Magnetism and Superconductivity in $EuFe_2(As_{1-x}P_x)_2$ single crystals with x = 0.13, 0.19 and 0.28 studied by μSR and ^{57}Fe Mössbauer spectroscopy

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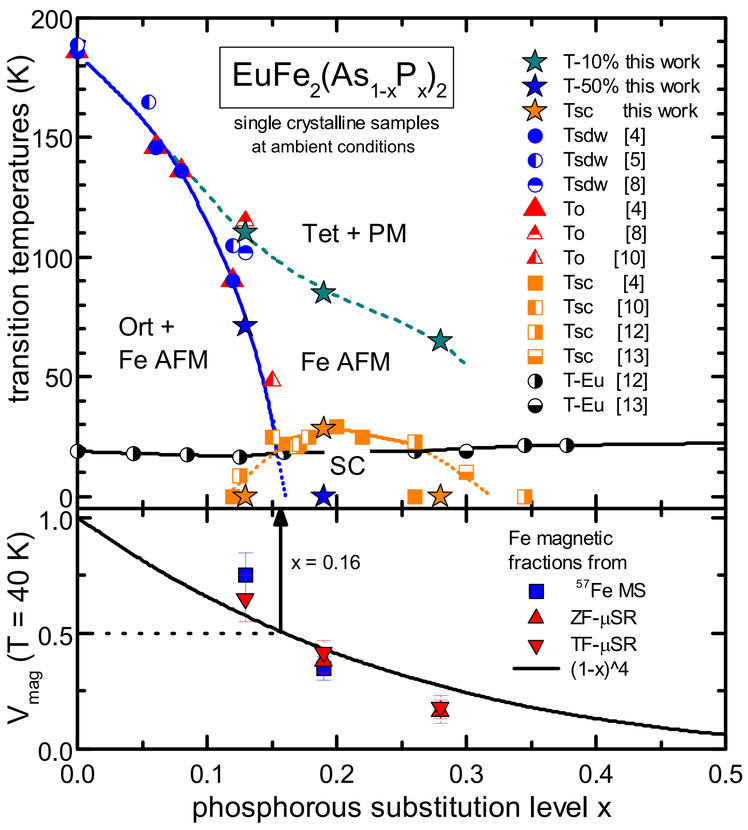
Introduction

The interplay of magnetism and superconductivity is one of the central topics in the contemporary studies on ferropnictides. Of particular interest within the AFe_2As_2 compounds [1-3] is the $EuFe_2(As_{1-x}P_x)_2$ system because of two reasons: Firstly, the substition of As by P is (nominally) isovalent thus superconductivity is not introduced by extra charge carriers and secondly, it contains a magnetic rare earth element on the *A*-site. Previous studies reported that the Fe AFM ordering and the accompanying structural transition from tetragonal to orthorhombic is suppressed upon P substitution and eventually vanishes prior to the appearance of a superconducting dome [4-7]. In contrast, pressure studies demonstrated the presence of a precursory structural and Fe AFM transition above T_{SC} between p = 0.4 and 0.8 GPa [8,9] but conclude that the SDW ground state is differently affected by x and p. Only recently, Nandi et al. [10] showed the existence of a small but finite orthorhombic splitting reminiscent of weak Fe ordering [11] below 50K in a superconducting (T_{SC}=25K) single crystal with x=0.15 at ambient conditions.
Up to now, no comprehensive microscopic study of the (T-x) electronic phase diagram on single crystals without any explicit symmetry-breaking forces is available. In view of this gap, this work was carried out and emphazises further microscopic studies of single crystalline $EuFe_2(As_{1-x}P_x)_2$ in the full temperature range to confirm our findings and improve the understanding of the precursory ($T>T^{Eu}$) Fe order and its possible importance for the appearance of superconductivity. Our ZF-MuSR data for x=0.13 is not conclusive because of insufficient sample mass (~10mg) and therefore not shown here.

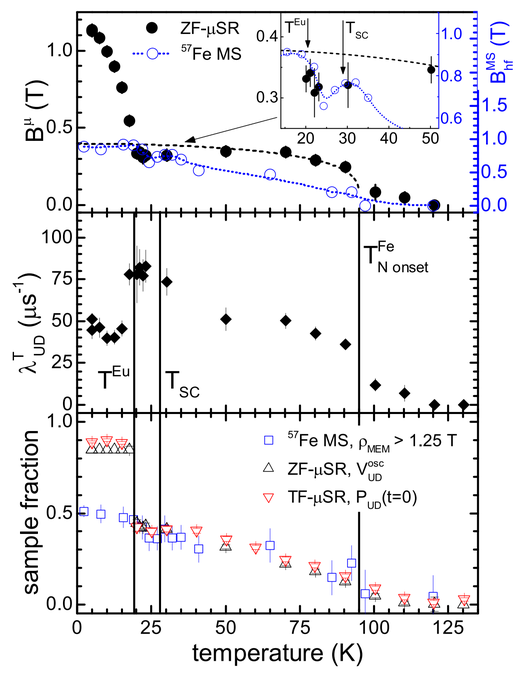
$EuFe_2As_{1-x}P_x$ single crystal phase diagram

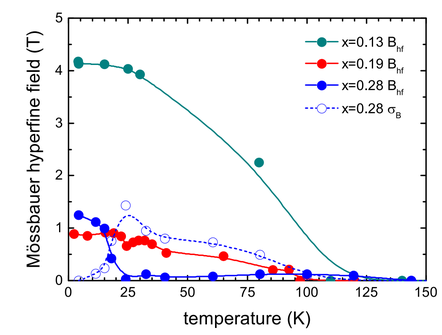


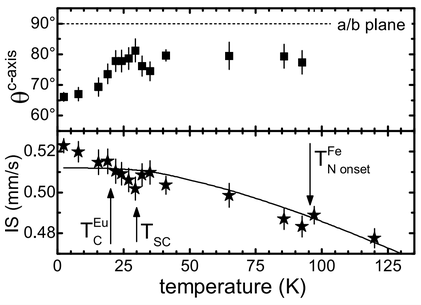
Our experiments evidence (weak) Fe magnetism for all three investigated samples with x=0.13, 0.19 and 0.28. The Fe AFM magnetic volume fraction is related to the number of iron atoms which are surrounded only by As atoms, given by the propabilistic function $(1-x)^4$.
Our interpretation is that only short range Fe order on the atomic lenght scale persists for x>0.16 (calculated from the percolation treshold $(1-x)^4$=0.5). Due to the gradual increase of the magnetic volume fraction as a function of temperature, macroscopic probes such as resistivity or specific heat might not display pronounced anomalies. This interpretation is consistent with results of a recent muon spin relaxation study on powdered $EuFe_2As_{1-x}P_x$ by Gugucchia et al., [9] who showed that for x=0.20 a disorderd SDW phase supersedes the coherent Fe AFM order observed for x<0.12.

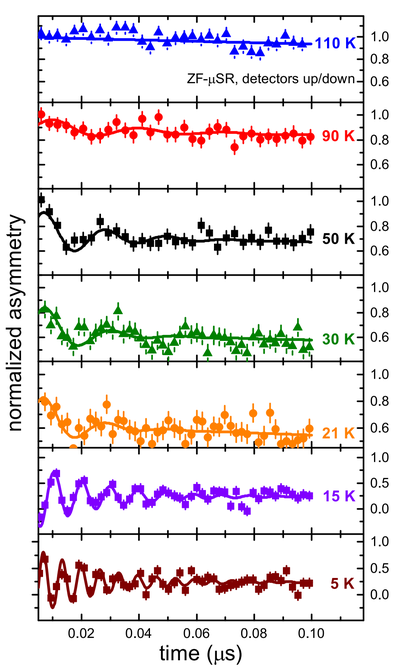
Compilation of main results for x=0.13 and x = 0.19

- **static Fe order below 115K and 95K**
- **gradual increase of the magnetic volume fraction**
- **static ferromagnetic Eu order below 20 K**
- **interplay of Fe and Eu magnetic sublattices**
- **coexistence of AFM Fe magnetism and superconductivity**
- **enhanced spin dynamics**

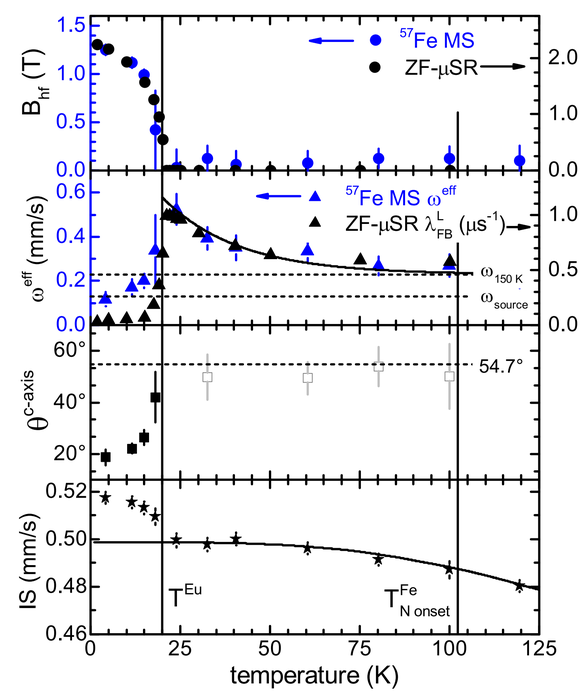


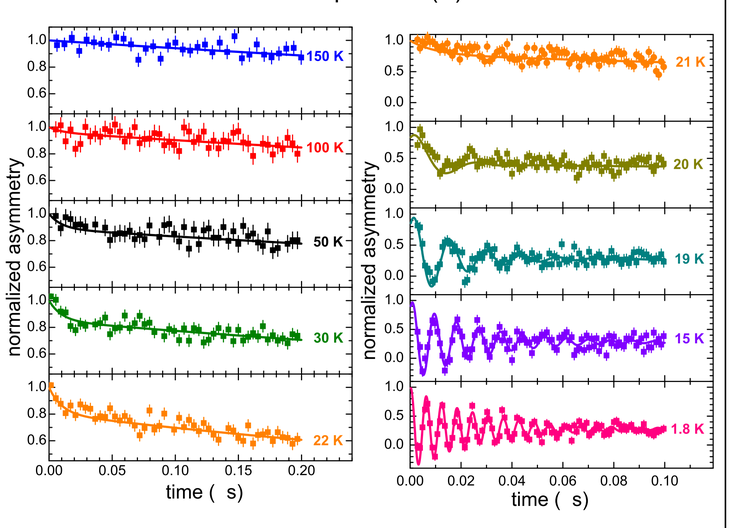






Compilation of main results for x = 0.28

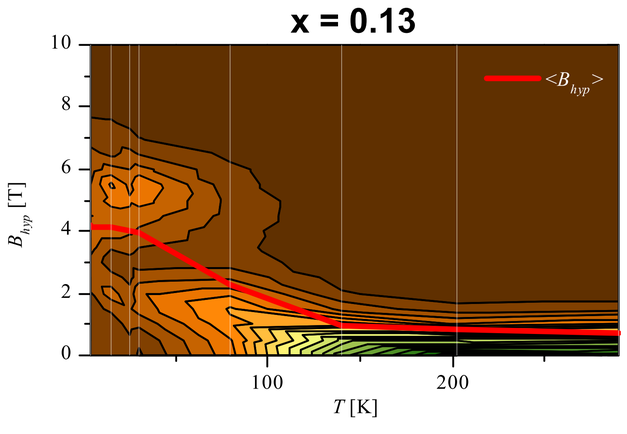


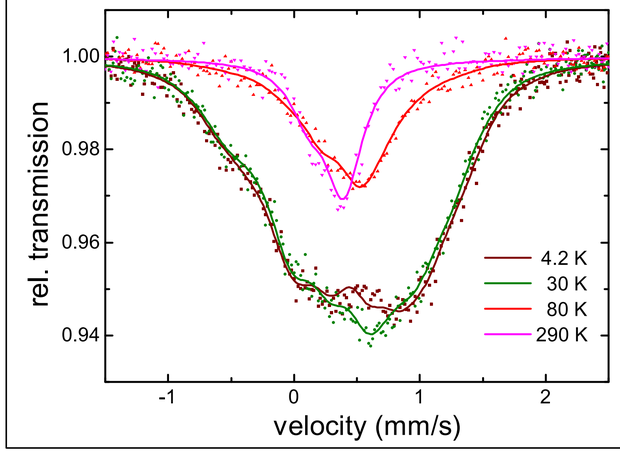


- **clear signatures of Fe order below 75 K**
- **interplay of Fe anf Eu sublattices**
- **static ferromagnetic Eu order below 21 K**

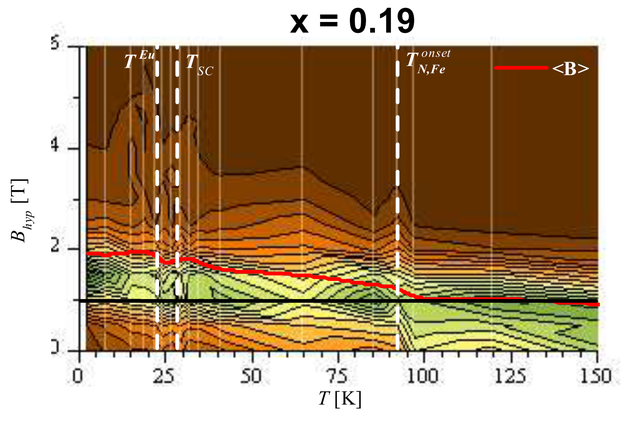
^{57}Fe Mössbauer spectroscopy: Hyperfine field distribution

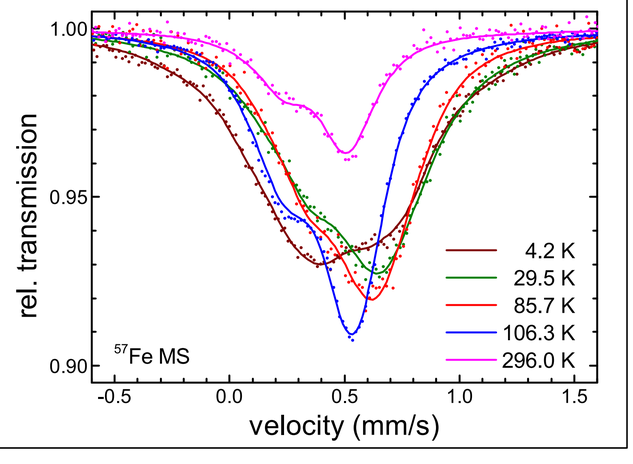
x = 0.13





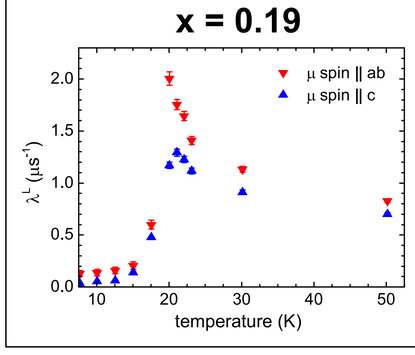
x = 0.19



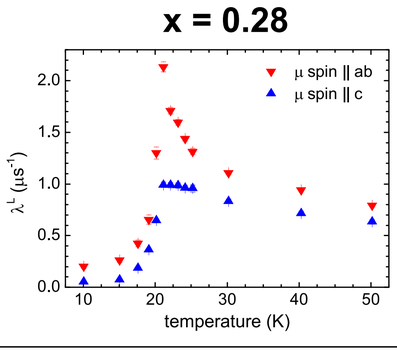


anisotropic spin fluctuations for x=0.19 and x=0.28

x = 0.19



x = 0.28



spin dynamics are stronger parallel to the c-axis than in the ab-plane and dominated by Eu fluctuations

References and Acknowledgements

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