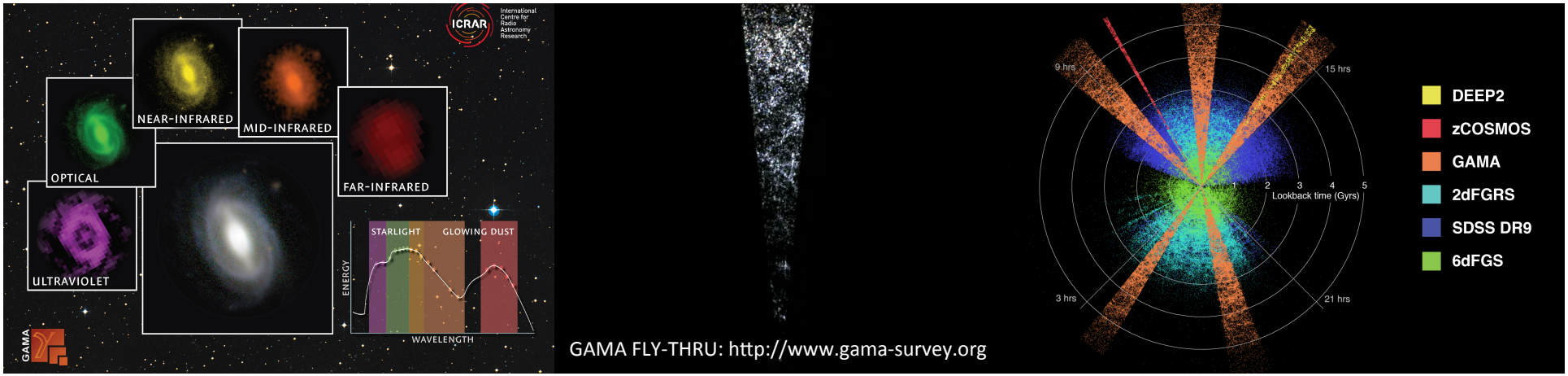
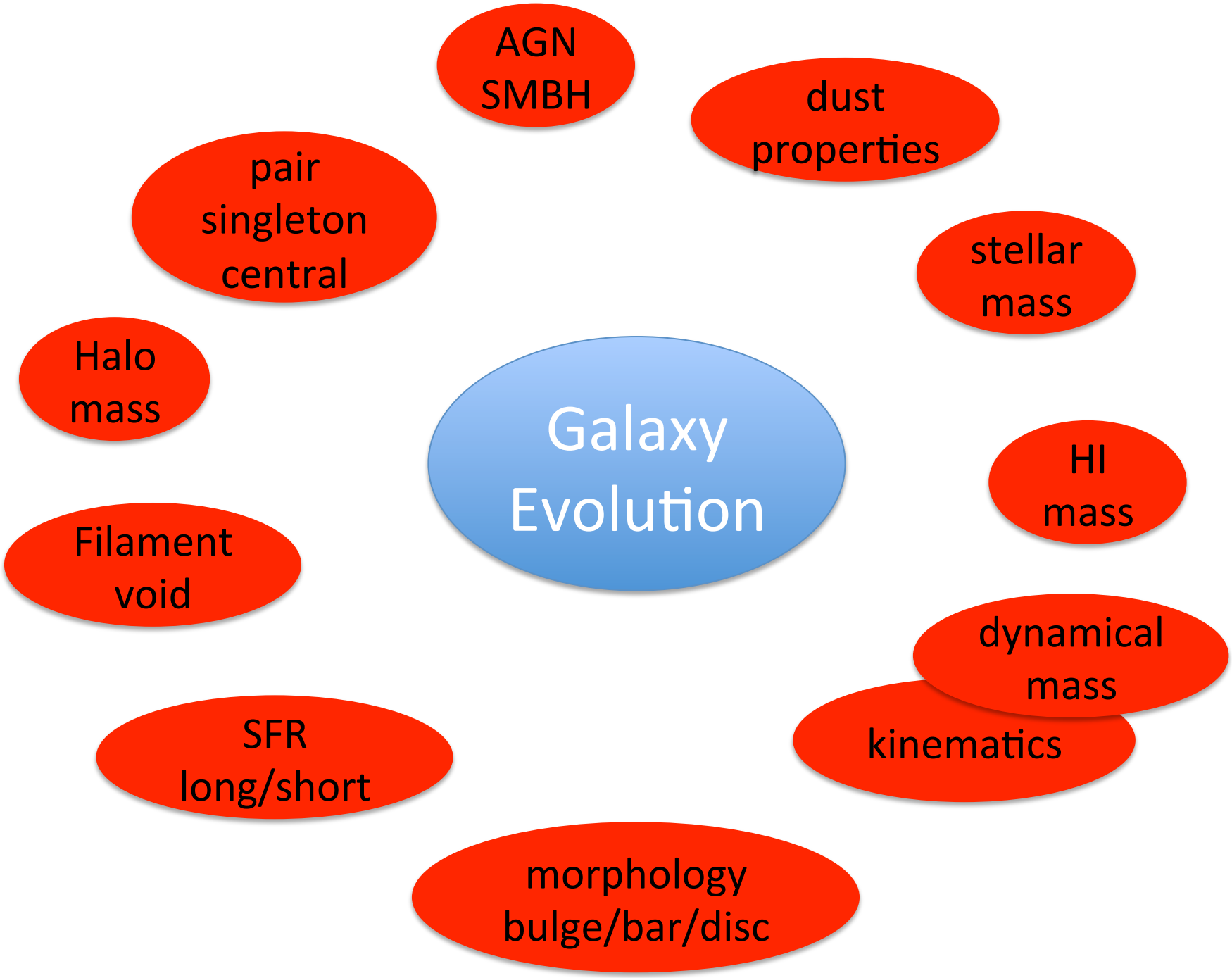


Bridging the gap: What's required to understand *galaxy evolution*?

Simon P Driver
University of Western Australia
&
University of St Andrews


AGN
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properties
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stellar
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Halo
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Galaxy
Evolution
HI
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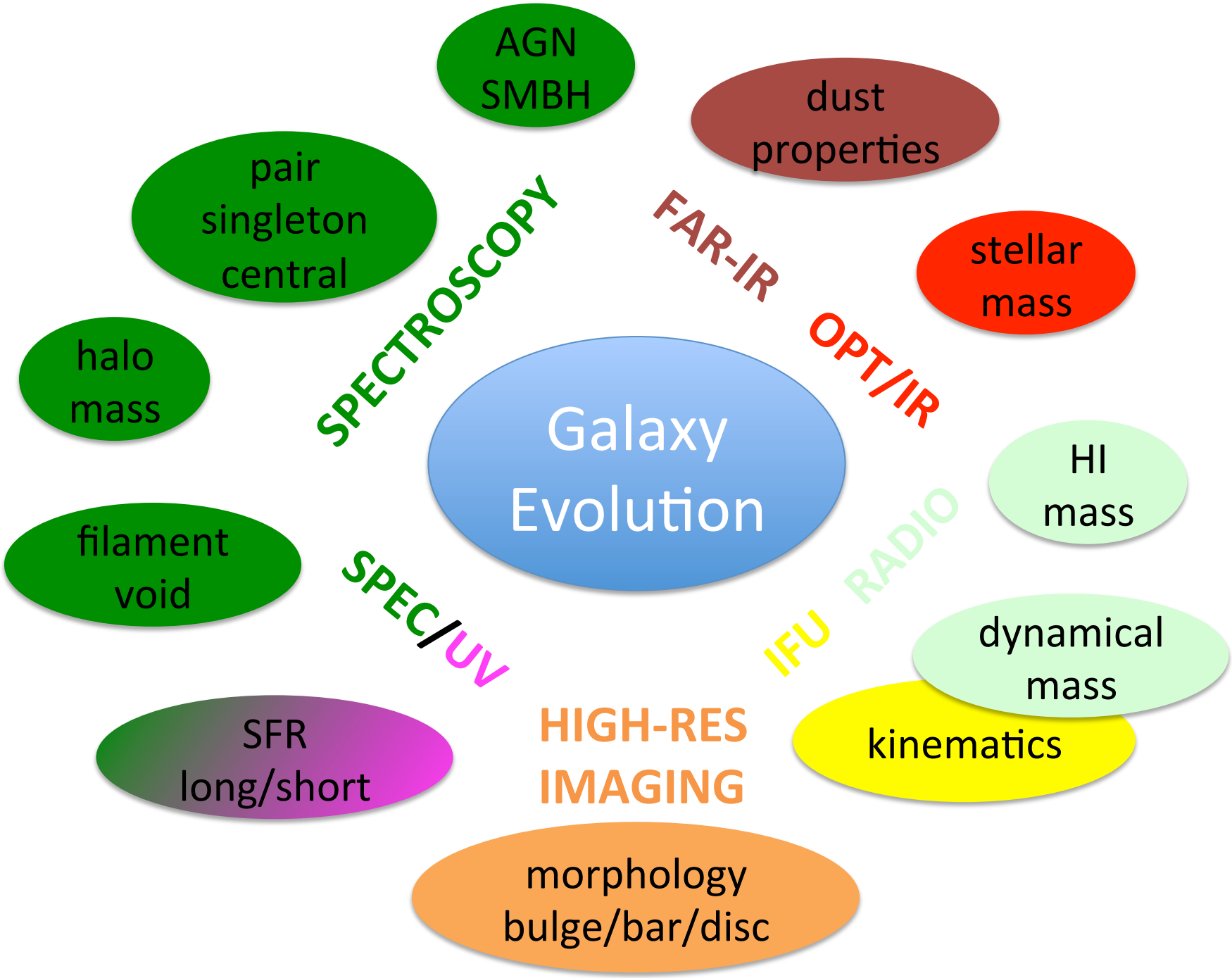
Filament
void
dynamical
mass
kinematics
SFR
long/short
morphology
bulge/bar/disc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void
RADIO
SPEC/UV
IFU
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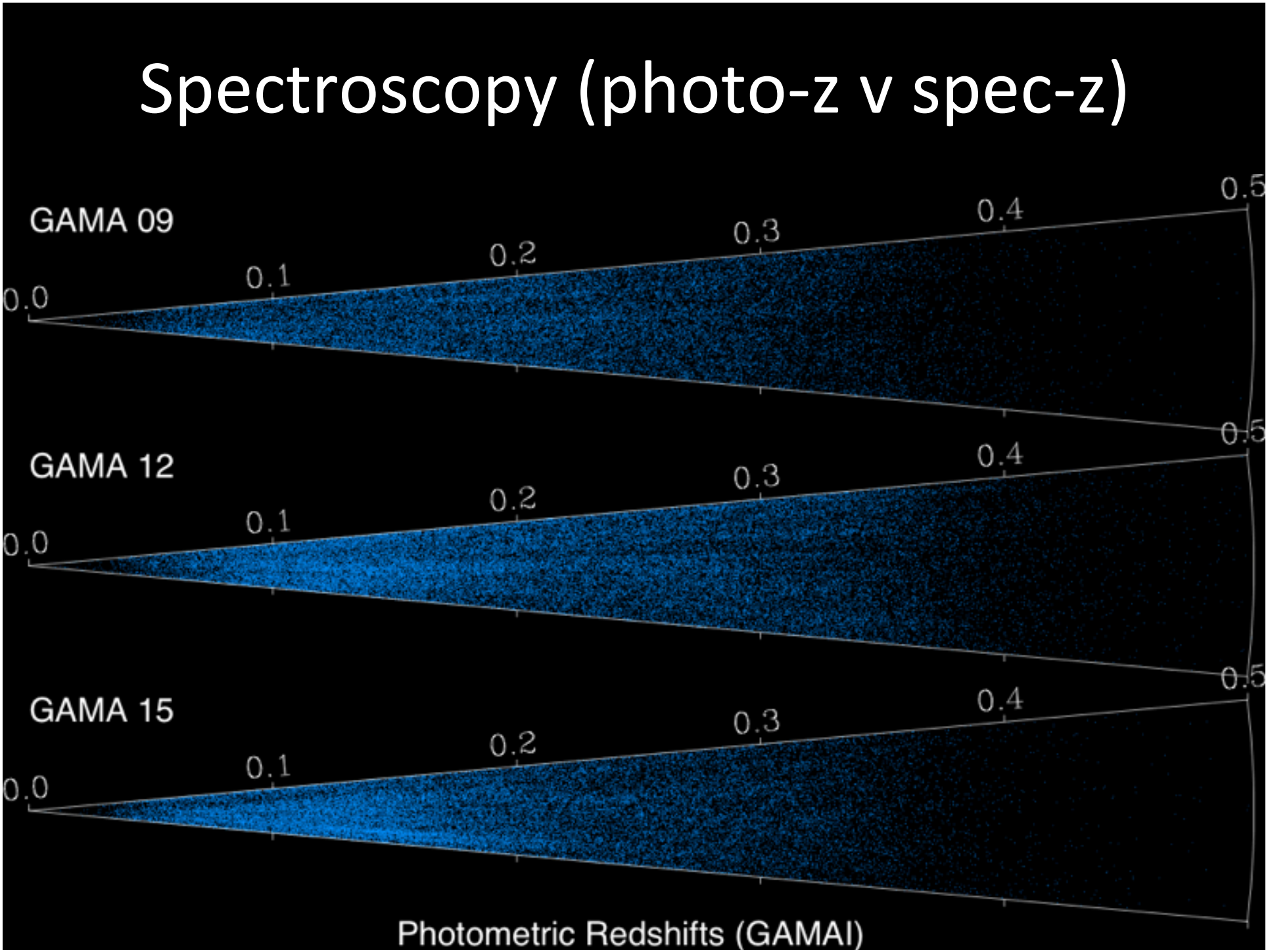
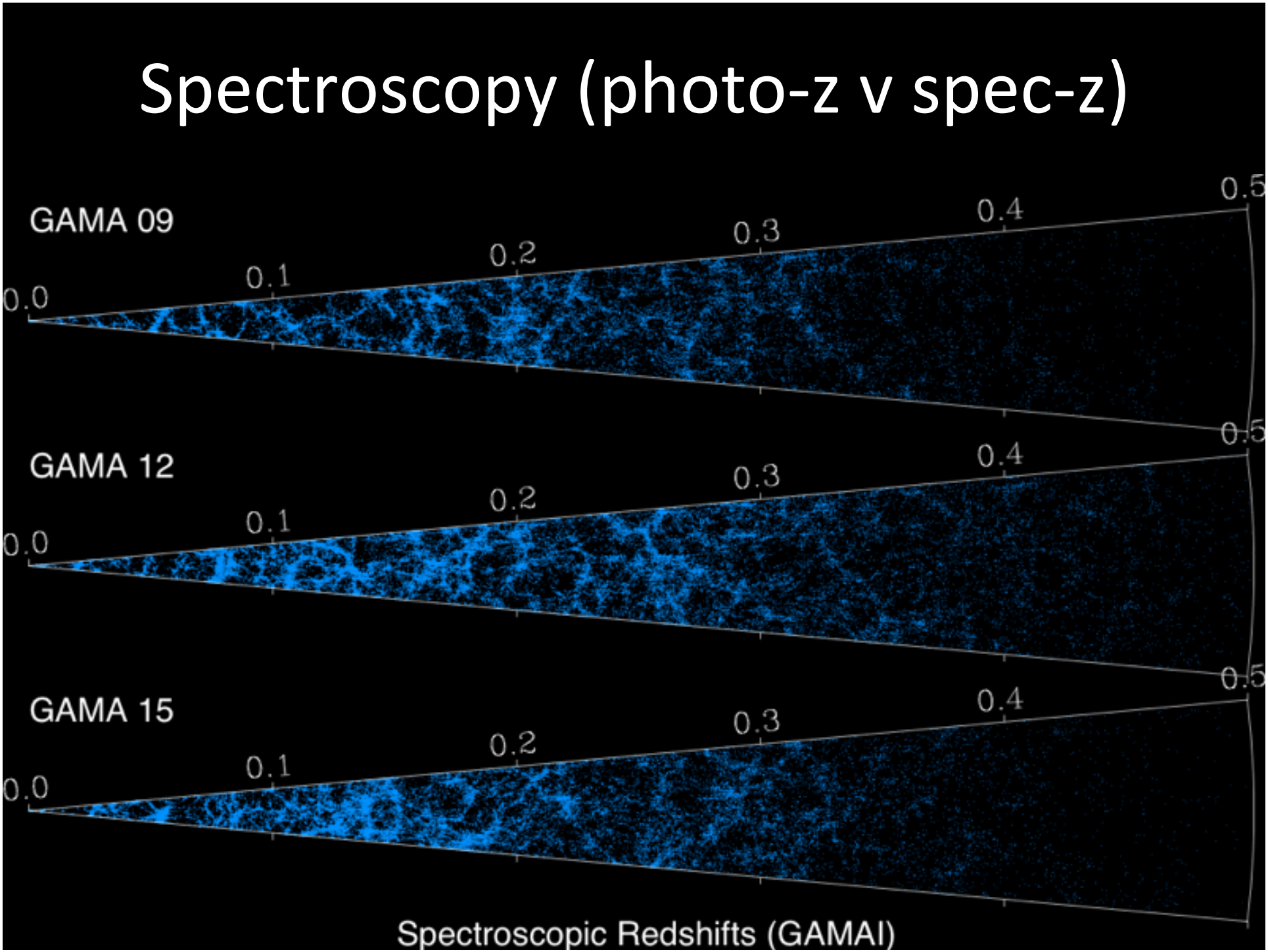
long/short
HIGH-RES
IMAGING
morphology
bulge/bar/disc

Spectroscopy (photo-z v spec-z)



Spectroscopy (photo-z v spec-z)



Spectroscopy (photo-z v spec-z)

- Spec-z: $\Delta z/(1+z) \sim 0.0001$ v Photo-z: $\Delta z/(1+z) \sim 0.02$
  $\sim 30 kms^{-1}$ v $\sim 6000 kms^{-1}$

- Halo mass ($60 kms^{-1}$), pairs ($25 kms^{-1}$), filaments ($1000 kms^{-1}$)

- SFRs (Hα, [OII], OIII) and metalicities (Mg, Na etc)

- Do DESI, BOSS, eBOSS, EUCLID, WFIRST provide this?

.....No

- Cosmology and galaxy surveys have diverged →

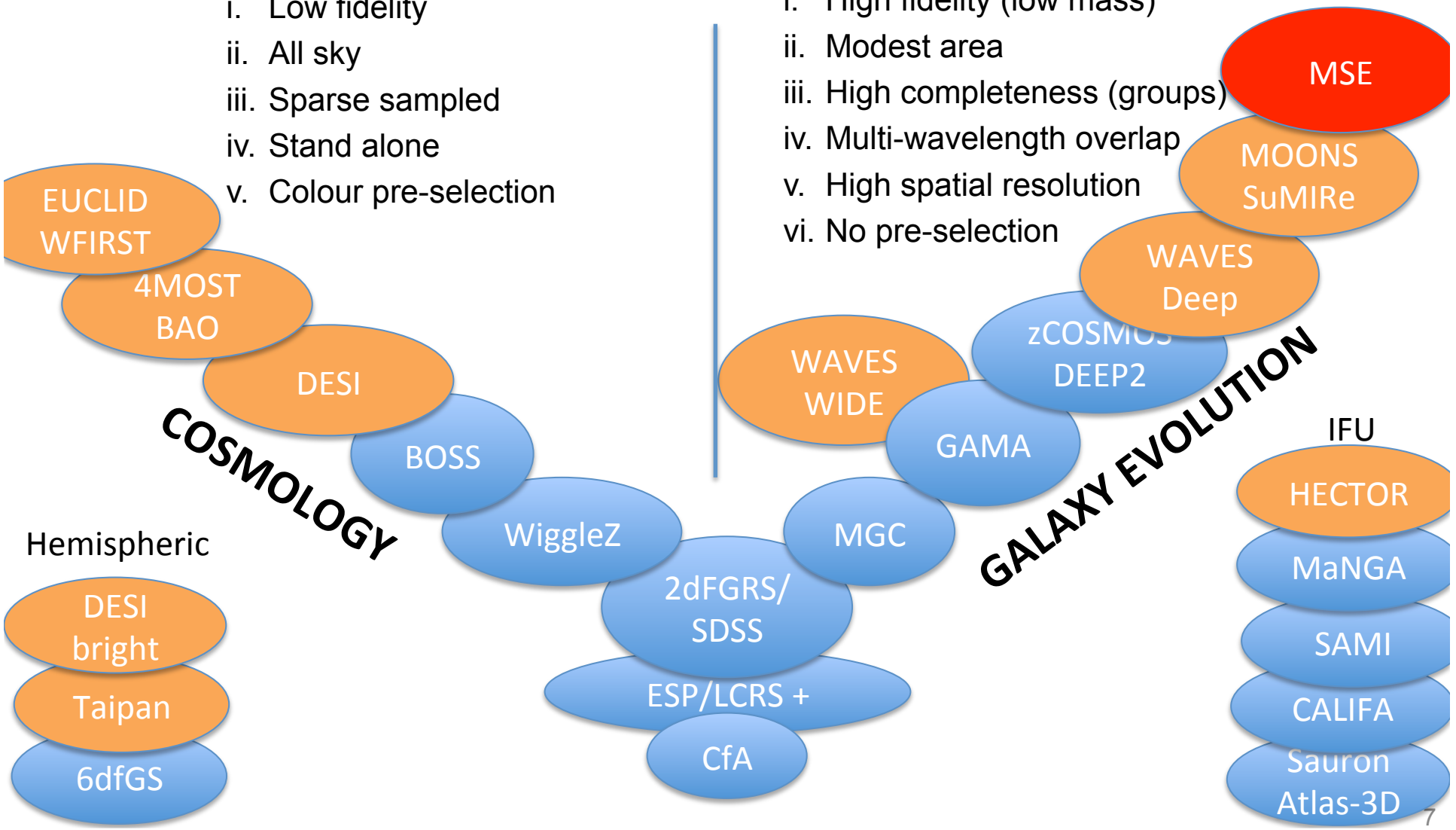
Cosmology v Galaxy Surveys

Optimal cosmology survey

i. Low fidelity
ii. All sky
iii. Sparse sampled
iv. Stand alone
v. Colour pre-selection

Optimal galaxy survey

i. High fidelity (low mass)
ii. Modest area
iii. High completeness (groups)
iv. Multi-wavelength overlap
v. High spatial resolution
vi. No pre-selection



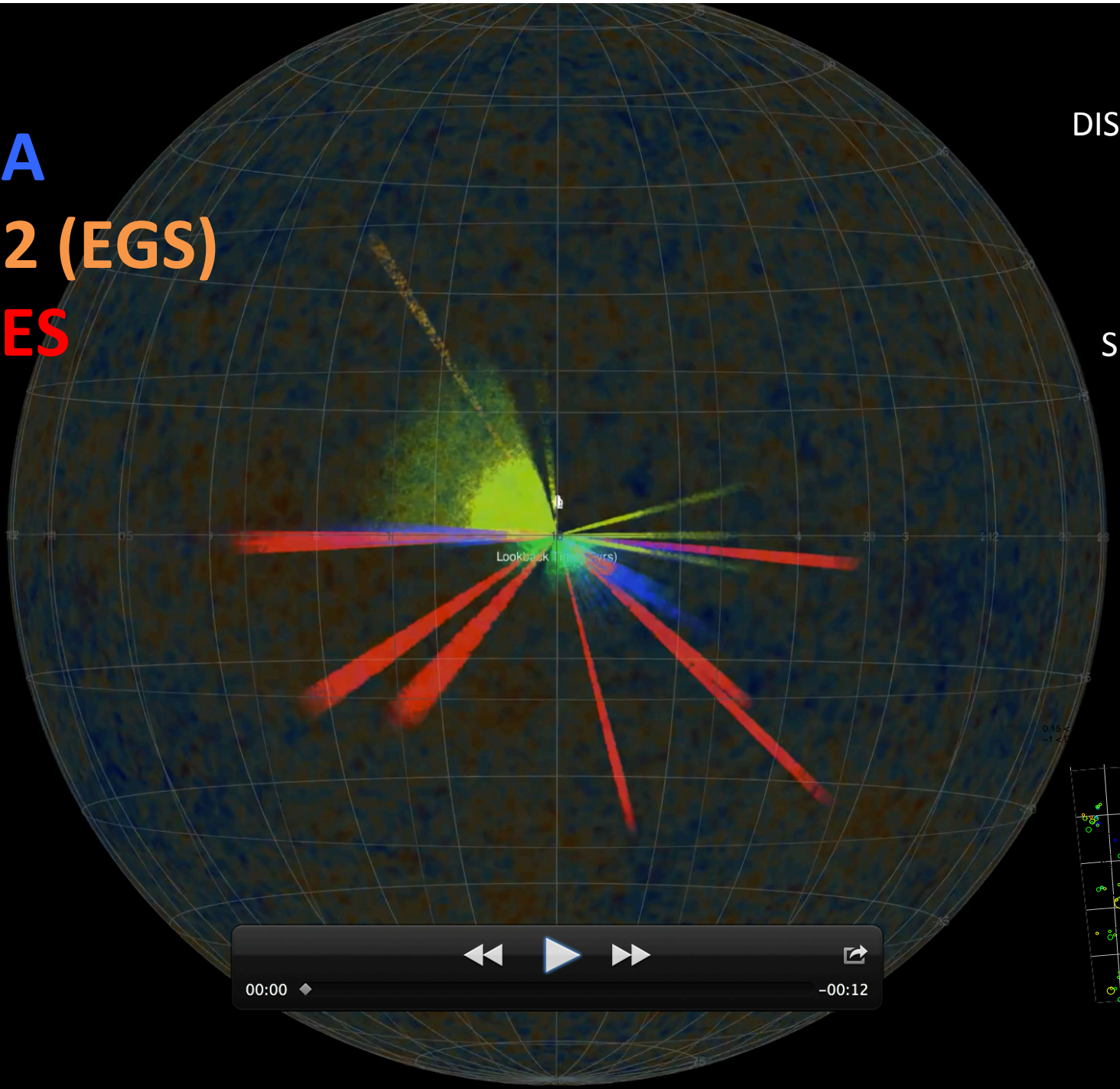
SDSS

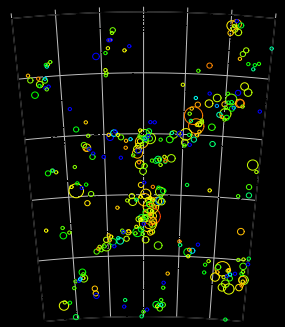
GAMA

DEEP2 (EGS)

WAVES

DARK MATTER DISTRIBUTION KNOWN ROBUSTLY ALONG THESE SIGHT-LINES VIA GROUP FINDING





WAVES

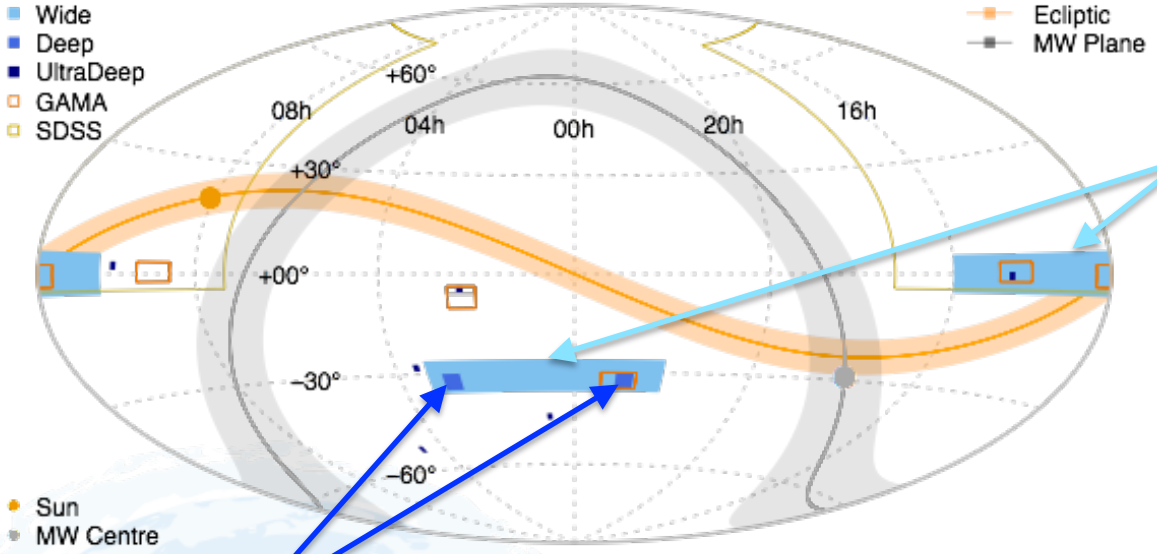
wide area vista extragalactic survey

4MOST

PI: Simon Driver, Joe Liske
PS: Aaron Robotham, Luke Davies
PM: Liz Mannering





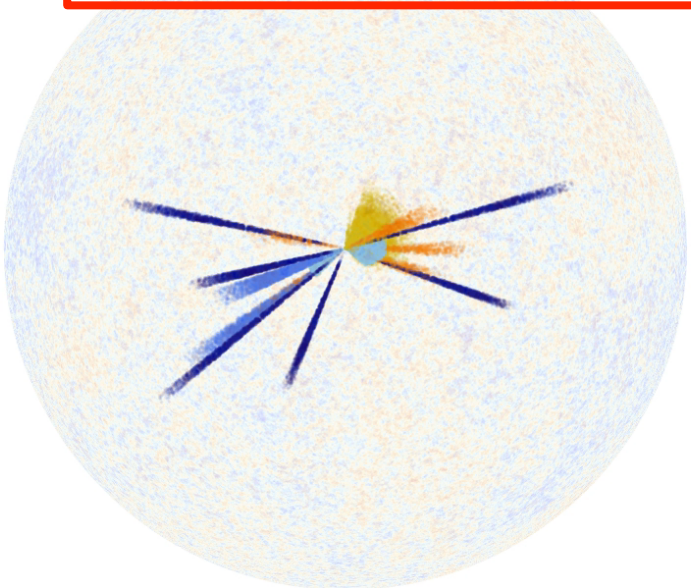


WAVES-Wide

- Stellar mass function down to 10^7 $M_\odot$
- Detect groups and halos below the peak in stellar mass efficiency.

2x750sq deg r<22mag z_{phot}<0.2

2million galaxies to r<22mag
100,000 halo masses z<1



WAVES-Deep

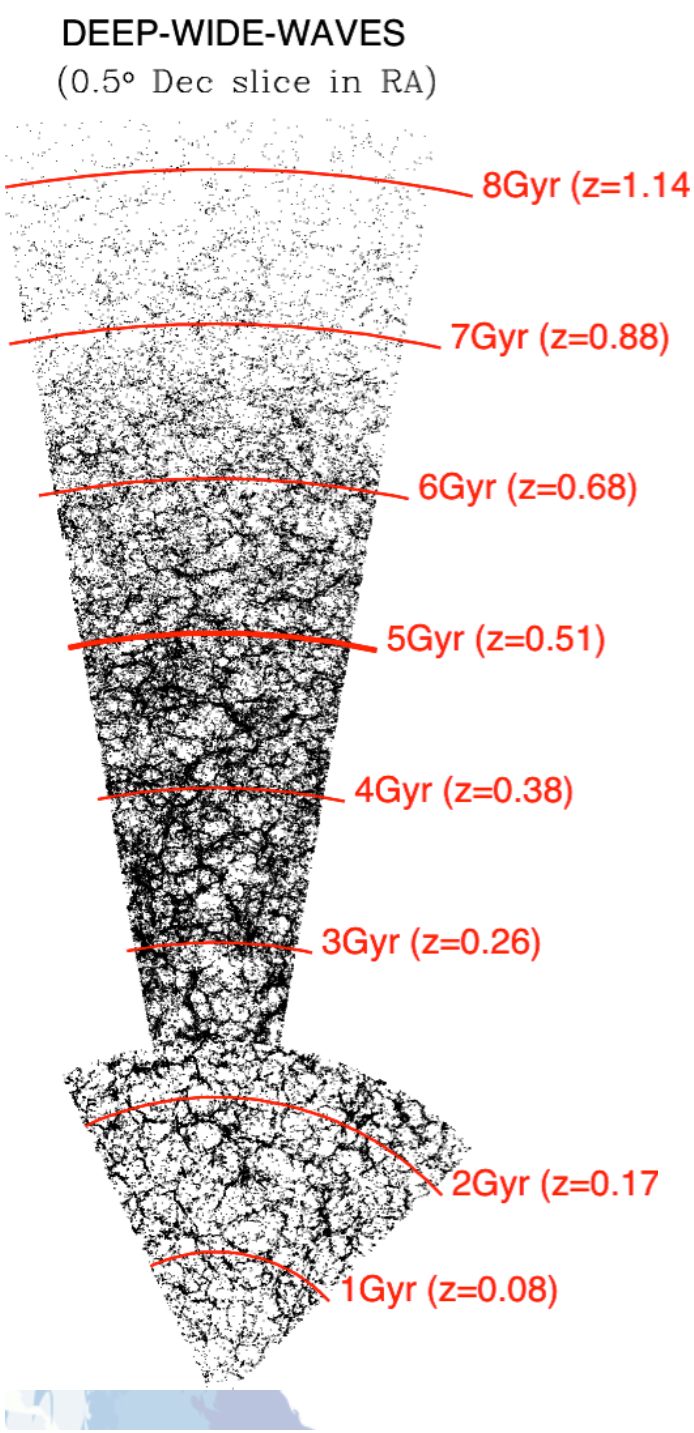
- Follow-up of ASKAP and SKA deep fields.
- Measure the evolution of filaments and clusters since z=1.

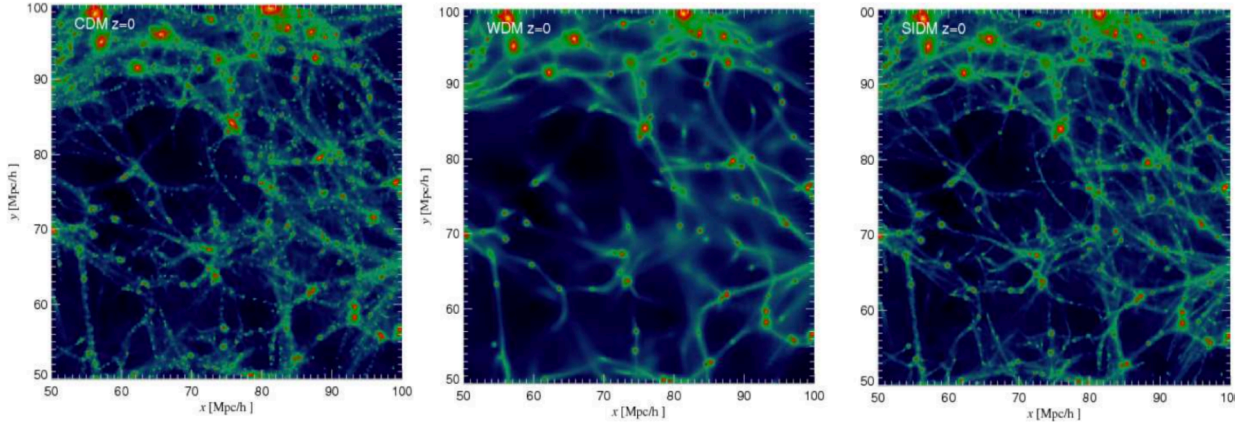
2x50 sq deg r<22 mag

WAVES-UltraDeep

- Follow-up of multiple classic deep fields (SKA-Mid and SKA ultra-deep).
- Measure the mass growth of galaxies via mergers and star formation since z=2.

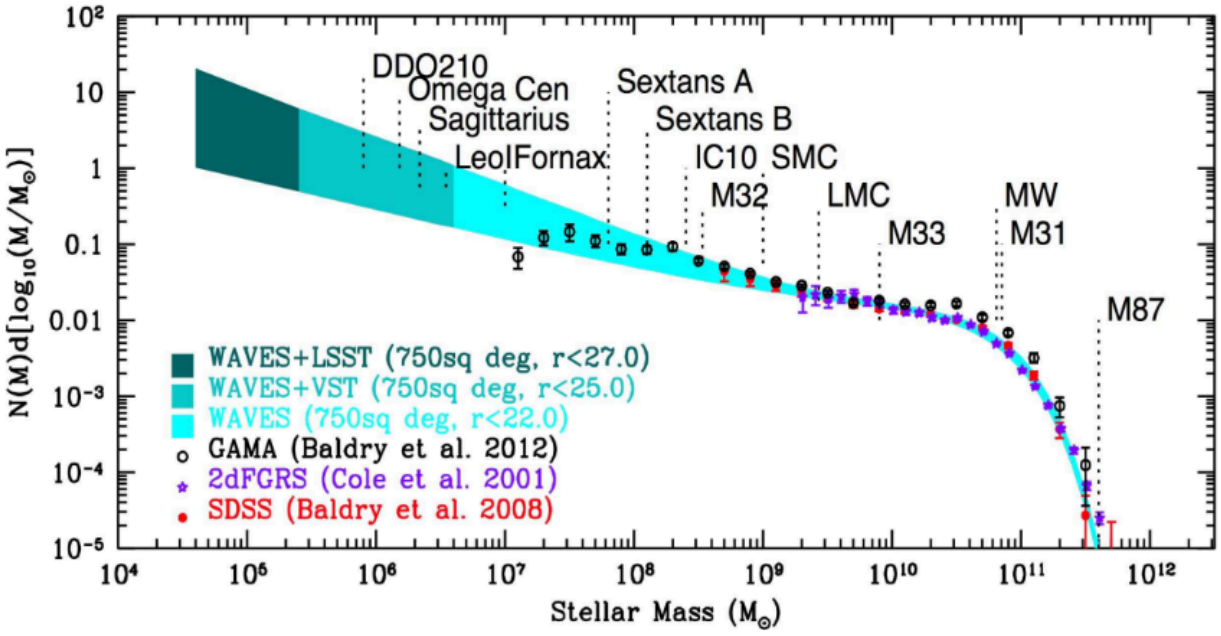
6x2 sq deg r<23

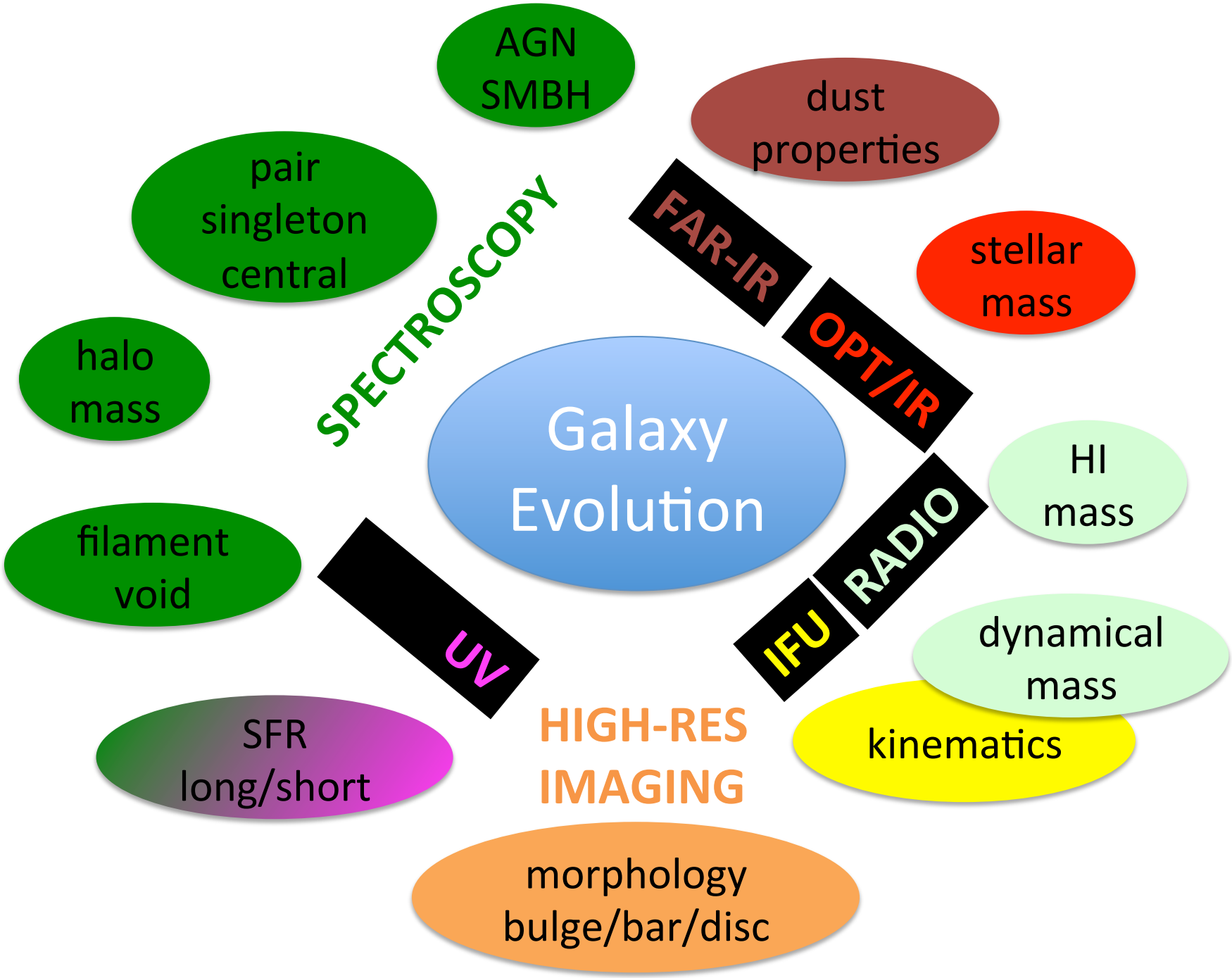




WAVES Science Headlines

- Distinguish between CDM, WDM and SIDM
- Probe to very very low stellar masses
- Halo evolution to z~1
- Bulge-disc decomposition to z~1 (disc growth)




AGN
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Evolution
HI
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filament
void
UV
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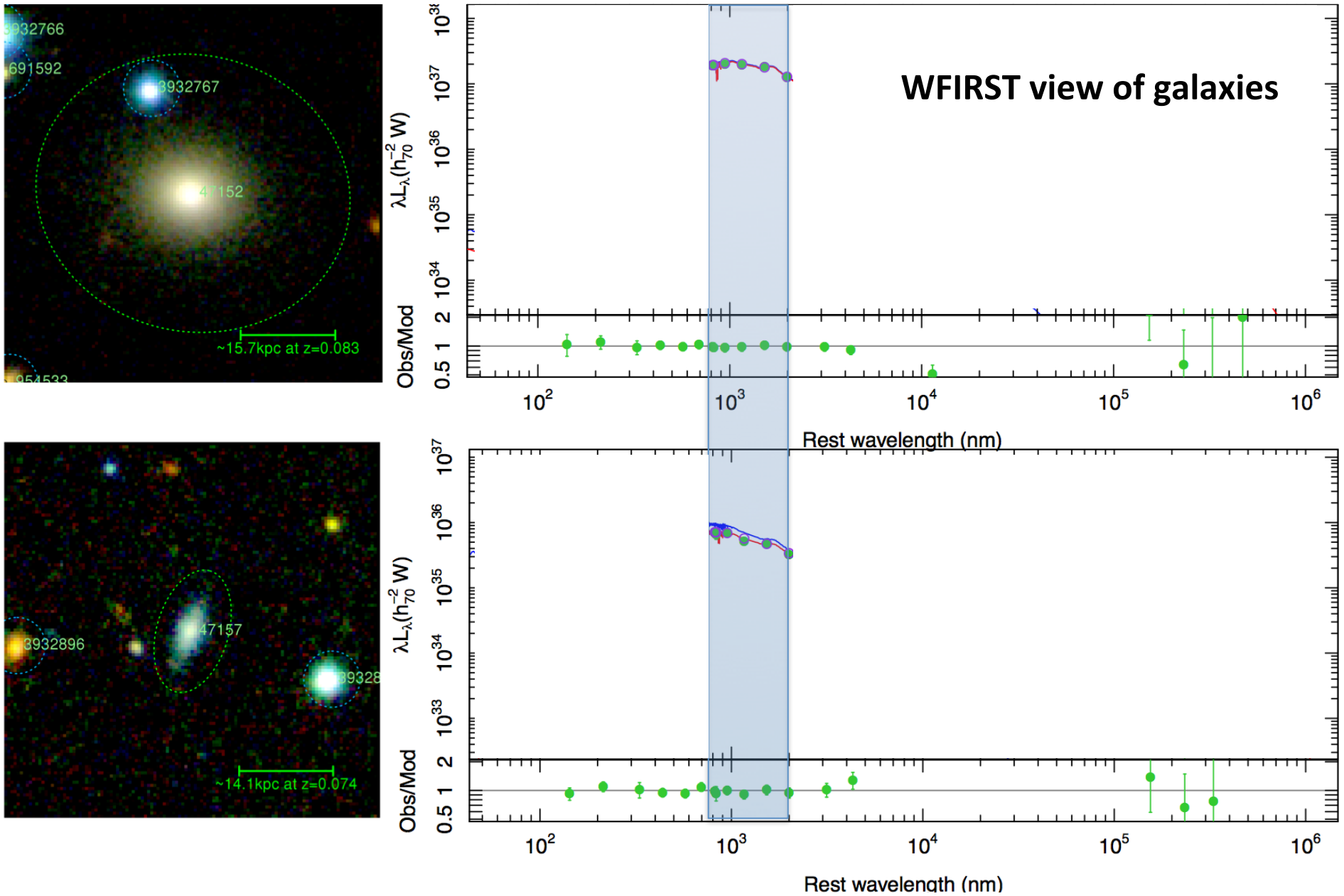
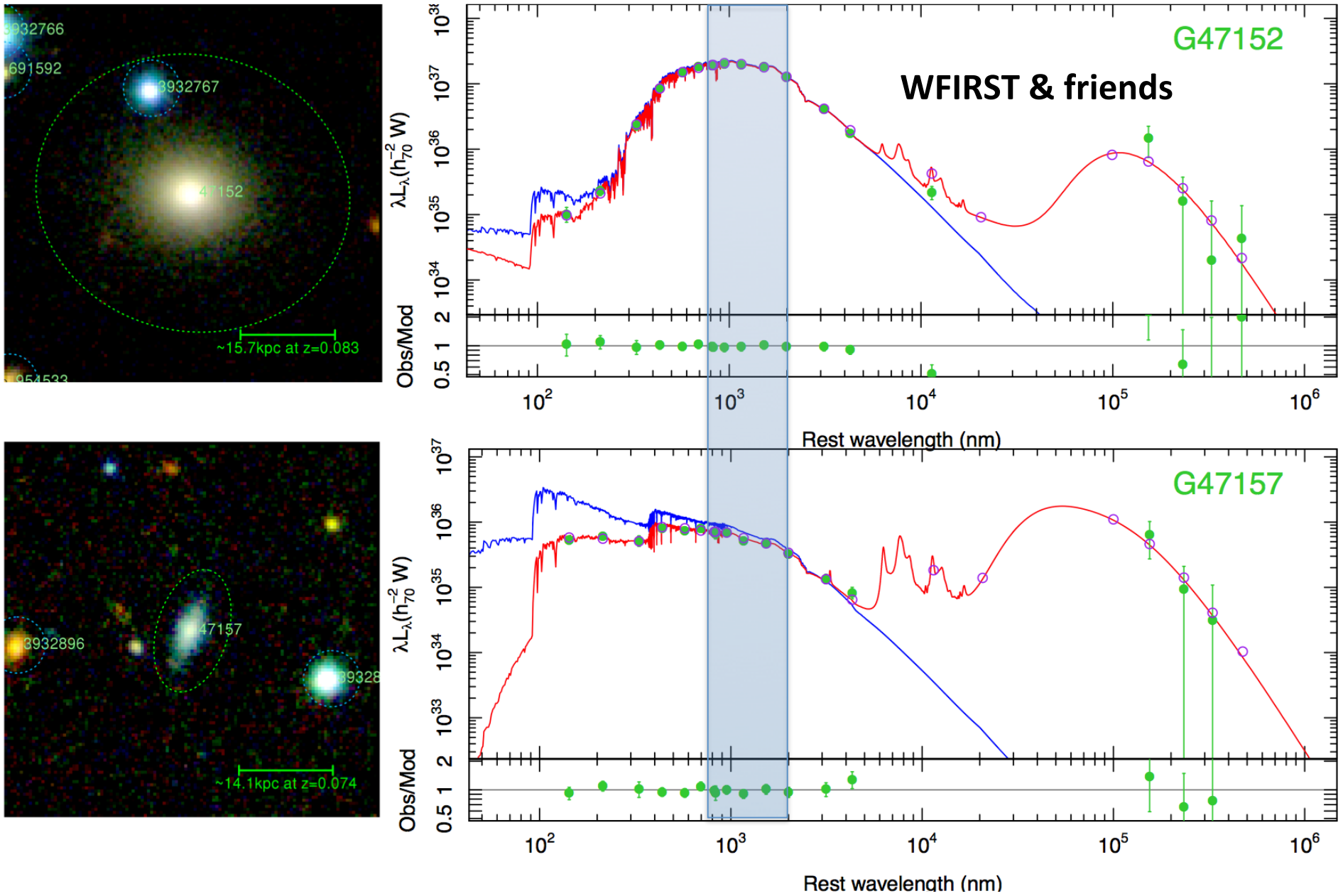
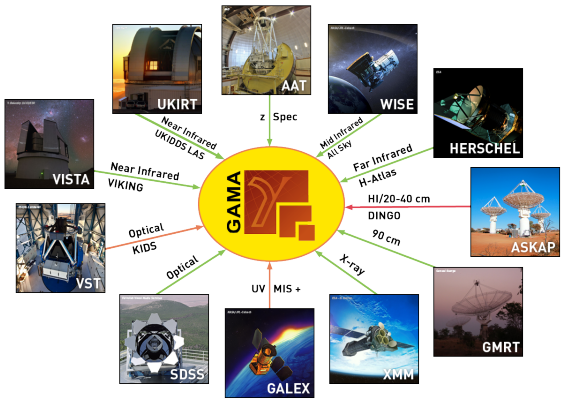
SFR
long/short
HIGH-RES
IMAGING
kinematics
morphology
bulge/bar/disc

Panchromatic Data



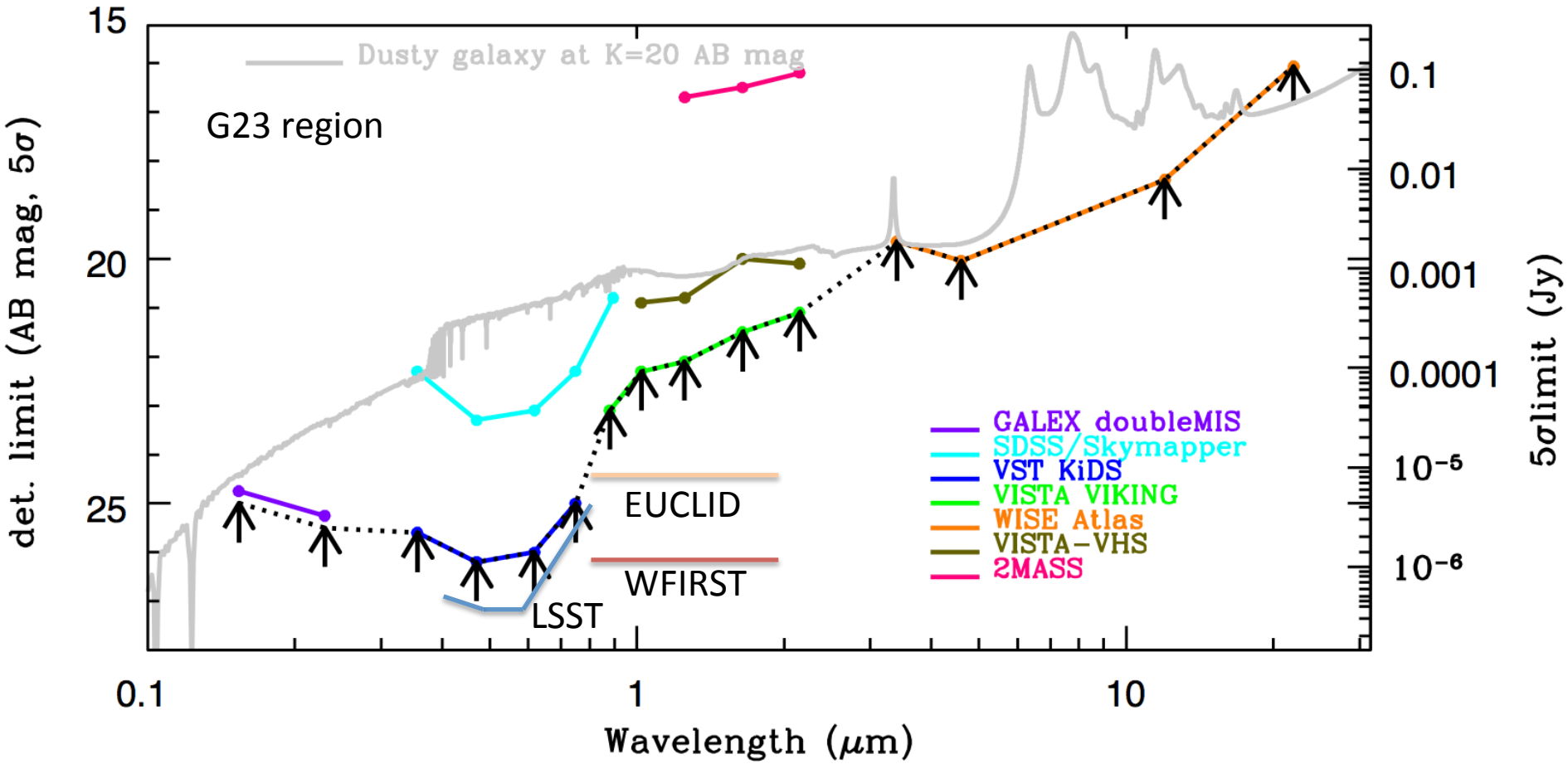
Panchromatic Data





GAMA regions

Deepest wide-area panchromatic coverage:
GALEX, VST, VISTA, WISE, HERSCHEL, ASKAP



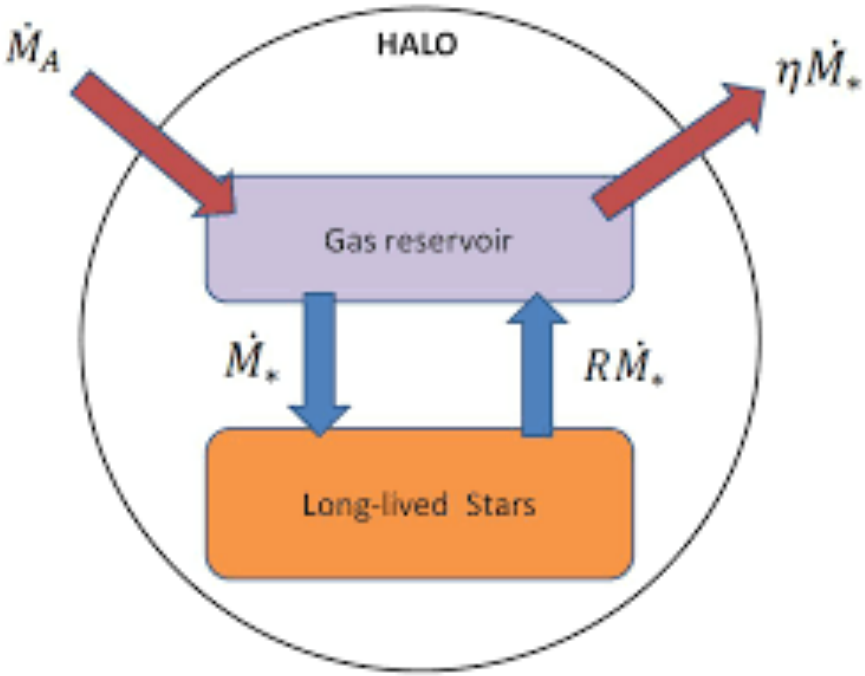
Panchromatic = galaxy masses

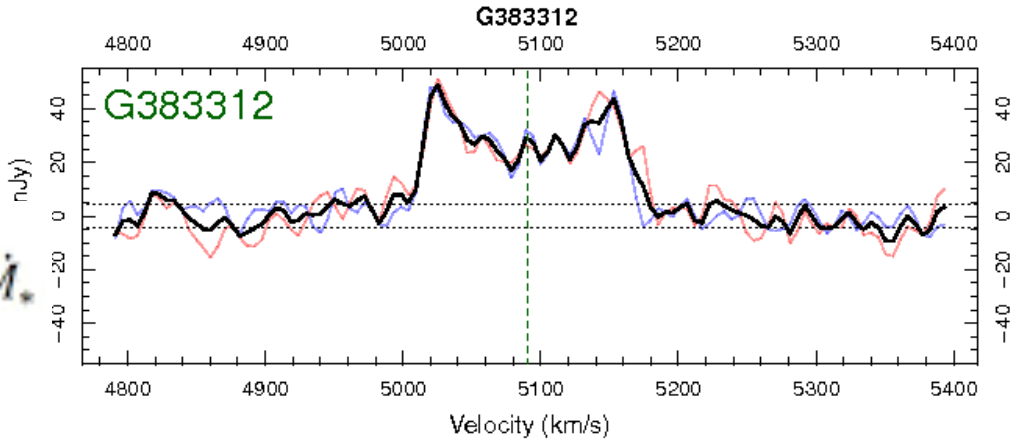
Halo mass	← Spectroscopy (groups)	← GAMA/WAVES/MSE
Dynamical mass	← Radio (21cm line)	← SKA
HI mass	← Radio (21cm line)	← ASKAP/SKA
Molecular mass	← mm (CO)	← ALMA/LMT/CCAT?
Stellar mass	← Optical/near-IR (M/L)	← LSST/WFIRST
Bulge mass	←optical or near-IR	← EUCLID/WFIRST
Disc mass	←Optical or near-IR	← EUCLID/WFIRST
Dust mass	←far-IR (BB peak)	← Herschel/SPICA?
SMBH mass	←optical/near-IR (bulge)	← EUCLID/WFIRST

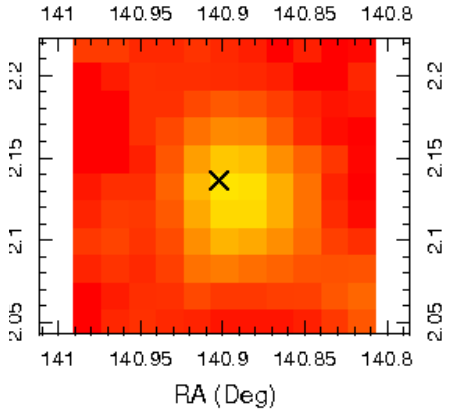
APPROVED WORKING ON IT NOT YET MAYBE? STATUS UNKNOWN?

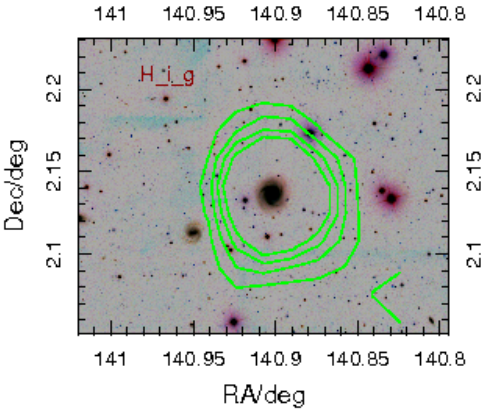
HI & continuum spectral indices for all 2million galaxies via SKA!

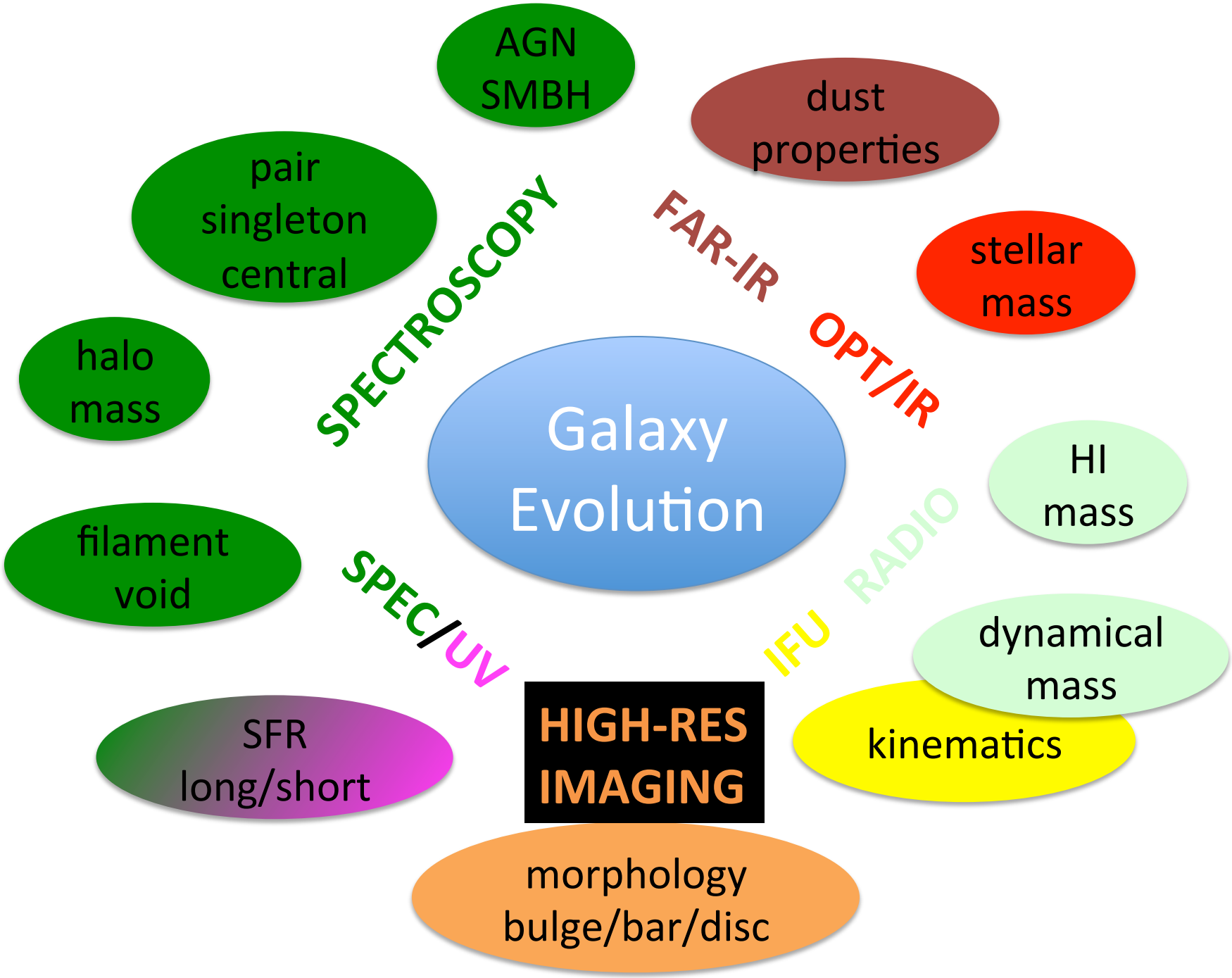
Bathtub model










AGN
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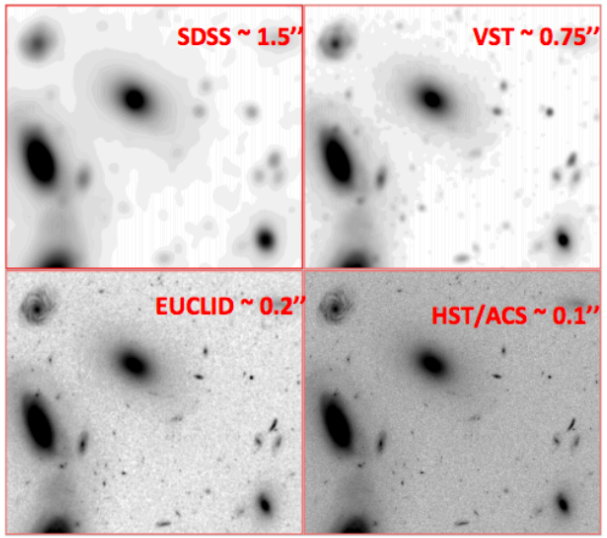
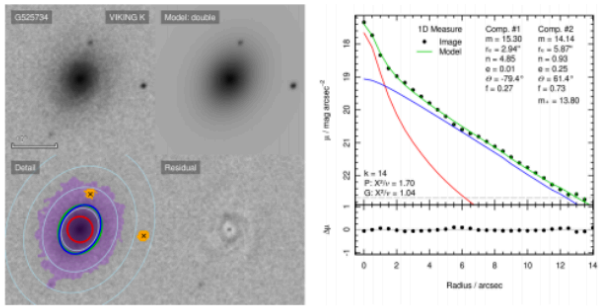
RADIO
IFU
dynamical
mass
kinematics
SFR
long/short
HIGH-RES
IMAGING
morphology
bulge/bar/disc

High resolution imaging

- Bulge-disc decomposition not possible from ground beyond z=0.1 (maybe z=0.2 with Subaru)
- HST provides too few objects at z<1, WFIRST will bridge the 0.1 < z < 1.5 gap
- Q. Why is this gap important?





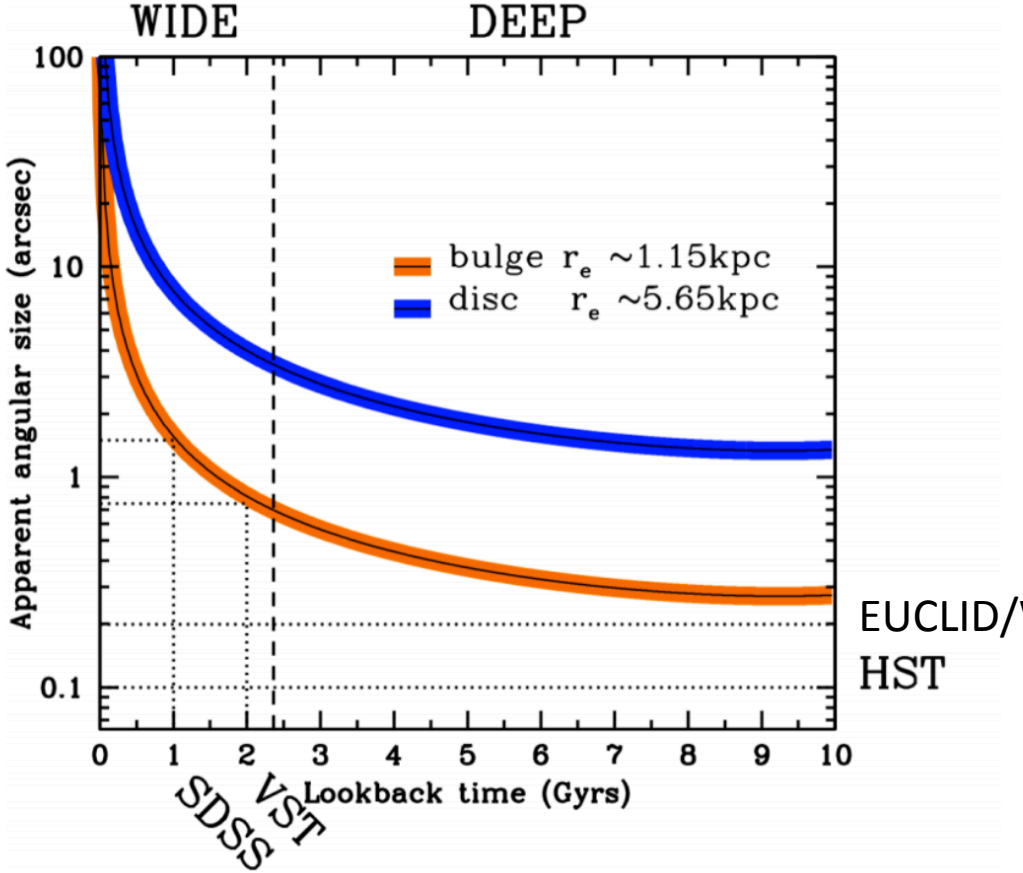
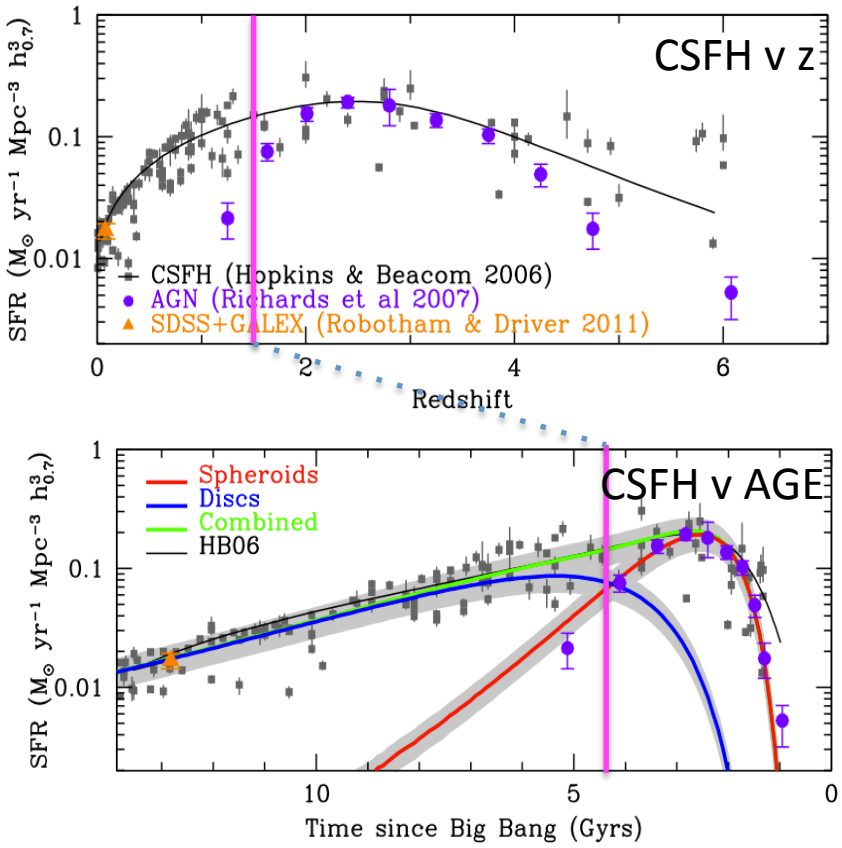
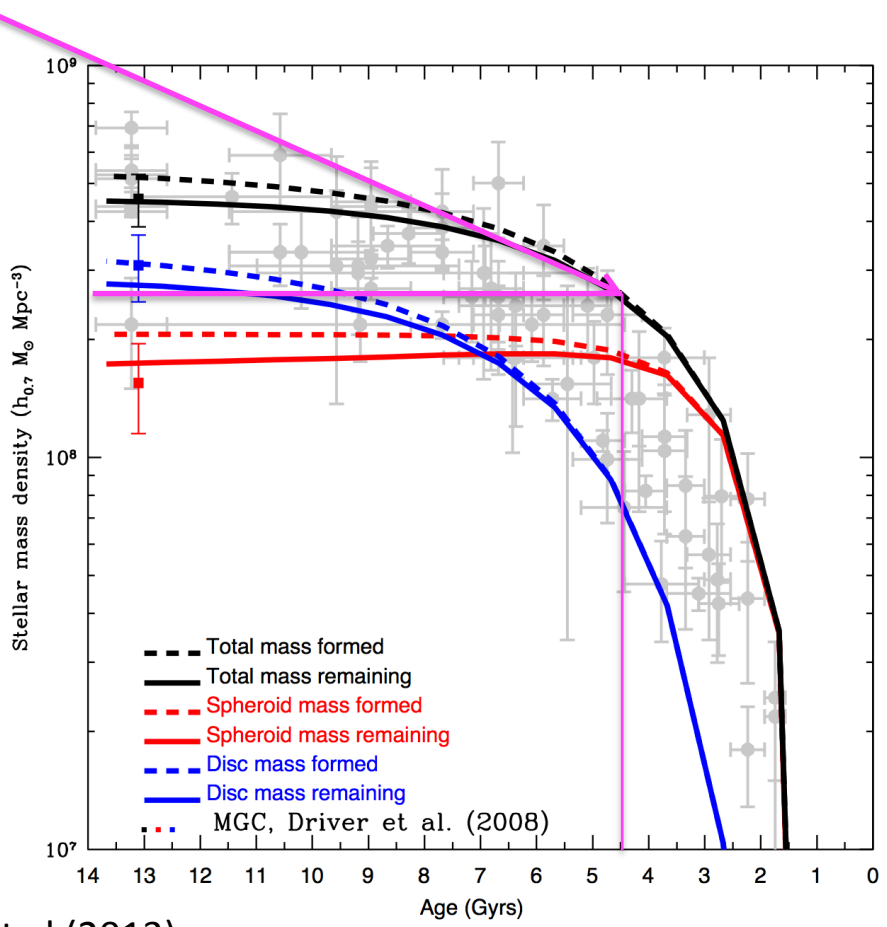


Fig. 1: Left-top: Comparison of various imaging datasets, with median seeing as indicated. Left-bottom: Structural decomposition fitting of galaxies. Right: Angular-size versus lookback time with the low-z limitations of the SDSS and VST shown.

High resolution imaging

- HST provides too few objects at z<1, WFIRST will bridge this 0.1 < z < 1.5 gap
- Q. Why is this gap important?
- A. Because most stars assembled in this interval, and its more than half the age of the Universe
- 90% of spheroid mass formed (but not merged), 25% of disc mass formed
  = era of disc growth and of spheroid relaxation



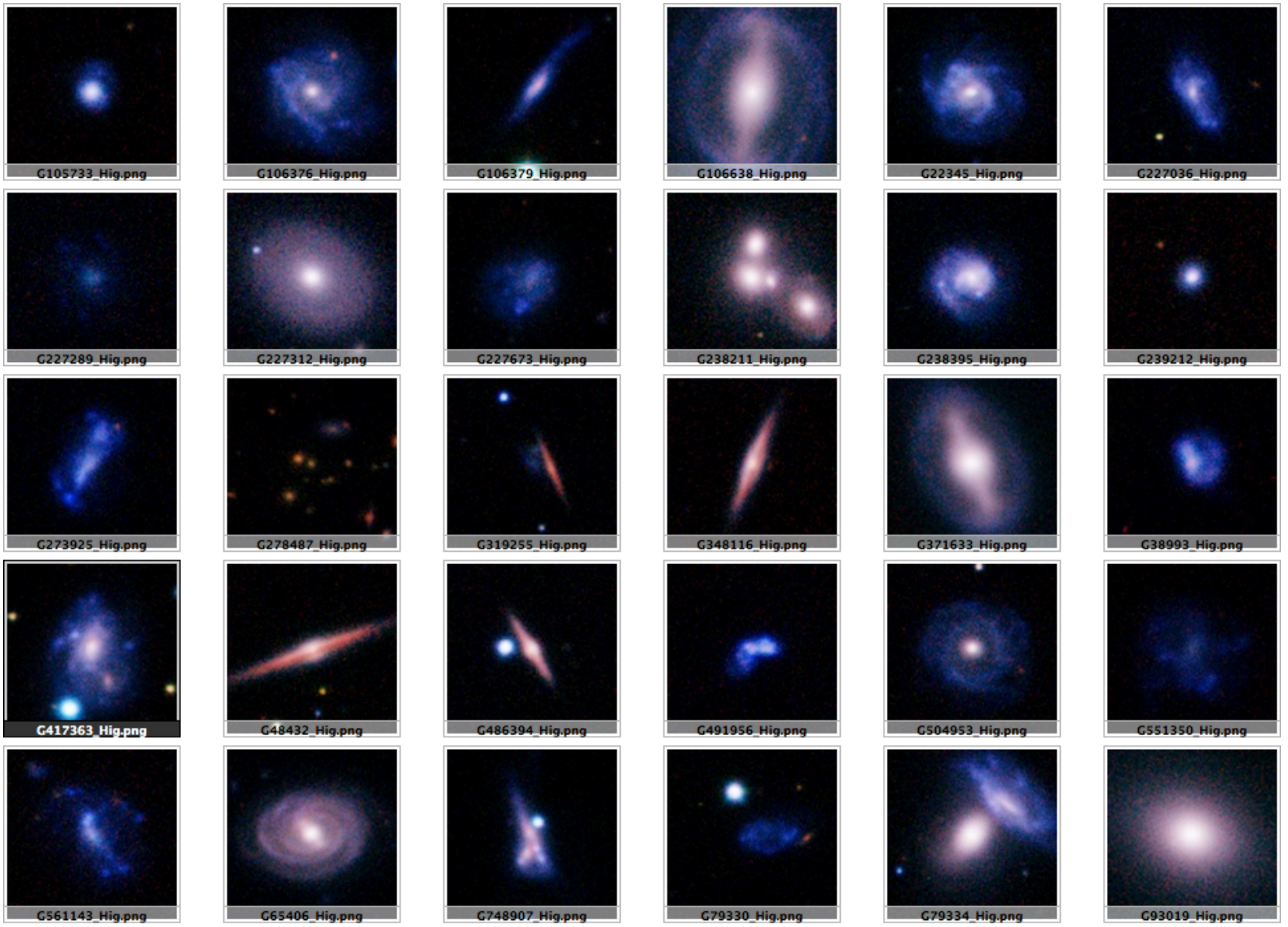


Driver et al (2013)

High resolution imaging

Driver et al (1998)

Endpoints: Nearby Galaxies

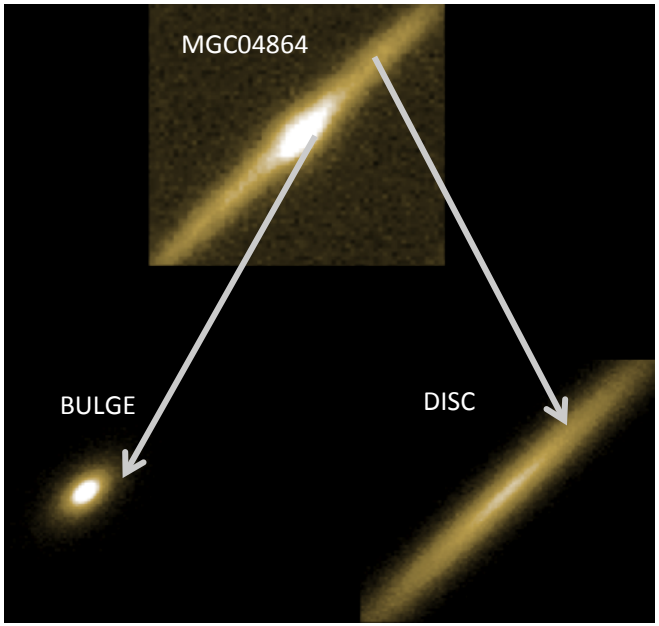


Components v colours ?

Components:

Defined by the orbits of ~1billon stars

Tracer of long-term formation history?

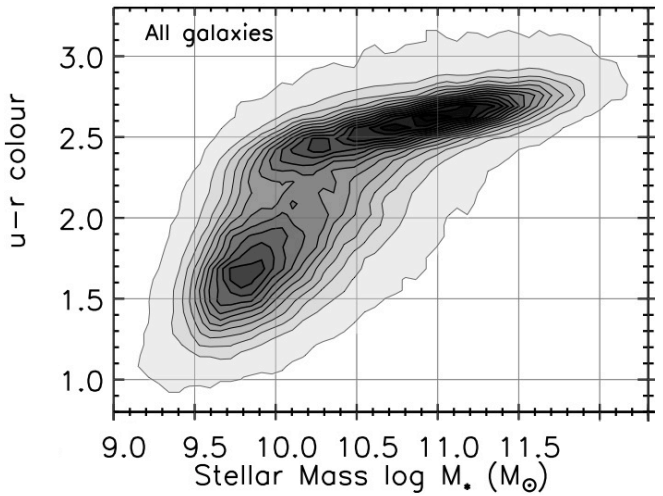


Colours:

Defined by the current star-formation rate

Tracer of instantaneous state of the system?

Current conversation on galaxy evolution is dominated by studies of red v blue but should it be bulge v disc? or both?

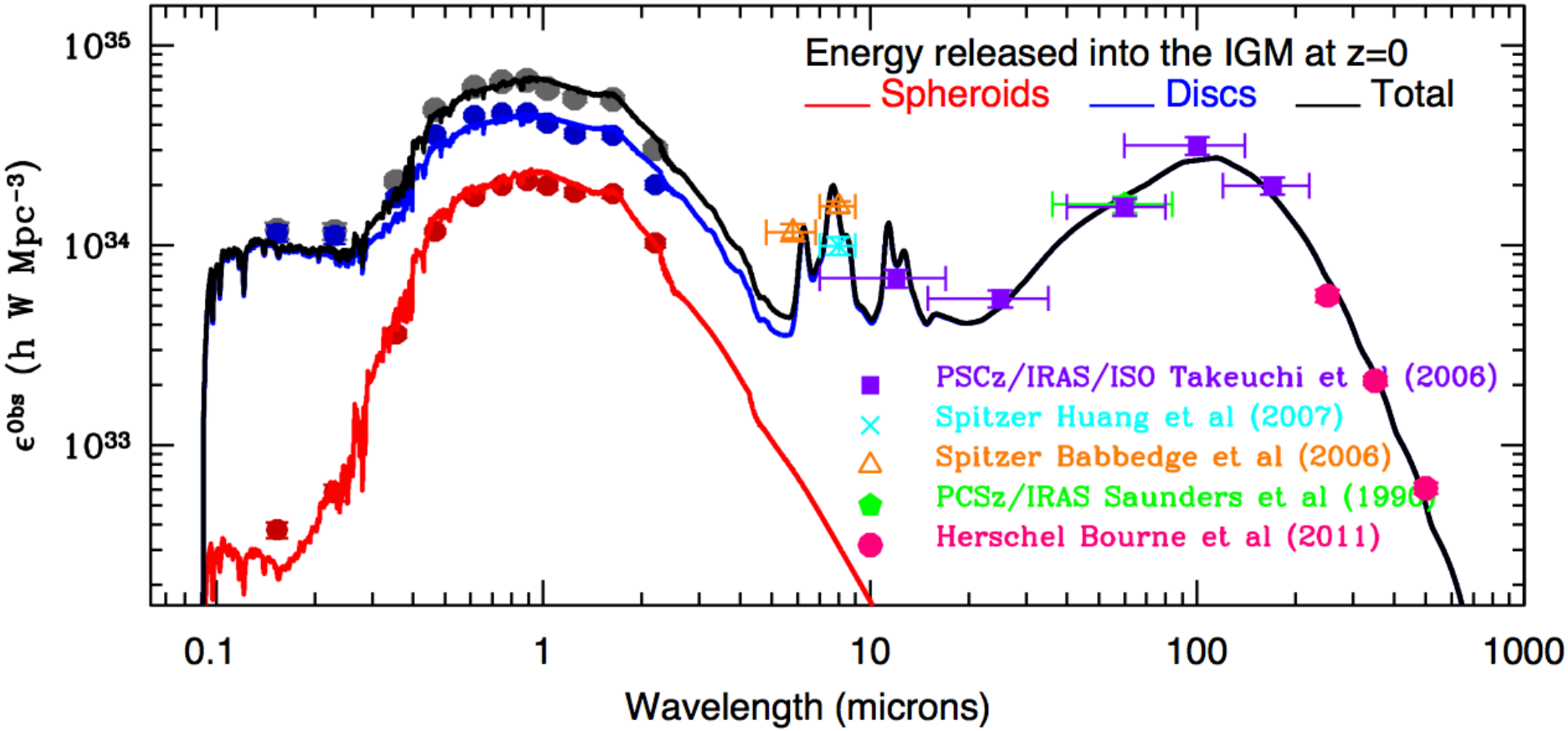


Low-z = nucleus, bulge, bar, ring, disc, disc-truncation

High-z = red sequence, green valley, and blue cloud

Spheroids and discs

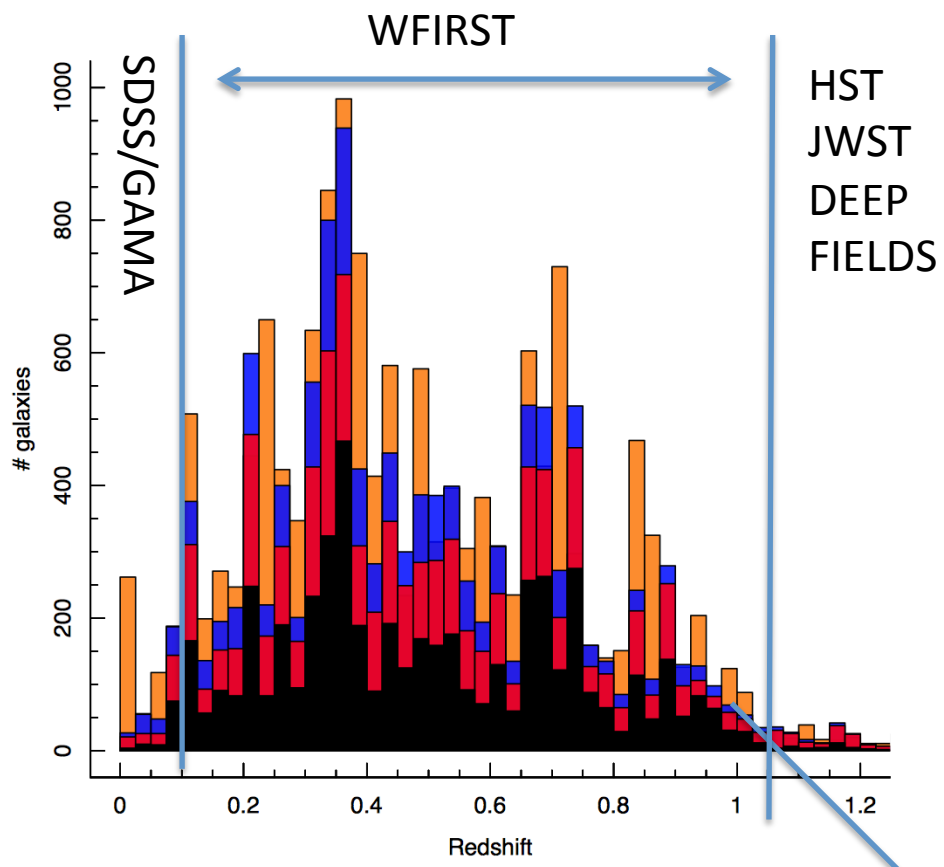
Spheroids/bulges = old stars dust free, gas free, minimal SF, pressure supported
Discs/irregulars = new stars, dusty, gassy, high-SF, rotating
Evolution of components is NOT coeval, ∴ need to decompose

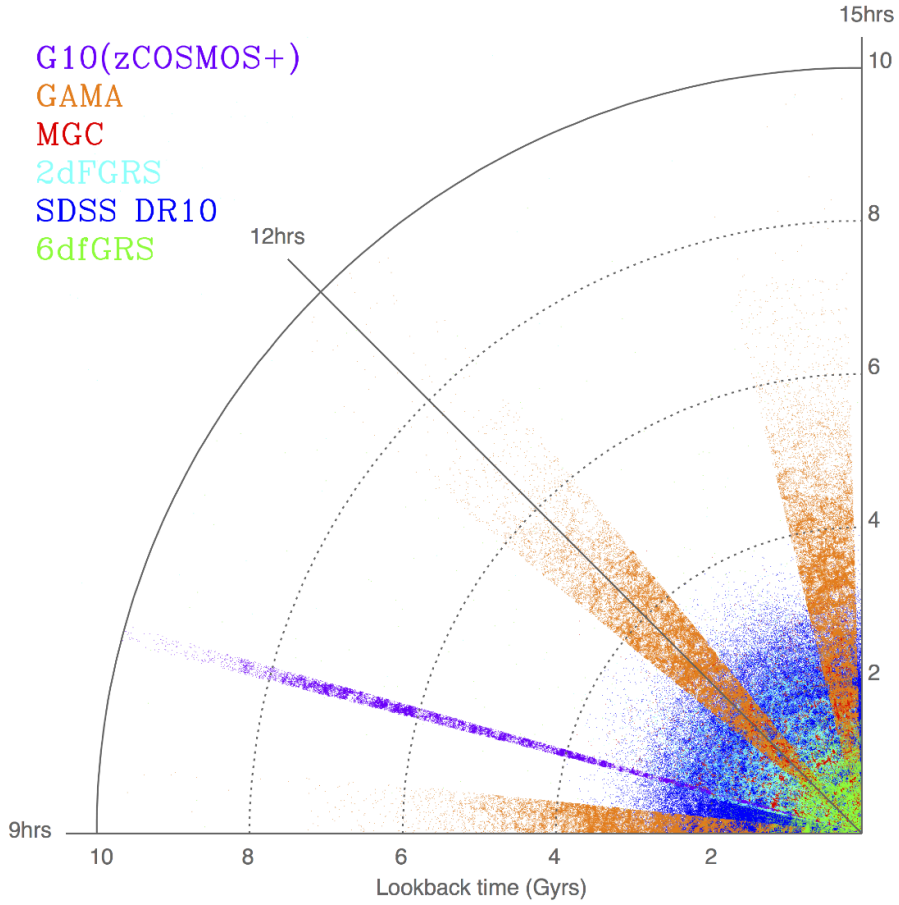


Scoville et al (2007)
Lilly et al (2007)
Capak et al (2007)
Koekemoer et al (2007)

COSMOS/zCOSMOS

Awesome panchromatic dataset but numbers small, need 50-100x COSMOS=100sq deg=WFIRST





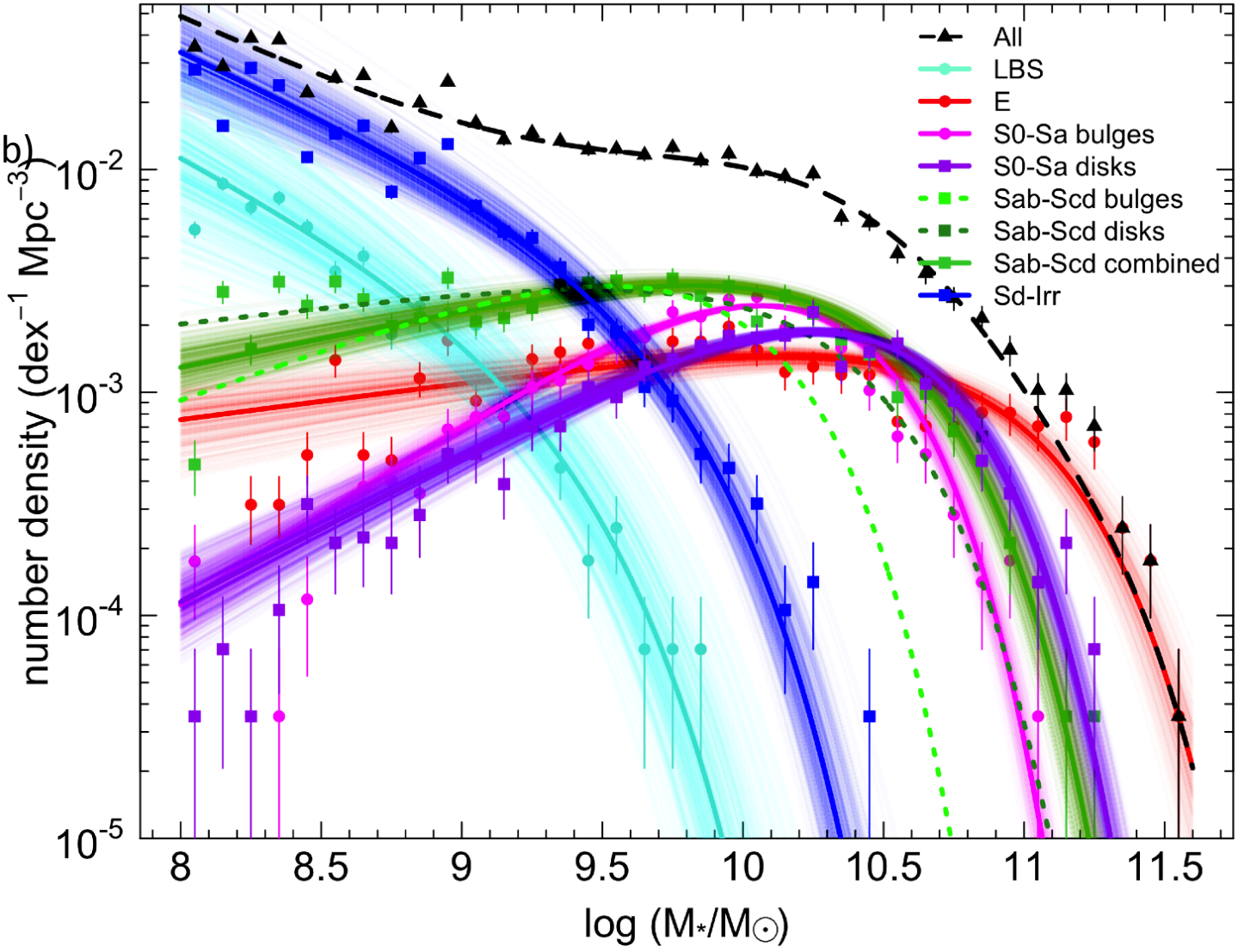
Davies et al (2015)

WFIRST: Evolution of stellar mass functions *by component*

z<0.1 result
from GAMA
Moffet et al (2016, sub)

WFIRST: Capable
of tracing build-up
of disc and spheroid
mass with redshift

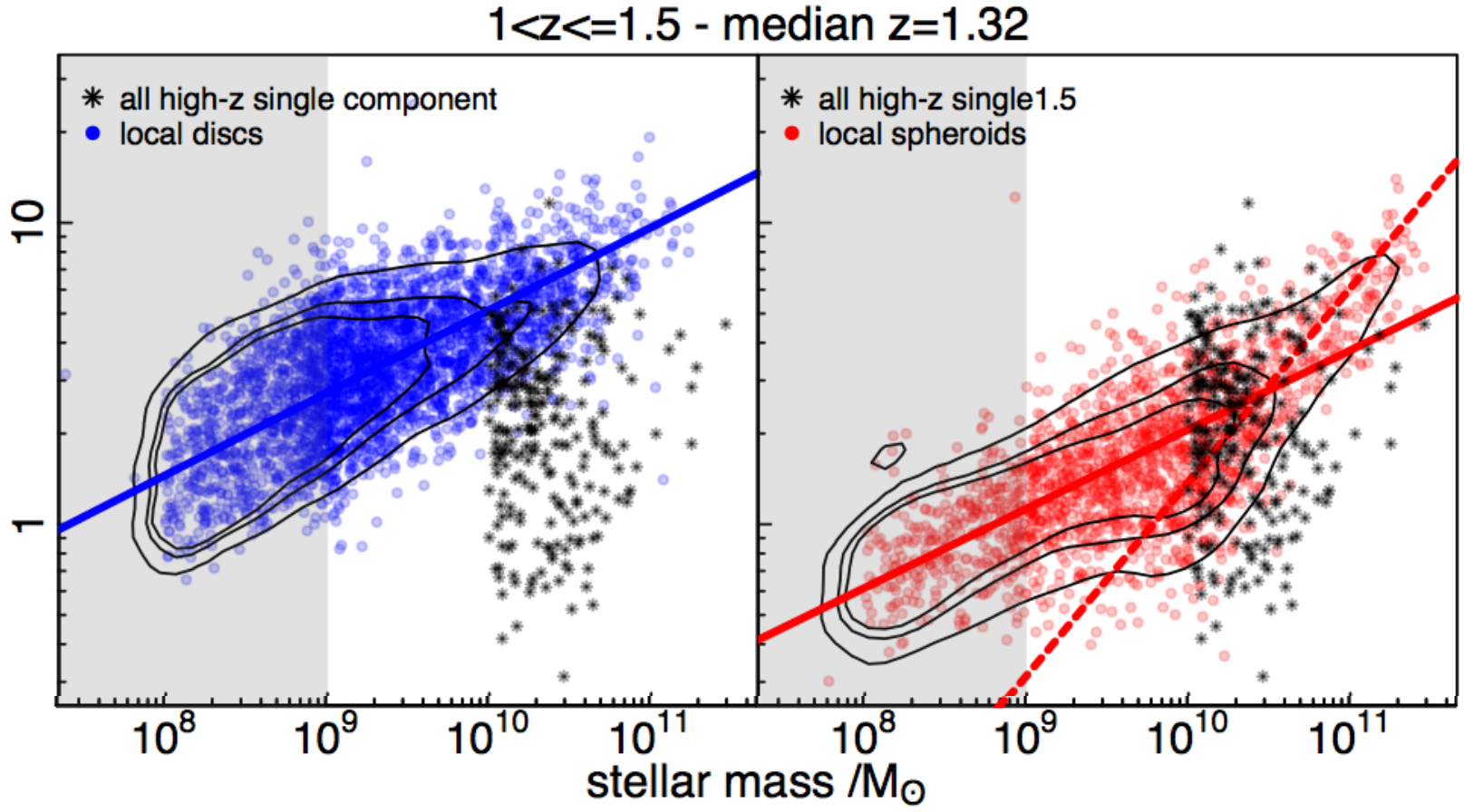
AN
EMPIRICAL
BLUEPRINT



WFIRST: Evolution of mass-size relation (structure) *by component*

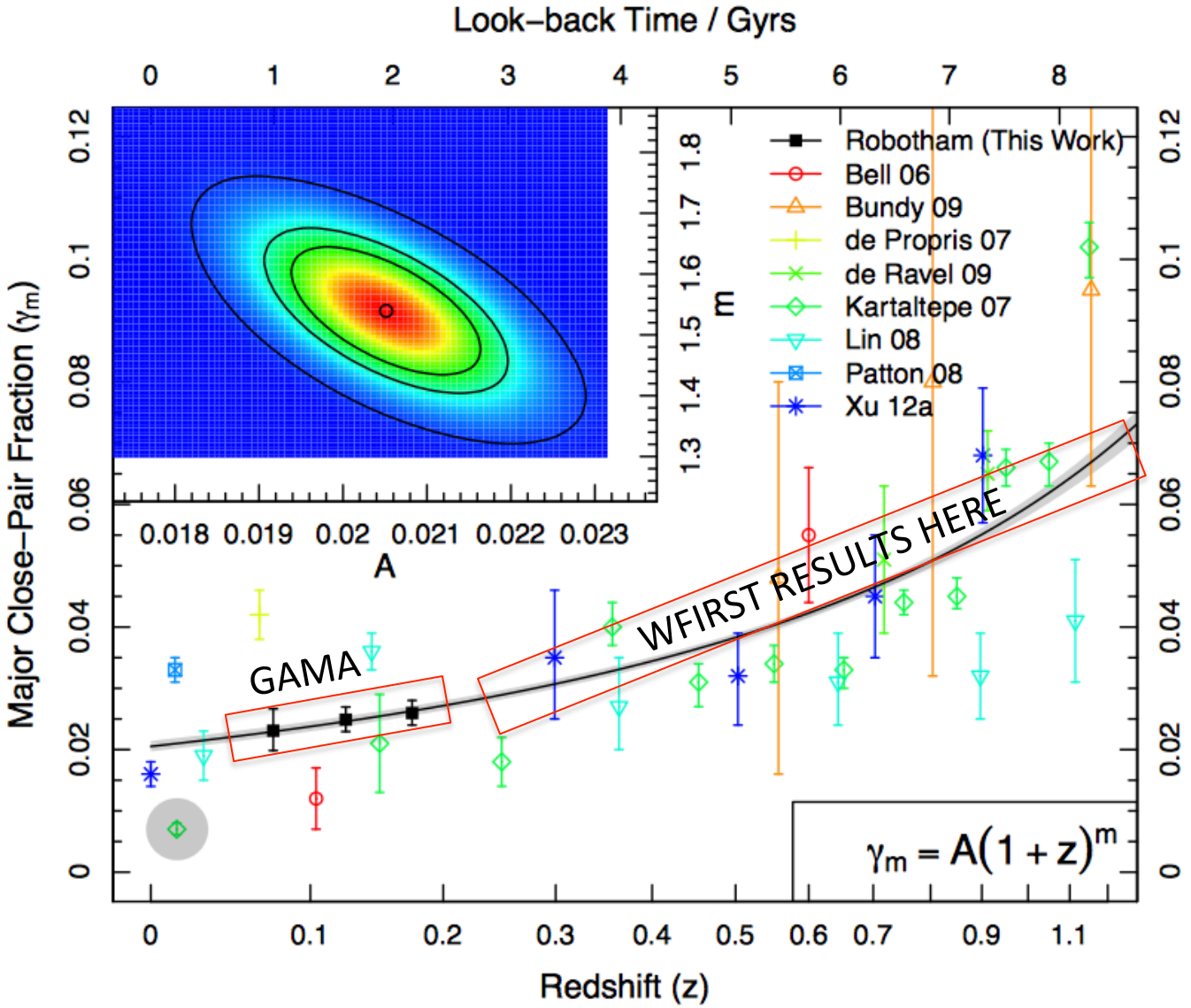
Intermediate z systems from Bruce et al are co-located with spheroid sequence (Es+bulges)

Lange et al (2016, sub)



WFIRST: Evolution of the major and minor merger rates (structure) *via asymmetry*

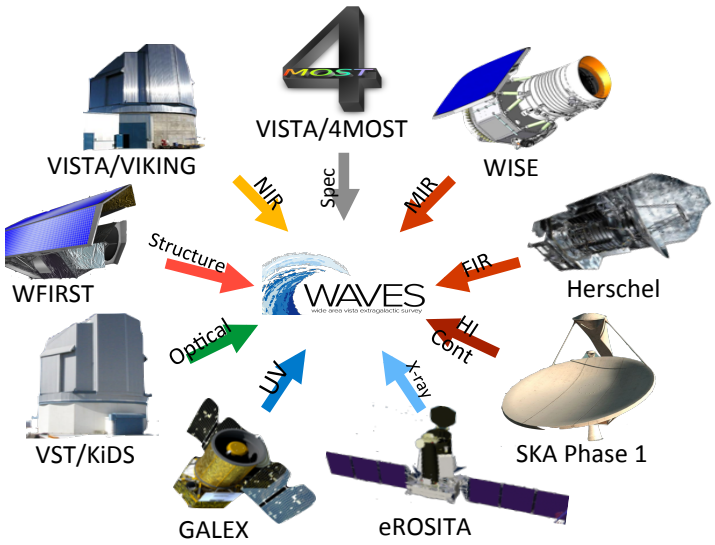
Need spectra plus high-res imaging to identify genuine mergers via asymmetry, tidal-tails, and distortions.

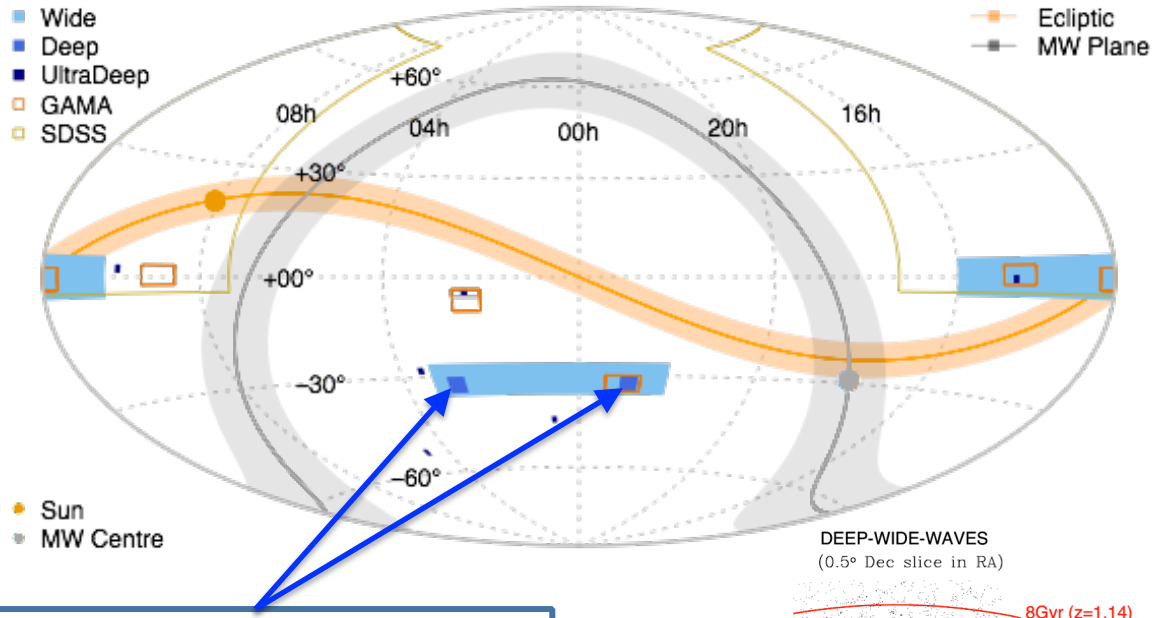


Robotham et al (2015)

GO Proposal

- WFIRST to survey the WAVES-DEEP fields:
  - spectra + imaging + HI
  - 23^h, -27^d (or thereabouts)
  - 2.5^h, -27^d (or thereabouts)
- 2 x 50 sq deg, H~26.7mag
- as part of cosmology footprint
- open access for WFIRST to all contributing datasets

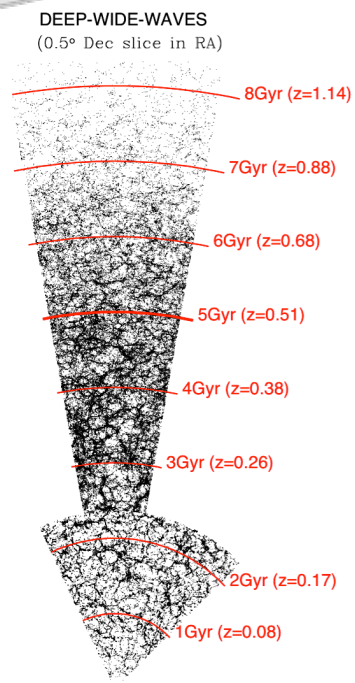




WAVES-Deep

- Follow-up of ASKAP and SKA deep fields.
- Measure the evolution of filaments and clusters since z=1.

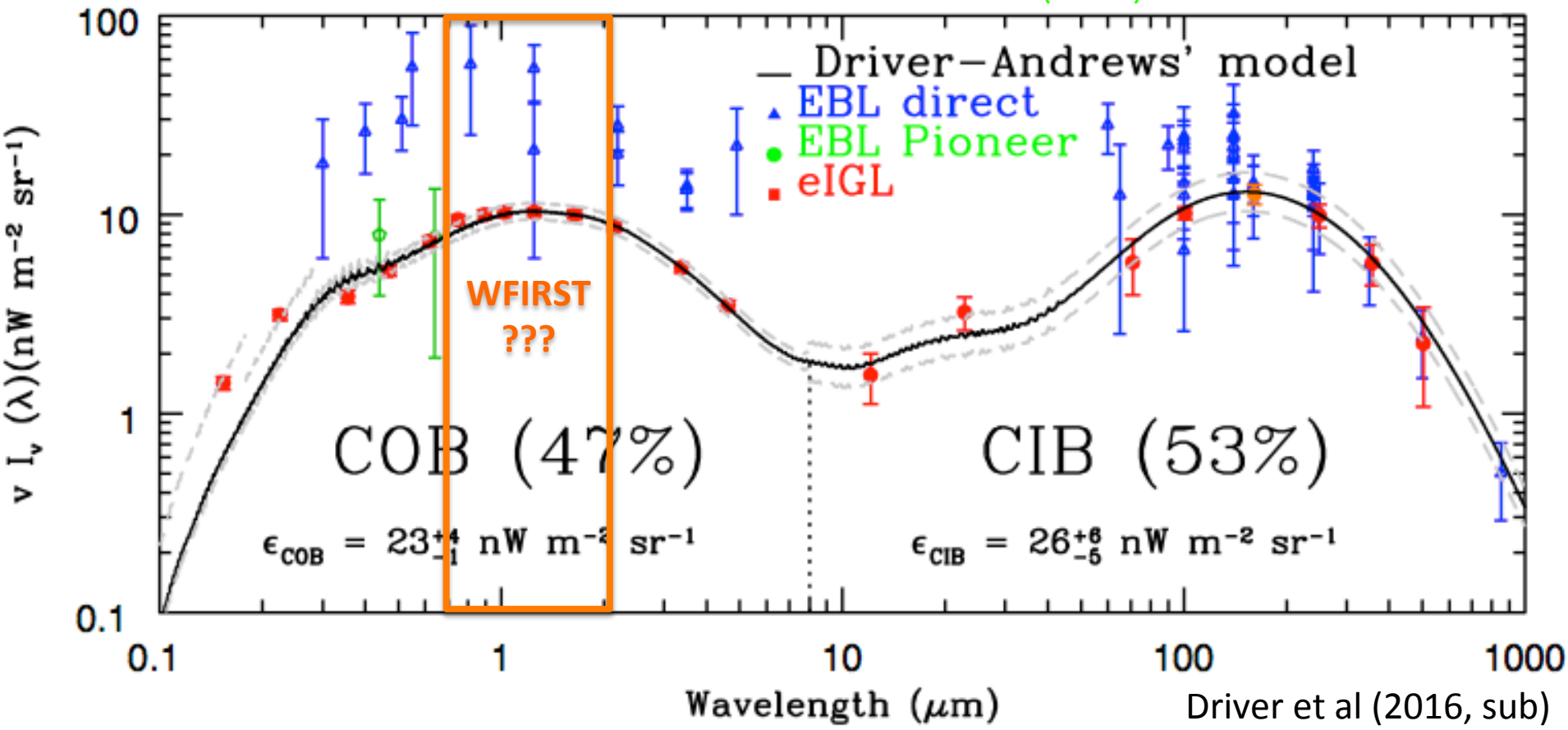
2x50 sq deg r<22 mag



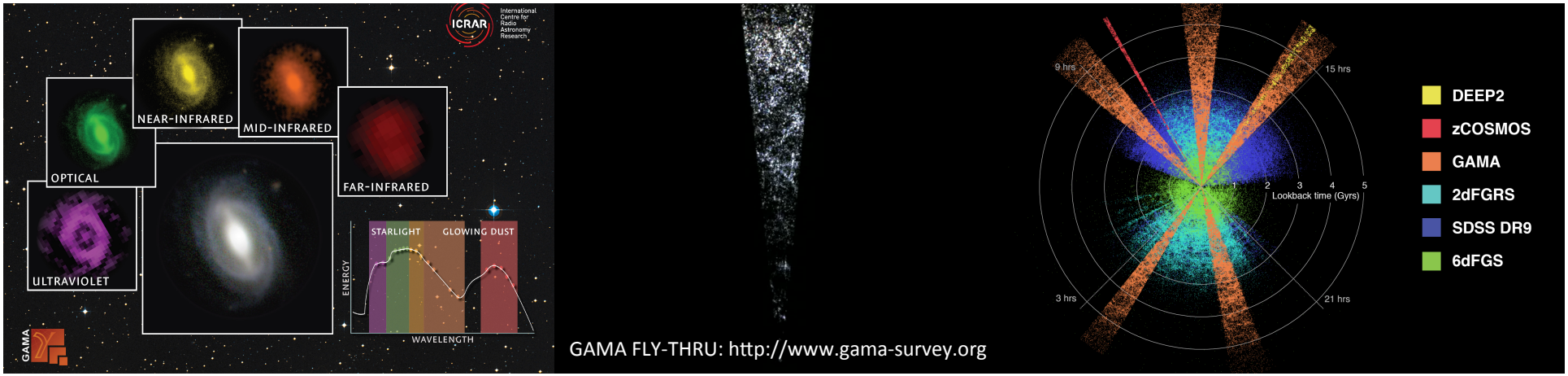
Digression: Zodiacal light?

What's with the direct estimates of the EBL?
Can WFIRST re-measure the Zodiacal light model?

Matsumoto et al (2011)



Driver et al (2016, sub)



BRIDGE THE GAP

http://www.wavesurvey.org/

?