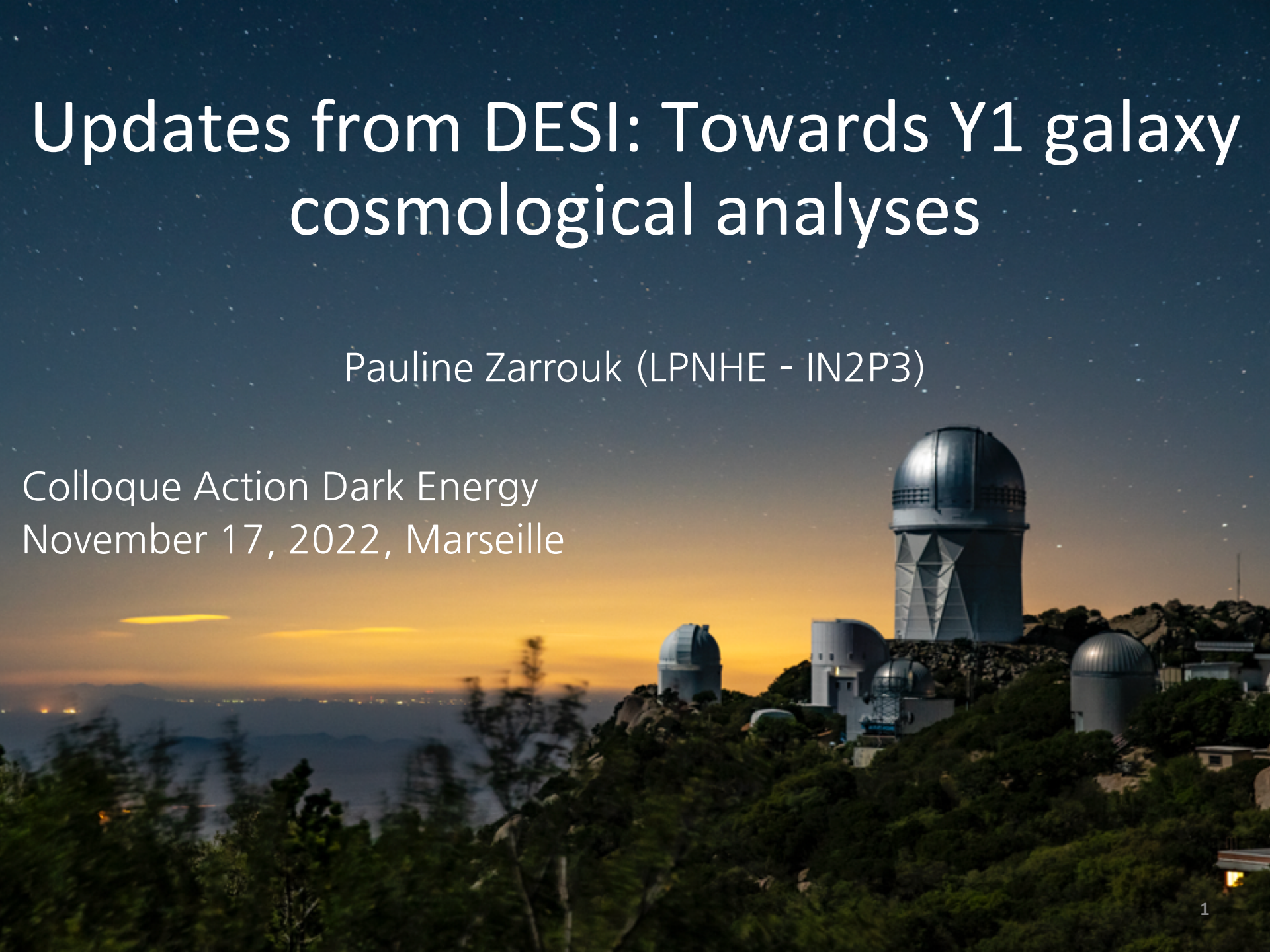
Updates from DESI: Towards Y1 galaxy cosmological analyses

Pauline Zarrouk (LPNHE - IN2P3)

Colloque Action Dark Energy
November 17, 2022, Marseille



DESI tracers

Five target classes

~40 million redshifts

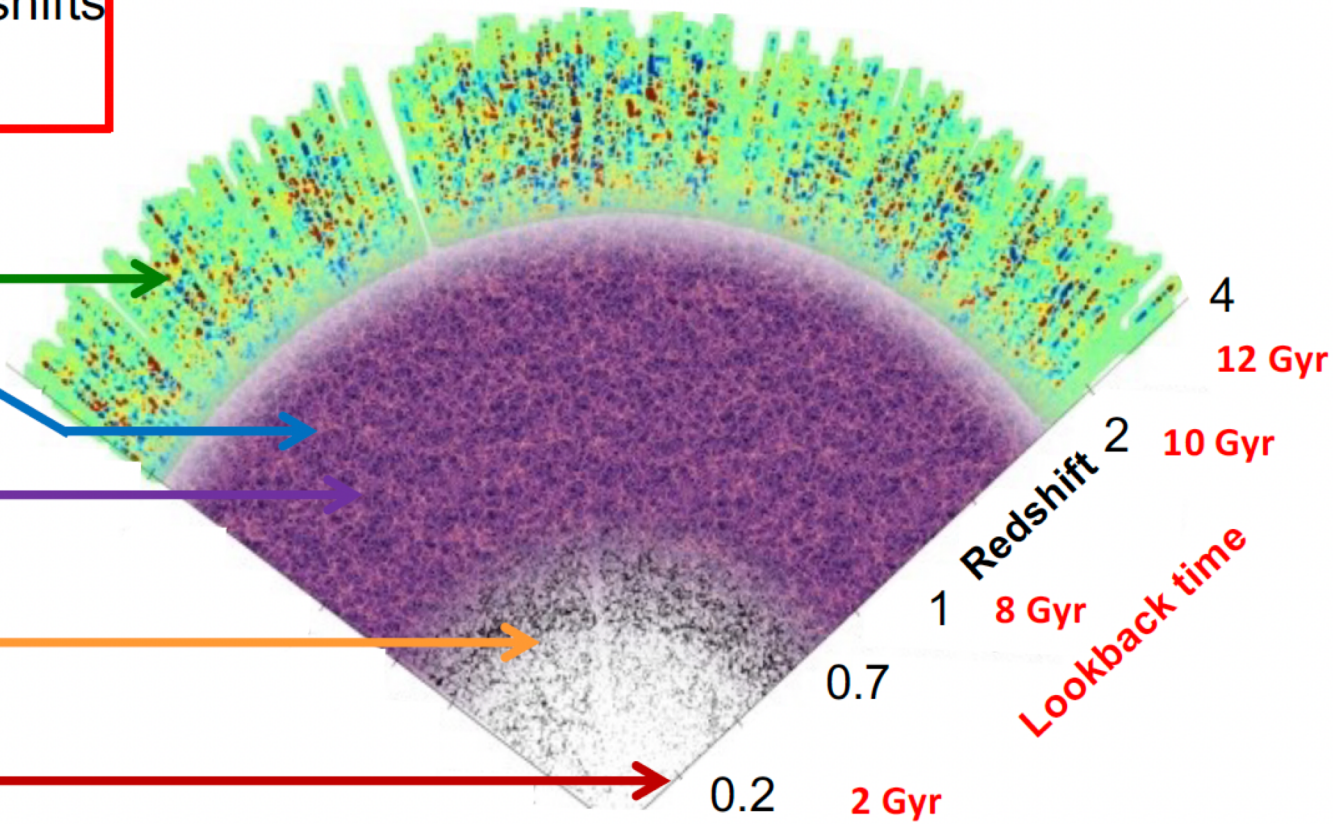
in 5 years

3 million QSOs
Ly-α $z > 2.1$
Tracers $0.9 < z < 2.1$

16 million ELGs
$0.6 < z < 1.6$

8 million LRGs
$0.4 < z < 1.0$

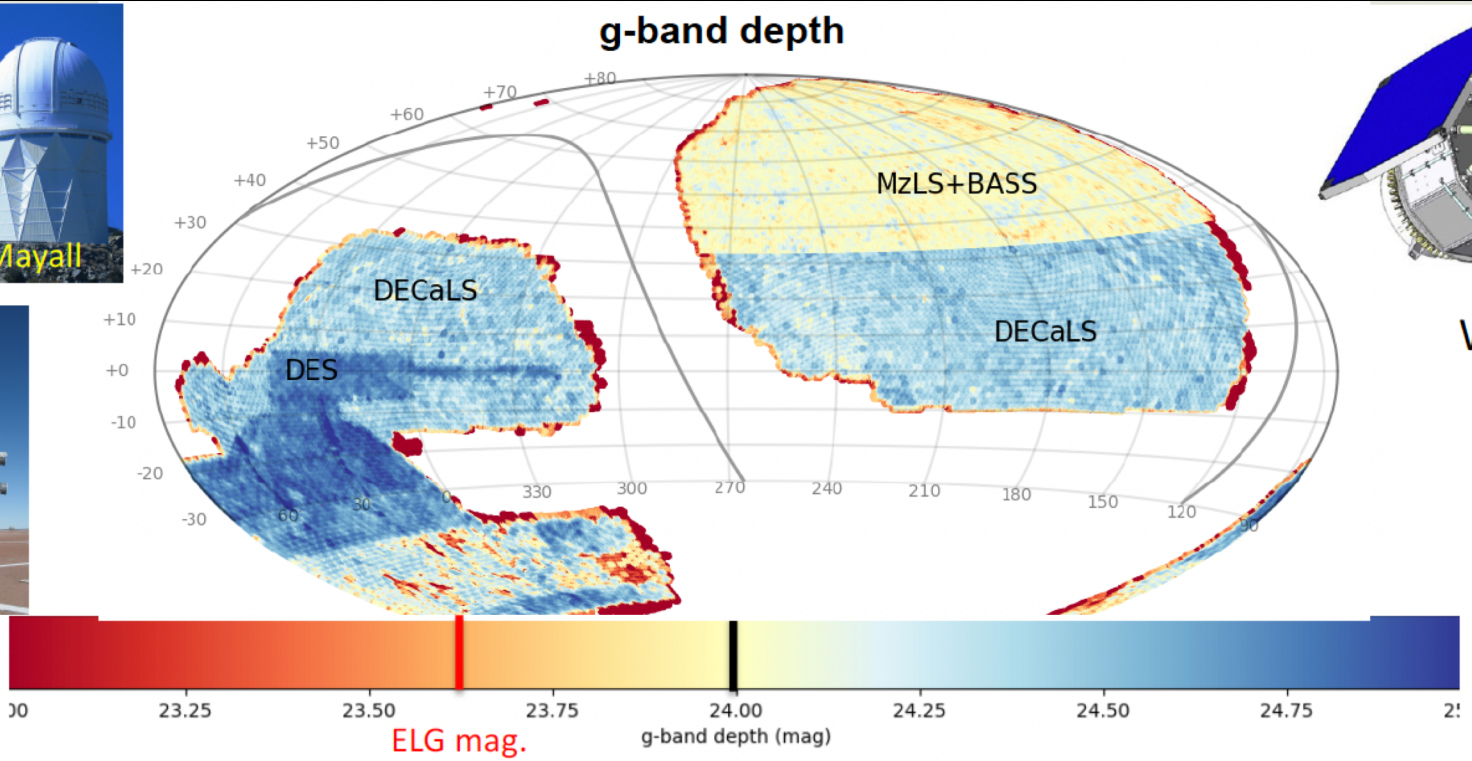
13.5 million Brightest galaxies
$0.0 < z < 0.4$

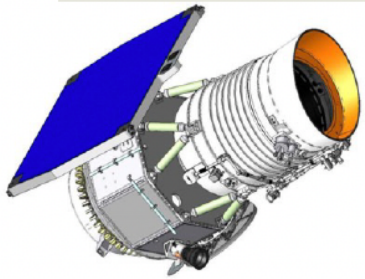


DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Legacy Imaging Surveys





WISE

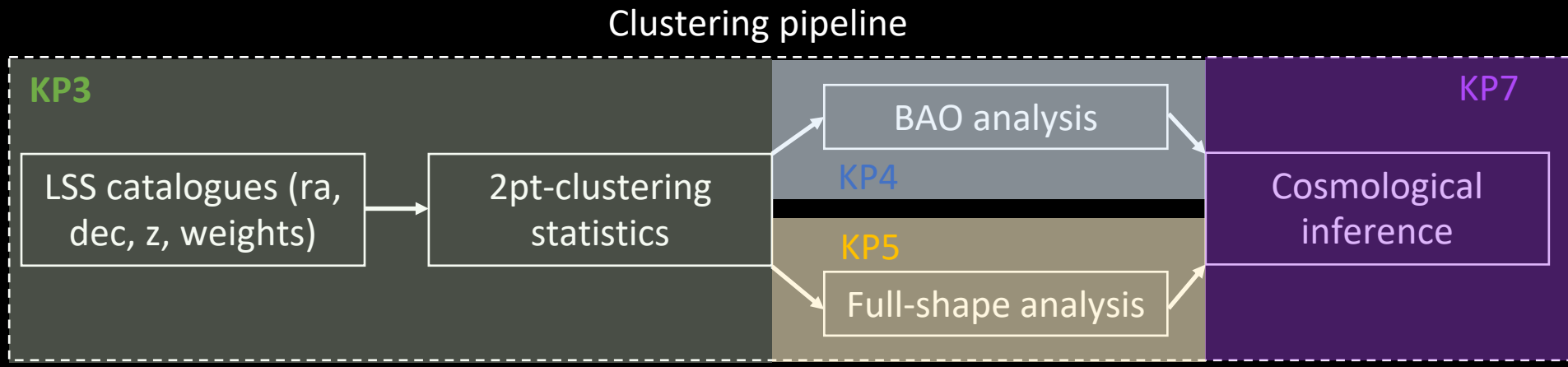
- Optical bands with
  - g=24.0, r=23.4, z=22.5
  - DECAM deeper in g,r,z
- Footprint
  - 14,000 deg^2 required
  - 16,000 deg^2 available for δ>-30^0
- WISE imaging
  - Two bands W1,W2
  - 6 years with all-sky coverage
  - Used for LRG/QSO

DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

DESI Y1 Key Projects

- KP1: Data Release of DESI Survey Validation
- KP2: Data Release of DESI Y1
- KP3: DESI Y1 LSS catalogues
- KP4: DESI Y1 BAO analysis with galaxy samples
- KP5: DESI Y1 Full-shape analysis with galaxy samples
- KP6: DESI Y1 Ly-alpha forest
- KP7: DESI Y1 Cosmological inference



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

DESI Y1 Key Projects

- KP1: Data Release of DESI Survey Validation
- KP2: Data Release of DESI Y1
- KP3: DESI Y1 LSS catalogues
- KP4: DESI Y1 BAO analysis with galaxy samples
- KP5: DESI Y1 Full-shape analysis with galaxy samples
- KP6: DESI Y1 Ly-alpha forest
- KP7: DESI Y1 Cosmological inference

arXiv:2208.08514 [pdf, other] astro-ph.GA astro-ph.CO

Overview of the DESI Milky Way Survey — Cooper et al.

arXiv:2208.08518 [pdf, other] astro-ph.IM astro-ph.CO astro-ph.GA

The Target Selection Pipeline for the Dark Energy Spectroscopic Instrument — Myers et al.

arXiv:2208.08512 [pdf, other] astro-ph.CO astro-ph.GA

DESI Bright Galaxy Survey: Final Target Selection, Design, and Validation — Hahn et al.

arXiv:2208.08515 [pdf, other] astro-ph.CO astro-ph.GA

Target Selection and Validation of DESI Luminous Red Galaxies — Zhou et al.

arXiv:2208.08513 [pdf, other] astro-ph.CO

Target Selection and Validation of DESI Emission Line Galaxies — Raichoor et al.

arXiv:2208.08511 [pdf, other] astro-ph.CO

Target Selection and Validation of DESI Quasars — Chaussidon et al.

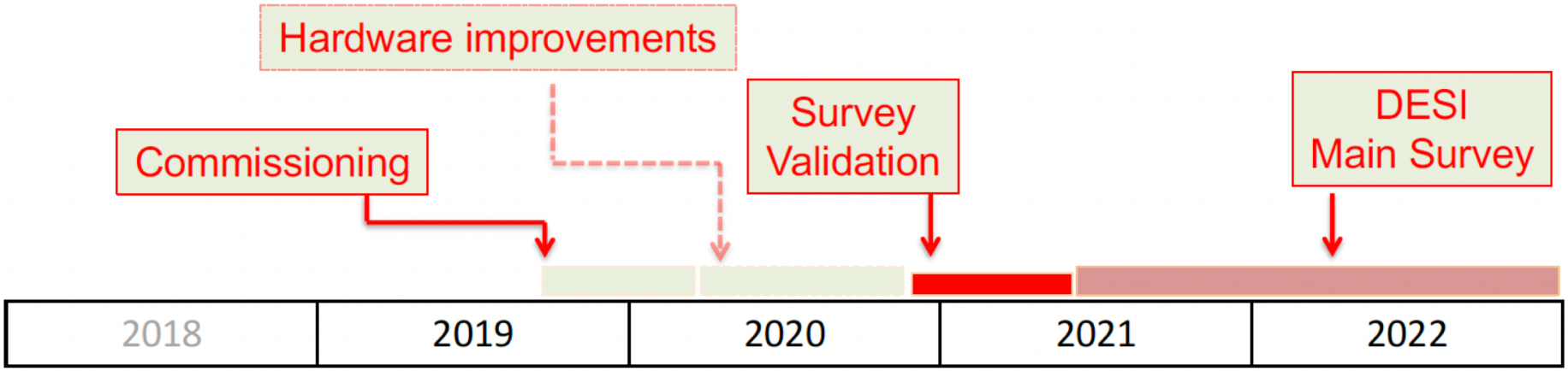
arXiv:2208.08516 [pdf, other] astro-ph.CO astro-ph.GA

The DESI Survey Validation: Results from Visual Inspection of Bright Galaxies, Luminous Red Galaxies, and Emission Line Galaxies — Lan et al.

arXiv:2208.08517 [pdf, other] astro-ph.GA astro-ph.CO

The DESI Survey Validation: Results from Visual Inspection of the Quasar Survey Spectra — Alexander et al.

Survey Validation

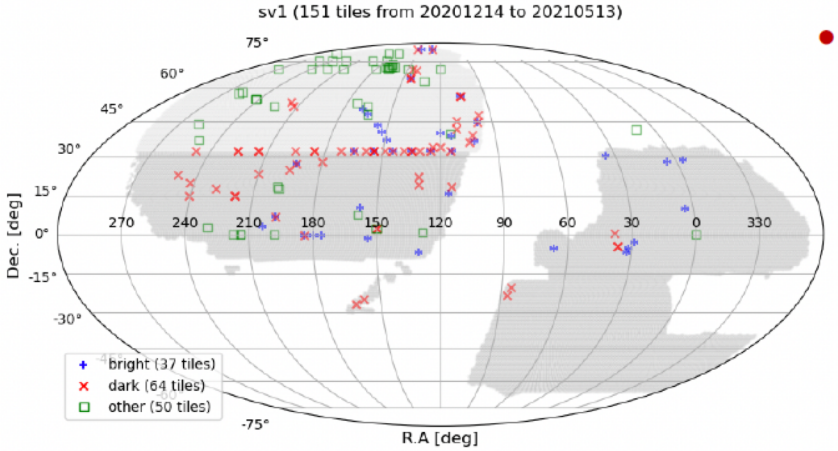


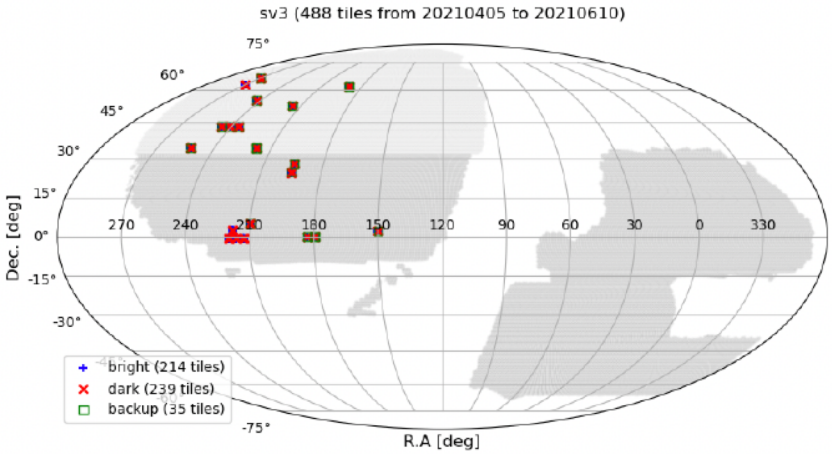
- **Goals of Survey Validation (SV)**
  - Quality of the spectra
    - Positioner, spectrograph
    - Exposure time
    - Pipeline: achieve redshift accuracy
  - Validation of Target Selection
    - Optimization of TS for each tracer
    - Final n(z)

DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Survey Validation: two parts





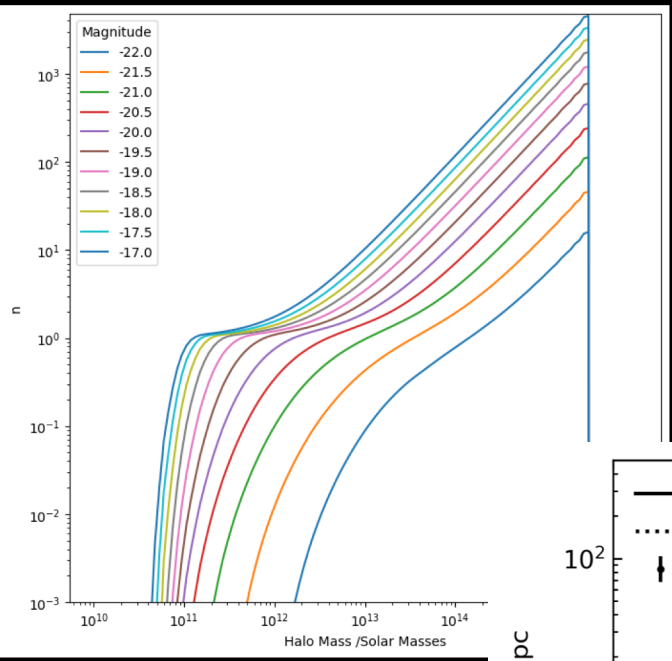
Credits: Christophe Yèche

- **Deep Observations (x4) – 3 months**
  - TS validation
  - Non overlapping tiles (not complete!)
  - Higher Exposure Time (x4)
  - 150 tiles
  - ~230k spectra (BGS/LRG/ELG/QSO)
- **1% Survey (x1.2) – 1 month**
  - Final target selection
  - ~200 deg^2
  - Exposure Time (1.2x nominal time)
  - 20x2 fields designed with very high completeness
  - ~500 tiles
  - ~1M spectra (BGS/LRG/ELG/QSO)

DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

1% survey HOD papers: BGS

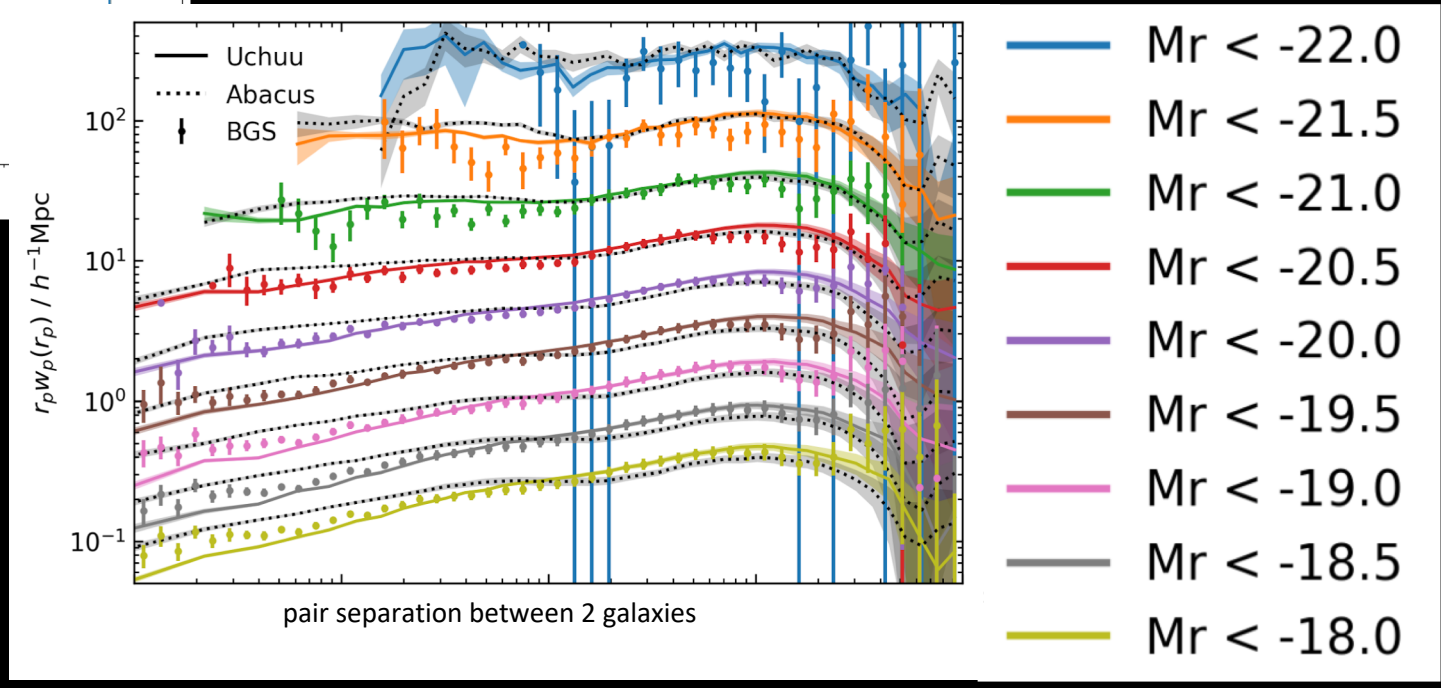


- Standard 5-parameter HODs
- In order to assign magnitudes to galaxies we need to define the HOD at any magnitude

→ magnitude-dependent HODs

- Evolving target luminosity function from SDSS and GAMA

→ BGS mocks with magnitude and colours



Credits: Alex Smith, Cameron Grove

DARK ENERGY SPECTROSCOPIC INSTRUMENT

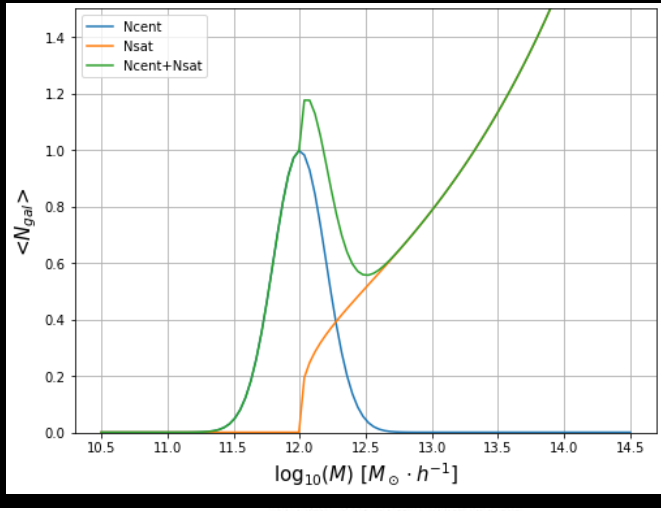
U.S. Department of Energy Office of Science

1% survey HOD papers: ELG

Gaussian HOD model GHOD *(eBOSS studies, Avila et al. 2020) :*

$$\langle N_{cent} \rangle (M_h) = \frac{A_c}{\sqrt{2\pi}\sigma} \cdot e^{-\frac{(\log_{10}(M_h) - \log_{10}(M_c))^2}{2\sigma^2}}$$

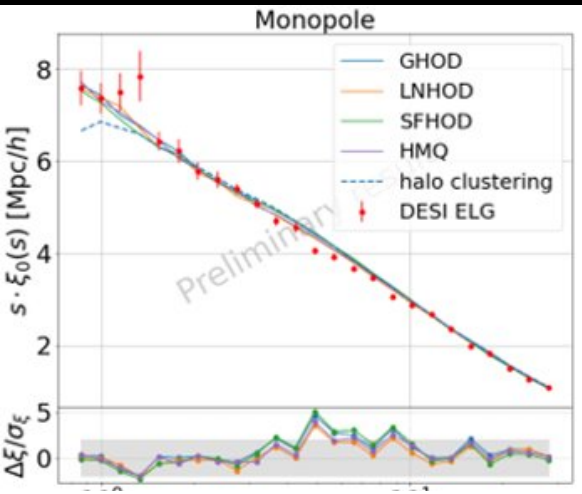
$$\langle N_{sat} \rangle (M) = A_s \left(\frac{M - M_0}{M_1} \right)^{\alpha}$$

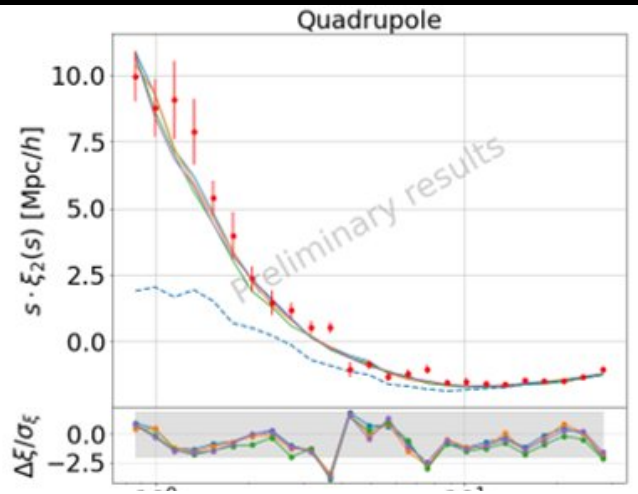


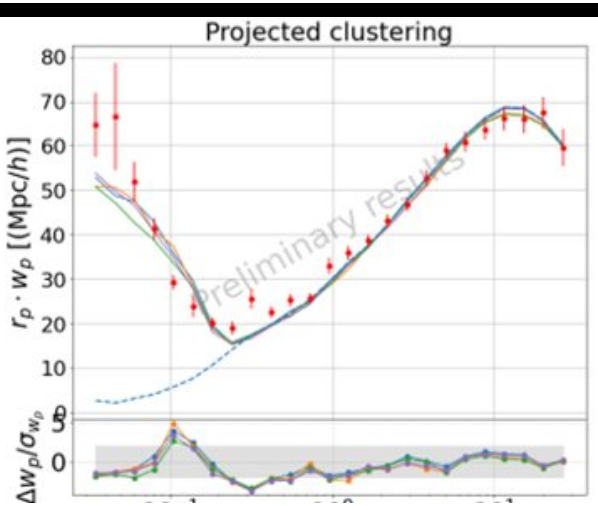
Other HOD models for ELGs (N_{cent} asymmetric Gaussian)

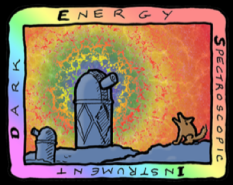
- High mass quenched (HMQ) *(Alam et al. 2019)*
- Star forming HOD (SFHOD) *(Avila et al. 2020)*

Credits: Antoine Rocher









DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

DESI Y1 Key Projects

- KP1: Data Release of DESI Survey Validation
- KP2: Data Release of DESI Y1
- KP3: DESI Y1 LSS catalogues
- KP4: DESI Y1 BAO analysis with galaxy samples
- KP5: DESI Y1 Full-shape analysis with galaxy samples
- KP6: DESI Y1 Ly-alpha forest
- KP7: DESI Y1 Cosmological inference

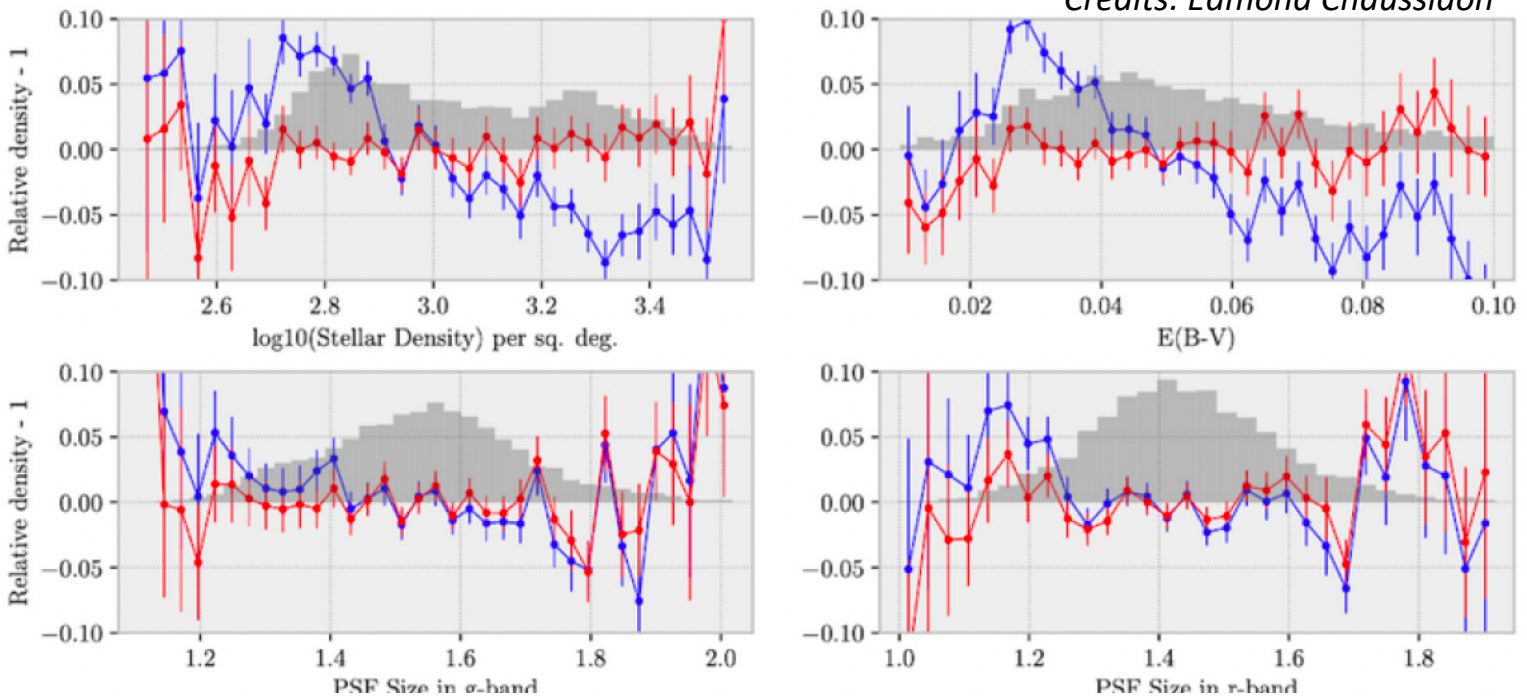
KP3 is in charge of the creation of LSS catalogues that produce minimally biased 2-pt statistics measurements.

Imaging systematics

imaging systematics

anisotropies in the Legacy Imaging surveys (depth, seeing, stellar density, galactic extinction...)
⇒ variations in the density of targets
⇒ variations in the density of galaxies

Credits: Edmond Chaussidon



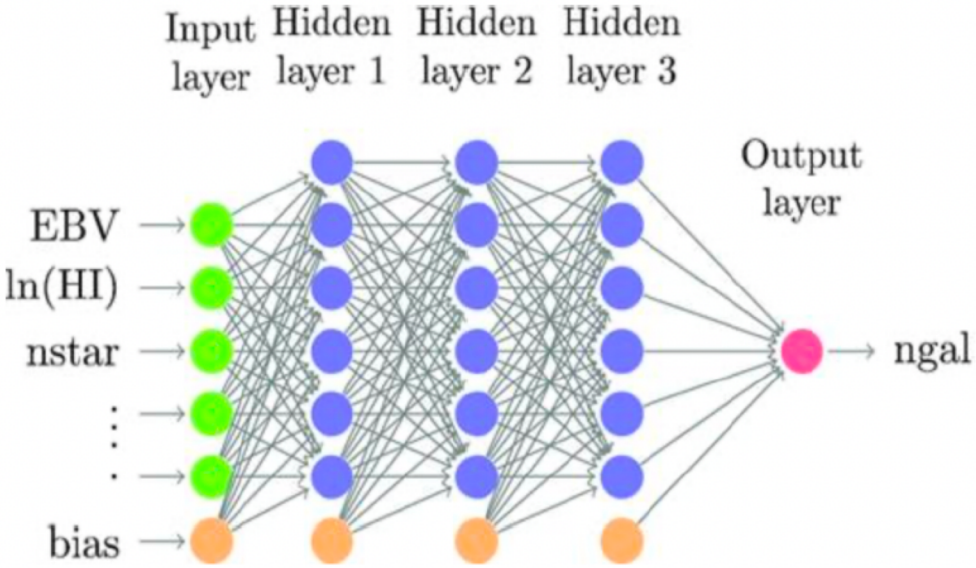
ELG DA0.2: raw (blue), after applying weights (red)

Imaging systematics: regression

template fitting

galaxy density = f(depth, seeing, ...) + noise
weight = 1/f(depth, seeing, ...) applied to galaxies

- regressis (E. Chaussidon): based on `scikit-learn` random forests & neural nets
- sysnetdev (M. Rezaie): based on `pytorch` neural nets
- limitations: overfitting, exhaustive set of templates?



Credits: Mehdi Rezaie

Spectroscopic systematics

fiber assignment

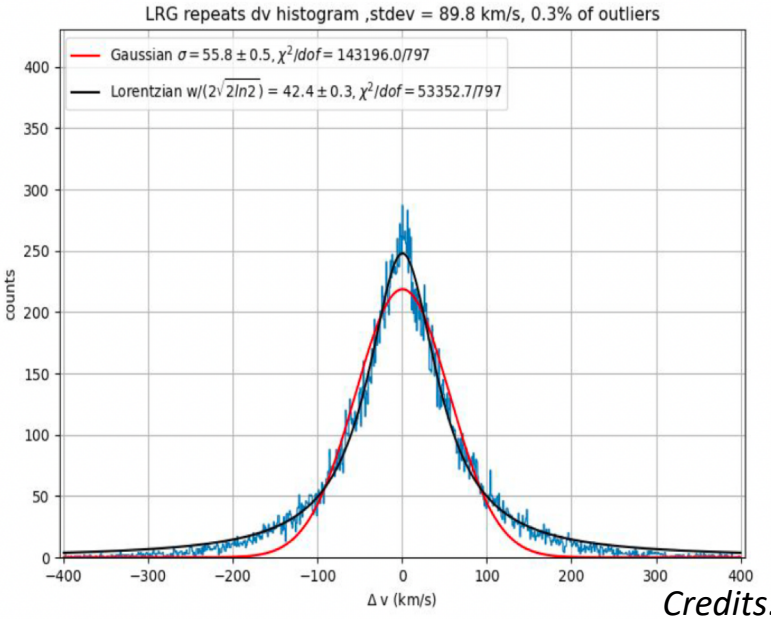
targets are assigned spectroscopic fibers, depending on their (sub)priorities, hardware state, sky fibers

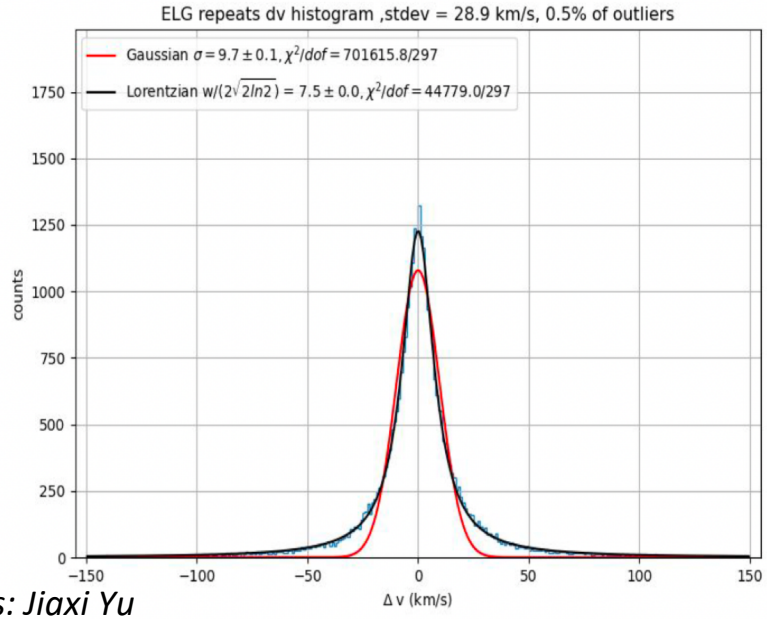
To simulate this complex process: rerun fiber assignment multiple times, shuffling subpriorities.

- for each target, list of flags specifying whether the target has been assigned a fiber
- each pair of galaxies weighted by the inverse of the number of times it has been assigned fibers: "PIP weights" (+ angular upweights for zero-prob. pairs) (Bianchi and Percival 2017; Bianchi and Verde 2020)

Spectroscopic systematics

- **fraction of "good" redshifts** depends on observing conditions and flux
- **redshift uncertainty** may be broad[2]: must be accounted for in the theory
- some "good" redshifts may be totally wrong: estimate fraction of **catastrophic redshifts** and failure modes (line confusion).

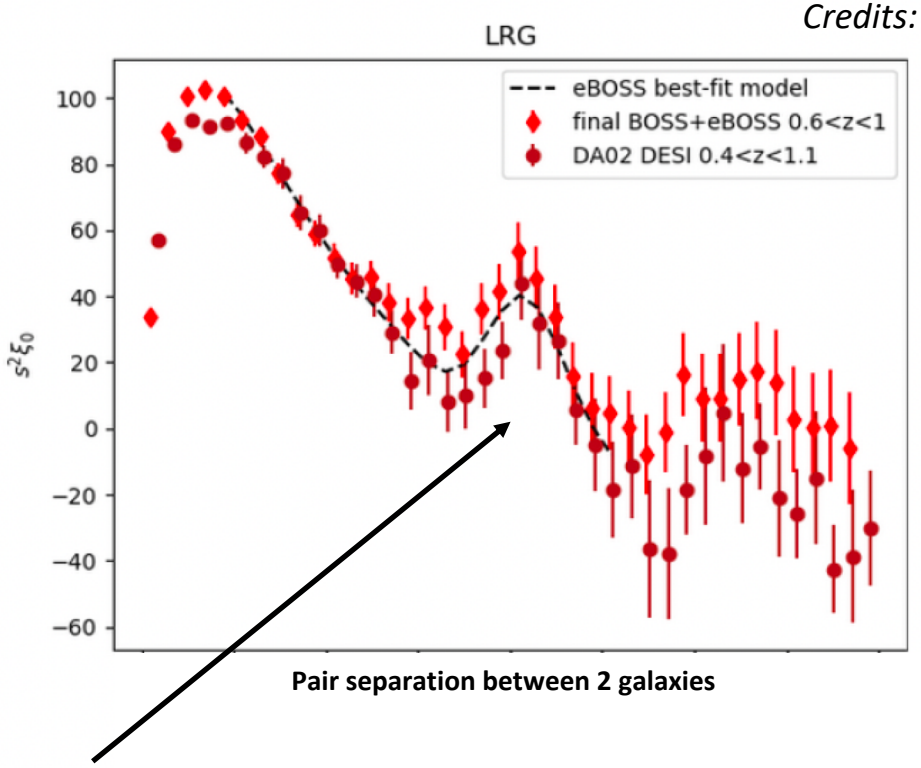


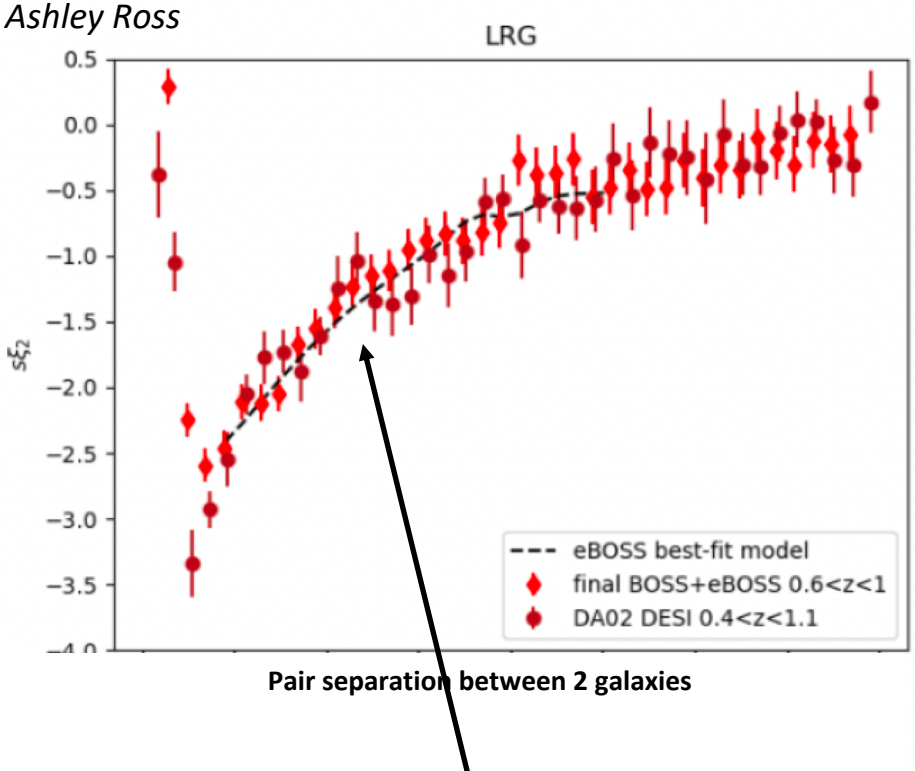


Credits: Jiaxi Yu

2-point statistics measurements

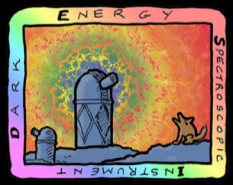
Credits: Ashley Ross





BAO peak: characteristic distance in the galaxy clustering
→ Standard ruler to measure H(z)

Non-zero quadrupole
→ anisotropies due to the LOS component of galaxy peculiar velocities when measuring the redshift / radial distance of galaxies



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

DESI Y1 Key Projects

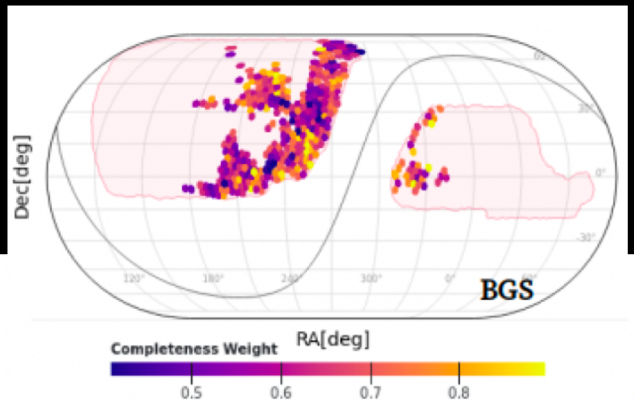
- KP1: Data Release of DESI Survey Validation
- KP2: Data Release of DESI Y1
- KP3: DESI Y1 LSS catalogues
- KP4: DESI Y1 BAO analysis with galaxy samples
- KP5: DESI Y1 Full-shape analysis with galaxy samples
- KP6: DESI Y1 Ly-alpha forest
- KP7: DESI Y1 Cosmological inference

KP4 is in charge of coordinating the BAO measurements (including reconstruction) from the 2-pt statistics of the year 1 DESI data using the BGS, LRG, ELG and QSO tracers .

DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

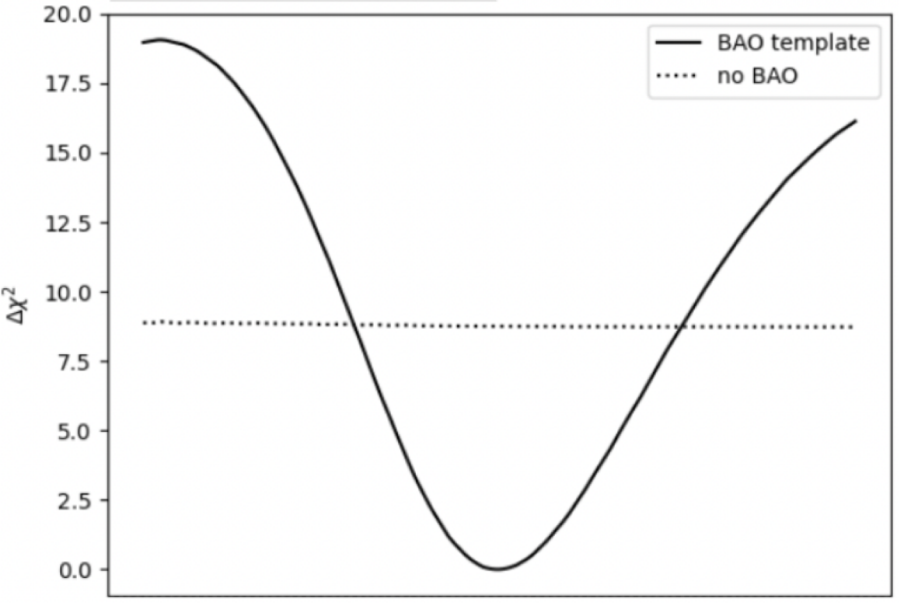
BAO in EDR (DA0.2) BGS

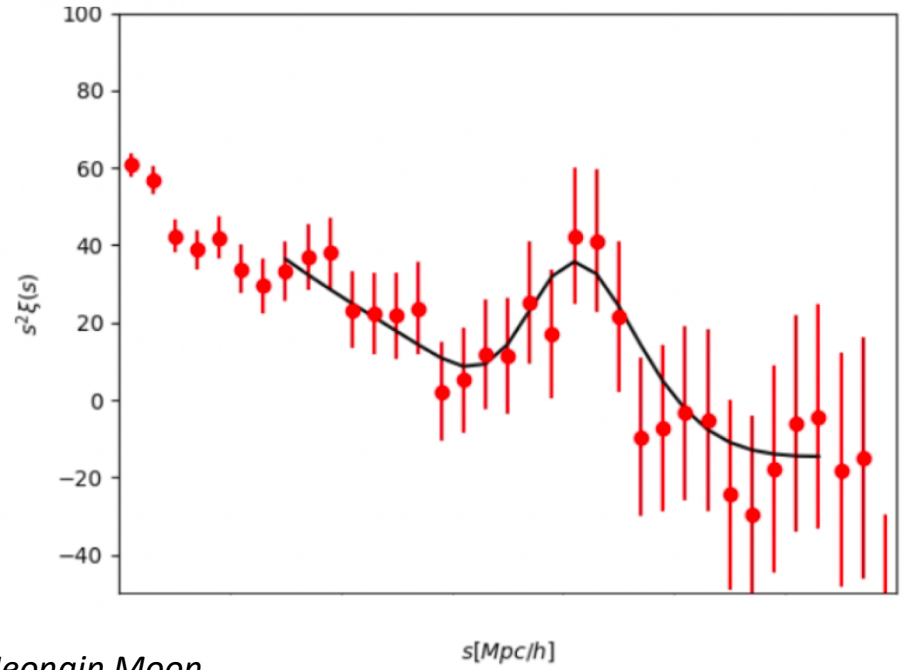


Redshift range 0.1 < z < 0.5

PRELIMINARY

DA0.2 BGS
2.6%(~3σ) BAO detection



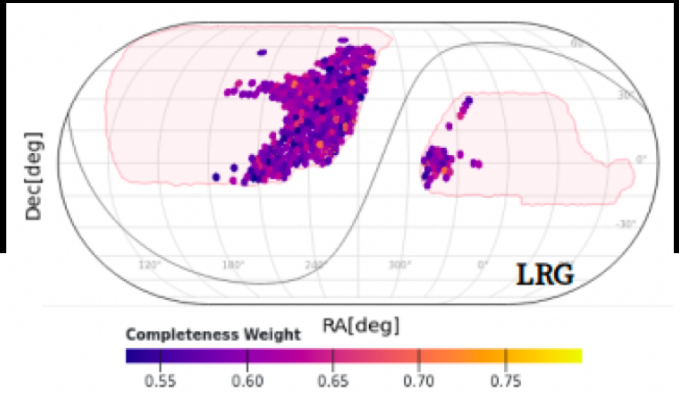


Credits: Jeongin Moon

DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

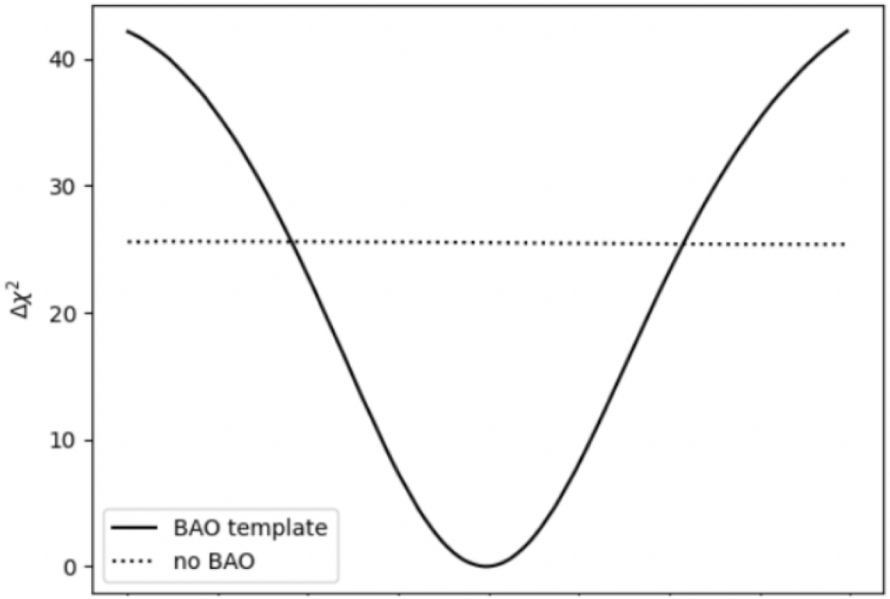
BAO in EDR (DA0.2) LRG

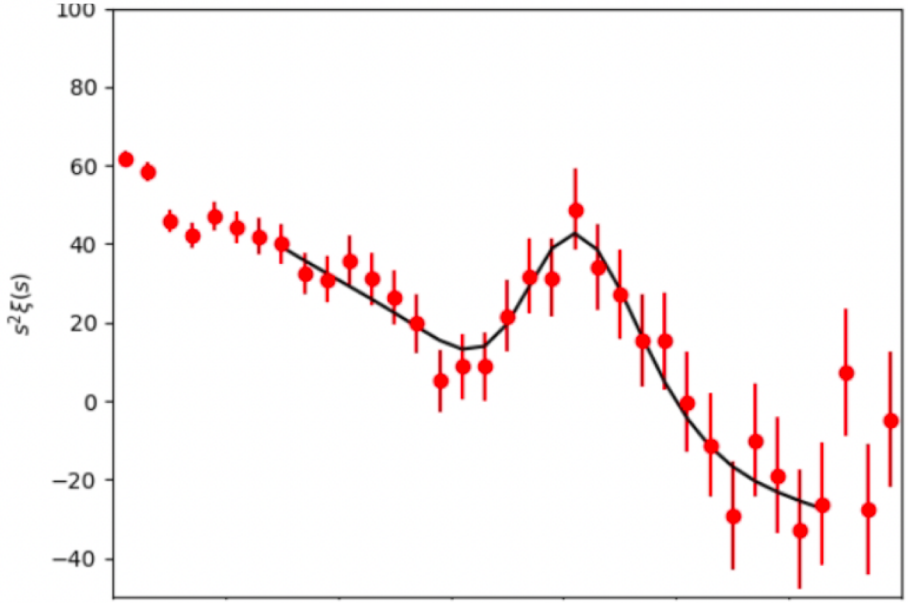


Redshift range 0.4 < z < 1.1

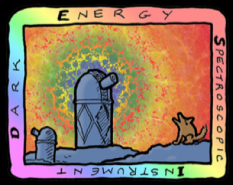
PRELIMINARY

DA0.2 LRG
1.7%(~5σ) BAO detection





Credits: Jeongin Moon



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

DESI Y1 Key Projects

- KP1: Data Release of DESI Survey Validation
- KP2: Data Release of DESI Y1
- KP3: LSS catalogues
- KP4: BAO analysis with galaxy samples
- KP5: Full-shape analysis with galaxy samples
- KP6: Ly-alpha forest
- KP7: Cosmological inference

KP5 is in charge of coordinating the Full-Shape measurements (RSD, primordial non-Gaussianities) from the 2-pt statistics of the year 1 DESI data using the BGS, LRG, ELG and QSO tracers .

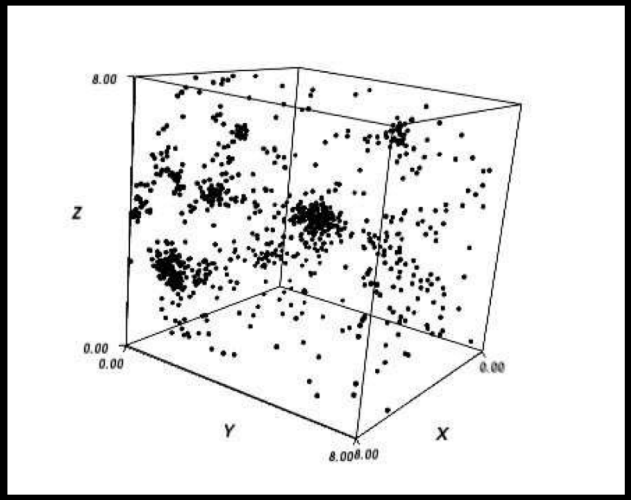
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

DESI Y1 KP5

Systematic error budget

Accurate N-body simulations



- Systematics related to the theoretical modelling
- Systematics related to the galaxy-halo connection
- Systematics related to the choice of fiducial cosmology

+ specific issues to each tracer

Approximate simulations

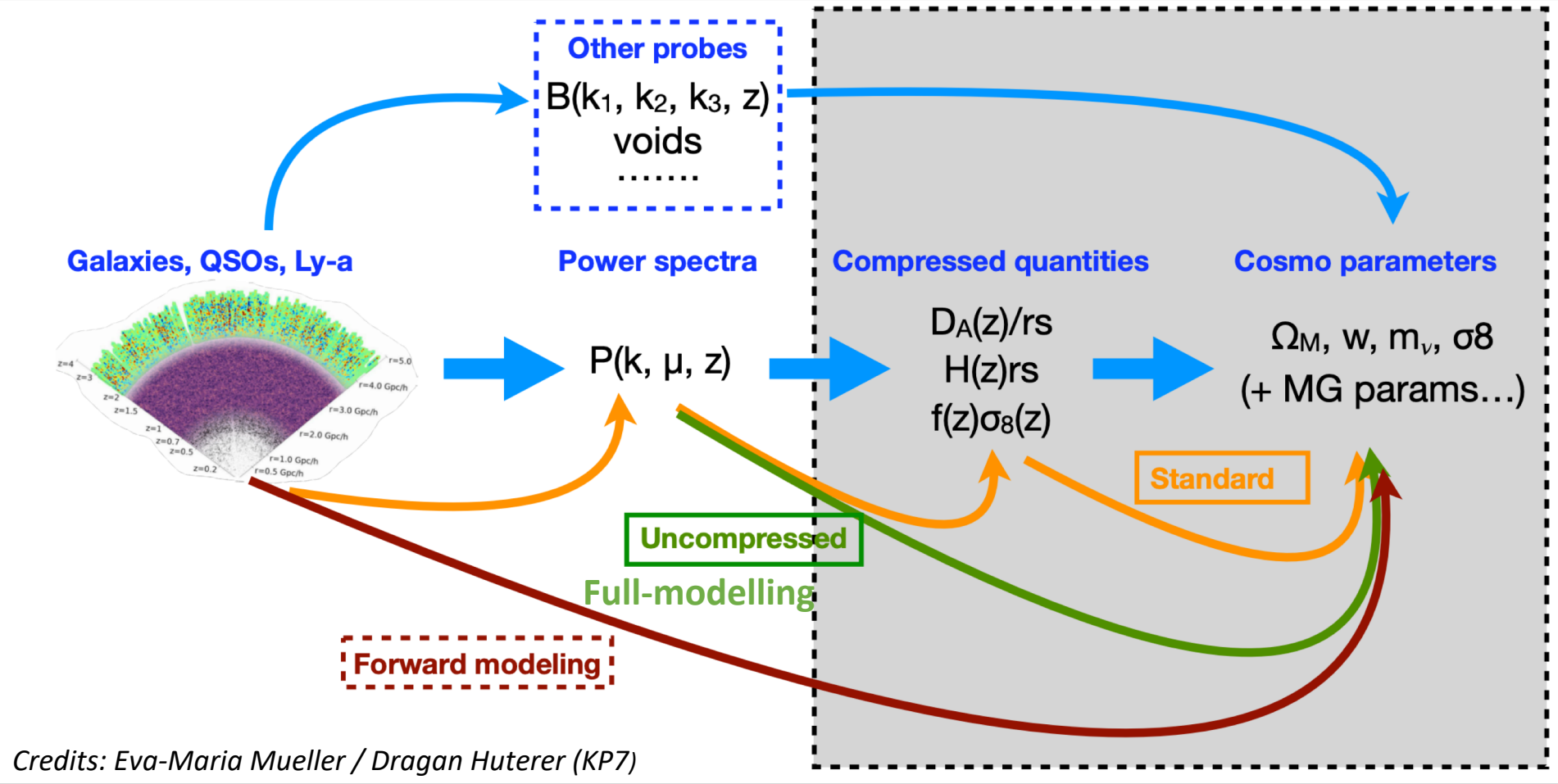
- Systematics related to the observing conditions: imaging systematics
- Systematics related to the instrument: spectroscopic systematics (missing targets due to fibre assignment, redshift success rate and redshift failures)
- Estimate error bars → covariance matrix

+ specific issues to each tracer

DARK ENERGY SPECTROSCOPIC INSTRUMENT

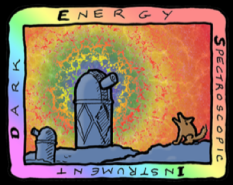
U.S. Department of Energy Office of Science

Compressed vs uncompressed



Credits: Eva-Maria Mueller / Dragan Huterer (KP7)

Within KP5 and KP7: Compare the performance of standard/extended compression with uncompressed (full-modelling) for a set of cosmological models.



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Takeaway

- DESI: 40 million spectra up to z=3.5, 14 000 deg^2
- DESI main survey started on May, 17th 2021
- DESI Y1 sample: observations from May 2021 to June 2022

- DESI Y1 KP1: Survey Validation Data Release

→ Papers submitted: Target Selection, Visual Inspection

- DESI Y1 KP3: Large-scale structures catalogues

→ Huge effort to understand and mitigate imaging and spectroscopic systematics

- BAO in DESI Early Data Release (EDR, 2 months of main survey observations)

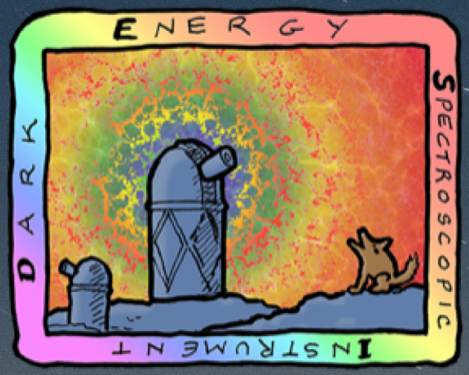
→ 1.7% precision using LRG, 2.6% using BGS

- DESI Y1 KP4/5: BAO and Full-Shape analysis

→ Ongoing work using DESI mocks to estimate the systematic error budget

- DESI Y1 cosmological papers around summer 2023

STAY TUNED!!!



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Thanks to our sponsors and 69 Participating Institutions!