General idea: to implement a *self-consistent*, *Qiskit-powered*, sandbox with which to demonstrate and further probe *quantum information scrambling* both in simulations and on current IBM quantum devices with the overarching goal of being to further study the insights these exotic dynamics provide on the holographic conjecture of nature

Impact – key value metrics:

- Develop the Qiskit implementation of scrambling-dependent teleportation protocols in order to characterize scrambling timescales of quantum many body systems by means of entropy measures so as to compare and contrast with theoretical results from Anti-de Sitter / Conformal Field Theory approaches describing a black hole's information scrambling behavior.

- To persue the above in a self-consistent manner, an extension to Qiskit Terra's "Operators" library for the purpose of scrambling analysis via characterization of so-called "scrambling unitaries" necessary to realize the abovementioned protocols. This characterization is done via the block decomposition method (BDM)

Goals:

- Establish and characterize via BDM the scrambling unitary needed by the teleportation protocol – thus guaranteeing the presence of scrambling
- Quantitatively describe quantum scrambling time via entropy measures (von Neumann- & Rényi-type)
- Argue and consolidate views from both the quantum perspective as well as AdS/CFT arguments on scrambling time ("butterfly" velocity, Lyapunov exponent characterization, universal entropy measures, etc...)

Resources:

Main papers:

- Landsman et.al.: Verified quantum information scrambling
- Schleier-Smith et.al.: Measuring the scrambling of quantum information
- Saraswat & Afshordi: Quantum nature of black holes: fast scrambling ver sus echoes
- Keselman et.al.: Scrambling and Lyapunov exponent in spatially exte nded systems

Supplementary papers:

- Shor: Scrambling time and causal structure of the photon sphere of a Schwarzschild black hole
- Liu, Lloyd, Zhu & Zhu: Entanglement, quantum randomness and complexit y beyond scrambling
- Hayden & Preskill: Black holes as mirrors: quantum information in ran dom subsystems
- Choi, Bao, Qi & Altman: Quantum error correction in scrambling dynamics a nd measurement-induced phase transition

Action plan – team players, responsibilities & time projection:

*not Joaquín

J. Abraham Hernández – Education, physics, simulations

- Project proposal & coordination
- Unitary characterization
- Application & interpretation of complexity/entropy measures
- Benchmark scripting

Hannah Reber – Hardware, QML, physics

- Circuit design & adaptation
- Team coordination support
- Benchmark scripting
- Code depolyment & simulation

Joaquín Mata – Mathematics, physics, CS

- Black hole scrambling characterization (scrambling time, features, consequences for external observers)
- Interpretation of simulation results from AdS/CFT's perspective

For a more detailed view, please consult the full spreadsheet here.

QISA TIMELINE

PROJECT TITLE	QISA - Quantum information scrambling analysis	COLOR CODE:	DONE DOING TO-DO IMPORTANT DATES
PROJECT MANAGERS	Abe Hernández, Joaquin Castillo, Hannah Reber	DATE	4/22/21

PHASE		DETAILS
	PROJECT WEEK:	
1	Project conception	-Pitch -Proposal overview -Breakdown
2	Scope definition & literature review	-Environment setup (Qiskit, Github, etc...) -Lit. review -Goal definition -Project proposal definition (3-slides)
3	Qiskit testing: minimal implementation	-Teleportation protocol development in Qiskit -Experimental signature extrapolation -BDM application and scrambling unitary characterization -MVP (minimum viable project - addition to Qiskit's operators)
4	Further testing / result interpretation	-Additional benchmarking simulations / run code on real IBM device -Interpretation of results within AdS/CFT theory -Code commenting and presentation improvement -Distilling figures of merit
5	Closure	-Scientific report (3-pages) -Github repo -Video presentation

Phase 1: W1 (19–2), W2 (3–9)

Phase 2: W1 (10–16), W2 (17–23), W3 (24–30), W4 (31–5), W5

PROPOSAL DUE

1ST PHASE

2ND PHASE

PLAY W/QISKIT ENV

CIRCUIT/PULSE SCHEDULE DESIGN

SIMULATOR OUTPUT ANALYSIS

BDM as an extension to Qiskit's ran

WHAT? HOW? WHY? - results

CHECK QUBIT INTE

REFINE MATHEMATICAL CONCEPTS - EXI

IN PREPARATION FOR GITHUB REP

WHICH NEW FINDINGS CAN WE RE

WHAT? HOW? WHY? RESULTS?

SCRIPTING, RECORI

TOP 20 ANNOUNCED

FINAL PROJECT DUE