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# LQG propagator from the new spin foams

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**Abstract**

We compute metric correlations in loop quantum gravity with the dynamics defined by the *new* spin foam models. The analysis is done at the lowest order in a vertex expansion and at the leading order in a large spin expansion. The result is compared to the graviton propagator of perturbative quantum gravity.
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## 1. Introduction

In this paper we compute metric correlations in Loop Quantum Gravity (LQG) [1–3] and we compare them with the scaling and the tensorial structure of the graviton propagator in perturbative Quantum Gravity [4–6]. The strategy is the one introduced in [7] and developed in [8–15]. In particular, we use the boundary amplitude formalism [1,16–18]. The dynamics is implemented in terms of (the group field theory expansion of) the new spin foam models introduced by Engle, Pereira, Rovelli and Livine ($\text{EPRL}_\gamma$ model) [19] and by Freidel and Krasnov ($\text{FK}_\gamma$ model) [20]. We restrict attention to Euclidean signature and Immirzi parameter smaller than one: $0 < \gamma < 1$. In this case the two models coincide.

Previous attempts to derive the graviton propagator from LQG adopted the Barrett–Crane spin foam vertex [21] as model for the dynamics [7–15] (see also [22–24] for investigations in the three-dimensional case). The analysis of [12,13] shows that the Barrett–Crane model fails to

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give the correct scaling behavior for off-diagonal components of the graviton propagator. The problem can be traced back to a missing coherent cancellation of phases between the intertwiner wave function of the semiclassical boundary state and the intertwiner dependence of the model. The attempt to correct this problem was part of the motivation for the lively search of *new* spin foam models with non-trivial intertwiner dependence [19,20,25–27]. The intertwiner dynamics of the new models was investigated numerically in [28–31]. The analysis of the large spin asymptotics of the vertex amplitude of the new models was performed in [32–34] and in [35]. In [14], the obstacle that prevented the Barrett–Crane model from yielding the correct behaviour of the propagator was shown to be absent for the new models: the new spin foams feature the correct dependence on intertwiners to allow a coherent cancellation of phases with the boundary semiclassical state. In this paper we restart from scratch the calculation and derive the graviton propagator from the new spin foam models.

In this introduction we briefly describe the quantity we want to compute. We consider a manifold $\mathcal{R}$ with the topology of a 4-ball. Its boundary is a 3-manifold $\Sigma$ with the topology of a 3-sphere $S^3$. We associate to $\Sigma$ a boundary Hilbert space of states: the LQG Hilbert space $\mathcal{H}_\Sigma$ spanned by (abstract) spin networks. We call $|\Psi\rangle$ a generic state in $\mathcal{H}_\Sigma$. A spin foam model for the region $\mathcal{R}$ provides a map from the boundary Hilbert space to $\mathbb{C}$. We call this map $\langle W|$. It provides a sum over the bulk geometries with a weight that defines our model for quantum gravity. The dynamical expectation value of an operator $\mathcal{O}$ on the state $|\Psi\rangle$ is defined via the following expression[2]

$$\langle\mathcal{O}\rangle = \frac{\langle W|\mathcal{O}|\Psi\rangle}{\langle W|\Psi\rangle}. \tag{2}$$

The operator $\mathcal{O}$ can be a geometric operator as the area, the volume or the length [36–42]. The geometric operator we are interested in here is the (density-two inverse-) metric operator $q^{ab}(x) = \delta^{ij} E^a_i(x) E^b_j(x)$. We focus on the *connected* two-point correlation function $G^{abcd}(x,y)$ on a semiclassical boundary state $|\Psi_0\rangle$. It is defined as

$$G^{abcd}(x,y) = \big\langle q^{ab}(x) q^{cd}(y)\big\rangle - \big\langle q^{ab}(x)\big\rangle\big\langle q^{cd}(y)\big\rangle. \tag{3}$$

The boundary state $|\Psi_0\rangle$ is semiclassical in the following sense: it is peaked on a given configuration of the intrinsic and the extrinsic geometry of the boundary manifold $\Sigma$. In terms of Ashtekar–Barbero variables these boundary data correspond to a couple $(E_0, A_0)$. The boundary data are chosen so that there is a solution of Einstein equations in the bulk which induces them on the boundary. A spin foam model has good semiclassical properties if the dominant contribution to the amplitude $\langle W|\Psi_0\rangle$ comes from the bulk configurations close to the classical 4-geometries compatible with the boundary data $(E_0, A_0)$. By *classical* we mean that they satisfy Einstein equations.

The classical bulk configuration we focus on is flat space. The boundary configuration that we consider is the following: we decompose the boundary manifold $S^3$ in five tetrahedral regions with the same connectivity as the boundary of a 4-simplex; then we choose the intrinsic

[2] This expression corresponds to the standard definition in (perturbative) quantum field theory where the *vacuum* expectation value of a product of local observables is defined as

$$\big\langle O(x_1)\cdots O(x_n)\big\rangle_0 = \frac{\int D[\varphi] O(x_1)\cdots O(x_n) e^{iS[\varphi]}}{\int D[\varphi] e^{iS[\varphi]}} \equiv \frac{\int D[\phi] W[\phi] O(x_1)\cdots O(x_n) \Psi_0[\phi]}{\int D[\phi] W[\phi] \Psi_0[\phi]}. \tag{1}$$

The vacuum state $\Psi_0[\phi]$ codes the boundary conditions at infinity.

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