Composite Operators in Quantum (super)gravity

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Marseille
France

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NAWI Graz
Natural Sciences
FWF Österreichischer Wissenschaftsfonds

Setup

- QFT setting – no strings or other non-QFT structures

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$$Z = \int_{\Omega} Dg_{\mu\nu} D\phi^a e^{iS[\phi,e]+iS_{EH}[e]}$$

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- QFT setting – no strings or other non-QFT structures
- Diffeomorphism is like a gauge symmetry [Hehl et al.'76]
  - Arbitrary local choices of coordinates do not affect observables – pure passive formulation

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- Integration variable currently arbitrary choice
  - Manifold topolgies when factoring out diffeomorphisms
  - Other choices (e.g. vierbein) possible when integrating over diffeomorphism orbits

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Other fields

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- Setup of FRG/Asymptotic safety, CDT, EDT

Dynamical formulation

$$\langle O \rangle = \int_{\Omega} Dg_{\mu\nu} D\phi^{a} O\, e^{iS[\phi,e]+iS_{EH}[e]}$$

Dynamical formulation

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Needs to be invariant

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- Locally under Diffeomorphism
- Locally under Lorentz transformation
- Locally under gauge transformation
- Globally under custodial,... transformation

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[Ambjorn et al.'12,19, Maas'19]

- Average metric vanishes: $\langle g_{\mu\nu}(x) \rangle = 0$
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  - Local observables need to be composite
    - E.g. again curvature scalars
  - Arguments/distances need to be invariants
    - E.g. geodesic distances [Ambjorn et al.’12, Schaden ‘15, Maas’19]

Causal Dynamical Triangulation

[Ambjorn et al.'12,19]

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– diffeomorphism invariant!

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Restricted to foliable,
pseudo-Riemannian manifolds
with fixed global structure

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Replaced with a finite, discrete triangulation
by simplices – basically tetrads
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Systematic errors due to statistics, finite volume and discretization

Space-time in CDT

[Ambjorn et al.'12,'19
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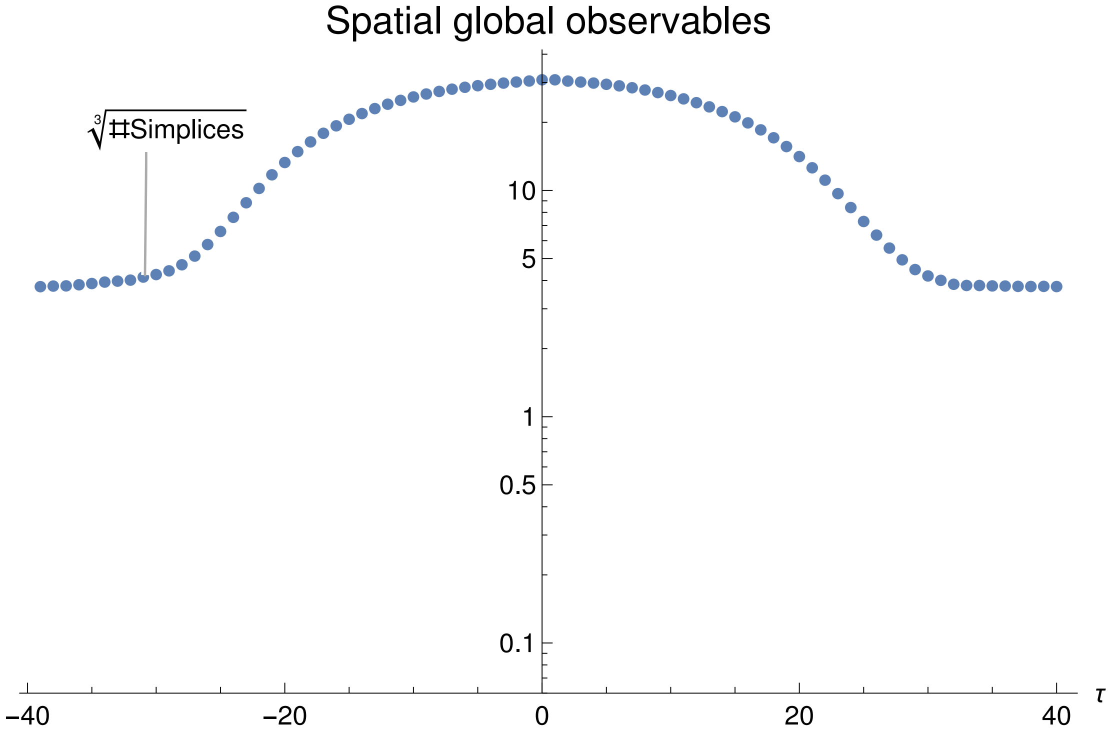

Space-time in CDT

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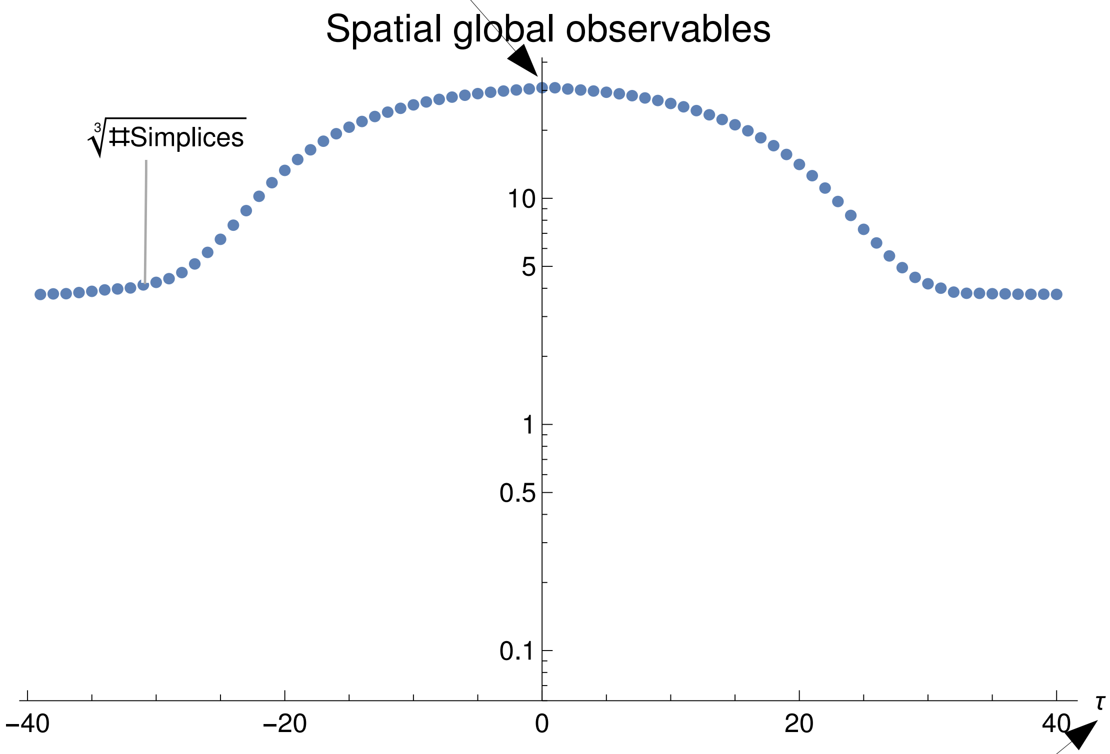
Maximum volume
constrained by finite size



Cosmological time
with respect to
maximal extension

Space-time in CDT

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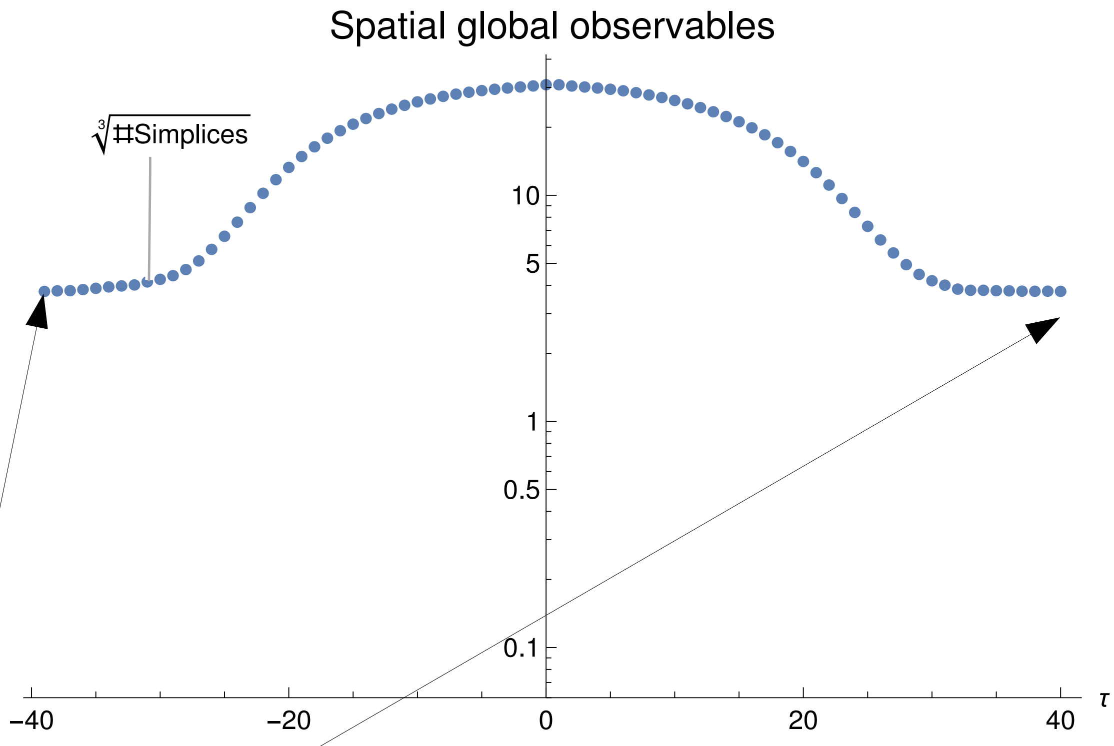

Periodicity
by boundary conditions

Space-time in CDT

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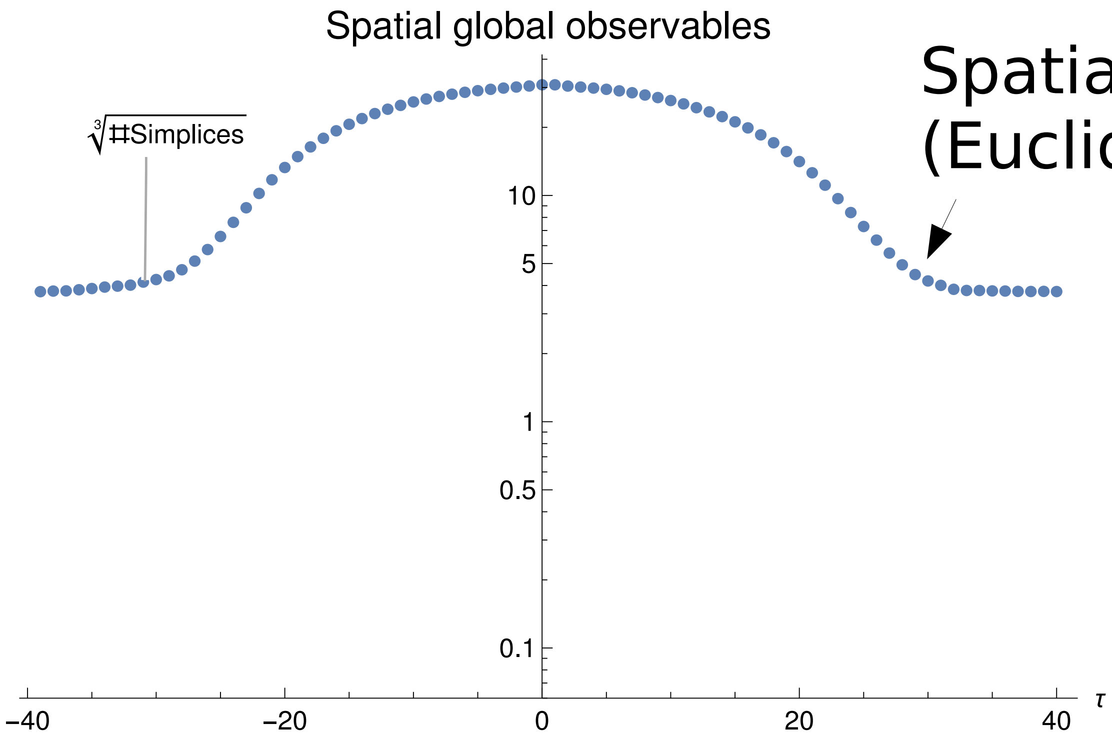

Spatial profile consistent with (Euclidean) de Sitter ~ radius

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Rapid expansion

Spatial profile consistent with
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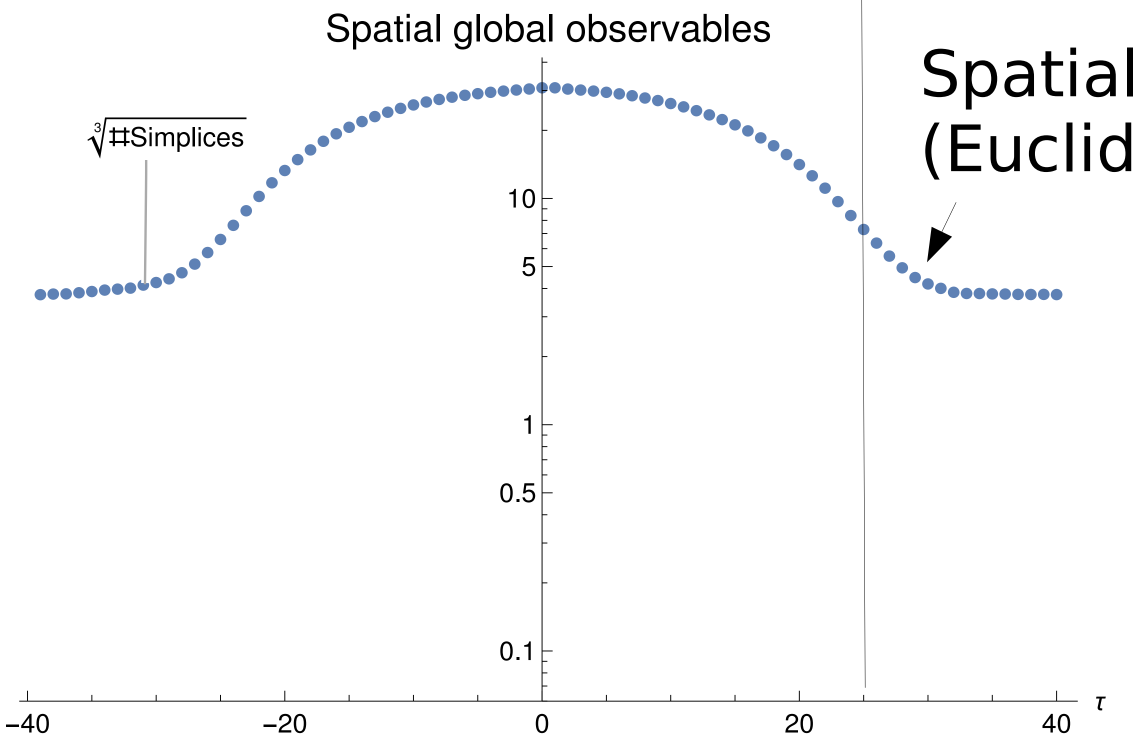

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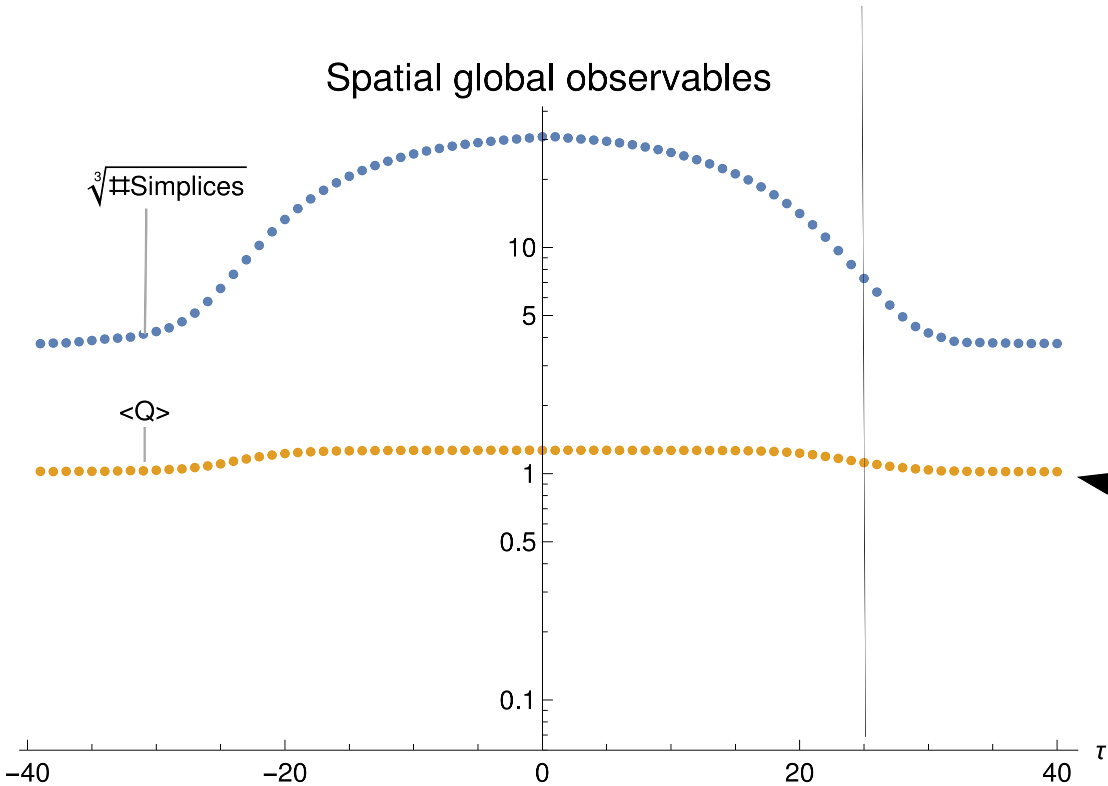

Quantum curvature Q

Basically distances of surface points on a sphere

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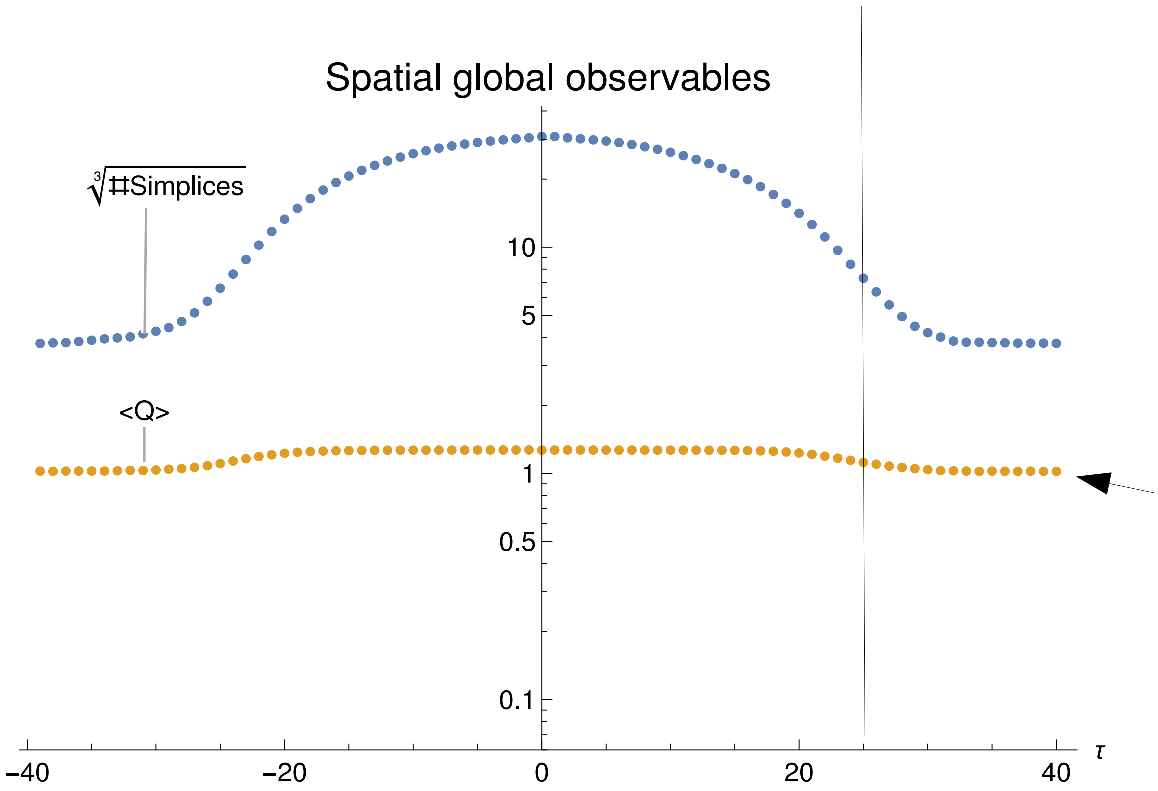

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Curvature scalar R can be numerically Estimated from Q

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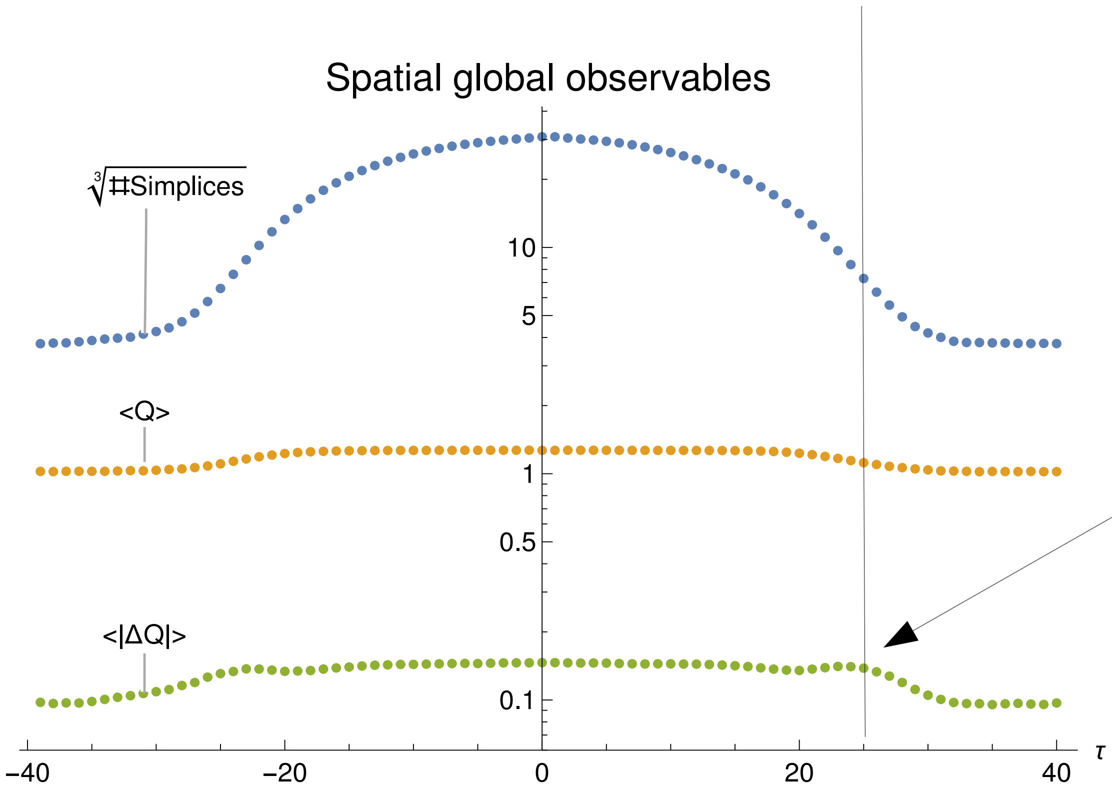

Quantum curvature fluctuations peak around fastest expansion

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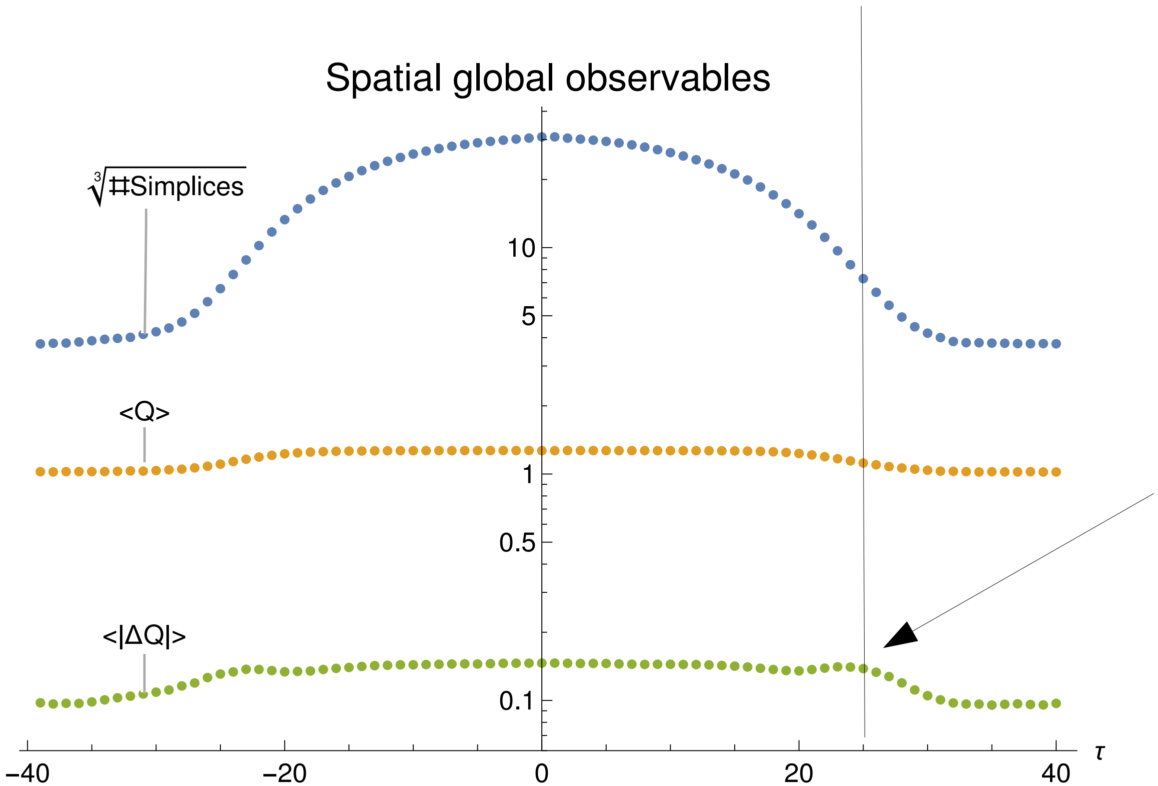

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Only cosmological constant, no inflation!

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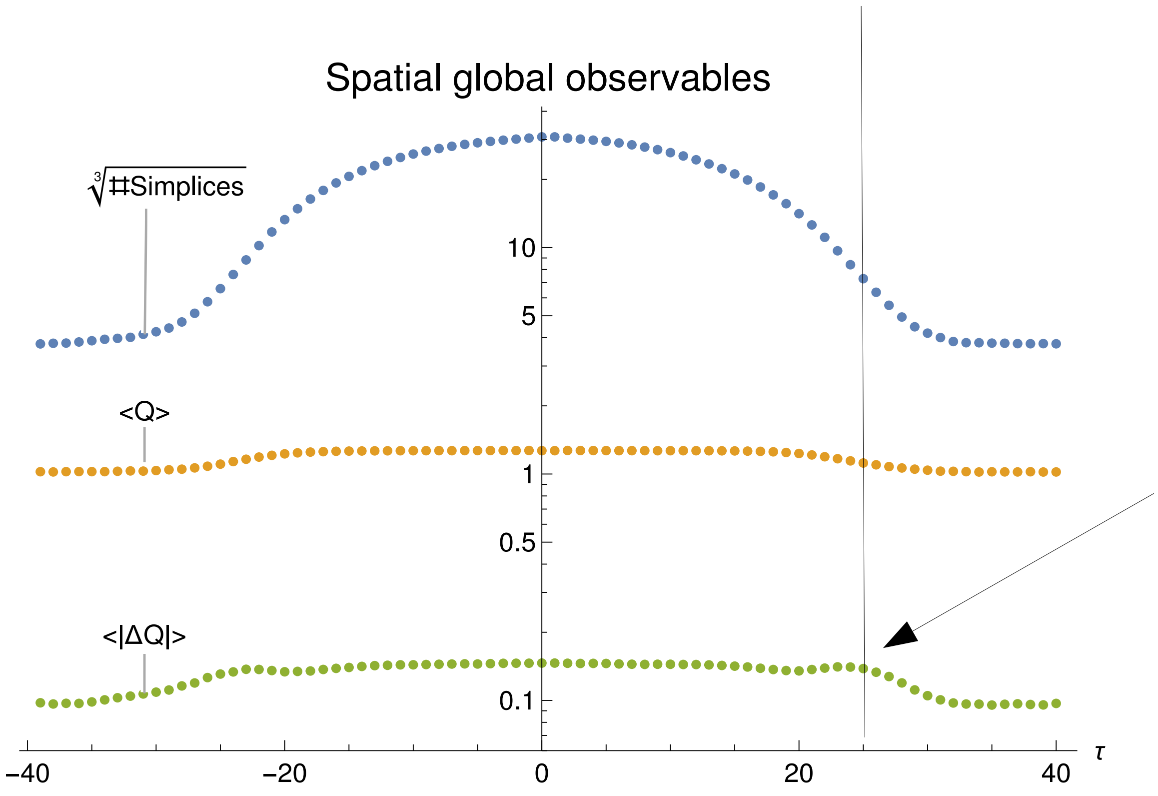

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An average gauge-fixed metric would be close to the de Sitter-like

Like in classical general relativity

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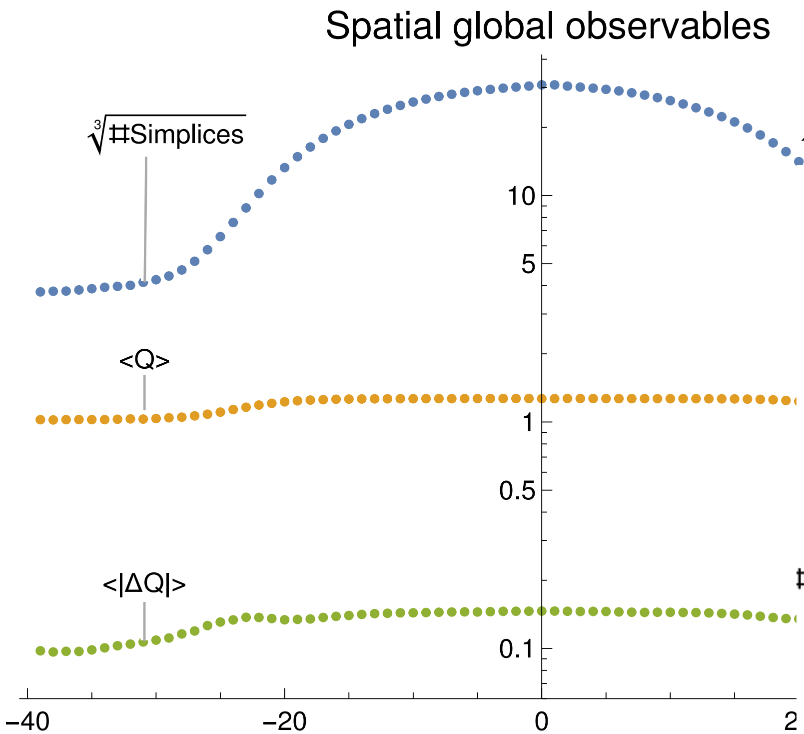
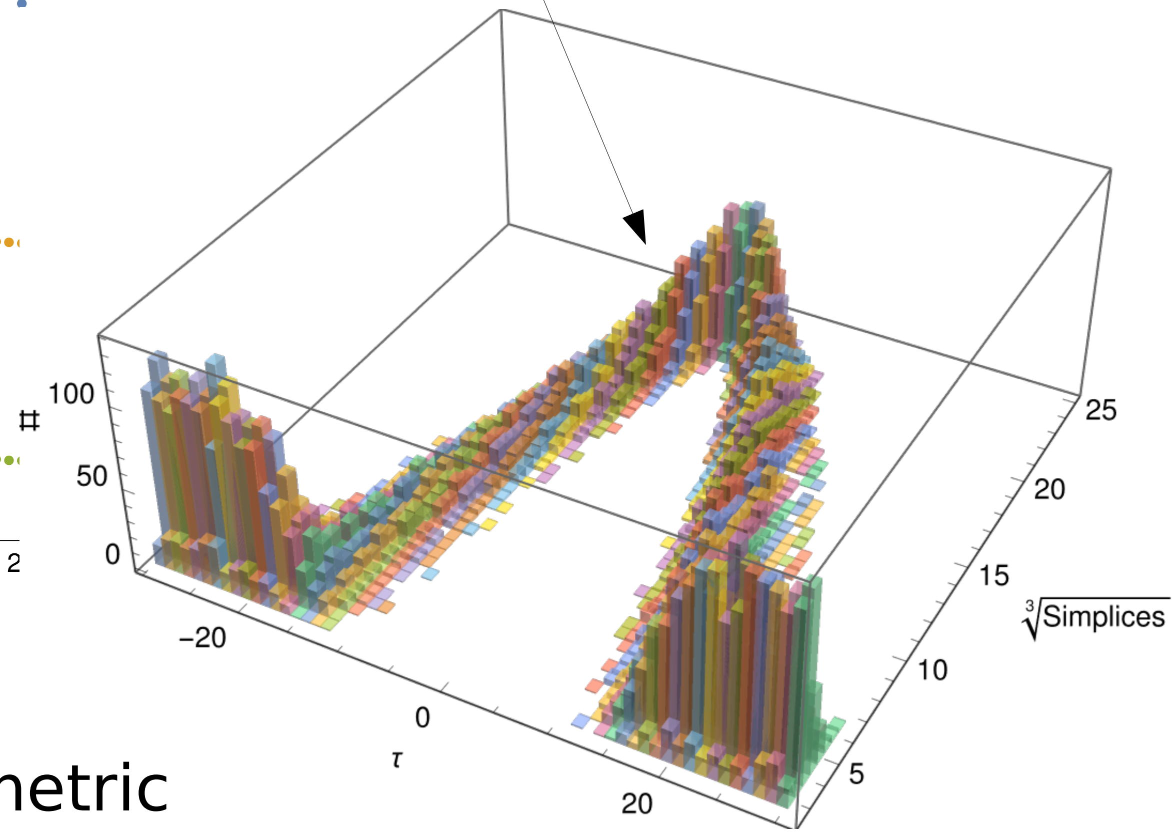
Per configuration histogram of the size
- relatively similar, no large fluctuations





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Geon correlator

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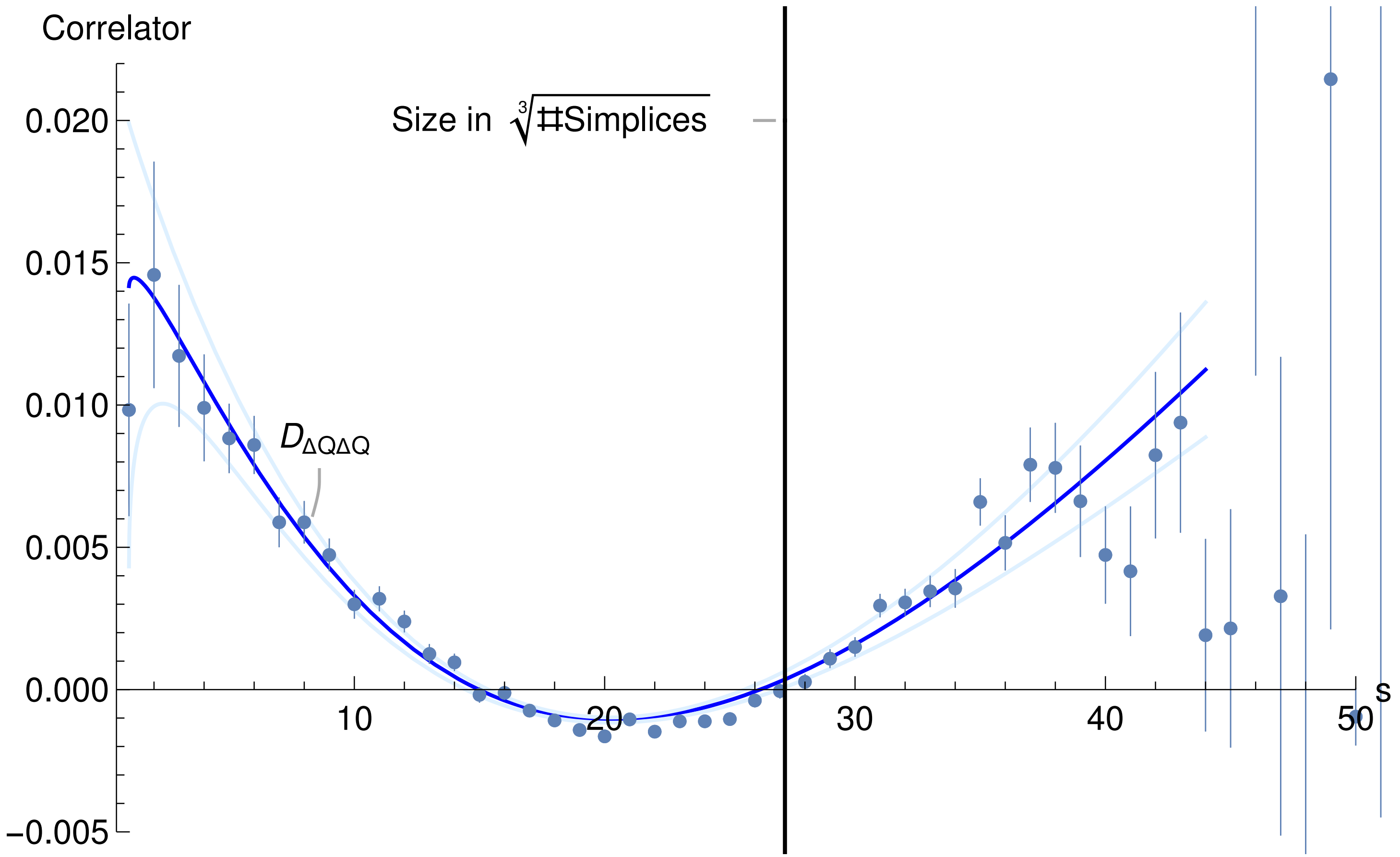

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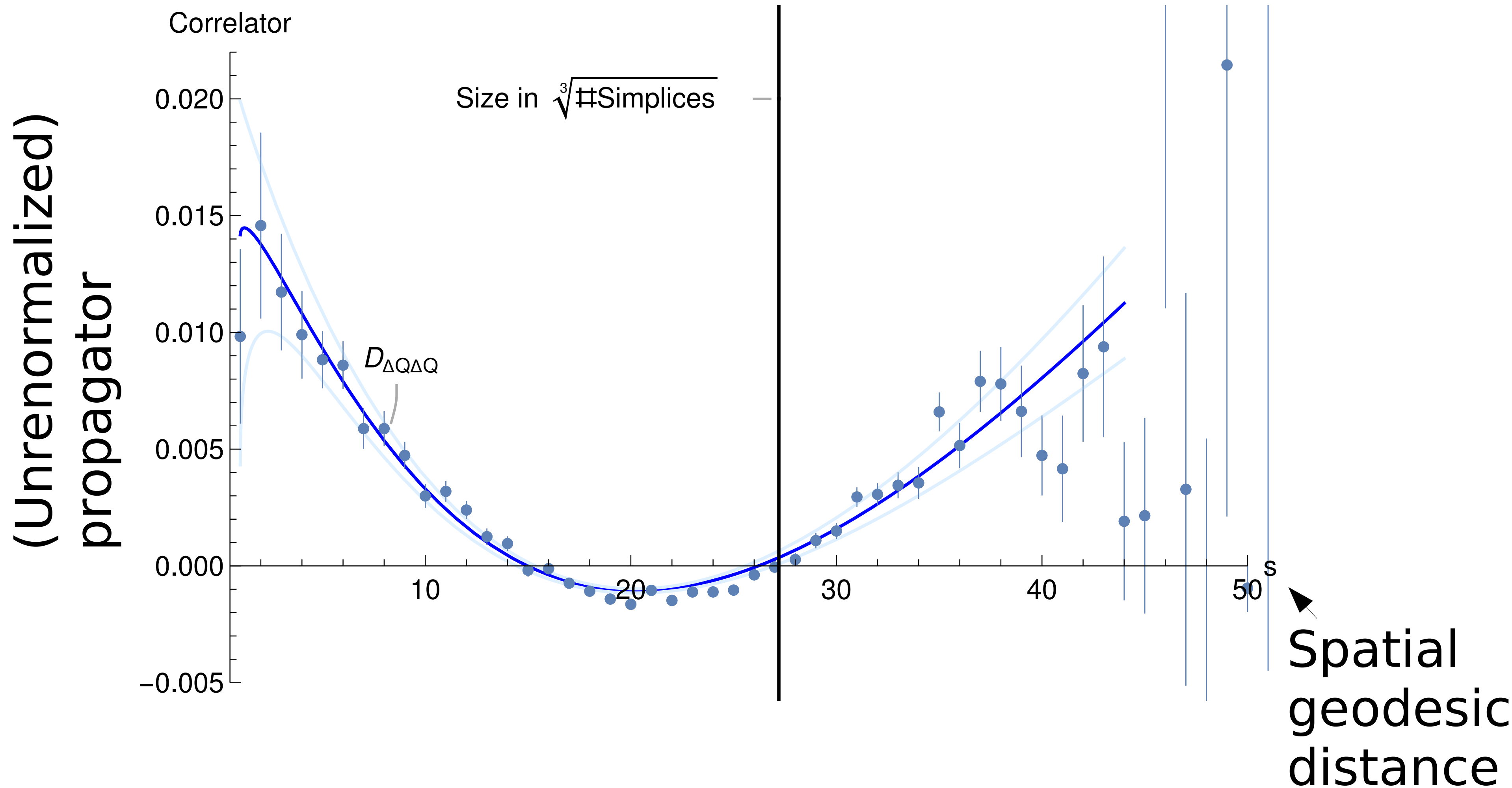

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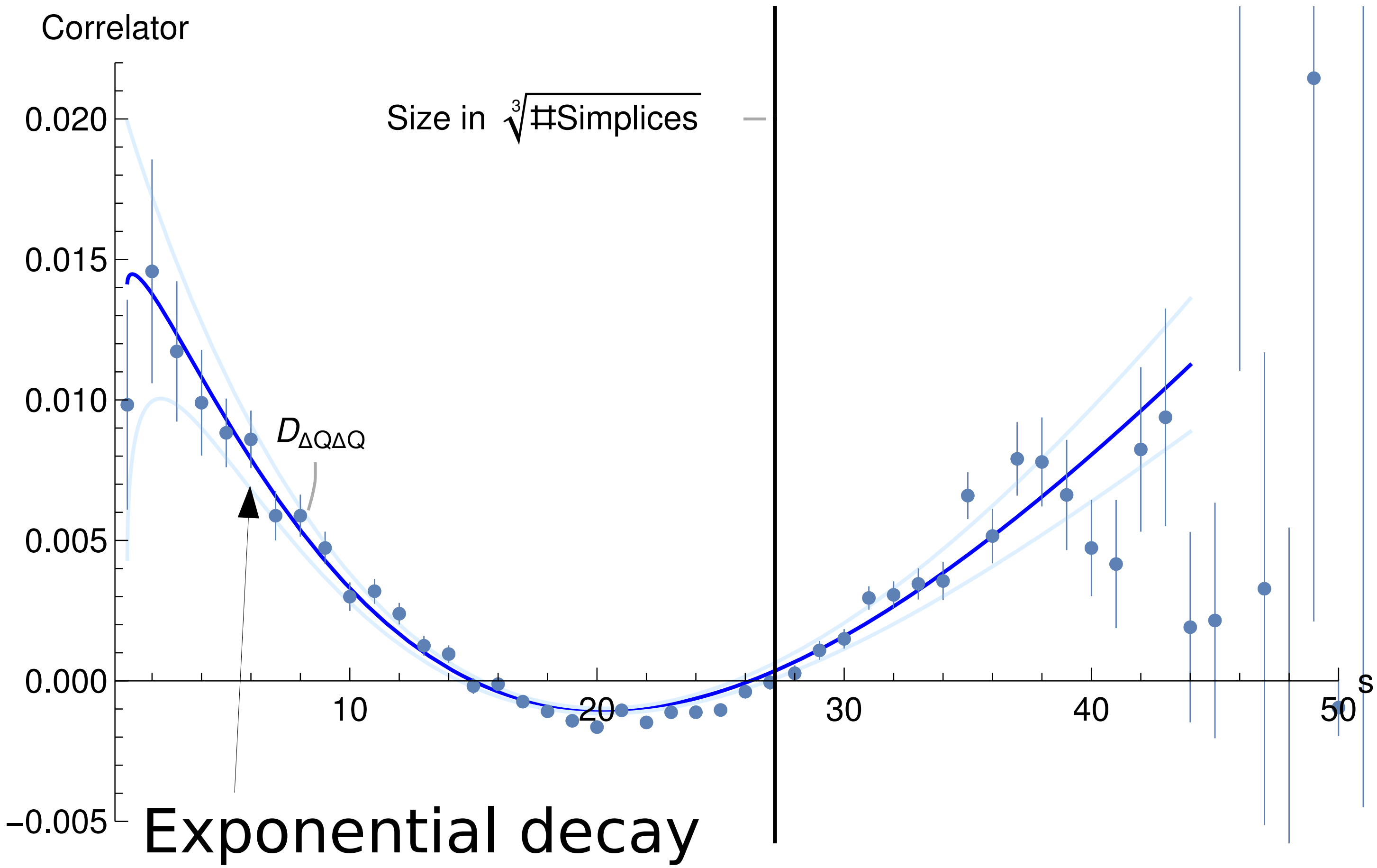

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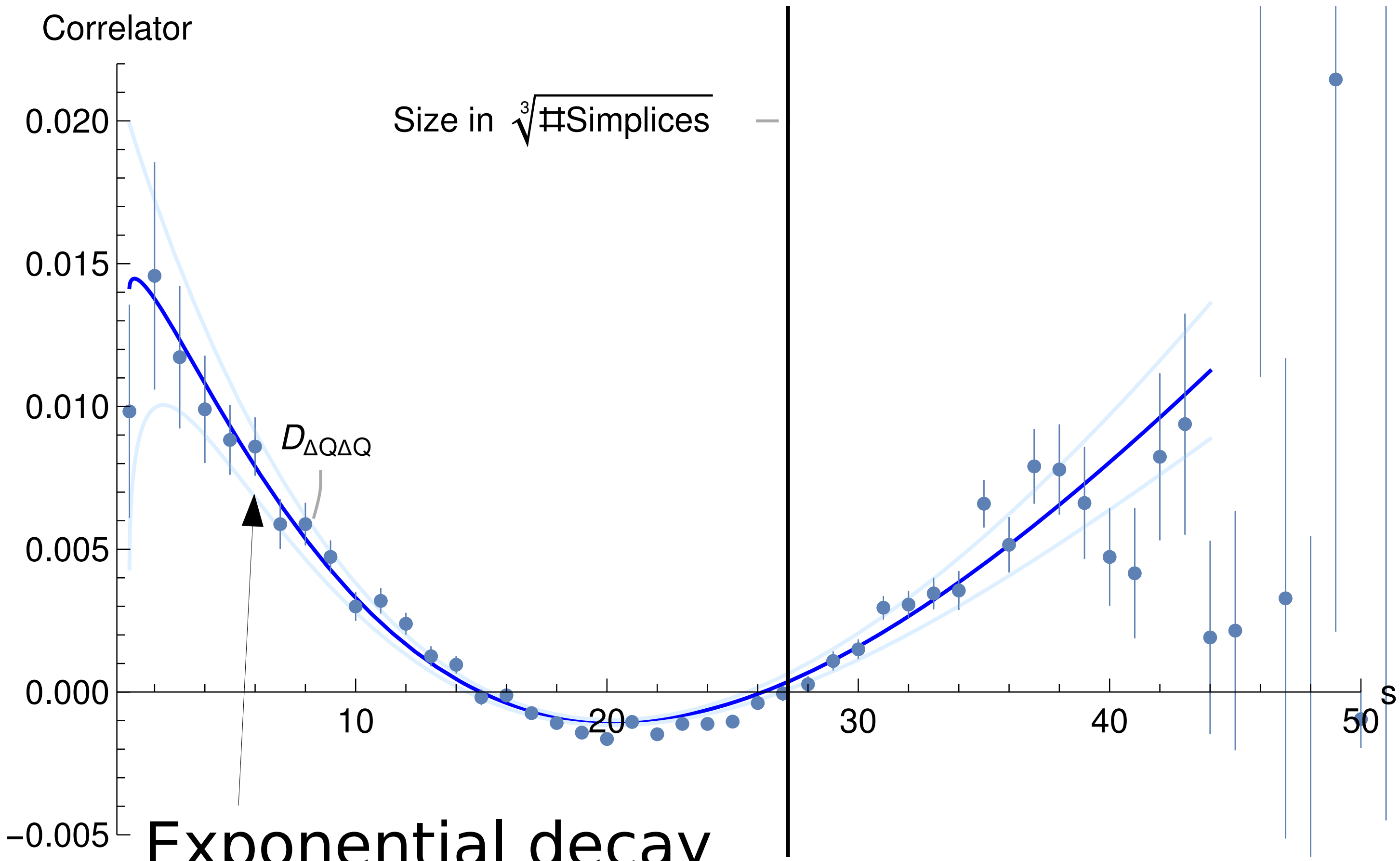

Exponential decay
- as in flat space-time for a massive particle

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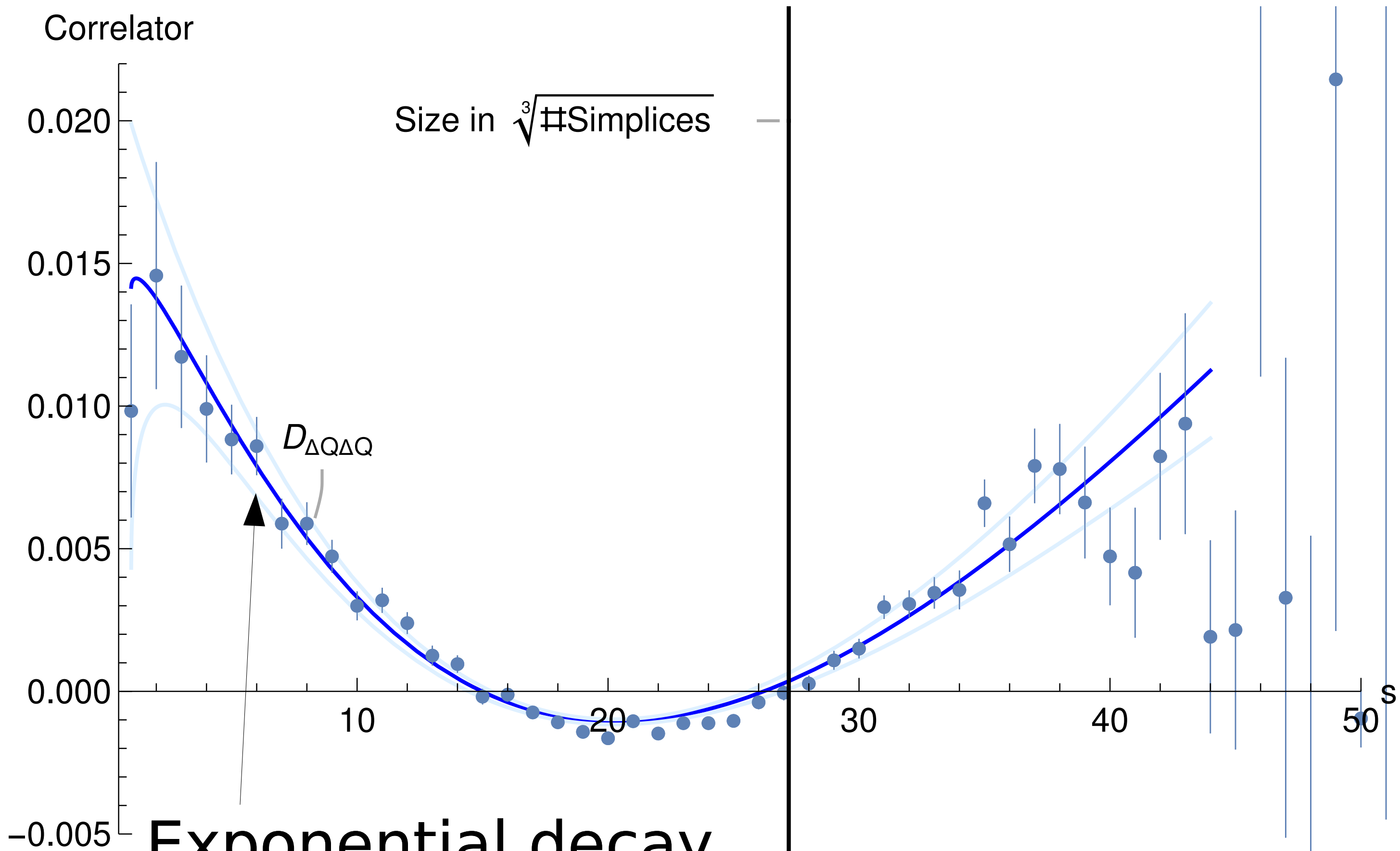

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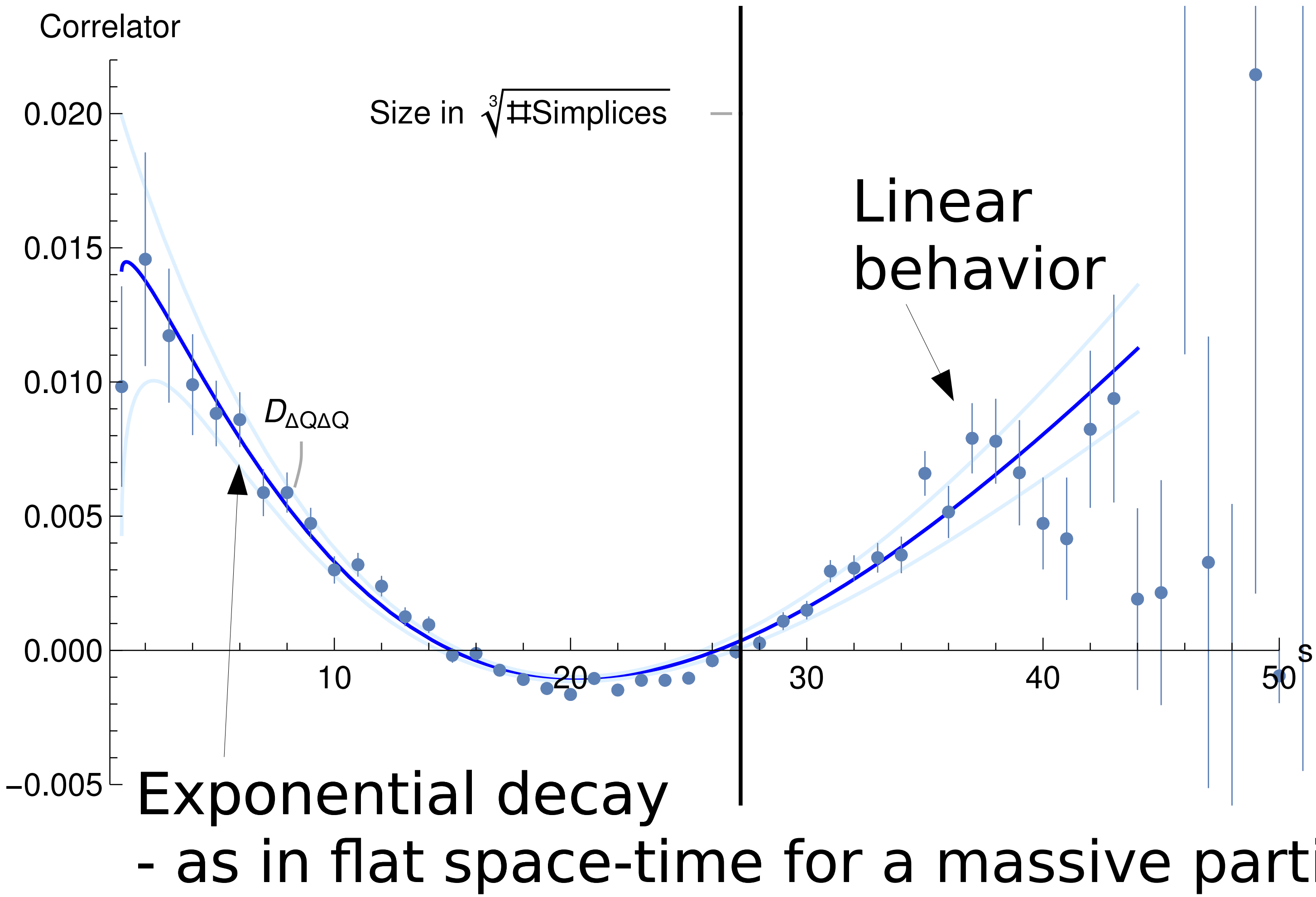

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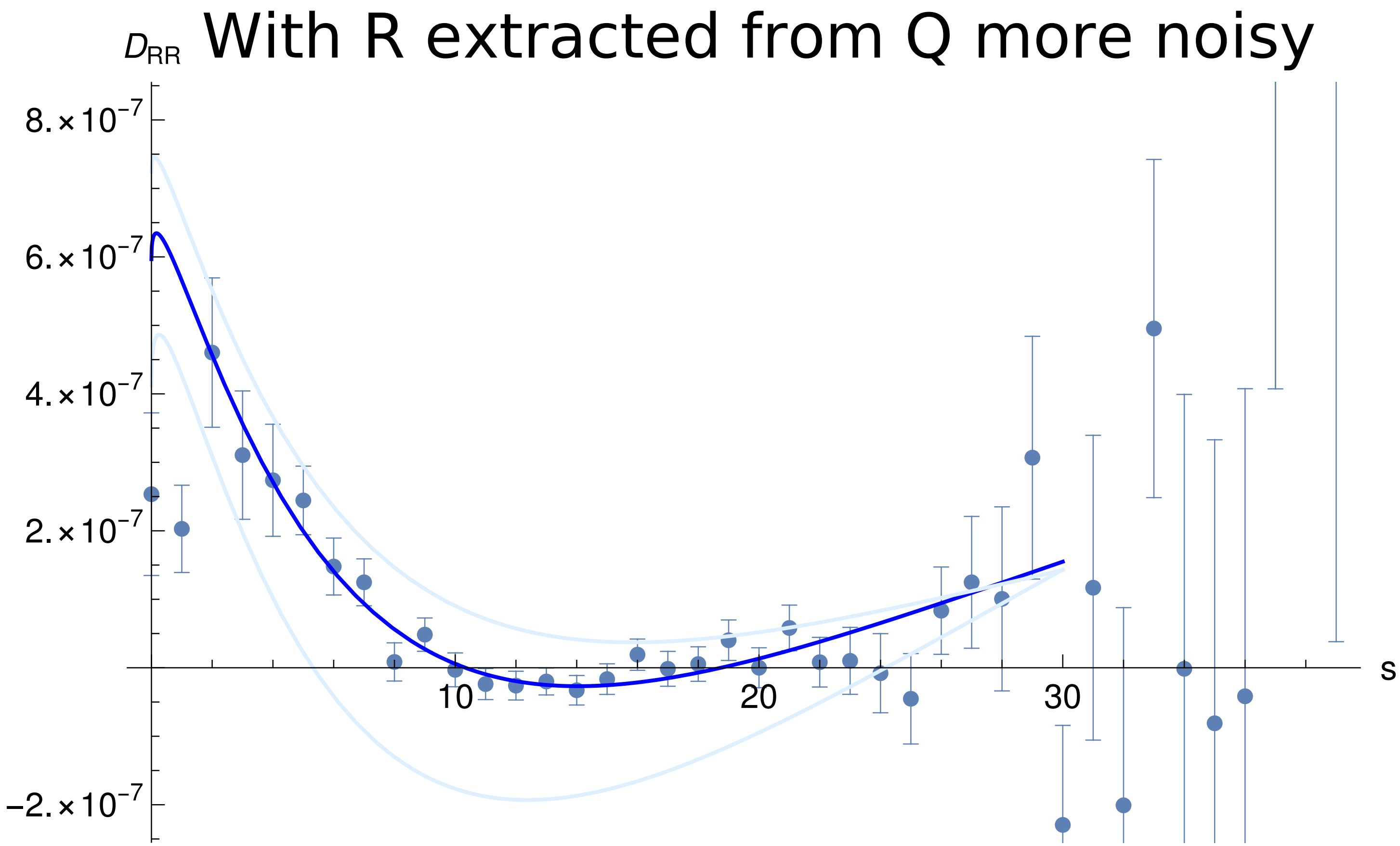

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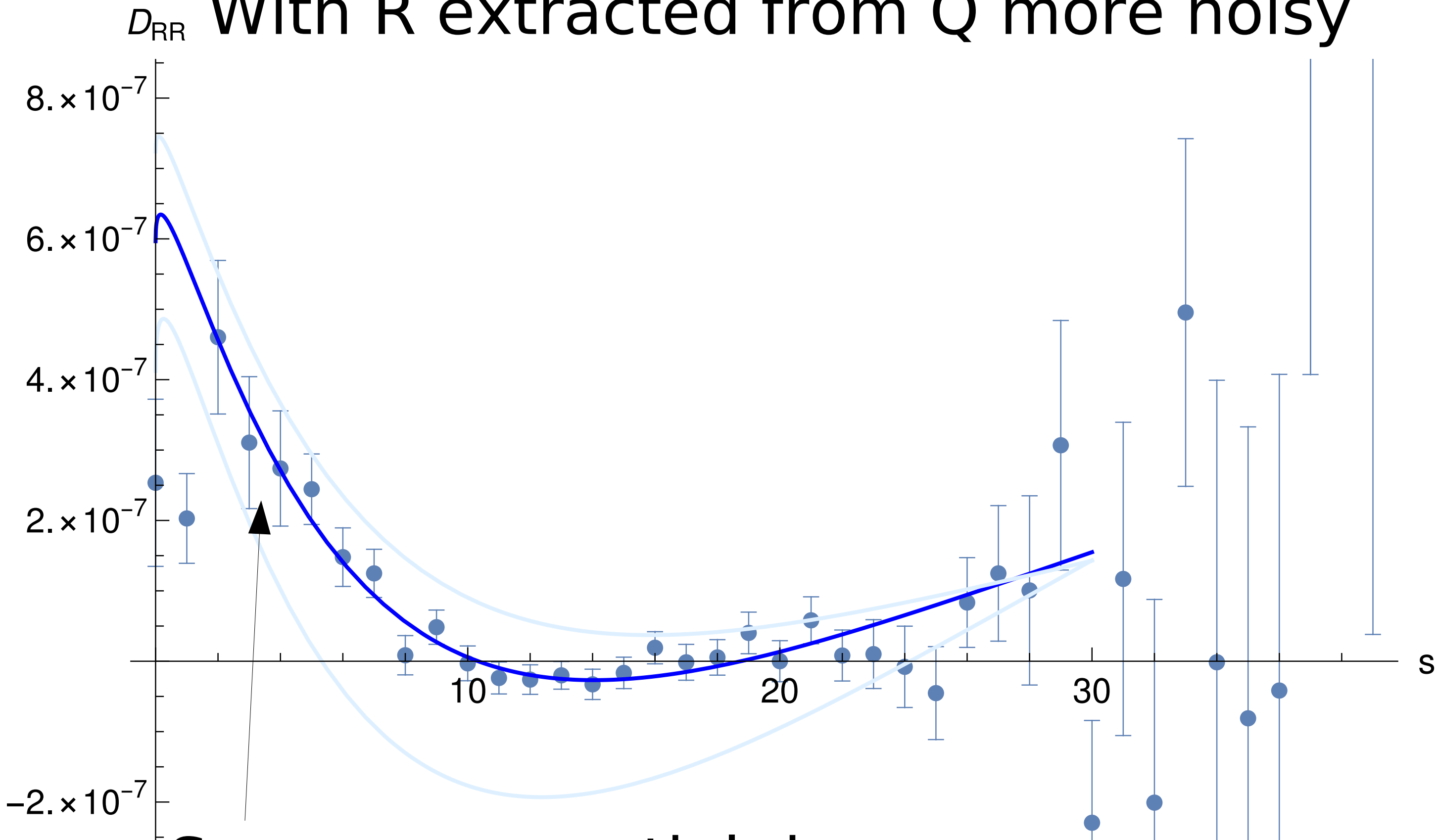
With R extracted from Q more noisy



Same exponential decay

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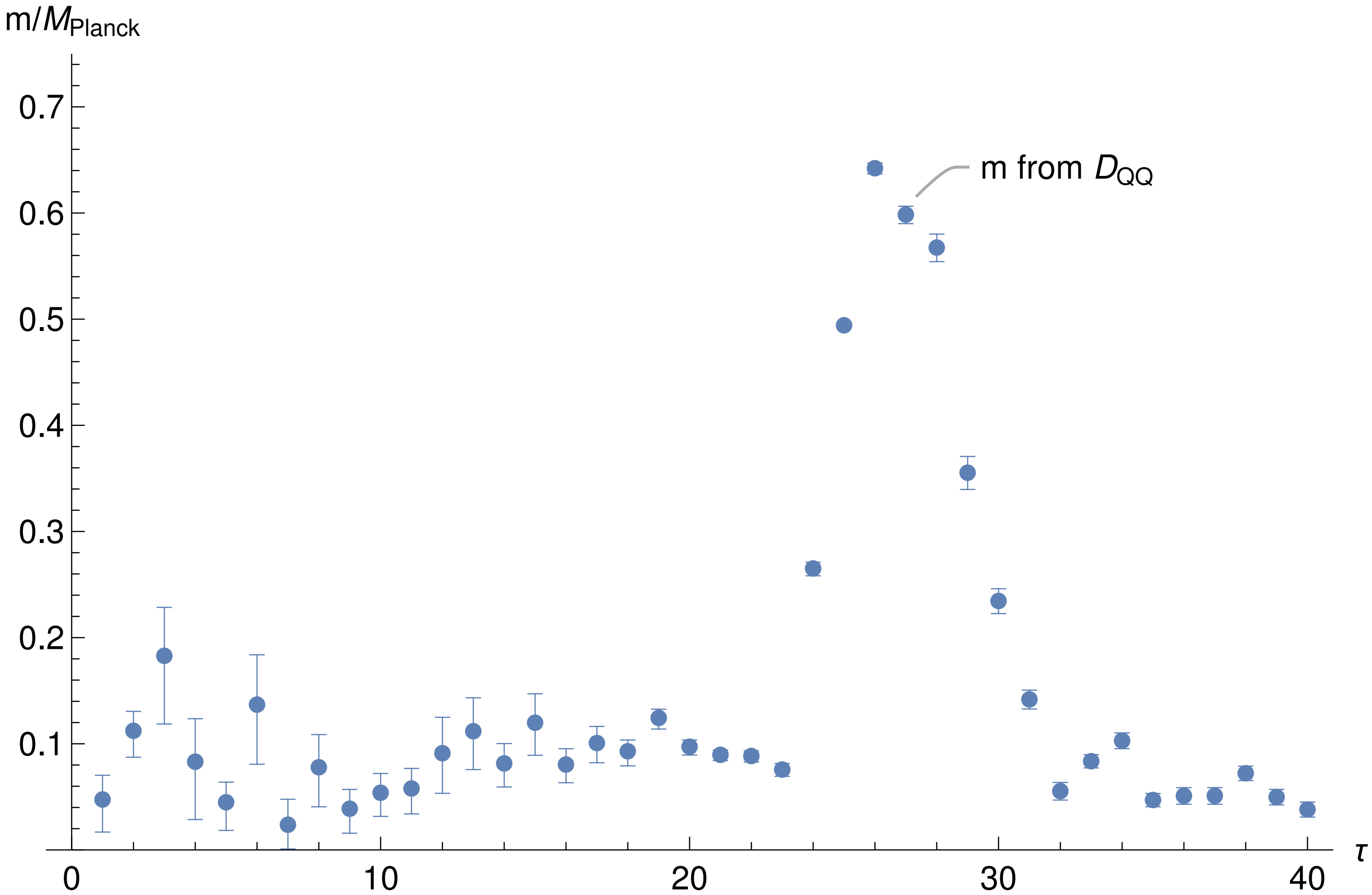

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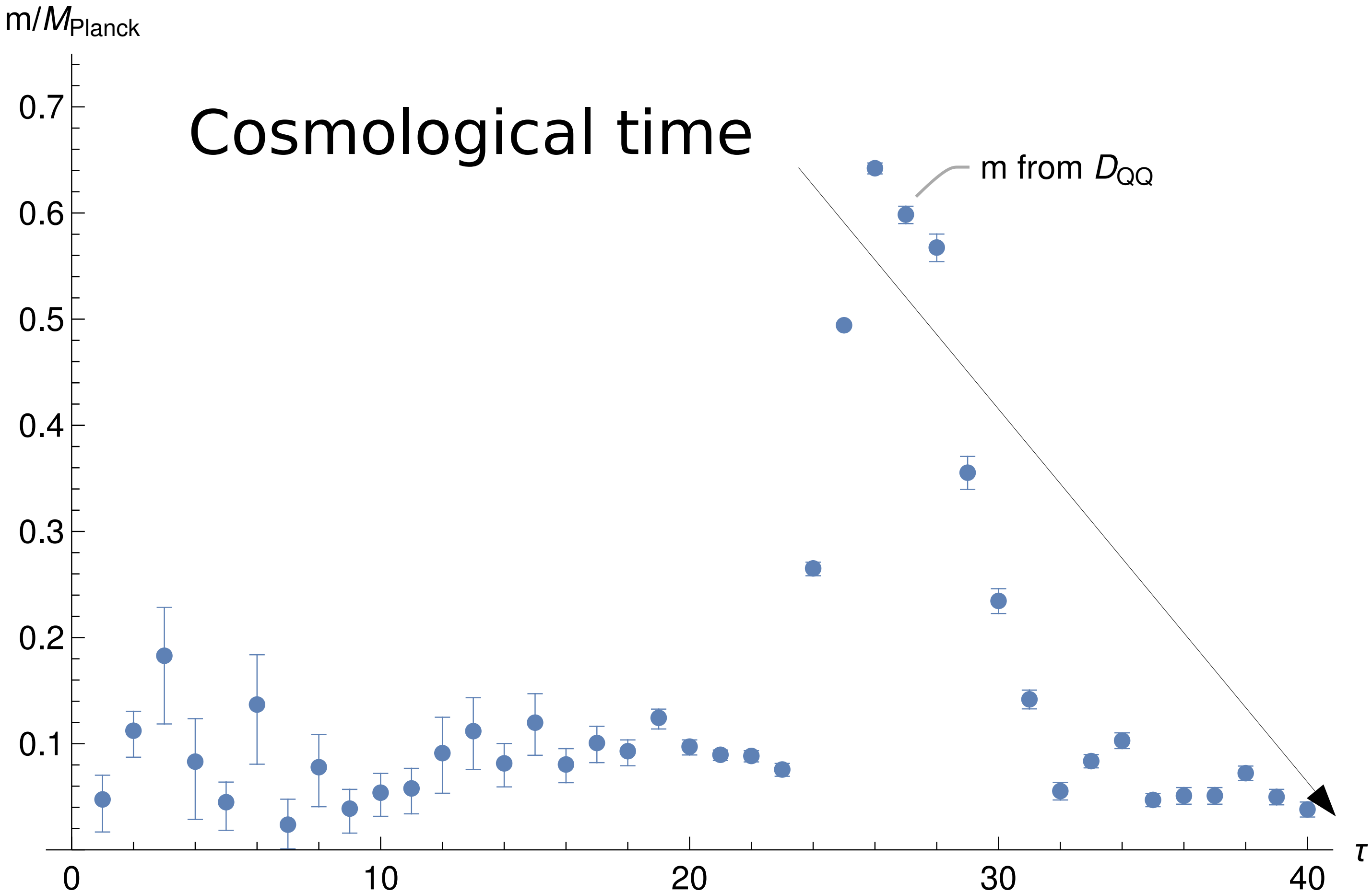

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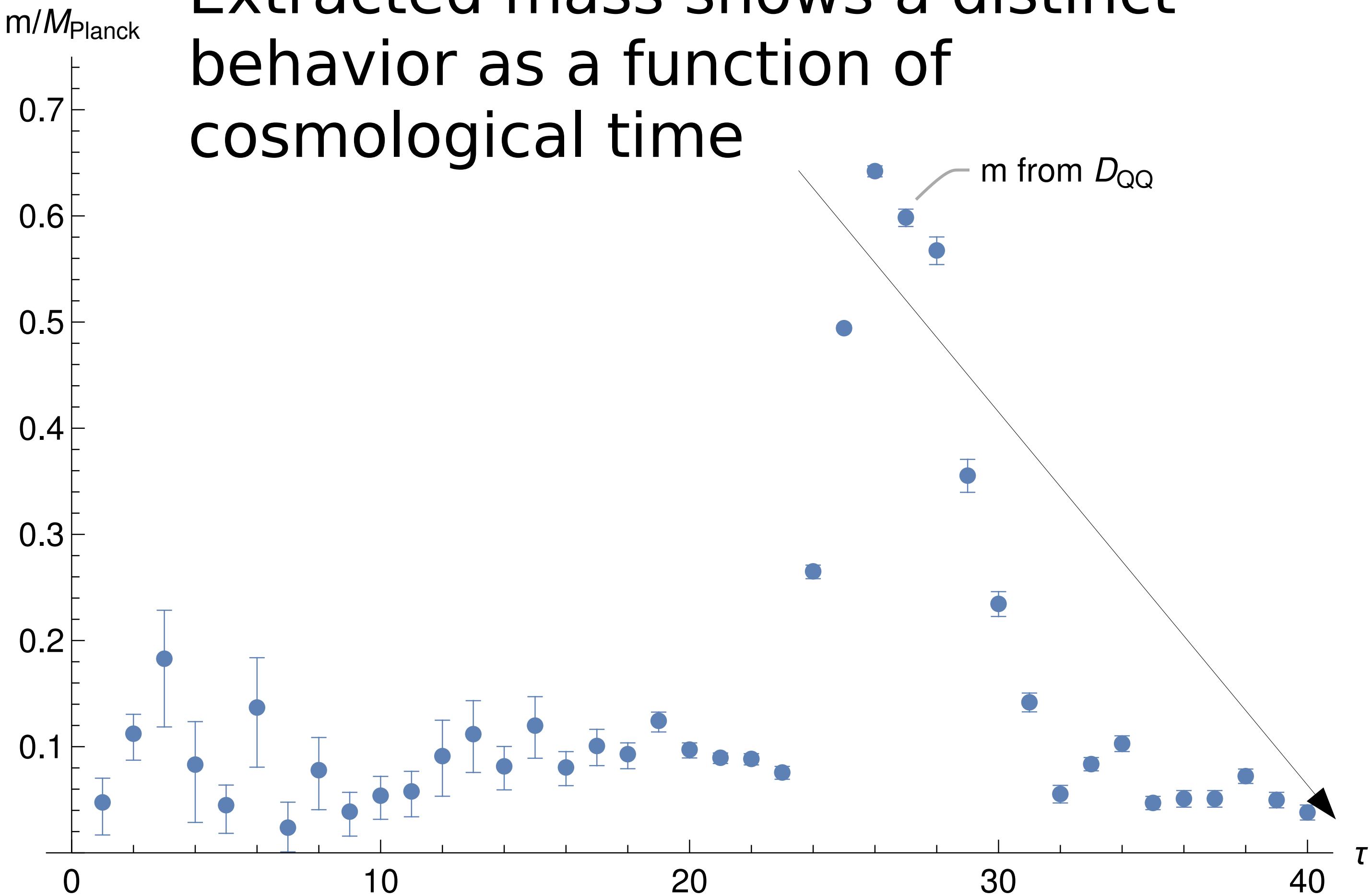
Extracted mass shows a distinct behavior as a function of cosmological time



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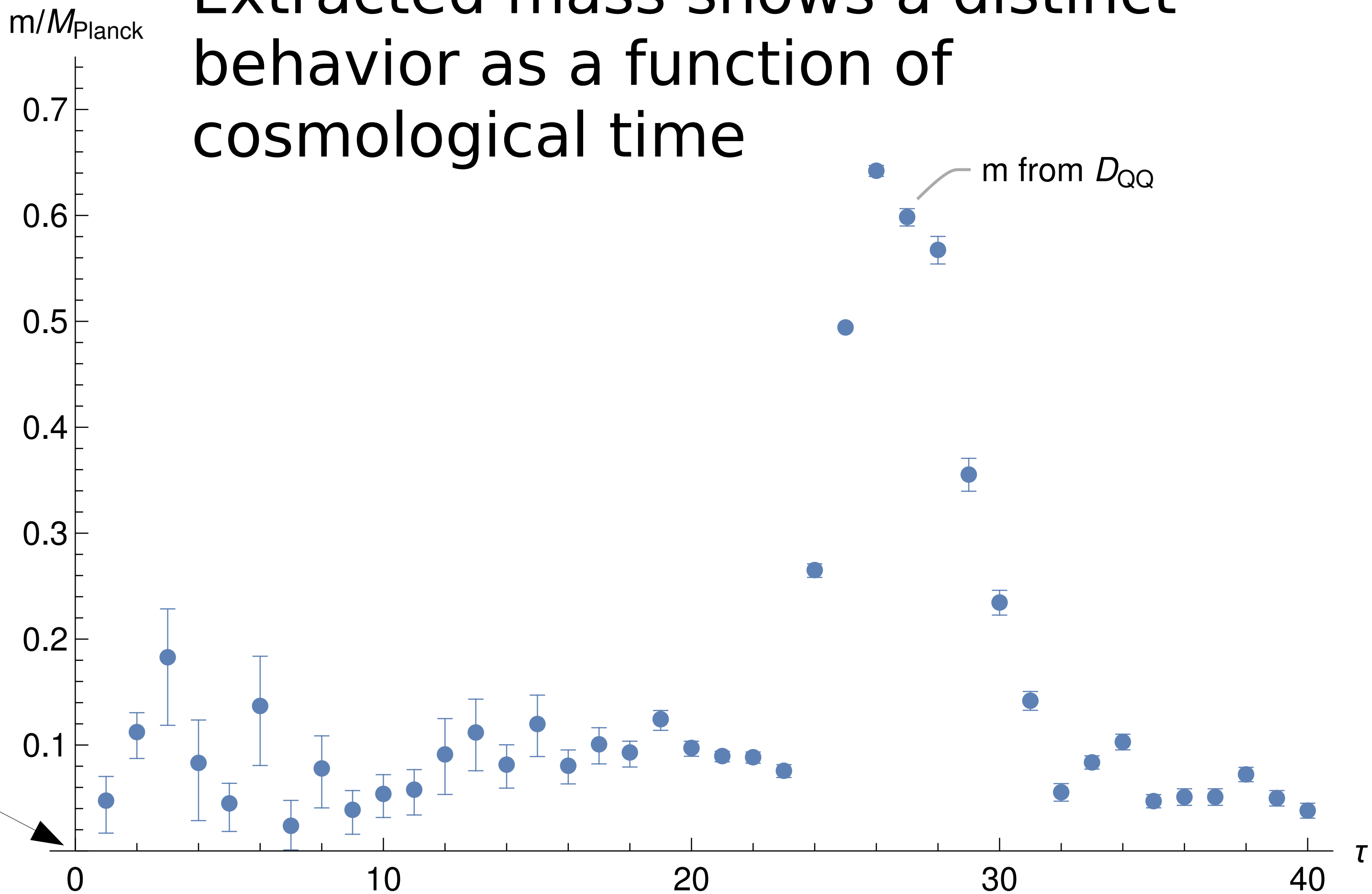

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Smallest extent

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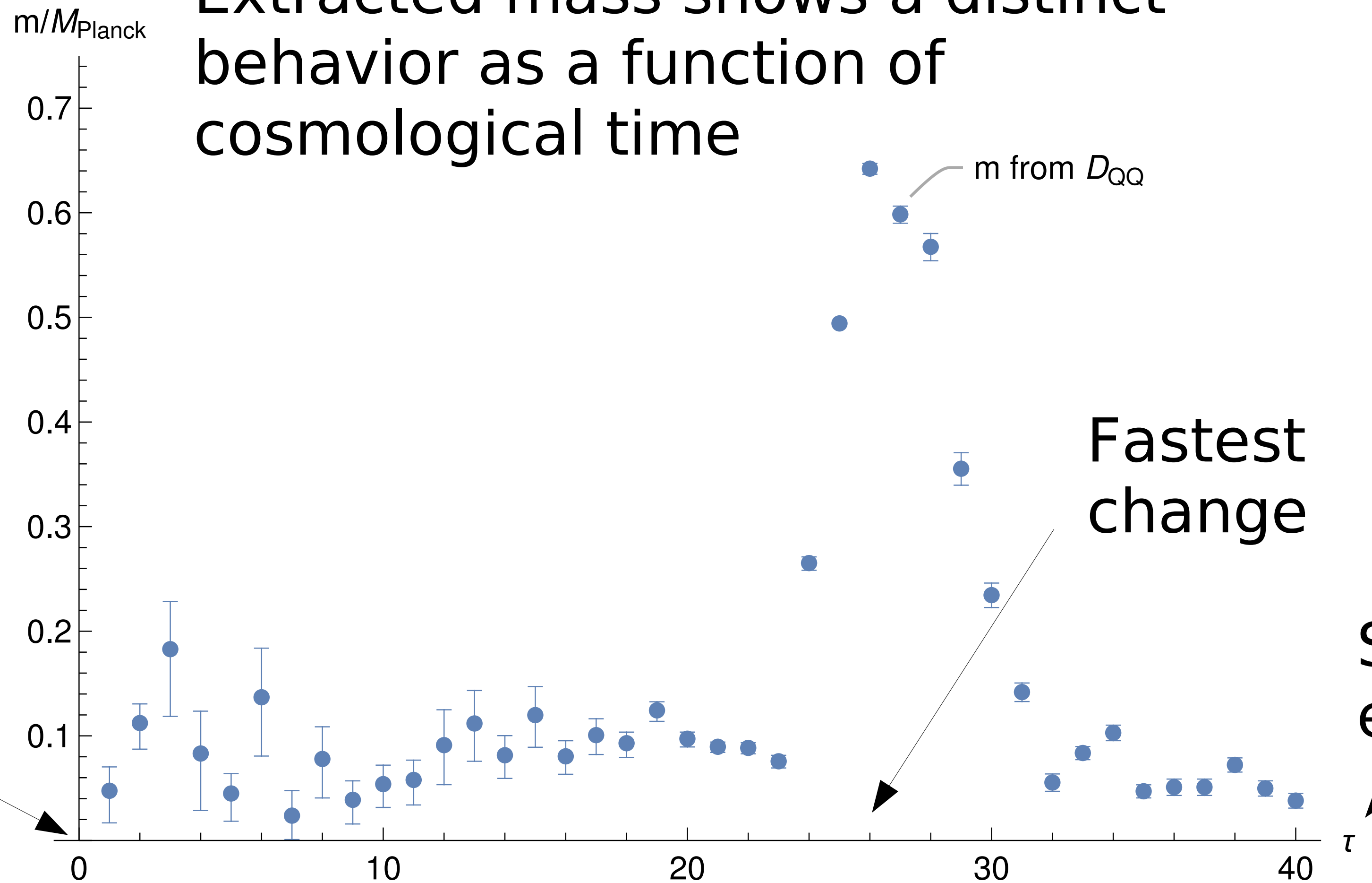

Fastest change

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[Maas'23]

Supergravity

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    - Supermultiplets are as color multiplets
    - Spin of particles can be locally changed – spin cannot be an observable

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[Maas'23,'19]

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  - A vacuum expectation value from the classical solution – a Brout-Englert-Higgs effect for gravity

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- Yields an new view on supersymmetry …and why it may escape conventional detection