Building galaxies with 4MOST/WAVES and MSE

Jon Loveday
University of Sussex

www.4MOST.eu

Overview

- I will briefly review status of existing, ongoing, and planned spectroscopic surveys of representative samples of galaxies:
  - SDSS
  - GAMA
  - 4MOST WAVES
- Look ahead to extragalactic surveys with MSE (based on Chapter 7 of MSE Detailed Science Case, 2019)

Questions

- How do galaxies and structure evolve over time?

- Low-mass ends of the halo and stellar mass functions?

- How are galaxies affected by host halo properties and larger-scale environment?

- What is typical merger history?

- How are galaxies affected by dark matter and dark energy?

- What quenching mechanisms dominate in different environments?

SDSS

- Perhaps first major survey to systematically address such questions was the Sloan Digital Sky Survey (SDSS)

- Main galaxy sample (MGS)

  - ~1 million galaxy spectra to $r < 17.77$ $(\bar{z} \approx 0.1)$ plus 5-colour imaging over 8423 deg^2

- Huge volume, high redshift-success rate

- Incomplete in high-density regions (fibre collisions)

- 18,752 pubs to date with SDSS in abstract
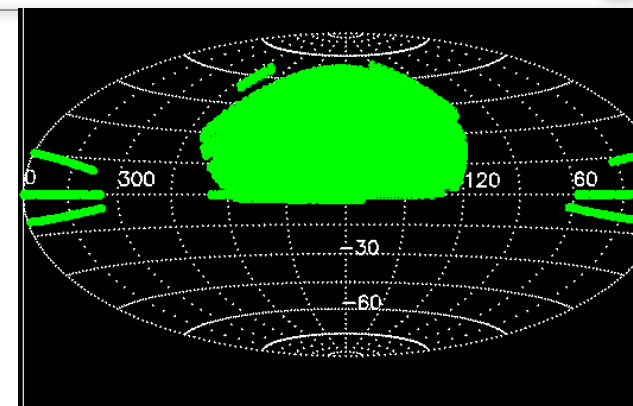
RA=18.70282, DEC=−0.49613, MJD=51789, Plate= 398, Fiber=261
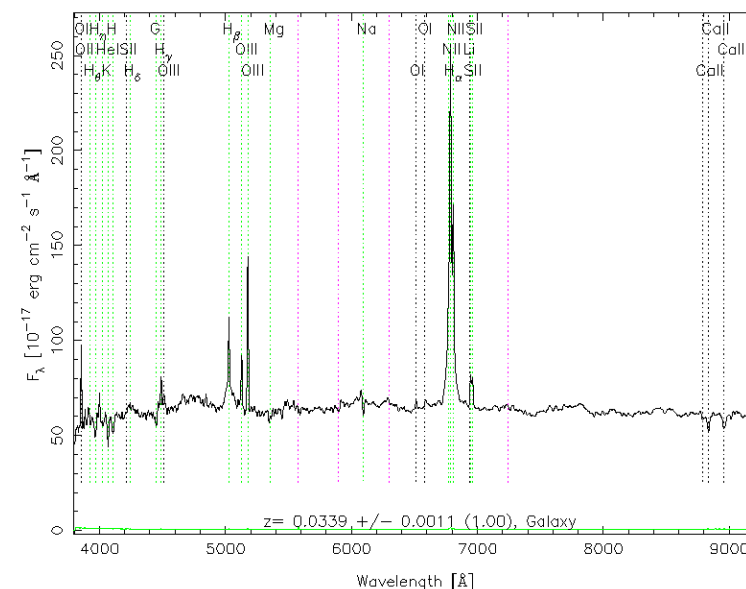
Galaxy and Mass Assembly (GAMA)

- AAOmega spectra for 183,000 SDSS galaxies with $r < 19.8$ ($\bar{z} \approx 0.23$) over three equatorial fields, each 12×5 deg
- FUV—FIR imaging
- On average 40 visits to each area of sky: 98.5% complete even in high-density regions
- Ideal for group-finding and environment studies
- ~1/5 volume of SDSS MGS
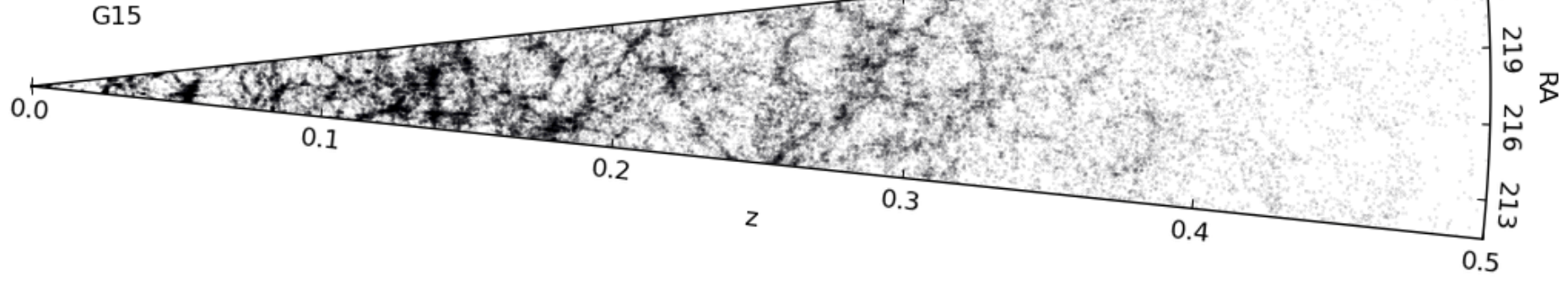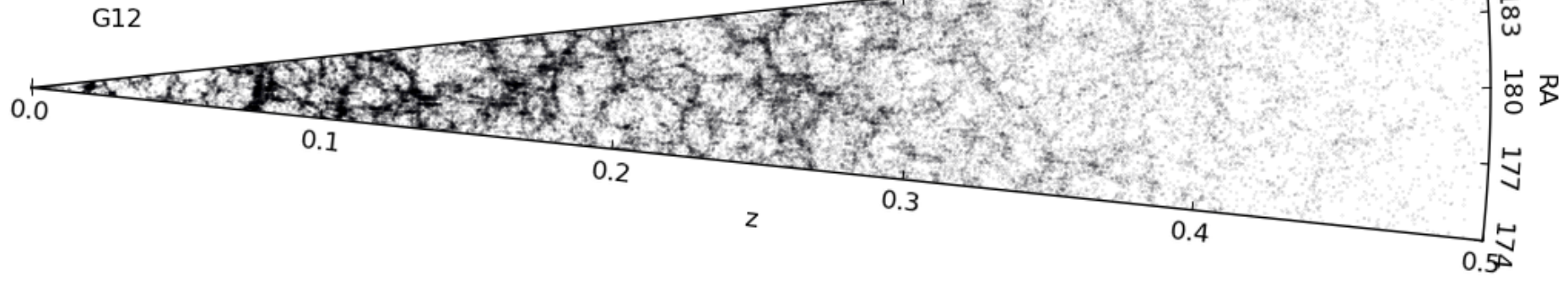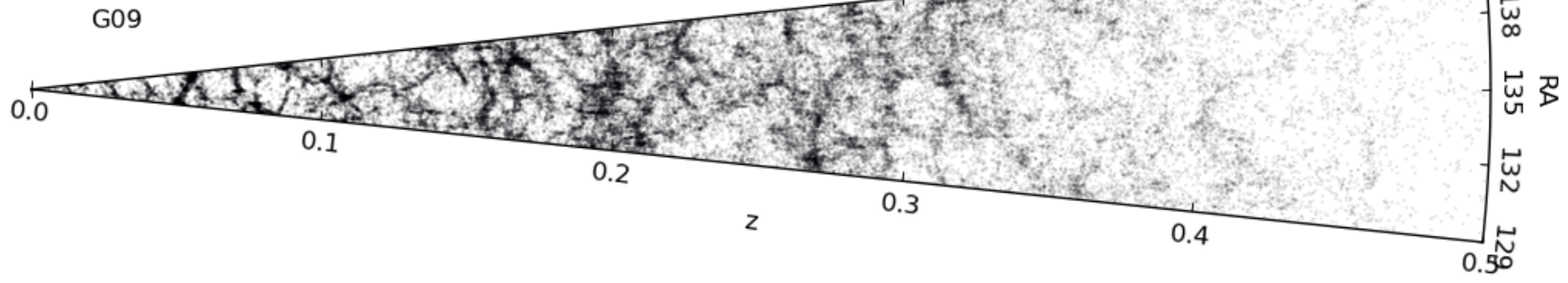- 190 pubs to date using GAMA data
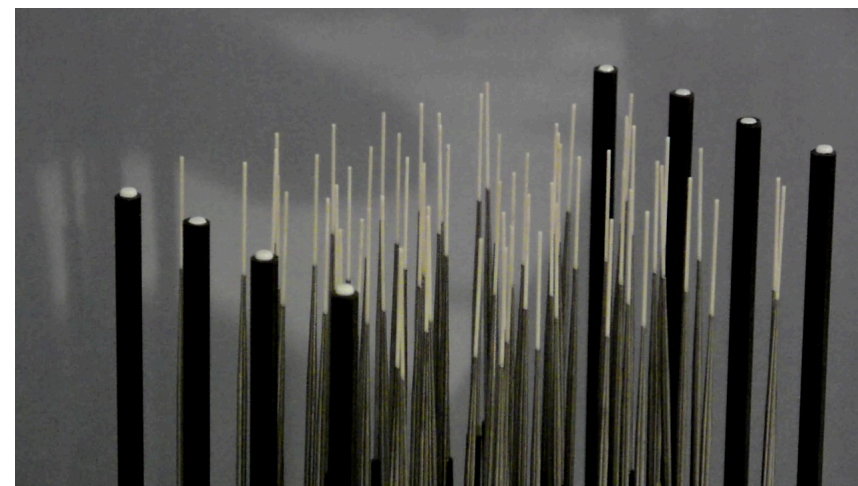- http://www.gama-survey.org/
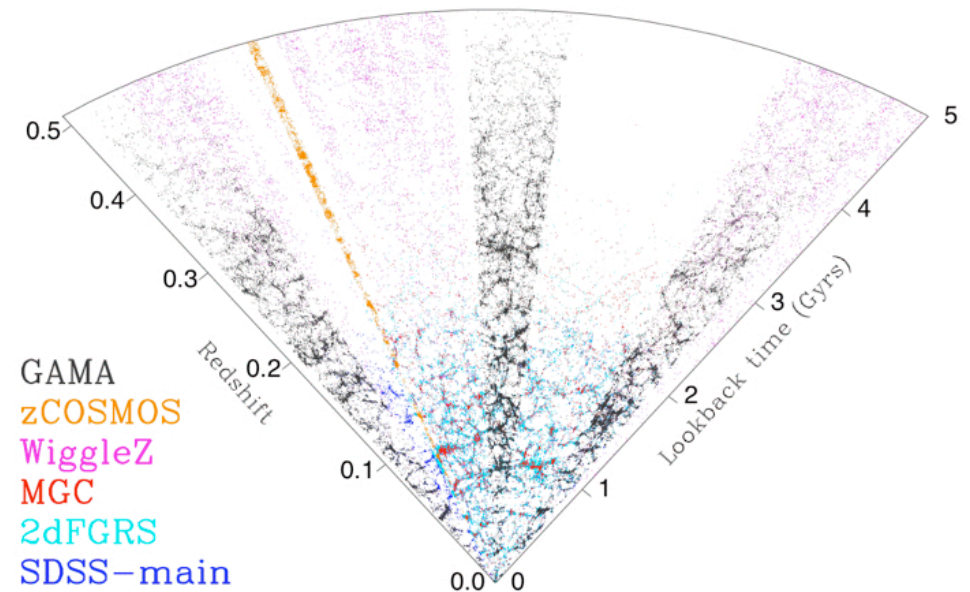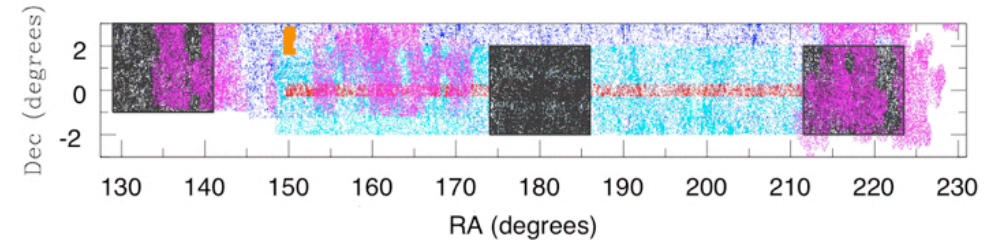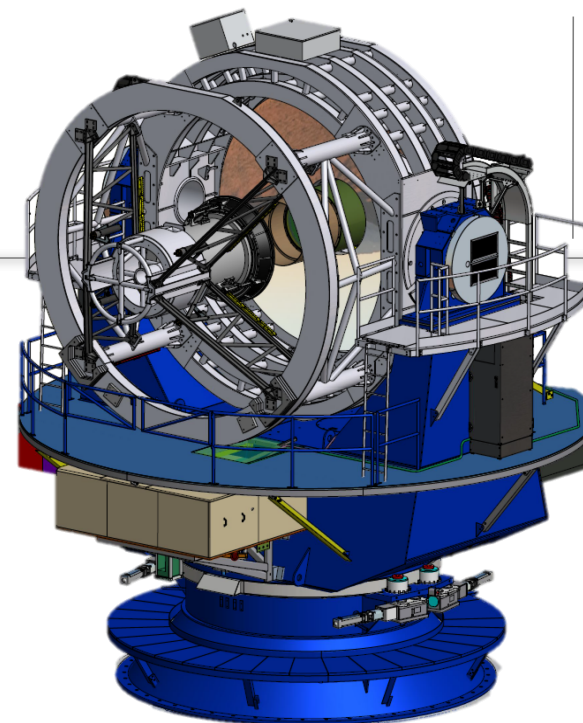

Driver+2009 (mock GAMA data)

SDSS Main
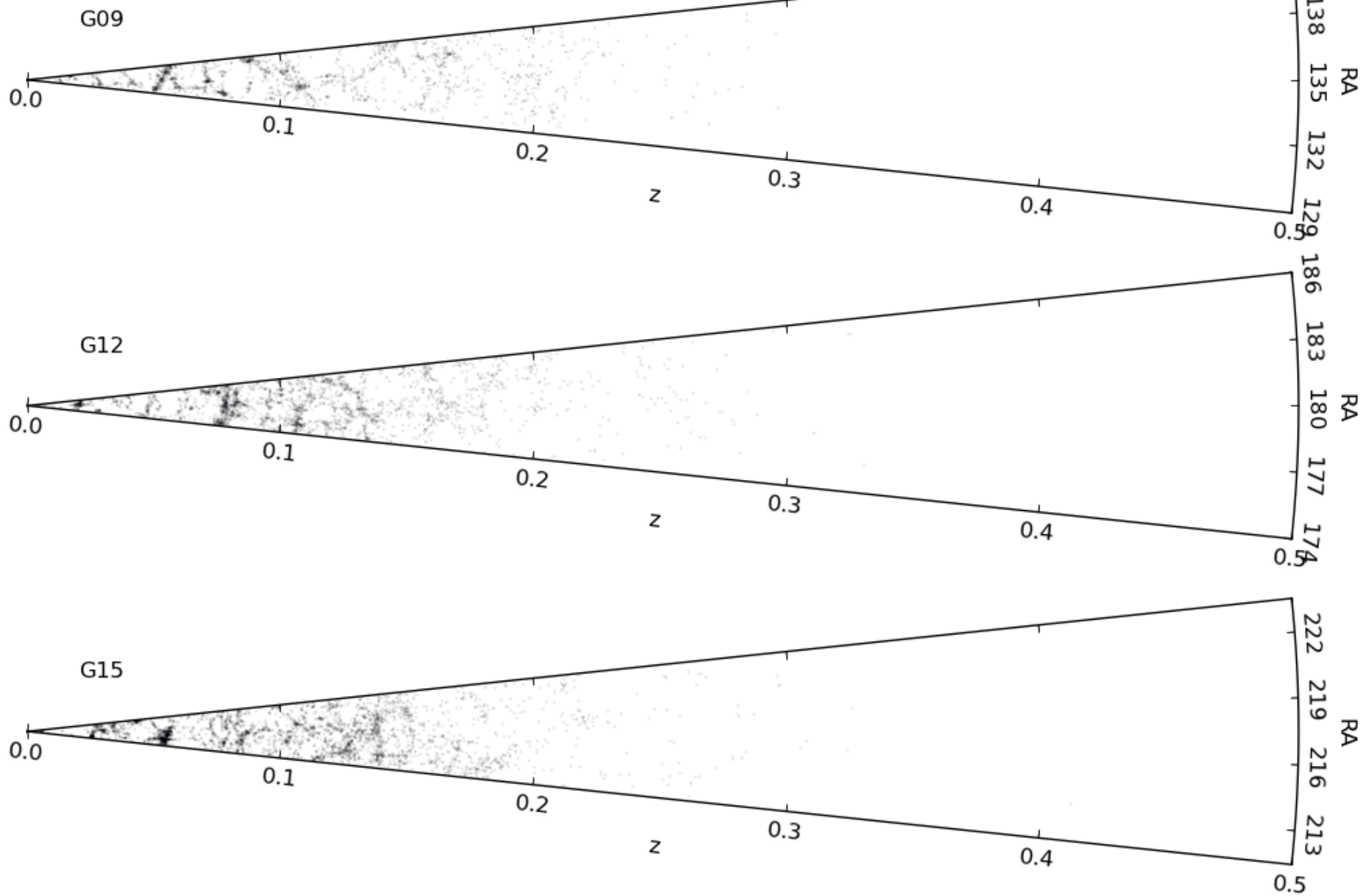
GAMA-II

4MOST

- Spectroscopic facility for 4m VISTA telescope @ Paranal

- 2.5 deg FoV

- Covers southern sky with 5000 pointings (~2 years)

- 2400 fibres (AESOP positioner)

- 1600 low-res spectra ($R \sim 5000$)

- 800 high-res spectra ($R \sim 20000$)

- 5-year public surveys run in parallel, commencing late 2022

4MOST Science Themes

Cosmology
Euclid/LSST

High-energy sky
eROSITA

Galaxy evolution
VST/VISTA

Galactic Archeology
Gaia and PLATO

4MOST Consortium surveys

- 70% of time for 5 years; all described in March 2019 *ESO Messenger*

  1. Low Res MW Halo
  2. High Res MW Halo
  3. Low Res MW Disk + Bulge
  4. 4MIDABLE - High Res MW Disk + Bulge
  5. eRosita Galaxy Clusters
  6. eRosita AGN + QSO Survey
  7. **Wide Area Vista Extragalactic Survey (WAVES)**
  8. Cosmology
  9. 1001MC
  10. Time-Domain Extragalactic Survey (TIDES)

4MOST WAVES
https://wavesurvey.org/

| Survey	Redshift range	Area [deg²]	Density [deg⁻²]	Targets [thousand]
Wide	0.0 – 0.2	545 + 625	750	880
Deep	0.2 – 0.9	50 + 4 x 4	11,000	730
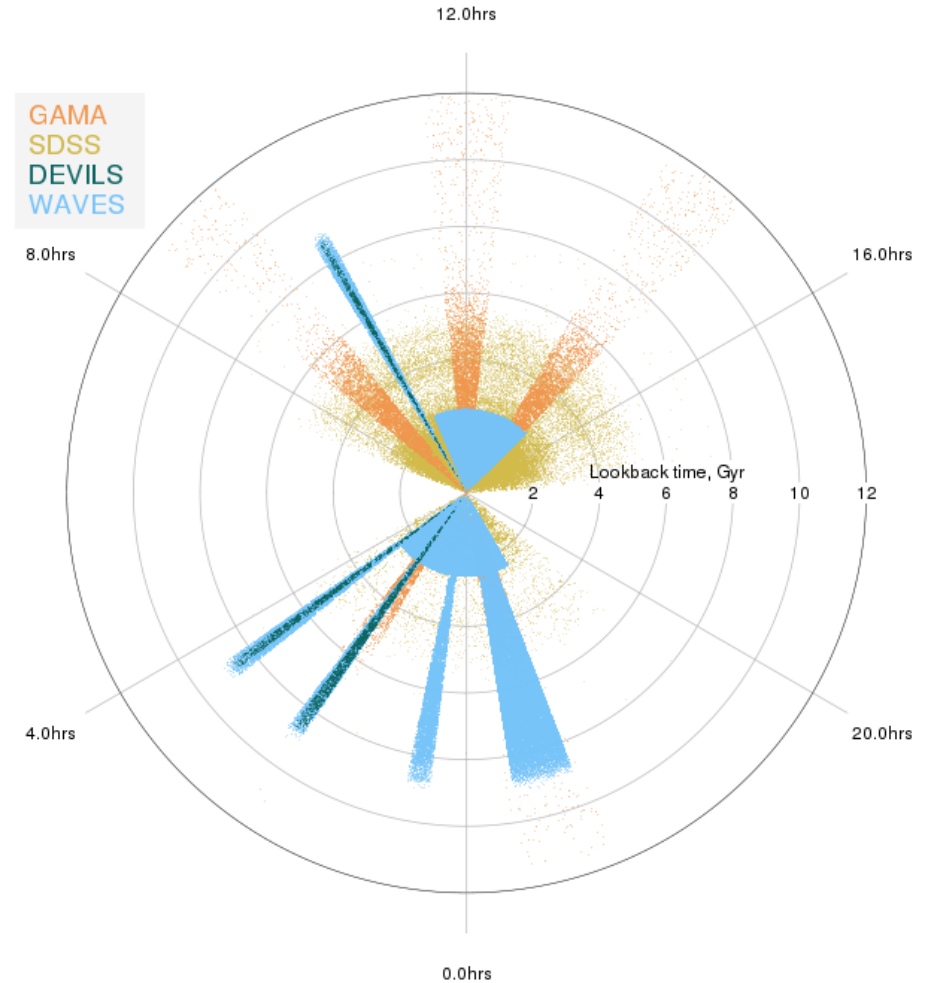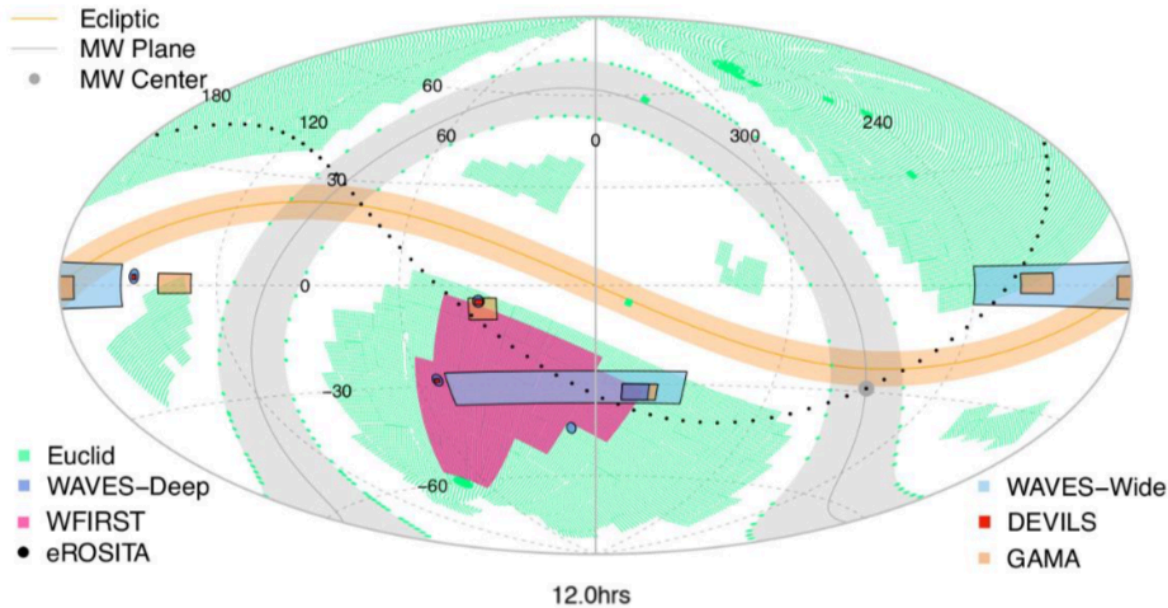
WAVES Wide

- VST-KiDS target selection: $m_z < 21.1$ mag, $z_{phot} < 0.2 \rightarrow$ 50,000 haloes to ~10^{11} M$_\odot$
    - Halo and stellar mass functions
    - Void distribution function
    - Quantify SFR, masses, and structural properties across wide range of halo masses
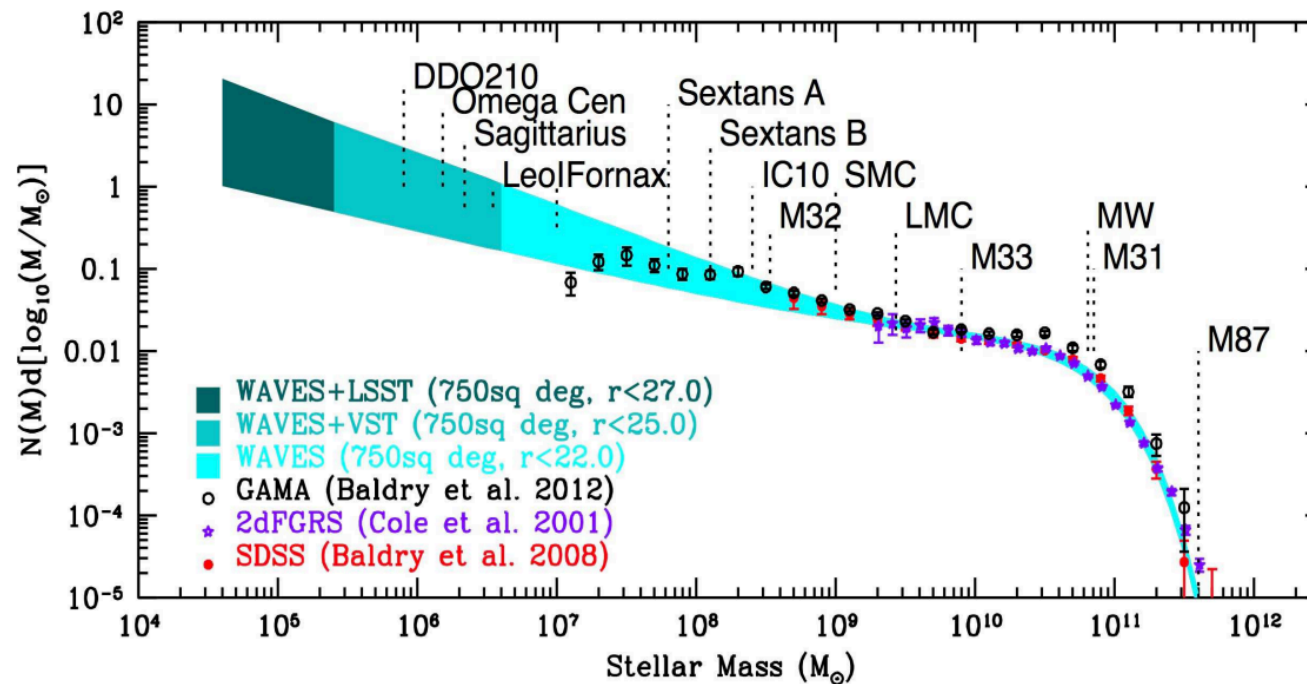
WAVES Deep

- VST-KiDS target selection: $m_z < 21.25$ mag, $z_{phot} < 0.8$ → 20,000 haloes to ~10^{14} M$_\odot$
  - Evolution of high-mass end of HMF
  - Major and minor galaxy merger rates
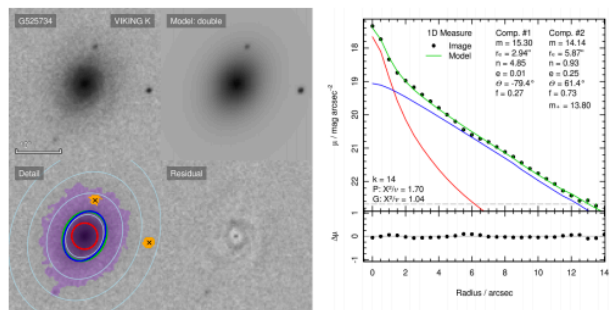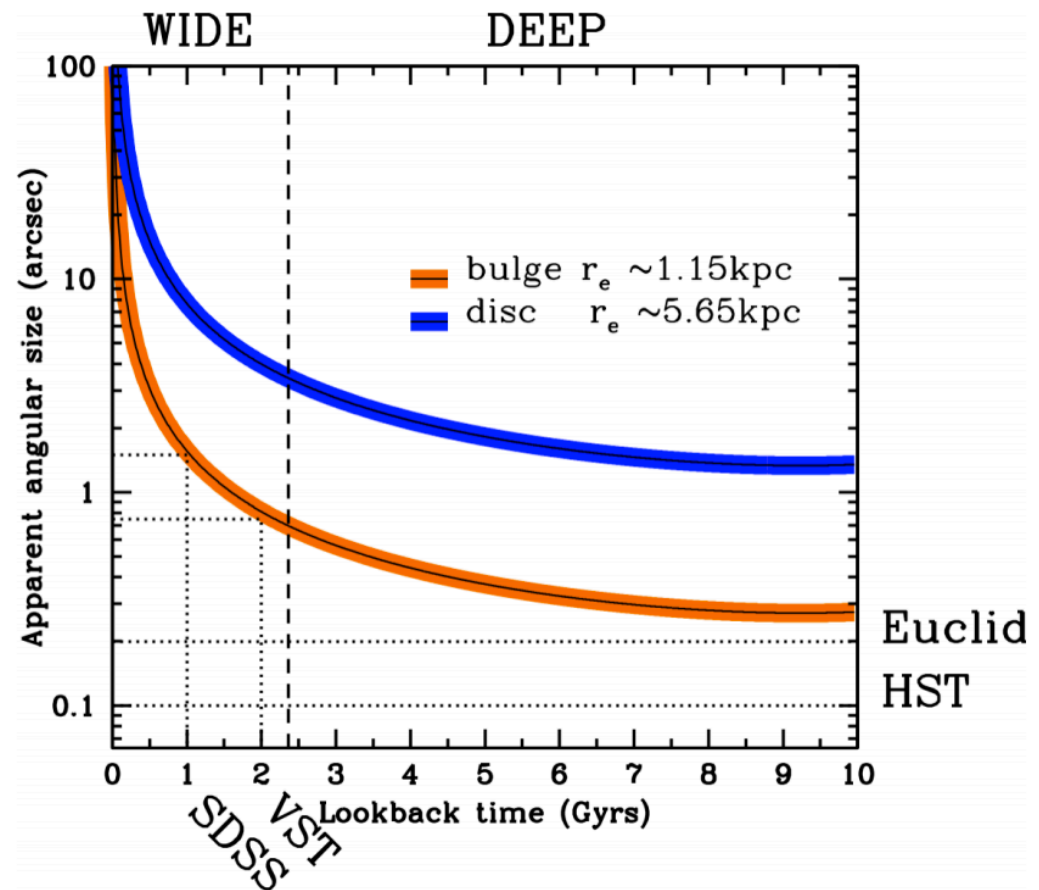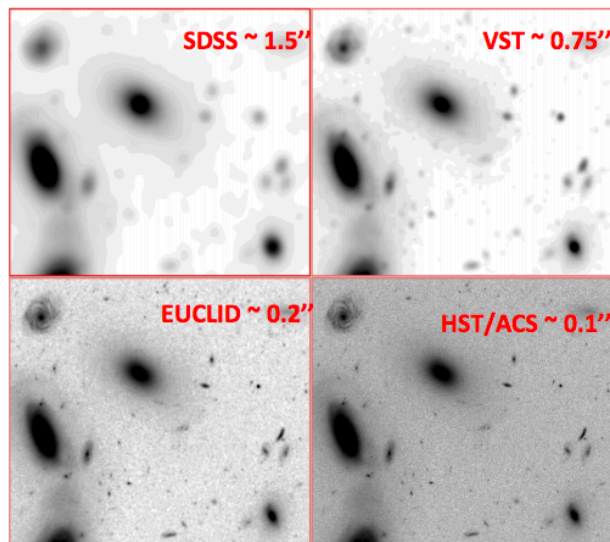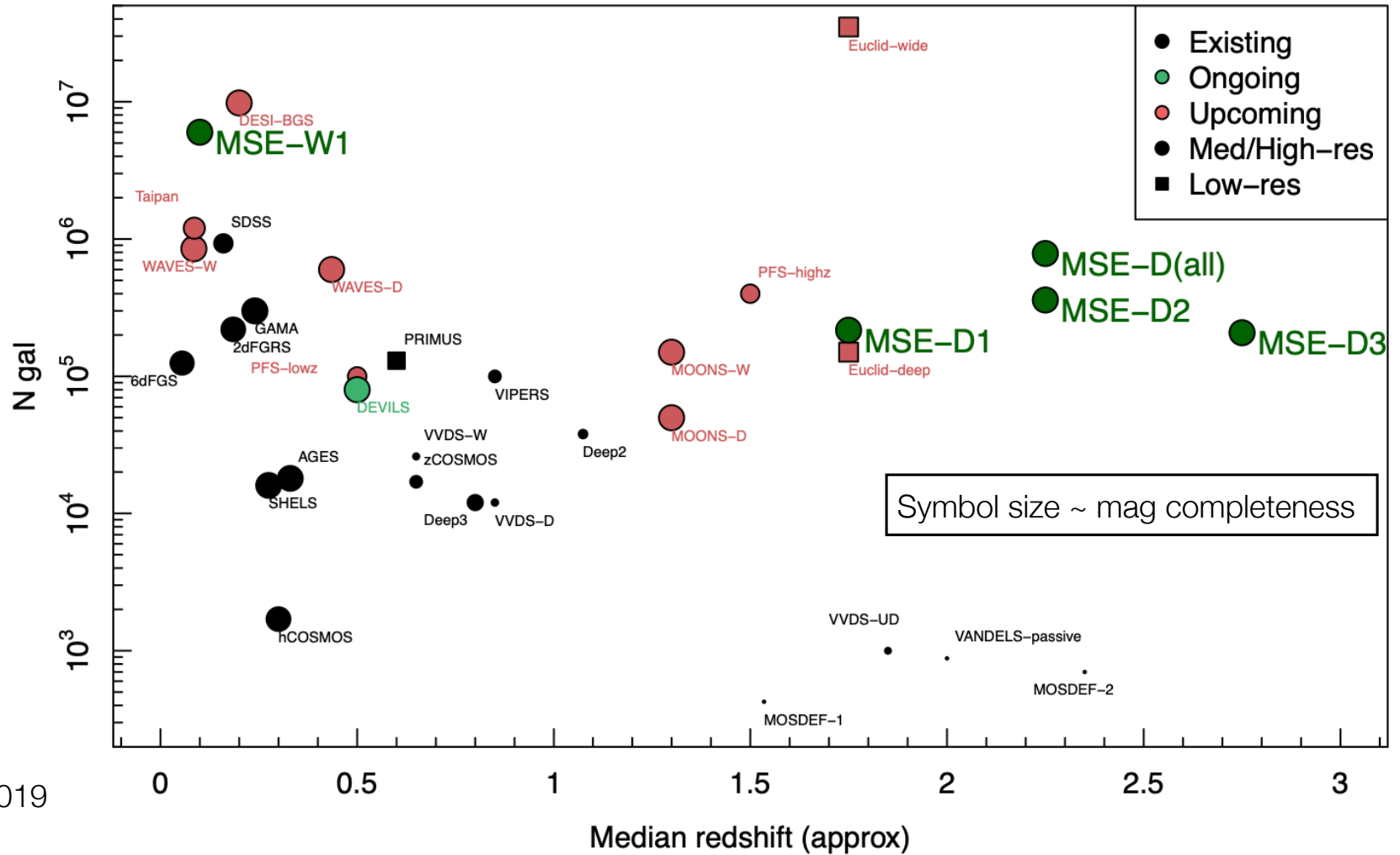 - Gas, stellar and dust mass growth of galaxies
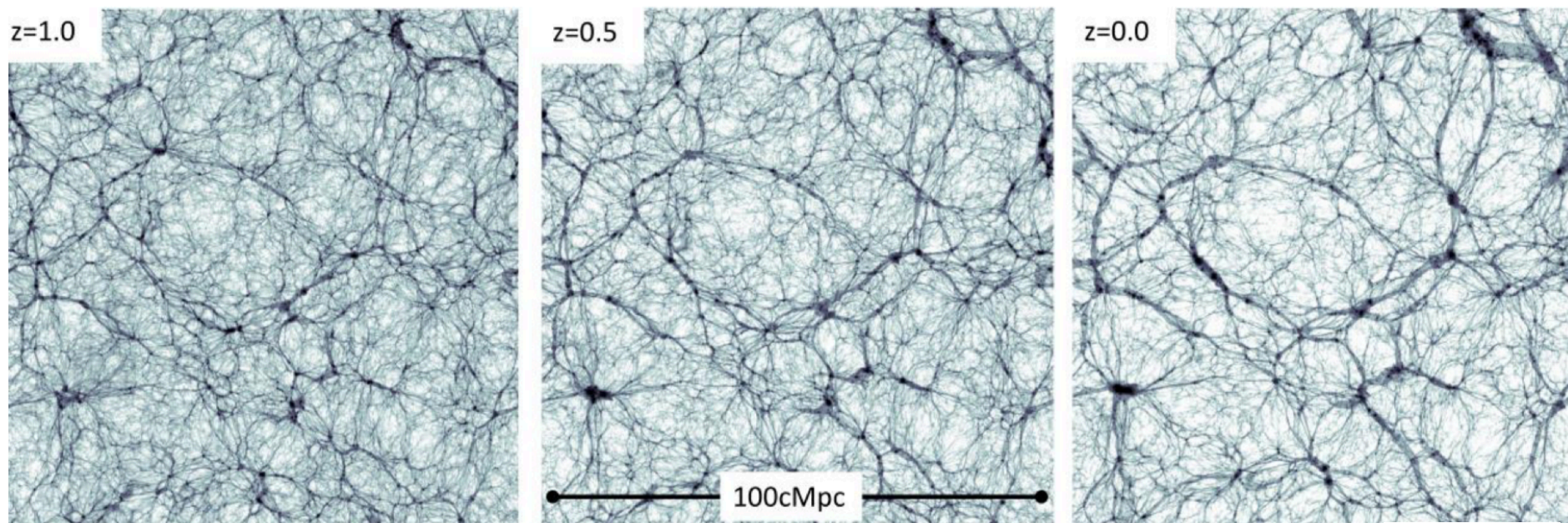
Elahi+2018

WAVES Wide + Deep Evolution of Structure

- Euclid+WAVES will measure bulge and disk growth since *z* ~1

MSE extragalactic surveys

Maunakea Spectroscopic Explorer
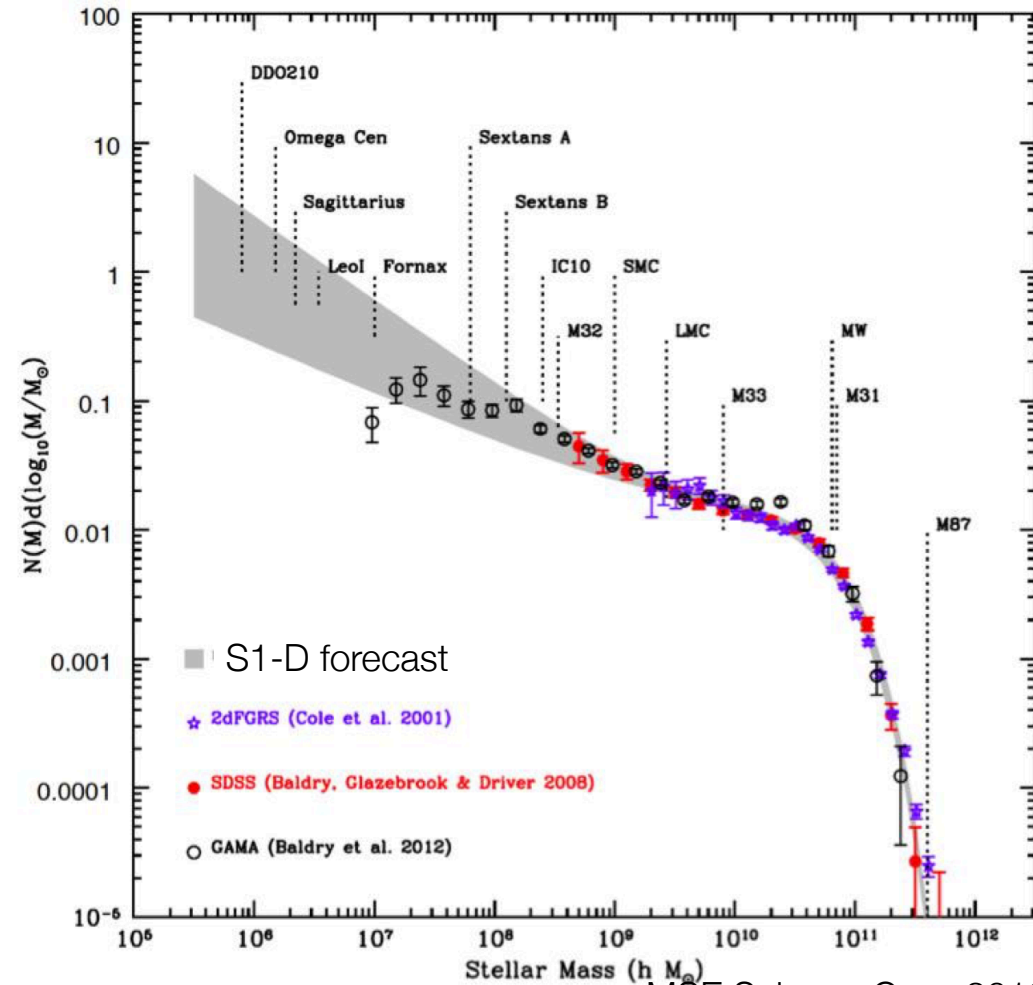
MSE Science Case 2019

MSE low-z surveys

- Complete ($M_* \gtrsim 10^7 \, M_\odot$) census of galaxies in local universe

- Requires input catalogue complete in LSB galaxies (Euclid, LSST)

- Photo-z selection: $z < 0.2$

- S1-W: expect > 200 clusters with $M_h > 5 \times 10^{14} \, M_\odot$ in ~ 0.18 Gpc^3

- S1-D: extreme dwarf galaxies ($M_* \gtrsim 10^6 \, M_\odot$)

Survey	Area (sq. deg)	Depth (Selection band)	Depth (equivalent i)	Sample size
S1-W	3200	$i < 23$	$i < 23$	6M
S1-D	100	$i < 24.5$	$i < 24.5$	800k

MSE Science Case 2019

MSE low-z surveys

Maunakea Spectroscopic Explorer

S1-W forecast

MSE survey: ~3000 sq deg / 0<z<0.2 / i<23

S1-D forecast

2dFGRS (Cole et al. 2001)

SDSS (Baldry, Glazebrook & Driver 2008)

GAMA (Baldry et al. 2012)

MSE Science Case 2019

MSE high-z surveys

Maunakea Spectroscopic Explorer
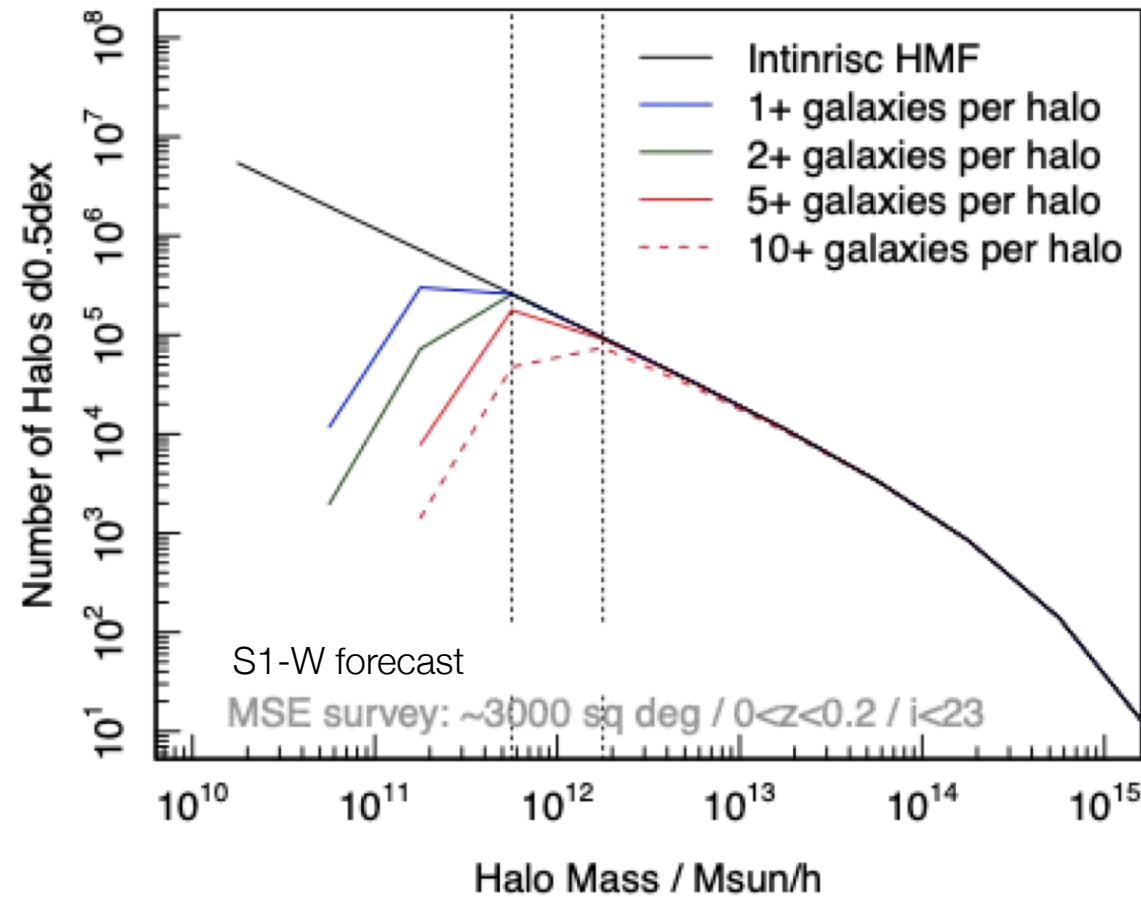
- Highly complete, mag-limited samples spanning 'cosmic noon', $1.5 < z < 3.0$

- Full range of environments

- Large enough samples to subdivide on mass, colour, environment

- Three sub-surveys proposed in MSE Science Case

Area (sq.deg)	z_{lo}	z_{hi}	Vol / Gpc^3	Selection	N (10^3)	Density (10^3/sq.deg)
20	1.5	2.0	0.04	$i < 25.3$	220	11.0
80	2.0	2.5	0.16	$i < 25.3$	360	4.5
80	2.5	3.0	0.16	$i < 25.3$	200	2.6

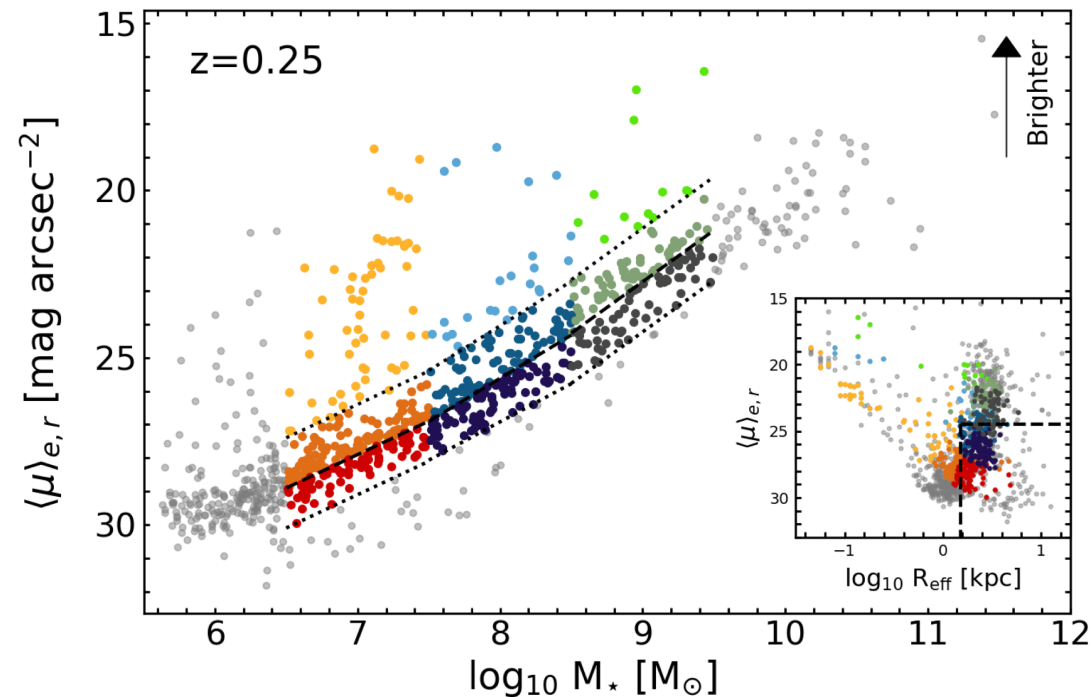MSE Science Case 2019

MSE high-z surveys
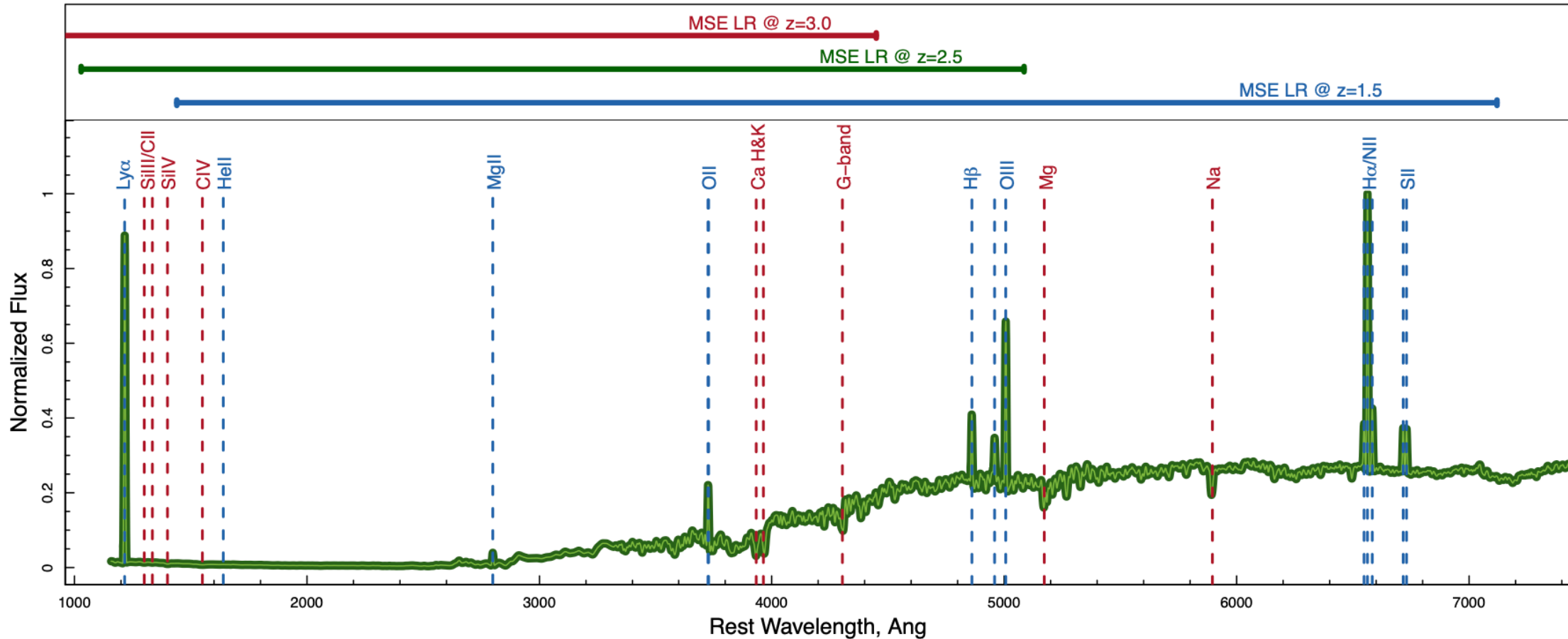
MSE Science Case 2019

Summary

- Current surveys constrain $M_* \gtrsim 10^8\,M_\odot$ galaxies at $z \lesssim 0.1$

- 4MOST WAVES will push to lower mass (wide) and higher redshift (deep)

- MSE will enable SDSS-like science at $z \sim 2$

- Complete census of low mass galaxies will require highly-complete imaging at very low surface brightnesses

- A challenge even for LSST and Euclid

Jackson+2020 arXiv:2007.06591