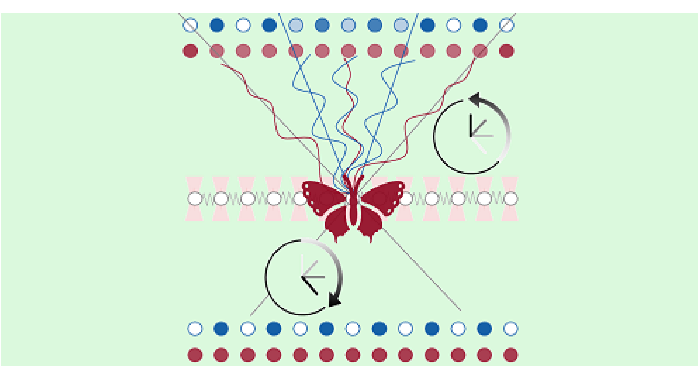
Quantum Scrambling Goes Anomalous

Evidence that quantum information can get scrambled unconventionally in a chain of atoms could improve our understanding of quantum many-body dynamics.

By **Ryan Wilkinson**

From quantum communication networks to black holes, many quantum systems are thought to exhibit a phenomenon known as information scrambling. In this process, initially localized quantum information gets dispersed across a system and can no longer be easily accessed. Typically, scrambling is fast and uniform. But now Xinhui Liang at Tsinghua University in China and his colleagues have observed slow, nonuniform scrambling in an atomic system [1]. They say that this anomalous behavior could offer insights into how quantum many-body systems evolve toward thermal equilibrium.

Liang and his colleagues used optical tweezers to produce a linear chain of regularly spaced, laser-cooled rubidium atoms. Each atom could be in its ground state or a highly excited state. When an atom was excited, its strong van der Waals interaction with its neighbors prevented those atoms from also being excited. The team explored two initial configurations: a polarized pattern, where every atom was in its ground state; and a Néel pattern, where the atoms alternated between ground and excited states. In each configuration, the researchers tracked how a small change to the central atom's quantum state affected the rest of the chain, revealing how that initially localized quantum information spread through the system.



Credit: X. Liang/Tsinghua University

A useful metric for quantifying the degree of information scrambling is the so-called out-of-time-order correlator (OTOC). For the polarized pattern, the researchers measured a rapidly decaying OTOC, characteristic of conventional scrambling. But for the Néel pattern, the OTOC slowly decayed and had steady oscillations, suggesting an anomalous type of scrambling that had previously been predicted but not observed. According to the team, this finding implies that the quantum information did not simply disperse across the atomic system but instead periodically returned—as if the system partially remembered its past.

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REFERENCES

1. X. Liang *et al.*, "Observation of anomalous information scrambling in a Rydberg atom array," **Phys. Rev. Lett. 135, 050201 (2025).**