



The Dark Energy Spectroscopic Instrument and Spectroscopic Futures

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A plea:

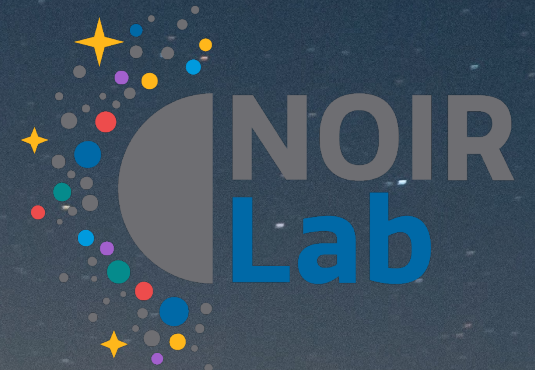
- UVEX should target all of Andromeda as a deep survey (to ~ 26 mag)
- Time-domain survey of the main disk
- Deep survey of full halo out to at least Triangulum ~ 500 deg²
- Structure of stellar halo, low metallicity stars, dust properties, LBVs, novae, hot stars, etc., etc.





DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science



Thanks to our sponsors and
69 Participating Institutions

... and the staff of KPNO

An Introduction to DESI

- 5000-fiber, 3-deg dia field, prime-focus spectrograph at Mayall 4m telescope at Kitt Peak National Observatory

“Largest cosmic cartography experiment ever!”

- Spectra of >40 million astronomical targets
 - See Myers et al. 2022 for details (+ other target selection papers)
- Primary surveys for cosmological constraints:
 - “Bright Galaxy Survey” : >10 million galaxies at $z < 0.6$, $r < 20.175$ (complete to 19.5)
 - Luminous Red Galaxies + Emission Line Galaxies: >20 million at $0.6 < z < 1.6$
 - QSOs: ~3 million
- Stellar surveys:
 - “Milky Way Survey” : >7 million stars with $16 < r < 19$ mag
 - + special targets: WDs (66k), Nearby (21k), BHBs (9k), RR Lyrae (18k), etc.

DESI at a glance

Prime-focus fiber spectrograph

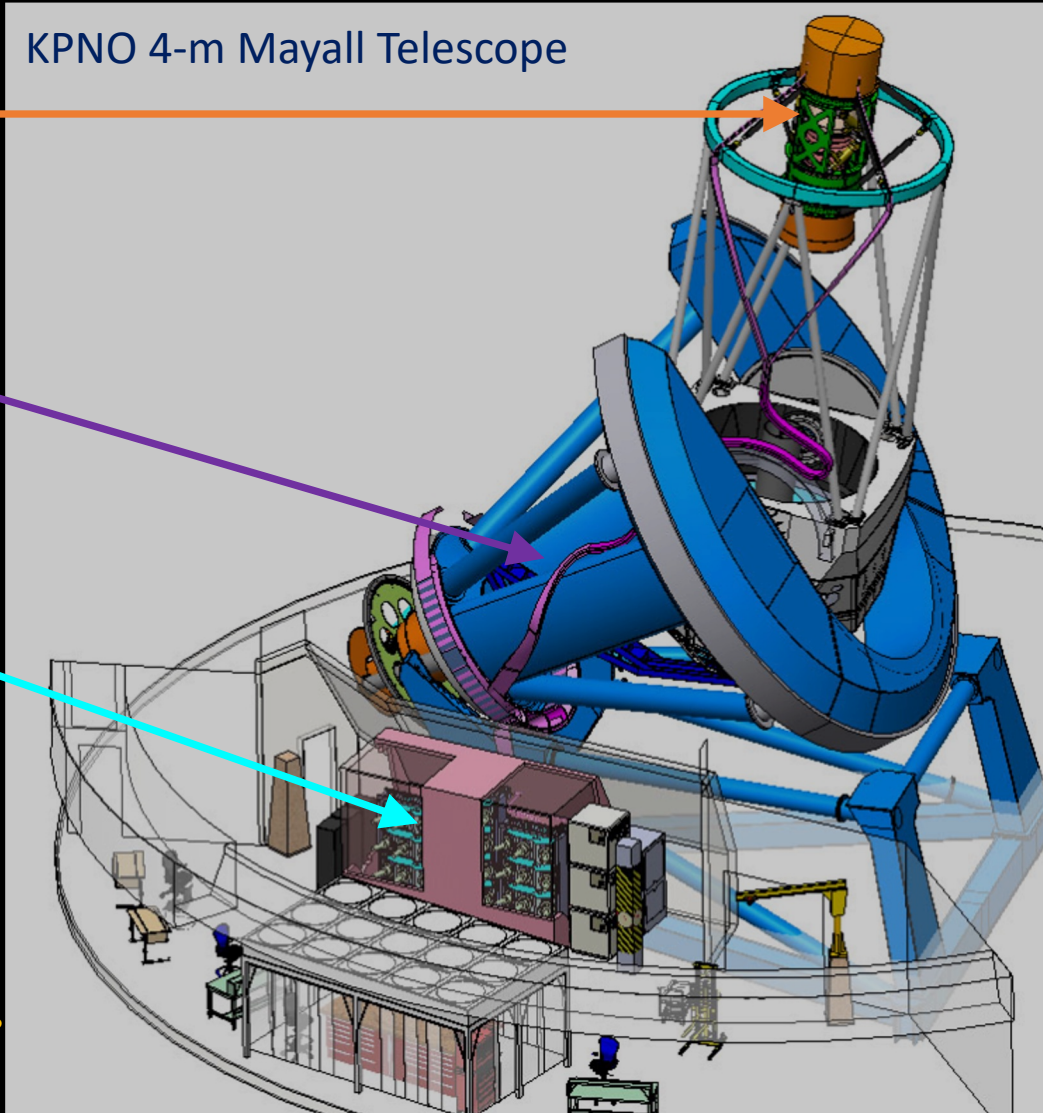
- 3.2 deg diameter field of view
- 5020 robotically positioned fibers

- ~50-m of fiber cable

- 10 3-arm spectrographs covering 360 – 980 nm at $\lambda/d\lambda=2000 - 5000$

- Overhead is ~ 1-2 min/exposure! → 60k-100k redshifts/night
- Very stable instrument - On the telescope every night, all the time!
- Data will be public
 - “Early Data Release” in early-mid 2023
 - DR1 in early 2024

DESI construction and operations are funded by the Department of Energy’s Office of Science, private foundations, and 69 participating institutions



DESI Selects Targets from the Legacy Surveys imaging

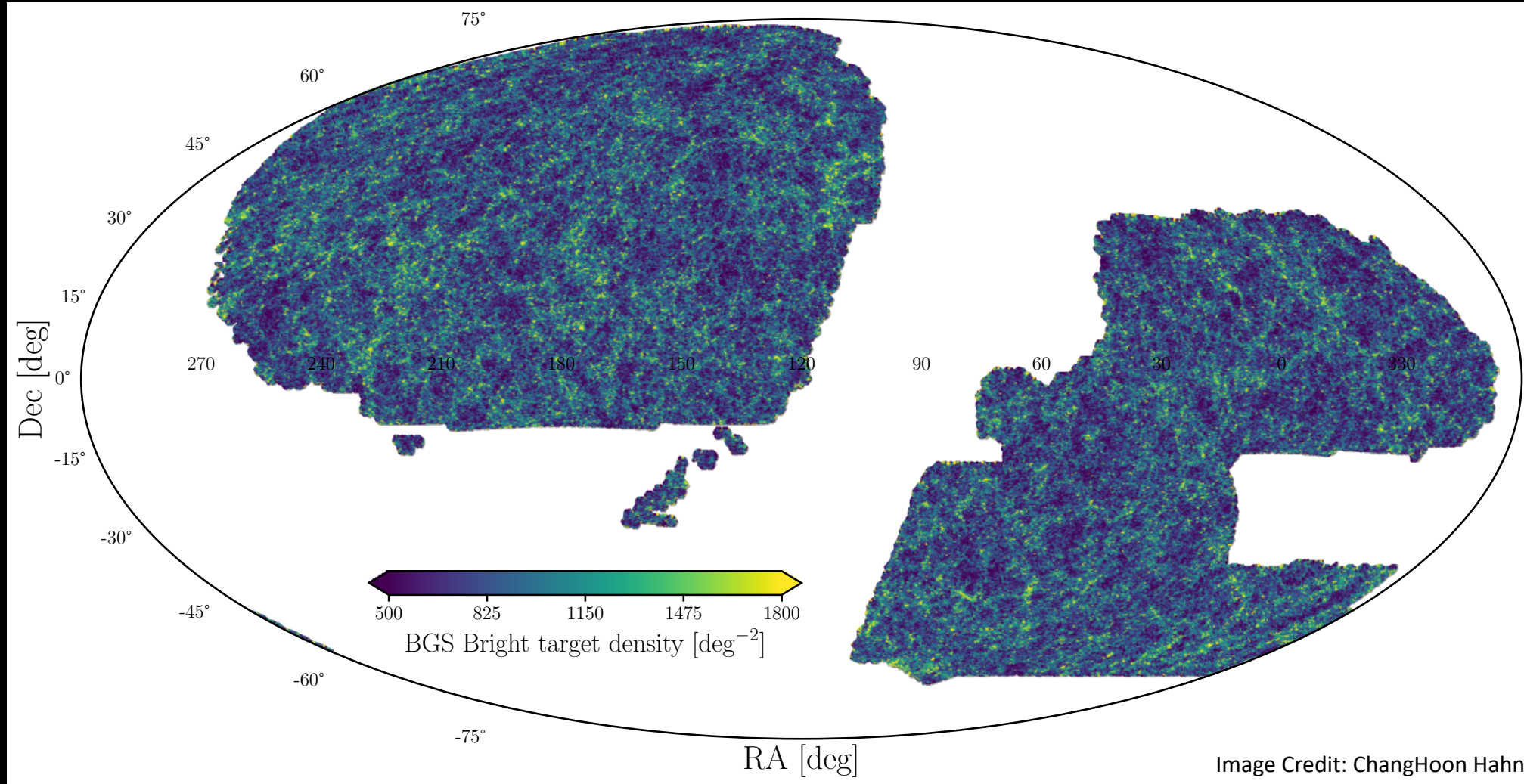
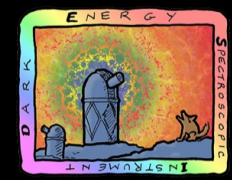
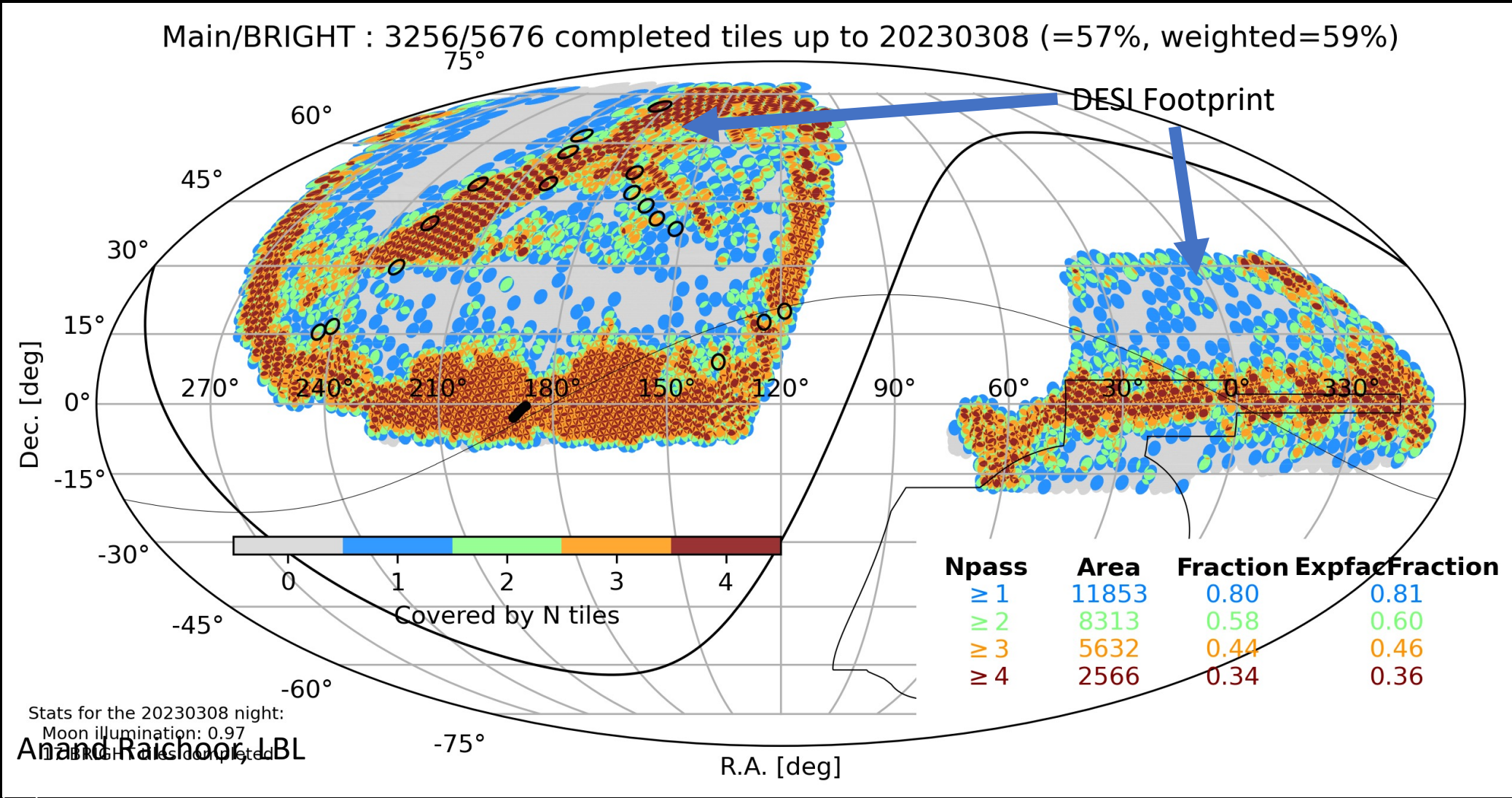


Image Credit: ChangHoon Hahn

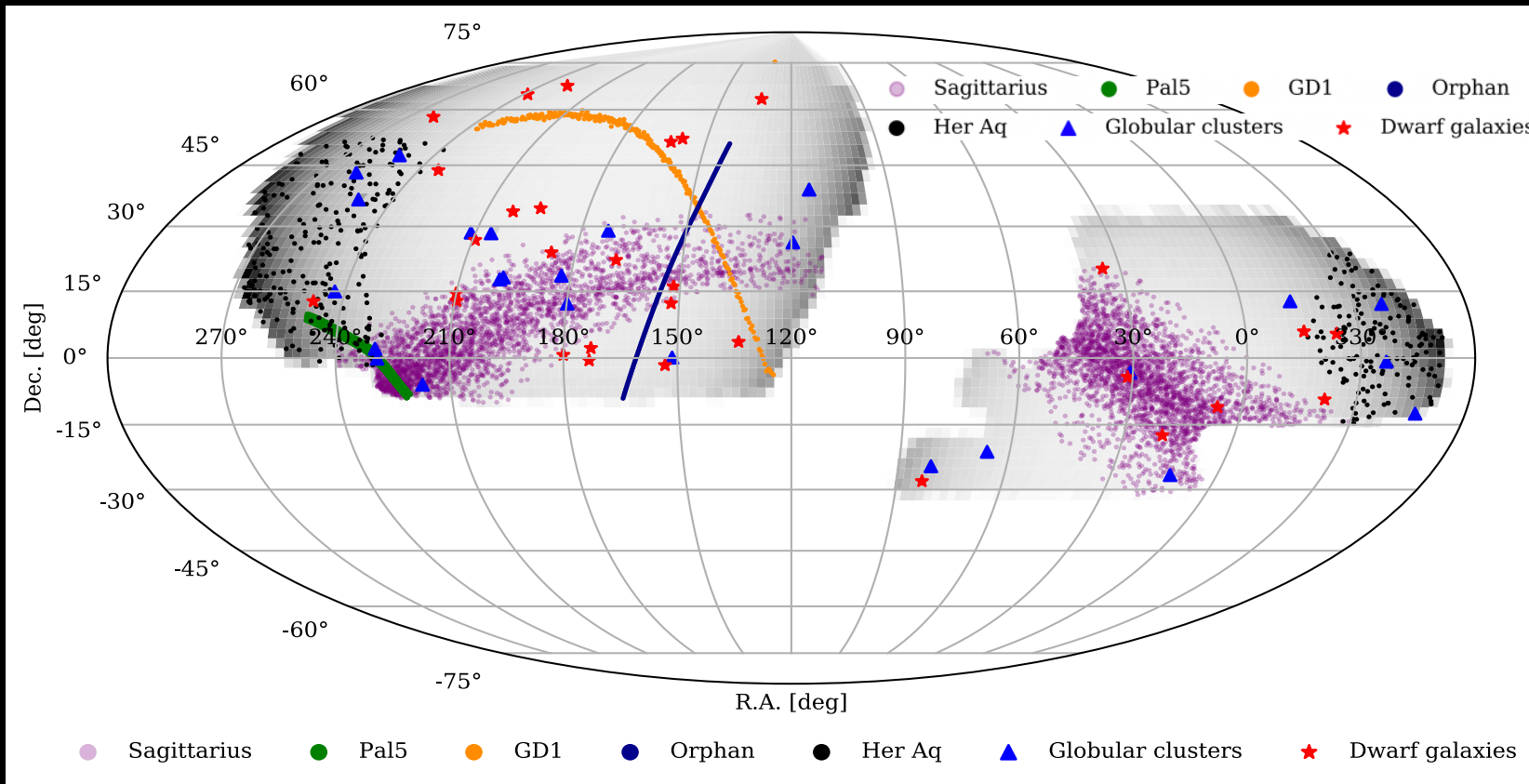
DESI Spectroscopy covers 14,000 deg²

In progress -- Coverage as of March 8, 2023

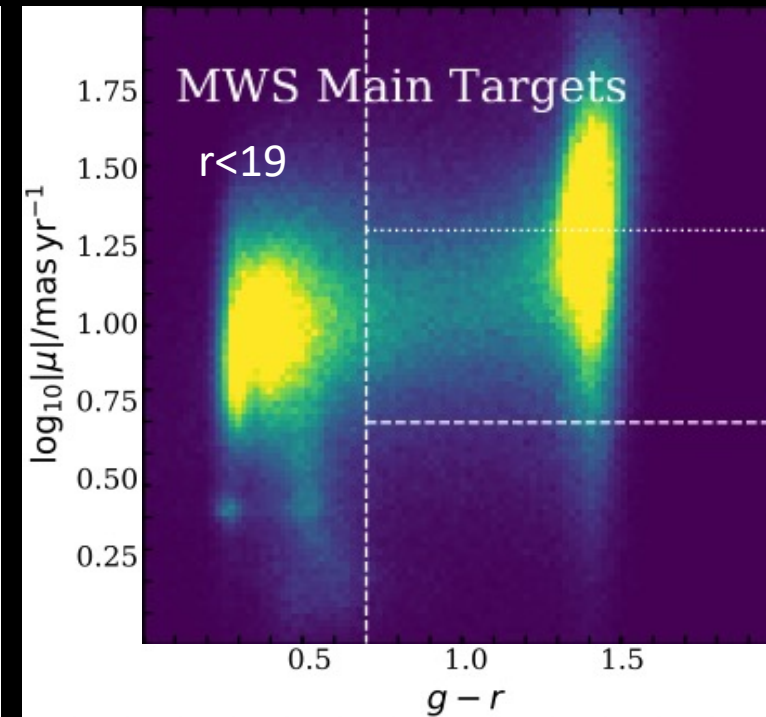


Anand Raichoor, LBL

DESI Milky Way Survey: Spectra of $\sim 7-10$ M Gaia stars



Cooper et al. (2023)



- + Gaia white dwarfs
- + RR Lyrae and BHBs
- + Nearby sample $\pi > 10$ mas/yr
- + some clusters, streams, dwarfs

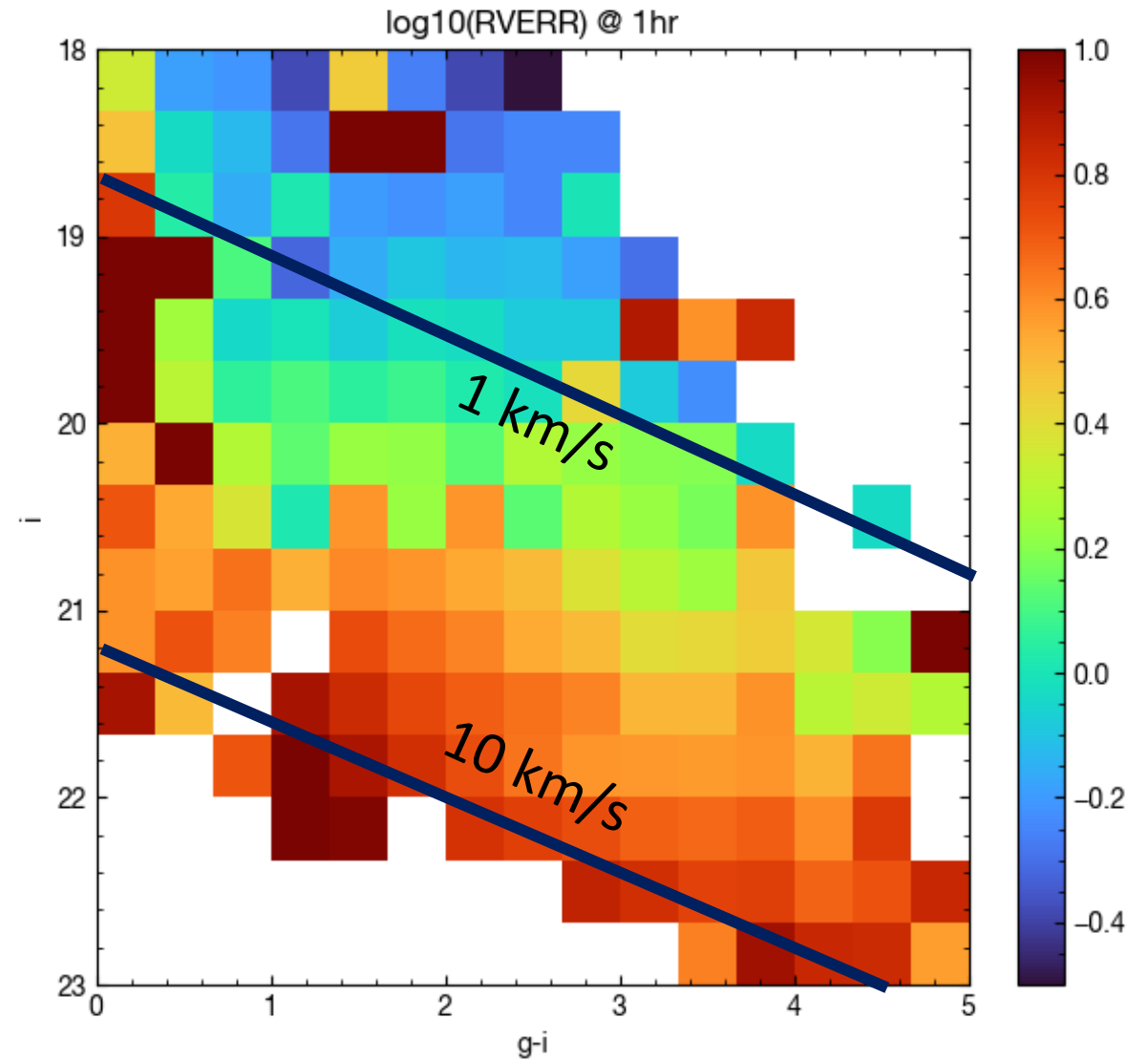
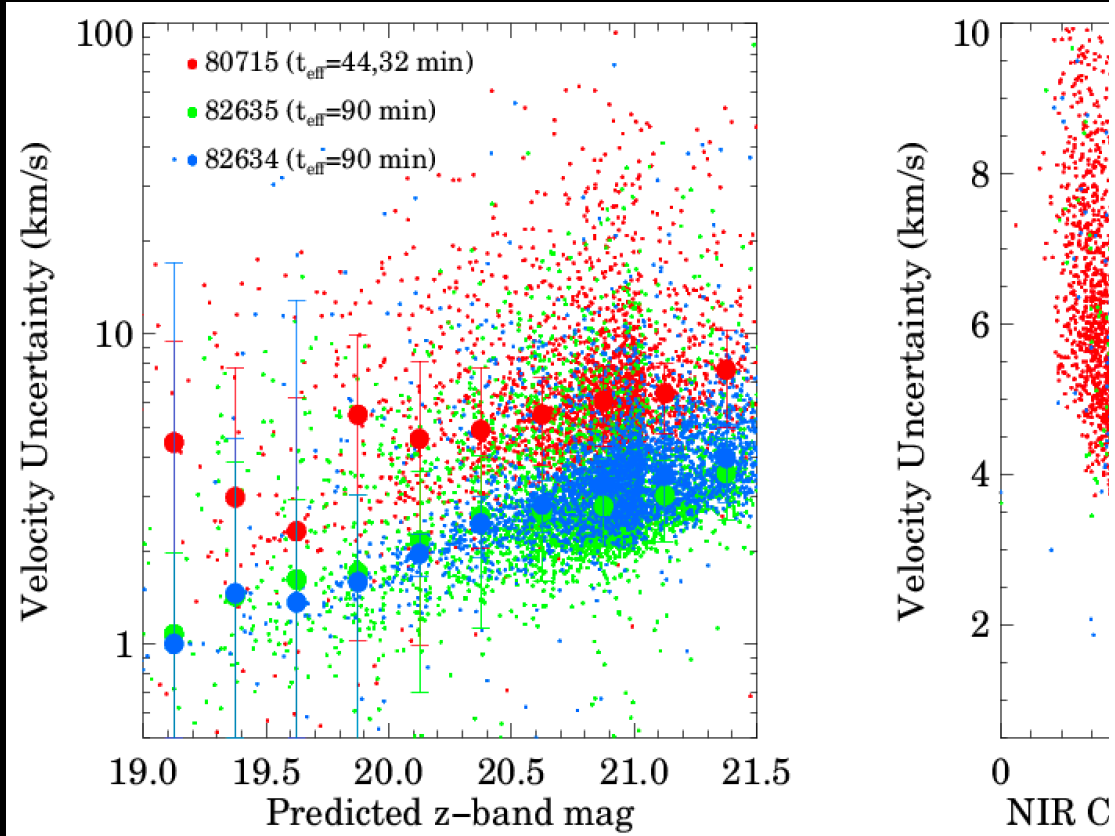
DESI is Revolutionary

- Radial velocities for faint stars to $i=22$ mag
- Spectroscopy of Lyman Break Galaxies to $r<24.5$ mag
- Spectroscopy of Lyman Alpha Emitters to $r>26$ mag
- 100,000 spectra per night

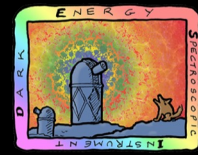
A spectroscopic “utility”

... on a 4-m telescope!

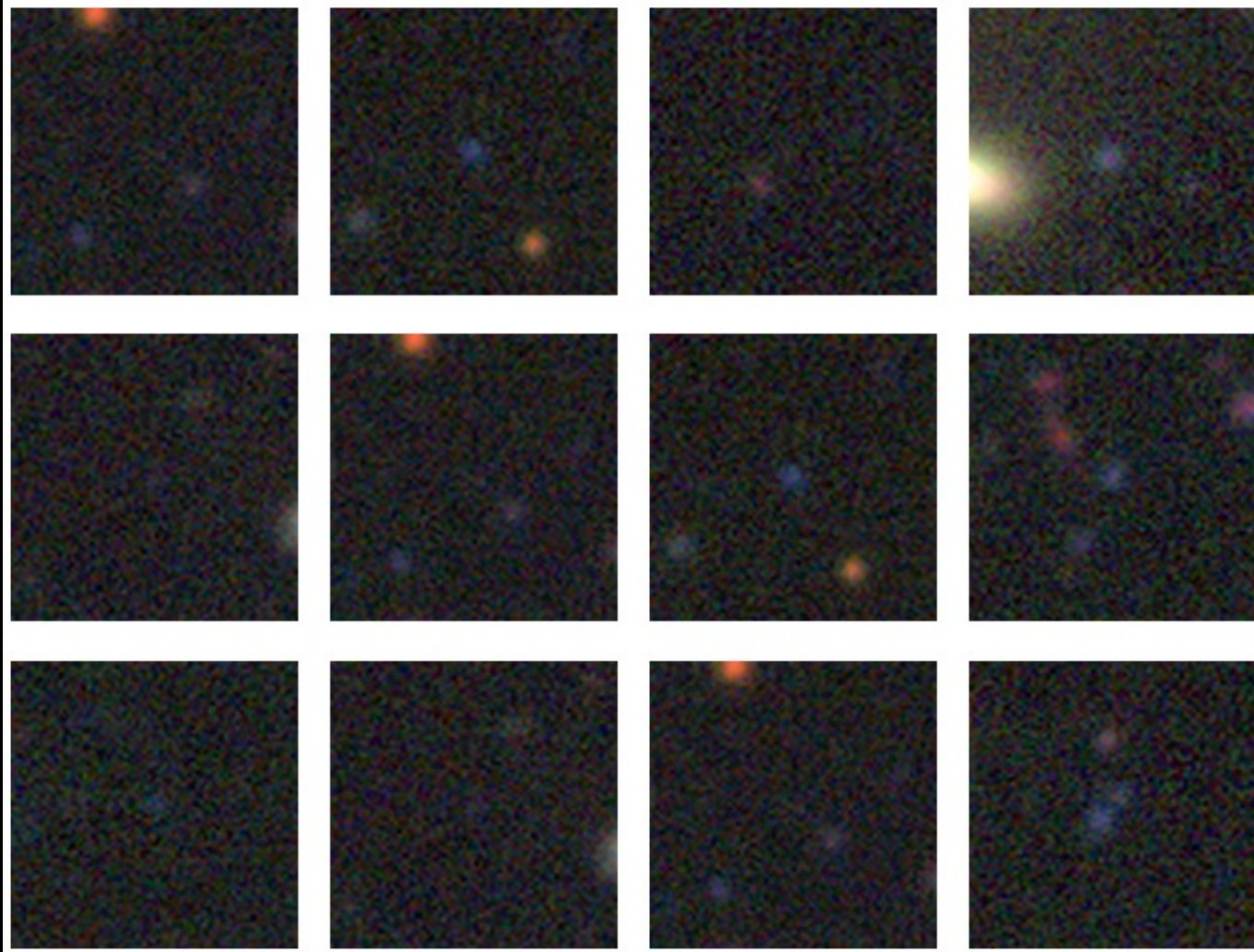
DESI can measure $i \sim 22$ mag stellar spectra



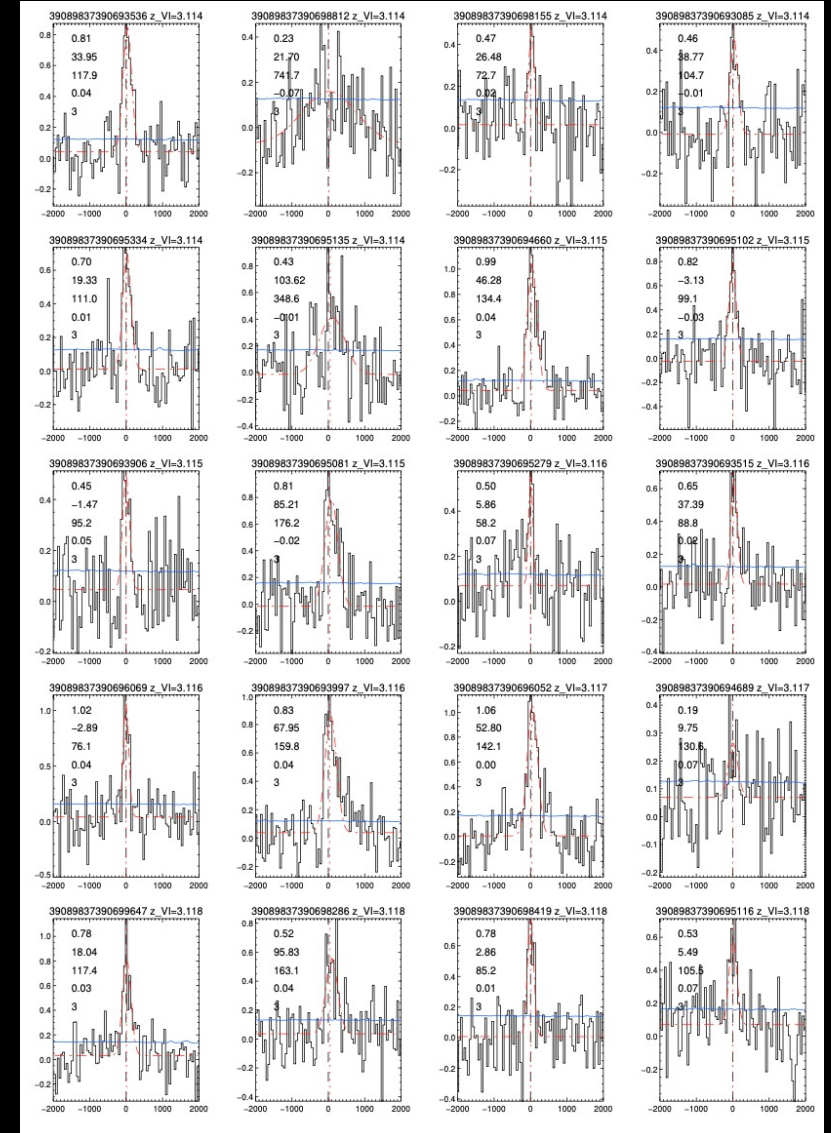
DESI easily measures redshifts for very faint LAEs!



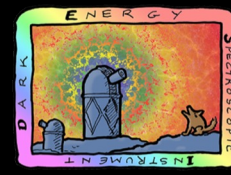
Images from Subaru Hyper-Suprime Cam DR2



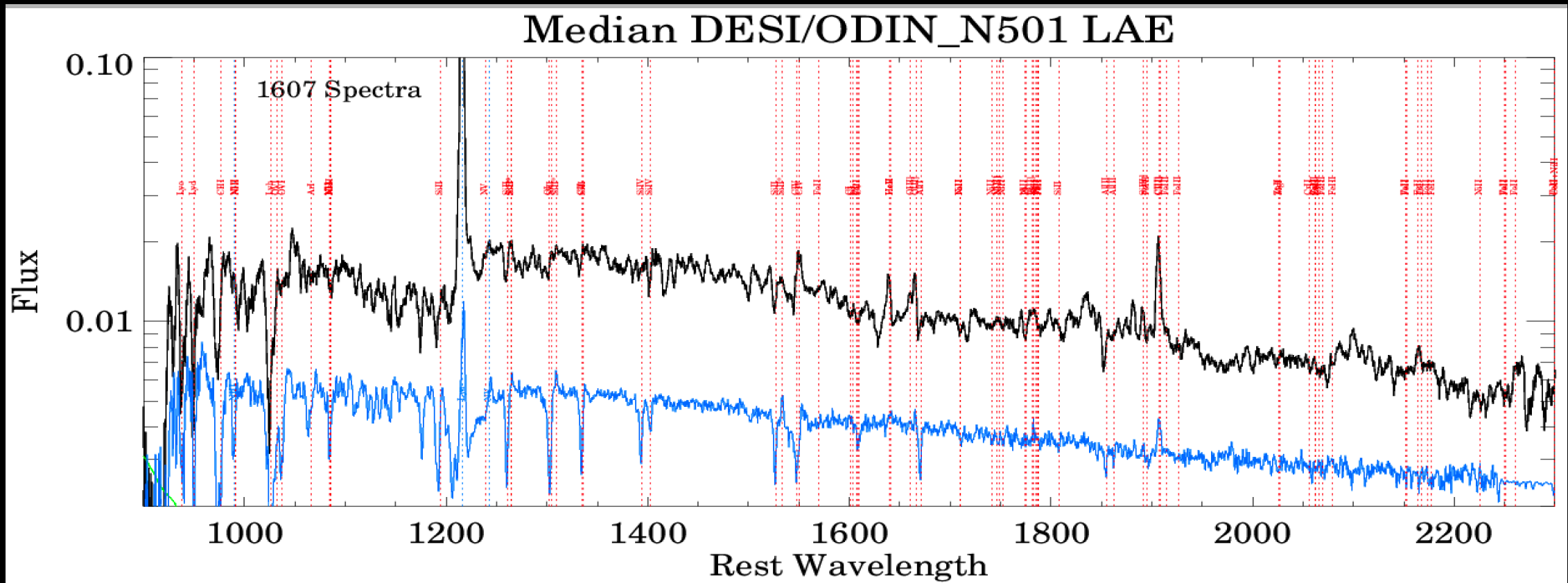
Spectra from DESI



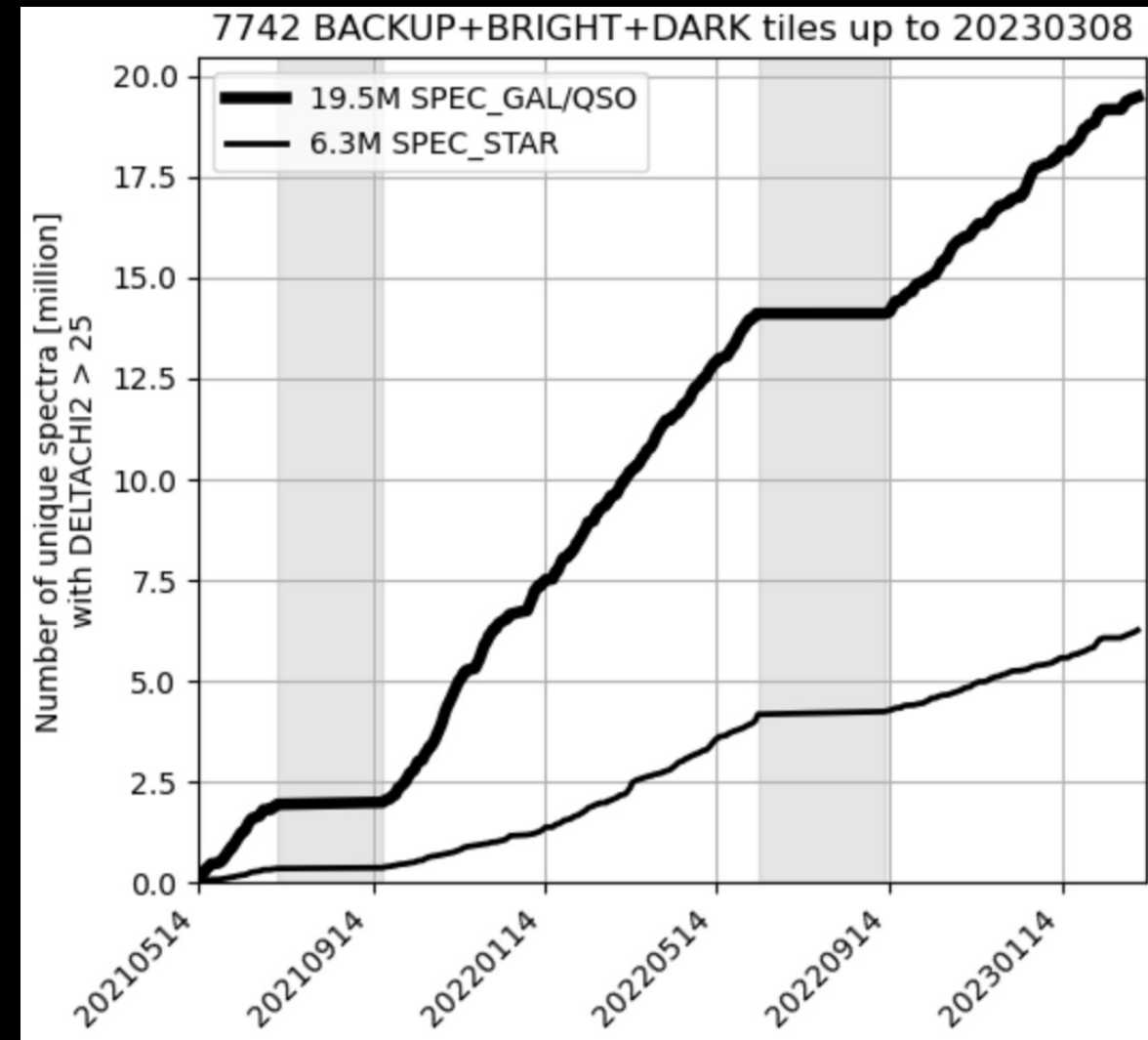
DESI Can Access Faint Galaxies at $z \sim 2-4$



- several thousand spectra of Lyman Alpha Emitters and Lyman Break Galaxies
- DESI should be able to measure redshifts for most emission line UVEX sources down to FUV/NUV $\sim 24-25$ mag
- Observing large samples of star-forming LMCs out to $z \sim 4$ with 4m Mayall



- Spectroscopic survey 2021 to 2026, but running ahead of schedule
 - ~27M spectra taken
 - All data should be public < UVEX launch
- Currently planning an extension to DESI
 - Extend areal coverage to 17k deg²
 - Higher density low-z survey
 - New high-z survey at $2 < z < 4$
 - Targeted survey for DM constraints from dwarf galaxies, streams, etc.
- Next-generation spectroscopic surveys
 - DESI upgrades
 - Standalone facilities



- “Stage 5 Spectroscopy” for next-generation cosmology surveys
- Need at least 5-10X gain over DESI

Many options under consideration

1. DESI-Mayall upgrade + DESI-Blanco clone = 2 x (14k fibers, 8 deg² FoV)
2. 6.5m platform + 24k fibers (in existing dome or new construction)
3. >10m platform (“SpecTel-like” or “MSE-like”)
 - For UVEX timescale, only option 1. is of any interest
 - Waiting for signal from P5 on how to proceed

UVEX + DESI Synergies

- Existing spectroscopic catalogs (>40M redshifts from DESI)
 - High spectroscopic-completeness low-z redshifts
 - Spectroscopically-selected samples of low-metallicity galaxies
 - Spectral types for millions of stars for calibrating UV-optical photometry
 - Tuning methods for removing high-z interlopers from low-z galaxy samples
 - Redshift filtering for identification of GW EM counterparts
- Improved small-scale dust maps for cosmological & 3-d Galactic structure studies
 - Why use photometry when spectra => T_{eff} and $\log(g)$?
- UV photometry + spectroscopy are excellent counterparts to DESI MW survey
- FoV (DESI) \sim FoV (UVEX)
- For DESI-N+S option, all-sky spectroscopic coverage over wide-fields for UVEX TD follow-up

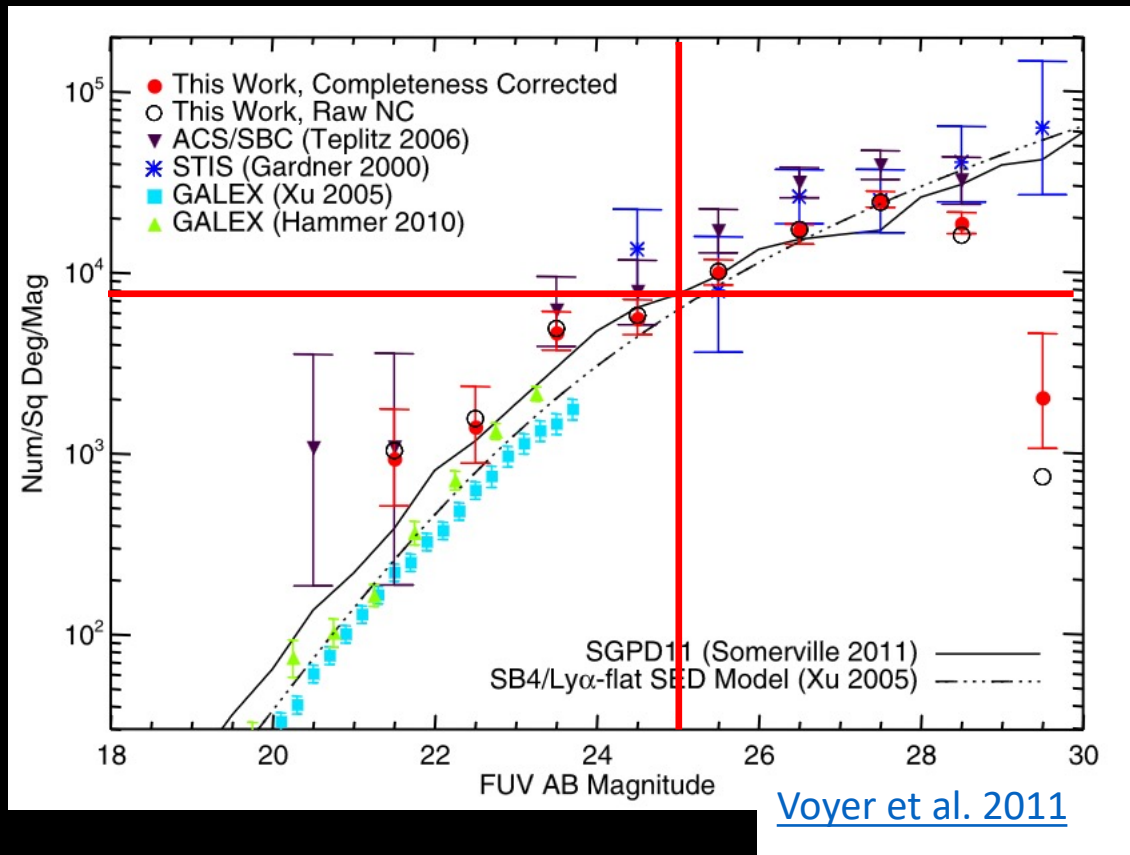
- Engage with development plans for DESI-2 and Stage 5 spectroscopy
 - NASA support for ground-based spectroscopy?
- Investigate joint synergies between Rubin/LSST + DESI + UVEX
 - "Stronger together"
- Include info from ground-based spectroscopic surveys when selecting UVEX spectroscopic targets or strategizing GW follow-up
 - DESI + PFS + WEAVE + 4MOST + ... Spectroscopic landscape is being revolutionized
- Mid-scale 4m-class telescopes may be well-suited to depth of UVEX for most emission-line targets

DESI FoV – Fiber Density is well matched to UVEX

$N(<25 \text{ mag}) \sim 15,000 / \text{deg}^2 / \text{mag}$ (NUV)

$N(<25 \text{ mag}) \sim 8,000 / \text{deg}^2 / \text{mag}$ (NUV)

DESI $\sim 700 / \text{deg}^2$



[Hoversten et al. 2009](#)

