

## Investigating the interplay of real space and momentum space Berry curvature on the physical properties of Quantum magnets

In this project, we investigated two systems, one is  $\text{Eu}_{1-x}\text{Ba}_x\text{AuBi}$  and other distorted Kagome system  $\text{Tb}_6\text{Ti}_4\text{Al}_{13}$ . In first work, we carried out magnetic and electrical transport studies to uncover the effect of partial Ba substitution at the  $\text{Eu}^{2+}$  site in topological semimetal  $\text{EuAuBi}$ . Single crystal growth of  $\text{Eu}_{1-x}\text{Ba}_x\text{AuBi}$  was optimized using the flux method. Preliminary measurements, XRD and EDX confirm the elemental composition and orientation of the single crystal, further through field-dependent ac measurements we observe non-monotonic changes in the dip anomaly, consistent with the topological Hall effect measurements proving substitution as an effective path to control the spin textures. In the second work, we investigated of the magnetic, electrical, and thermodynamic properties of single-crystalline  $\text{Tb}_6\text{Ti}_4\text{Al}_{13}$ , in which Tb atoms form a distorted Kagome lattice embedded within a complex Ti-Al framework. The geometrical frustration inherent to the distorted Kagome planes leads to pronounced magnetic anisotropy in the system, which is clearly depicted in the magnetic and electrical transport measurements.

1. Introduction The real-space magnetic spin textures have been experimentally observed in Dirac semimetal  $\text{EuAuBi}$  [1]. Prior theoretical studies, predict that the partial substitution of Eu with Ba in  $\text{EuAuBi}$  can modify the long-range magnetic interactions and can drive a transition between Dirac semimetal and Weyl Semimetal. This establishes elemental substitution as an effective tuning parameter for controlling the interplay between magnetism and band topology [2]. Motivated by this, we aimed to understand its effect on the real-space magnetic textures observed in  $\text{EuAuBi}$ . Since magnetic structure directly governs both real-space and momentum-space Berry curvature in such systems, tuning magnetic interactions via Ba doping provides a pathway to manipulate emergent spin textures and their associated transport signatures. Secondly, kagome lattice systems have attracted attention in the magnetic systems due to their unique geometry of corner sharing triangles, which naturally introduces geometric frustration in the system, particularly in antiferromagnetic systems. These materials host wide range of unconventional phenomena such as flat bands due to localization of electrons in real space, Dirac-like dispersions, strong geometric frustration, skyrmionic spin textures, superconductivity, and charge density waves. An important aspect of these Kagome systems is the highly degenerate energy states associated with the different spin arrangements. Distortions can partially lift the geometric frustration, leading to stabilized magnetic order and field-induced transitions, and it can reconstruct the band structure to enhance the Berry curvature, leading to increased anomalous Hall response. In the second work, we investigate the distorted Kagome lattice system  $\text{Tb}_6\text{Ti}_4\text{Al}_{13}$ , in which Tb atoms form a distorted

Kagome lattice embedded within a complex Ti-Al framework. The geometrical frustration inherent to the distorted Kagome planes leads to pronounced magnetic anisotropy in the system.

2. Experimental procedure Single crystal growth: Single crystal growth of  $\text{Eu}_{1-x}\text{Ba}_x\text{AuBi}$  was optimized using the flux method. Similarly single crystal of  $\text{Tb}_6\text{Ti}_4\text{Al}_{13}$  was also formed by similar flux method using Al as flux and decanted at  $700^\circ\text{C}$ . Energy-dispersive X-ray (EDX): After crystal growth, the elemental composition of the constituent element was verified using EDX, which was found to be accurate for all the crystals within the uncertainties. X-ray Diffraction (XRD): The XRD of the different crystals indicated the single crystallinity of all the crystals, with peak corresponding to (00l) for both the crystals. Physical Property measurement system (PPMS): To measure the electrical properties of the crystals. Quantum design PPMS with fields upto 9 T was used. The contacts on crystals were made using the 25-micron Pt wire following the four-probe technique for the measurement of Hall signal and magnetoresistance. SQUID: For the measurement of magnetization at different temperatures and fields. 3. Results and discussion 1. Partial substitution of Eu with Ba in  $\text{EuAuBi}$  : With increasing Ba concentration, decrease in hysteresis feature is observed, consistent with the dilution of magnetic  $\text{Eu}^{2+}$  interactions by non-magnetic Ba. However, at 15% substitution, hysteresis with magnitude comparable to pristine  $\text{EuAuBi}$  is observed, which is again suppressed at higher substitution indicating a non-monotonic evolution of magnetic correlations. To further probe the evolution of spin textures, Hall measurements were performed to extract the changes in the topological Hall effect, which can serve as a sensitive tool to probe

real-space Berry curvature. For,  $\text{Eu}_{0.95}\text{Ba}_{0.05}\text{AuBi}$  and  $\text{Eu}_{0.90}\text{Ba}_{0.10}\text{AuBi}$ , a negative topological Hall effect signal, which is in contrary to positive THE in  $\text{EuAuBi}$ . Notably, the field window of the negative THE does not coincide with the dip observed in ac susceptibility, suggesting that the associated spin-textures maybe either weakly stabilized or too small to generate a strong emergent magnetic field. Nevertheless, the sign reversal of THE points indicates the presence of spin textures with opposite chirality compared to the parent compound. 2.  $\text{Tb}_6\text{Ti}_4\text{Al}_4\text{O}_{20}$ : The crystal exhibits the antiferromagnetic ground state ordering with  $T_N \sim 20$  K. For magnetic field applied along the c-axis ( $B \parallel c$ ), a strong metamagnetic switching is observed, accompanied by clear asymmetric hysteresis at low temperatures, whereas for field applied along the ab plane, the spin-flop transition is observed. Additionally, the metamagnetic transition is strongly reflected in magnetotransport measurements, giving rise to pronounced anomalies in magnetoresistance and an anomalous Hall

contribution, despite the ground state of the system being antiferromagnetic. 4. Conclusion 1. In conclusion, this study demonstrates that Ba substitution acts as a tuning parameter for controlling real-space spin textures in the system. 2. Our results highlight the interplay of geometrical frustration, anisotropic magnetic interactions, and spin-charge coupling in a distorted Kagome antiferromagnet, establishing  $\text{Tb}_6\text{Ti}_4\text{Al}_4\text{O}_{20}$  as a promising platform for studying field-induced magnetic phase transitions in frustrated systems. Acknowledgement We would like to acknowledge Prof. Rie Umetsu, CRDAM, for her support to conduct experiments in her laboratory. We would also like to thank GIMRT ICC-IMR for the funding and support. Reference 1) Lipika, S. Singh, A. Saraswati, et al., Phys. Rev. B 2026,113, 104406 2) Y. Du, B. Wan, D. Wang, et al, Sci Rep 2015,5:14423 List of equipment used : 2-9 and 2-14

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