Review of the scientific quality of the Habilitation Thesis

“*Magnetism of UTX compounds*” by Doctor Jan Prokleška

I provide this review on a request of the Vice-Dean of Faculty of Mathematics and Physics of Charles University Professor Zdeněk Doležal. I am honoured to fulfil this task because of the long-standing prominence of the Charles University, and especially, of this Faculty in the field of condensed matter physics. It was a pleasure to write this review, because the subject of the Thesis coincides well with my personal experience in research of magnetic compounds of uranium, their magnetic structures and phase transitions.

The Thesis is divided into three main parts: the first is a brief overview of magnetic phase transitions, the second describes the group of studied compounds, and the third one summarizes particular results and conclusions of research described in related papers co-authored by Dr. Jan Prokleška, and published in years 2015–2020. All nine articles appeared in renowned journals: *Physical Review B* (A8, A9), *npj Quantum Materials* (A6), *Materials Today Commun.* (A3), *J. Magn. Magn. Mater.* (A2), *AIP Advances* (A4, A5, A7), and *Adv. Nat. Sci.: Nanosci. Nanotechnol*. (A1). Four of them were published in proceedings of recognized international conferences. Dr. Jan Prokleška was the last author of two key-note papers in *Phys. Rev. B,* whereas in six of presented papers the first author was Petr Opletal, a PhD student under his direct supervision. He was also the main proposer and leading investigator of the grant no. 16-06422S of the Czech Science Foundation, which supported research reported in seven papers included in the Thesis, except the first and the last (A1, A9). Therefore, I am convinced that contribution of Dr. Jan Prokleška to all these publications was dominant.

As for the scientific quality and impact of Thesis, all included papers represent a comprehensive approach to quantum criticality through the study of magnetic phase transitions in a series of isostructural ternary (and pseudo-ternary) uranium compounds. According to *Web of Science* database (of Jan. 28, 2022) these 9 papers got 31 citations (19 without self-citations). These numbers may seem low, but what should be considered is that three of the papers were published recently, in 2020, and that scientific community working on uranium compounds is relatively small, thus the impact of these papers is significant.

Work on $UCo_{1-x}Ru_xAl$ single crystals (A1) firmly confirms previous results on polycrystalline samples of that material, indicating transition from metamagnet (UCoAl) to ferromagnet, due to very small (0.5%) doping with Ru, as well as presence of a quantum critical point (suppression of ferromagnetism) in the 0.70–0.78 range of doping. I have to criticize lack of a proper legend in Fig. 5 of that paper, nevertheless this does not diminish the quality of results.

In the paper A2, the effect of crystal growth and annealing conditions (and therefore of the density of crystalline defects, directly reflected in their resistivity) on magnetic properties of UCoGa was examined and analyzed using a model of domain wall pinning. A step further was made in the work A3, where domain structure in the same compound was directly observed with magnetic force microscope, changing with temperature and applied magnetic field, consistently with a large uniaxial magnetic anisotropy. Pinning of domains was observed in accordance with results from the previous article (A2).

Two following papers, A4 and A5, describe the effect of application of high (up to 9 GPa) hydrostatic pressure on magnetism of single crystals of UCoGa and URhGa, respectively. In both cases (*p*-*T*) phase diagrams were devised, showing opposite behavior of Curie temperature, T_C, in both compounds, decreasing and increasing with applied pressure, respectively. For UCoGa the authors locate a tricritical point approximately at 30 K and 6 GPa. This seems to me to be an overstatement because this point can be located at any temperature below 30 K, and to establish its position precisely more measurements are necessary between 6 and 7 GPa. For URhGa the T_C saturates above 6 GPa, but coercive field continues to increase. This hints at the important role of spin fluctuations, investigated in greater detail later, in the paper A9.

As described in the papers A6 and A7, Dr. Prokleška and coworkers continued high-pressure studies of single crystals of UCoAl slightly doped with Ru. They examined magnetization and electrical resistivity of two differently doped samples in magnetic fields and under hydrostatic pressures, and constructed a 3-dimensional (*p*-*T*-*H*) phase diagram. They have also shown that TCP-QPT phase separation is achievable by both doping or application of pressure.

Publication A8 contains extensive analysis of magnetization isotherms of URhGa, UCoGa, and $UCo_{0.98}Ru_{0.02}Al$ measured in the vicinity of their Curie temperature. Techniques such as Arrott-Noakes plots, Kouvel-Fisher plots, critical isotherms, scaling theory, and Widom scaling relations allowed determination of the critical exponents β, γ, and δ, and subsequently attribution of universality class to each of studied materials. Change of dimensionality of Ising interaction from 2 to 3 between two former and the latter materials is proposed as a consequence of change of delocalization of 5*f*-electrons.

The last of papers included in the Thesis reveals correlations between the degree of the 5*f*-electron localization represented by the spin-fluctuation parameters in the framework of the Takahashi theory and the dependence of T_C on the applied pressure. Here the ratio T_C/T_0 , which corresponds to the degree of localization of the electrons (T_0 represents the distribution width of the spin-fluctuation spectrum in energy space), decreases and increases upon applied pressure, in UCoGa and URhGa, respectively, mirroring behavior of $T_C(p)$. Finally, the authors compared UCoGa and URhGa with several other isostructural U*TX* compounds, and two other uranium intermetallics UGe_2 and UGa_2 (all are ferromagnets with known pressure effects), discussing general connection between the character of the spin fluctuation spectra and the pressure influence on the T_C.

After reading this paper I wondered, if the Rhodes-Wohlfarth scenario (measuring the degree of localization through the ratio of the effective to the spontaneous magnetic moments) would bring similar (or maybe more apparent) correlation with $T_C(p)$. Answer would be easy if the magnetization measurements under pressure (Figs. 1 and 2 of A9) were extended to higher temperatures, allowing determination of effective moments. It would be interesting if Dr. Prokleška could discuss whether there exist such data and if Rhodes-Wohlfarth scenario could be used.

Conclusion

Habilitation Thesis of Dr. Jan Prokleška clearly and concisely summarizes systematic study of magnetic phase transitions in a series of isostructural U*TX* compounds. It also shows scientific development of the Author, increasing complexity of his research and span of conclusions. Papers included in the Thesis are of sound scientific quality and significant impact, and brought many interesting original results and considerably extended our knowledge of 5*f*-electron ferromagnets. Evaluation of originality of Thesis (the output of the plagiarism check) shows noticeable textual overlap only with the articles on which this Thesis is based. I am convinced that this Thesis is fully adequate for the habilitation procedure of Dr. Jan Prokleška.

Thus, I sincerely recommend the Thesis for defense.

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