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Behind the paper: A bridge between theory and experiment

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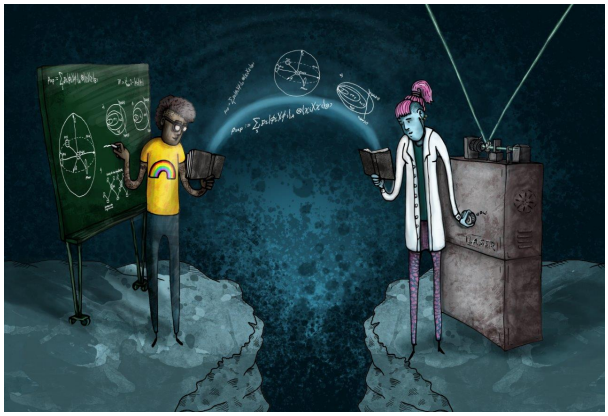
On behalf of Marcus Huber



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Supposedly, there are two very different species of physicists: theorists and experimentalists. This alleged division is the subject of numerous nerdy jokes, but is more seriously reflected in university curricula, academic positions, grants, papers and non-surprisingly, reviews. Our review is an attempt to bridge the apparent gap that often complicates communication, focussing on a specific area of quantum physics that has seen a close connection between theory and experiment.

The story behind this review starts well before it was conceived. After finishing my PhD in theoretical physics, I remember being approached by experimentalist colleagues, asking seemingly simple questions about quantifying high-dimensional entanglement. At first, I couldn't comprehend their dissatisfaction with my writing down a self-adjoint operator—after all, this is what constitutes a 'measurement' according to the postulates of quantum mechanics. After being presented with a bunch of tangible tools that were screwed to an optical table and asked to explain how to realise that specific measurement, I realised how little I actually understood quantum experiments and how pointless all of my theorems seemed for answering the simplest of questions.

This initially painstaking interaction with the mysterious species of experimentalists eventually bore fruit and led to a series of collaborations with experimental groups. There was a recurrent theme in our interactions experienced also by many theorist colleagues—we were presented with final experimental data and asked to tell if it is possible to certify or even quantify entanglement. The answers would have always been easy had they done the experiment in a slightly different manner, but alas, what was done, was done. I then spent sleepless nights trying to understand what each particular setup meant and how one could construct theoretical tests of entanglement for each specific situation—a process that could have been much simpler had there been a comprehensive review bridging this divide.

At some point, one of my frequent experimental collaborators approached me with an interesting proposition: we could run experiments together. And indeed a short time later, Mehul Malik joined my group as a senior postdoc and we

started exploring the intricacies of multipartite and high-dimensional entanglement of ‘twisted’ photons. The first ‘experimental’ papers with a majority of theory authors were born and slowly the entire group developed a common language. Two more senior postdocs of the group had reported very similar experiences in different experimental collaborations, with Giuseppe Vitagliano working on spin squeezing in cold atoms and Nicolai Friis analysing ion traps with 20 qubits. We had often talked and decided the field really needs a review that covers all aspects in a unifying language, but never found the time to actually materialise it.

When I was invited to write a review for *Nature Reviews Physics*, we knew this was the chance to finally realise that dictionary that should become a handbook for both theorists and experimentalists to talk to each other, while comprehensively showcasing the state-of-the-art of quantum technologies. Of course, our initial dream was a bit too ambitious, given that there are dozens of experimental platforms, each with their own techniques and whole books could be written just about the theory of entanglement. So while trying to remain as objective and comprehensive as possible, we naturally decided to focus on aspects that we found most exciting at the moment.

The time we were planning to write the review also coincided with the move of Mehul Malik to his new professorship in Edinburgh and overlapped with the parental leaves of both Nicolai Friis and Giuseppe Vitagliano. While all joyous occasions, it was hard to gather the crowd even in the same Skype conversation. Collectively editing, planning and writing a comprehensive review with strict length constraints seemed an insurmountable task under these circumstances. So we turned to collaborative online LaTeX editors and at different hours of day and night wrote and commented the present review. When *Nature Reviews Physics* approached us about whether we would be willing to try Overleaf for collaborating with the editorial team, we were already well acquainted with the workflow, and went through several rounds of excellent editorial feedback, without ever having to worry about version control or sending a single document via email.

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