# CSC-RUB PhD Project Proposal

**Title:** Electronic nematicity in metals and insulators

**Sector of research:** Dr. rer. nat.

**Degree awarded**: Physics

**Keywords**: solid-state physics, strongly-correlated electrons, superconductivity, nematicity, strain

**Supervisors of PhD project:**

Prof. Dr. Anna Böhmer,Fakultät für Physik und Astronomie, Ruhr-Universität Bochum

Email: boehmer@physik.rub.de, Website: [www.ep4.rub.de](www.ep4.rub.de)

Prof. Dr. Achim von Keudell, Chair for Experimental Physics II ''Reactive Plasmas'', Faculty for Physics and Astronomy

**Research focus of supervisor:**

We study quantum materials, i.e., materials whose properties are dominated by quantum mechanical effects. We focus in particular on correlated-electron materials, where the interaction of electrons with each other and with the crystal lattice leads to rich phenomena, including magnetic order, charge-density waves and superconductivity. We prepare single crystals of such compounds and study their – frequently still unknown – structural and electronic properties with a variety of techniques, ranging from crystal structure determination and chemical analysis, via electrical transport and thermodynamic properties, to x-ray and neutron diffraction at low temperatures and in high magnetic fields. Special attention is given to the effect of anisotropic stress and strain. Thus, we aim to understand and control the properties of complex materials and search for new quantum materials with exotic properties.

**Publications: Total 61 publications, h=29 (google scholar, since 2016)**

1. P. Wiecki, M. Frachet, A.-A. Haghighirad, T. Wolf, C. Meingast, R. Heid and A. E. Böhmer, Nature Communications 12, 4824 (2021).
2. P. Wiecki, A.-A. Haghighirad, F. Weber, M. Merz, R. Heid, and A. E. Böhmer, Phys. Rev. Lett. 125, 187001 (2020).
3. A. E. Böhmer, A. Sapkota, A. Kreyssig, S. L. Bud'ko, G. Drachuck, S. M. Saunders, A. I. Goldman, and P. C. Canfield, Phys. Rev. Lett. 118, 107002 (2017).
4. K. Kothapalli*, A. E. Böhmer*, W. T. Jayasekara, B. G. Ueland, P. Das, A. Sapkota, V. Taufour, Y. Xiao, E. E. Alp, S. L. Bud'ko, P. C. Canfield, A. Kreyssig and A. I. Goldman, Nature Communications 7, 12728 (2016). *these authors contributed equally
5. Anna Böhmer and Christoph Meingast, Comptes Rendus Physique 17, 90, (2016). (invited review contribution)

**Summary of research plan**:

**Background:** Nematicity in crystalline solids describes the breaking of rotational symmetry via an electronic mechanism. It has become an intensely studied research topic since its discovery in iron-based superconductors in 2008 and has since been suggested in various unconventional superconductors. It is a central issue whether nematicity in the iron-based materials derives from localized or itinerant electrons. As itinerant electrons are a characteristic of metals, the report of nematicity in semiconducting $KFe_{0.8}Ag_{1.2}Te_2$ [Phys. Rev. Lett. 122, 087201 (2019)] and $BaFe_2S_3$ [Phys. Rev. Research 2, 043293 (2020)] is intriguing.

**Study objective:** We will investigate nematicity in $KFe_{0.8}Ag_{1.2}Te_2$ and $BaFe_2S_3$. To this end, we will map the nematic order parameter and nematic susceptibility via corresponding lattice distortions and elastic moduli as a function of temperature, magnetic field and chemical-composition changes. We will also investigate the closely related antiferromagnetic order. Finally, we will determine the effect of uniaxial stress on these compounds.

**Expected Results:** We will elucidate the impact of electron itineracy vs. localization on nematicity. It is strongly expected that at least one paper per compound will be published in a journal of high reputation. Results will be presented at various international conferences.

**Methods:** We will prepare single crystals of the proposed compounds and fully characterize them in-house using x-ray powder diffraction and chemical analysis. The physical properties of the samples will be characterized in detail via macroscopic measurements. We will then employ an established set of techniques to characterize nematicity at low temperatures, including elasto-transport measurements, high-resolution single-crystal x-ray diffraction, thermal expansivity and elastic-modulus measurements. The corresponding infrastructure is partially still in the build-up phase and will be available during the project.

**Candidate Requirements:** MSc in Physics. Solid knowledge of both experimental and theoretical solid-state physics, strong background in quantum mechanics and laboratory experience. Good English language skills.

**Motivation for CSC application**: We are an international group working on quantum materials and with a strong background in iron-based superconductivity. I have many close colleagues working in China, whom I appreciate highly. Our group will provide training in all aspects of quantum materials research, from sample preparation to the detailed analysis of complex experiments. We closely collaborate with the strong solid-state theory department at the university, using a broad range of theoretical methods. The Ruhr-University Research School, into which graduate students are integrated, furthermore offers opportunities for advanced qualification beyond the borders of a specific discipline and broad range of language classes are also offered.