Panchromatic Properties of Galaxies in Wide-Field Optical Spectroscopic and Photometric Surveys

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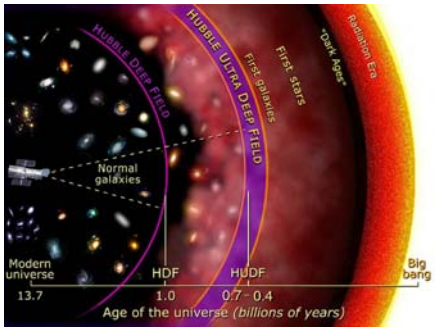
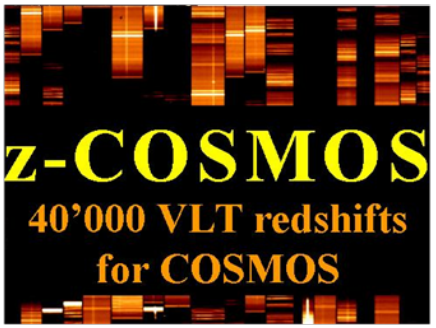
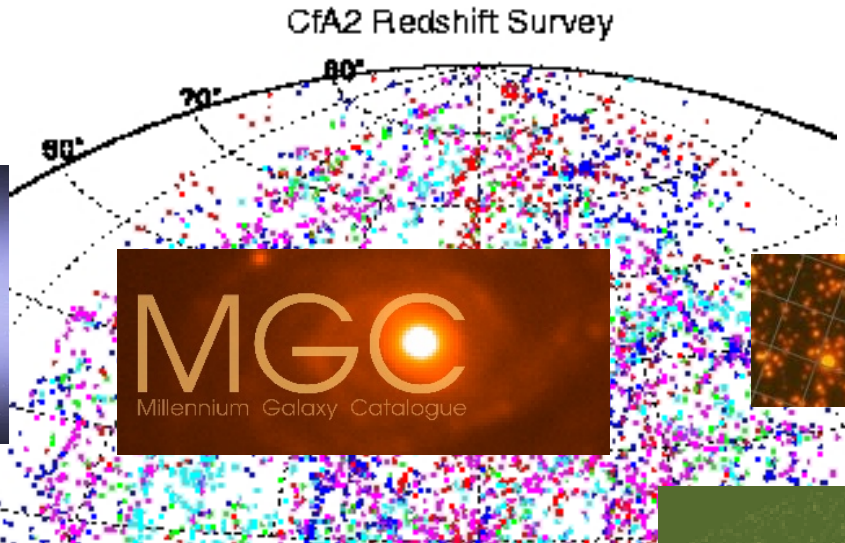






Overview

- Wide-Field Optical Galaxy redshift surveys:
  - Photo-z's v spectro-z's
  - Luminosity functions (ESP→2dFGRS → SDSS → MGC → GAMA)
  - Galaxy Stellar Mass function (SDSS→GAMA)
- Expansion in wavelength:
  - Bimodality (SDSS)
  - Star-formation (CFRS→HST→GALEX)
  - Dust (2MASS→UKIDSS→HERSCHEL)
  - Gas (HI) (Parkes→ARECIBO→ASKAP/MeerKAT→SKA)
- Increase in spatial resolution:
  - Morphology (HST →SDSS→MGC→GAMA)
  - Surface brightness and selection bias (SDSS & MGC)
  - Sersic profiles & structural analysis (GIM2D, BUDDHA, GALFIT3)
  - Size evolution
- Galaxy formation: a two-stage process?

Photo-z v Spec-z

SDSS photo-z
v
GAMA spec-z

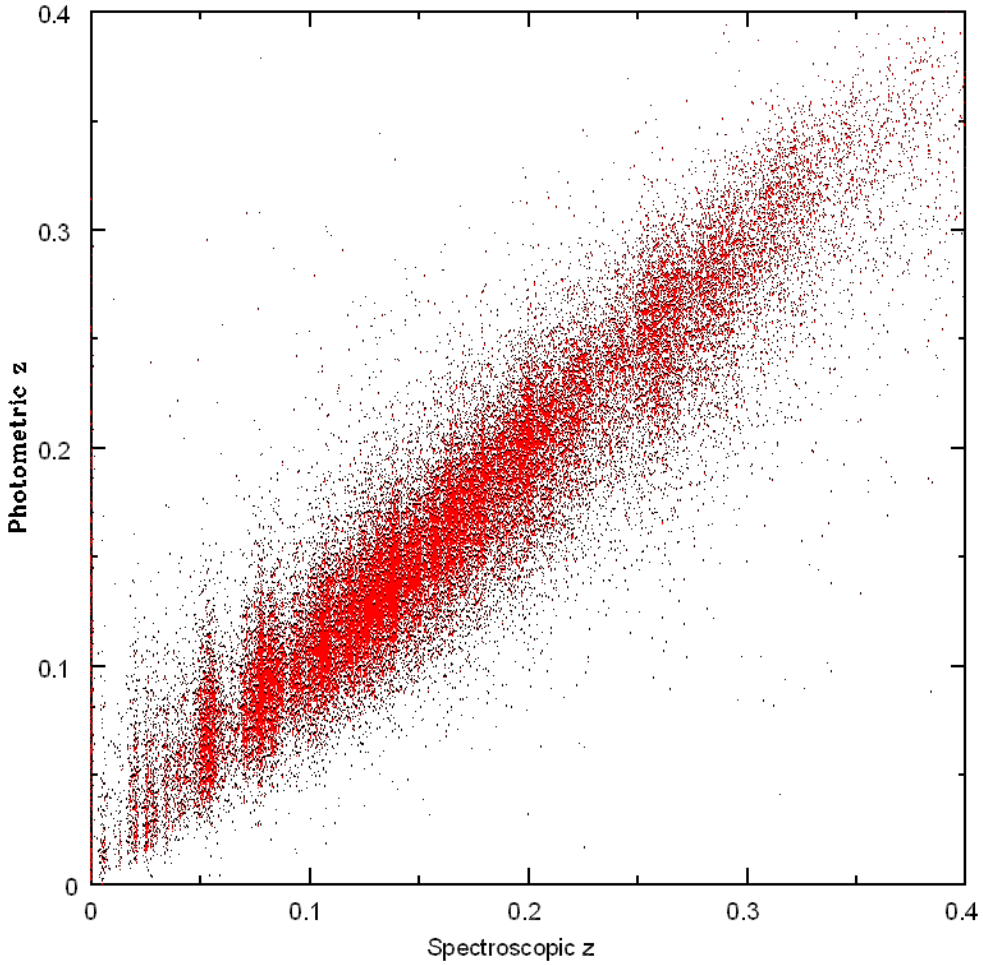
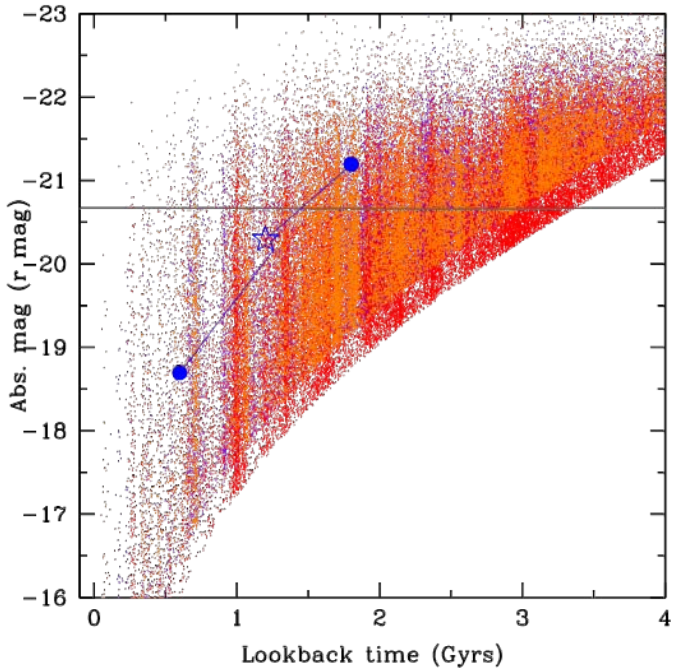


Photo-z v Spec-z

Beware of relying on them too much

at low-z

Scaling relations and luminosity functions



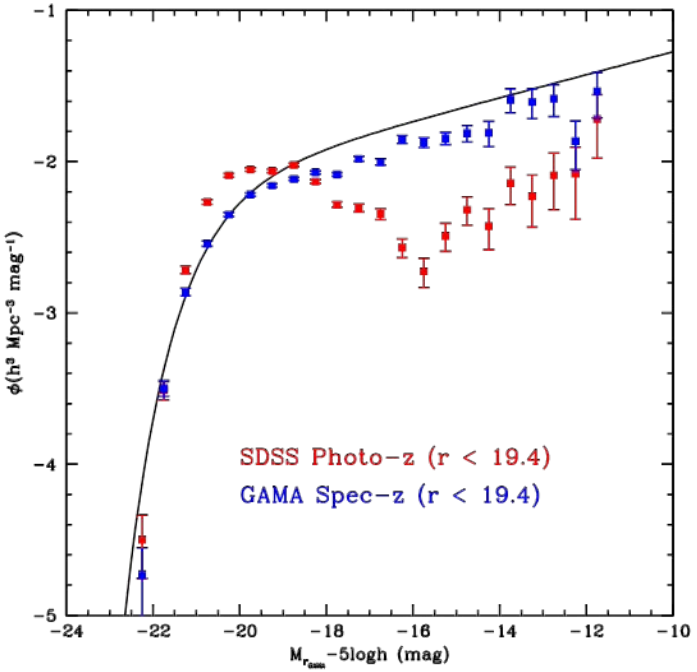
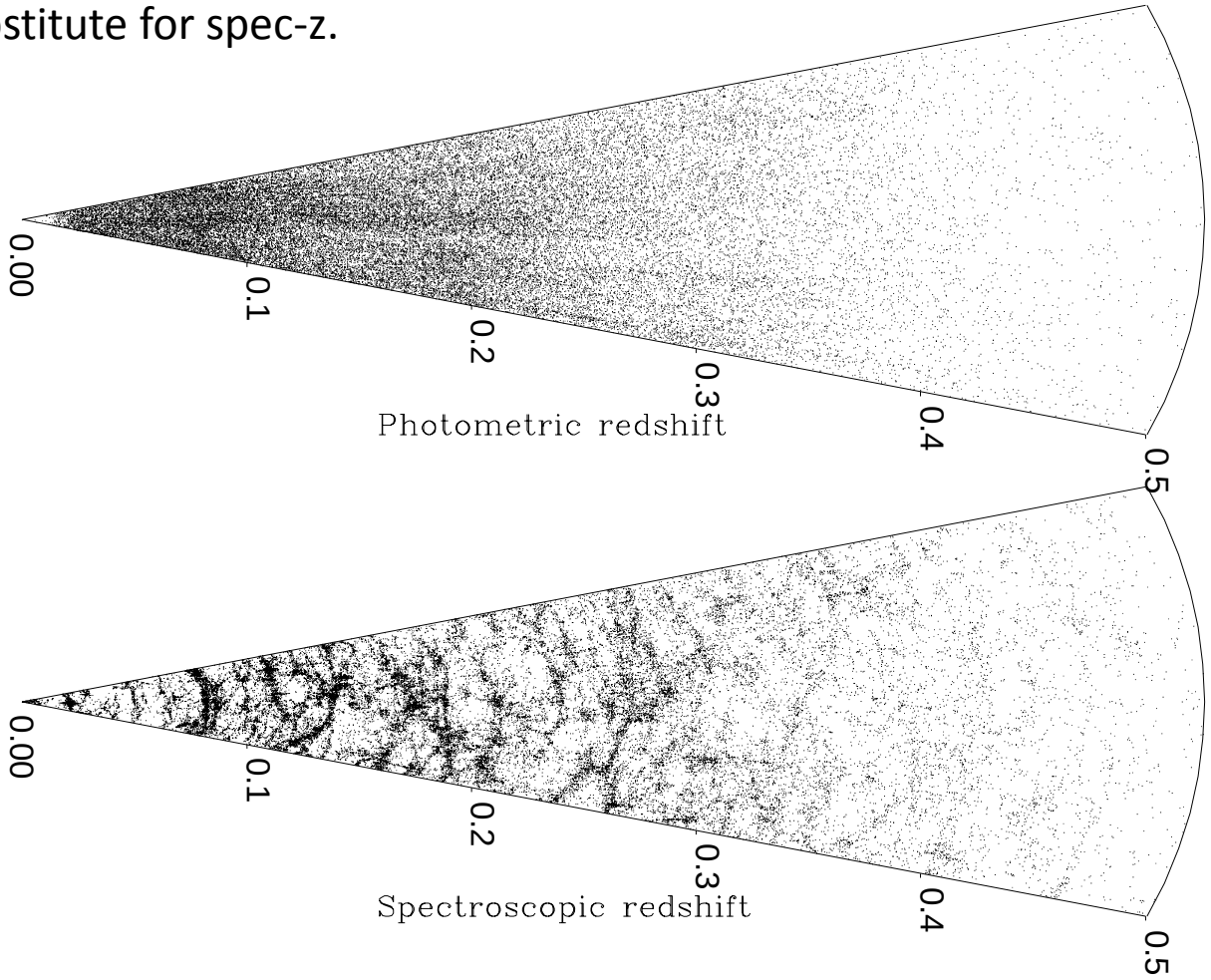
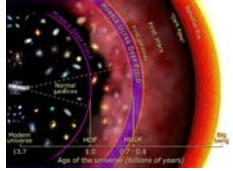


Photo-z v Spec-z

For many applications
there is no substitute for spec-z.





Driver et al (1998, ApJ, 496, 93)

Impact of UV/optical/NIR surveys

Survey	Papers	Citations
SDSS	2065	86241
2MASS	704	19812
HDF/UDF/GOODs/GEMs	555	32561
2dF	371	23457
GALEX	336	7940
CfA1&2	277	15444
zCOSMOS/VVDS/DEEP/GDDS	158	6530
COMBO-17	83	5743
UKIDSS	80	2564

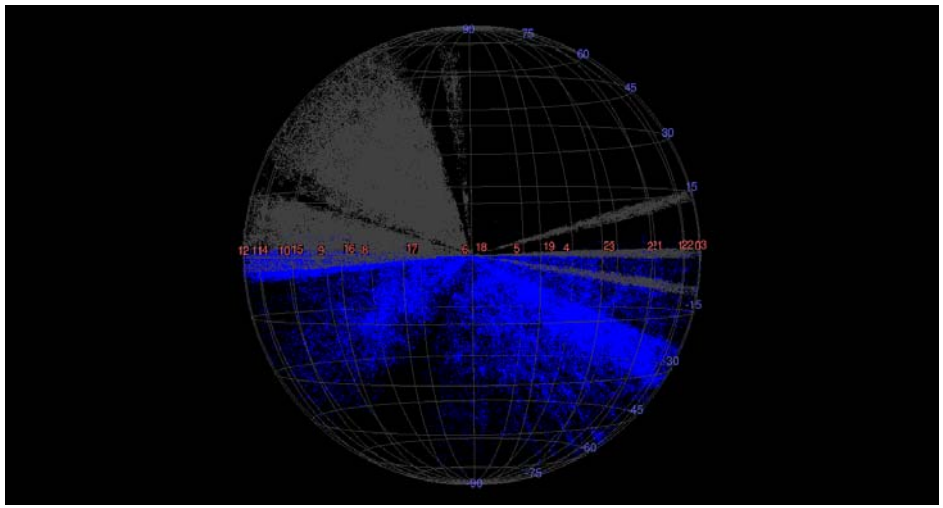
ADS abstract search on <survey>+”galaxy”

All known redshifts: ~2.7million

Table 4: Redshift surveys from Anglo-Australian Observatory

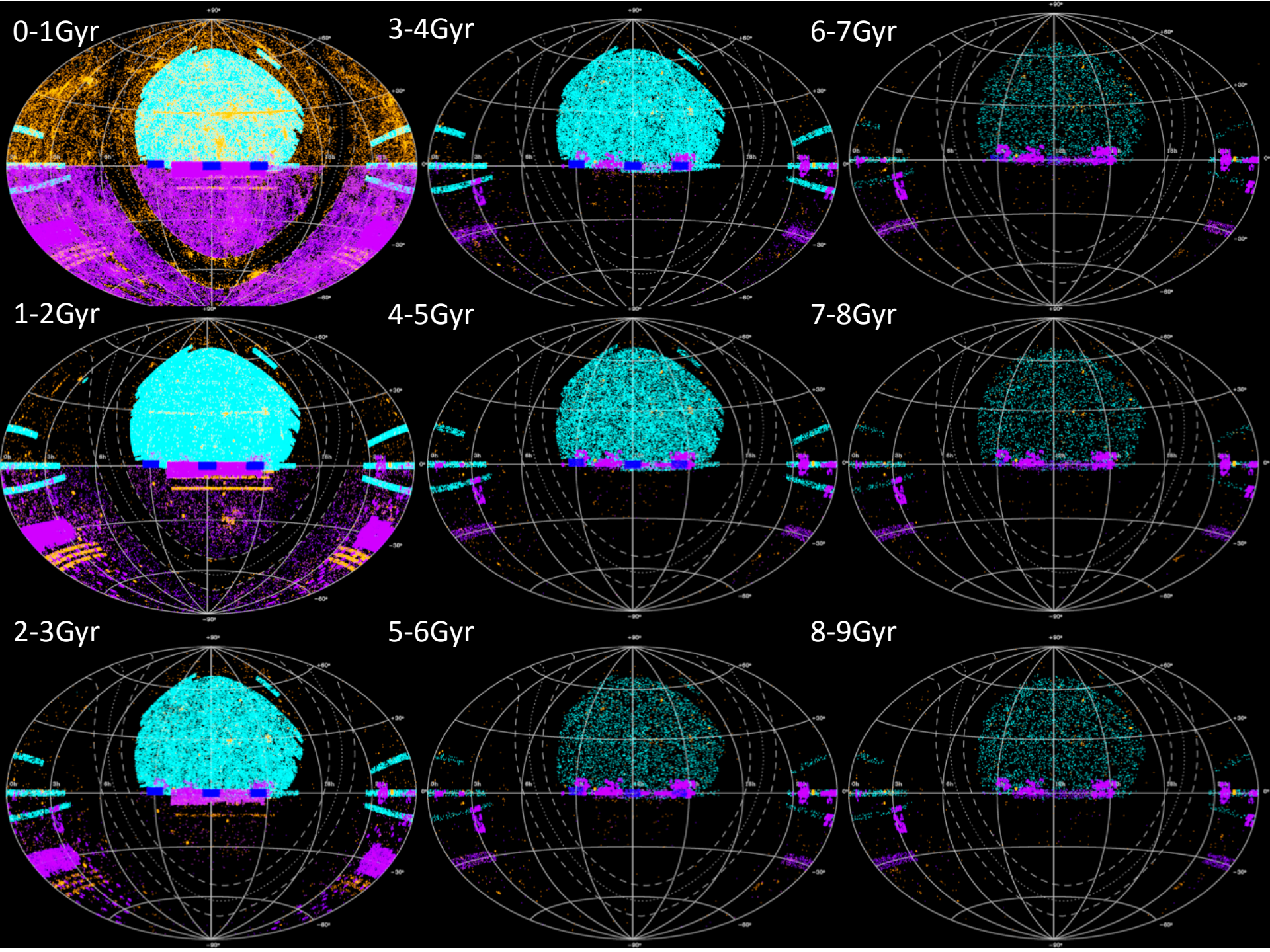
survey	dates	observations
2dFGRS	1996–2001	227k
2QZ	1996–2001	28k
MGC	2002–2006	8k
2SLAQ-LRG	2003–2006	16k
2SLAQ-QSO	2003–2006	3k
6dFGS	2003–2008	110k
UCD/Fornax	2002–2006	16k
AUS	2006+	50k
WiggleZ	2007+	140k (200k)
GAMA	2008+	90k (250k)
total		688k (910k)

Driver et al 2009, A&G, 50, 12



CfA/2MASS	1990s	45k
ESP	1999	15k
SDSS	1999-2006	1400k
VVDS	2006-	150k
zCOSMOS	2006-	40k
VIPERs	2009-	100k
Deep1&2	2000-	65k
		1815k

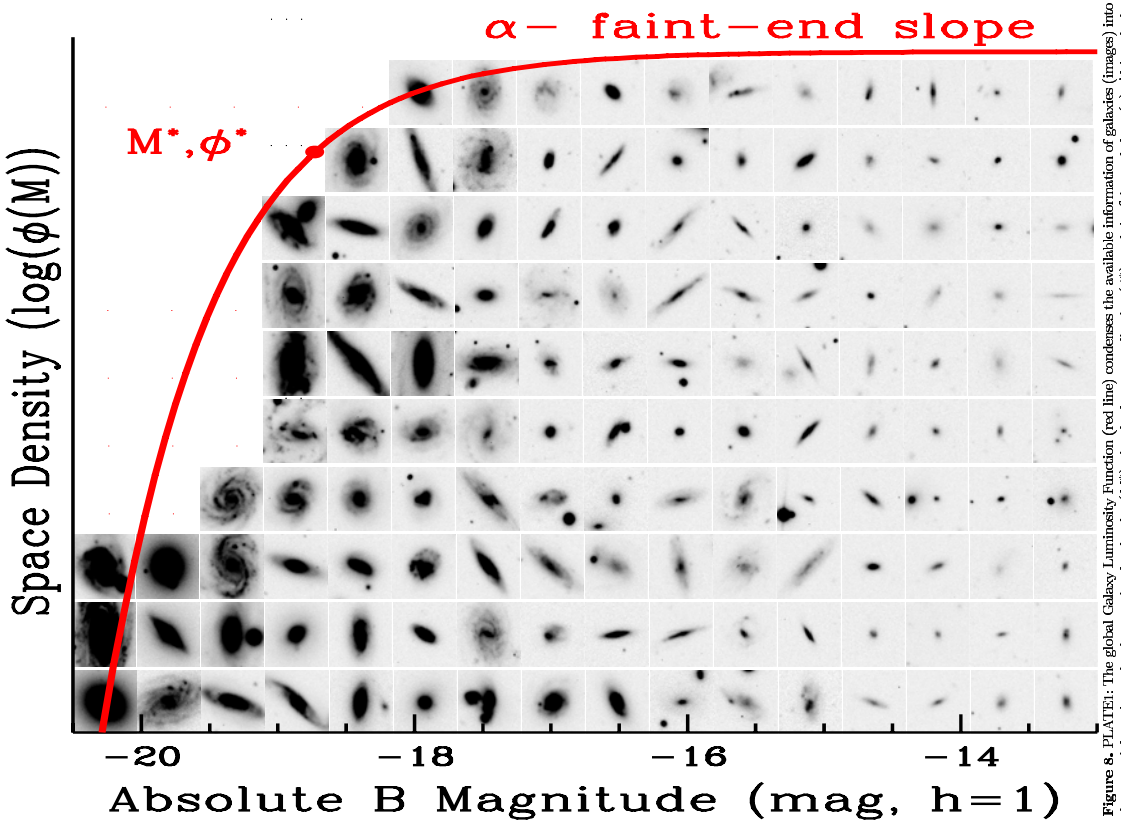
AAO responsible for: 35%
SDSS responsible for: 50%
Other : 15%!


0-1Gyr
3-4Gyr
6-7Gyr
1-2Gyr
4-5Gyr
7-8Gyr
2-3Gyr
5-6Gyr
8-9Gyr

Key topics

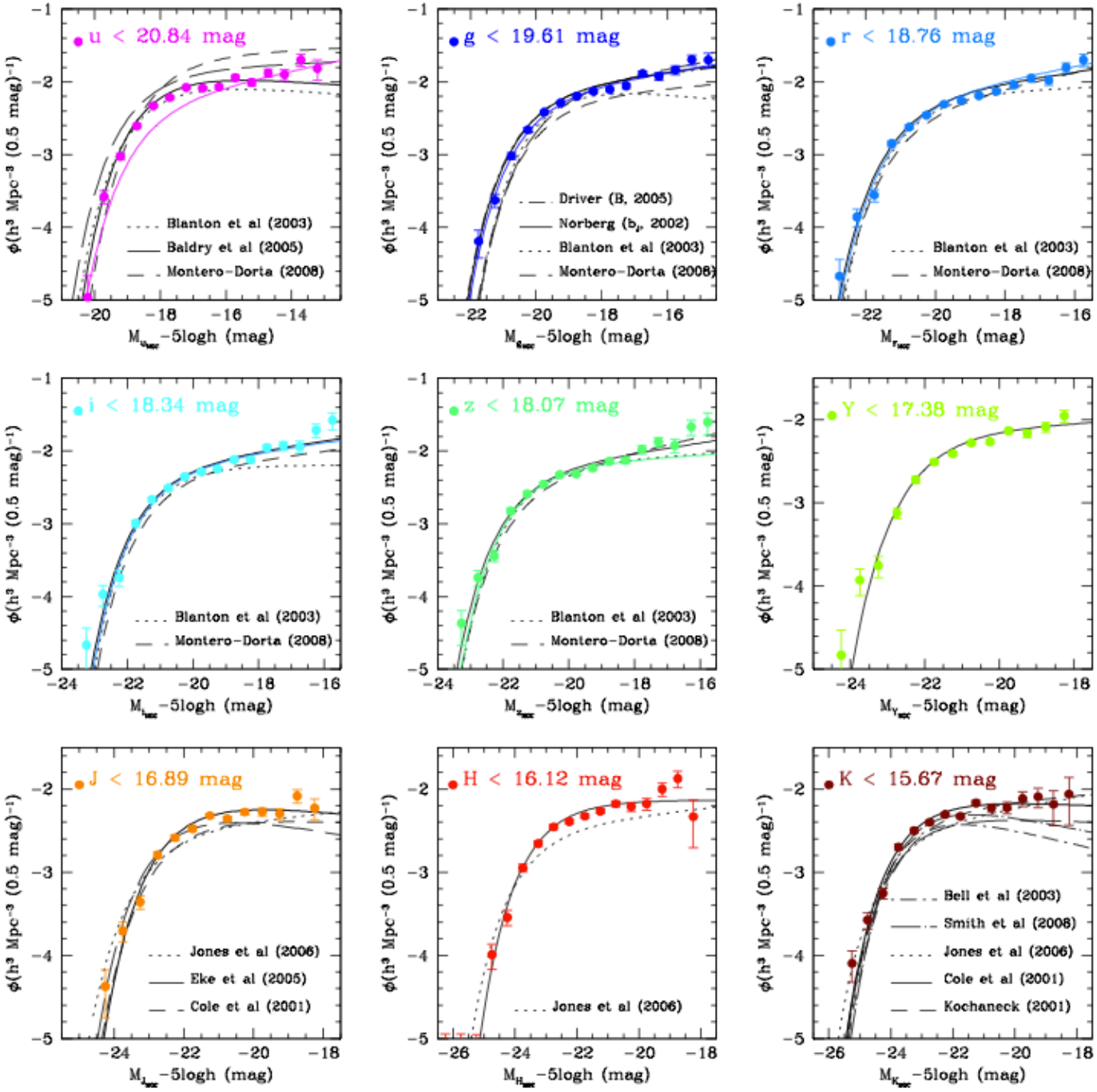
Topic	Key papers
Luminosity Fns	Bell et al 03; Cole et al 01; Faber et al 07; Blanton et al 03, 05; Bouwens et al 06, 07; Driver et al 2011
Mass estimation	Kauffmann et al 03; Bell & de Jong 01; Bundy et al 06, Taylor et al 11
Galaxy Mass Fns	Bell et al 03; Baldry et al 08, 11; Fonatanna et al 04; Ilbert et al 10
Bimodality	Strateva et al 01; Baldry et al 04, 06; Driver et al 06
SMBHs and galaxies	Gebhardt et al 00; Ferrarese & Merritt 00; Marconi et al 04; Vika et al 11
Dust and opacity	Calzetti et al 00; Choi et al 07; Shao et al 07; Driver et al 07, 08
Mass-metallicity rel'n	Tremonti et al 04; Savaglio et al 2005; Erb et al 06; Baldry et al 08
Mass-size rel'n	Shen et al 03; Blanton et al 05; Driver et al 05, Trujillo et al 06, 07
Star-formation rates	Brinchmann et al 04; Kauffmann et al 03; Salim et al 07; Juneau et al 05, Hopkins & Beacom 06

Luminosity functions



8 *Driver*

Figure 8. 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.



Hill et al (2010)

Relatively little variation with Wavelength

Discrepancies between surveys large

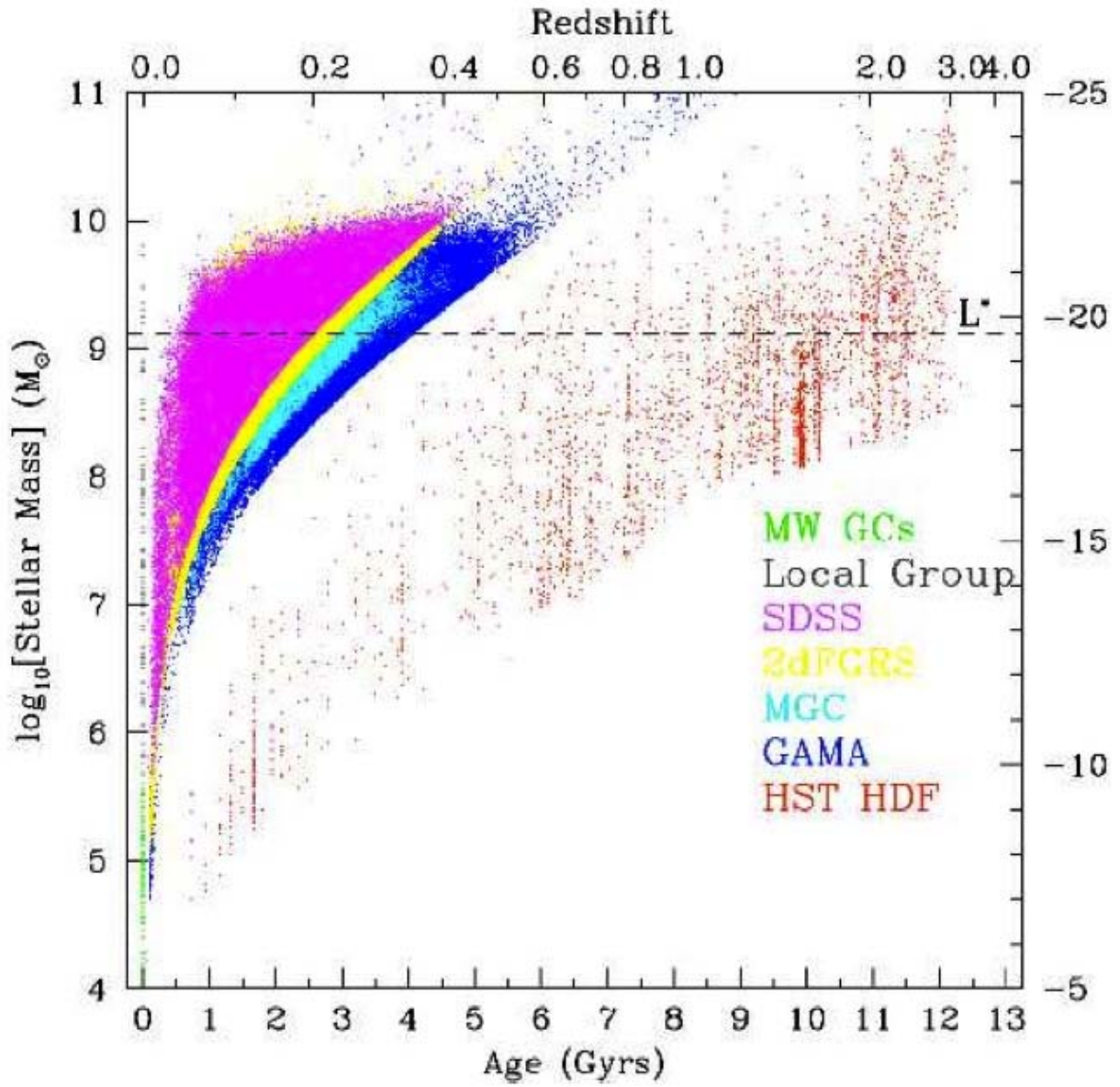
Systematic >> Random

SDSS

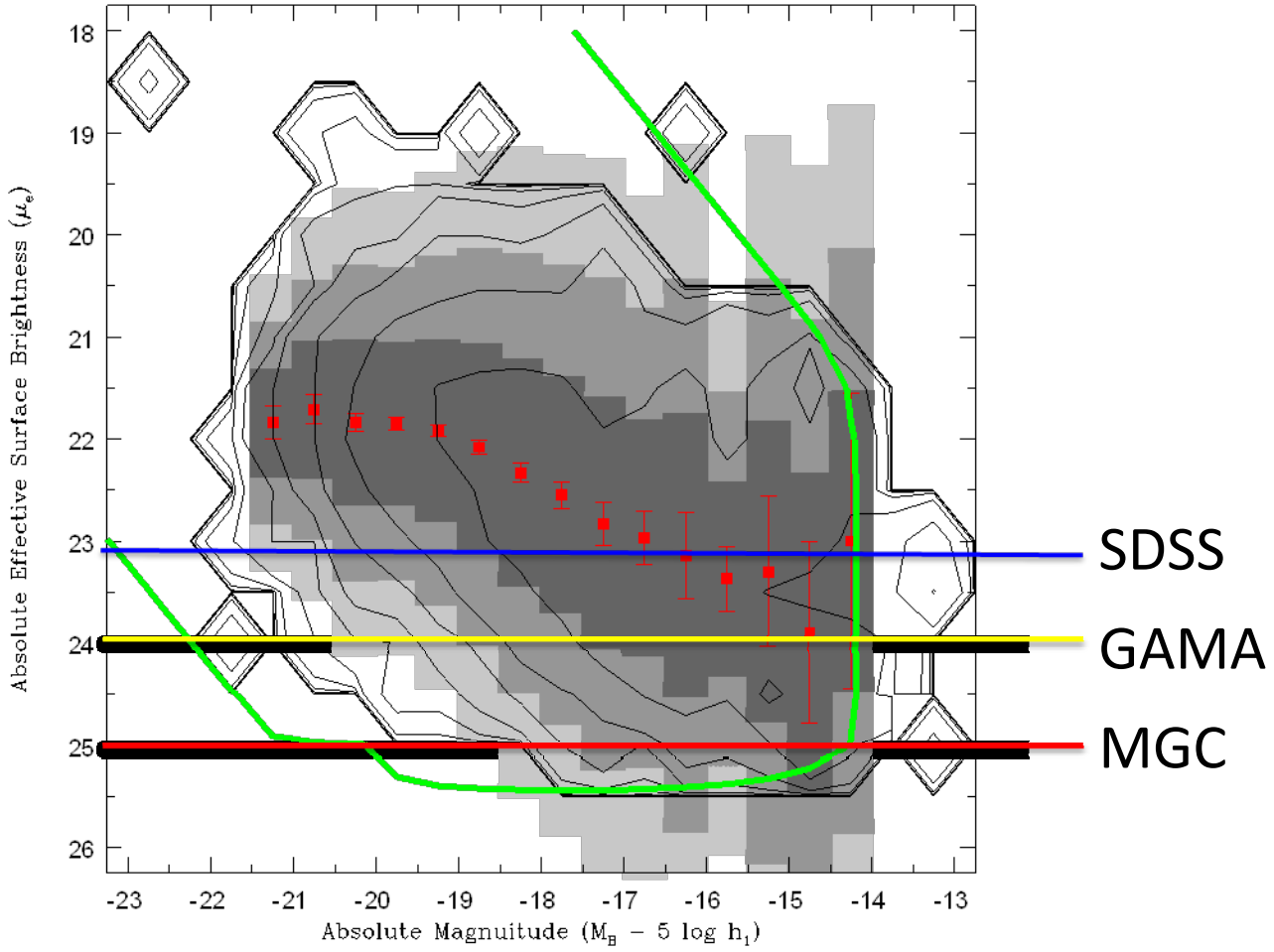
MGC
Millennium Galaxy Catalogue

UKIDSS

Parameter space probed by galaxy surveys

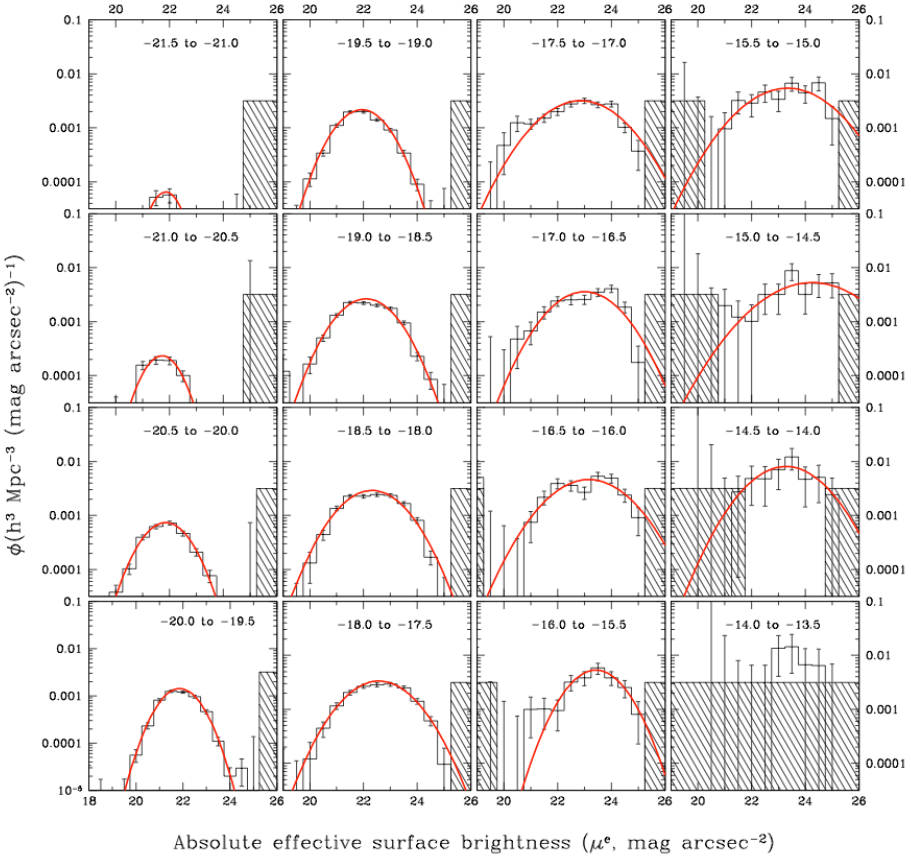


Survey limits…
…biggest is not always best

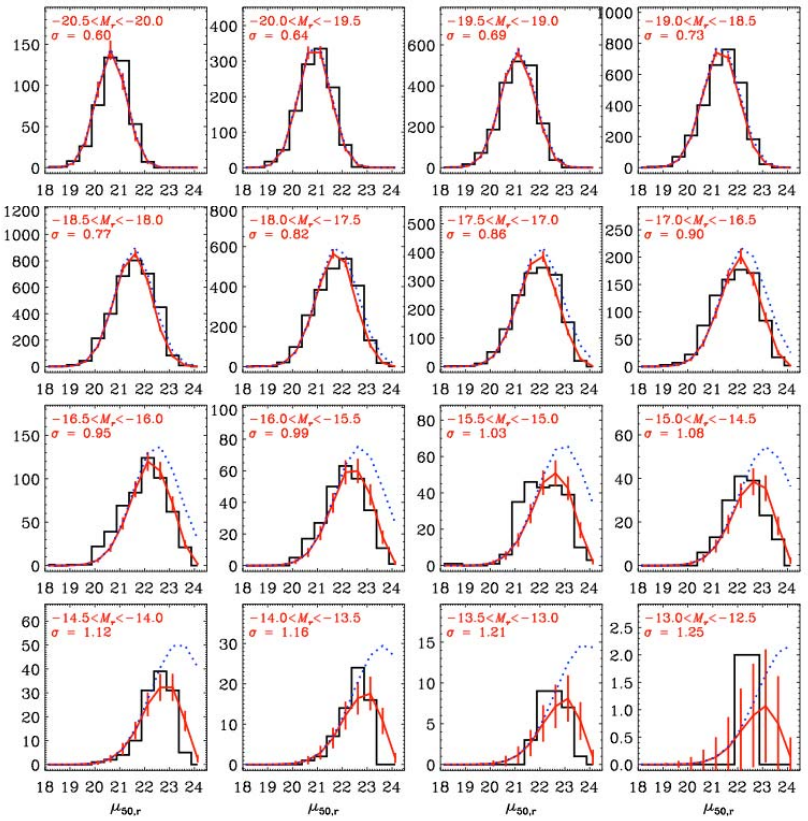


Mass-size or Lum-SB relation

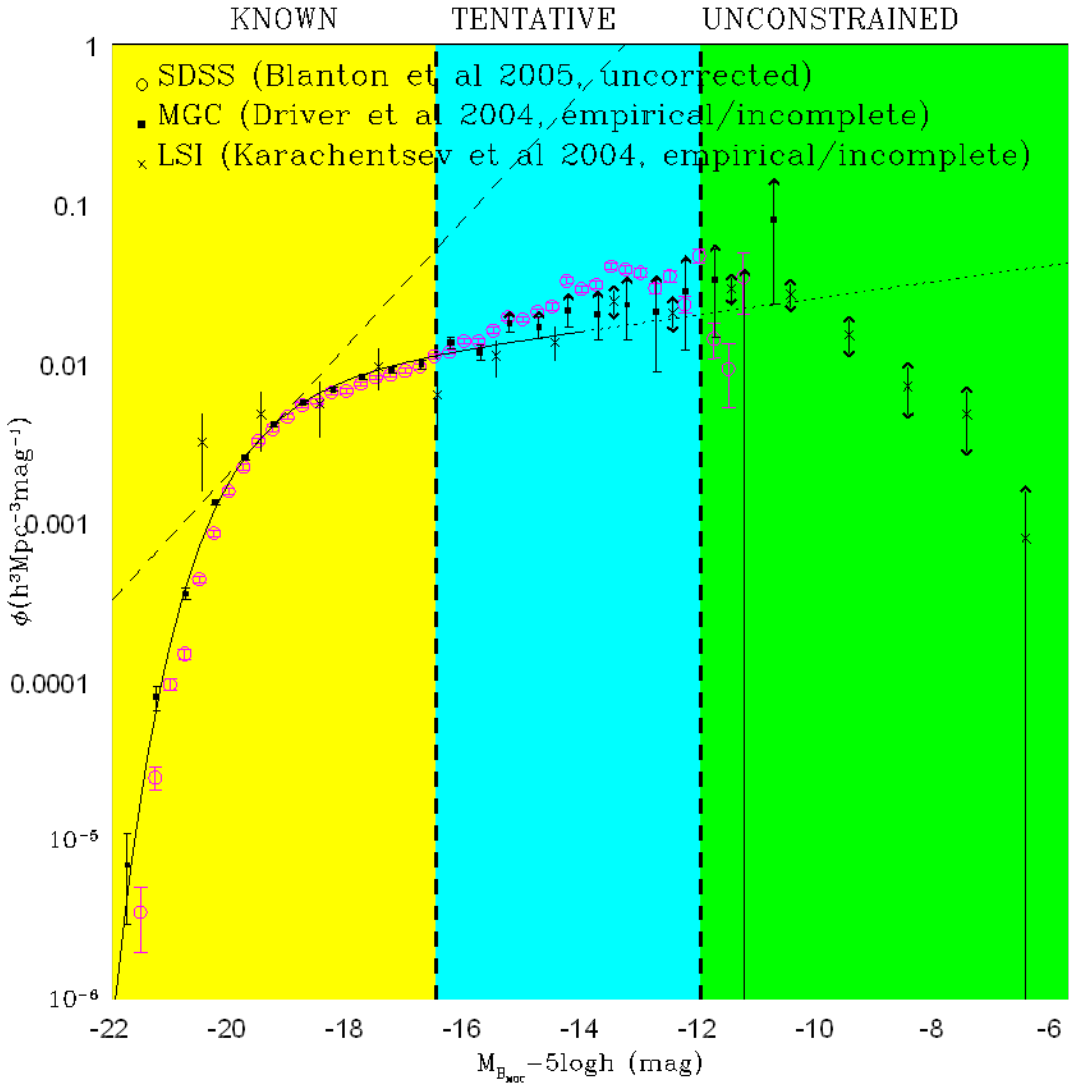
MGC: Driver et al 05



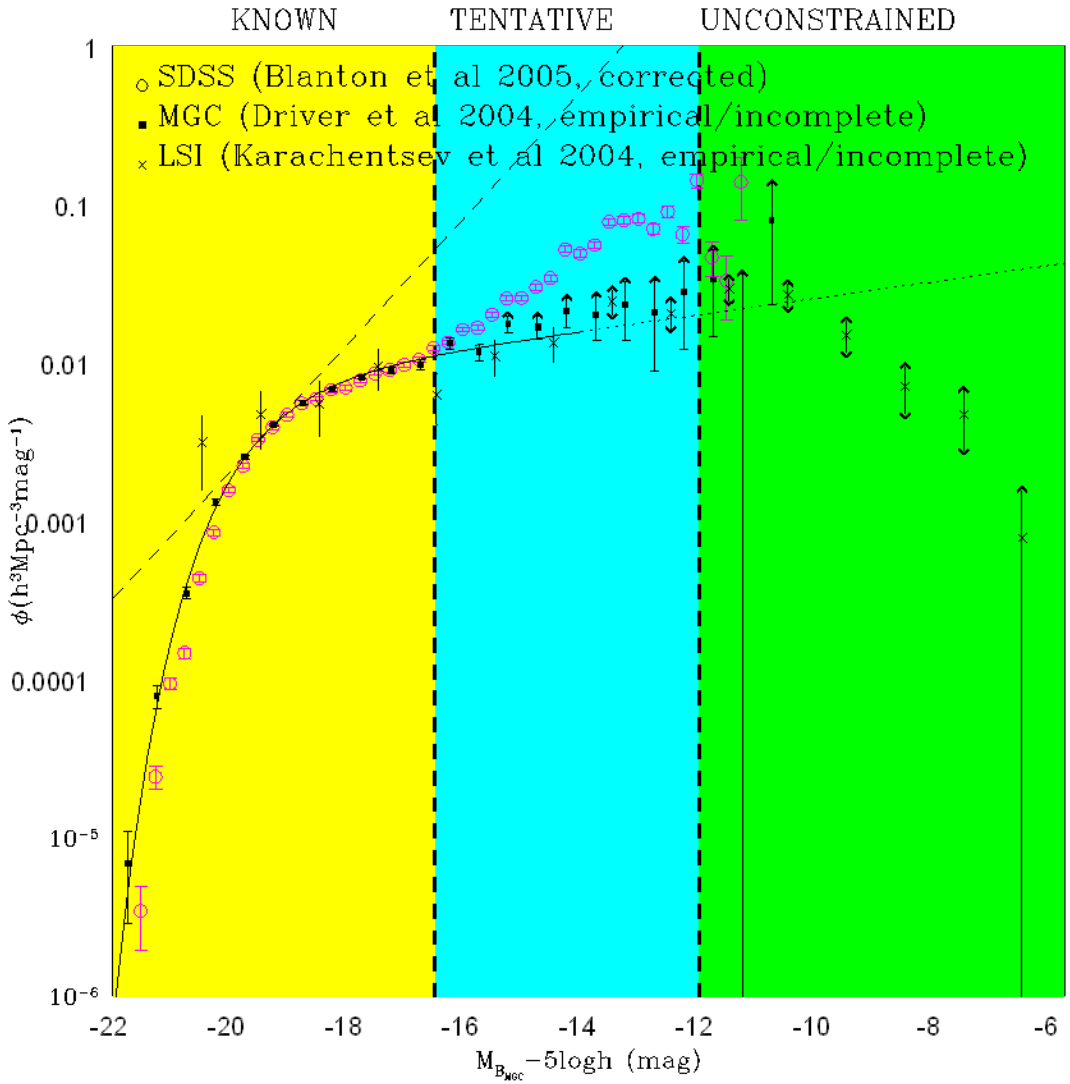
SDSS NYUVAGC: Blanton et al 05



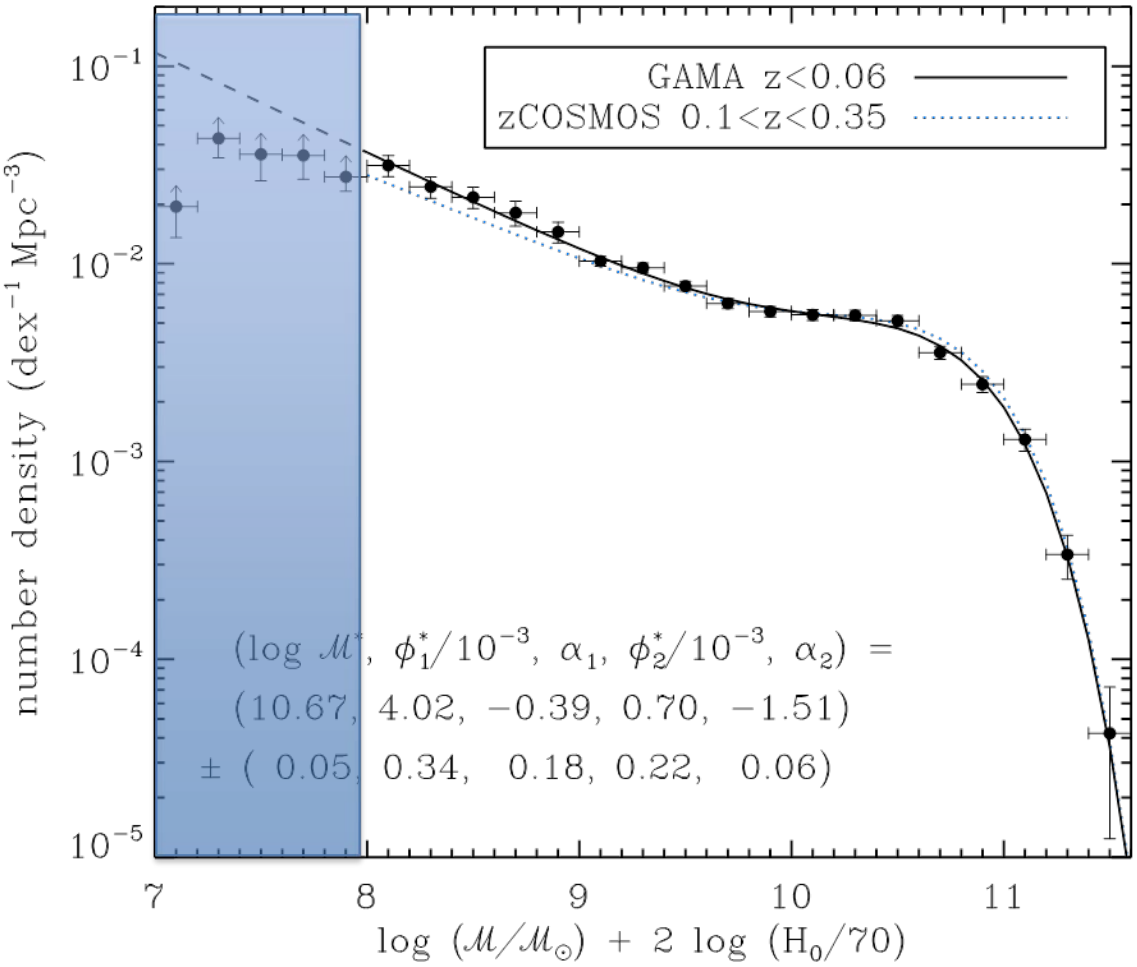
Luminosity functions (field)



Luminosity functions (field)



Galaxy Mass Function



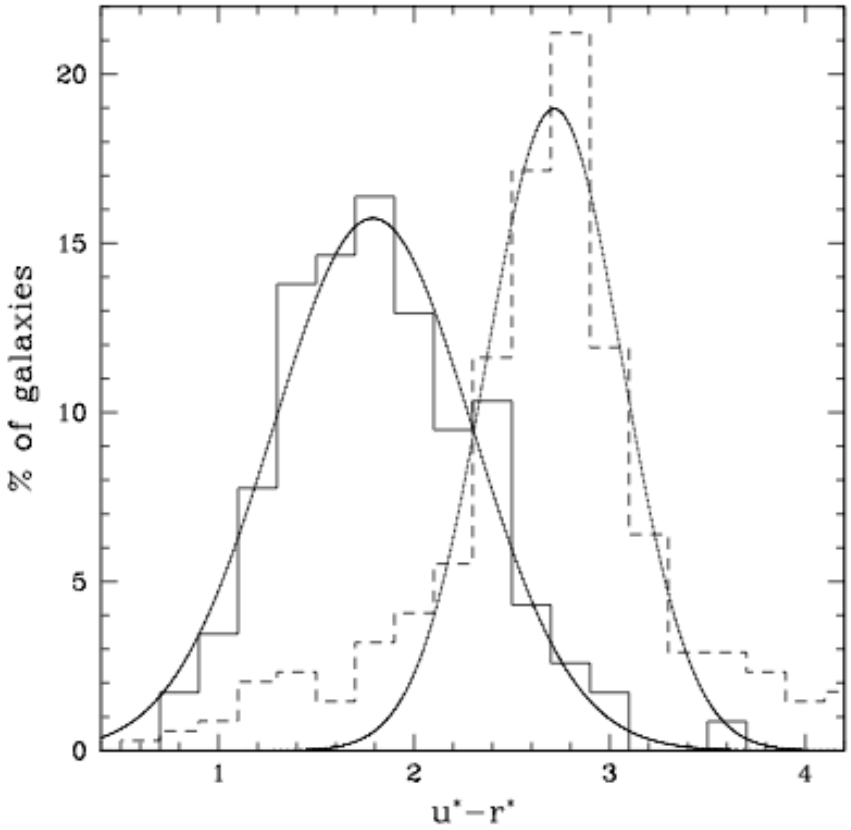
GAMA:
Baldry et al 2011
zCOSMOS:
Pozetta et al 2010

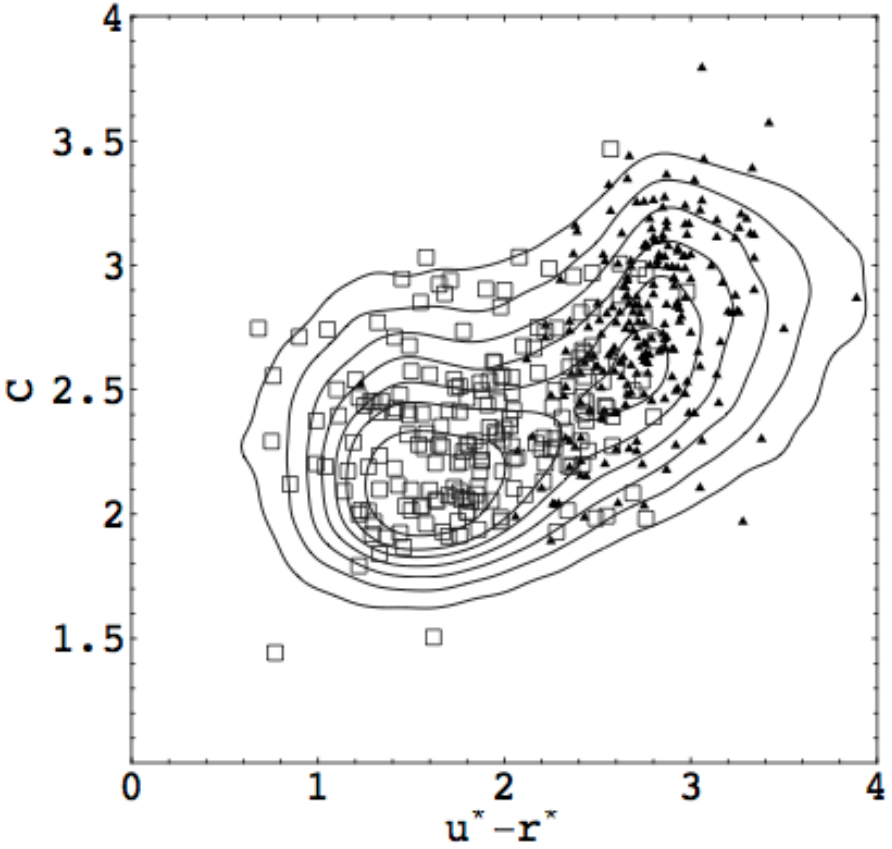
Definite
Upturn

Known to
$10^8 M_{solar}$

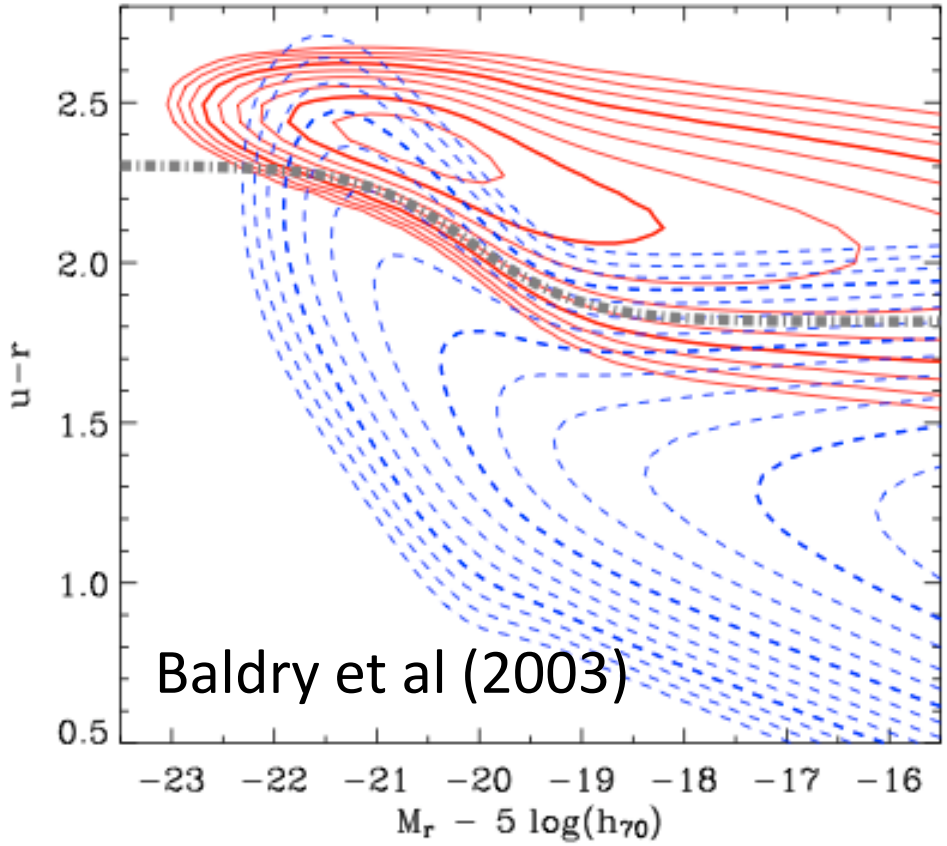
Bimodality

Strateva et al (2001)



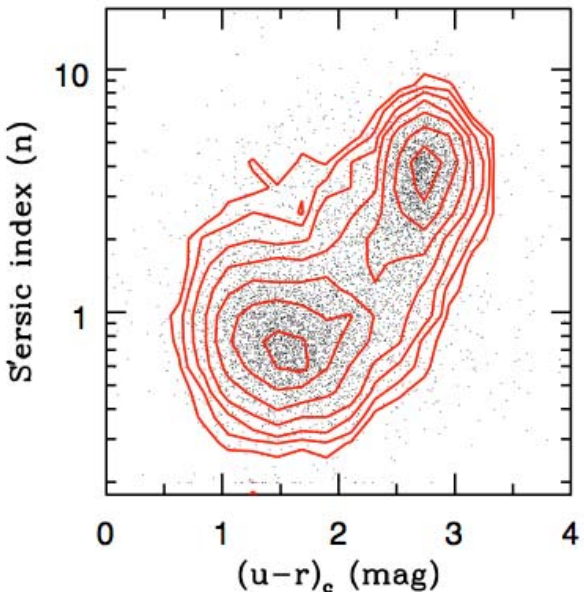


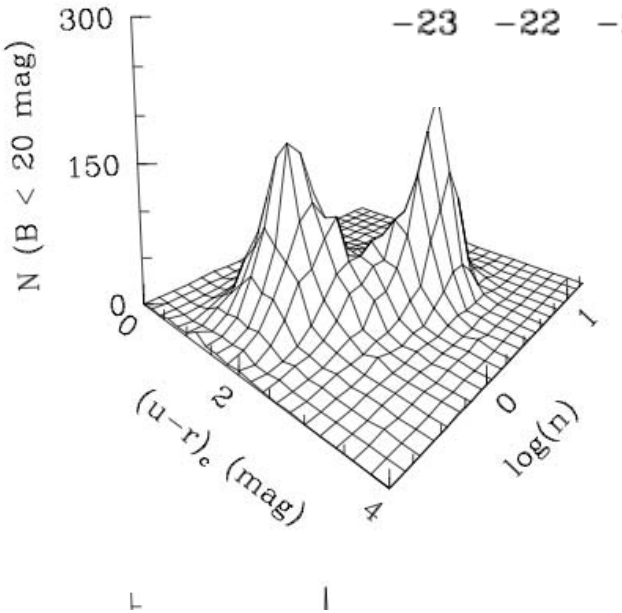
Bimodality



Baldry et al (2003)

Driver et al (2006)





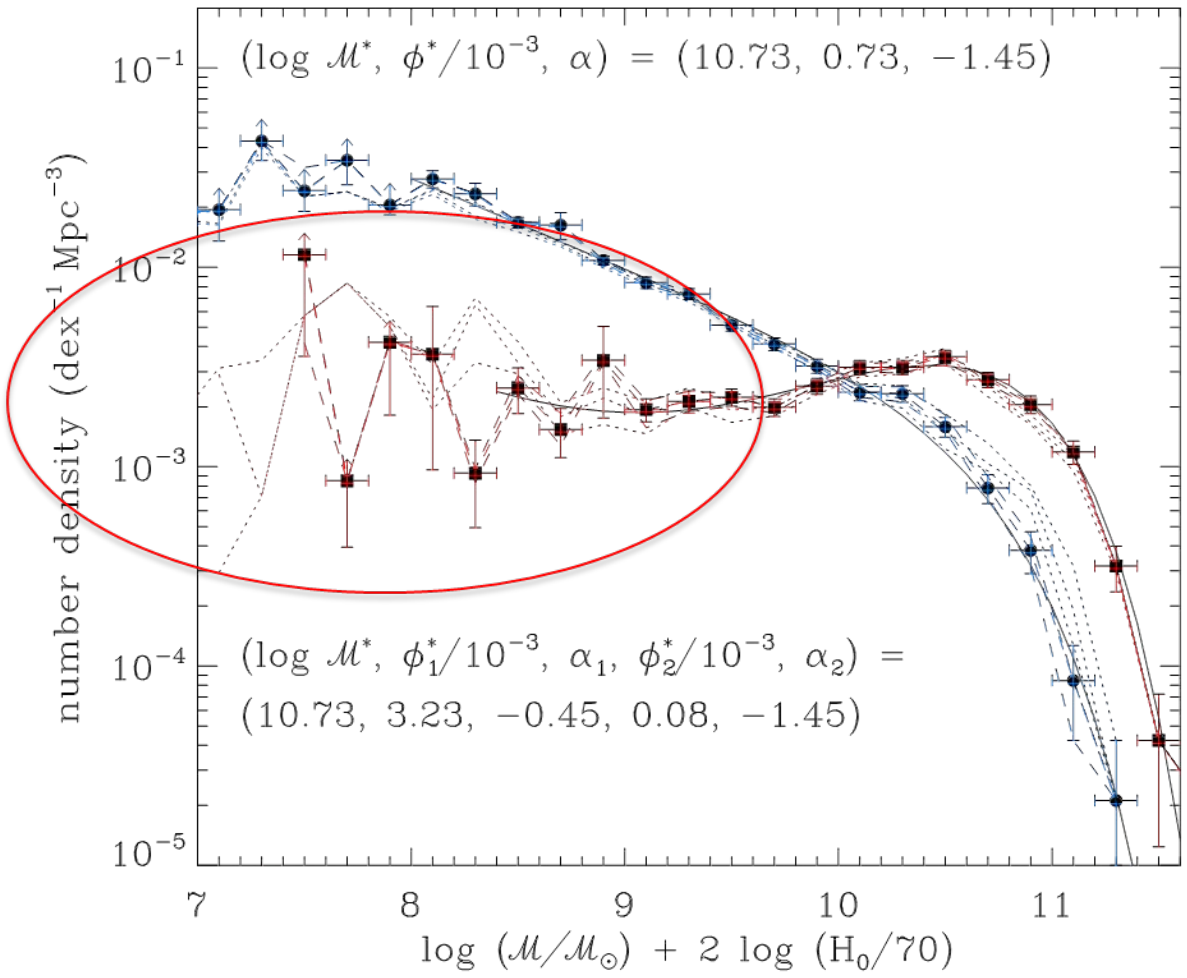
Galaxy Mass Function

Baldry et al (2011)

Upturn seems to be due to bimodality

Red upturn?

Possibly due to contamination from dusty systems



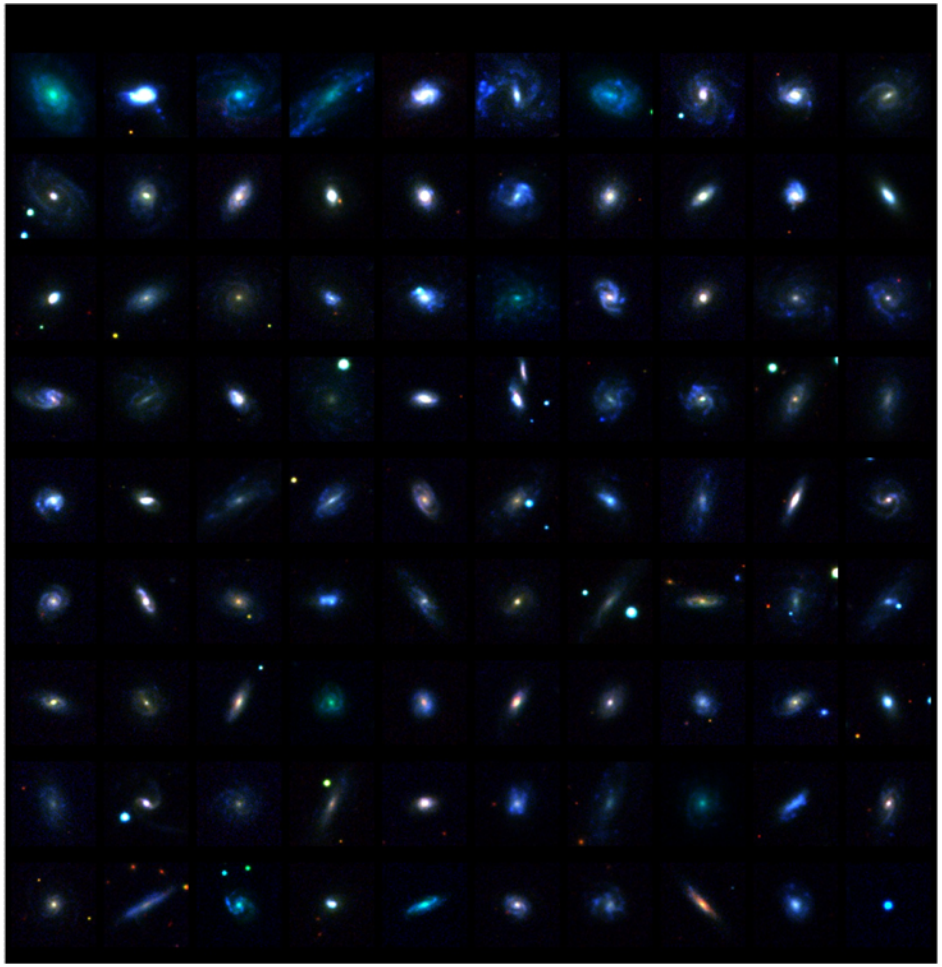
GAMA

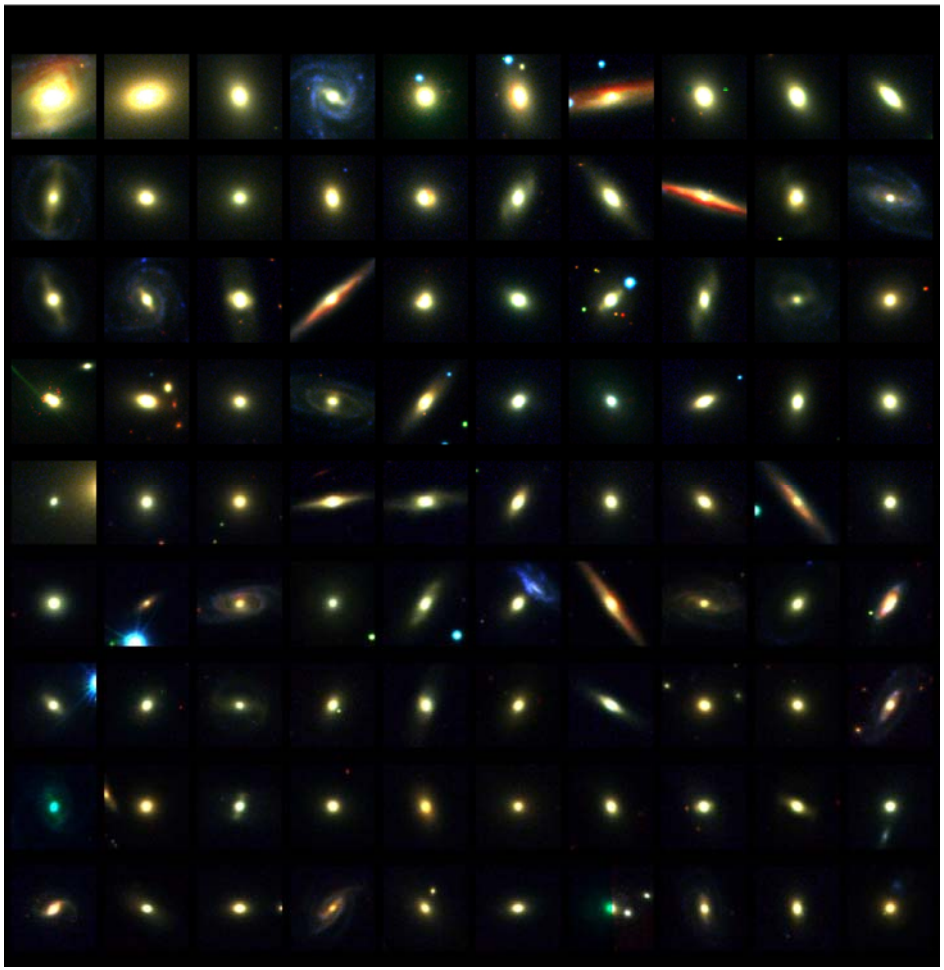
SDSS

The reddest galaxies in the Universe!

UKIDSS

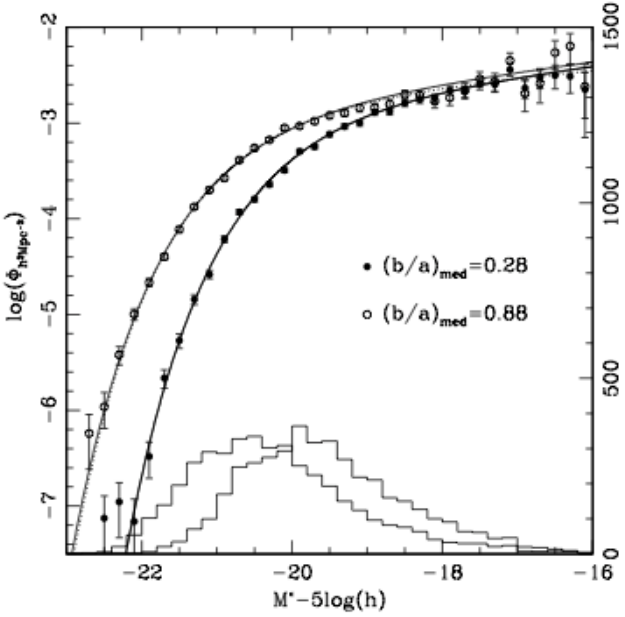
Blue and red galaxies (2<u-r<2.5)



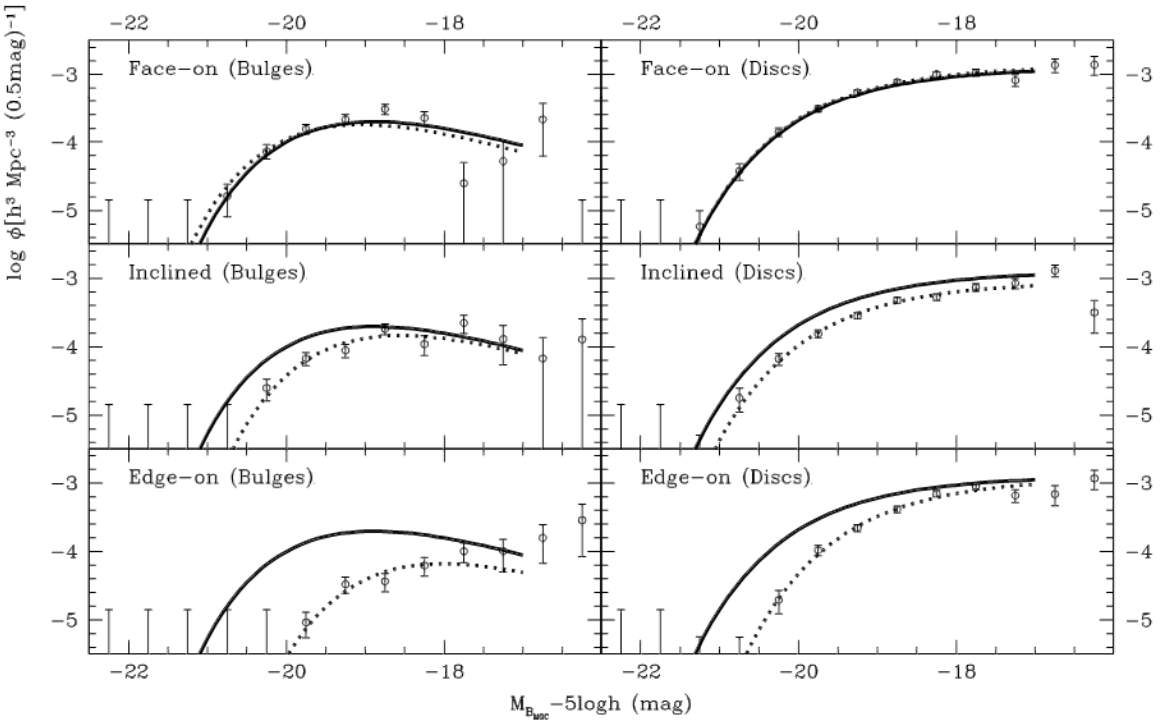


Dust opacity

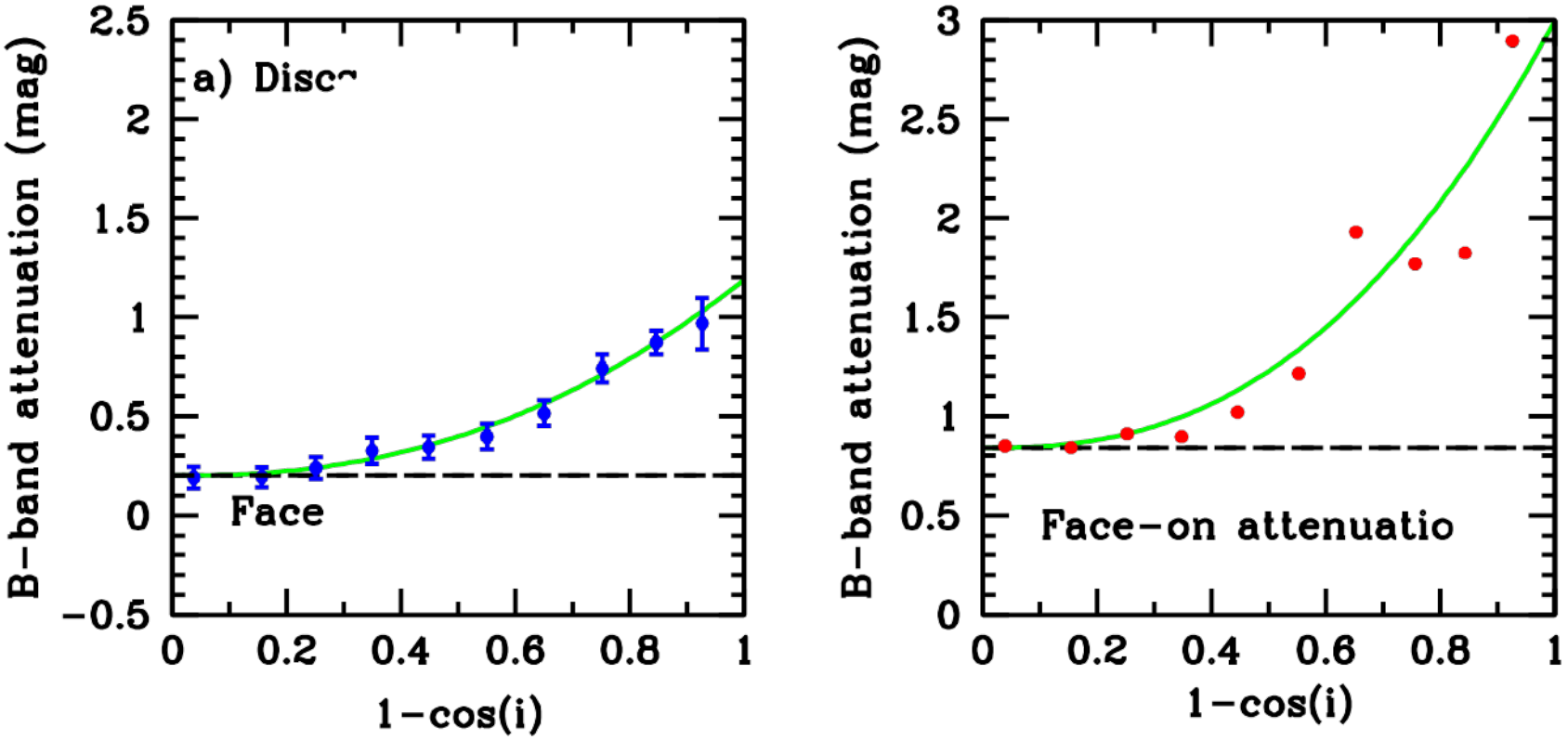
Shao et al 2007



Driver et al 2007

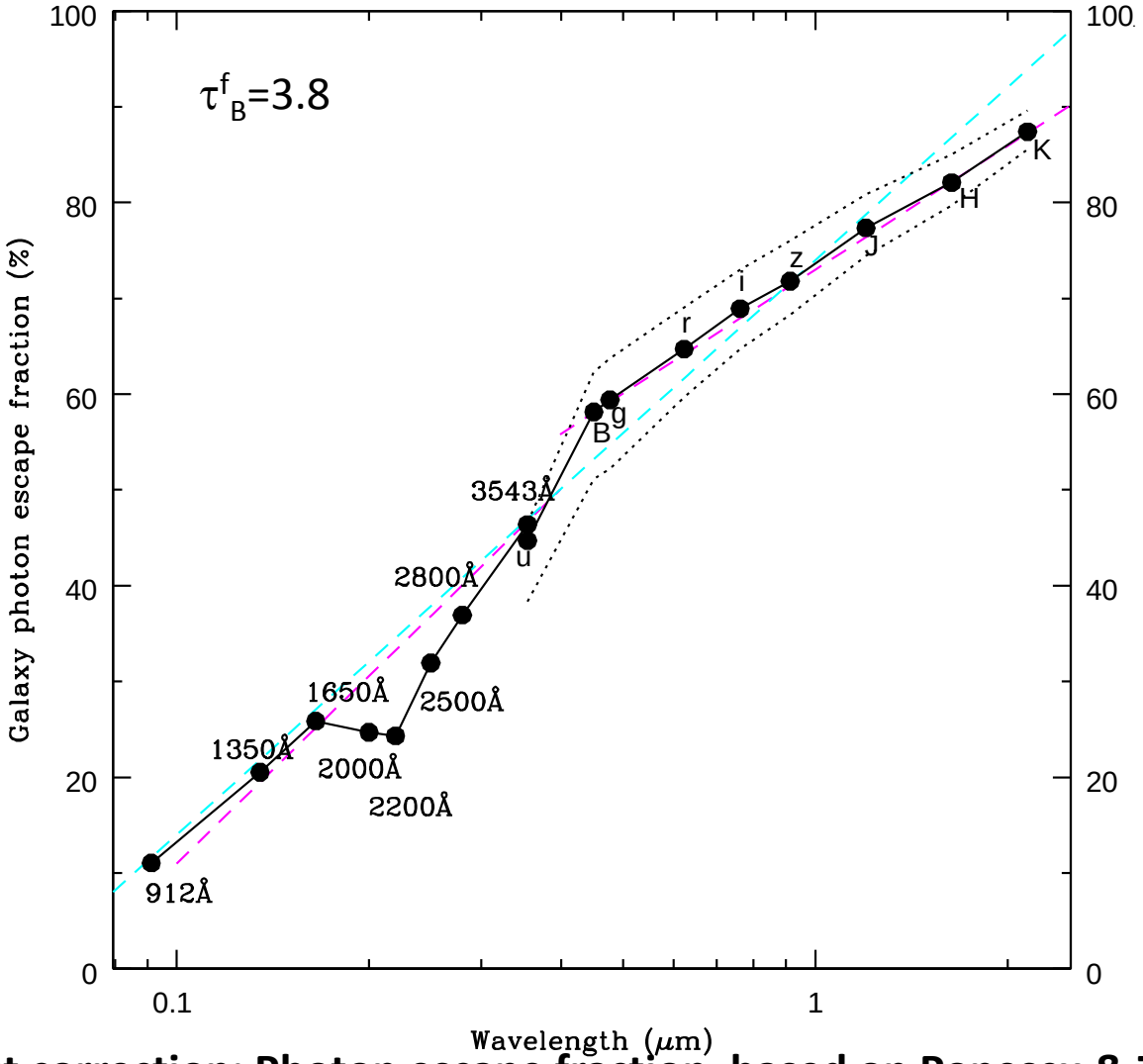


Dust attenutation a major effect



Models from: Popescu et al (2000); Tuffs et al (2004), see also Popescu et al (2011)
2 dust discs plus clumpy dust, central face on B band opacity = 3.8

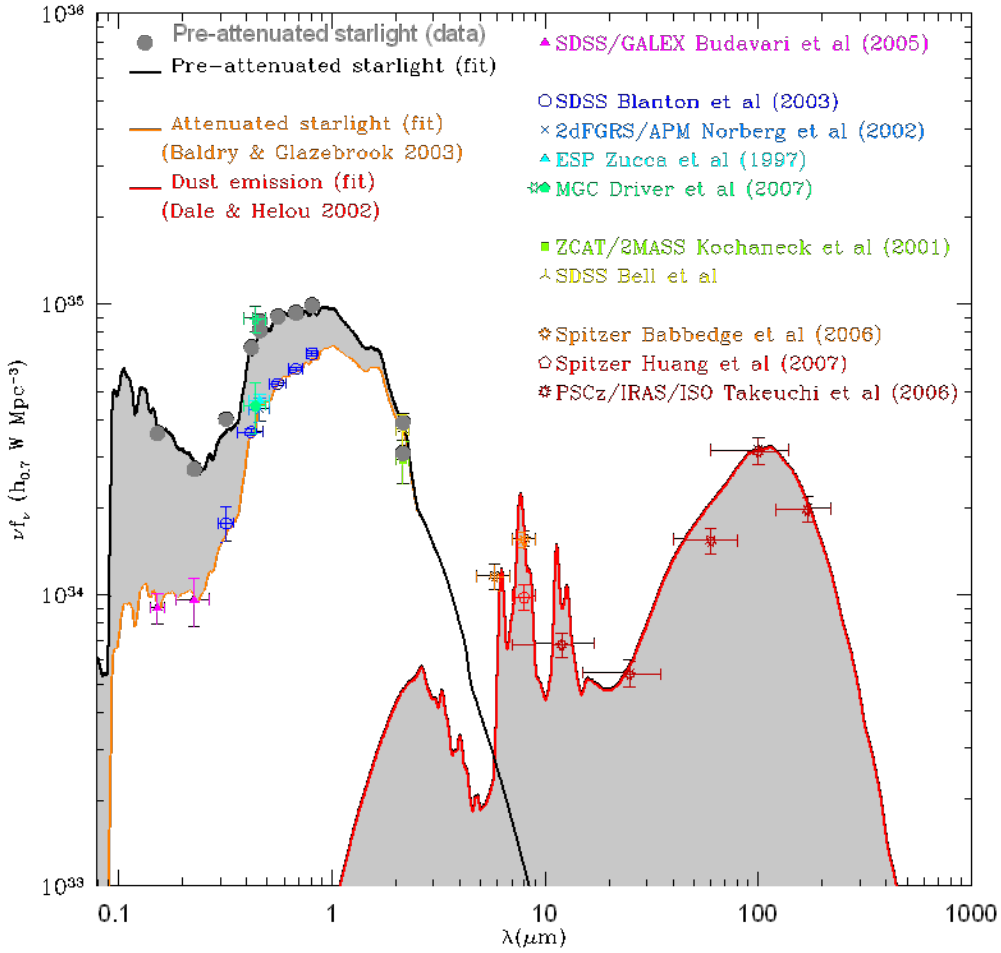
The mean photon escape fraction



Dust correction: Photon escape fraction, based on Popescu & Tuffs 2component+clumpy dust model matched to MGC data

Driver et al 2007; 2008

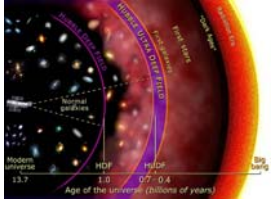
Sanity check: Energy balances

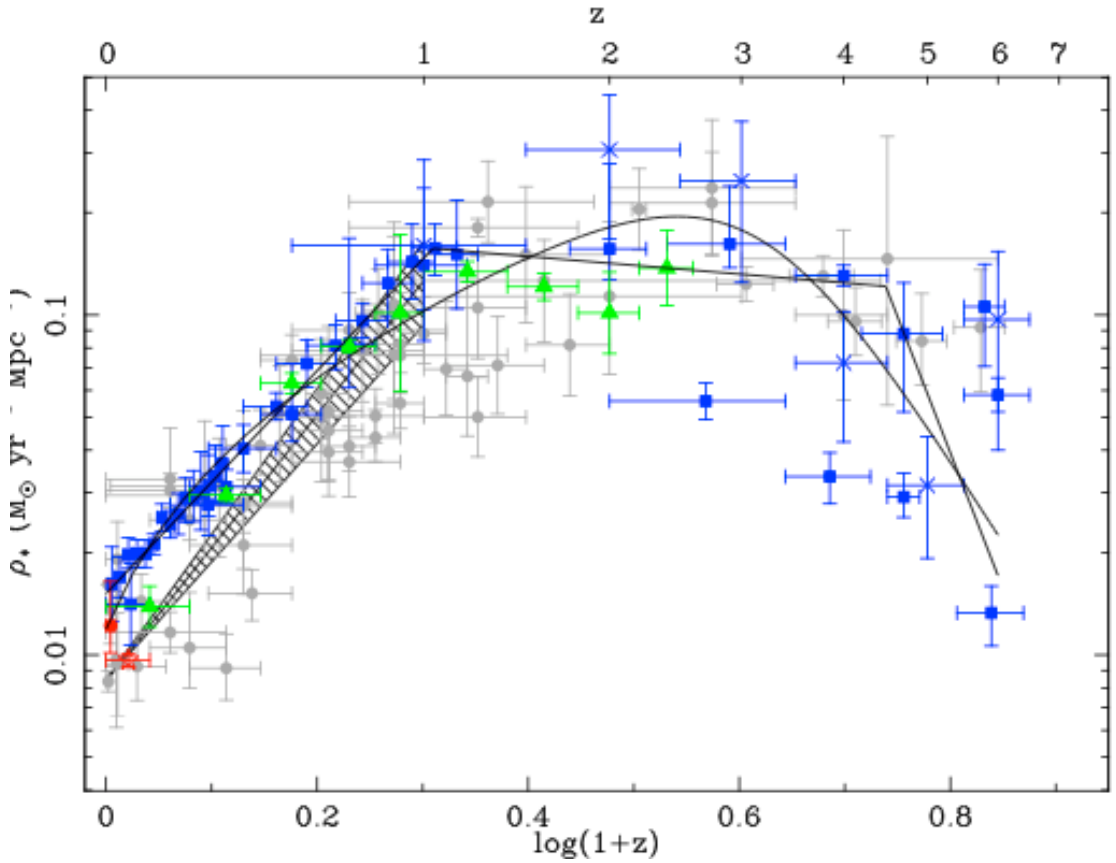


Driver et al (2008)

CFRS LF)

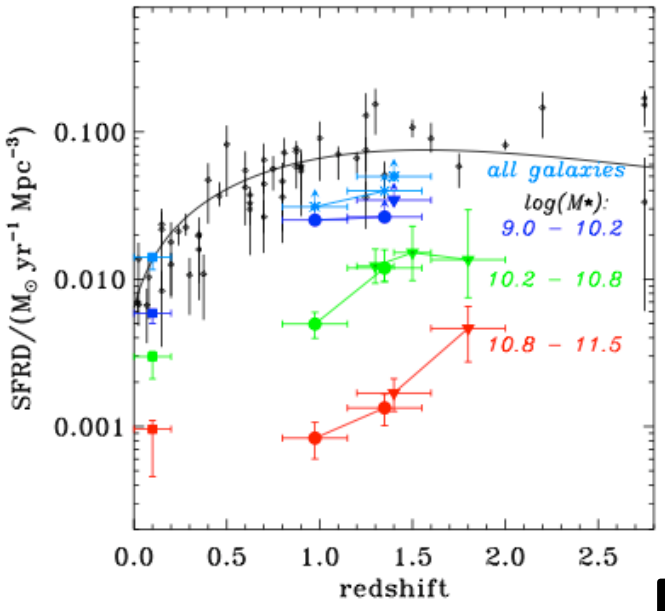
The Cosmic Star-formation History





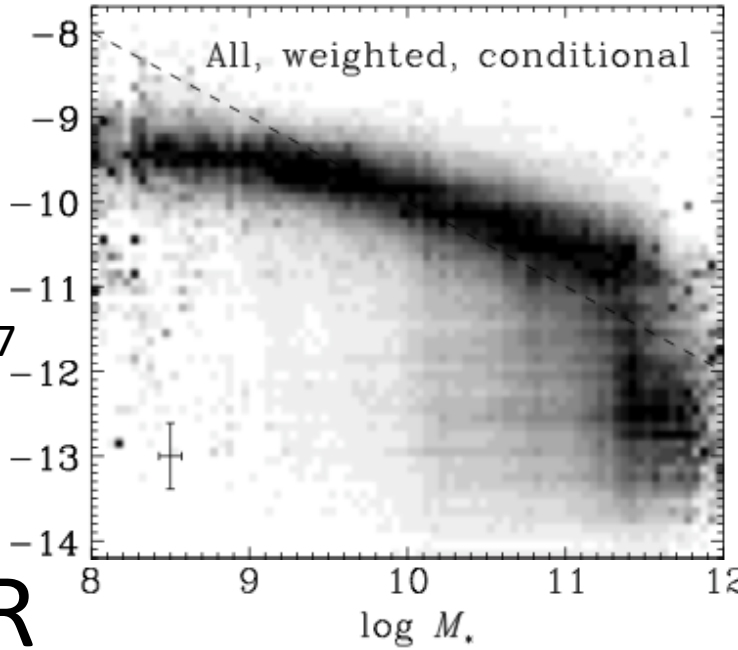
Hopkins & Beacom (2003): Cosmic SFH compendium

GALEX
Galaxy Evolution Explorer



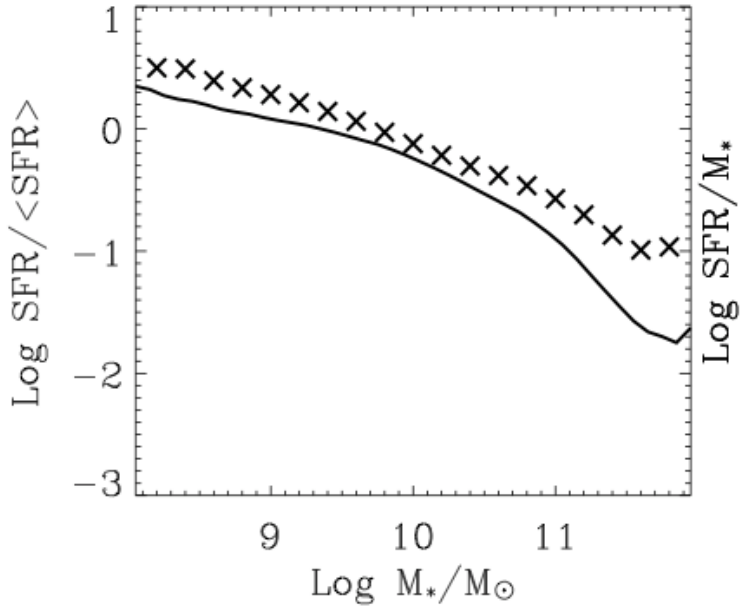
Juneau et al 2005

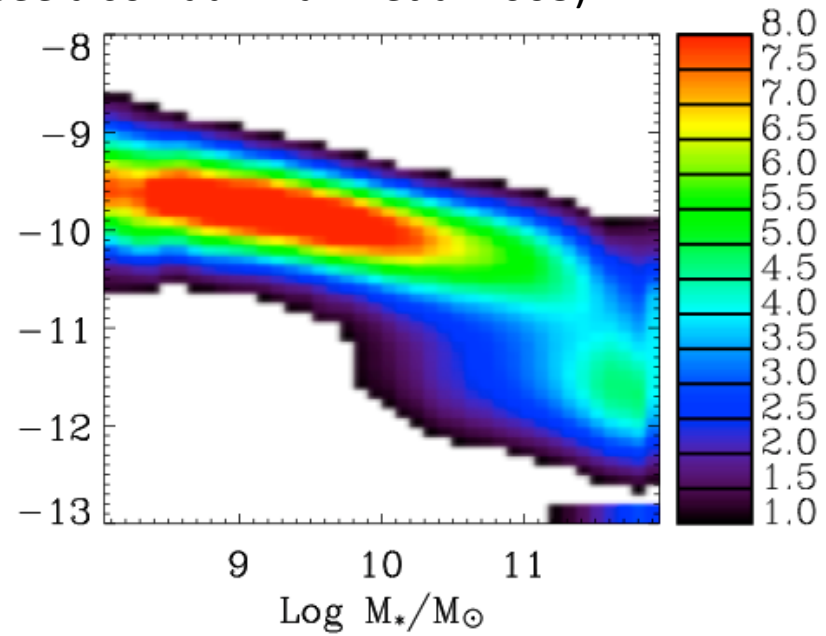
Salim et al 2007



Mass v SSFR

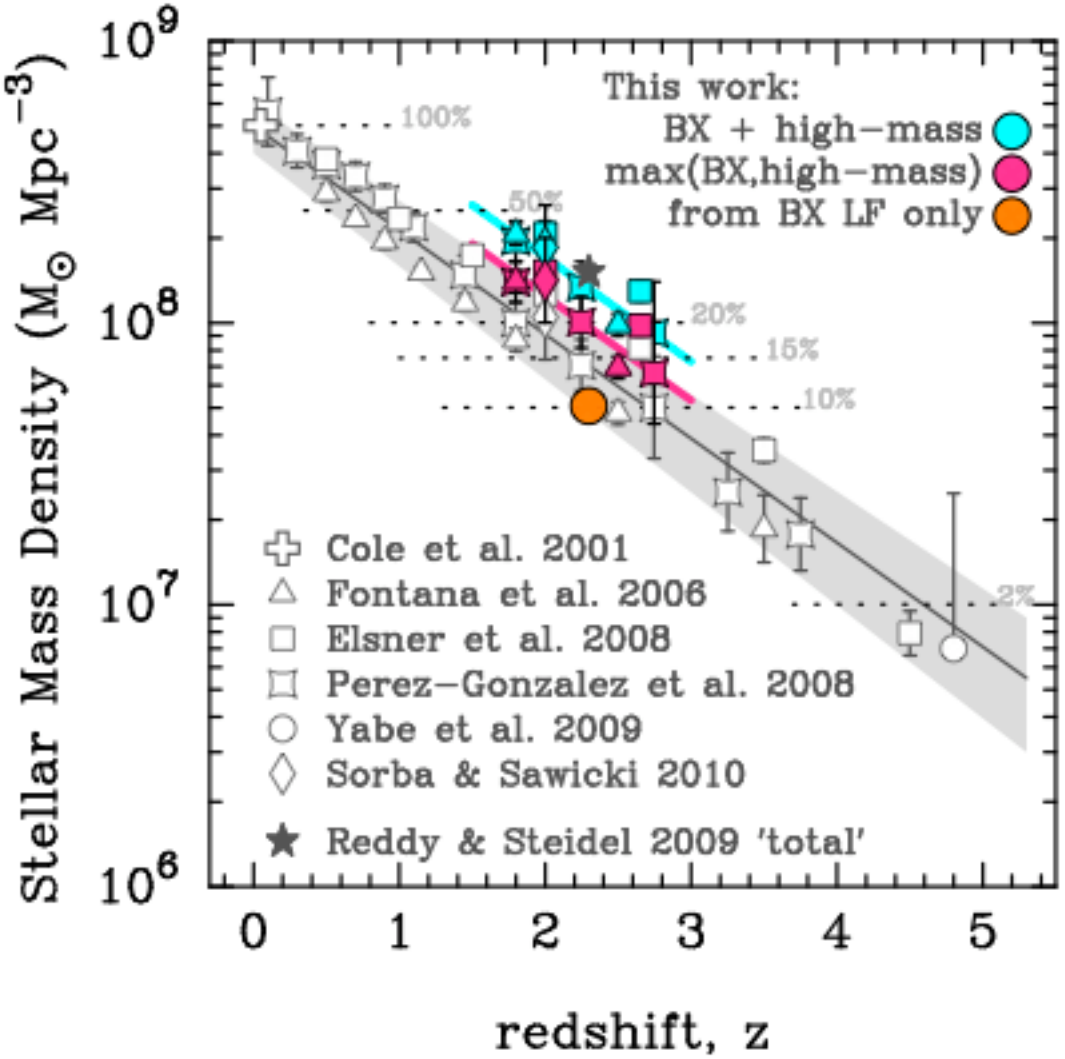
Brinchmann et al 2004 (see also Kauffmann et al 2003)





SDSS

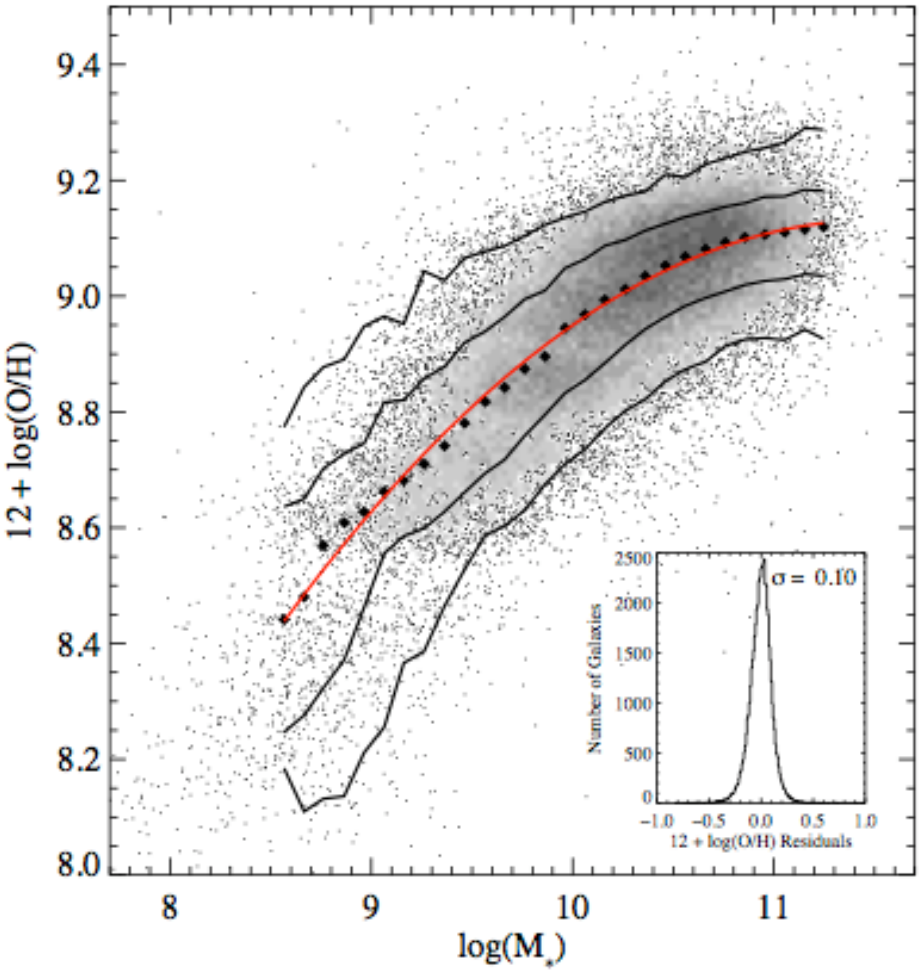
Build-up of stellar mass



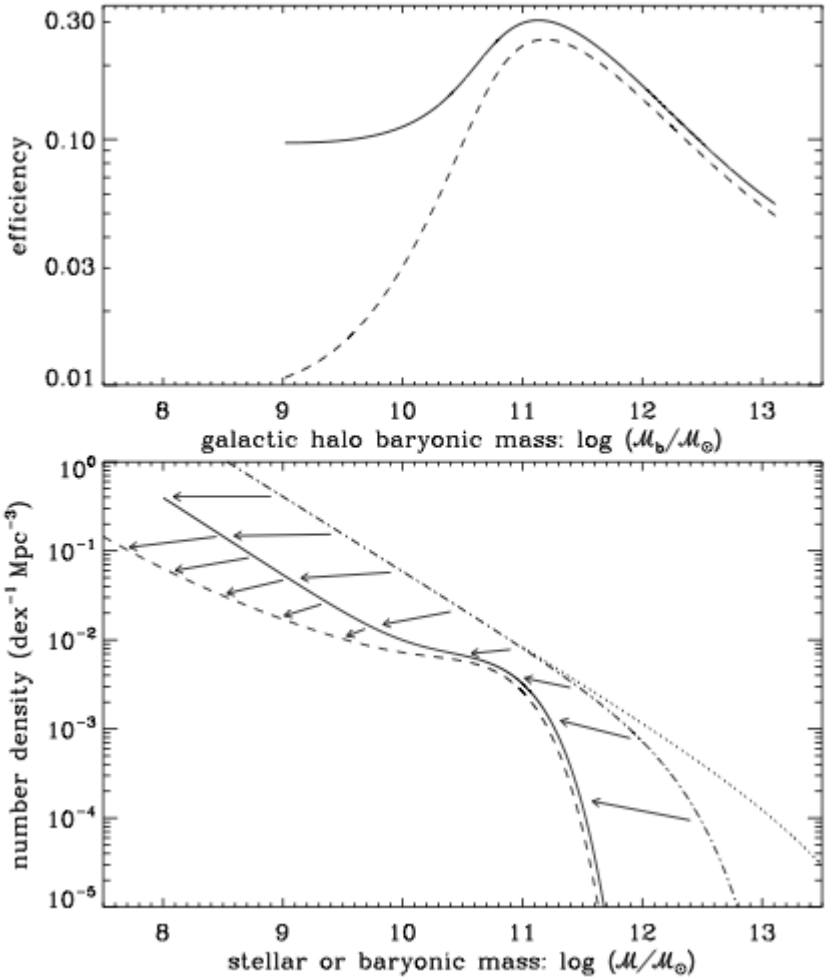
Sawicki et al 2011
(astro-ph/1108.5186)

Mass-metallicity relation

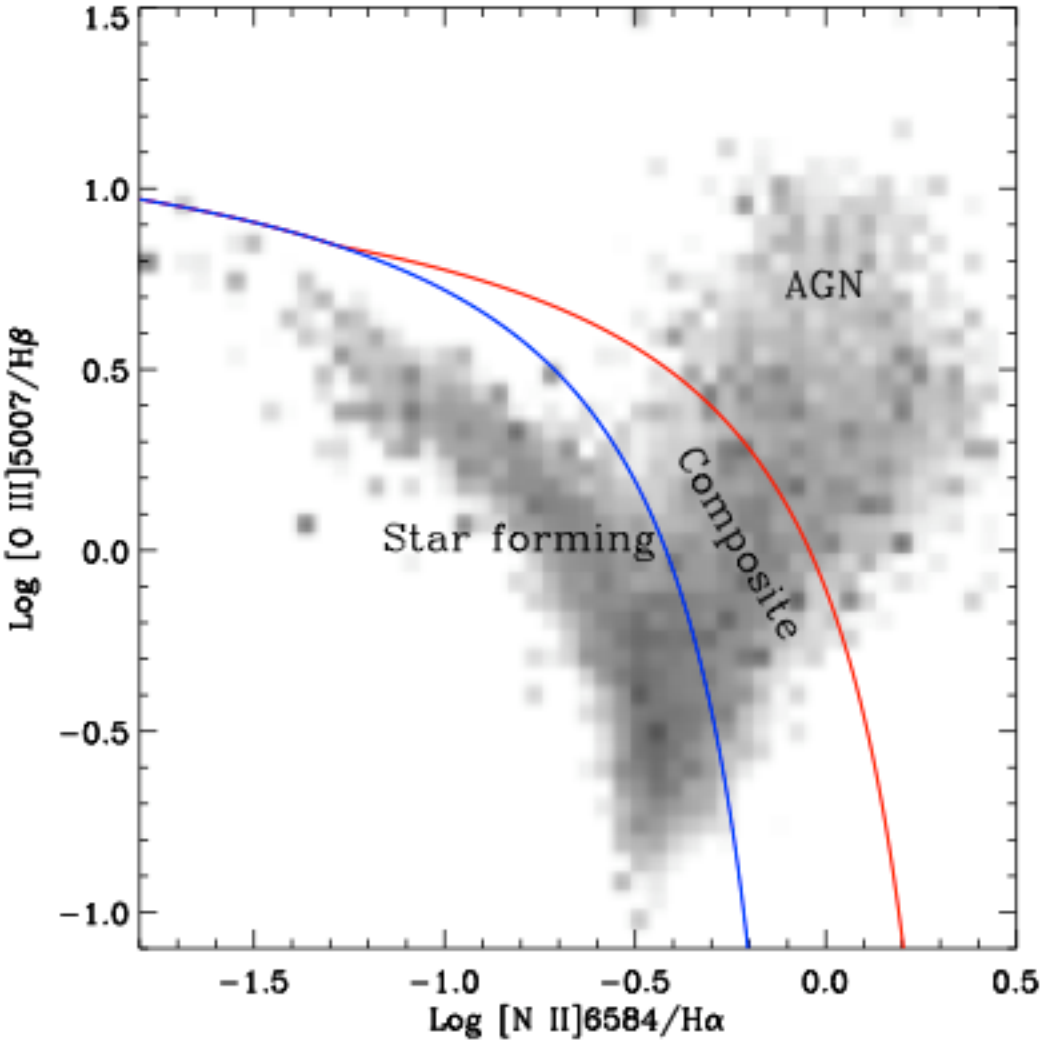
Tremonti et al 2008



Baldry, Glazebrook & Driver 2008

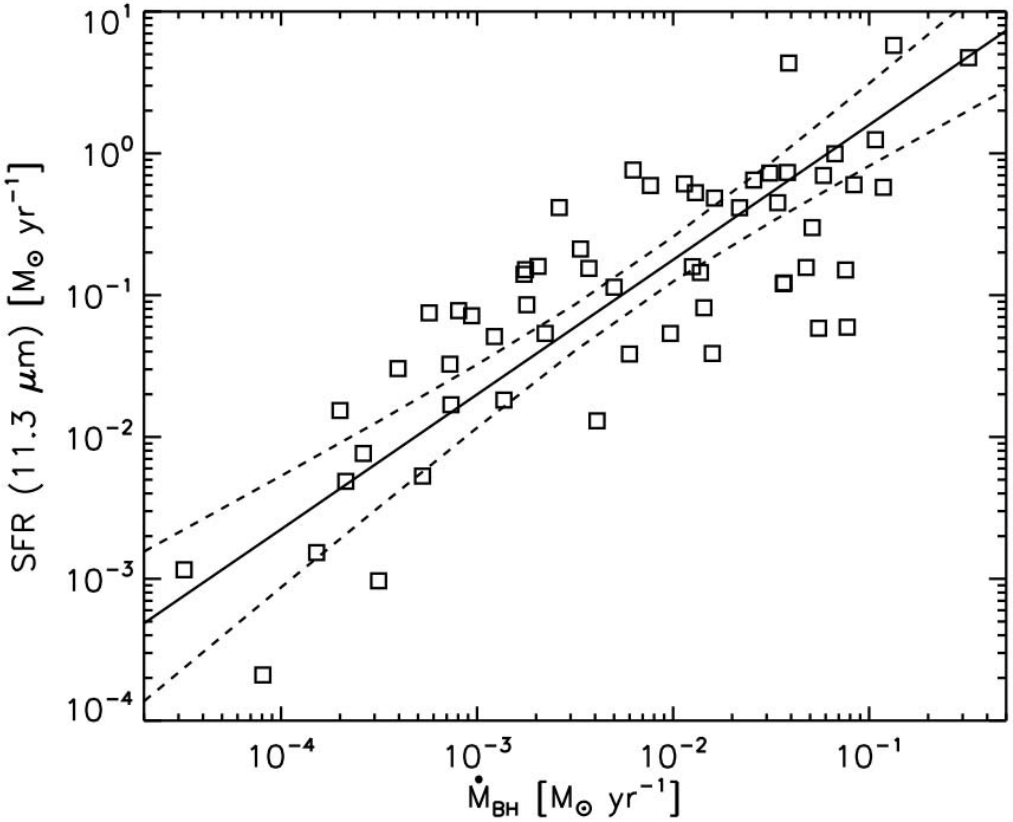


AGN Galaxy connection



Brinchmann et al 2004

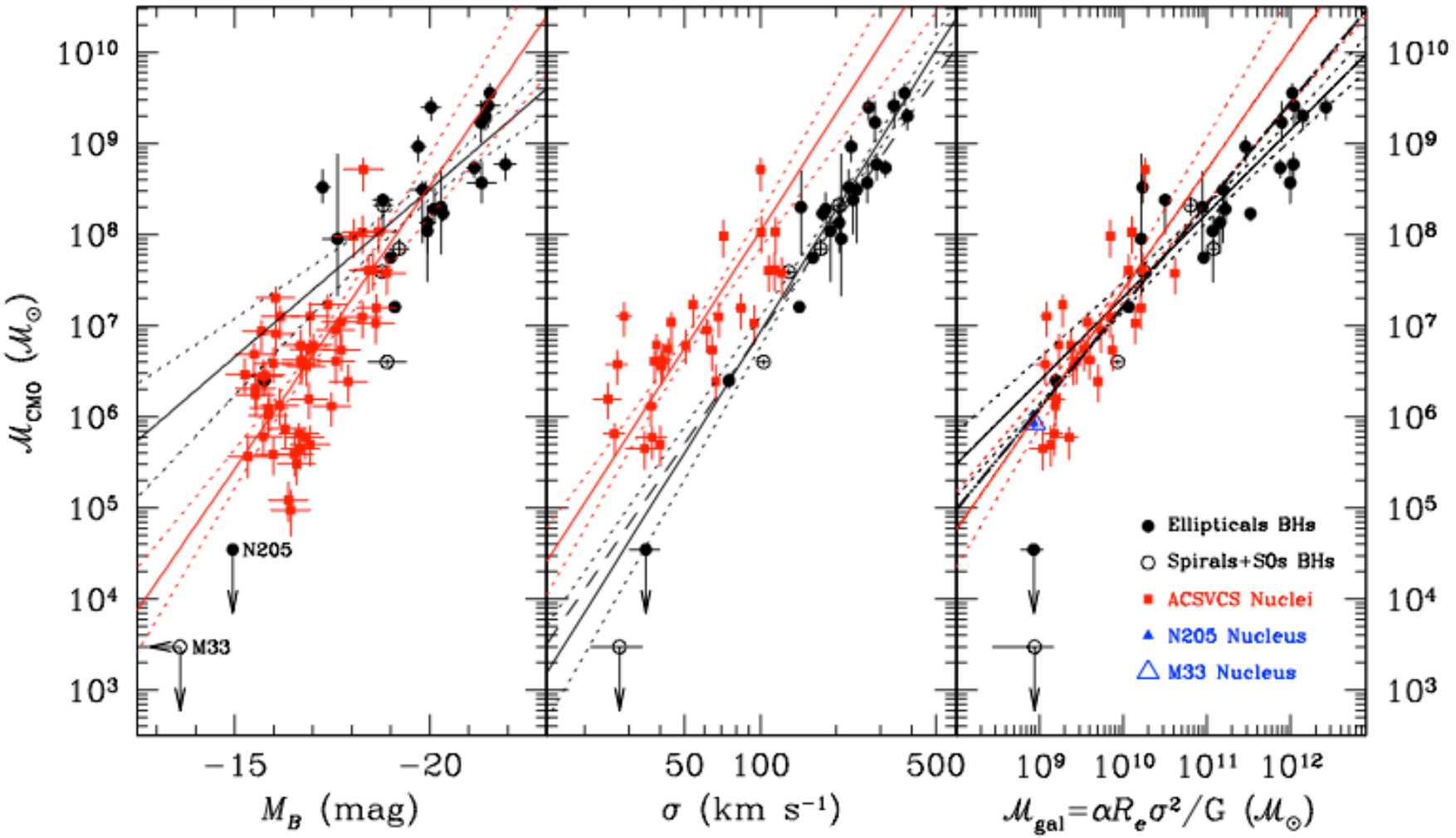
Star-formation and BH accretion



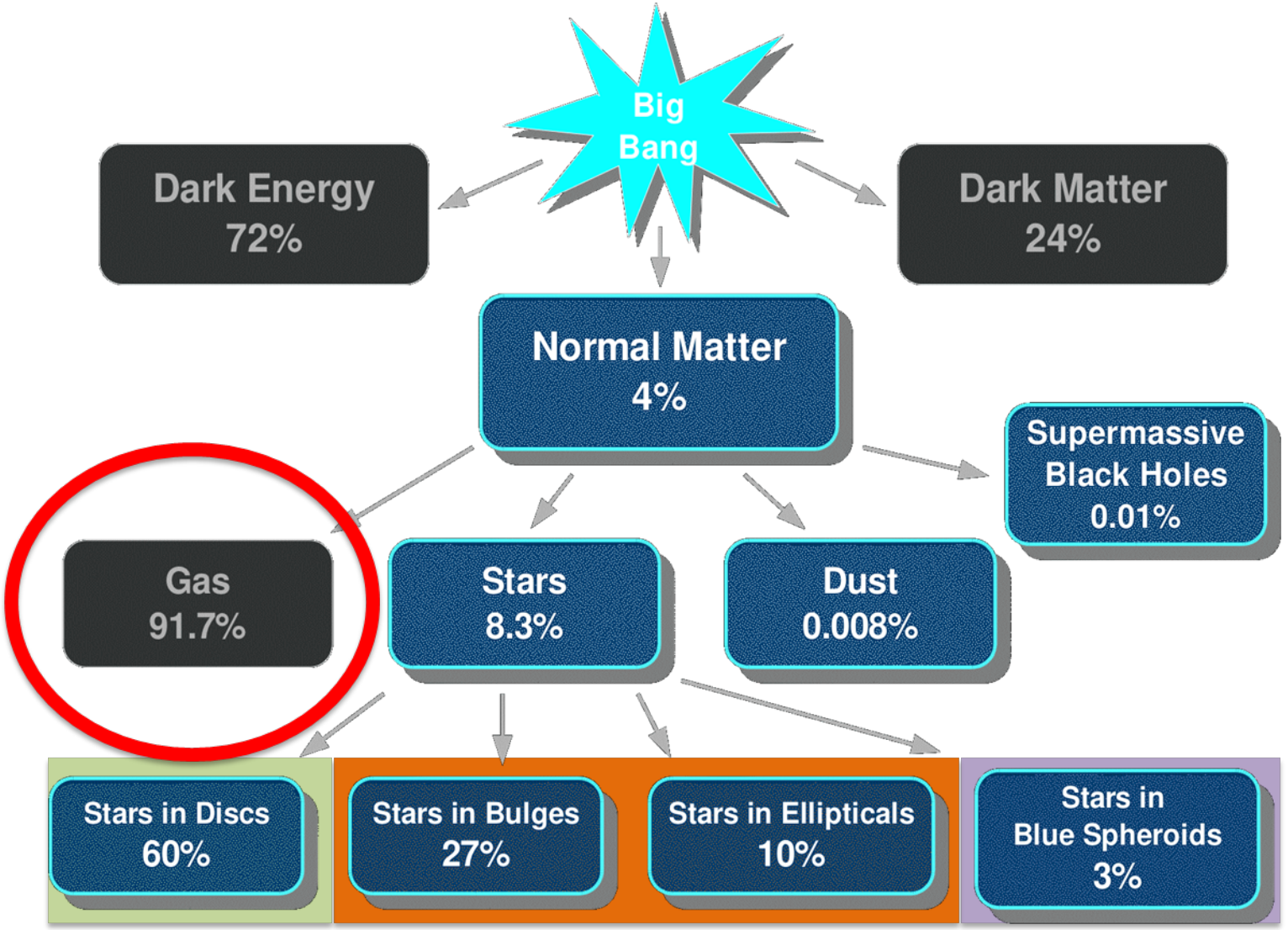
Central star-formation rate v BH growth

Diamond-Stanic &Rieke (2011)

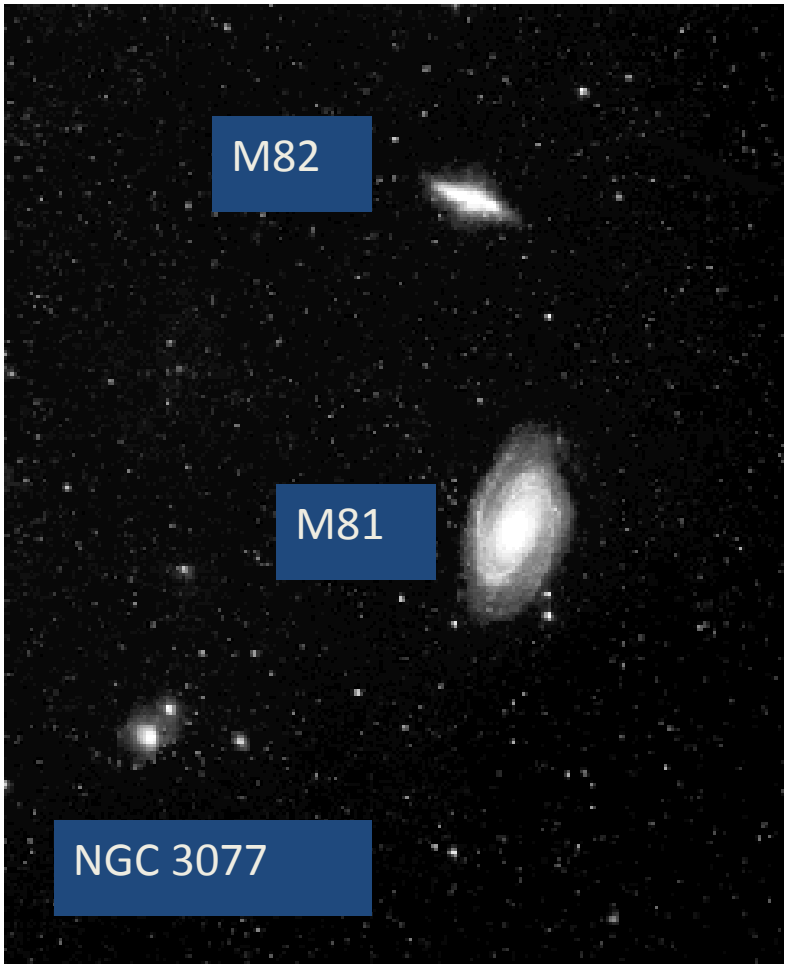
SMBH-Bulge relations

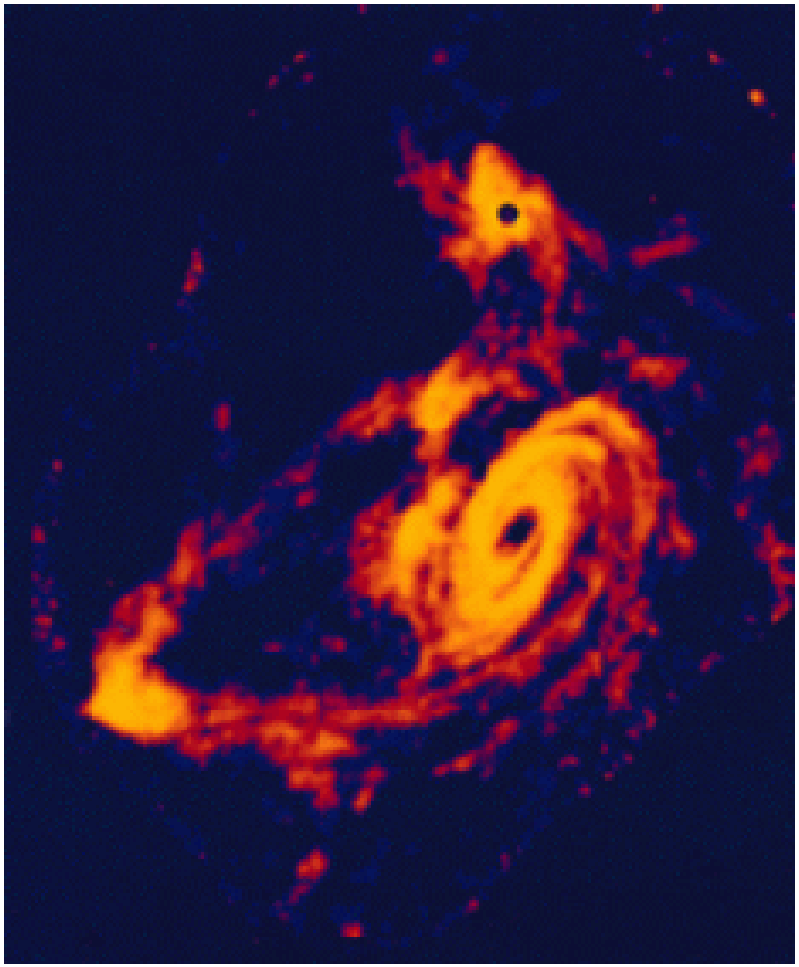


How the mass is distributed



How to combine optical/radio data?

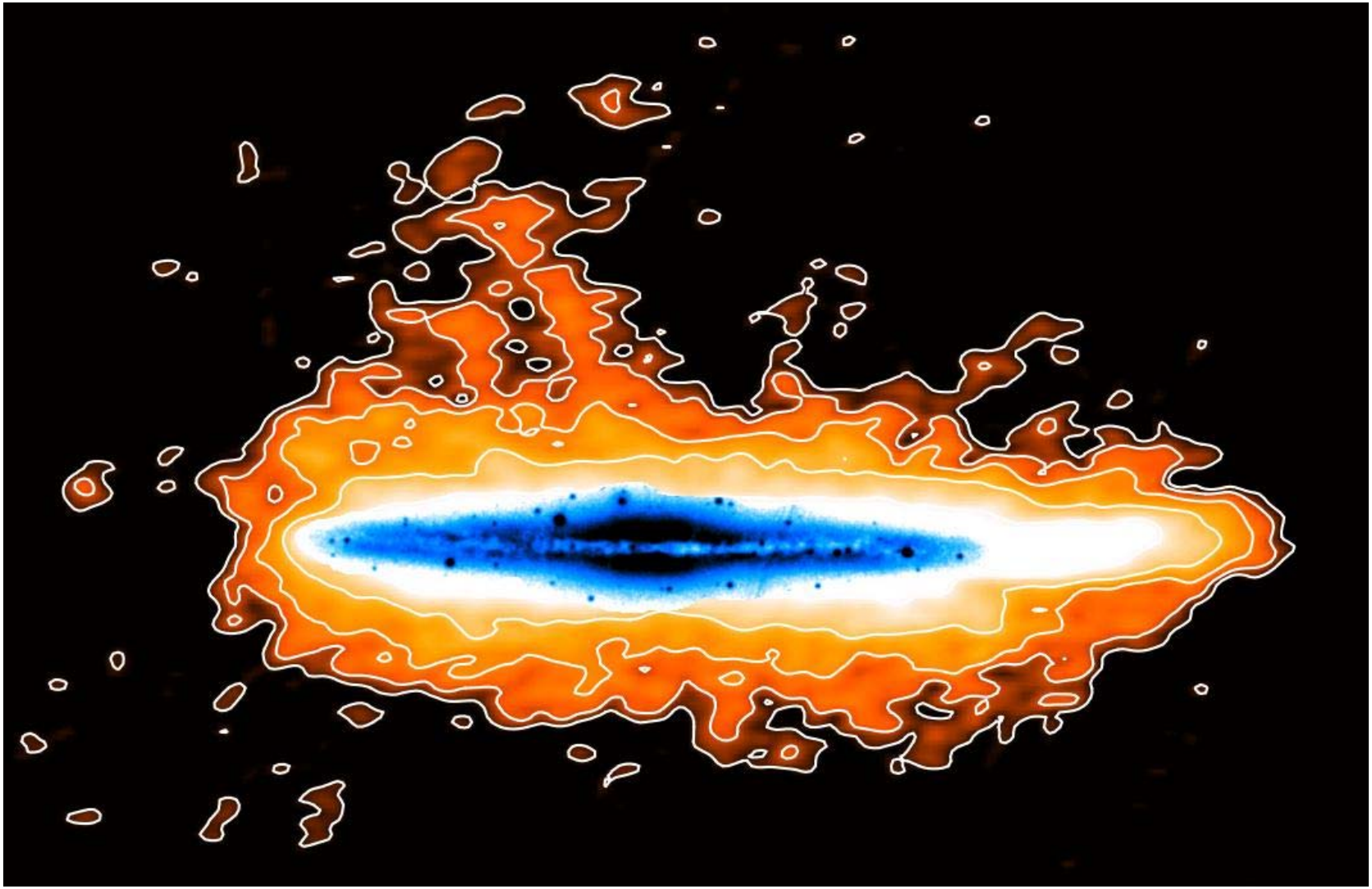




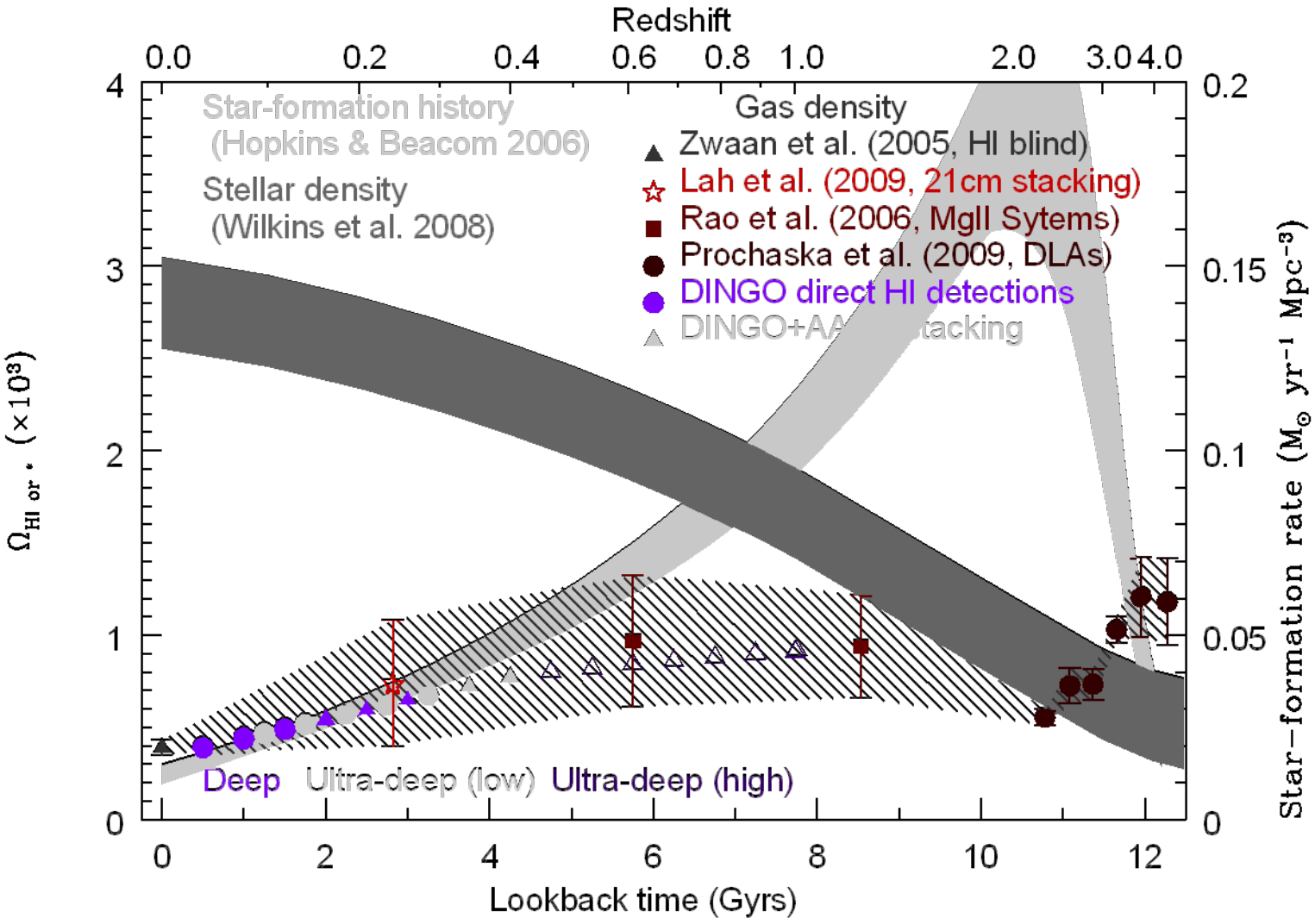
STARLIGHT

GAS (HI)

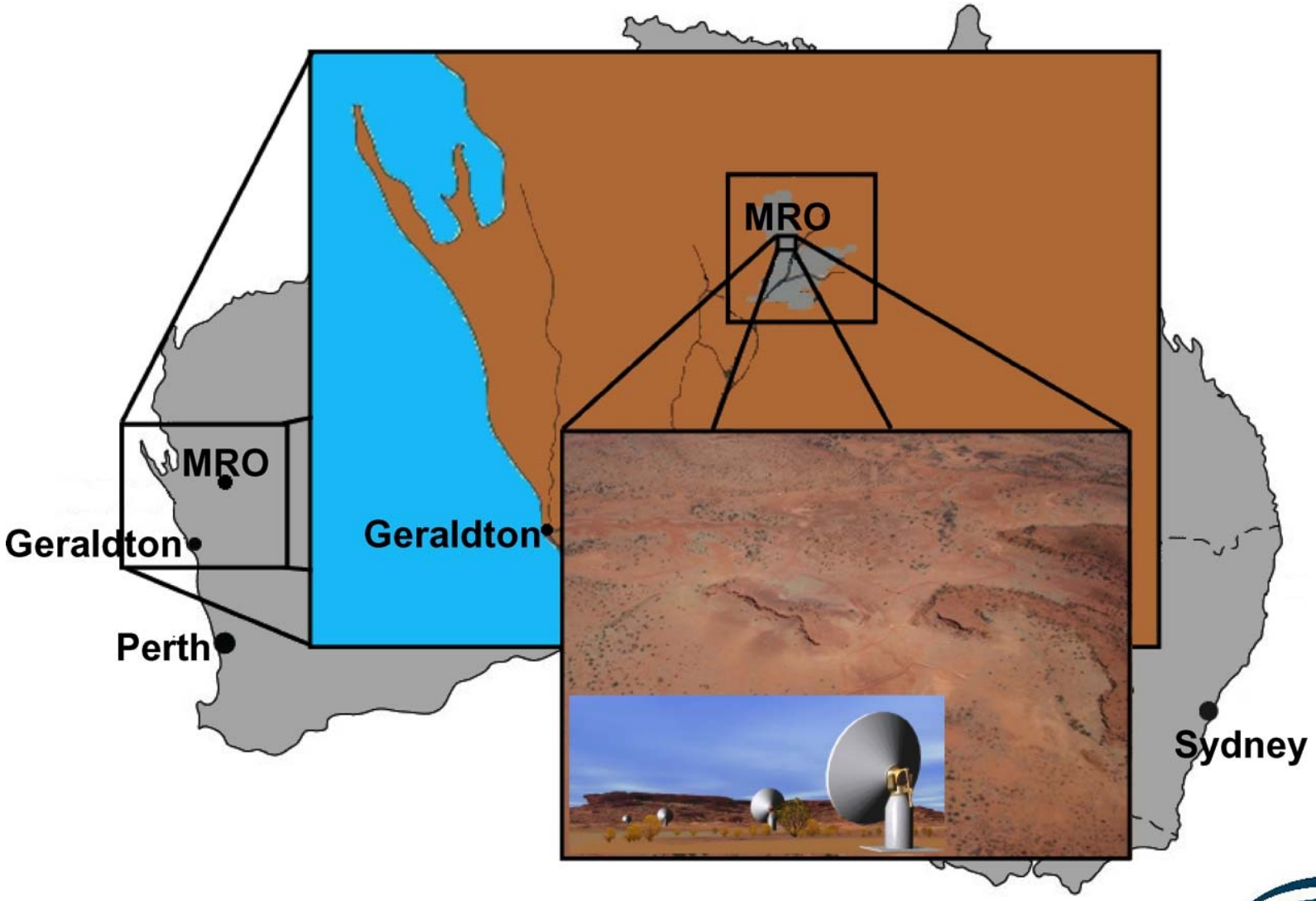
Optical and radio image of NGC891

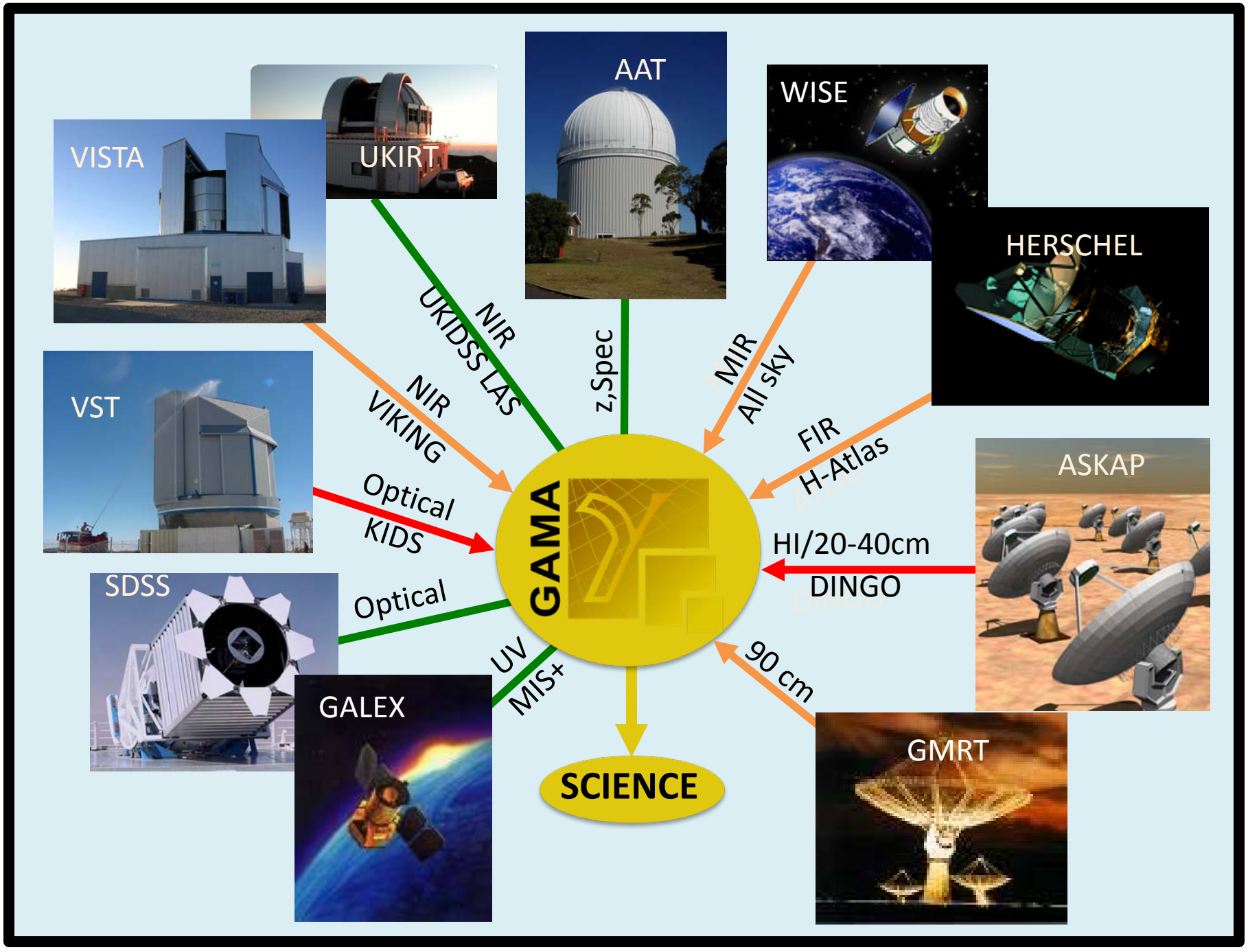


Evolution of the HI (or not?)

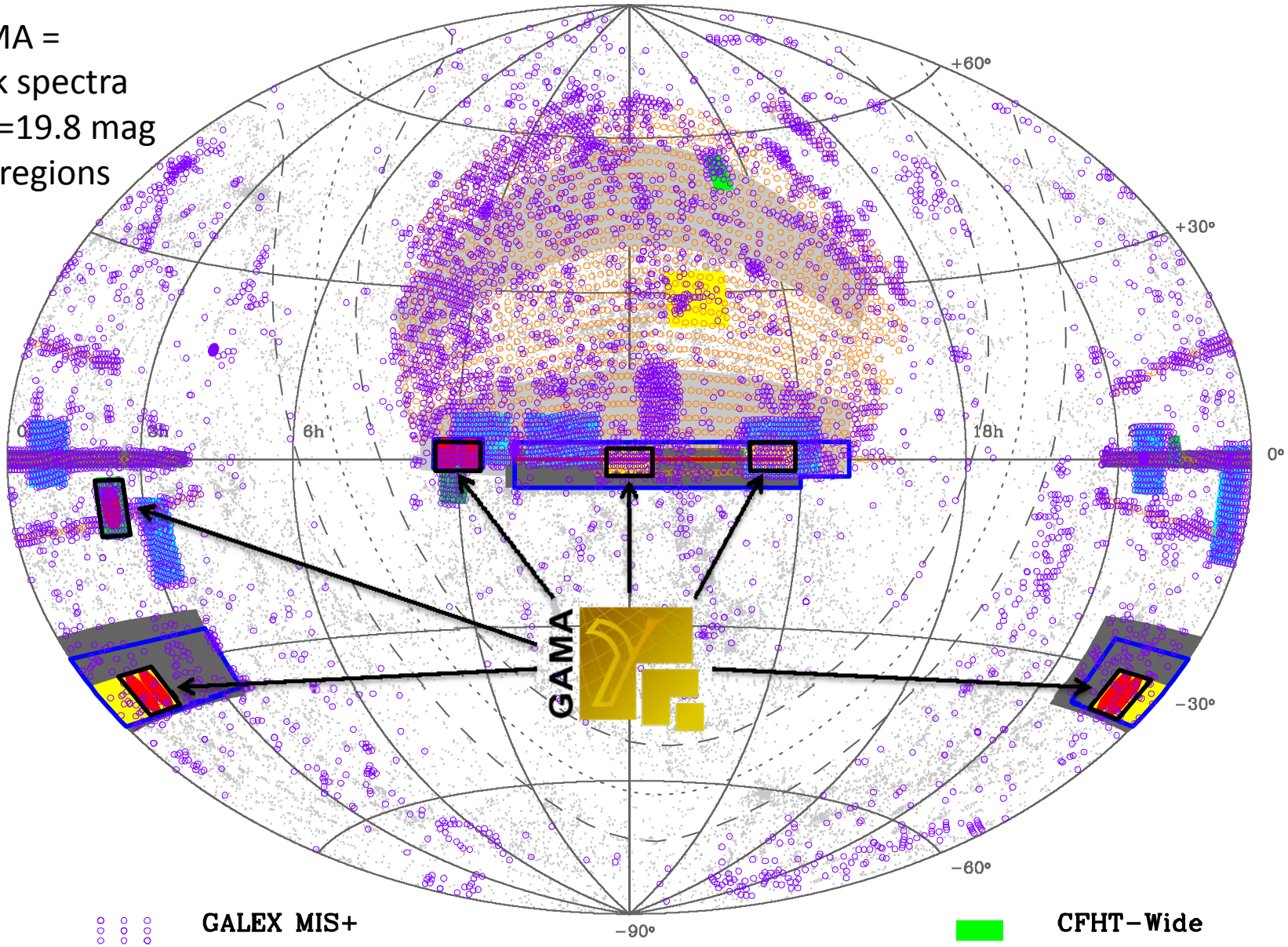


ASKAP (Australian Square Kilometer Array Pathfinder)
A$150 million investment to construct unique radio facility to study gas in galaxies



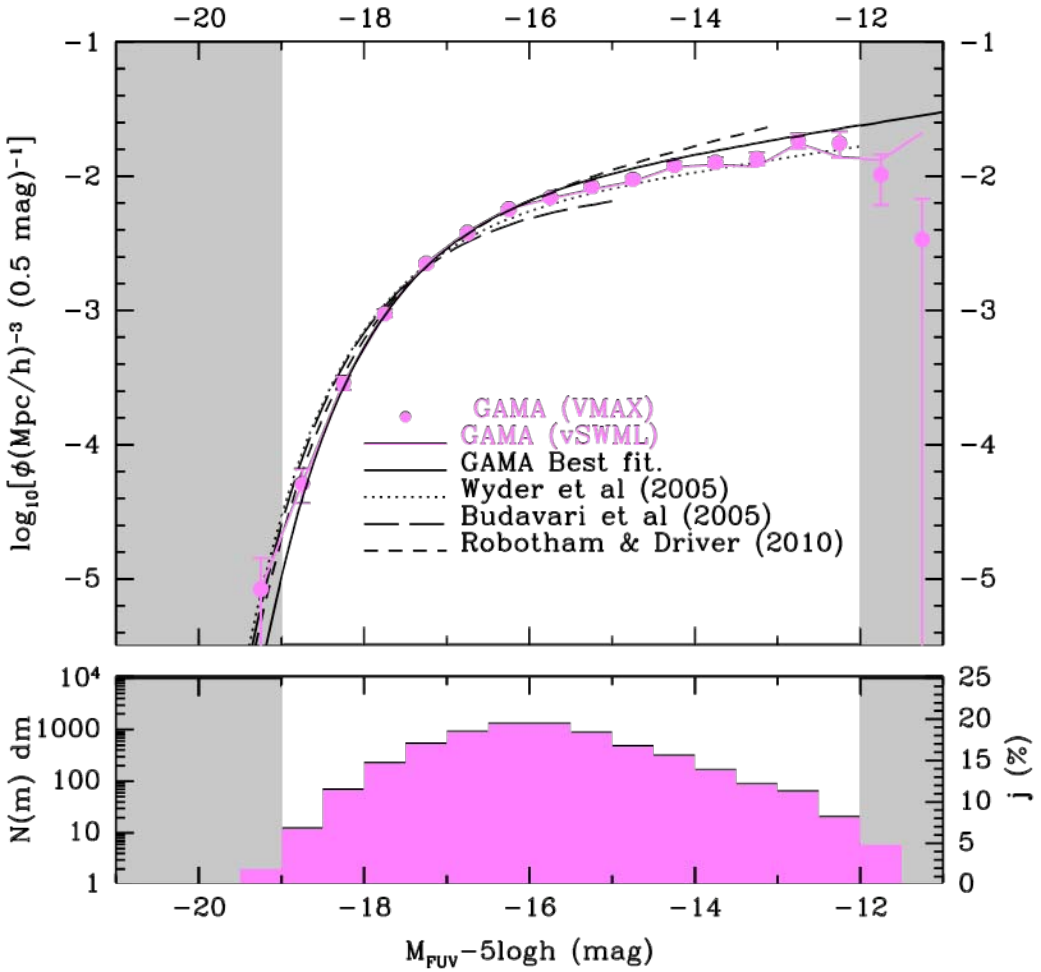

AAT
WISE
UKIRT
VISTA
HERSCHEL
NIR
UKIDSS LAS
z,Spec
MIR
All sky
NIR
VIKING
FIR
H-Atlas
VST
Optical
KIDS
ASKAP
GAMA
HI/20-40cm
DINGO
SDSS
Optical
UV
MIS+
90 cm
GALEX
GMRT
SCIENCE

GAMA =
400k spectra
to r =19.8 mag
in 5 regions



GALEX MIS+
GAMA
HERSCHEL−ATLAS
Millennium Galaxy Cat.
ASKAP−DINGO
SDSS−Main (spec. only)
WiggleZ
CFHT−Wide
2dFGRS
UKIDSS−LAS
VST−KIDS/VISTA VIKING

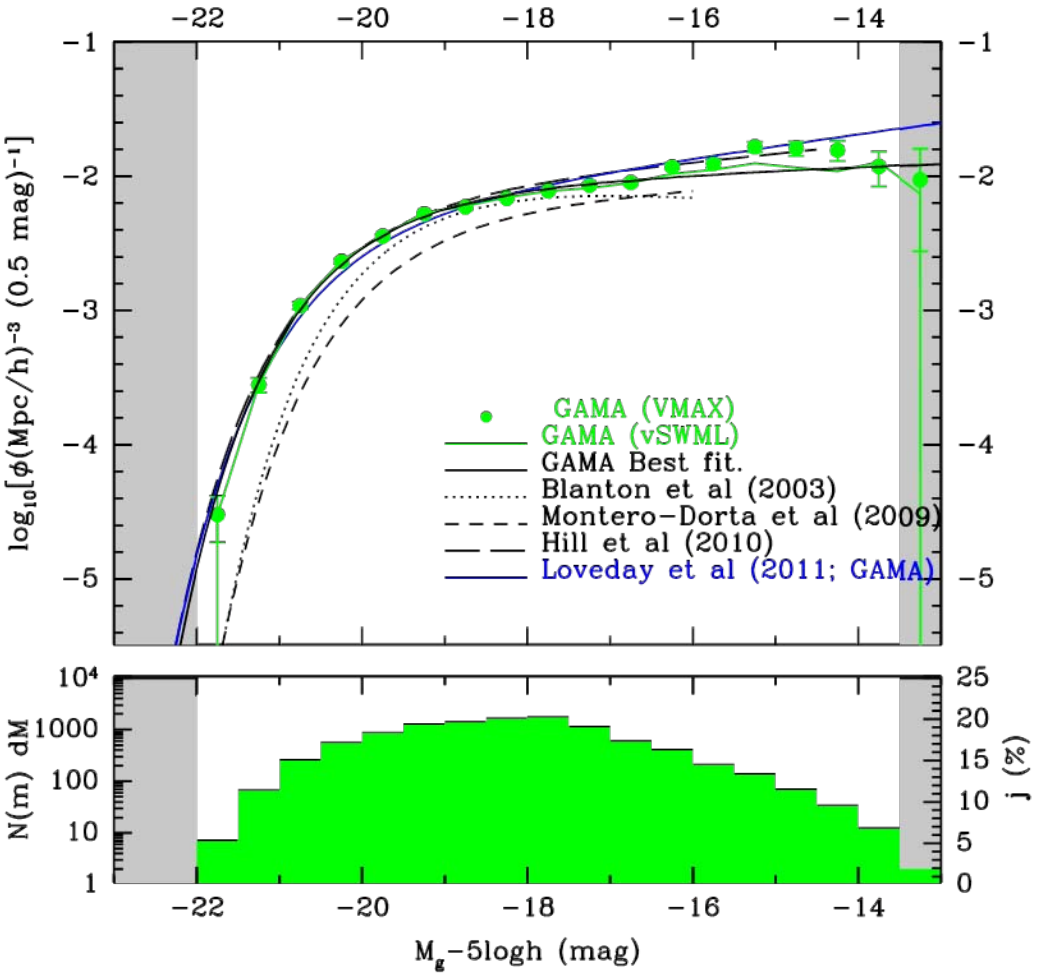
Luminosity functions (FUV)



Faint-ends uncertain
But luminosity density
OK ➔ Cosmic SED

Wyder et al 05
Budavari et al 10
Robotham & Driver 10
Driver 11

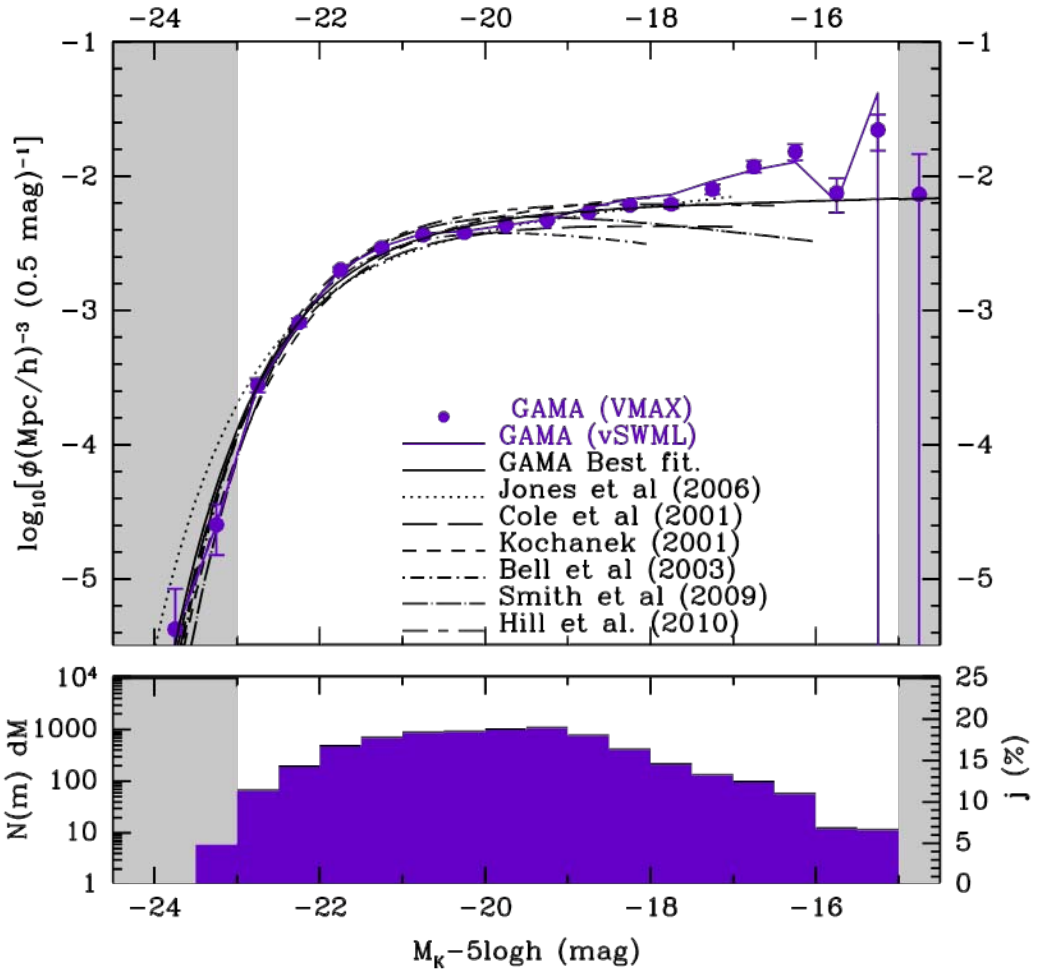
Luminosity functions (g)



Faint-ends uncertain
But luminosity density
OK ➔ Cosmic SED

Blanton et al 03
Montero-Dorta et al 09
Hill et al 10
Loveday et al 11
Driver et al 11

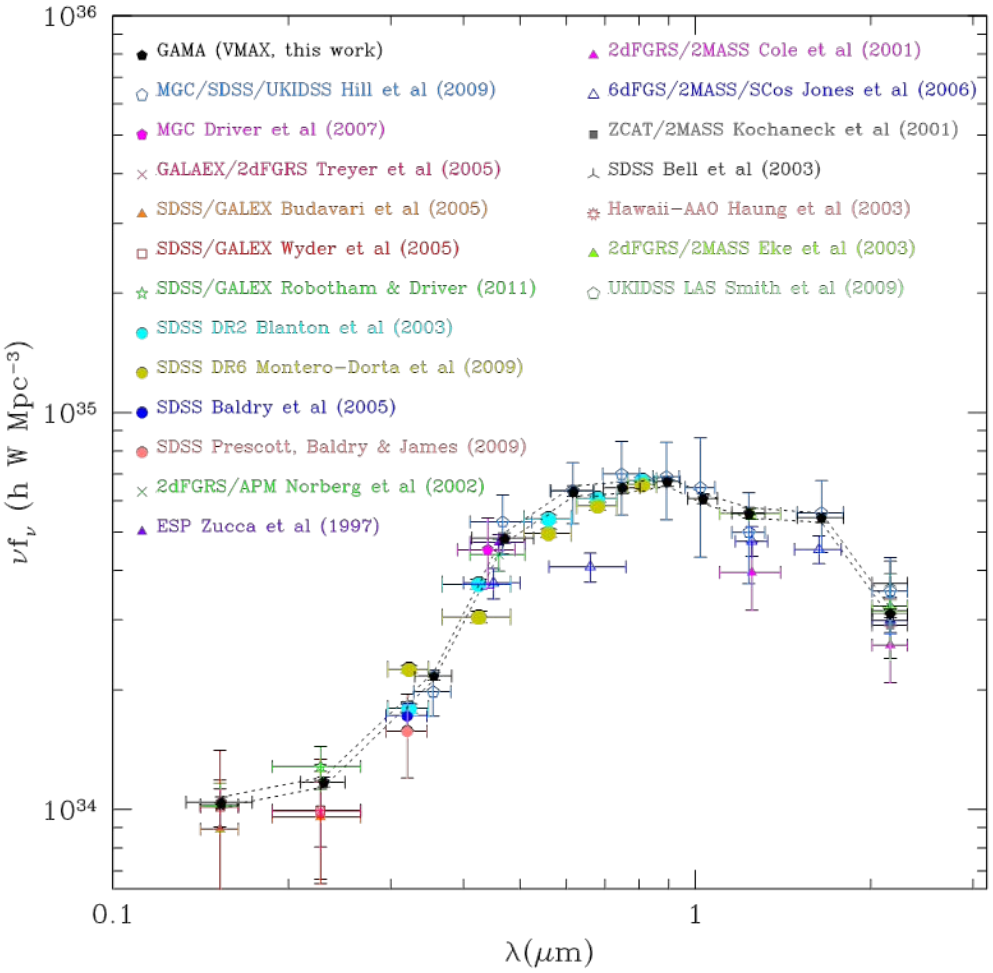
Luminosity functions (K)



Faint-ends uncertain
But luminosity density
OK ➔ Cosmic SED

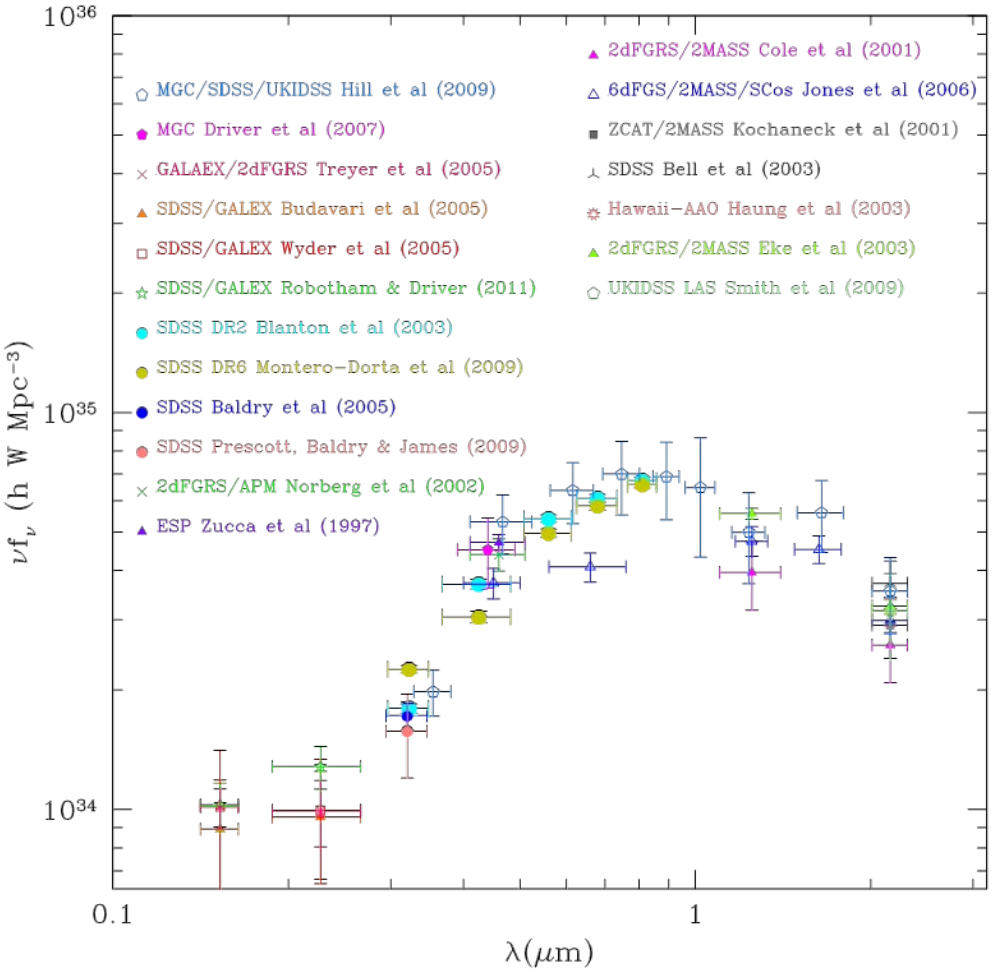
Jones et al 06
Cole et al 02
Kochaneck et al 01
Bell et al 03
Smith et al 09
Hill et al 10
Driver et al 11

Compendium of LFs: CSED



Compendium of LFs: CSED

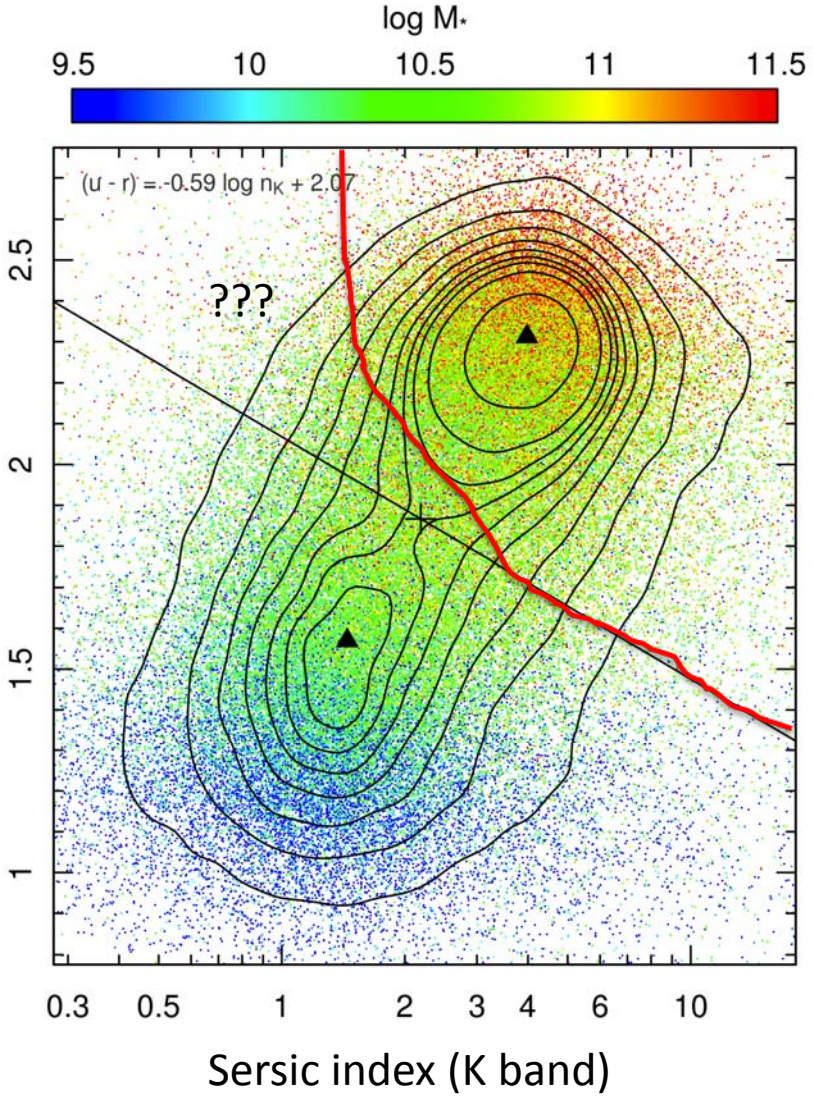
Hill et al (2010)



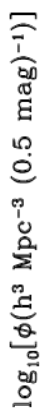
Joint structure colour cut

Kelvin et al (2011)

Bimodality or duality ?

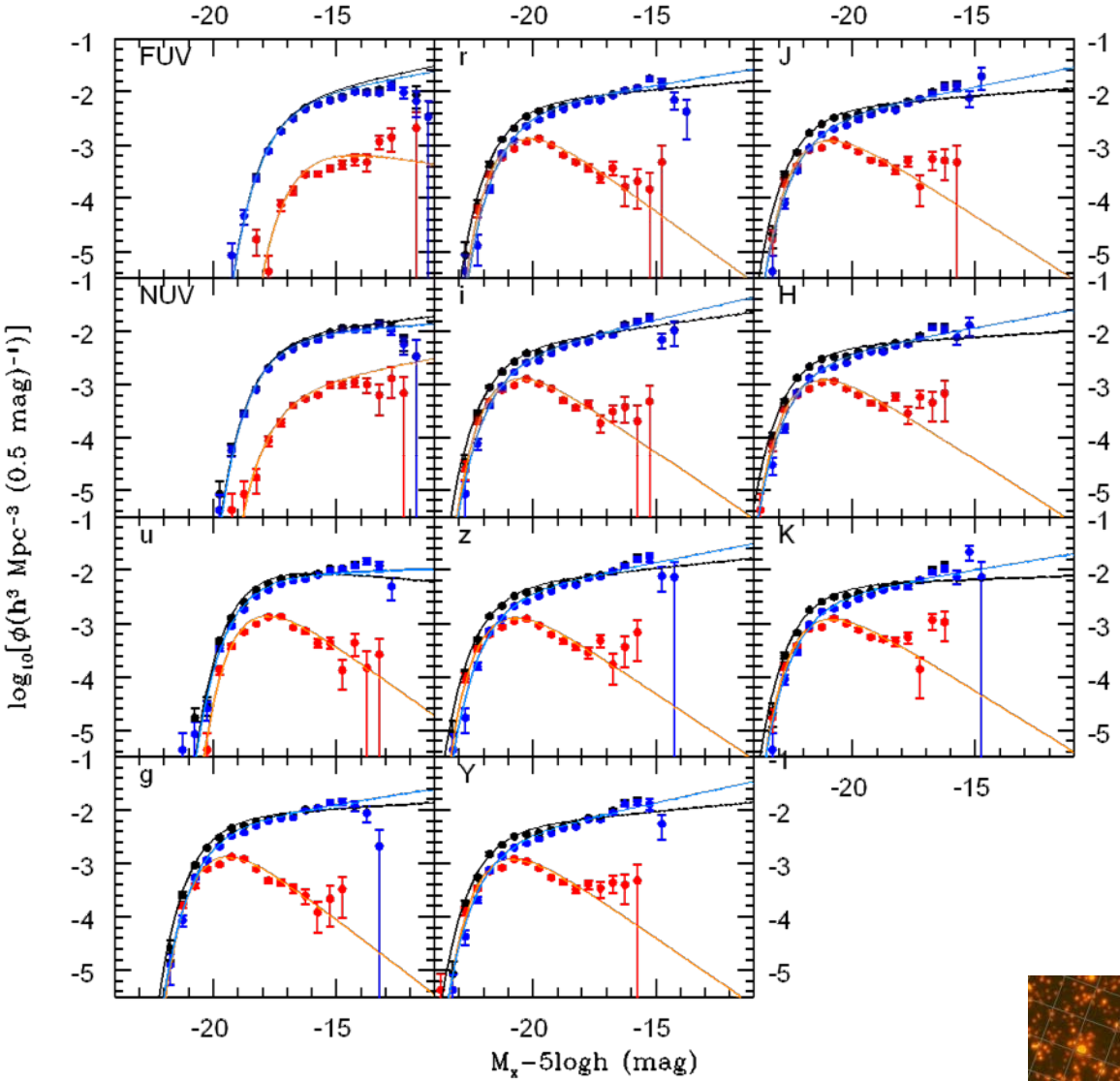


FUV-K LFs by colour cut



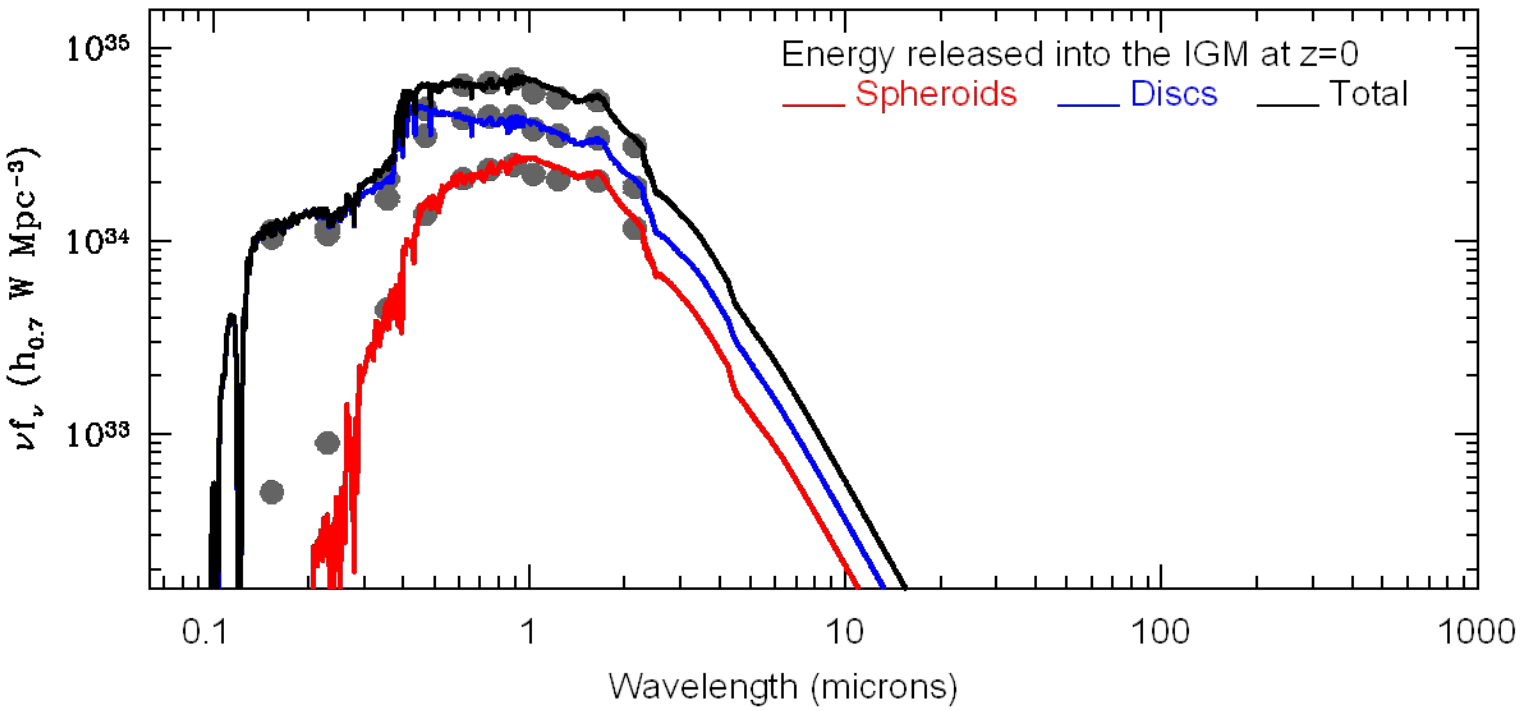
$M_x - 5\log h\ (\mathrm{mag})$

FUV-K LFs by morphological type



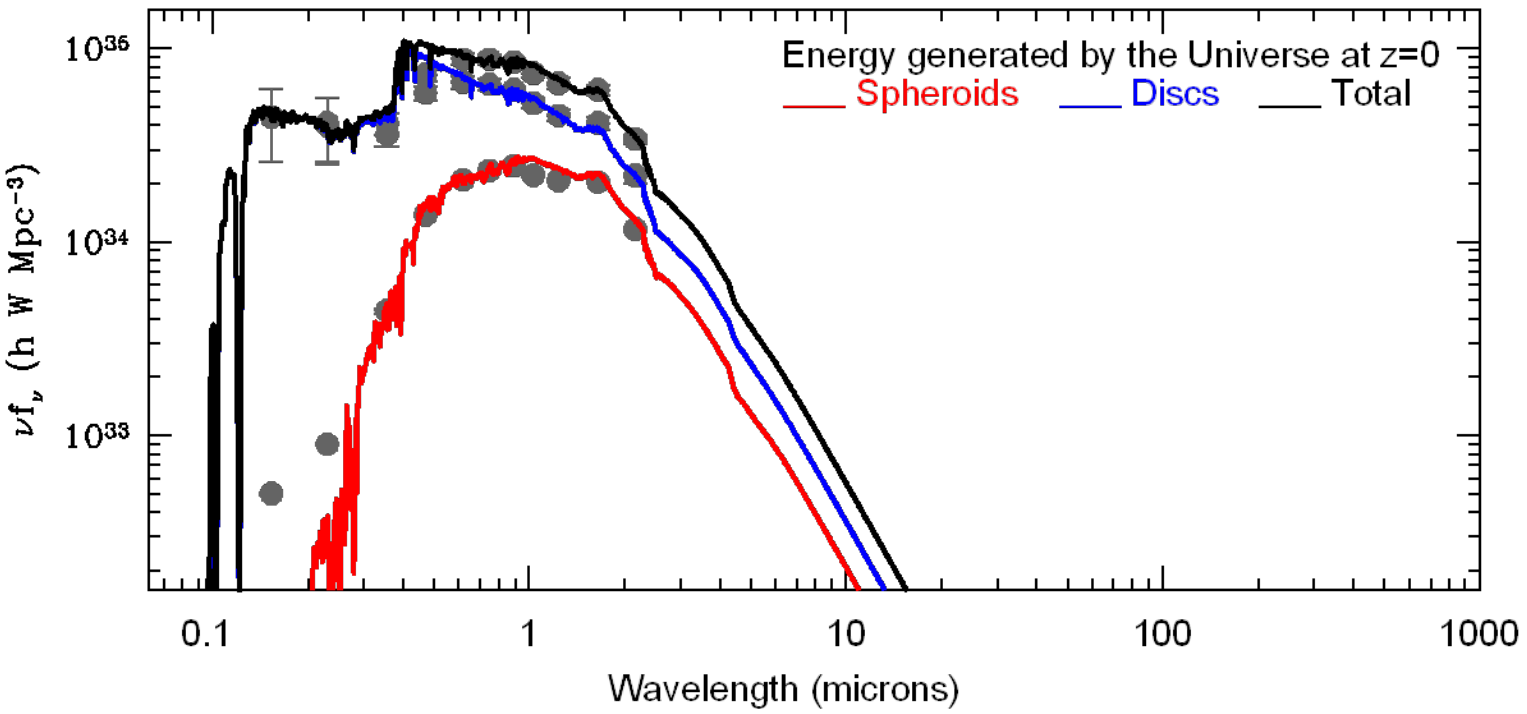
SED of Universe at z=0

Attenuated spectrum for spheroids and discs



SED of Universe at z=0

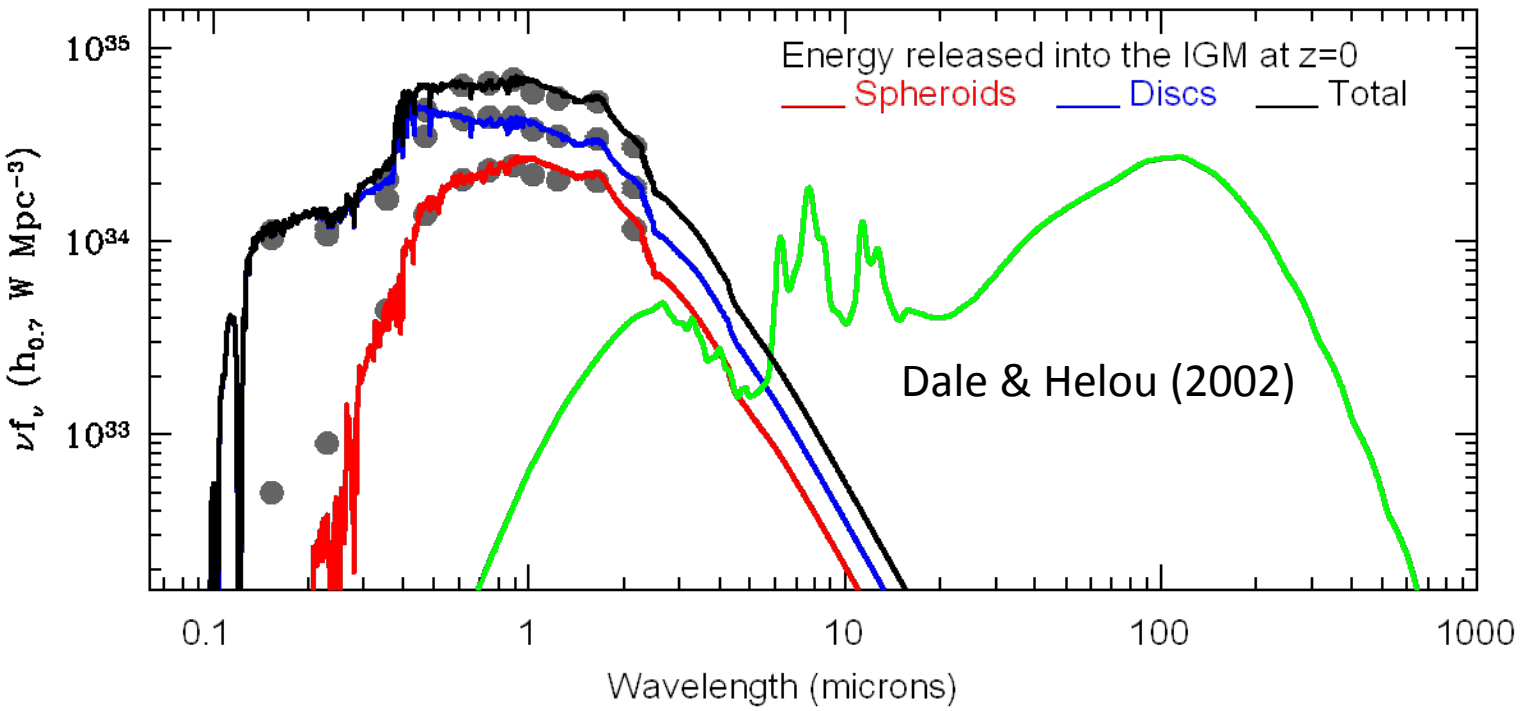
Unattenuated spectrum for spheroids and discs



Using photon escape fraction from Driver et al (2008)

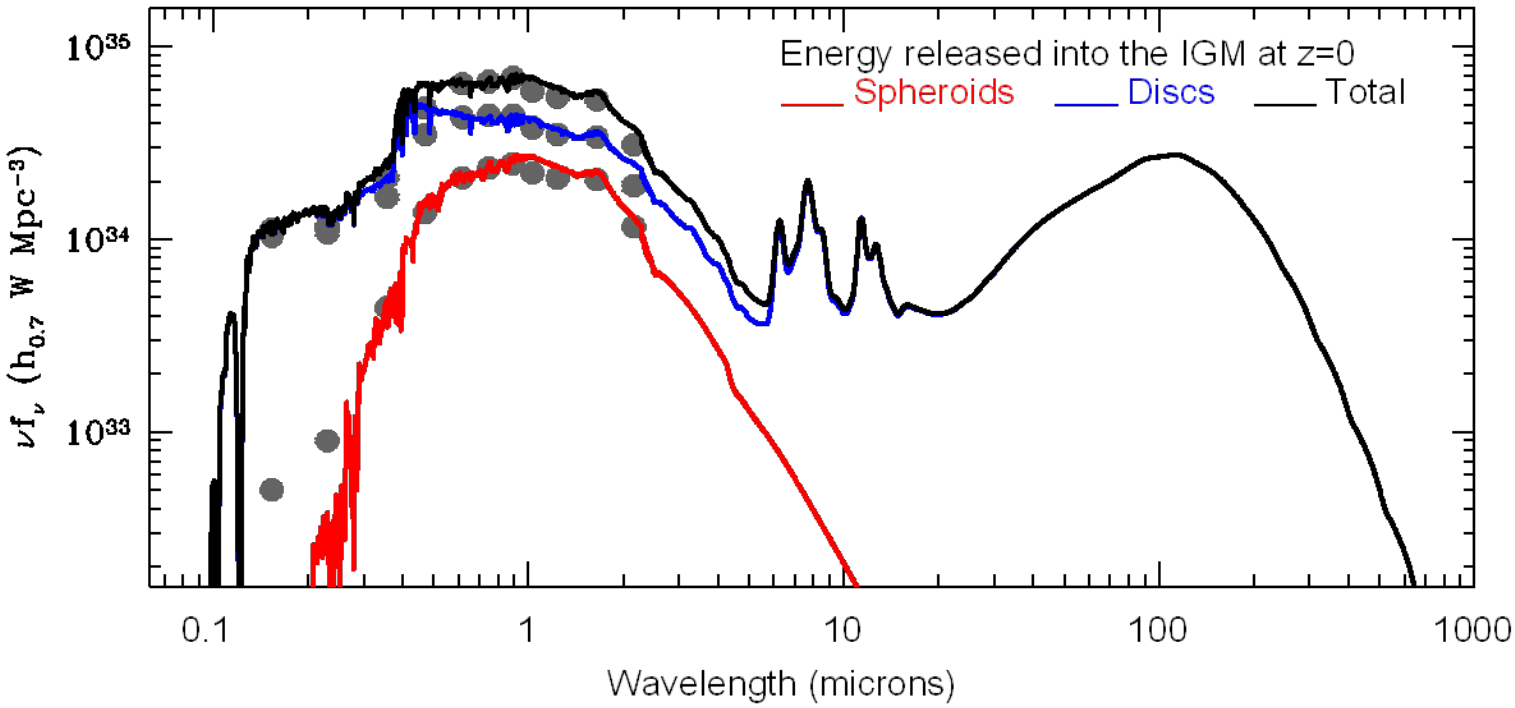
SED of Universe at z=0

Missing energy transferred to dust



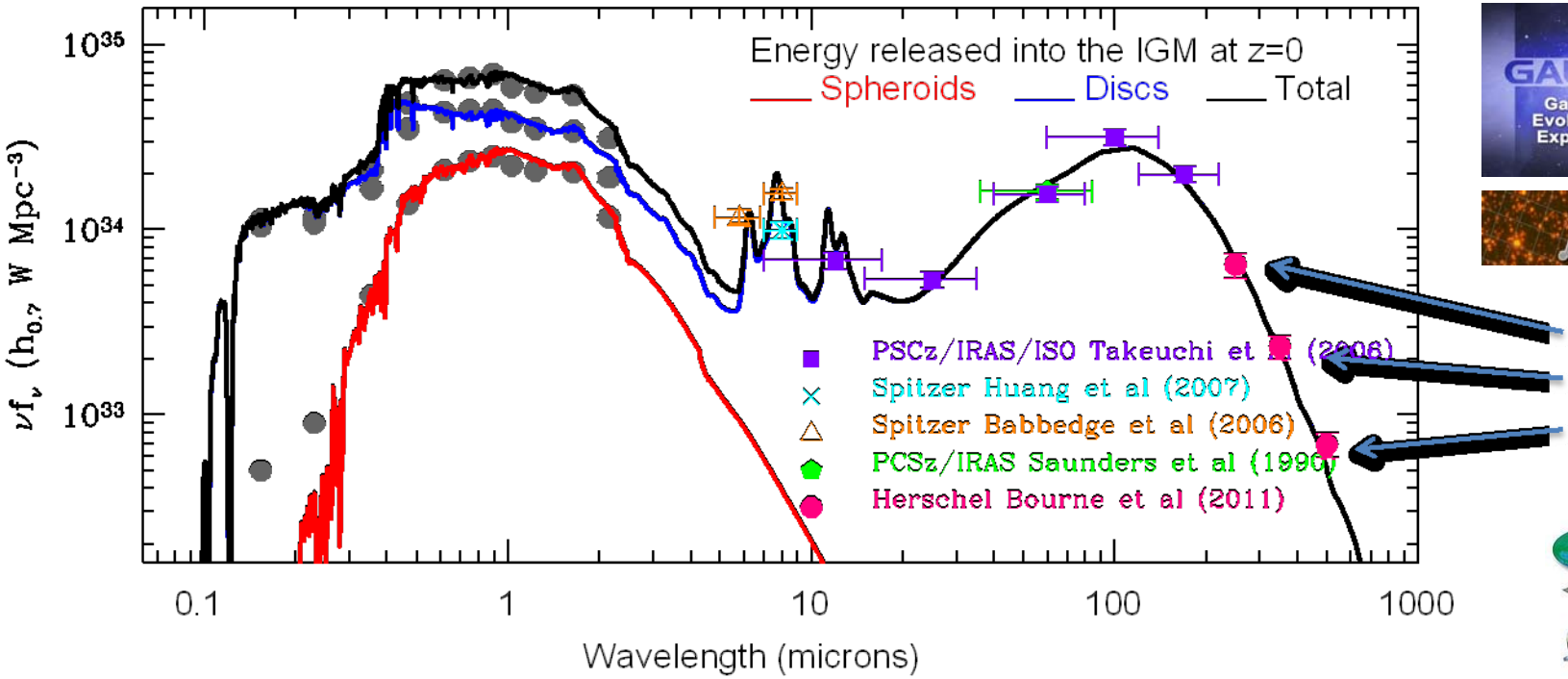
SED of Universe at z=0

PREDICTED far-IR emission



SED of Universe at z=0

PREDICTION v FIR data

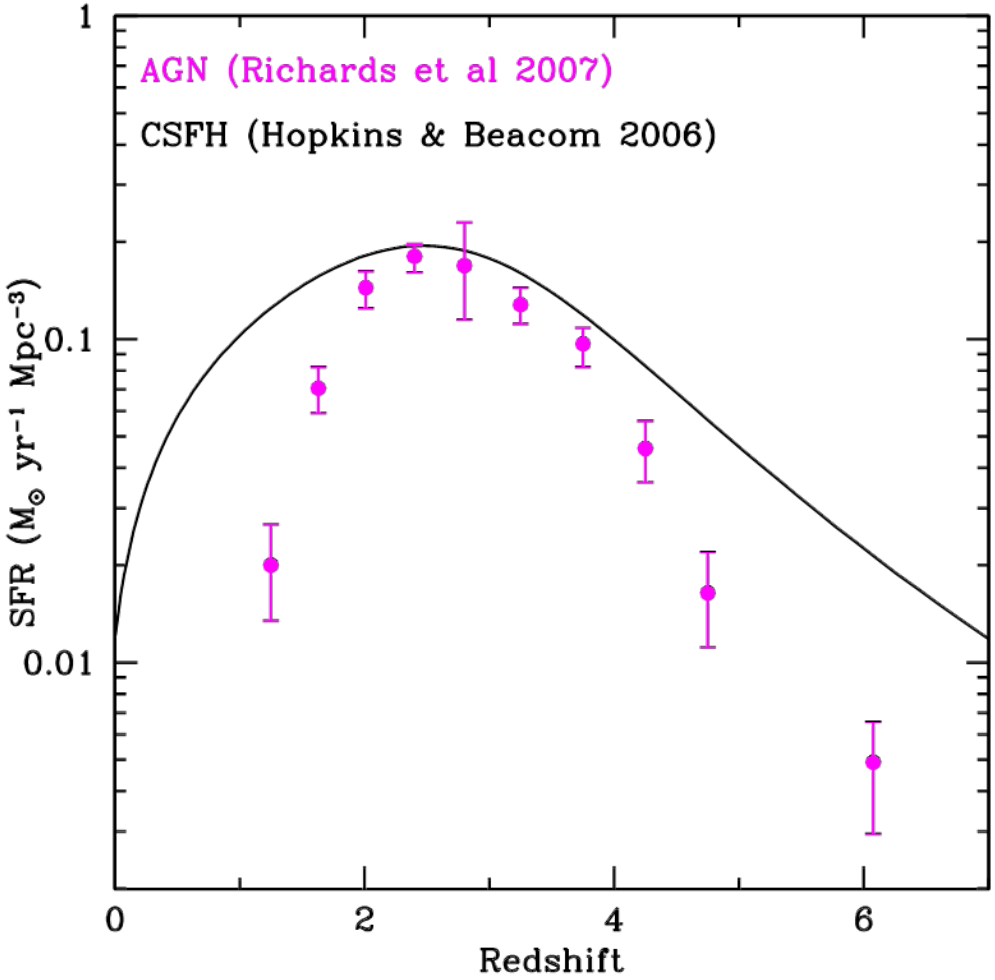


Modelling the Cosmic SED

[Duality not bimodality]

- Two axioms:
  - AGN activity traces spheroid formation
    - SMBH-bulge relations
    - AGN coincident with star-formation
  - Spheroid formation dominates at high-z
    - Ages & metallicities of nearby Ellipticals

CSFH v AGN Activity

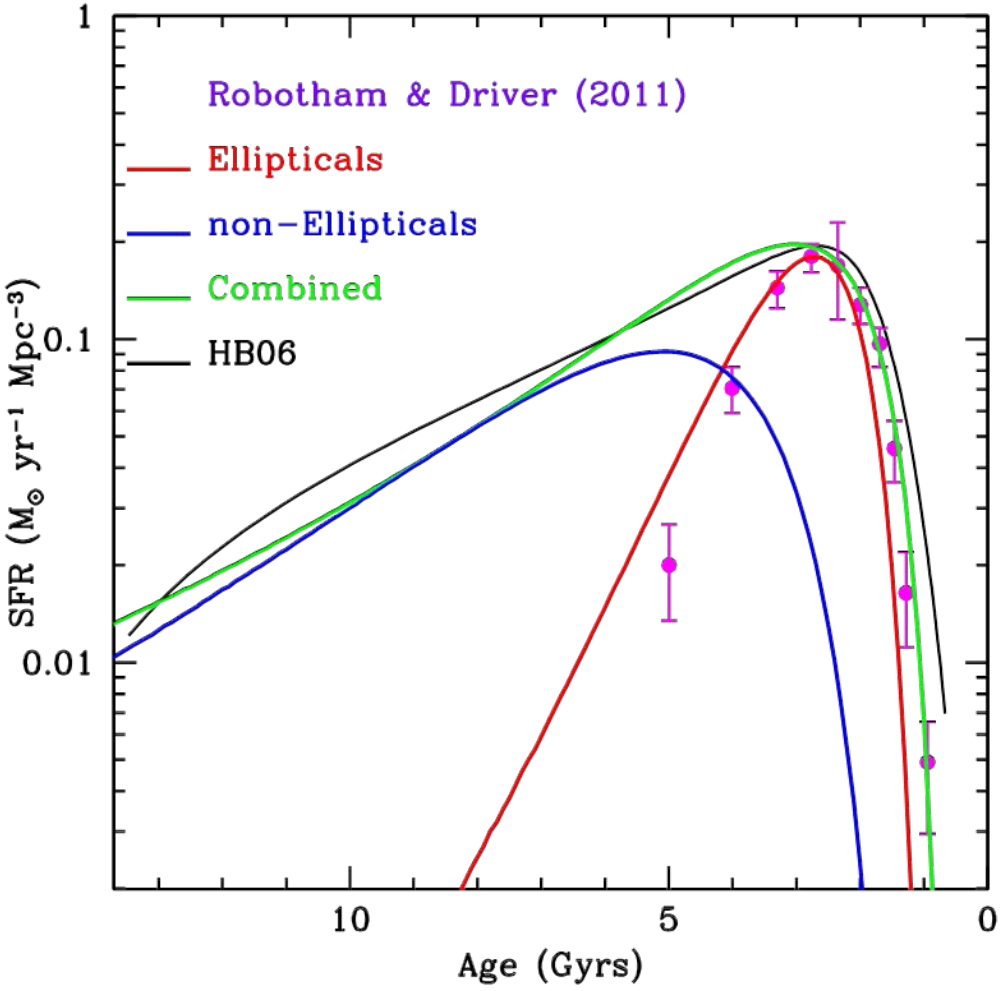


AGN activity does not seem to trace SFH at high-z

1. Data uncertain
2. Redshift axis misleading

.....lets switch to time →

CSFH v AGN activity v Time



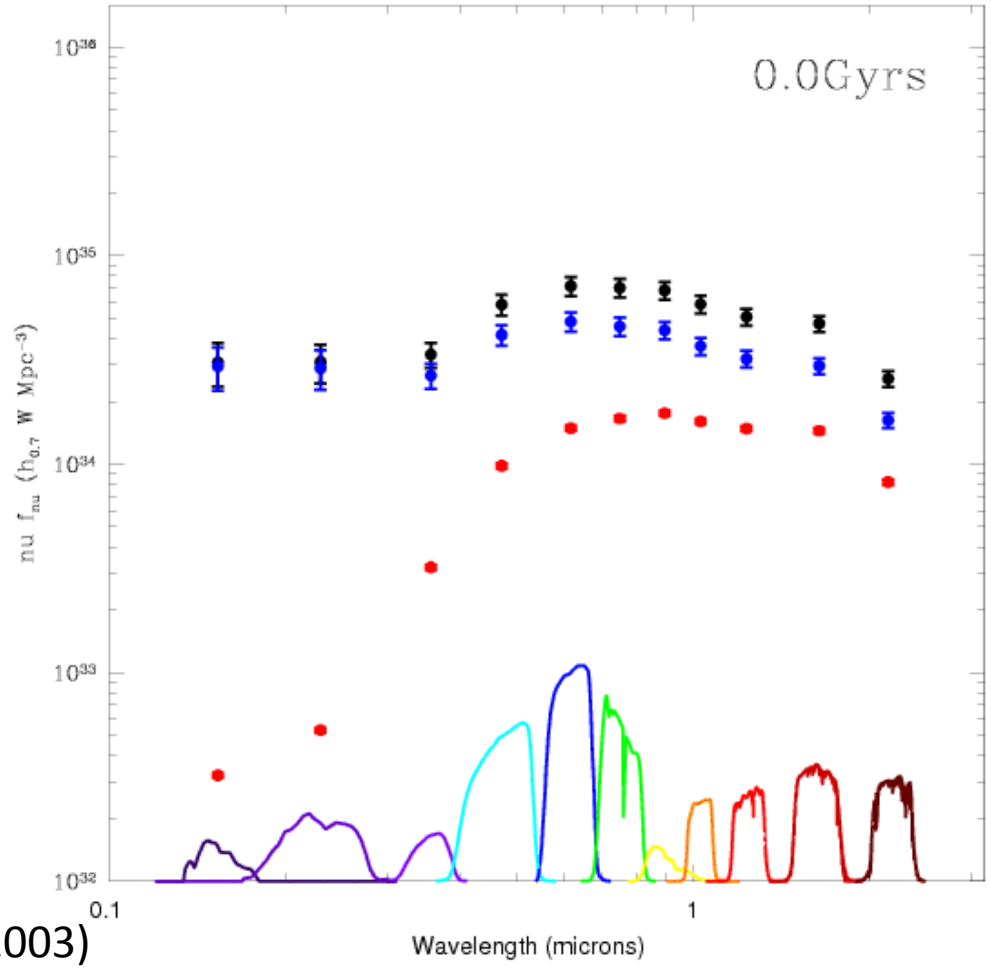
Simple fits to empirical data:
SFR v time

$$\log_{10}(\dot{\rho}_S) = 2.44 \times 10^{-7}(\frac{27.76}{t_U})^{10.21} \exp(-\frac{27.76}{t_U})$$

$$\log_{10}(\dot{\rho}_D) = 7.78 \times 10^{-4}(\frac{30.54}{t_U})^{6.01} \exp(-\frac{30.54}{t_U})$$

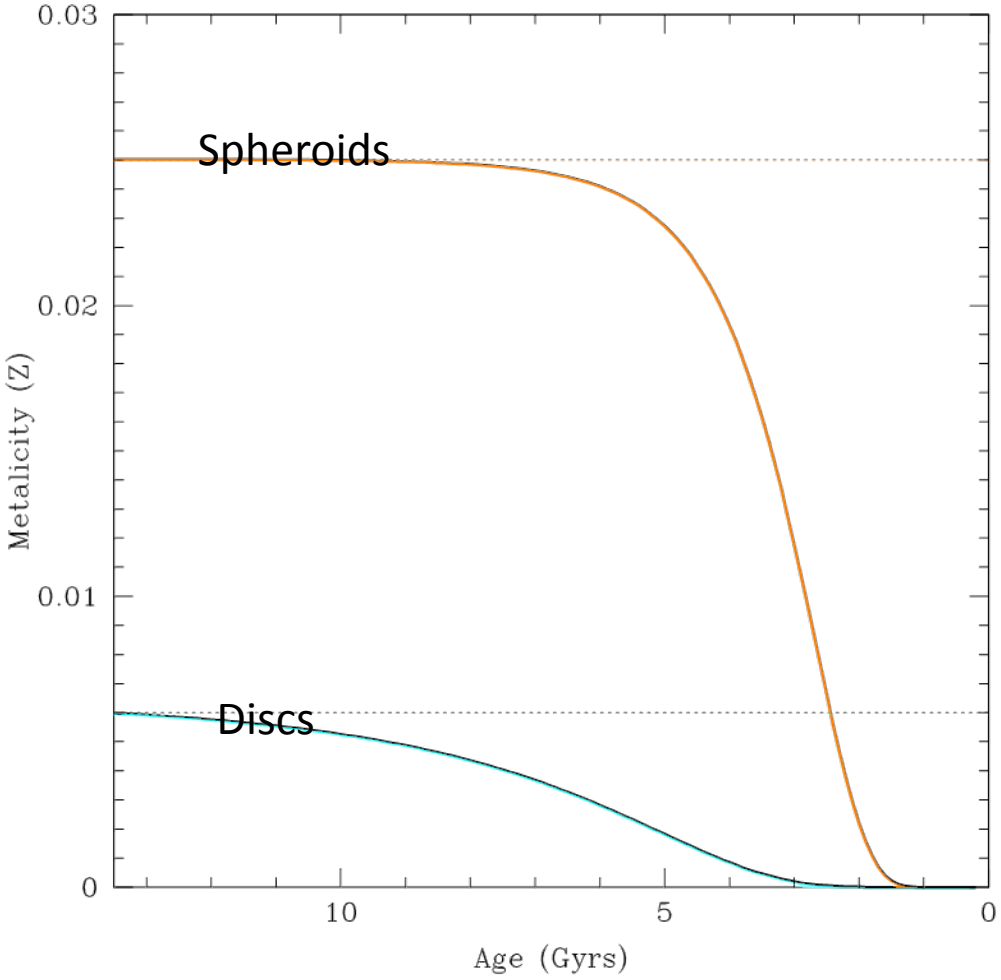
$$\log_{10}(\dot{\rho}_{All}) = 6.33 \times 10^{-2}(\frac{11.18}{t_U})^{3.69} \exp(-\frac{11.18}{t_U})$$

Fully constrained zero parameter model!



MODEL:
Pegase.2 (default options)
IMF =Baldry & Glazebrook (2003)
CSFH= Hopkins & Beacom (2006)
AGN activity=Richards et al (2007)
$Z_{z=0}$= Gallazzi et al (2005)
No free parameters….it just works.

Mean metallicity of the Universe

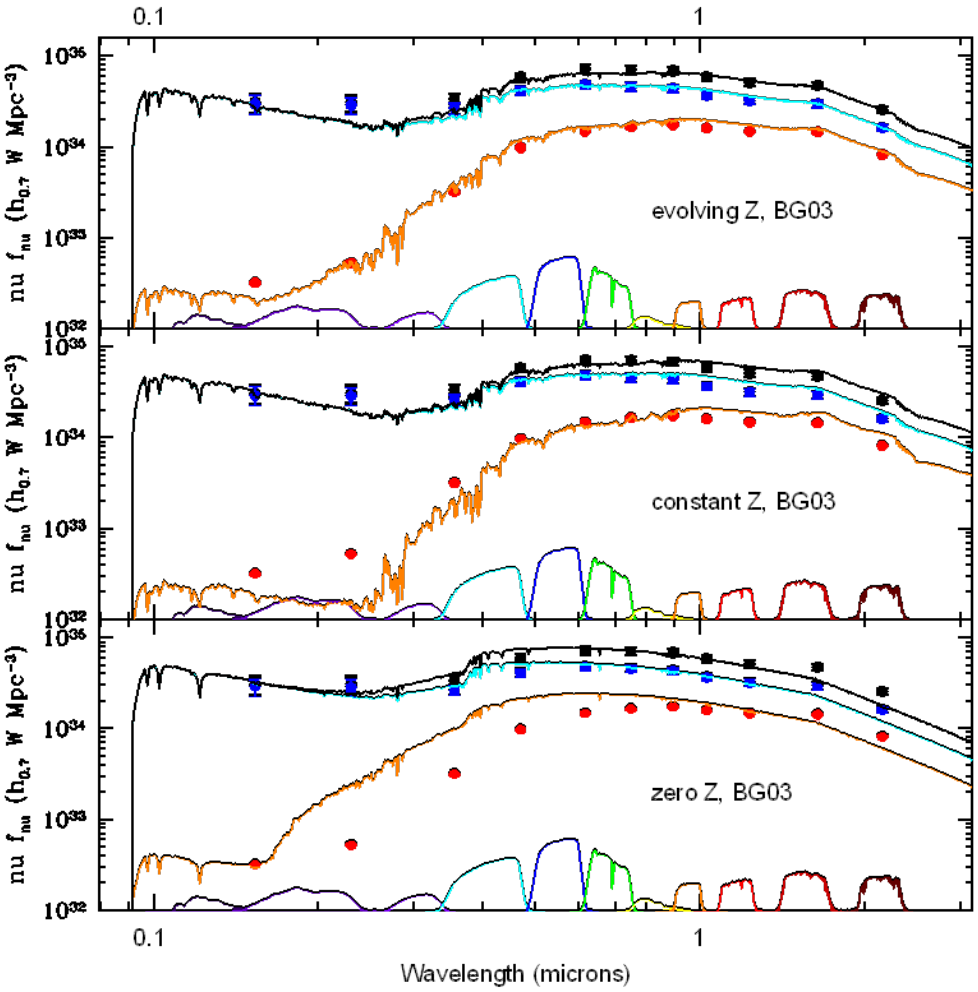


Derived from cumulative SFH.

Normalised to match local constraints on the mean low-z metalicity of spheroids and discs

i.e.,
Gallazzi et al (2005):
Spheroids Z=0.025
Discs Z=0.06

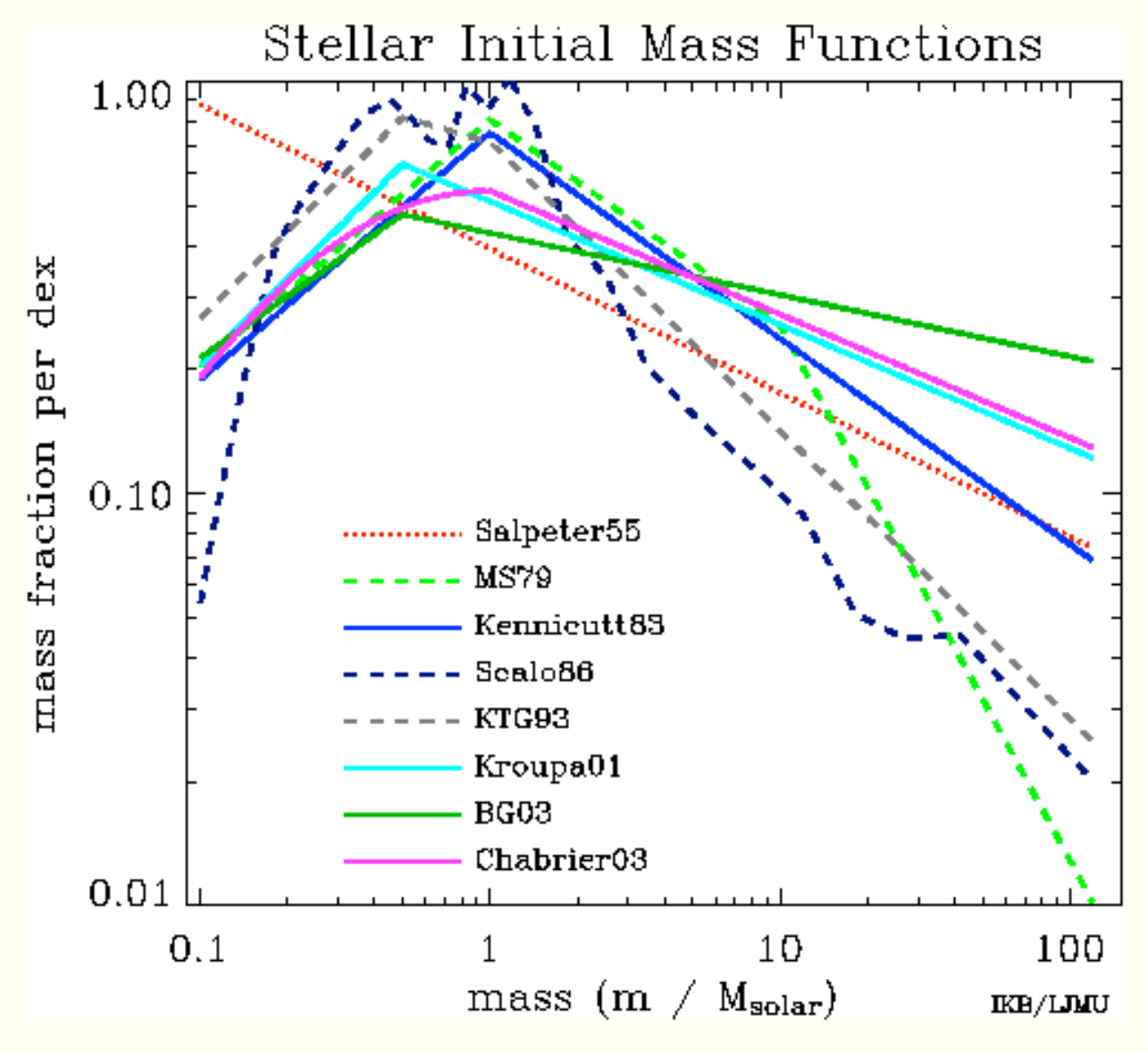
Fixed metallicity



Z=0.025 (Spheroids)
Z=0.05 (Discs)

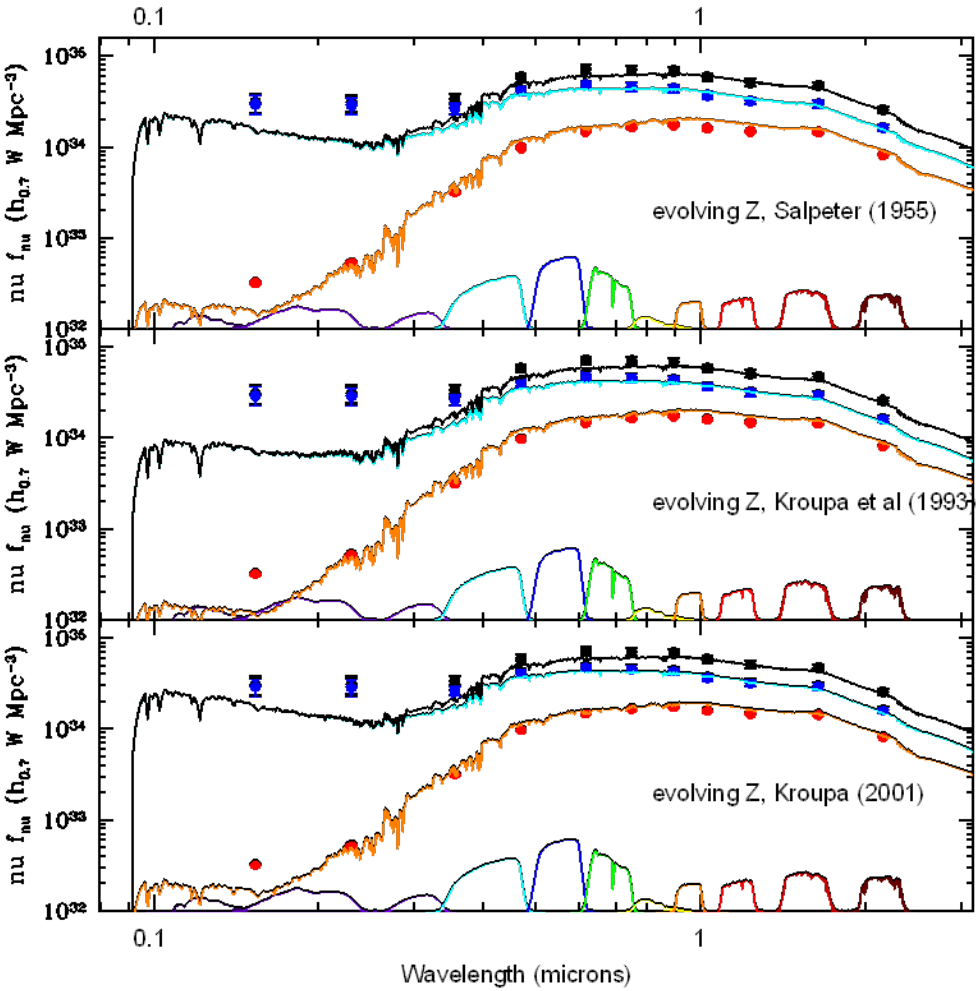
Z=0.0 (Spheroids)
Z=0.0 (Discs)

Modeling the CSED



Baldry & Glazebrook (2003): Initial Mass Function

Alternative IMFs



Stellar mass evolution

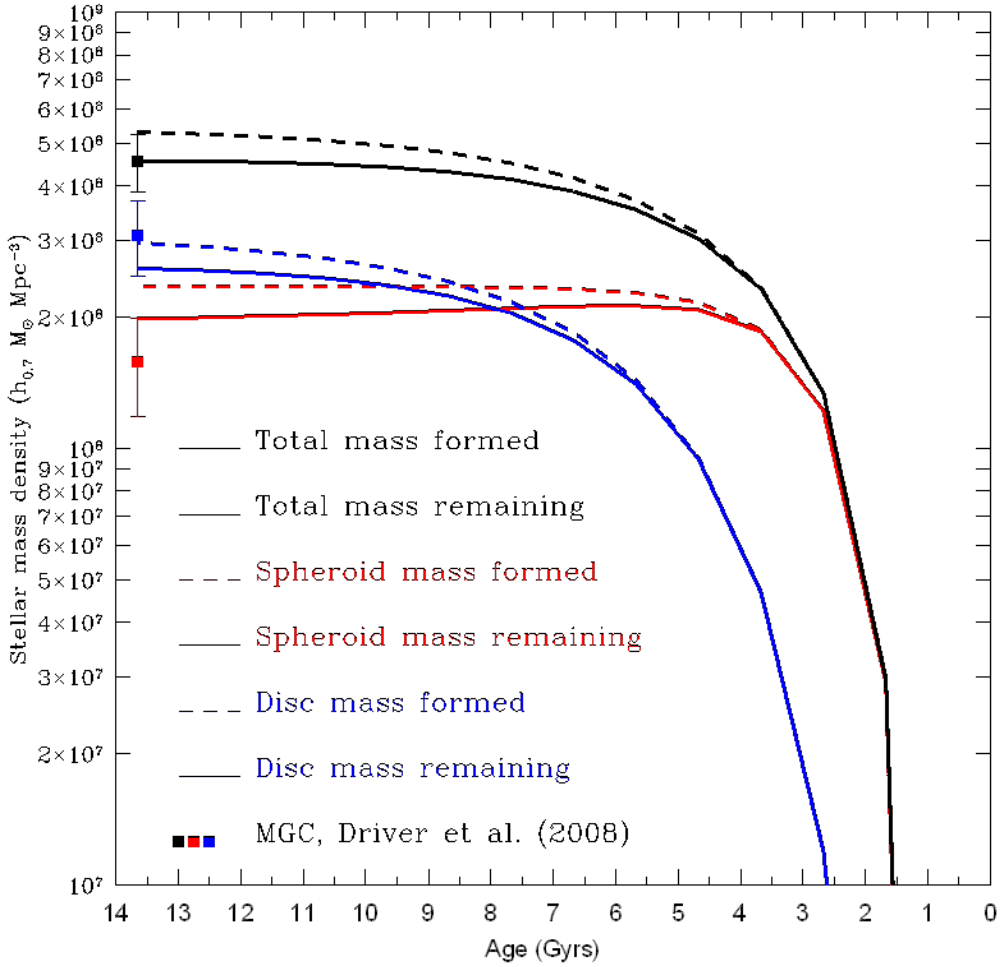
Again no free params.

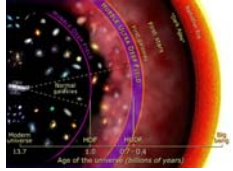
Aside:

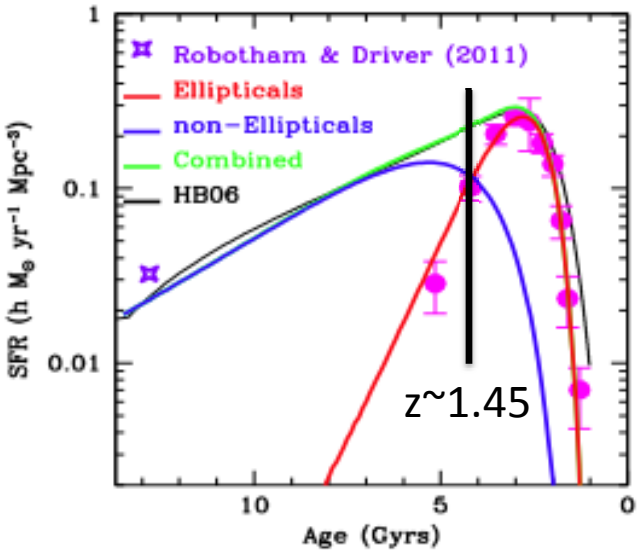
Mass loss > $\dot{\rho}$

Spheroids slowly evaporating

ρ_* close to maximum







Disc formation

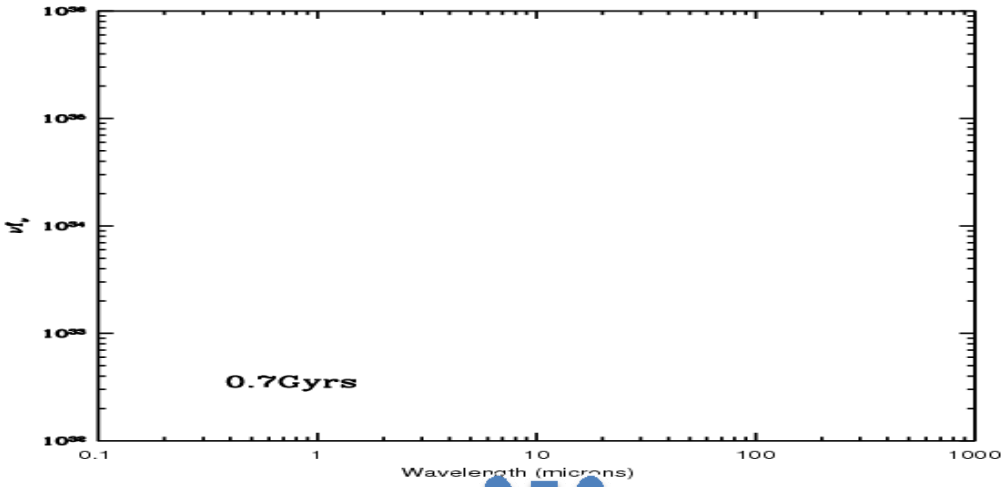
Spheroid formation

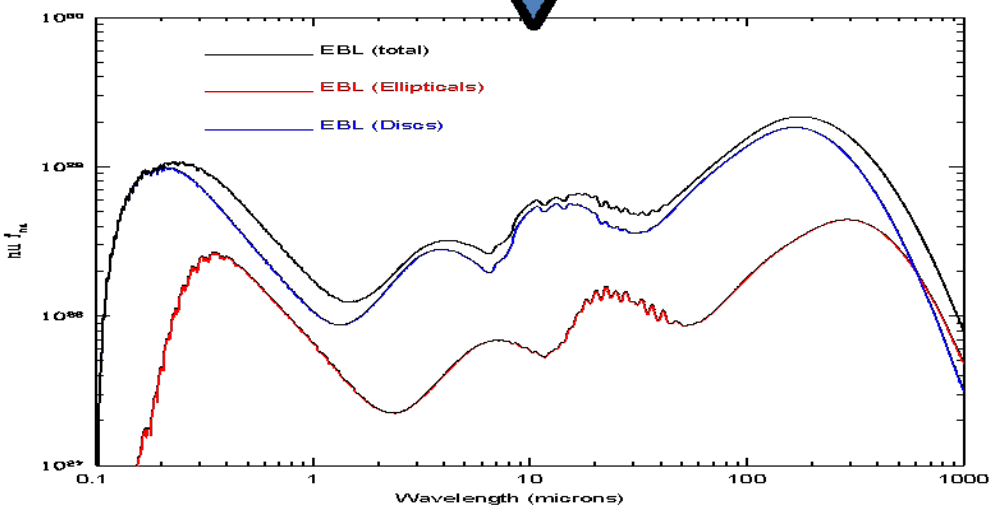
Driver et al (1998, ApJ, 496, 93)

The EBL

Entire energy output of Universe from stars z=7 to 0

Assumes basic dust properties do not evolve





Summary

- Wide-Field Optical Galaxy redshift surveys:
  - ~~Photo-z's~~ v spectro-z's
  - Luminosity functions (ESP→2dFGRS → SDSS → MGC → GAMA) → CSED
  - Galaxy Stellar Mass function (SDSS→GAMA) Upturn seen
- Expansion in wavelength:
  - Bimodality (SDSS) or bulge-disc duality
  - Star-formation (CFRS→HST→GALEX) now divided into spheroids and discs
  - Dust (2MASS→UKIDSS→HERSCHEL) big problem how to deal with it (FIR)
  - Gas (HI) (Parkes→ARECIBO→ASKAP/MeerKAT→SKA) coming soon
- Increase in spatial resolution:
  - Morphology (HST →SDSS→MGC→GAMA) bulge-disc decomp needed
  - Surface brightness and selection bias (SDSS & MGC) a big issue for dwarf systems
  - Sersic profiles & structural analysis (GIM2D, BUDDHA, GALFIT3)
  - Size evolution = disc growth
- Galaxy formation: a two-stage process?
  - Transition at z=1.5
  - Zero parameter prediction of energy output of Universe