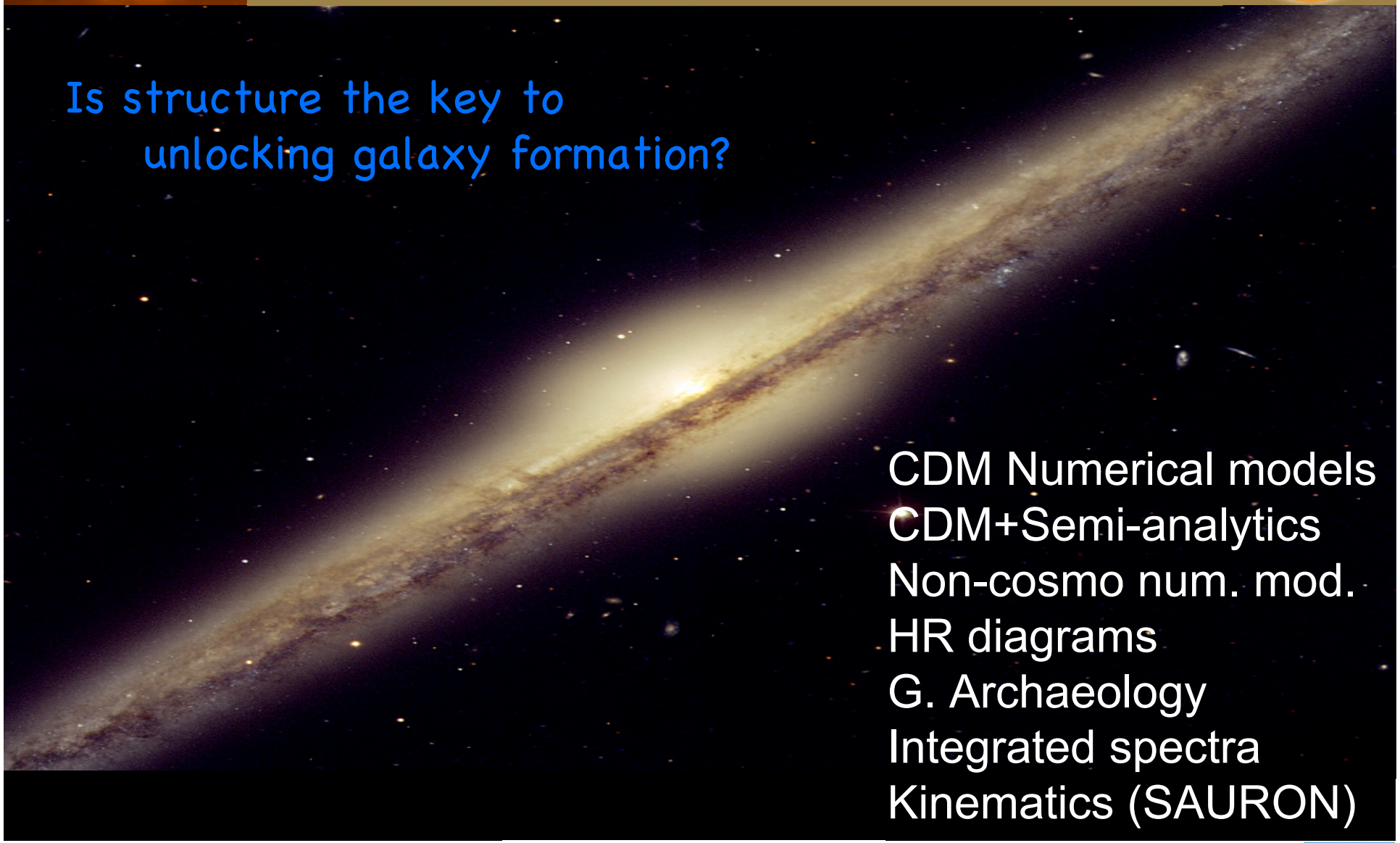
A Blueprint for Galaxy Formation?
Simon Driver (St Andrews)



NGC4565

ESO PR Photo 24a/05 (August 10, 2005)

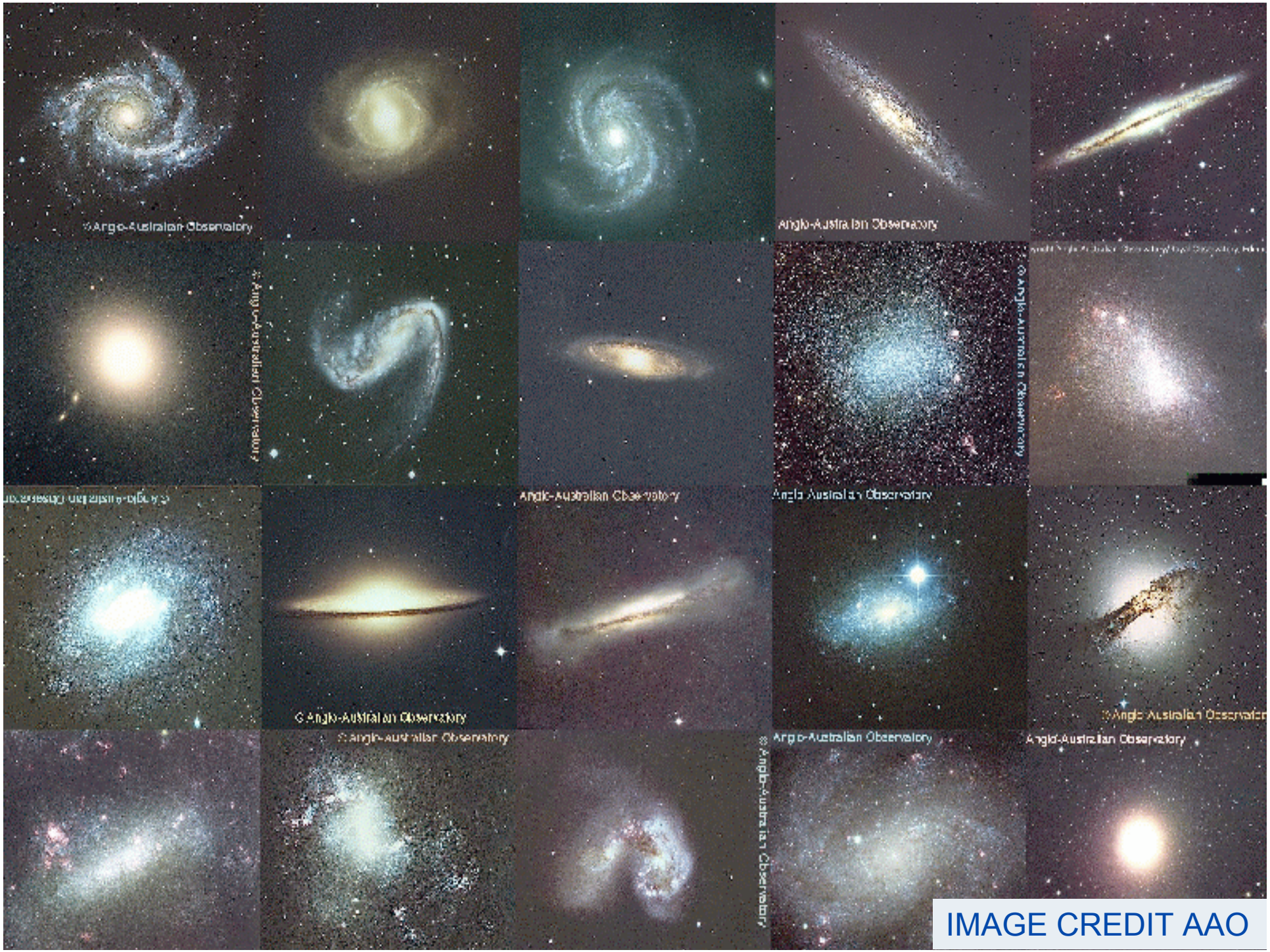
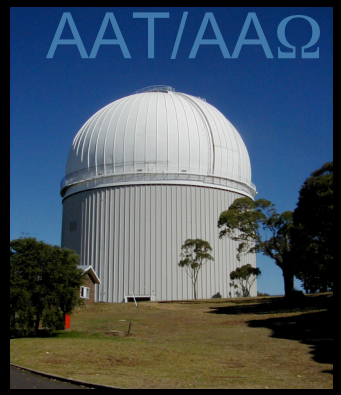


IMAGE CREDIT AAO

The Millennium Galaxy Catalogue

UKIRT/LAS 8 nights

AAT/AAΩ



15 nights+2dFGRS

GEMINI/GMOS

3 nights

SDSS

INT/WFC

14 nights

Near-IR (JHK)

ugriz+z's

z, spectra

z, LSBGs

B, morph
B/D decomp

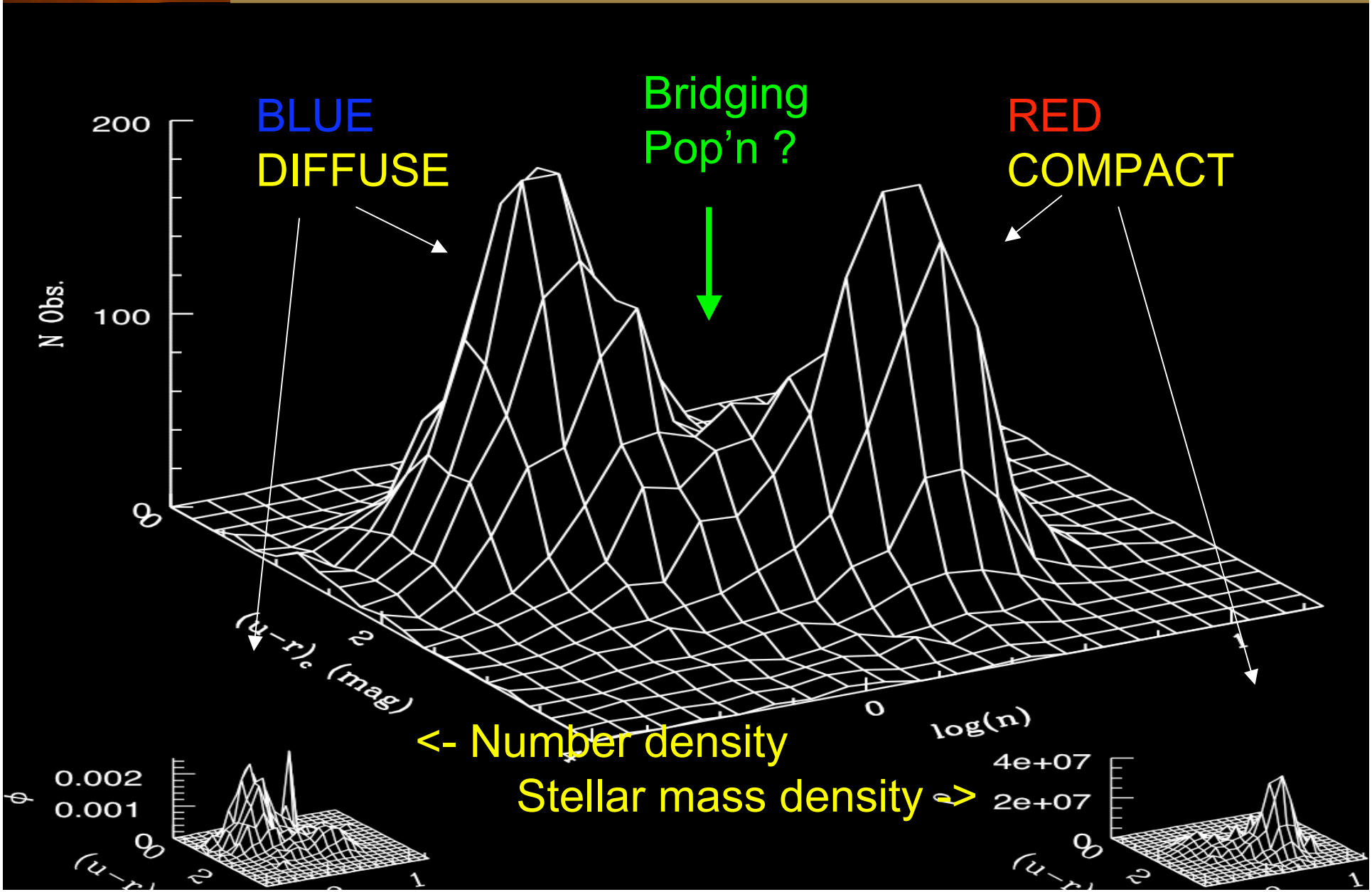
MGC

Z, LSBG
HSBGS

TNG 4nights
NTT 3nights
2.3m ANU
12 nights

SCIENCE

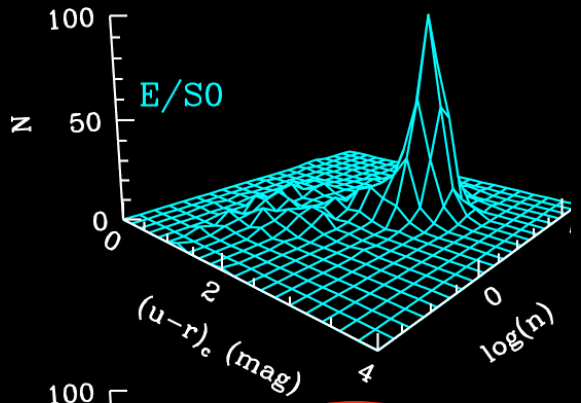
Galaxy bimodality



Two populations or two components ?

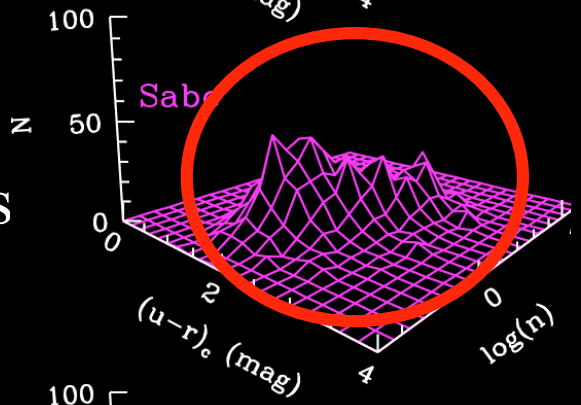
E/S0s

Spheroidal systems



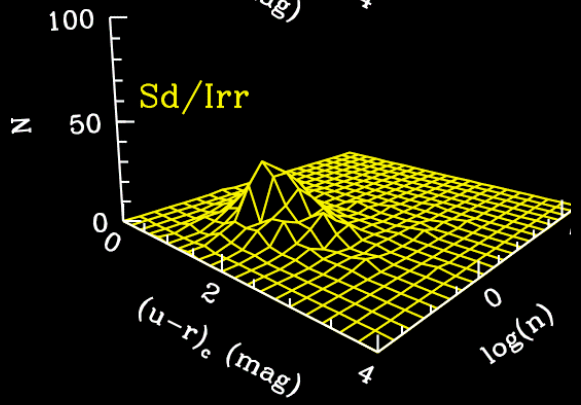
Sabc

Bulge+Disks



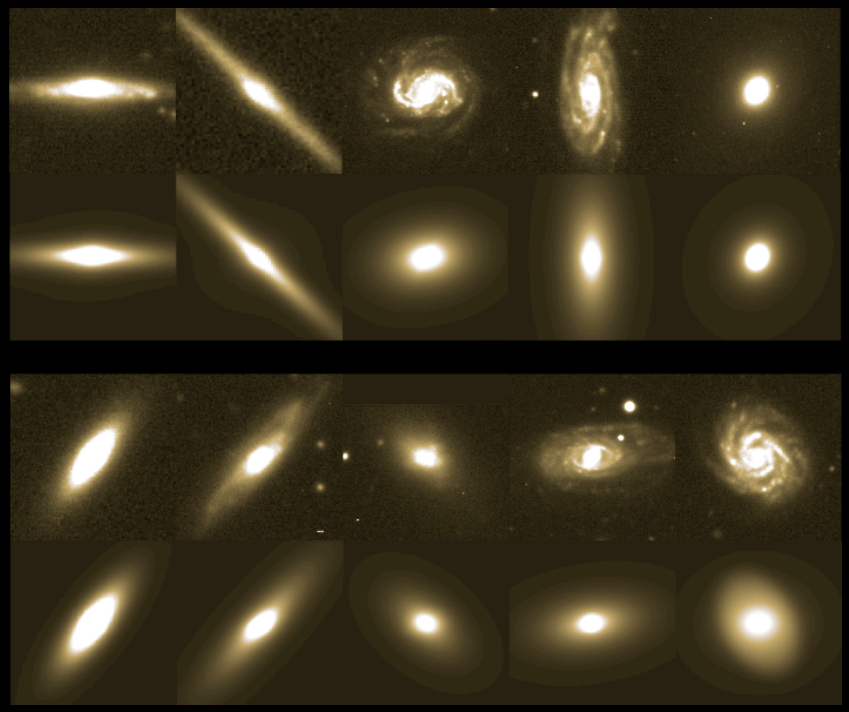
Sd/Irr

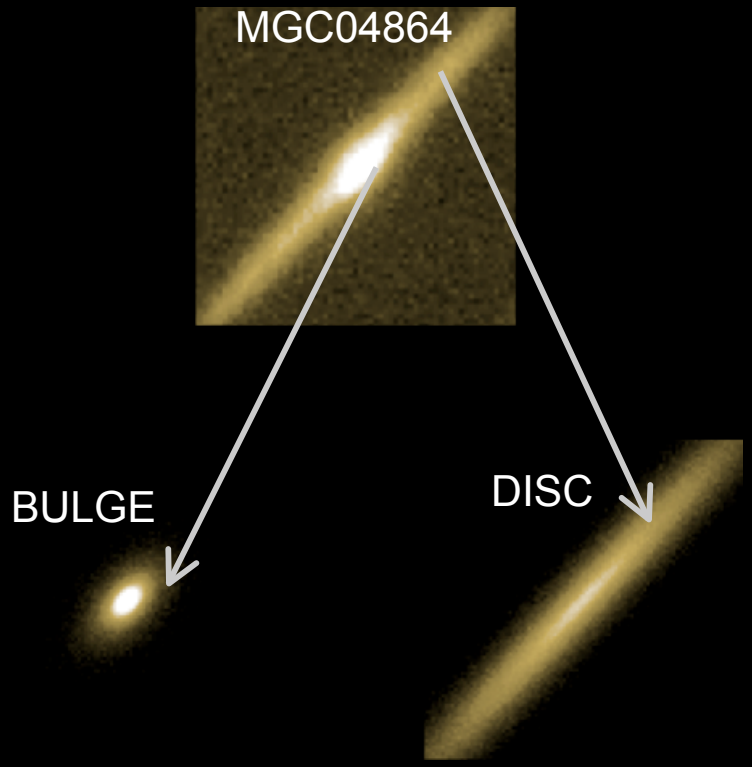
Disk systems



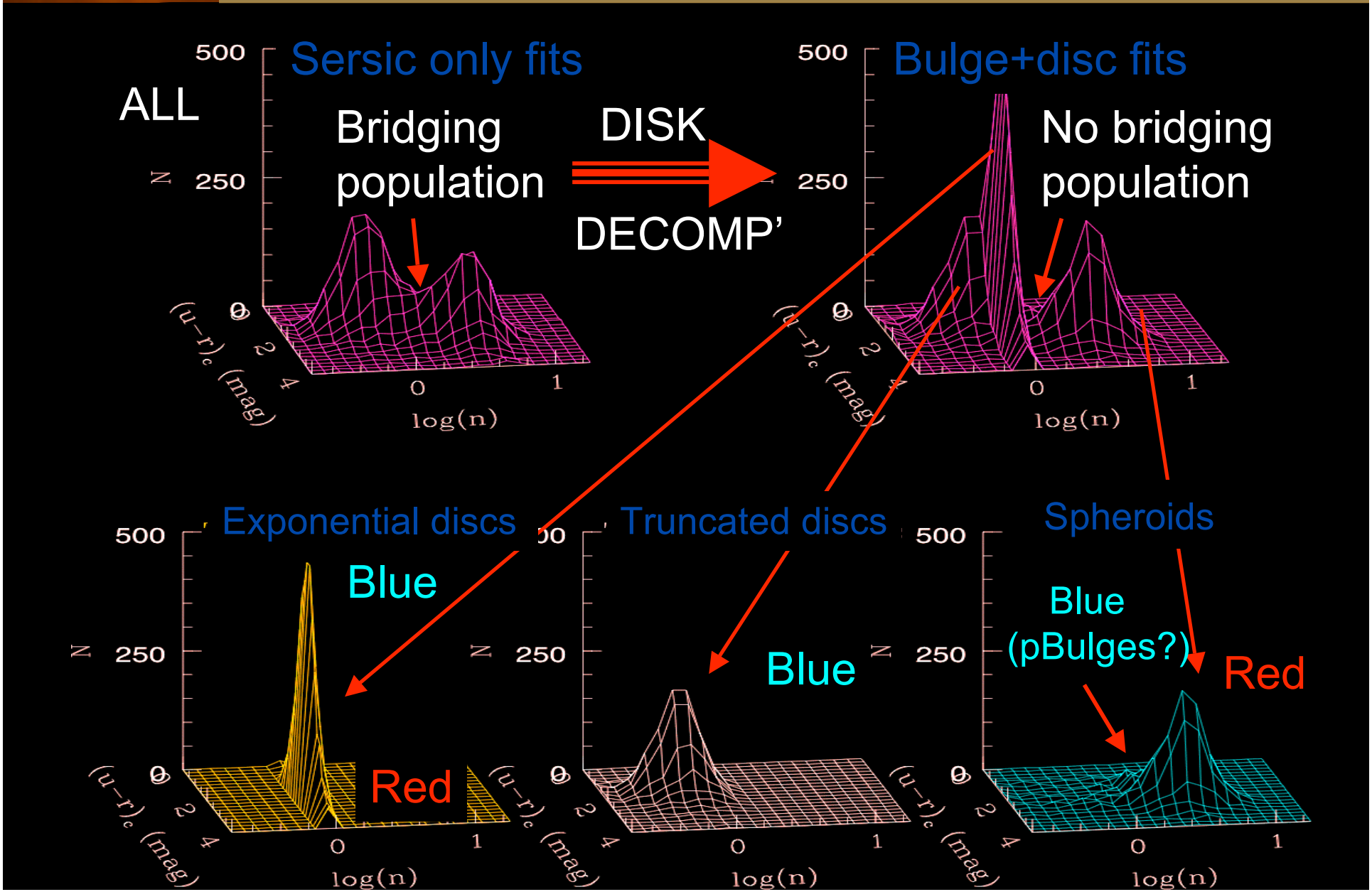
GIM2D bulge/disc decompositions

- Sersic+exponential profiles+PSF convolution via GIM2D, Simard et al (1998)
- 10,095 gals = largest available sample, Allen et al (2006) (robust/reproduceable)
- 96% redshift completeness (AAT/GEMINI) to B=20.0 mag, Driver et al (2005)
- B(INT) + ugriz(SDSS) + YJHK(UKIRT) imaging now 100% complete.
- All data available online: http://www.eso.org/~jliske/mgc/





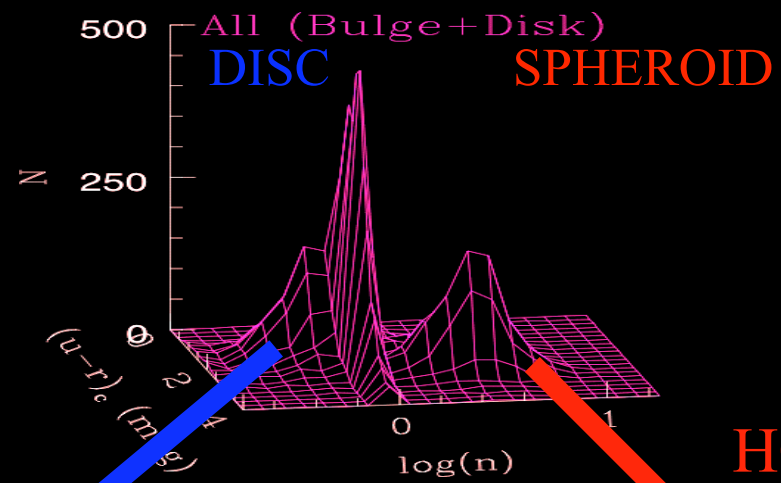
Two pop's or two components ?




MG
Millennium Galaxy
NGC4565

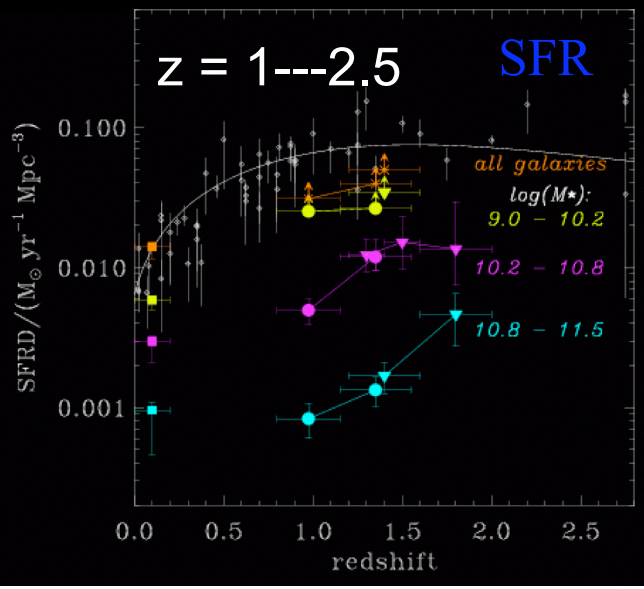
Two distinct modes of evolution ?

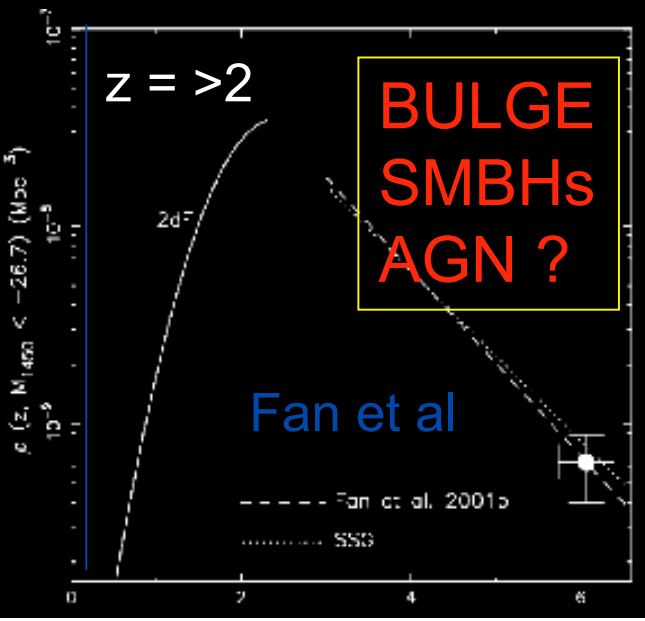
Structure more fundamental than colour.



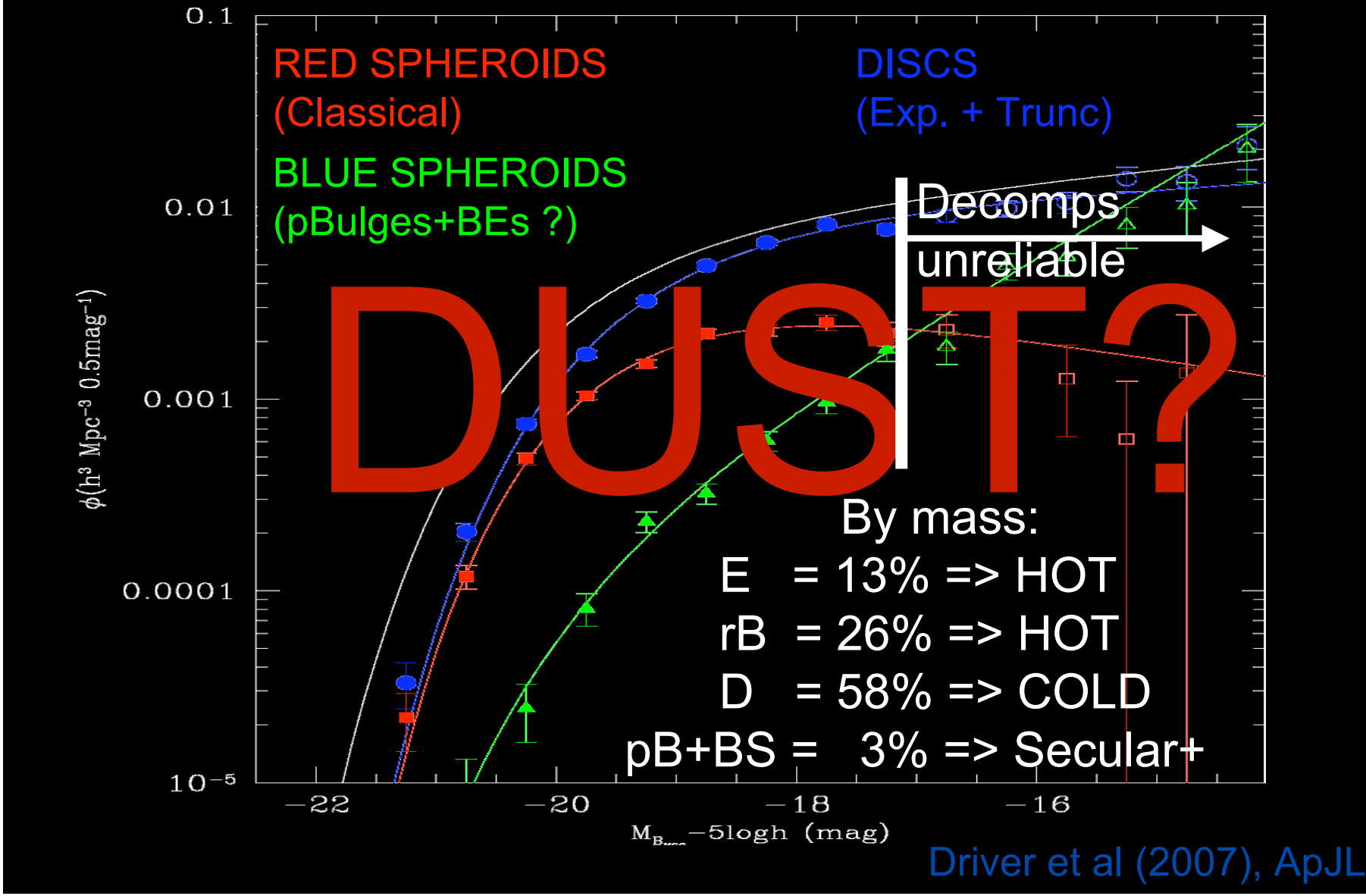
COLD MODE

HOT MODE





The Component Luminosity Functions



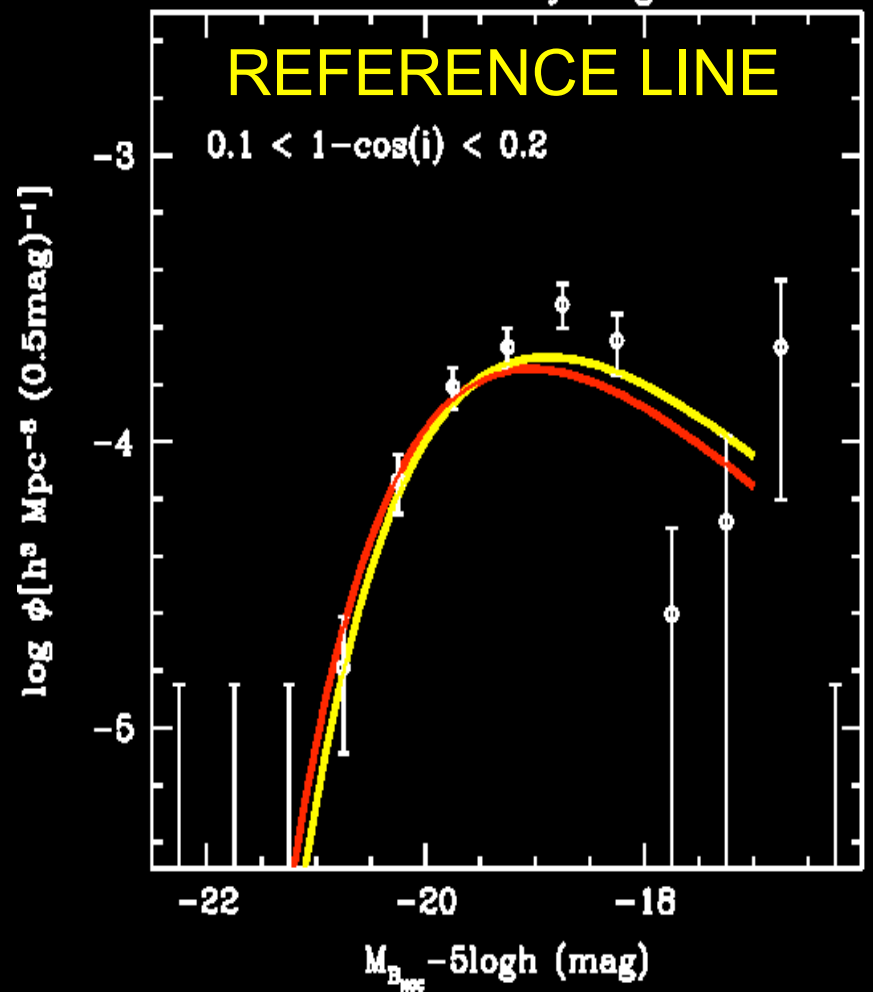
Driver et al (2007), ApJL

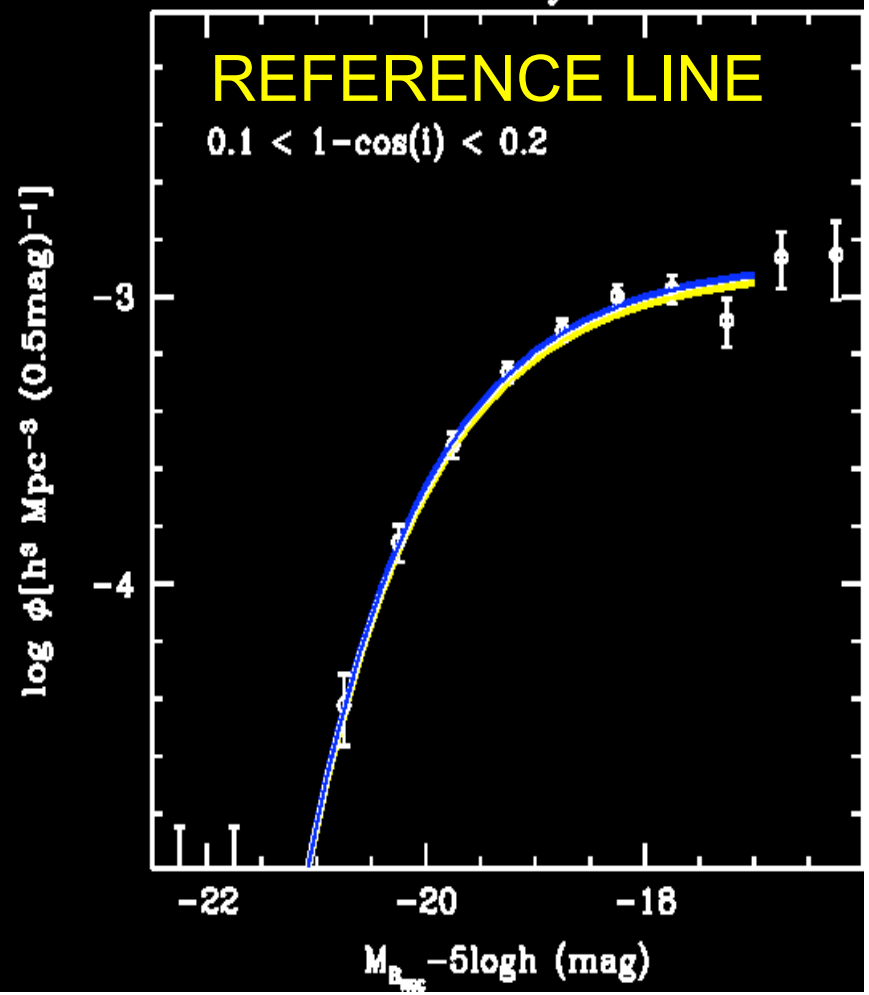
MGC
Millennium Galaxy Catalogue

Component LFs v cos(*i*)

NEARLY FACE-ON GALAXIES

Bulges 0.1 < 1-cos(*i*) < 0.2 Discs

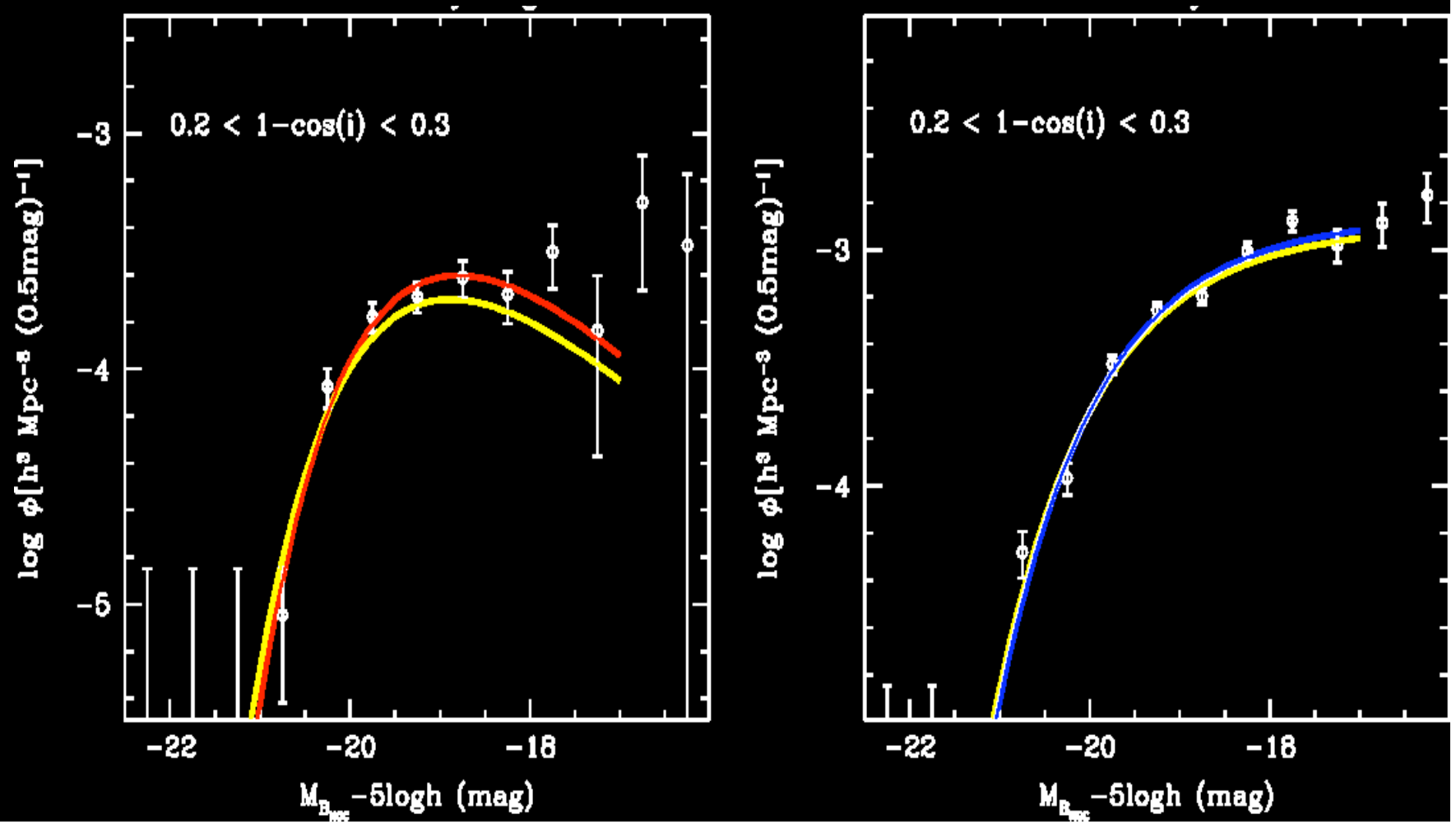




MGC
Millennium Galaxy Catalogue

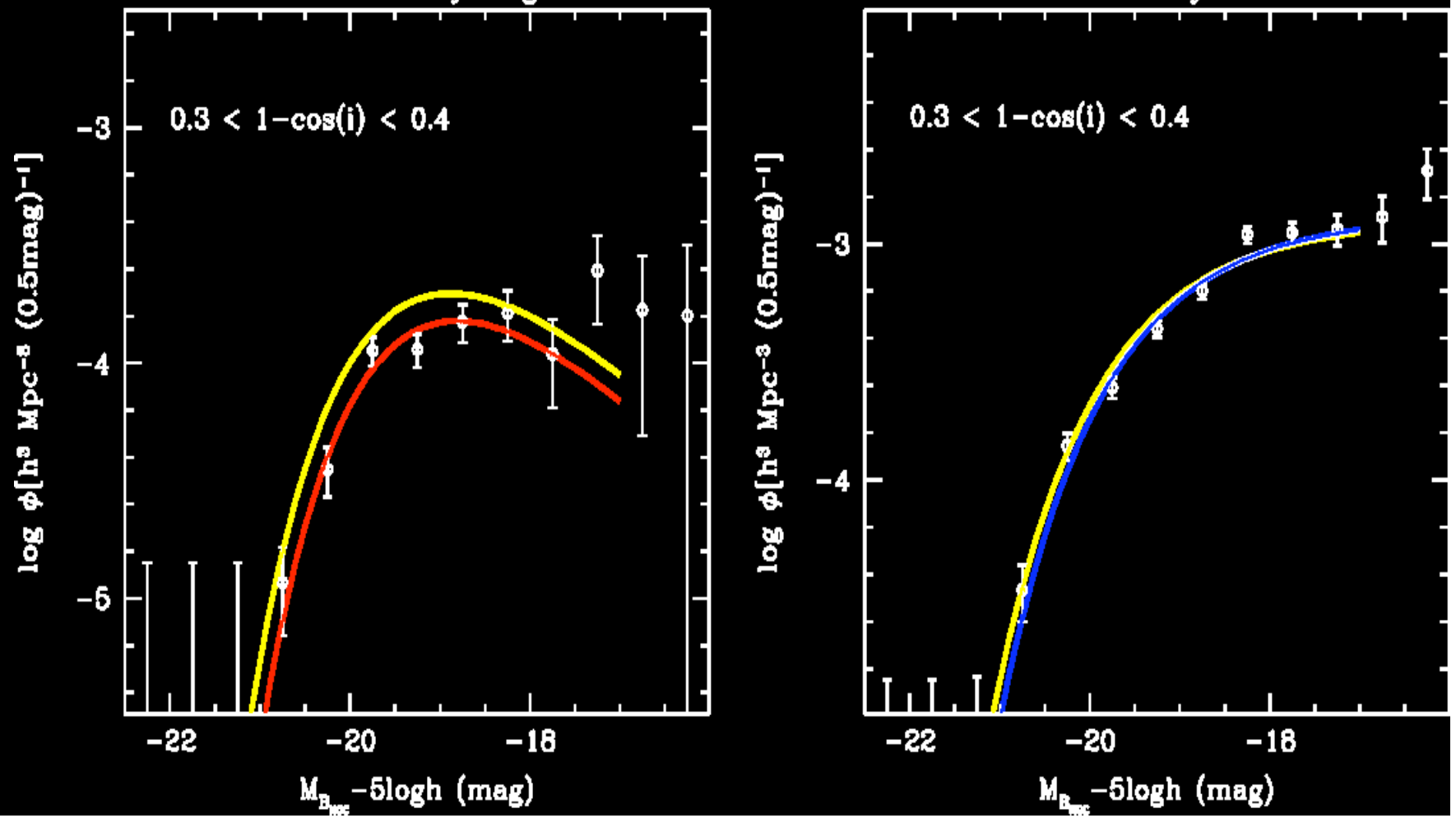
Component LFs v cos(*i*)

Bulges 0.2 < 1-cos(*i*) < 0.3 Discs



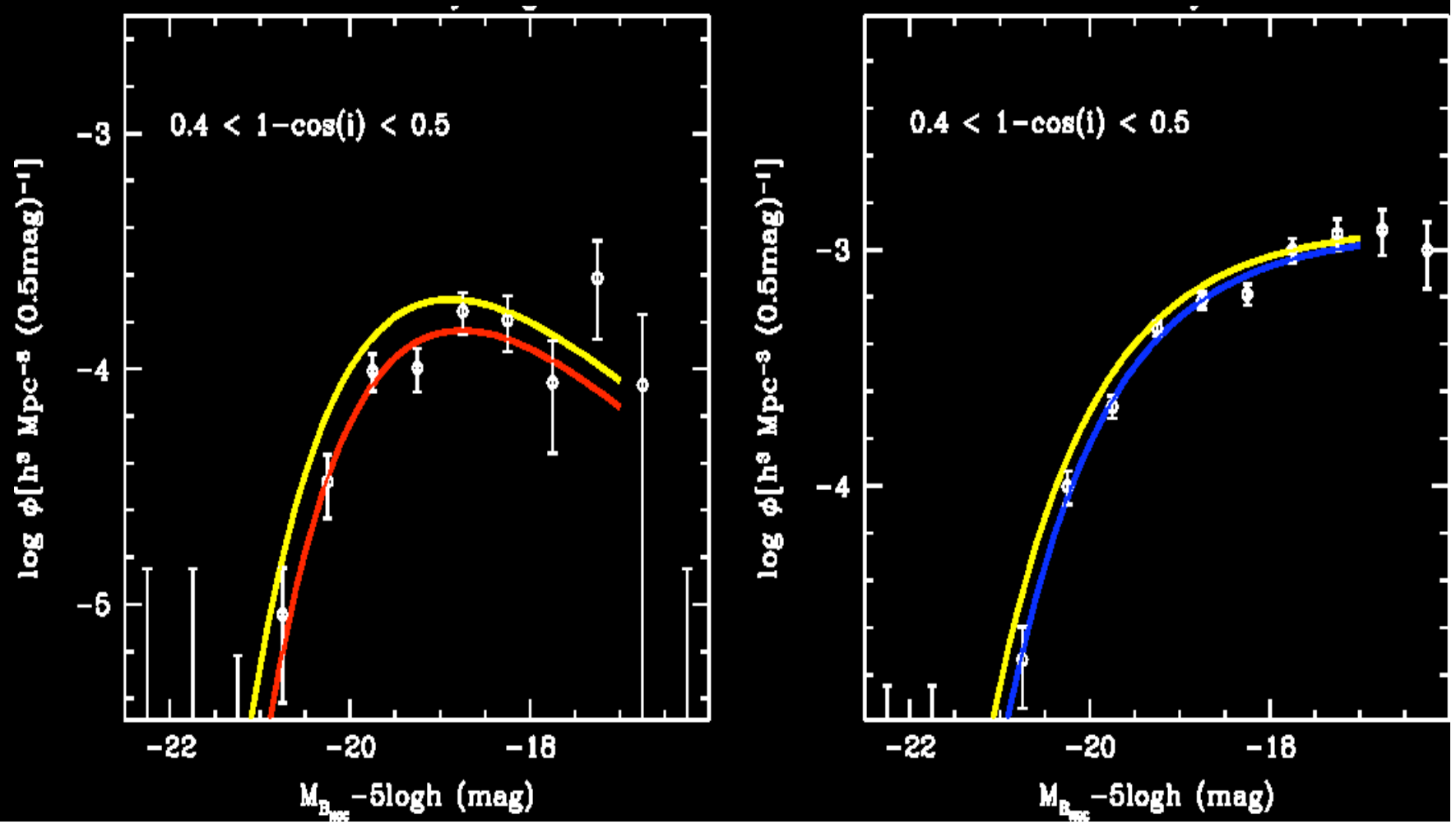
Component LFs v cos(*i*)

Bulges 0.3 < 1-cos(*i*) < 0.4 Discs



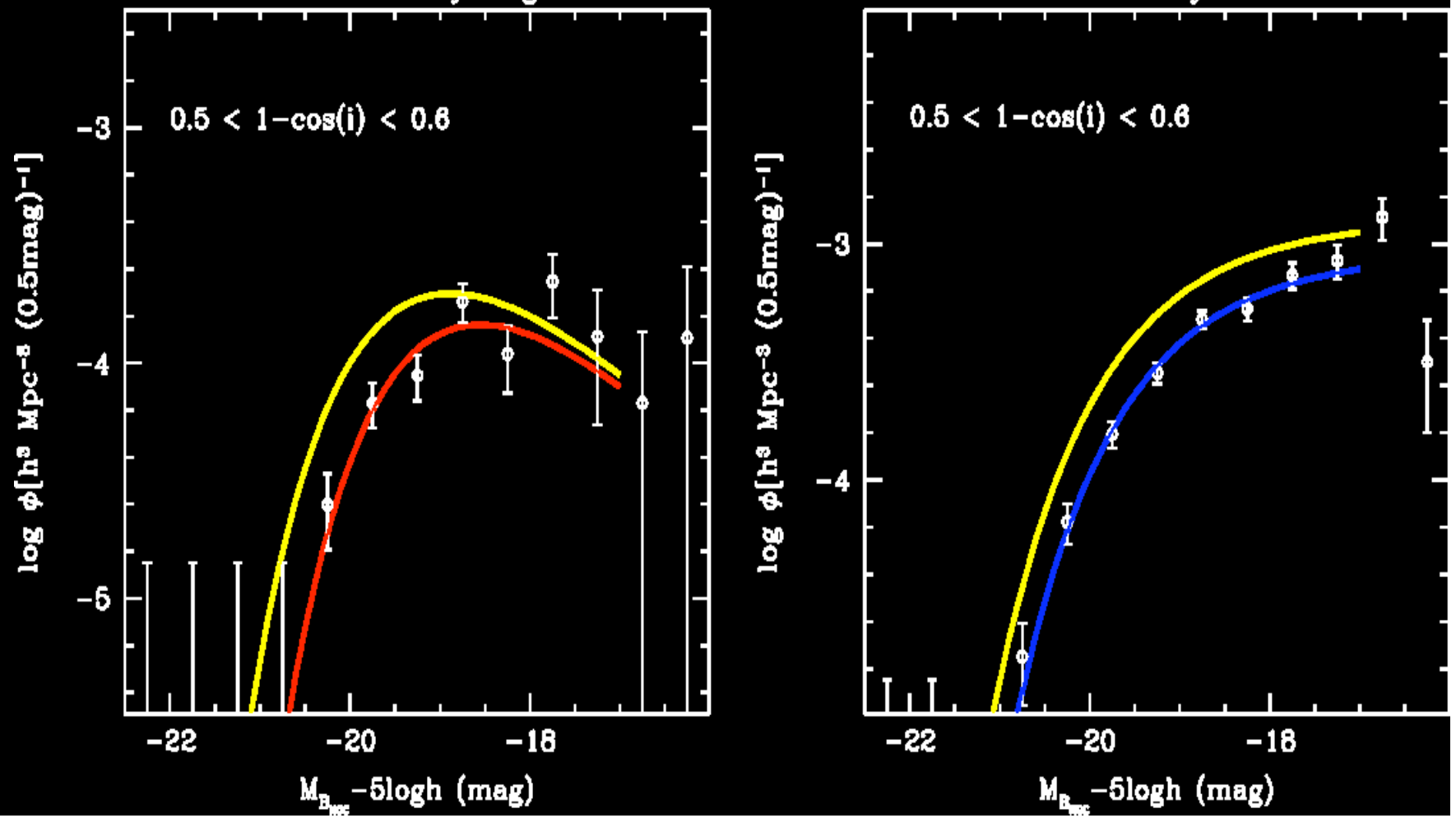
Component LFs v cos(*i*)

Bulges 0.4 < 1-cos(*i*) < 0.5 Discs



Component LFs v cos(*i*)

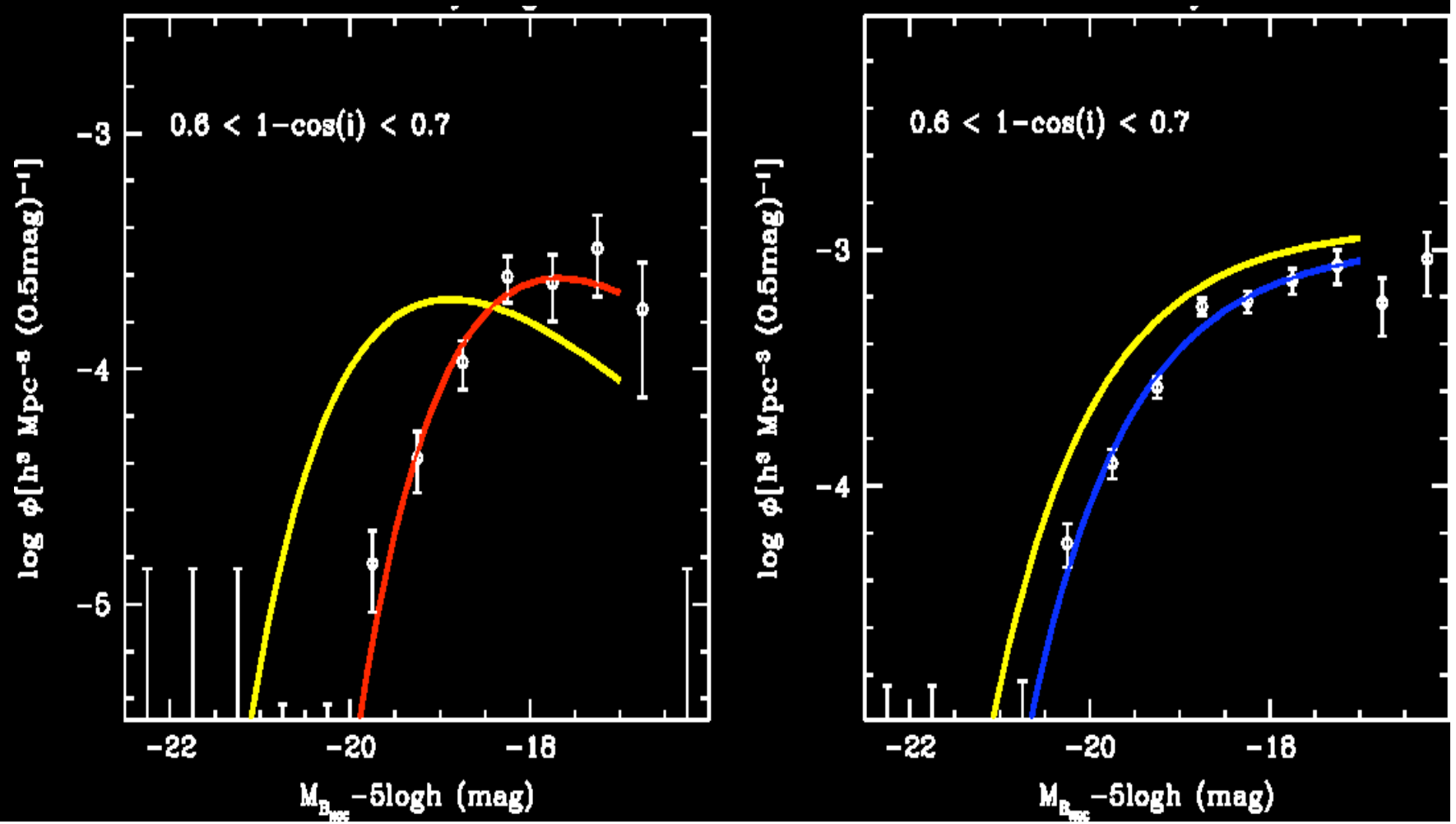
Bulges 0.5 < 1-cos(*i*) < 0.6 Discs



MGC
Millennium Galaxy Catalogue

Component LFs v cos(*i*)

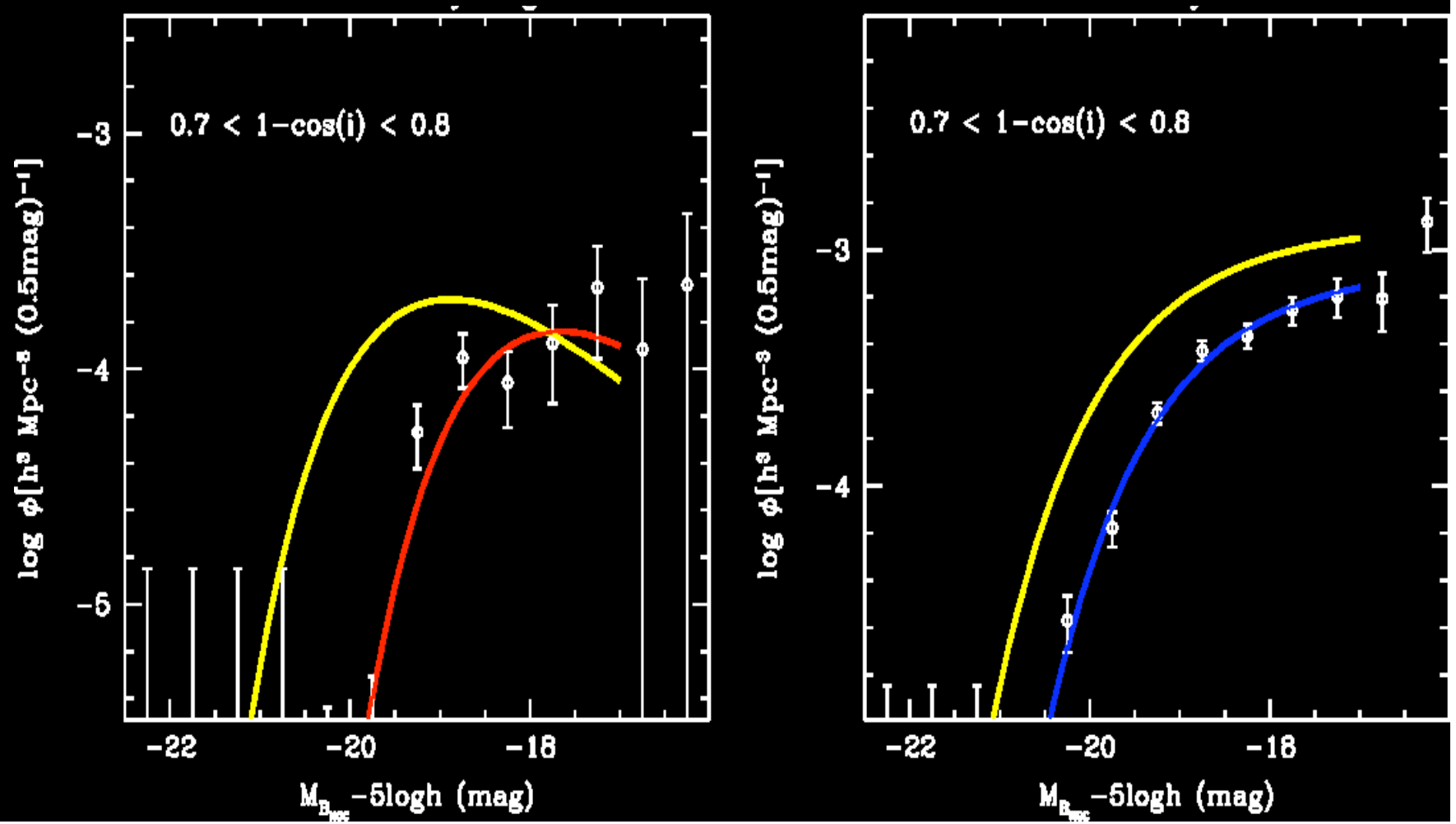
Bulges 0.6 < 1-cos(*i*) < 0.6 Discs



MGC
Millennium Galaxy Catalogue

Component LFs v cos(*i*)

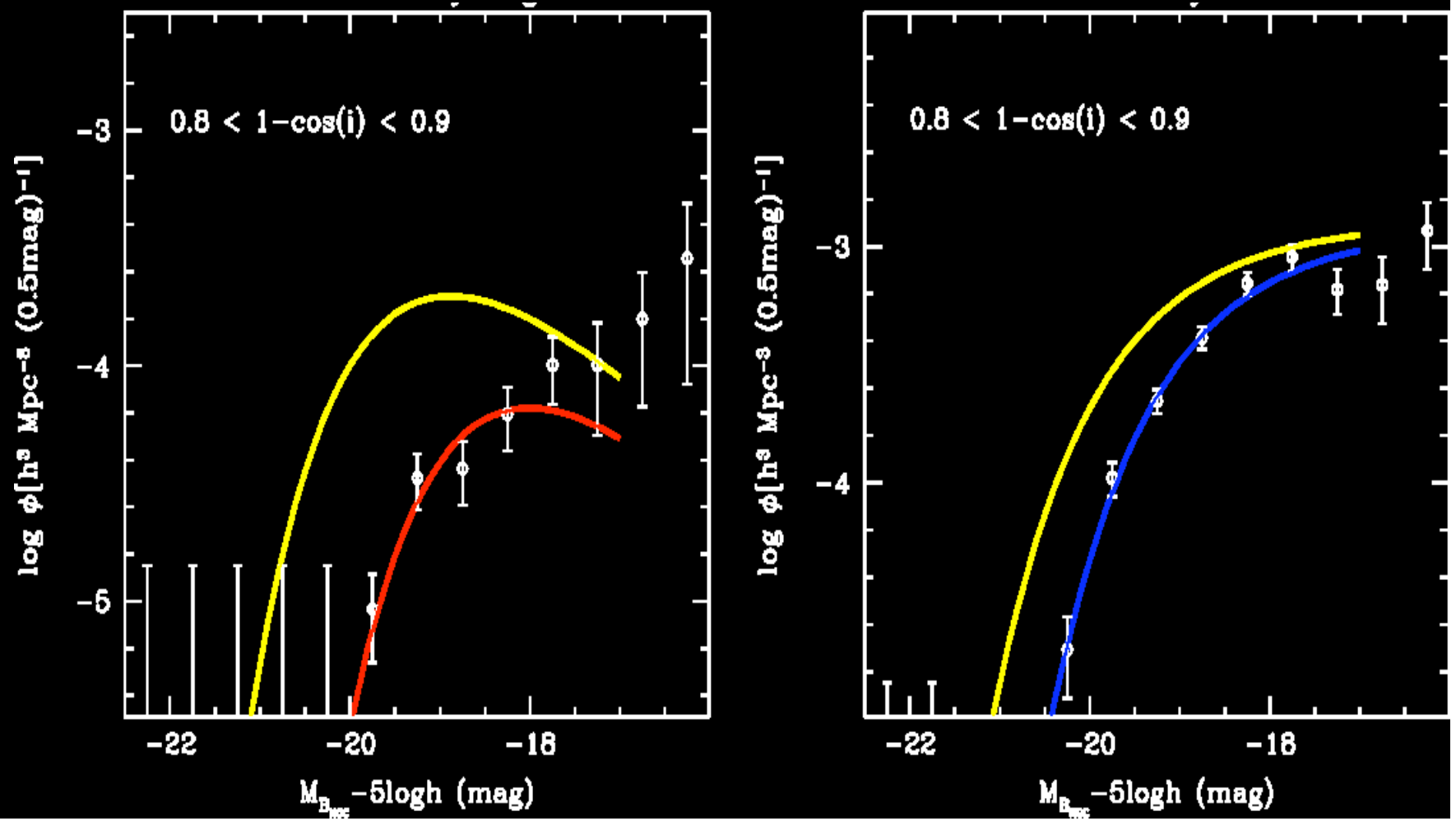
Bulges 0.7 < 1-cos(*i*) < 0.8 Discs



MGC
Millennium Galaxy Catalogue

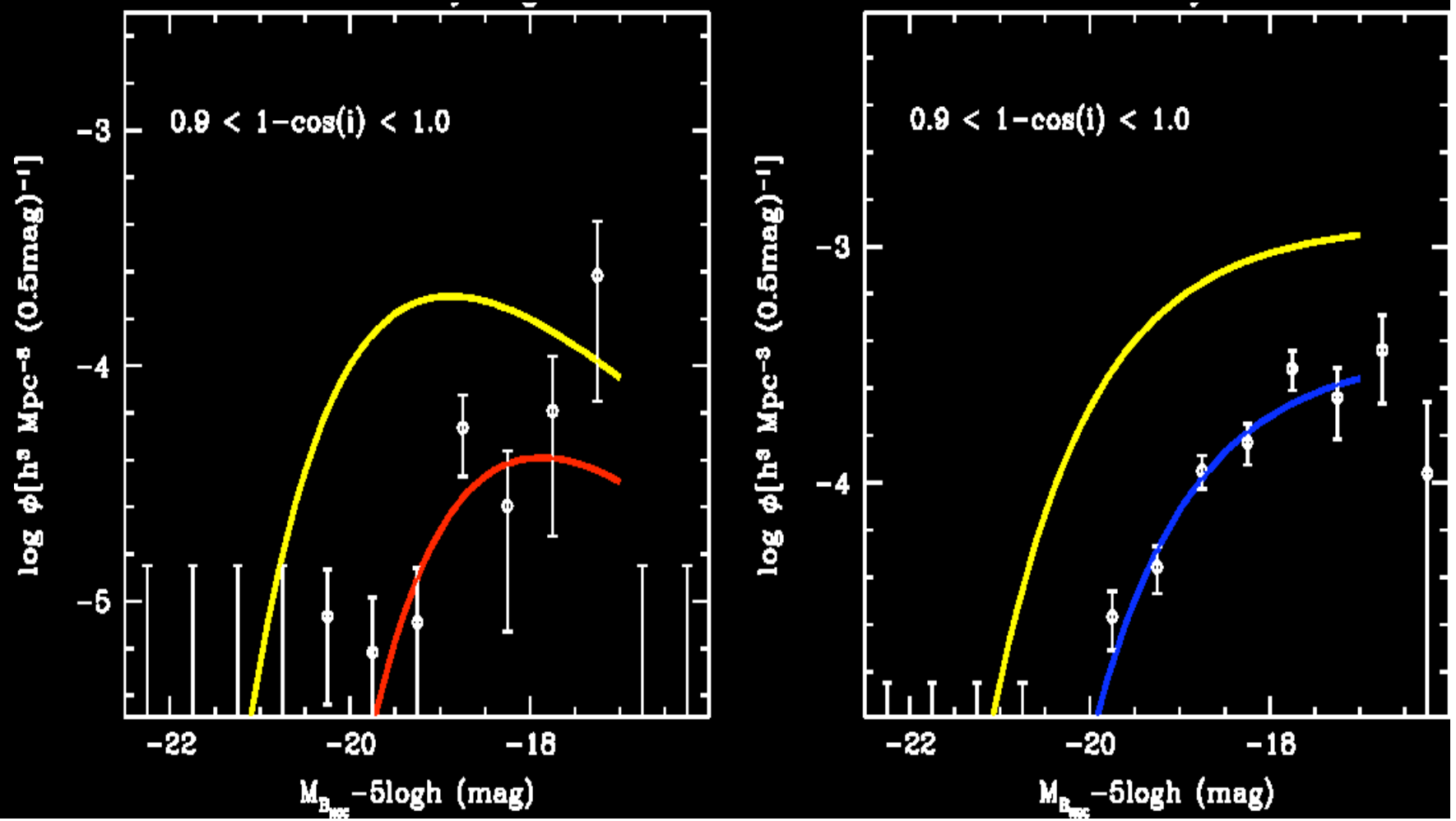
Component LFs v cos(*i*)

Bulges 0.8 < 1-cos(*i*) < 0.9 Discs



Component LFs v cos(*i*)

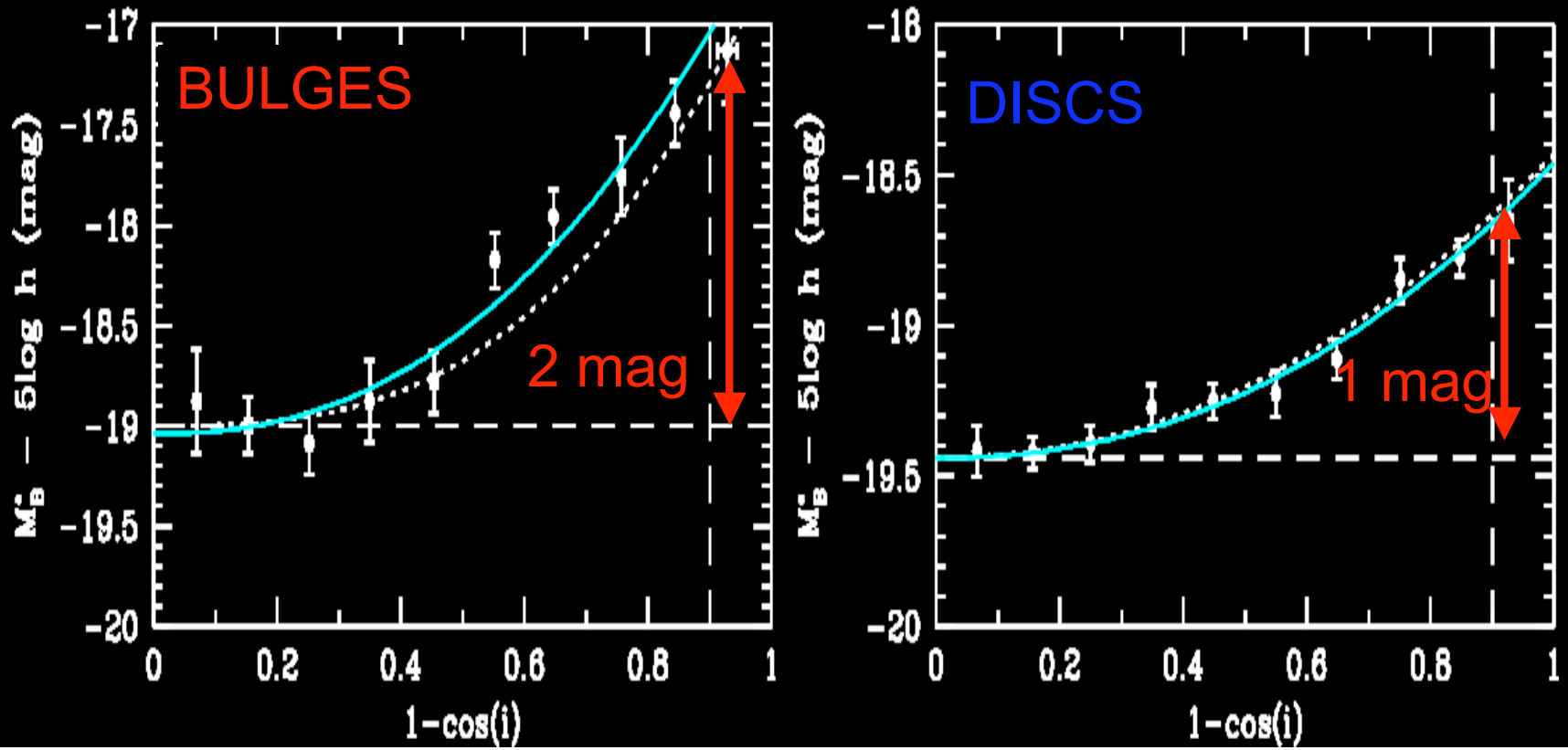
Bulges 0.9 < 1-cos(*i*) < 1.0 Discs



Empirical dust attenuation

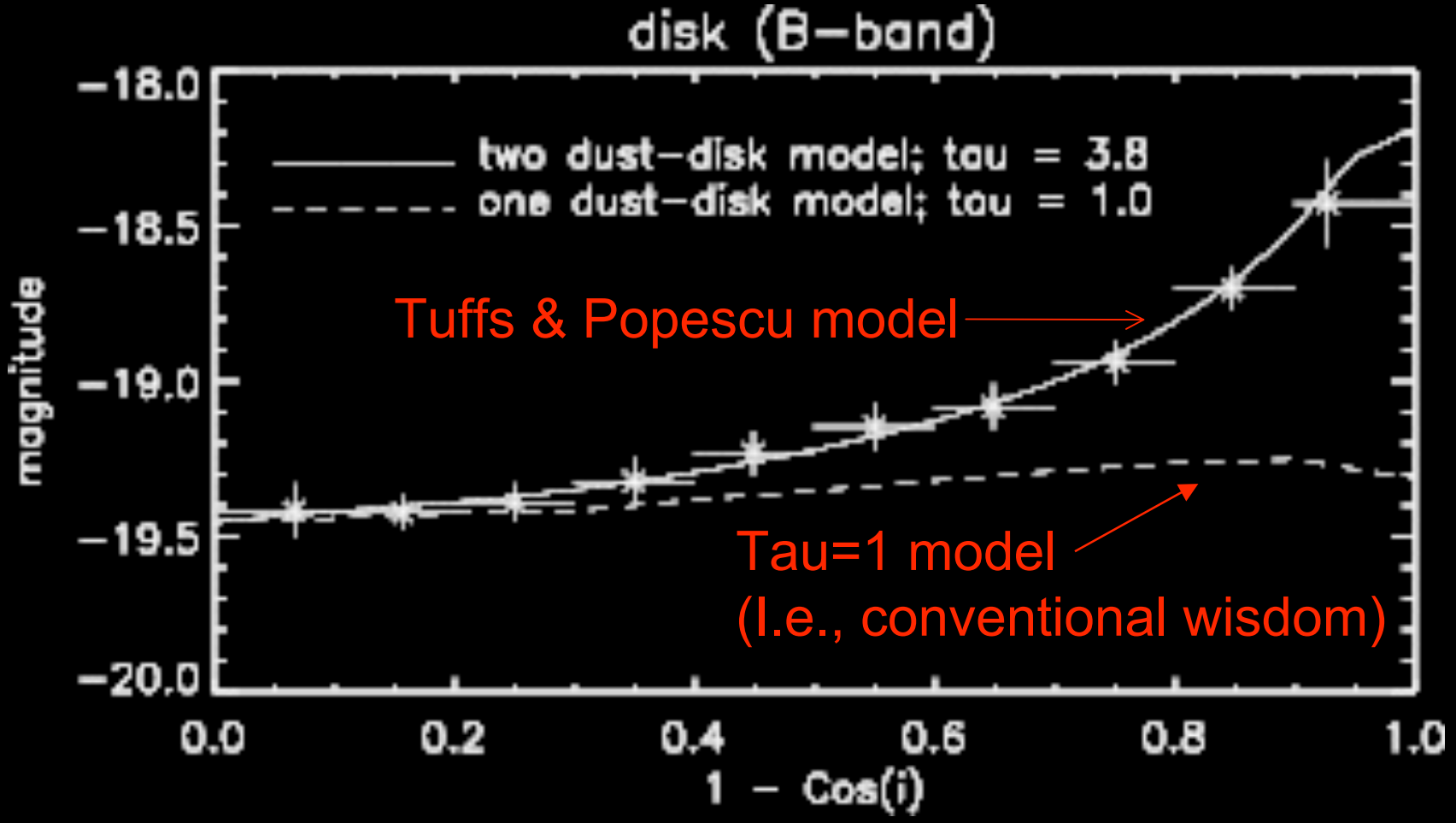
BULGES SEVERELY ATTENUATED IN INCLINED SYSTEMS UP TO 2 MAG EX. FACE-ON CORRECTION !

DRIVER ET AL (2007), MNRAS,(ASTRO-PH/0704.2140)

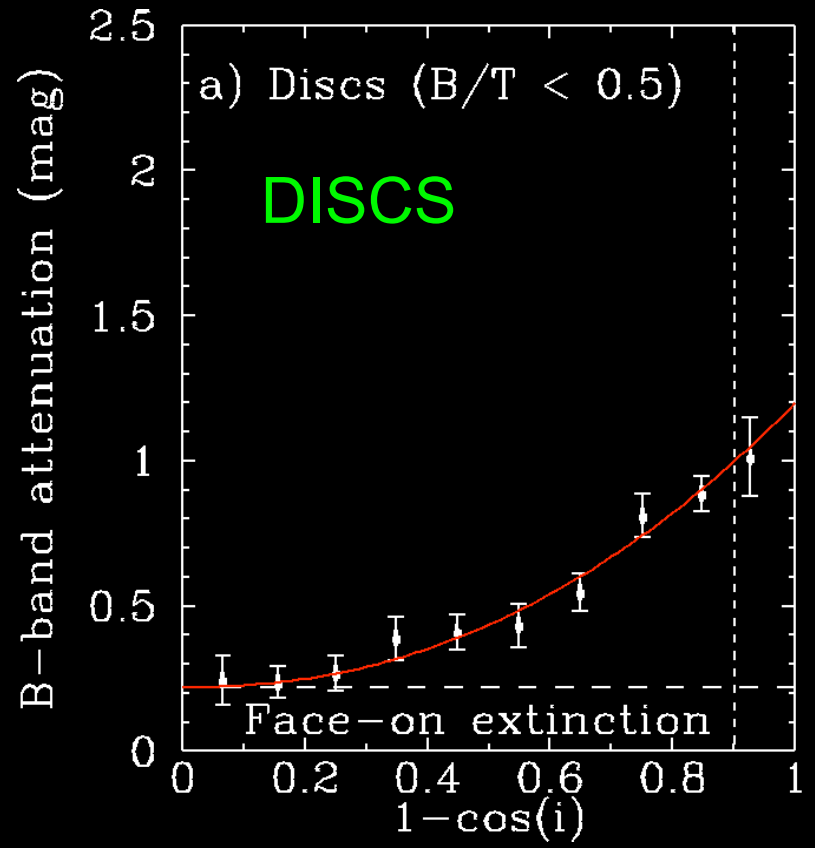


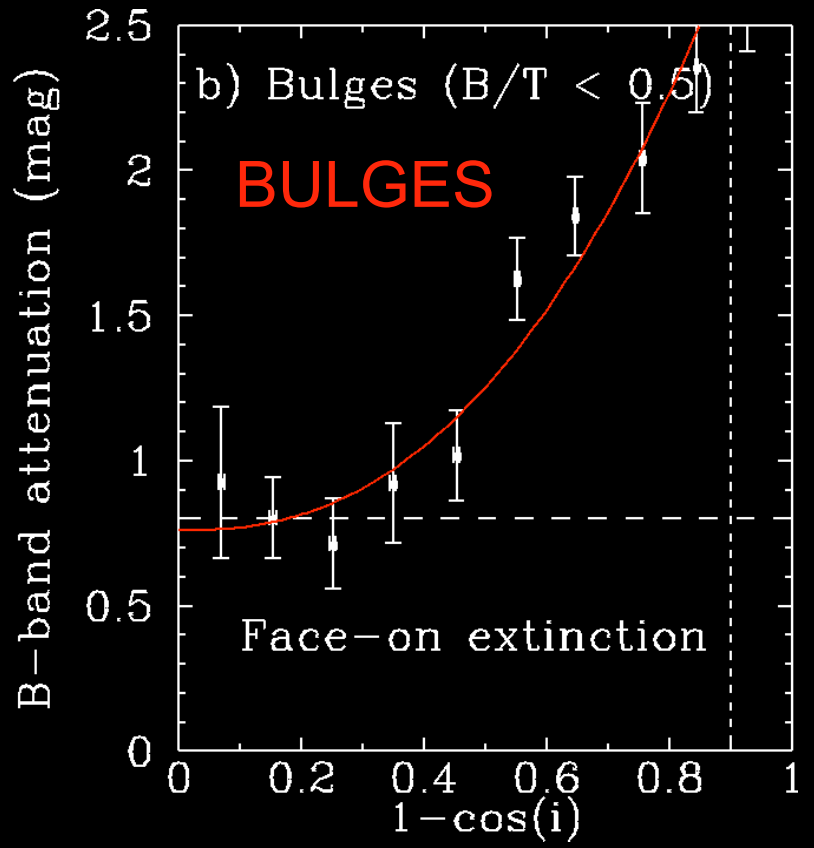
Multiple component dust model required

Dust model previously calibrated to multi-λ NGC891
Leaving one free parameter (the face on central opacity)



Total dust attenuations !!

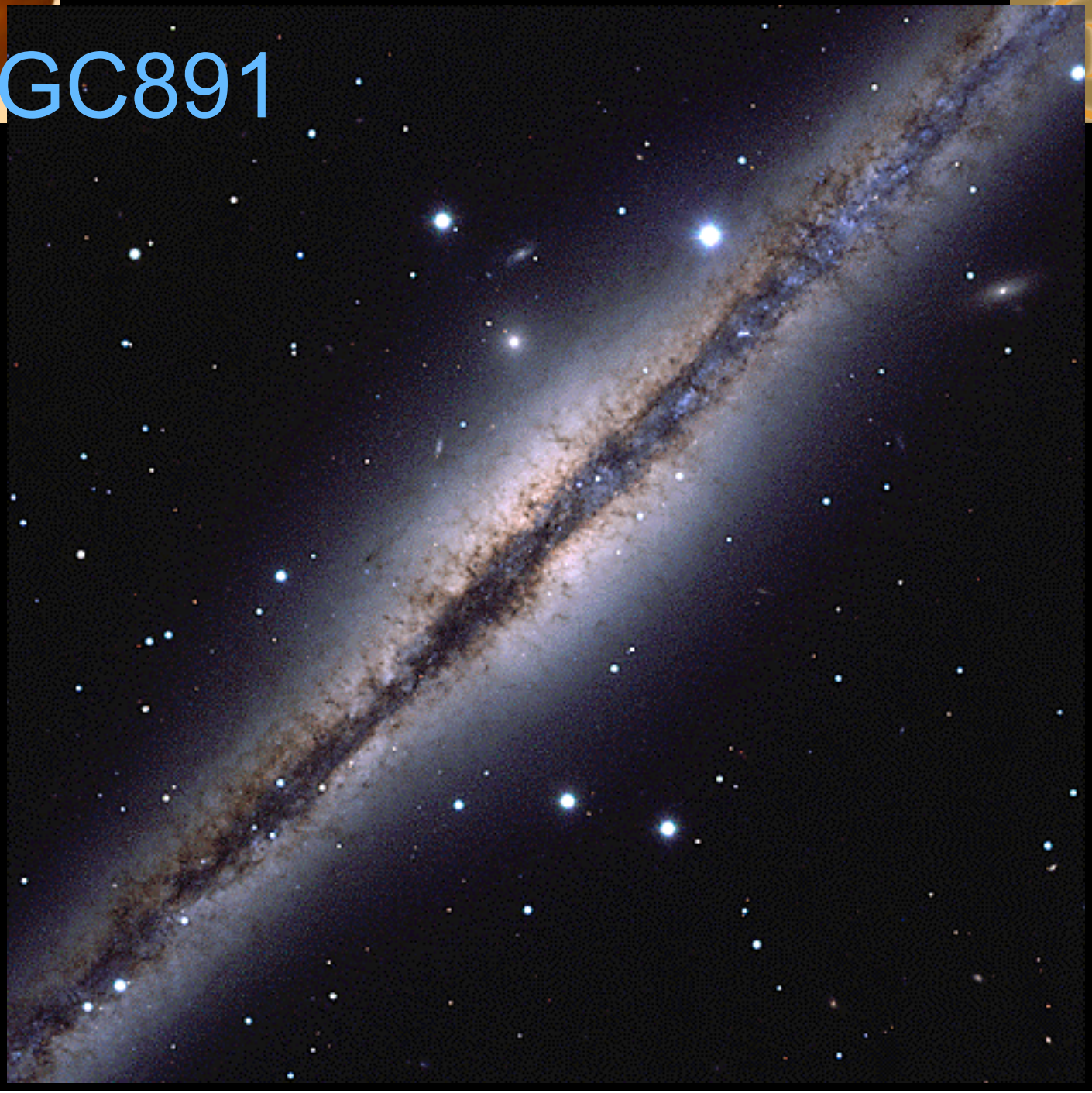




Tuffs & Popescu 3 component dust model implies that discs are on average optically thick in the centres (τ=3.8) and predicts bulge trend.

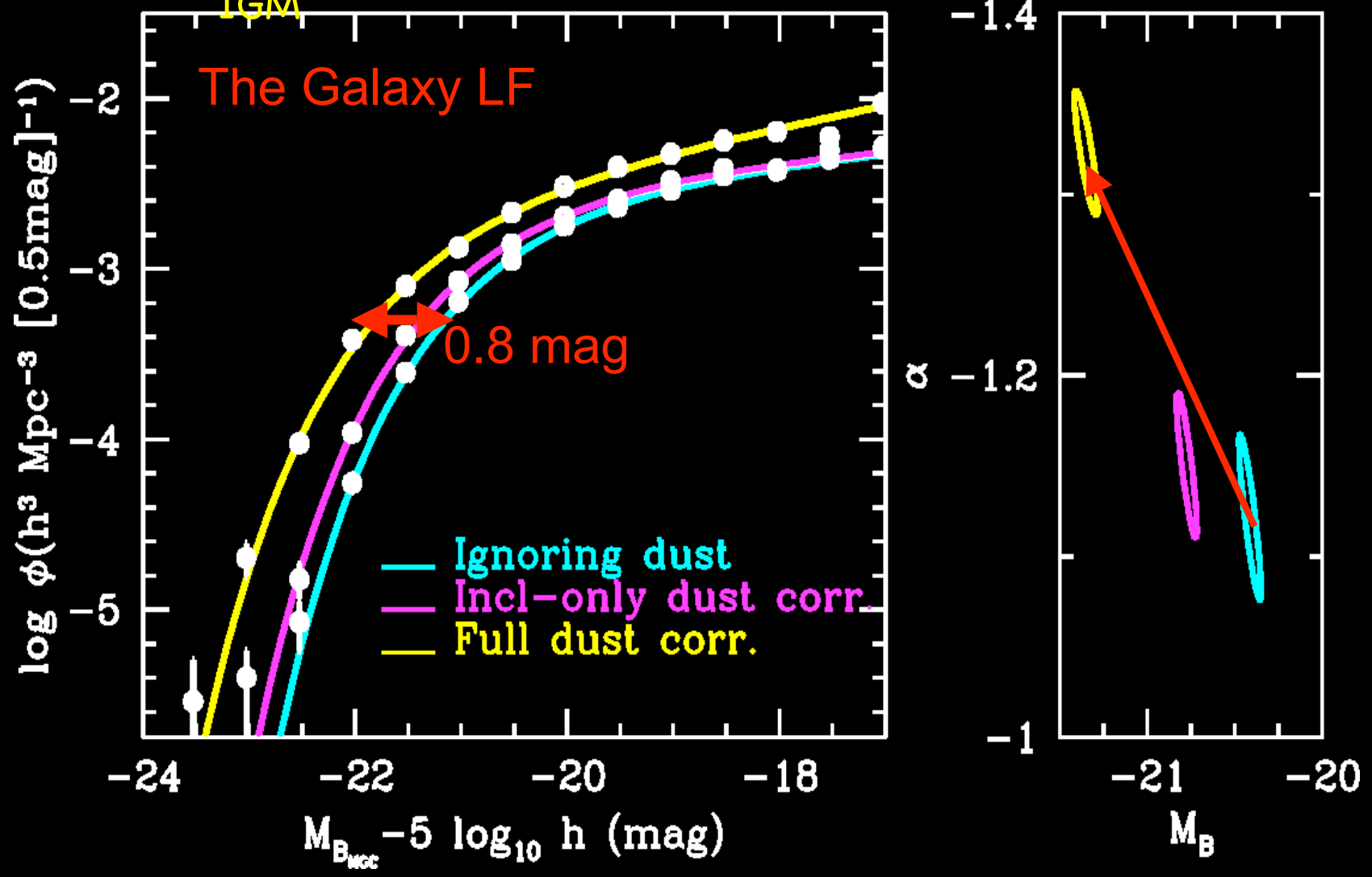
MGC
Millennium Galaxy Catalogue

NGC891

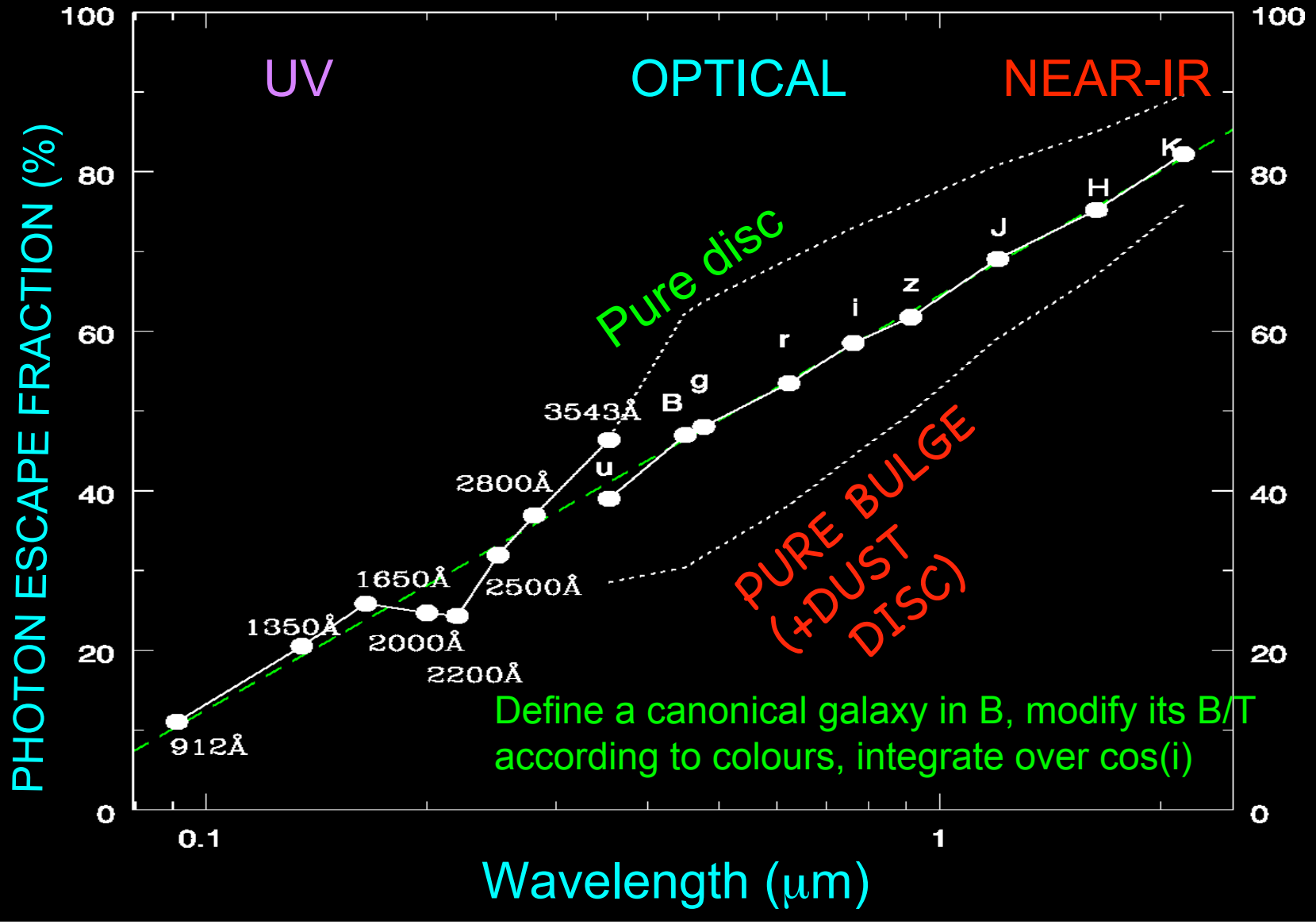


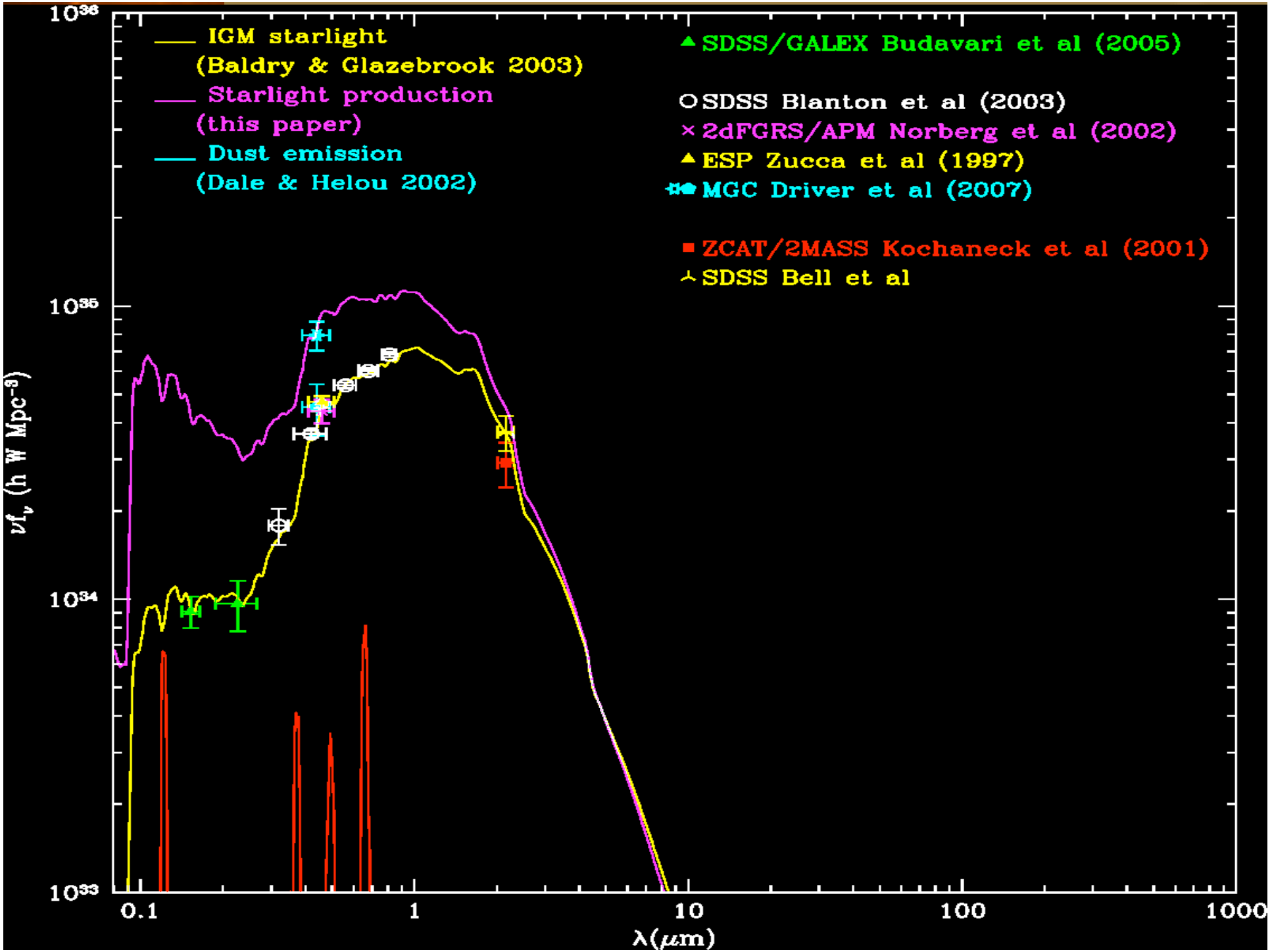
Impact on global B band LF

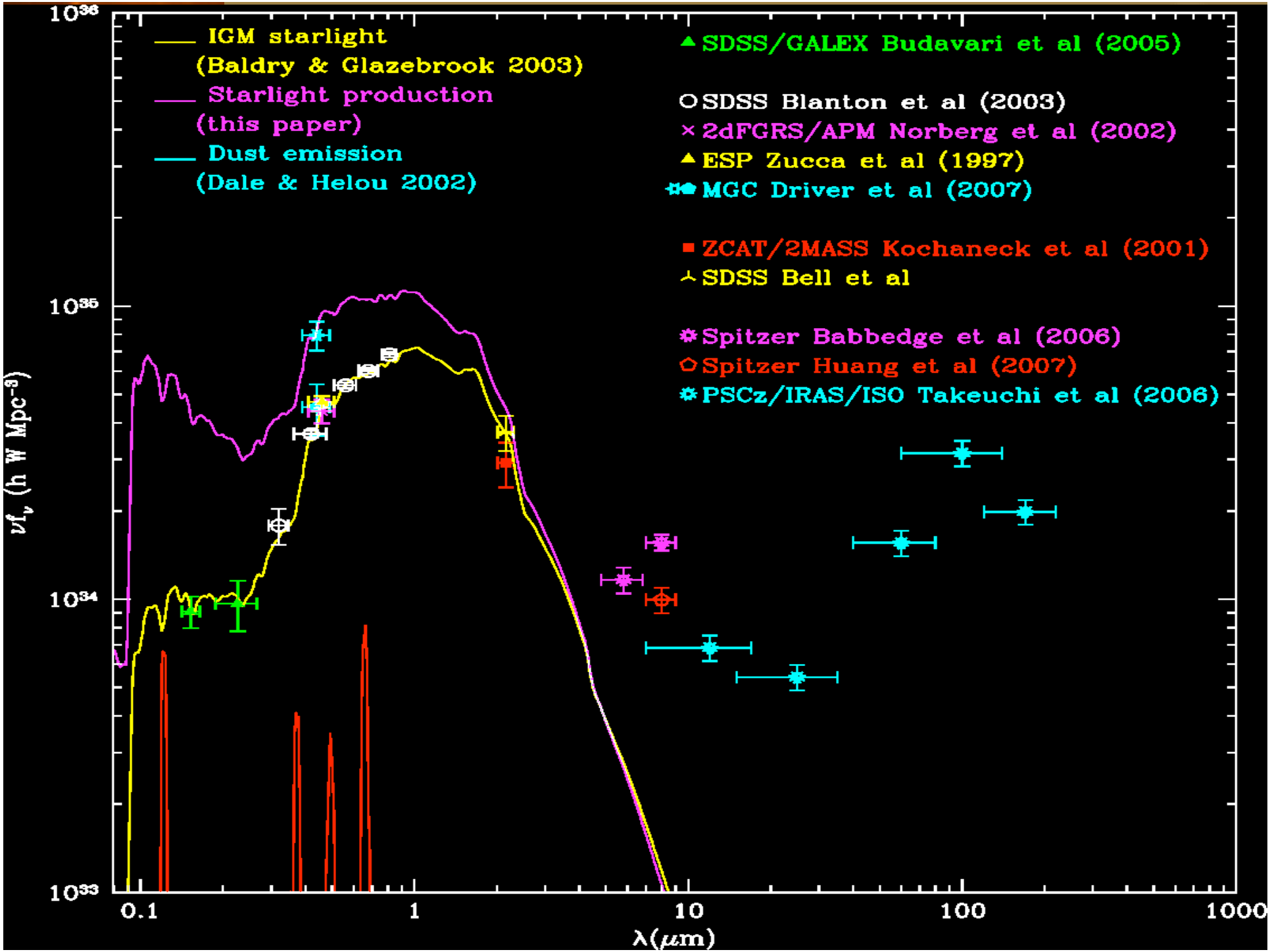
I.E., ONLY 48% OF B-BAND PHOTONS ESCAPE INTO THE IGM



Photon escape fraction averaged over entire nearby galaxy population




IGM starlight
(Baldry & Glazebrook 2003)
Starlight production
(this paper)
Dust emission
(Dale & Helou 2002)
SDSS/GALEX Budavari et al (2005)
SDSS Blanton et al (2003)
2dFGRS/APM Norberg et al (2002)
ESP Zucca et al (1997)
MGC Driver et al (2007)
ZCAT/2MASS Kochaneck et al (2001)
SDSS Bell et al
10^{36}
10^{35}
10^{34}
10^{33}
νI_ν (h W Mpc^{-3})
0.1
1
10
100
1000
$\lambda(\mu m)$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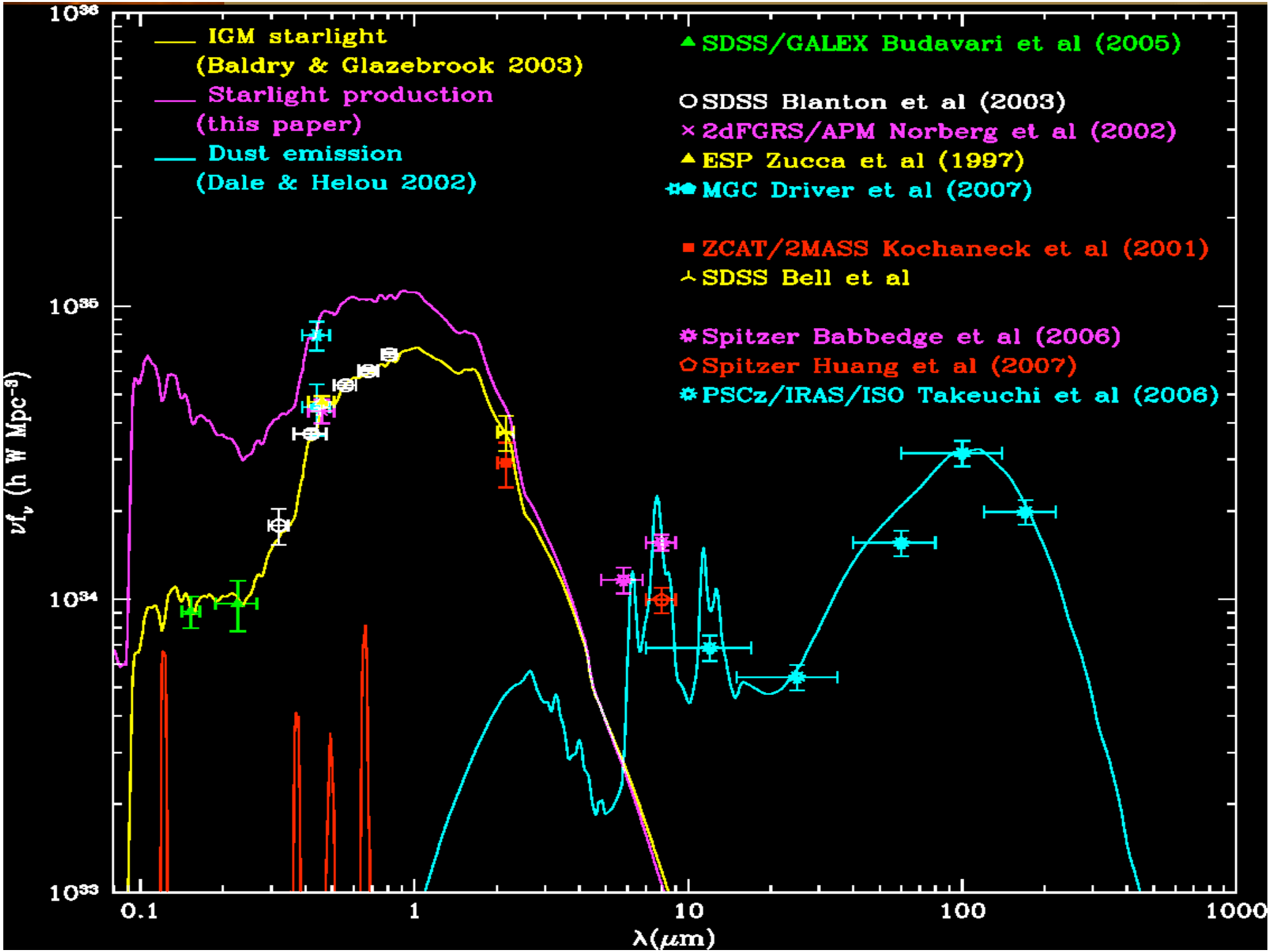
ZCAT/2MASS Kochaneck et al (2001)
SDSS Bell et al
Spitzer Babbedge et al (2006)
Spitzer Huang et al (2007)
PSCz/IRAS/ISO Takeuchi et al (2006)
10^{36}
10^{35}
10^{34}
10^{33}
νl_ν (h W Mpc^{-3})
0.1
1
10
100
1000
$\lambda(\mu m)$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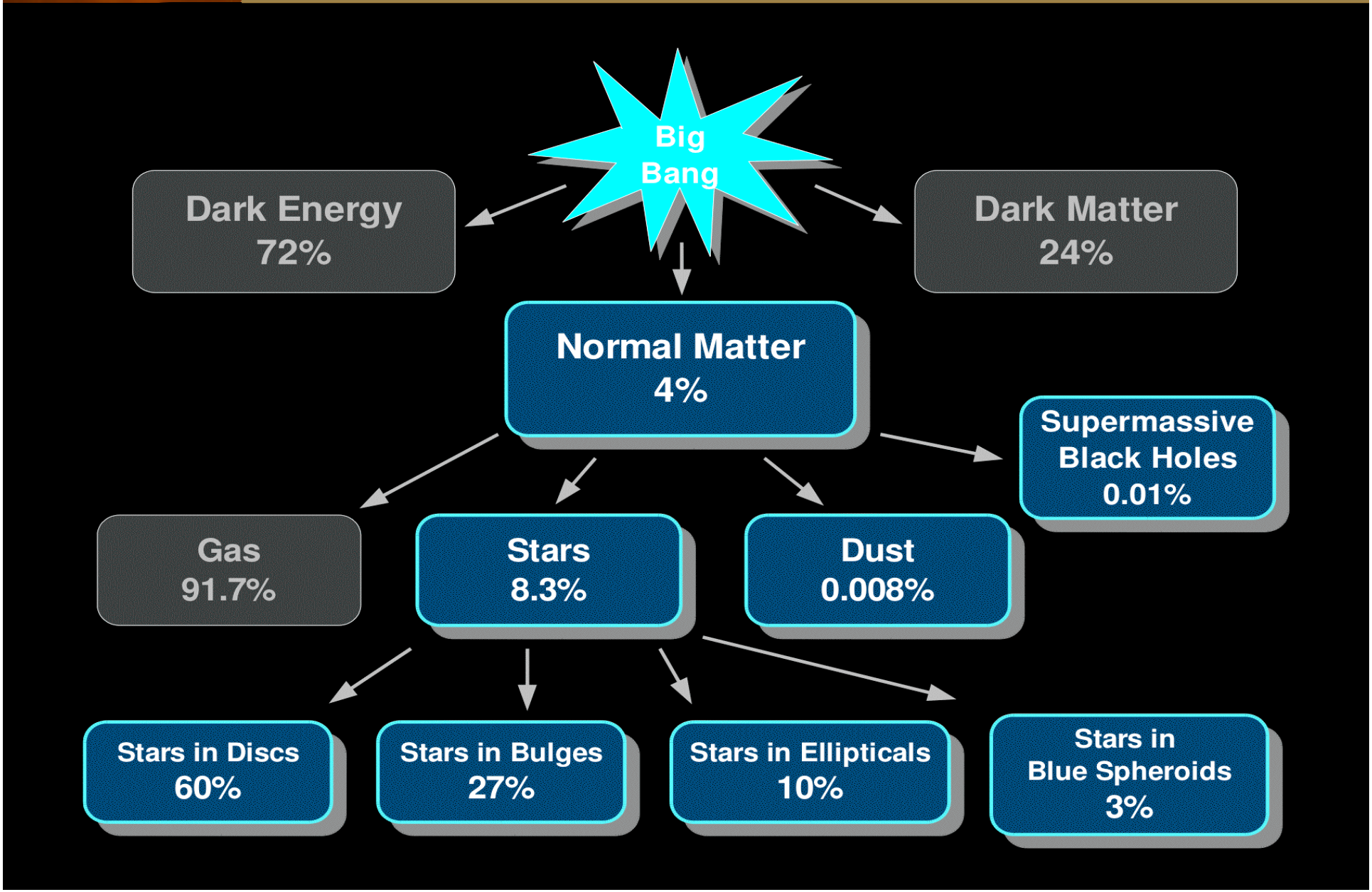
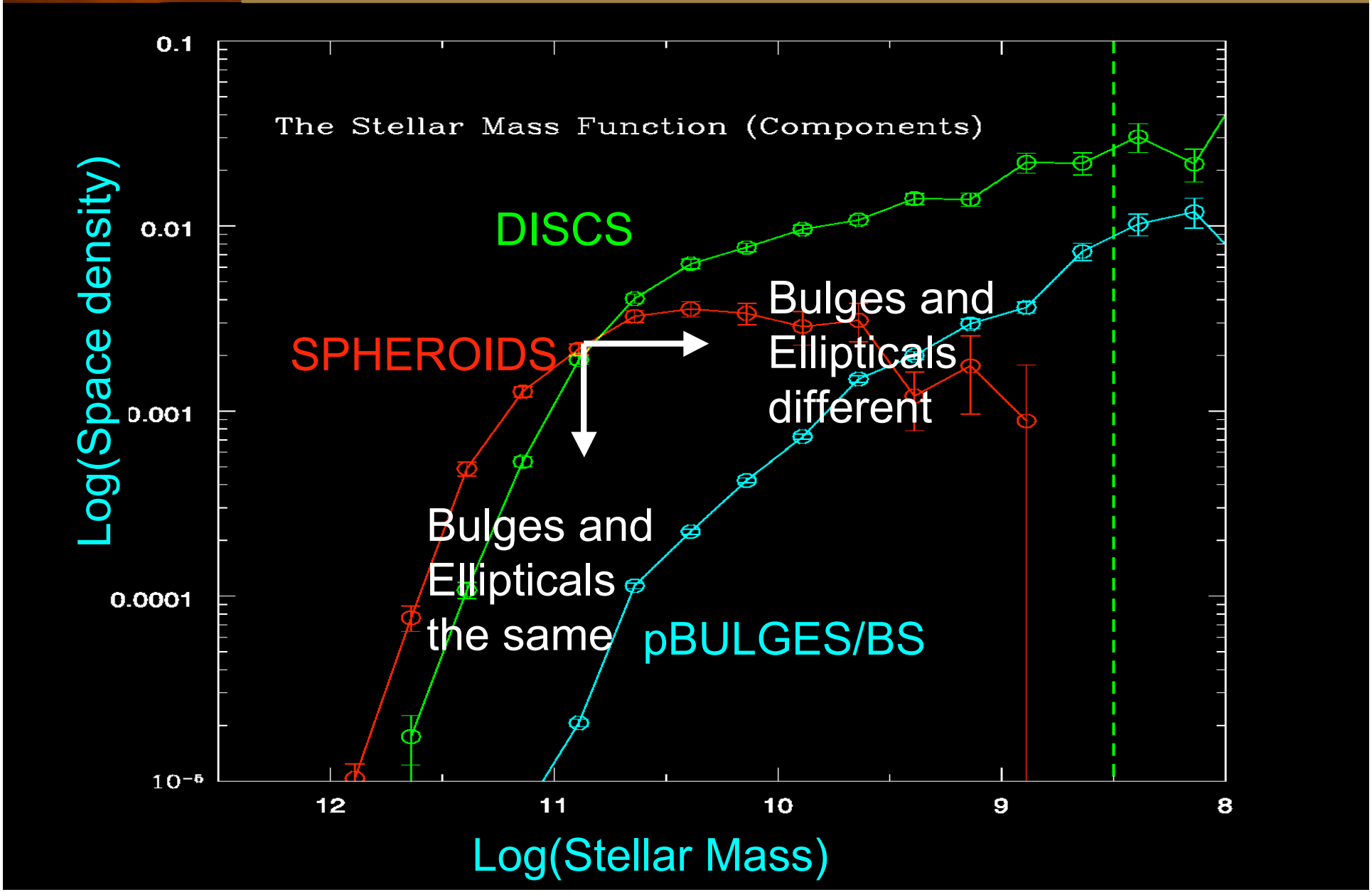
MGC Driver et al (2007)
ZCAT/2MASS Kochaneck et al (2001)
SDSS Bell et al
Spitzer Babbedge et al (2006)
Spitzer Huang et al (2007)
PSCz/IRAS/ISO Takeuchi et al (2006)
10^{36}
10^{35}
10^{34}
10^{33}
νl_ν (h W Mpc^{-3})
0.1
1
10
100
1000
$\lambda(\mu m)$

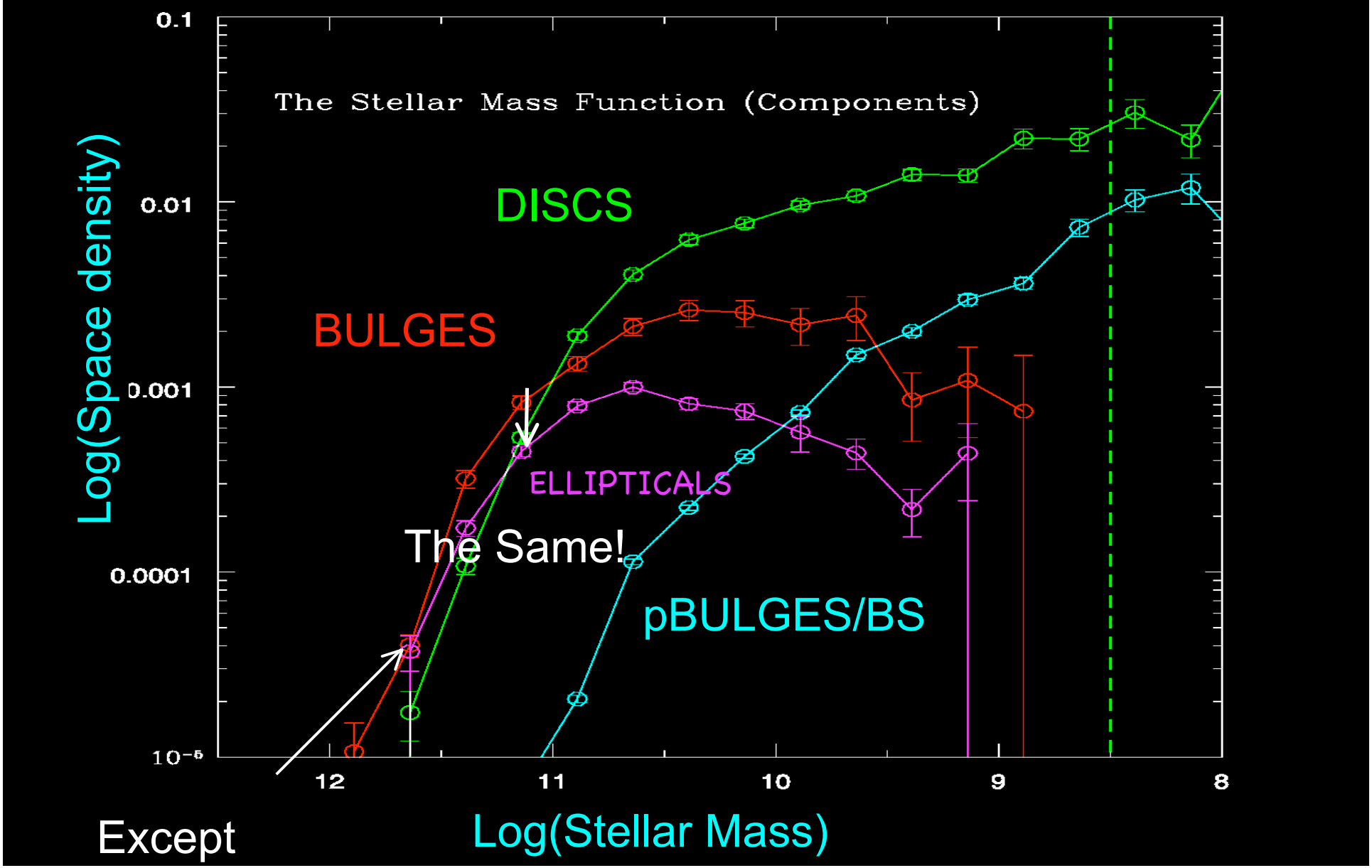
The baryon budget: stars, dust & SMBHs



Component Stellar Mass Functions



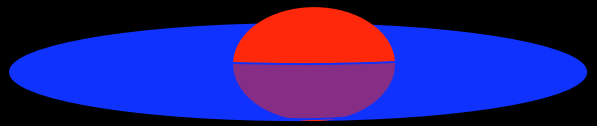
Component Stellar Mass Functions



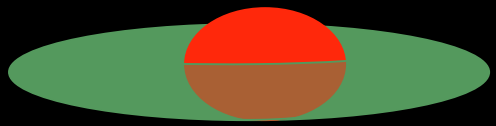
Hubble type transformation ?!

1. MID-TYPE SPIRAL FALLING INTO CLUSTER (COS*I*=0.5):
   B=0.2, D=0.8, B/T=0.2, L=1.0, BLUE
   SC (NB: COS(I)=0.0=SA, COS(I)=1=SD)

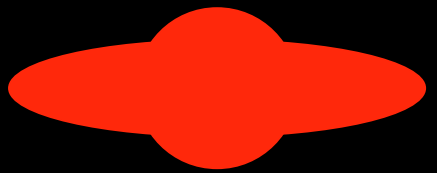
2. *DESTROY DUST* (HEATING):
   B=0.6, D=1.2, B/T=0.3, L=1.8 GREEN
   SAB



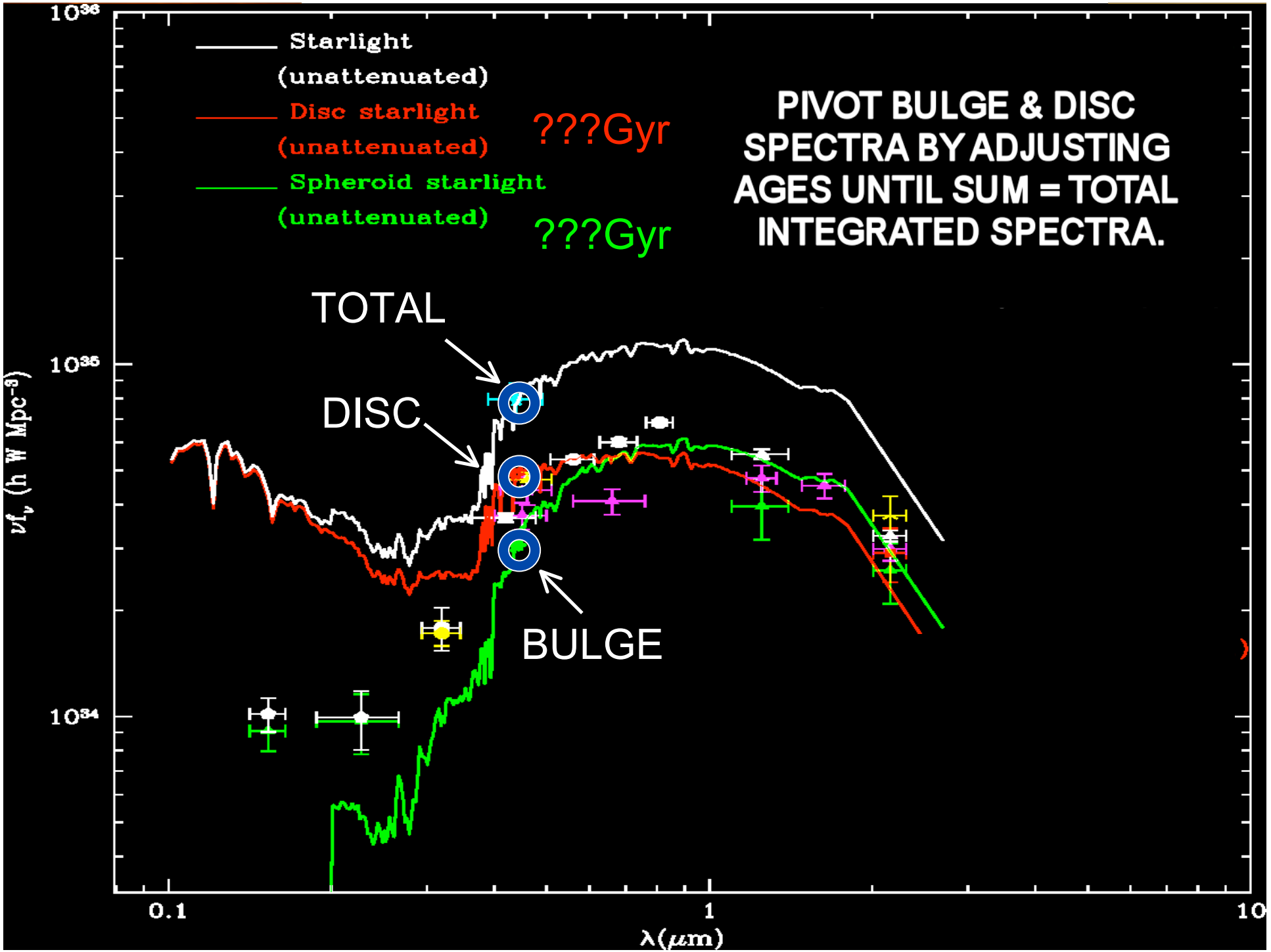
3. TRUNCATE STAR-FORMATION IN DISC (STRIPPING):
   B=0.6, D=0.8, B/T=0.4, L=1.4, RED
   SA/S0

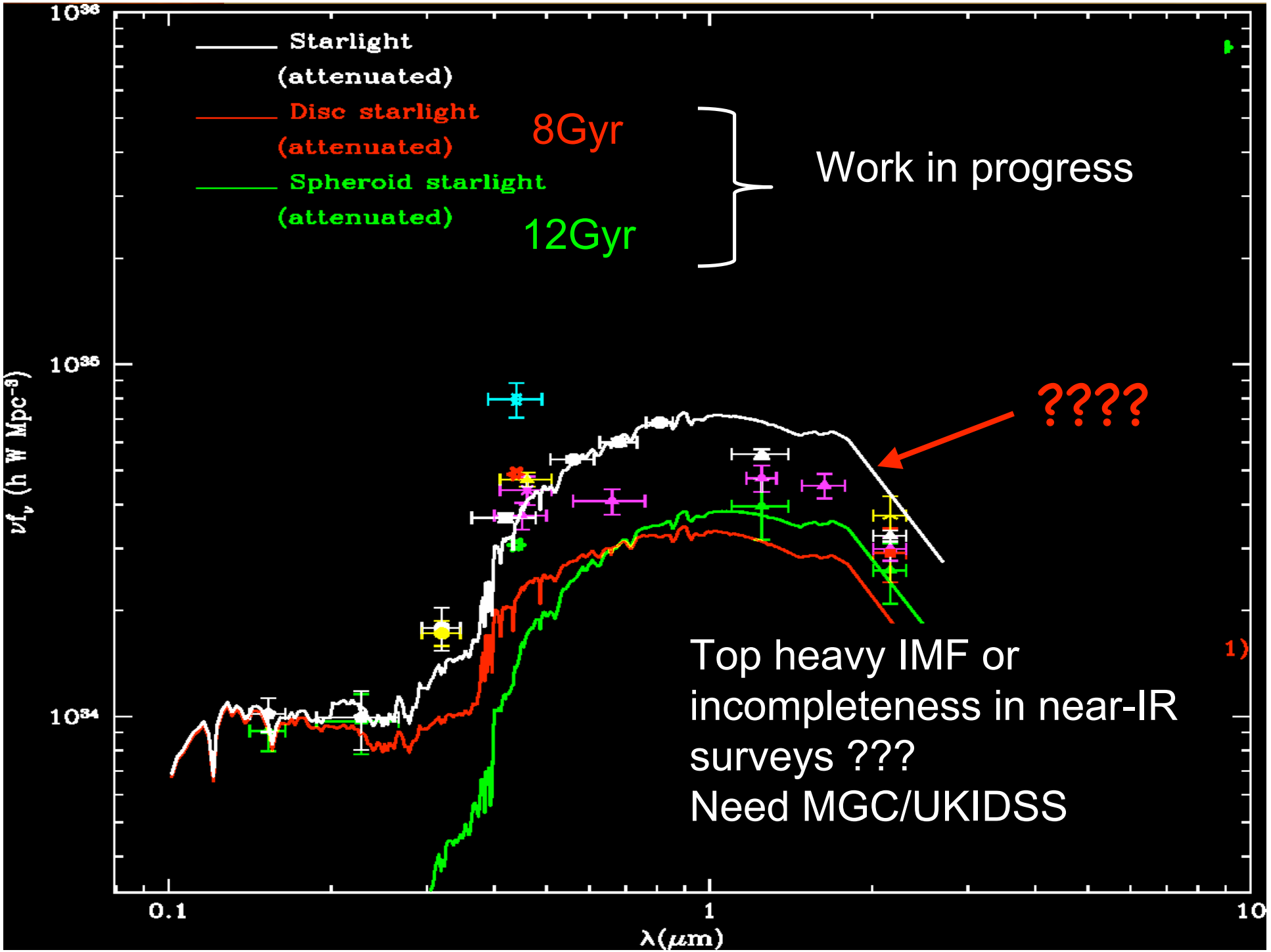


4. FURTHER FADING AND HARASSMENT ETC:
   B=0.6, D=0.6, B/T=0.5, L=1.2, RED
   S0A



5. TRANSFORMATION FROM SC-S0 PURELY BY REMOVING DUST AND SWITCHING OFF SF! IT GETS ***REDDER*** AND ***BRIGHTER*** WITHOUT DRY MERGERS!


Starlight
(unattenuated)
Disc starlight
(unattenuated)
Spheroid starlight
(unattenuated)
???Gyr
???Gyr
PIVOT BULGE & DISC SPECTRA BY ADJUSTING AGES UNTIL SUM = TOTAL INTEGRATED SPECTRA.
TOTAL
DISC
BULGE
10^{36}
10^{35}
10^{34}
νL_ν (h W Mpc^{-3})
0.1
1
10
λ(μm)


Starlight
(attenuated)
Disc starlight
(attenuated)
Spheroid starlight
(attenuated)
8Gyr
12Gyr
Work in progress
????
Top heavy IMF or
incompleteness in near-IR
surveys ???
Need MGC/UKIDSS
10^{36}
10^{35}
10^{34}
νl_ν (h W Mpc^{-3})
0.1
1
10
$\lambda(\mu m)$

Summary

- BIMODALITY DUE TO TWO COMPONENT NATURE OF GALAXIES (D06)
  - STRUCTURE MORE FUNDAMENTAL THAN COLOUR: STRUCTURE=TRACER OF FORMATION
    - FAST/HOT MODE (COLLAPSE/RAPID MERGER) > SPHEROIDS/AGN/SMBHS/HIGH-[α/FE], Z > 2
    - SLOW/COLD MODE (ACCRETION[LUMPY]) > DISCS BUILT SLOWLY IN FIELD Z < 2-3
- STELLAR MASS IN EACH COMPONENT: (D07 APJL)
  - DISCS = 60% INFALL MODE (HALF EXPONENTIAL, HALF TRUNCATED?, TRUNC'D BLUER)
  - SPHEROIDS = 37% COLLAPSE/MERGER MODE (ELLIPTICALS 10%, BULGES 27%)
  - PBULGES < 2% SECULAR MODE (ALSO SEE BLUE SPHEROIDS AT SIMILAR LEVEL)
- MEAN DISC DUST OPACITY HIGH, BULGES OBSCURED BY 0.8-2.5 MAGS ! (D07)
  - HTF AN ENVIRONMENTAL EFFECT OF IGM & ICM ?
    - IGM ALLOWS DISC CONSTRUCTION VIA INFALL, DUST PRODUCTION OBSCURES BULGES
    - ICM SHUTS DOWN SF AND DESTROYS DUST DIMINISHING DISC AND UNVEILING BULGE
  - REMOVING DUST MAKES A GALAXY REDDER AND BRIGHTER (DRY MERGERS NOT NEEDED ?)
- COSMIC ENERGY BUDGET: LOST STARLIGHT=FAR-IR DUST EMISSION (D08)

MGC
Millennium Galaxy Catalogue

A blueprint for massive galaxy formation ?

8+ GYRS — DM ASSEMBLY VIA RAPID MERGING

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Galaxy And Matter Assembly

- COMPREHENSIVE
  - 250 SQ DEGREES (5X50 SQ DEG. CHUNKS), 250K GALAXIES (25X MGC)
- GENERAL SCIENCE:
  - A STUDY OF STRUCTURE ON 1KPC-1MPC SCALES, WHERE BARYON PHYSICS CRUCIAL
- SPECIFIC GOALS:
  - THE CDM HALO MASS FUNCTION FROM GROUP VELOCITY DISPERSIONS
  - THE STELLAR MASS FUNCTION INTO THE INTERMEDIATE MASS REGIME
  - BUILDING TOTAL SEDS FOR GALAXIES AND THEIR COMPONENTS AT $Z < 0.5$
- GOING MASSIVELY MULTI-WAVELENGTH:
  - UV (GALEX)
  - OPTICAL: UGRI (VST, SDSS), SPECTRA (AAT)
  - NEAR-IR: ZYJHK (VISTA, UKIRT)
  - FAR-IR (HERSCHEL), SUB-MM SCUBA-II
  - RADIO: 21CM (ASKAP)
- OVERCOME SECONDARY STRUCTURAL ISSUES:
  - NUCLEI-BULGE-BAR-DISC-DISC TRUNCATION DECOMPOSITIONS
- DISENTANGLE ENVIRONMENTAL DEPENDENCIES

GAMA Team (MGC in yellow)

WORKING GROUPS/HEADS

SCIENCE	CATS	DATABASE	OBS	MOCKS	RADIO	SPEC. PIPE.	IMAGE. PIPE.
Peacock (ROE)	Baldry (LJMU)	Liske (ESO)	Driver (PI, St And)	Norberg (ROE)	Hopkins (USyd)	Loveday (Sussex)	Bamford (Nott.)

TEAM MEMBERS

Bridges (AAO)
Bland-Haw'n (U.Syd)
Cameron (St And)
Conselice (Nott.)
Couch (Swin.)
Croom (U.Syd)
Cross (Edin.)
Frenk (Durham)
Graham (Swin)
Hill (StA)
Edmonson (Ports)
Jones (AAO)
Kuijken (Leiden)
Lahav (UCL)
Nichol (Ports.)
Oliver (Sussex)
Parkinson (Edin.)
Phillipps (Bristol)
Popescu (UCLan)
Eales (Cardiff)
Ellis (USyd)
Prescott (LJMU)
Proctor (Swin.)
Sharp (AAO)
Staveley-Smith (UWA)
Sutherland (Camb.)
Tuffs (MPIK)
van Kampen (Innsbruck)
Warren (Imperial)
Dunne (Nottingham)

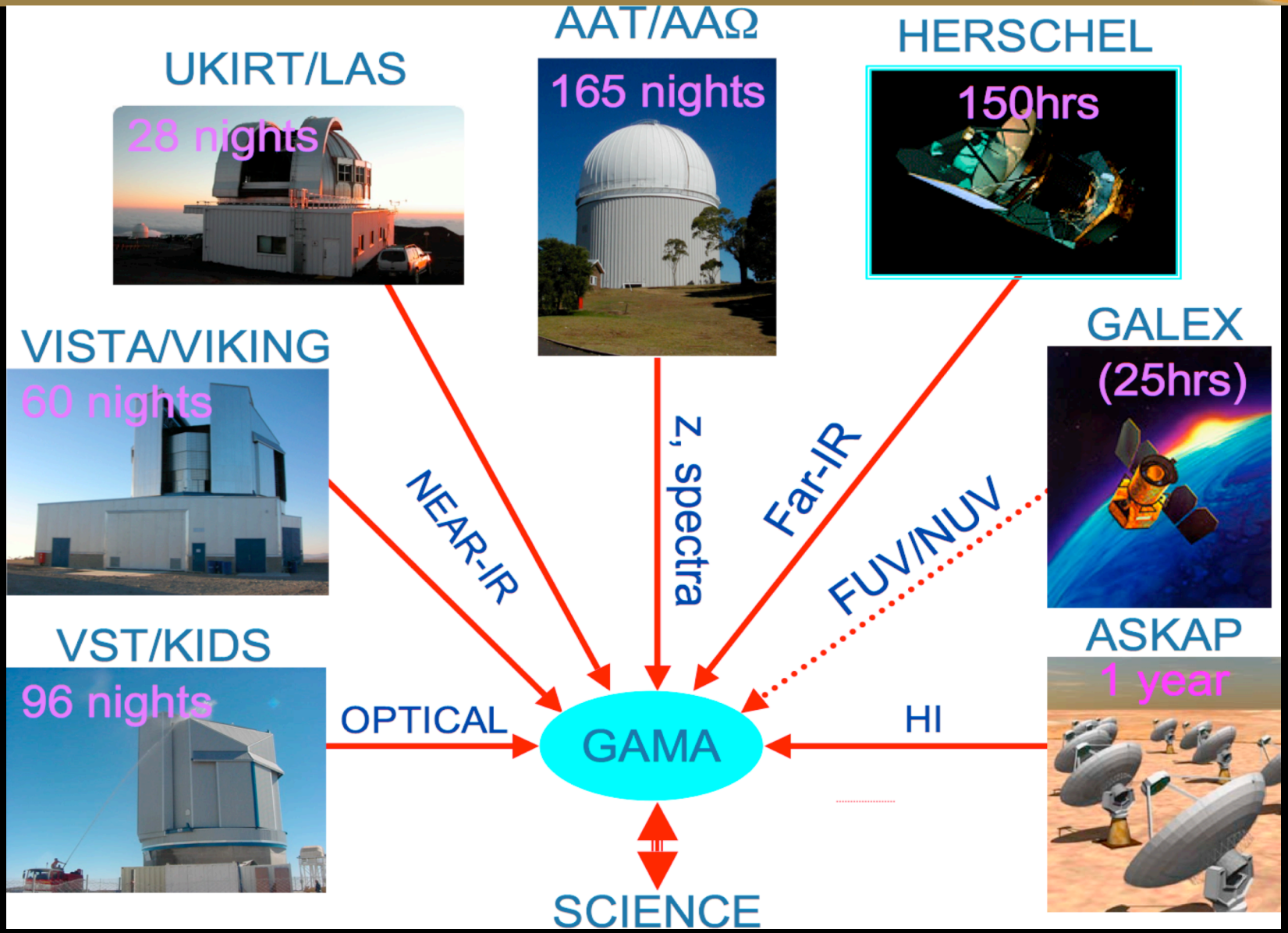
TEAM AFFILITATIONS:

UKIRT/LAS, VST/KIDS, VISTA/VIKING, HERSCHEL-ATLAS, DURHAM ICC

WEBSITE:

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

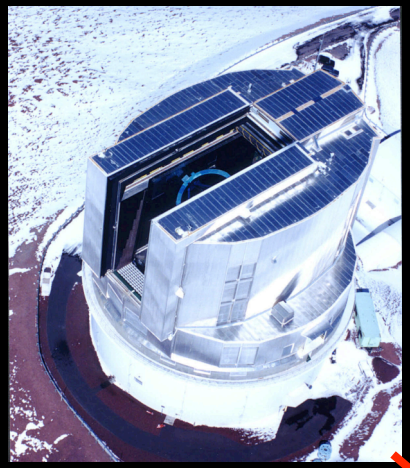
Galaxy And Mass Assembly



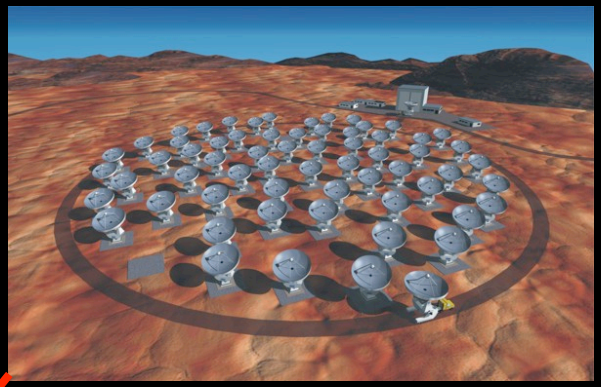
MGC
Millennium Galaxy Catalogue

GAMA DEEP

SUBARU/WFMOS



ALMA



MGC

GAMA

JWST

220 hours

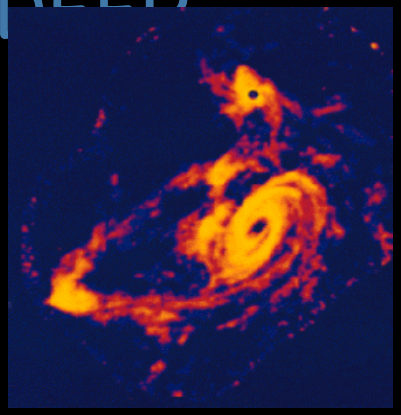
GAMA DEEP

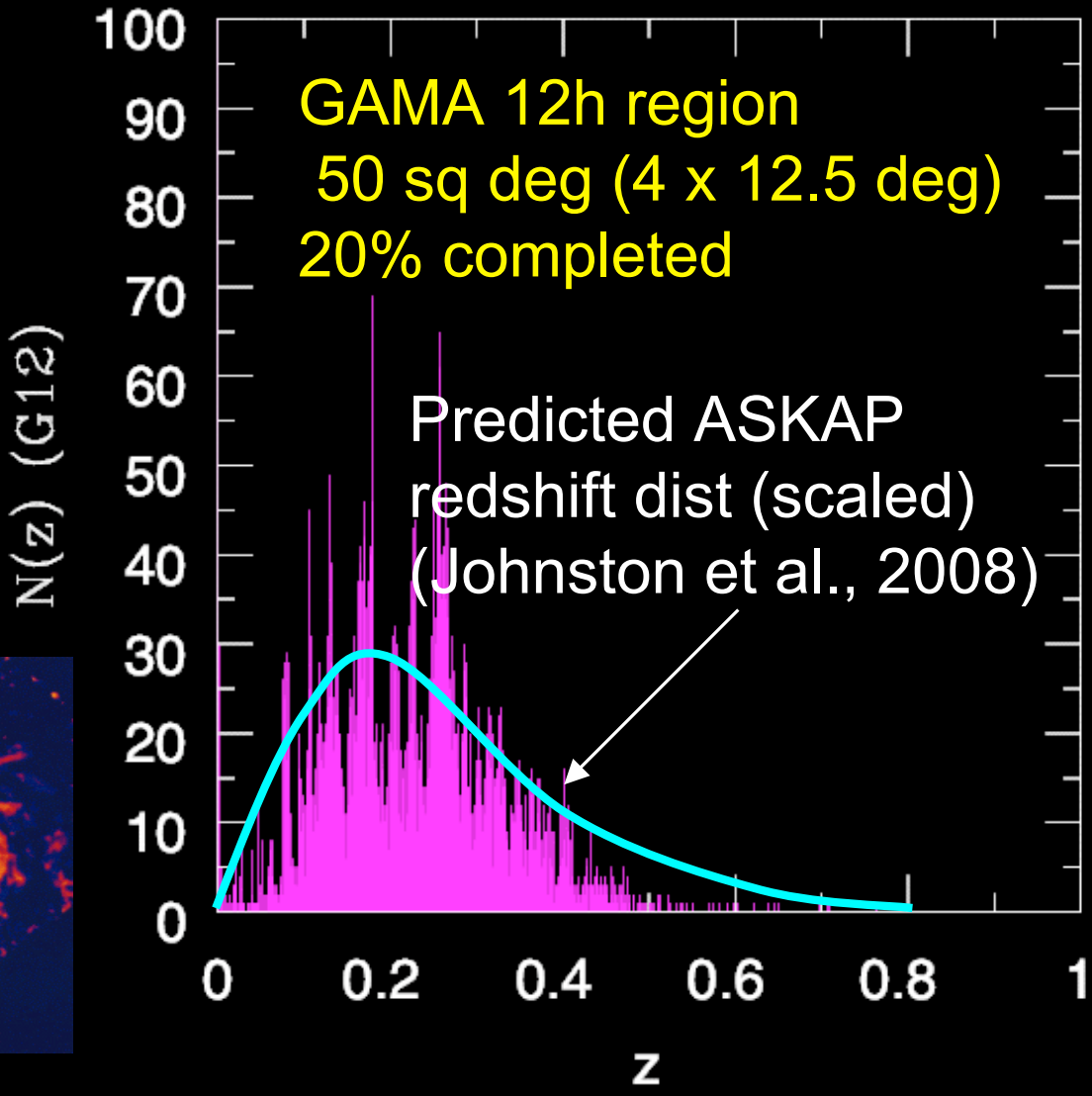
SKA

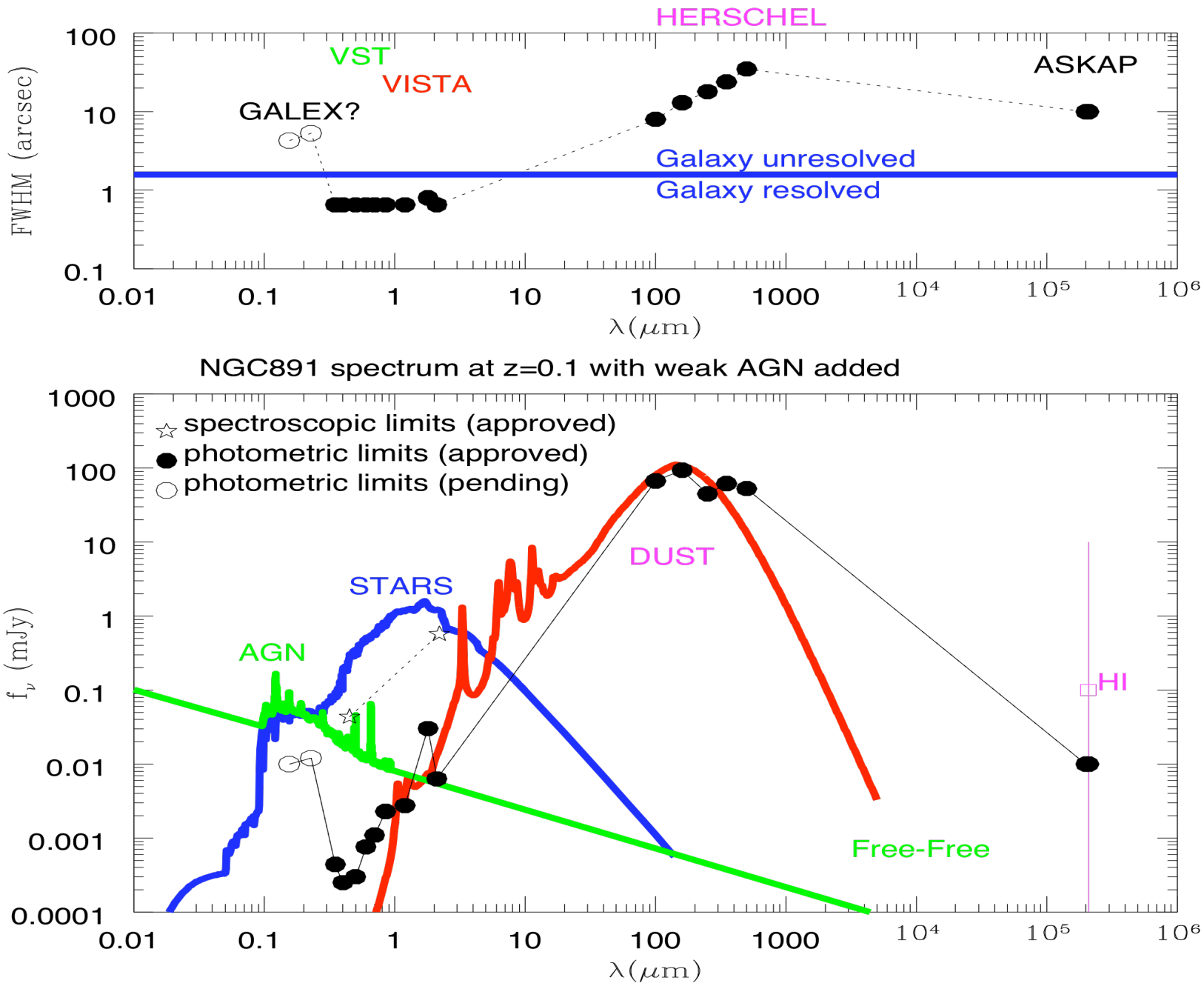
SCIENCE

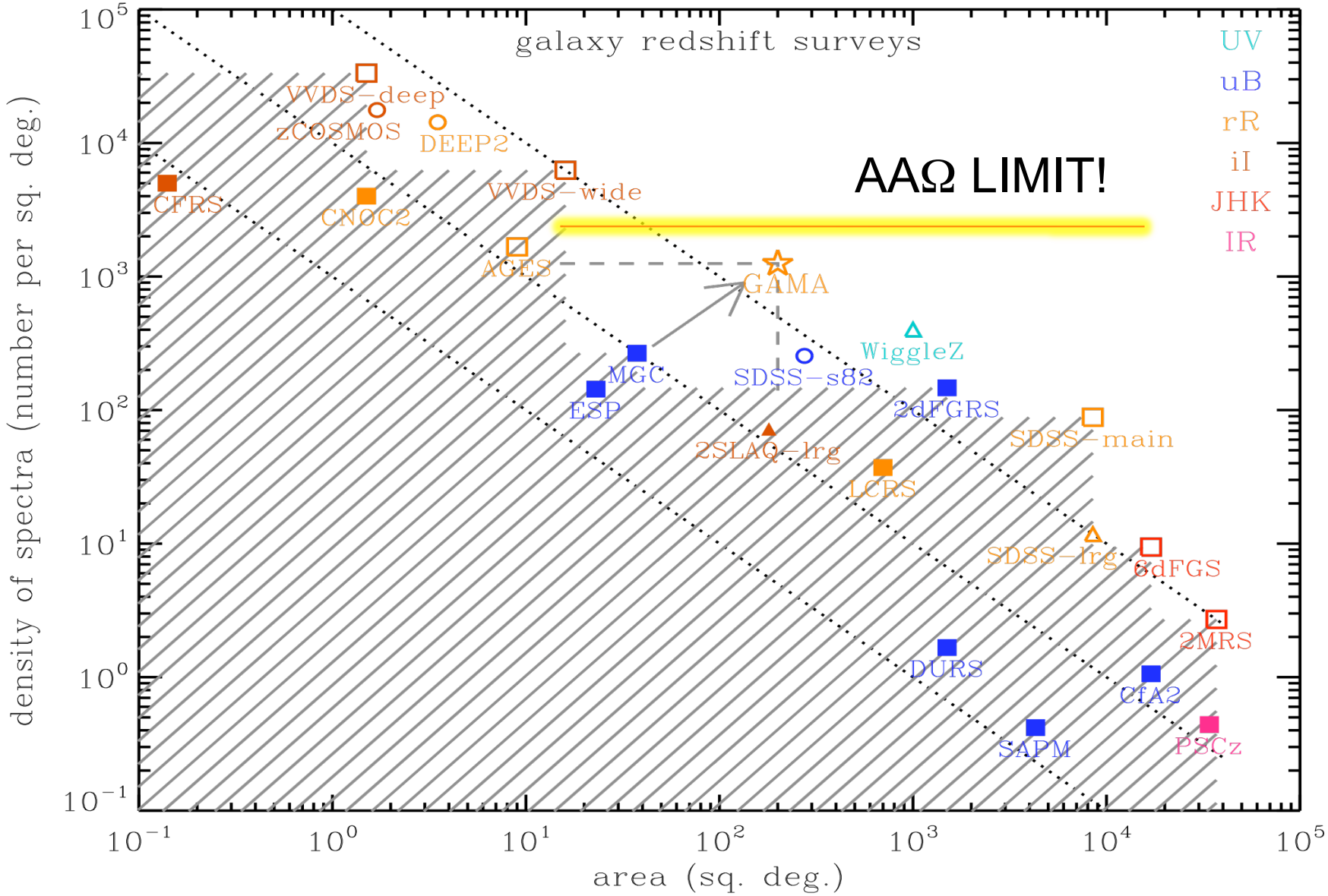
HI and continuum coverage via ASKAP

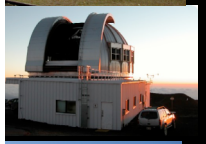
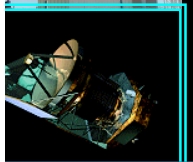
- GAMA DEPTH AND AREA WELL MATCHED TO THE PROPOSED ASKAP DEEP

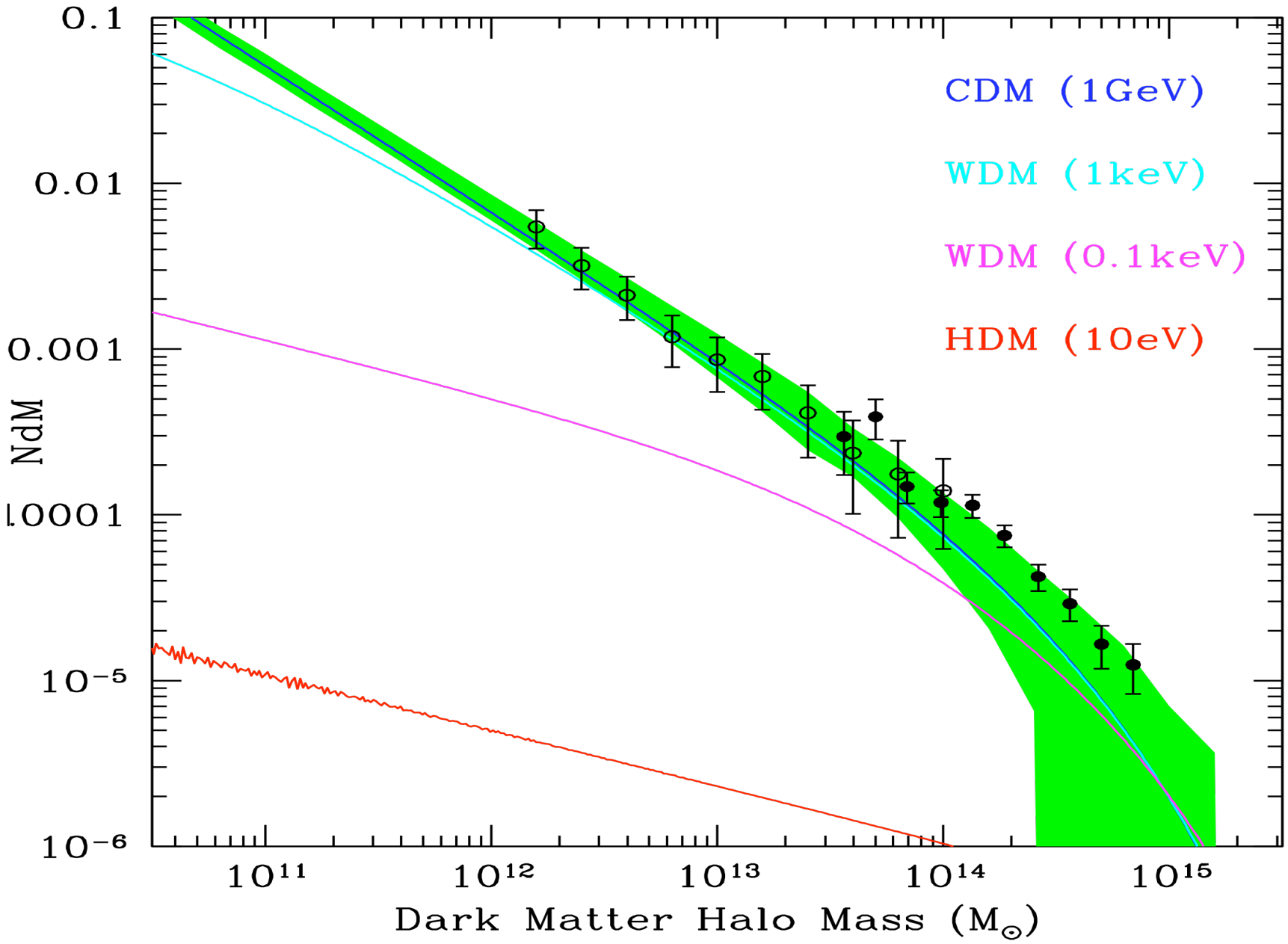


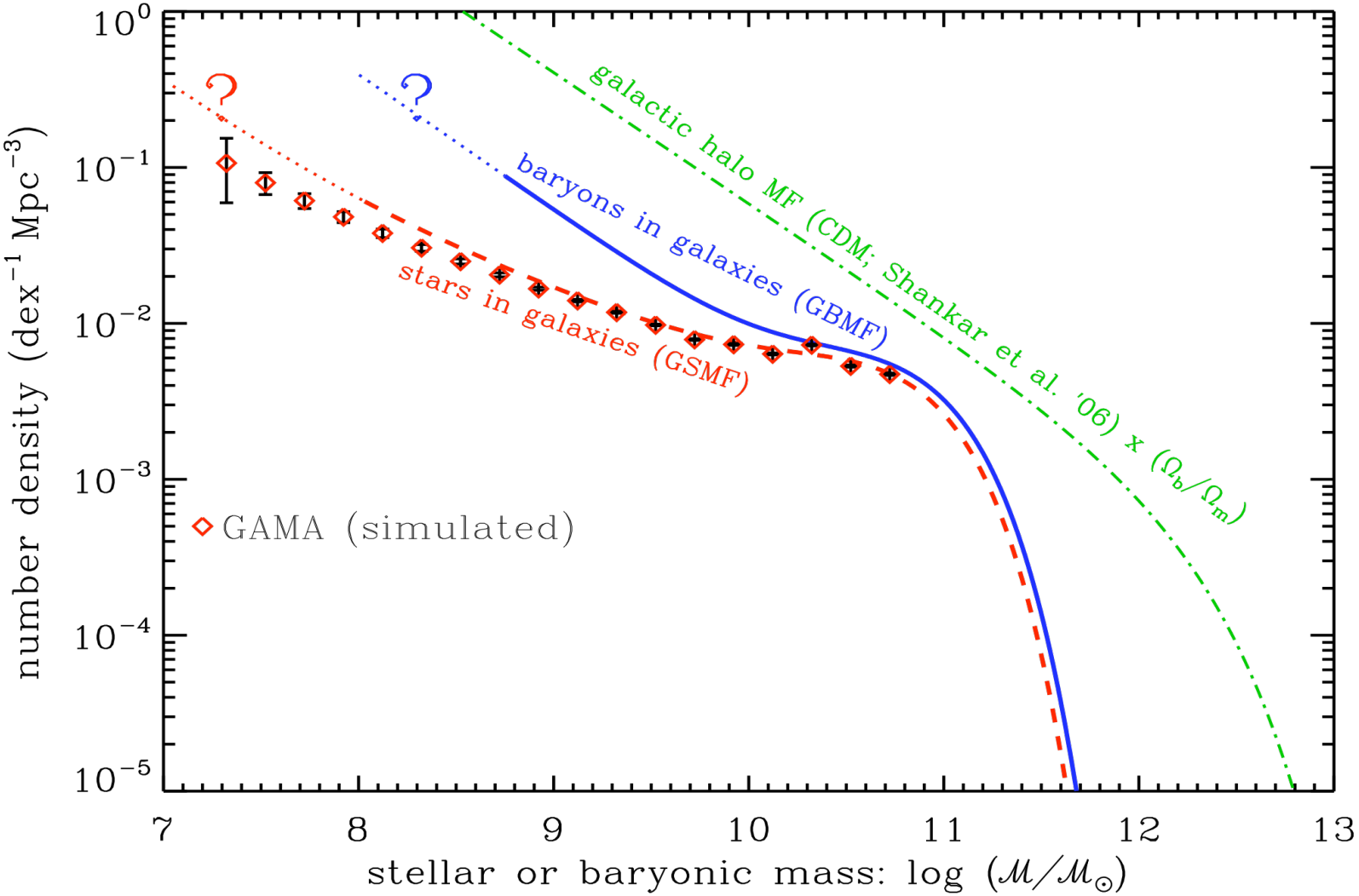



HERSCHEL
VST
VISTA
GALEX?
ASKAP
Galaxy unresolved
Galaxy resolved
FWHM (arcsec)
λ(μm)
NGC891 spectrum at z=0.1 with weak AGN added
spectroscopic limits (approved)
photometric limits (approved)
photometric limits (pending)
STARS
DUST
AGN
HI
Free-Free
f_ν (mJy)
λ(μm)

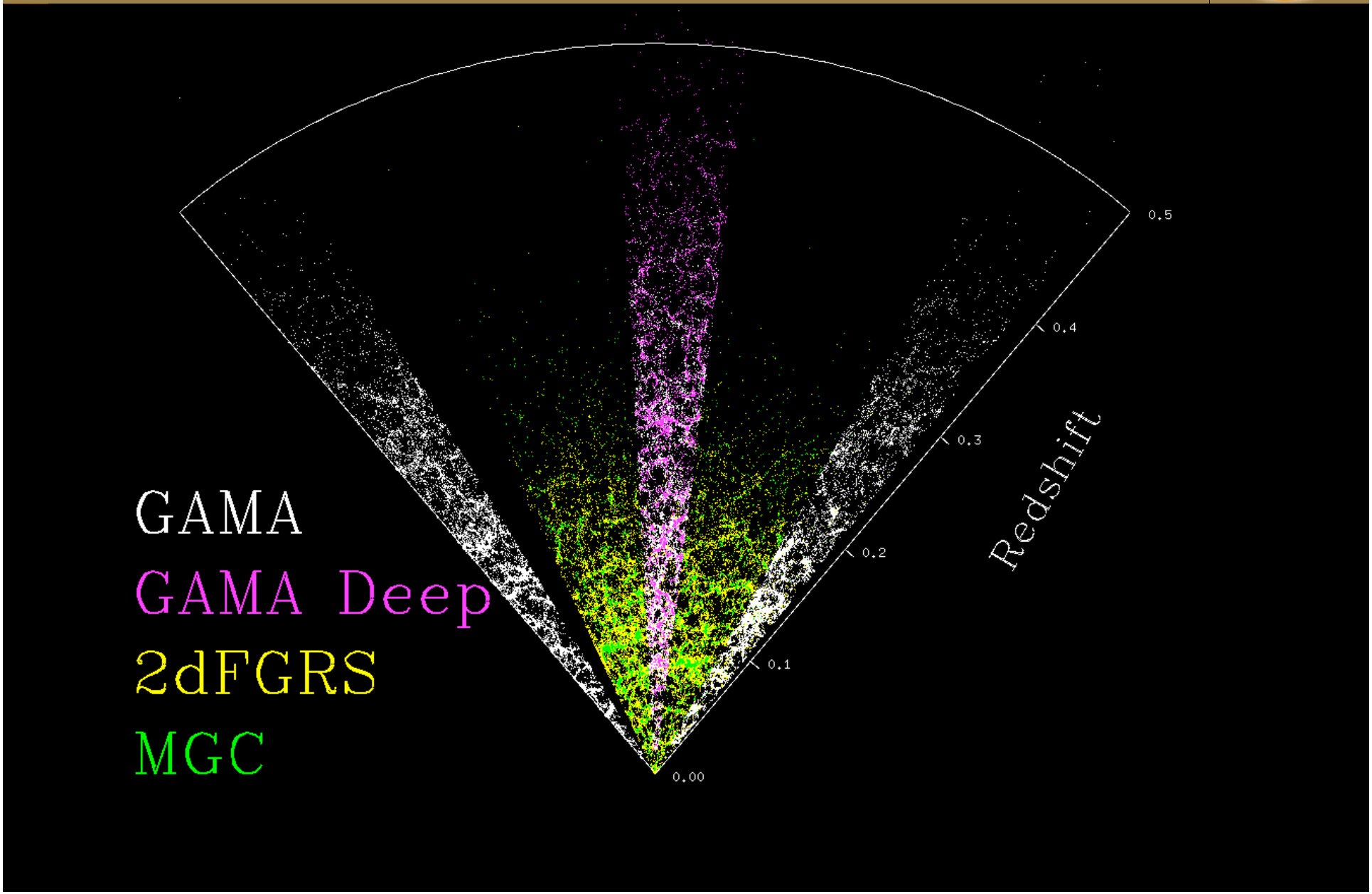

galaxy redshift surveys
density of spectra (number per sq. deg.)
area (sq. deg.)
AAΩ LIMIT!
UV
uB
rR
iI
JHK
IR
VVDS−deep
zCOSMOS
DEEP2
CFRS
CNOC2
VVDS−wide
ACES
GAMA
WiggleZ
MGC
SDSS−s82
ESP
2dFGRS
2SLAQ−lrg
SDSS−main
LCRS
SDSS−lrg
6dFGS
2MRS
DURS
CfA2
SAPM
PSCz

GAMA: Facility	Wavelength	Time (on GAMA)	Depth (5σ, AB)	Status
 AAT/AAΩ GAMA	Spectra	165nights	r < 19.8, K=17.0 mag	in progress
 UKIRT LAS	Near-IR (YJHK)	35nights	Y=20.9, J=20.6, H=20.3, K=20.1	Done.
 VISTA VIKING	Near-IR (YJHK)	75nights	Z=23.1, Y=22.3, J=22.1, K=21.1	Mar 09
 VST VST	Optical (ugriz)	120nights	u=24.8, g=25.4, r=25.2, i=24.2	09/10?
 HERSCHEL ATLAS	Far-IR	200hrs	110,170,250,350,500 microns 67, 94, 45, 62, 53 mJy	Aug 09
 GALEX MIS+prop pending	UV	25hrs+25hrs	NUV/FUV 23.0, 23.0mag	50% done 50%
ASKAP DEEP	Radio	1 year?	[21cm,continuum] 0.1μJsky, 40μJsky	2013?


0.1
0.01
0.001
.0001
10^{-5}
10^{-6}
NdM
10^{11}
10^{12}
10^{13}
10^{14}
10^{15}
Dark Matter Halo Mass ($M_\odot$)
CDM (1GeV)
WDM (1keV)
WDM (0.1keV)
HDM (10eV)


galactic halo MF (CDM; Shankar et al. '06) x (Ω_b/Ω_m)
baryons in galaxies (GBMF)
stars in galaxies (GSMF)
GAMA (simulated)
?
?
number density (dex^{-1} Mpc^{-3})
stellar or baryonic mass: log ($\mathcal{M}/\mathcal{M}_\odot$)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
7
8
9
10
11
12
13

Current CONE plot (80k z's)



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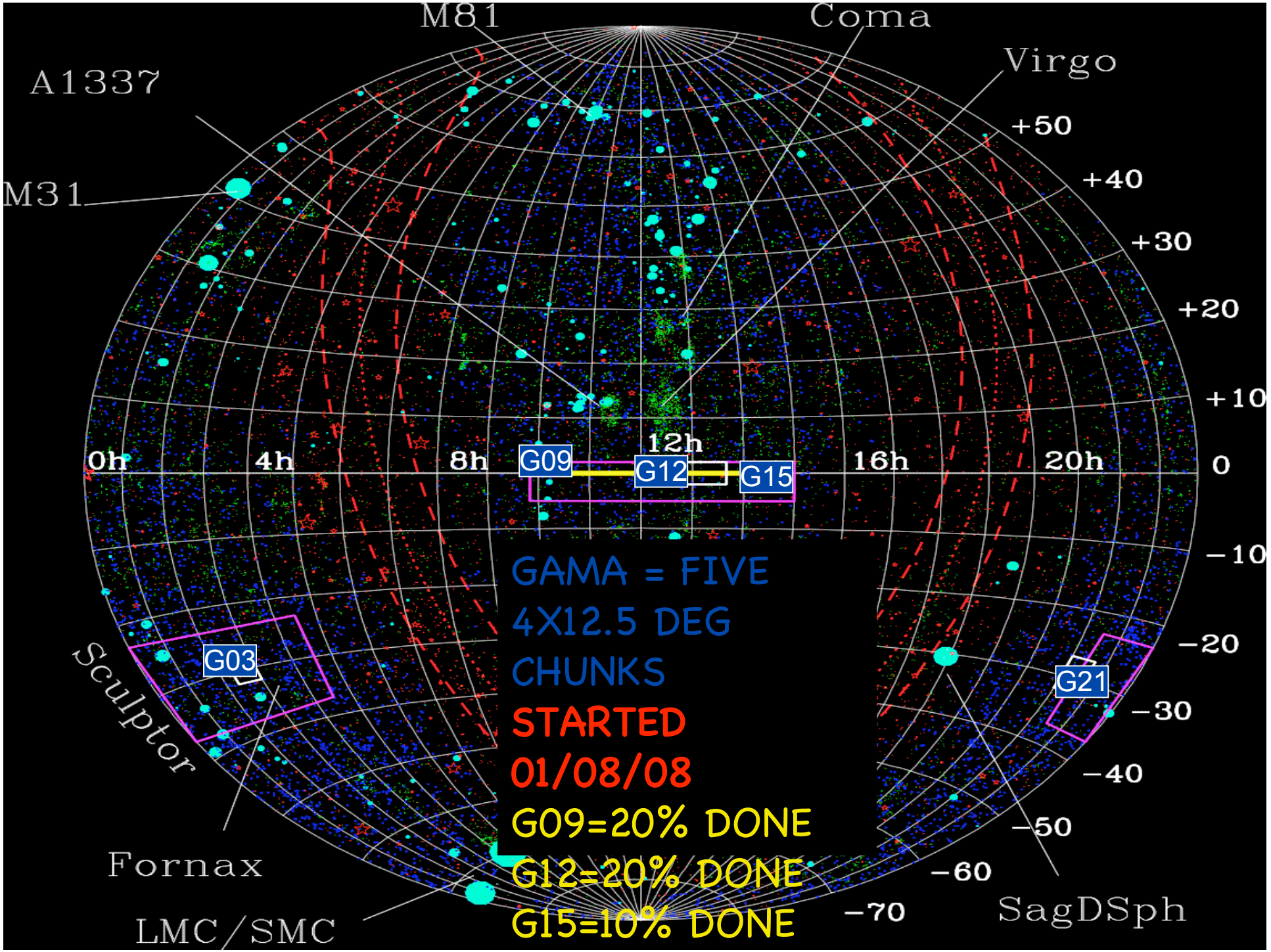
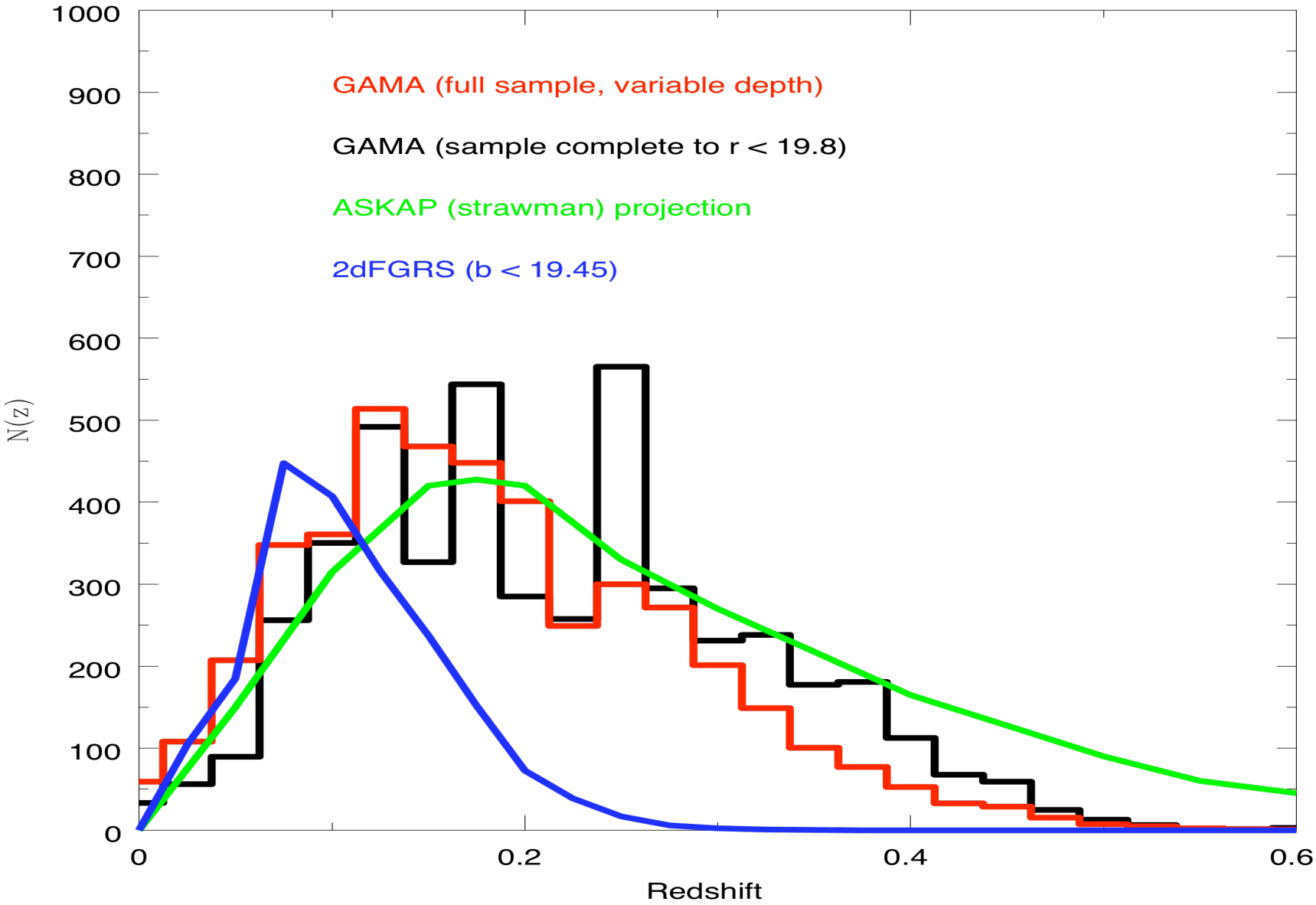
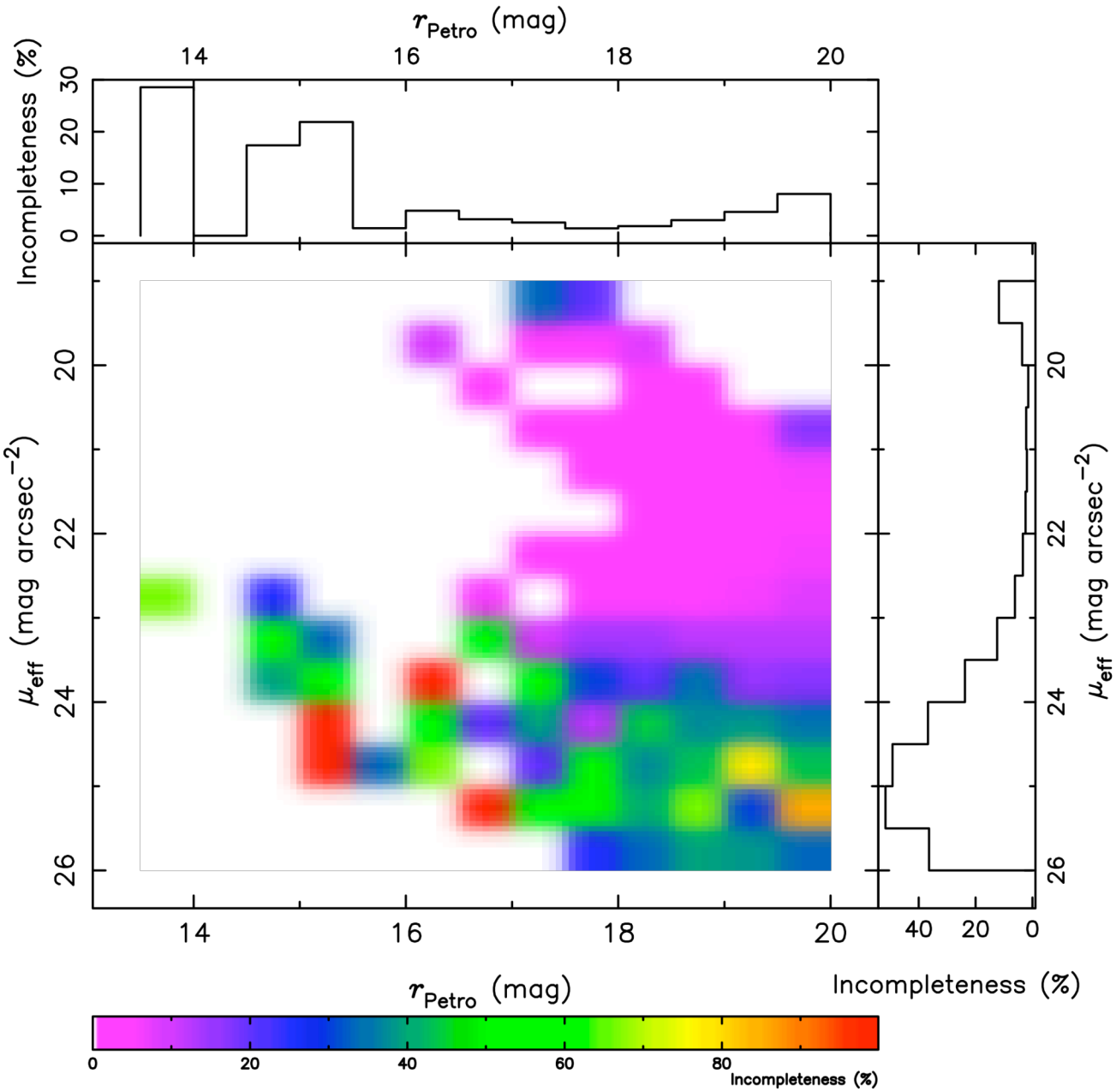
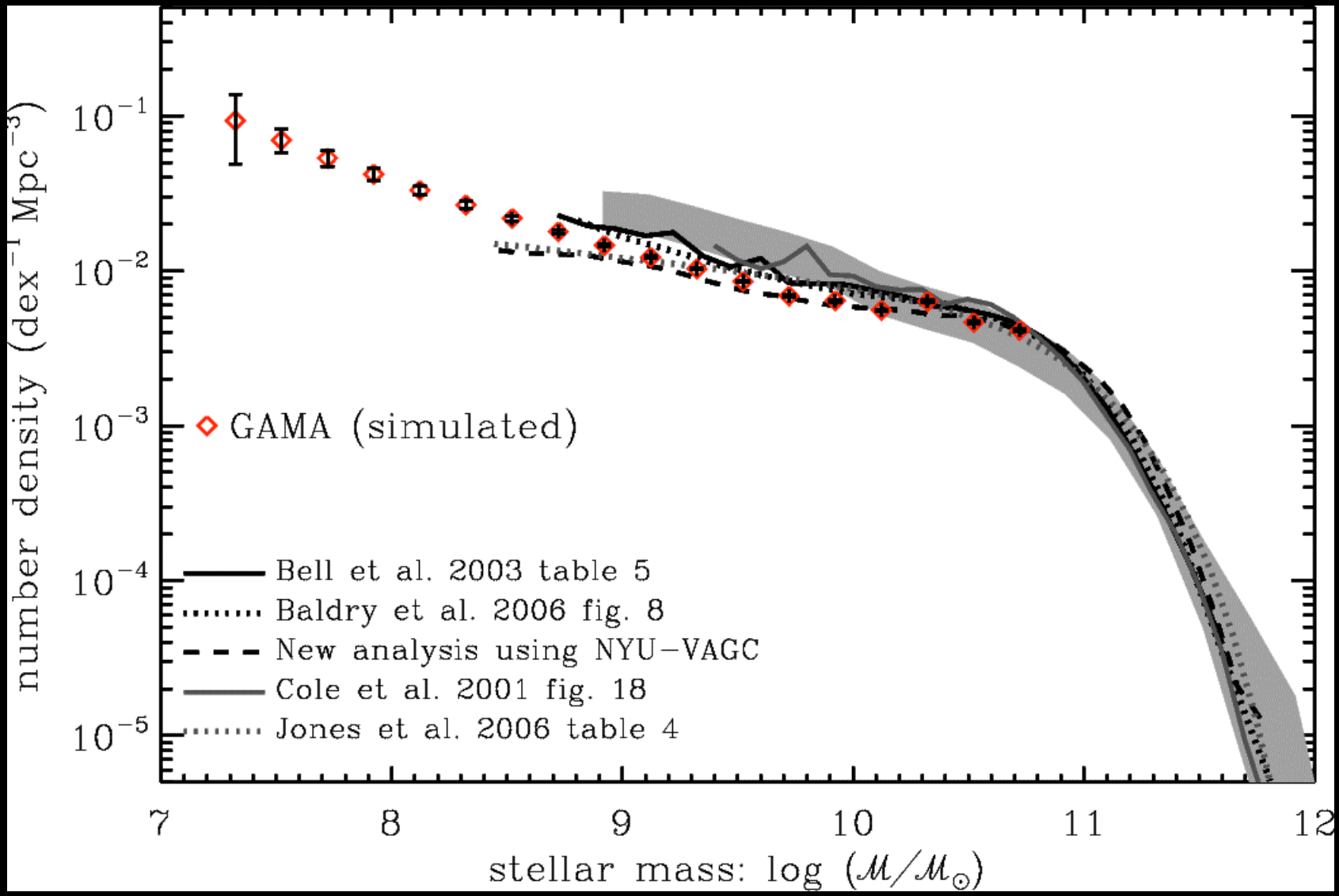

M81
Coma
Virgo
A1337
M31
+50
+40
+30
+20
+10
0
−10
−20
−30
−40
−50
−60
−70
0h
4h
8h
12h
16h
20h
G09
G12
G15
G03
G21
Sculptor
Fornax
LMC/SMC
SagDSph
GAMA = FIVE
4X12.5 DEG
CHUNKS
STARTED
01/08/08
G09=20% DONE
G12=20% DONE
G15=10% DONE

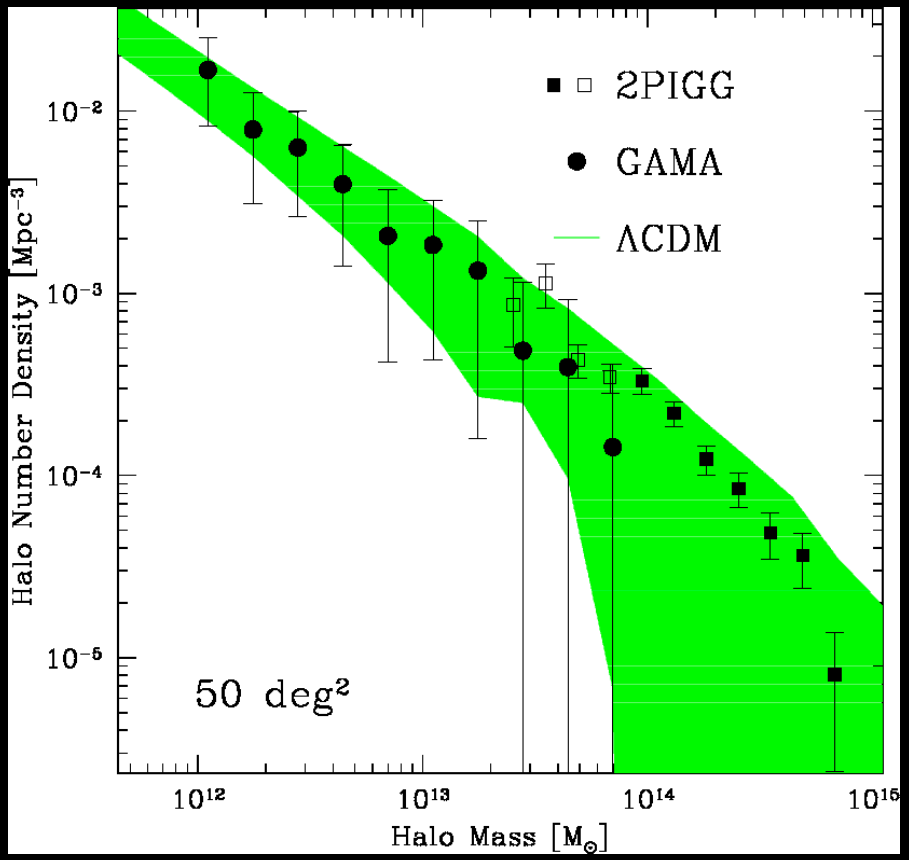

GAMA (full sample, variable depth)
GAMA (sample complete to r < 19.8)
ASKAP (strawman) projection
2dFGRS (b < 19.45)
N(z)
Redshift
0
100
200
300
400
500
600
700
800
900
1000
0
0.2
0.4
0.6

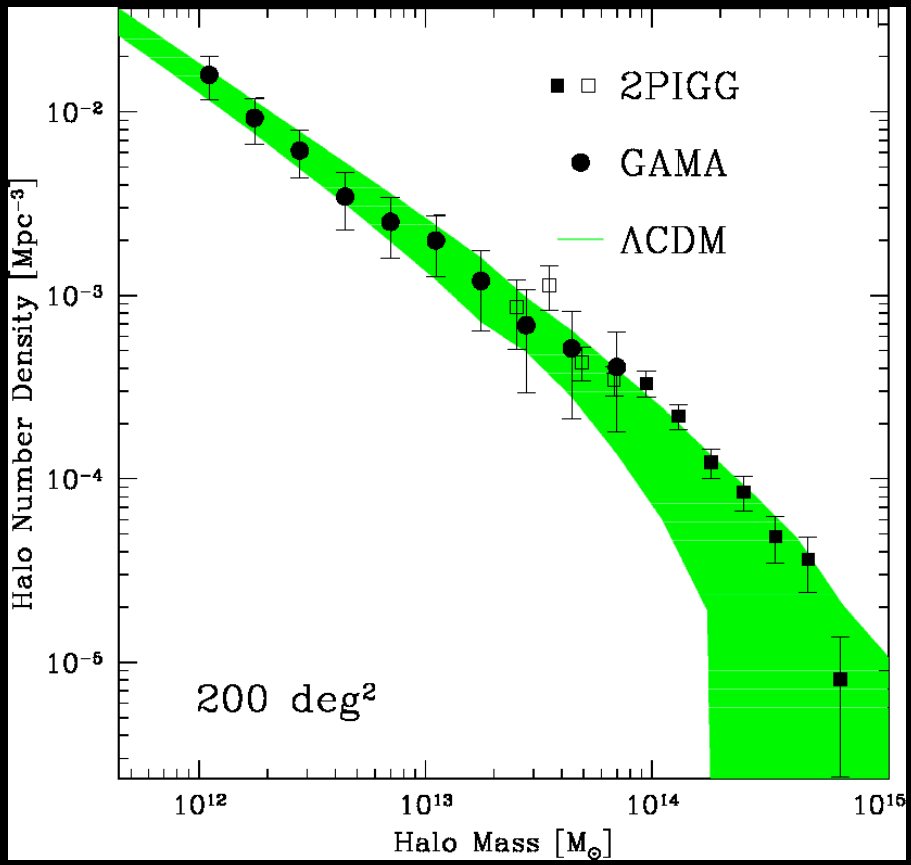

r_{Petro} (mag)
14
16
18
20
Incompleteness (%)
0
10
20
30
μ_{eff} (mag arcsec^{-2})
20
22
24
26
40
20
0
Incompleteness (%)
0
20
40
60
80
Incompleteness (%)

The GAMA Stellar Mass fn



The Halo Mass Function





The Global luminosity distribution