Tunable Magnetism and Transport in $Al_{13}Cr_2$ Quasicrystal Approximants: Toward Quantum Criticality and Emergent States

1. Project Overview

$Al_{13}Cr_2$, an approximant to icosahedral quasicrystals, features complex local icosahedral cluster geometry capable of hosting unconventional electronic and magnetic behavior. This project aims to systematically investigate how controlled disorder and competing interactions govern transport and magnetism in this system. By establishing a composition-dependent quantum phase diagram, it provides a robust platform to explore non-Fermi-liquid behavior, quantum criticality, and the emergence of novel electronic states, with long-term prospects for magnetic topological phases. Insights from Kagome lattice metals, where geometrical frustration produces flat-band and Dirac-like electronic features, motivate the study of $Al_{13}Cr_2$, whose 3D cluster network may realize analogous frustration-driven electronic phenomena.

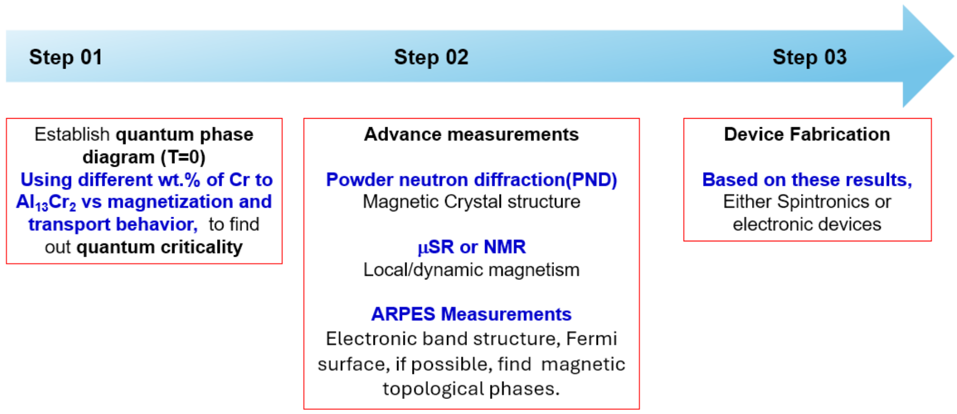
2. Introduction

The interplay of disorder, geometrical frustration, and electronic correlations is a central challenge in condensed matter physics. $Al_{13}Cr_2$, a monoclinic approximant to icosahedral quasicrystals, features interpenetrating icosahedral clusters forming a three-dimensional frustrated network with inequivalent Cr–Cr separations. Structural motifs in $Al_{13}Cr_2$ have been confirmed via TEM and synchrotron X-ray diffraction, establishing quasi-icosahedral order within the monoclinic lattice. Neutron diffraction is proposed to further probe magnetic correlations and validate competing AFM/FM interactions, while low-temperature magnetism, transport, and thermal properties remain largely unexplored.

Preliminary data indicate competing antiferromagnetic and ferromagnetic interactions, low-temperature resistivity upturns, and lattice softening, suggesting proximity to quantum criticality. Insights from Kagome lattice metals, where geometrical frustration produces flat-band and Dirac-like features, motivate the investigation of $Al_{13}Cr_2$, whose 3D cluster network may realize analogous frustration-driven electronic phenomena.

This project aims to establish a composition-dependent phase diagram of $Al_{13}Cr_2$, uncover emergent quantum states, and correlate magnetic, transport, and thermal properties. By combining bulk measurements with advanced techniques such as neutron diffraction and synchrotron ARPES, it will provide a foundation to bridge toward true icosahedral quasicrystals and guide the design of next-generation quantum materials with potential applications in topological magnetism and spintronics.

Research concept and its objectives:



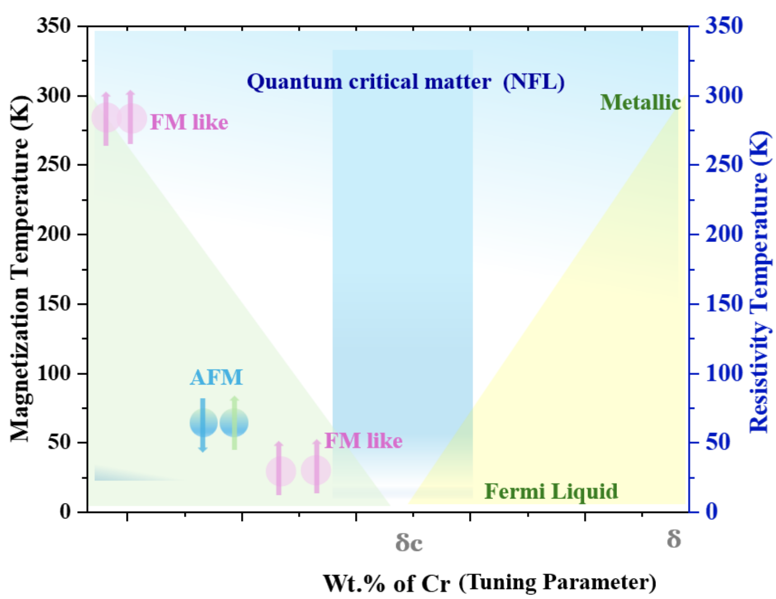
Step 01:

Establish Quantum Phase Diagram (T = 0)

$Al_{13}Cr_2$, an approximant to icosahedral quasicrystals, hosts complex local icosahedral cluster geometry that can give rise to unconventional electronic and magnetic behavior. By tuning Cr concentration, this project explores how disorder and competing magnetic interactions influence transport and magnetism, aiming to identify non-Fermi liquid behavior and signatures of quantum criticality.

Quantum Phase Diagram

This diagram illustrates how disorder tuning via Cr substitution can drive the system across magnetic, Fermi-liquid, and quantum critical regimes.



Dr. Samreen Rashid (Ph.D.)
Assistant Professor, Gachon University, South Korea
Email: samreen@skku.edu / samarrashid49@gmail.com | Phone: 010-5948-8503
Specialization: Experimental Condensed Matter Physics

Profile

Physicist specializing in quantum materials, magnetism, and superconductivity, with a focus on frustrated magnetic systems and magneto-transport properties. Experienced in exploring quantum phenomena for applications in spintronics and advanced electronic technologies.

Education

Ph.D. in Physics, Sungkyunkwan University, South Korea (2025)
Thesis: *$Al_{13}Cr_2$ single crystal – quasicrystal approximant Professor Park Tuson*

Research training at NUST, Pakistan under Prof. Asghar Qadir (2013–2015)

Research Expertise

- Single crystal growth (flux methods), thin films (magnetron sputtering)
- Solid-state synthesis (arc furnace)
- Characterization: PXRD, FESEM/EDS, MPMS, PPMS, heat capacity
- Software: FullProf, VESTA, Origin

Key Contributions

- **$Al_{13}Cr_2$**: Single crystal growth and characterization (Publication, 2022)
- **SmC_{10}**: Coexistence of superconductivity & ferromagnetism (Publication, 2025)
- **$LaRu_3Si_2$**: Kagome superconductor (Collaborative work, 2025)
- Review article on geometrical frustration (under revision)

Core Skills

Critical thinking • Research innovation • Scientific writing • Leadership