Critical events and mergers

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Outline

I. Large scale structures

II. Critical event theory

III. Attraction cones

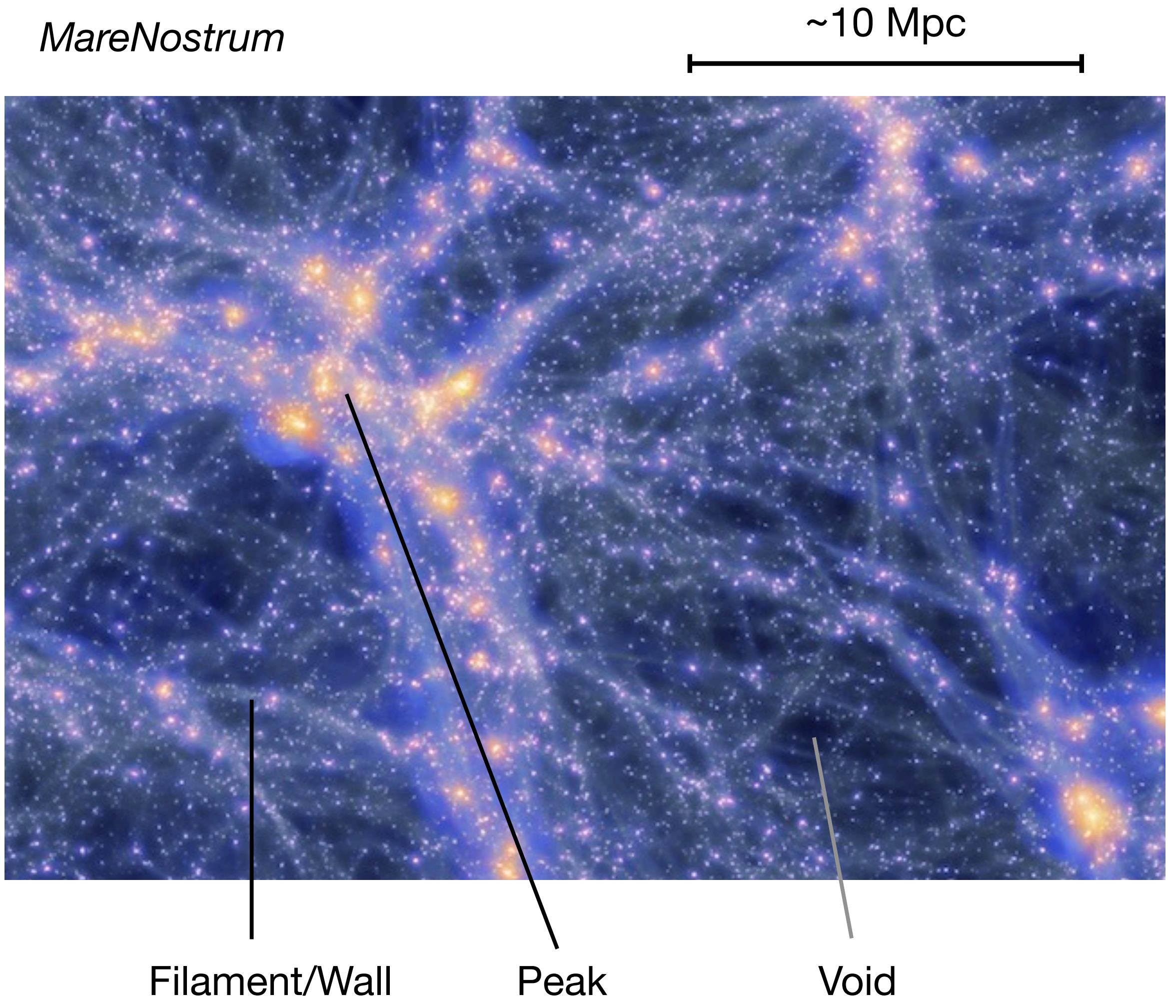
IV. Merger characteristics

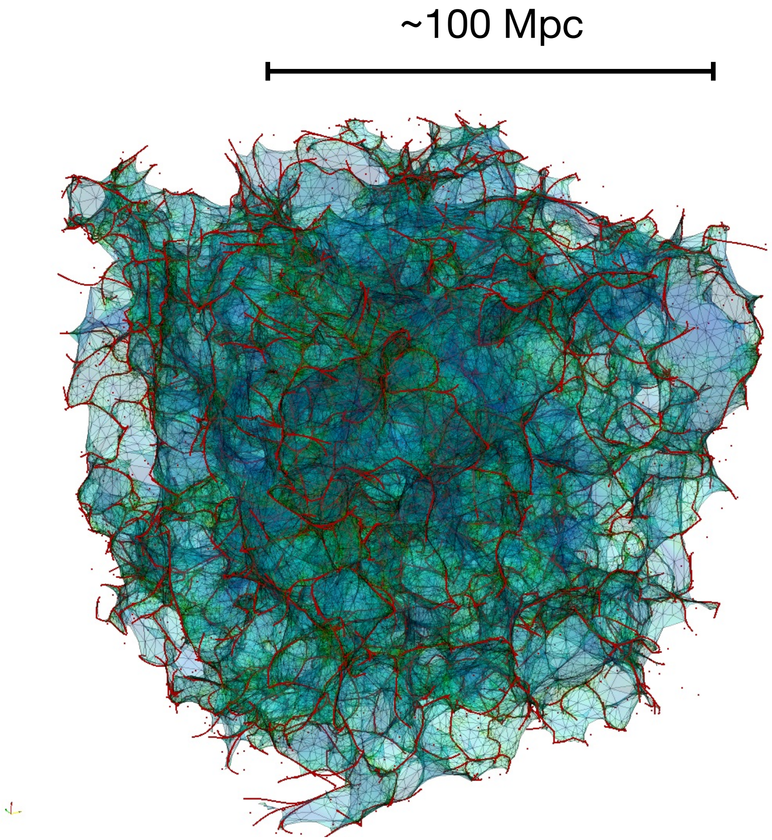
V. Conclusions and perspectives

Outline

Web like structure

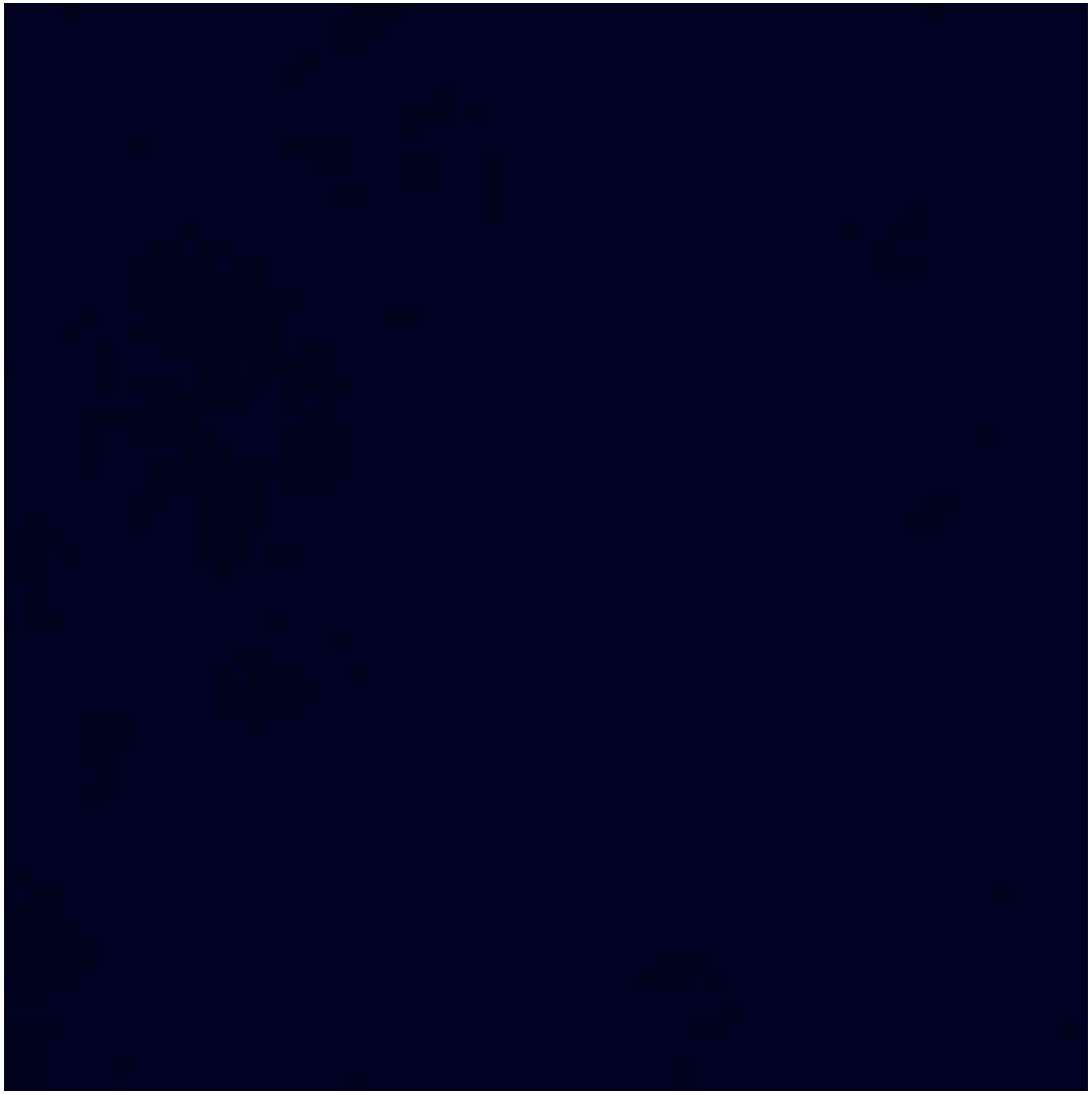
MareNostrum





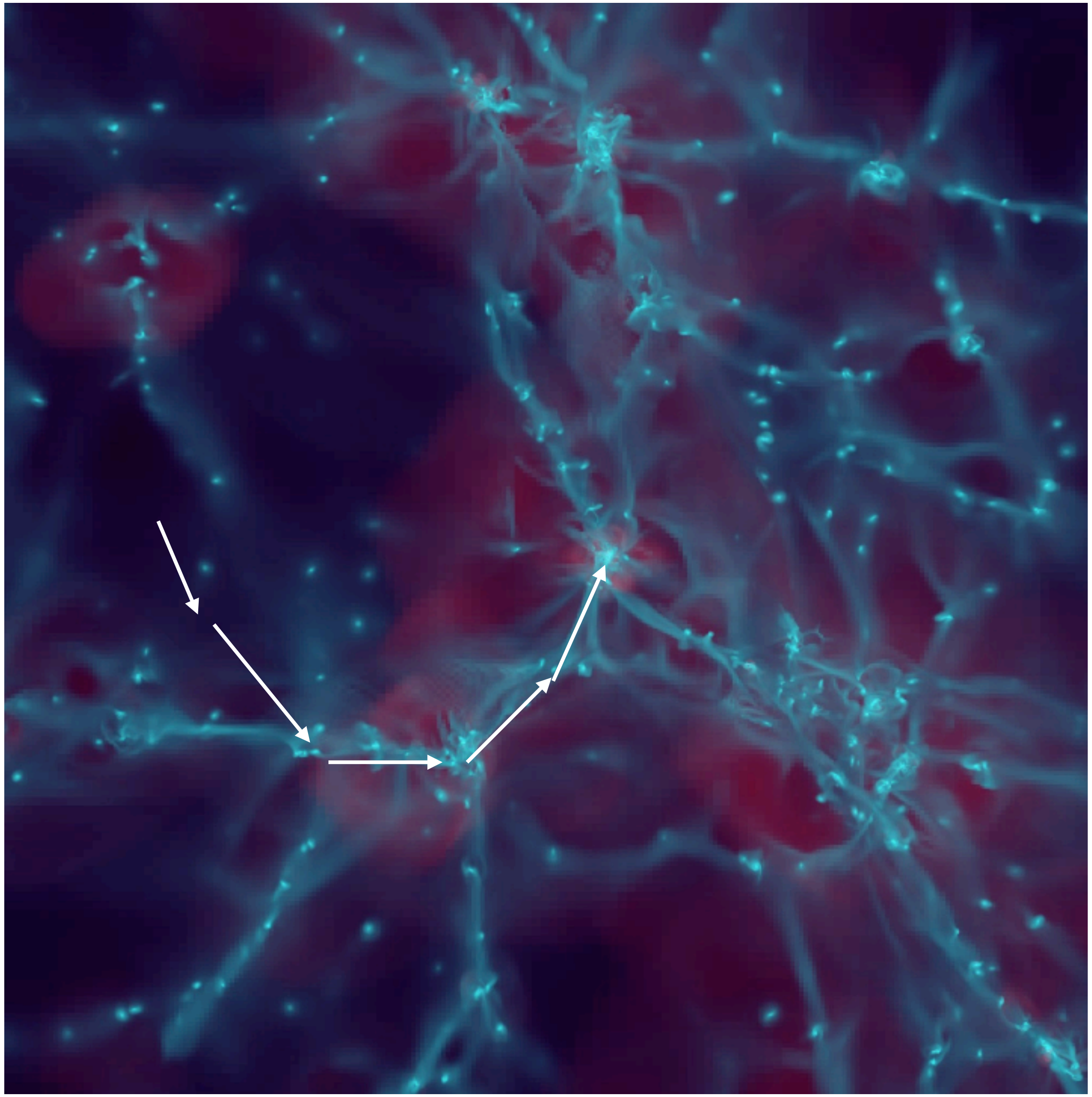
The Horizon Simulation

~10 Mpc

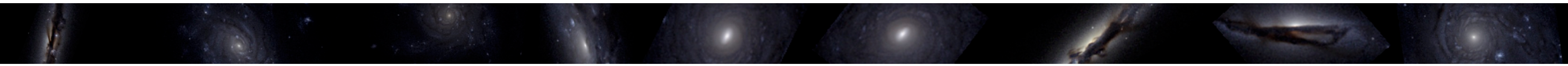


The NewHorizon Simulation

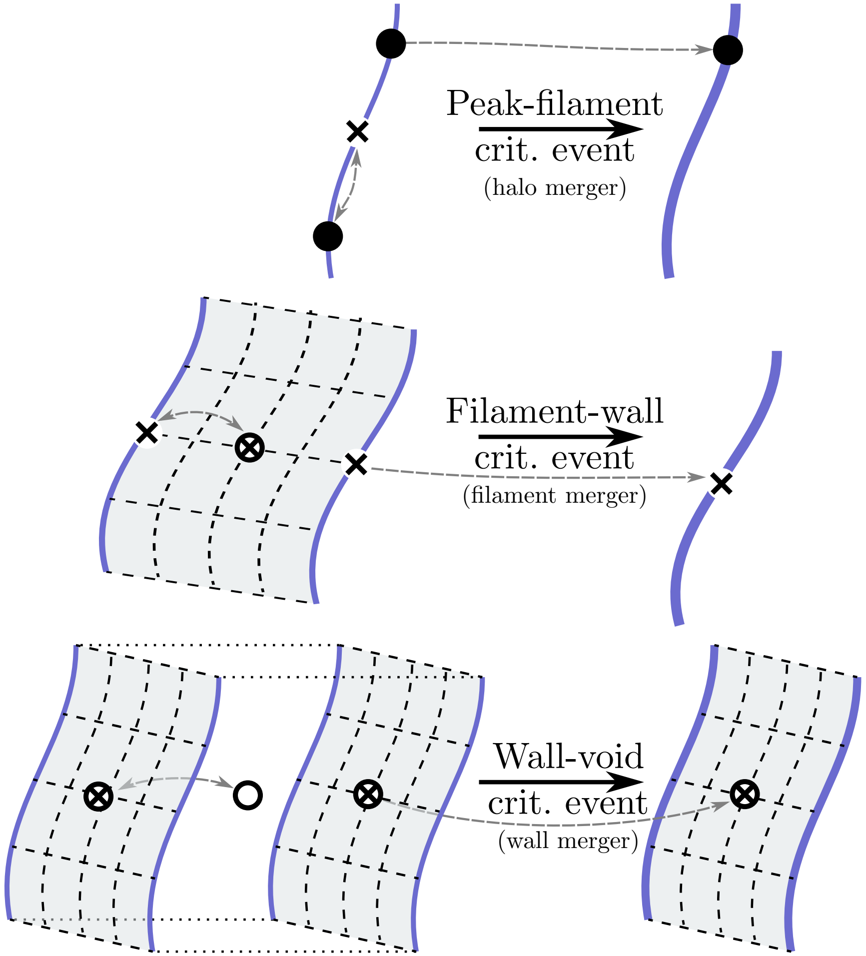
~10 Mpc

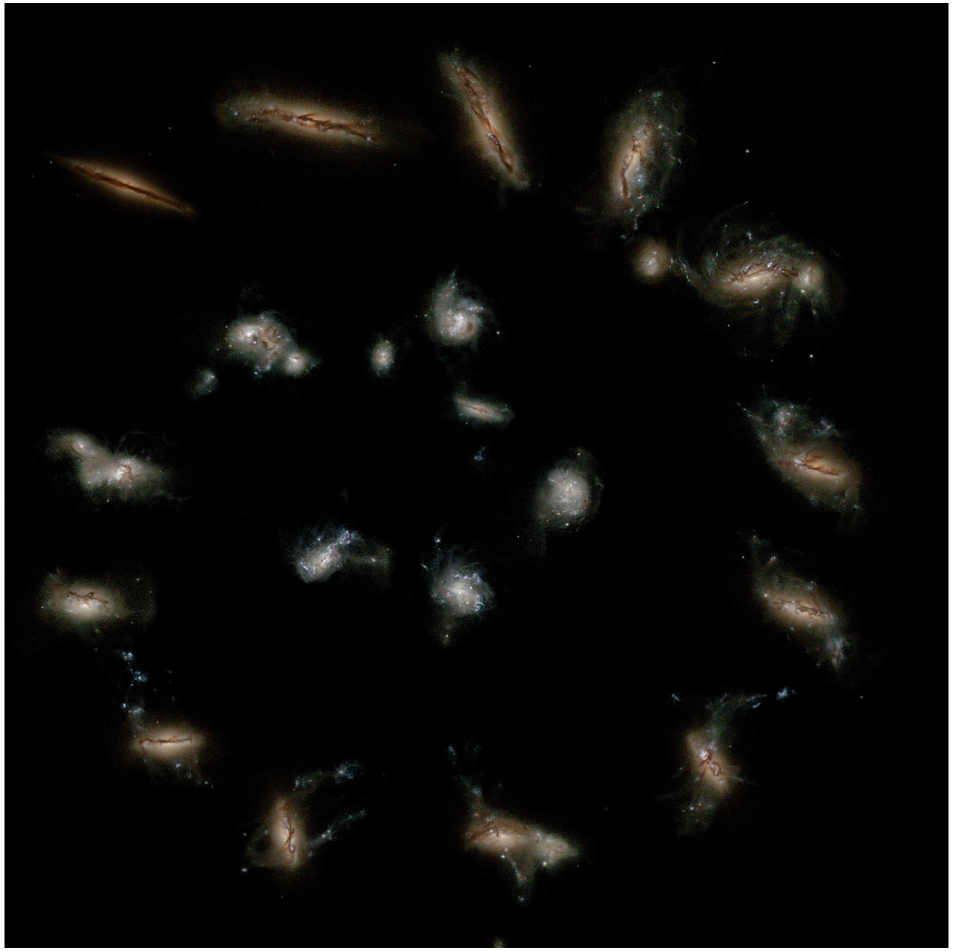


The NewHorizon Simulation

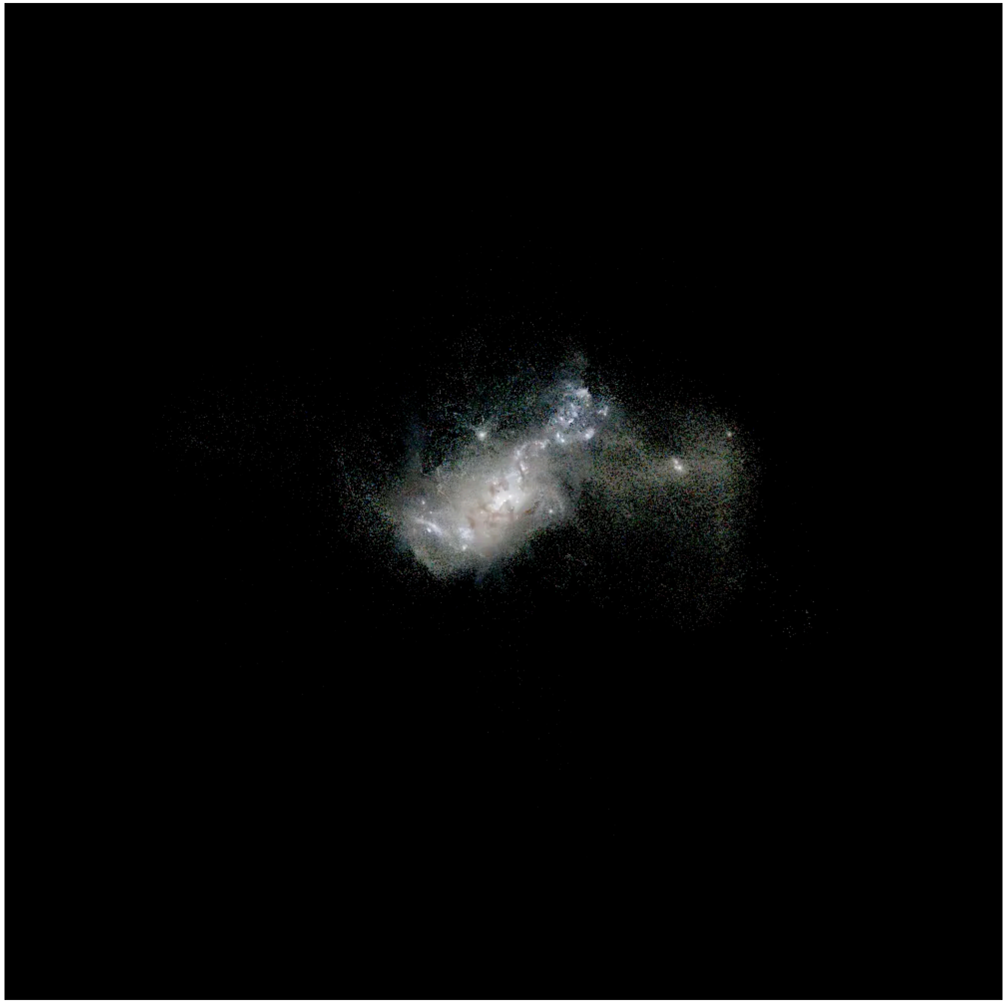


The cosmic web has an impact on galaxy morphology

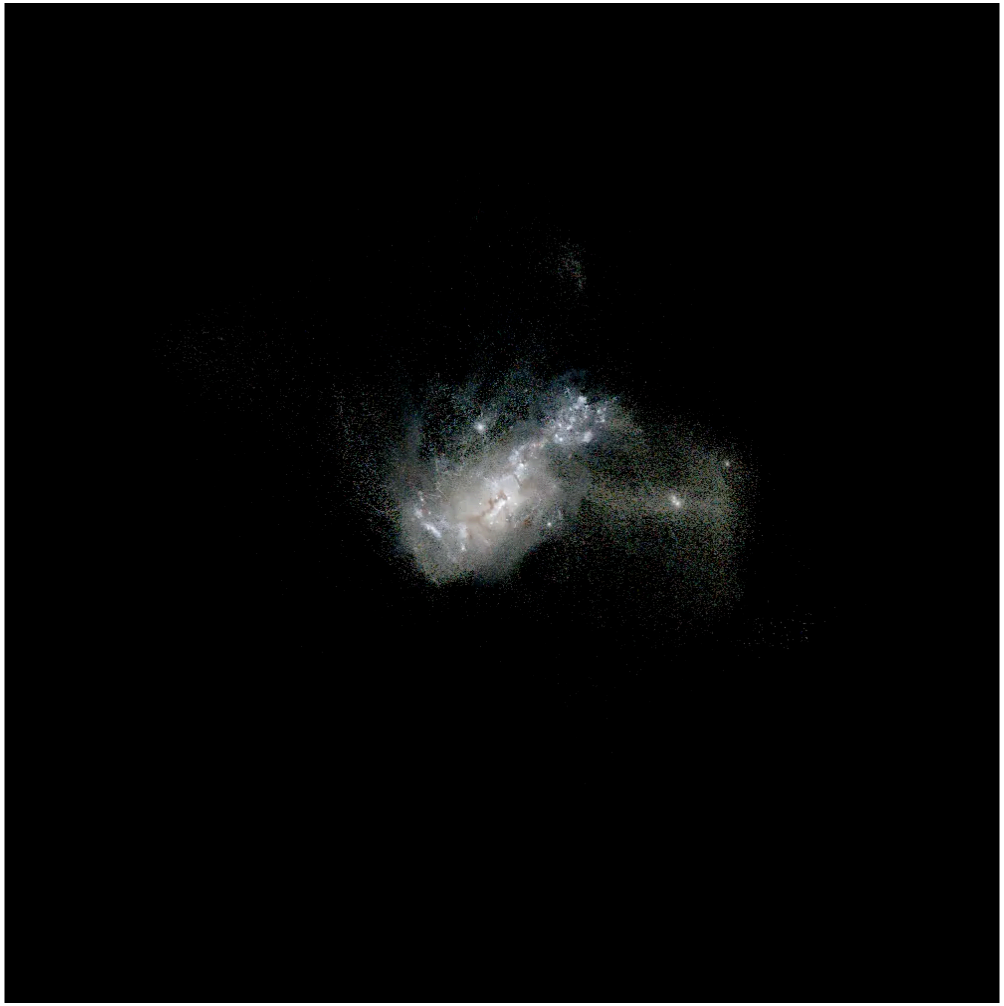




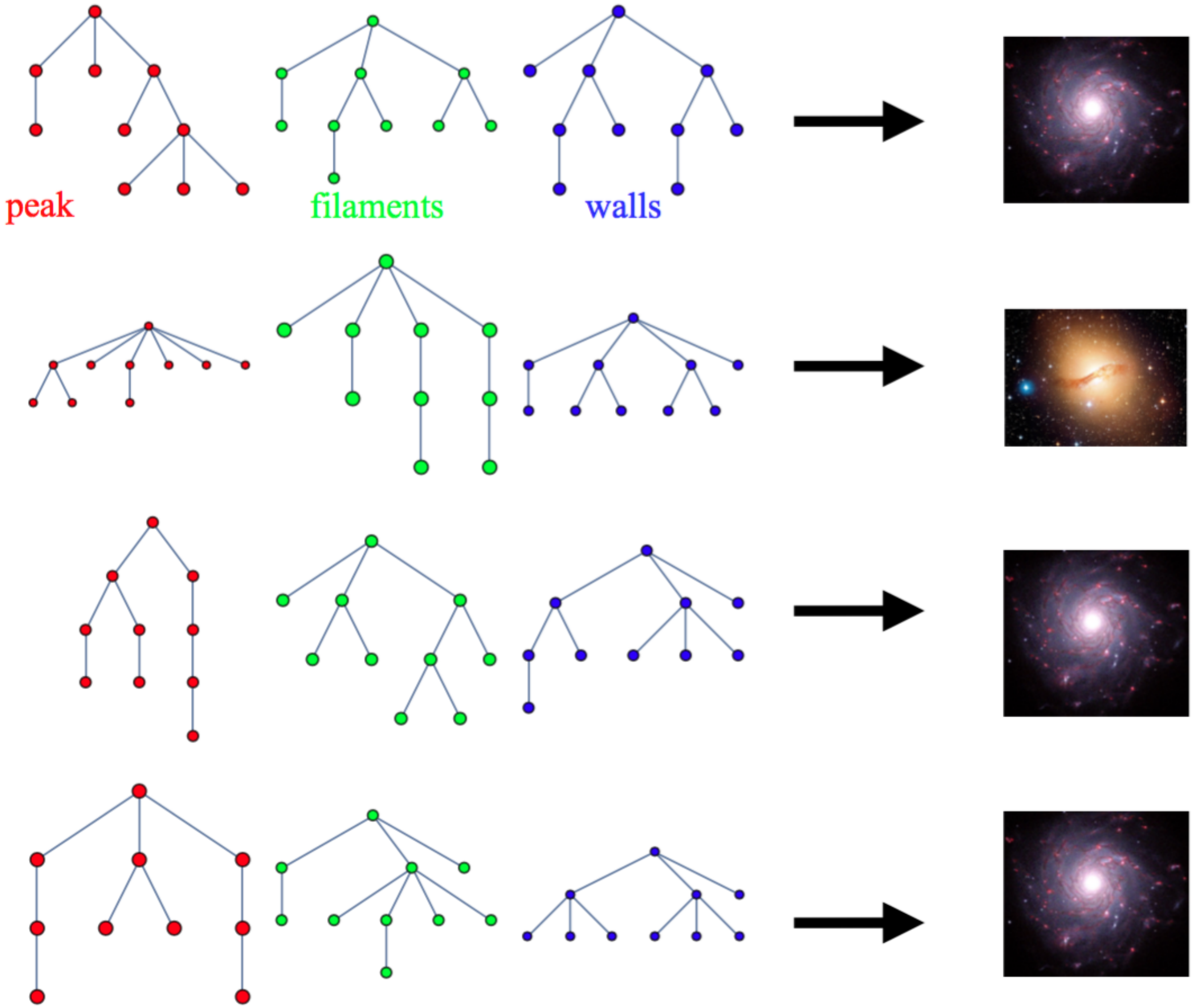
From above



Lateral view



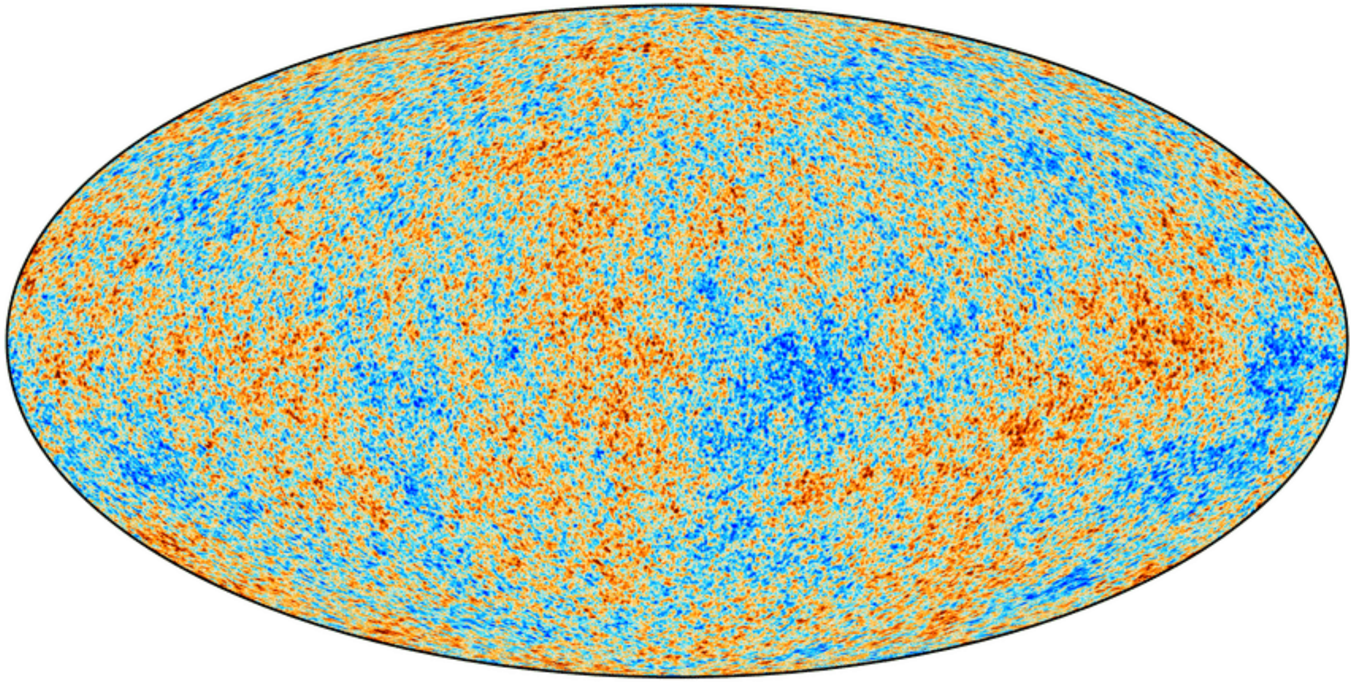
The New Horizon Simulation



The morphology of a galaxy is dictated by its **merger history**, as well as the evolution of its environment.

It is in particular sensible to **coalescence of filaments**, which bring cold gas necessary to star formation.

Can we predict the main characteristics of the universe directly from its initial conditions? ?



Planck

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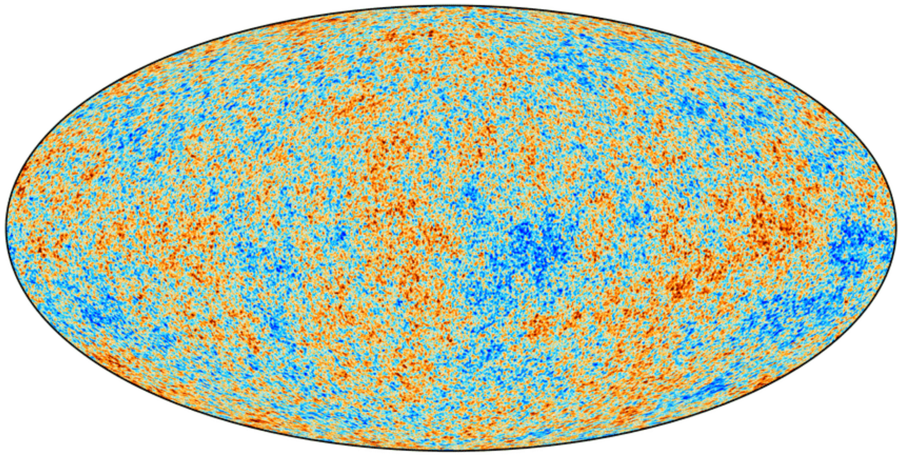
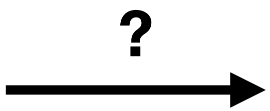
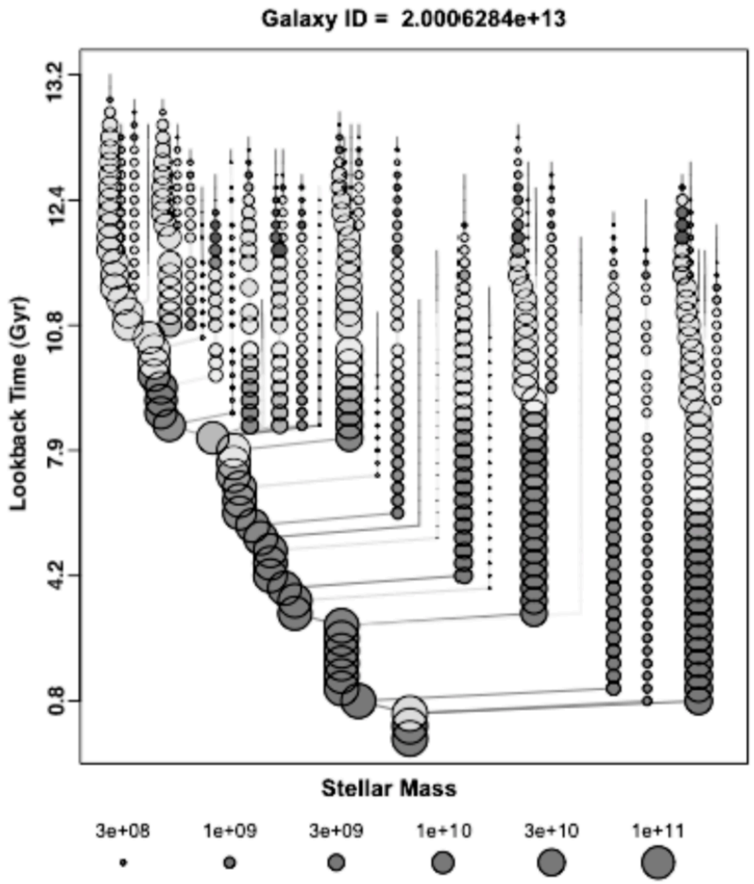
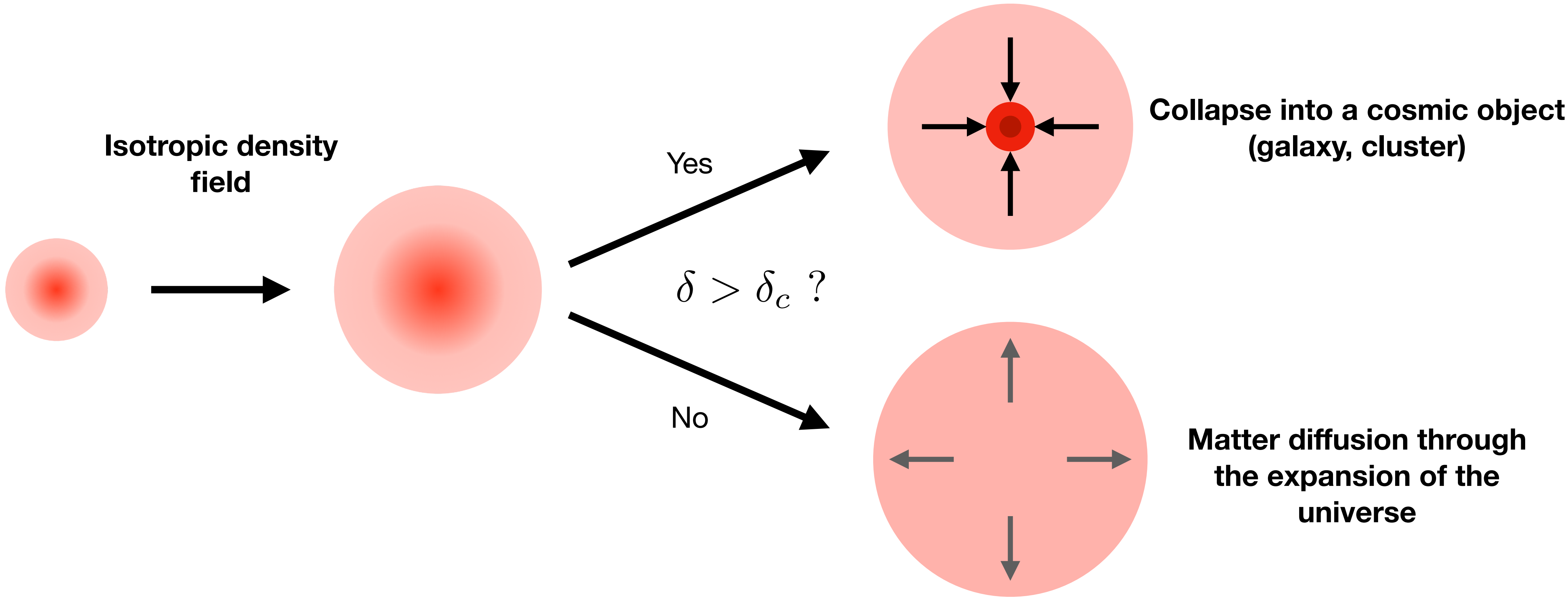
Can we make statistical predictions based solely on the initial conditions?



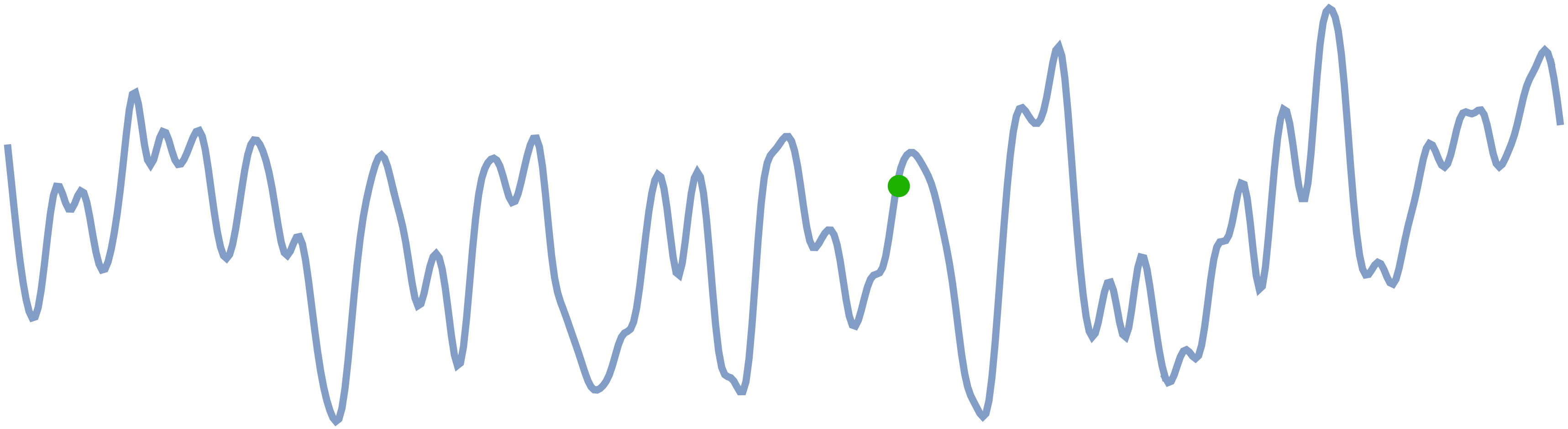




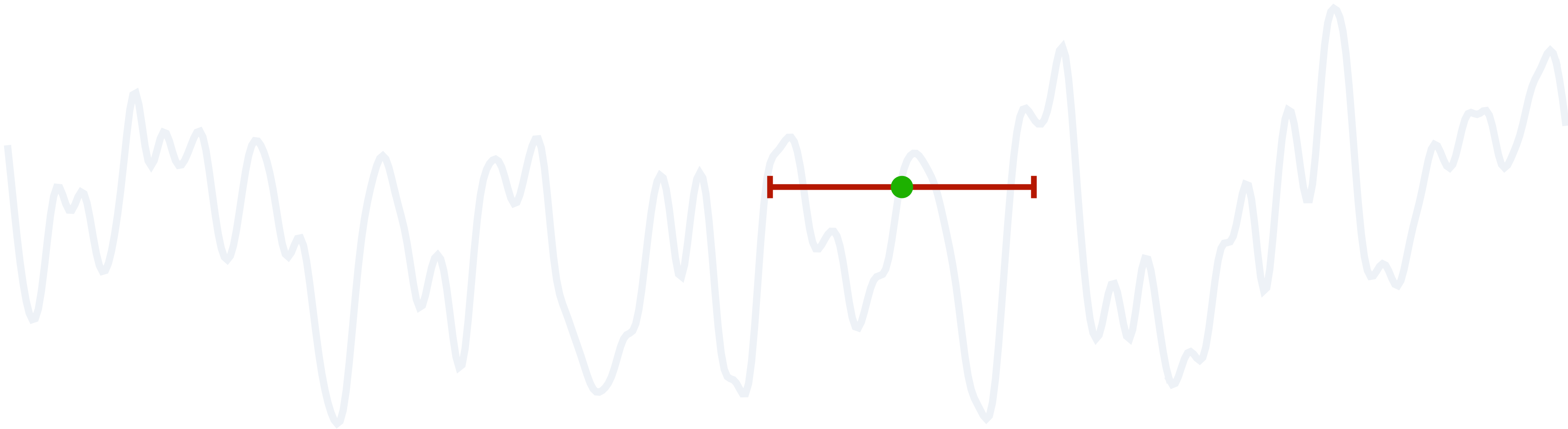
The spherical collapse model



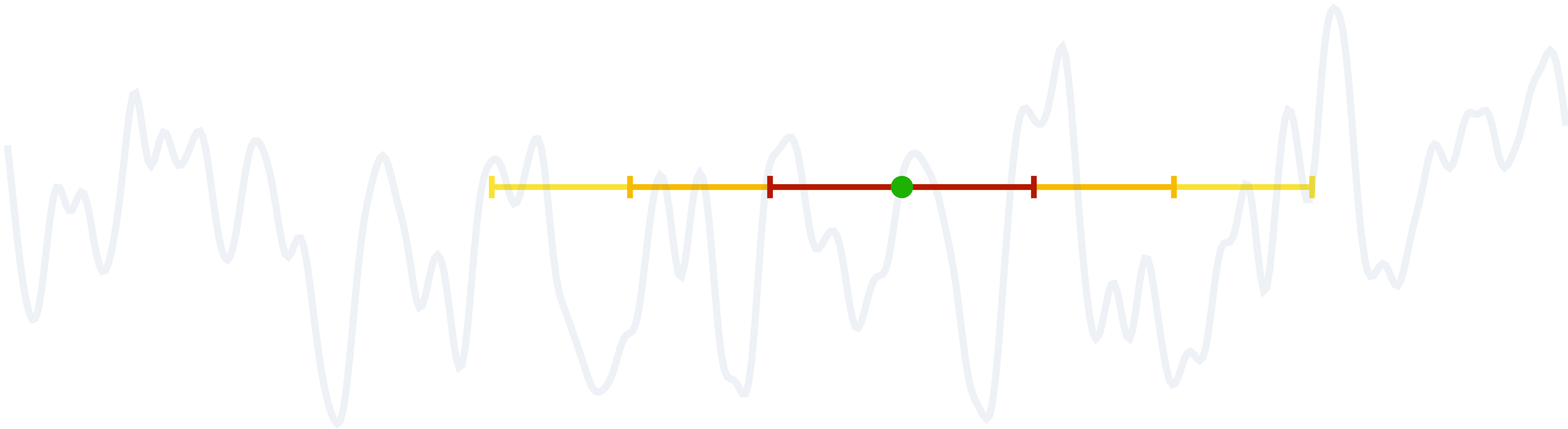
The spherical collapse model



The spherical collapse model



The spherical collapse model

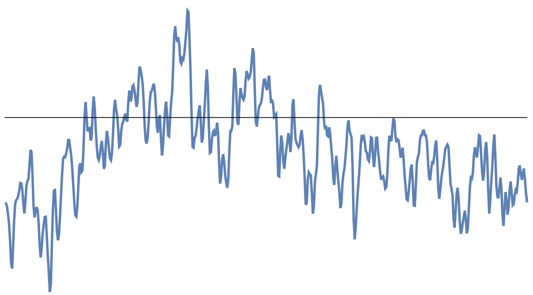


The cosmic web as critical points

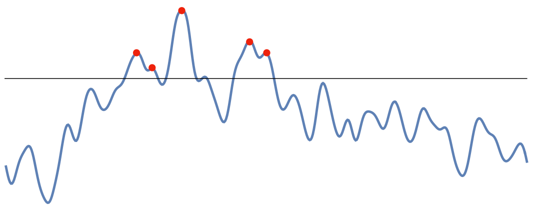
At every point of the field, we take the average density in a sphere of increasing radius

This amounts to smoothing the field with a **top-hat filter**.

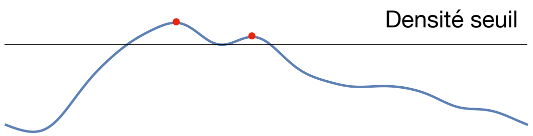
Initial field



Slightly smoothed field



Strongly smoothed field

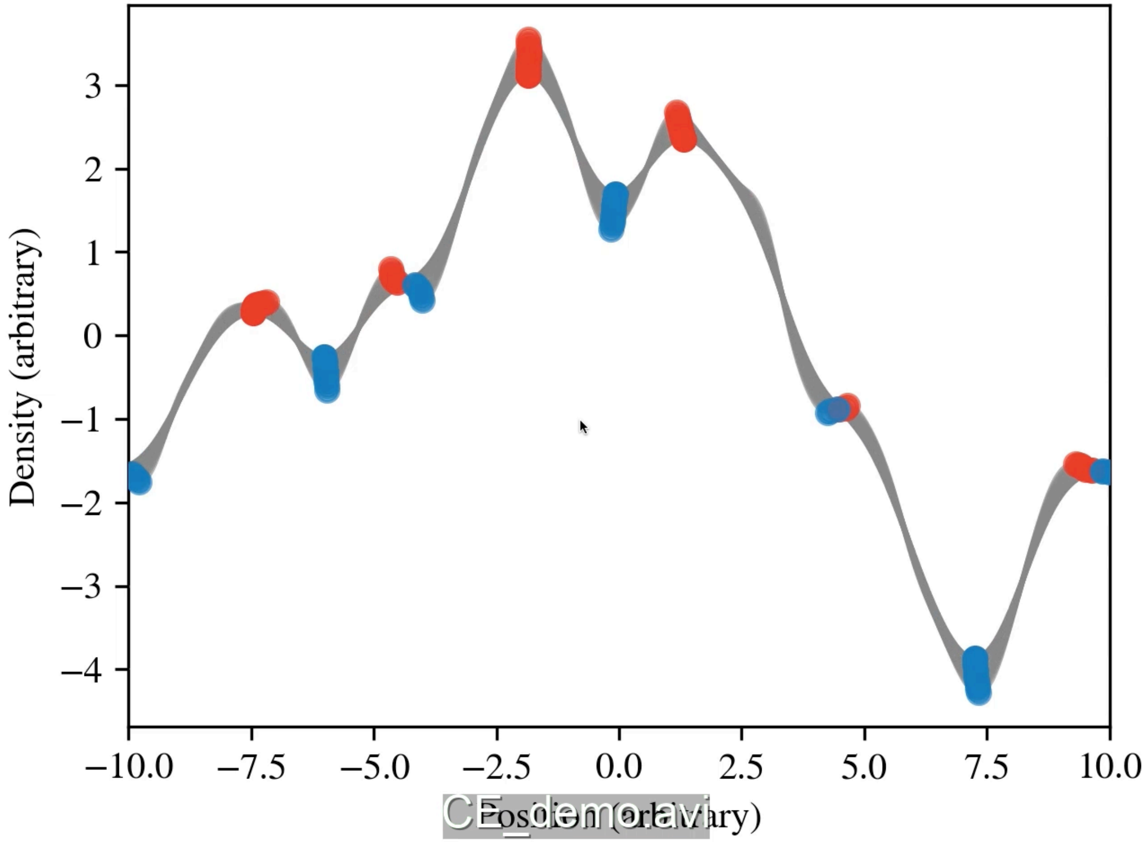


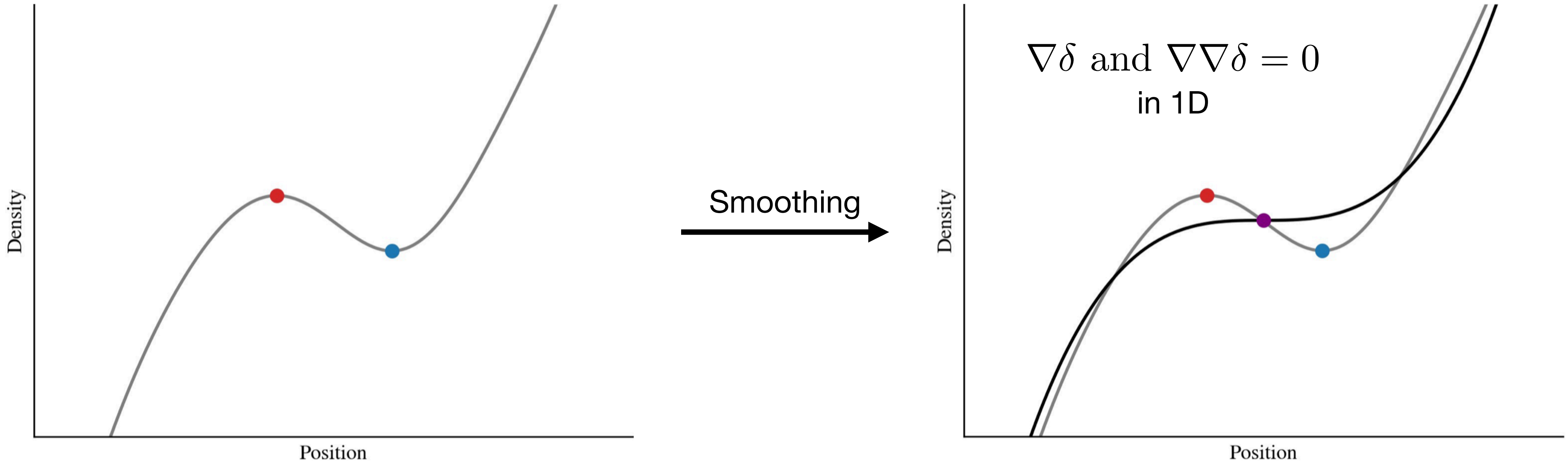
We may link the critical points of the field (minima, maxima, saddle points) to the particular points of the cosmic web (voids, nodes, walls and filaments)

The spherical collapse model gives a correspondance betweem the **density/smoothing** and the **cosmic time/mass** of objects.

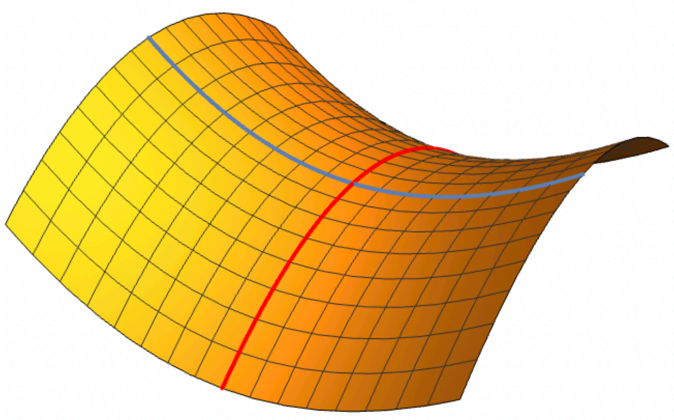
In particular, the **smoothing radius** monotonically increases with time at the peaks, and is thus a **proxy for time**.

Mergers and critical events

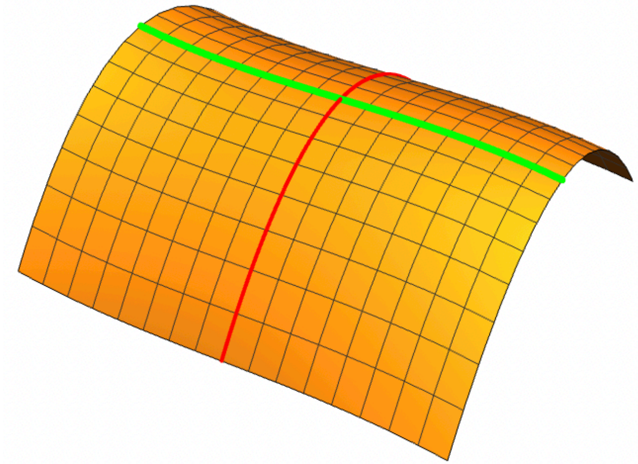



Density
Position
Smoothing
$\nabla\delta$ and $\nabla\nabla\delta = 0$
in 1D
Density
Position

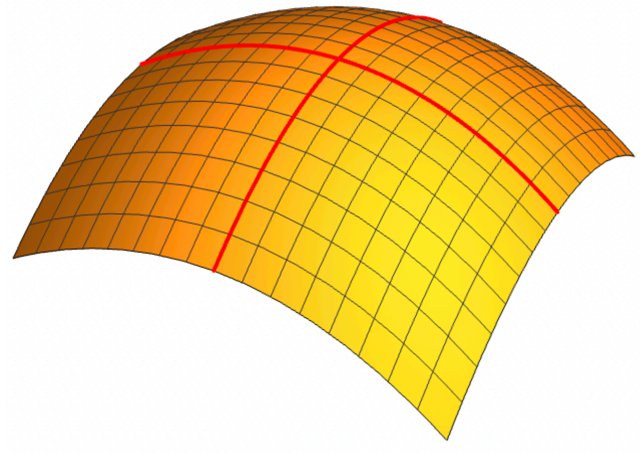
Critical point	Voids	Walls	Filaments	Peaks
Signature of the Hessian	$+++$	$-++$	$--+$	$---$



Saddle point
$-+$



Saddle-maximum critical event
-0

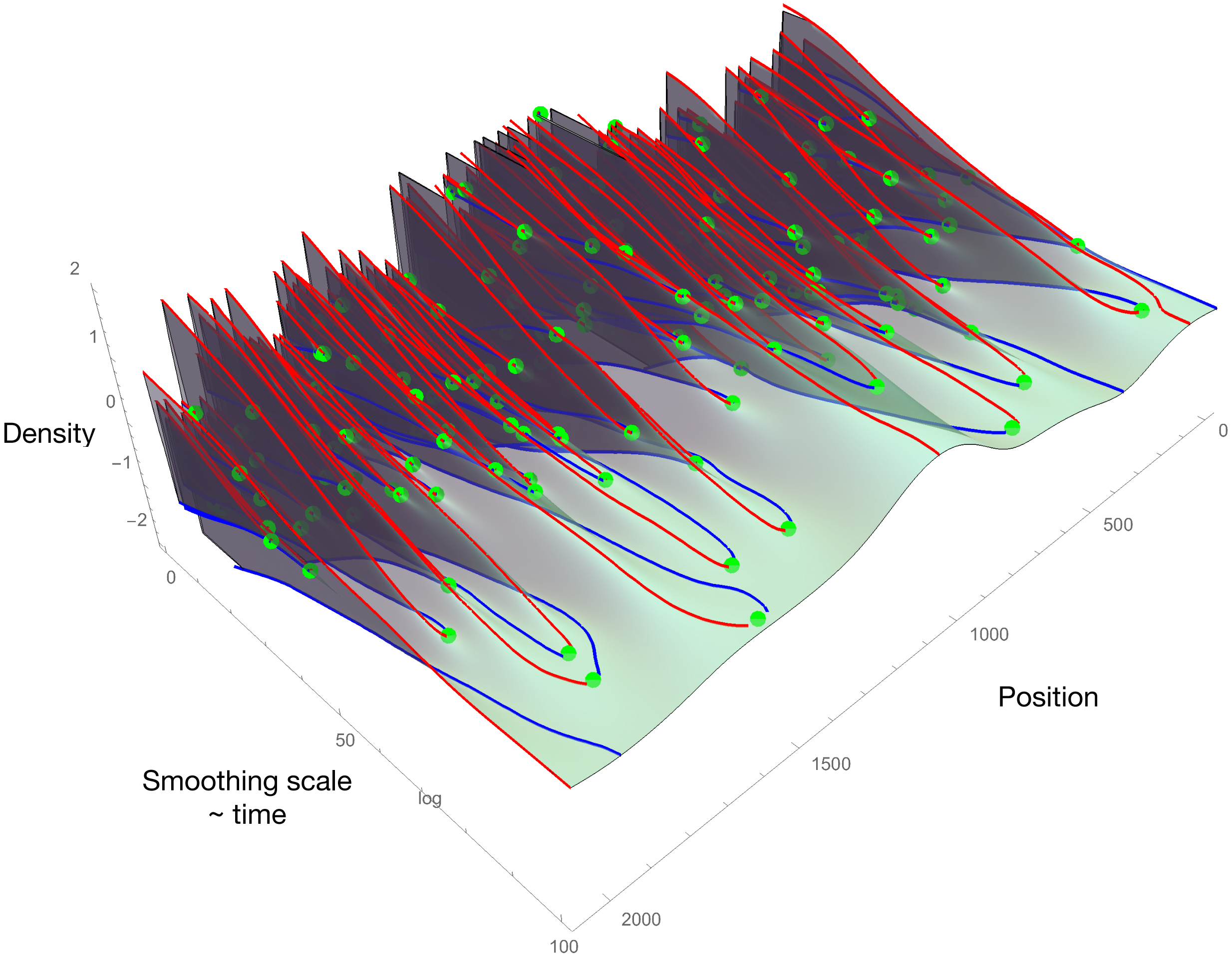


Maximum
$--$

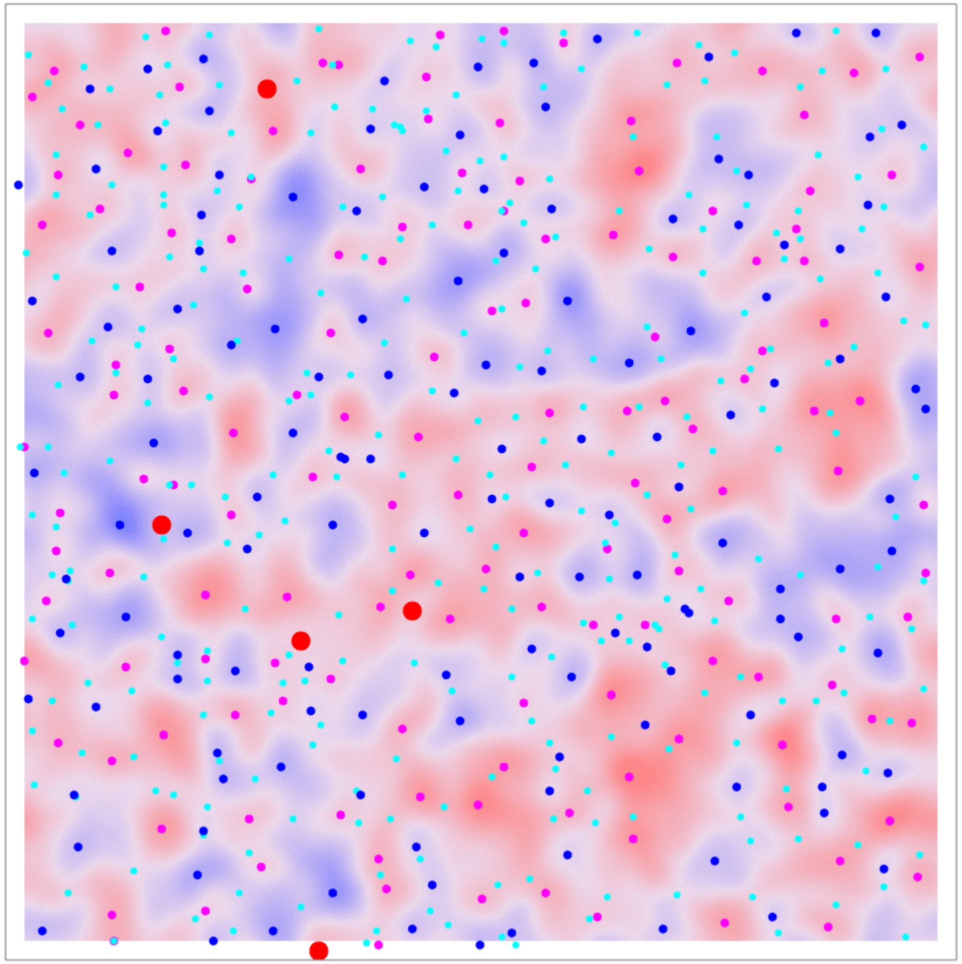
$$\nabla\delta = 0 \text{ and } \det(\nabla\nabla\delta) = 0$$

Replacing the top-hat filter with a Gaussian filter, we may get analytical expressions for statistical properties of events.

Critical events

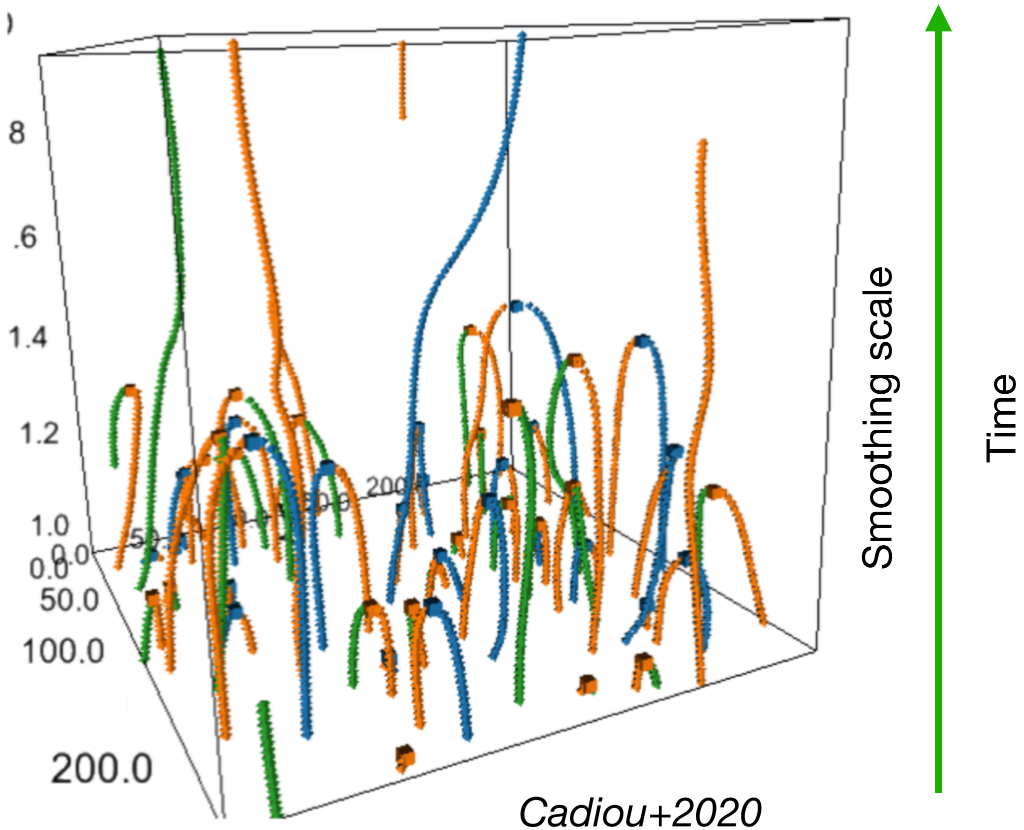


In one …



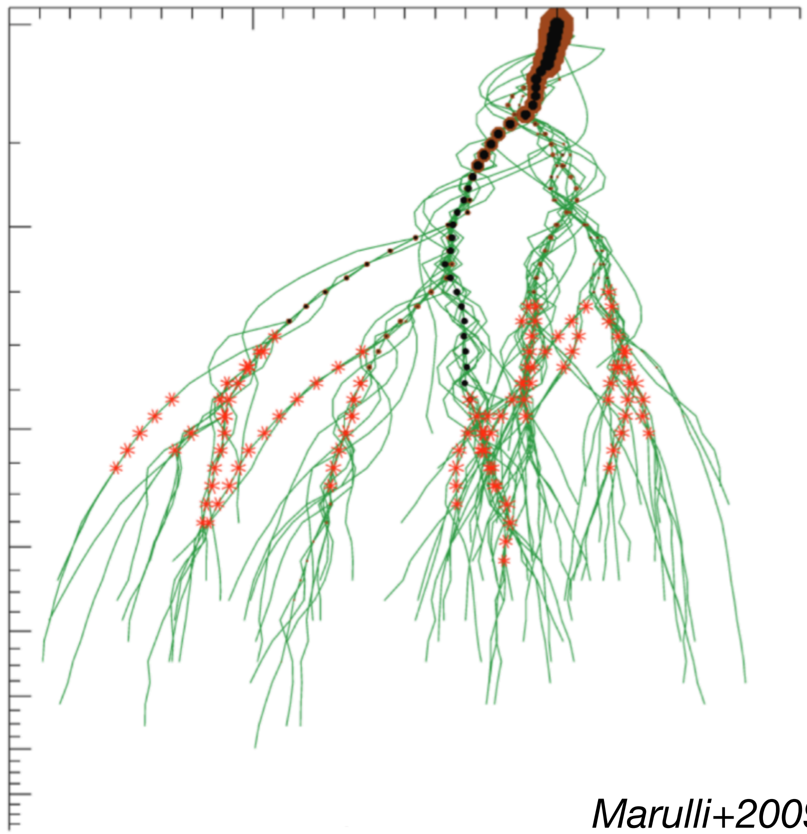
… and two dimensions

Statistic analysis from critical event theory



Cadiou+2020

Merging history of a cosmological object, obtained from simulations



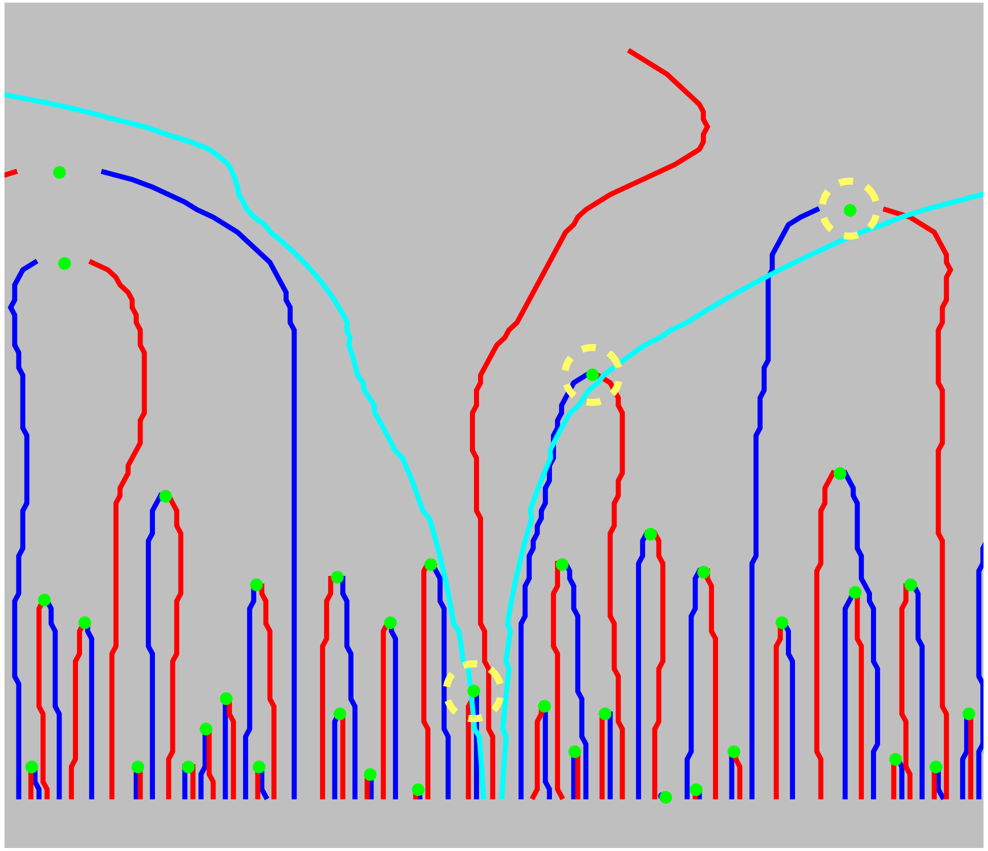
Marulli+2009

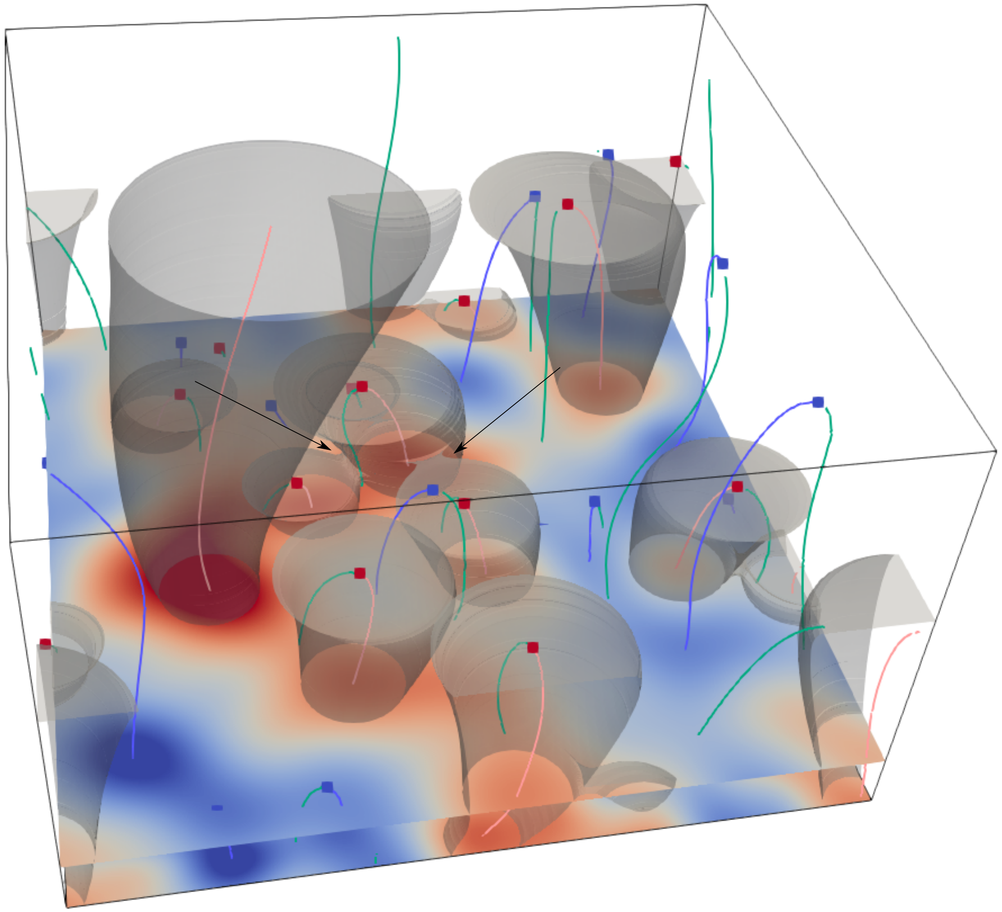
How can we recover the pair of peaks involved in a merging event?

Outline

Attraction cones

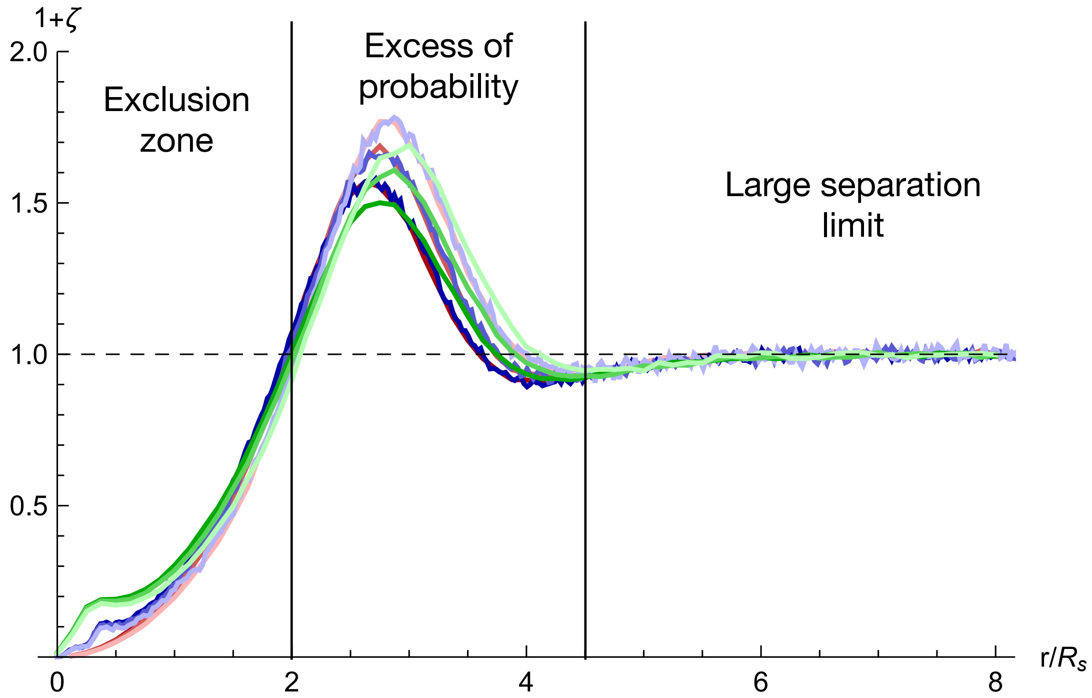
We use the **distance from the critical points** to decide in which objet a critical event merges.

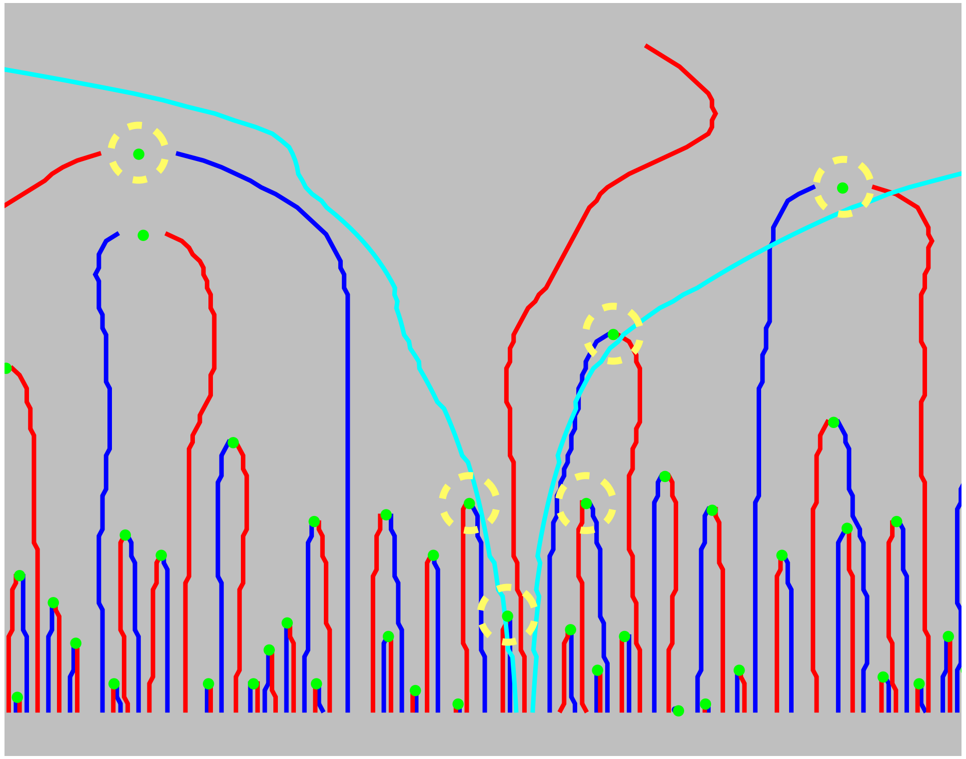




What cone opening angle should we consider ?

To answer this question, we analyse the **mixed two point correlation function** between critical events and peaks.

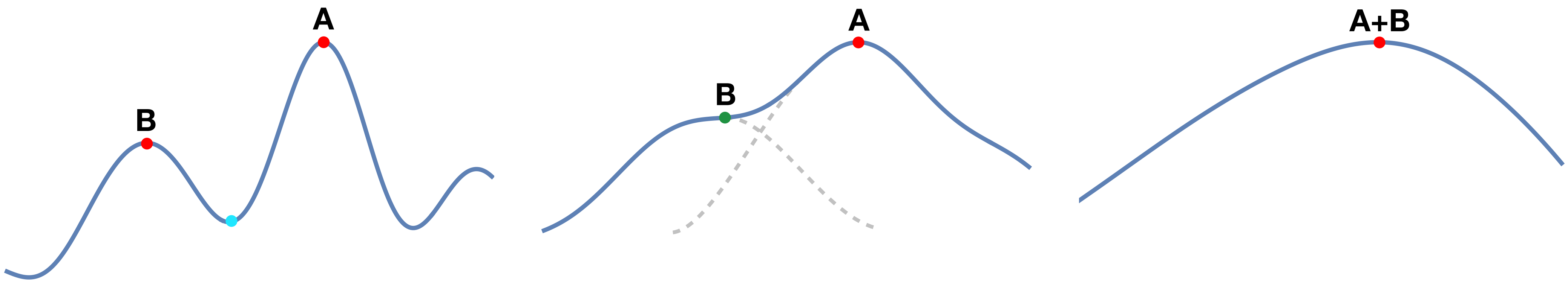




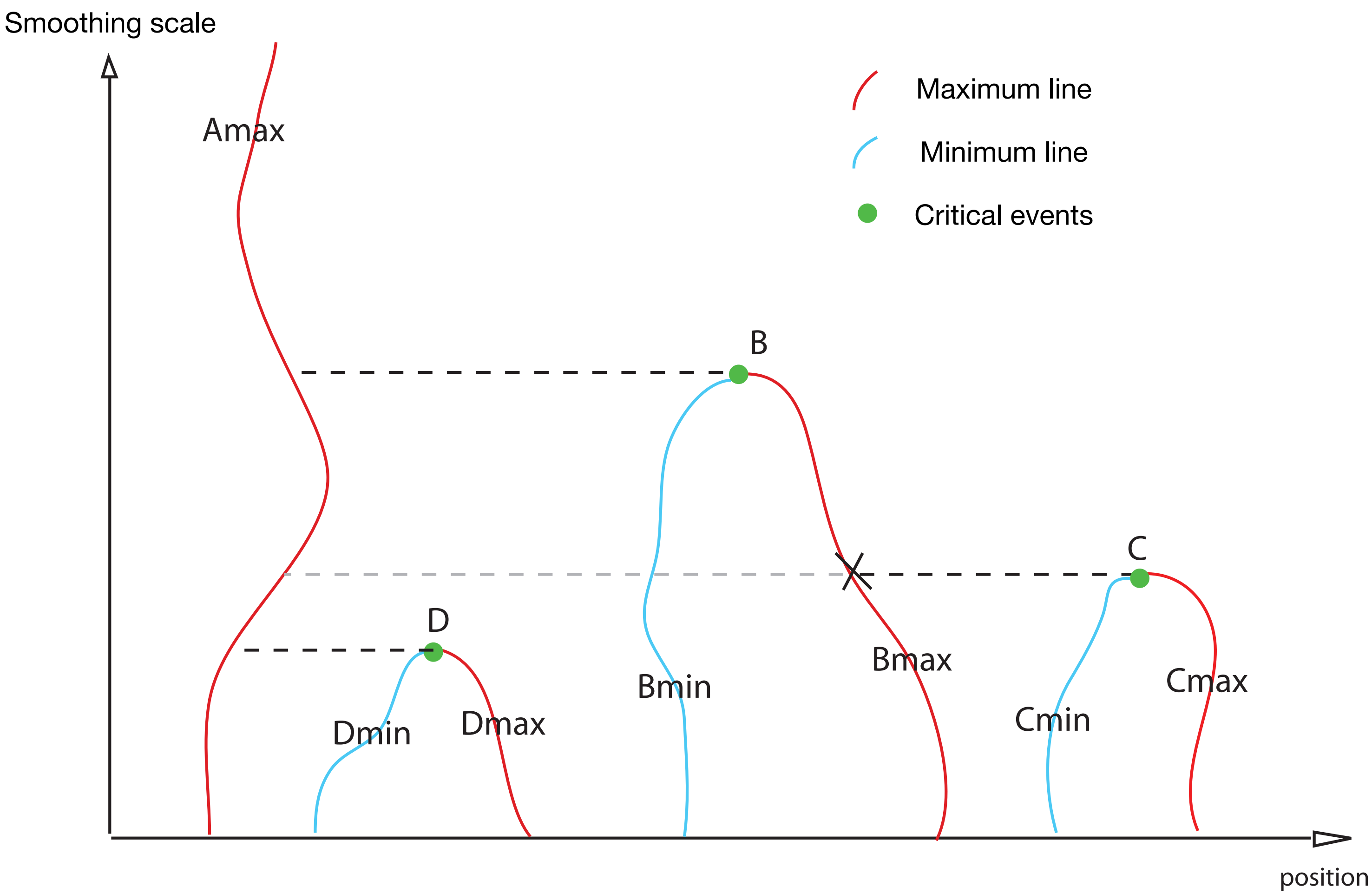
Cone angle equal to 2

Topological mergers in 1D

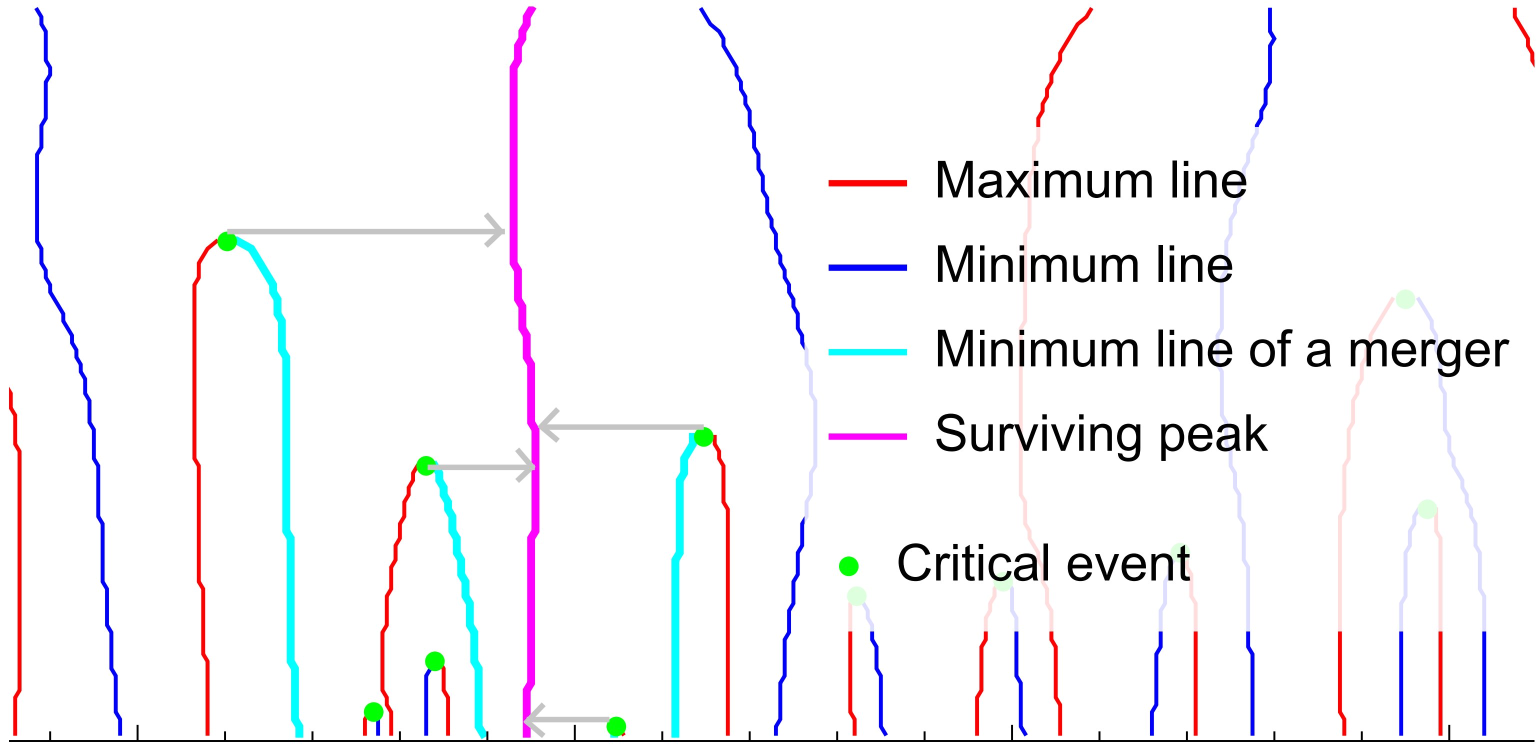
In one dimension, the peak associated to the merging of a critical event is the **adjacent peak.**



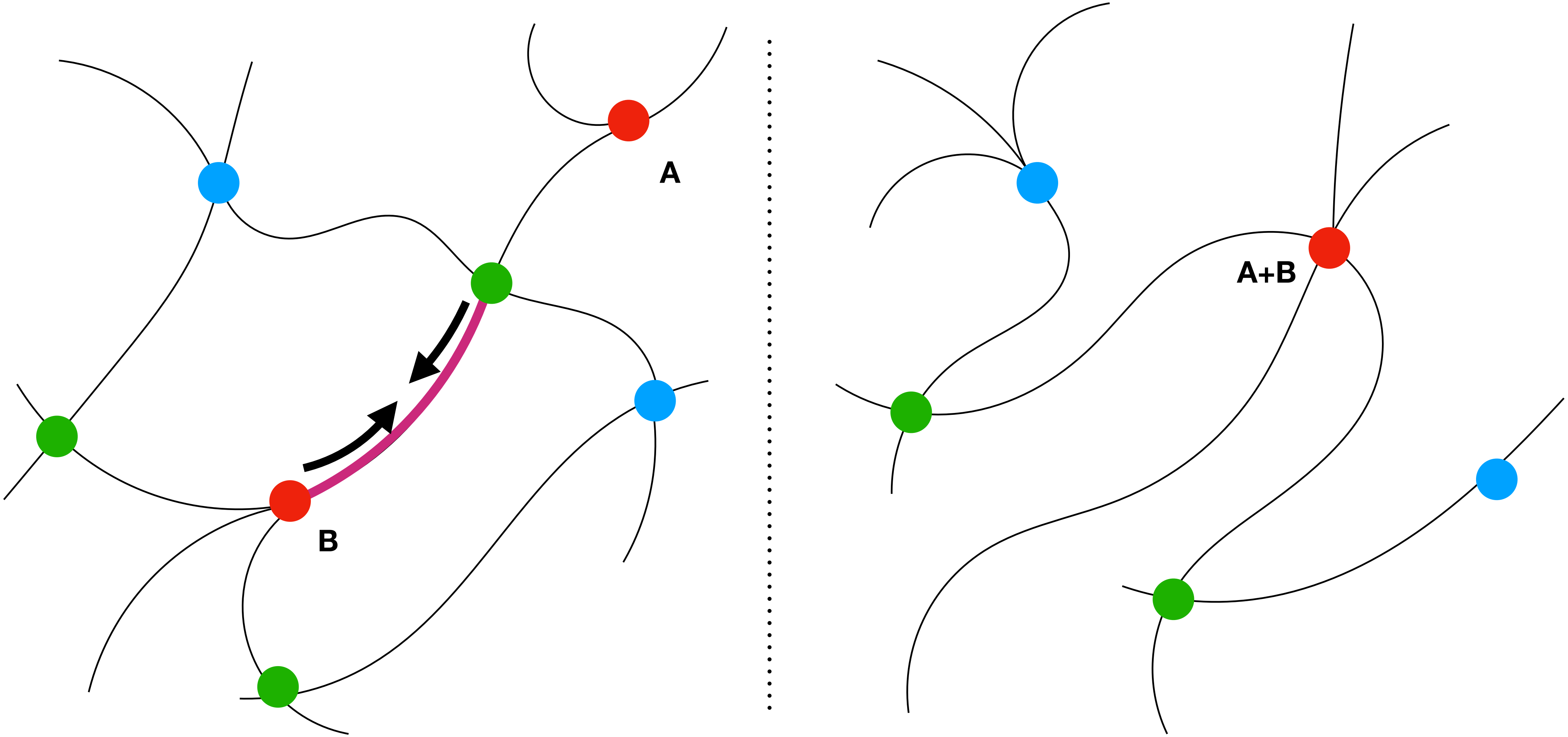
Topological mergers in 1D



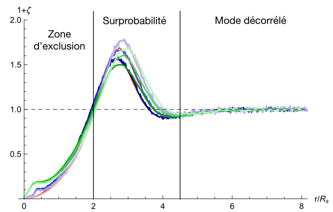
Topological mergers in 1D

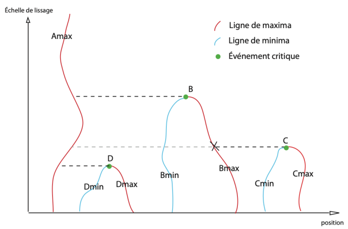


Topological mergers in 2D (and 3D), using the skeleton

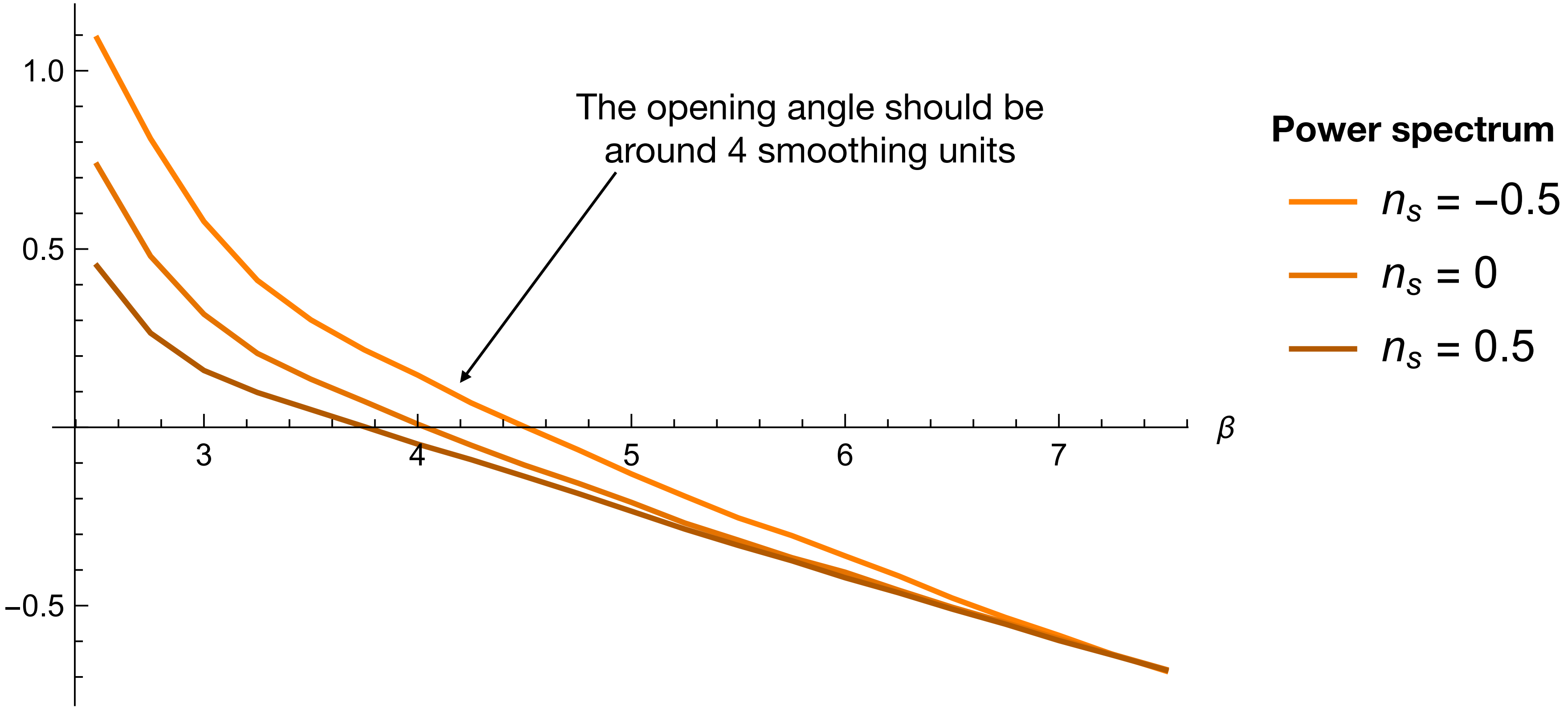


Comparison with cones (in 1D)





Mean difference between number of topological mergers and number of mergers in a cone of angle β



Can we use critical event theory to make pertinent cosmological predictions?

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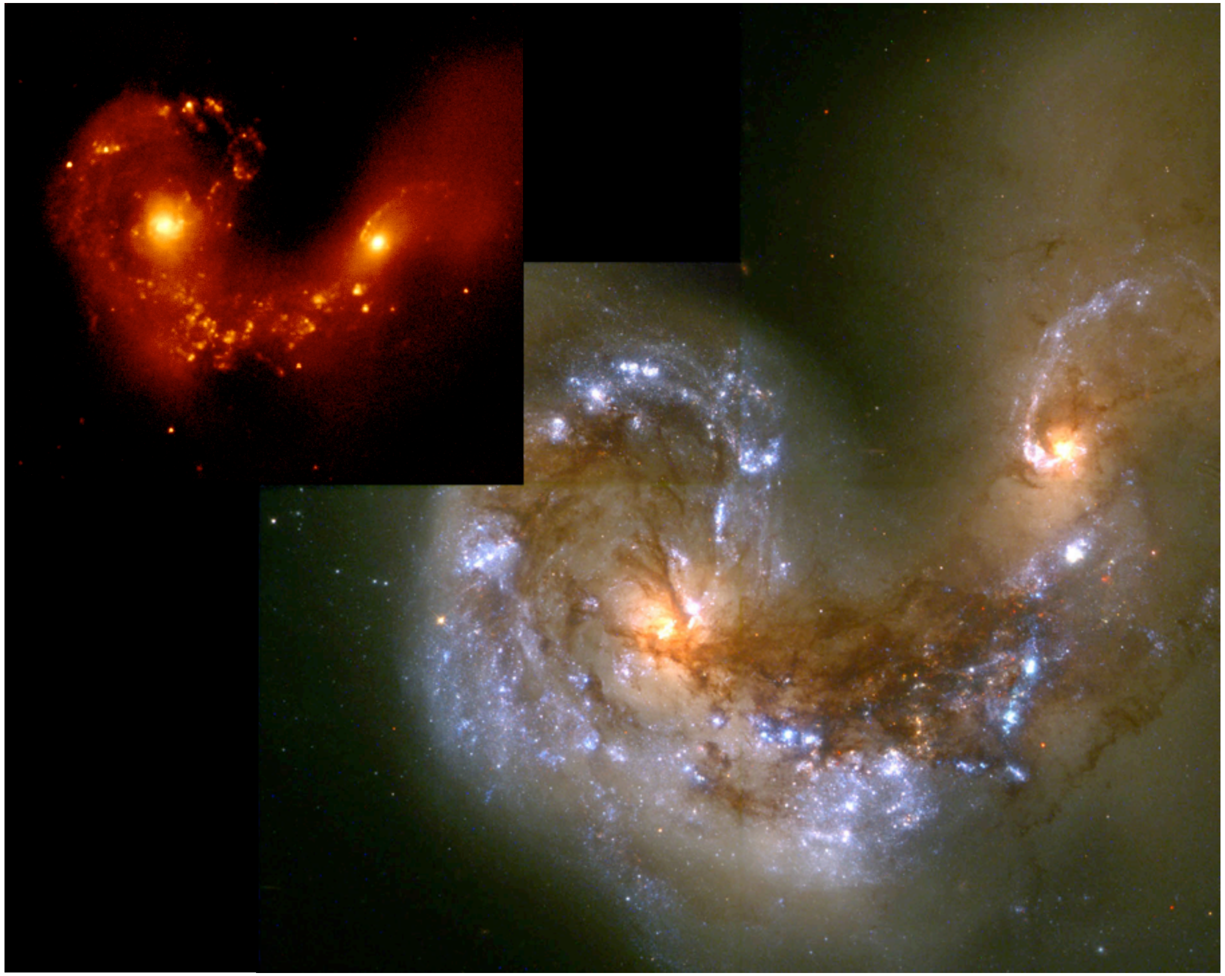
Mass acquired by mergers



The morphology of a galaxy is linked to its **merger history**, as well as the **characteristics** of these mergers (mass, number, time).

We use the spherical collapse model to assign a coherent mass to mergers associated to a critical event.

Mass accreted by mergers

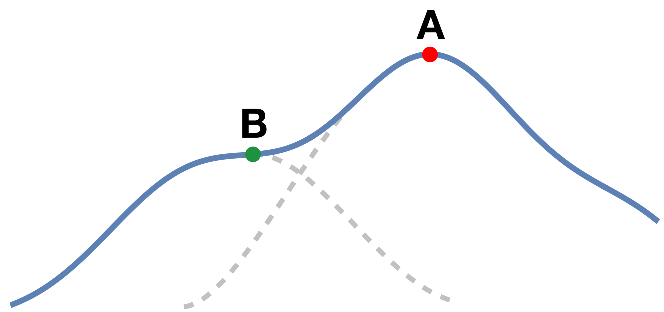
Mass is proportional to the cube of the smoothing radius

$$M = \bar{\rho} \times V \propto \bar{\rho} \times R^3$$

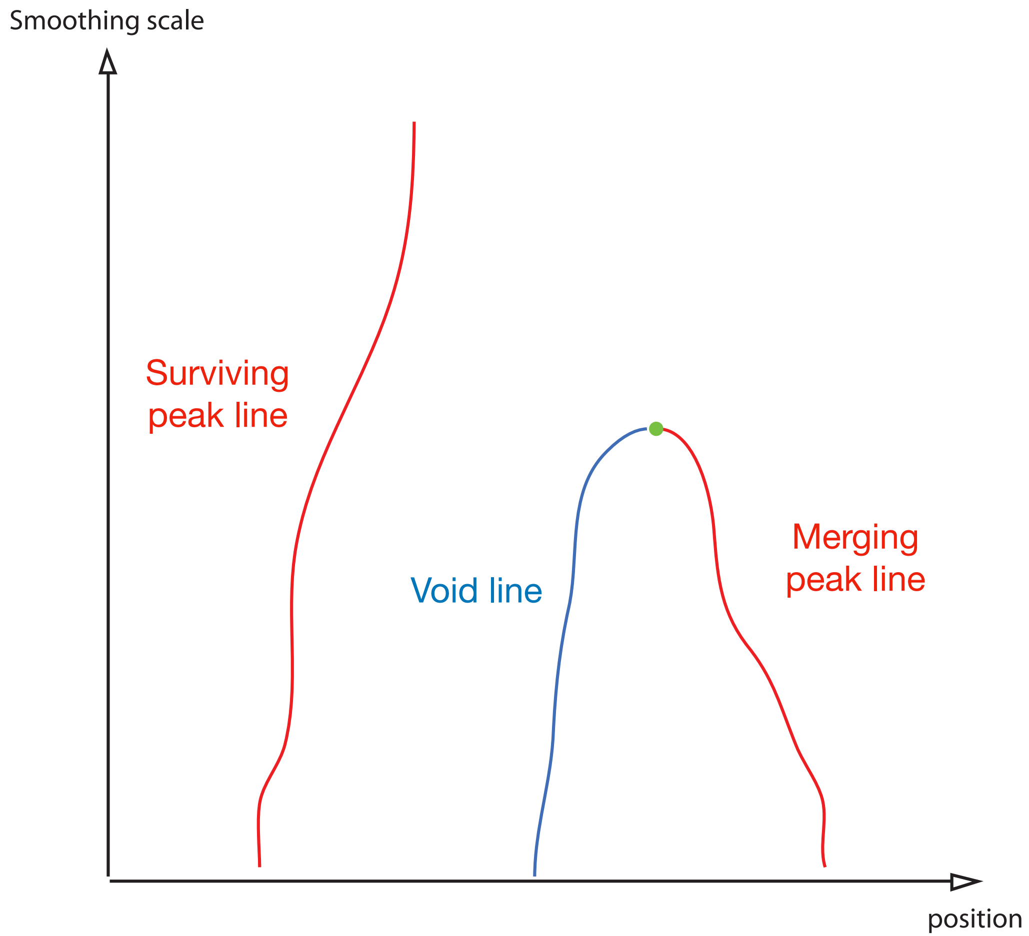
The **existence time** of an object is a decreasing function of the **overdensity** of the peak that is associated to it.

$$z = \mathrm{f}\left(\frac{\delta_c}{\delta}\right)$$

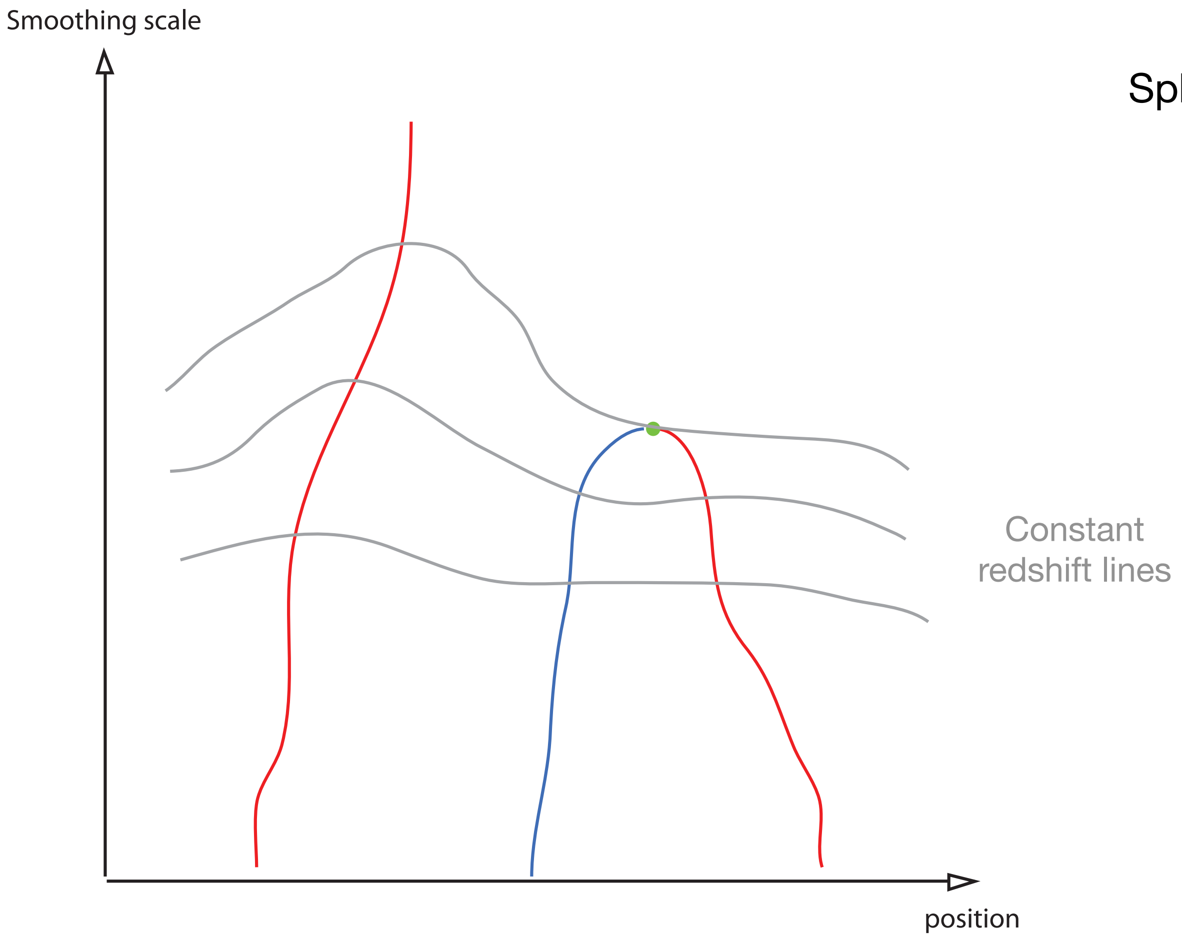
We wish to compare the mass of two merging objects **at a given time**, taking care to **not count mass twice**.



The double pointer method



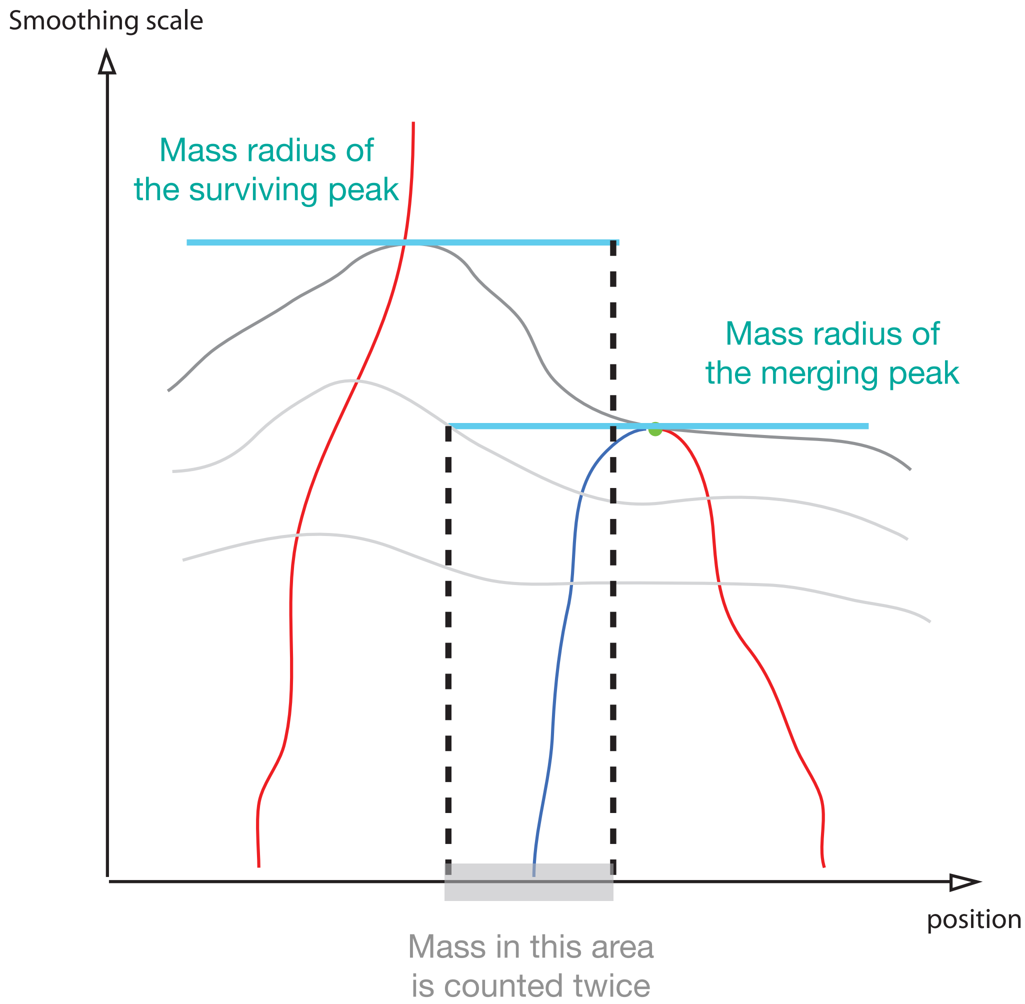
The double pointer method



Spherical collapse time

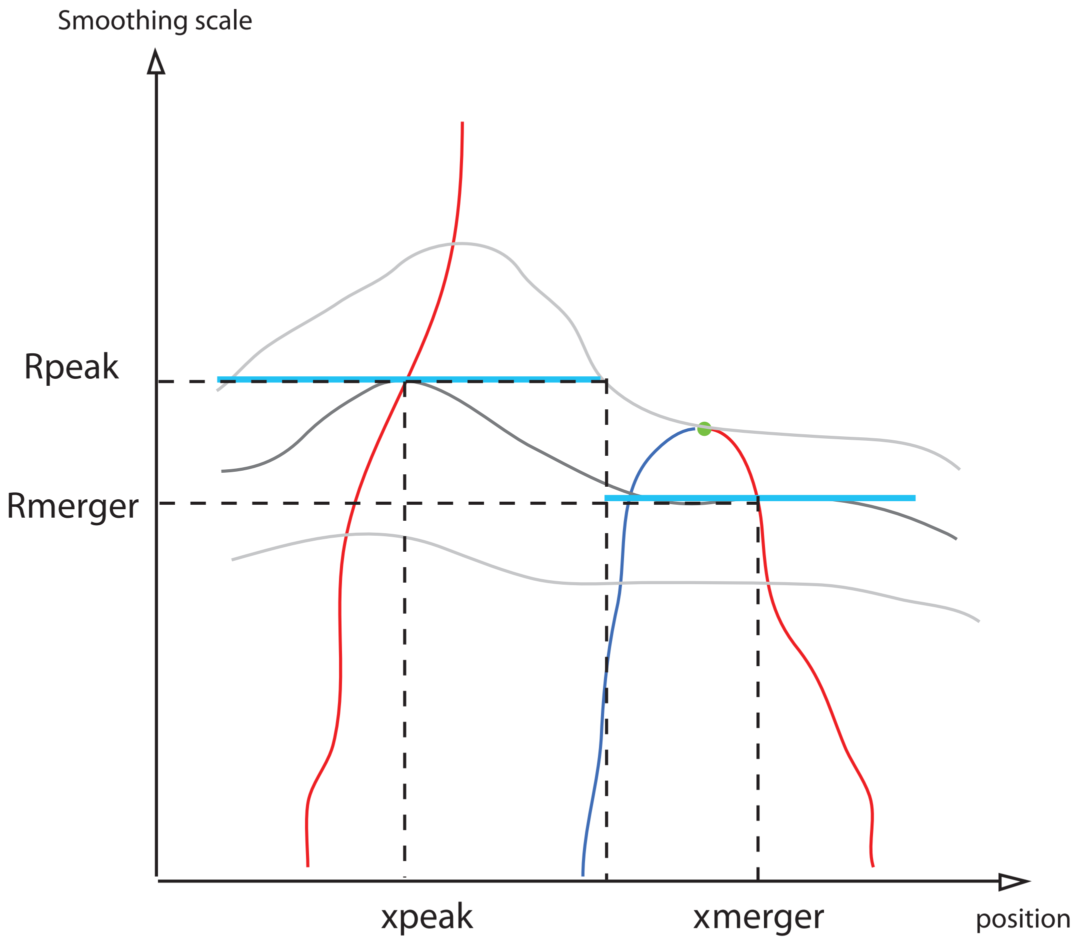
$$t = f(\delta)$$

The double pointer method

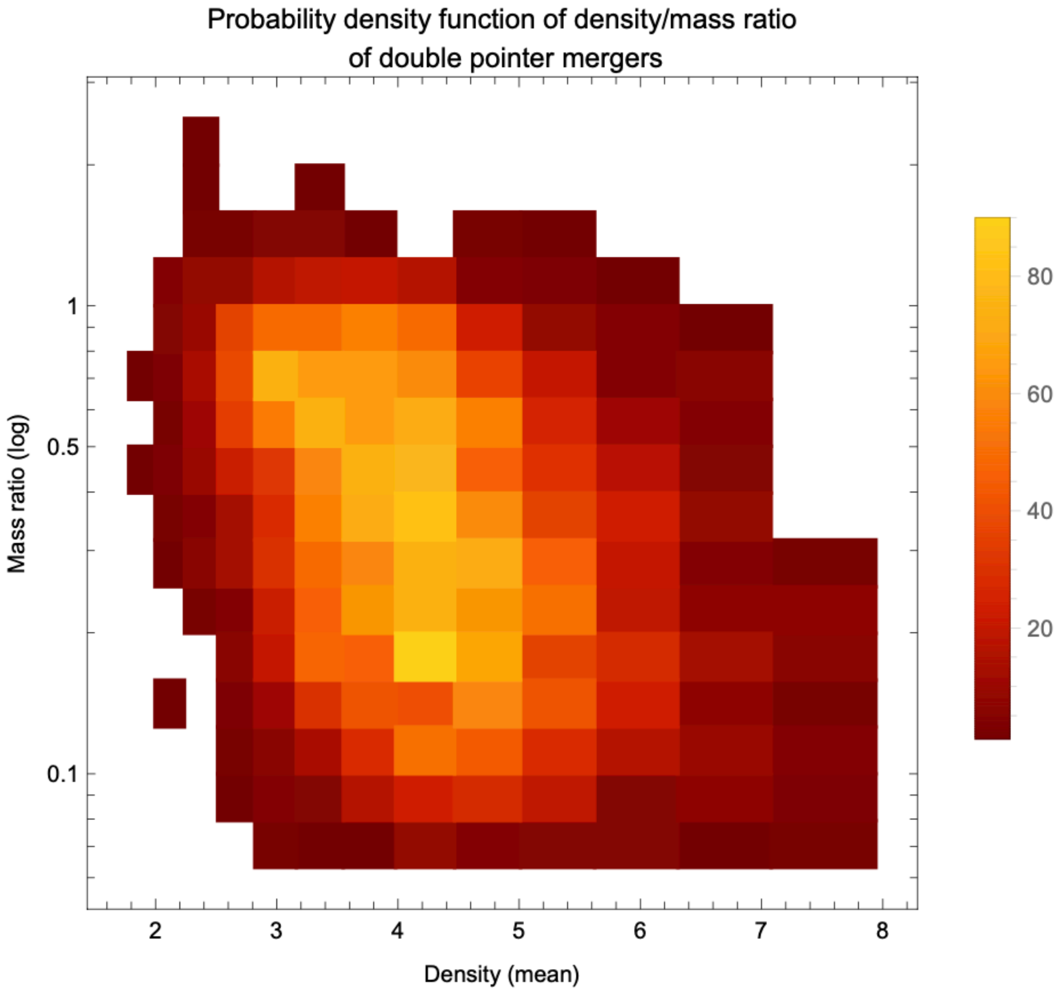


$M = \bar{\rho} \times V \propto \bar{\rho} \times R^3$ In 3D

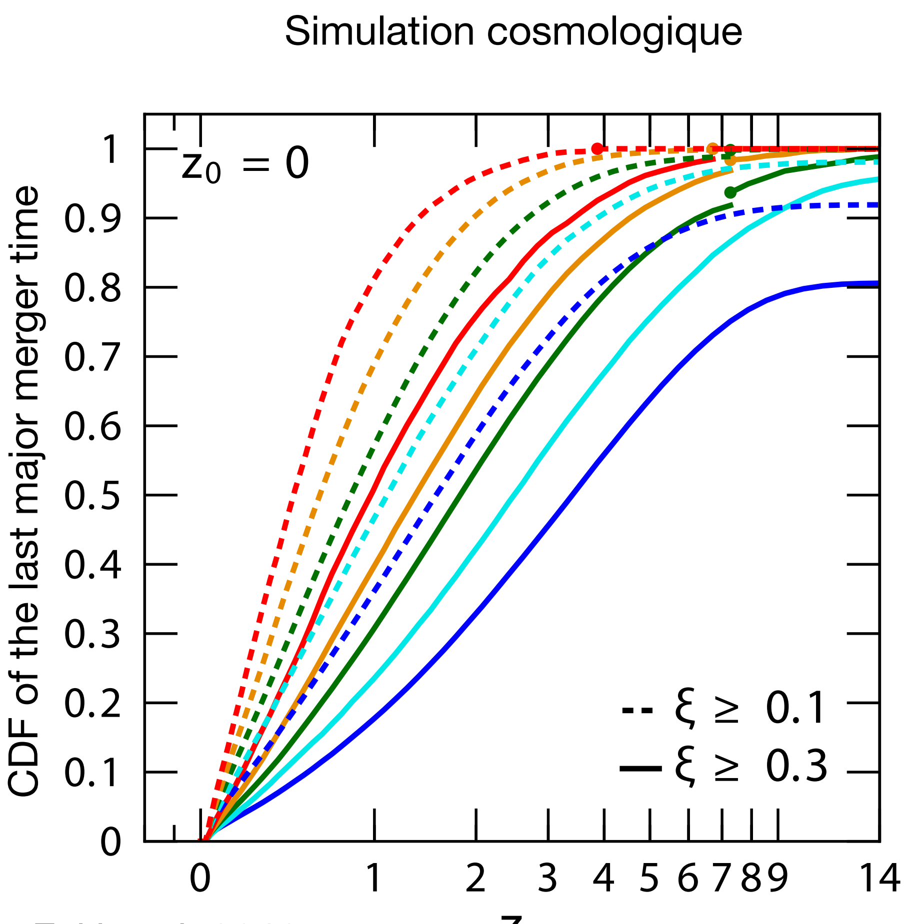
The double pointer method



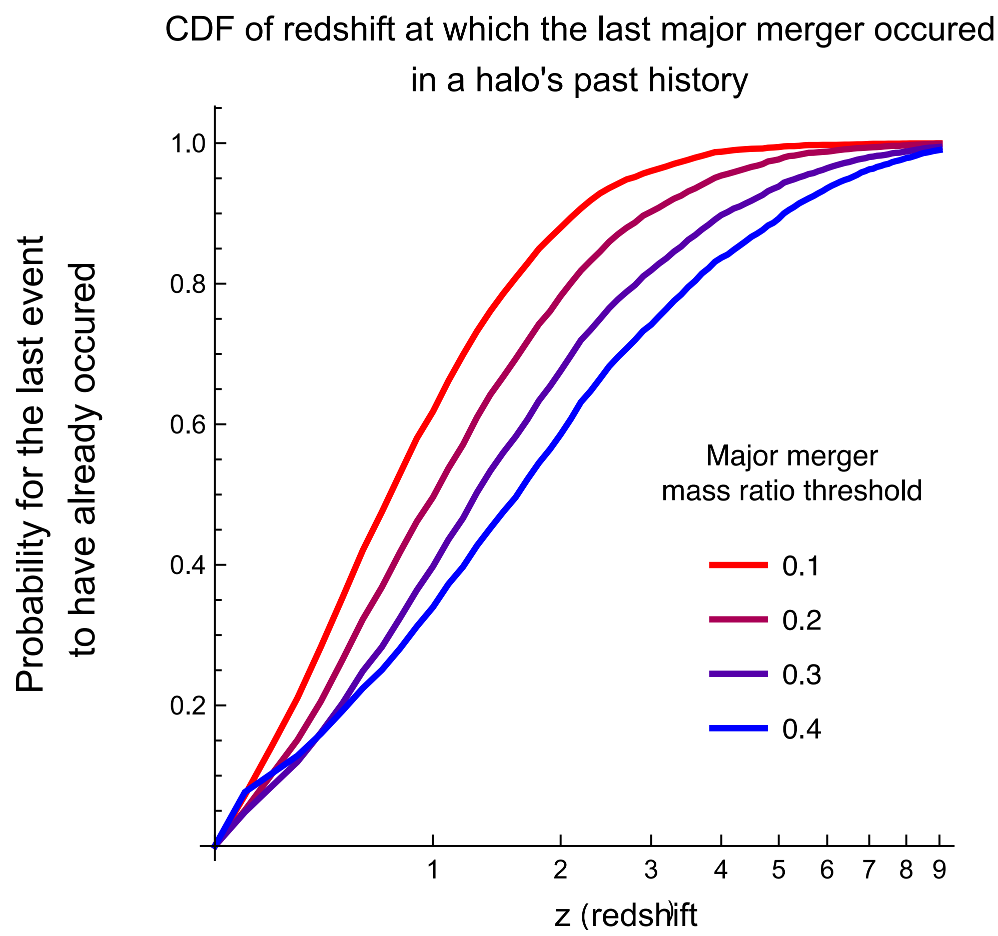
Merger characteristics



First comparison to cosmological simulations



Fakhouri+2010



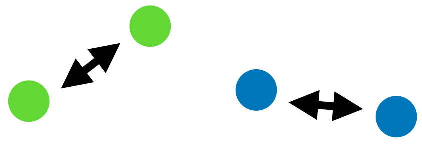
Outline

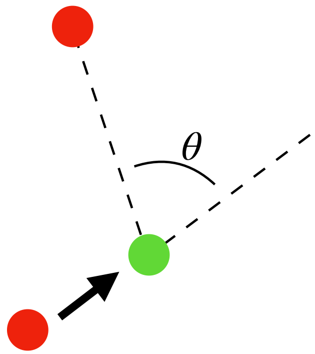
Conclusions

Critical event theory provides a useful framework to make predictions about the geometry of mergers from first principle.

Perspectives

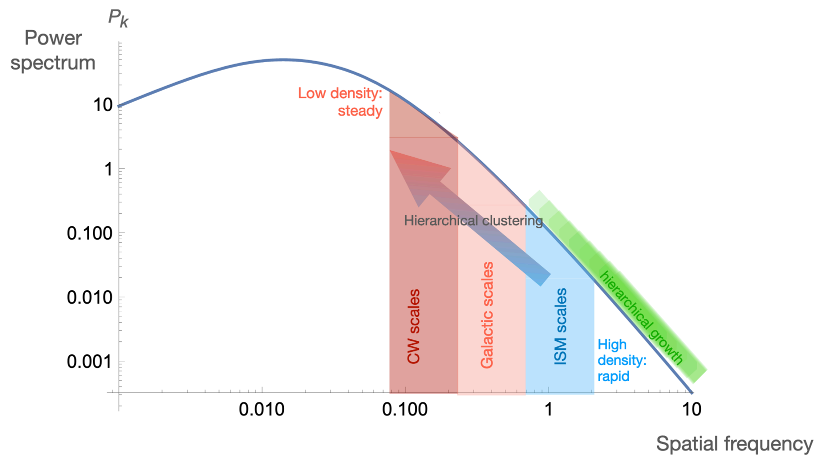
- Filament-filament and wall-wall mergers

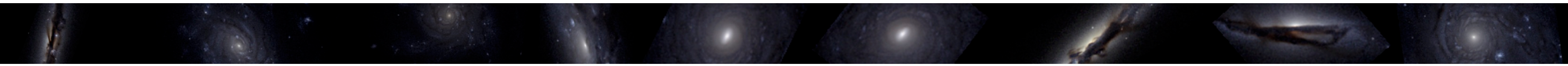




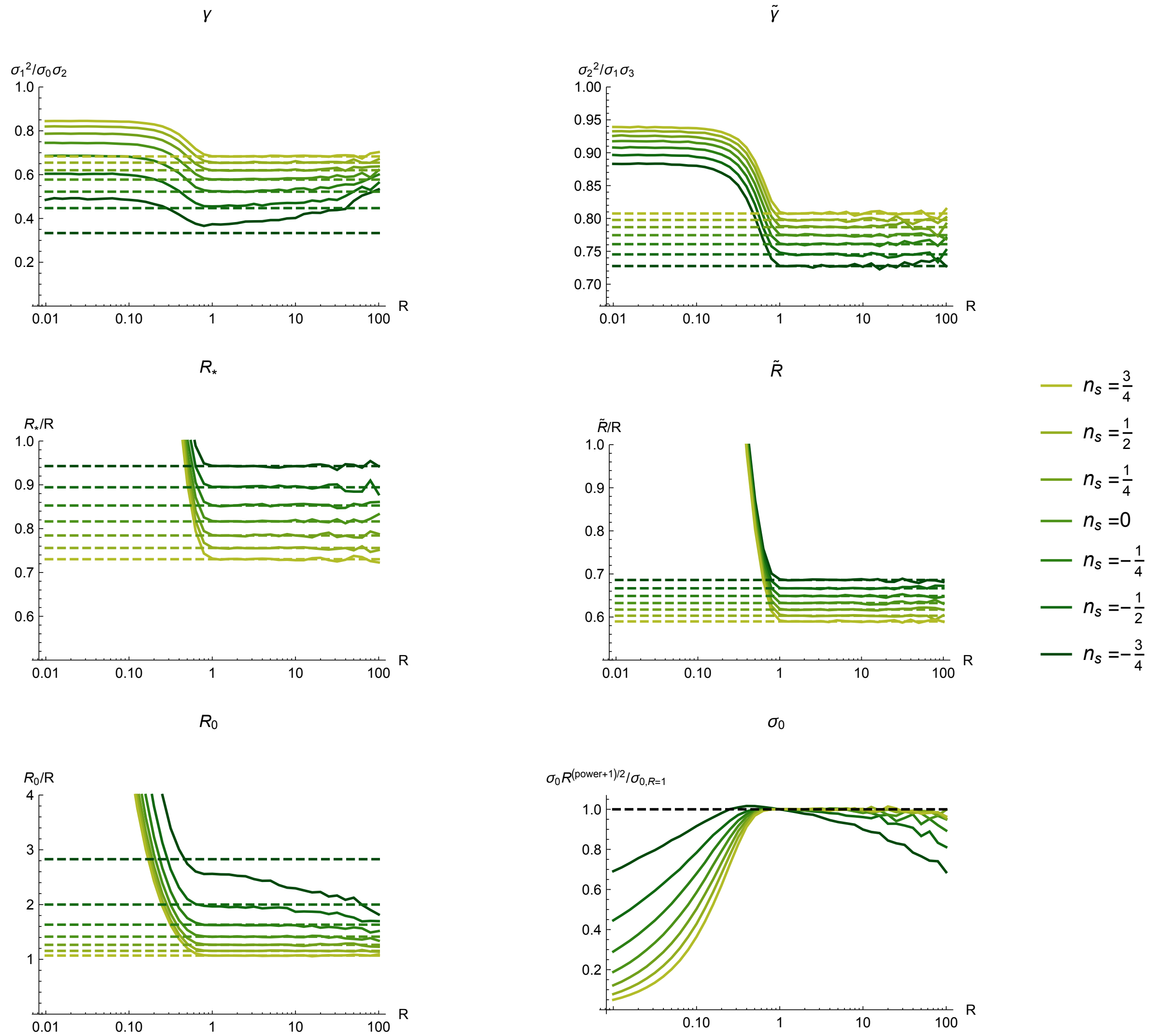
- Proxy for angular momentum associated to mergers by parametrising by the direction of the vanishing eigenvalue of the Hessian

- Make merger rate evolution predictions with respect to the power spectrum





Thank you!


γ
σ1²/σ0σ2
γ̃
σ2²/σ1σ3
R*
R*/R
R̃
R̃/R
R0
R0/R
σ0
σ0R^(power+1)/2/σ0,R=1
R
0.01
0.10
1
10
100
ns = 3/4
ns = 1/2
ns = 1/4
ns = 0
ns = −1/4
ns = −1/2
ns = −3/4

Fonctions de correlation à deux points mixtes pic/événement