MGC

Millennium Galaxy Catalogue

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Mount Stromlo Observatory

Overview

- The Millennium Galaxy Catalogue
  - http://www.eso.org/jliske/mgc/
- The Galaxy Luminosity Function (The Space Density of Galaxies)
  - 2dFGRS v SLOAN Luminosity Function
  - Understanding Selection Bias
  - Getting the Luminosity Function Right
- Beyond the Luminosity Function
  - Morphological Madness
  - Colour Distributions
  - Bulge-Disk Decomposition
  - Tie-in to CDM ?
- Future directions
  - Deciphering Galaxy Evolution
  - Dwarf hunting (AAOmega)
  - Starting over (Non-linear PCA, ANNs, and group finding in catalogue space)
  - The near-IR (UKIRT, VISTA, JWST)

MGC

Millennium Galaxy Catalogue

Driver[PI], Allen, Graham (RSAA)
Liske (ESO), Cross (JHU), De Propris, Ellis (AAO)
[Phillipps (Bristol), Couch (UNSW), Conselice (CalTech), Davies (Cardiff), Drinkwater (UQLD), Horne (St And), Jerjen (RSAA), Ryder (AAO), Peacock (ROE), Wyse (JHU)]

Aims:

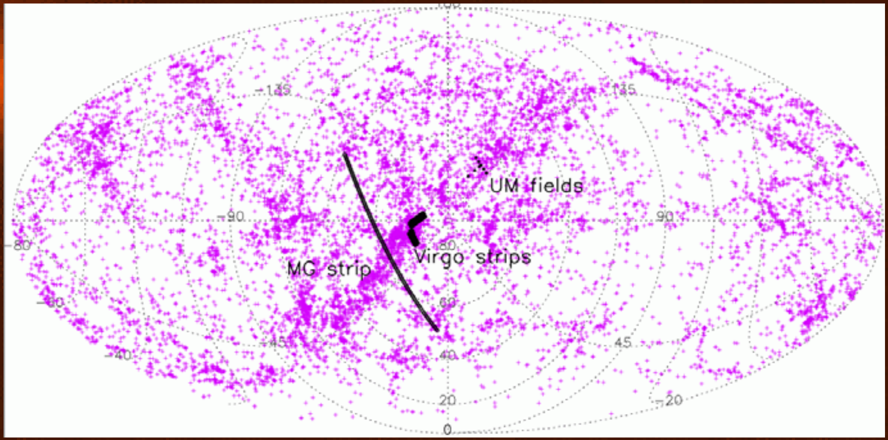
- To revise local calibration data (in advance of ACS/GOODs and JWST)
- To manage selection effects throughout (observation, detection and analysis phases)
- To identify new meaningful ways to represent galaxies: The LSP and CD

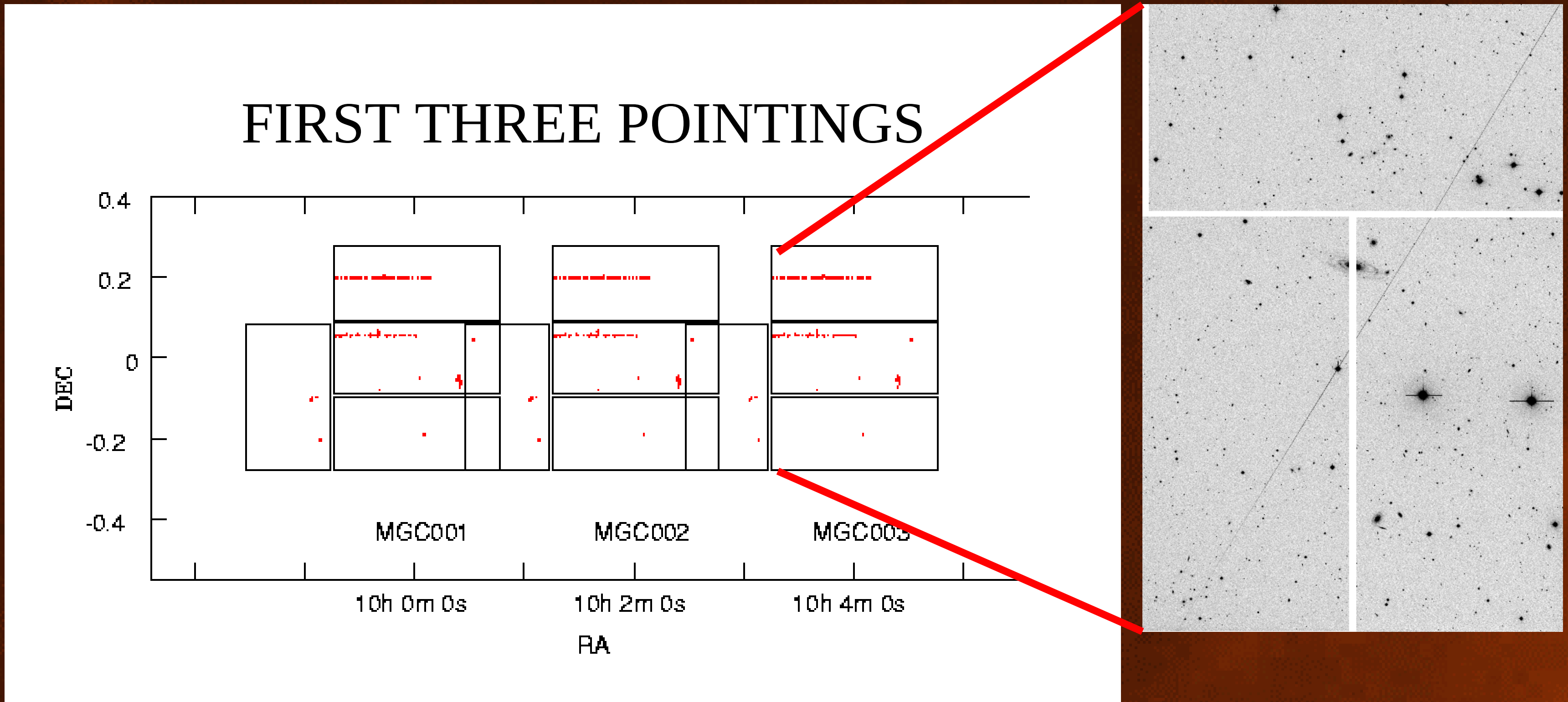
Details:

- Imaging INT/WFC + SDSS-DR1: *uBgriz*
  - 37 sq degrees along equatorial strip (0.5 x 75 deg)
  - Detection Limit μ(B limit) = 26 mags/sq arcsec
  - 10,095 resolved galaxies to B=20
  - All objects verified by eye (reclassified, rebuilt & deblended as necessary)
- Spectroscopy: 2dFGRS+SDSS-DR1+AAT/2dF, RSAA/2.3m, NTT, TNG, Gemini
  - Over 95% complete and aiming for 100% (99% complete to B=19 mags)

The WFC Footprint

- 144 pointings at δ=0 (10h00m-14h50min)
- 576 individual 2048x4100 CCD images
- 0.33'' pixels, FWHM ~ 1.2'', each 750 sec
- B-band only (u,g,r,i,z from SDSS-EDR)
- High Galactic Latitude

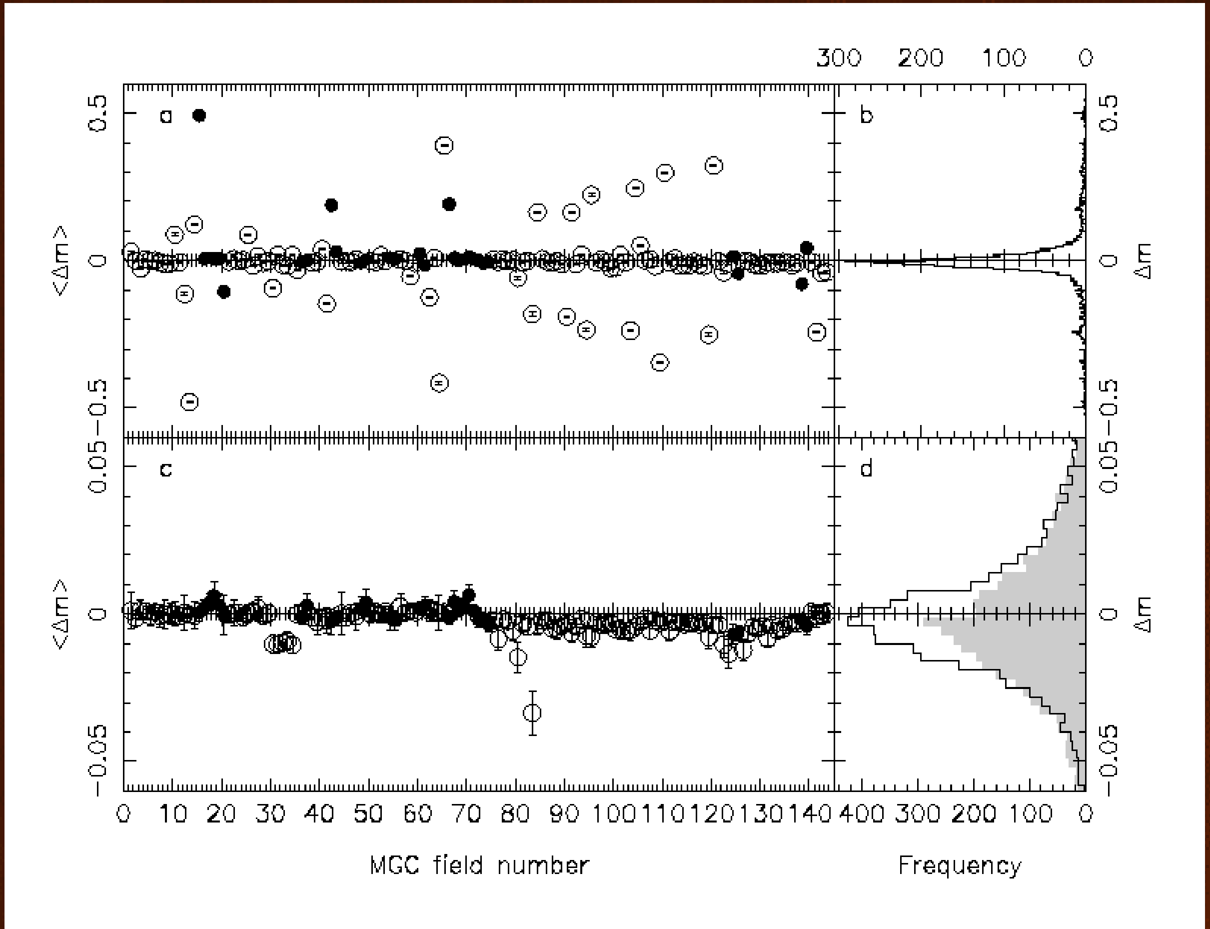




Photometric Calibration

- 10 standard fields across strip
- Large overlap regions (~50 stars)
- Linear least squares used to adjust zeropoints to minimise:

$$\chi^2 = \sum_{All} \left(\frac{\langle \Delta B'_{MGC} \rangle}{\sigma_{\langle \Delta B'_{MGC} \rangle}} \right)^2 + \sum_{Phot} \left(\frac{ZP - ZP_{th}}{\sigma_{ZP}} \right)^2$$

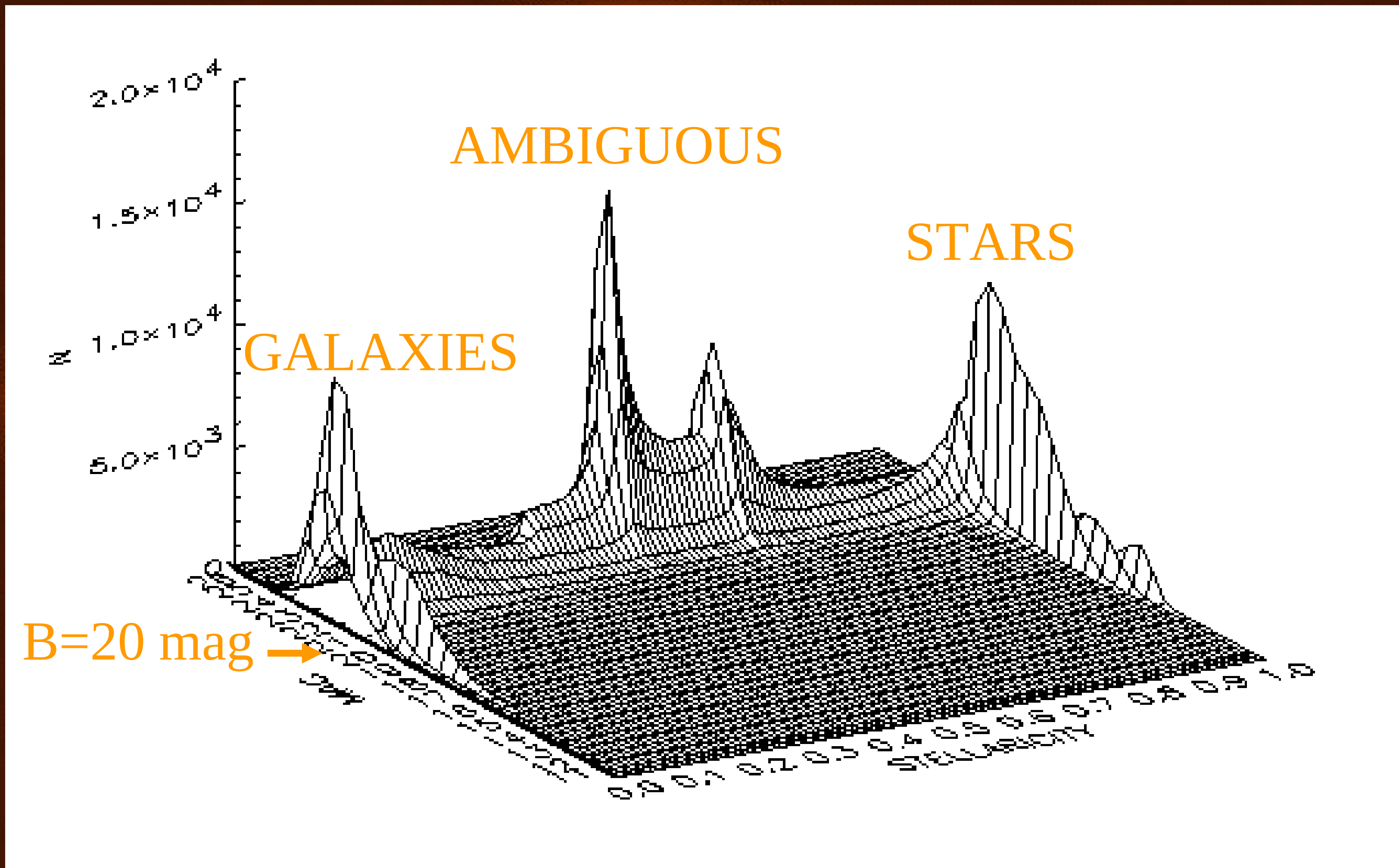


INITIAL

FINAL

Δm +/- 0.03 mag

Star/galaxy separation



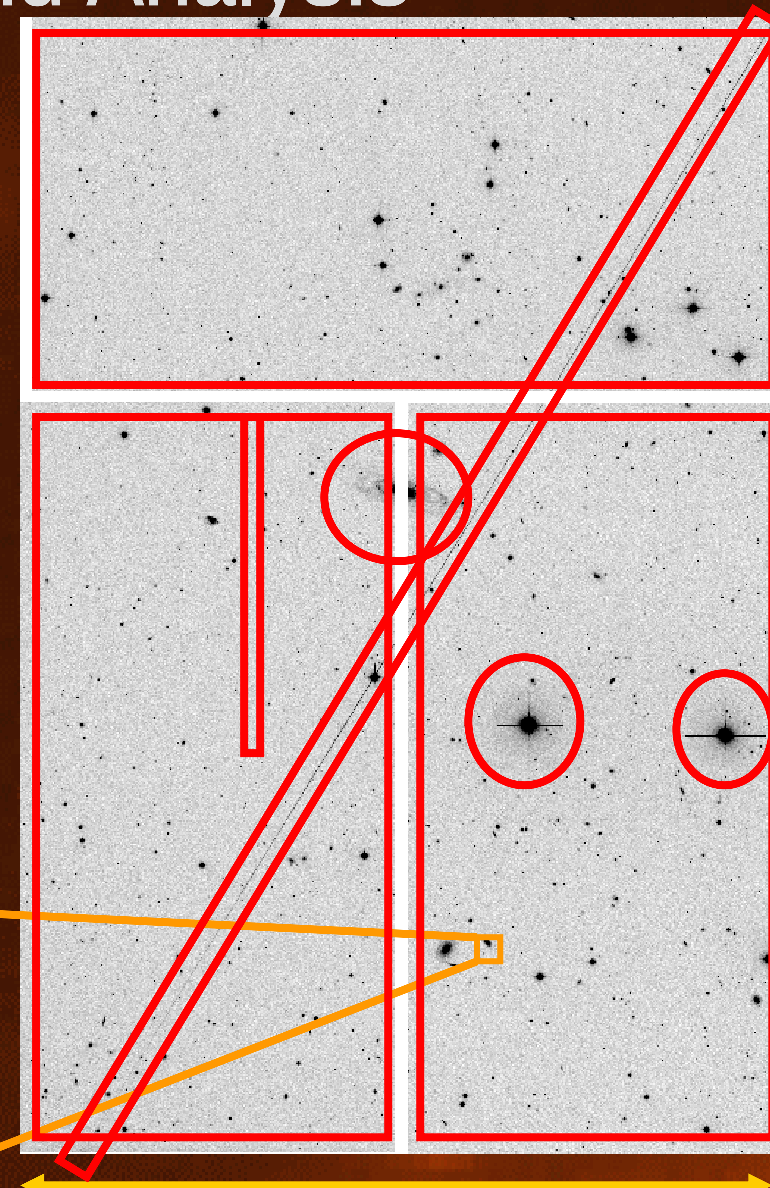
Viable to B ~ 21 mags,
For B > 21 mags use statistical method

Image Detection and Analysis

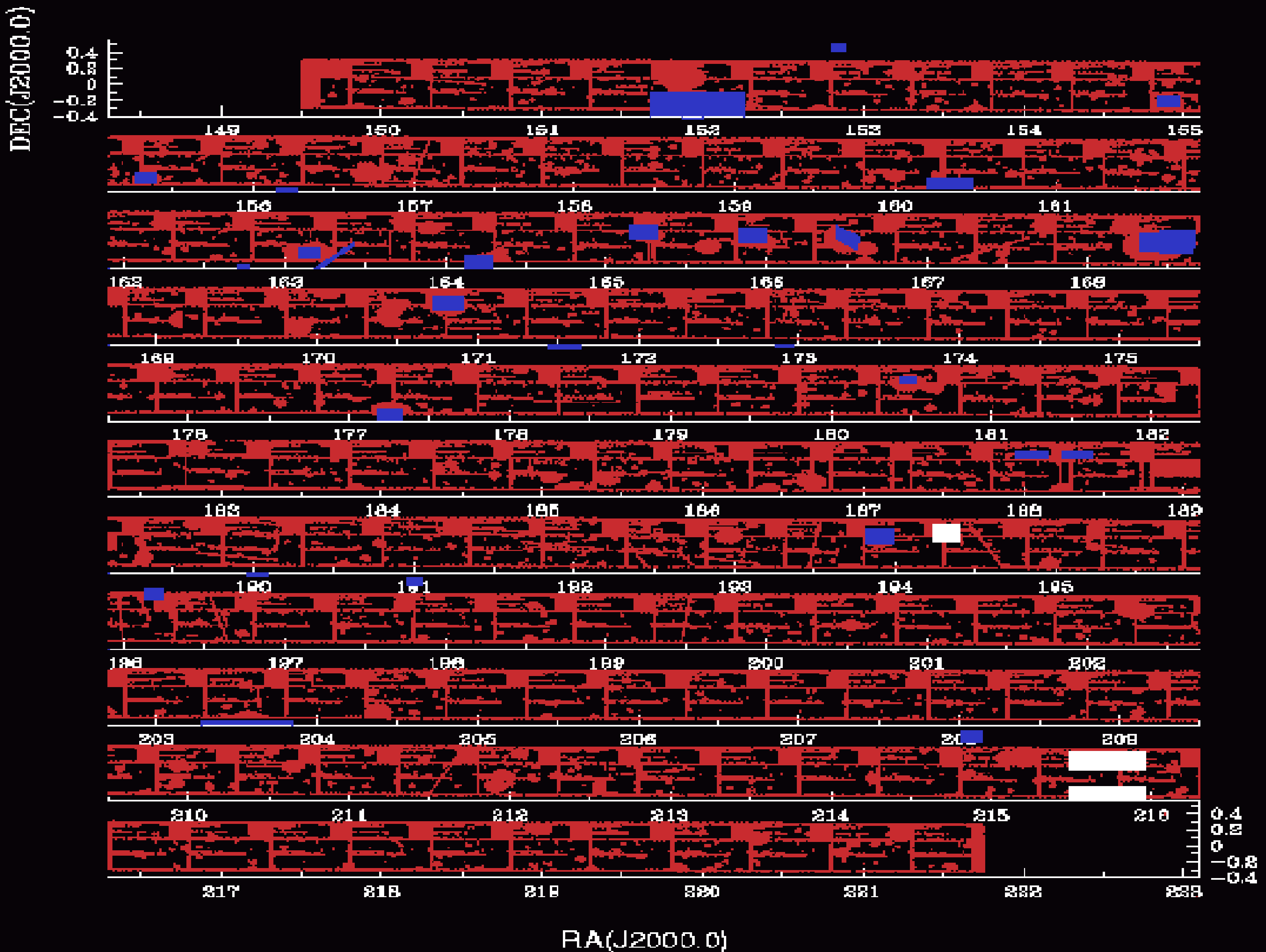
- Model sky: Median filtering onto coarse mesh
- Search for connected pixels above background threshold: 26 mags/sq arcsec
- Reanalyse each peak to get isophotal ellipse
- Kron magnitudes within elliptical apertures
- 144 fields or 576 CCDs
- Over 2 million detections
- All B<20mag objects checked by eye !
    - Galaxies (12374)
    - Stars (51284)
    - Cosmic Rays (113)
    - Diffraction Spikes (263, 2%)
    - Satellites (162,1%)
    - Dead Pixels (3027)
    - Noise/Artifacts (2023, 16%)
    - Asteroids (145, 1%)
    - Deblends (140, 1%)   I.e., 20% contamination !

$$2.5R_{Kron} = \sum \frac{rI(r)}{I(r)}$$

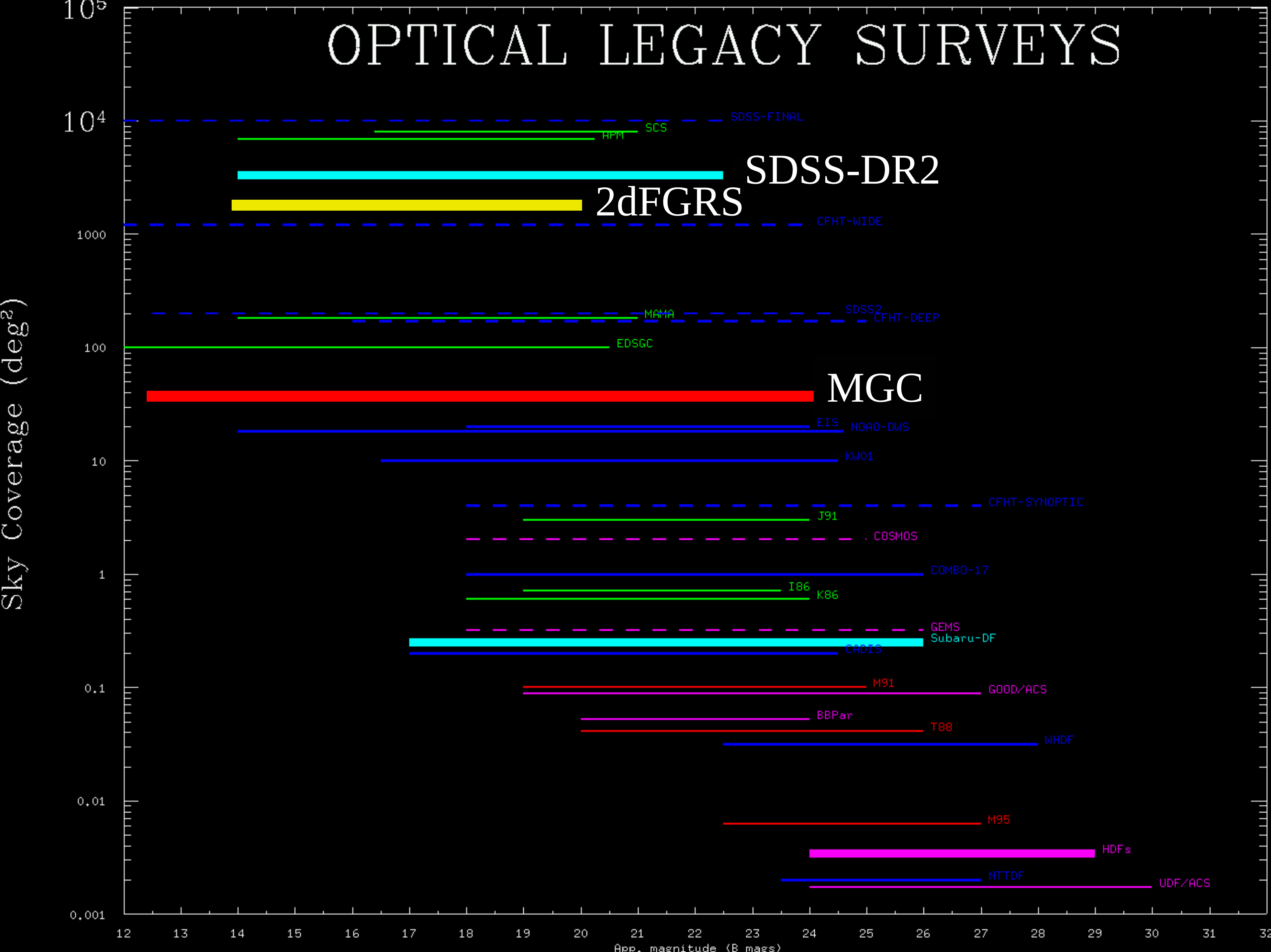
m=16th mag



20’

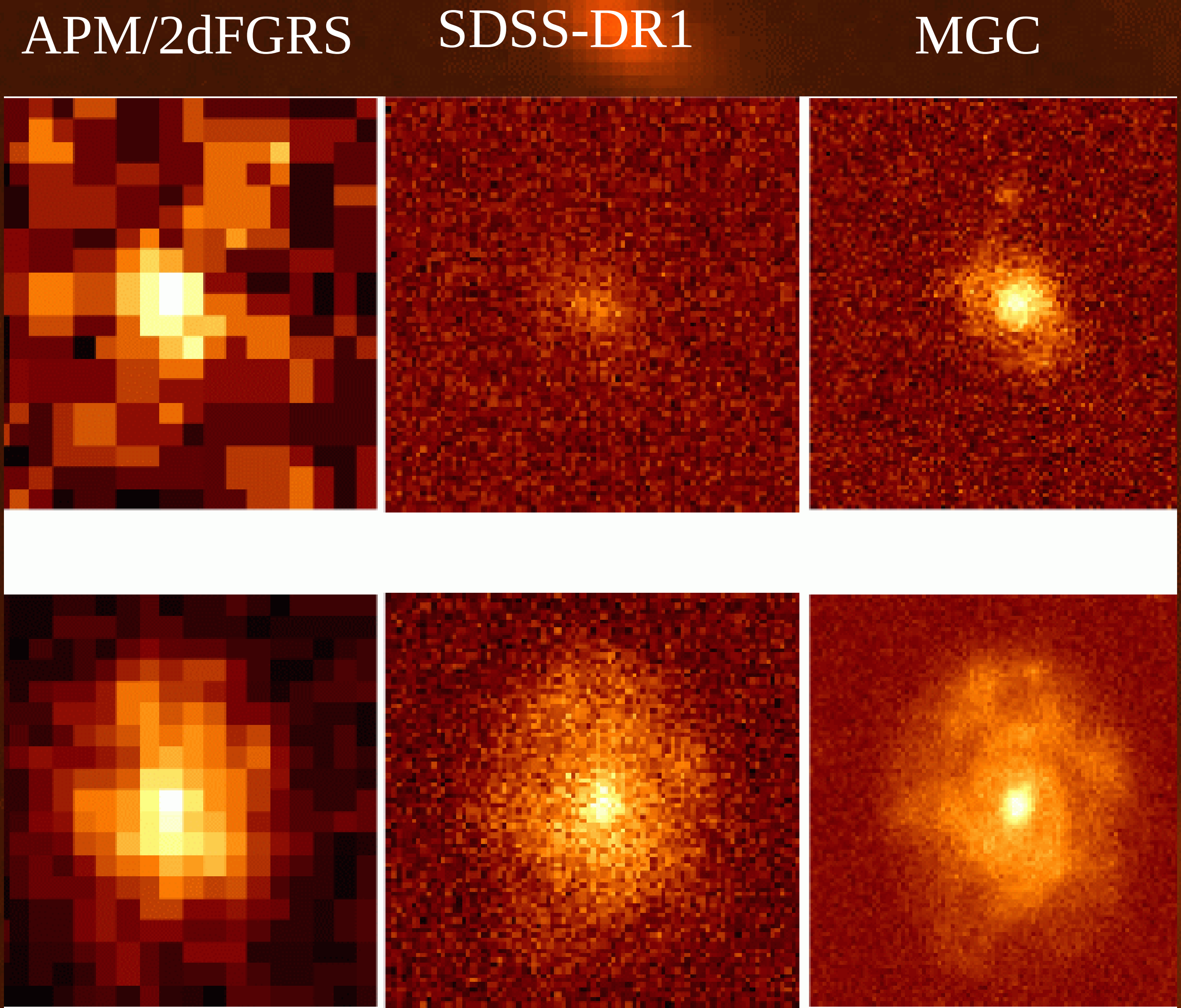


DEC(J2000.0)
0.4
0.2
0
−0.2
−0.4
RA(J2000.0)



OPTICAL LEGACY SURVEYS
SDSS-FINAL
SCS
APM
SDSS-DR2
2dFGRS
CFHT-WIDE
MAMA
SDSS2
CFHT-DEEP
EDSGC
MGC
EIS
NOAO-DWS
KWO1
CFHT-SYNOPTIC
J91
COSMOS
COMBO-17
I86
K86
GEMS
Subaru-DF
CADIS
M91
GOOD/ACS
BBPar
T88
WHDF
M95
HDFs
NTTDF
UDF/ACS
Sky Coverage (deg^2)
10^5
10^4
1000
100
10
1
0.1
0.01
0.001
12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
App. magnitude (B mags)

MGC data quality v APM & SDSS



MGCz: The Redshift Survey

- Region overlaps with 2dFGRS and SDSS

SDSS-DR1	2901	1523
2dFGRS	4127	3150
2QZ	11	7
PF QSO	37	28
LSBG	11	2
NED	1201	29

} Pre-existing

- MGCz

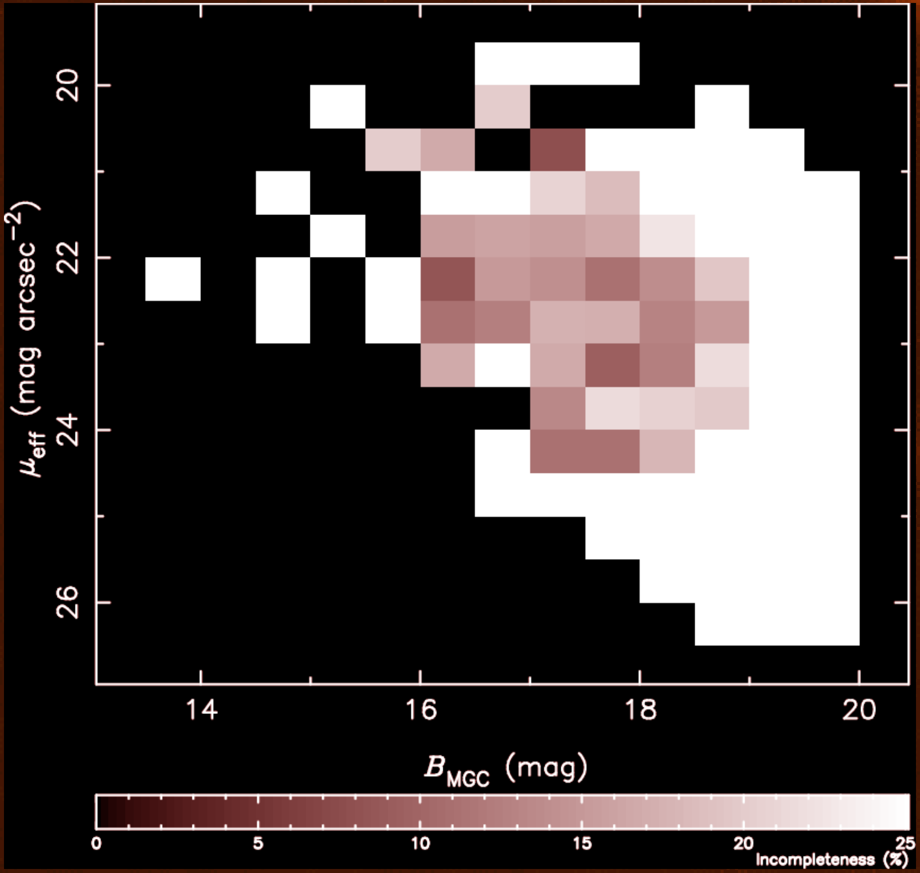
2dFGRS	4810	4701	11 nights
RSAA2.3m	120	120	8 nights
NTT	51	51	4 nights
Gemini	5	5	5 hrs
TNG	44	44	5 nights

} MGC Campaign

- Total 9580 out of 10061 = 95% complete (98.8% to B=19)
- Plan to extend survey to B=22 (AAΩ) and B=24 (KAOS)

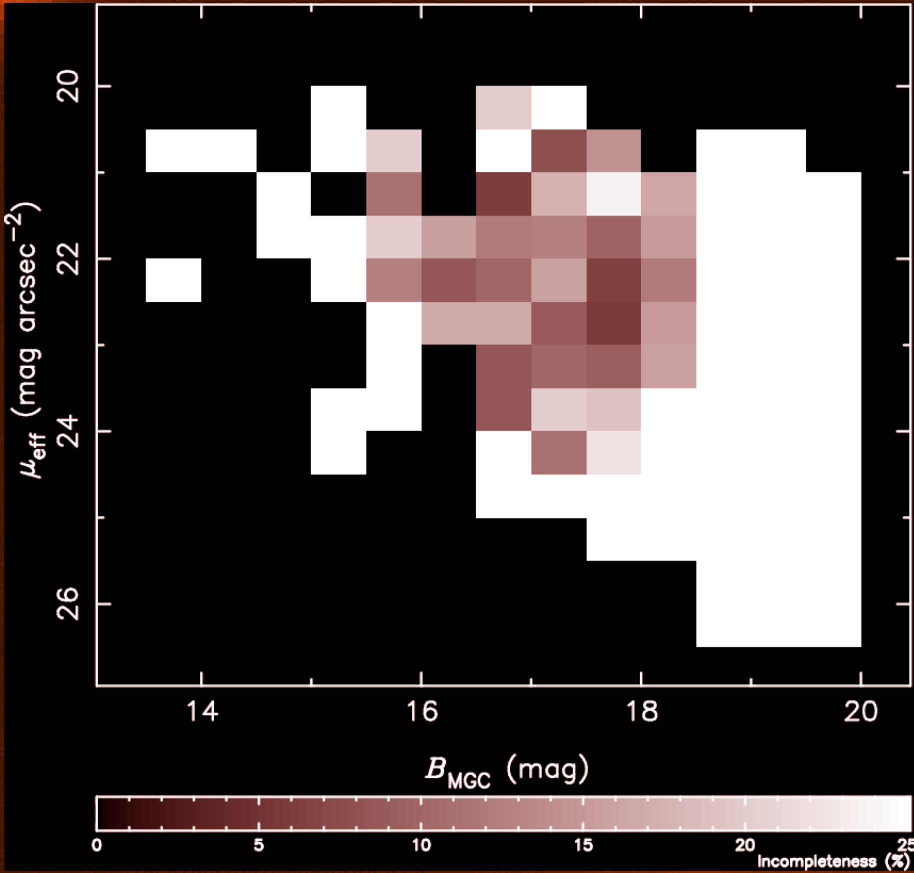
Spectroscopic Incompleteness

2dFGRS



Incompleteness (%)

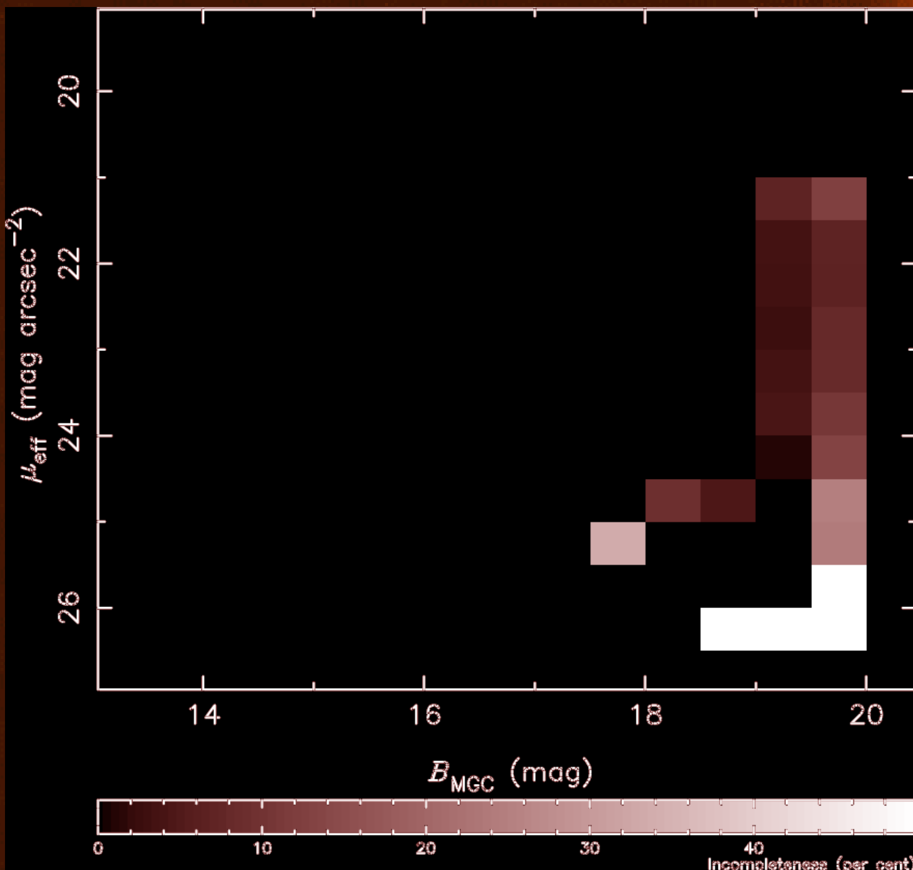
SDSS



Incompleteness (%)

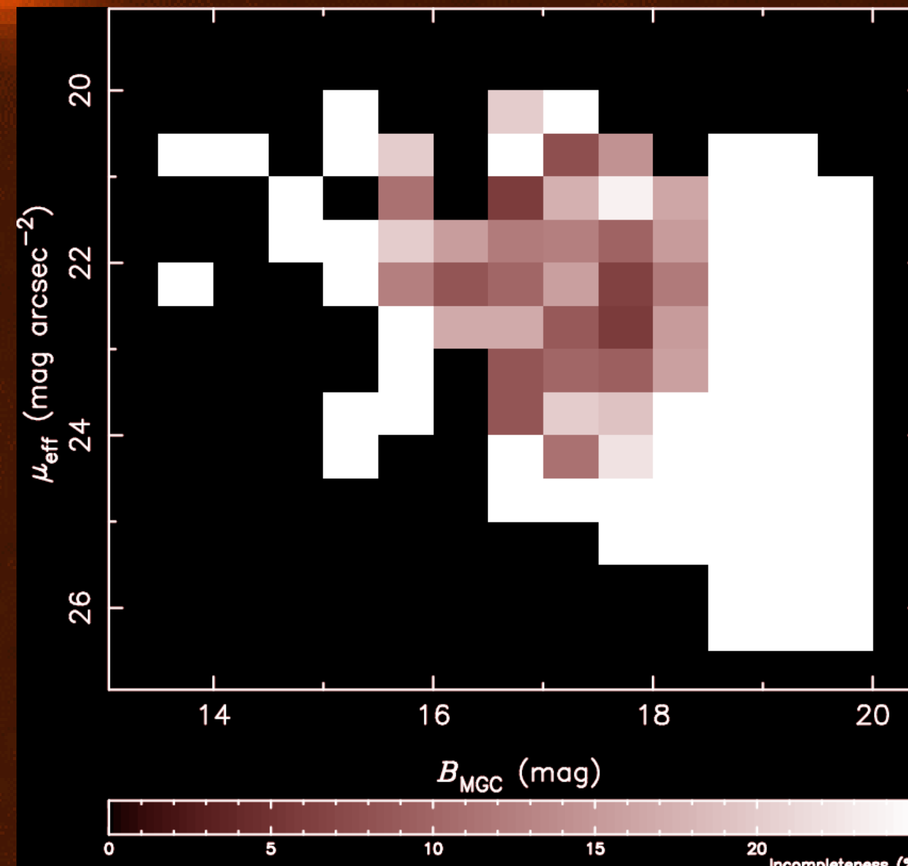
Spectroscopic Incompleteness

MGC

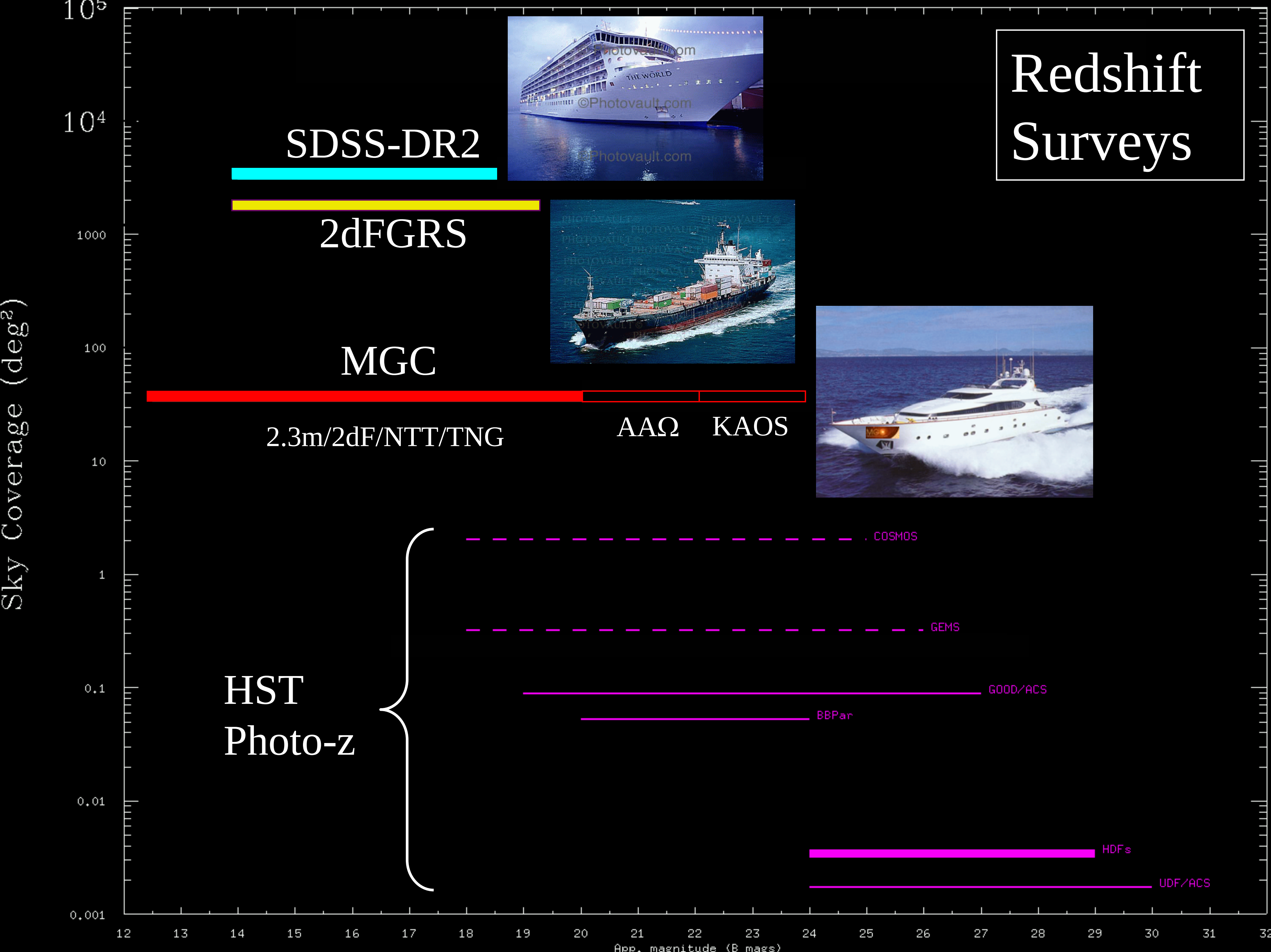


Incompleteness (%)

SDSS



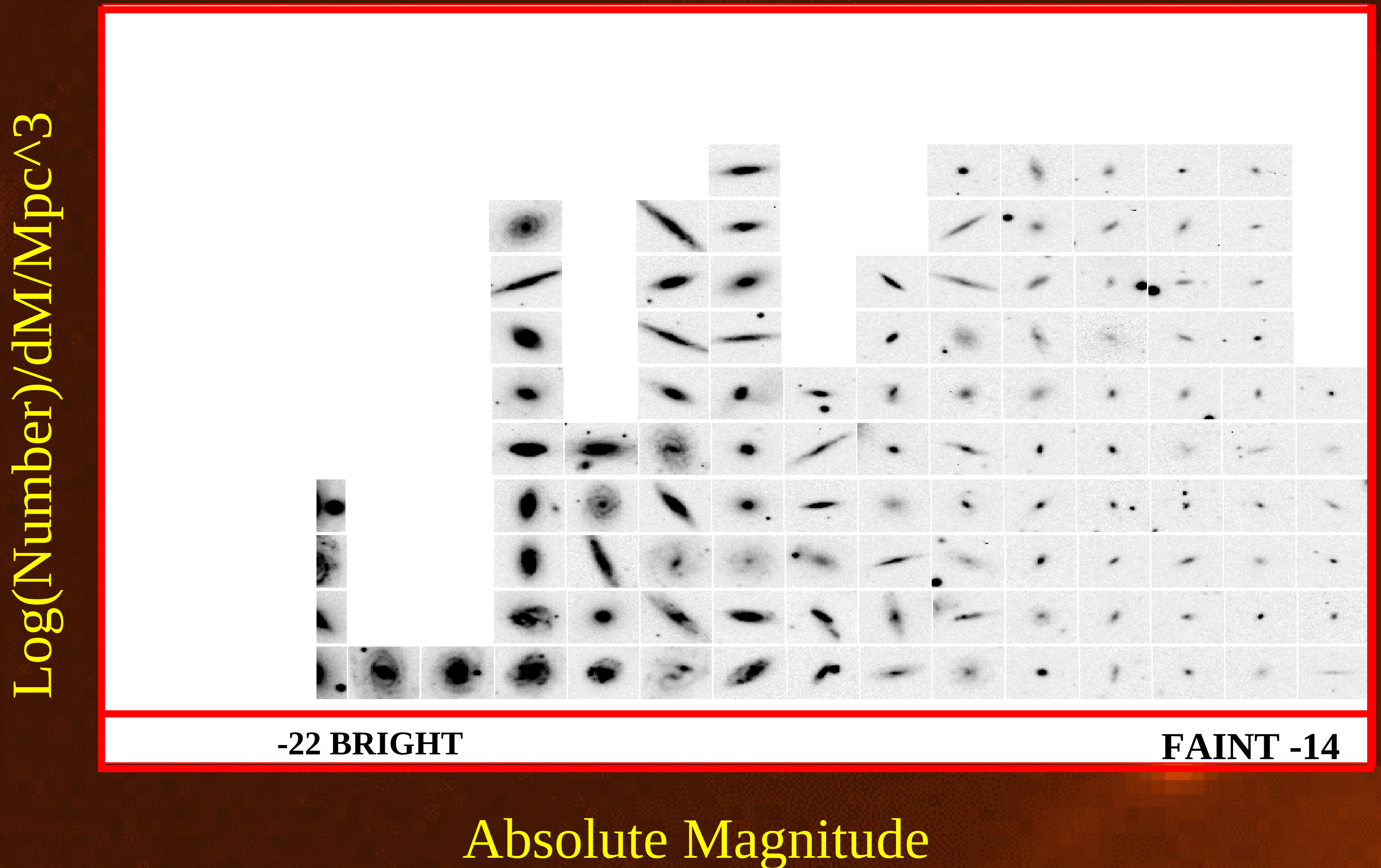
Incompleteness (%)



Redshift Surveys
SDSS-DR2
2dFGRS
MGC
2.3m/2dF/NTT/TNG
AAΩ
KAOS
HST Photo-z
COSMOS
GEMS
GOOD/ACS
BBPar
HDFs
UDF/ACS
THE WORLD
©Photovault.com
Sky Coverage (deg^2)
10^5
10^4
1000
100
10
1
0.1
0.01
0.001
12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
App. magnitude (B mags)

The Space Density of Galaxies

- Galaxies are known to range in B luminosity: -22 to -8 mags (I.e., x400,000 in L)
- We want to know the number per dM per cubic Mpc.

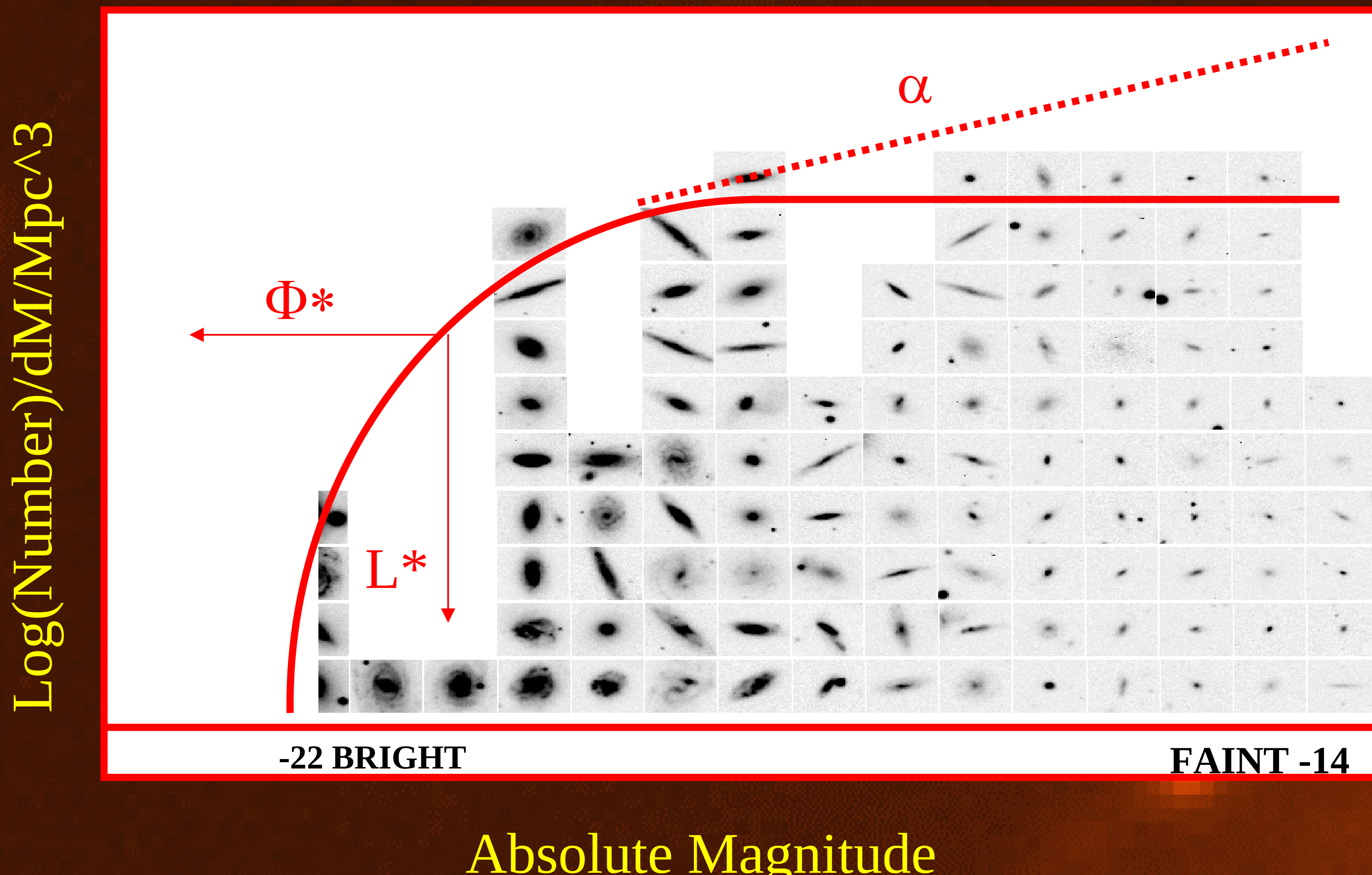


The LF:

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

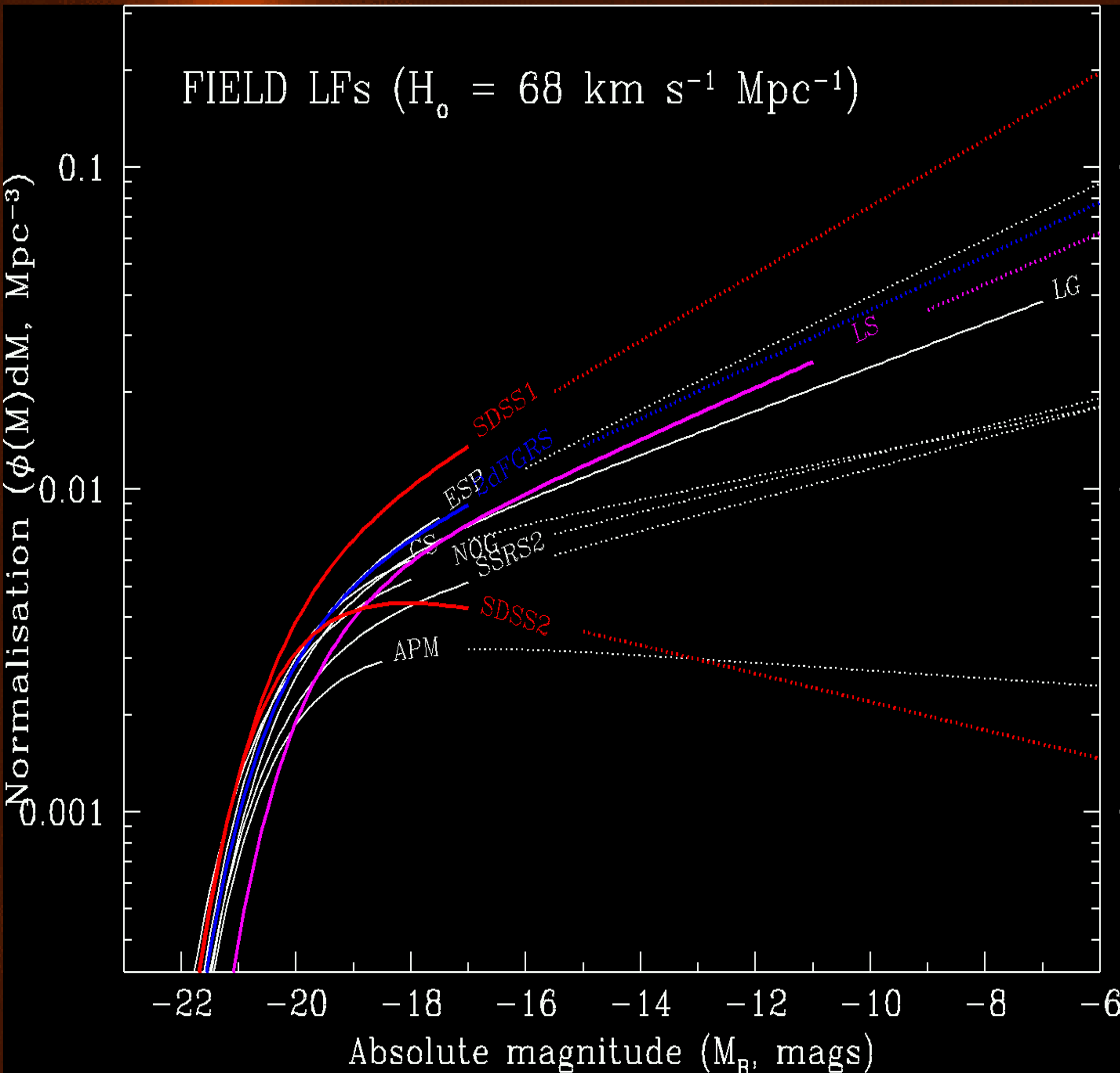
$$j=\phi^*L^*\Gamma(\alpha+2)$$

- Represented by a Schechter fn with 3 free params: L^*, ϕ^*, α
- Derived from Press-Schechter theory of halo formation



The Galaxy Luminosity Function

- No consensus
  - x2 uncertainty at M*
  - M > -16 unknown
- SDSS & 2dFGRS:
  - SDSS1 resolved
  - SDSS2 puzzling
- ESP & 2dFGRS OK
- LG best insight ? (~50 galaxies)
- MGC (see later)



Key Issues

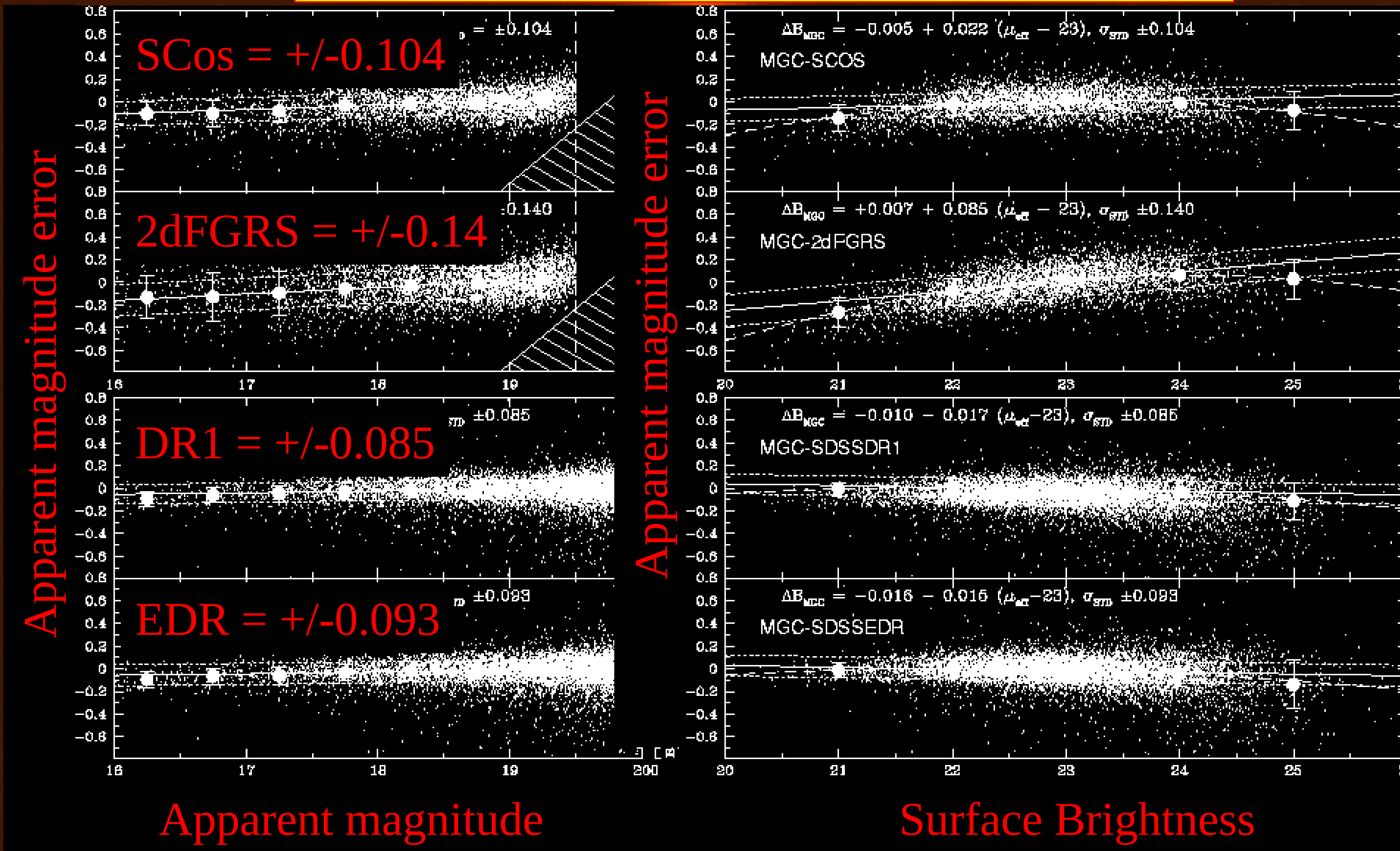
- Cosmic Variance: Surely not in the 2dFGRS or SDSS data sets ?
- Malmquist Bias: Poor Statistics at the faint-end despite catalogue sizes !
- Photometric Accuracy: Plate versus CCD
- Magnitudes: Petrosian v Isophotally Corrected v Kron

  } No Cross [Driver] et al (2004)

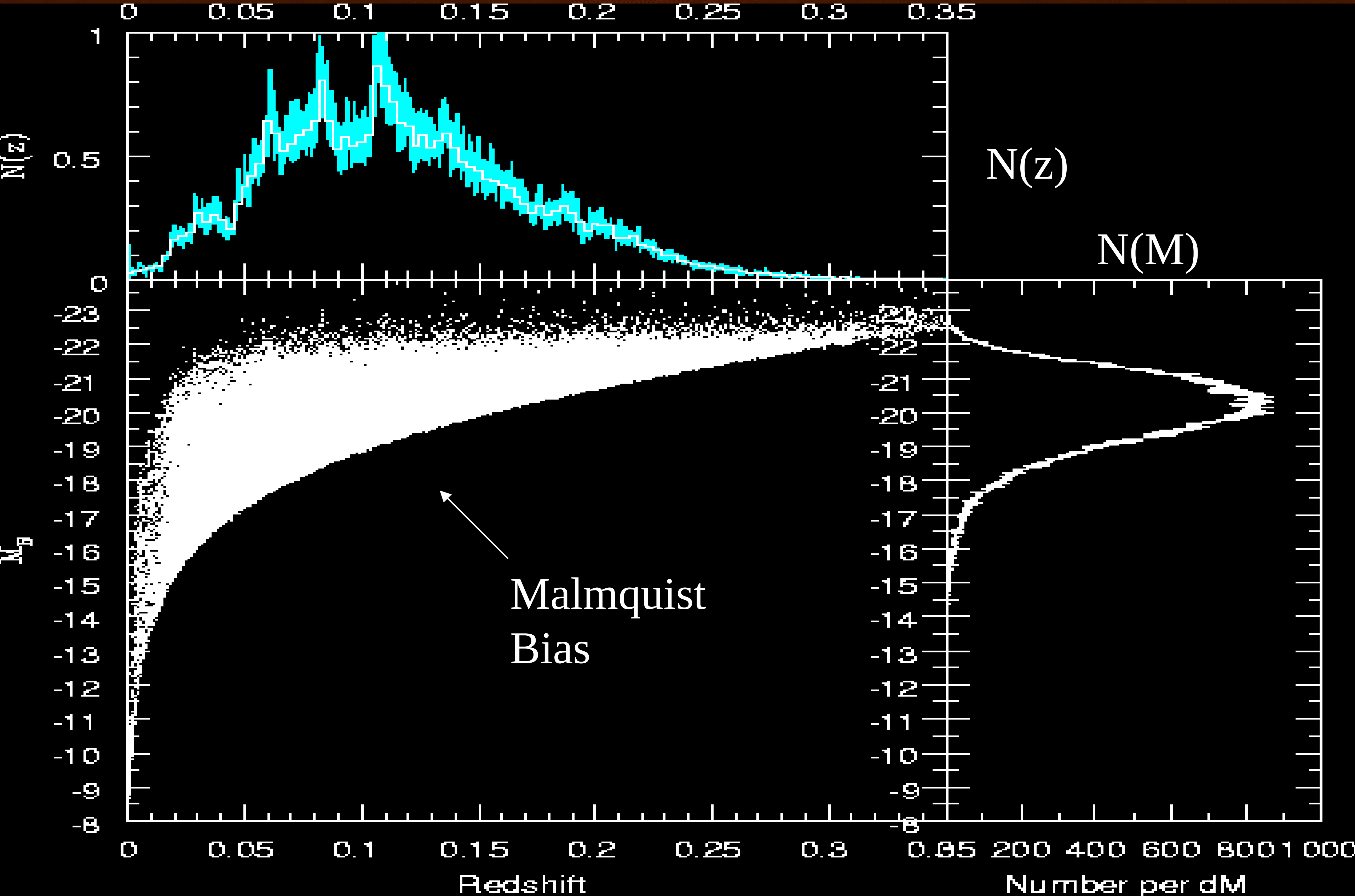
- Automated Detection/Analysis Algorithms ?
- Selection Bias
  - Imaging Completeness (Can only quantify by comparison to a deeper survey)
  - Spectroscopic Completeness (Most surveys are 90-95% complete)
  - High and Low Surface Brightness galaxies likely to be missed
- Analysis Problems
  - The Schechter function and degeneracy of α ☎♌◆♦ ♑□□♎ χ□❼♦)
  - Methodologies: SWML v STY v 1/Vmax v C-method etc
  - Incompleteness usually assumed unbiased but may be important
  - Adopted evolution varies (but low-z surveys)
  - Cosmology, I.e., k-corrections (global versus individual)

2dFGRS & SDSS Photometry v MGC

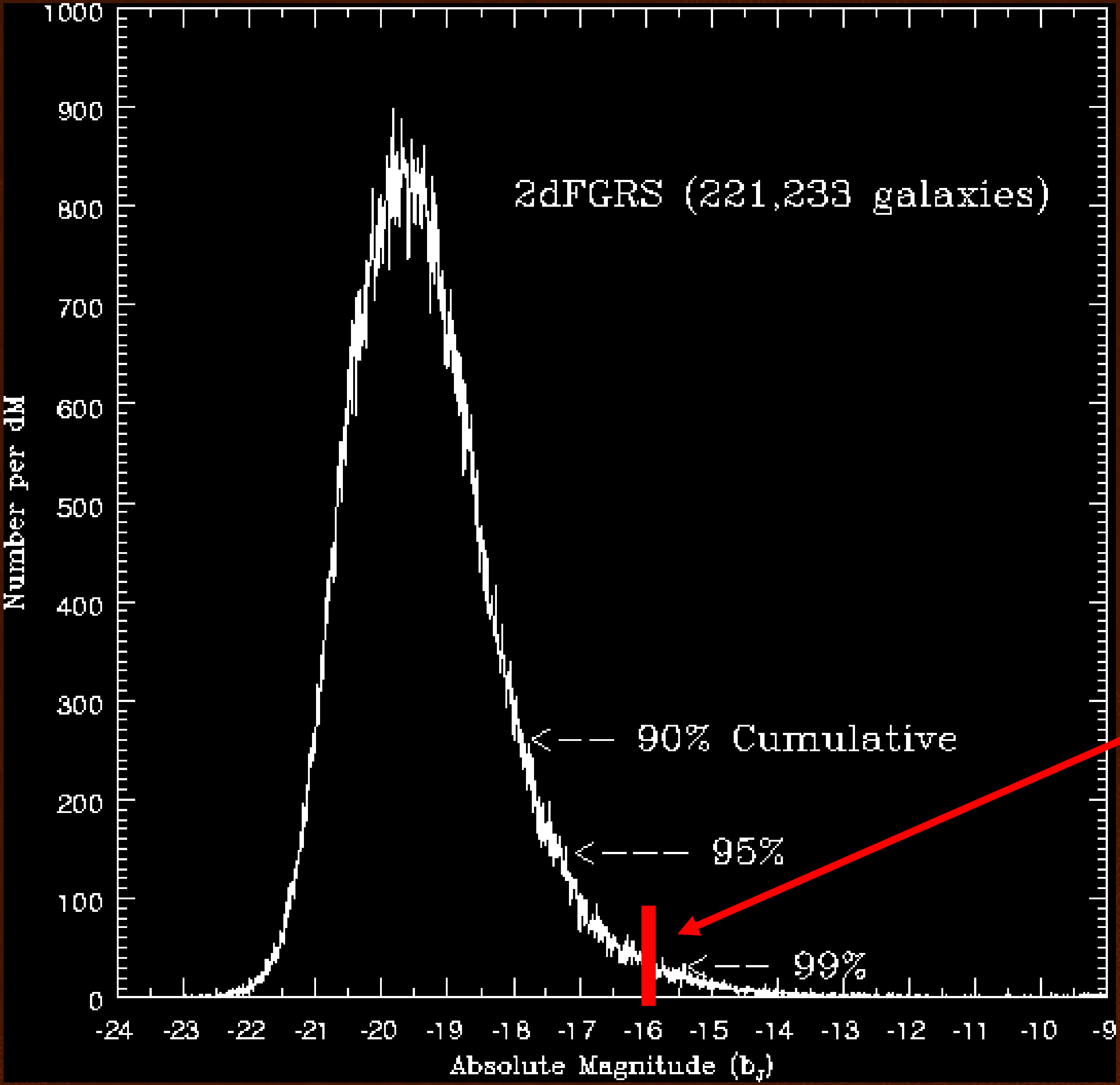
Above specified accuracies but nevertheless OK



Malmquist Bias



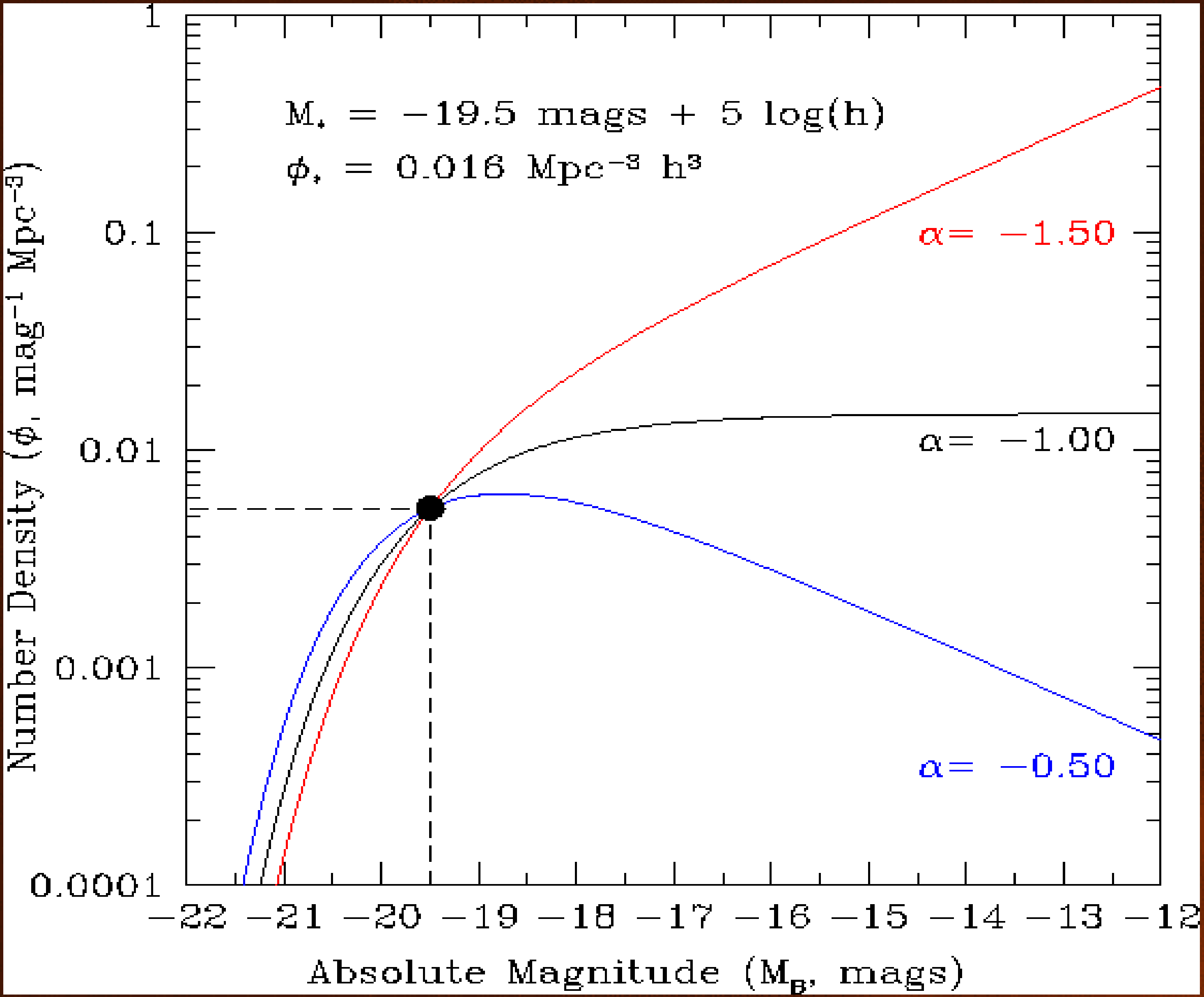
Poor Statistics at the faint-end



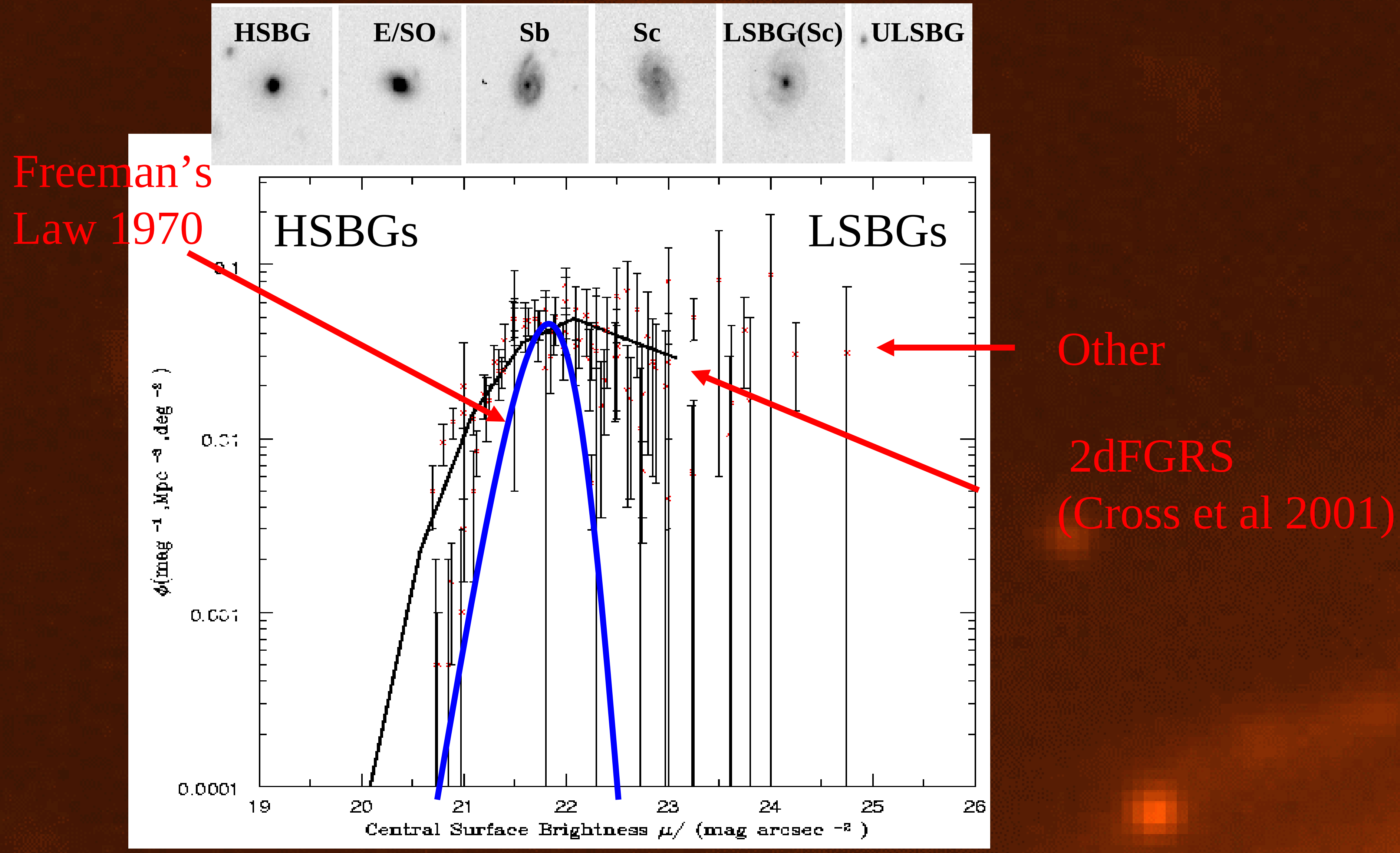
Lower M limit is set by combination of m limit and z min.

I.e., set z > 0.013 for analysis to be robust to peculiar velocites

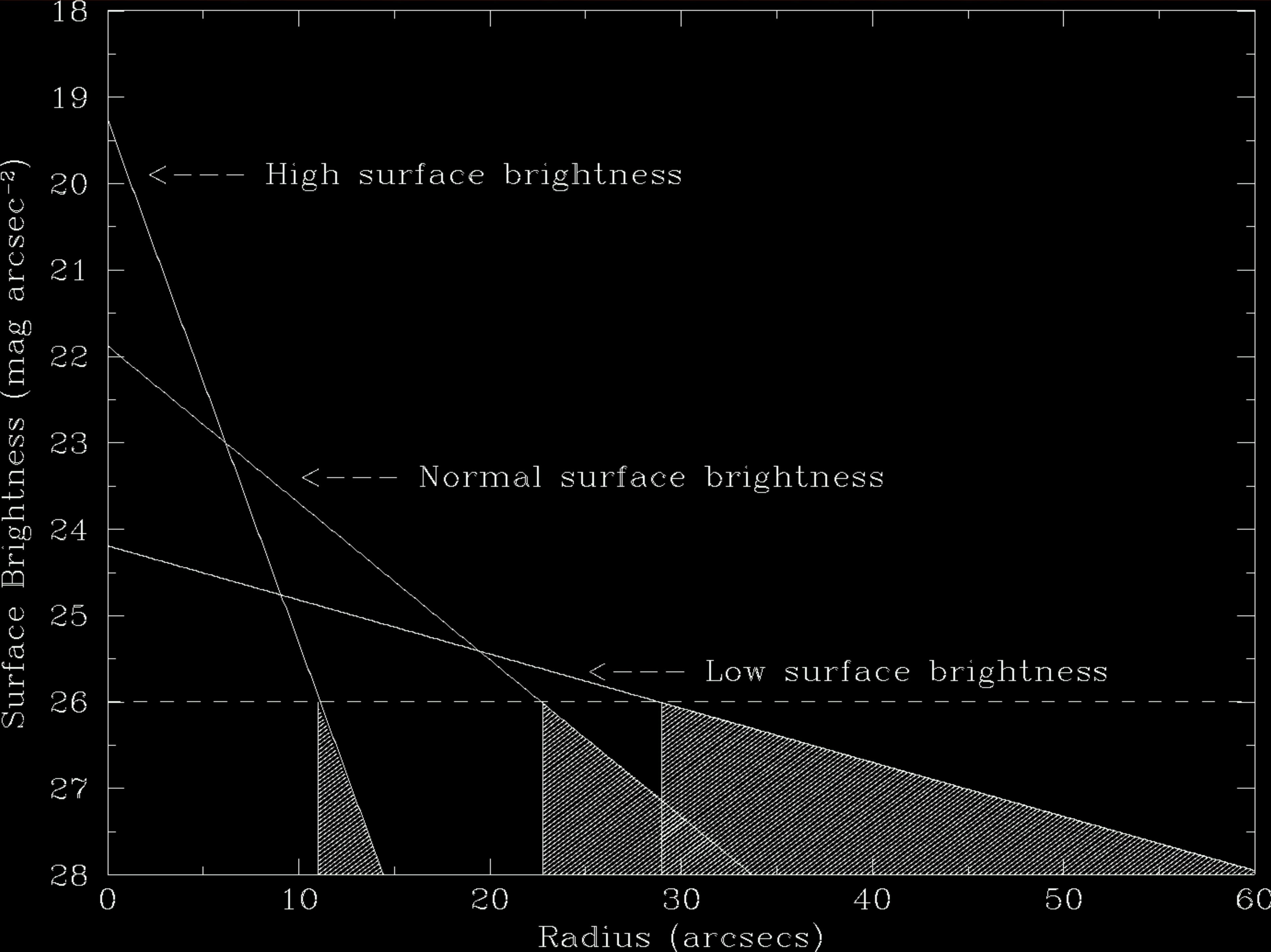
Degeneracy of α



The Surface Brightness Distribution



Central Surface Brightness



Surface Brightness (mag arcsec^{-2})
Radius (arcsecs)
18
19
20
21
22
23
24
25
26
27
28
0
10
20
30
40
50
60
<--- High surface brightness
<--- Normal surface brightness
<--- Low surface brightness

Illustration: Galaxies of equal luminosity B=16

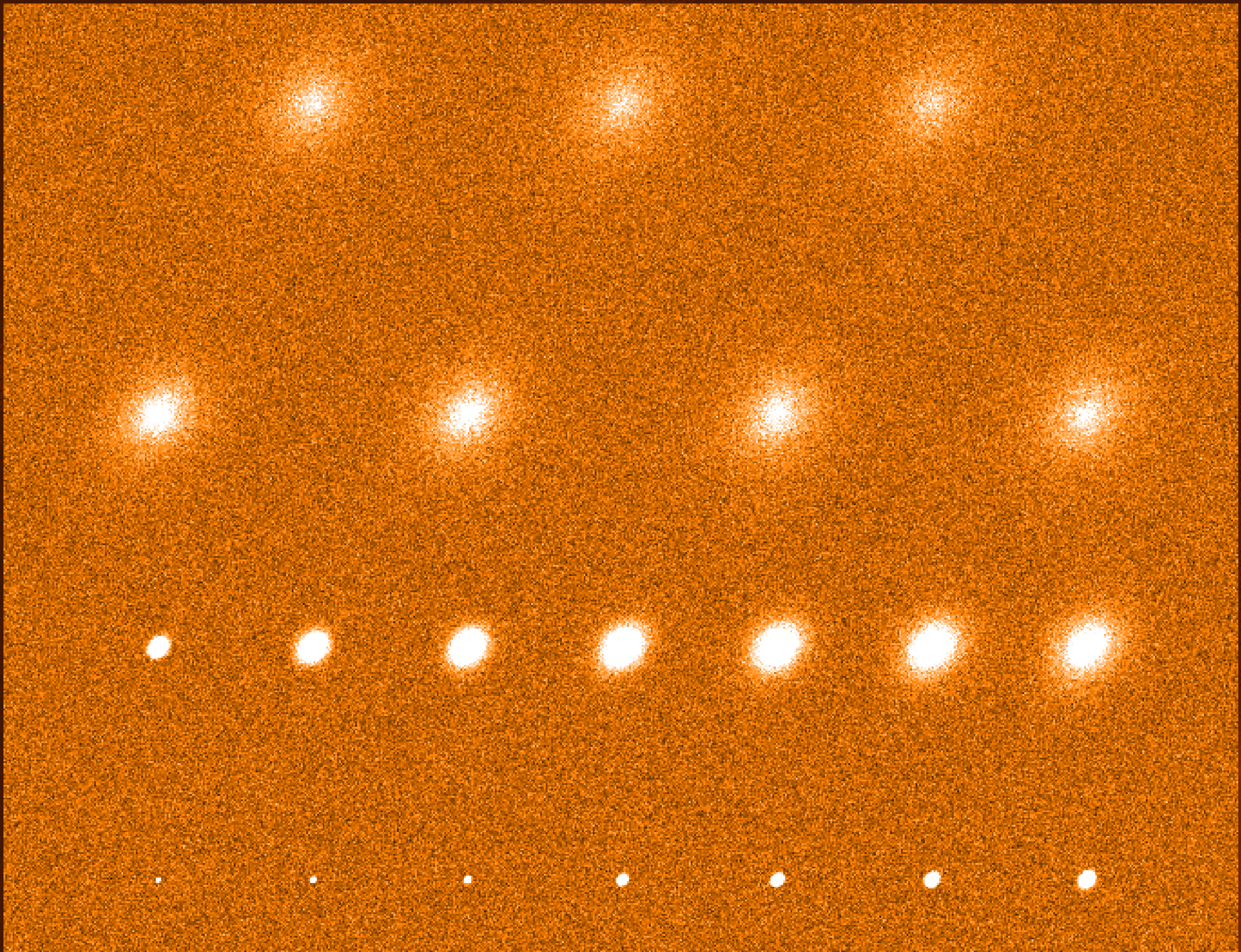
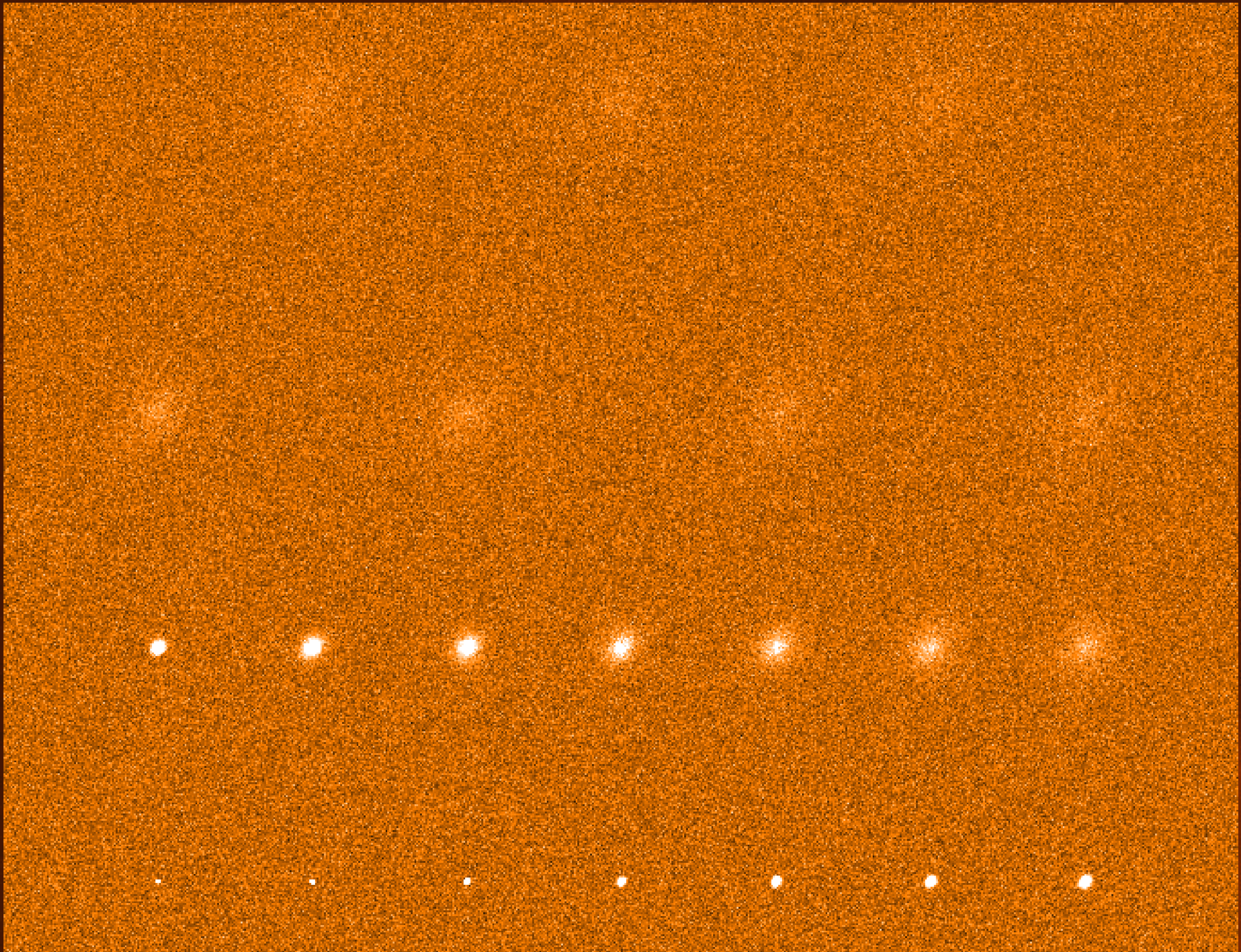
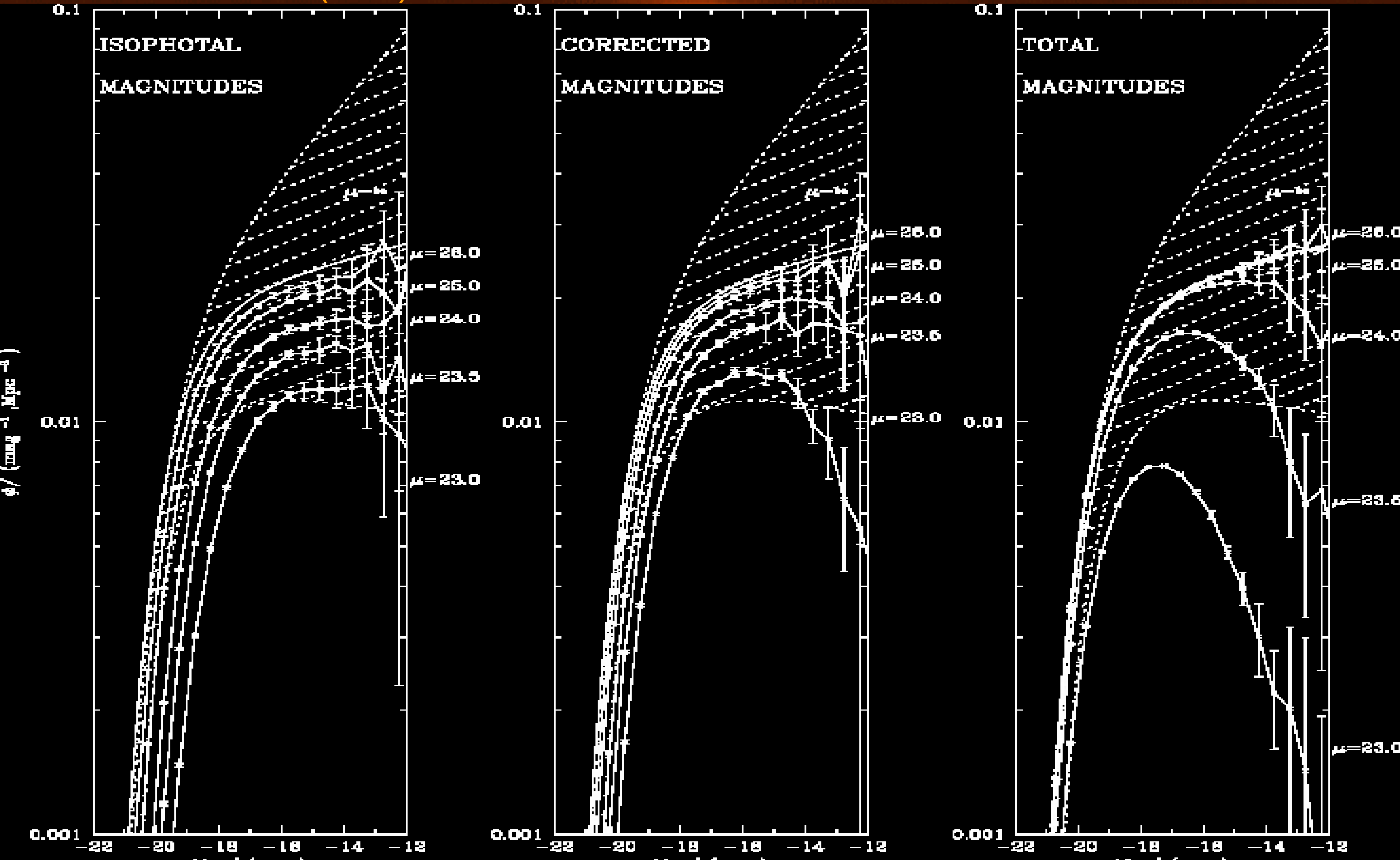


Illustration: Galaxies of equal luminosity B=18



Surface Brightness Selection Bias

- Cross & Driver (2002)



Unchecked Automated Algorithms

- B=18 mag
- The trouble with automated alogorithms !

Getting the LF right ?

- Aim: To recover the LF inclusive of selection bias
- Requires:
  - Cosmology [Ω=0.3,Λ=0.7,Ho=75 km/s/Mpc]
  - Wide area high quality deep CCD-based survey
  - Seeing corrected size/surface brightness measurements
  - High spectroscopic completeness
  - Faint spectroscopic limit to probe faint-end
  - K and E corrections [(K(z) per galaxy]
  - Expanded SWML to manage key selection biases:
    - Maximum size
    - Miniumum size
    - Maximum flux
    - Minimum flux
    - Maximum SB
    - Minimum SB

⇒ MGC Millennium Galaxy Catalogue + SIMULATIONS

MGC K(z),E(z),r-corrections

- Individual K(z)
  - k(z) derived for each galaxy from 27 synthetic templates (Poggianti 1998)
- E(z) currently fixed:

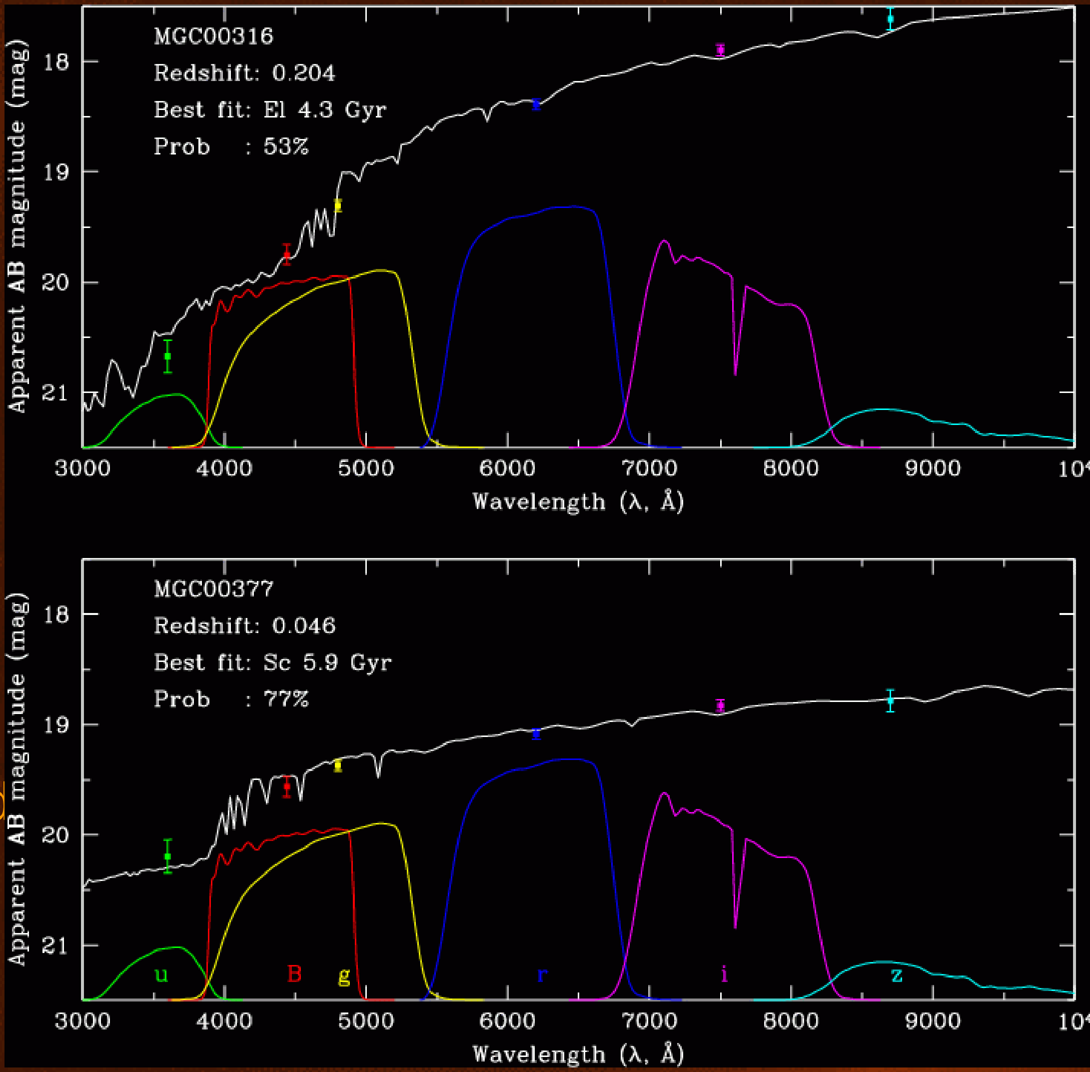
$$L \propto L_o (1+z)^{0.75}$$

- z limits
  - z > 0.013 (local velocity field)
  - z < 0.18 (QSO contamination)
- Half-light radius measured directly and seeing corrected:

$$r_{hlr^o} = \sqrt{r_{hlr}^2 - 0.33\Gamma^2}$$

- Effective surface brightness derived from half-light radius:

$$\mu_{eff,i} = m_i + 2.5\log(2\pi r_{hlr^o,i}^2) - 10\log(1+z) - K_i(z) - E(z)$$

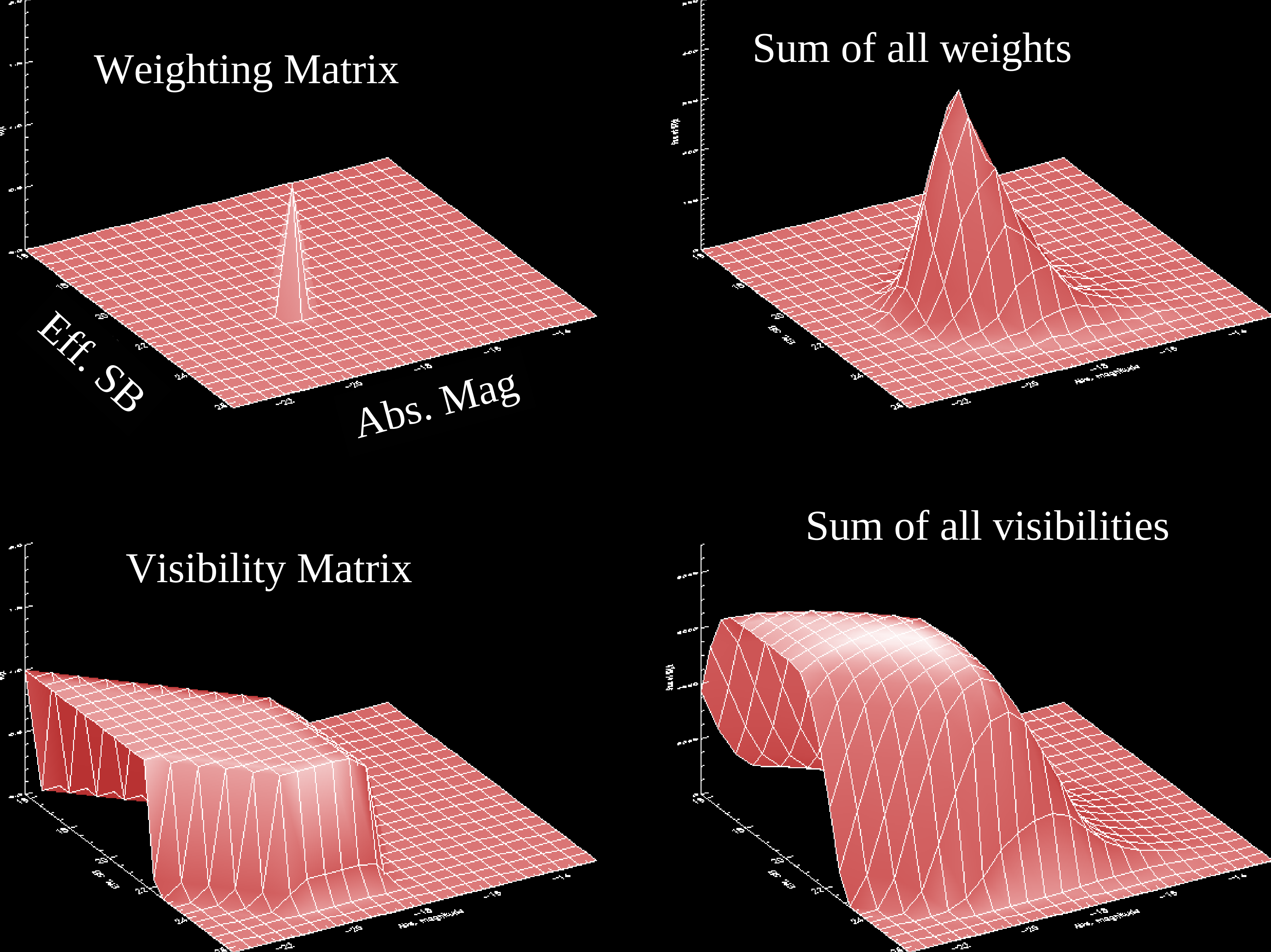


MGCz: 2D Step-Wise Maximum Likelihood

- SWML developed by Efstathiou, Ellis & Peterson (1988)
  - Robust to galaxy clustering
- 2D variant proposed by Sodré & Lahav (1993)
- 2D variant inclusive of selection effects Driver et al (2004)
  - Iteratively evaluate the solution of the Likelihood function:

$$\phi_{jk} = \frac{\sum_{i=1}^{N} W_{ijk}}{\sum_{i=1}^{N} [H_{ijk} / \sum_{l=1}^{L} \sum_{m=1}^{M} \bar{\phi}_{ilm} H_{ilm}]}$$

  - Wijk = weighting matrix to accommodate for redshift incompleteness (by L & Σ)
  - Hijk = 2D selection matrix incorporating the 5 selection limits
  - I=1,N objects (6324 galaxies)
  - J=1,J absolute magnitude bins (-23 to -11 mag)
  - K=1,K effective surface brightness bins (16 to 28 mag/sq arcsec)
  - $\bar{\phi}$ = old space density values


Weighting Matrix
Eff. SB
Abs. Mag
Sum of all weights
Visibility Matrix
Sum of all visibilities

Defining Hijk

- 5 key selection boundaries:
  - Maximum detectable luminosity (due to choice of pointing, B=13.0 mags)

$$M_{\rm bright} = m_{\rm bright} - 5\log d(z) - 25 - k(z) - E(z)$$

  - Minimum detectable luminosity (due to faint magnitude cut-off, B=20.0 mags)

$$M_{\rm faint} = m_{\rm faint} - 5\log d(z) - 25 - k(z) - E(z)$$

  - Maximum detectable surface brightness (due to background smoothing, r(max) = 15'')

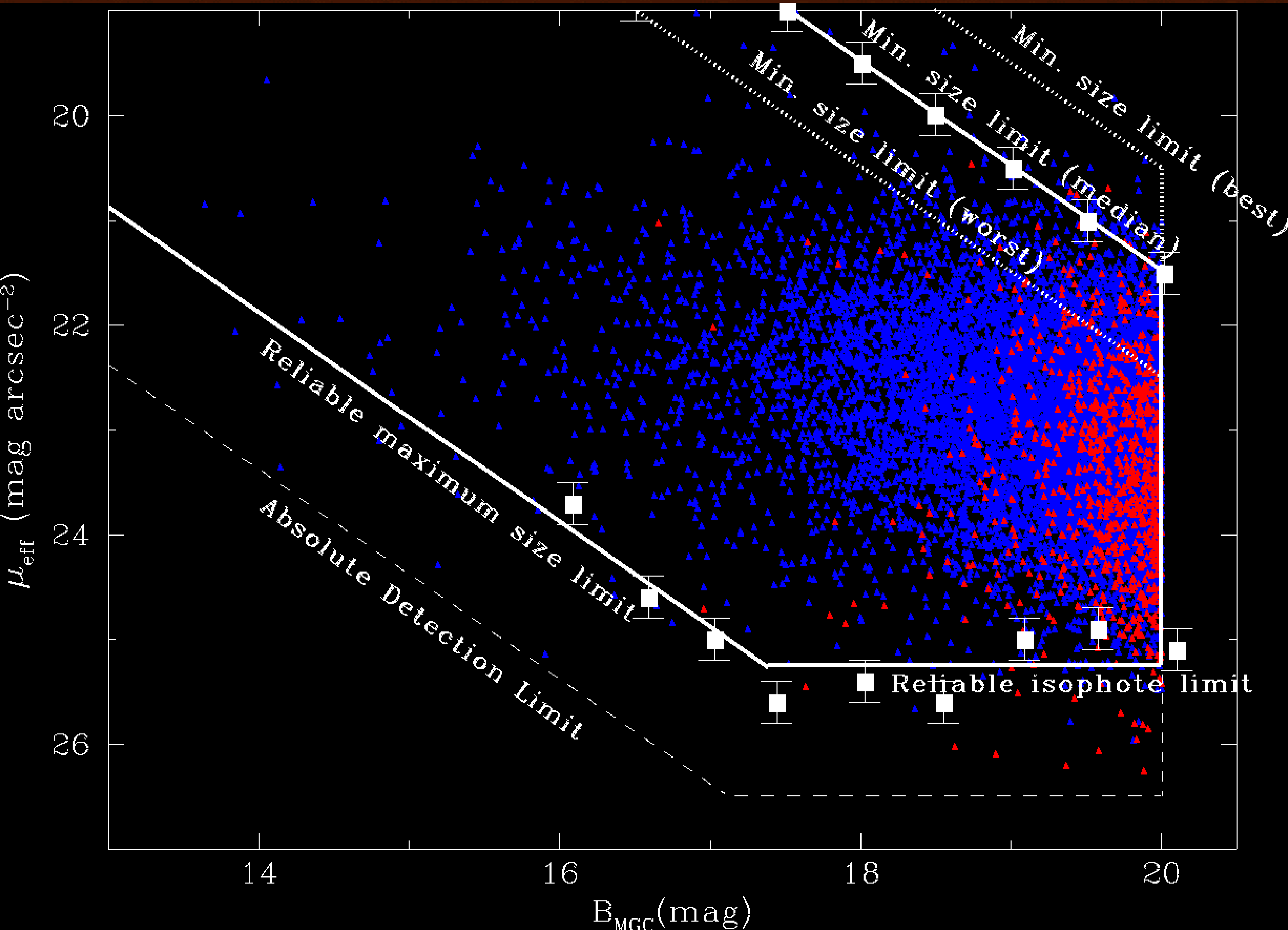
$$\mu_{\rm high} = M + 5\log d(z) + 25 + 2.5\log(2\pi r_{\rm min}^{2}) - 10\log(1+z)$$

  - Minimum detectable surface brightness (due to resolution, r(min) = 0.63 FWHM)

$$\mu_{\rm low} = M + 5\log d(z) + 25 + 2.5\log(2\pi r_{\rm max}^{2}) - 10\log(1+z)$$

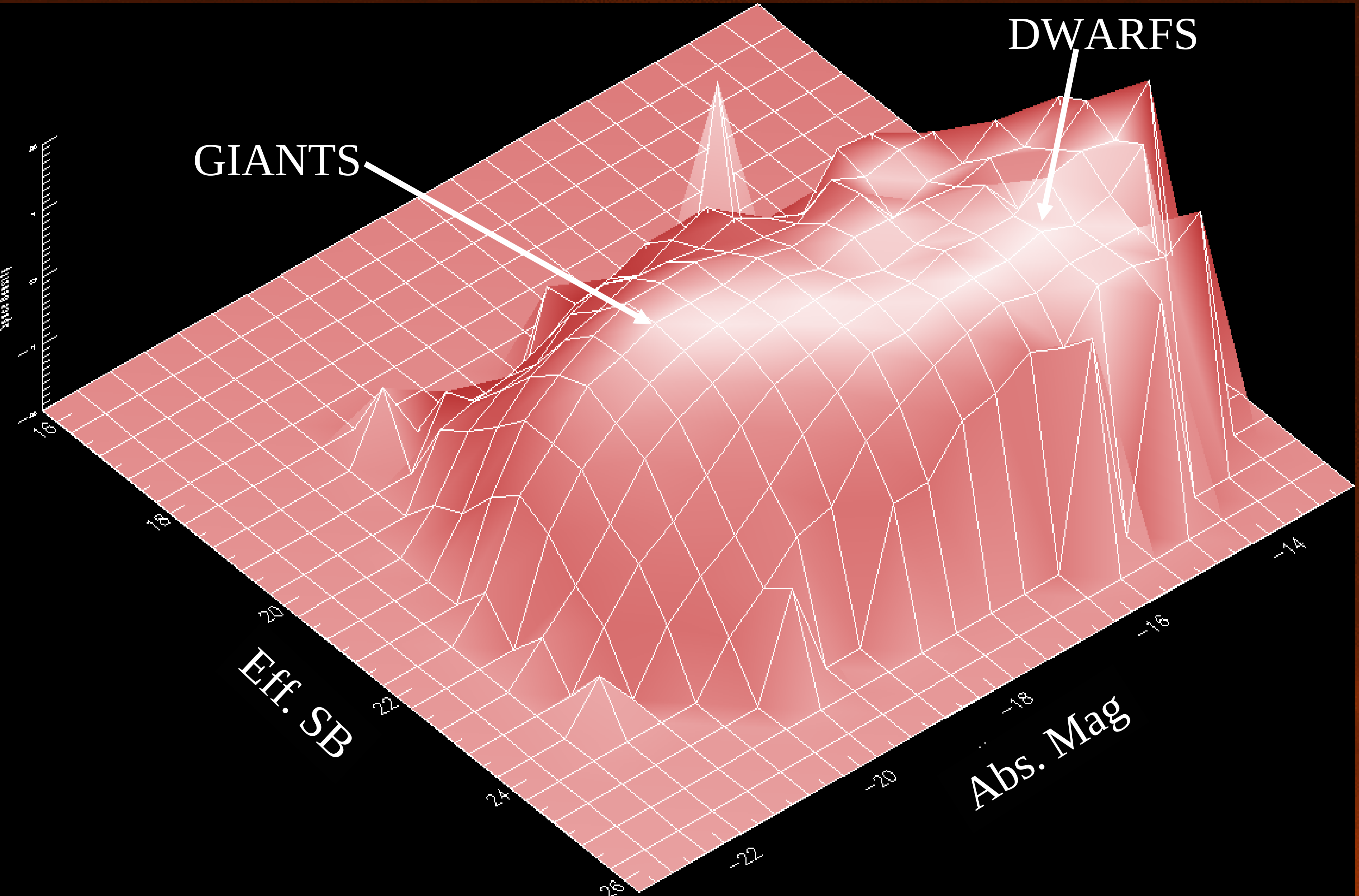
  - Minimum detectable surface brightness (due to detection isophote, μ = 26.0 mag sq arcsec)

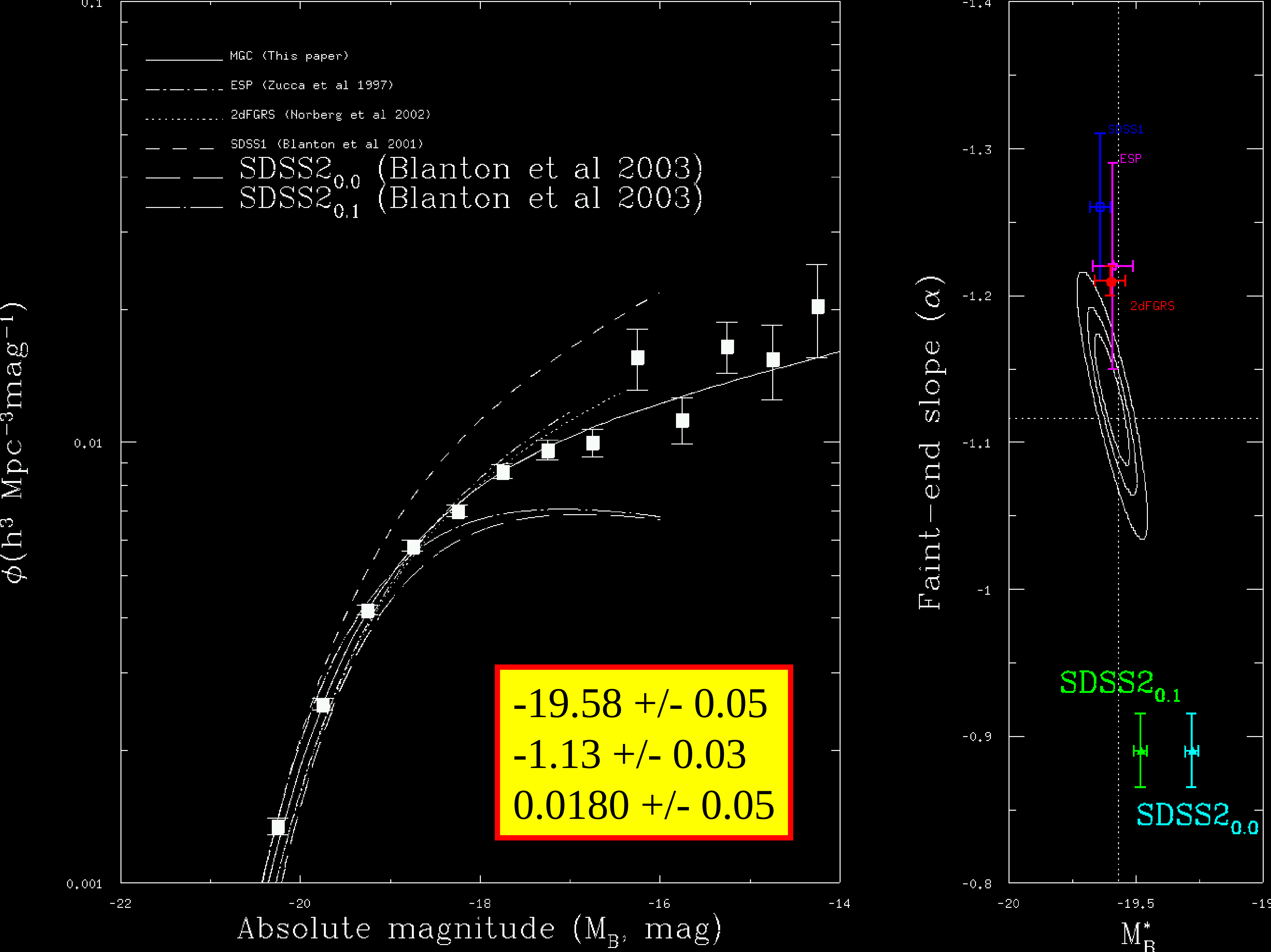
$$\mu_{\rm low} = \mu_{\rm lim} - 10\log(1+z) - K(z) - E(z)$$



Min. size limit (worst)
Min. size limit (median)
Min. size limit (best)
Reliable maximum size limit
Absolute Detection Limit
Reliable isophote limit
20
22
24
26
μ_{eff} (mag arcsec^{-2})
14
16
18
20
B_{MGC}(mag)

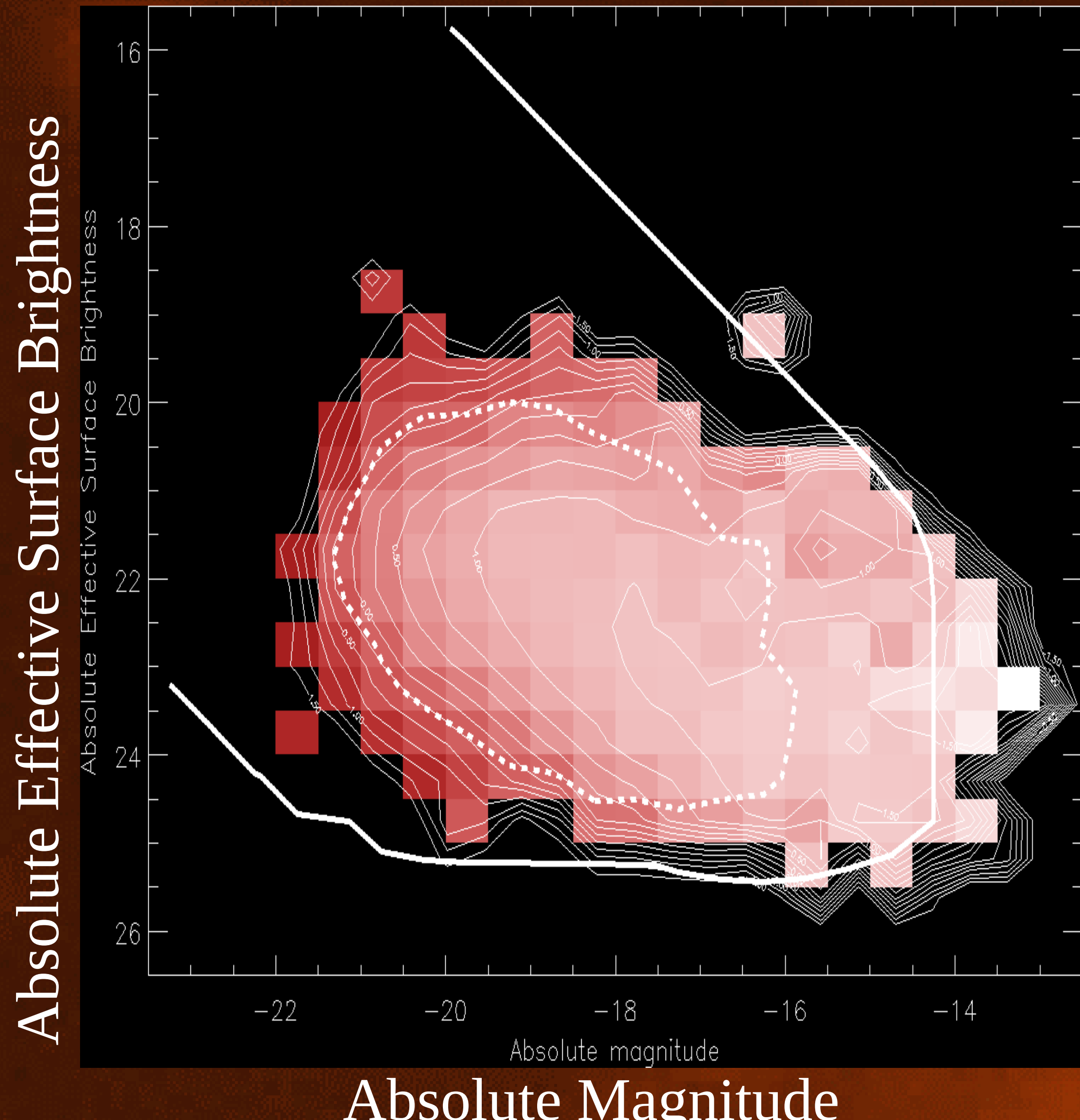
The Joint Luminosity Surface Brightness Distr'n



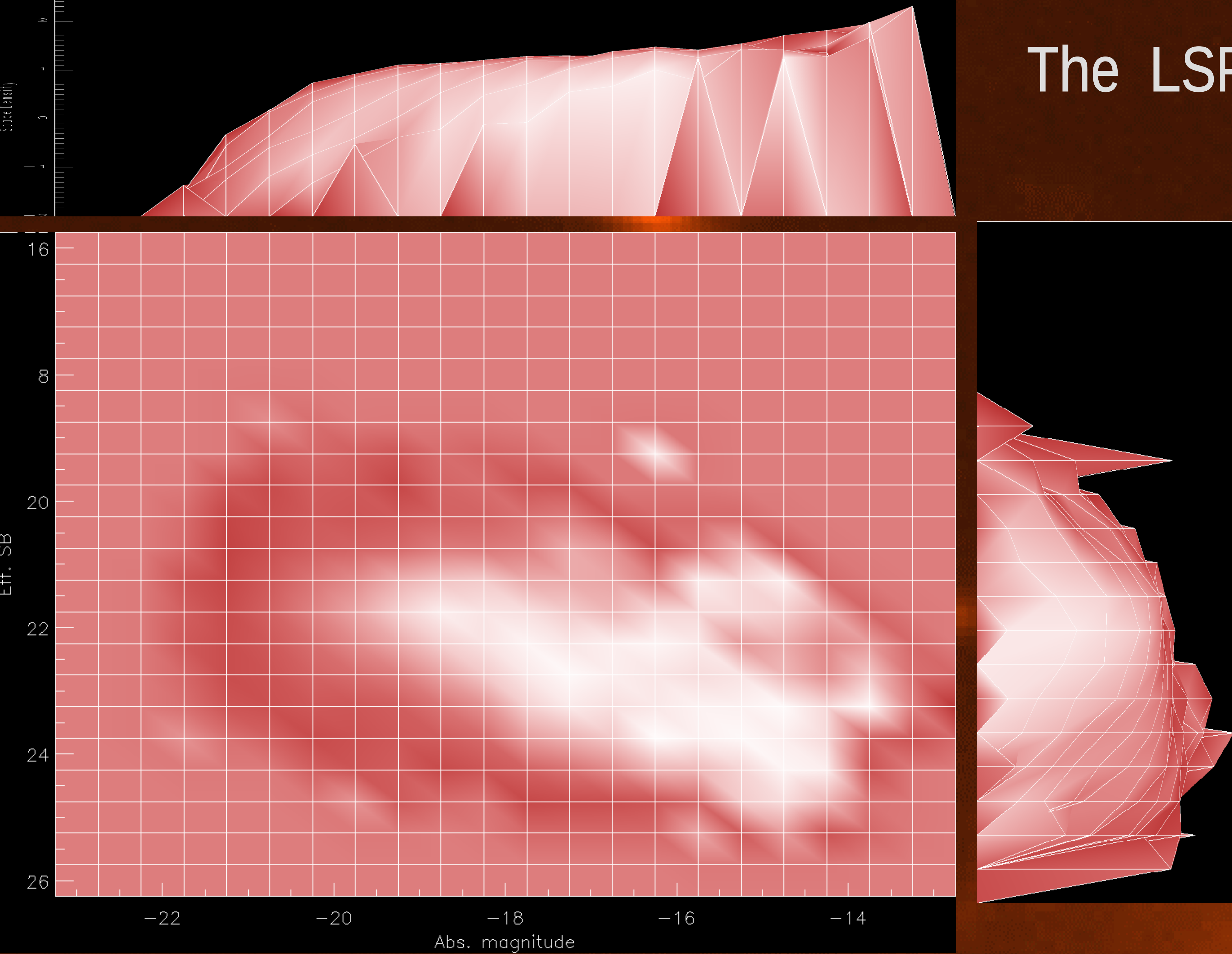

MGC (This paper)
ESP (Zucca et al 1997)
2dFGRS (Norberg et al 2002)
SDSS1 (Blanton et al 2001)
SDSS2$_{0.0}$ (Blanton et al 2003)
SDSS2$_{0.1}$ (Blanton et al 2003)
ϕ(h^3 Mpc^{-3}mag^{-1})
Absolute magnitude (M_B, mag)
0.1
0.01
0.001
-22
-20
-18
-16
-14
-19.58 +/- 0.05
-1.13 +/- 0.03
0.0180 +/- 0.05
Faint-end slope (α)
M^*_B
SDSS1
ESP
2dFGRS
SDSS2$_{0.1}$
SDSS2$_{0.0}$
-1.4
-1.3
-1.2
-1.1
-1
-0.9
-0.8
-20
-19.5

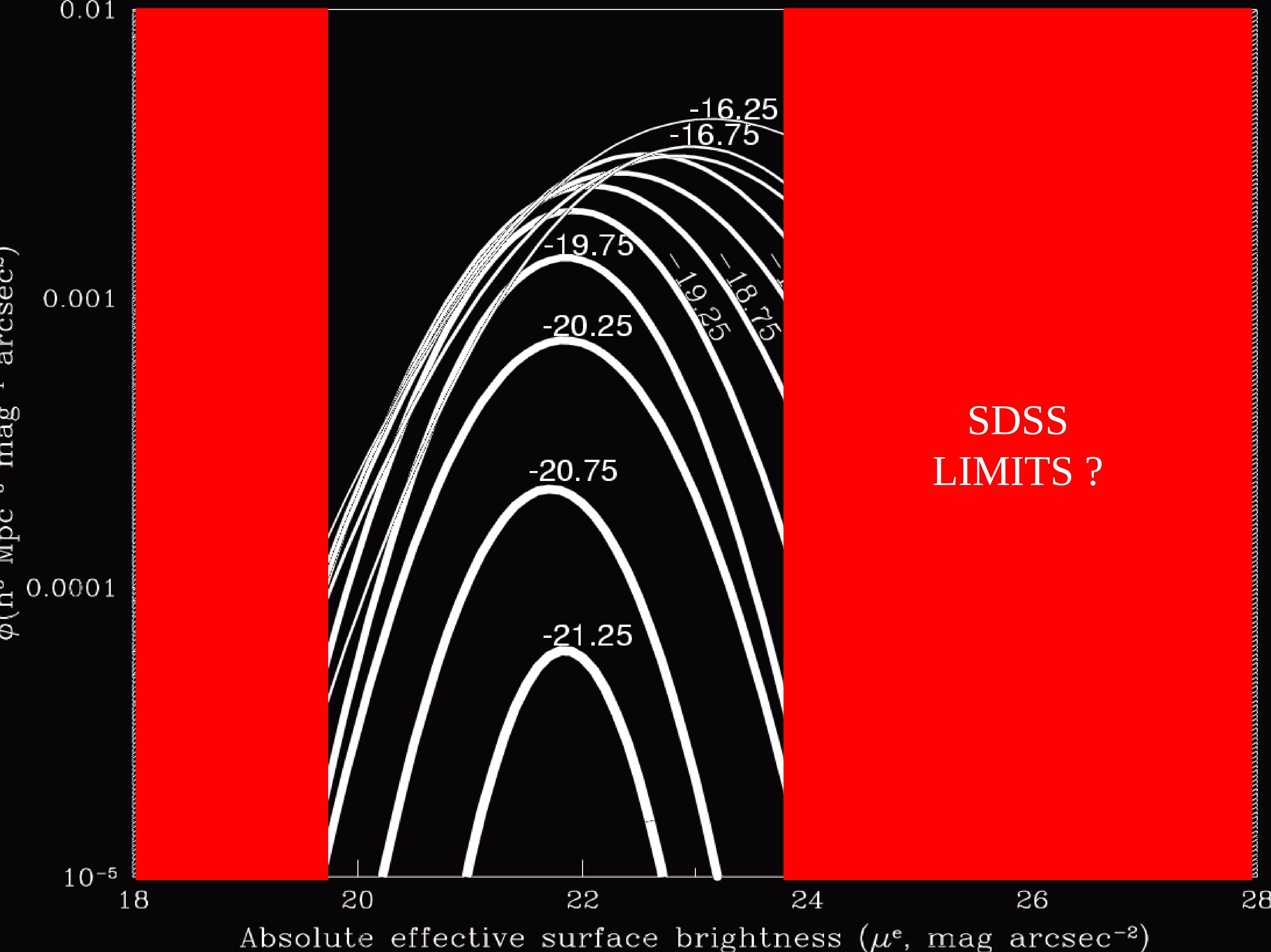
MGCz LSP in more detail

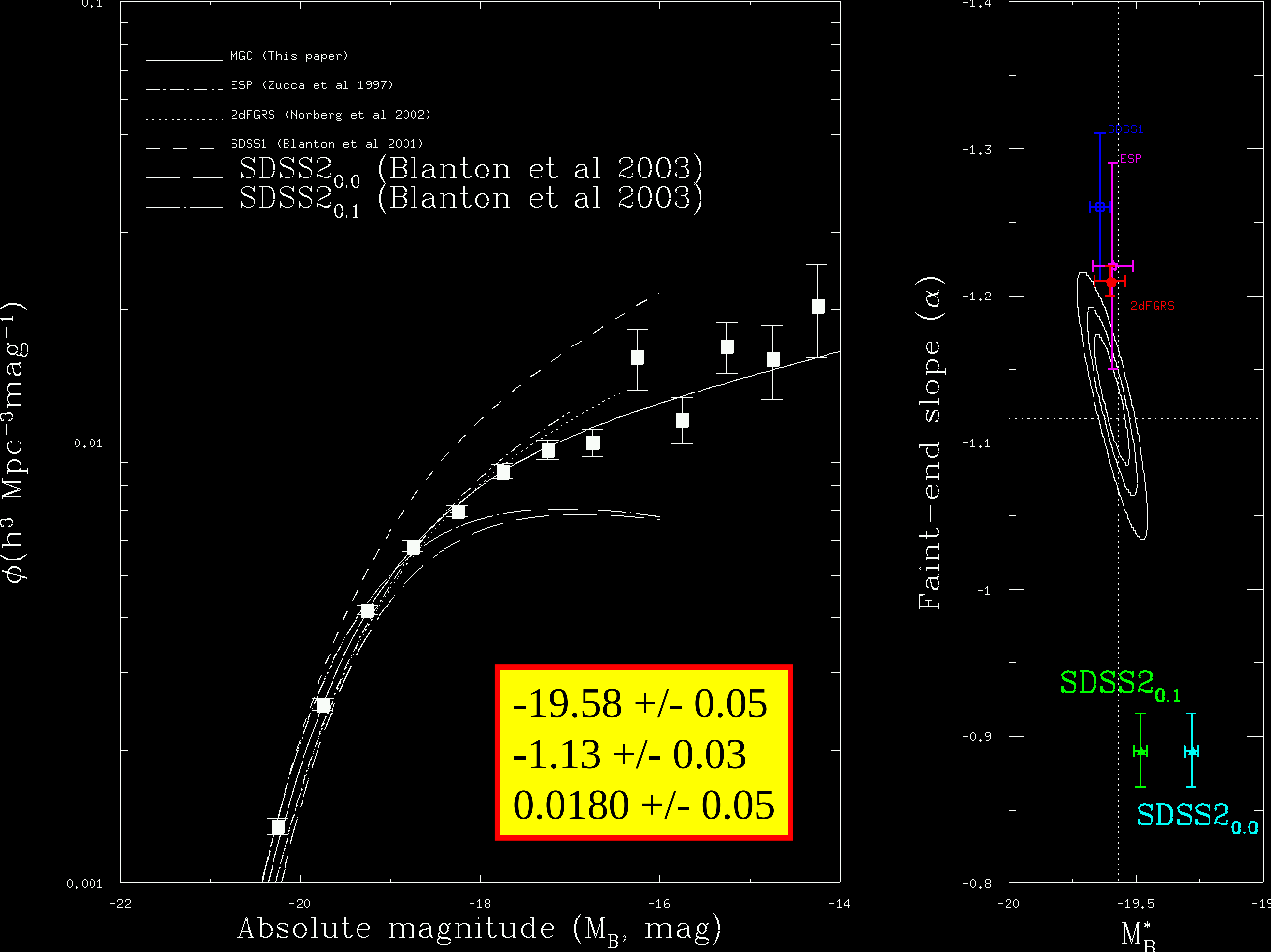
- Selection boundary is defined as the region sampled by at least 100 galaxies
- We see a clear L-Σ relation
- Not due to selection bias
- Clear decline in space density of low surface brightness giants
- Selection effects become severe for the dwarf population
- However to M < -15 LF is flat
  - Negligible contribution to:
    - Light
    - Mass
    - Faint Counts
- Evidence for the dwarf population diving into two or distribution broadening ?



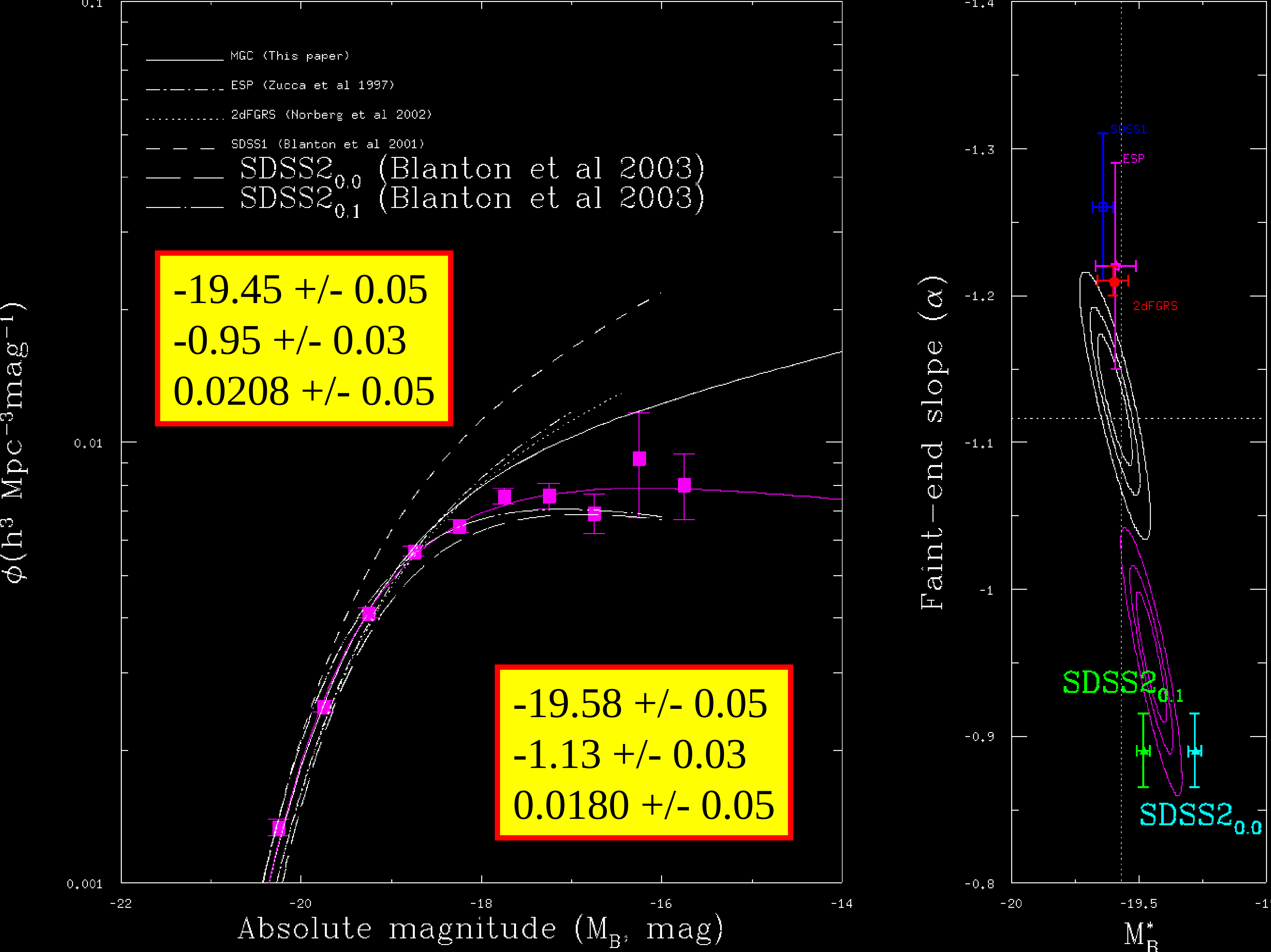
The LSP




0.01
0.001
0.0001
10⁻⁵
18
20
22
24
26
28
Absolute effective surface brightness (μe, mag arcsec⁻²)
-16.25
-16.75
-19.75
-19.25
-18.75
-20.25
-20.75
-21.25
SDSS
LIMITS ?

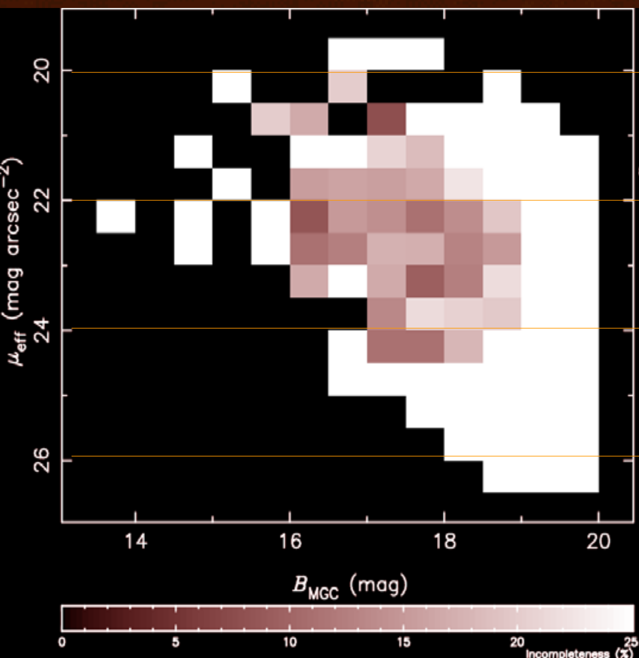


MGC (This paper)
ESP (Zucca et al 1997)
2dFGRS (Norberg et al 2002)
SDSS1 (Blanton et al 2001)
SDSS2$_{0.0}$ (Blanton et al 2003)
SDSS2$_{0.1}$ (Blanton et al 2003)
-19.58 +/- 0.05
-1.13 +/- 0.03
0.0180 +/- 0.05
ϕ(h^3 Mpc^{-3}mag^{-1})
Absolute magnitude (M_B, mag)
0.1
0.01
0.001
-22
-20
-18
-16
-14
Faint-end slope (α)
M_B^*
SDSS1
ESP
2dFGRS
SDSS2$_{0.1}$
SDSS2$_{0.0}$
-1.4
-1.3
-1.2
-1.1
-1
-0.9
-0.8
-20
-19.5

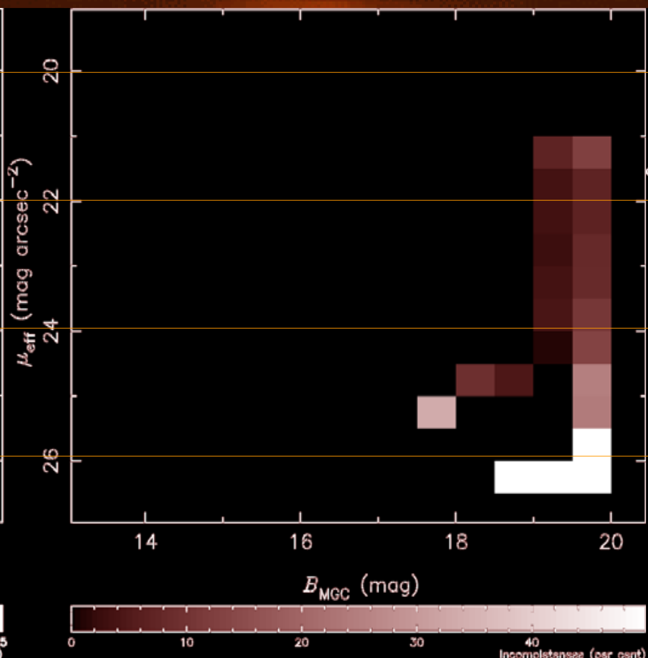

MGC (This paper)
ESP (Zucca et al 1997)
2dFGRS (Norberg et al 2002)
SDSS1 (Blanton et al 2001)
SDSS2$_{0.0}$ (Blanton et al 2003)
SDSS2$_{0.1}$ (Blanton et al 2003)
-19.45 +/- 0.05
-0.95 +/- 0.03
0.0208 +/- 0.05
-19.58 +/- 0.05
-1.13 +/- 0.03
0.0180 +/- 0.05
$\phi(h^3\ Mpc^{-3} mag^{-1})$
Absolute magnitude (M_B, mag)
0.1
0.01
0.001
-22
-20
-18
-16
-14
Faint-end slope (α)
SDSS1
ESP
2dFGRS
SDSS2$_{0.1}$
SDSS2$_{0.0}$
-1.4
-1.3
-1.2
-1.1
-1
-0.9
-0.8
-20
-19.5
M_B^*

Incompleteness Bias

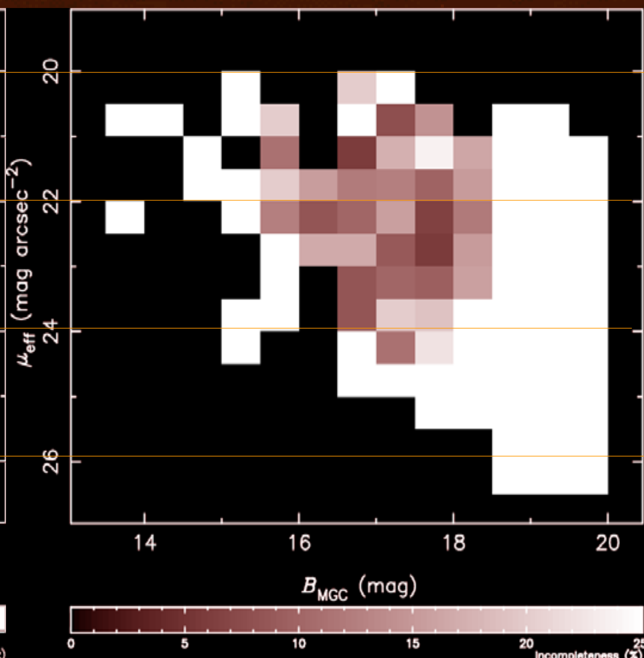
2dFGRS



MGC



SDSS



Incompleteness (%)

Beyond The Galaxy Luminosity Function ?

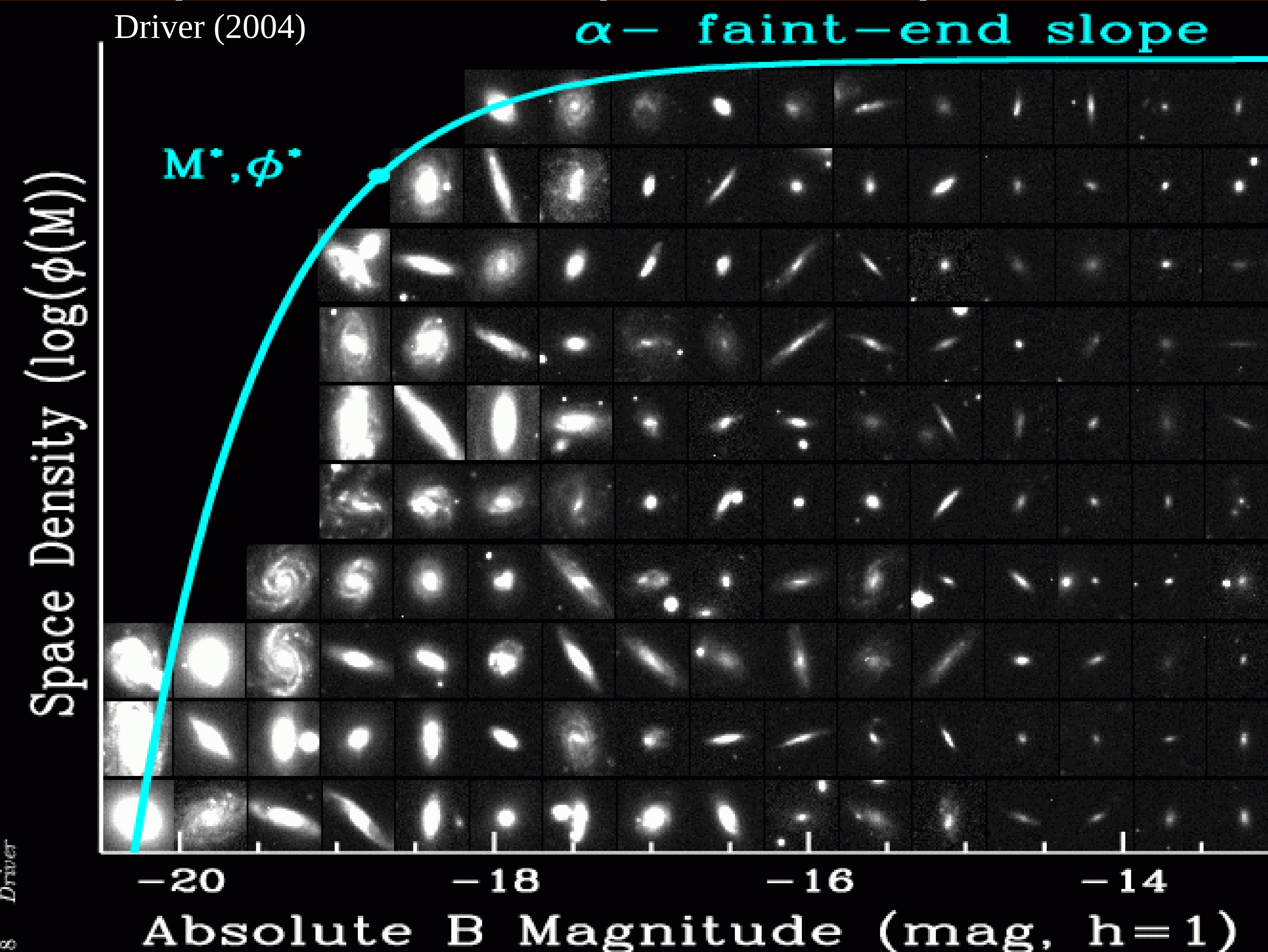
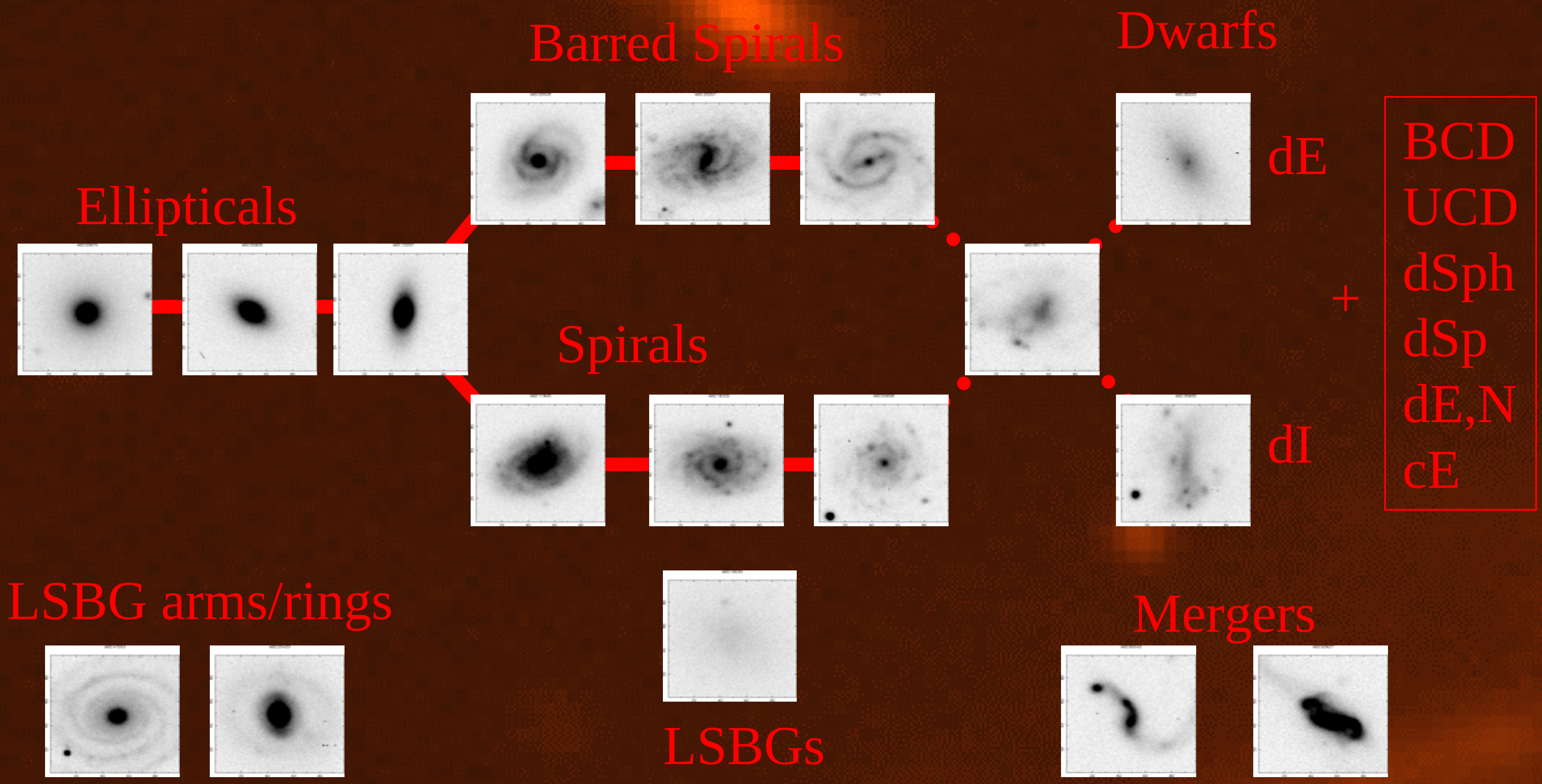


Figure 9. PLATE1: The Global Galaxy Luminosity Function (red line) condenses the available information of galaxies (images) into three crucial numbers: the characteristic luminosity (M^*); the absolute normalisation (ϕ^*); and the faint-end slope (α). Although the Schechter parameterisation is more often that not a remarkably good fit, one cannot help but feel that too much important information may have been lost, for instance the sizes and bulge-to-total parameters.

Galaxy Classification: The Hubble Tuning Fork

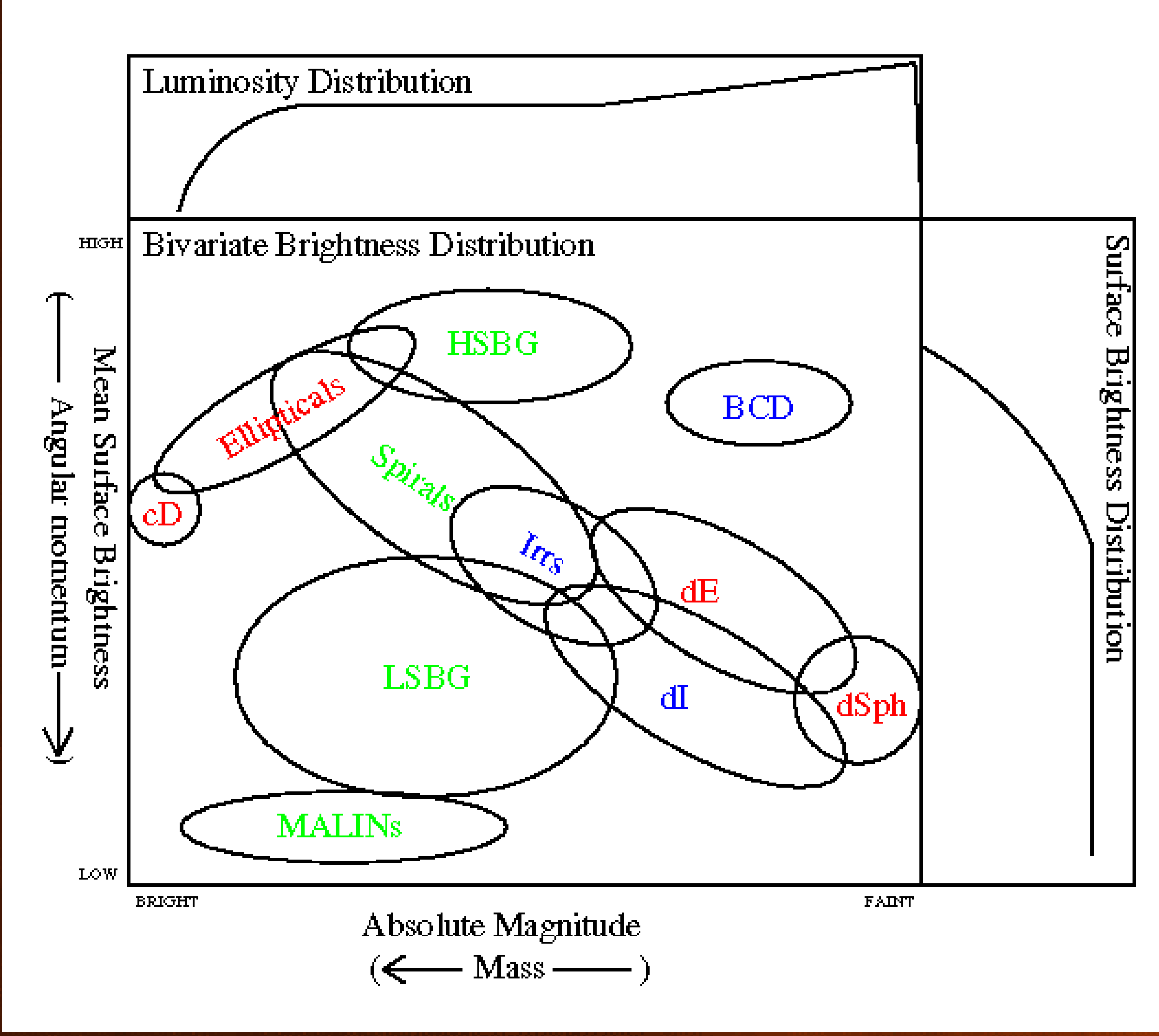
- The Hubble Tuning Fork is no-longer viable, with many types defying classification:



- Diversity implies multiple evolutionary paths (epochs)
- But how to incorporate this diversity into the modeling ?

The Luminosity-Surface Brightness Plane

- Combines all 3 representations
- Quantitative
  - Reproducible
  - Universal
- Theoretical basis
  - μ —> λ (Spin)
  - L —> M (Mass)
- Manages selection bias



Galaxy Formation: CDM

- Press & Schechter (1974) - Derive expression for the initial halo mass distribution
- White & Rees (1978) - Cold Dark Matter and Hierarchical merging
- Fall & Efstathiou (1980) - Basic prescription for formation of galaxies
- The New CDM Battleground:
  - Over production of low mass haloes (mass function v luminosity function) => feedback ?
  - Angular momentum (short stumpy disks) => cold gas infall, minor mergers to feed disk ?
  - [Cuspy cores (NFW haloes inconsistent with rotation) => lack of baryon physics/resolution ?
- General scenario:
  - Initial dark matter haloes have relatively low initial angular momentum
  - Haloes exert torques which can introduce large angular momentum
  - Angular momentum of pre-collapse haloes grows linearly with time (White 1984)
  - Alignment of spin vectors debated (Cole & Lacey 1996)
  - Haloes continually accrete, introducing additional mass and angular momentum
  - However the typical dark matter profile shape results in
    - Too much mass at small radii caused by too much low angular momentum particles
    - Too much mass at large radii caused by too much high angular momentum particles

Galaxy Formation: The Angular Momentum

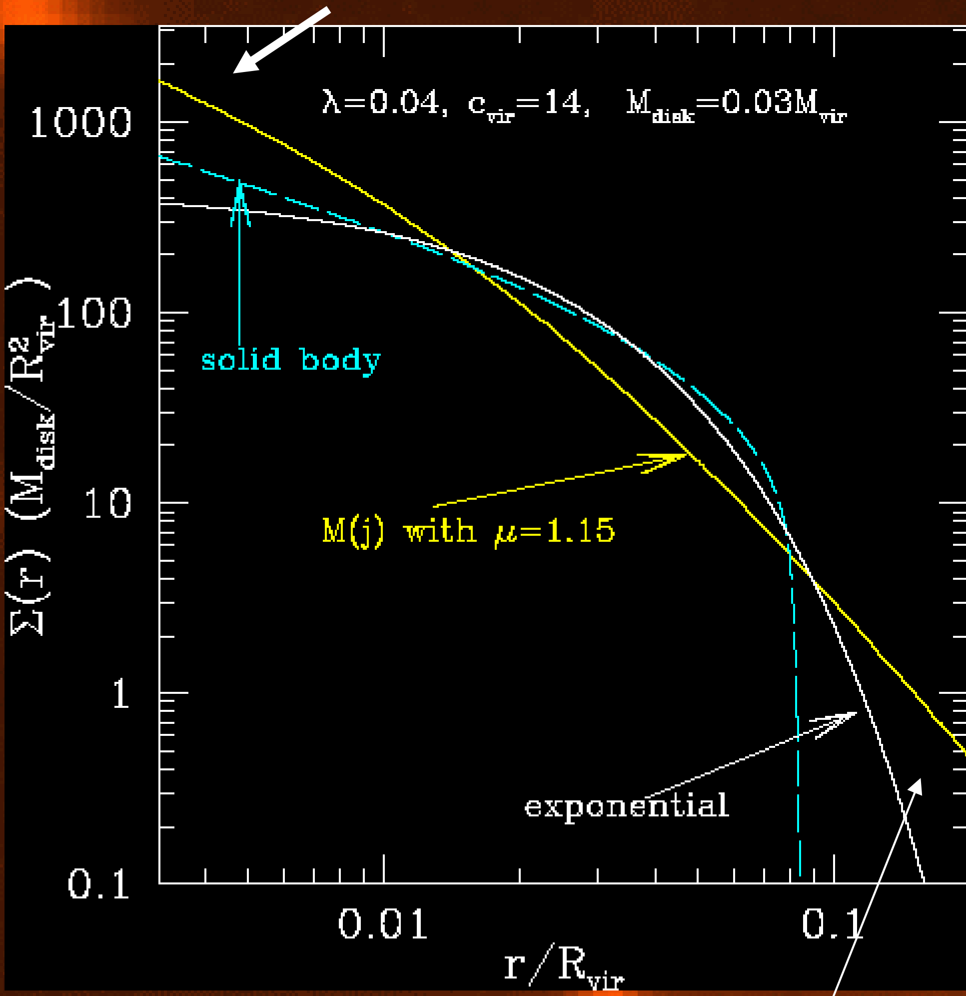
- Primack (2003)
  - Expect Ang. Mom. of baryons to follow that of the potential (Tully-Fisher)
  - Currently difficult to form realistic disks
  - Major mergers ==> bulges
  - Minor mergers ==> build disks
- Peebles (1969) - Defines λ, the dimensionless spin parameter

$$\lambda \equiv \frac{J\,|E|^{1/2}}{GM^{5/2}}$$

- J = Angular Momentum (Mvr)
- E= Total Energy (Mv^2)
- M=Halo Mass

- High spin parameter = rotational system
- Low spin parameter = negligible rotation

Too much mass in core



Too much mass at large radii

Galaxy Formation: Connecting λ and Σ

- Fall & Efstathiou (1980), Dalcanton, Spergel & Summers (1997), Mo, Mao & White (1998), de Jong & Lacey (2000) all relate λ to either μ or r_d under varying assumptions

$$\lambda \propto r_d \qquad \Sigma_o \propto F M_{tot}^{1/3} \lambda^{-(2+6F)} \qquad \lambda \propto L^{1/6} \Sigma^{-1/2}$$

- All agree that at fixed Mass or Luminosity: $\lambda \propto \Sigma^{-1/2}$
- Hence surface brightness distribution should follow same distribution as Spin
- Currently we agree with the Gaussian form but find a much narrower distribution at M*
- Theory: $\sigma_\lambda \sim 0.5$ or $\sigma_\mu \sim 1.085$ in MGC we find 0.4 for giants and 0.9 for dwarfs

Galaxy Formation:The Spin Distribution

- Analytically and numerically (Barnes & Efstathiou 1987; Warren et al 1992; Eisenstein & Loeb 1995; Catelan & Theuns 1996) the distribution of spin angular momentum of collapsed haloes is lognormal distribution, I.e,:

$$p(\lambda) = \frac{1}{\sigma_\lambda \sqrt{2\pi}} \exp[-\frac{\ln^2(\lambda / <\lambda>)}{2\sigma_\lambda^2}] \frac{d\lambda}{\lambda}$$

- Typically: $0.03 < <\lambda> < 0.05$ and $0.5 < \sigma_\lambda < 0.7$
- E.g., Bullock et al (2001): $<\lambda>=0.042+/-0.006$ and $\sigma_\lambda =0.50+/-0.04$

⇒ Should we expand the LF to include a Gaussian SB distribution ?

Schechter versus Cholienewski function

- Schechter (1976) proposed the now standard functional fit to the galaxy luminsity dist'n:

$$\phi(M) = 0.4\ln(10)\phi^{*}10^{0.4(M^{*}-M)(\alpha+1)}e^{-10^{0.4(M^{*}-M)}}$$

  - α = faint-end power-law
  - ϕ* = normalisation point
  - M* = Characteristic turnover luminosity

- Cholienewski (1983) proposed a bivariate functional formal, essentially the Schechter function multiplied by a Gaussian in surface brightness:

$$\phi(M,\mu) = \frac{0.4\ln(10)}{\sqrt{2\pi}\sigma_{\mu_{eff}}}\phi^{*}10^{0.4(M^{*}-M)(\alpha+1)}e^{-10^{0.4(M^{*}-M)}}\exp[-\frac{1}{2}(\frac{\mu_e-\mu_e^{*}-\beta(M-M^{*})_e}{\sigma_{\mu_e}})^2]$$

  - α = faint-end power-law
  - ϕ* = normalisation point
  - M* = Characteristic turnover luminosity

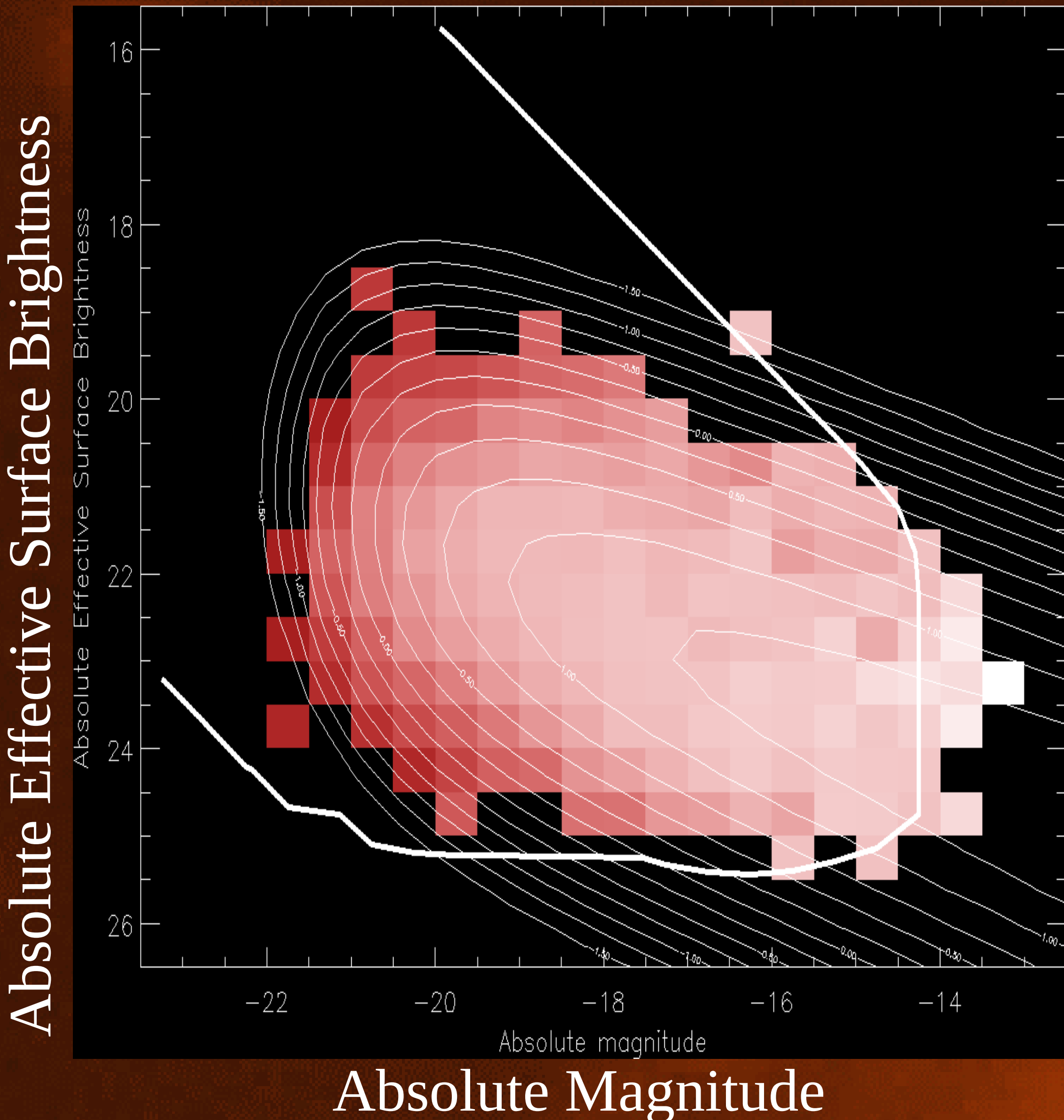
  } Identical to Schechter fn

  - μ* = Characteristic surface brightness at M*
  - β = slope of luminosity surface brightness relation
  - σ = width of Gaussian distribution

  } Gaussian SB multiplier

MGCz LSP:Chołoniewski Function ?

- Minimise via Ameoba algorithm
- Fit extremely poor (χ^2 =617/149)
- Two reasons:
  - Change in slope of L-Σ relation from giants to dwarfs
  - Broadening of SB distribution at faint mags
- Neither effect predicted by CDM
- However possible indications in CDM literature



Galaxy formation: Evolution of Spin

- Vitvitska et al (2003)
  - Major mergers can radically change λ
  - Minor mergers generally leave unchanged
  - λ damps with mass and time
  - gradually decreases

- Expect distribution of λ (Σ) ♦□ ♌♏ ♌❐□♋♎♏❐ ♐□❐ ●□⬥ ❍♋⬥⬥ ⬥⍓⬥⧫♏❍⬥ ✍

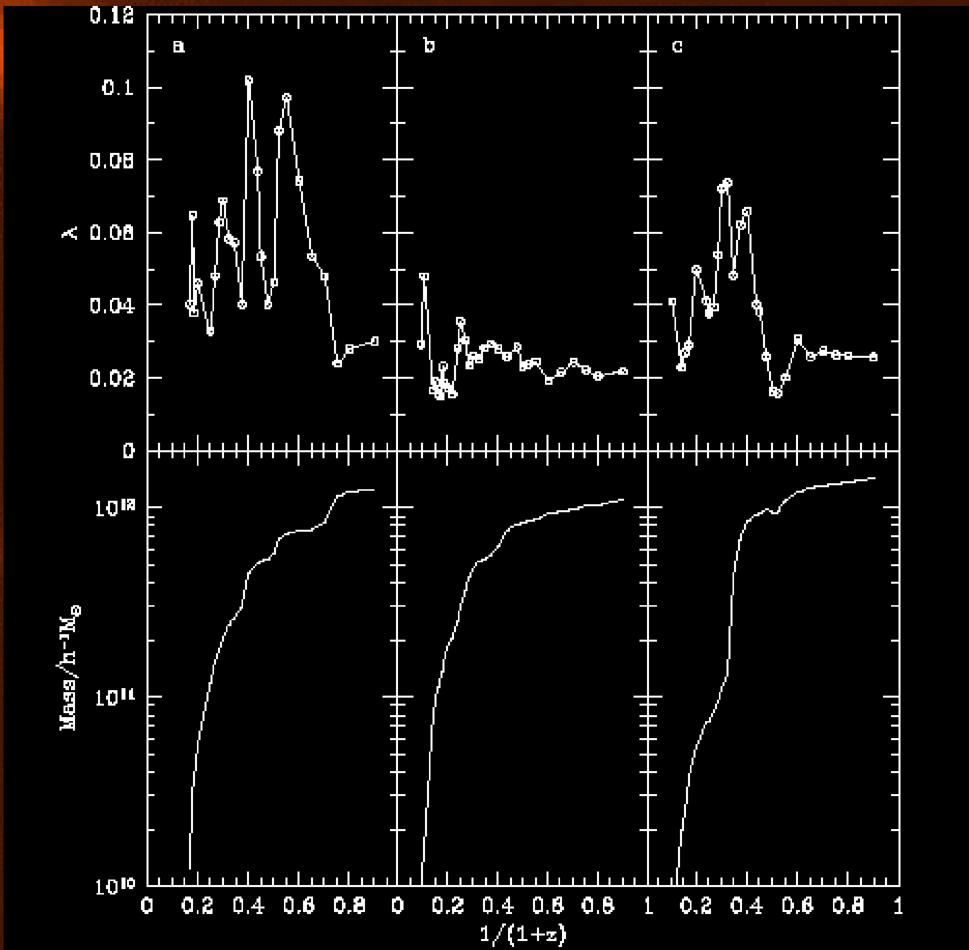


Figure 3. Mass accretion (lower panels) and spin parameter evolution (upper panels) of three galaxy-mass halos. Halos typically show fast mass growth at high redshift with rapid changes of spin parameter, followed by slower mass accretion with spin parameter usually declining. (From Vitvitska et al. 2002.)

Galaxy formation: Evolution of Spin

- Peirani et al (2004)
  - Mergers increase λ – Builds Bulges ?
  - Accretion decreases λ – 👌◆♓●♎⬧ ☟♓⬧&⬧ ✍

- Bulge dominated and disk dominated systems should have distinct SB distributions ?

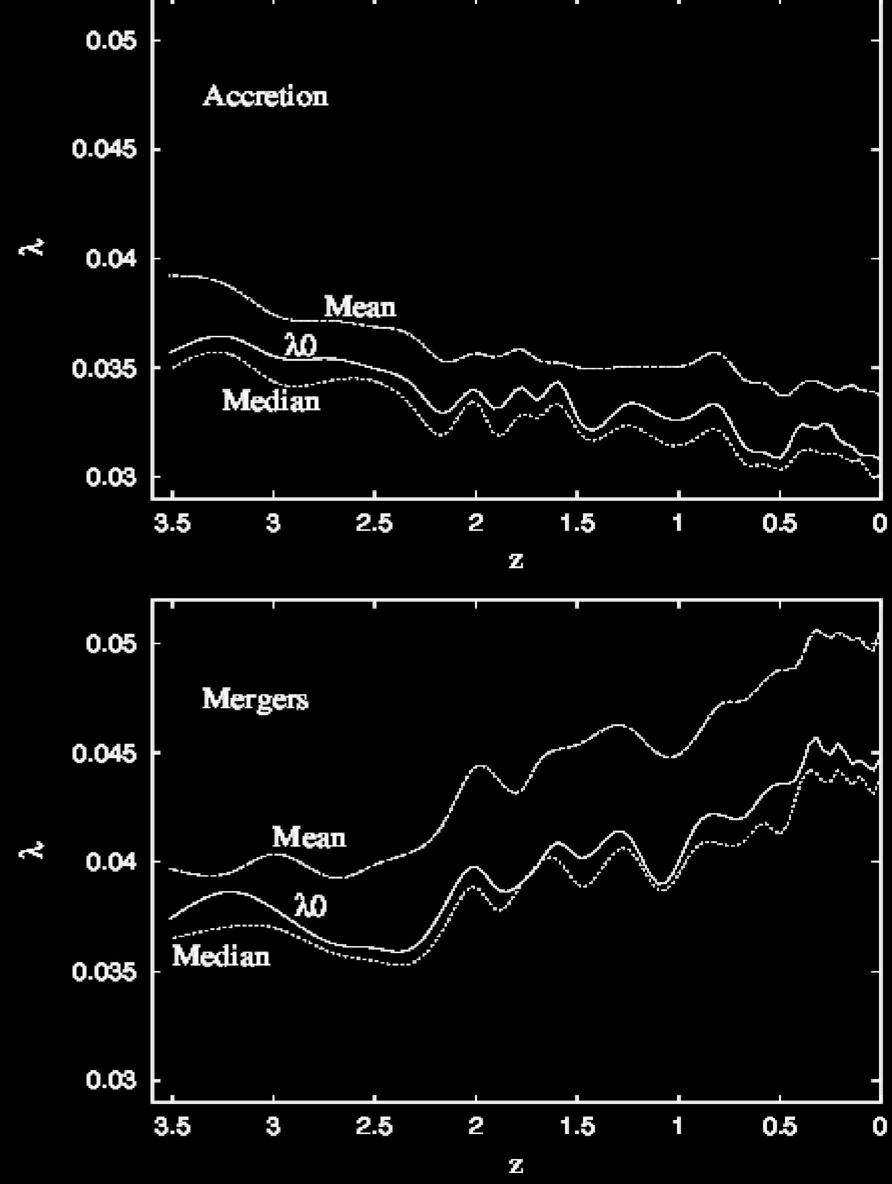


Figure 8. Panels from up to down: a) evolution of the spin parameter for all the halos (accretion + merger). Three statistical parameters are shown: the median, the mean and λ_0; evolution of the same parameters but for halos of the accreting catalog only (b) and for halos of the merger catalog (c).

Galaxy Formation: Mergers v Accretion

4.3 The evolution of the spin parameter

Previous works have shown that the spin parameter λ, obtained from simulations, has a log-normal distribution (Barnes & Efstathiou 1987; Cole & Lacey 1996; van den Bosch 1998; Ryden 1998),

$$P(\lambda)d\lambda = \frac{1}{\sigma_\lambda\sqrt{2\pi}} exp\left(-\frac{ln^2(\lambda/\lambda_0)}{2\sigma_\lambda^2}\right)\frac{d\lambda}{\lambda} \quad (14)$$

which seems to be a universal result, independent of the cosmological model. In Fig. 7 we show the distribution of the spin parameter at $z = 0$ for the two catalogs considered here. An inspection of this plot confirms again that halos which have undergone important merger episodes have, on the average, a larger spin parameter and a wider distribution than those evolved by accretion only. We will return to this point later in this section.

If the halos of both samples are considered together, the parameters defining the distribution at $z = 0$ are: $\lambda_0 = 0.036$ and $\sigma_\lambda = 0.57$, in agreement with previous

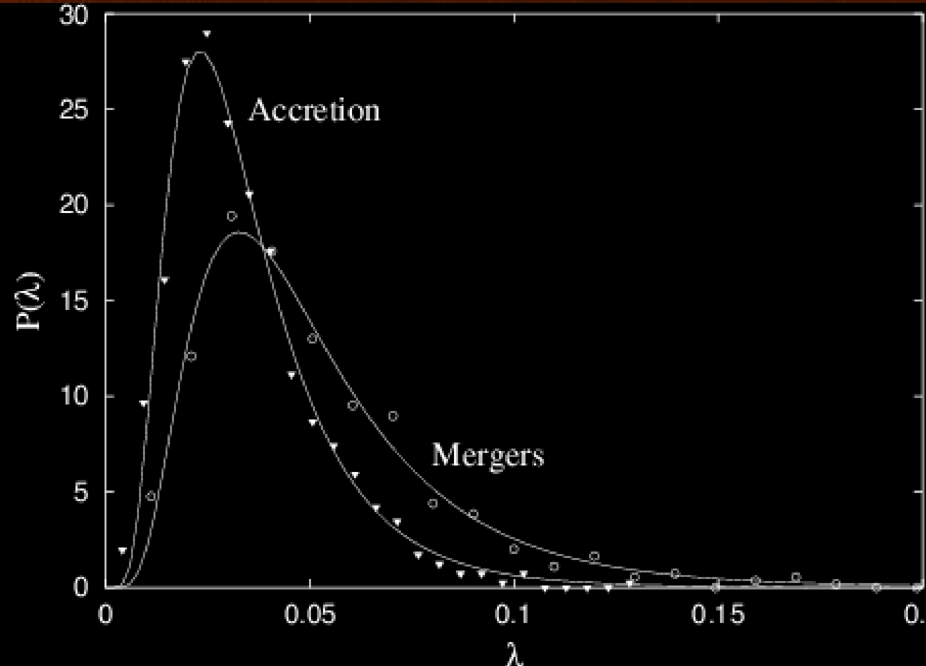


Figure 7. The distribution of the spin parameter for halo that grow by merger and those which grow by accretion a $z = 0$. The average spin parameter is higher for halos un derwent merger events than for halos which have growth b accretion only.

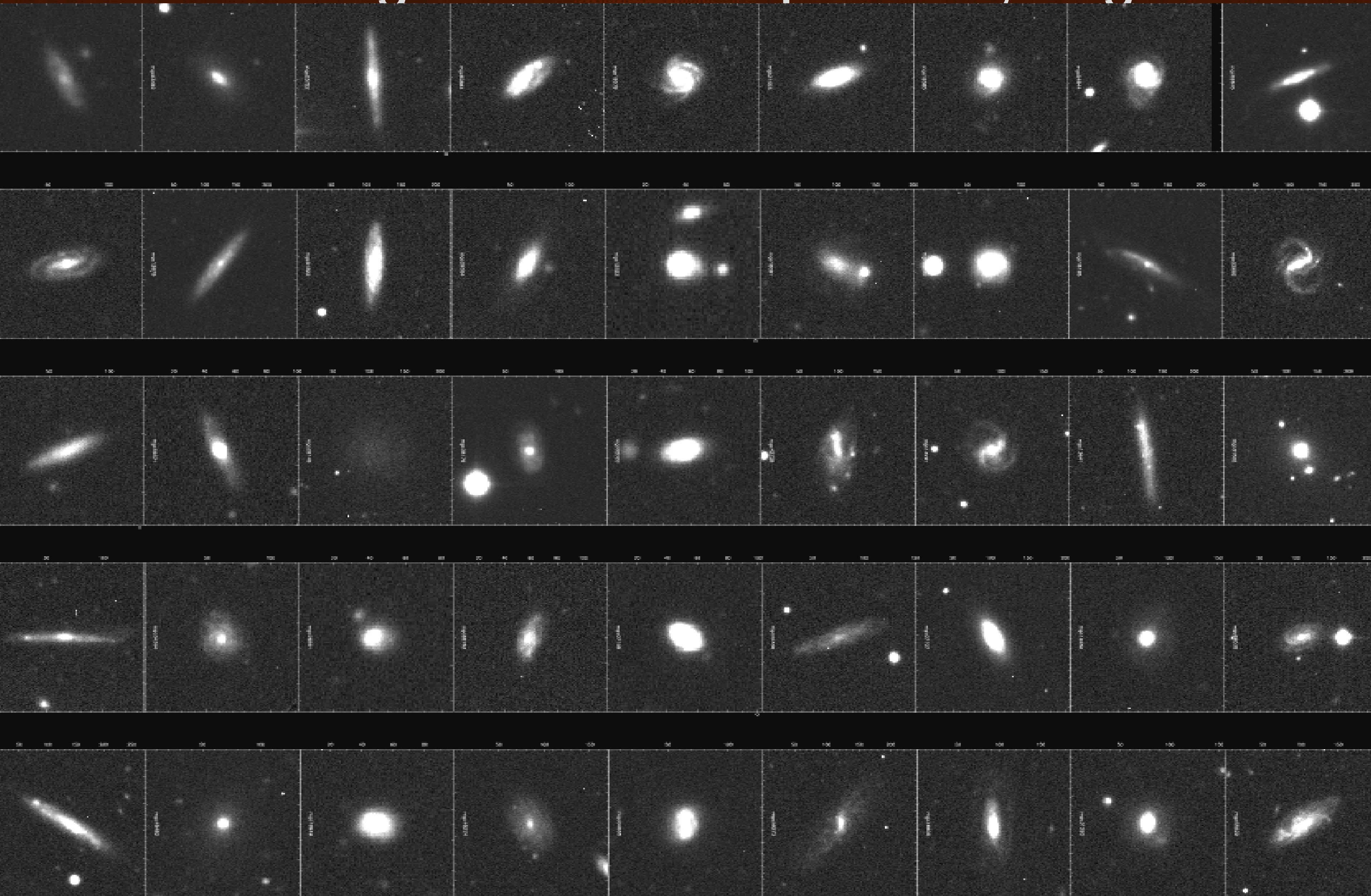
Peirani et al 2004

Bulge Disk Decomposition with GIM2D

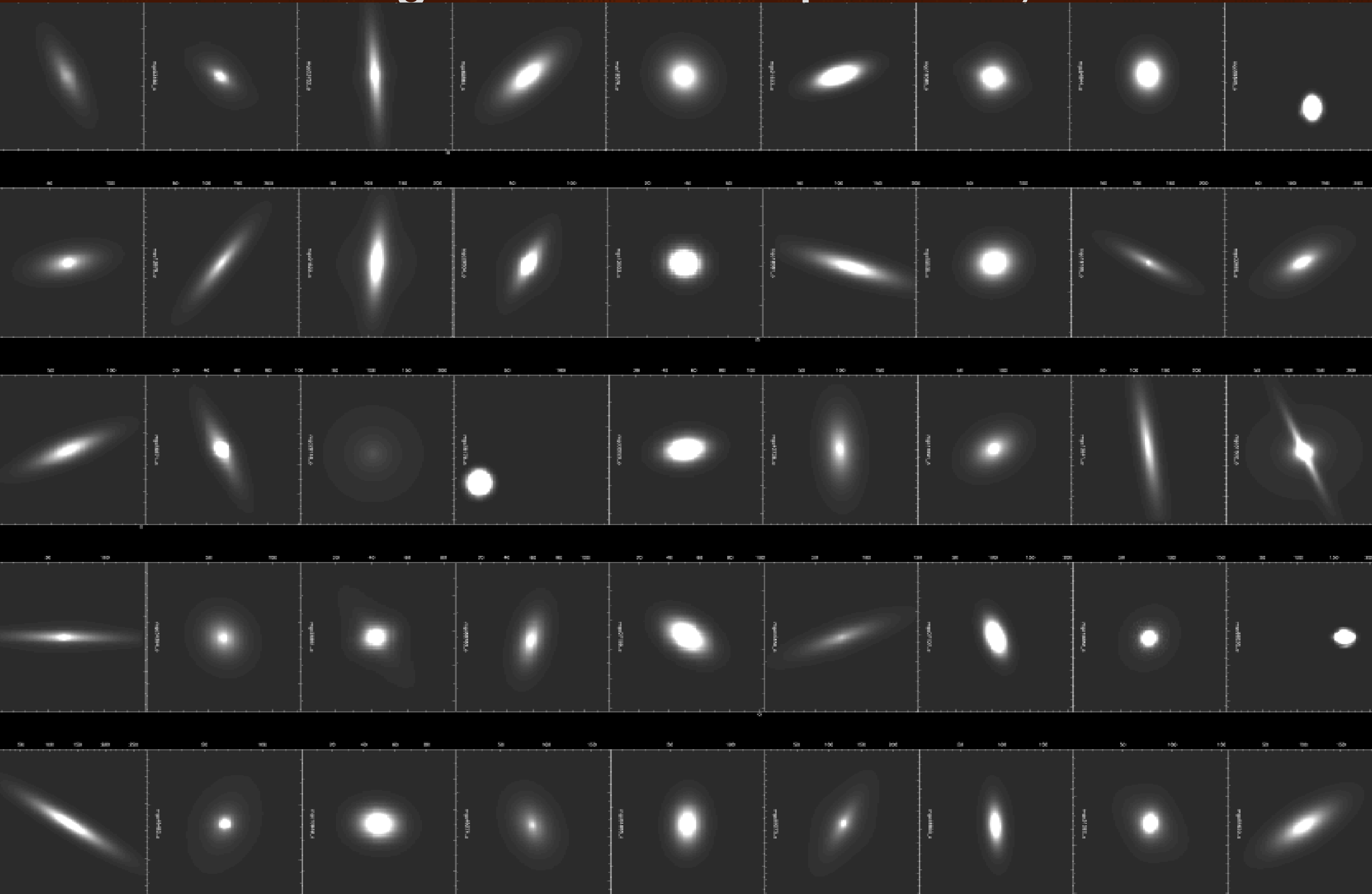
- Requires:
  - Postage stamp image
  - Mask identifying which pixels to use in Chi sq
  - Model of the point spread function
- 12 free parameters:
  - B/T, L, Re,ε,φ,α,

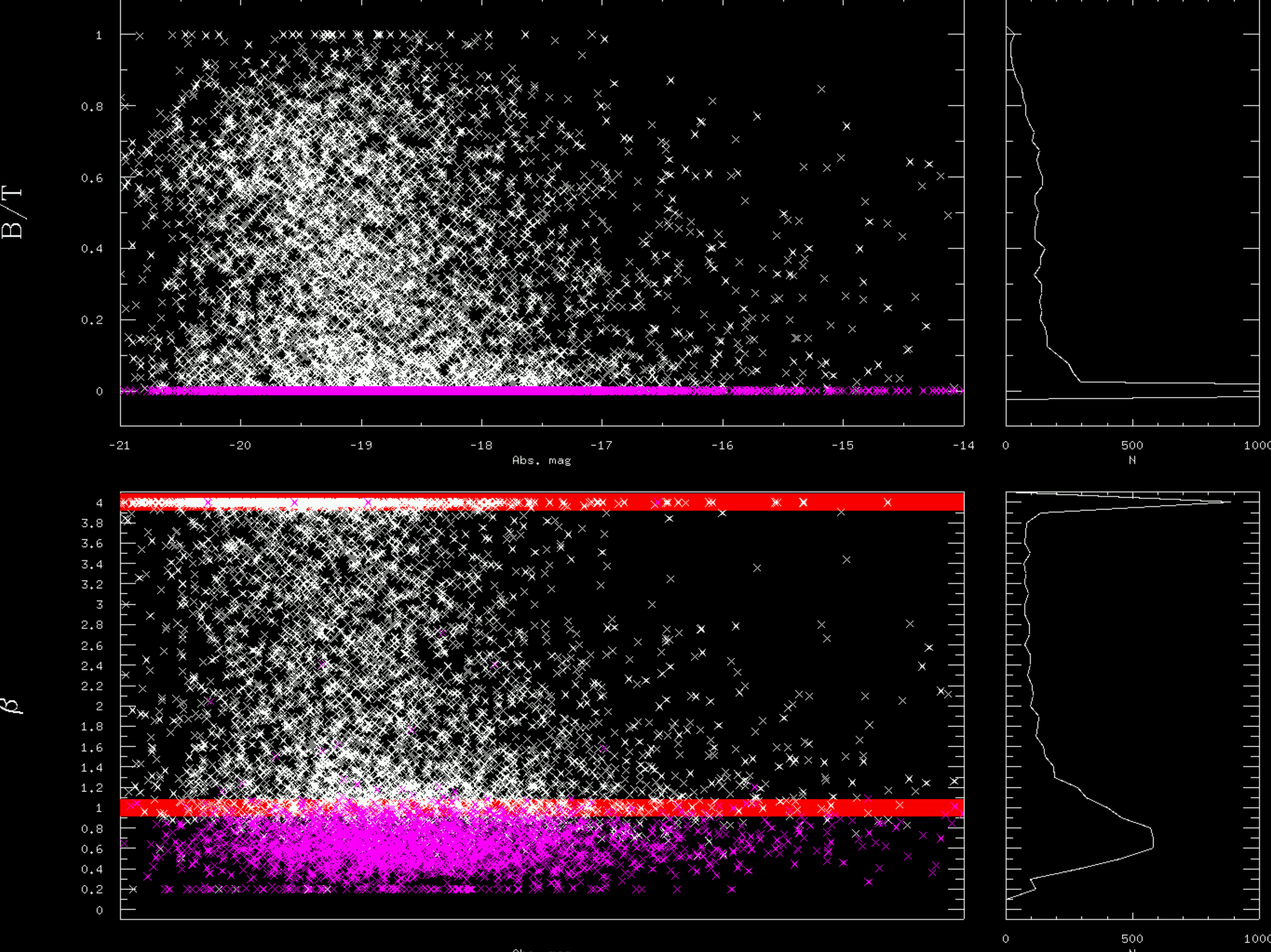
Work in Progress

MGC: Bulge Disk Decomposition, originals

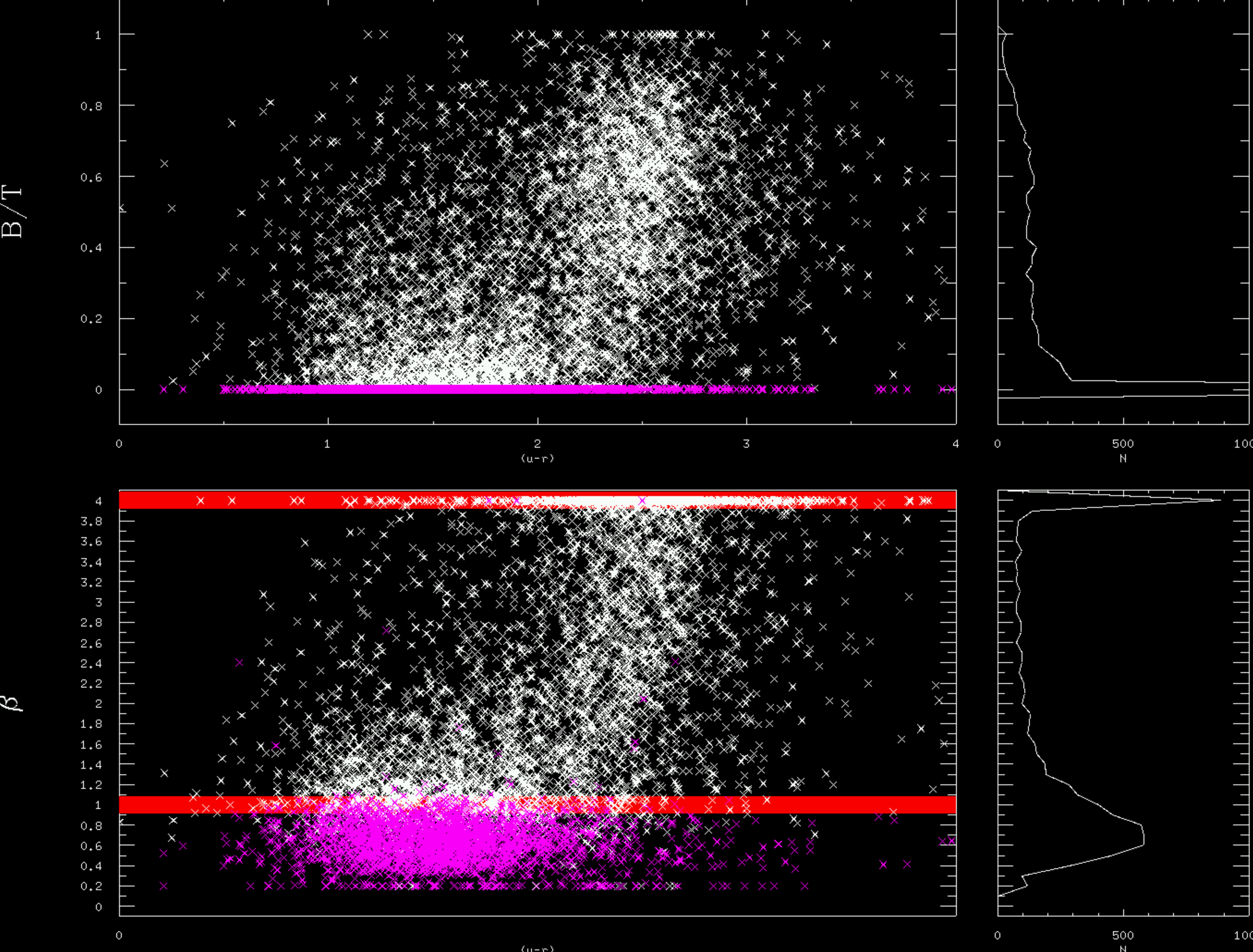


MGC: Bulge Disk Decomposition, models

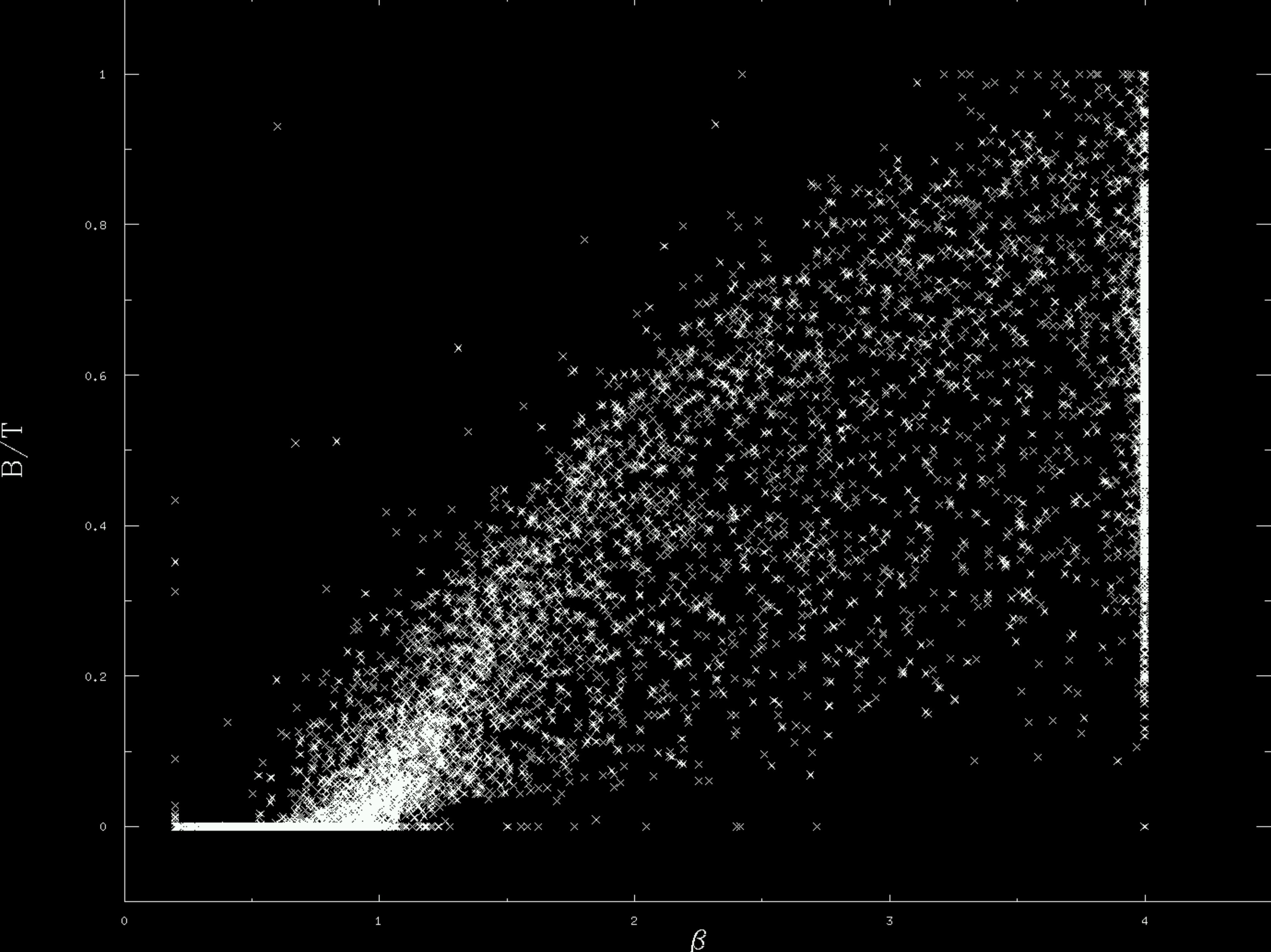




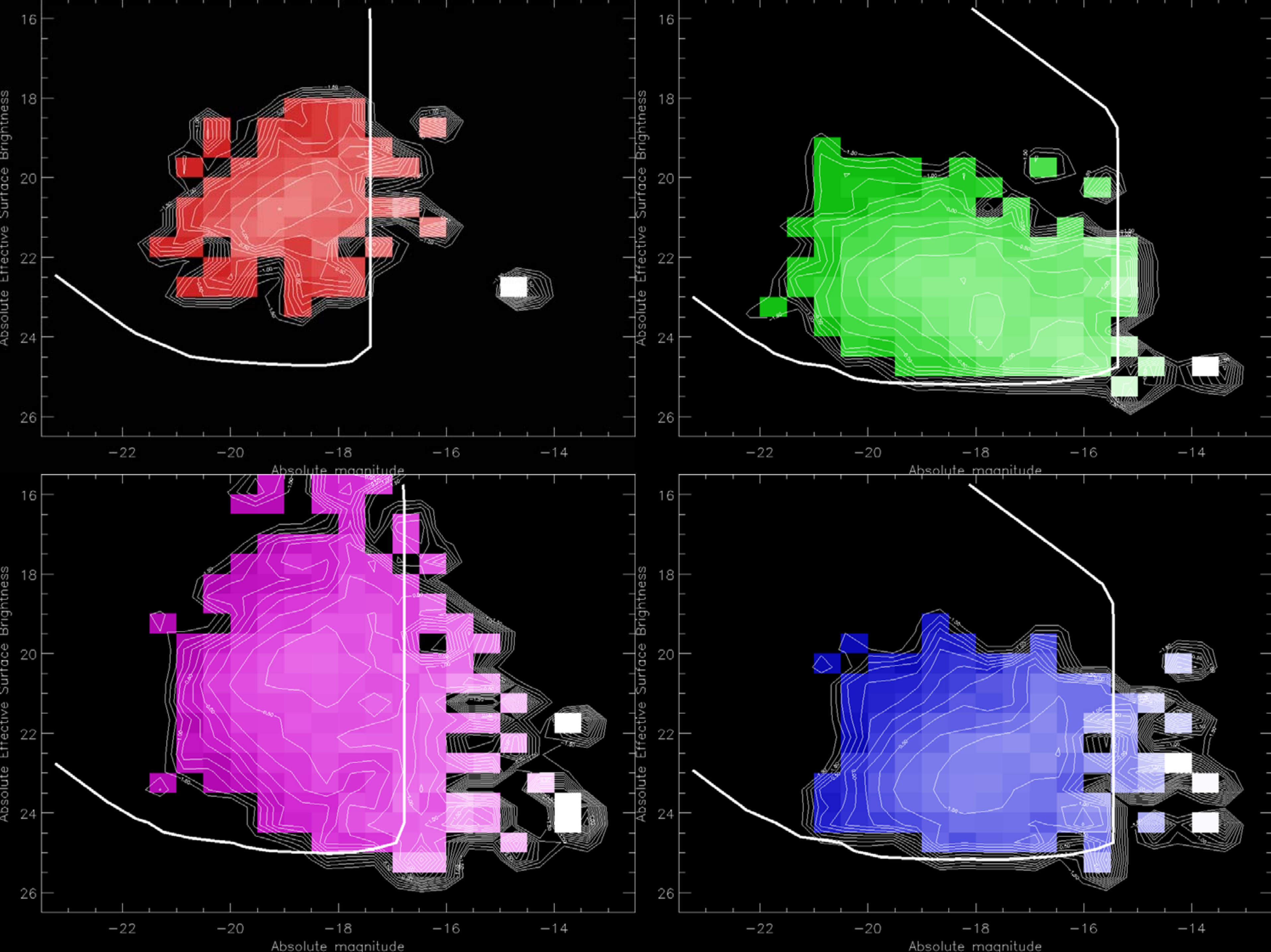
B/T
1
0.8
0.6
0.4
0.2
0
-21
-20
-19
-18
-17
-16
-15
-14
Abs. mag
0
500
1000
N
β
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
500
1000

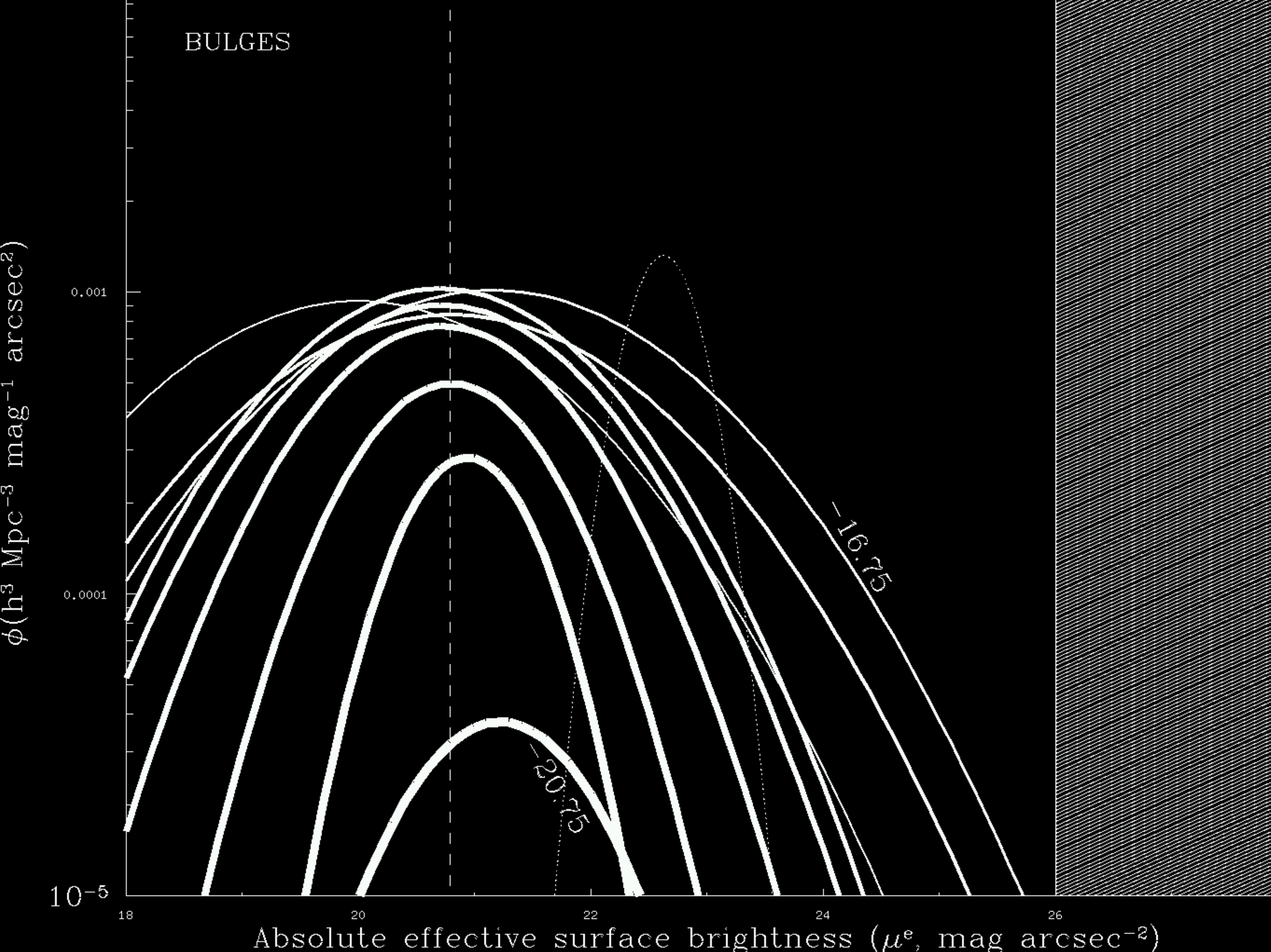


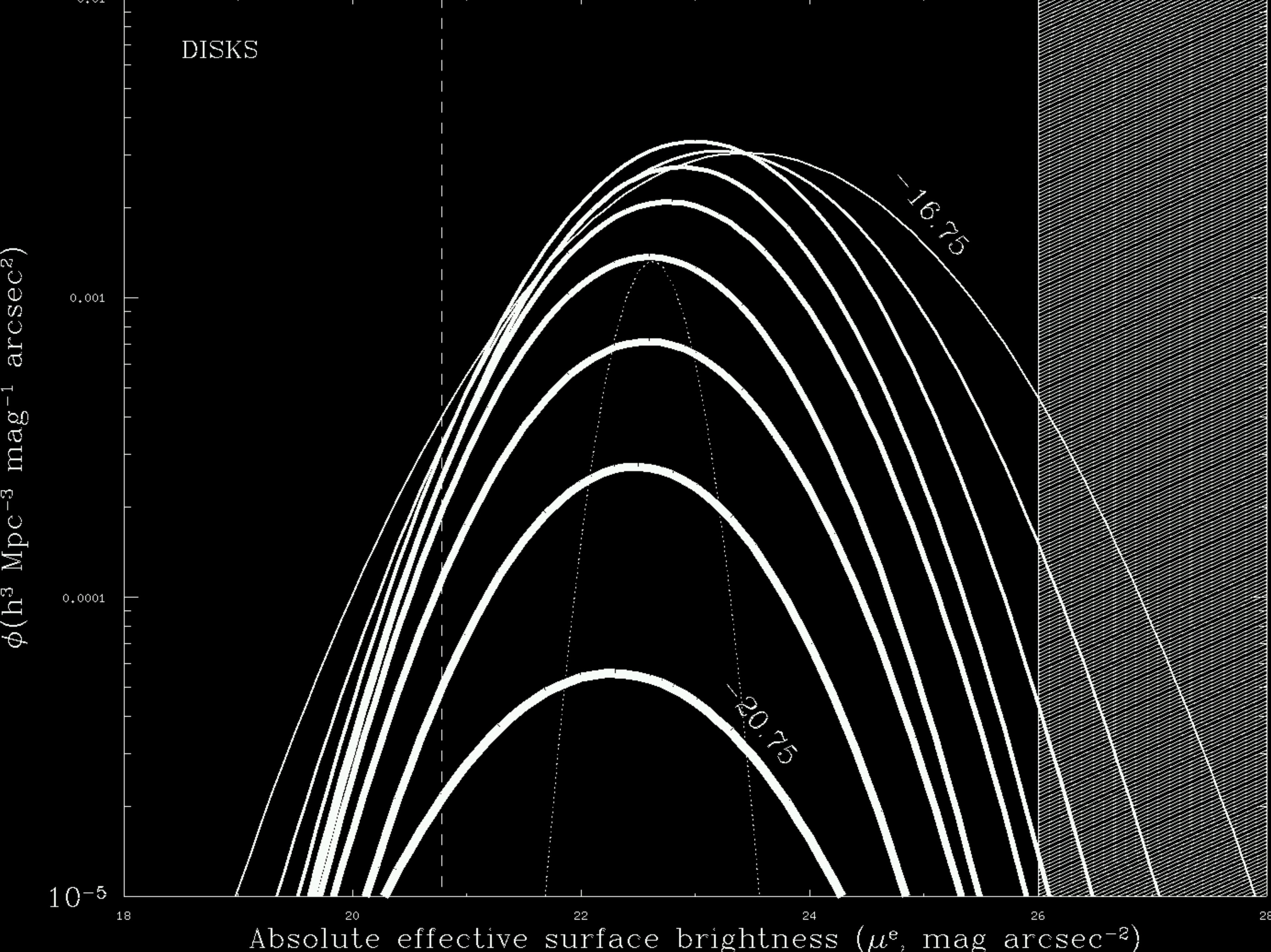
B/T
(u-r)
N
β
(u-r)
N



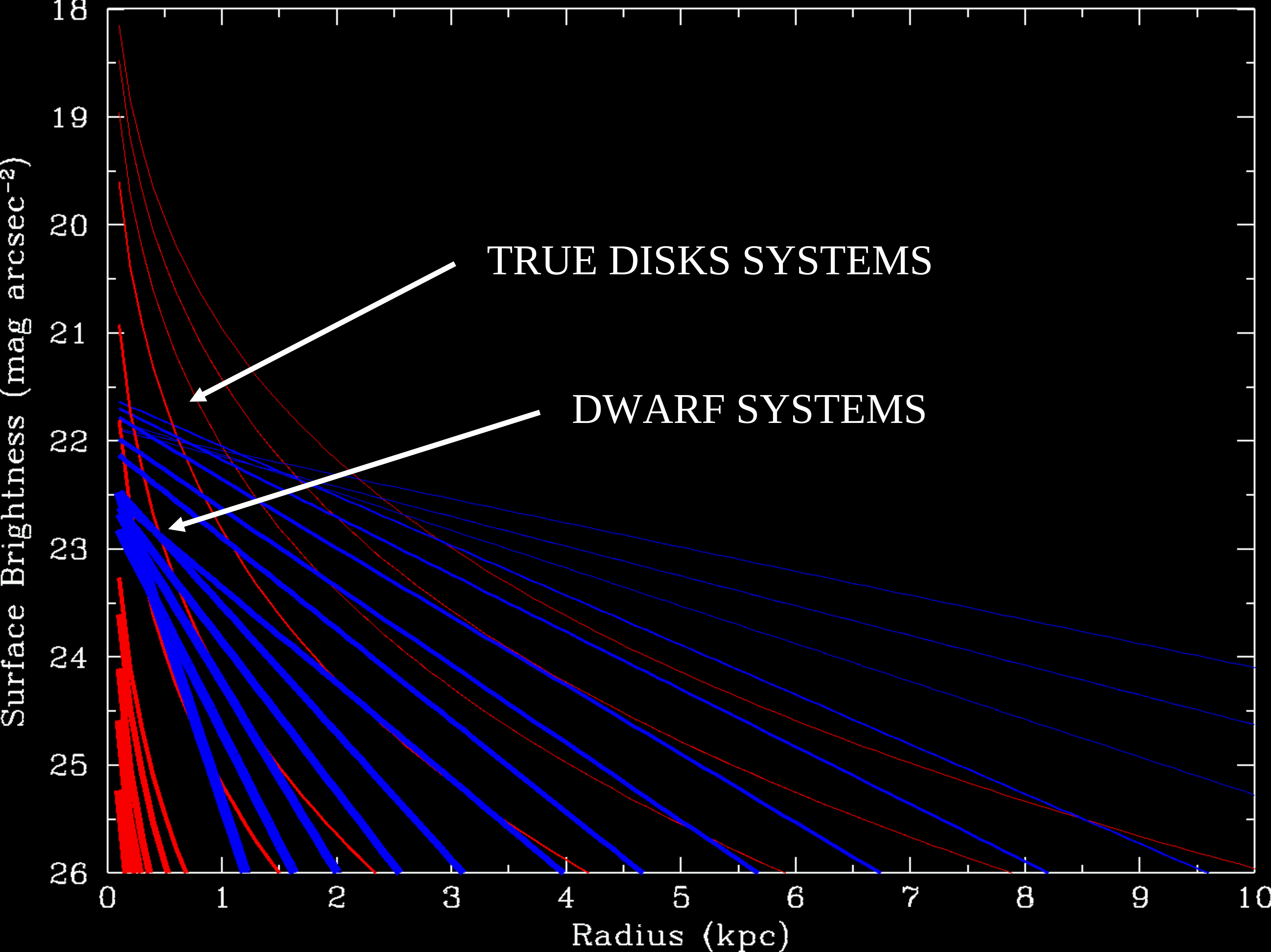
B/T
0
0.2
0.4
0.6
0.8
1
0
1
2
3
4
β


Absolute Effective Surface Brightness
Absolute magnitude
16
18
20
22
24
26
−22
−20
−18
−16
−14


BULGES
−16.75
−20.75
0.001
0.0001
10^{-5}
18
20
22
24
26
ϕ(h^3 Mpc^{-3} mag^{-1} arcsec^2)
Absolute effective surface brightness (μ^e, mag arcsec^{-2})



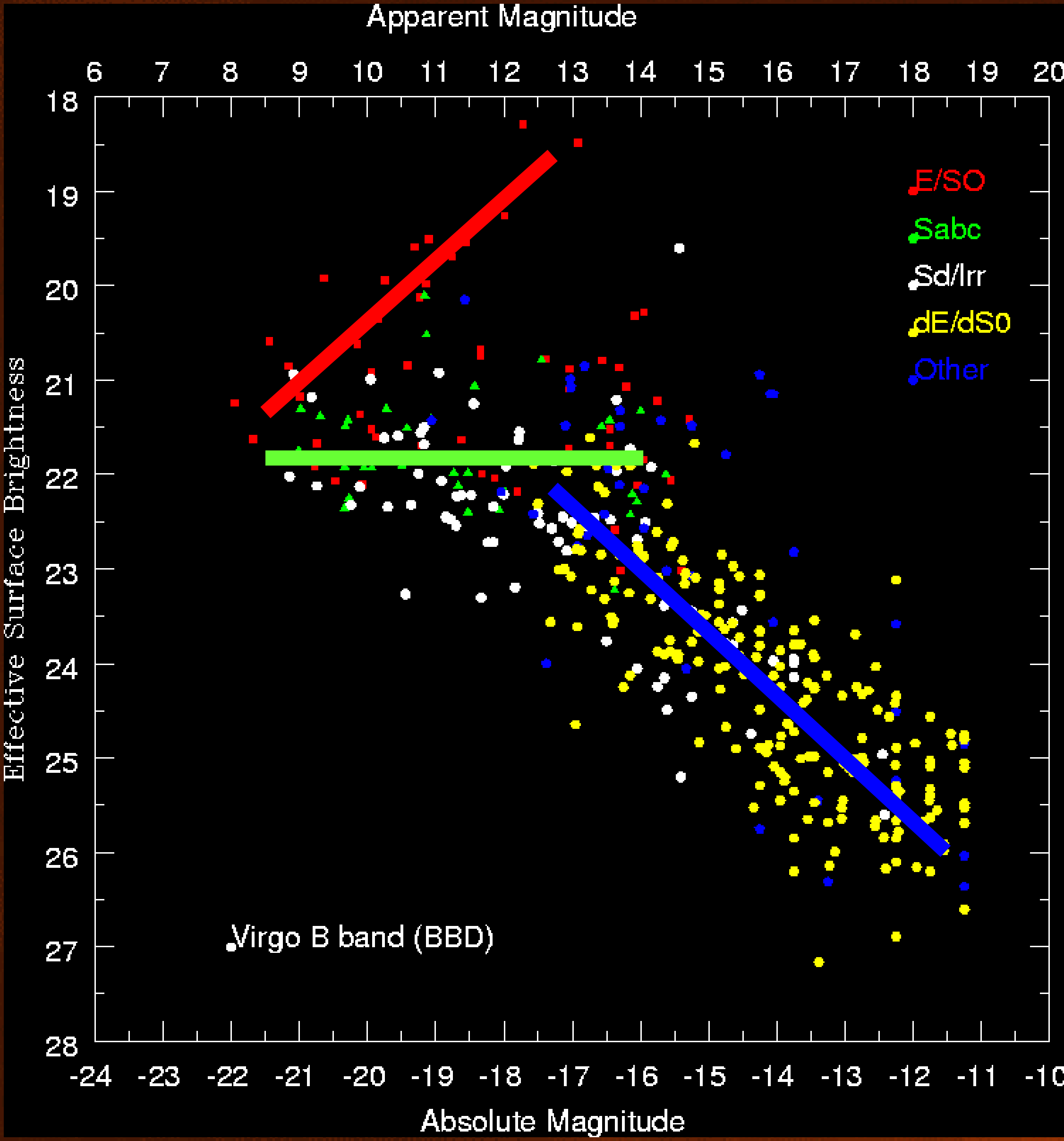
DISKS
−16.75
−20.75
0.001
0.0001
10^{-5}
18
20
22
24
26
28
$\phi(h^3$ Mpc^{-3} mag^{-1} arcsec$^2)$
Absolute effective surface brightness (μ^e, mag arcsec^{-2})



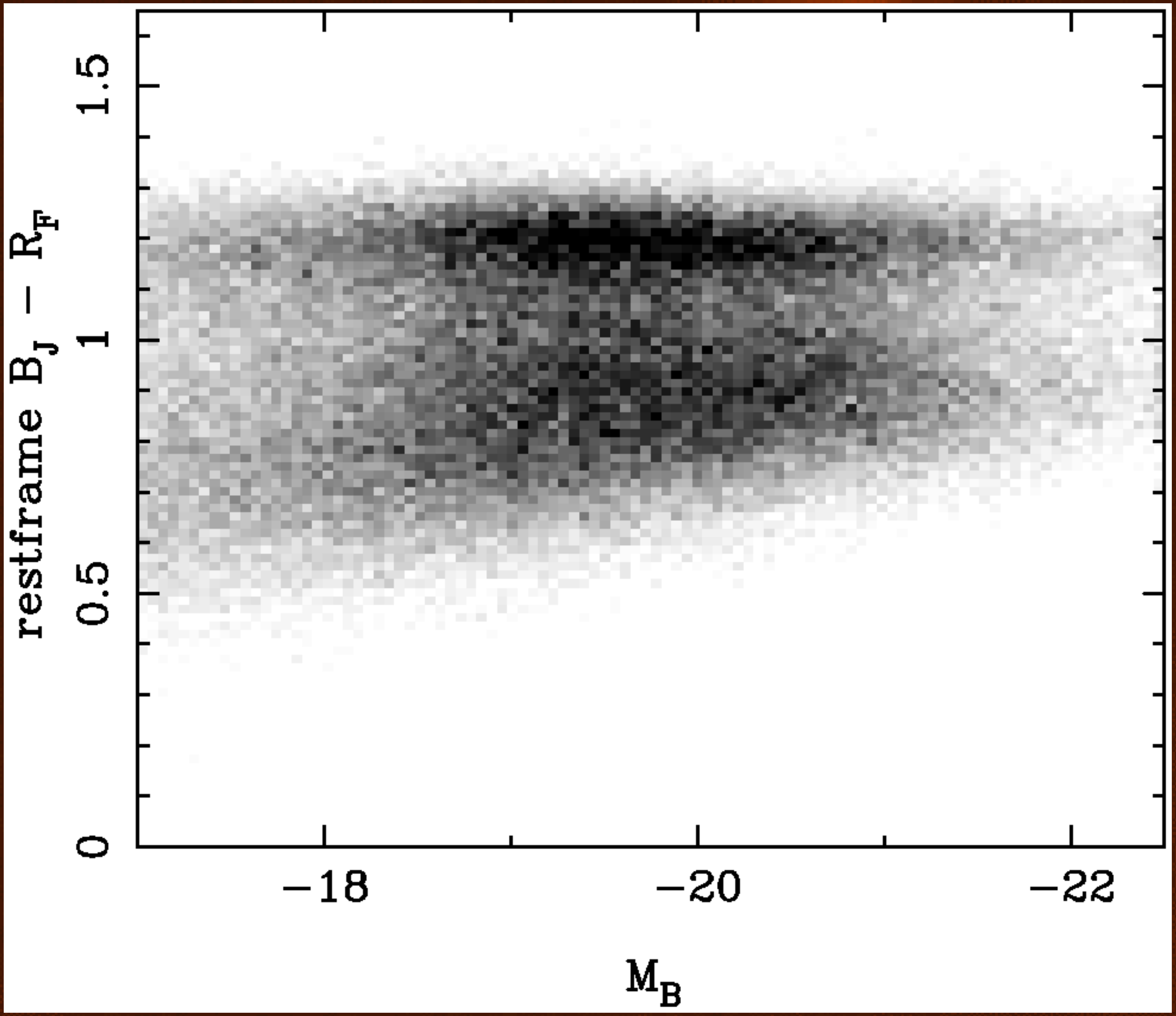
TRUE DISKS SYSTEMS
DWARF SYSTEMS
Surface Brightness (mag arcsec^{-2})
Radius (kpc)
18
19
20
21
22
23
24
25
26
0
1
2
3
4
5
6
7
8
9
10

The Virgo BBD

- 3 distinct relations ?
  - Kormendy Relation
  - Freeman's Law
  - Dwarf trend
- Real of Bias ?
- Why ?
- 2, 3 or more ?
- Environmental ?
- Variation with z ?
- Gradients & dispersions ?
- Physics ?



2dFGRS in COLOUR

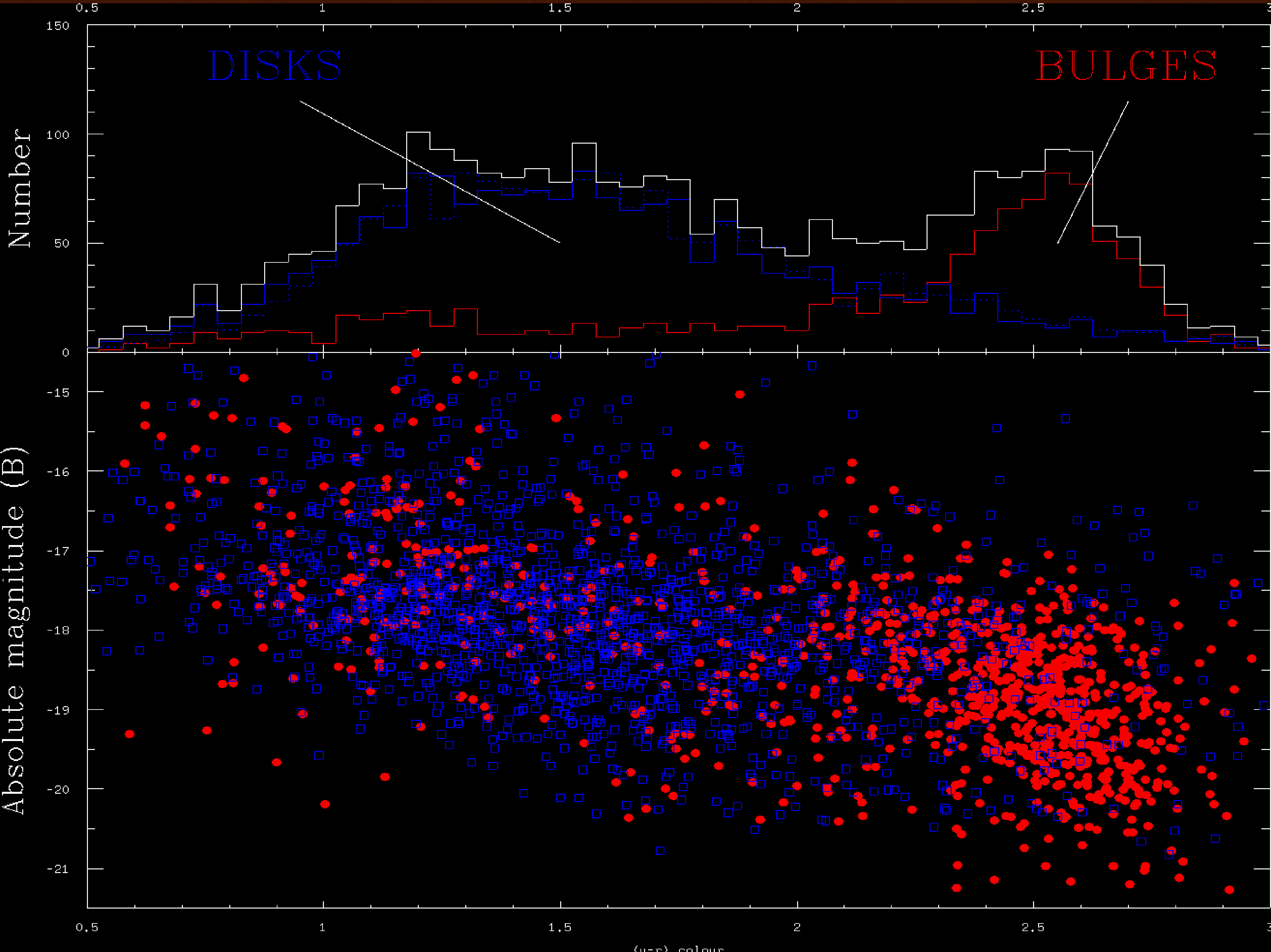


Colour bi-modality
Peacock (priv.comm)

Ellipticals/Spirals

or

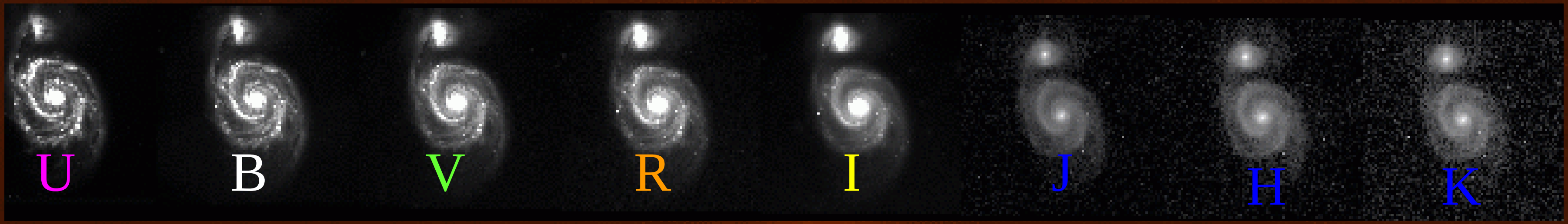
Bulges/Disks ?

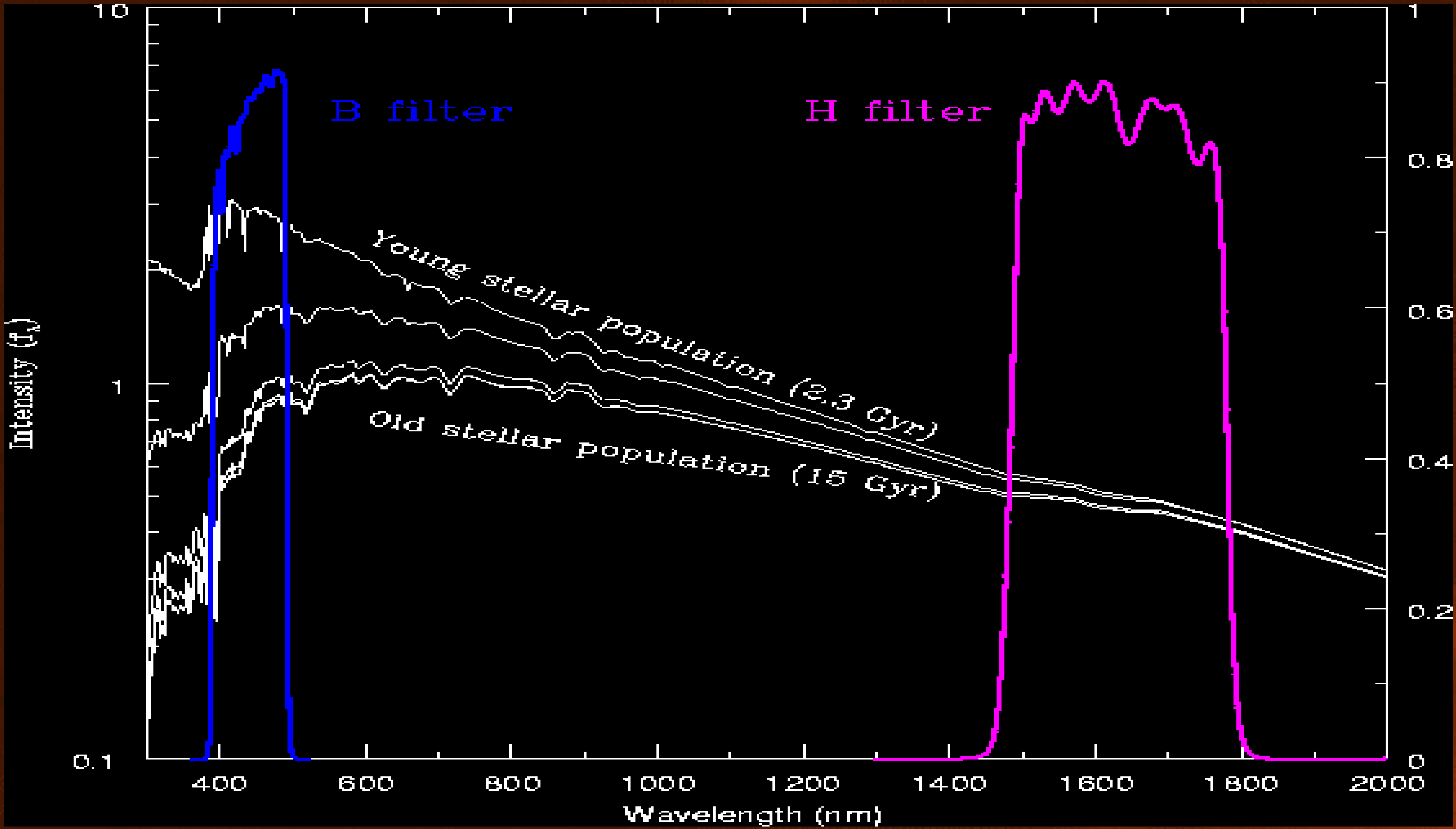

DISKS
BULGES
Number
Absolute magnitude (B)
(u-r) colour

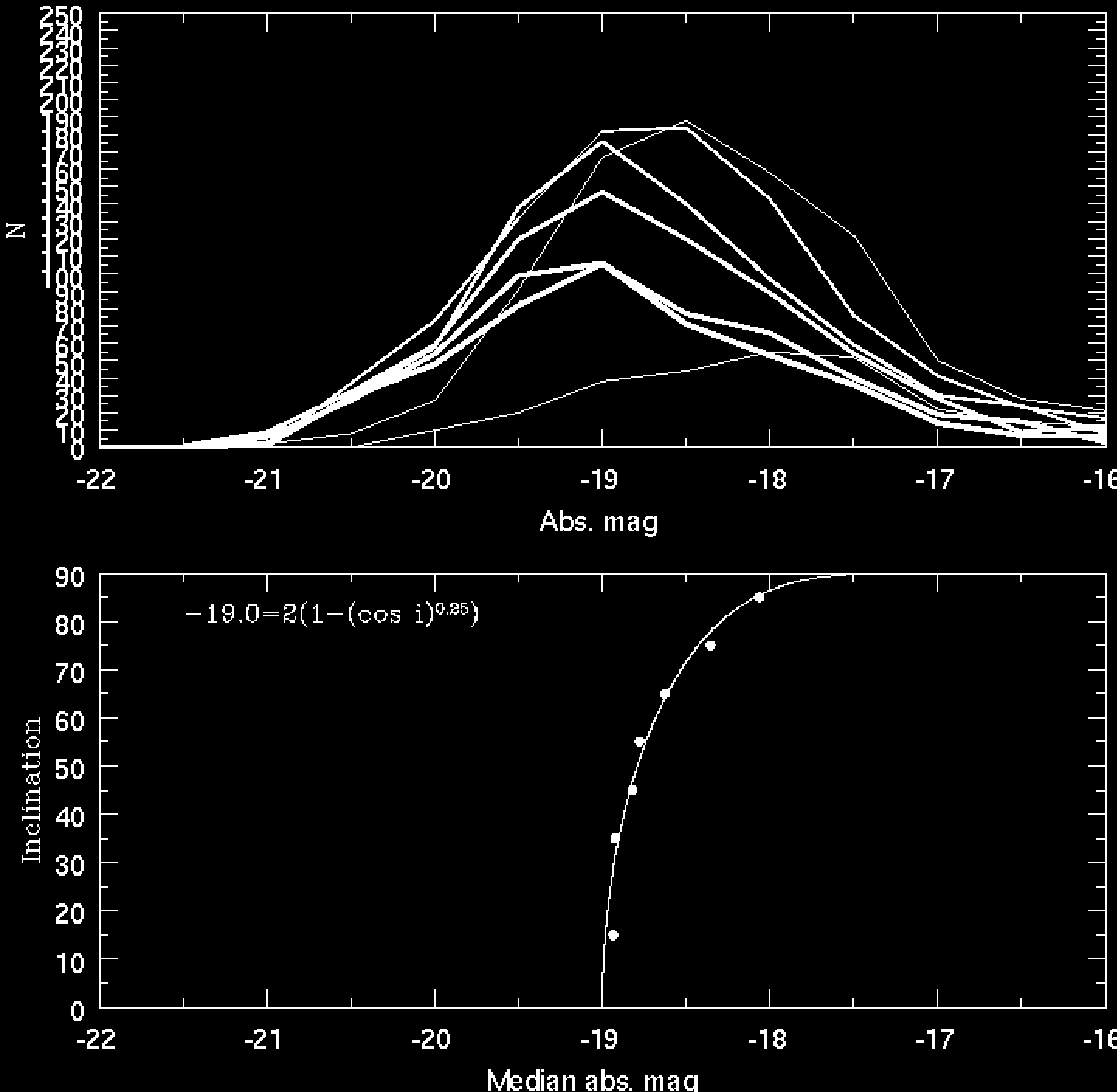
Future Plans/PhDs Projects

- Theoretical and Numerical Connection
  - Detailed comparison of LSPs with numerical simulations
- A deep Near-IR extension of the MGC (paving the way for JWST)
  - UKIRT/WFCAM available in Semester 2005A
  - VISTA commissioning in Semester 2007A
- IFU follow up of bulge and disk components (following the key components)
  - MGC galaxies (GMOS)
  - z=1 galaxies (NIFSII)
- Tracing the Luminosity-Surface Brightness Plane with HST (data now available)
  - GOODs catalogue release Sept 2004
  - UDF available March 2004
- Multi-wavelength analysis of volume limited samples (stars, dust and gas)
  - Far-IR (Spitzer)
  - mm (LMT)
  - HI (Parkes, Arecibo)
- A deep low redshift survey (MGC extension)
  - AAΩ/KAOS
  - Skymapper (Precision photometric z's)

Future Plans

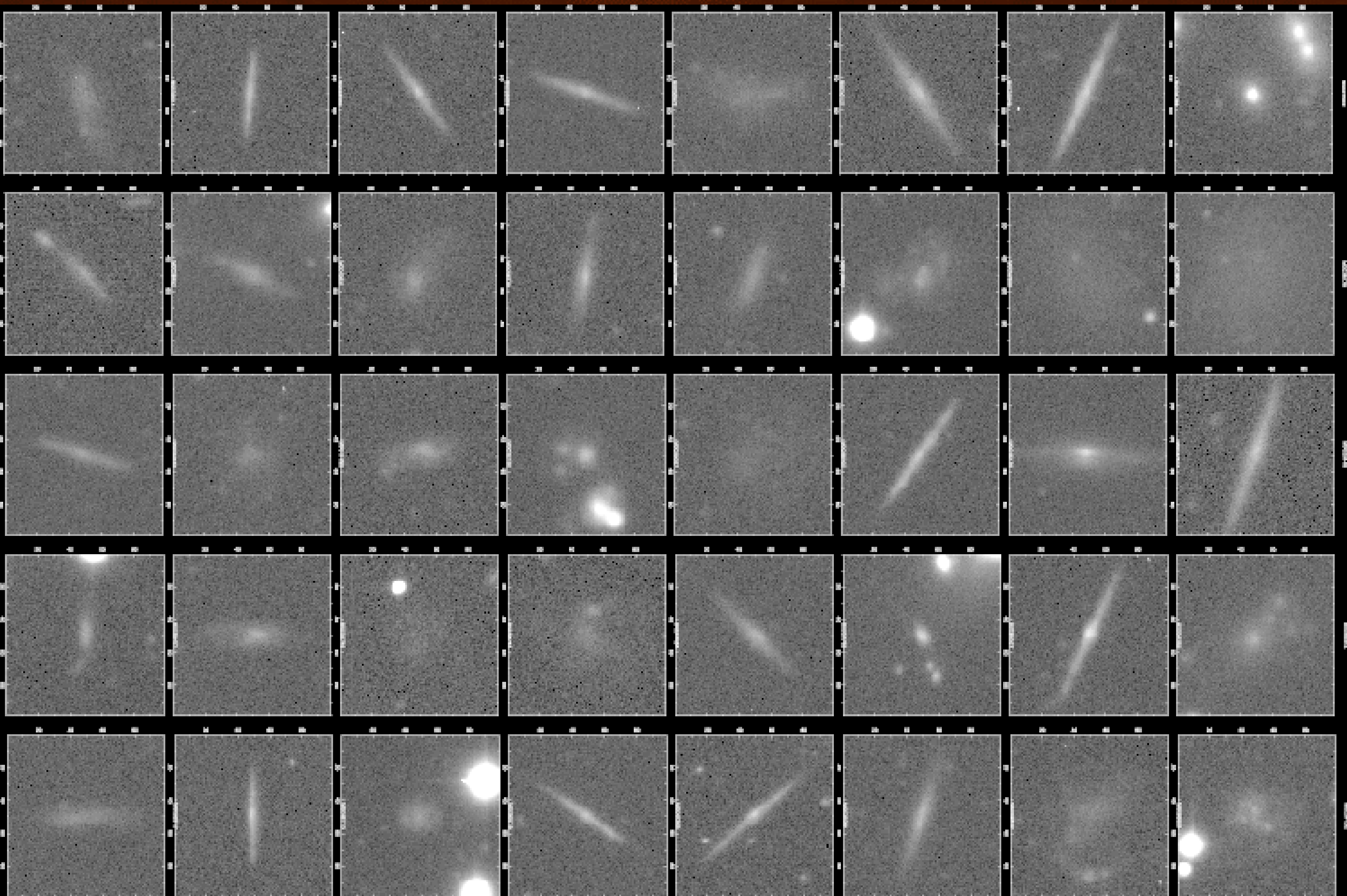




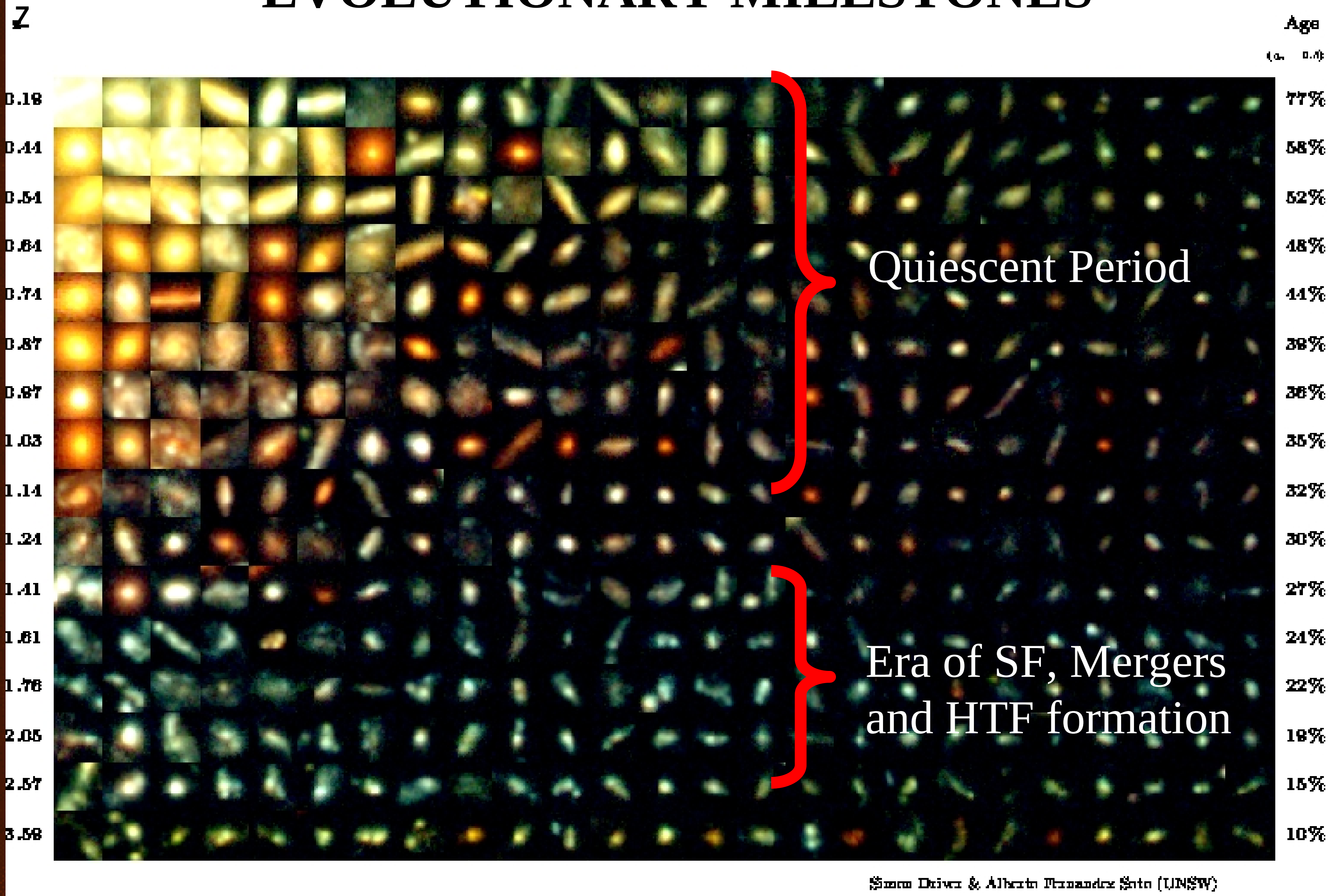


N
Abs. mag
−19.0=2(1−(cos i)^0.25)
Inclination
Median abs. mag

MGC:Low Surface Brightness Galaxies (z's)



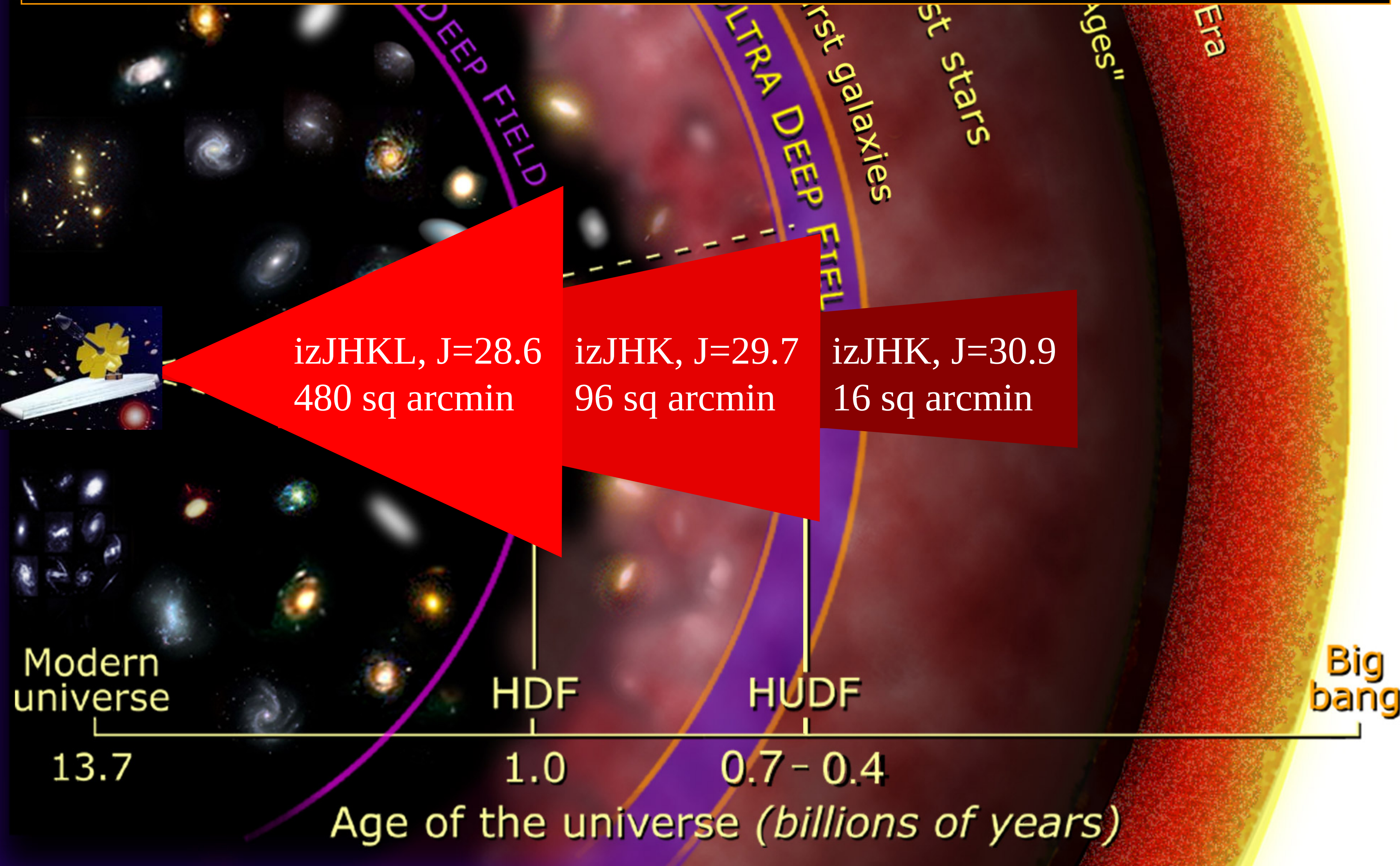
EVOLUTIONARY MILESTONES



Driver et al (1998)

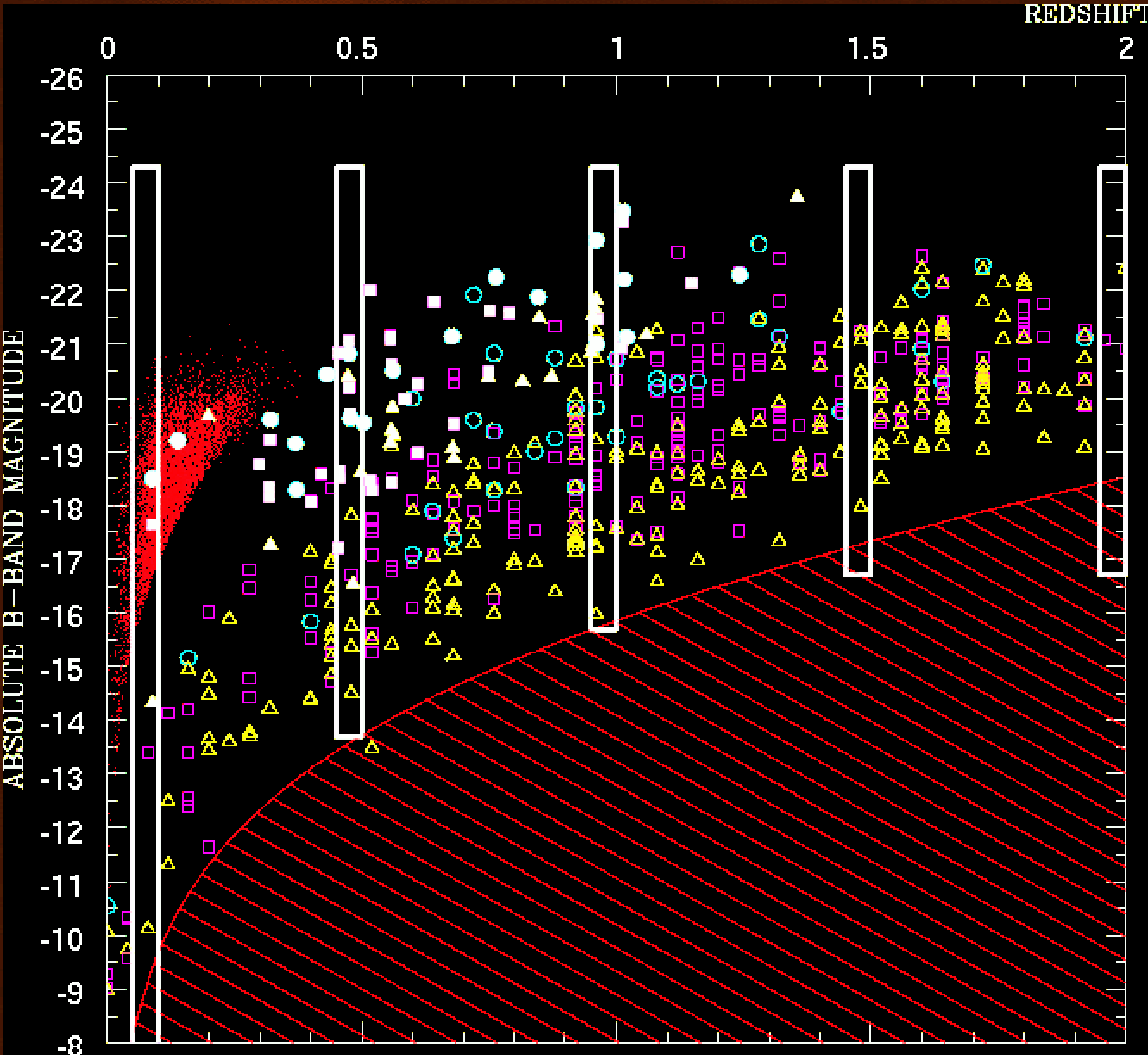
JWST: MEDEA SURVEY (110hrs GTO)

Windhorst, Conselice, Driver, Jansen, Odewahn, Waddington, Yan



MGC+GOODs+UDF+JWST

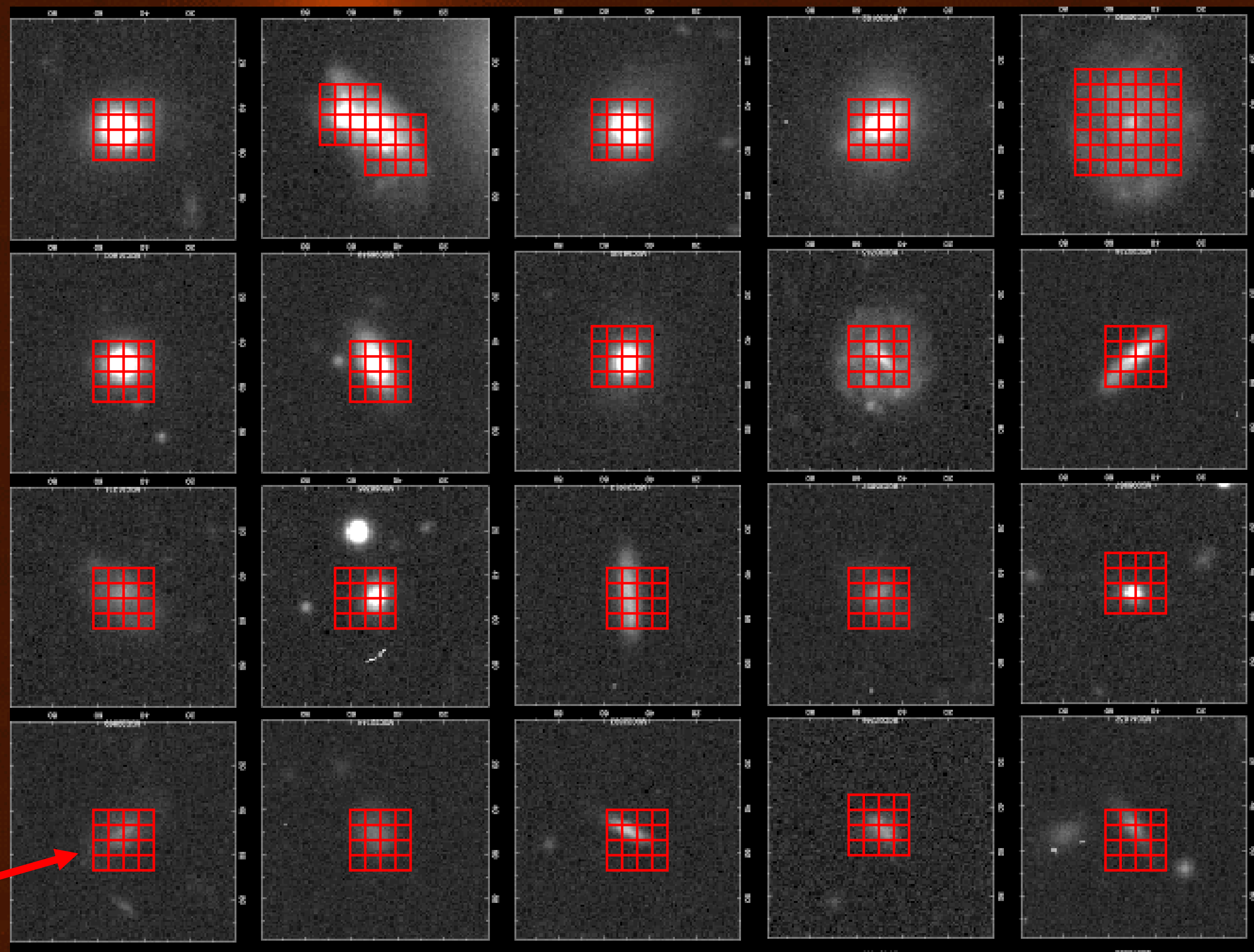
- From combined data can construct volume limited slices (MGC+ HDFn shown, GOODs x50 more data).
- By measuring the global properties within these volumes one should recover the roadmap of galaxy evolution.
- Ideally suited to Gemini/IFU follow-up to determine stellar population charachteristics



MGC+GOODs+UDF+JWST+ IFUs

- Gemini GMOS/IFU
  - 5”x7” (1000 slitlets)
  - Ideal for z < 0.5
- Gemini NIFS/IFU
  - 3”x3” (29 slits)
  - IR ideal for z ~1
- Unique opportunity for RSAA with prospect of 22 NIFS nights

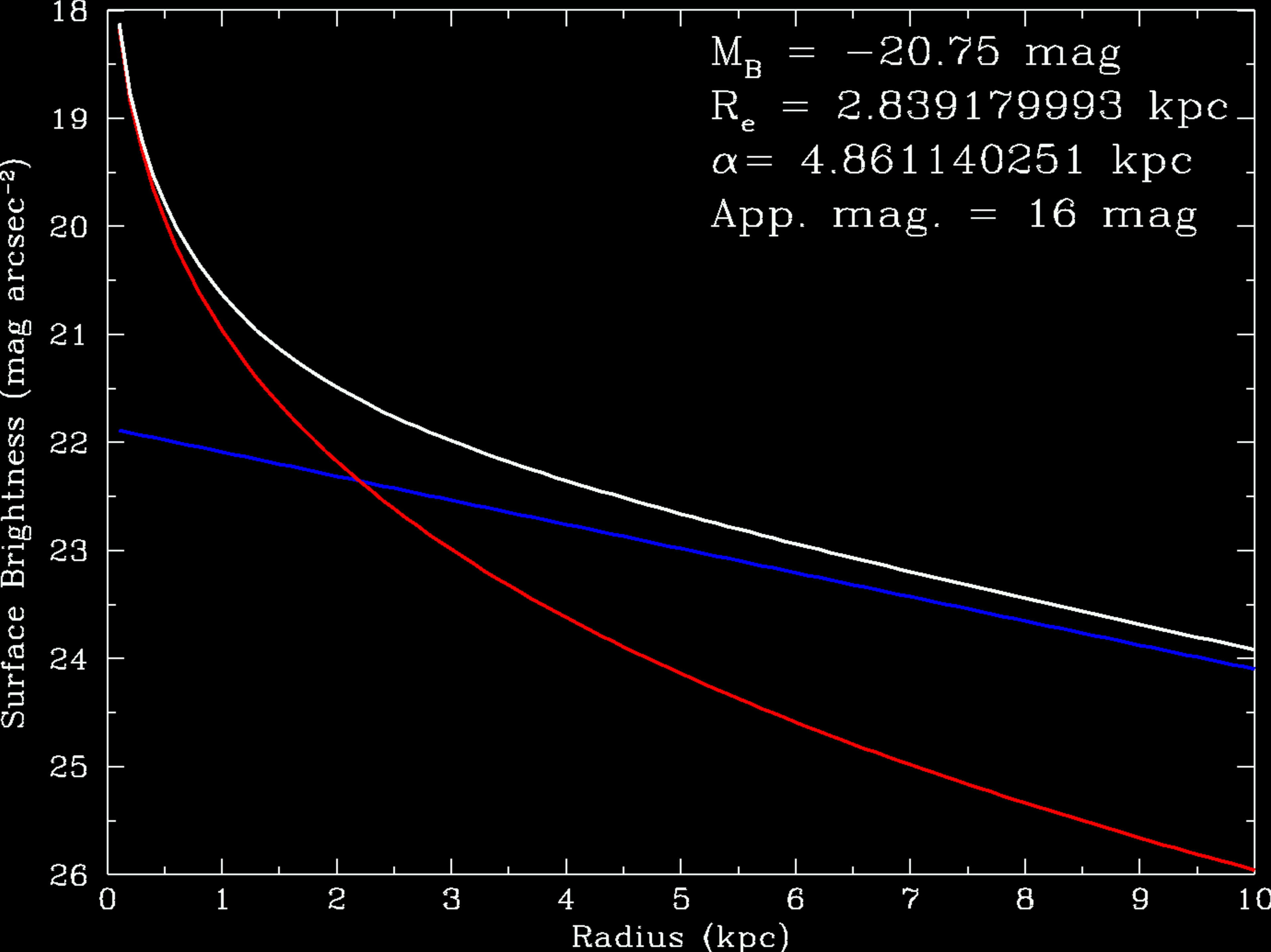
Integral Field Unit to Map Hα



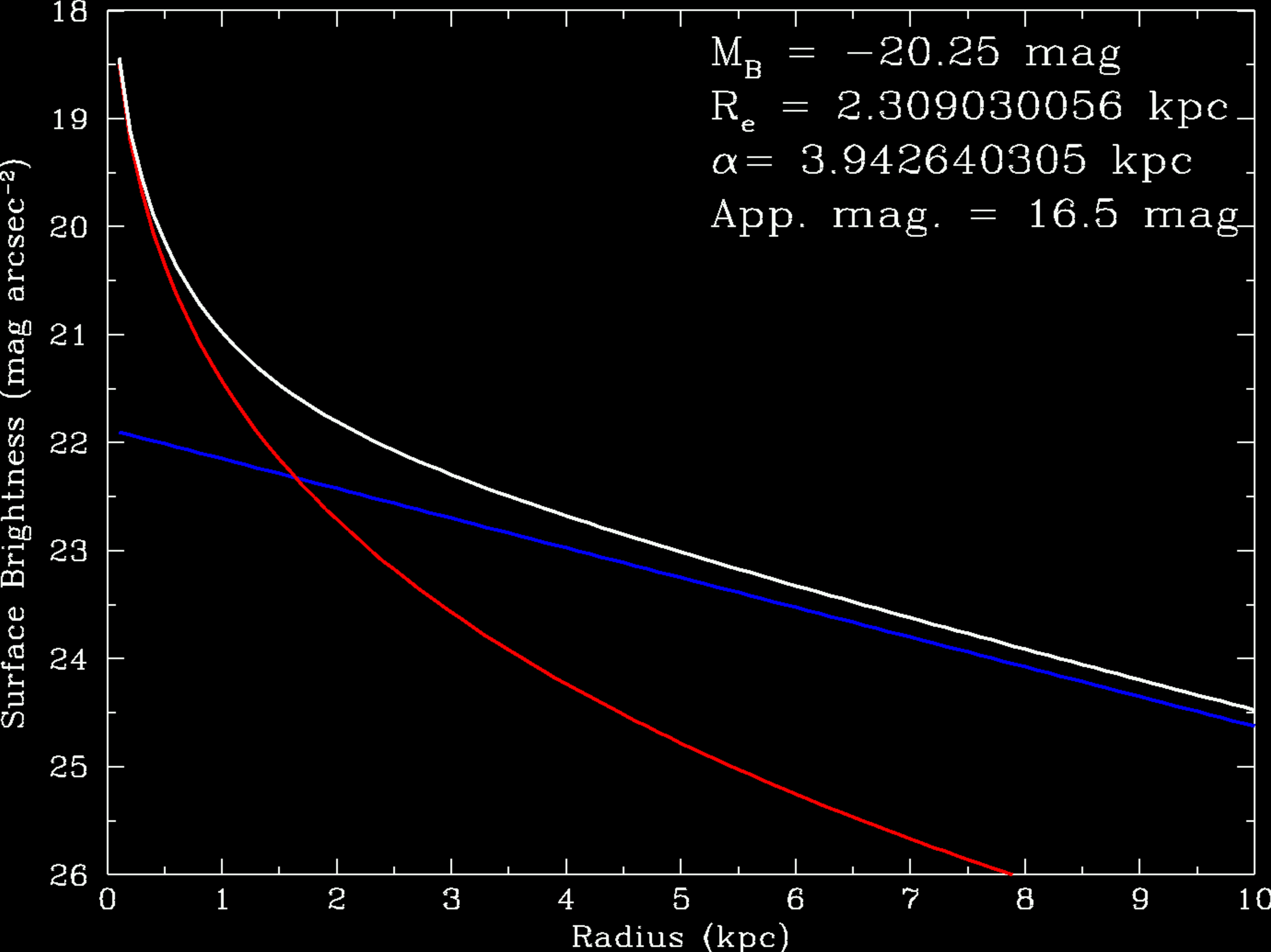
~~Overview~~ Summary

- The Millennium Galaxy Catalogue - A “Rolls-Royce” Catalogue to study galaxy diversity
  - Available via http://www.eso.org/jliske/mgc/ - Images, Redshifts, Spectra & Catalogues
- The Galaxy Luminosity Function (Space Density of Galaxies)
  - 2dFGRS v SLOAN Luminosity Function - Major Inconsistency
  - Understanding Selection Bias - Crucial to get right
  - Getting the Luminosity Function Right - M^*_B = -19.59+/-0.05+5logh,
- Beyond the Luminosity Function φ [illegible] $\alpha = -1.13 +/- 0.03$
  - Morphological Madness - Need new methods/algorithms to sub-divide galaxies
  - Colour Distributions - Bimodality due to bulge and disk components
  - Bulge-Disk Decomposition - Essential if secular evolution is occurring
  - Tie-in to CDM ? - Luminosity and Mass, Size and Spin ?
- Future directions
  - Deciphering Galaxy Evolution - Not viable until after we fix z=0
  - Dwarf hunting (AAOmega & KAOS) - Sledgehammer approach that will work
  - Starting over (Non-linear PCA, ANNs, and group finding in catalogue space)
  - The near-IR (UKIRT, VISTA, JWST) - Dust free, robust to SF, smoother to profile

User beware: Not all surveys are equal



M_B = −20.75 mag
R_e = 2.839179993 kpc
α= 4.861140251 kpc
App. mag. = 16 mag
Surface Brightness (mag arcsec^{-2})
Radius (kpc)
18
19
20
21
22
23
24
25
26
0
1
2
3
4
5
6
7
8
9
10



M_B = −20.25 mag
R_e = 2.309030056 kpc
α= 3.942640305 kpc
App. mag. = 16.5 mag
Surface Brightness (mag arcsec^{-2})
Radius (kpc)
18
19
20
21
22
23
24
25
26
0
1
2
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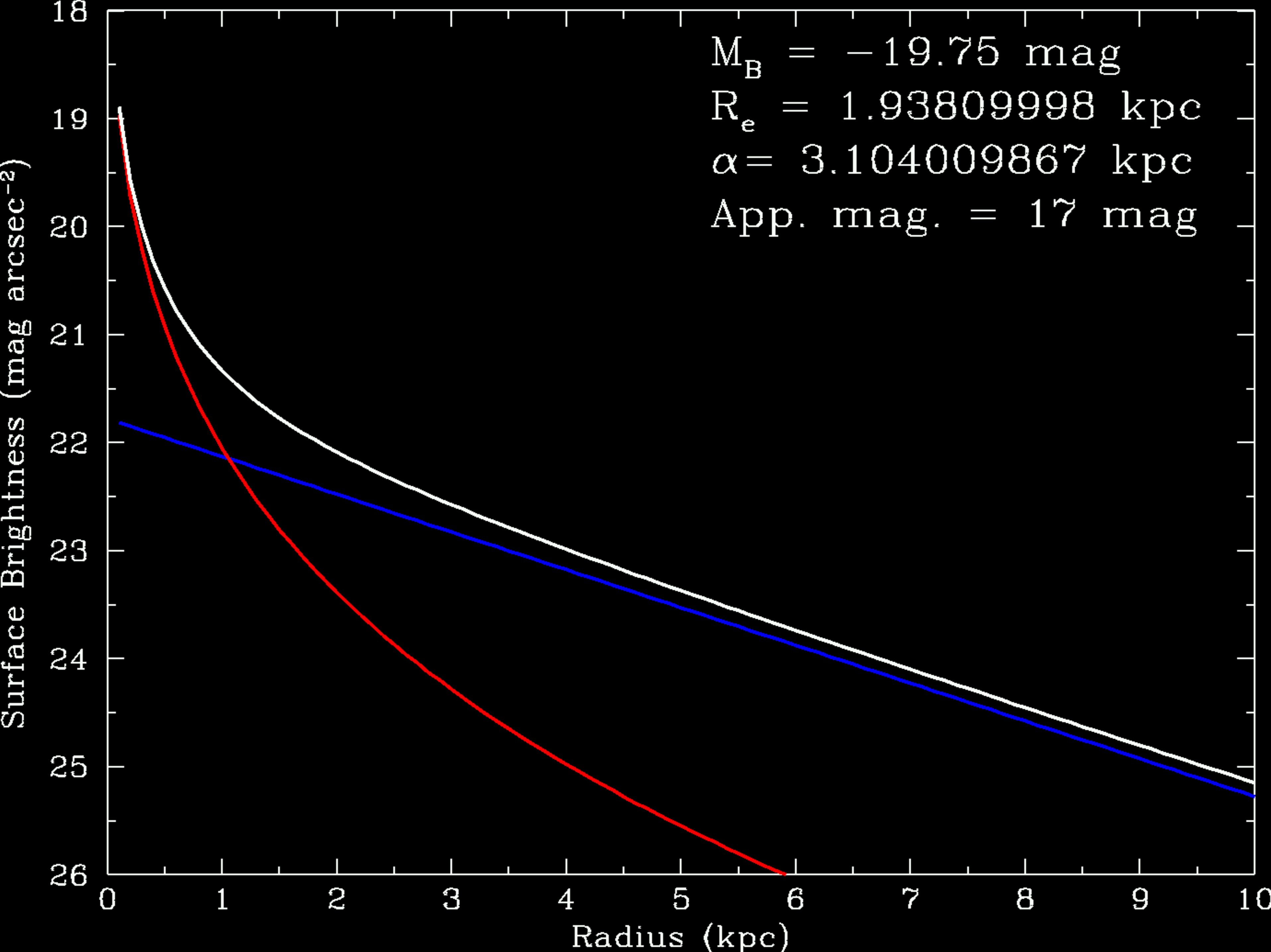

M_B = −19.75 mag
R_e = 1.93809998 kpc
α= 3.104009867 kpc
App. mag. = 17 mag
Surface Brightness (mag arcsec^{-2})
Radius (kpc)
18
19
20
21
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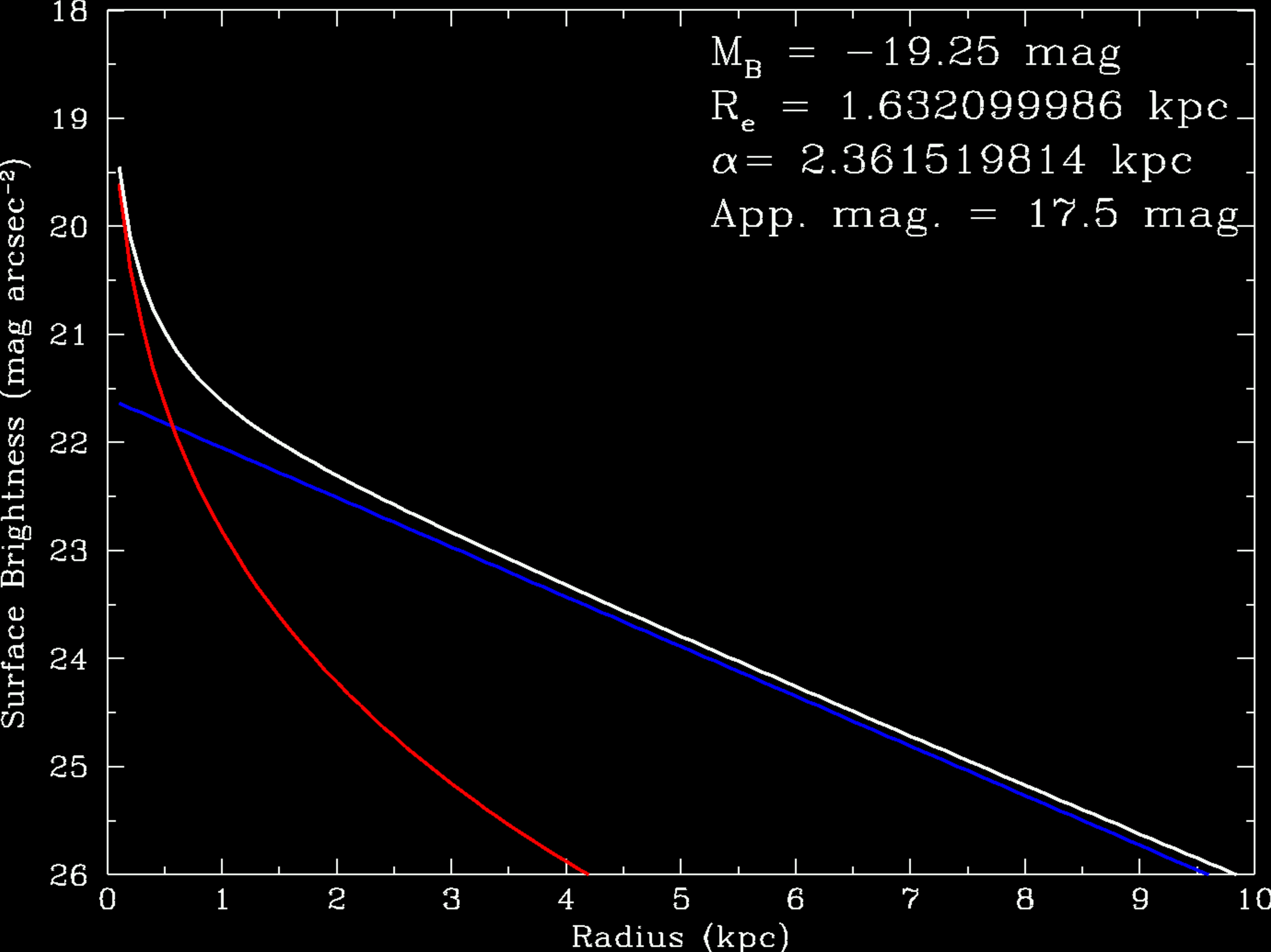

M_B = −19.25 mag
R_e = 1.632099986 kpc
α= 2.361519814 kpc
App. mag. = 17.5 mag
Surface Brightness (mag arcsec^{-2})
Radius (kpc)
18
19
20
21
22
23
24
25
26
0
1
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3
4
5
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7
8
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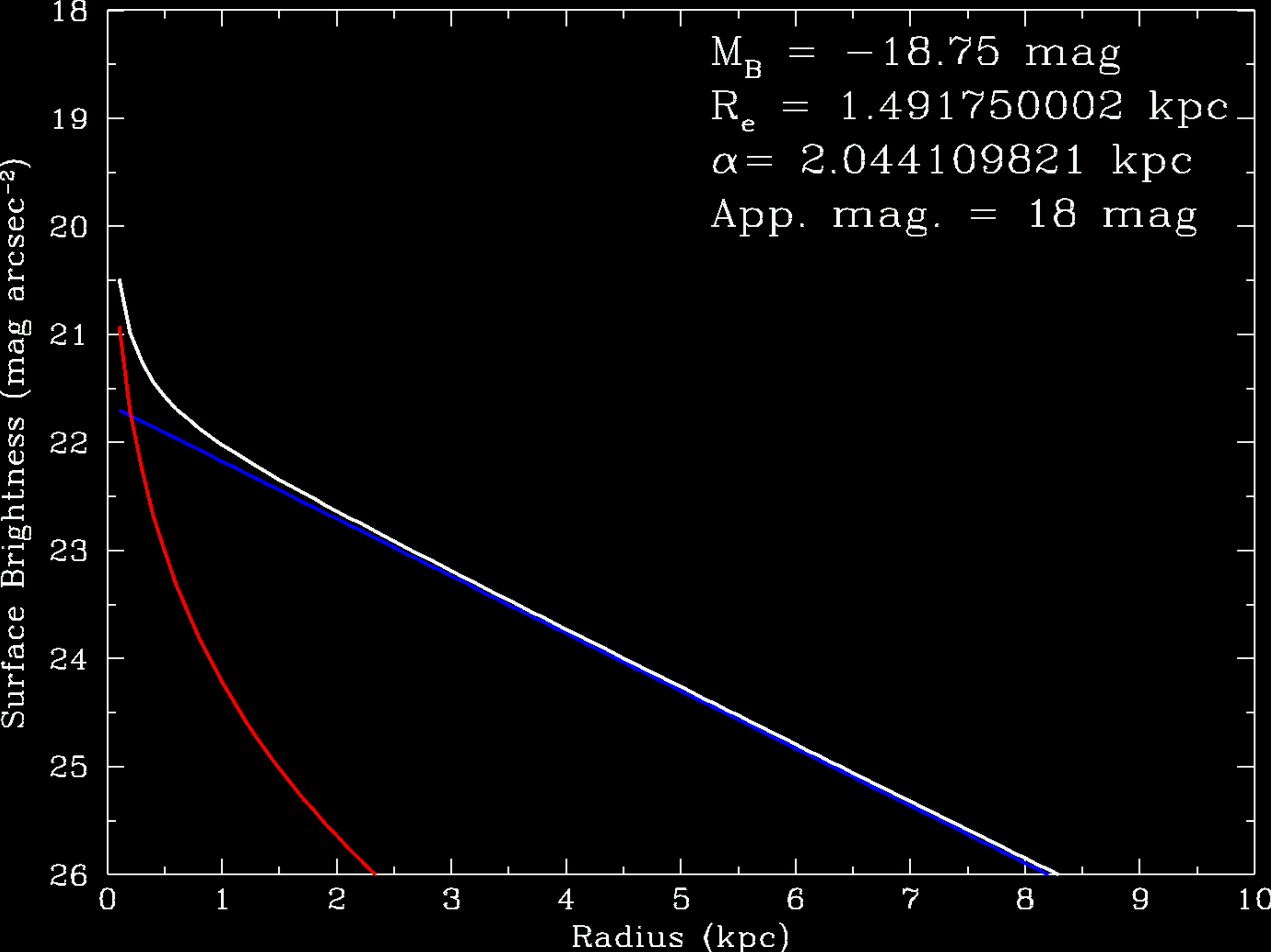

M_B = −18.75 mag
R_e = 1.491750002 kpc
α= 2.044109821 kpc
App. mag. = 18 mag
Surface Brightness (mag arcsec^{-2})
Radius (kpc)
18
19
20
21
22
23
24
25
26
0
1
2
3
4
5
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7
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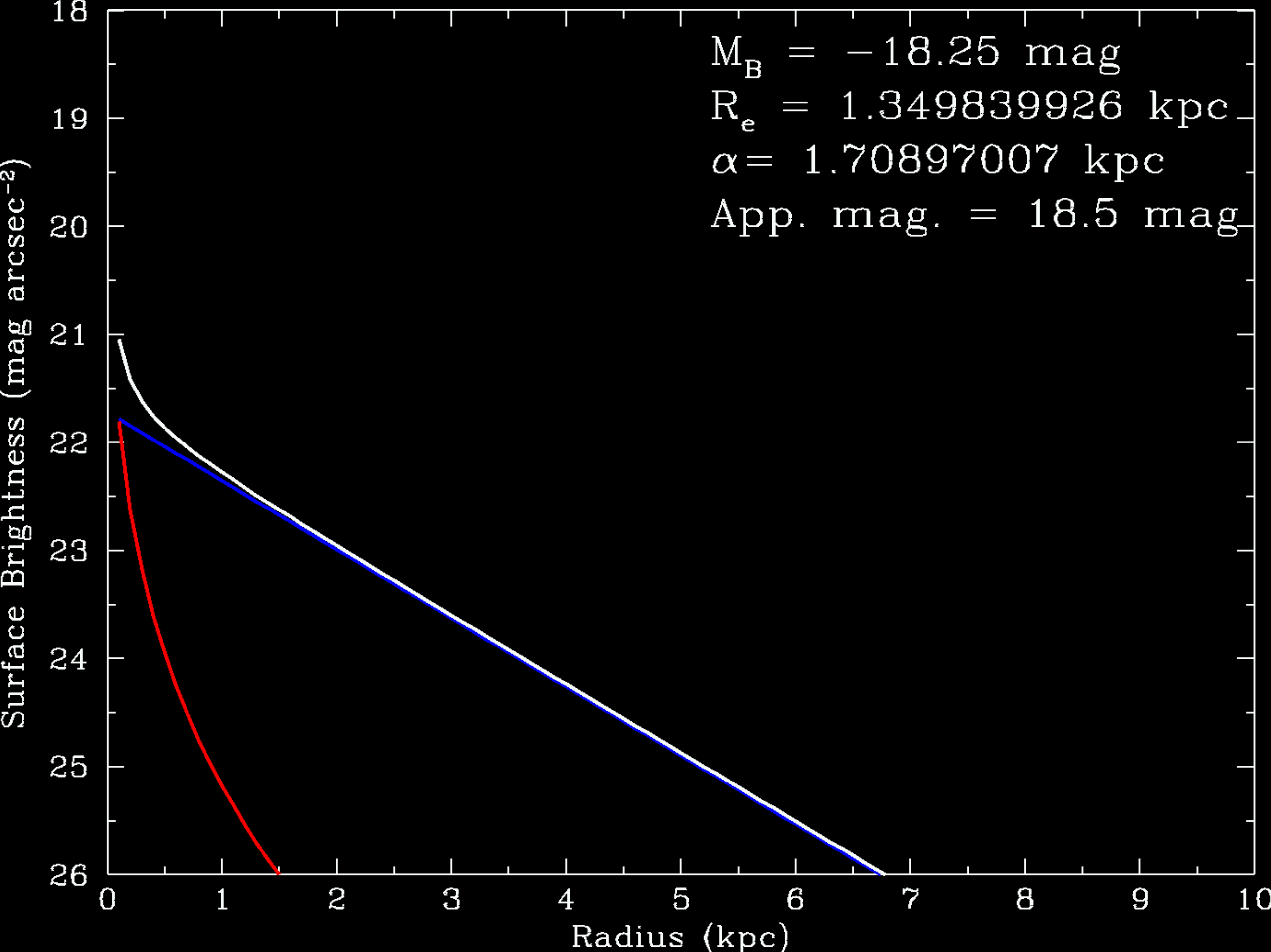

M_B = −18.25 mag
R_e = 1.349839926 kpc
α= 1.70897007 kpc
App. mag. = 18.5 mag
Surface Brightness (mag arcsec^{-2})
Radius (kpc)
18
19
20
21
22
23
24
25
26
0
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3
4
5
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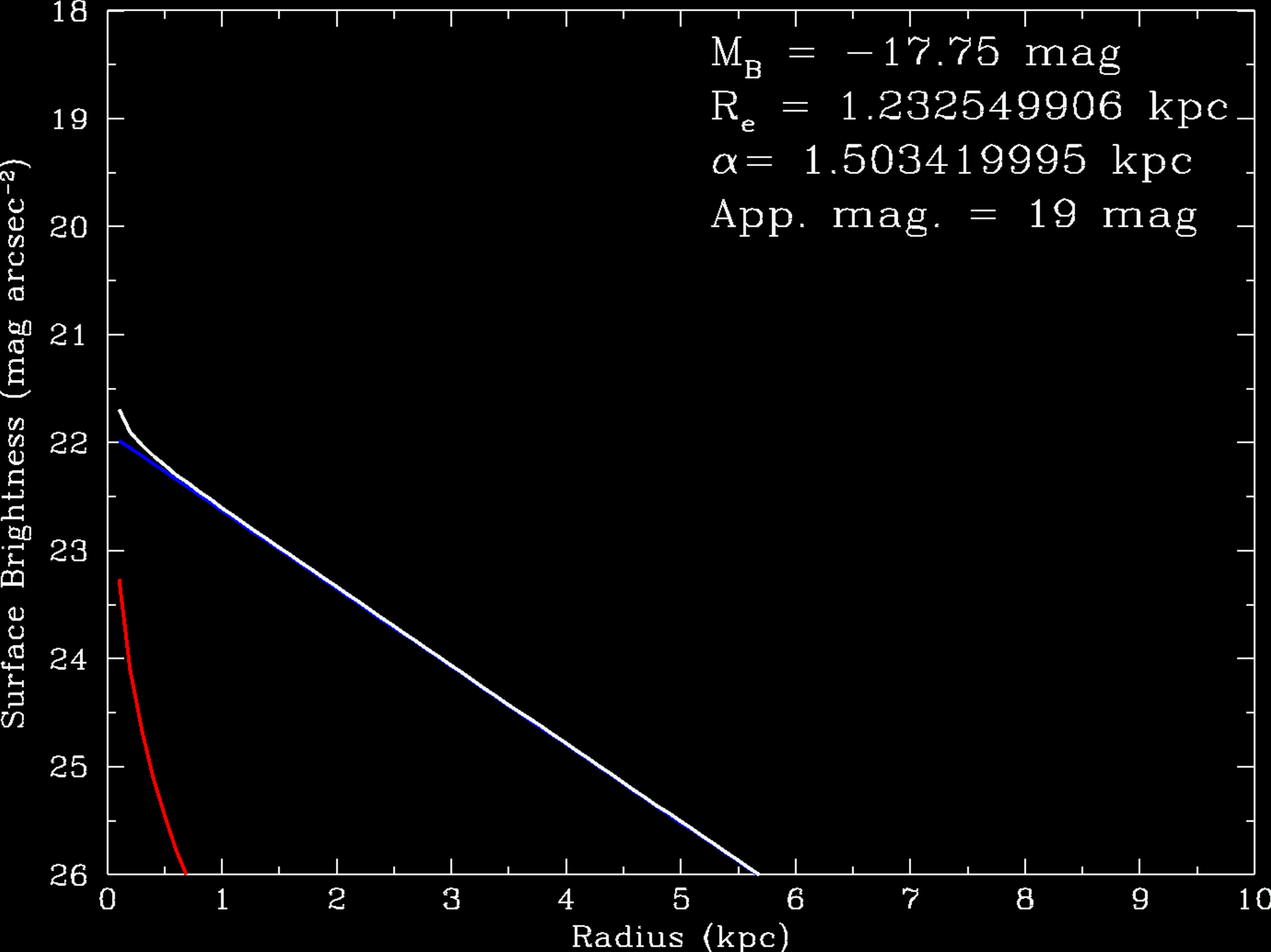

M_B = −17.75 mag
R_e = 1.232549906 kpc
α= 1.503419995 kpc
App. mag. = 19 mag
Surface Brightness (mag arcsec^{-2})
Radius (kpc)
18
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20
21
22
23
24
25
26
0
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4
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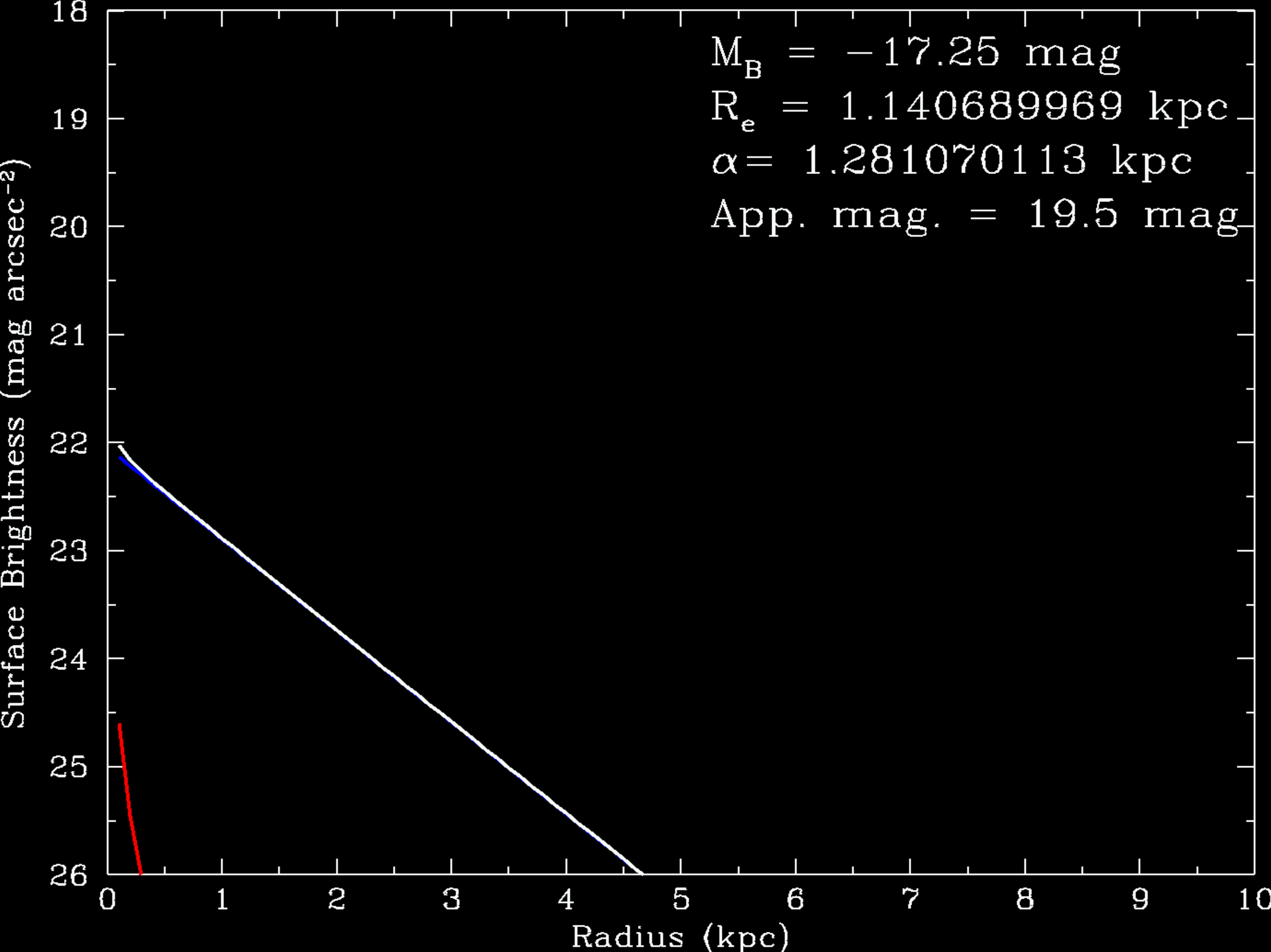
M_B = −17.25 mag
R_e = 1.140689969 kpc
α= 1.281070113 kpc
App. mag. = 19.5 mag
Surface Brightness (mag arcsec^{-2})
Radius (kpc)
18
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24
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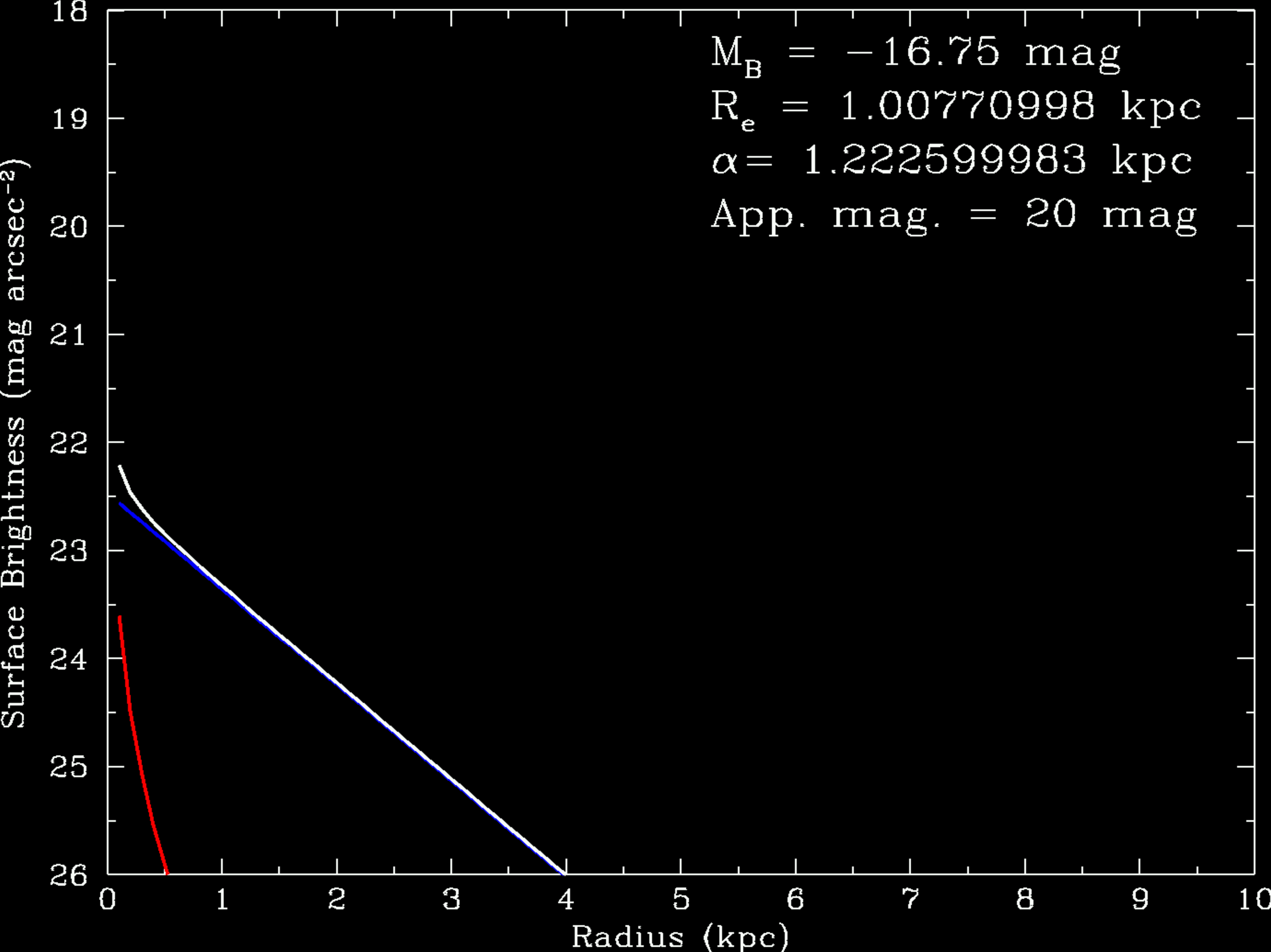

M_B = −16.75 mag
R_e = 1.00770998 kpc
α= 1.222599983 kpc
App. mag. = 20 mag
Surface Brightness (mag arcsec^-2)
Radius (kpc)
18
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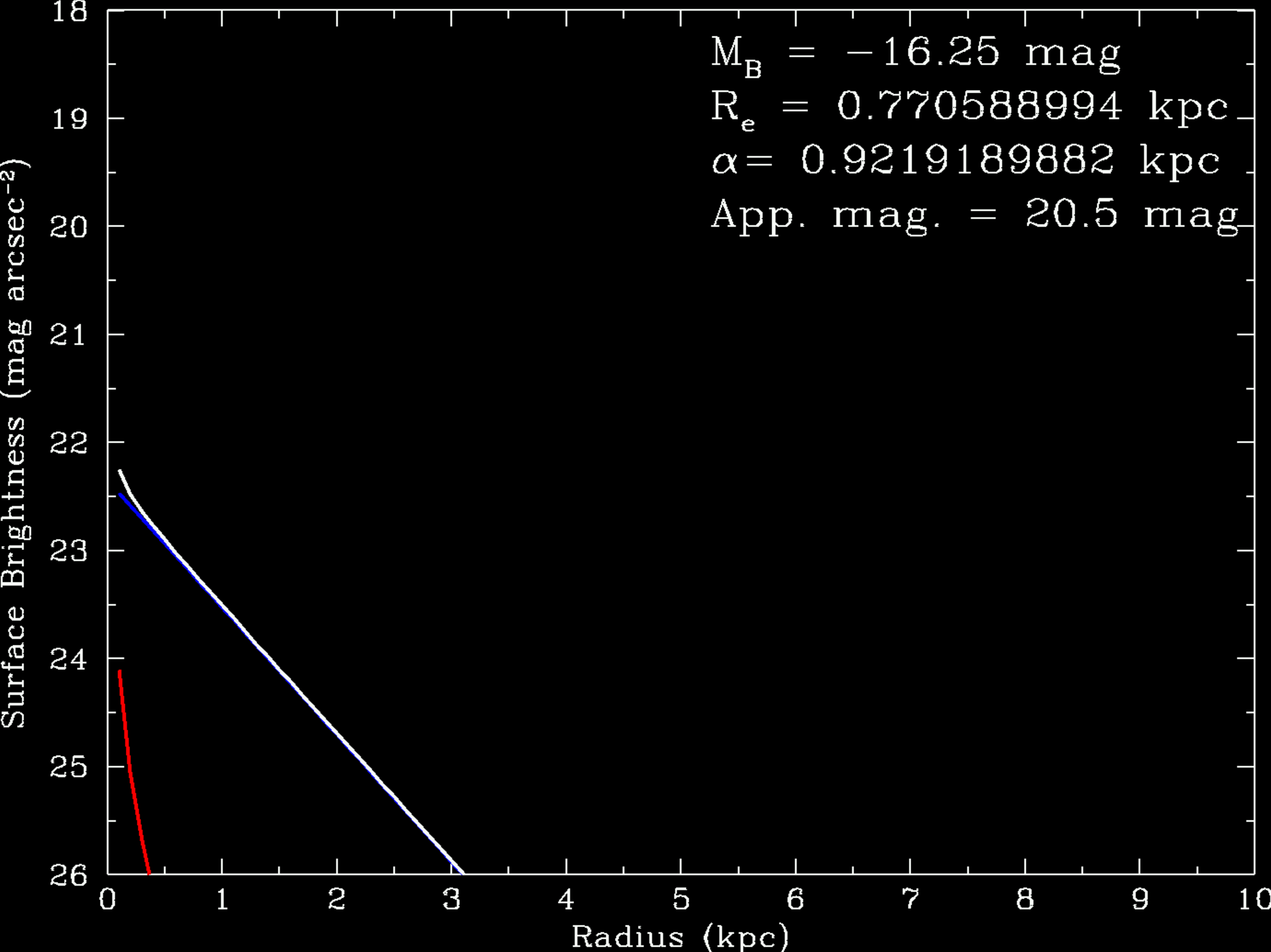

M_B = −16.25 mag
R_e = 0.770588994 kpc
α= 0.9219189882 kpc
App. mag. = 20.5 mag
Surface Brightness (mag arcsec^{-2})
Radius (kpc)
18
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20
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22
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24
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26
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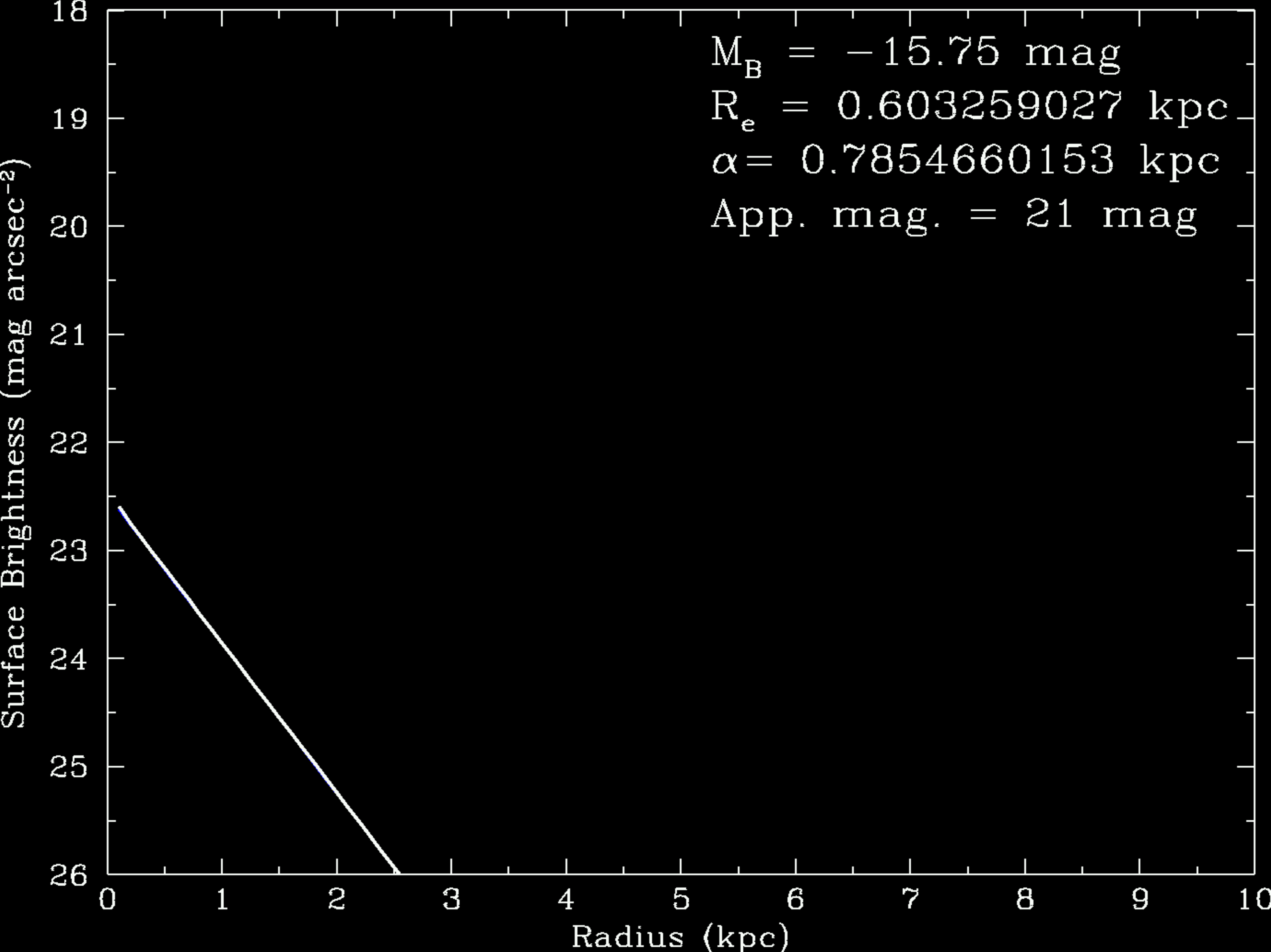

M_B = −15.75 mag
R_e = 0.603259027 kpc
α= 0.7854660153 kpc
App. mag. = 21 mag
Surface Brightness (mag arcsec^-2)
Radius (kpc)
18
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24
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26
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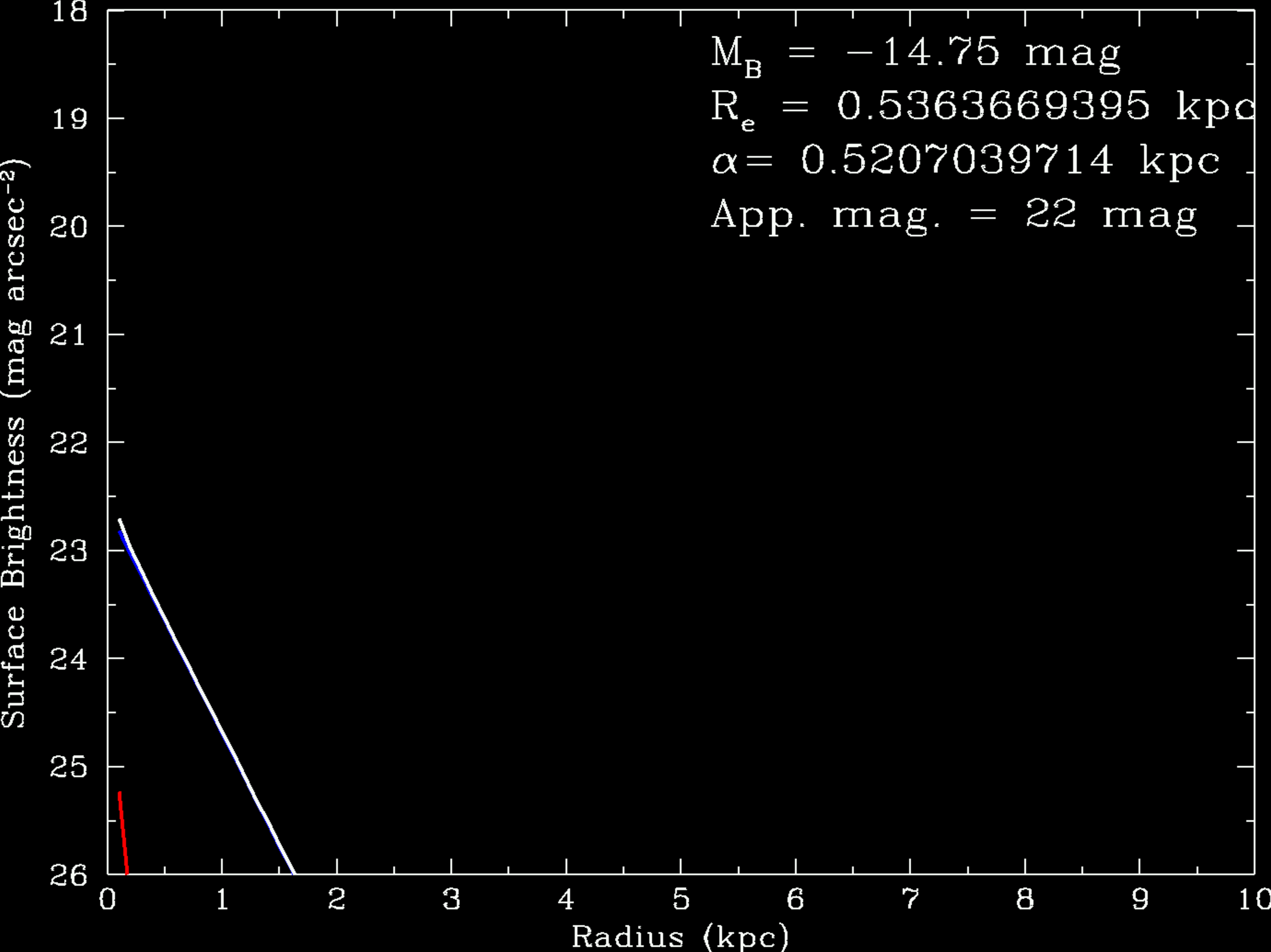

M_B = −14.75 mag
R_e = 0.5363669395 kpc
α= 0.5207039714 kpc
App. mag. = 22 mag
Surface Brightness (mag arcsec^{-2})
Radius (kpc)
18
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23
24
25
26
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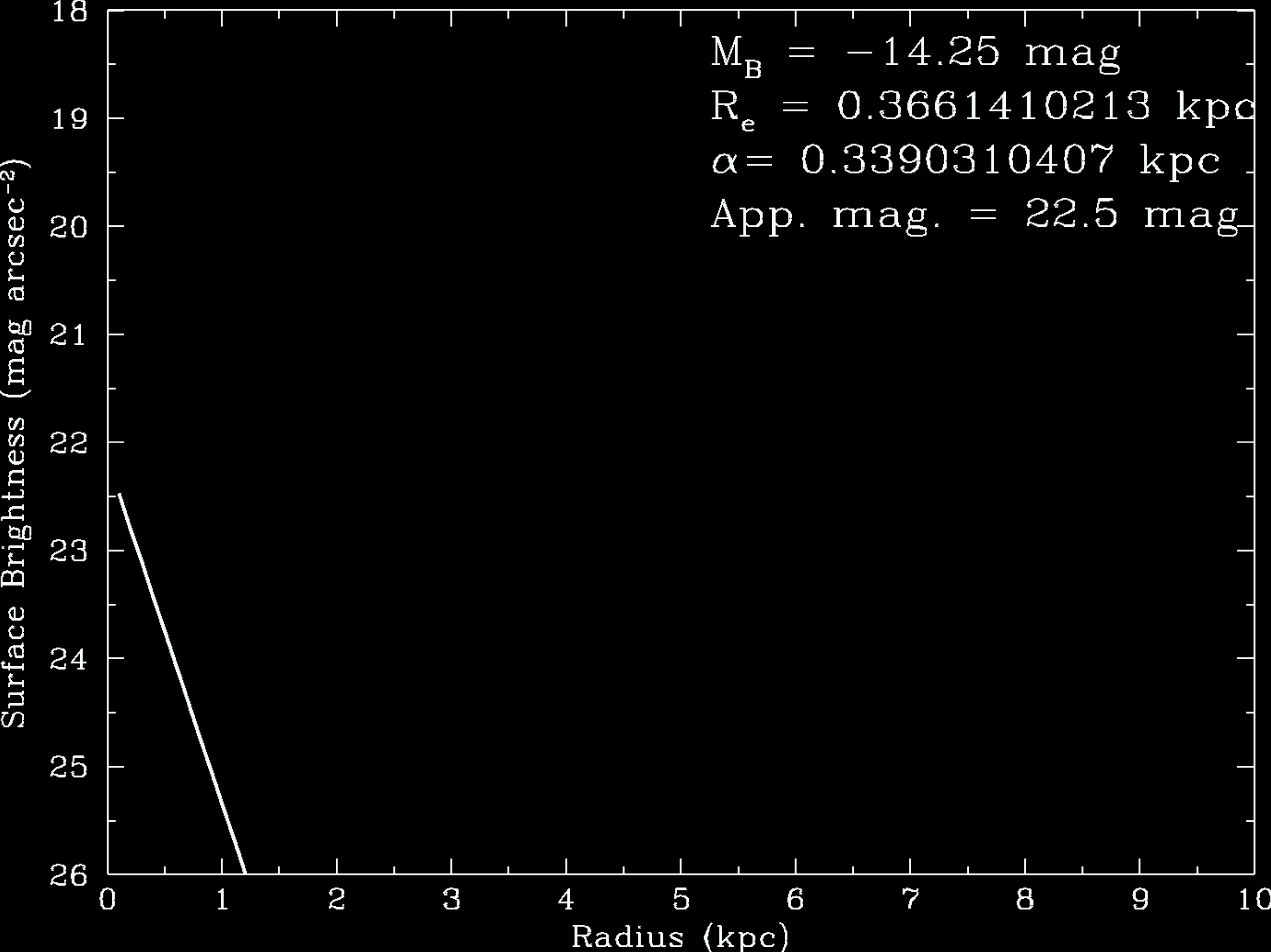

M_B = −14.25 mag
R_e = 0.3661410213 kpc
α= 0.3390310407 kpc
App. mag. = 22.5 mag
Surface Brightness (mag arcsec^{-2})
Radius (kpc)
18
19
20
21
22
23
24
25
26
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