How to measure cosmology from nothing: void-galaxy cross-correlation with DESI

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GDR CoPhy - Clermont Ferrand

2 June 2026

Photo credit: Chris Wren, and Kenn Brown / mondoworks

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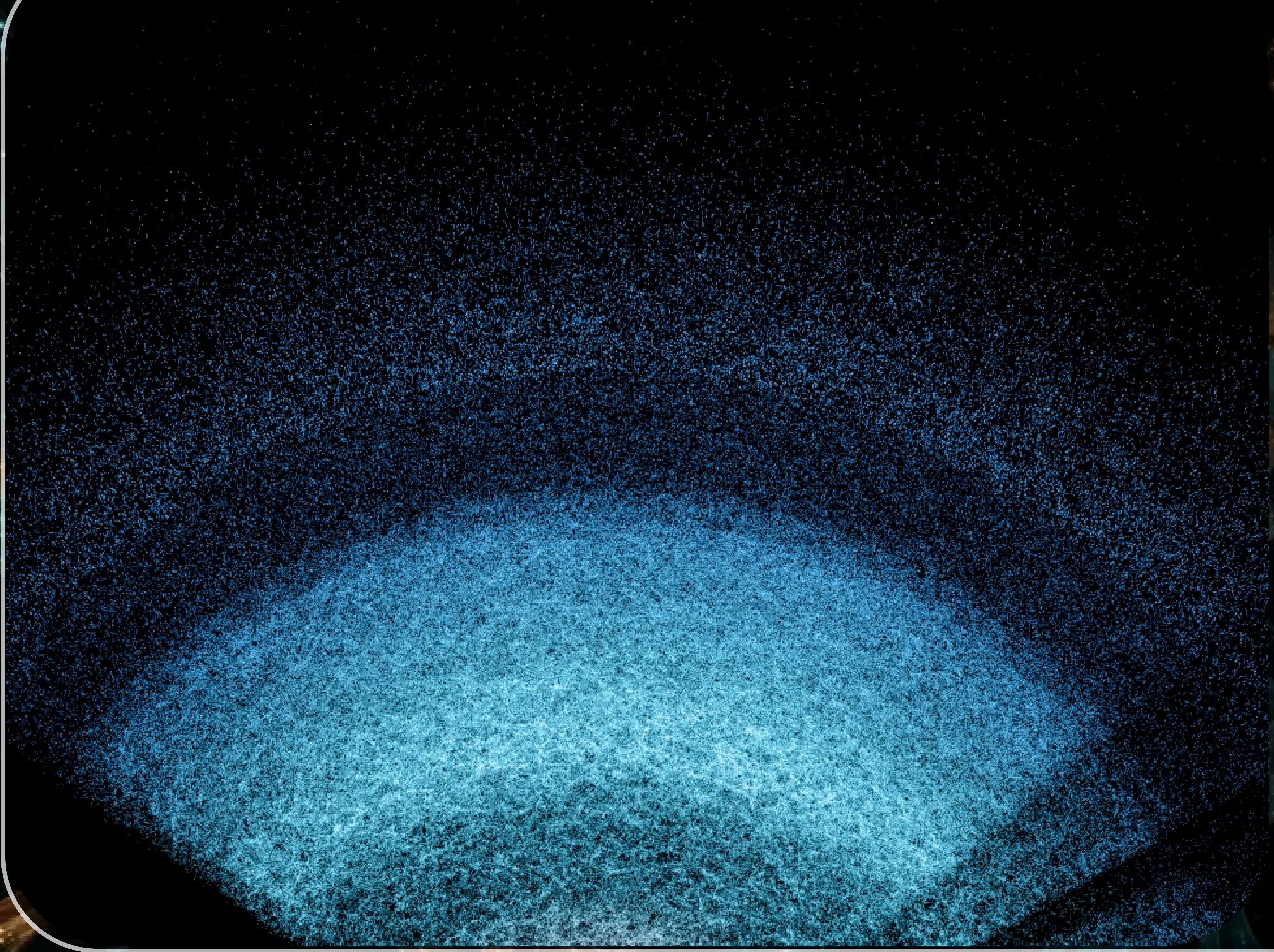
Cosmic voids

Credit: DESI collaboration



- Large under-dense regions in the universe
- Sensitive to structure growth, dark energy, modified gravity, sum of neutrino masses and galaxy formation

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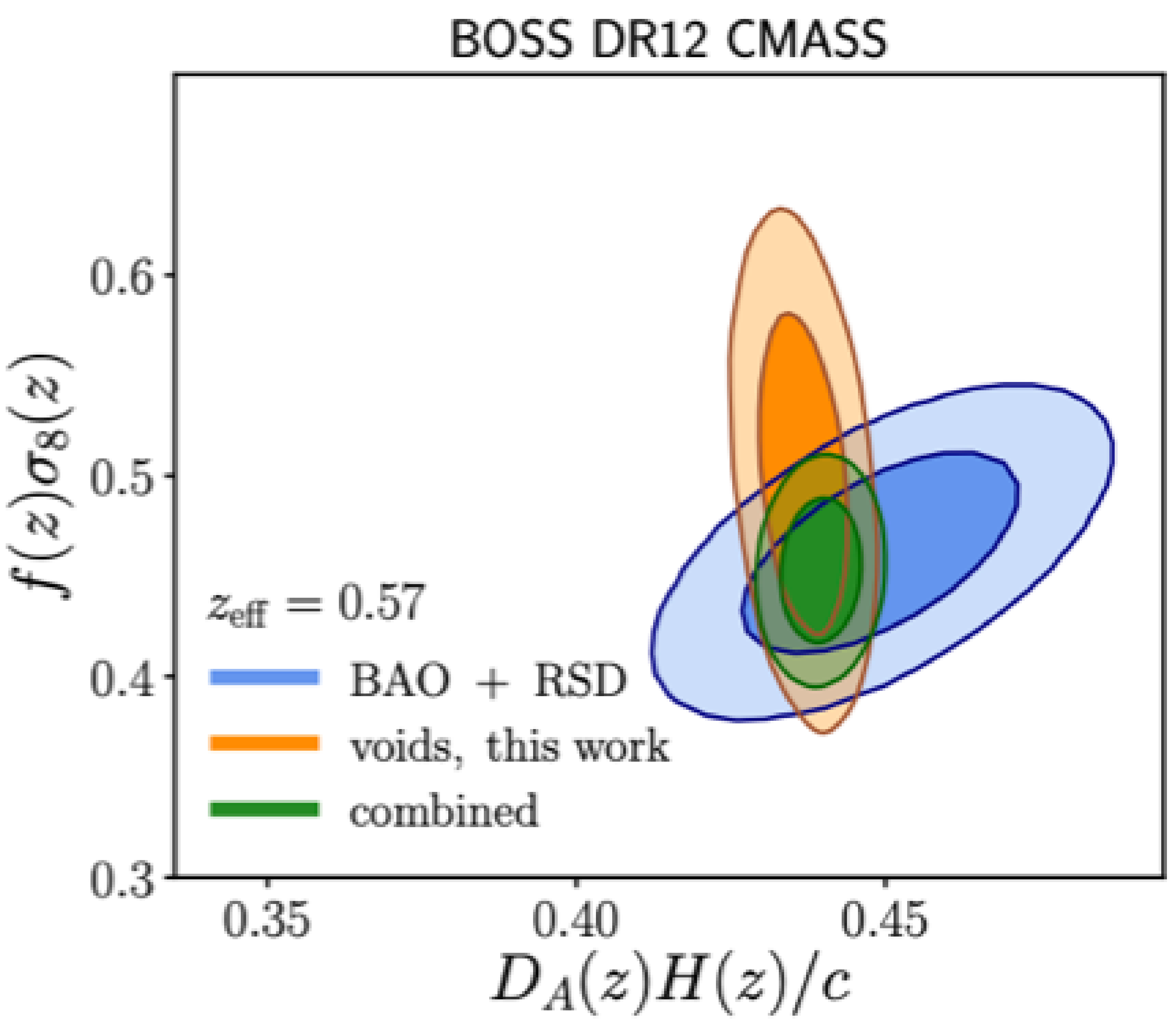
Why study cosmic voids?



arxiv: 1904.01030

Voids: complementary probes

tighter constraints

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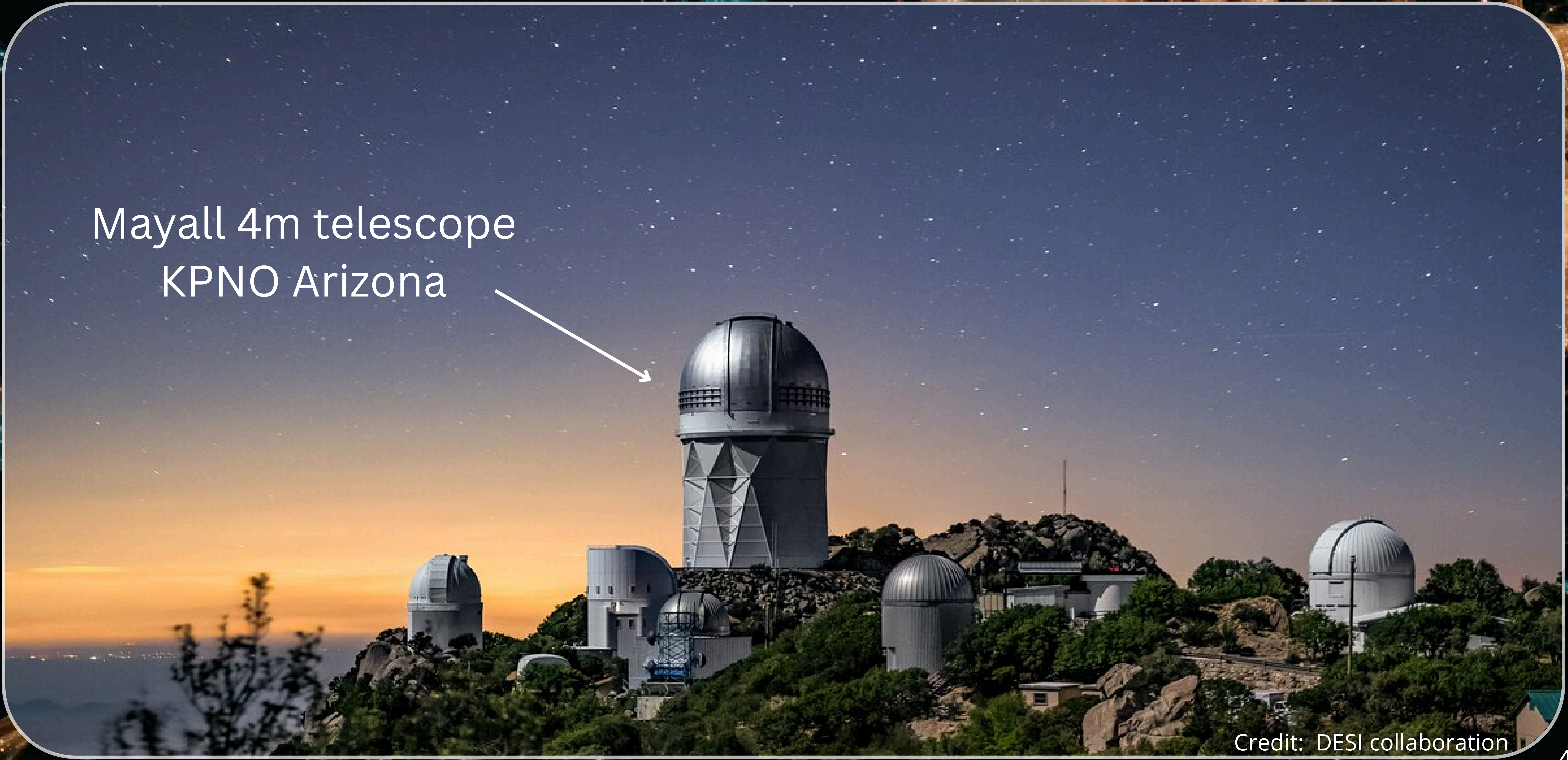
Dark Energy Spectroscopic Instrument



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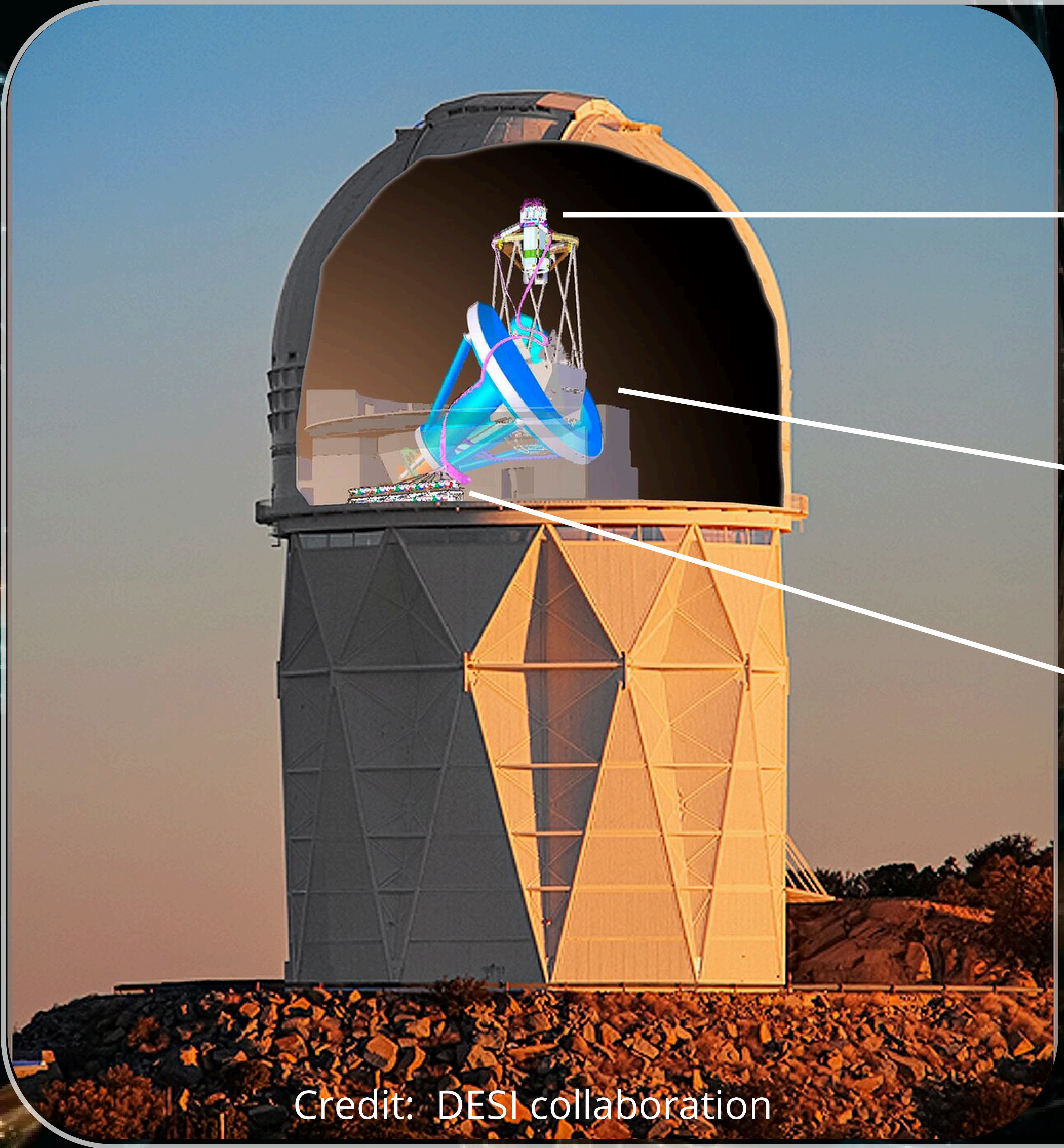
DESI: the instrument


Credit: DESI collaboration

5000 robotic positioners

3.8m primary mirror

10 spectrographs

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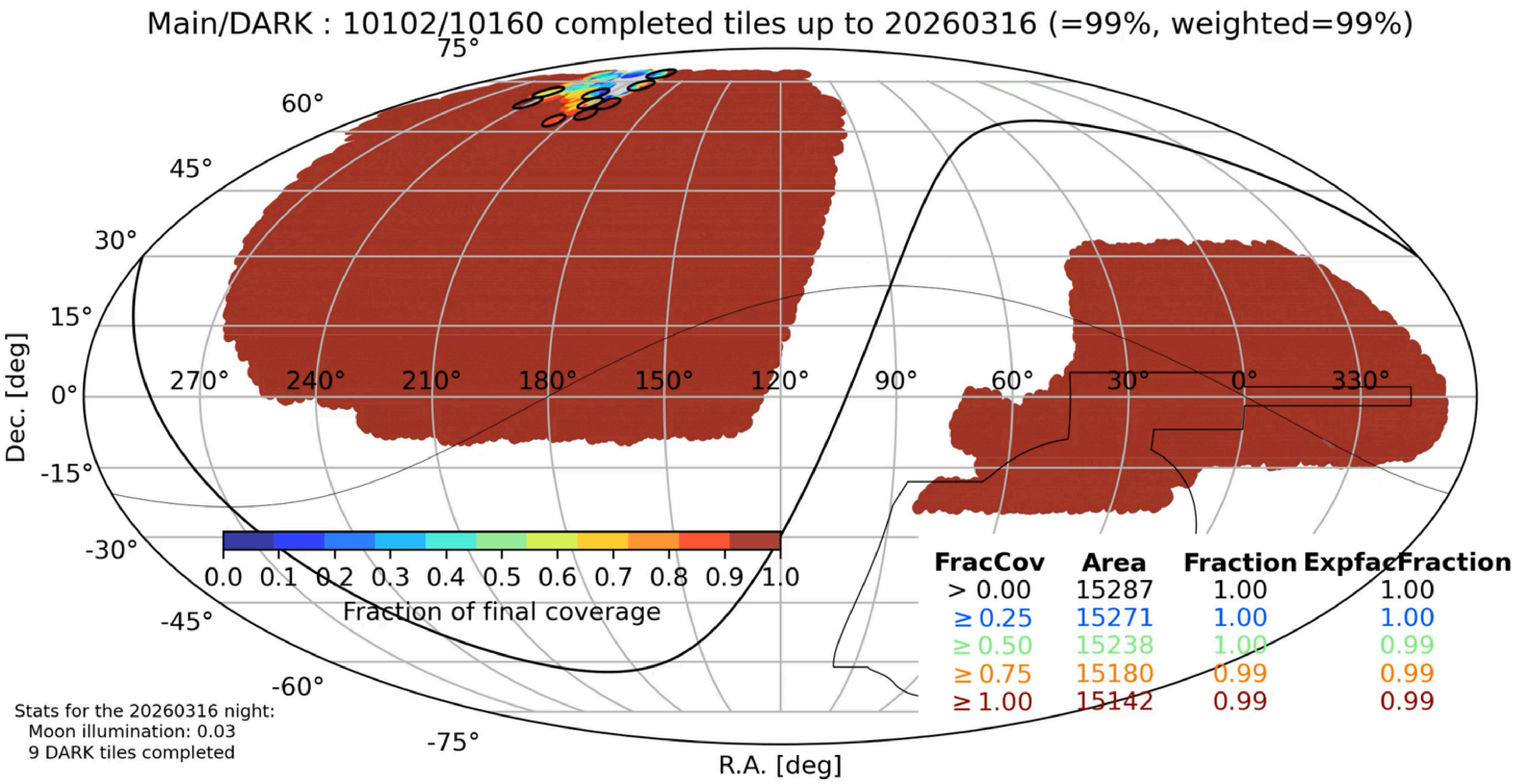
DESI: survey status

~ 17,000 square degrees

~ 60 million galaxies in 8 years

DR3 footprint



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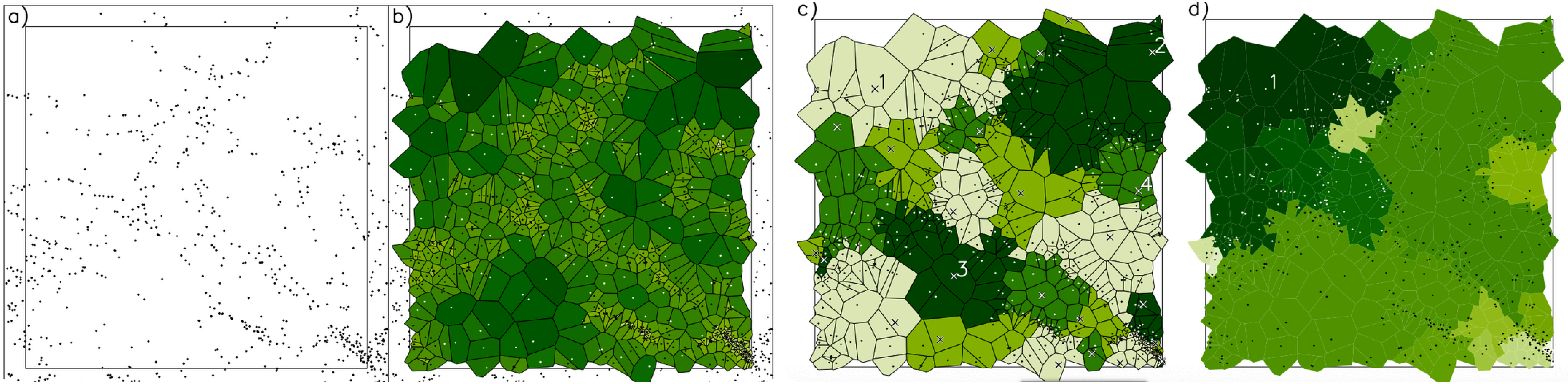
Void finding



arxiv: 0712.3049

VIDE arxiv: 1406.1191

Geometrical underdensities

Voronoi tessellation + watershed algorithm based void finder

DESI voids

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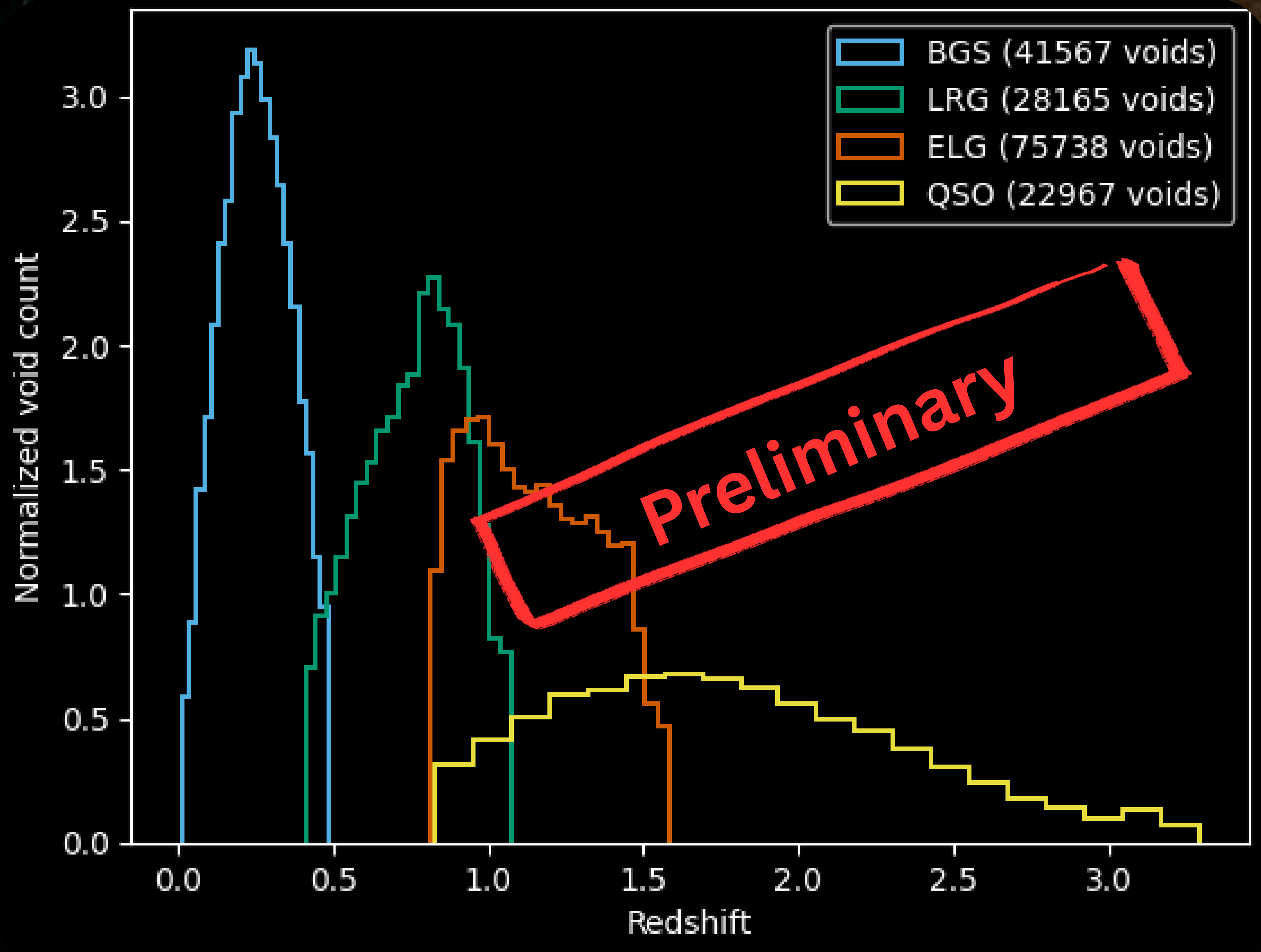
Bright Galaxy Sample (BGS)

Luminous Red Galaxies (LRG)

Emission Line Galaxies (ELG)

Quasars (QSO)



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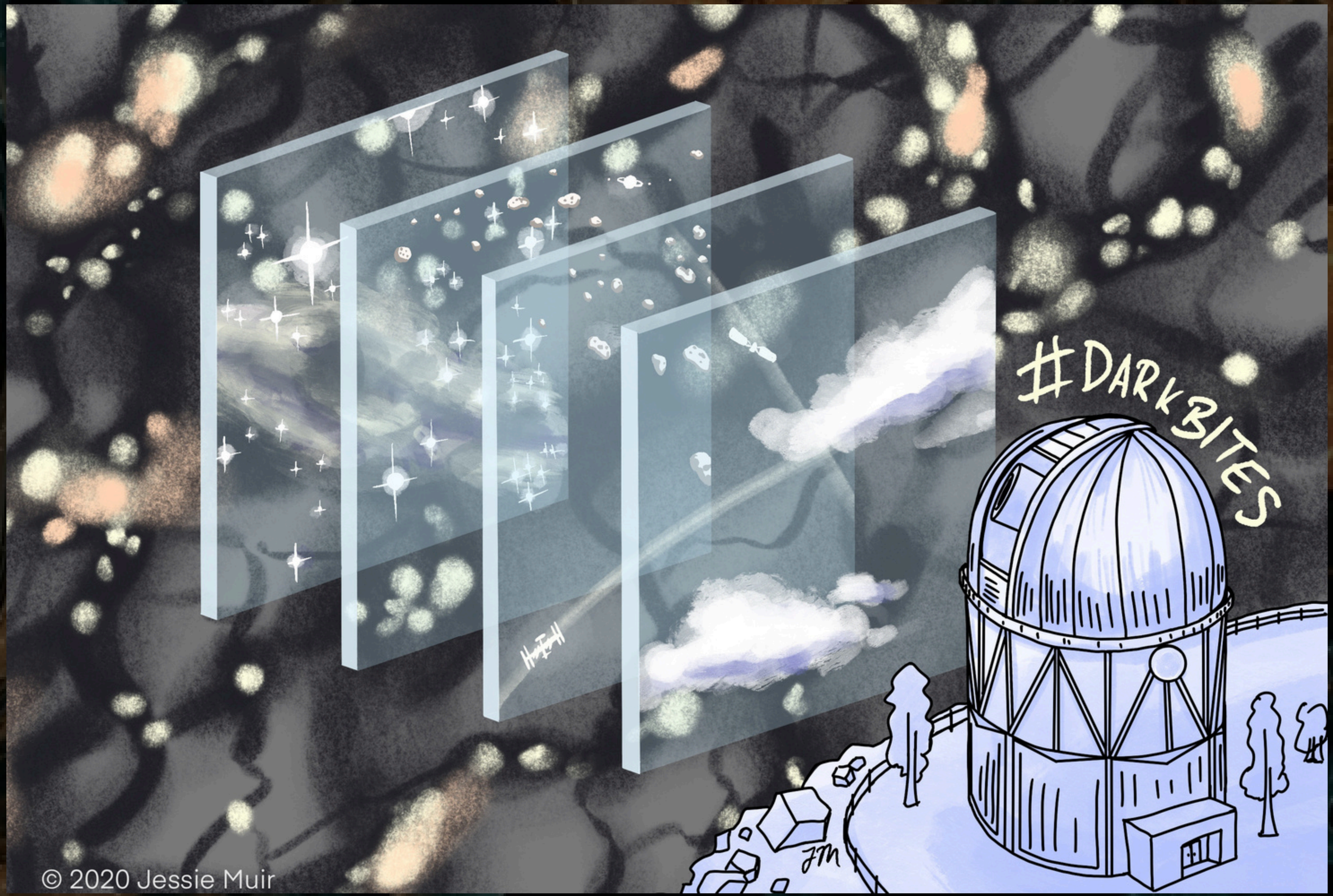
Systematic effects

- Survey mask
- Fiber assignment
- Fiducial cosmology



H. Rincon, K. Ghaemi et. al. in preparation:

DESI DR2 Void Catalogs: Joint Release and Systematics Testing

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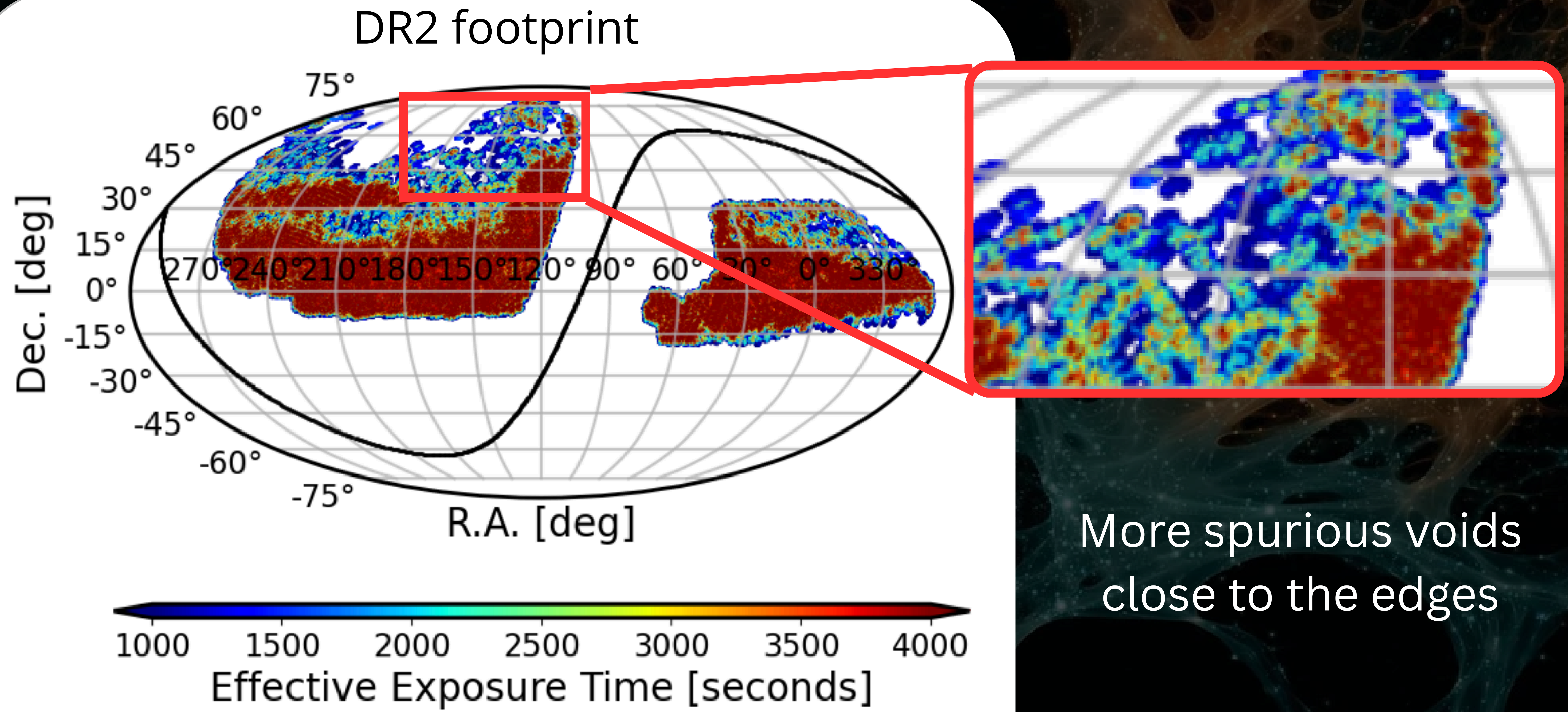
Systematic effects: Survey mask



arxiv: 2503.14741

More spurious voids close to the edges

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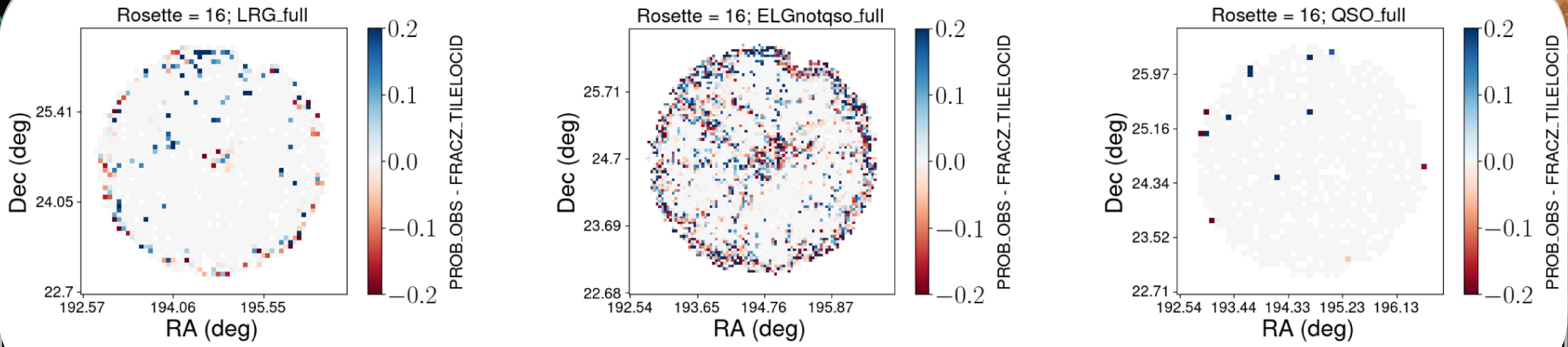
Systematic effects: Fiber assignment



arxiv: 2404.03006

Nearby galaxies compete for the same fiber!

Fiber collision can not be captured by standard incompleteness corrections!

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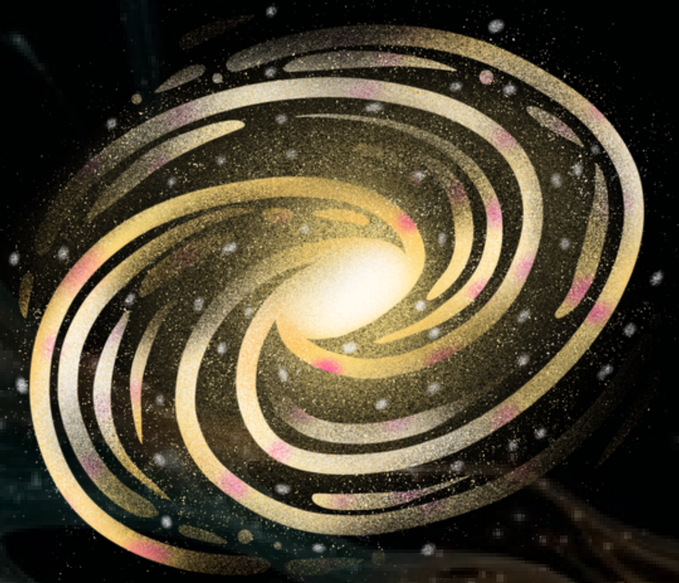
Systematic effects: Fiducial cosmology

Observation



RA, Dec, redshift

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Systematic effects: Fiducial cosmology

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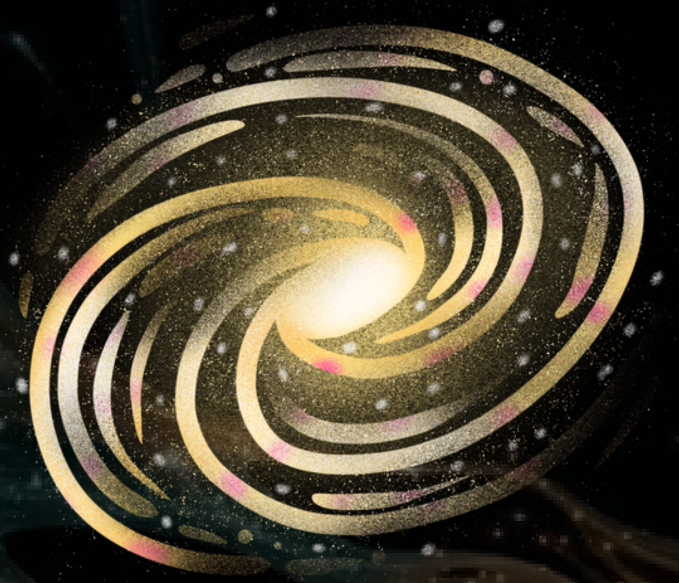

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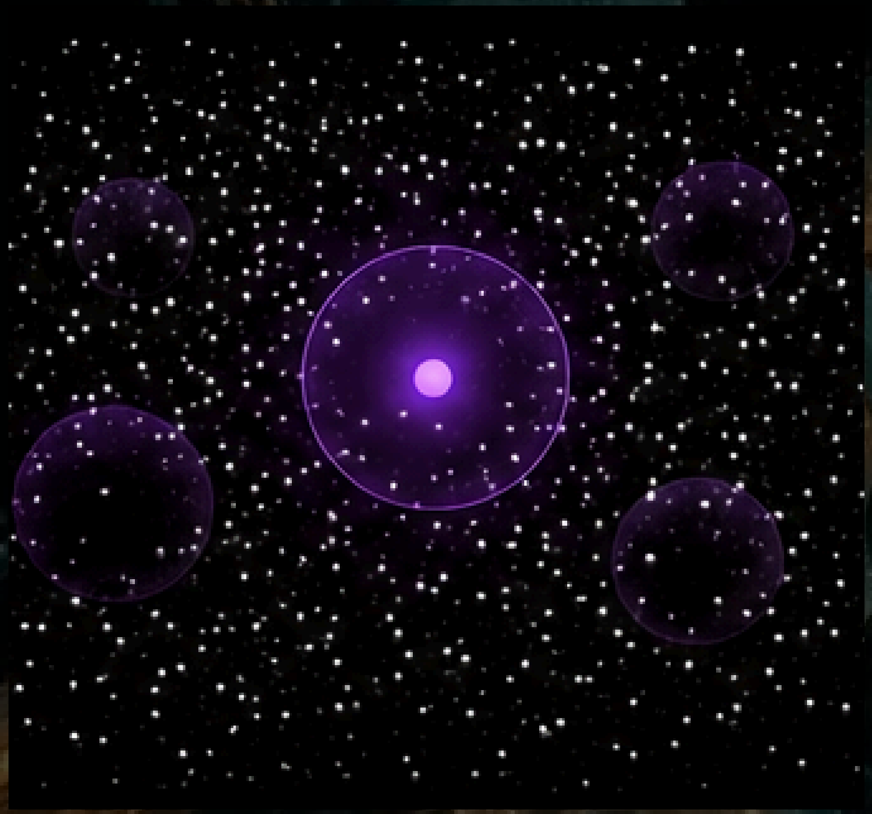
Void finding



X, Y, Z

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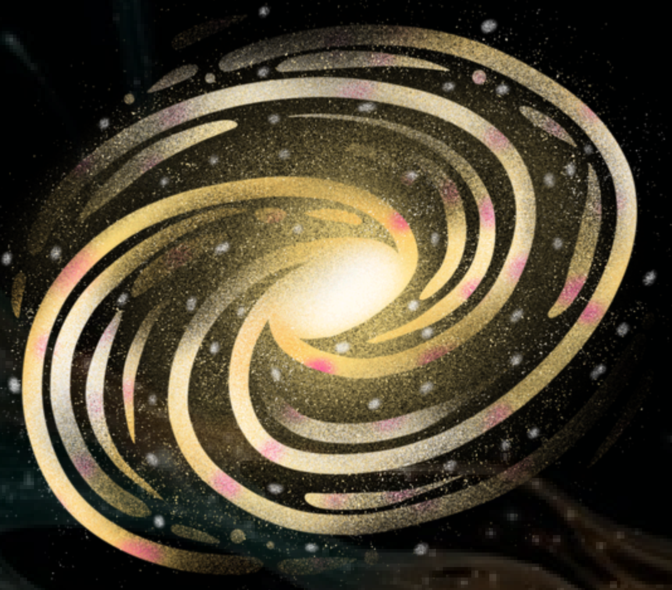

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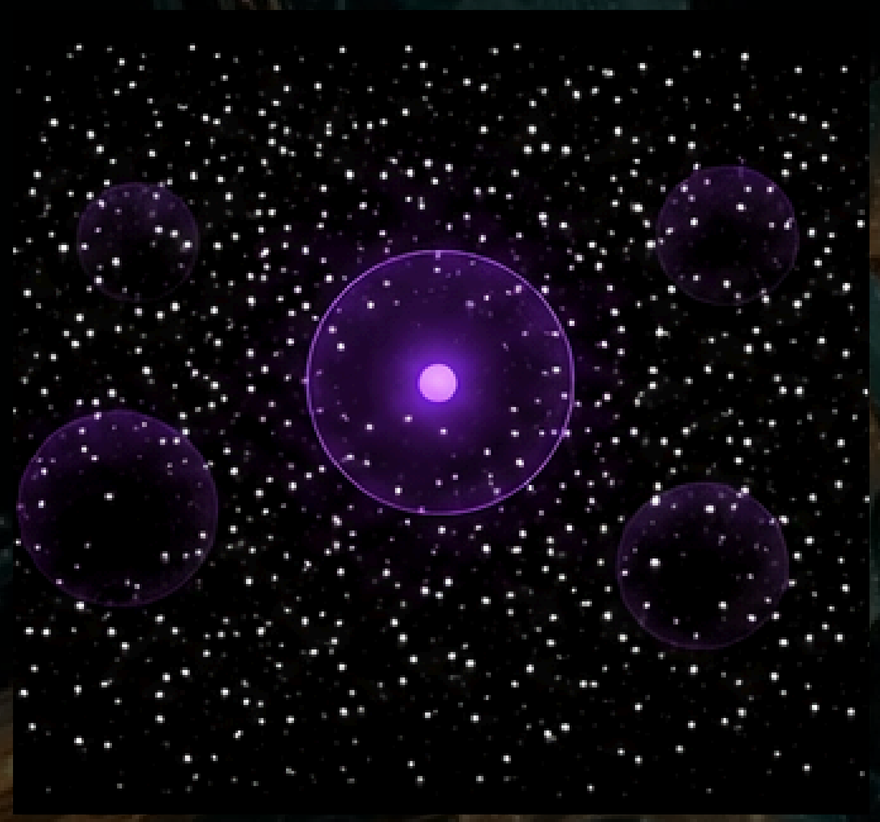

X, Y, Z

Assumption of a fiducial cosmoligy

Ω_m

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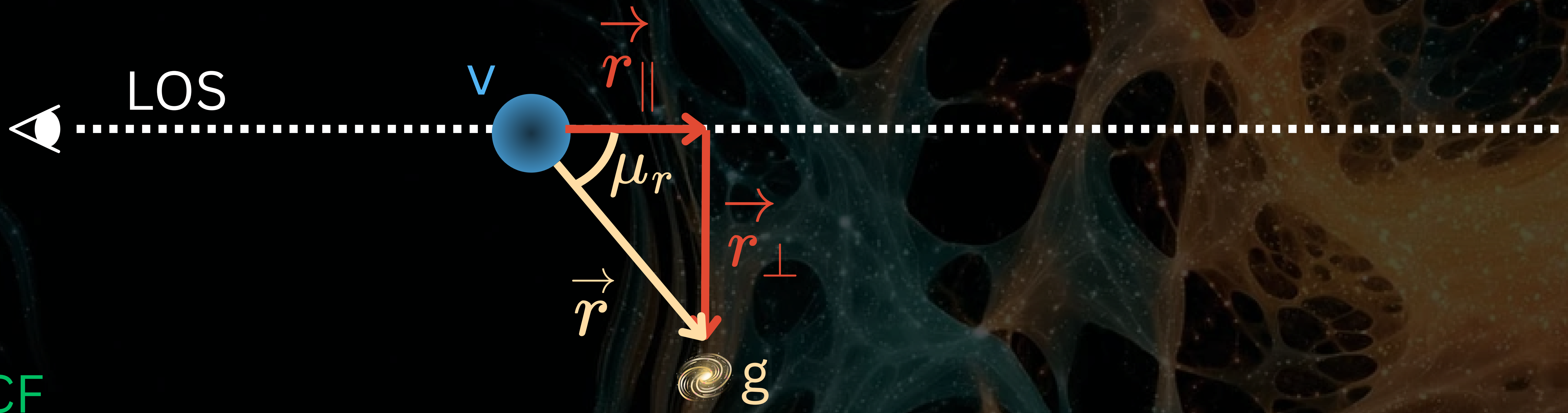
Void galaxy cross-correlation function



VGCF

Probability of finding a galaxy at comoving distance r and angle μ = cosθ from a void center.

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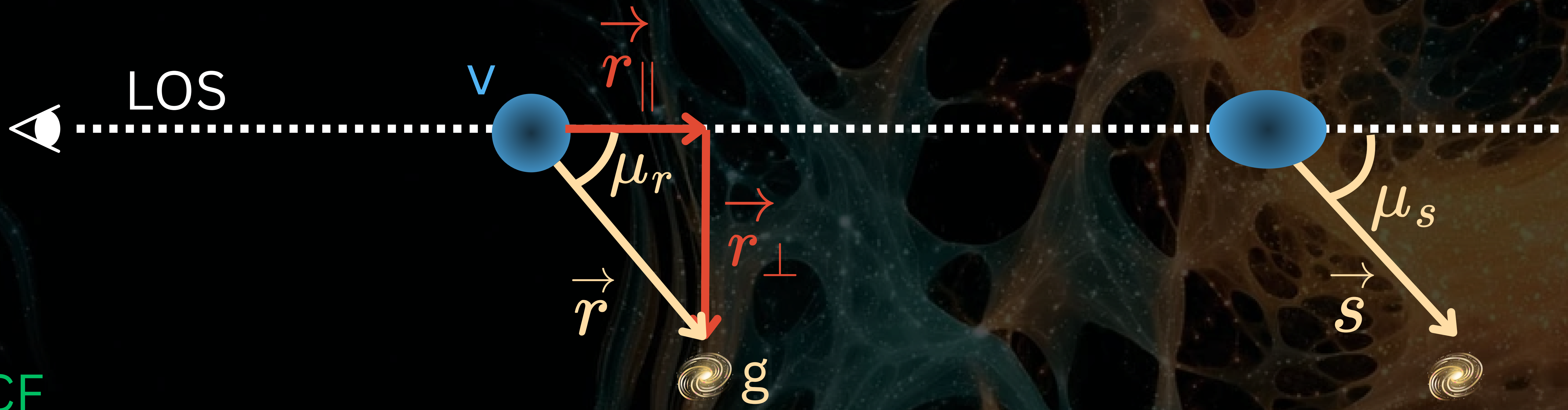
Void galaxy cross-correlation function



VGCF

Probability of finding a galaxy at comoving distance r and angle μ = cosθ from a void center.

Observed voids are affected by:

- Alcock-Paczynski distortions (AP)
- Redshift Space Distortions (RSD)

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Alcock-Paczynski distortions (AP)

Distances estimated from observed redshift: $d\left(z\right) = \int_0^z \frac{c dz'}{H\left(z'\right)}$

Assuming a fiducial cosmology (Flat ΛCDM)

$$H\left(z\right) = H_0\sqrt{\Omega_m\left(1+z\right)^3 + \Omega_\Lambda}$$

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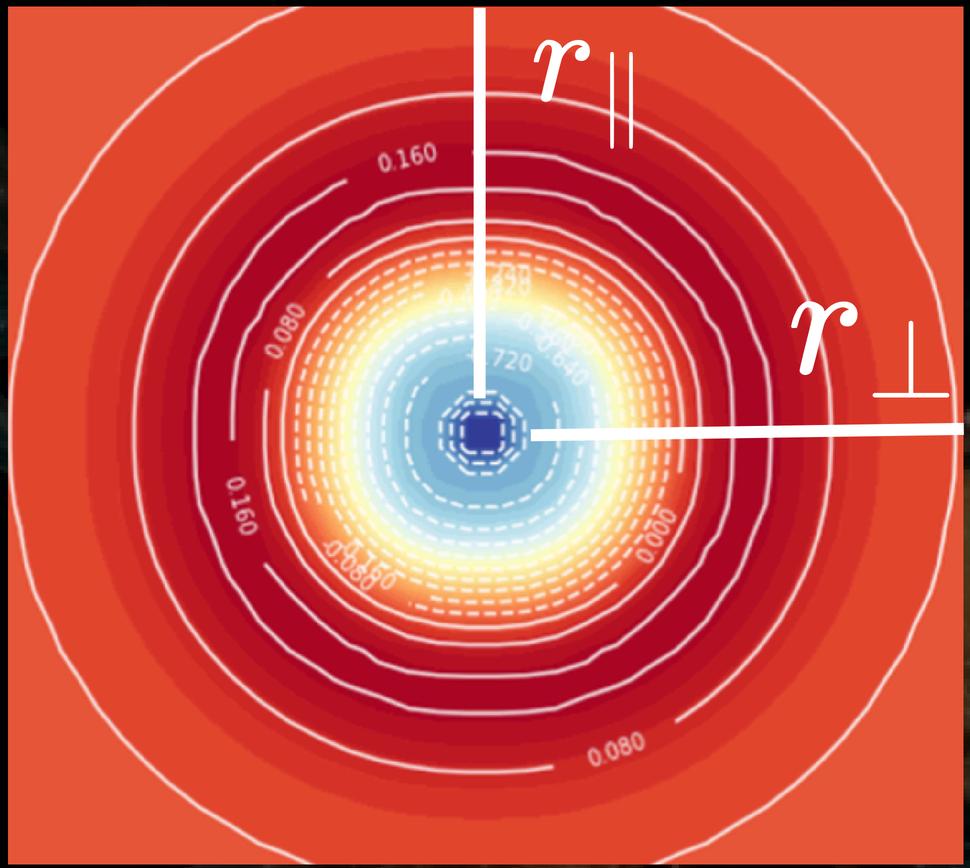
Real space

True Cosmology



Credit: Giulia Degni

$r_\parallel = r_\perp$

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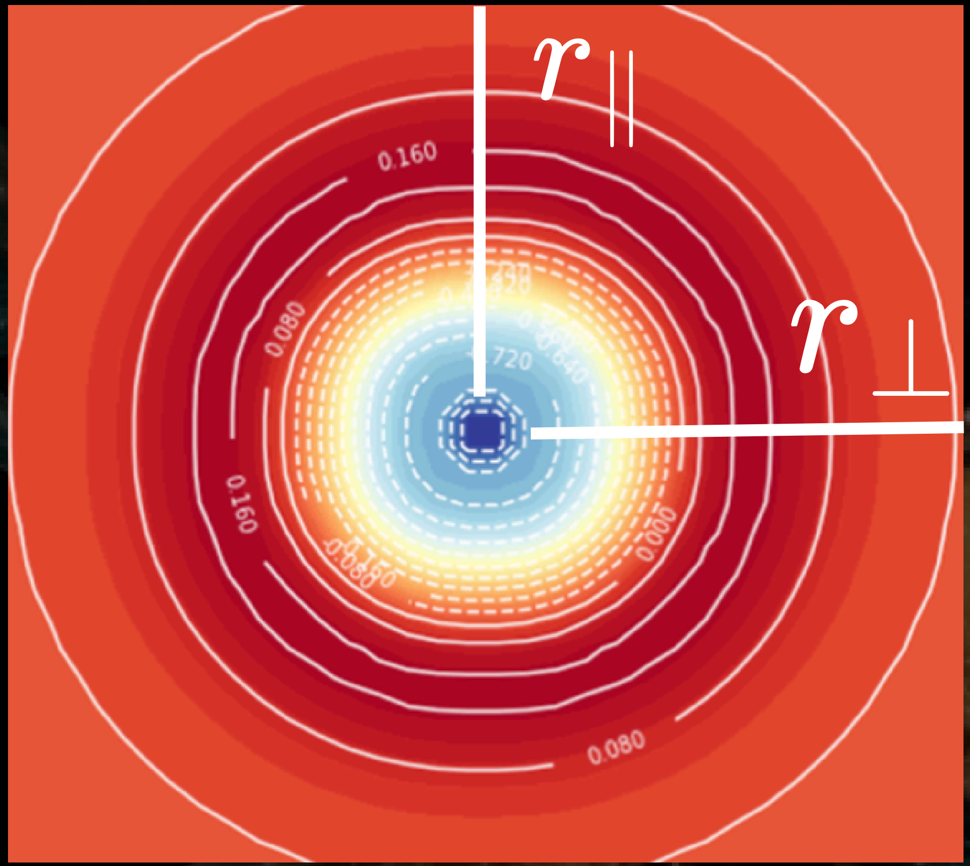

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$$r_\parallel = r_\perp$$

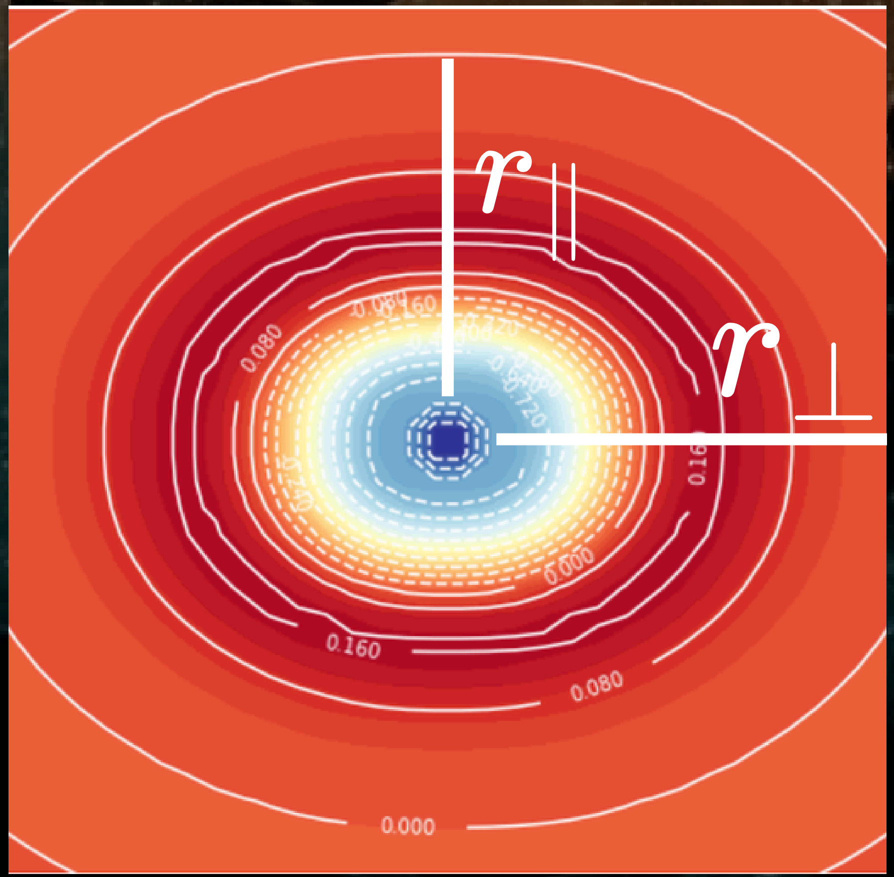
AP distortions

Fiducial cosmology

$$r_\parallel = q_\parallel r'_\parallel$$

$$r_\perp = q_\perp r'_\perp$$

$$\varepsilon = \frac{q_\perp}{q_\parallel} = \frac{D_A\left(z\right) H\left(z\right)}{D'_A\left(z\right) H'\left(z\right)}$$



Credit: Giulia Degni

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Redshift Space Distortions (RSD)

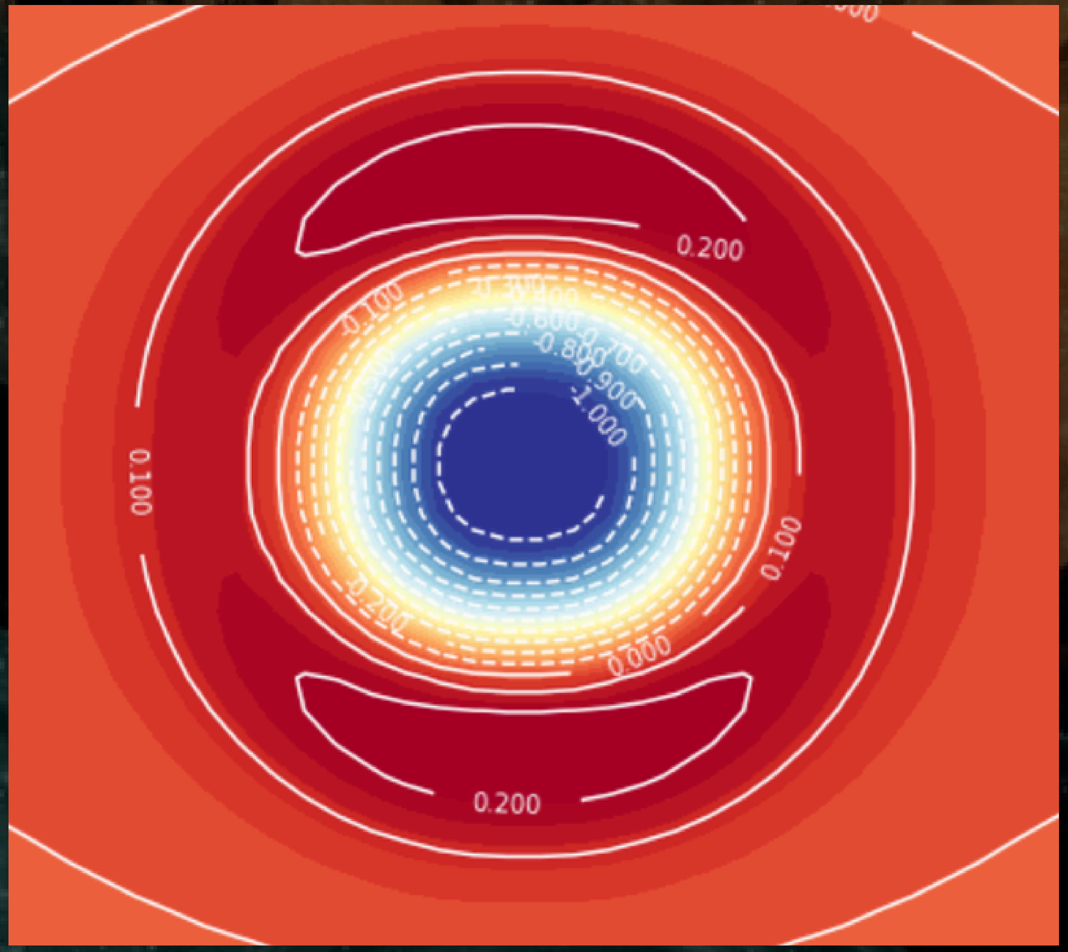
Dynamical distortions due to peculiar velocity of galaxies and Hubble expansion

$$(1 + z_{obs}) = (1 + z_h)\,(1 + z_d)$$

Hubble expansion (z_h)

Doppler effect (z_d)

We assume: $z_d \ll z_h$



Credit: Giulia Degni

$$\beta = \frac{f}{b}$$

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Modelling AP and RSD in VGCF

Linear model introduced in arxiv: 1603.05184

AP and RSD are modeled in this approach.

VGCF in real space is computed

$$\xi^s\left(s_\perp, s_\parallel\right) = M\{\xi(r) + \frac{1}{3}\beta\bar{\xi}(r) + Q\beta\mu^2[\xi(r) - \bar{\xi}(r)]\}$$

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Nuisance parameters

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Growth rate of structures / galaxy bias

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Nuisance parameters

AP parameter measured through the coordinates r, μ

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Nuisance parameters

Constrains $D_A H \longrightarrow \Omega_m, w_0 w_a, \frac{f}{b}$

AP parameter measured through the coordinates r, μ

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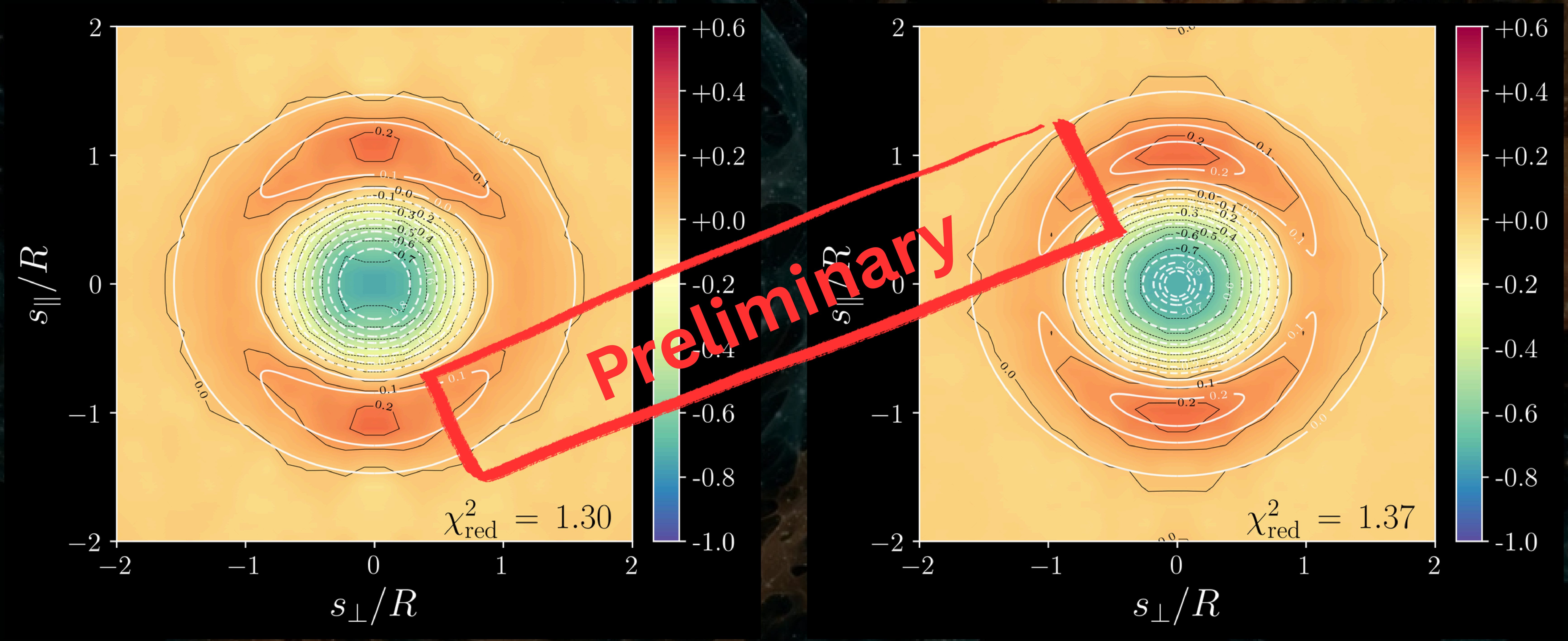
VGCF with DESI



LRG Blinded

LRG Mock

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Challenges

- Galaxy bias

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Challenges

- Galaxy bias
- Systematic effects:
  - Survey mask
  - Fiber assignment

Credit: Jessie Muir

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Challenges

- Galaxy bias
- Systematic effects:
  - Survey mask
  - Fiber assignment
- Treatment of spurious voids

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Conclusions

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- VGCF is a powerful tool
- Impressive statistical power with DESI
- Systematic treatment is important

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Stayed tuned!

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Thank you!