The Millennium Galaxy Catalogue:
The Super Massive Black Hole Mass Function

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Overview

- The M[SMBH]-n relation (Graham et al 2001)
- Sersic profiles (Graham & Driver 2005)
- M[SMBH]-n vs M[SMBH]-sigma

- The Millennium Galaxy Catalogue (Liske et al 2003)
- Image quality and completeness (Driver et al 2005)
- GIM2D analysis (Allen et al 2005, Monday)
- Identifying the Bulges
- The Bulge LF (Liske et al 2005, Monday)

- The SMBH Mass function (Graham et al 2005)
  - Method: Indirect 1/Vmax
- Summary

# The M[SMBH]-n relation

Relation between SMBH mass and Sersic index of bulge
(Graham et al 2001, Graham et al 2003)
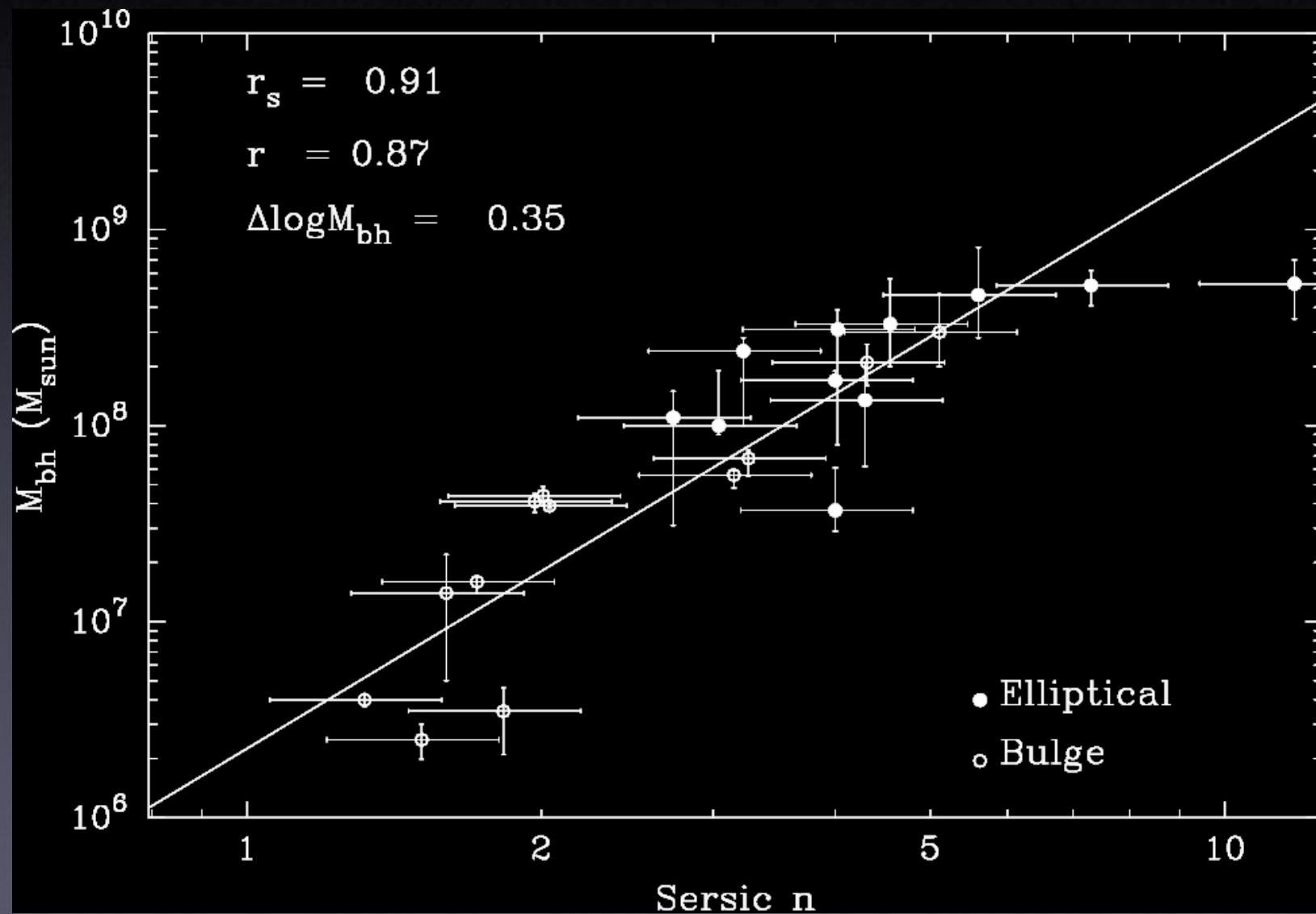
The Sersic index (n)

The Sersic index (Sersic 1963, 1968; Graham & Driver 2005) describes the projected light distribution of spheriods and bulges.

Sersic profiles:

$$I(r) = I_o \; \exp(-(r/\alpha)^{1/n})$$

n=0.5 (Gaussian)

n=4 (de Vaucouleur)

n=6

n=1 (Exponential)
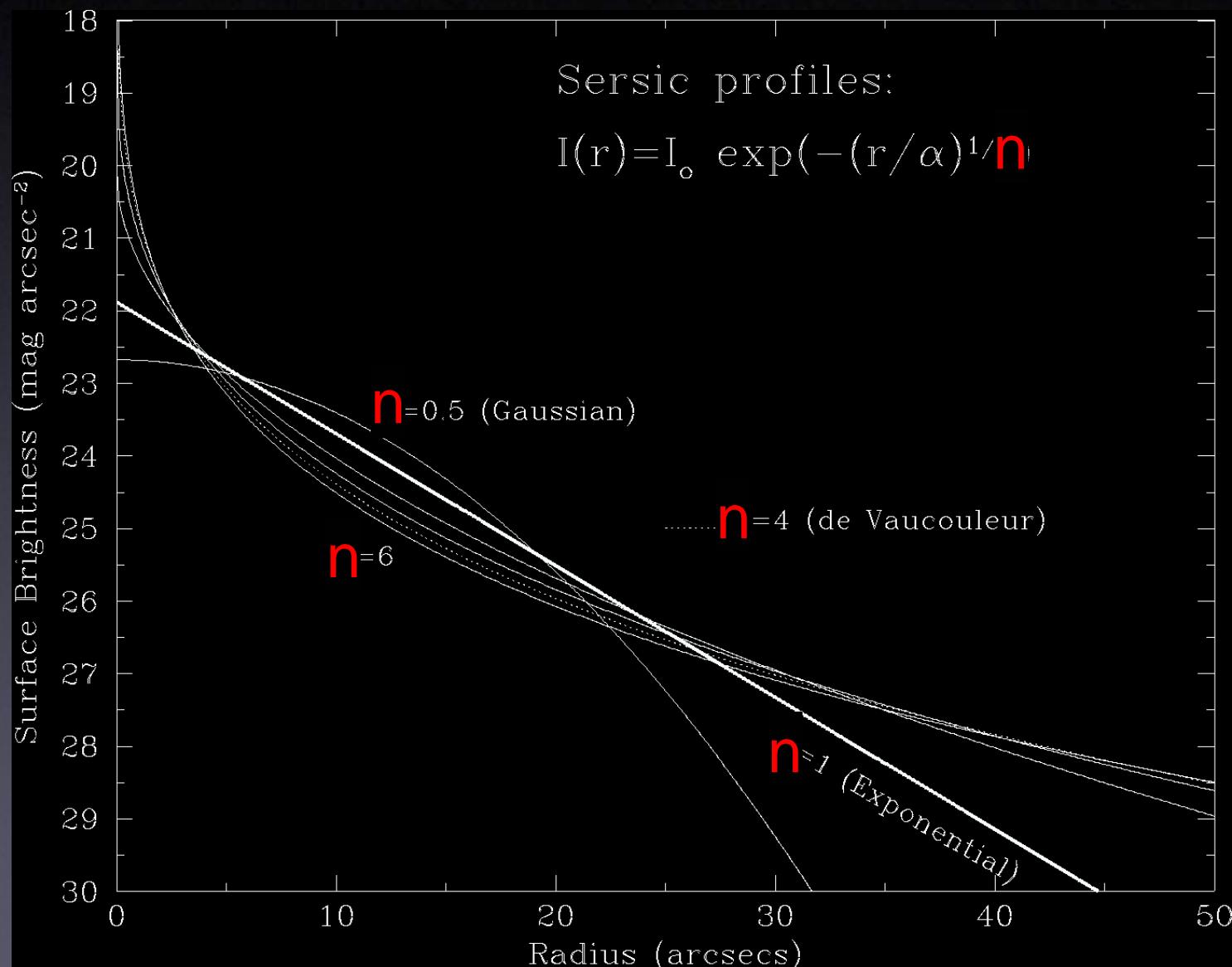
Measuring n: e.g.,
NGC4374/M84
n=5.60

Galaxy M84 Nucleus

WFPC2

Hubble Space Telescope

STIS
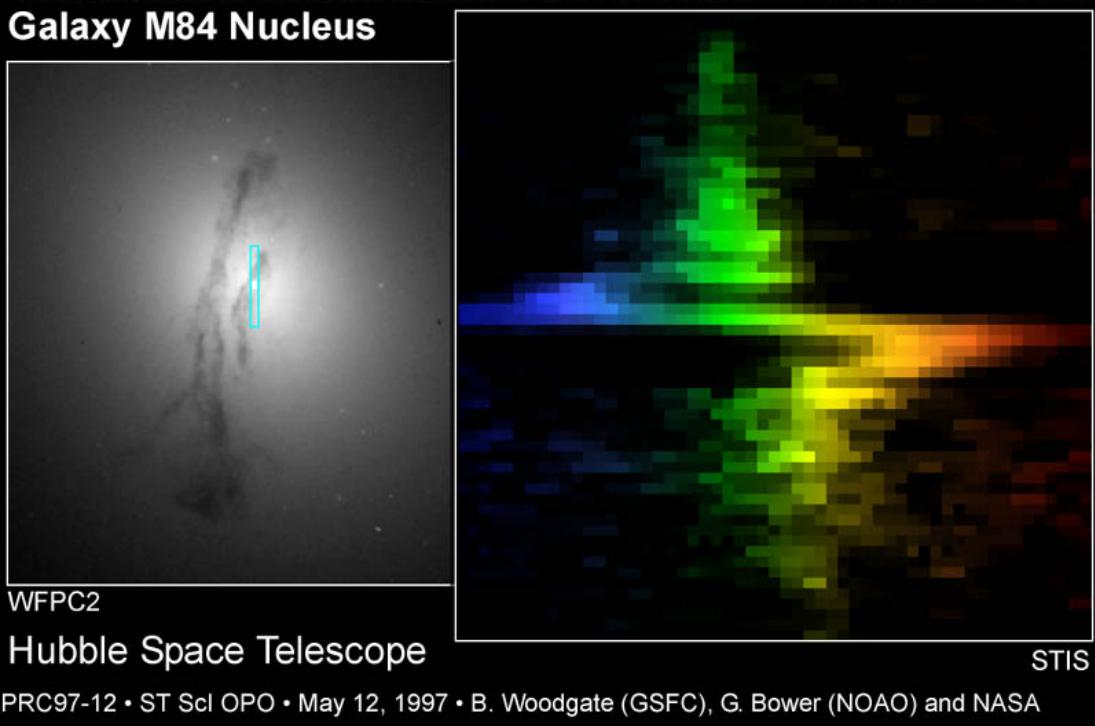
PRC97-12 • ST ScI OPO • May 12, 1997 • B. Woodgate (GSFC), G. Bower (NOAO) and NASA
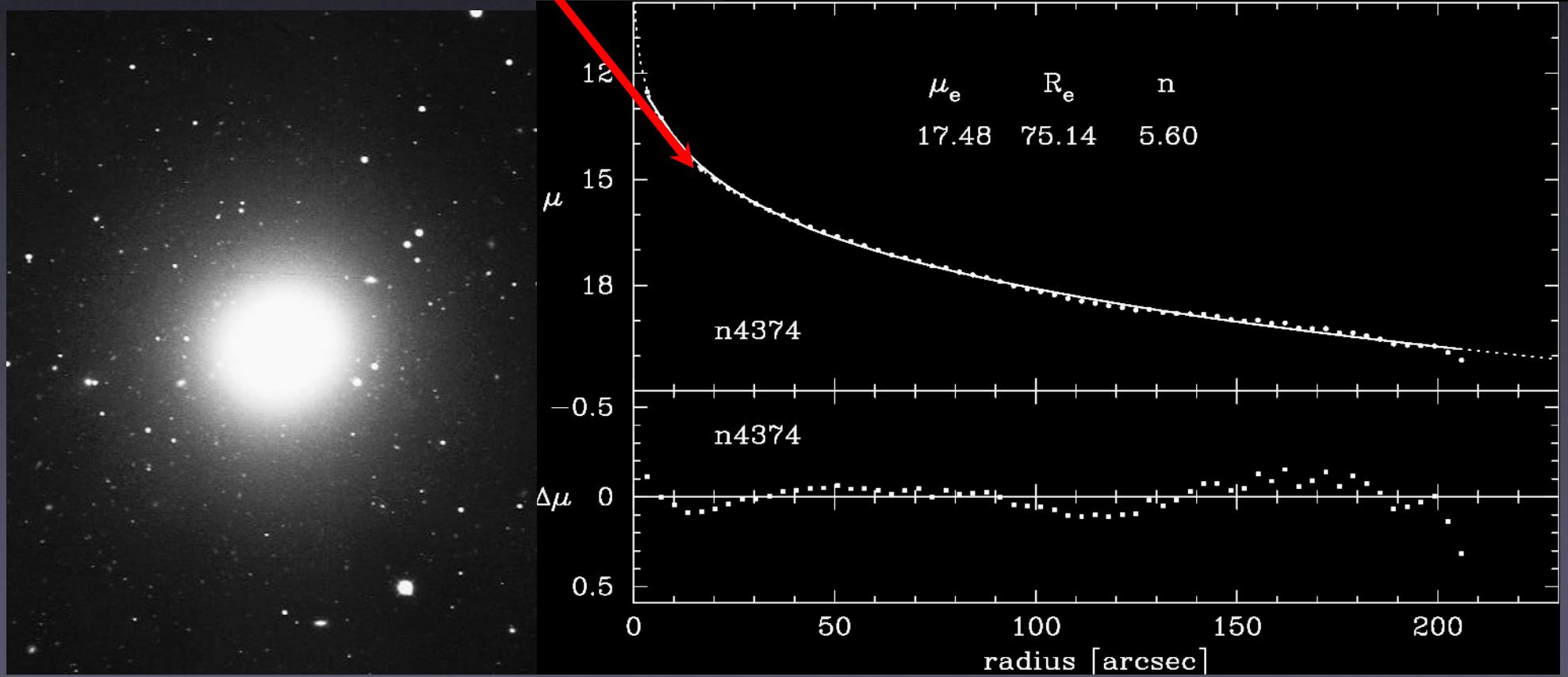
| Ellipticals	Distance (Mpc) Tonry et al 2001	M[SMBH] (10^8Mo)	Sersic index (n)	Reference
NGC821	24.1	0.37	4.00	Tremaine et al 2002
NGC3377	11.2	1.00	3.04	Tremaine et al 2002
NGC3379	10.6	1.35	4.29	Gebhardt et al 2000
NGC4261	31.6	5.20	7.30	Tremaine et al 2002
NGC4291	26.2	3.10	4.02	Tremaine et al 2002
NGC4374	18.4	4.64	5.60	Maciejewski & Binney 2001+
NGC4473	15.7	1.10	2.73	Tremaine et al 2002
NGC4697	11.7	1.70	4.00	Tremaine et al 2002
NGC5845	25.9	2.42	3.22	Tremaine et al 2002
NGC6251	-	5.30	11.8	Tremaine et al 2002
NGC7052	-	3.30	4.55	Tremaine et al 2002
Bulges	Distance (Mpc) Tonry et al 2001	M[SMBH] (10^8Mo)	Sersic index (n)	
MW	0.008	0.040	1.32	Ghez et al 2003
NGC221	0.81	0.025	1.51	Tremaine et al 2002
NGC1023	11.4	0.44	2.01	Tremaine et al 2002
NGC2778	22.9	0.14	1.60	Tremaine et al 2002
NGC2787	7.5	0.41	1.97	Tremaine et al 2002
NGC3031	3.9	0.68	3.26	Merritt & Ferrarese 2001
NGC3245	20.9	2.10	4.31	Tremaine et al 2002
NGC3384	11.6	0.16	1.72	Tremaine et al 2002
NGC4258	7.2	0.39	2.04	Tremaine et al 2002
NGC4342	-	3.00	5.11	Tremaine et al 2002
NGC4564	15.0	0.56	3.15	Tremaine et al 2002
NGC7457	13.2	0.035	1.83	Tremaine et al 2002

M[SMBH]-n vs M[SMBH]-σ

Graham et al (2001):
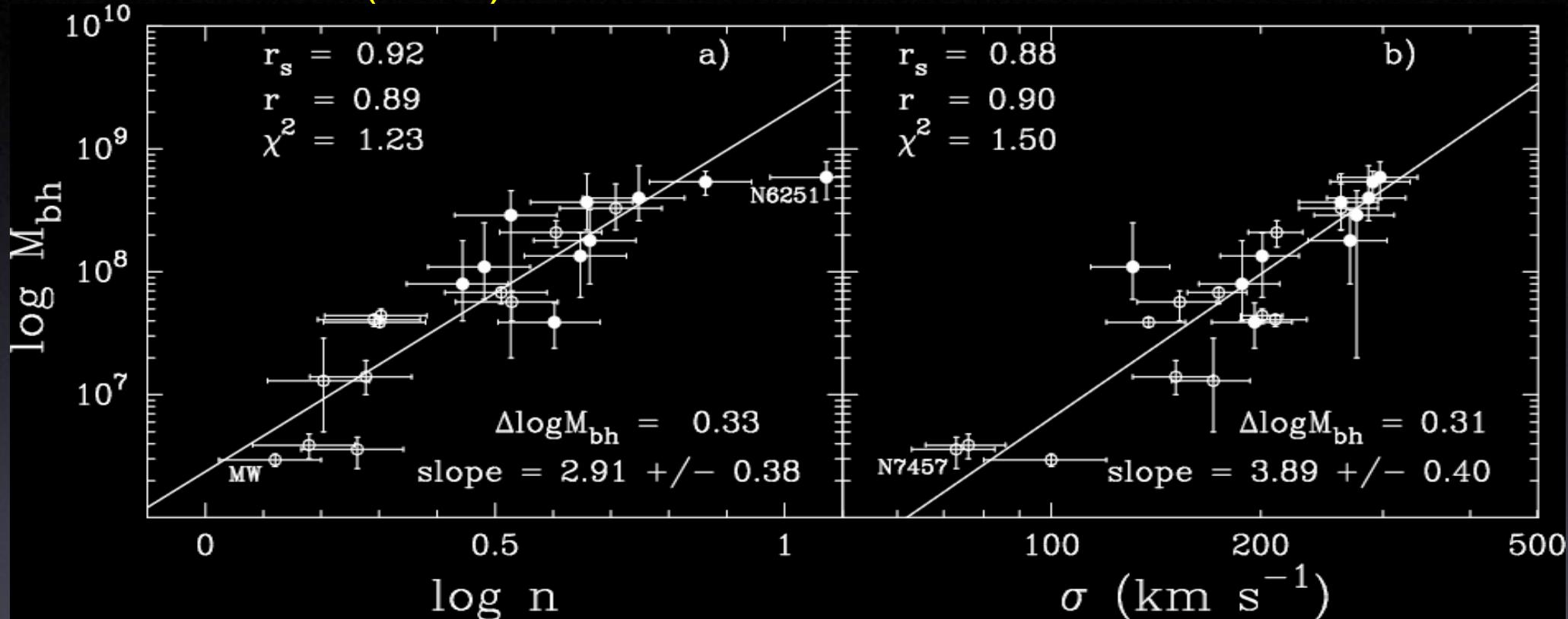
- M[SMBH]-n has similarly *tight correlation*.
- M[SMBH]-n *direct* and easier to measure.
- M[SMBH]-n imaging and distance *only* required.
- M[SMBH]-n larger *available* samples (e.g. MGC).
- Can measure n *at any z* with HST/JWST.

Driver (RSAA -> St Andrews)
Liske (ESO)
Allen (RSAA -> St Andrews)
Graham (RSAA)
Cross (ROE)
Ellis (AAO)
De Propris (Bristol)
Phillipps (Bristol)
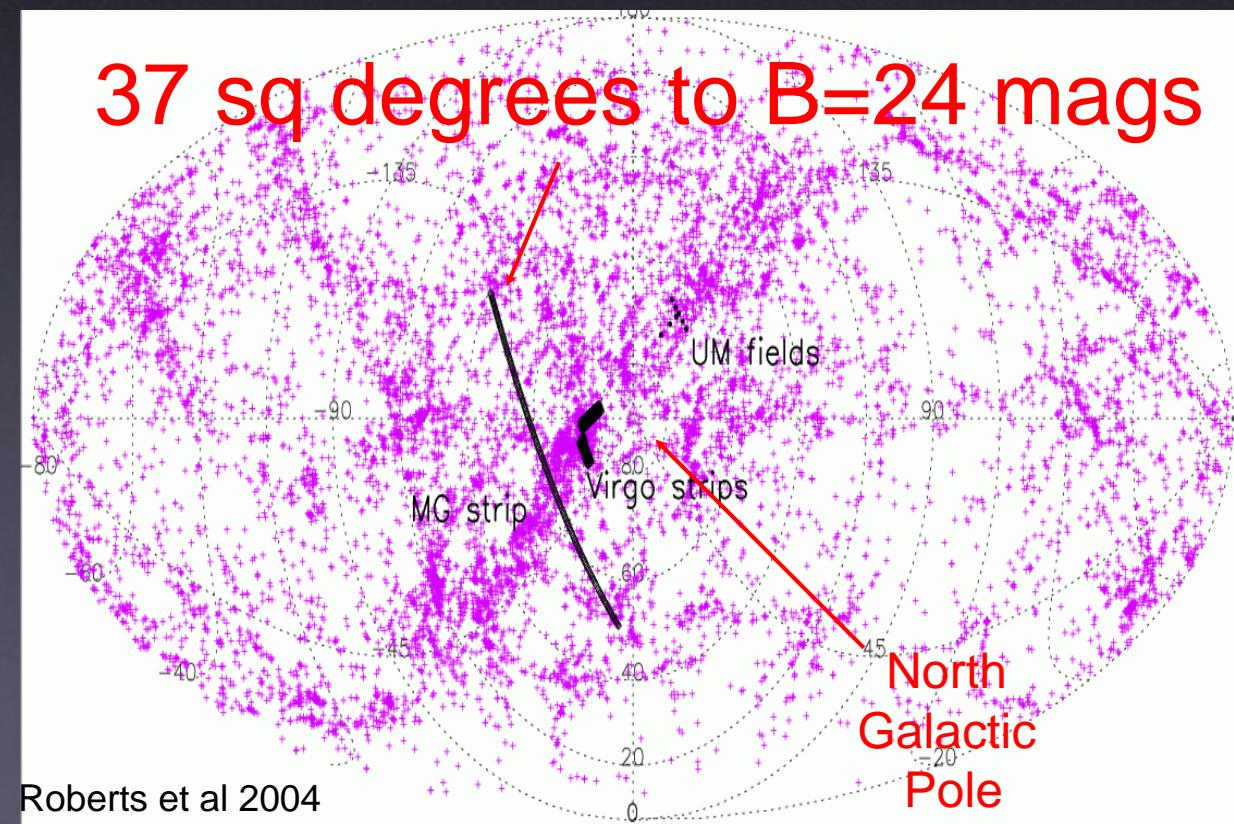
Nearby galaxy census.
Structural analysis of 10k galaxies.
LFs, mass fn's & baryon density of:
- Galaxies
  - Spheriods
  - Bulges
 - Pseudo-Bulges
  - Disks
  - SMBHs

37 sq degrees to B=24 mags

Roberts et al 2004

Structural Analysis (GIM2D)

o 12-parameter model fit (Sersic+exponential profiles+PSF convolution)
o 10,095 galaxies now completed, largest available sample (talk by Allen, Monday)
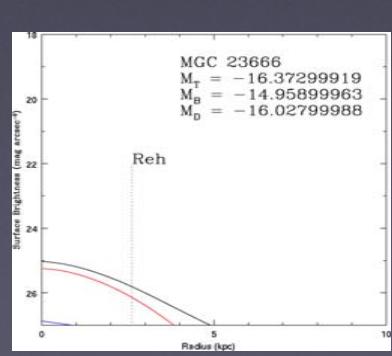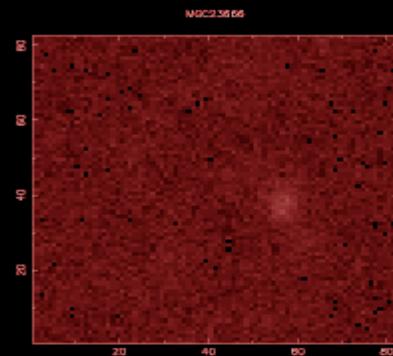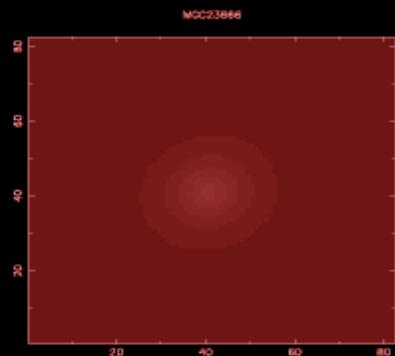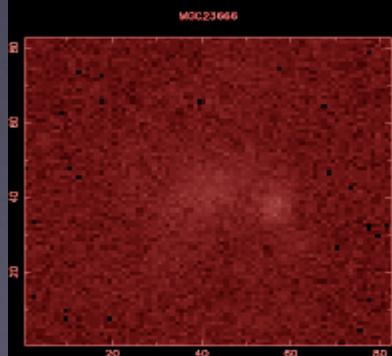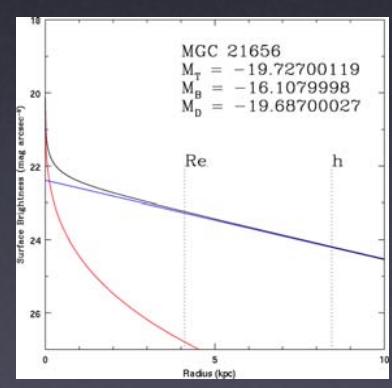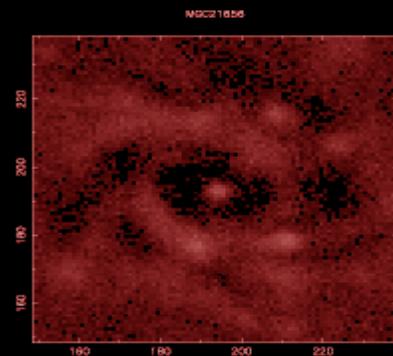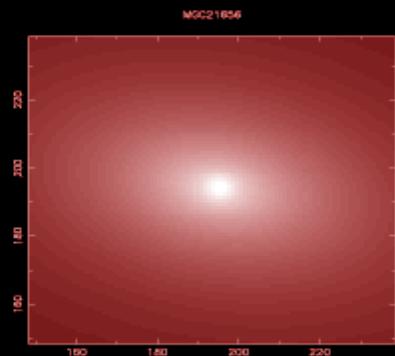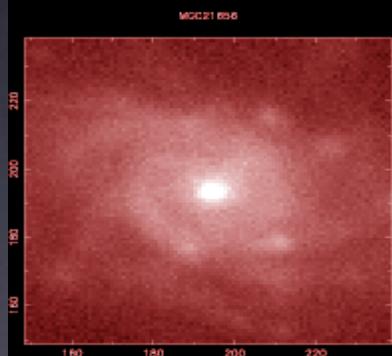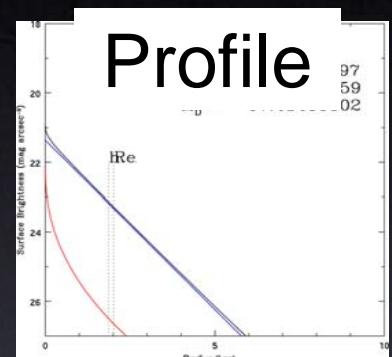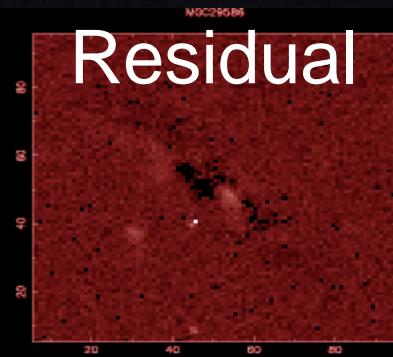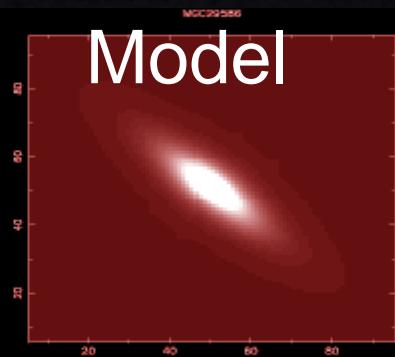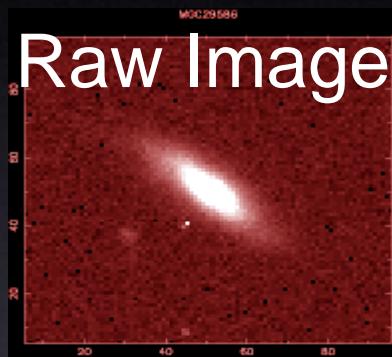
MGC: Bulge Disk Decomposition, originals
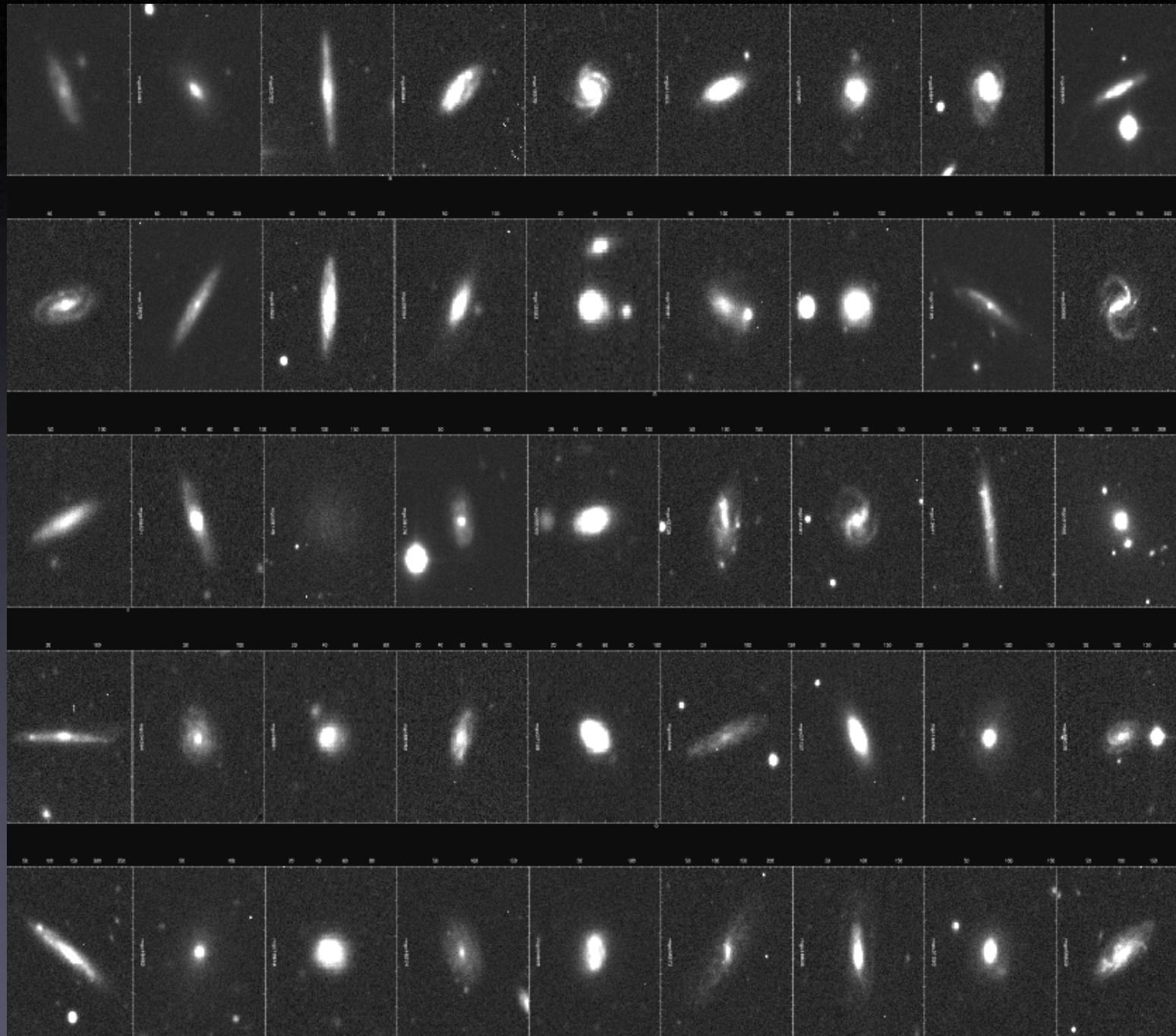
MGC: Bulge Disk Decomposition, models
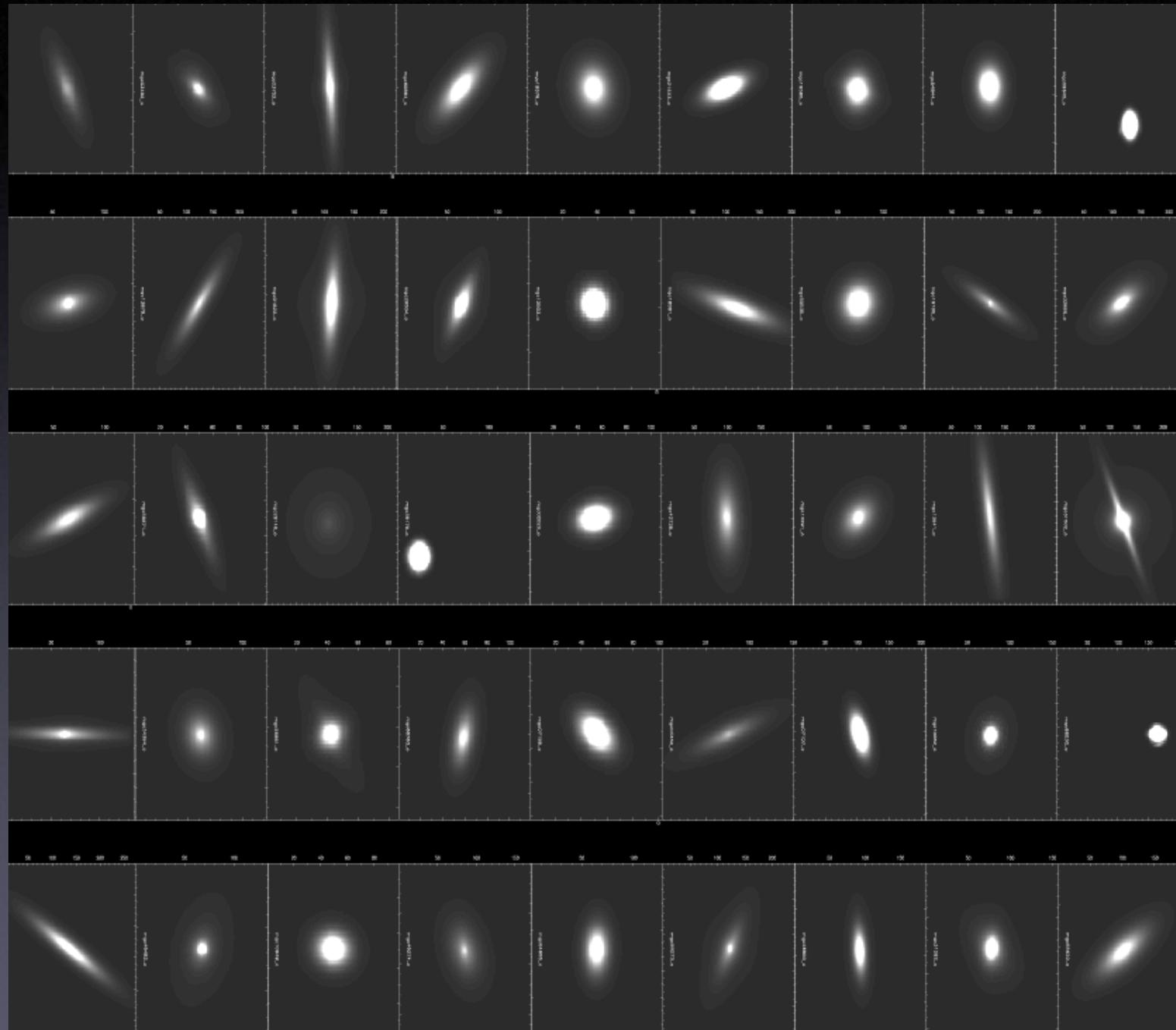
GIM2D Accuracy

- Sersic+exponential fits to all B < 20 mag
- Spectroscopic completeness 96%
- 10 095 fits in total, 700 repeats
- Accuracy of GIM2D fits:
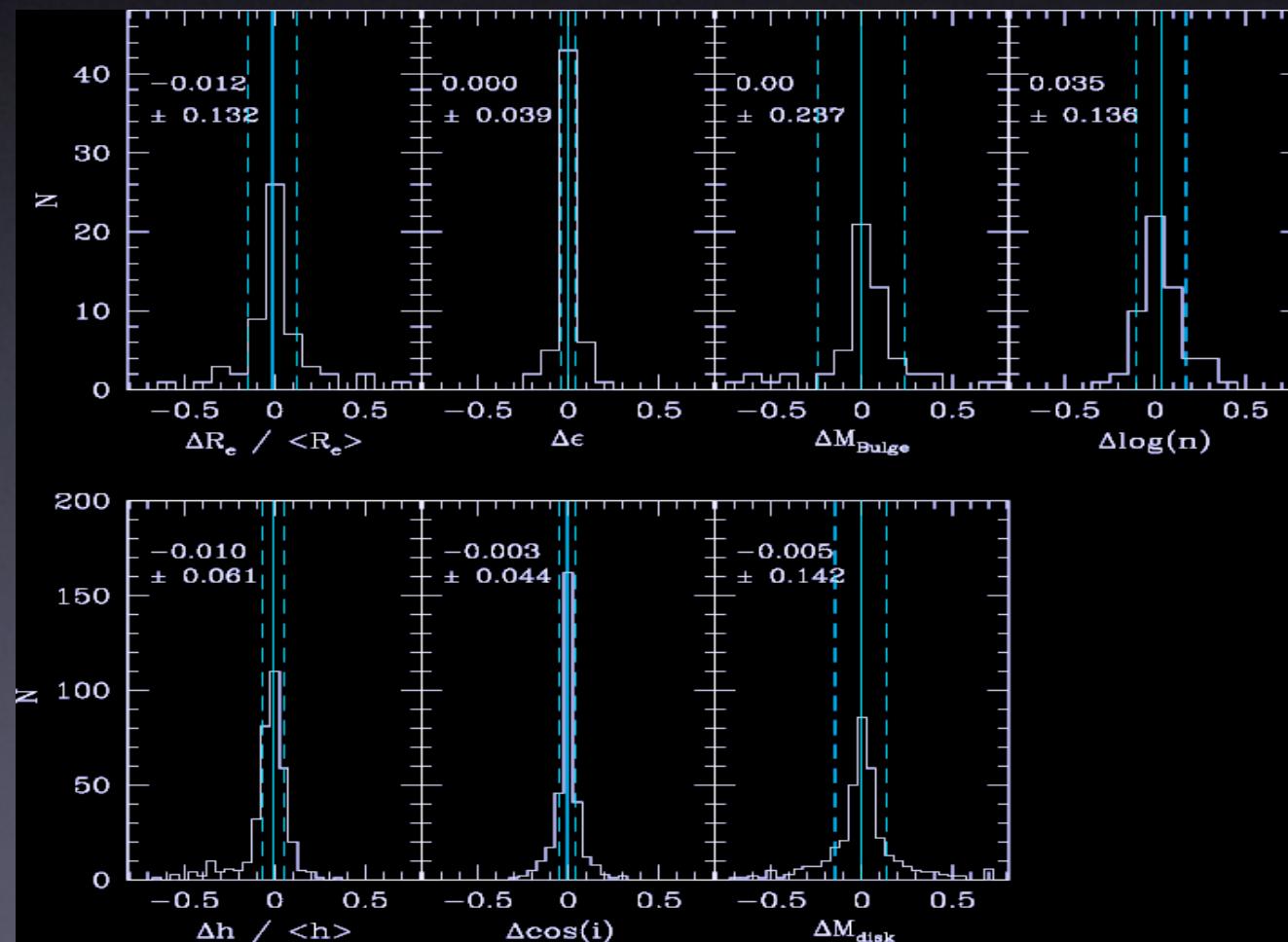
# MGC Structural LF?
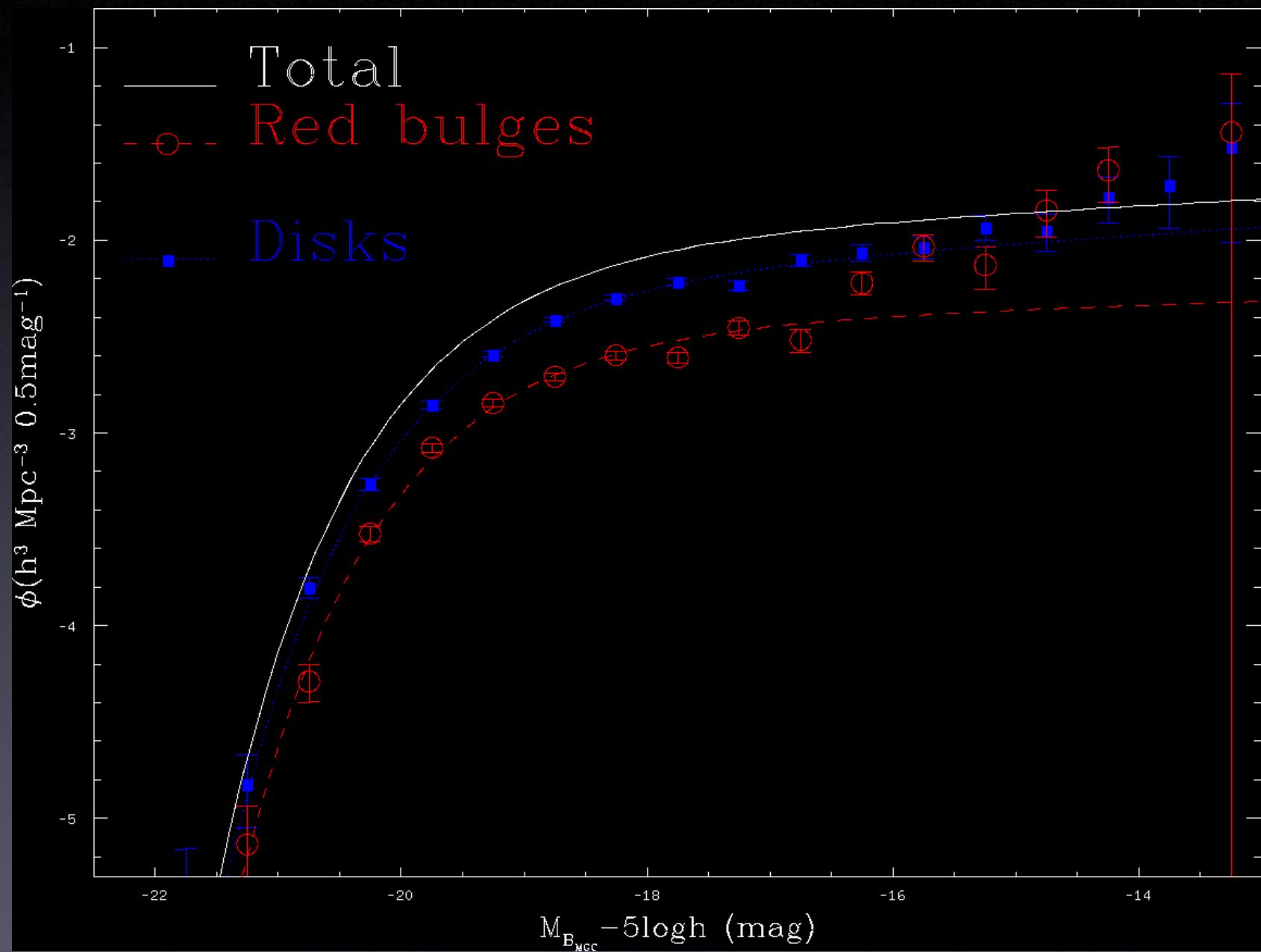
Structural Segregation
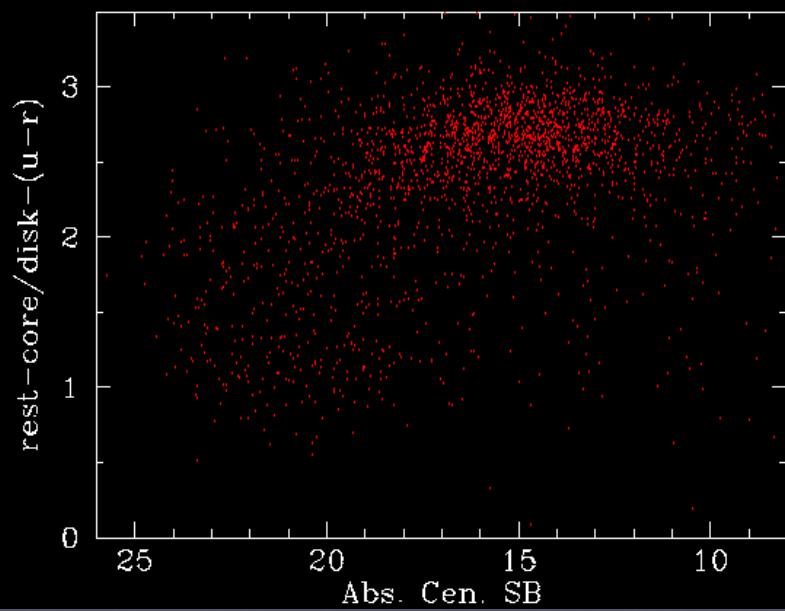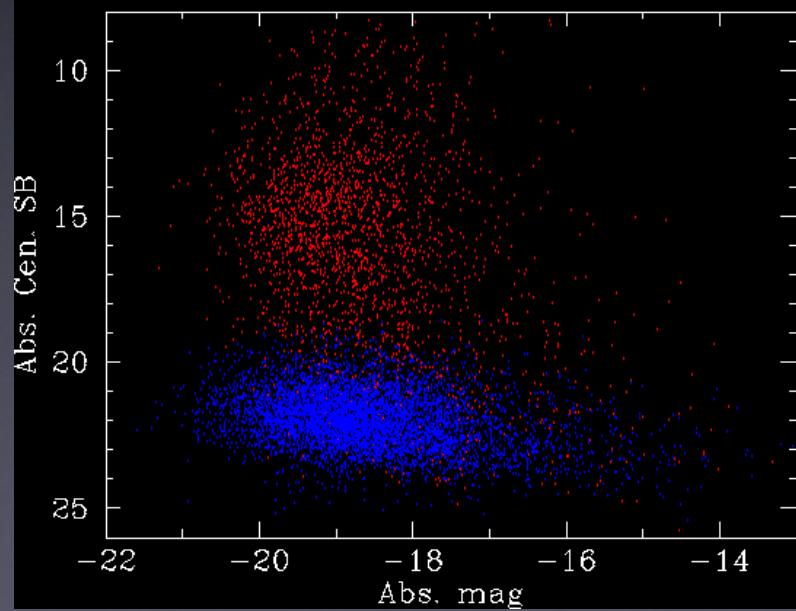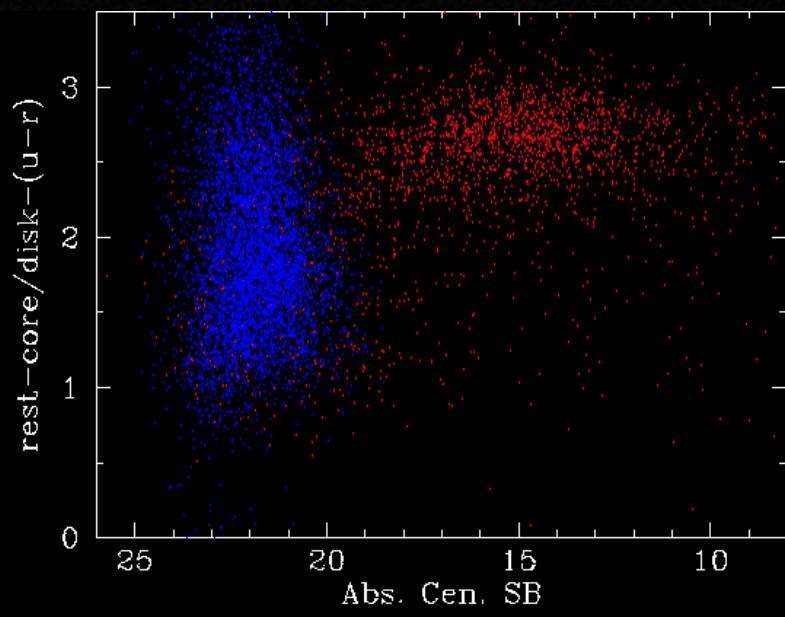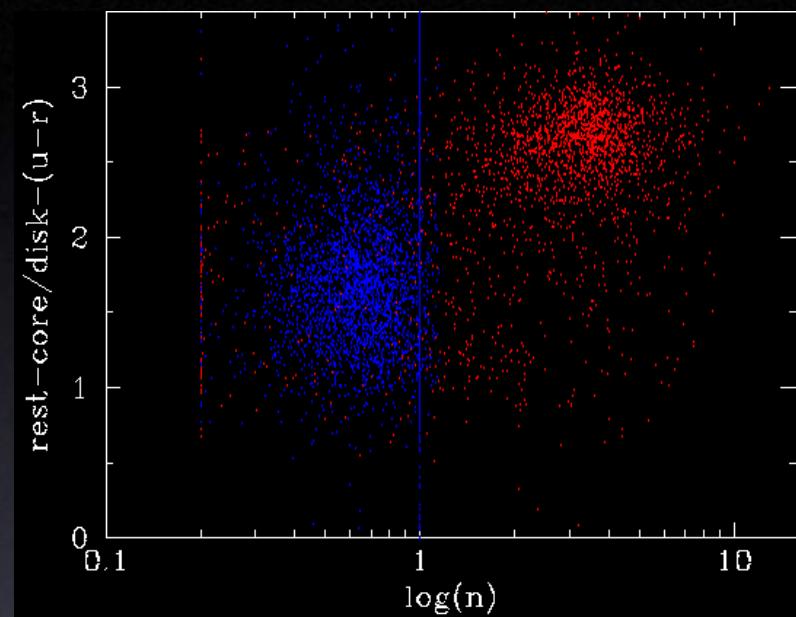
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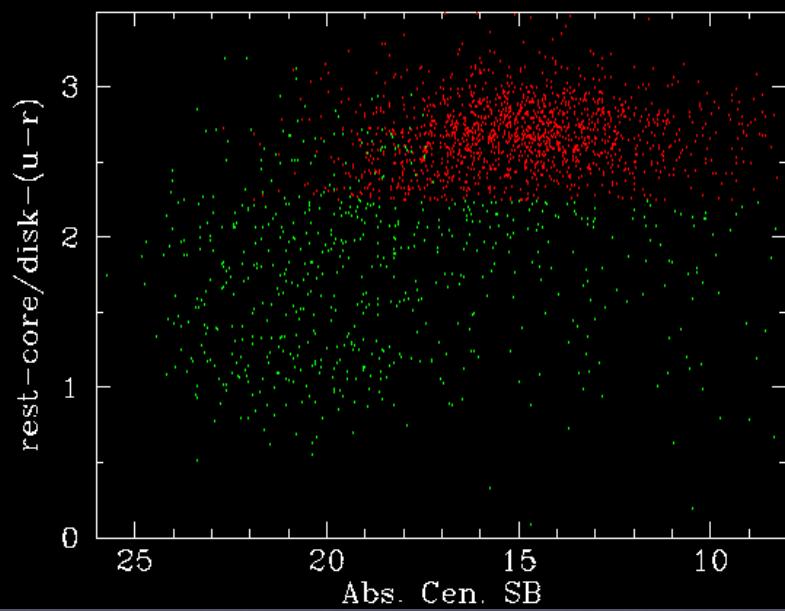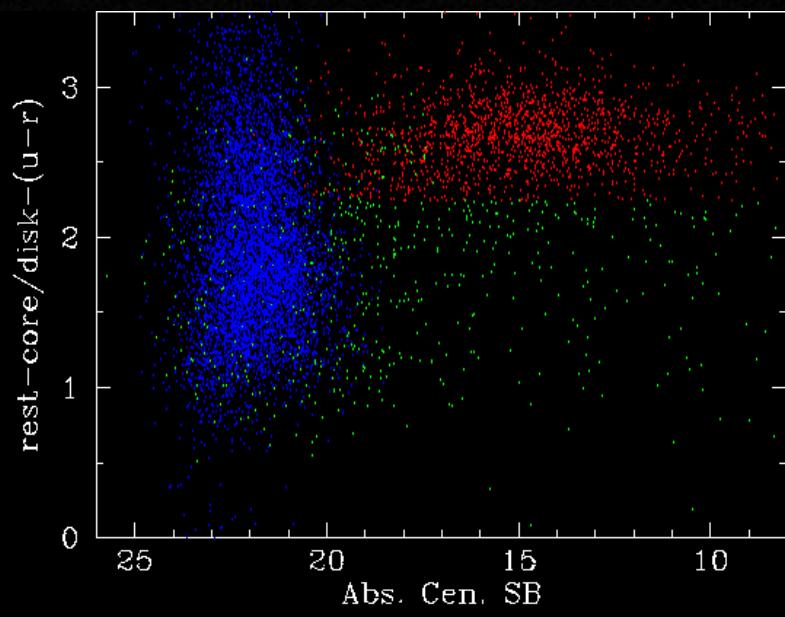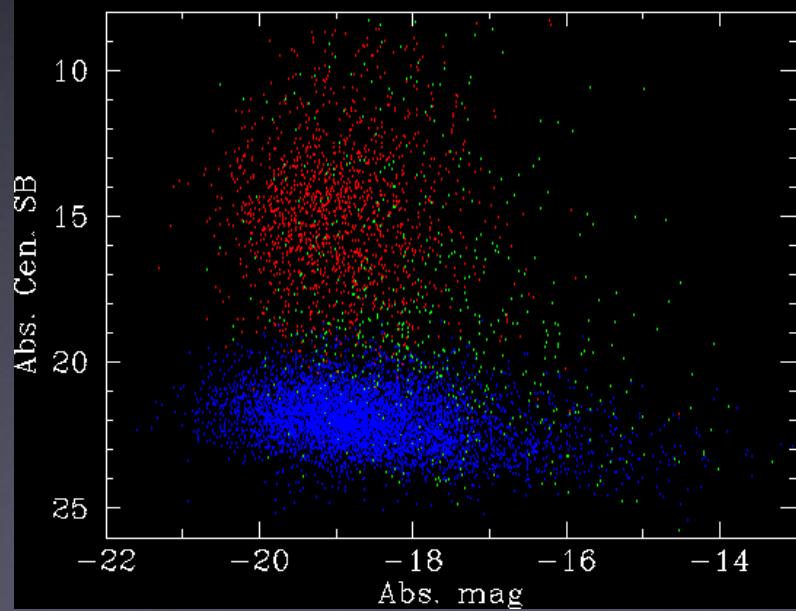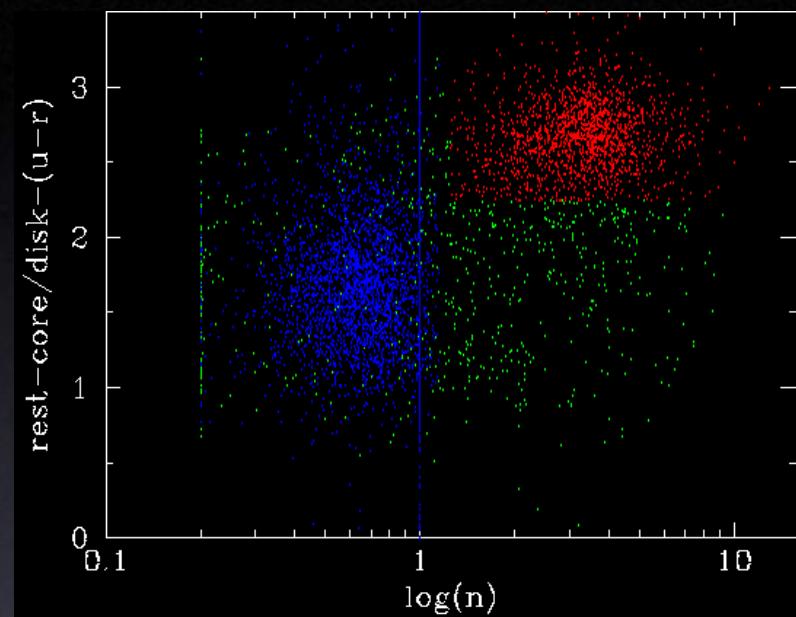
MGC Structural LF
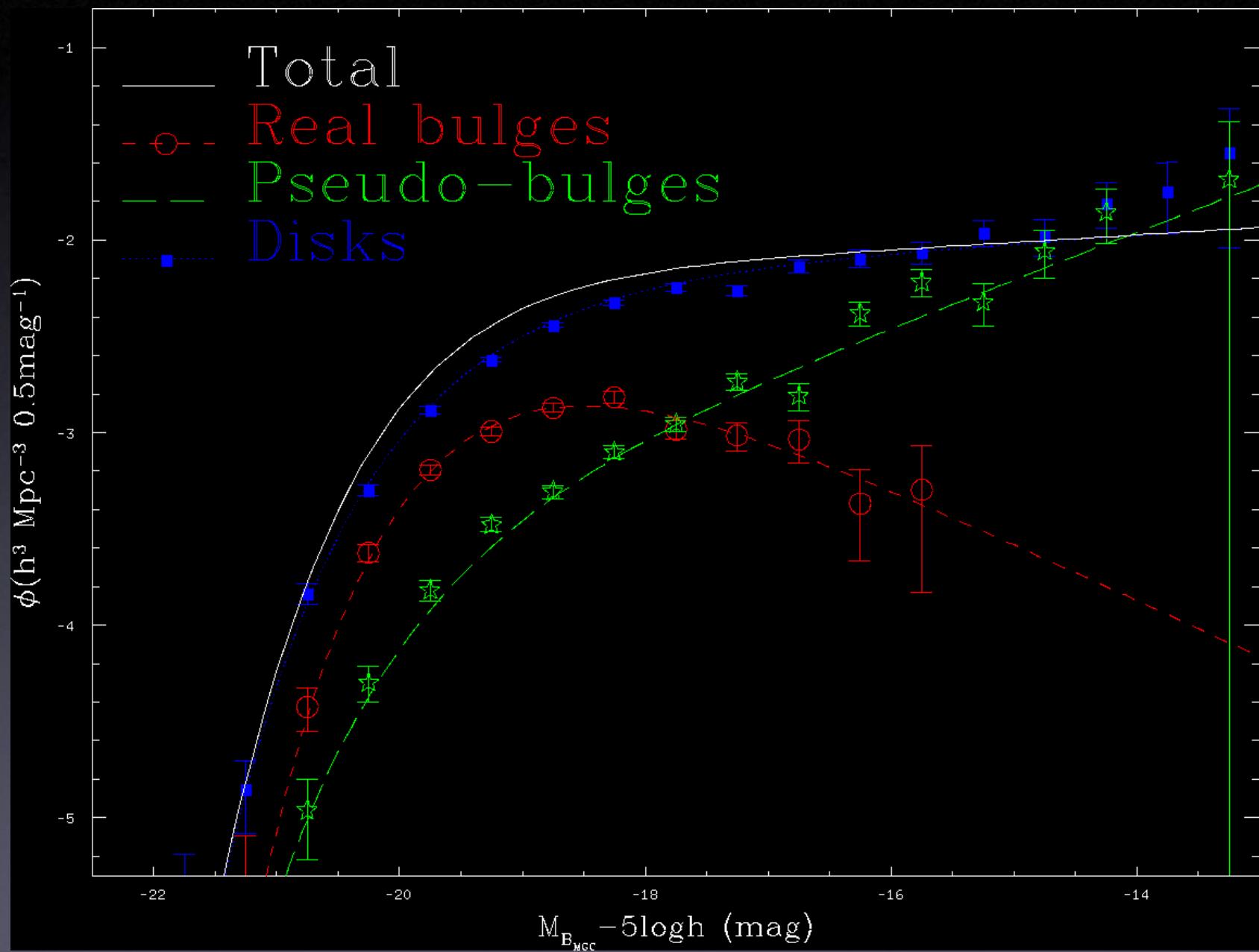
Constructing the SMBH MF

- Construct bulge BBD (talk by J. Liske, Monday)
- Assign a weight to each bulge:

$$W_i = \phi(M,\mu)/N(M,\mu) \cong 1/V_{MAX}$$

- Assign SMBH mass via M[SMBH]-n relation:

$$\log(M_{SMBH}) = 3.00(+/-0.51)\log(n/3) + 7.80(+/-0.07)$$

- Construct SMBH mass function:

$$N(M_{SMBH})d\log M_{SMBH} = \sum W_i M[SMBH]_i d\log M_{SMBH}$$

MGC SMBH Mass fn
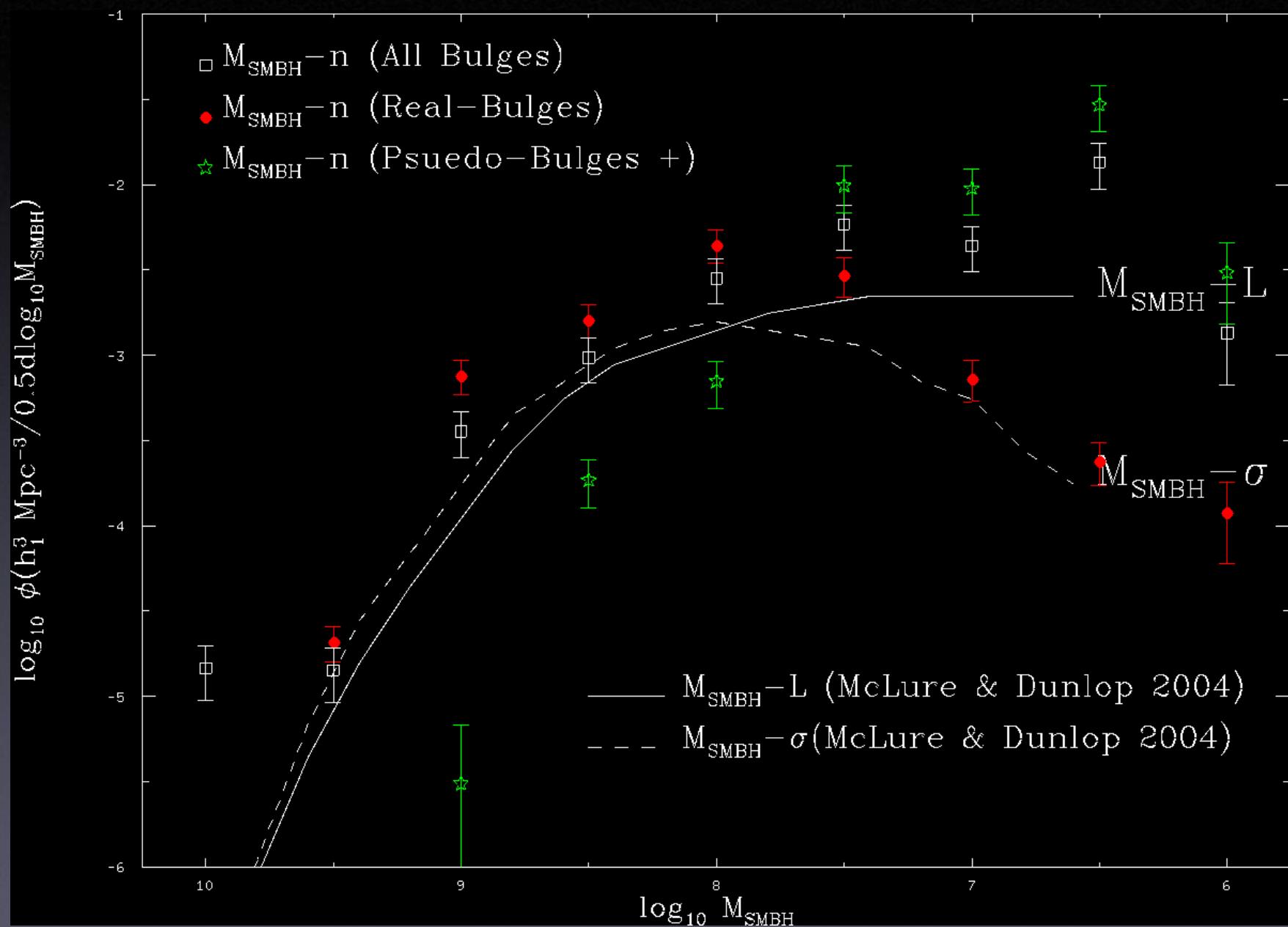
MGC SMBH Mass fn
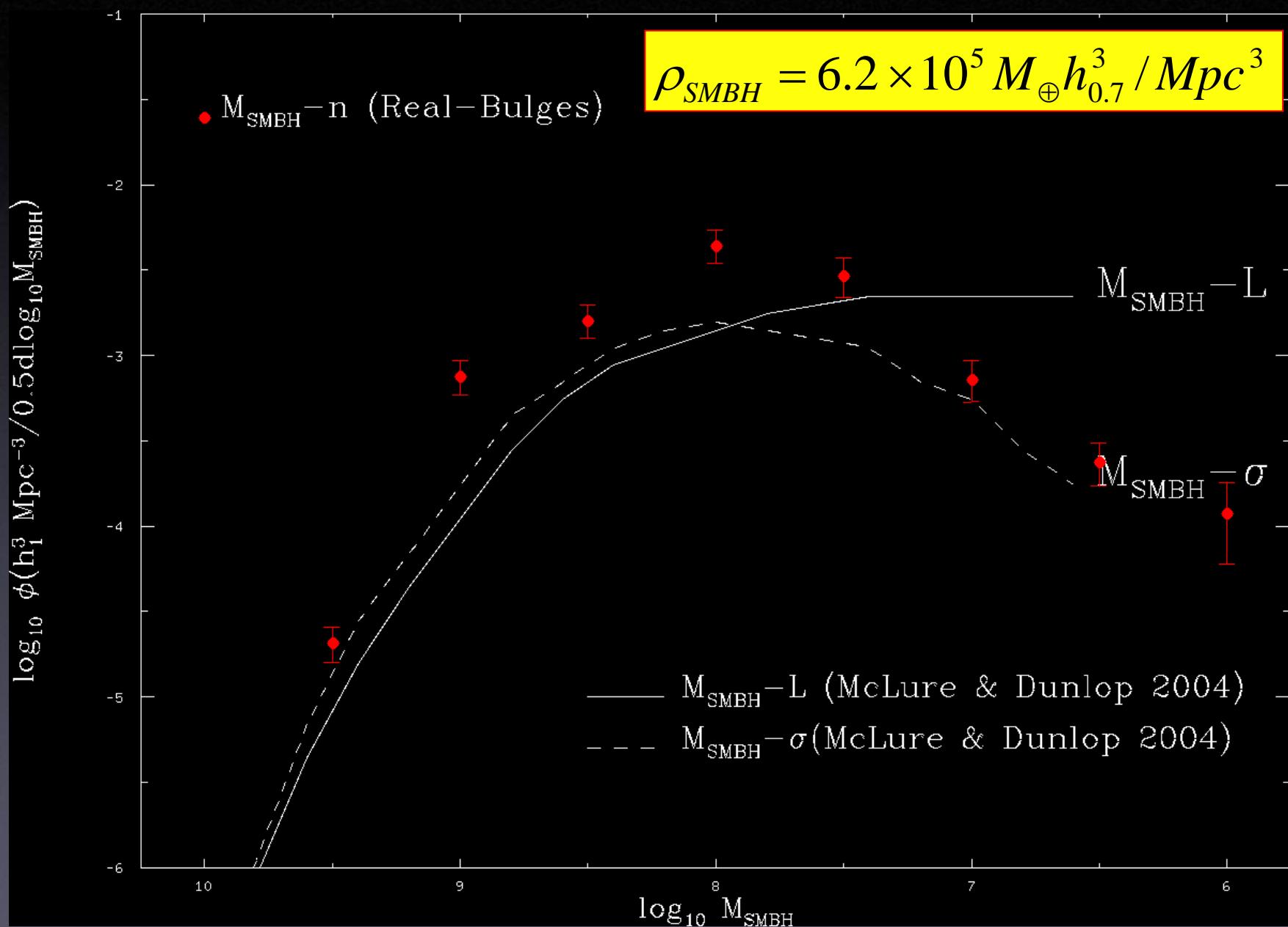
Summary

- M[SMBH]-n relation (Graham et al 2001; Graham et al 2005)
  - As tightly correlated as M[SMBH]-σ relation
  - Observationally easier (only quality imaging and z's required)
  - Potential to measure SMBH MF at any z (HST, JWST)
  - Currently based on 20 systems ---> ~40 systems
  - Better to measure Sersic index in near-IR ?
  - Quadratic relation a better fit ?

$$\log(M_{\mathrm{SMBH}}) = 3.00(+/-0.51)\ \log(n/3) + 7.80(+/-0.07)$$

- MGC SMBH Mass Function (in progress; Graham et al 2005)
  - Contains 2420 accurate Sersic bulge indices (Allen et al 2005)
  - Bulge/P-Bulge/Disks LFs/BBDs measured (Liske et al 2005)
  - Bulges 'consistent' with M[SMBH]-σ
  - Pseudo-Bulges+Bulges 'consistent' with M[SMBH]-L

$$\rho_{SMBH} = 6.2 - 8.2 \times 10^5\, M_{SOLAR} h_{0.7}^3 / Mpc^3$$