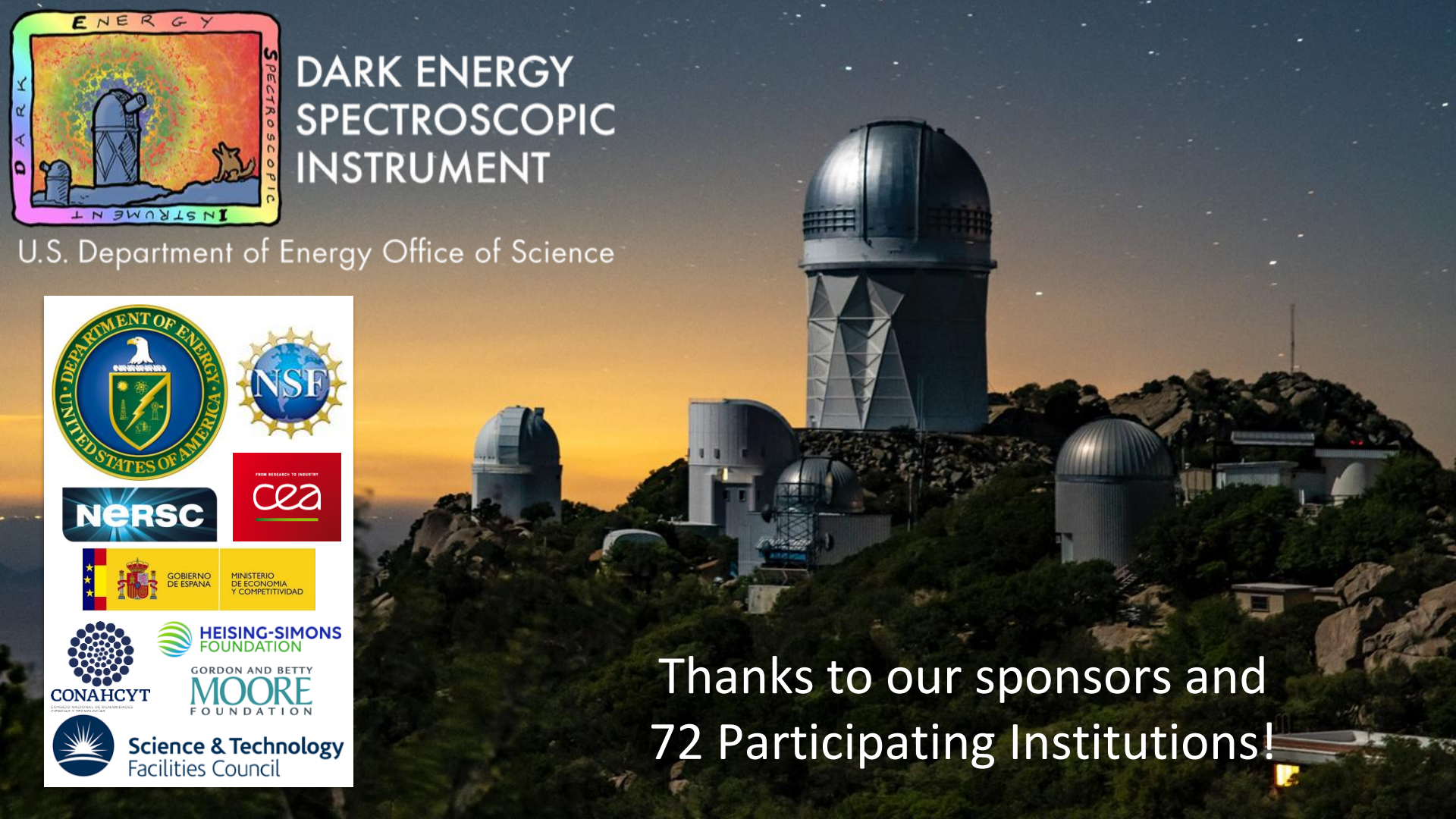
DESI and DESI Run 2

Kyle Dawson (University of Utah)

On behalf of the DESI collaboration


DARK ENERGY SPECTROSCOPIC INSTRUMENT
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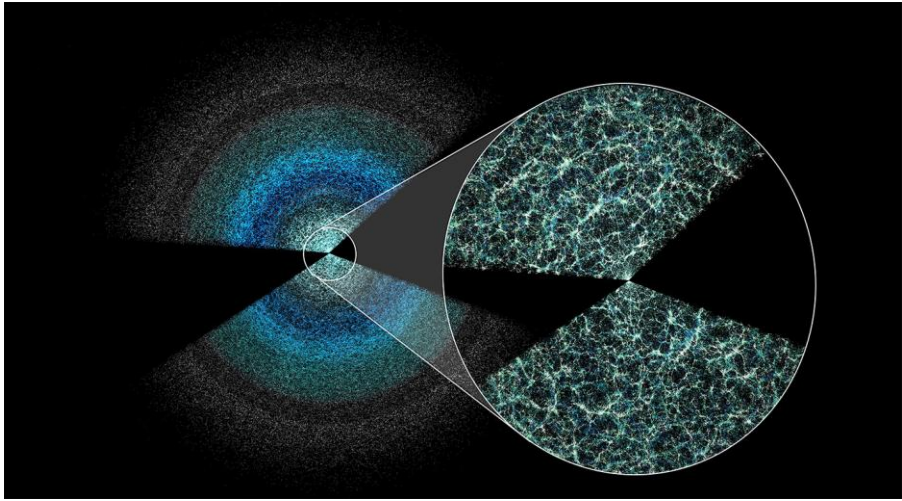
Dark Energy Spectroscopic Instrument

- **Located at 4-meter Mayall Telescope in Arizona**
  - Now dedicated to DESI
- **First Stage-IV Dark Energy Experiment**
  - Optimized for baryon acoustic oscillation (BAO) measurements
- **BAO Measurements and Forecasts**
  - Year-1 Cosmology: top HEP citation in 2024
  - Year-3 BAO: Results released within 1 year
  - Year-3 Cosmology: top HEP citation in 2025
  - Year-5 BAO: results expected in 2027
  - Final sample: 73% more tracers than in 2016 plan
  - Nearly optimized for z<1 BAO precision from telescope in northern hemisphere



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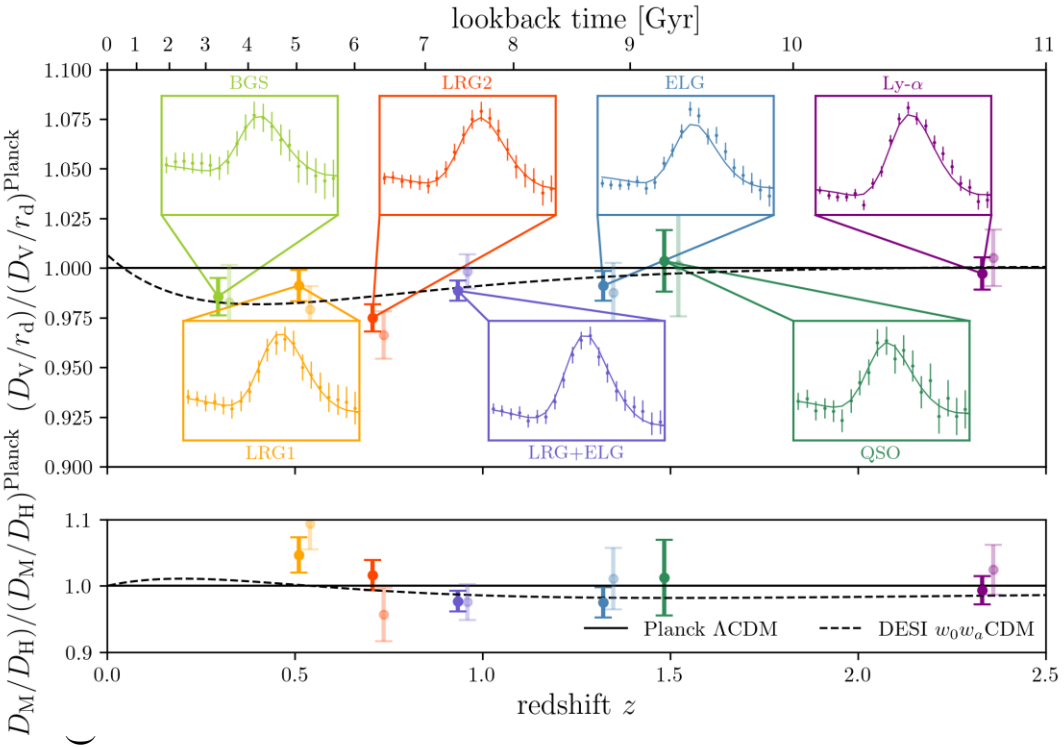
Precise Measurements of Expansion History



BAO data: $\Delta\theta$ and Δz ⟶ D_M / r_d and D_H / r_d

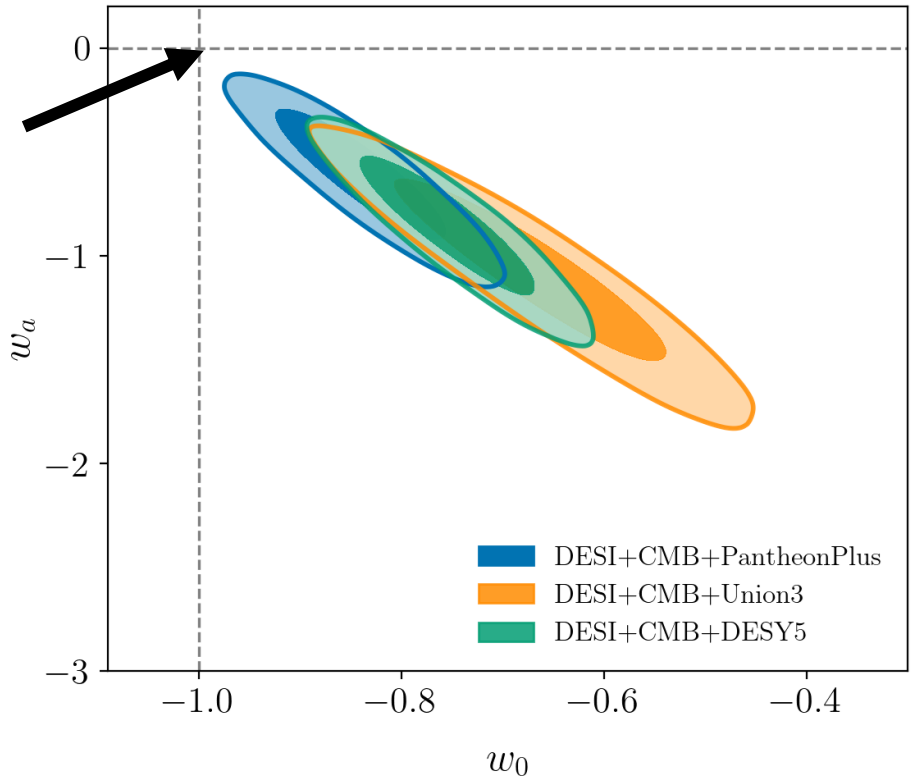
$$D_V = \left(zD_M(z)^2 D_H(z)\right)^{1/3}$$

- **Two Measurements of Distance/redshift relation**
  - Internally consistent
  - Dominated by statistical uncertainties
- **Cosmology implications**
  - Highest precision probe of cosmic expansion over 0.5<z<2.5

Aggregate precision on BAO distance scale: 0.3%

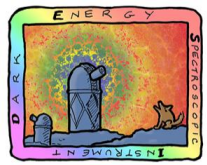
Beyond ΛCDM: Time-evolving Dark Energy

Cosmological constant
(ΛCDM)



Stress on the standard cosmological model **3.2σ - 3.4σ** when combined with CMB and Type Ia supernovae

Confirmation of a time evolution of Dark Energy would be a paradigm shift from the standard model



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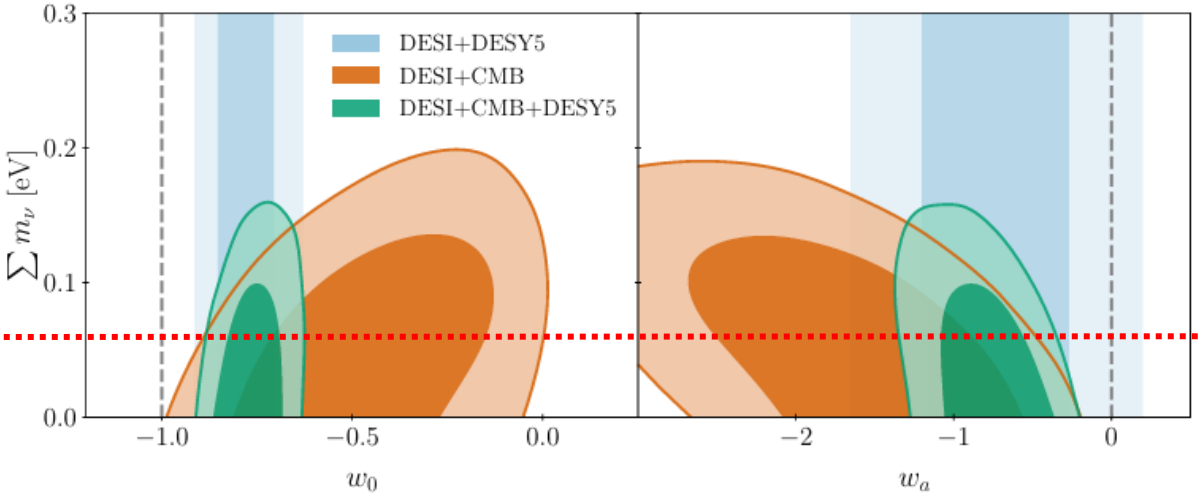
DESI Measures Sum of the Neutrino Masses

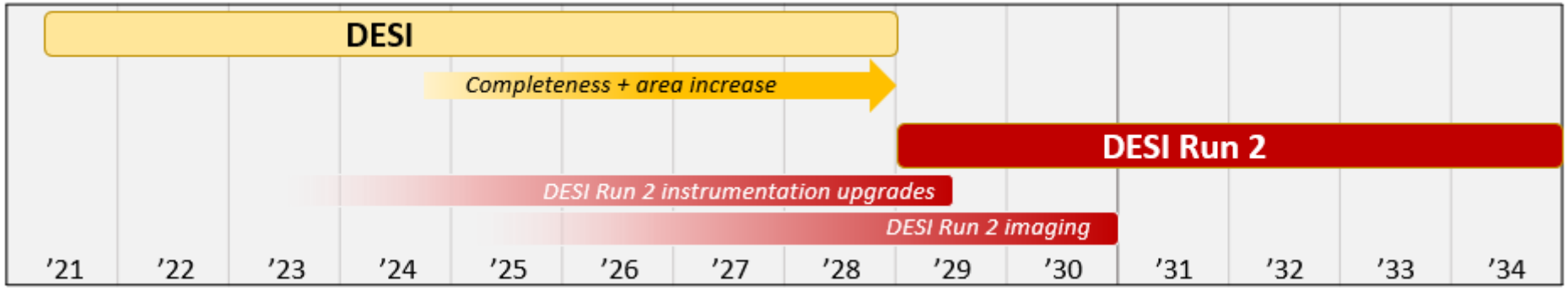
Minimum allowed from oscillations (0.059 eV) Esteban et al, 2024



ΛCDM → $\sum m_\nu < 0.077\,\mathrm{eV}$ (95%, DESI+CMB[L-H])

With time-evolving dark energy → $\sum m_\nu < 0.129\,\mathrm{eV}$ (95%, w_0w_aCDM: DESI+CMB+DESY5)

DESI Operations Plan Extends to 2035



- **Push program boundaries**
  - Extended cosmology constraints
  - Critical synergies with LSST
- **Continue operations at Kitt Peak observatory**
  - Focused instrumentation upgrades
  - Targets from new imaging surveys

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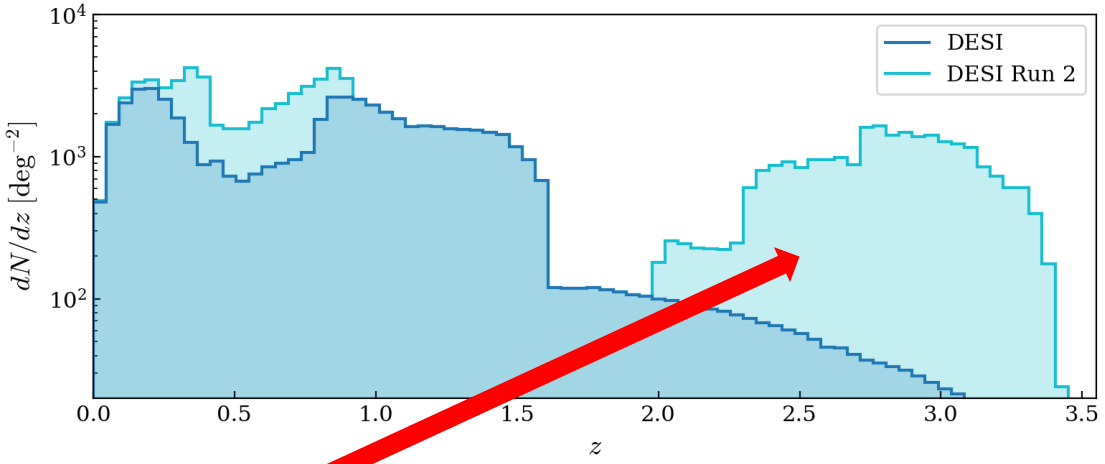
DESI Run 2: a 4-Fold Program



- **High-z Dark Energy Survey**
  - Enhanced BAO at 2<z<3.5
  - Primary focus of Run 2

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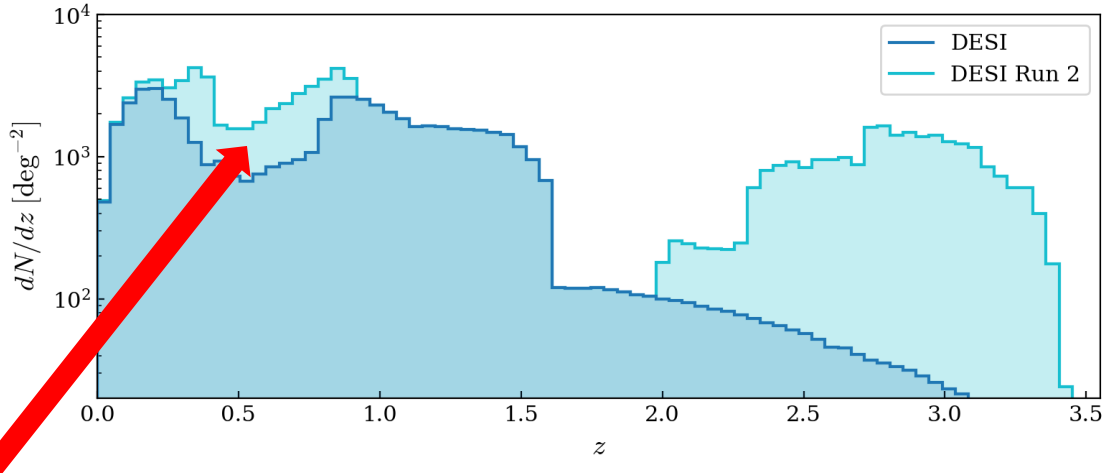

- **High-z Dark Energy Survey**
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- **Cosmic Growth Survey**
  - Enhanced growth measurements at z<1
  - Complementary to Run 1

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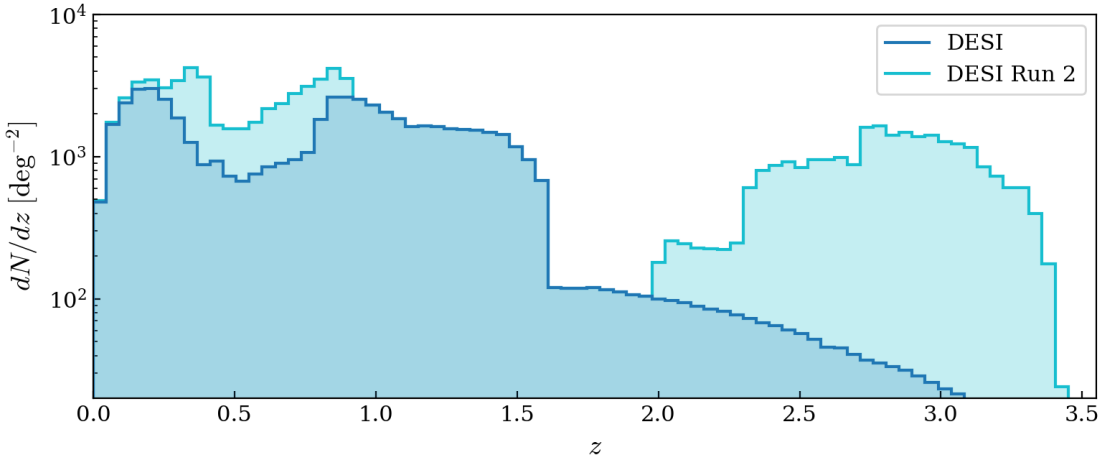

- **High-z Dark Energy Survey**
  - Enhanced BAO at 2<z<3.5
  - Primary focus of Run 2
- **Cosmic Growth Survey**
  - Enhanced growth measurements at z<1
  - Complementary to Run 1
- **Dark Matter Survey**
  - Stellar spectroscopy
  - Dark matter at dwarf galaxy scales
- **DESI/Rubin Synergies**
  - Classification of Type Ia Supernovae
  - Models for weak lensing

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High-z Dark Energy Survey

- **Dark energy**

  Driver for science requirements and survey design

  ⟹ independent, sub-percent precision, BAO measurement

  x2 improvement on s (BAO) over DESI at z>2

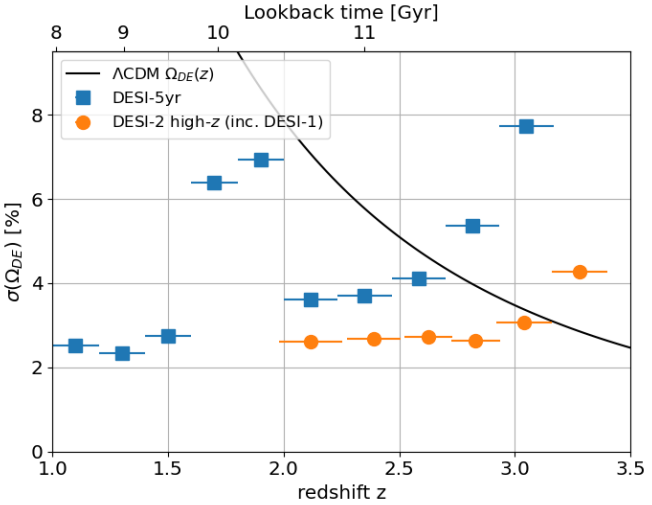
- **Inflation**

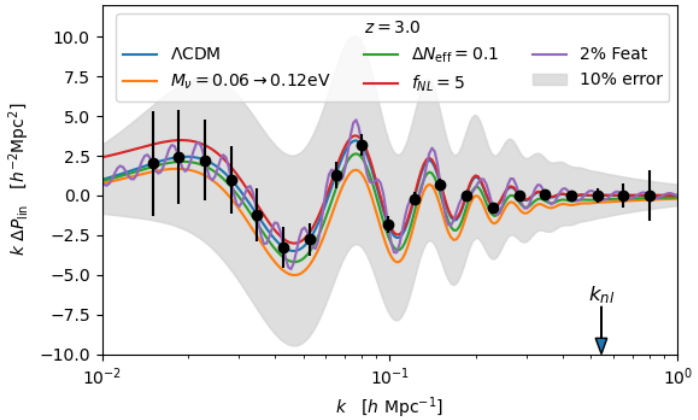
  ⟹ non-Gaussianity and primordial features

- **Neutrino masses**

  $s(Sm_n)$ = 20 meV ⟶ at least a 3s measurement

Targets: Ly-break galaxies, Ly-a emitters, Ly-a forest





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Cosmic Growth Survey (z<1)

- **Structure growth**

  Precise measurement of structure growth

  $\Longrightarrow$ x3 improvement over DESI

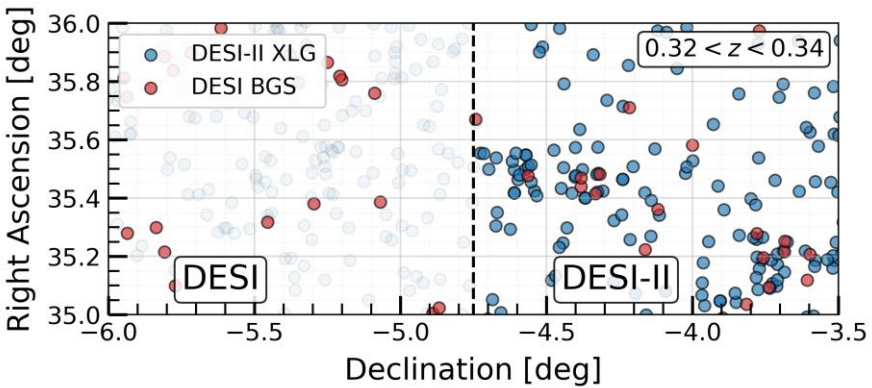
- **Advanced modeling & inference with AI/ML**

  up to 40% improvement on BAO reconstruction

- **Dark energy**

  Independent BAO measurement at low z (largest difference LCDM vs. w_0w_aCDM)

Targets: Extreme emission-line galaxies (z<0.9)



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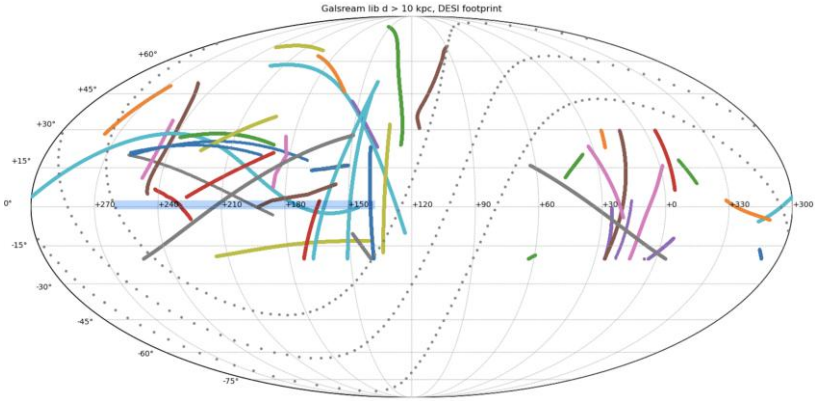
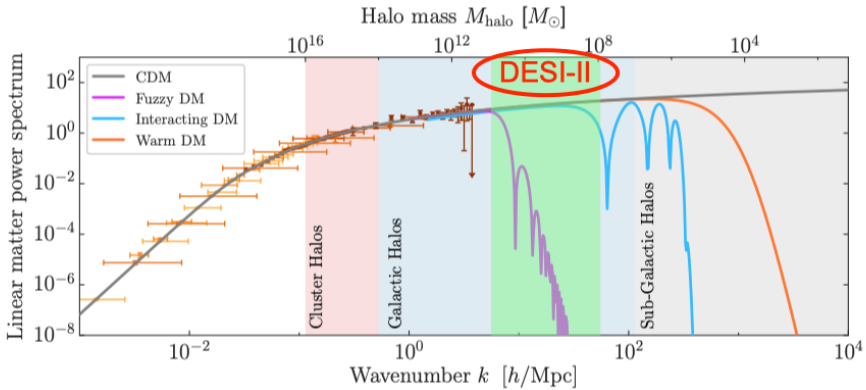
Dark Matter Survey



- **Dark matter properties & alternative models**
  - sensitive to $m_{WDM} > 7$ keV ($M_{sub\ halo} = 10^8\ M_\odot$)
  - velocity profiles CDM vs. alternative DM

Targets: Spectroscopic observations of local universe

- Stellar streams in Milky Way
- Milky Way satellites
- Extragalactic dwarf galaxies



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Combining DESI and Rubin

DESI: More efficient than 10m Keck+DEIMOS
Will leverage Rubin imaging for target selection

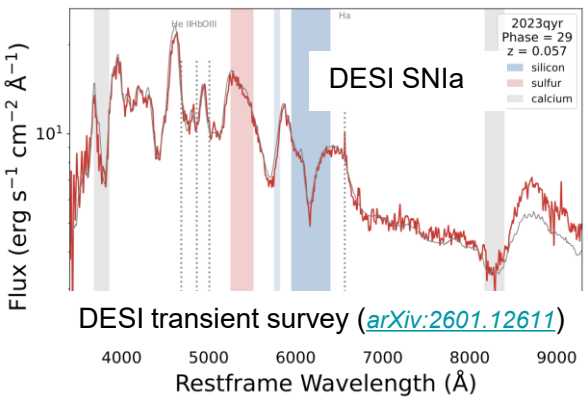
Rubin: Will leverage DESI spectroscopy

- **Supernova cosmology**
  Spectra of live SNIa, SNIa hosts, other transients

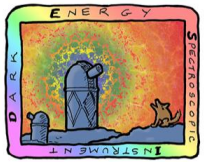
- **Weak lensing**
  Photo-z calibration for LSST
  Faint sources: up to 80-hr spectroscopic stacks
  Galaxy-lensing cross-correlation on dedicated sample: $s(S_8) \sim 1\%$

Note: special programs in deep drilling fields have already led to public release of >200k redshifts (Ratacjzak et al. 2026)

Proposed Rubin-DESI data exchange agreement in the works



DESI transient survey (arXiv:2601.12611)



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Summary

DESI: Exceeding original survey design

Efficient release of BAO results

~3σ tension with ΛCDM with DESI, CMB, and SNe

350 PhD students

278 refereed papers; 22k citations

DESI Run 2: already demonstrated with pilot surveys

New dark energy tests at z>2

New growth of structure measurements at z<1

Tests of Dark matter and synergies with Rubin