



# Galaxy protoclusters in Ly $\alpha$ Tomography

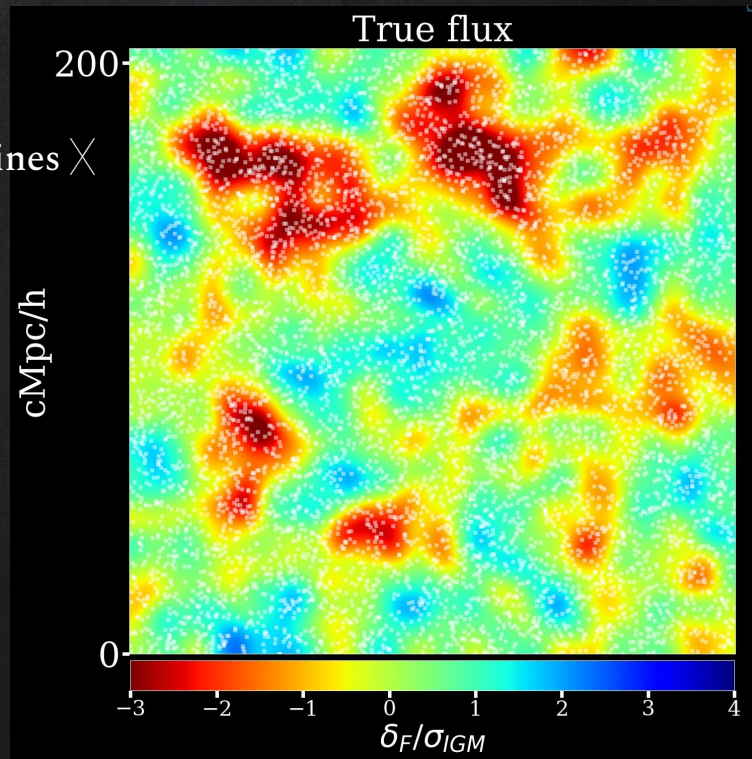


CARNEGIE  
SCIENCE

Observing the Ly $\alpha$  forest in the spectra of many background galaxies.  
(Lee et al. 2014)

Interpolating the absorption in between the sightlines to infer the 3D distribution of HI. (Pichon et.al 2001; Caucci et al. 2008)

Sightlines  $\times$





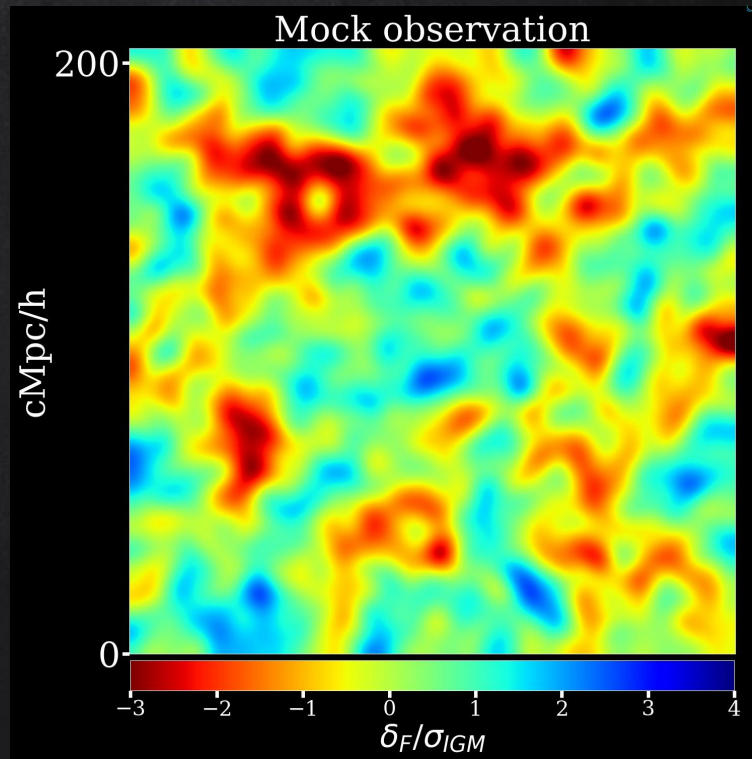
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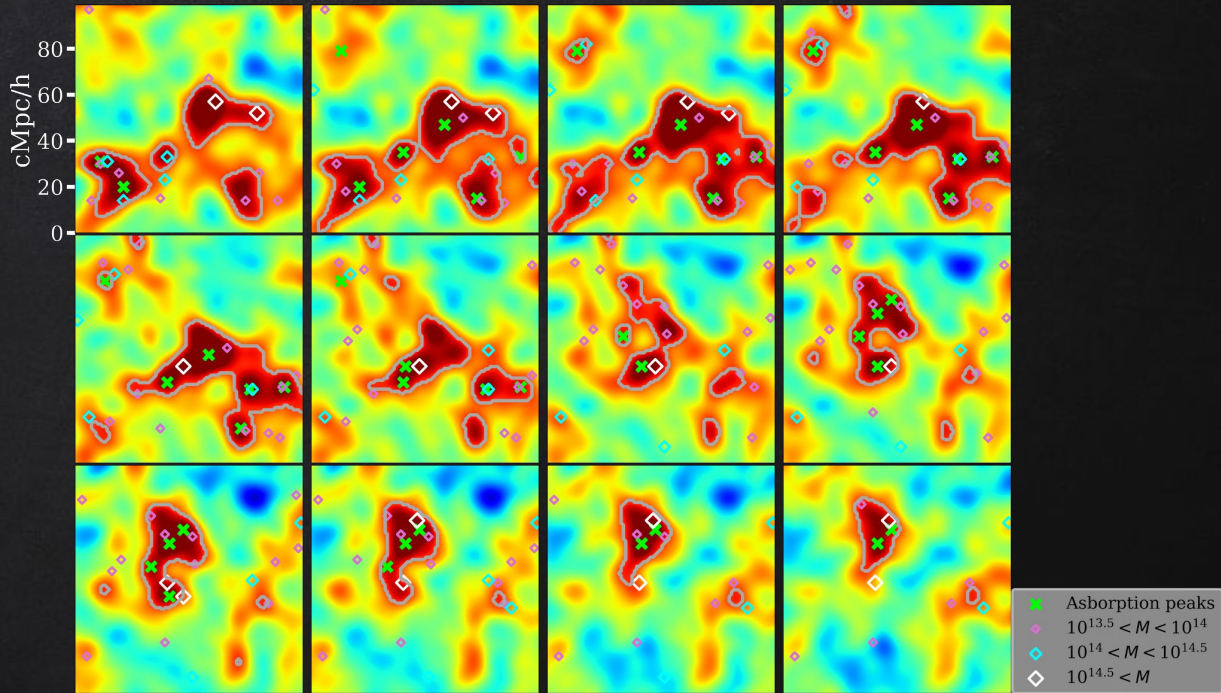
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# Highly blended structures

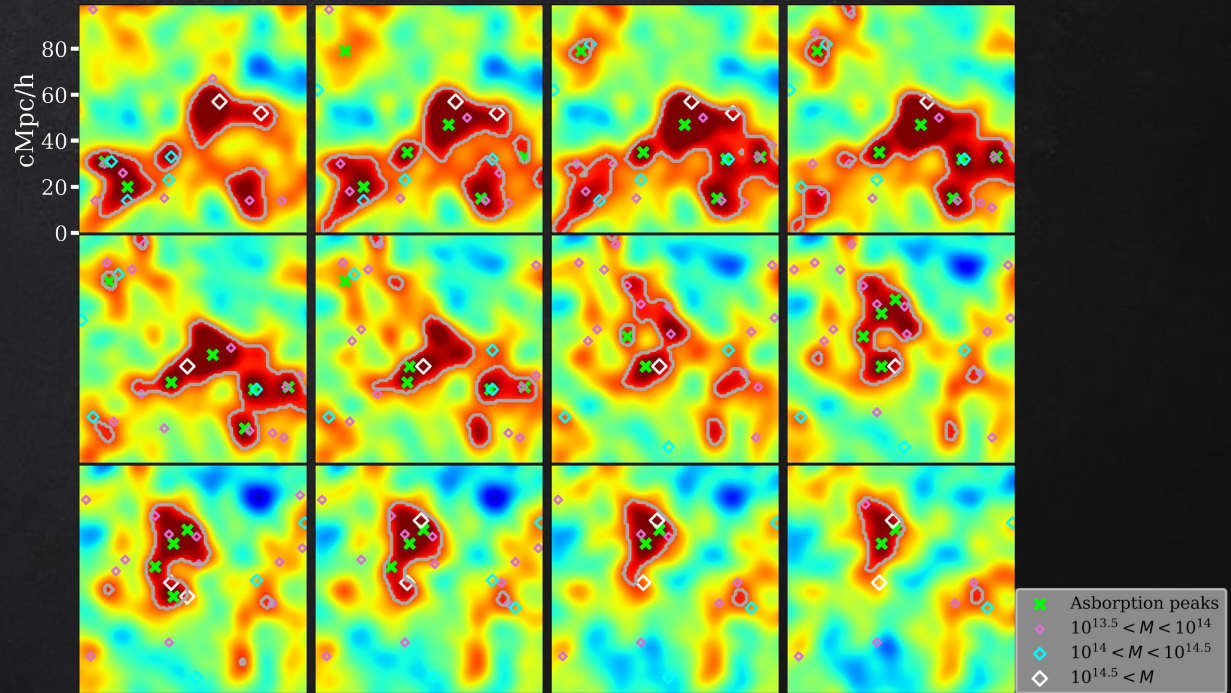
Lya forest traces the large-scale structures including galaxy protoclusters/groups. (Rauch 1998, McQuinn 2016)

We developed a method based on the Watershed algorithm to delineate the protoclusters/groups.



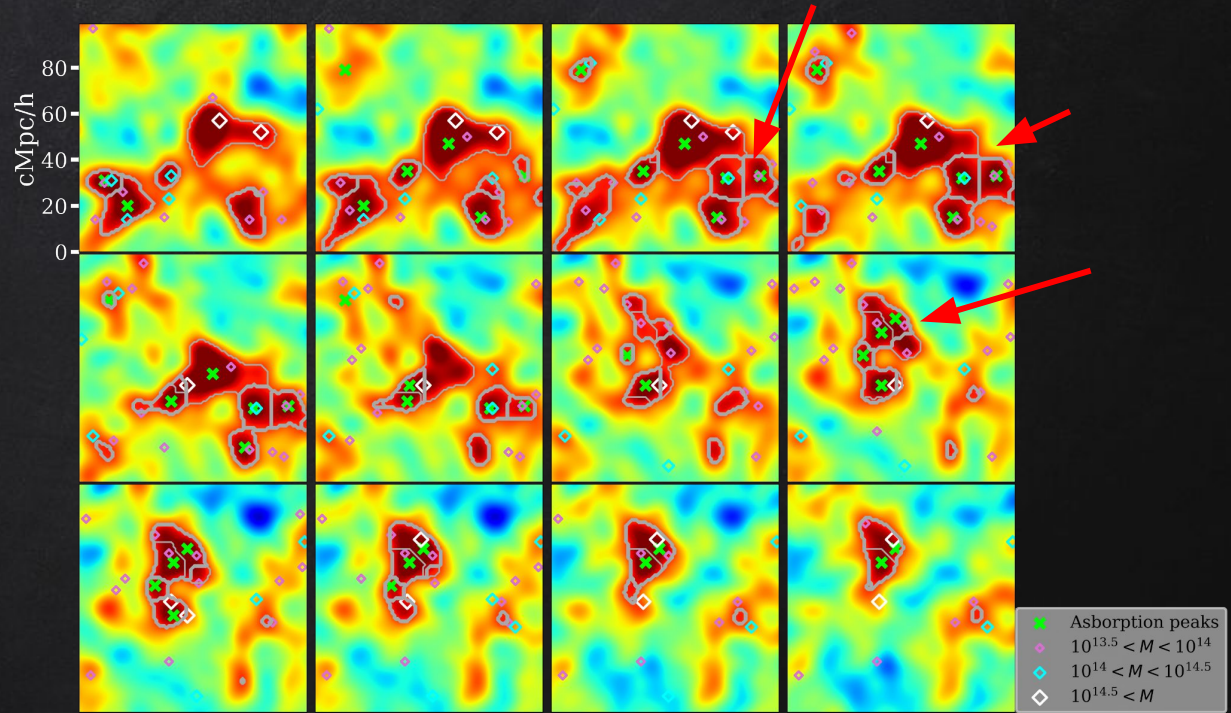
# Highly blended structures

Simple methods:



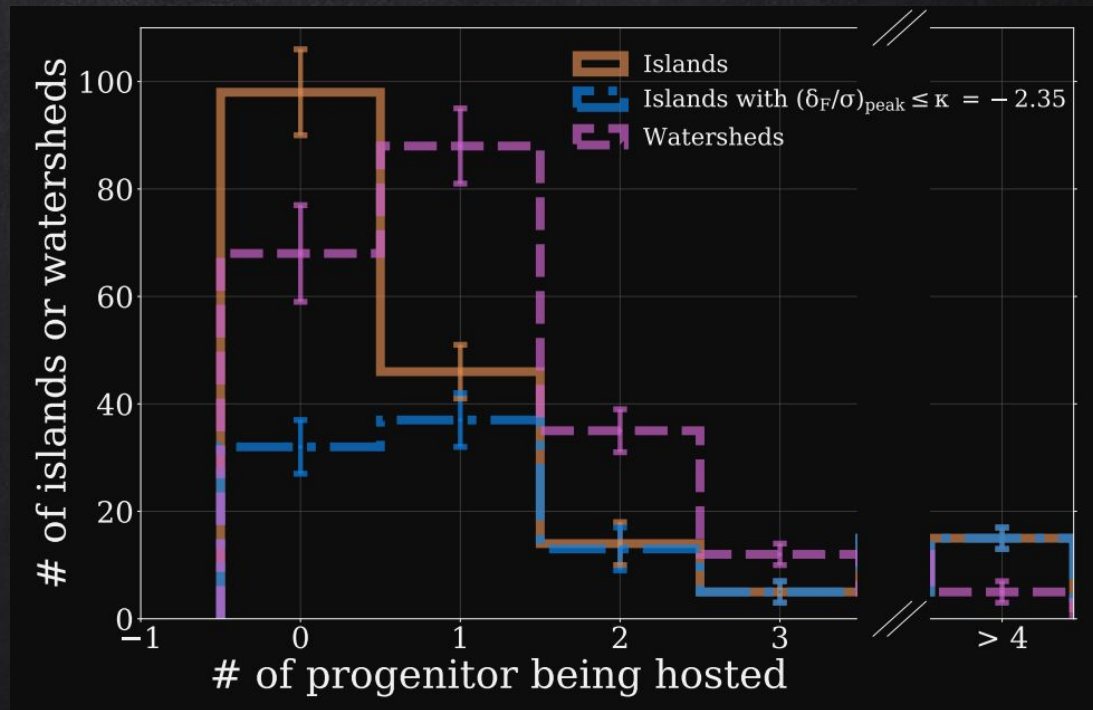
# Highly blended structures

Our method:



# Protoclusters in Lya Tomography

arXiv:2112.03930  
Qezlou et al. 2022



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## Characterizing Protoclusters and Protogroups at $z \sim 2.5$ Using Ly $\alpha$ Tomography

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### Abstract

Ly $\alpha$  tomography surveys have begun to produce 3D maps of the intergalactic medium opacity at  $z \sim 2.5$  with megaparsec resolution. These surveys provide an exciting new way to discover and characterize high-redshift overdensities, including the progenitors of today's massive groups and clusters of galaxies, known as protogroups and protoclusters. We use the IllustrisTNG-300 hydrodynamical simulation to build mock maps that realistically mimic those observed in the Ly $\alpha$  Tomographic IMACS Survey. We introduce a novel method for delineating the boundaries of structures detected in 3D Ly $\alpha$  flux maps by applying the watershed algorithm. We provide estimators for the dark matter masses of these structures (at  $z \sim 2.5$ ), their descendant halo masses at  $z = 0$ ,

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Abstract

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