Born Rule and Algorithmic Randomness

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The Born rule, formulated by physicist Max Born in 1926, is one of the key principles of quantum mechanics.

The time evolution of a quantum system is entirely deterministic according to the Schrödinger equation. The probability enters into the quantum theory via the Born Rule which gives the probability that a measurement on a quantum system will yield a given result. In its simplest form it states that the probability density of finding a particle at a given point is proportional to the square of the magnitude of the particle's wave function at that point.

Algorithmic information theory [3, 2, 4] is a field of mathematics in which randomness of individual infinite sequences are studied. An important symptom of randomness of a sequence is typicality, the property of passing every statistical test of randomness.

The goal of this project is to study the article [6] in which an operational form of the Born rule is studied using algorithmic information theory derived from a single postulate, called the *principle of typicality*.

More advanced problems involve other symptom of randomness studied in algorithmic information theory, like unpredictability [1] or incompressibility [2, 4, 5] and/or applications of this new rule to important quantum protocols (in the spirit of the application to the BB84 quantum key distribution protocol presented in [6]).

References

[1] A. Abbott, C. S. Calude, K. Svozil. A non-probabilistic model of relativised predictability in physics, *Information* 6, (2015), 773–789

[2] C. S. Calude. *Information and Randomness: An Algorithmic Perspective*, 2nd Edition, Revised and Extended, Springer-Verlag, Berlin, 2002.

[3] G. J. Chaitin. *Algorithmic Information Theory*, Cambridge University Press, Cambridge, 1987. (third printing 1990)

[4] R. Downey, D. Hirschfeldt. *Algorithmic Randomness and Complexity*, Springer, Heidelberg, 2010.

[5] K. Landsman. Randomness? What Randomness? `http://philsci-archive.pitt.edu/16273/`, July 2019.

[6] K. Tadaki. A refinement of quantum mechanics by algorithmic randomness, `arXiv:1804.10174`, April 2018.