make up a significant portion of cases in which quantitative approaches are likely to be applied. By using additional career data for 200 highly cited physicists, we further confirmed our observation of much lower R^2 values in the early career (t up to 3 or 4 years).

Recent work by Amin Mazloumian hints at one of the underlying difficulties of predicting a scientist's future success.[5] By differentiating between citations accrued by papers already published at the time of prediction and citations accrued by papers published after the prediction time, Mazloumian shows that regression approaches do a reasonable job of predicting future citations to past papers but do not reliably predict future citations to future papers. Therefore, those who would predict a scientist's future value should be aware that the impact of papers published in the past does not necessarily correlate with that of papers published in the future.

Going forward, the metric-based approaches and their successors will be increasingly exploited in decision-making processes. However, little is known presently about the strengths and weaknesses of the state-of-the-art predictive indicators. Where the responsibility lies for vetting current and new quantitative measures is still an open question. But scientists themselves, particularly young ones, clearly stand to lose the most should quantitative measures be weighted too heavily in decisions affecting their careers. It behooves us to engage with the institutions that seek to use these quantitative measures of impact in their decision making and to impress upon them a skepticism backed up by quantitative and rigorous analysis of the specific measures they seek to employ.

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Letters

Strange connections to strange metals

The June 2012 issue of PHYSICS TODAY has, beginning on page 68, the Quick Study "From black holes to strange metals," by Hong Liu. It is one of many quasi-journalistic discussions I have seen of results using the AdS/CFT (anti–de Sitter/conformal field theory) correspondence from quantum gravitation theory ostensibly to solve condensed-matter physics problems such as the "strange metal" in the cuprate (high T_c) superconducting metals. As the probable source of the buzzword phrase "strange metal" to describe the phenomena observed in the cuprates and of a theory that bids well to explain those phenomena in detail, I think I have a reasonable motivation to object to the publication of those claims, even though advanced tentatively, when so much is known about this particular phase.

The strange-metal region of the cuprate phase diagram exhibits not only a linear dependence on temperature of the conductivity relaxation rate, which is generally taken by string theorists as *the* characteristic symptom identifying a strange metal and is the only feature they discuss. The region also exhibits several additional anomalies that in my experience are unique to this phase:

▶ The IR conductivity—the "Drude tail" of the DC conductivity—falls off with frequency with a noninteger power law, and the exponent apparently varies continuously with doping. That behavior was demonstrated by Nicole Bontemps and coworkers[1] in 1993 and further nailed down by Dirk van der Marel and coworkers[2] in 1995.

▶ The relaxation rate as measured by the Hall angle θ_H of deviation of the current from the electric field direction, using the formula $\theta_H = 1/\omega_c\tau$, is quite different from that of the conductivity, and has a different, T^2 temperature dependence, as N. P. Ong and coauthors demonstrated[3] in 1989.

▶ Over broad regions of doping, the two kinds of relaxation rates, the one for the conductivity and the one for the Hall rotation, seem to add as inverses: Conductivity is proportional to $1/T + 1/T^2$—that is, it obeys an anti-Matthiessen law.

▶ Angle-integrated photoelectron spectra, tunneling spectra, and angle-resolved photoemission spectra all fit better to power-law dependences on energy than to conventional fits.

All of those symptoms were explained without the use of arbitrary free parameters in the final papers of a long sequence dating back to 2004, by me and by Philip Casey and me,[4] while the AdS/CFT literature holds nothing resembling a connection back to the parameters of the real solids, nor any discussion of the other anomalies. I believe that our theories are exact, in the sense of continuation, in a considerable region of the phase diagram.

Incidentally, the phase diagram of the real cuprates is only vaguely similar to the conventional diagram shown in Liu's figure. For instance, the strange metal shows no evidence of terminating on the right in a true Fermi liquid.

It is amusing that the methods we use *are* closely related to results in quantum field theory, but to discoveries of three decades or more ago about "anomalies" such as the well-known chiral anomaly of Roman Jackiw and Claudio Rebbi. At about the same period, we condensed-matter theorists were concerned with what we called "x-ray edge anomalies," but we did not realize they were related to our colleagues' anomalies.

As a very general problem with the AdS/CFT approach in condensed-matter theory, we can point to those telltale initials "CFT"—conformal field theory. Condensed-matter problems are, in general, neither relativistic nor conformal. Near a quantum critical point, both time and space may be scaling, but even there we still have a preferred coordinate system and, usually, a lattice. There is some evidence of other linear-T phases to the left of the strange metal about which they are welcome to speculate, but again in this case the condensed-matter problem is overdetermined by experimental facts.

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■ **Liu replies:** While many ingenious ideas have been advanced to explain the strange-metal phase, the community has not reached a consensus, and many of the phase's properties remain mysterious. Philip W. Anderson's hidden Fermi liquid theory, arguably a most ambitious attempt, has provided a useful lens to view various aspects of the phase, but further developments are worthwhile.

As described in my Quick Study, a key obstacle in the pursuit to explain the strange metal phase is the lack of a suitable mathematical framework to characterize "quantum soups"—strongly interacting, dense quantum matter whose constituents have lost their individuality. Holographic duality has now provided such a framework, although only for the class of systems that have gravity duals. It does for those quantum soups what Boltzmann equations do for a dilute gas of quasiparticles: It enables one to calculate reliably all equilibrium and nonequilibrium properties.

At short distances, holographic systems are conformal, Lorentz invariant, and often supersymmetric, all of which make them seem poor models for real-life condensed-matter systems. Those symmetries, however, are all destroyed at long distances if a temperature or a chemical potential is turned on. The surprise of the past few years is that despite significant differences in short-distance details, at long distances most states of matter that have been understood—superfluids, Fermi liquids, magnets, stripes, and so on—can be described in terms of dual gravity systems. Such insensitivity to microscopic detail gives hope that the striking parallels in macroscopic behavior found between black holes and strange metals are not accidents, and gravity may help us decipher the mysteries of strange metals.

I thank Anderson for emphasizing other anomalies exhibited by the strange-metal phase of cuprates that I did not have space to mention. He is correct that the holographic approach has not yet produced a model that could account for all anomalous properties. However, the power-law dependence of photoemission spectra on energy, his last bullet point, is a hallmark of holographic strange metals. I discussed that point in the last part of the Quick Study, in terms of the power-law temperature dependence of scattering rates. Such power laws follow from the semilocal property emphasized in the second-to-last paragraph.

Whether or not one finds a "conventional" explanation for strange metals, connections between the physics of strange metals and black holes are worth exploring. They hint at a new paradigm for thinking about strongly correlated quantum soups. As an added bonus, we may also obtain new insights into quantum gravity from advances in condensed-matter physics.

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Edmund Stoner and the Bohr atom

The 100th anniversary of the Bohr atom this year is an opportune time to call attention to a little known paper that Edmund Stoner, then a student of Ernest Rutherford and Ralph Fowler at Cambridge University, wrote in 1924. Called "The distribution of electrons among atomic levels,"[1] it was the first paper to give a correct formulation of the Bohr atom for many electrons.

In Arnold Sommerfeld's preface to the fourth edition of his *Atomic Structure and Spectral Lines*, the author gave special mention to *einen grossen Fortschritt* (a great advancement) brought about by Stoner's analysis. As a result, Stoner's paper came to the attention of Wolfgang Pauli and was of great value to his formulation of the exclusion principle in quantum physics.[2] Subsequently, Stoner applied the exclusion principle to calculate the maximum mass of white dwarfs a year before Subrahmanyan Chandrasekhar, who generally is given credit for the discovery (reference 3; see also PHYSICS TODAY, July 2011, page 8).

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A note on compacted networks

In their cover article "Networks in motion" (PHYSICS TODAY, April 2012, page 43), Adilson Motter and Réka Albert present an interesting gallery of networks (their figure 1) comprising human brains, social networks, and internet service providers. Their gallery provides much food for thought for mathematicians and physicists inter-