

High-redshift LBG selection for wide spectroscopic surveys

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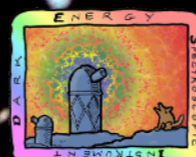
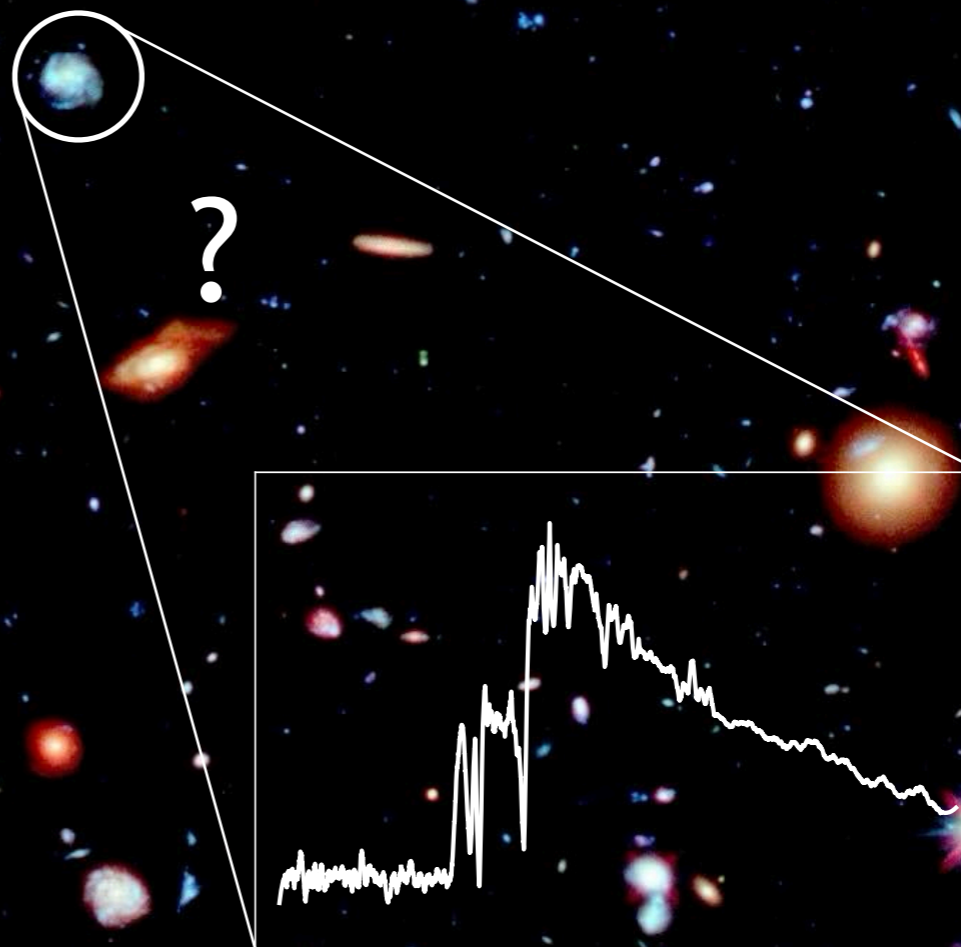
Collaborators:

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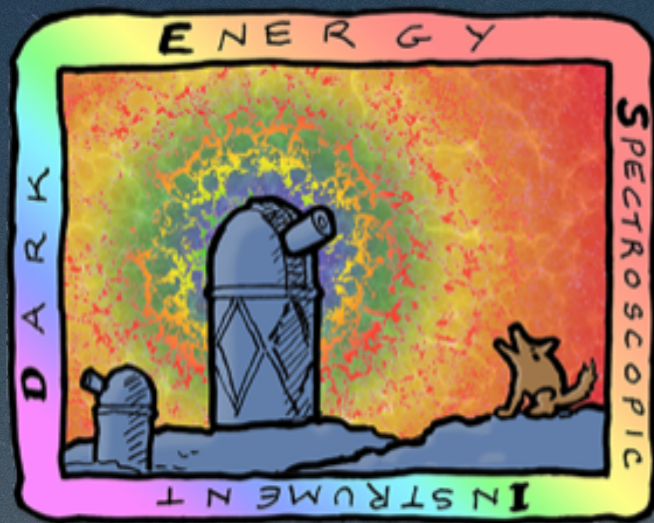
Vanina Ruhlmann–Kleider (Irfu)

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DARK ENERGY
SPECTROSCOPIC
INSTRUMENT

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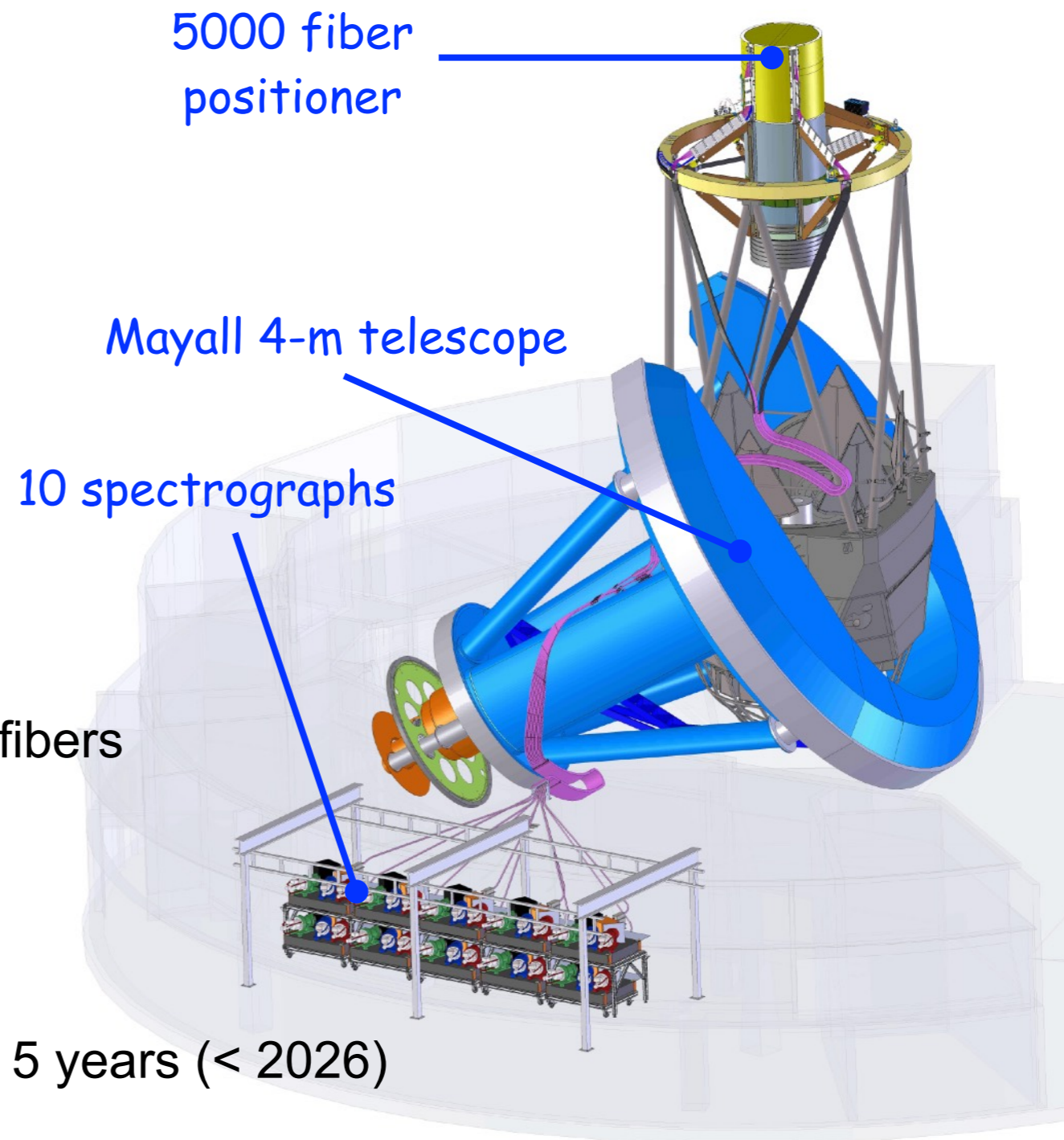
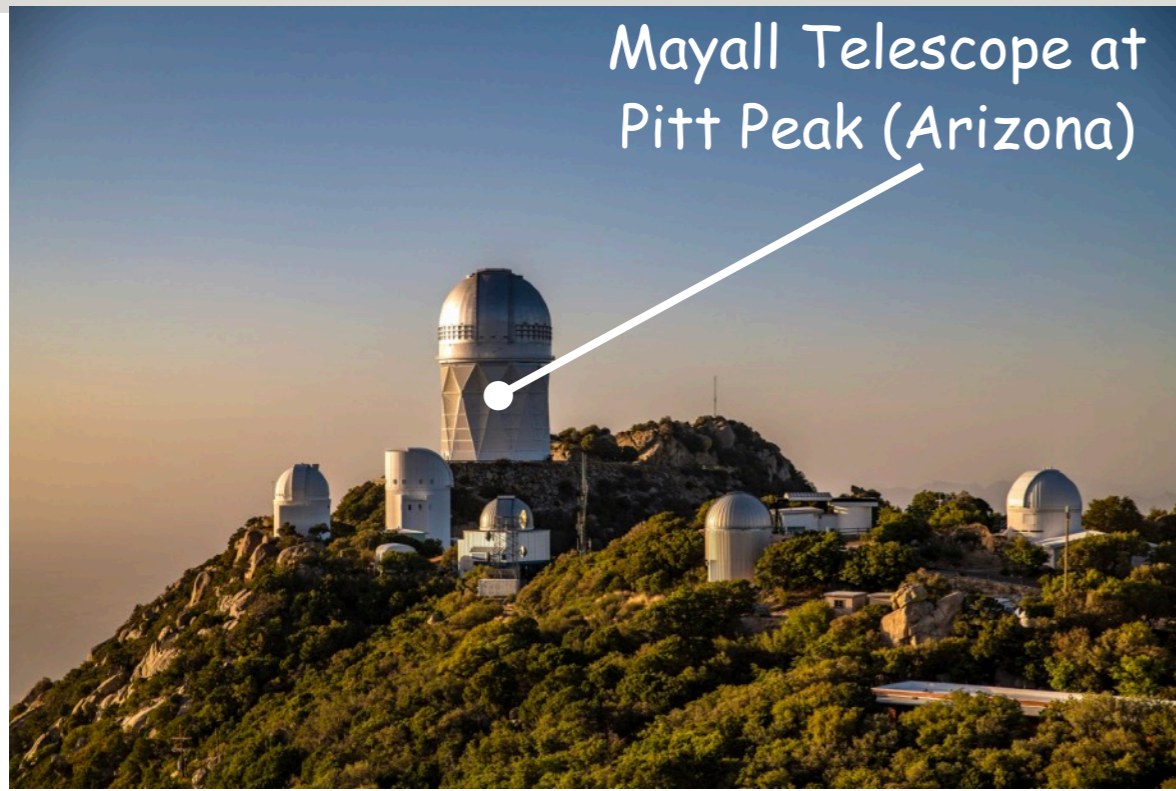


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The Dark Energy Spectroscopic Instrument

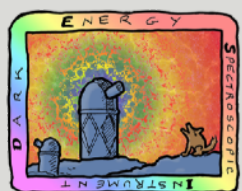


Instrument

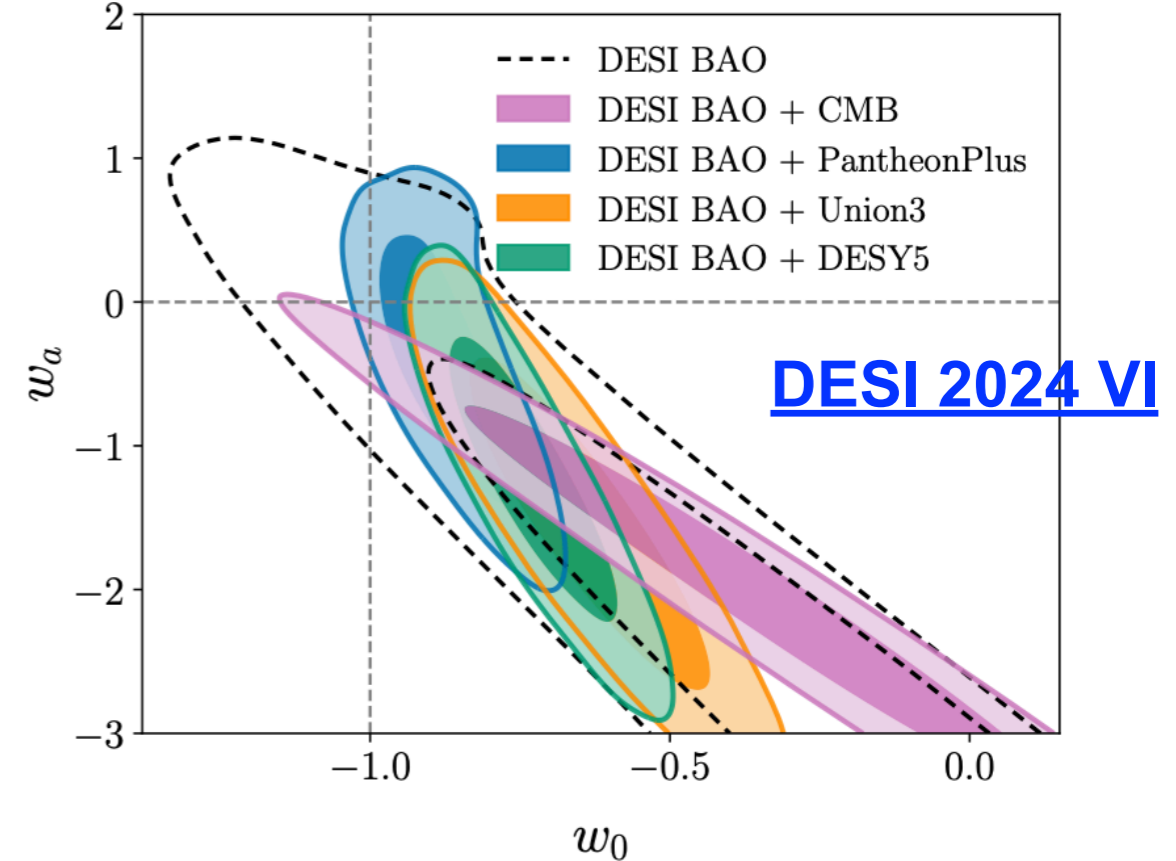
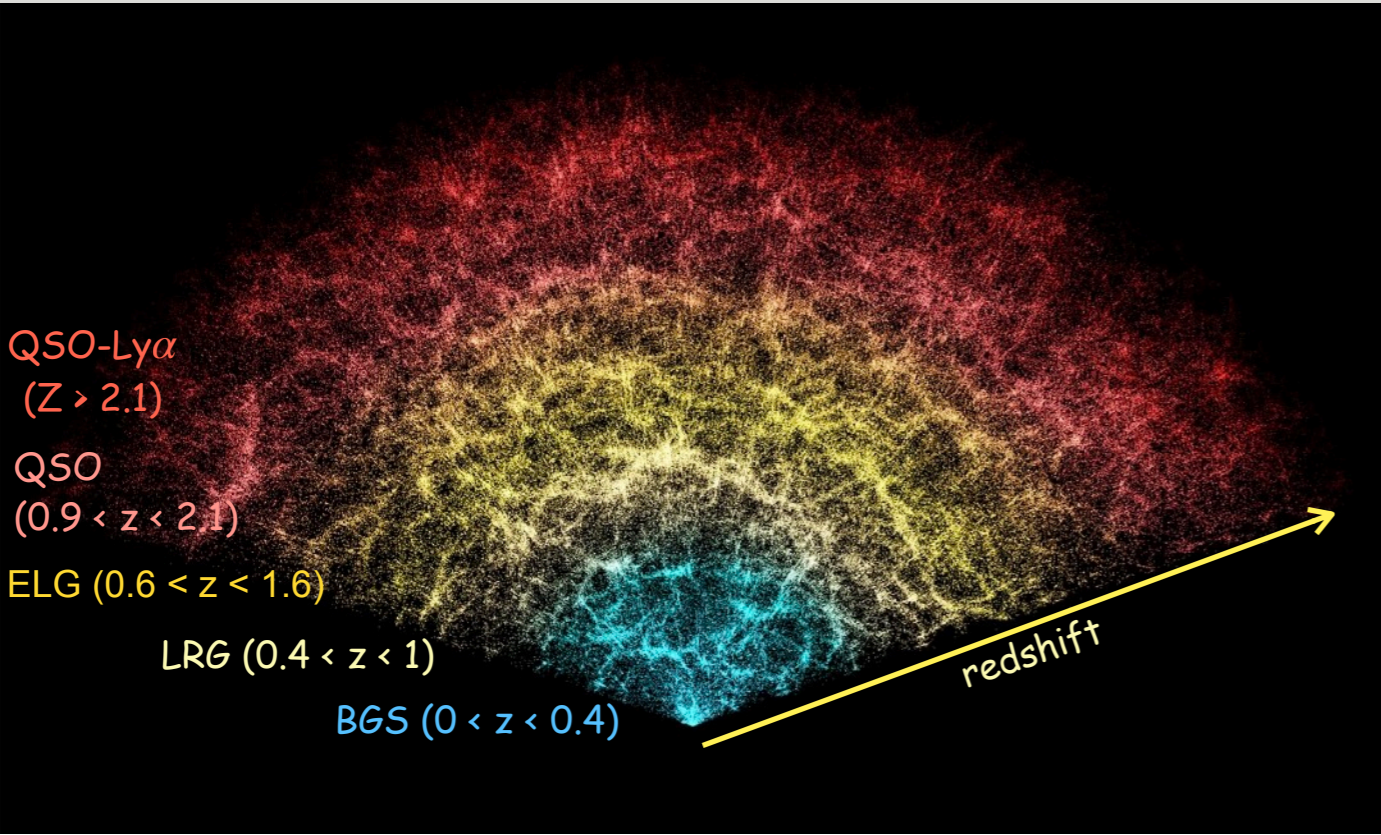
- Wide field of view (8 deg²)
- Automated robotic positioners with 5000 fibers
- Spectrograph from 320 to 1020 nm

DESI Science project

- 14,000 deg² survey
- **~40 million spectroscopic redshifts** in 5 years (< 2026)
- For different tracers for $0 < z < 4$
- International collaboration (650 members, 69 institutions, 46 non-US)



Cosmology with DESI and DESI-II

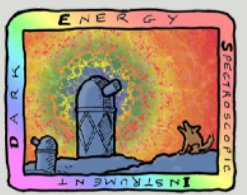


DESI-Y1 results in 2024 !

- **DESI 2024 VI:** From the measurement of the BAO peak
 - $z < 2.1$: clustering of tracers
 - $z > 2.1$: QSO-Ly α forest
- **DESI 2024 VII:** « full-shape » (+RSD)
- Evidence of time varying w_{DE}
- PNGs from LRGs+QSOs = $\sigma(f_{NL}) \sim 10$
 (**Chaussidon+2024**, yesterday on arXiv !)

DESI-II (> 2029): « High-z » cosmology

- Will focus on the high-z Universe ($2 < z < 4.5$)
 - Inflation: $\sigma(f_{NL}) \sim 1$ (distinguish single and multi-field inflationary models)
 - $\sigma(\text{Sum neutrino mass}) < 20 \text{ meV}$
 - DE fraction at 2% in the deep matter-dominated regime - Rule out Early DE models

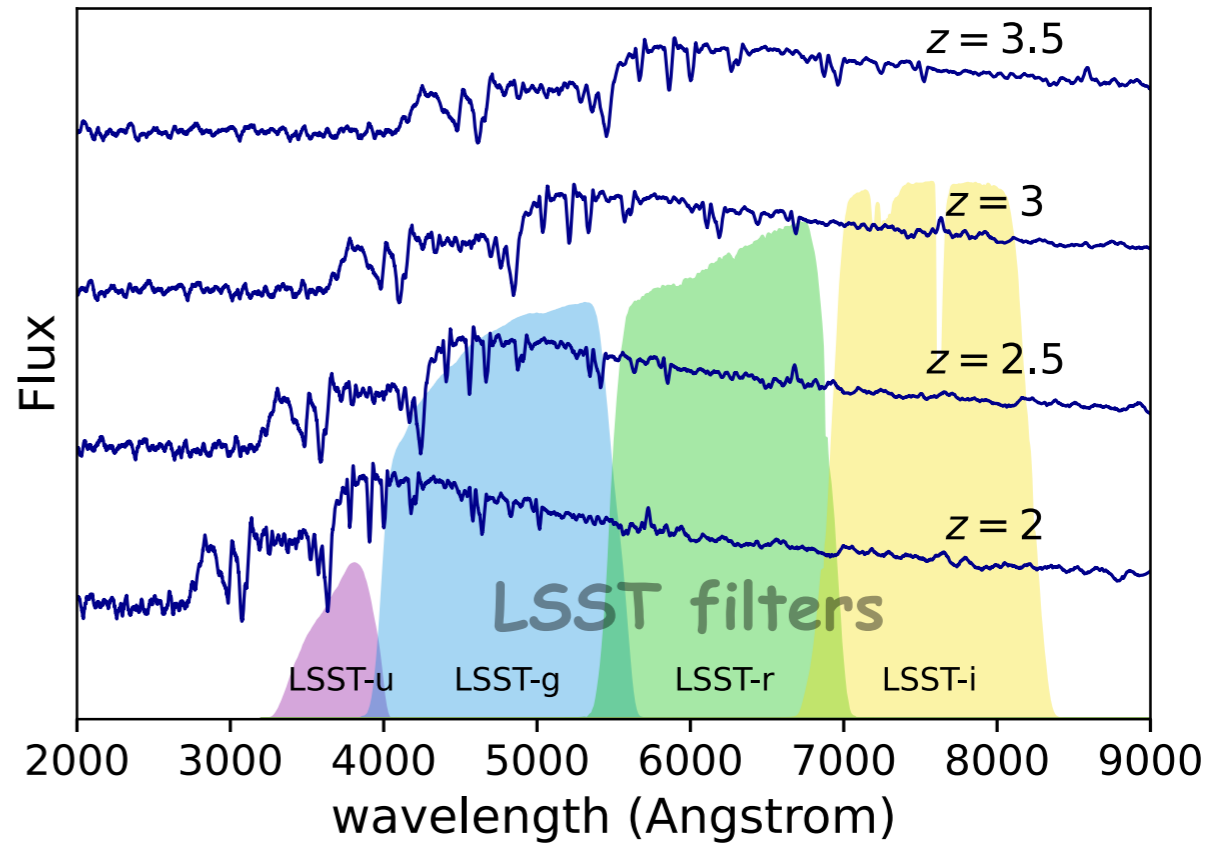
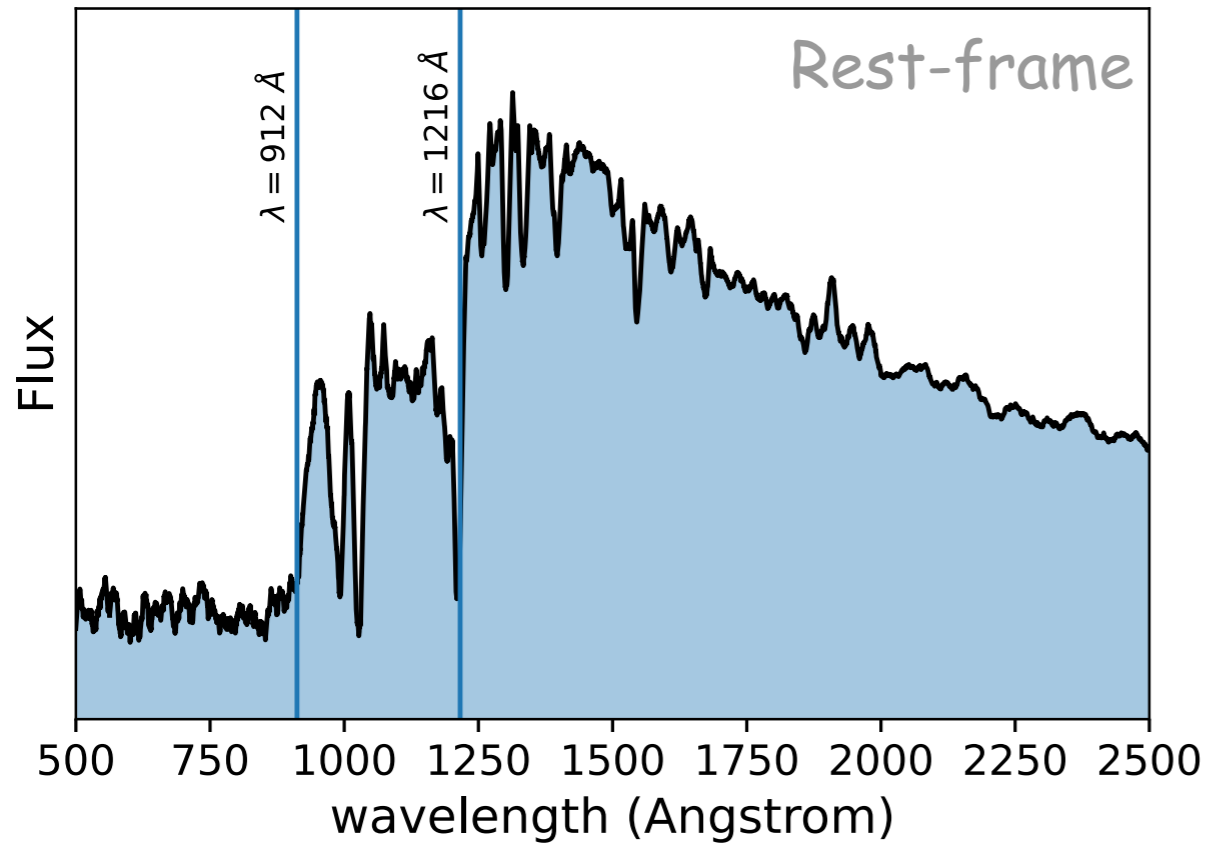


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Target selection for Lyman Break Galaxies



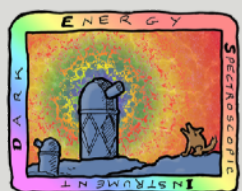
LBGs

- Are most of $z > 1.5$ star-forming galaxies
- Show distinct flux decrement
 - Below the Lyman limit (912 Å)
 - Below the Ly- α line (1216 Å)
 - Possible Ly- α emission

Why LBGs to study the $z > 2$ Universe ?

Target selection

- $z > 2.5$, Ly-Break(s) lie in optical range
- $2.5 \leq z_{\text{LBG}} \leq 3.5$ - lack of flux in the U-band
- **Target selection: u -dropout $u - g > 0$**
- Privileged tracers for $z > 2$! So far only explored by QSO-Ly α forests
- **Relies on high-quality U -imaging !**



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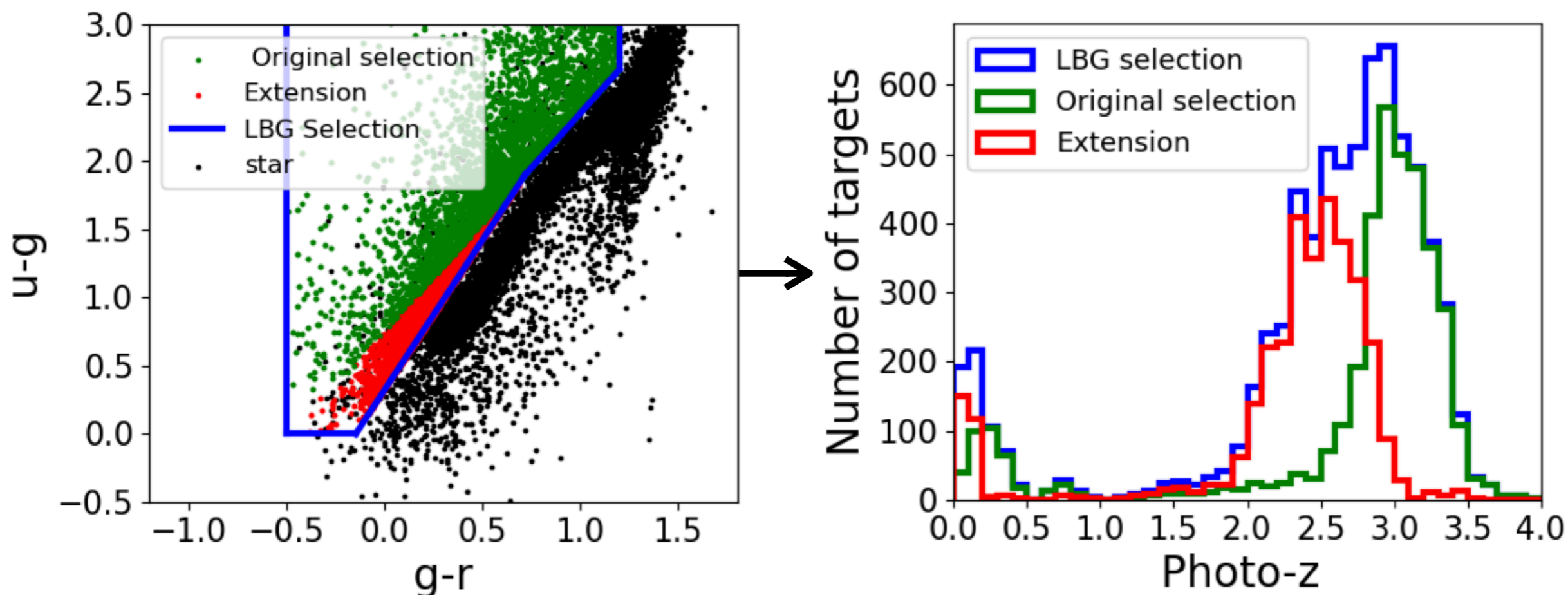
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Slide 5

LBG samples from deep imaging

CLAUDS+HSC: *Ruhmann-Kleider et al. arXiv:2404.03569*

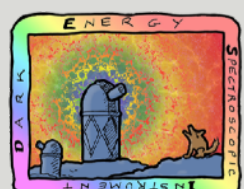


Target selection with deep imaging

- LBG selection on $\sim 4 \text{ deg}^2$ fields
- Using
 - CLAUDS (u-band, depth = 27.1)
 - HSC (grz, 27.4; 27.1; 26.3)
- **U-dropout + ugr cuts + cut in $r < 24.2$**

Results

- TS retained ~ 1100 targets per deg^2
- **620 LBGs per squ. degrees** after DESI spectro-z confirmation in $2.3 < z < 3.4$
- **So far, deep imaging data are available for 10-100 sq. degrees only**



LBG target selection for DESI-II

DESI Legacy Surveys

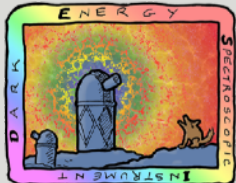
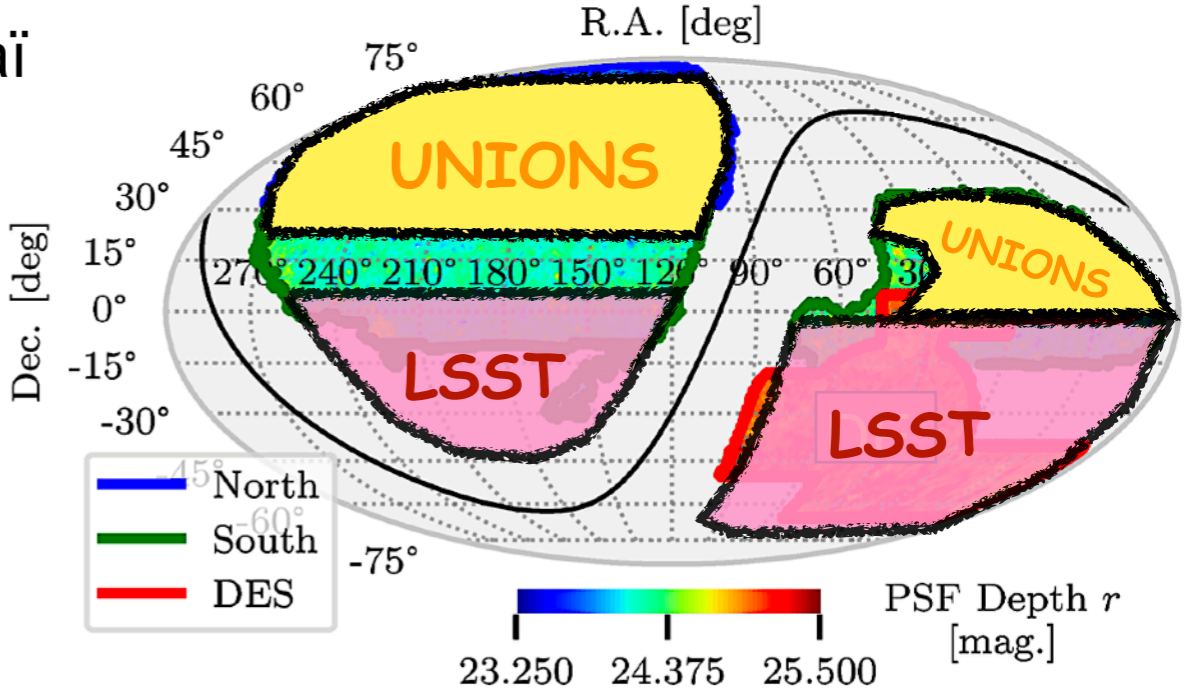
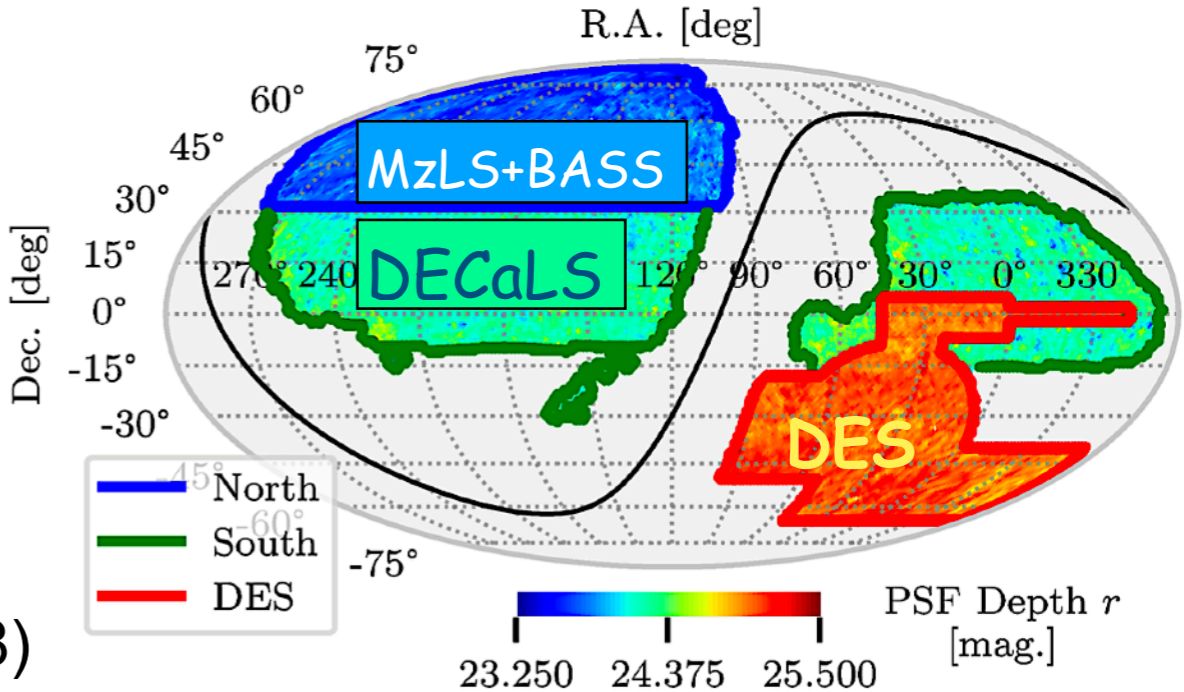
- Grz data: available with DES, DeCALS, MzLS+BASS
- **For LBGs: Missing *U*-band imaging !**

Wide (*U*-band + ...) photometric surveys

- **Rubin LSST (~soon !)**
 - Overlap with DESI in the South (DR1 > 2028)
- **UNIONS**
 - CFHT+Pan-STARR+Subaru (*ugriz*) in Hawaiï
 - 5,000 deg² compatible with DESI
 - Deepest wide survey until ~ LSST-Y1/2
 - *ugriz* depth = {24.6; 25.5; 25.5; 24.2; 24.4}
- More challenging target selection at shallower depth !

→ *Payerne et al. arXiv:2410.08062*

DESI Legacy Imaging Surveys



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Random Forest approach

Beyond u -dropout

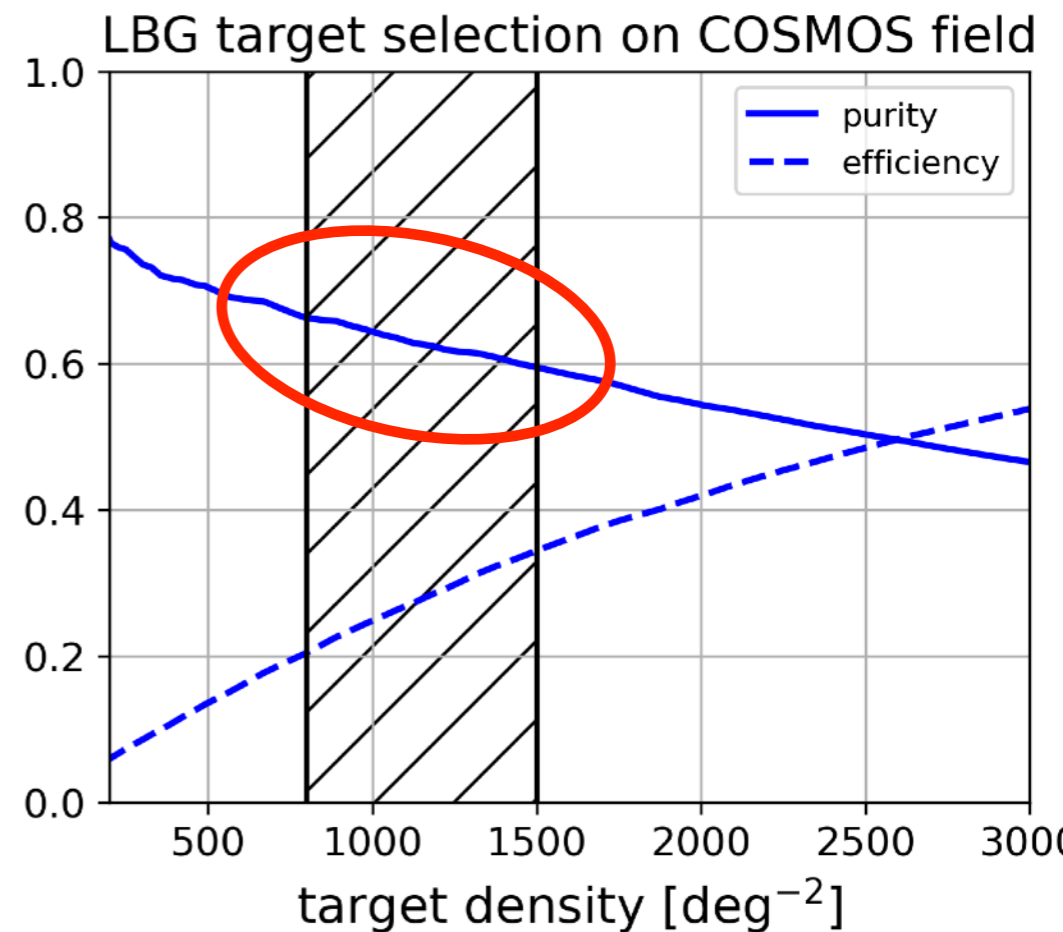
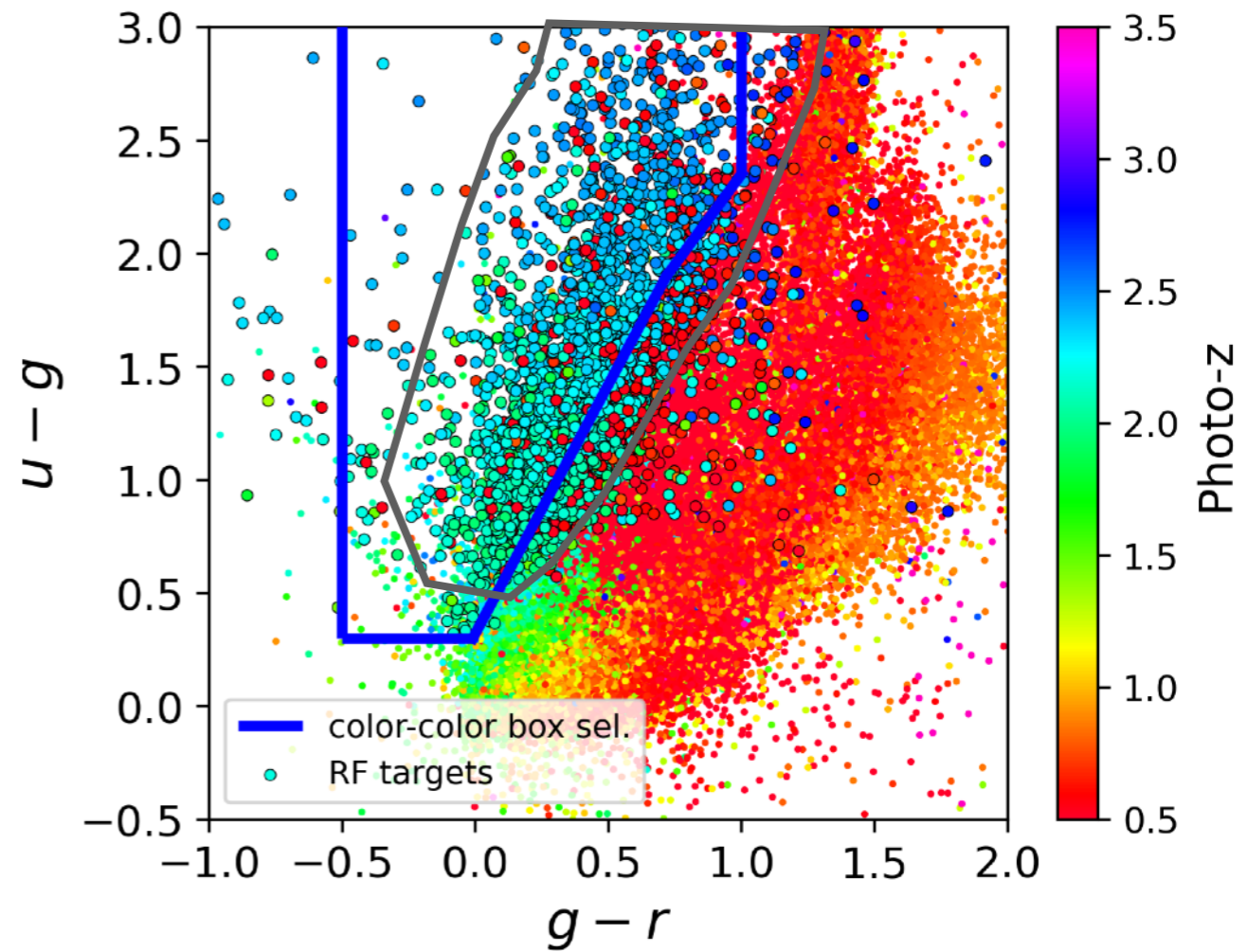
- We can use Random Forest for classification $z \in [2.5, 3.5]$ (i.e. « LBGs »)
- Learn best splitting conditions (decision tree)
- **Improve U -dropout by 10-15% (tested on CLAUDS)**

In practice

- **UNIONS data not available at this time !**
- Degrade CLAUDS to UNIONS depth
- Classification: we use LePhare photoz's on COSMOS
- RF Features: 5 colors $\{u, g, r, i, z\} \rightarrow p_i$
- After RF, « quality threshold » cut:
 - Targets for DESI = $\{p_i > P_{\text{lim}}\}$
 - Target density $\sim 800 - 1500 \text{ deg}^{-2}$

Results

- **Purity stable between 70% and 60%**
- **For $n_{\text{target}} = 1,100 \text{ per deg}^2$**
 - $n_{\text{RF}}(2.5 < z < 3.5) = 683 \text{ per deg}^2$
 - $\langle z \rangle_{\text{RF}} = 2.85$



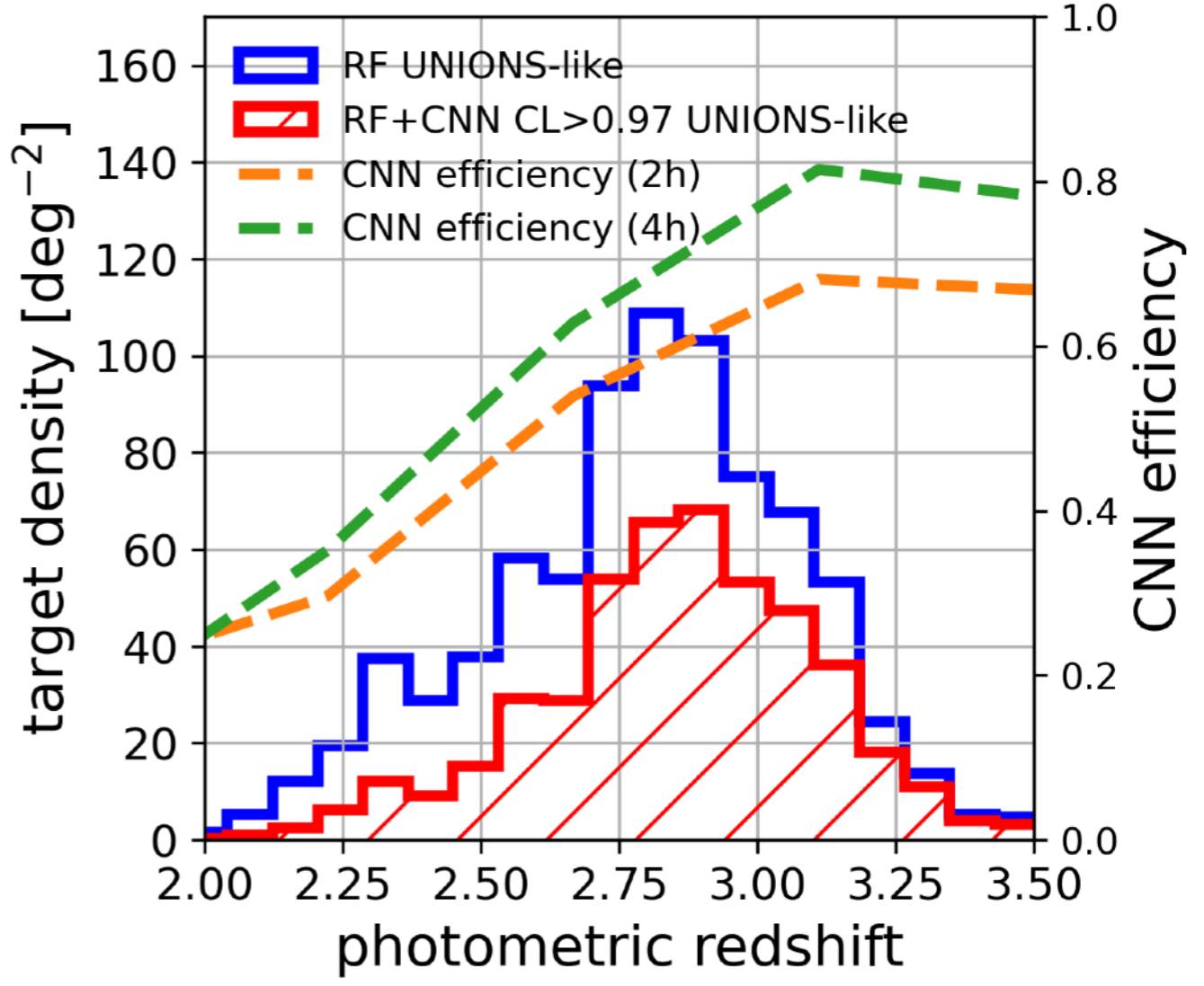
Spectroscopic efficiency

Spectroscopic redshift efficiency

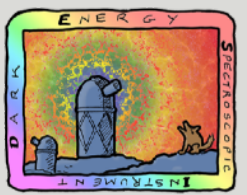
- i.e. our ability to recover LBG redshifts
- Spec-z determined with CNN + template fitting
 - Calibrated from DESI obs. in 2021 (CLAUDS+HSC TS)
 - Efficiency is 20% at $z=2$, and 80% at $z=3.5$
 - $\sim 10\%$ improvement from 2 to 4h of exposure time

For $n_{\text{target}} = 1,100$ per deg^2

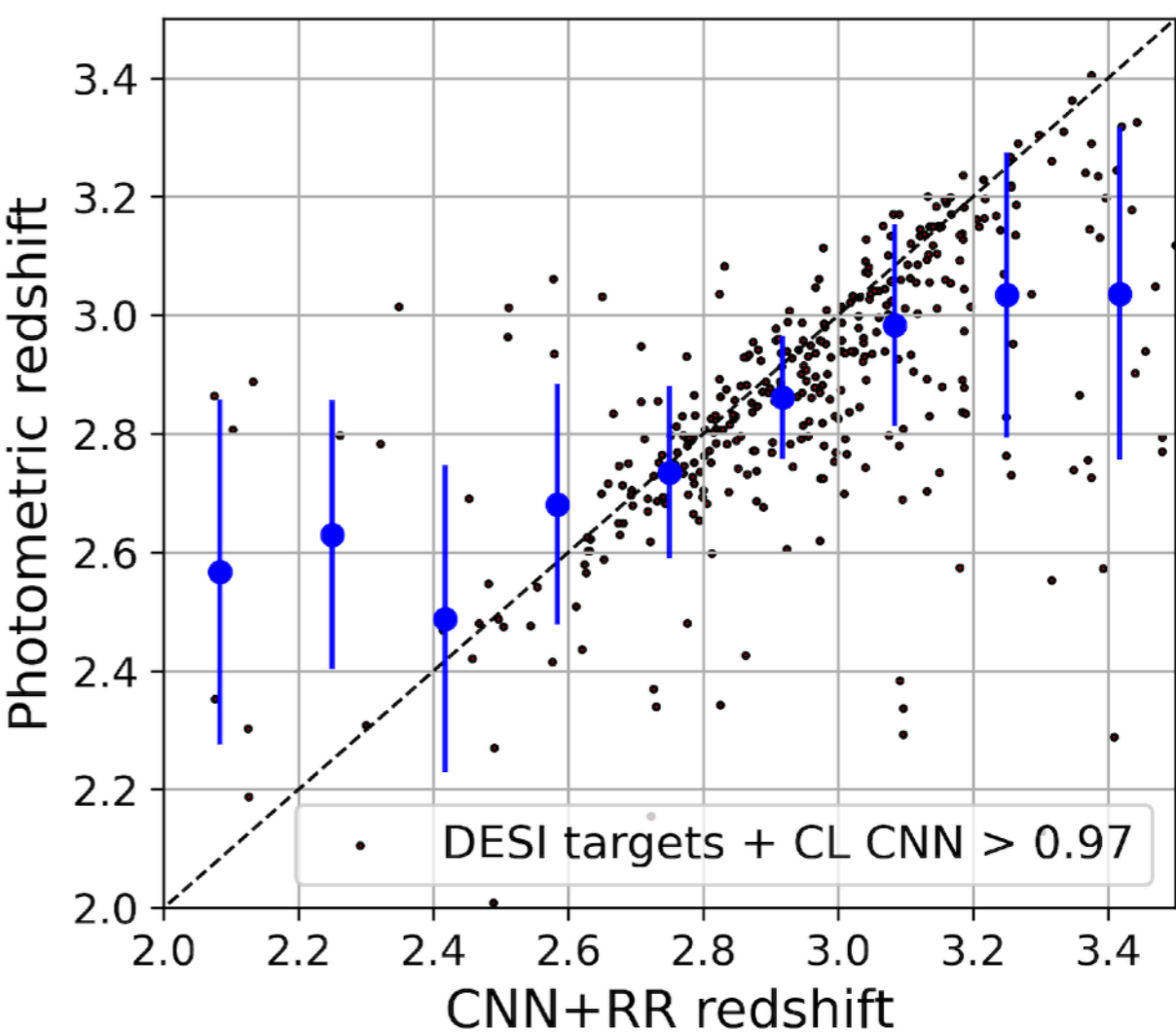
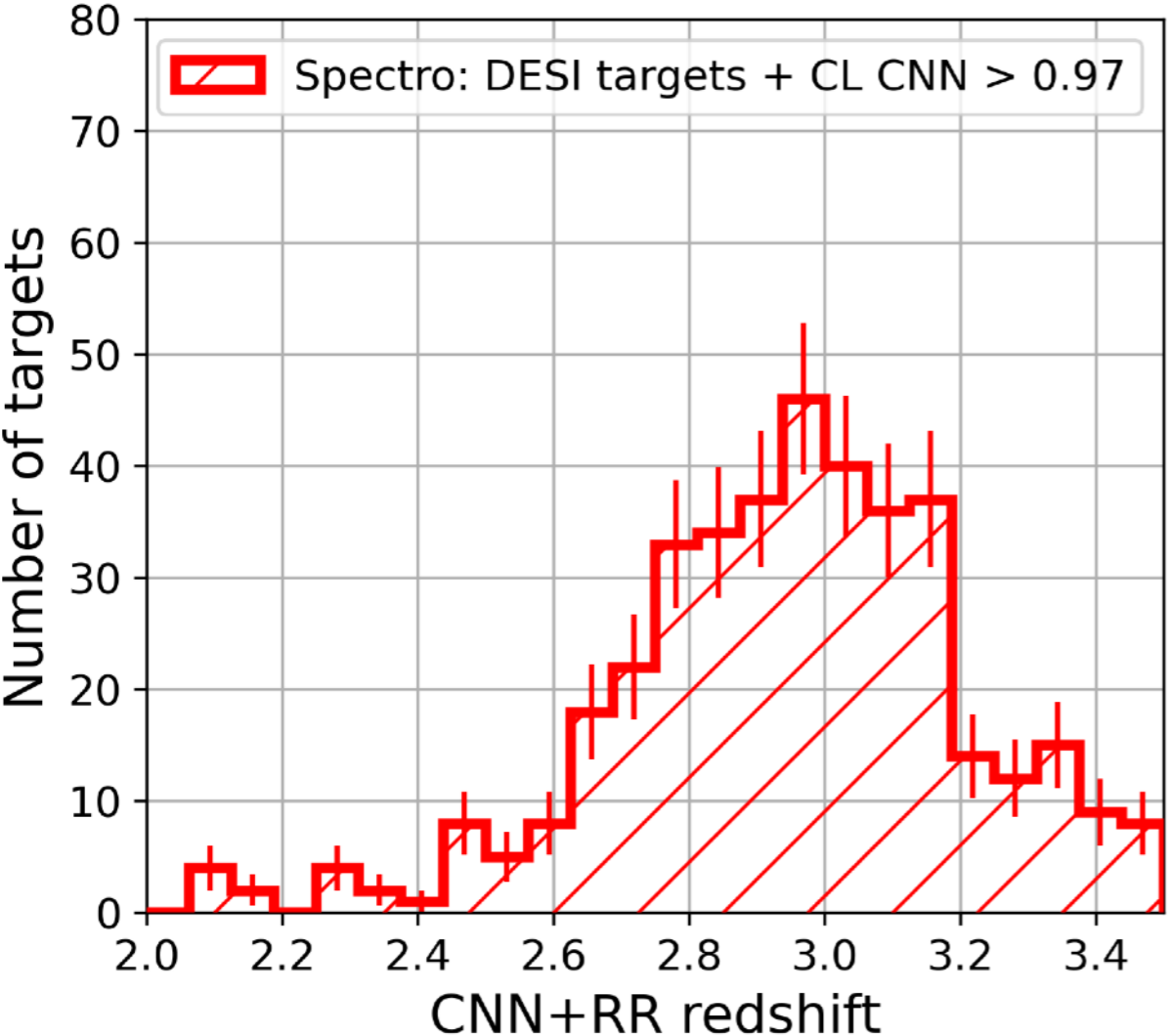
- $n_{\text{RF}}(2.5 < z < 3.5) \sim 680$ per deg^2
- $\langle z \rangle_{\text{RF}} = 2.85$
- $n_{\text{spec}}(z > 2) \sim 430$ per deg^2
- $\langle z | z > 2 \rangle_{\text{spec}} = 2.83$



← 45% - For LBG science with DESI !

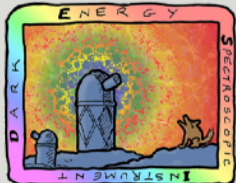


DESI observations on COSMOS in 2024 !



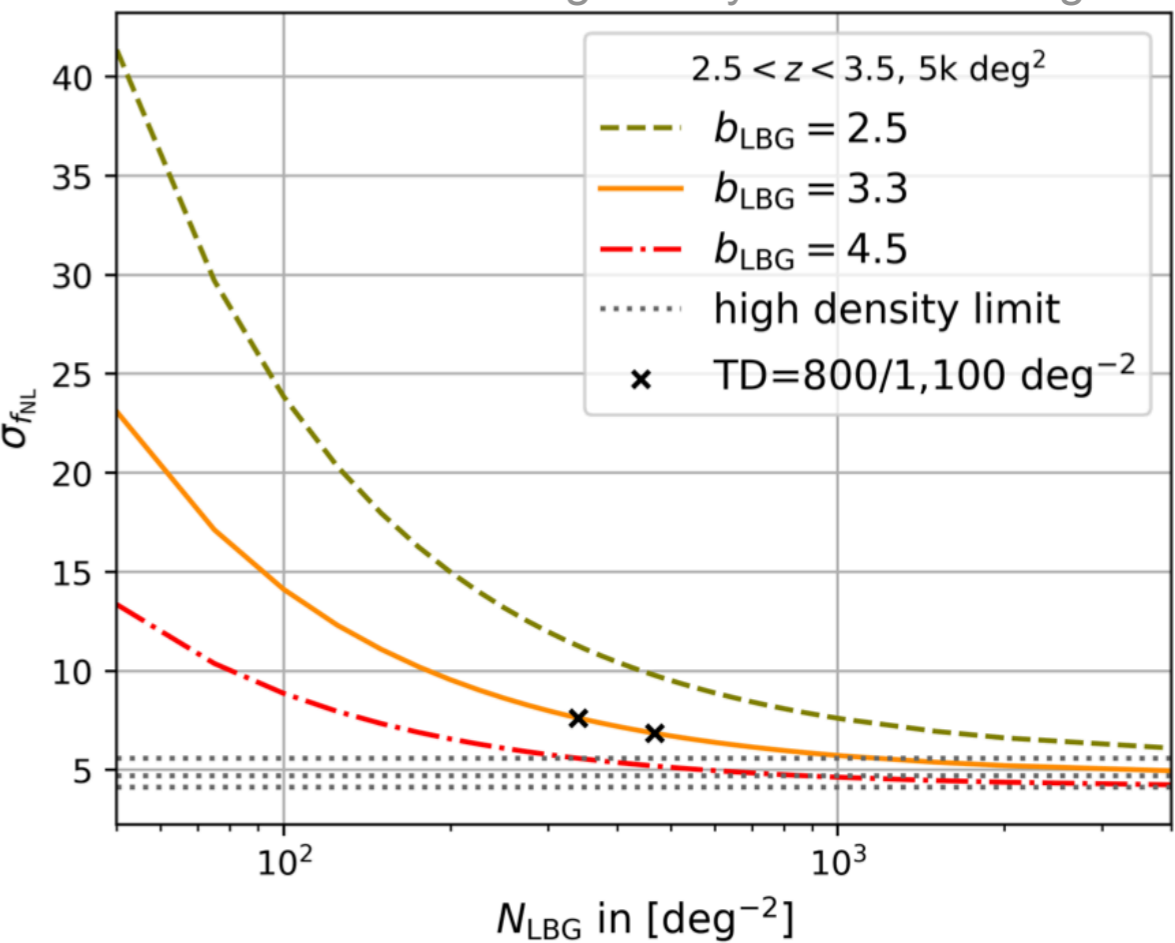
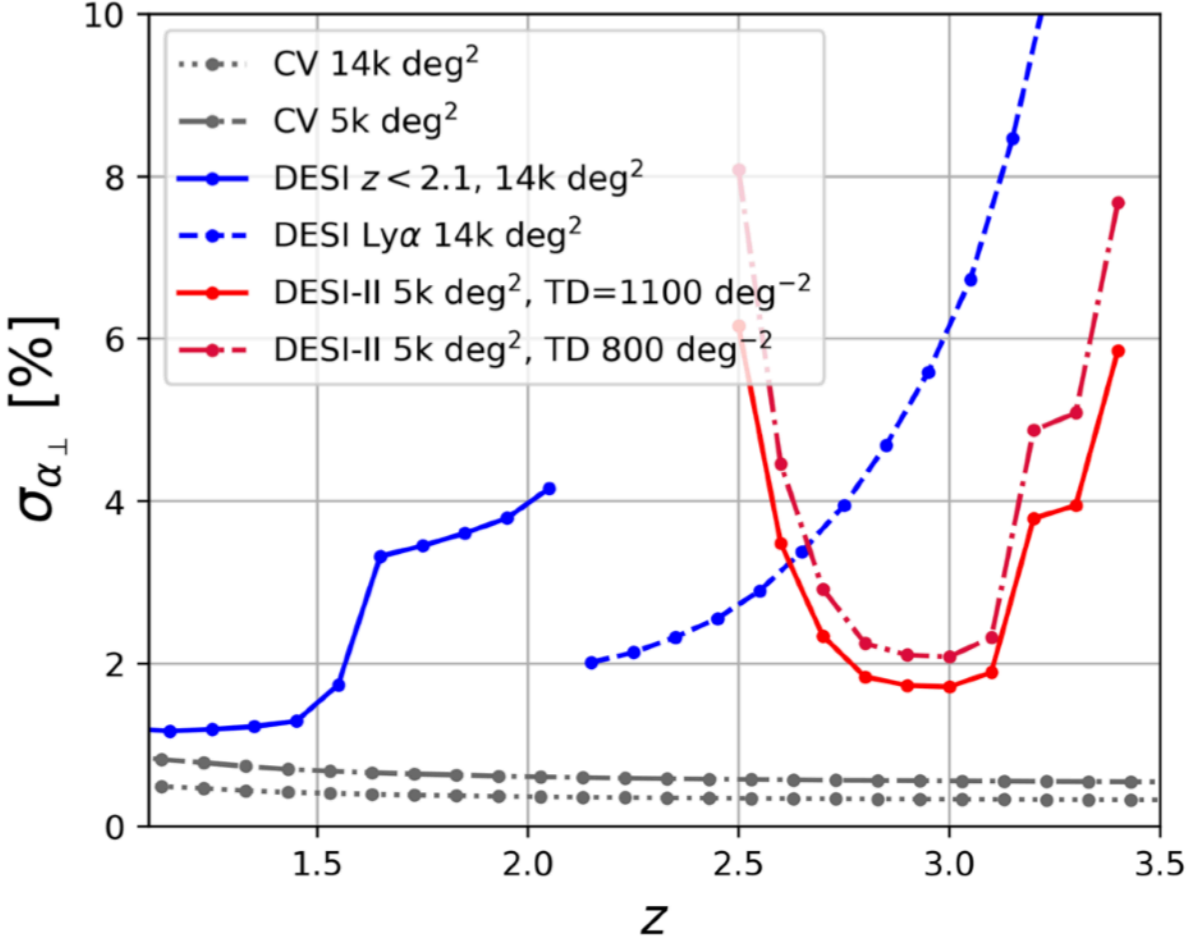
DESI observations in 2024

- TS provided with a purity = 0.6 (similar to $1,100 \text{ deg}^{-2}$)
- DESI observed 1000 targets
- **420 LBG with secure spec-z**
- Compatible with forecasts (approx 40%: spectro-z efficiency)
- $\langle z_{\text{spec}} \rangle = 3.0 \pm 0.3$



Forecasts

Figures by William d'Assignies

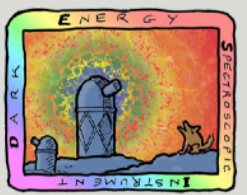


Forecasts (FishLSS)

- Redshift-space power spectrum
- Bias $b_{\text{LBG}}=3.3$
- DESI-II footprint=5,000 deg^2
- Redshift bin = 0.1
- Comparison with DESI main (blue)

Results

- $\sim 0.7\%$ precision for α_{\perp} and α_{\parallel} in $2.6 < z < 3$
 - $\rightarrow 2\%$ precision on $z > 2$ DE fraction
- ## Primordial Universe
- Through the large-scale dependent bias
 - $\sigma_{f_{\text{NL}}} \approx 7$ (CMB: $f_{\text{NL}} = 0.9 \pm 5.1$)



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Summary

Lyman Break Galaxies

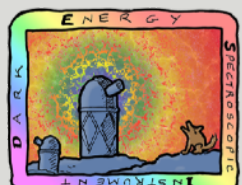
- Are promising tracers to study the high- z Universe ($z > 2$)
- U -imaging is crucial to detect LBGs
 - **Deep imaging CLAUDS+HSC:** *Ruhmann-Kleider et al. [arXiv:2404.03569](https://arxiv.org/abs/2404.03569)*
 - U -dropout **620 LBG/deg²** after DESI spectro- z confirmation in $2.3 < z < 3.4$

Target selection of LBGs for DESI-II

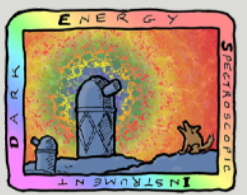
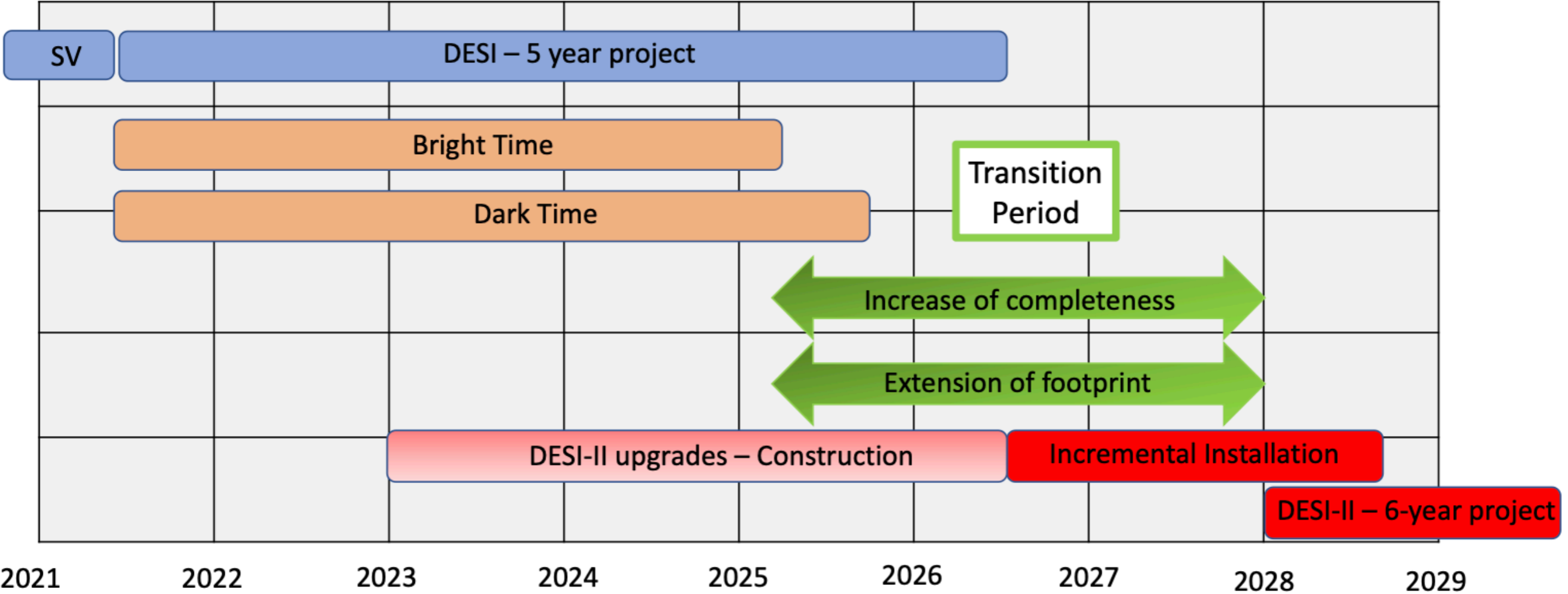
- **Wide U -band (LSST; South, UNIONS; North)** are essential for Stage-V spectro. surveys
- UNIONS-like: *Payerne et al. [arXiv:2410.08062](https://arxiv.org/abs/2410.08062)*
 - Degraded photometry to UNIONS depths
 - RF: **430 LBG/deg² for $z > 2$** with secure spectro. redshifts
 - Confirmed with DESI dedicated observations on COSMOS
- LSST-like (simple rescaling of LSST-Y10 depths)
 - LSST-Y1: **470 LBG/deg² for $z > 2$** with secure spectro. redshifts
 - LSST-Y5: **660 LBG/deg² for $z > 2$** with secure spectro. redshifts

Forecasts on cosmology with DESI-II (UNIONS-based TS)

- Strong constraining power at $z \sim 2.8 - 3$
- Competitive constraints on A. P. parameters wrt to $\text{Ly}\alpha$ (same z range), and on f_{NL}
- **LSST focus: Calibration of photo z methods with high- z samples**
- **LSST focus: $n(z)$ for LBG magnification - high- z Cluster mass calibration !**



DESI timeline



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Neutrinos in cosmology

