# MuSR in MnSi: First order versus second order quantum evolutions, and detection of static and dynamic effects of Skyrmions

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MnSi is a special material which has given deep impacts in historical development of the MuSR technique. Following epoch-making discoveries were made with MnSi specimens: (1) the first observation of Zero-Field Kubo-Toyabe relaxation by nuclear dipolar field (TRIUMF, 1978), and (2) the first MuSR observation of the spin-lattice relaxation $1/T_1$ process due to critical spin fluctuations, which led to confirmation of the Moriya theory in weak itinerant magnets (TRIUMF, 1978).

In 2007, we reported MuSR studies in MnSi with applied pressure, and demonstrated that pure MnSi exhibits first-order quantum evolution from helically ordered to paramagnetic state with increasing pressure, associated with suppression of dynamical critical behavior in $1/T_1$ and phase separation near the disappearance of the magnetic order.

Recently, we discovered by MuSR that (Mn,Fe)Si in applied pressure does not show the first-order behavior, but rather exhibit clear second order quantum evolution, revealing quantum critical point which was hidden in pure MnSi due to first-order transition, Similar behavior was also observed in another weak ferromagnet based on itinerant electrons $Sc_3In$, in which pure system shows first-order quantum evolution while (Sc,La) substitution REVIVES second order quantum behavior.

We also report our effort in detecting Skyrmion states in MnSi and (Mn.Fe)Si by MuSR, in which we found (a) signatures of characteristic increase of $1/T_1$ due to spin fluctuations in the Skyrmion state in MnSi, (b) suppression of critical behavior by application of external magnetic fields having the magnitude comparable to the field required to generate the Skyrmion phases and (c) signatures of internal field at the muon site due to Skyrmion spin patterns.

It was really fortunate that I was able to work on all these MuSR projects related to MnSi. We hope to share this excitement with Japanese colleagues working on MuSR, quantum criticality and Skyrmions.

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