CRI

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The Network Behind the Cosmic Web

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Big Data Course - Reverse Classroom

- Cosmic web is nothing but the structure of our universe.
- Viewing the Universe as set of discrete galaxies held together by gravity is deeply ingrained in cosmology.

So, why does our universe have this peculiar structure?

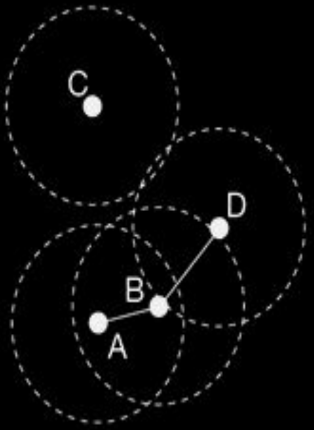
- A very less amount of knowledge is known about the most effective construction and characteristics of the underlying network.
- Now we shall explore models with network construction algorithms that uses various galaxy properties that is from their location, size and relative velocity.
- A network is assigned to galaxy distributions provided by both simulations and observations.

What can be found in these observations and simulations?

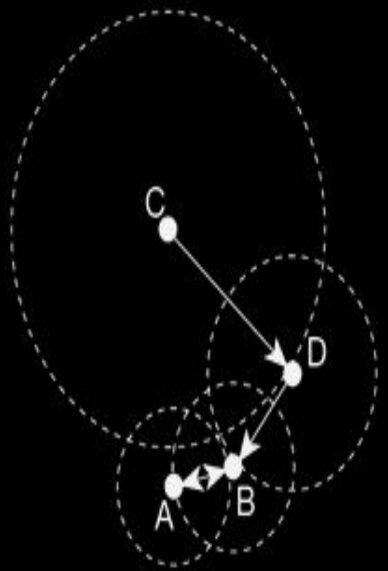
- Finding a model relying only on spatial proximity offers the best correlations between the physical characteristics of the connected galaxies.
- It can also be shown that the properties of networks generated from simulations and observations identical,unveiling a deep universality of the cosmic web.

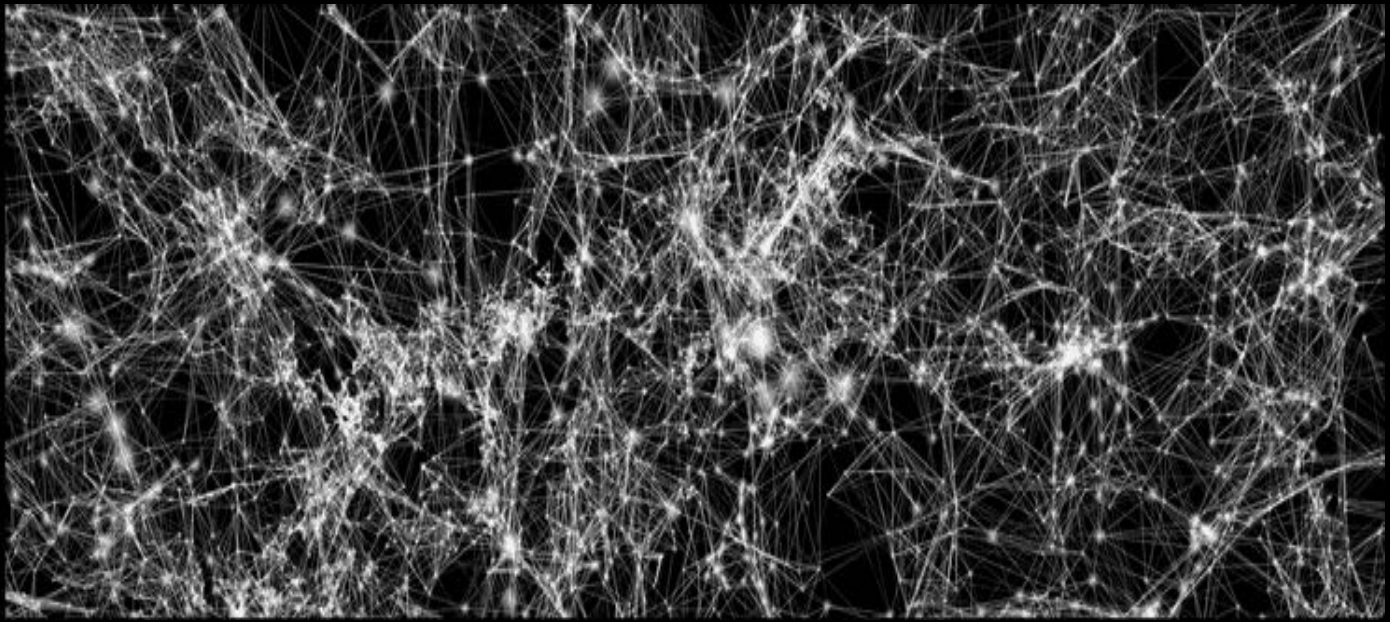
- There are multiple ways of building a network and from those, we can get three kinds of models that can be gained based upon the subhalo /galaxy catalogs.

- This model is the simplest links two nodes with an undirected link if the distance between them is smaller than a predefined length, l. This is called the **Fixed Length Model.**



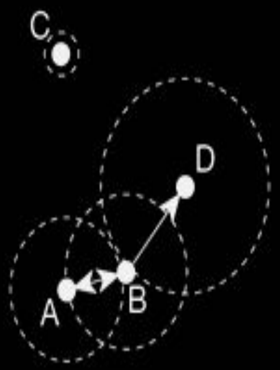
- The second model represents the directed versions of the first model, drawing a directed link from i to the closest (k) nodes.
- A galaxy is connected to the closest galaxy with a directed link; therefore the linking length depends on the position of the closest galaxy.
- Hence in this model, the length of each link depends on the distance to the nearest galaxy. This model is called as **Nearest Neighbors Model**.





- The last model shows the linking length scales with the galaxy size, $l = a\, R_i^{1/2}$. The length of each link is proportional to the " size "of the galaxy.

- This model is called as **The Varying Length Model**.



Centre for complex research used data from 24,000 galaxies multiple models of the cosmic web, offering complex blueprints for how the galaxies fit together.

The Result:

- In total 71 parameters are analyzed that characterize each subhalo, ranging from their peculiar velocity to star formation rate that allows us to identify the network representation that offers the best correlation between them.
- When the models are generated and correlation method is applied, four properties that consistently display correlations between the connected nodes are found. They are peculiar velocity, stellar metallicity, specific star formation rate, and color.
- However, this exercise demonstrates that it is indeed possible to uncover underlying properties of the network without prior knowledge.
- Numerous network construction algorithms were defined. The second model, which relies on spatial proximity only, captures the best correlations between the physical characteristics of nearby galaxies.
- Also in many ways, the results of this paper represent only the first step towards a network-based understanding of the Universe.
- It offers a framework on with one could build various applications, from halo finders to exploring the fundamental characteristics of the cosmic web.

What I contributed to Wikipedia as a Consequence?

Network Behind Cosmic Web [edit source]

The concept of the cosmic web, viewing the Universe as a set of discrete galaxies held together by gravity, is deeply engrained in cosmology. Yet, little is known about the most effective construction and the characteristics of the underlying network. Here we explore seven network construction algorithms that use various galaxy properties, from their location, to their size and relative velocity, to assign a network to galaxy distributions provided by both simulations and observations. We find that a model relying only on spatial proximity offers the best correlations between the physical characteristics of the connected galaxies. We show that the properties of the networks generated from simulations and observations are identical, unveiling a deep universality of the cosmic web. This paper was written by B. C. Coutinho,1 Sungryong Hong,2, 3 Kim Albrecht,1 Arjun Dey,2 Albert-L´aszl´o Barab´asi,1, 4, 5, 6 Paul Torrey,7, 8 Mark Vogelsberger,9 and Lars Hernquist9.

Introduction [edit source]

The cosmic web, the desire to view the large-scalestructure of the Universe as a network, is deeply embedded both in cosmology and in public consciousness [1–5]. Yet, it remains little more than a metaphor, typically used to capture the dark matter's ability to agglomerate the galaxies in a web-like-fashion. Numerous halo finder algorithms [6, 7], made possible by the increasingly precise simulations of the evolution of the Universe [1, 8], exploit the network-like binding of the galaxies [9]. Yet, very little is known about the graph theoretical characteristics of the resulting cosmic web. Our goal here is to test and explore various meaningful definitions of the cosmic web, and use the tools of network science to characterize the generated networks. In particularly, we explore which network definition offers the best description of the observed correlations between the physical characteristics of connected galaxies. The resulting network-based framework, tested in both simulations and observational data, offers a new tool to investigate the topological properties of the large scale structure distribution of the Universe.

Summary [edit source]

In summary, here we used the tools of network science to characterize the large structure of the Universe both in simulations and observational data. While we can define numerous network construction algorithms, we find that the simple model M3, which relies on spatial proximity only, captures the best correlations between the physical characteristics of nearby galaxies. The results are distinct from the random case, which assumes random galaxy localizations, indicating that the obtained structure of the cosmic web is intricately tied to the underlying structure of the Universe. It is particular encouraging that the network characteristics of the cosmic web, from the degree distribution to the clustering and degree correlations, show remarkable agreement between simulations and observations. In many ways, our results represent only the first step towards a network-based understanding of the Universe. Yet, they provide guidance for the nature of the data needed for a systematic exploration of the underlying network, offering a framework on with one could build various applications, from halo finders to exploring the fundamental characteristics of the cosmic web.

Sources:

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