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Undecidability in Quantum Physics: Hilbert's Second and Sixth Problems Meet

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The pioneering work of Goedel and Turing in the 30s showed that there exist problems in mathematics and computer science that cannot be solved. They are called undecidable. Since then, several problems in physics have been shown to be undecidable too. In this talk I will show that many interesting properties of a quantum many body system are indeed undecidable. This negative result has, however, a positive side. It predicts the existence of a new effect that we name "size-driven quantum phase transition". I will present this effect, its characteristic features, as well as our recent ideas to try to observe it.