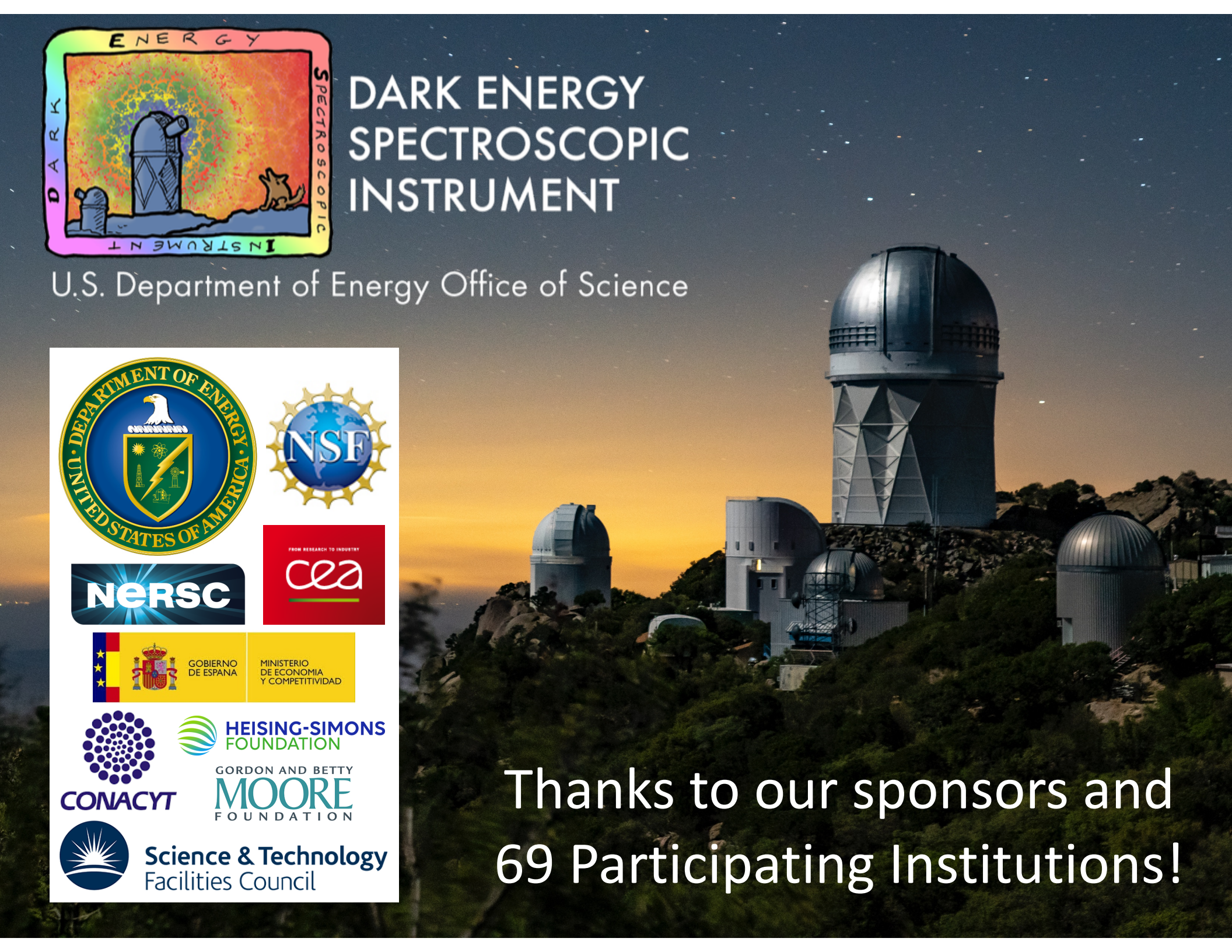
CMB lensing cross-correlations on large scales: a clean probe of primordial non-Gaussianity with DESI quasars and Planck lensing

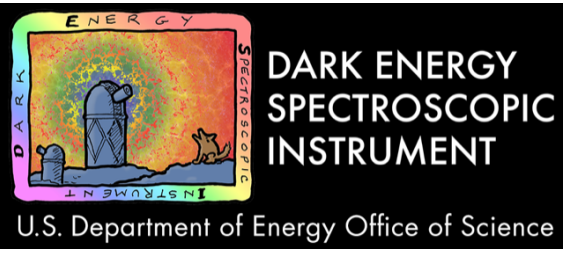
Alex Krolewski, Perimeter Institute & University of Waterloo

CMB S4 conference, 1 August 2023

arXiv: 2305.07650

Alex Krolewski, Will Percival, Simone Ferraro, Edmond Chaussidon, Mehdi Rezaie, + DESI collaboration


ENERGY
DARK
SPECTROSCOPIC
INSTRUMENT
DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science
DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA ·
NSF
NERSC
FROM RESEARCH TO INDUSTRY
cea
GOBIERNO DE ESPANA
MINISTERIO DE ECONOMIA Y COMPETITIVIDAD
CONACYT
HEISING-SIMONS FOUNDATION
GORDON AND BETTY MOORE FOUNDATION
Science & Technology Facilities Council
Thanks to our sponsors and
69 Participating Institutions!



CMB lensing cross-correlation and primordial non-Gaussianity

- Primordial non-Gaussianity creates scale-dependent galaxy bias

$$\Delta b(k) = b_\phi \frac{f_{\rm NL}}{\alpha(k)} = 2(b-p) f_{\rm NL} \frac{\delta_c}{\alpha(k)} \qquad \alpha(k) \propto k^2$$

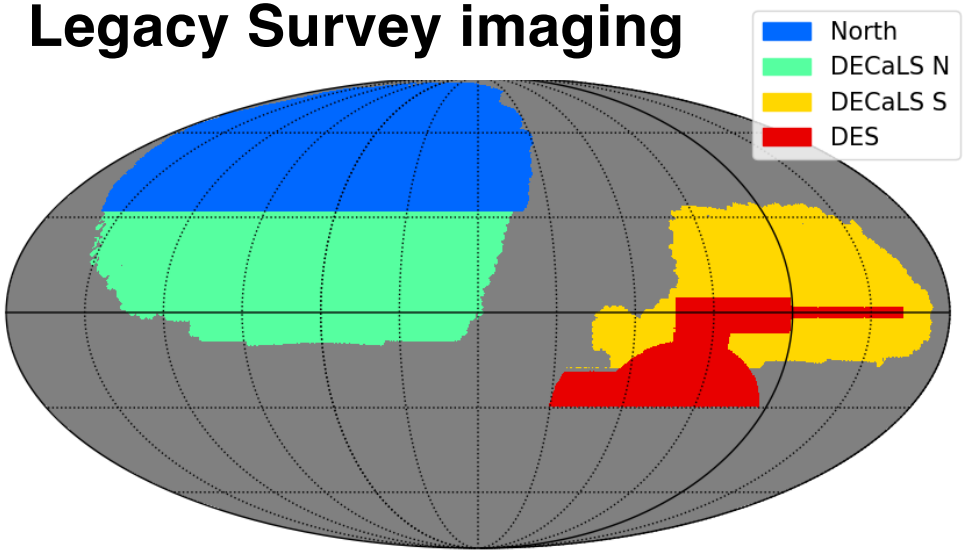
- CMB lensing cross-correlation is a *much* cleaner alternative to the galaxy auto-correlation
  - No noise bias: Survey-specific systematics increase covariance but don't add signal (if uncorrelated between galaxies & CMB)
  - CMB lensing kernel pushes to higher redshift, where the PNG signal is larger and more large-scale modes are accessible

DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

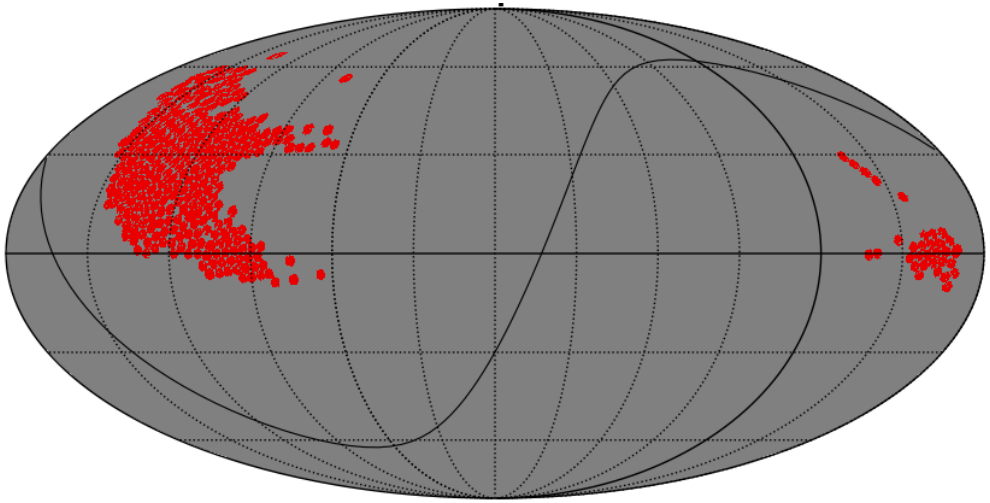
Early DESI data: quasar targets and spectroscopic dN/dz

- DESI 5 year main survey started in May 2021
- Spectroscopic data only *partially* covers sky
  - But we need wide area for PNG constraints
- Solution: DESI quasar targets across entire footprint (14700 deg^2) + spectroscopic dN/dz measurement from early DESI data
  - DESI Y5 will do better: analysis of spectroscopic (Y1) quasar x CMB lensing in prep

Legacy Survey imaging



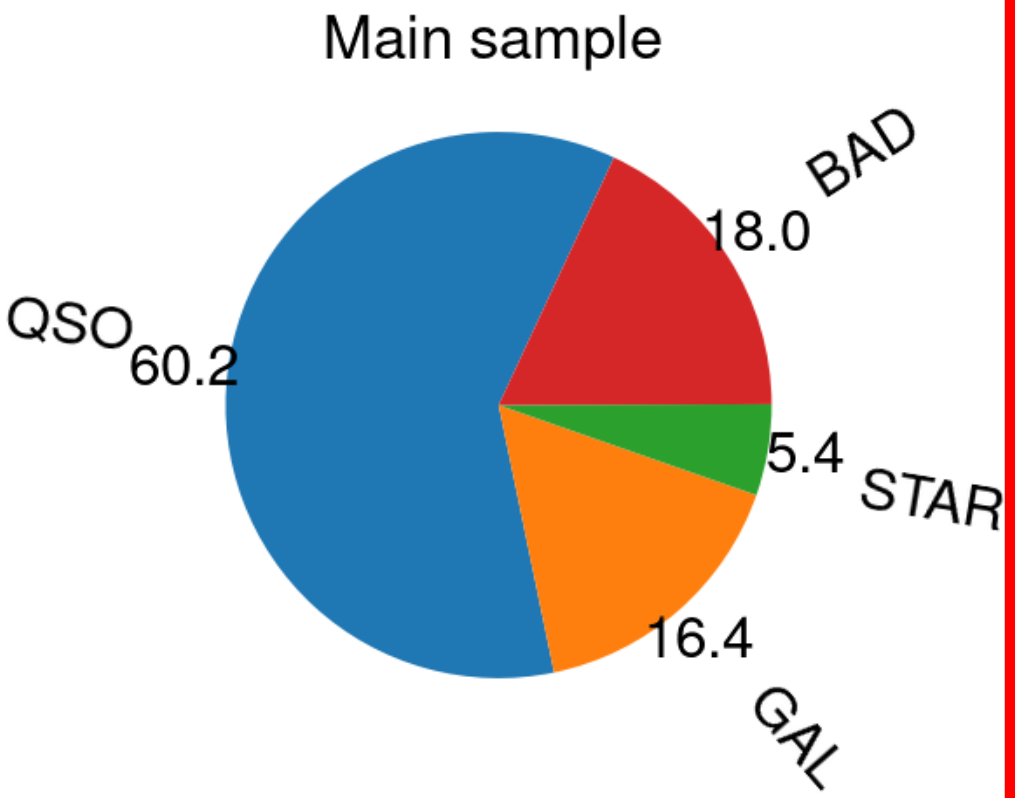
Early DESI spectra

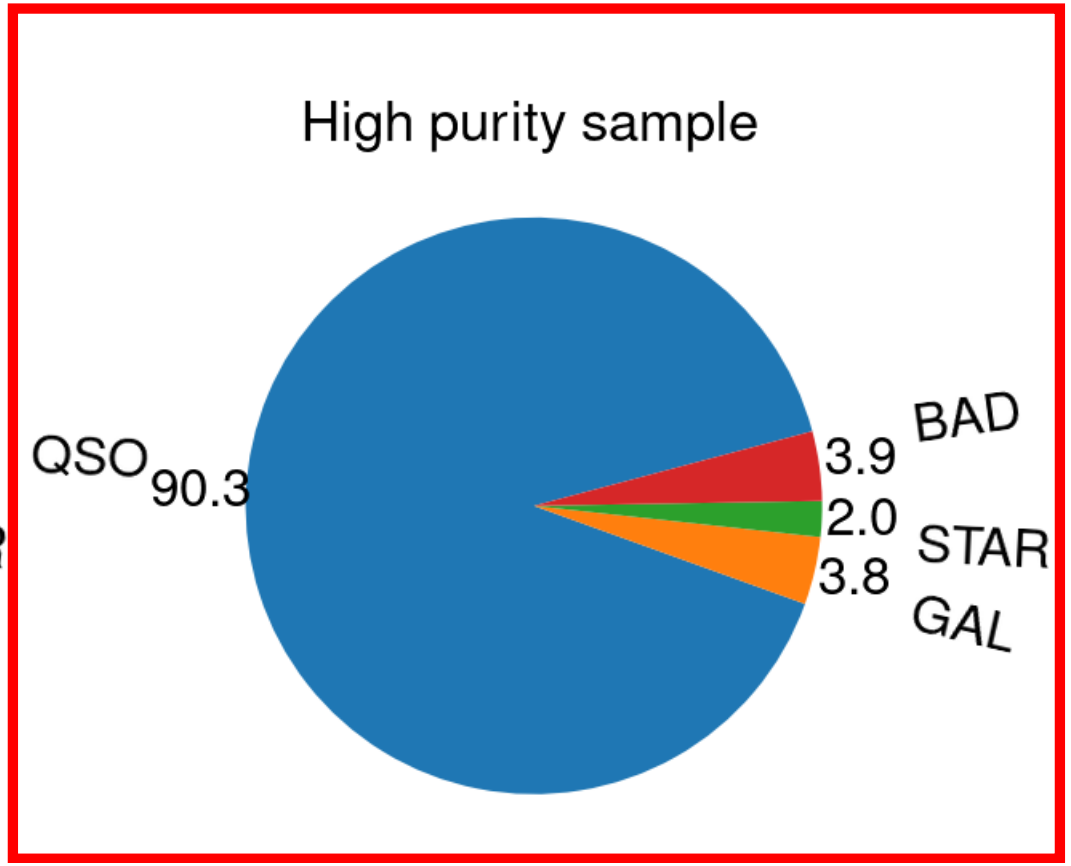


DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

Early DESI data: quasar targets and spectroscopic dN/dz

- The price we pay: 18% of main DESI quasar targets are “unclassified redshifts”
  - Unknown dN/dz, stellar contamination fraction
- Reduce stellar contamination and redshift failure rate by removing faint quasar targets with colors more likely to be stars
- Trade number density (~2x drop) against purity (down to 4% failure rate)

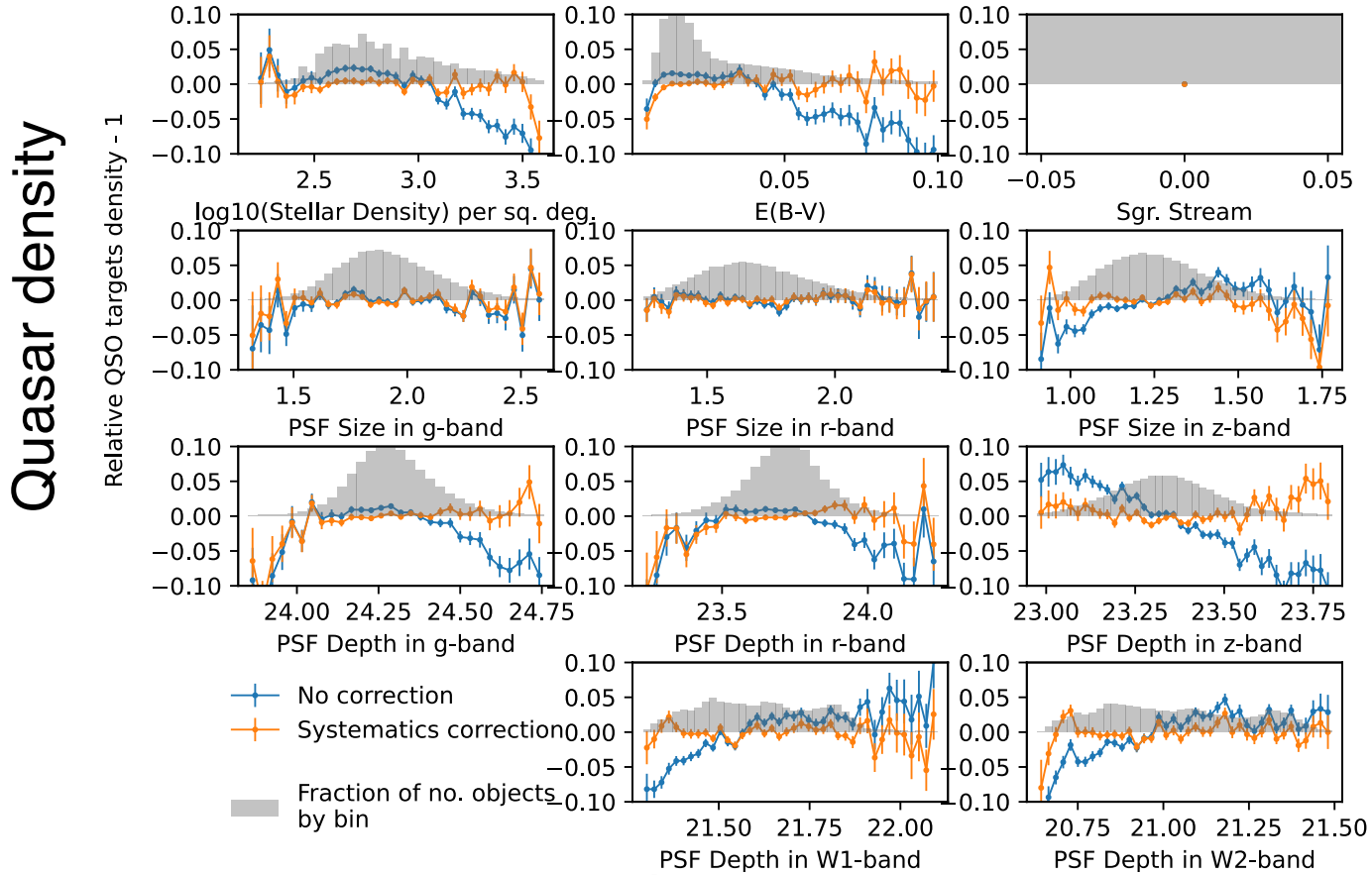




DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

Mitigating imaging systematics

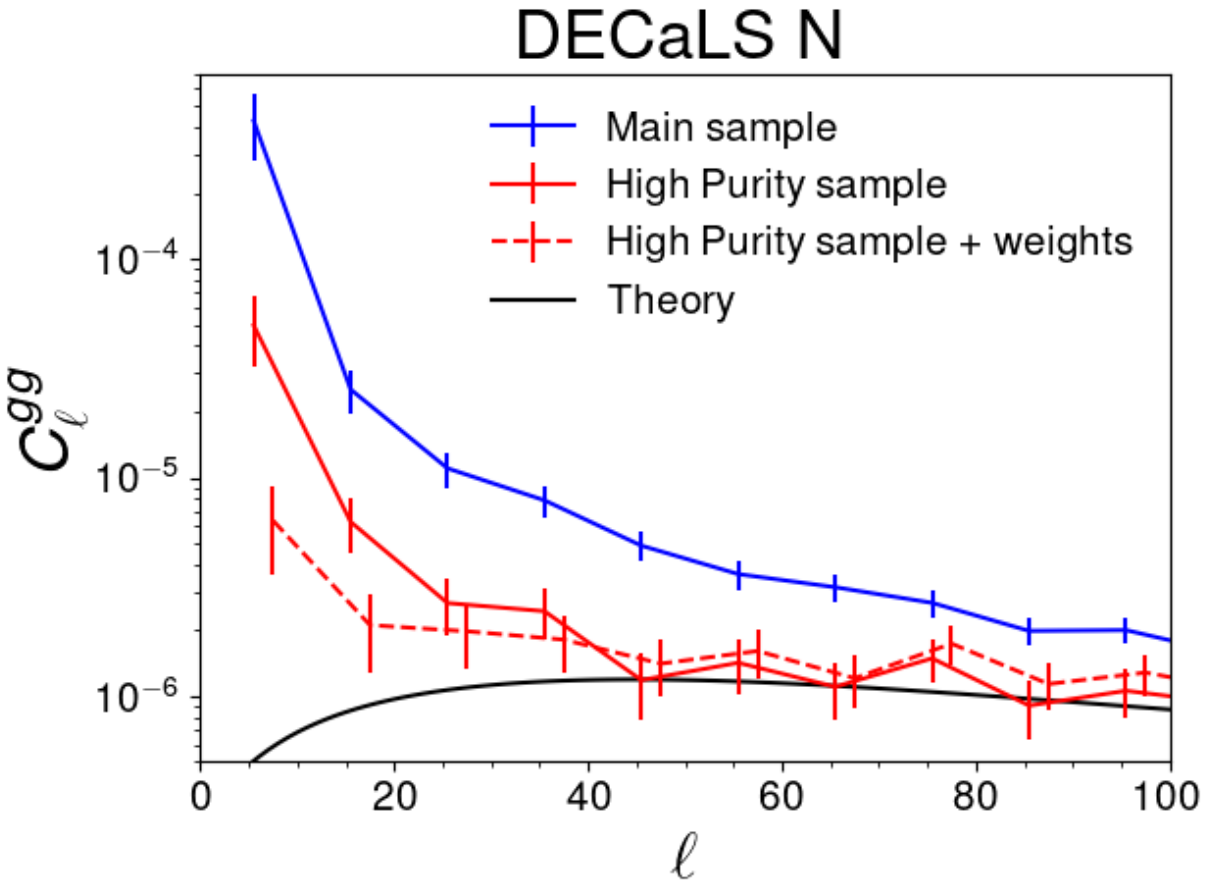
- Quasar targets are faint sources near the detection threshold of imaging surveys
  - Leads to spurious correlations with survey properties, Galactic extinction, stellar density (like CMB foregrounds)
- Linearly regress quasar density against imaging templates to explicitly remove these correlations and reduce excess large-scale power by ~5x



DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

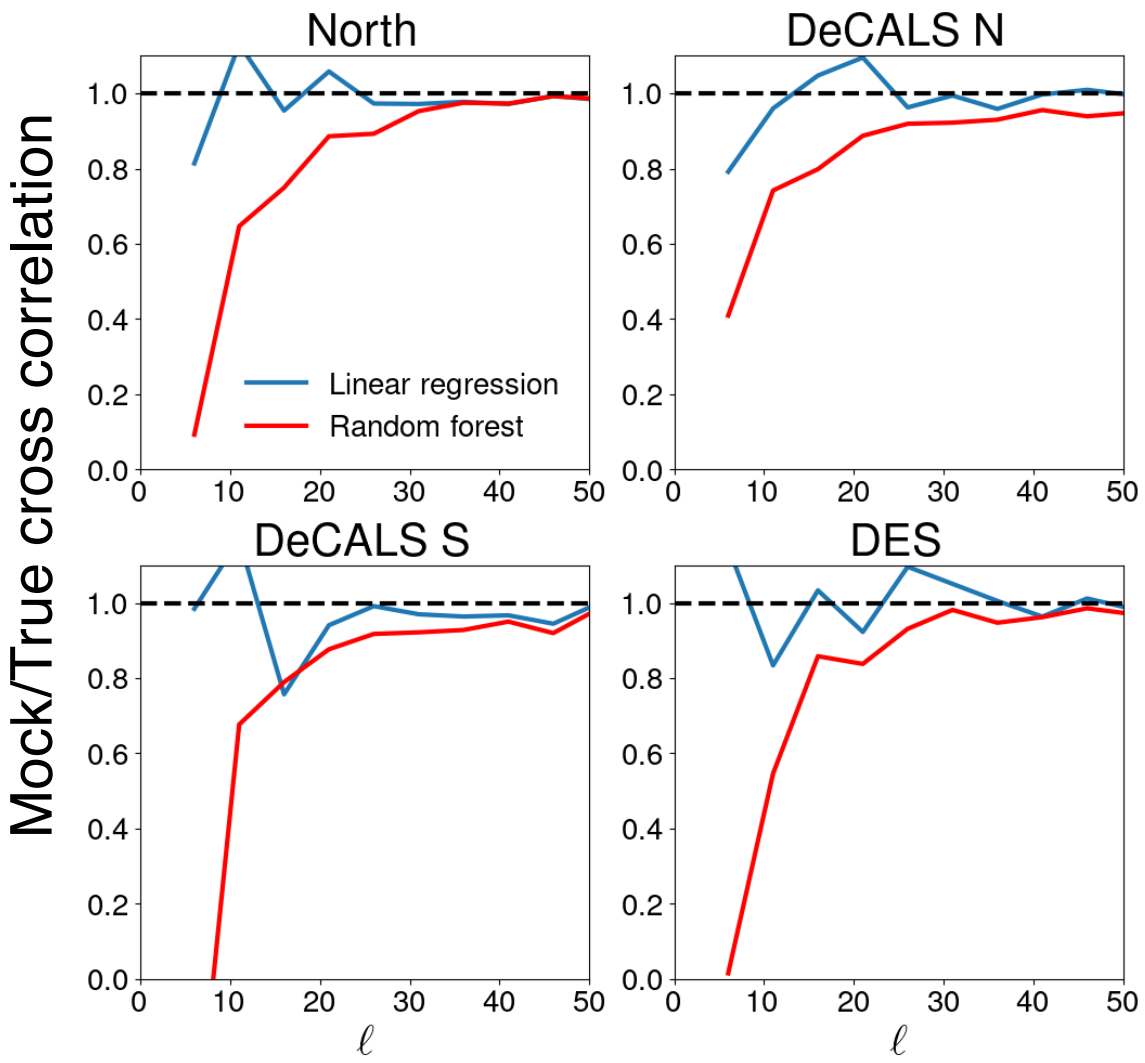
Mitigating imaging systematics

- Quasar targets are faint sources near the detection threshold of imaging surveys
  - Leads to spurious correlations with survey properties, Galactic extinction, stellar density (like CMB foregrounds)
- Linearly regress quasar density against imaging templates to explicitly remove these correlations and reduce excess large-scale power by ~5x



DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

Testing on contaminated mocks

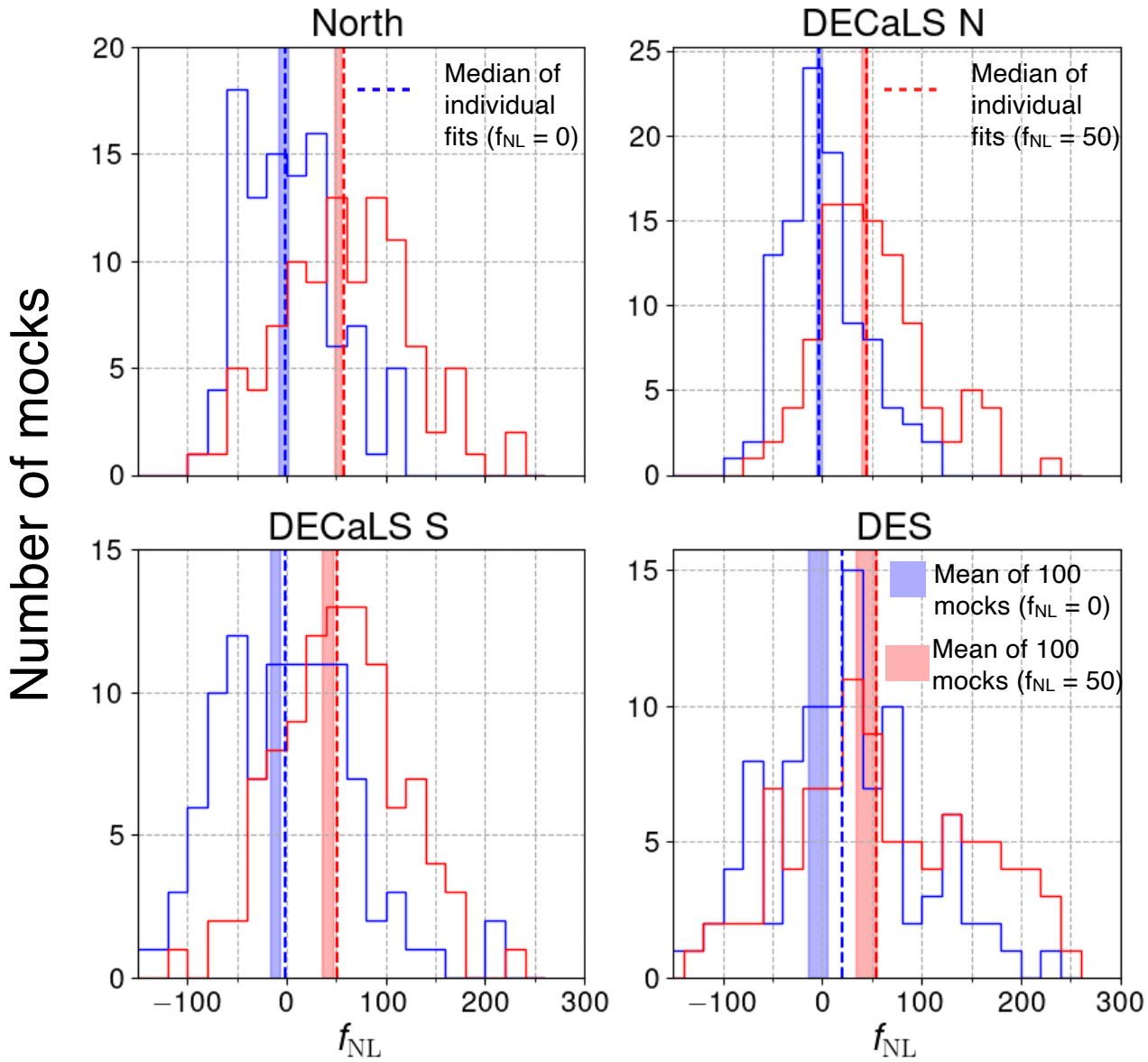


- Overfitting is a potential issue: regression may remove real cosmological signal!
  - Test *linear* vs *random forest* mitigation on contaminated mocks
- Linear regression recovers $C_\ell^{\kappa g}$ well on all scales
  - Random Forest method is too flexible and reduces $C_\ell^{\kappa g}$ by >2x on large scales

DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Testing on contaminated mocks

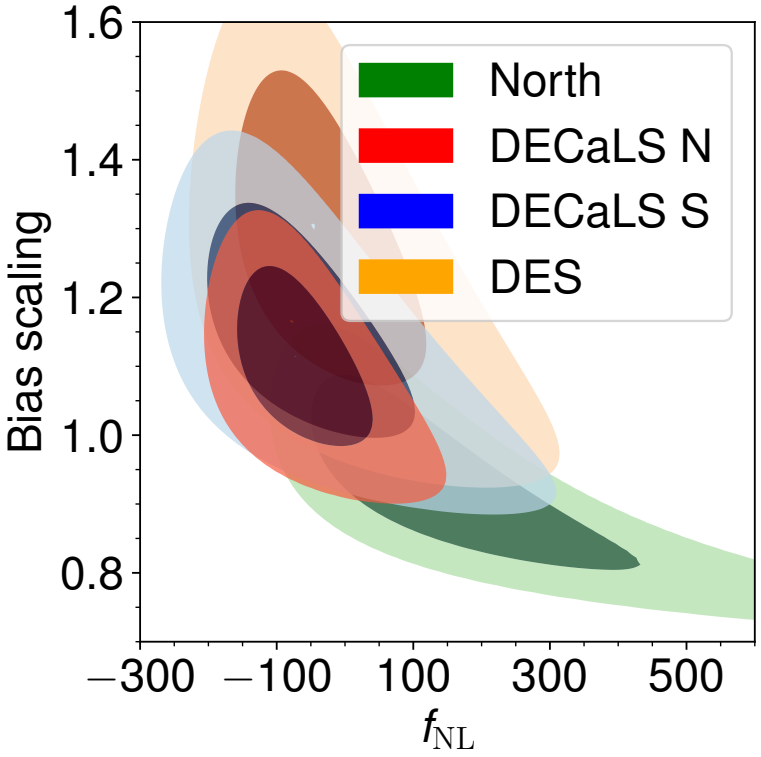


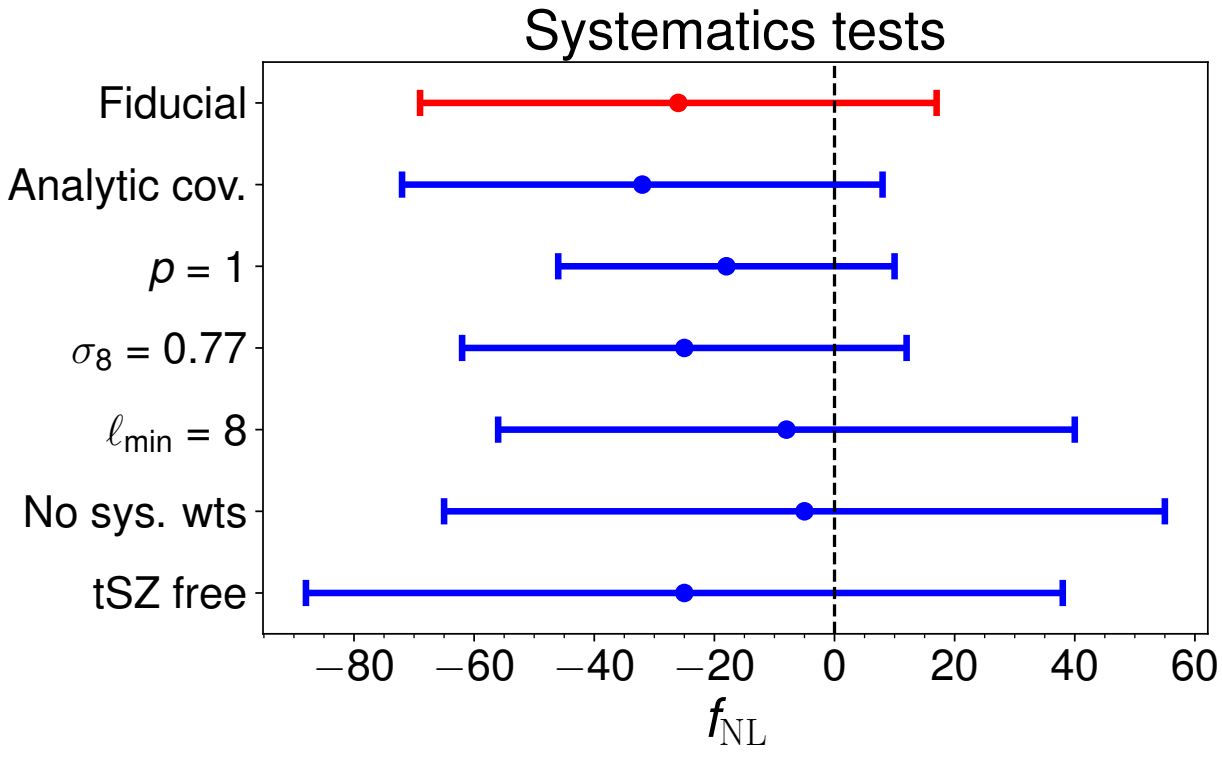
- End-to-end test on contaminated mocks: recovers true input f_{NL}

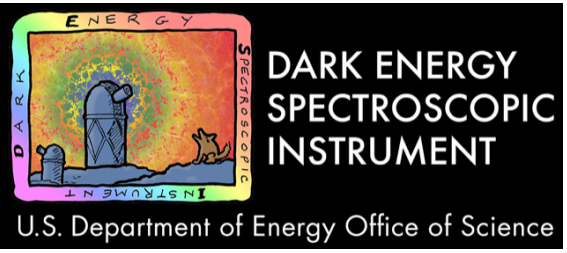
DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

PNG constraints

- Results from 4 regions are consistent, with decent χ^2(p = 0.15)
- Combined constraint: $f_{\rm NL} = -26^{+45}_{-40}$
- Error consistent with Fisher forecast given extra noise from residual systematics







Conclusions and future work

- Despite strong excess angular power in photometric quasar sample, we can nevertheless constrain PNG using CMB lensing cross-correlation
  - No evidence for any correlated systematics! Cross-correlation much cleaner & easier to deal with than auto
- Slightly weaker PNG constraints than BOSS/eBOSS P(k) ($\sigma_{f\mathrm{NL}}$ ~20-30): limited by excess noise in quasar auto-spectrum at low ℓ
- CMB lensing x spectroscopic quasars has cleaner large-scale power and will likely allow us to use the full sample (2x higher number density)
  - Work in progress with DESI Y1 QSO x CMB lensing