

Probing galaxies in voids, the loneliest places?

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Gas in Galaxies: from Cosmic Web to Molecular Clouds
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Observations and Simulations

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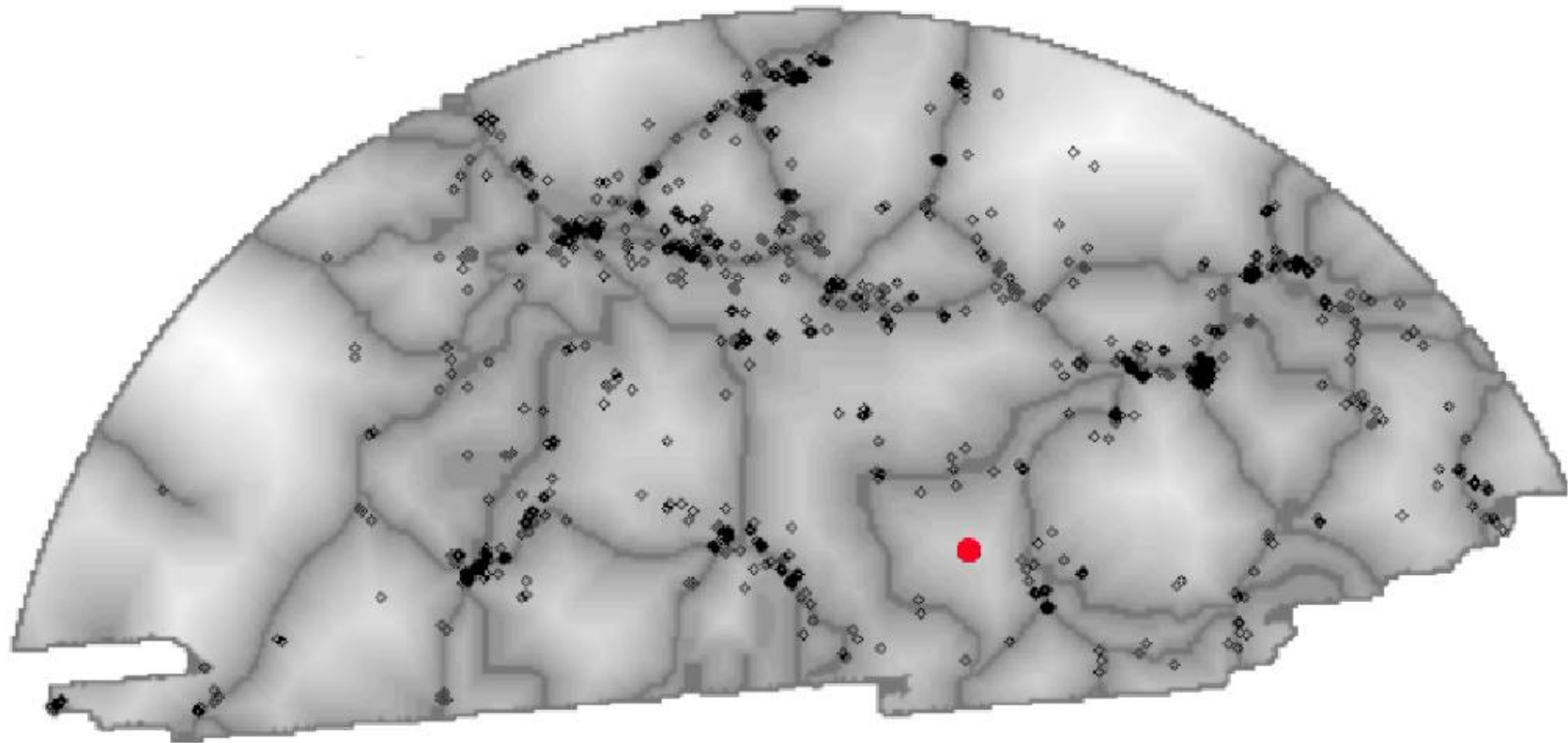
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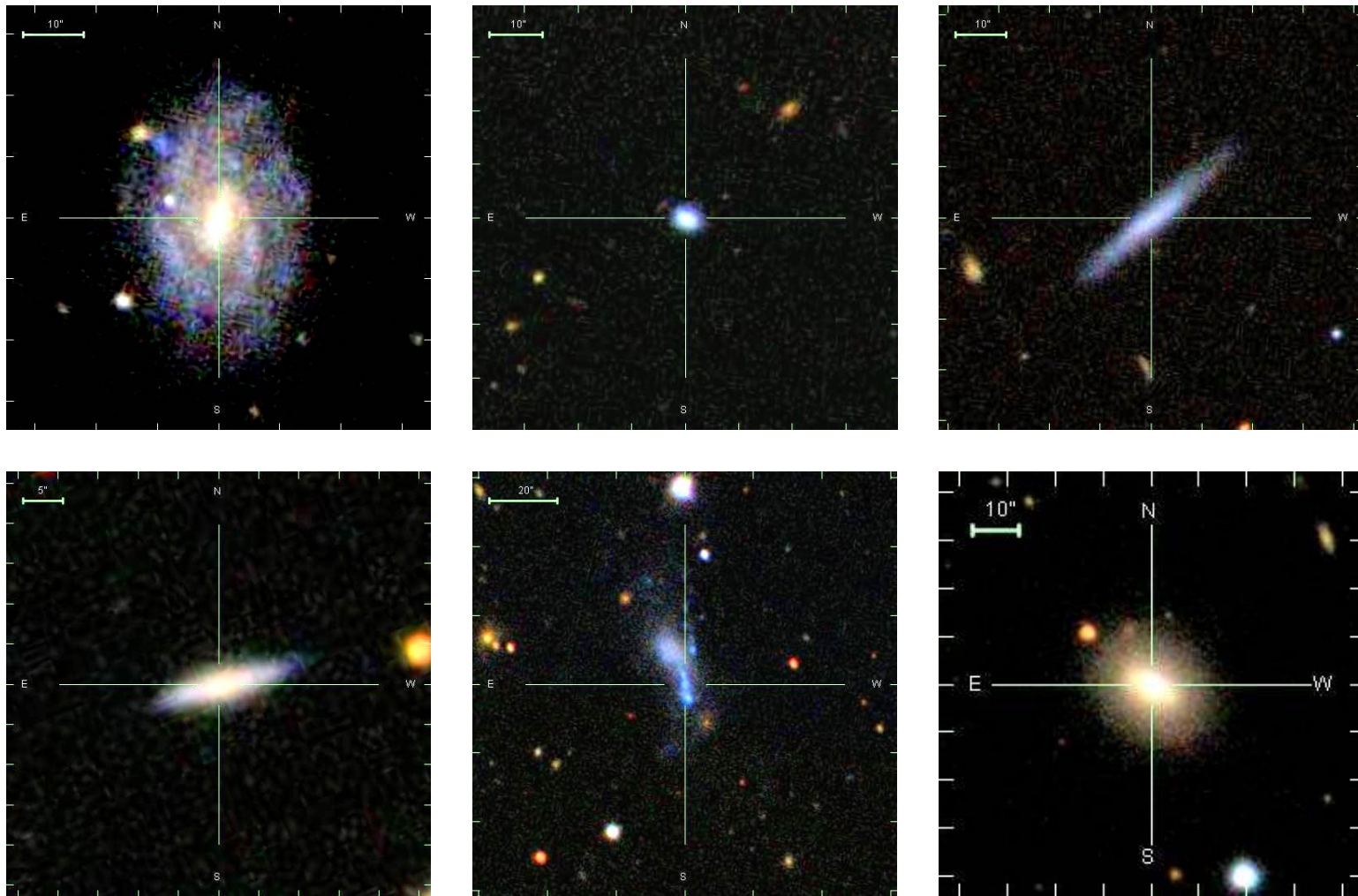
Geometrically Identified Void Galaxies

Carefully selected to be centrally located within well defined voids



The Void Galaxy Survey (VGS)

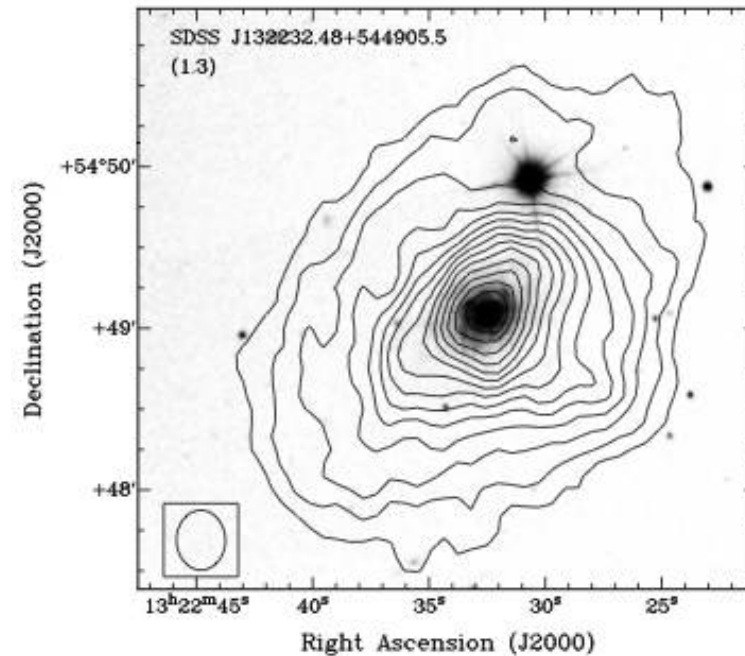
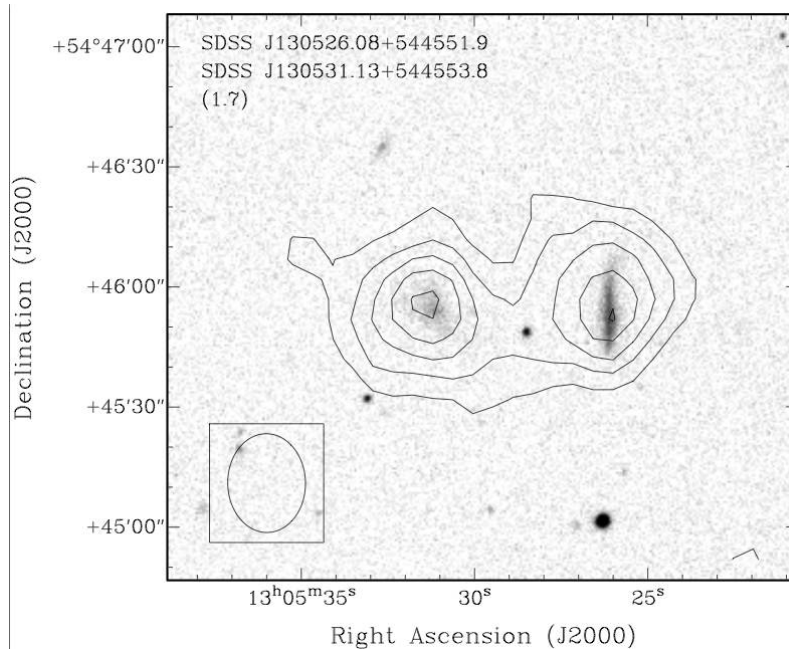
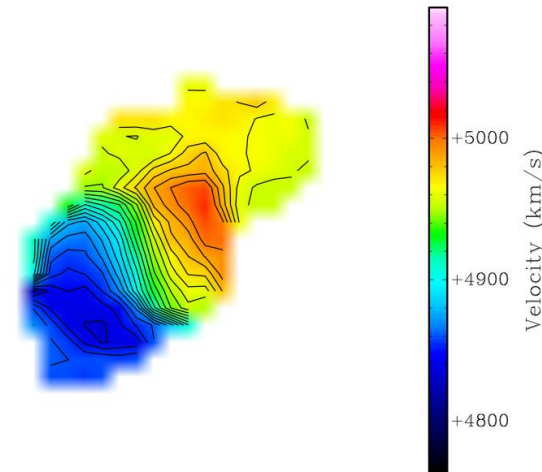
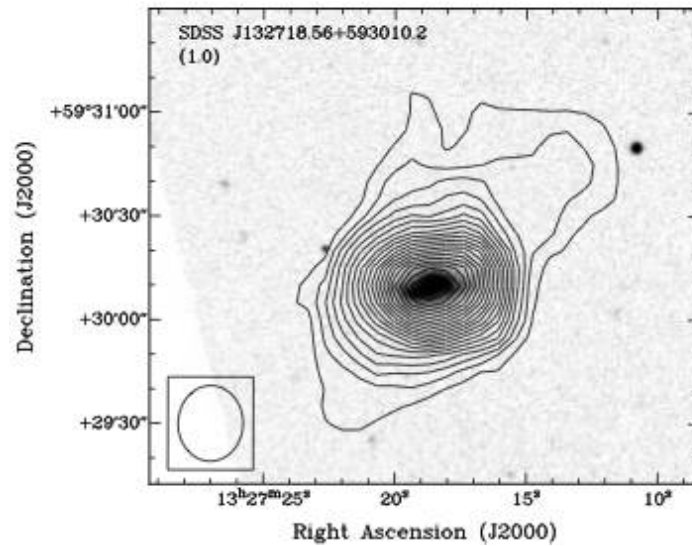
A sample of 60 galaxies, selected purely geometrically, containing a wide range of galaxy morphologies



SDSS color images, scaled to the same physical size

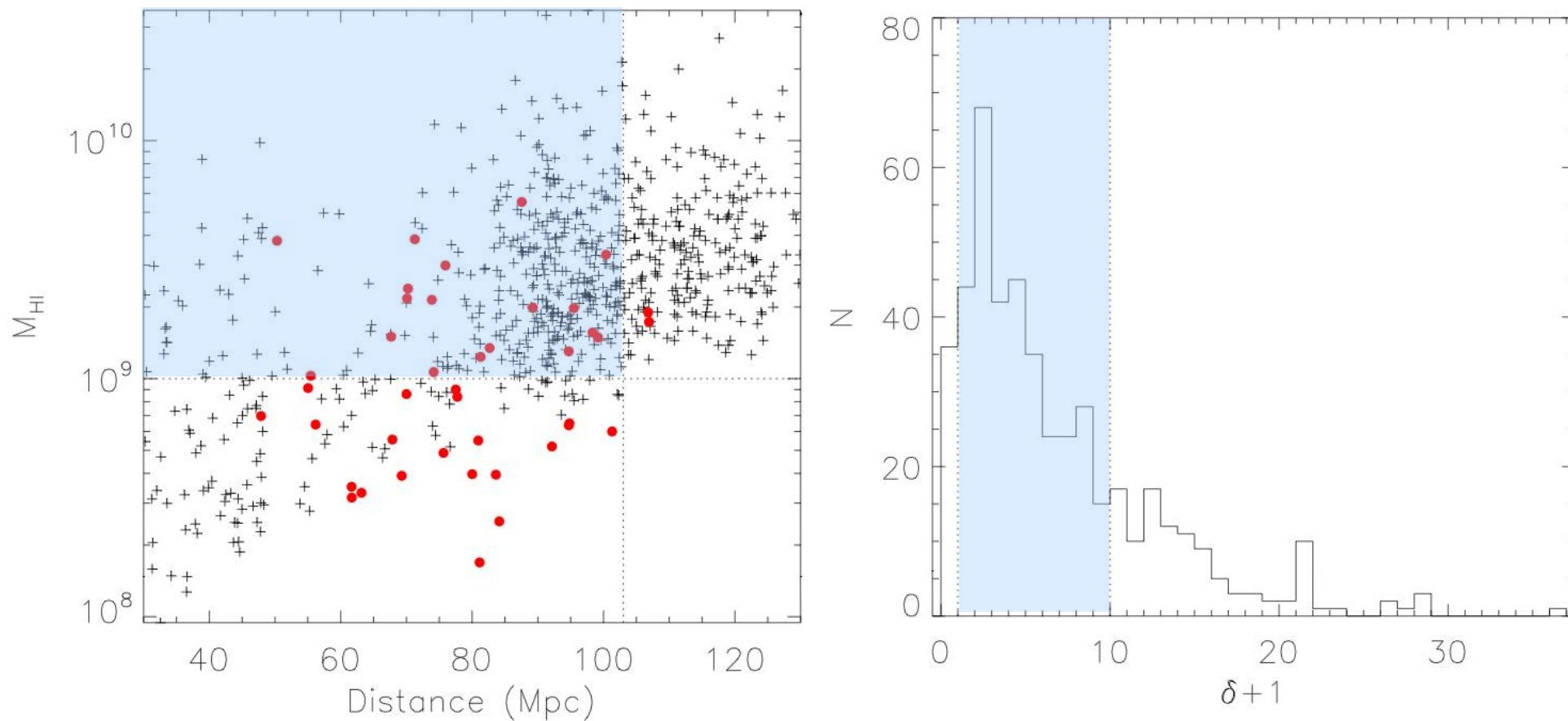
VGS - HI Observations

WSRT observations reveal a wide range of HI morphologies, including extended, irregular and interacting systems. 1σ sensitivity $\sim 5 \times 10^{19} \text{ cm}^{-2}$



VGS – ALFALFA Control Sample

ALFALFA HI catalogs are cross matched with the SDSS DR7 catalog

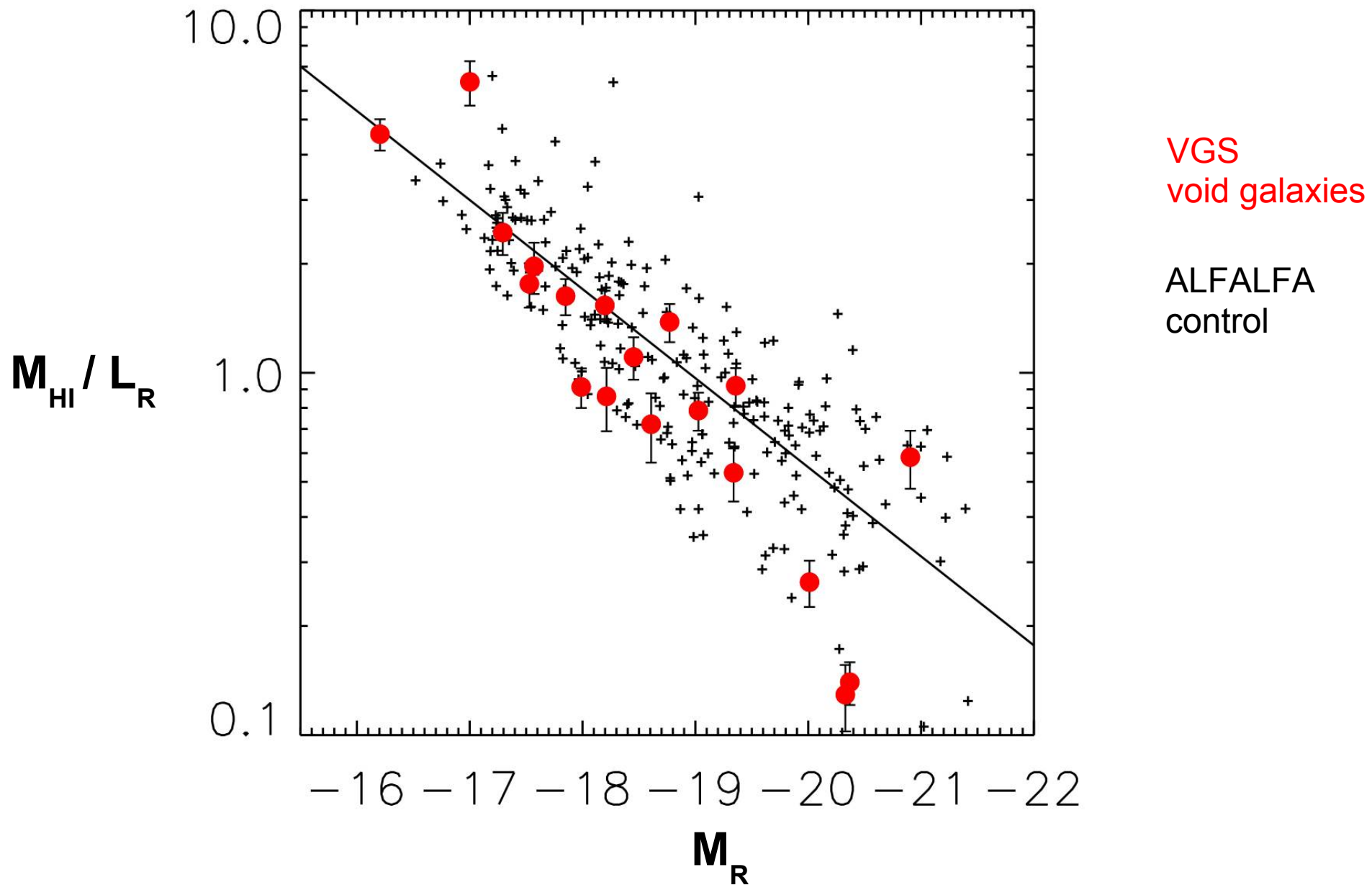


~200 ALFALFA control galaxies

18 VGS void galaxies

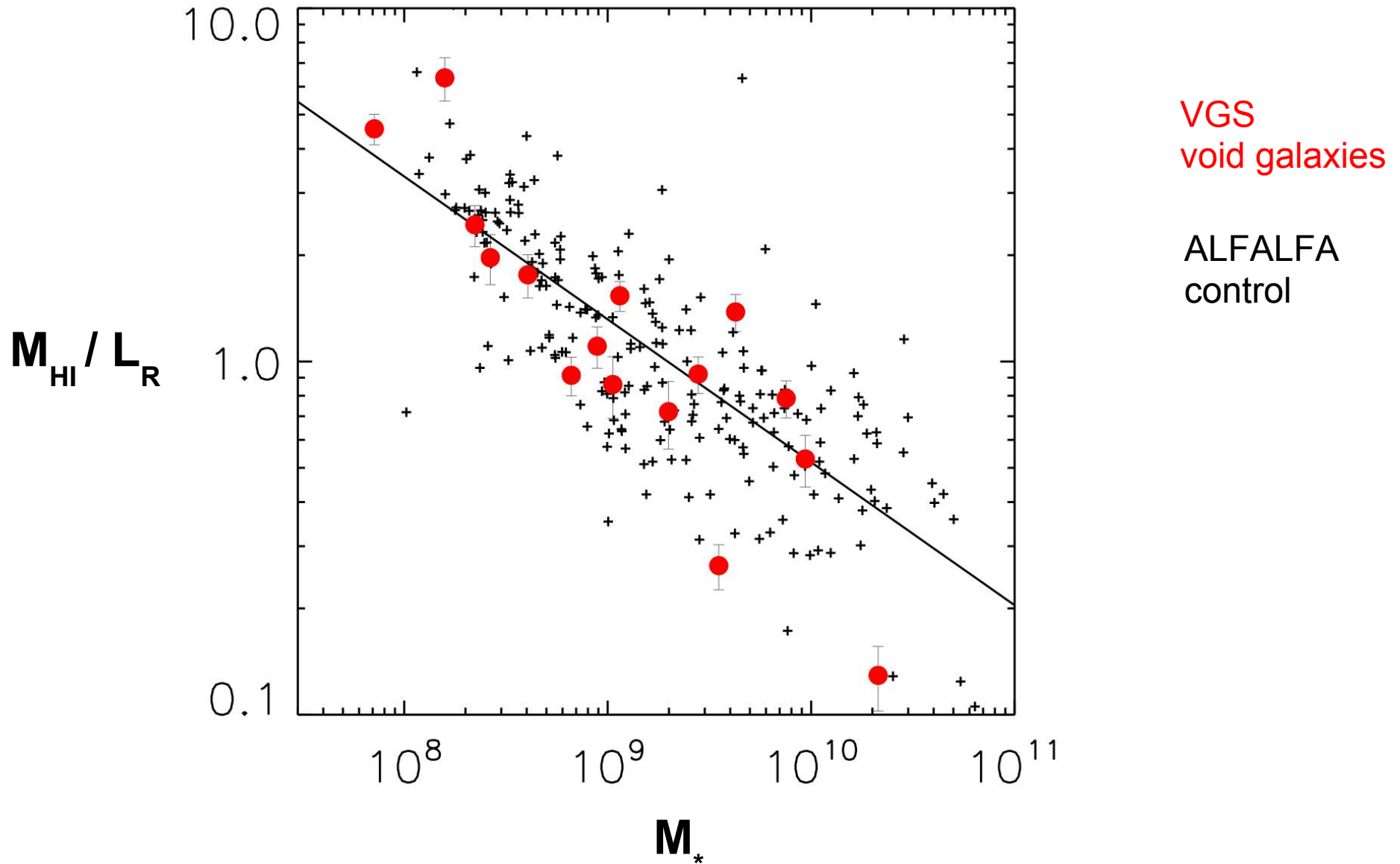
VGS – HI Mass to Light Ratio

Void galaxies have slightly lower HI mass to light ratios



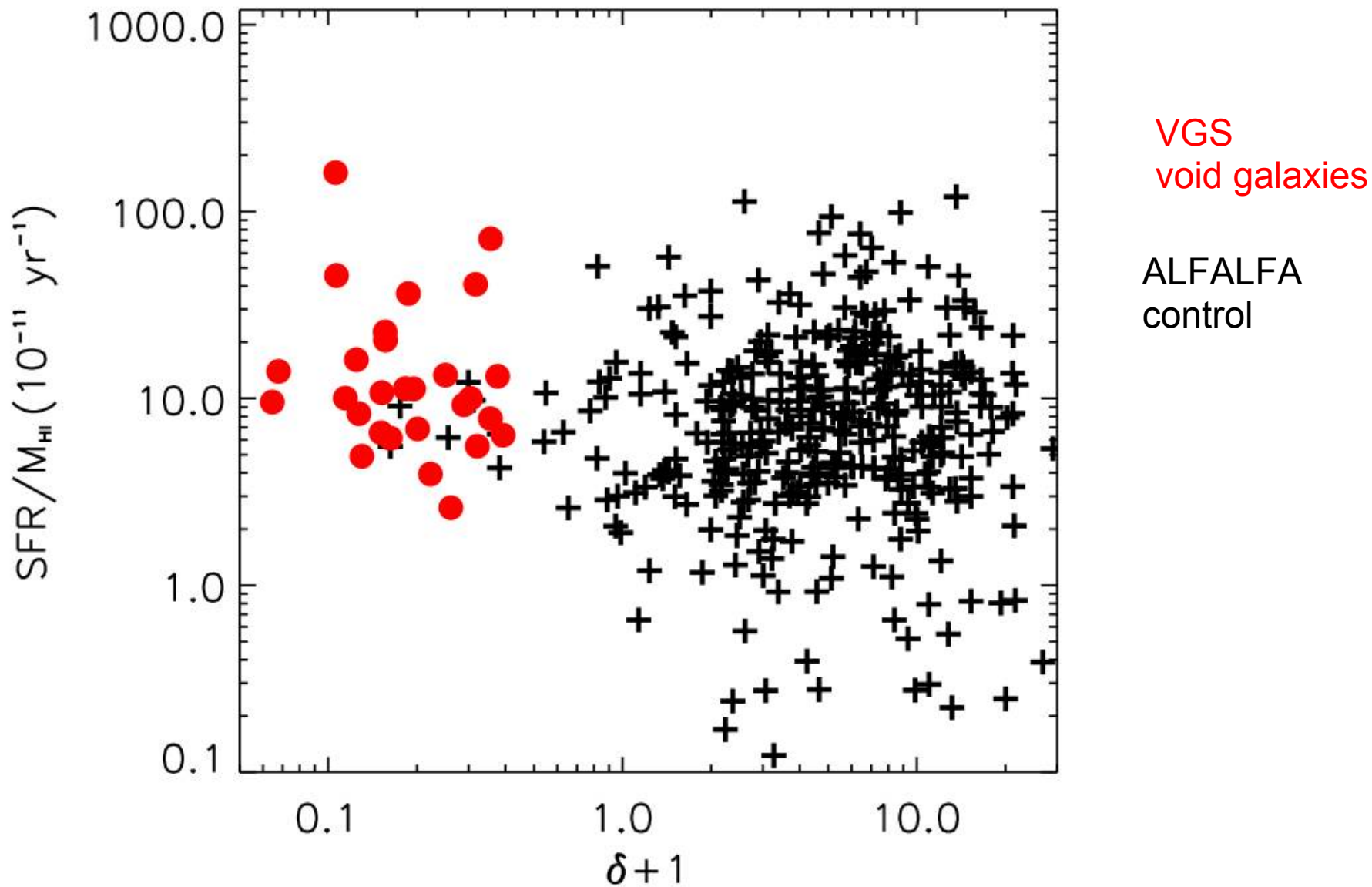
VGS – HI Mass to Light Ratio

Void galaxies appear slightly over-luminous, and the HI content is more typical when compared to the stellar masses



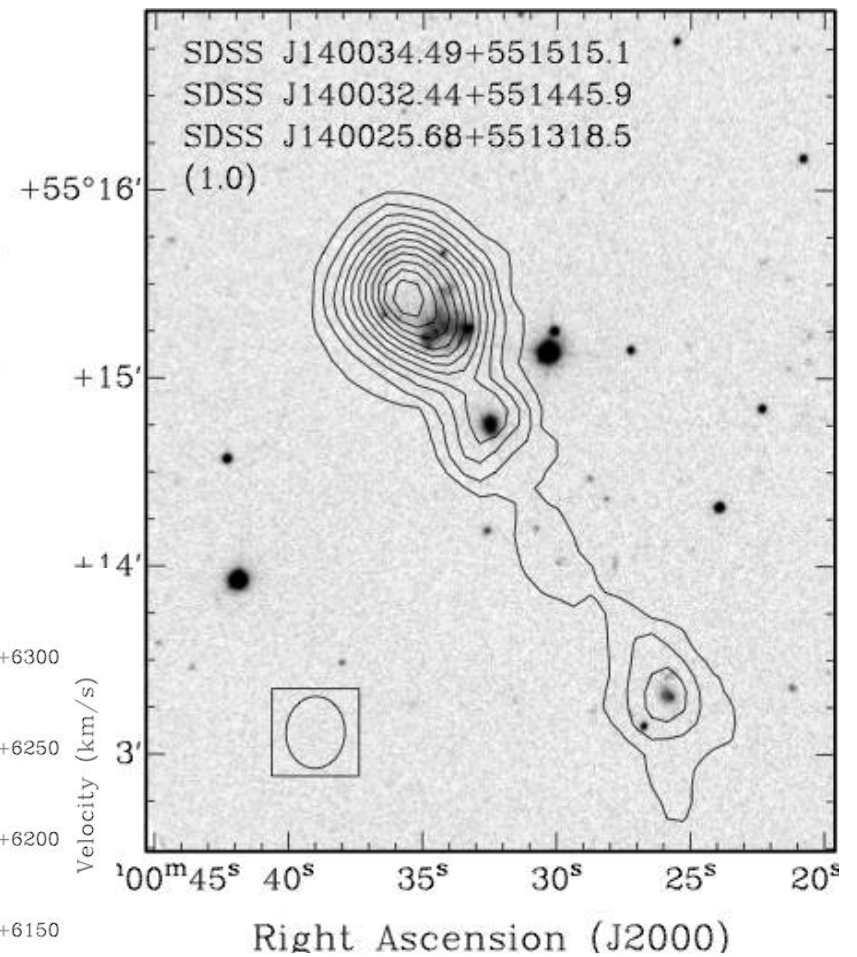
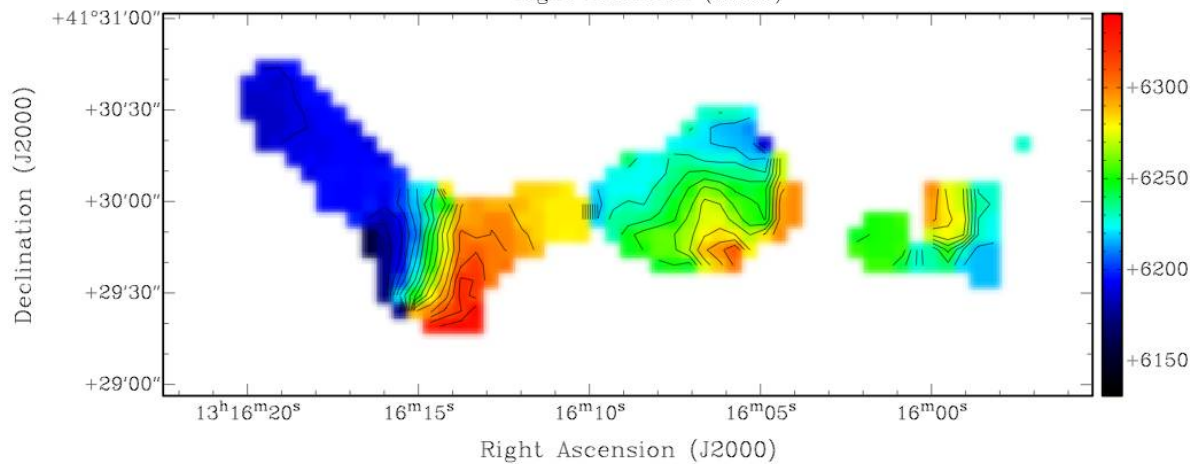
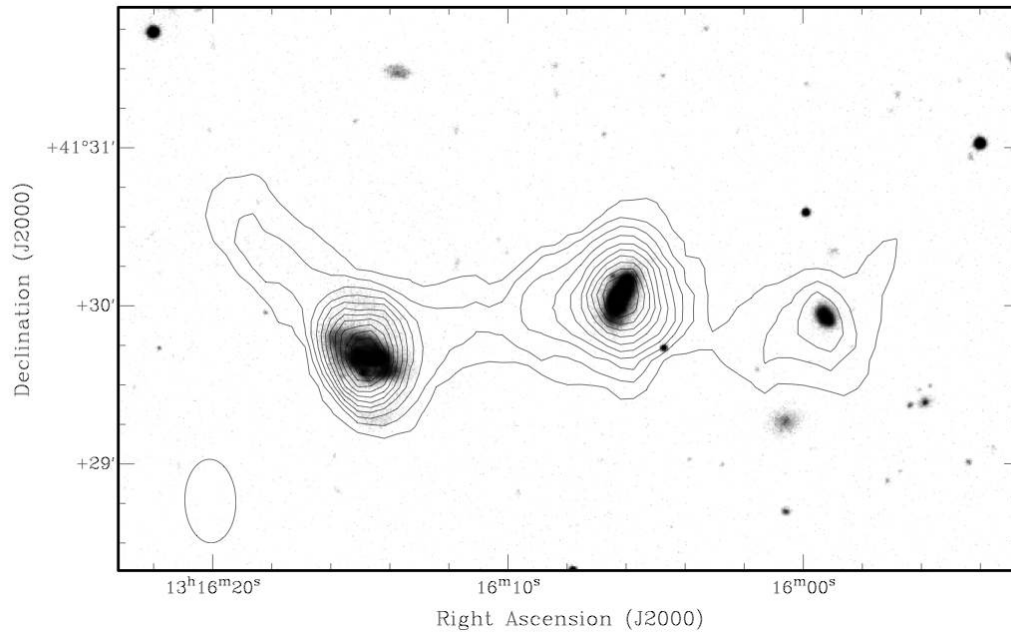
VGS - Star Formation

SFR normalized by the HI mass is slightly higher in void galaxies



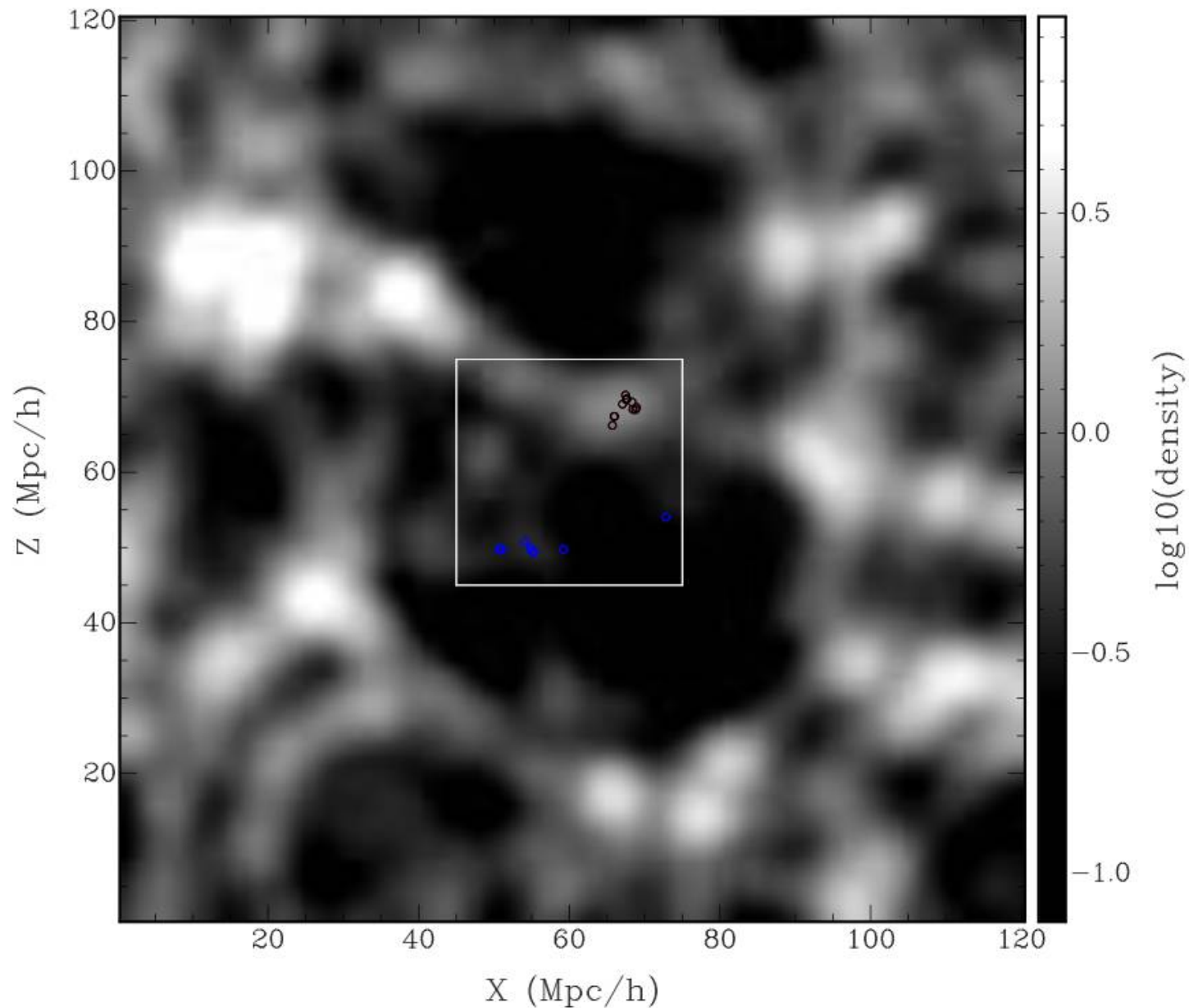
Observed Substructure in Voids?

Alignment between galaxies and connecting HI bridges are suggestive of filament formation within the void



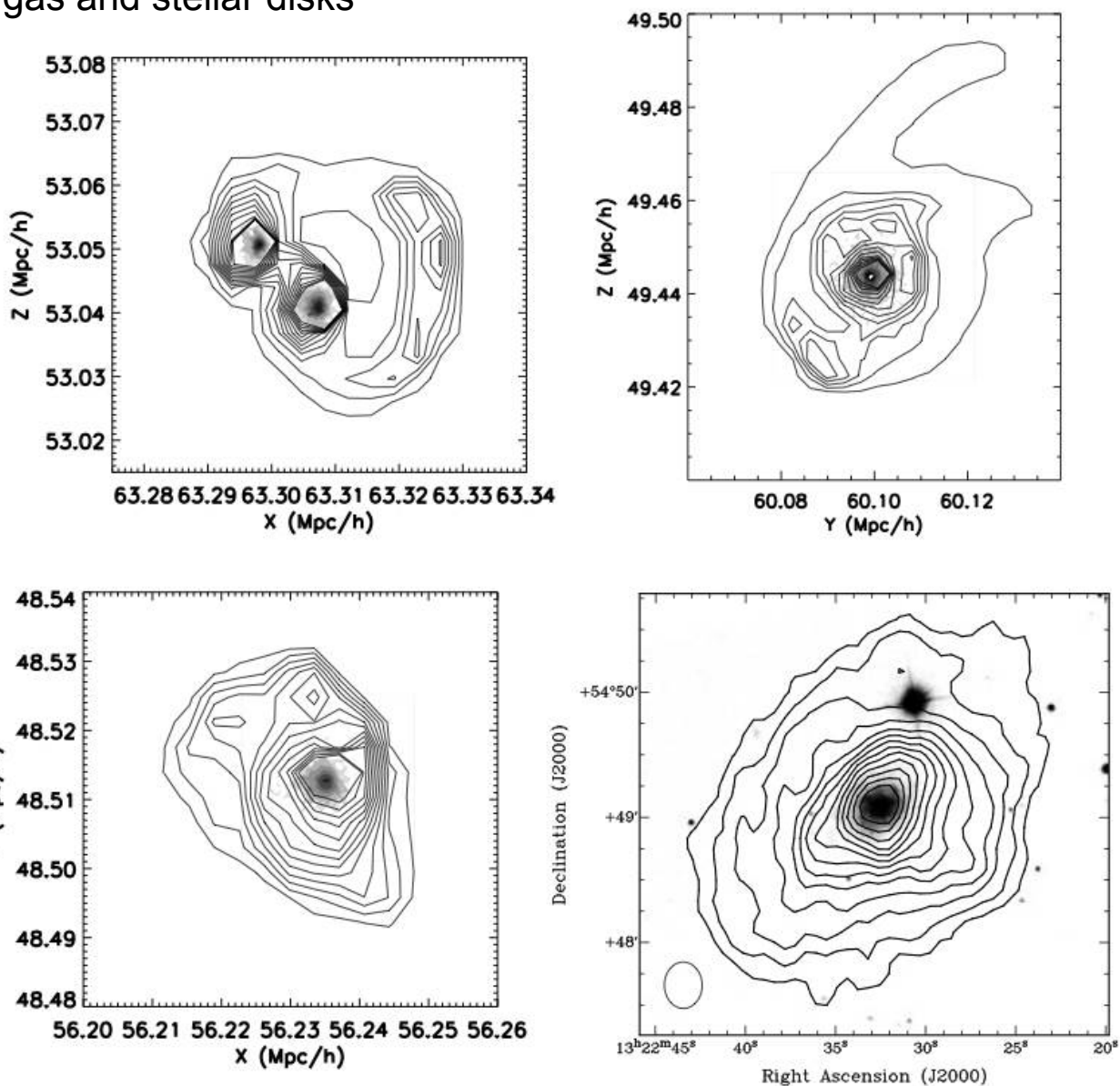
Cosmological Hydrodynamic Simulation of Voids

AMR region contains a ~ 30 Mpc void with maximum ~ 1 kpc resolution



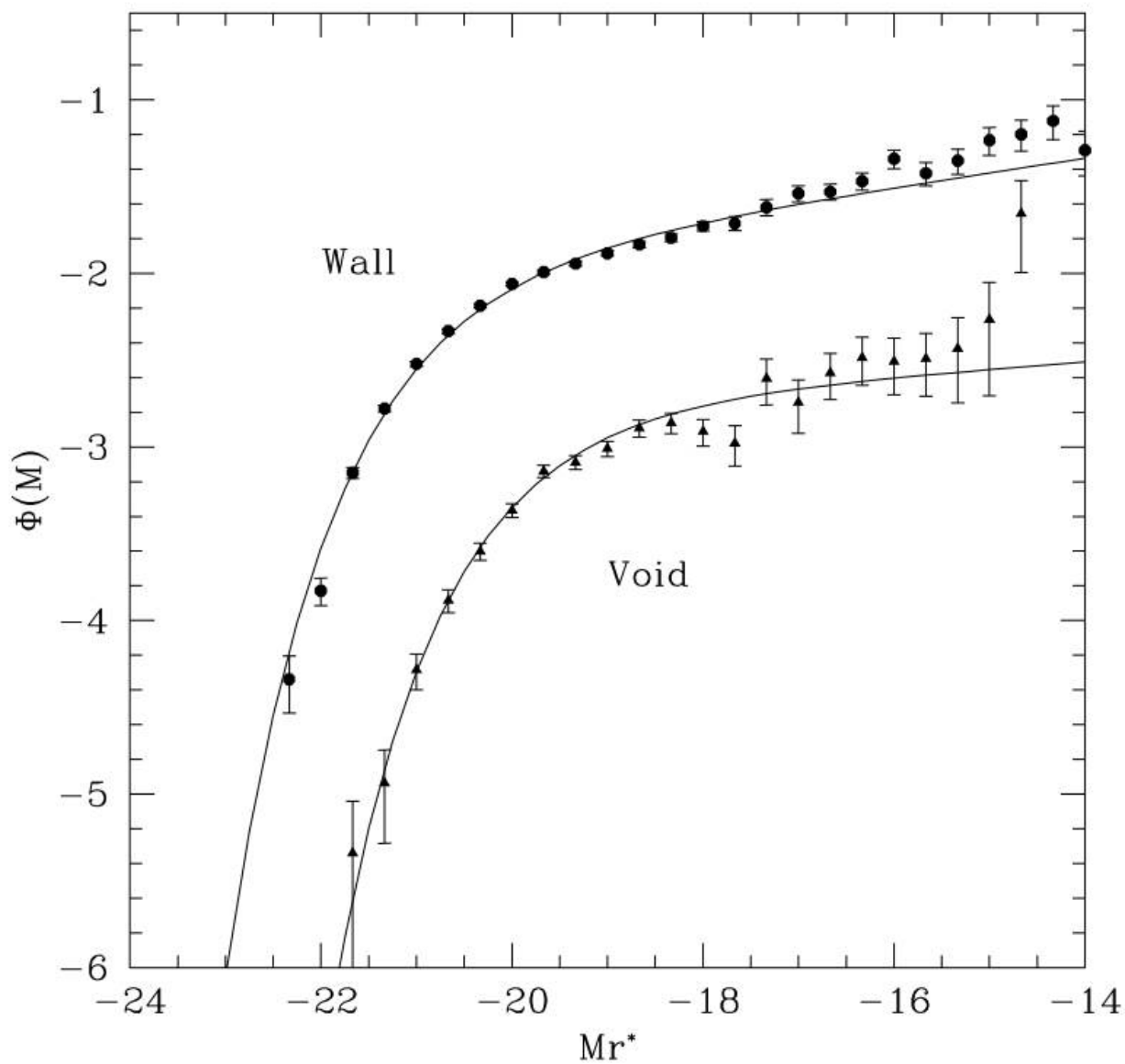
Cosmological Hydrodynamic Simulation of Voids

Realistic gas and stellar disks



Luminosity Function in Voids

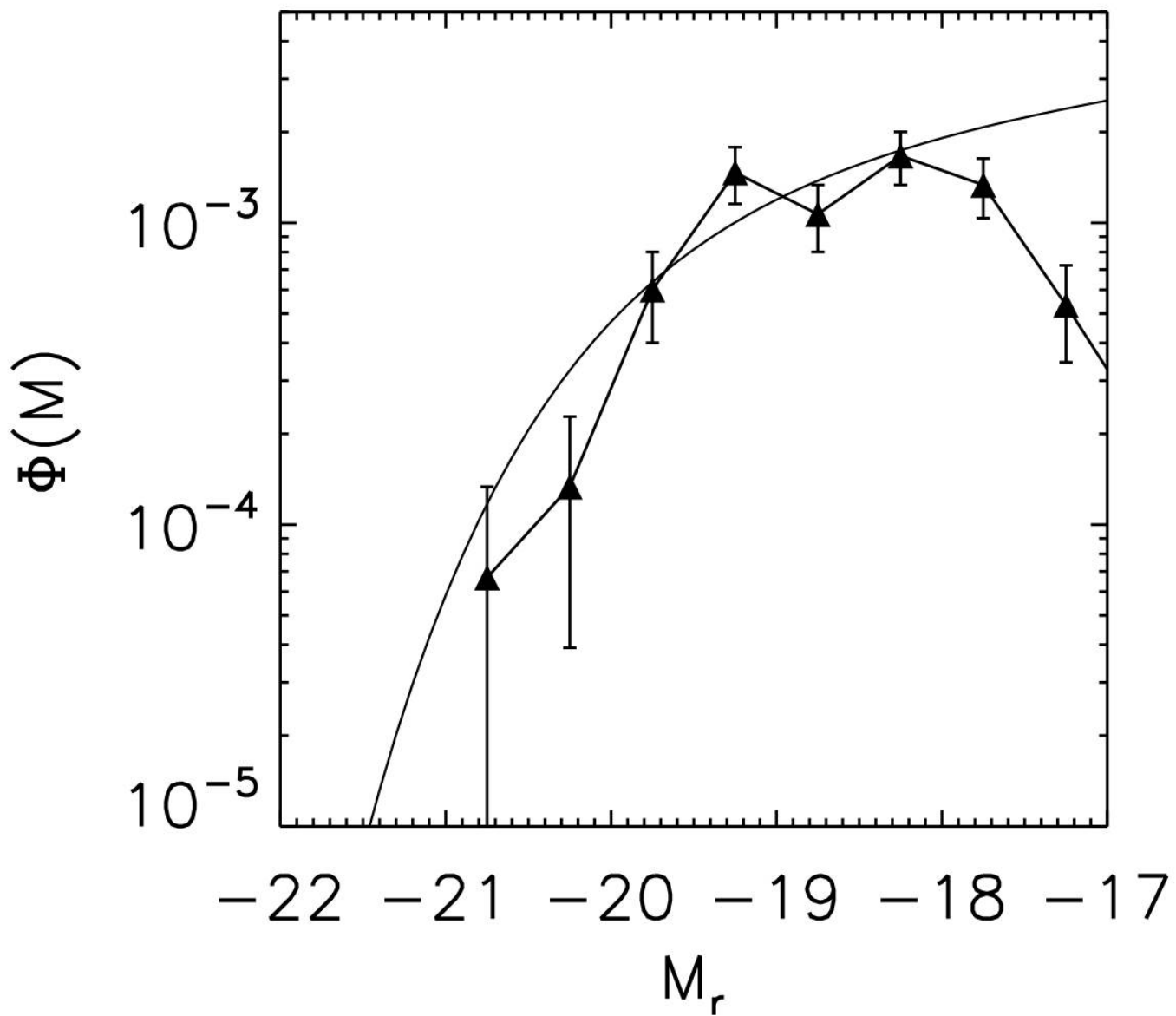
Observed shift in the luminosity function in voids



Hoyle et al. 2005

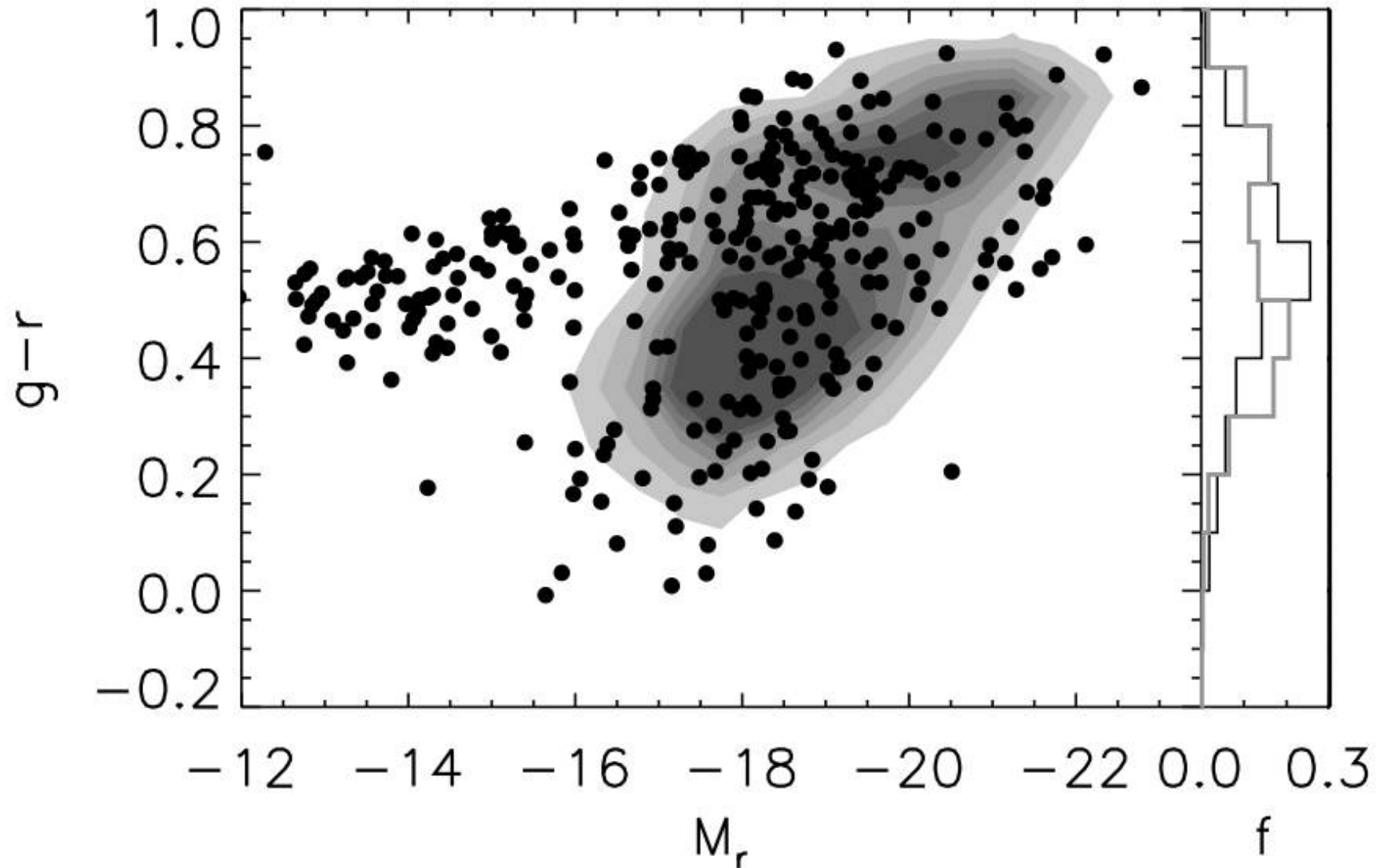
Luminosity Function in Voids

Shifted void luminosity function is well fit by CDM simulations



Color-Magnitude Diagram

Simulated galaxies span the same range of colors and luminosities as SDSS galaxies (in grey)



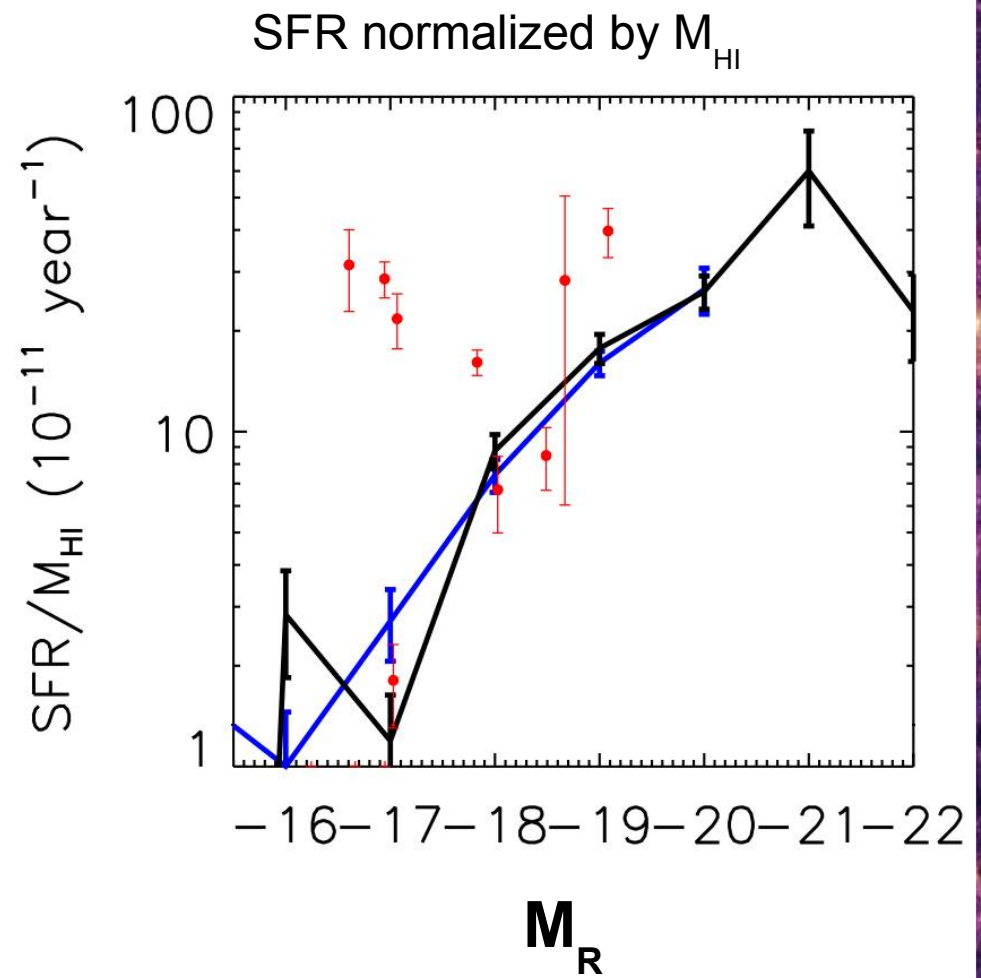
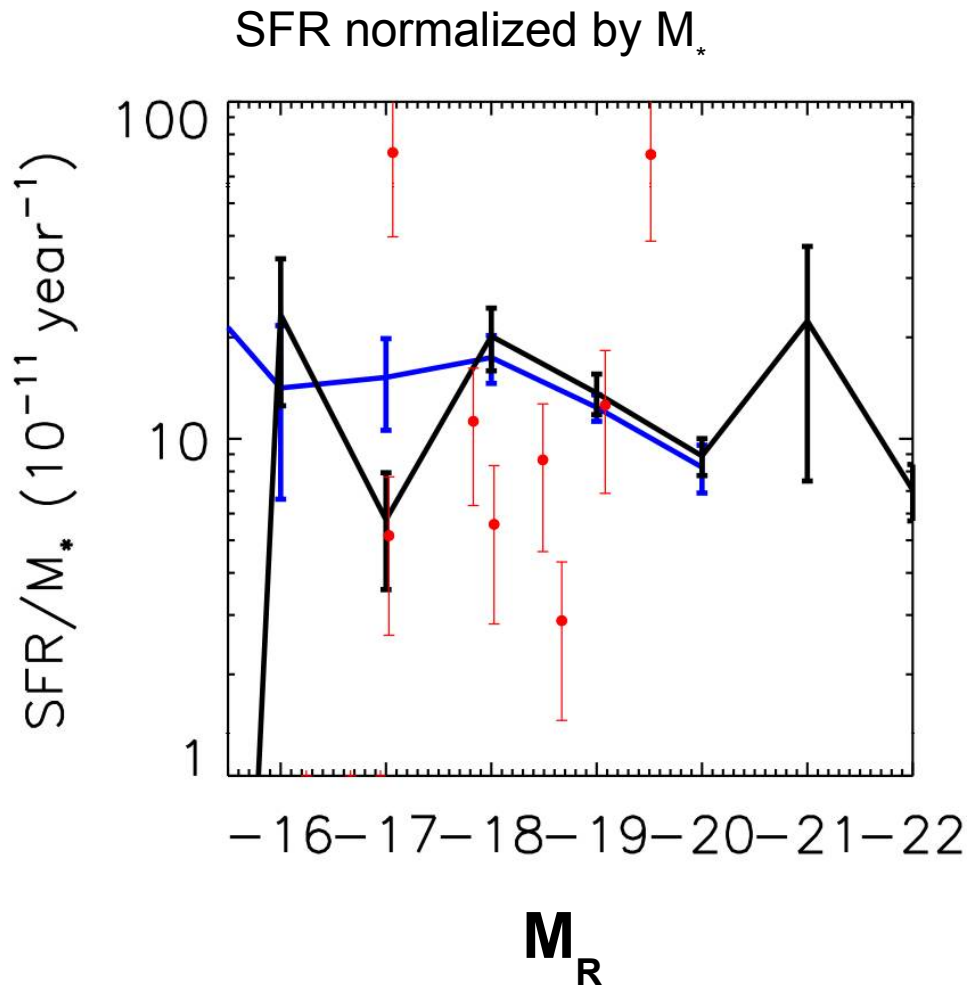
Normalized Star Formation Rates

No trend with density for simulated void galaxies

VGS

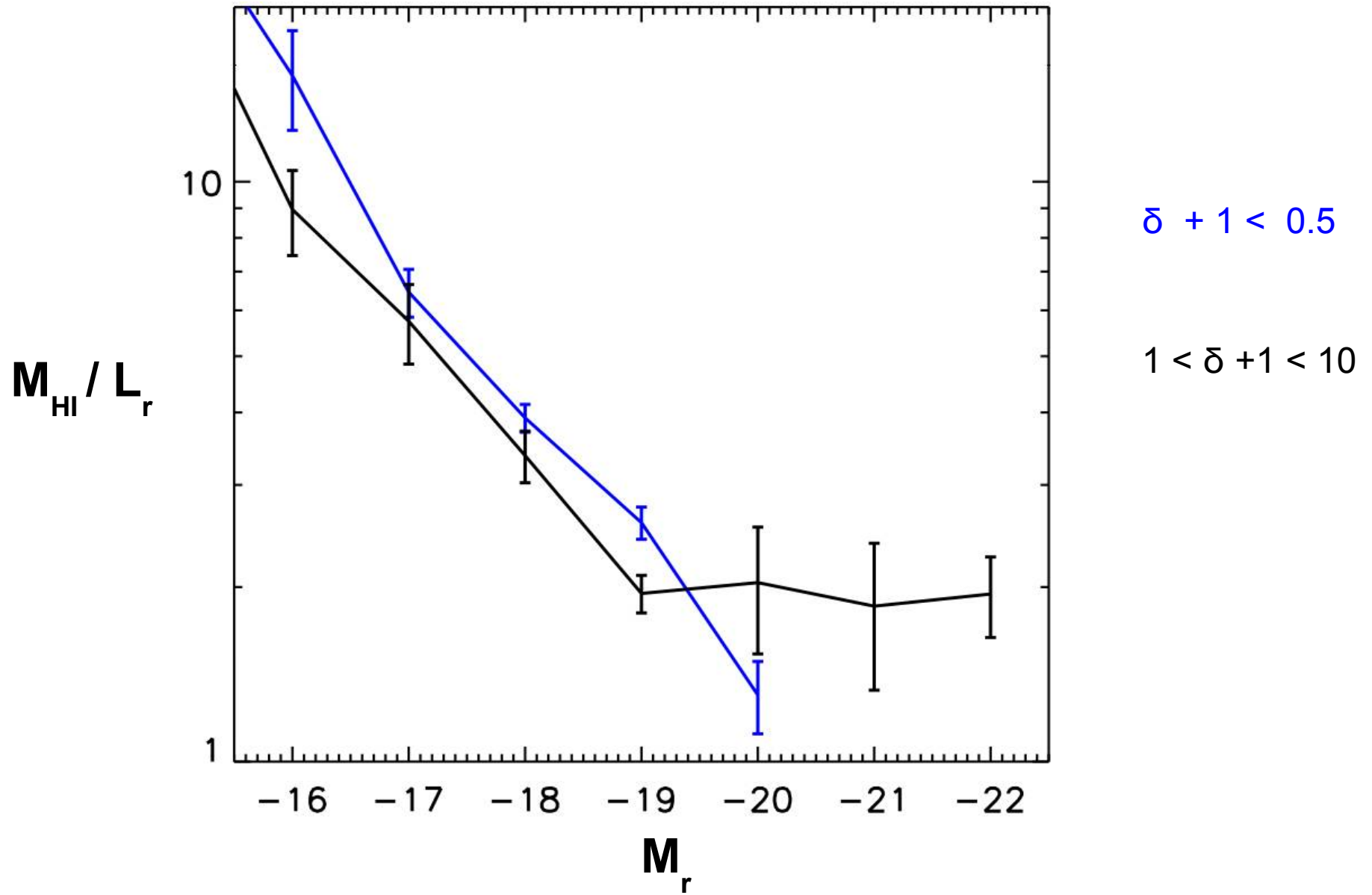
$\delta + 1 < 0.5$

$1 < \delta + 1 < 10$



HI Mass to Light Ratio

Simulations predict slight increase in HI mass-to-light ratio for void galaxies



Summary

Observations

- Void galaxies are forming more stars more efficiently
- Void galaxies appear to have fairly typical HI content for their size, and may be slightly HI deficient

Simulations

- Cutting-edge cosmological hydrodynamic simulations reproduce many features of observed galaxies
- Simulated void galaxies do not reproduce the systematic SF and HI differences between void and average galaxies

