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The promise of WST for Cosmology

mostly based on Mainieri et al. (2023) https://arxiv.org/abs/2403.05398

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WST Italian Workshop
10/03/2025

The most pressing open questions yesterday

Let's do the exercise of trying to project ourselves years in the future:

A search for two numbers:

All of observational cosmology is the search for two numbers: H_0 and q_0

Sandage, 1970

The most pressing open questions today

Let's do the exercise of trying to project ourselves years in the future:

A search for two numbers:

All of observational cosmology is the search for two numbers: H_0 and q_0

Sandage, 1970

- What is the nature of Dark Matter and Dark Energy (or modified GR)?
- What is the large scale structure of the Universe?
- What is the explanation for the Hubble constant tension and other cosmological ones?

The (probably) most pressing open questions tomorrow

- nature of dark matter
- MG/quantum gravity
- primordial non-gaussianity (more extended than f_{NL} local, considering scale dependencies)
- massive neutrino
- deviation from GR
- parity violation

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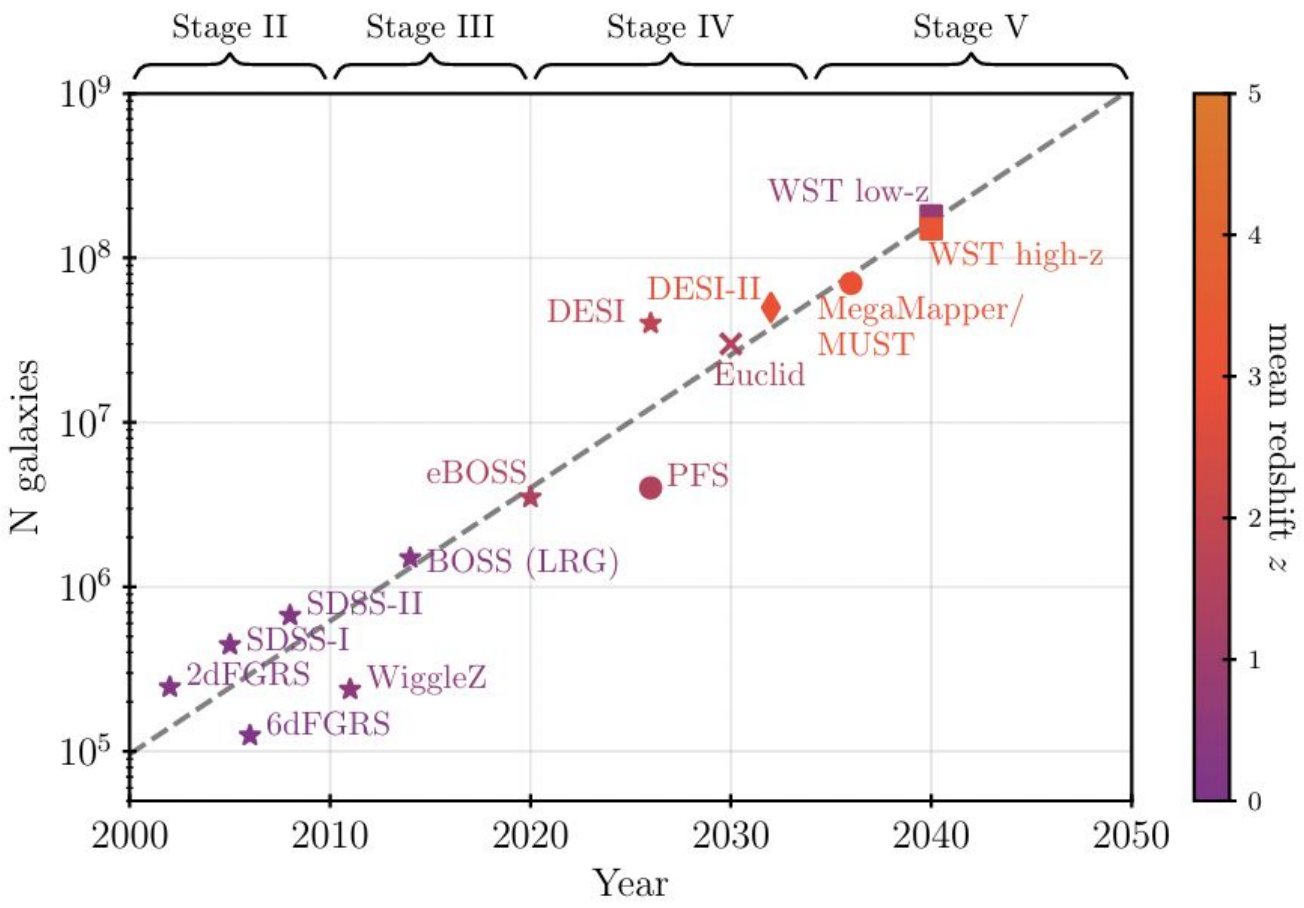
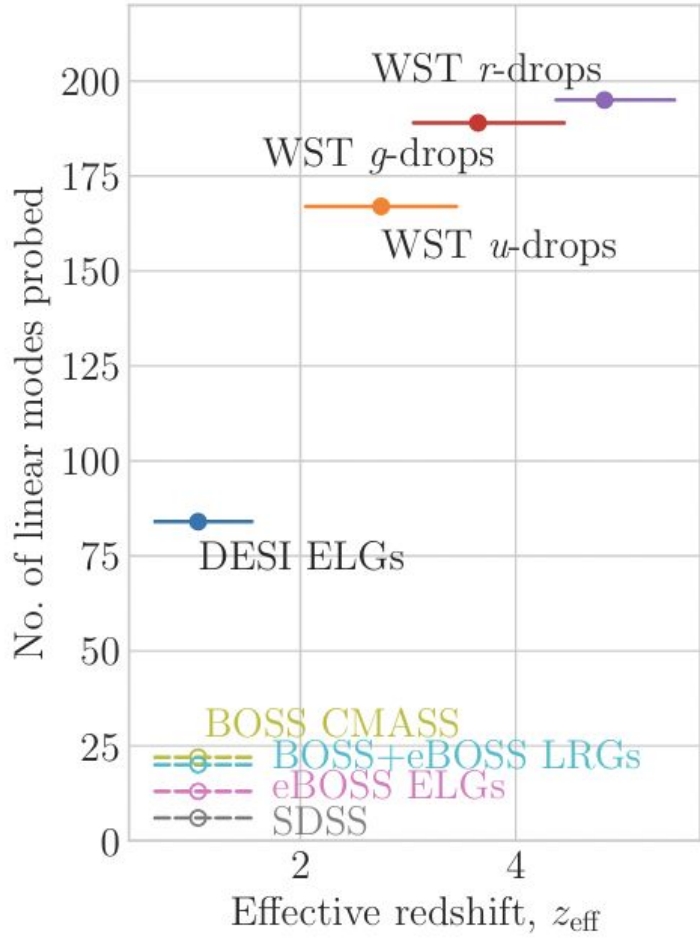
What about:

- cosmological tensions in the light of stage IV surveys?
- dark energy?

Expanding the horizons





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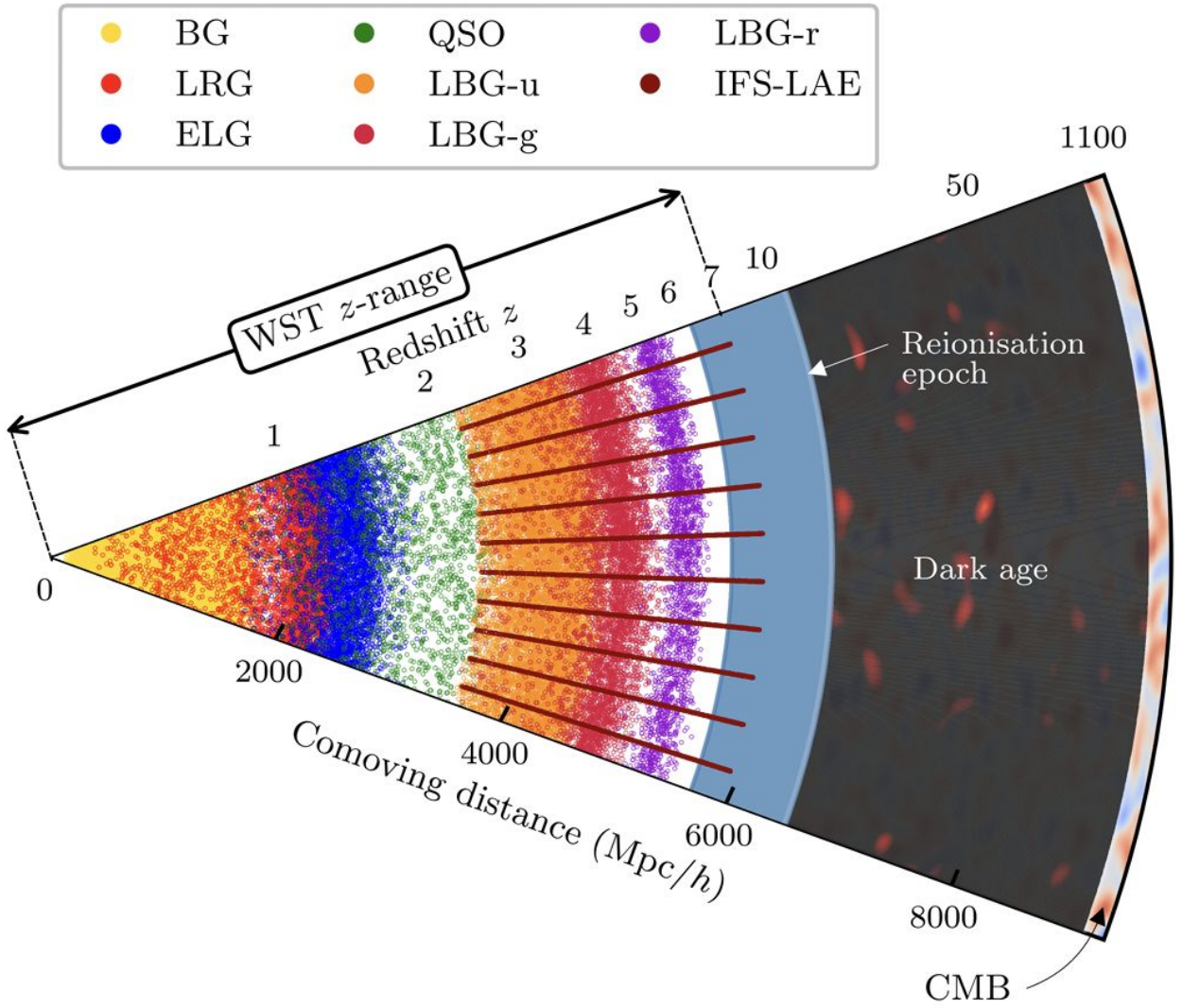

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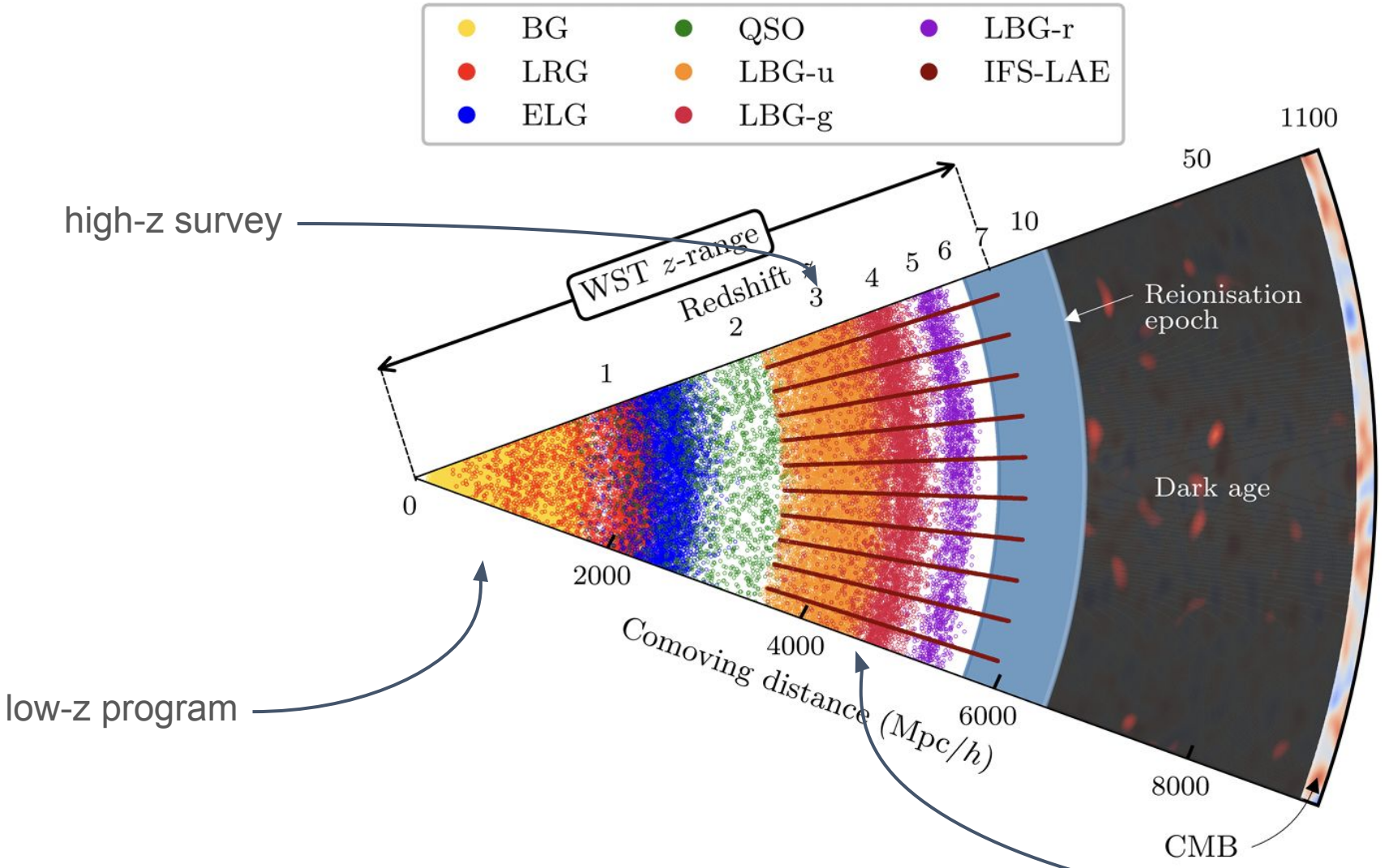


Two surveys

High-z survey (dark time):

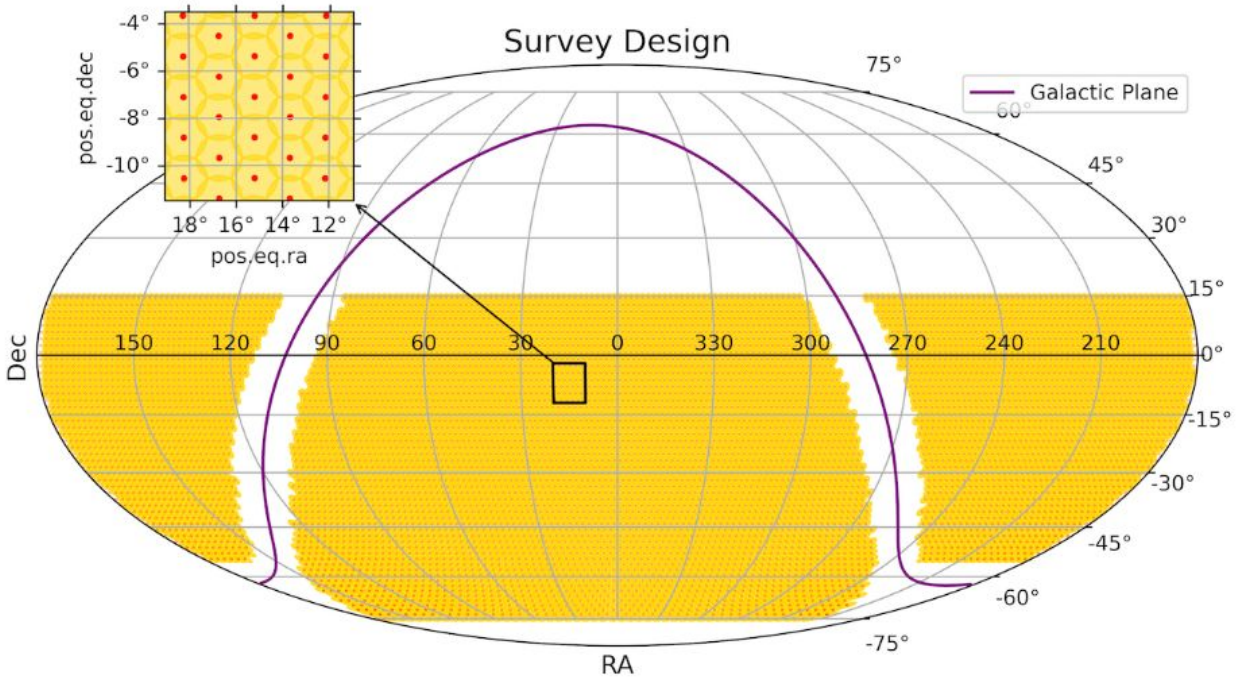
- **BAO, EDE, PNG**
- QSO, z>1.5, grz+w1, ~400/deg2 (r<24)
- LBGs, ugr-drop, 2<z<5
  - ~4000/deg2 (u/g-drop)
  - ~1500/deg2 (r-drop)

Low-z program (z < 1.6) (bright/grey time)

- BGs: r-band mag limit, z<0.5, 3000/deg2
- LRGs: color-color sel. (grz+w1), 0.4<z<1.2, ~3000/deg2
- ELGs: color-color sel. (grz), 0.6<z<1.6, ~8000/deg2

Low-z + High-z: 20,000 targets/deg2

Available photometry at the time of WST: White Paper based on LSST-Y10 (ugriz: 25.5, 27, 27, 26.5, 25.5, largest overlap with WST)+CSST+Euclid



Full-sky area ~18,000 deg2 (7000 pointings)

Dark-time: High-redshift survey

⇒ **7-year observation**

Grey-time: Low-redshift Legacy Surveys + Clusters

⇒ **7-year observation**

Top-level science cases

1. **Galaxy and Quasar Clustering + IGM/Lya-alpha forest**
   a. 2-point and 3-point statistics and full-shape analysis
   b. BAO of LAE 1D auto- and cross-correlation

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   a. A combined MOS-LR+IFS survey of the growth of galaxy clusters
   b. Reconstruction of the velocity field in the periphery of the cluster with nonlinear methods
   c. Connectivity (i.e. the number of filaments) as a cosmological probe
   d. Testing gravity with gravitational redshifts
   e. Void size function, void-galaxy cross-correlation function

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   a. GW as standard sirens
   b. variation of fundamental constants
   c. ages as cosmological probes

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   → transformative for the redshift range 2<z<5.5 and BAO up to z~7

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   → innovative use of IFS +synergy with MOS

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   → strong synergies with other facilities, WST could be enabling for some science cases (GW)

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3. **Alternative and innovative probes**
   a. GW as standard sirens (see talks by Bisero and Borghi)
   b. variation of fundamental constants (see talks by Milakovic)
   c. ages as cosmological probes

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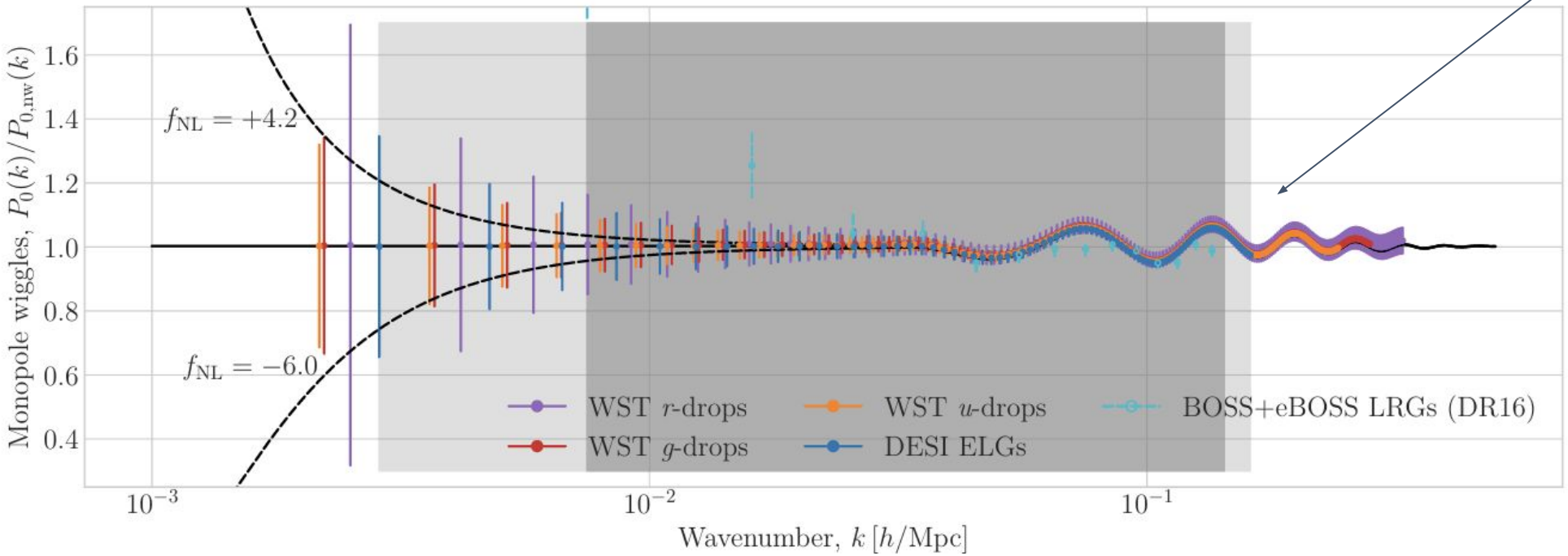
4. **Synergy with Lensing and Radio Surveys**

Galaxy and QSO clustering

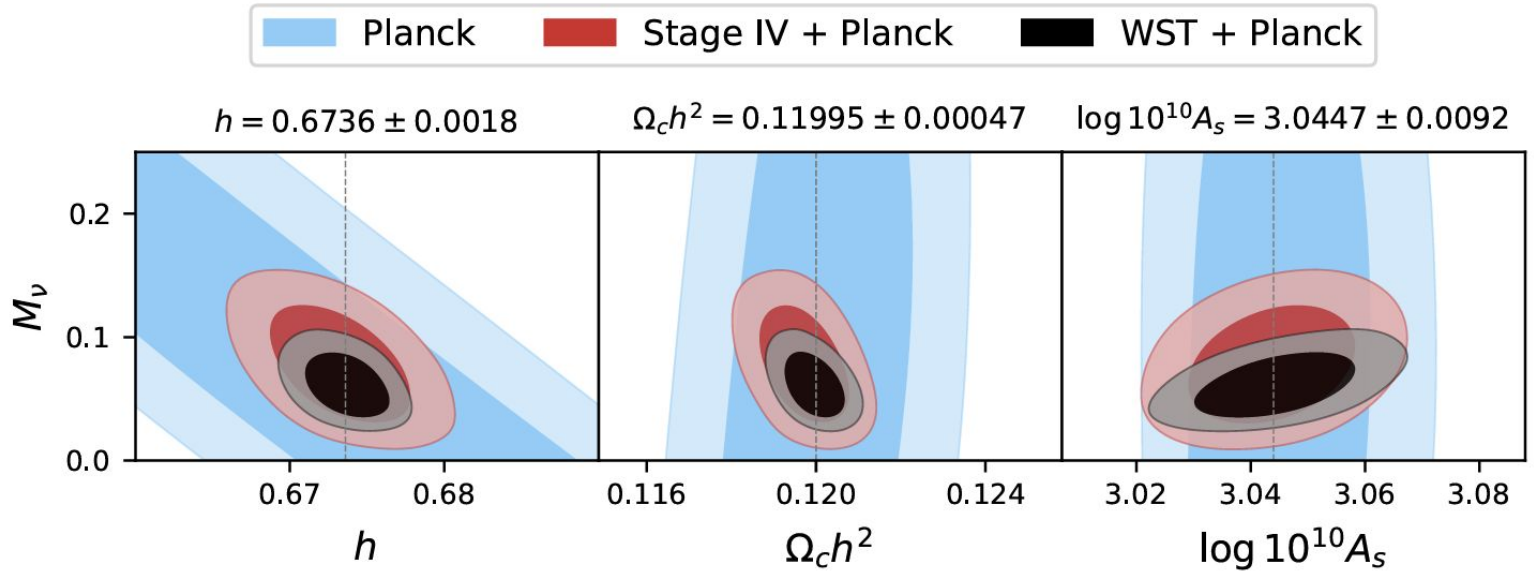
Baryon Acoustic Oscillations

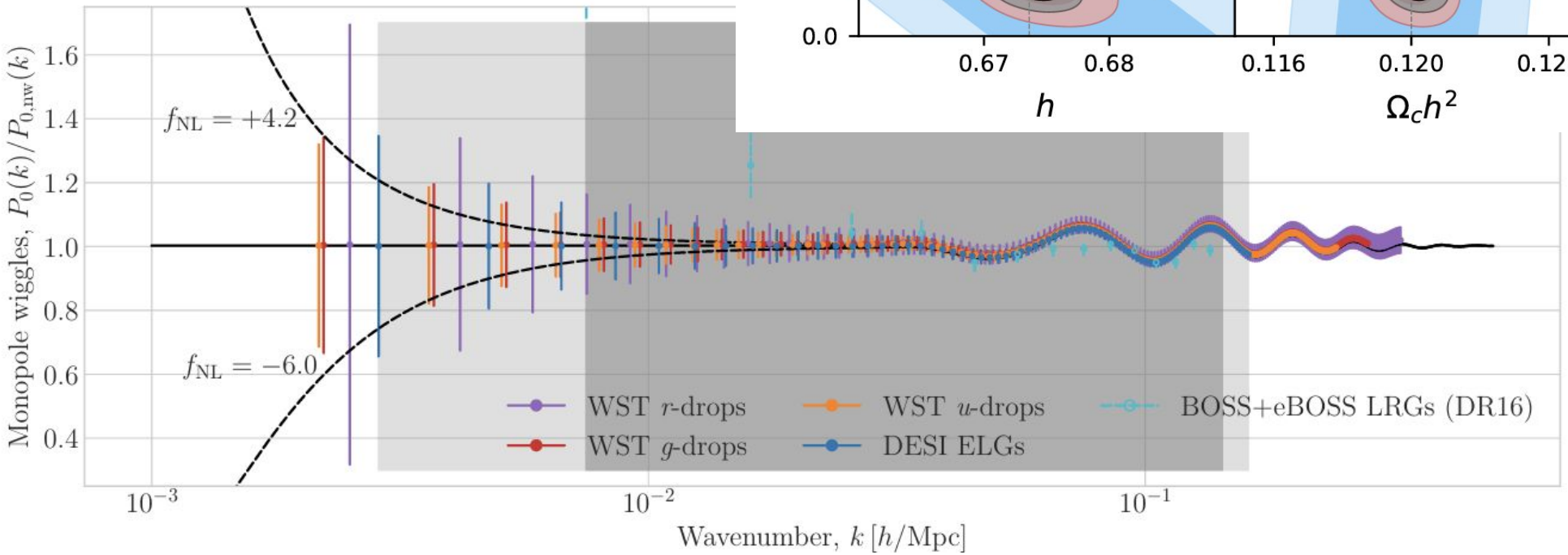
constraints at both higher and lower scales



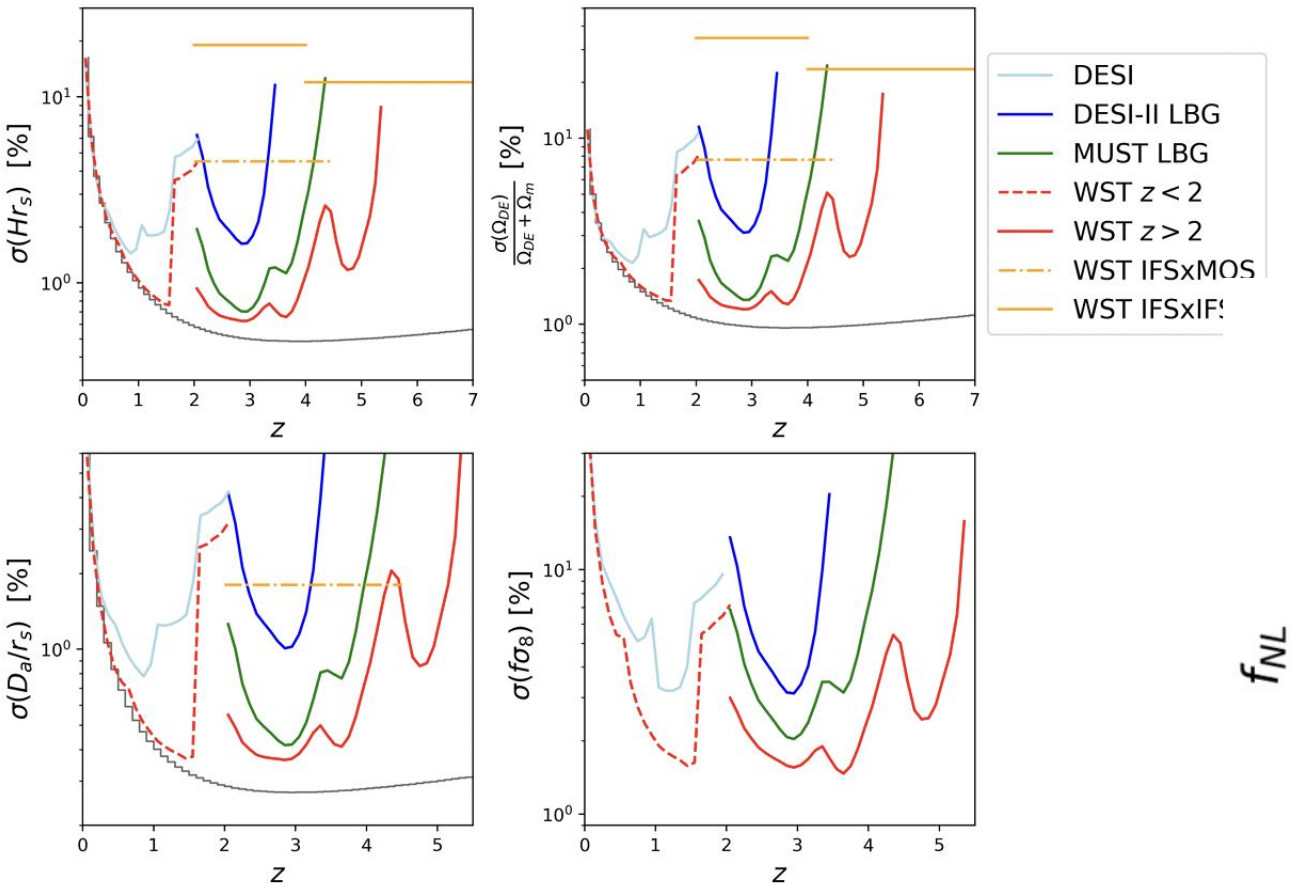
Galaxy and QSO clustering

huge step forward in neutrino mass constraints, and not only…

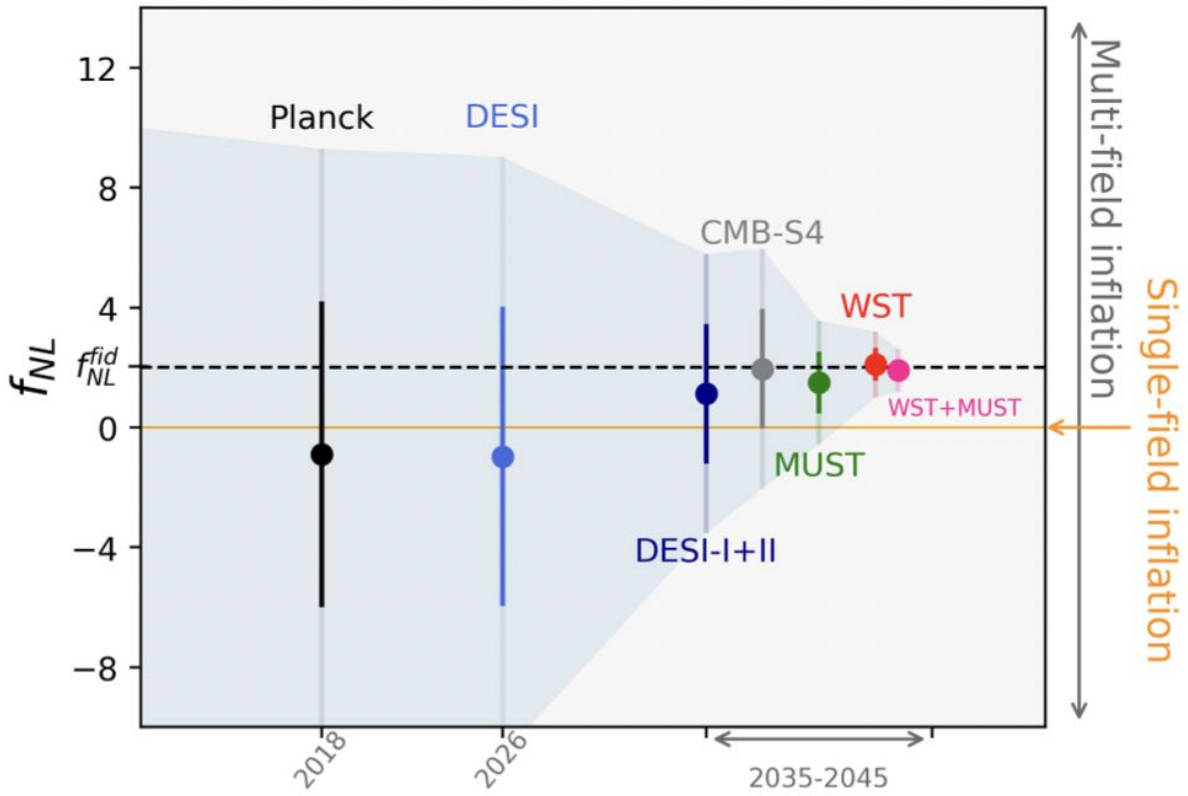




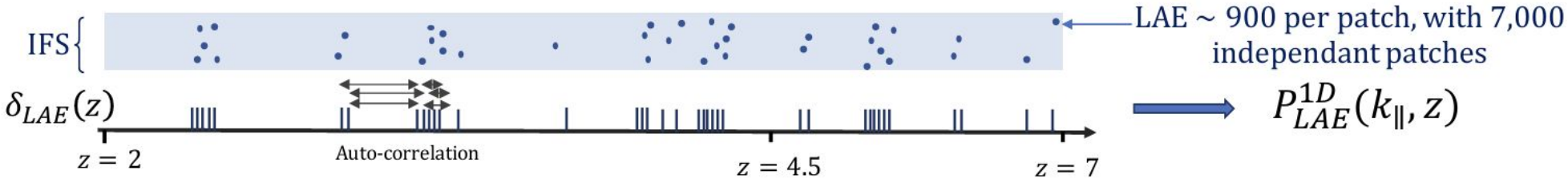
Galaxy and QSO clustering

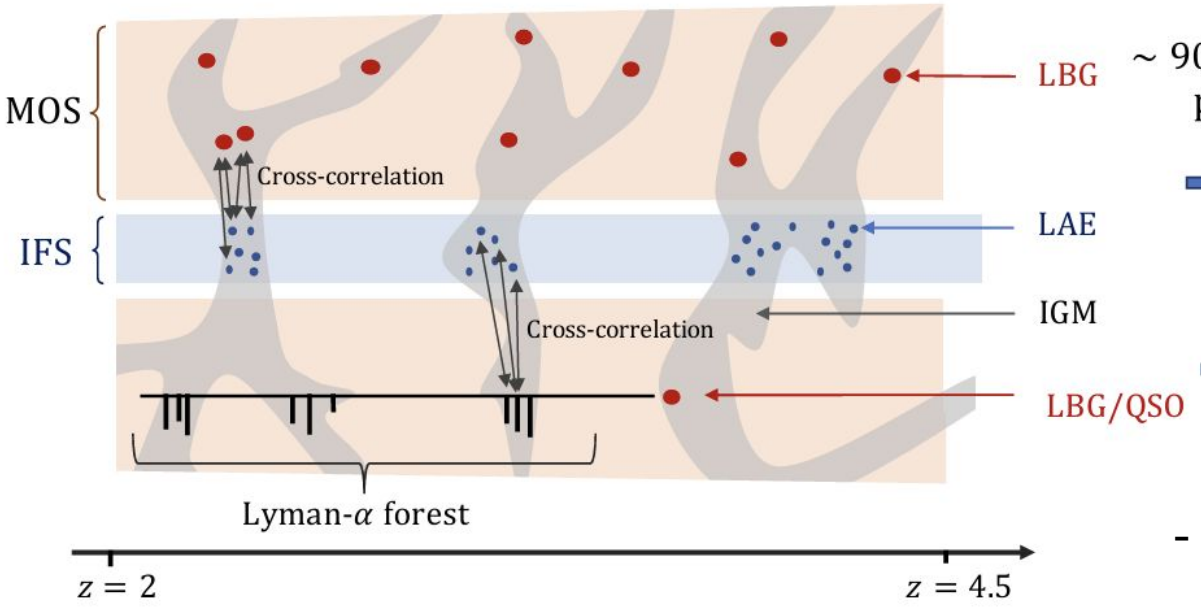


significant gain in constraining cosmological parameters and non-Gaussianity



LAE auto- and cross-correlation





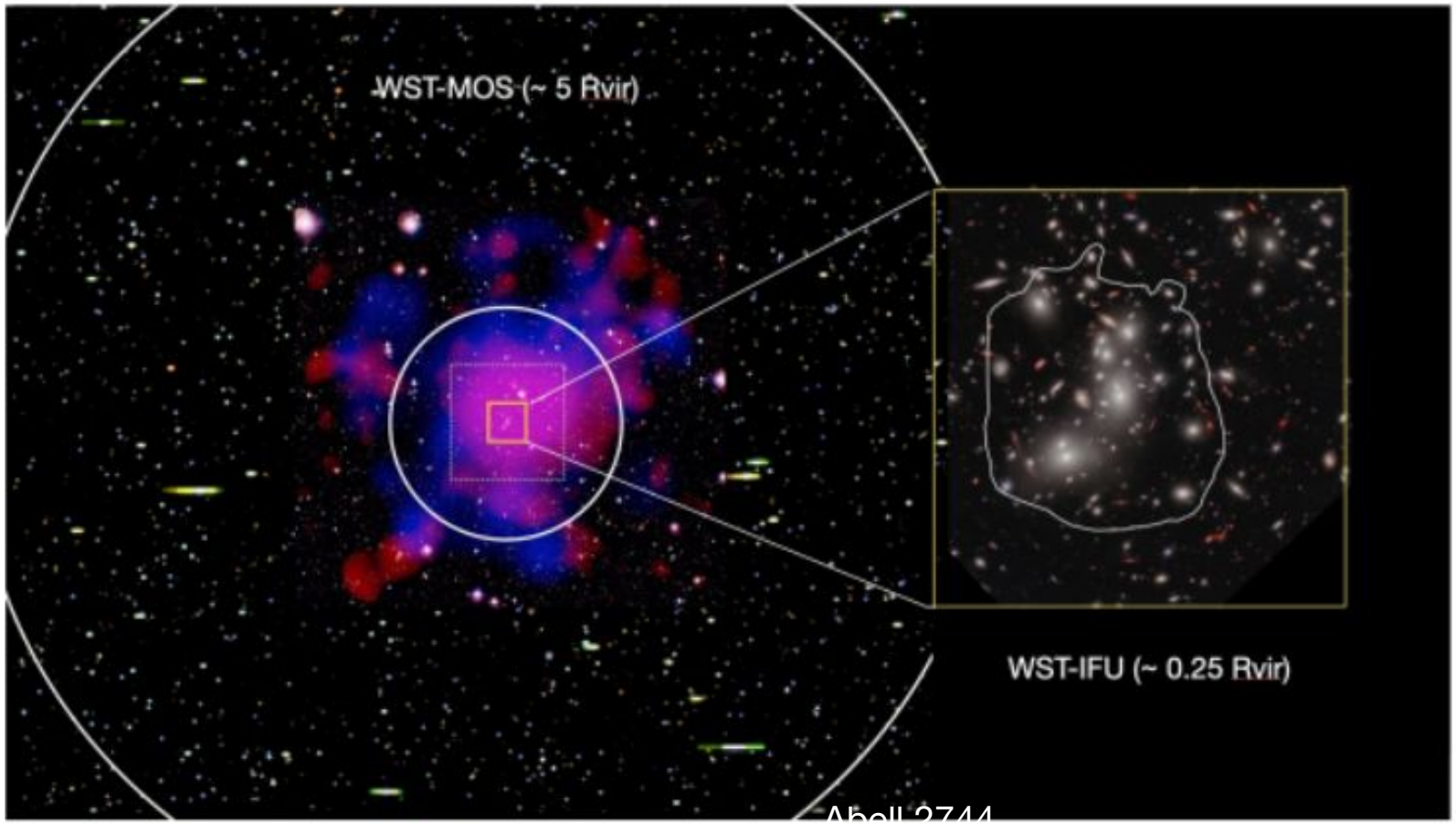
~ 900 LAEs × (10,000 LBGs +250 QSOs) per WST pointing (IFSxMOS) with ~ 7,000 pointings

$P^{3D}_{LAE\times LBG}(k, \mu, z)$

$P^{3D}_{LAE\times Ly\alpha}(k, \mu, z)$

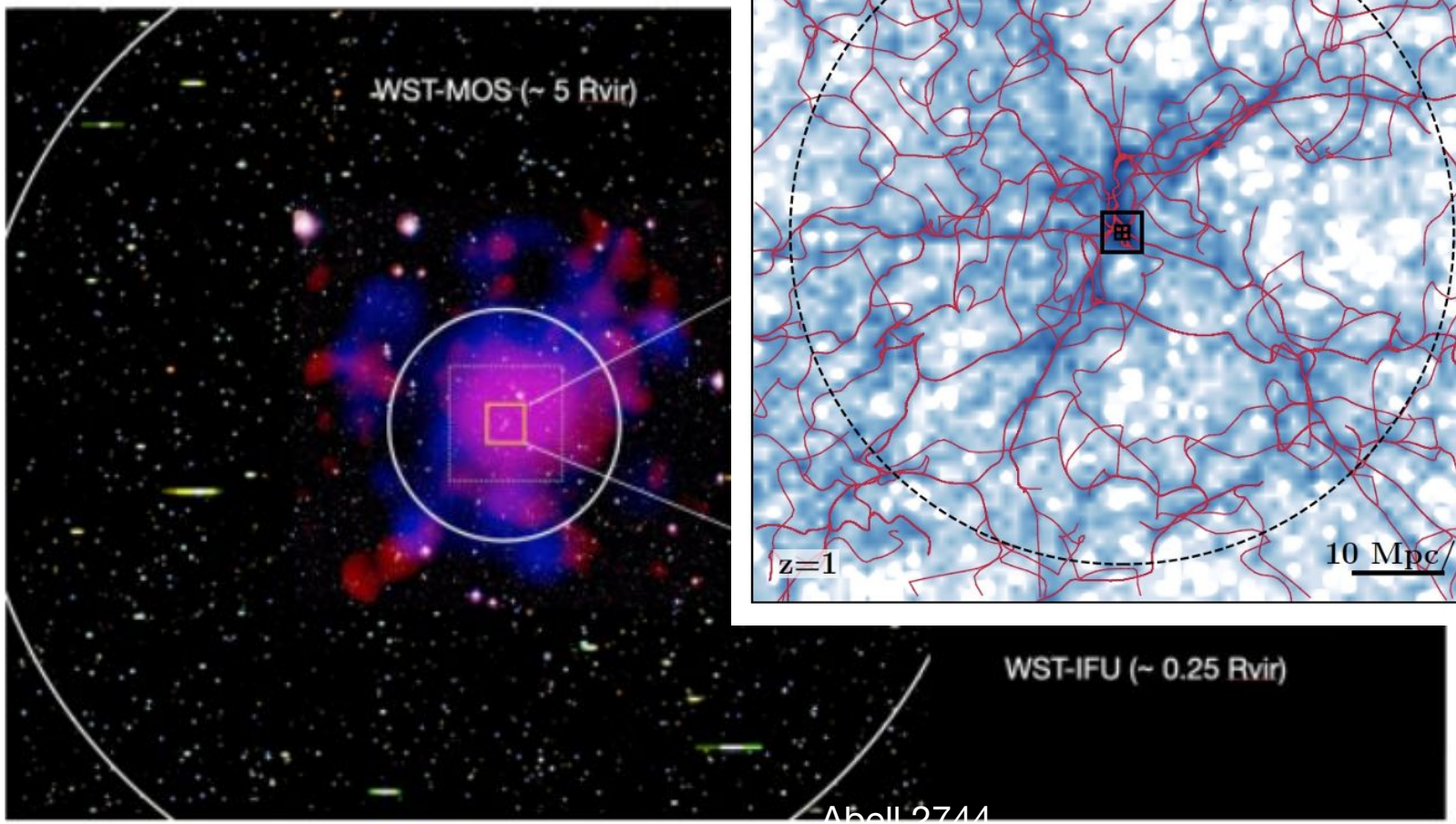
- LAE discovery without needing to preselect them
- BAO up to z~7

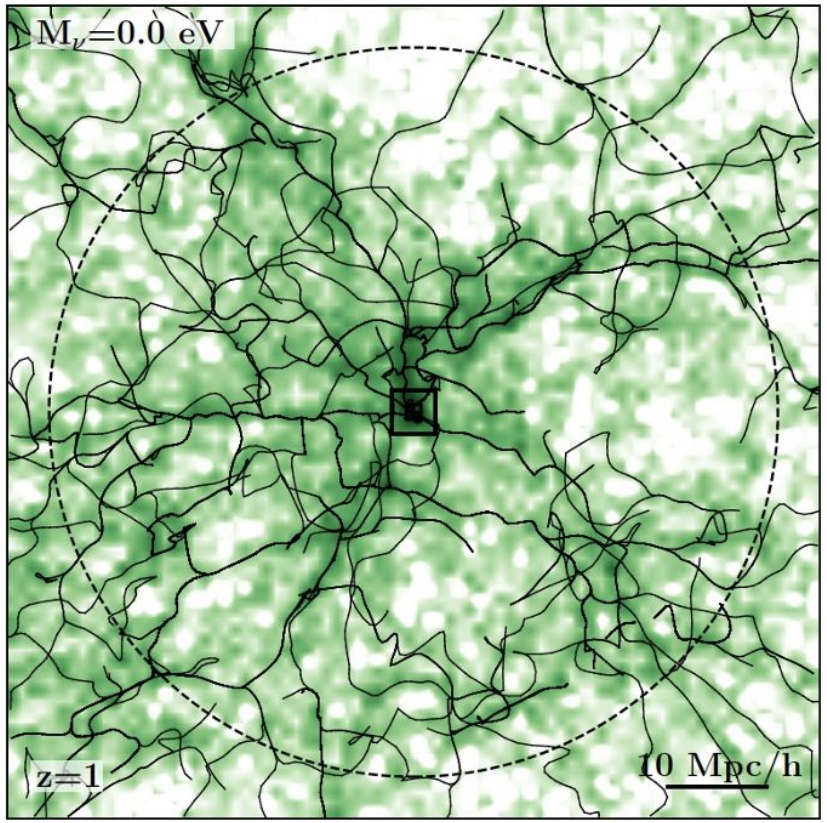
Dense regions: clusters



- thousands of cluster member redshifts measured out to ~10 Mpc
- high-precision strong lensing models out to radii $\gtrsim$0.5Mpc
- hundreds of multiply lensed images per cluster
- detailed maps of the filamentary structure

Dense regions: clusters



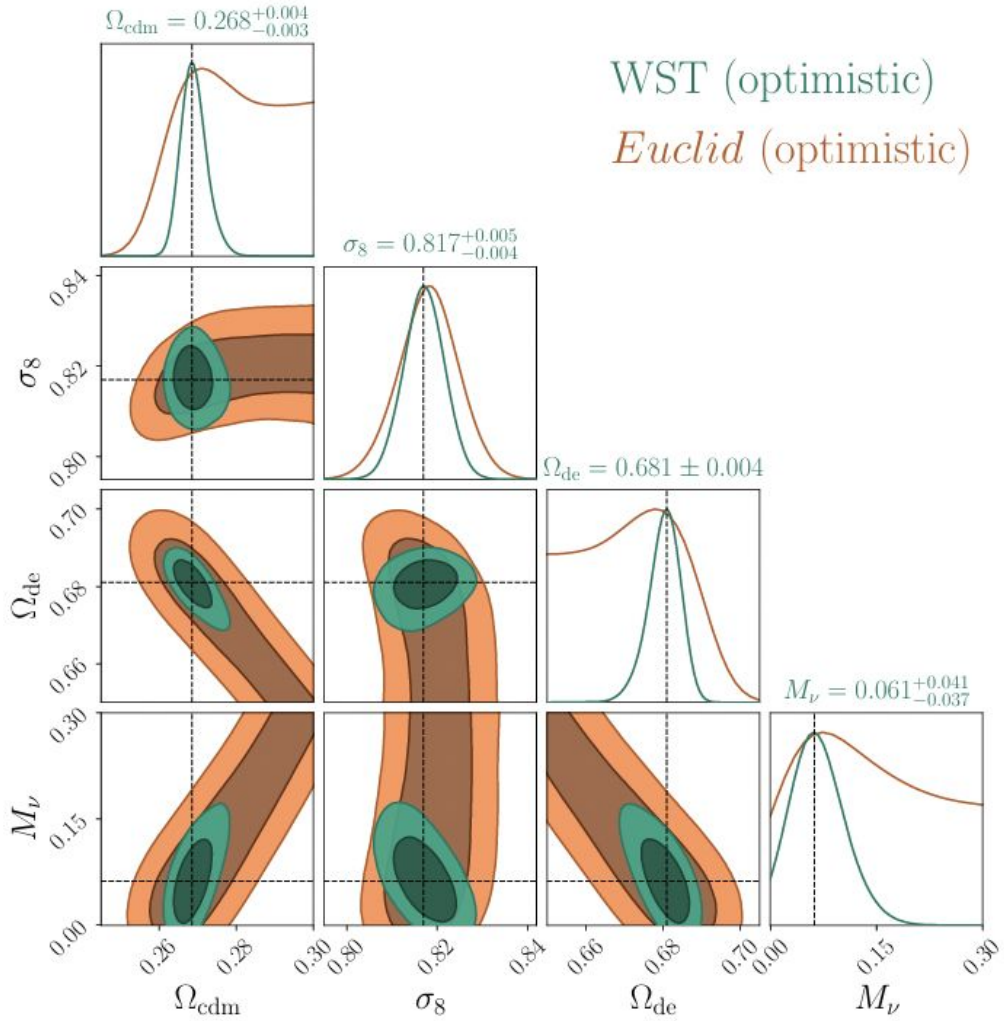


Underdense regions: voids

Voids as cosmological probes

standard approaches: void size function, void-galaxy cross-correlation function

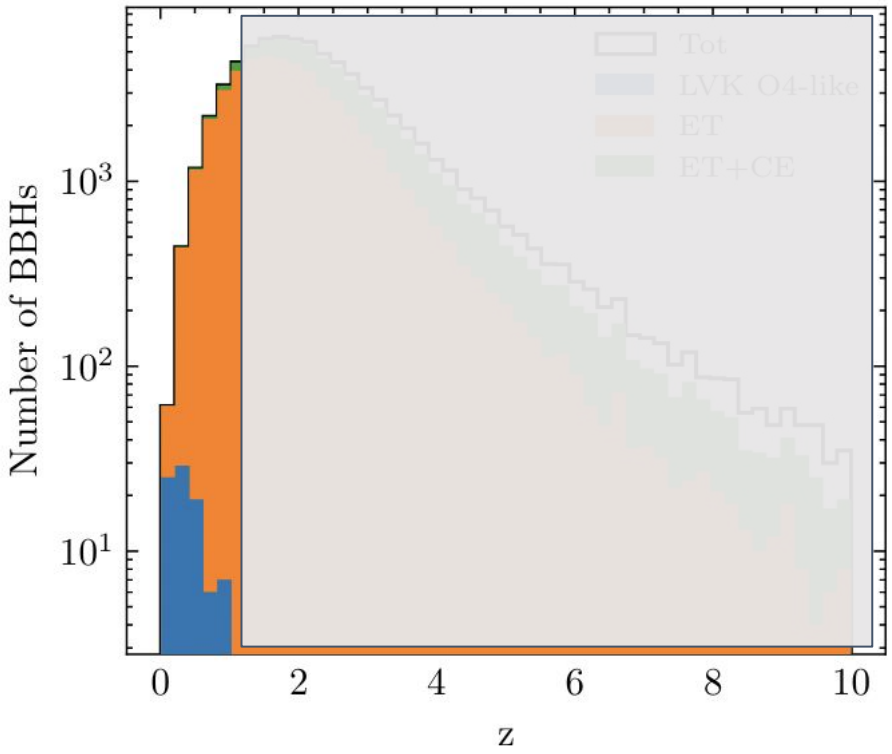
extended approaches: void lensing, void-CMB cross-correlation, velocity profiles (reconstruction), void auto-correlation function, combination with cluster counts, 2pt and higher-order statistics, galaxy evolution in voids, galaxy spin in voids, ...

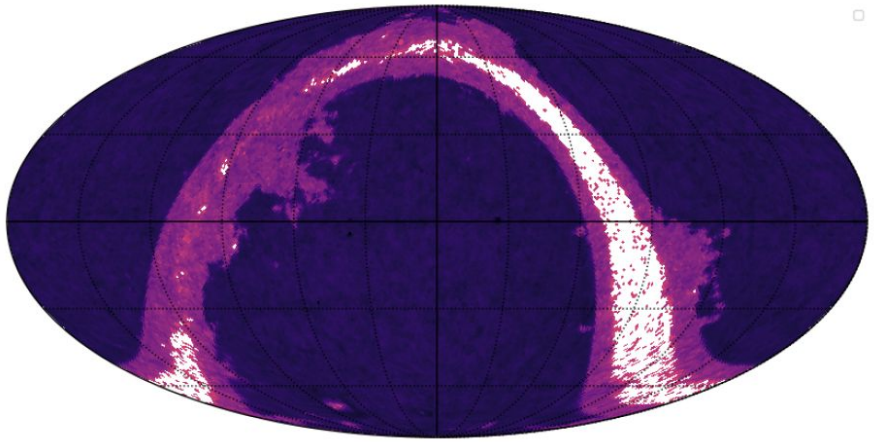


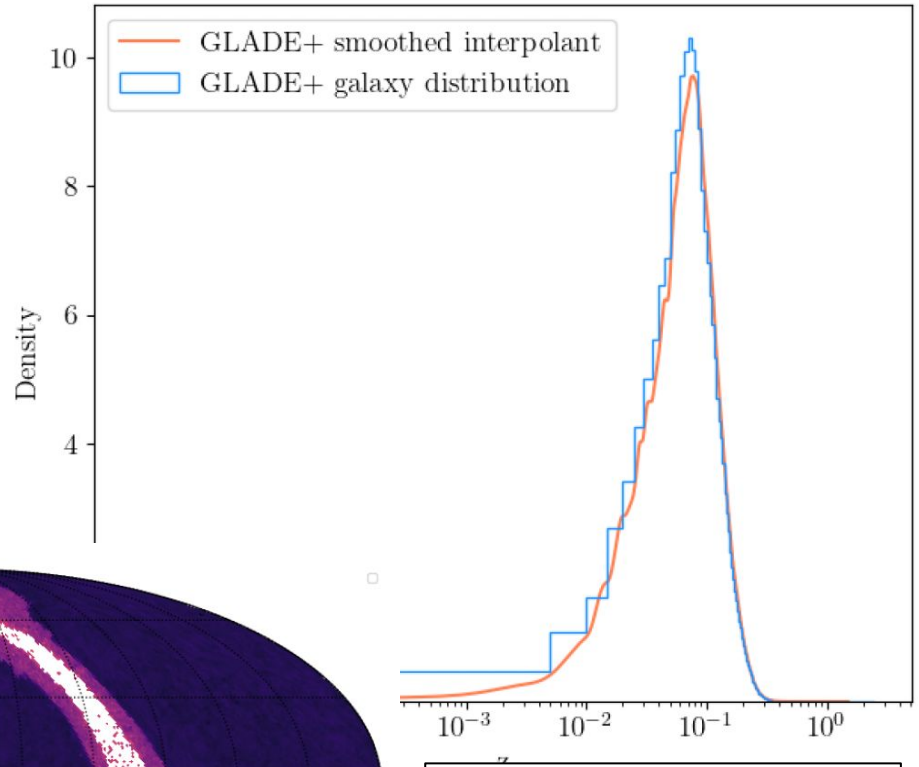
see talks by Sartori and Degni

Beyond standard methods (1/2)

For dark sirens, a deep and complete **spectroscopic** catalog is a game-changer







galaxy catalog **today**

see talks by Bisero and Borghi

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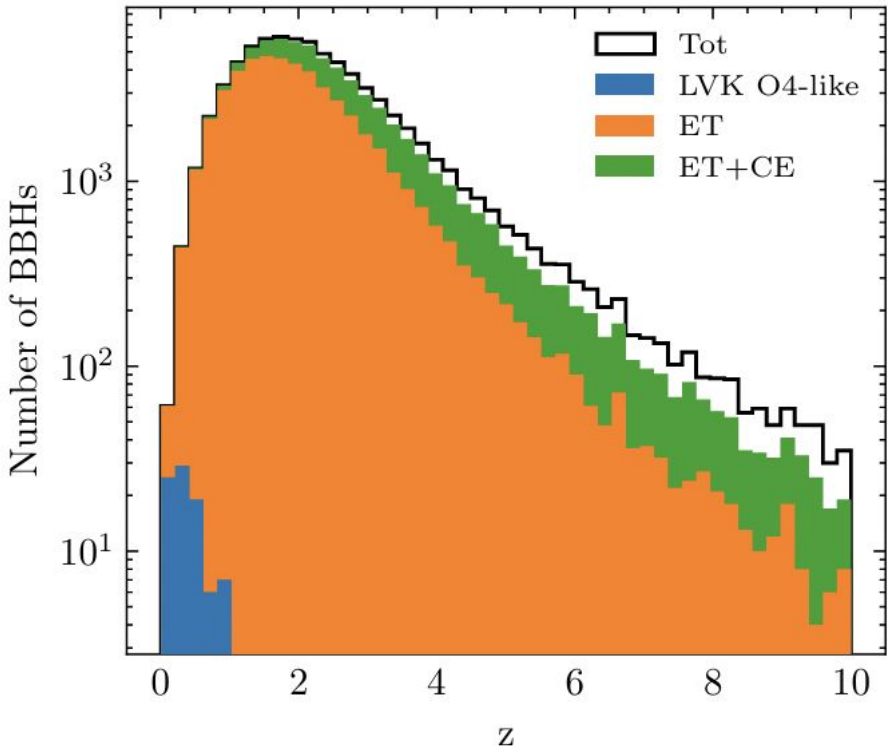

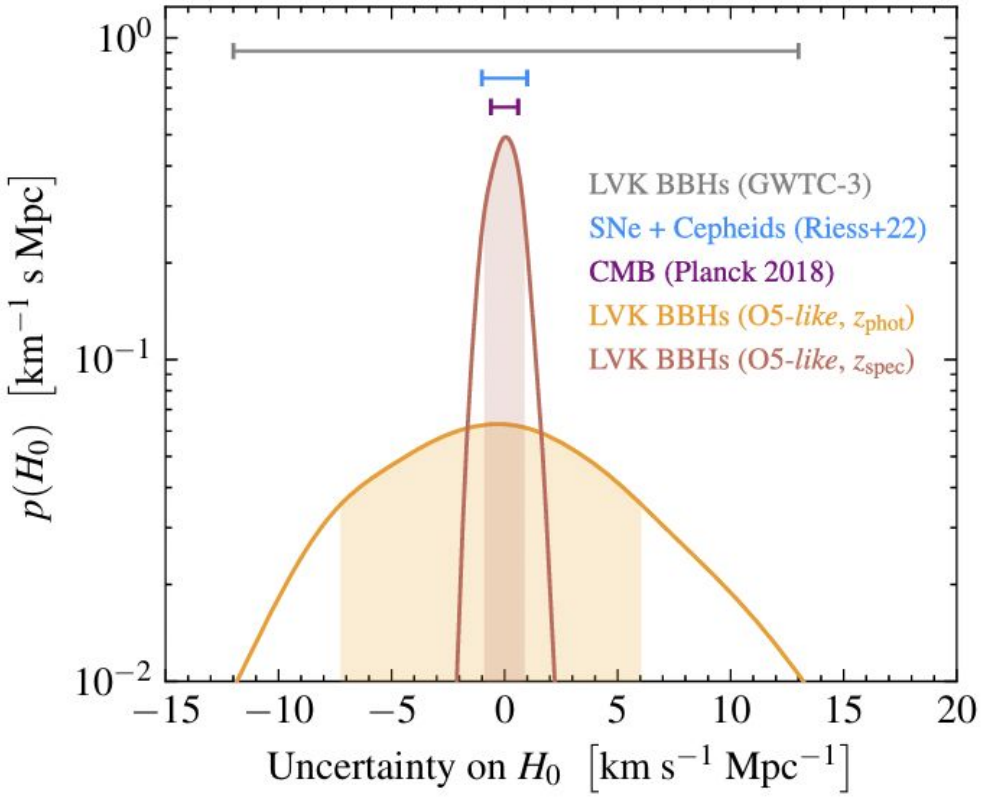

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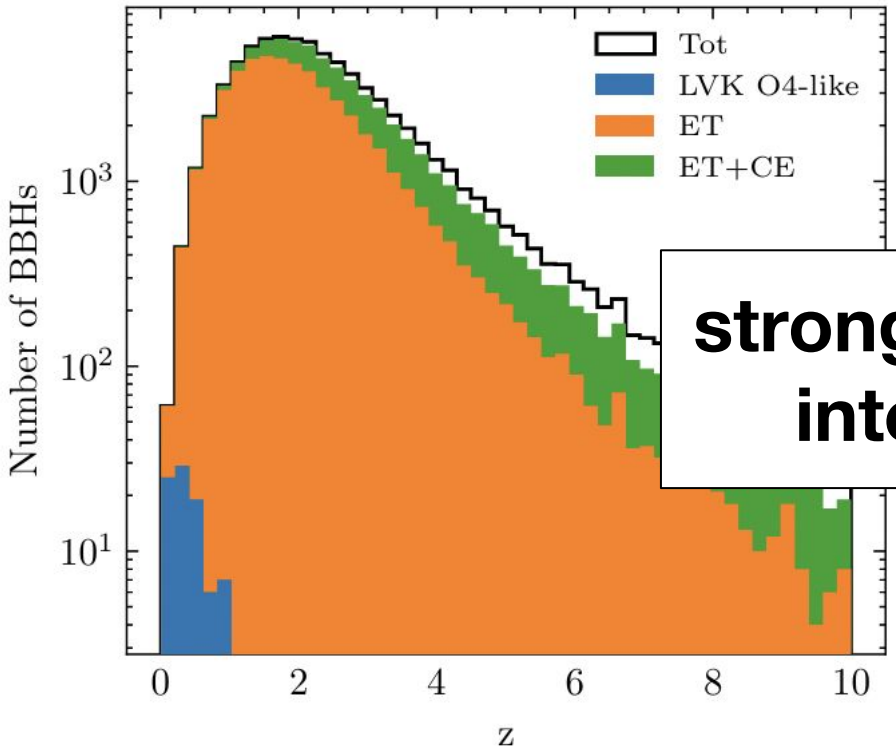
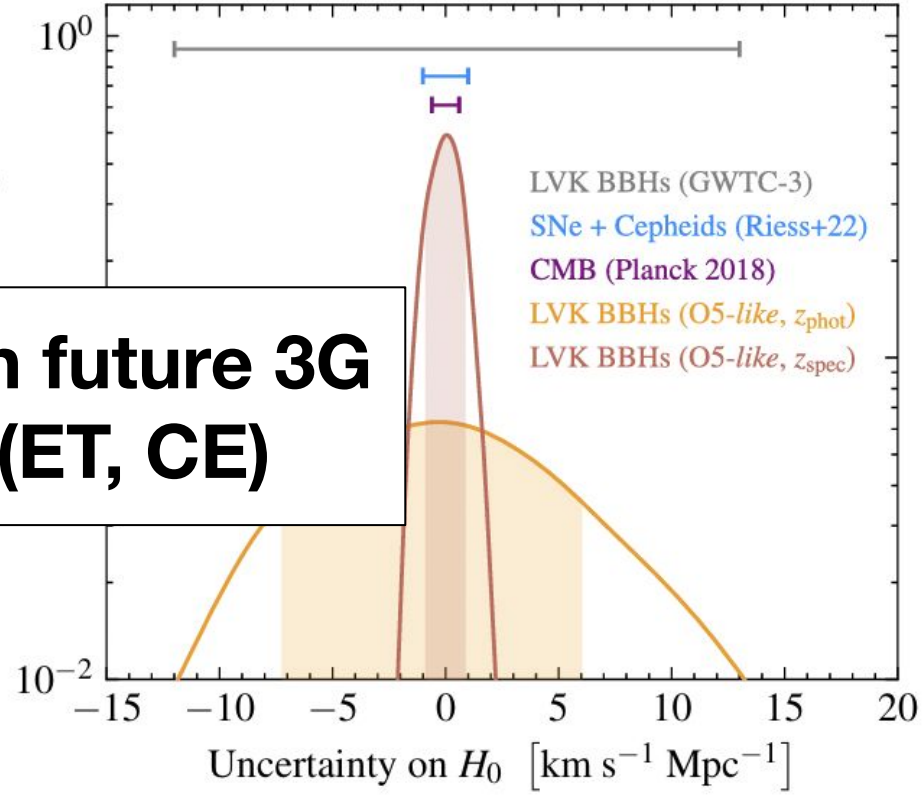


strong synergy with future 3G interferometers (ET, CE)



see talks by Bisero and Borghi

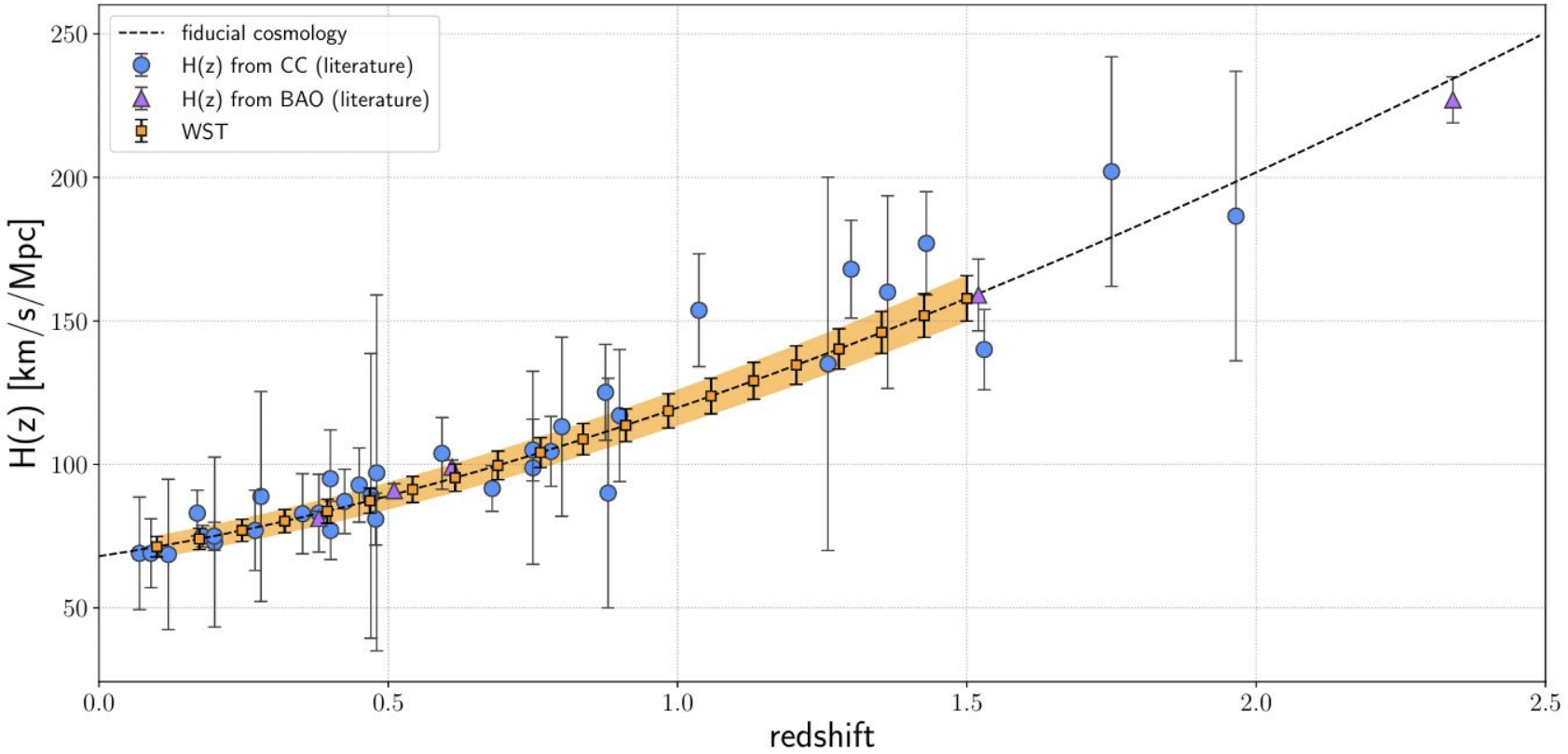
Beyond standard methods (2/2)

The ages of the oldest objects in the Universe can also be used to directly measure the expansion history of the Universe.

Cosmic chronometers:
relative ages of massive and passive galaxies

$H(z) = -1/(1+z)\, dz/dt$

Cosmic clocks:
ages of the oldest stars as lower limit to the age of the Universe



What's next?

- Identify the key open questions for 2040
- Several transformative science cases already identified, but open for new ones
- Maximize the scientific return of WST from the combination of MOS and IFS
- explore in-depth the synergies with other future facilities (ET, LISA, CTAO, SKAO, THESEUS, ACME…) and establish further contacts

	Primary (m^2)	Nfiber	Refelction	Product	Speed over DESI	First Light
SDSS	3,68	640	0,81	1908	0,045	
BOSS	3,68	1000	0,81	2981	0,070	
DESI	9,5	5000	0,9	42750	1	
PFS	50	2400	0,9	108000	2,5	
4MOST	12	1624	0,81	15785	0,4	
MUST	**28**	**21168**	**0,81**	**487879**	**11,4**	**2030**
Spec-S5	25	26000	0,81	522249	12,2	2035
WST	113	20000	0,81	1831248	42,8	2040

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