Measurement-invisible quantum correlations in scrambling dynamics

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If two parties have access to entangled parts of a quantum state, the common lore suggests that when measurements are made by one of the parties and its outcomes are classically communicated to the other party, it changes the state of the part accessible to the other party. Here we show that this lore is not necessarily true – in generic scrambling dynamics within a tripartite setting (with the R, S and E labelling the three parts), a new kind of dynamical phase emerges, wherein local measurements on S are invisible to one of the remaining two parts, say R, despite there existing non-trivial quantum correlations and entanglement between R and S. At the heart of this lies the fact that information scrambling transmutes local quantum information into a complex non-local web of spatio-temporal quantum correlations. This non-locality in the information then means that ignorance of the state of part E can leave R and S with sufficient information for them to be quantum correlated or entangled but not enough for measurements on S to have a non-trivial back-action on the state of R. This new dynamical phase is sandwiched between two conventionally expected phases where the R and S are either disentangled from each other or are entangled along with non-trivial measurement back-action. This provides a new characterisation of entanglement phases in terms of their response to measurements instead of the more ubiquitous measurement-induced entanglement transitions. Our results have implications for the kind of tasks that can be performed using measurement feedback within the framework of quantum interactive dynamics.