Mapping Distant Universe with Lyman Break Galaxies

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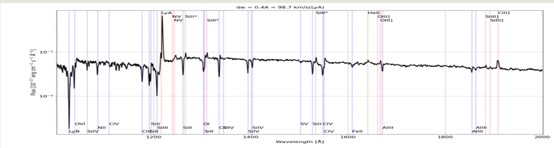
High redshift LBGs from deep broadband imaging for future spectroscopic surveys, Ruhlmann-Kleider V. et al., arXiv:2404.03569

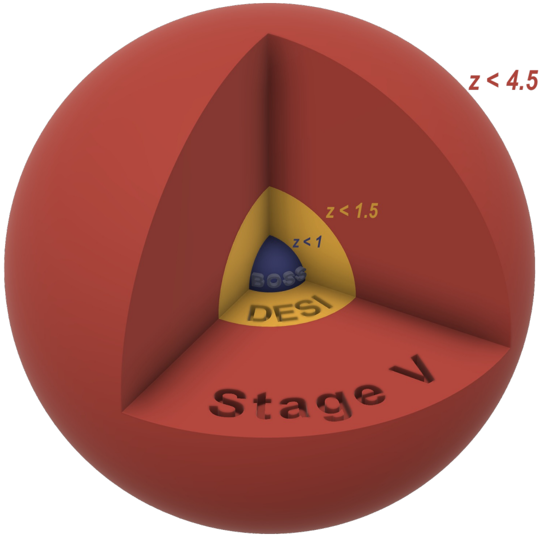
Fundamental Physics from Future Spectroscopic Surveys, Berkeley, May 6-8, 2024



Motivations and strategy

Science case at z>2 in LSS

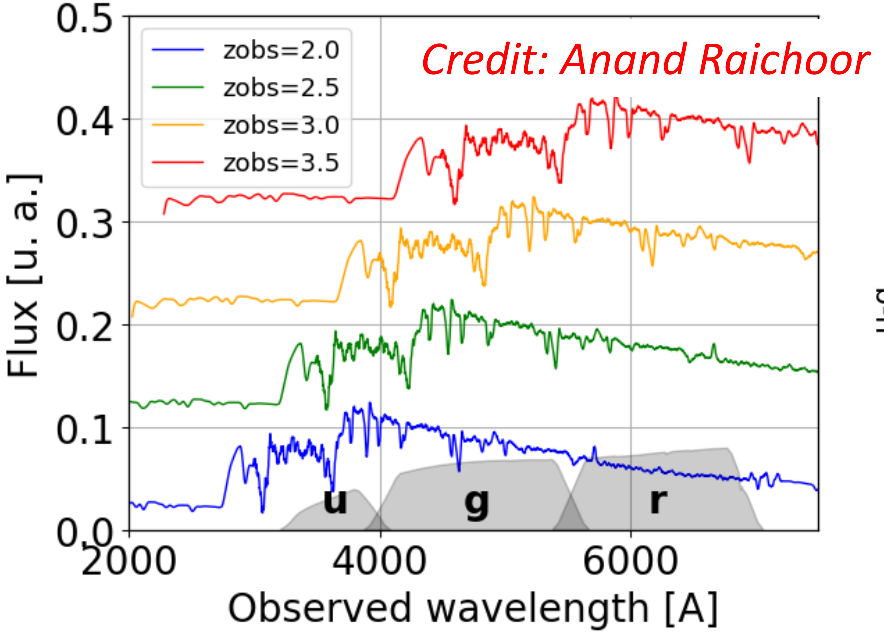
- H_0 tension: Early Dark Energy
- Dynamical EoS Dark Energy
- S8 tension: Growth of the structures
- Inflation: Scale dependence of bias, bi-spectrum
- Neutrino masses

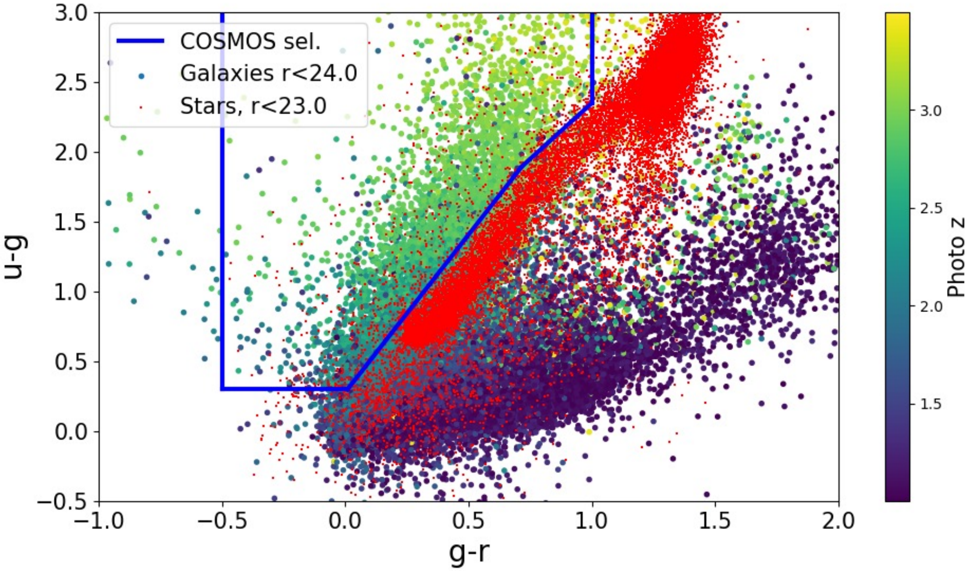


Future spectroscopic surveys require mapping 2<z<4.5 (even 2<z<5.5) Universe

- Larger redshift range and therefore volume
- Several projects
  - **Spec-S5:** twin 6m telescopes with 13,000 robotic positioners
  - **MUST:** 6.5 telescope with ~20,000 robotic positioners
  - **MSE and WST**: ~12m telescope with ~20,000 robotic positioners
- New-developed technologies ⟶ **x10 modes** compared to DESI and Euclid
- z>2 galaxies and quasars as tracers of the matter
  - Lyman-Break galaxies: **LBG** and Ly-α Emitter Galaxies: **LAE**

LBG selection with u-dropouts

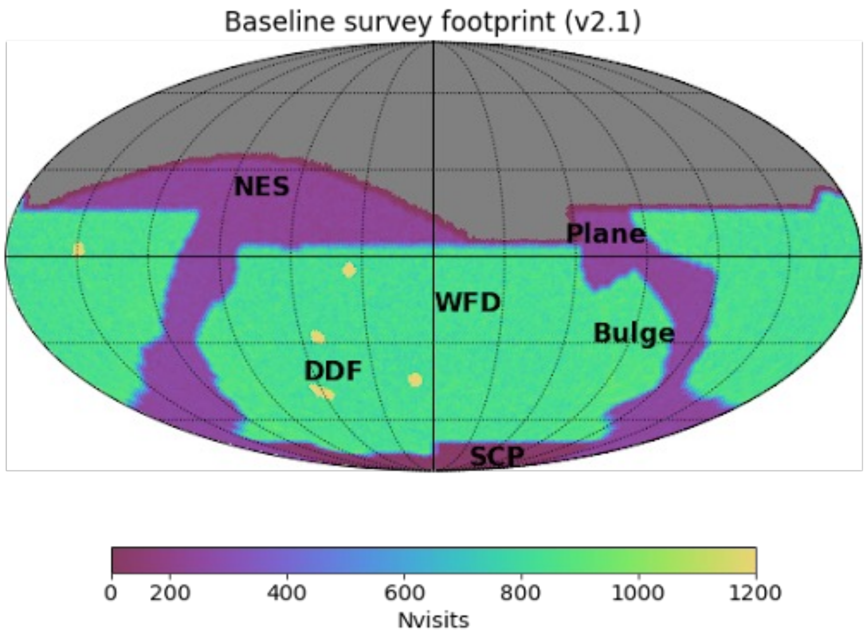


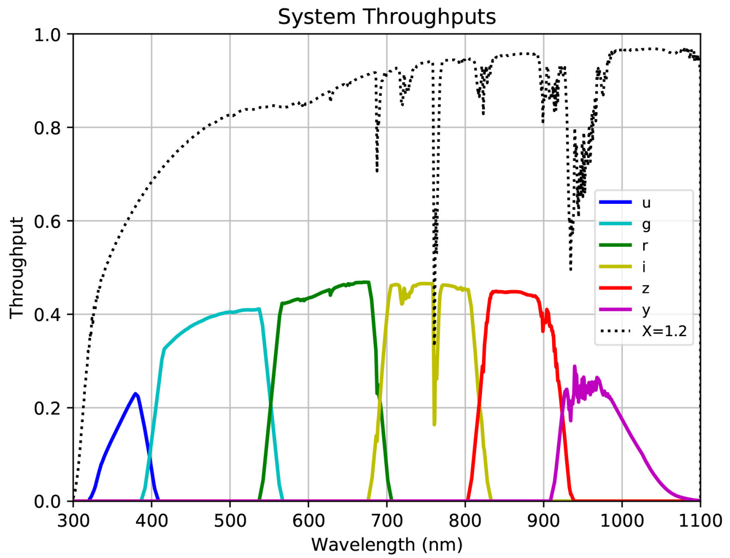


Principles

- Redshift range: 2<z<2.5
- Use the flux decrement bluewards of the Lyman limit due to HI absorption
- Need a deep u-band: LSST/Rubin In South

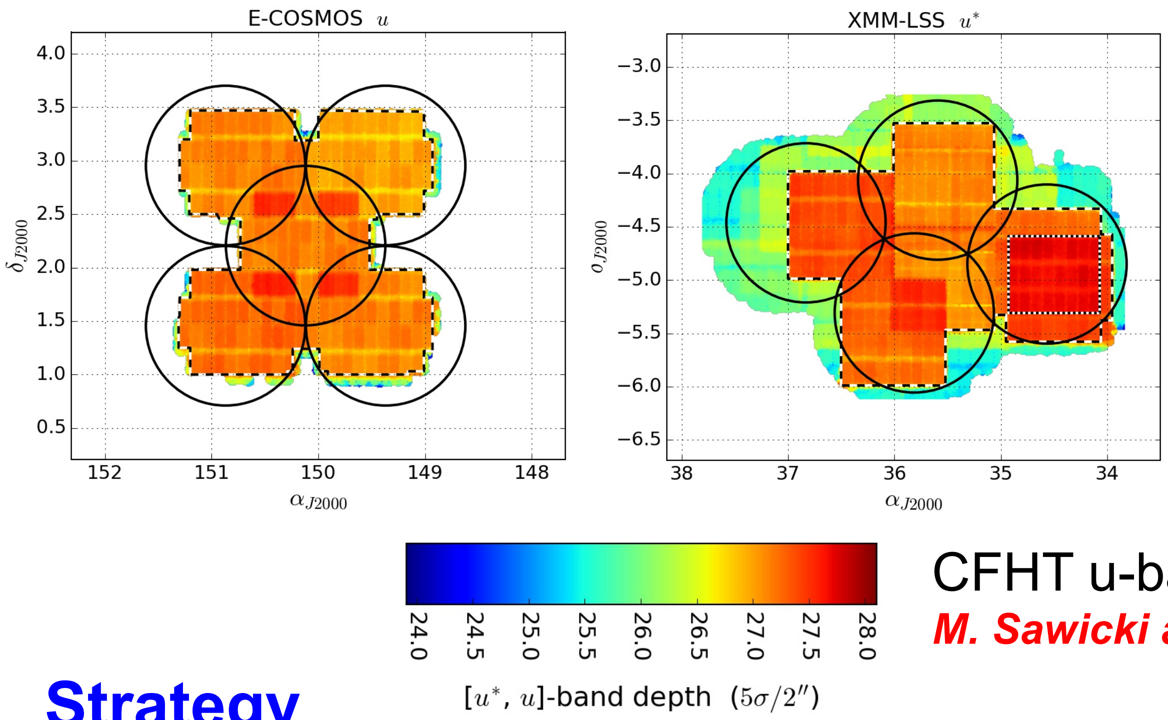
Future Imaging in South

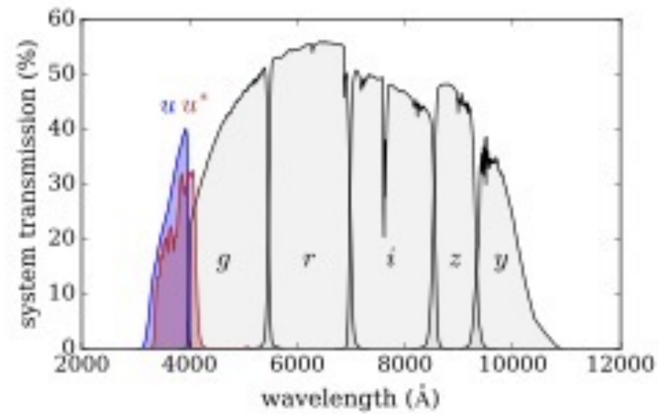




- LSST-Rubin will be available at the time of S5 generation
- Footprint ~15,000 deg^2
- **Depth (10 years), u: 26.1**, g: 27.4, r: 27.5, i: 26.8, z:26.1, y:24.1
- Proof of principle with DESI and with CLAUDS imaging

Deep u-band imaging with CLAUDS for pilot survey





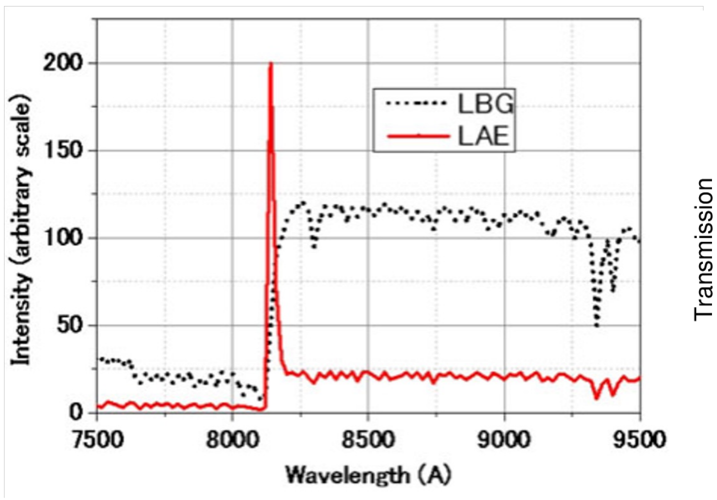
CFHT u-band + HSC grizy-bands

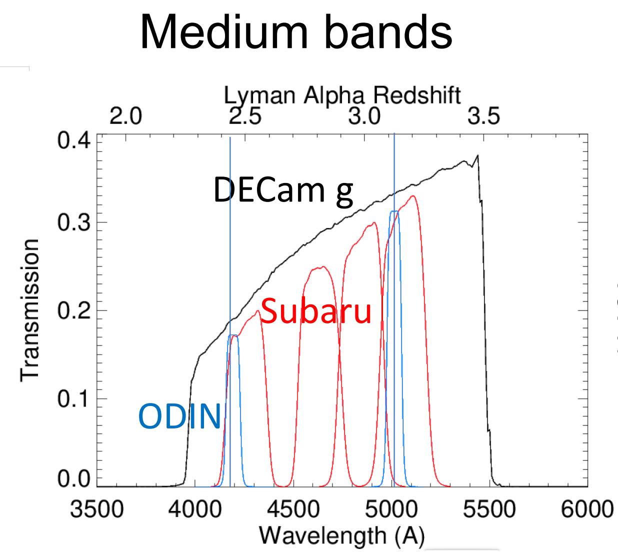
M. Sawicki and S. Arnouts, arXiv:1909.0589

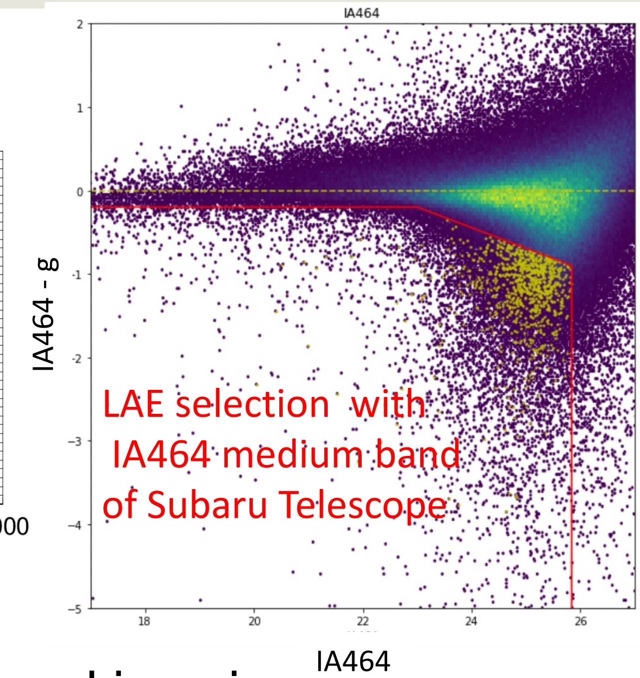
Strategy

- u-dropout with CLAUDS in COSMOS and XMM fields
- Ultra-deep u-bands: u-depth better than ~27-27.5
- The depth is sufficient to validate the imaging that will be available for future spectroscopic surveys (Spec-S5, WST,….)

LAE selection with medium bands







Credit: D. Schlegel and A. Dey

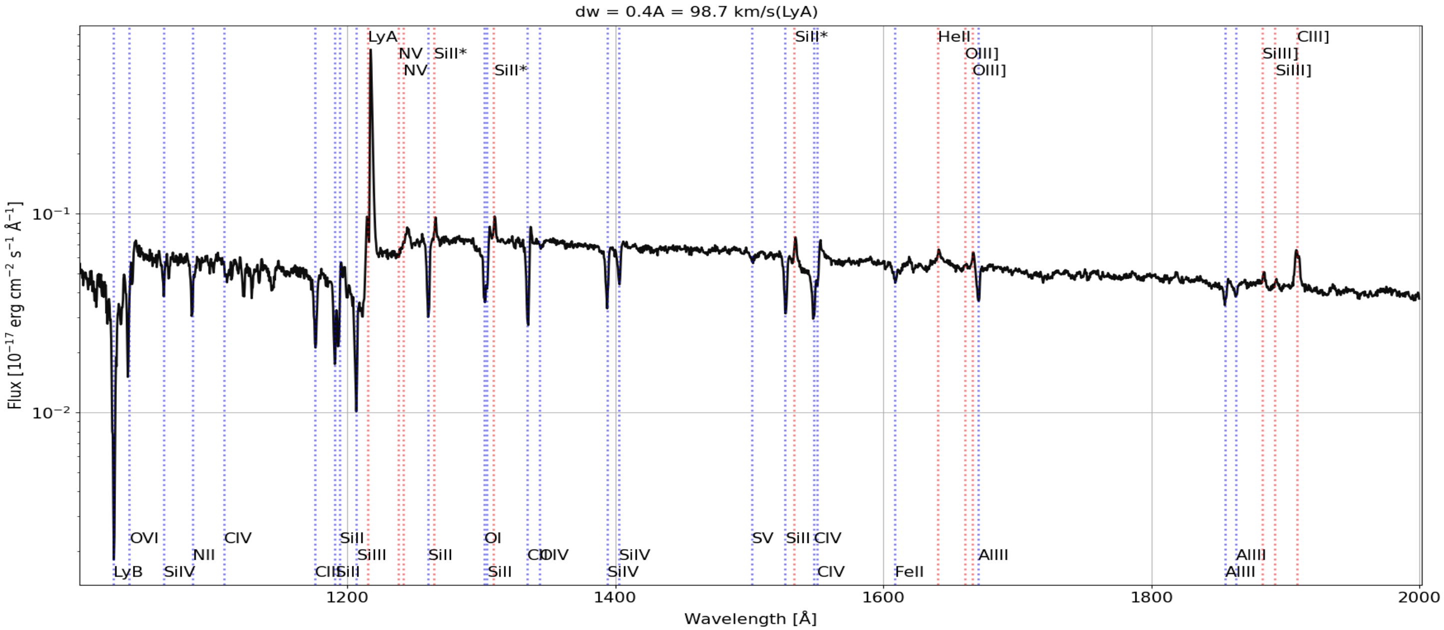
Principle

- Target selection: color excess using medium-band imaging
- Redshift measurement: accurate spectroscopic z in short exposure time
- Different galaxy population: low stellar mass, young ages

Hybrid approach

- Combining medium bands → Usual dropouts → LBG selection
- Color excess with a medium band → LAE selection

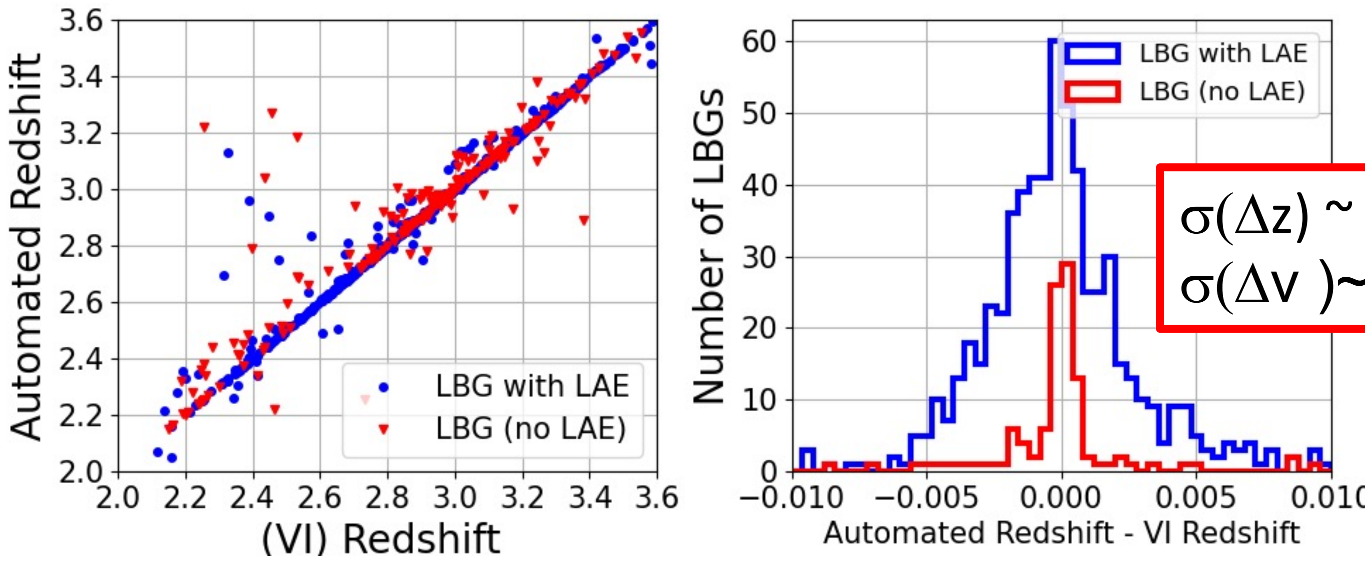
Pilot survey with DESI



– 15000 LBG Targets observed with DESI
– Two observed fields (COSMOS and XMM)
– Exposure time: from 2 hours to 5 hours
– 2000 spectra with Visual Inspection
– ***Ruhlmann-Kleider V. et al., arXiv:2404.03569***

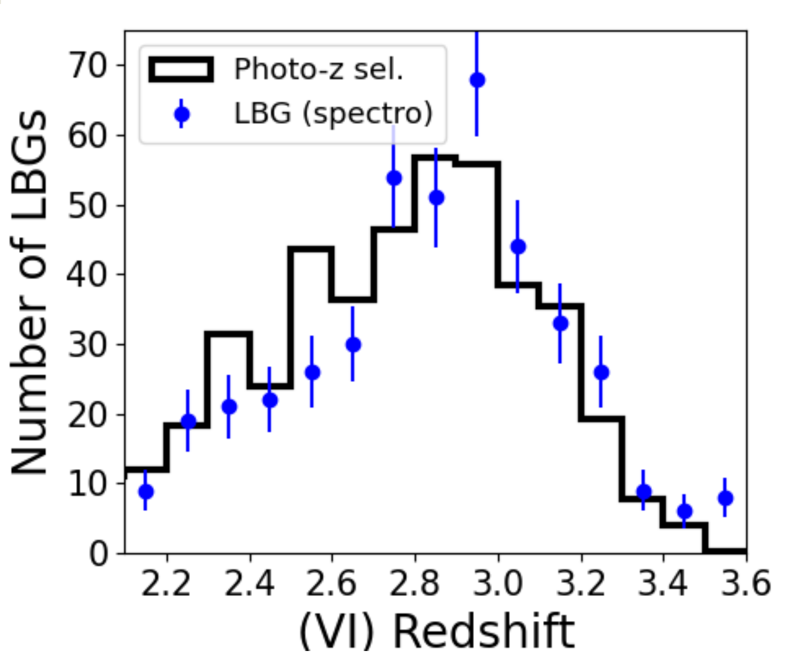
Determination of redshift

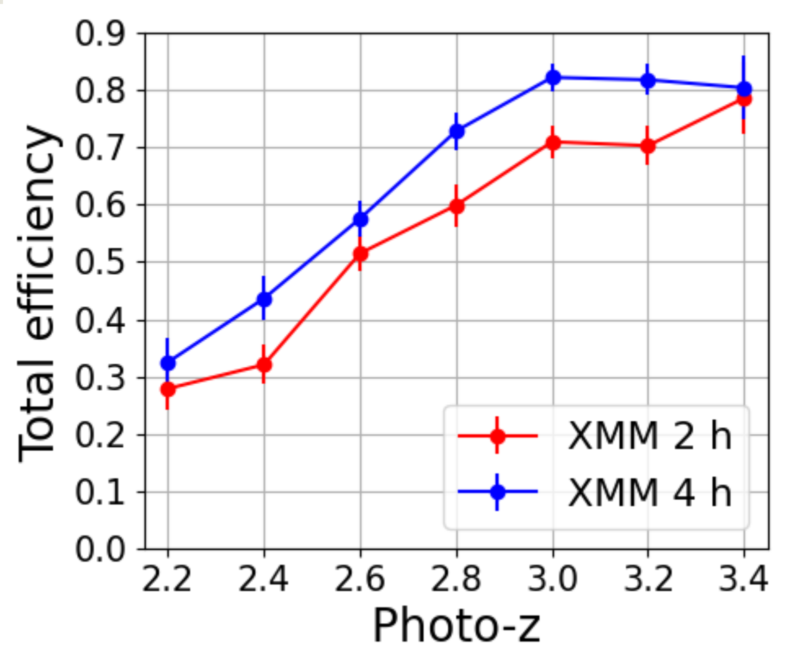
- Two-step approach:
  - A CNN provides the identification and a redshift prior
  - A template fitting method (Redrock) computes the redshift using a +/- 0.10 prior given by the CNN
- Purity: ~90% for (CL>97%) estimated with VI



$\sigma(\Delta z) \sim 0.003$
$\sigma(\Delta v) \sim 200$ km/s

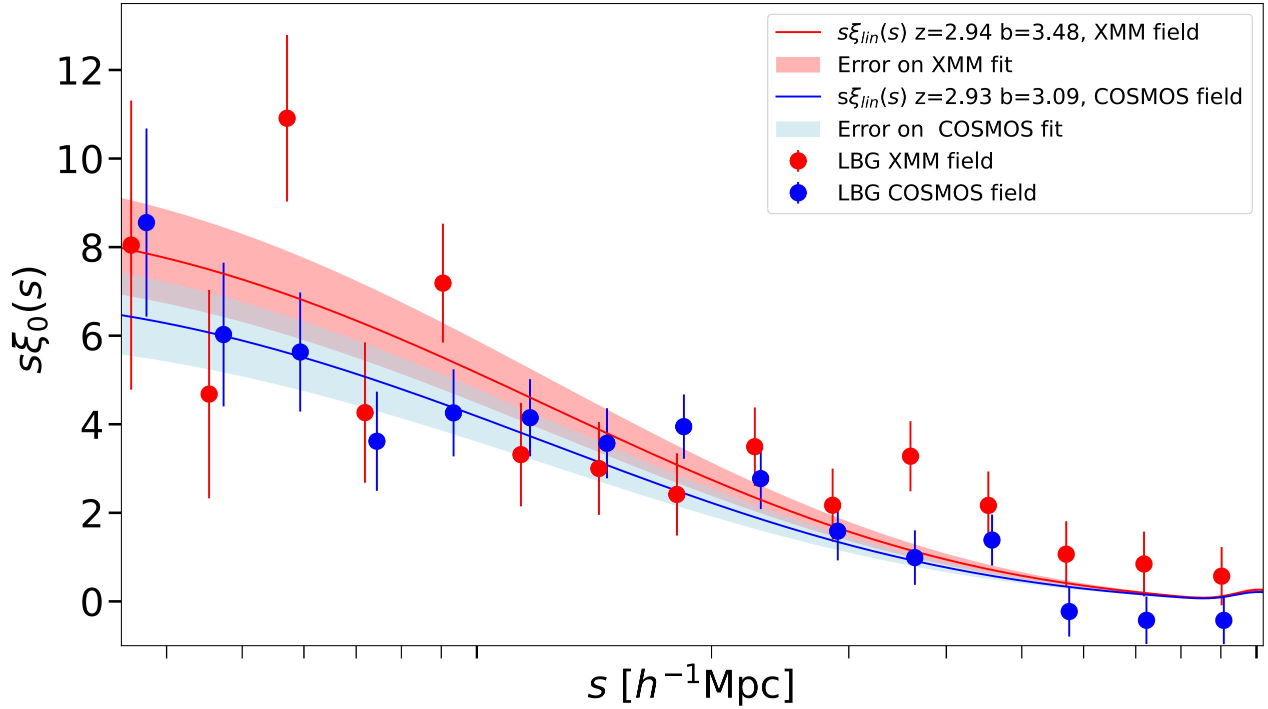
Redshift and Efficiencies





- Excellent agreement between photo-z and spectro redshifts
- Total efficiency >70% for 2 hours and z>2.8 (<0.5h with 12m Tel.)
- Low efficiency for z<2.5, two possible origins:
  - Lower SNR due to degraded throughput of the instrument in blue
  - Lower fraction of Ly-α emission (galaxy evolution)

XMM field –Clustering with LBGs

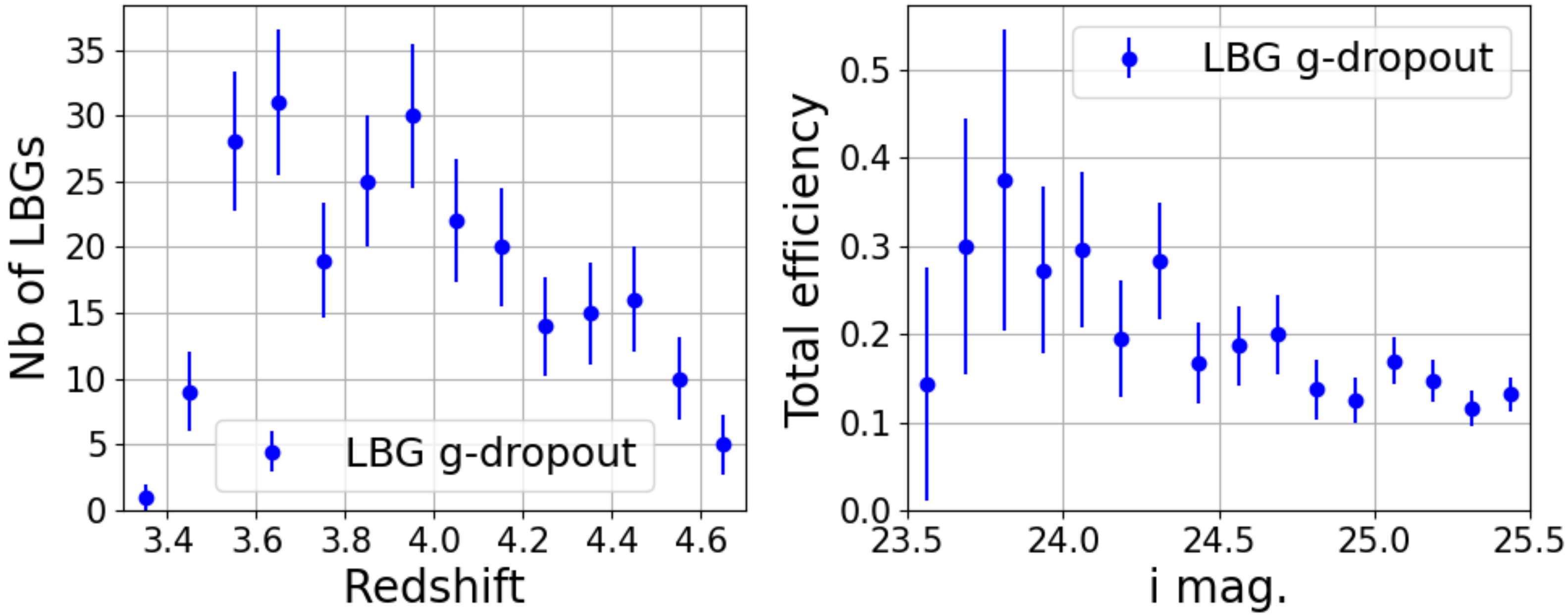


– With a refined LBG sample (purity~95%)

– Enough LBGs to get an estimate of LBG bias

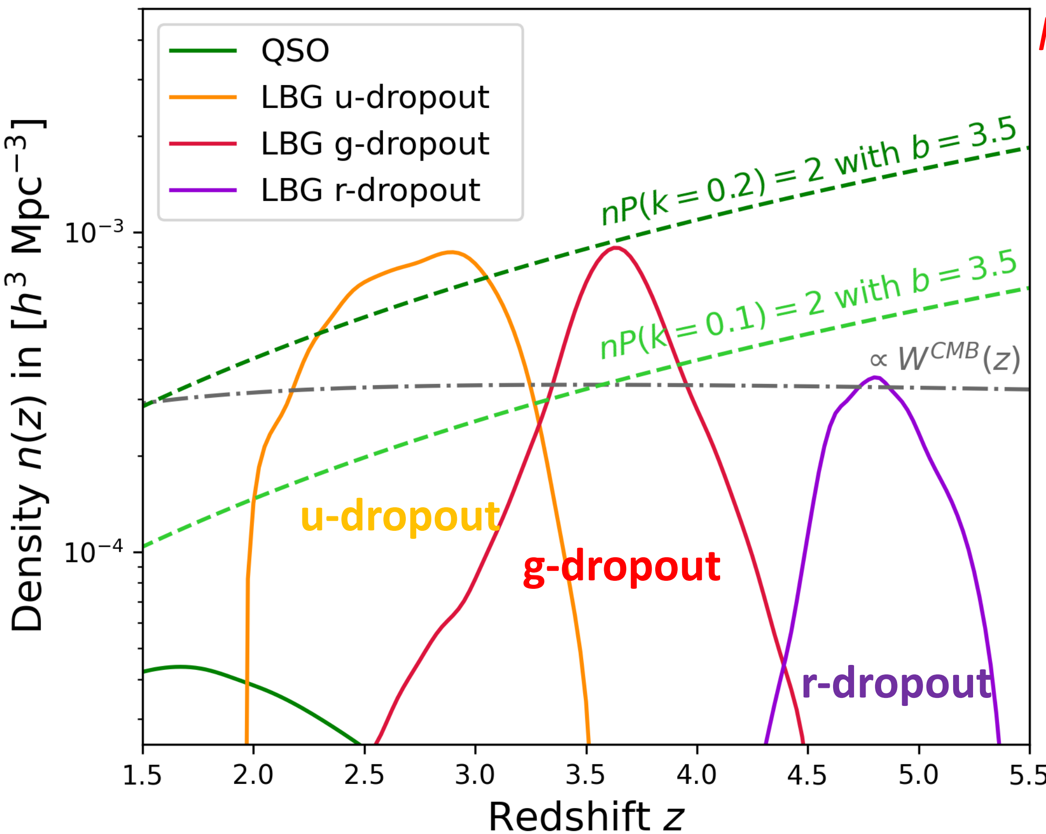
– At z=3, b ~3.3 $\pm$ 0.3 ⇒ Used in the forecasts

g-dropout with HSC and DESI



- Same principle: ugr bands ⟶ gri bands
- Specto redshift distribution (3.5<z<4.5)
- Efficiency: ~20% with 2 hours and ~35% with 5.5 hours
- For 12m telescope, it will require ~1 hour to get a efficiency at ~50%

LBG surveys – n(z)



Mainieri et al., 2024, arXiv:2403.05398

u-dropout

- r<25.0
- Exposure time < 0.5h
- Efficiency vs z: up to 70%

g-dropout

- i<25.0
- Exposure time ~ 1h
- Efficiency: 50%

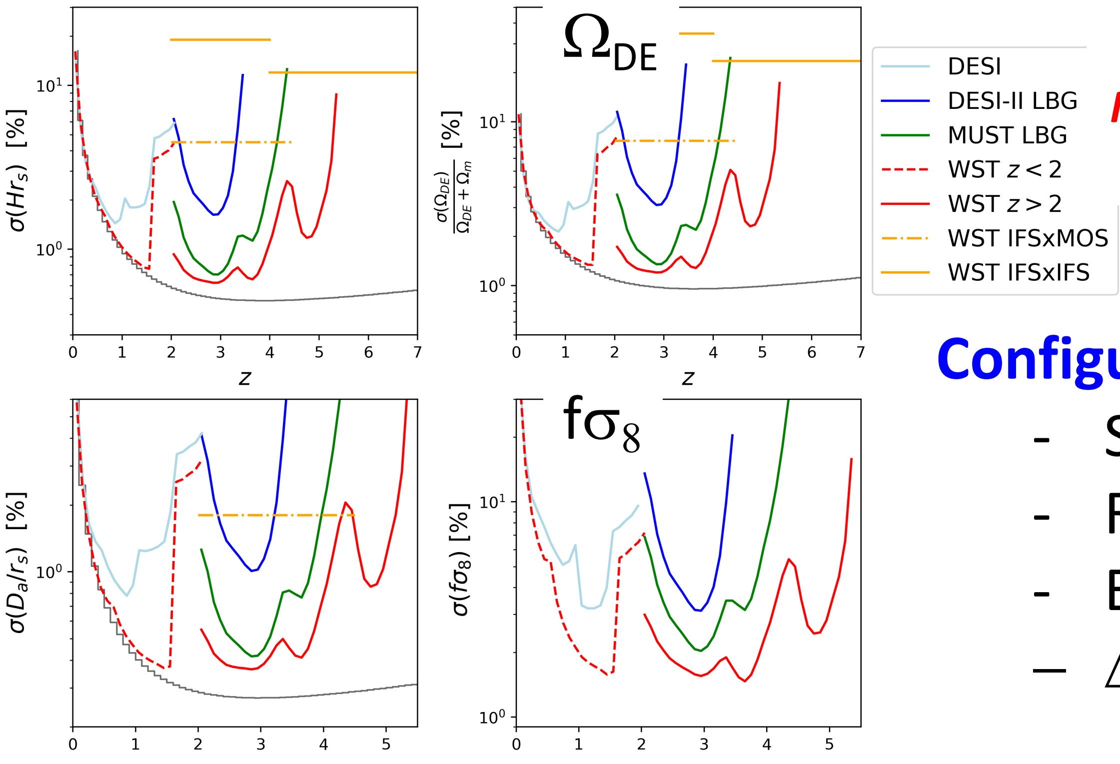
r-dropout

- z<25.5
- Exposure time ~ 2h
- Efficiency: 50%

– u/g/r dropouts to select LBGs ⇒ redshift 2.0<z<5.5

– r-dropout possible with 12m telescope ⇒ Eff=50% for 2 hours

Dark Energy and structure growth



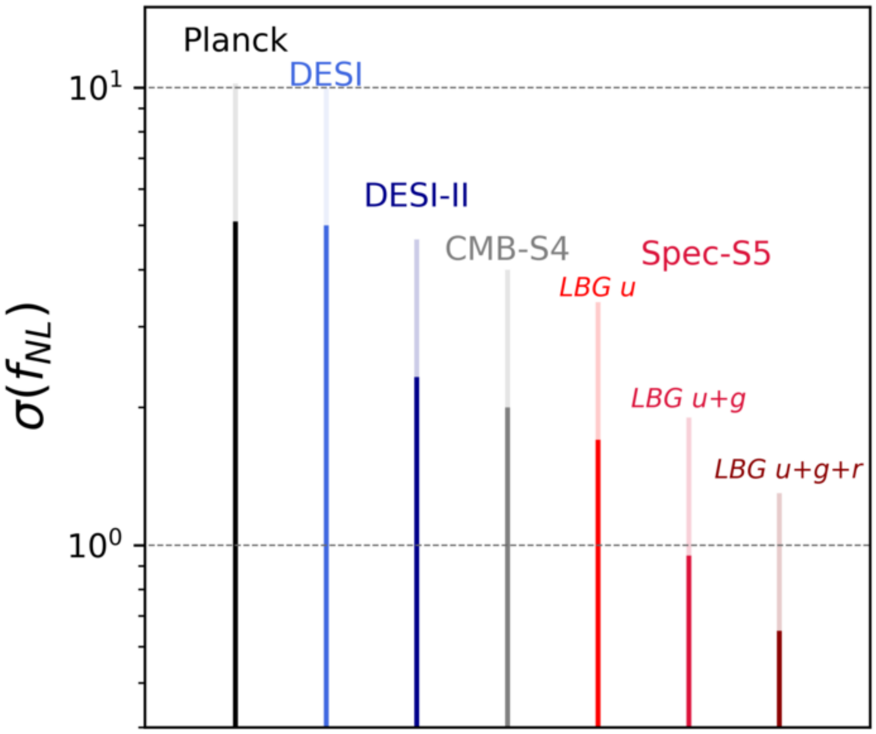
WST white Paper
Mainieri et al., 2024, arXiv:2403.05398
Credit: William d'Assignies D.

Configuration for

- Surface: 15,000 deg^2
- Redshift range: 2.0<z<5.5
- Exposure time: 0.5h, 1h, 2h
- Δz binning: 0.1

- DE content: for 2<z<4, almost at cosmic variance limitation
- Measurements up to z=5.5 (matter-dominated era)
- Indirect constraints on EDE models and exotic models

Primordial Non-Gaussianities

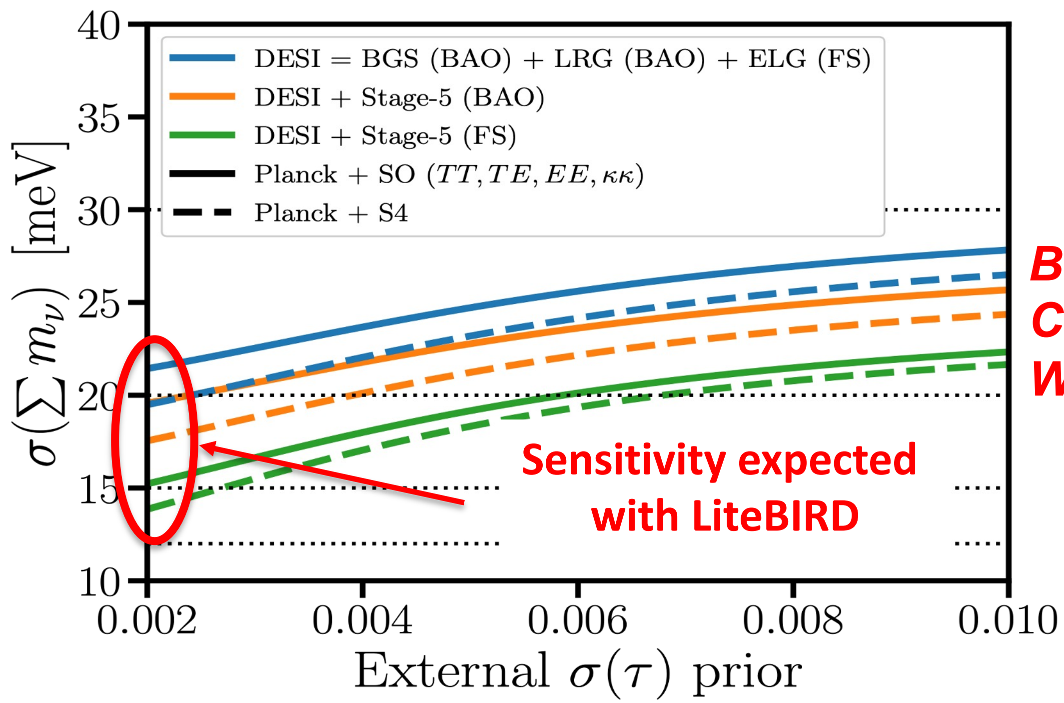


Credit: William d'Assignies D.

- With u/g dropouts we can break $\sigma(f_{NL})$ ~1 barrier
- Sensitive to inflation models with multi-fields
- Significant gain by adding r-dropouts:

  $\sigma(f_{NL})=0.95 \longrightarrow \sigma(f_{NL})=0.65$
- Worthwhile to study if we can use re-dropouts with 6-m telescopes

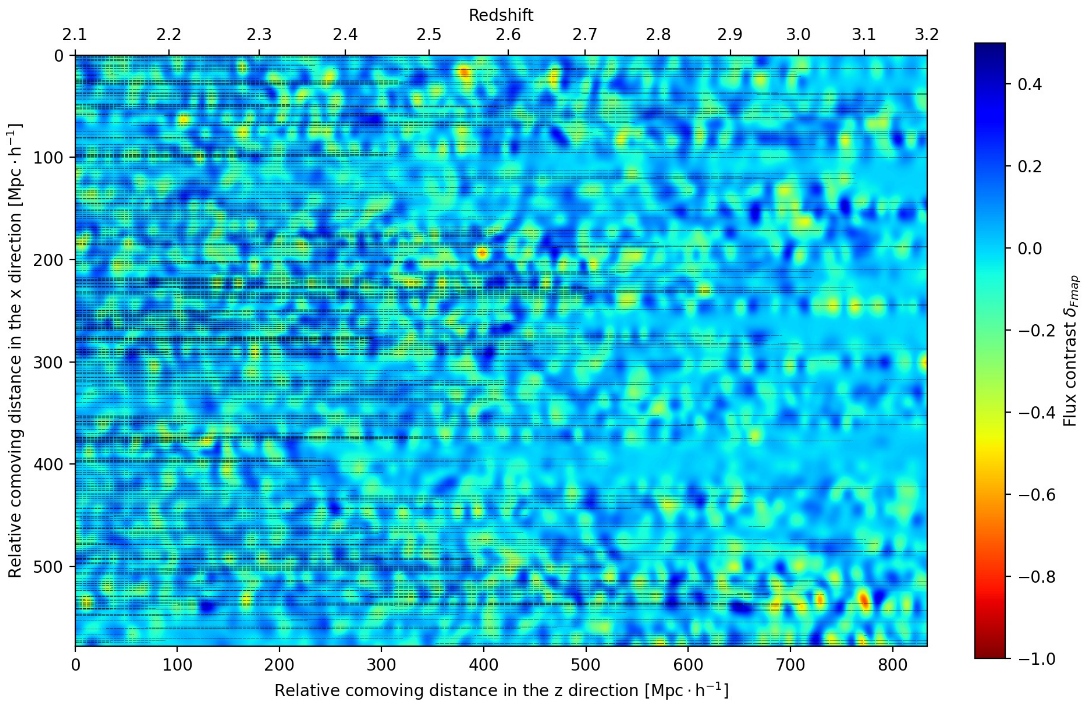
Neutrino mass



Based on Sailer, Castorina, Ferraro & White, arXiv: 2106.09713

- With LiteBIRD, expected error on $\sigma(\tau)$: ~0.02
- Sensitivity on $\Sigma m_\nu < 15$ meV
- Measurement of Σm_ν better than 4σ

Ly-α Tomography



– 3D map: use Ly-a forest as tracer of IGM for 2.0<z<3.5
– u-dropouts: 500 to 1000 LoS per deg^2 with LBGs
– 100 to 150 LoS per deg^2 with QSOs
– Proto-clusters Science and Voids Science

Conclusions

DESI Pilot surveys

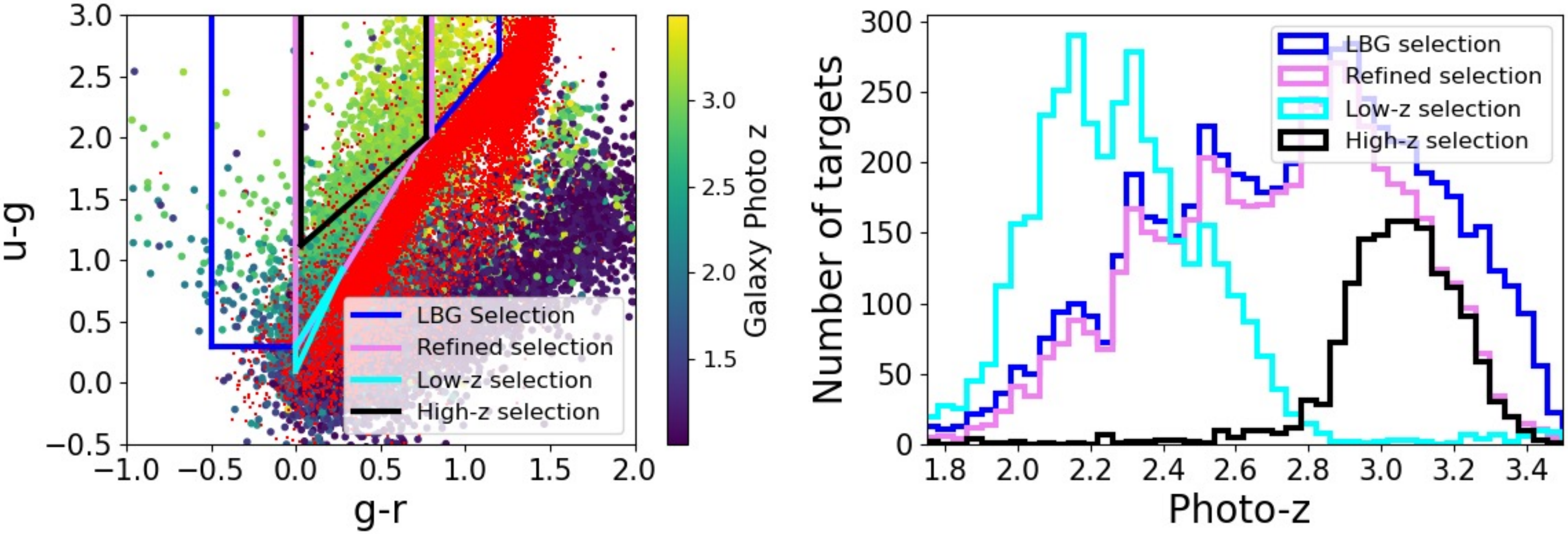
- Test of target selection with CLAUDS (u-CFHT + HSC)
- Target efficiency >70 % for u-drop selection for z>2.8 with 2 hours.
- Validation of both the u-dropout and g-dropout selections for LBGs with DESI

Lessons for future spectroscopic surveys

- ~8000-10000 targets per sq. deg. with LSST 10 years
- Redshift range with LBGs: $2.0<z<5.5$
- Worthwhile to study if we can use re-dropouts with 6-m telescopes

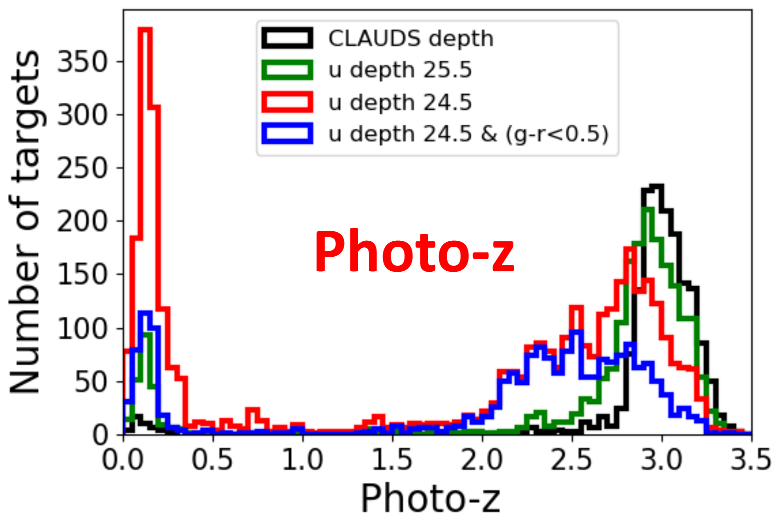
Additional slides

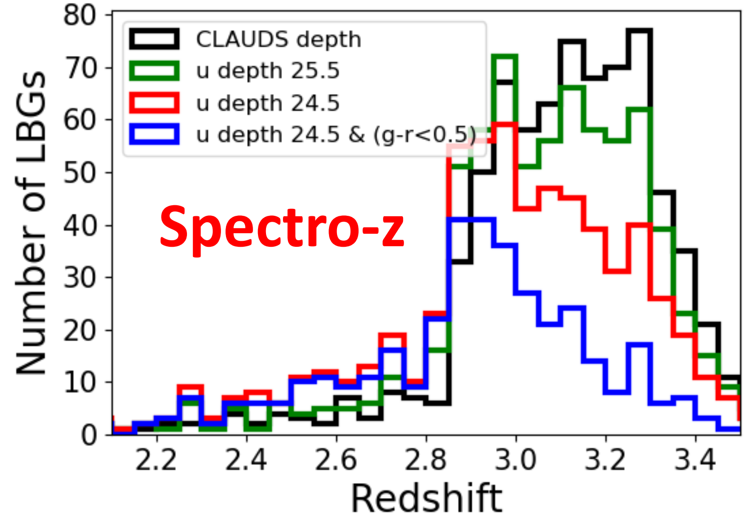
Optimization of color box



- Possibility to tune the n(z) bay applying different definition of the color box
- 'Black' box on the left figure, LBG with 2.5<z<3.5

Sensitivity to u-depth





– u-depth, LSST 1Y (UNIONS, u-CFIS) ~ 24.5
– u-depth, LSST 10Y ~ 26.0
– Even for a u-depth at 25.5, no effect on the selection