Galaxy and Mass Assembly: Pitfalls and Progress

Simon Driver and the MGC & GAMA teams

University of St Andrews + Many

- 10 reasons why we're struggling…
- Highlighting the issue of dust attenuation
- GAMA (going beyond SDSS, in progress)

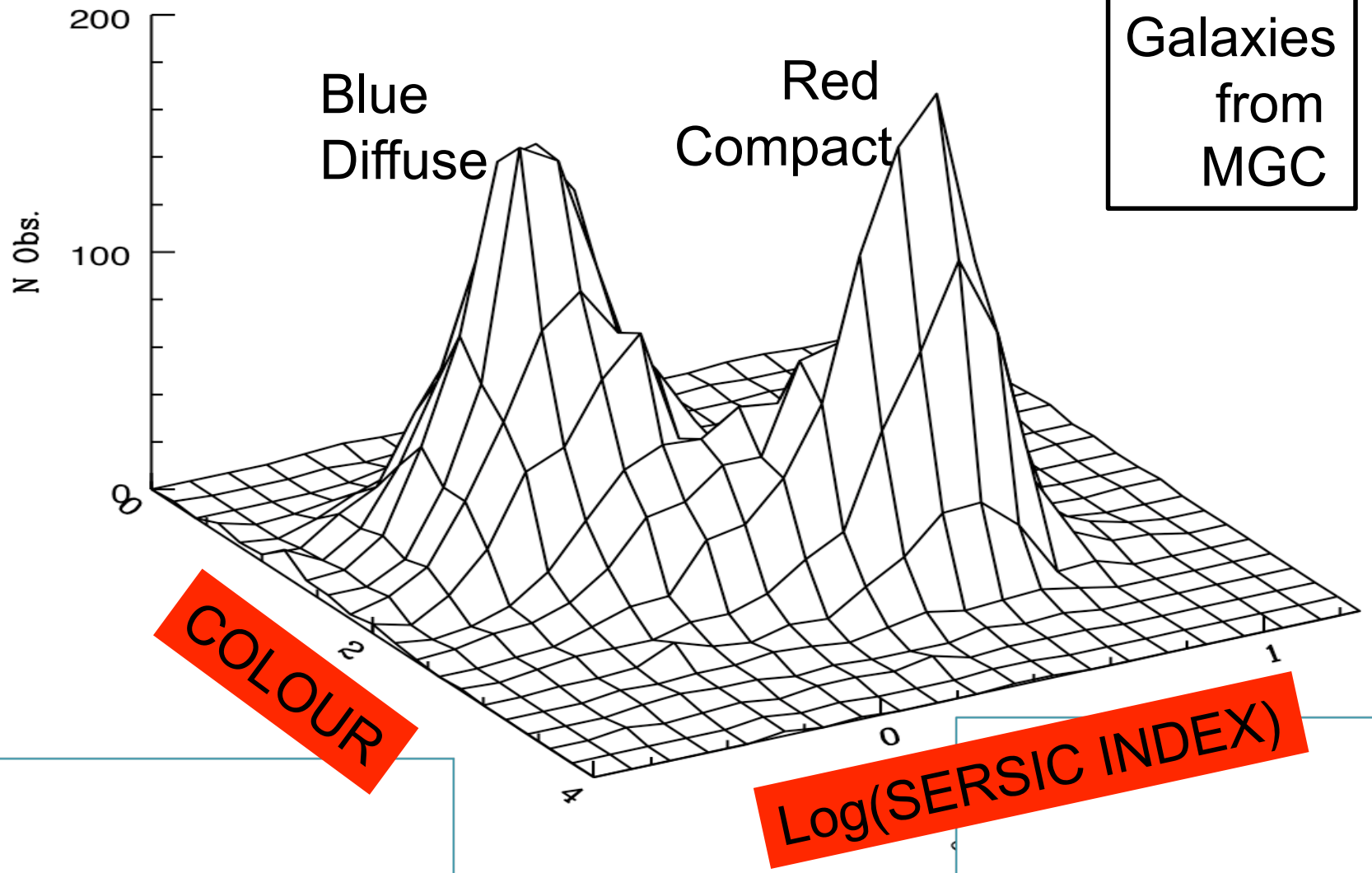
10 reasons why we're struggling

1. Global v component measurements?
2. The hierarchy of components?
3. Photometry (flux, size & component bias)
4. Incomplete sampling (dwarf pops, LSBGs)
5. Cosmic variance (dominates HDF etc)
6. SFH v stellar mas density (incompatible)
7. Photo-z v spectro-z (no substitute)
8. Wavelength bias (UV/opt./far-IR/radio divide)
9. Dust attenuation (1-3 mags in B !)
10. Disconnect with hierarchical-CDM

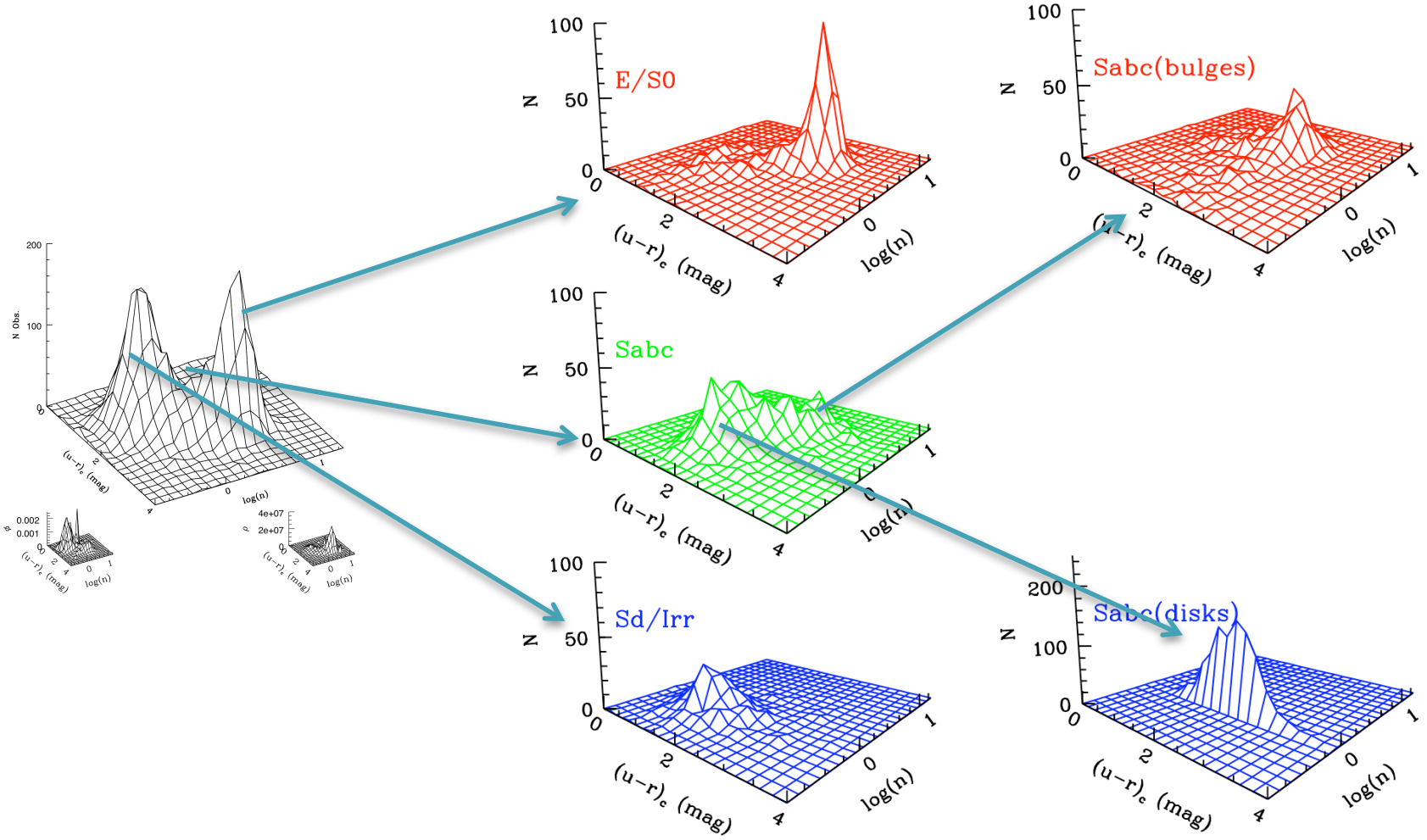
1. Global v component measures

- Bimodality, what does it mean?

10,000 Galaxies from MGC

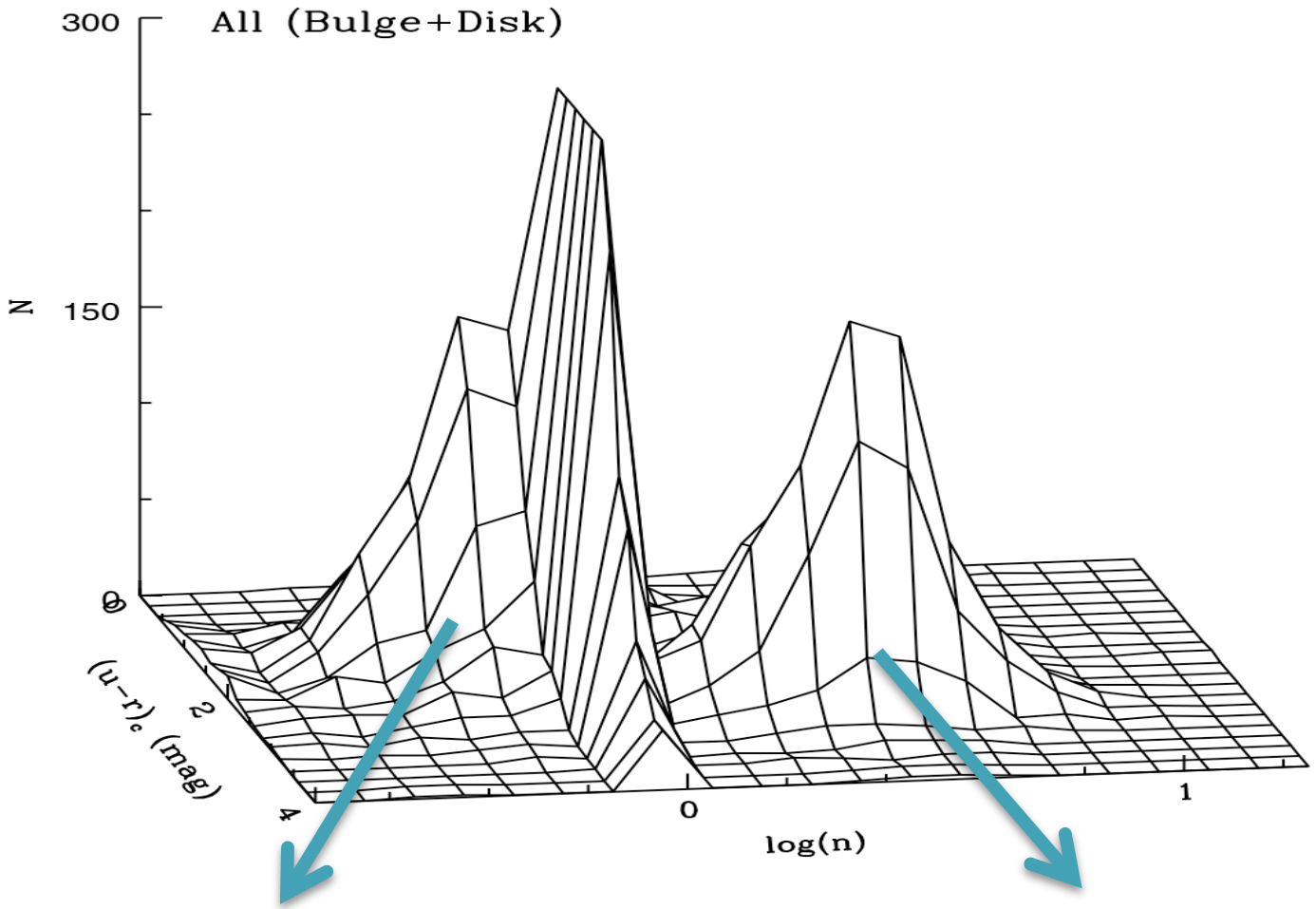


1. Global v component measures



(Driver et al. 2005)

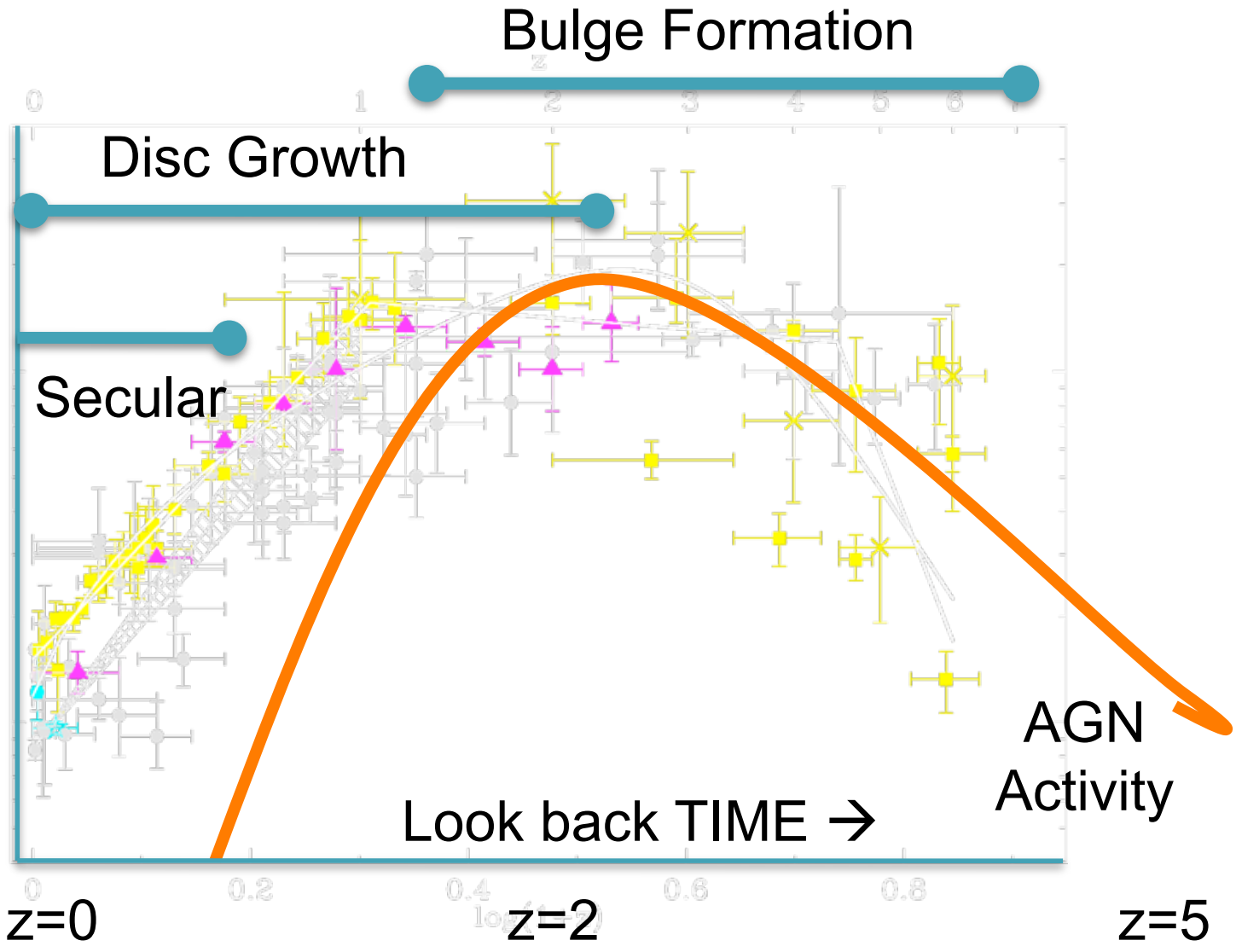
(Allen et al 2006)



Disc growth
Dynamical cool
Accretion &
Secular evolution
Star-form' History z <2

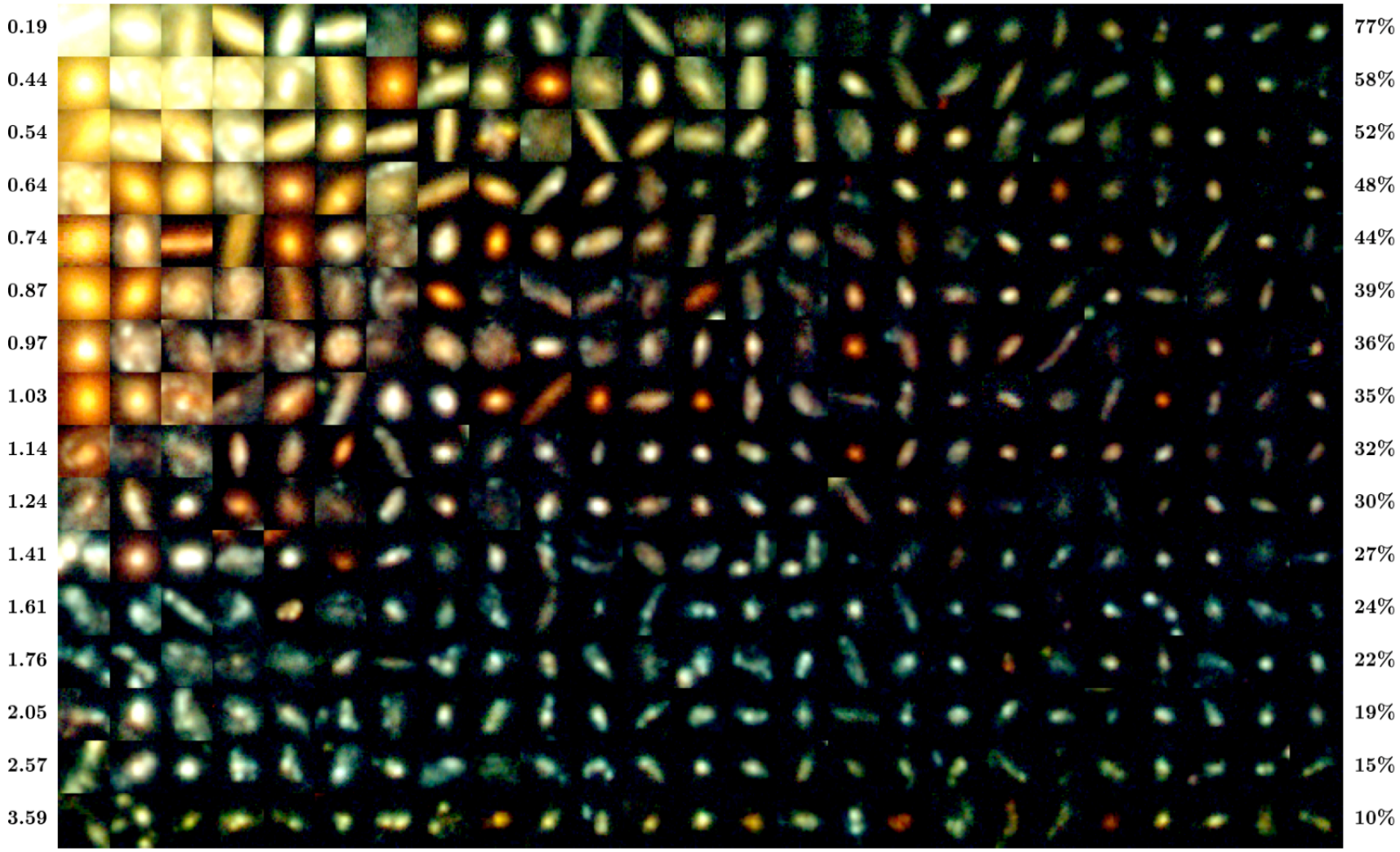
Bulge formation
Dynamically hot phase
Rapid Collapse/merger
AGN/SMBH formation
QSO activity z>2

The cosmic star-formation history



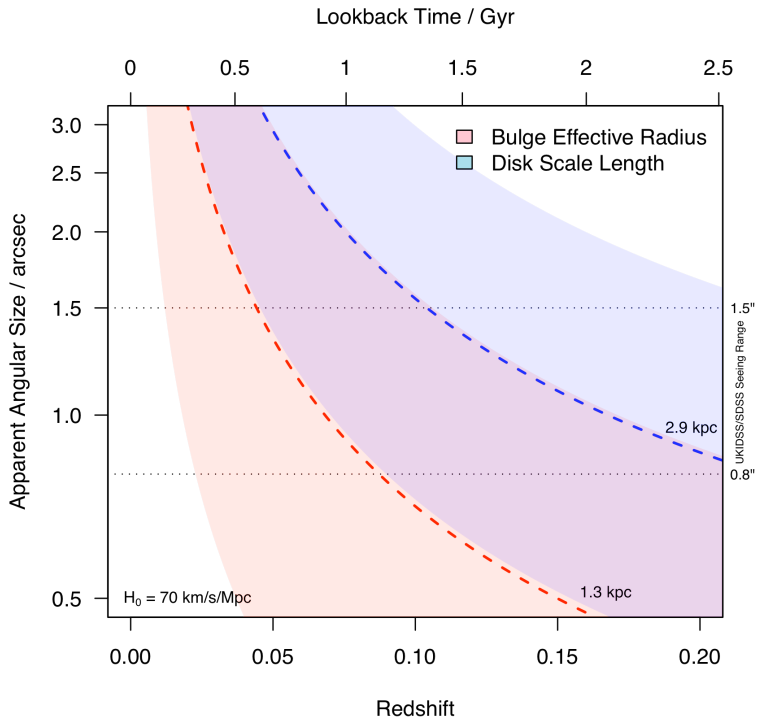
Hopkins & Beacom (2006)

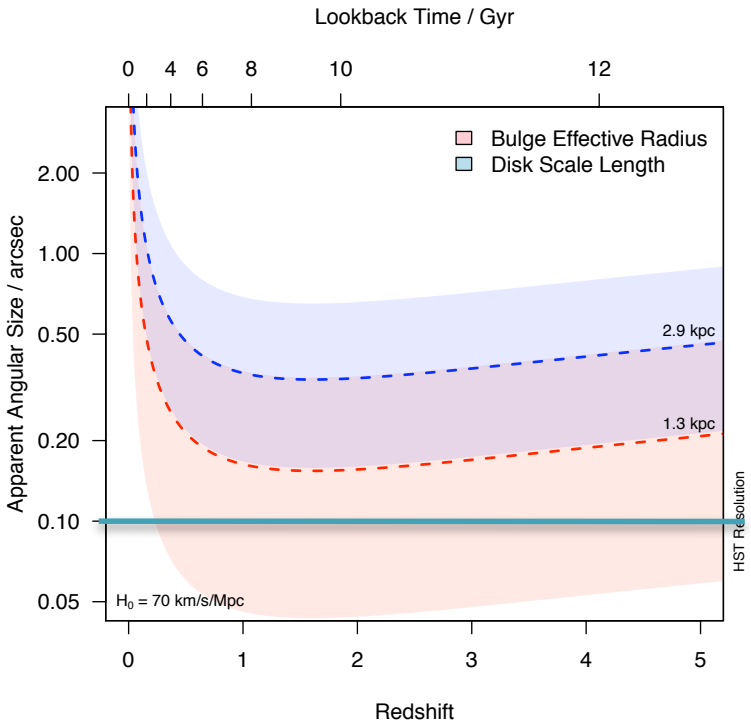
THE HUBBLE DEEP FIELD CORE SAMPLE ($I < 26.0$)



Simon Driver & Alberto Fernandez-Soto (UNSW)

1. Global v component measures





HST

Spatial resolution crucial:

Ground-based limit: $z<0.15$

Space-based limit : None

Current space-based samples prone to Cosmic Variance
& other issues, need space-based survey telescope: Euclid

(Kelvin et al, in prep)

2. The hierarchy of components?

GALAXY

BULGE	DISC
Core depletion Nucleus SMBH/CMC Boxiness Triaxiality	Pseudo-bulge Bar Truncation Thick/thin

What physical process is each linked too?

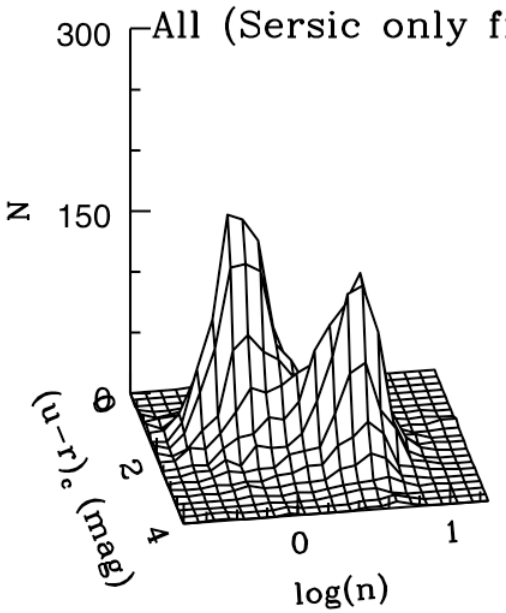
HOT? COLD?

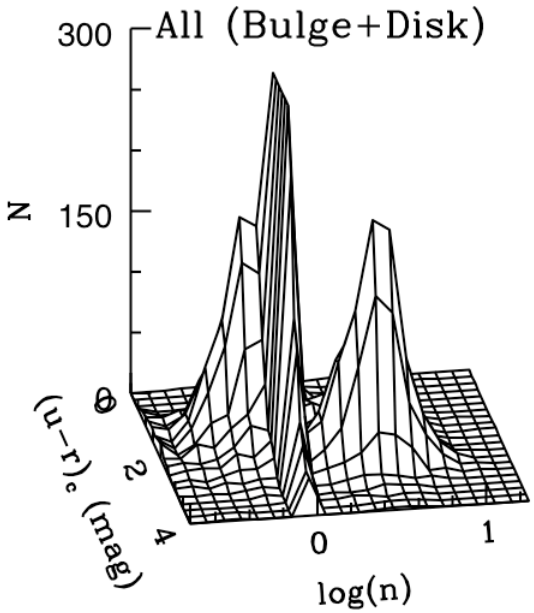
2. The hierarchy of components?

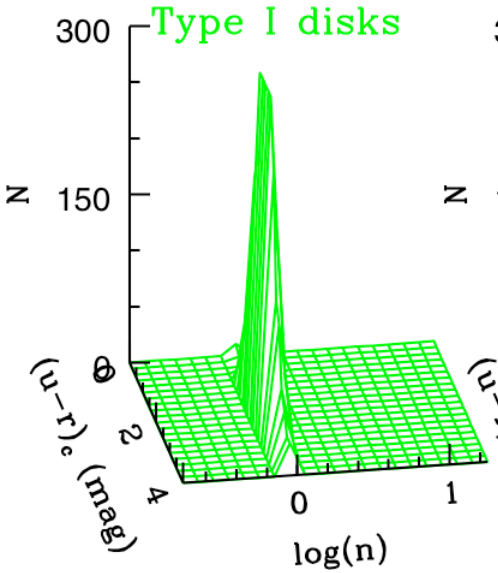
GALAXY

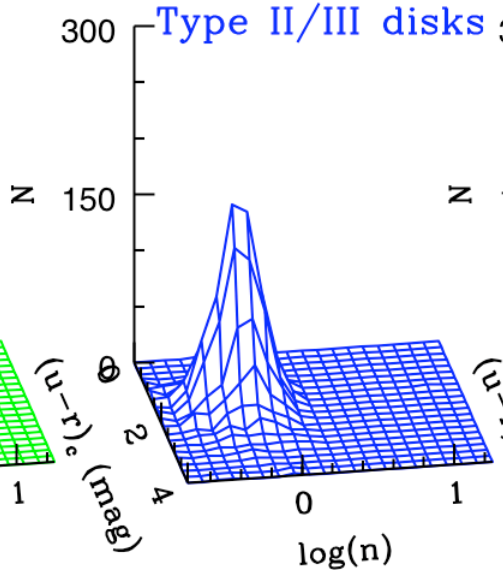
NUCLEUS	BULGE	P-BULGE	DISC
Core depletion SMBH/CMC	Boxiness Triaxiality	Bar	Truncation Thick/Thin
Hot accretion	Collapse	Secular	Cold Accretion

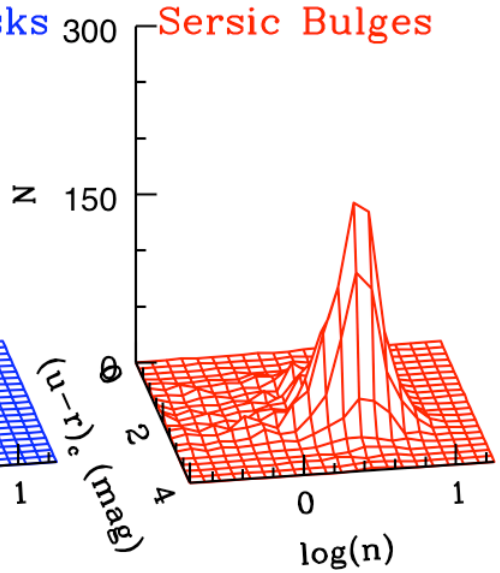
What physical process is each linked too?


All (Sersic only fits)
300
150
0
N
0
2
4
(u−r)c (mag)
0
1
log(n)

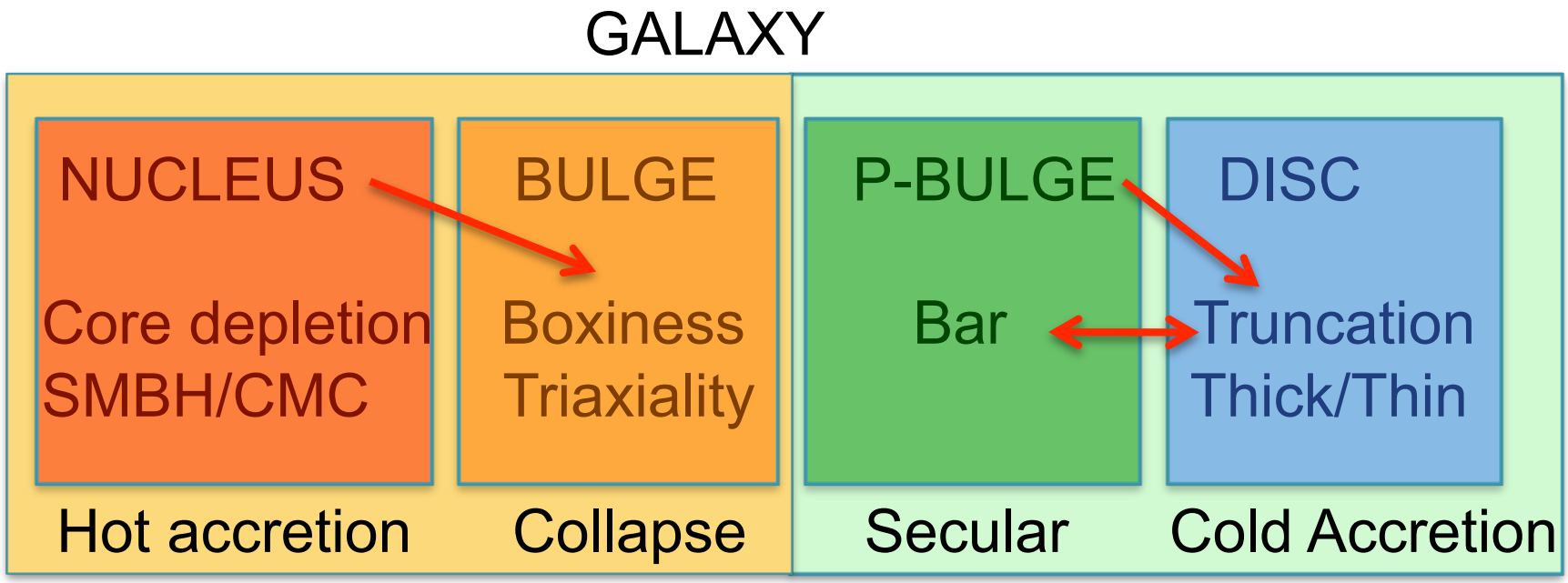

All (Bulge+Disk)
300
150
0
N
0
2
4
(u−r)c (mag)
0
1
log(n)


Type I disks
300
150
0
N
0
2
4
(u−r)c (mag)
0
1
log(n)


Type II/III disks
300
150
0
N
0
2
4
(u−r)c (mag)
0
1
log(n)

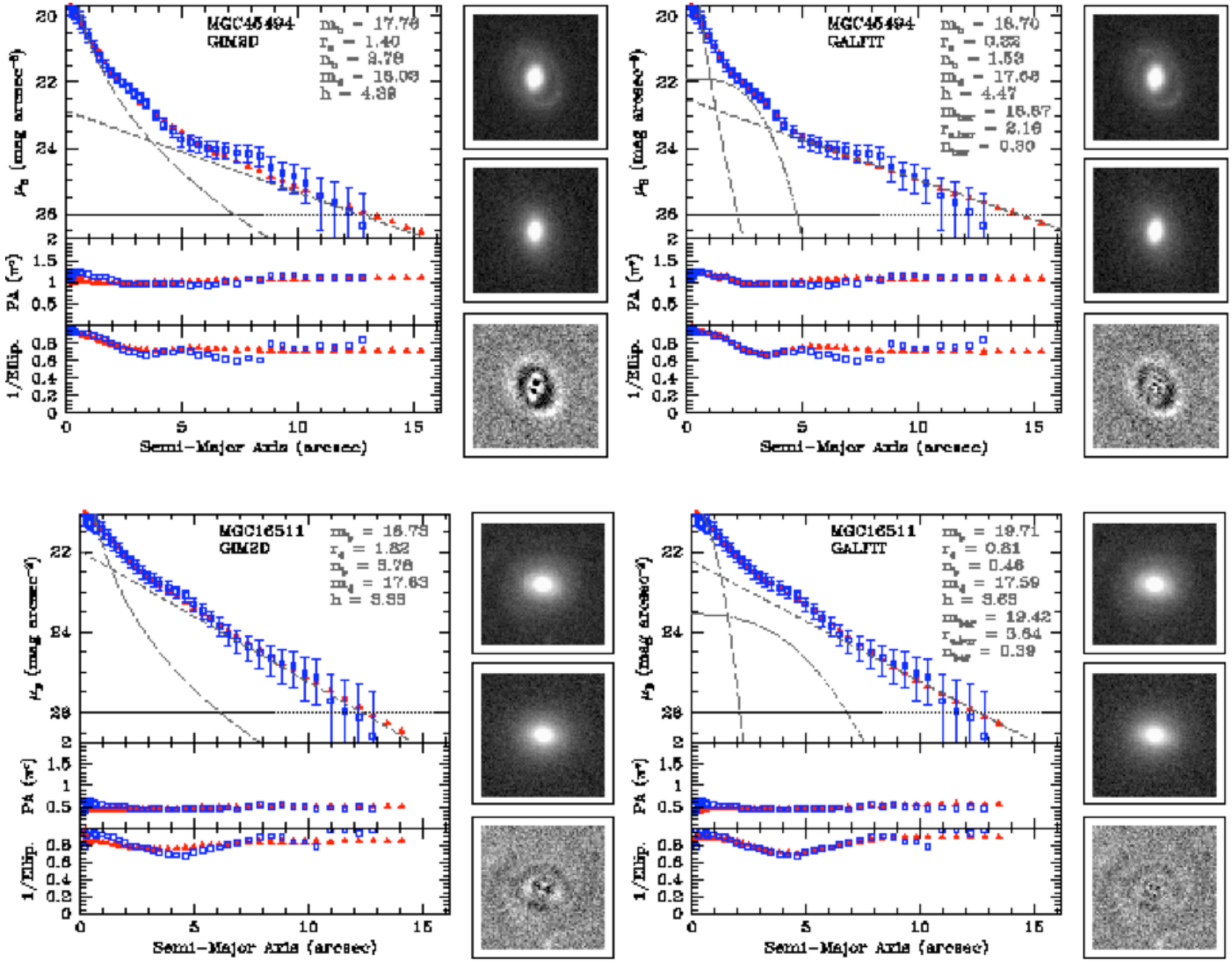

Sersic Bulges
300
150
0
N
0
2
4
(u−r)c (mag)
0
1
log(n)

2. The hierarchy of components?

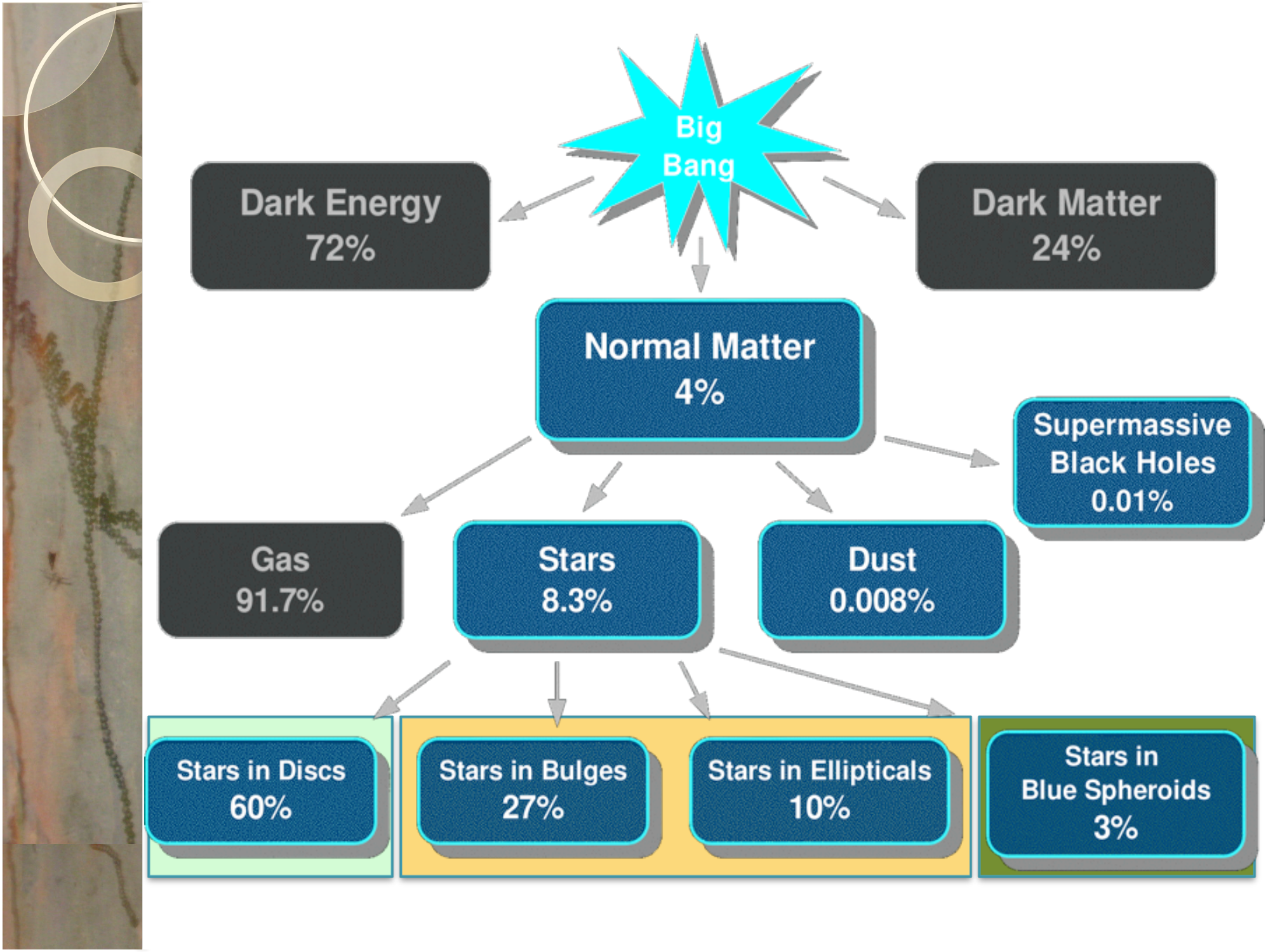


What physical process is each linked too?

2. The dark art of profiling…



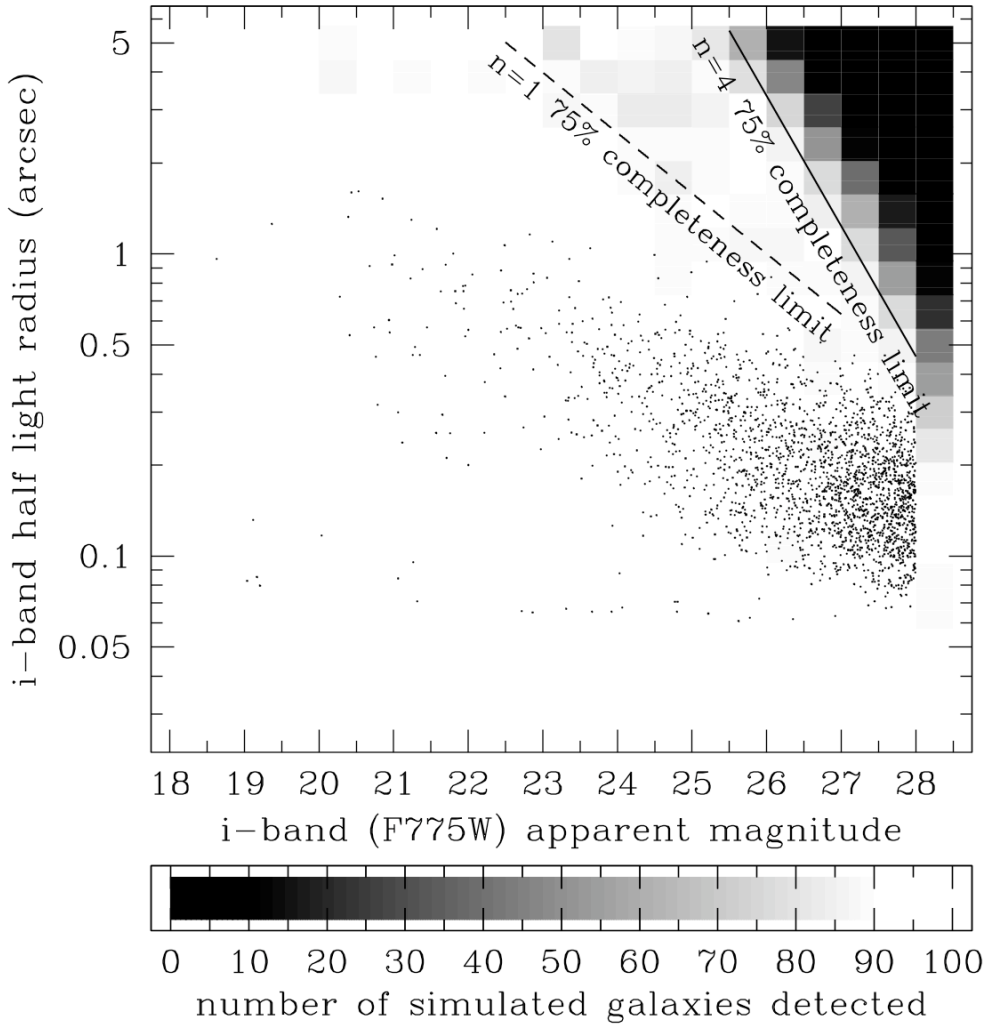
(Cameron et al 2009)


Big Bang
Dark Energy 72%
Dark Matter 24%
Normal Matter 4%
Supermassive Black Holes 0.01%
Gas 91.7%
Stars 8.3%
Dust 0.008%
Stars in Discs 60%
Stars in Bulges 27%
Stars in Ellipticals 10%
Stars in Blue Spheroids 3%

3. Photometric bias

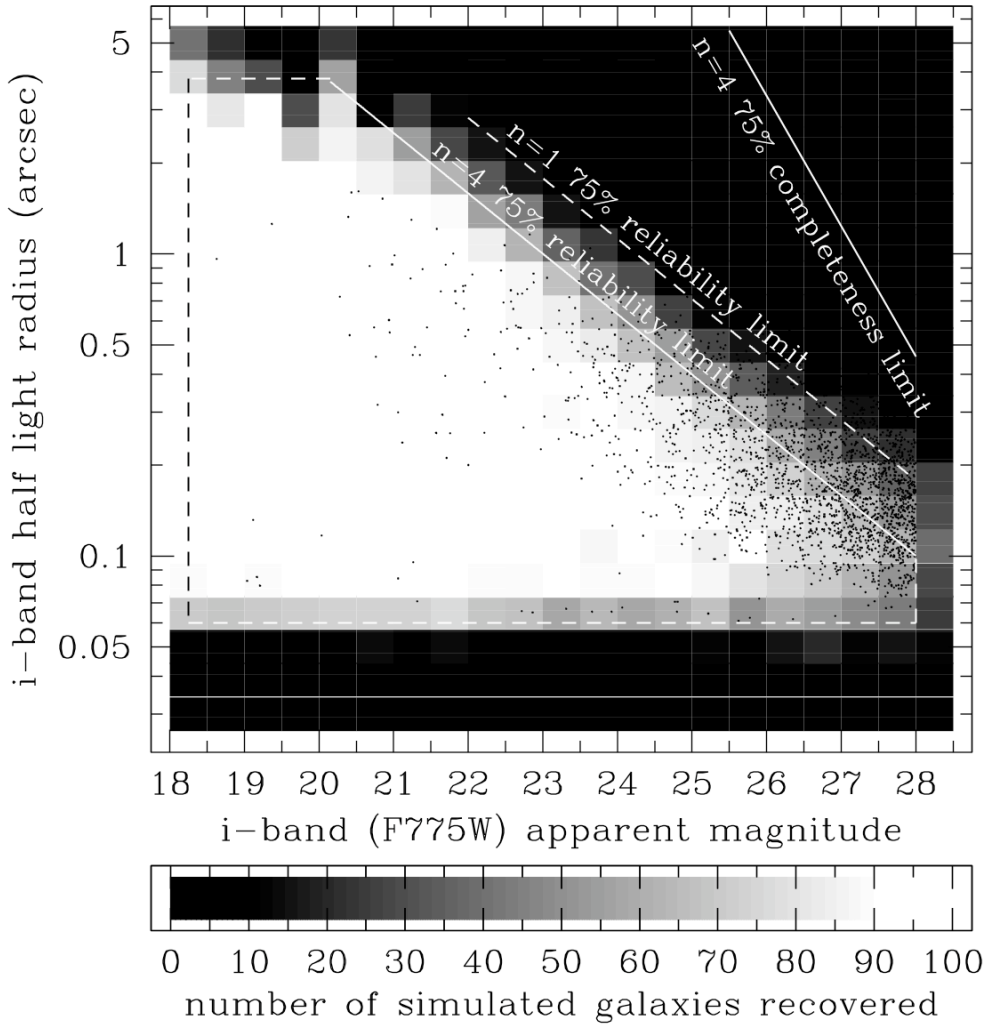
- Many systems in use:
  - Isophotally corrected: APM(2dFGRS)
  - Petrosian (circular): SDSS, UKIDSS
  - Kron (elliptical): MGC
  - Model (de Vauc v exponential): SDSS
  - Fitted Sersic: GAMA
- Suitable for multi-component systems?
  - Detection of disc dependent on bulge?
- Above only robust if Re,α above isophote
  - Missing discs in 2MASS/UKIDSS
  - Bias against LSBGs and HSBGs (i.e., dwarfs)
  - At high-z bias towards faint compact systems
- Detection AND Measurement bias

3. Photometric bias: Detection



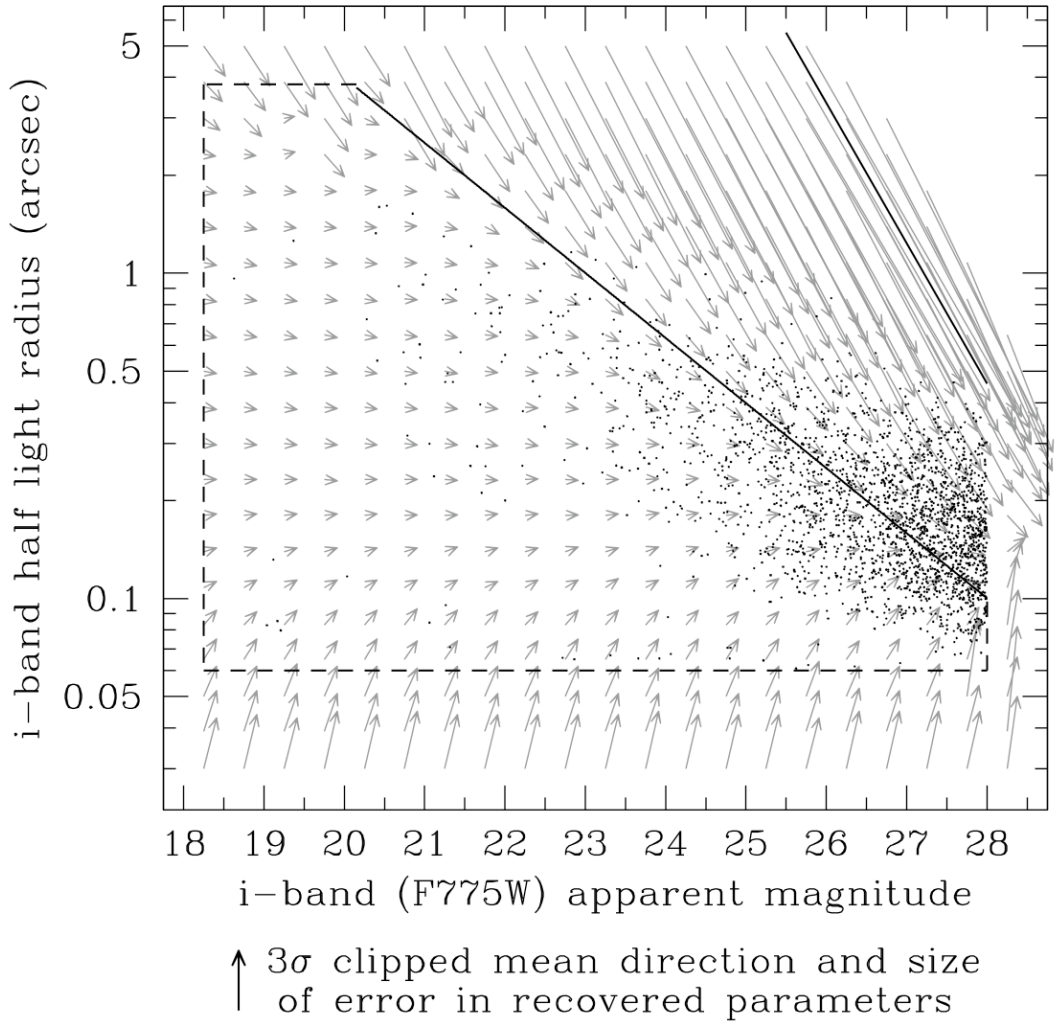
(Cameron & Driver 2009)

3. Photometric bias: Measurement



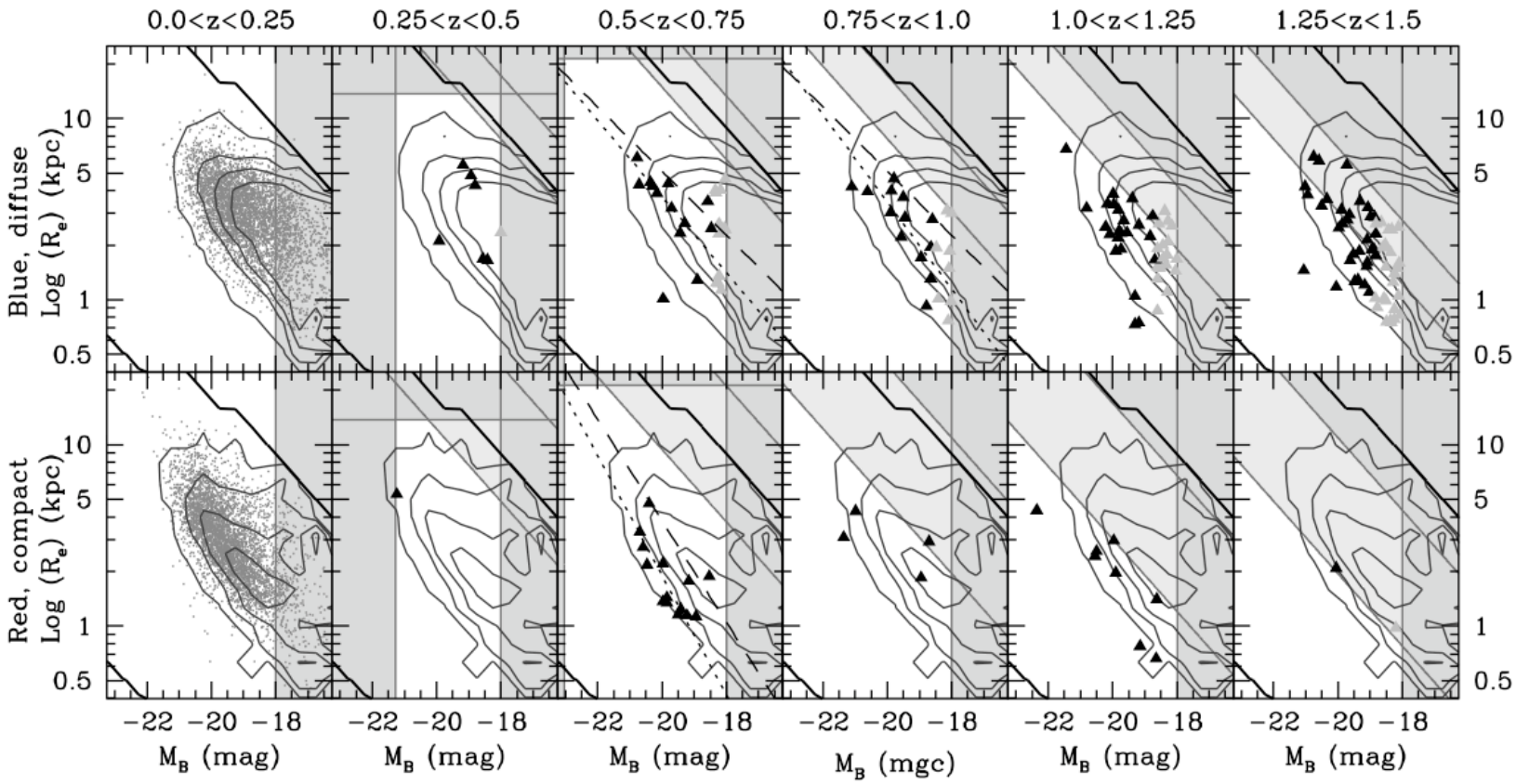
(Cameron & Driver 2009)

3. Photometric bias: Systematic



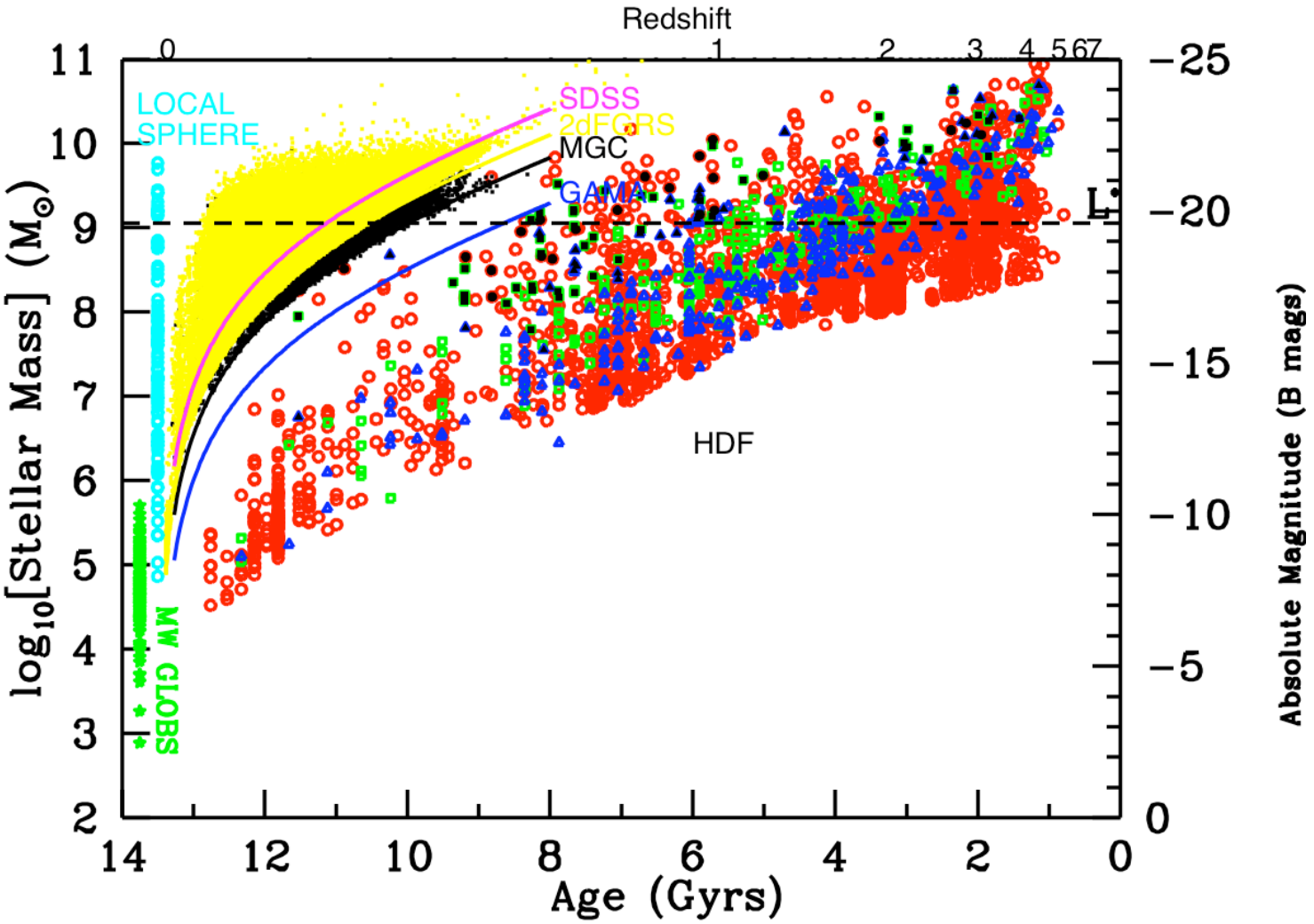
(Cameron & Driver 2009)

3. Photometric bias: with redshift

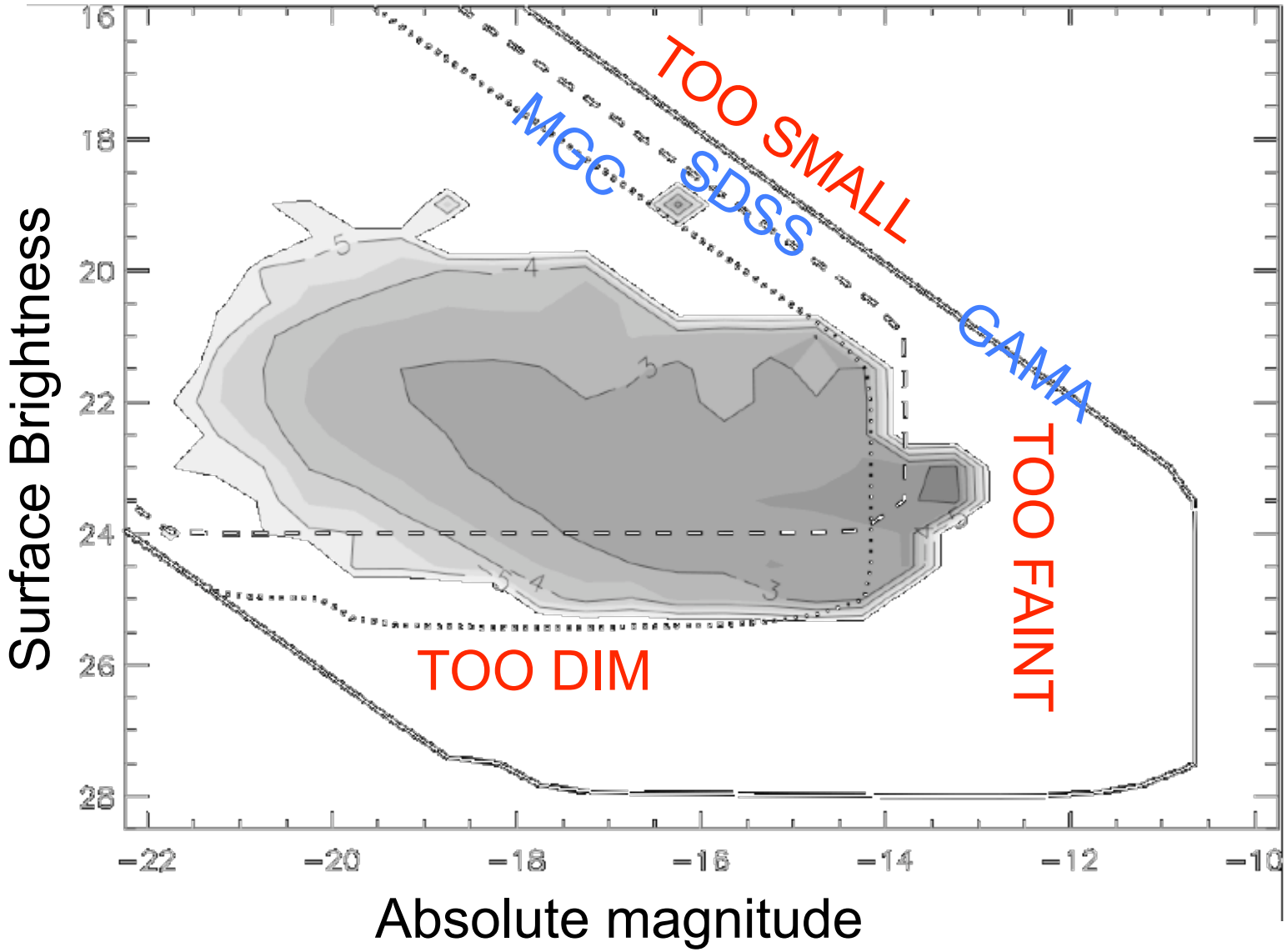


(Cameron & Driver 2009)

4. Sample incompleteness



4. Sample incompletness: BBD



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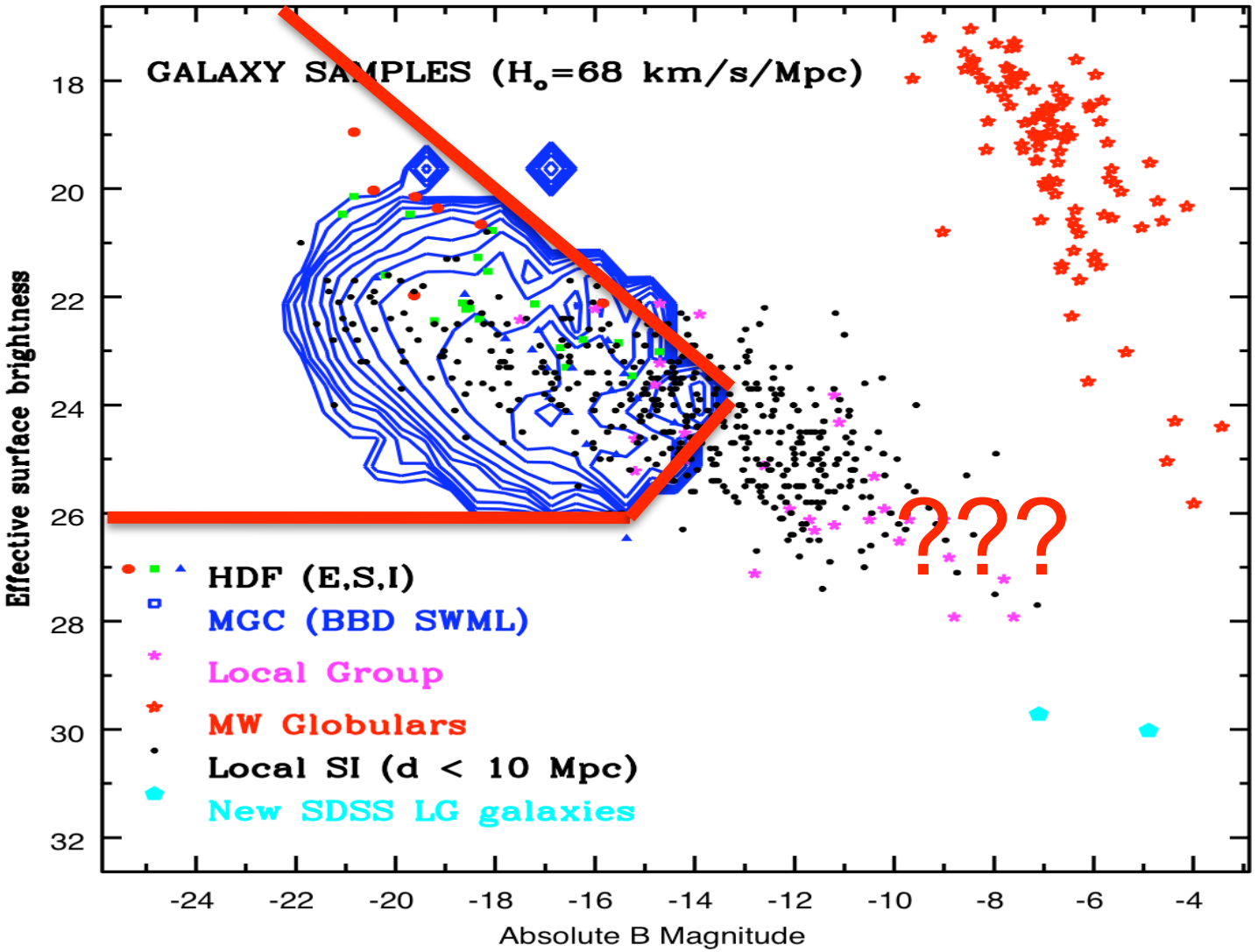
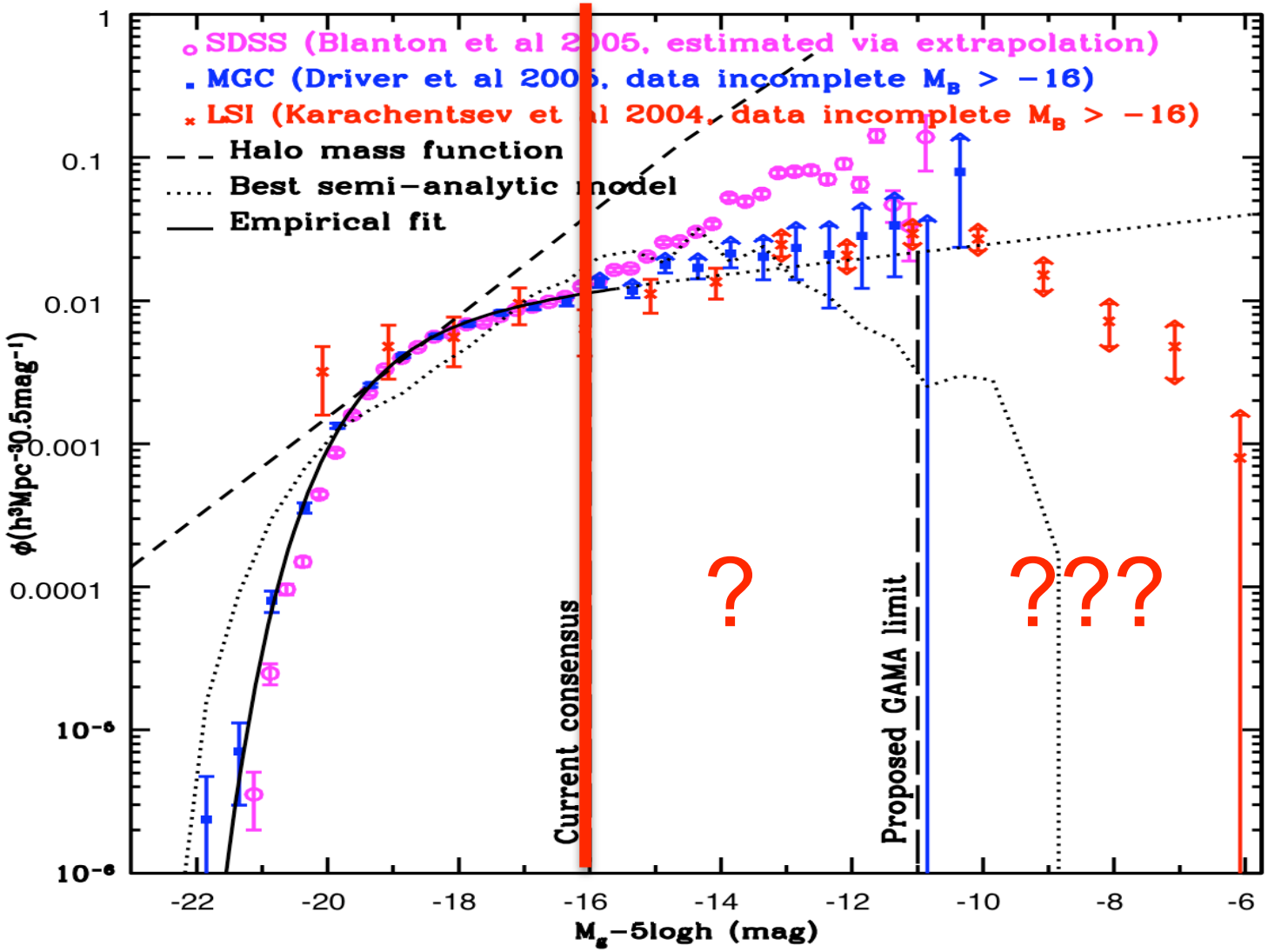
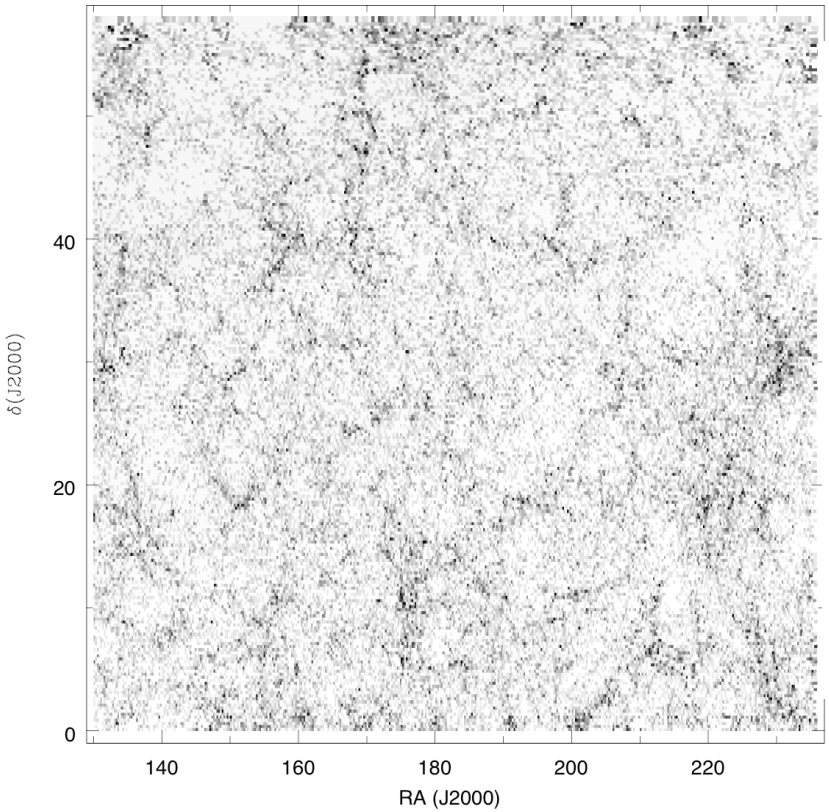


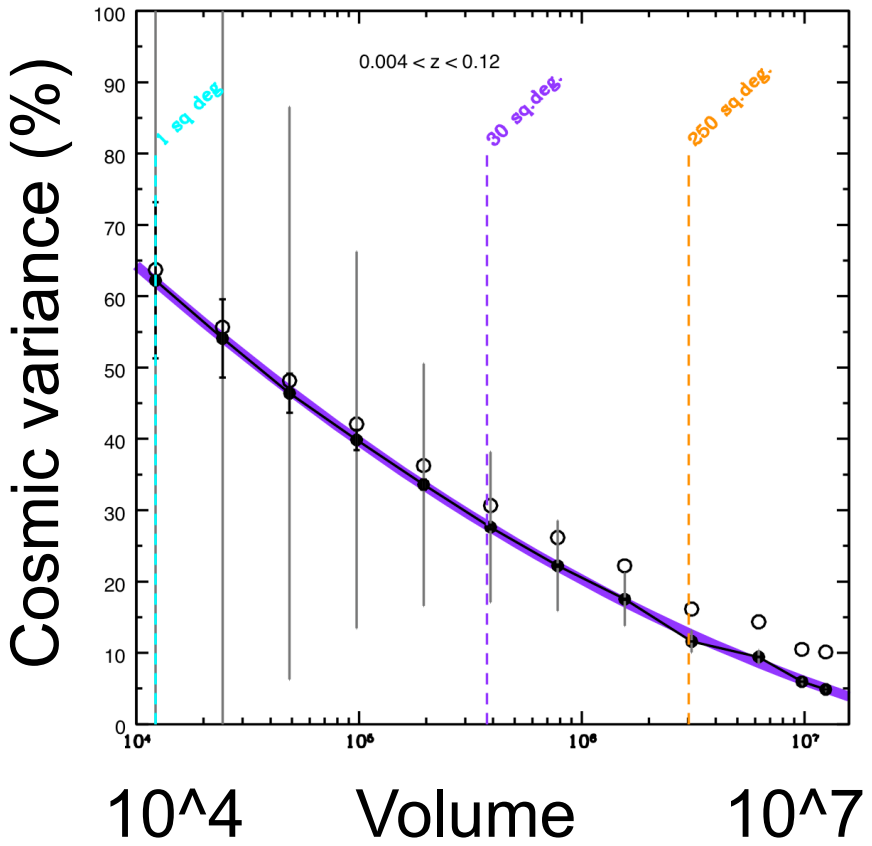
4. Sample incompleteness: LF



5. Cosmic variance

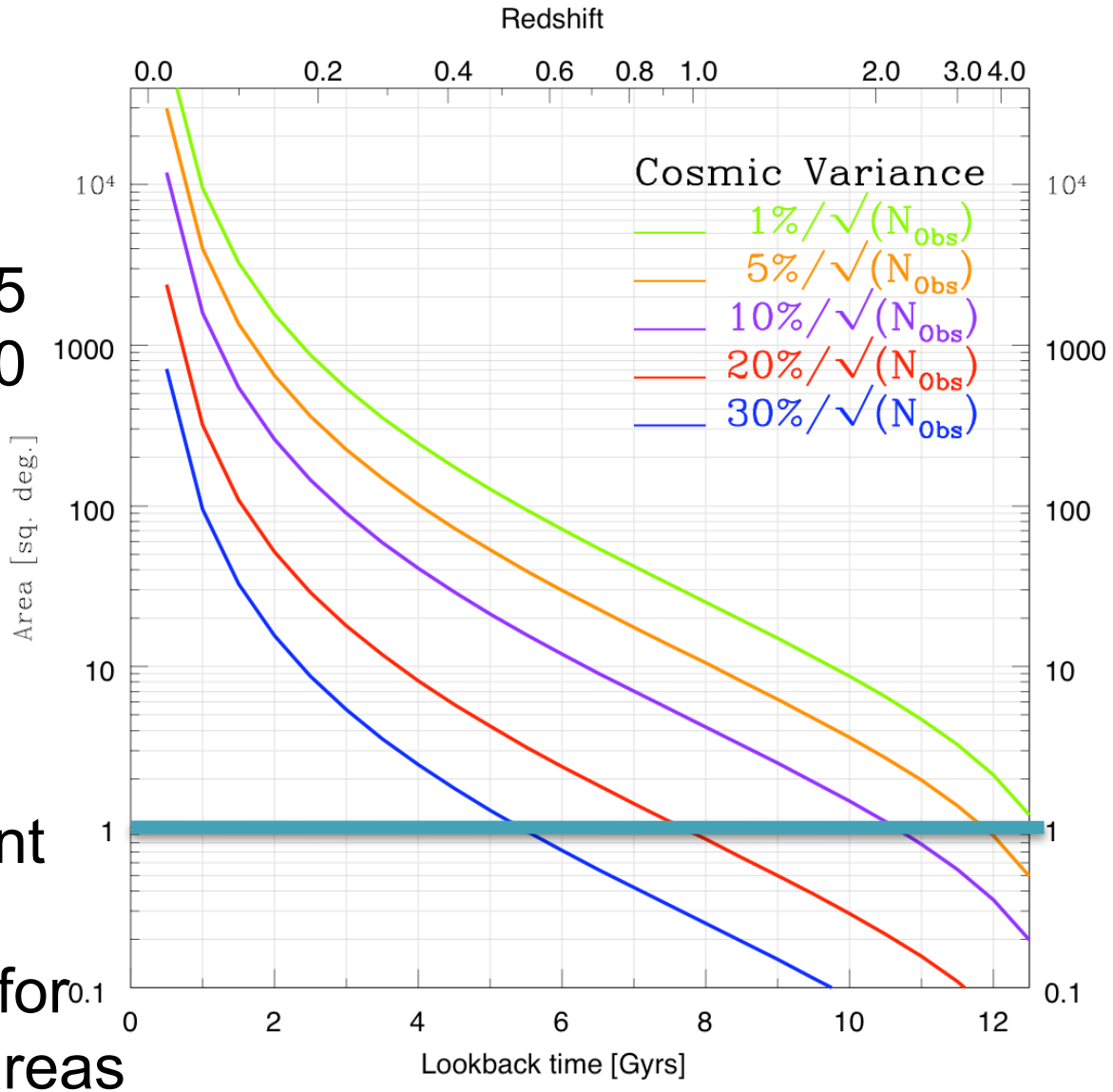
Distribution of L* galaxies to z<0.1 over 5000 sq deg





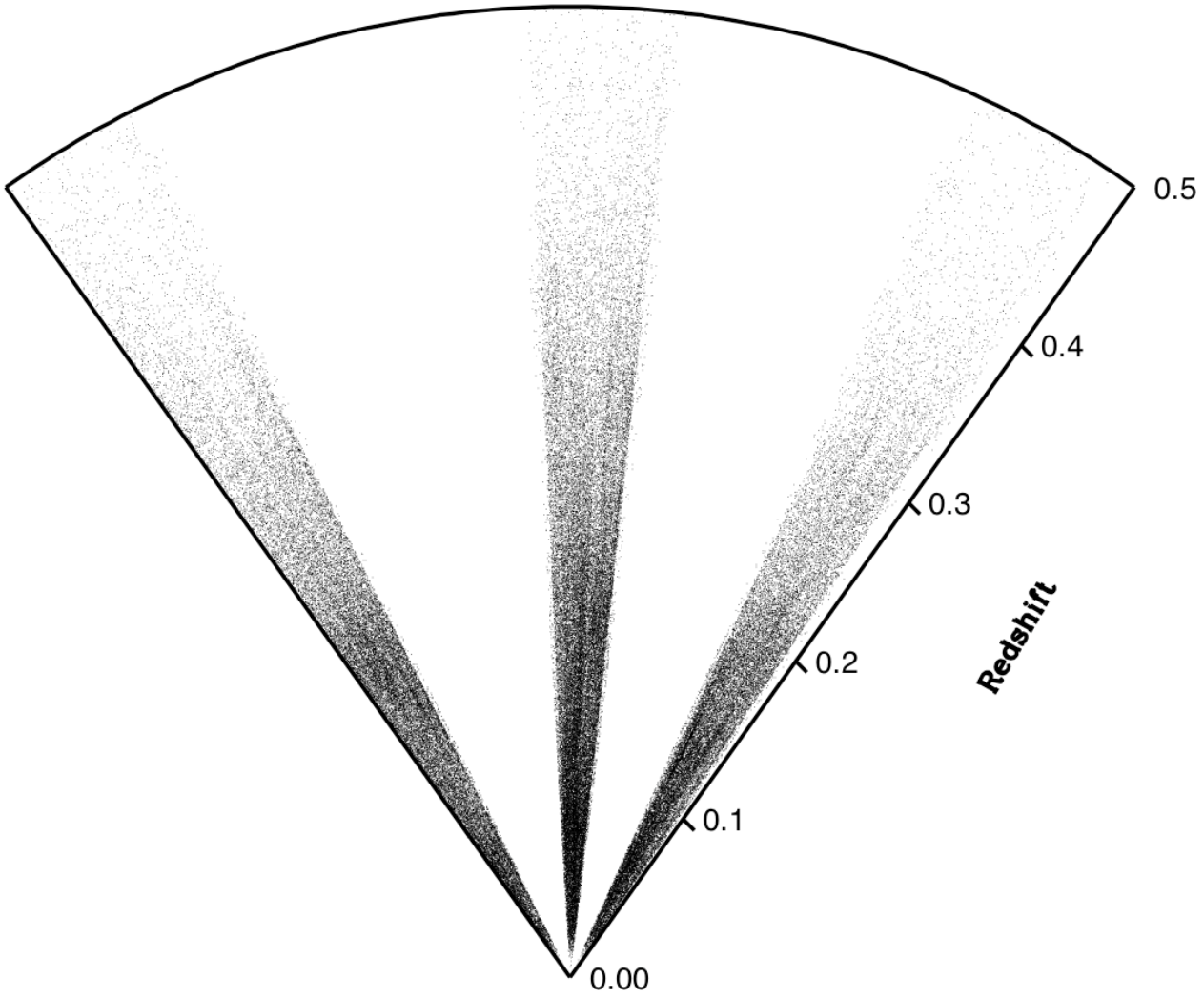
For 1 sq deg
Cosmic Var.
30% @ z=0.5
10% @ z=2.0

Reduces by root-n for n independent pointings.
More slowly for contiguous areas



(Driver 2009)

6. Photo-z versus spectro-z



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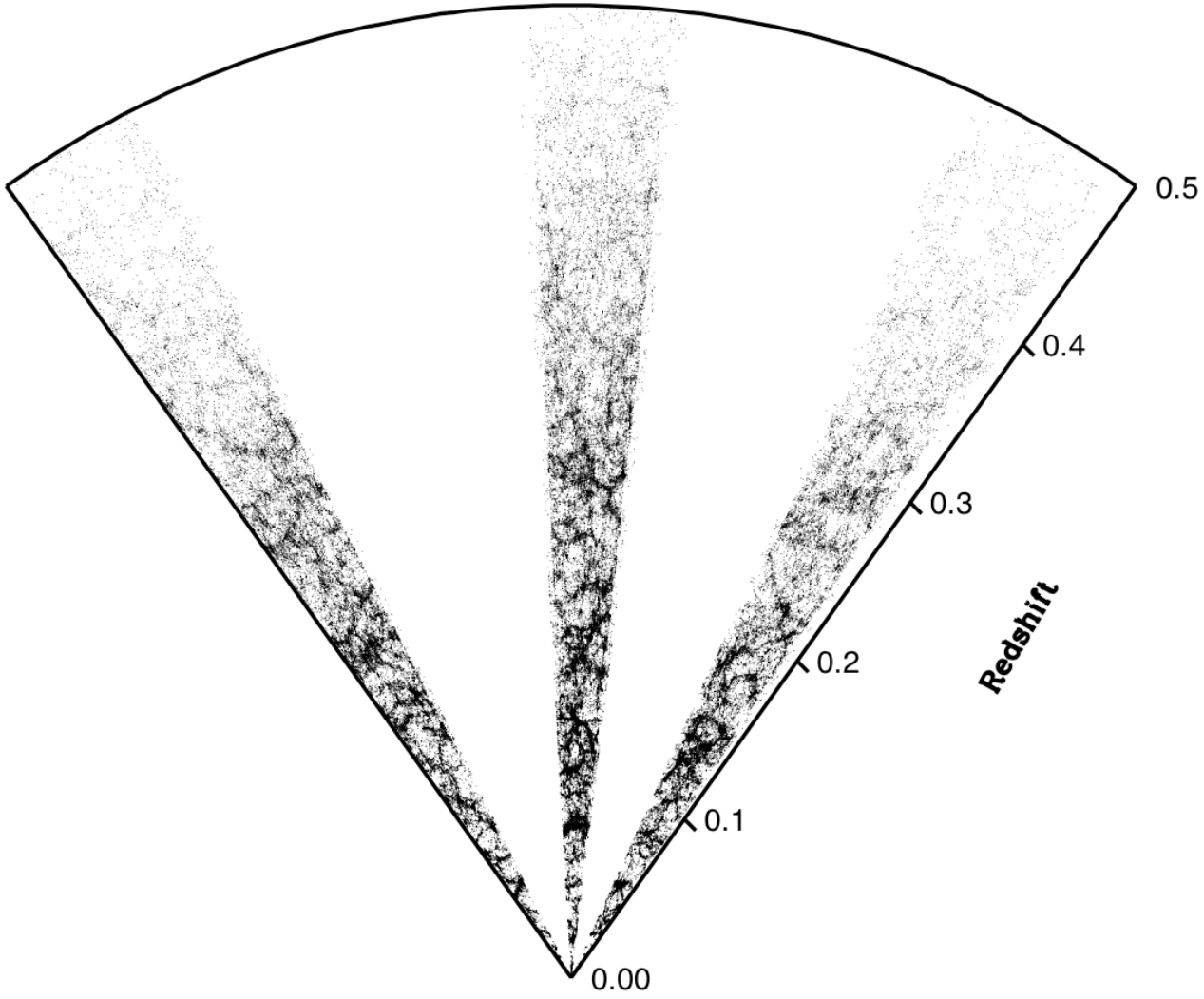
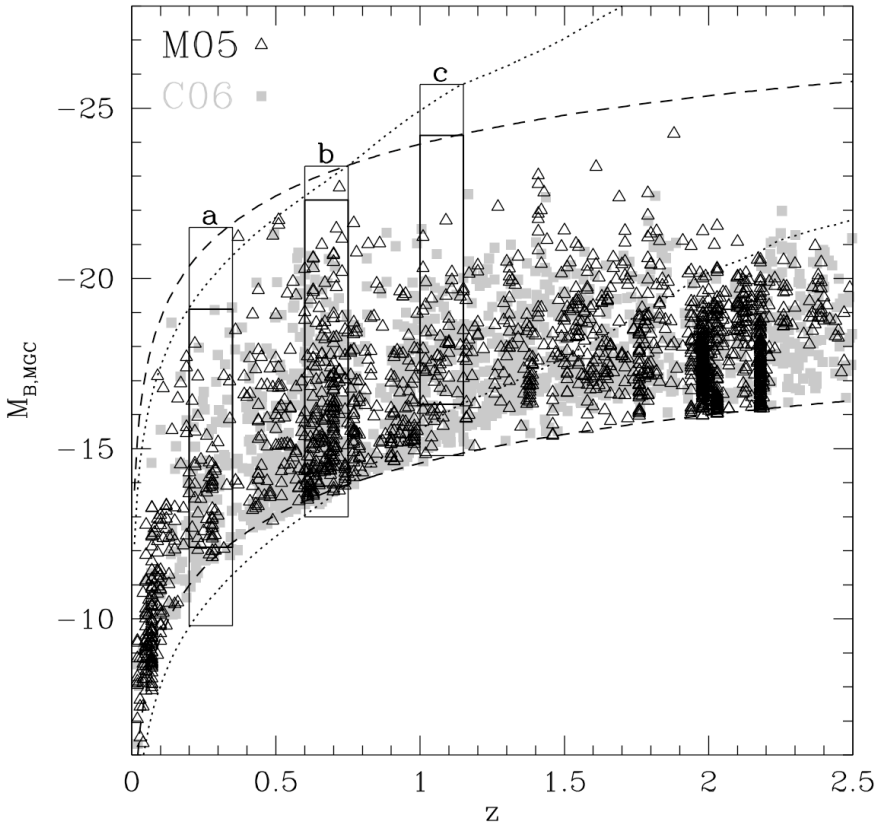
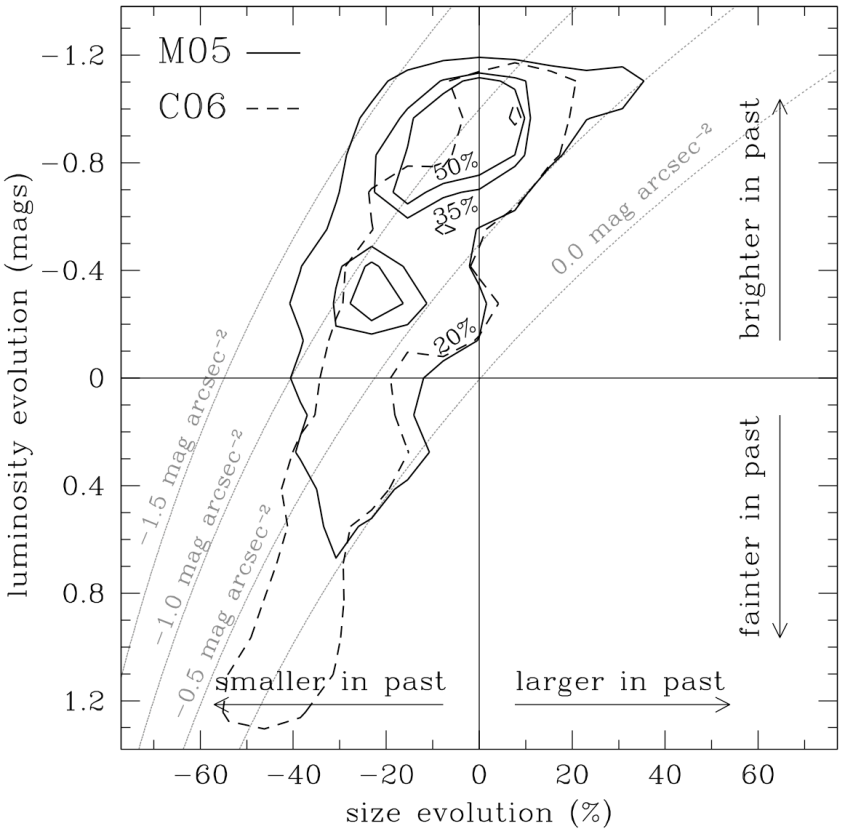


6. Phot-z v spectro-z: HDF analysis





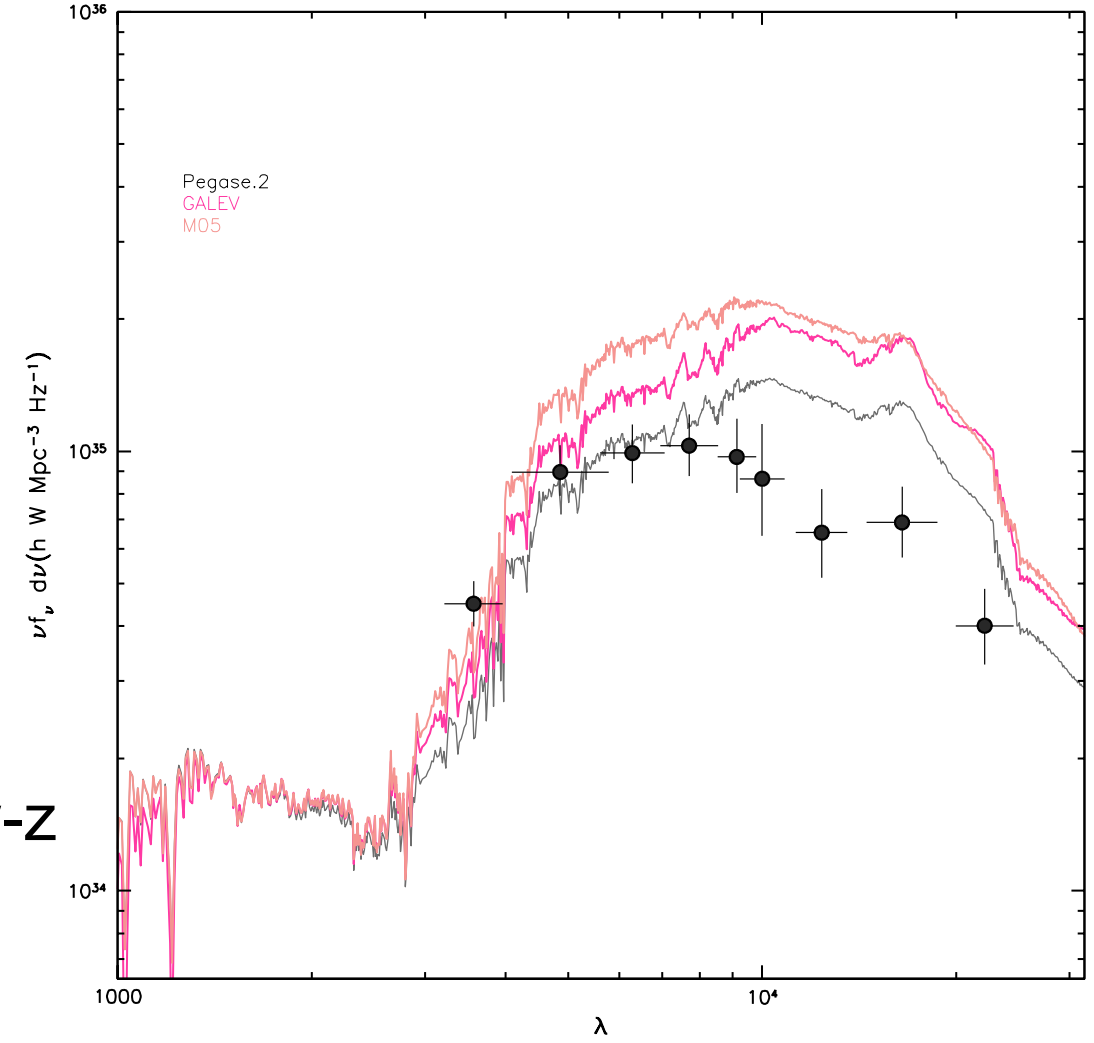
Cameron & Driver 2007)

7. SFH v Stellar Mass Density

Cosmic SFH
+ Univ. IMF =
Cosmic SED

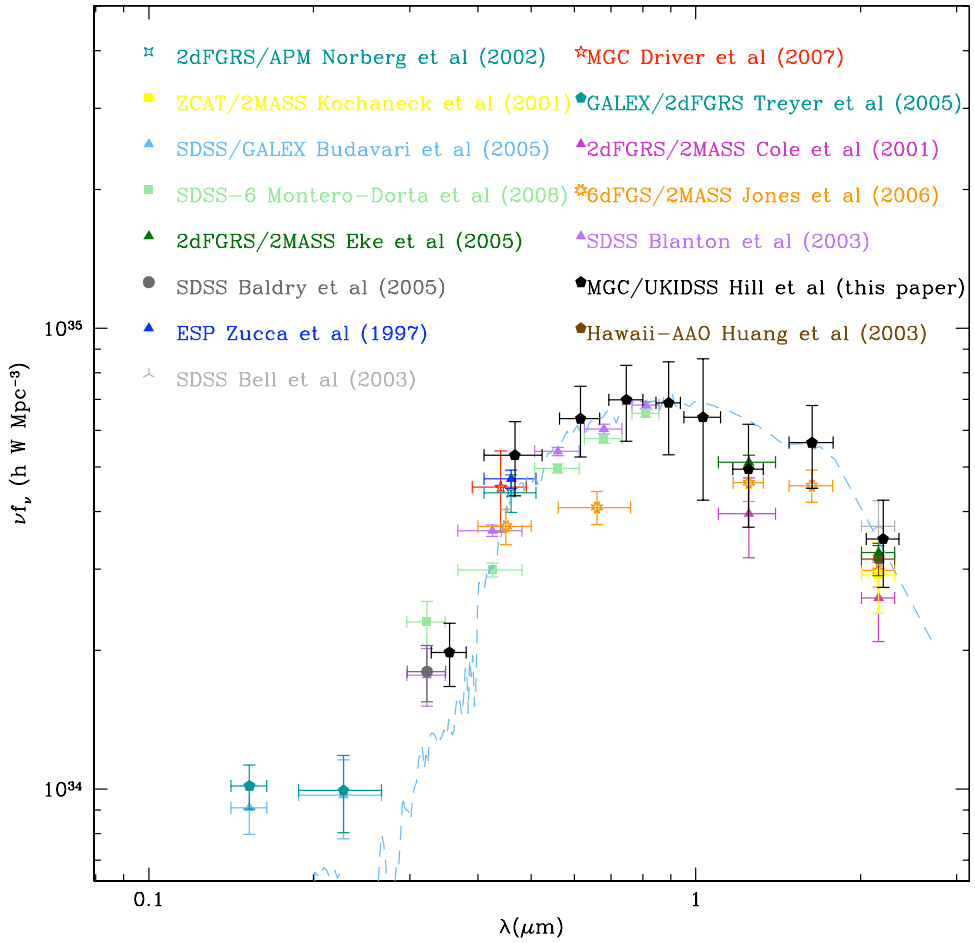
x2 discrepancy
in stellar mass

Variable IMF
Incorrect SFH
Hidden SF at low-z

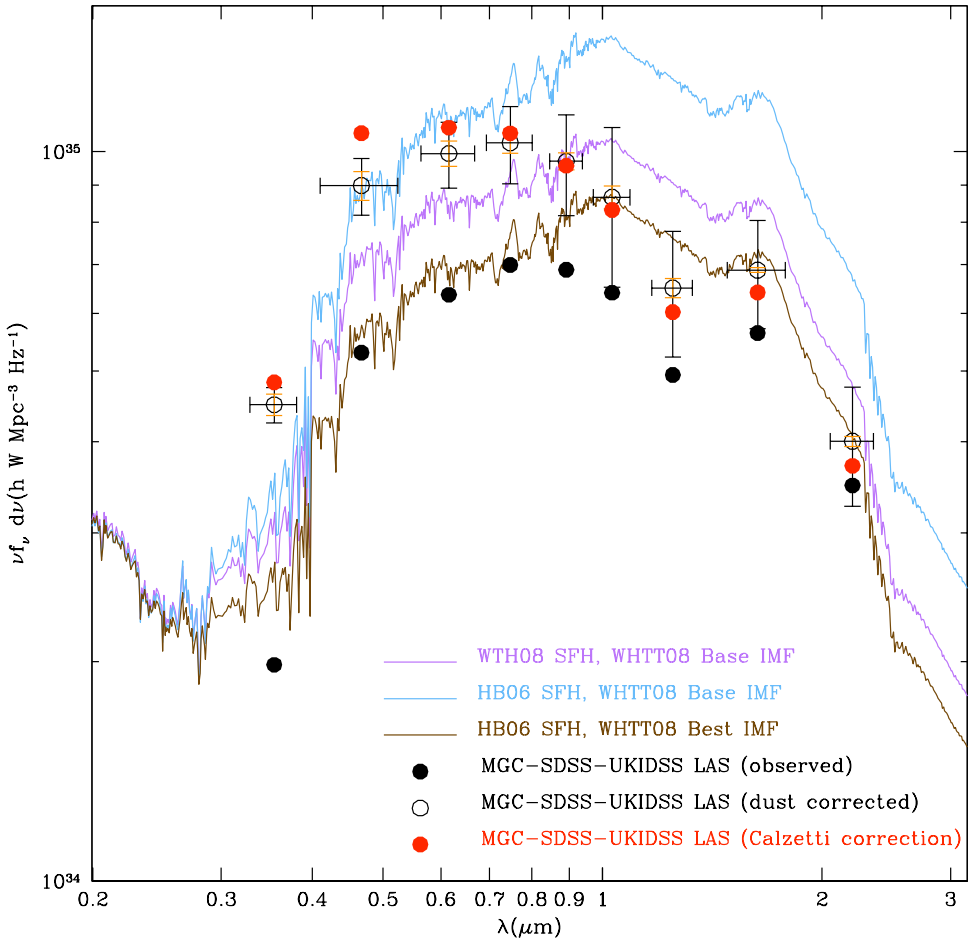


(Data: Hill et al submitted; Model: Wilkins et al, in prep)

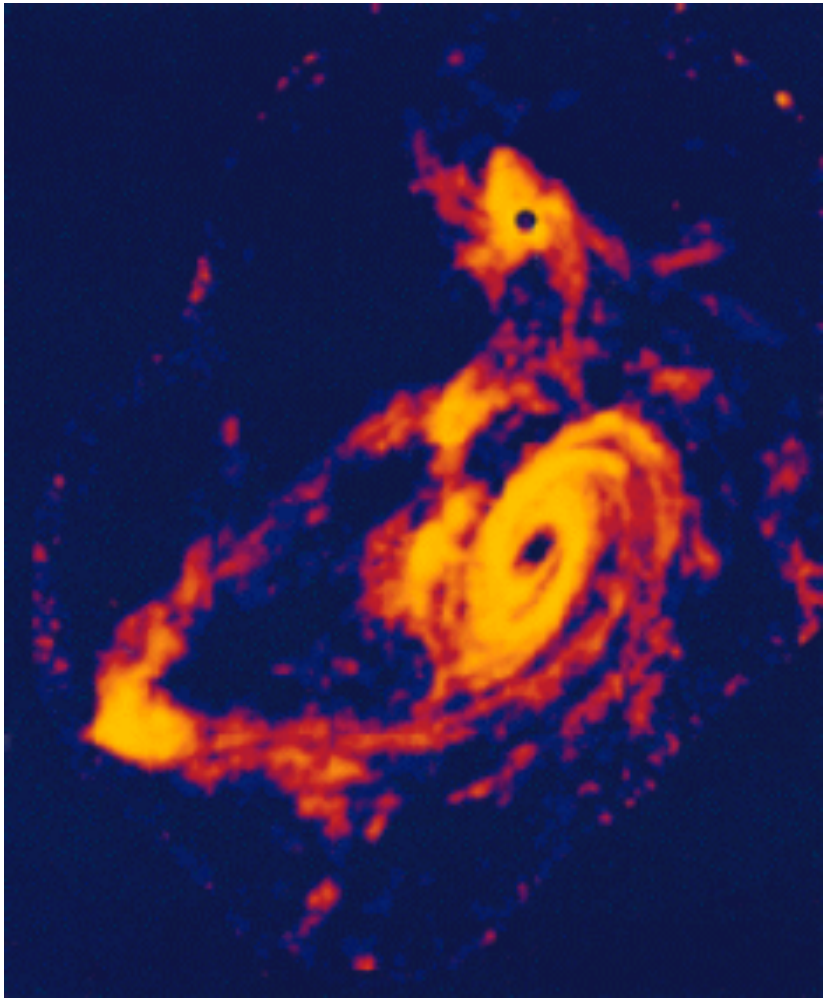
7. SFH v Stellar mass desnity

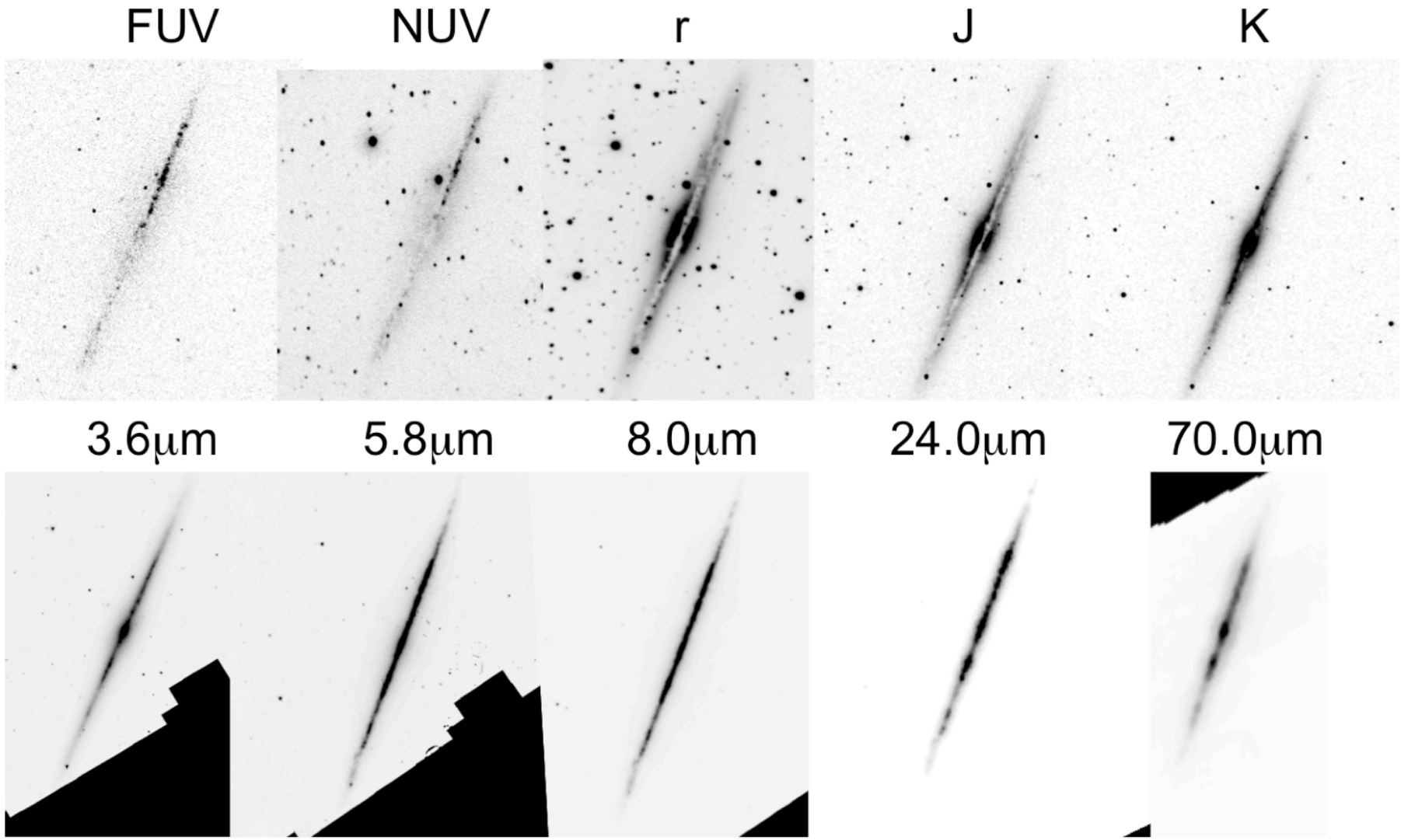


7. SFH v Stellar mass density

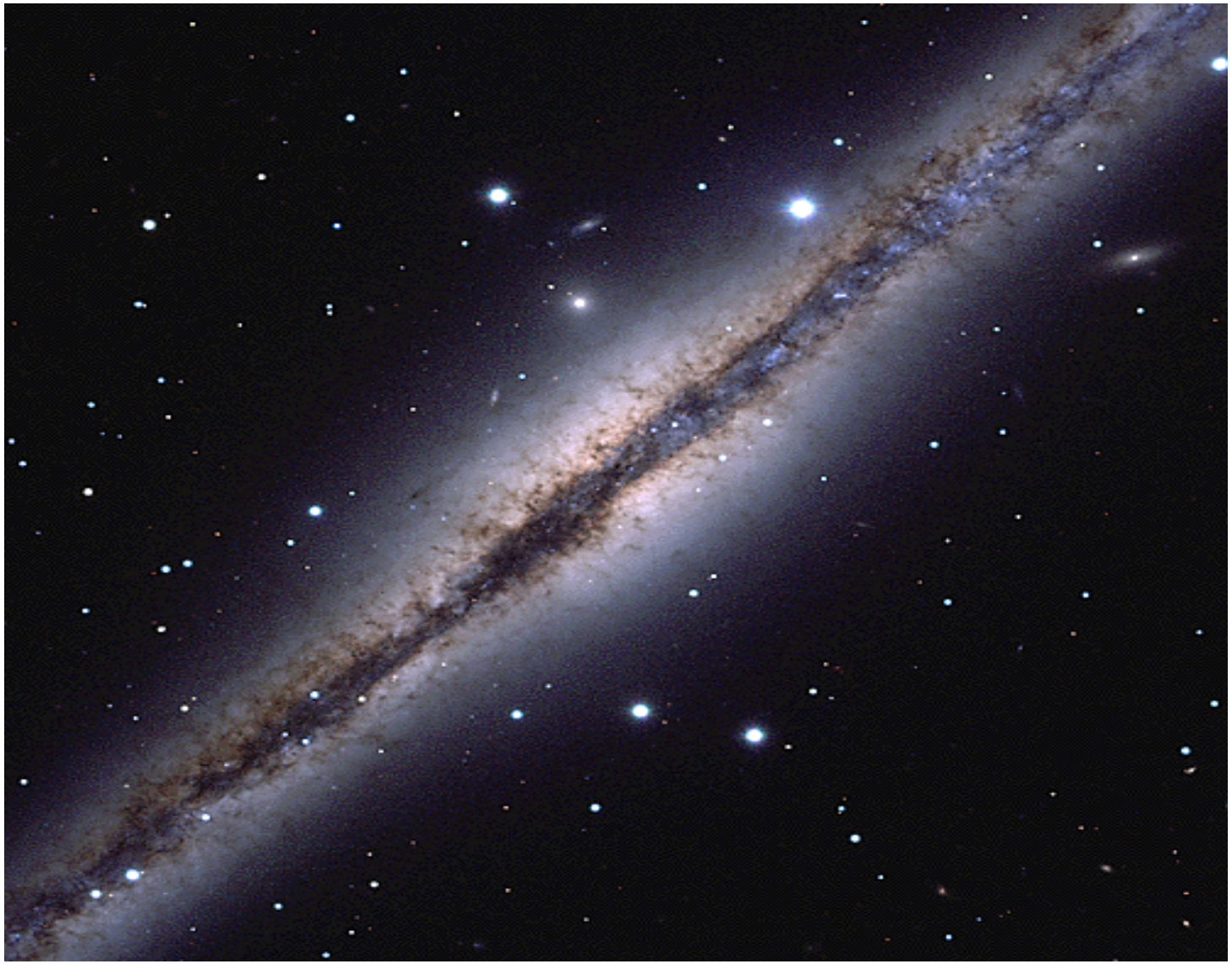


8. Wavelength bias




NGC891
FUV
NUV
r
J
K
3.6μm
5.8μm
8.0μm
24.0μm
70.0μm

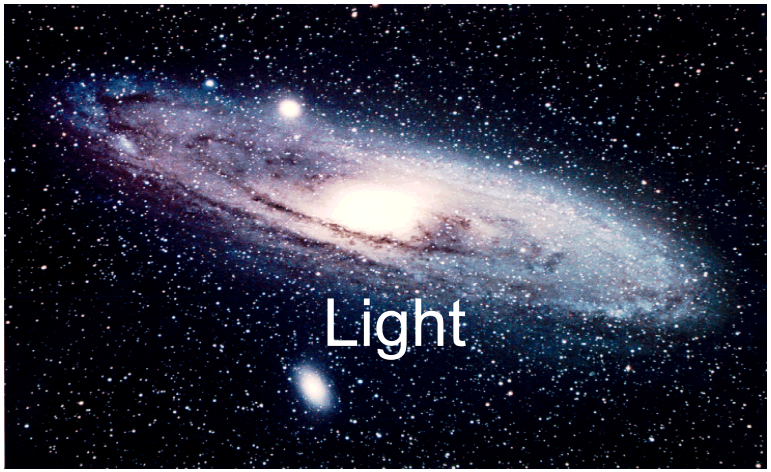
9. Dust attenuation



10. Disconnect with CDM

- Ben Moore's talk?

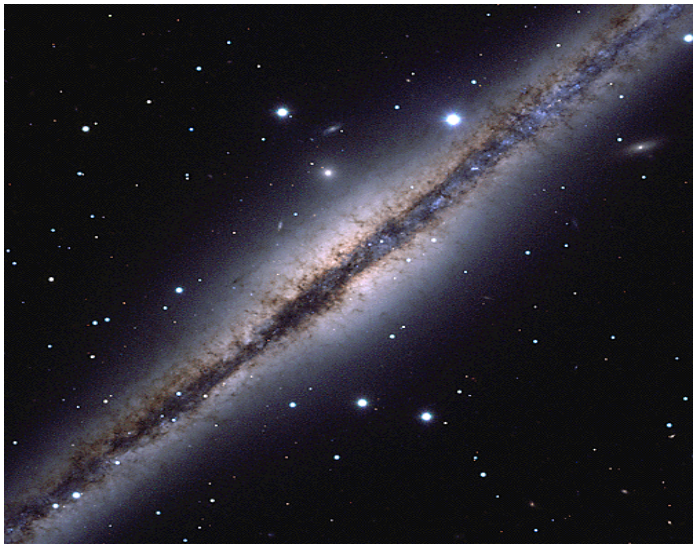
Numerical galaxy

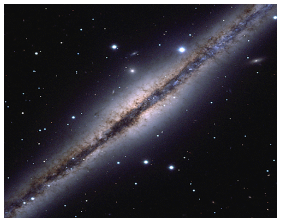


Observed galaxy

Dust: Recent (optical) papers

- Shao et al (2007)
- Choi et al (2007)
- Driver et al (2007, 2008)
- Graham & Worthy (2008)
- Balin & Harris (2008)
- Unterborn & Ryden (2008)
- Padilla & Strauss (2008)
- Cho & Park (2009)
- Maller et al (2009)
- Ganda et al (2009)
- Brice et al (2009)
- Masters et al (2009)
- Yip et al (2009)



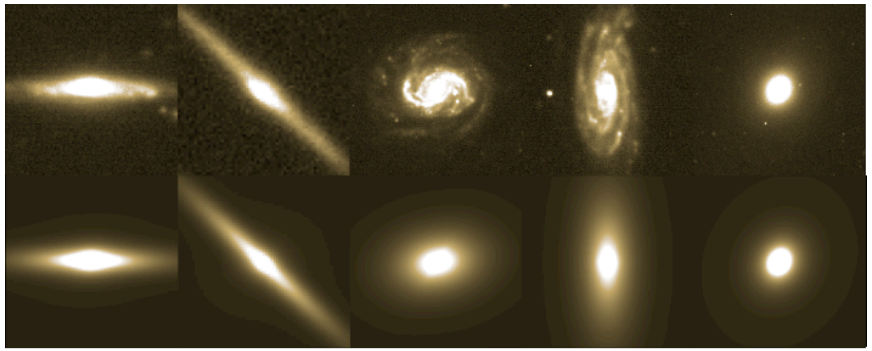


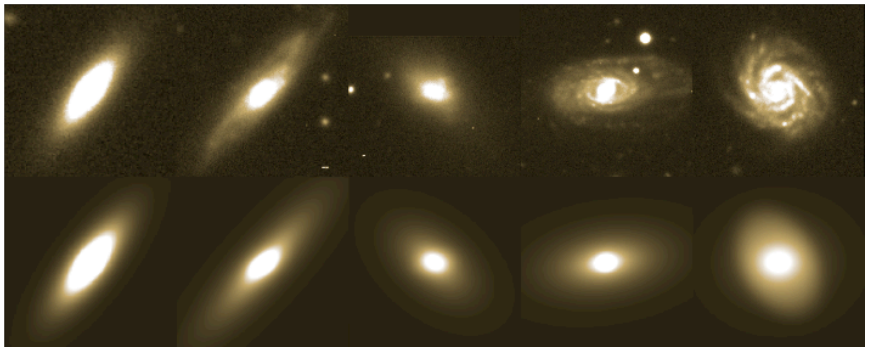
Dust: The MGC

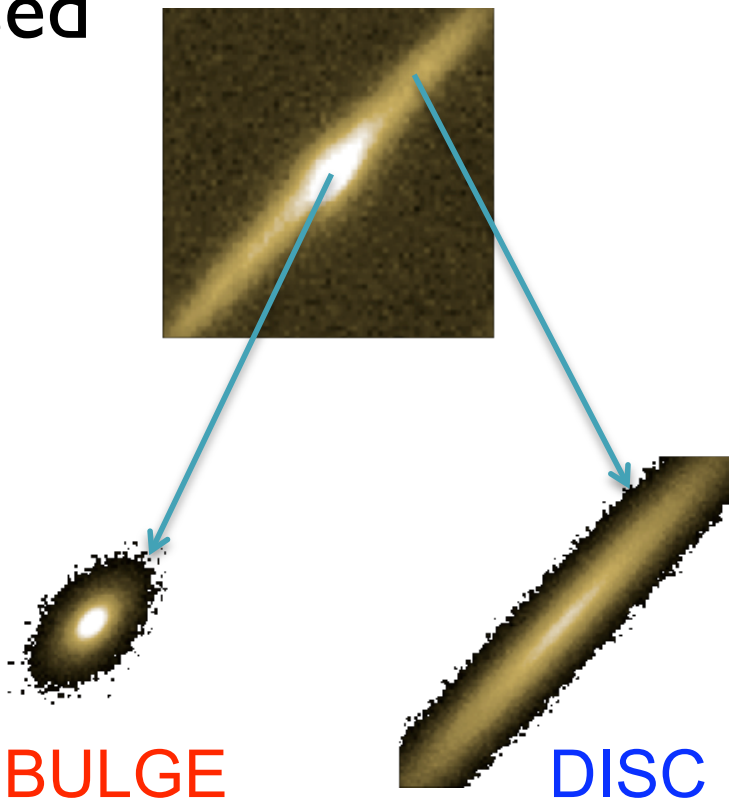
- 36 sq deg equatorial strip
- B band only 1” + SDSS ugriz + UKIDSS YJHK
- 10,092 galaxies with B < 20 (resolved)
- 98% redshift complete (SDSS+AAT)

Dust: Bulge disc decompositions

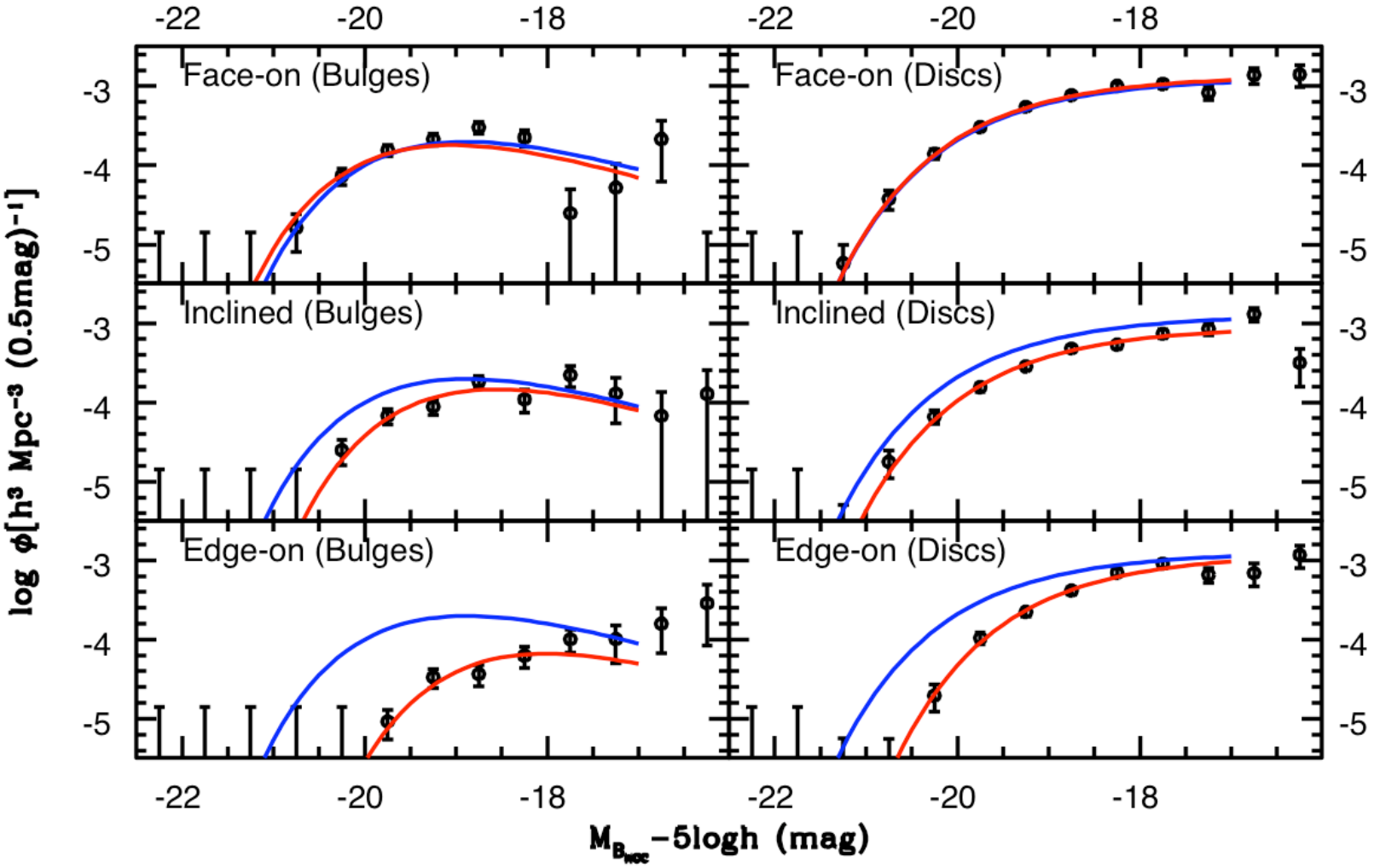
- 10,092 galaxies via GIM2D (Allen et al 06)
- Verified via 1000 repeat observations
- Only resolved bulges used





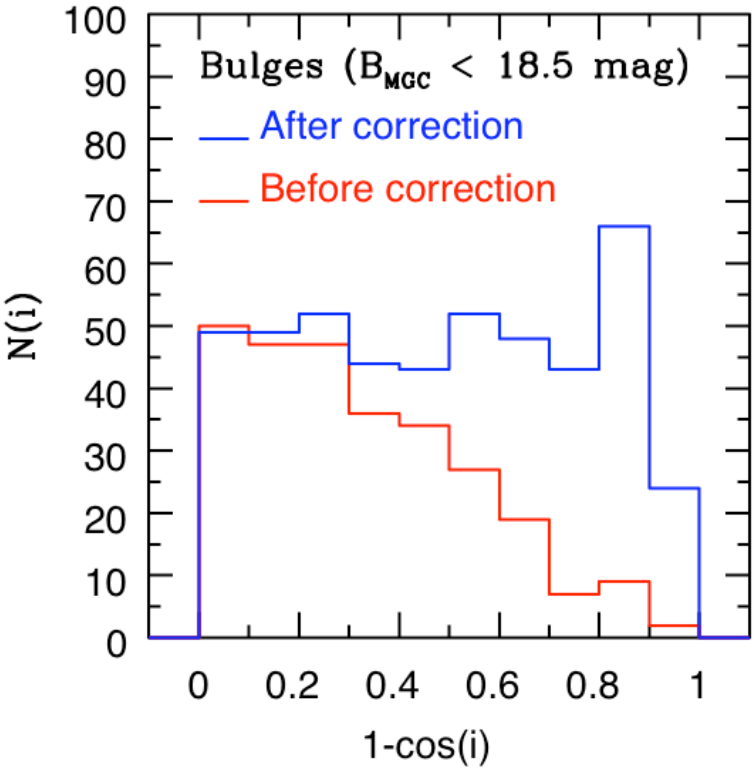


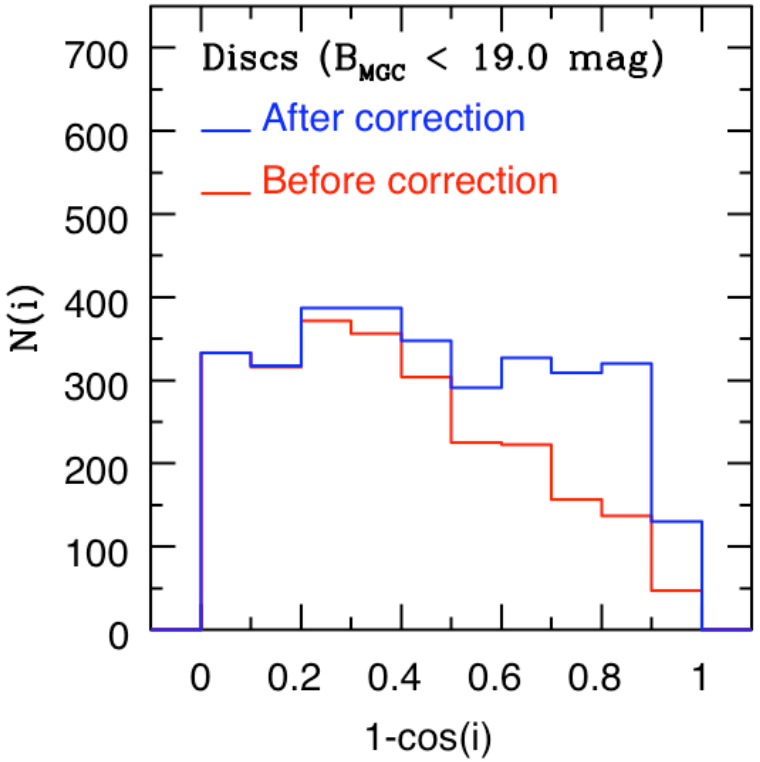
Dust: LF v cos(i)



(Driver et al 2007)

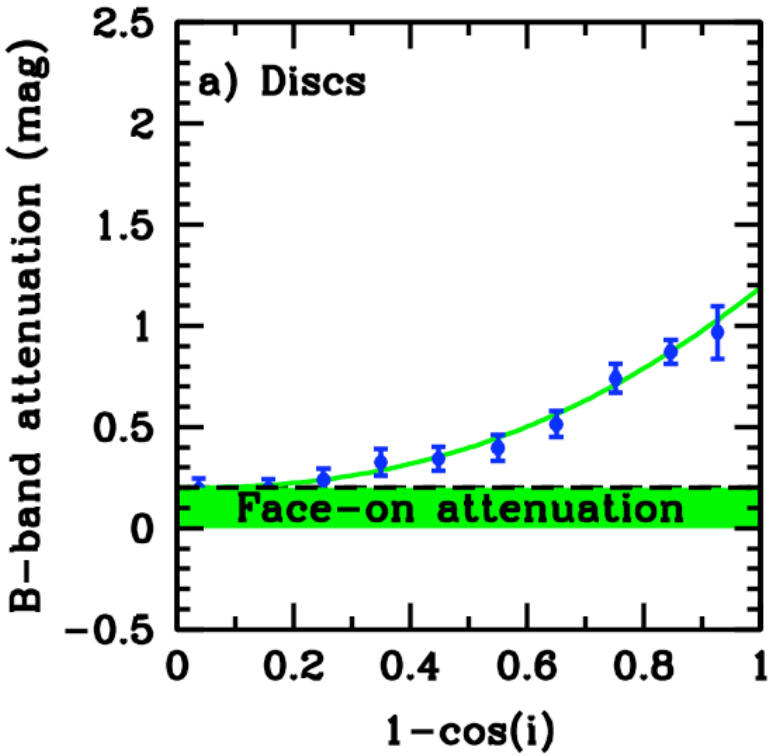
Dust: cos(i) before and after

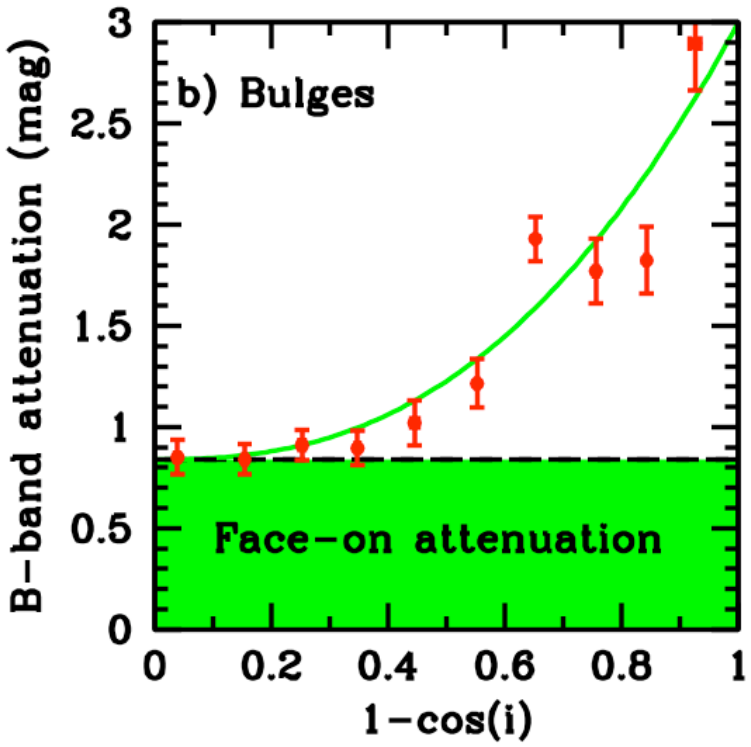




(Driver et al 2007)

Dust: Bulge and disc attenuation



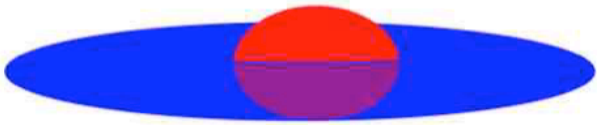


(Driver et al 2007)

Dust transformation ?

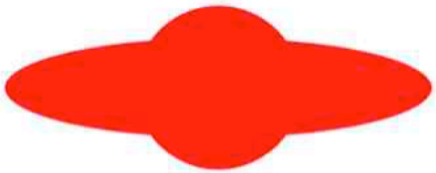
1. Mid-type spiral falling into cluster (cos*i*=0.5):
   B=0.2, D=0.8, B/T=0.2, L=1.0, Blue
   Sc (NB: cos(i)=0.0=Sa, cos(i)=1=Sd)

2. *destroy dust* (heating):
   B=0.6, D=1.2, B/T=0.3, L=1.8 Green
   Sab



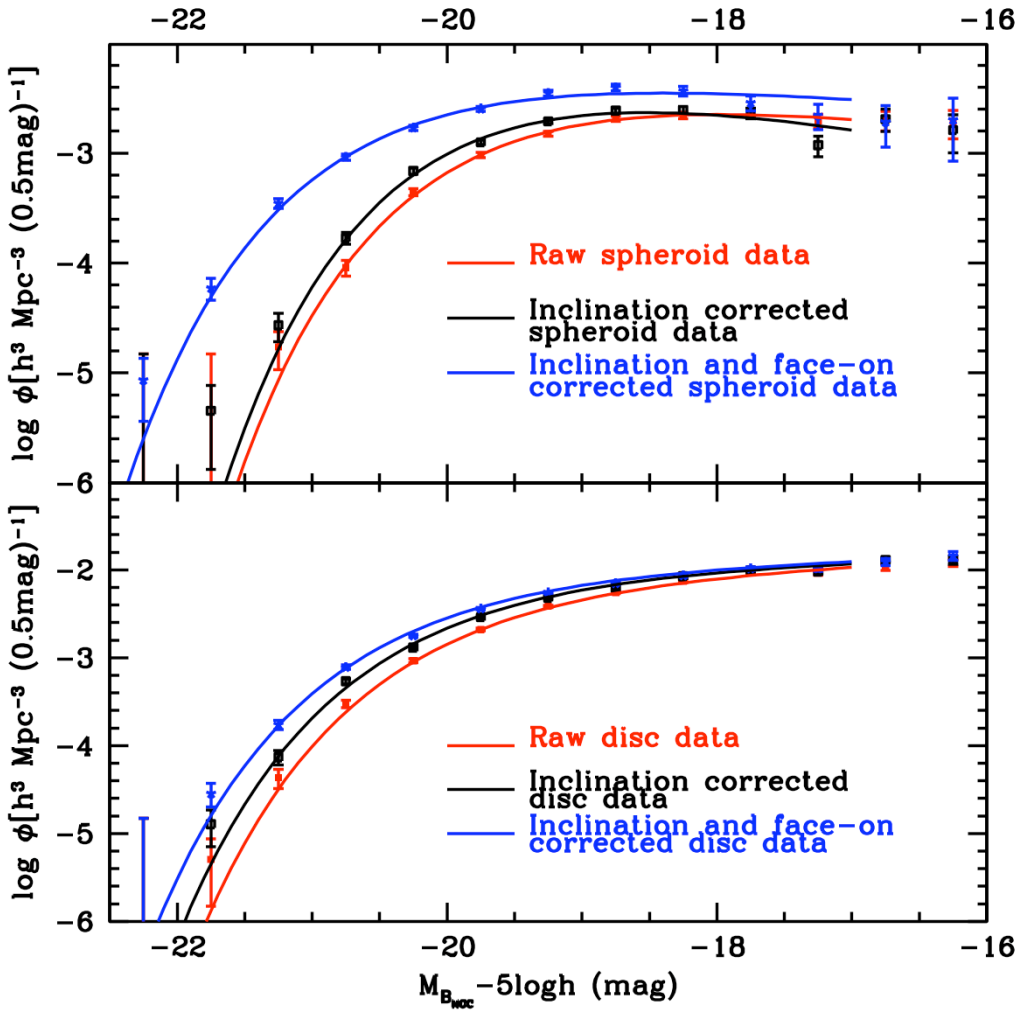
3. Truncate star-formation in disc (stripping):
   B=0.6, D=0.8, B/T=0.4, L=1.4, Red
   Sa/S0

4. Further fading and harassment etc:
   B=0.6, D=0.6, B/T=0.5, L=1.2, Red
   S0a



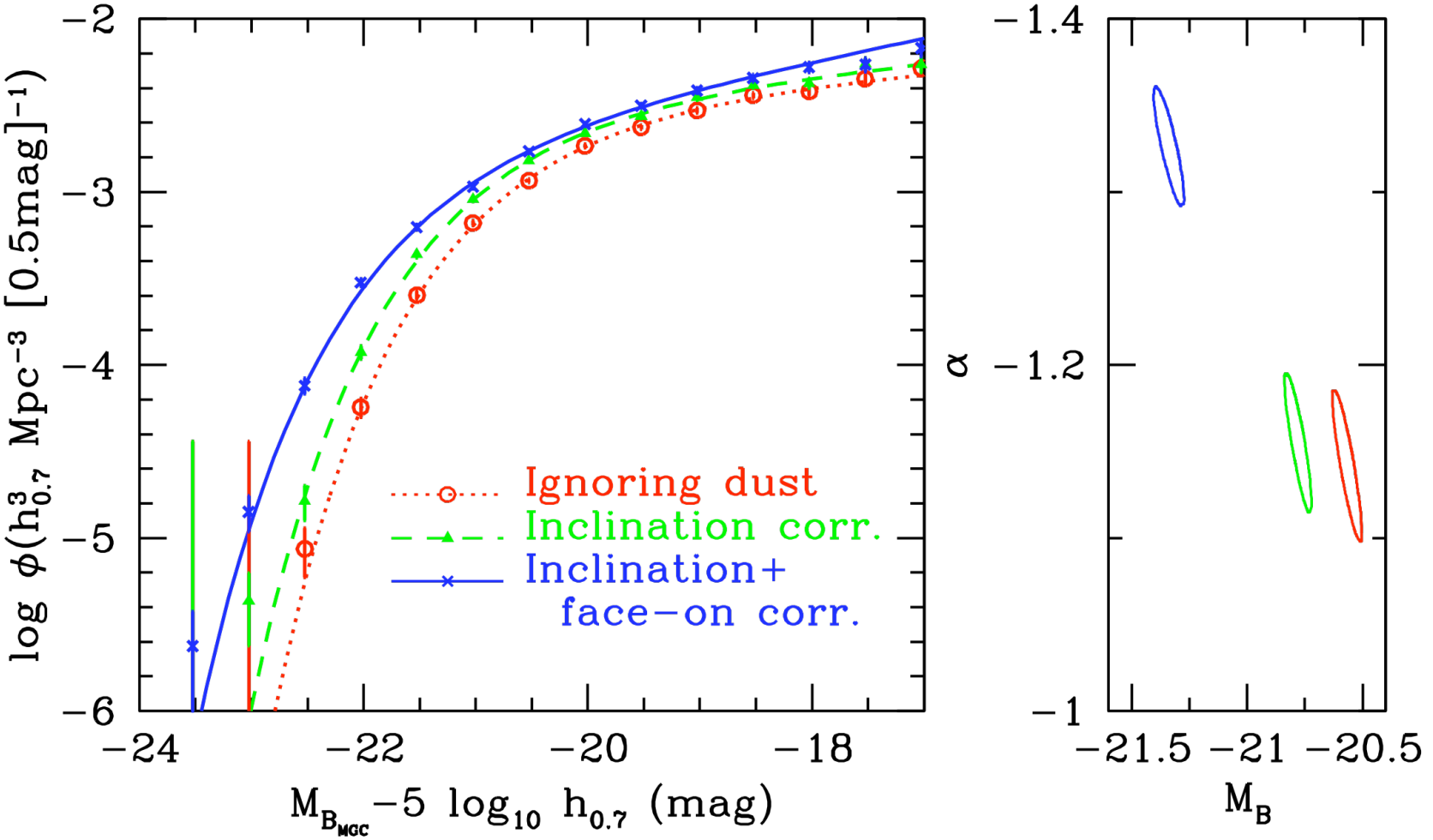
5. Transformation from Sc-S0a purely by removing dust and switching off SF! it gets ***earlier***, ***redder*** and ***brighter*** without dry mergers!

Dust: Impact on bulge & disc LFs



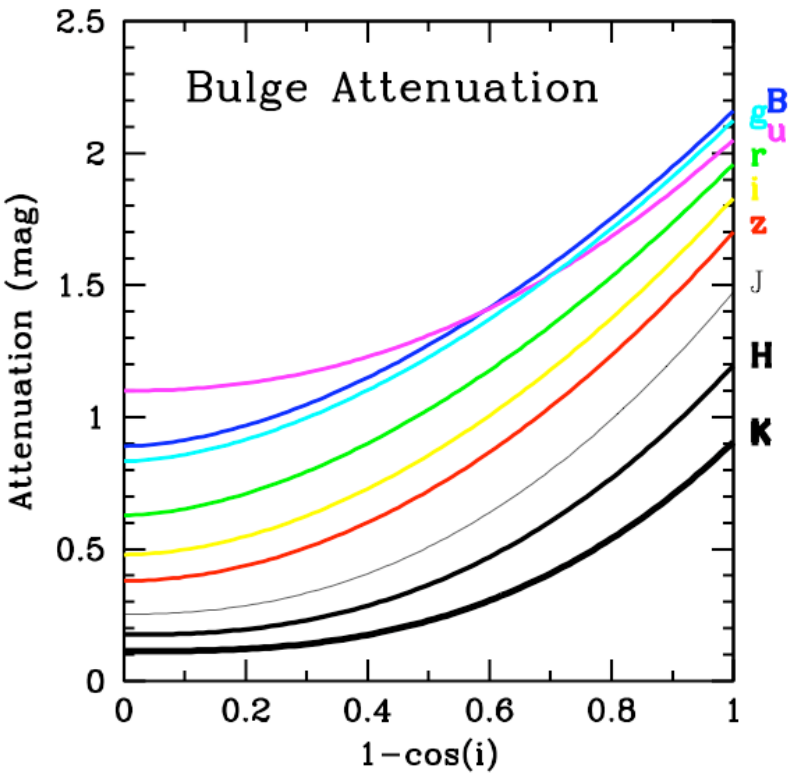
(Driver et al 2007)

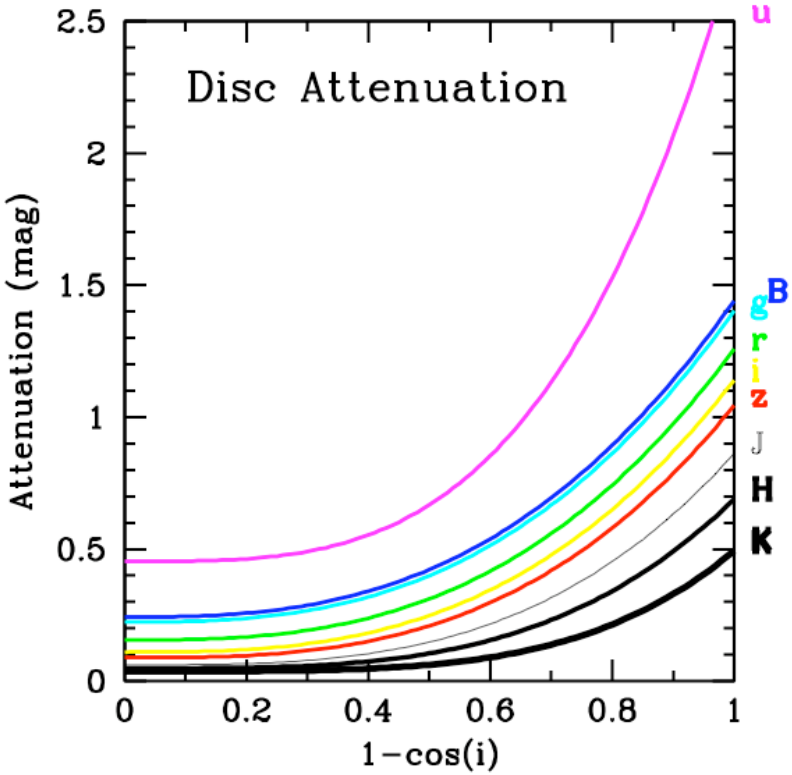
Dust: Impact on global LF



(Driver et al 2008)

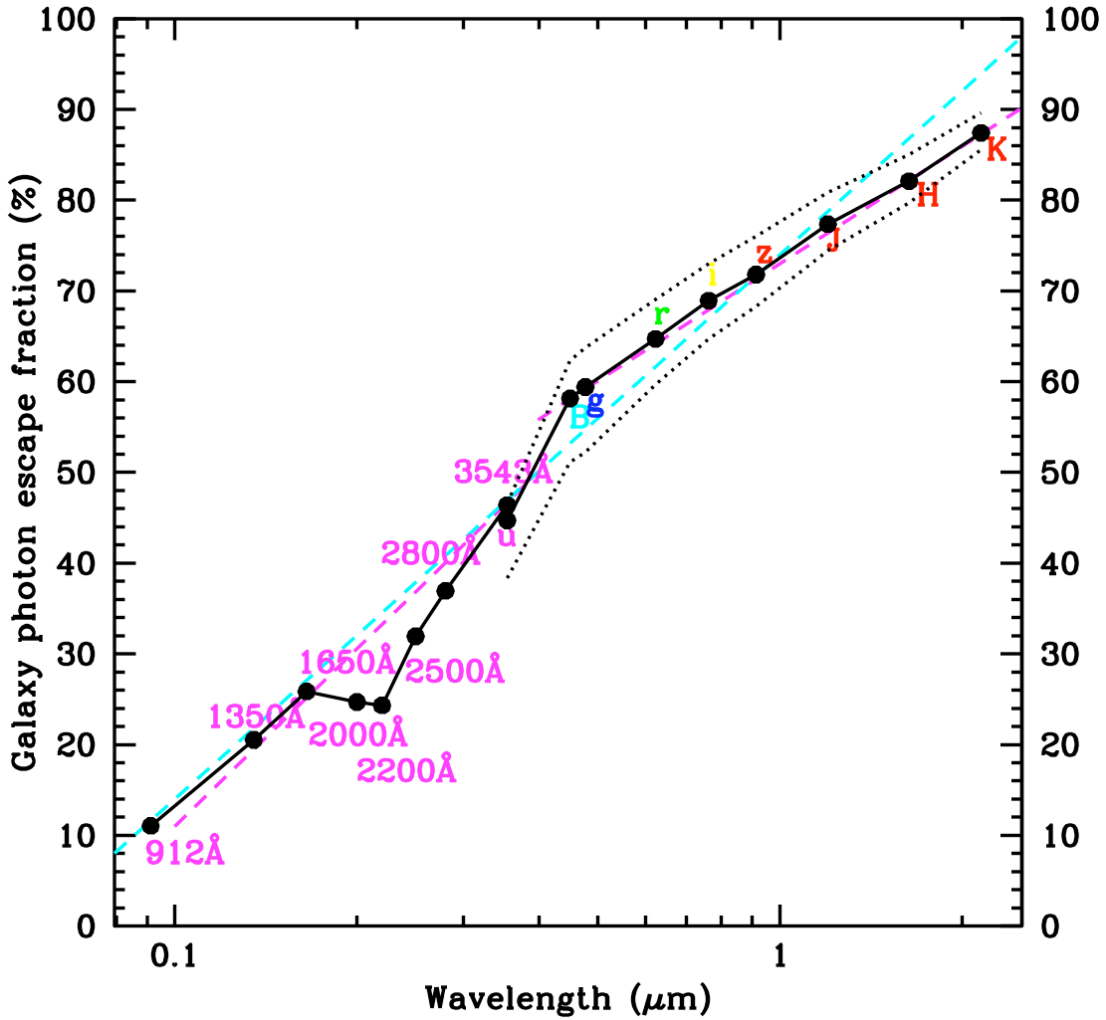
Dust: Wavelength dependence





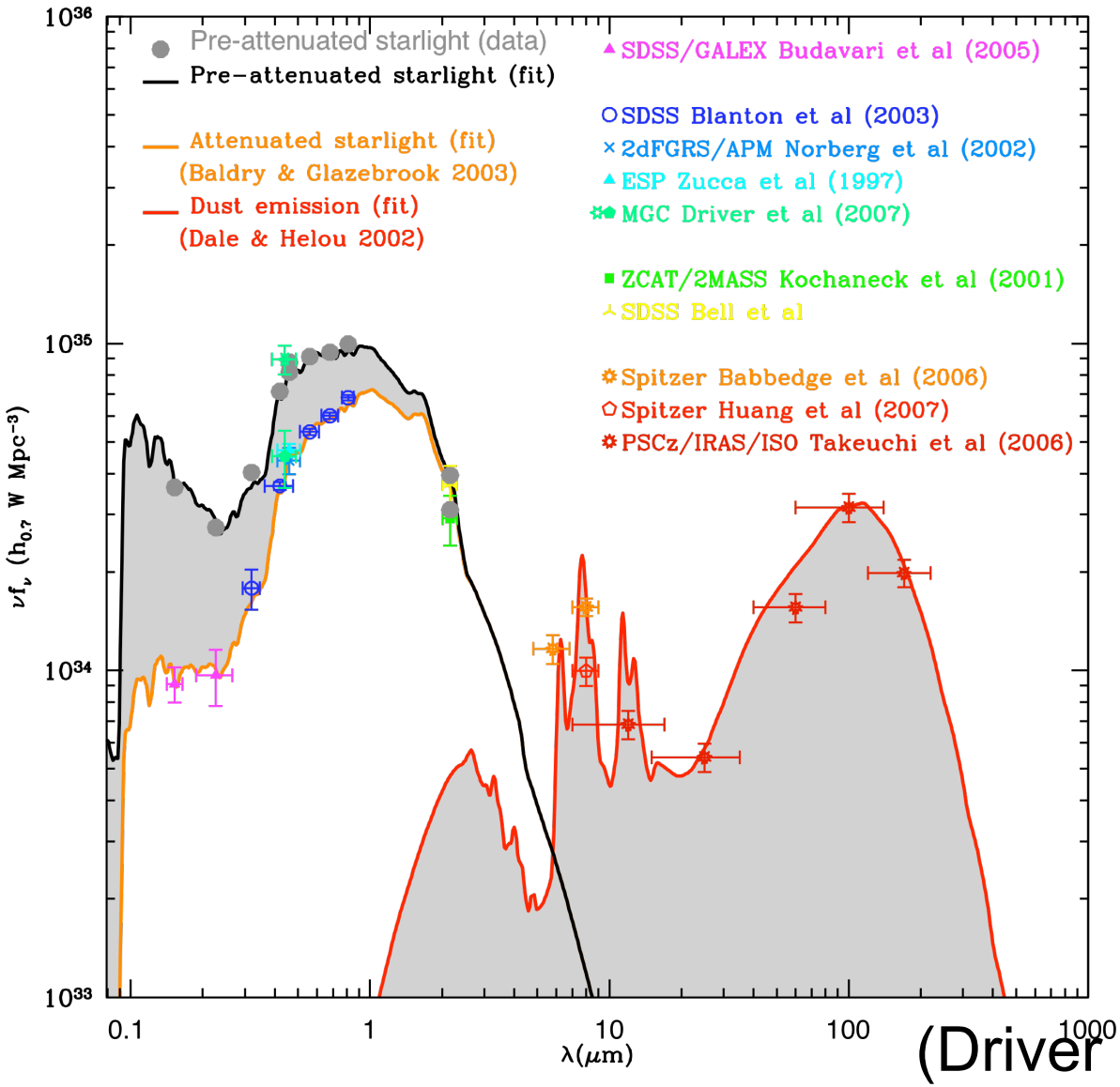
(Driver et al 2008)

Dust: Mean photon escape fraction



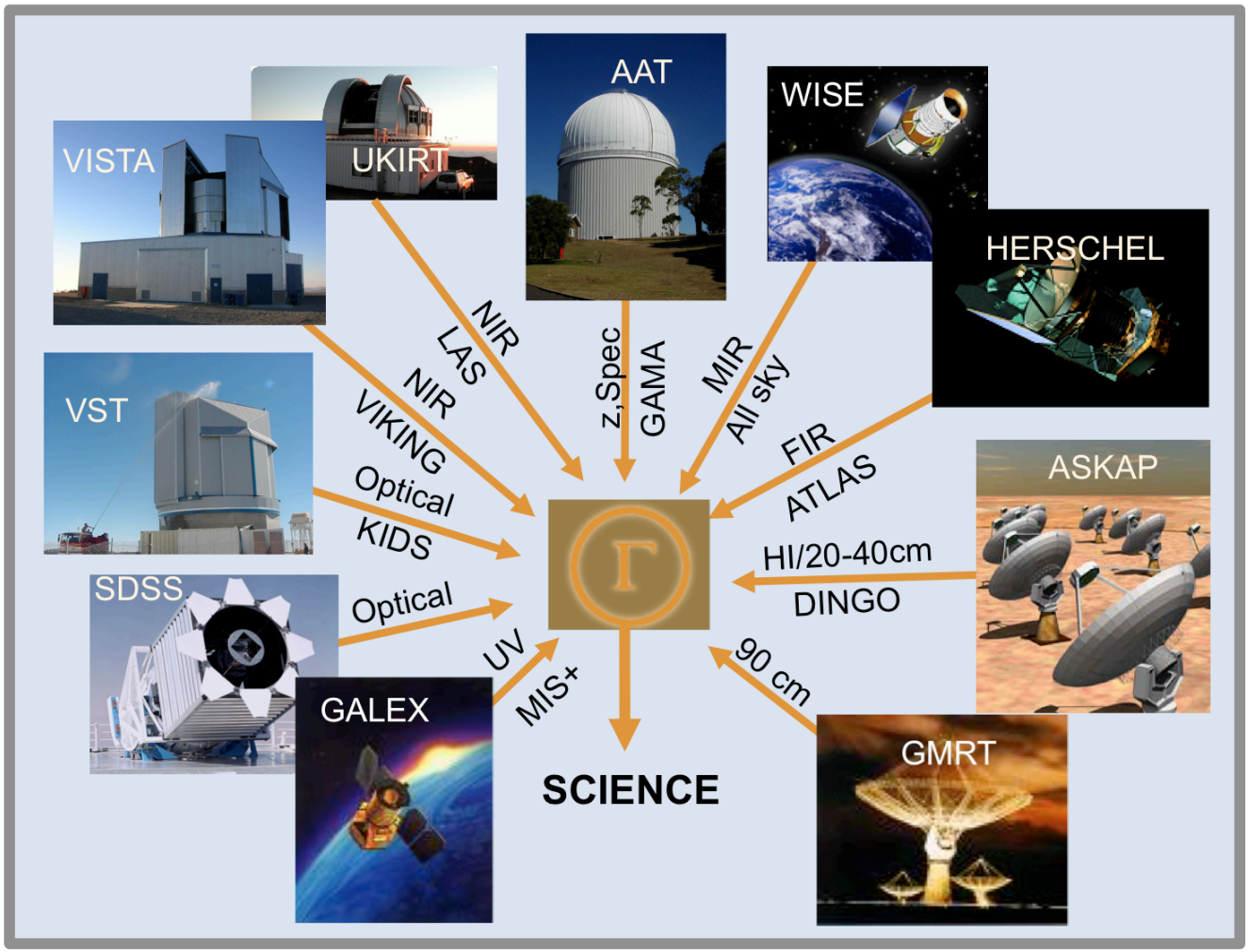
(Driver et al 2008)

Dust: Balancing the energy budget



(Driver et al 2008)

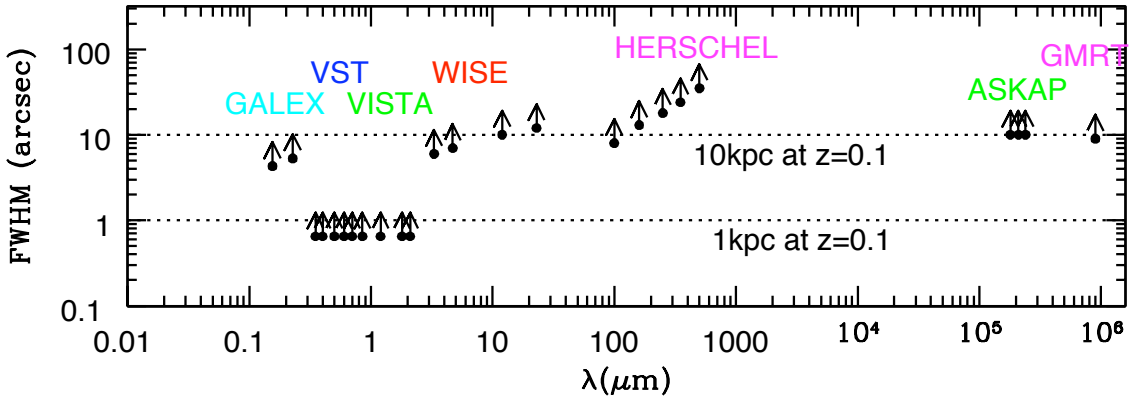
Galaxy and Mass Assembly (GAMA)



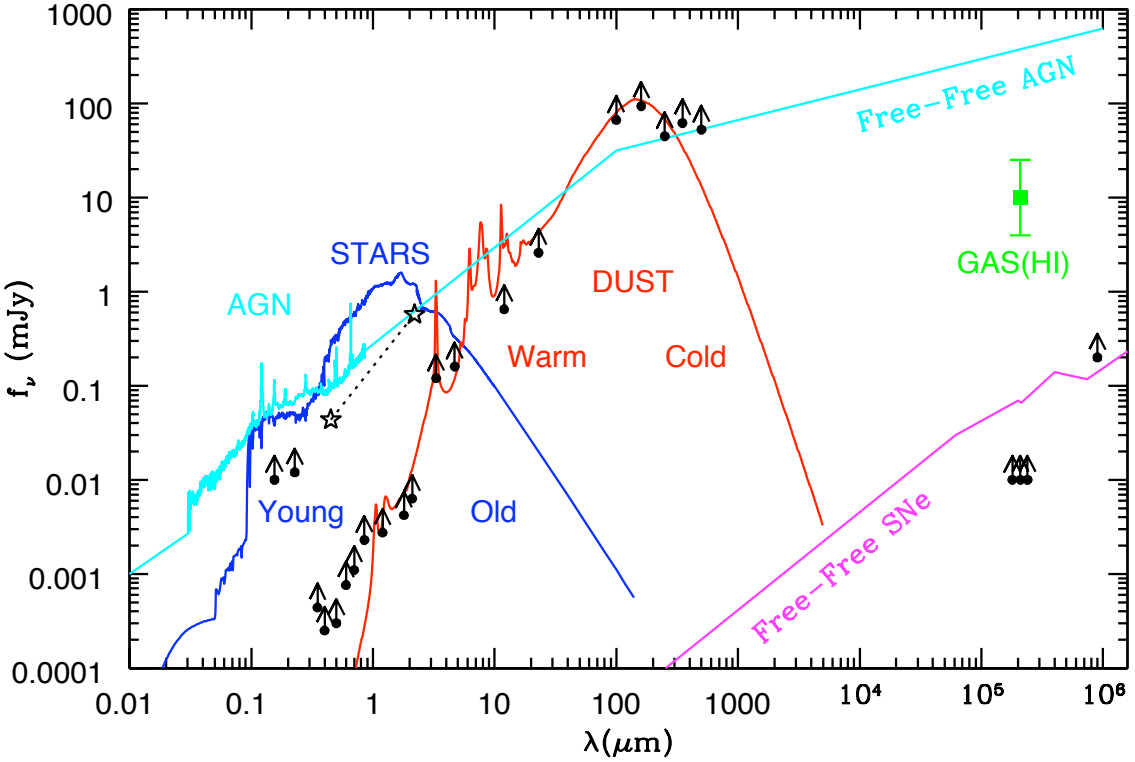
GAMA: Science goals

- Generic galaxy database (150/500k systems)
- Halo Mass Function
- Stellar Mass Function
- Baryonic Mass Function
- Bulge-disc decomp to $z < 0.1$ (30k)
- Star-formation rates via UV, Hα, Far-IR
- All above versus environment, galaxy type, galaxy mass, and redshift ($z<0.5$)

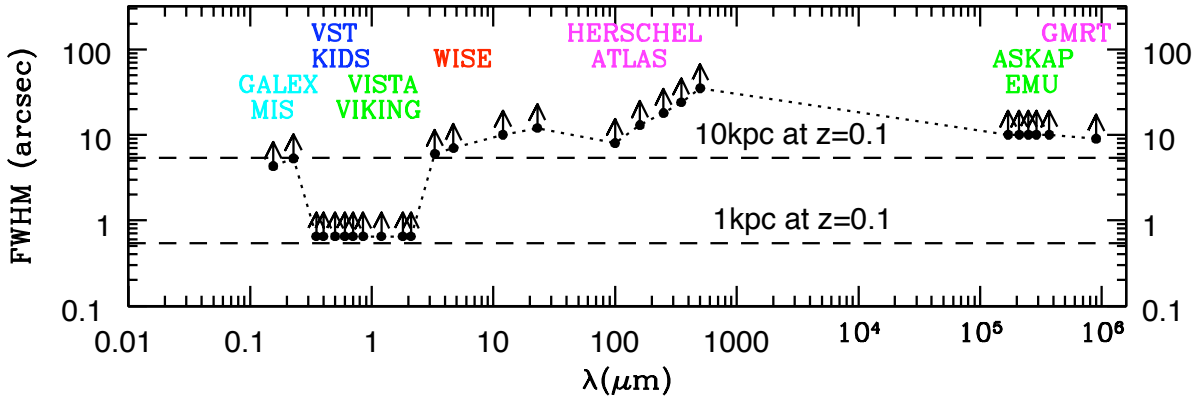
GAMA Spatial Resolution



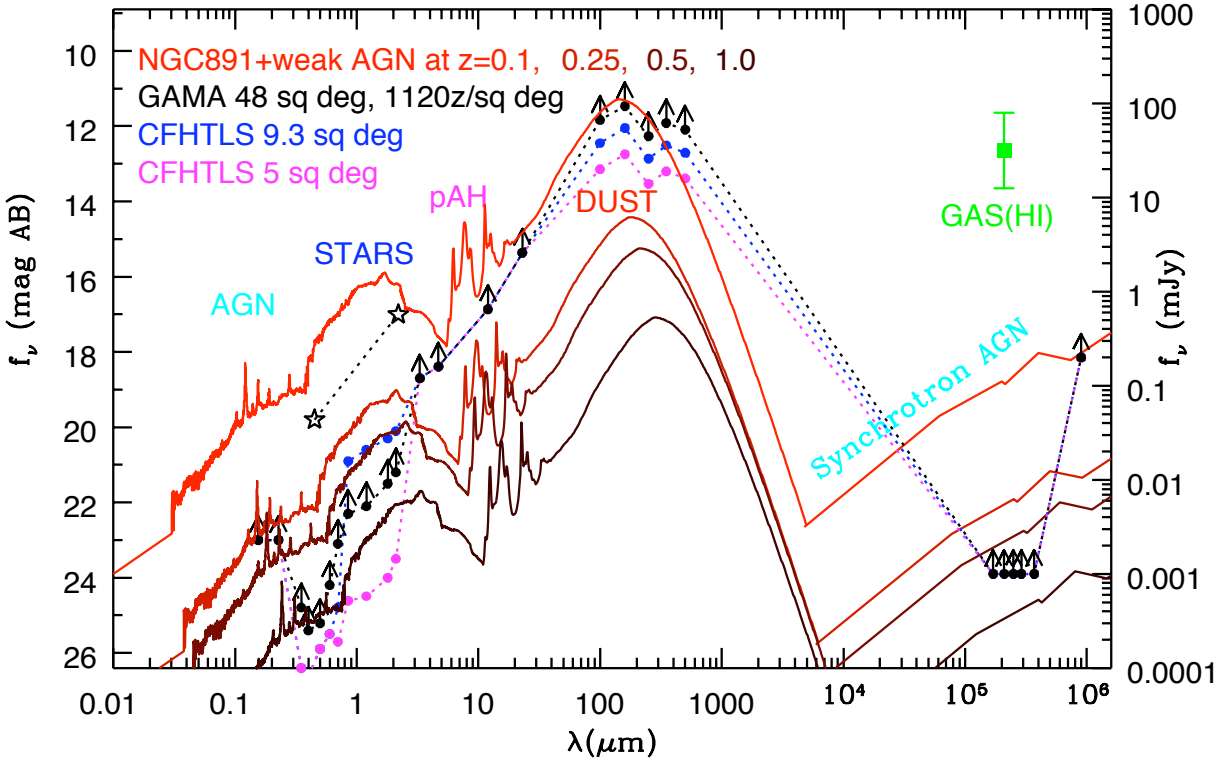
GAMA Sensitivity



GAMA Spatial Resolution



GAMA Sensitivity



All (~250k):

General: GAMA ID : SDSS ID : z (heliocentric) : z quality

Flux: UV : optical : near-IR : mid-IR : far-IR : radio (20,rest-21,30,40,90cm)

Shape: CAS : Sersic index: half-light radii : b/a : PA in *ugrizYJHK*

Opacity: $\tau_{UV,ugriz,YJHK}$

Spectral features: Emission: Hα,Hβ,Hγ,Hδ,OII,OIII,NII

Abs.: Dn4000,Ca4227,Hα,Hβ,Hγ,Hδ,Mgb,Fe

SFR: UV : Hα : far-IR : radio continuum

Fossil record: Age : SFH : element abundance

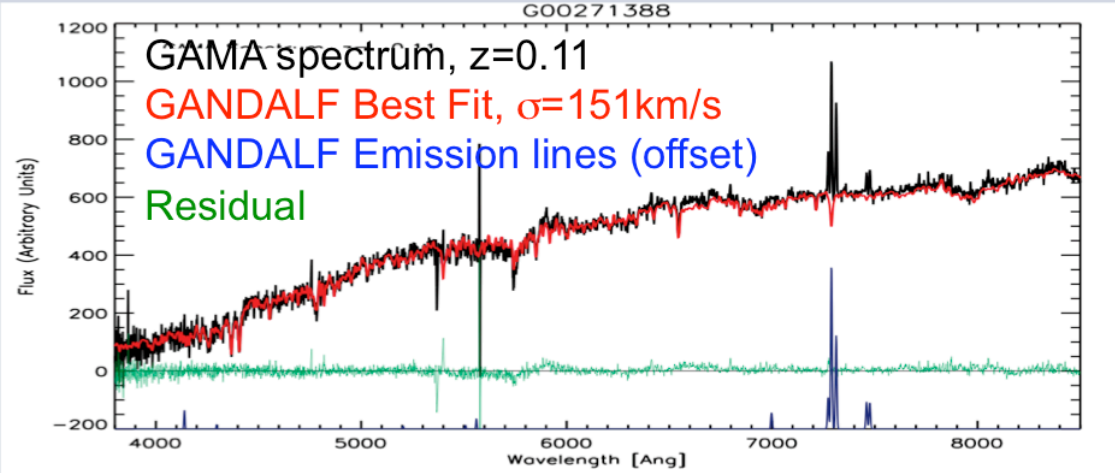
AGN: BPT diagnostics : type : strength : ionisation state

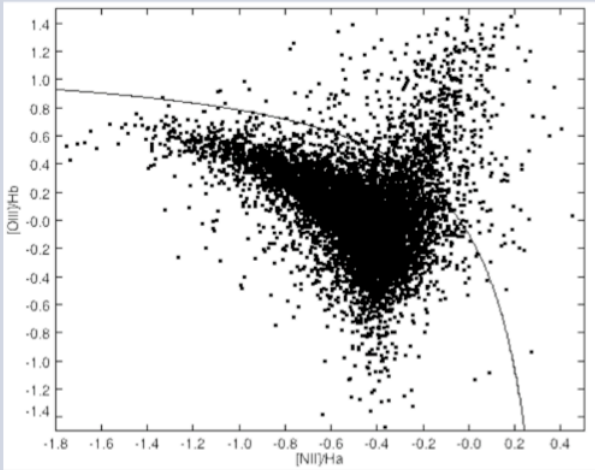
Dynamics: σ_{spec} (GANDALF) : W_{21}: HI line profile

Distances: Tully-Fisher : Faber-Jackson

Masses: Stellar : SMBH : HI : dust : baryon : dynamical

Environment/Halo: Local density : group membership : group halo mass





For z<0.1 (~30k):

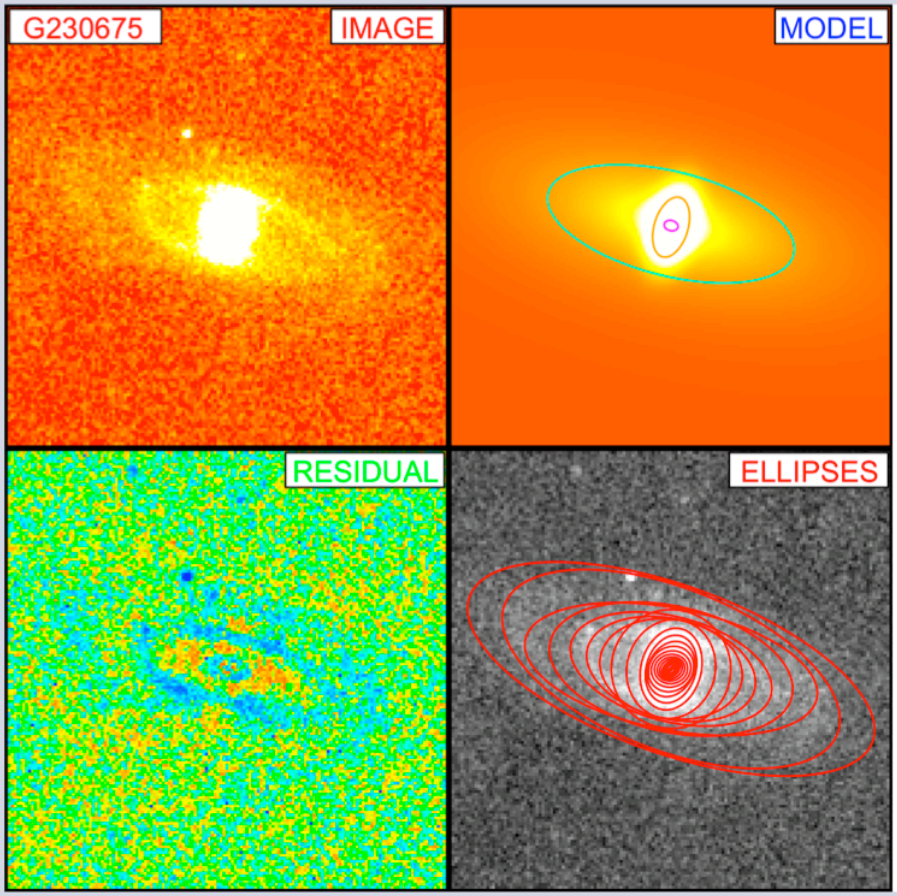
Structural: Bulge/Bar/Disc decomp. in *ugrizYJHK* (GALFIT3)

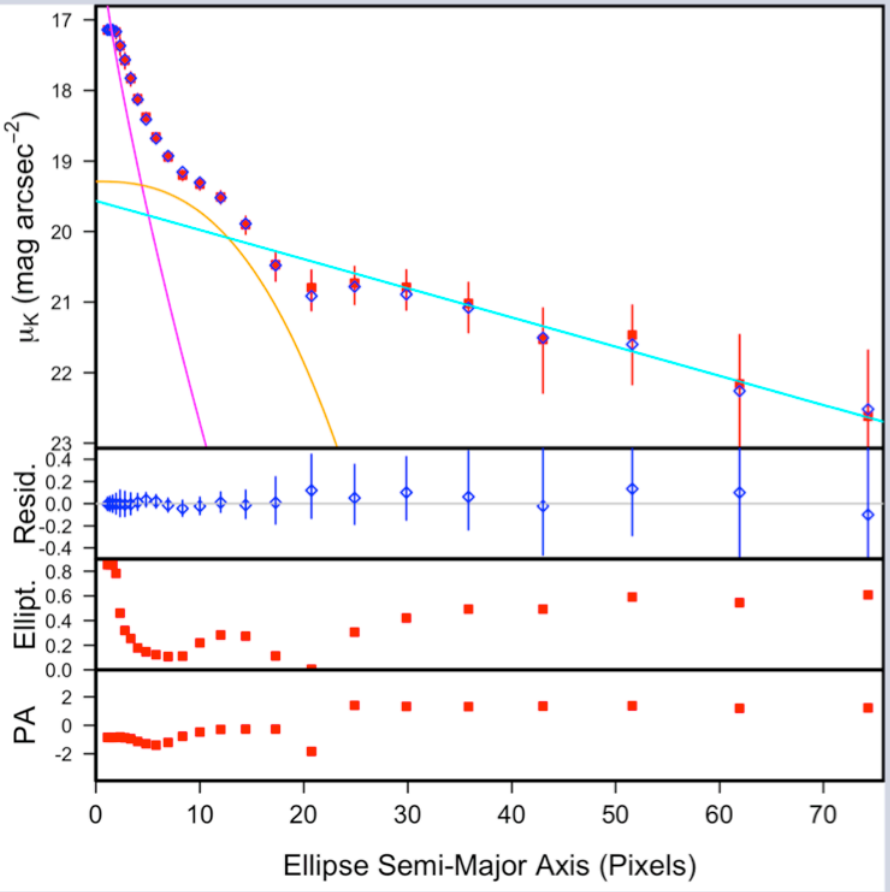
Bulge: Sersic index, half light radius, PA, ellipticity

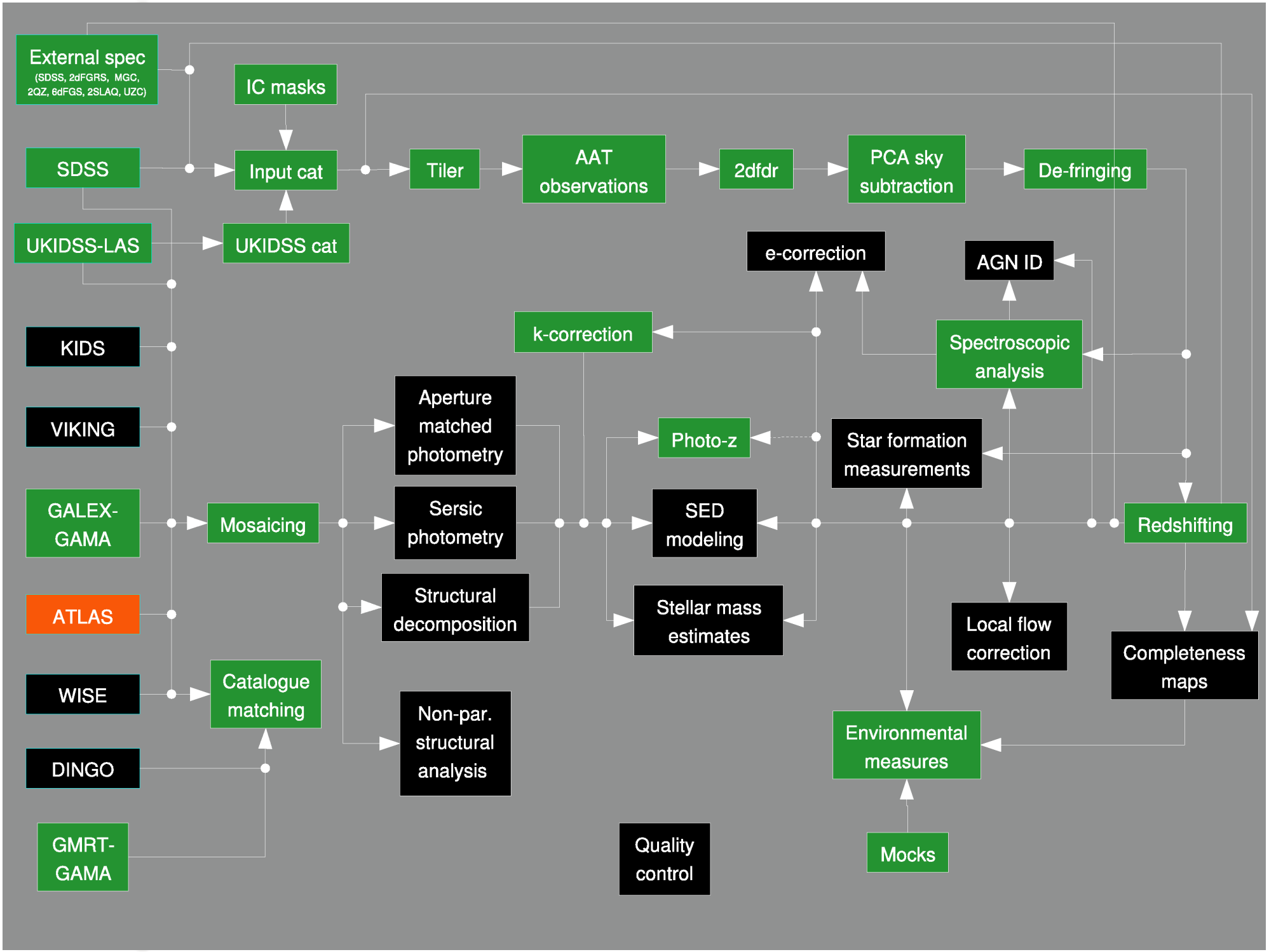
Bar: Sersic index, half light radius, scale-length

Disc: Scalelength, PA, b/a

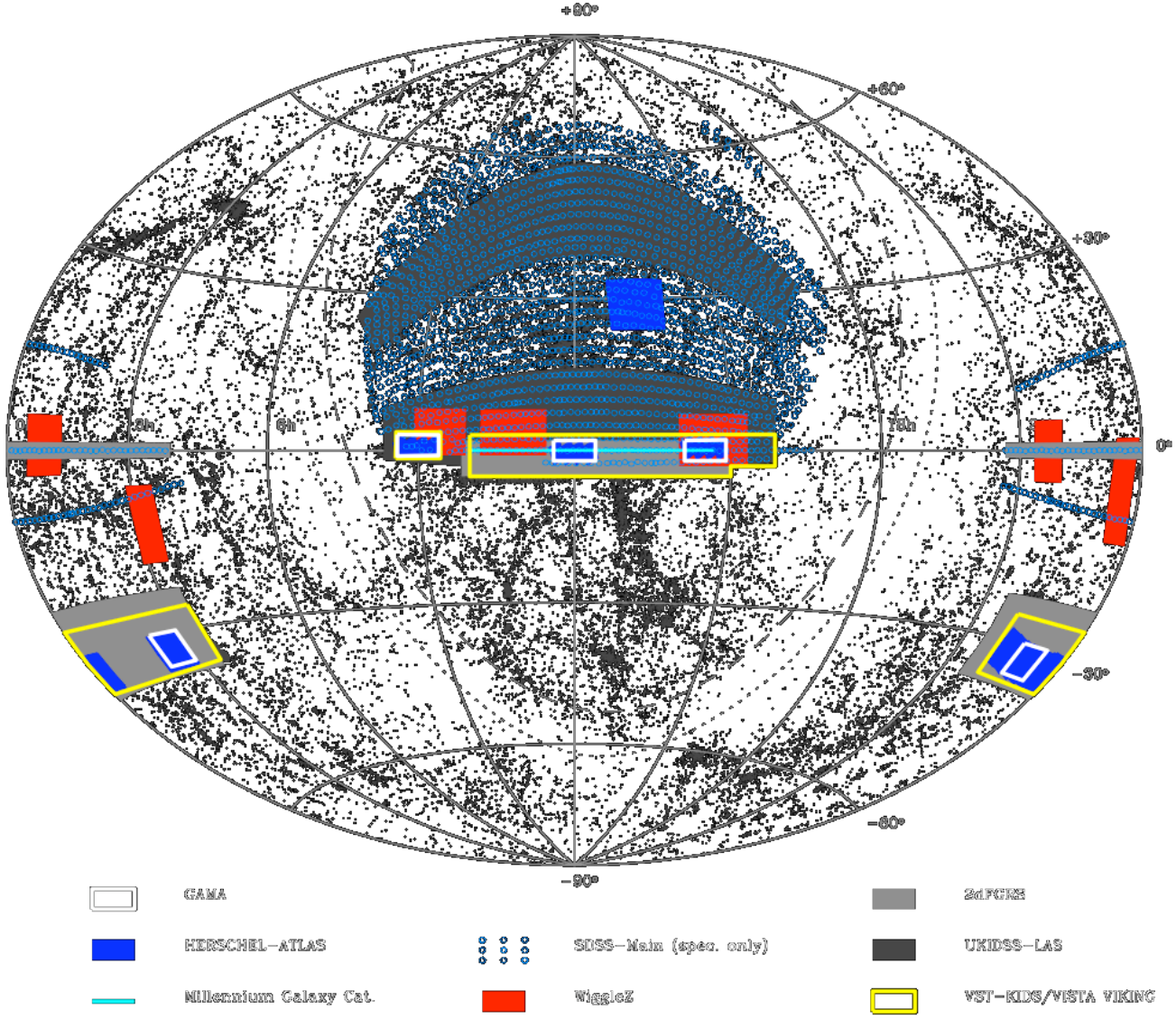
SMBH Mass: via M-σ, M-L , M-n relations






External spec
(SDSS, 2dFGRS, MGC, 2QZ, 6dFGS, 2SLAQ, UZC)
IC masks
SDSS
Input cat
Tiler
AAT observations
2dfdr
PCA sky subtraction
De-fringing
UKIDSS-LAS
UKIDSS cat
e-correction
AGN ID
KIDS
k-correction
Spectroscopic analysis
Aperture matched photometry
VIKING
Photo-z
Star formation measurements
GALEX-GAMA
Mosaicing
Sersic photometry
SED modeling
Redshifting
ATLAS
Structural decomposition
Stellar mass estimates
Local flow correction
Completeness maps
WISE
Catalogue matching
Non-par. structural analysis
DINGO
Environmental measures
GMRT-GAMA
Quality control
Mocks

GAMA Survey regions



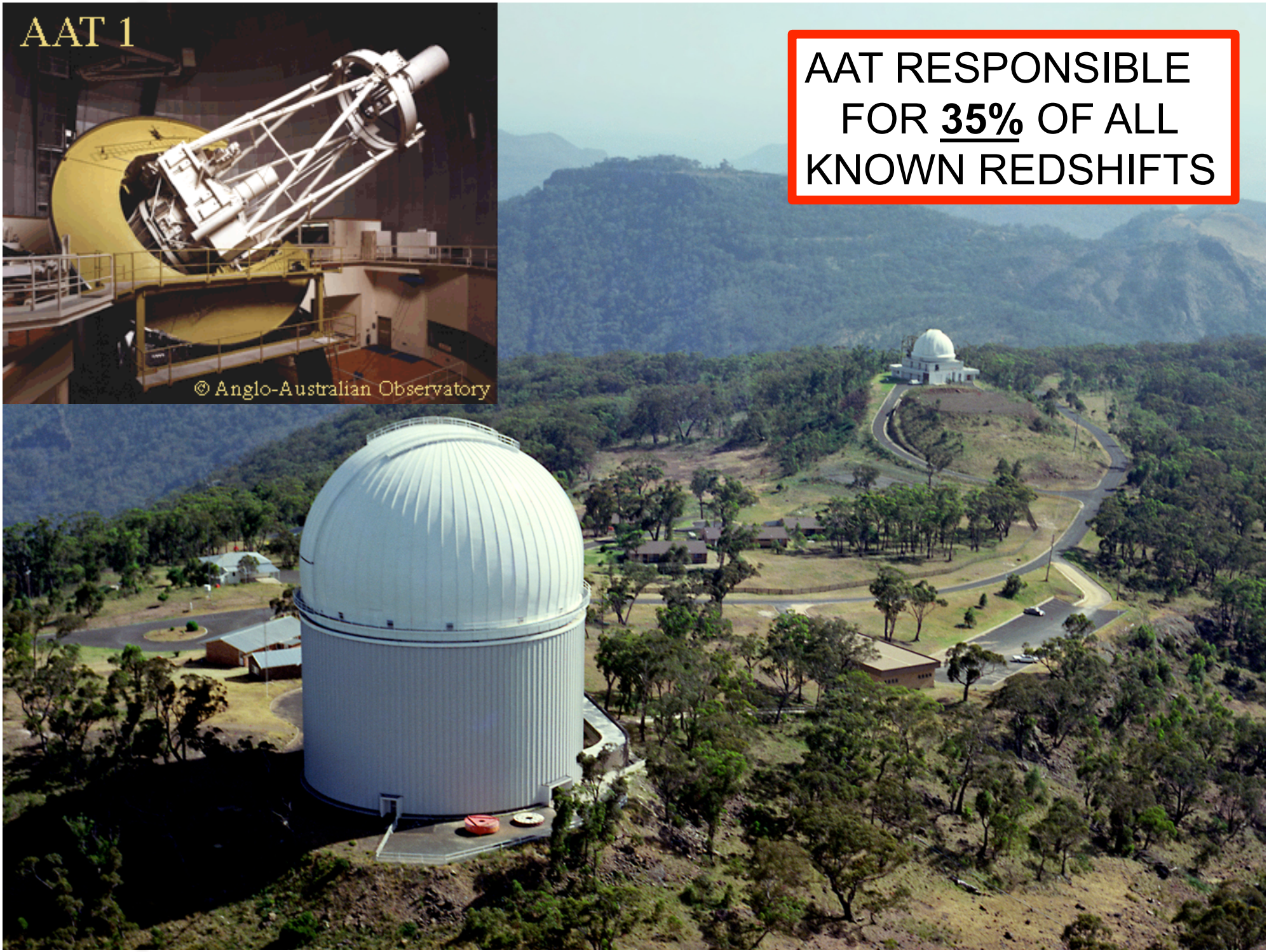
GAMA Redshift Survey

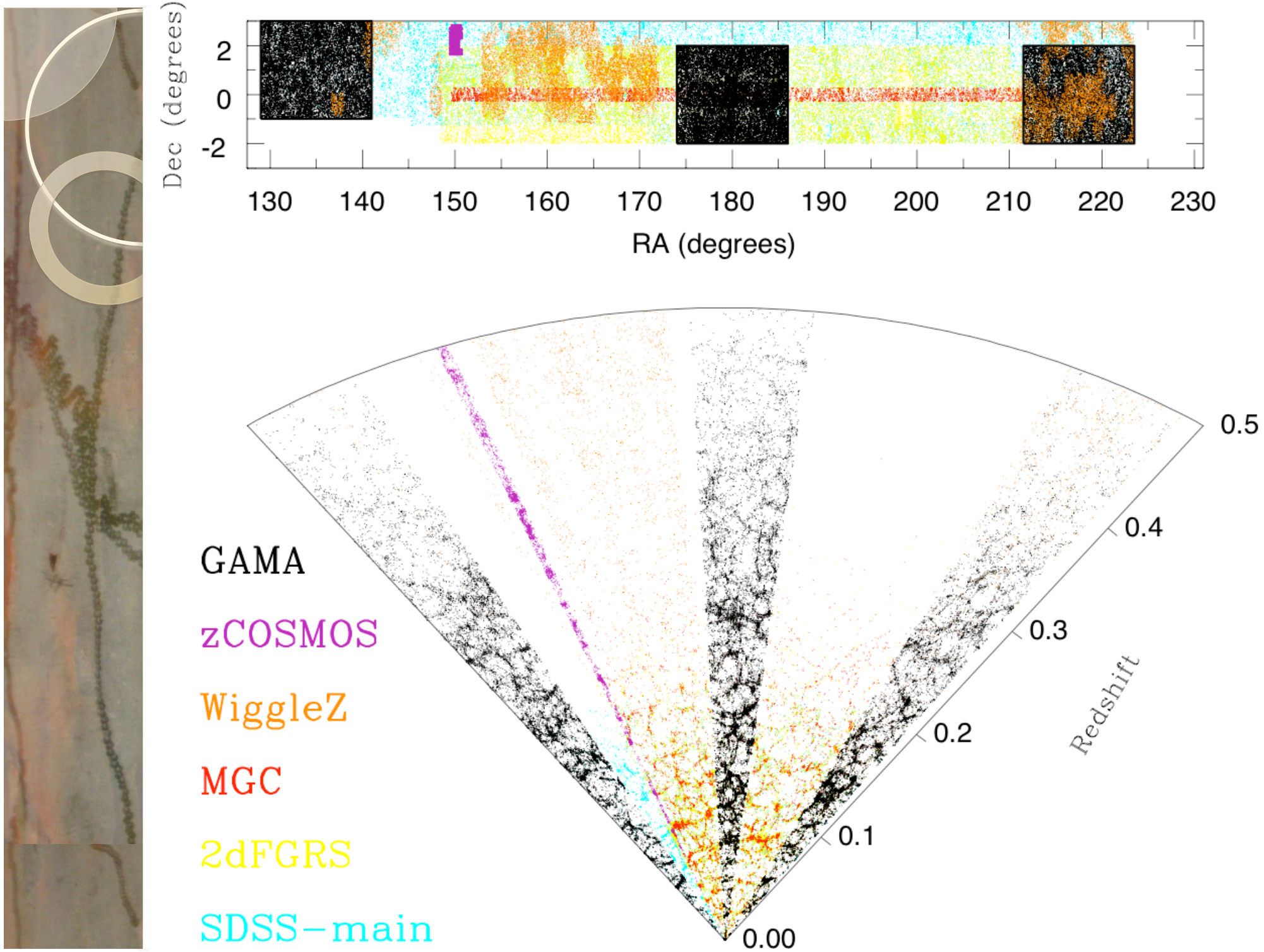
- Aims to be 99% complete down to:
  - r < 19.4 (G09 / G15), 19.8 (G12)
  - K_{AB} < 17.6 (All)
  - z < 18.2 (All)

- High fidelity redshifts will be our first data product (100k so far)

- Full SWARPed images in ugrizYJHK (20GB per image) + GALEX
  - Common: gain/ zero point/ res (0.4” per pix).
  - Co-addition weight-maps also produced.

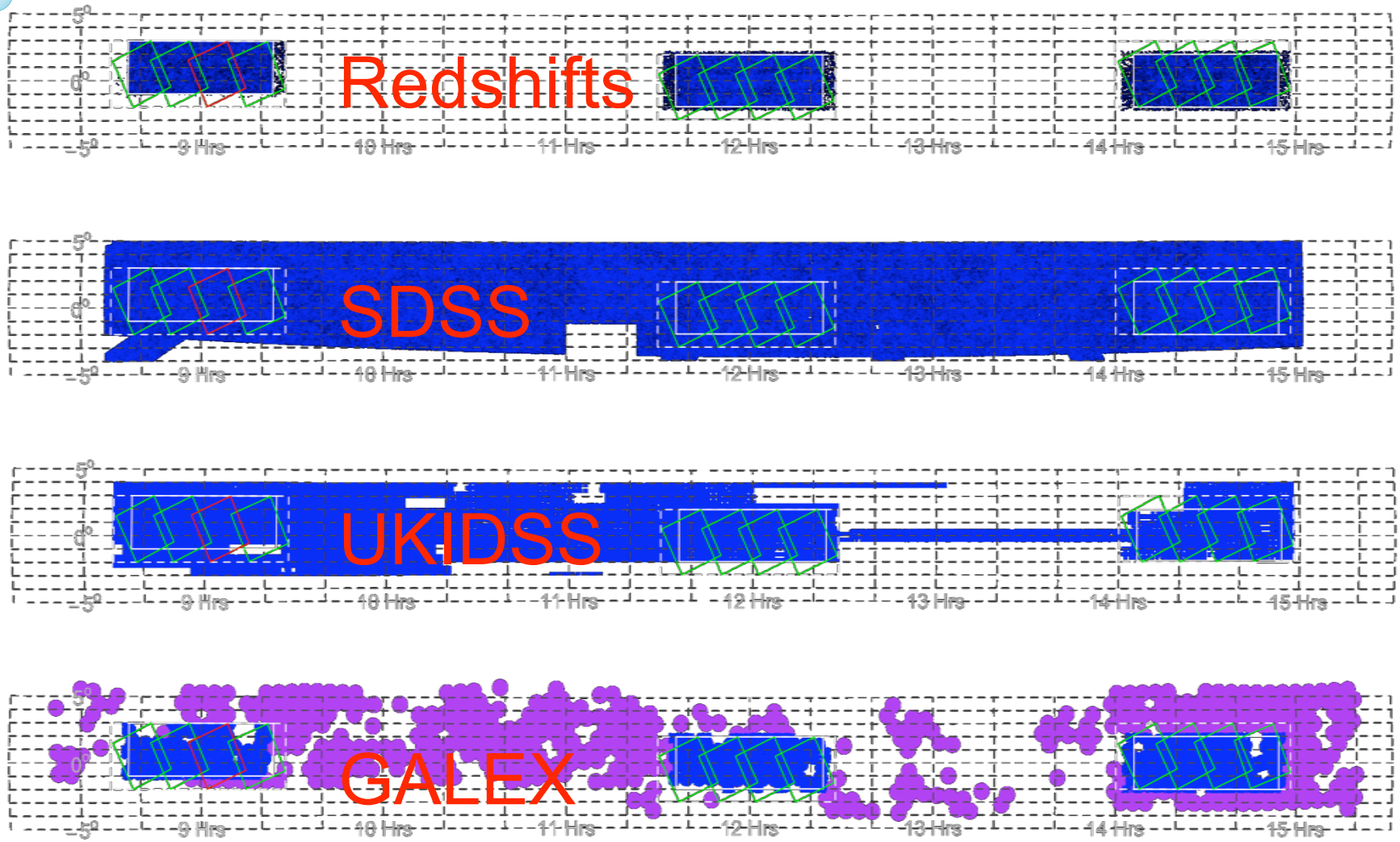
- Standalone SExtracted catalogues in each band.
- Aperture matched catalogues using r and K defined apertures.


AAT 1
© Anglo-Australian Observatory
AAT RESPONSIBLE FOR 35% OF ALL KNOWN REDSHIFTS


Dec (degrees)
2
0
-2
130
140
150
160
170
180
190
200
210
220
230
RA (degrees)
GAMA
zCOSMOS
WiggleZ
MGC
2dFGRS
SDSS−main
0.5
0.4
0.3
0.2
0.1
0.00
Redshift

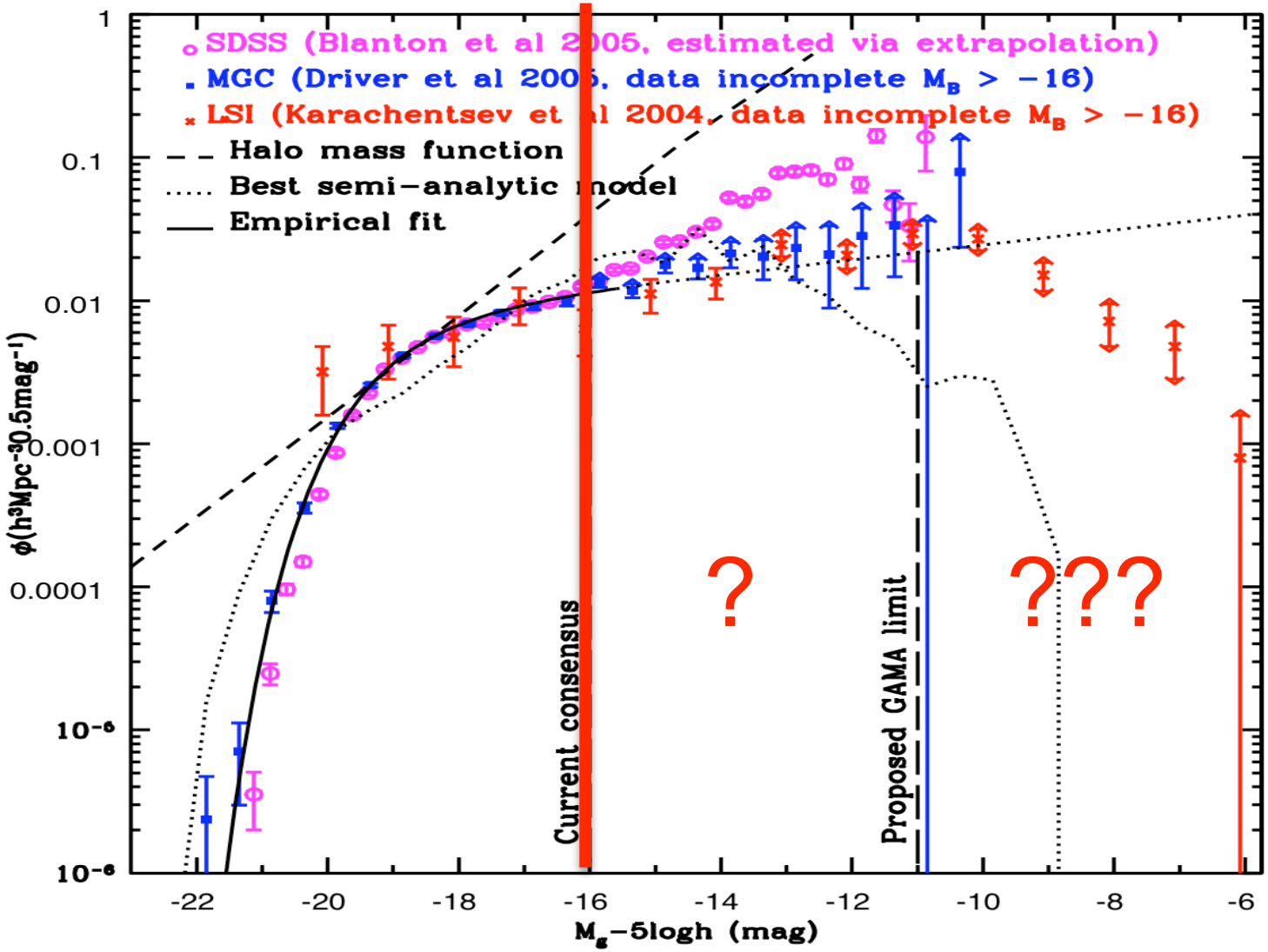
GAMA coverage to date

GAMA 09 GAMA12 GAMA15

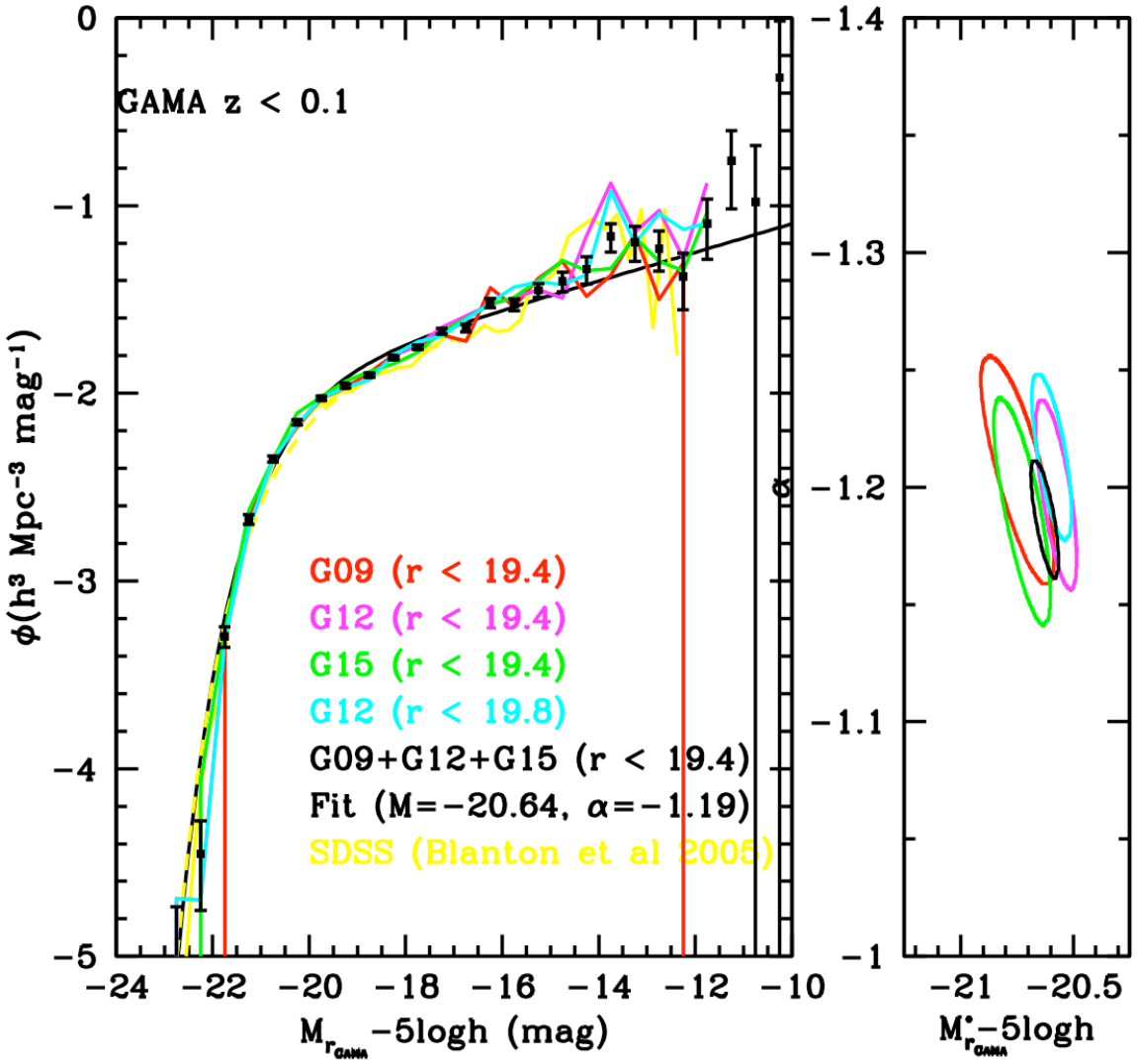


23 more nights next year to complete Equatorial regions

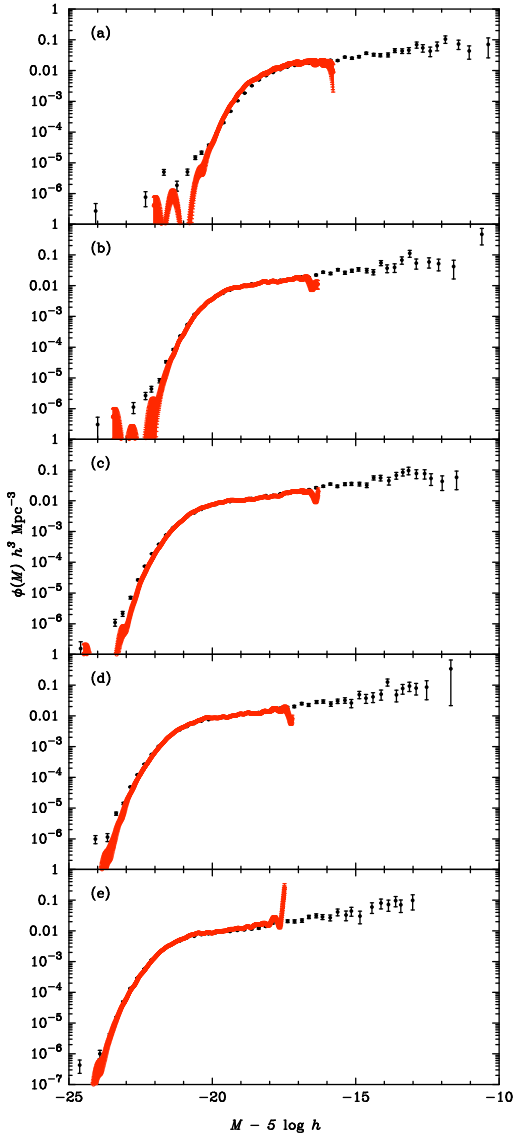
4. Sample incompleteness: LF

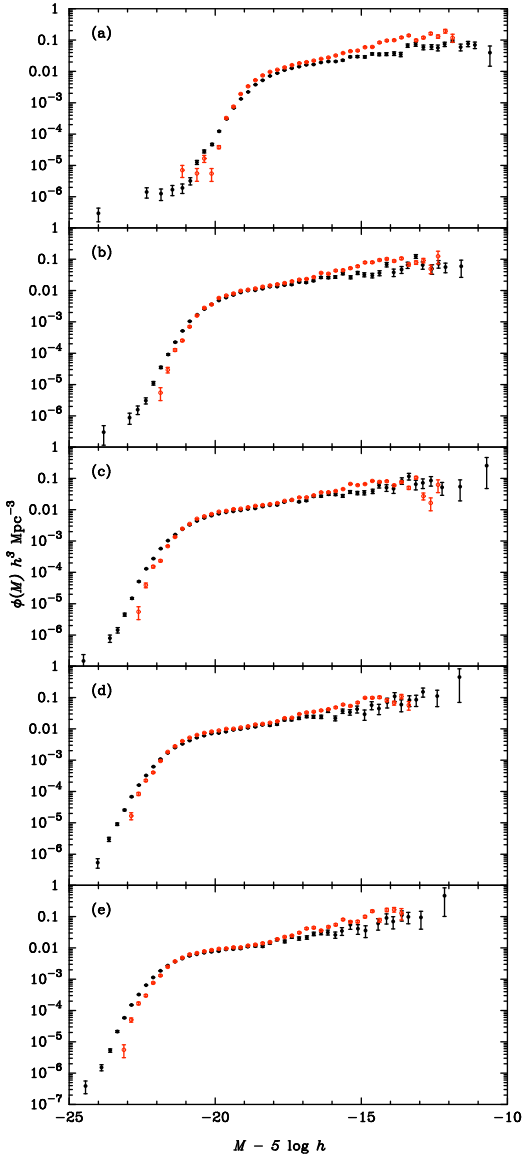


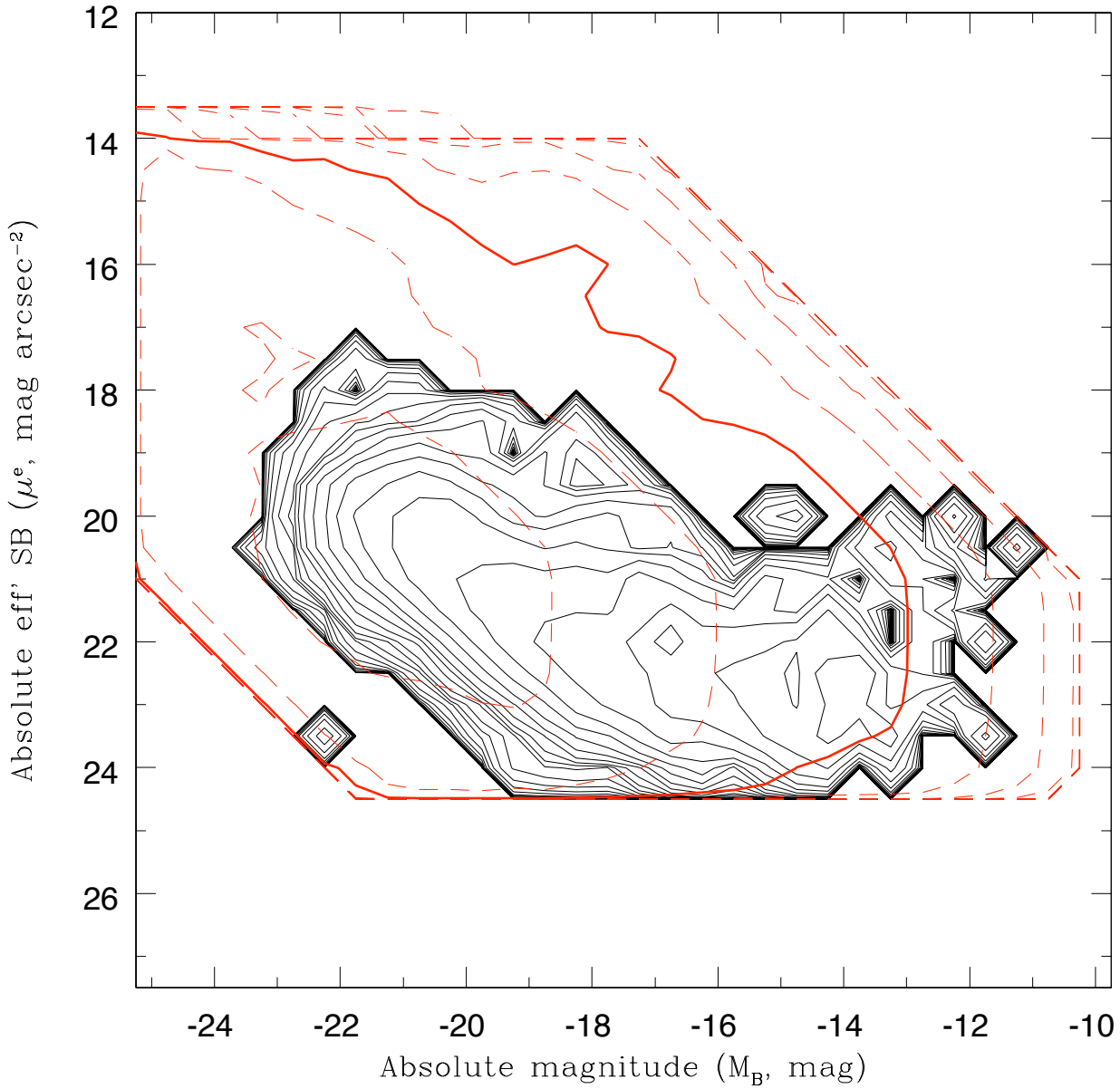
GAMA: r band LF v SDSS



GAMA: r band LF v SDSS






12
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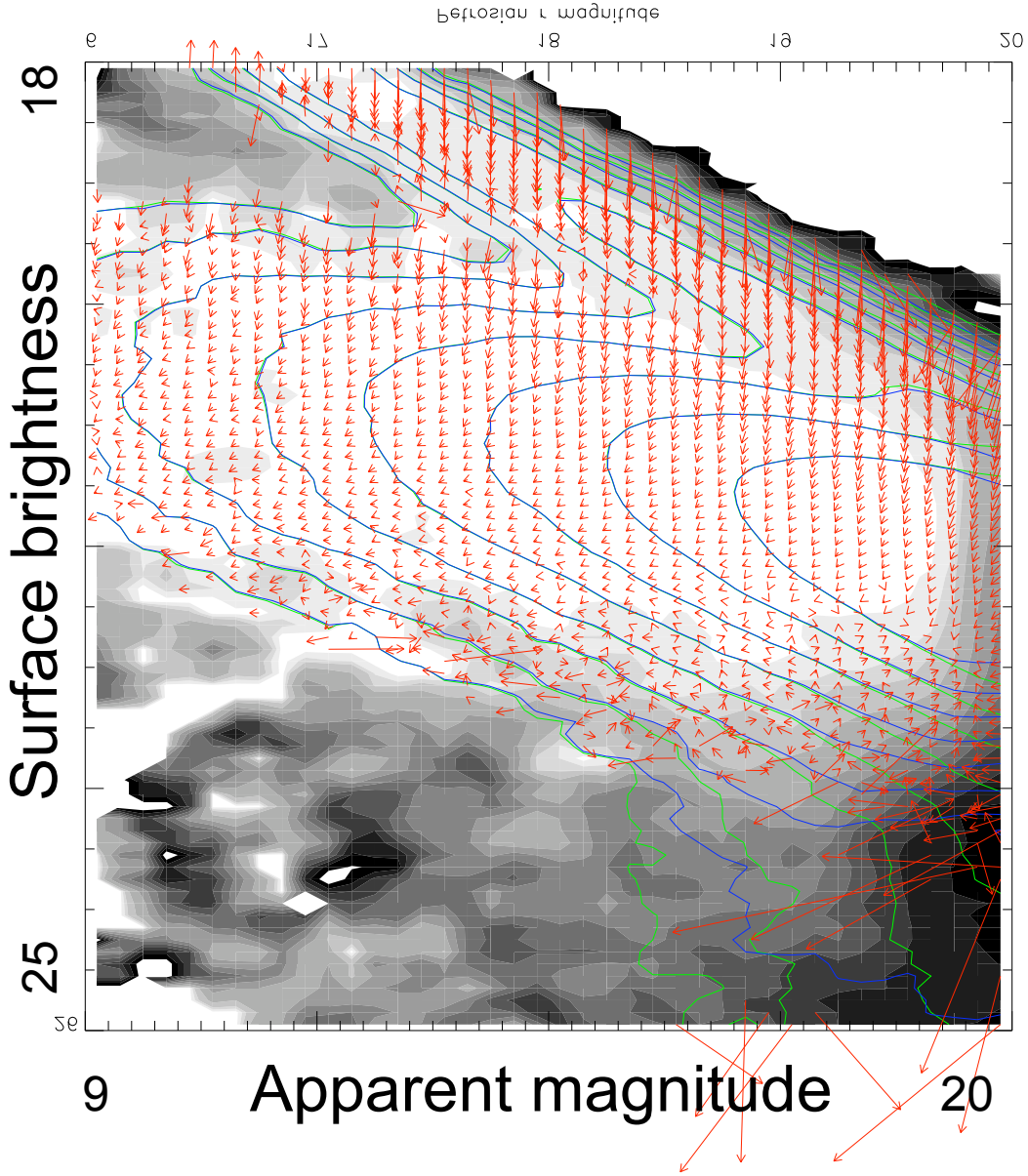
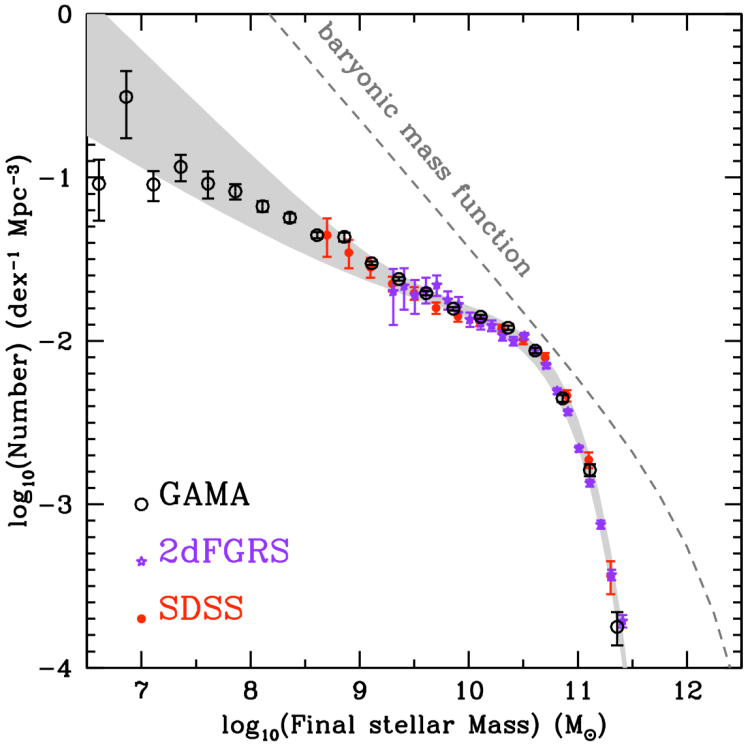
Absolute eff' SB (μ^e, mag arcsec^{-2})
Absolute magnitude (M_B, mag)

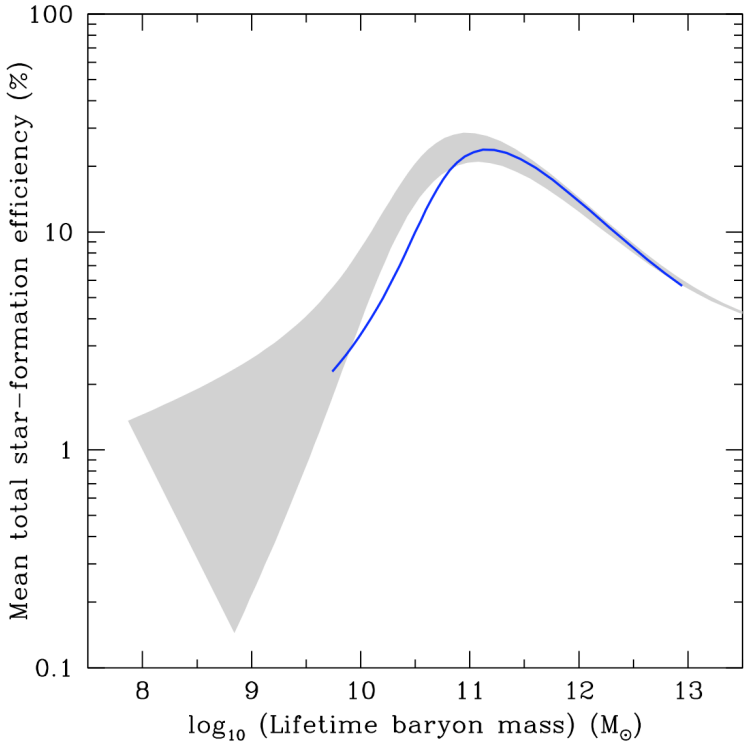
GAMA: r band LF v SDSS



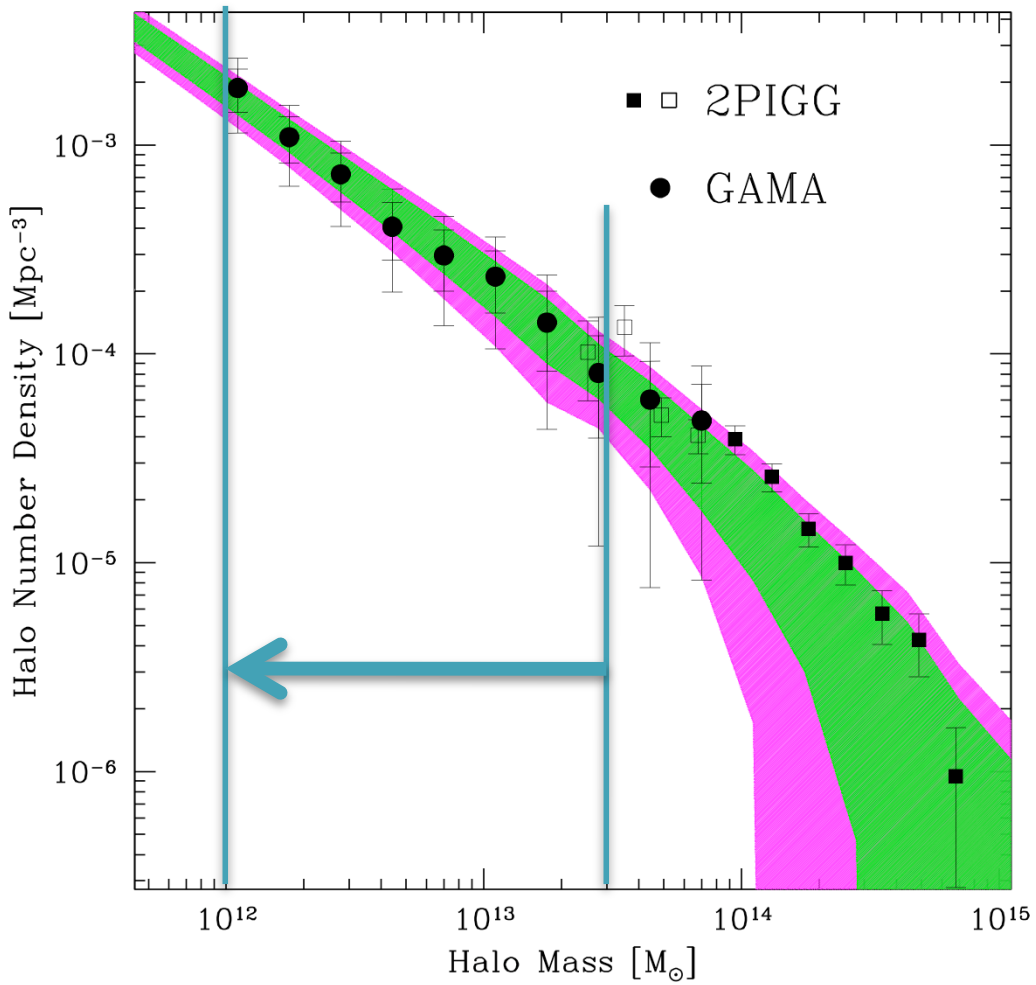
GAMA: Stellar mass function

Required star-formation Efficiency:

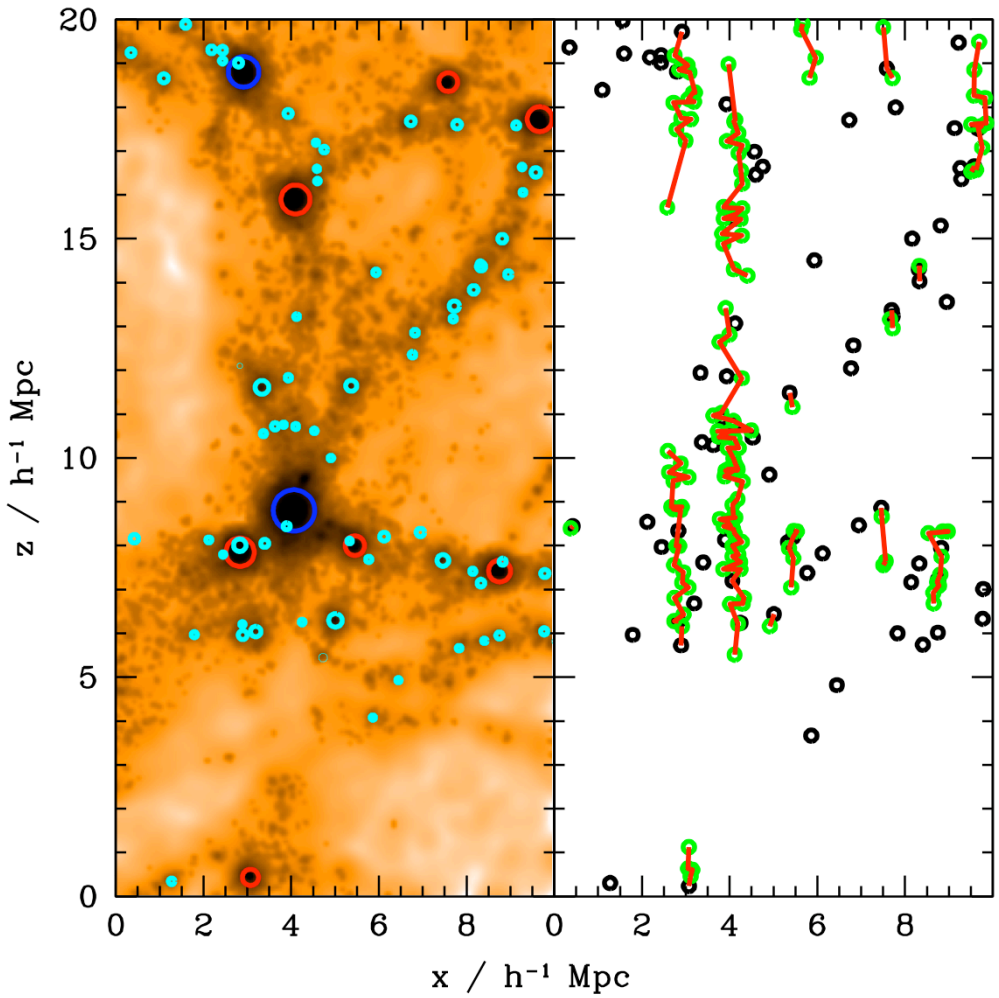


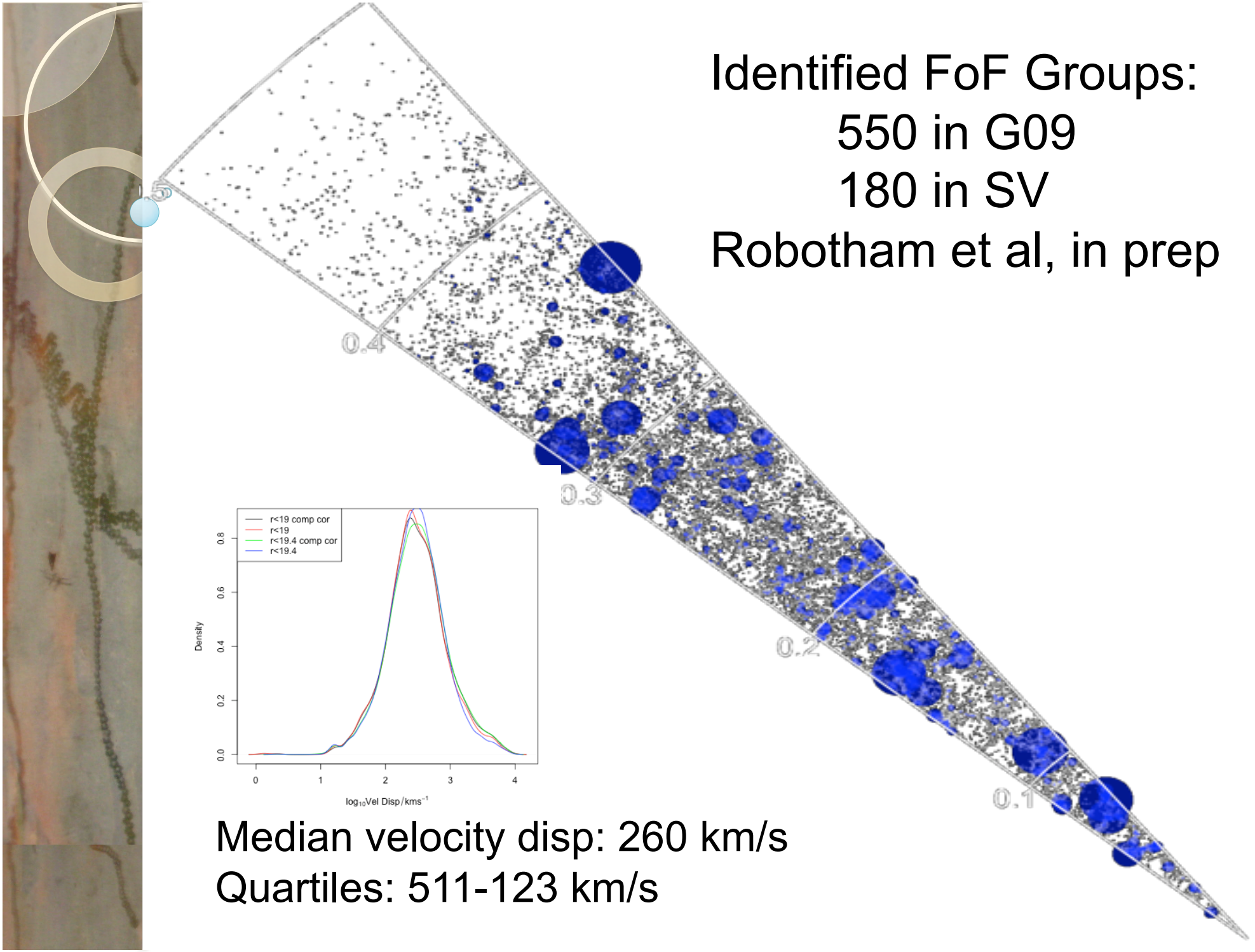


GAMA: Halo Mass Function



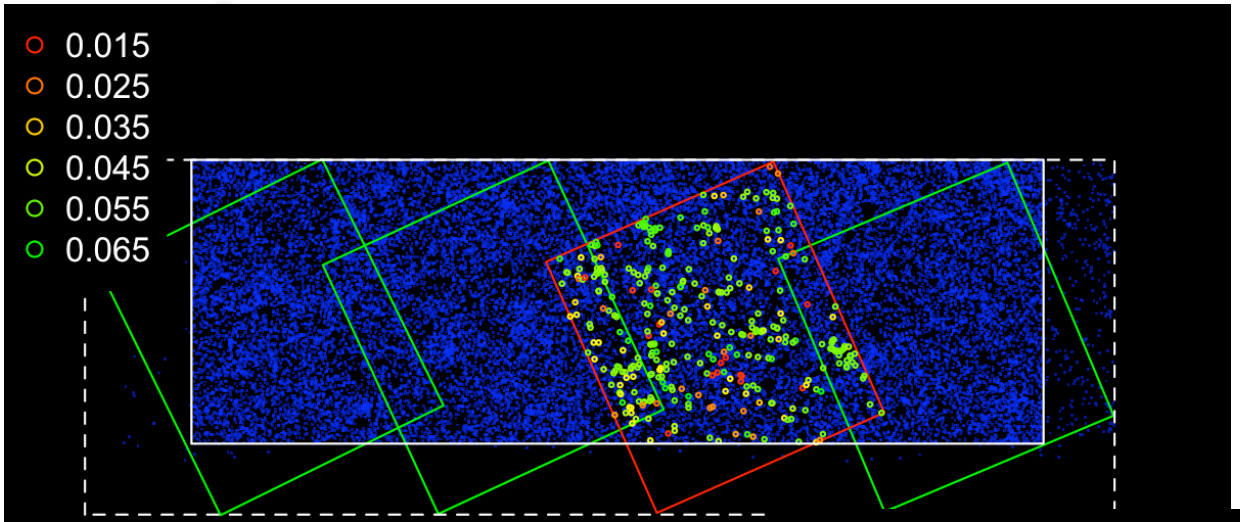
GAMA: Group finding progress





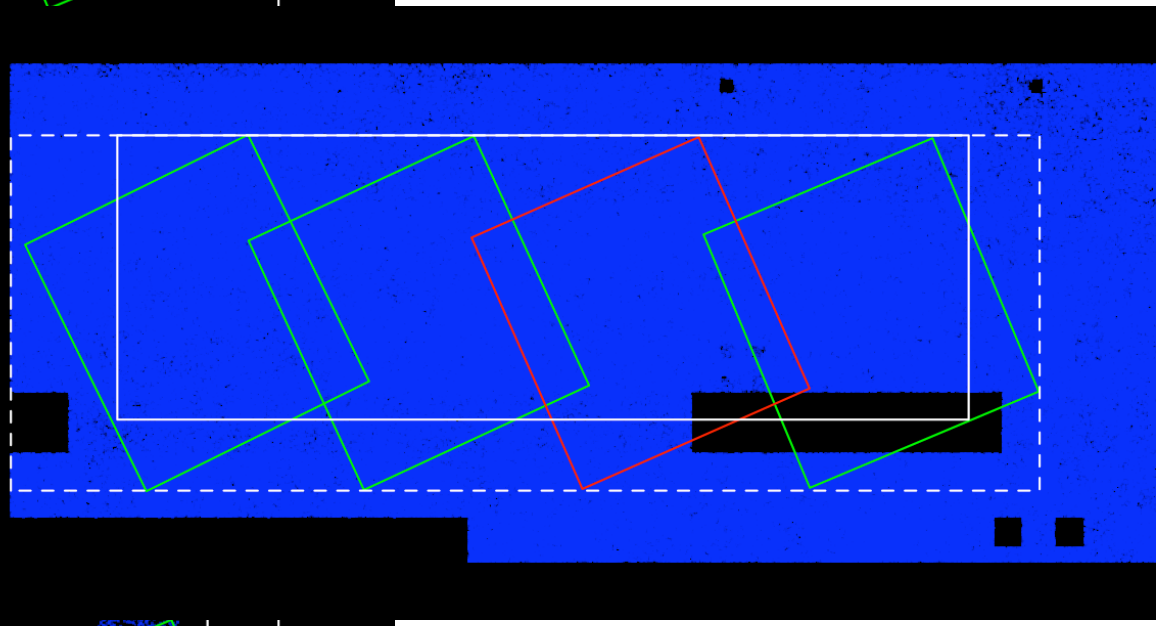
Identified FoF Groups:
550 in G09
180 in SV
Robotham et al, in prep

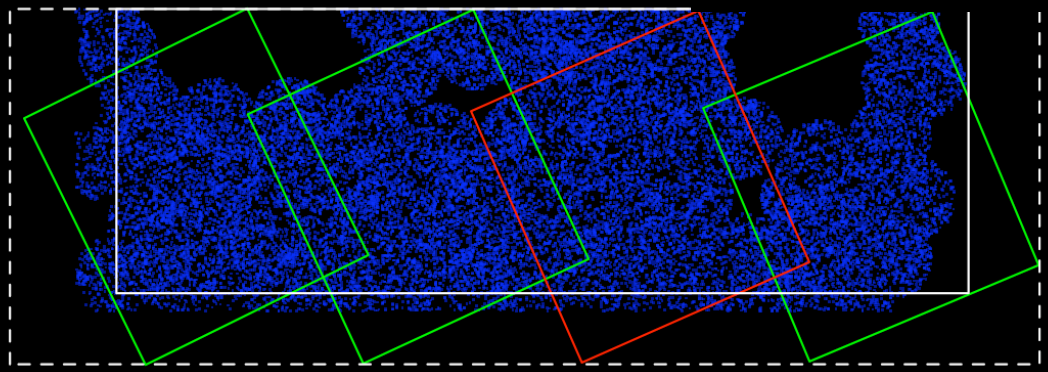
Median velocity disp: 260 km/s
Quartiles: 511-123 km/s



Herschel-Atlas
Red= SV
Blue=GAMA z's

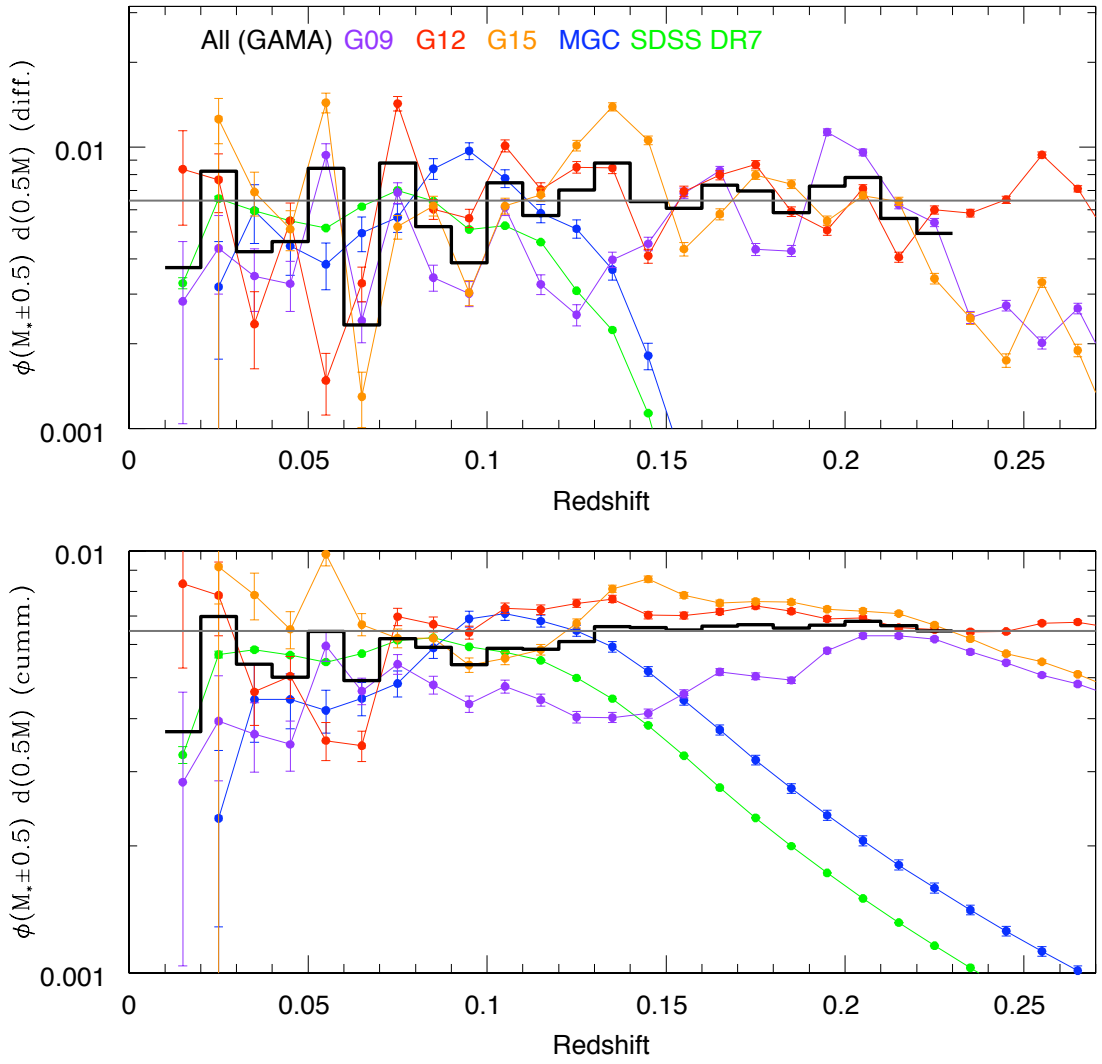
UKIDSS
Coverage

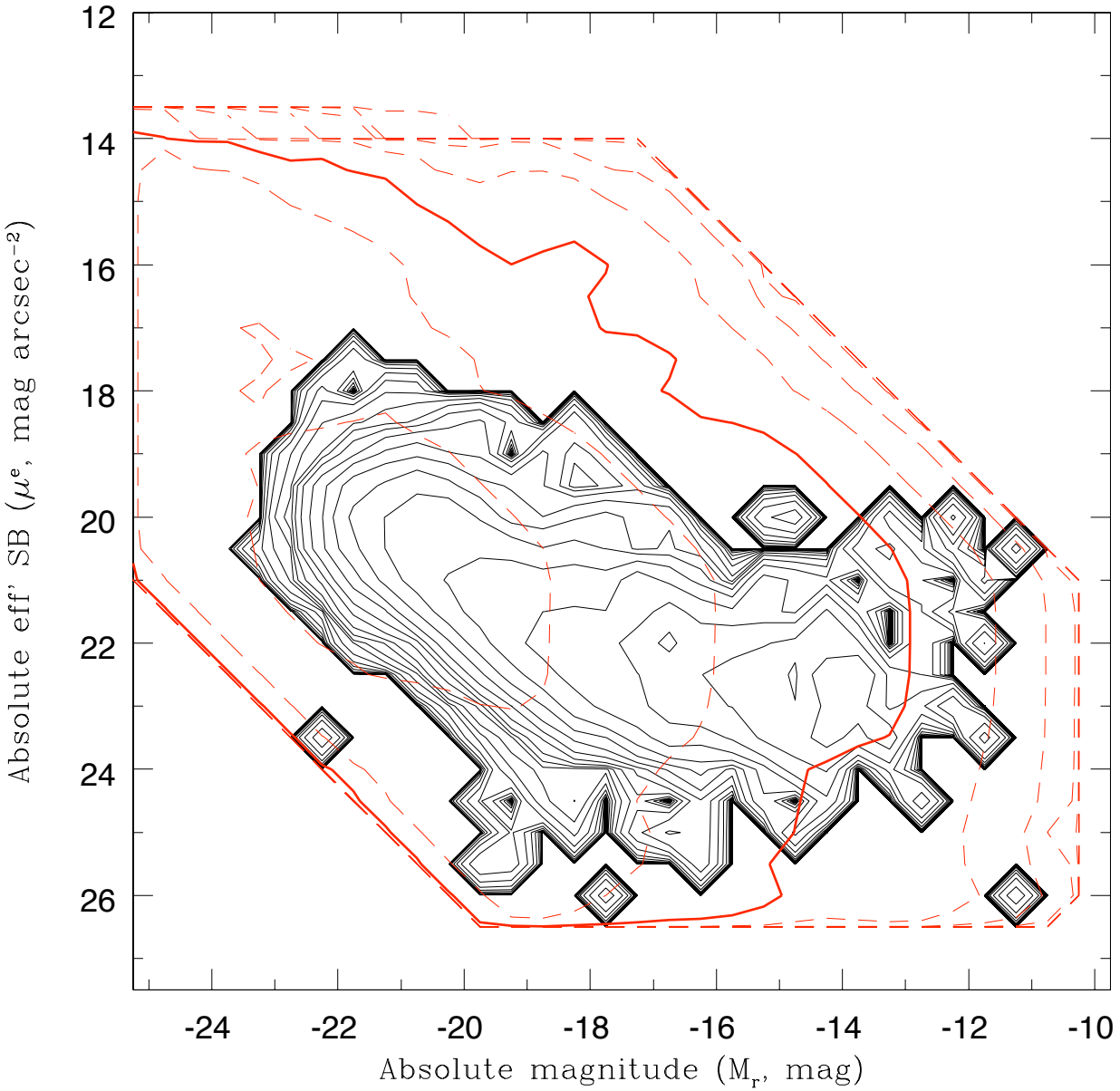




GALEX
Coverage

GAMA: Cosmic variance

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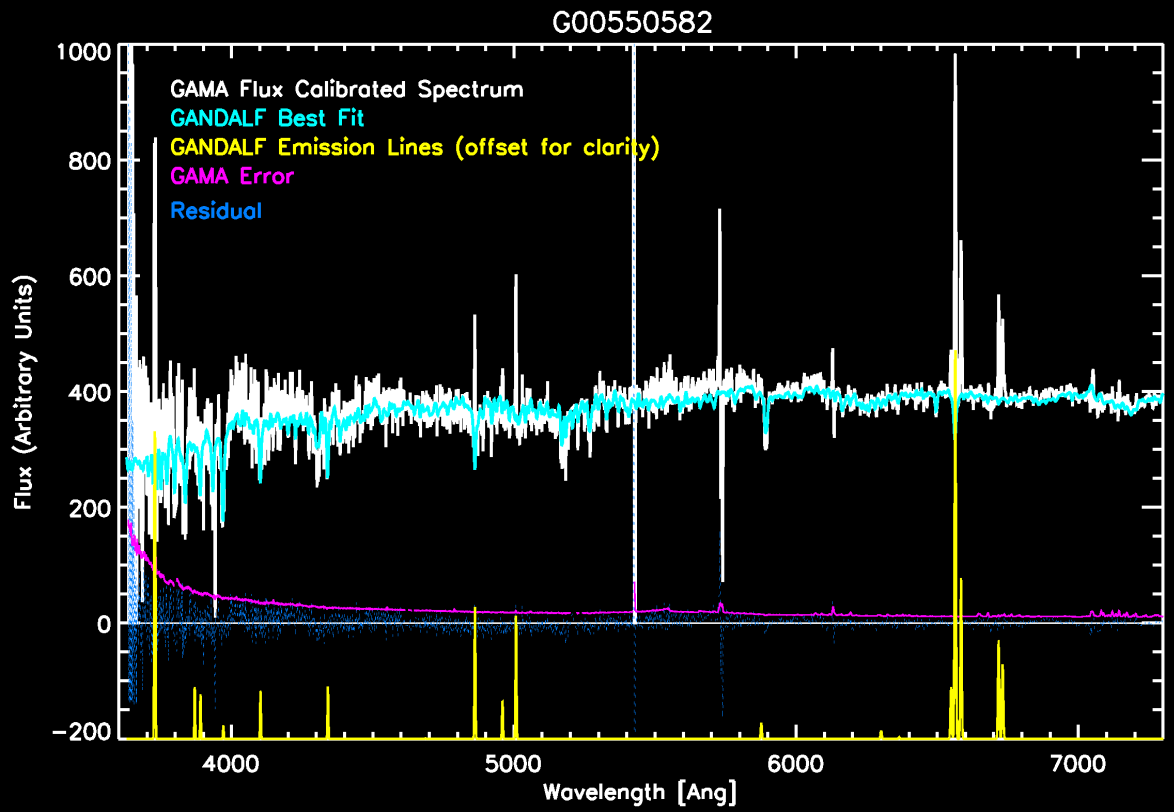
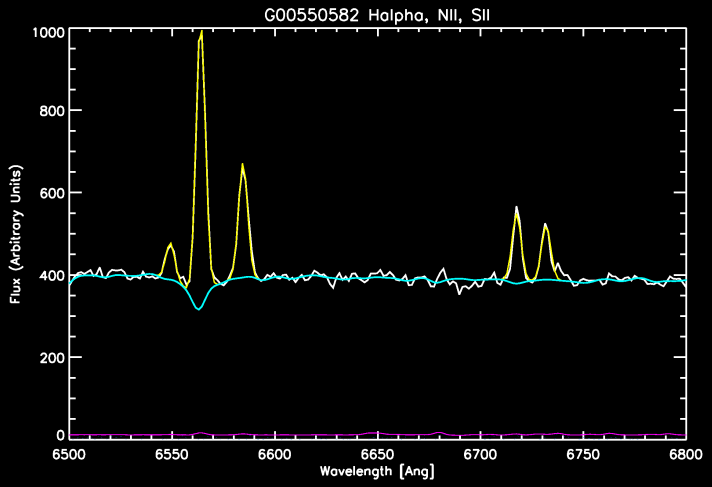
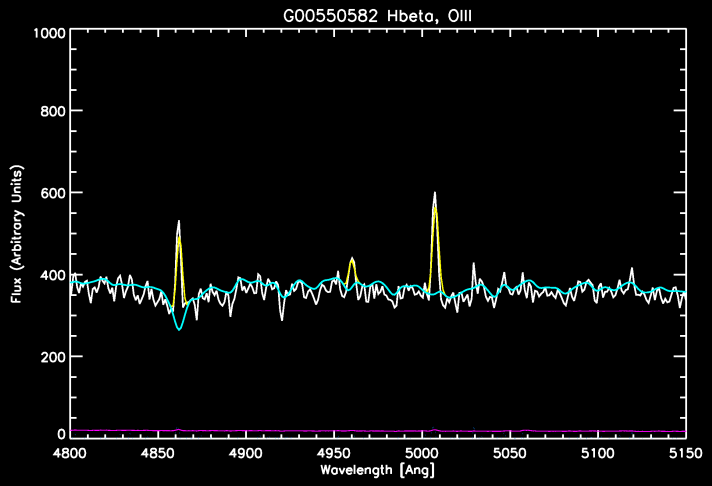
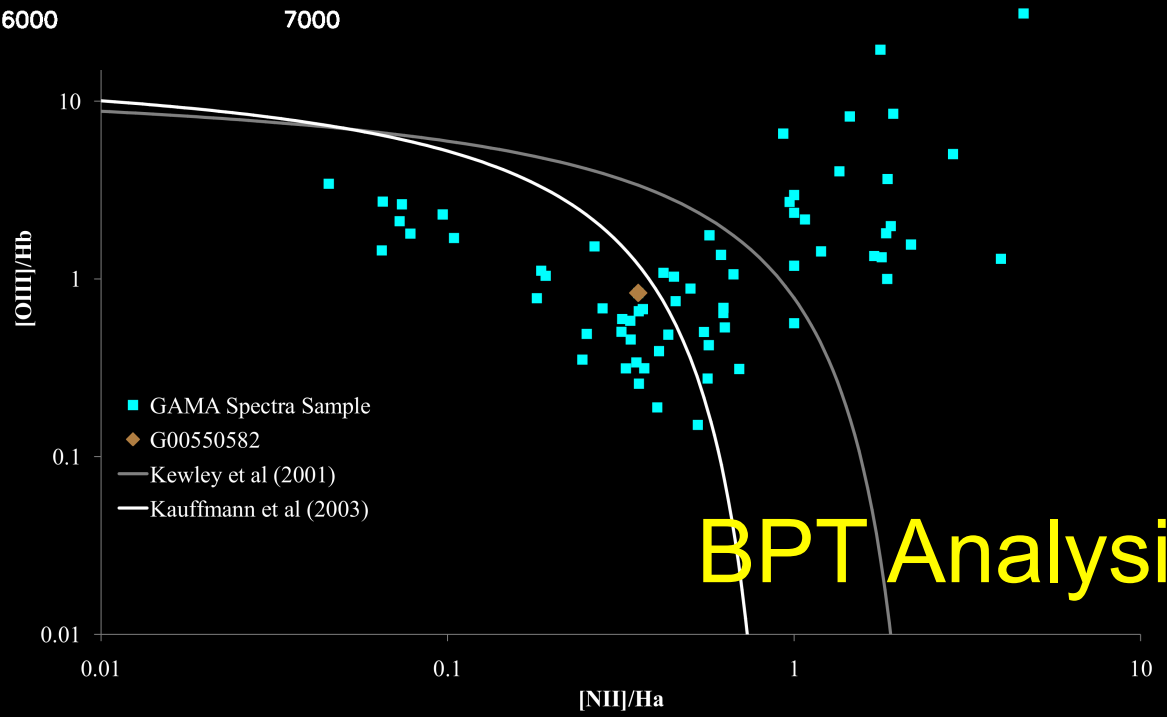
Absolute eff' SB (μ^e, mag arcsec^{-2})
Absolute magnitude (M_r, mag)

Gandalf Analysis



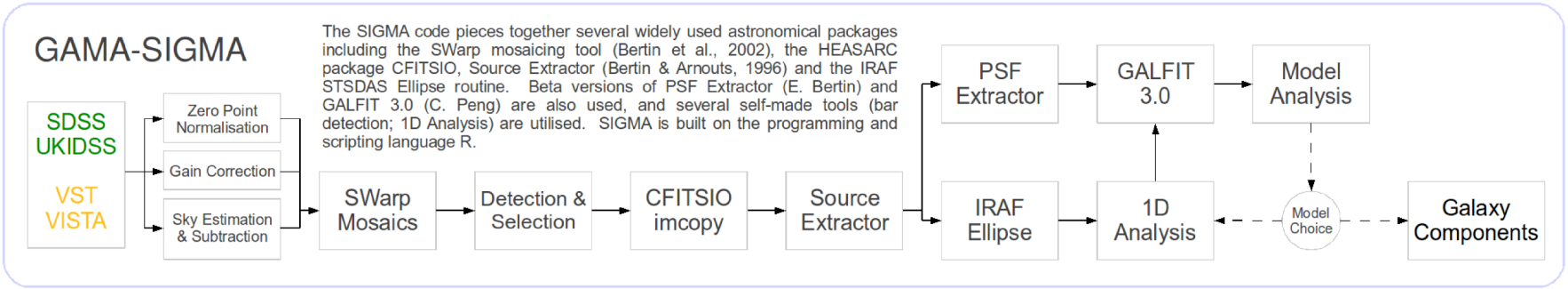


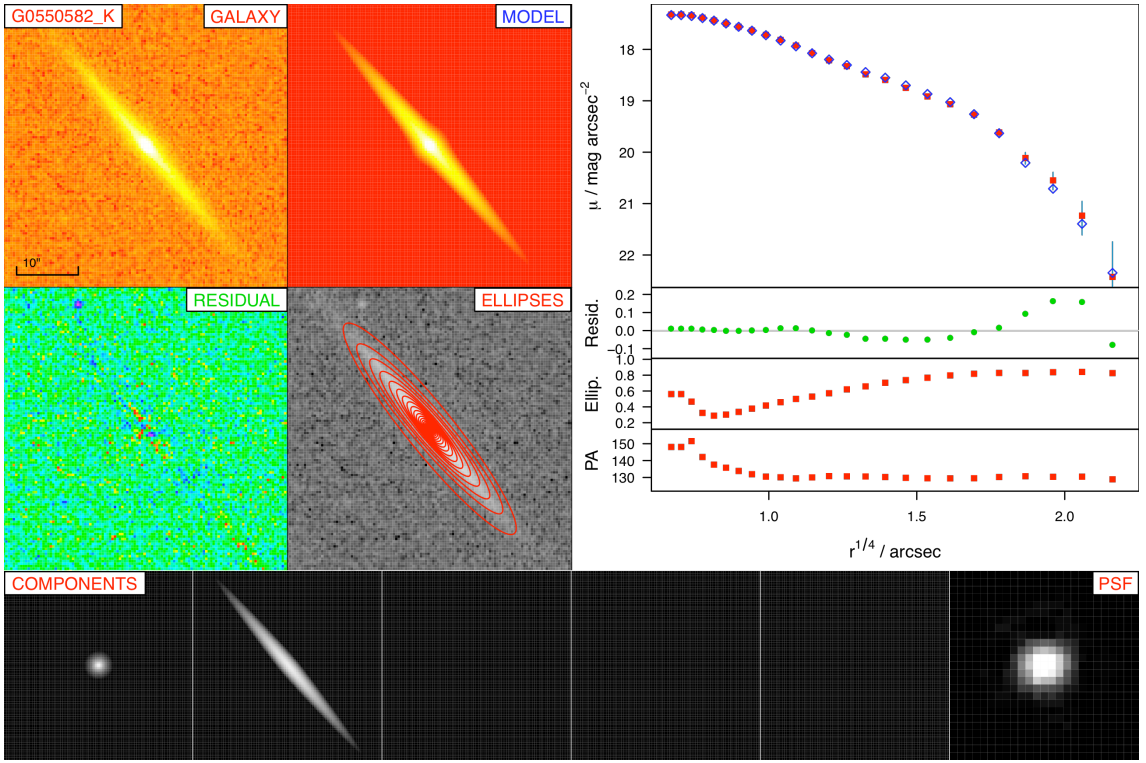




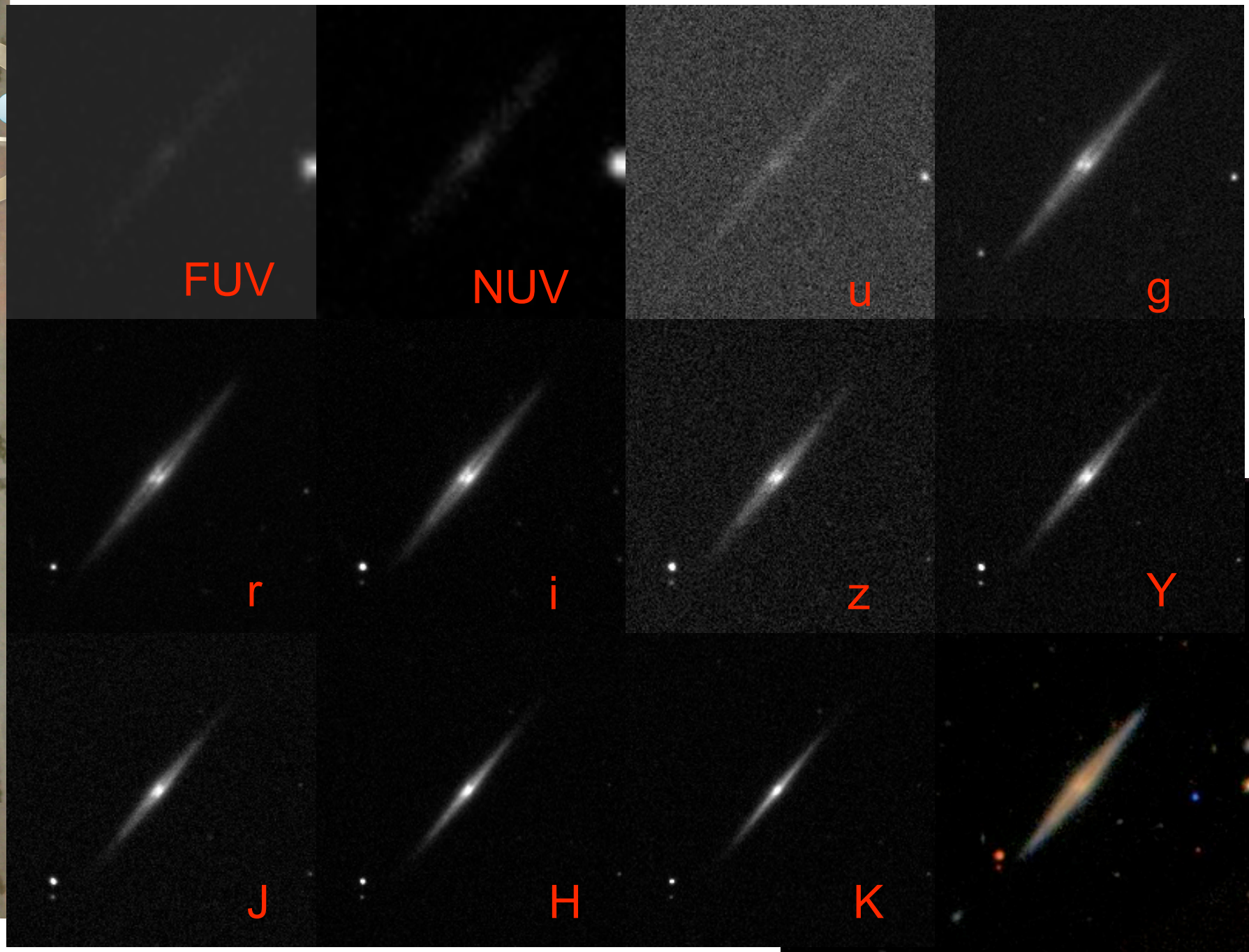
BPT Analysis

GAMA: SIGMA-GAMA





Case Study- G550582



Summary

- Multiple component systems (Bulge+disc+?):
  - Implies two or more evolutionary modes?
  - How useful are global measurements (colour, SFR etc)?
- Multi-constituent systems (Gas, stars, dust):
  - Multi-wavelength approach essential
- Severe biases in most datasets (including mine!):
  - Photometry (Detection AND Measurement bias), bias towards faint compact systems
  - Cosmic variance: 10% at $10^6 Mpc^3$
  - e, k and now d-corrections (even in near-IR)
- GAMA:
  - Aiming for 500k galaxies over 500 sq deg (Herschel-Atlas Eq. & SGP regions)
  - Study of structure on 1kpc to 1Mpc scales to z <0.5
  - Measurement of Halo Mass Function to $10^6 M_o$
  - Constrain feedback via HMF, BMF, and SMF
  - Direct measurement of galaxy merger rate via close pairs and assymmetry
  - Group finding completed in one 30 sq deg region (G09) to z=0.5
  - Total SED modeling (UV to far-IR)
  - Bulge-disc-bar decomposition for ~30k systems
  - First data release Dec 2009
  - High priority target regions for: GALEX, Herschel, VISTA, VST, GMRT, ASKAP, [X-Ray?]