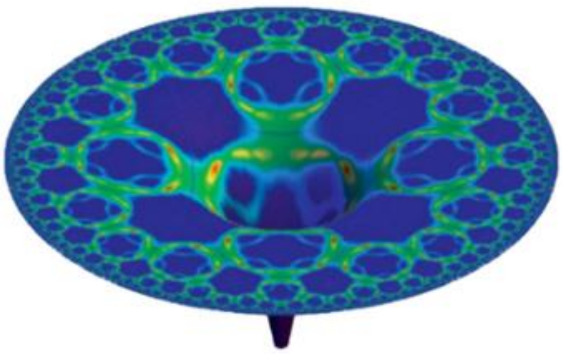
Program FYSICA 2019

Friday, April 5
Amsterdam Science Park
www.fysica.nl

Title: **Strange metals**

Abstract: You think we know all about metals? This session challenges you to think again. Metals are extraordinary: put countless electrons together and new 'quasi-particles' result behaving as if each electron inhabits its own world. Alix McCollam (RU Nijmegen) will explain this prime example of emergence, a concept underpinning many exotic phenomena including superconductivity and spacetime itself. Crystal clear experimental evidence shows our successful picture of simple metals fails spectacularly in a growing class of strange metals. Nigel Hussey (RU Nijmegen) will pinpoint the essential experimental signatures distinguishing between simple and strange. The data demand old theoretical dogmas about metals are replaced with exceptional, new ideas. Consequently, Koenraad Schalm (UL Leiden) will seek to persuade us that terrestrial strange metals dance to the same physics tune as black holes in higher dimensions. The last word goes to experiment, as Erik van Heumen (UvA Amsterdam) shows how this revolutionary new description is undergoing rigorous testing in a network of Dutch laboratories.



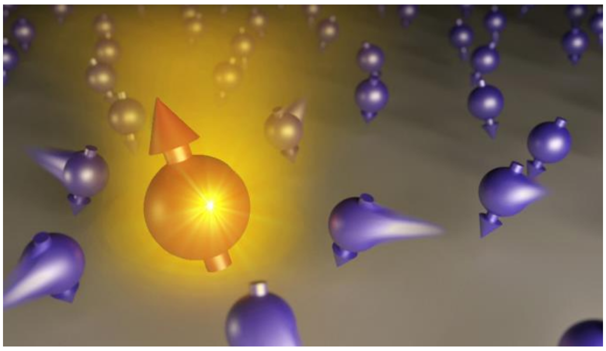
Convener: Mark Golden (UvA)

Speakers (in order of appearance)

Title: **More than the sum of the parts: What makes a metal?**

Alix McCollam (HFML, RU)

Abstract: Electrons in metals can move around through the material and transport both charge and heat, which is what makes metals good electrical and thermal conductors. However, the electrons also interact with each other, for example, via Coulomb repulsion, and this complicates their behaviour a lot, so that we cannot understand a metal by 'summing up' the properties of all the individual electrons: there is an element of collective behaviour that we must account for. A way to

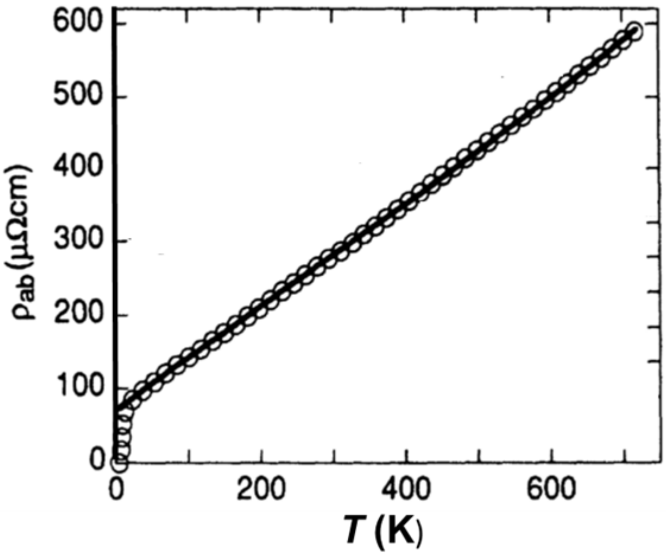


do this is by considering not simple electrons carrying charge and heat, but objects that are a combination of electrons plus their interactions, and that move and respond differently. We call these objects 'quasiparticles', and the stronger the electronic interactions, the more exotic the quasiparticles become. I will give an introduction to quasiparticles in metals, how they emerge from the sea of conduction electrons, and how they determine the properties of a metal. I will also explain how the quasiparticle picture has been immensely successful in describing metallic behaviour, even in extreme conditions, but that we now know a number of materials for which this theory fails dramatically. This will set the stage for the strangest of metals.

Title: **The allure of linearity**

Nigel Hussey (HFML, RU)

Abstract: The electrical resistivity of a copper oxide high-temperature superconductor varies linearly with temperature from essentially absolute zero right up to its melting point. At both extremes, the strictly T–linear form of the resistivity reveals that the conventional metallic picture of coherent electronic states (that predicts T-quadratic behaviour) breaks down.



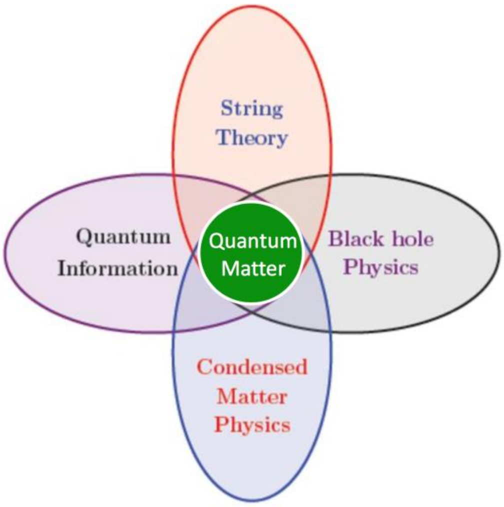
The remarkable simplicity of this functional form for the resistivity naturally belies the complexity of the underlying physics and despite immense research effort, this so-called 'strange metal' behaviour has dominated the field of correlated electrons for more than three decades, yet scientists' fascination with its core mystery shows no sign of abating.

The very fact that the electronic states are on the verge of incoherence, at all temperatures, begs the question; what sort of entity actually transports charge in a high-temperature superconductor? And how can something that appears so incoherent in its metallic state give rise to a macroscopically coherent superconductor with zero resistance up to such elevated temperatures? It is precisely these key questions that we will seek to explore in this presentation.

Title: **Applied string theory: Understanding strange metals in the lab with virtual black holes**

Koenraad Schalm (UL)

Abstract: The Anti-de-Sitter/Conformal Field Theory correspondence, also known as AdS/CFT, has given us an unprecedented new window onto the strongly coupled physics of interacting electrons in metals (in 3 space dimensions) by a mathematical mapping to Einstein's theory of General Relativity and black holes (in 4 space dimensions).

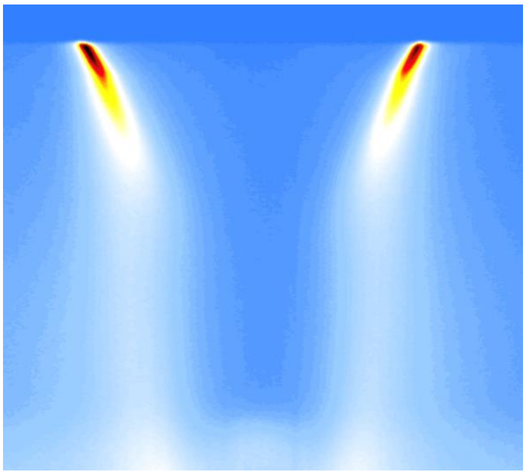


In particular, the existence of charged black holes in AdS predicts the existence of special points showing a quantum critical behaviour in quantum matter, different from existing theory of critical phenomena. I will review how the distinct features of these novel quantum critical points show a remarkable resemblance with the profoundly mysterious behavior of exotic strange metal states such as those in high Tc superconductors. Recent experiments of the past two years strongly indicate that this resemblance is more than superficial. This has put us at the cusp of a new era in physics: we will present the case that current experiments will test a holographic gravity model as the theory of the strange metal state.

Title: **Putting holographic theories for strange metals to the test: latest reports from the lab**

Erik van Heumen (UvA)

Abstract: The development of AdS/CFT as a toolbox to understand strongly correlated electron systems has some similarities to string theory: it being a mathematical framework developed by some very clever people. The most important *difference* is that AdS/CFT applied to condensed matter systems opens the door to something 'new' and vitally important: experiments!



It is only fitting that the photoelectric effect that earned Einstein his Nobel prize enables us to test predictions coming out of the general relativity theory for which he is best known. The premier experiment for this is called angle resolved photoemission spectroscopy (or ARPES), and is widely used as a direct measure of the properties of quasiparticles in solids. What AdS/CFT predicts for the strange metal phase is that we should see a complete breakdown of the quasiparticle concept that Alix McCollam explained in the first talk has been at the heart of our understanding of metals for nearly a century. To experimentally distinguish between the baby and the theoretical bathwater in

this case demands that we push this experiment to its very limits, and in this talk is a report from the experimental frontlines in this concerted campaign.