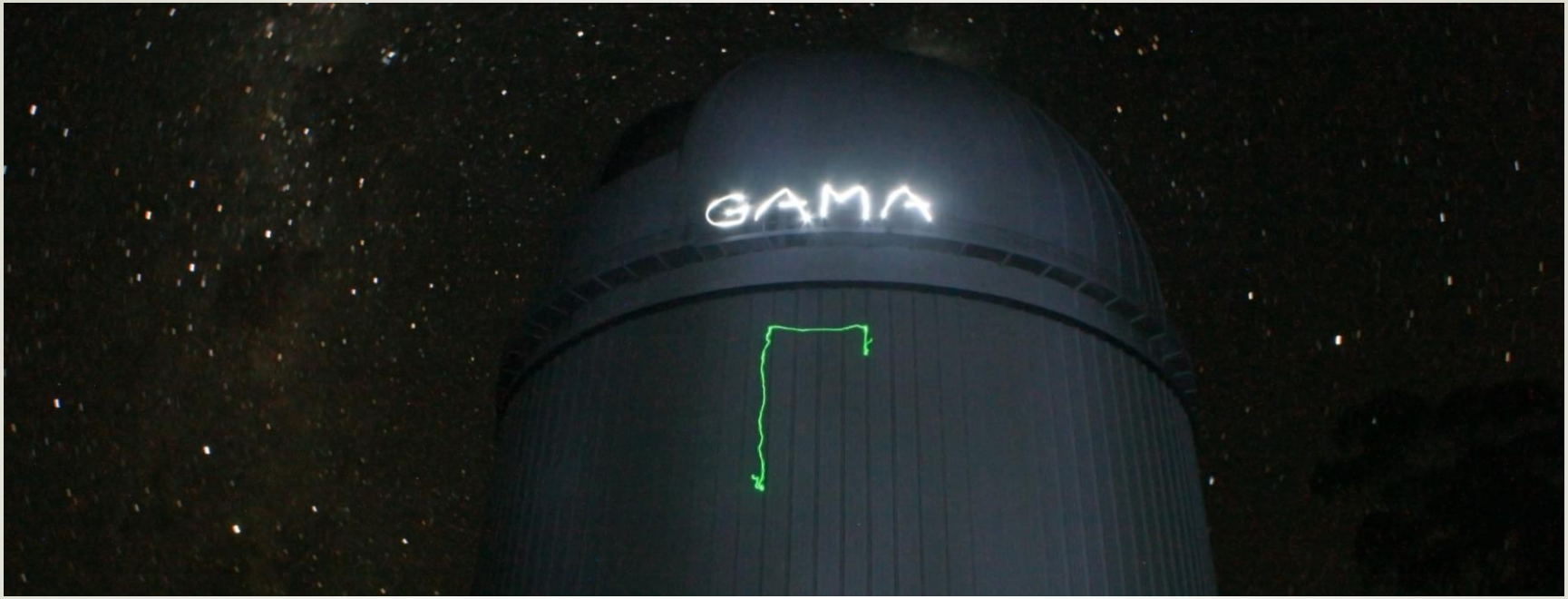
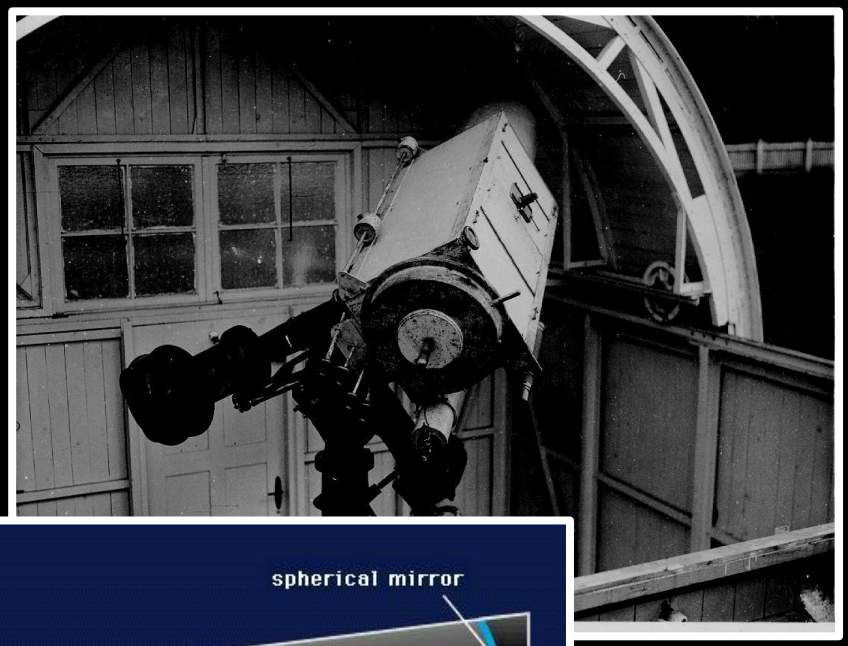
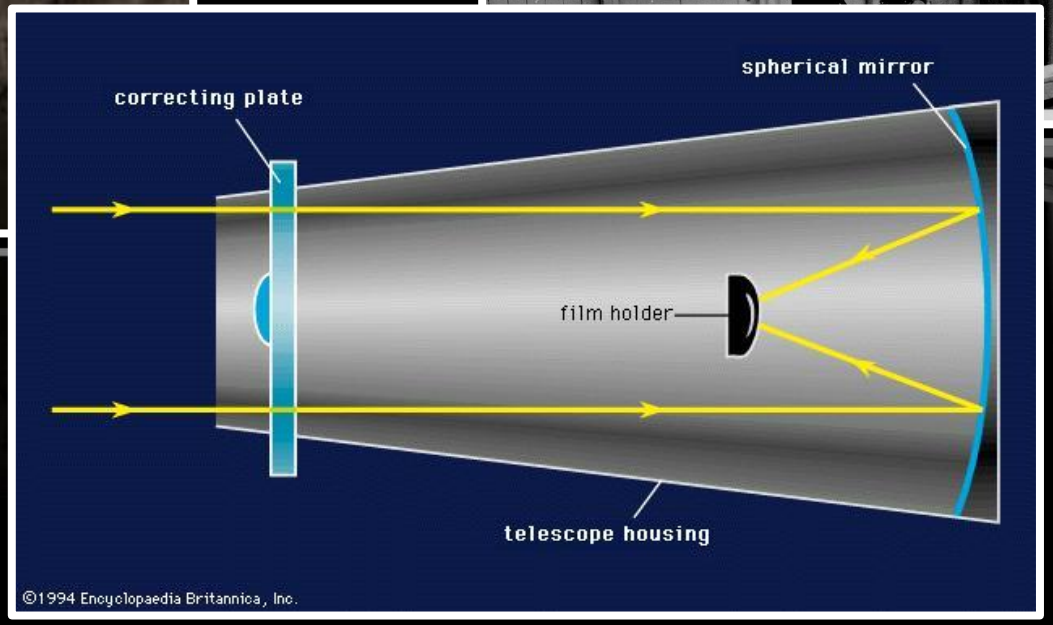


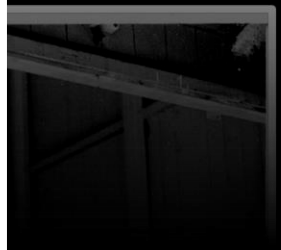
The low-redshift universe as seen by the **Galaxy And Mass Assembly** survey

Jochen Liske
UHH

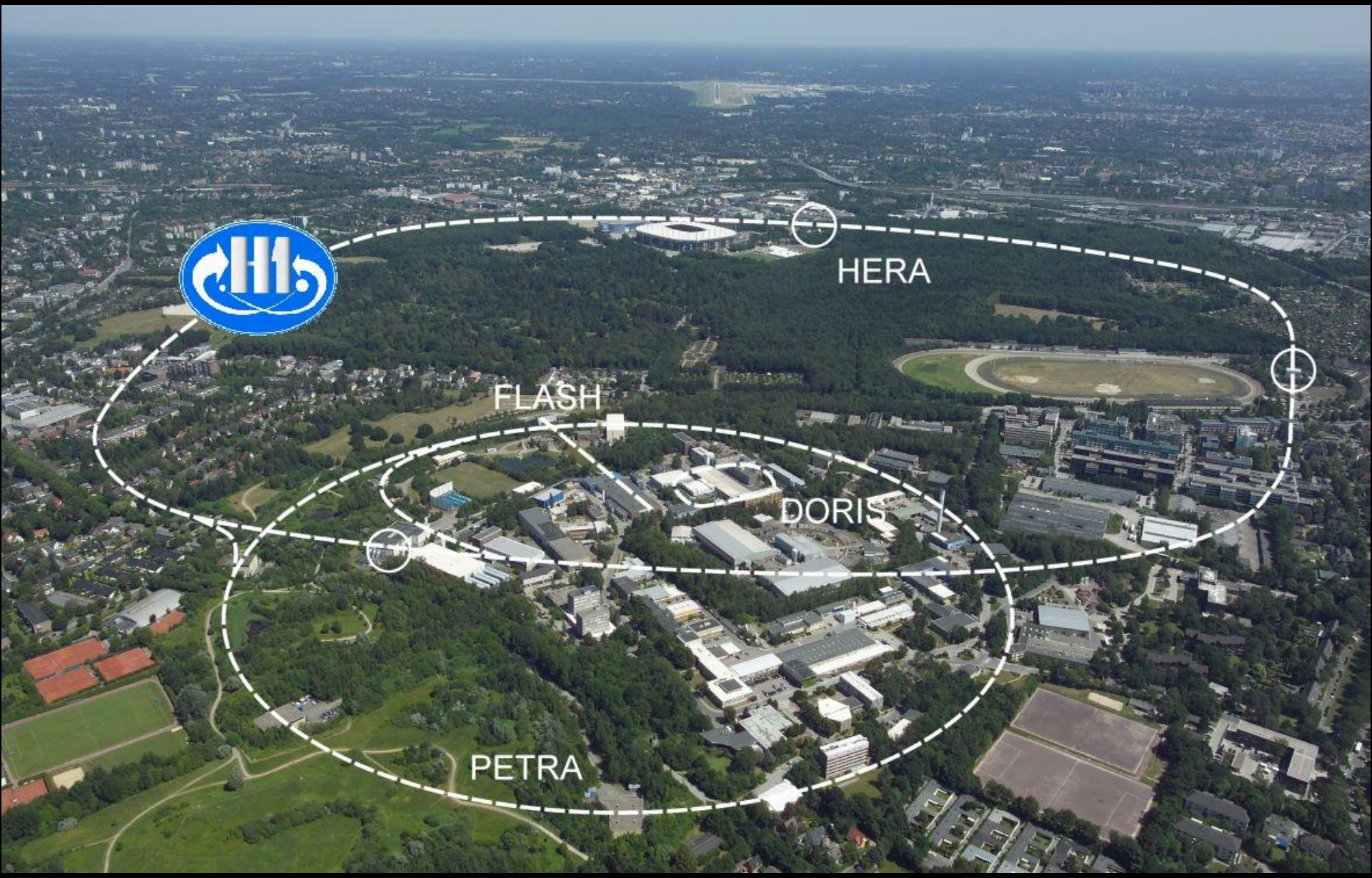
Bernhard Schmidt

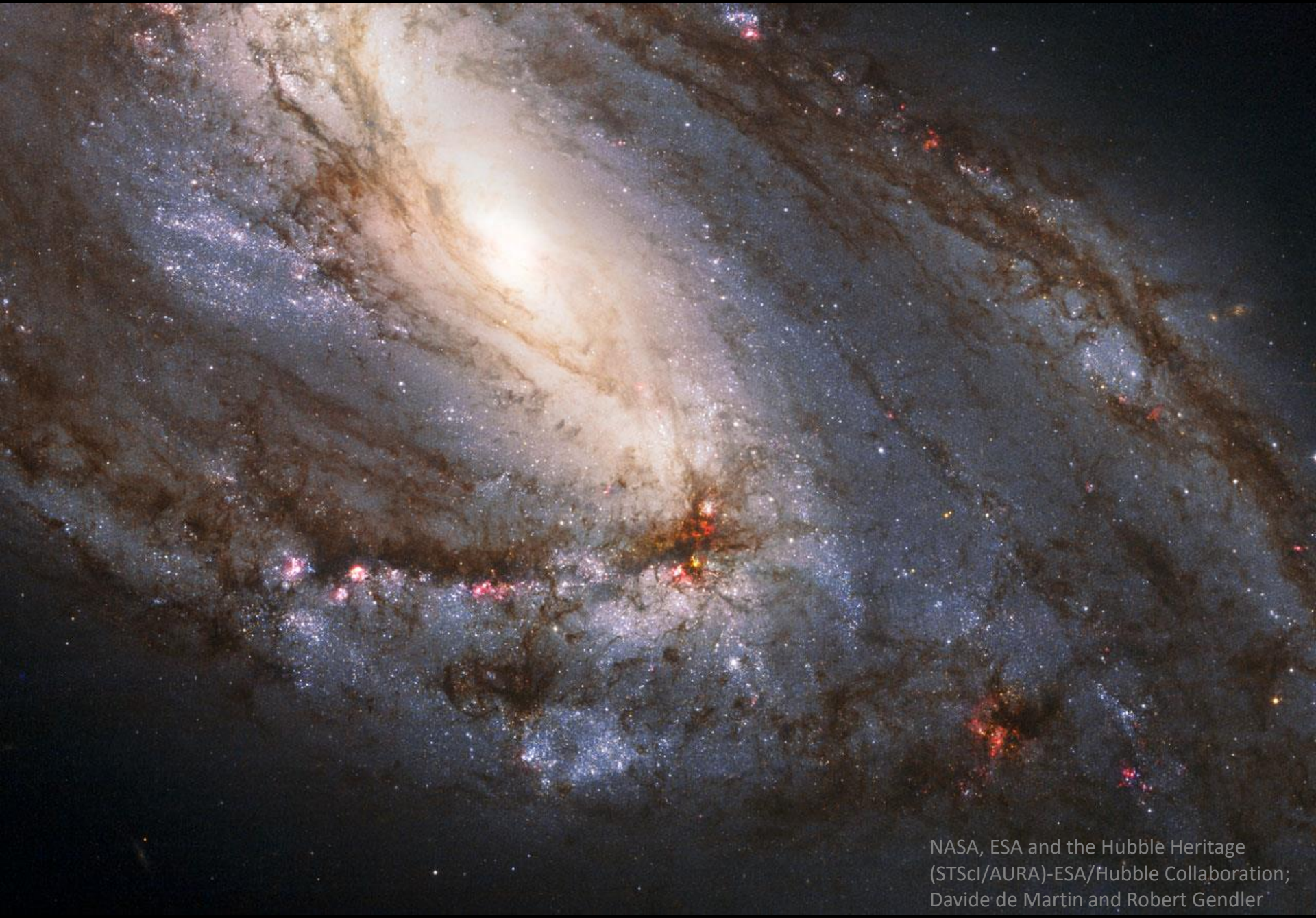




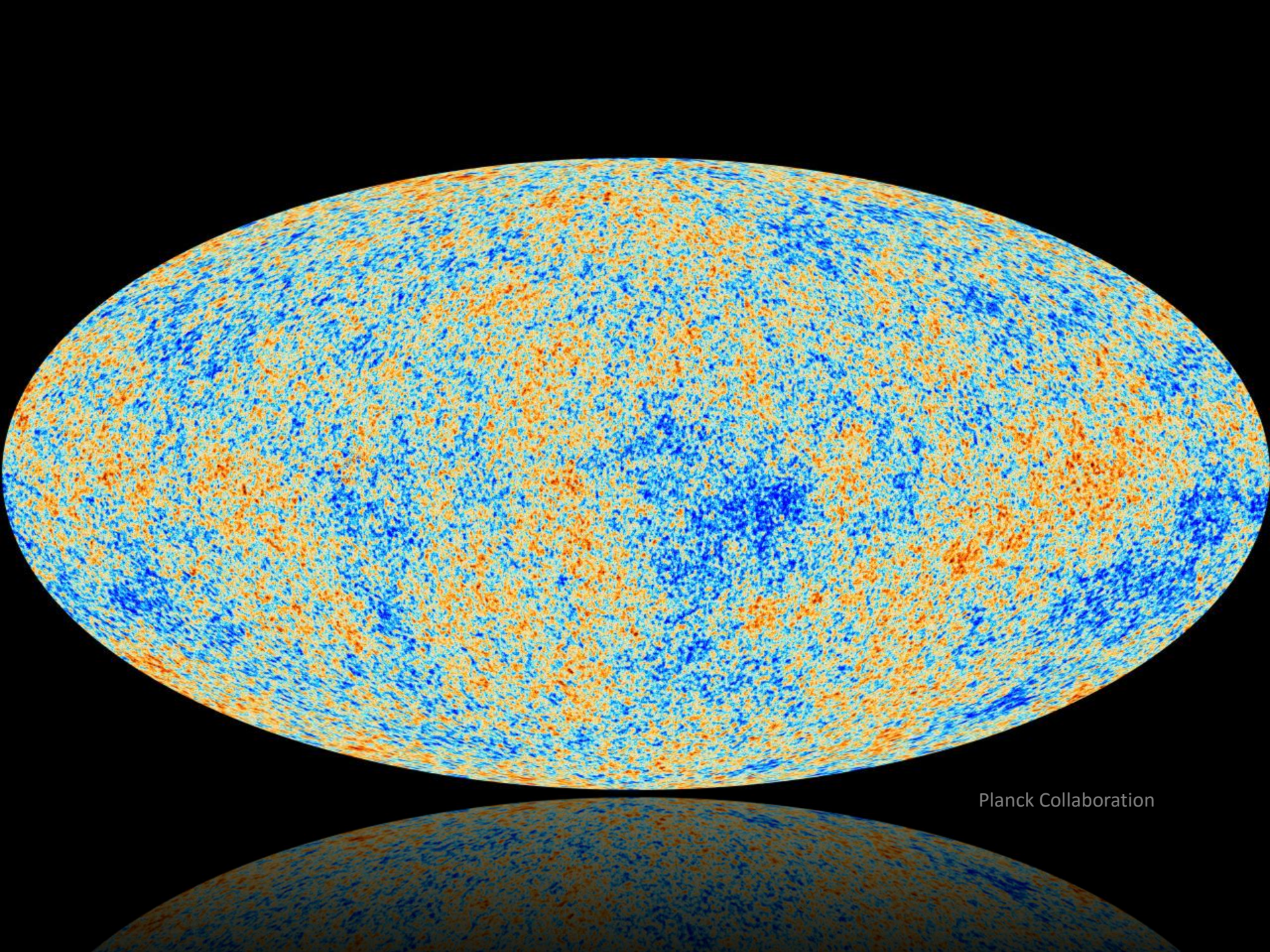


Otto Heckmann


H1
HERA
FLASH
DORIS
PETRA

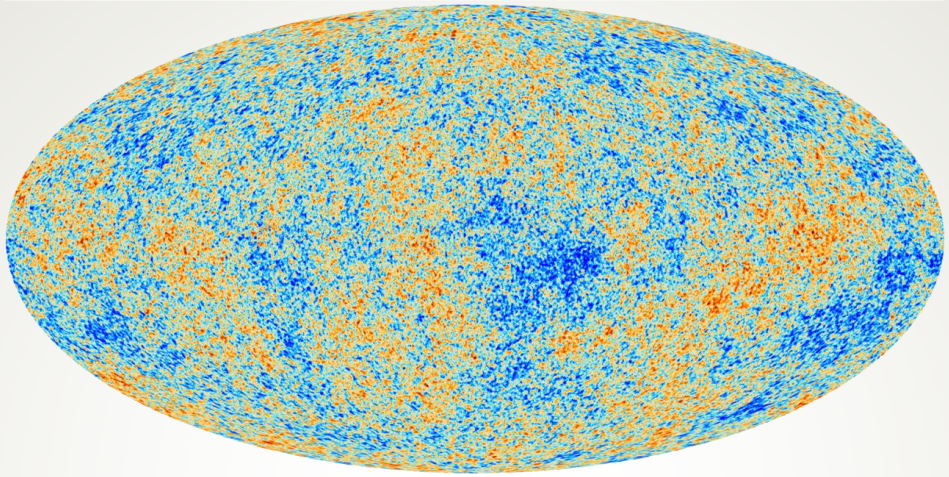


NASA, ESA and the Hubble Heritage (STScI/AURA)-ESA/Hubble Collaboration; Davide de Martin and Robert Gendler

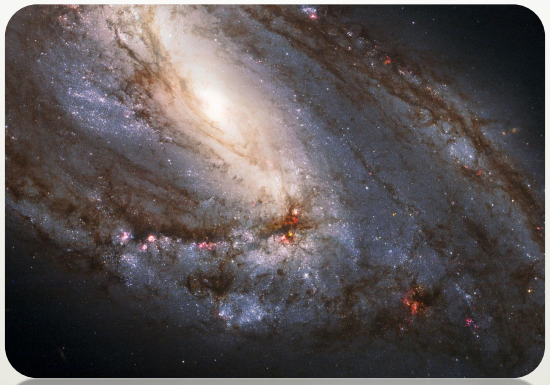

Planck Collaboration

Structure formation

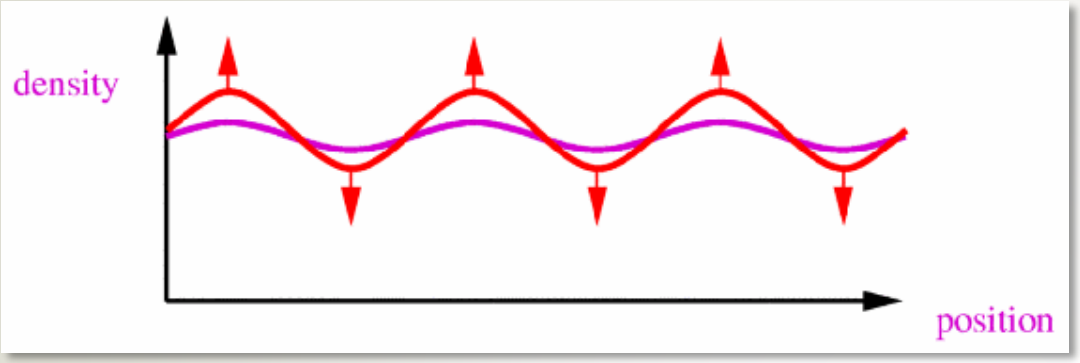
$t = 4 \times 10^5$ yr
$\Delta\rho/\rho = 10^{-5}$

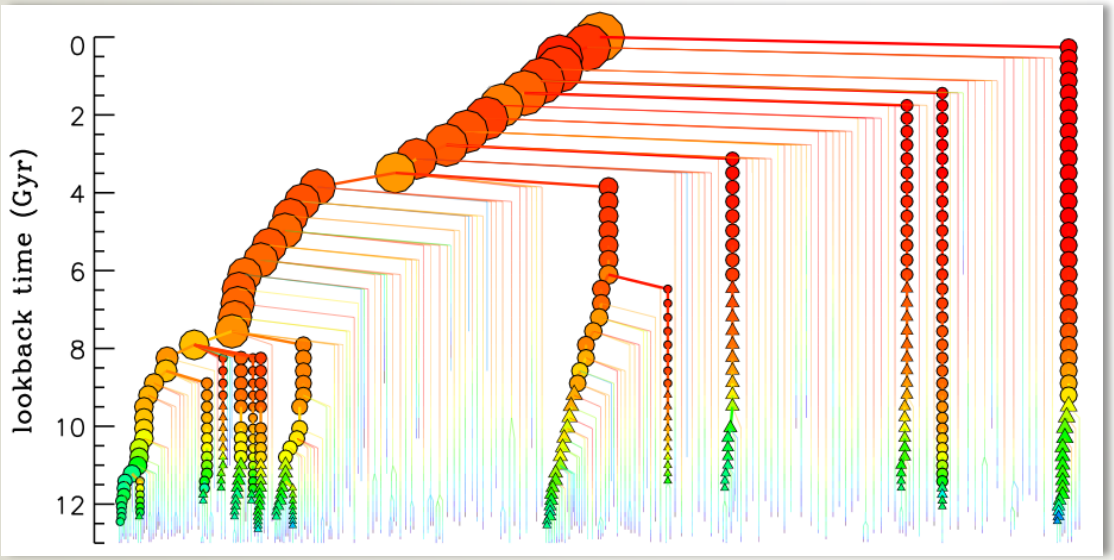


$t = 1.37 \times 10^{10}$ yr
$\Delta\rho/\rho = 10^9$



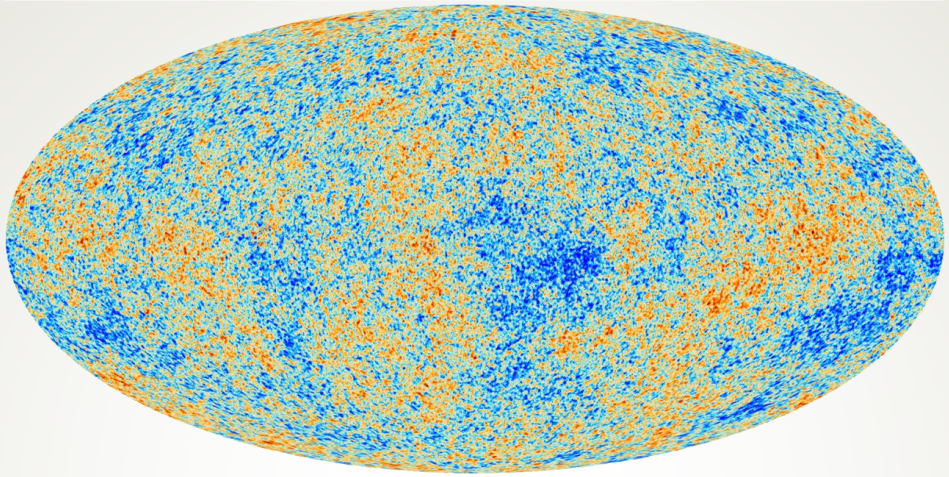
Gravitational instability and hierarchical build-up

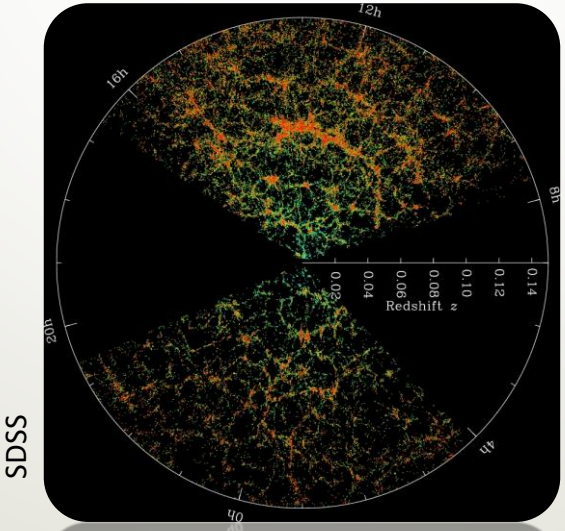




De Lucia & Blaizot (2007)

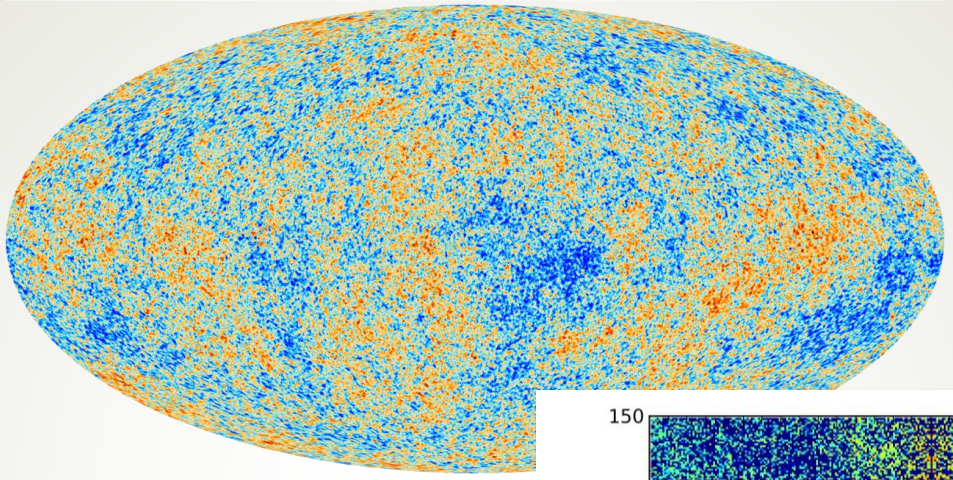
Structure formation



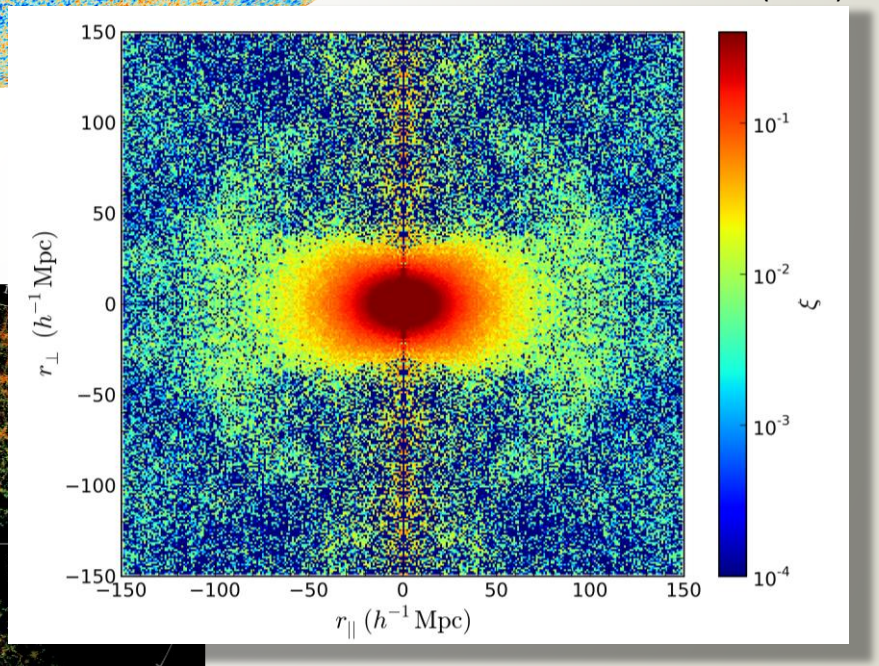


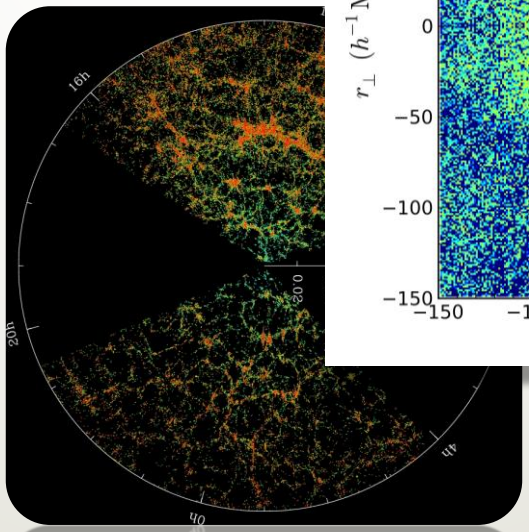
SDSS

Structure formation



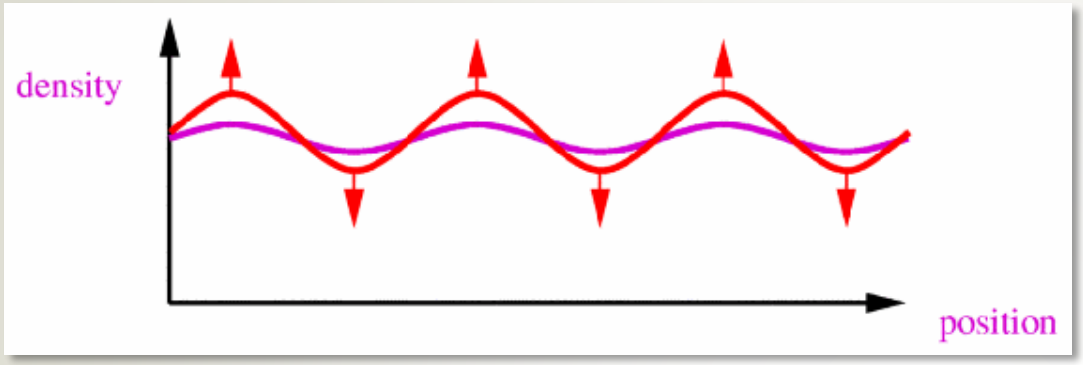
Samushia et al. (2013)

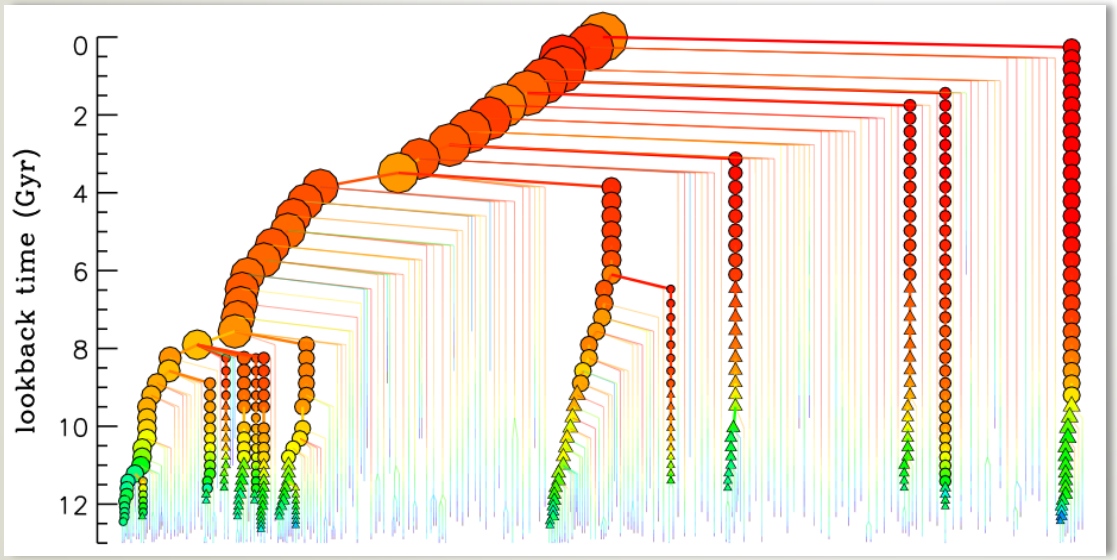




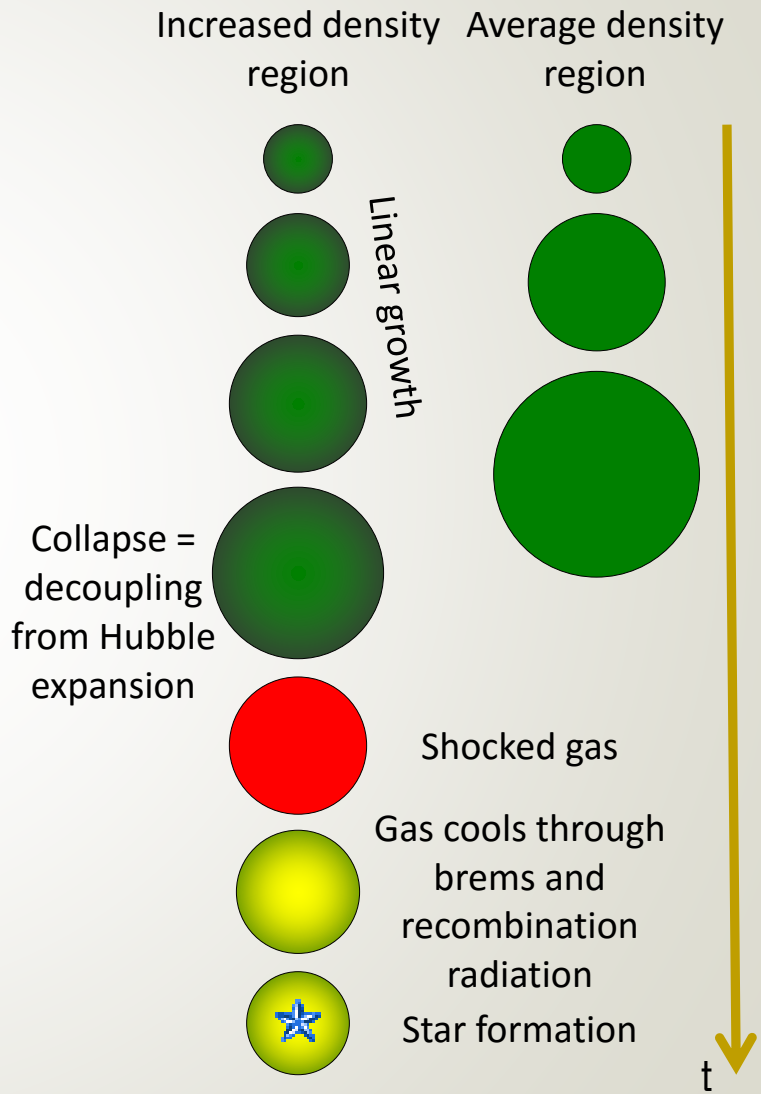
SDSS

Gravitational instability and hierarchical build-up

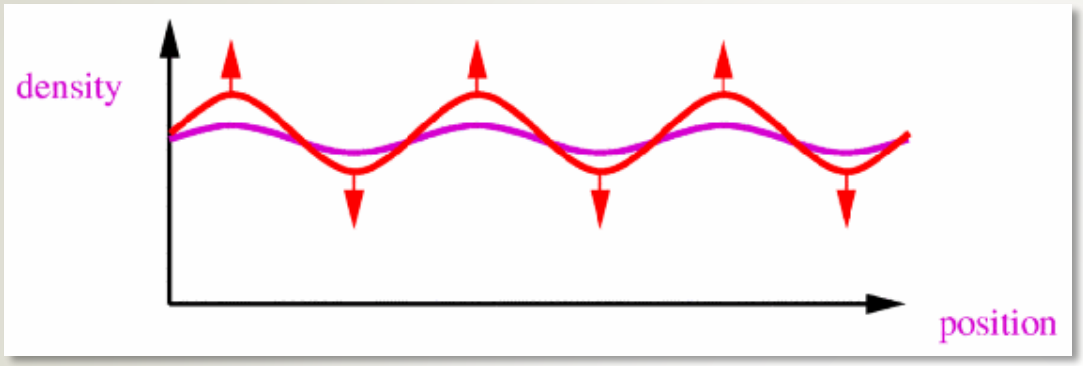


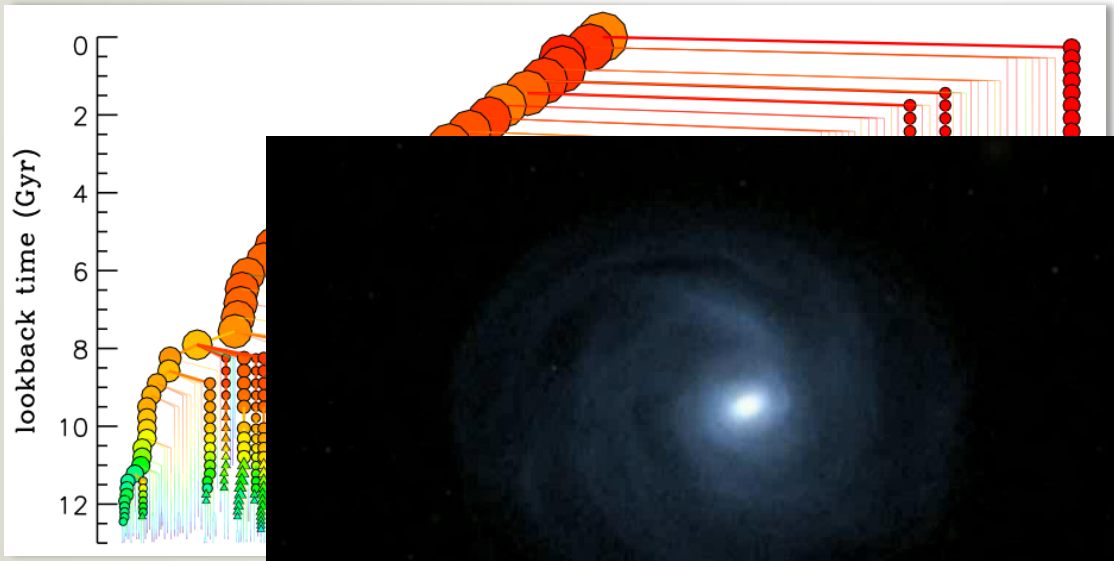


De Lucia & Blaizot (2007)



Gravitational instability and hierarchical build-up





De Lucia & Blaizot (

Increased density region

Average density region

Linear growth

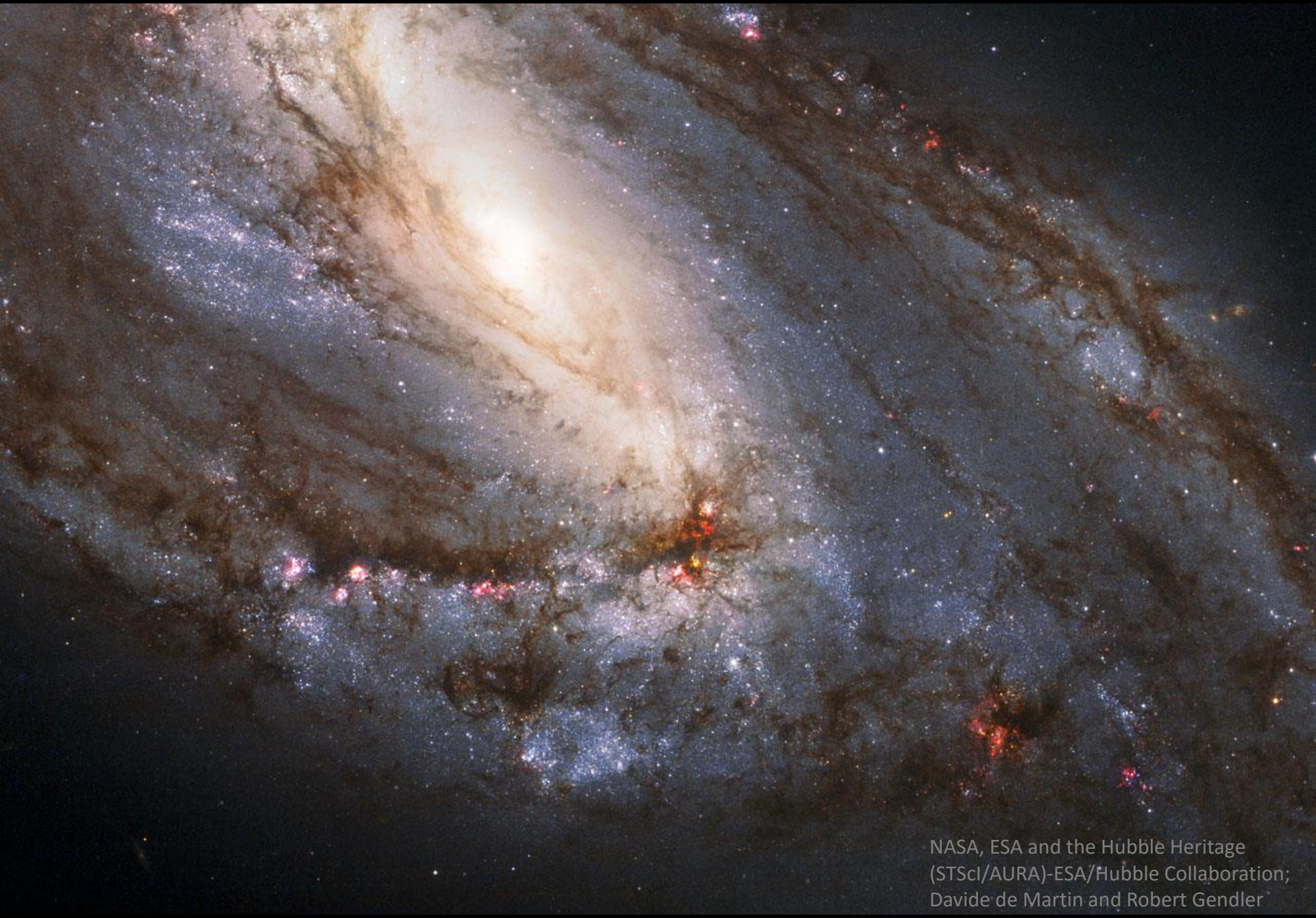
Collapse = decoupling
Hubble
pansion

Shocked gas

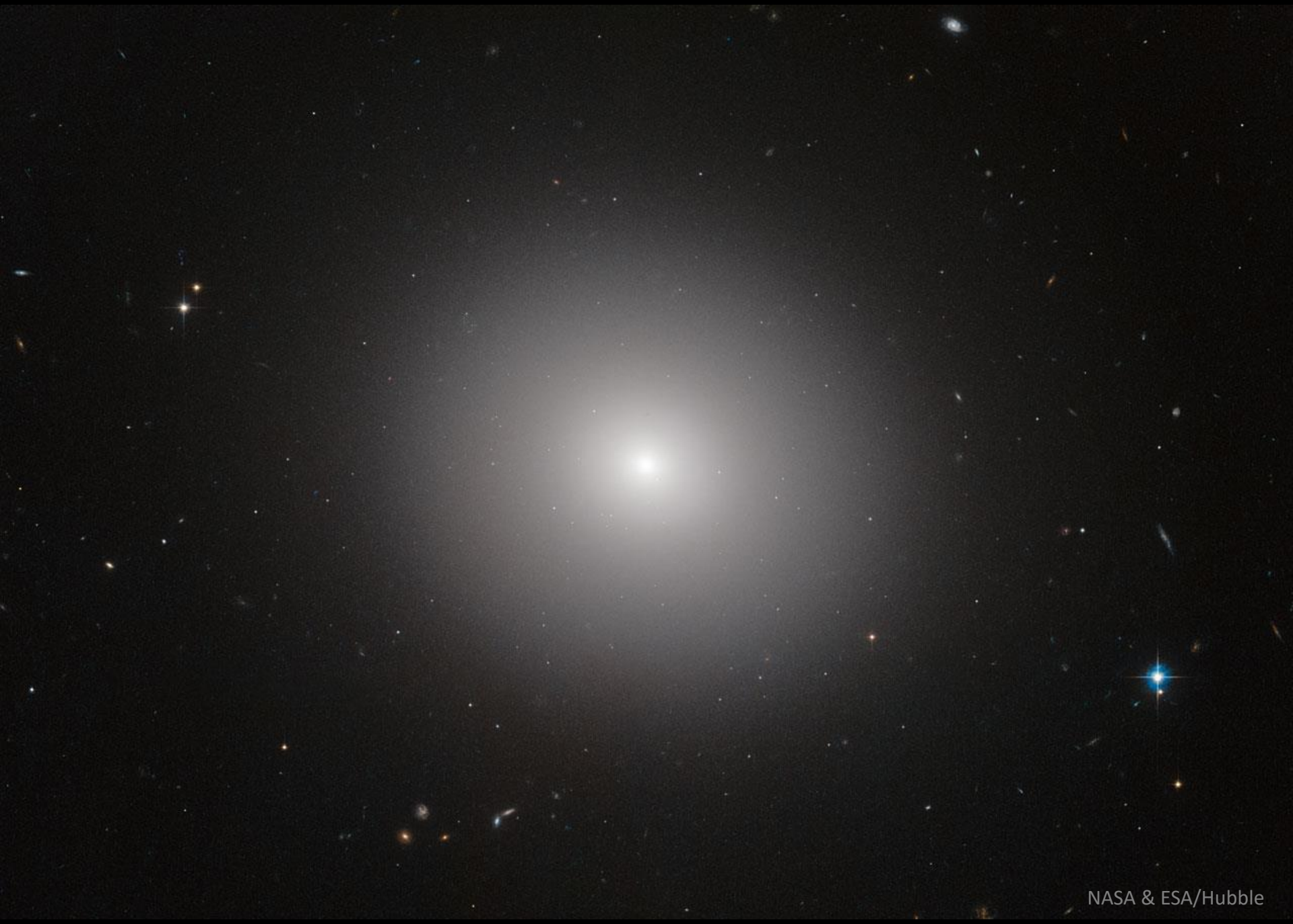
Gas cools through brems and recombination radiation

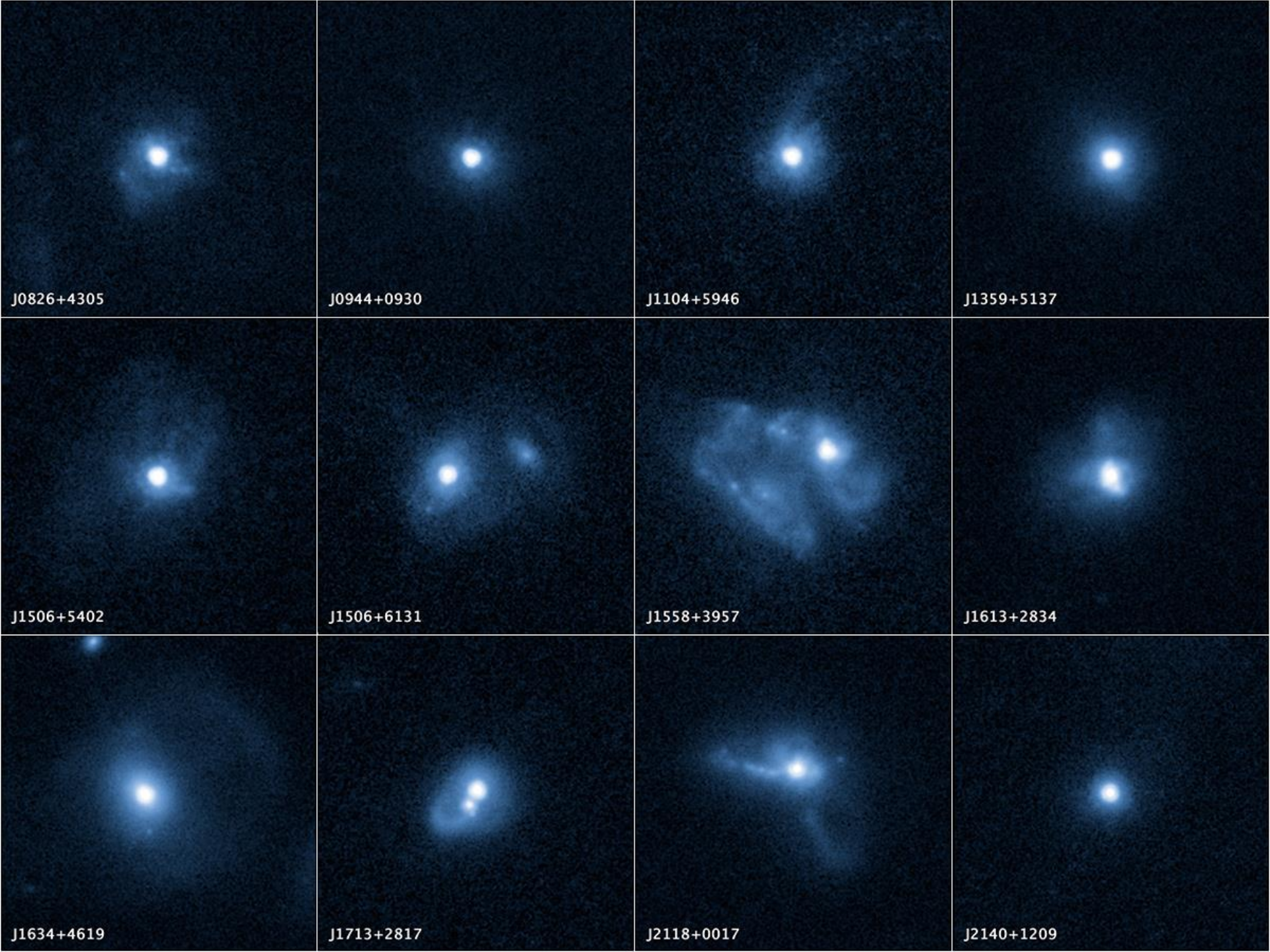
Star formation

t



NASA, ESA and the Hubble Heritage (STScI/AURA)-ESA/Hubble Collaboration; Davide de Martin and Robert Gendler


NASA & ESA/Hubble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J0944+0930
J1104+5946
J1359+5137
J1506+5402
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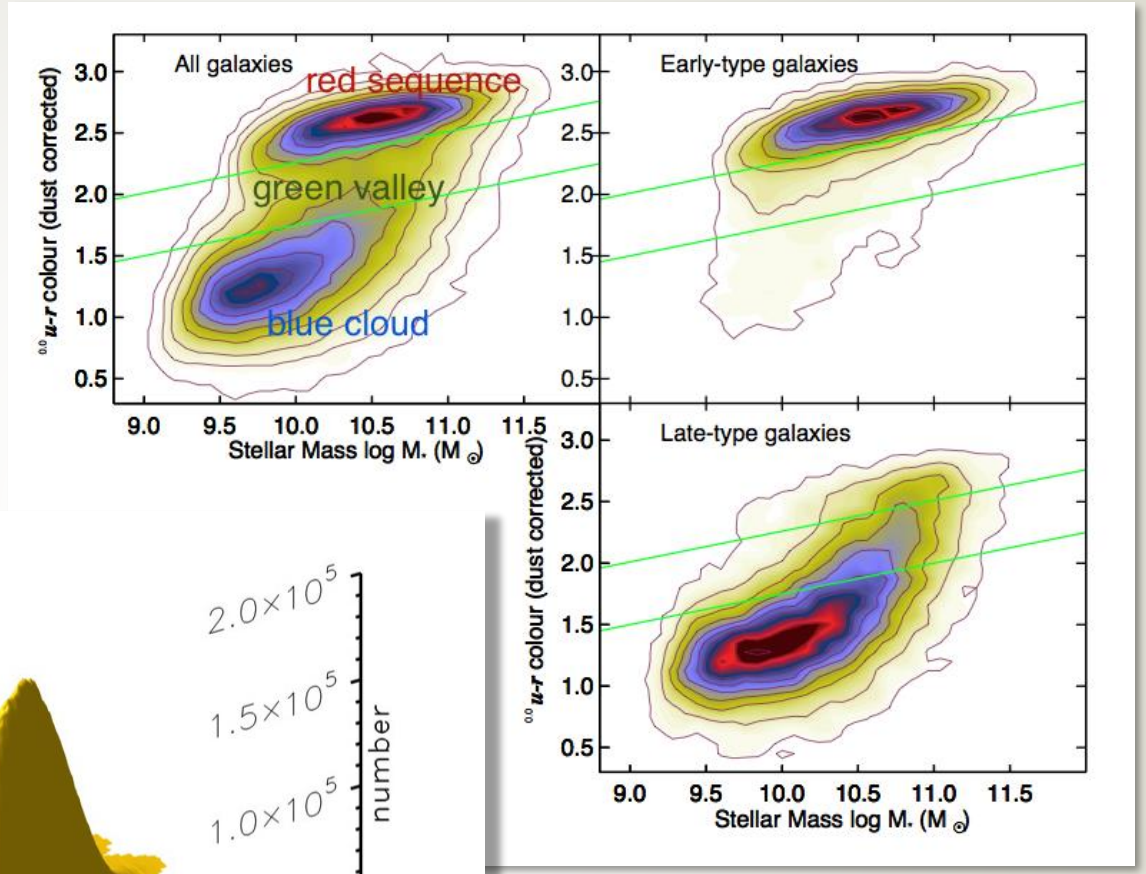
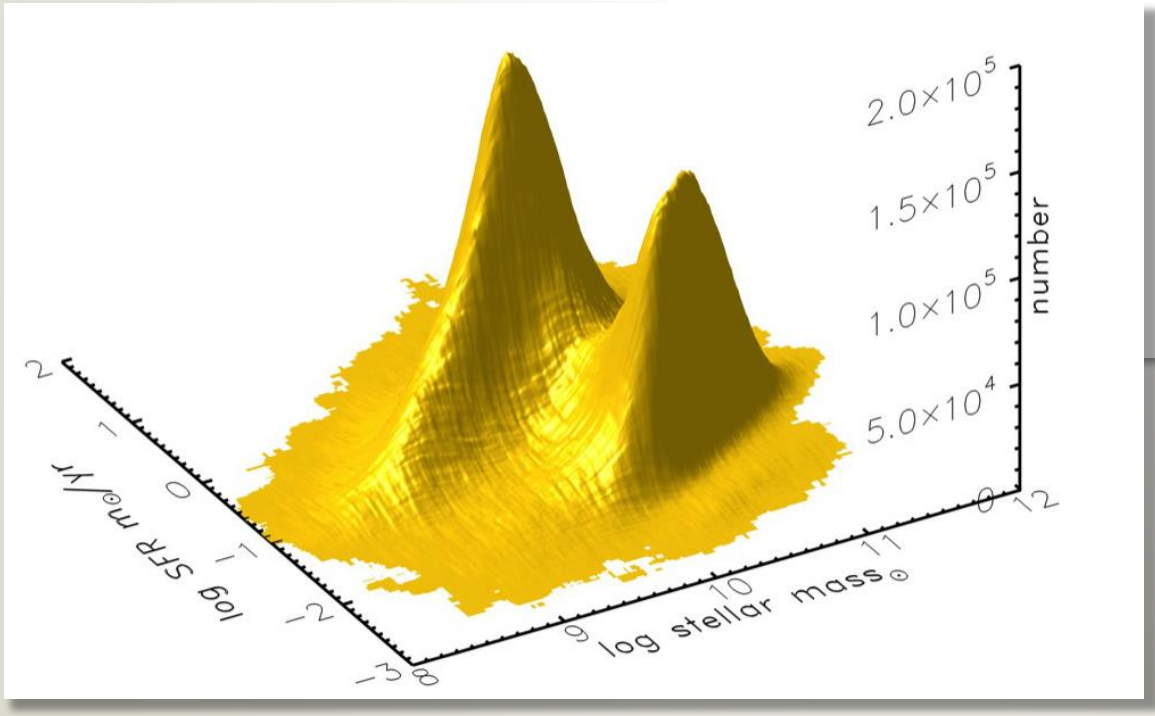
J1613+2834
J1634+4619
J1713+2817
J2118+0017
J2140+1209

Bimodality

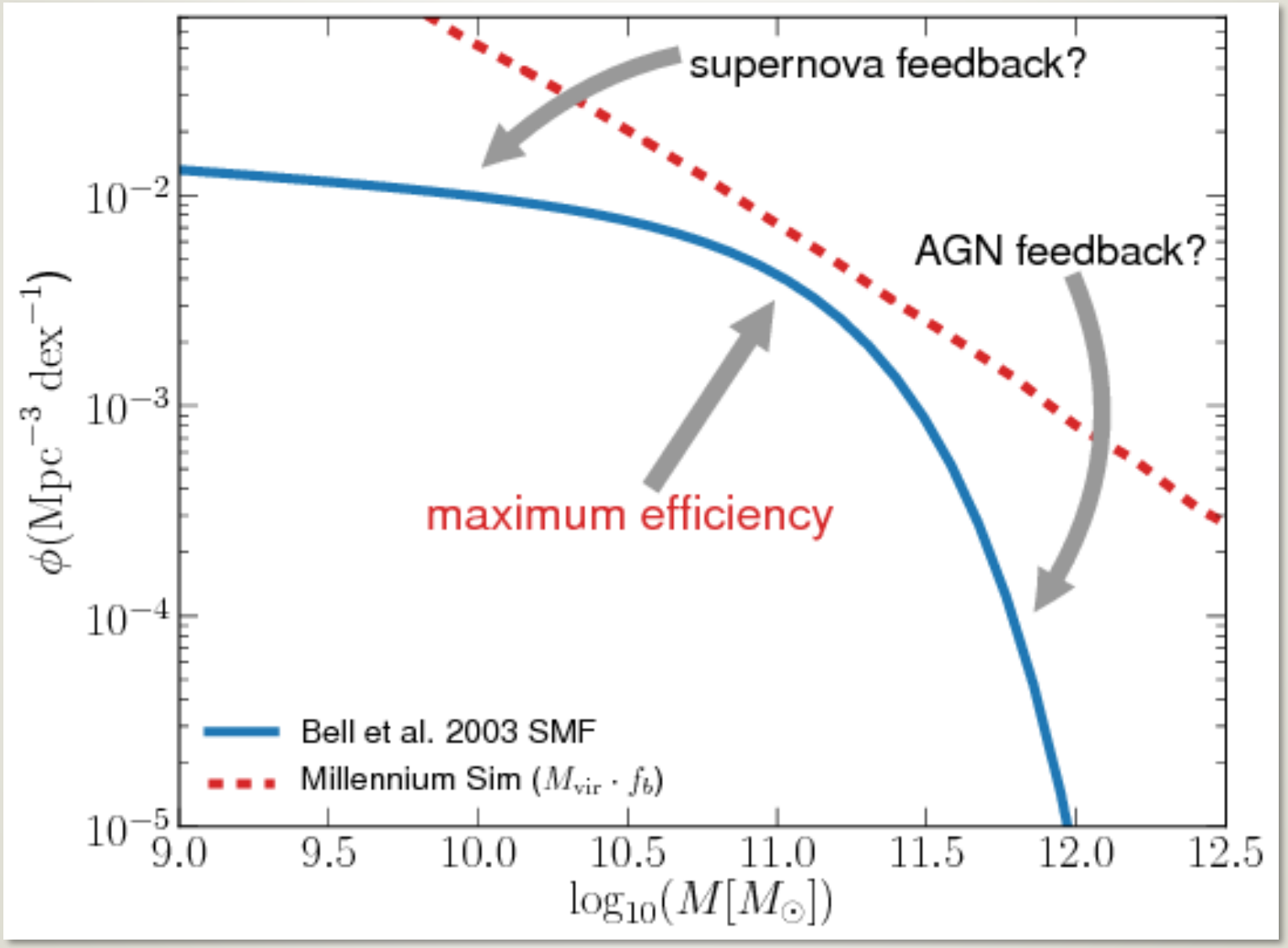


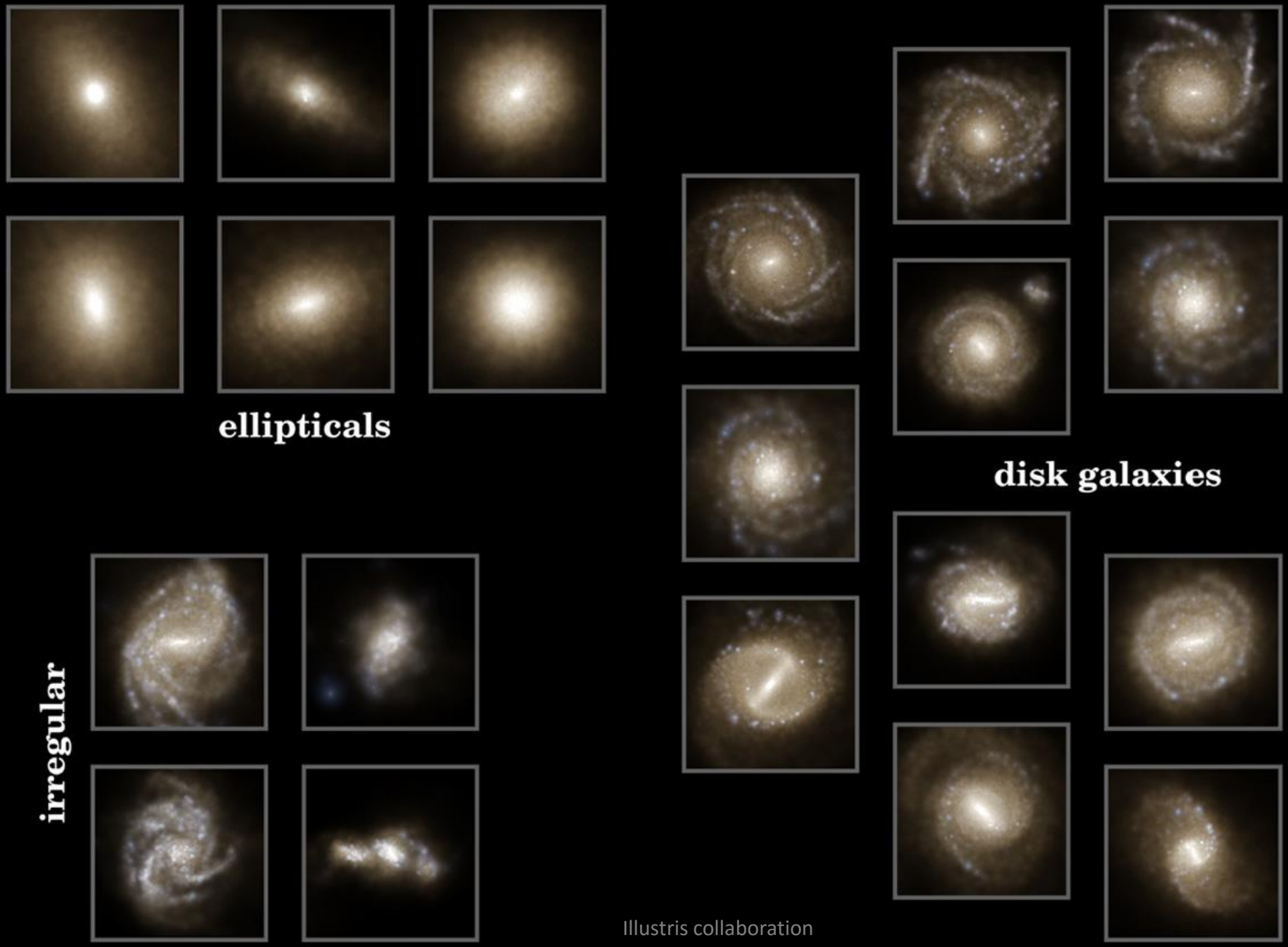
Schawinski et al. (2014)

Renzini & Peng (2015)



Mass distribution of galaxies





Illustris collaboration

The complexity of galaxies

Galaxy constituents

- Dark matter
- Stars and star clusters
- Molecular, atomic and ionised gas
- Dust
- Central SMBH
- IGM

Physical processes

- Gravitational collapse and evolution
- Gas hydrodynamics
- Star formation
- Stellar evolution
- Feedback
- Interaction with the environment
- ...

Outstanding issues

- Star formation efficiency and the nature of feedback as a function of halo mass
- Fuelling and cessation of star formation
- Roles of galaxy interactions and mergers versus in-situ processes
- Relative prevalence of disks and spheroids
- Mass-size relations of disks and spheroids
- Downsizing
- Co-evolution of central SMBH and their host galaxies
- ...

Complementary approaches

Observations

Statistical investigations of large samples (surveys)

Level of detail

Statistical power, completeness

Detailed studies of small samples

Theory

Analytical, semi-analytical, numerical

The Galaxy And Mass Assembly survey

www.gama-survey.org

What is GAMA?

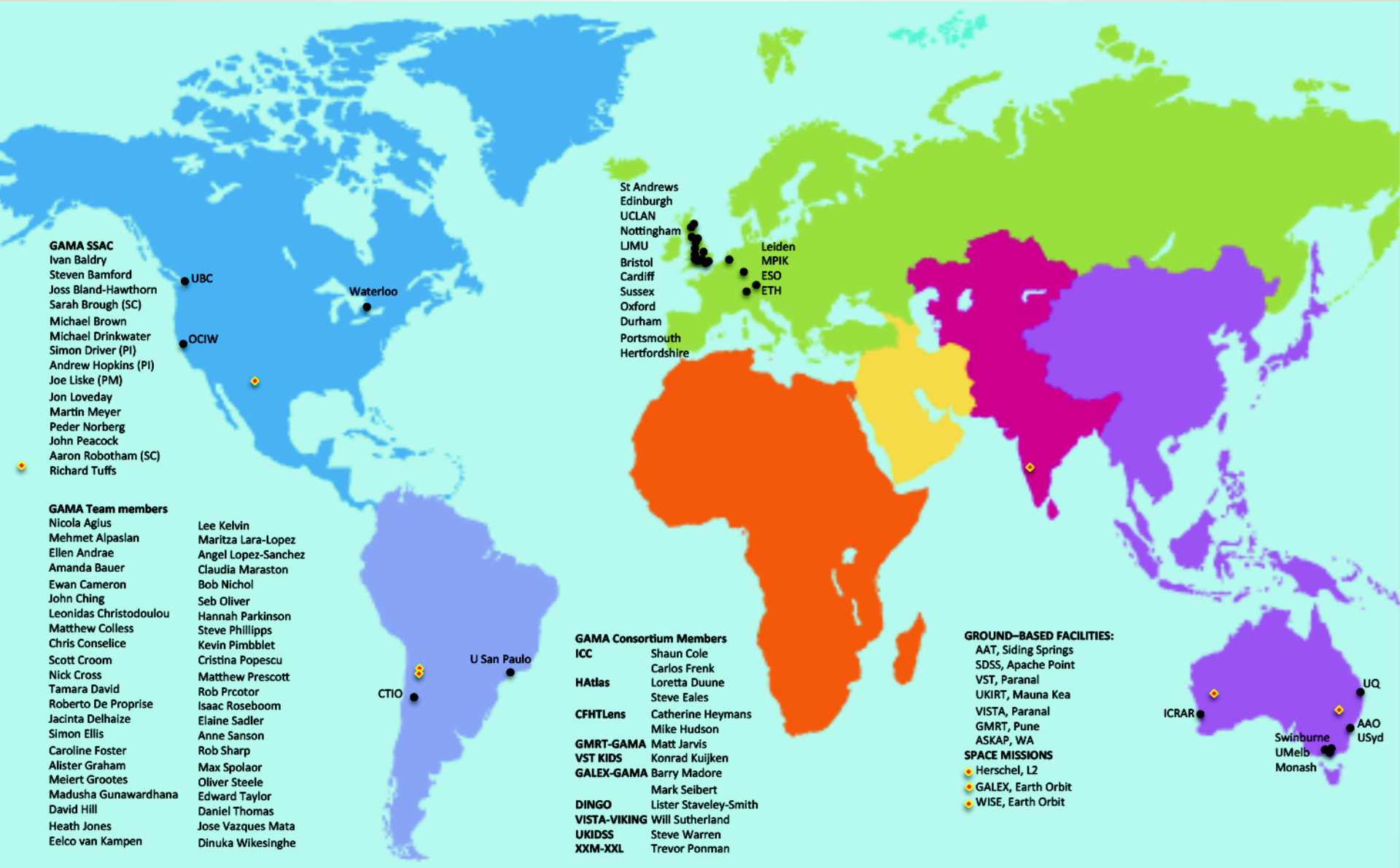
- A comprehensive survey of low-redshift ($z < 0.5$) galaxies to study galaxy evolution and cosmology
- GAMA = spectroscopic survey + alliance of imaging surveys

Key features

- $r < 19.8$ mag
- Area = 286 deg^2
- N_{gal} = 270,000
- Spectroscopy: 2 mag deeper than SDSS, multi-pass
- Imaging: near-complete wavelength coverage, ~2x better resolution

The team

101 team members, 53 collaborators

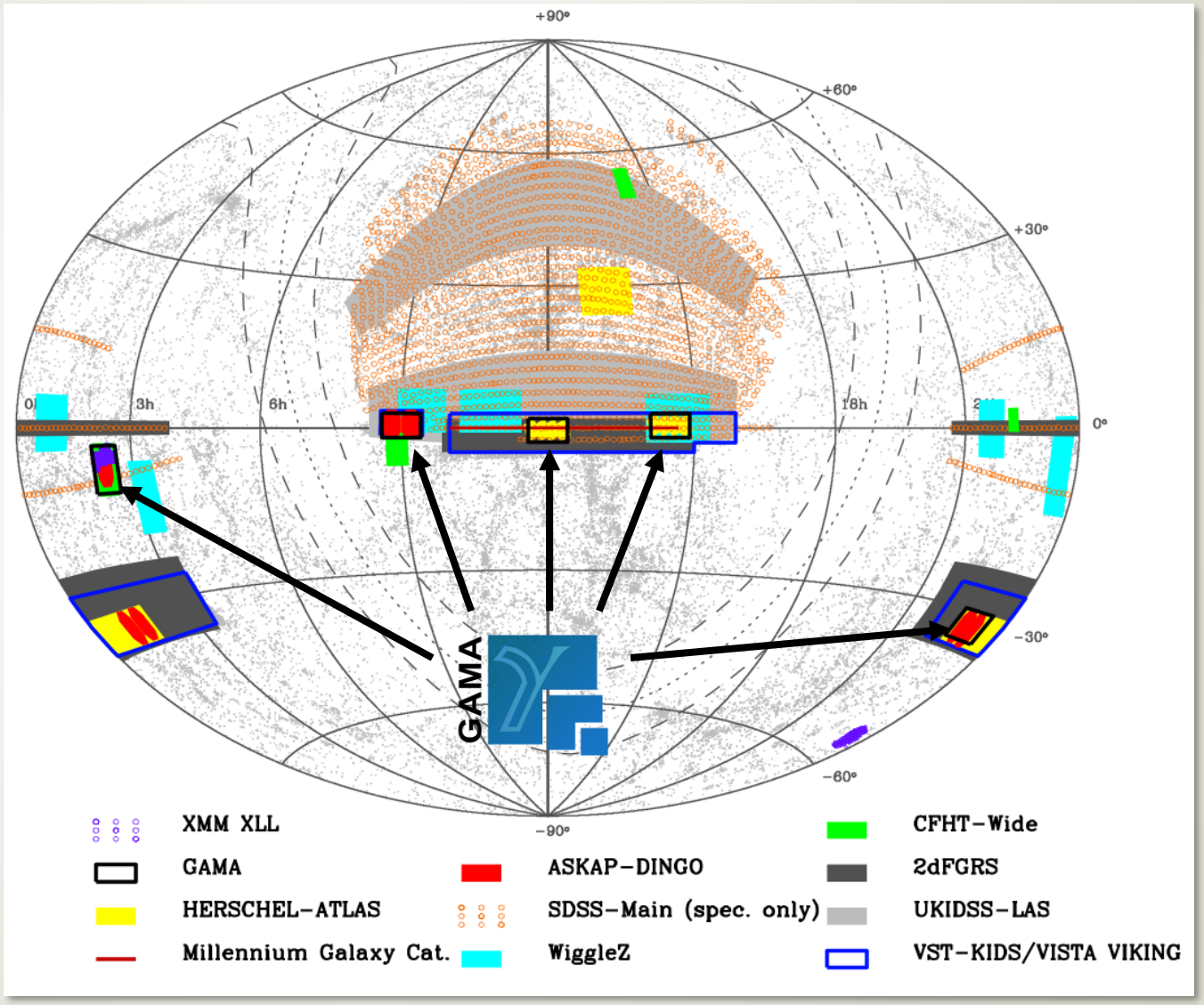


GAMA survey regions

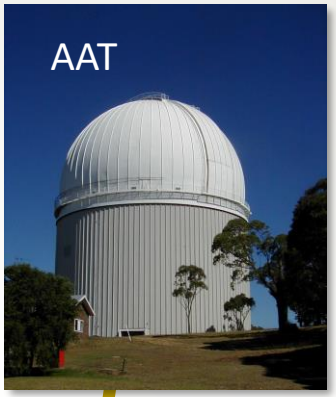
5 survey regions:

- 3 equatorial
- 2 southern

Total area = 286 deg^2



Photometry: 1 nm – 1 m



VIKING

UKIDSS-LAS

KiDS

CFHTLenS

MIS

XXL

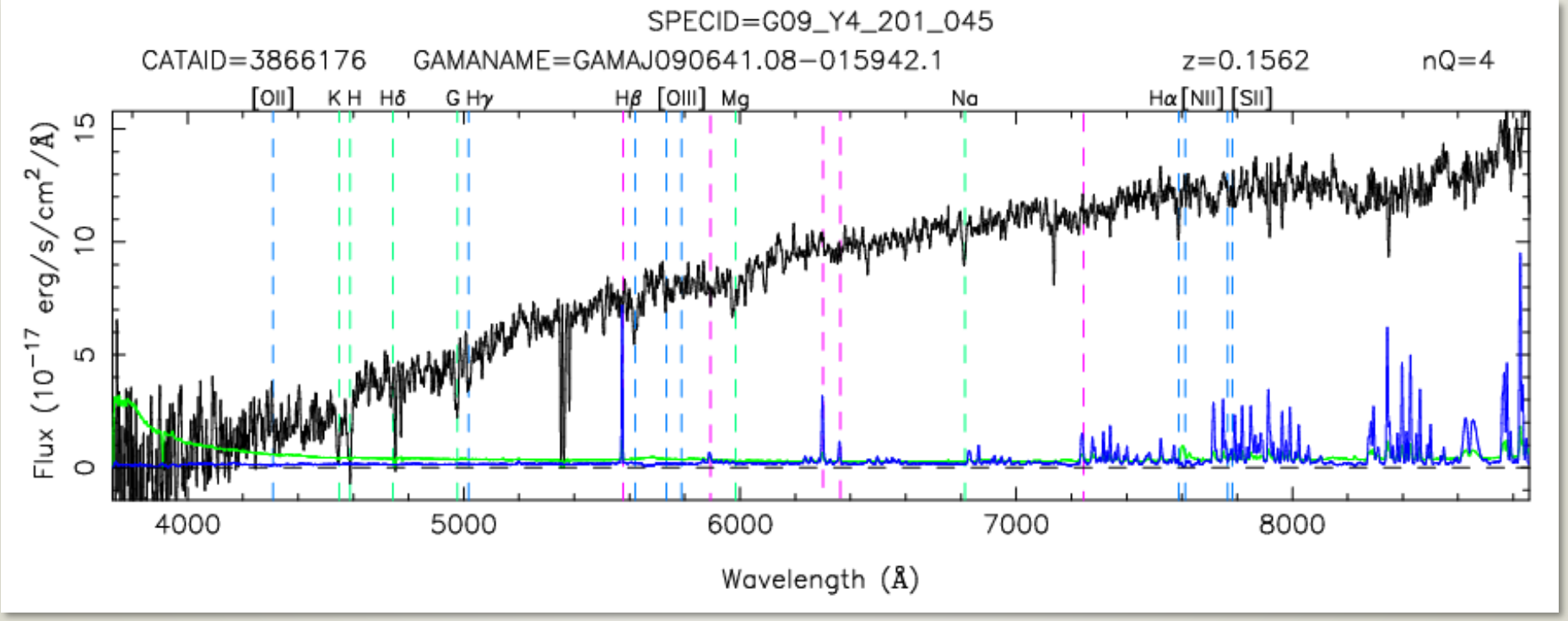
H-ATLAS

DINGO

GAMA

GAMA spectroscopy

- 210 nights (4 FTEs!) of multi-object fibre spectroscopy using AAT/2dF+AAOmega
- Area: 286 deg^2 split over 5 survey regions
- Main sample: ~270k galaxies to r < 19.8 mag
- R = 1300, 370 < λ < 880 nm
- <z> = 0.27



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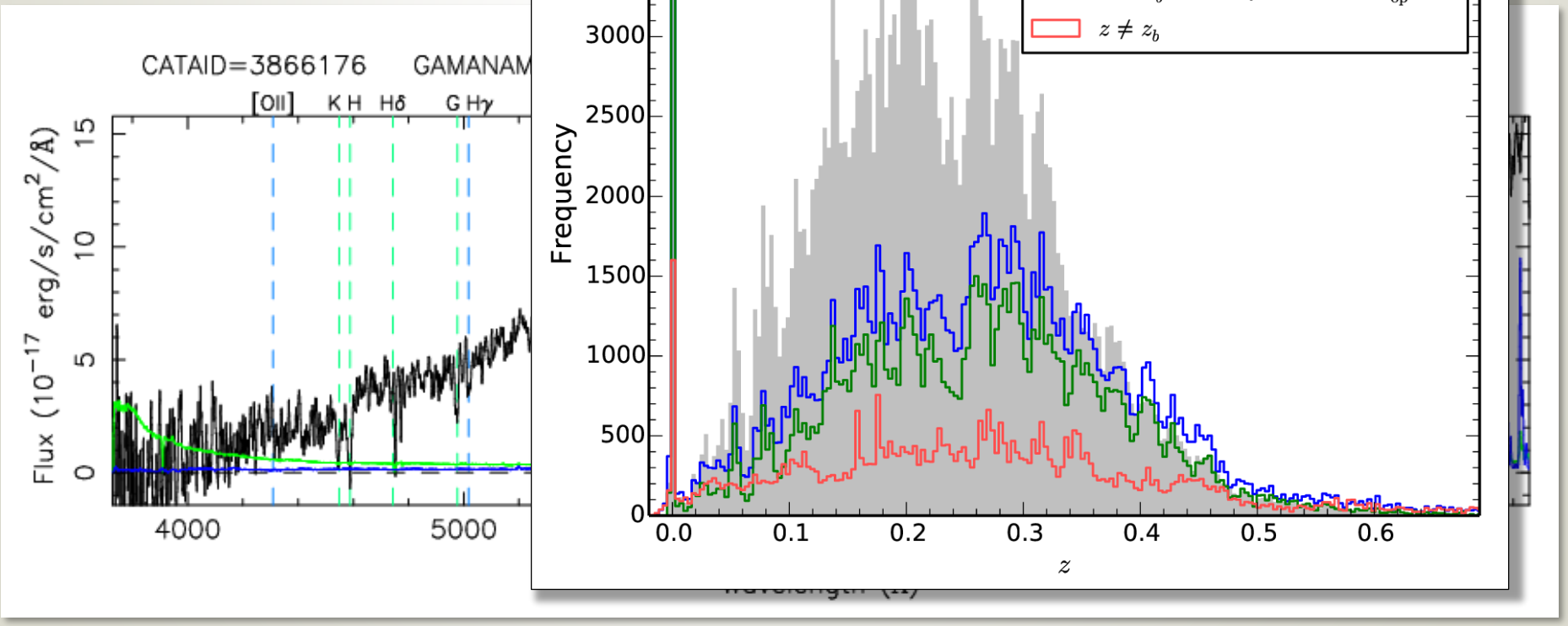
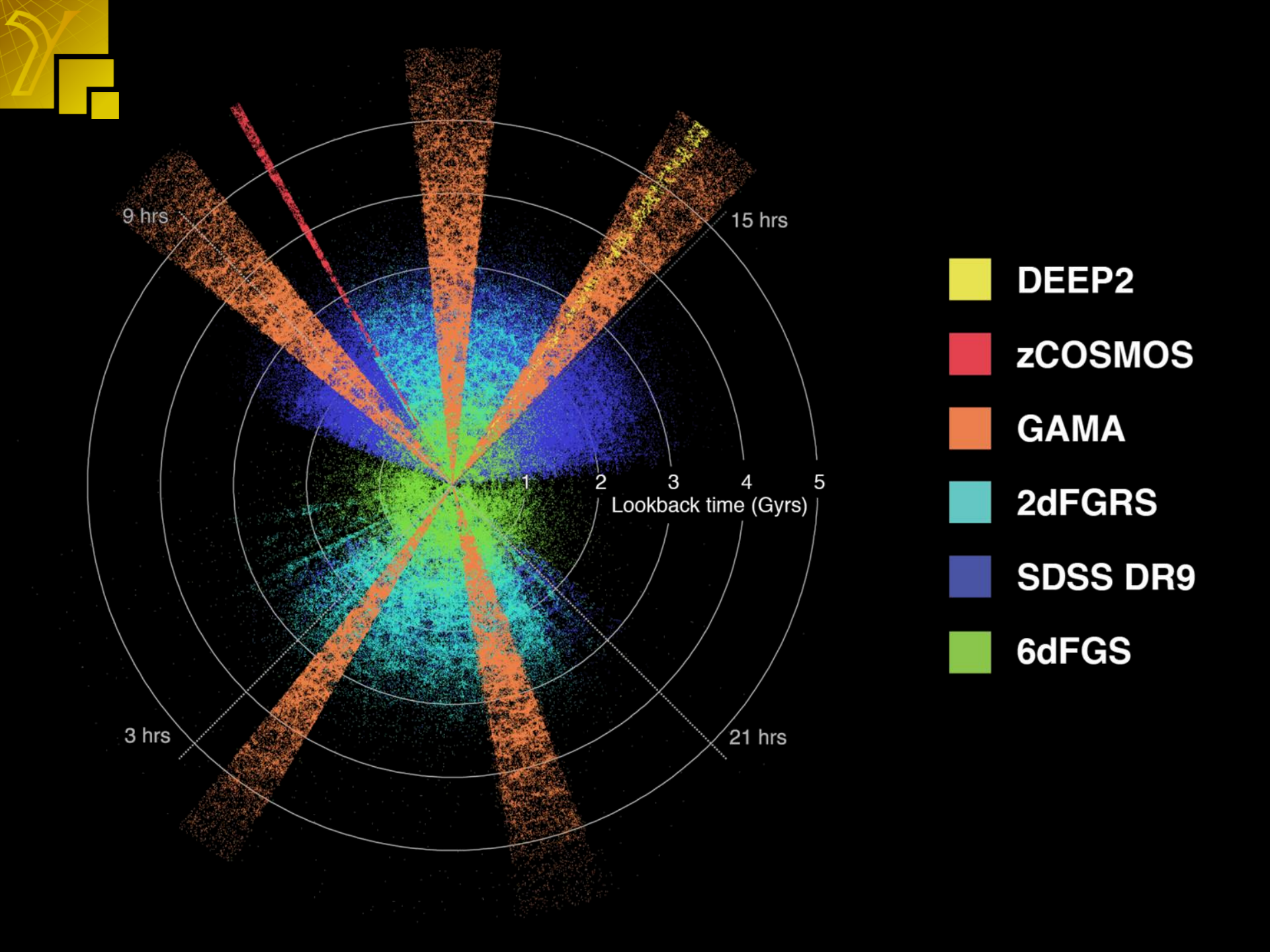
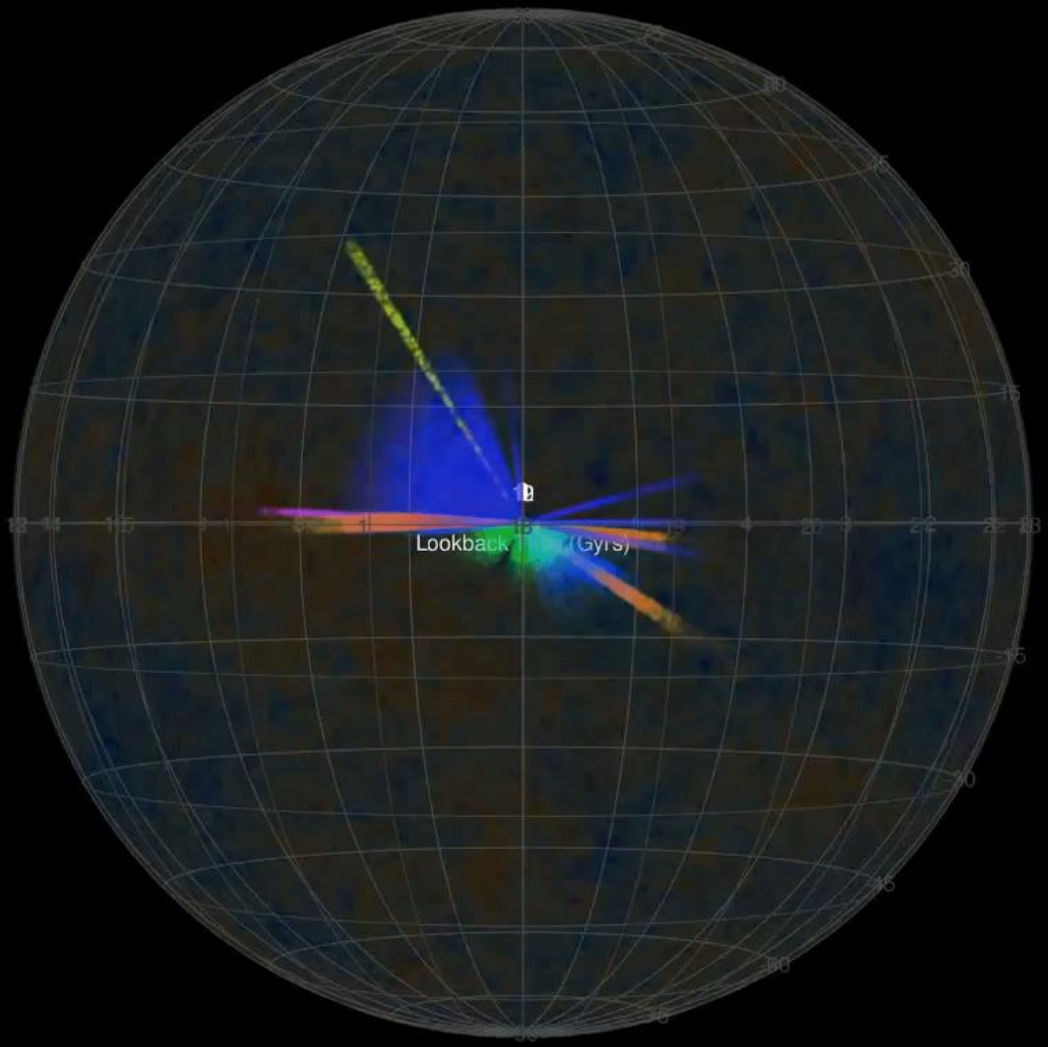
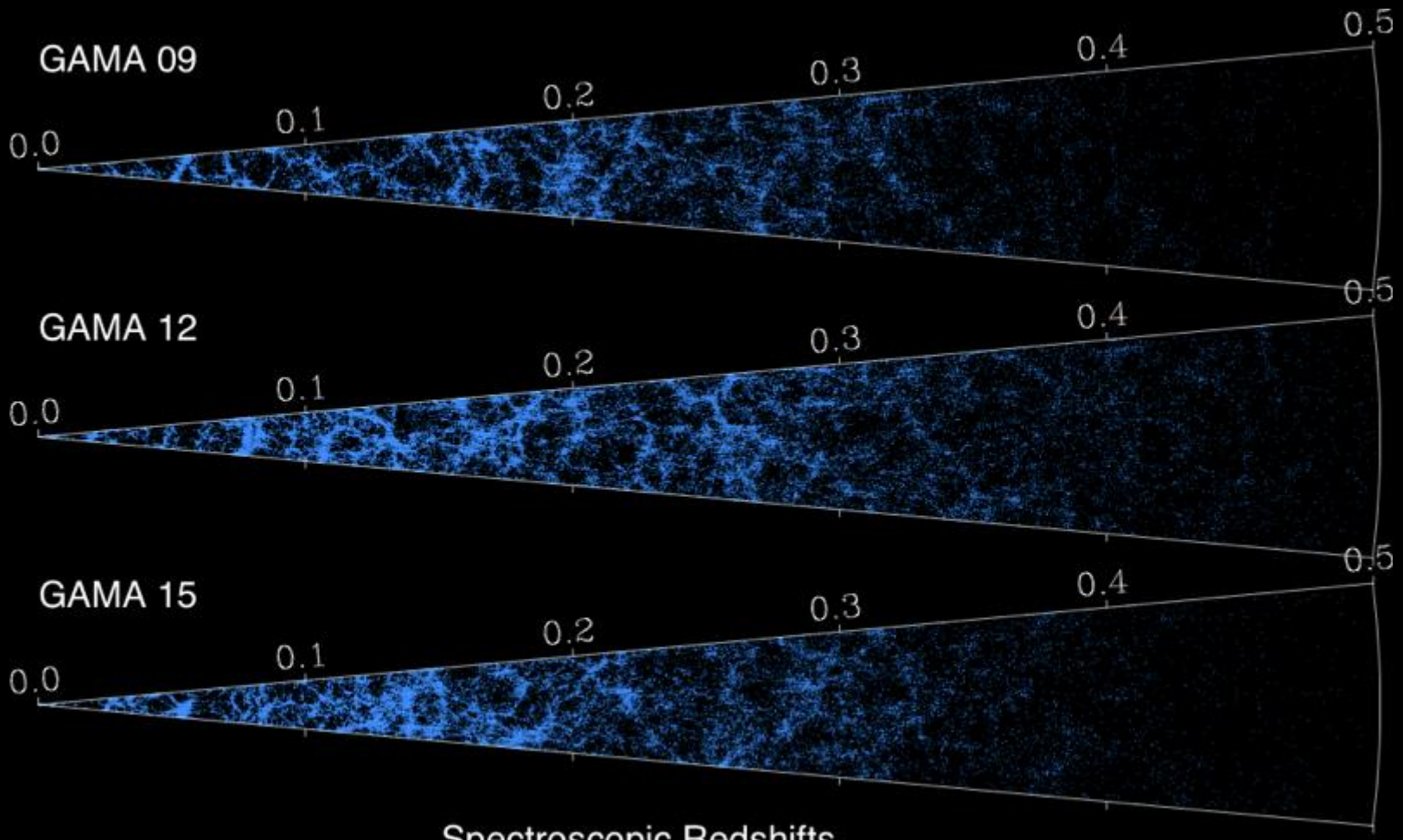
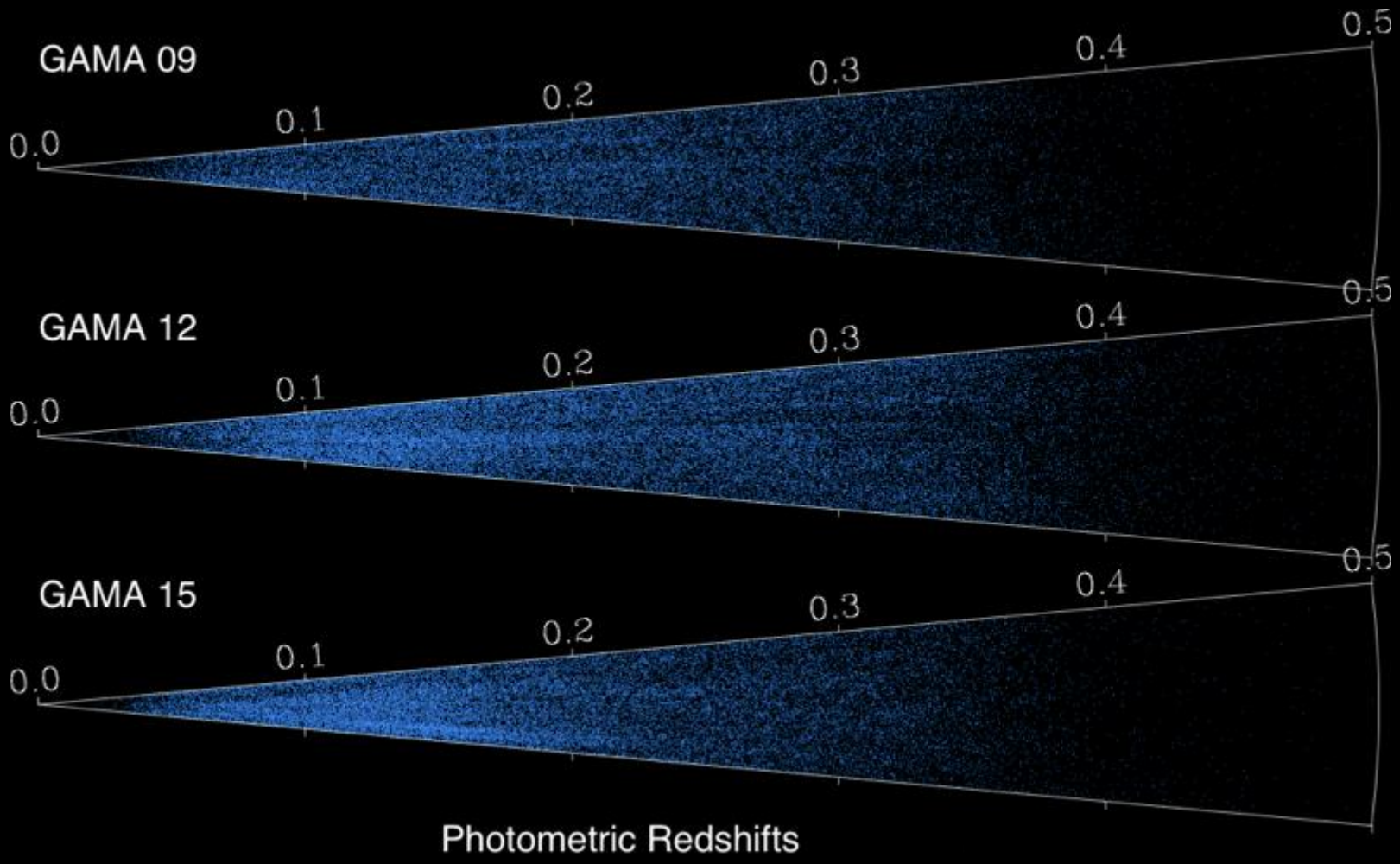



9 hrs
15 hrs
3 hrs
21 hrs
1
2
3
4
5
Lookback time (Gyrs)
DEEP2
zCOSMOS
GAMA
2dFGRS
SDSS DR9
6dFGS


Lookback
(Gyrs)


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


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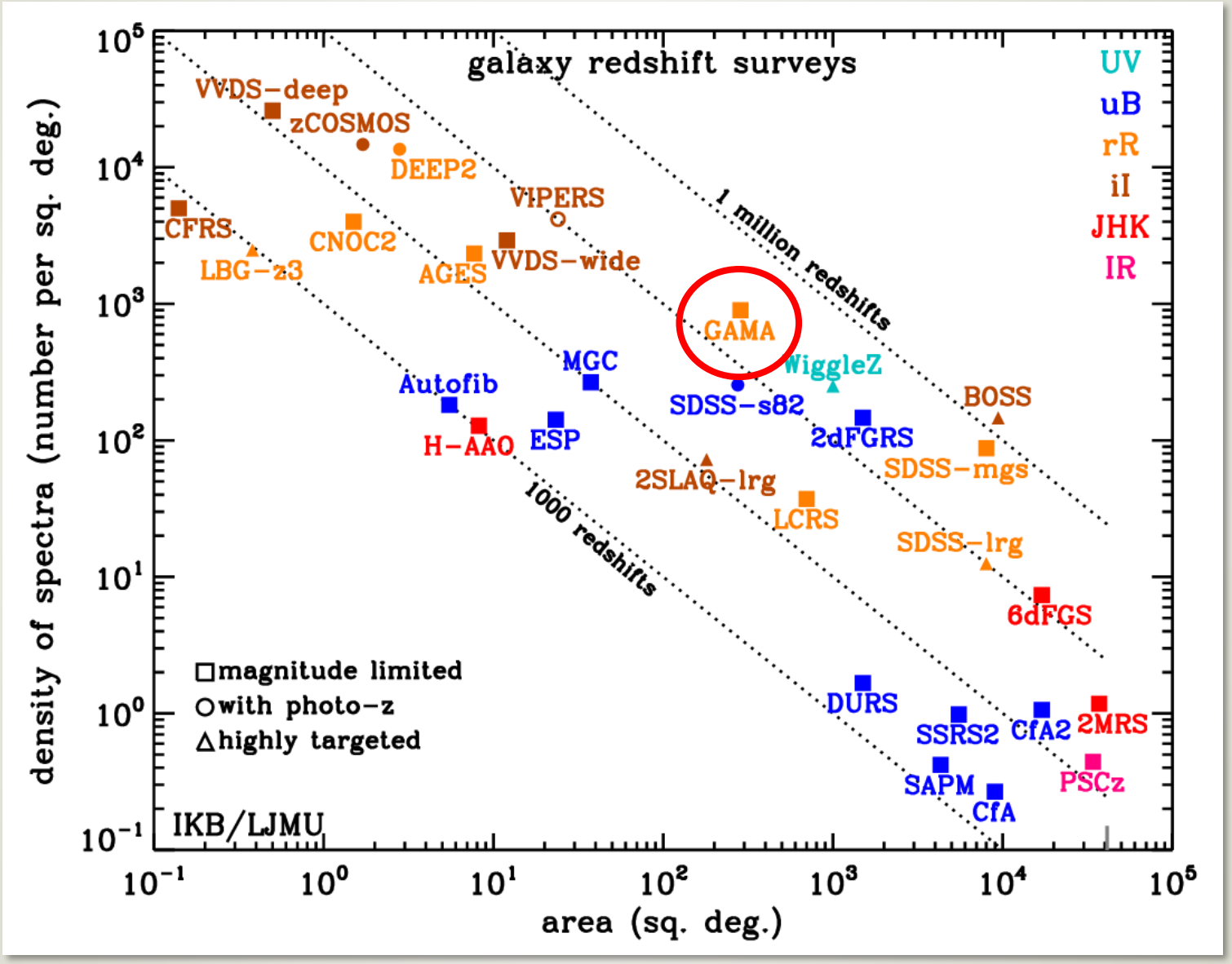
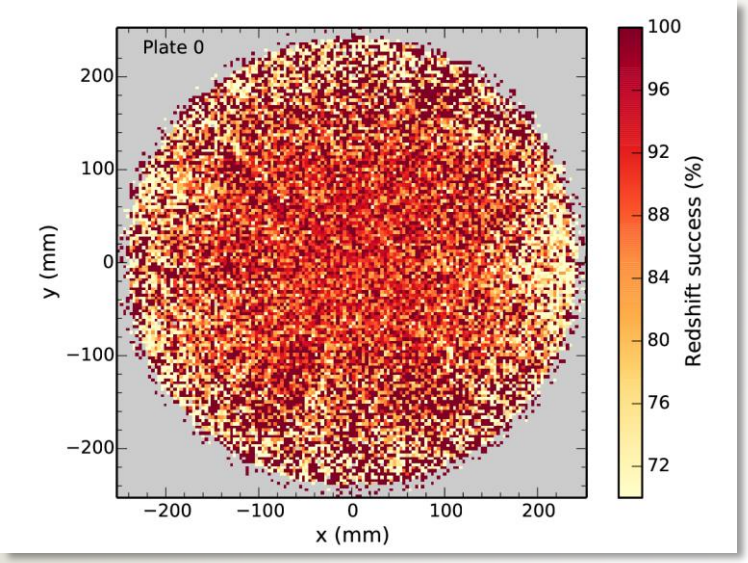
0.2
0.3
0.4
0.5
GAMA 15
0.0
0.1
0.2
0.3
0.4
0.5
Photometric Redshifts

How does GAMA fit in?

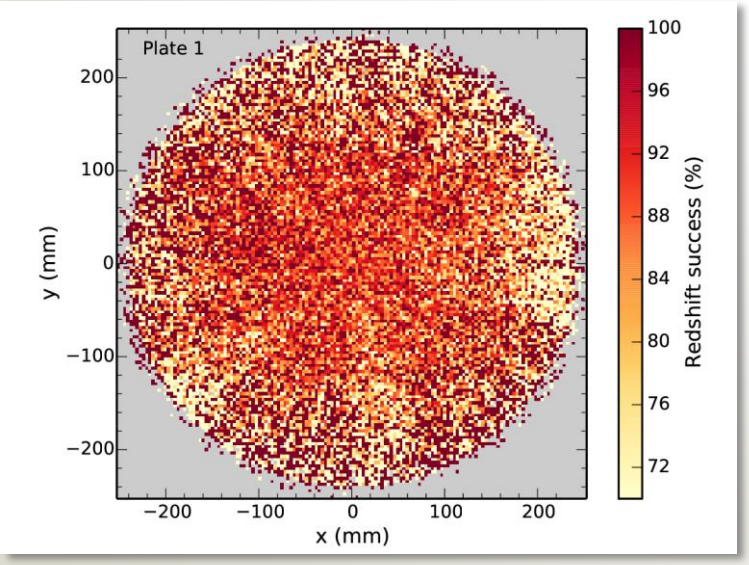


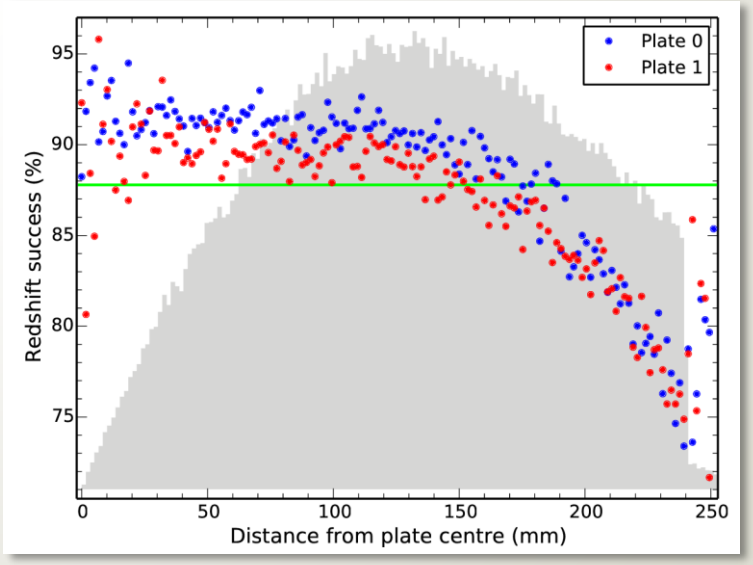
by Ivan Baldry

Selection function management



- Dependence of redshift success on fibre position on the plate.
- Several possible causes, including:
  - Systematic errors in astrometry, field rotation, correction for atmospheric refraction, …
  - Radial variation of apparent fibre diameter, focal ratio degradation, non-telecentricity, …

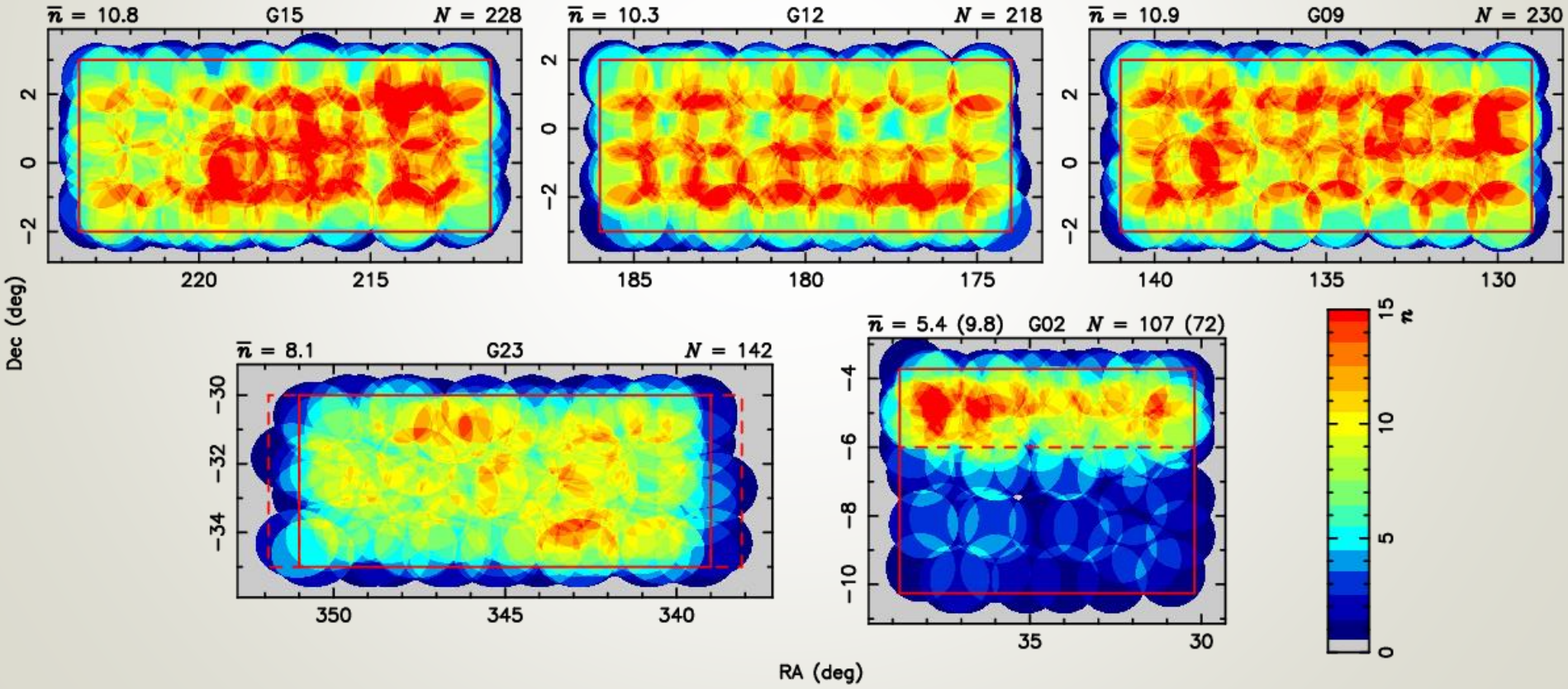




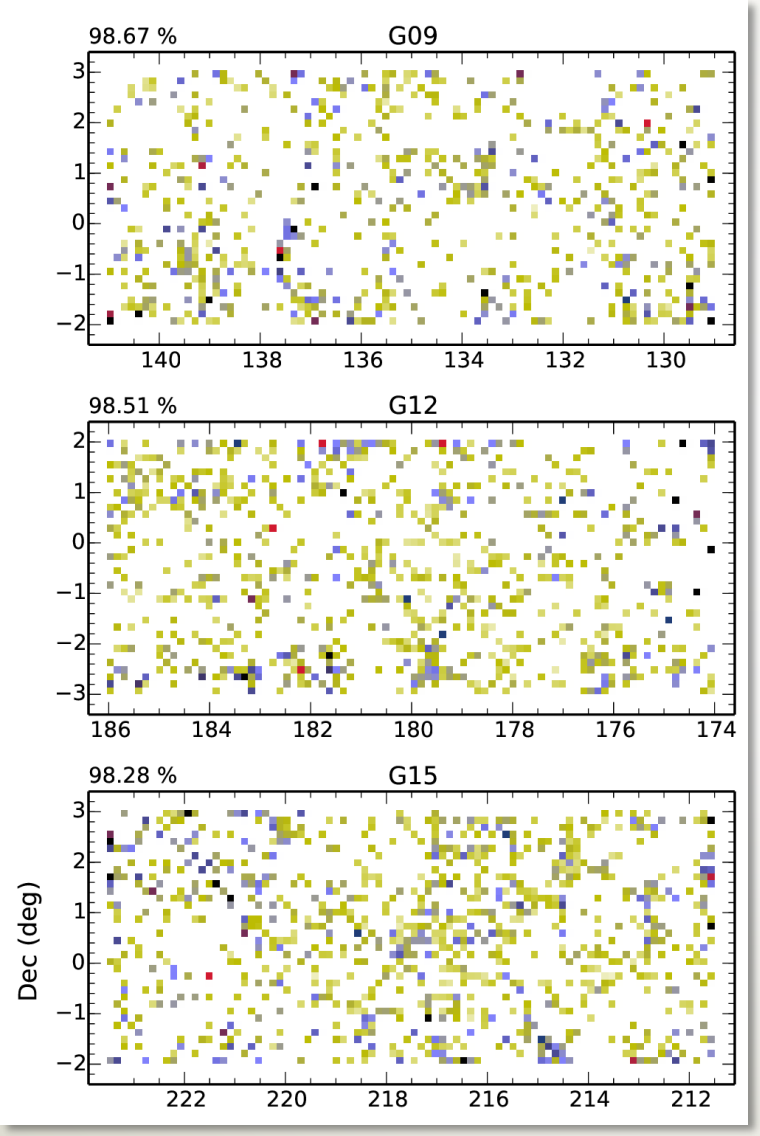
Liske et al. (2015)

Selection function management

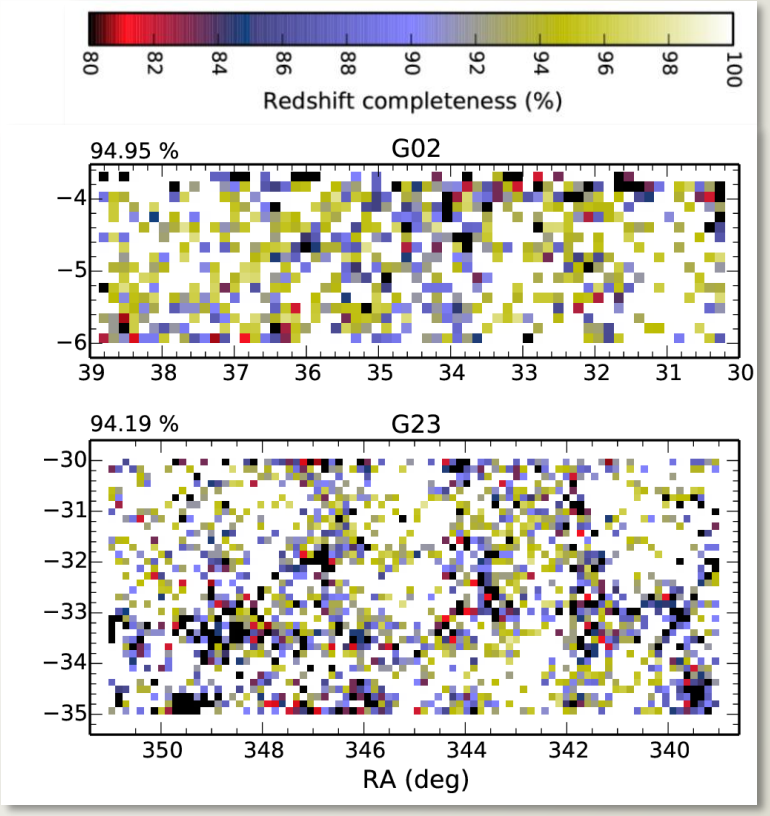
- GAMA is a multi-pass survey by design.
- Tiling strategy is important! It affects the homogeneity of the incompleteness as well as survey efficiency.
- In GAMA: next tile placed where it most decreases local incompleteness.



Selection function management



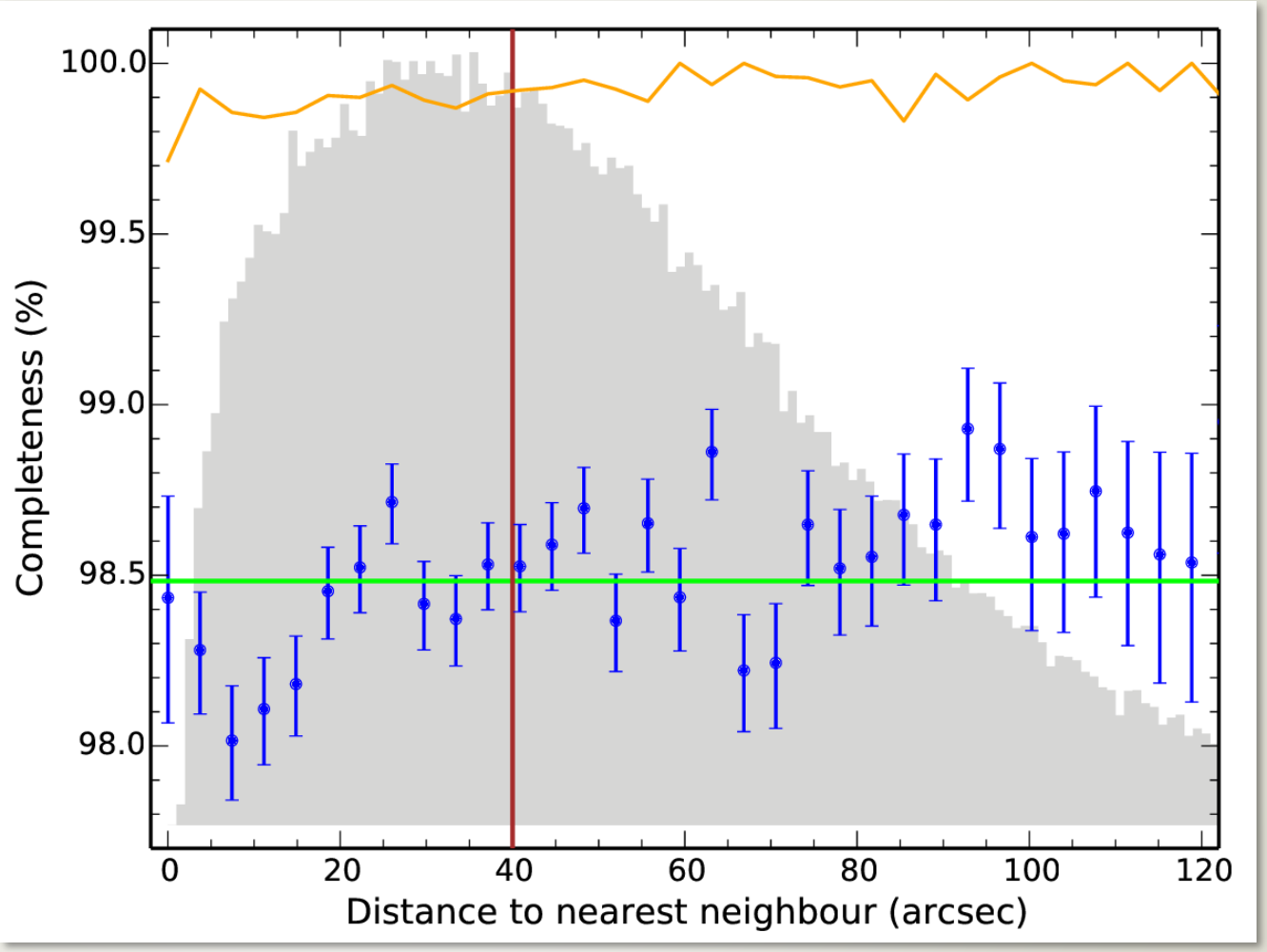
- Smooth large-scale distribution of incompleteness.



Liske et al. (2015)

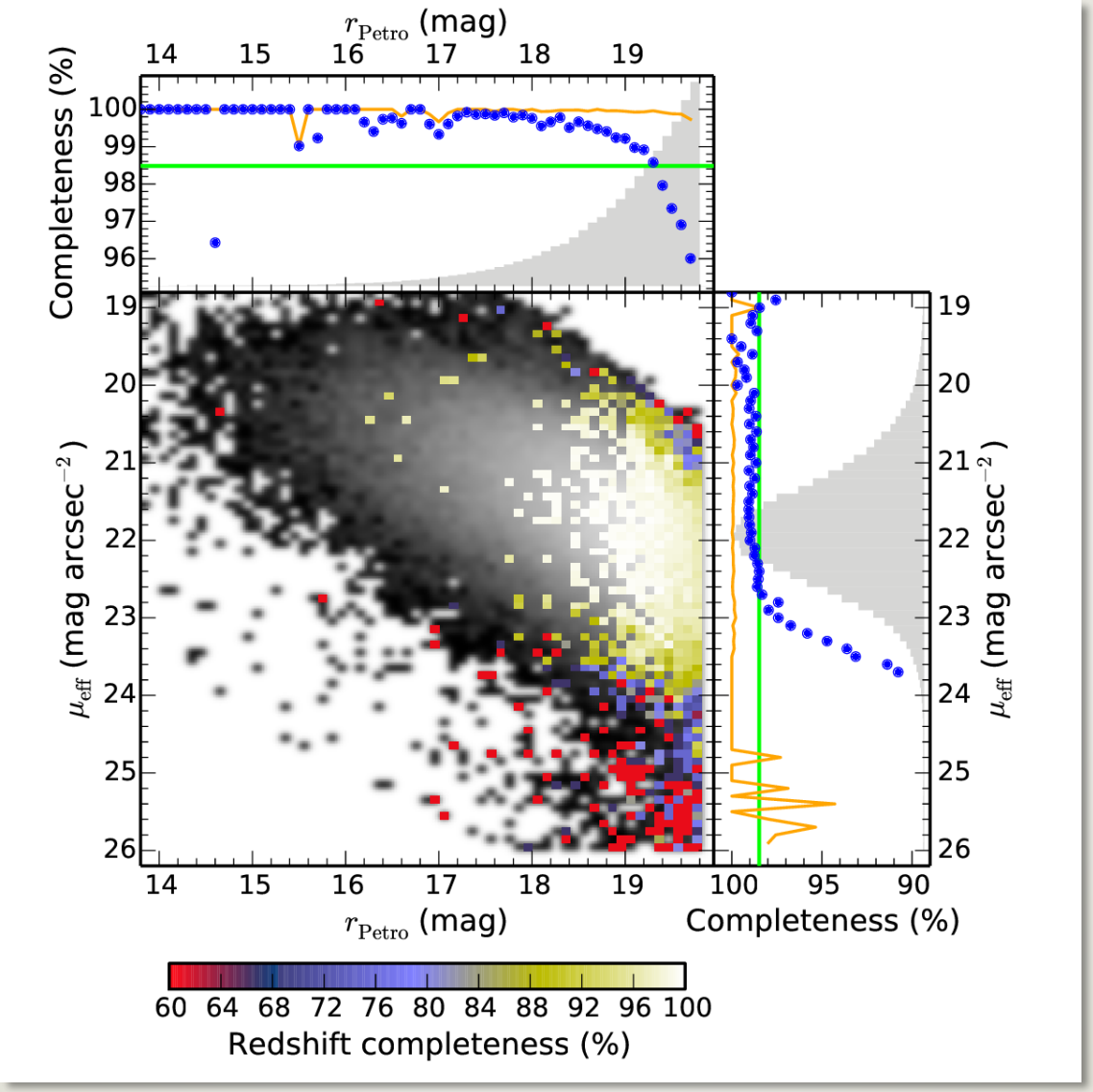
Selection function management

Maintaining high redshift completeness in dense regions is crucial for the identification of groups and mergers.



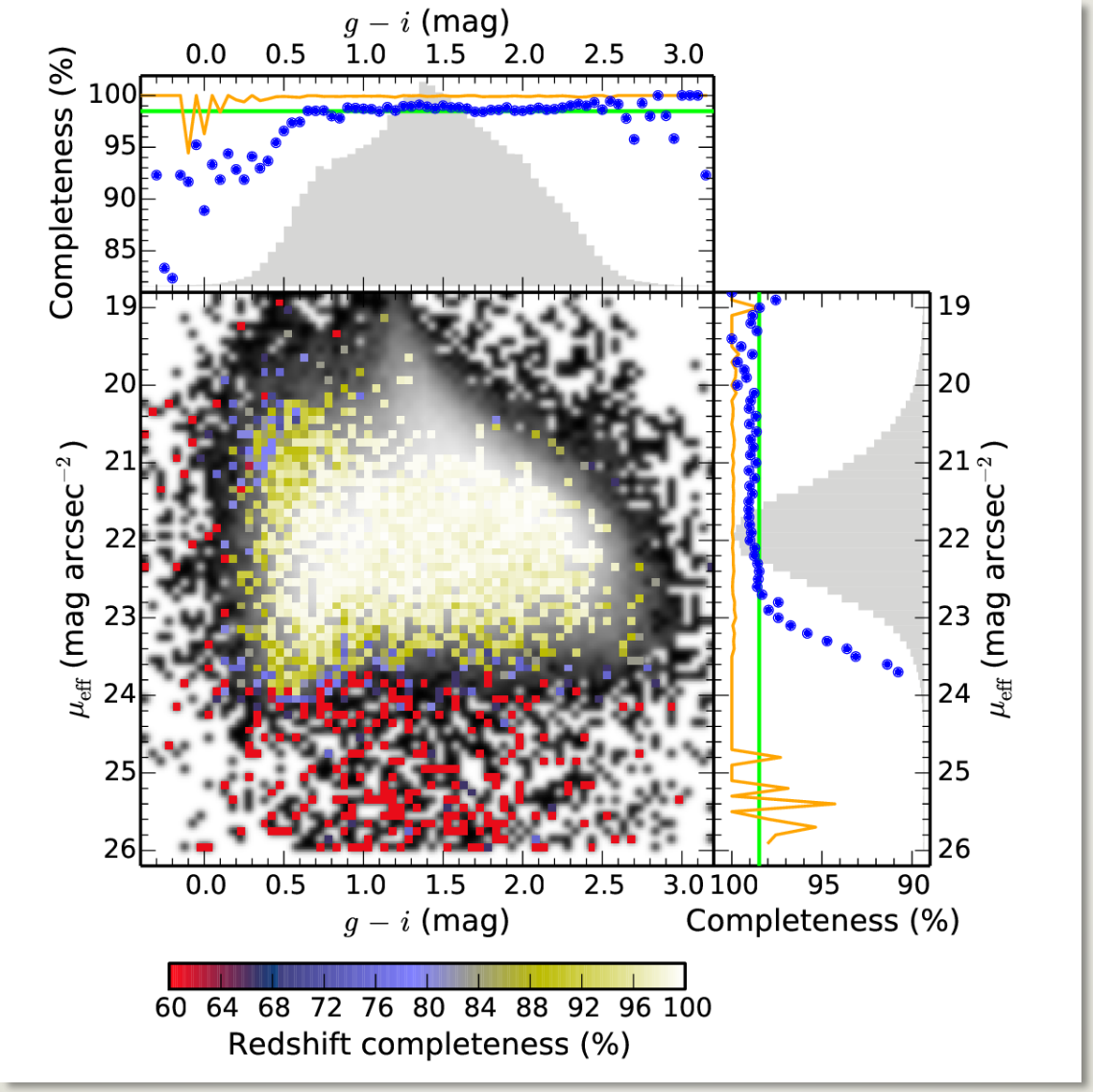
Liske et al. (2015)

Selection function management



Liske et al. (2015)

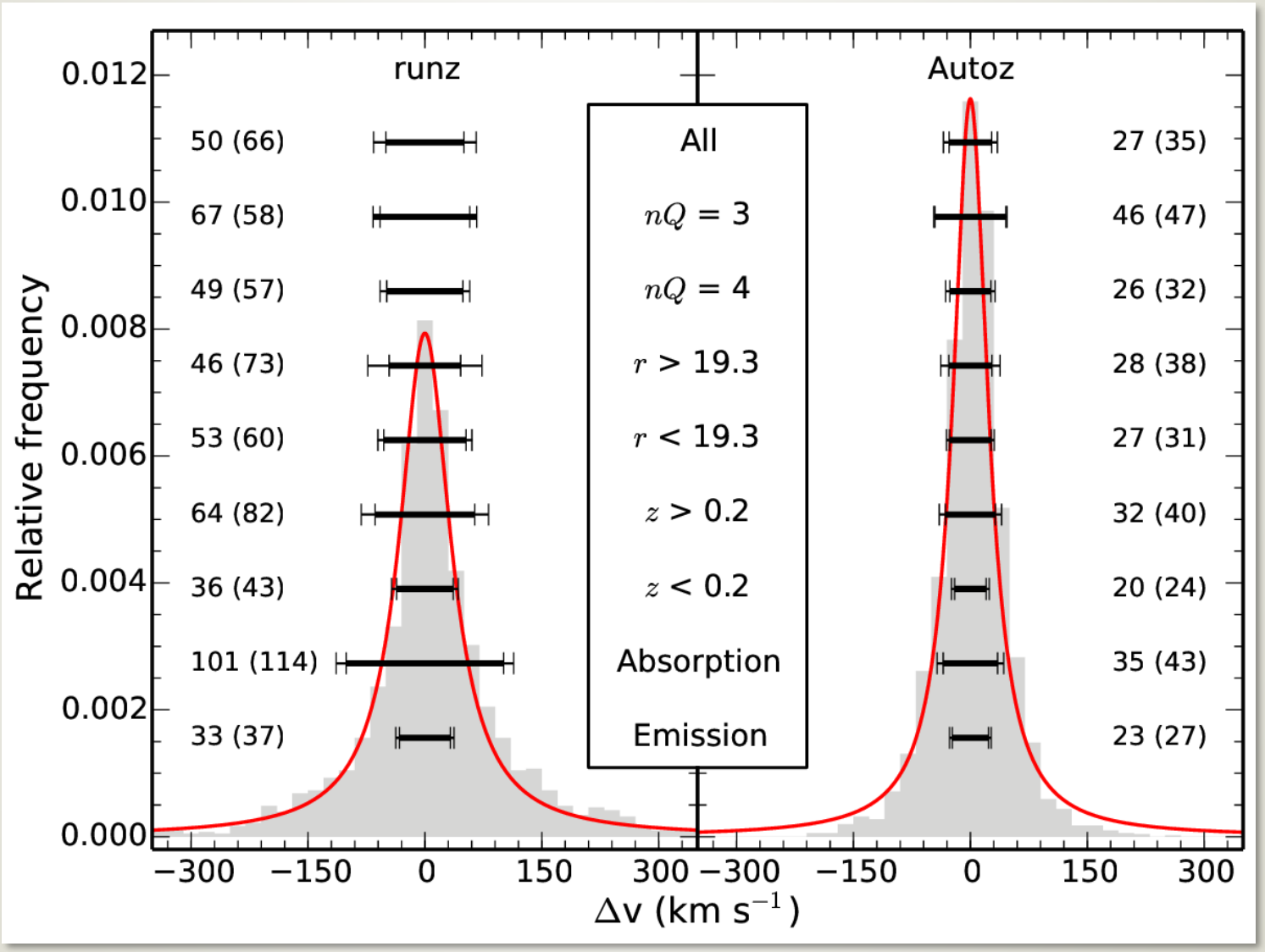
Selection function management



Liske et al. (2015)

Redshift precision…

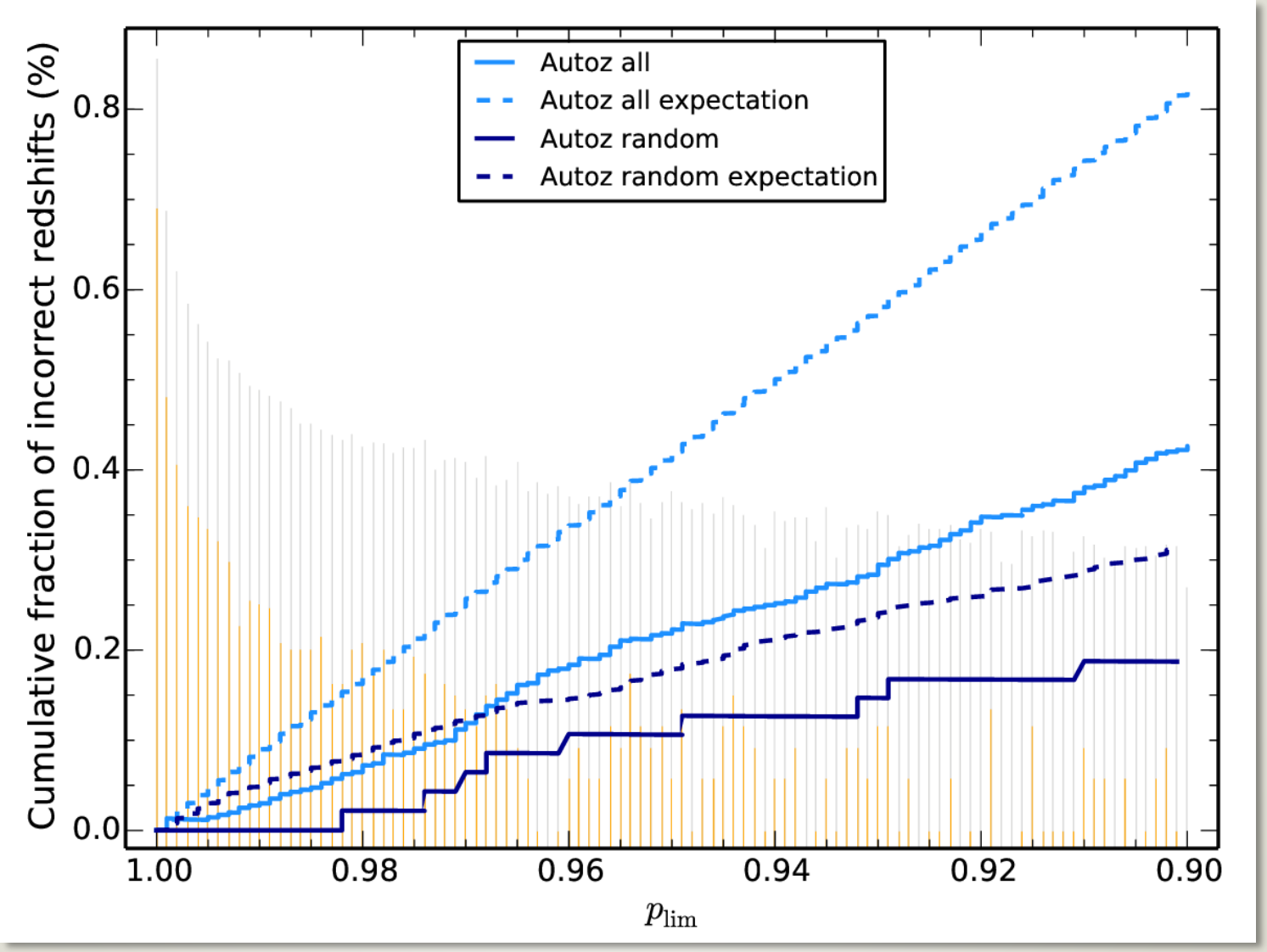
From ~2000 duplicate observations:



Liske et al. (2015)

…and accuracy

From ~2000 duplicate observations:



Liske et al. (2015)

Technical papers

Spectroscopy

• Baldry et al. (2010)	input catalogue
• Robotham et al. (2010)	tiling strategy
• Hopkins et al. (2013)	data reduction
• Driver et al. (2011)	survey procedures, DR1
• Baldry et al. (2014)	redshift measurement code
• Liske et al. (2015)	end of survey report, QC, DR2

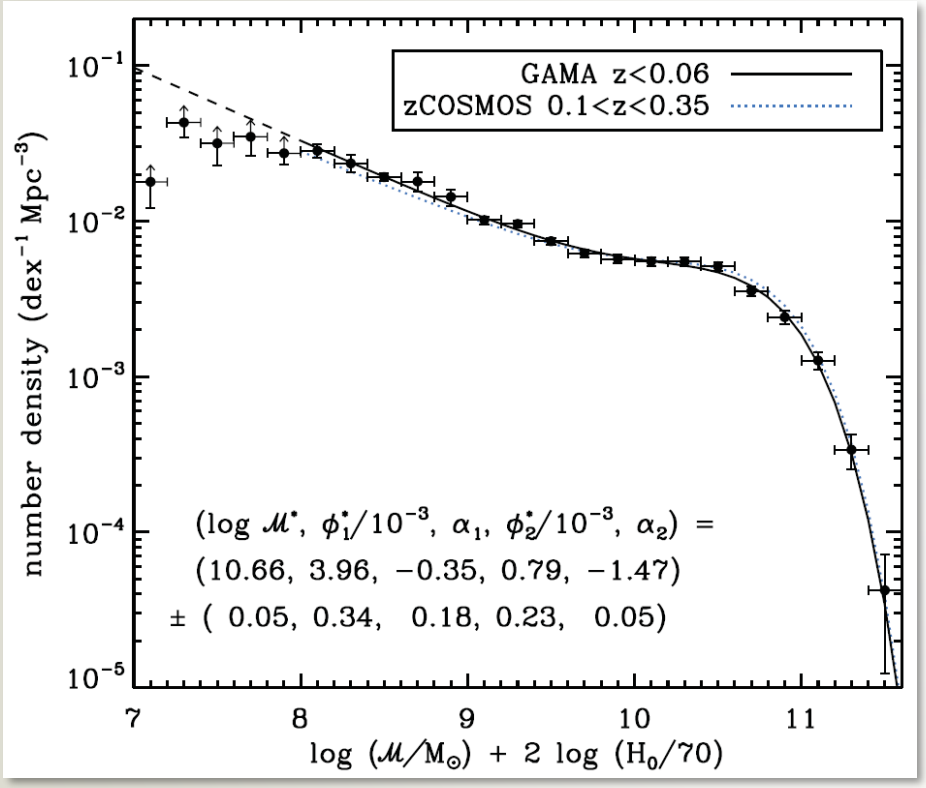
Photometry

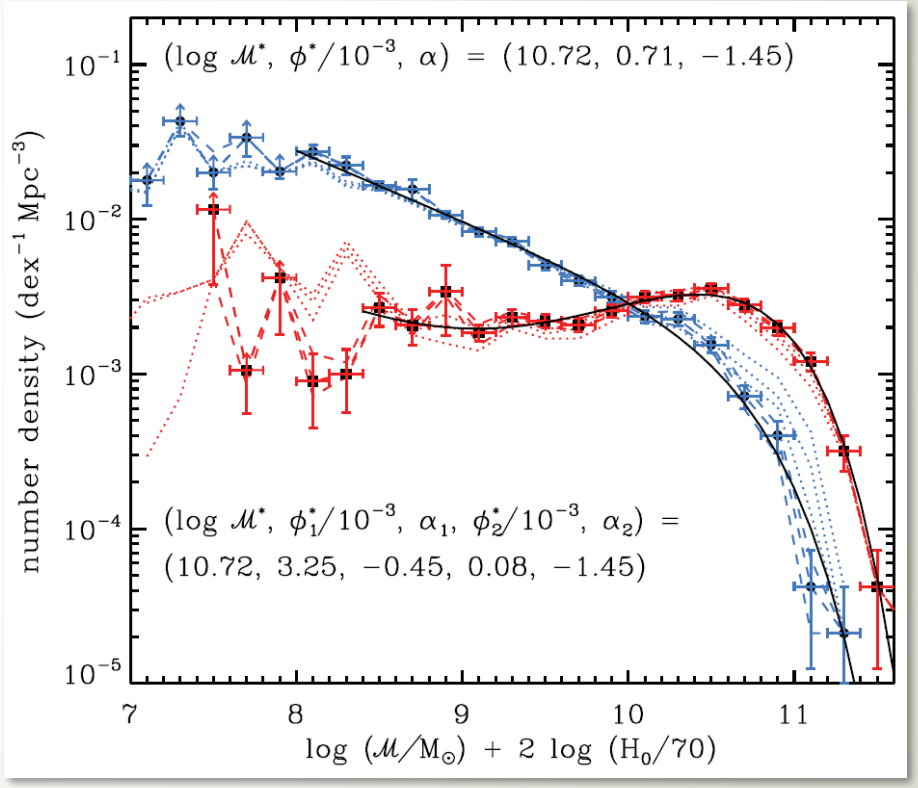
• Hill et al. (2011), Driver et al. (2016)	u – K aperture matched photometry
• Kelvin et al. (2012), Häußler et al. (2013)	u – K Sérsic photometry
• Smith et al. (2011)	matching with Herschel sources
• Cluver et al. (2014)	WISE photometry
• Liske et al. (2015)	GALEX photometry
• Driver et al. (2016)	integrating all photometry, PDR
• Prescott et al. (2016)	radio fluxes
• Pacaud et al. (2016) Fotopoulou et al. (2016)	X-ray fluxes

Other

• Baldry et al. (2012)	local flow corrections
• Hopkins et al. (2013)	spectral line measurements
• Loveday et al. (2012)	k-corrections
• Taylor et al. (2011)	stellar masses
• Robotham et al. (2011)	group catalogue
• Alpaslan et al (2014)	large-scale structure catalogue
• Moffett et al. (2016)	morphologies

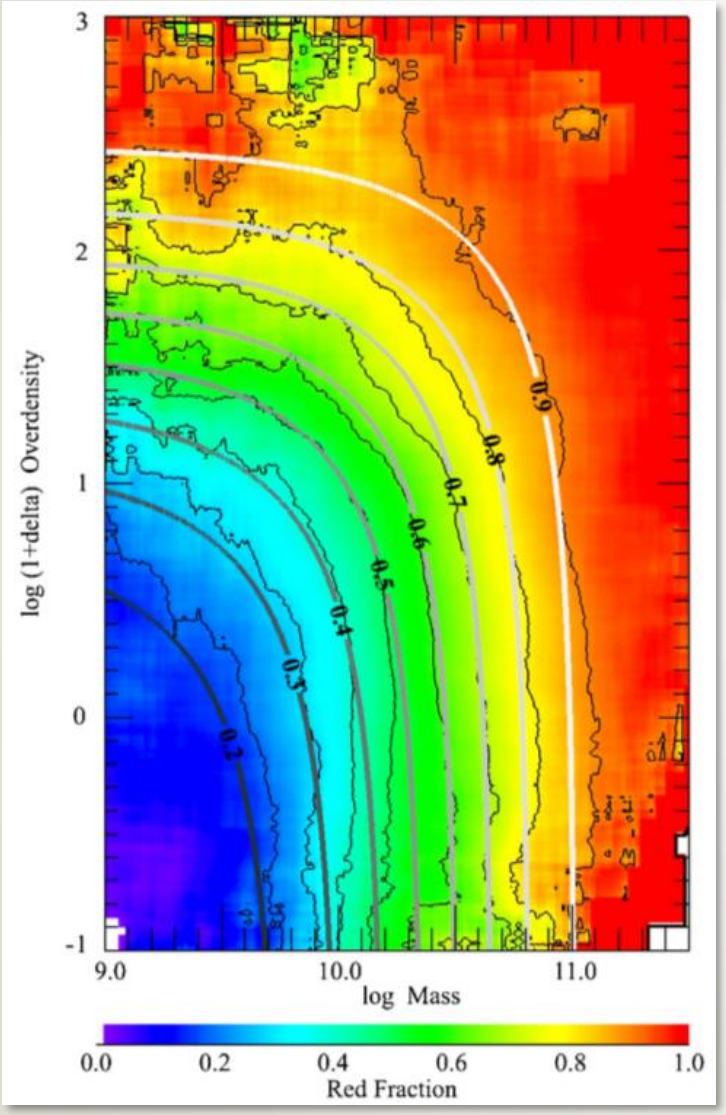
The stellar mass function



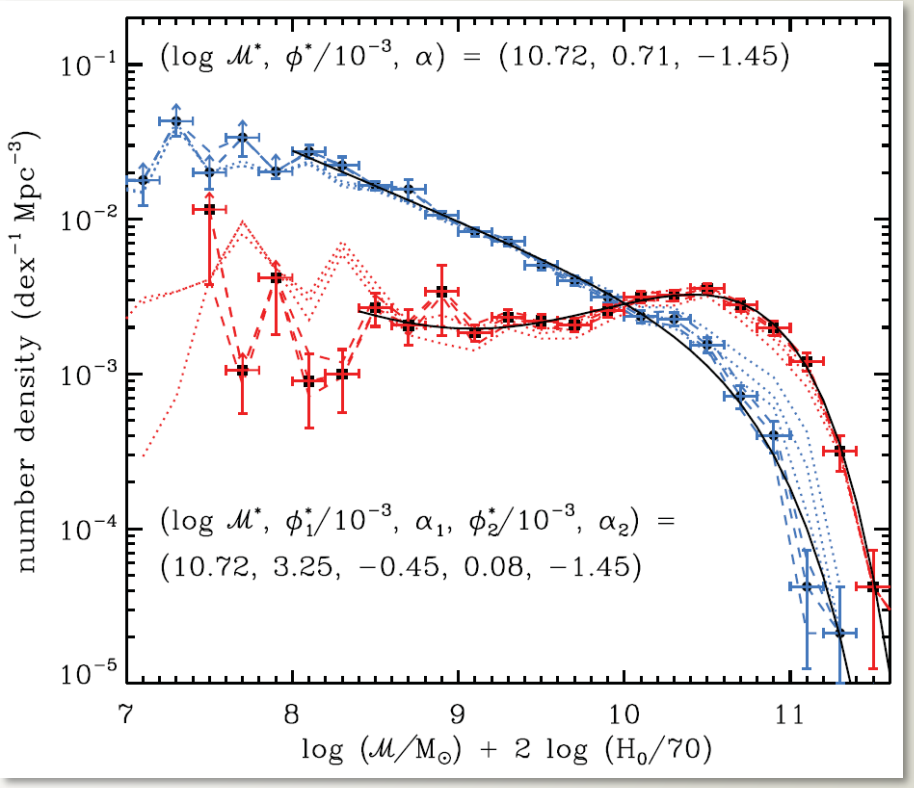


Baldry et al. (2012)

The stellar mass function



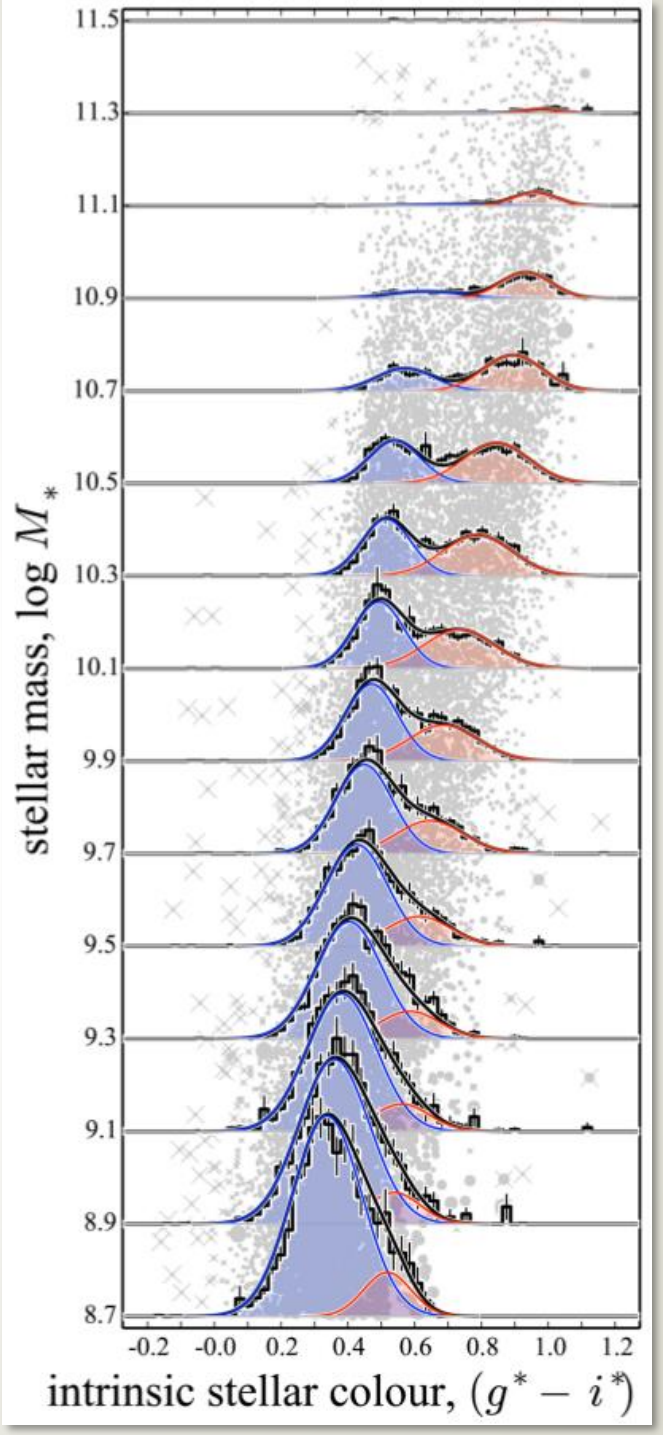
Peng et al. (2010)



Baldry et al. (2012)

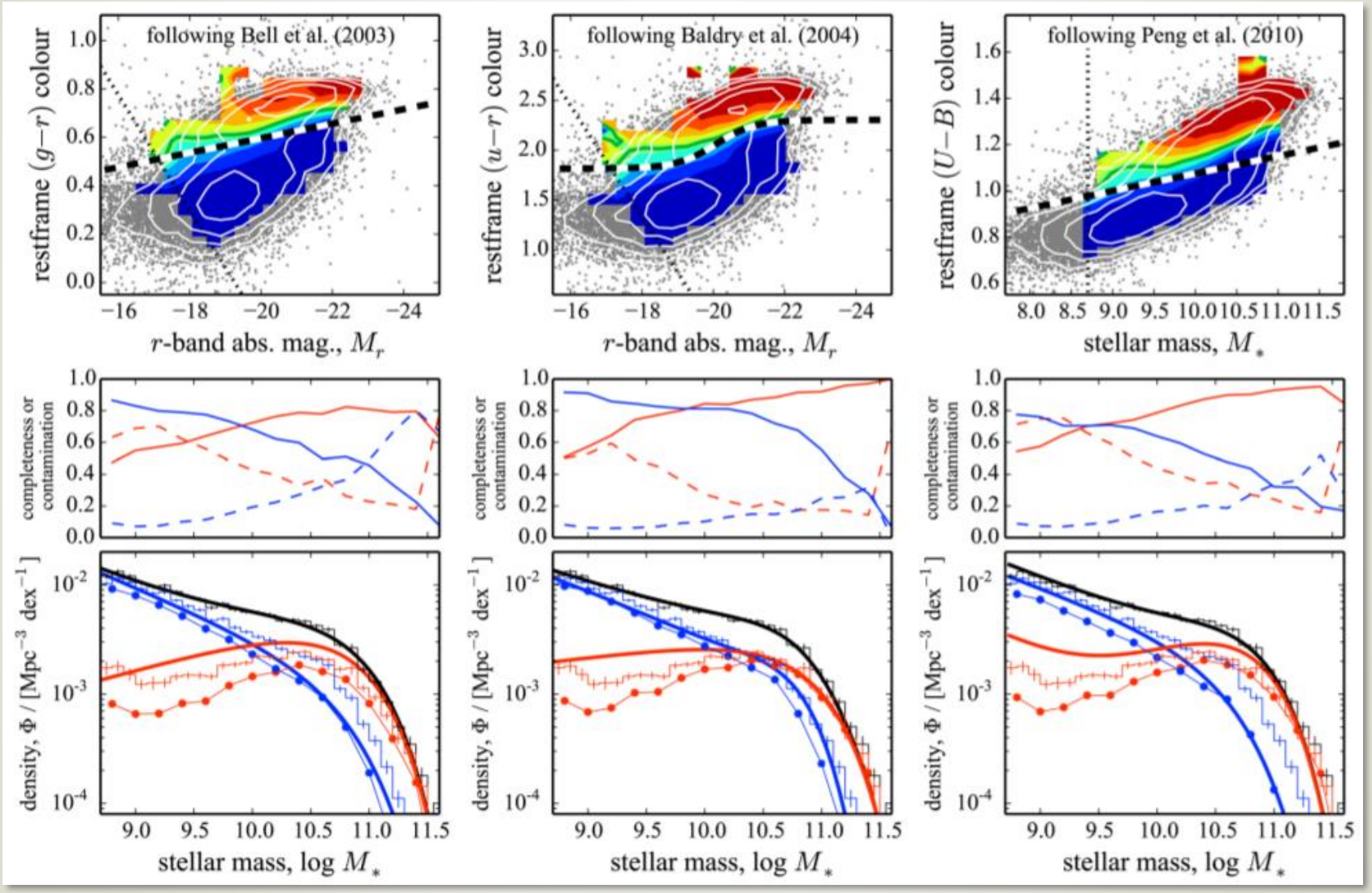
BUT....

- Dust correction
- Issue is completely dominated by how you define *red.*
- A simple, hard colour cut is too simple.
- Not much evidence of a red population below log M* ~ 9.



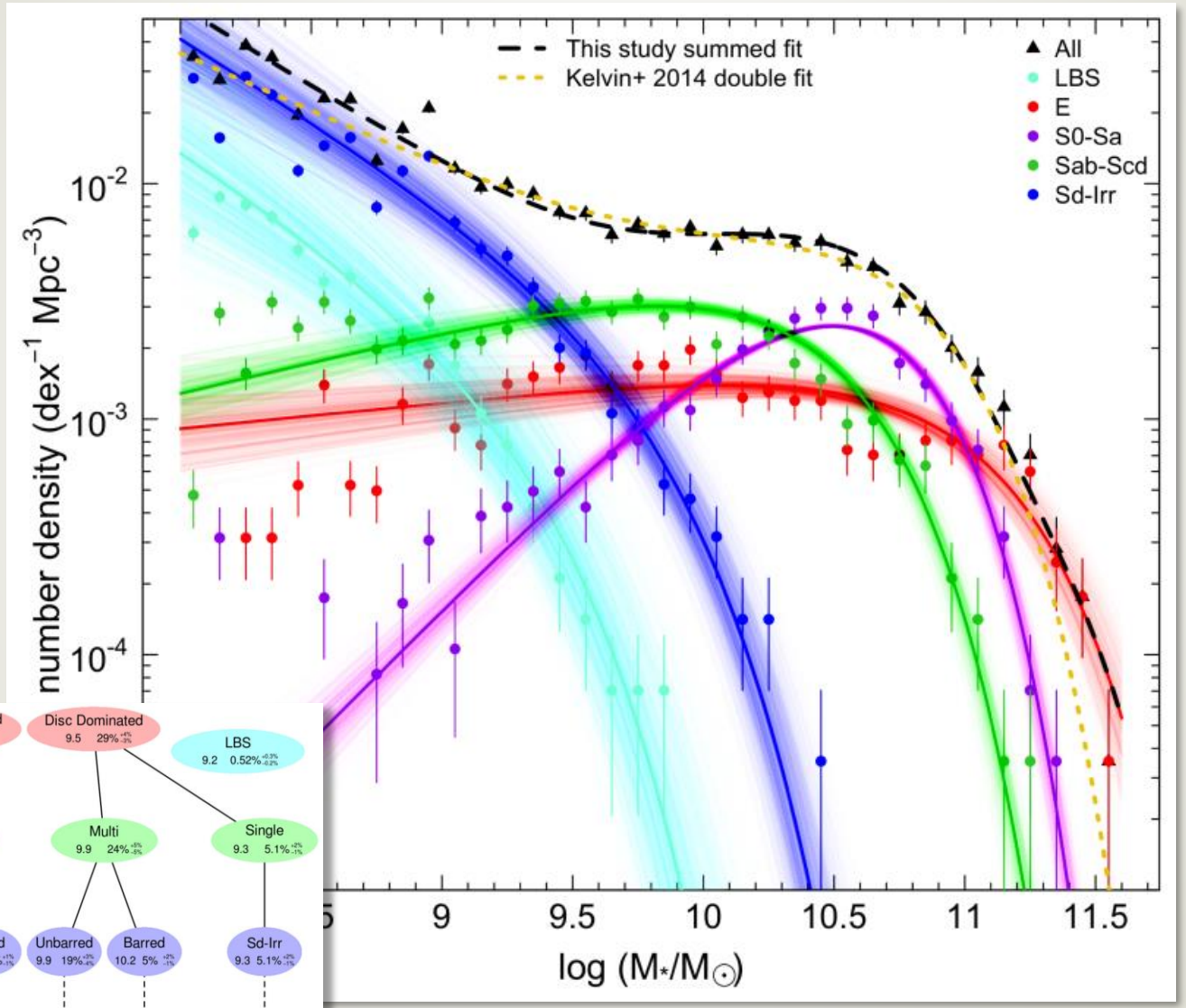
Taylor et al. (2015)

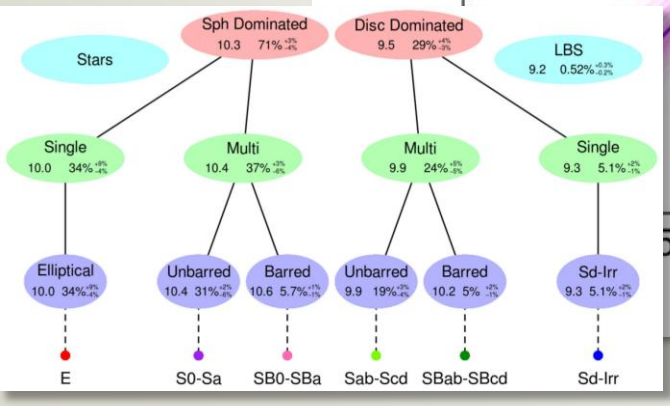
Is the red faint upturn real?



Taylor et al. (2015)

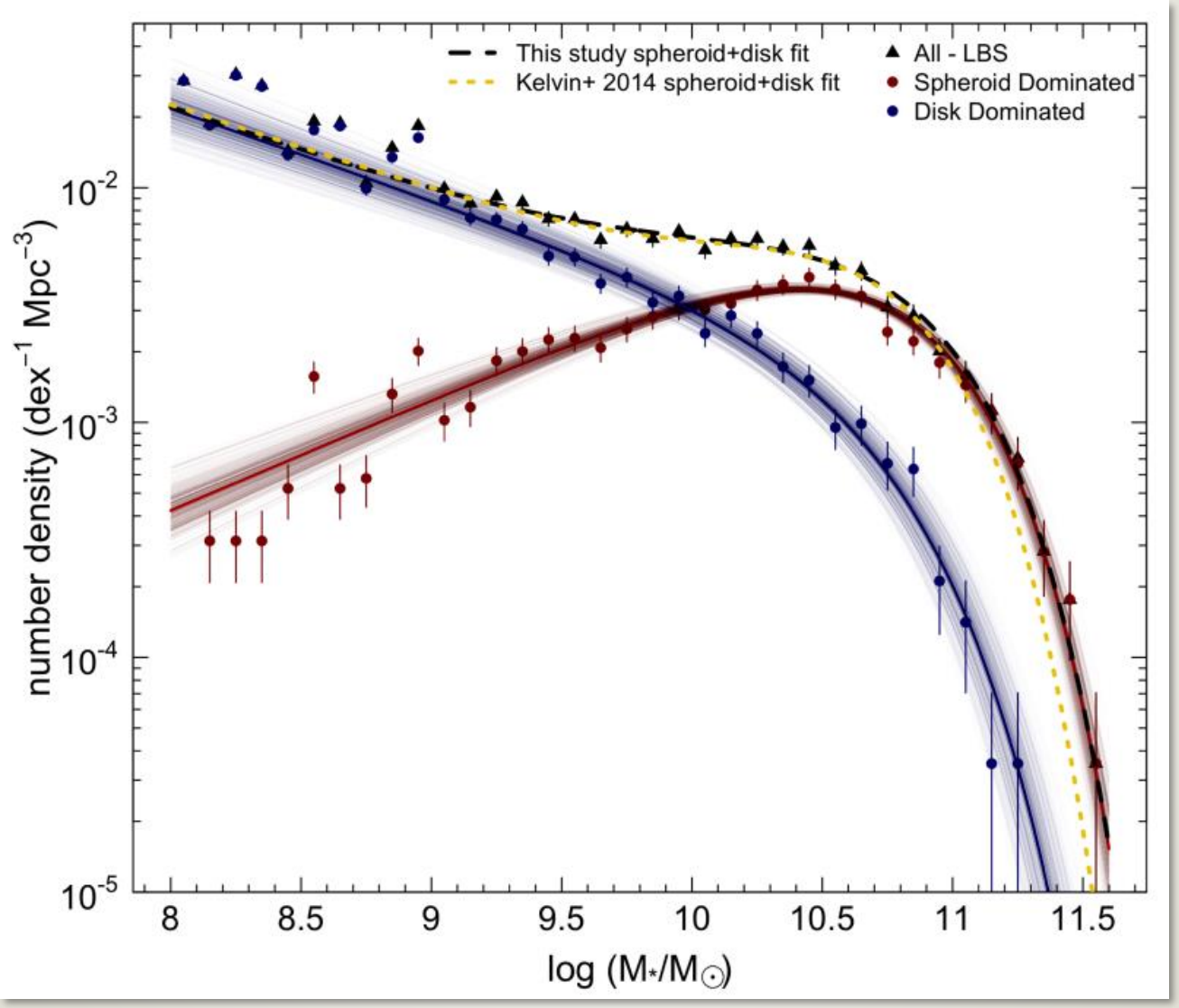
GSMF by morphological type





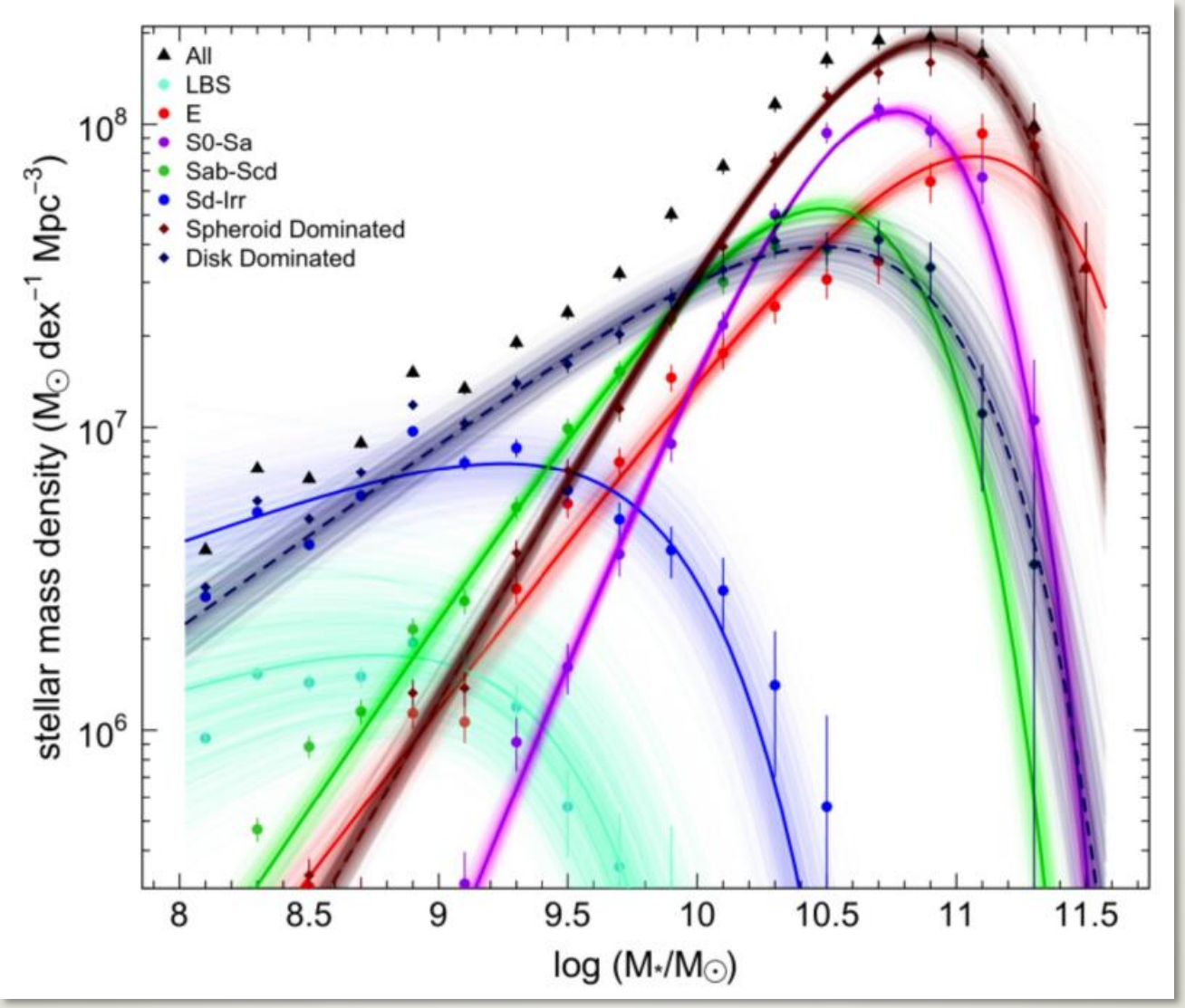
Moffett et al. (2016)

GSMF by morphological type



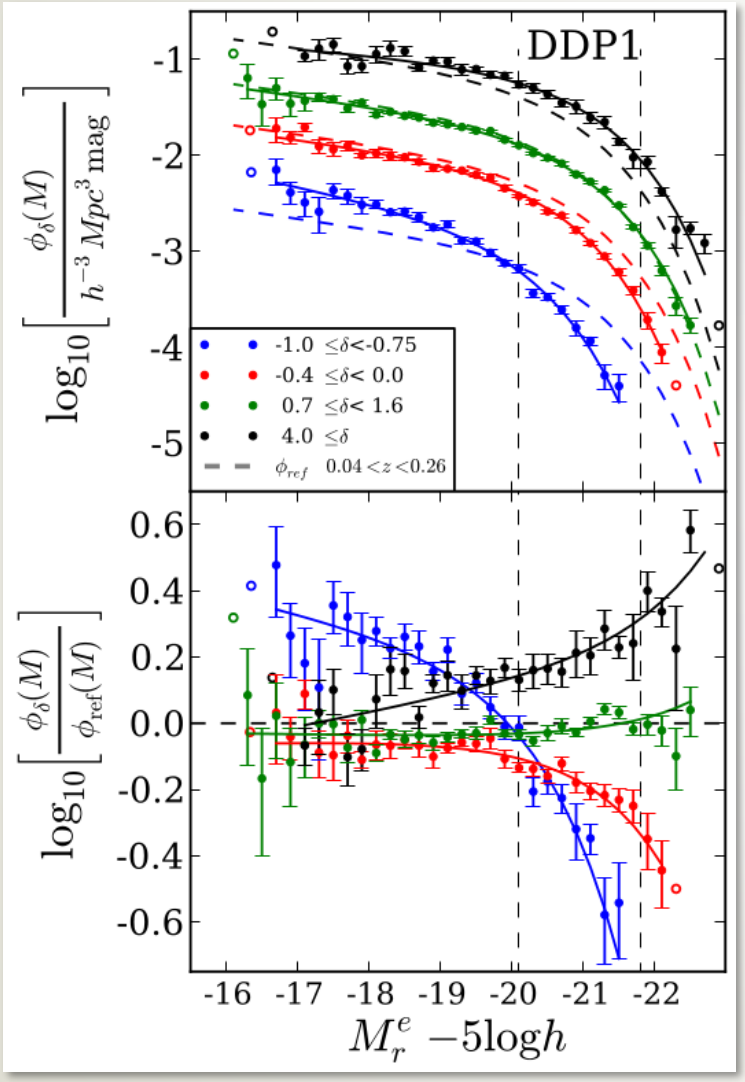
Moffett et al. (2016)

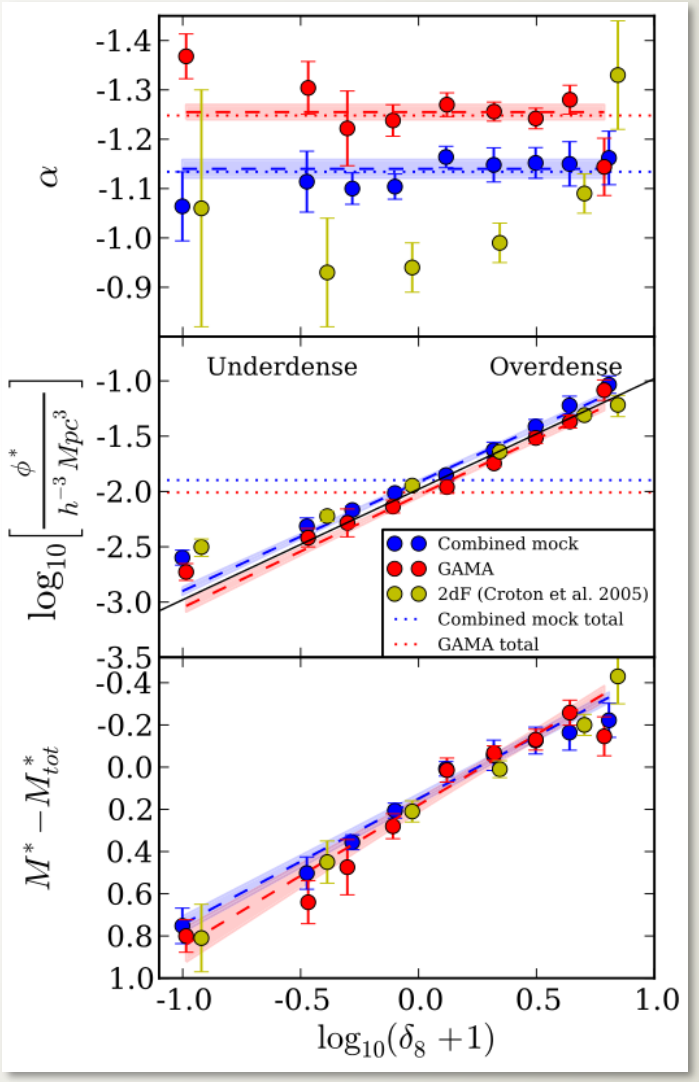
GSMF by morphological type



Moffett et al. (2016)

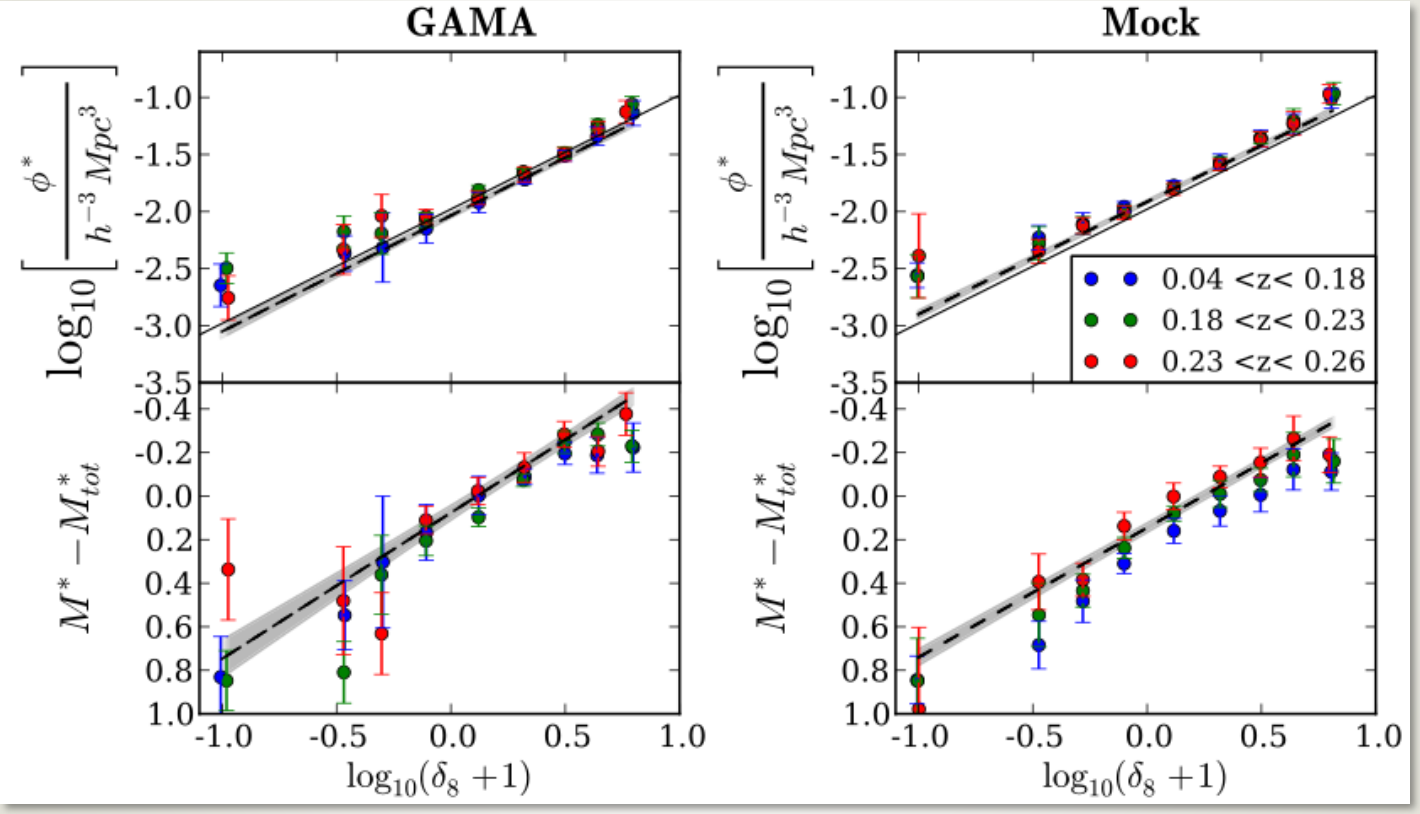
GSMF by local environment





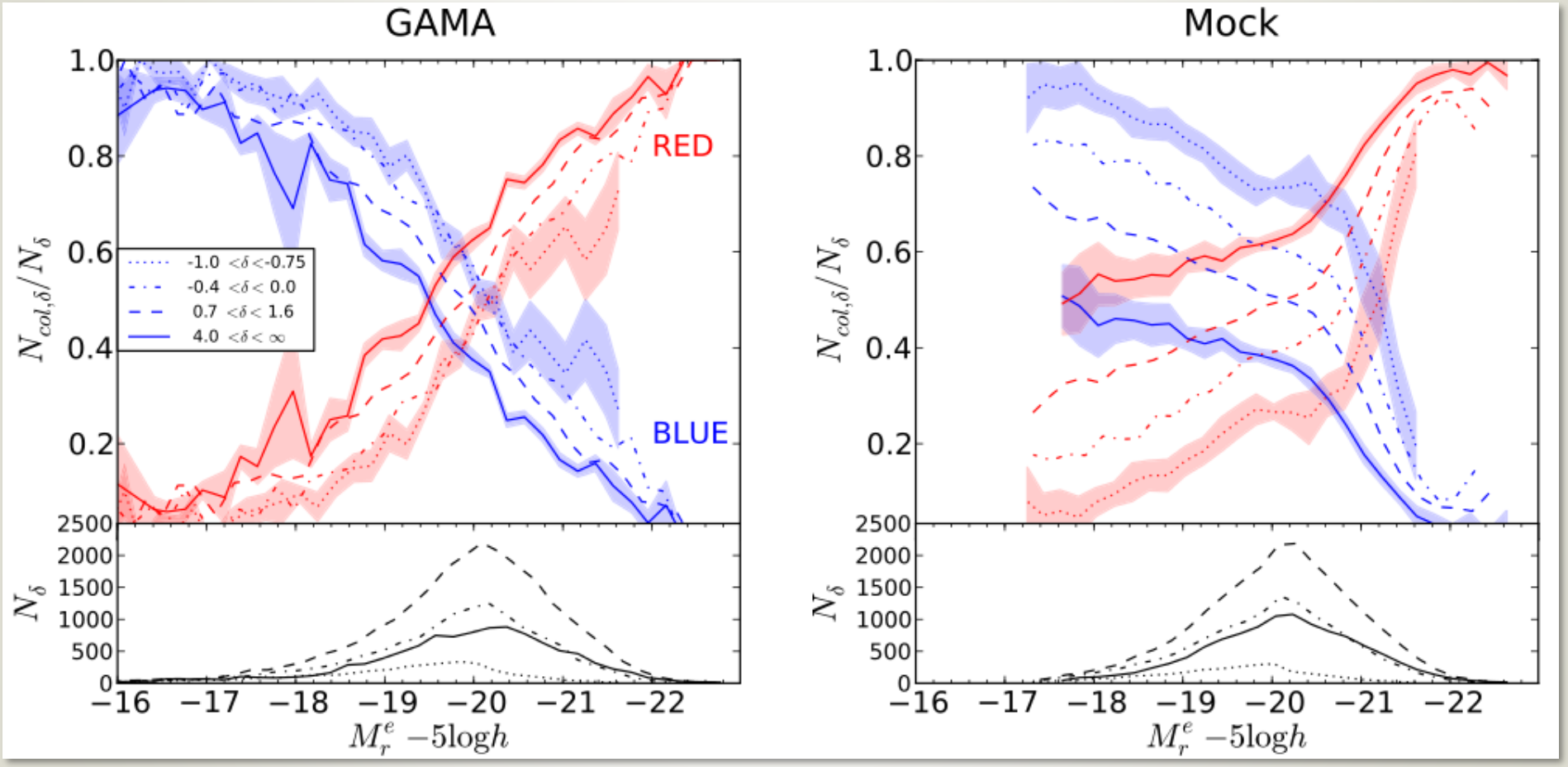
McNaught-Roberts et al. (2014)

GSMF by local environment and z



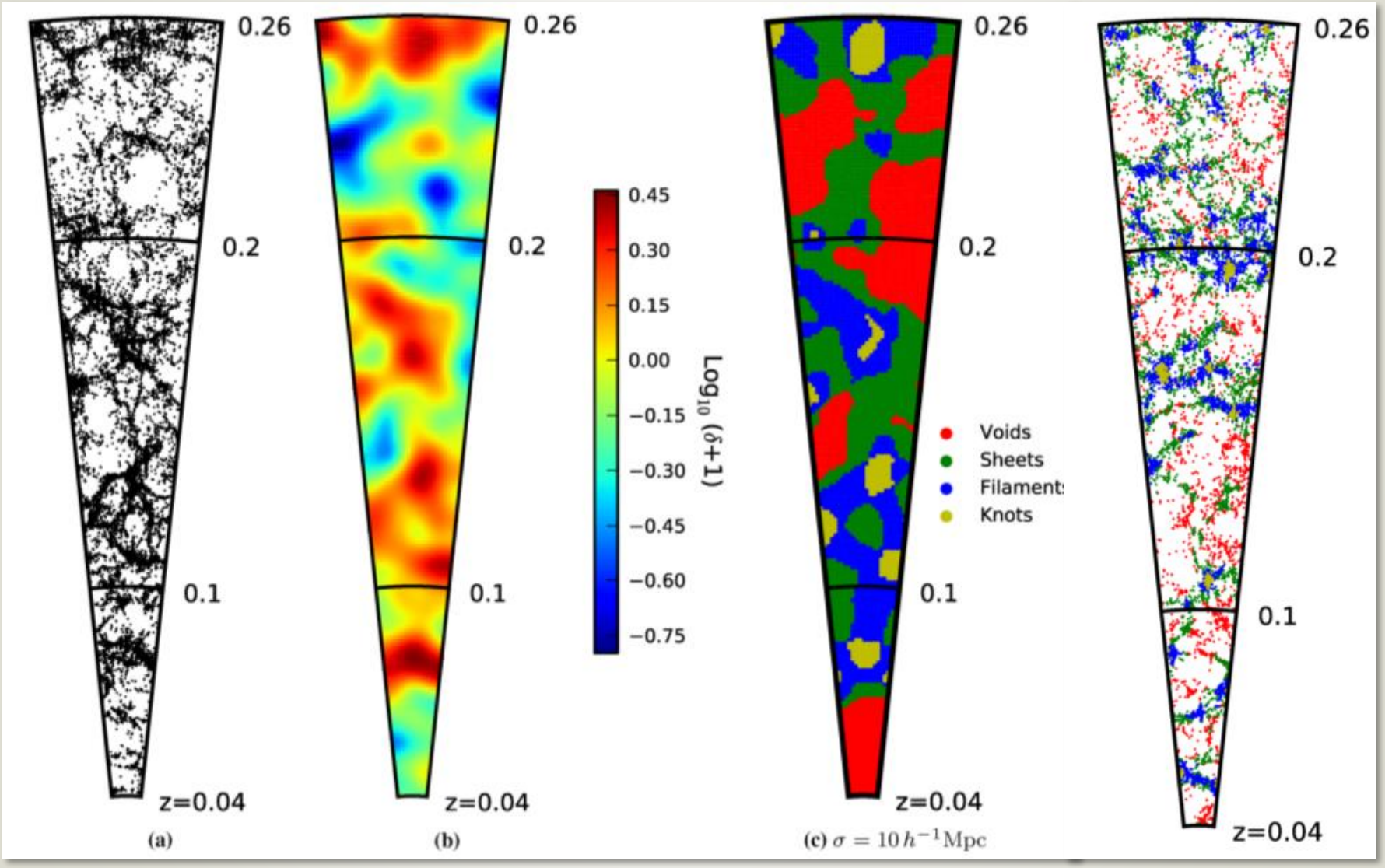
McNaught-Roberts et al. (2014)

Model constraints



McNaught-Roberts et al. (2014)

Does the GSMF depend on LSS?



Eardley et al. (2015)

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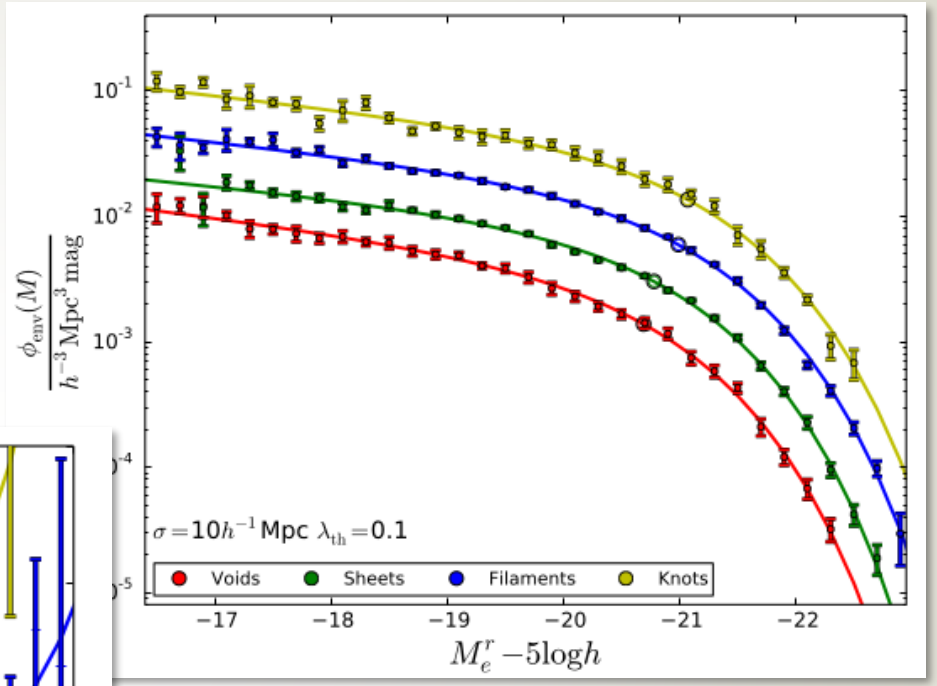
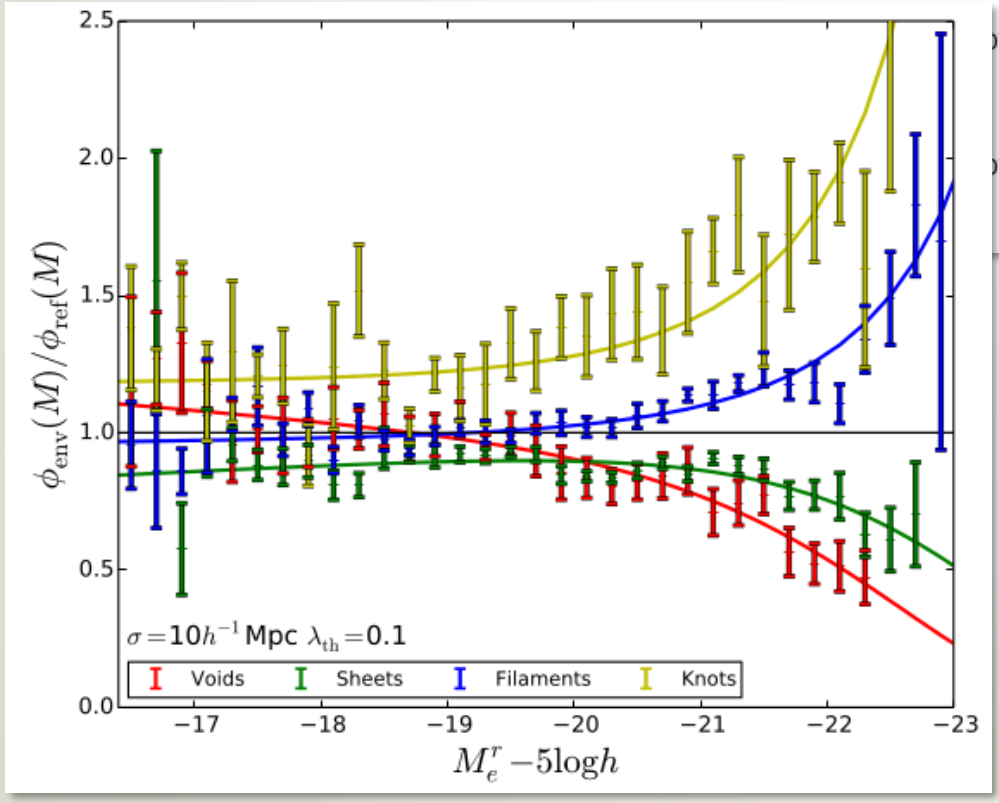
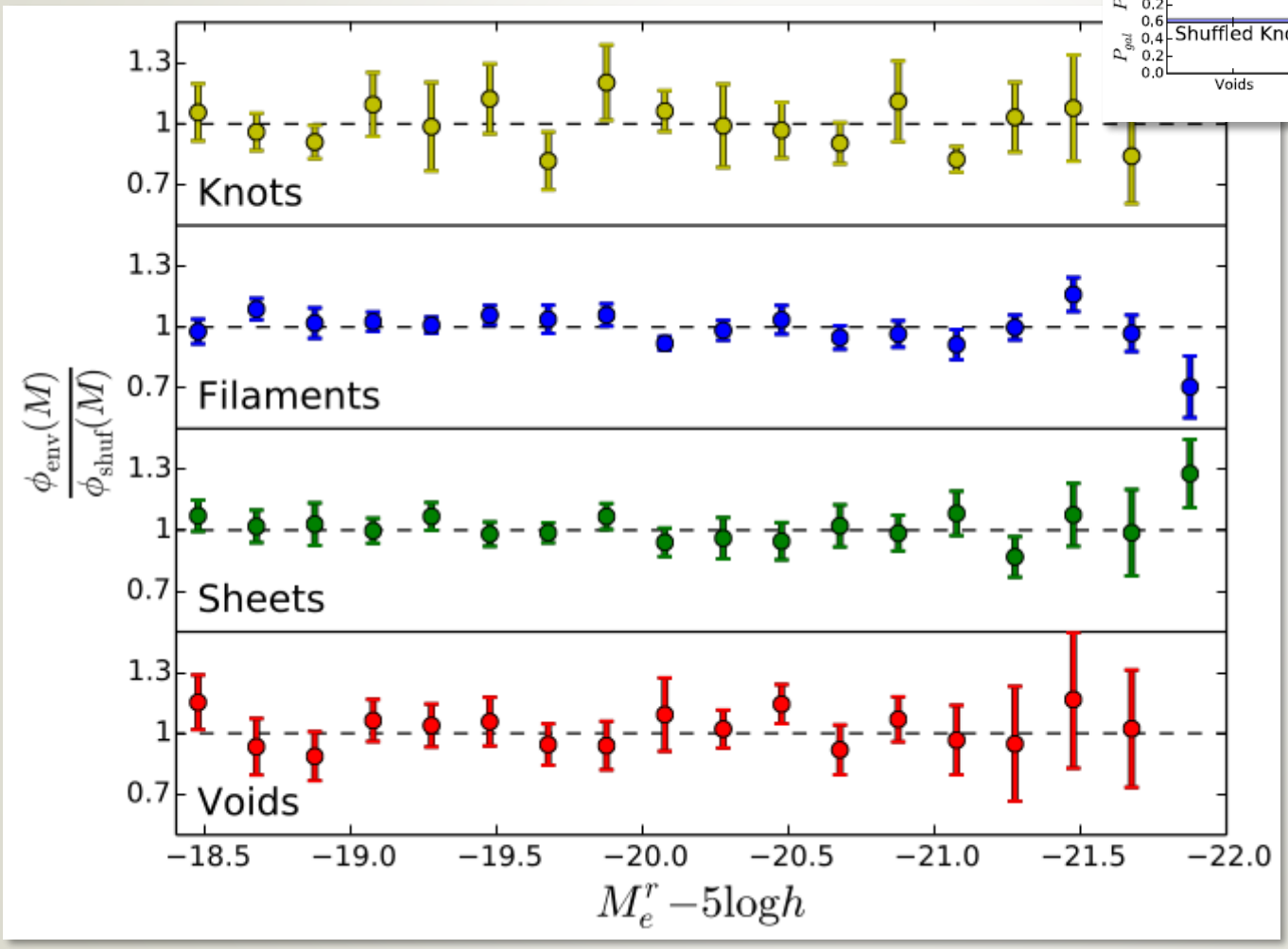
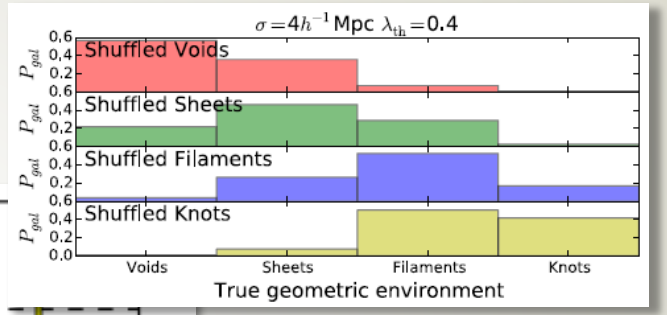




Eardley et al. (2015)

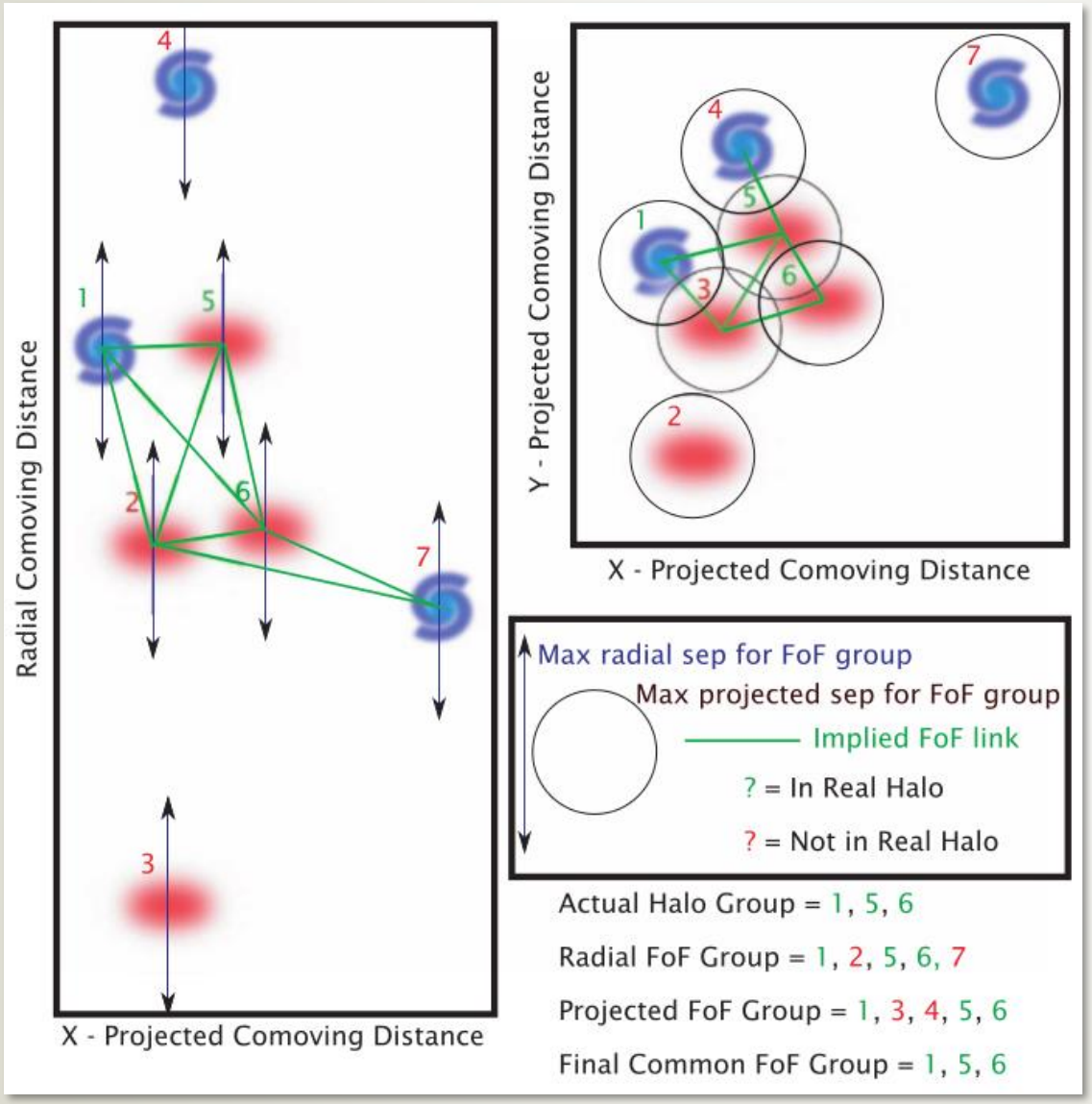
Does the GSMF depend on LSS? No.





Eardley et al. (2015)

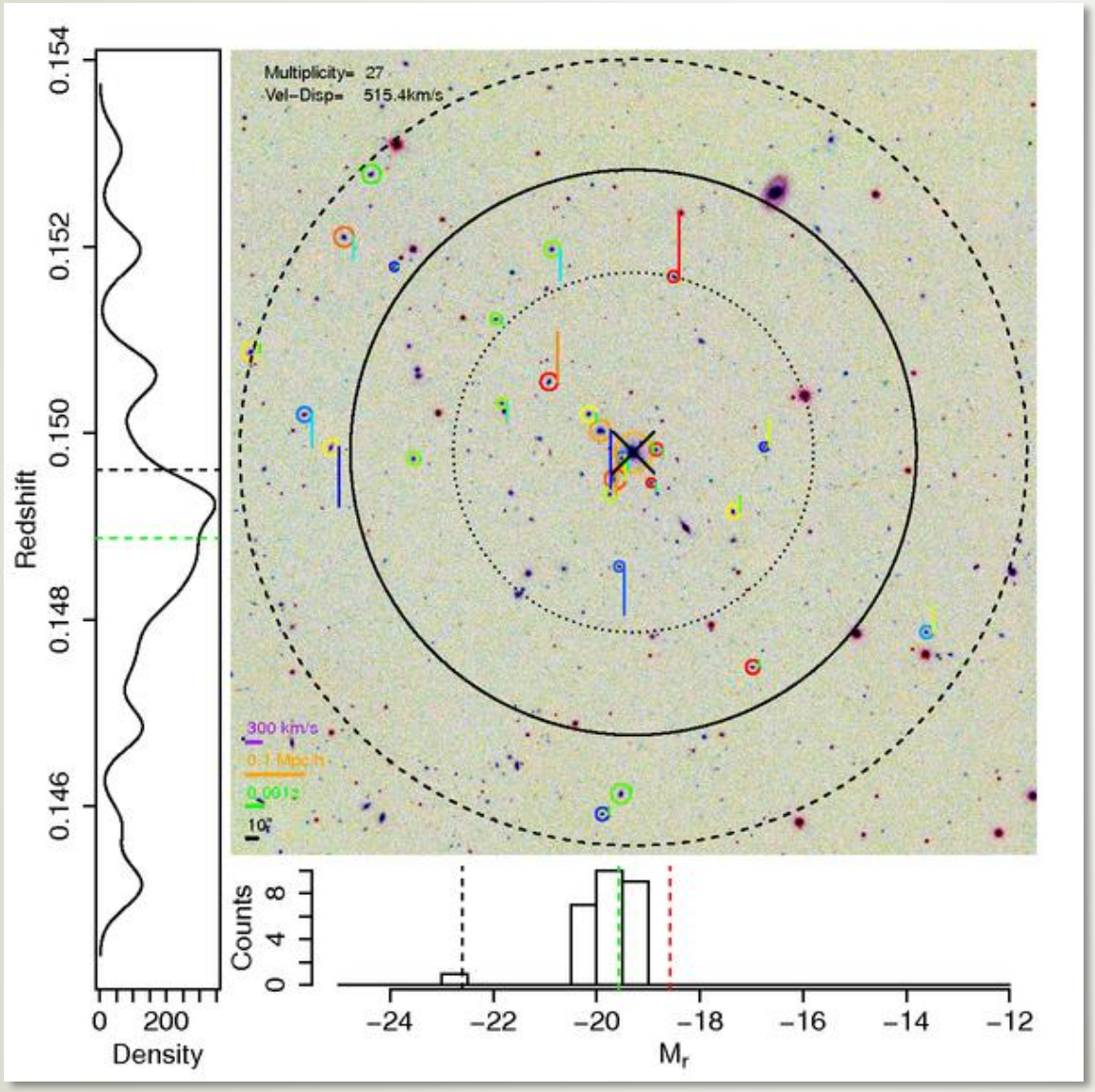
The GAMA group catalogue



- FoF algorithm to identify galaxy groups.
- FoF parameters carefully calibrated on mocks.
- ~24,000 groups in equatorial survey regions.
- 2754 groups with $N_{fof} > 4$

Robotham et al. (2011)

The GAMA group catalogue



Robotham et al. (2011)

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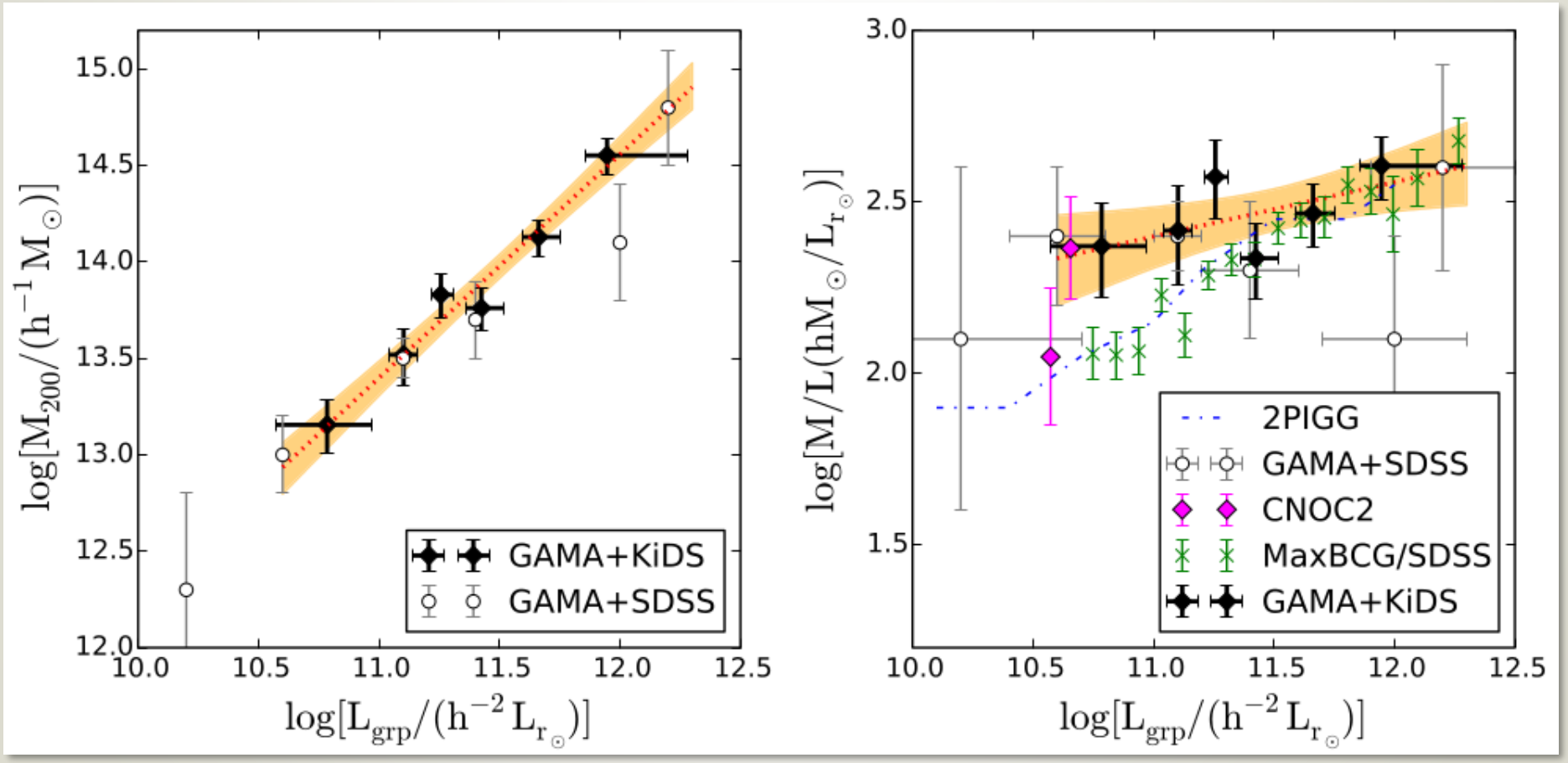
GAMA + KiDS → weak lensing

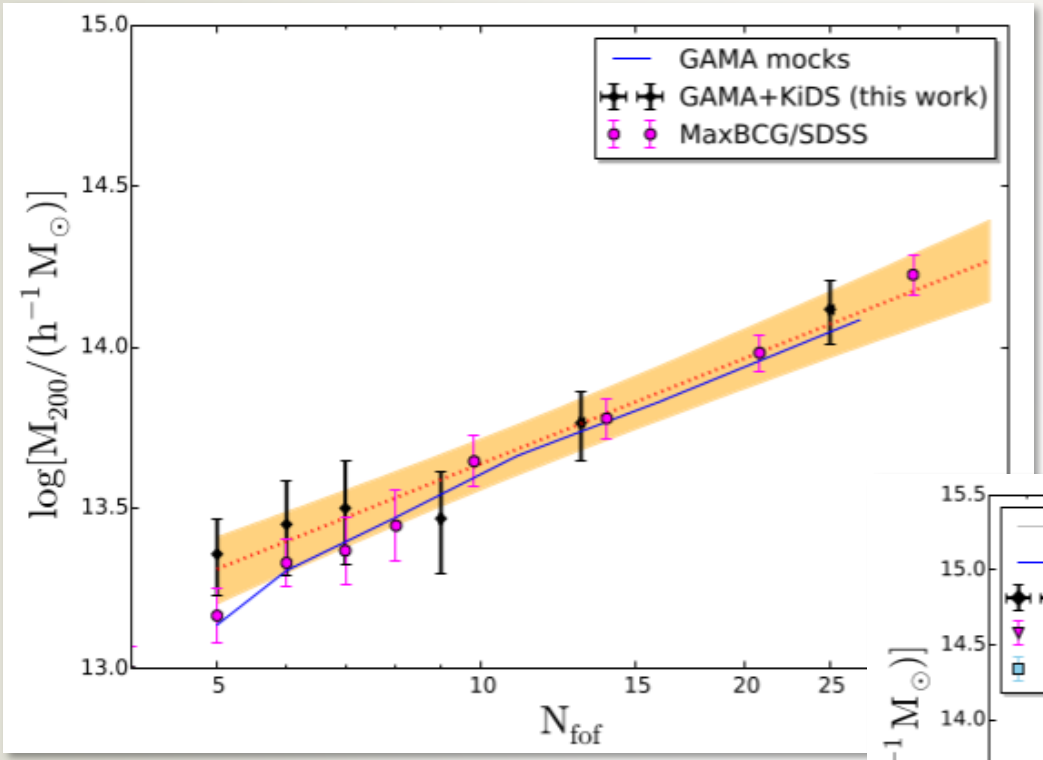
Analysis of an initial joint GAMA+KiDS dataset covering 100 deg^2

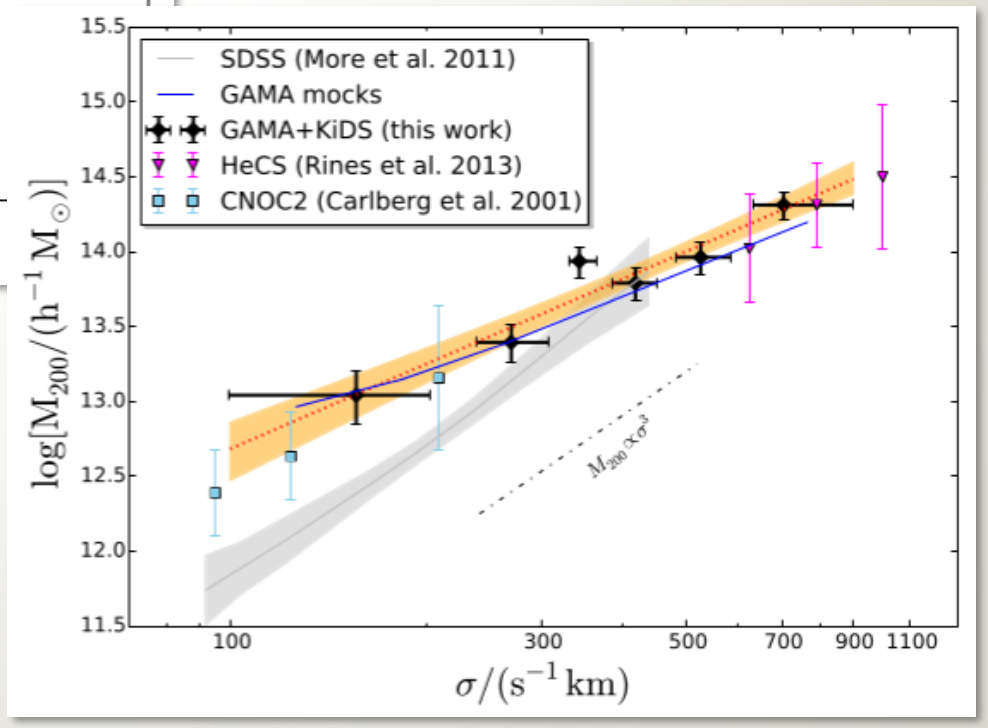
- The DM density profiles of group halos are well described by NFW
- Average halo masses → scaling relations
- Provides constraints on feedback models on group scales



Viola et al. (2015)

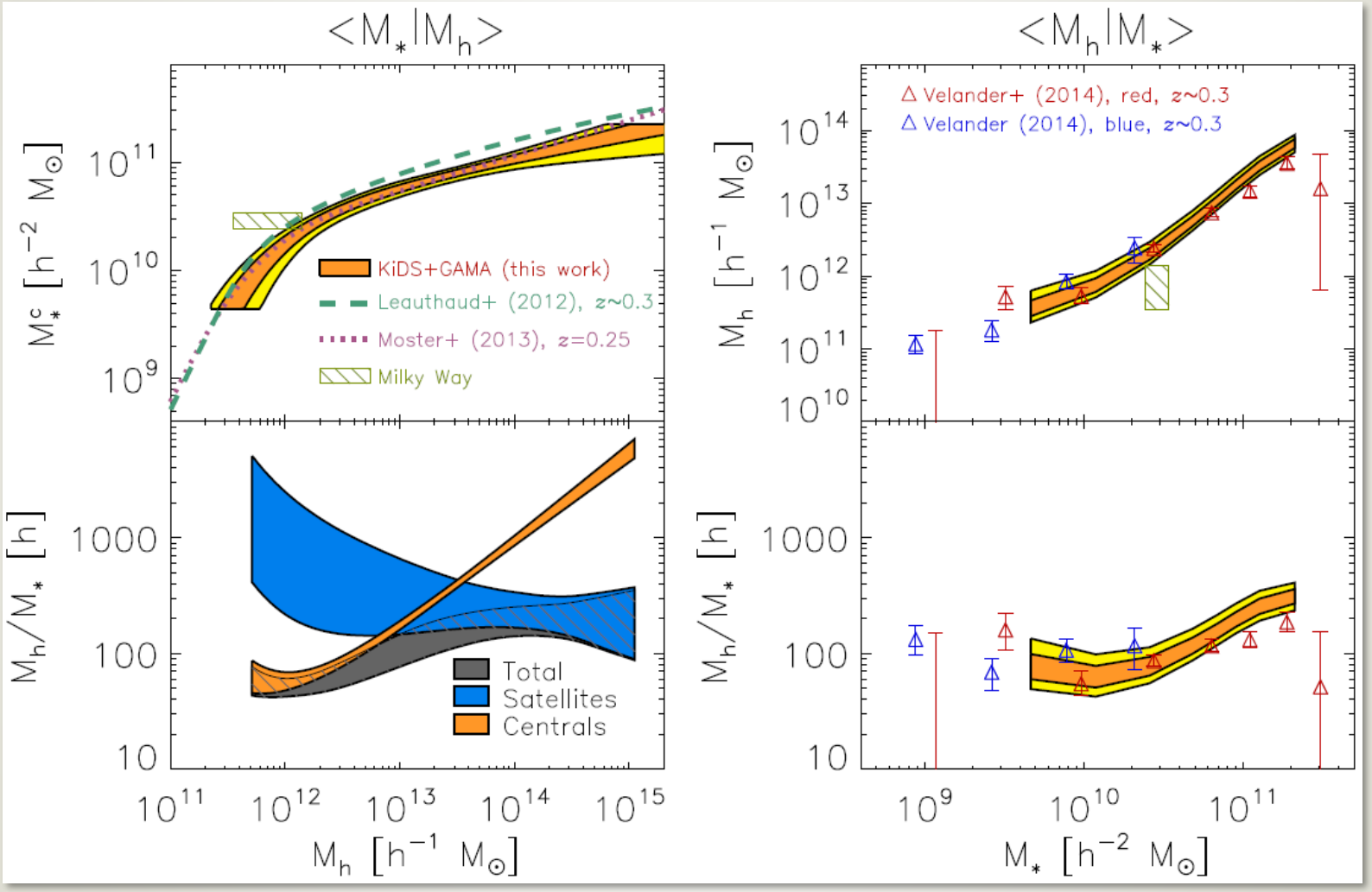
GAMA + KiDS → weak lensing





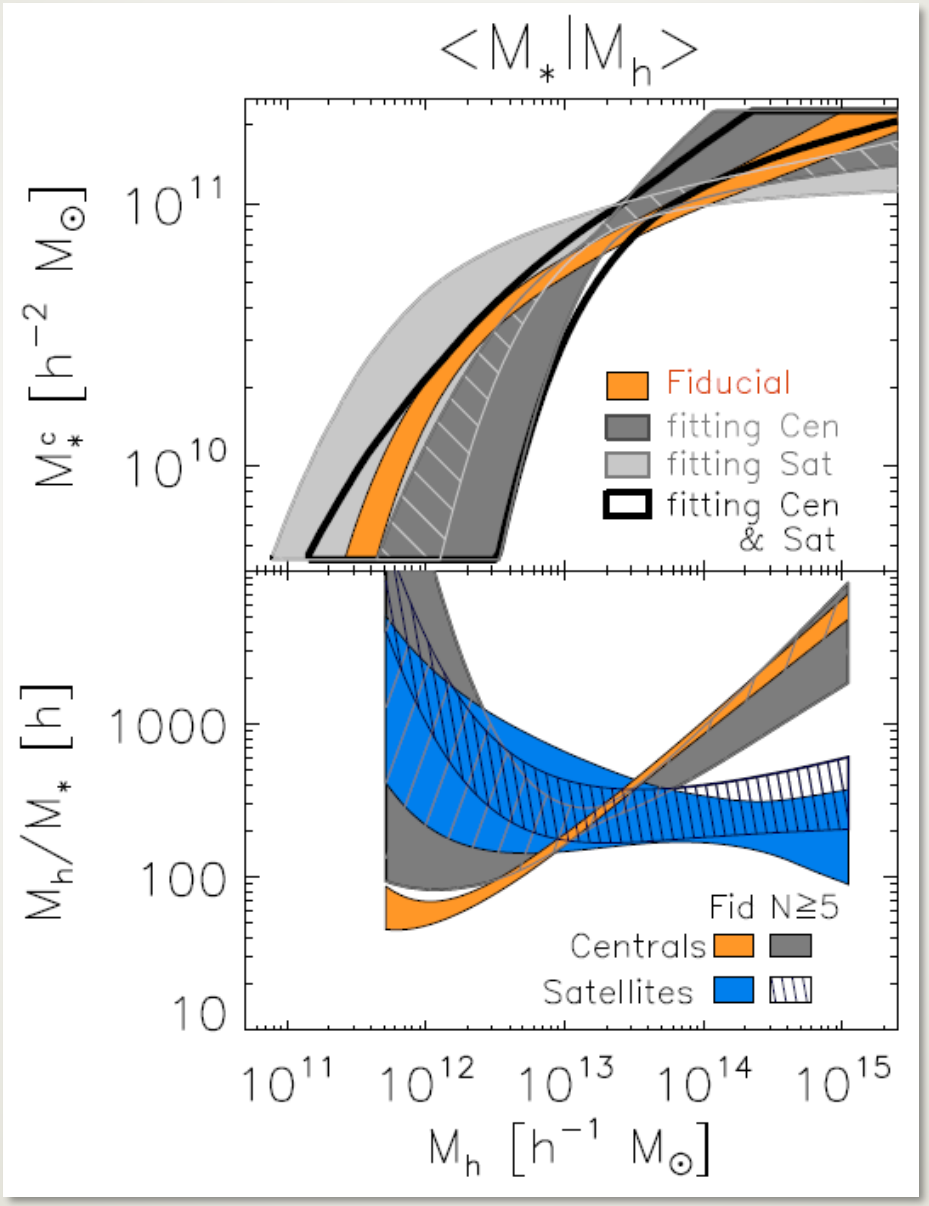
Viola et al. (2015)

Galaxy-galaxy weak lensing



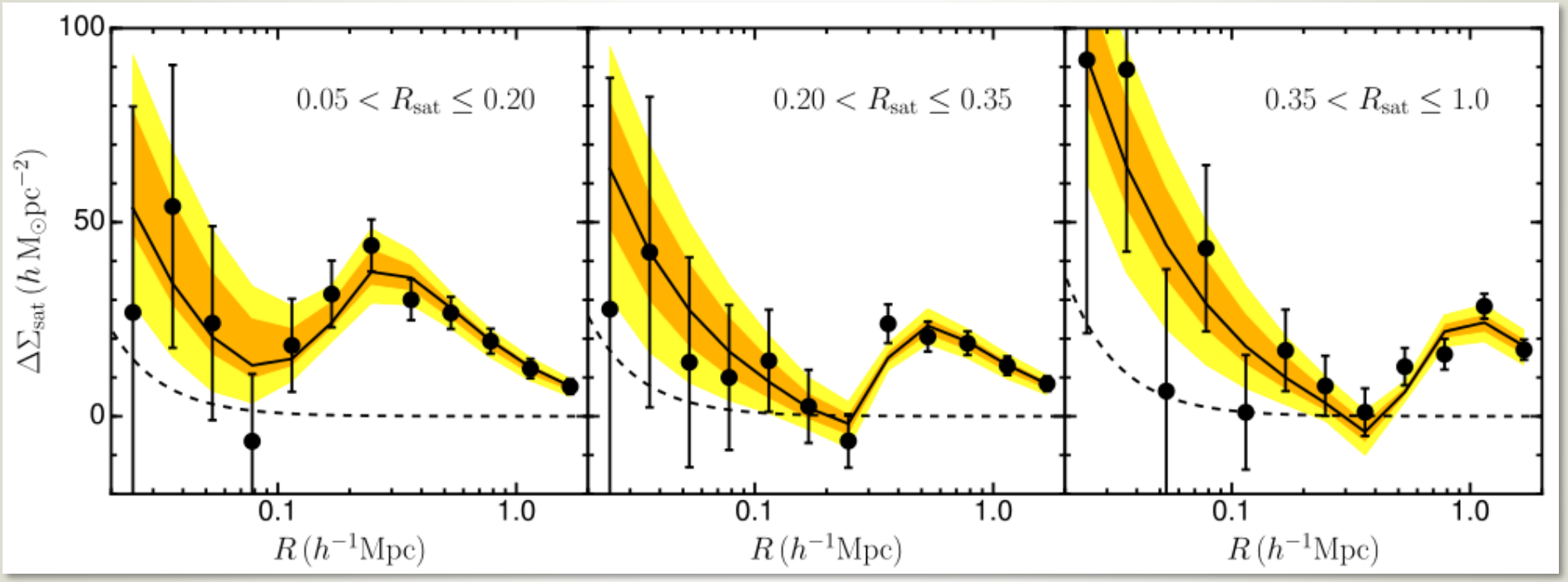
Van Uitert et al. (in prep)

Stallar-halo mass ratio in dense environments



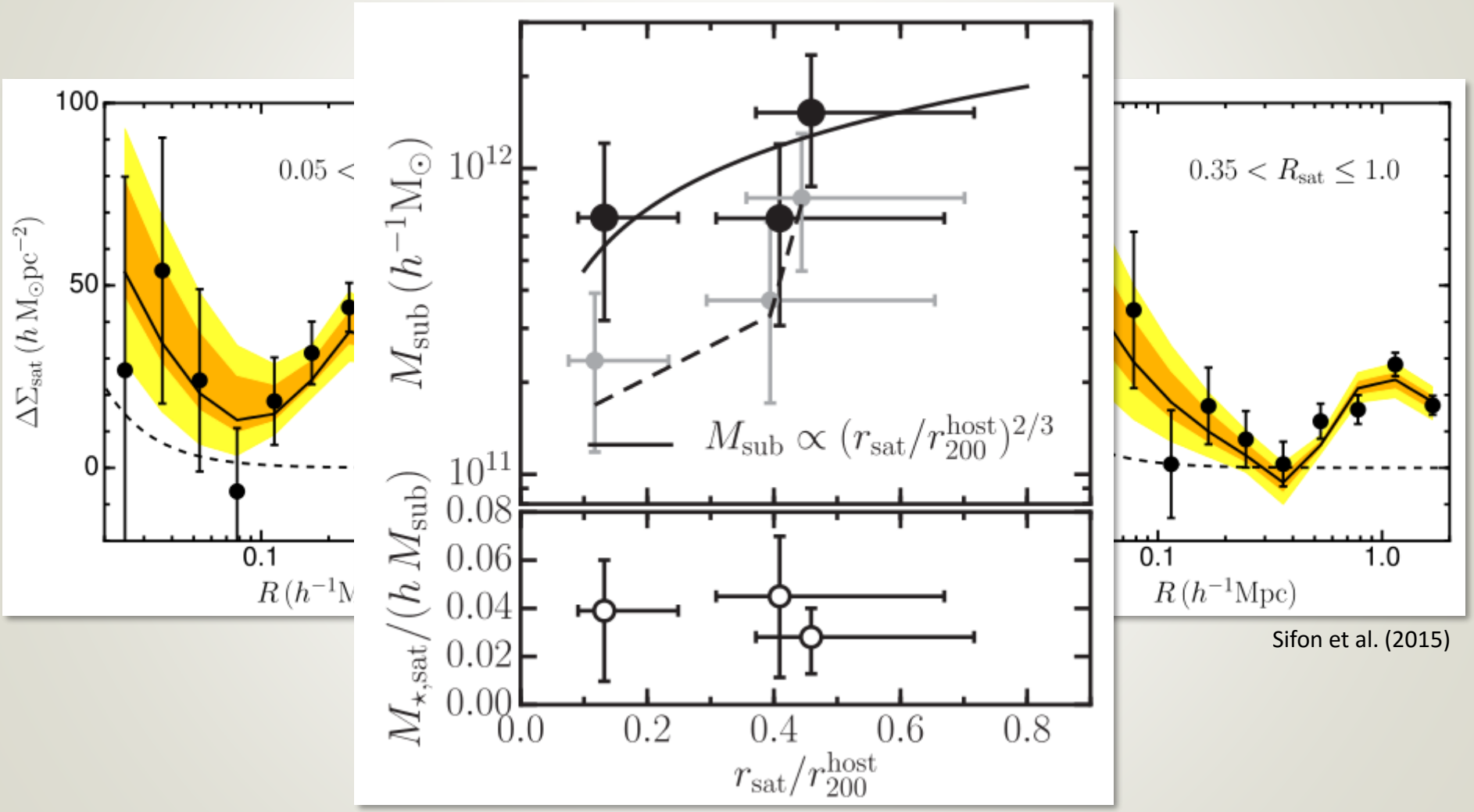
Van Uitert et al. (in prep)

The masses of infalling sub-halos



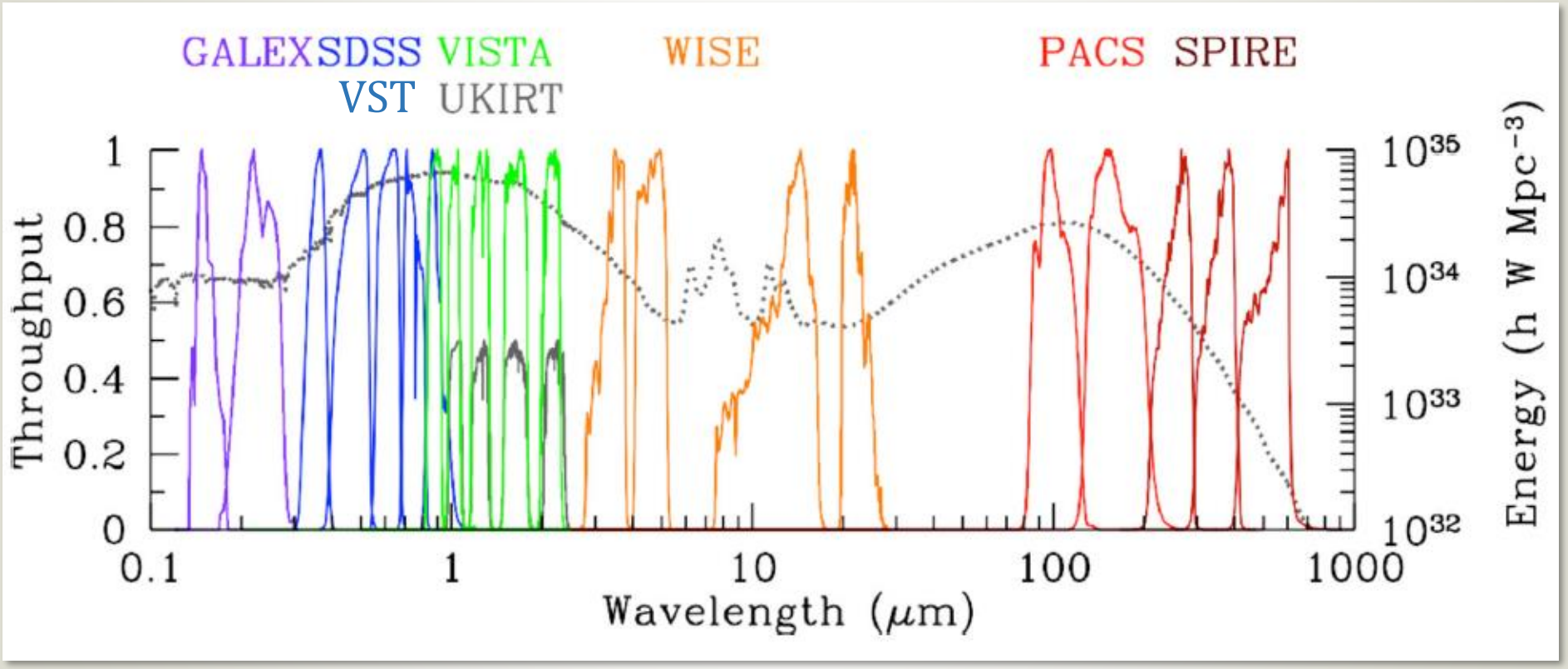
Sifon et al. (2015)

The masses of infalling sub-halos

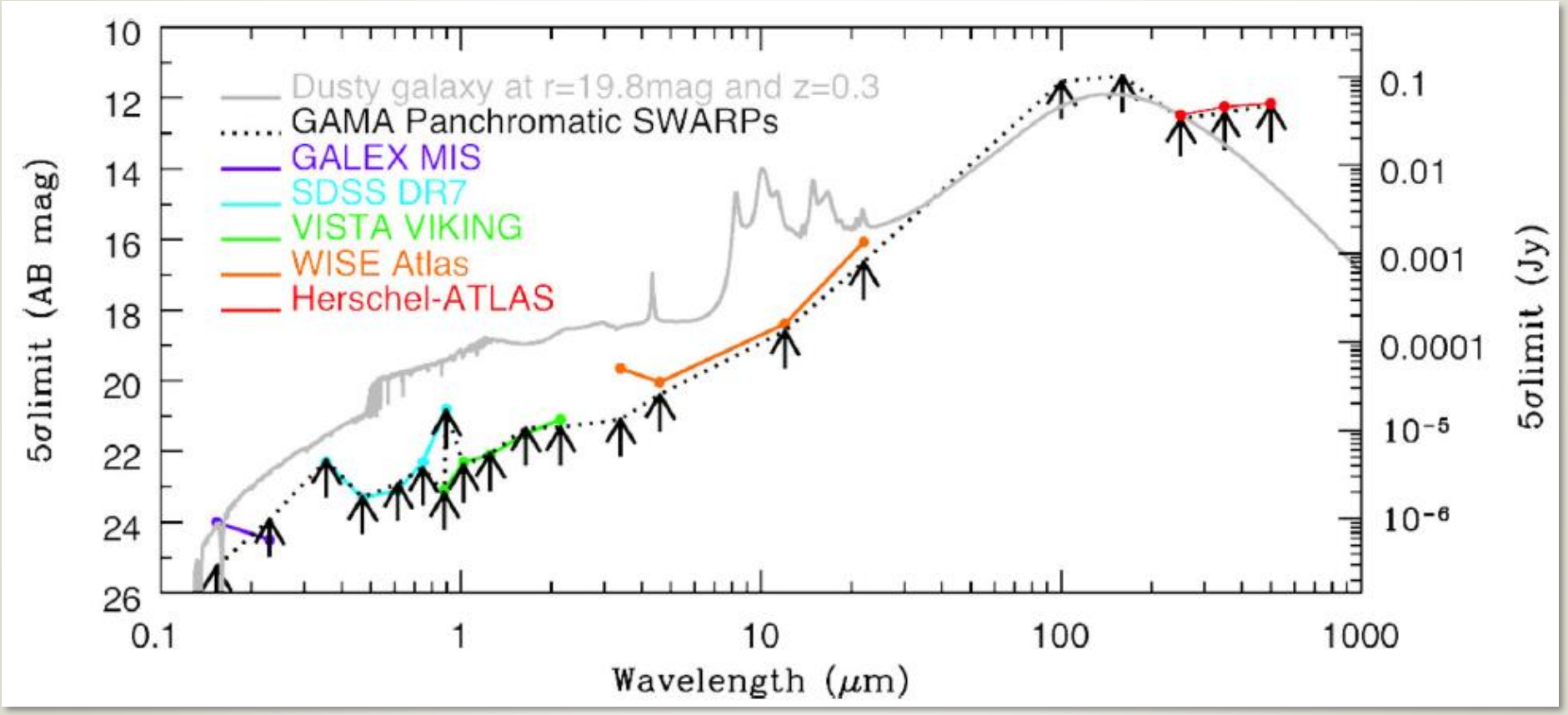


Sifon et al. (2015)

Panchromatic photometry

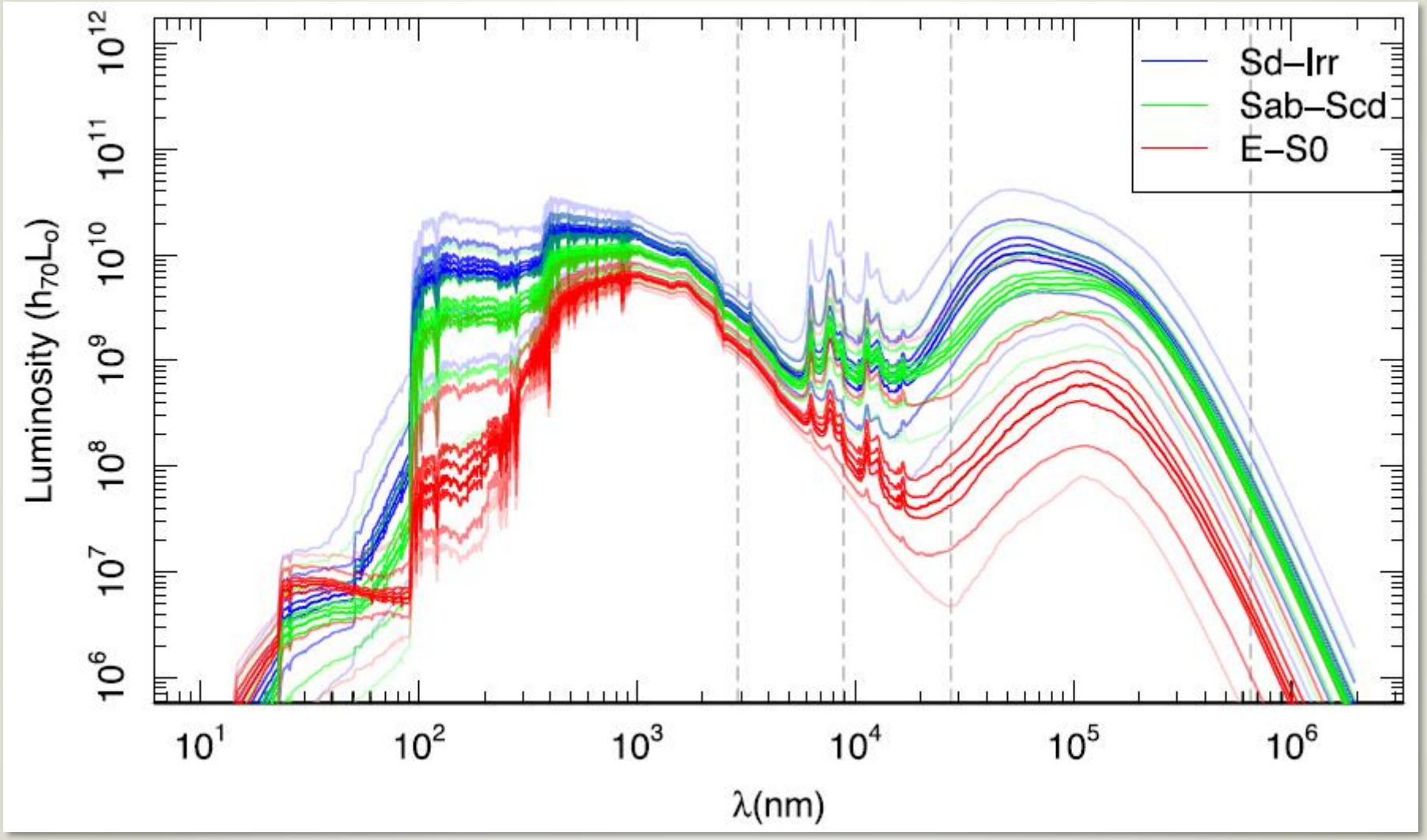


Panchromatic photometry



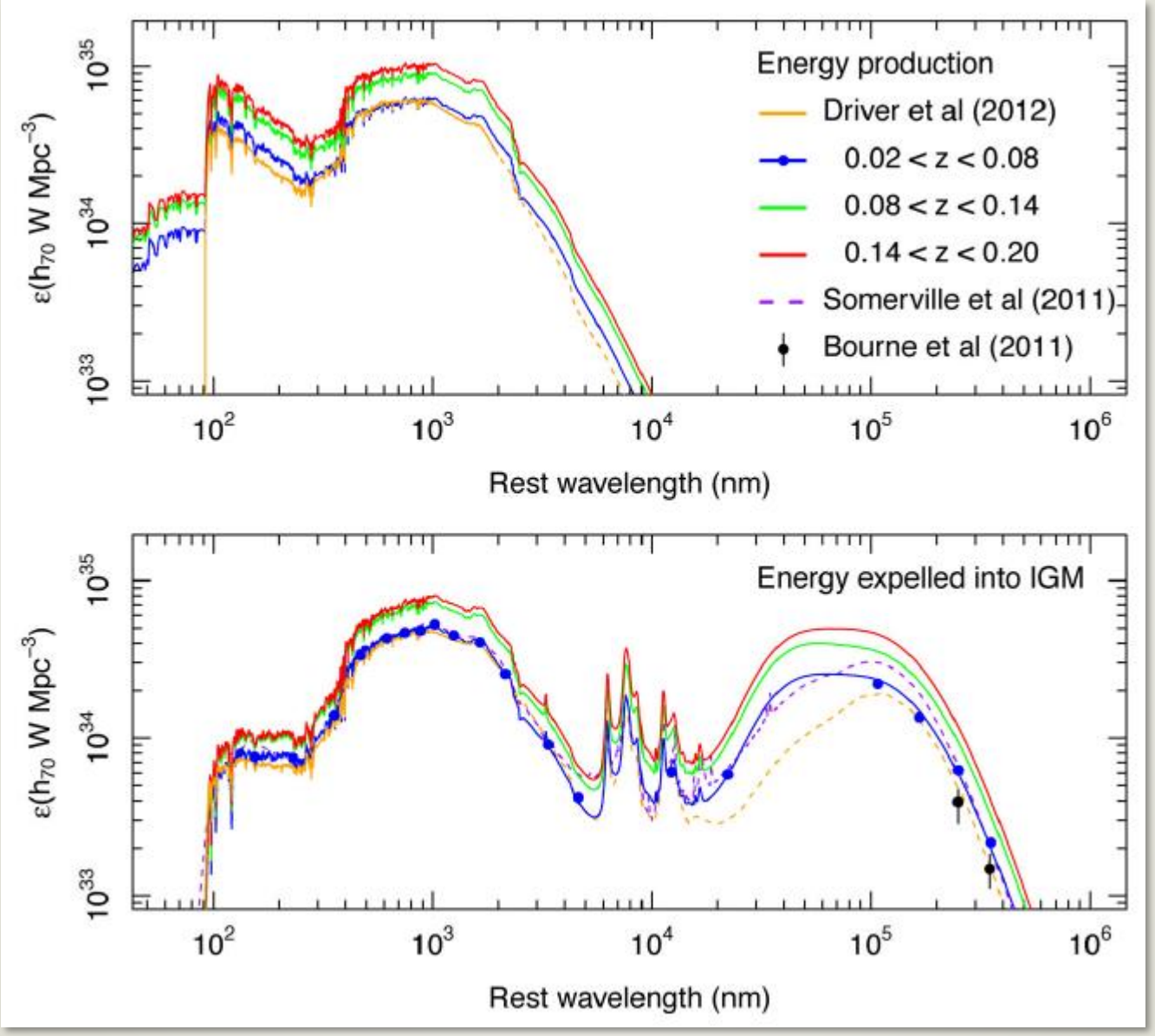
Driver et al. (2016)

Panchromatic photometry



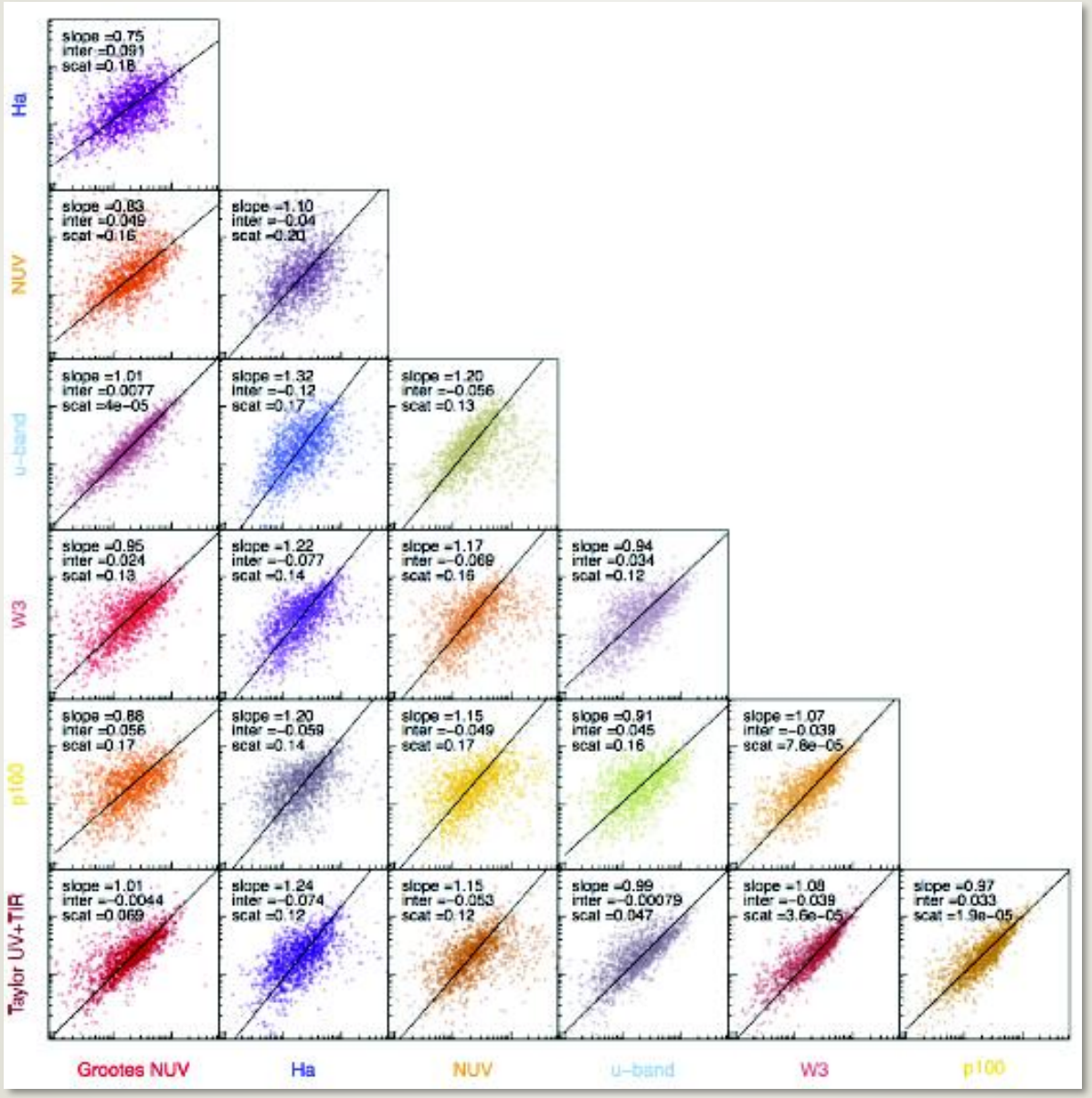
Driver et al. (2016)

Panchromatic photometry



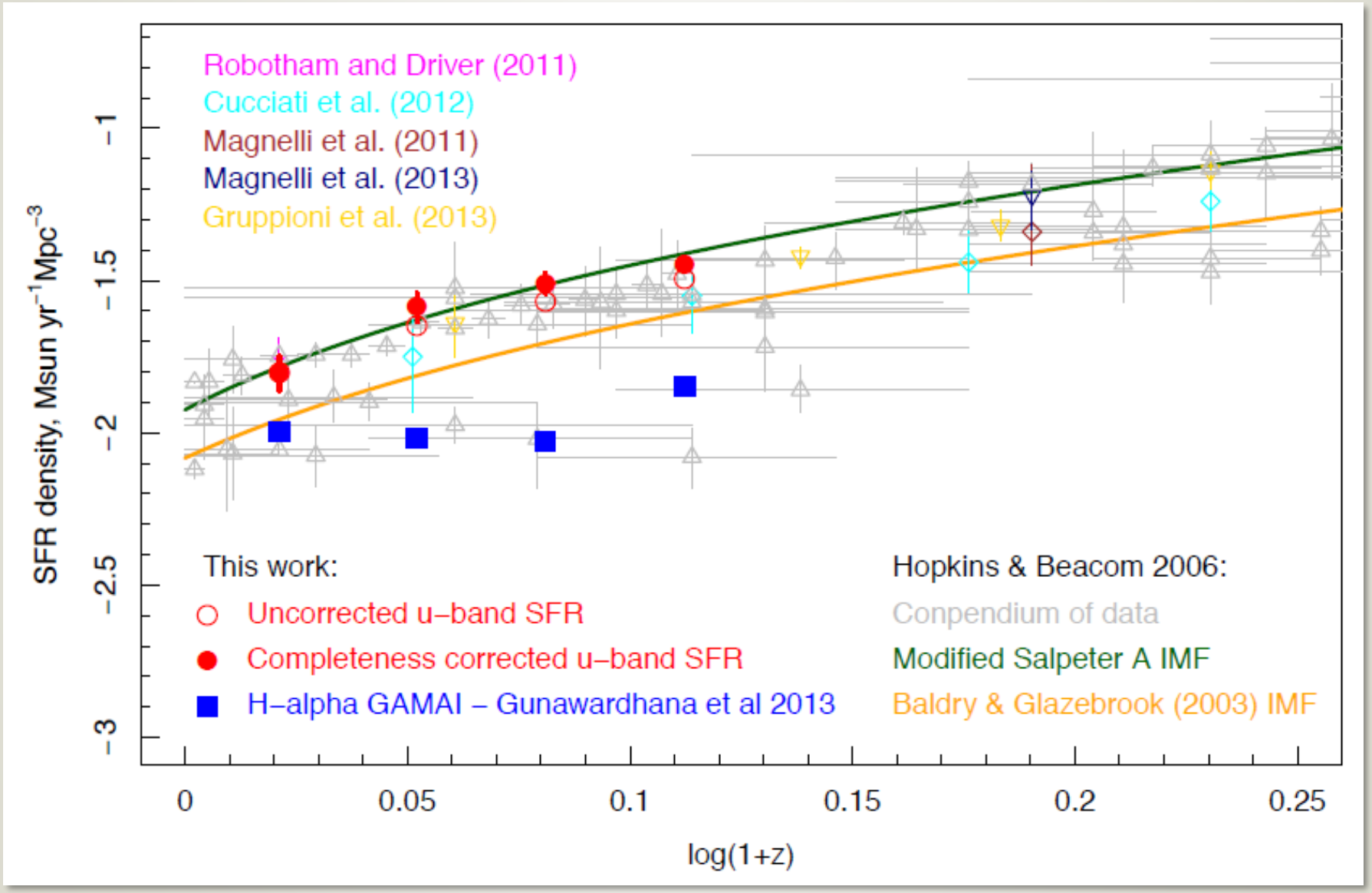
Driver et al. (2016)

Recalibrating SFR indicators



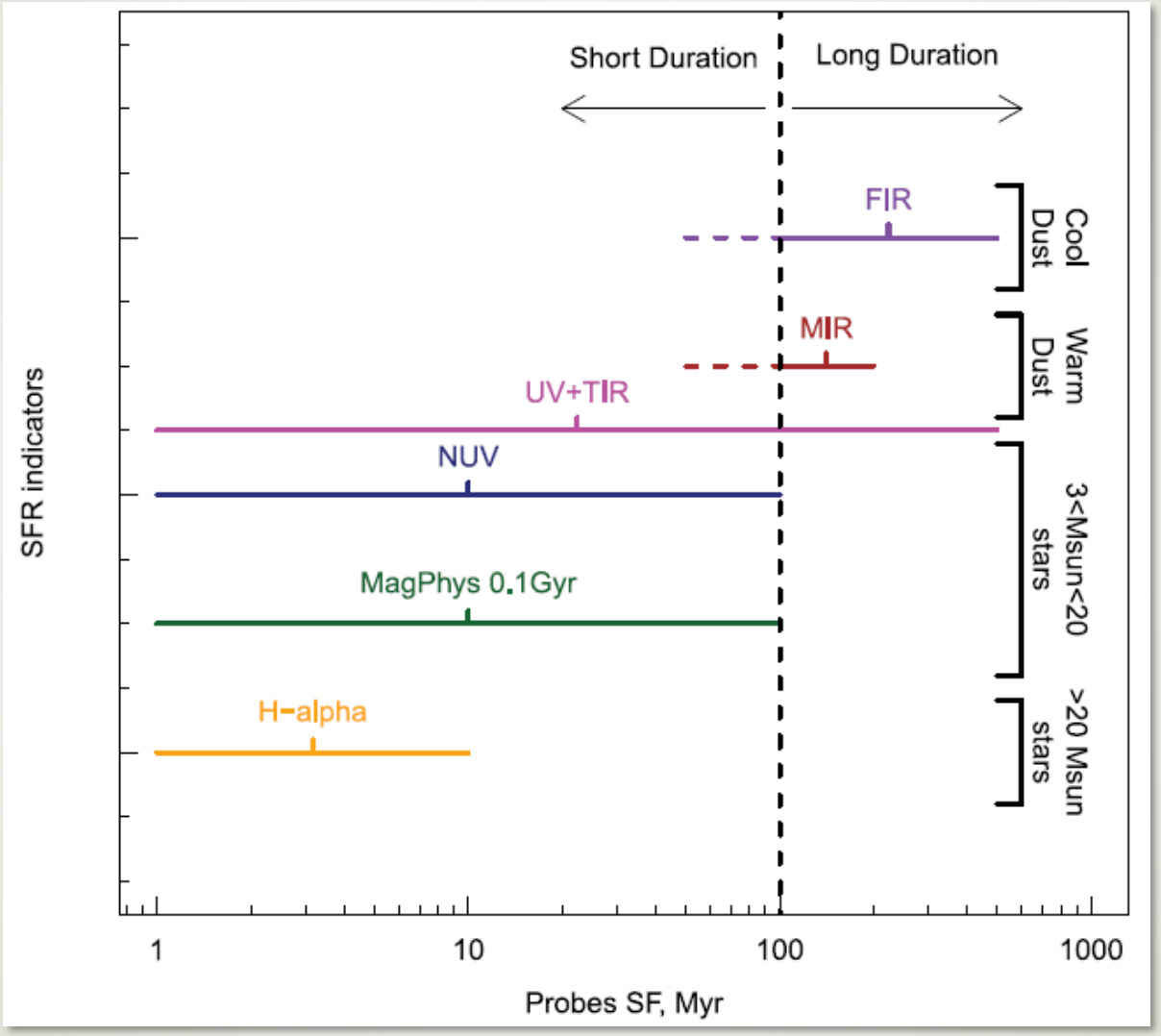
Davies et al. (in prep)

SFR density evolution



Davies et al. (in prep)

The effect of galaxy interactions on the SFR



Davies et al. (2015)

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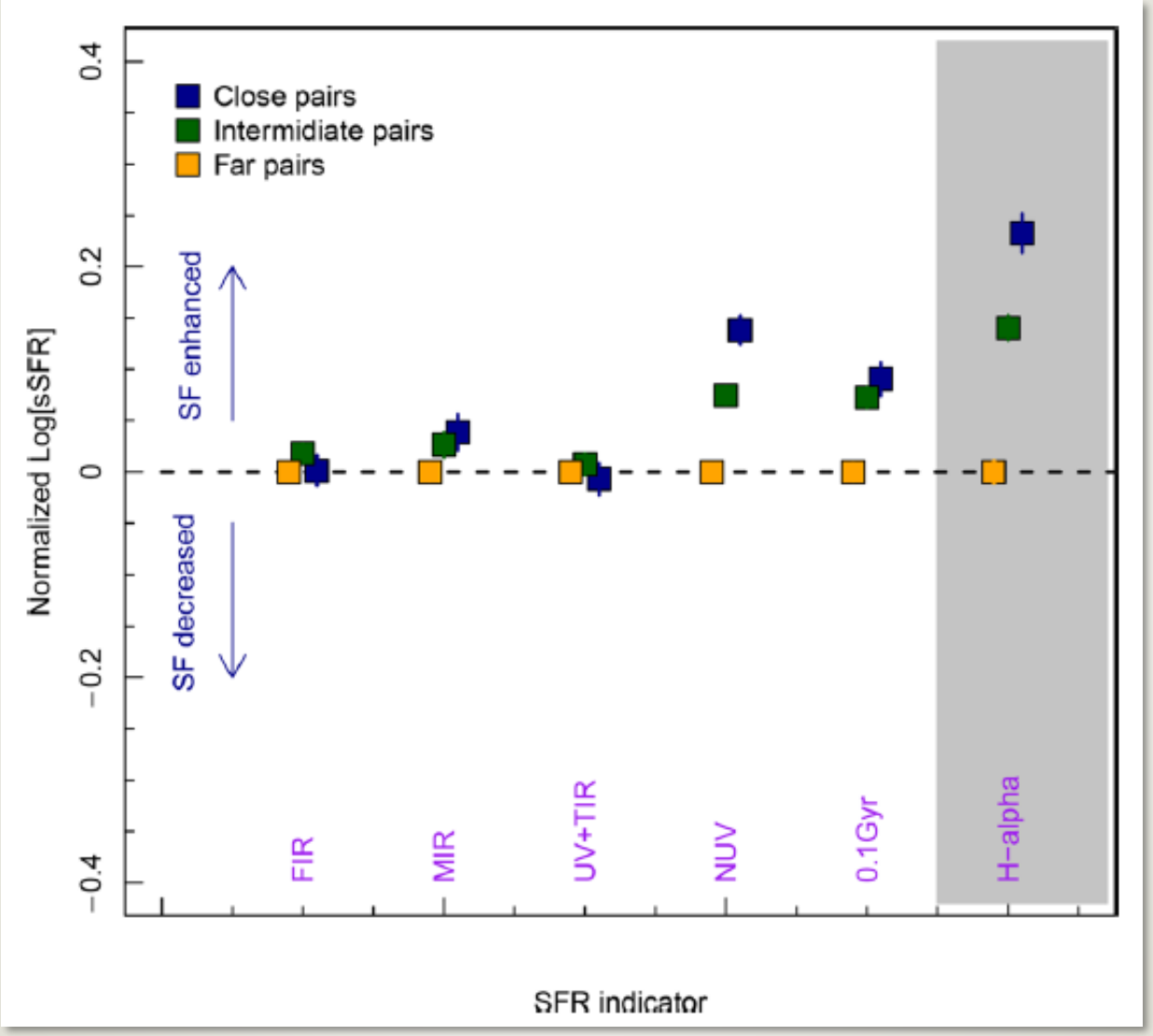

Davies et al. (2015)

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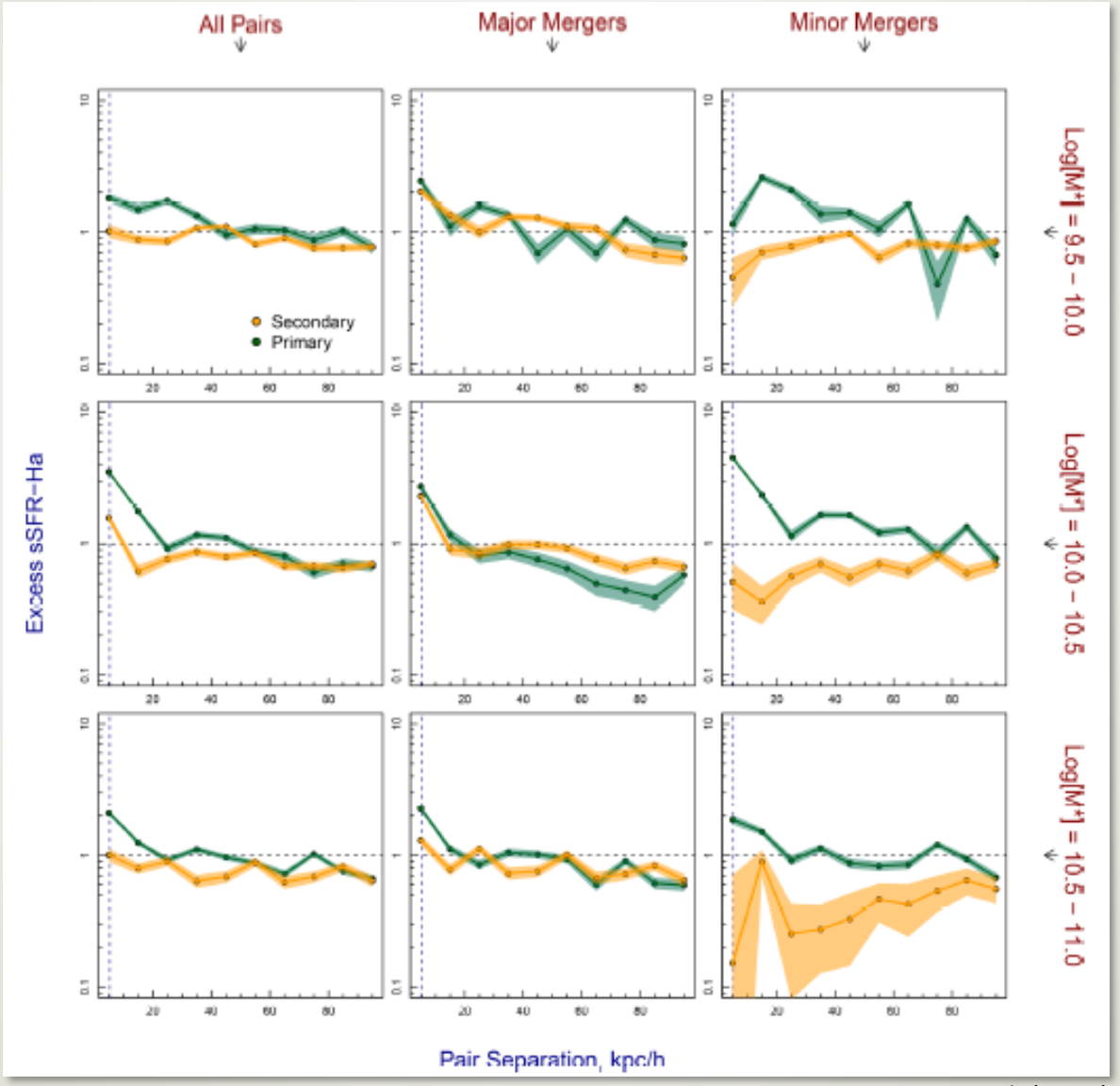
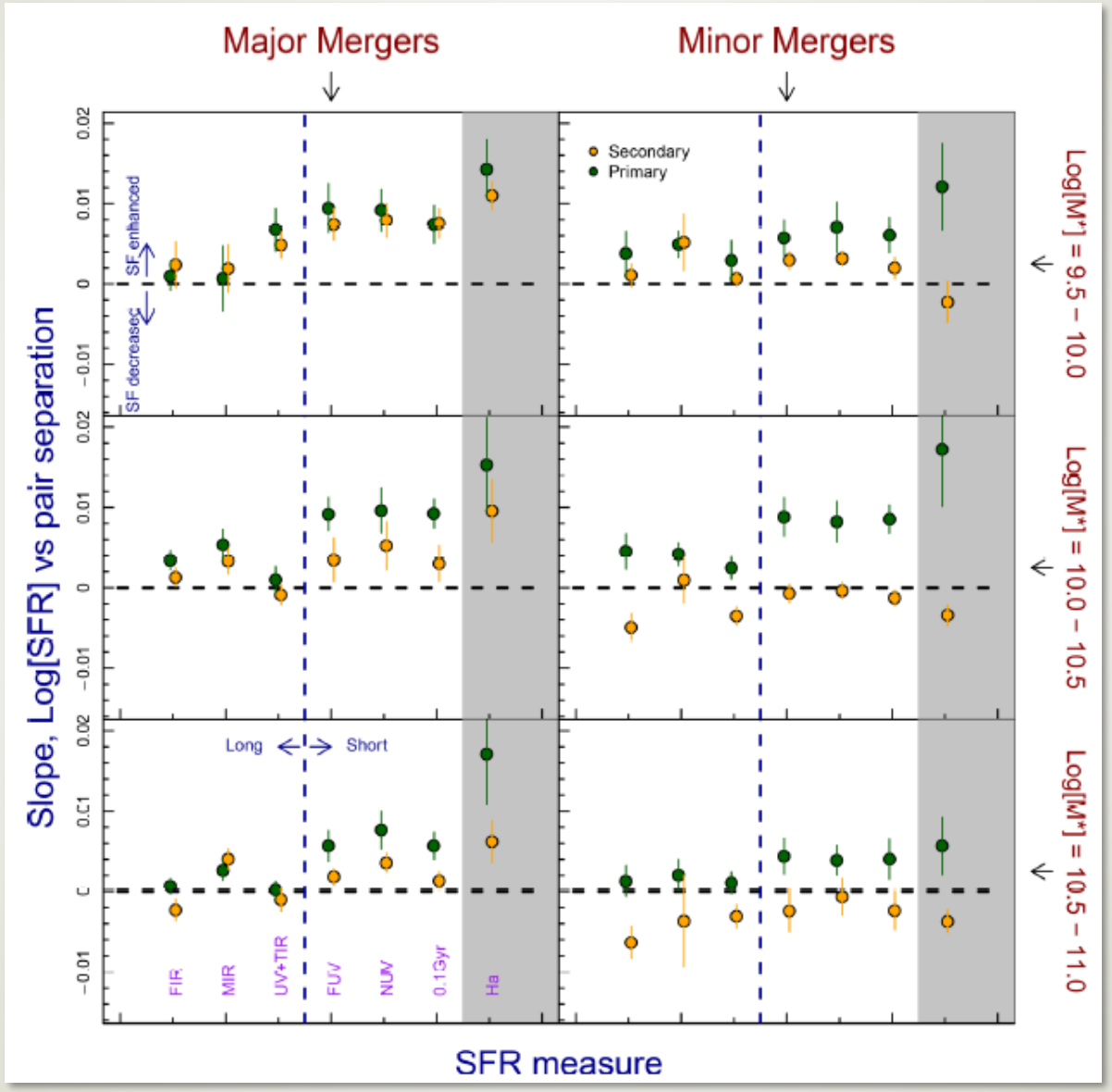


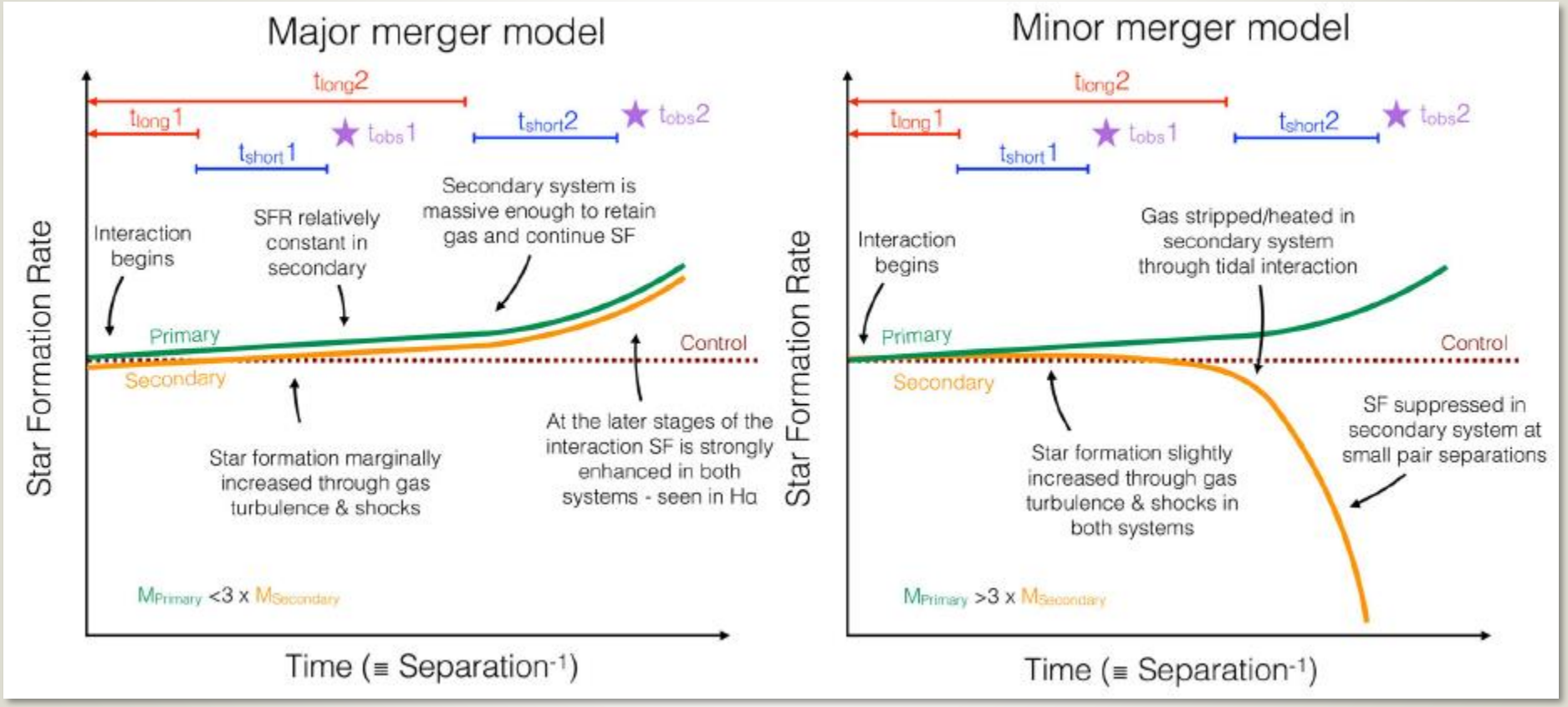
Davies et al. (2015)

The effect of galaxy interactions on the SFR



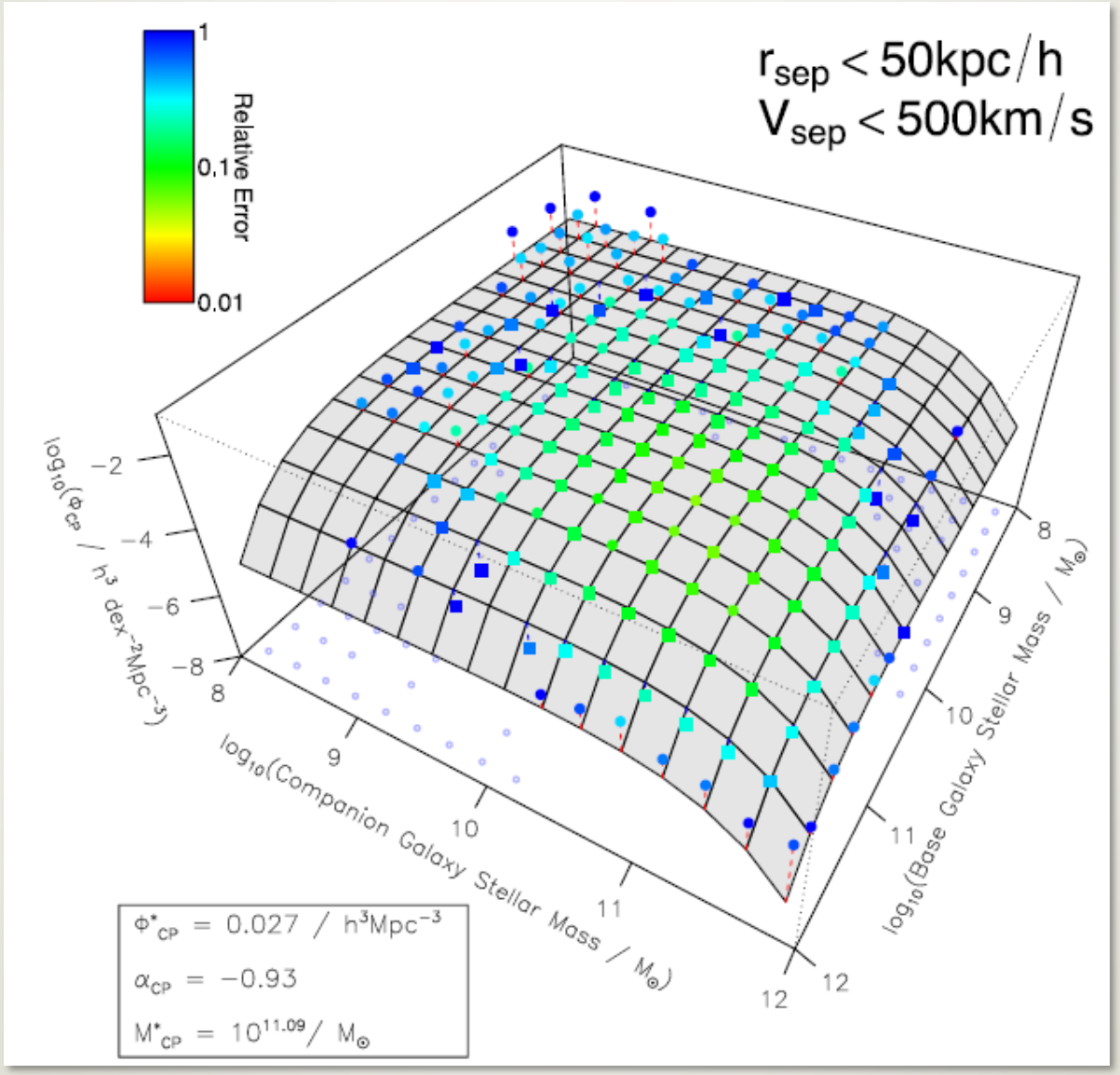
Davies et al. (2015)

The effect of galaxy interactions on the SFR



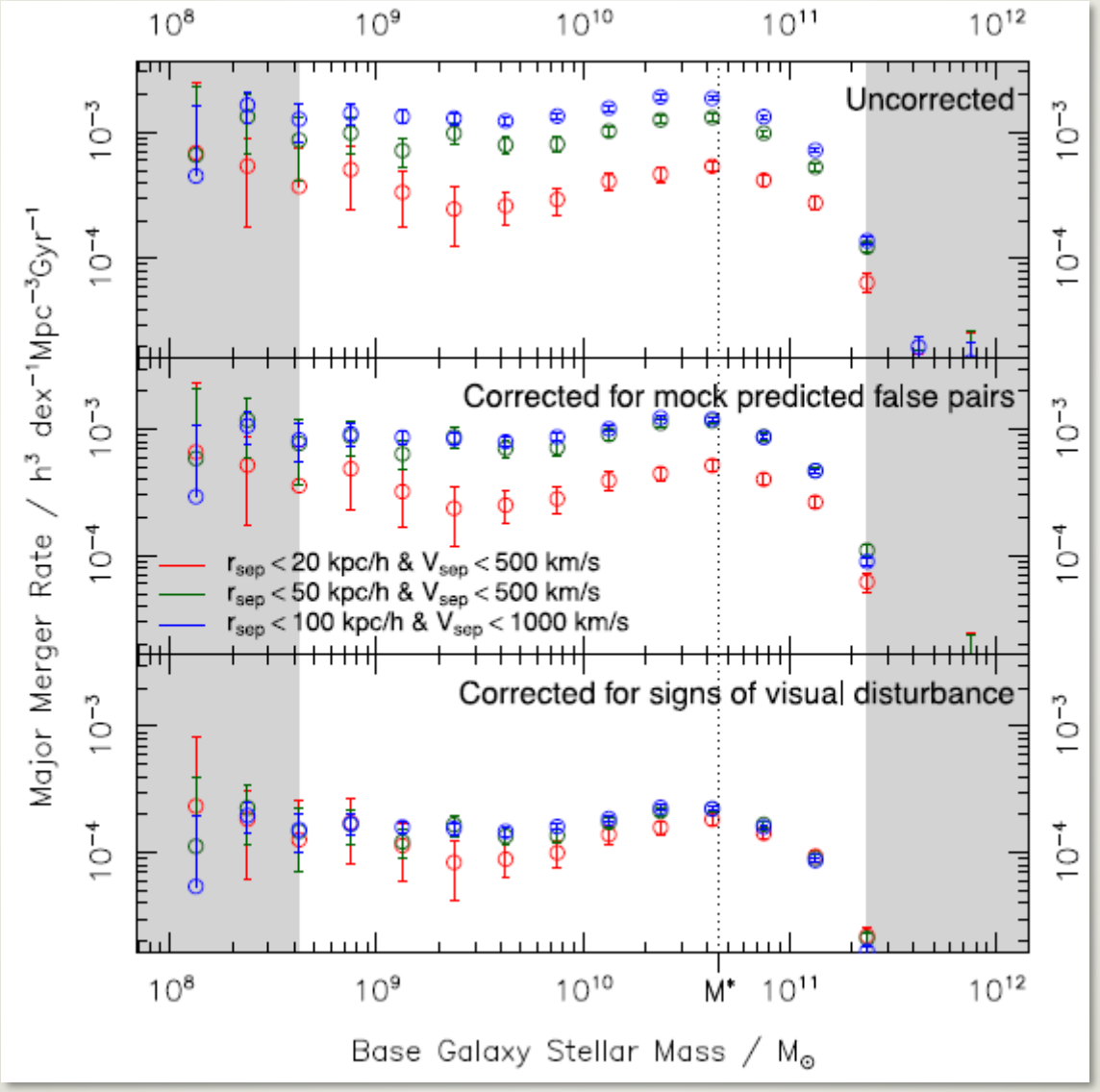
Davies et al. (2015)

The stellar mass dependence of close pairs



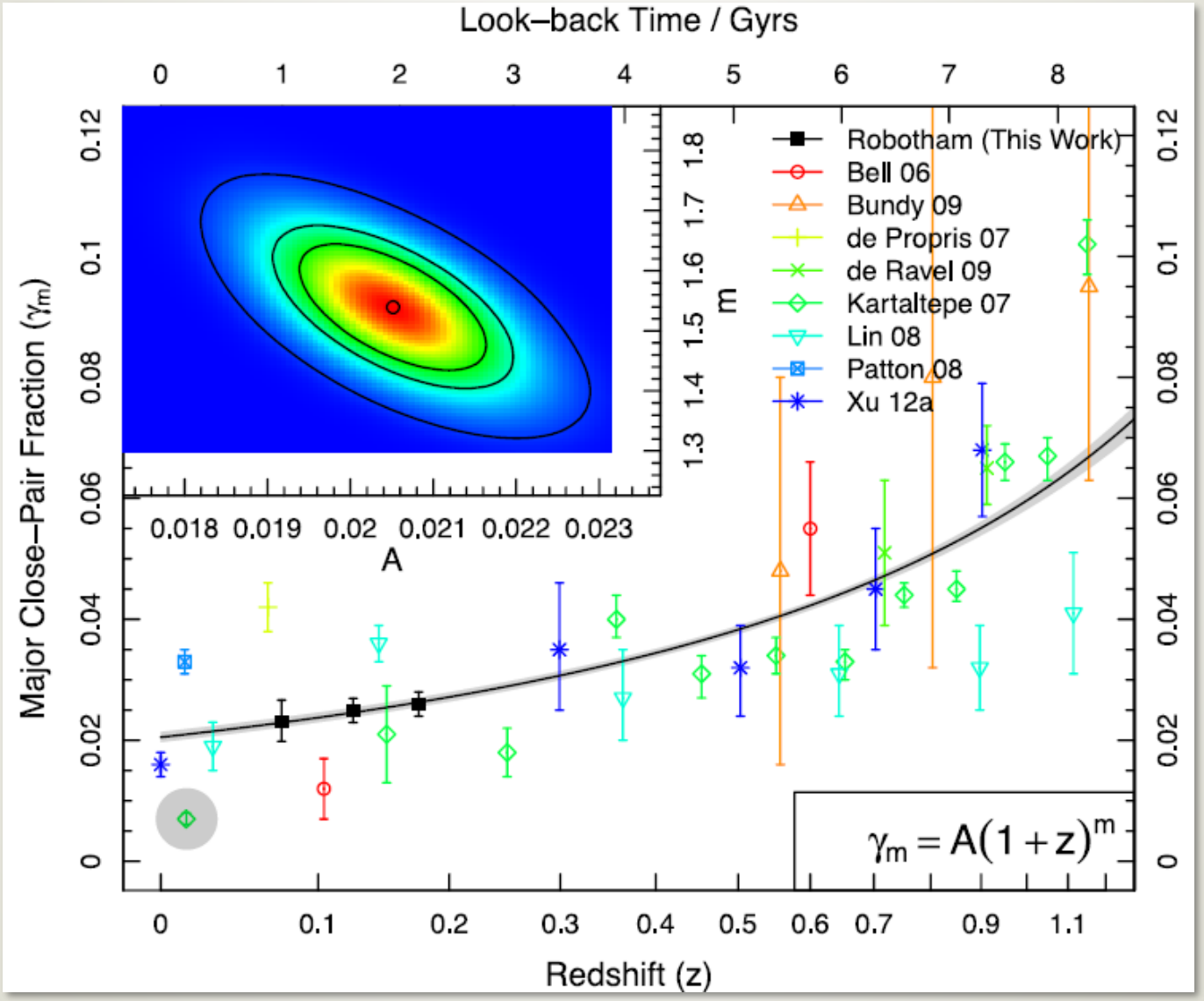
Robotham et al. (2014)

Stellar mass deppendence of major merger rate



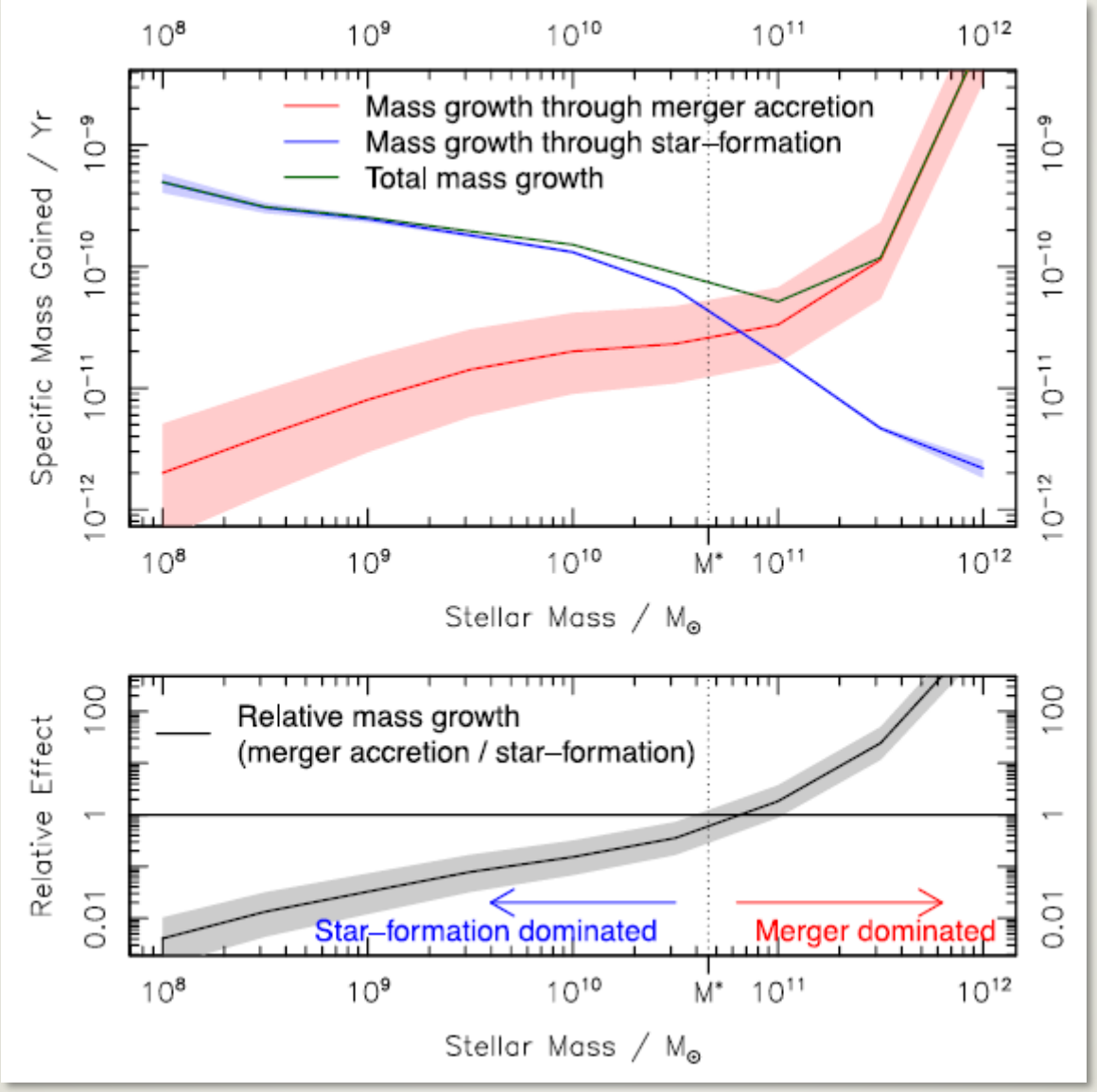
Robotham et al. (2014)

The evolution of the M* close pair fraction



Robotham et al. (2014)

The role of mergers in building up stellar mass



Robotham et al. (2014)

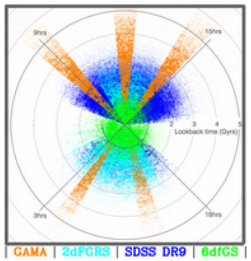
You, too, can use GAMA data

▶ DR2

GAMA Data Release 2

The second GAMA data release (DR2) provides AAT/AAOmega spectra, redshifts and a wealth of ancillary information for 72,225 objects from the first phase of the GAMA survey (2008 - 2010, usually referred to as GAMA I). The DR2 web pages describe the data included in this release, and provide access to an SQL database as well as to the actual data (spectra and catalogues).

If you are using GAMA DR2 data in a publication then please cite the DR2 paper (Liske et al. 2015) and acknowledge GAMA.



What is released?

The GAMA I survey extends over three equatorial survey regions of 48 deg^2 each (called G09, G12 and G15) and down to magnitude limits of r < 19.4 mag in G09 and G15, and r < 19.8 mag in G12. In DR2 we are releasing data for all GAMA I main survey objects with r < 19.0 mag (G09 and G12) or r < 19.4 mag (G15). Note that for G15 we are essentially releasing all GAMA I data. The total number of objects included in DR2 is 72,225. Of these, 70,726 objects (98%) have secure redshifts.

Details of the object selection for DR2:

- The qualifier 'GAMA I' refers to the fact that the objects for DR2 were selected from the input catalogue for the first phase of the GAMA survey (= GAMA I), see Baldry et al. (2010) for a detailed description of the GAMA I input catalogue.
- The qualifier 'main survey' refers to the fact that some targets were selected in different ways and for different reasons than those of the main GAMA survey. These so-called 'filler' targets were only observed when a fibre could not be allocated to a main survey target. Filler targets are not included in DR2.
- The r-band magnitude is the Petrosian r-band magnitude from SDSS DR6, corrected for Galactic extinction. This is the GAMA I selection magnitude.
- The three GAMA I survey regions are each 12×4 deg^2 in size, for a total survey area of 144 deg^2:

Region	RA range	DEC range	r-band mag limits		
			DR2	GAMA I	GAMA II
G09	129.0 - 141.0	−1 - +3	19.0	19.4	19.8
G12	174.0 - 186.0	−2 - +2	19.0	19.8	19.8
G15	211.5 - 223.5	−2 - +2	19.4	19.4	19.8

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▶ DR2 > Schema browser

GAMA Schema Browser

The schema browser allows you to explore the contents of the DR2 SQL database. It shows you which tables/catalogues are available for queries and what they contain. The GAMA data flow is organised around so-called Data Management Units (DMUs), and it is these DMUs that produce the tables in this database. The schema browser provides access to all of the meta-information provided by each DMU, both on the DMU itself as well as on individual tables/catalogues. If you find any of this information unclear, incomplete or incorrect then you may either directly get in touch with the contact person of that DMU or table, or else contact the database team.

The table below provides an overview of the contents of the database. It lists all DMUs for which products are being released in DR2. Begin exploring the database by clicking on the DMU names.

DMU name	Version	Description
InputCat	v16	This DMU provides various input catalogues for the spectroscopy.
ExternalSpec	v01	This DMU collects spectra for GAMA DR2 objects from previous spectroscopic surveys such as the SDSS.
SpecCat	v08	This DMU provides the final spectra and redshift catalogues, including GAMA AAT and external data.
LocalFlowCorrection	v07	This DMU performs local flow correction, and provides redshifts in different frames of reference.
ApMatchedPhotom	v02	This DMU provides aperture matched ugrizYJHK photometry.
SersicPhotometry	v07	This DMU provides a single-component Sersic fit in each of the ugrizYJHK bands for every GAMA DR2 galaxy.
GalexPhotometry	v02	This DMU provides GALEX NUV and FUV photometry for GAMA DR2 objects.
kCorrections	v02	This DMU provides k-corrections in the GALEX FUV and NUV bands, the SDSS ugriz bands and the UKIDSS YJHK bands for all GAMA DR2 galaxies.
SpecLineSFR	v04	This DMU provides emission and absorption line measurements for all GAMA DR2 AAT spectra, as well as derived physical properties, including the star-formation rate, for all GAMA DR2 spectra and for all SDSS spectra of GAMA DR2 objects.
StellarMasses	v08	This DMU provides stellar masses, restframe photometry, and other ancillary stellar population parameters for all z < 0.65 galaxies in the GAMA DR2 sample.
EnvironmentMeasures	v02	This DMU provides several different metrics of the local environment of GAMA DR2 galaxies: a surface density, the number of galaxies within a cylinder, and the density of galaxies within an adaptive Gaussian ellipsoid.
GroupFinding	v05	This DMU provides the GAMA Galaxy Group Catalogue (G3C).

You, too, can use GAMA data

Current:

- DR2
- Panchromatic DR

Soon:

- DR3

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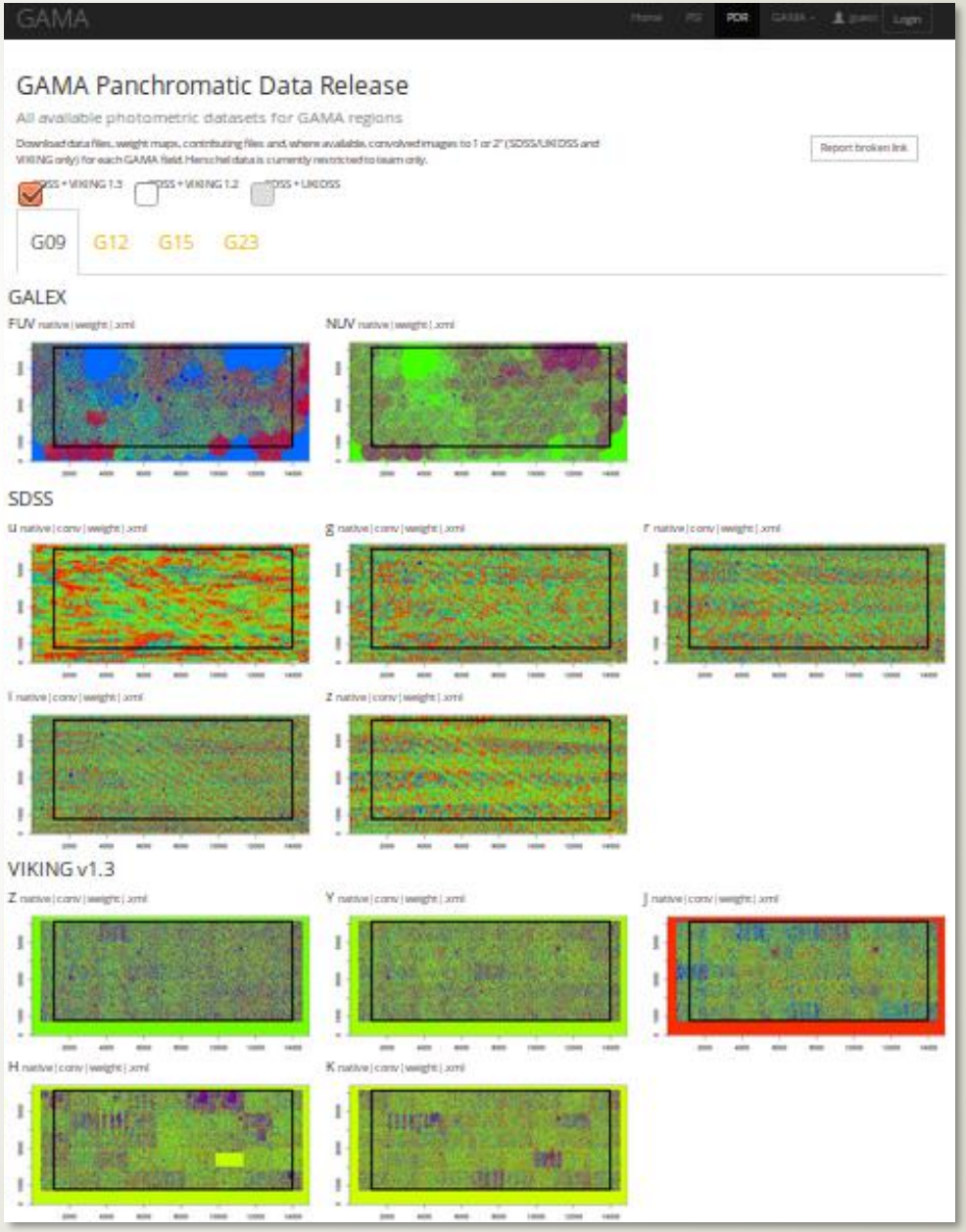
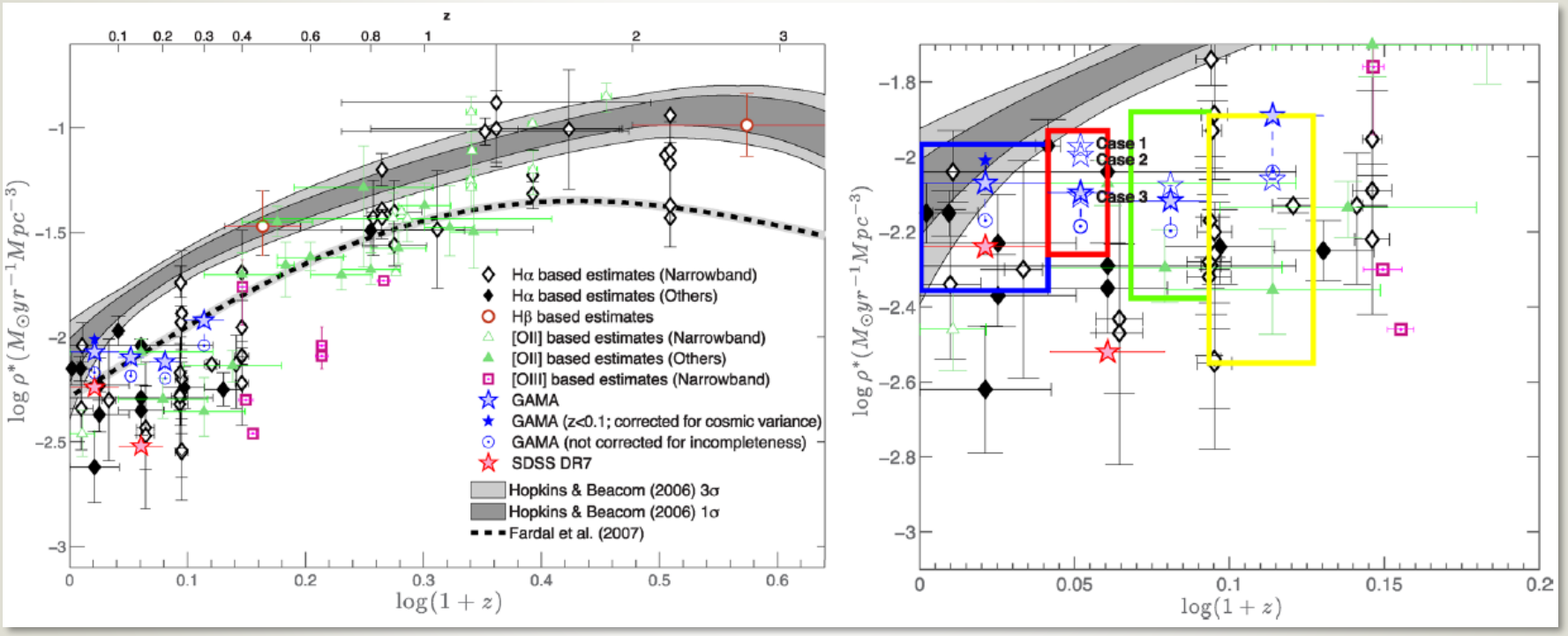
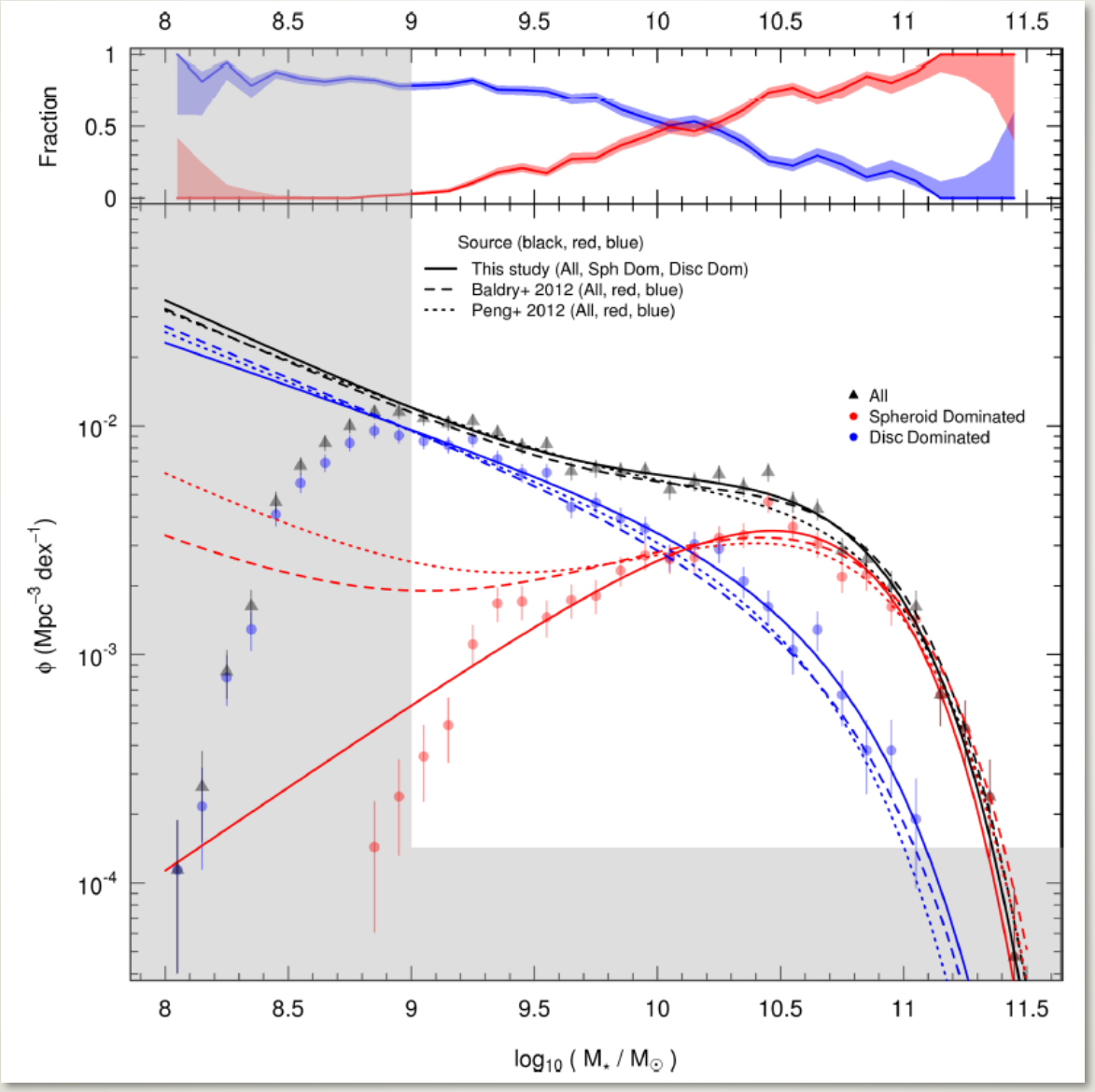
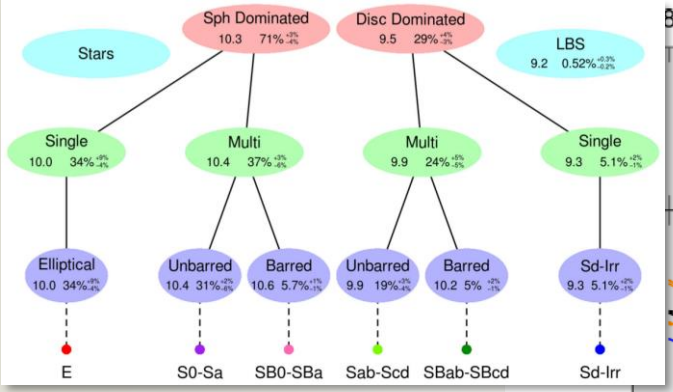


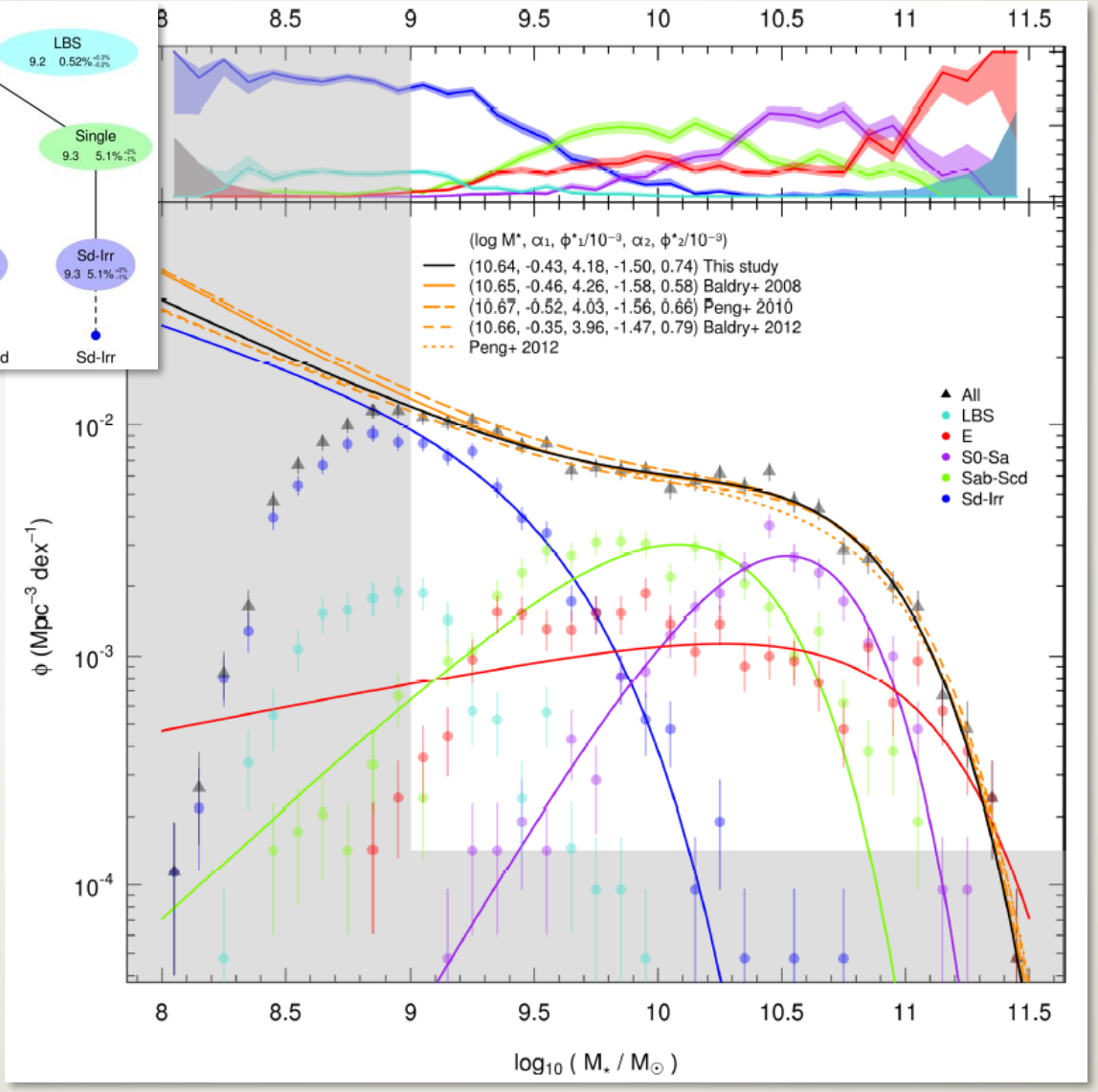


Gunawardhana et al. (2013)

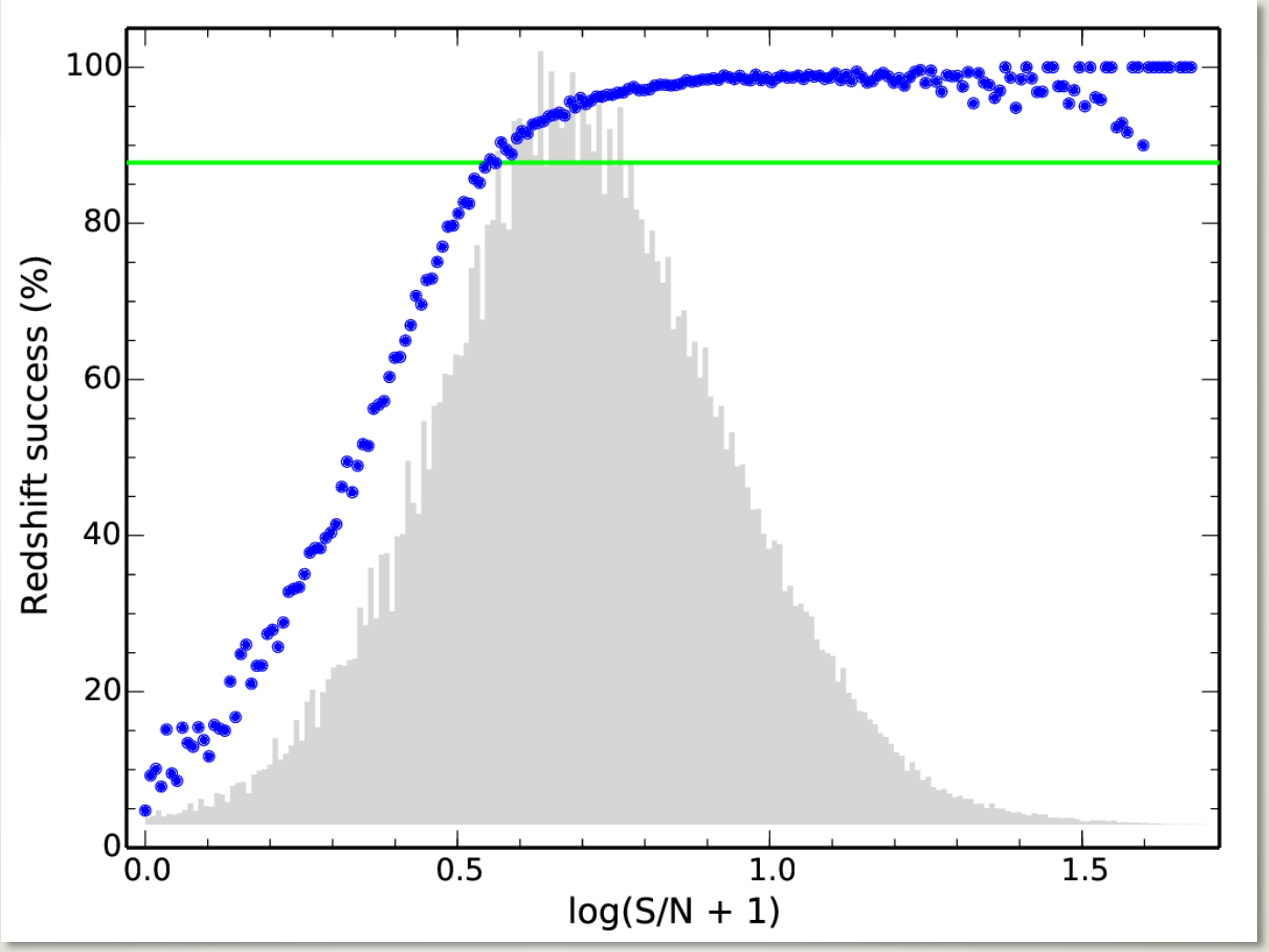


Kelvin et al. (2014)





Kelvin et al. (2014)


Redshift success (%)
100
80
60
40
20
0
0.0
0.5
1.0
1.5
log(S/N + 1)