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Quantum information can be negative

Even the most ignorant among us cannot know less than nothing. What could negative knowledge mean? In the everyday world we are accustomed to, negative knowledge makes no sense. But in the world where the laws of quantum mechanics hold sway, knowledge can be negative. In essence, one can have situations where someone knows more than everything, and it is in these situations where one finds negative knowledge. This negative knowledge turns out to be precisely the right amount to cancel the fact that we can know too much. Negative knowledge is due to exotic features of quantum information theory and by understanding that quantum knowledge can be negative, we gain deeper insights into such phenomena as quantum networks, quantum teleportation, quantum computation, and the very structure of the quantum world.

In more detail, given part of an unknown quantum state, we determine how much quantum communication is needed to obtain the full state. This is the partial information we need conditional on our previous information. It turns out to be given by an extremely simple formula, the conditional entropy. In the classical case, partial information must always be positive, but we find that in the quantum world this physical quantity can be negative. If the partial information is positive, the sender of the partial information needs to communicate this number of quantum bits to the receiver; if it is negative, they instead gain the corresponding potential for quantum communication in the future. The primitive that is introduced—quantum state merging—enables a systematic understanding of quantum network theory, and several such applications will be discussed.