A response to arXiv:1310.2791: “A self-consistent public catalogue of voids and superclusters in the SDSS Data Release 7 galaxy surveys”

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ABSTRACT

Recently, Nadathur & Hotchkiss (2013) submitted a paper discussing a new cosmic void catalog. This paper includes claims about the void catalog described in Sutter et al. (2012). In this note, we respond to those claims, clarify some discrepancies between the text of Sutter et al. (2012) and the most recent version of the catalog, and provide some comments on the differences between our catalog and that of Nadathur & Hotchkiss (2013). All updates and documentation for our catalog are available at http://www.cosmicvoids.net.

The potential of voids to constrain cosmology and fundamental physics is being increasingly recognized (van de Weygaert & Platen 2011) and it is therefore very important to have a clear understanding of void definition used. In last week’s arXiv submission Nadathur & Hotchkiss (2013) (hereafter NH13) described a different procedure for building a void catalog based on ZOBOV (Neyrinck 2008). NH13 contained several implied or explicit criticisms of the catalog we made available at http://www.cosmicvoids.net (Sutter et al. 2012; hereafter S12). We take this opportunity to provide some clarifications in this comment.

The principal criticism in NH13 of the S12 void catalog is that the regions identified as voids are not, on the whole, underdense. This is by design: the ZOBOV watershed algorithm includes the surrounding high-density walls in the void definition (Neyrinck 2008). Indeed, Figure 7 of NH13 shows identical behavior in their voids. However, the voids in S12 are underdense near the center, as demonstrated by the radial density profiles plotted in Figure 9 of S12.

Another major criticism in NH13 is that some voids in S12 have high minimum densities (and also high mean densities). When these voids are included, a stacked radial density profile of all voids shows no clear underdensity (Figure 9 of NH13). However, as Figure 1 shows, voids with high $\rho_{\text{min}}$ (and hence also high $\rho_{\text{void}}$) tend to have radii near the mean intergalaxy separation $n_g$. These voids are naturally more sensitive to Poisson noise fluctuations and less robust in properties than larger voids. Small voids tend to have higher compensation regions (Cecarelli et al. 2013; Hamaus et al. 2013), leading to higher mean densities in the watershed. However, they also have lower density contrasts (Sutter et al. 2013). These effects combined will tend to wash out a stacked density profile.

In our catalog we impose a sharp cutoff at $R_{\text{eff}} = n_g^{-1/3}$, but in the catalog documentation we caution users that voids near this cutoff may not be reliable and we recommend that a higher threshold (e.g., $R_{\text{eff}} > 2R_{\text{eff,min}}$) be adopted for most analyses. In general our approach has been to provide a catalog with loose cuts but offer advice on targeted cuts that users may wish to impose for their analyses, while NH13’s approach is to impose what they consider best-practice cuts in the catalog that they provide. Obviously, each approach has its virtues.

Below we respond to the other main points raised by NH13.

1 OTHER RESPONSES

Survey boundary contamination - NH13 claim that 30% of our voids have core particles that are adjacent to boundary particles (mock particles introduced to handle survey edge effects). We cannot replicate this claim. We have modified the original ZOBOV algorithm to enforce bijectivity in
the Voronoi graph and use a different splitting technique to minimize problems when joining subregions. Not including these refinements may explain why NH find a different result. Also, the use of earlier versions of the qhull library\(^1\) which ZOBOV uses to construct the Voronoi graph, can result in different tessellations.

**Statistical significance of voids** - NH13 claim that most of our voids are indistinguishable from Poisson fluctuations based on low density contrasts. The voids in NH13 also have very low contrasts (their Figure 4), and the cut on contrast ratio recommended by ZOBOV would eliminate nearly all voids. Instead, they cut their sample on \(\rho_{\text{min}}\). As Figure 1 shows, the most problematic voids are the ones nearest the mean galaxy separation, and if these voids were to be judged undesirable for a particular application a simple cut on larger void radii would remove most of them.

**Choice of coordinate system** - NH13 claim that our catalog is problematic because the abundances of voids in redshift space (with galaxy 3-d positions computed using \(D_A(z) = cz\)) and comoving space (assigning positions in comoving coordinates for an assumed \(\Lambda\)CDM cosmology) do not match. Since we impose a fixed radius cutoff, and the mean galaxy separation changes with the coordinate transformation, we will naturally get different abundances. While voids in redshift and comoving space tend to have different shapes and sizes (Ryden & Melott 1996), and the robustness of watershed techniques under coordinate transformations needs to be more carefully studied, the analyses of Planck Collaboration (2013), Pisani et al. (2013), and Melchior et al. (2013) indicate that we still capture physical underdensities. Additionally, there is significant correspondence in the positions on the sky between the redshift- and comoving-space voids in our catalog. We identified voids in redshift space for our application of the Alcock-Paczynski test (Sutter et al. 2012), but we have always provided a comoving-space version of the catalog and clearly noted this in the documentation. Note that in both coordinate systems we do not attempt to remove peculiar velocities.

## 2 DISCREPANCIES BETWEEN S12 TEXT & CATALOG

Some of the criticisms in NH13 arise from discrepancies between the text of S12 and the actual procedure used to generate our catalog. Most importantly, we stated in S12 that we applied a maximum density threshold for each void. This was incorrect: we applied a minimum density criterion for merging adjacent zones into voids (as described in Neyrinck 2008). This does not limit the overall density of the voids, and if a void contains only a single zone it does not restrict the inclusion of that void.

Secondly, we misstated the handling of edge galaxies: we did not remove any galaxies, but followed a similar procedure as described in NH13 and removed their adjacencies from the Voronoi graph, preventing \(\text{ZOBOV}\) from including them in the watershed. Also, we considered any galaxy with any adjacency to a boundary particle as an “edge” galaxy, not just those that were closer to a boundary particle than any other galaxy. Finally, in the original catalog the central density cut was erroneously applied at fixed radius, rather than at \(0.25R_{\text{eff}}\).

We have also made several improvements, including the addition of void shape estimation and tools to extract void member particles. We have documented all known bug fixes and improvements at http://www.cosmicvoids.net and in the catalog README.

## 3 DIFFERENCES BETWEEN S12 AND NH13

While the approach of NH13 is nearly identical to ours (e.g., the division into volume-limited samples, the use of \(\text{ZOBOV}\), and the procedure for handling boundaries), they do introduce some innovations. Most importantly, they reject voids with \(\rho_{\text{min}} > 0.2\bar{\rho}\), account for slight redshift-dependence in the mean galaxy density, include a bright-star mask, and apply different criteria for merging zones together. We are currently investigating the merits or demerits of such adjustments to assess whether we should include them in future versions of our catalog.

However, our fundamental philosophy is to minimally interfere with the void finding operation itself, produce a catalog with as many voids as possible, and allow users to apply post-processing filters and cuts as they see fit — for example, users can already apply a \(\rho_{\text{min}}\) cut with the information we provide. The primary criticisms of NH13 rest on our choice to include the smallest voids in our catalog, and this study serves as a reminder that small voids are more subject to Poisson noise and statistically have different properties than larger voids.

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\(^1\) http://www.qhull.org
though we disagree with them on the significance of a number of their points.

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