# A Quick Assessment of the Paper 'Quantum Hair from Gravity'

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Parth, thanks. The paper [1] is fascinating, and your presentation [2] on it was insightful. My immediate reaction was: Not hair, *holography* [3][4]. The authors noticed this also since they mentioned holography three times. Holography emerges via the Fourier relationship between the complementary spatial and momentum wave function descriptions of the black hole, representing the same information in different forms. The vast and ever-expanding light cone of each infalling particle encodes its state holographically. As with an ordinary hologram, this information spreads over a large and intensively shared volume of space and matter but is never lost.

The Calmet, Casadio, Hsu, and Kuipers (CCH&K) paper may be more radical than it sounds.

The first and still-ongoing round of holographic cosmology proposals began when Gerard 't Hooft [5] asserted by fiat that black hole event horizons may consist of an effectively infinite number of Planck-scale bits with perfect memories. All actual instances of bits have non-trivial mass-energy costs and are quantum-impossible to make perfect, so this was at best an assumption made from a lack of understanding of the nature of real memory. Furthermore, associating the holographic process only with inaccessible phenomena undermined recognition of the profound universality of the complementary space and momentum view of the cosmos at multiple energy levels.

Notice, however, that CCH&K just proposed the *opposite* holographic scenario from that of 't Hooft and others. In CCH&K, the black hole is, for all practical purposes, *encoded* by the ordinary mass and energy of some vast volume of space surrounding it. Now that is a nicely radical concept!

Why? Well, for one thing, since the space around the black hole encodes *all* available information on the black hole, the black hole no longer has an independent existence from its surrounding encoding. Black holes become little more than holographic projections created by the rest of the universe. While I find that image insightful, deeply intriguing, and delightfully funny, others may not react that way.

Why intriguing? Because it's likely to be predictive. For example, CCH&K may have just accidentally proposed an explanation for why giant black holes only seem to occur in the center of large galaxies. Only a large galaxy has enough mass and energy to encode such a supermassive hole. Now there's a fun thought for further exploration!

The second point is that all holographic images are *blurry*. They have a finite resolution that depends on encoding their information in the surrounding "emulsion" of spacetime. If you are a big fan of using Planck scale ideas to merge all forces into a unified force, even supermassive black holes cannot access such extreme energies.

Since 2019, I've tended to refer to this kind of matter-based encoding as a "soft holographic" interpretation of the universe versus "hard holographic" approaches that use an inexplicably infinite-memory external brane. A soft holographic view — a holographic cosmos in which available mass-energy limits low-end resolution — profoundly impacts topics such as quantum uncertainty. A full elaboration of such ideas impacts several fundamental physics math assumptions, such as how superpositions work.

Finally: What gravitons? Since no mathematically self-consistent formulation of gravitons exists, why should the paper get a free pass here? Fortunately, there are other paths to quantizing gravity, so I don't think this is a killer issue for now.

So: Great paper, great idea, but likely more radical in impact than it might seem.

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References

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