DESI-2

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DESI co-Spokesperson

Rubin/LSST Community Workshop
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DARK ENERGY SPECTROSCOPIC INSTRUMENT

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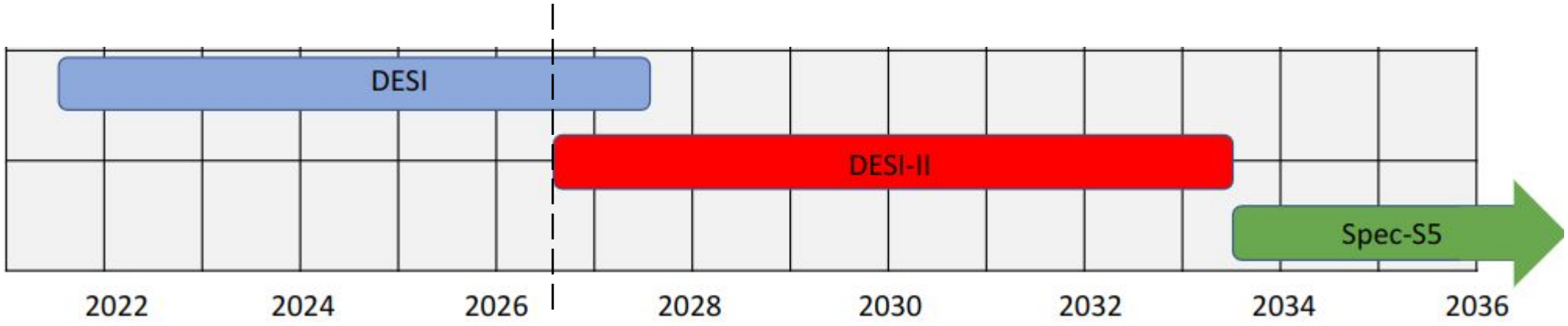
Staging Spectroscopic Surveys

- **Dark Energy Spectroscopic Instrument (DESI; primarily z<1.5)**
  - Dark Energy with Baryon Acoustic Oscillations (BAO) and Redshift Space Distortions (RSD)
- **DESI-2 (primarily z>2)**
  - As powerful as DESI, but at z>2
  - Early dark energy and growth of structure in matter-dominated regime
  - Synergies with other Cosmic Frontier experiments
- **Spec-S5**
  - Primordial physics (more constraining than the CMB in important areas)



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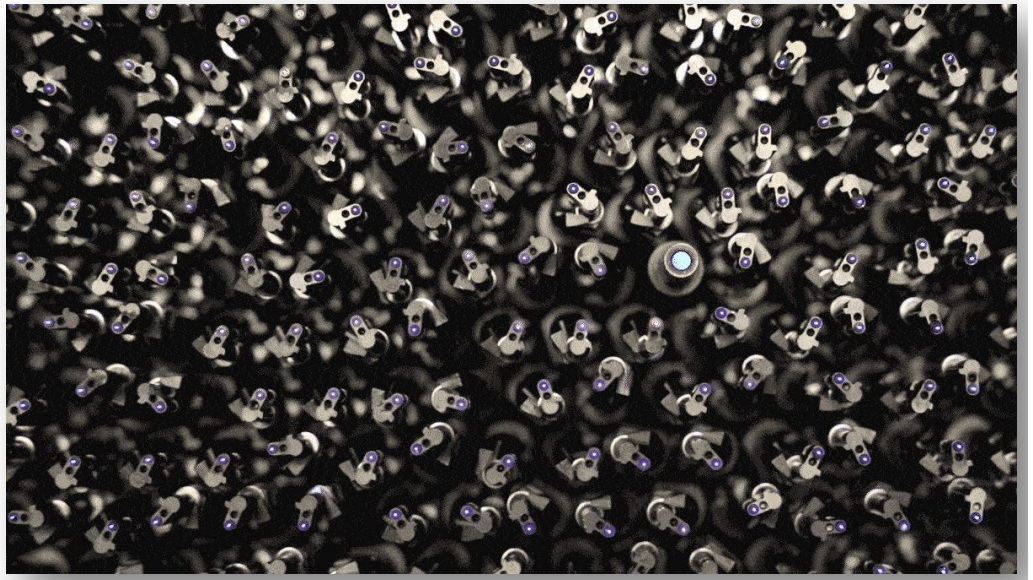
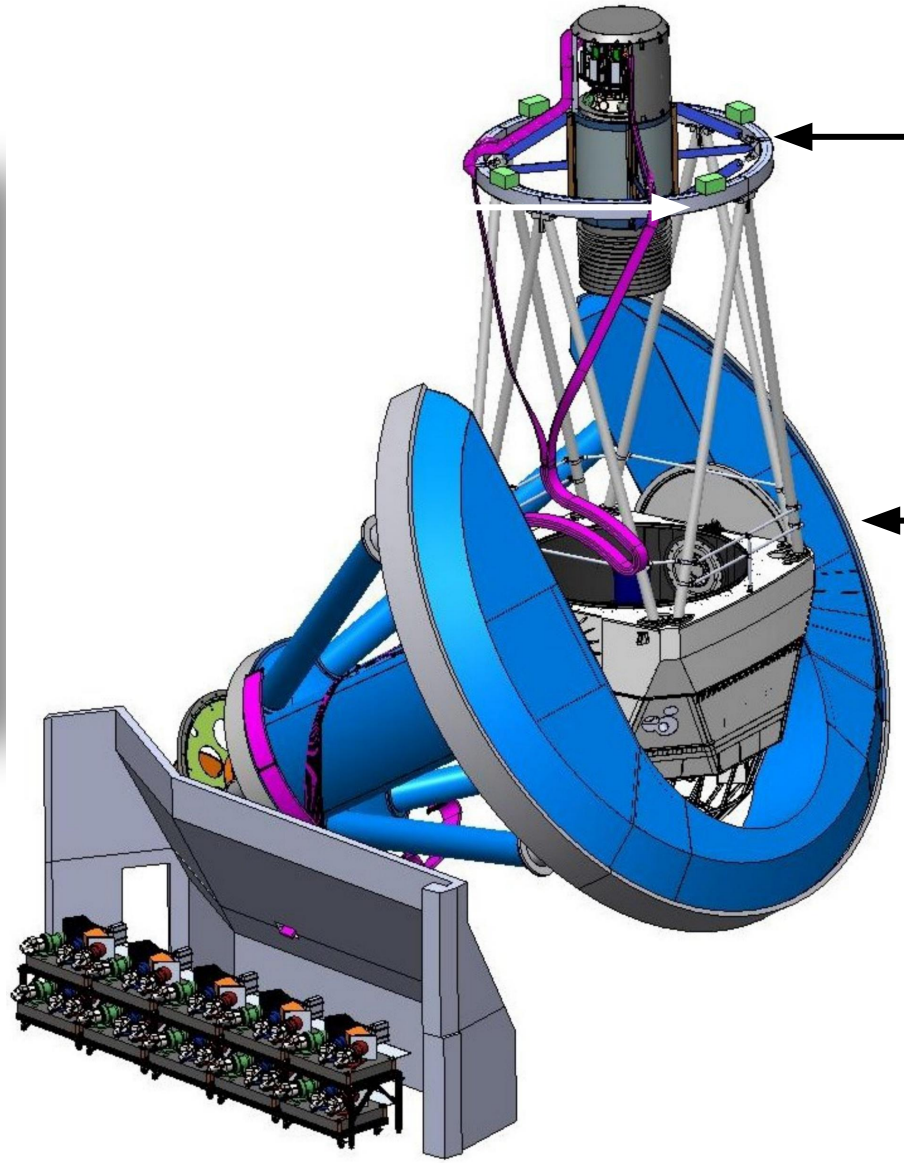
DESI: Massively-multiplexed Spectroscopy



Robotic fiber positioners!



Focal plane assembly with 5000 fiber positioners

Mayall 4m telescope

10 spectrographs (360-980nm)

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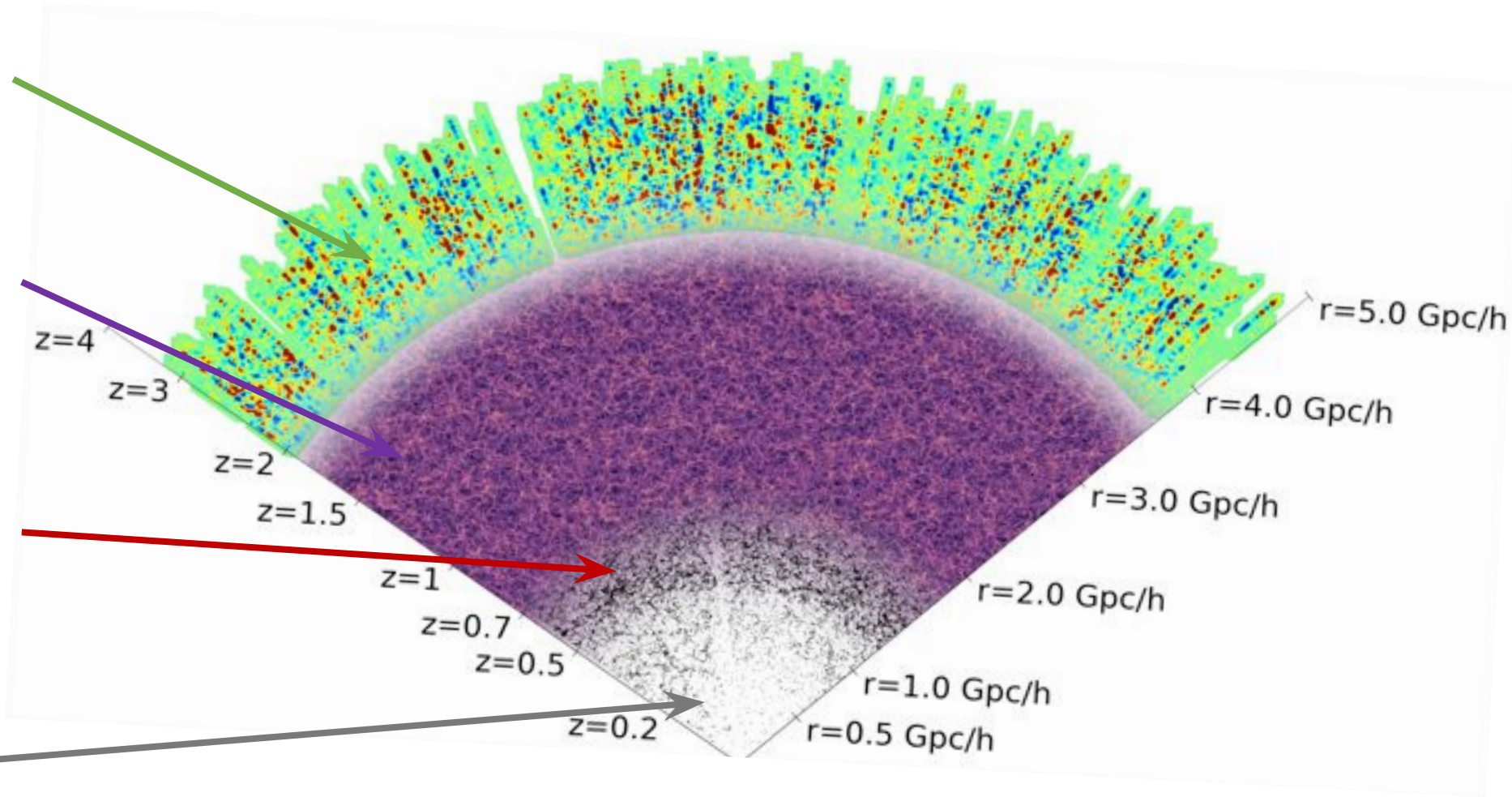
Uninterrupted Galaxy and Quasars from 0<z<3.5

3 million quasars + Ly-α forest (1 < z < 3.5)

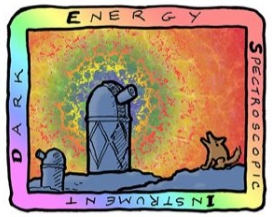
16 million Emission Line Galaxies (0.6 < z < 1.6)

8 million Luminous Red Galaxies (0.4 < z < 1.1)

13 million Bright Galaxies (0.0 < z < 0.4)



40M extragalactic redshifts plus 10M Milky Way stars



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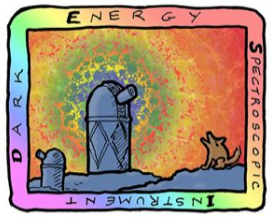
Planning for DESI-2

- **Snowmass:** "Continue operation of DESI (via a new DESI-II program) to constrain dark energy in new domains and as a step towards a Stage V spectroscopic facility (Spec-S5)."
  - Provide new insights into the high redshift Universe
  - **Strengthen synergies with other Cosmic Frontier facilities**
  - Provide a bridge to a Stage V spectroscopic experiment.
- Completed Pilot Surveys
  - Explore capabilities of DESI spectrograph beyond core BAO/RSD program
- Targeted fields to probe Milky Way
  - **Stellar spectroscopy in dwarf galaxies and stellar streams**
- >200,000 spectra collected in Rubin Deep Drilling fields
  - z>2 galaxies for primordial physics
  - **host galaxies for supernova cosmology**
  - **faint (for spectroscopy) galaxies for photometric redshift calibration**
  - **z<1 galaxies for galaxy-galaxy lensing science**
  - **dwarf galaxies for dark matter**



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Wide reaching DESI-2 program

- Skeleton (draft) outline of DESI-2 program
  - **Primary driver: dedicated z>2 survey for early dark energy and primordial physics**
  - Dark Time: spare fibers for spectroscopically faint Rubin source galaxies, dwarf galaxies, or other faint targets.
  - Gray Time: time-series observations of Rubin deep drilling fields
  - Gray Time: z<1 galaxies to characterize Rubin lens population
  - Bright Time: stellar spectroscopy to probe Milky Way dark matter

Designed for broad BSM discovery potential while being sensitive to existing tensions.

Snowmass: "New data from other facilities will be needed as a complement to unlock the full constraining power of LSST, including follow-up observations of strong gravitational lenses, supernovae, and gravitational wave standard sirens, as well as measurements of spectroscopic redshifts for deep training samples of objects to enable precision photometric redshift measurements."

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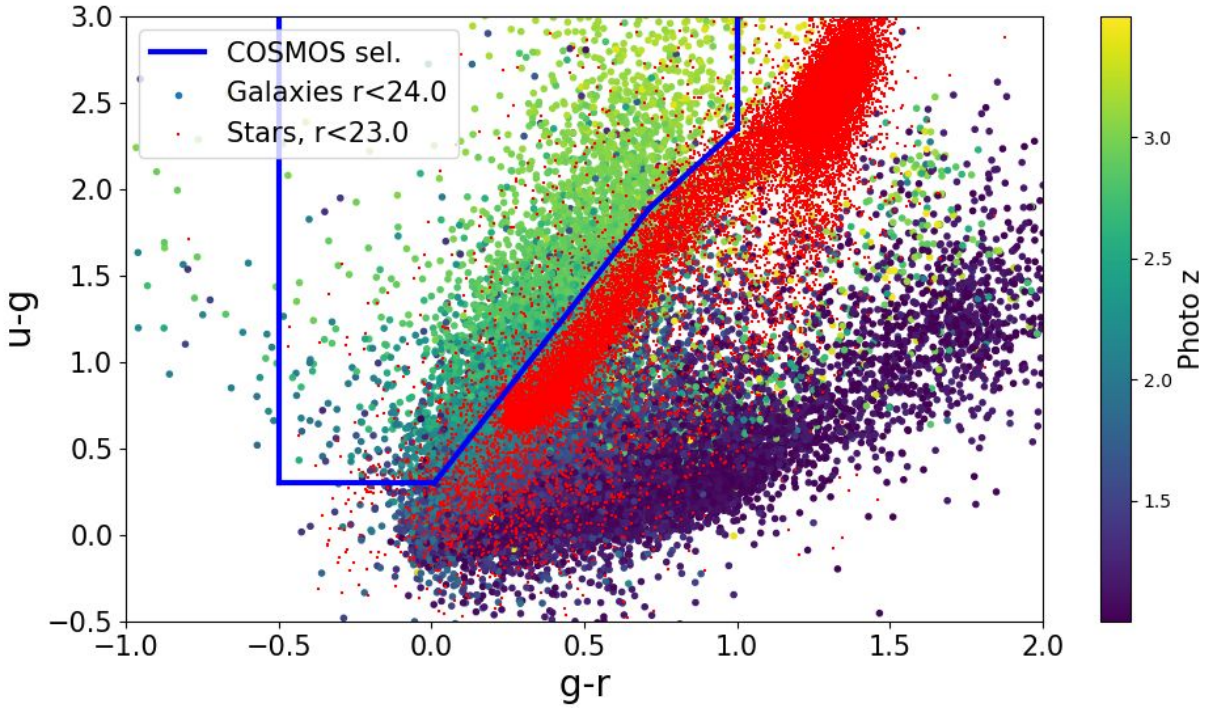
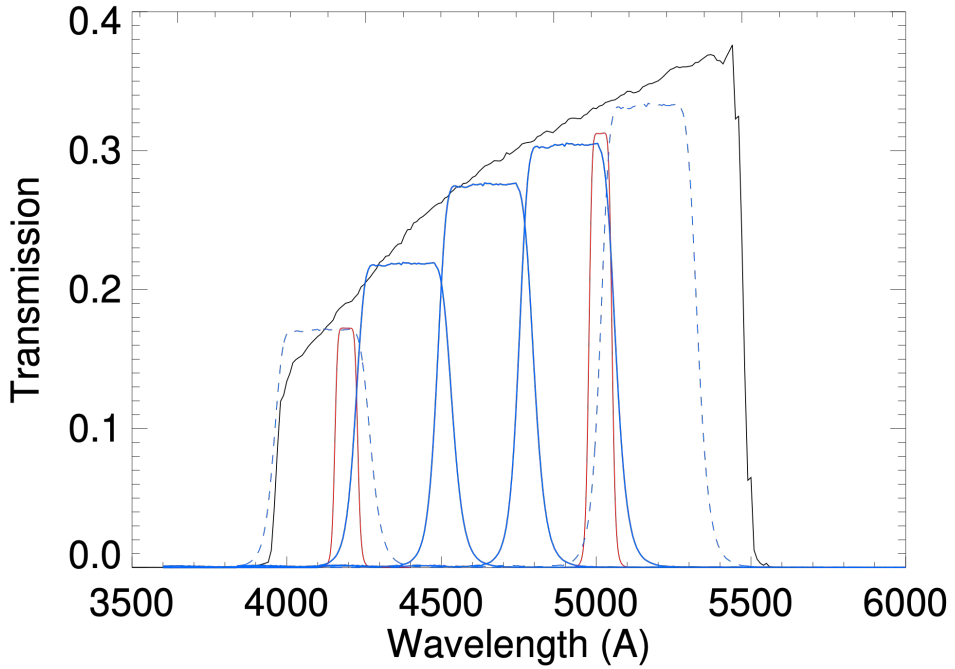
Target Selection: LSS at z>2

- Select galaxy targets in the redshift range(s) that we want: 2.0<z<3.5.
- Considering two different approaches for selection from imaging data
  - **Rubin ugr: targets in LSST-DESC overlap**
  - DECam medium band filters: emission line galaxies for efficient redshift classification

Requires Rubin u-band imaging to 2yr depth in equatorial regions



Approved imaging from DECam complements Rubin photometry



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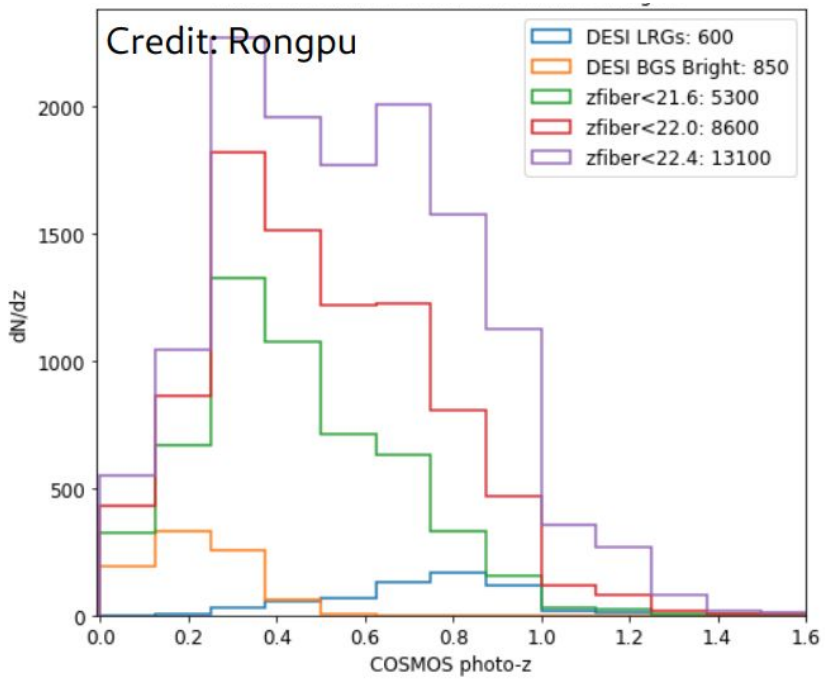
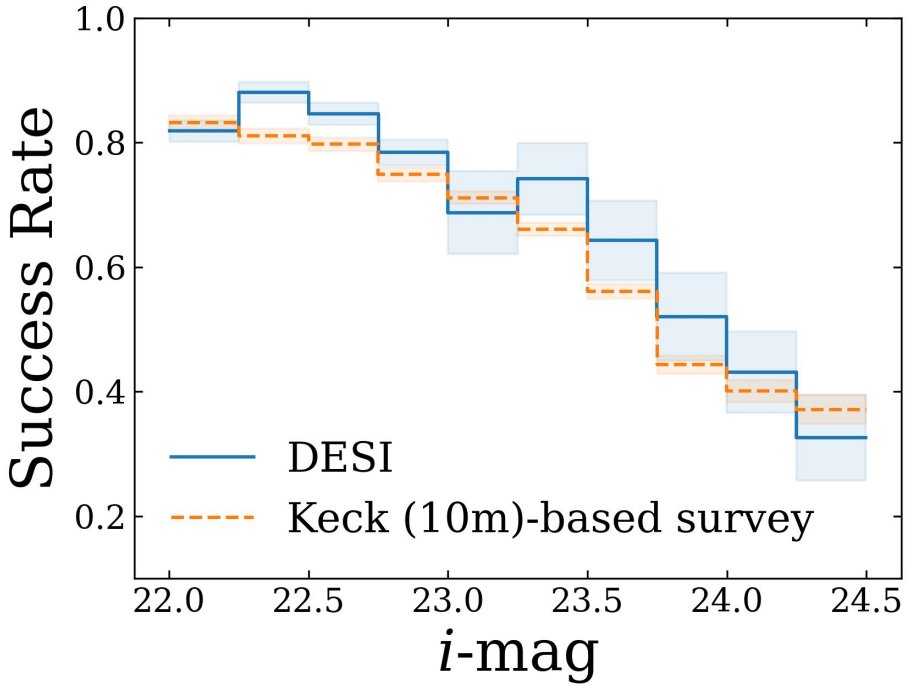
Capabilities: Supporting Rubin Cosmology

- 99% redshift completeness for z<1 galaxies
  - order of magnitude increase in surface density relative to DESI



- Galaxies at 22<i<24.5
  - Comparable to 10m class telescopes in only 50% more observing time
  - 40 times more galaxies per exposure



Characterize lens and source populations for cosmic shear and lensing studies

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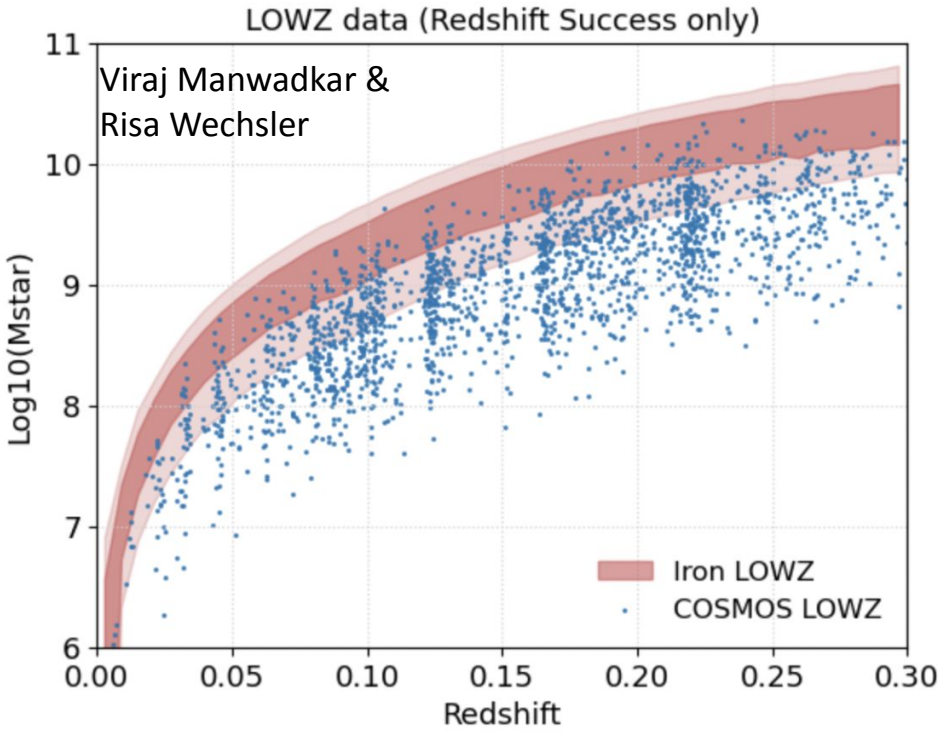
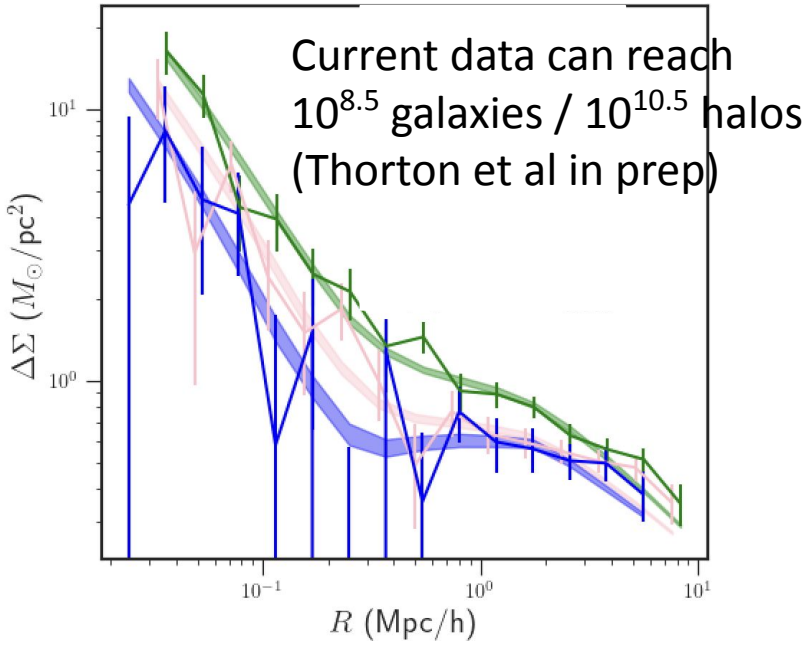
Capabilities: Beyond Cosmology – dwarf galaxies

- DESI already has redshifts for 500K dwarf galaxies ($M_* < 10^9 M_{sun}$). With deeper exposures, could obtain excellent redshift completeness for lower mass galaxies.



Red: DESI Year 1 data (BGS plus lowz secondary program)
Blue points: pilot COSMOS survey with 1-2 hour DESI exposures

- A dark-time secondary target program to get redshifts for low-mass galaxies combined with Rubin lensing measurements could probe significantly lower mass halos than previously possible – potential to map M_*-M_{halo} to ~ 10^6 galaxies / 10^9 halos.



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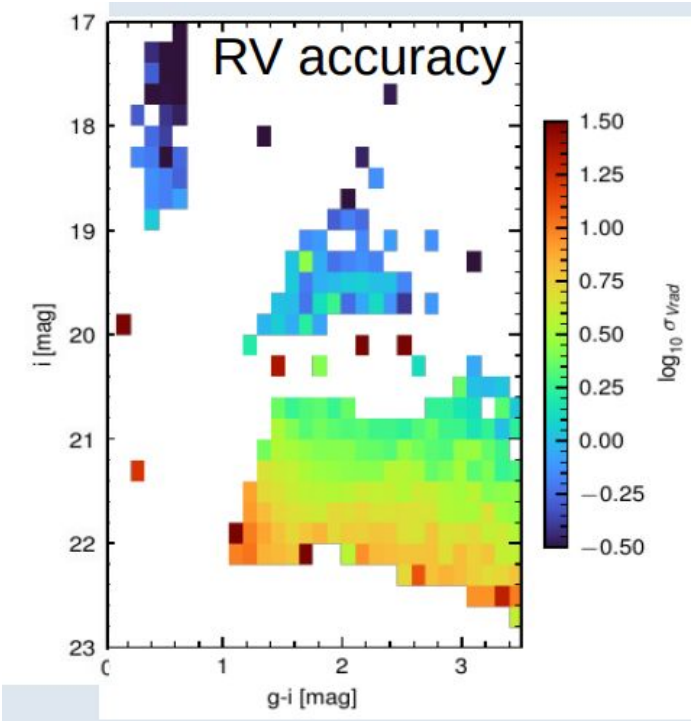
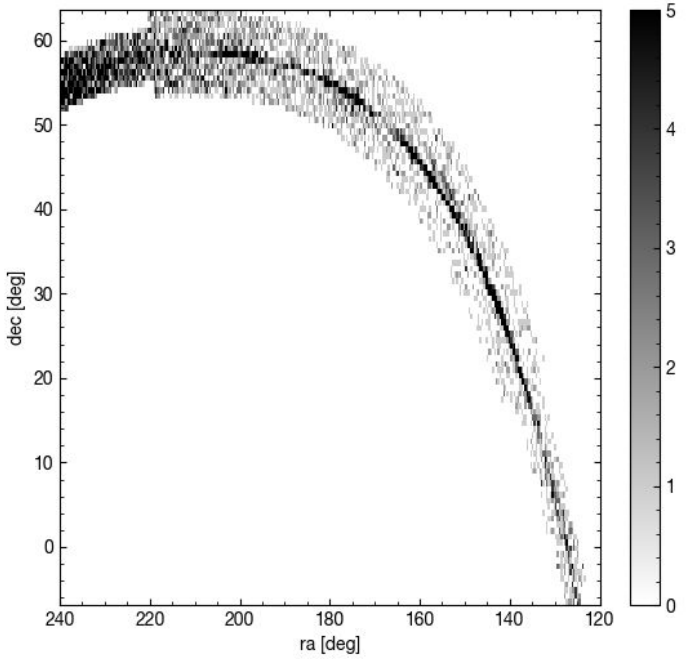
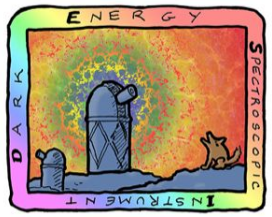
Capabilities: Beyond Cosmology - Stellar spectroscopy

- Stellar spectroscopy likely to be conducted in bright time
- Pilot: radial velocities to 10 km/s precision at i=22
  - Main sequence stars to >50 kpc
  - Giant stars in M31
  - Discussing observations of GD-1 stream now (i<20.5 targets)







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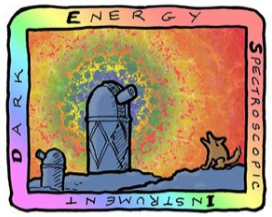
Capabilities: Rubin Deep Drilling Fields

- Pilot spectroscopy in XMM-LSS and COSMOS field
- >200k spectra in COSMOS; >100k spectra in XMM-LSS
  - Broad range of galaxy types already observed
  - Potential to continue through DESI-2 with time-domain focus
  - Specific program not defined

- DESI has time-domain working group
  - Already coordinating spectroscopic follow-up of SN hosts from DECam
  - Key Project to combine SN, Tully Fisher, and fundamental plane measurements to constrain low redshift growth of structure
  - Contributions to DESI-2 planning

- General statement: feel free to talk with Risa, Jeff, myself, or Nathalie Palanque about DESI-2 plans and opportunities



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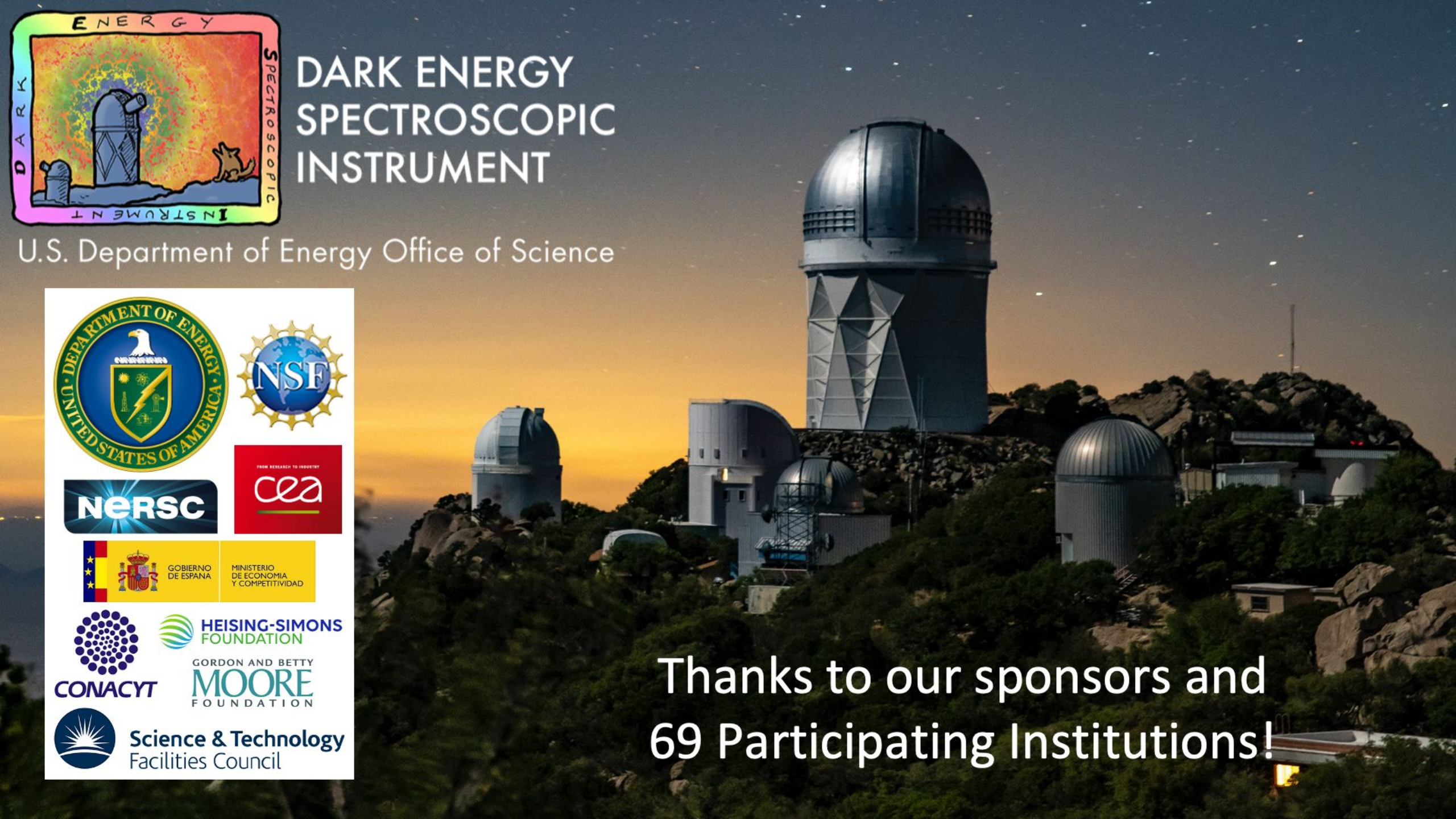
Summary

- DESI
  - Order of magnitude increase over preceding spectroscopic samples
- DESI capabilities
  - Tens of millions of galaxies accessible with current instrument
  - Even more powerful with modest upgrades
- Wide reaching DESI-II program
  - **Dark Time: dedicated LSS survey at z>2 for primordial physics**
  - Dark Time: spare fibers for faint Rubin source galaxies
  - Gray Time: time-series observations of Rubin deep drilling fields
  - Gray Time: z<1 galaxies to characterize Rubin lens population
  - Bright Time: stellar spectroscopy to probe Milky Way dark matter
  - Still being defined, plan to propose in Spring 2024

Snowmass: "Continue operation of DESI (via a new DESI-II program) to constrain dark energy in new domains and as a step towards a Stage V spectroscopic facility (Spec-S5)."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