Q&A
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Learning to Control Quantum Systems Robustly
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Q1: I just want to go back to the beginning. This issue with the quantum control and the ability to be robust as well as optimal in a way that you'd expect the normal control to compromise. This seems really very interesting and holds out hope for much more than we might have expected. Can you say something a bit more about that?

In some sense that's why we stuck with energy landscape control schemes because initially we started with our system to show "well, here's an example that is not fully controllable, so it should not work". And then it works. That's literally the first paper that came out on this. And then we'll see that extra robustness effectively. I don't want to go on too much about this because we don't have a complete explanation, but we have an additional degree of freedom. Because the global faces cannot be observed. And that seems to be responsible for why we will see that contradiction to the classical theory. That's as far as I would go with that. The sort of difficult discussions with the global phase of course involved, but we have to struggle a lot particularly for the new analysis to get that inverse working strictly with the theory and not just "oh it should work, and let's compute some kind of inverse with it to actually fully prove this". And the papers are very, very technical. They're not easy to read. So out of that, there is a lot of promise. Can we fully explain why we see that? Not yet. We might still be missing something in the whole process. But there are systems that seem to be able to break that, finding these controllers. And then also actually experimentally realising this. We are not just sending an RF pulse into a system, we need to be able to shape the energy landscape, possibly locally very, very precisely. But then if you get some leakage of some fields into neighbouring spins, if they are, then sufficiently robust that there is a lot of promise in that. The proof will lie in the experiment to verify this, and it can be sure that this will actually happen right now.

It's a very interesting alternative view on things.

We'll stick with it for now.

Q2: Although you've phrased this in terms of SPIN systems and so on. Presumably this does apply to any sort of system where you got an energy landscape that in principle you could control, like a chemical system. With the laser we can control some of these levels, and so on. It's not as easy as a SPIN system, because there was quite a lot of early work done on optimal control to divert quantum chemical systems around, but it seemed to peter out a bit. We could do some basic stuff of shifting populations into certain states, but we never seem to do much chemistry with it, but I just wonder whether the time is right for a new look?

I mean, in some sense a lot of this can work. I skipped very quickly over the MRI scheme, which is still the dynamic control and the robust dynamic control. But you cannot do so much from the mathematics with it. All of this up and everything moves, so you have no handle on any limits with it anymore. Yes, I think quantum control actually comes out of this Chemistry can we control, our reactions. The problem seems to be that you can never get to any sensible yields. OK, if you have something very valuable and only need a few atoms, maybe more than a few, but really not as a mass production type of system, I think that that remains the problem. There has been quite a bit of progress what they can do in chemistry, well known on that end. In sort of breaking bonds, in actually forming bonds again, and controlled so driving reactions, but it is very low yield, which I think is the problem in the chemistry space. But in principle what we're doing here should apply to a lot of these other systems. The only option is of course if you make your system ever larger, the decoherence becomes ever harder to fight and then we get the classical behaviour then. So, we're looking at very small isolated systems here. But curiously, on the other hand, with NMR or in MR sort of in low fields, messy room temperature, biological systems, some of these controls actually still work. MRI works, so these pulses do something. They're not as complex as what we need for quantum computing, we don't need to implement or gates in that sense. But they're still operating, this still works, so I would not completely rule out the possibility that at some stage you might be able to get there.