

*This article has recently been published online in Foundations of Physics 56, 8 (2028), and is dedicated to the memory of Umut Gürsoy, who tragically passed away on 24 April 2025, during the last stages of the paper's completion. Co-author Henk Stoof writes about his co-orporation and friendship with Umut and how this article was established.*

# Holographic Strange Metals for Philosophers and Physicists

In the last 15 years I have closely collaborated with Umut in an attempt to apply advanced string-theory methods to the study of condensed-matter physics, in particular strongly correlated quantum matter. We have written five papers together on this topic. During this long-lasting collaboration Umut's insight and physical intuition was always crucial for making progress when we were stuck and he acted as my mentor to make sure that a simple-minded condensed-matter physicist does not go astray in the complicated mathematics of string theory and the so-called AdS/CFT correspondence. I have always been very grateful for his patience with my ignorance, and I remember vividly the many fruitful discussions we had, and the pleasant times we spent together over the years.

Our efforts lead to a specific prediction for the behavior of the electrons in the cuprate strange metals, that was ultimately confirmed experimentally by the group of Mark Golden in Amsterdam. As a follow-up of this achievement, the above paper introduces the physics and philosophy of strange metals, which are characterized by unusual electrical and thermal properties that deviate from conventional metallic behaviour. The anomalous behavior of the electrons discussed here appears in the normal state of a copper-oxide high-temperature superconductor, and currently cannot be described using standard condensed-matter techniques. However, it can be described through the AdS/CFT correspondence from string theory that is also known as holography for short. This paper first introduces the theory of, and the specific experiments carried out on, strange metals. Then it discusses a number of philosophical questions that strange metals open up regarding the experimental evidence for holography and its realist interpretation. Strange metals invert the explanatory arrows, in

that usual holographic arguments are seen as giving explanations of the bulk quantum-gravity theory from the boundary. By contrast, the aim here is to explain the experimental discovery and anomalous properties of strange metals by using holography.



*Read the full article as published in Foundations of Physics authored by Umut Gürsoy and myself, among others from the University of Amsterdam.*



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