Normal Mass and Normal Energy

Simon Driver

University of St Andrews &

University of Western Australia

- The Galaxy And Mass Assembly survey (GAMA)
- The stellar mass budget
- The UV to Far-IR cosmic energy budget
- The two-phase evolution of galaxies

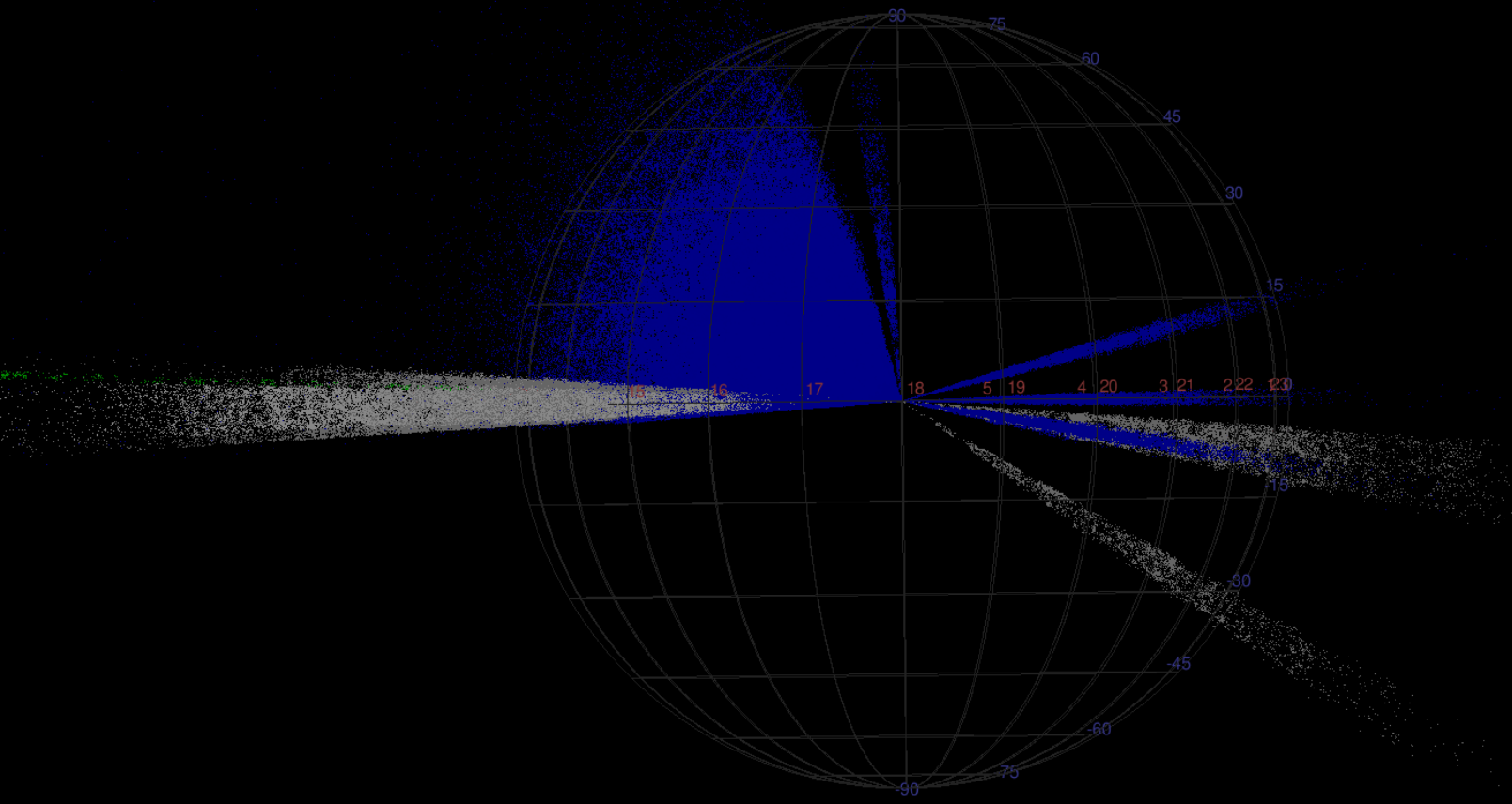
SUPA Physics Scotland

University of St Andrews

ICRAR International Centre for Radio Astronomy Research

~320,000 redshifts over 300 sq deg (5 regions), r<19.8 mag

FUV,NUV,ugriz,YJHK,WISE,HERSCHEL,ASKAP,GMRT

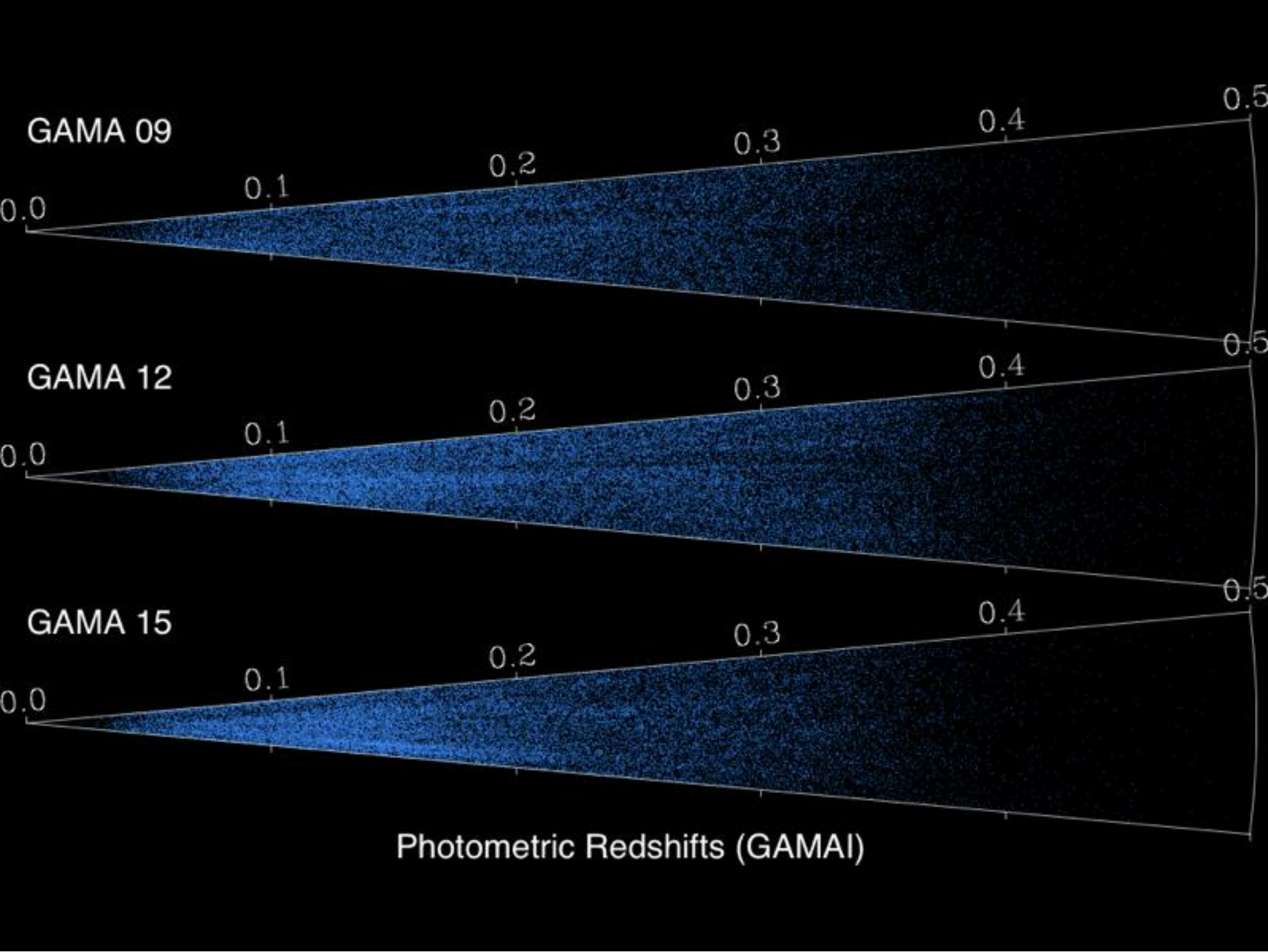


GAMAI

GAMAII

SDSS DR9

zCOSMOS


GAMA 09
0.0
0.1
0.2
0.3
0.4
0.5
GAMA 12
0.0
0.1
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0.3
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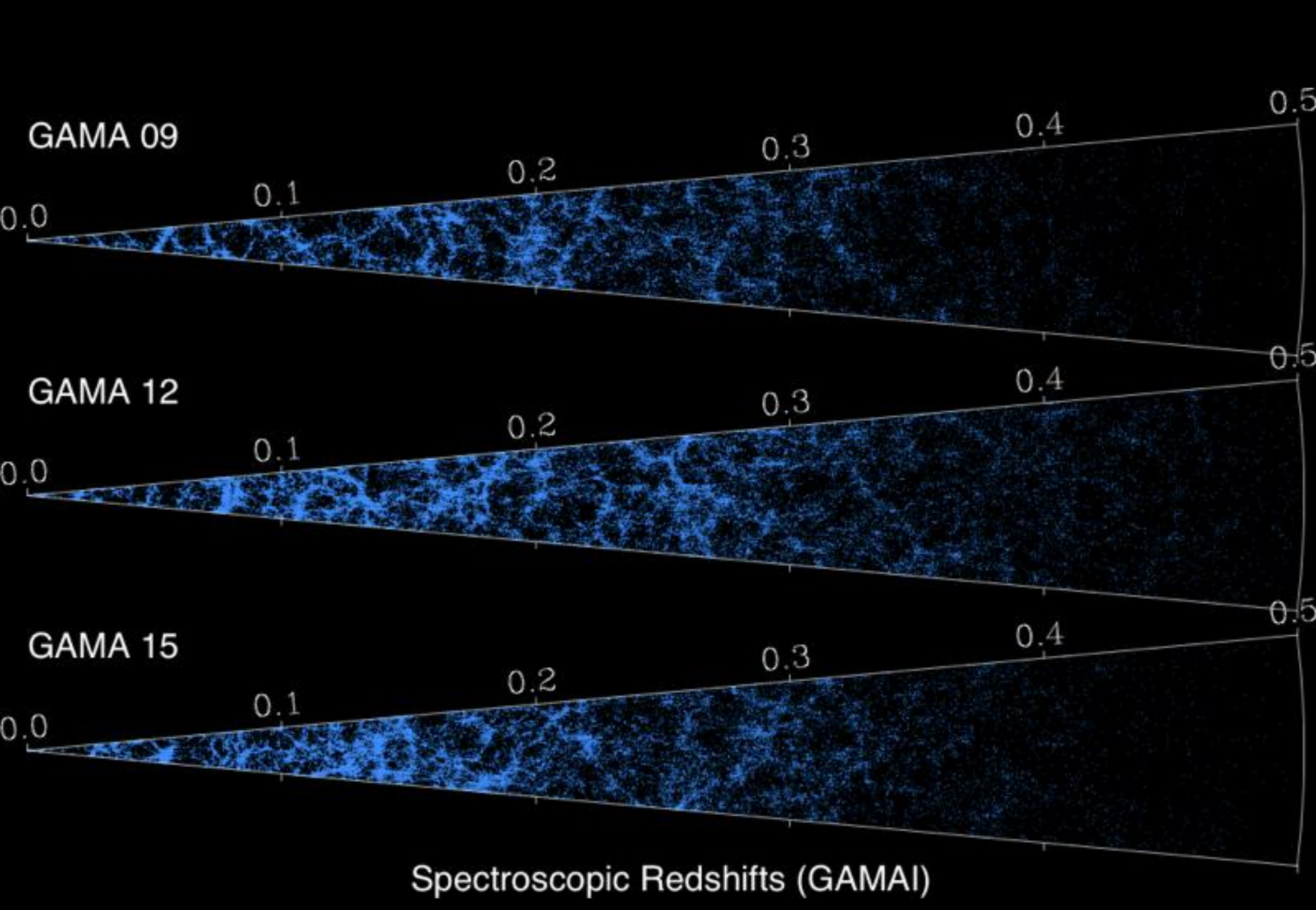
GAMA 15
0.0
0.1
0.2
0.3
0.4
0.5
Photometric Redshifts (GAMAI)


GAMA 09
0.0
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GAMA 12
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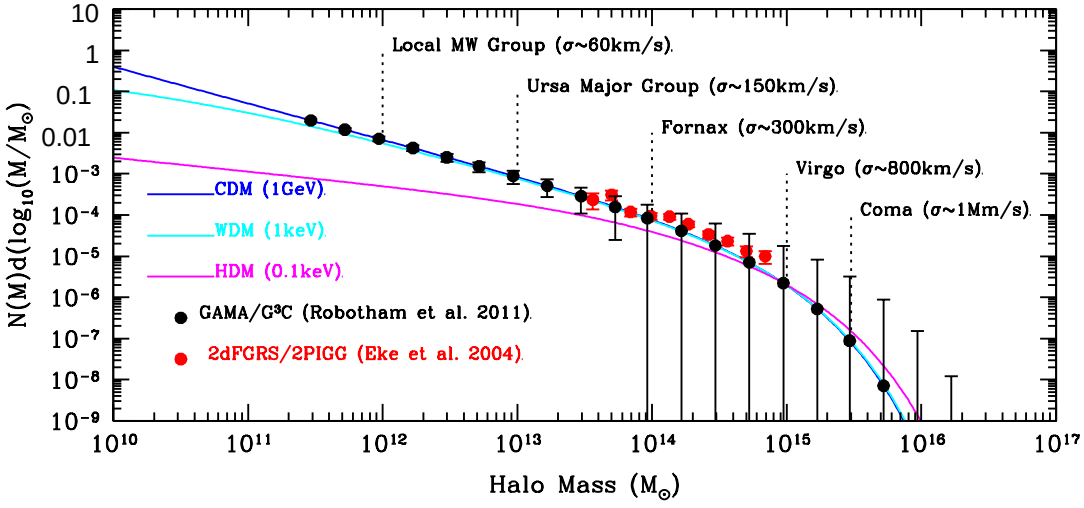
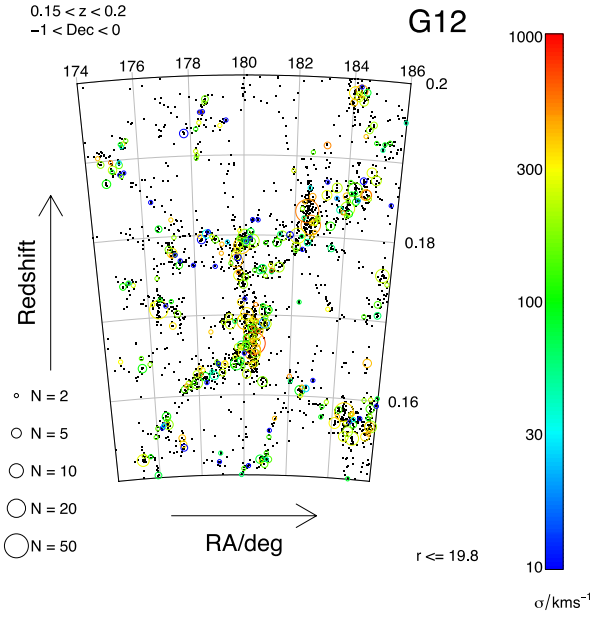
0.2
0.3
0.4
0.5
GAMA 15
0.0
0.1
0.2
0.3
0.4
0.5
Spectroscopic Redshifts (GAMAI)

GAMA Groups & Filaments

Direct measure of Halo Mass Function to below Local Group Masses
Robotham et al (2011)

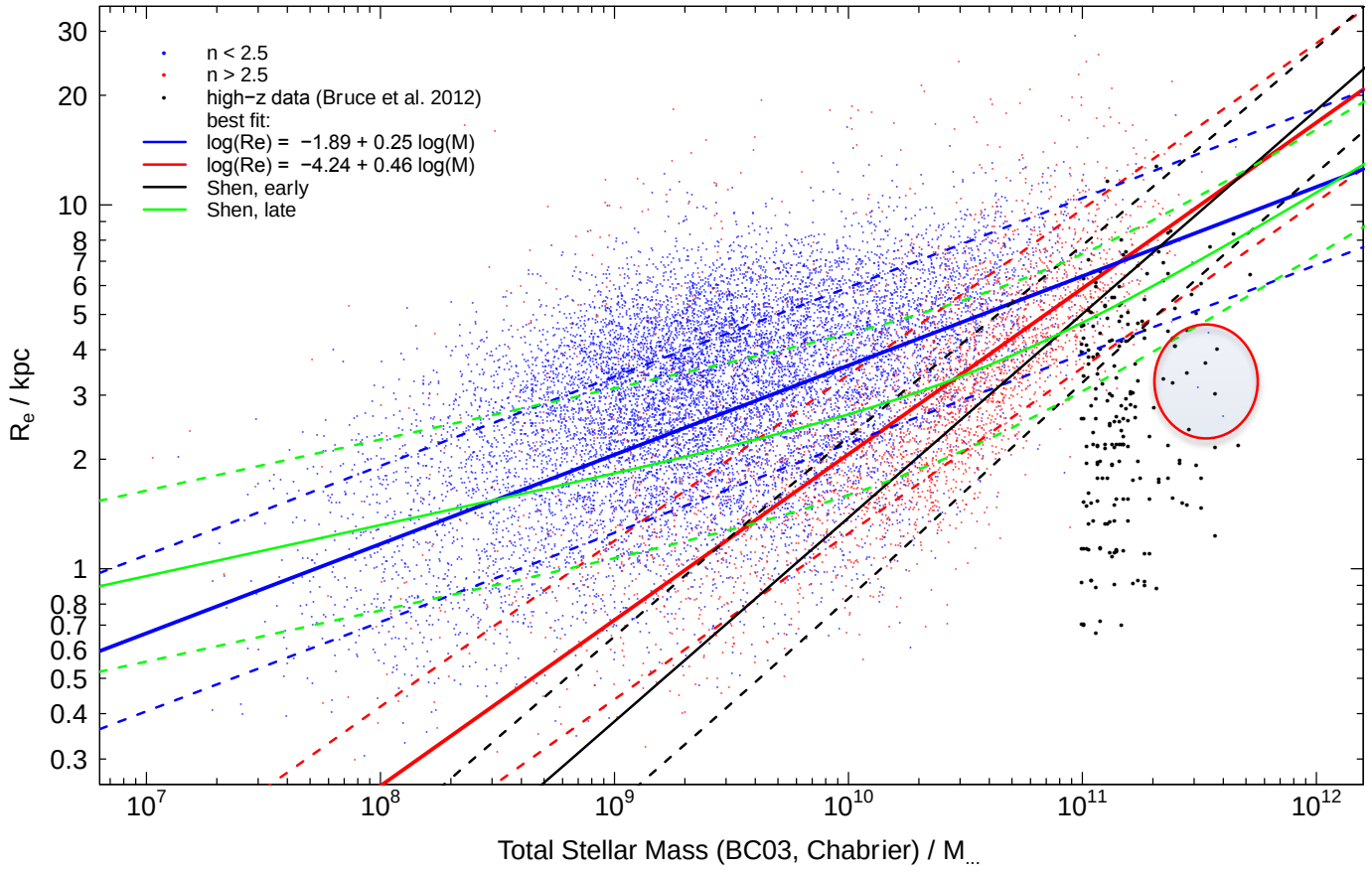


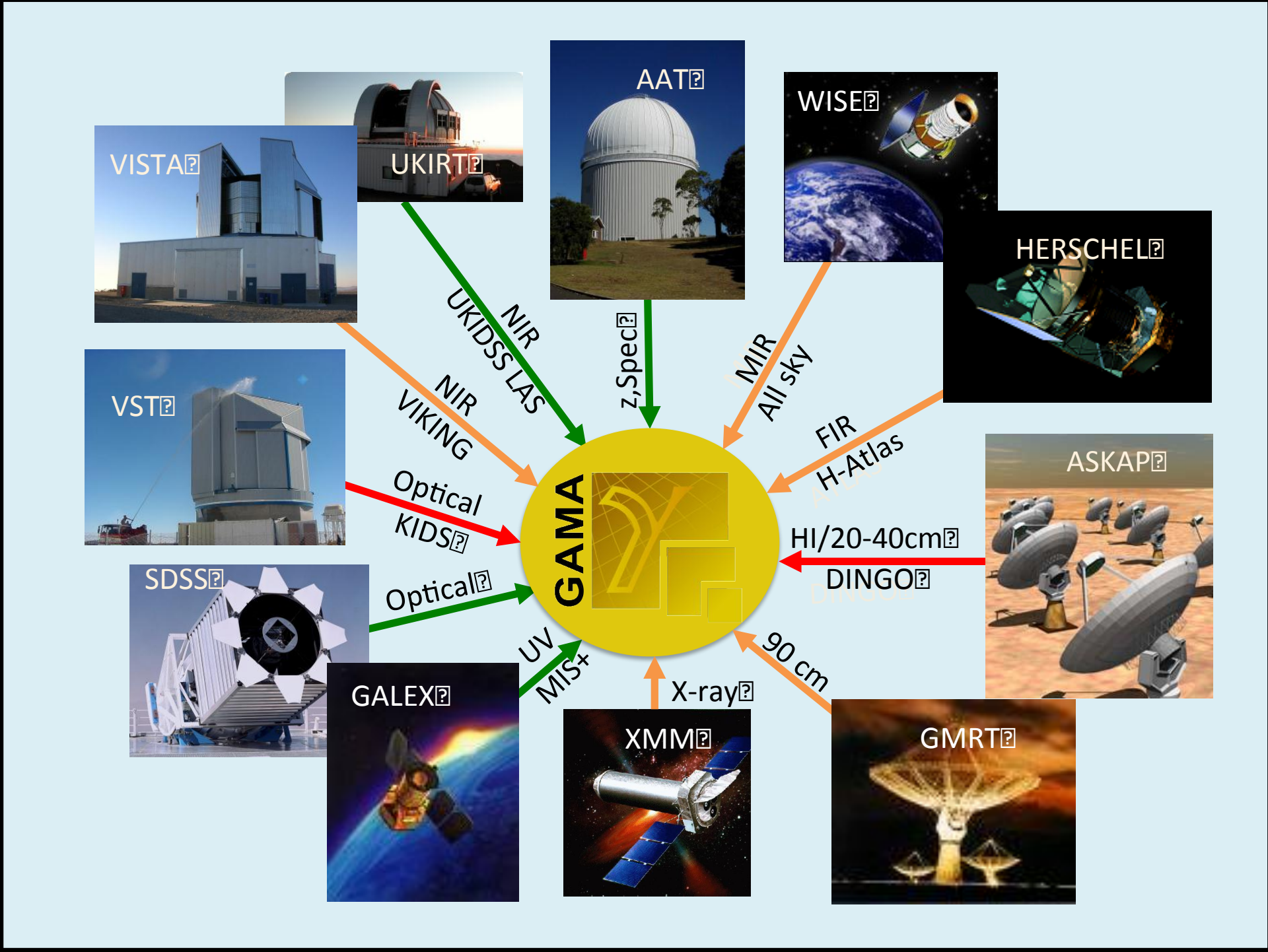
Filament detection & characterisation using the groups (in progress)



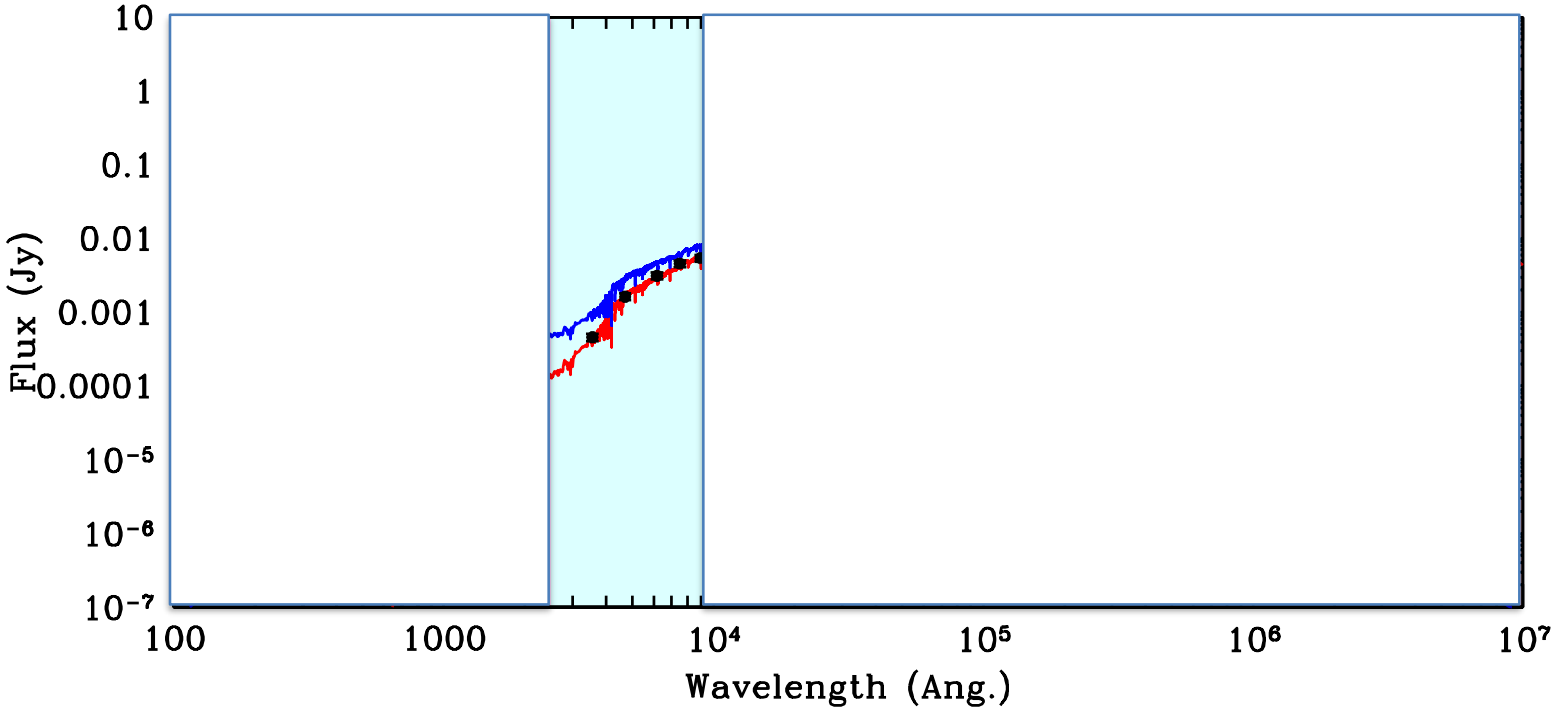
z=<0.1 scaling relations to 10^8Mo

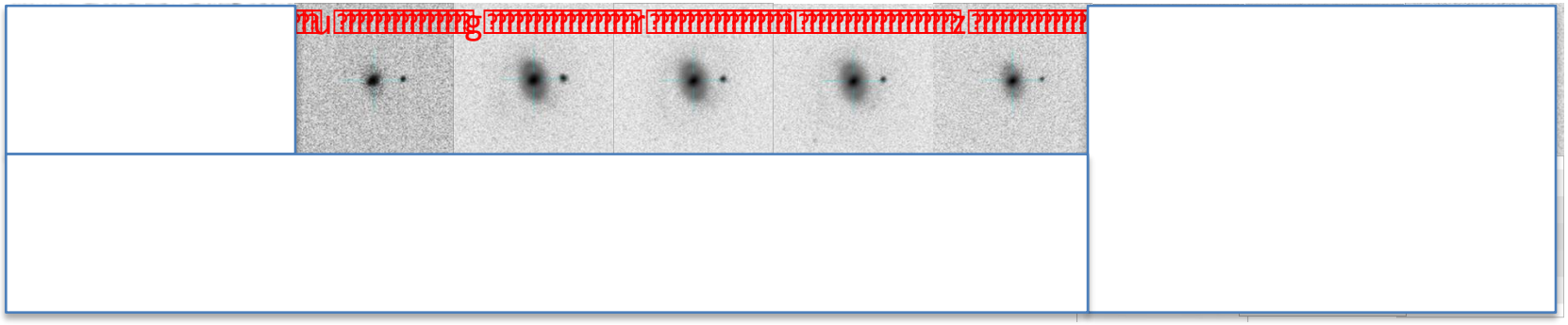
E.g., Mass-size relation



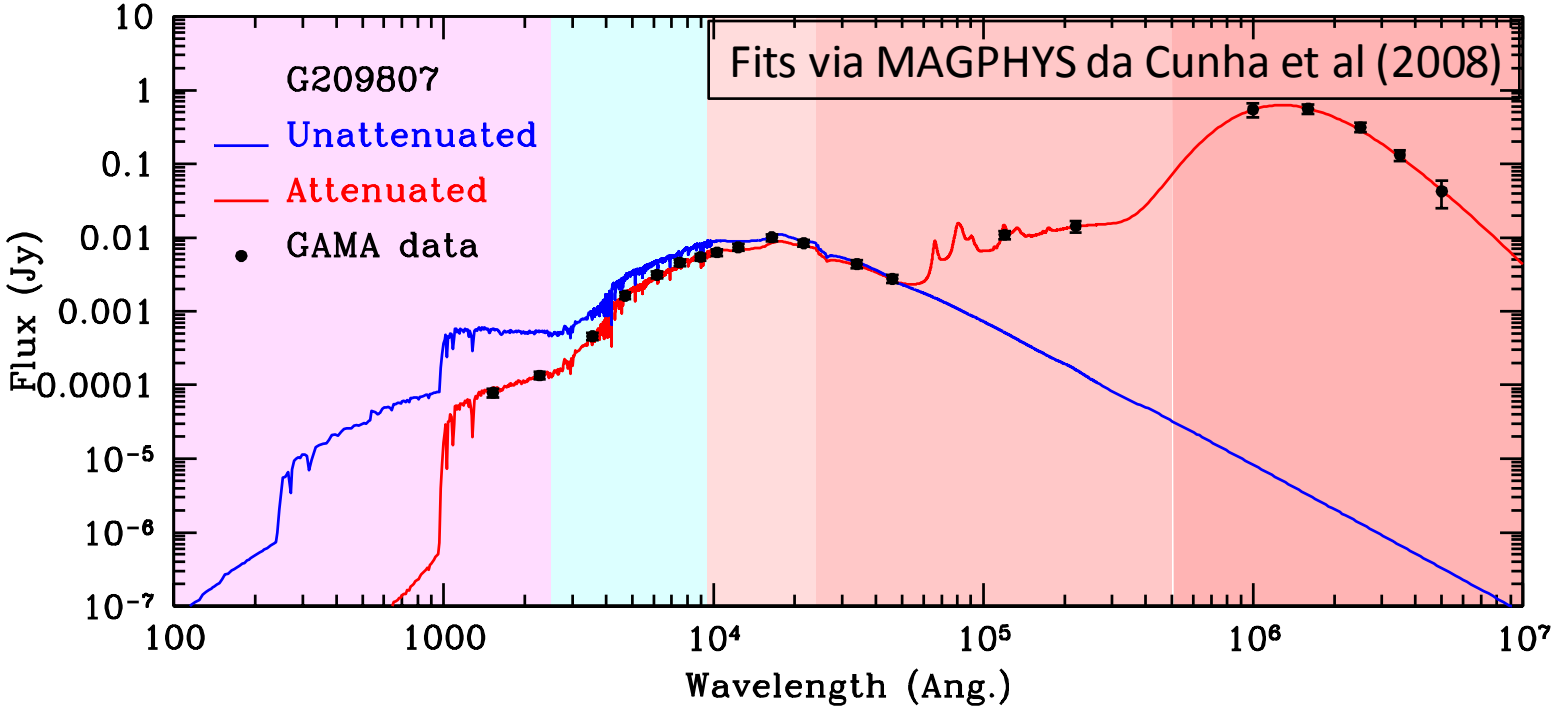

AAT
WISE
UKIRT
VISTA
HERSCHEL
NIR
UKIDSS LAS
z,Spec
MIR
All sky
NIR
VIKING
FIR
H-Atlas
VST
Optical
KIDS
GAMA
ASKAP
HI/20-40cm
DINGO
SDSS
Optical
UV
MIS+
90 cm
X-ray
GALEX
XMM
GMRT

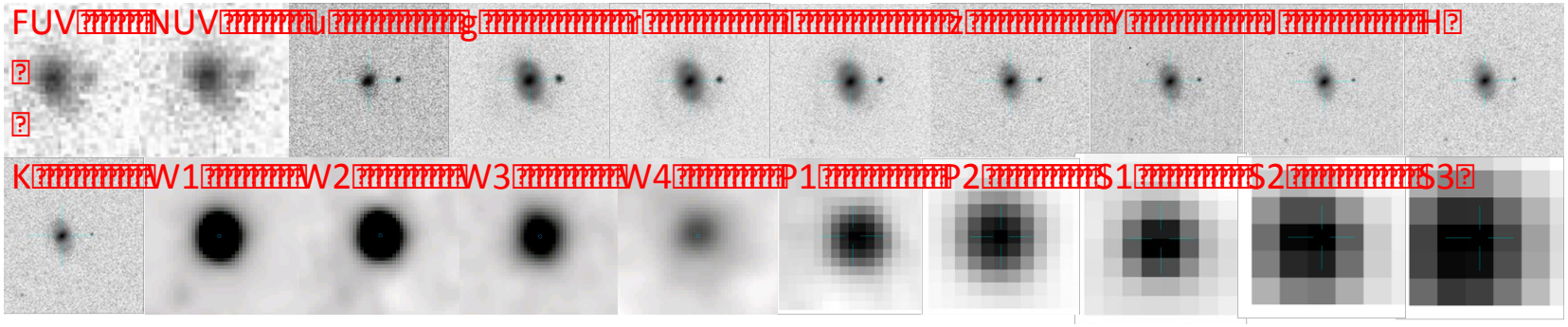
The optical view of galaxies





The multi-wavelength view of galaxies





G209807

r = -15.2+/0.01

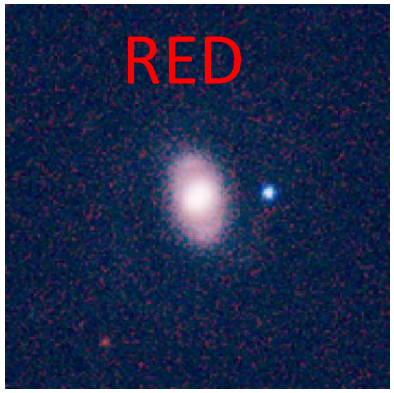
z = 0.0539

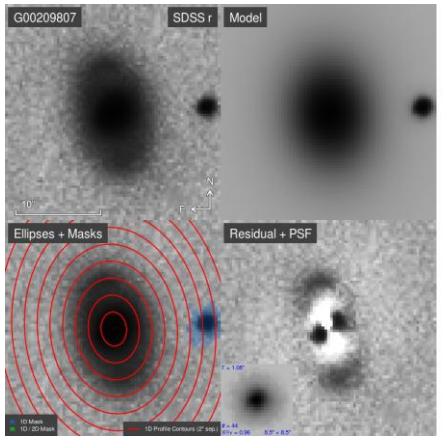
n = 3.15

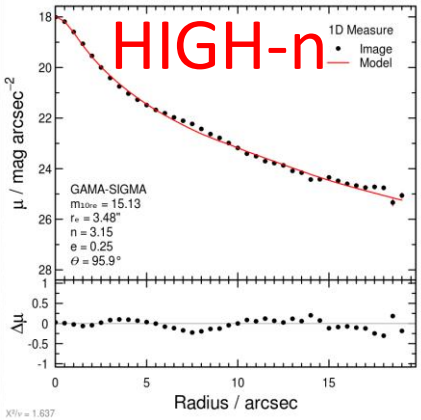
R_e= 3.48”

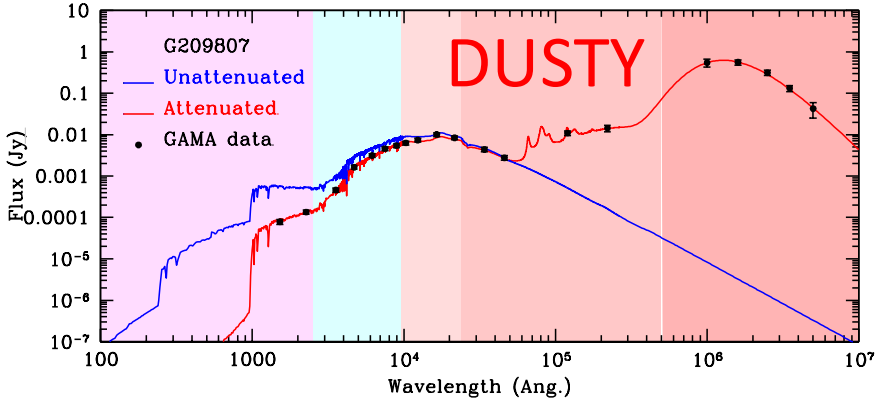
M_r = -22.0+/-0.02

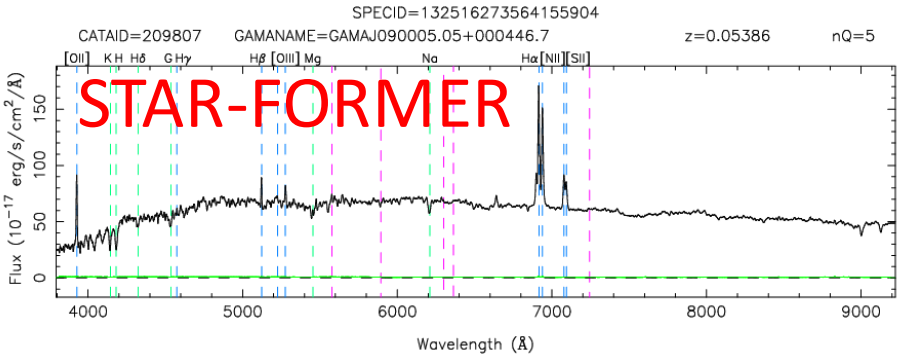
logM_*= 10.8+/-0.1

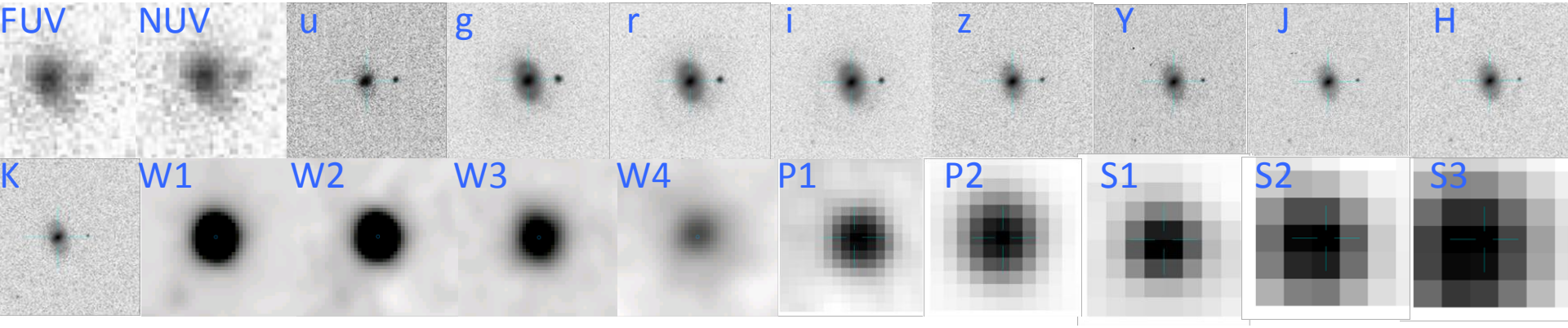












One down 319,999 to go….in reality many data will be upper limits only….deblends…interlopers

GAMA Data Release 2 (Oct)

All redshifts in G15 to r<19.4mag (Liske et al in prep)
GAMA Groups (Robotham et al 2011)
Stellar Masses (Taylor et al 2011)
9 band Sersic profiles (Kelvin et al 2011)
ugrizYJHK matched aperture photometry (Hill et al 2011)
GALEX Photometry (Seibert et al in prep)
Spectroscopic line indicees (Hopkins et al submitted)

Sponsors

SUPA Physics Scotland
University of St Andrews
ICRAR International Centre for Radio Astronomy Research
Australian Government Department of Industry Innovation, Science, Research and Tertiary Education
AAO

Funding Agency Support

Science & Technology Facilities Council
Australian Government Australian Research Council
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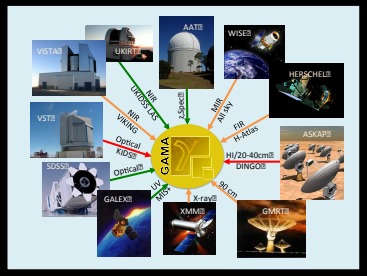


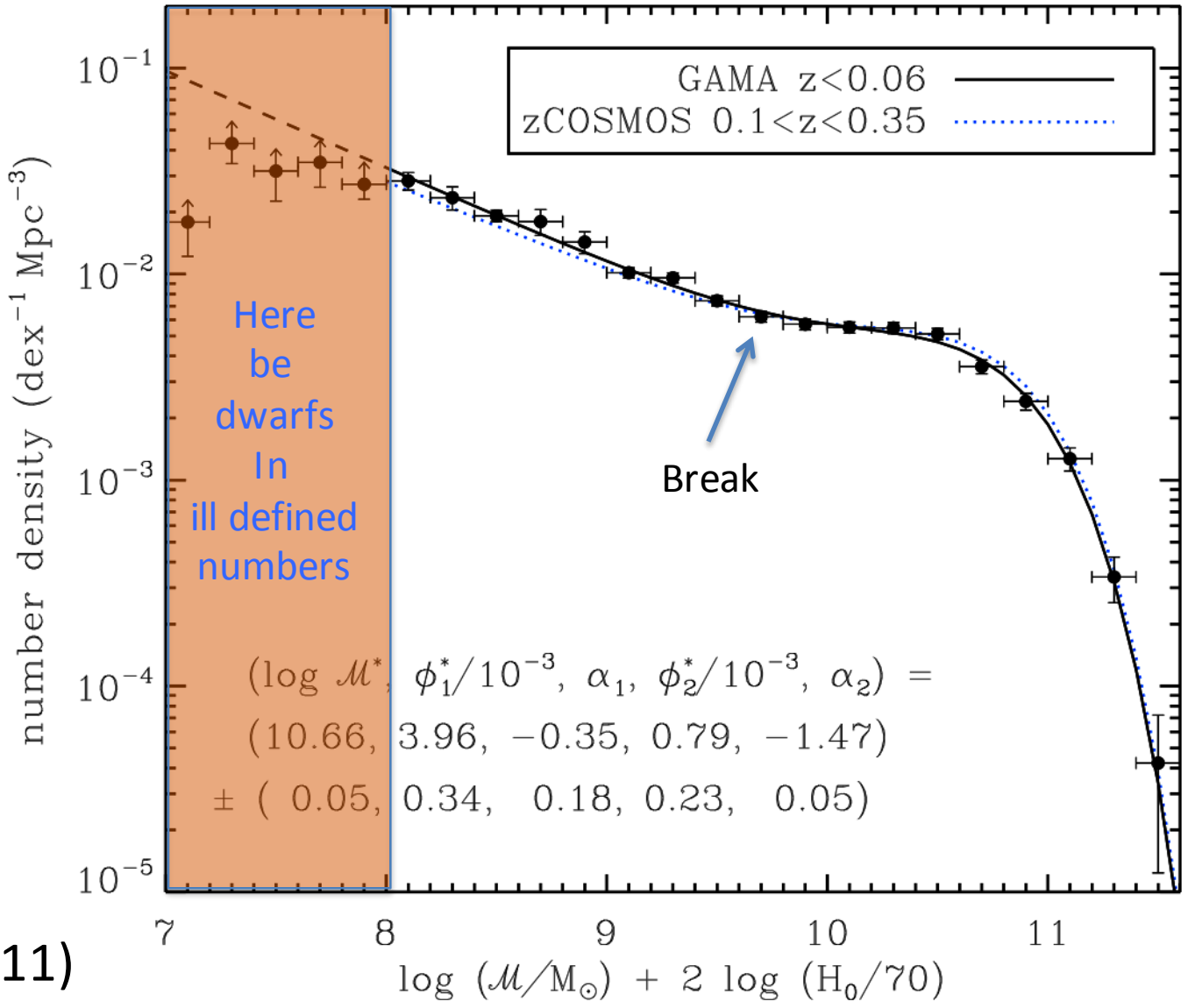
GAMA Team

60 researchers (including 15 PhD students) across 20 institutions

Progress

30+ publications (50% HAtlas led)
80 papers in progress (50% led by non GAMA-team members)
http://www.gama-survey.org/
gama@gama-survey.org

Galaxy Stellar Mass Function



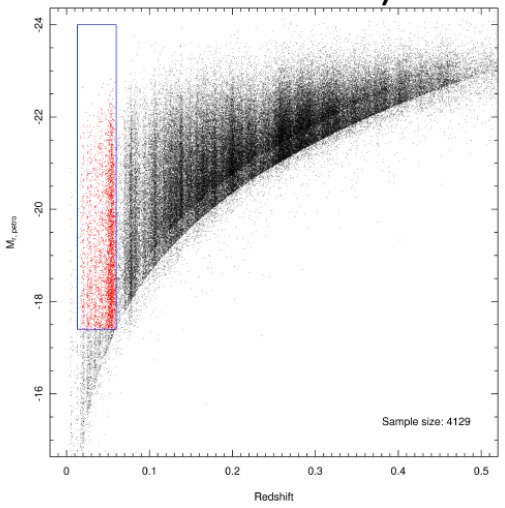
Baldry et al (2011)

From galaxies to components via morphology

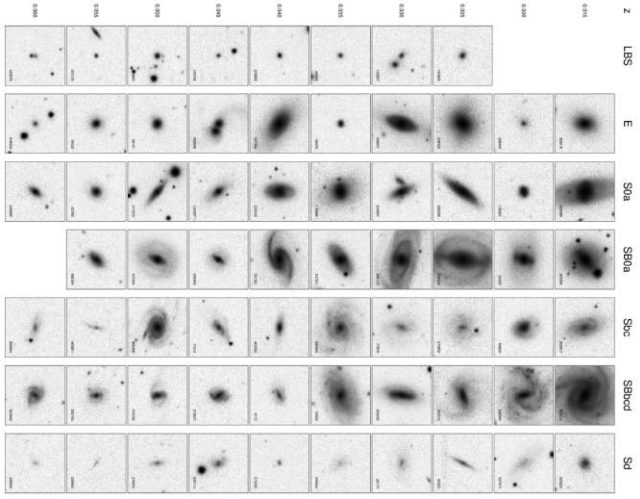
Credit: Lee Kelvin
(PhD Thesis)

Summary of
last weeks talk
during Secular evolution
Special session

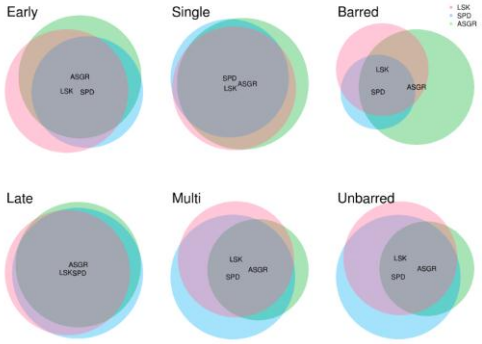
Sample Selection Volume Limited)



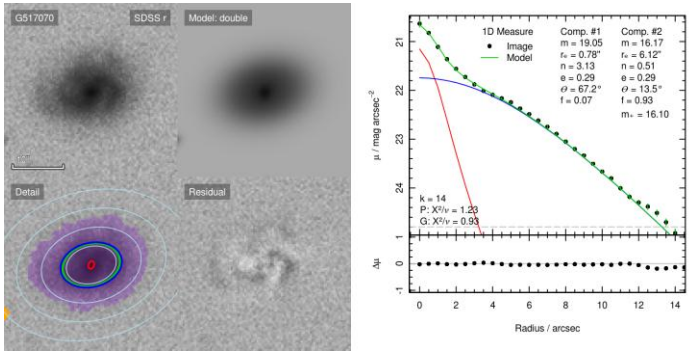
Morphology classification



Classification consensus

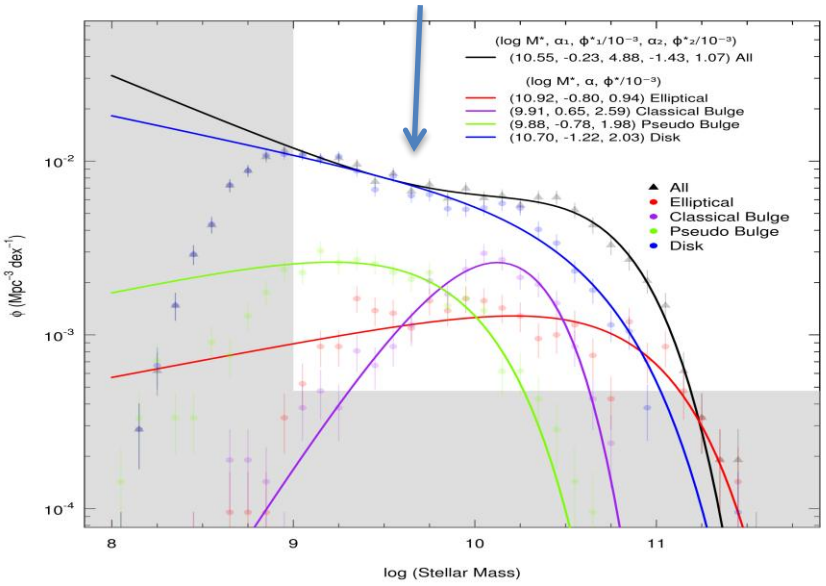


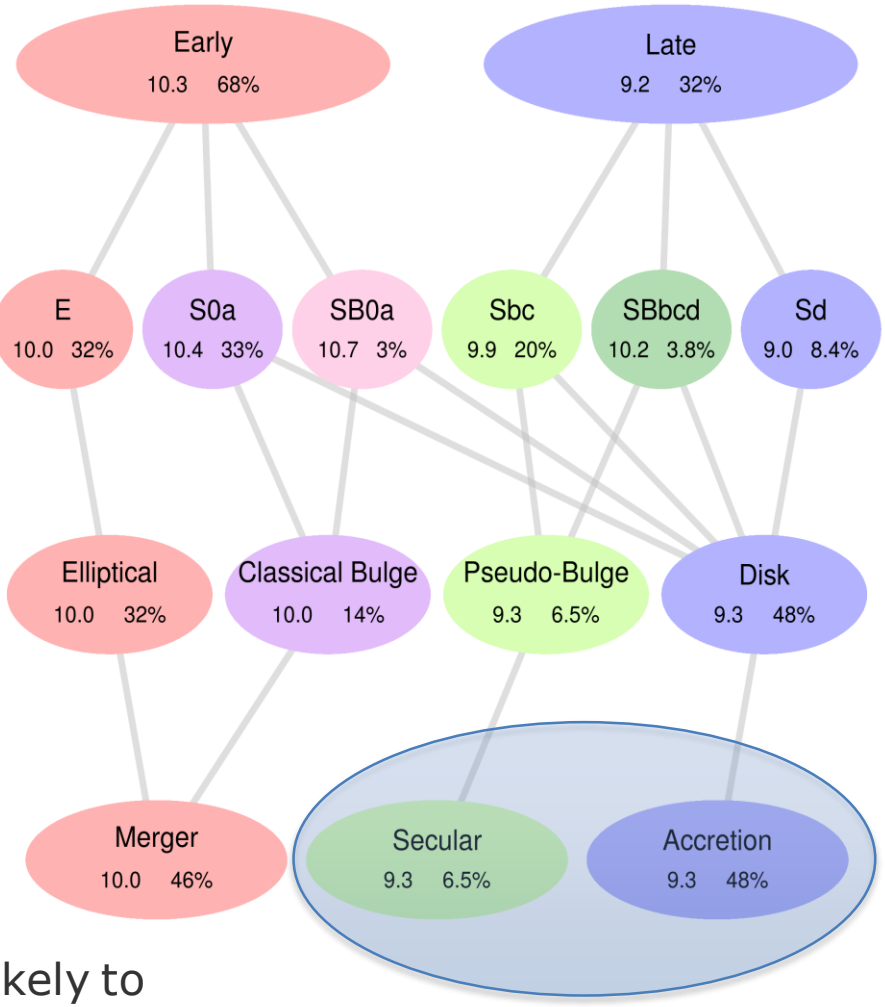
Bulge disc decompositions (GALFIT)



Stellar mass function by component

Break due to declining bulge mass





Hot mode (mergers?) ~45.8%

Cold mode (accretion?) ~54.2%

[Secularstructures ~6.5%]

Morphologies and bulge-disc decompositions still under review but unlikely to change much (<5%)

Energy

- Three types of energy:
  - Dark energy (required to explain accelerated expansion)
  - Primordial energy (CMB, relic radiation from early Universe)
  - Normal energy generated by baryon evolution:
    - Starlight
    - Active Galactic Nuclei
    - Energy attenuated and redistributed in wavelength by dust

- EBL and CSED:
  - EBL=Extragalactic background light
    - Sum of all photons within a representative volume (excluding CMB)
  - CSED=Cosmic Spectral Energy Distribution
    - Sum of photons created within a representative volume at time of observation
  - A descrition of the CSED over all time provides a prediction of the EBL

- Use GAMA to measure CSED from UV to far-IR and attempt to model it.

GAMA FUV Luminosity Function and Luminosity Density

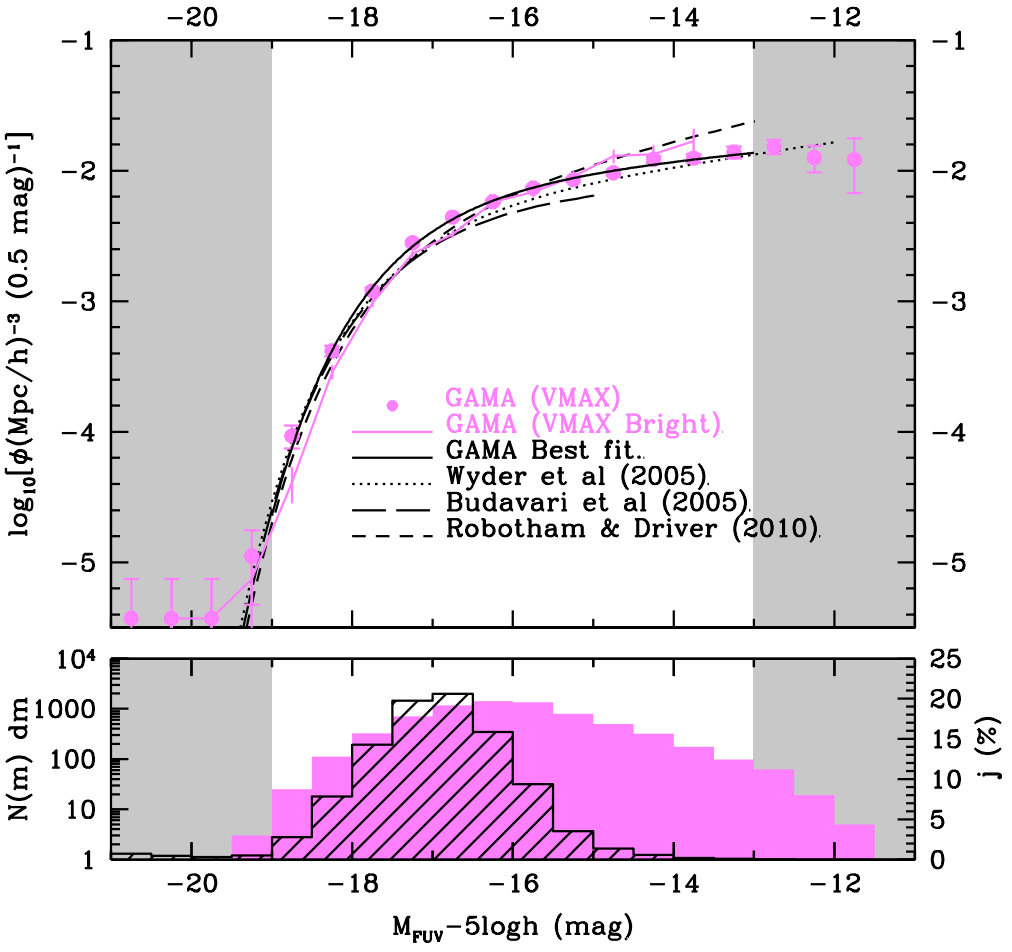
FUV LF consistent with previous measures

SFR(hM./yr/Mpc^3) = 0.034 (Kennicutt 1998)
+/- 0.003 Random
+/- 0.009 Dust Correction
+/- 0.002 Cosmic Variance

$$\zeta_{\rm Cos.Var.}(\%) = (1.00 - 0.03\sqrt{A/B}) \times (219.7 - 52.4\log_{10}[A.B.291.0] + 3.21(\log_{10}[A.B.291.0])^2) / (\sqrt{N.\frac{C}{291.0}})$$

Driver & Robotham (2010), or use online tool at:

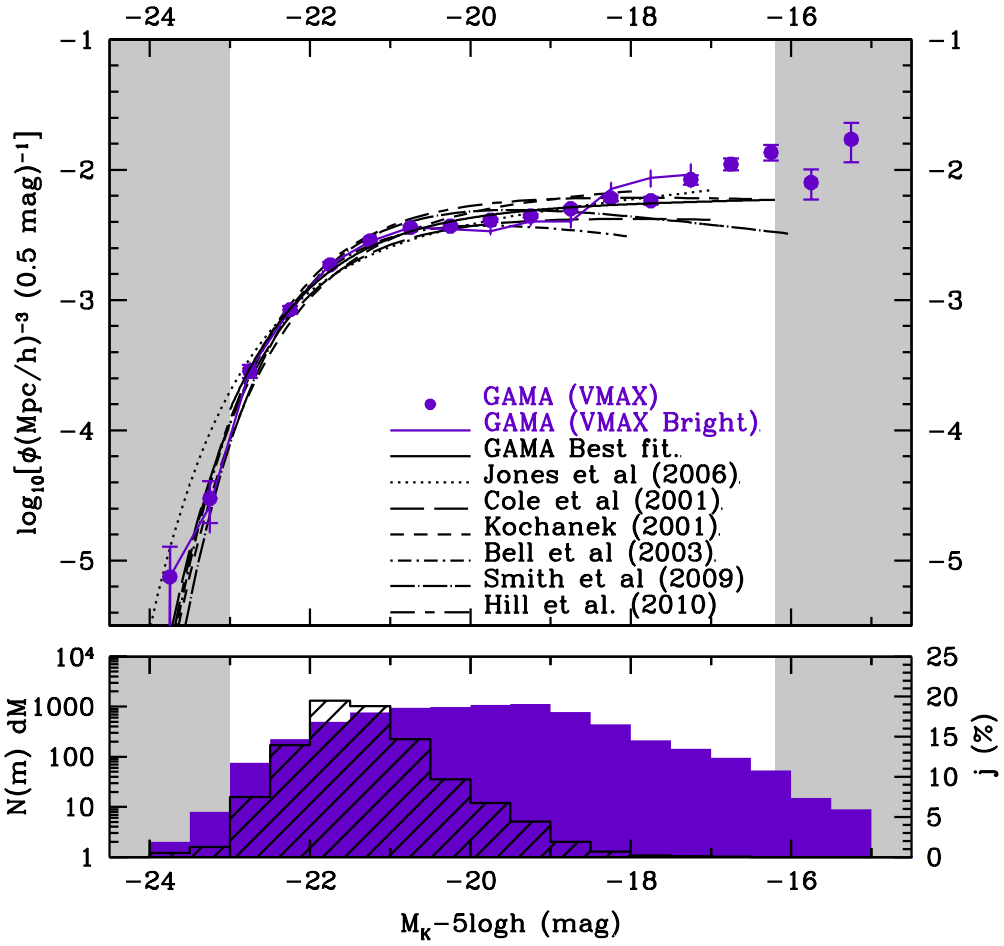
http://star-www.st-and.ac.uk/~asgr/cosvar/



GAMA K band Luminosity Function and Luminosity Density

LFs and LDs derived in *ugrizYJHK* bands for the common coverage region

Matched aperture photometry from u to K via Sextractor using SDSS and UKIDSS data astrometrically aligned, convolved to a common seeing, and SWARPED into single large mosaics (60Gbyte images).



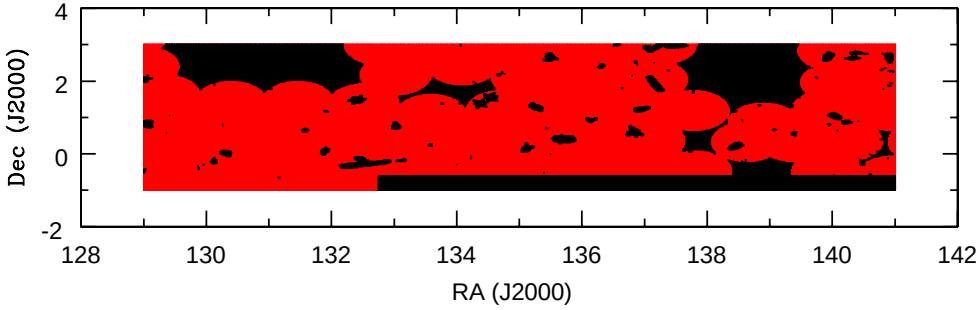
Common FUV,NUV,ugriz,YJHK coverage

Complete coverage in ugriz

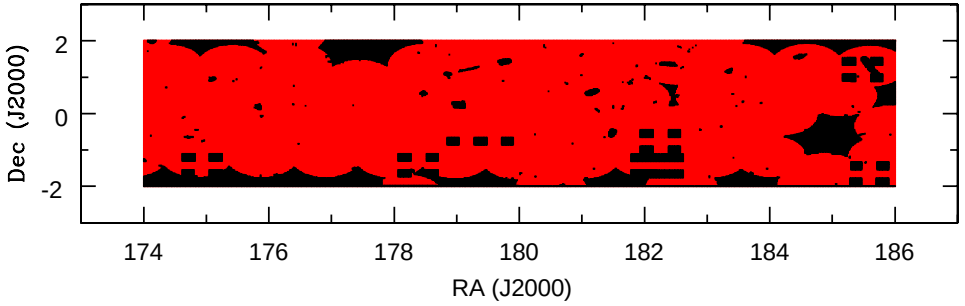
Patchy coverage with GALEX and UKIDSS

Common region spans 125.06deg^2

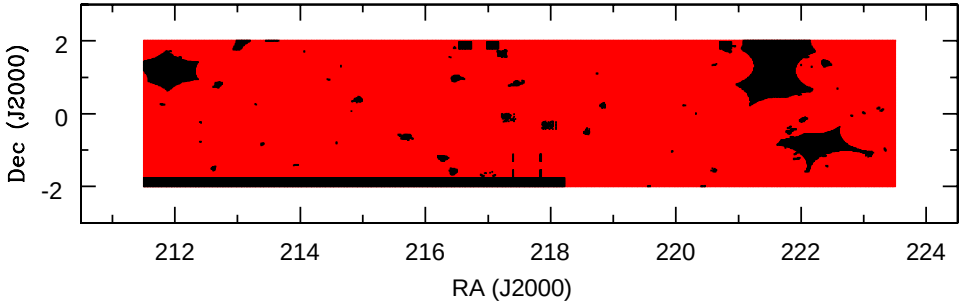
G09



G12



G15



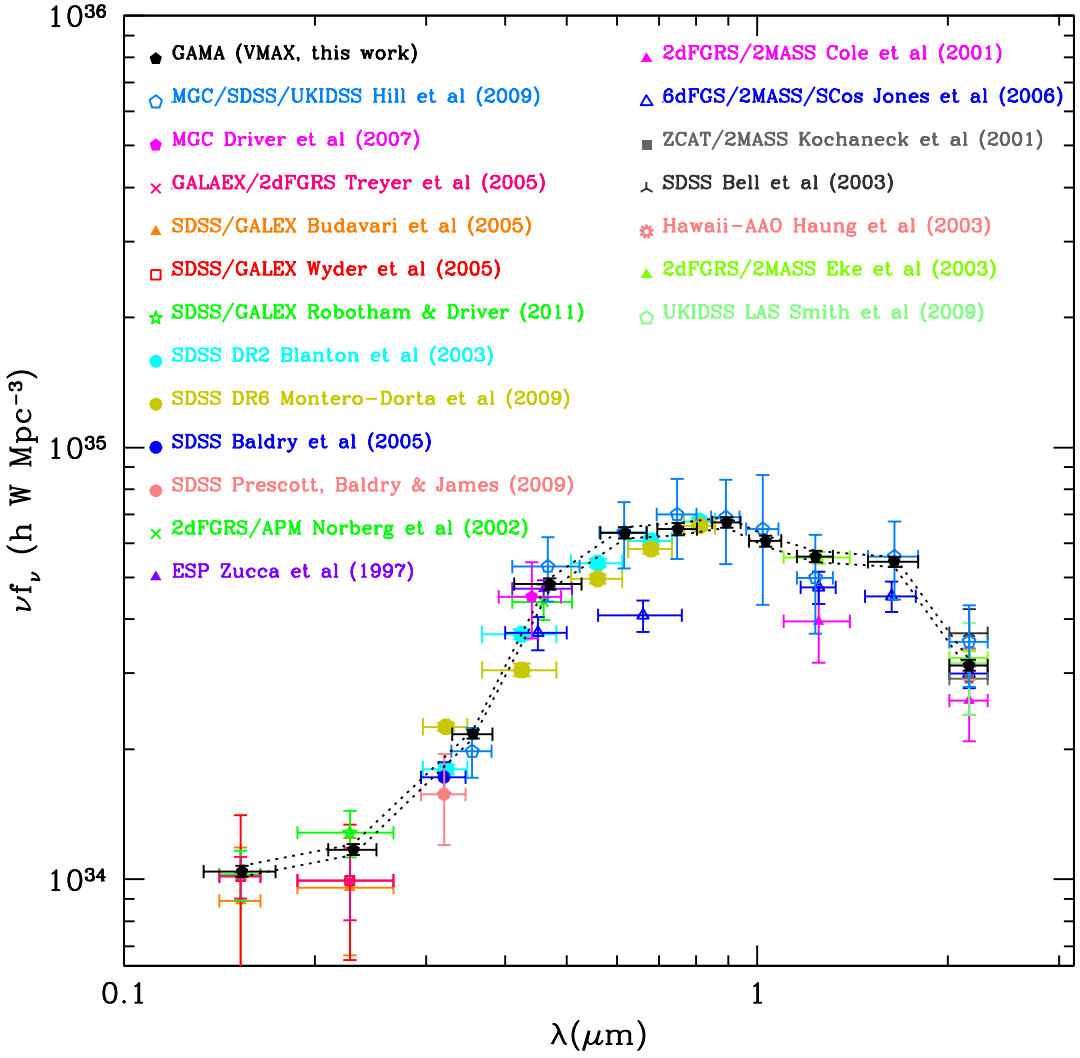
Luminosities densities from FUV to K

Observed energy production of nearby Universe →

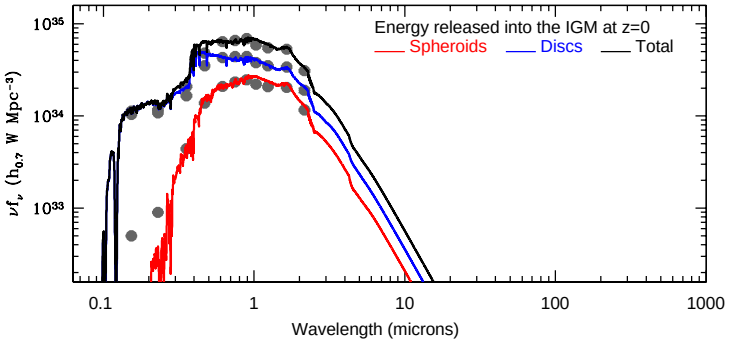
Wavelength dependent cosmic variance removed

But what about dust attenuation?

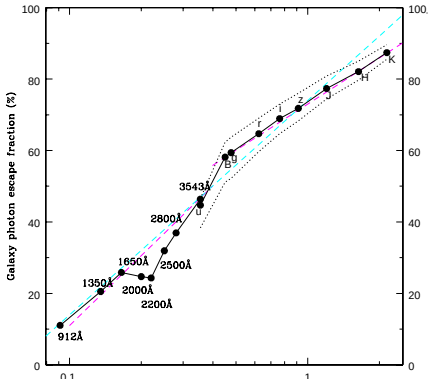
Need to isolate the ellipticals (dust free, Rowlands et al 2012) and correct the non-ellipticals for dust attenuation using photon escape fraction curve (Driver et al 2008)

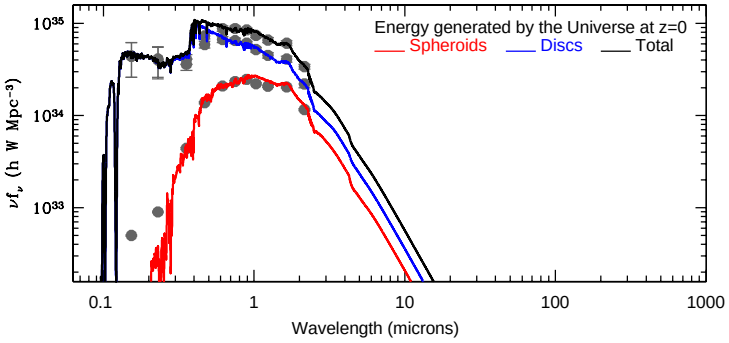


Observed energy output of Ellipticals and non-ellipticals (Driver et al 2012)

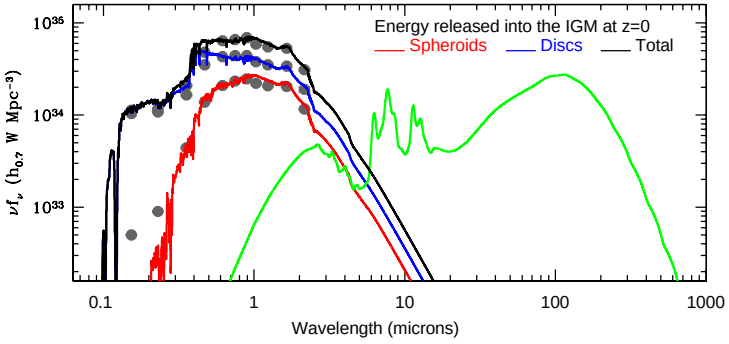


Energy corrected for dust attenuation using Driver et al (2008) photon escape fraction via λ:

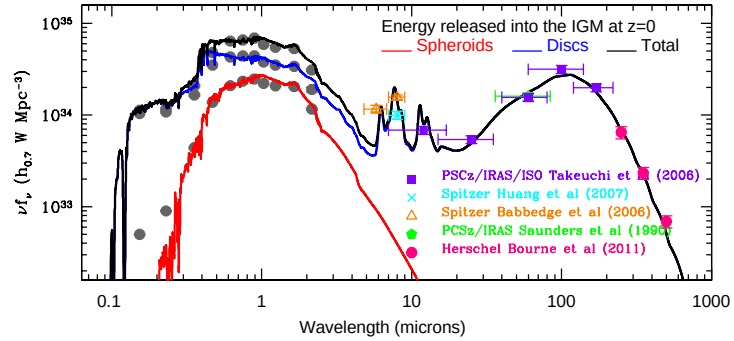




Predicted far-IR output using Dale & Helou (2005)



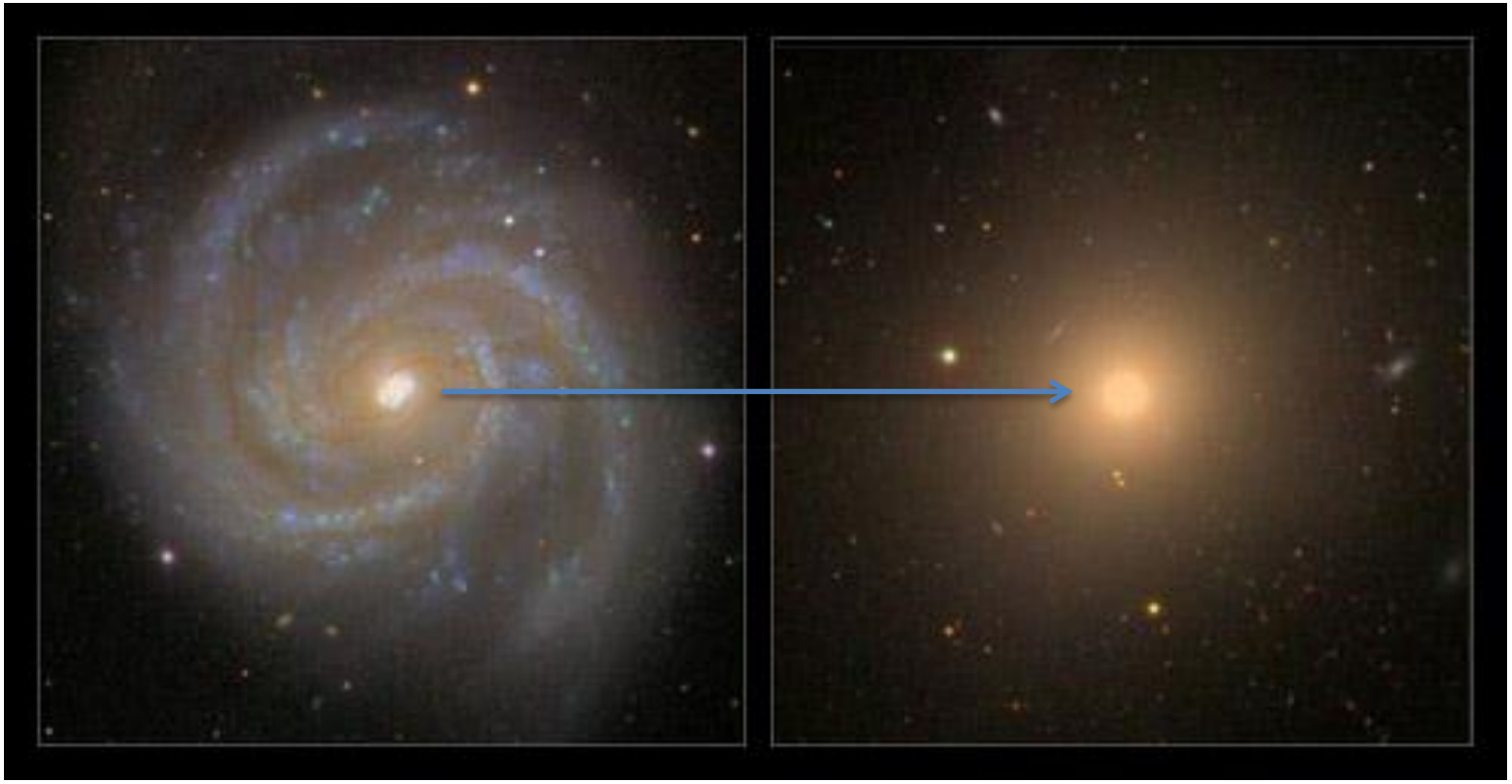
Universe currently generating (1.8+/-0.3) x 10^{35}hWMpc^{-3} [0.1micron-1mm]
67% escapes directly into the IGM
33% attenuated by dust
Balances with far-IR implying minimal dust heating by any other source (e.g., AGN).



Two phase galaxy formation?

Bimodality or Duality?

Red v blue or spheroid v disc?



Two phase galaxy formation?

Axioms:

AGN activity traces spheroid formation

Spheroid formation dominates at high-z

Fully constrained, as CSFH and AGN activity known

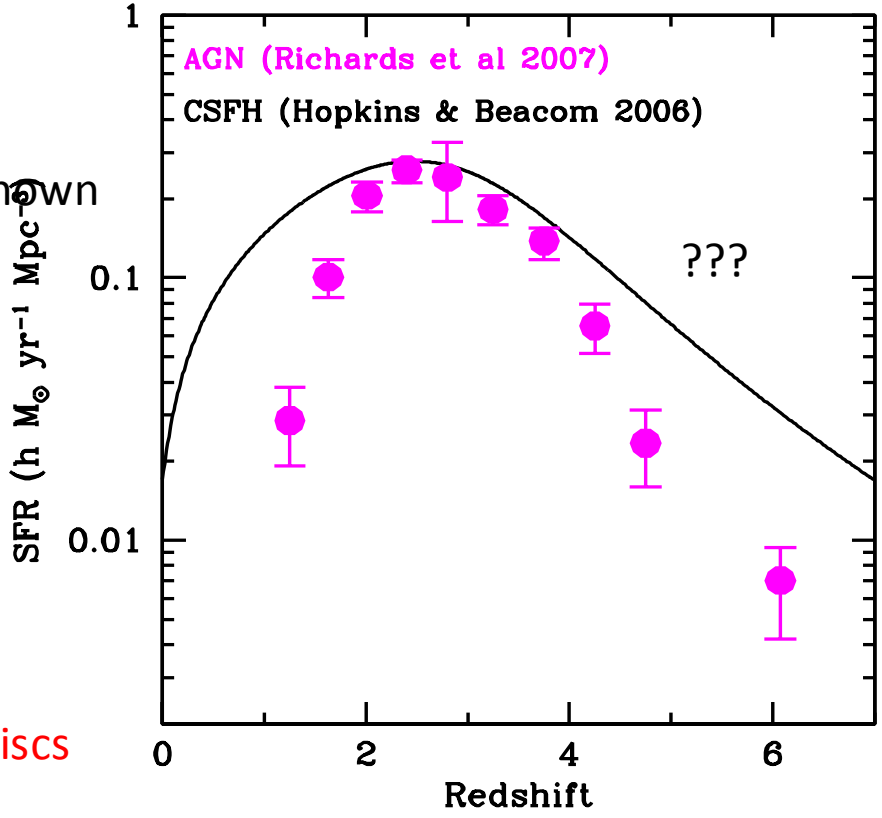
Hopkins & Beacom (2006)

Richards et al (2007)

Can adopt an Universal IMF + stellar evolution model and run clock forward to predict:

Cosmic SED at all redshifts

How stars are distributed in spheroids+discs at all redshifts



… runs on a Mac in 15mins

Two phase galaxy formation?

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- Hopkins & Beacom (2006)
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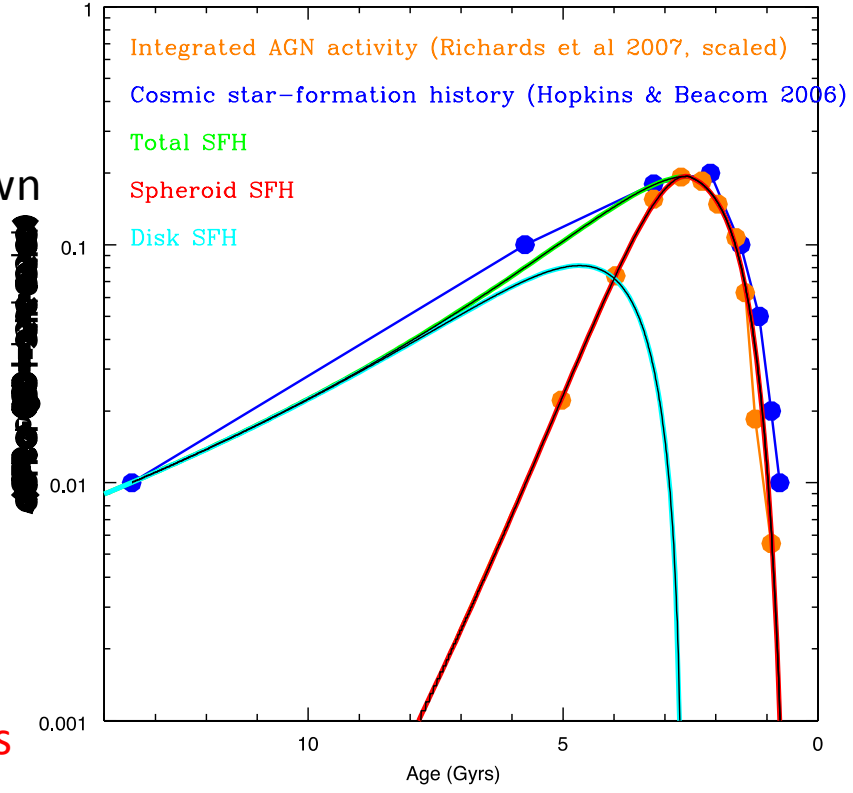


… runs on a Mac in 15mins

Two phase galaxy formation?

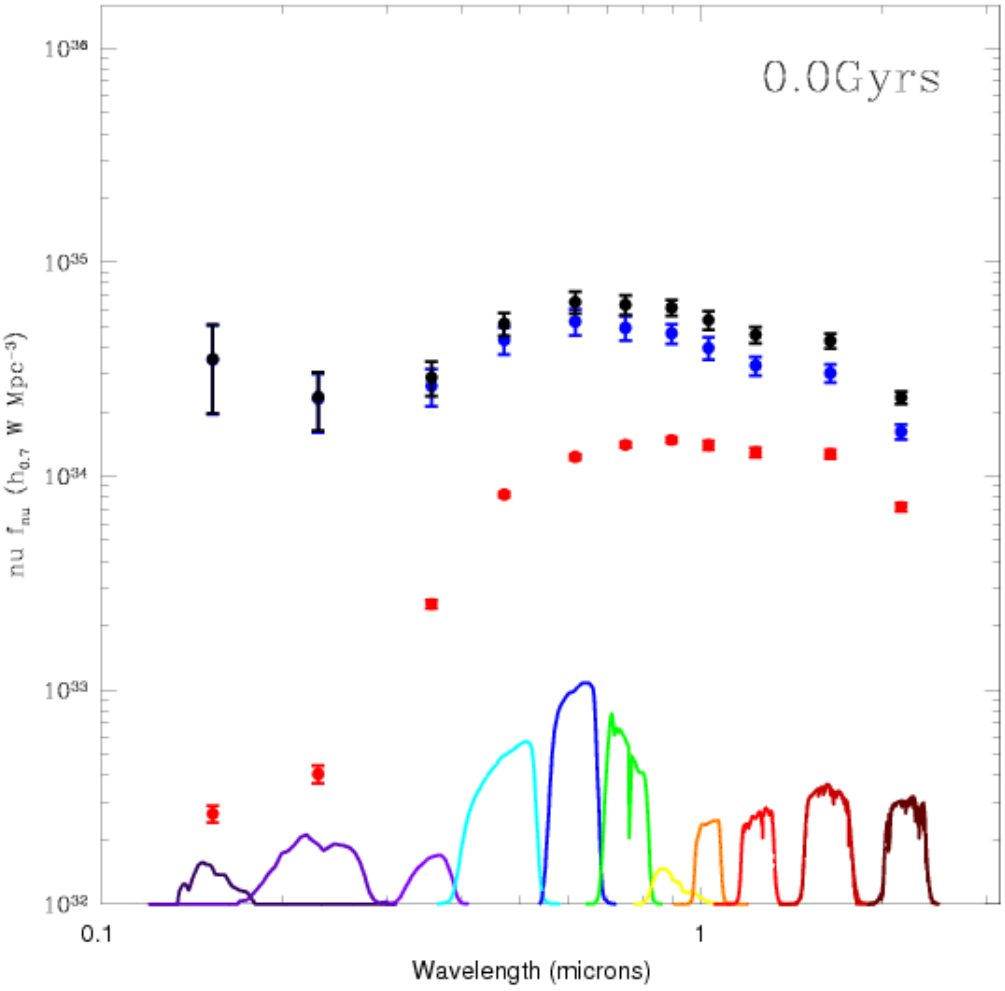
Zero-free parameter model:

Implies axioms provide an acceptable model:

- Spheroid formation follows AGN
- Spheroid dominates early CSFH
- Baldry & Glazebrook (2003) IMF
- Linear metalicity evolution
- CSFH (Hopkins & Beacom 2003)
- AGN Activity (Richards et al 2005)

Next steps:

Trace CSED v redshift
Include AGN energy
Predict EBL
Total model of energy production since reionisation



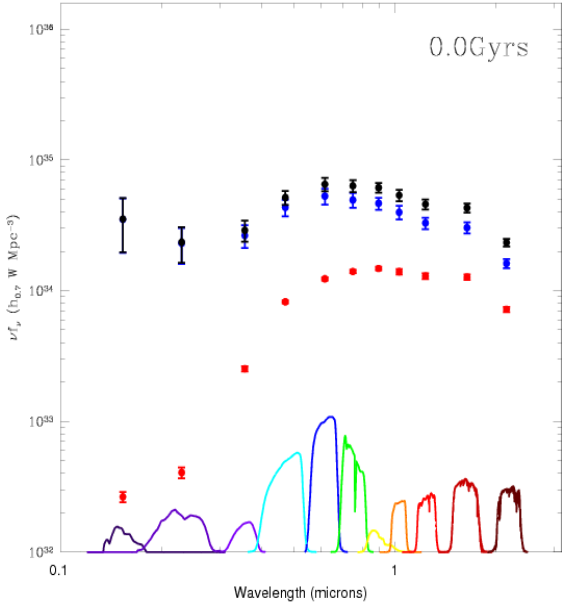
However inconsistency with stellar mass

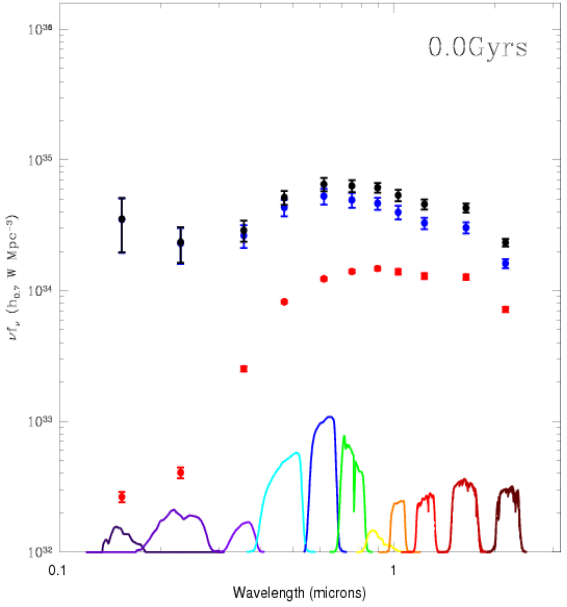
Two phase galaxy formation?

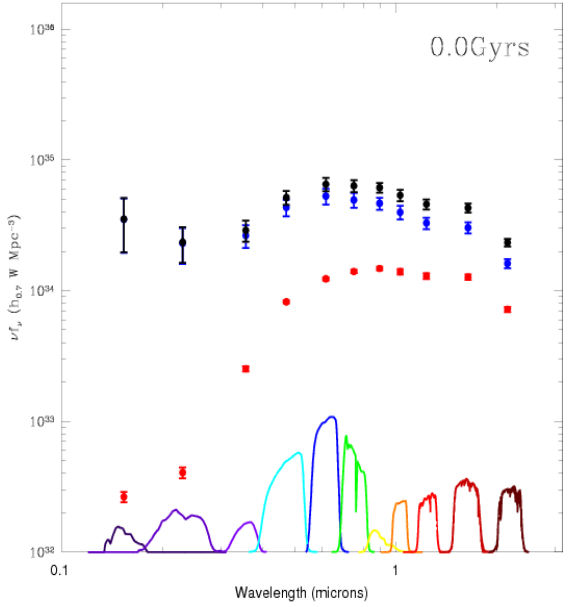
Evolving Z

$Z=Z_{local}$

Z=0







Minimal dependence on the IMF slope

Two phase galaxy formation?

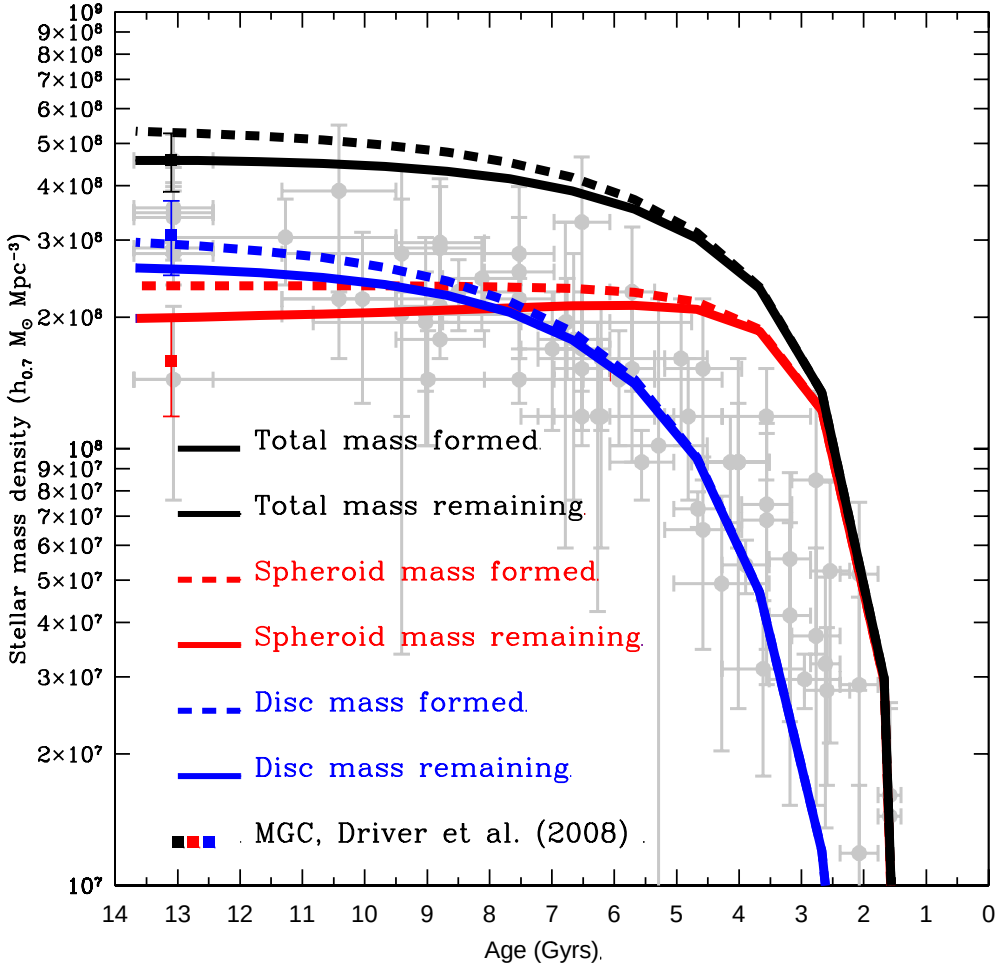
Predicted stellar mass build-up v z=0 GAMA measurements

Comparison to low-z dust corrected data good.

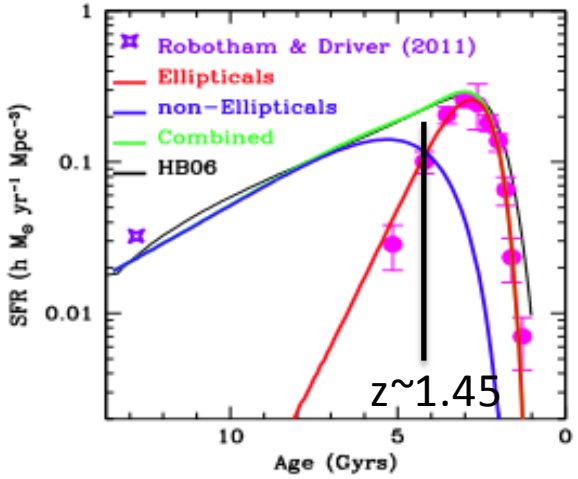
Comparison to high-z non-corrected data not so good.

Problems

- top-heavy IMF at high-z
- stellar masses at high-z low
- model wrong
- …



Implied transition redshift



Disc formation

Spheroid formation

Conclusions

GAMA (http://www.gama-survey.org):

- Pre-eminent local survey for: Halo Masses, pair studies, multi-λ coverage, structural analysis
- Data Release 2 in October (everything we have in G15 to r <19.4 mag)
- Email us for full access at: gama@gama-survey.org

Stellar Mass:

- 46% lies in spheroids, 54% in discs (6% in secular structres)
- Hot (turbulent) and cold (smooth) modes equally important

Energy output:

- Universe currently generating $(1.8+/-0.3)x10^{35}hWMpc^{-3}$ at z<0.1
- 33% of this energy attenuated by dust
- Balances perfectly with far-IR observations (no AGN heating required)
- Have a good understanding of cosmological energy production at z=0 from 0.1micron to 1mm

Proposed two-phase model:

- 2 basic axioms: AGN activity traces spheroid formation, spheroid formation dominates at high-z
- Zero-parameter model based on above explains z=0 stellar mass breakdown and CSED
- Implies transition redshift at z~1.5 between domination by hot or cold mode evolution

WARNING:

- Purely photometric studies must worry about the impact of dust and its evolution