New ideas for a deterministic relativistic model of spin in accordance with the Stern-Gerlach-experiment

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May 4, 2024

Abstract

In 1922 Einstein, wondered how the Stern-Gerlach-experiment could be explained within deterministic relativity rather than ”god playing dice”. With the help of recent experiments, such an explanation may have been found.

Das Interessanteste aber ist gegenwärtig das Experiment von Stern und Gerlach. Die Einstellung der Atome ohne Zusammenstöße ist nach den jetzigen Überlegungs-Methoden durch Strahlung nicht zu verstehen; eine Einstellung sollte von Rechts wegen mehr als 100 Jahre dauern.

Albert Einstein (1922) [a]

[a] Einstein, Born, Briefwechsel, Langen-Müller, S. 102f, Brief Nr. 42

1 Introduction

The translation of above quote to English is the following:
"But the most interesting thing at the moment is the experiment by Stern and Gerlach. The adjustment of atoms without collisions cannot be understood by radiation according to the current methods of reasoning; By law, an adjustment should last more than 100 years."
My spontaneous answer to that is that the electron is just rotating so fast, that the adjustment takes less than a microsecond. The spin aligns parallel or antiparallel to a surrounding magnetic field spontaneously, seemingly instantaneously relative to our macroscopic timescales. The absolute speeds must be highly relativistic, while the orbital radii are described as points. But it is not necessary here to speculate on the precise composition of an electron, as only the overall angular momentum and magnetic moment matter for our considerations here.

2 A new type of experiment (ultrafast)

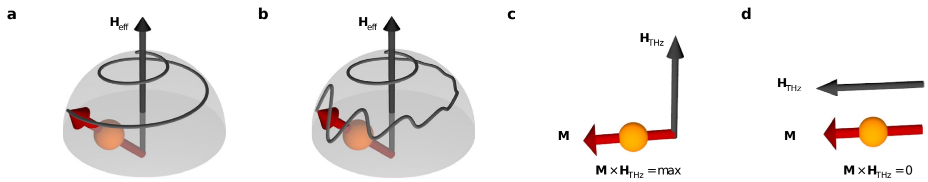

Figure 1: Adapted from [1]. (a) Spin precession without nutation included. (b) Nutation included in the consideration. (c) Torque due to the magnetic field is maximal in the horizontal spin orientation. (d) Torque is zero in the parallel orientation.

We consider nutation of an electron spin in analogy to the experiment from a relatively recent paper [1], as can be seen in figure 1(b).
Now, if we apply a Hadamard gate to a spin state, we can imagine that the polar vector of the angular momentum is oscillating heavily up and down around the fully horizontal position (and very quickly). It depends on which time we measure, whether the spin points above or below the horizontal line and hence collapses to the parallel or anti-parallel position. Therefore, on macroscopic timescales, it appear random.

A very interesting observation in figure 1(d) is the following: A spin oriented perfectly parallel to a magnetic field line experiences no torque. Therefore, this is a fixed point of the dynamics. Even if the magnetic moment points in the opposite direction the vector product remains zero. In analogy to a tippe top, it is possible to remain stable in the energetically higher dynamic state. This might explain why in the Stern-Gerlach-experiment, it's not simply that all spins collapse to an orientation parallel to the magnetic field, but equally many collapse to an orientation anti-parallel to the magnetic field.

There are further counter-arguments to deterministic spin models, some of which I will try to address in the following.

3 Deterministic spin model counter-arguments

3.1 CHSH inequality

Sure, you cannot reproduce the same results using only classical probabilistic state vectors, but who is to say that deterministic chaos cannot produce probability amplitudes?

3.2 3 spots for spin 1 particles

For spin 1 (2 electron spins) particles, you have deterministic chaos for each of the component particles. Thus, you have 3 distinguishable possibilities of collapse along the magnetic field: Both up, both down, one-up-one-down.

3.3 Bad idea

Please, be patient with me, even if I am wrong. Humans always make mistakes and even bad ideas have often led to good new developments - and no human-made model is ever perfect.

References

[1] Neeraj, K., Awari, N., Kovalev, S. et al. Inertial spin dynamics in ferromagnets. Nat. Phys. 17, 245–250 (2021). https://doi.org/10.1038/s41567-020-01040-y