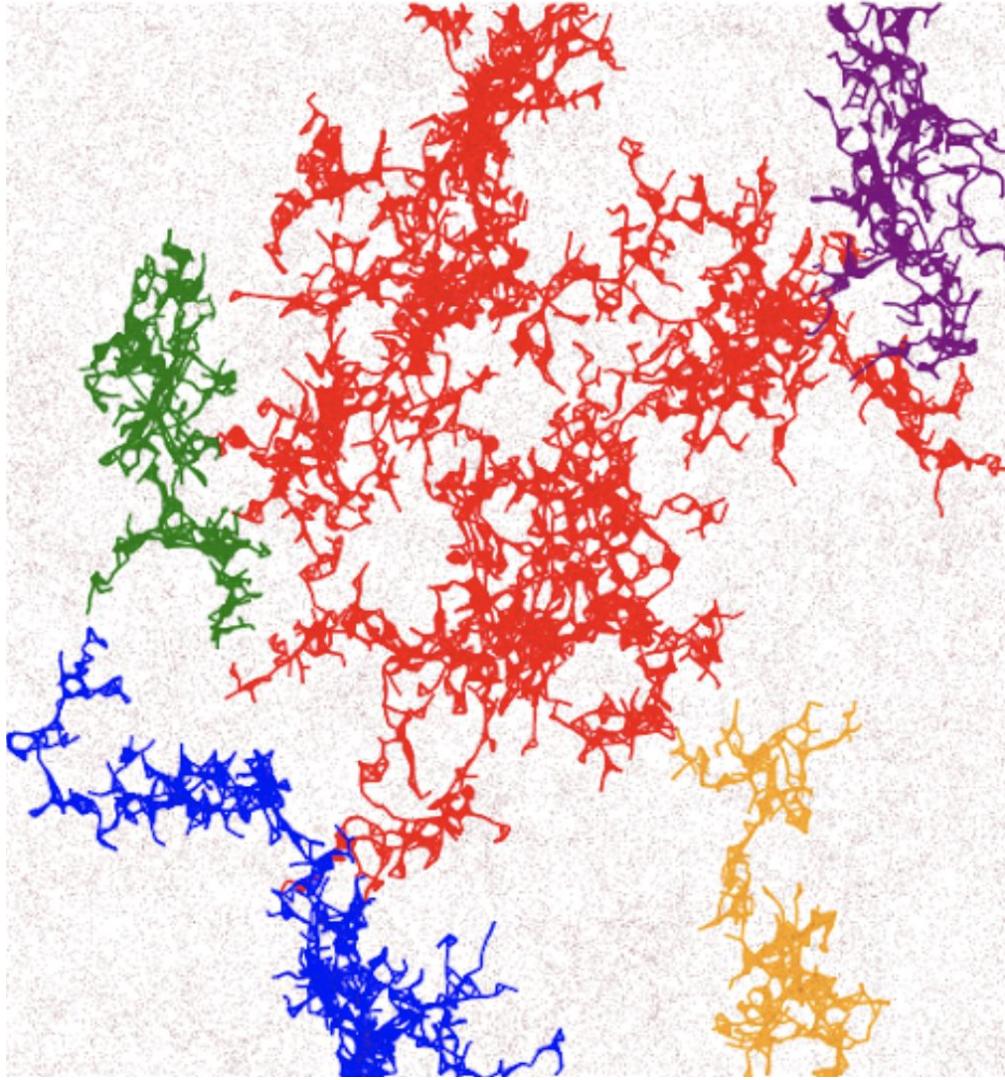


Discriminating between cosmological simulations with graph algorithm

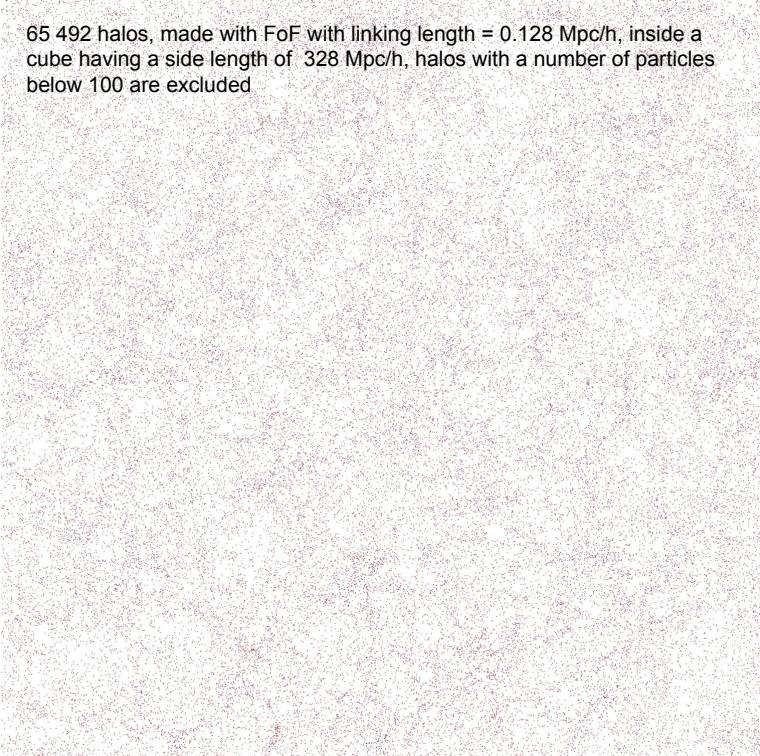
Internship (3 oct 2022 - 10 nov 2022)

Ali Hamié
Supervisor: Dr. Stephane Plaszczynski



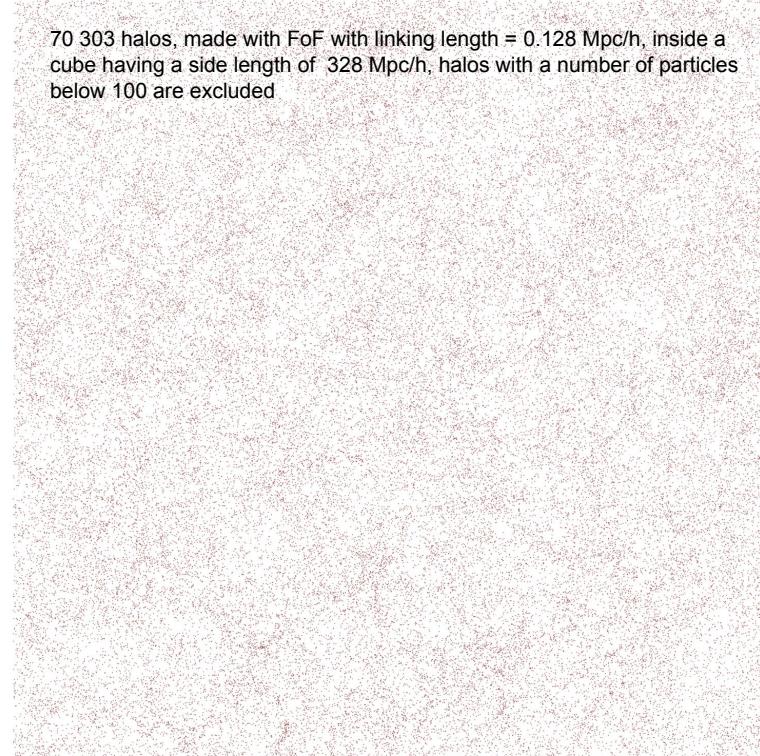
Aim: discriminating between F5 and LCDM

65 492 halos, made with FoF with linking length = 0.128 Mpc/h, inside a cube having a side length of 328 Mpc/h, halos with a number of particles below 100 are excluded



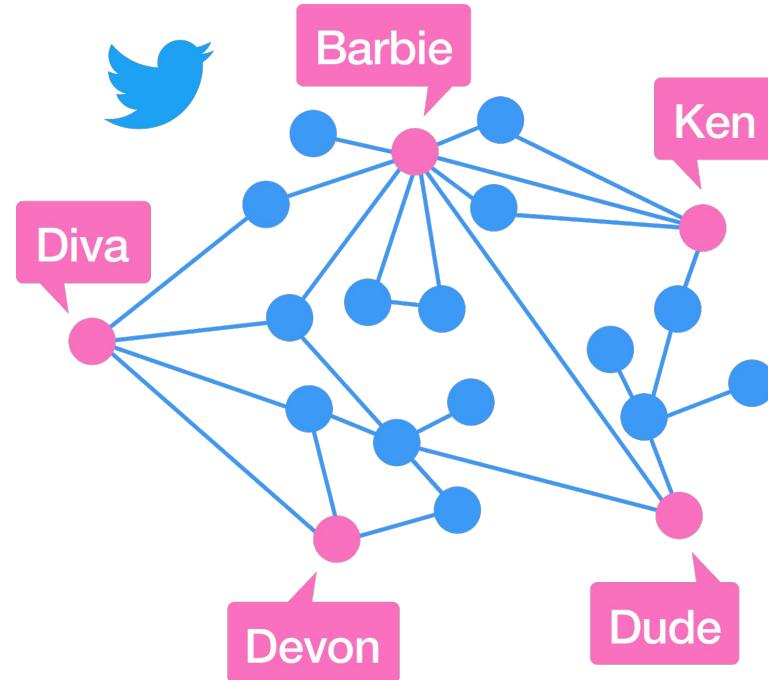
LCDM

70 303 halos, made with FoF with linking length = 0.128 Mpc/h, inside a cube having a side length of 328 Mpc/h, halos with a number of particles below 100 are excluded

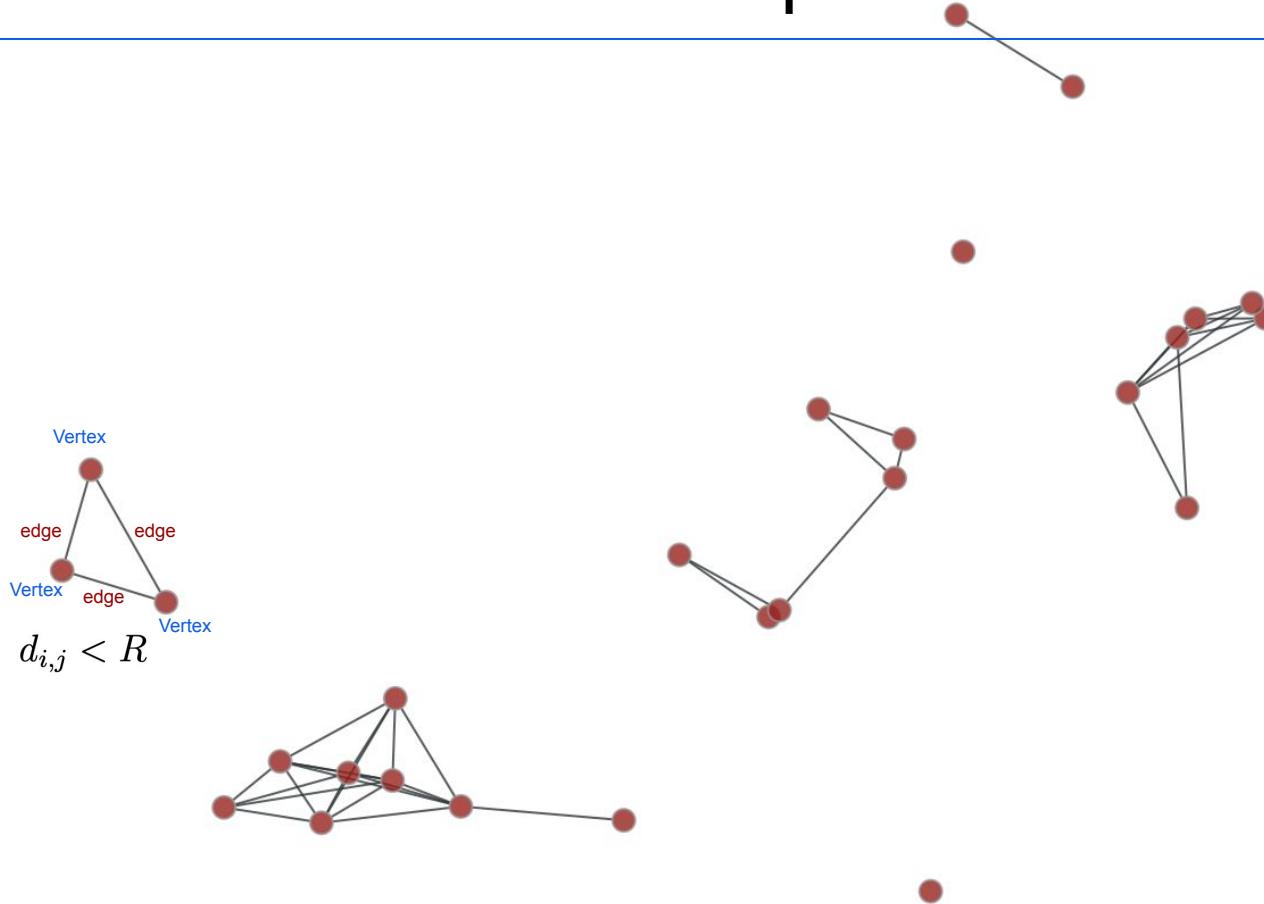


F5

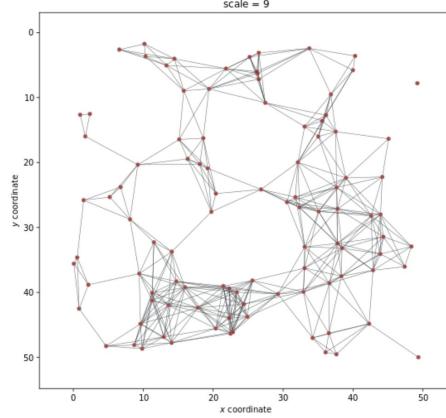
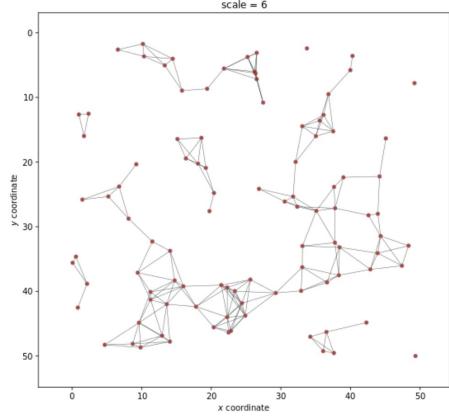
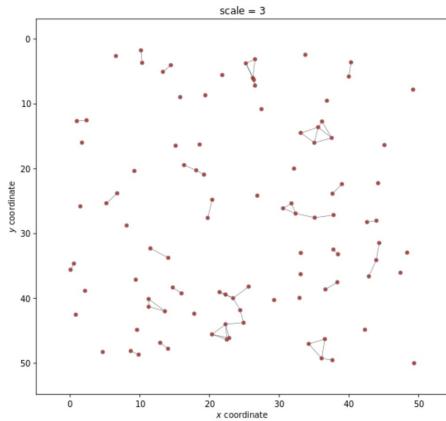
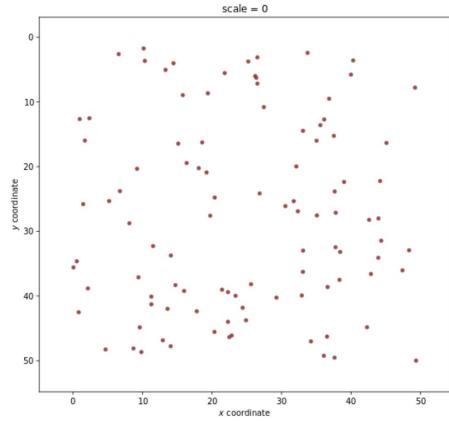
Graph Theory



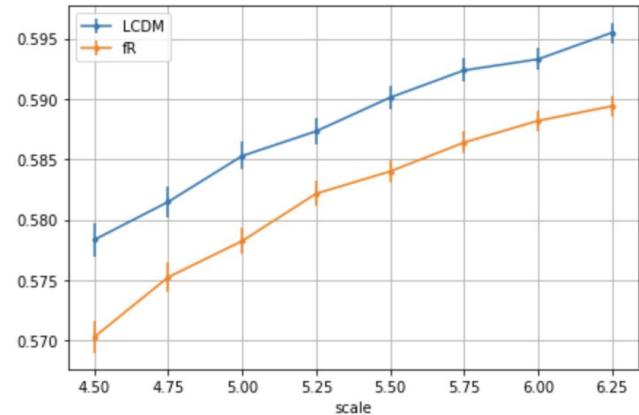
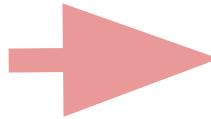
Geometric Graph \leftrightarrow FoF



Method - Graph evolution

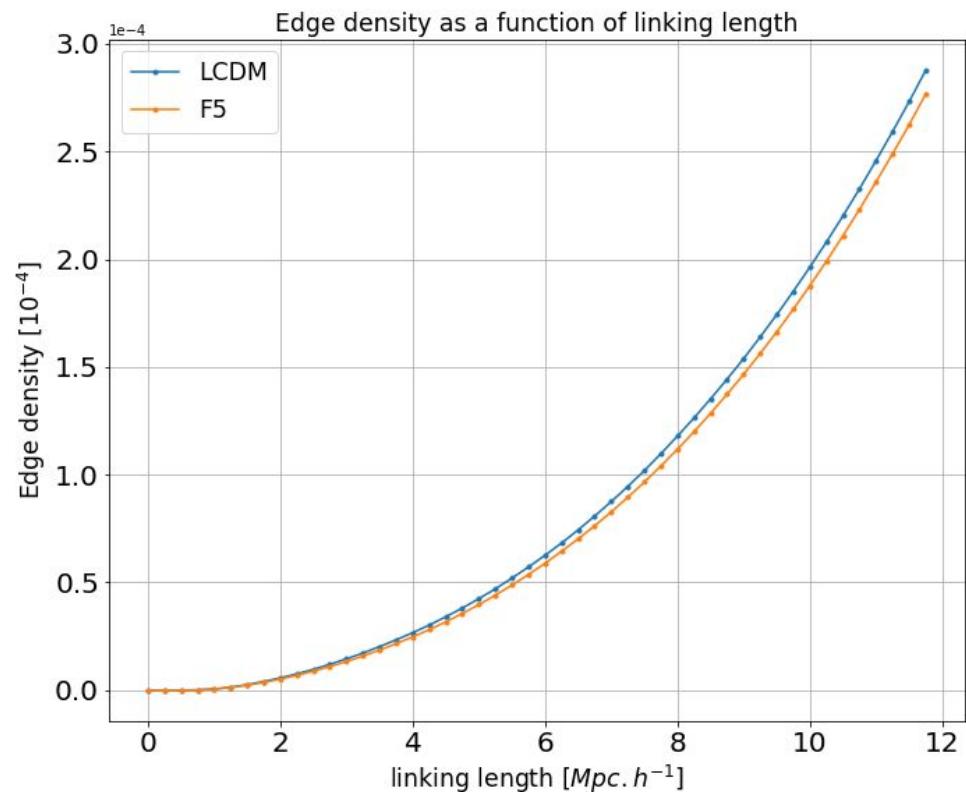


Topological
indicators

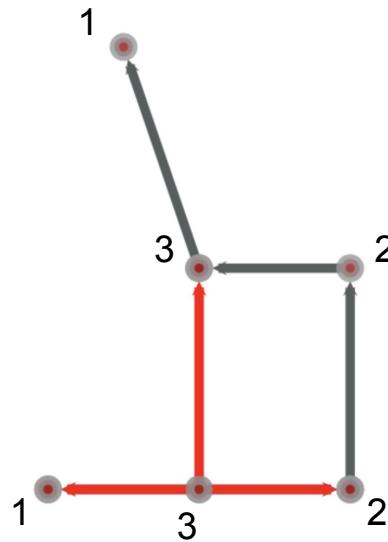


Graph parameters - Edge density

$$P = \frac{N_E}{\frac{1}{2}N_V(N_V - 1)}$$



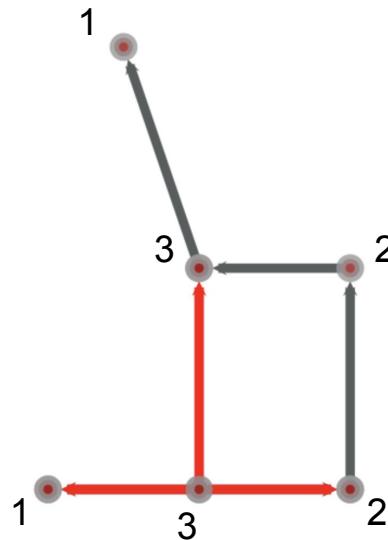
Graph parameters - Degree



Peebles - The large-scale structure of the universe - p.145

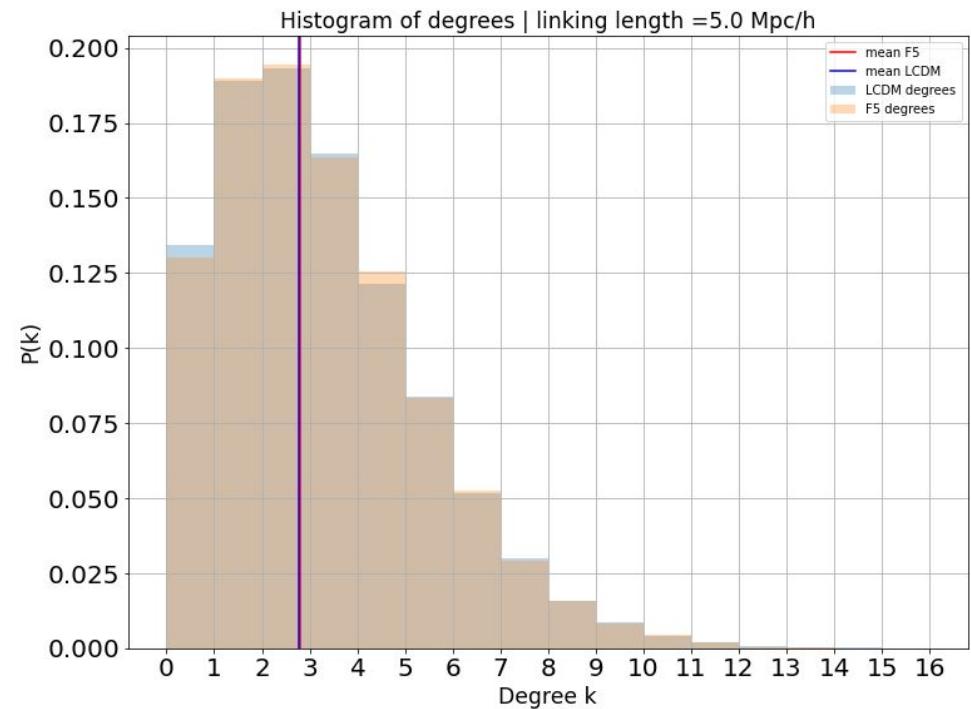
$$\langle N(r) \rangle = \frac{4}{3}\pi r^3 n + n \int_0^r \xi(r) dV$$

Graph parameters - Degree

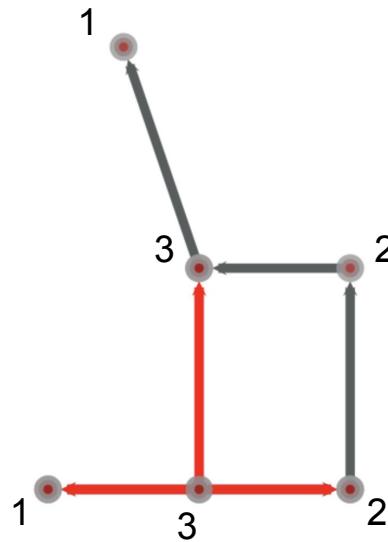


Peebles - The large-scale structure of the universe - p.145

$$\langle N(r) \rangle = \frac{4}{3}\pi r^3 n + n \int_0^r \xi(r) dV$$

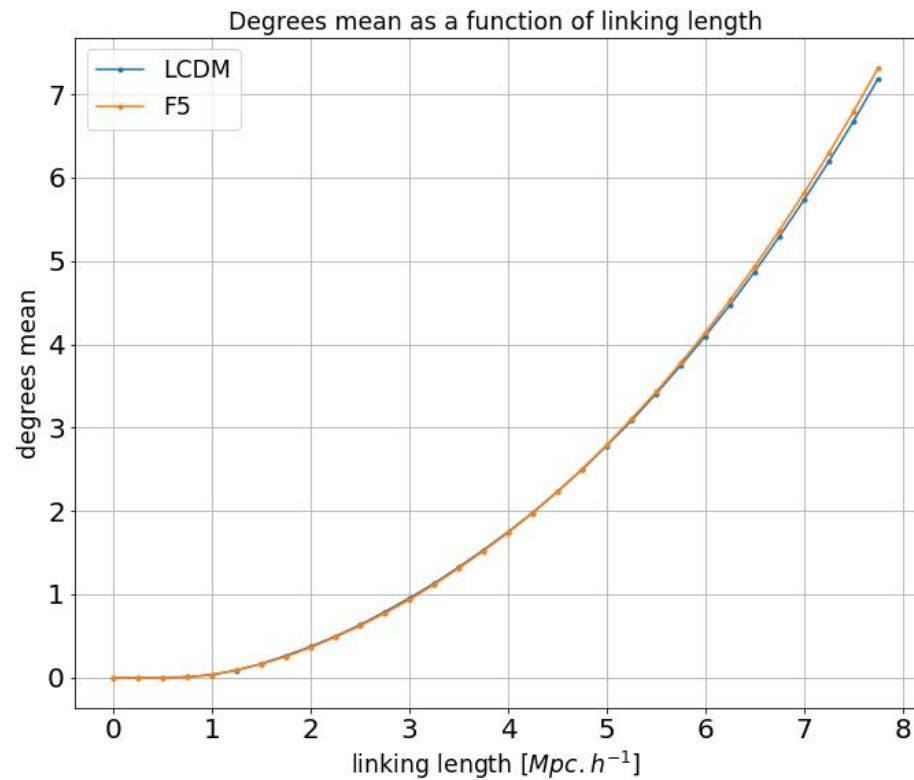


Graph parameters - Degree



Peebles - The large-scale structure of the universe - p.145

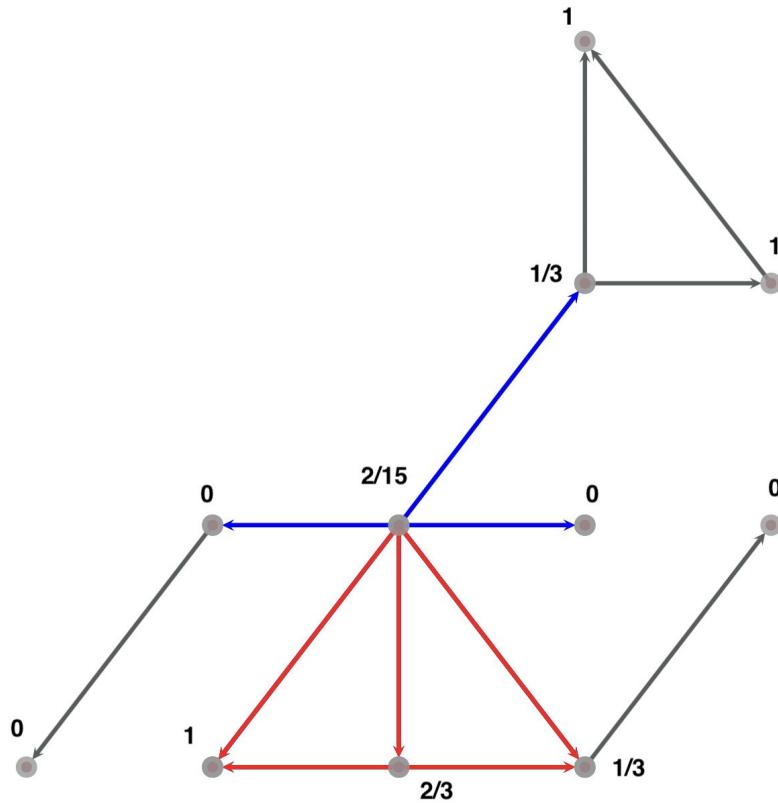
$$\langle N(r) \rangle = \frac{4}{3}\pi r^3 n + n \int_0^r \xi(r) dV$$



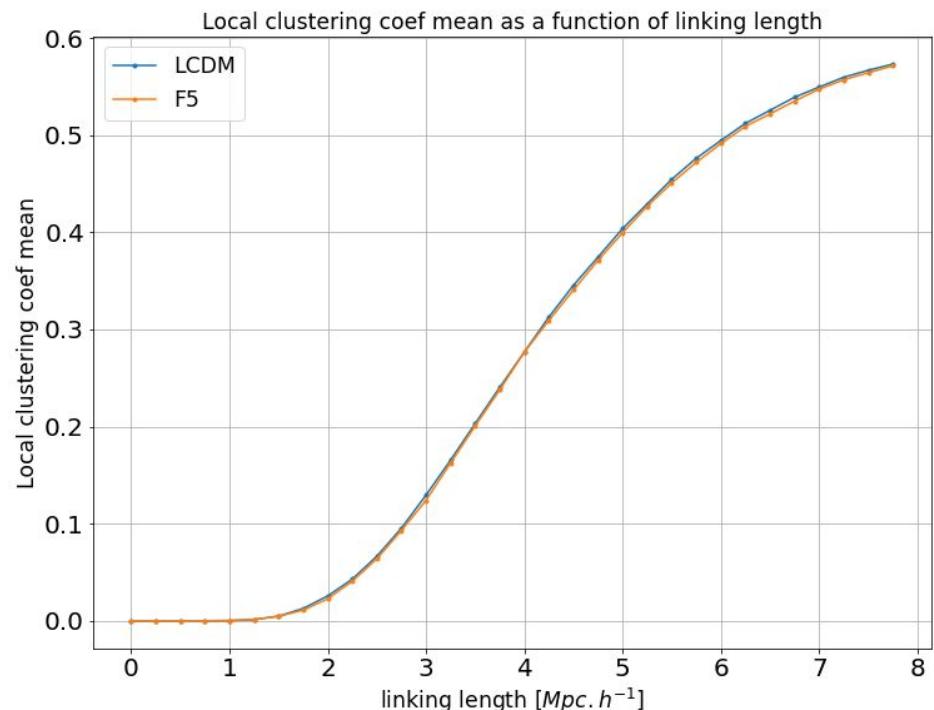
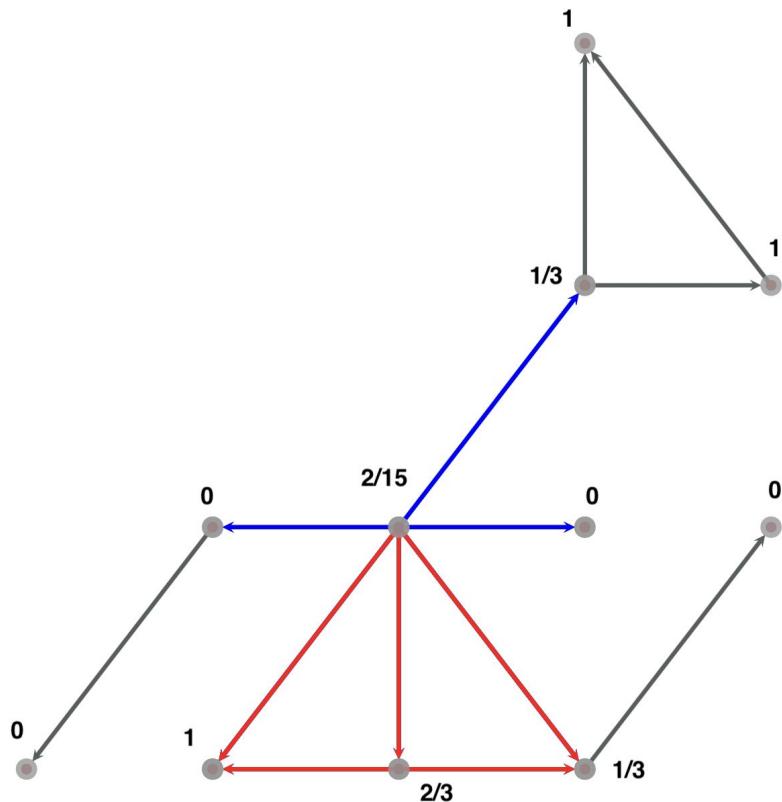
Graph parameters - Degree

- Two points correlation function is unable to discriminate topology below 8 Mpc/h

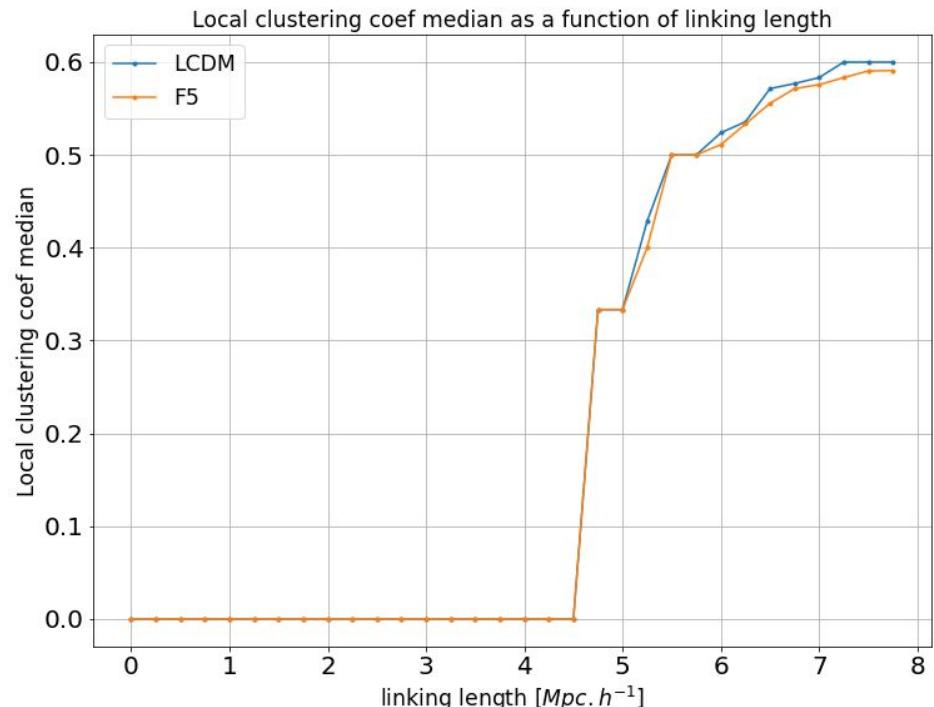
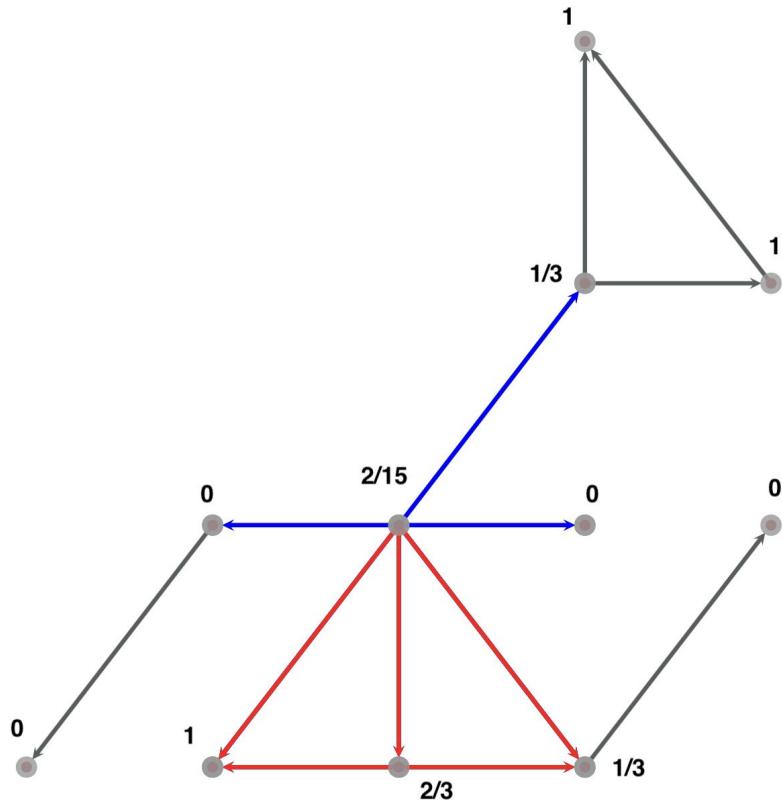
Graph parameters - Local Clustering



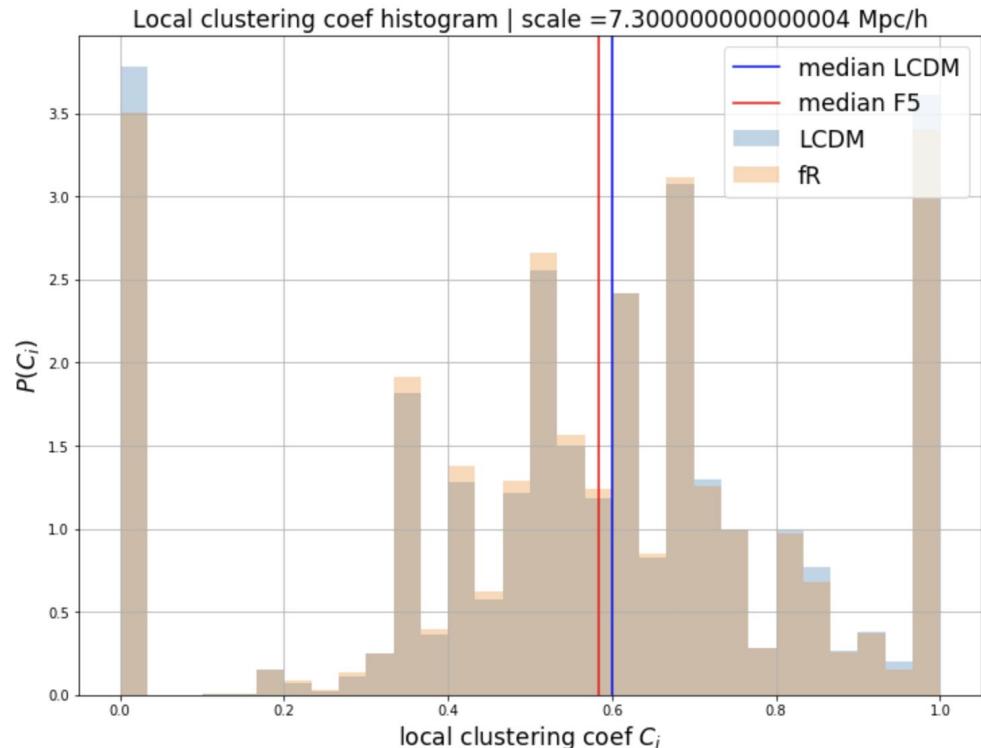
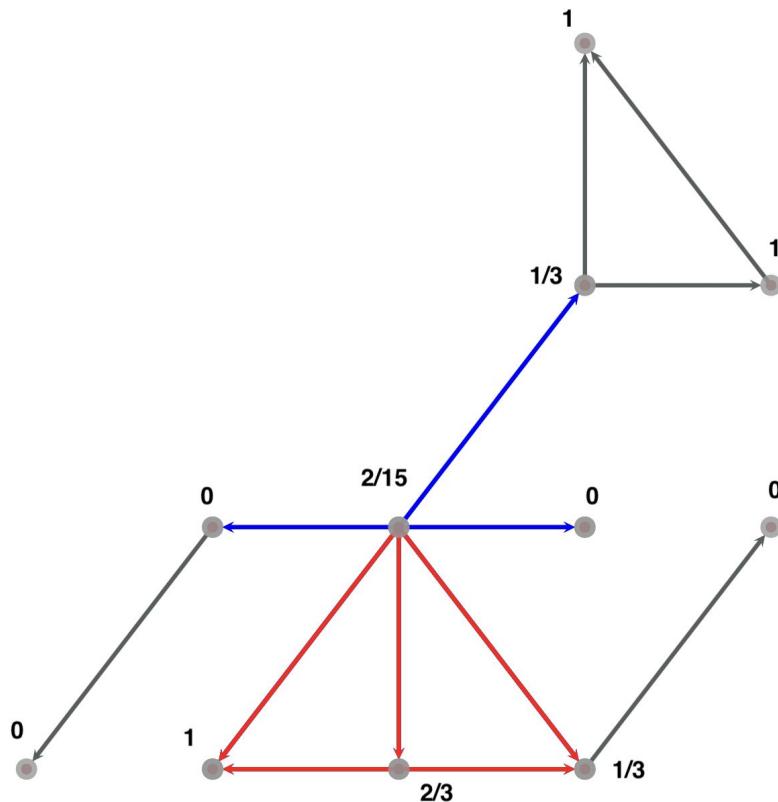
Graph parameters - Local Clustering



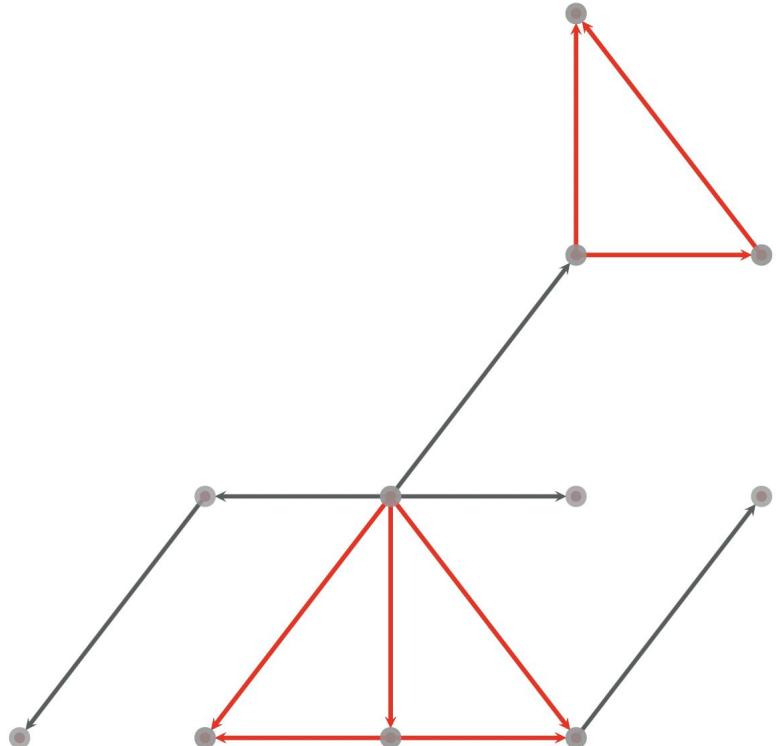
Graph parameters - Local Clustering



Graph parameters - Local Clustering



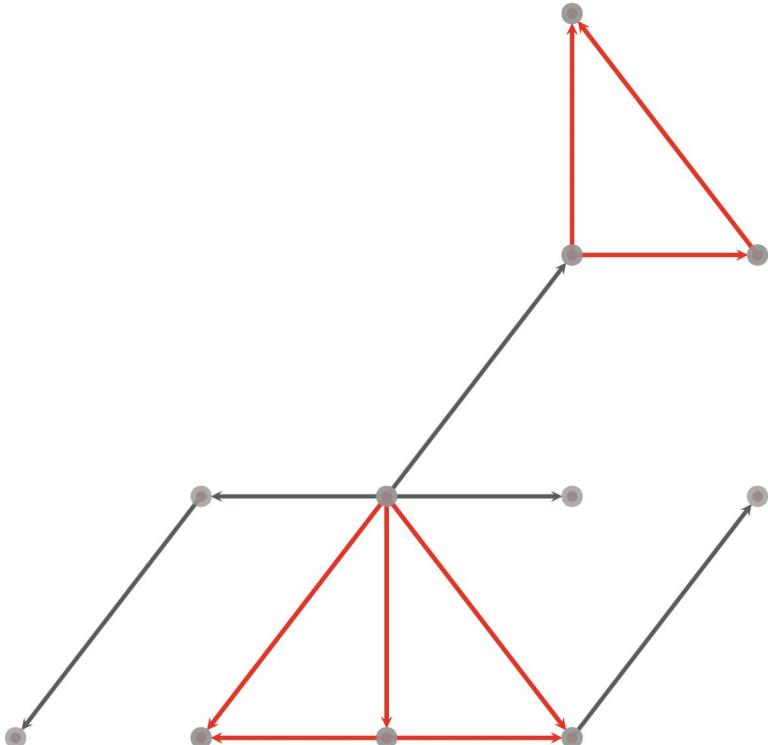
Graph parameters - Global clustering



Hong et al 2019

$$\tau_{\Delta} \equiv \frac{\text{number of closed triples}}{\text{number of connected triples}}$$

Graph parameters - Global clustering



Hong et al 2019

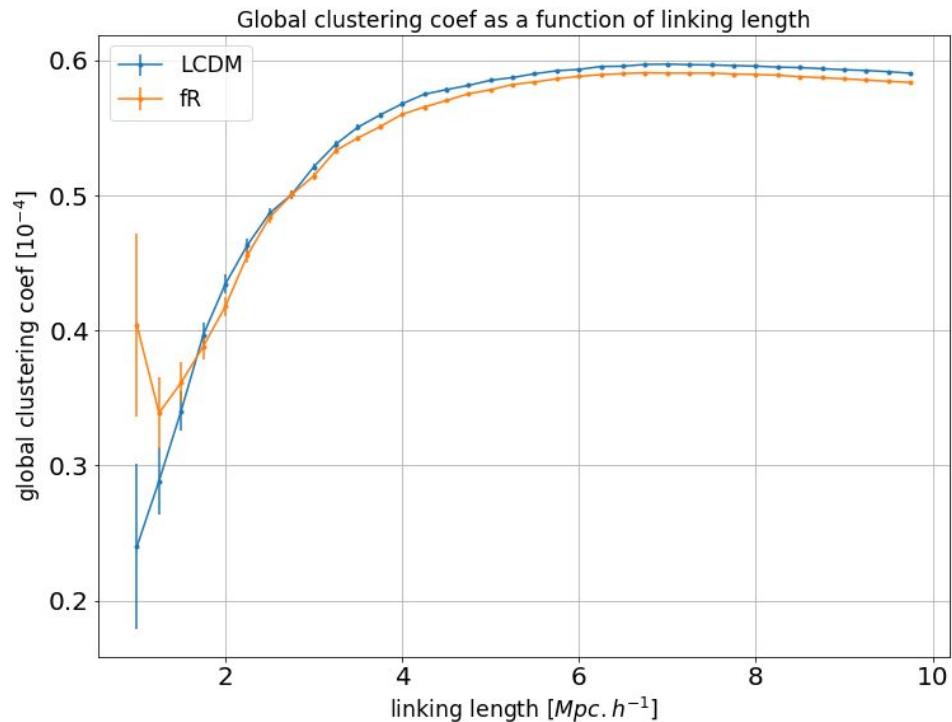
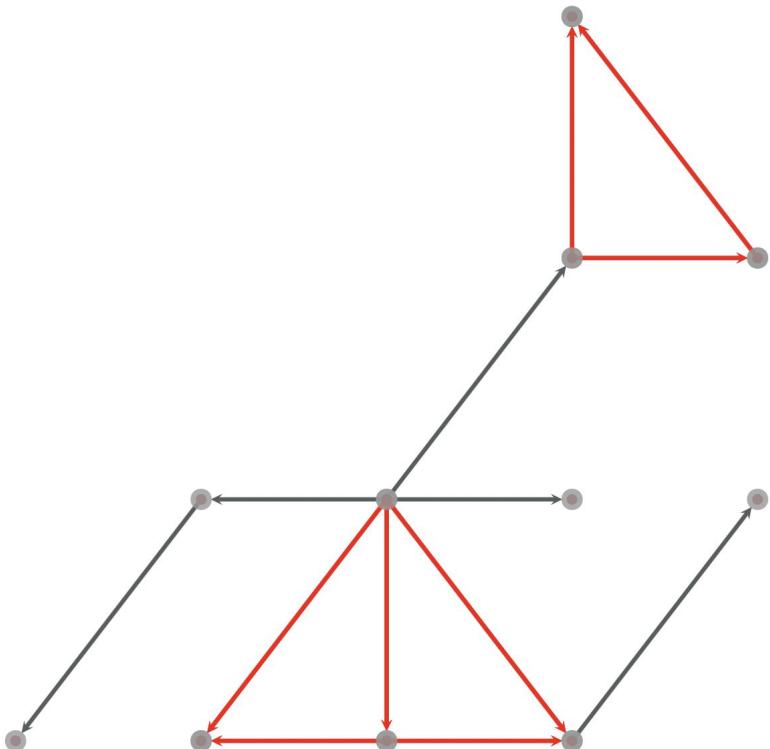
$$\tau_{\Delta} \equiv \frac{3 \text{ number of closed triples}}{\text{number of connected triples}}$$

Hong et al 2019

$$\tau_{\Delta} = \frac{\int_{V_l} d^3 r_1 \int_{V_l} d^3 r_2 p_3(\mathbf{r}_1, \mathbf{r}_2) \Theta(l - r_{12})}{\int_{V_l} d^3 r_1 \int_{V_l} d^3 r_2 p_3(\mathbf{r}_1, \mathbf{r}_2)}, \quad (22)$$

$$p_3(\mathbf{r}_1, \mathbf{r}_2) \equiv \bar{n}^3 [1 + \xi(r_1) + \xi(r_2) + \xi(r_{12}) + \zeta(r_1, r_2, r_{12})]$$

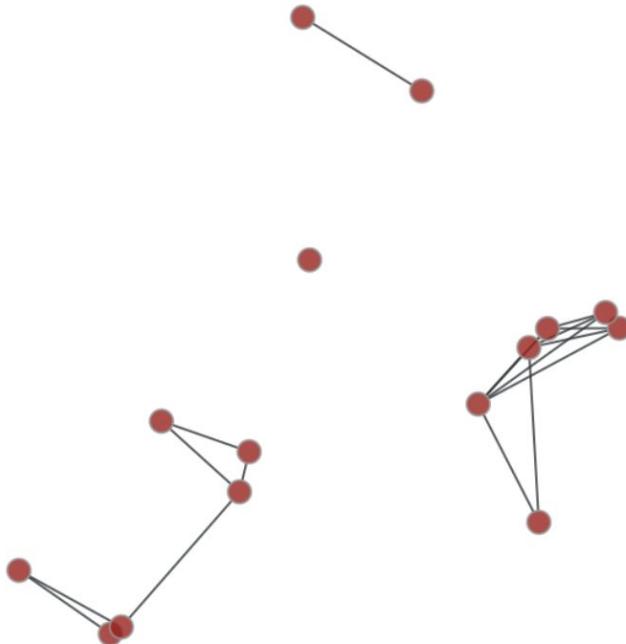
Graph parameters - Global clustering



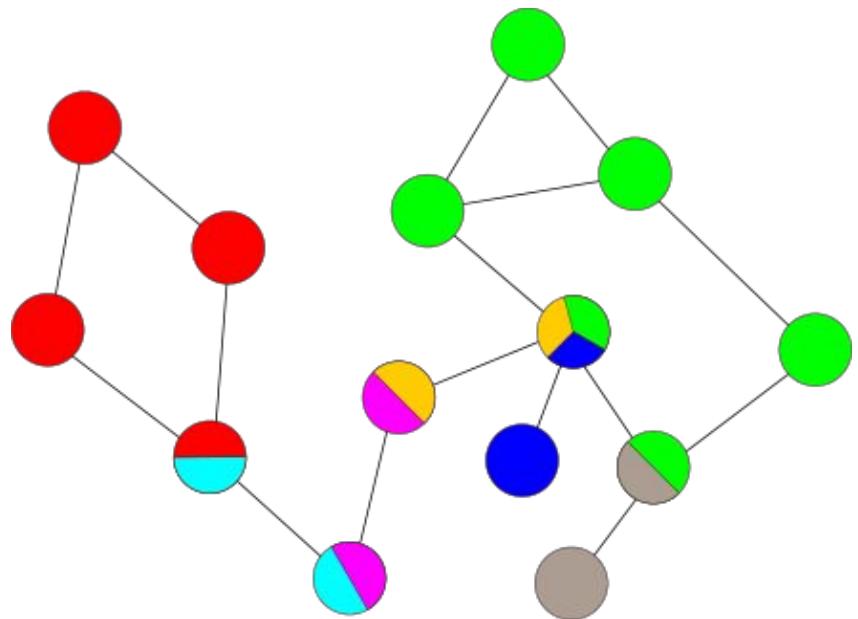
Graph parameters - clustering

- Global clustering represent a good indicator at all scales

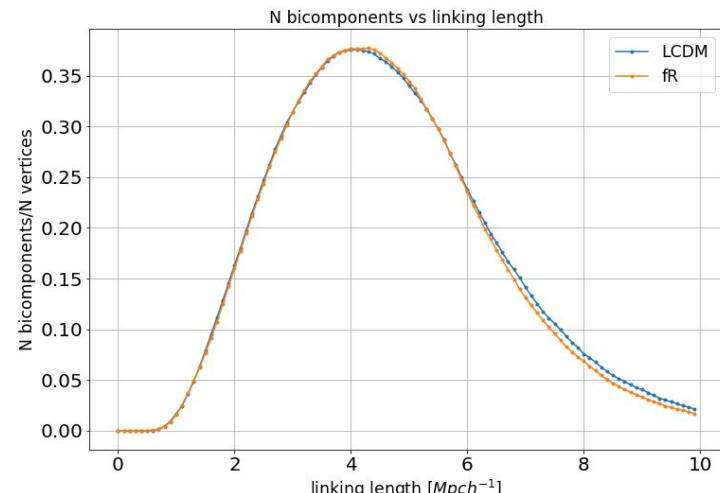
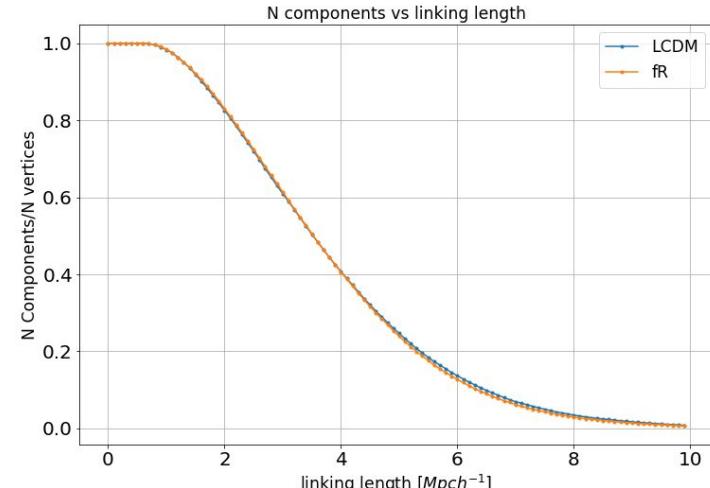
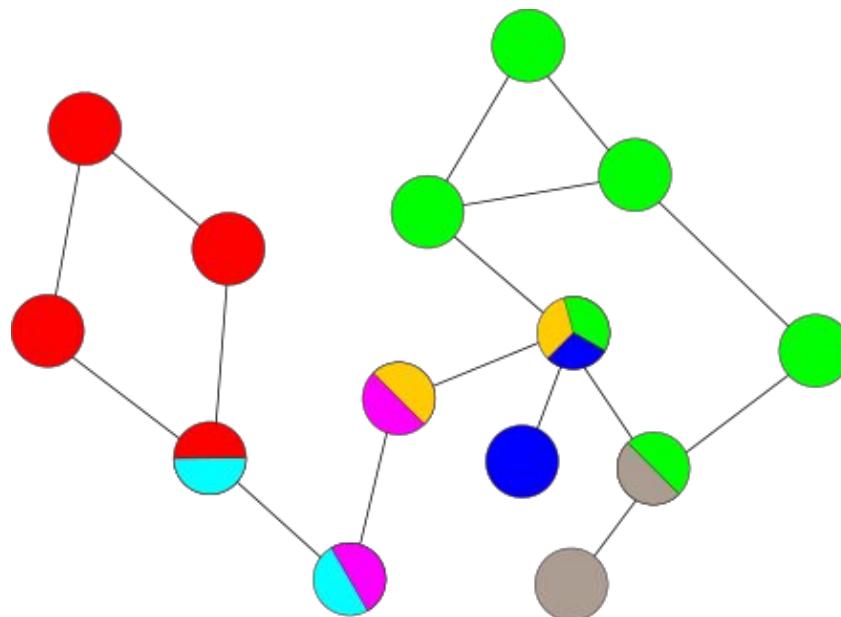
Graph parameters - components



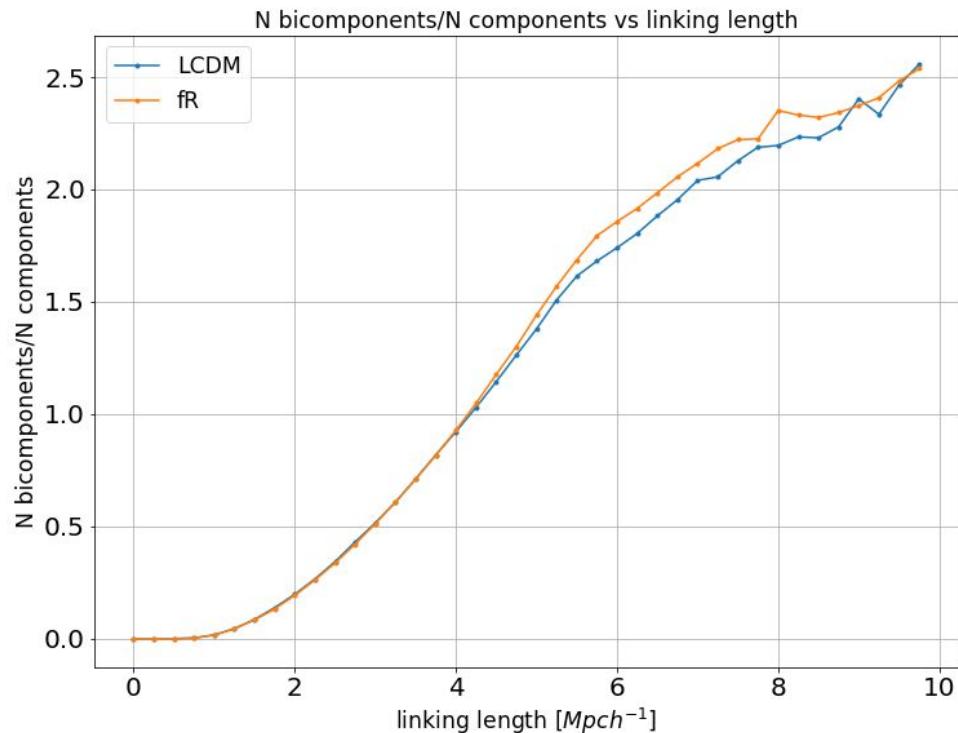
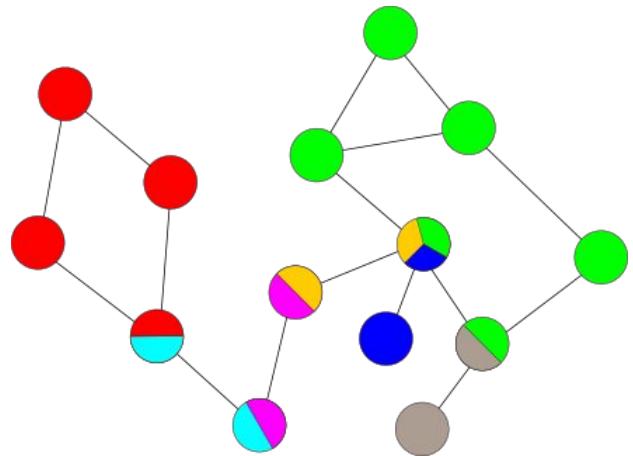
Graph parameters - Connected and biconnected components



Graph parameters - Biconnected components



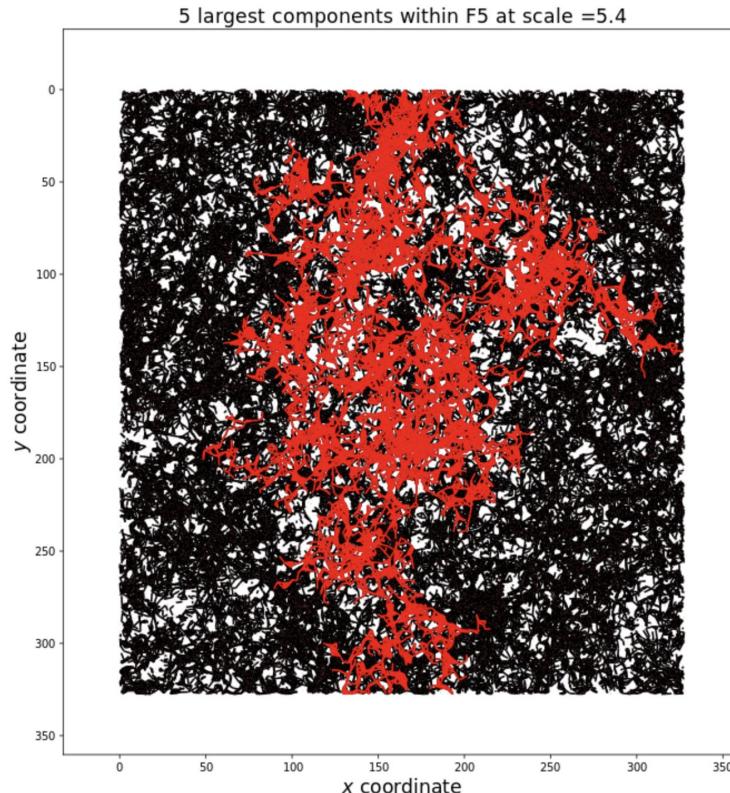
Graph parameters - Biconnected components



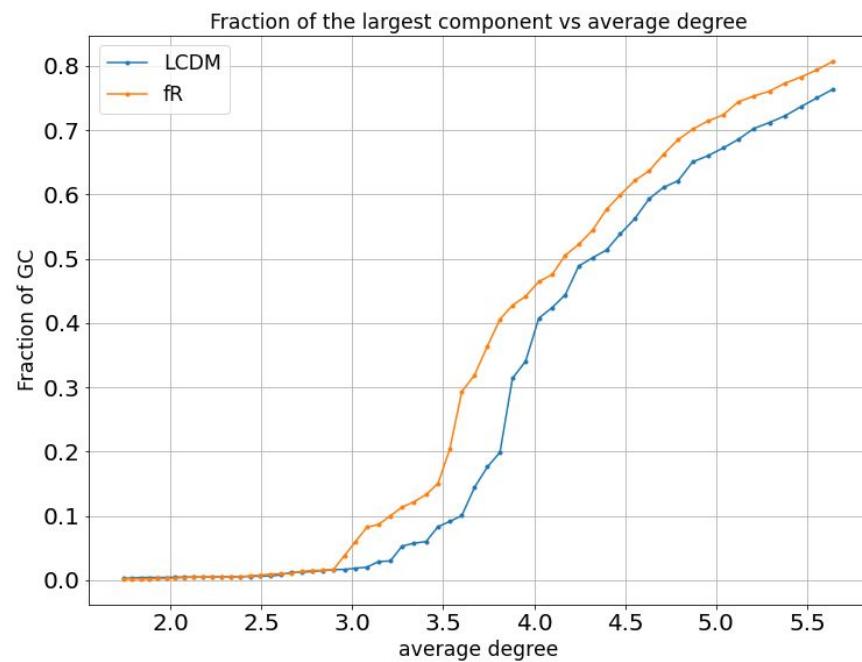
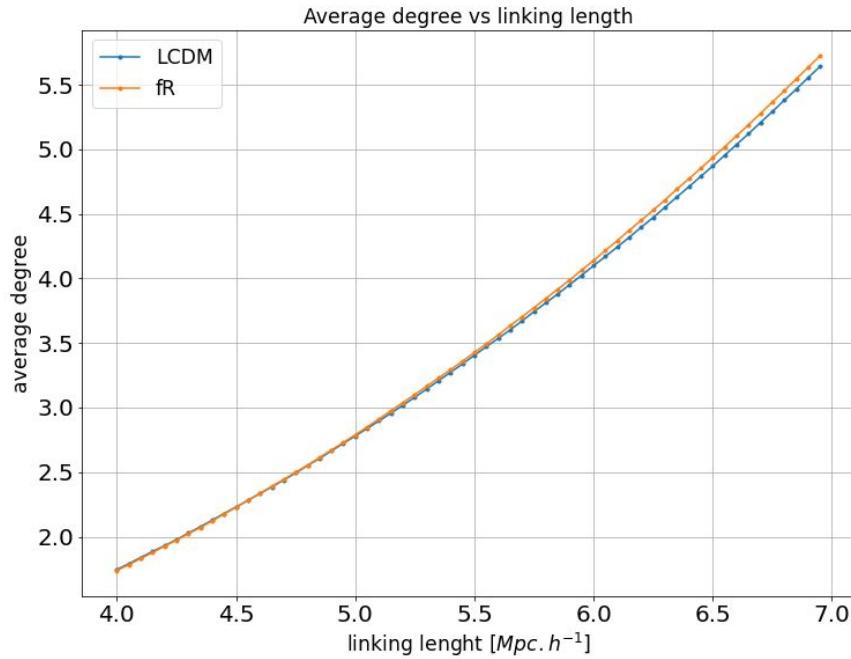
Graph parameters - components

- The ratio of N bicomponents/ N components represent a good indicator above 5 Mpc/h

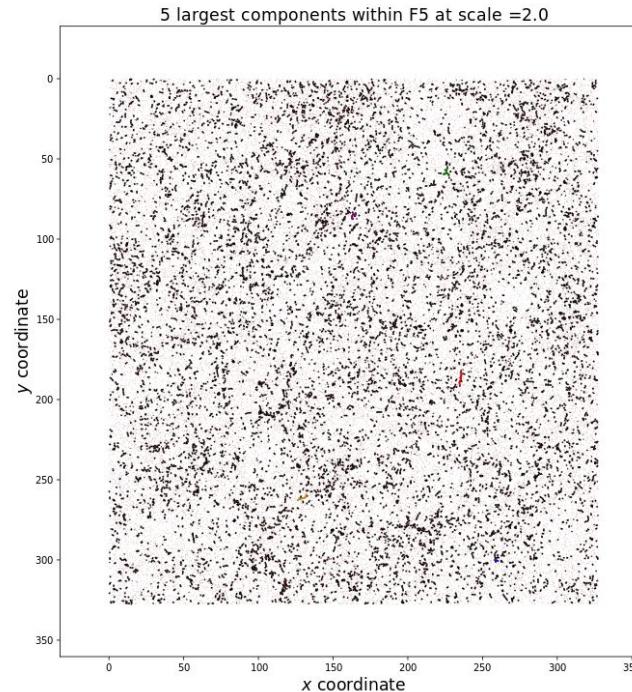
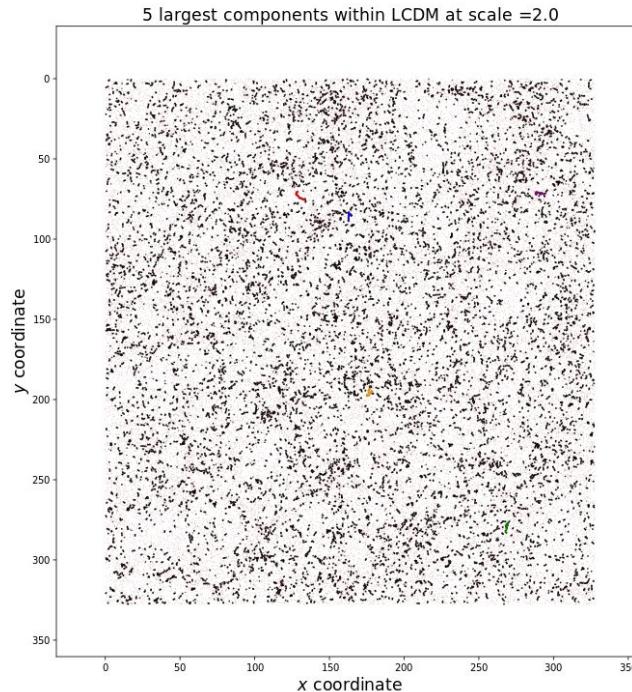
Graph parameters - Giant Component



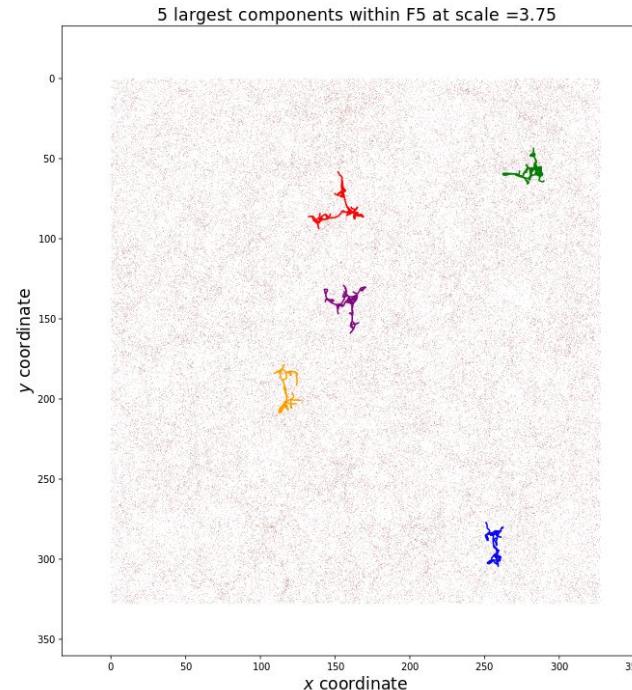
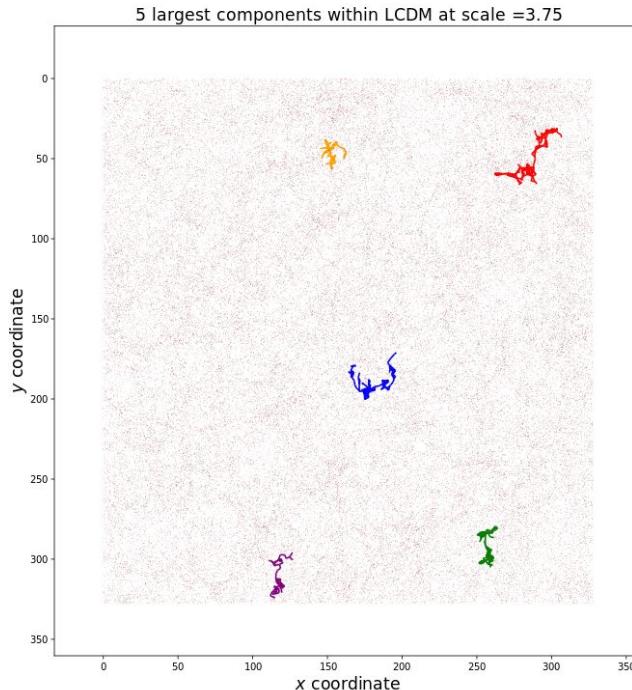
Graph parameters - Percolation



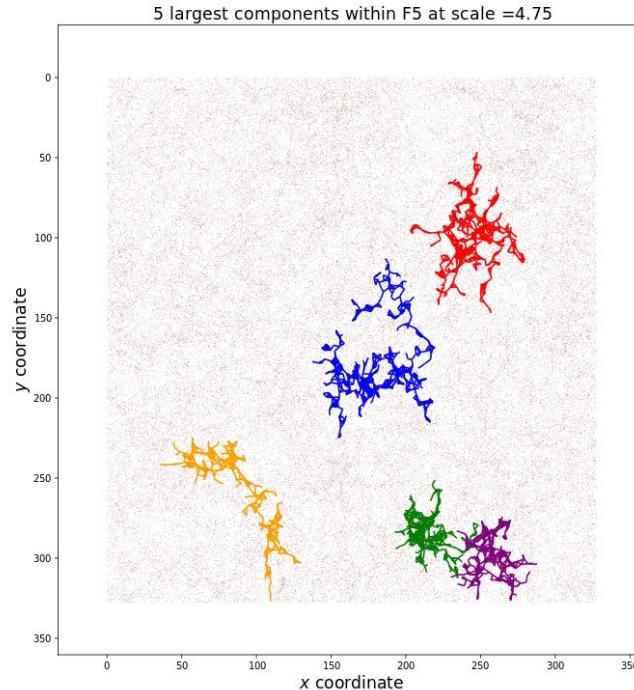
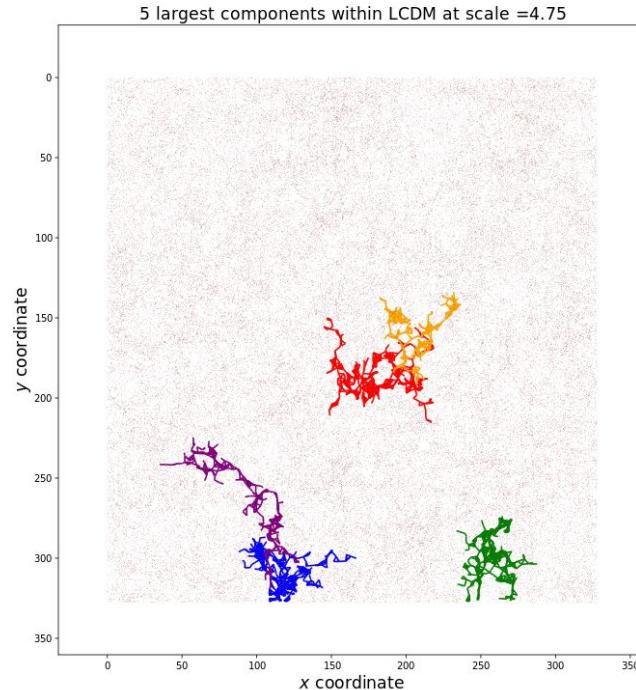
Visualization



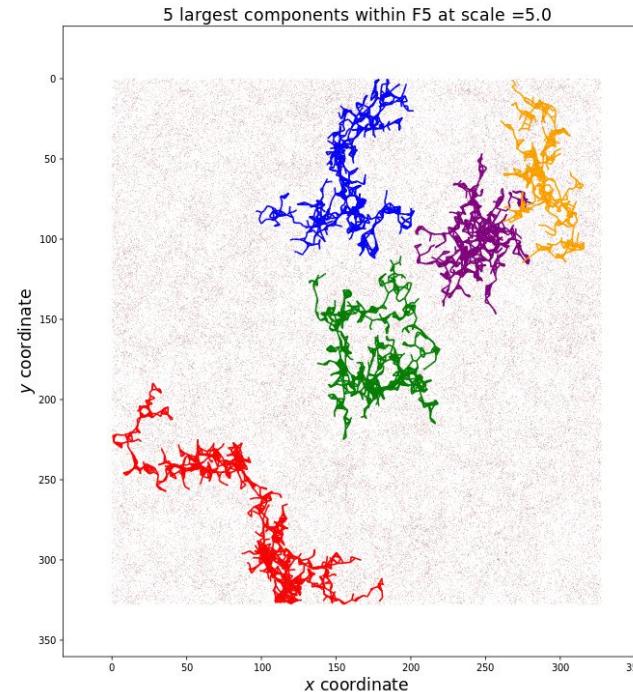
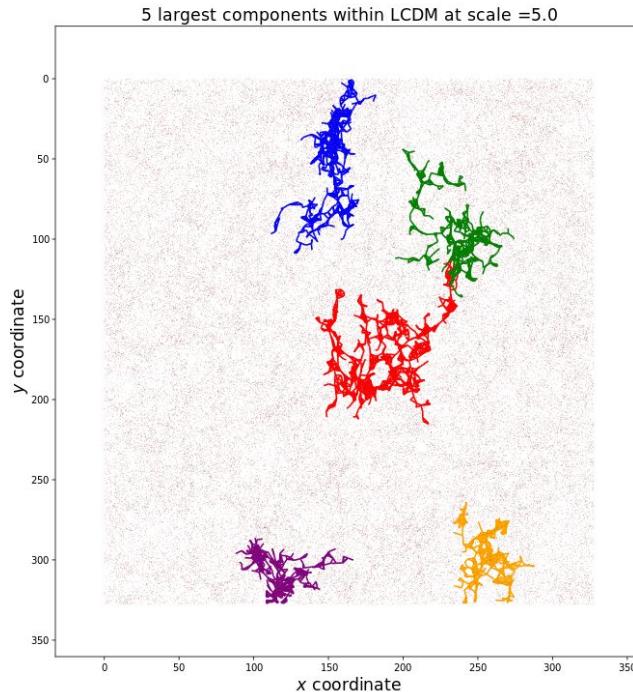
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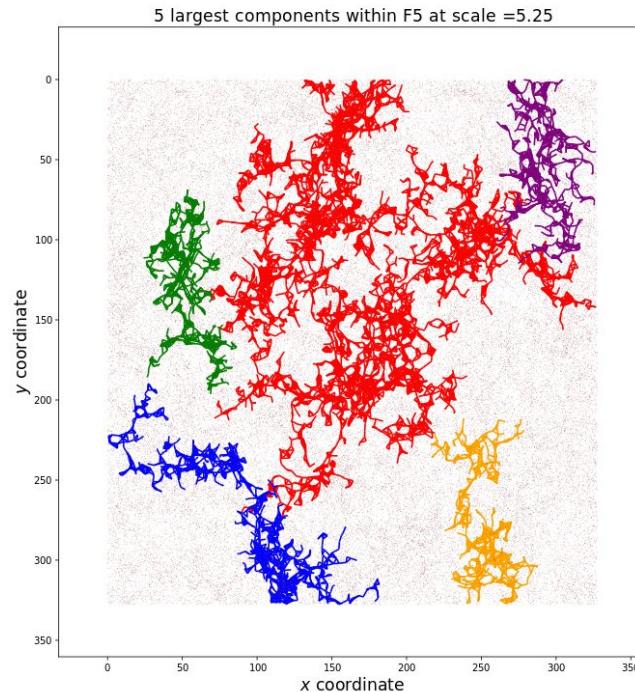
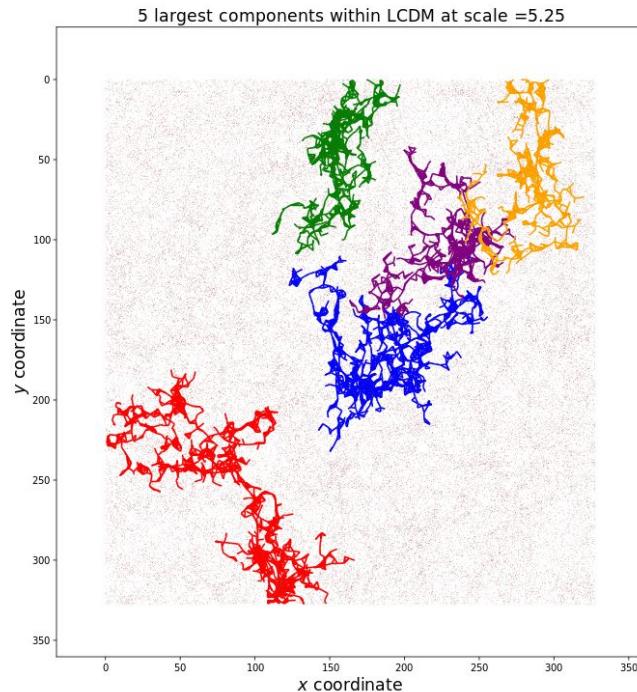
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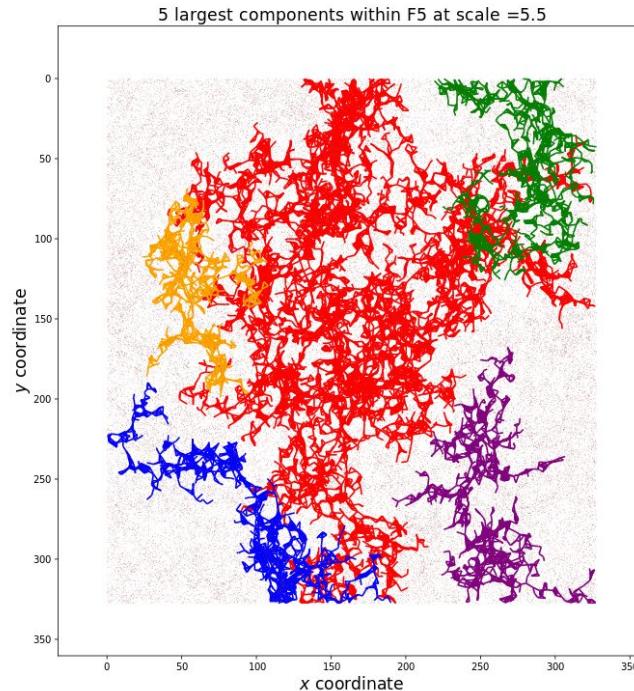
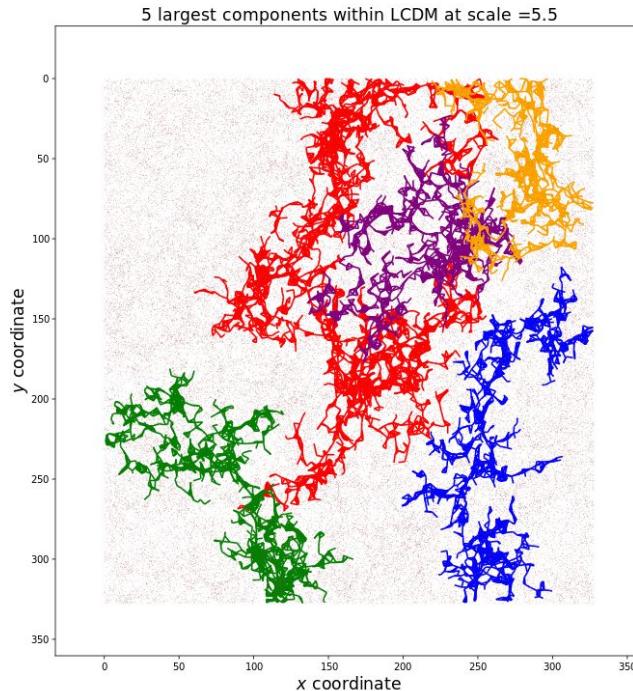
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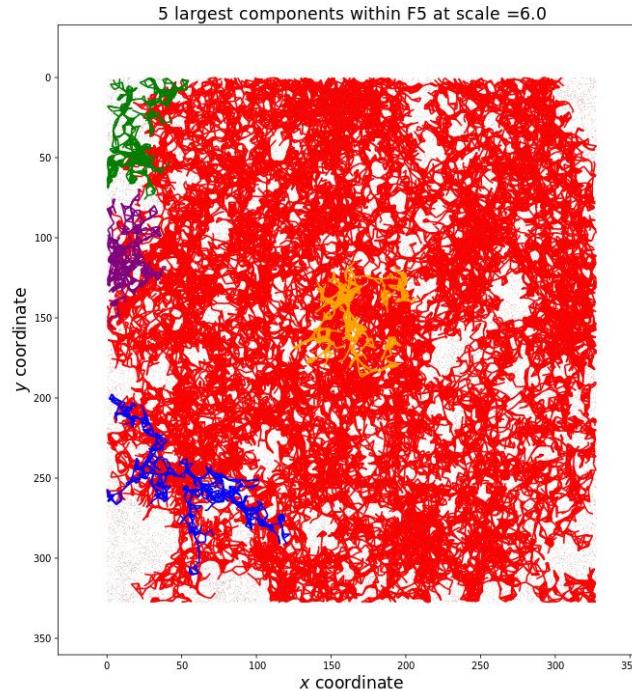
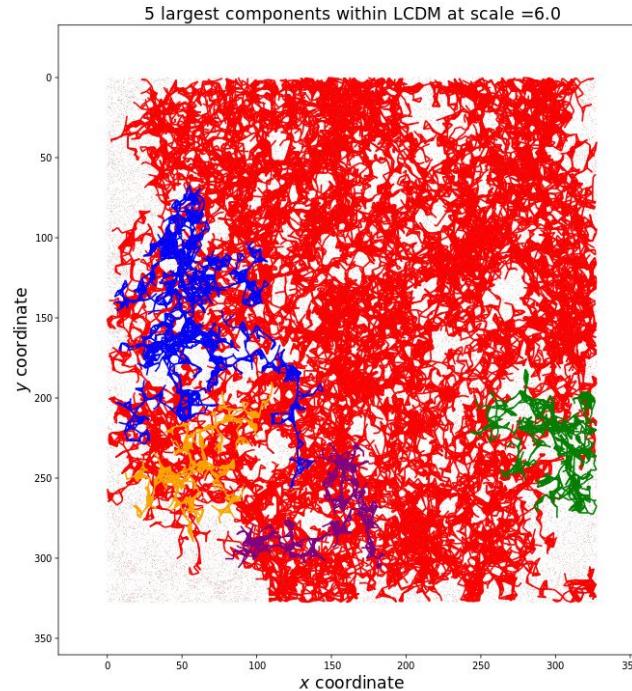
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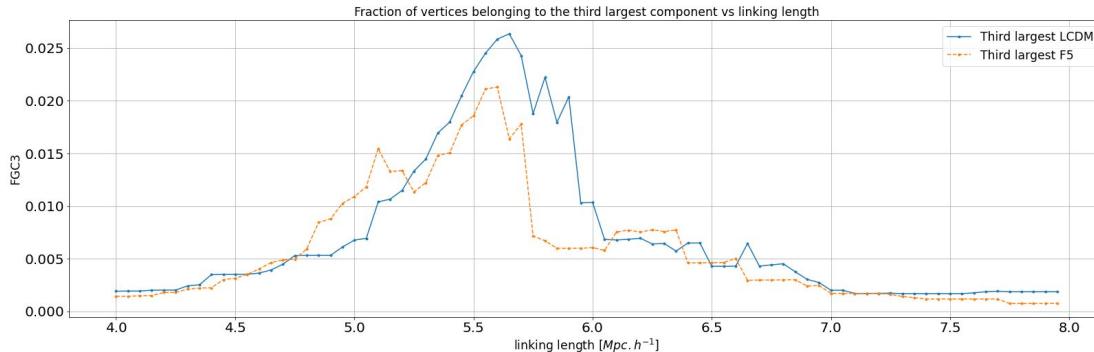
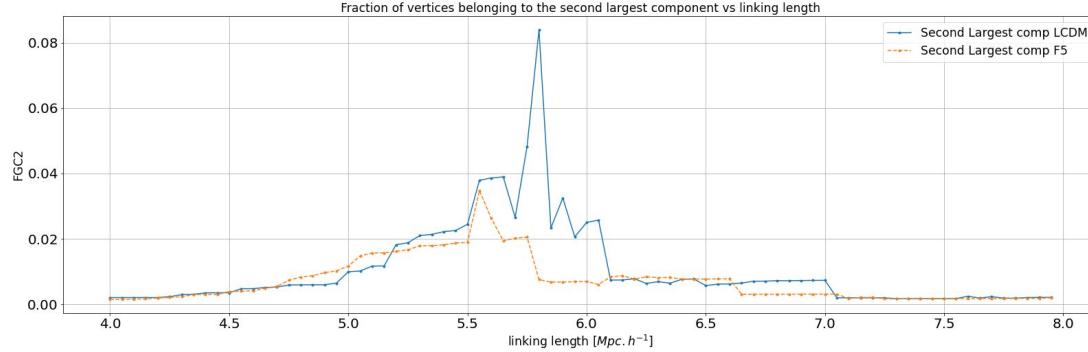
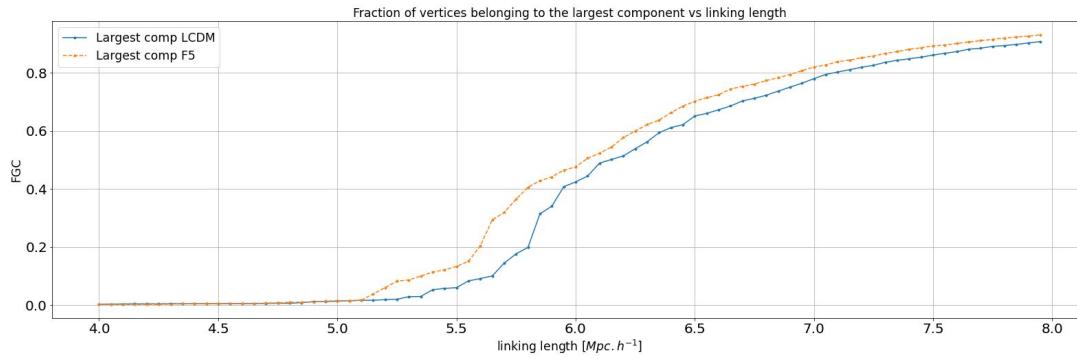


Visualization



Visualization





Conclusion

- The ratio of N bicomponents/N components represent a good indicator above 5 Mpc/h
- Global clustering represent a good indicator at all scales: bispectrum may be promising
- The fraction of giant component represent the best discriminator near the percolation threshold ([5,6]Mpc/h) at cut=100 part

Indicators residuals

