Singular density fluctuations in the strange metal phase of a copper-oxide superconductor

M. Mitrano[1], A. A. Husain[1], S. Vig[1], A. Kogar[1,2], M. S. Rak[1], S. I. Rubeck[1], J. Schmalian[3], B. Uchoa[4], J. Schneeloch[5], R. Zhong[5], G. D. Gu[5], P. Abbamonte[1]

[1]*Department of Physics, Materials Research Laboratory, University of Illinois, Urbana, IL 61801, USA*

[2]*Department of Physics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA*

[3]*Institute for the Theory of Condensed Matter, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany*

[4]*Department of Physics and Astronomy, University of Oklahoma, Norman, OK 73069, USA*

[5]*Condensed Matter Physics and Materials Science Department, Brookhaven National Laboratory, Upton, NY 11973, USA*

Email: mmitrano@illinois.edu

High-temperature superconductivity often arises out of an anomalous normal state commonly referred to as a "bad" or "strange" metal, currently regarded as one of the least understood phases of matter. A fundamental hallmark of the strange metal is the lack of well-defined electron quasiparticles. In ordinary metals, quasiparticles manifest as propagating collective modes encoded in the dynamic charge susceptibility, $\chi(q,\omega)$, which describes the response of the system to applied fields. However, the analogous collective modes of a strange metal are currently unknown.

Here, we present the first measurement of $\chi(q,\omega)$ for a prototypical strange metal, $Bi_{2.1}Sr_{1.9}CaCu_2O_{8+x}$ (BSCCO), using momentum-resolved inelastic electron scattering [1,2]. We discover a surprising energy- and momentum-independent continuum of fluctuations extending up to 1 eV, at odds with the dispersive plasmons expected in normal metals [2]. This spectrum is found to exhibit scale-invariance and to be temperature-independent across the superconducting phase transition at optimal doping.

Tuning the composition to overdoping, where a crossover to Fermi liquid behavior is expected, this momentum-independent continuum is found to persist, though a 0.5 eV gap-like feature now emerges at low temperature. On the underdoped side of the phase diagram, the low-energy spectral weight is found to increase with decreasing temperature, pointing towards a monotonic doping dependence of the charge fluctuations. Our results indicate that the phenomenon underlying the strange metal is a singular form of charge dynamics of a new kind, not described by any known theory of quantum matter. Implications of these observations beyond the copper-oxide superconductors will be also discussed.

References

[1] S. Vig, A. Kogar, M. Mitrano et al *2017 SciPost Phys.* 3 026

[2] M. Mitrano, A. A. Husain, S. Vig et al 2017 *arXiv:1708.01929*