

Galaxy clustering analysis with DESI

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Euclid France Theory and Likelihood Workshop
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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

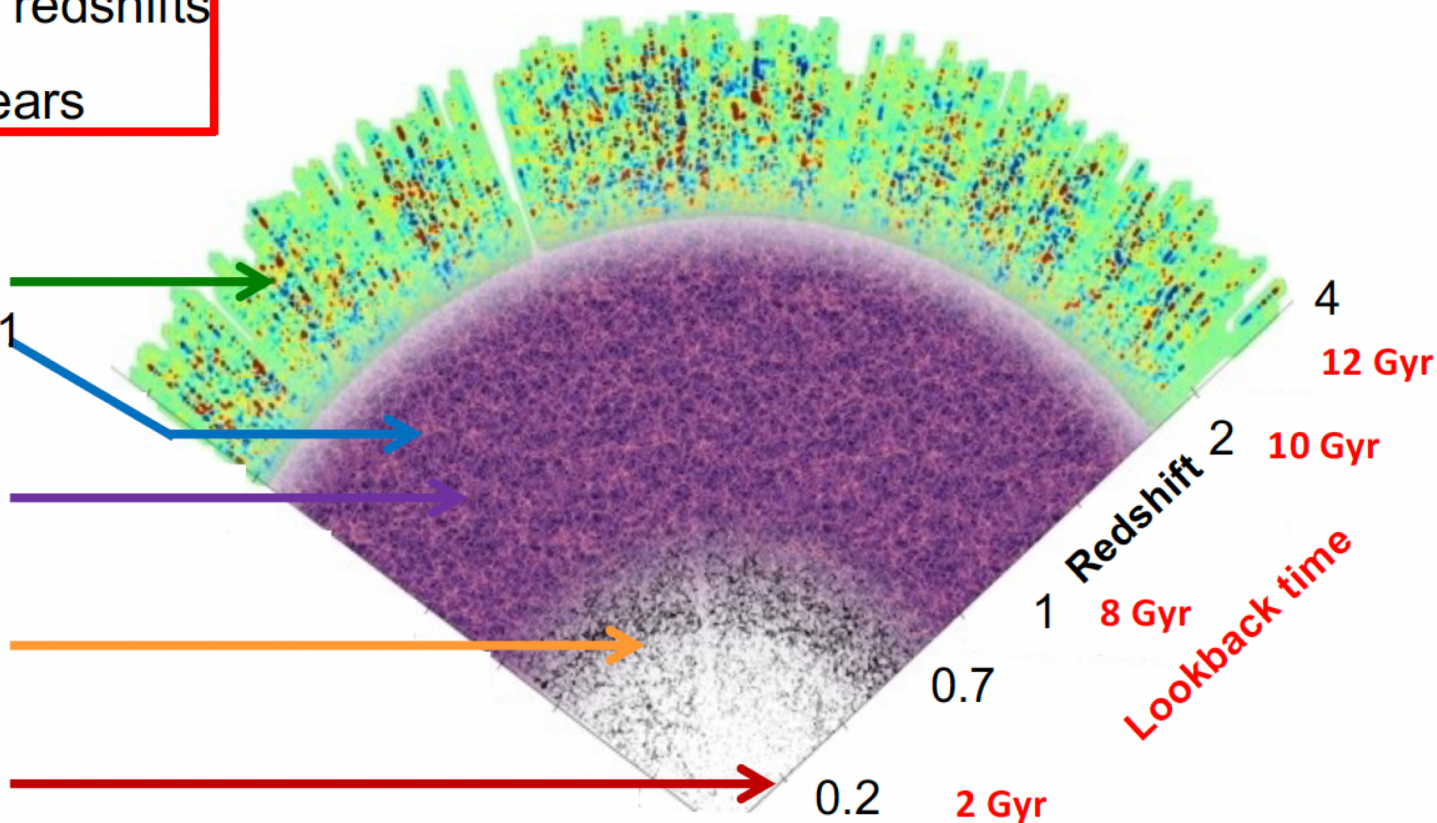
$0.6 < z < 1.6$

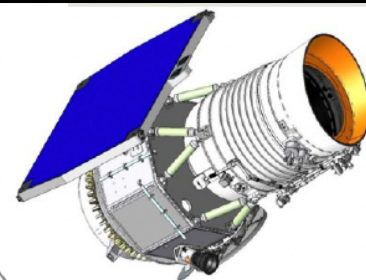
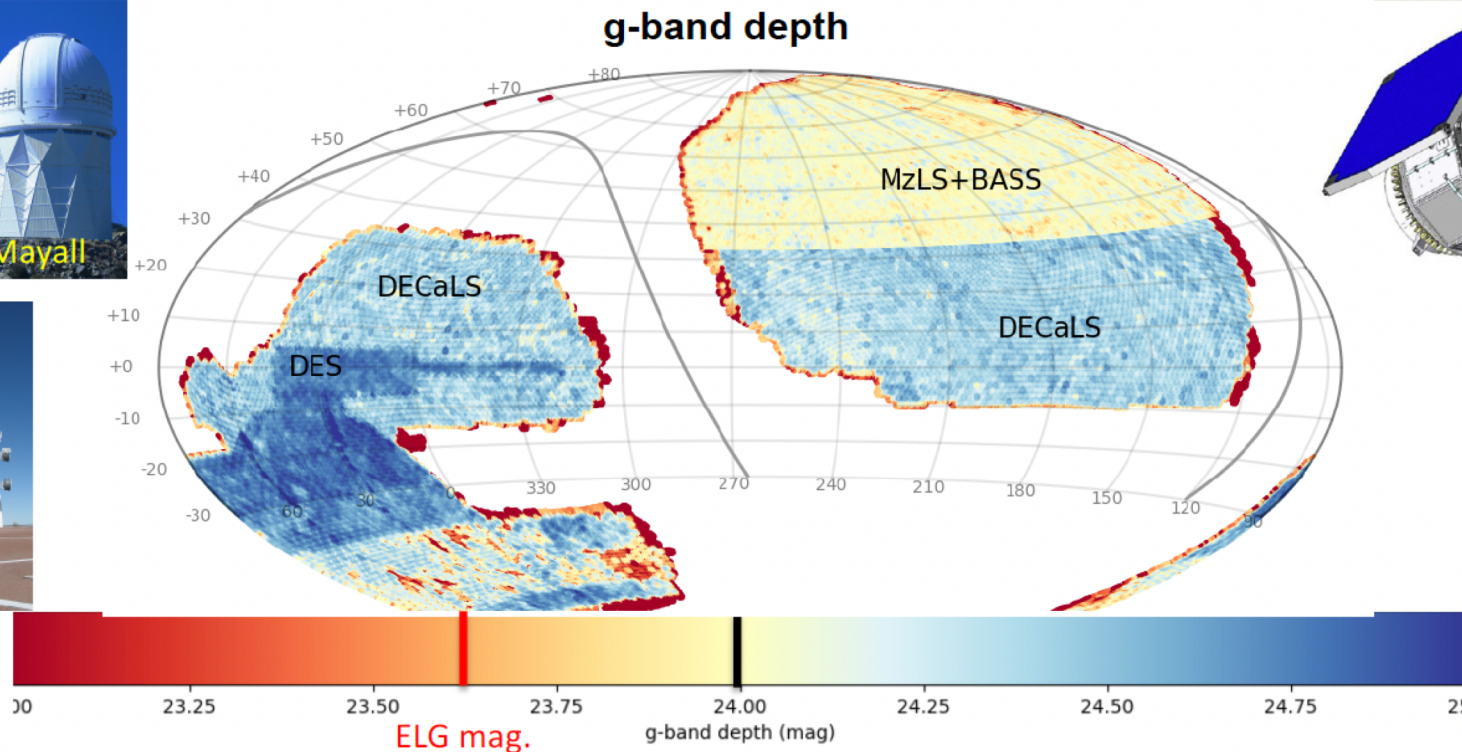
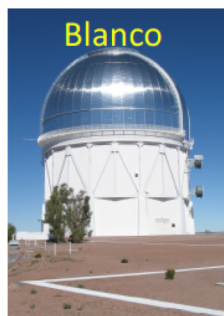
8 million LRGs

$0.4 < z < 1.0$

**13.5 million
Brightest galaxies**

$0.0 < z < 0.4$





WISE

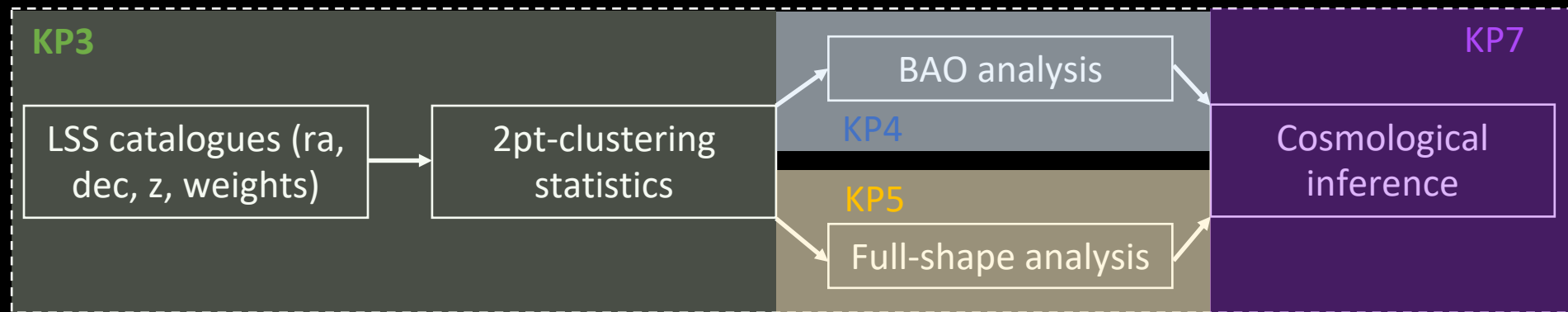
- Optical bands with
 - $g=24.0$, $r=23.4$, $z=22.5$
 - DECam deeper in g,r,z
- Footprint
 - 14,000 deg^2 required
 - 16,000 deg^2 available for $\delta > -30^\circ$
- WISE imaging
 - Two bands W1, W2
 - 6 years with all-sky coverage
 - Used for LRG/QSO

DESI Y1 Key Projects

U.S. Department of Energy Office of Science

- 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

Clustering pipeline



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[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](#)

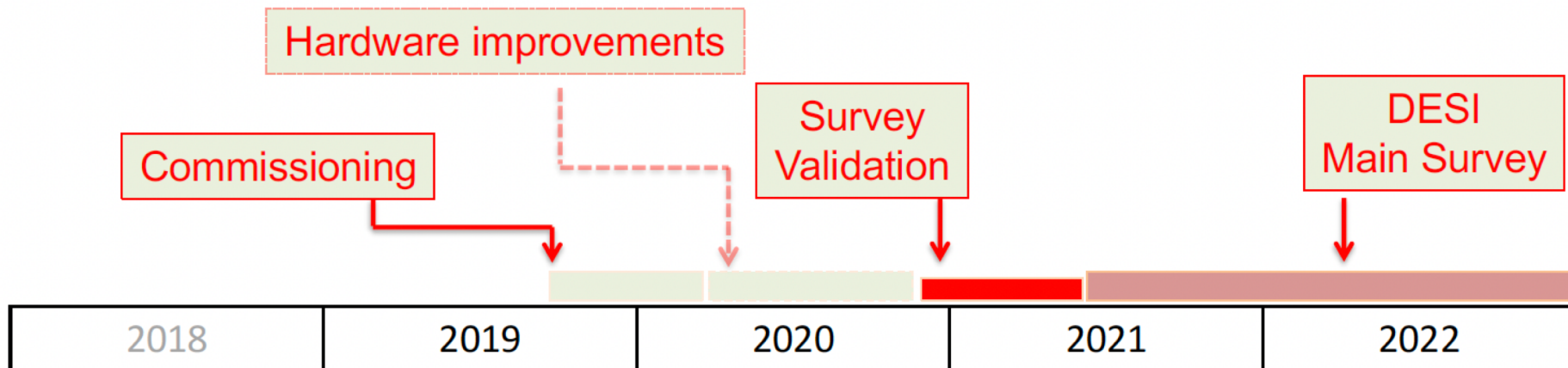
The DESI Survey Validation: Results from Visual Inspection of Bright Galaxies, Luminous Red Galaxies, and Emission Line Galaxies

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

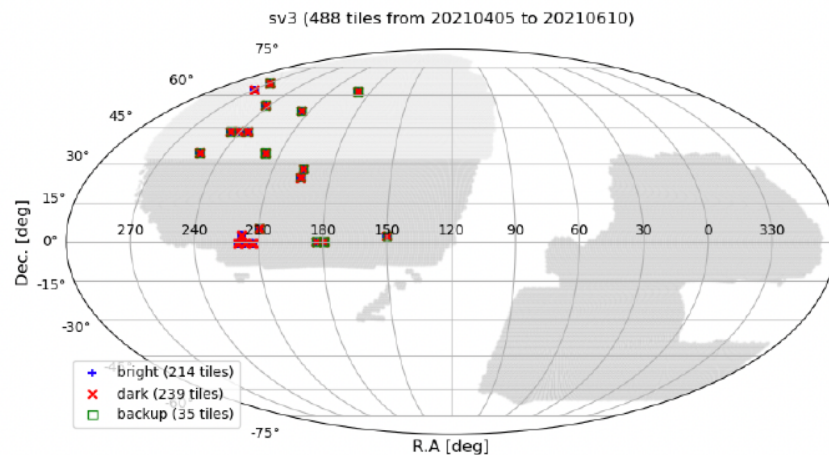
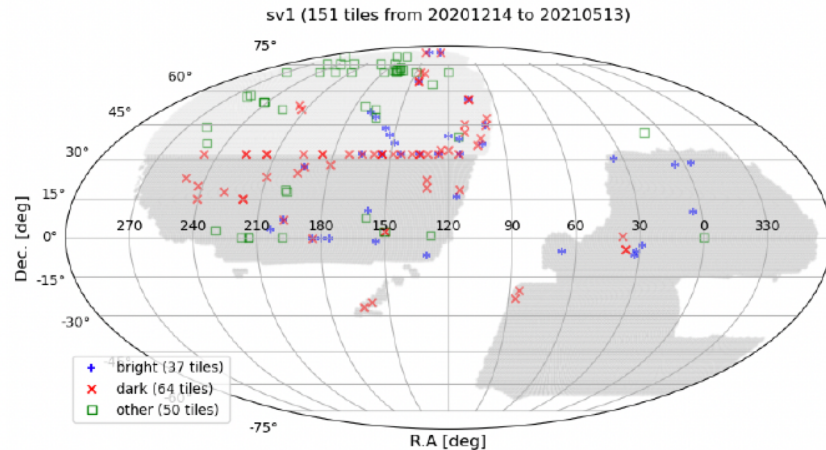
Alexander et al.



- **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 $n(z)$

Survey Validation: two parts

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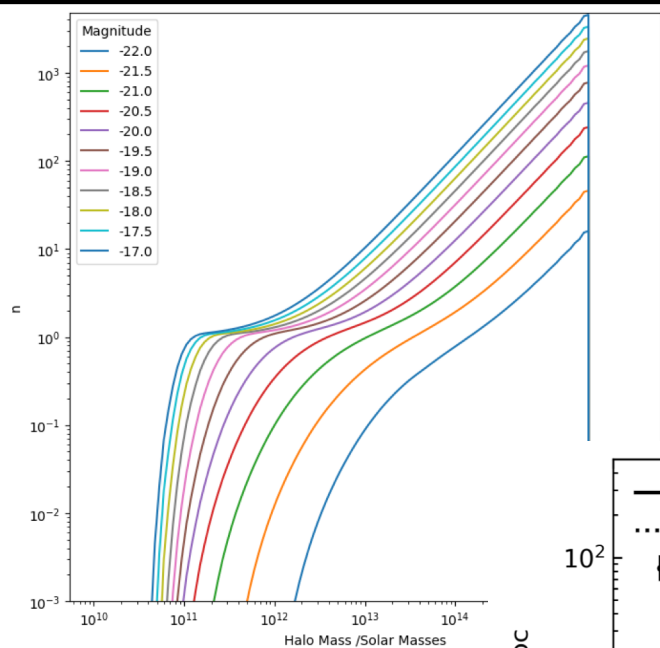


- **Deep Observations (x4) – 3 months**
 - TS validation
 - Non overlapping tiles (not complete!)
 - Higher Exposure Time (x4)
 - 150 tiles
 - ~230k spectra (BGS/LRG/ELG/QSO)
- **1% Survey (x1.2) – 1 month**
 - Final target selection
 - ~200 deg²
 - Exposure Time (1.2x nominal time)
 - 20x2 fields designed with very high completeness
 - ~500 tiles
 - ~1M spectra (BGS/LRG/ELG/QSO)

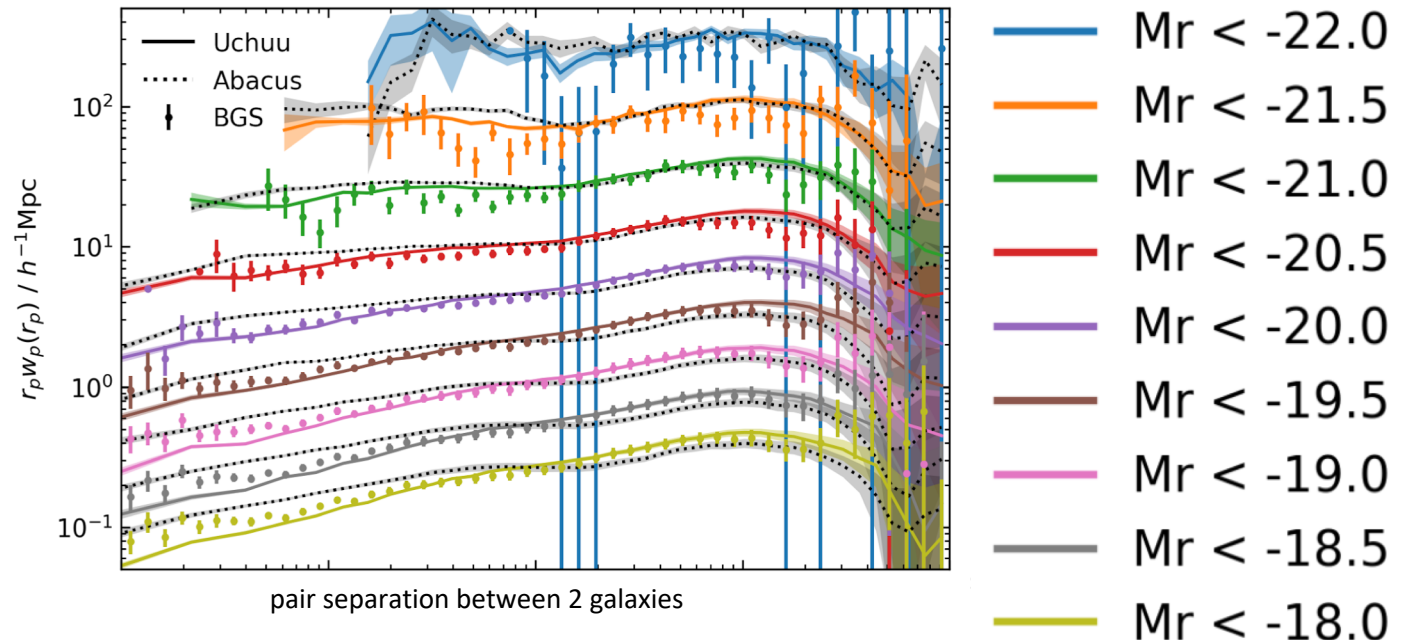
Credits: Christophe Yèche

1% survey HOD papers: BGS

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- 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*

1% survey HOD papers: ELG

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

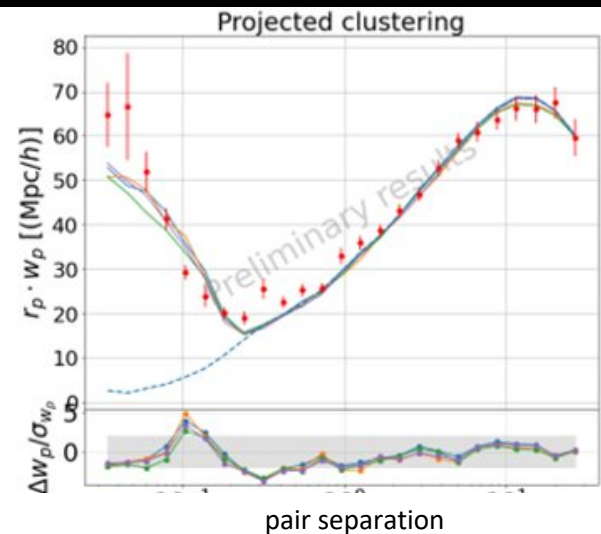
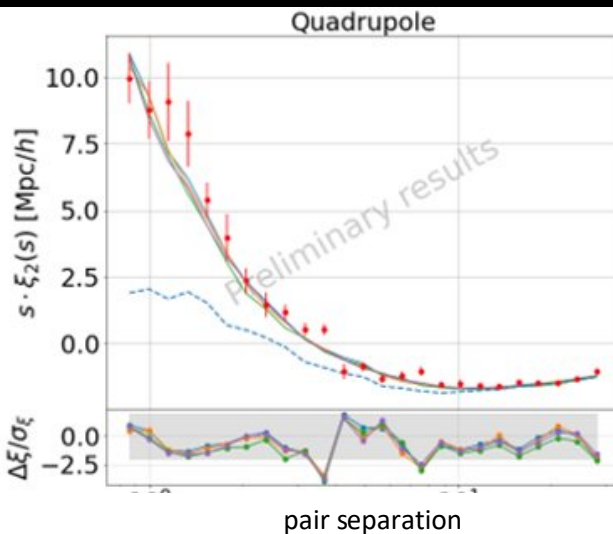
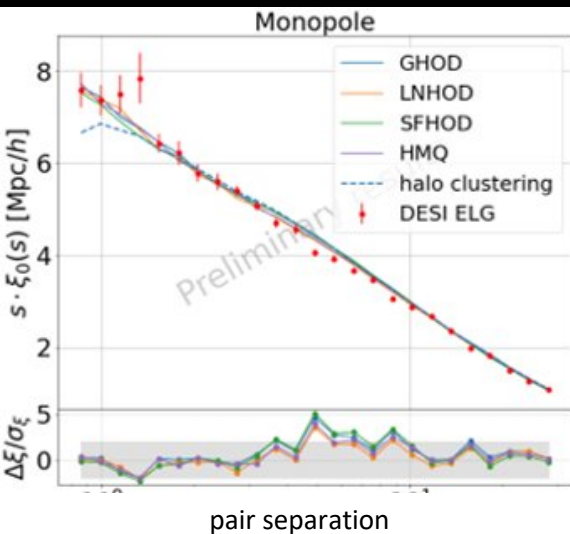
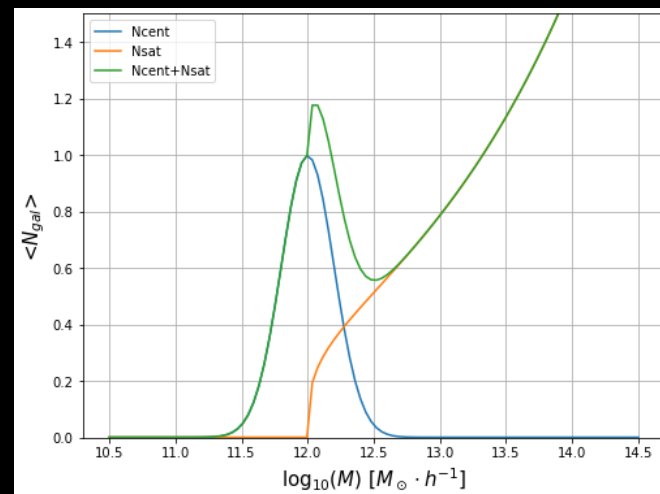
$$\langle N_{cent} \rangle (M_h) = \frac{A_c}{\sqrt{2\pi}\sigma} \cdot e^{-\frac{(\log_{10}(M_h) - \log_{10}(M_c))^2}{2\sigma^2}}$$

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

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



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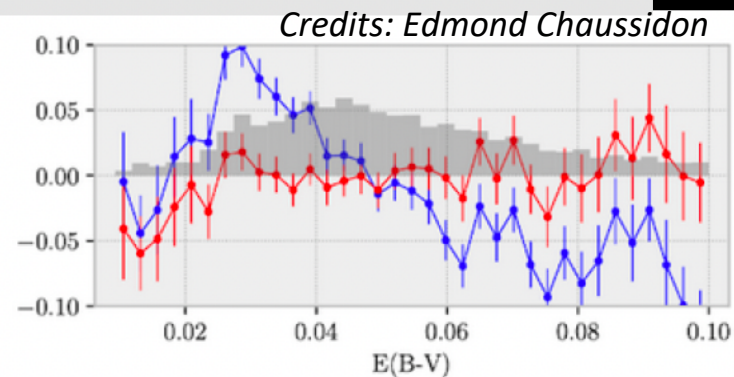
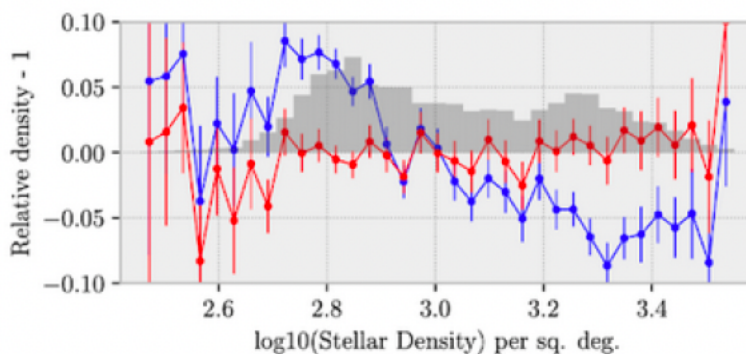
KP3 is in charge of the creation of LSS catalogues that produce minimally biased 2-pt statistics measurements.

imaging systematics

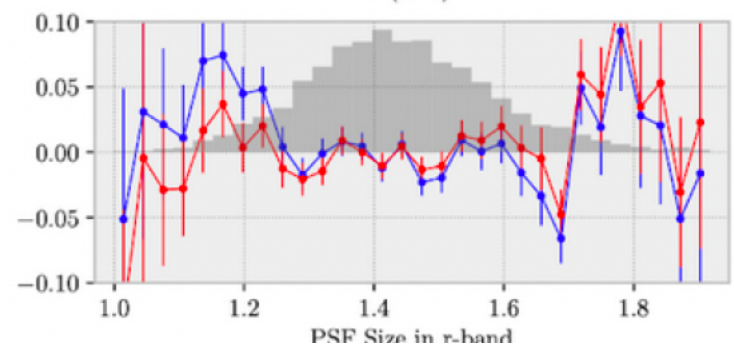
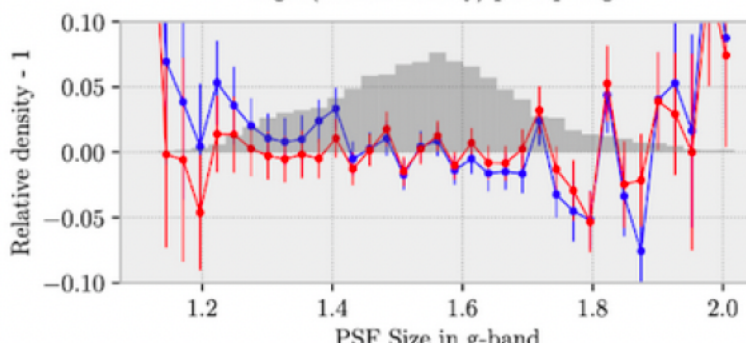
anisotropies in the Legacy Imaging surveys (depth, seeing, stellar density, galactic extinction...)

⇒ variations in the density of targets

⇒ variations in the density of galaxies



Credits: Edmond Chaussidon



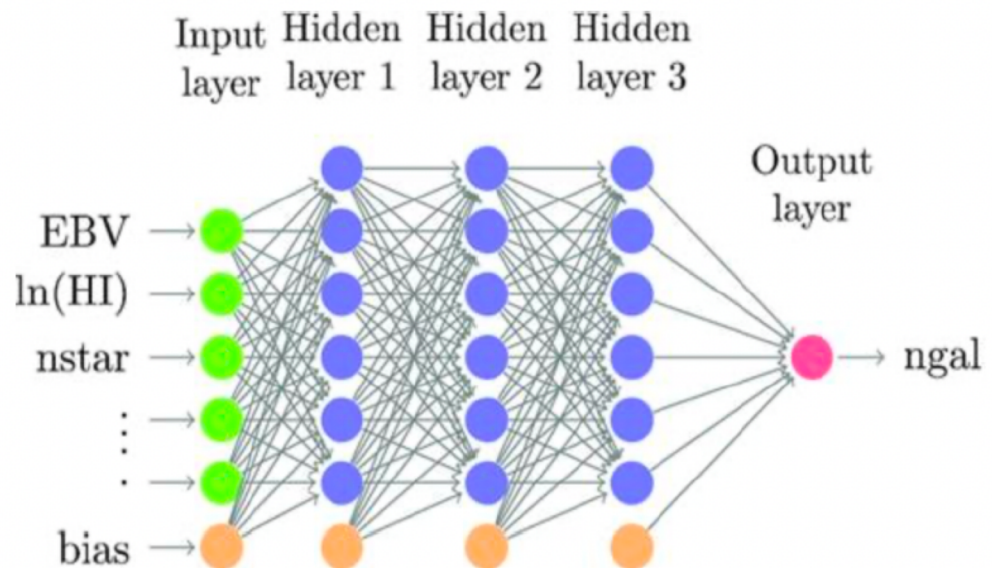
ELG DA0.2: raw (blue), after applying weights (red)

template fitting

galaxy density = $f(\text{depth, seeing, ...}) + \text{noise}$

weight = $1/f(\text{depth, seeing, ...})$ 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

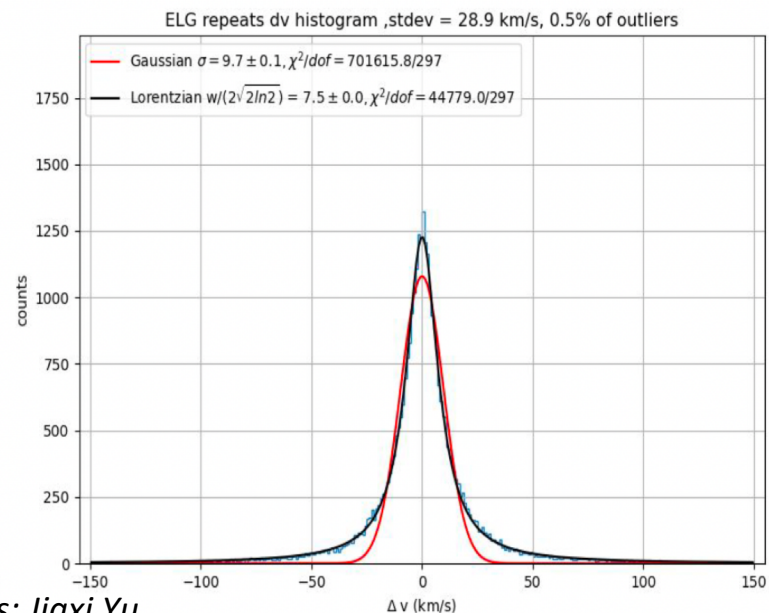
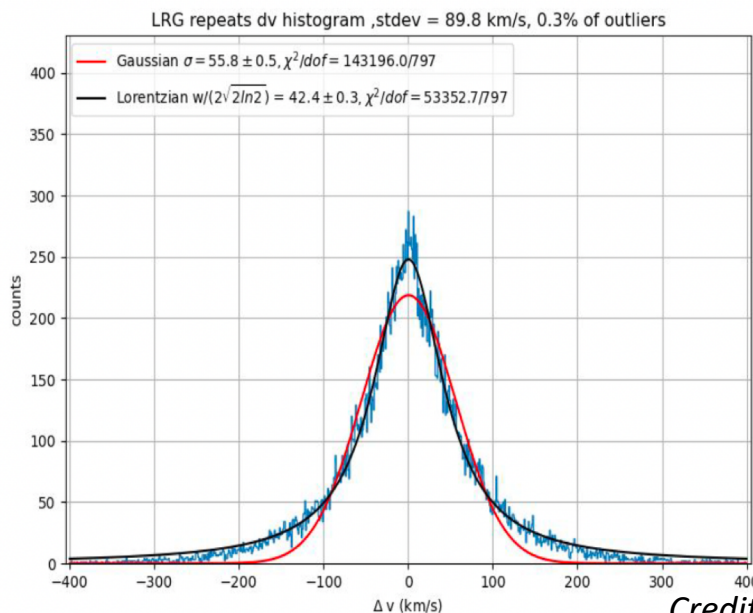
fiber assignment

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)

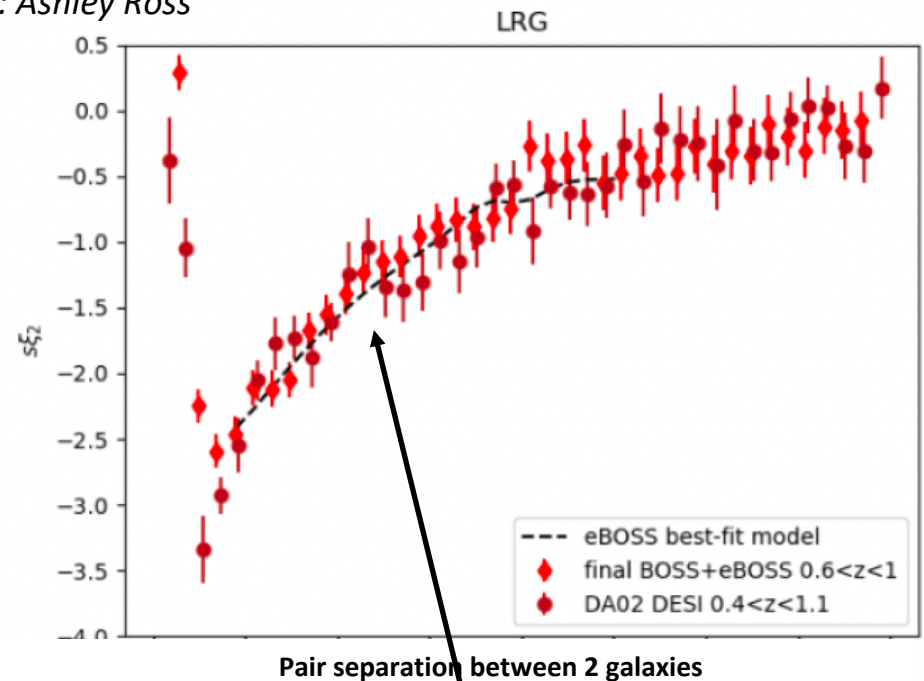
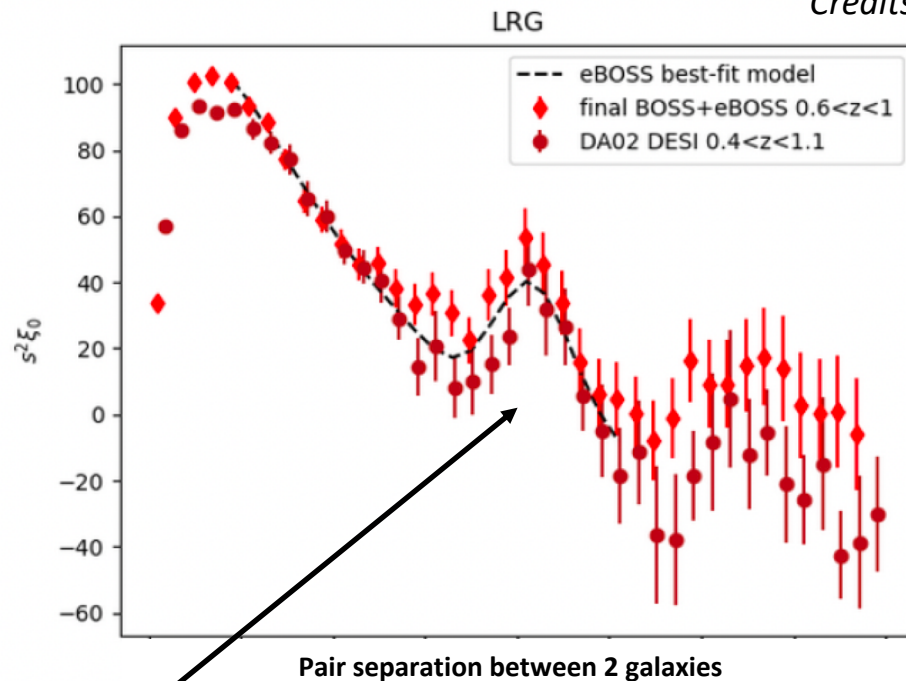
- fraction of "good" redshifts depends on observing conditions and flux
- redshift uncertainty may be broad²: must be accounted for in the theory
- some "good" redshifts may be totally wrong: estimate fraction of catastrophic redshifts and failure modes (line confusion).



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

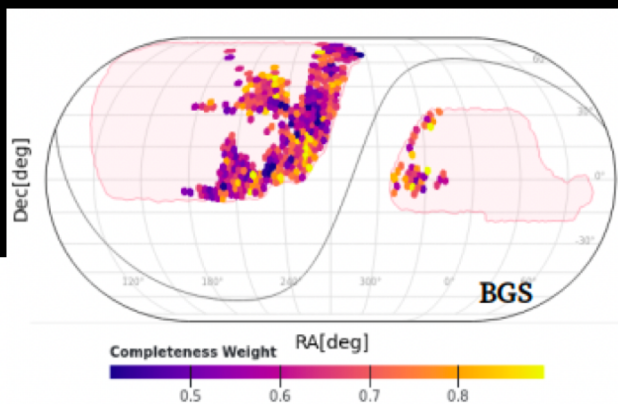
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KP4 is in charge of coordinating the BAO measurements (including reconstruction) from the 2-pt statistics of the year 1 DESI data using the BGS, LRG, ELG and QSO tracers .

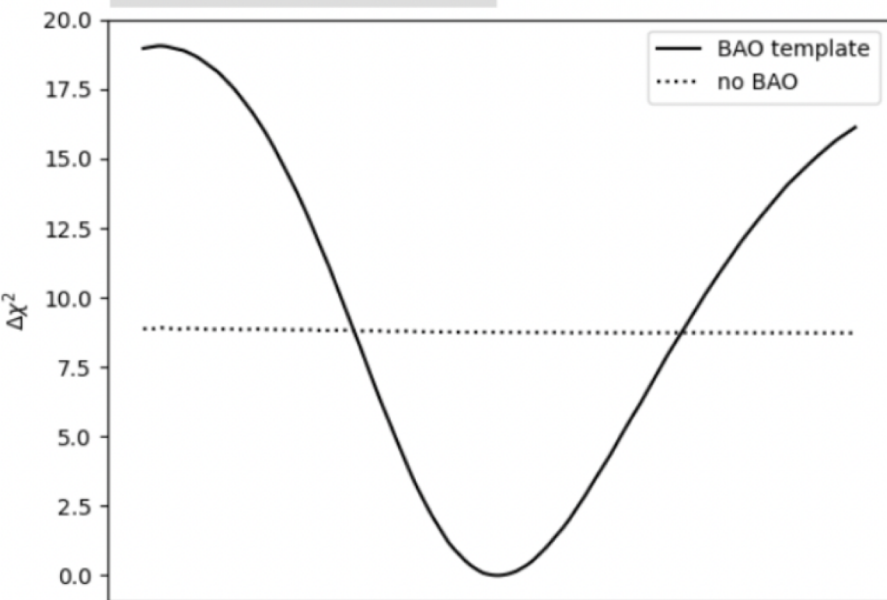
BAO in EDR (DA0.2) BGS



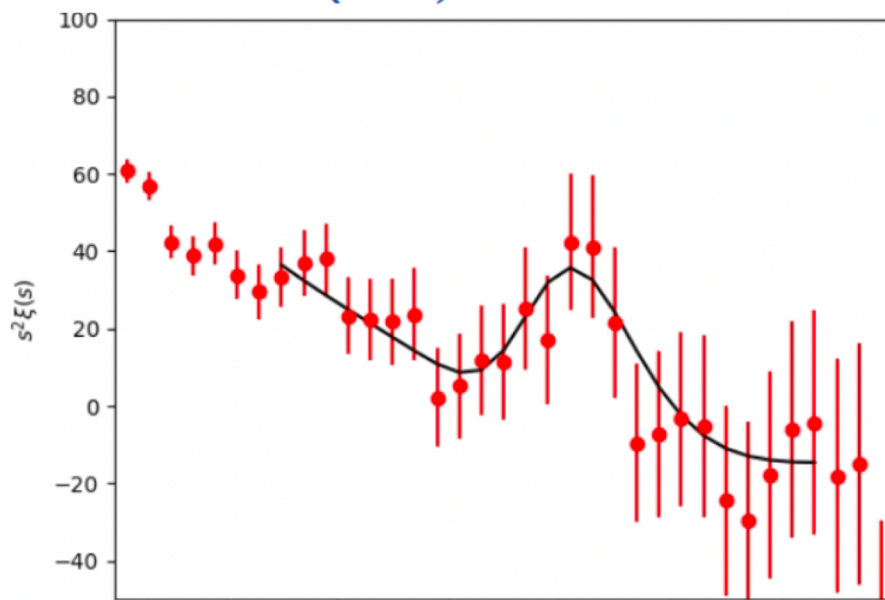
Redshift range $0.1 < z < 0.5$
BAO code: Barry
<https://github.com/Samreay/Barry>

DA0.2 BGS
2.6% ($\sim 3\sigma$) BAO detection

PRELIMINARY



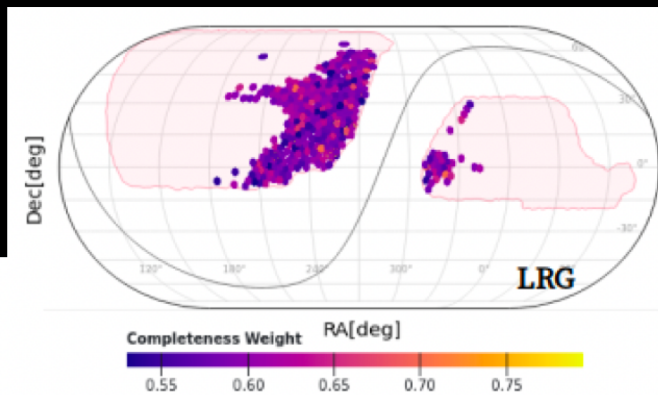
α (relative isotropic BAO scale)



s [Mpc/h]

Credits: Jeongin Moon

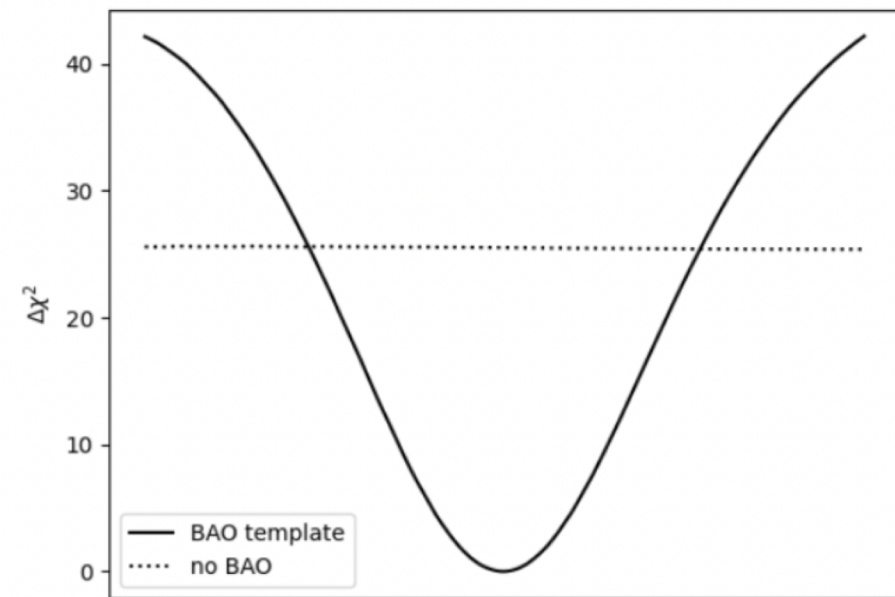
BAO in EDR (DA0.2) LRG



Redshift range $0.4 < z < 1.1$
BAO code: Barry
<https://github.com/Samreay/Barry>

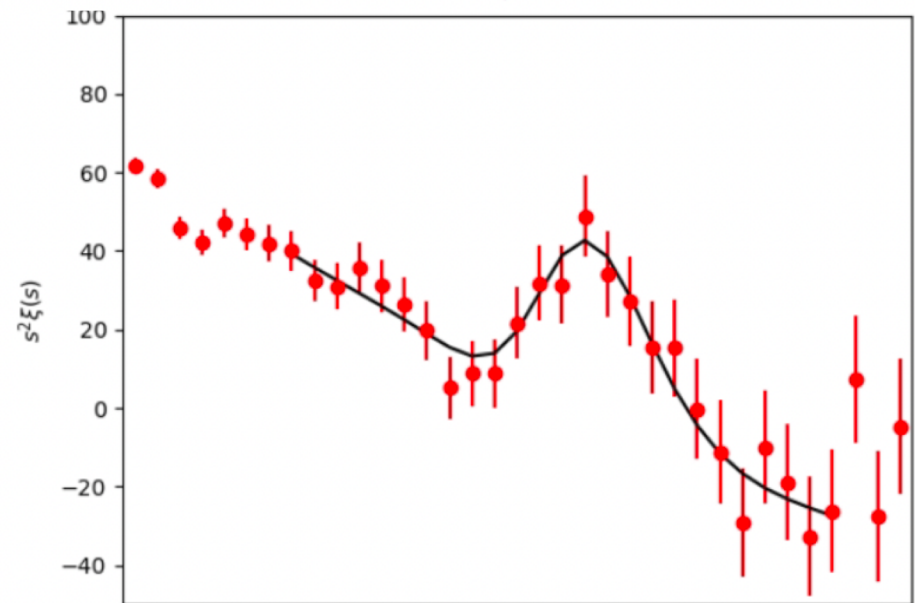
DA0.2 LRG
1.7% ($\sim 5\sigma$) BAO detection

PRELIMINARY



α (relative isotropic BAO scale)

Credits: Jeongin Moon



$s[Mpc/h]$

DESI Y1 Key Projects

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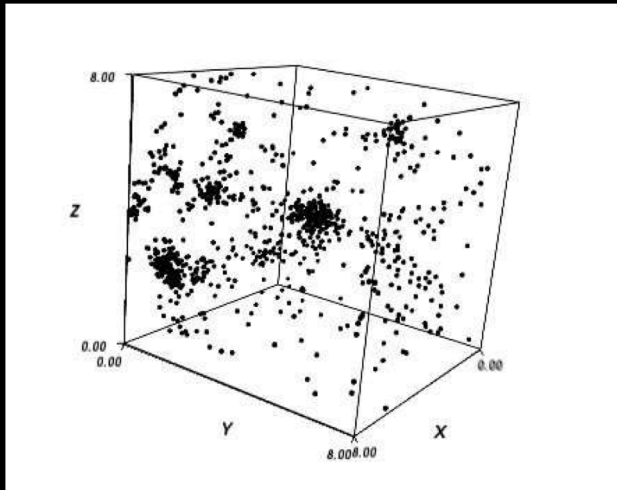
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KP5 is in charge of coordinating the Full-Shape measurements (RSD, primordial non-Gaussianities) from the 2-pt statistics of the year 1 DESI data using the BGS, LRG, ELG and QSO tracers .

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

For DESI: Abacus, Uchuu

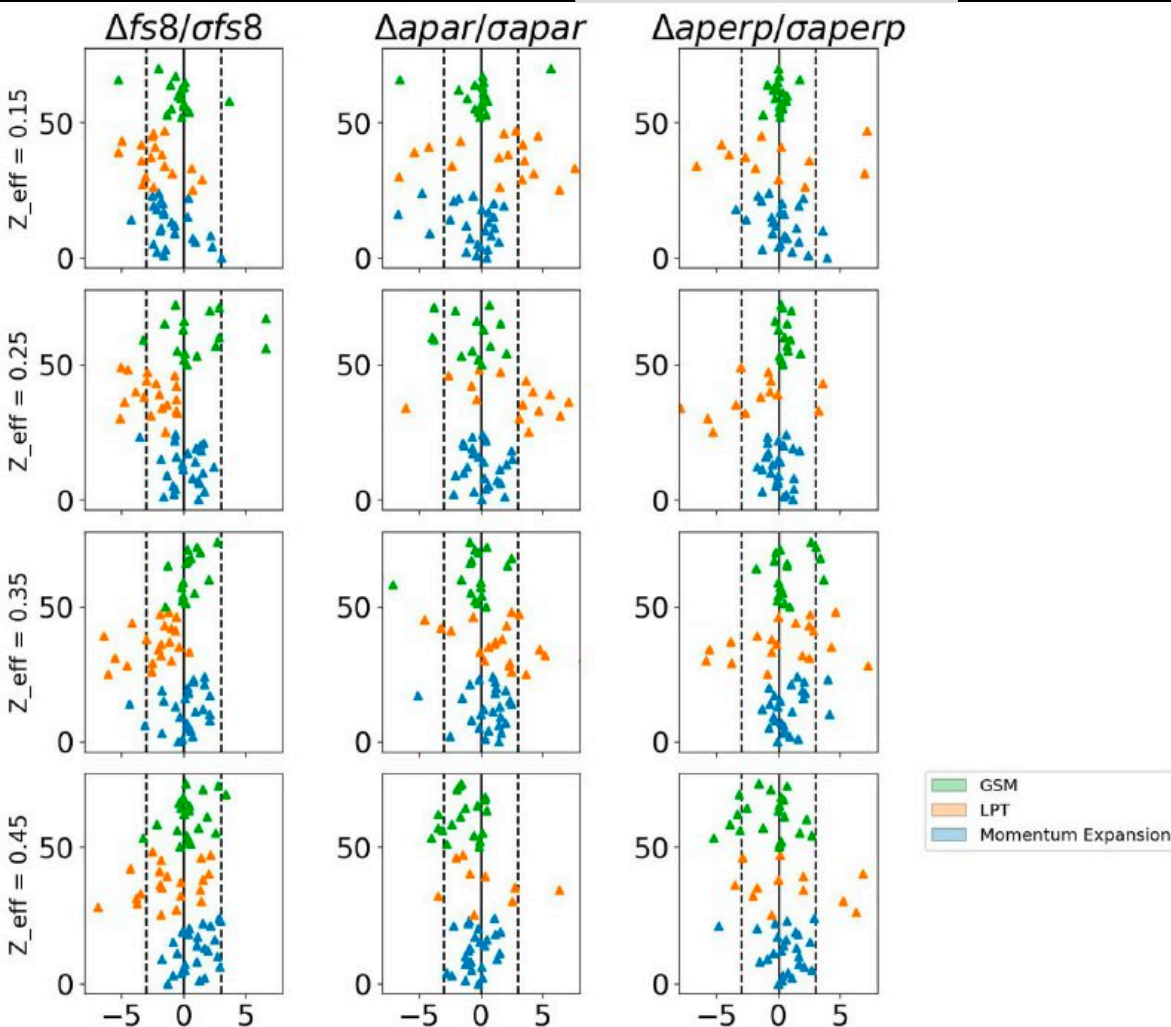
Approximate simulations

- 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 \rightarrow covariance matrix

+ specific issues to each tracer For DESI: Ezmock, GLAM, FastPM

DESI Y1 KP5: case of BGS

PRELIMINARY



EFT code: velocileptors

<https://github.com/sfschen/velocileptors>

- different PT models available
- turn on/turn off EFT counterterms
- Additional bias terms

+ also PyBird, FOLPSnu

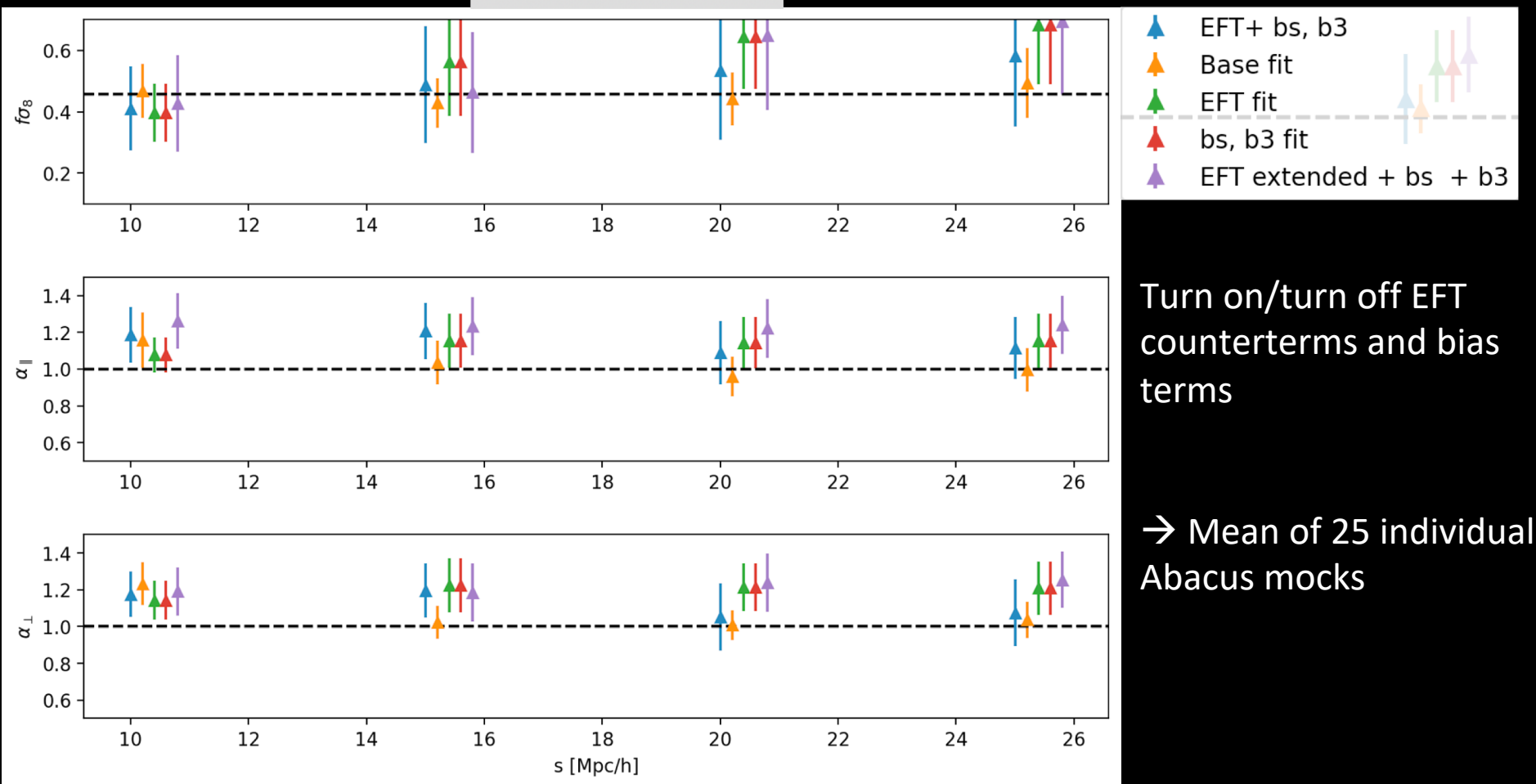
→ Tests on 25 AbacusSummit BGS mocks

<https://abacussummit.readthedocs.io/en/latest/>

Credits: Svyatoslav Trusov

DESI Y1 KP5: case of BGS

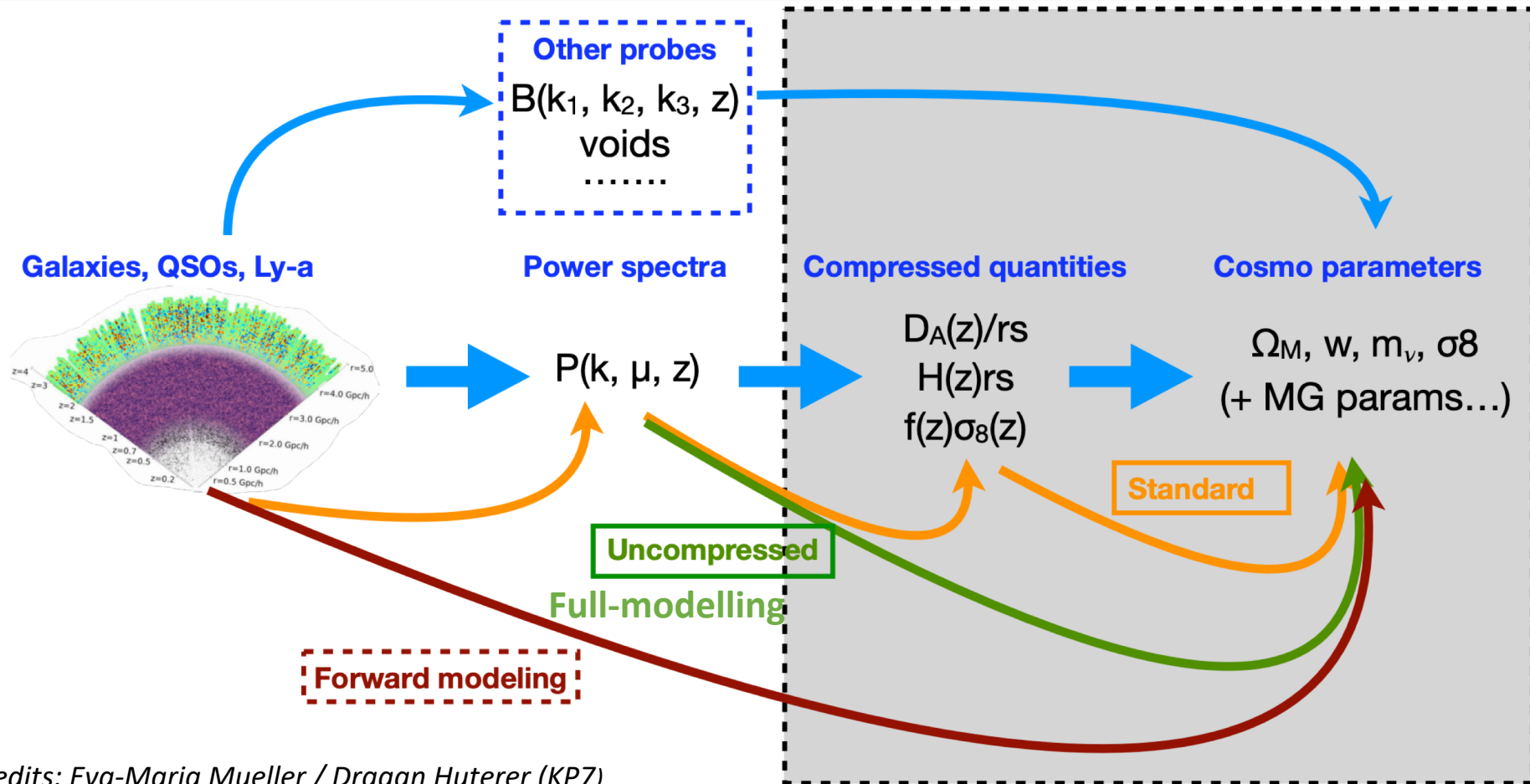
PRELIMINARY



Credits: Svyatoslav Trusov

Compressed vs uncompressed

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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.



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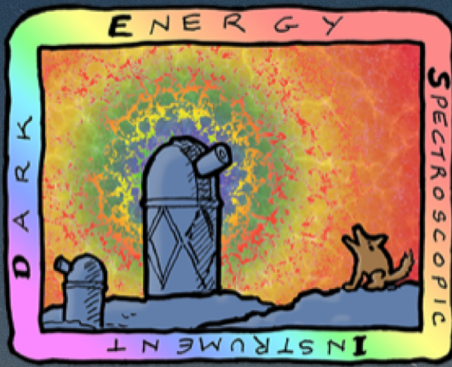
Codes currently tested:

- CosmoMC: <https://cosmologist.info/cosmomc/>
- Cobaya: <https://github.com/CobayaSampler/cobaya>
- CosmoSIS: <https://github.com/joezuntz/cosmosis>

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!!!



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