

The Dark Energy Spectroscopic Instrument (DESI): LSST Synergies

DESI is and will remain the most competitive instrument for large-scale spectroscopic surveys for the remainder of this decade, and the DESI survey is by far the largest wide-area spectroscopic survey ever done. This session will present and discuss how the DESI observations that will help to realize the primary science goals of the LSST, and the options and advantages of coordinating surveys to enhance the science goals of each.

Agenda

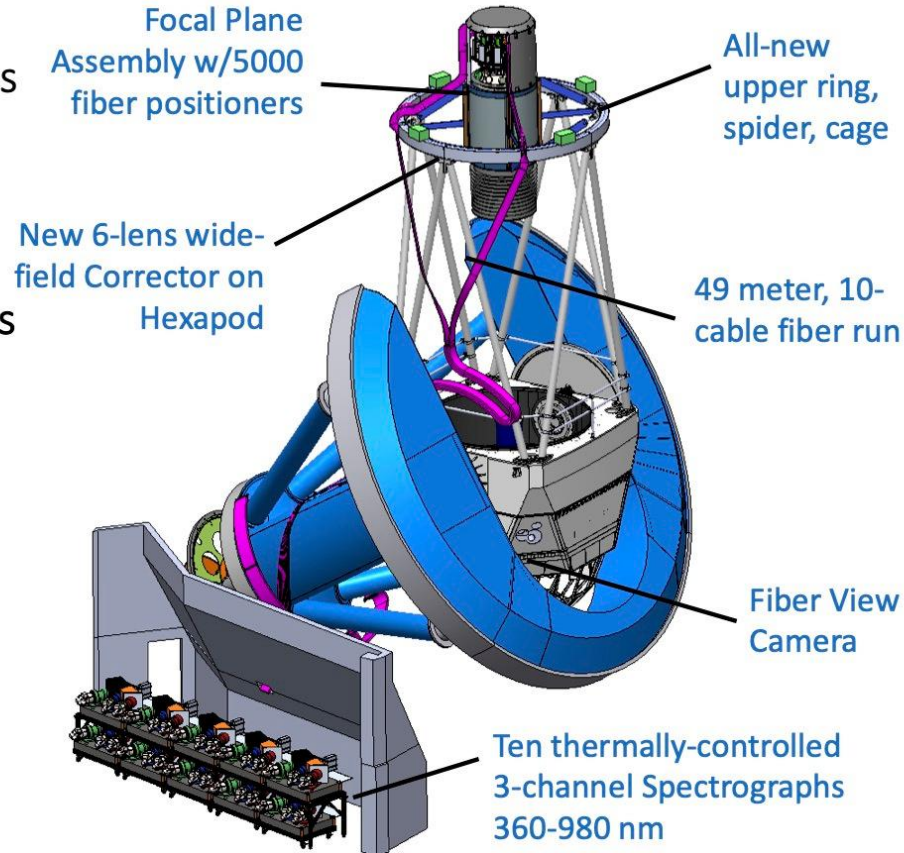
- Overview of DESI and plans for DESI-II - Julien Guy
- The DESI-2 LBG survey - Anand Raichoor
- LSST x DESI science - Joseph DeRose
- DESI redshifts for LSST transients - Segev BenZvi
- LSST and DESI Milky Way science - Connie Rockosi

Overview of DESI and plans for DESI-II

Julien Guy (LBNL)
Vera C. Rubin Observatory Project & Community Workshop
Aug. 2022

DESI by the Numbers

- DESI is a Fiber-fed multi-object spectrograph. It uses robotic control to position optical fibers onto the location of a known galaxy
- 5000 fiber positioner robots on the focal plane
- 8 sq. deg. FOV
- Ten 3-channel spectrographs



Five target classes

40 million redshifts

in 5 years

DESI (2021-2026)

3 million QSOs

Lya $z > 2.1$

Tracers $0.9 < z < 2.1$

16 million ELGs

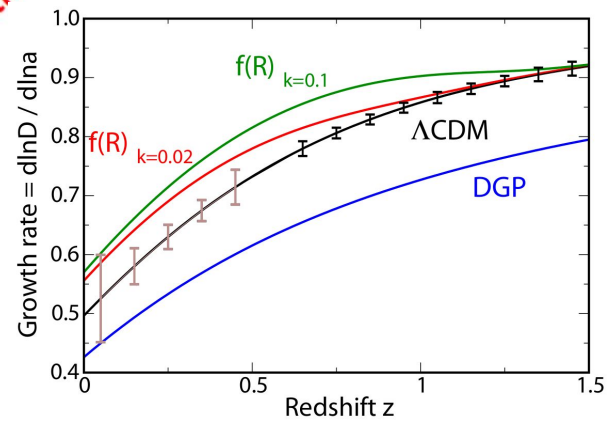
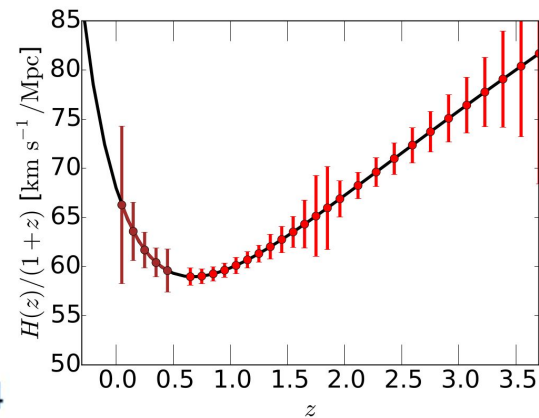
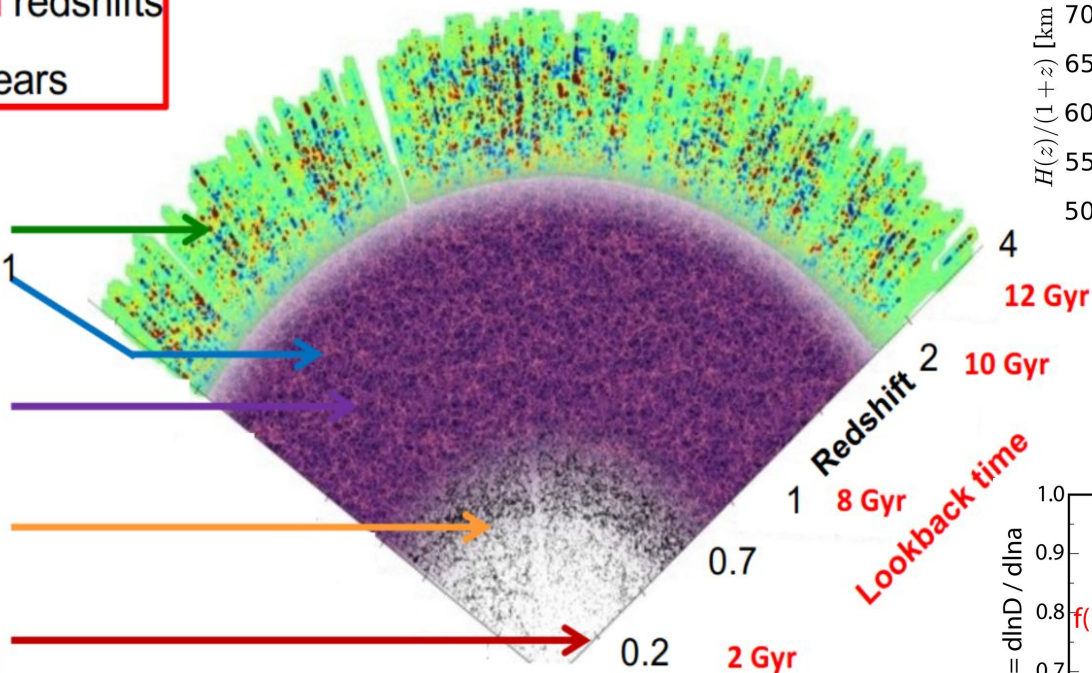
$0.6 < z < 1.6$

8 million LRGs

$0.4 < z < 1.0$

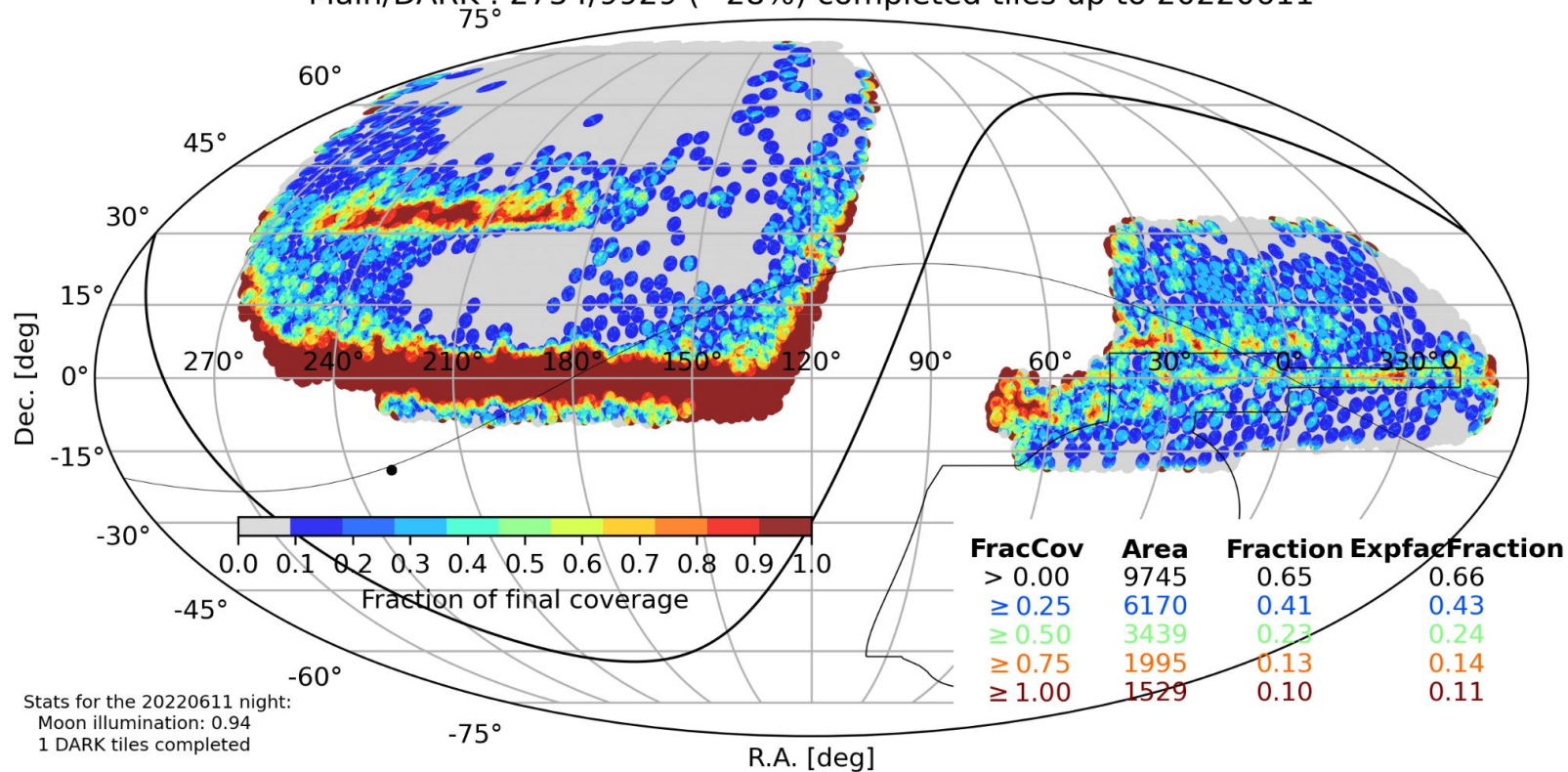
13.5 million
Brightest galaxies

$0.0 < z < 0.4$



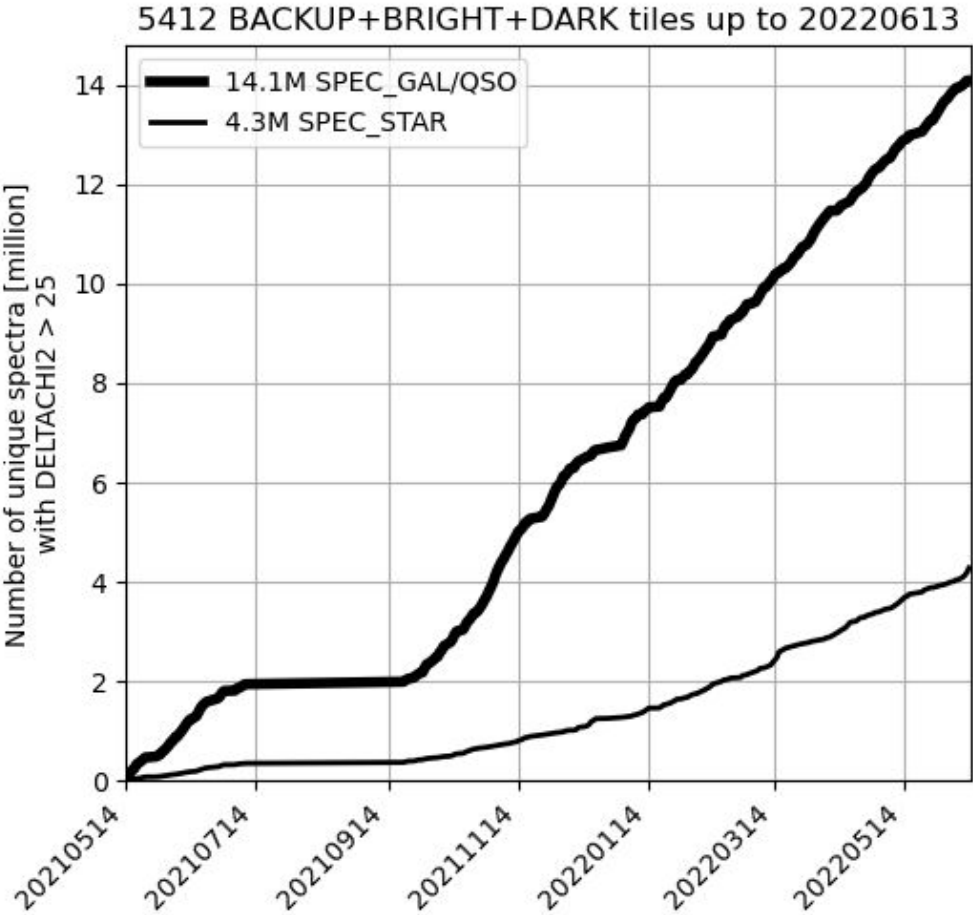
DESI survey progress: 28% of dark time program done as of June 2022

Main/DARK : 2754/9929 (=28%) completed tiles up to 20220611

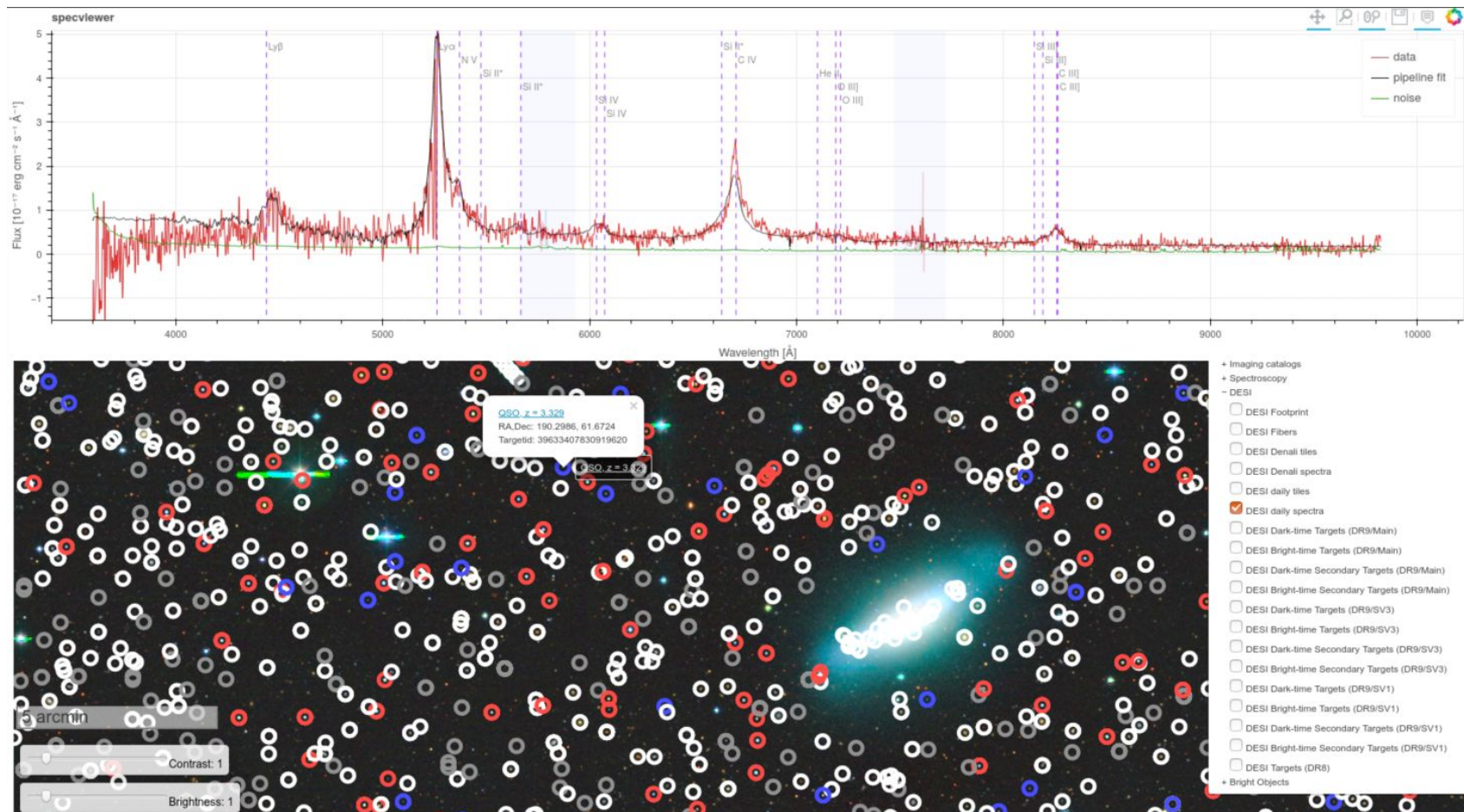


also, Main/BRIGHT 40% completed

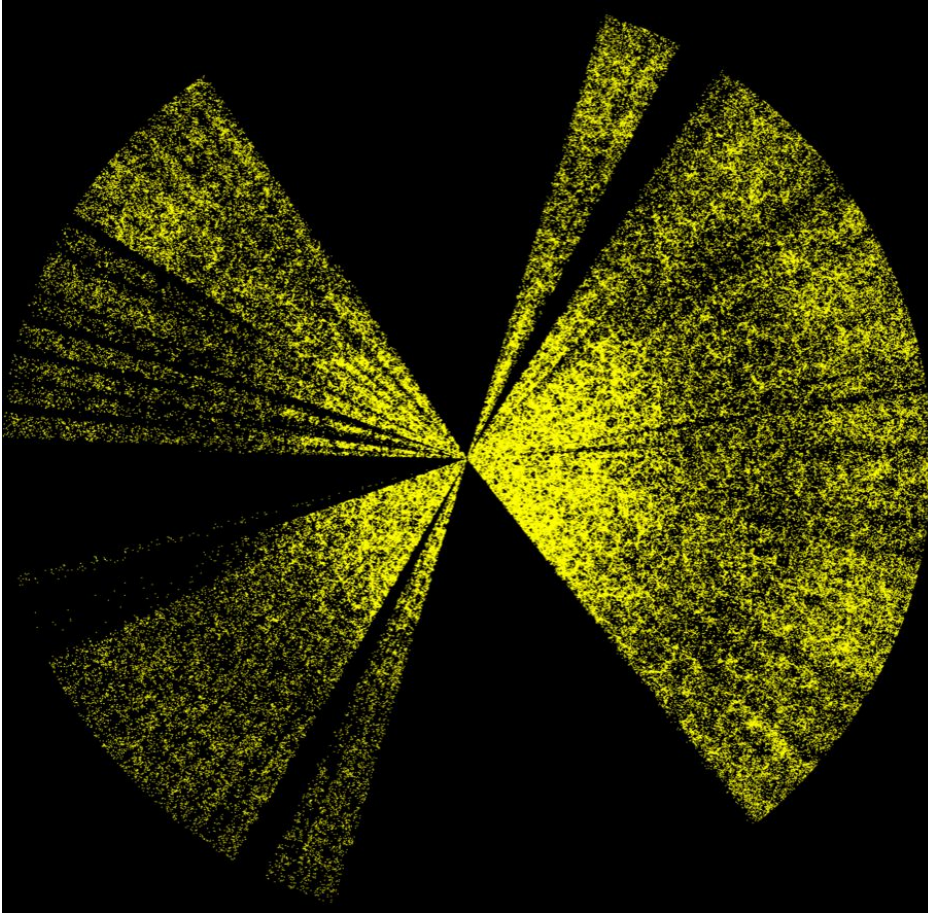
DESI survey progress:
>14 million galaxy and quasar spectra with redshifts in June 2022
>4 million stars



DESI survey progress: >14 million galaxy and quasar spectra with redshifts in June 2022



DESI survey progress: >14 million galaxy and quasar spectra with redshifts in June 2022

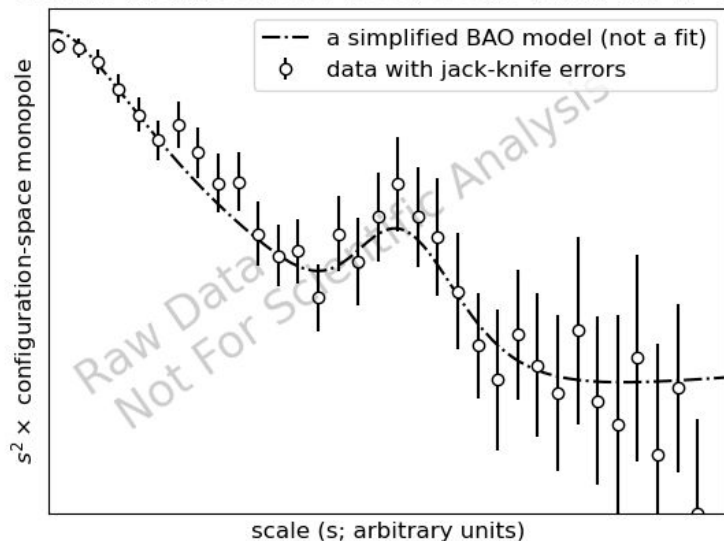


One slice in the DESI survey down to $z=1$

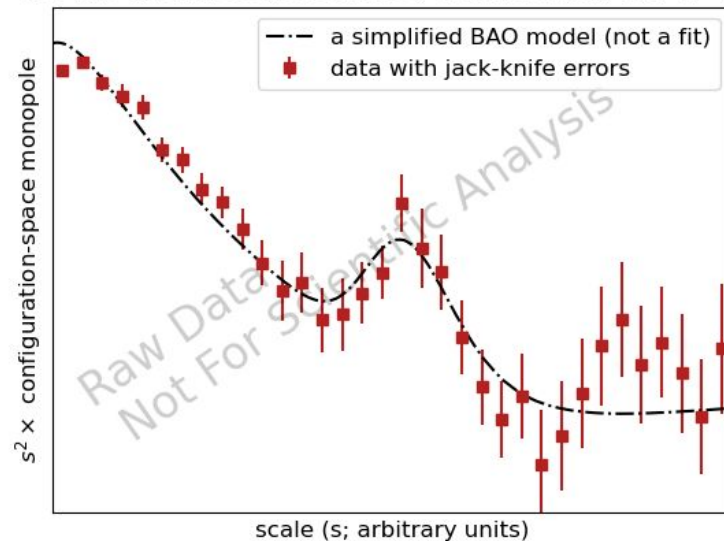
DESI survey progress

BAO signal visible in the data set from just the first 2 months

1st two months of DESI BGSs; 633204 with $0.1 < z < 0.5$

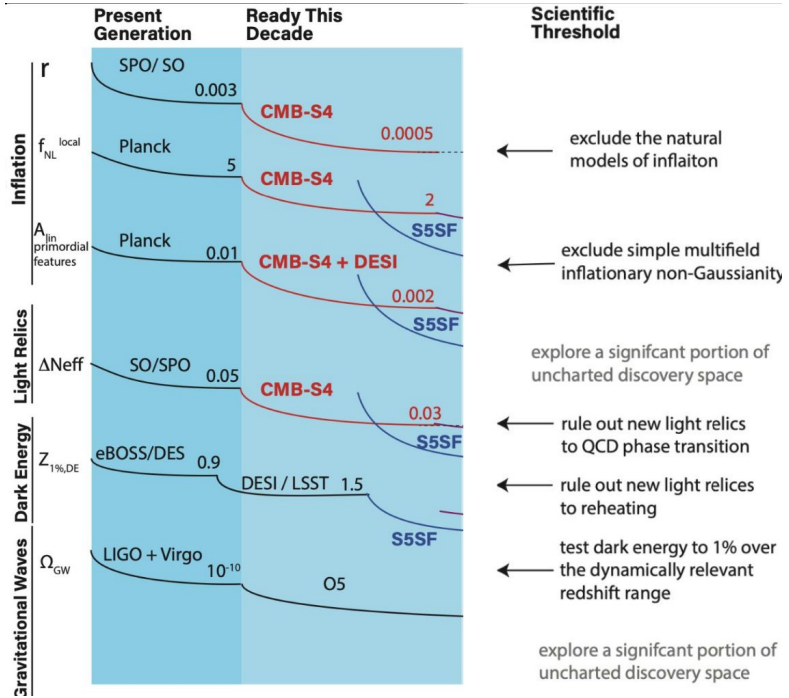
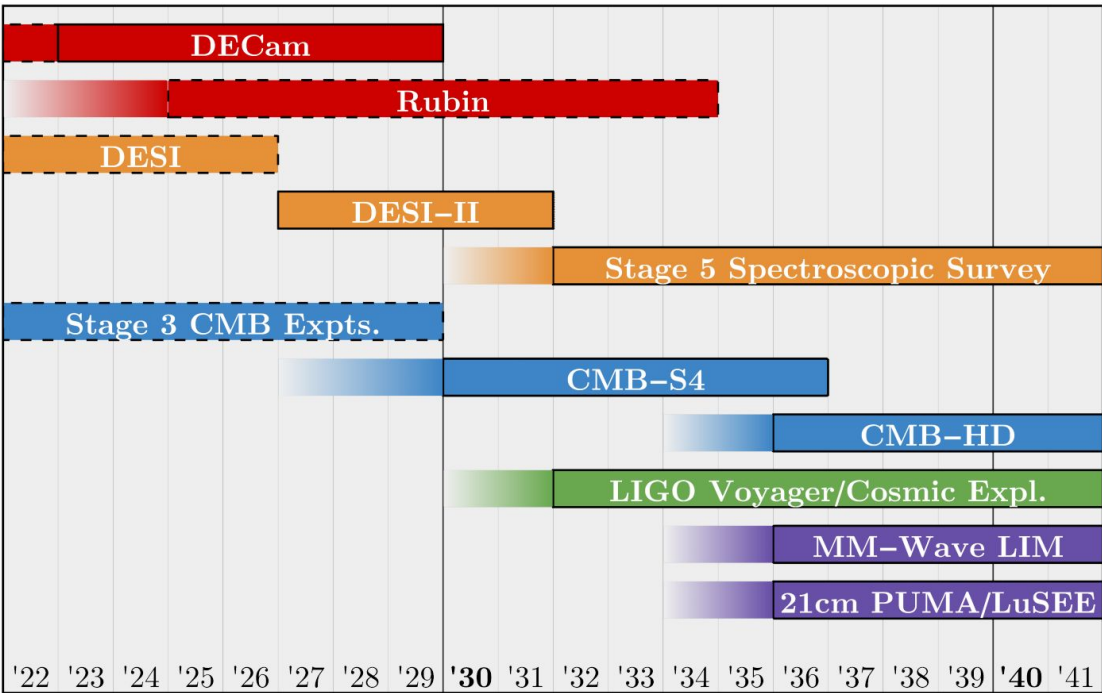


1st two months of DESI LRGs; 262269 with $0.4 < z < 1.1$



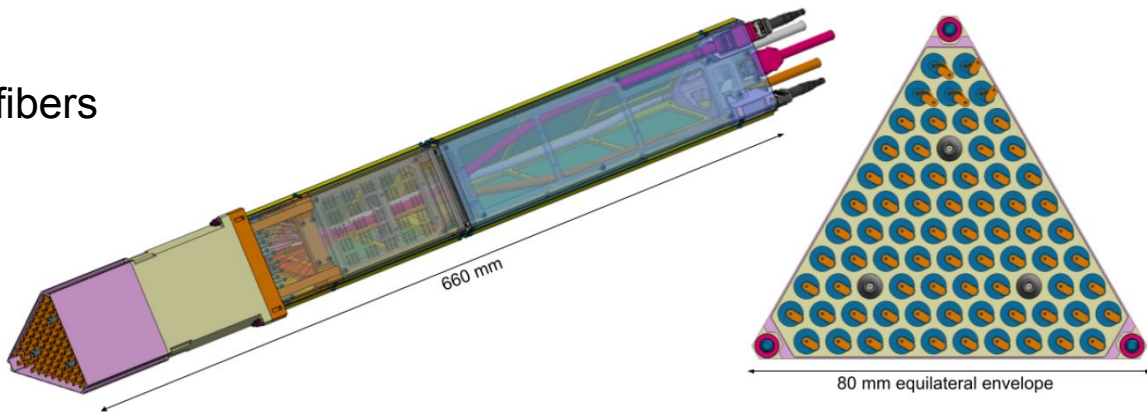
Now past one year of data taking ...

Rubin Observatory and DESI, DESI-II, Stage 5 Spectroscopy Survey in Snowmass Cosmic Frontier



DESI-II upgrade :

- upgrade of focal plane: >10,000 fibers
- more spectrographs
- better CCDs



DESI-II main science driver :

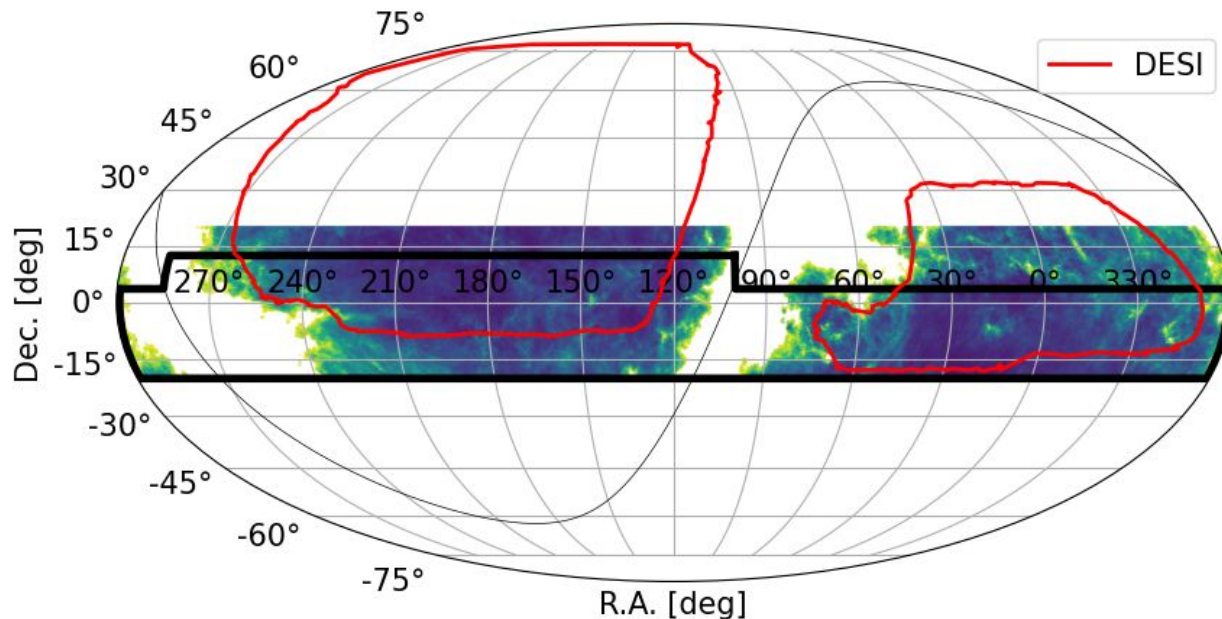
**Cosmic expansion and growth rate of structure in the redshift range 2.5-3.5
with Lyman Break Galaxies**

with extensions of DESI surveys (LRG, ELG, extended Bright Galaxy Survey, QSOs),
a Lyman-alpha Emitter program and an extended Milky Way Survey

DESI-II Lyman Break Galaxy (LBG) program at $z \sim 3$

Reference LBG survey

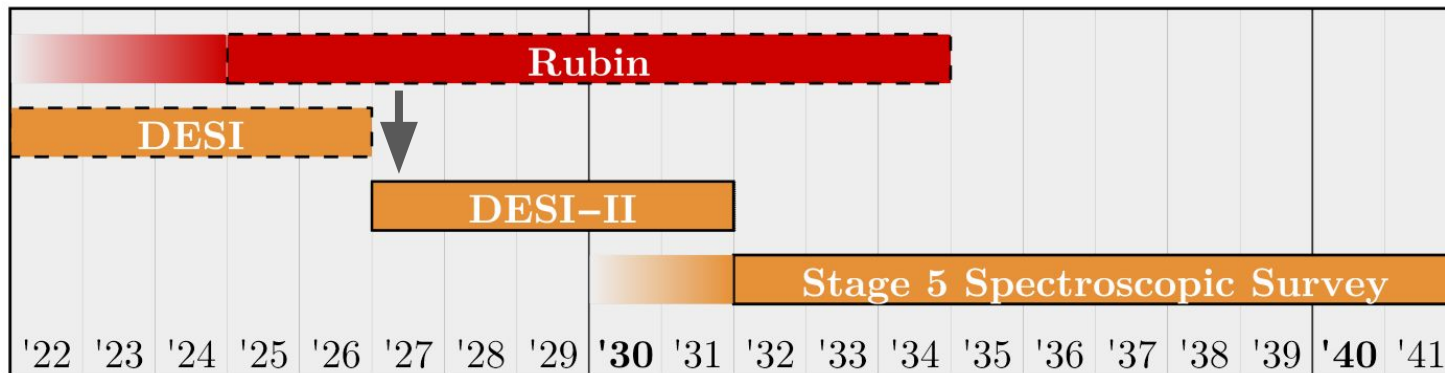
- **Declination range** : $[-20, +20]$ deg , excluding regions close to Galactic plane with $E(B-V) > 0.2$
- **Survey area** : 10900 deg^2
- Target selection based on LSST 2-year sample
(assumption: 5-sigma depth of $u=24.8, g=25.7, r=25.8$, AB, for extended sources)



DESI-II Lyman Break Galaxy (LBG) program at $z \sim 3$

Reference LBG survey

- **Declination range** : $[-20, +20]$ deg , excluding regions close to Galactic plane with $E(B-V) > 0.2$
- **Survey area** : 10900 deg^2
- Target selection based on LSST 2-year sample
(assumption: 5-sigma depth of $u=24.8$, $g=25.7$, $r=25.8$, AB, for extended sources)
- Before 2028



DESI-II Lyman Break Galaxy (LBG) program at $z \sim 3$

Reference LBG survey

- **Declination range** : $[-20, +20]$ deg , excluding regions close to Galactic plane with $E(B-V) > 0.2$
- **Survey area** : 10900 deg^2
- Expected survey duration : 4-5 years
- Expected LBG target density of 1000 deg^{-2} for $300\text{-}500 \text{ deg}^{-2}$ good redshifts
(new pilot surveys being planned for DESI;
see current pilot survey results in Anand Raichoor's talk)
- Complemented with extended LRG (higher z) , ELG (density), and BGS (low redshift deeper magnitude selected sample), + Milky Way survey in bright time
- Survey can also be done with current DESI hardware with modest reduction of target density

Cosmology forecast

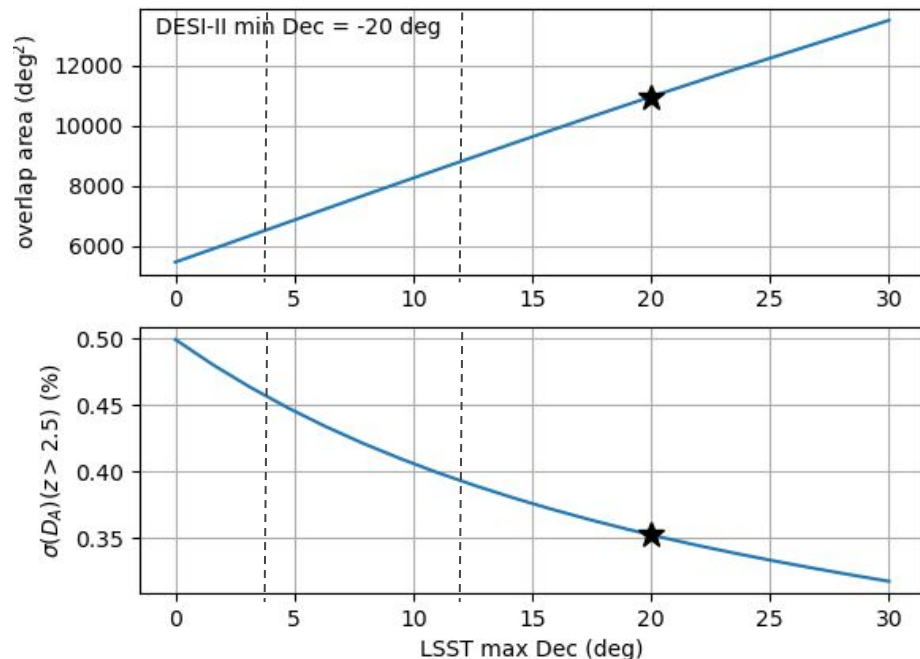
- assumption: LBG bias=5, density = 300 deg^{-2} , redshifts in the range $[2.5, 3.5]$, 10900 deg^2
- $\sigma(D_a) (z > 2.5) = 0.35 \%$
- $\sigma(H) (z > 2.5) = 0.65 \%$
- $\sigma(f \text{ Sigma}8) (z > 2.5) = 4.7 \%$

DESI-II Lyman Break Galaxy (LBG) program at $z \sim 3$

Strongly depends on LSST cadence and footprint

trade-offs with dec range

precision scales with $(\text{overlap area})^{-1/2}$



trade-offs with u-band depth

- Shallower u means more contamination in the original selection.
- More sophisticated target selection algorithms in dev.

see next talk from Anand Raichoor

Conclusion

- DESI survey is well advanced (28% for dark time), promising early science results
- DESI will continue to operate during the LSST survey, an upgrade doubling the number of fibers is being considered.
- DESI-II and a stage 5 spectroscopic survey are part of the Snowmass roadmap
- DESI-II will aim at measuring cosmic expansion and growth rate at $z \sim 3$ along with science from other lower- z tracers.
- Its scientific outcome is tied to the footprint overlap with LSST and its cadence. **We advocate for an early northern survey in the Dec range $[-20,20]$ with deeper u-band in the first 2 years (+g,r at nominal 2 year depth)**
- LSST science would benefit a lot from DESI (photo- z calibration, cross-correlations, clusters, transients, dark matter in Milky-Way and its satellites)

Next talks in this session

- The DESI-2 LBG survey - Anand Raichoor
- LSST x DESI science - Joseph DeRose
- DESI redshifts for LSST transients - Segev BenZvi
- LSST and DESI Milky Way science - Connie Rockosi

backup

DESI-II Observation program

Designed around $z > 2$ LBG as primary science driver
but with several other programs (spare fibers, bright time)

Many configurations are possible

- $z > 2$ (Ly α) QSO : 100/deg²
- $0.8 < z < 1.2$ LRG: 800/deg²
- $z > 1$ ELG: 500-1000/deg²
- $z < 1$ magnitude-limited sample: up to 3500/deg²
- very low- z sample ($z < 0.05$): 400/deg²

