Structural Properties of Galaxies in the Local Universe

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Galaxy Formation and Evolution

- Theory: Different origins for bulges, disks, and pseudobulges -hierarchical merging, accretion, monolithic collapse and secular evolution (e.g. Cole et al 2000, Kormendy and Kennicutt 2004)
- ΛCDM: Mass- Luminosity, Spin-size-surface brightness -Dalcanton et al (1997), Mo et al (1998), Navarro and Steinmetz (2000), Bouwens and Silk (2004)
- High z surveys (e.g. GOODS, GEMS)
- Provide a representative, complete sample at low redshift
- Need to measure SB distribution but with something more quantitative than Hubble classes -Bulge-Disk decomposition
- Definitive Local calibration

HUDF: Credit: NASA, ESA, S. Beckwith (STScI) and the HUDF Team

The Millennium Galaxy Catalogue (MGC)

- 144 pointings at δ=0 (10h00m-14h50min)
- 37 sq degrees along an equatorial strip
- High Galactic Latitude
- B-band INT/WFC
- 0.333" pixels, FWHM ~ 1.2"
- 576 individual 2048x4100 CCD images
- 1M Galaxies to B=24

http://www.eso.org/~jliske/mgc

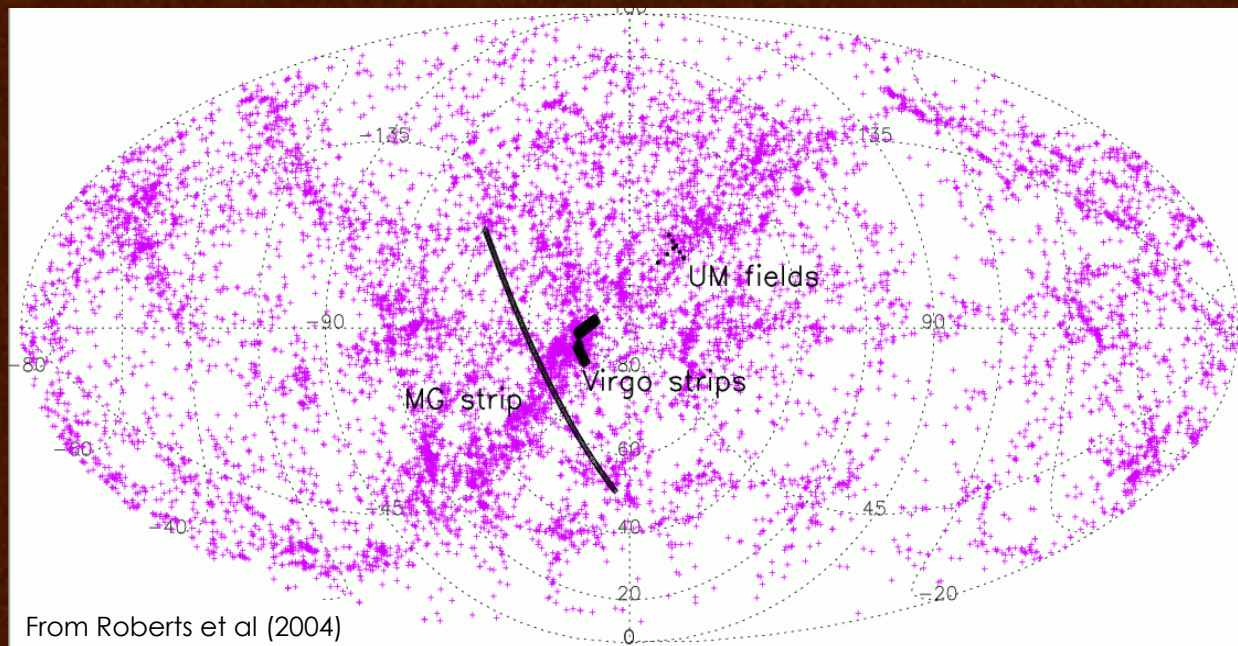
Liske et al (2003)

MNRAS 344, 307

Imaging

+

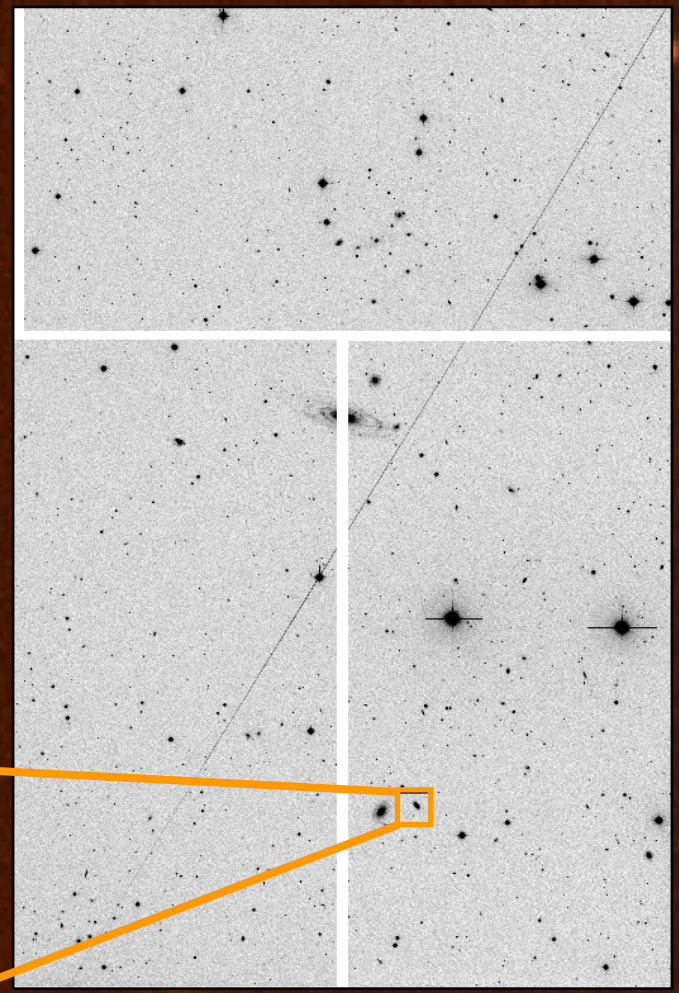
Spectroscopy

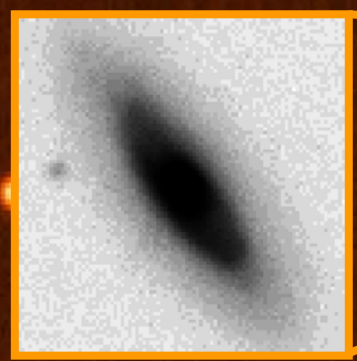


From Roberts et al (2004)

MGC Imaging

- B-band INT/WFC
  - limit μ_{lim}= 26 mags arsec^2
  - Use SExtractor for catalogue creation and photometry
  - Over 2 million detections
  - Star-galaxy separation to B=21
  - 10095 resolved galaxies to B=20
  - All objects to B<20 checked by eye
  - u'g'r'i'z' photometry from SDSS





B=16th mag

MGC Spectroscopy

- Pre-existing
  - 2dFGRS 3152
  - SDSS 1528
  - Others 72

4752

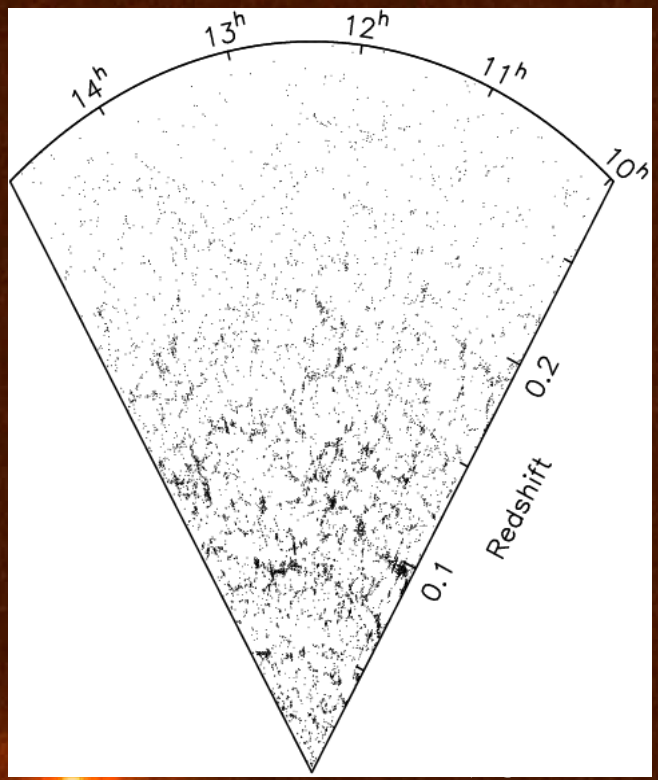
- MGCz
  - 2dF 4766
  - NTT 51
  - TNG 43
  - Gemini 4
  - RSAA 2.3m 80

4944

Total 9660 Redshifts out of 10095 objects (96.05% complete)

99.79% Complete to B=19.2

MGC Spectroscopy



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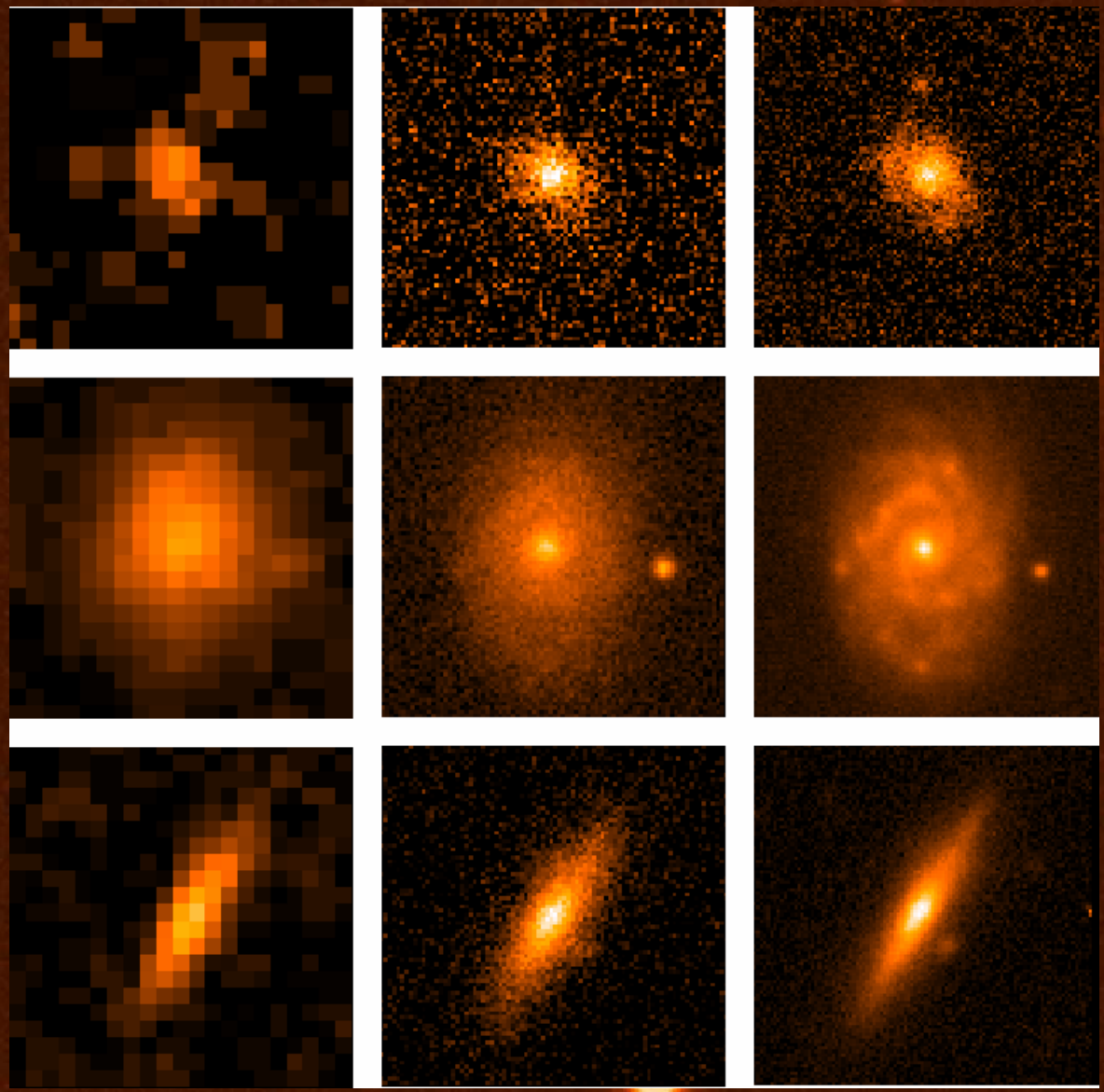
MGC
Millennium Galaxy Catalogue

THE MGC COMPARED

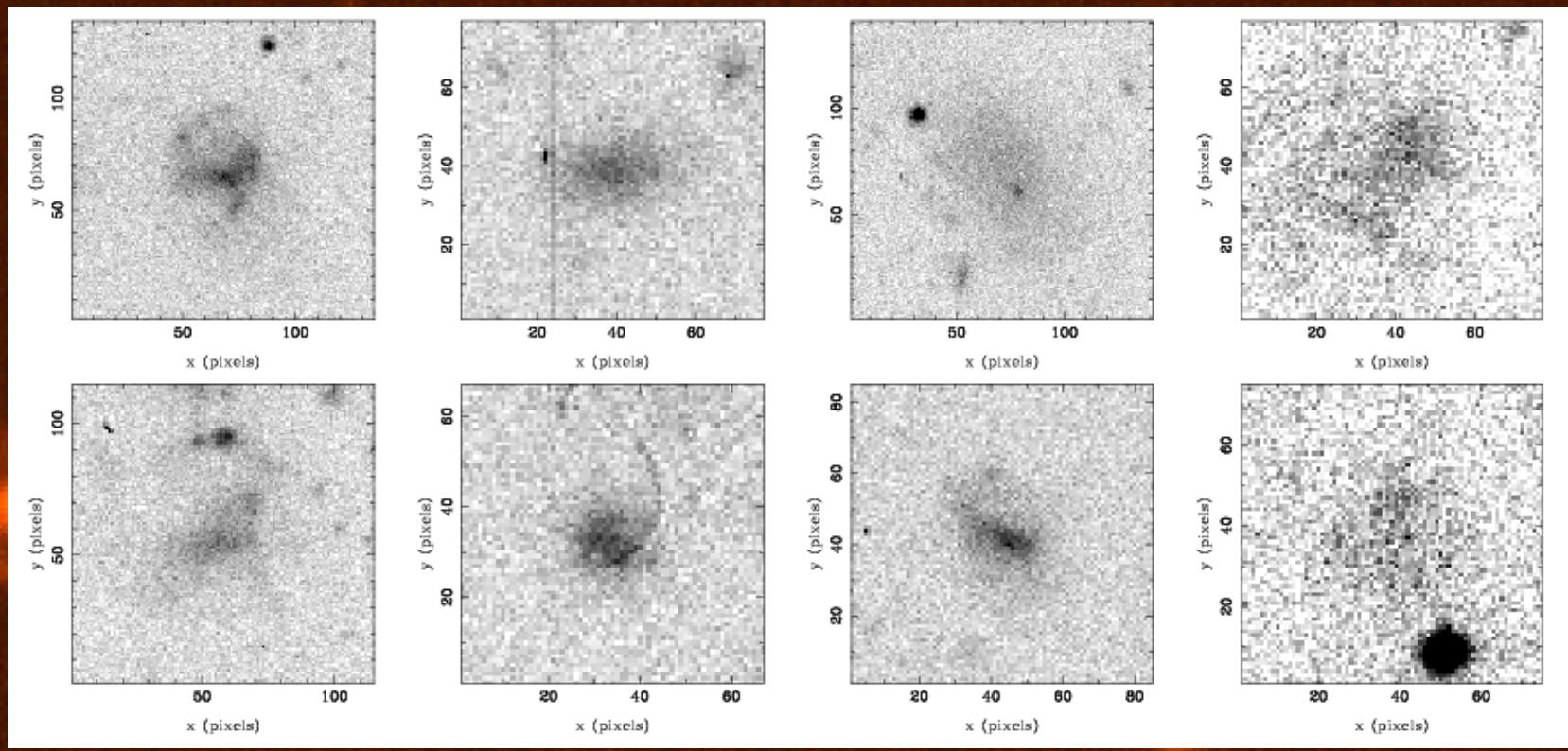
1) Depth and Resolution



MGC
Millennium Galaxy Catalogue

2) Low Surface Brightness Galaxies

- Many Objects that are not detected in SDSS
- Spectroscopy with Gemini/GMOS



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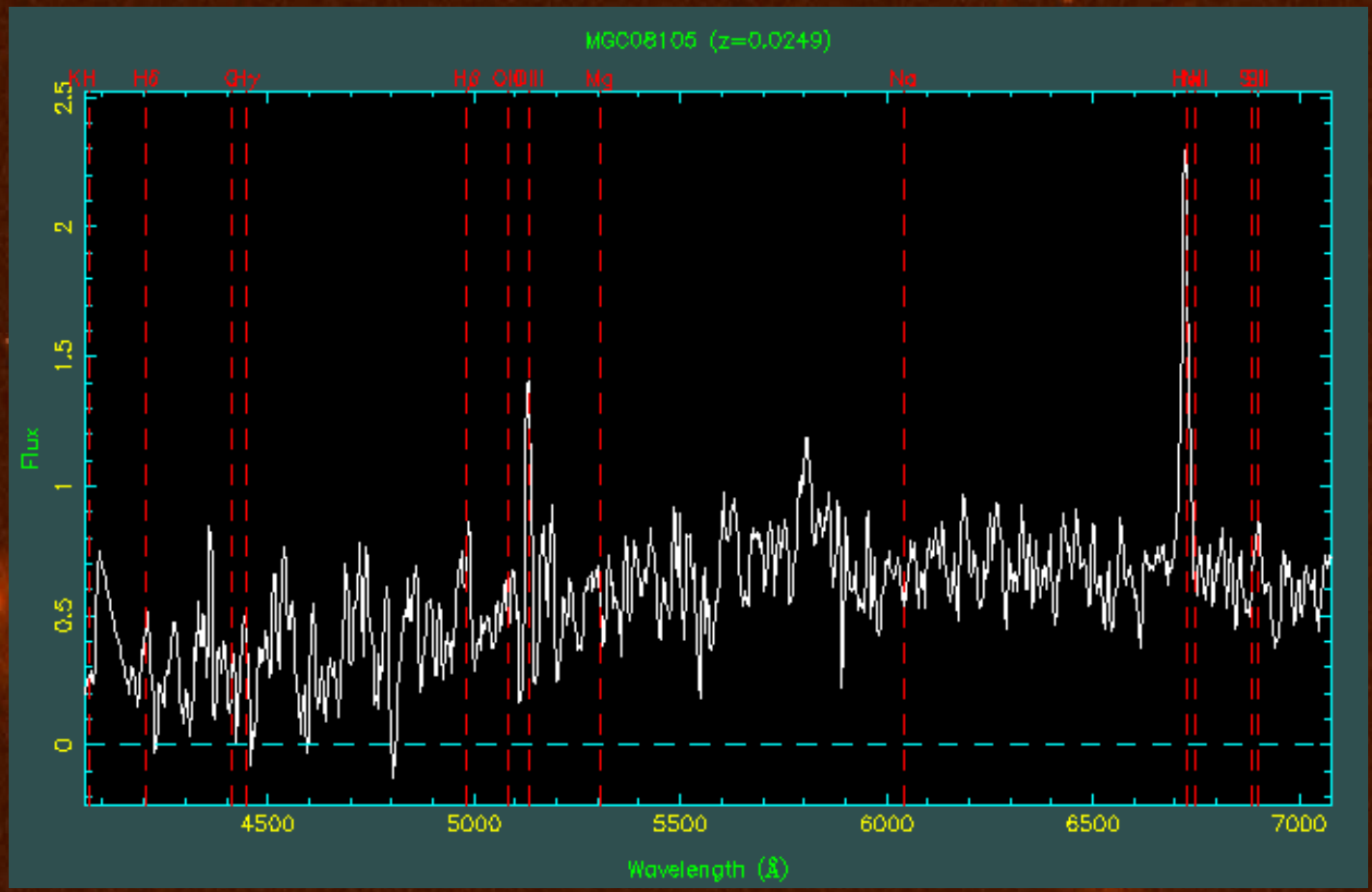
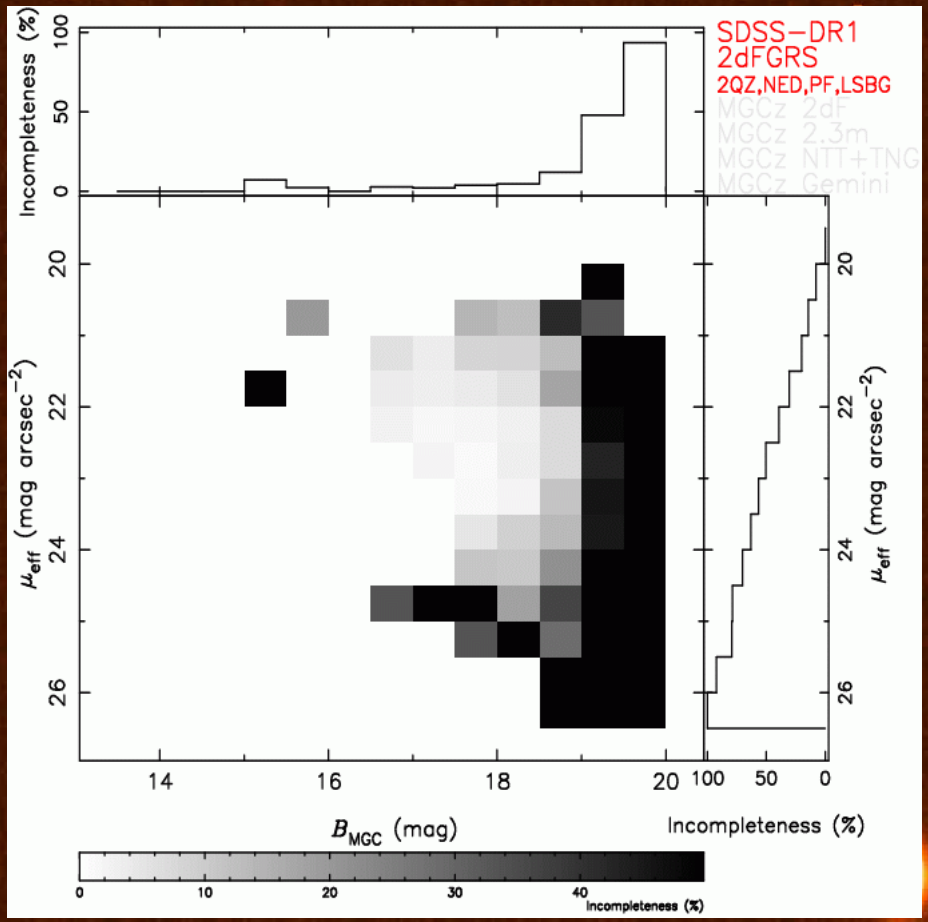


MGC
Millennium Galaxy Catalogue

3) Spectroscopic Completeness

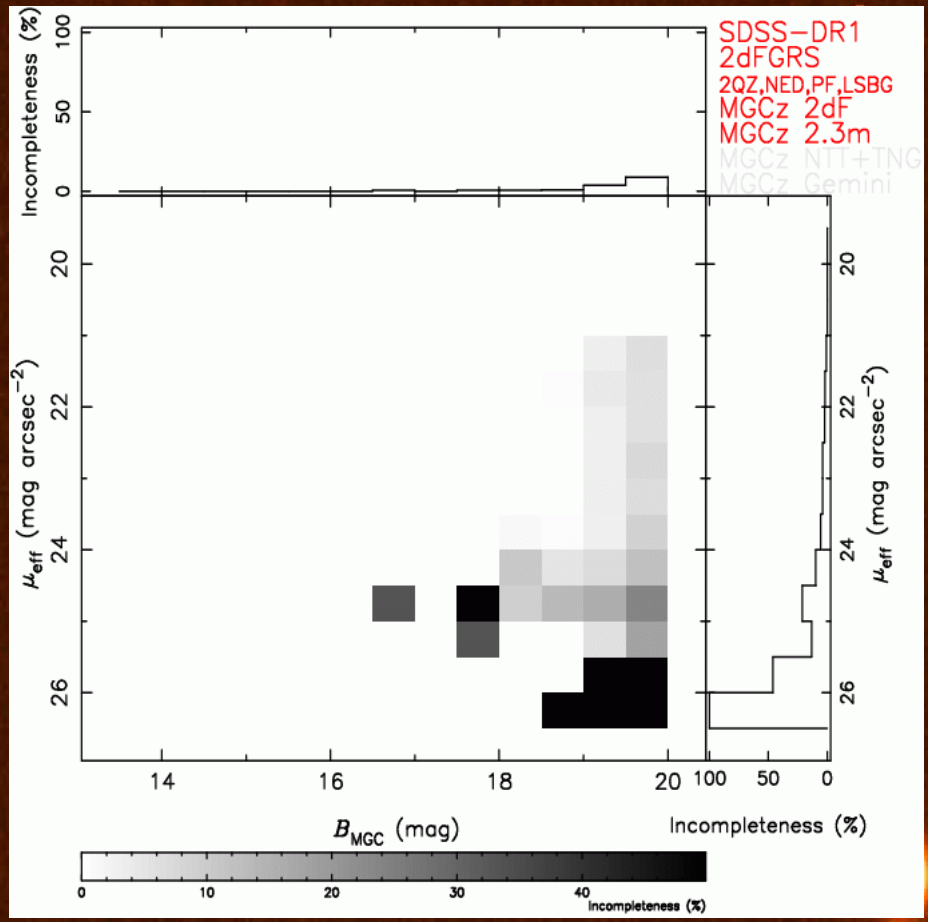
Pre-existing (mainly 2dFGRS +SDSS)



MGC
Millennium Galaxy Catalogue

3) Spectroscopic Completeness

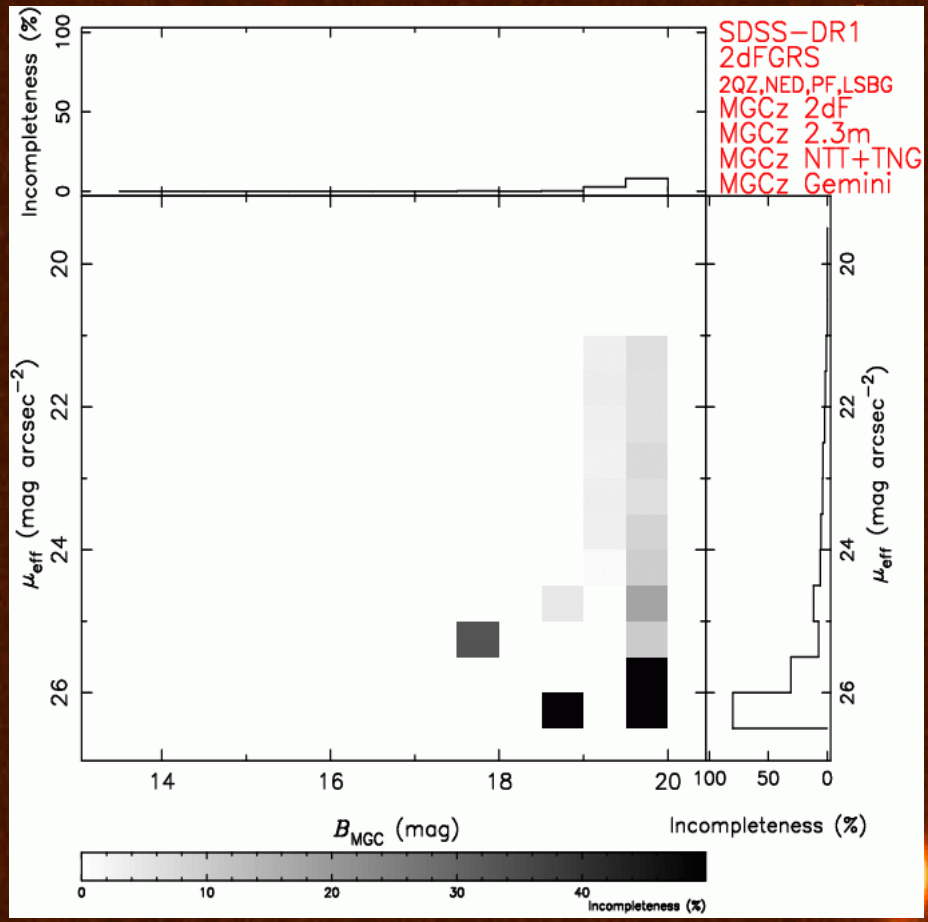
Pre-exisiting + MGCz (2dF + 2.3m)



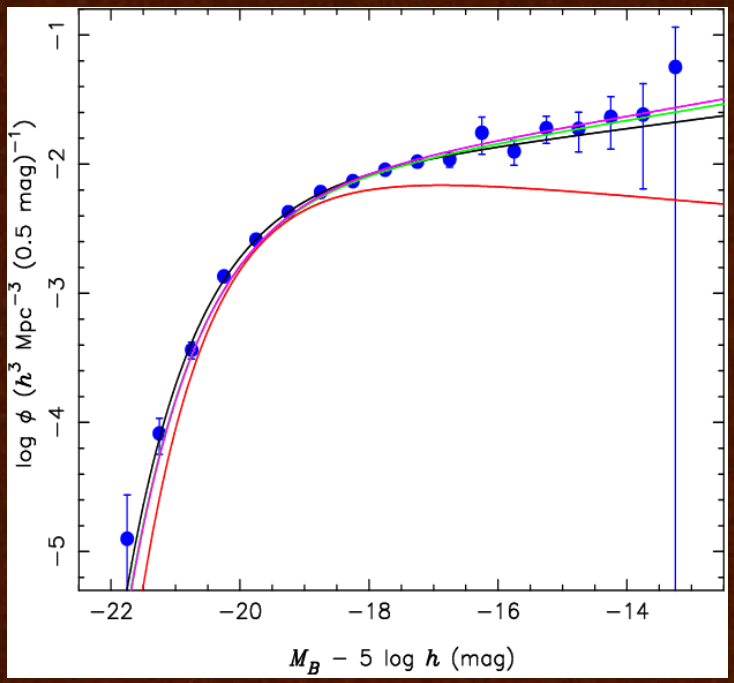
MGC
Millennium Galaxy Catalogue

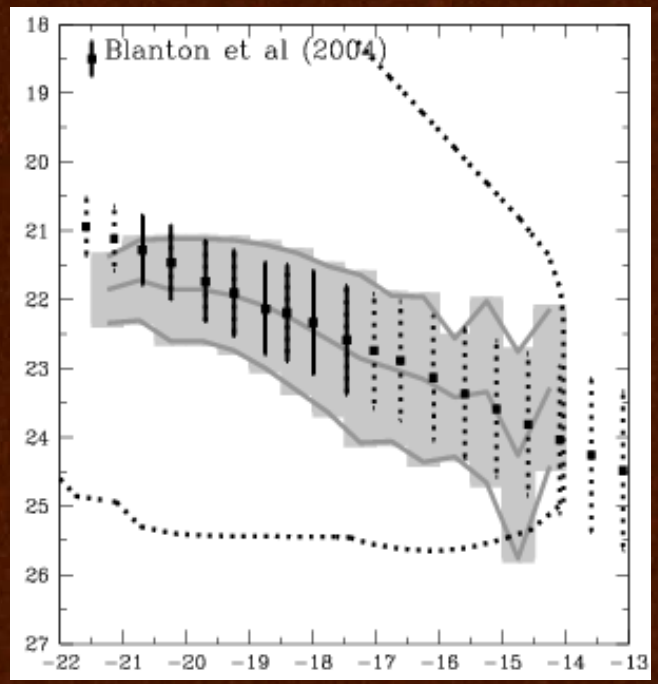
3) Spectroscopic Completeness

Pre-existing + MGCz (2dF + 2.3m + 4m + Gemini)



Luminosity Function and Bivariate Brightness Distributions





Driver et al (2005)

- Accurate luminosity functions and size distributions
- At M^* Σ_{lnR}=0.35, increasing to 0.5-0.7 at fainter mags
- Simulations (e.g. Bullock et al 2001)Σ_{lnR}=0.56

Bulge Disk Decomposition

- Using **GIM2D** (Simard et al., 2001)
- 2 Components
- 12 Parameters

  Flux, B/T

  x,y,back

  R_e,ellipticity, PA_{bulge}, n (bulge)

  h,inclination,PA_{disk} (disk)

$$B/T = \frac{L_B}{L_B + L_D}$$

$$I_b(r) = I_e \exp\{-b_n[(R/R_e)^{1/n} - 1]\}$$

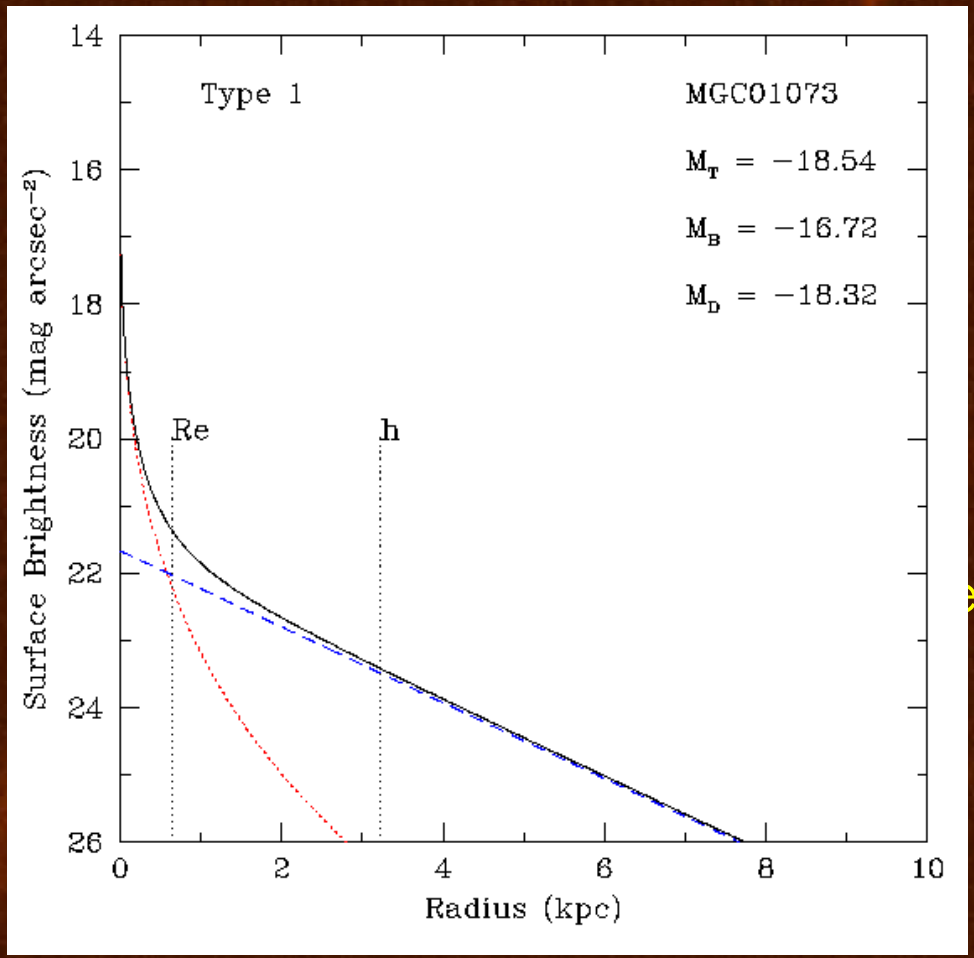
Sersic

$$I_d(R) = I_0 \exp(-R/h)$$

Exponential (n=1)

- Chi^2 minimisation + Metropolis algorithm

Bulge Disk Decomposition



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Exponential

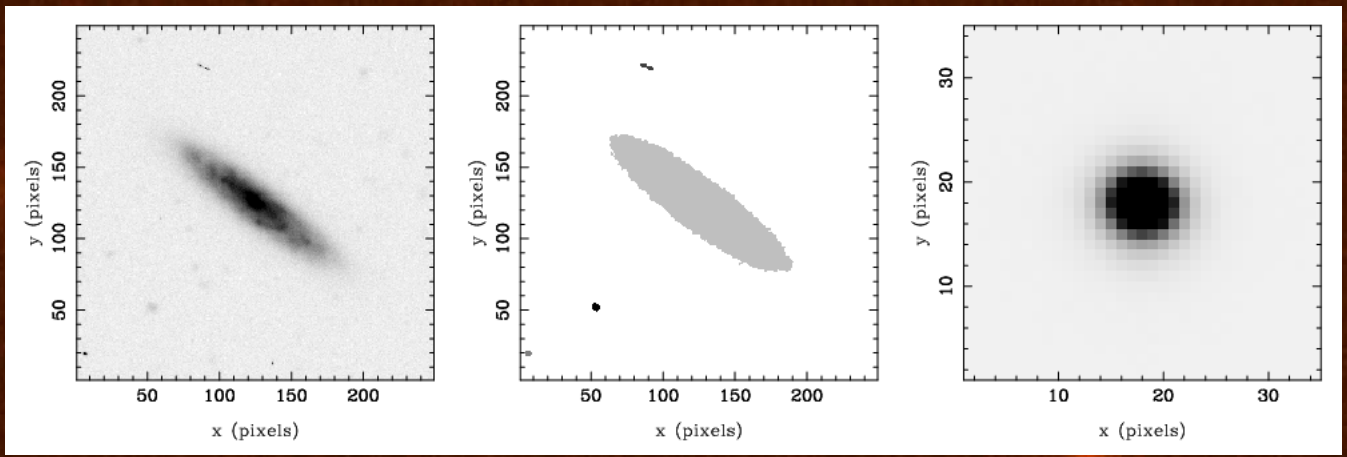
(n=1)

- Chi^2 minimisation + Metropolis algorithm

More about GIM2D

- Make postage stamps for each galaxy
- Make corresponding SExtractor segmentation images
- Model the PSF (PENNY2 function - Gaussian with Lorentzian wings) using stars in each frame & create a fake star at the location of each galaxy.

Image Mask PSF



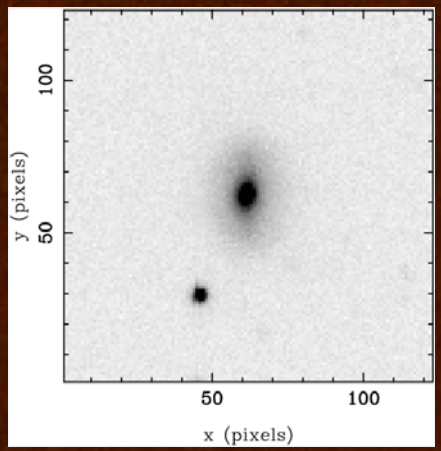
Structural Analysis of the MGC

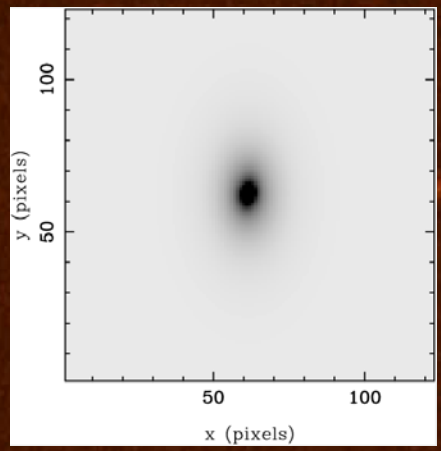
- Run GIM2D over all 10095 galaxies
- 3 models

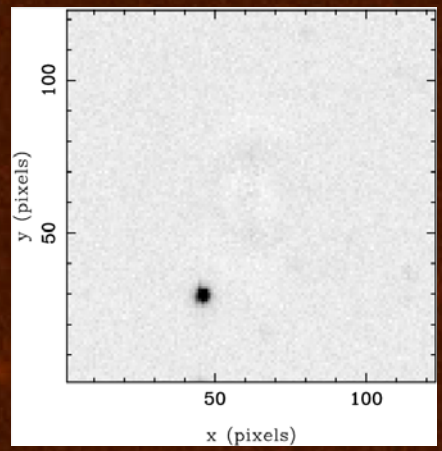
1) Sersic ($R^{1/n}$) Only - 1 component fit, fix B/T=1

2) $R^{1/4}$ + exponential - 2 component fit, fix n=4

3) Sersic ($R^{1/n}$) + exponential - 2 component fit







MGC59407

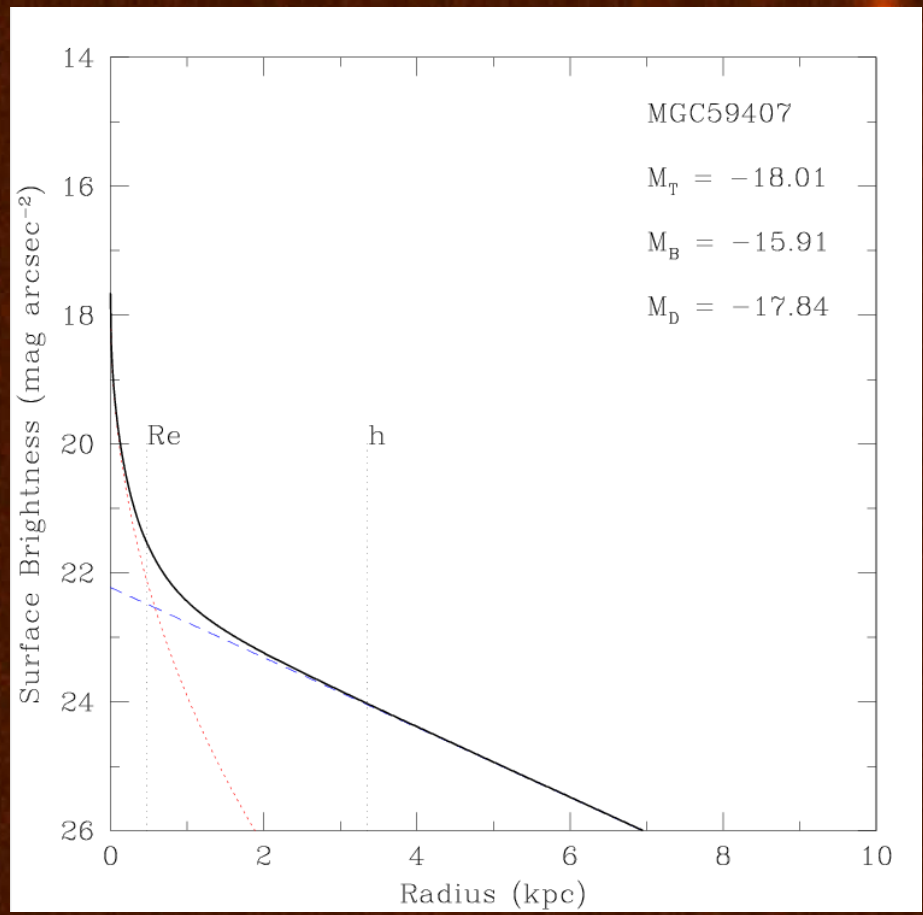
Sa Galaxy

B=18.2 z=0.05

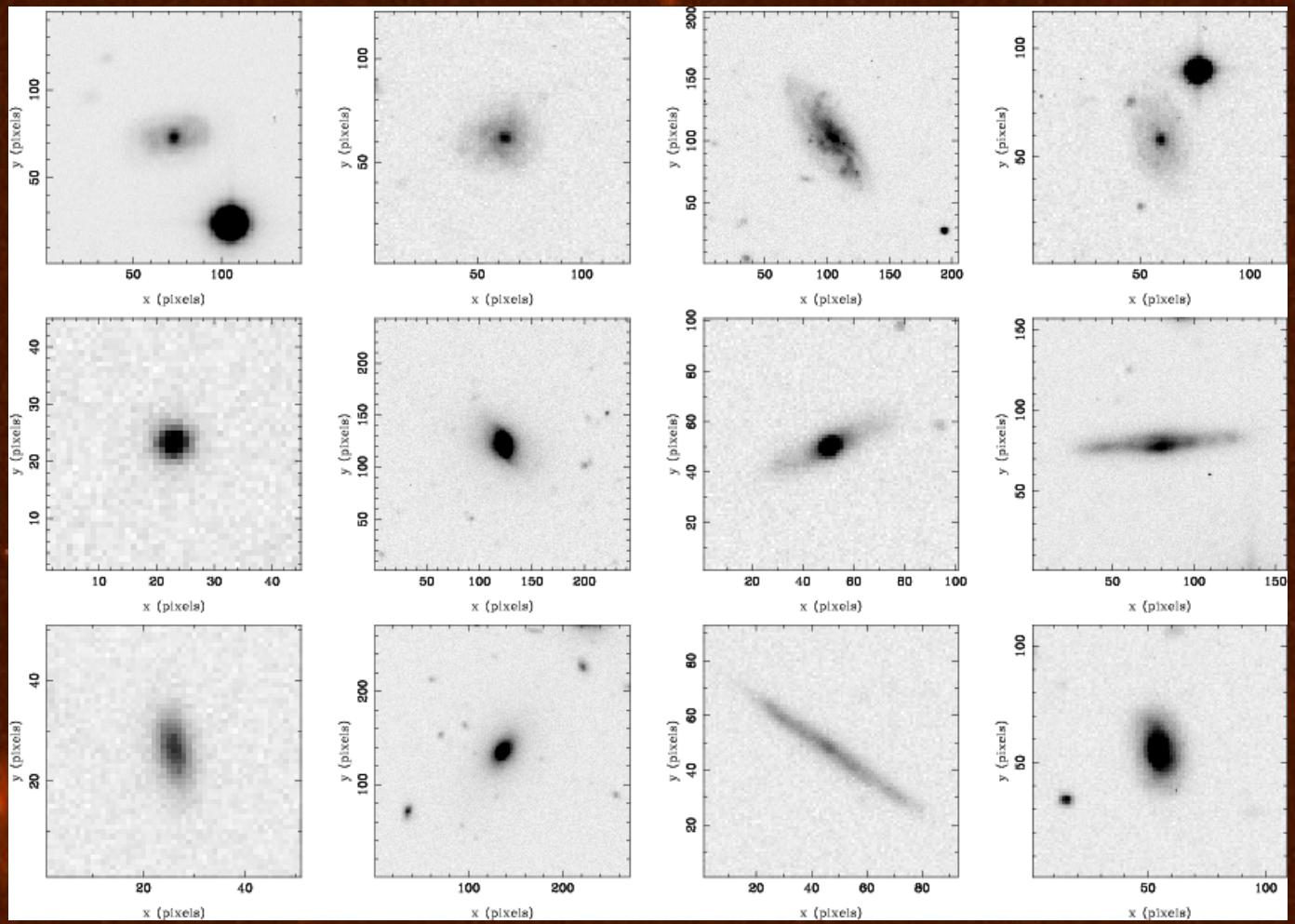
B/T=0.24

Sersic bulge, n=2.2

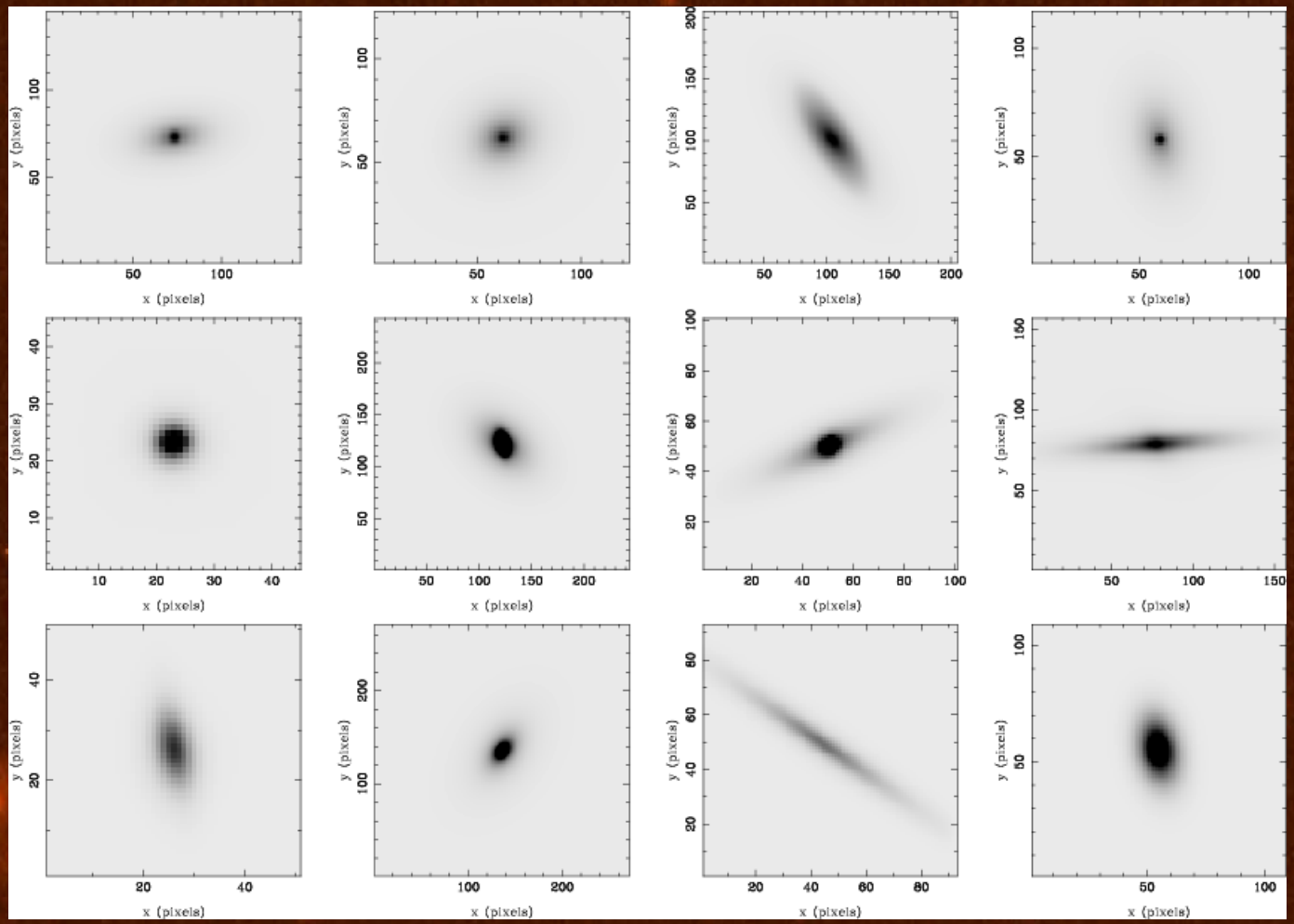
+ Exponential Disk



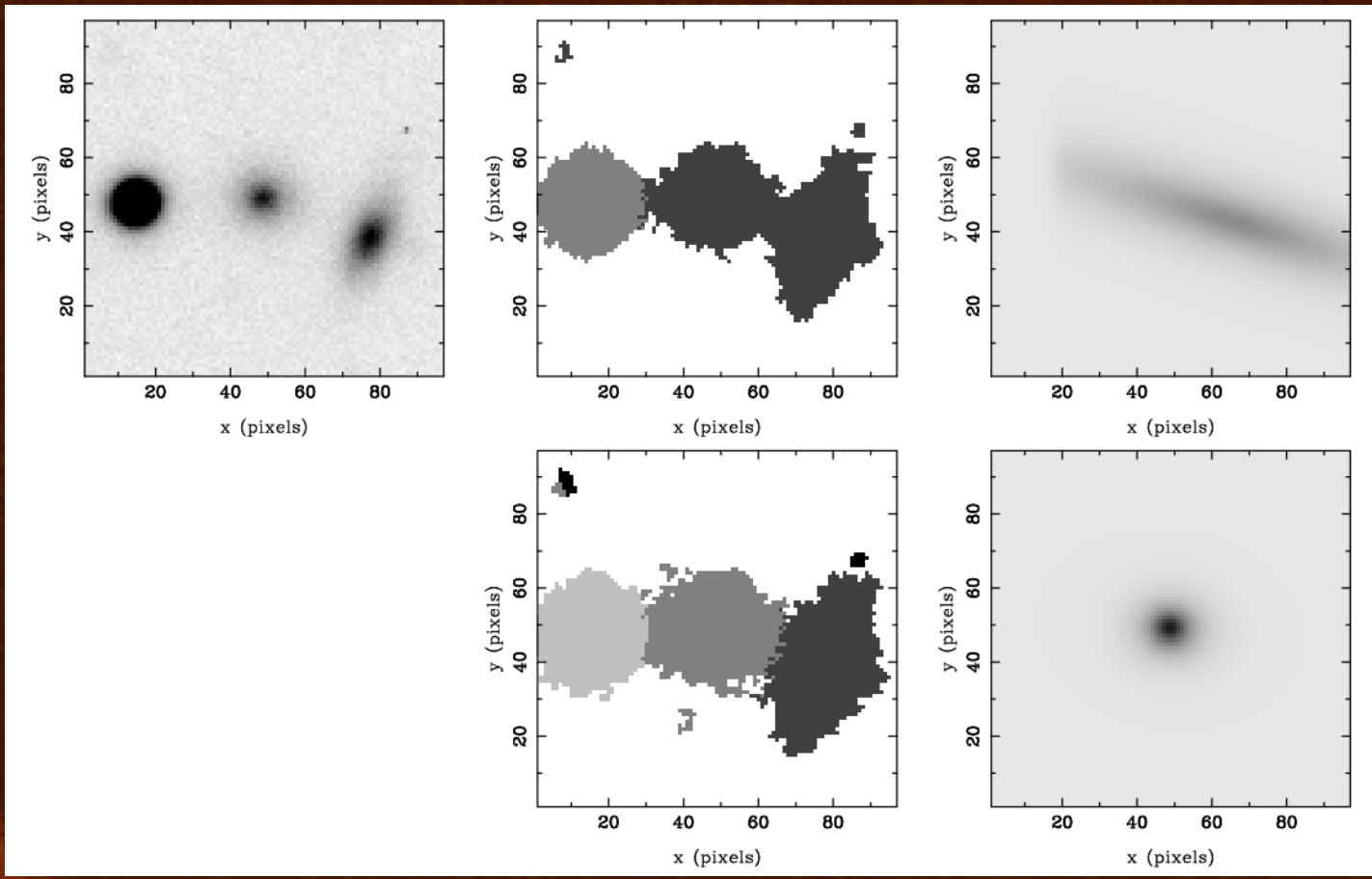
Data



Models



When Things Go (Horribly) Wrong!



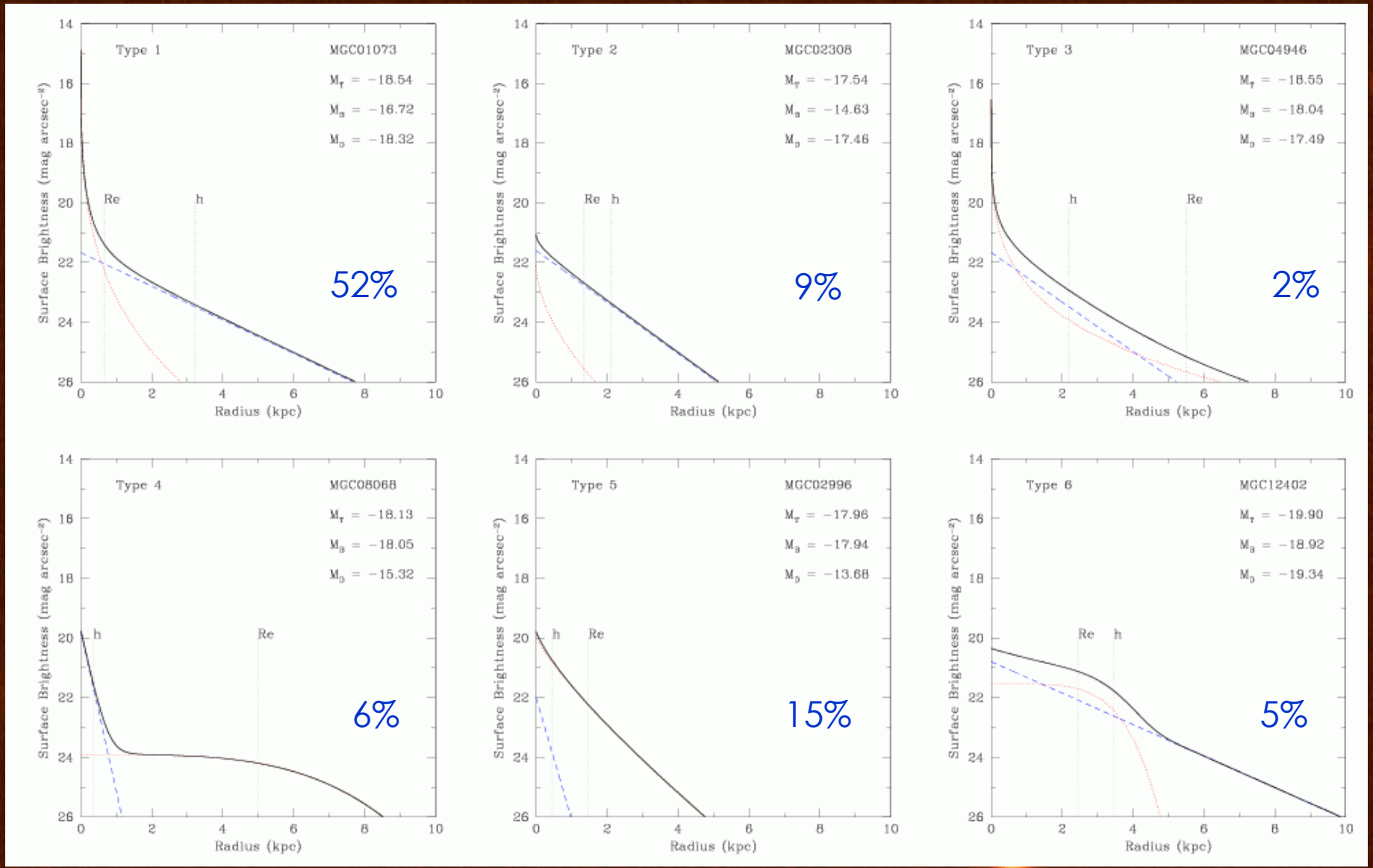
The perils of automated detection algorithms

Bad SExtractor segmentation images

800 Galaxies corrected

Interpreting GIM2D: Is a 'bulge' really a Bulge?

Apply a 'logical filter' to the output

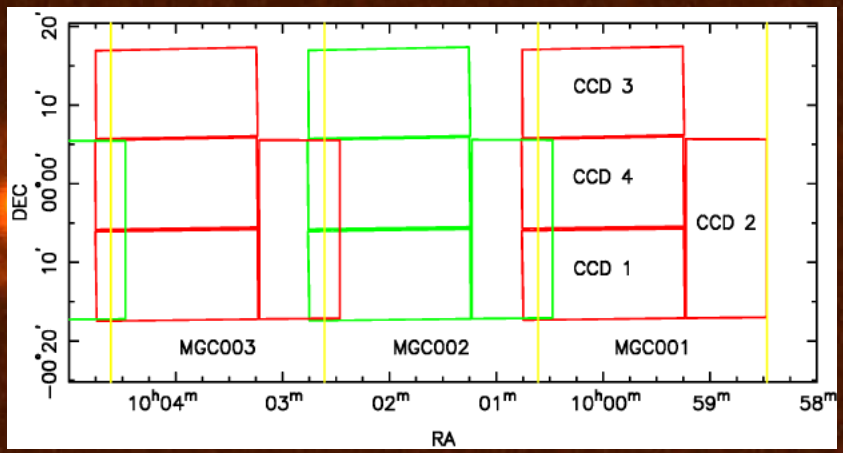


+12% single component

Repeatability and Accuracy

- How stable and repeatable are GIM2D measurements?
- Each pointing of the WFC overlaps every other by ~0.027 deg^2
- 702 Galaxies with two observations
- In every case the repeat is on a different CCD
- Different airmasses, seeing, sky brightness
- Sometimes different nights or even observing runs

TOTALLY DIFFERENT PSFs !



- Rerun SExtractor for overlap regions
- Make new PSFs
- Rerun GIM2D

Sersic + Exponential

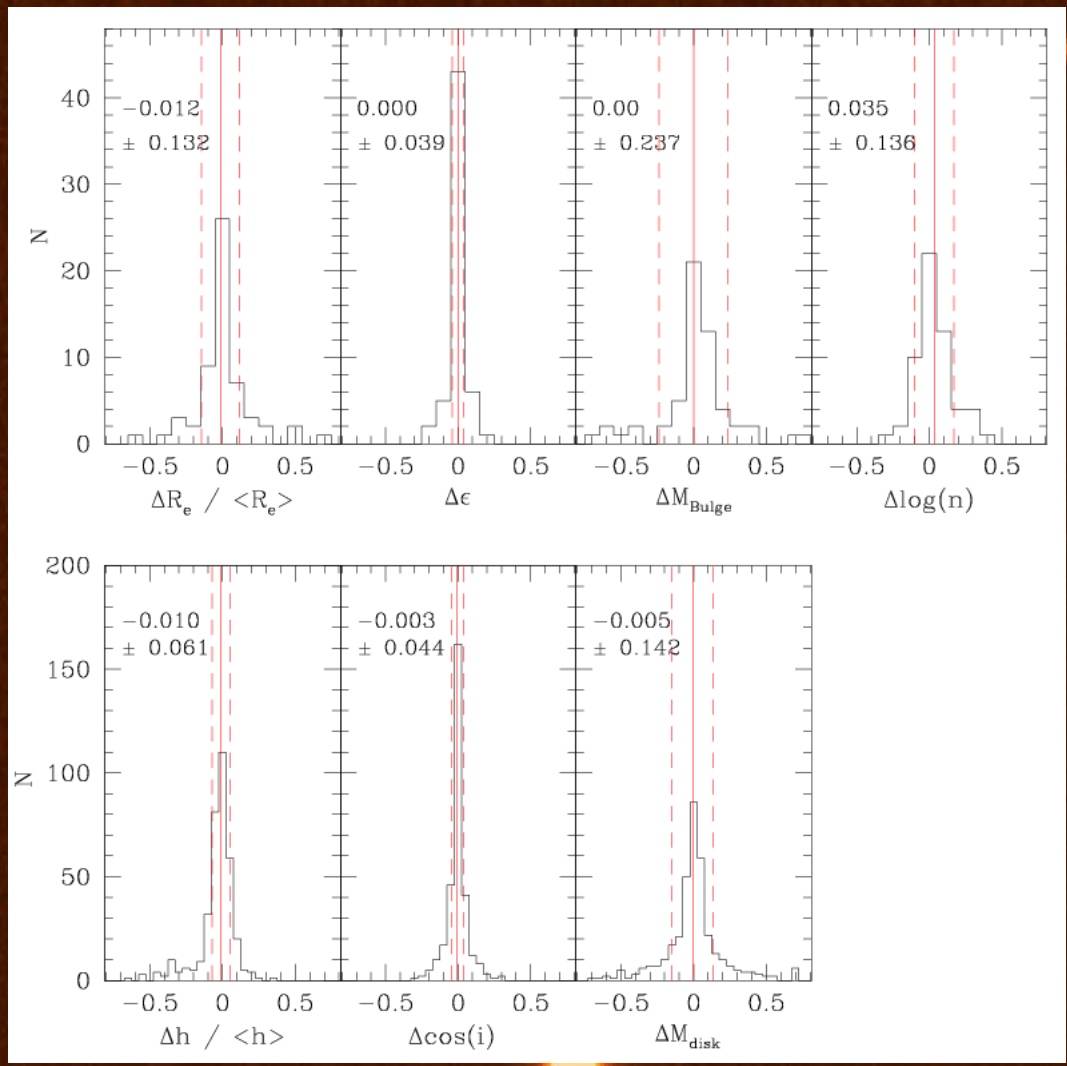
Make Cuts

hlr > 0.8 x seeing

$$R_e > 0.8 \times \Gamma$$

$$1.678h > 0.8 \times \Gamma$$

- Bulges
  - R_e, log(n) ~14%
  - M_{bulge} ~0.24 mags
- Disks
  - h, cos(i) ~6%
  - M_{disk} ~ 0.14 mags



Sersic Only

Make Cuts

hlr > 0.8 x seeing

$$R_e > 0.8 \times \Gamma$$

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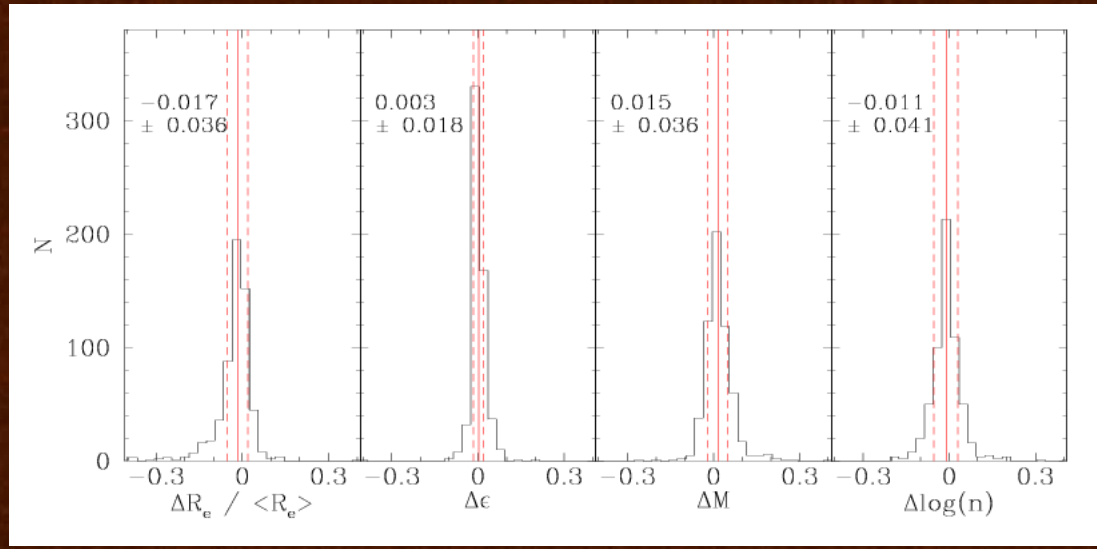
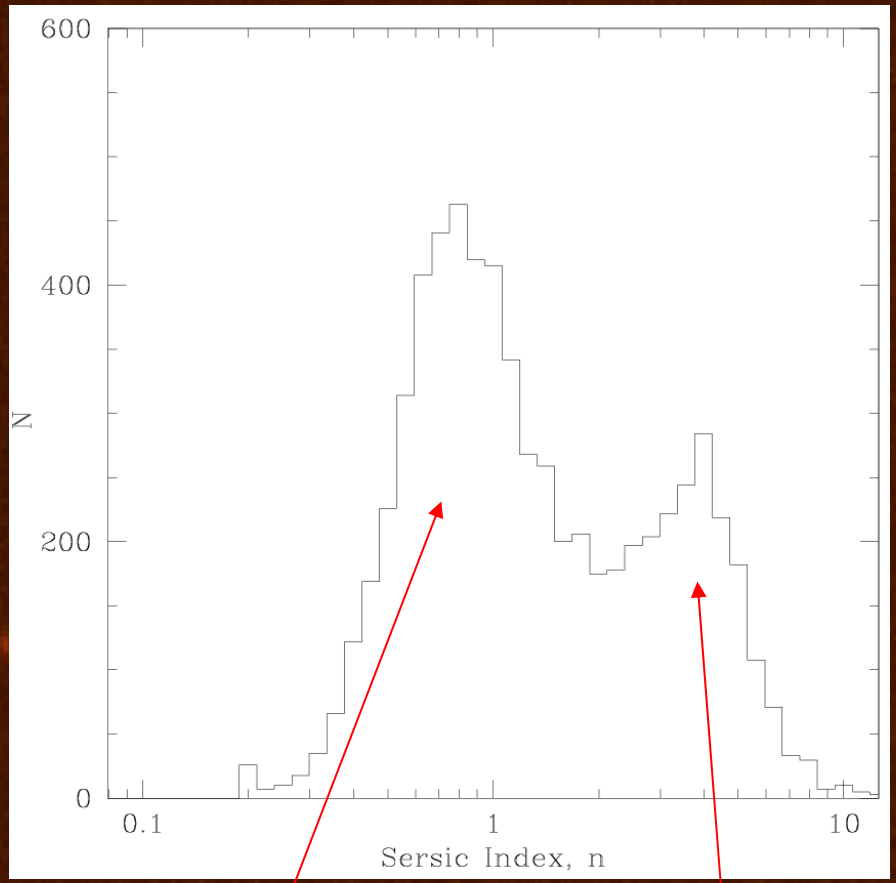


- Single Component

  all parameters < 4%

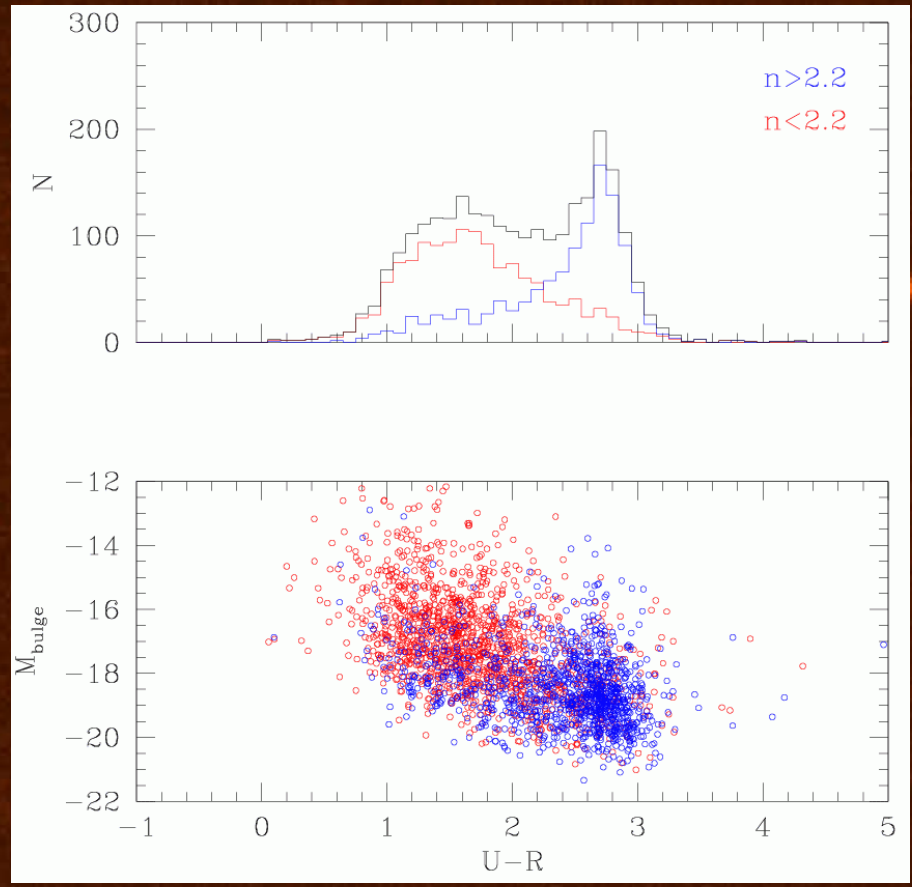
  M ~ 0.04 mags



disks

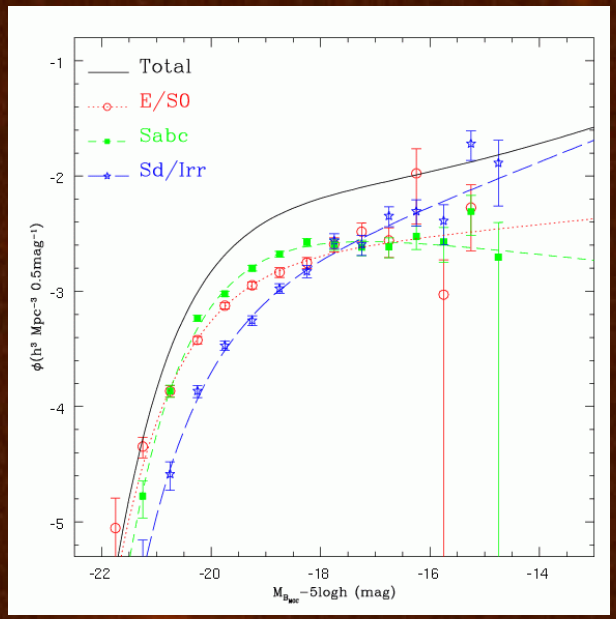
ellipticals

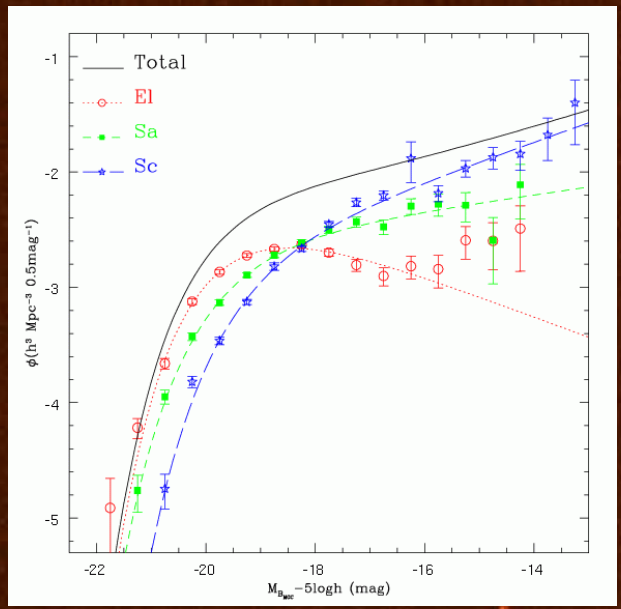
Distribution of Sersic indices.



- Bulges bimodal in colour, surface brightness, and Sersic index, n
- Classical high surface brightness, red population
- Blue lower surface brightness population (pseudobulges)

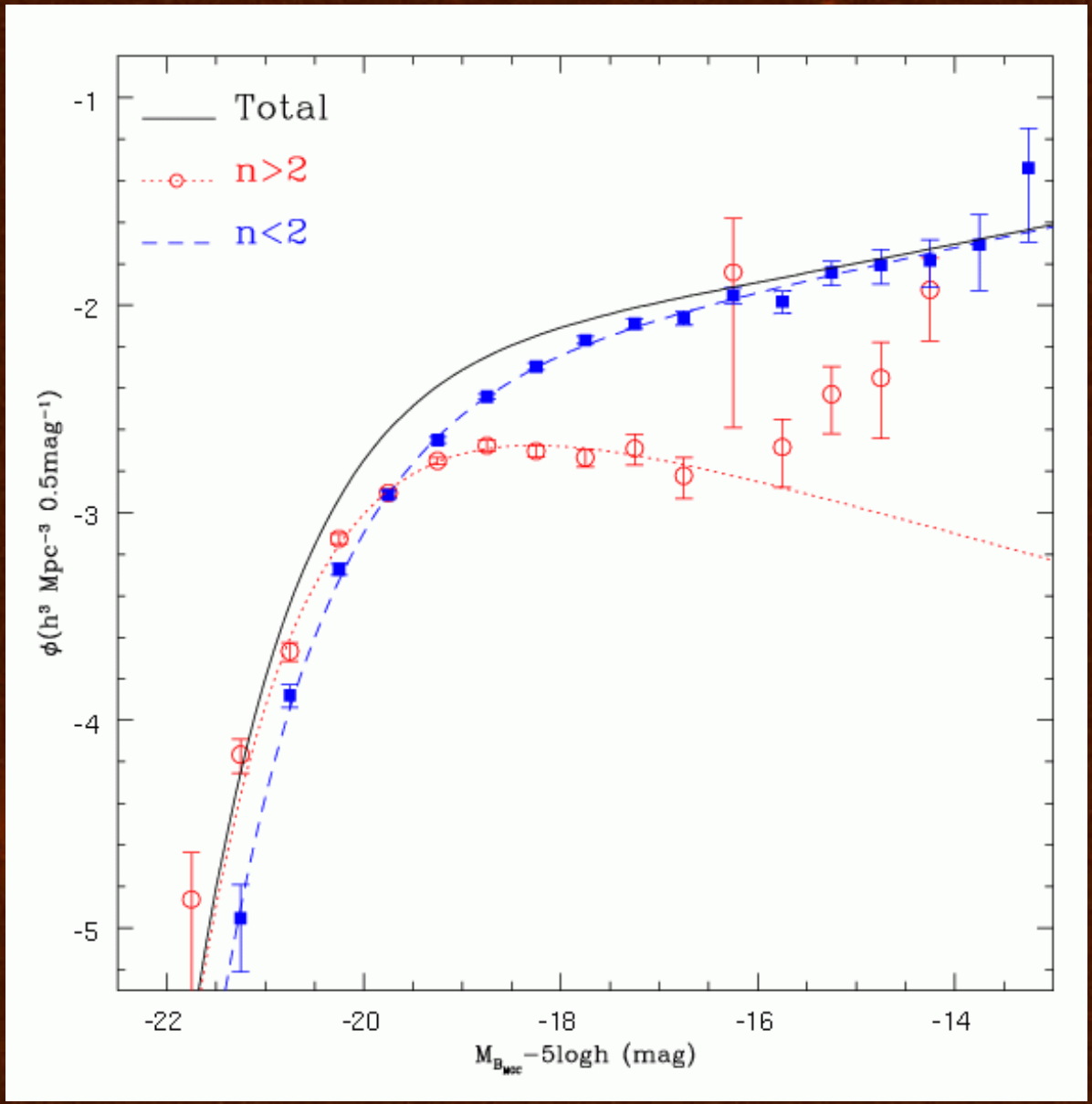
Component Luminosity Functions?





- Bulges bimodal in colour, surface brightness, and Sersic index, n.
- Luminosity Functions for Bulges, Blue (pseudo-)bulges and Disks
- Disks 80%, Bulges 17%, Pseudobulges 3% by light

Component Luminosity Functions?



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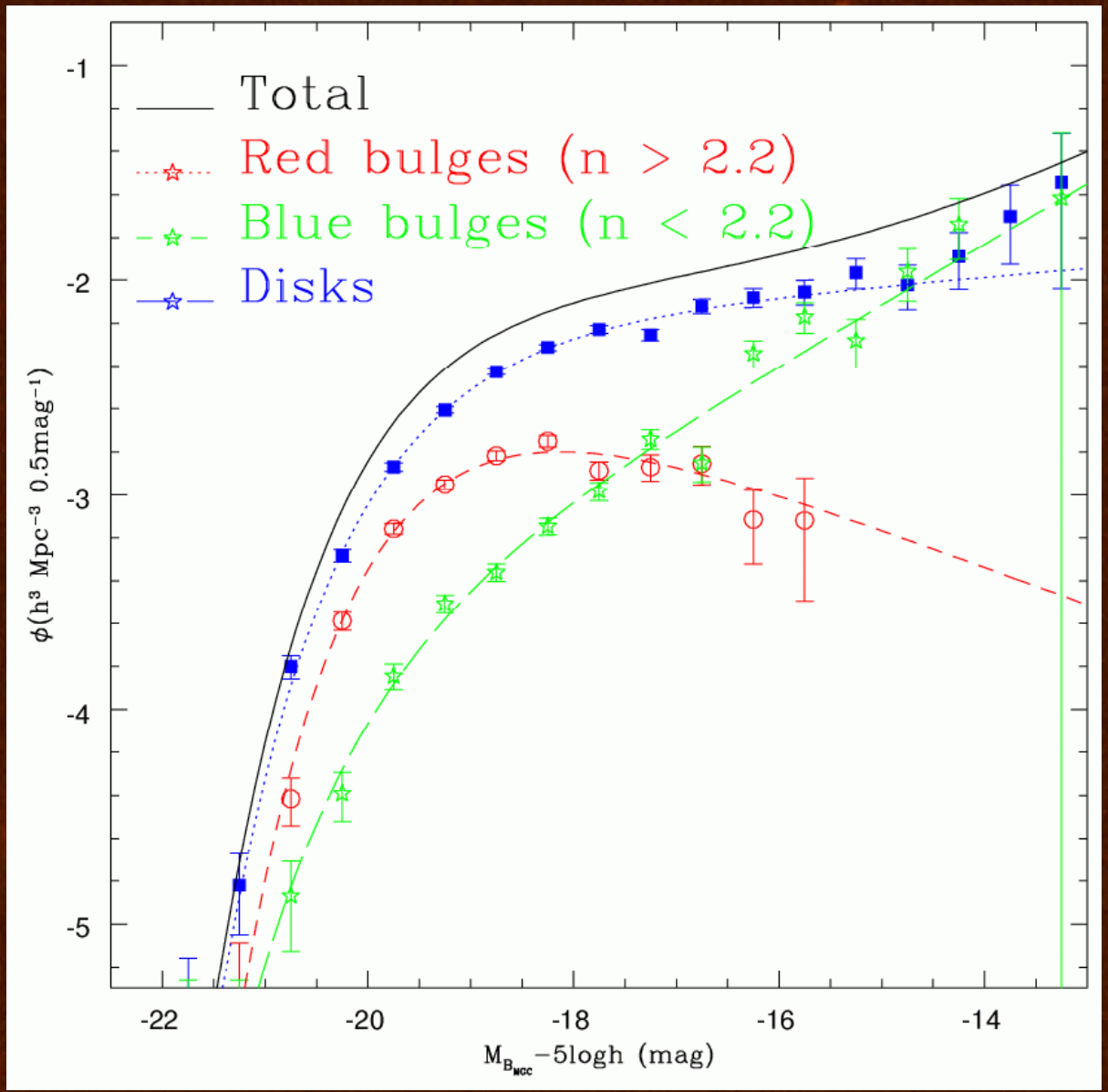

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Summary

- MGC: deep imaging and redshifts for 10095 galaxies
  - smaller area but deeper (~2 mags arcsec^2), high resolution and much more complete than SDSS
  - Public - http://www.eso.org/~jliske/mgc
- Bulge/disk decomposition:

  bulges ~14% repeatability

  disks ~6%
- Sersic only fits ~4%
- **Largest and most complete database of galaxy bulge and disk structural parameters in the local Universe!**
- 3 Components clearly identified -Disks, Blue Bulges, and Red Bulges => Luminosity Functions and BBDs