Contribution ID: **21** Type: **not specified**

Deep Learning based discovery of Integrable Systems

Wednesday 10 December 2025 11:45 (45 minutes)

Integrable systems are exactly solvable models that play a central role in QFT, string theory and statistical physics offering an ideal setting for understanding complex physical phenomena and developing novel analytical methods. However, the discovery of new integrable systems remains a major open challenge due to the nonlinearity of the Yang–Baxter equation (YBE) that defines them, and the vastness of its solution space. Here we present the first AI-based framework that enables the discovery of new quantum integrable systems in exact analytical form. Our method combines an ensemble of neural networks, trained to identify high-precision numerical solutions to the YBE, with an algebraic extraction procedure based on the Reshetikhin integrability condition, which reconstructs the corresponding Hamiltonian families analytically. When applied
to spin chains with three- and four-dimensional site spaces, we discover hundreds of previously unknown integrable Hamiltonians. Remarkably, these Hamiltonians organize into rational algebraic
varieties, and we conjecture that this rationality holds universally —revealing a deep and previously unexplored connection between quantum integrability and algebraic geometry. By unlocking integrable systems far beyond the reach of traditional methods, this AI-driven approach substantially
expands the landscape of exactly solvable models and opens a scalable path to further discoveries.

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