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Observational effects on cosmic voids

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Lendület program
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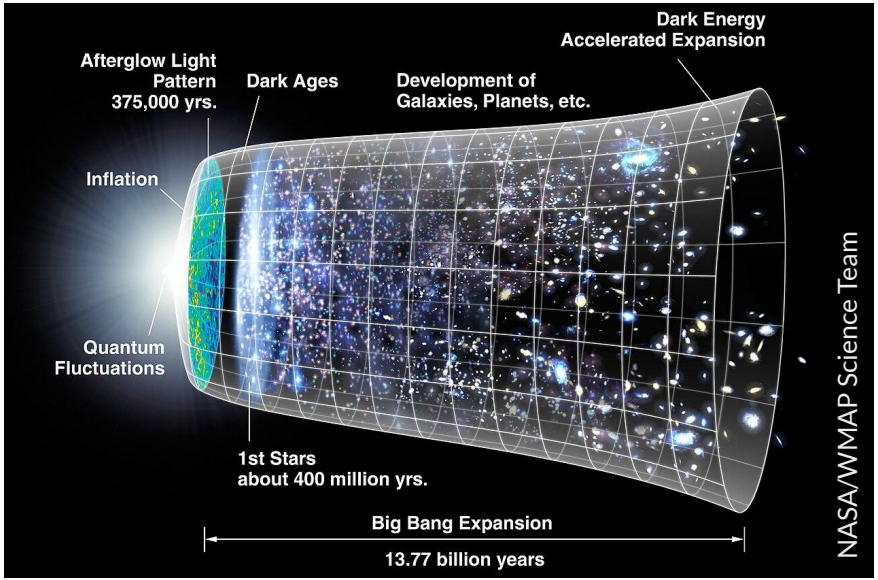
Large-scale structure

Structure formation depends on…

- composition of the early universe
- dominant component(s)

Structure = information on dark matter, dark energy, neutrino mass etc.

A very brief history of the universe



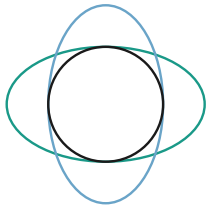
Dark matter distribution forms a web



Cosmic voids

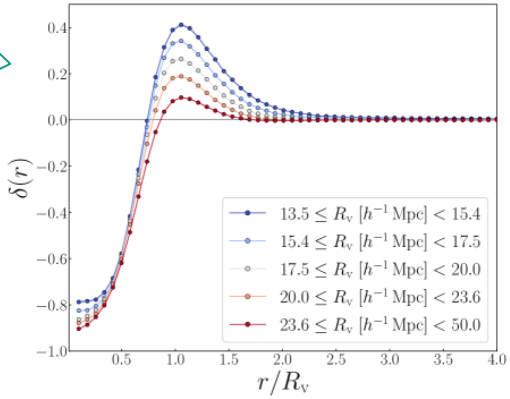
- Large (>10 Mpc)
- Underdense = lower than the mean density of the universe, but not empty

Density contrast:
$\delta=(\varrho-\varrho_{avg})/\varrho_{avg}$



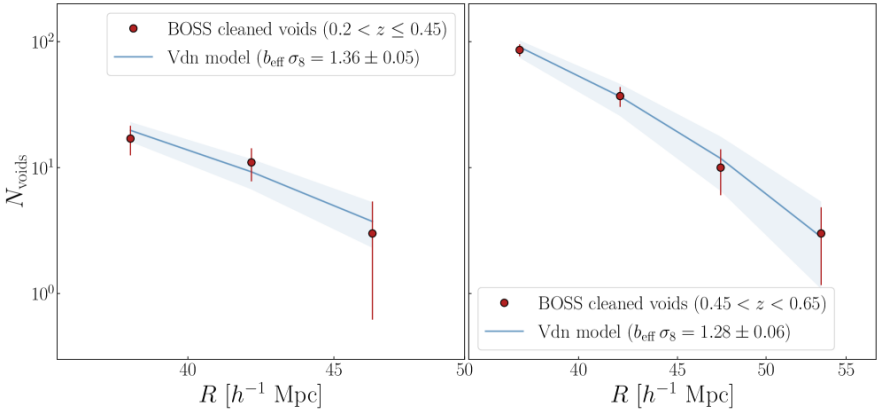
Shape

Contarini, Verza, Pisani (2026)



Density or galaxy distribution

Contarini et al. (2022)



Size distribution

Problem question

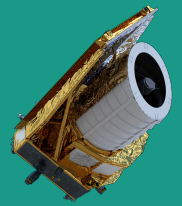
How do observational effects appear in the inferred large-scale structure and cosmological information?

Case study:
Cosmic voids in the Flagship simulation

Flagship

- **Simulation:** N-body based galaxy catalog in a lightcone, for the *Euclid* mission

Euclid - spectroscopic sample

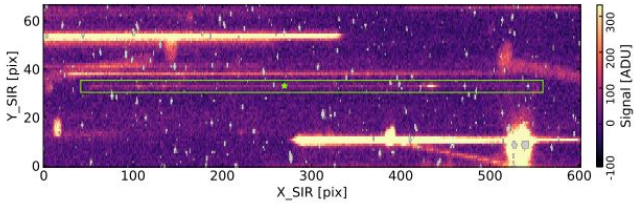


- **Redshift range:** $0.9<z<1.8$
- **Redshift error of correct identification:** $\sigma \sim 0.001$
- **Number of galaxies expected:** 9 million in an octant of the sky
- **Data release:** DR1-F in November 2026 (first galaxy catalogues in 2027)

Starforming galaxies with strong emission lines

Mapping with emission line galaxies

Copin et al. (2026)



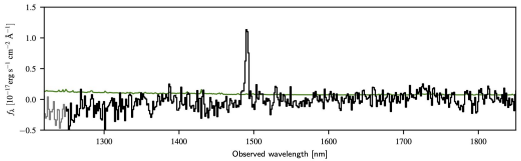
Slitless spectrograph

- Limited bandwidth
- Low resolution
- No preselection needed

Emission line detection

Choose bandwidth and tracer for only one strong line

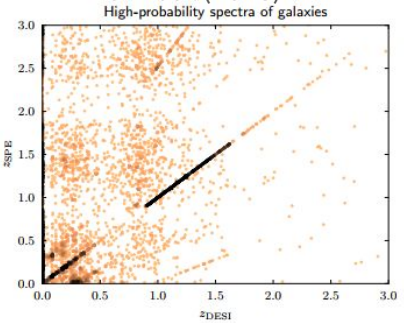
Le Brun et al. (2026)



Hα and [NII] complex at λ6565

DESI vs Euclid spectroscopic redshift

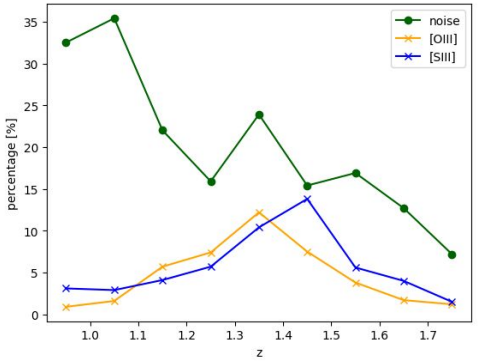
Le Brun et al. (2026)



Cross-checking redshift

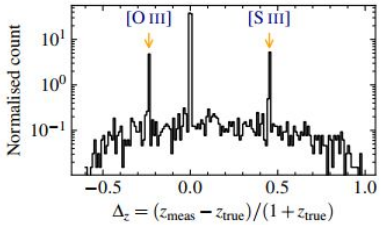
with higher resolution spectra or other surveys

Interloper fractions



Line interlopers

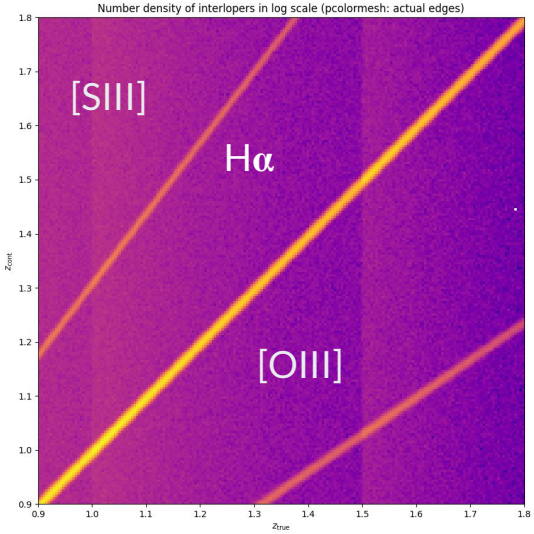
Granett et al. (in prep.)



Interloper strategy
for redshift errors

- **What fraction is affected?** Spectroscopic skies simulated and processed by Granett et al. (2026, in prep.)
- **What kind of interlopers?**
  - **Noise** = extreme noise, totally random, independent of redshift or wavelength ~ uniform
    Application: assign a random redshift in the redshift range
  - **Lines: [OIII] λ5008 and [SIII] λ9531**
    Application: with a transfer function based on redshift

Correct vs interloper contaminated redshifts

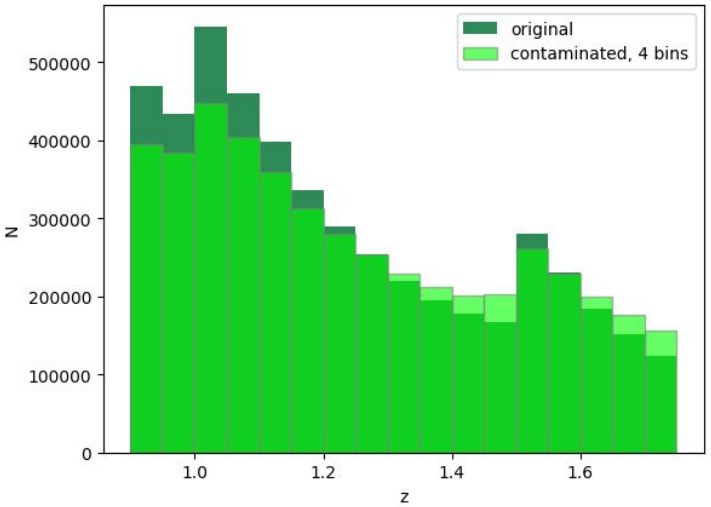


Not "noise interlopers" received a Gaussian noise with σ ~ 0.005

Galaxy statistics
with interlopers

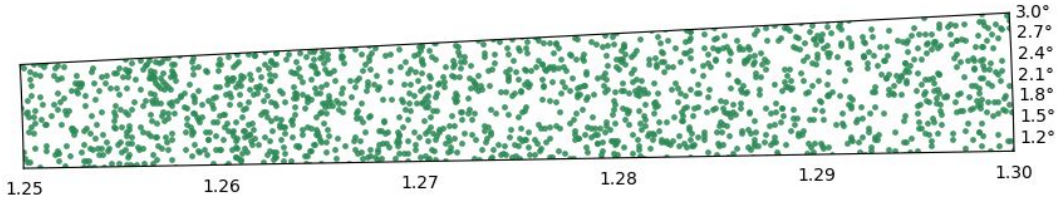
Interlopers cause galaxies to move in or out of redshift bins

Galaxy distribution is “smoothed out”



Redshift distribution
Up to 30-40% difference

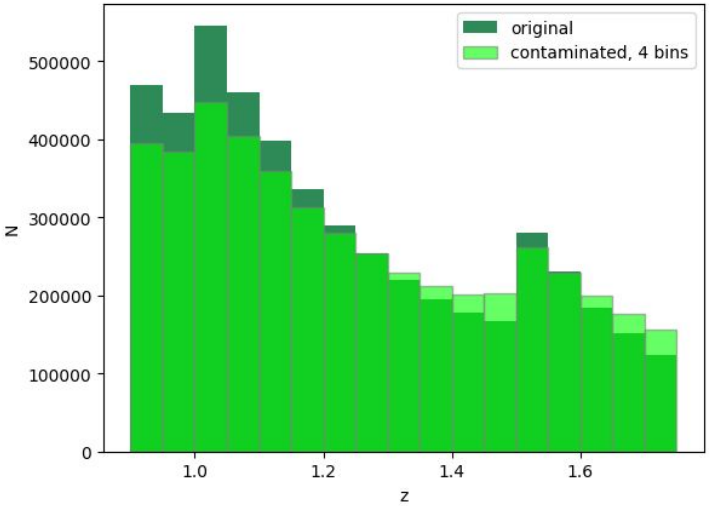
Original



Galaxy statistics
with interlopers

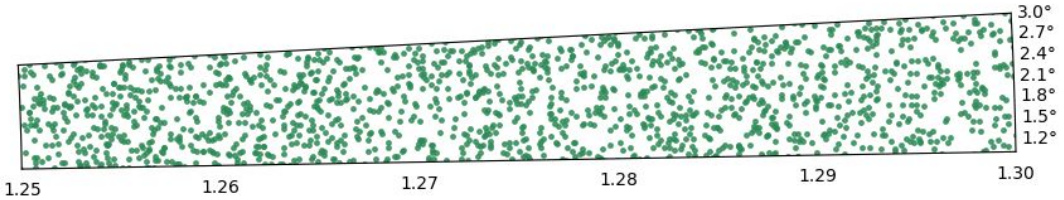
Interlopers cause galaxies to move in or out of redshift bins

Galaxy distribution is “smoothed out”



Redshift distribution
Up to 30-40% difference

Contaminated



Galaxy statistics
with interlopers

All redshift bins (0.9<z<1.8)

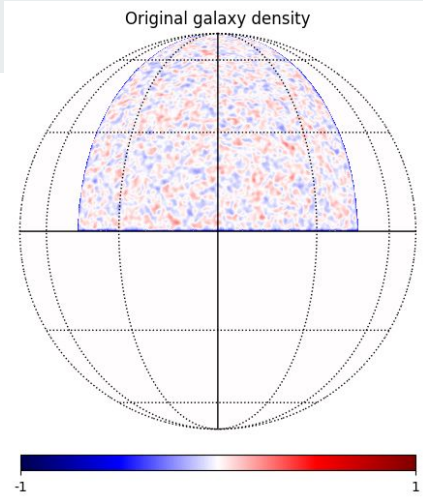
Difference in density:

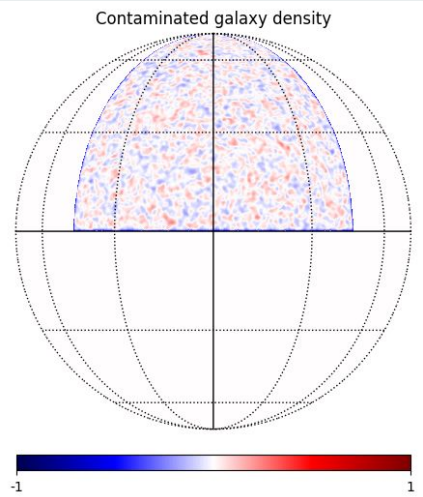
$\mu = -0.0164$

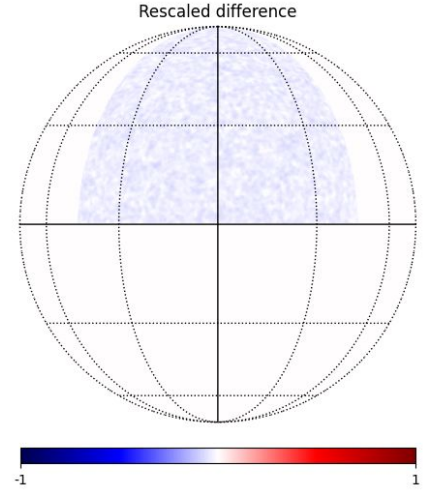
$\sigma = 0.0064$

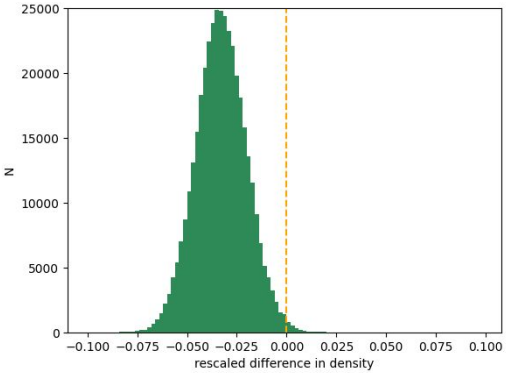
$-1.6\% \text{ pm } 0.6\%$

Density map is very similar







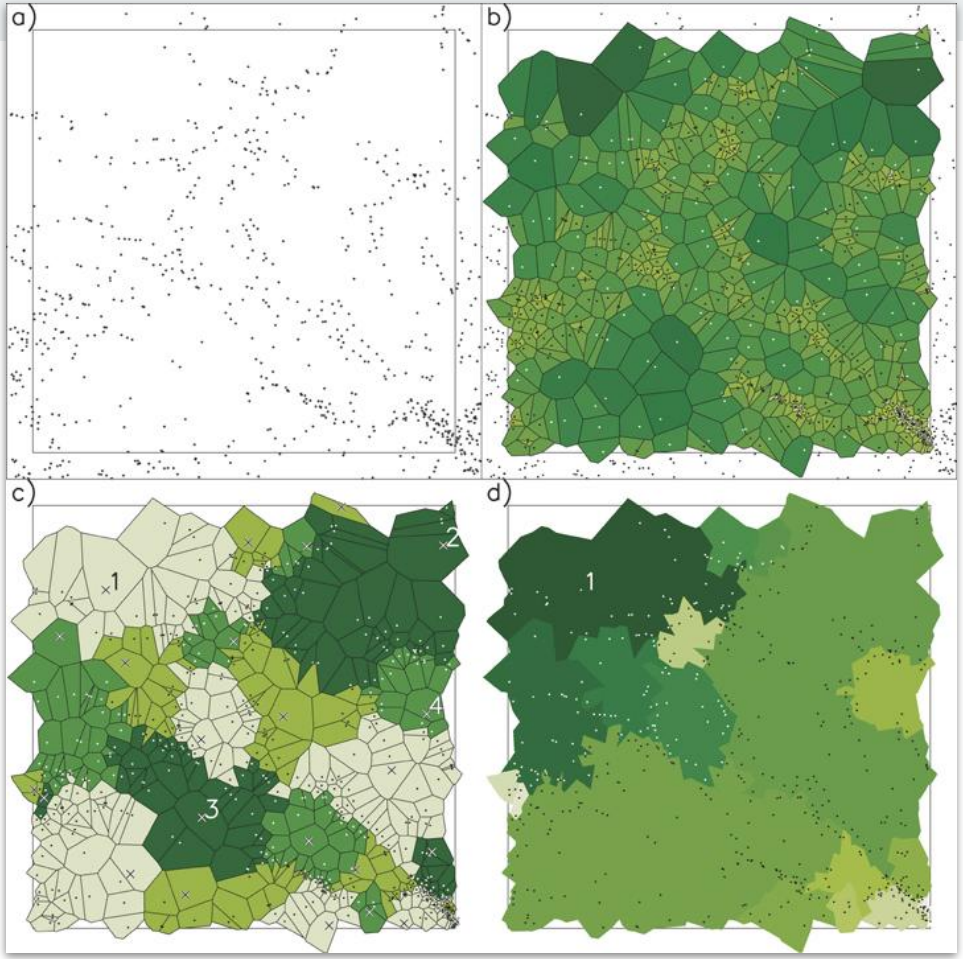


Voidfinding

REVOLVER software
uses the ZOBOV algorithm

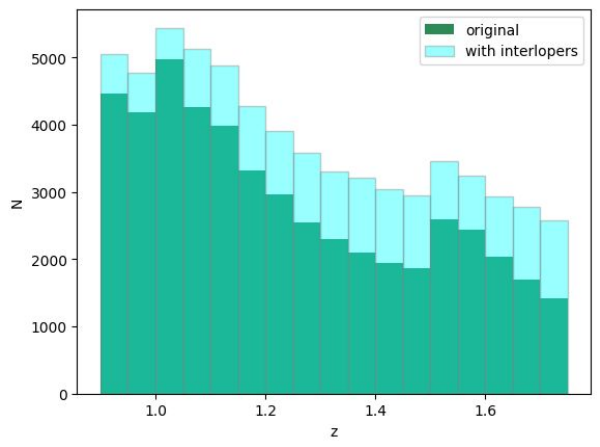
- **Voronoi tessellation**
  3D polyhedra cells & density estimation
- **Watershed algorithm**
  nonparametric

Neyrinck (2008)

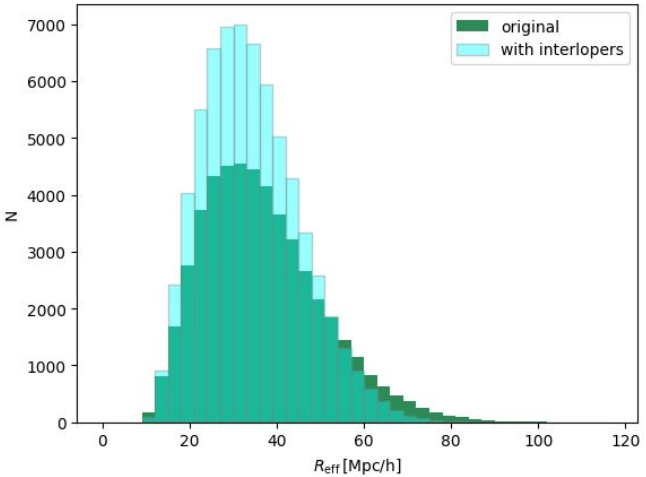


Void statistics
with interlopers

01 | Voids are more numerous



02 | Voids are smaller in size



Void numbers: 50311 → 66785
≈38% increase per redshift bin

Void sizes: μ = 36.61 → 34.18 Mpc/h
≈ 6% decrease
σ = 13.62 → 11.23 Mpc/h
≈ 17.5% decrease

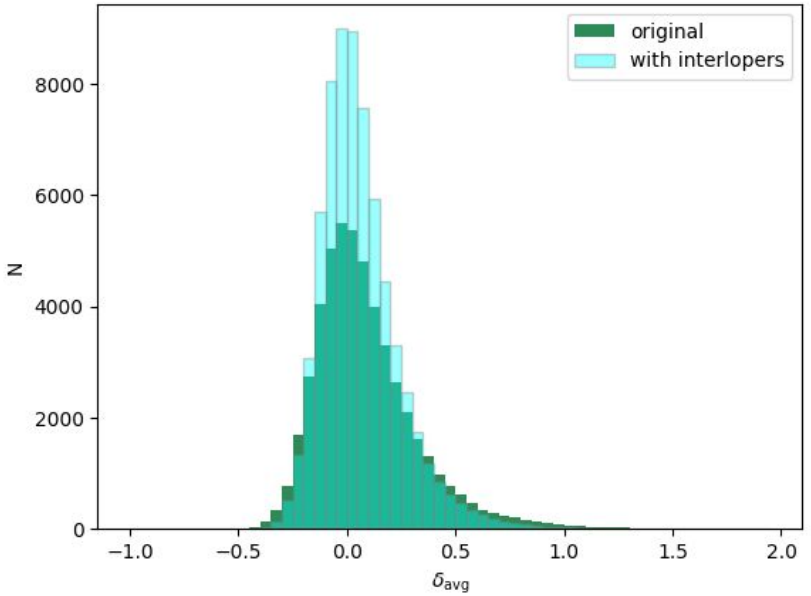
Void statistics
with interlopers

Density contrast of void mean density compared to the mean density of the universe :
$\delta=(\varrho-\varrho_{avg})/\varrho_{avg}$

03 | The density contrast is more centered on zero, the density field becomes “smoother”

$\mu = 0.0450 \rightarrow 0.0304$
≈ 32% decrease

$\sigma = 0.2464 \rightarrow 0.1846$
≈ 25% decrease



After contamination, we found more and smaller voids, that are also shallower and more smoothed out.

Conclusion:

Cosmic void statistics are sensitive to redshift errors

Cosmological implications

If we considered this a clean sample, we could make the following assumptions about the cosmology behind such large-scale structure:

Less
dark matter

could explain shallower voids

Weaker
dark energy

could explain the smoother density field

More massive
neutrinos

could explain smaller voids

Further investigations and mitigation of impact

Survey area and completeness

Cosmic Microwave Background Radiation

Simulations with different cosmologies

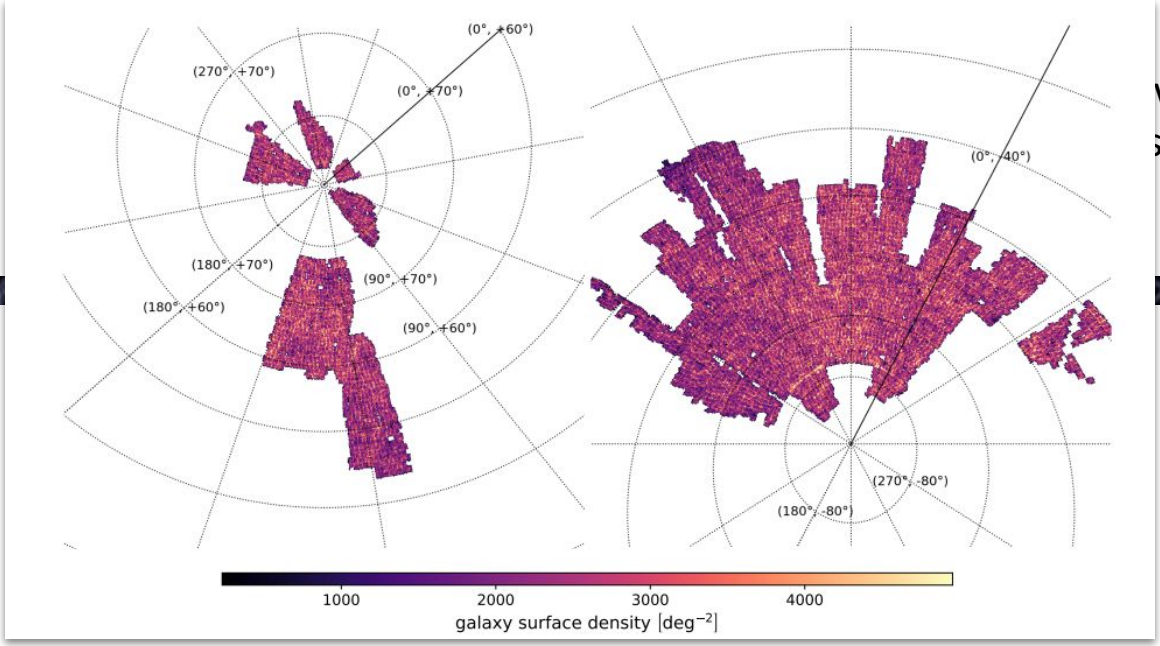
Galaxy 2-point correlation functions

Cosmological parameter inference

Further investigations and mitigation of impact

Granett et al. (in prep.)

Survey area and completeness



with smologies

Summary

- ✓ Created a redshift error contamination strategy to model observational effects.
- ✓ Large-scale structure was smoothed out by the contamination.
- ✓ As a result, voids became more numerous and smaller, while also shallower.
- ✓ If this was a real observation, conclusions on the cosmological context might be incorrect or uncertain.

Large-scale structure statistics are sensitive to observational effects.

- ➔ We need to investigate further observational effects, their interactions, and ways to mitigate their impact.

References

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