# Multiparty entanglement: When everything is connected

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In a multiparty entangled quantum world, everything can be connected. Credit: TheDigitalArtist

Entanglement is an ubiquitous concept in modern physics research: it occurs in subjects ranging from quantum gravity to quantum computing. In a publication that appeared in *Physical Review Letters* last week, UvA-IoP physicist Michael Walter and his collaborator Sepehr Nezami shed new light on the properties of quantum entanglement—in particular, for cases in which many particles are involved.

In the quantum world, physical phenomena occur that we never observe in our large scale everyday world. One of these phenomena is quantum entanglement, where two or more quantum systems share certain properties in a way that affects measurements on the systems. The famous example is that of two electrons that can be entangled in such a way that—even when taken very far apart—they can be observed to spin in the same direction, say clockwise or counterclockwise, despite the fact that the spinning direction of neither of the individual electrons can be predicted beforehand.

## Multiparty entanglement

This example is somewhat limited: entanglement does not necessarily have to be between two quantum systems. Multi-particle systems can also be entangled, even in such an extreme way that if for one of them a certain property is observed (think of 'spinning clockwise' again), the same property will be observed for all the other systems. This multiparty entanglement is known as a GHZ state (after physicists Daniel Greenberger, Michael Horne and Anton Zeilinger).

In general, multiparty entanglement is poorly understood, and physicists don't have much systematic insight into its workings. In a new paper that was published in *Physical Review Letters* this week, UvA physicist Michael Walter and his collaborator Sepehr Nezami from Caltech begin to fill this gap by theoretically investigating a rich class of many-body states and their entanglement properties. To this end, they employ a mathematical technique known as a 'tensor network.' The researchers show that the geometrical properties of this network provide a host of useful information about the entanglement properties of the states under investigation.

The more detailed understanding of quantum entanglement that the authors obtain could have many future applications. The research was originally motivated by questions in the search for a better understanding of the quantum properties of gravity, but the technical tools that have been developed are also very useful in the theory of quantum information that is used to develop quantum computers and quantum software.

**More information:** Sepehr Nezami et al. Multipartite Entanglement in Stabilizer Tensor Networks, *Physical Review Letters* (2020). DOI: 10.1103/PhysRevLett.125.241602

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