Universiteit Utrecht

Large-Scale Physics from

Coarse-graining and quantum gravity

Coarse-graining CDTs

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- Propose a coarse-graining scheme suitable for CDTs;

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We need more information on the large-scale behaviour of the CDT theory. Is GR an approximation?

I will:

- Describe the goal and solutions in lattice QFT;
- Propose a coarse-graining scheme suitable for CDTs;
- Give some tentative results in the 3D model.

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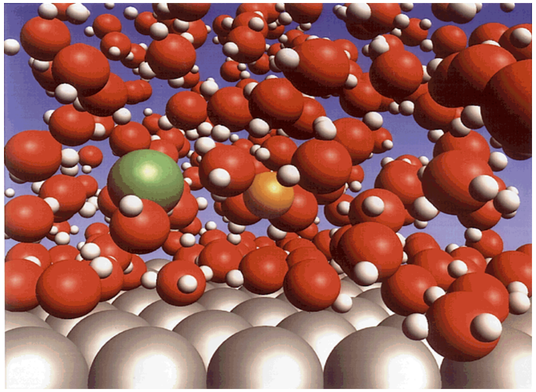
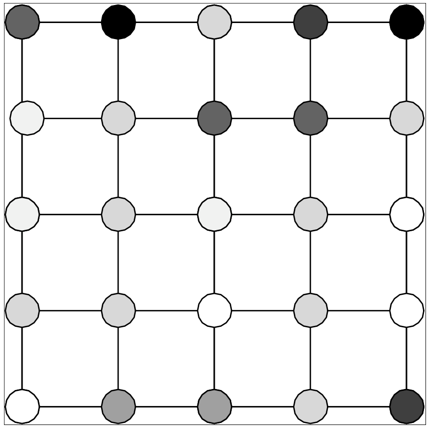
Good example: Spectral dimension

Coarse-graining lattices

In lattice field theory many ways to remove short scale detail are known:





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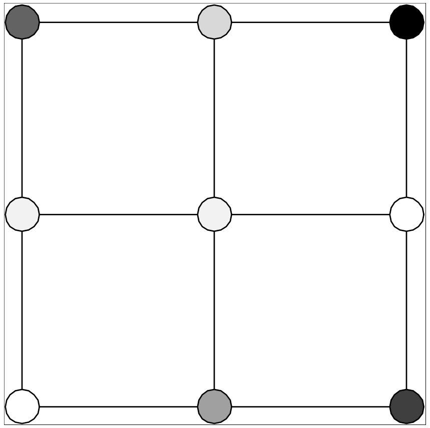

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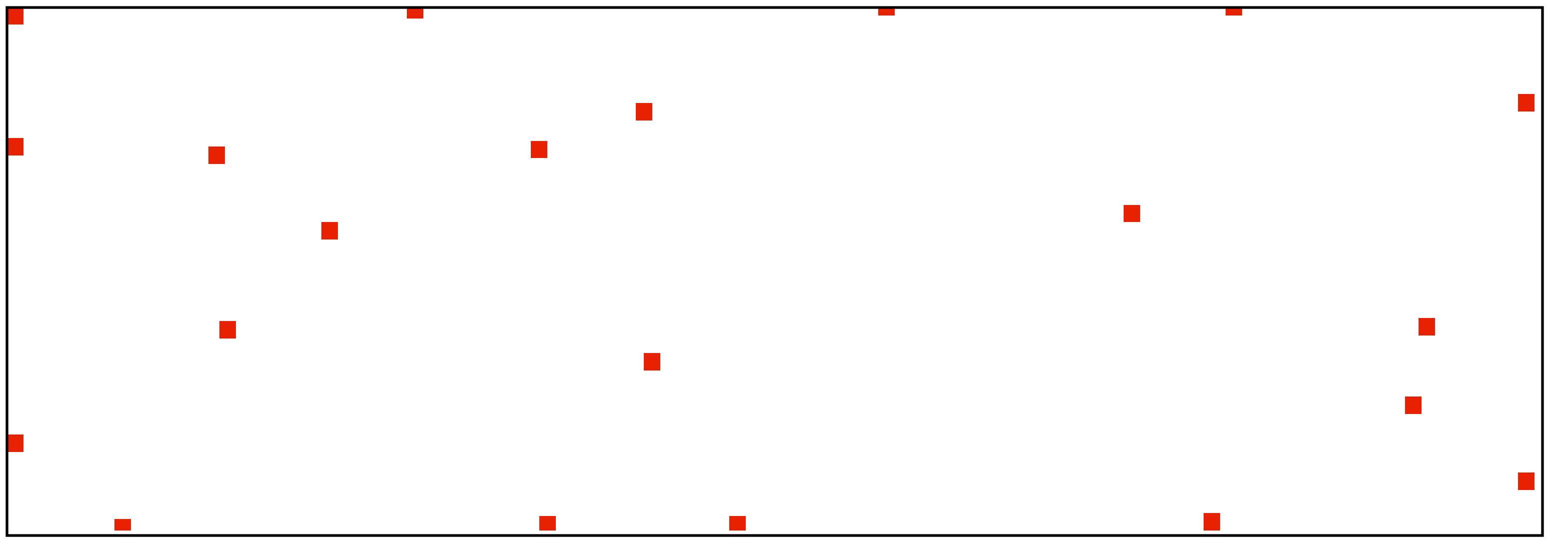
We need a new way to extract large scale information from geometries.

Delaunay Triangulations

Consider the Voronoi neighbourhoods of a set of points in a metric space:



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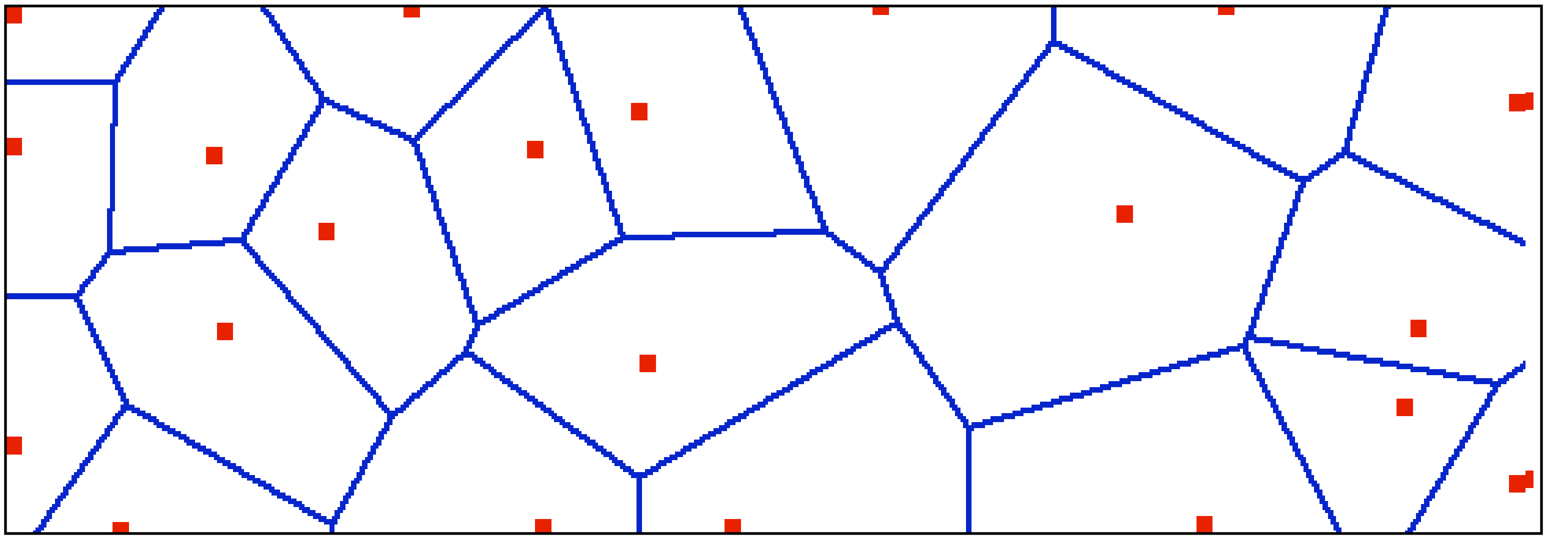

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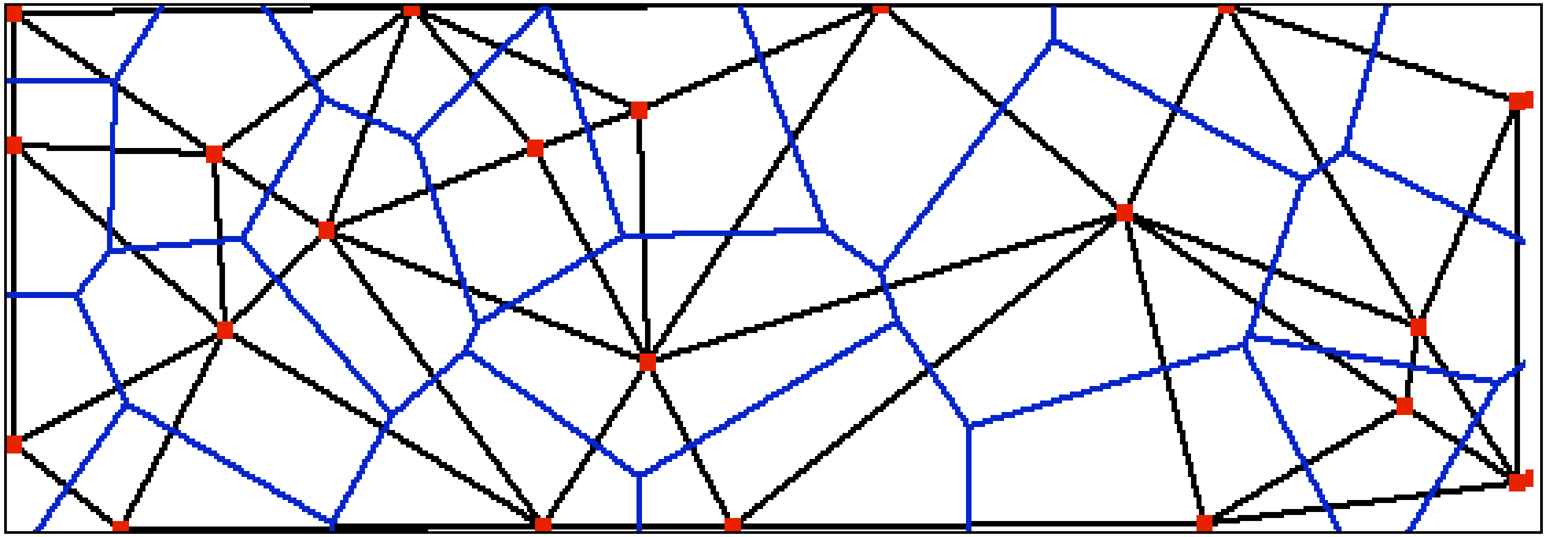

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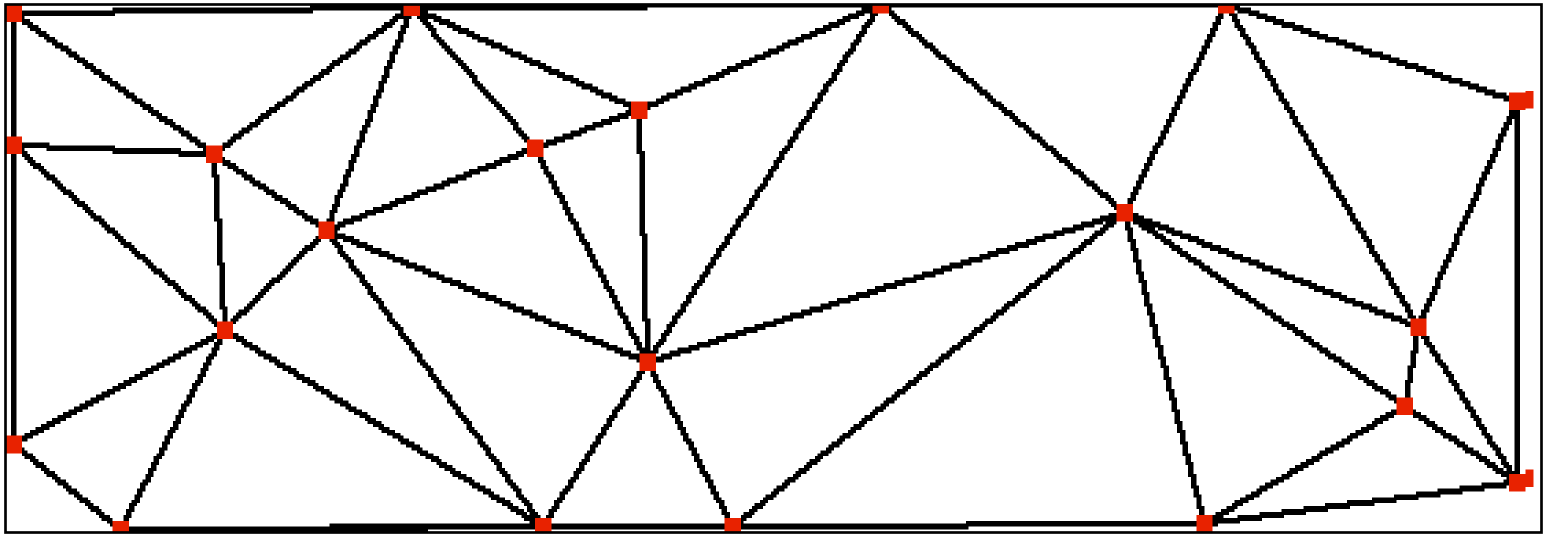

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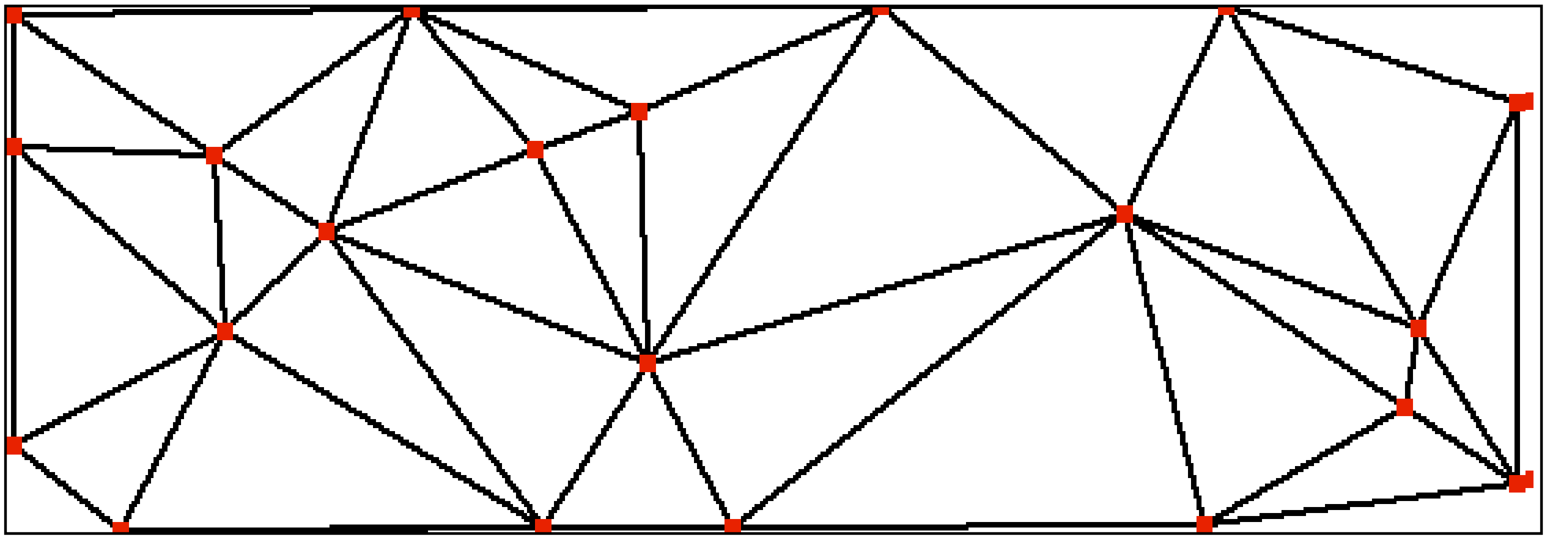

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$$\mathrm{del} : \{\text{metric spaces, subset of points}\} \longrightarrow \text{simplicial complexes}$$

Deluanay complex Observables

Consider the following type of observable:

$$O_f = \int_{\mathcal{M}} d^4 p_1 \sqrt{-g(p_1)} \int_{\mathcal{M}} d^4 p_2 \sqrt{-g(p_2)} \ldots \int_{\mathcal{M}} d^4 p_N \sqrt{-g(p_N)} f(\mathrm{del}(\mathcal{M}, \{p_i\})),$$

where $\{p_i\} = \{p_1, p_2, ..., p_N\}$.

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Integrating over position of all *N* points

A function on simplicial complexes

The Delaunay complex of the set of points

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where $\{p_i\} = \{p_1, p_2, ..., p_N\}$.

These quantities:

- Are generally covariant observables
- Can be estimated by random sampling
- Possible to define in CDTs
- Conjecture: Relevant when probing the system at large scales

Why this choice?

Bombelli, Corichi & Winkler's conjecture: random Delaunay complexes capture all large scale geometrical information.

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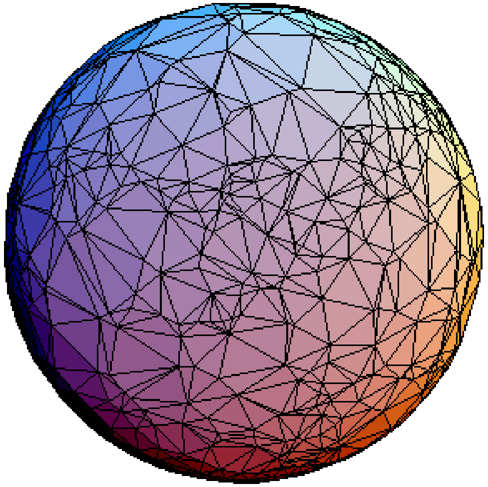

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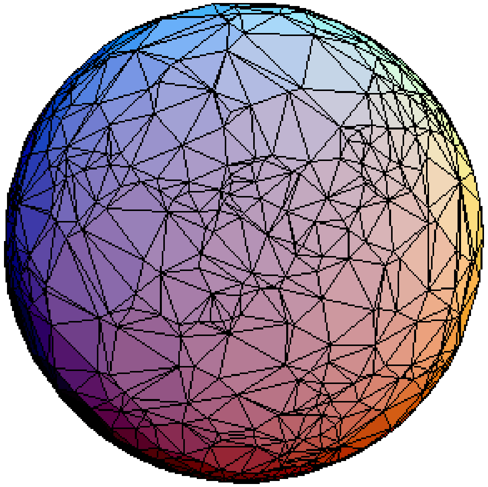

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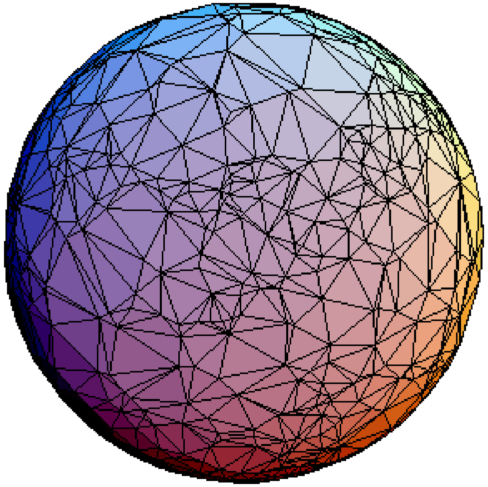

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Delaunay complexes depend only on distance comparisions.

Hopefully, edge placements will not be affected by small scale fluctuations in the geometry.

Results in 3D

We hope that the 3D CDT model is producing configurations that are close to spheres.

The task: compare the statistics of random Delaunay complexes on (a) 3D spheres and (b) the results of CDT simulations.

First: do these observables converge?

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A coarse-graining scheme for CDTs, using statistical geometry.

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- GH distance, physical aptness of coarse-graining.
- More statistical geometry in 3D and 4D.
- 4D simulations.