Unlocking low-redshift science across the southern sky.

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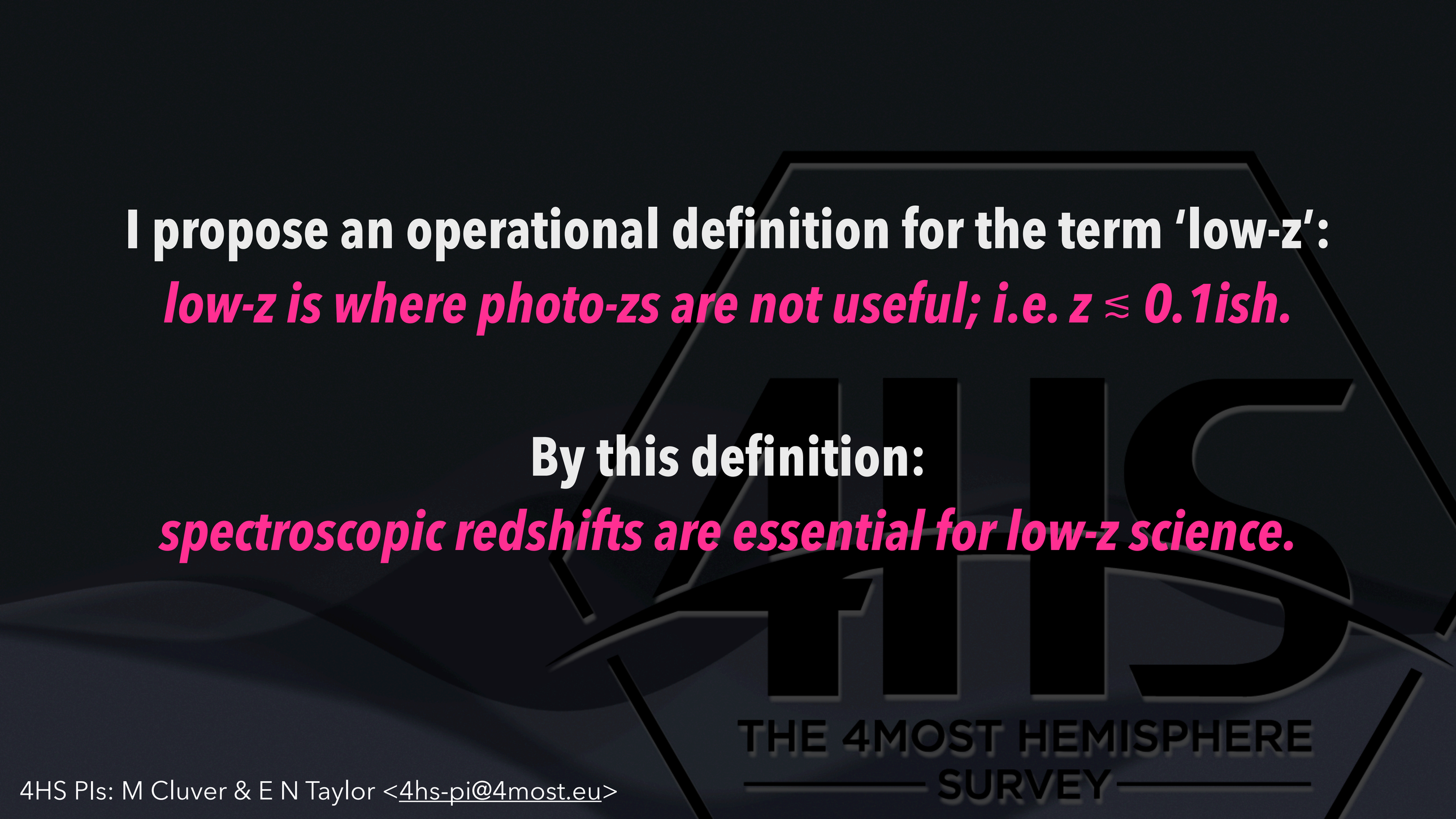
Fink workshop, Swinburne - Nov 2025

I propose an operational definition for the term ‘low-z’:

low-z is where photo-zs are not useful; i.e. $z \lesssim 0.1$ish.

By this definition:

spectroscopic redshifts are essential for low-z science.



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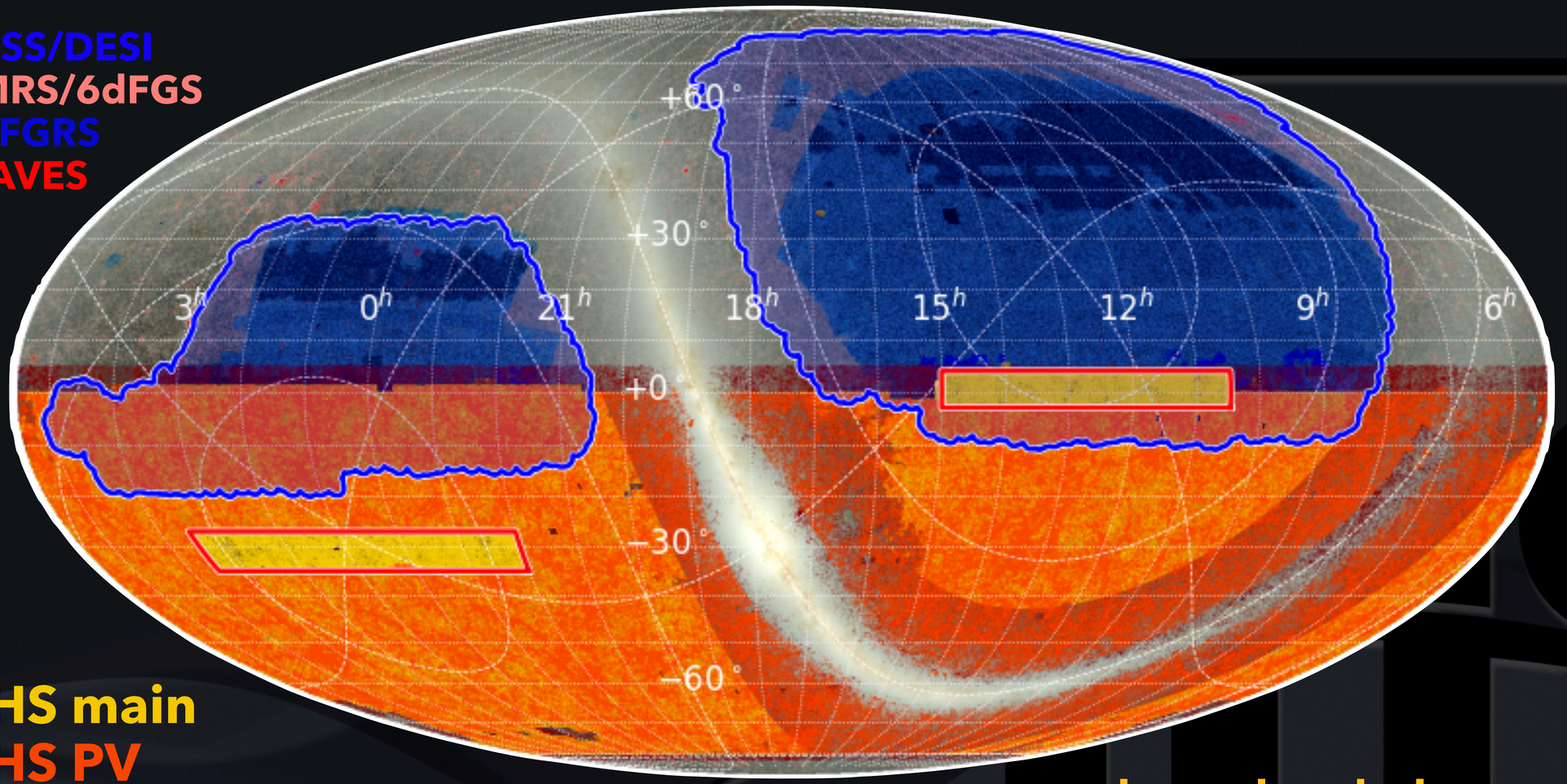
Can you imagine a Universe in which we have:



eRosita

Rubin

Euclid

Roman

WISE

SKA

LISA

... but lack low-z redshifts?

THE 4MOST HEMISPHERE SURVEY

4HS PIs: M Cluver & E N Taylor <4hs-pi@4most.eu>

4HS: The 4MOST Hemisphere Survey

See ENT, MC, et al. 2023, Msngr 190, 46

Spectroscopy and redshifts for ~4.5 M galaxies over ~17.500 deg² with high and unbiased completeness for z < 0.15.

4HS key science:

I. Map mass and motion over ~1 Gpc to measure gravity and cosmological growth of structure (approaching variance limit).

II. Map galaxy demographics as a function of local and large scale environment, to resolve the environmental processes/effects that most influence galaxy formation and evolution.

III. Produce the definitive low-z galaxy reference sample for the next era of wide-area multiwavelength surveys (eROSITA, LSST, Euclid, ASKAP/MeerKAT/SKA, LISA, ...) and large/high resolution simulations (following EAGLE, IllustrisTNG, FIRE-2, SIMBA, ...).

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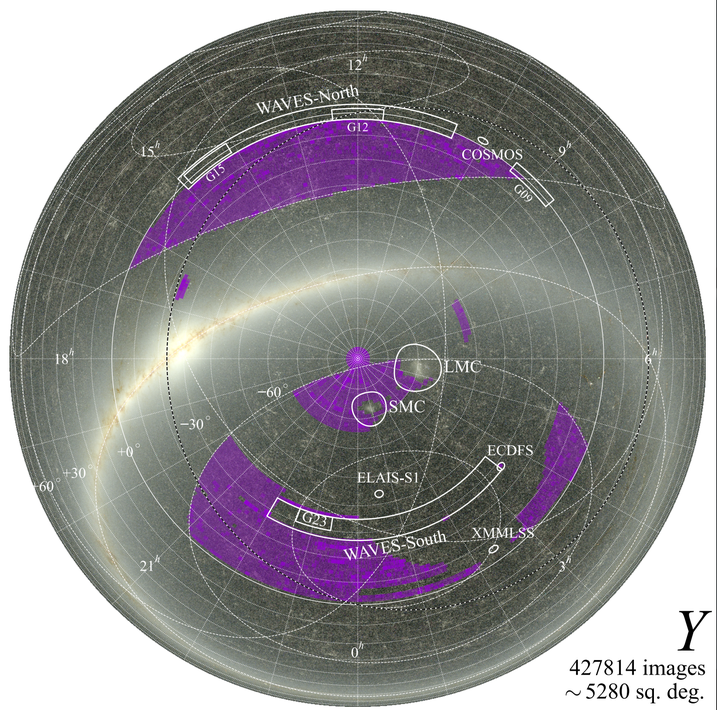
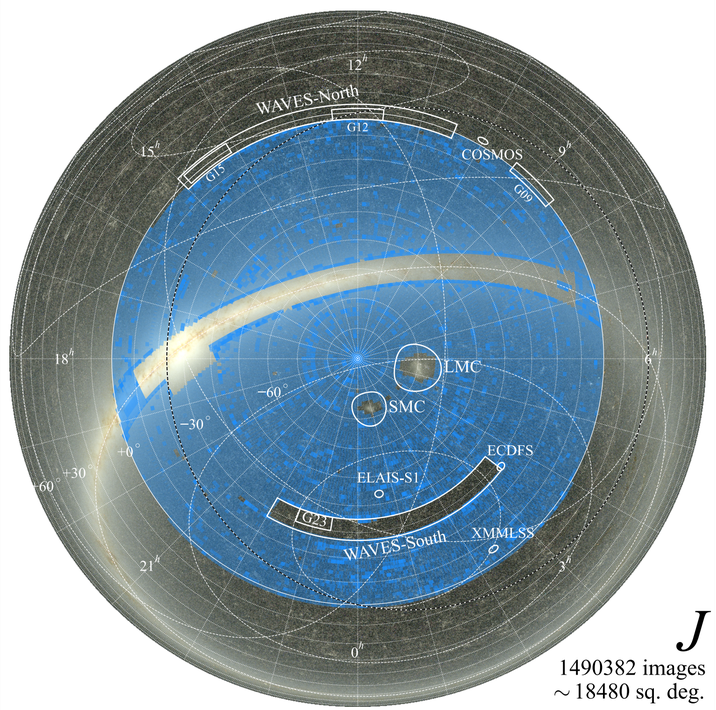
Imaging data

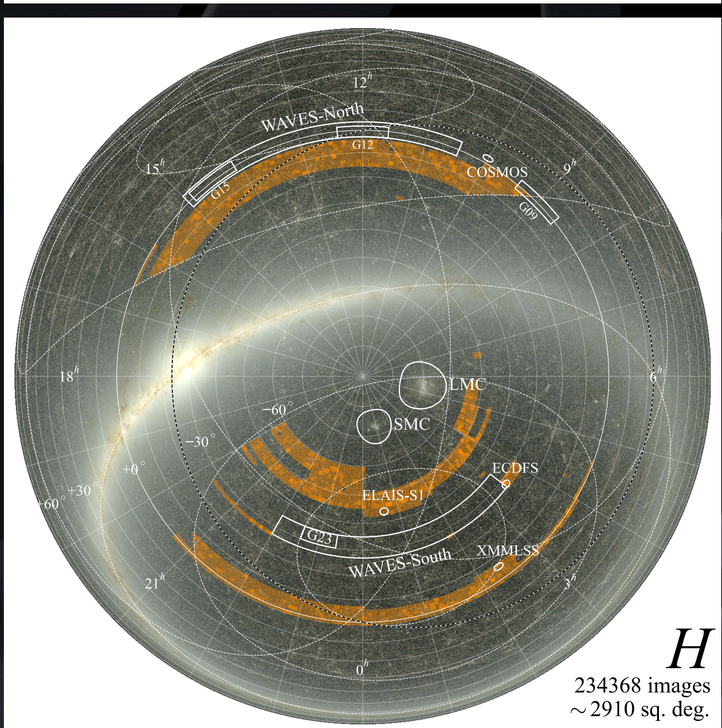
- Founded on JK from VHS; supplemented by auxiliary programs.
- ***Improves on every aspect of calibration and photometry; Repeatability ~ 0.015 mag.***
- Includes grizy PanSTARRS1 where available; Dec > -30.
- ***Now extended to WISE 1–4.***
- ***Plus single-Sersic fits for J < 18.5***



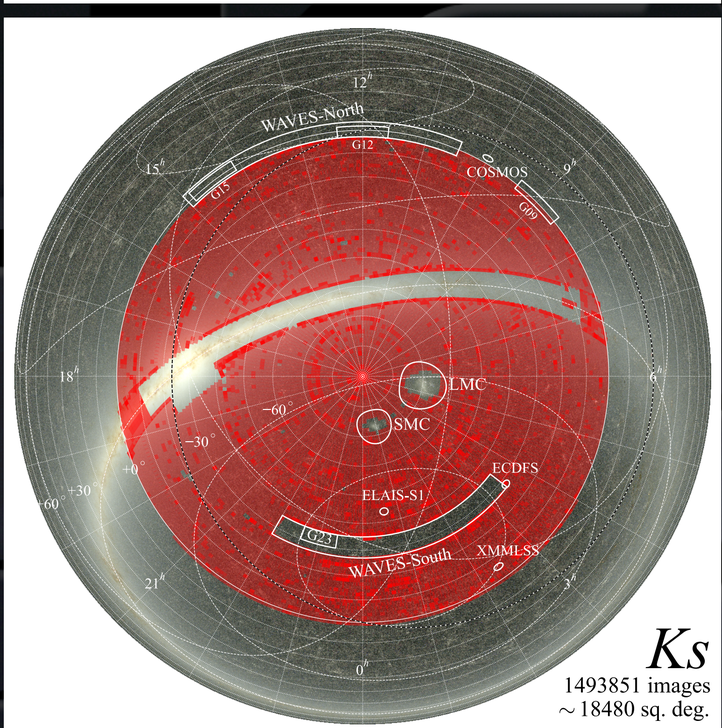
Y
427814 images
~5280 sq. deg.



J
1490382 images
~18480 sq. deg.

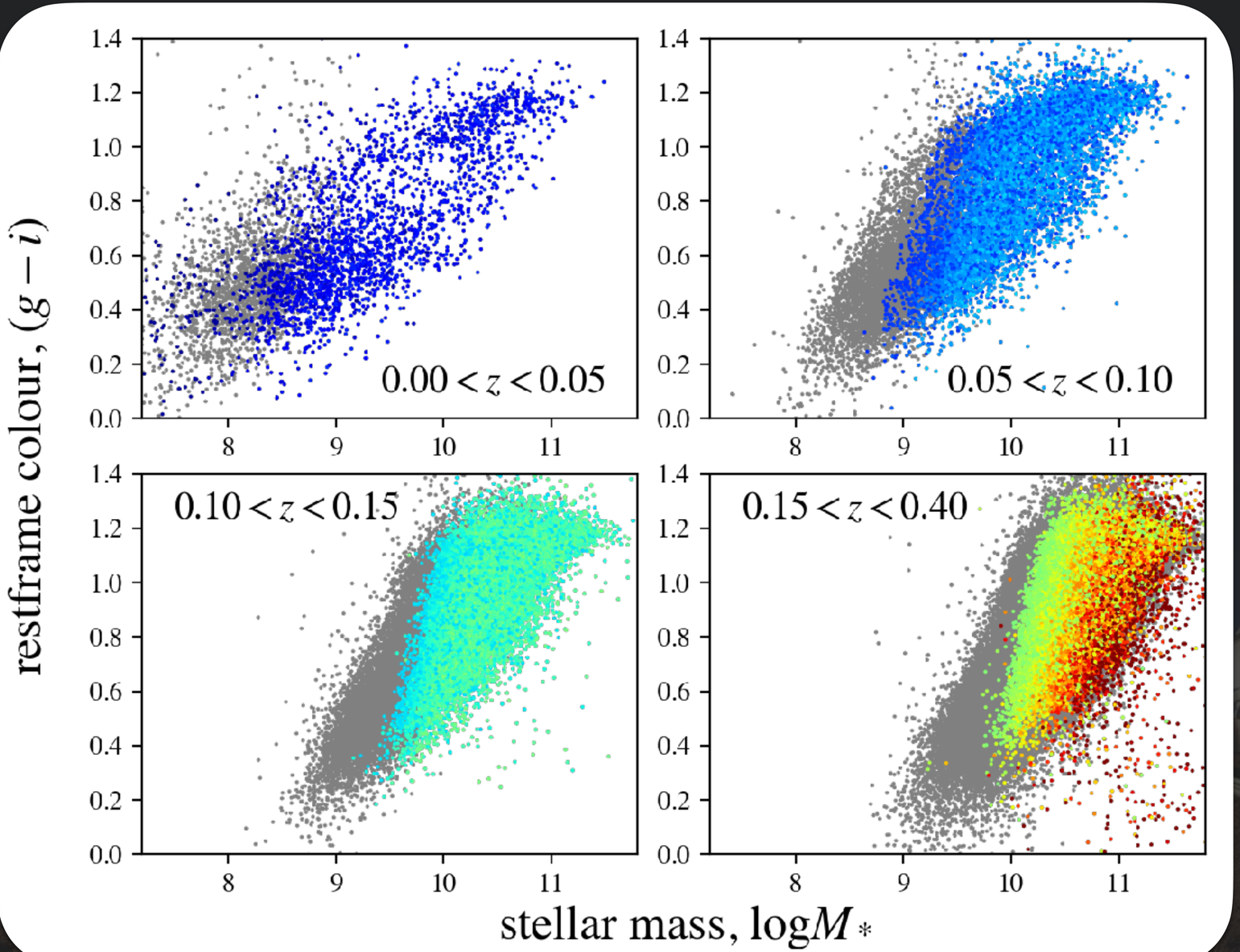


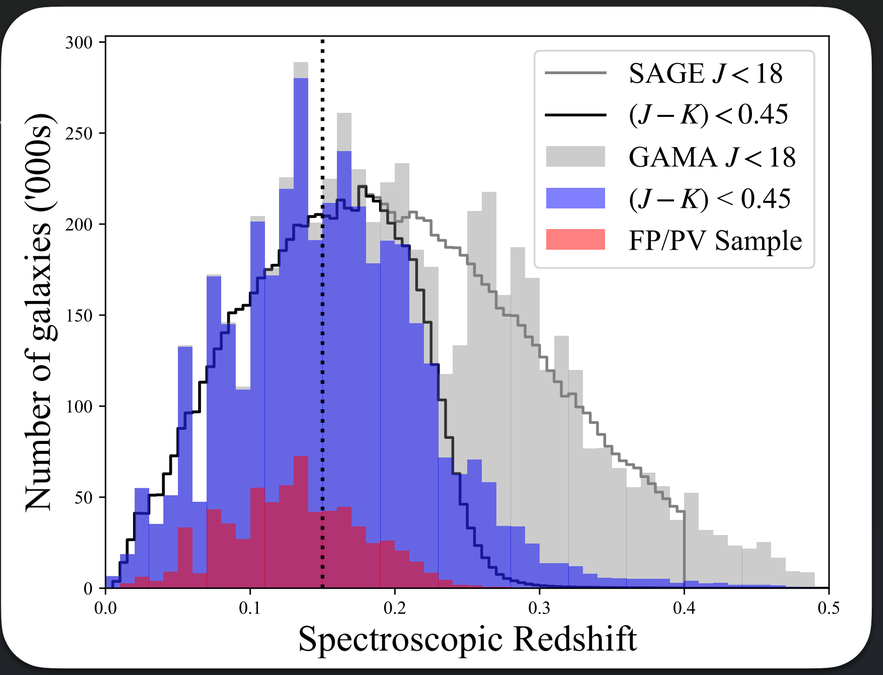
H
234368 images
~2910 sq. deg.

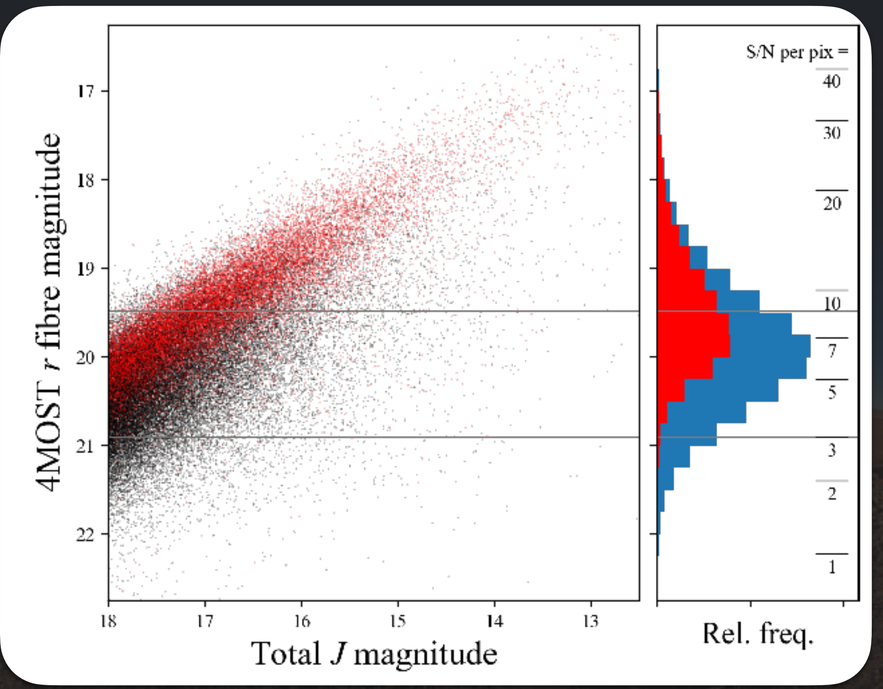


Ks
1493851 images
~18480 sq. deg.

4HS: THE 4MOST HEMISPHERE SURVEY







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4HS PIs (Cluver & Taylor): 4HS-PI@4most.eu

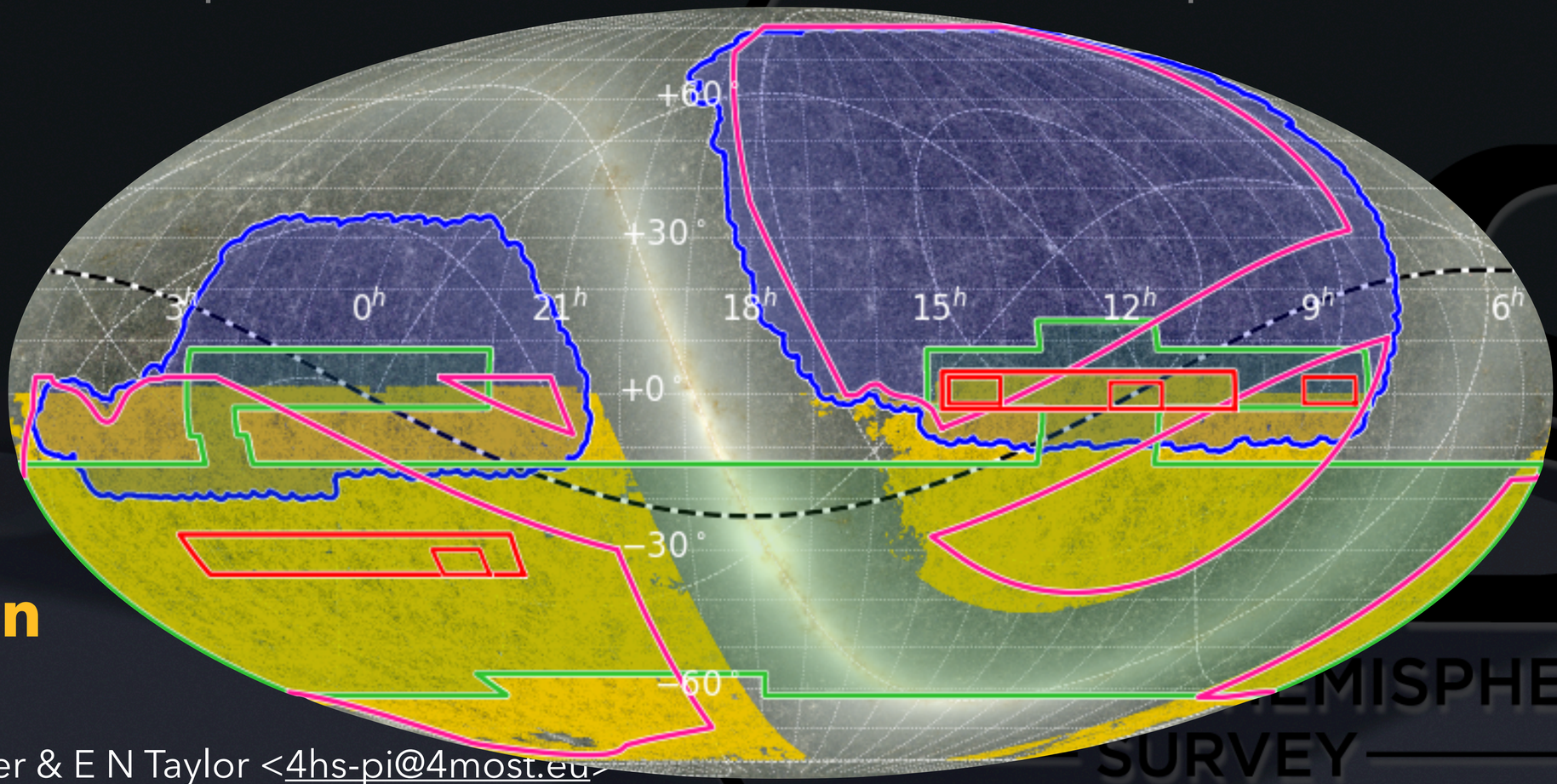
4HS: The 4MOST Hemisphere Survey

See ENT, MC, et al. 2023, Msngr 190, 46

Spectroscopy and redshifts for ~4.5 M galaxies over ~17.500 deg² with high and unbiased completeness for z < 0.15.

- ***Main sample: J < 18 and (J-K) < 0.45 --> ~300 / deg² x ~14.200 deg²***
  GAMA-like depth over ~100 times the area; near-total completeness for z < 0.15.

DESI
eRosita
Euclid
Wallaby
GAMA
WAVES
4HS main



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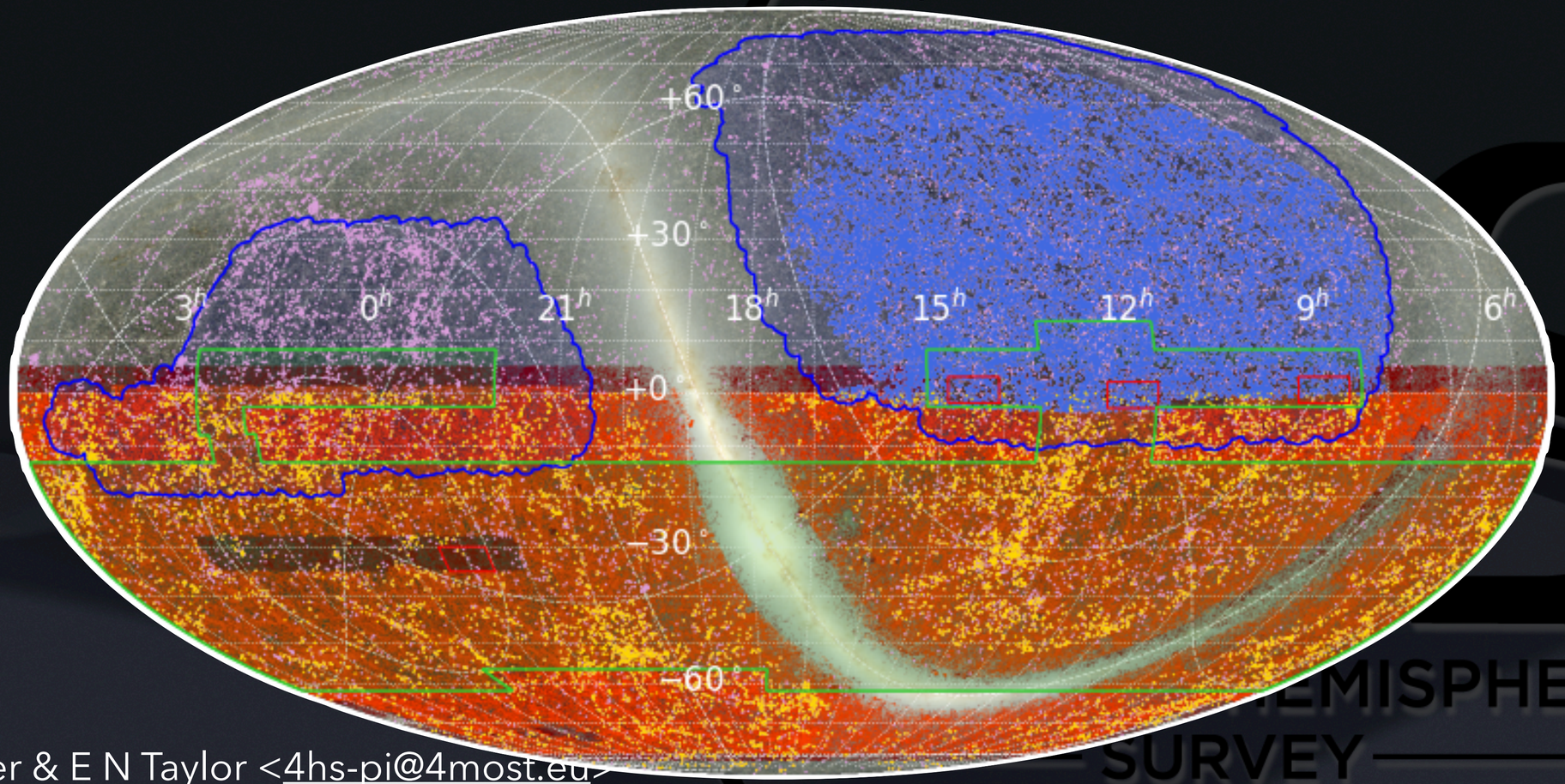
Spectroscopy and redshifts for ~4.5 M galaxies over ~17.500 deg² with high and unbiased completeness for z < 0.15.

- ***PV cosmology sample: J < 16.5 and (J-K) < 0.3 --> ~65 / deg² x ~17.500 deg²***
  ~500.000+ PV measurements over the largest possible area/volume.

CF4
6dFGS
SDSS
DESI
Wallaby
4HS PV



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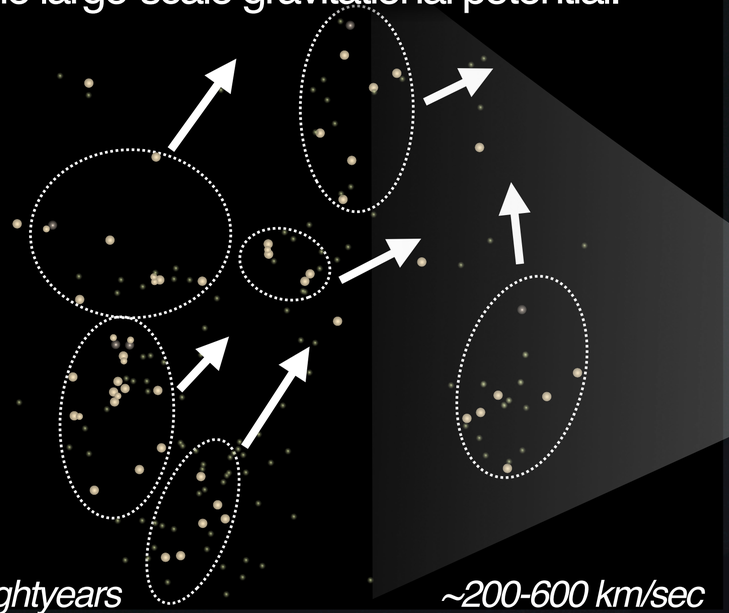
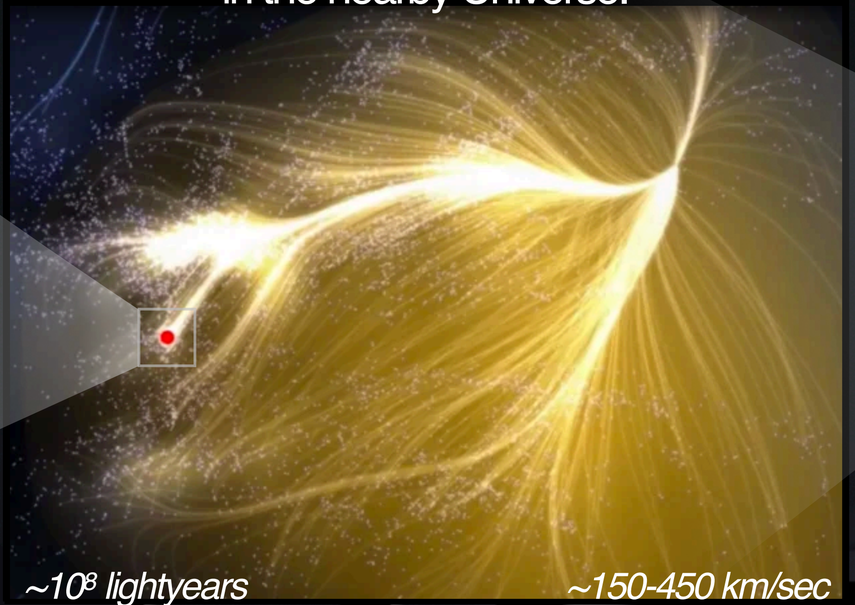
Peculiar velocities, bulk flows, and cosmology

Coherent bulk motions of galaxies trace the large-scale gravitational potential.



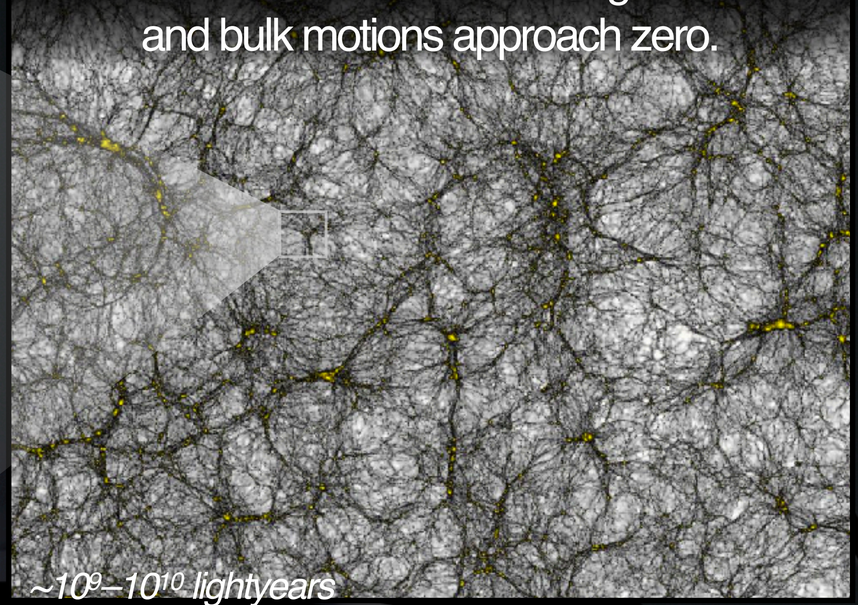
~10^7 lightyears *~200-600 km/sec*

Galaxies' motions reveal the mass distribution in the nearby Universe.



~10^8 lightyears *~150-450 km/sec*

Averaging over very large scales, the mass distribution is homogeneous and bulk motions approach zero.



~10^9–10^{10} lightyears

Peculiar velocities trace the cosmic velocity field, and 'bulk flows' trace the gravitational growth of cosmological structure.

THE 4MOST HEMISPHERE SURVEY

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Peculiar velocities, bulk flows, and cosmology

Redshifts add: $\ln(1 + z_{observed}) = \ln(1 + z_{cosmological}) + \ln(1 + v_{peculiar}/c)$

'Hubble flow': $z_{cosmological} \cong D_{estimated} / H_0 c$

Rearrange: $\ln(1 + z_{observed}) - \ln(1 + D_{estimated}/H_0 c) \cong \ln(1 + v_{peculiar}/c)$

Cosmology-independent distances yield peculiar velocity measurements.

Peculiar velocities trace the cosmic velocity field, and 'bulk flows' trace the gravitational growth of cosmological structure.

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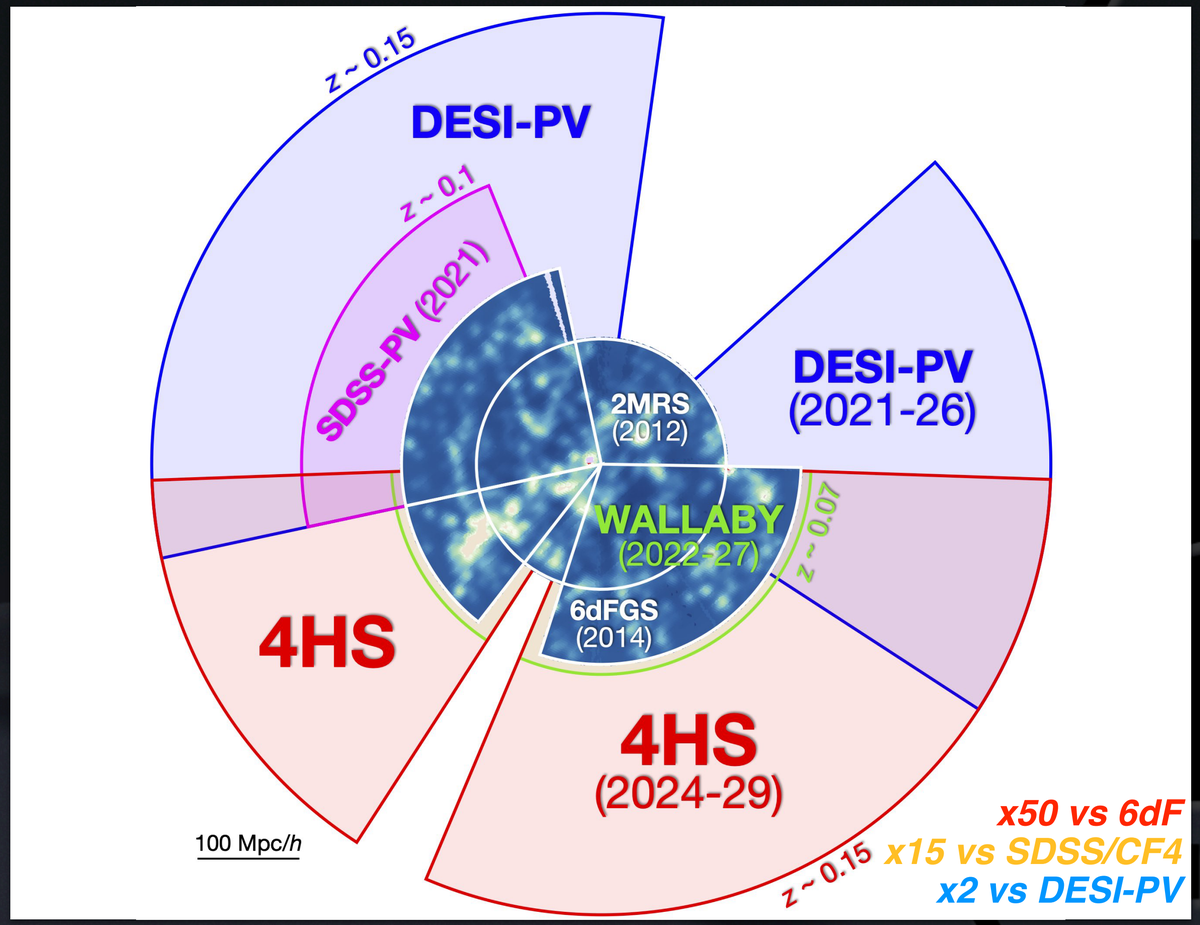
4HS + DESI-PV + WALLABY

See ENT, MC, et al. 2023, Msngr 190, 46

Mapping the cosmic density and velocity field over 80% of the sky, to and beyond the point of convergence to the CMB.



- 4HS will measure basically every FP distance that can be measured.
- Complementarity with WALLABY, substantial overlap with DESI-PV, and many repeats within 4HS mean we can control systematics.
- ***Culmination and realisation of a ~50 year project of PV cosmology.***

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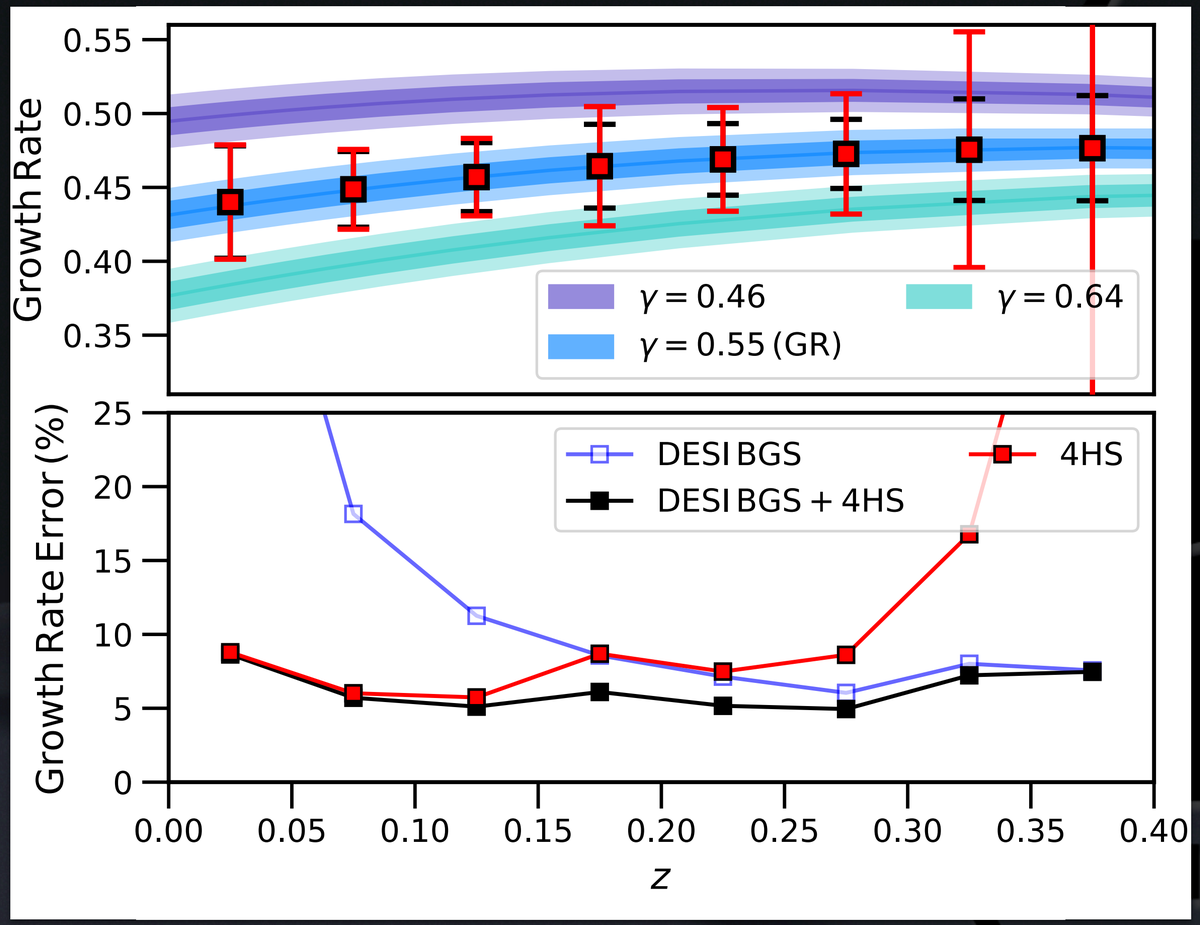
4HS: The 4MOST Hemisphere Survey

See ENT, MC, et al. 2023, Msngr 190, 46

1. 4HS will map mass and motion over ~1 Gpc to measure gravity and cosmological growth of structure (approaching variance limit).
   SWG leads: Cullan Howlett, John Lucey, Jenny Sorce



- 4HS is the critical Southern companion to DESI-BGS/DESI-PV.
- Galaxy distribution maps the cosmic density field, plus …
- … FP-derived peculiar velocities map the cosmic velocity field.
- Net result: measurement of gravity and instantaneous snapshot of late-time cosmic structure formation and on the largest possible scales (complementary to BAO&RSD).

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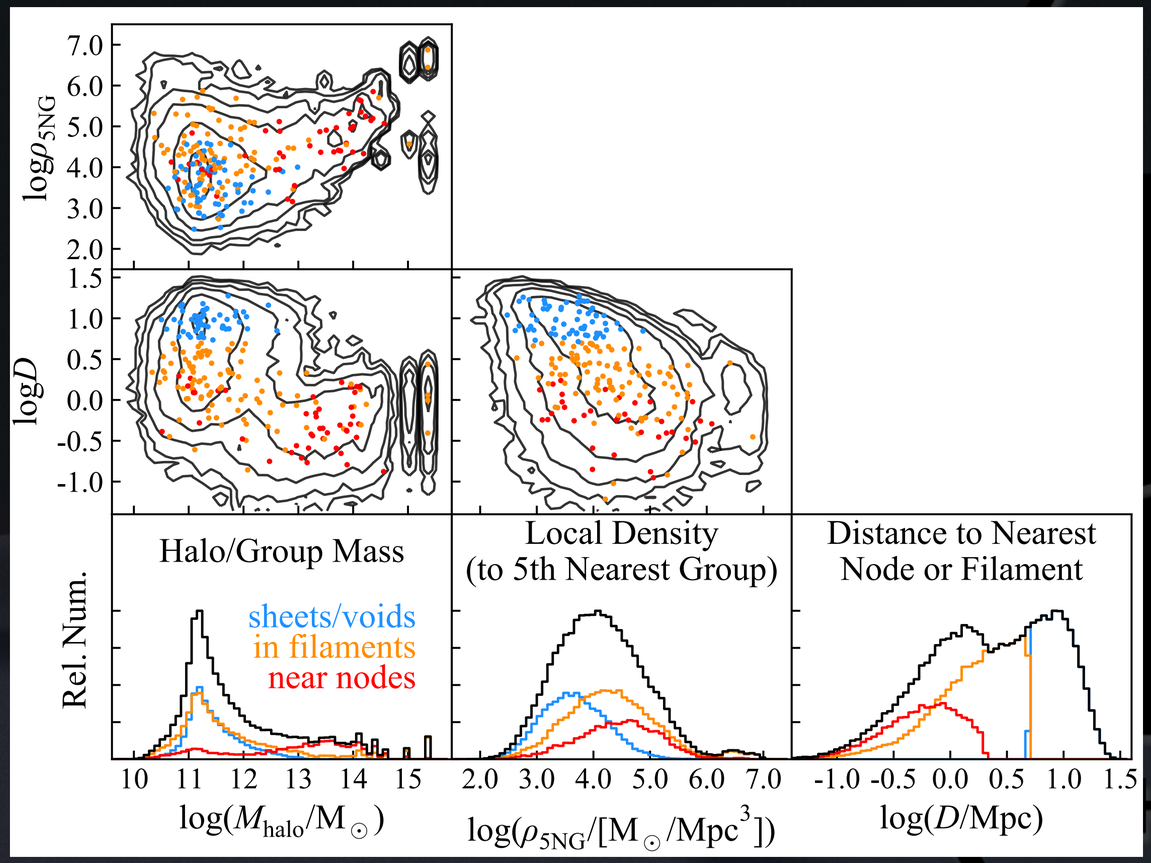
II. 4HS will map galaxy demographics as a function of local and large scale environment, to resolve the processes/effects that most influence galaxy formation and evolution.
SWG leads: Sean McGee, Ilani Loubser, Moses Mogotsi



- ***'Environment' has many facets.*** This figure shows 4 distinct measures of 'environment'.
- The disjoint distributions show that ***these different quantities measure different physics.***
- Disentangling 'environment' will require overwhelming statistics.
- With >30,000 groups in the low-to-intermediate mass range, 4HS will motivate and challenge the next generations of simulations/models.

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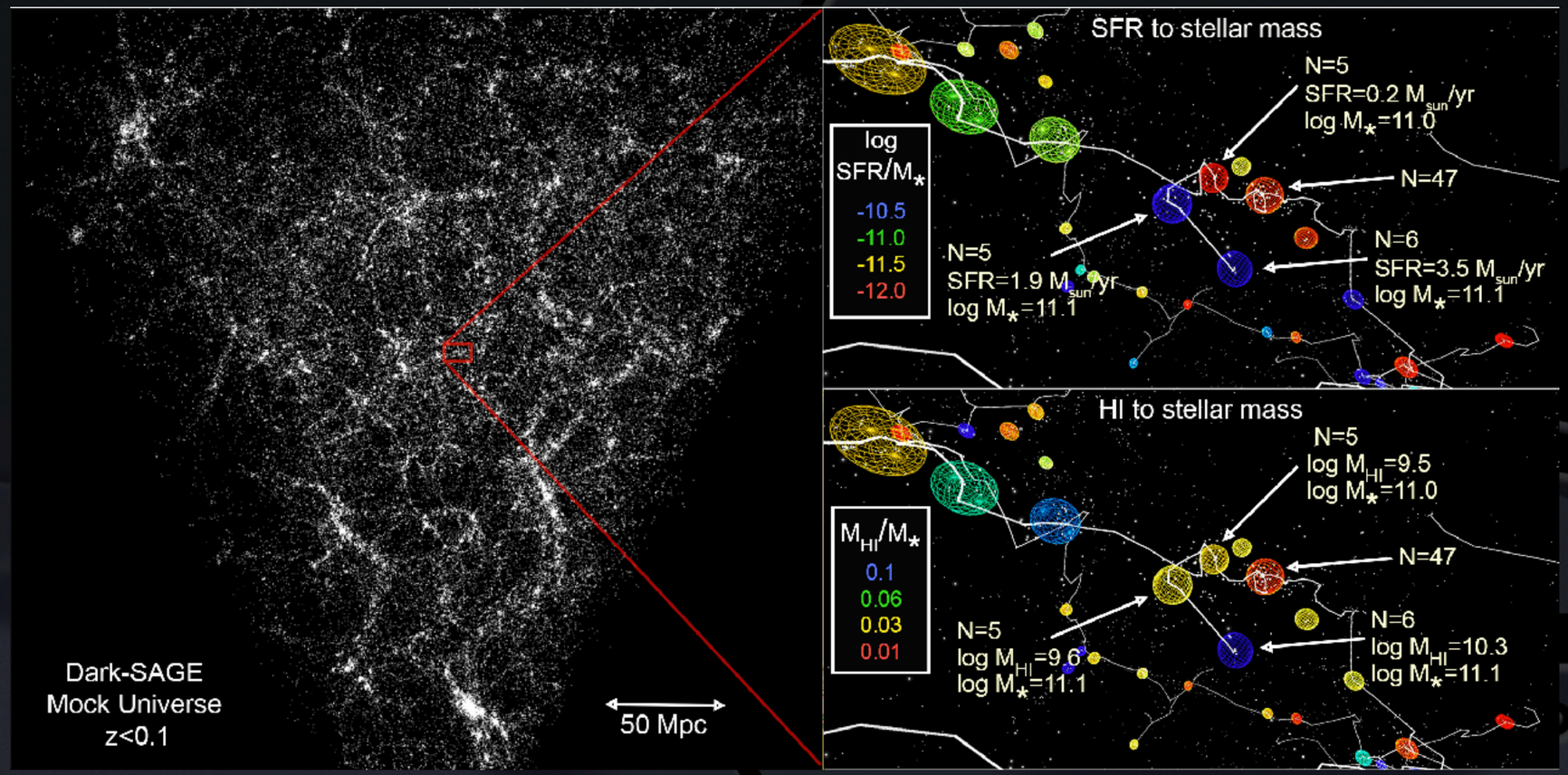

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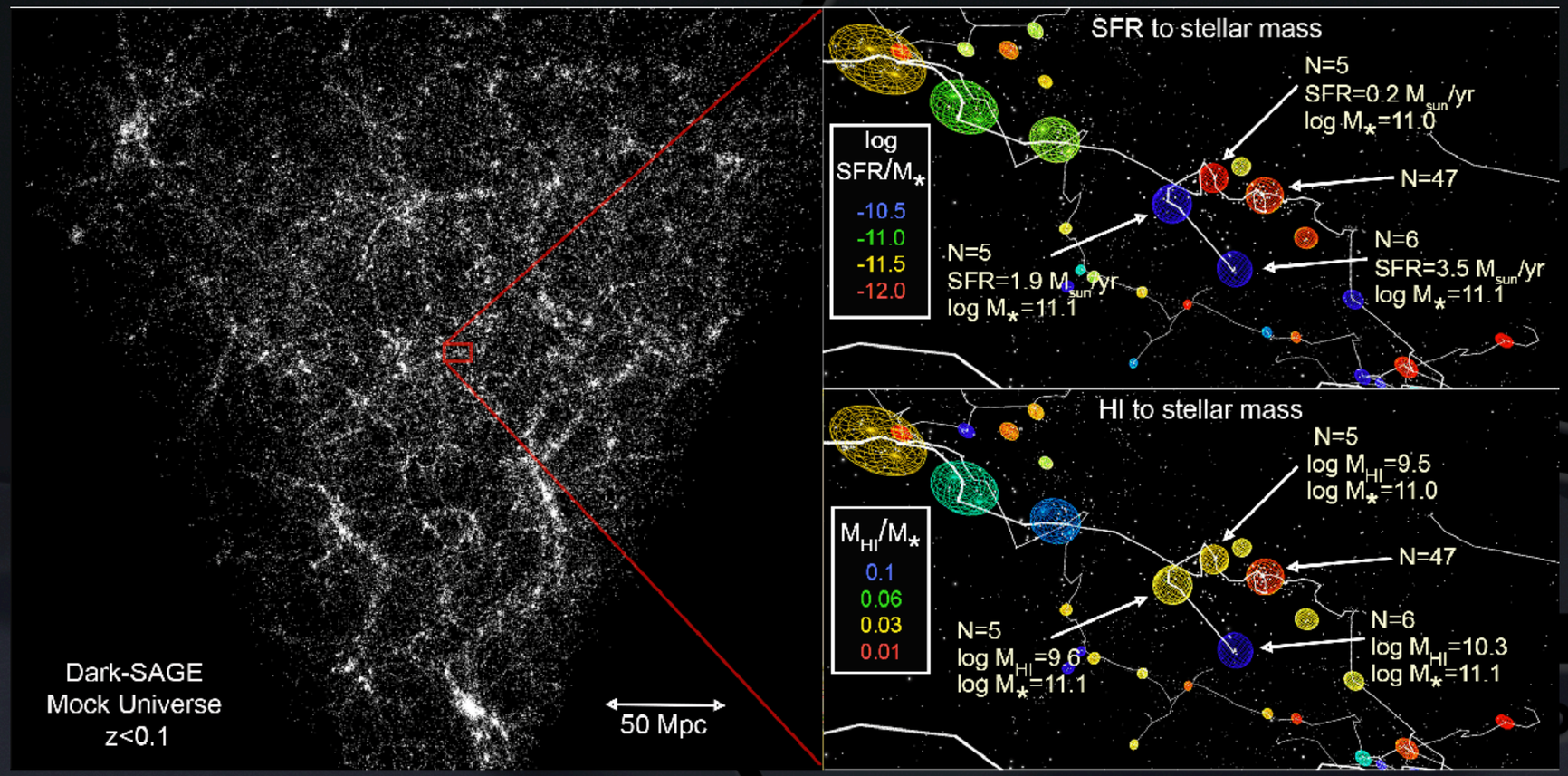
III. 4HS includes a dedicated and coordinated numerical simulation effort, including ~1 Gpc^3 (N = 4096^3) DMO simulations + SHARK SAM.
SWG leads: Claudia Lagos, Wojciech Hellwing, Anna de Graaf.



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IV. 4HS will produce the definitive low-*z* galaxy reference sample for the VRO-LSST/Euclid/Roman/SKA/LIGO/LISA era.
SWG leads: Stefania Barsanti, Eric Bell, Michael Maseda

- ***4HS spectra:*** redshifts, group/env. metrics, halo masses
- ***LSST:*** stellar masses and pops, sizes, morphologies, lensing
- ***VHS –> Euclid:*** stellar masses, sizes, morphologies, lensing
- ***WISE:*** stellar masses, star formation, AGN diagnostics
- ***ASKAP –> SKA 21cm:*** integrated, resolved, and intragroup HI
- ***ASKAP –> SKA continuum:*** star formation, AGN power
- ***eRosita Xray:*** AGN, intragroup filaments, hot cluster gas

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4HS
c. 2020
Everything, Everywhere, ~~All at Once~~

4HS: The 4MOST Hemisphere Survey

See ENT, MC, et al. 2023, Msngr 190, 46

- ***Whatever the astrophysics, low-z science is driven – or limited – by the availability of spectroscopic redshifts.***

- 4HS + ASKAP/MeerKAT/SKA: the full baryon cycle as a function of mass & environment.
  4HS: redshifts, stellar populations, SF/AGN diagnostics, environment statistics;
  21cm: HI masses and dynamics in the ISM and CGM – and minimal RFI at $z < 0.12$!

- 4HS + VRO-LSST/Euclid/Roman: enabling weak lensing science at all scales; e.g.:
  unique opportunities for matching 4HS density field to LSST-VRO lensing maps;
  lensing at ~kpc scales with 4HS+Euclid/Roman – only possible at low-z!

- 4HS as the definitive reference catalogue for low-z transient host/counterparts:
  Including SFRs, stellar populations, masses, group/halo/environment metrics, …
  for astrophysics of low-z transients of all kinds, including calibrating SN Ia systematics;
  Improved distance/redshift measures through group-averaging and/or bulk-flow models.

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- ***Whatever the astrophysics, low-z science is driven – or limited – by the availability of spectroscopic redshifts.***
  - ~4.5 M galaxy redshifts for Dec < 0.
  - ~800,000 redshift independent D/PV measures.
  - 650,000 galaxy groups with N > 3.
  - Group-averaged redshifts for all of these.
  - Group-averaged D/PV measures for ~65,000 groups.
  - Complete, all-sky flow modelling to convergence with CMB.
  - ***An essential complement to all low-z cosmology … esp. SNe and GW!***

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- ***Whatever the astrophysics, low-z science is driven – or limited – by the availability of spectroscopic redshifts.***

now – *The first activity of 4HS is to cement the legacy of VHS high-quality NIR imaging/catalogues over the Southern sky.*

Q1 2026 – *Our hope is for this to immediately become a valuable piece of data infrastructure for wide-field astronomy in the South.*

c. 2026-30 – 4HS will produce a comprehensive census of galaxies at $z < 0.15$, with broad and lasting impact in cosmology and galaxy evolution.

c. 2030 – 4HS will provide the definitive galaxy low-z reference sample for Southern extragalactic astronomy at all wavelengths, incl.: Xray (eRosita), O-NIR (VRO-LSST, Euclid), radio (SKA), and GW (LIGO/LISA).

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