CASPEN Exit Report

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Abstract

Report on CASPEN Visit to the CCA, 13th-17th February 2023

1 Workplan for Visit

The goal of the visit was to discuss synergies between different void definitions, and their information content. In particular, we wanted to examine the complementarity between the anti-halos void definition [1], spherical voids [2, 3], with the goal of answering whether they can access information on different scales. Further, we wanted to examine the possibility of applying both of these to reconstructions of the local matter density in the Universe made with the Bayesian Origin Reconstruction from Galaxies (`BORG`) code [4].

2 Results

We discussed firstly where we believe the cosmological information from voids comes from, compared to clusters. The anti-halos mass definition makes this a particularly interesting issue, since the abundance of anti-halo voids is typically predicted via the anti-halo mass function (since anti-halo voids are the direct equivalent of halos, identified in simulations by reversing the density contrast of an N-body simulation's initial conditions, evolving to redshift zero to obtain an "anti-universe", and mapping the anti-universe halos into the original simulation). Ostensibly, the anti-halo mass function should therefore contain the same information as the halo mass function. Spherical voids on the other hand, are typically studied with a void-size function that predicts the number of voids with a given radius. Therefore, if voids do contain different information to clusters (allowing, for instance to break the degeneracy between σ_8 and Ω_m in studies of the Λ-CDM model), this information must enter via the relationship between anti-halo mass, and anti-halo radius.

This led us to examine the void size function for anti-halos, in order to compare with that of spherical voids. With only a limited number of simulations on hand, we were not yet able to do a full analysis of the cosmological dependence, however, we detected an indication (not yet with statistical significance) that there is indeed cosmological dependence of the anti-halo void size function (see fig. 1). This would imply that anti-halos do potentially contain information not present in clusters, as with spherical voids. If so, this would be extremely valuable, as anti-halos that can be well-constrained typically have sizes in the range 10-25 $\mathrm{Mpc}h^{-1}$, which are scales not typically covered by spherical voids. This would suggest that the two different void definitions could provide complementary constraints.

This promising initial investigation suggests that there is benefit in running paired universe/anti-universe simulations with a range of cosmologies in order to perform a more detailed test of the cosmology dependence of the anti-halo void size function. We hope that this will provide useful results in the next couple of months that will lead to a paper comparing the information content of different void definitions and how they can be used to complement each other.

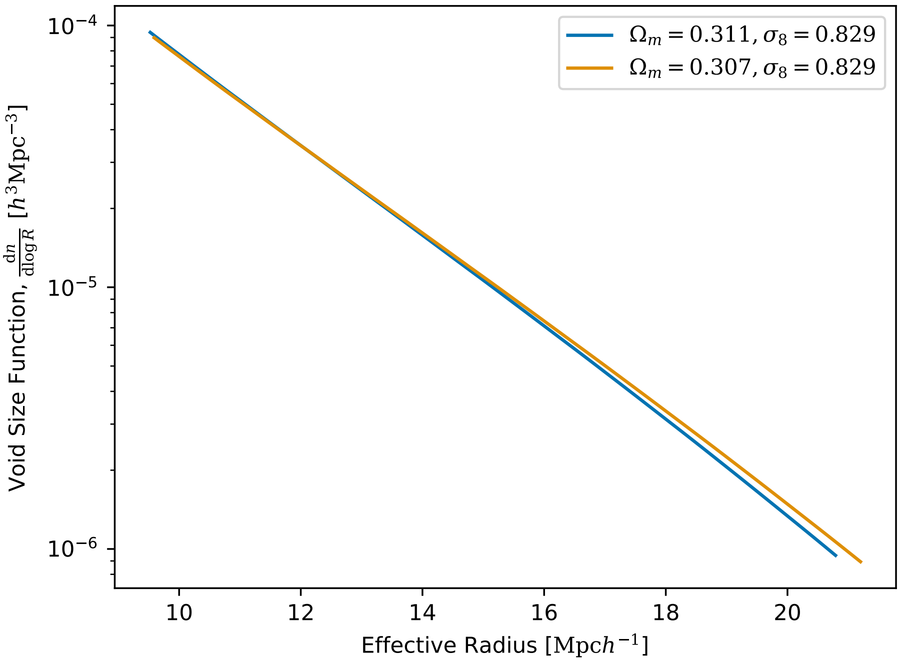

Figure 1: Void size function of anti-halos for two different cosmologies. We note that the cosmological dependence of the void size function is opposite to that of the halo mass function at large radii: increasing the amount of matter in the Universe increases the number of anti-halos in total, but counter-intuitively decreases the void size function at large radii. This effect arises because the increased matter density suppresses the average growth rate of voids, slightly decreasing the sizes of the largest voids at a level that exceeds the effect of the slight increase in the number of anti-halos overall. A similar effect is found for spherical voids, suggesting that anti-halos do indeed contain similar information to spherical voids that is not contained in the halo/anti-halo mass function.

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References

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