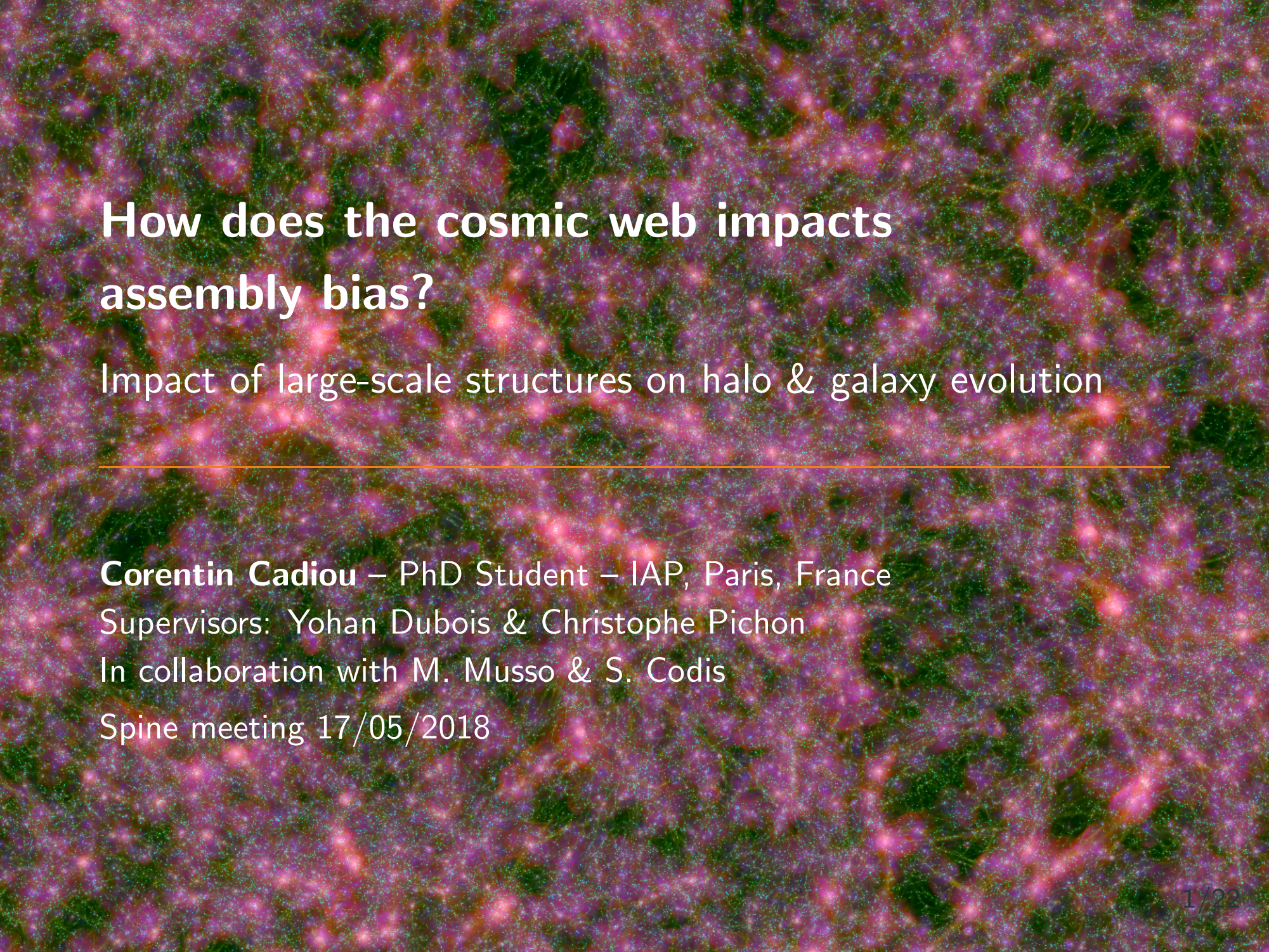


How does the cosmic web impacts assembly bias?

Impact of large-scale structures on halo & galaxy evolution

Corentin Cadiou – PhD Student – IAP, Paris, France
Supervisors: Yohan Dubois & Christophe Pichon
In collaboration with M. Musso & S. Codis

Spine meeting 17/05/2018

Table of contents

Introduction

Effect on assembly bias

- Including filaments?
- Typical mass
- Effect on (DM) accretion rate
- Effect of halo formation time
- Need for AGN feedback
- Comparison to observations & simulations

Filamentary accretion at high z

- Simple 2D setup
- Predicting the torque

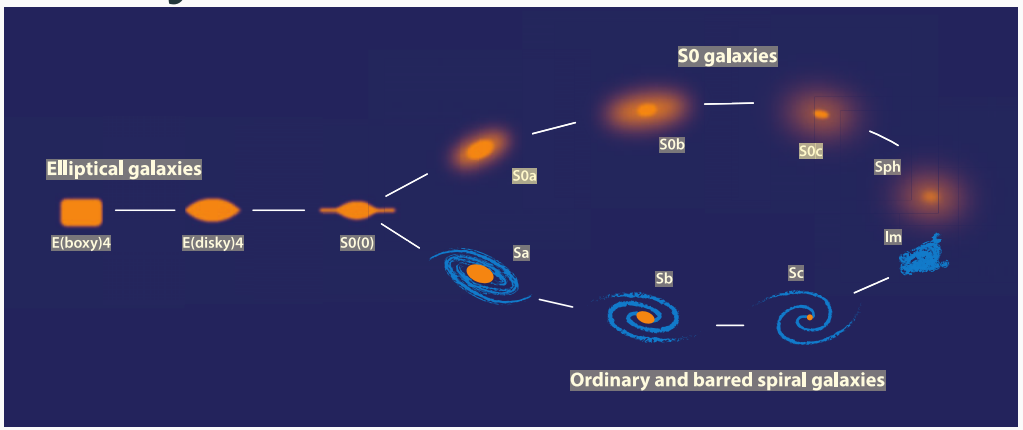
Conclusions

Introduction

What's the link between galaxy/halo formation and large-scale structures?

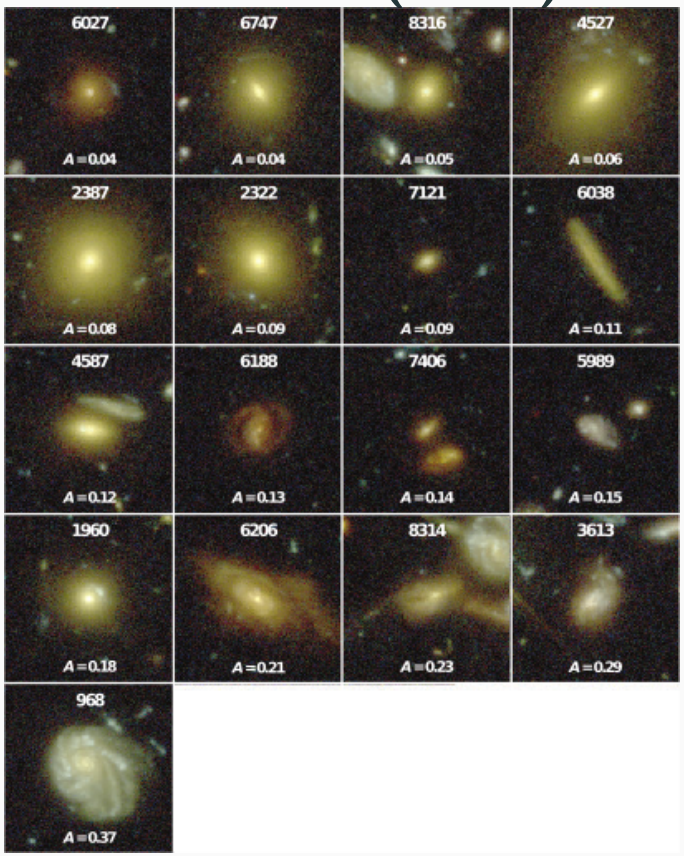
Describing galaxies?

Theory



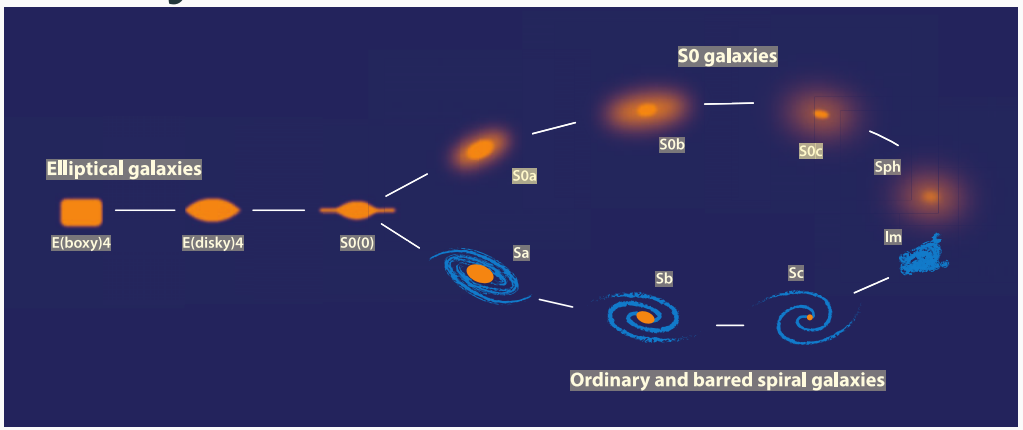
+ star forming?
+ bulge?
+ mass?
+ DM halo mass?
+ DM profile?
+ ...

Observations (HDF)

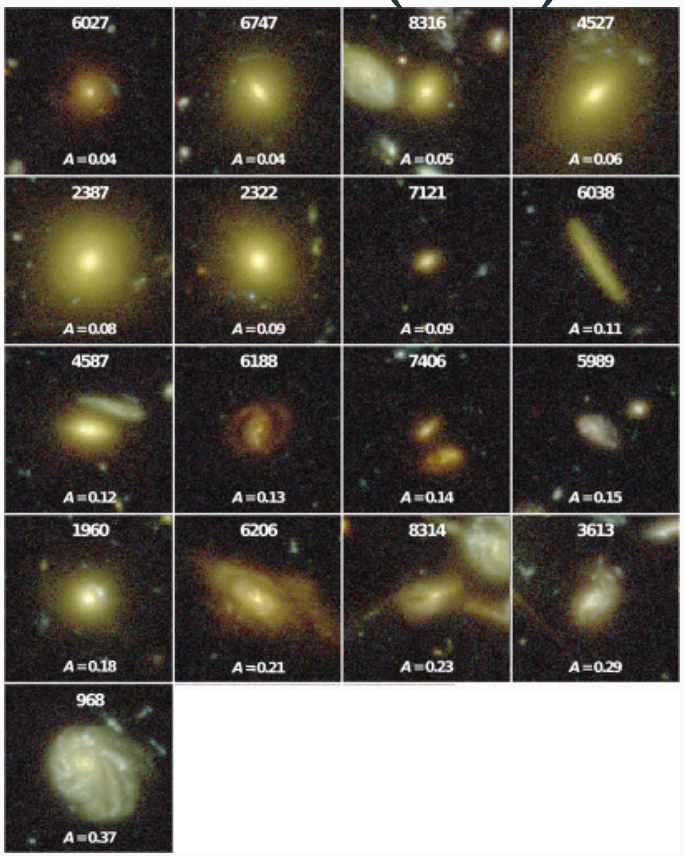


Describing galaxies?

Theory



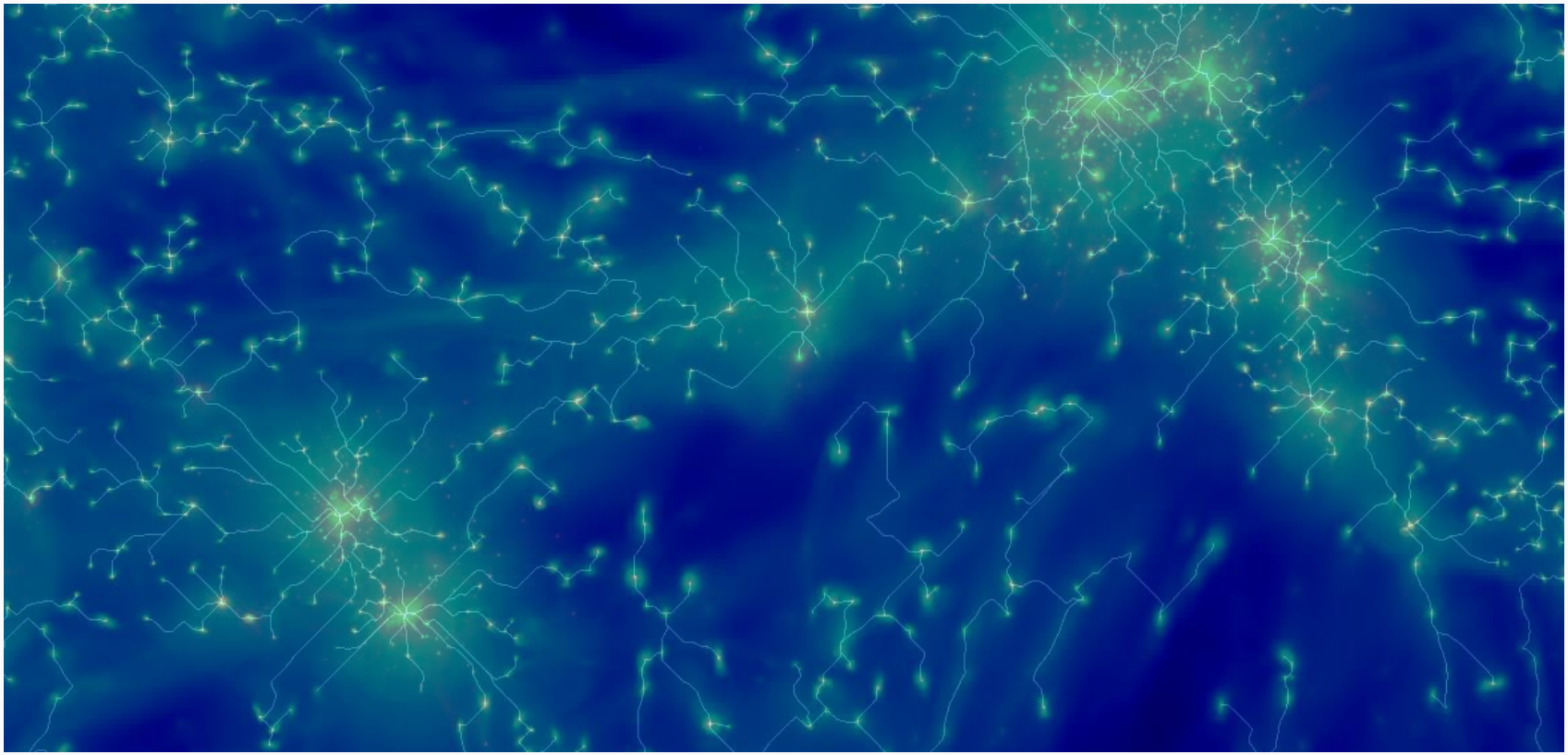
Observations (HDF)



+ star forming?
+ bulge?
+ mass?
+ DM halo mass?
+ DM profile?
+ ...

And all the properties **change with cosmic time**...

Cosmic Web

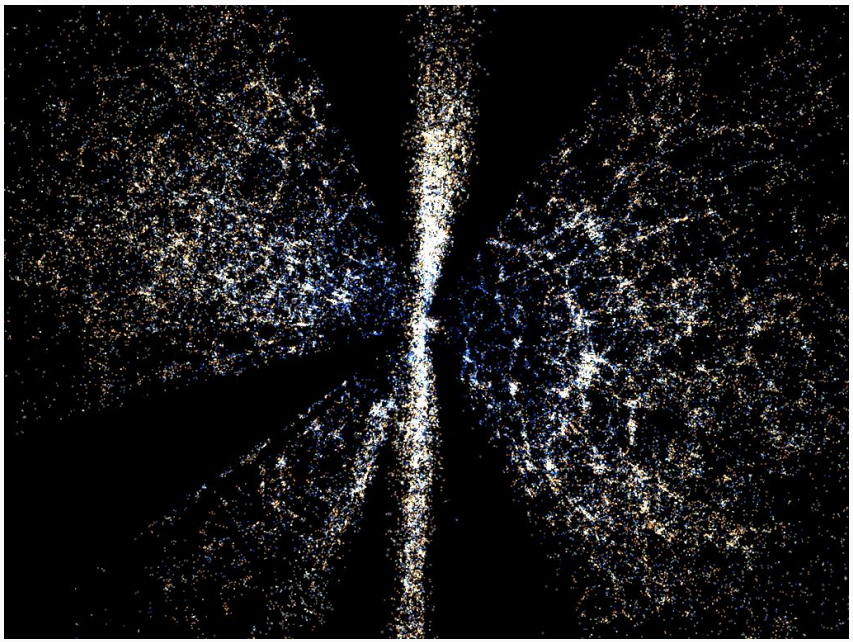


Horizon-AGN simulation with skeleton, Dubois+12

And all the properties **change with cosmic time** and location w.r.t. **the cosmic web** (see .e.g K. Kraljic+2017)!

Cosmic Web

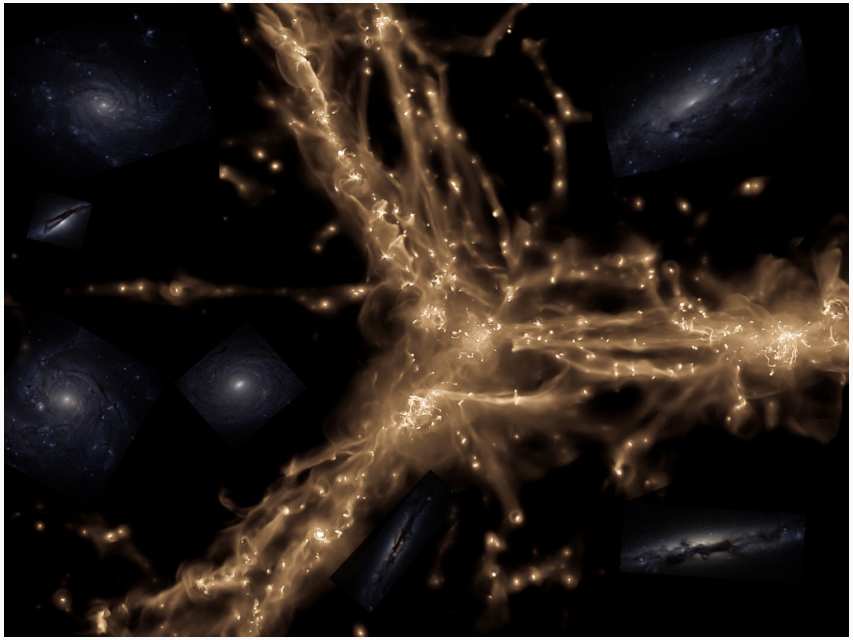
- Geometry of the density/potential field
- Voids, walls, filaments, peaks (resp. 3, 2, 1, 0D)



SDSS

Cosmic Web

- Geometry of the density/potential field
- Voids, walls, filaments, peaks (resp. 3, 2, 1, 0D)

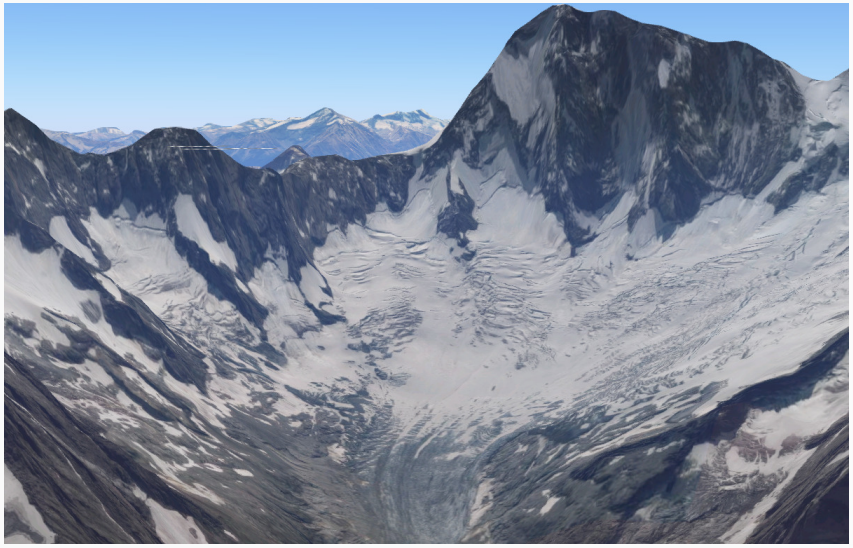


New Horizon simulation

Cosmic Web

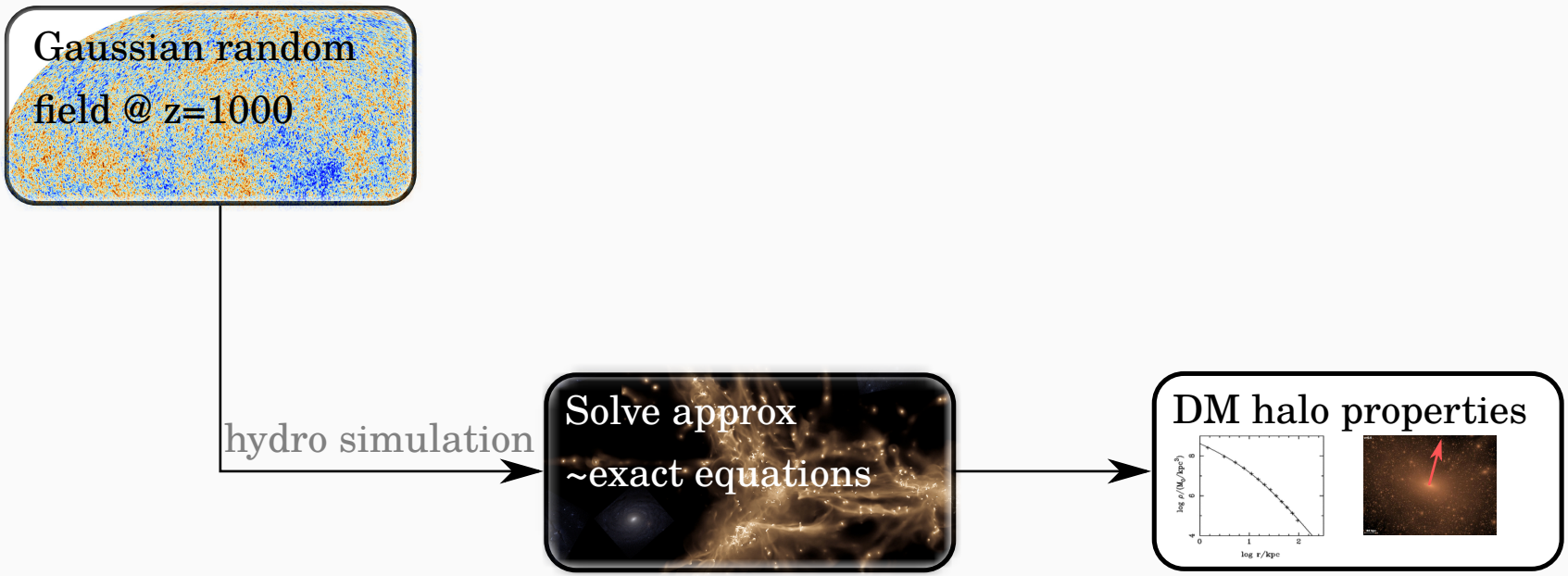
- Geometry of the density/potential field
- Voids, walls, filaments, peaks (resp. 3, 2, 1, 0D)

  or
- Critical points (0D)

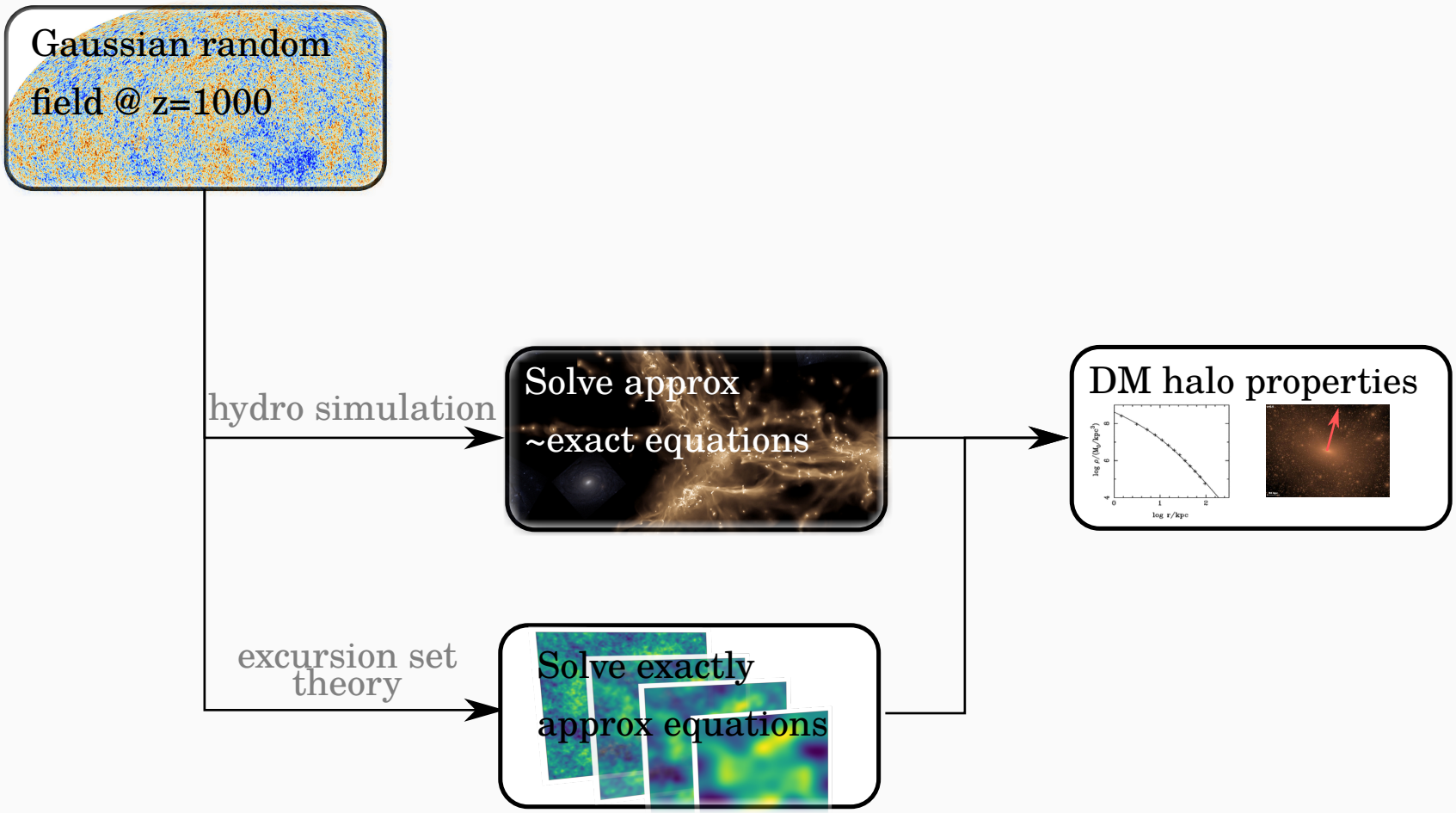


Effect on assembly bias

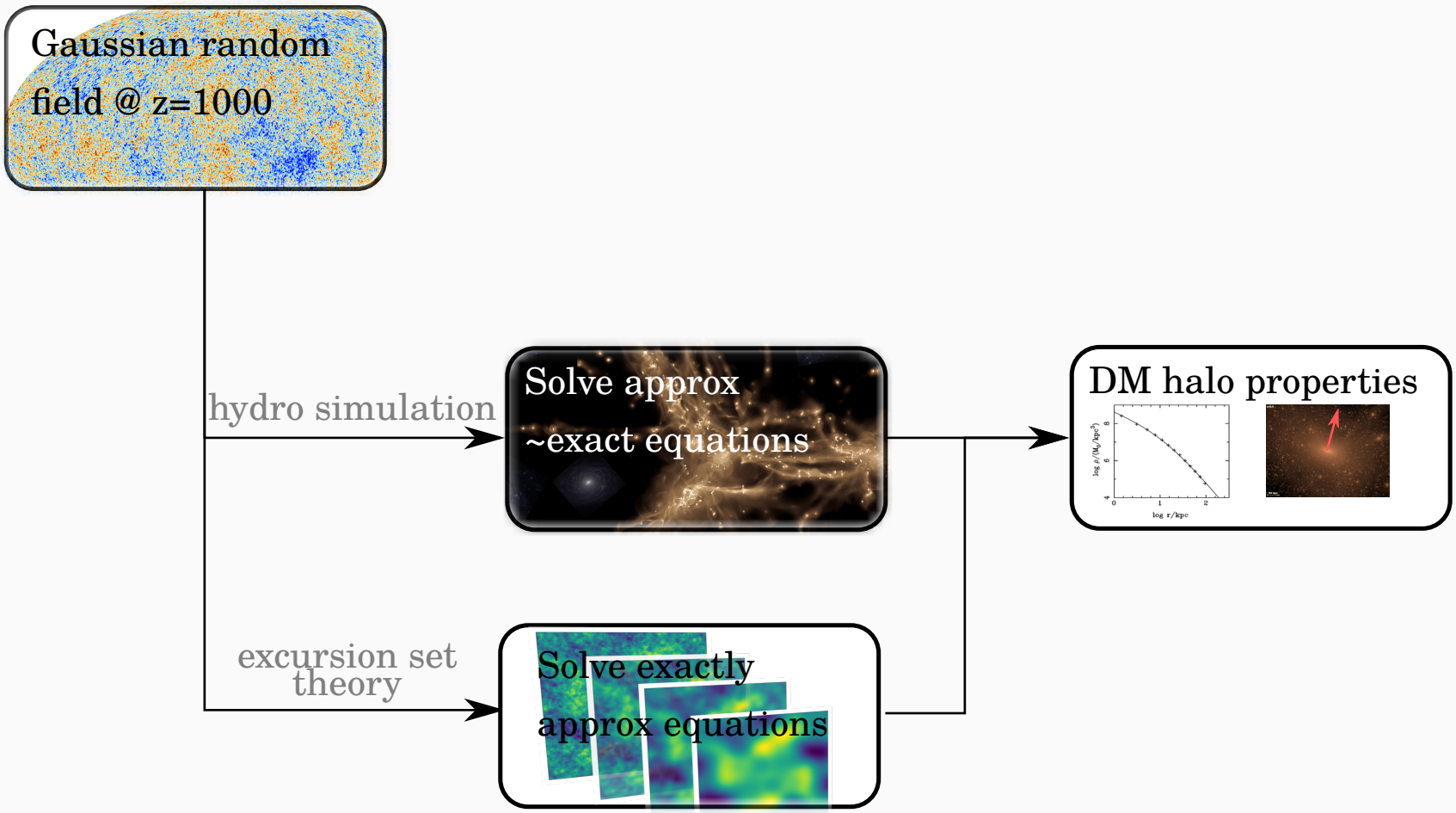
Excursion set theory – saving a few M CPU.hrs



Excursion set theory – saving a few M CPU.hrs



Excursion set theory – saving a few M CPU.hrs

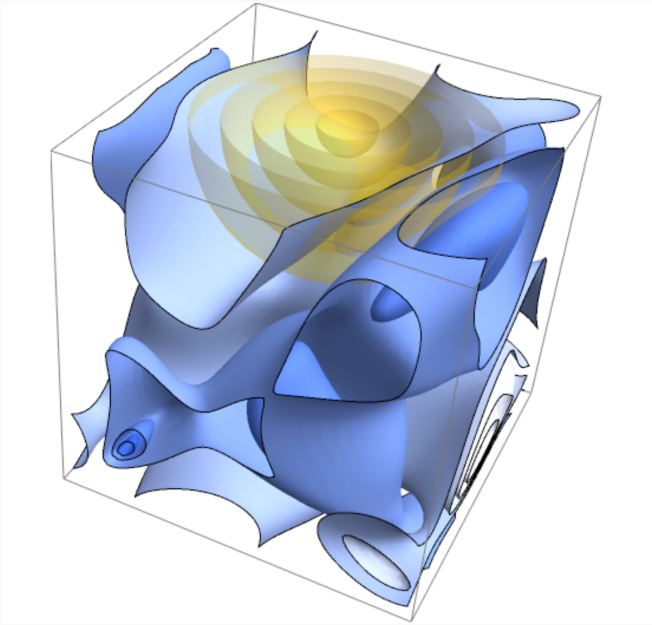


Press&Schechter 74, Bond+91, ...

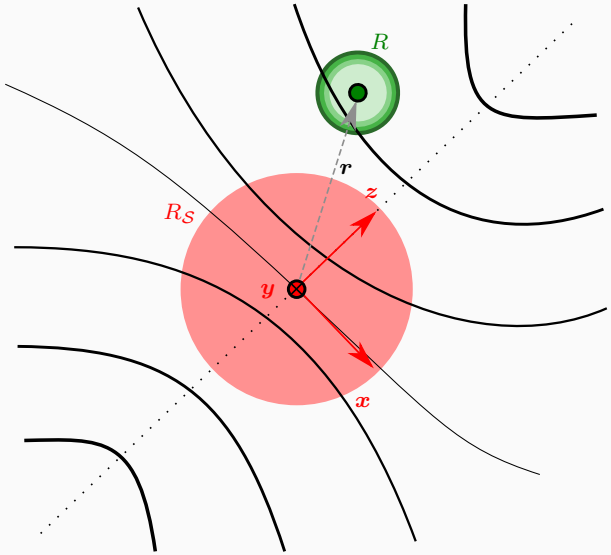
Theoretical setup

Excursion set theory
Galaxy properties & evolution from initial conditions

$\Rightarrow$ Find largest mass that will collapse by z at given location

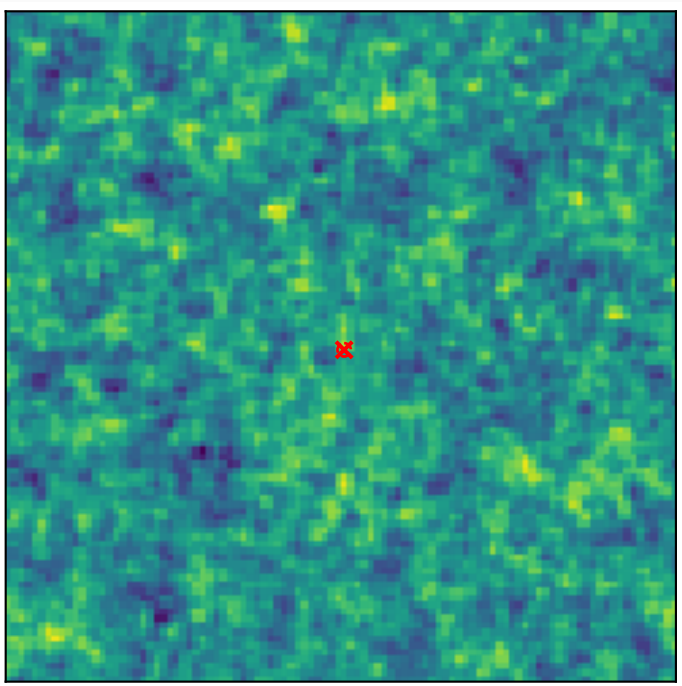


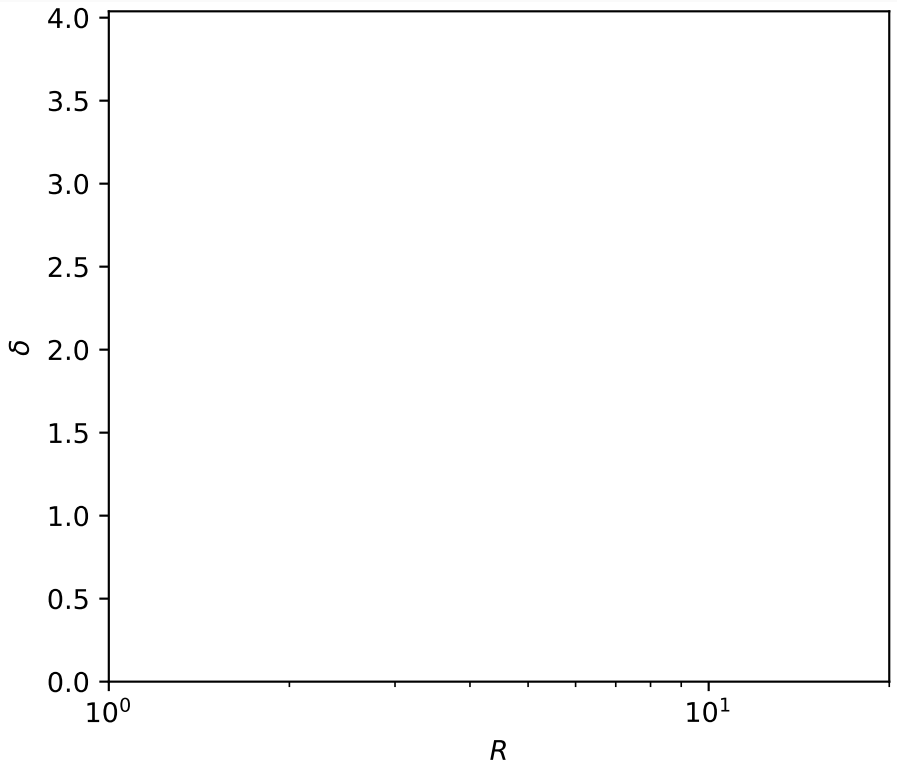
Courtesy of C. Pichon



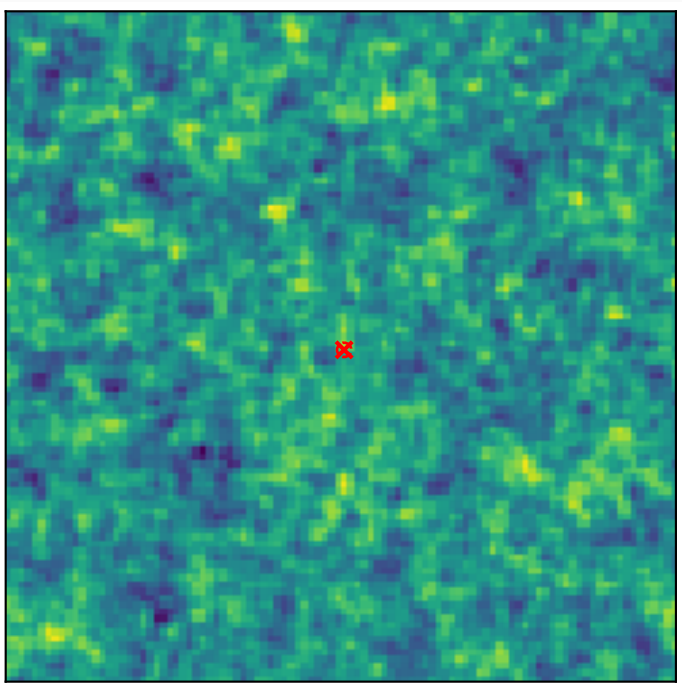
Simulation	Theory
M	R
z, t	$\delta = \frac{\rho - \bar{\rho}}{\bar{\rho}}$

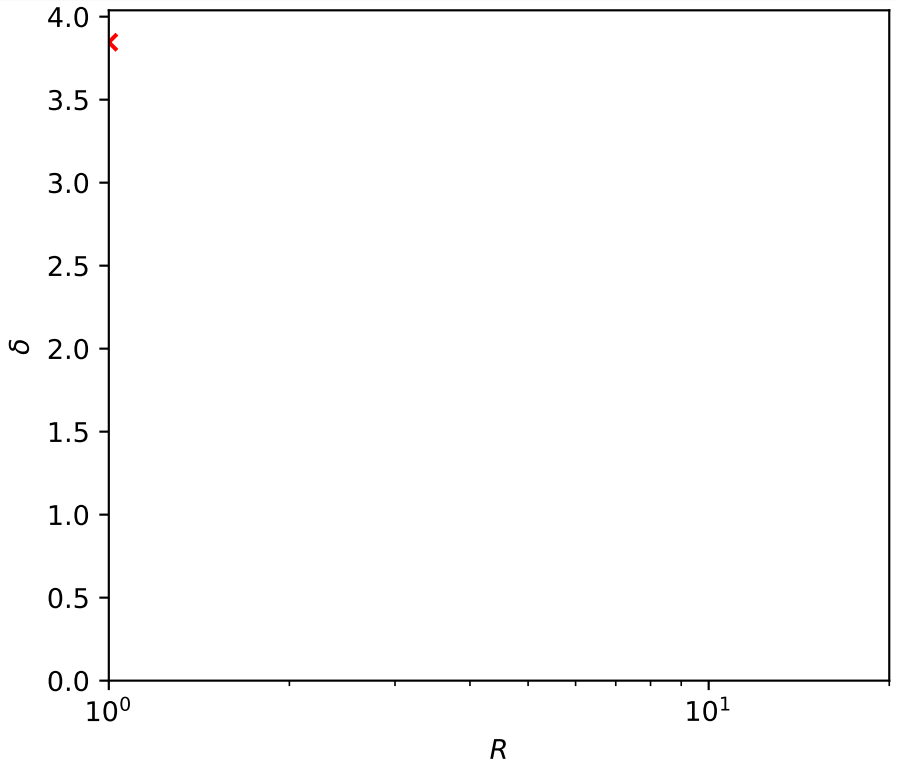
Excursion set illustrated



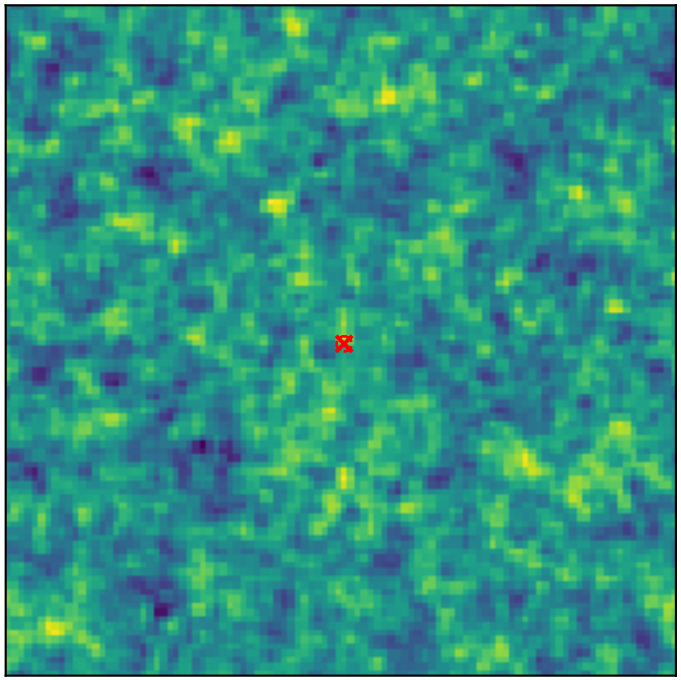


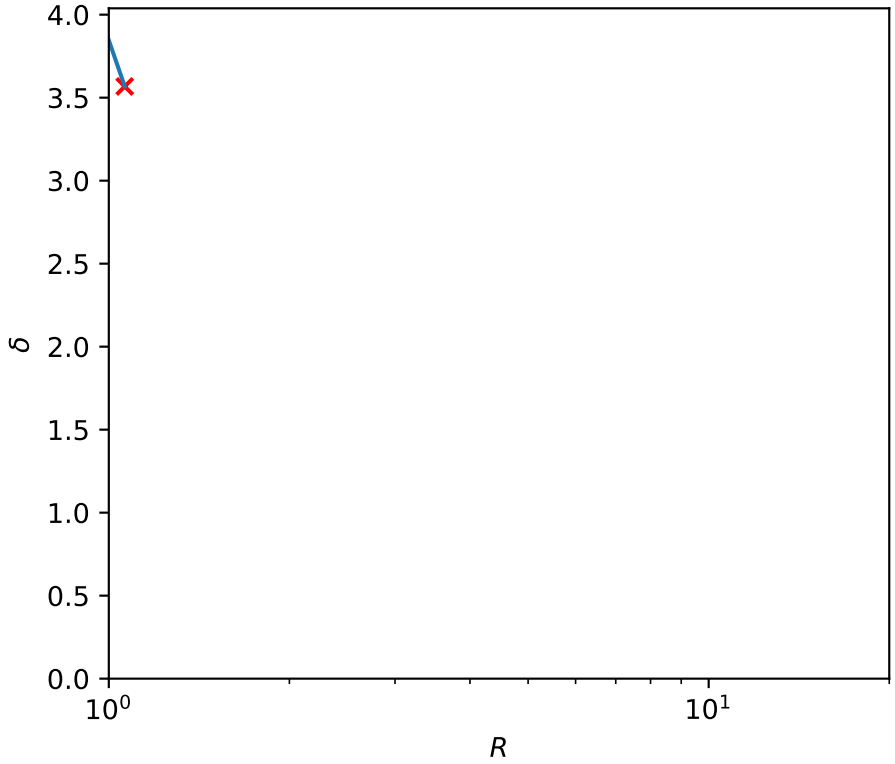
Excursion set illustrated



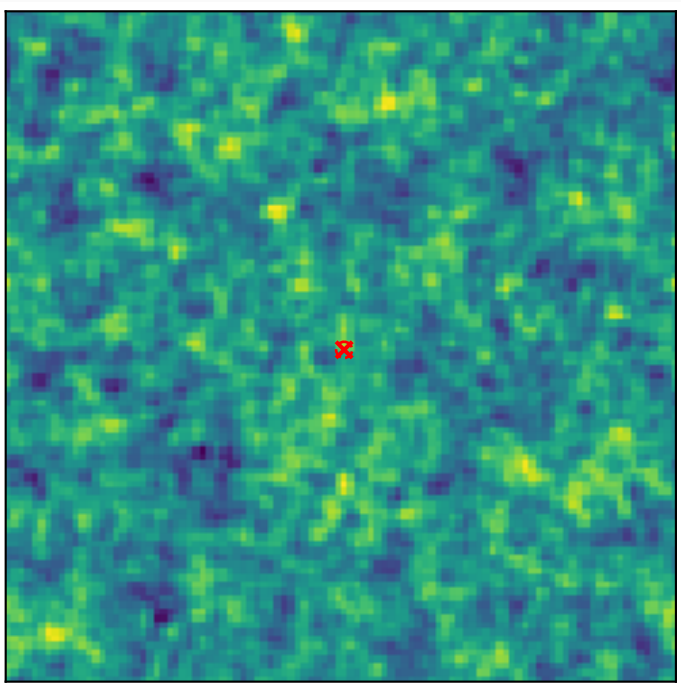


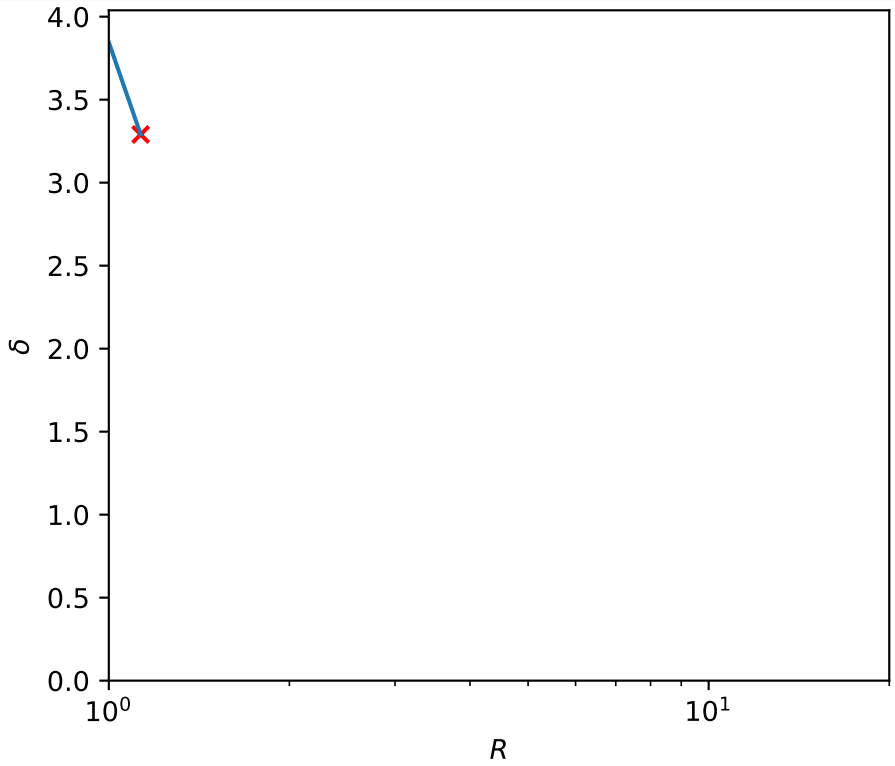
Excursion set illustrated



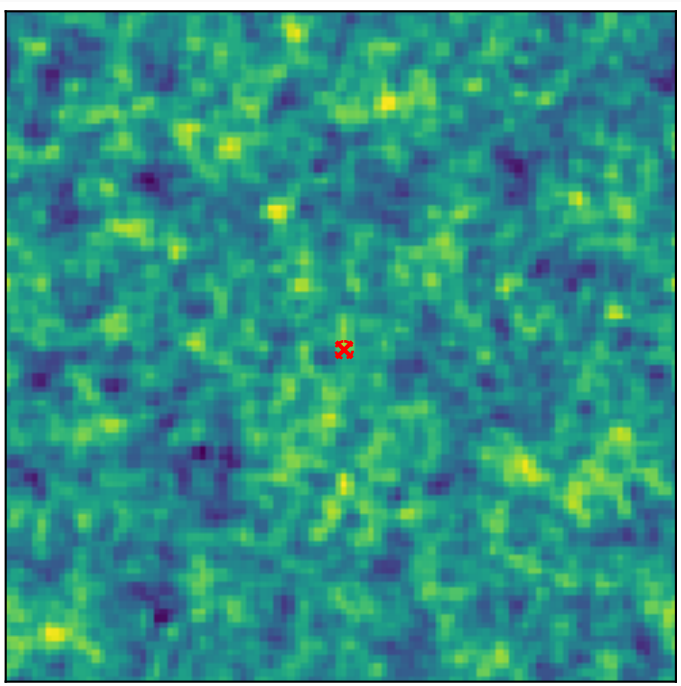


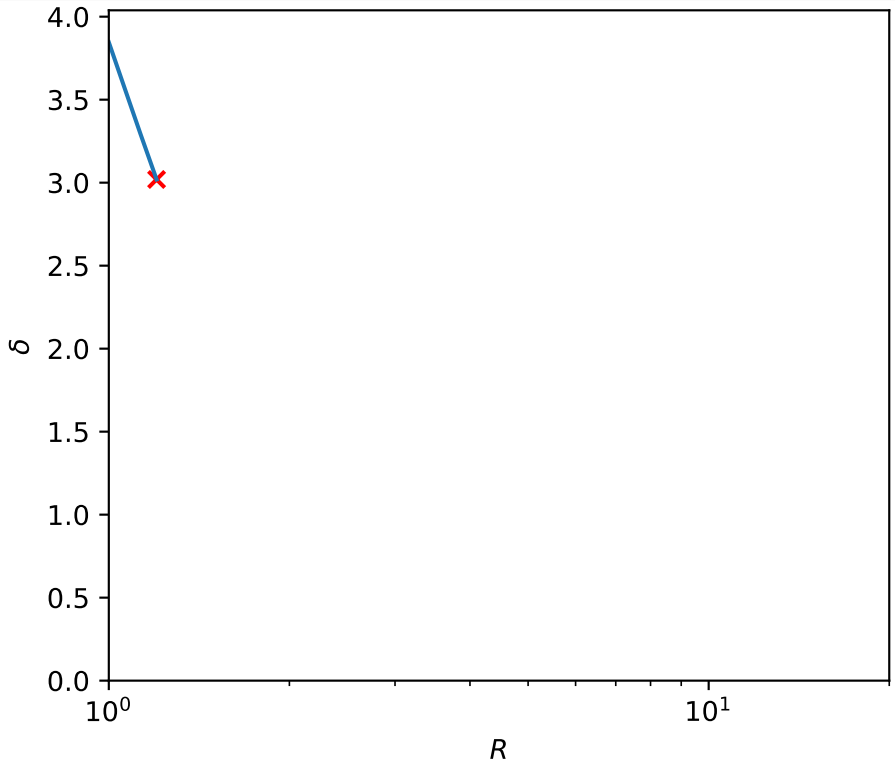
Excursion set illustrated



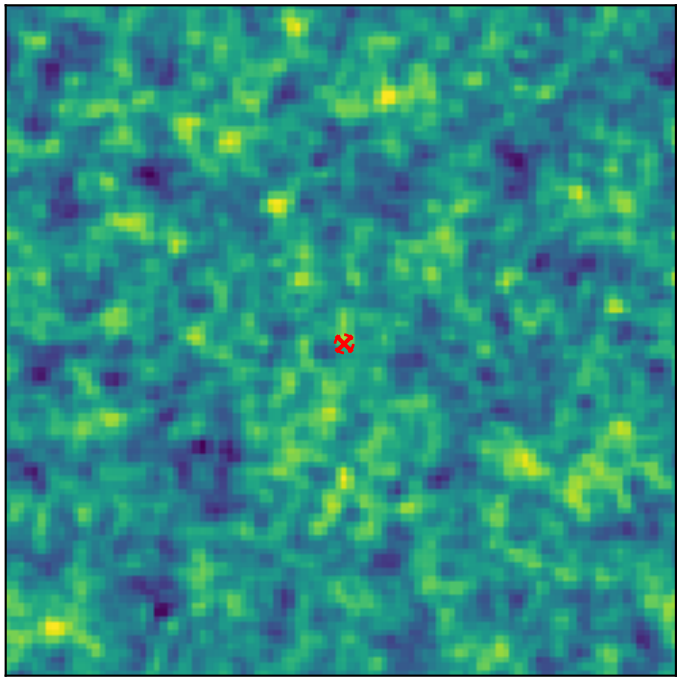


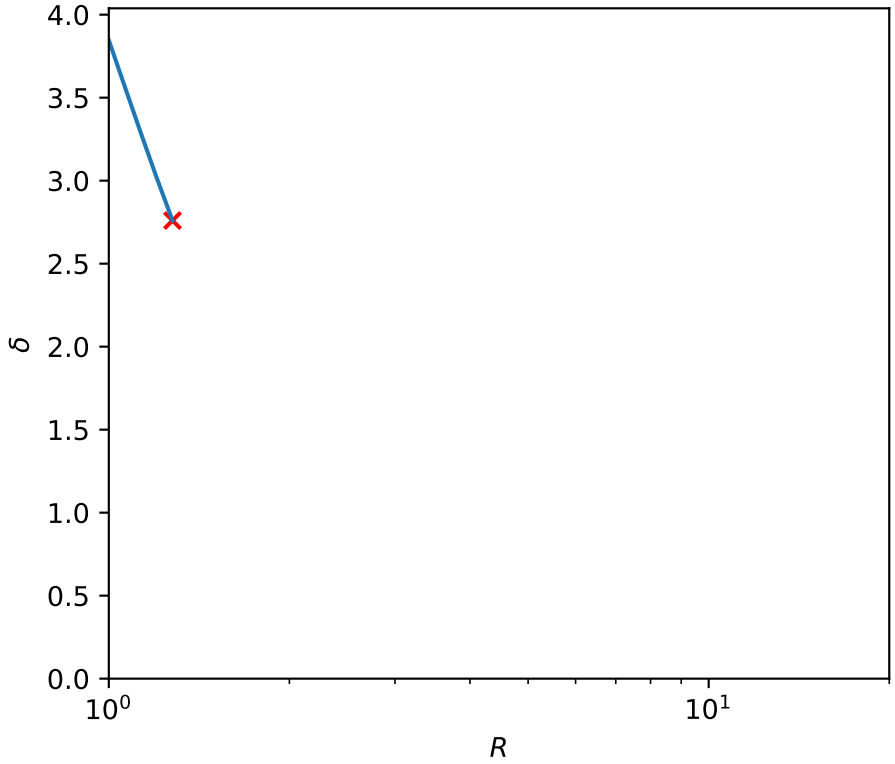
Excursion set illustrated



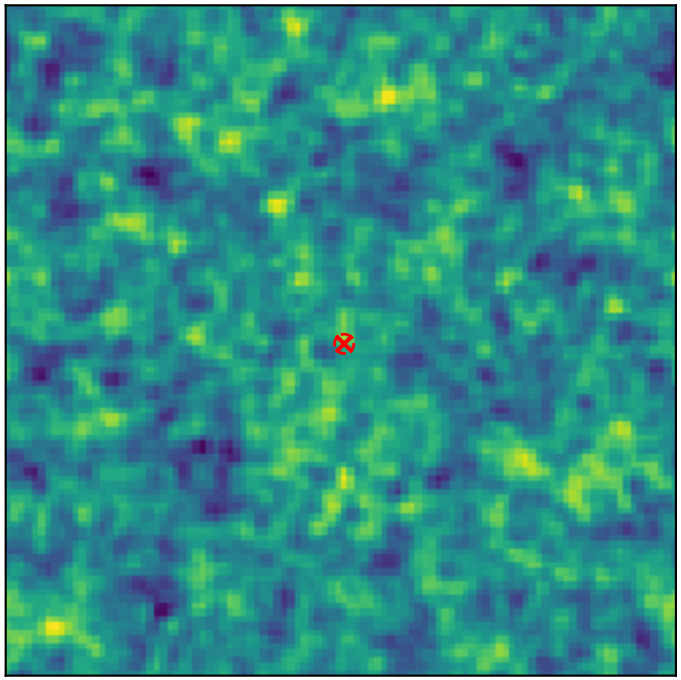


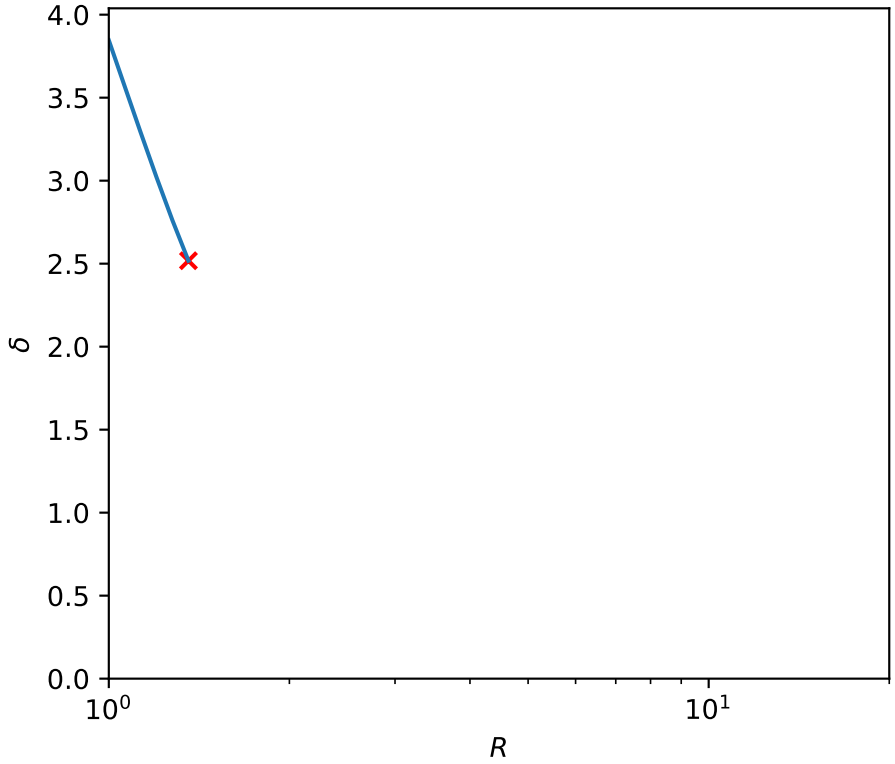
Excursion set illustrated



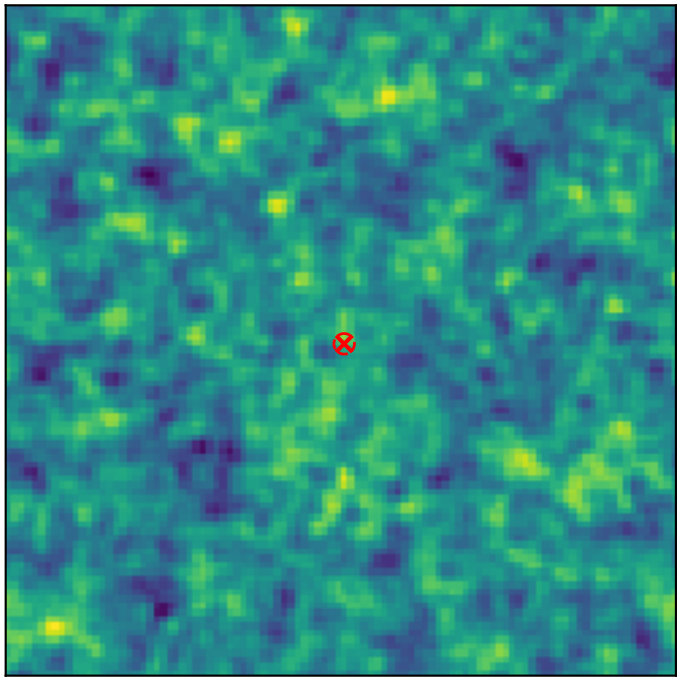


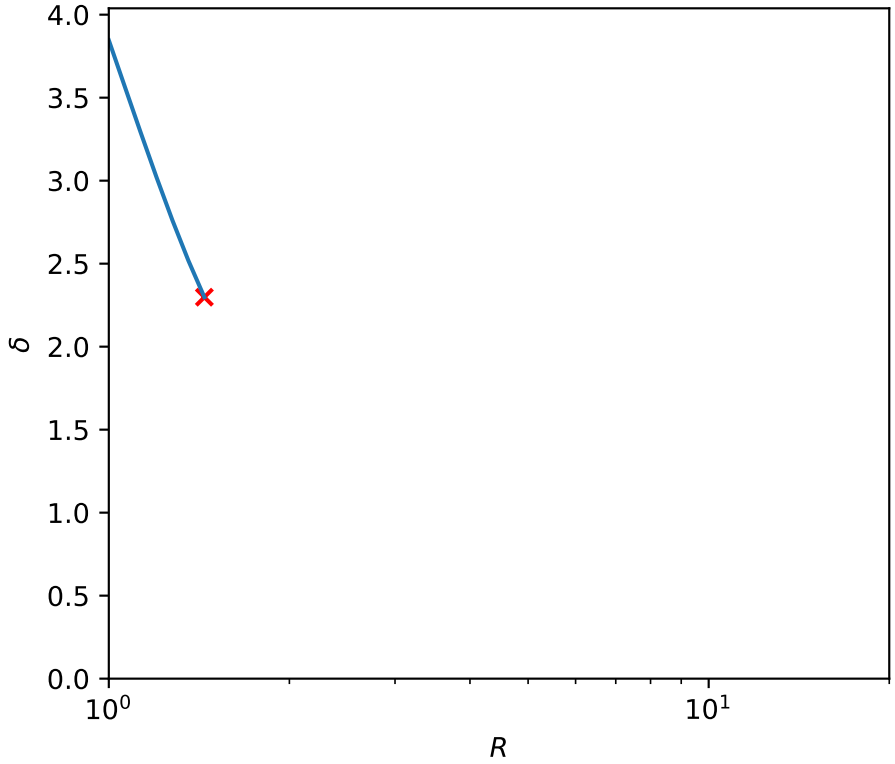
Excursion set illustrated



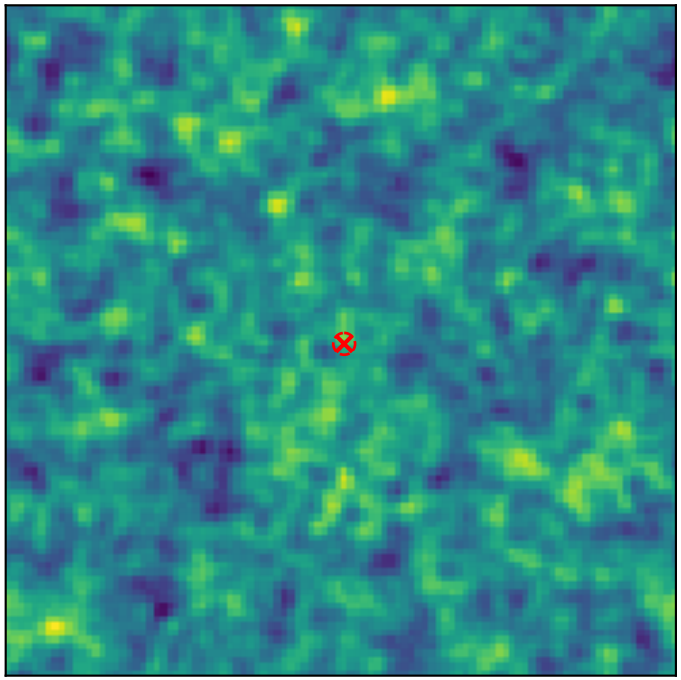


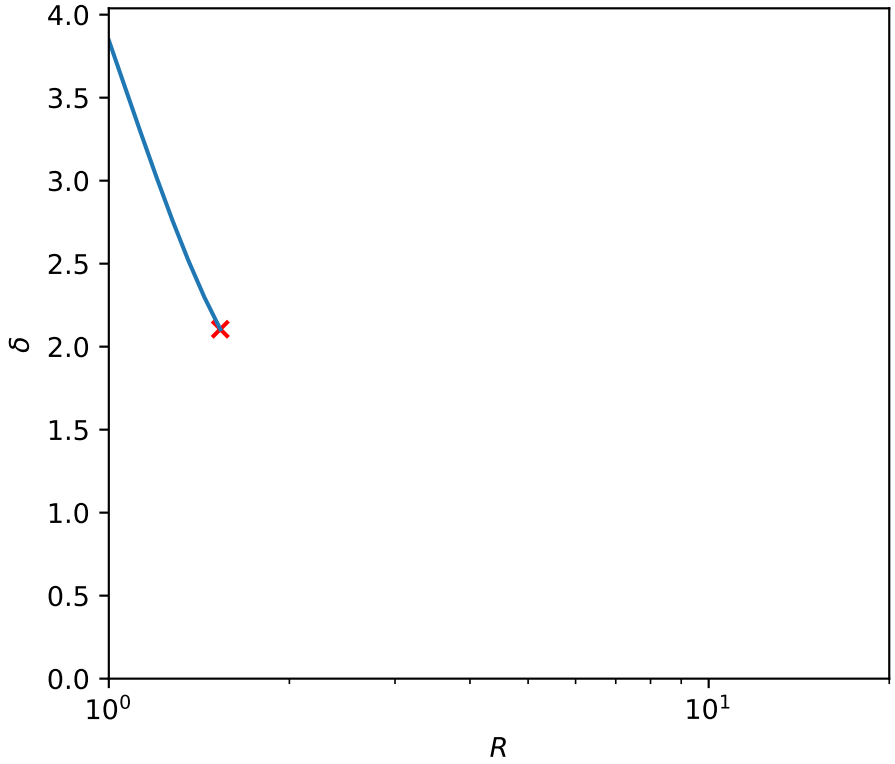
Excursion set illustrated



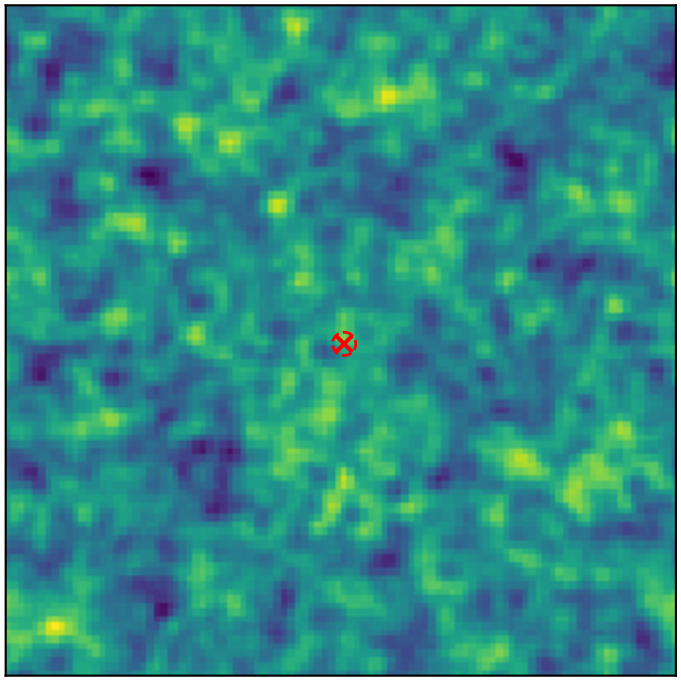


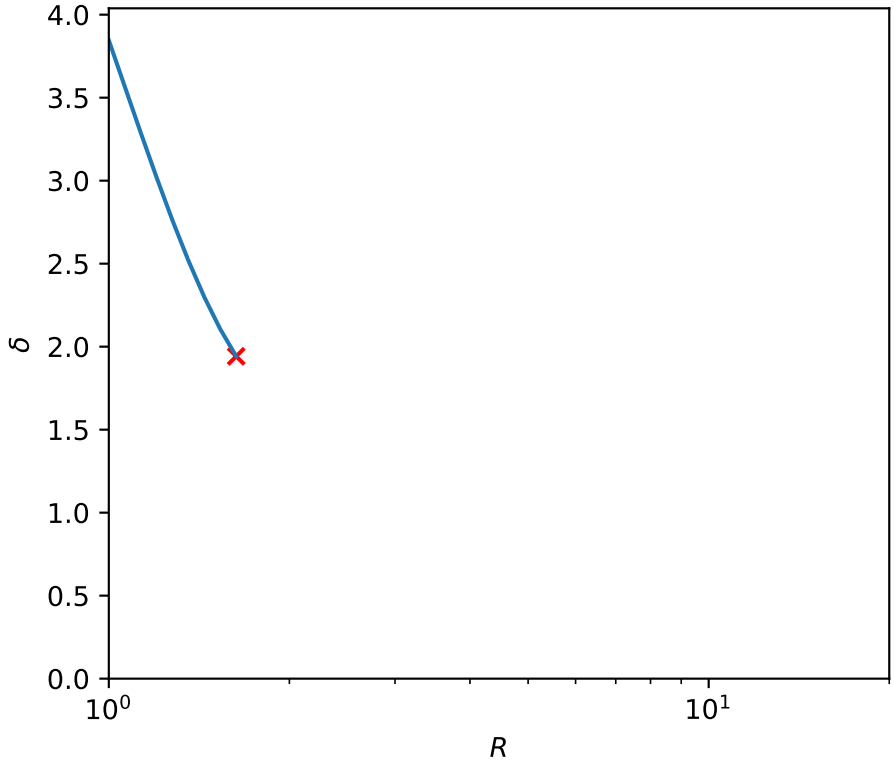
Excursion set illustrated



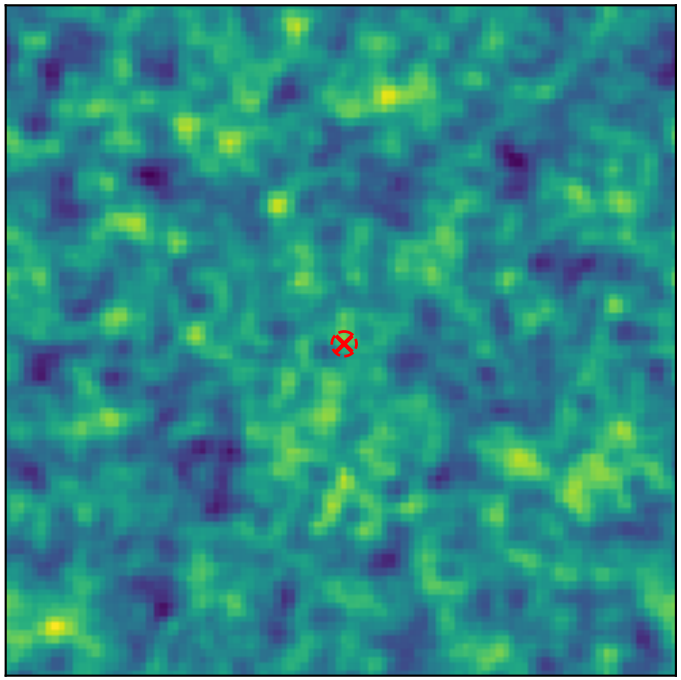


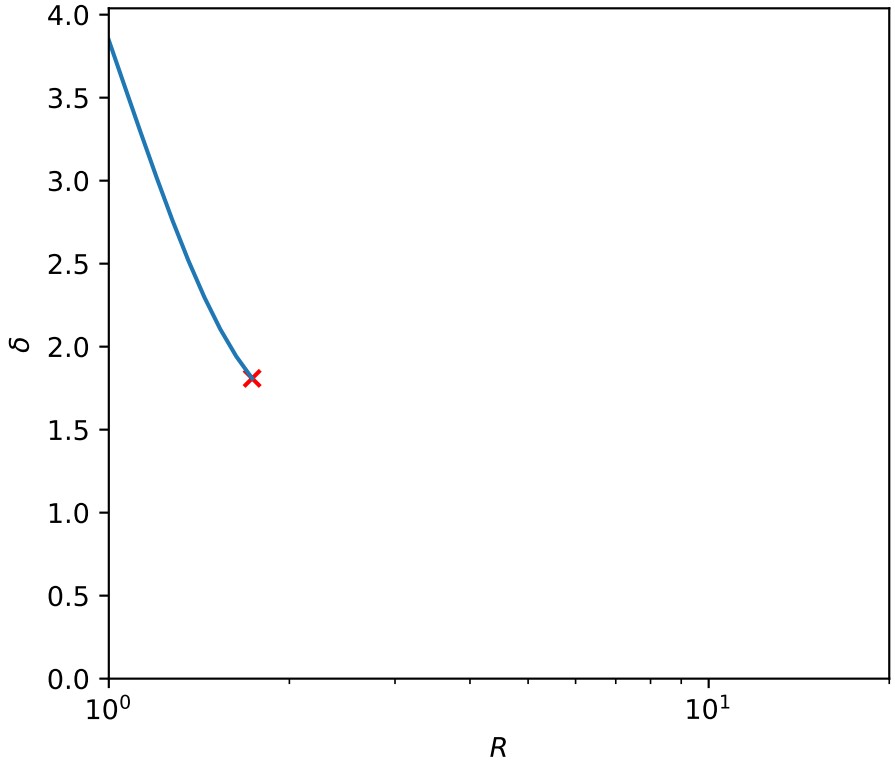
Excursion set illustrated



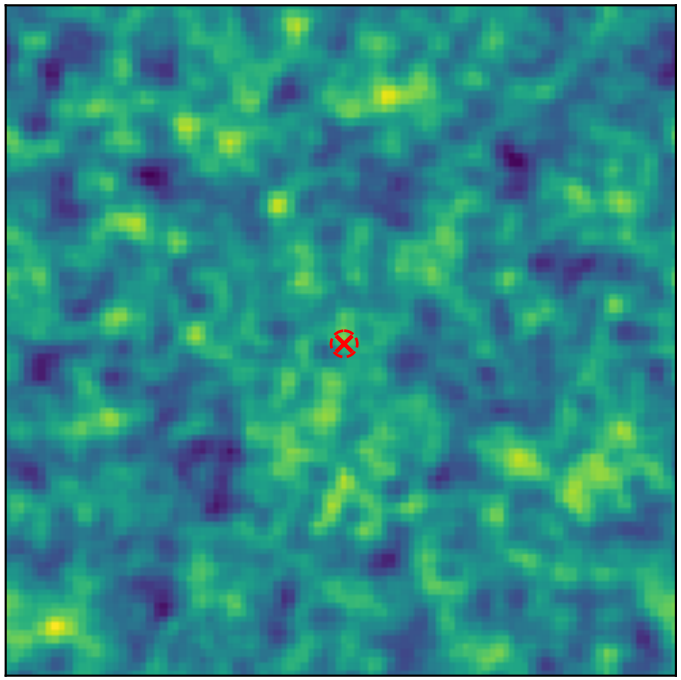


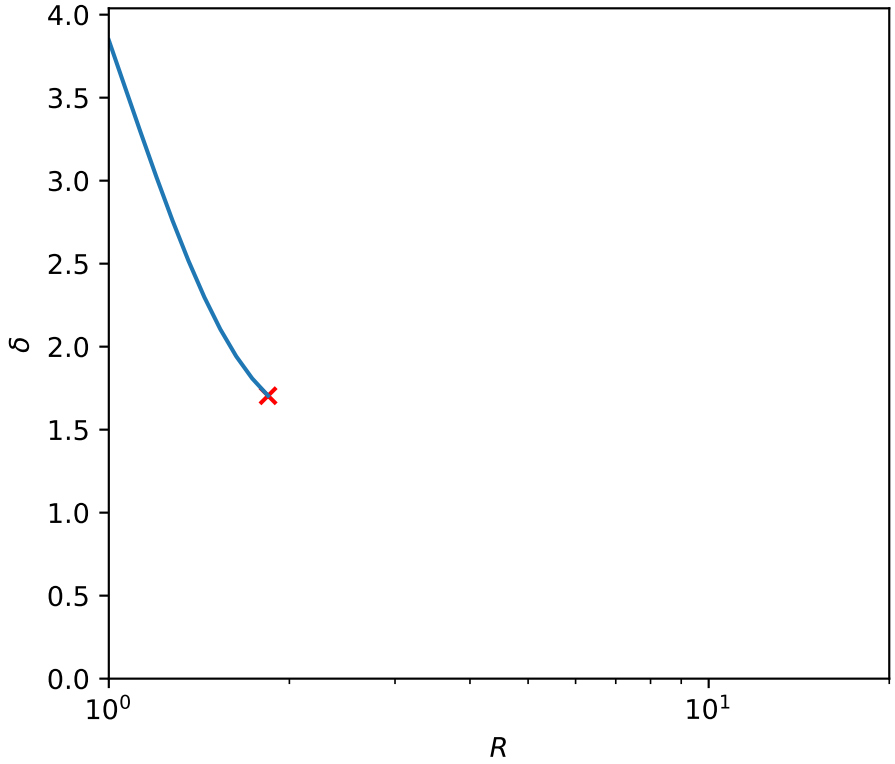
Excursion set illustrated



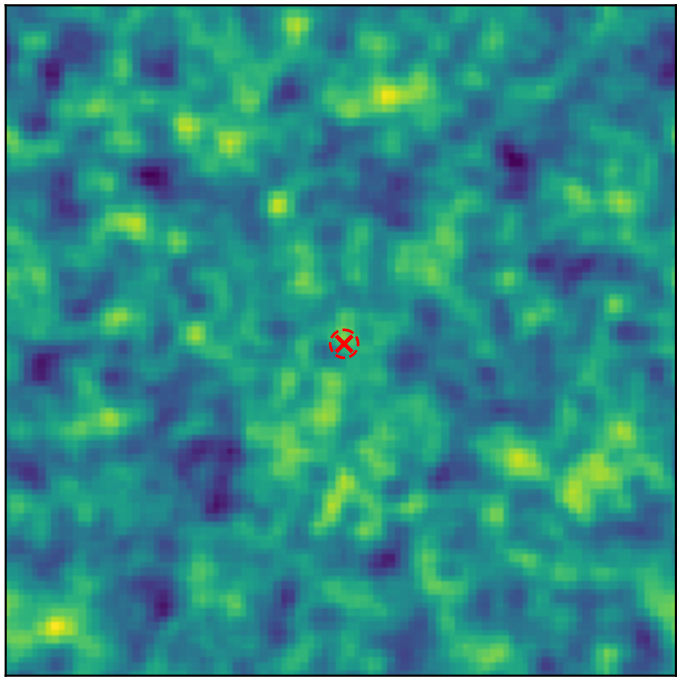


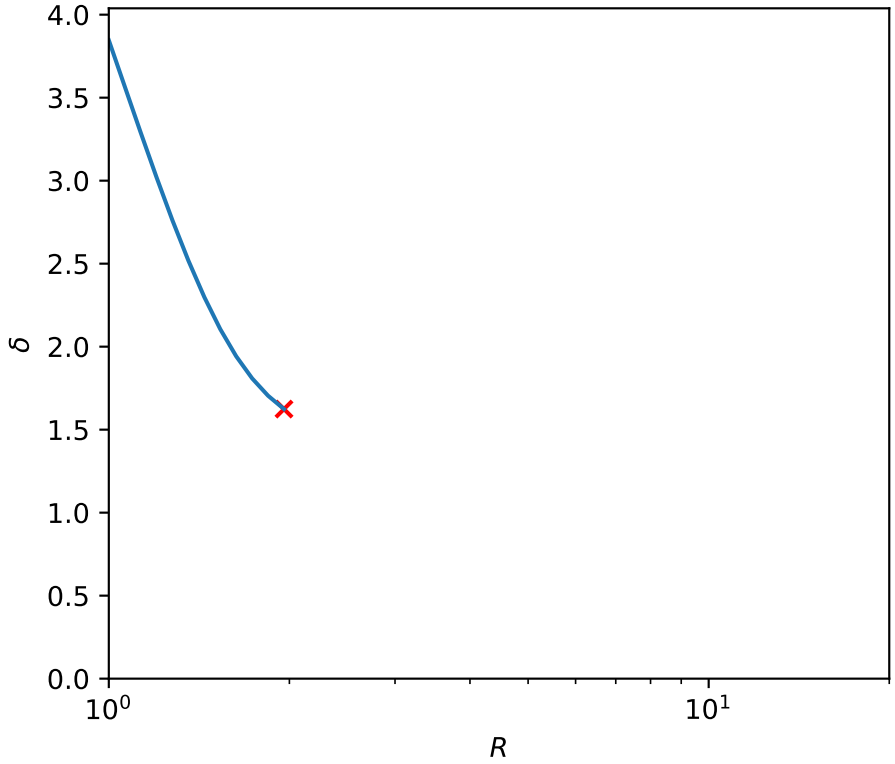
Excursion set illustrated



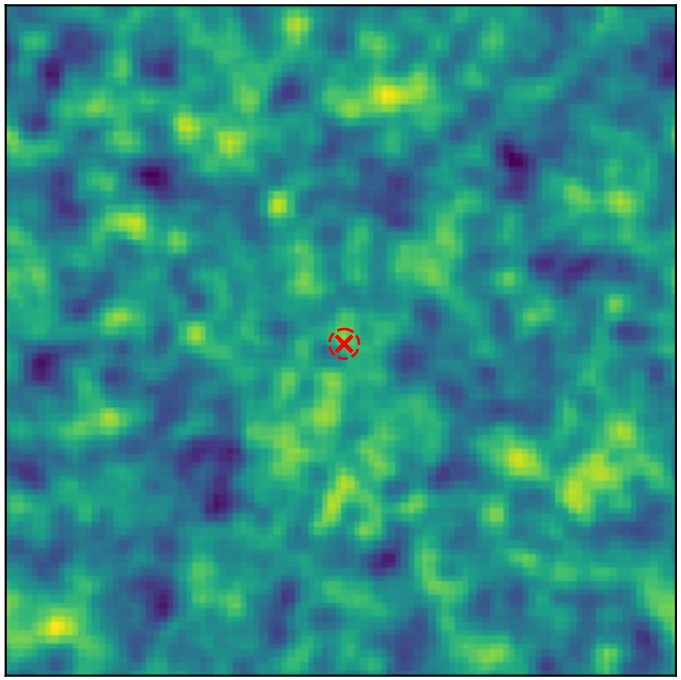


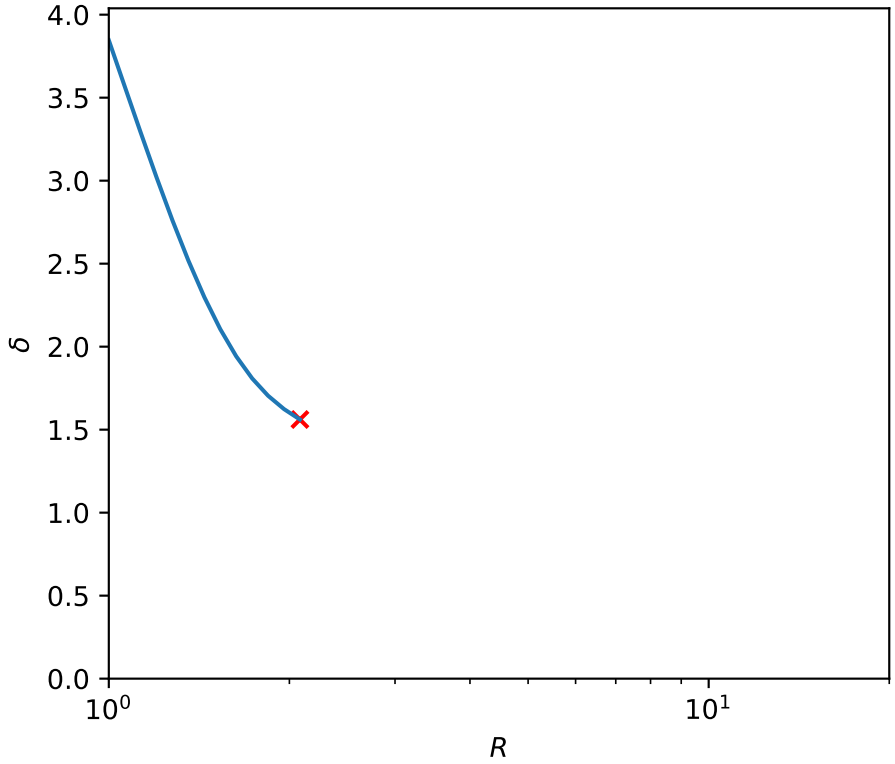
Excursion set illustrated



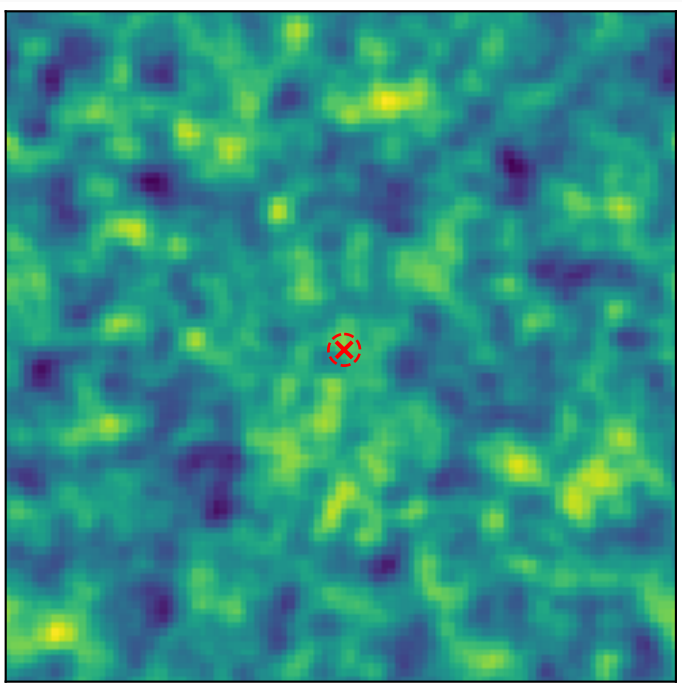


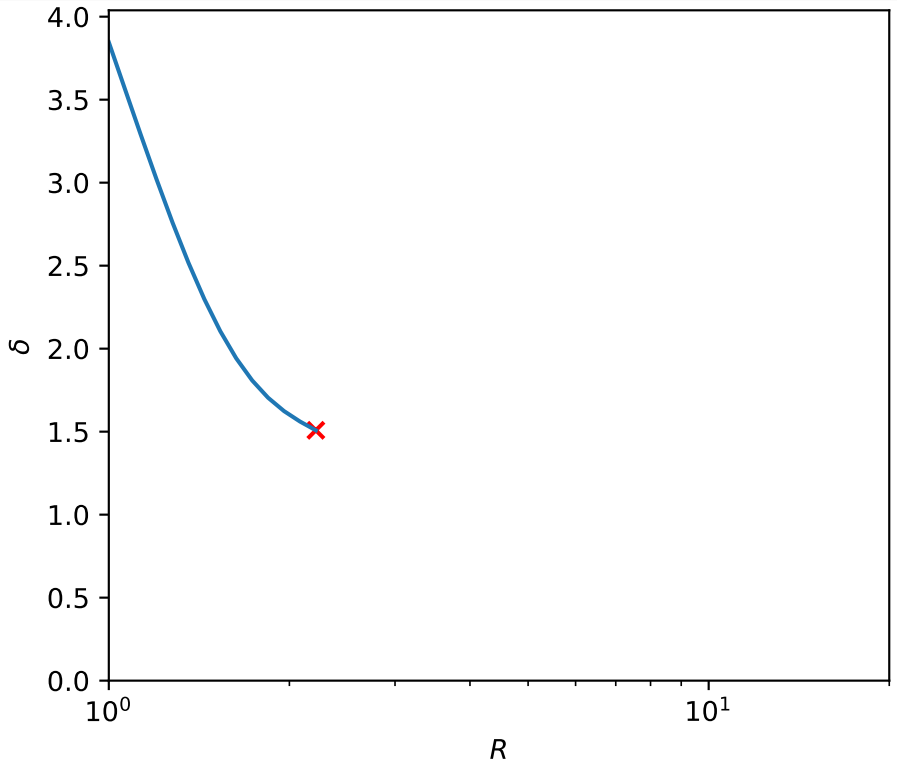
Excursion set illustrated



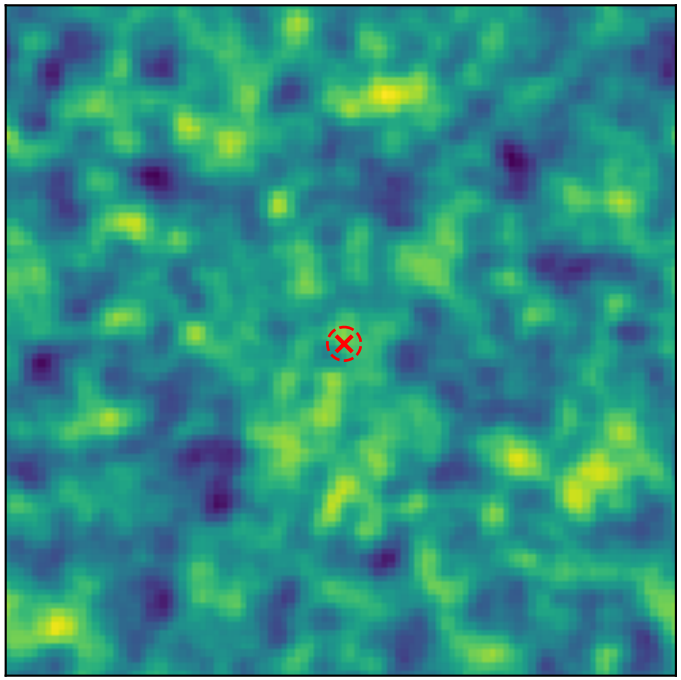


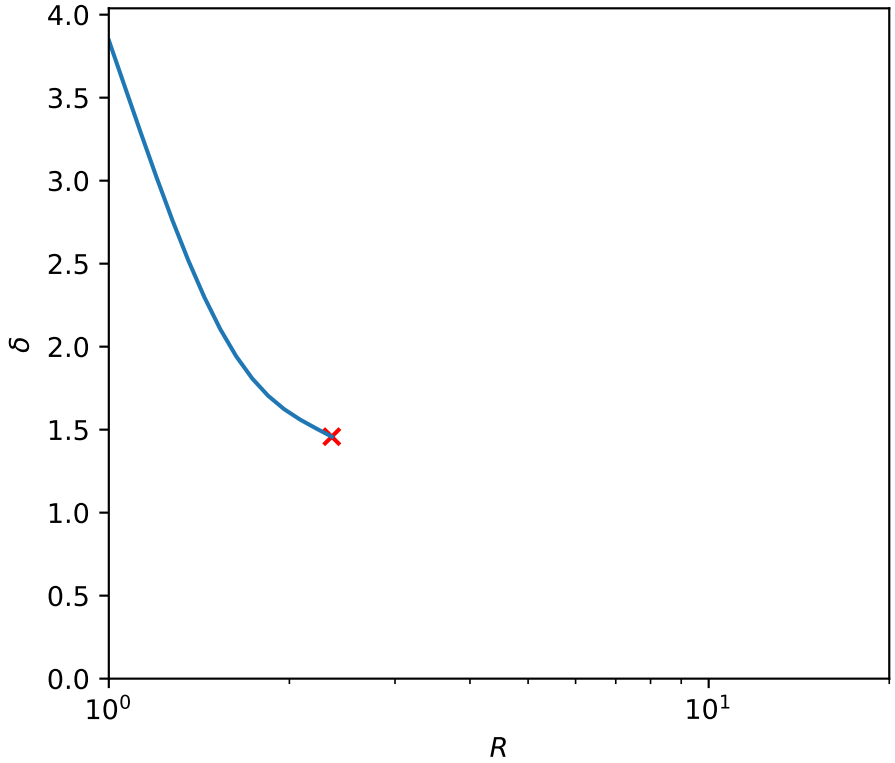
Excursion set illustrated



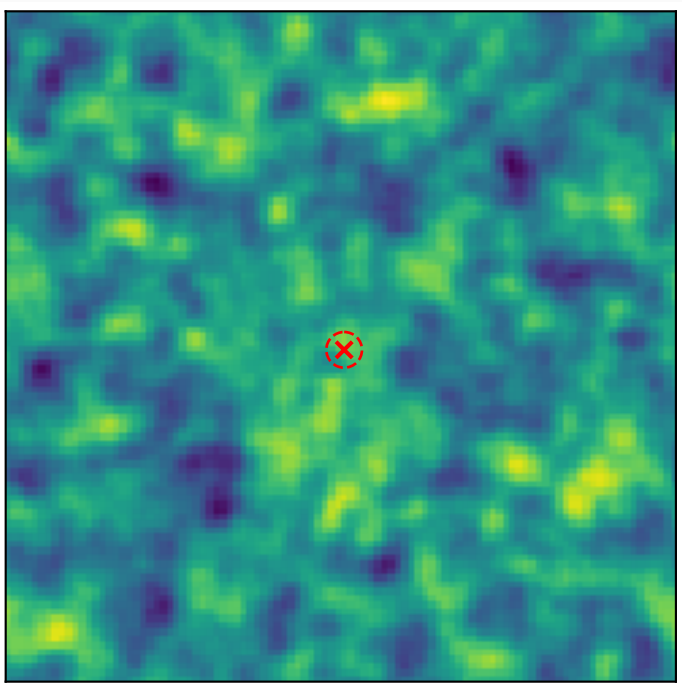


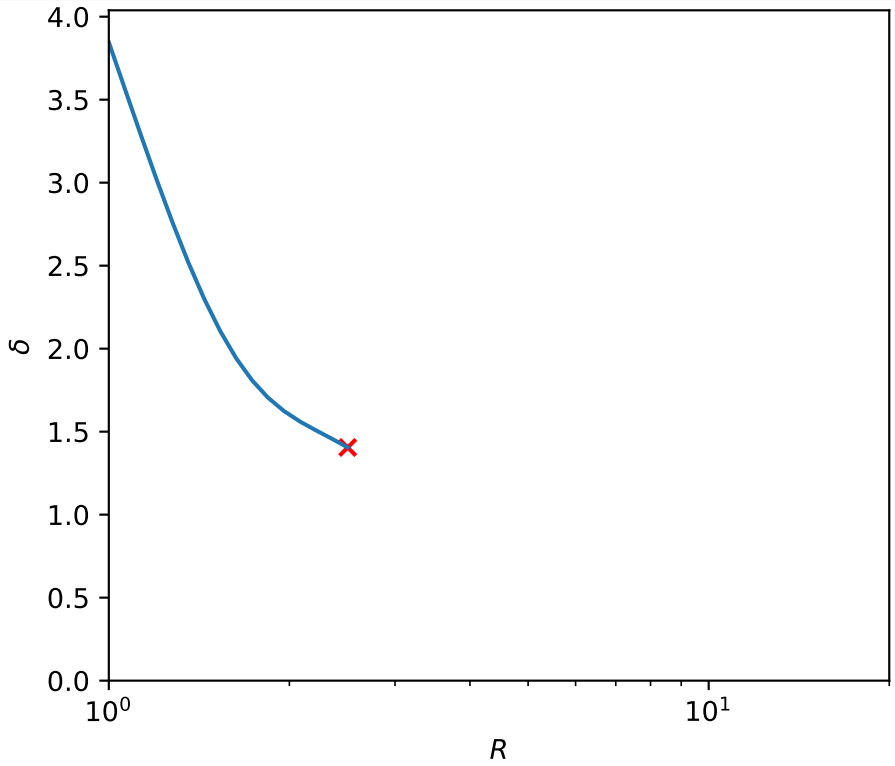
Excursion set illustrated



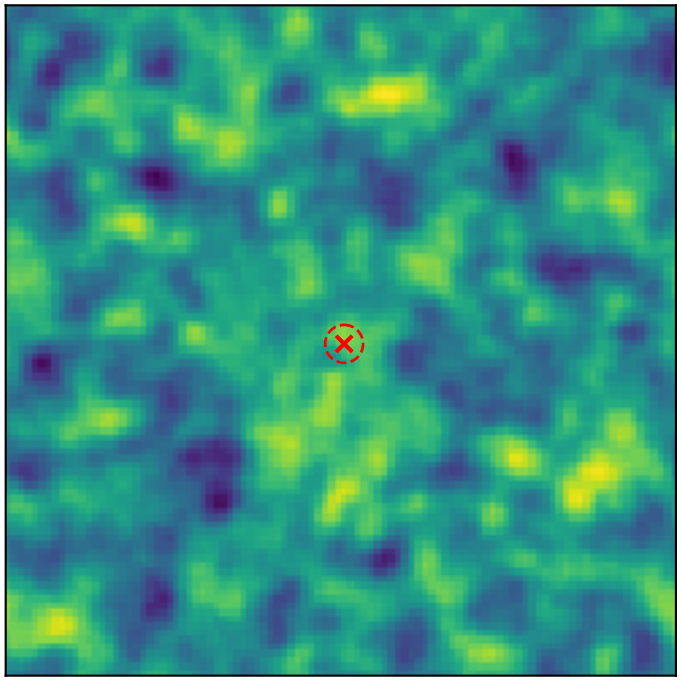


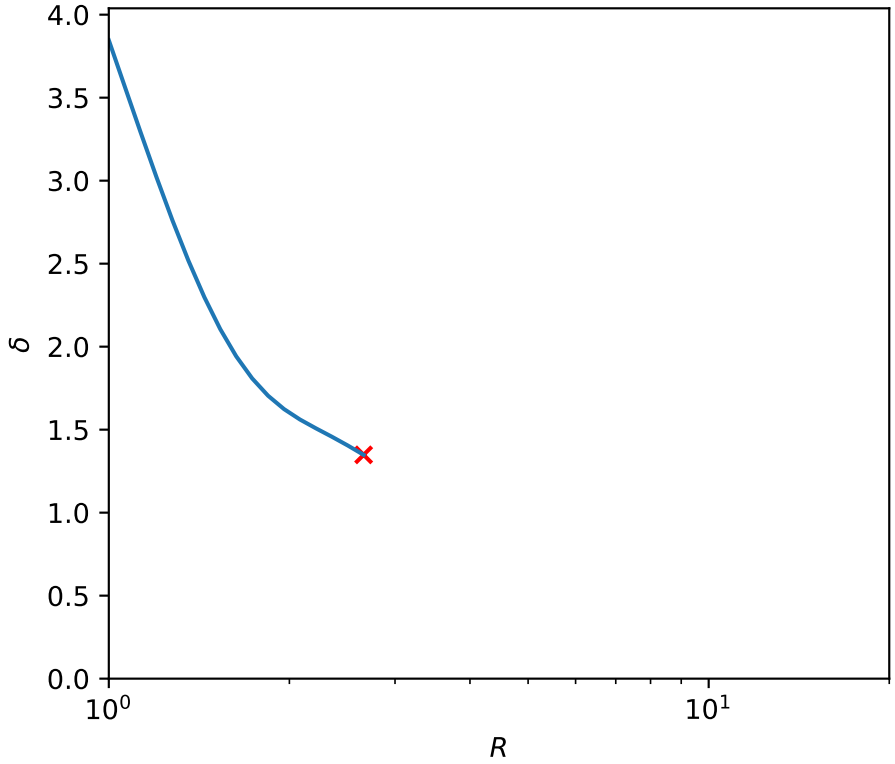
Excursion set illustrated



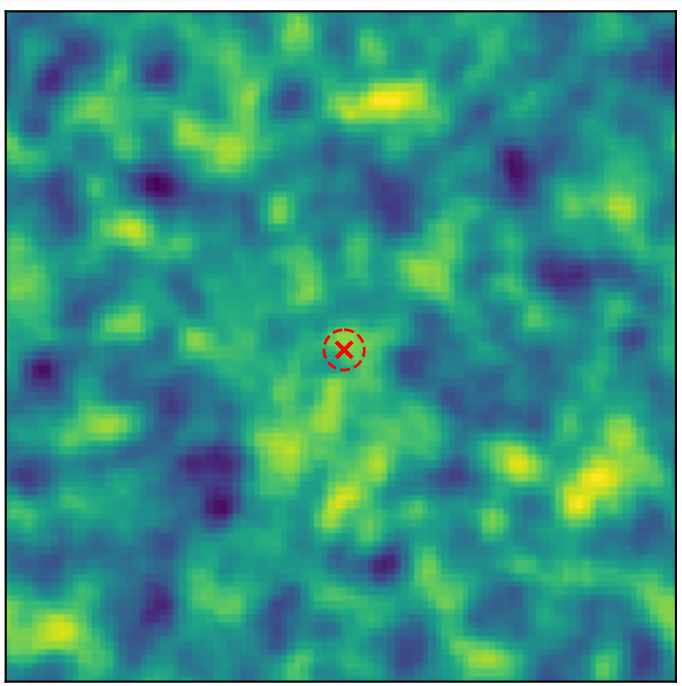


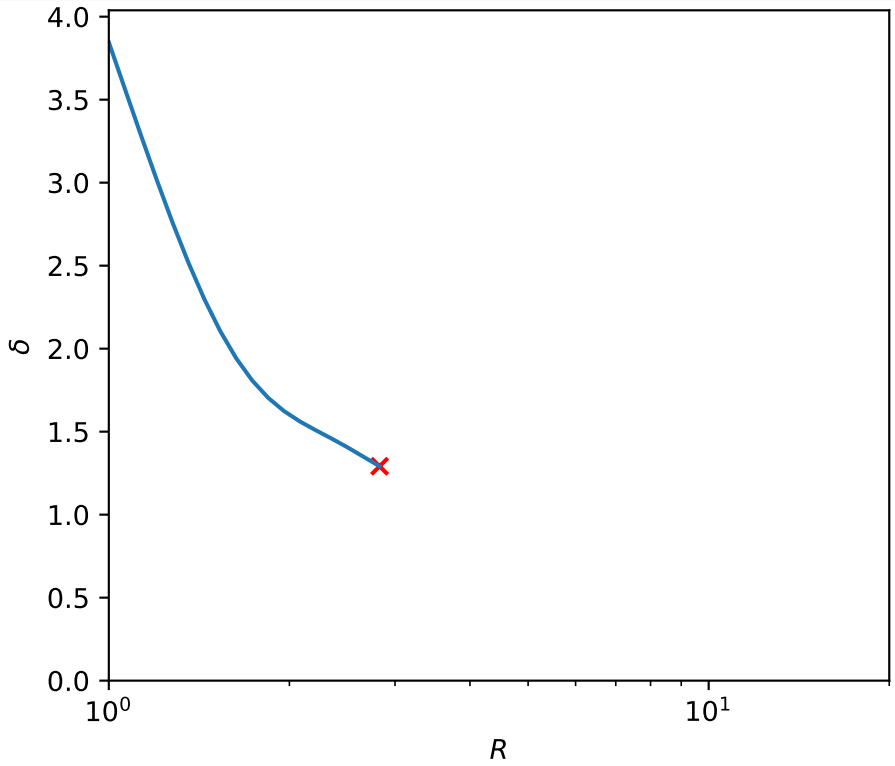
Excursion set illustrated



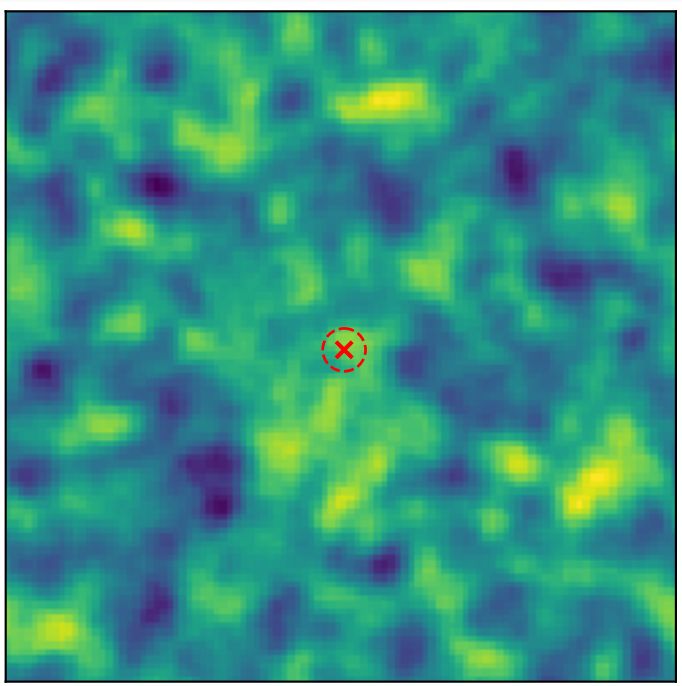


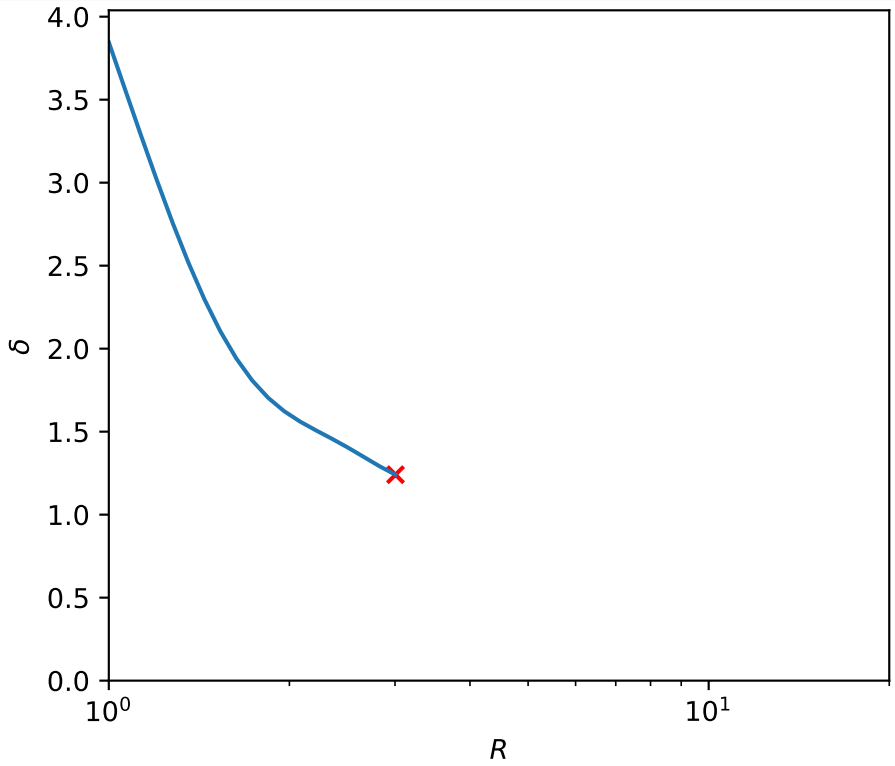
Excursion set illustrated



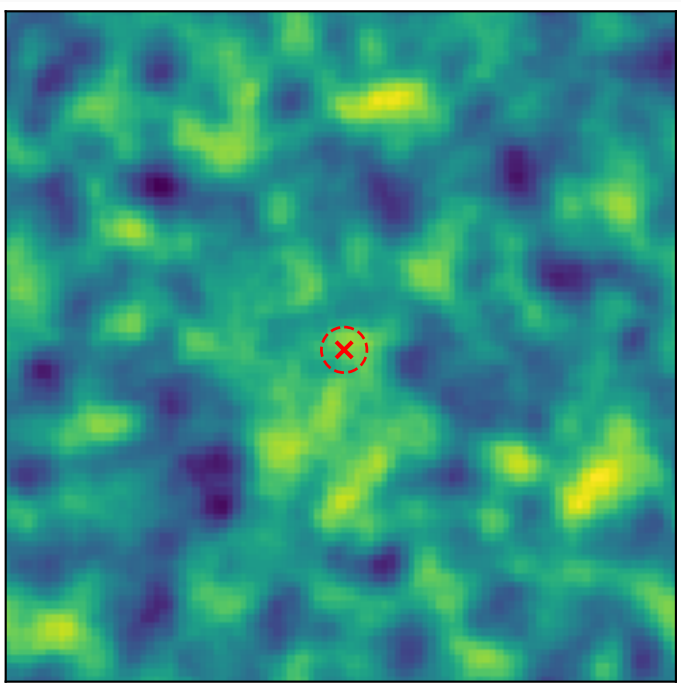


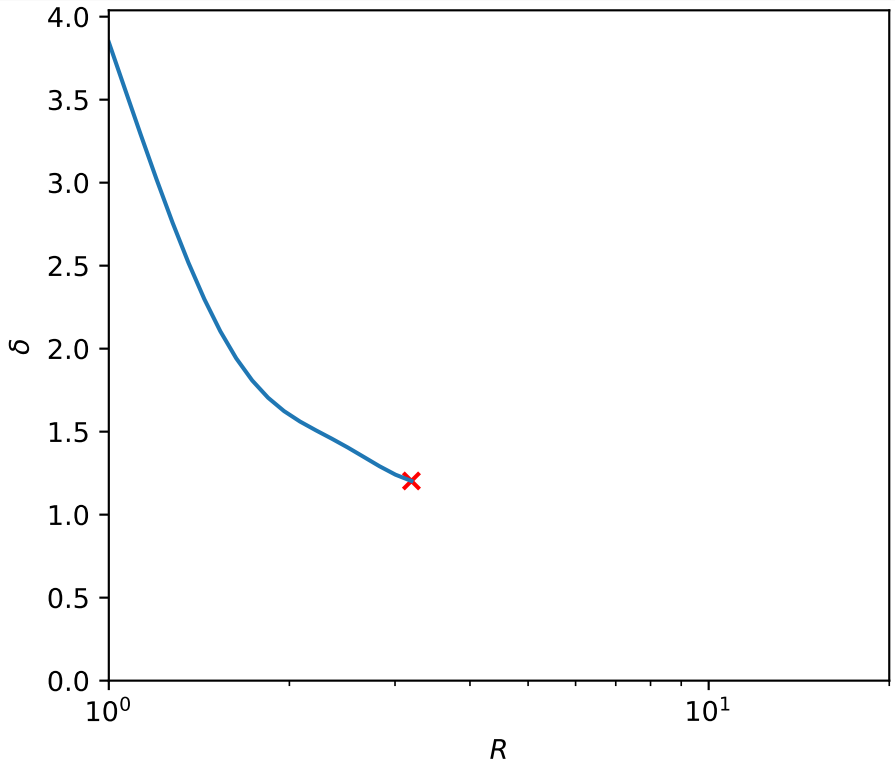
Excursion set illustrated



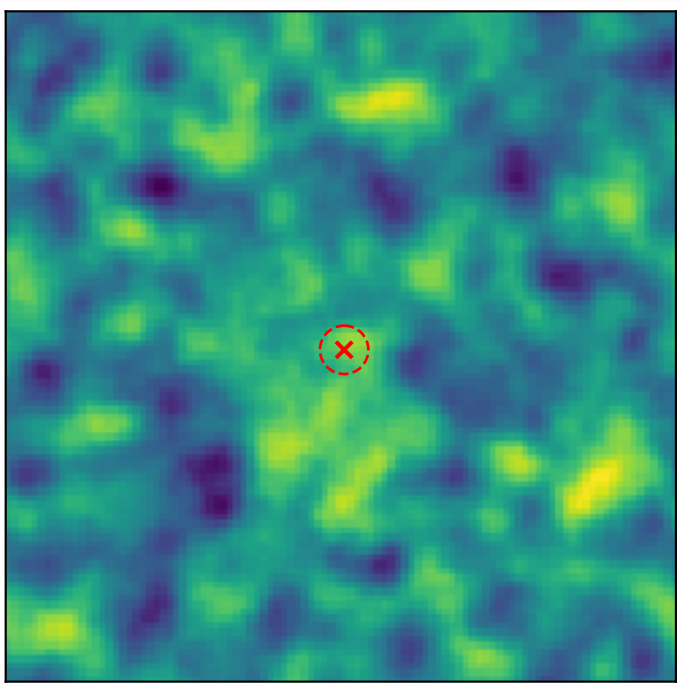


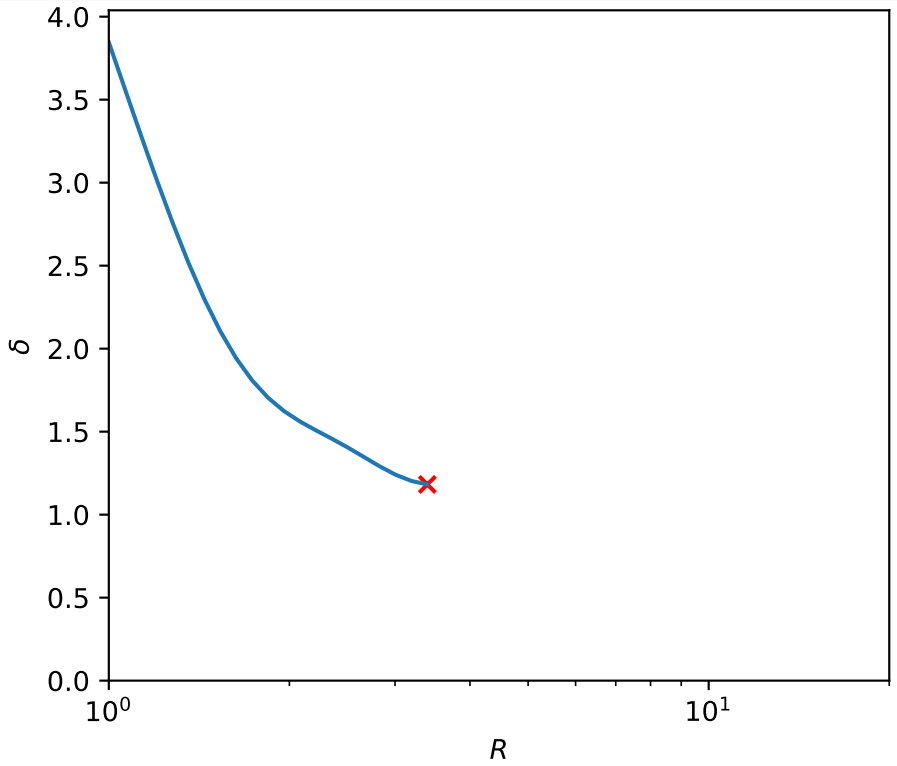
Excursion set illustrated



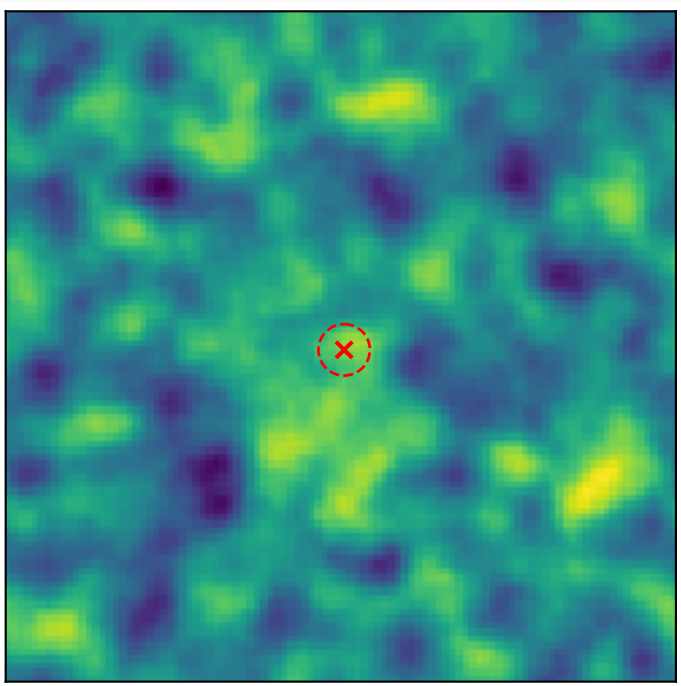


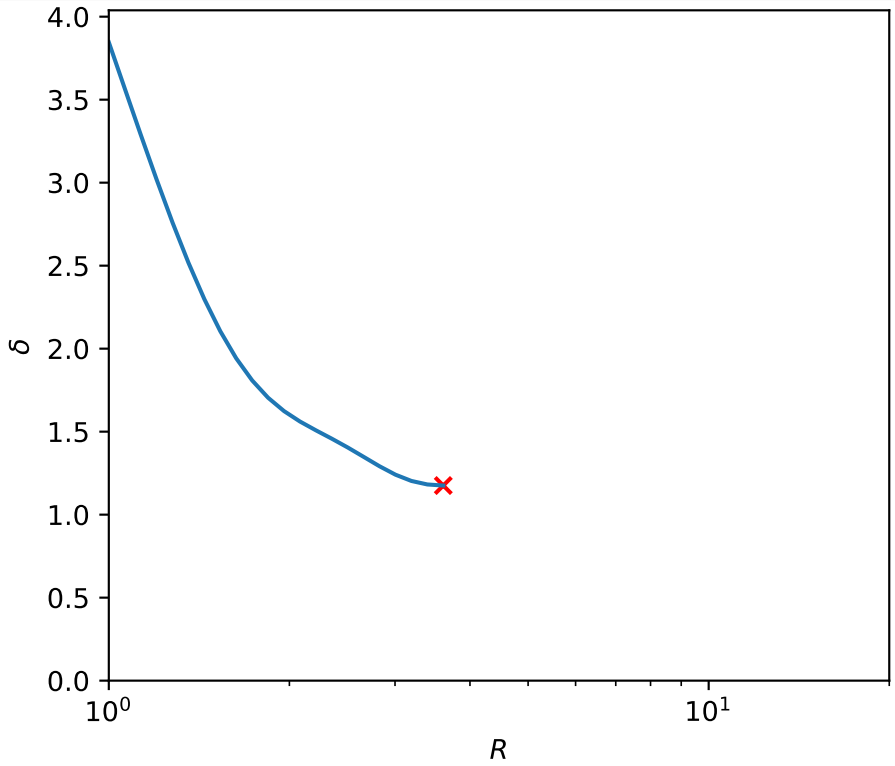
Excursion set illustrated



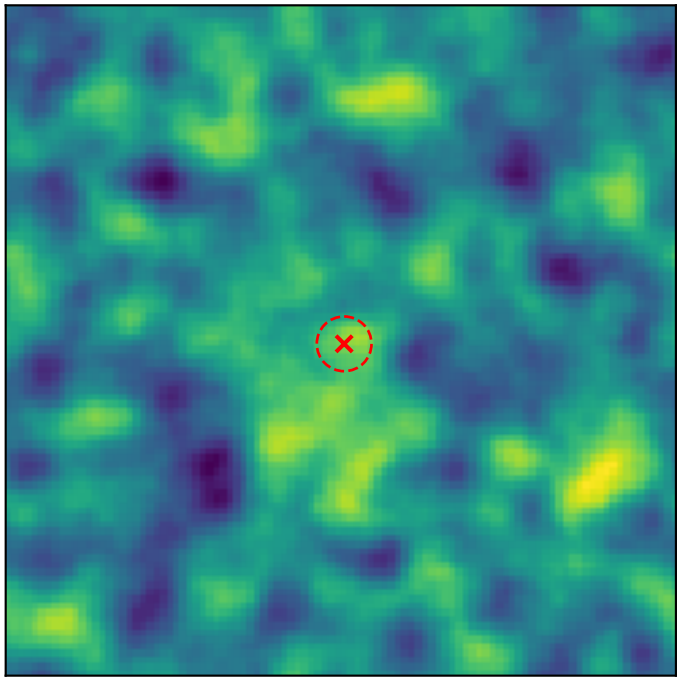


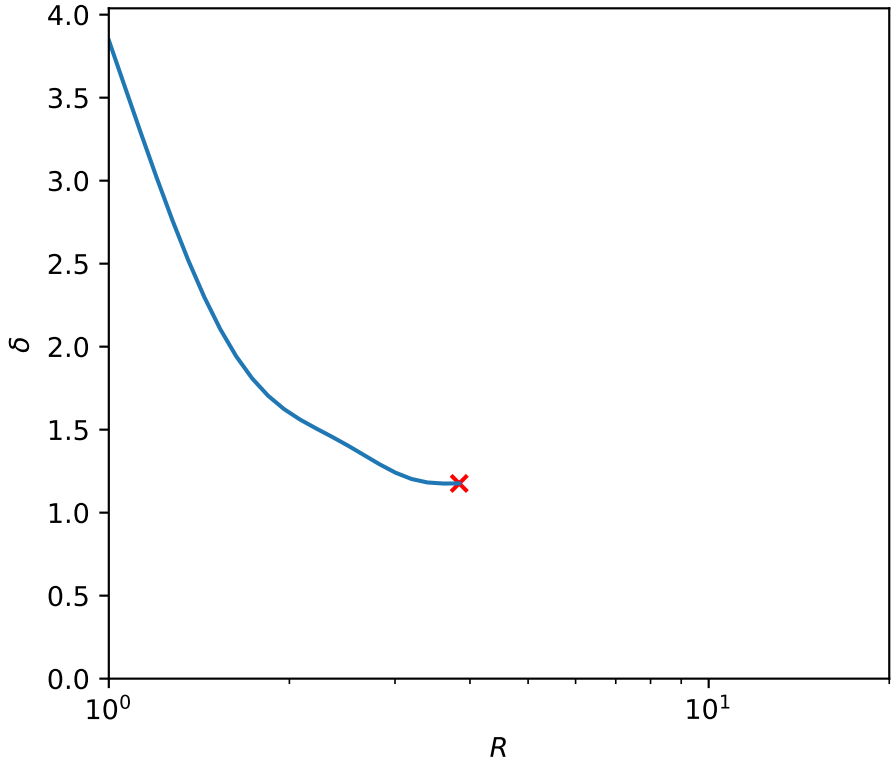
Excursion set illustrated



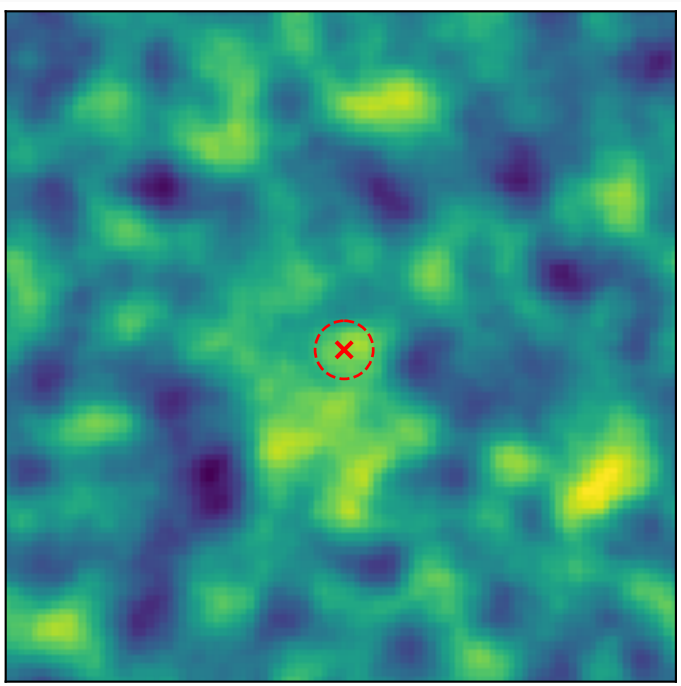


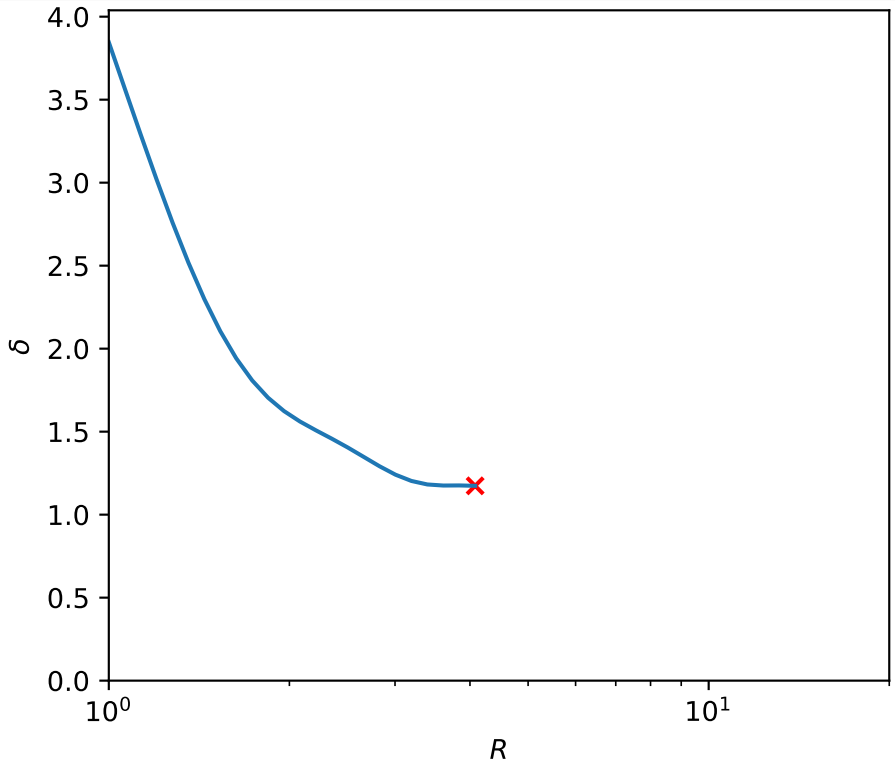
Excursion set illustrated



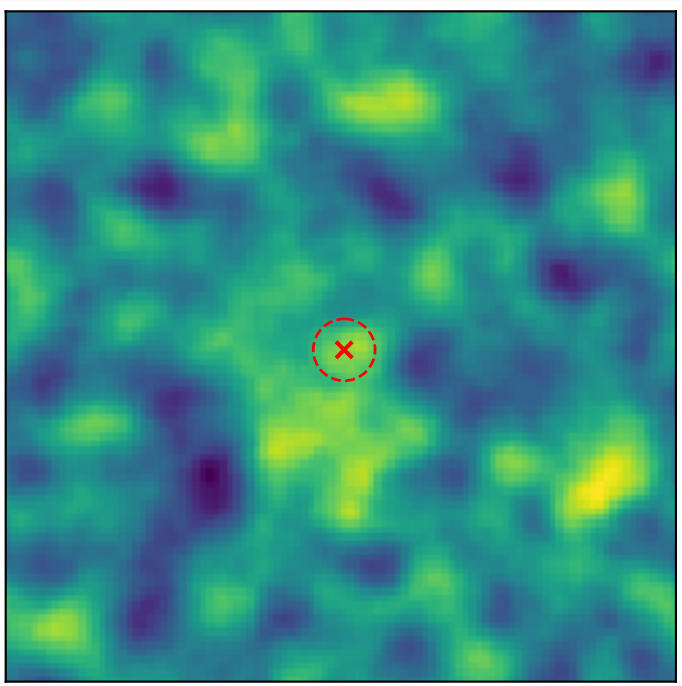


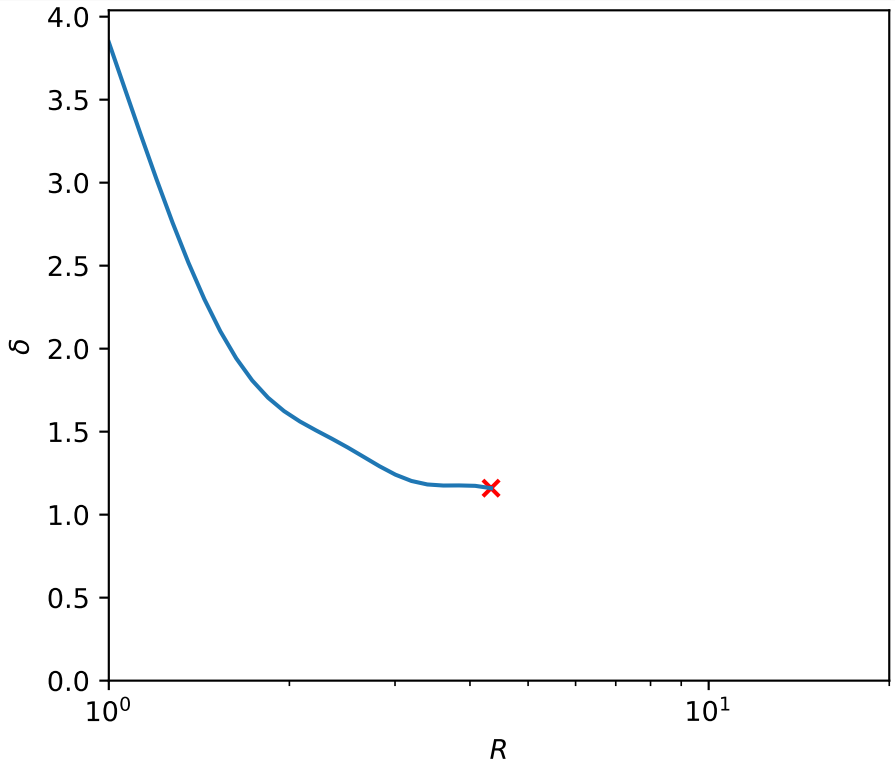
Excursion set illustrated



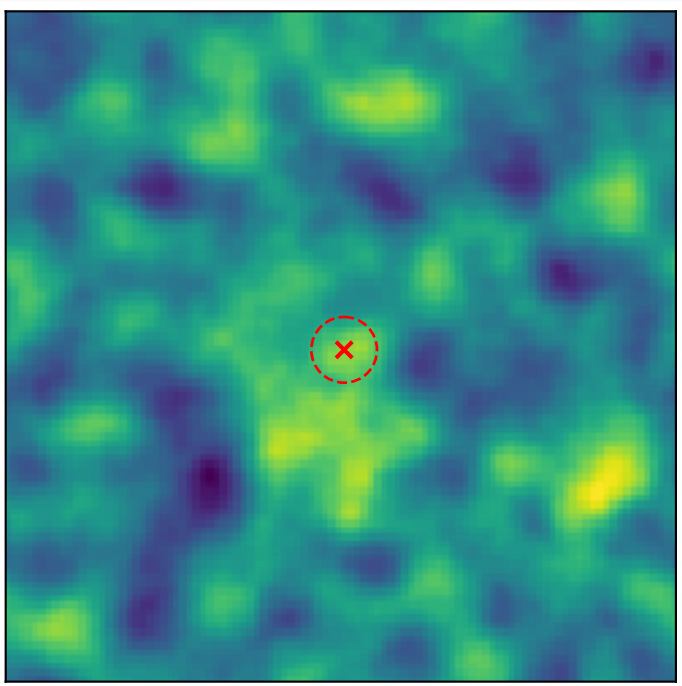


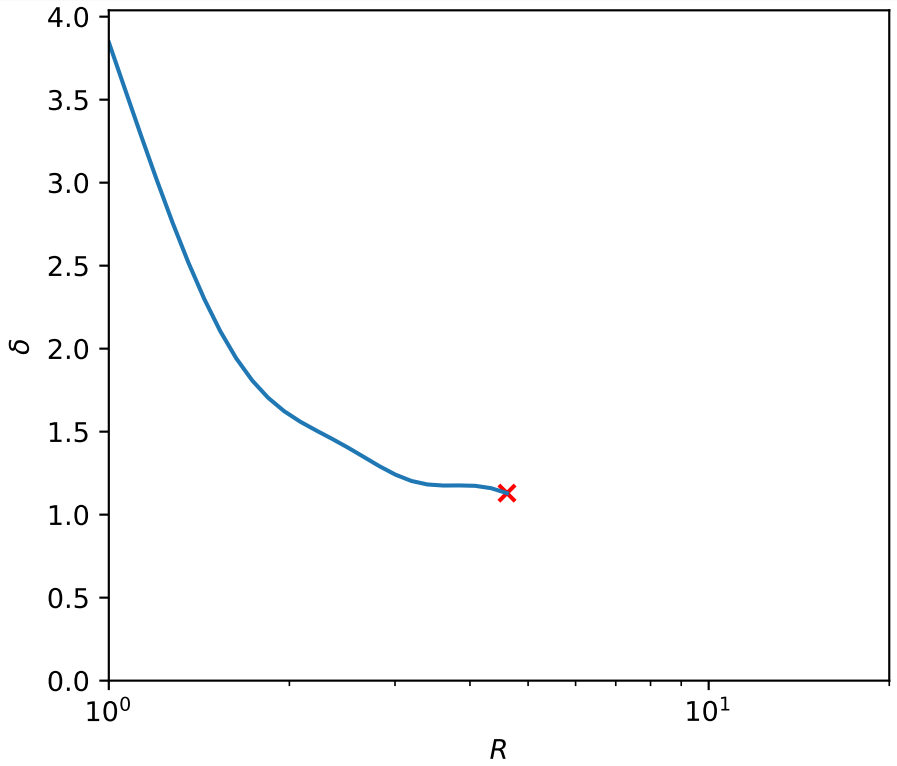
Excursion set illustrated



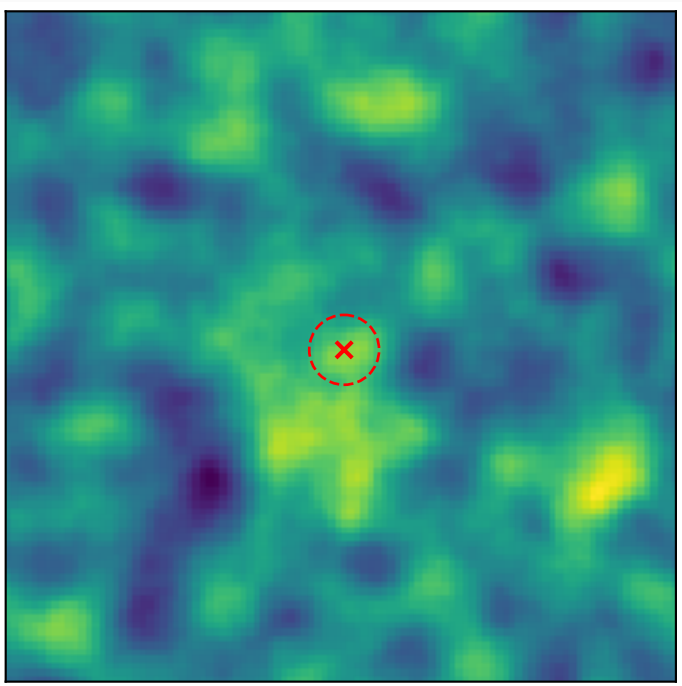


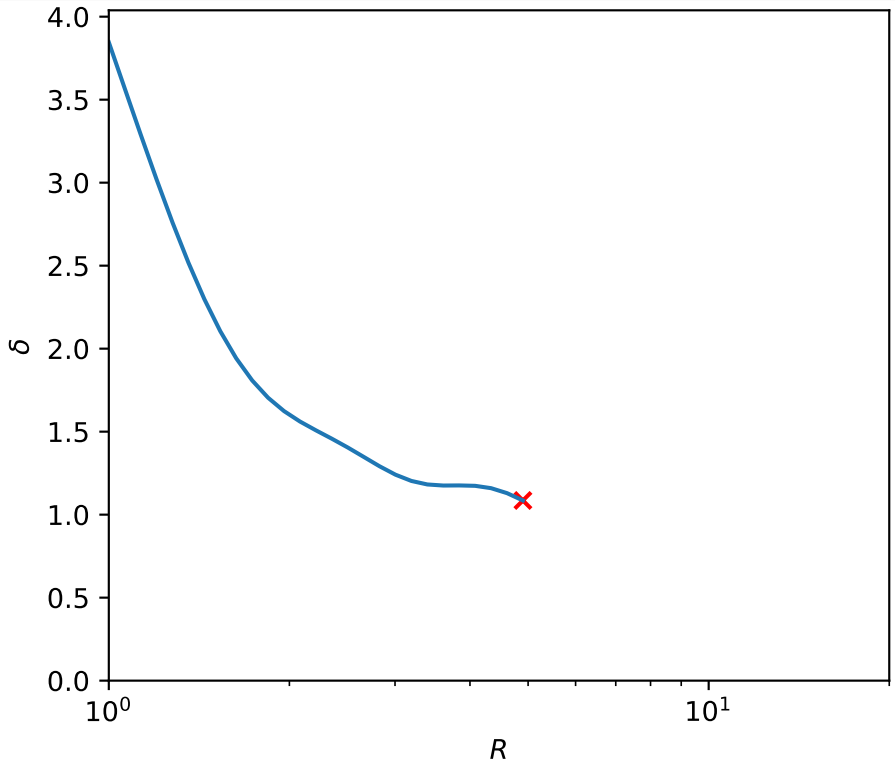
Excursion set illustrated



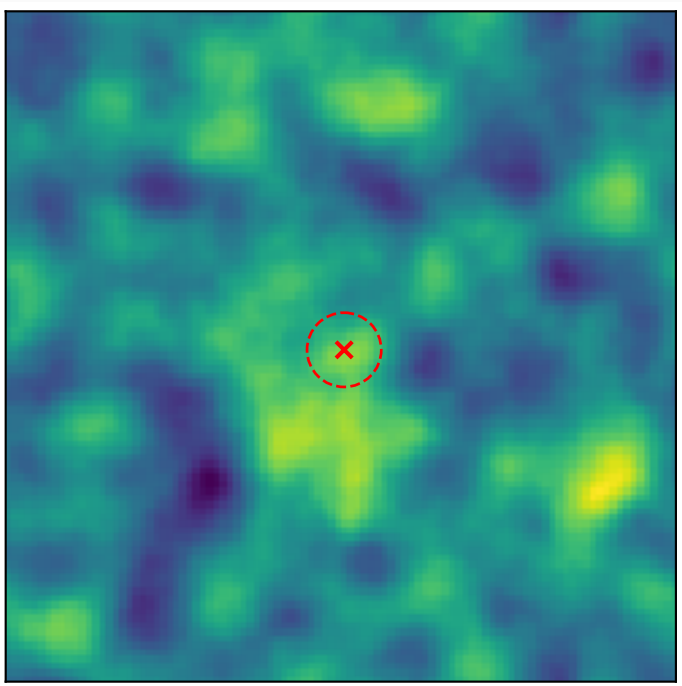


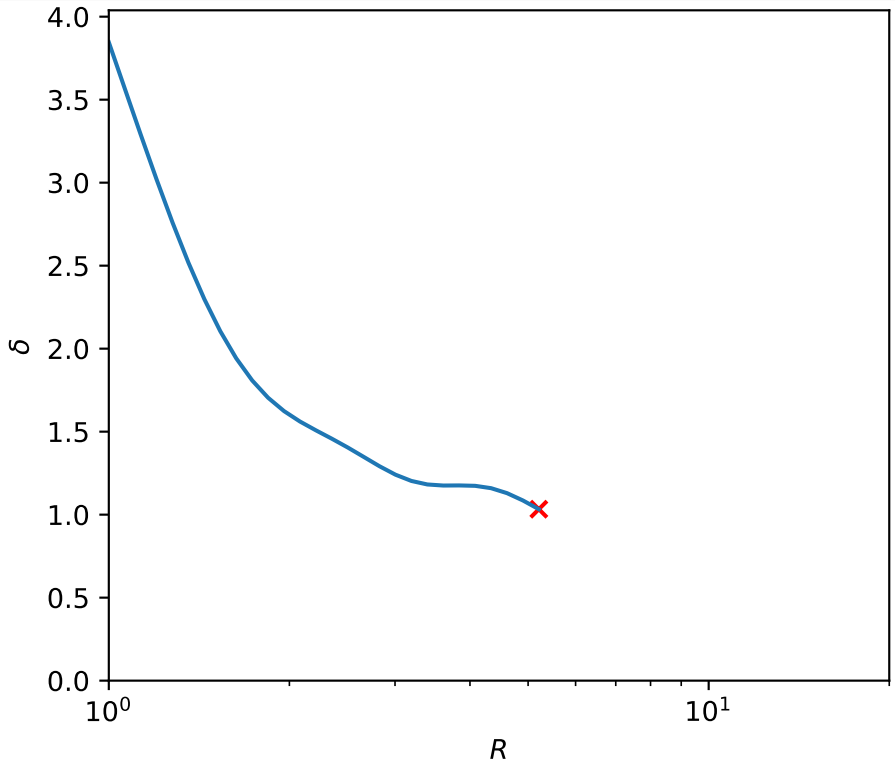
Excursion set illustrated



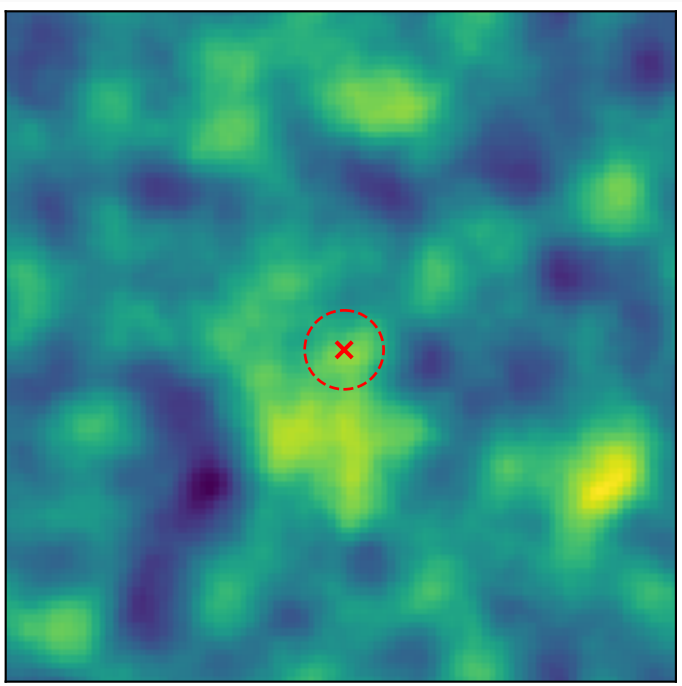


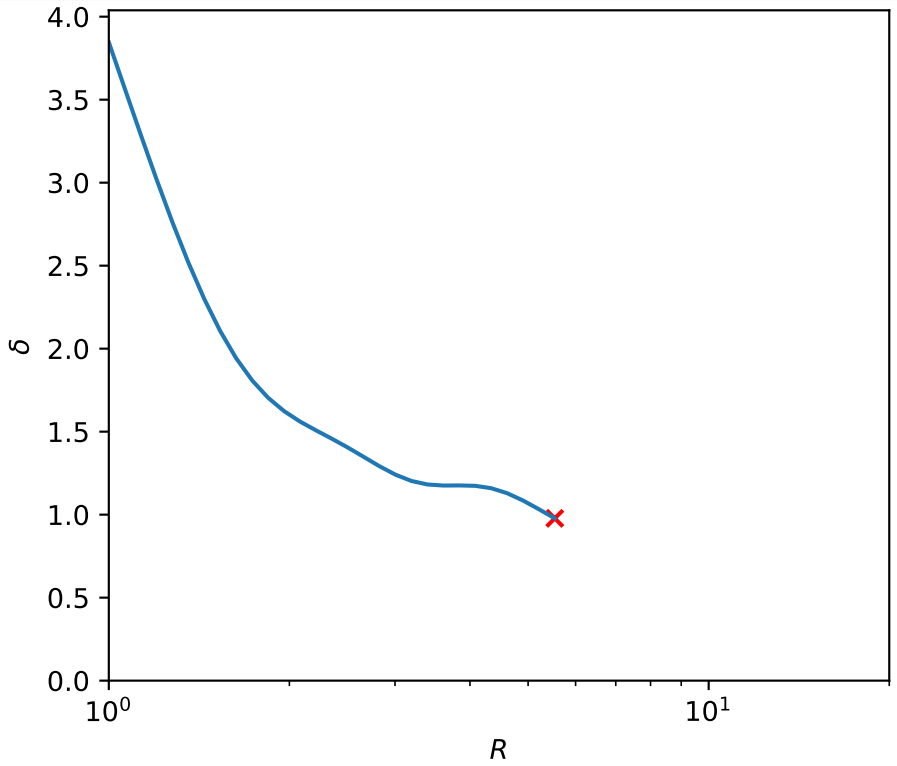
Excursion set illustrated



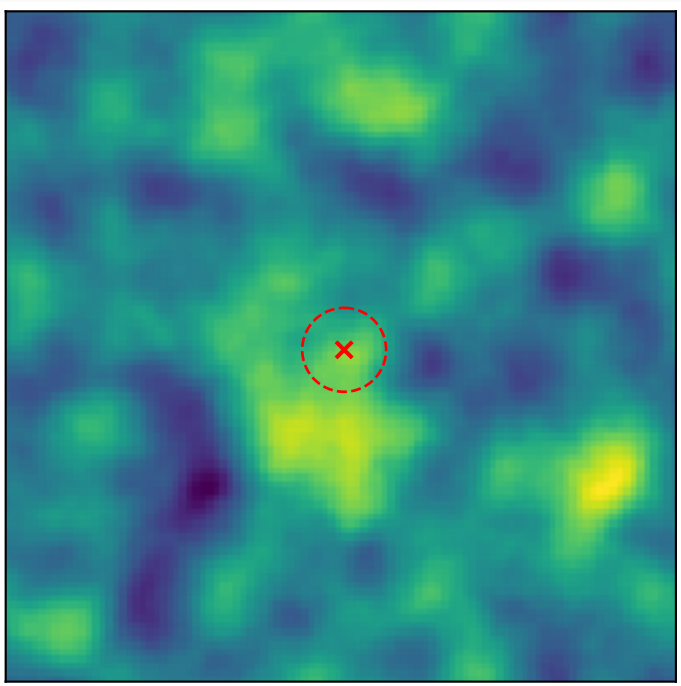


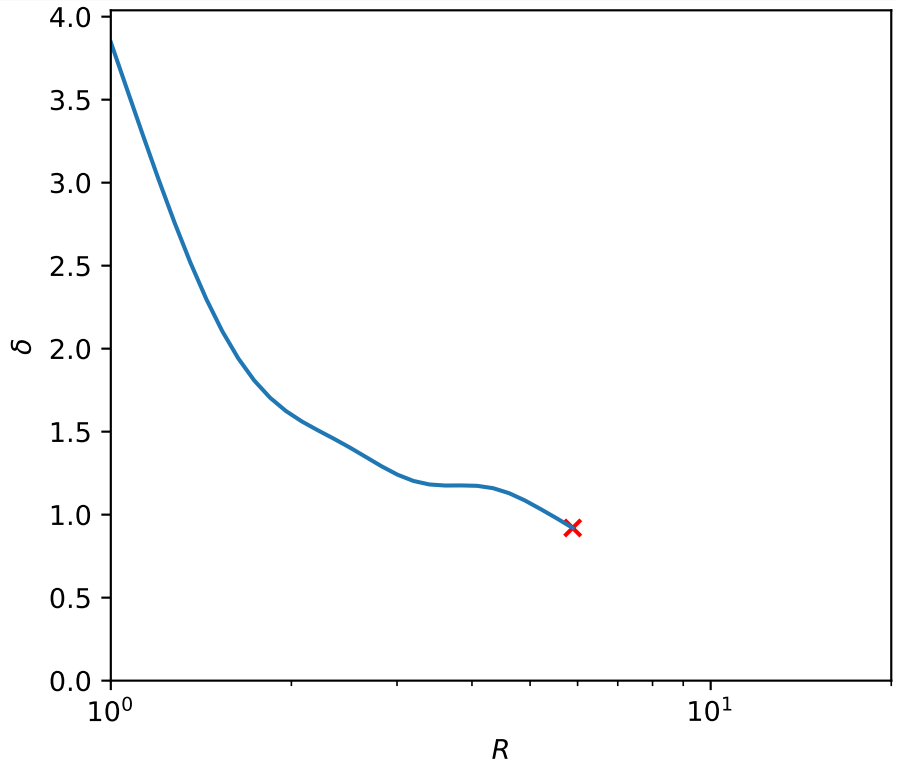
Excursion set illustrated



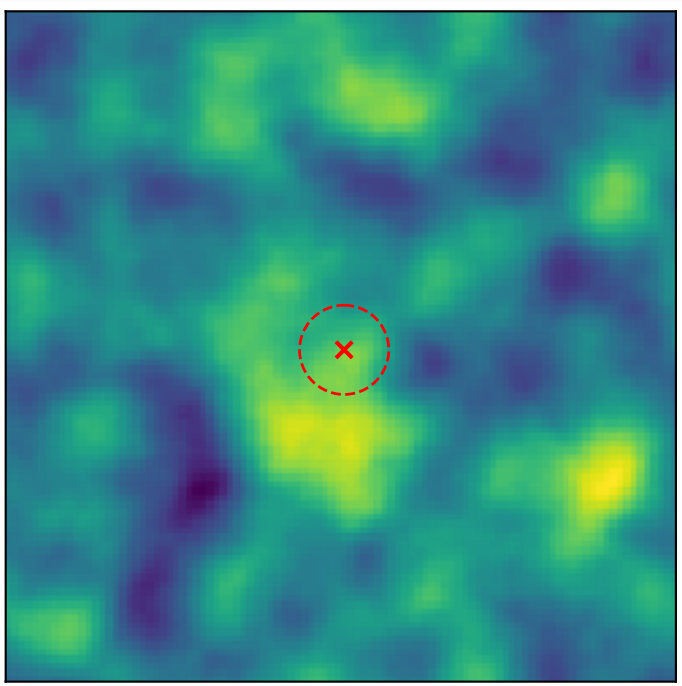


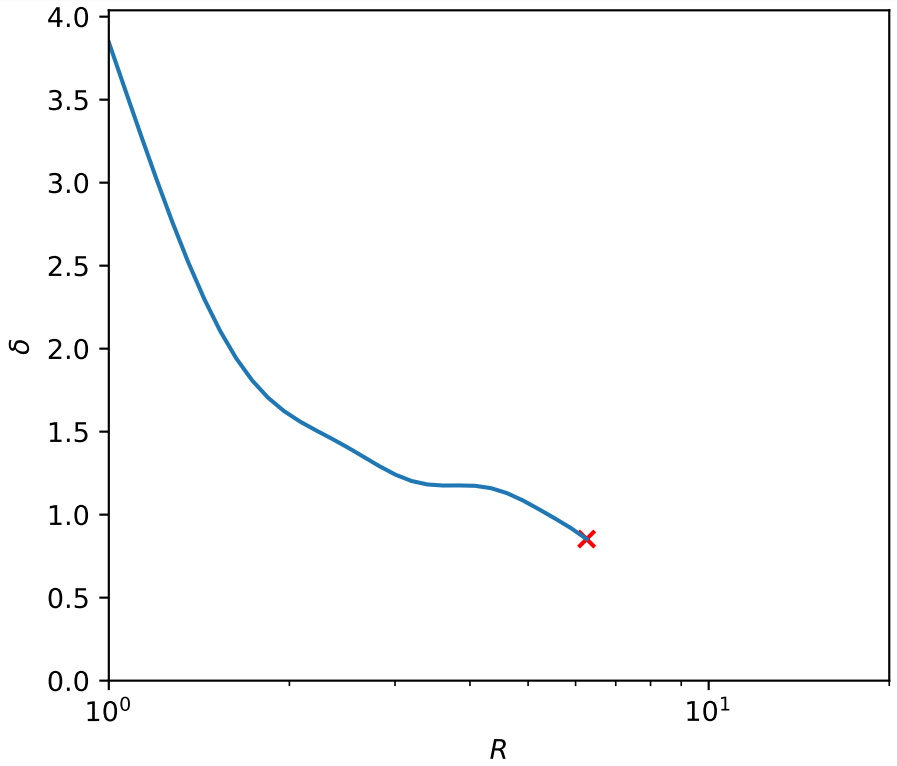
Excursion set illustrated



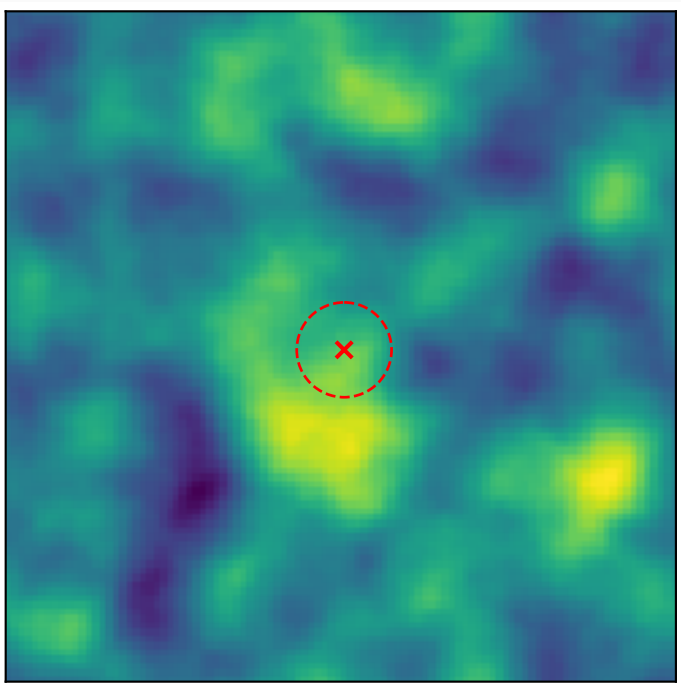


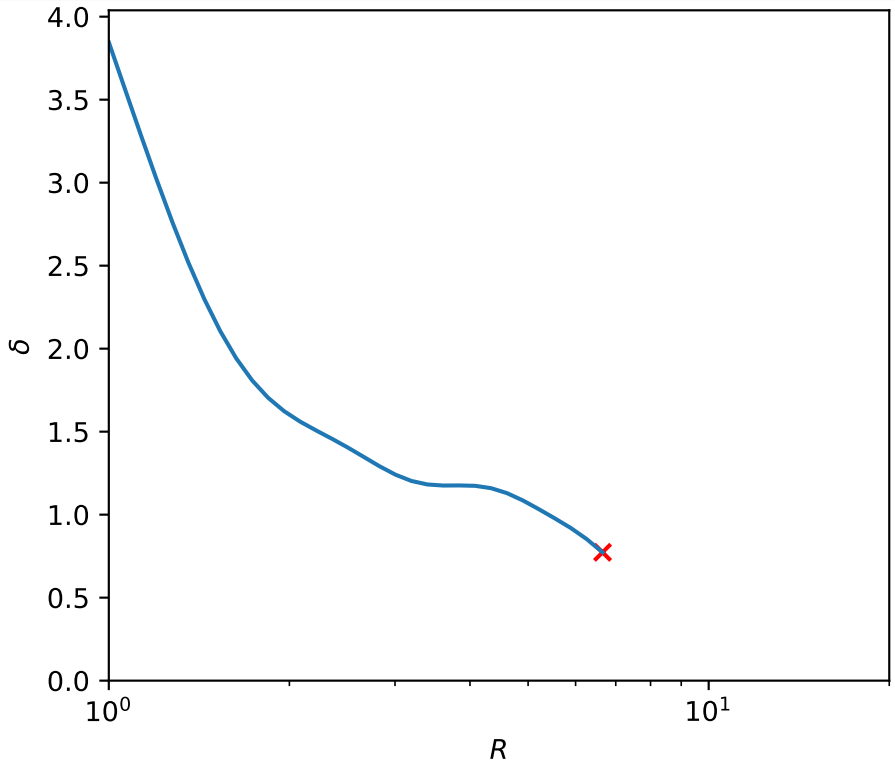
Excursion set illustrated



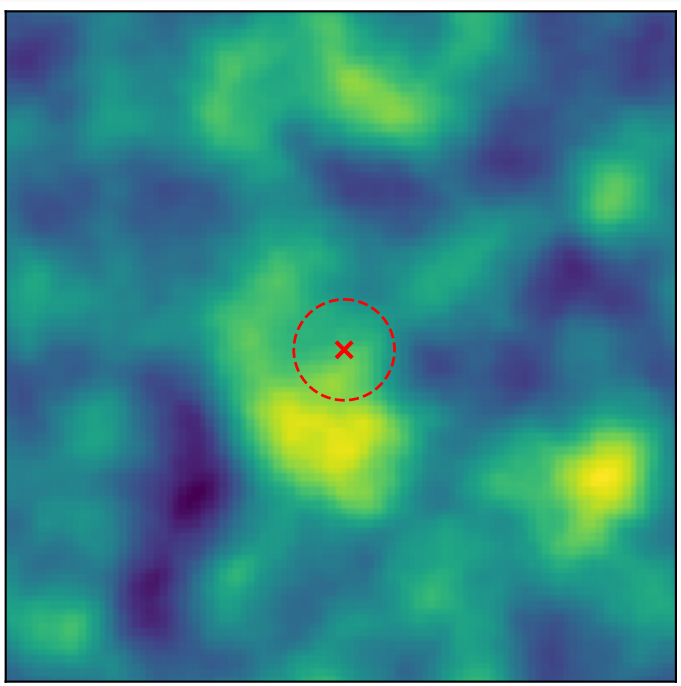


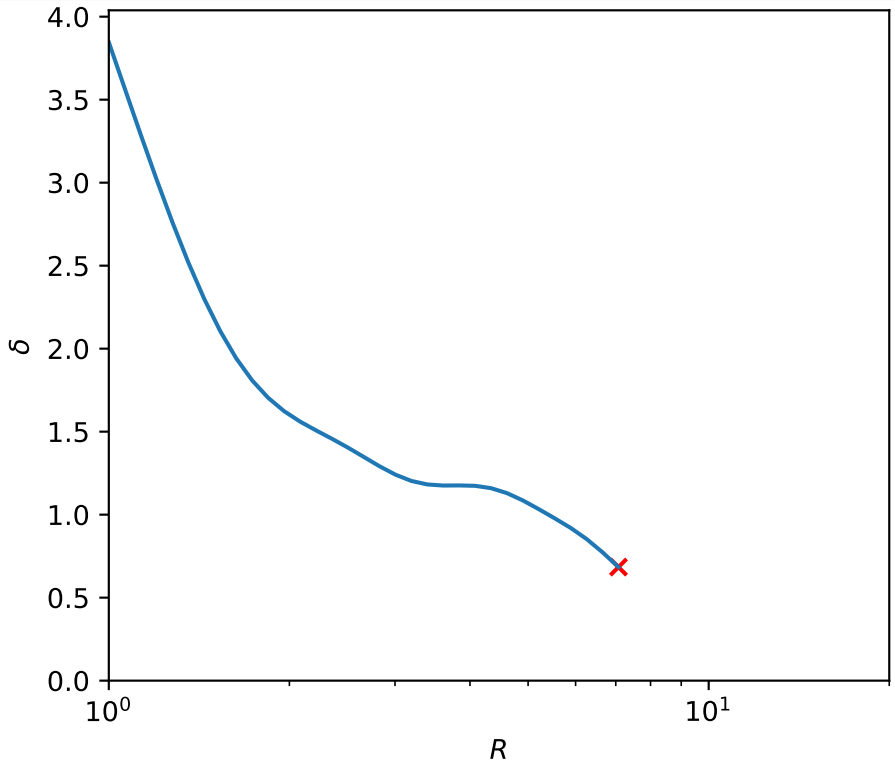
Excursion set illustrated



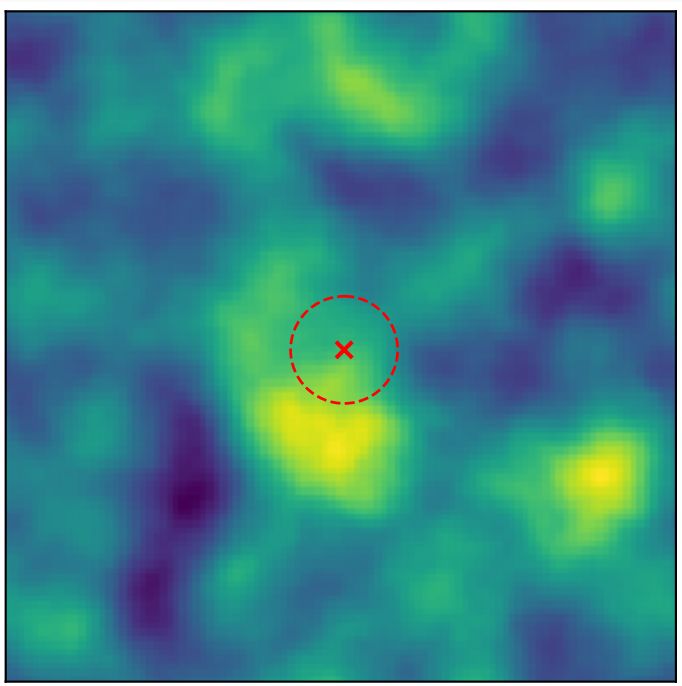


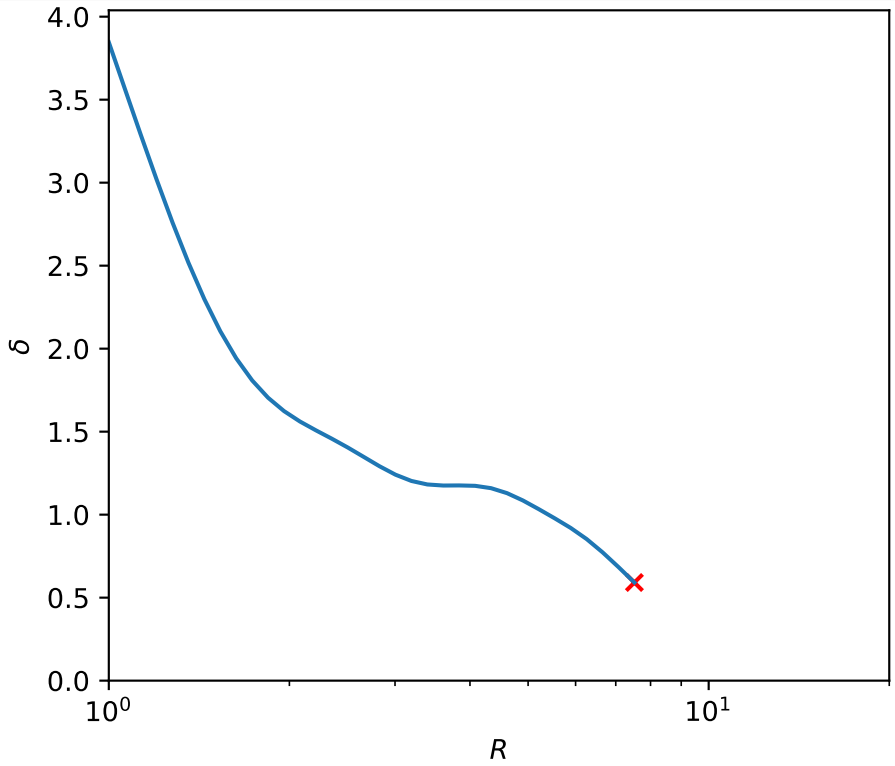
Excursion set illustrated



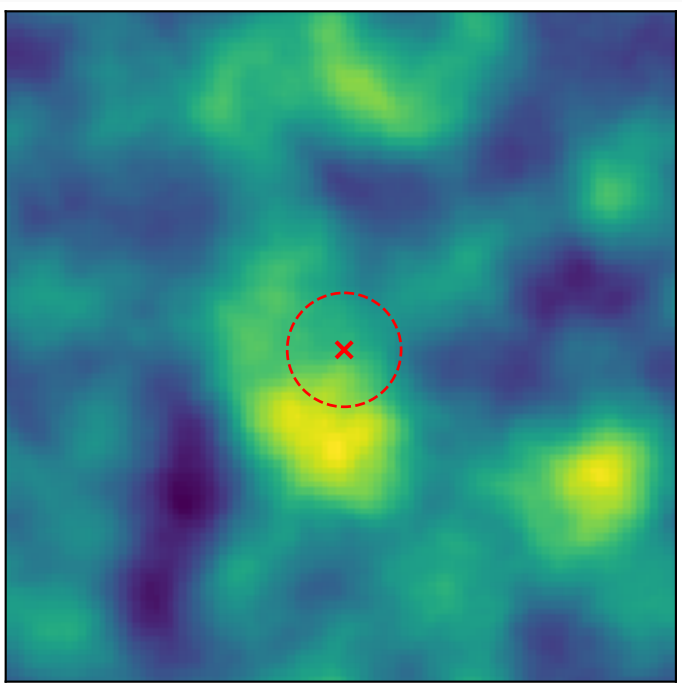


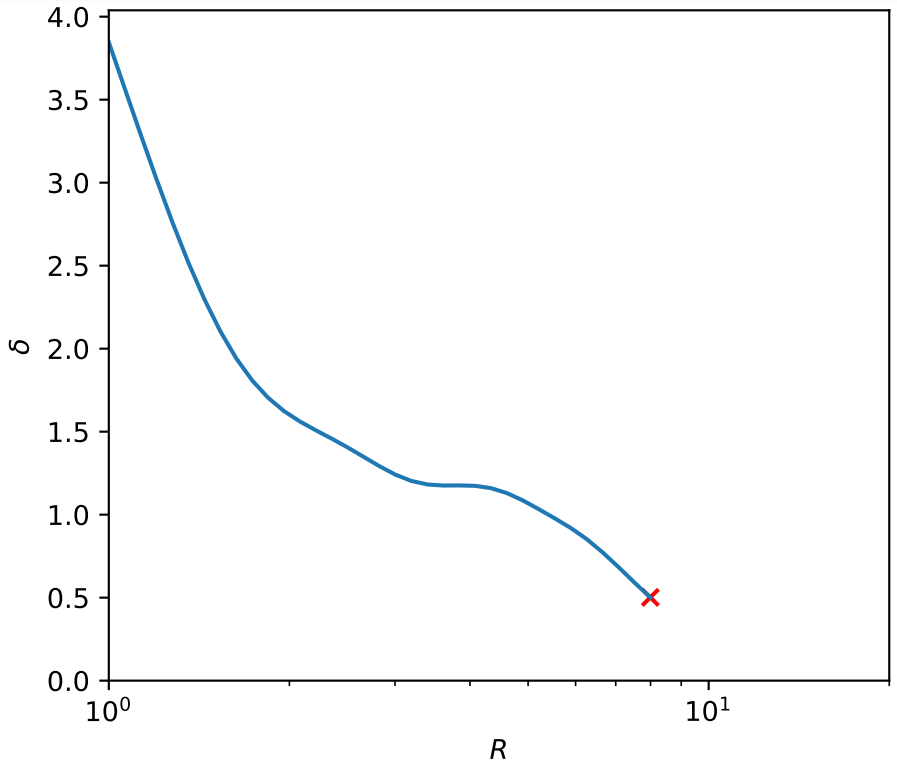
Excursion set illustrated



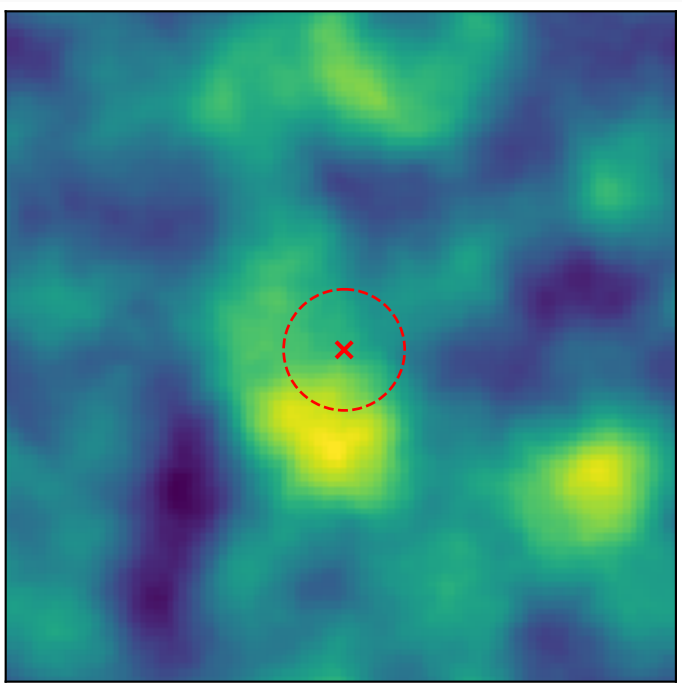


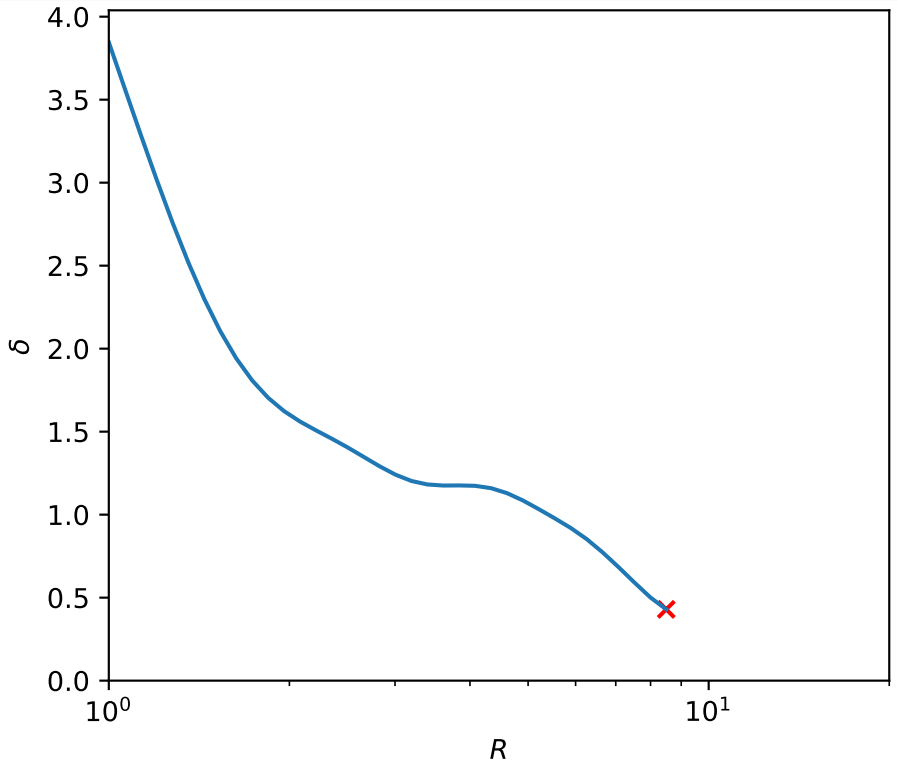
Excursion set illustrated



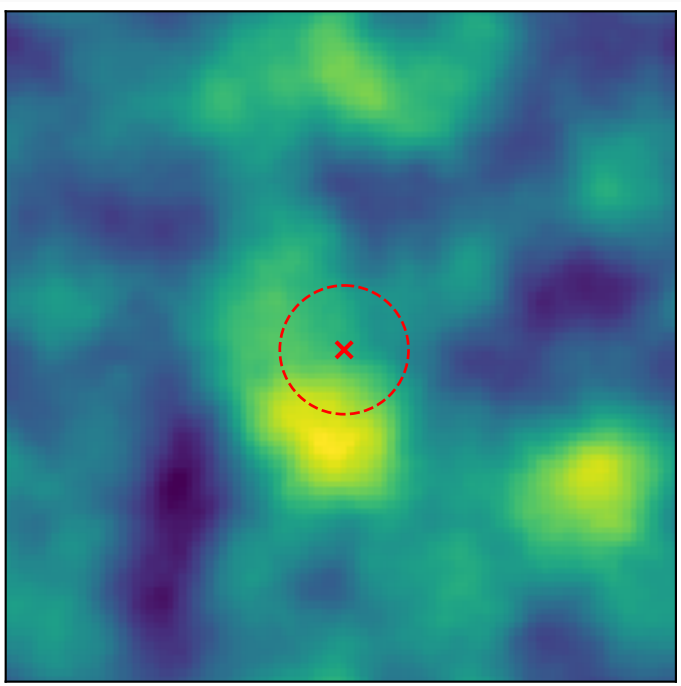


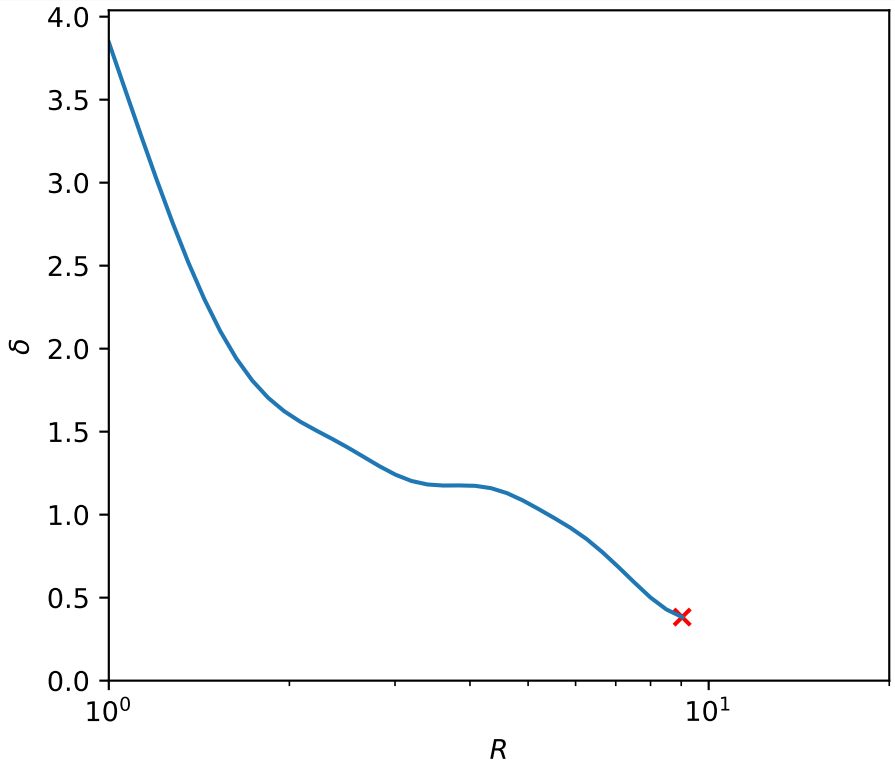
Excursion set illustrated



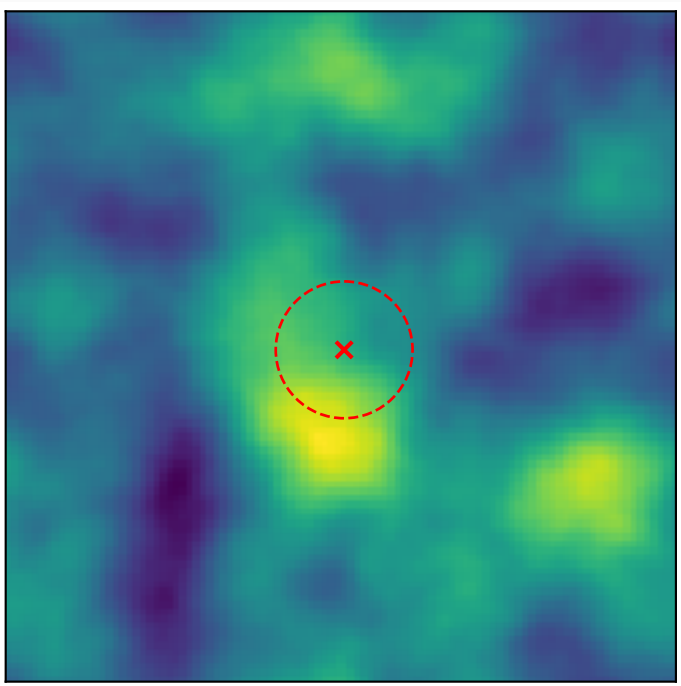


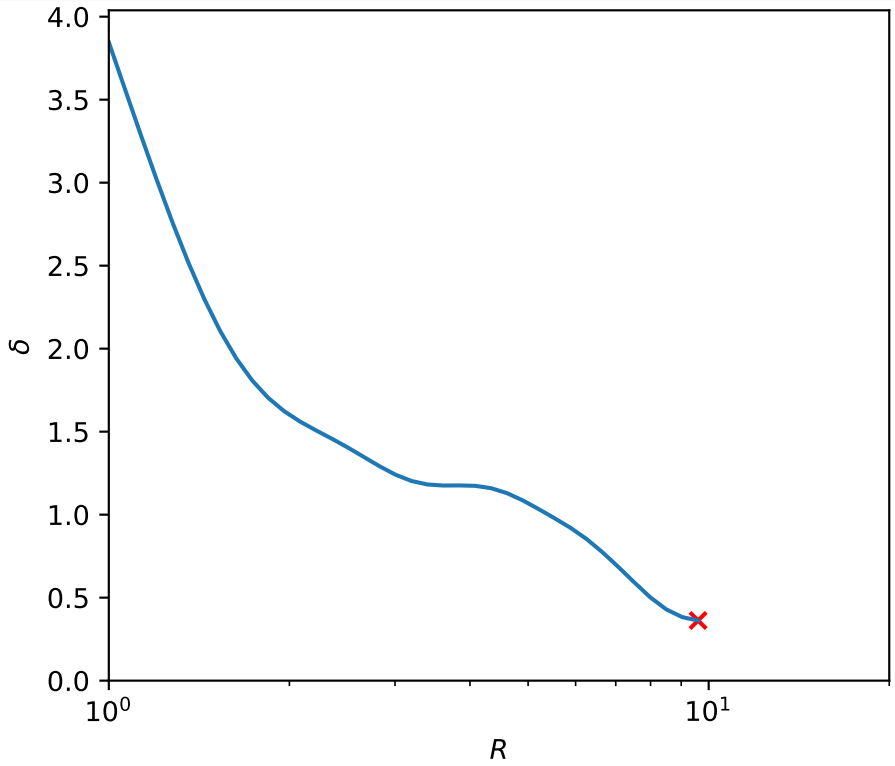
Excursion set illustrated



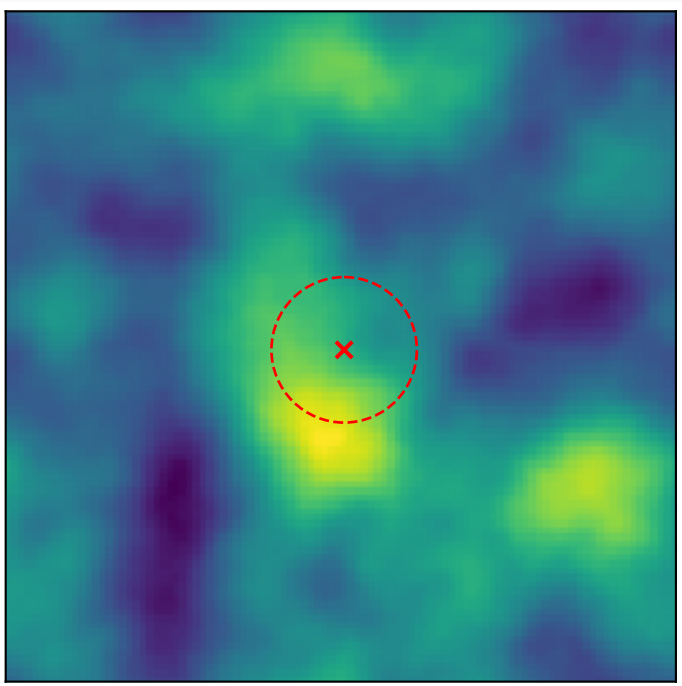


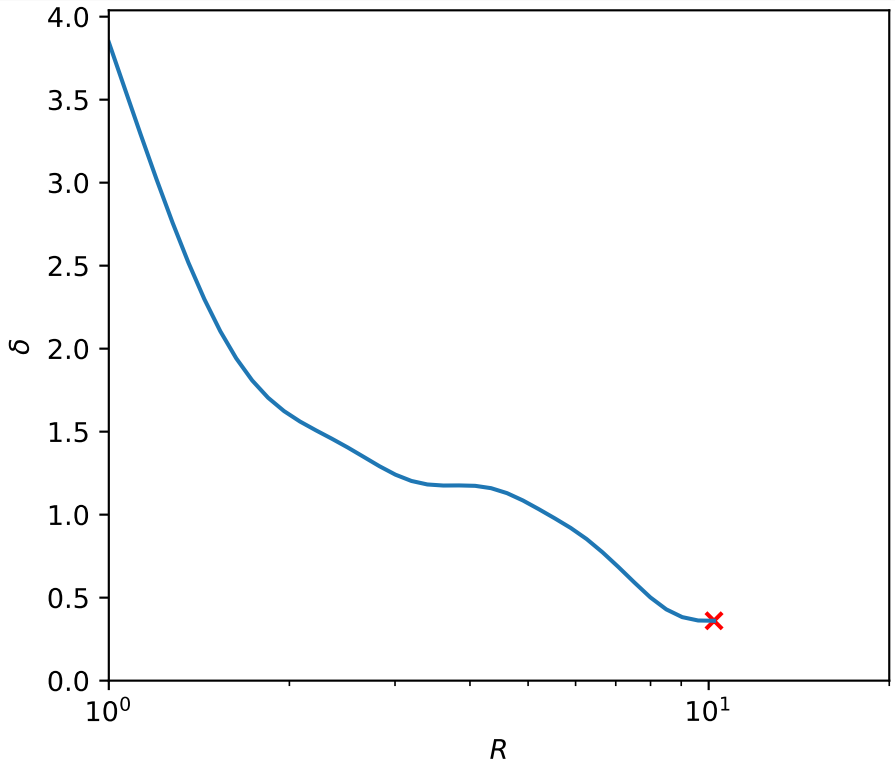
Excursion set illustrated



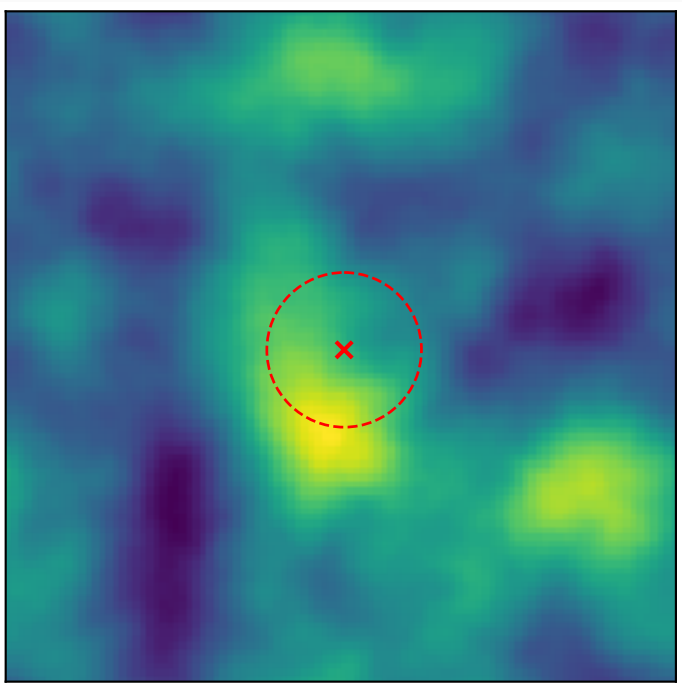


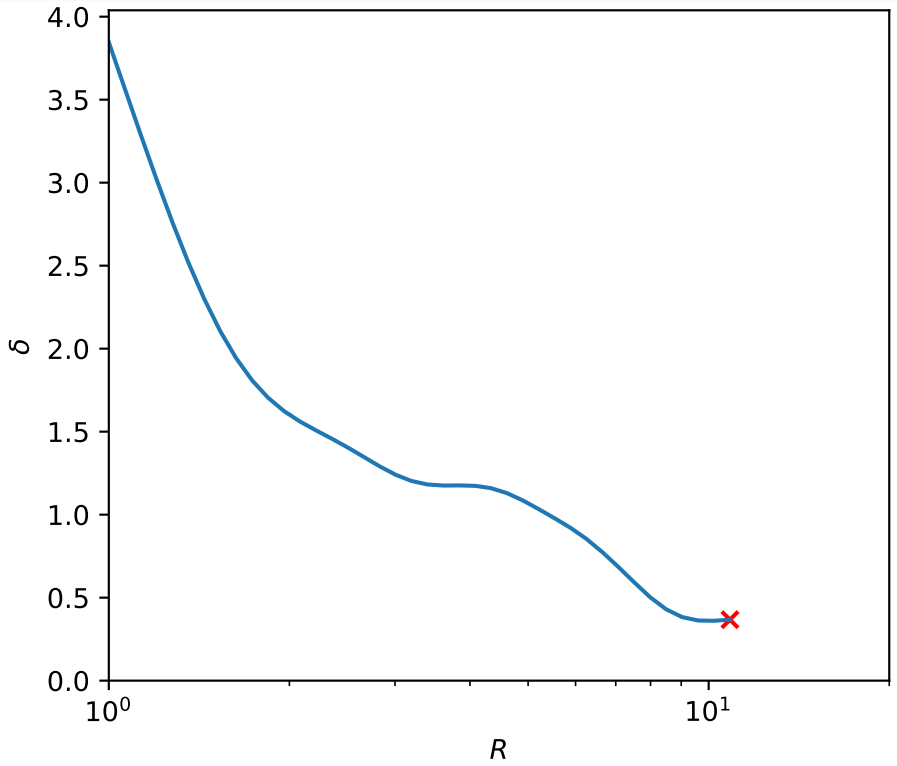
Excursion set illustrated



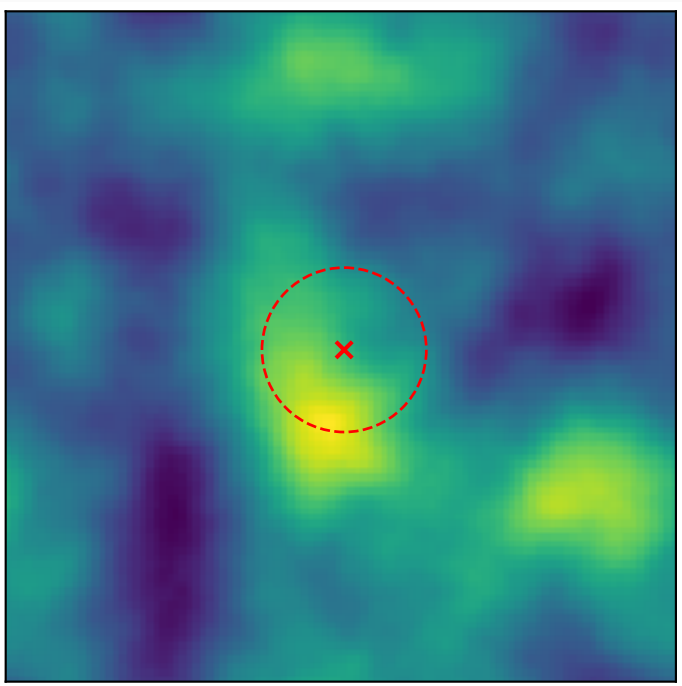


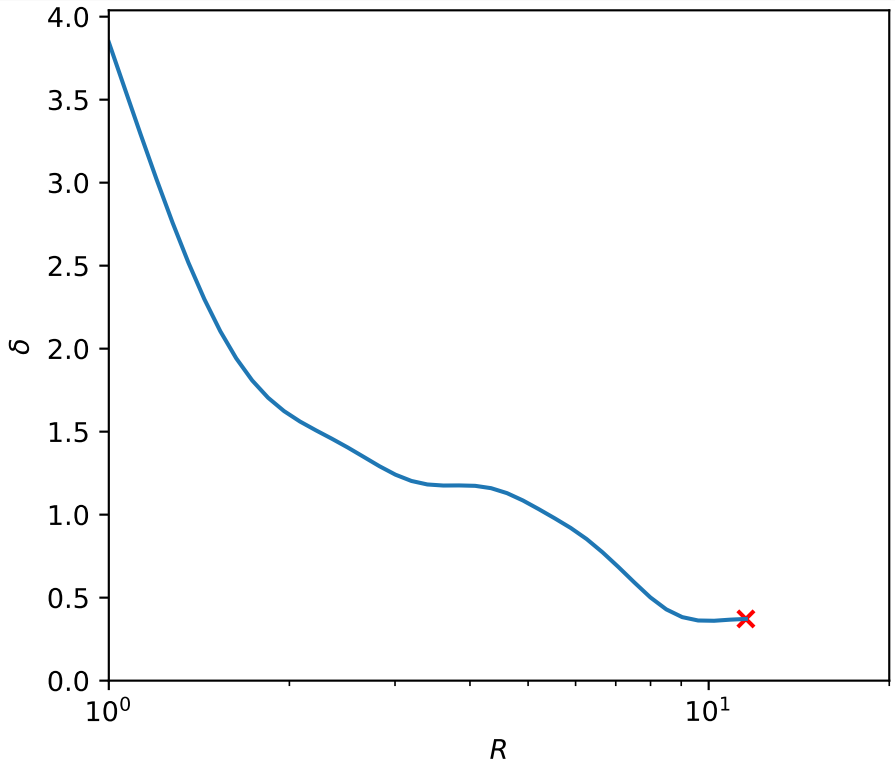
Excursion set illustrated



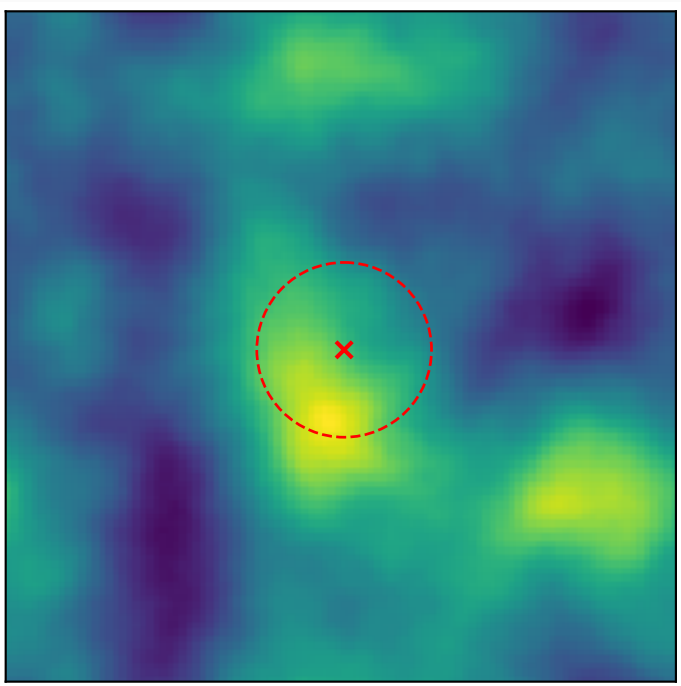


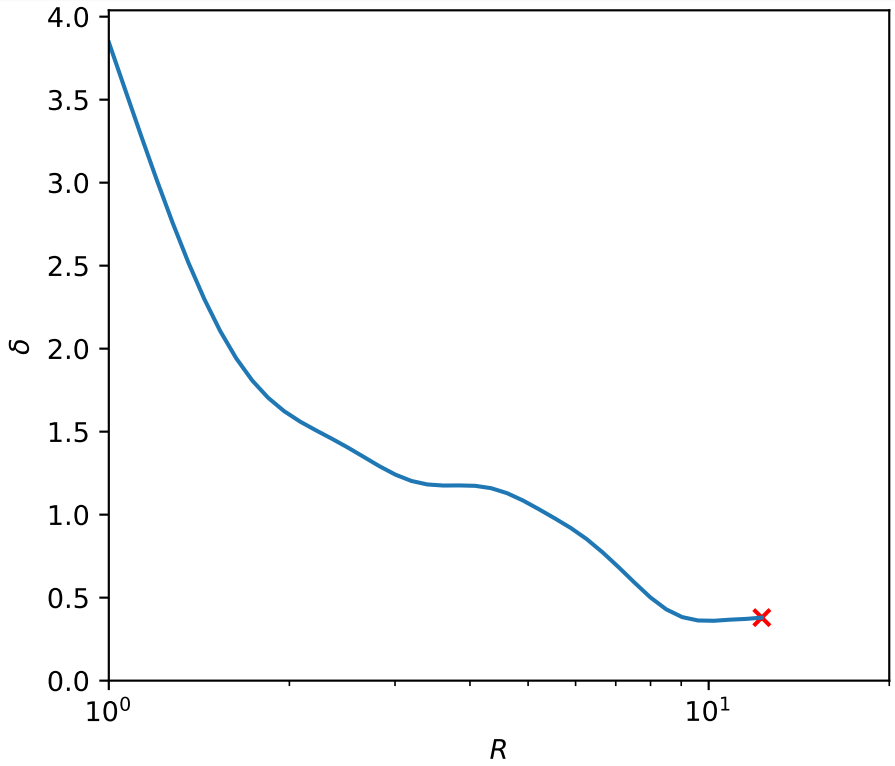
Excursion set illustrated



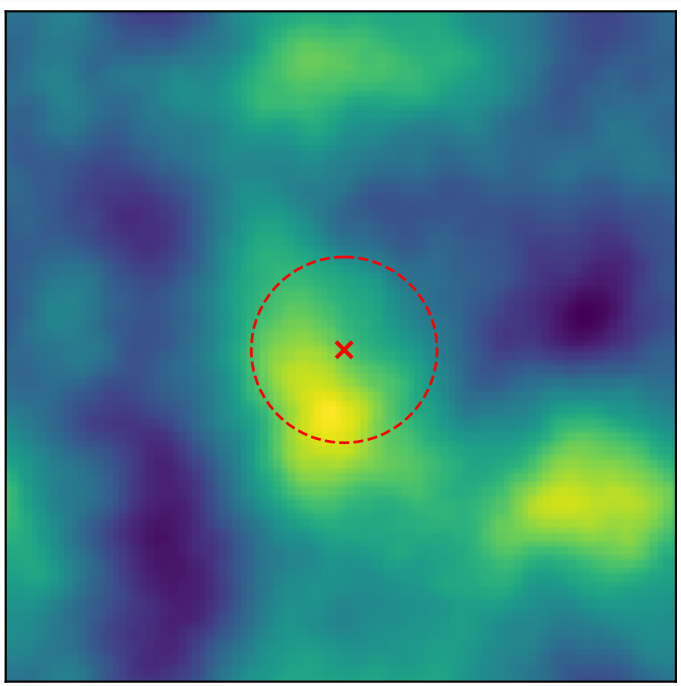


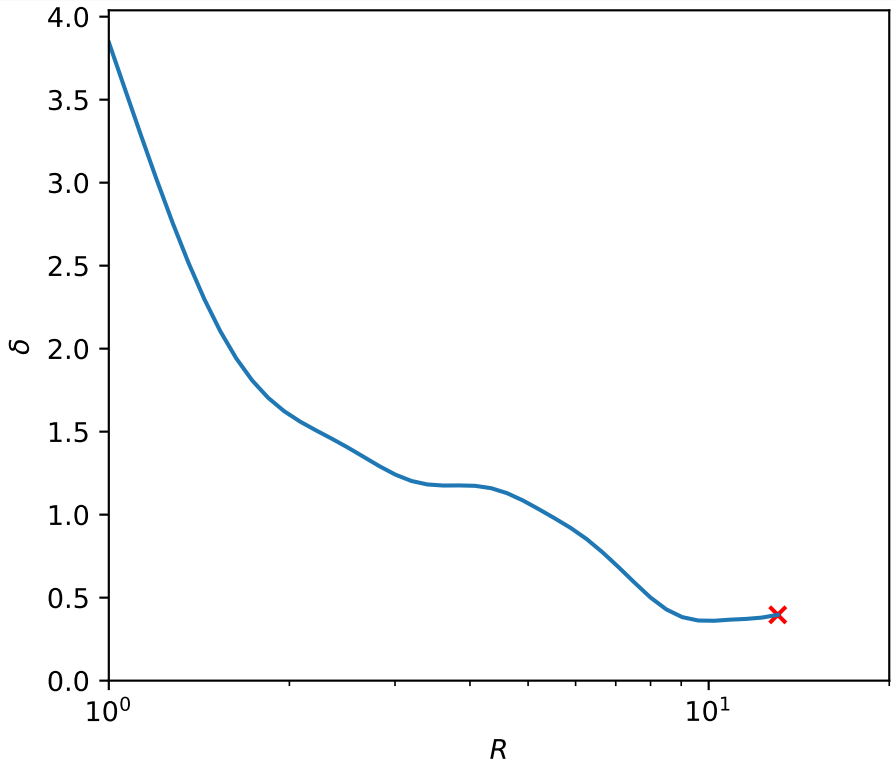
Excursion set illustrated



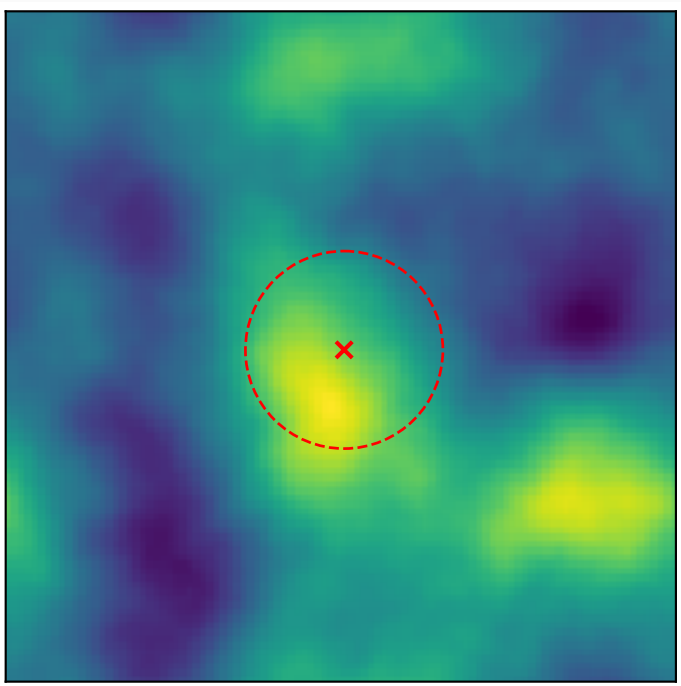


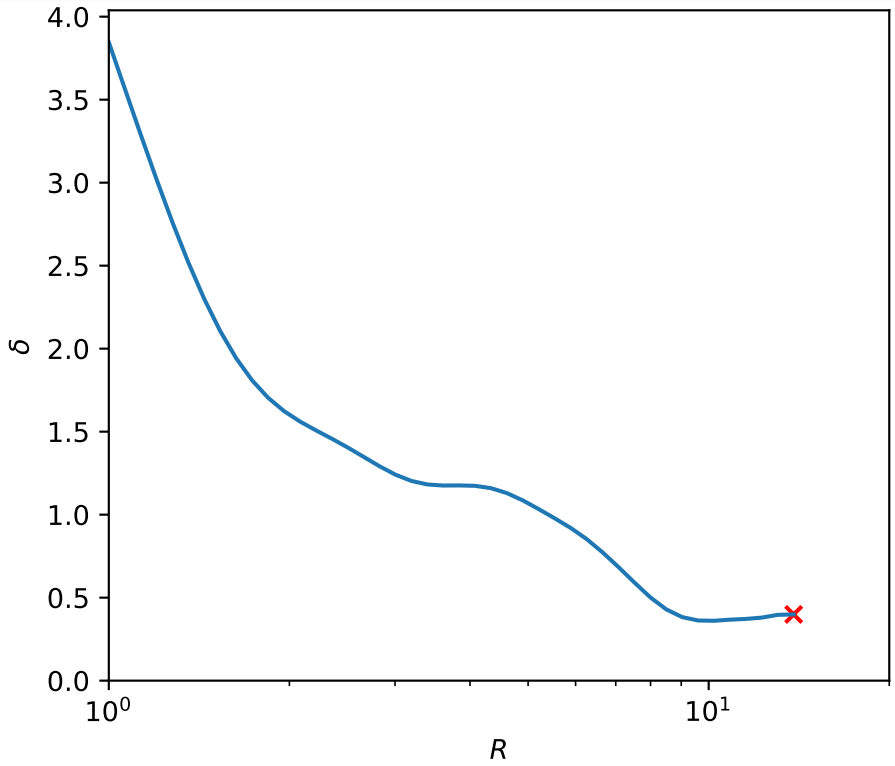
Excursion set illustrated



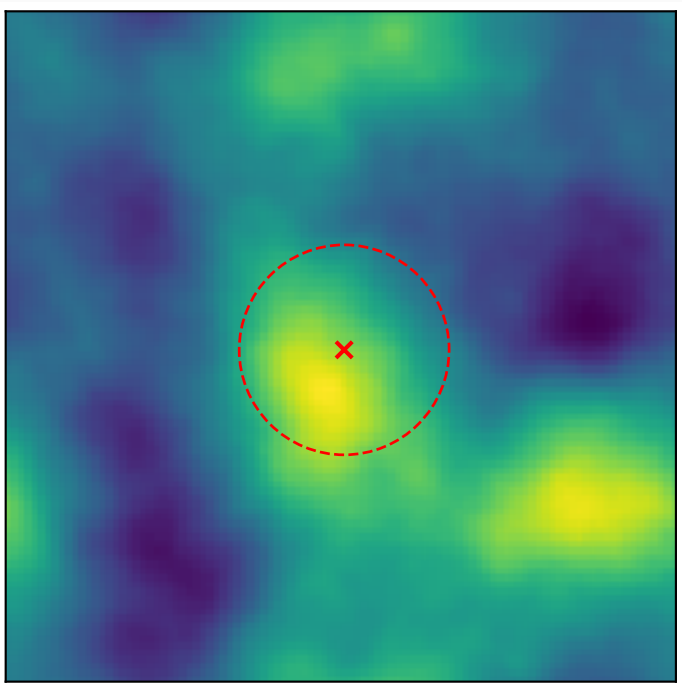


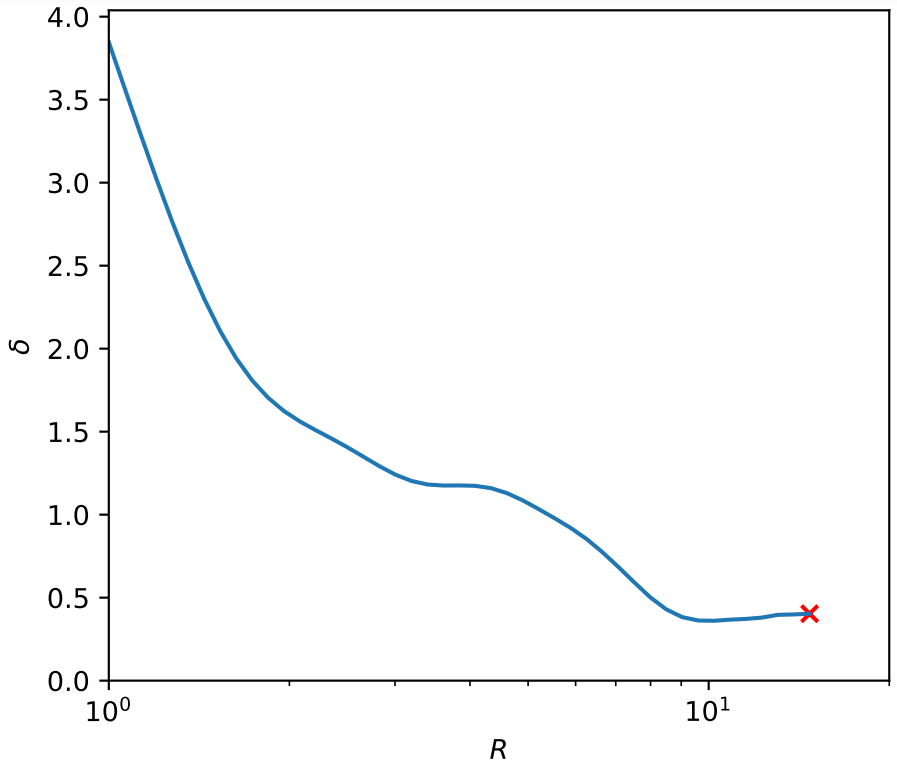
Excursion set illustrated



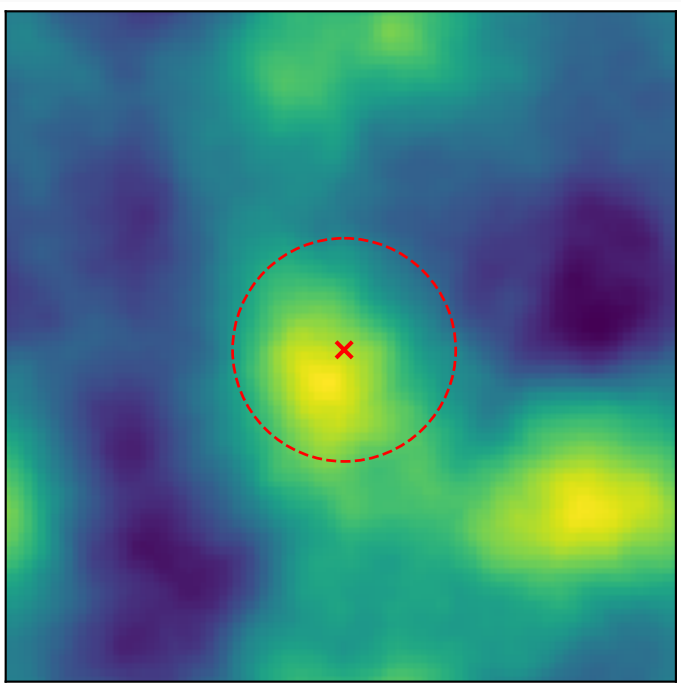


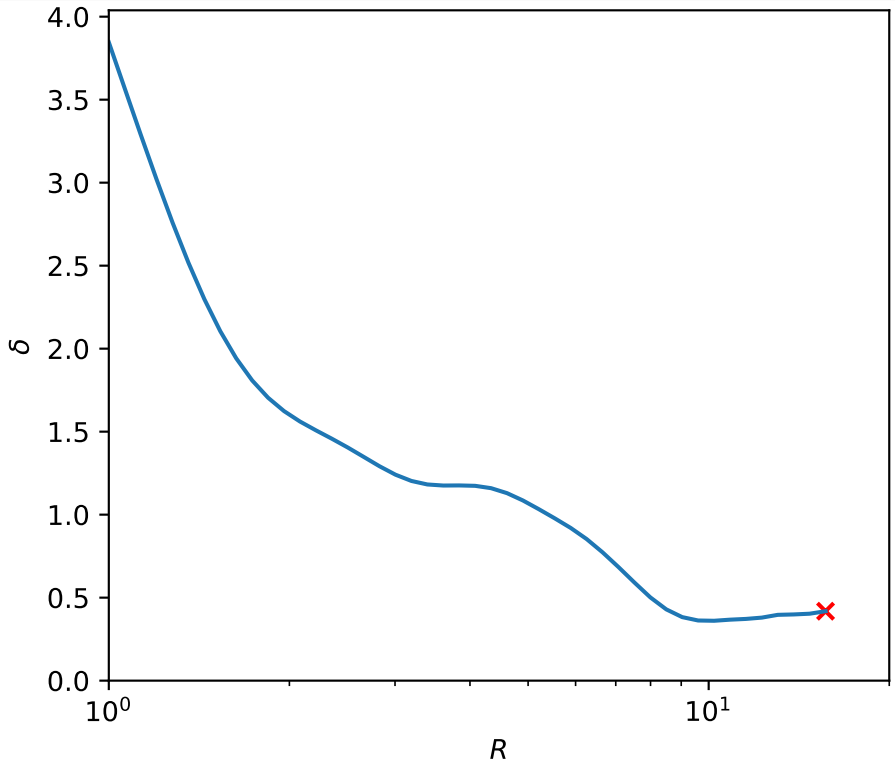
Excursion set illustrated



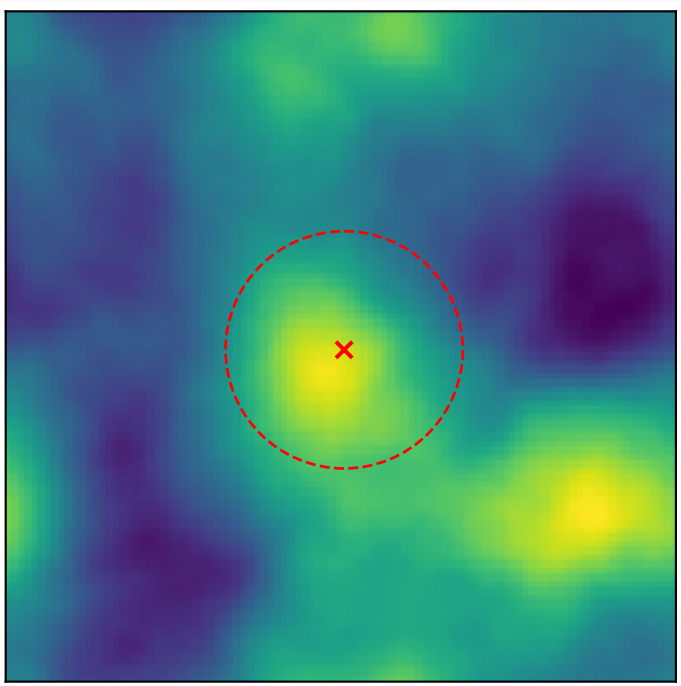


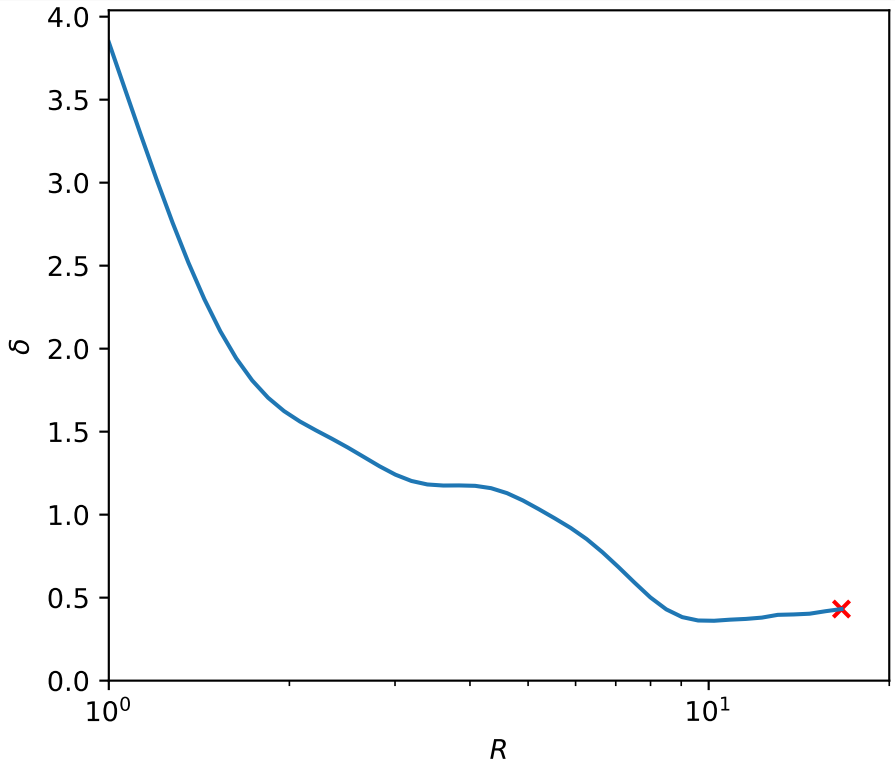
Excursion set illustrated



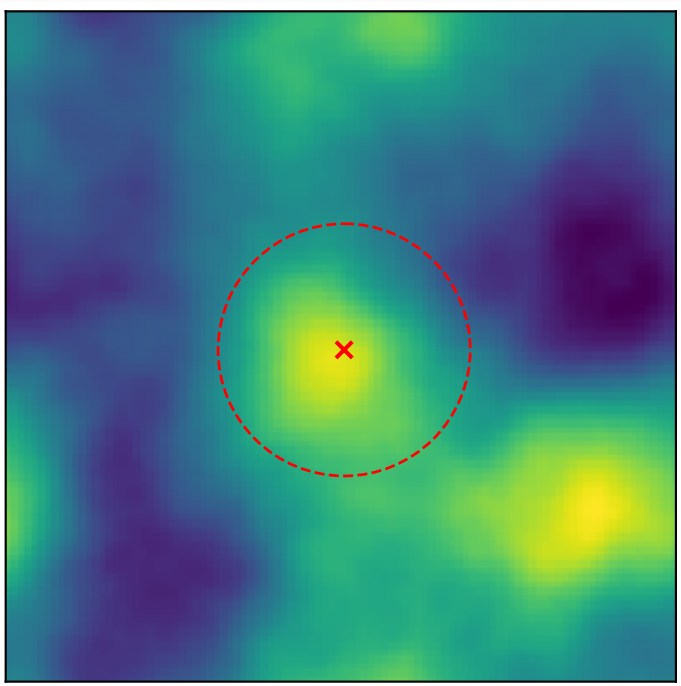


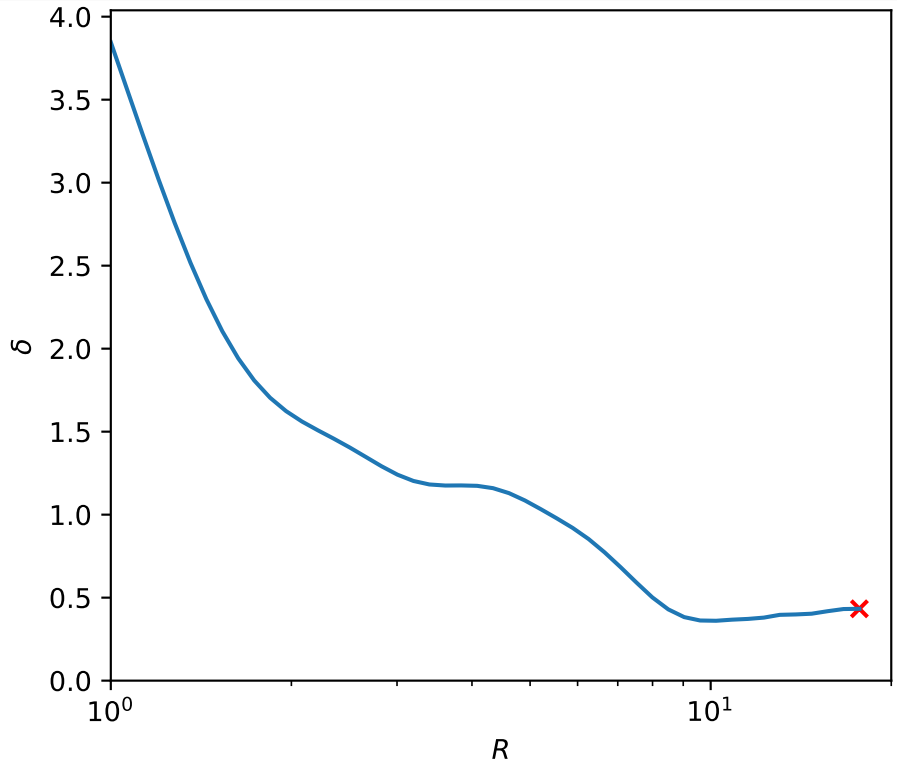
Excursion set illustrated



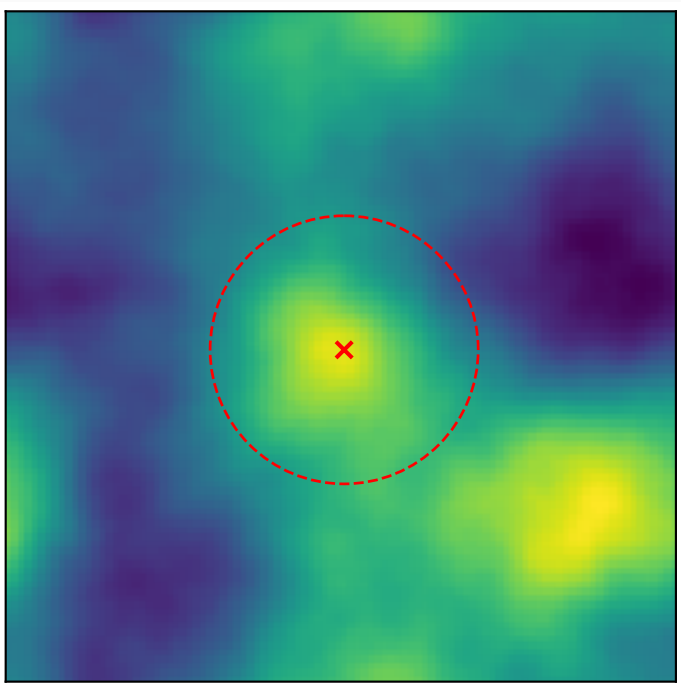


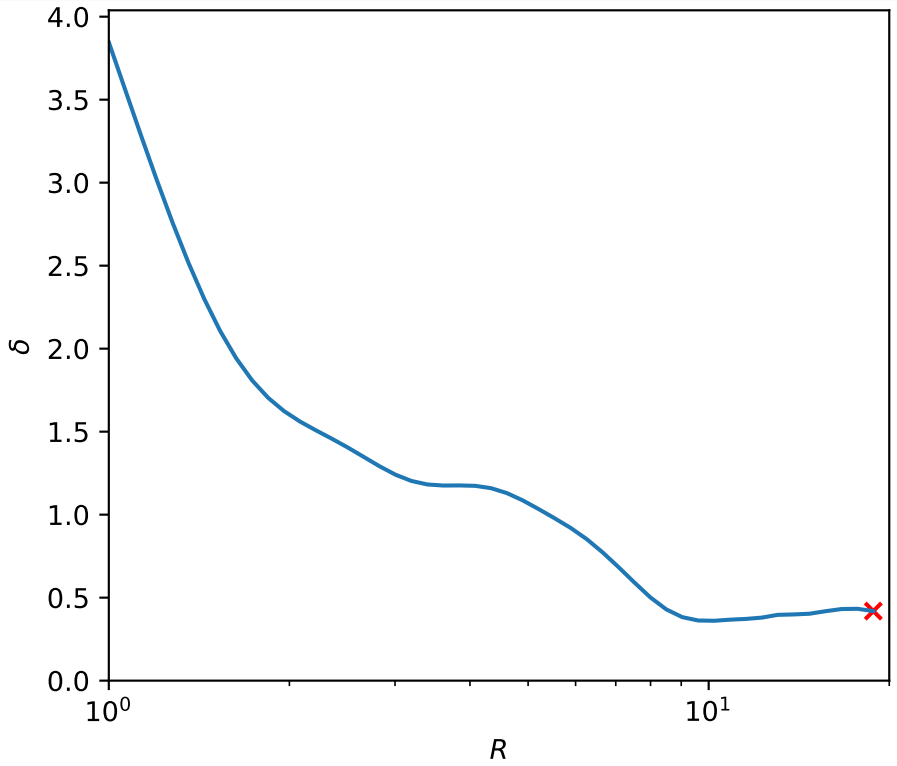
Excursion set illustrated



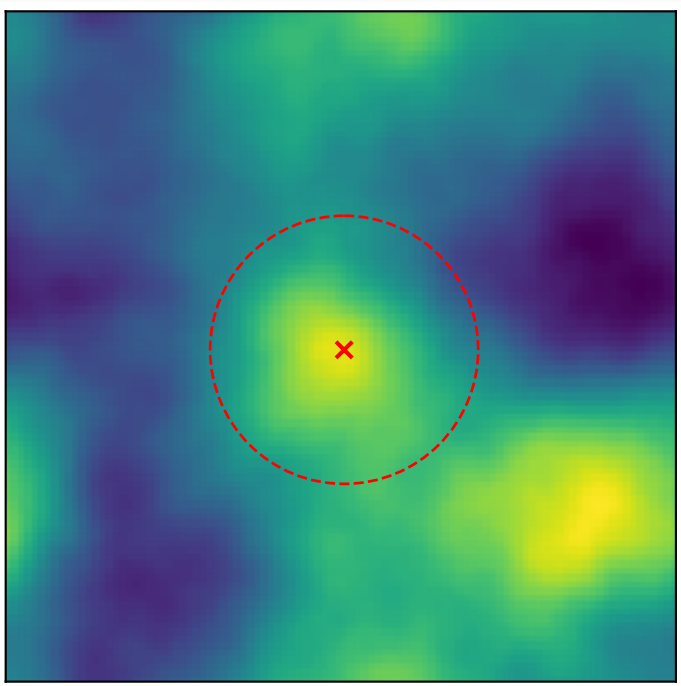


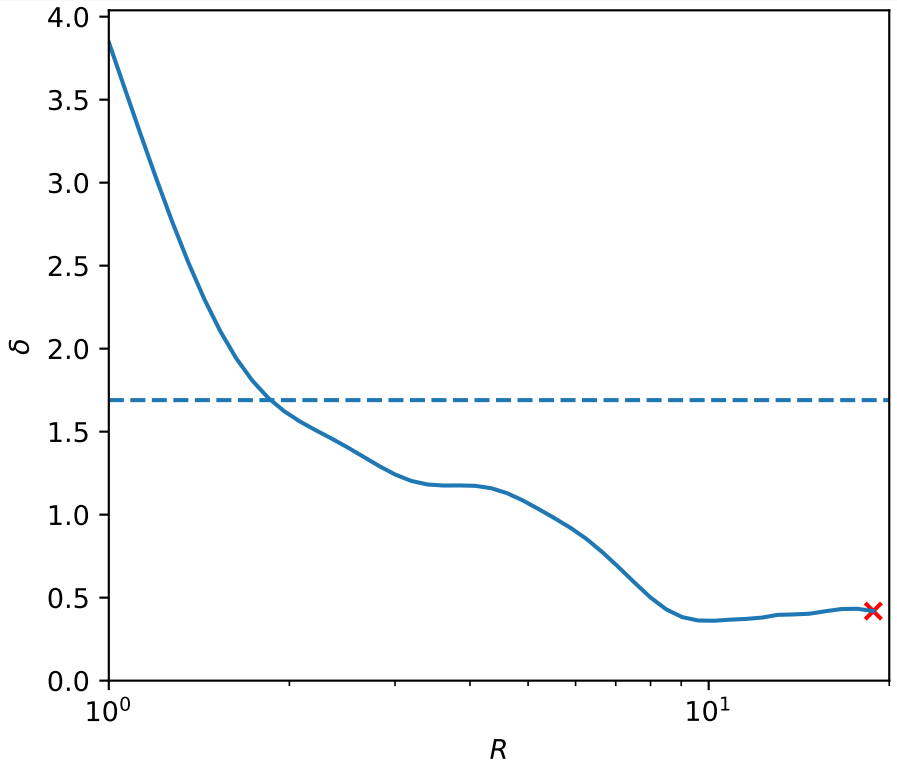
Excursion set illustrated



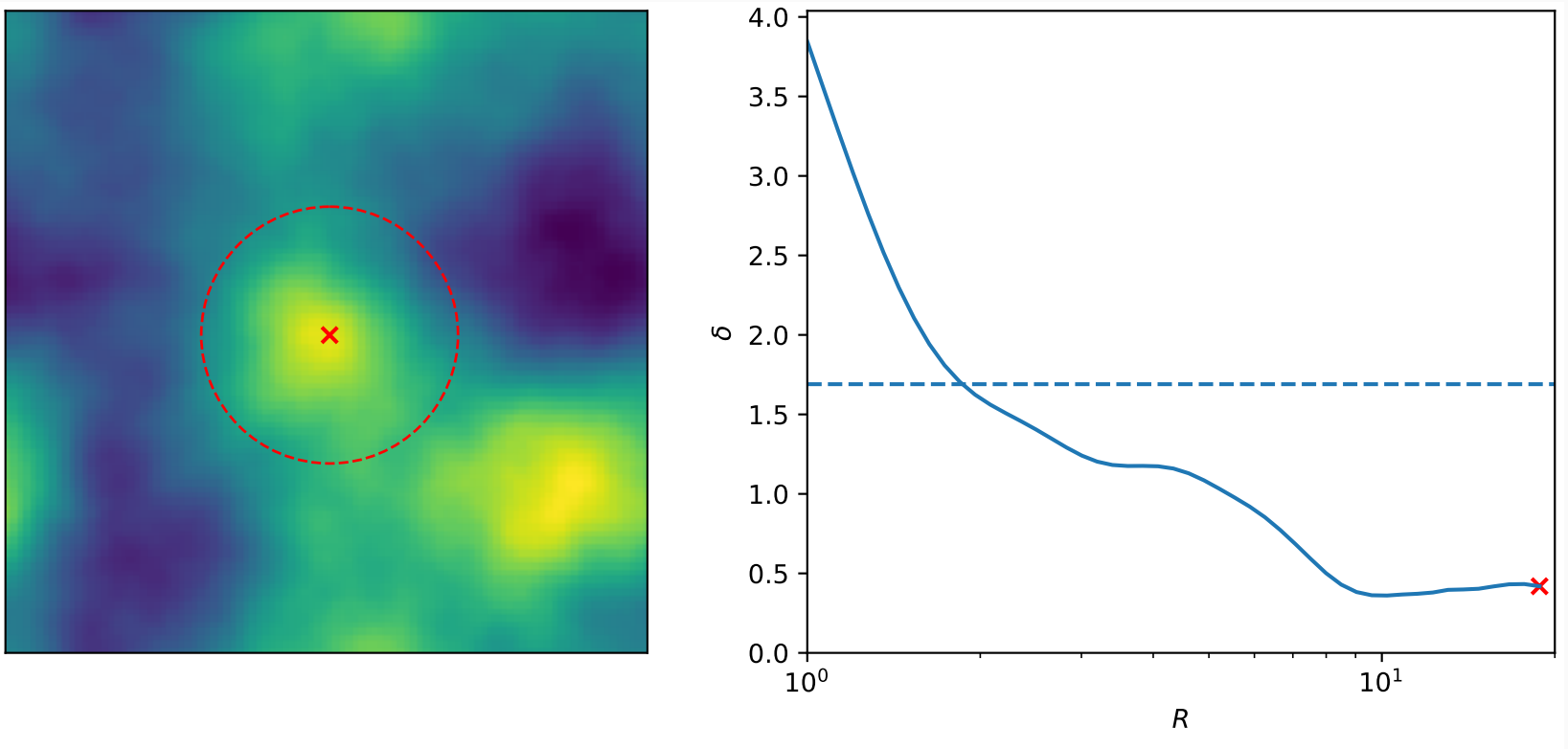


Excursion set illustrated





Excursion set illustrated



High density $\rightarrow$ early collapse

Large smoothing scale $\rightarrow$ large mass

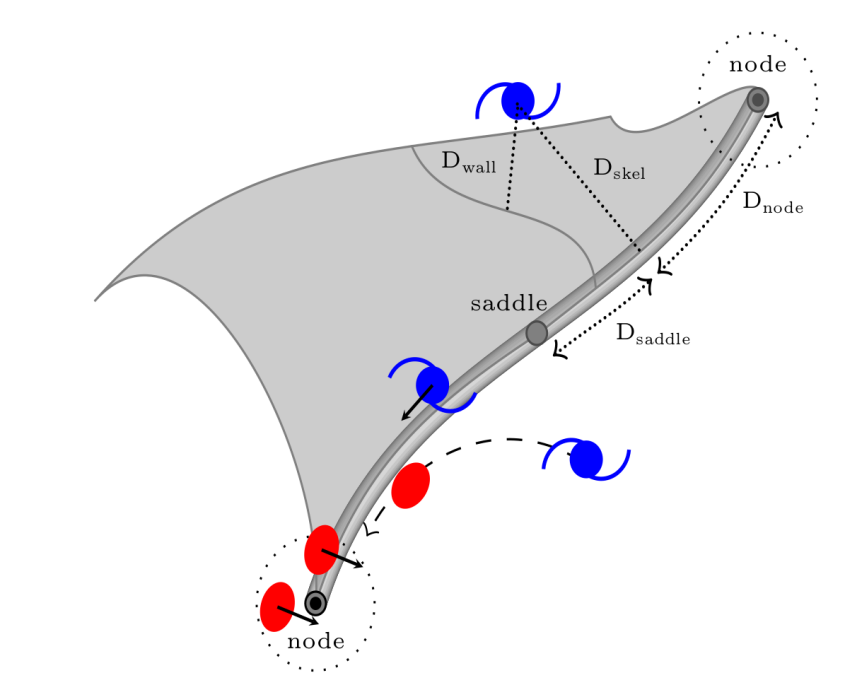
Including filaments

Anisotropy encoded in the Hessian of tidal tensor

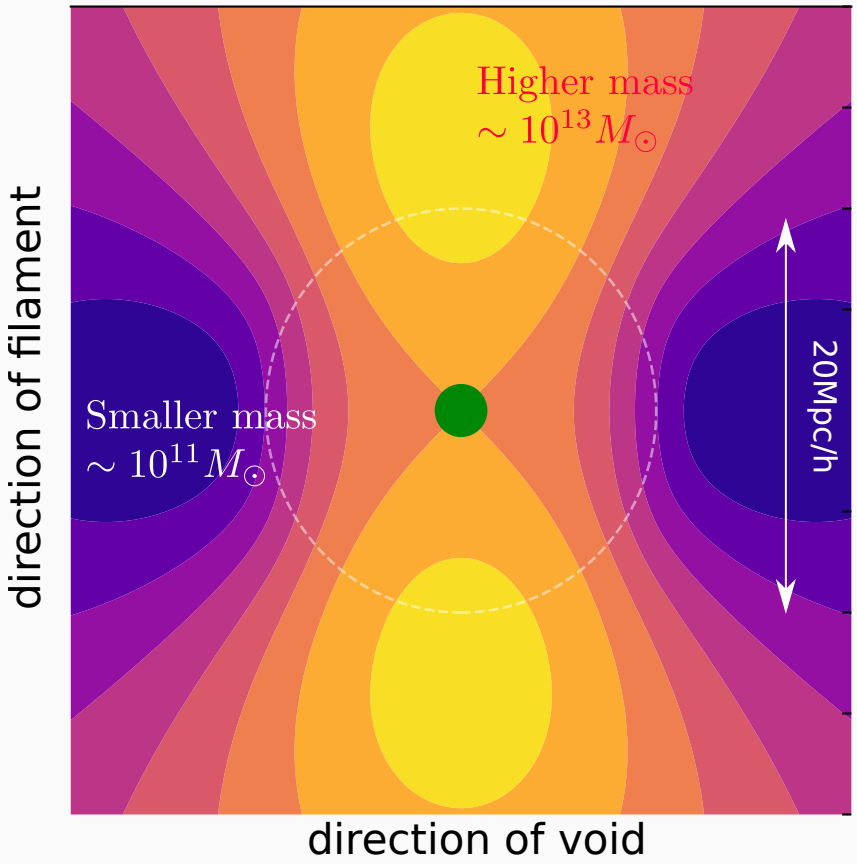
$$q_{ij} = \underbrace{\left(\phi_{ij} - \frac{\nu}{3}\delta_{ij}\right)}_{\text{traceless part}\rightarrow\text{ anisotropy}} + \underbrace{\frac{\nu}{3}\delta_{ij}}_{\text{density}}$$

via

$$\mathcal{Q} = \frac{r_i \bar{q}_{ij} r_j}{r_i r_j}$$



Typical mass of DM halo



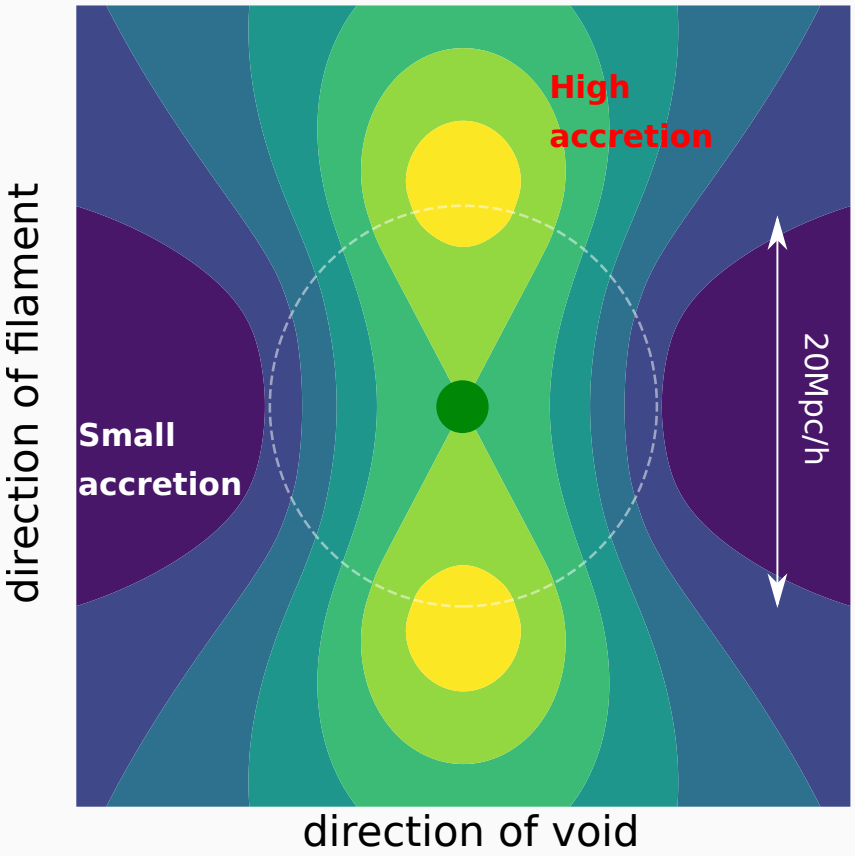
The typical mass at $z = 0$.

M. Musso, C. Cadiou *et al.*, MNRAS

1. Larger galaxies in nodes
2. Smaller galaxies in voids

In agreement with *n*-body simulations.

Effect on (DM) accretion rate



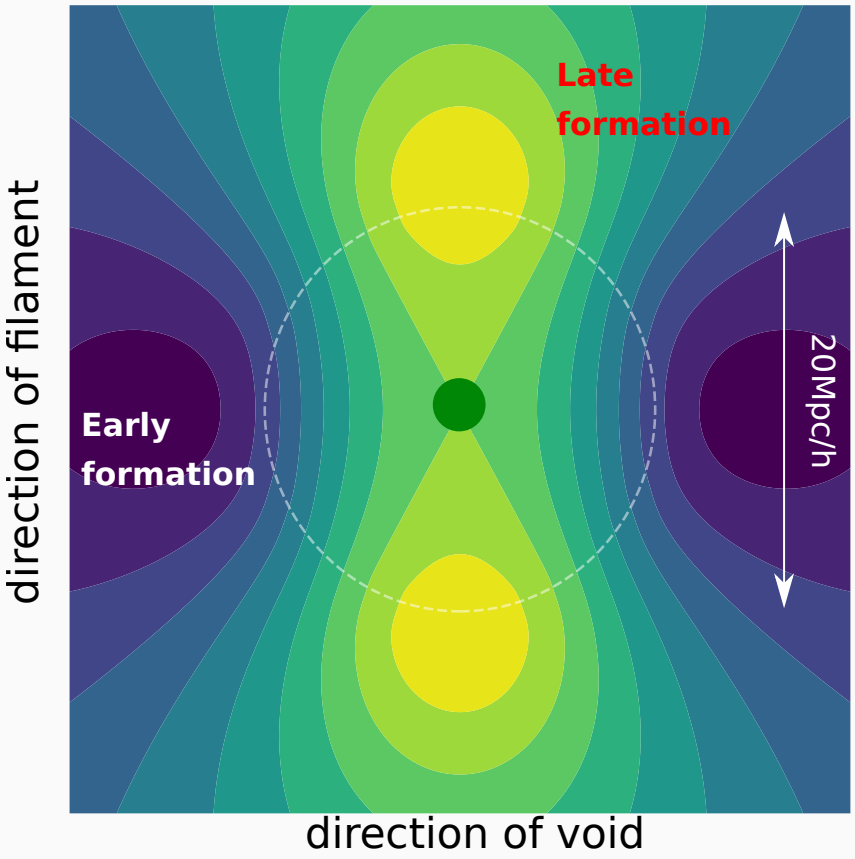
Accretion rate at **fixed** final mass

$$M \simeq 3 \times 10^{11}\,\mathrm{M}_{\odot}.$$

M. Musso, C. Cadiou *et al.*, MNRAS

1. High accretion rate in node
2. Small accretion rate in voids

Effect of halo formation time

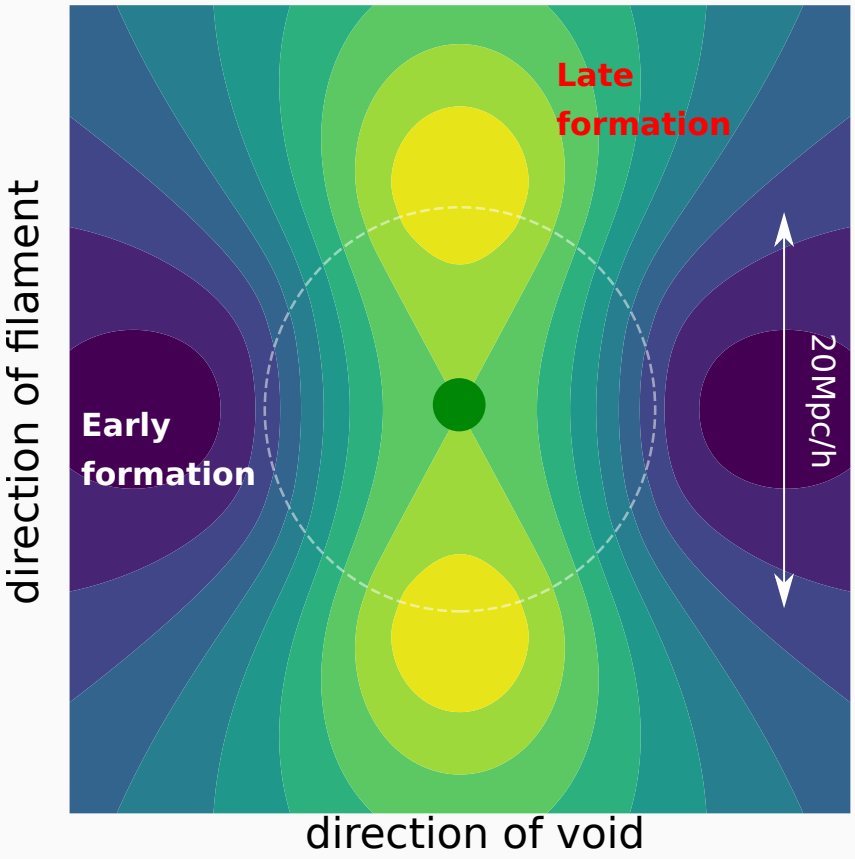


Formation time at **fixed** final mass $M \simeq 3 \times 10^{11}\,\mathrm{M}_{\odot}$.

1. Late formation in node (low z)
2. Early formation in voids (high z)

M. Musso, C. Cadiou *et al.*, MNRAS

Effect of halo formation time



Formation time at **fixed** final mass $M \simeq 3 \times 10^{11}\,\mathrm{M}_{\odot}$.

1. Late formation in node (low z)
2. Early formation in voids (high z)

Tension with observations?

M. Musso, C. Cadiou *et al.*, MNRAS

Need for AGN feedback?

Theory

Higher DM accretion + late formation:

blue central galaxy?

Observations

Massive red central galaxies

Need for AGN feedback?

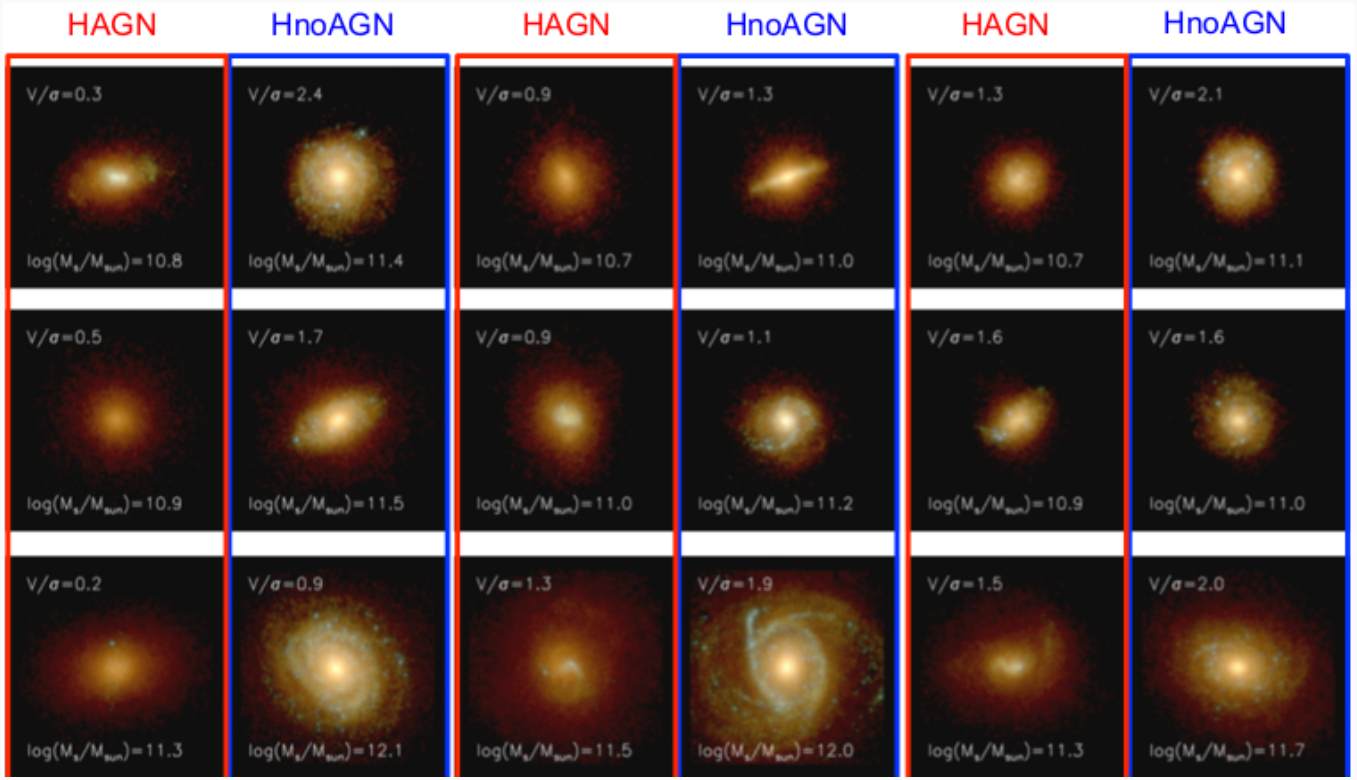
Theory

Higher DM accretion + late formation:

blue central galaxy?

Observations

Massive red central galaxies

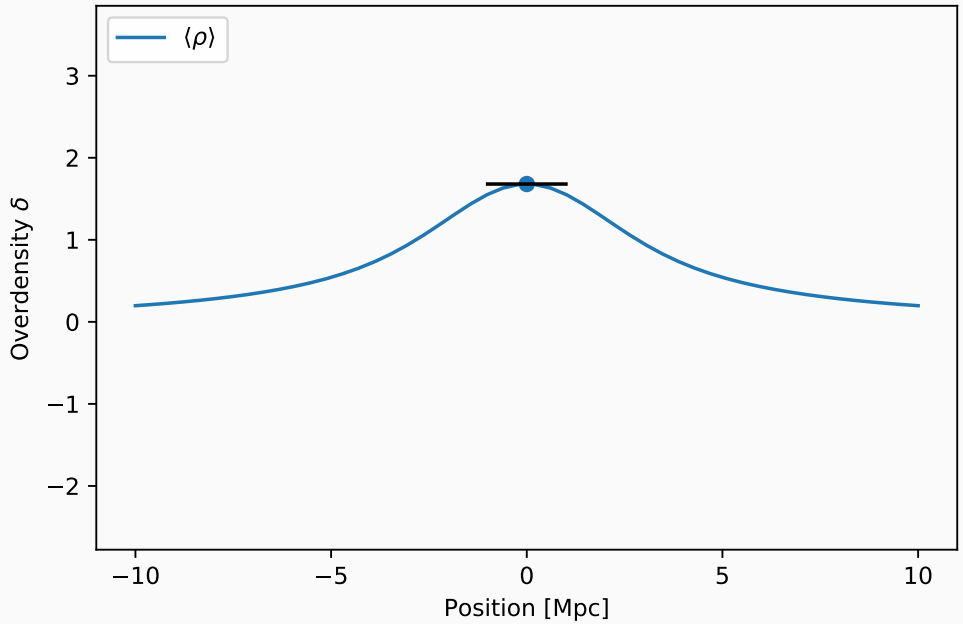


Dubois+16

Beyond Mass-Density

4 parameters dictate mass/accretion/formation time/. . . :

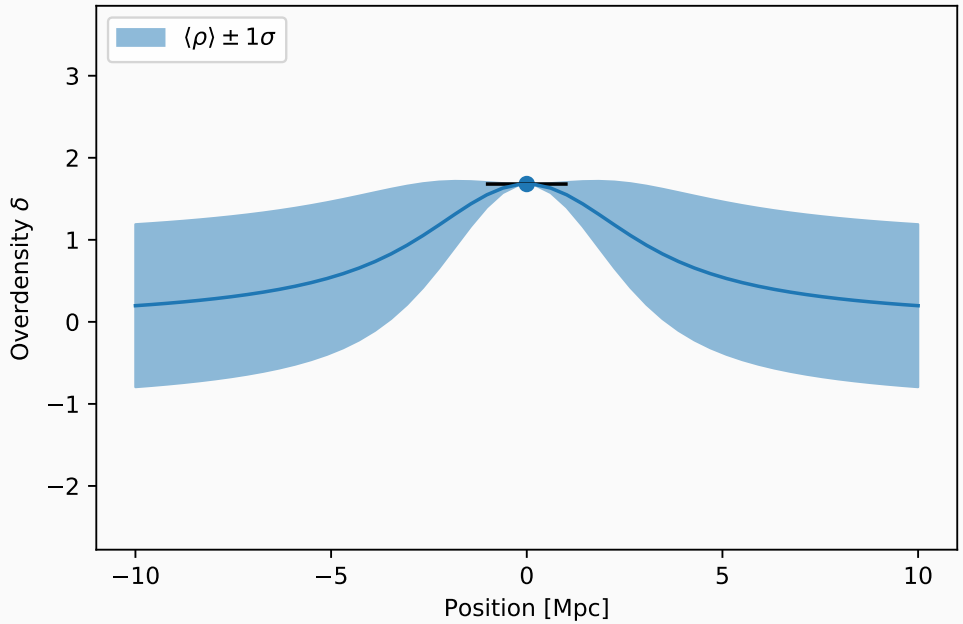
- mean density δ
- mean derived density $\delta' = \frac{\mathrm{d}\delta}{\mathrm{d}R}$



Beyond Mass-Density

4 parameters dictate mass/accretion/formation time/. . . :

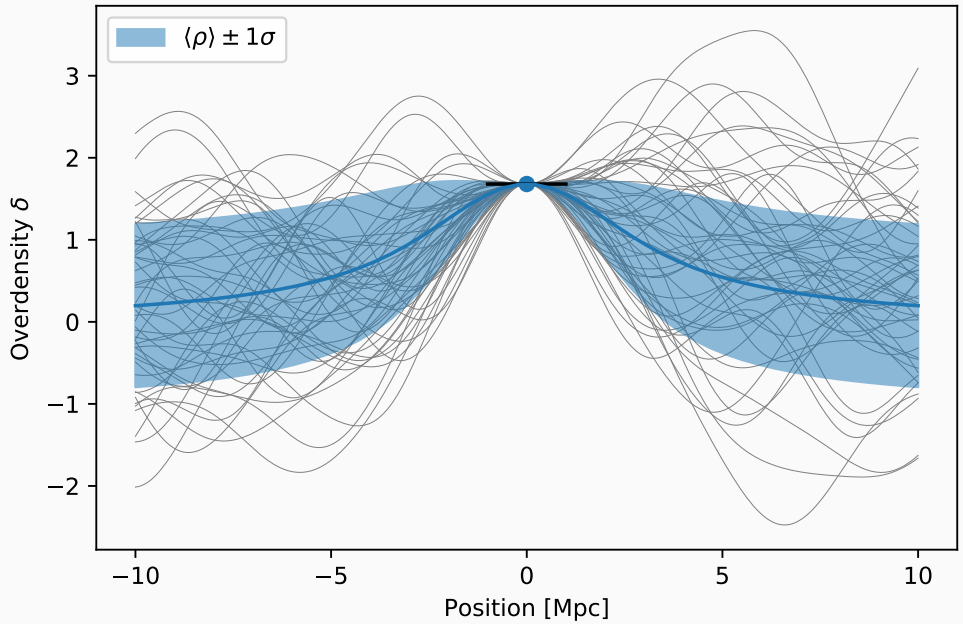
- mean density δ
- mean derived density $\delta' = \frac{\mathrm{d}\delta}{\mathrm{d}R}$
- variance of density
- variance of accretion



Beyond Mass-Density

4 parameters dictate mass/accretion/formation time/. . . :

- mean density δ
- mean derived density $\delta' = \frac{\mathrm{d}\delta}{\mathrm{d}R}$
- variance of density
- variance of accretion



Environments with different variance do not behave the same: what matters is $(\delta - \langle\delta\rangle)/\sqrt{\mathrm{Var}(\delta)}$

Take home message

Assembly variables are functions of

- mass

Take home message

Assembly variables are functions of

- mass
- density

Take home message

Assembly variables are functions of

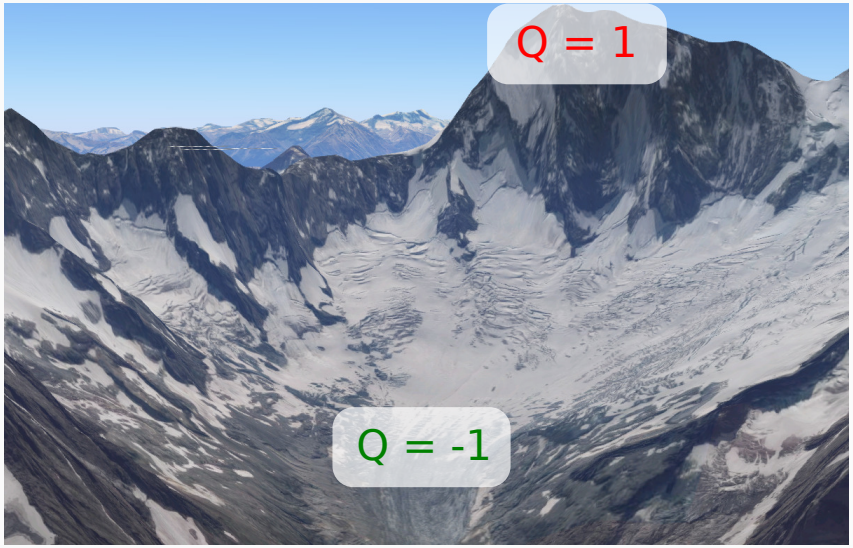
- mass
- density
- anisotropy, induced by saddle

Encoded by

$$\mathcal{Q} = \frac{r_i \bar{q}_{ij} r_j}{r^2} = \text{anisotropy variable}$$

$$+$$

$$r = (\text{distance})$$



How does that compare to reality?

How does that compare to reality?

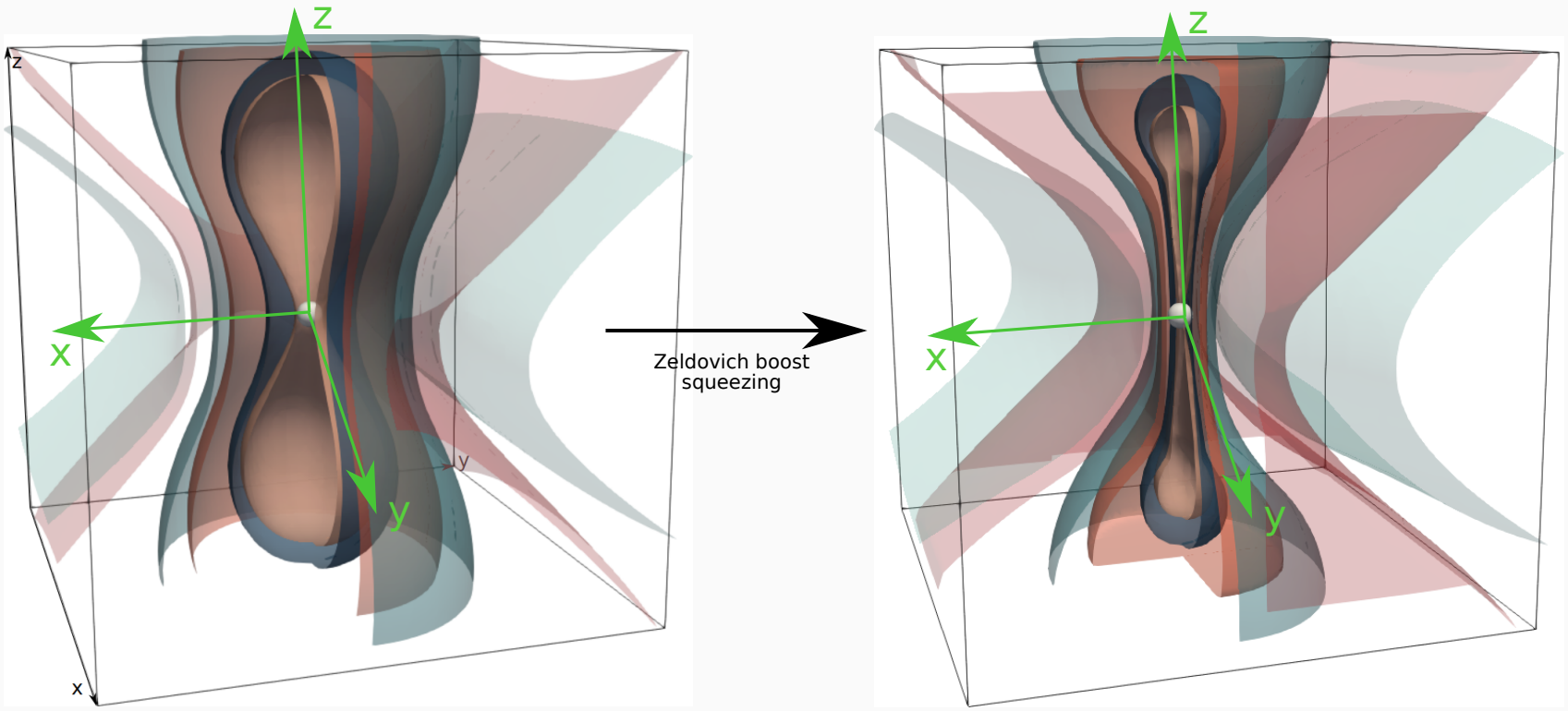
like observation

How does that compare to reality?

like observation

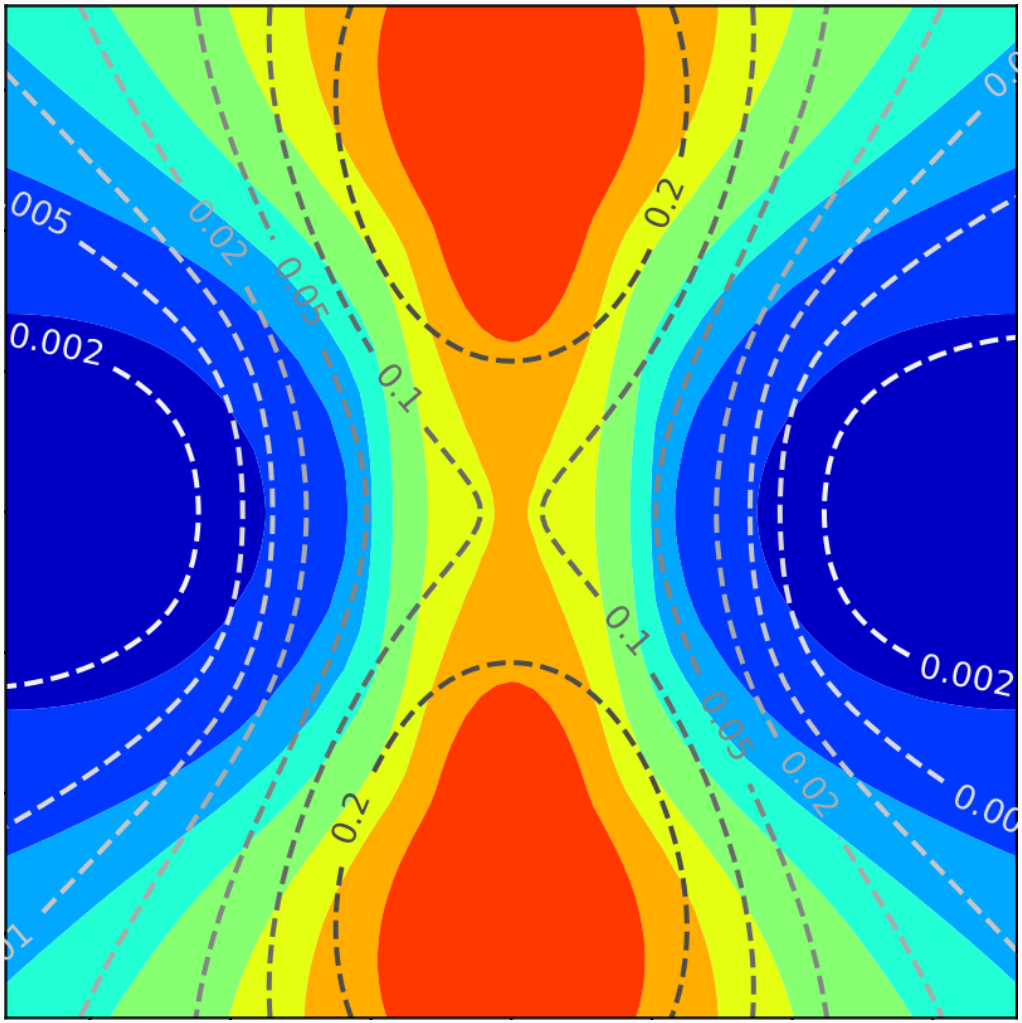
or actually simulations

Link to observation



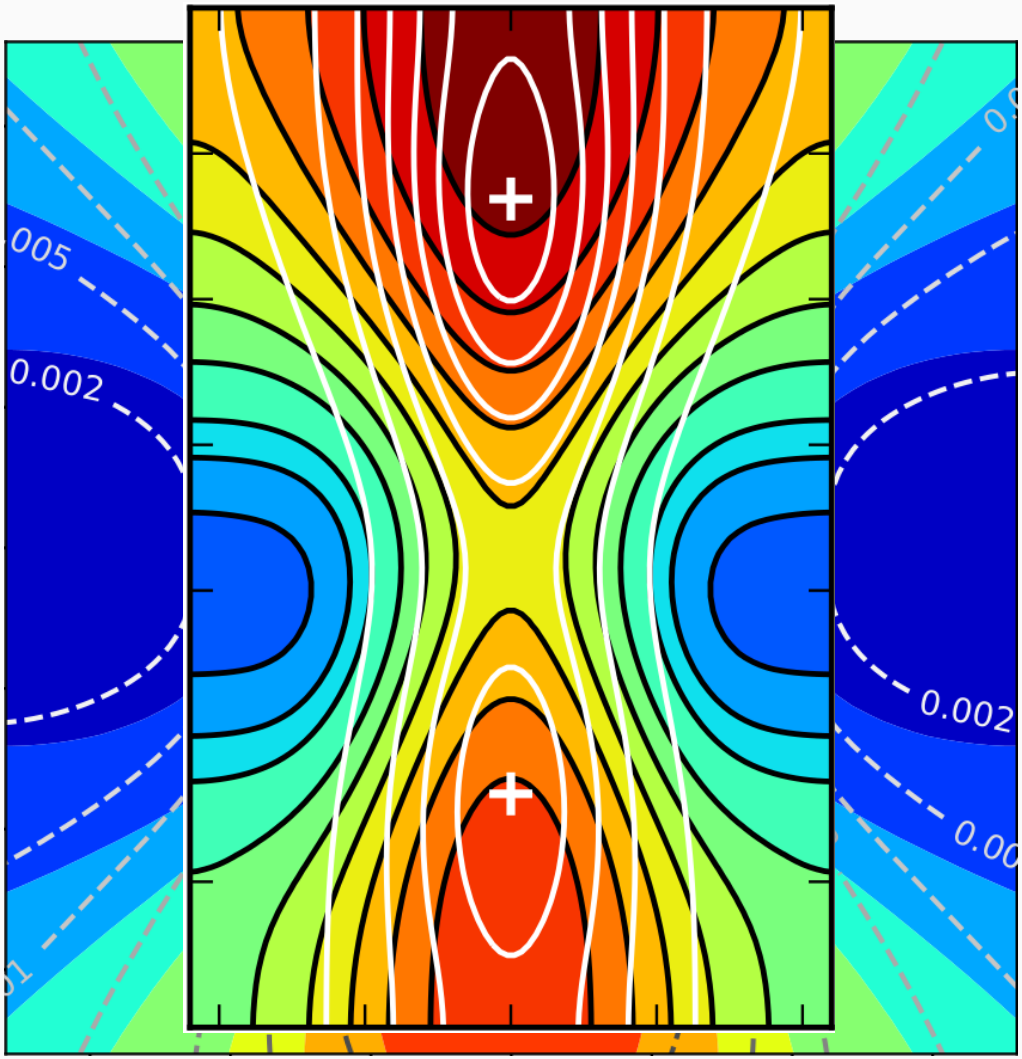
Need to map Lagrangian space (theoretical space) to Eulerian space (simulation/observation space).

Link to simulations



Kraljic+, in prep.

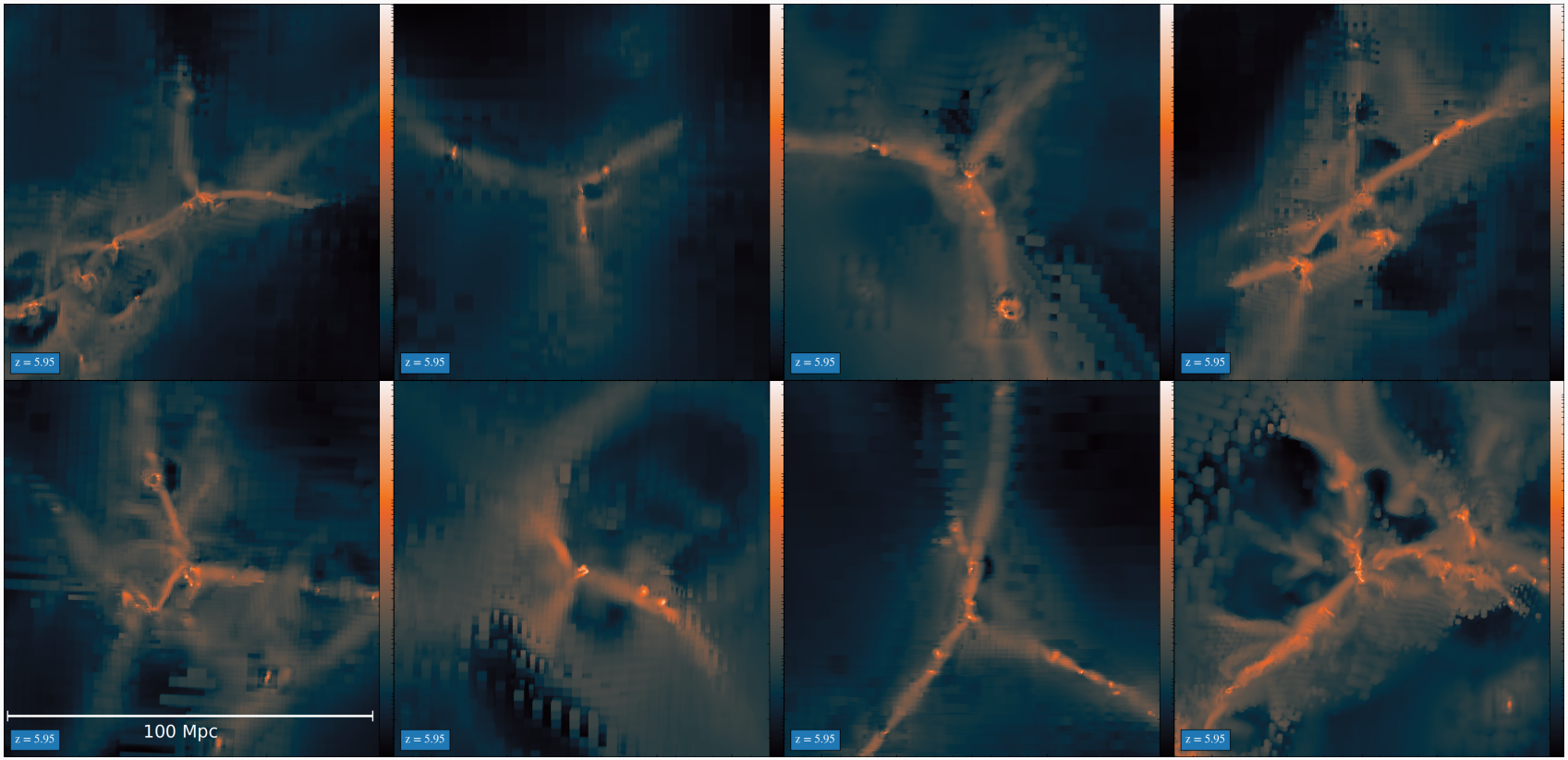
Link to simulations



Kraljic+, in prep.

Filamentary accretion at high z

From simulations



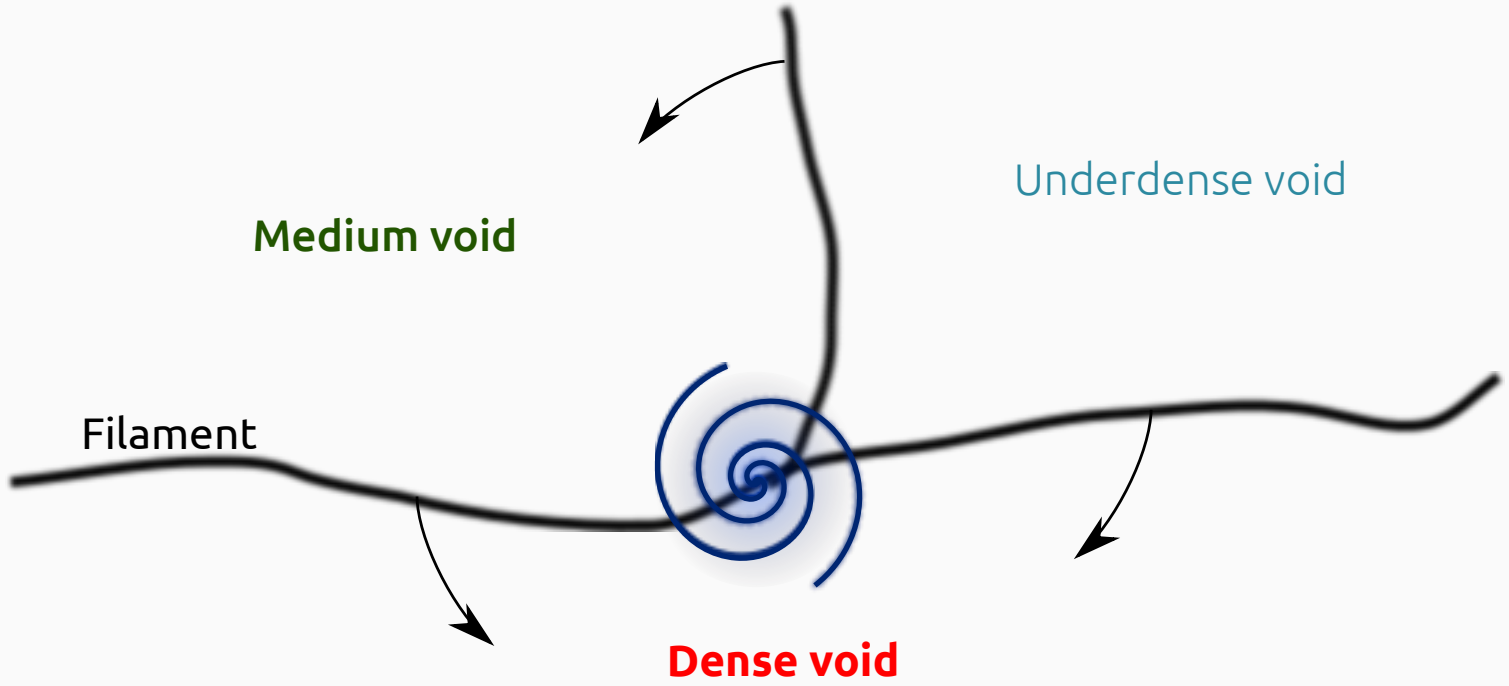
Density maps of galaxies from New Horizon simulation @ $z = 6$, Dubois+, in prep.

Typical setup: planar with 3 filaments

Simple 2D model

Open questions

- Net torque on filaments?
- Galaxy spin-up or down?
- Typical coherence scale?



C. Cadiou, C. Pichon & S.Codis, in prep

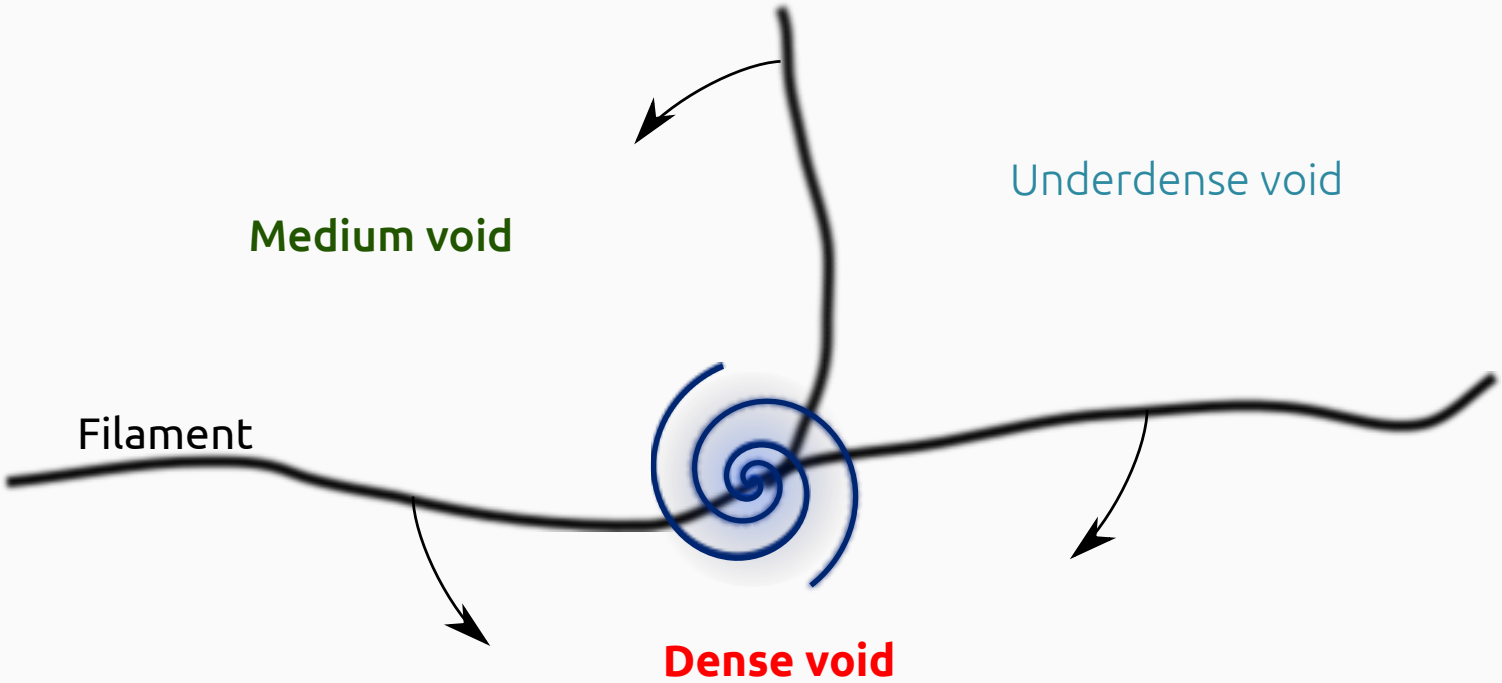
Simple 2D model

Open questions

- Net torque on filaments?
- Galaxy spin-up or down?
- Typical coherence scale?

Model

- Planar (2D)
- 3 voids $\rightarrow$ 3 filaments
- 1 central peak

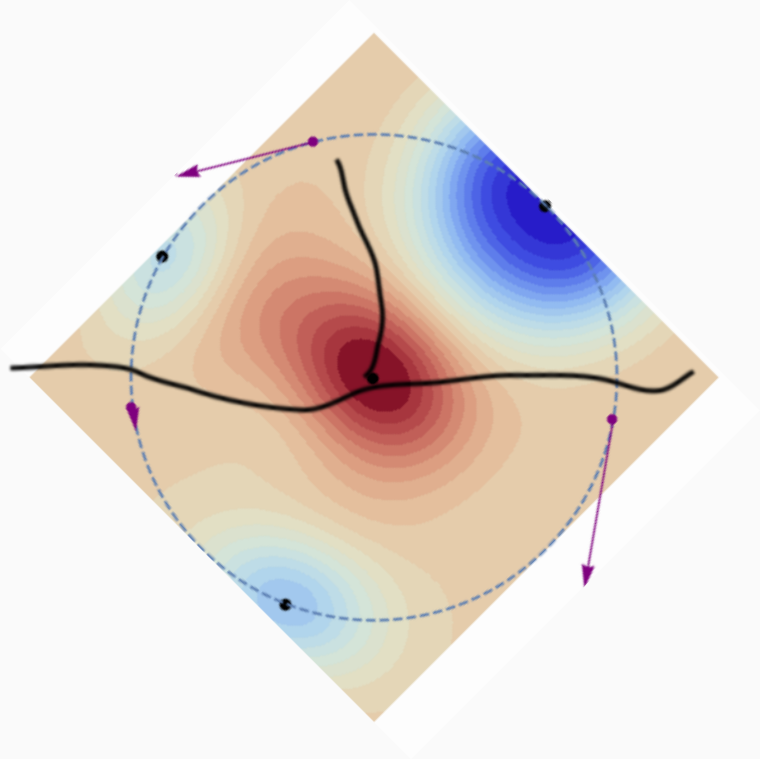


C. Cadiou, C. Pichon & S.Codis, in prep

Predicting the torque

Using constrained theory + Λ-CDM power spectrum

Voids are pushing filaments

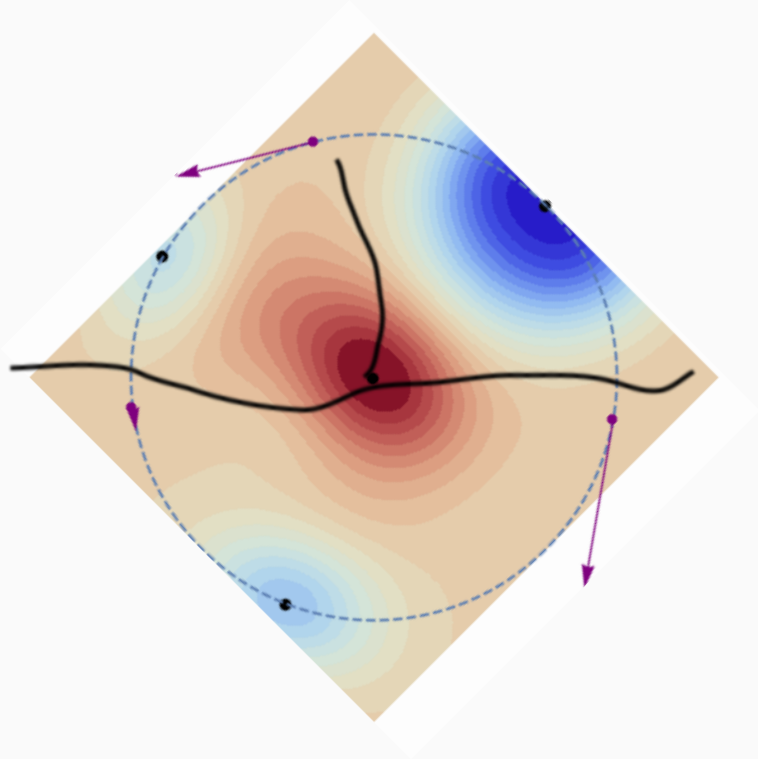


C. Cadiou, C. Pichon & S.Codis, in prep

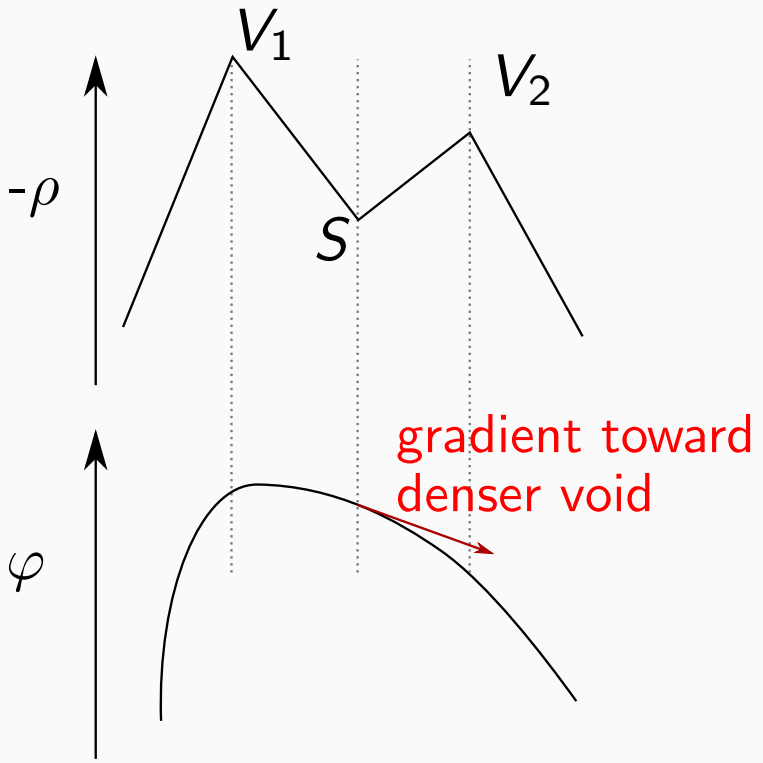
Predicting the torque

Using constrained theory + Λ-CDM power spectrum

Voids are pushing filaments



C. Cadiou, C. Pichon & S.Codis, in prep



Conclusions

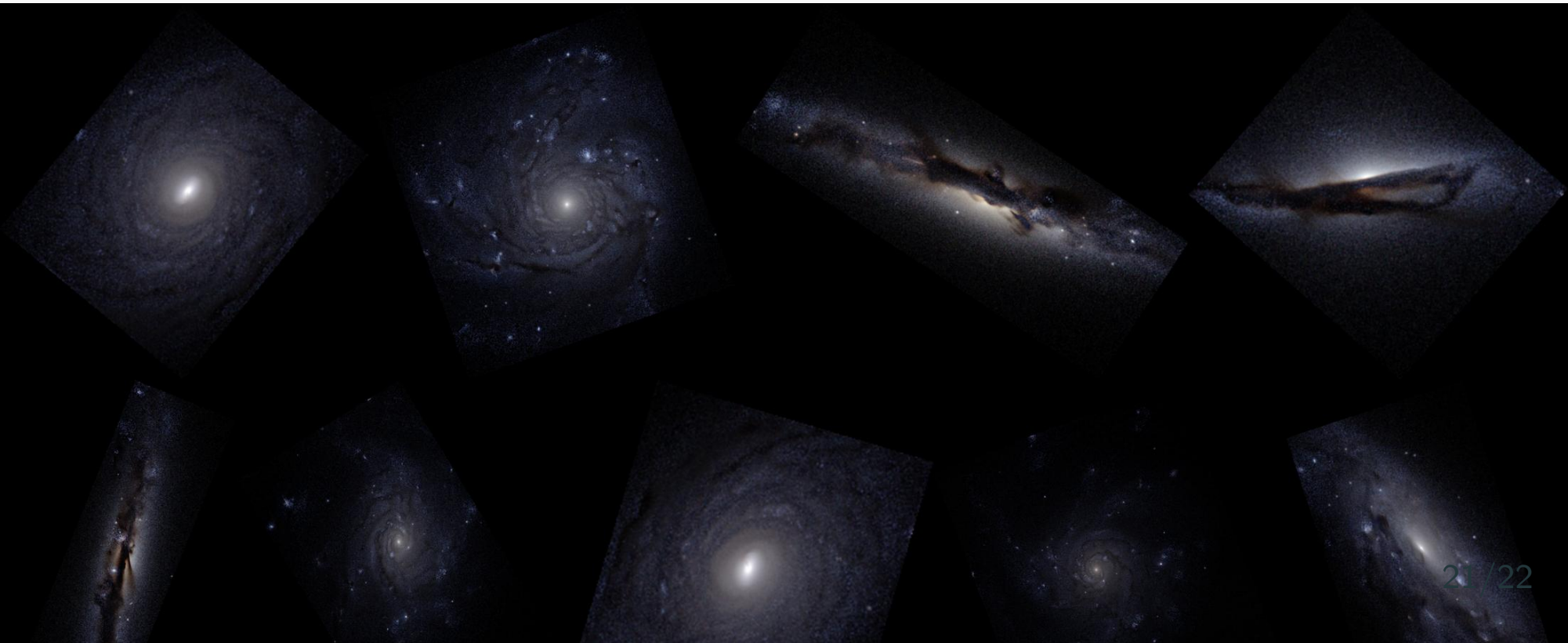
Conclusions

Assembly of DM halo

- Influenced by LSS
- Recovers *n*-body sim
- Still need baryonic physics

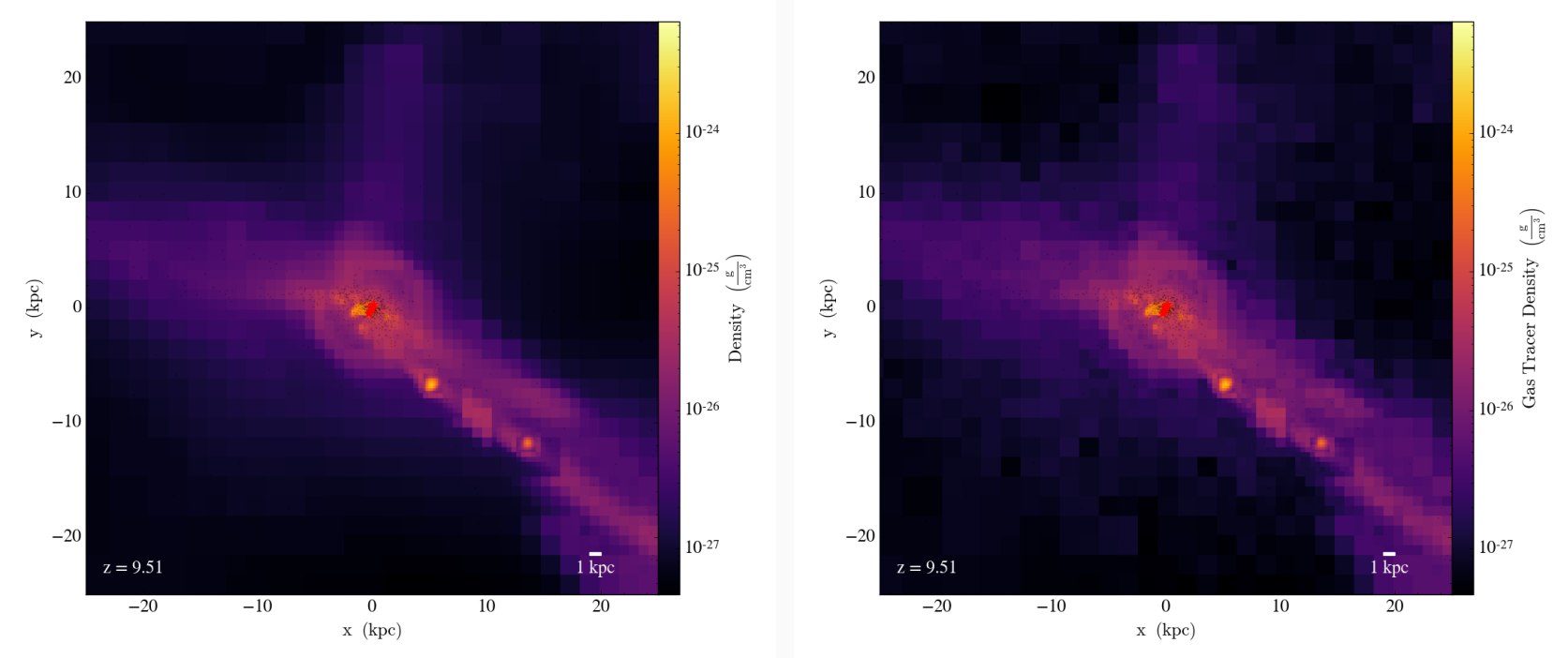
Torque on filament

- Expect torque on filament
- Quantitative results?
- Compare with simulations?



What's next?

Study of interaction cold flows/disk



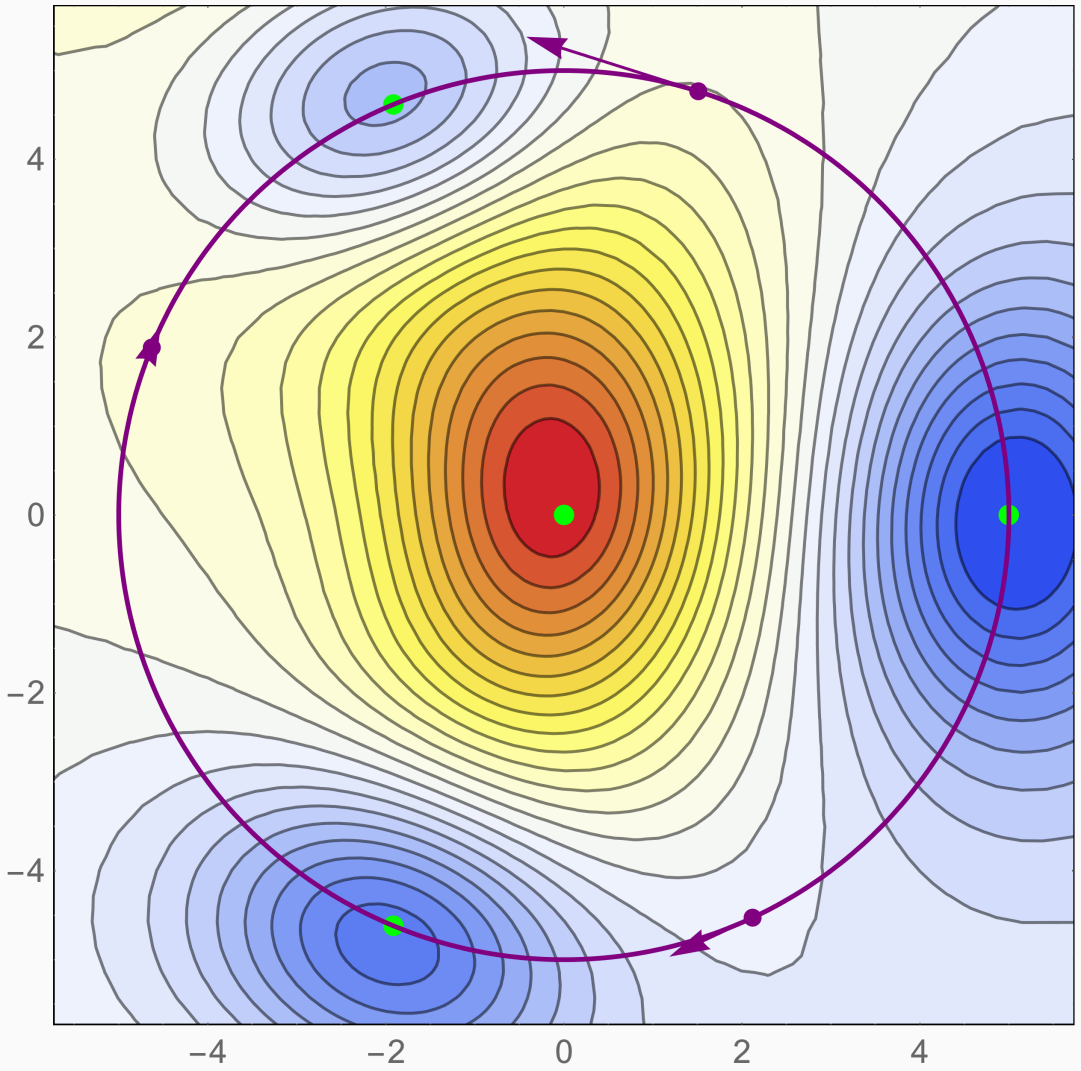
"Lagrangian in Eulerian method", see Genel+13

Fill the gap between large scale (filaments) and galaxy properties

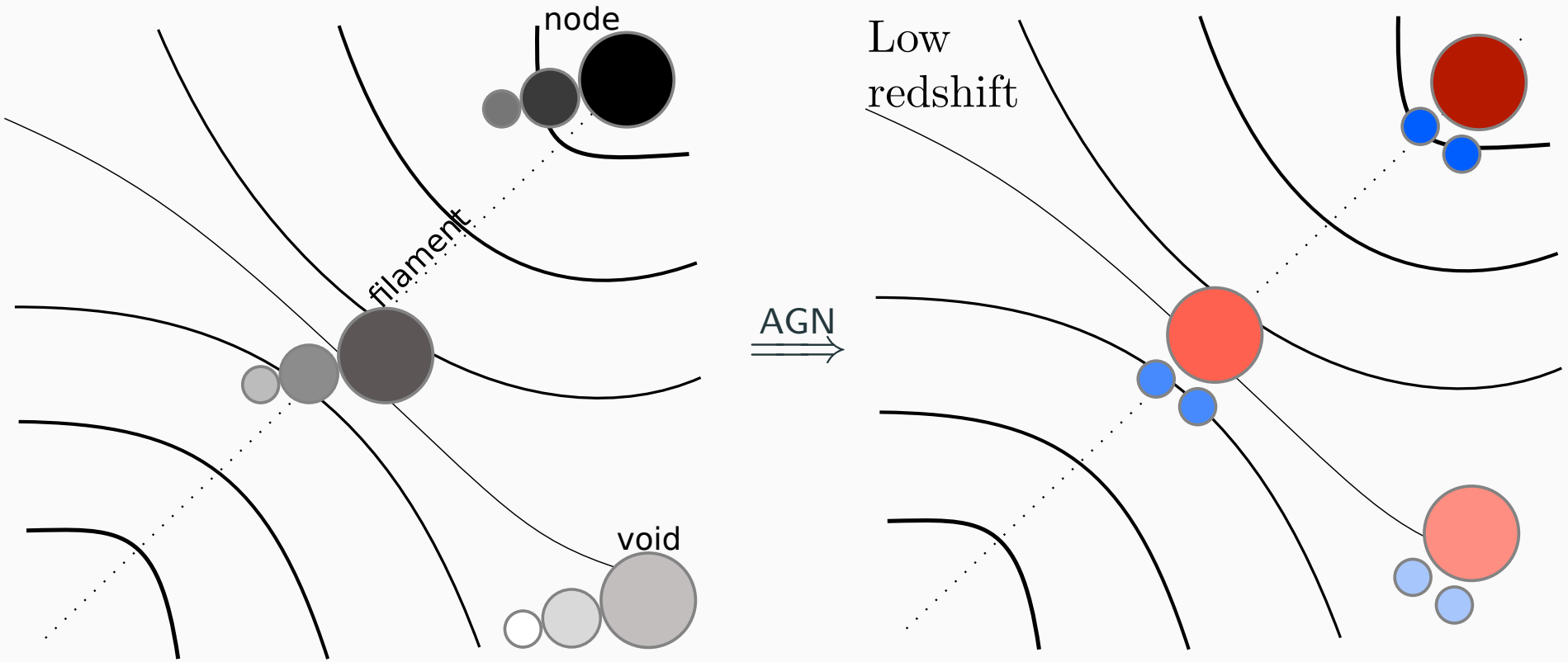
Thank you!

More torque plots

Torque on filament

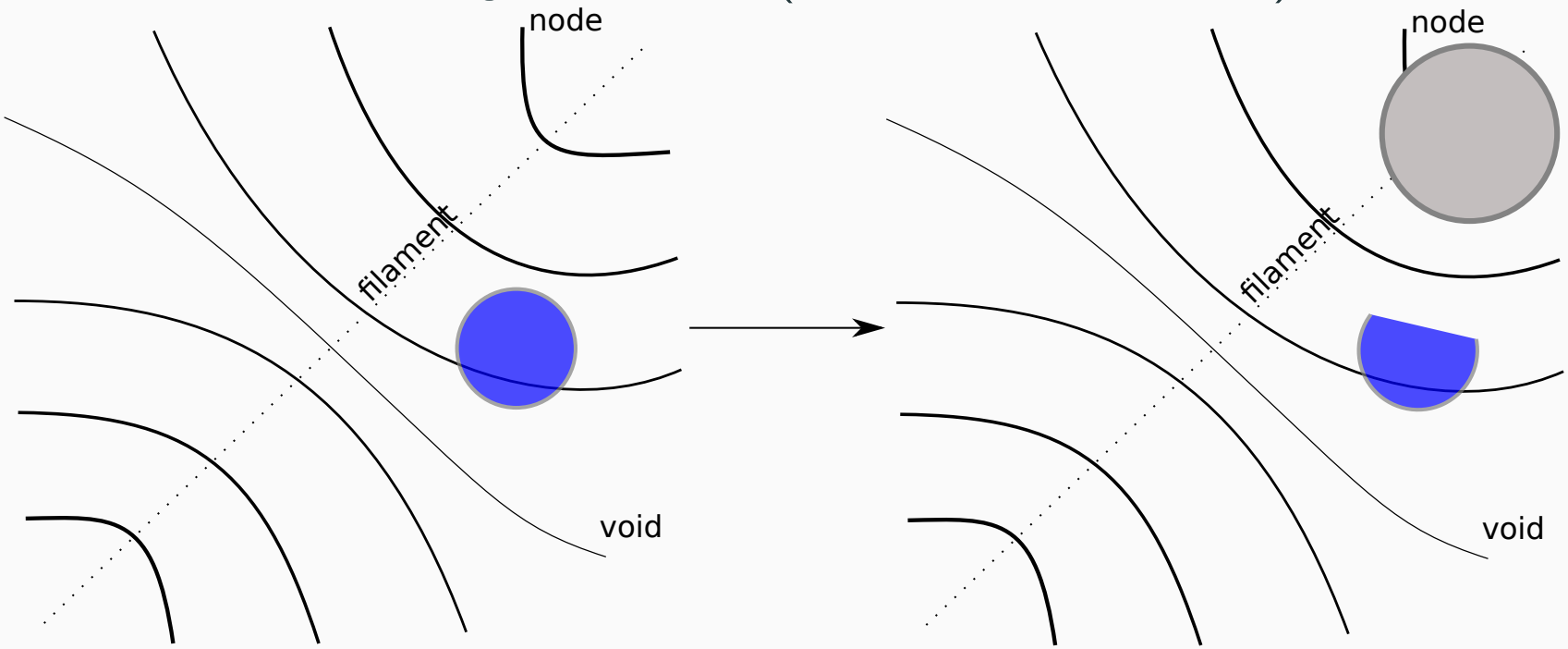


Effect of AGN



Tension with other results?

Tension with other results?

Hahn+2009: less accretion due to tidal effects from neighboring large halo

$\Rightarrow$ extra effect in large tide limit (halo-halo interaction)