



Voids in the Cosmic Web from DESI Data: Size Functions as Cosmological Probes

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The team



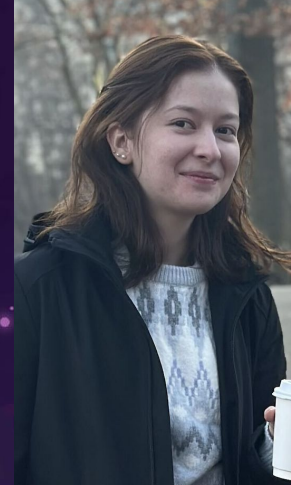
Diana



Juliana



Sofía



Valeria



Jaime



01

Introduction

Cosmic Web

Important → Cosmic web holds information about the **distribution of matter-energy** and the underlying **laws** governing its **evolution**.

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Full understanding of the cosmic web → Characterization of underdense regions.

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VOIDS!

Cosmological Constraints

Whereas much of the mass in the Universe is bound up in **virialized structures**, most of the volume is occupied by **large underdense voids**: voids are *the* dominant component of the megaparsec-scale galaxy and matter distributions

A hierarchy of voids: much ado about nothing, Sheth et al. (2004)

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The predicted **abundance of observed voids** for each galaxy redshift survey gives the power of the survey to **constrain the dark energy equation of state** through void counting.

Counting voids to probe dark energy - Pisani et al. (2015)

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More rarely with real survey catalogs.

Cosmological Constraints

VSF

$$\frac{dn}{d \ln R} = \frac{f_{\ln \sigma_m}(\sigma_m)}{V(R)} \frac{d \ln \sigma_m^{-1}}{d \ln R_L} \Bigg|_{R_L=R_L(R)}$$

Contarini et al. (2023)

The abundance of voids per logarithmic interval of radius R

Cosmological Constraints

VSF

Multiplicity function \rightarrow Volume fraction of the Universe occupied

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Contarini et al. (2023)

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Cosmological Constraints

VSF

Total matter density

$$\frac{dn}{d \ln R} = \frac{f_{\ln \sigma_m}(\sigma_m)}{V(R)} \frac{d \ln \sigma_m^{-1}}{d \ln R_L} \Bigg|_{R_L=R_L(R)}$$

Contarini et al. (2023)

The abundance of voids per logarithmic interval of radius R

The background of the slide is a Cosmic Microwave Background (CMB) fluctuation map. It shows a complex pattern of temperature variations across the sky, with colors ranging from dark blue (cooler) to red and orange (warmer). The pattern is roughly isotropic but shows some large-scale structure. The text '02' and 'DESI' is overlaid on the left side of the image.

02

DESI

DESI

- Detailed **map** of the evolving three-dimensional structure of the universe.

$$0 < z < 4$$

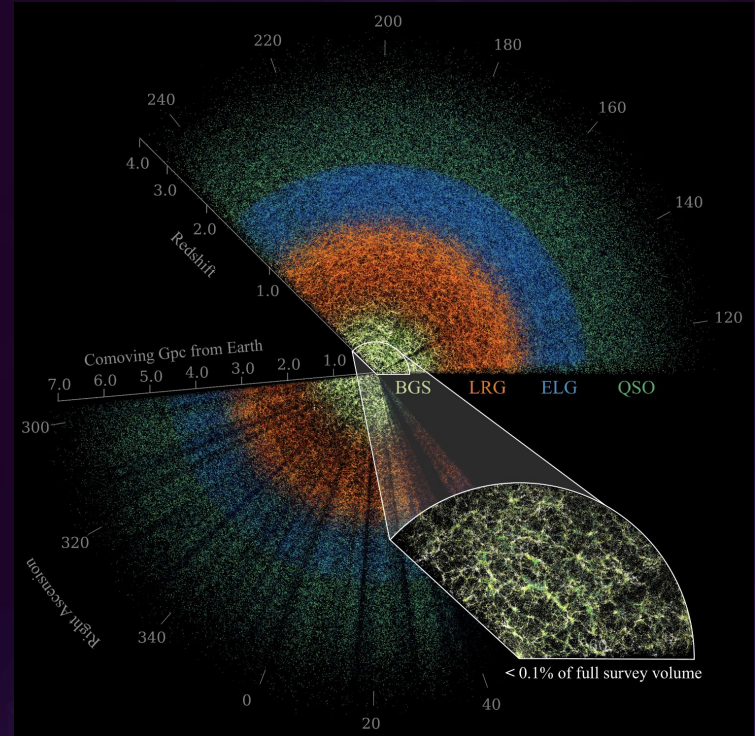
EDR (Early data release): 1.8 M objects

DR1 (Data release 1): 18.7 M objects

DR2 (Data release 2): Private data

DESI data: Tracers

1. **Bright Galaxy Survey (BGS)**
 $0 < z < 0.6$
2. Luminous Red Galaxy (LRG)
 $0.4 < z < 1.1$
3. Emission Line Galaxy (ELG)
 $0.6 < z < 1.6$
4. Quasi-Stellar Object (QSO)
 $0.6 < z < 3.5$



Cosmic Web Classification

EDR

20 Rosettes

DR1 (High-Completeness Region)

NGC1

$$110^{\circ} \leq \text{RA} \leq 260^{\circ}$$

$$-10^{\circ} \leq \text{DEC} \leq 8^{\circ}$$

NGC2

$$180^{\circ} \leq \text{RA} \leq 260^{\circ}$$

$$30^{\circ} \leq \text{DEC} \leq 40^{\circ}$$

**DATA PUBLIC ON
ZENODO**

EDR



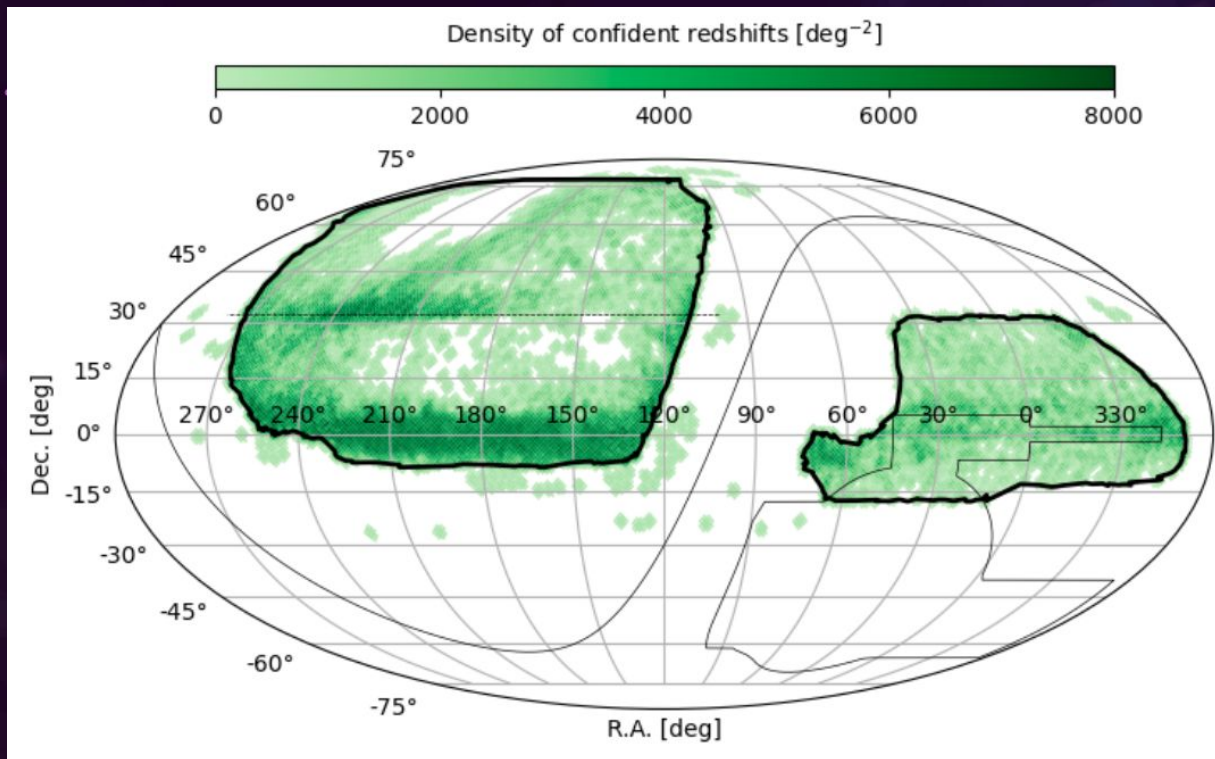
Zenodo Record ID: 17299085

DR1



Zenodo Record ID: 17299147

DESI: DR1



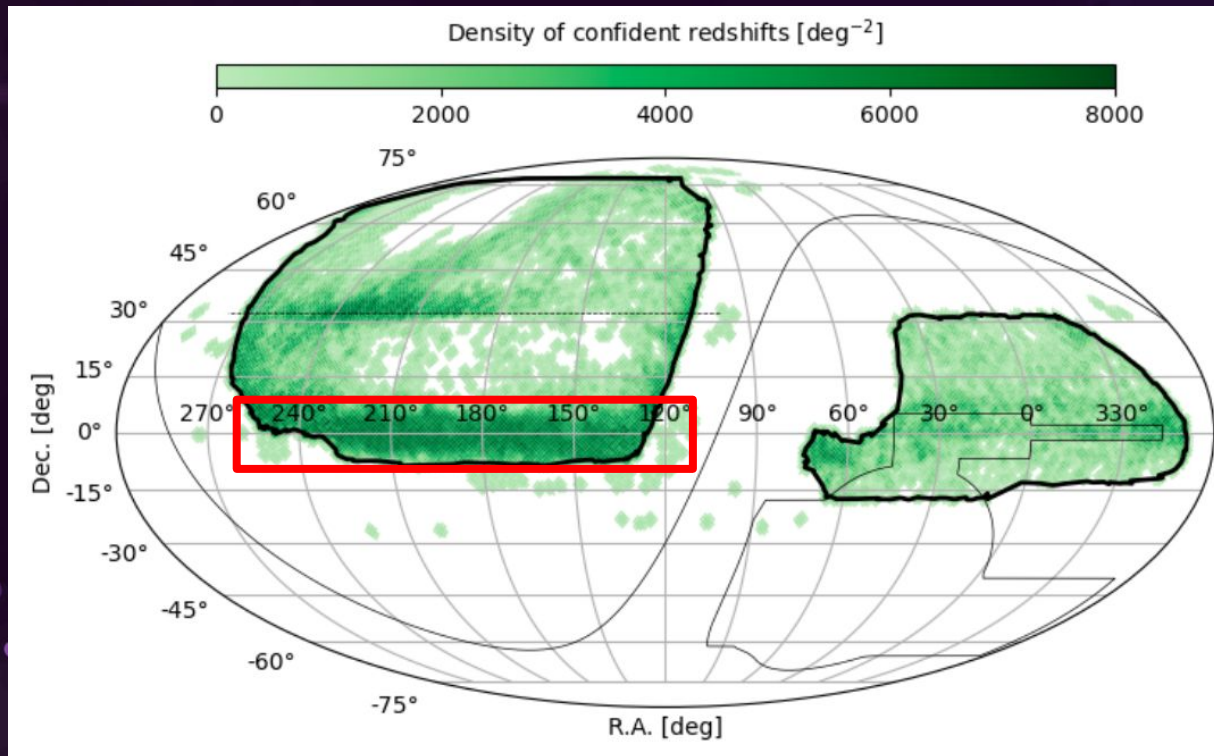
DESI Collaboration et al. (2024)

DESI: DR1

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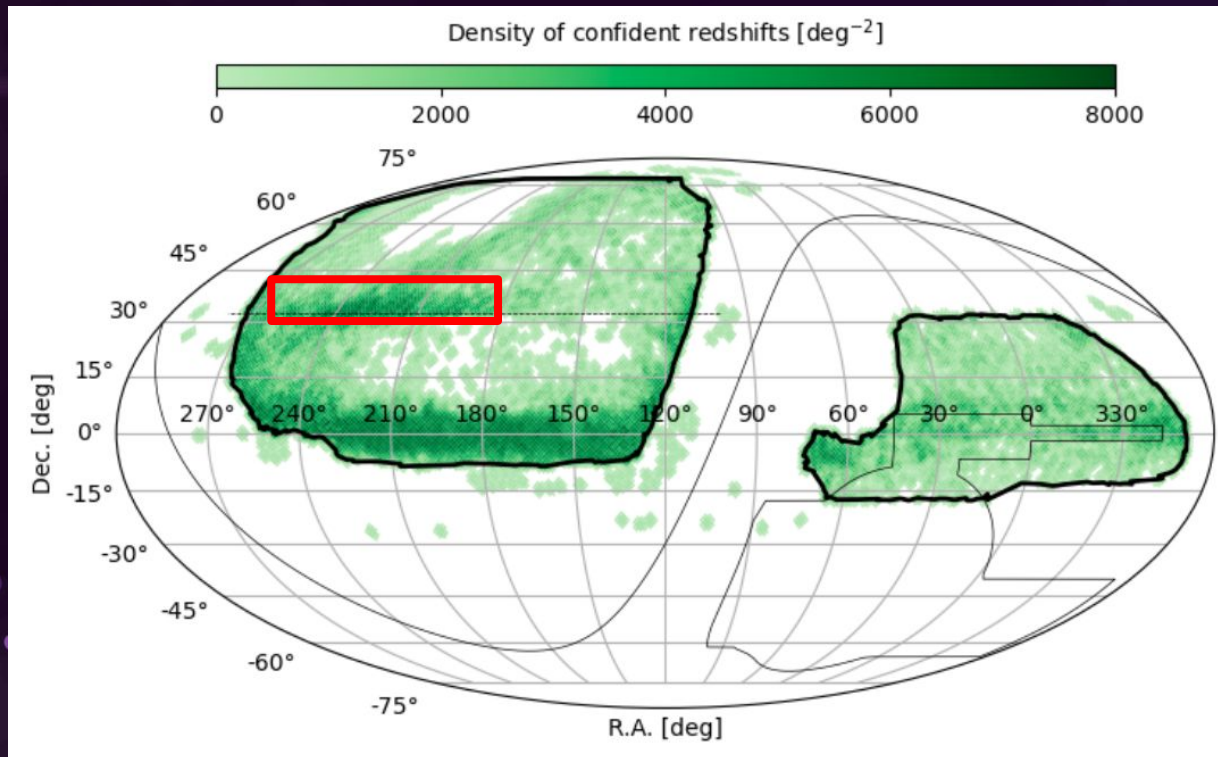


DR1



Zenodo Record ID: 17299147

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NGC2

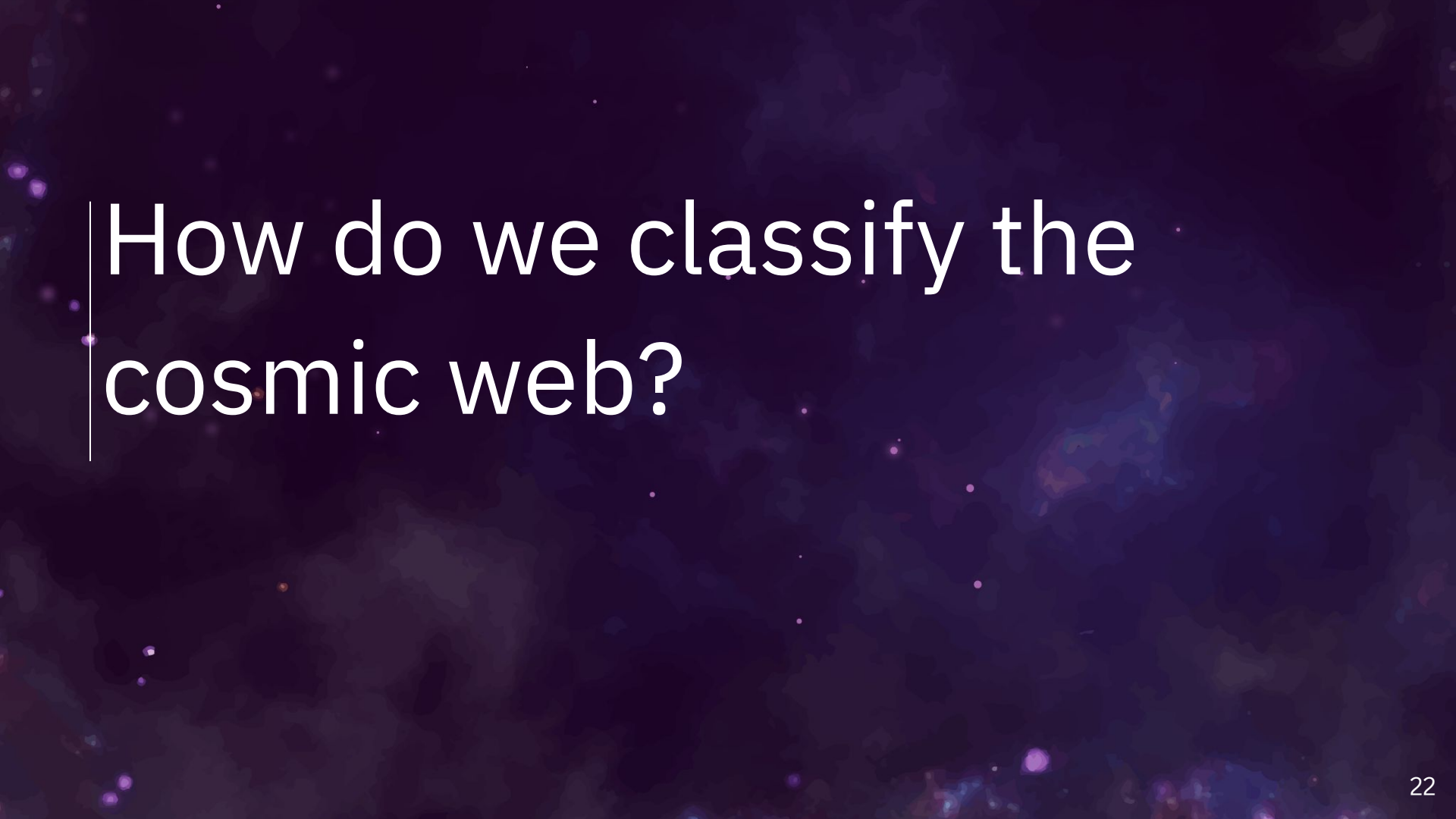
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DR1



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A visualization of the cosmic web, showing a complex network of dark matter filaments and galaxy clusters. The background is a deep purple and blue, with numerous small, bright points of light representing galaxies. The filaments are thin, dark lines that connect the clusters, forming a web-like structure. The overall appearance is that of a vast, interconnected network of matter in the universe.

How do we classify the
cosmic web?

The background is a dark, deep blue space filled with numerous small, bright white and light blue stars. A thin, vertical white line is positioned on the left side of the frame, extending from the top to the bottom. The text '03' and 'ASTRA' is overlaid on this background.

03

ASTRA

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1. Full cosmic web characterization → Filament, knots, sheets and voids

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Delaunay triangulation -> Galaxies + Random points

ASTRA

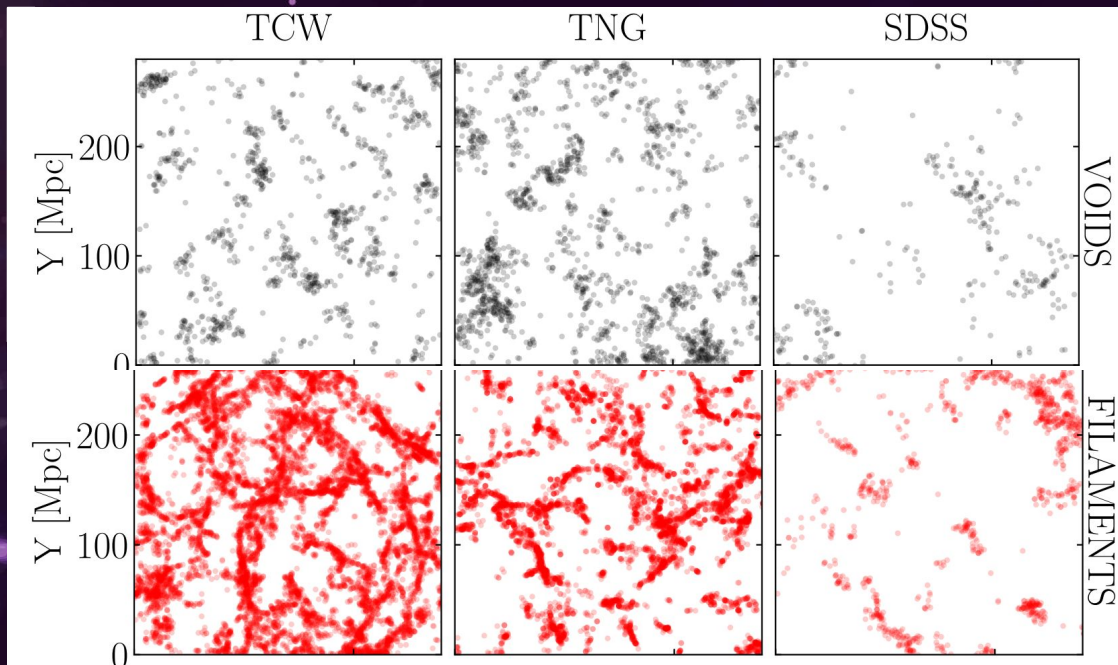
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Delaunay triangulation -> Galaxies + Random points → Classification of points

Random files come from LSS pipeline.

ASTRA – multiple iterations

Random files come from LSS pipeline.



RANDOM

$$r(p_i) = \frac{N_{\mathcal{O}}(p_i) - N_{\mathcal{R}}(p_i)}{N_{\mathcal{O}}(p_i) + N_{\mathcal{R}}(p_i)}$$

OBJECT

Condition	Classification
$-1 \leq r \leq -0.9$	<i>void</i>
$-0.9 < r \leq 0$	<i>sheet</i>
$0 < r \leq 0.9$	<i>filament</i>
$0.9 < r \leq 1$	<i>knot</i>

J. E. Forero-Romero et al. (2025)

A deep space background featuring a vast field of dark blue and purple hues, with numerous small, bright white and blue stars scattered throughout. The overall appearance is that of a cosmic void or a distant galaxy cluster.

04

Voids

Count fraction

Voids count fraction				
Data	BGS	LRG	ELG	QSO
Object	$(0.32 \pm 0.03)\%$	$(0.18 \pm 0.03)\%$	$(0.09 \pm 0.01)\%$	$(0.05 \pm 0.01)\%$
Random	$(4.55 \pm 0.88)\%$	$(3.44 \pm 0.47)\%$	$(3.84 \pm 0.55)\%$	$(3.05 \pm 0.43)\%$

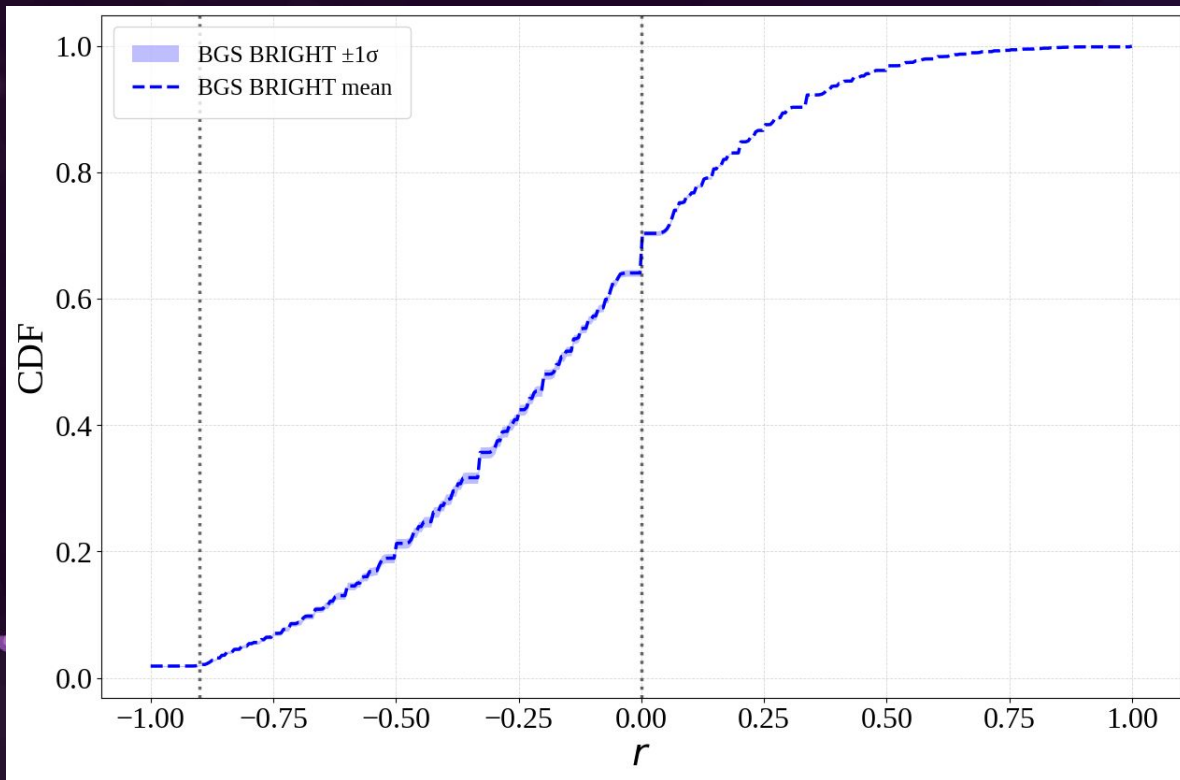
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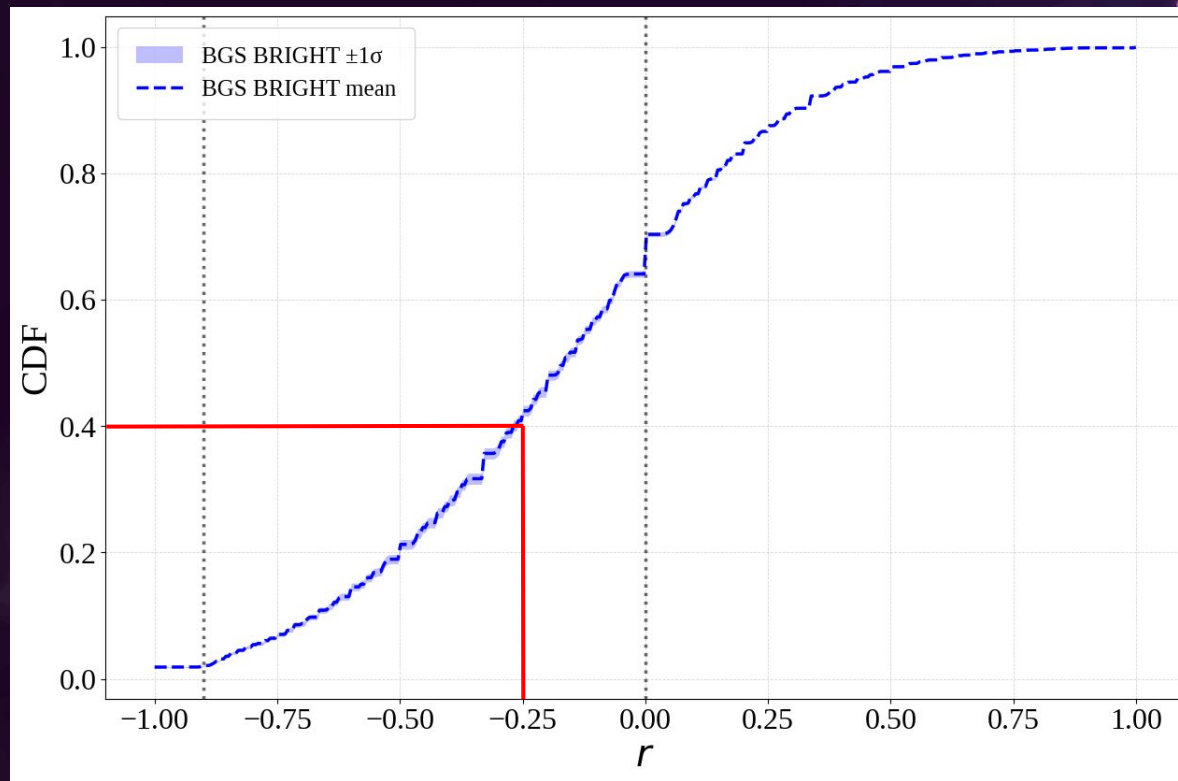
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5% of the volume is in voids



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We can make it up to 40%



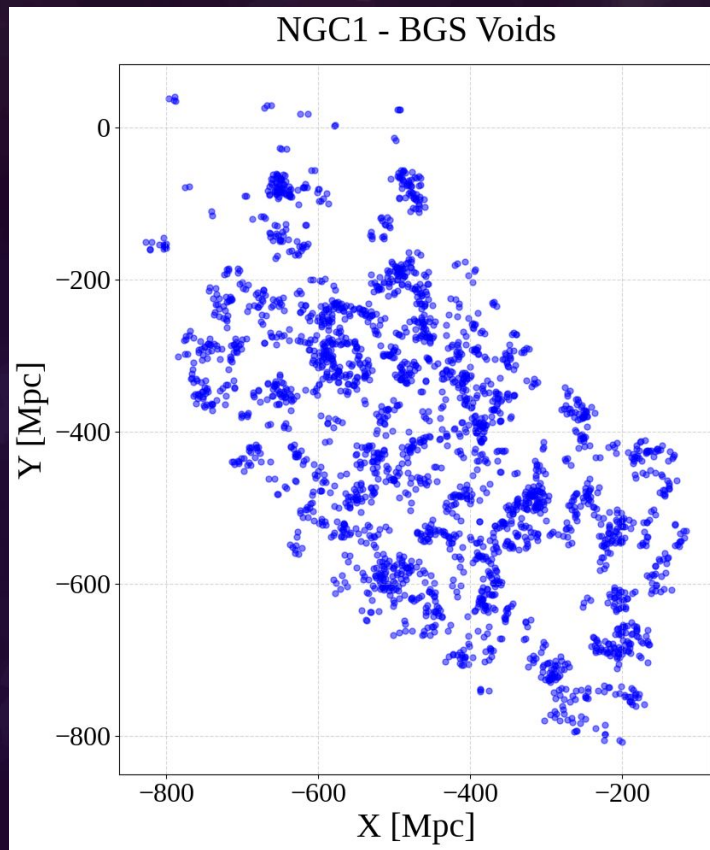
$0.1 < z < 0.2$
BGS Bright

NGC1 - Random points

NGC1

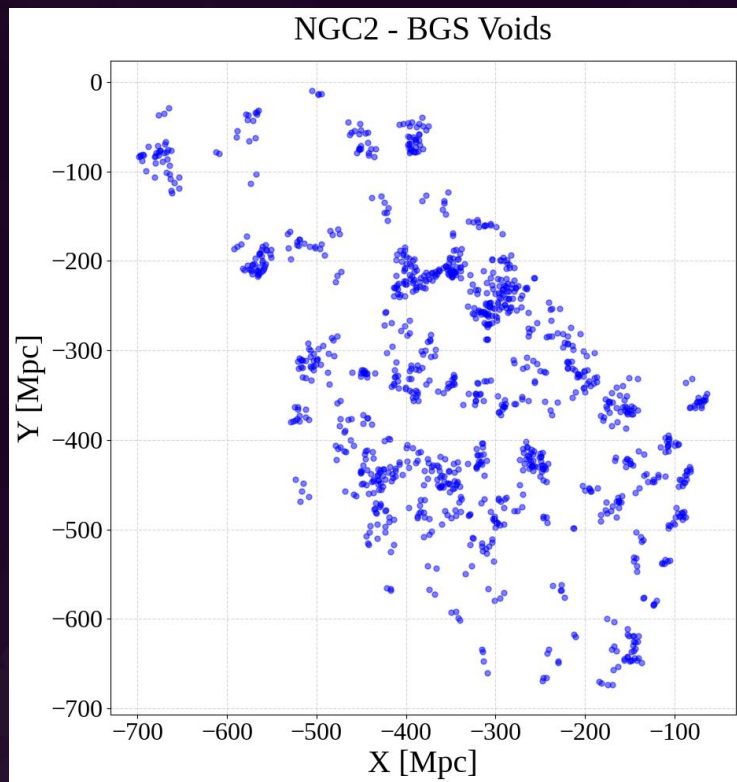
$$110^\circ \leq \text{RA} \leq 260^\circ$$

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NGC2 - Random points

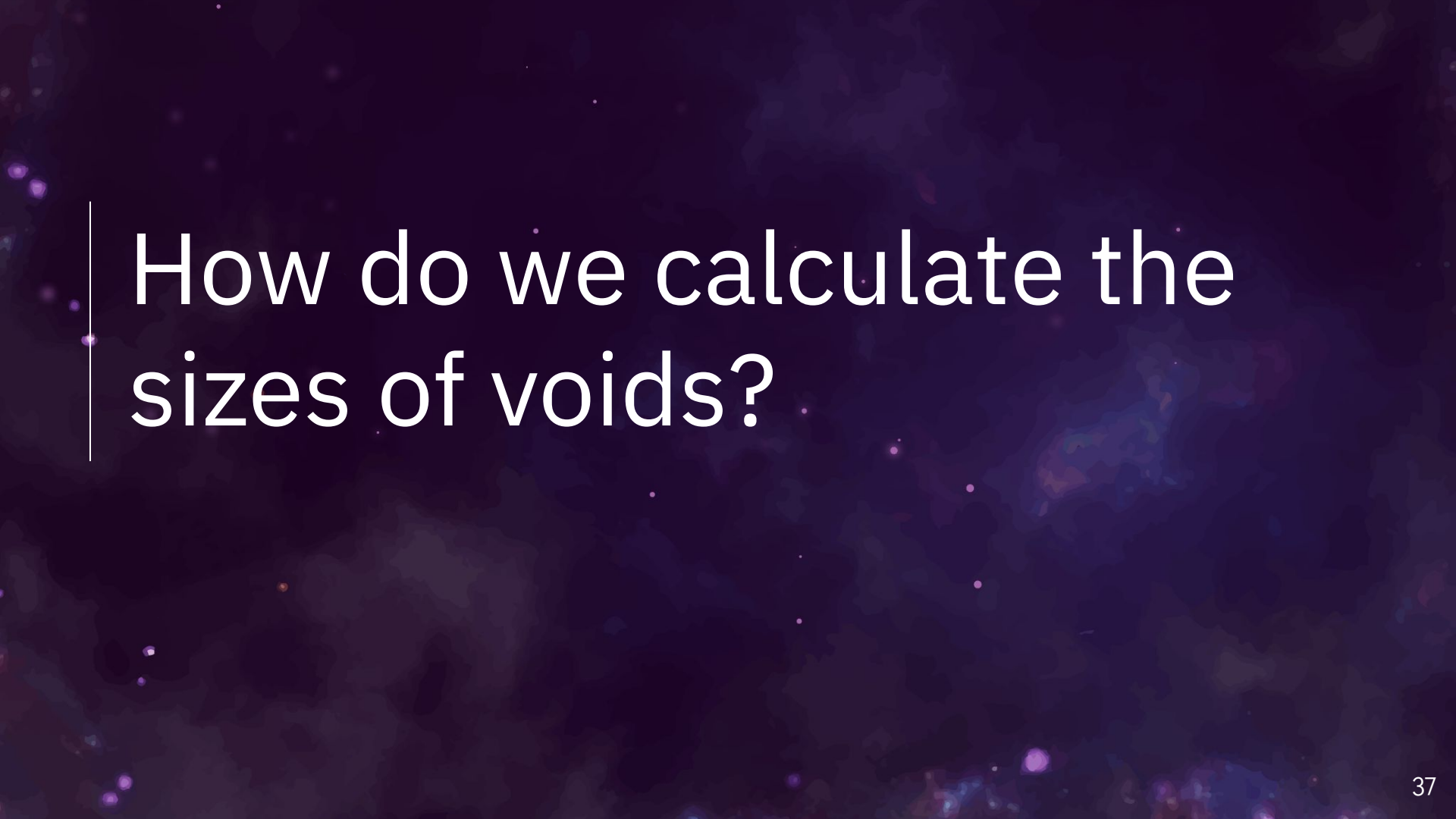
$0 < z < 0.2$
BGS Bright



NGC2

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How do we calculate the
sizes of voids?

The background of the slide is a deep space image showing a vast field of galaxies. There are several prominent galaxy clusters, some appearing as bright, dense regions of light. Between these clusters are large, dark, empty spaces known as voids. The overall color palette is dark blue and purple, with some brighter spots of light from distant galaxies.

05

Void Sizes

Friends-of-Friends (FoF) algorithm

We classify points.

Friends-of-Friends (FoF) algorithm

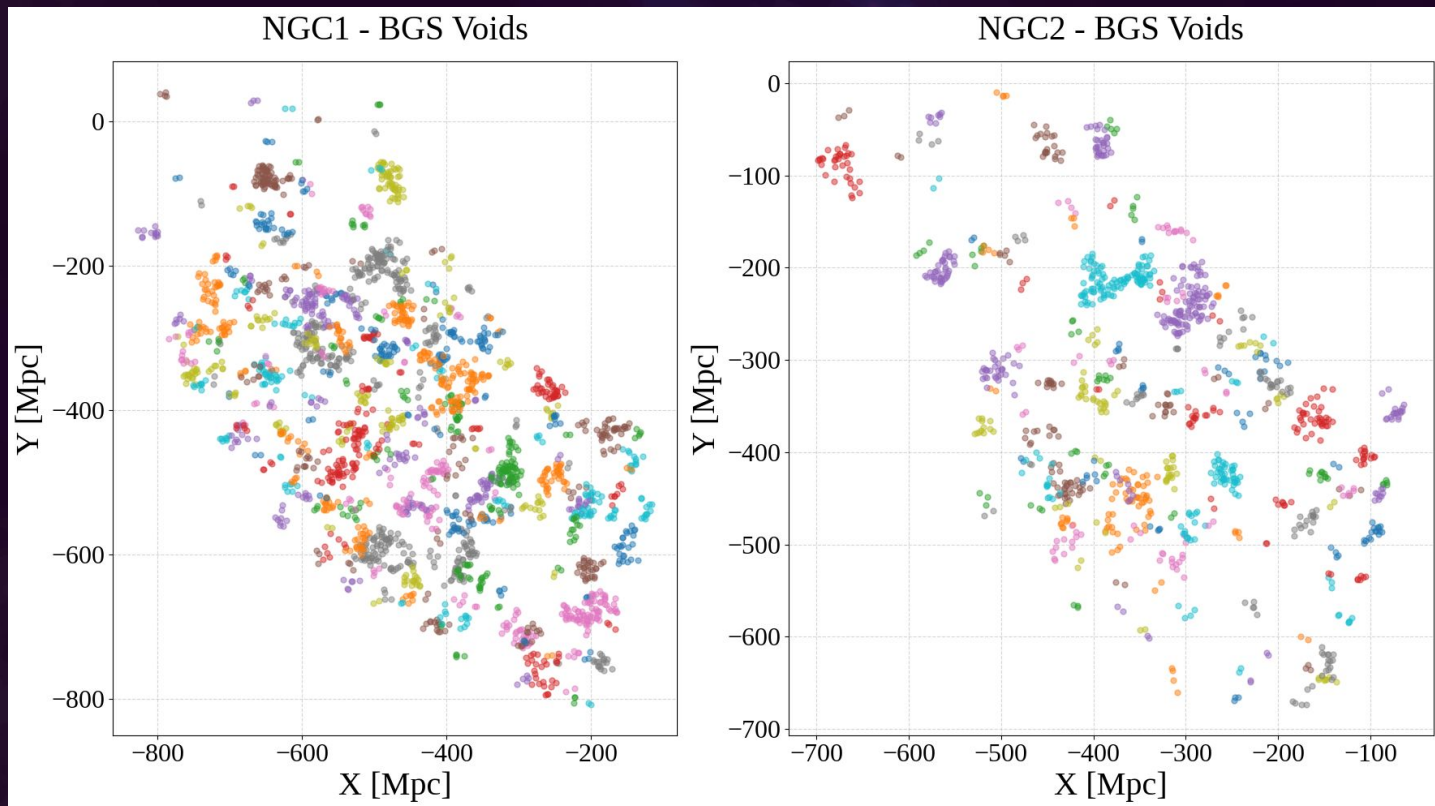
We classify points.  We need to group them.

Friends-of-Friends (FoF) algorithm

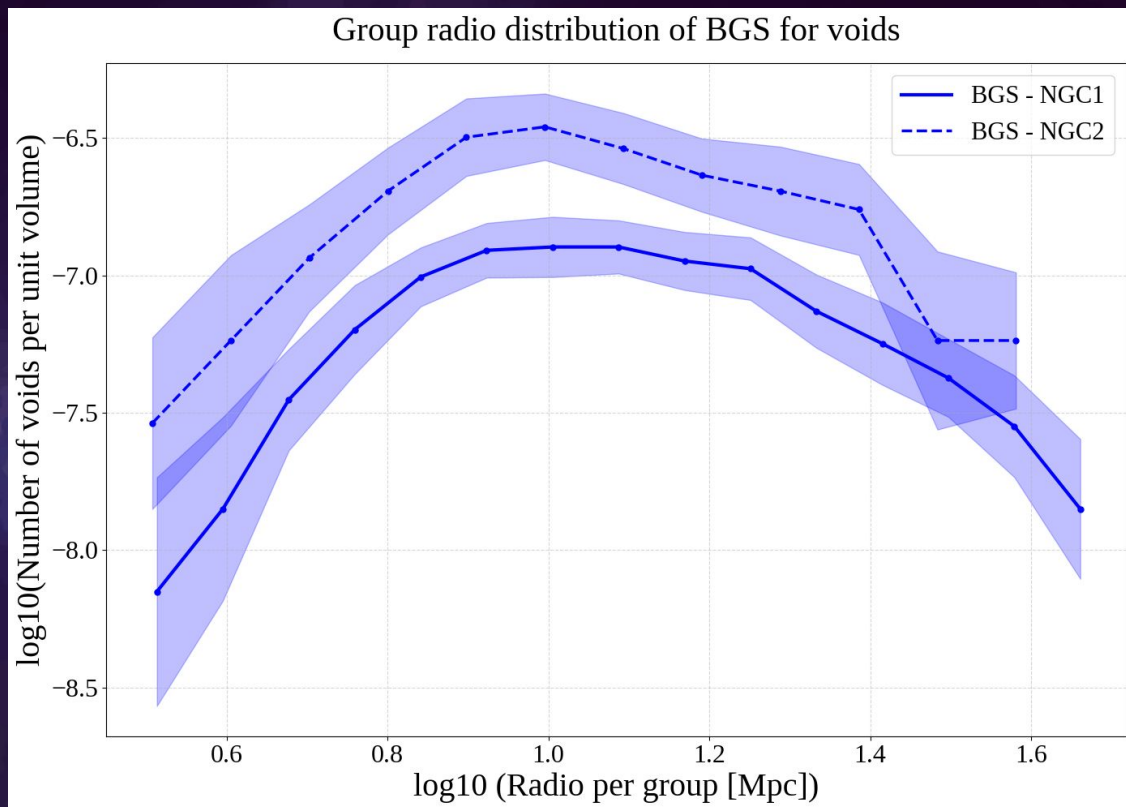
We classify points. \longrightarrow We need to group them.

We search for neighboring points within a given linking length.

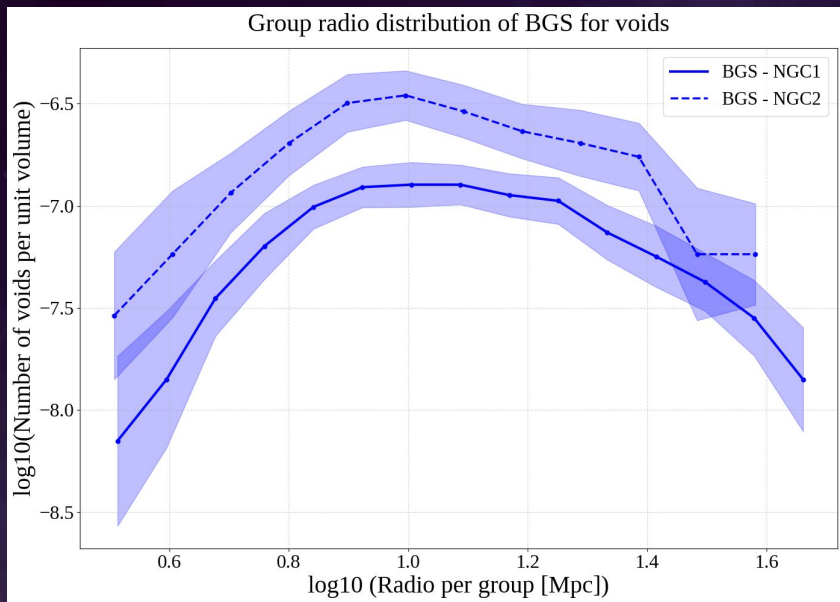
Void groups



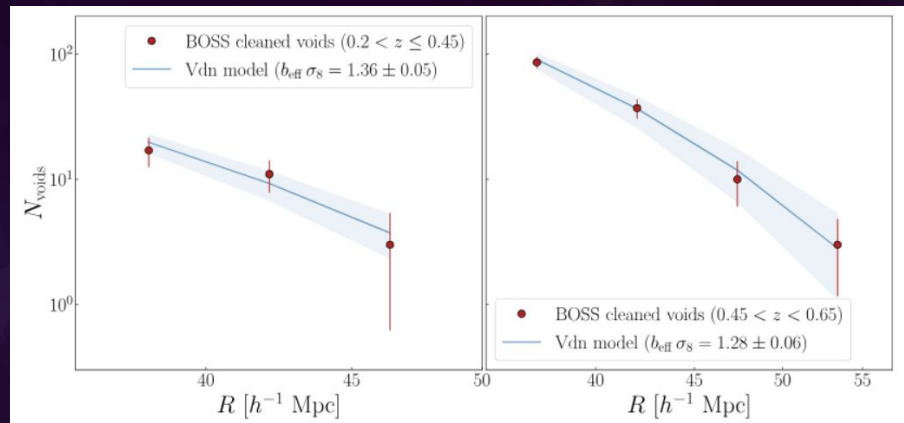
Void Size Function (ASTRA)



Comparison to other void finder



7 Mpc/h - 31 Mpc/h



Contarini et al. (2023)



06

Future steps

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- Compute cross-correlation functions between webtypes.
- Continue with DR2!

Thank you!

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