Future Algebras, Stringy AdS and Causal Structure

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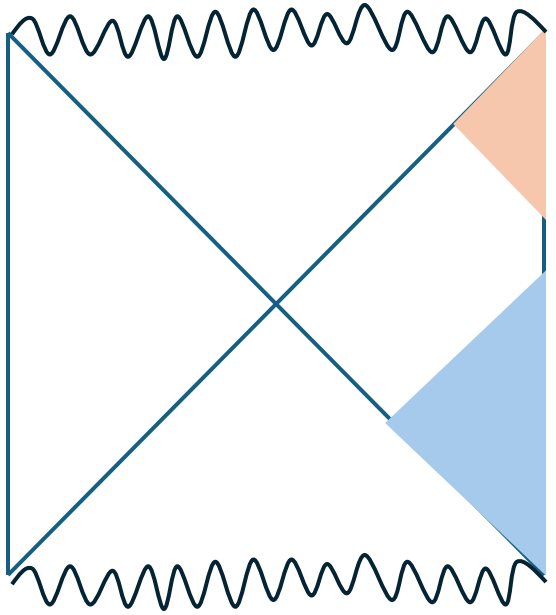
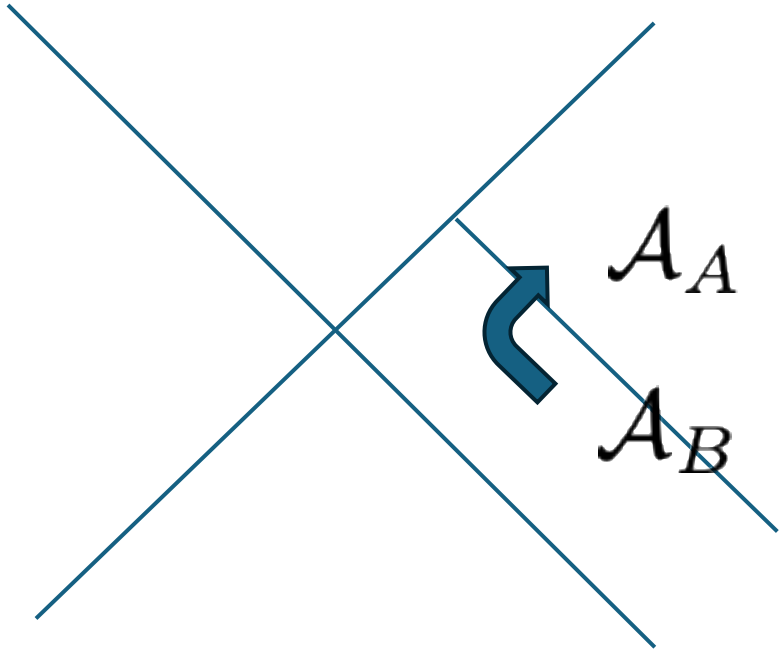


If the set of all observables from now until eternity forms a proper subalgebra of observables we call it a **future algebra**

Bisognano-Wichman theorem: Modular flow of a wedge is boost

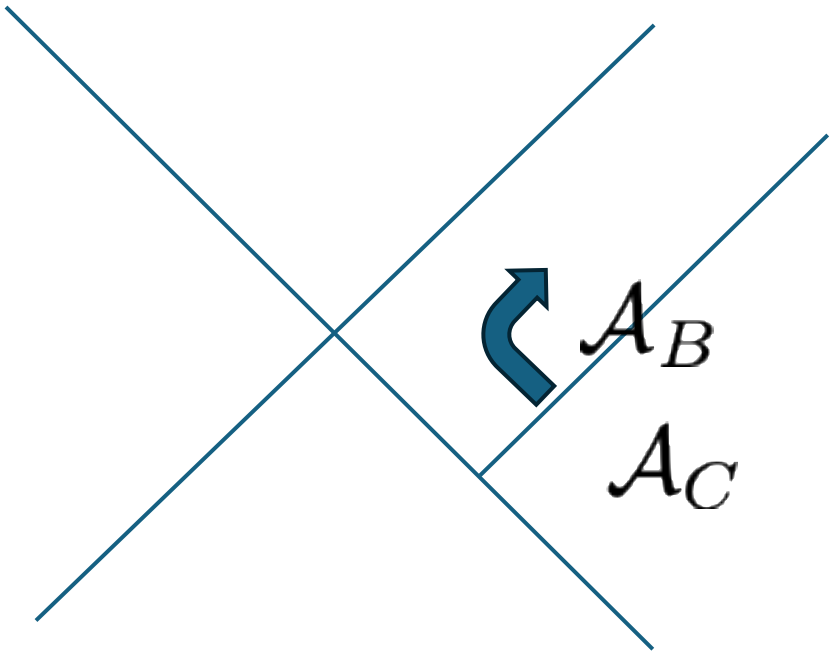
Wedge algebra $\mathcal{A}_A$ is a future algebra with respect to modular dynamics of $\mathcal{A}_B$

Seeing the Wedge in the Algebras



Modular Future Algebra

$$\mathcal{A}_A \subset \mathcal{A}_B$$



Modular Past Algebra

$$\mathcal{A}_C \subset \mathcal{A}_B$$

Wiesbrock; Summers; Ouseph, Furuya, NL, Leung, Moosa arXiv:2310.13736

- Local QFT is a map from wedge regions to von operator algebras $A \to \mathcal{A}_A$

  preserves inclusions, symmetries and causal complements

Wedges		Algebras
$A \subset B$	⟹	$\mathcal{A}_A \subset \mathcal{A}_B$
$A \to \alpha_g(A)$	⟹	$U_g \mathcal{A}_A U_g^\dagger = \mathcal{A}_{\alpha_g(A)}$
$A \to A'$	⟹	$J\mathcal{A}_A J = \mathcal{A}_{A'}$

Order preserving bijections

Seeing spacetime in modular future/past algebras

Wedges		Algebras
$A \subset B$	⟸	$\mathcal{A}_A \subset \mathcal{A}_B$
$A \to \alpha_g(A)$	⟸	$U_g \mathcal{A}_A U_g^\dagger = \mathcal{A}_{\alpha_g(A)}$
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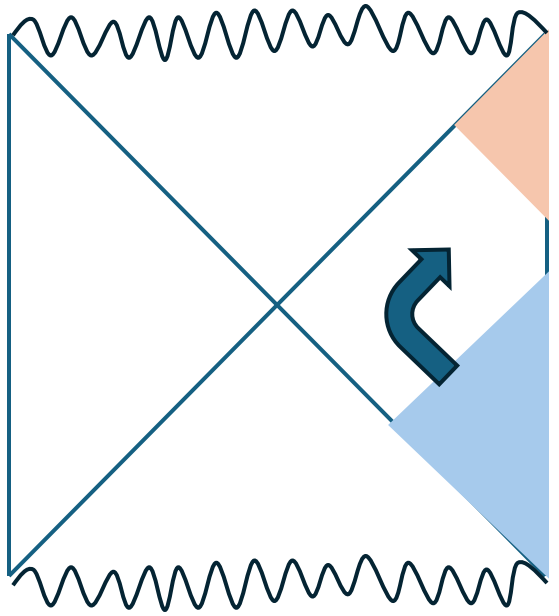


Algebraic Characterization of “Stringy spacetimes” in terms of modular flow and conjugation of future/past algebras

Examples:

Algebraic characterization of Stringy horizon
Leutheusser-Liu; Gesteau-Liu

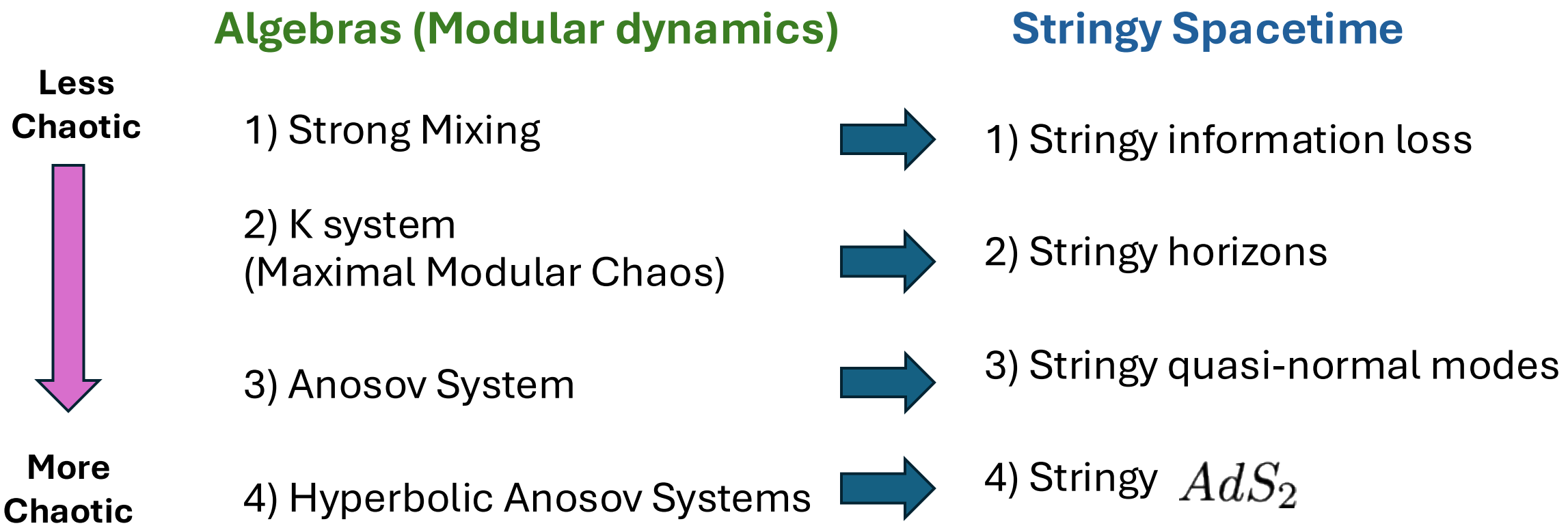
Algebraic characterization of Stringy local Poincare group at the bifurcate Killing horizon
Ouseph, Furuya, NL, Leung, Moosa

Algebraic characterization of Stringy AdS_2

(Twisted) modular Inclusion theorem, (Twisted) modular Intersection theorem.
NL, Leung, Moosa, Ouseph arXiv:2412.19882

In progress: An algebraic characterization of the causal structure (Penrose diagram) of Stringy spacetime from *order-preserving* modular conjugations.

Modular Ergodic Hierarchy and Stringy Spacetime



From Lorentzian Geometry to Algebras:

Local QFT is a map from the partially-ordered set of causally-complete regions (e.g. Wedges) to the partially ordered set of von Neumann Algebras

From Algebras to Lorentzian Geometry:

“Stringy” spacetime is a partially-ordered set of abstract von Neumann algebras with particular modular flow and conjugation properties sufficient for the emergence of a Lorentzian geometry