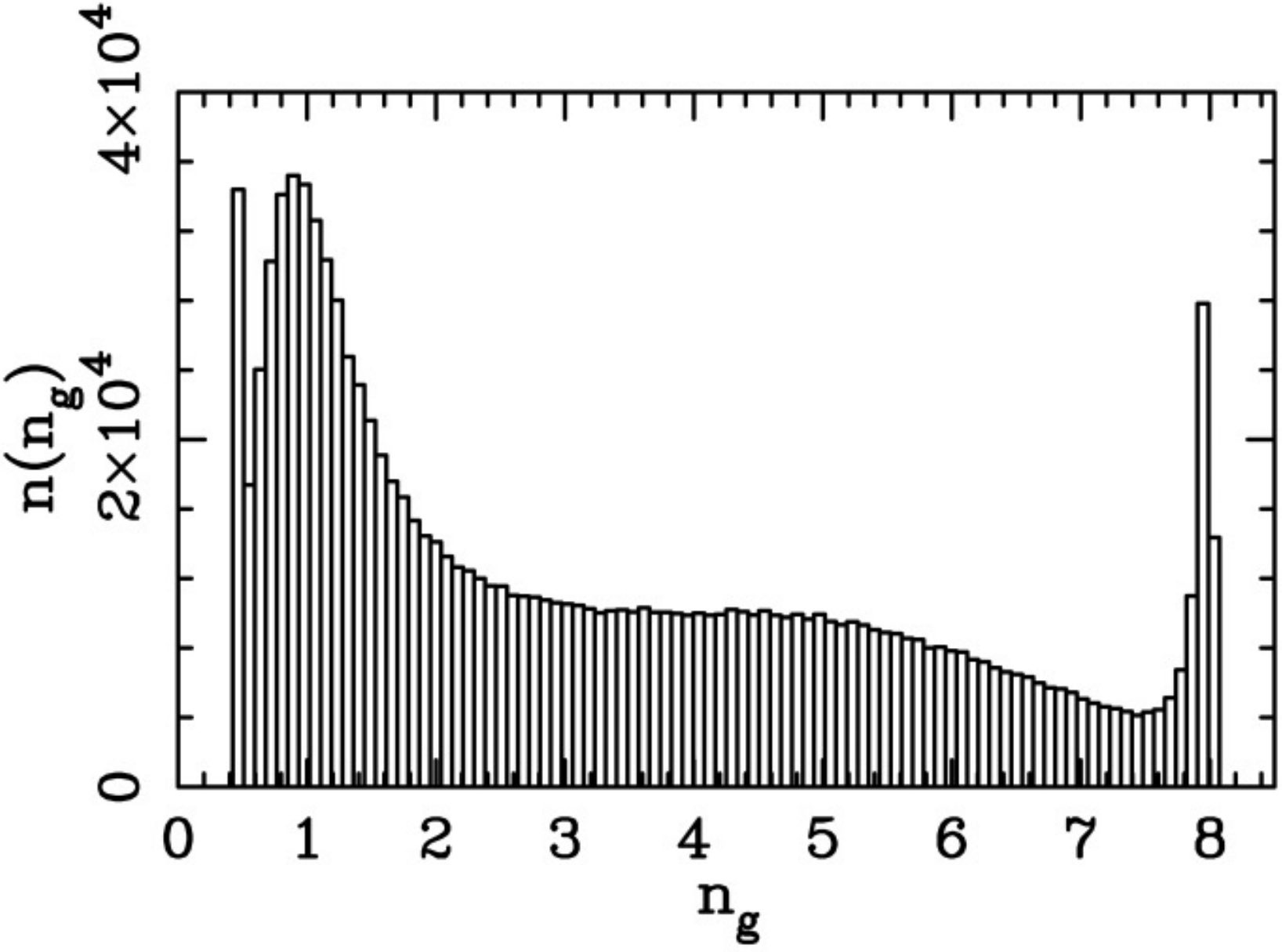
Davari+14 – double-Sérsic fit with single-Sérsic

Profile mismatch



Davari+14 – double-Sérsic fit with single-Sérsic

Catastrophic fits

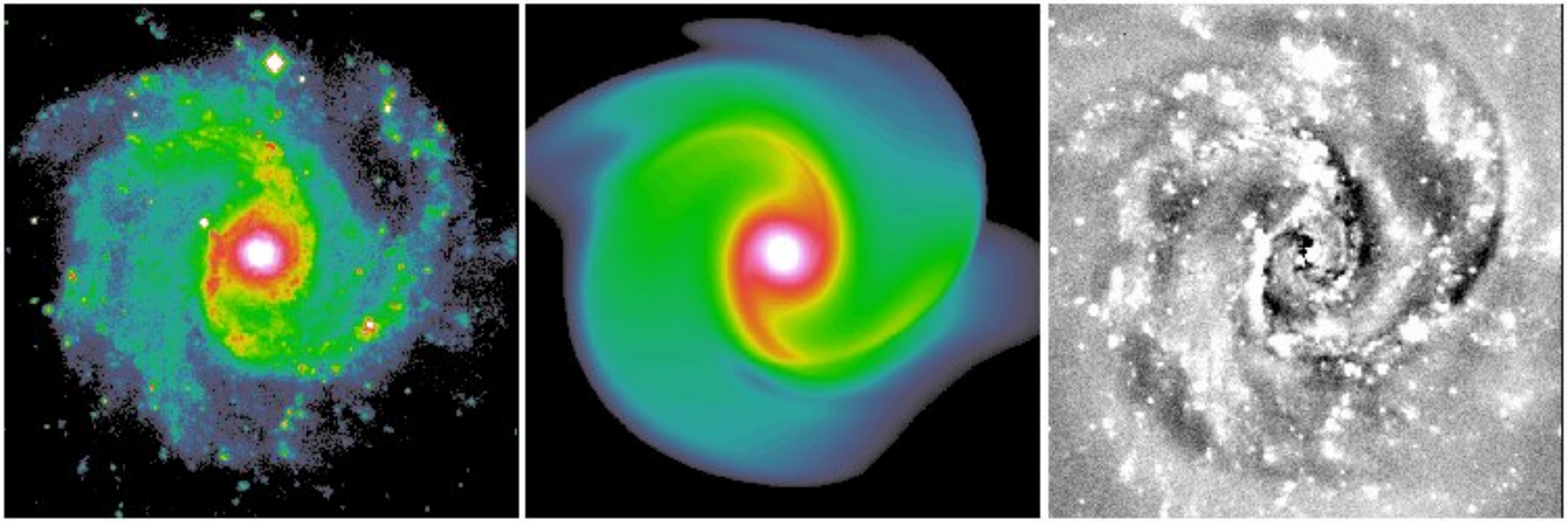


Simard+11 – but affects all

Azimuthal structure

Azimuthal structure

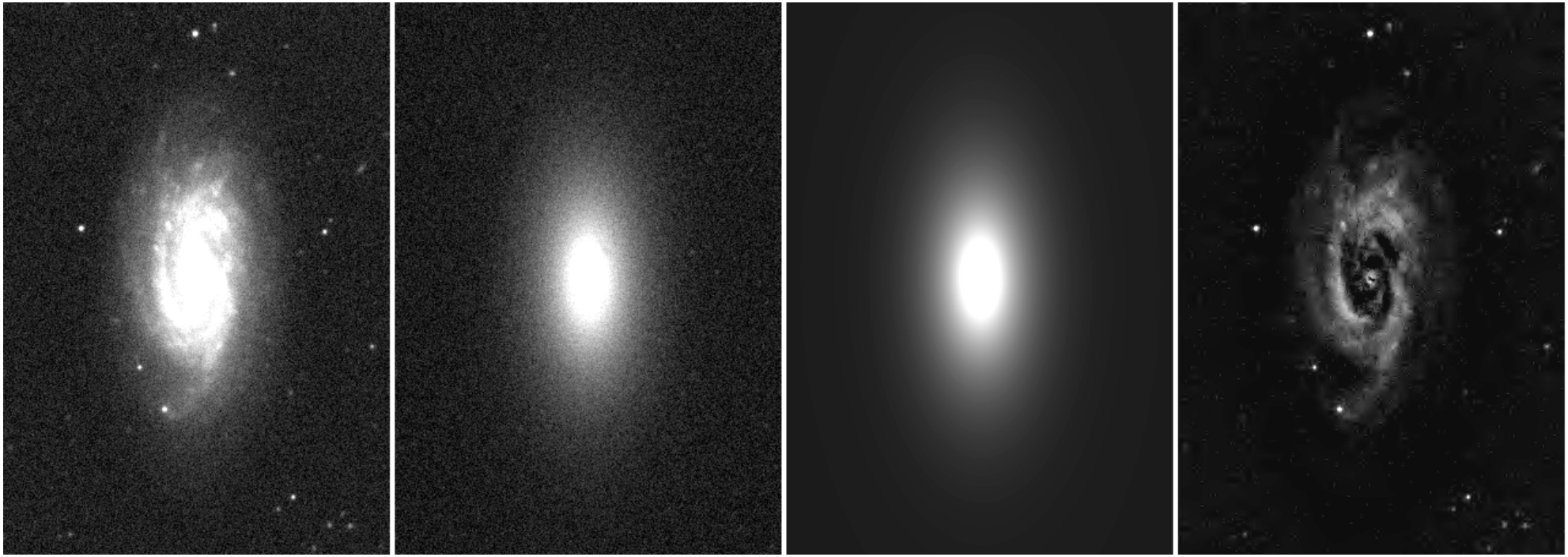
- GALFIT 3



Peng+2010

Azimuthal structure

- Semi-parametric methods



data

data
–
non-parametric
model

parametric model

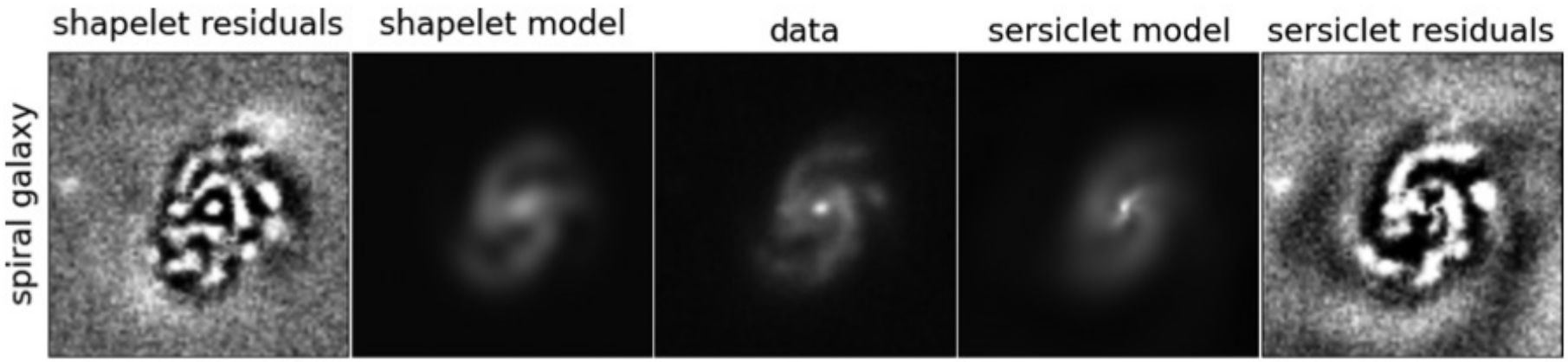
non-parametric
model

(intermediate
scale residuals)

In MegaMorph's GALFITM

Azimuthal structure

- Basis set decompositions



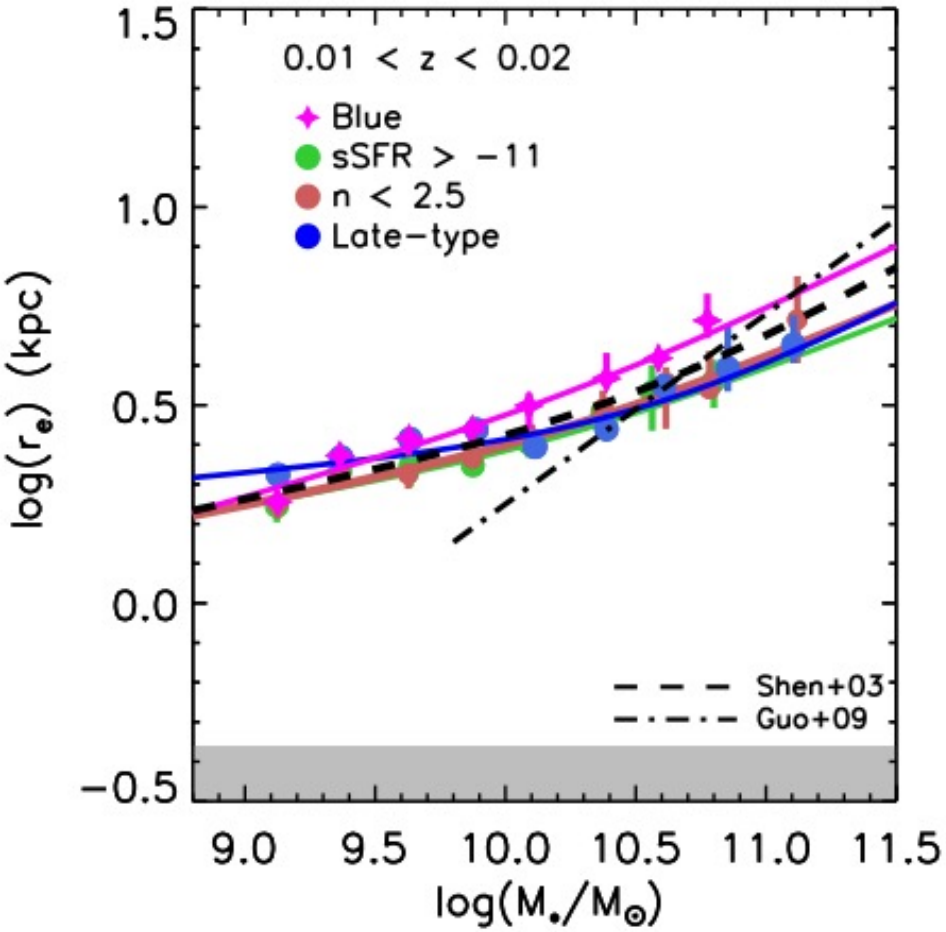
Andrae+11

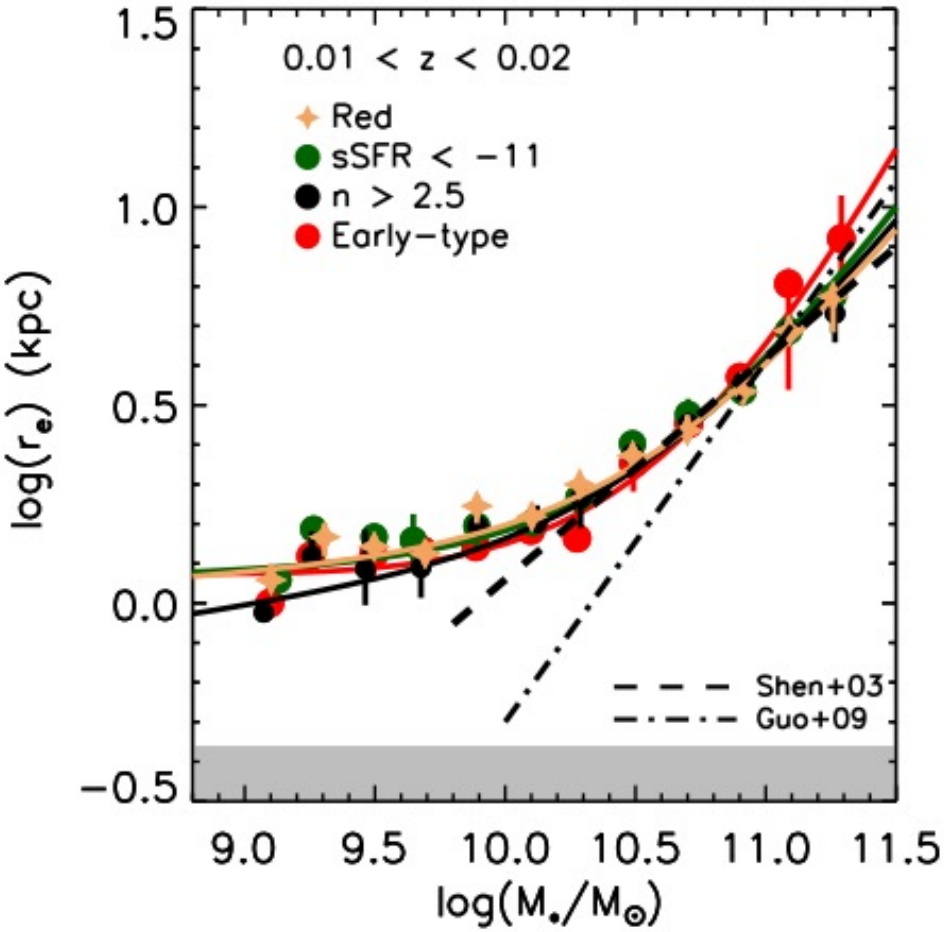
- Non-parametric methods:
  - Asymmetry, clumpiness, residual fraction
  - On image or residuals

Dividing by galaxy type

Dividing by galaxy type

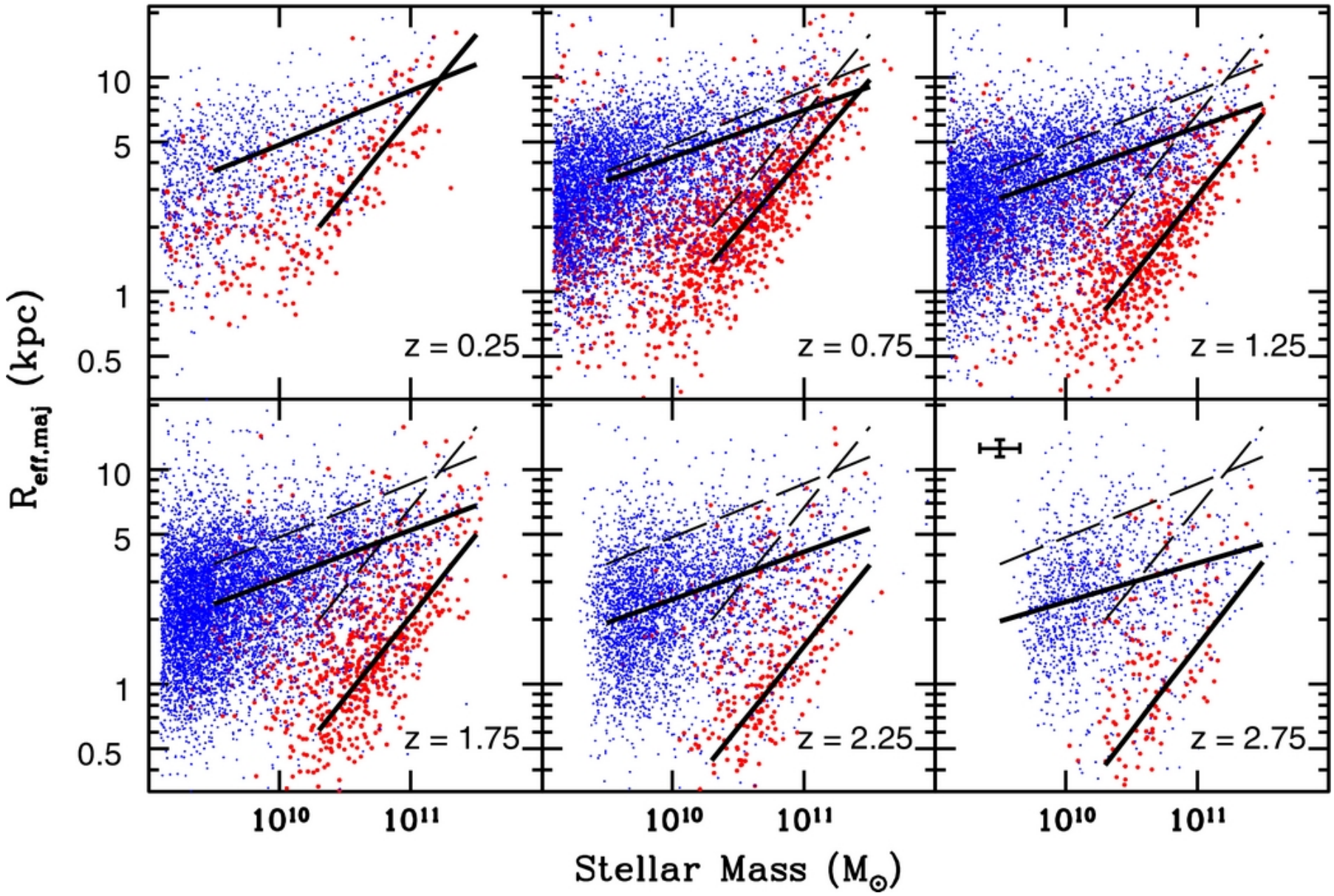
- Expect types to behave differently
- Doesn't matter how they are separated





Mosleh+13; also see Lange+14

Dividing by galaxy type



Arjen's "chopsticks" diagram

Dividing by galaxy type

- Even though exact type selection doesn't seem to matter…
- Word of caution:
  - Early/late division not the same at different redshifts, environments, masses
  - Need to think of progenitors in terms of galaxy components at lower masses

What's special about a Sérsic?

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Andrae+2011:

- Sersic profile is the first-order Taylor expansion of a realistic light profile
  - i.e. maximum at r=0, tends to zero at large radii

$$
\begin{aligned}
I_1(r) &= I(0)\exp\left[-b_n(r/\beta)^{1/n}\right] \\
&= I(0)\exp\left\{-\exp\left[\log(b_n)+(1/n)\log(r/\beta)\right]\right\} \\
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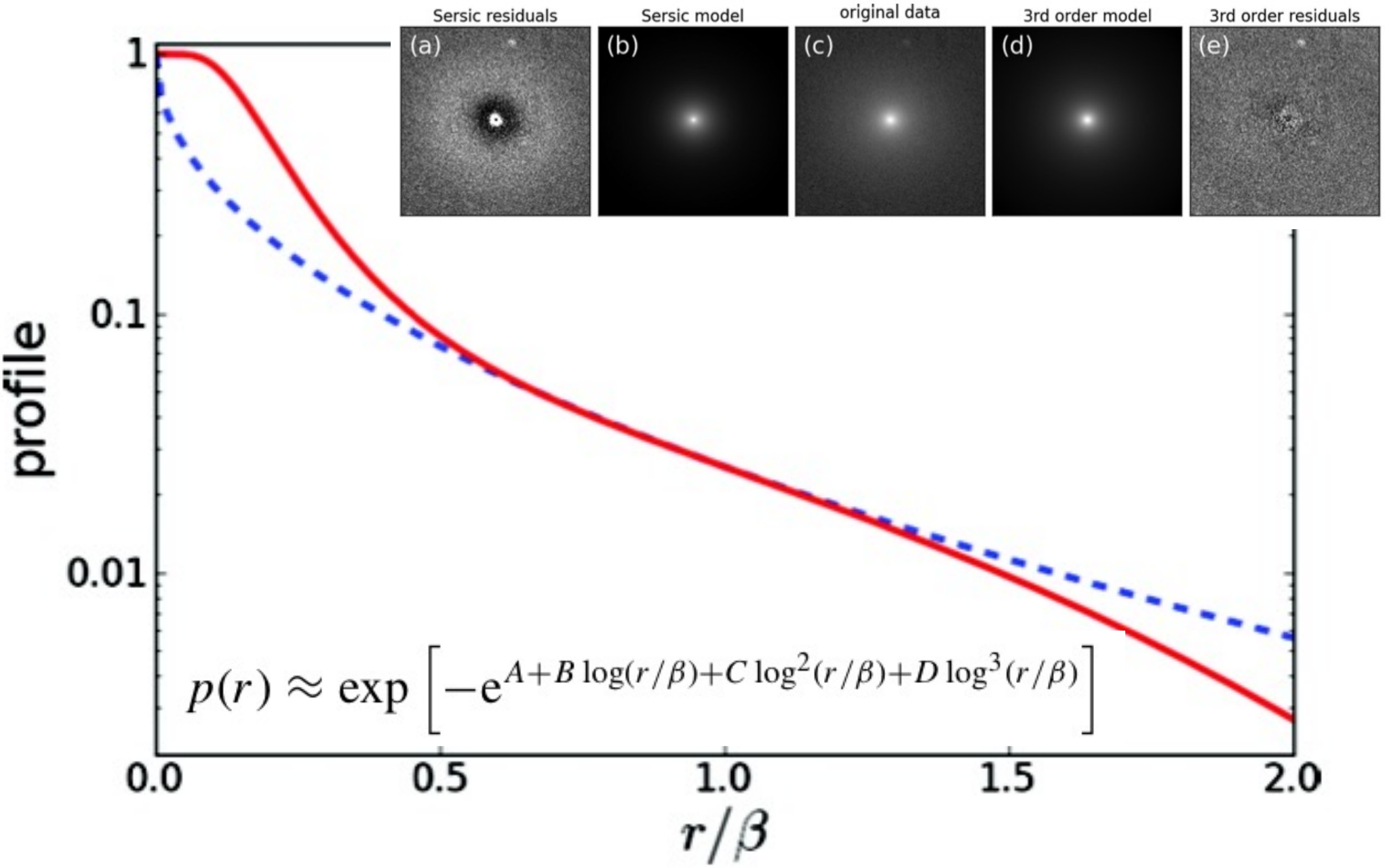
$$

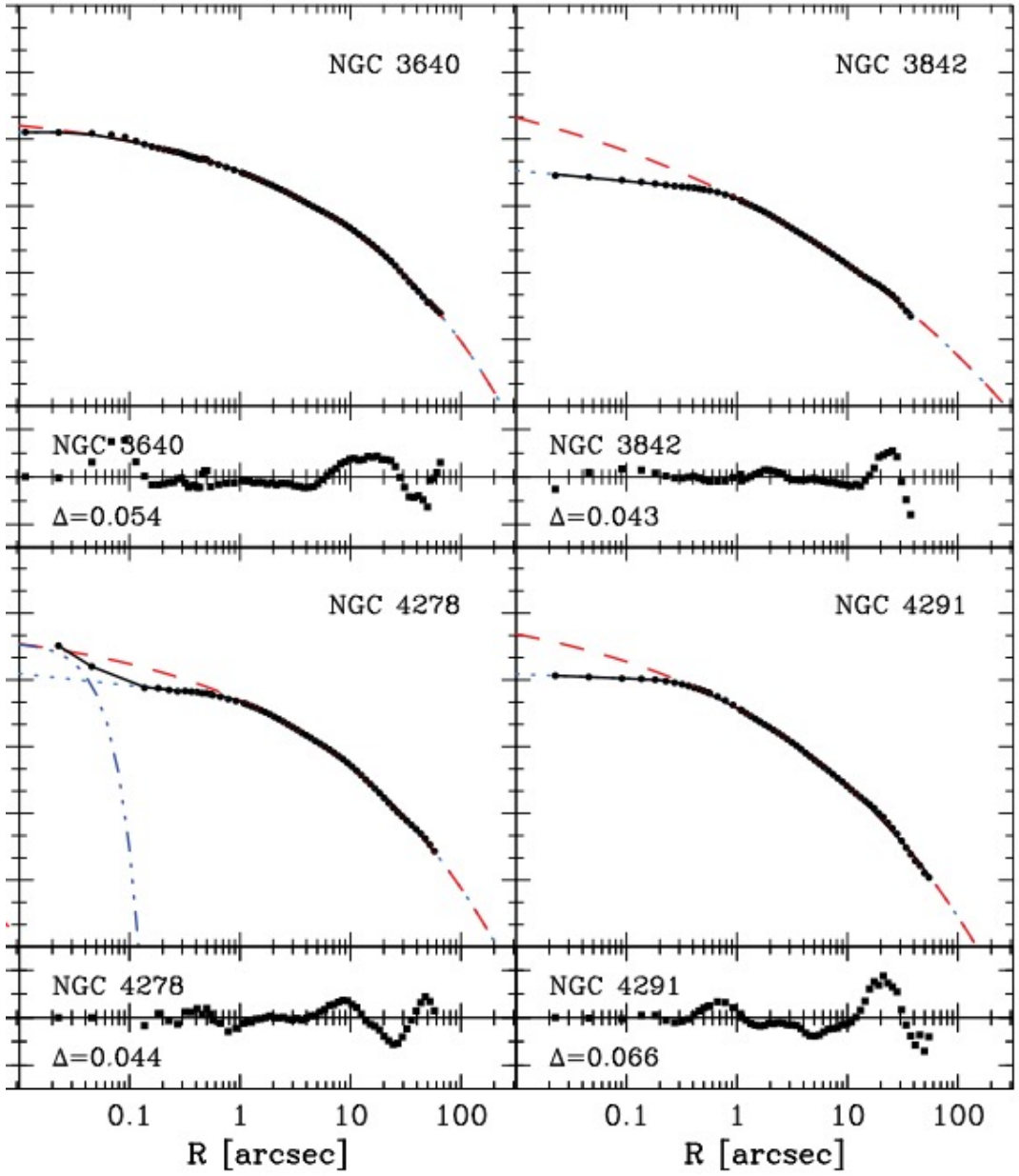
$$
I_3(r) = I(0)\exp\left\{-\exp\left[A+B\log(r/\beta)+C\log^2(r/\beta)+D\log^3(r/\beta)\right]\right\}
$$

Higher-order Sérsic functions



Core-Sérsic model

- A specific way to decouple centre and outskirts
- Well motivated
- Core unconstrained without resolution.
- Can we infer core profile from lower resolution data. Does it matter?

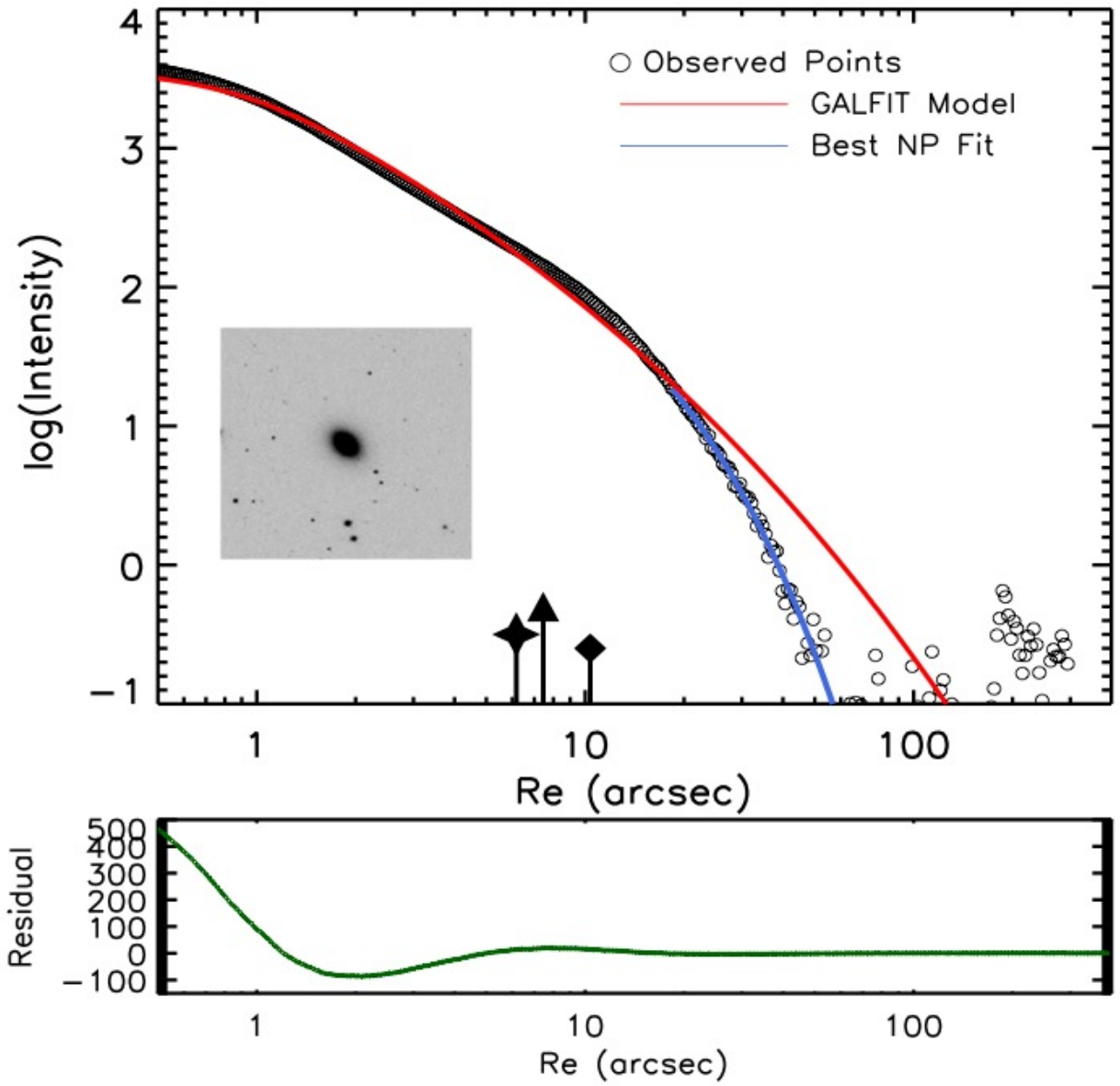


Dullo & Graham+13

Now in GALFIT – Bonfini+14

The sigma image

- Chi-squared computed using pixel flux errors
- Relative error tiny in centre
- Expect systematic deviations from Sérsic ~10% level
- Should these be accounted for?



Multiple components

- Physically justified
- Introduces complications

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- Introduces complications
- Sky a bigger issue

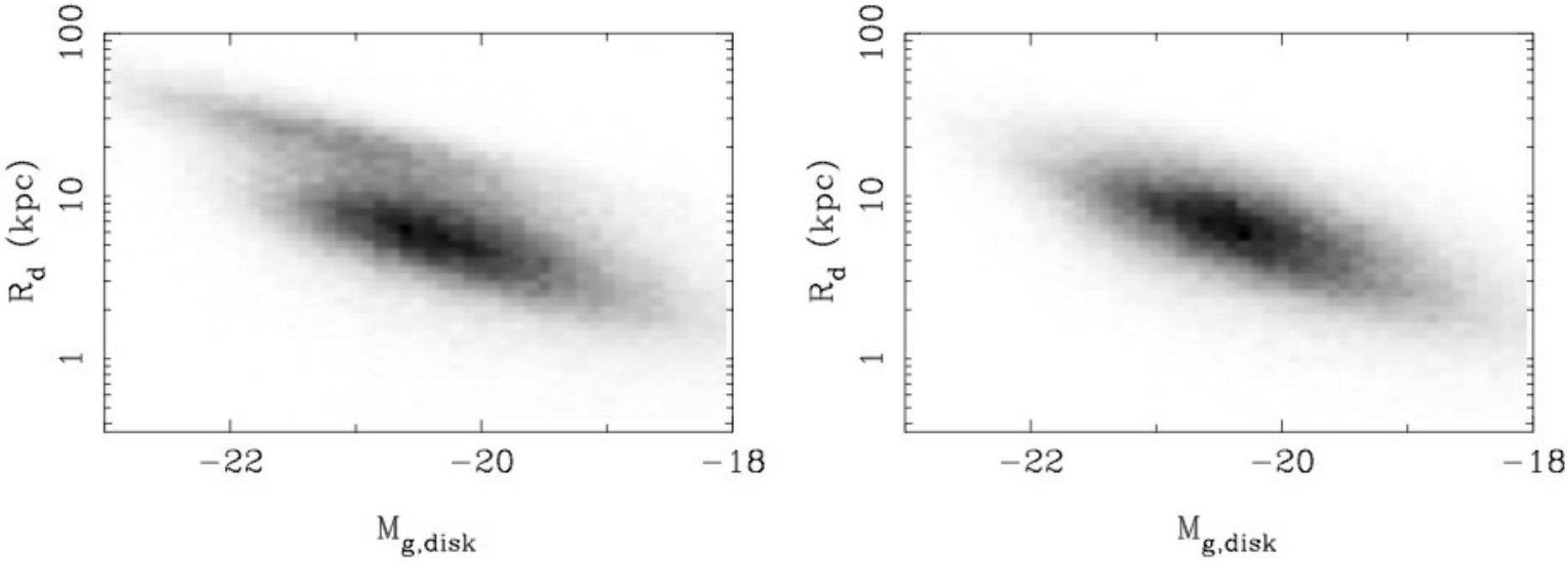
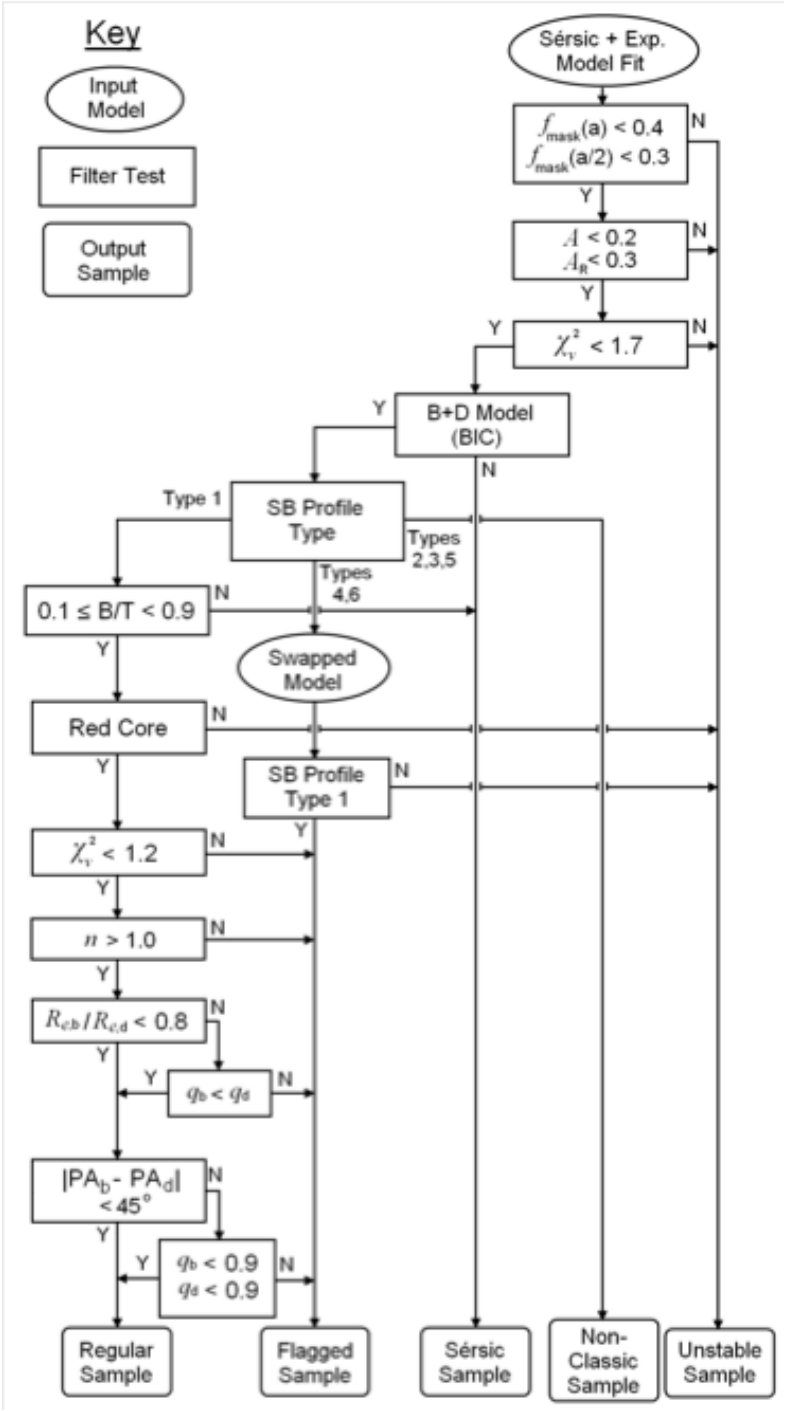


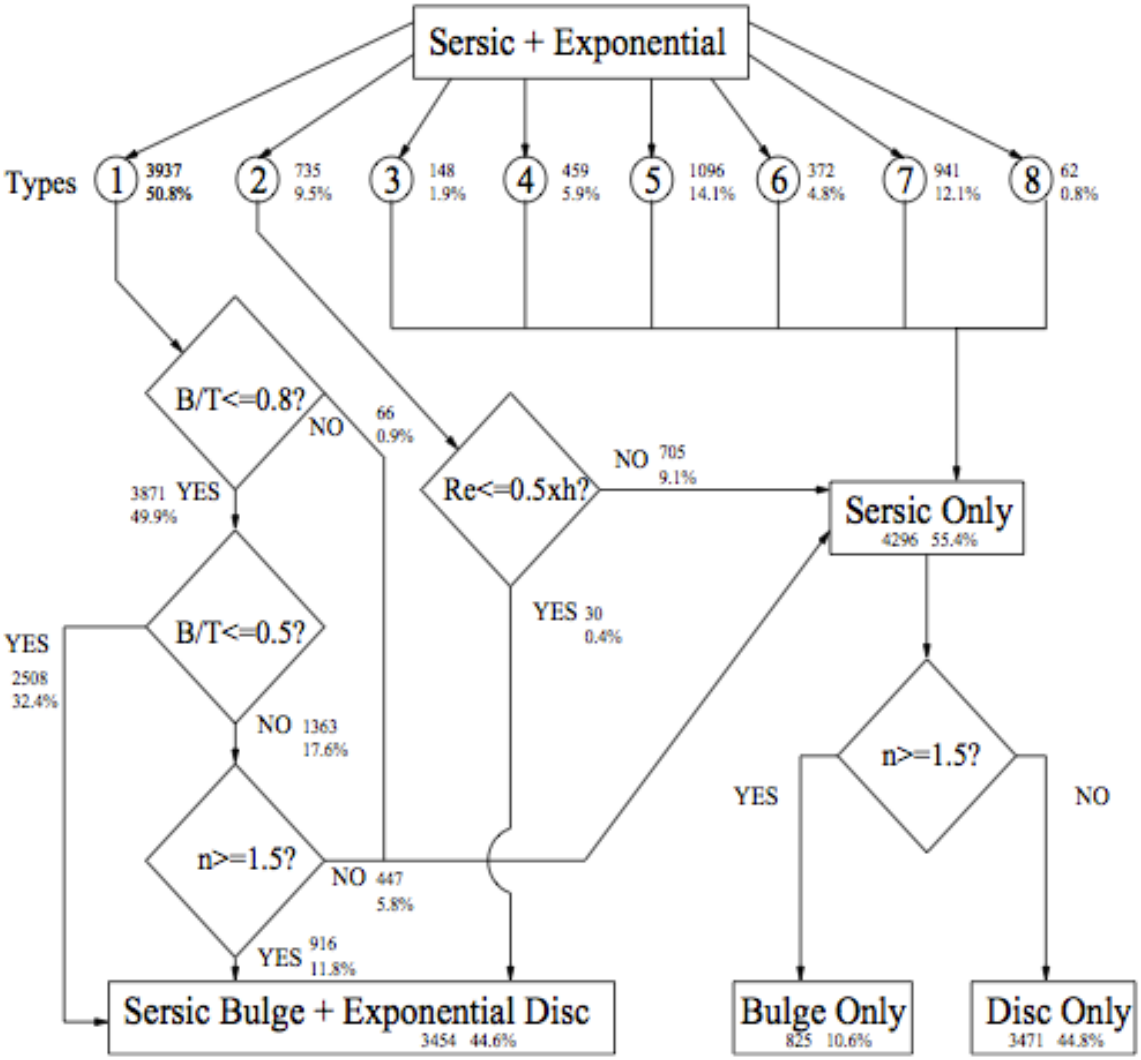
Illustration from Simard+11

Multiple components

- Physically justified
- Introduces complications
- Often statistically better fits
- Can be physically unrealistic or tricky to interpret

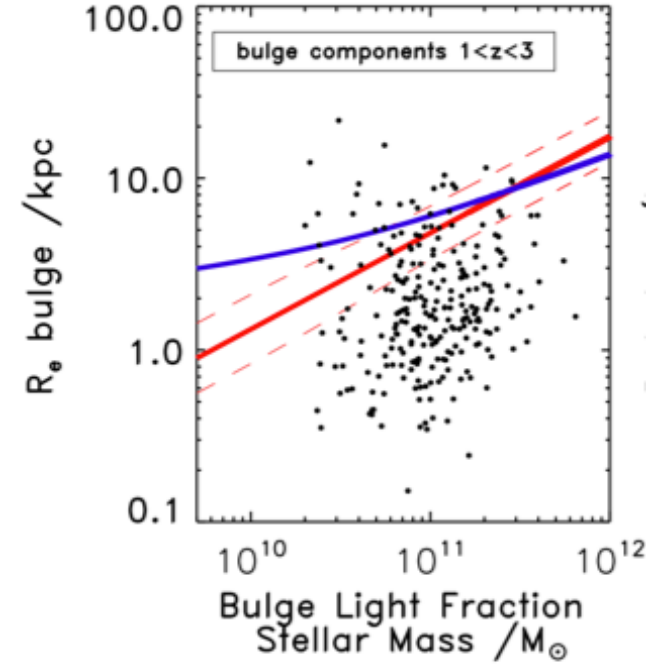


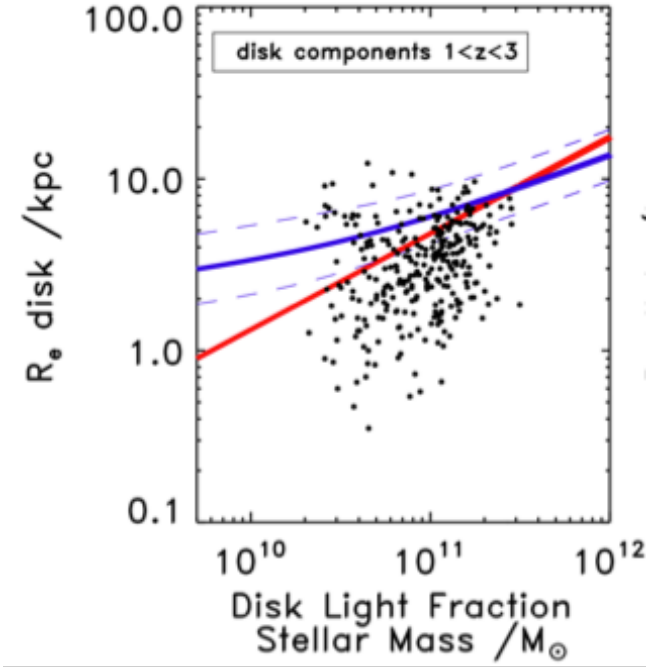
Head+14



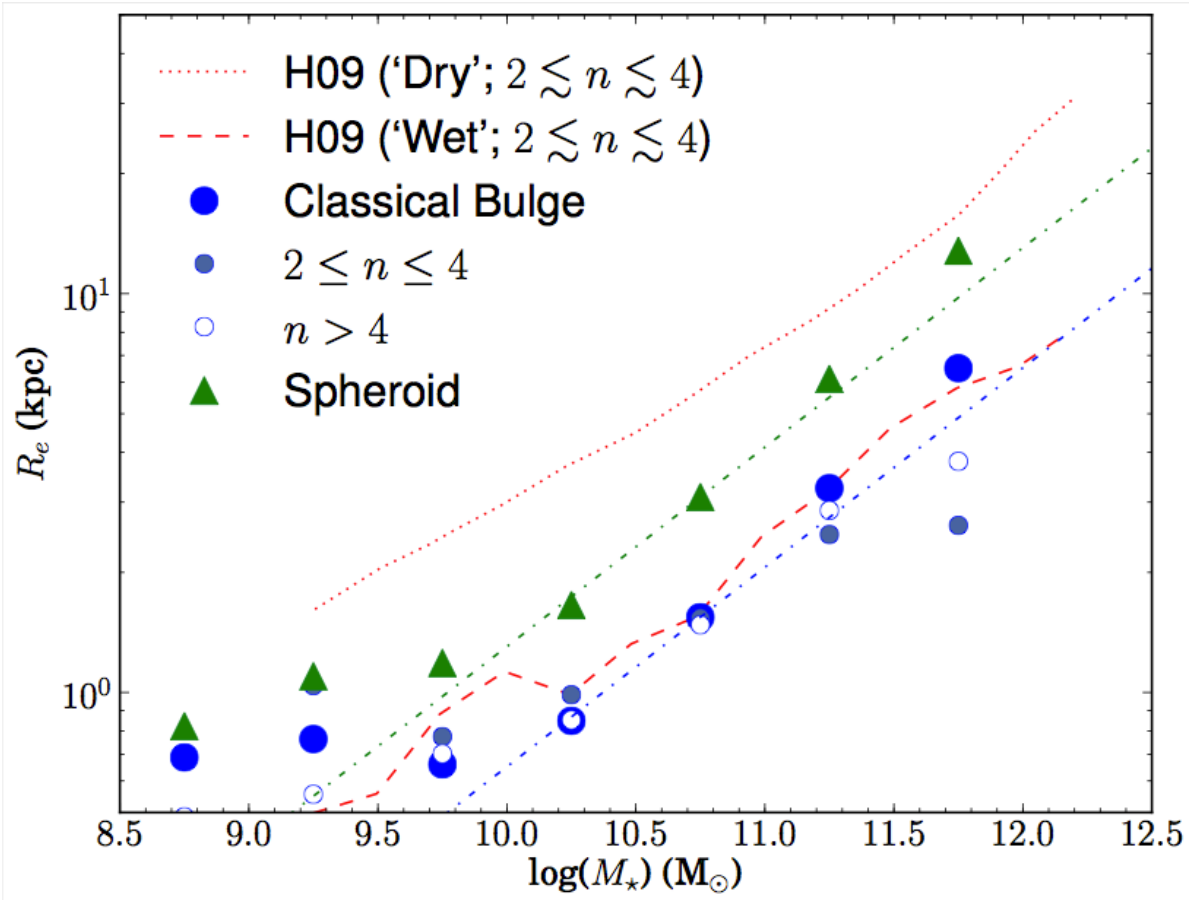
Allen+06

Model selection:
Visual, logical filter, F-test, BIC, Bayesian evidence,…





Bruce+2014



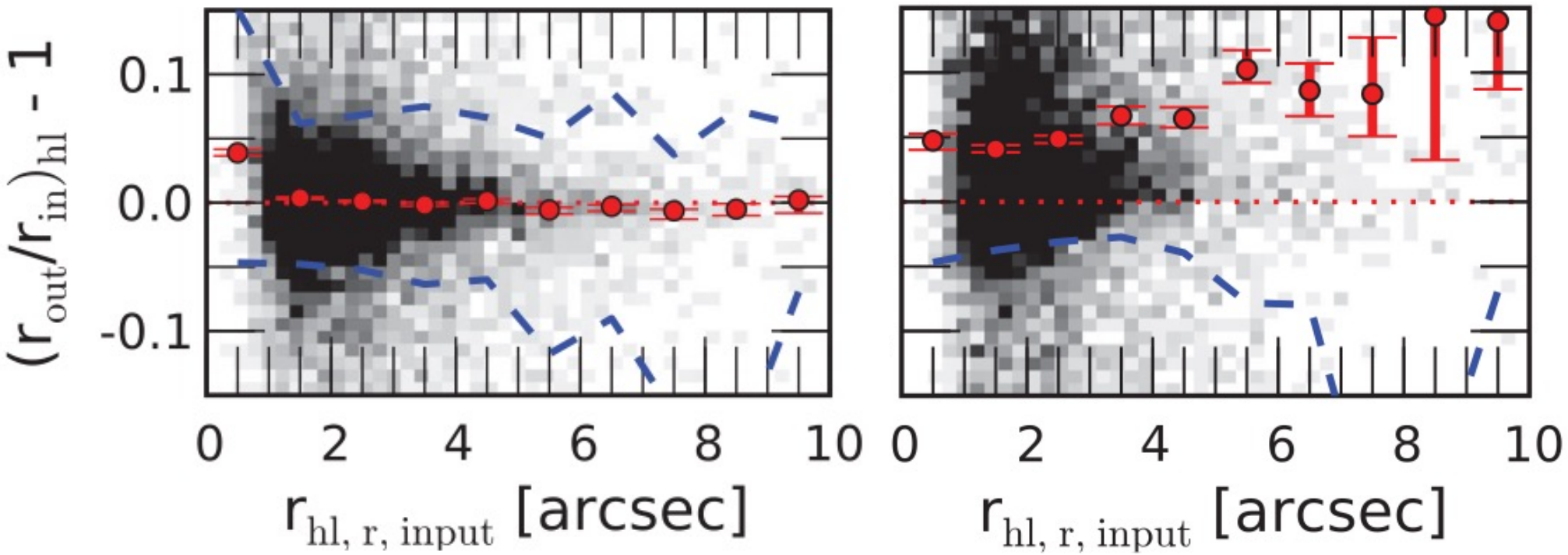
Berg+2014

Multiple components

- Physically justified
- Introduces complications
- Often statistically better fits
- Can be physically unrealistic or tricky to interpret
- Successful multi-component fit may be telling us something, or maybe not?

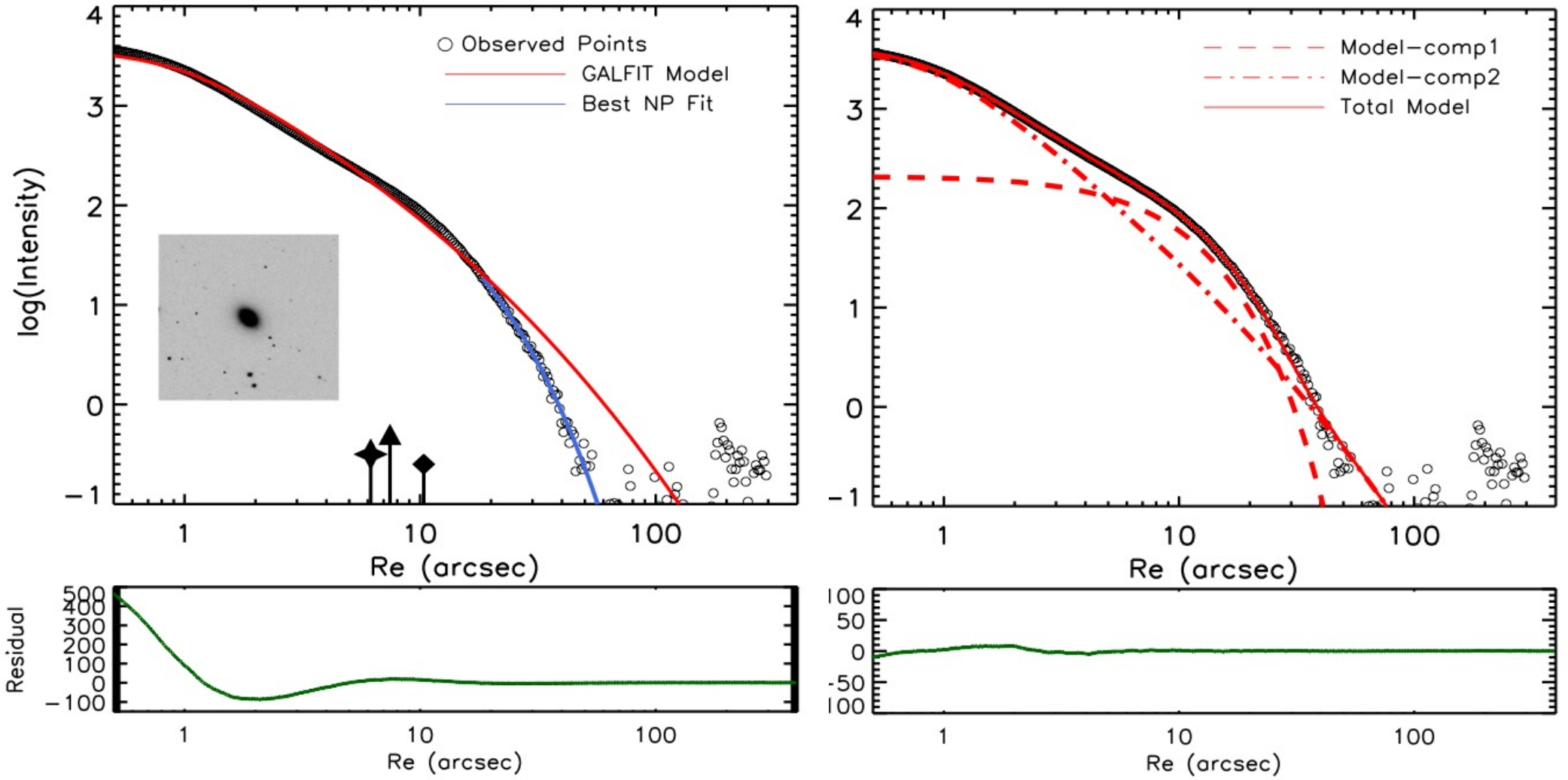
Just tell me the size!

- Physical meaning sometimes doesn't matter
- Two-component fits give better sizes



Meert+13 simulations of SDSS galaxies

Two are better than one



Mosleh+13

Looking for meaning

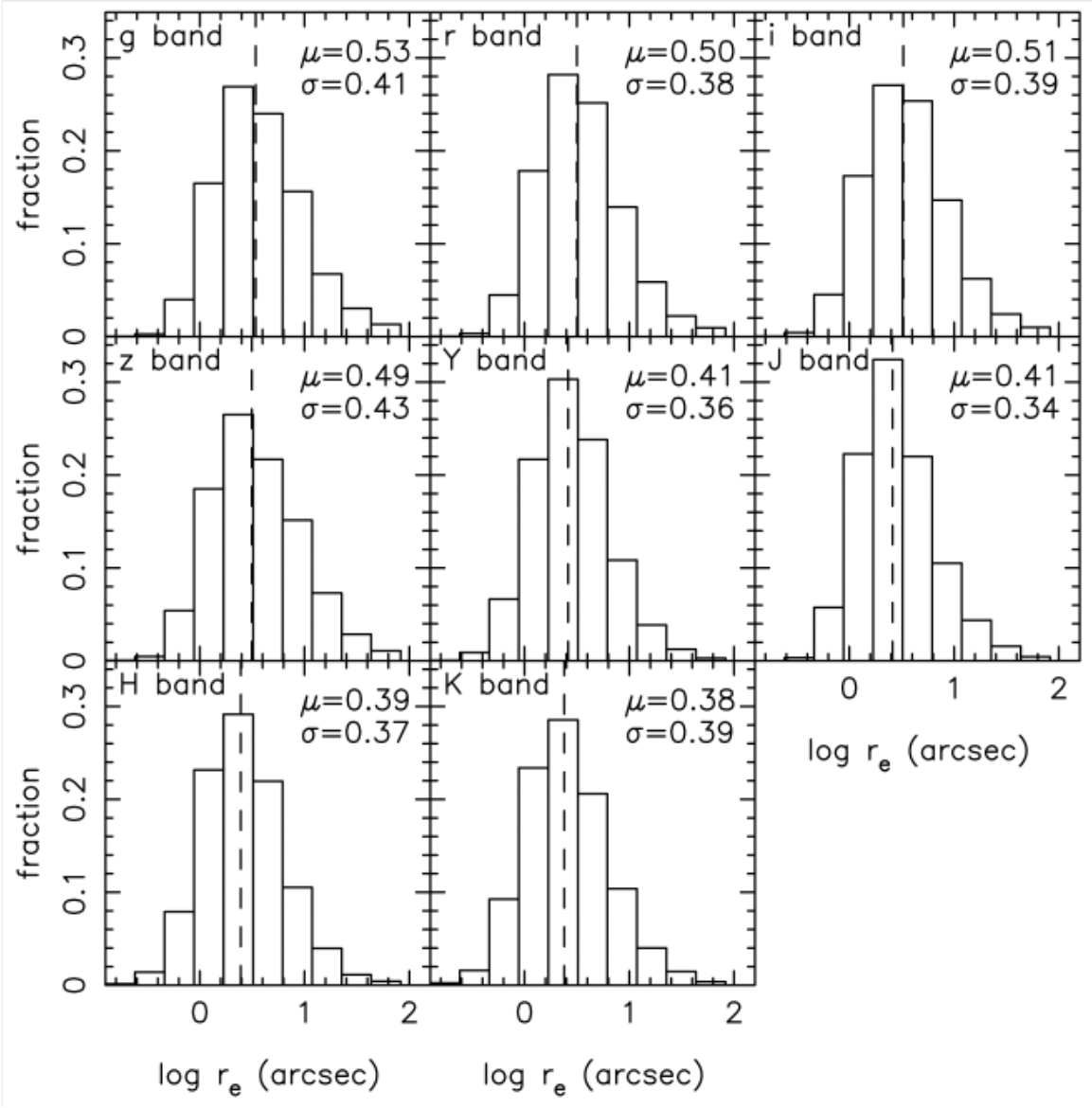
- Often want to ascribe meaning to the multiple components
- Obviously for bulge+disk, maybe for ellipticals
- Not enough that they provide a better surface-brightness profile
- They should have other distinguishing features (kinematics, stellar populations, …)
- Use colour information (e.g., MegaMorph)

Wavelength dependence of structure

- Obvious colour gradients in late-types
  - although not well characterised or understood
  - robust disk and bulge colours versus Mstar, B/T, environment will be powerful tool

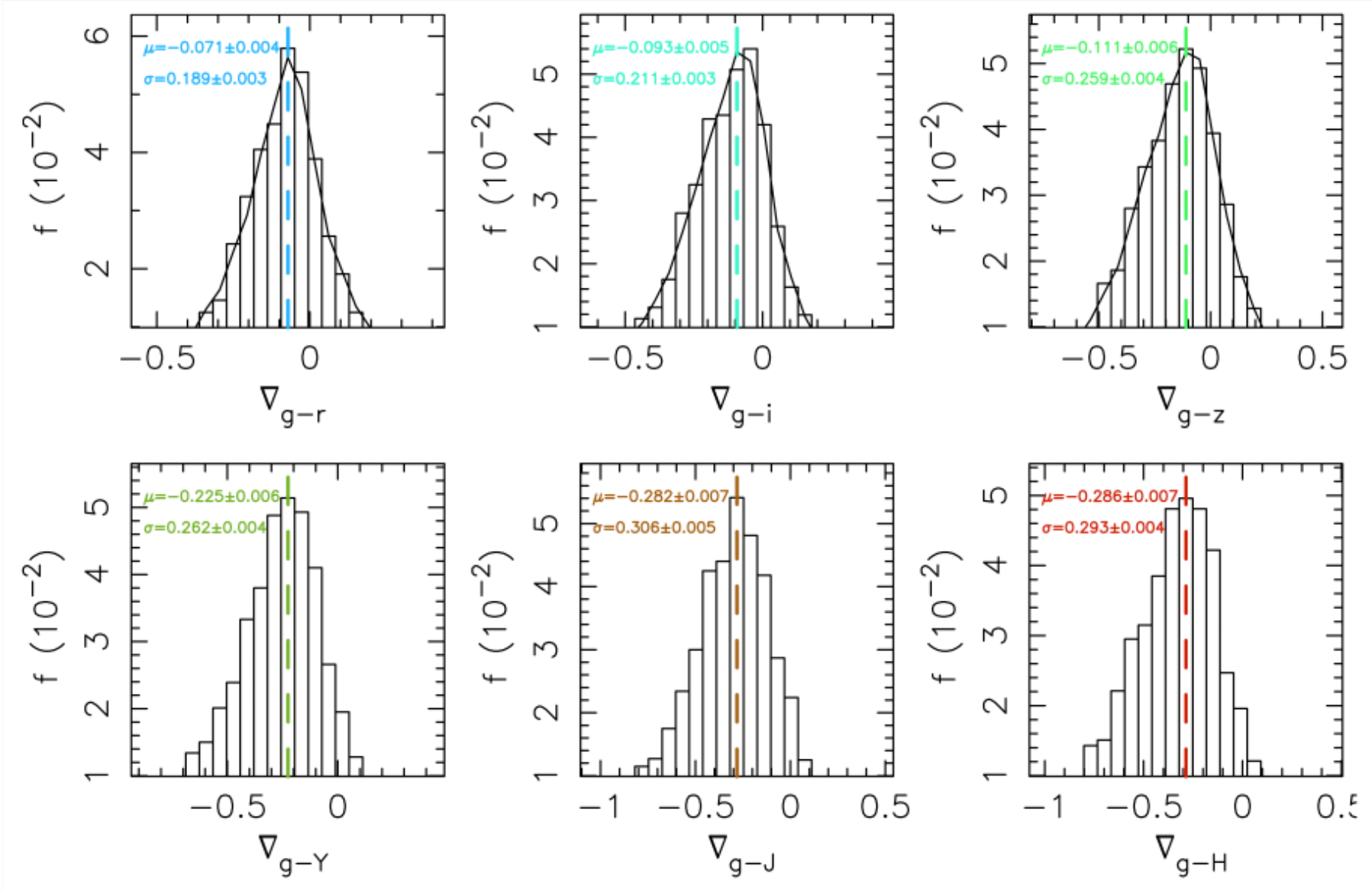
- Important to recognise that early-type sizes depend on wavelength (roughly 50% g-H)
- Outskirts are bluer

Sizes of early-types



La Barbera+10a,10b – SPIDERS project Also Vulcani+2014

Colour gradients in early-types



La Barbera+10a,10b – SPIDERS project

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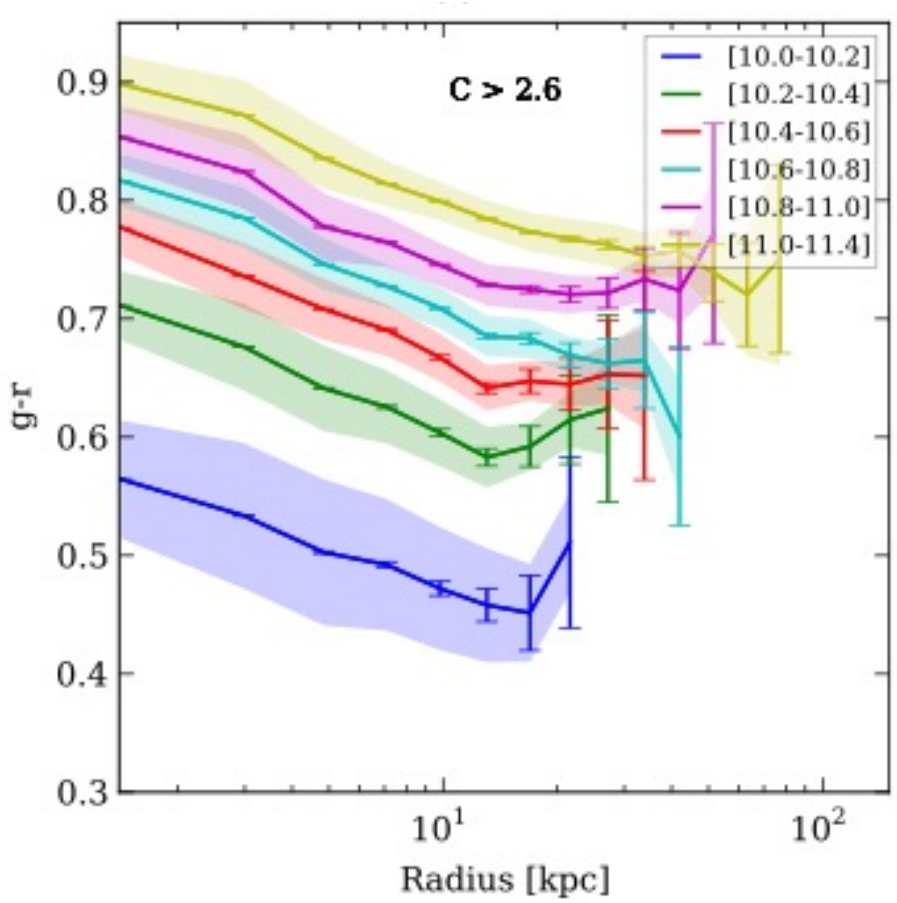
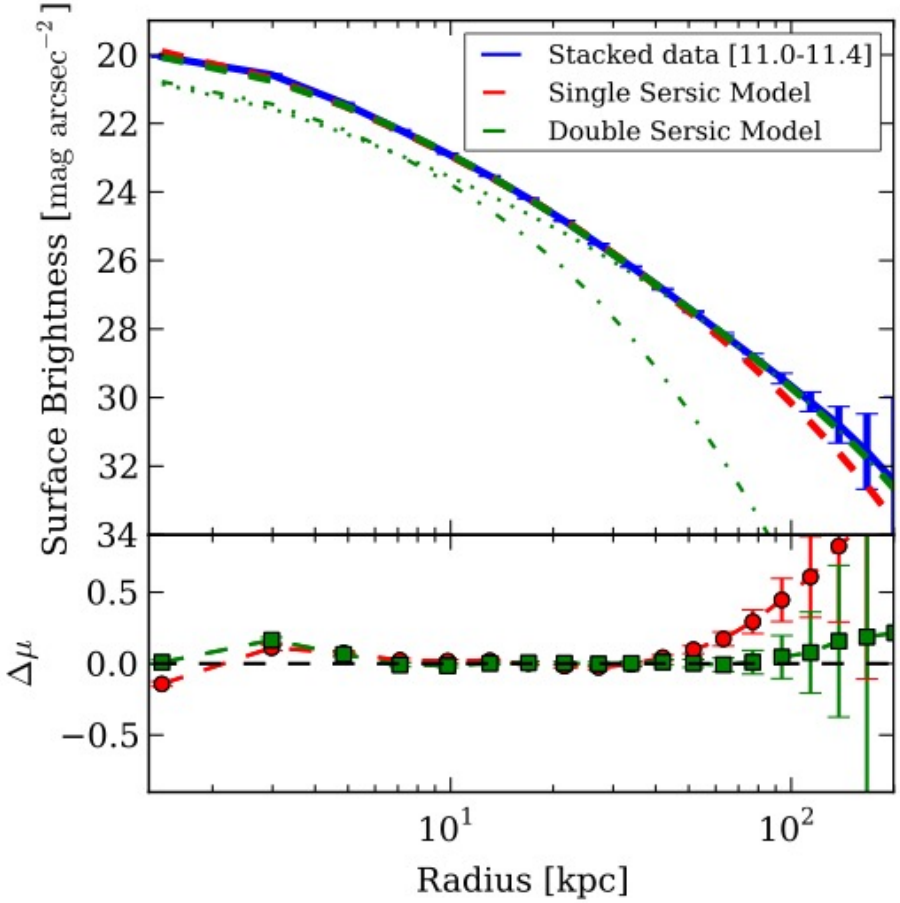
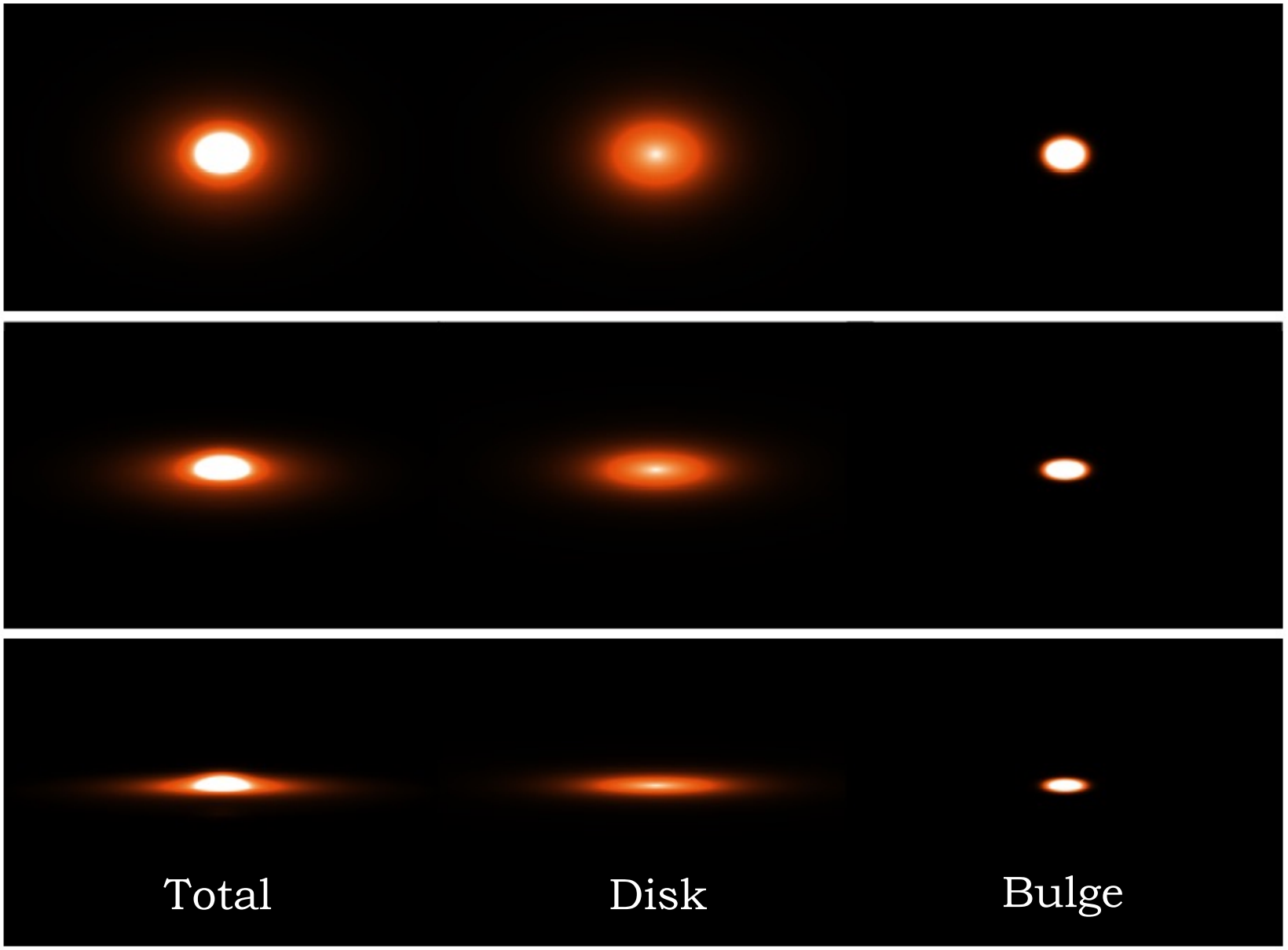




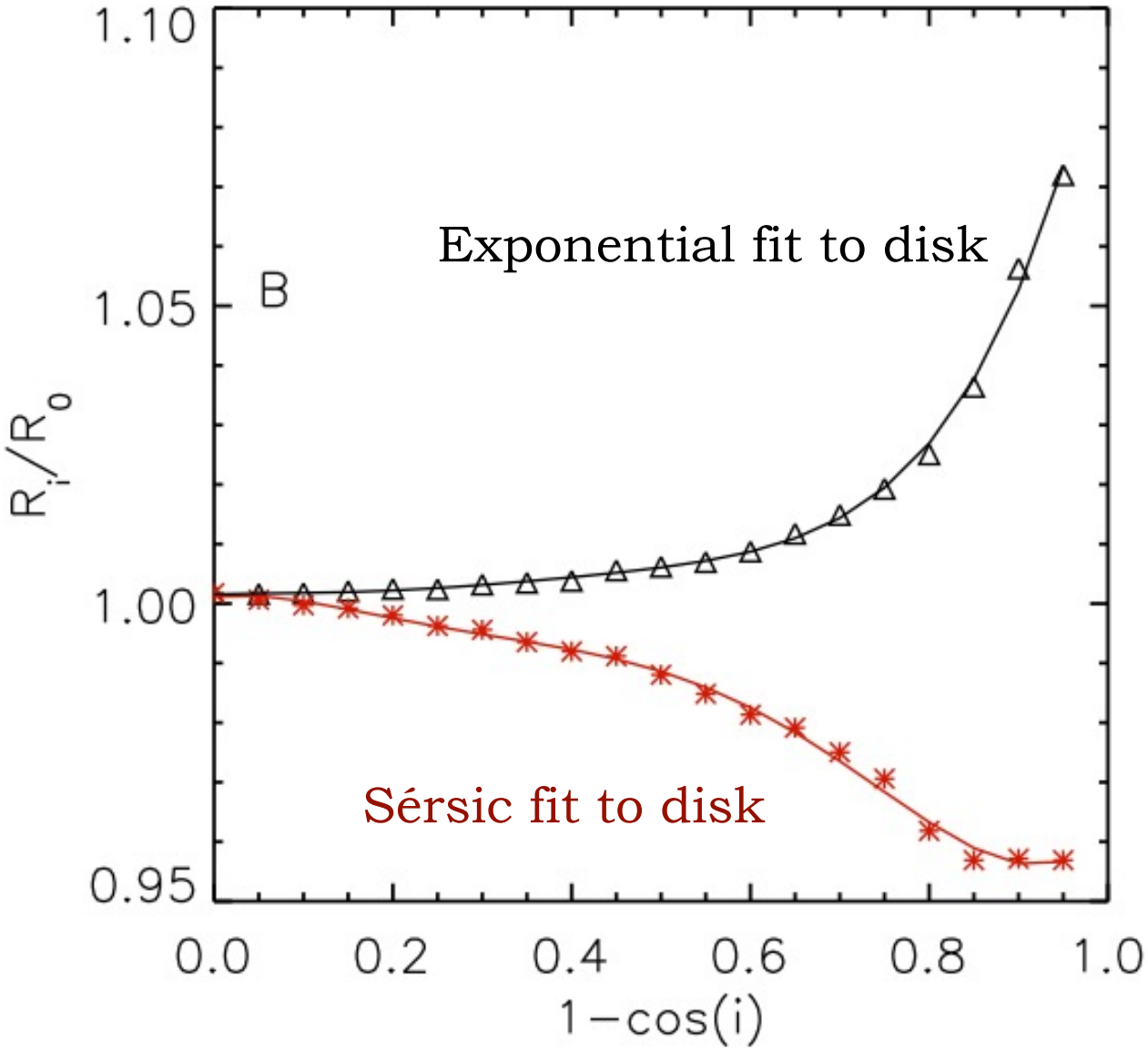
D'Souza+14

Mucky stuff



Bogdan+13a,b using RT models of Tuffs & Popescu

Projection effects



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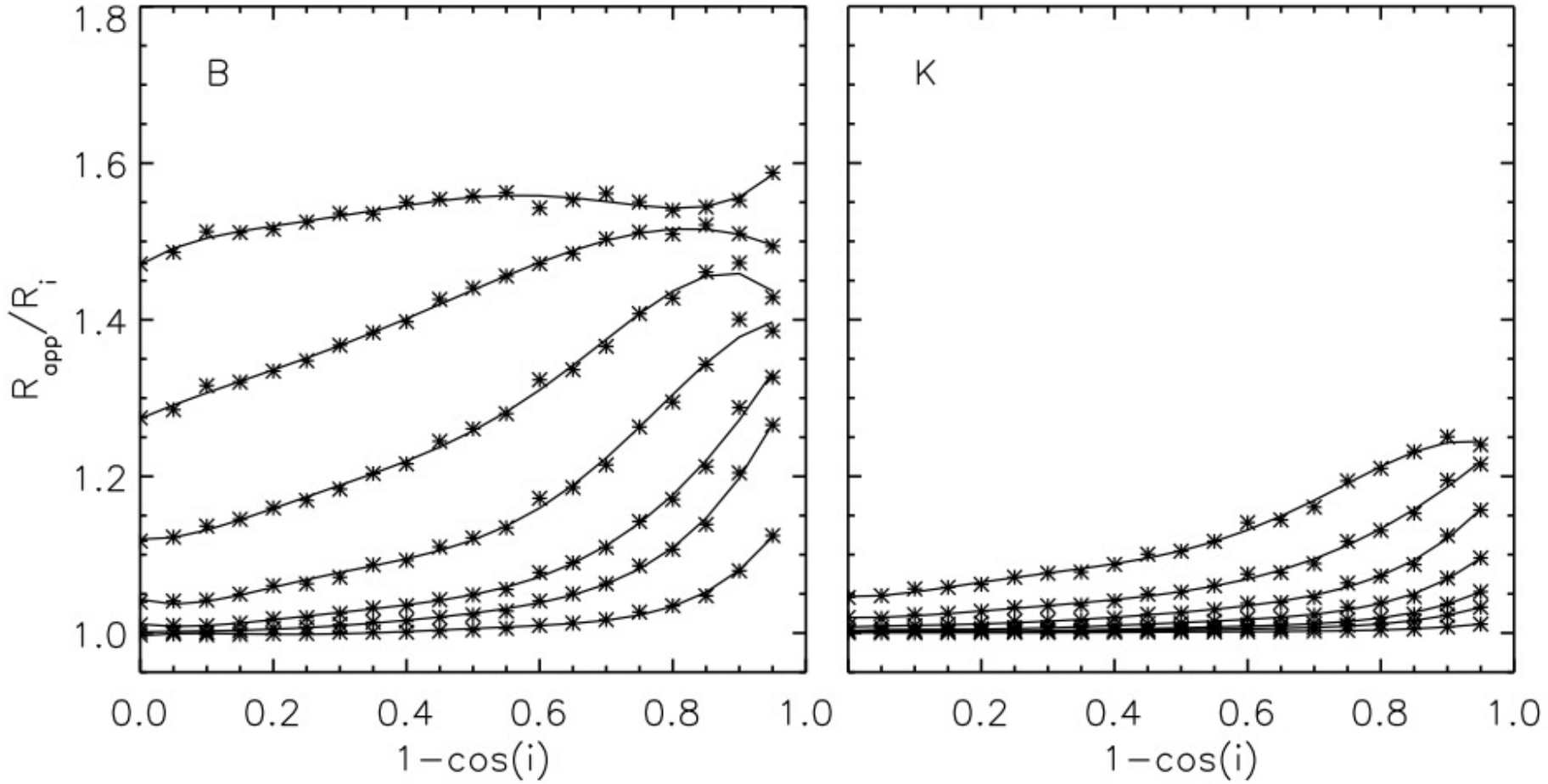
Extinction effects



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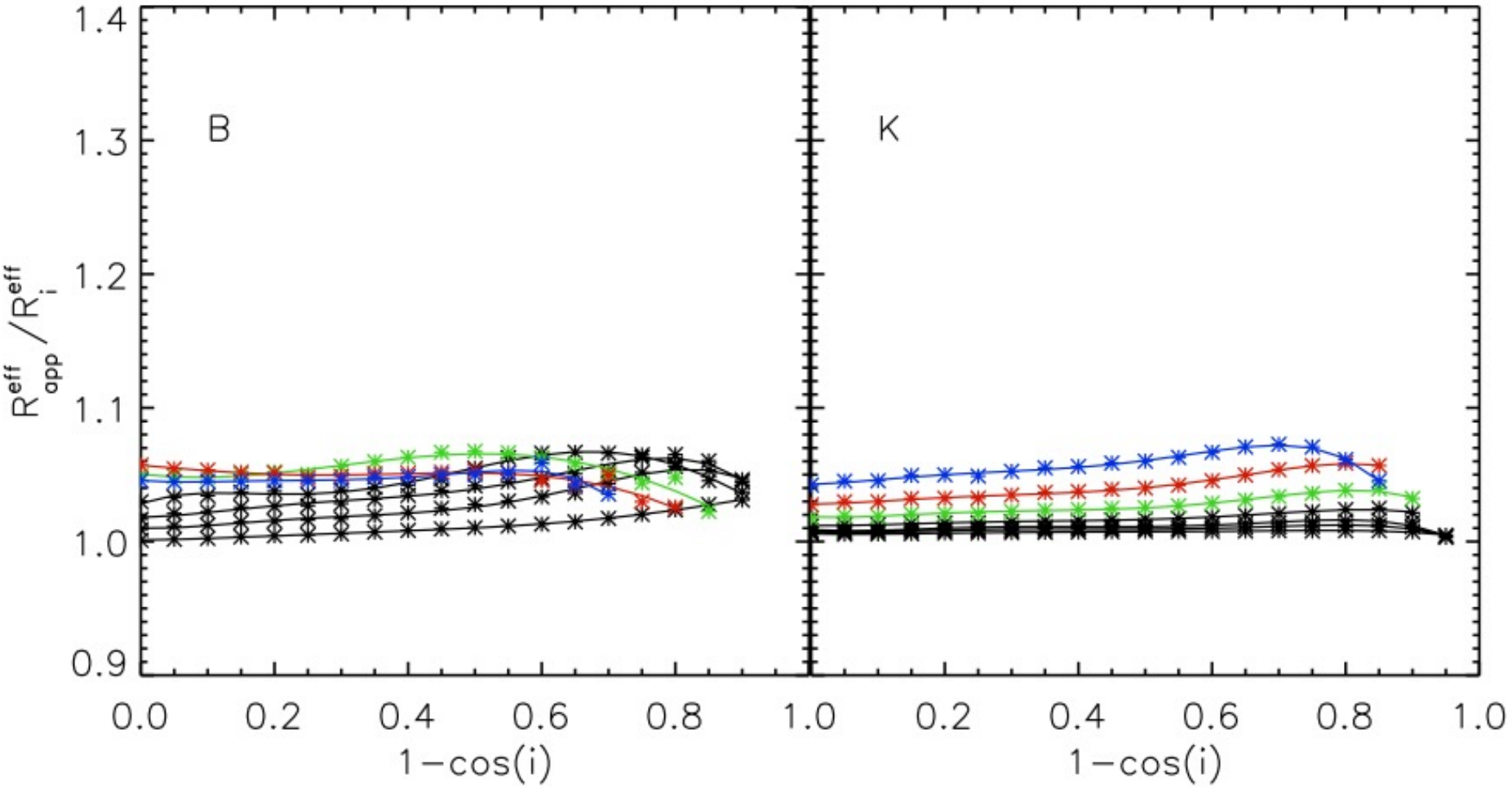

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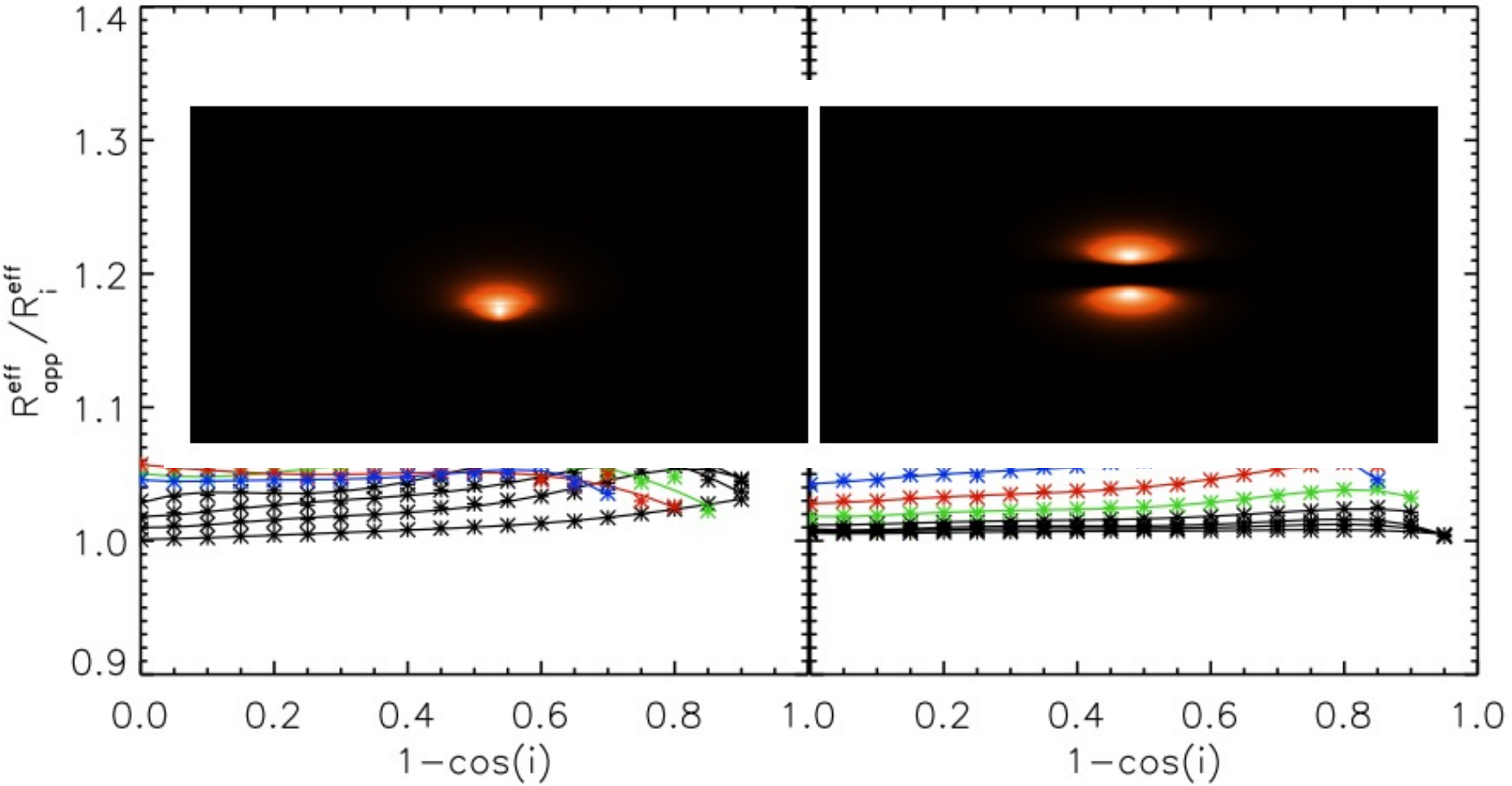

Bogdan+13a,b using RT models of Tuffs & Popescu

Measuring sizes

- Overall doing pretty well at total sizes
- Key studies are very careful
- Biases tend to reduce differences
- Robust redshift evolution (of measured sizes)
- Single-Sérsic (one-band) fits very successful
- Multi-component / higher-order looks better
- More subtle measurements required to distinguish evolutionary mechanisms

Questions

- Direct evidence that the blue outer flux in low-z ellipticals is due to accretion, rather than artefact of formation? Is it present in compact / high-z galaxies?
- Are higher-order Sersic profiles a good idea?
- Are multi-component ellipticals well-motivated?
- Are their more physically-motivated models we should be using?
- Can we identify reliably identify number and types of components from SB fitting?
- Is Monte Carlo sampling worth the trouble?
- What do we do about dust?