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Pre-Big Bang Physics: Homogeneity in Casual Set Cosmology

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MOTIVATION

Inflation provides a mechanism to generate the energy density perturbations that must have existed in the early Universe to produce the structure (galaxies, stars, etc.) we observe today. However, it has notable shortcomings, including the lack of a consensus on the mechanism driving inflation and the fine-tuning of various parameters, which can be adjusted to fit any observation [1].

AIMS

1. To investigate whether TP with small p can produce an almost homogenous universe at the end of the quantum gravity era, i.e. the period after a post and before the "moment" or hypersurface that we call Big Bang.

2. To explore the deviations from homogeneity and whether they could explain the primordial density perturbations.

BACKGROUND

Causal set theory is a proposal for quantum gravity in which spacetime is fundamentally discrete and modelled by a causal set.

A causal set or causet $(S, \prec)$ is a set S together with an order relation $\prec$ that is transitive, irreflexive, and locally finite [2].

Transitive percolation (TP) is a toy model of (classical) causal set dynamics in which causets grow through the sequential "birth" of new elements [3].

These causets will have an infinite number of posts if grown indefinitely. This suggests a cosmological interpretation as a bouncing universe [4].

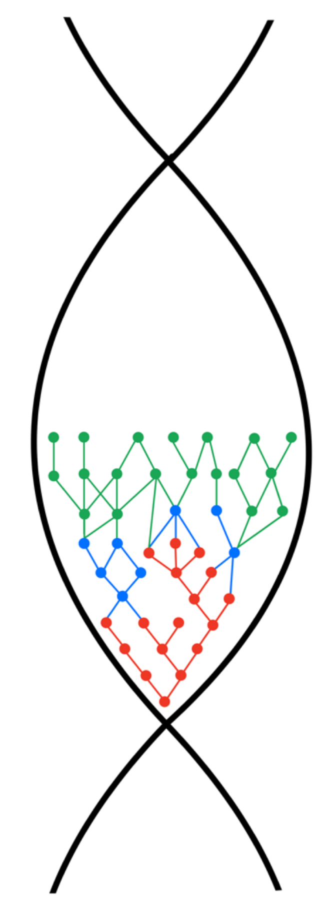
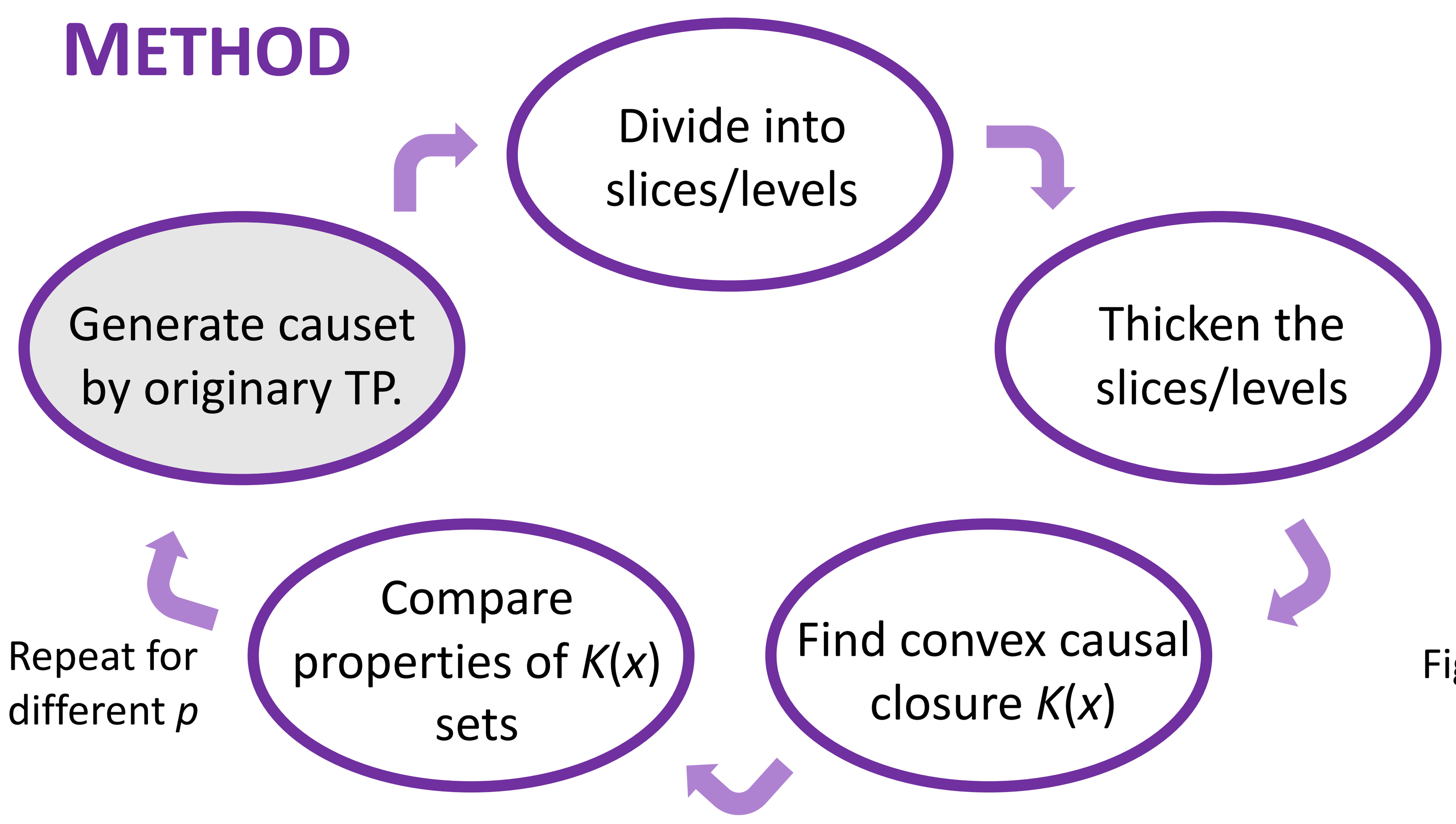


Fig. 1. Schematic of the bouncing universe produced by TP.

METHOD



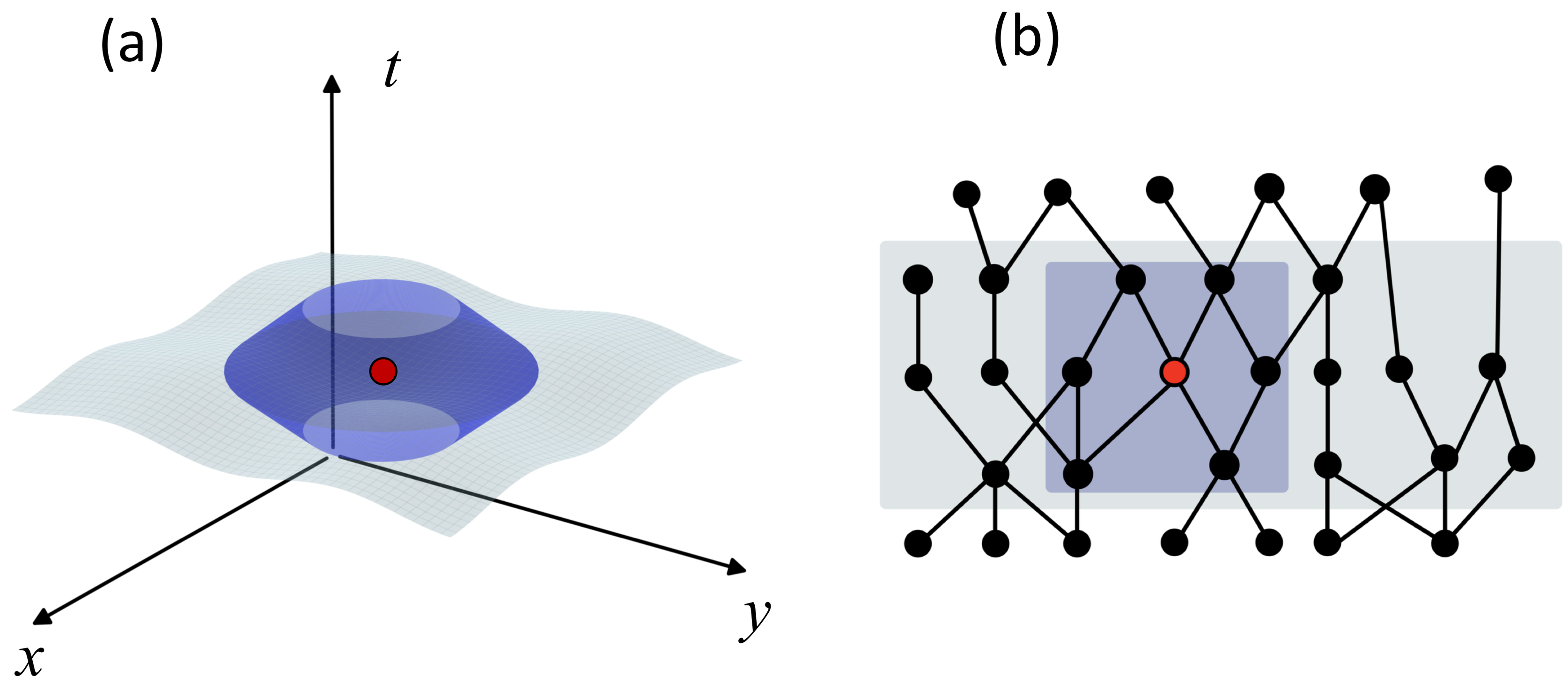


Fig. 2. Grey: a) a spatial hypersurface in the continuum and b) its discrete analogue. Blue: b) our definition of the neighbourhood $K(x)$ of a point x (red) and a) its schematic interpretation in the continuum.

RESULTS

- The three phases of a causet generated by originary TP can be clearly identified in the plot below.
- Levels and slices exhibit the same behaviour in the tree and stasis phases.
- The cardinality and ordering fraction of $K(x)$ vary within the levels and slices.

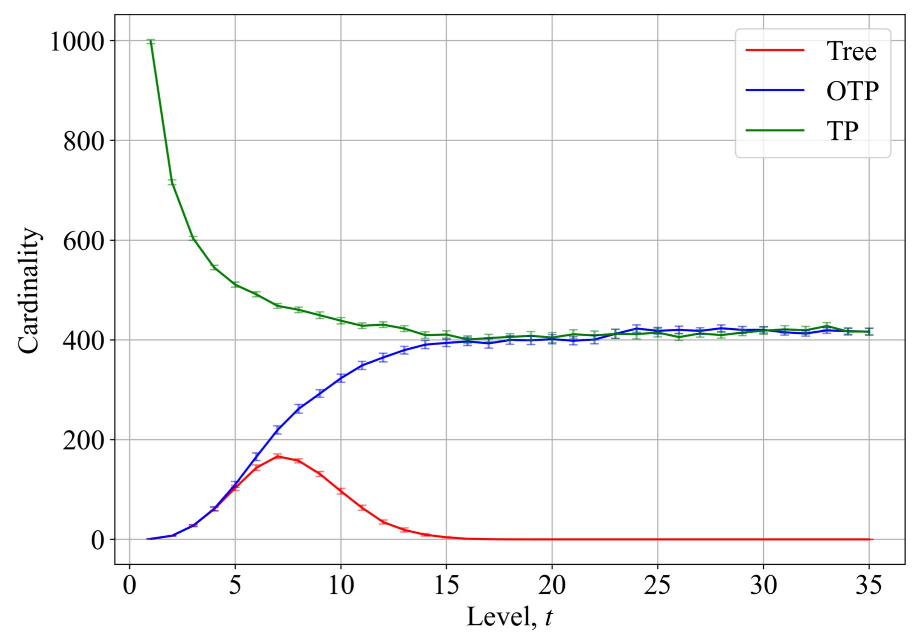


Fig. 3. Cardinality of the levels in causets generated by TP and originary TP for $p = 0.001$.

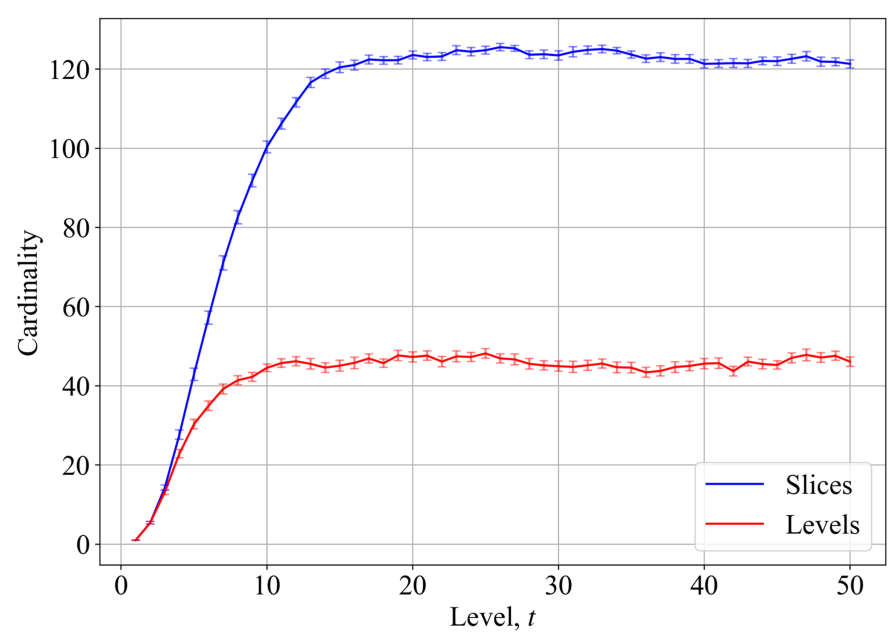


Fig. 4. Cardinality of levels and slices for $p = 0.01$.

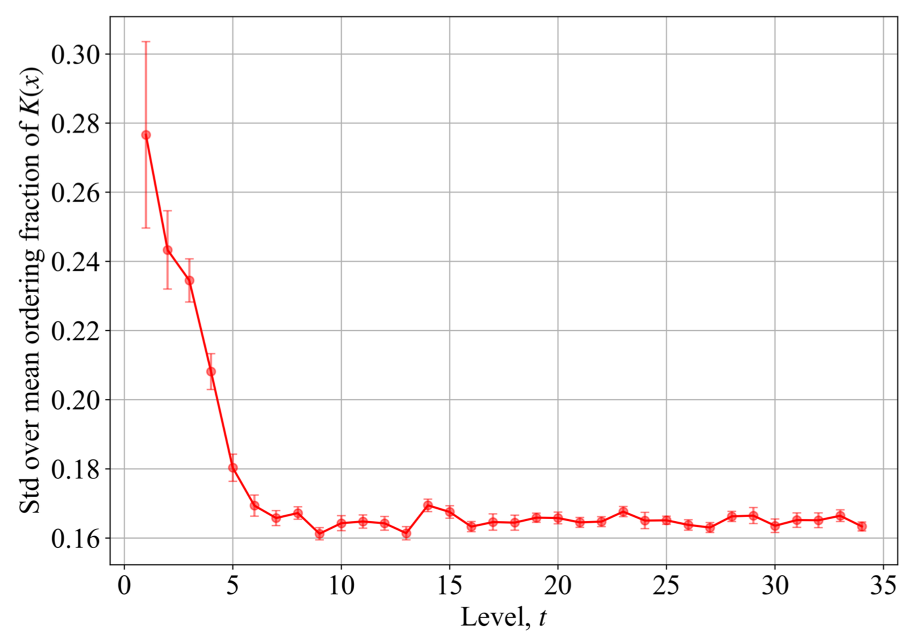


Fig. 5. Relative variation of the ordering fraction of $K(x)$ for the levels for $p = 0.001$.

CONCLUSION AND IMPACT

- TP can produce causets with a high degree of homogeneity (deviations of order 10^{-1}). However, inhomogeneities arise in the discrete analogues of spatial hypersurfaces considered.
- This paradigm has the potential to explain the density perturbations in the early Universe, especially if further research explores lower values of the probability p (our Universe would correspond to $p = 10^{-84}$).

REFERENCES

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