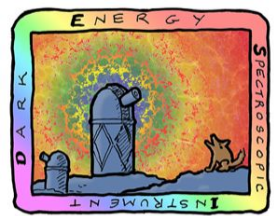


# The Dark Energy Spectroscopic Instrument (DESI)

**Kyle Dawson**, University of Utah  
On behalf of the DESI Collaboration

2022 CMB-S4 Collaboration Meeting

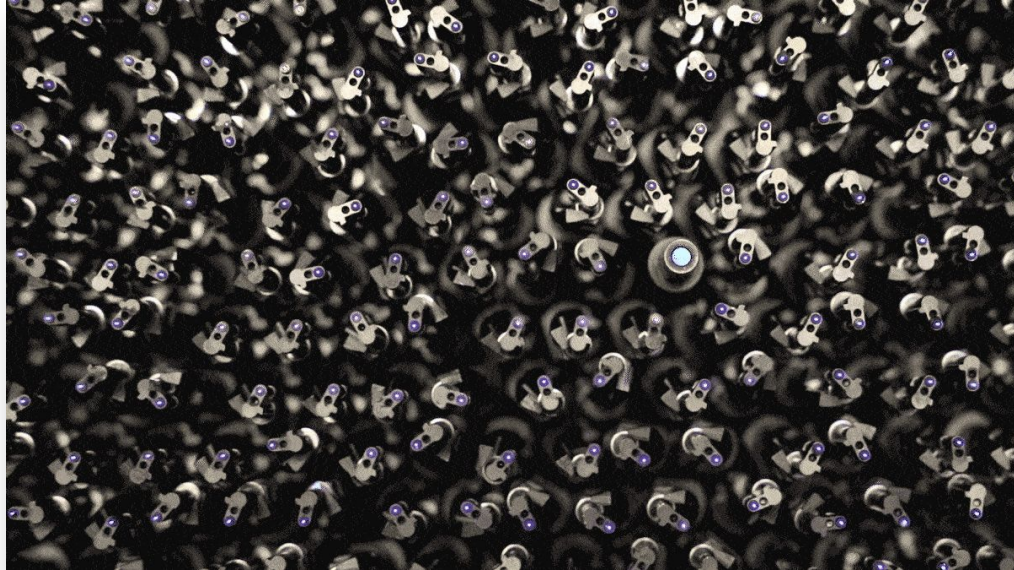




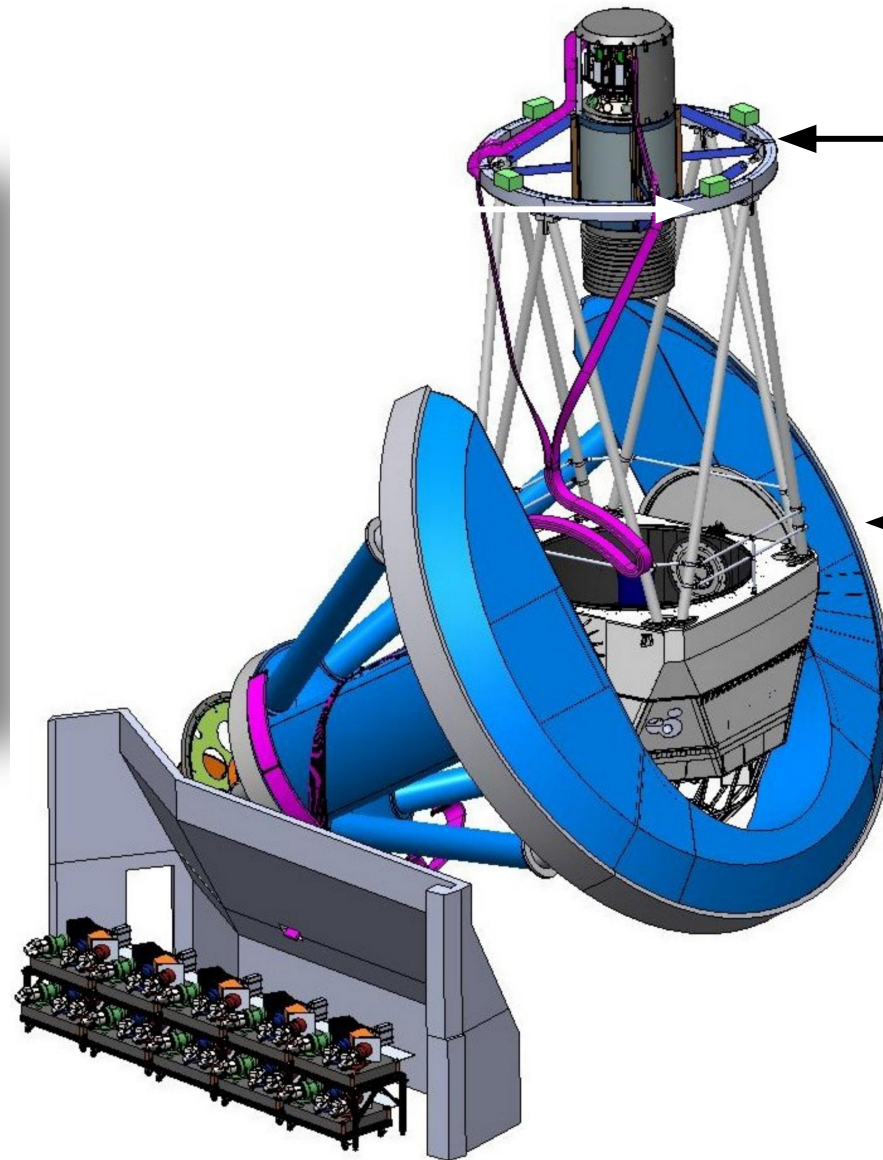
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# DESI: Massively-multiplexed Spectroscopy

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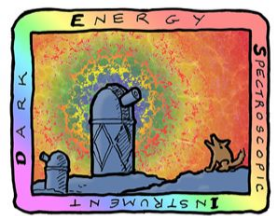
~1 minute to position fibers!



Focal plane  
assembly with  
5000 fiber  
positioners

Mayall 4m  
telescope

10 spectrographs  
(360-980nm)



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# Uninterrupted Galaxy and Quasars from $0 < z < 3.5$

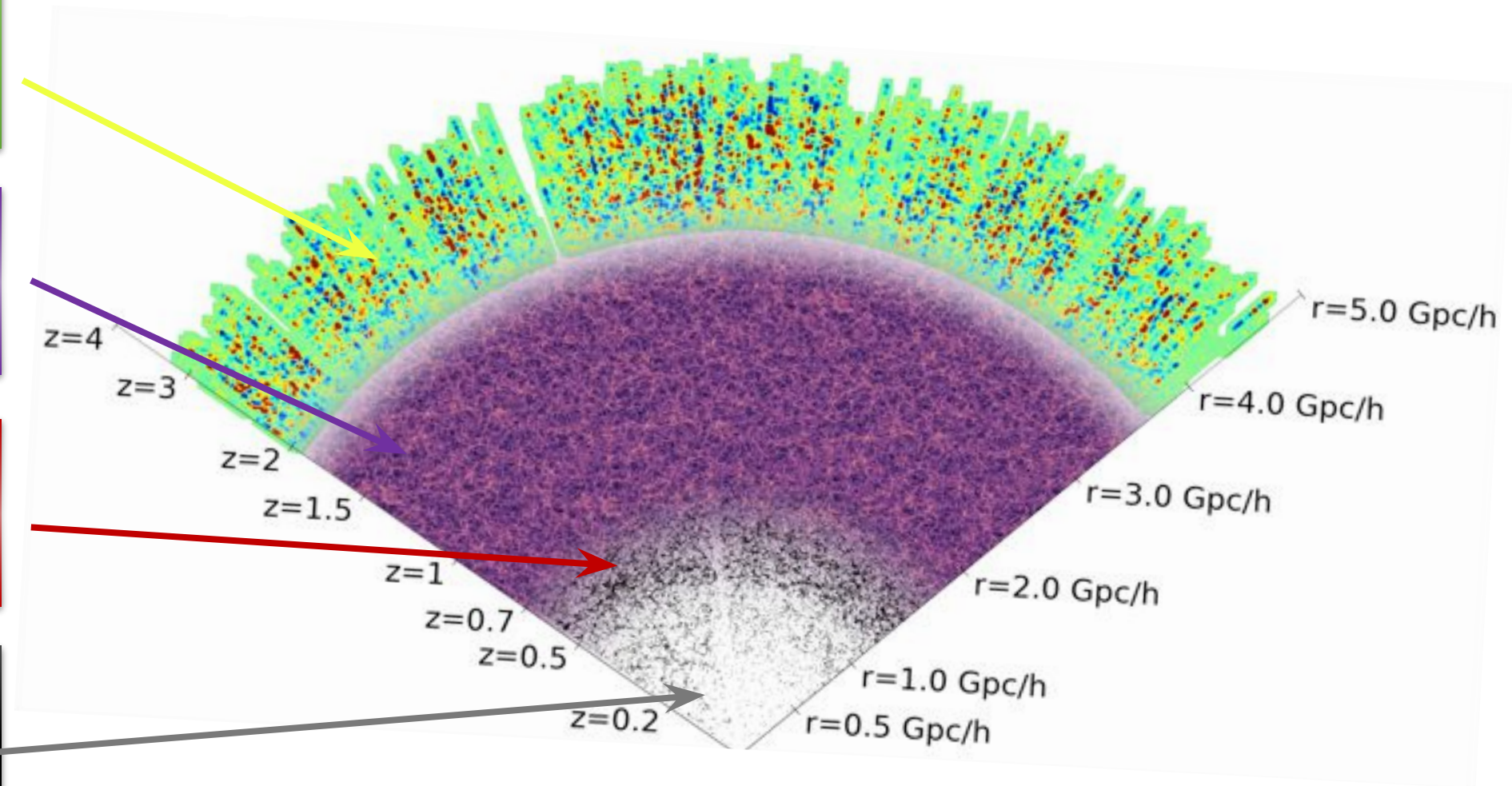
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3 million quasars +  
Ly- $\alpha$  forest ( $1 < z < 3.5$ )

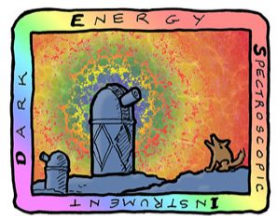
16 million Emission  
Line Galaxies  
( $0.6 < z < 1.6$ )

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

13 million Bright  
Galaxies  
( $0.0 < z < 0.4$ )



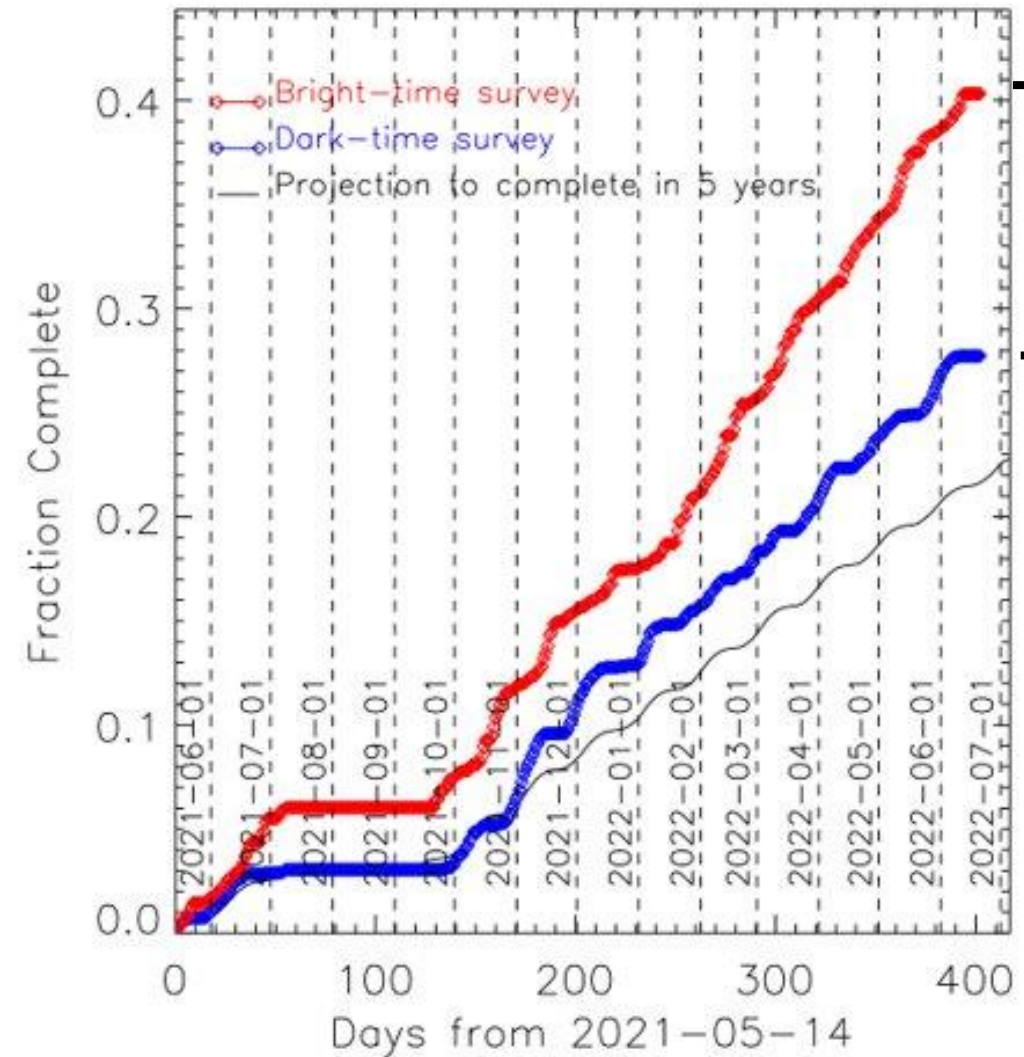
Plus 10 million Milky Way stars



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# First year sample

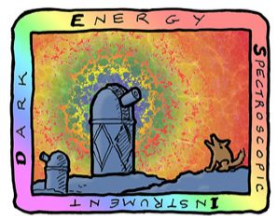
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- 6.3M Bright Galaxies ( $z < 0.5$ )
- 2.6M stars

- 2.7M LRGs ( $0.4 < z < 1.1$ )
- 4.1M Emission line galaxies ( $0.6 < z < 1.6$ )
- 1.7M QSOs ( $0.9 < z < 2.1$  tracers &  $z > 2.1$  with Ly $\alpha$  forest)

**First results on arxiv tonight**

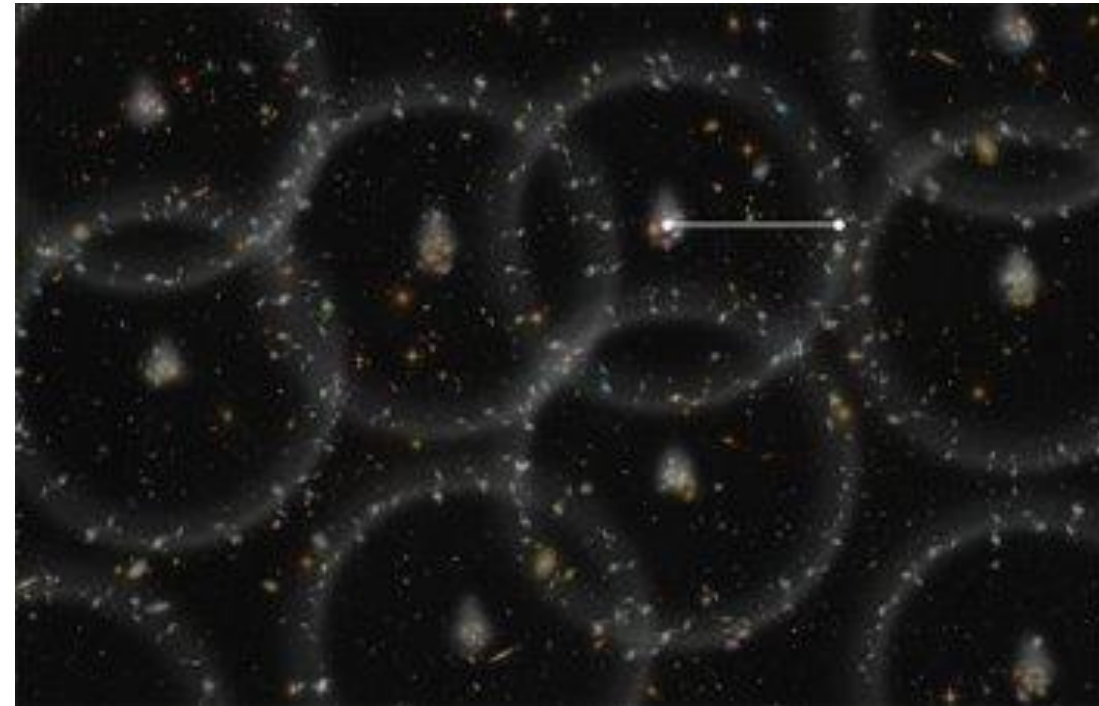


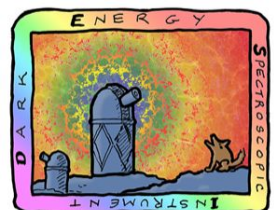
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# Primary Science Driver: Dark Energy with BAO

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- 10X improvement to  $w_0 w_a$  posterior area compared to Stage-II Supernova Ia
- Stage-III BAO distance measurements:
  - 0.70% precision at  $z < 1$
  - 1.19% precision at  $z > 1$
- **DESI BAO distance science requirement:**
  - **0.28% precision at  $z < 1.1$**
  - **0.39% precision at  $1.1 < z < 1.9$**
  - **<1% precision at  $z > 1.9$**
- Expect to exceed requirements by  $\sim 1.4X$  in final measurements





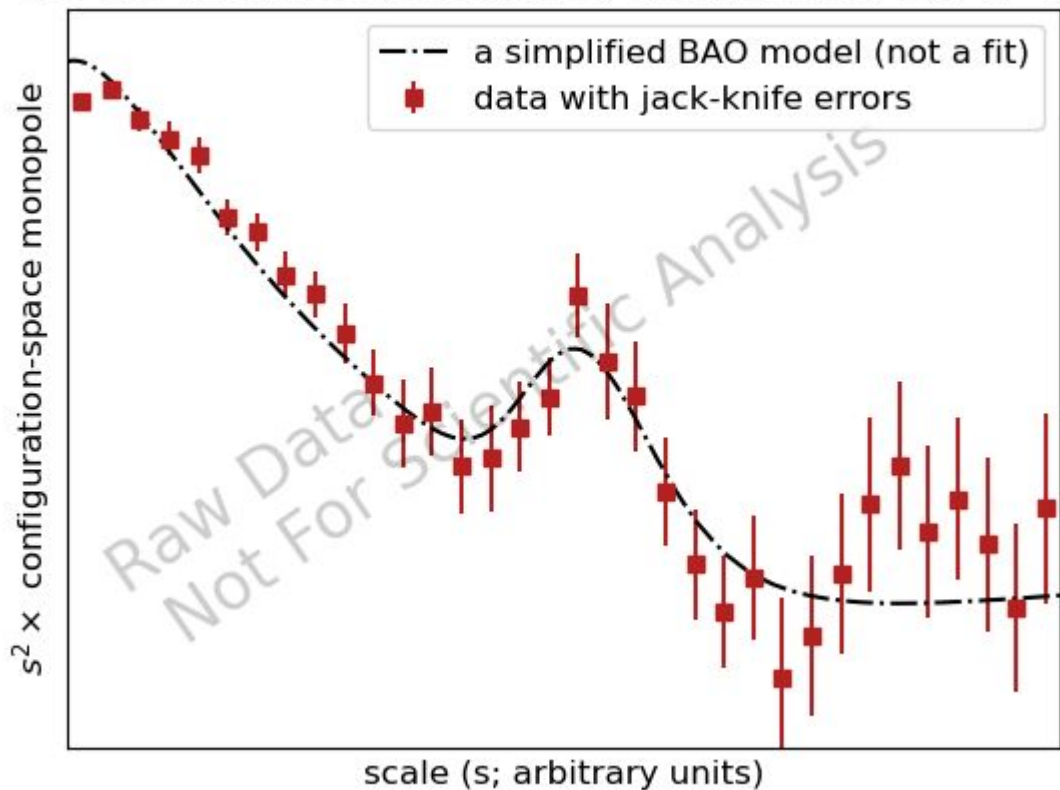
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# Early BAO results: Correlation function monopole

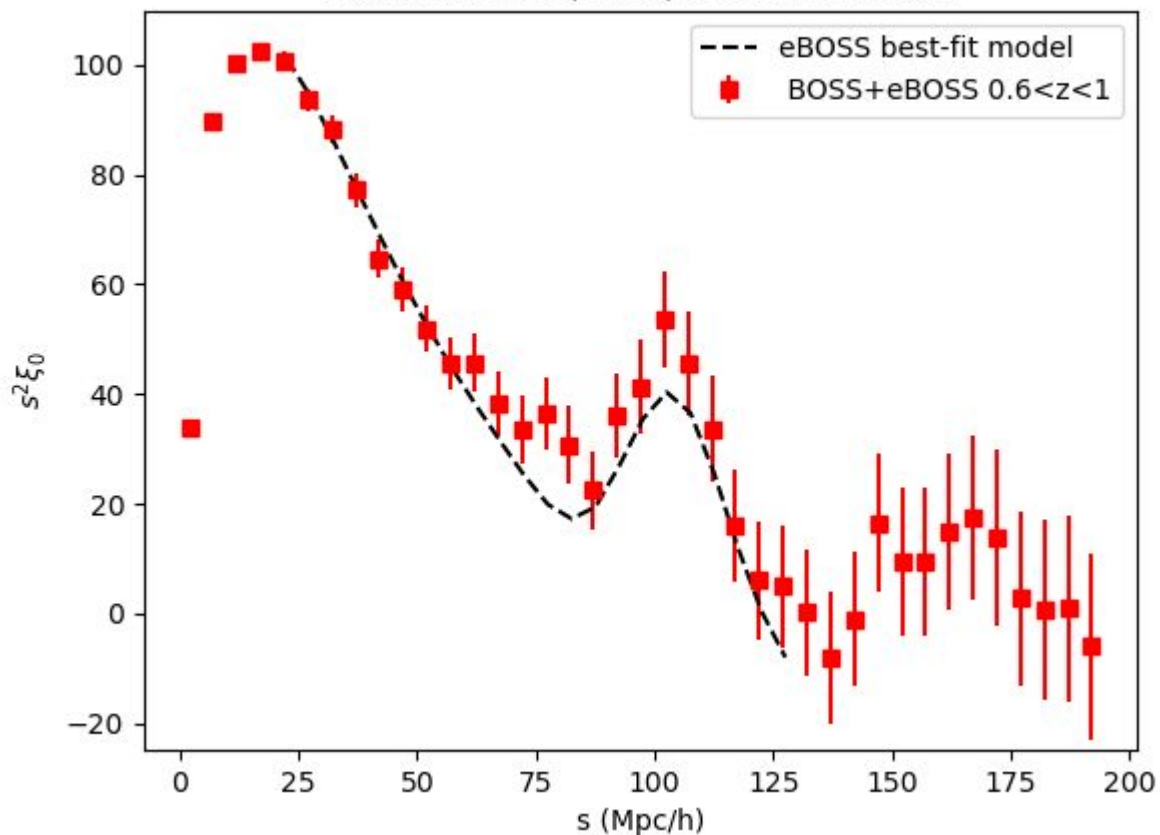
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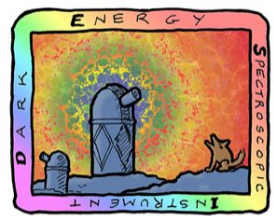
## 2 months of DESI LRGs vs. BOSS+eBOSS

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



Bautista et al. (2020) SDSS DR16 LRG



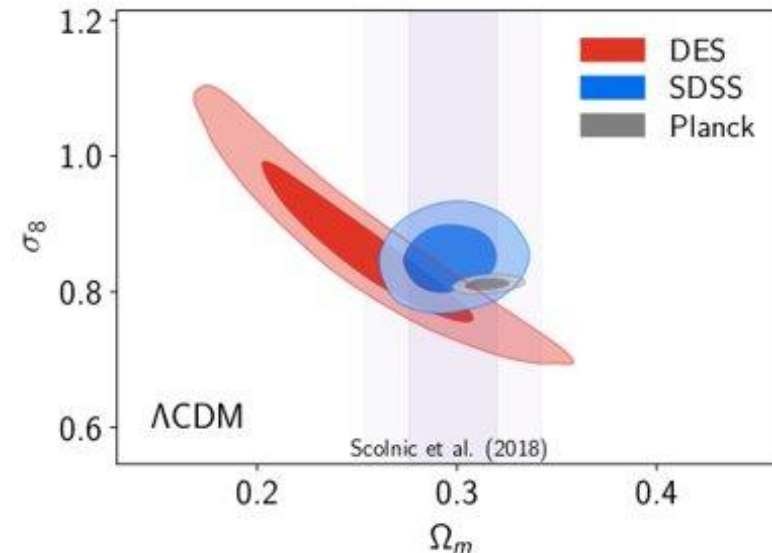
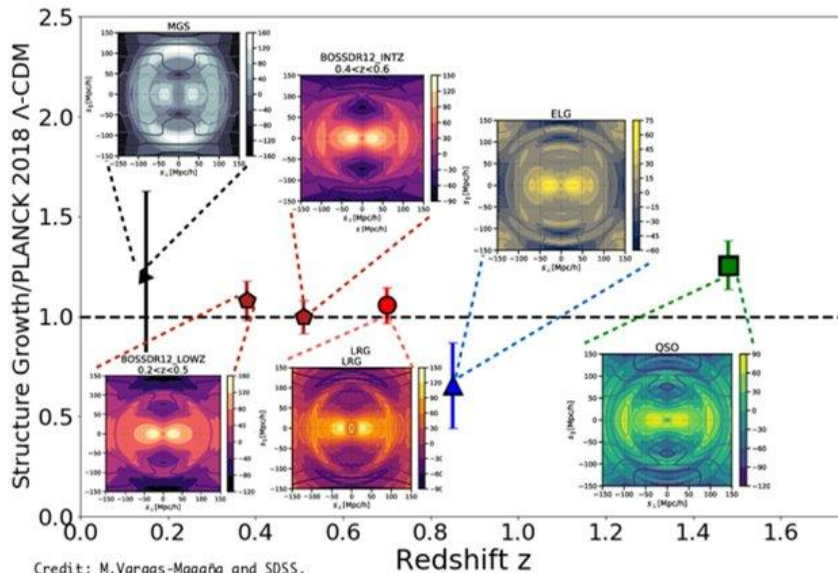


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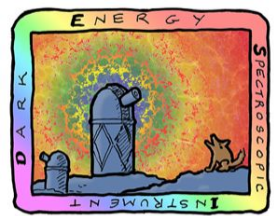
# Beyond BAO: Redshift Space Distortions

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- Anisotropic clustering: peculiar velocities and rate of infall
- Stage-III Spectroscopy
  - 4.78% precision over the redshift interval  $0 < z < 1.5$
  - 3.5% precision on  $\sigma_8$ , no tension with Planck
- DESI: 21 independent measurements to  $z < 2.1$  with median 5.2% precision



Alam et al. (eBOSS Collaboration), 2021



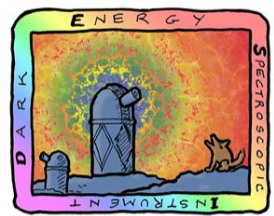
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# Beyond RSD: Growth of Structure

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- Year 1 strategy:
  - Collaboration-wide demonstration of primary BAO+RSD measurements
  - Measurements of primordial non-Gaussianity in power spectrum
- Year 3 strategy (in discussion now)
  - Collaboration-wide effort to enhance growth measurements over all redshifts
  - Introduce higher order statistics into cosmology results



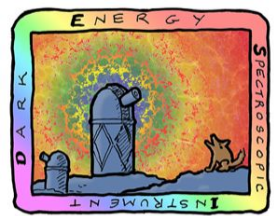


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# Beyond RSD: Growth of Structure

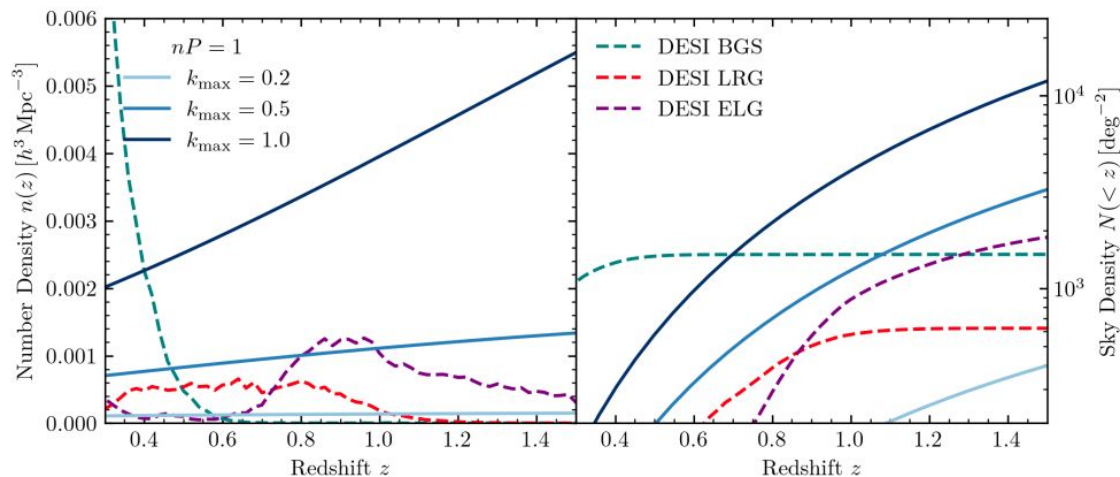
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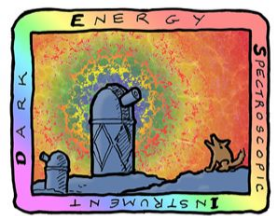
- Potential Year 3 Key Projects
  - $z < 0.1$  peculiar velocities with Tully Fisher + Fundamental plane + SNe Ia
  - $0.1 < z < 1.6$  bispectrum (fnl and  $\sim 30\%$  improvement on RSD)
  - galaxy-galaxy lensing to constrain RSD nuisance terms
  - CMB-DESI cross-correlations to directly measure  $\sigma_8(z)$
  - 1D power spectrum in Lyman-alpha forest for  $\sigma_8(z > 2)$
- **Expect sub-percent precision on  $\sigma_8$  with final RSD analysis**
- **What improvement on  $\sigma_8$  is possible relative to RSD only?**



# Beyond DESI: High Density Galaxy Clustering

- $0 < z < 1.5$ : covers matter-dominated to dark energy dominated regimes
  - Redshift range where most Dark Energy models are best explored
  - Limited by theory and computing
- $nP=1$  approximates optimal balance of number density at a fixed scale
  - 10,000 galaxies/sqdeg  $\rightarrow k_{\max}=1$  h/Mpc for  $z < 1.5$
- 180M galaxies over Rubin footprint “saturates” cosmological information



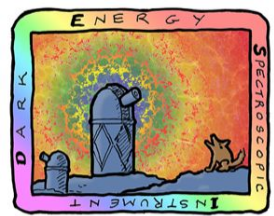


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# Beyond DESI: High Redshift Galaxy Clustering

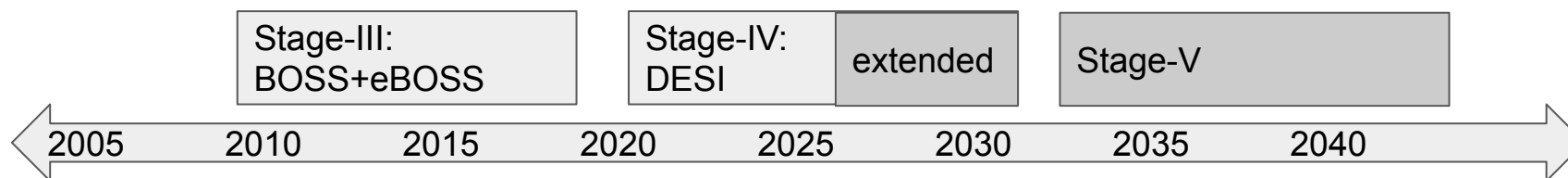
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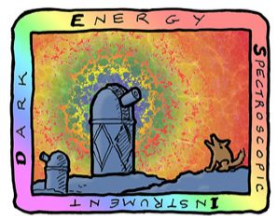
- $z > 2$ : matter-dominated regime with massive volume
  - Experimentally limited with current facilities
  - Spectroscopy of 10's of millions of galaxies over the Rubin footprint would provide high precision **BAO, RSD, neutrino mass, and inflationary constraints**
- Targets for spectroscopy
  - Plentiful (**and faint**) Lyman-break and Lyman-alpha emission galaxies
  - Spectroscopy challenging



# Beyond DESI: Stage-V Roadmap

- DESI will remain premier spectroscopic facility in late 2020's
  - $z < 1$  galaxies easily measured to  $z_{\text{fib}} < 21.6$
  - $z > 2$  Lyman Break galaxies:  $\sim 300/\text{sqdeg}$
  - $z > 2$  Lyman-alpha emission galaxies:  $> 1000/\text{sqdeg}$  w/new imaging
- $> 20\text{M}$  new galaxies overlapping a 10,000 sqdeg Rubin footprint
- Sub-percent BAO precision, percent level RSD precision possible at  $z > 2$
- Immediate tests of concordance cosmology
- Pilot new programs during Stage-V construction



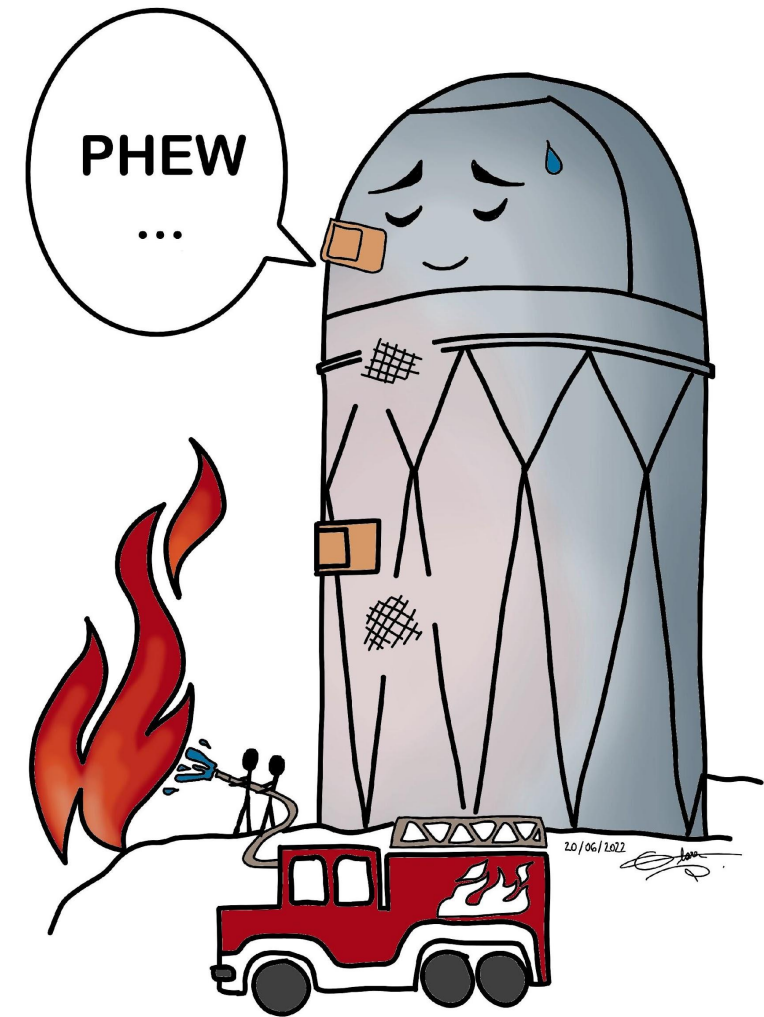


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# Summary

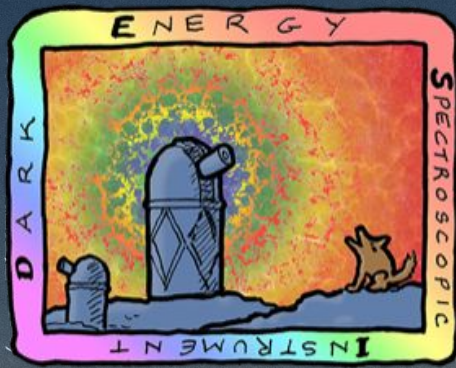
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- Check arxiv for first major release (1pt statistics)
- DESI likely to exceed BAO science requirement
- Demonstrate RSD precision in  $\sim 1.5$  yrs
- Explore  $\sigma_8$  improvements with 3yr sample
- Snowmass: motivate massive Stage-V expansion over all redshifts



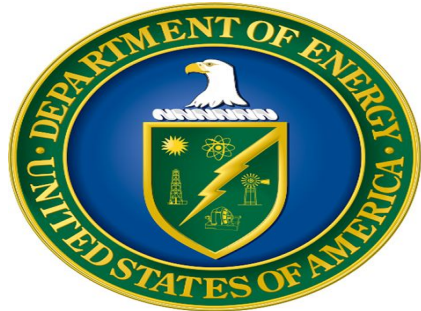
Credit: Clara Delabrouille

Most important: **Thank you to the firefighters and the NOIRLab staff**

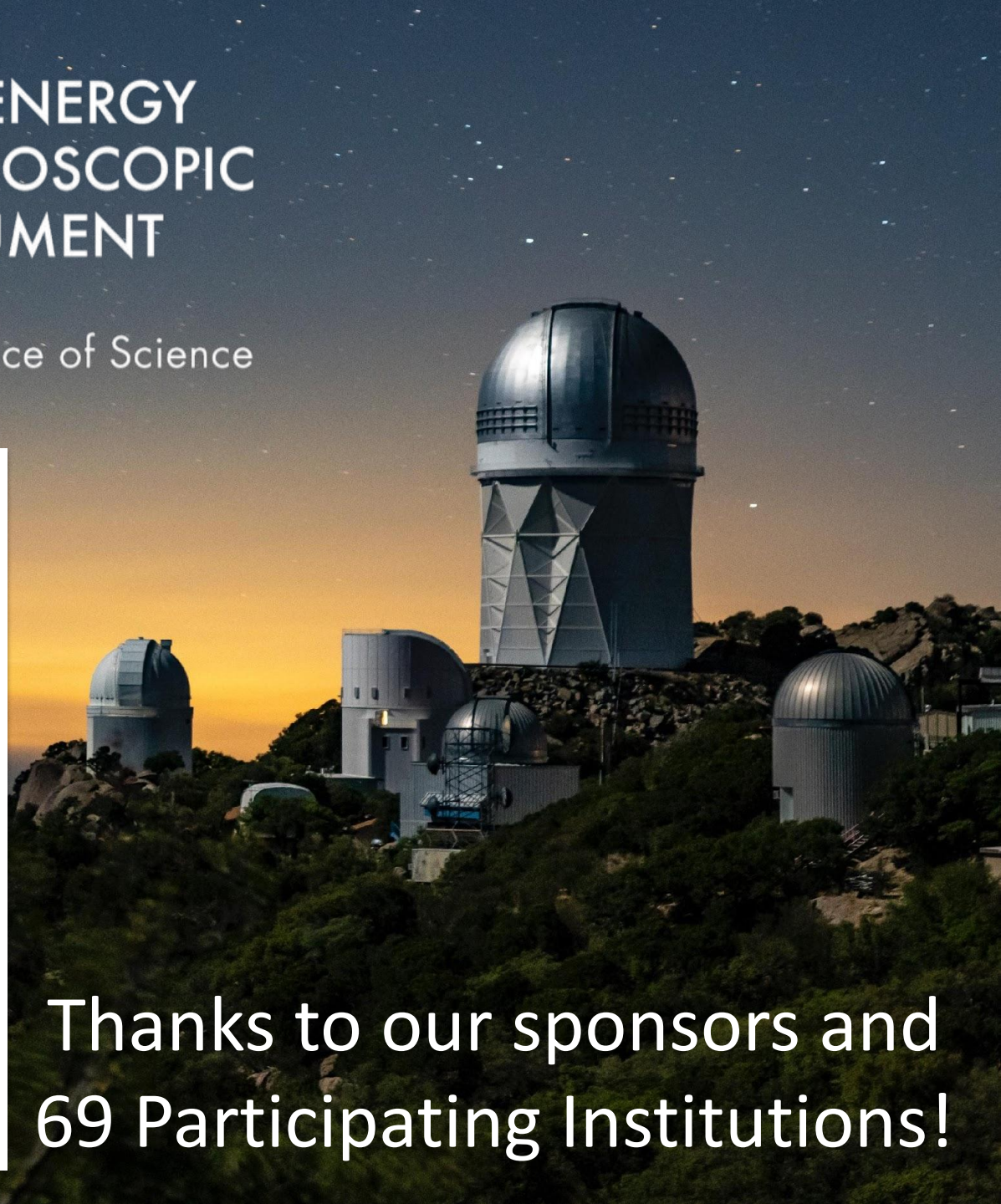


# DARK ENERGY SPECTROSCOPIC INSTRUMENT

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