Report for for SciPost: A microscopic realization of dS_3 by Scott Collier, Lorenz Eberhardt and Beatrix Mühlmann

This manuscript proposes a matrix model as a microscopic description of (2+1)-dimensional Einstein gravity with $\Lambda > 0$ coupled to massive scalar particles. Overall, the manuscript is engaging and presents its results and discussions with clarity. The technical analysis is robust—aside from a few conjectural steps that the authors candidly acknowledge—and offers several useful insights. In particular, I appreciate the discussion on the canonical quantization of Einstein gravity with $\Lambda > 0$ within the first-order or Chern-Simons formalism, which helps clarify certain points of confusion in the existing literature.

Although the model is far from a realistic description of our universe, its novelty and creative approach provides stimulating perspectives for quantum cosmology research. For example, the framework favors a natural quantum state that features a big bang singularity rather than the conventional no-boundary state.

I have a few questions for the authors:

- In reproducing the logarithm of the 3-sphere gravity partition function, $\log|\mathcal{Z}_{\text{grav}}^{S^3}|$, from the matrix model, the authors assert that the matching holds regardless of the specific value of $\mathcal{Z}_{\text{grav}}^{S^3}$. Could the authors please clarify this point? It appears that the matching relies on $\mathcal{Z}_{\text{grav}}^{S^3}$ taking the form (4.5), with the specific S_0 and b dependence. Is it accurate to conclude that the matching $S_{\text{dS}}^{\text{micro}} = \log|\mathcal{Z}_{\text{grav}}^{S^3}|$ would not hold if (4.5) is not correct?
- Relatedly, the proposed expression for $\mathcal{Z}_{\text{grav}}^{S^3}$ in (5.7) in principle should be verifiable through an independent higher-loop semiclassical calculation. If such a calculation were to refute (5.7), would that undermine the validity of the matching $S_{\text{dS}}^{\text{micro}} = \log|\mathcal{Z}_{\text{grav}}^{S^3}|$?
- Finally, could the authors comment on the prospects or challenges of extending their framework to include bulk matter fields? Any preliminary thoughts or speculations on this extension would be appreciated.