Cosmic web complexity

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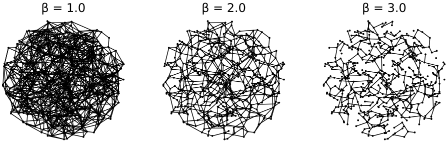
Motivation

- The two point correlation function is the customary way of describing the matter distribution of the universe, since it is easy to measure and interpret.
- Other approaches study the connectivity of different graphs constructed on the galaxy distribution.
- In this work we explore the statistical complexity of the β-skeleton graph as one of these alternatives.

Methodology

The β-skeleton is a graph in which the connectivity is controlled by a positive real number β. As β increases the graph tends to be more disconnected.



We construct this graph for a set of dark matter halos from N-body simulations from the Abacus Cosmos project. From this graph we compute the probability of a node to have n connections $P(n)$.

We then apply the definition of statistical complexity introduced by Lamberti et. al, given by the following equation:

$$C(P) = \frac{H(P)D(P,U)}{D^*},$$

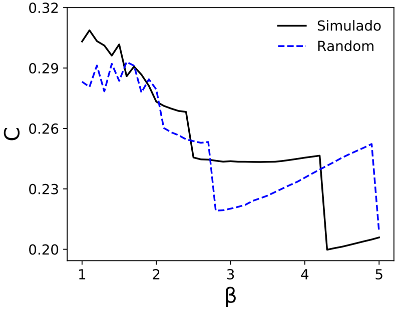
where $D(P,U)$ is the Jensen-Shannon divergence between P and the uniform distribution U

$$D(P,U) = S\left(\frac{P+U}{2}\right) - \frac{S(P)+S(U)}{2},$$

and D^* is a normalization constant.

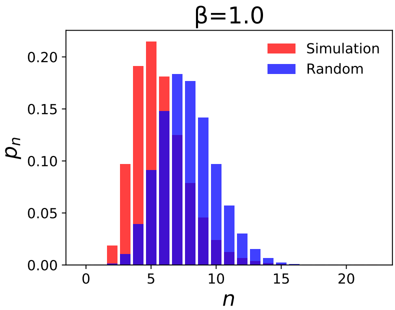
First results

In the figure below are shown the $C(\beta)$ curves for a simulated catalog and a random catalog.



This figure reveals the main problem of using this definition for this particular problem: the random points do not have a null complexity, as they should, making it hard to distinguish one catalog from the other.

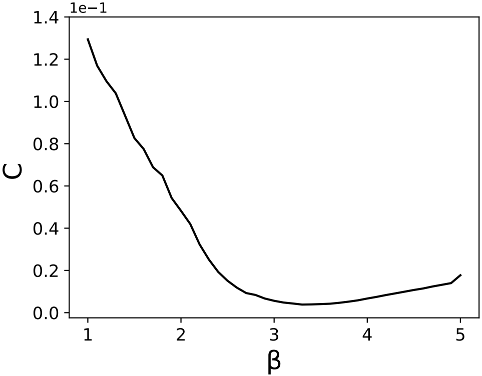
We can explain this issue by looking at the number distribution of both catalogs.



If the complexity for the random points were to be zero, the distribution has to be the uniform distribution. Since this is not the case, we can replace the term $D(P, U)$ by $D(P, R)$, where R is the number distribution of a random set of points.

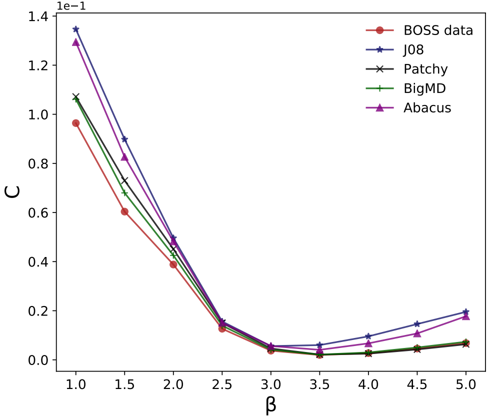
Results

We found this new complexity to be of order 10^{-1} bits^2 and reaching its minimum value at $\beta \approx 3.3$.



We explored the influence on complexity of different factors and parameters: cosmic variance, geometry, RSD, redshift evolution, number density and cosmological parameters.

We also compared the $C(\beta)$ curves of different simulated catalogs and observational data from the Baryon Oscillation Spectroscopic (BOSS) Data Release 12.



Complexity is able to distinguish between simulated and real data. Big MultiDark is the one that best fits the observations, especially for $\beta > 3.0$.