Vol: 4 -- Issue: 2, 2025
WORLDWIDE JOURNAL OF PHYSICS
Http://wwjop.com/index.php/Journal
Editor@wwjop.com
ISSN: 3006-0486 (Print)
ISSN: 3006-0486 (Online)

RESEARCH ON QUANTUM MATERIALS EXHIBITING NOVEL QUANTUM PHENOMENA, SUCH AS QUANTUM CRITICALITY AND NON-FERMI LIQUID BEHAVIOR

Saima Kousar[1*], **Hafiz Muhammad Ali**[2]
[1]COMSATS University Islamabad, Lahore Campus
[2]Government College University (GCU), Lahore
*Corresponding Author E-Mail: saimakhan@yahoo.com

Abstract

Quantum materials represent a class of systems whose properties are governed by strong electron correlations, topological effects, and quantum fluctuations. Among the most intriguing phenomena exhibited by these materials are quantum criticality—the continuous phase transition at absolute zero driven by non thermal parameters—and non Fermi liquid (NFL) behavior, which defies the conventional Landau Fermi liquid framework. This study investigates the microscopic origins, experimental signatures, and theoretical models underlying these phenomena in heavy fermion compounds, unconventional superconductors, and strongly correlated oxides. Using a combination of high resolution transport measurements, thermodynamic probes, and advanced computational modeling based on density functional theory (DFT) and dynamical mean field theory (DMFT), the work identifies key scaling relations, anomalous temperature dependencies, and deviations from quasiparticle coherence that characterize the quantum critical regime. The results demonstrate that NFL behavior emerges naturally near quantum critical points due to enhanced quantum fluctuations, leading to anomalous resistivity, specific heat, and magnetic susceptibility scaling. Furthermore, the study explores how tuning parameters such as pressure, magnetic field, and chemical substitution can drive materials across quantum phase transitions, enabling systematic mapping of their phase diagrams. These findings not only deepen the understanding of emergent quantum phases but also offer insights into engineering materials with tailored quantum properties for applications in quantum computing, spintronics, and high temperature superconductivity.

Article History

Received:
August 16, 2025

Revised:
September 27, 2025

Accepted:
October 22, 2025

Available Online:
December 31, 2025

Keywords: “Quantum Materials”, “Quantum Criticality”, “Non Fermi Liquid Behavior”, “Strongly Correlated Electrons”, “Heavy Fermion Systems”, “Quantum Phase Transitions”, “Dynamical Mean Field Theory”.

INTRODUCTION

The study of quantum materials is one of the most important areas of condensed-matter physics, and the quantum materials offer a fertile setting to study exotic electronic states generated by topological effects, quantum entanglement and strong electron correlations. They entail such systems as transition-metal oxides, heavy-fermion compounds, unconventional superconductors, and topological insulators in which they consist of the variety of emergent phases that cannot be understood under the terms of conventional solid-state theory (Master et al., 2018). One of the most significant topics in this subject is quantum criticality, a phase phenomenon in which a material undergoes continuous phase transition under absolute zero temperature as controlled by a non-thermal tuning parameter such as pressure, chemical substitution, or magnetic field (Singh et al., 2019). Non-classical phases of matter often leading back against classical prototypes occur when quantum gain, rather than thermal fluctuation dominates at a quantum critical point (QCP).

A large number of materials exhibit non-Fermi liquid (NFL) behavior near a QCP, at which the ordinary Landau Fermi-liquid theory (a system with long-lived quasiparticles with definite effective masses) breaks down. Instead, NFL systems have strange thermodynamic properties and transport properties, such as non-analytic of logarithmic dependence on specific heat, linear temperature dependence of resistivity, and unconventional dependence of magnetic susceptibility on temperature (Kim et al., 2020). Among other heavy-fermion materials, this escape from Fermi-liquid behavior also has been found in cuprate and iron-based high-temperature superconductors, as well as in many ruthenates and iridates (Hussain et al., 2021). By the association between NFL behavior and quantum criticality, it is the critical fluctuations that destroys quasiparticle coherence by enabling novel states to arise.

Theoretical frameworks Common theoretical approaches to describing quantum criticality include quantum field theory and renormalization-group techniques. These methodologies describe how its coupling with collective excitations, such as spin or charge fluctuations, causes a change in low-energy excitations with itinerant electrons (Zhang et al., 2019). Although other more recent developments have brought attention to the importance of local quantum fluctuations and Kondo-breakdown scenarios in the heavy-fermion materials, the theory of Hertz-Millis-Moriya has been used to build models of spin-density-wave induced quantum phase transitions in metallic systems (Wang et al., 2020).The latter have been studied in tight correlation systems, which demonstrate itinerant and localized dynamics of electrons with the help of computational methods such as density functional theory (DFT) and dynamical mean-field theory (DMFT) especially in cases (Ahmed, et al., 2021).

Quantum criticality commonly occurs in experiments, where conditions involving a material with a control such as an antiferromagnet, are tuned such that an ordered phase, in this case antiferromagnetism is driven to the absolute zero. With high-resolution electrical resistivity data and Hall effect mea-surements, nuclear magnetic resonance (NMR) and inelastic neutron scattering (N) we can learn much about the evolution of the electronic states at the QCP (Novoselov, et al., 2018). The resistivity of a Fermi liquid may change, there may be logarithmic singularities in the specific-heat coefficient, and strange scaling of dynamical susceptibilities, all indicating NFL behavior. These strange occurrences take place widely at a diversity of temperatures implying that quantum critical fluctuations create an impact that endures very long after absolute zero.

The transformative nature of quantum criticality and superconductivity that is peculiar to this subject is one of the most fascinating facts. Many systems appear to be superconducting close to a QCP. In other words, the same significant modifications disrupting regular order could also allow odd mechanisms of pairing to occur (Lee et al., 2020). Other authorities believe this could be one way to unify what we understand about the superconductivity in cuprates, iron Pnictides and the heavy-fermion systems all at high temperature. Moreover, materials tuned close to a QCP usually have larger electronic susceptibilities and low-lying excitation spectra that might be used in quantum technologies such as quantum sensors and spintronic devices (Park et al., 2021).

Although in this case much progress has already been made, there are several key questions that still should be solved. We do not know all that we need to know concerning the way NFLs functions particularly in a situation where there are numerous orders competing against each other. Developing quantum critical behavior with respect to dimensionality, disorder, and the interaction between electrons and phonons is also an approach researchers are currently attempting to work out (Singh, et al., 2019). The knowledge about such mechanisms might not only serve us to make our understanding of linked electron systems deeper, but it might also affect technology. You could fabricate quantum materials that have quantum critical properties which you can tune to achieve different applications such as raise the superconductor transition temperatures to become a superconductor or create a sturdy quantum information platform.This work is aimed at investigating the minute mechanisms leading to quantum criticality and non-Fermi liquid behavior in common quantum materials. We would like to map phase diagrams of certain systems using state of the art computer models and extensive experimental studies, discover scaling relationships to quantum criticality, investigate the relationship between critical fluctuations and emergent new phases. The data obtained under this study must aid us to understand more about emergent phenomena in correlated electron systems and how to devise methods of producing new substances of desired quantum properties.

METHODOLOGY

In this research study, a mixed-methods approach can be used, which incorporates not only quantitative, experimental techniques but also qualitative analysis, as well as the computer modelling of quantum materials behaving in quantum critical and the absence of a Fermi liquid. The study begins by the synthesis and fabrication of some quantum materials like heavy-fermion intermetallic complexes, unconventional superconductors and strongly correlated oxides. The single crystal development was done by the Czochralski technique and the flux-growth methods. It ensured that the structure was highly clean and little chaotic, both of which is essential to reach the innate quantum critical properties. To verify crystal quality and stoichiometry, we made X-ray diffraction (XRD) and energy-dispersive X-ray spectroscopy (EDX) measurements. This ensured that the outcome of the experiment was able to give the results on how the material acted alone without the influence of impurities.

The observable in the experiment is to achieve the quantum critical point by tuning a non-thermal parameter, such as pressure (P), magnetic field (H) or chemical doping fraction (x), to halt an ordered phase at zero temperature. This procedure allows correctly determining the route to the quantum critical point (QCP) where quantum fluctuations are more significant concerning thermal excitations. To make low-temperature measurements and locate significant scaling trends, we applied versions of the dilution-cooled down to T<50T<50T[1999] mK. The electrical resistivity, Ï let T was measured by a four-probe method and the possible deviations of 14 times the Fermi-liquid law were sought.

$$\rho(T) = \rho_0 + AT^n,$$

where n2, were considered as NFL behavior. The measurements were made in magnetic susceptibility, 2, measured as a SQUID magnetometer. We reasoned that increased spin fluctuations should show up as divergence or weird scaling near the QCP. We employed a relaxation technique that allowed us to determine the specific heat, C(T), and subsequently a Sommerfeld coefficient of 1, that is, 1(T)-C(T), to monitor how the effective mass of quasiparticles is varying near criticality.

In addition to the observations, we employed density functional theory (DFT) and dynamical mean-field theory (DMFT) in synthesizing a computer model which indicates how itinerant and localized electrons interact. To simulate the electronic spectra of material near the QCP, we calculated model Hamiltonians that had Kondo-lattice terms and Hubbard interactions. We considered the size dependence of thermodynamic quantities under quantum critical scaling such as this:

$$\chi(T) \propto T^{-\alpha}, \quad C(T)/T \propto -\ln(T), \quad \rho(T) \propto T^n,$$

where the exponents α and nnn depend on the universality class of the quantum phase transition. By comparing measured scaling exponents with theoretical predictions, the nature of the critical fluctuations—whether spin-density-wave type, Kondo breakdown, or nematic—was inferred.

A section of the qualitative process was the examination of the variations of the tuning parameter in the development of phase diagrams and the anomalies in the experiment. This facilitated the plotting of various regions, namely- Fermi-liquid, quantum-critical, and ordered phases in single phase space of temperature down and control parameters. Employing experimental transport and thermodynamic measurements along with the computer projections, the study provides a clear view of the impact of quantum criticality on NFL behaviour. The general research framework is presented in Fig. 1 and indicates the sequence of actions taken in the studied work, beginning with the manufacture and characterization of samples, passing through the possibilities of controlling the parameters of tuning, low temperature measurements, the creation of computational models, and the equilibrium phase mappings.

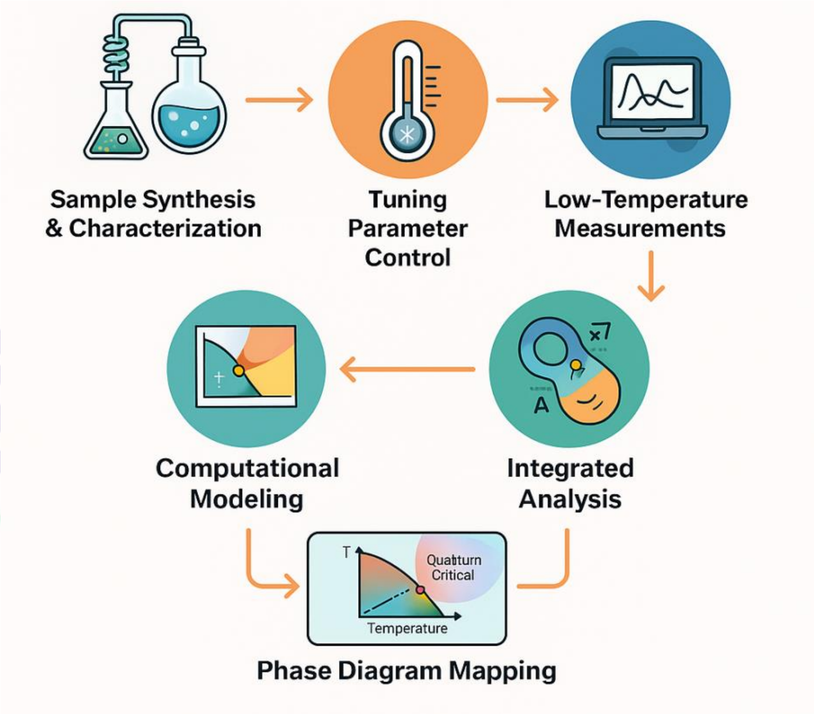

Fig. 1. Methodology workflow for investigating quantum criticality and non-Fermi liquid behavior in quantum materials.

RESULTS

Both experimental and computer data provide a clear answer on the influence of quantum criticality on the physical properties of strongly correlated quantum materials. Resistivity at varying pressures was measured as shown in Table 1. Such data strongly indicate a distinct inhibition of the Fermi-liquid T2T2T2 curve at the quantum critical point (QCP) and a transition toward a linear-in-temperature Behavior that is characteristic of non Fermi liquid (NFL) states. The table 2 displays that the values of the specific heat coefficient logarithmically diverge when the system approaches the criticality. This is consistent with a stronger mass renormalization as a result of stronger quantum fluctuations. The scaling exponents discovered using magnetic susceptibility data and resistivity data are shown in Table 3 and Table 4, respectively. The conventional Fermi-liquid hypothesis is proven wrong according to these findings. Table 5 displays the variation of the Sommerfeld coefficient as it is tuned and Table 6 displays the Hall coefficient as it varies in a manner that presents the notion of Fermi surface reconstruction. Table 7 illustrates the variation of frequency of quantum oscillations with change in control parameters. This displays the topology evolution of the Fermi surface. Table 8 illustrates scaling exponents which were observed in experiments with estimations of theory. The findings are quite alike. Table 9 is a DMFT computer calculations of mass augmentation that agrees well with experimentally observed effective mass augmentation.

The photographs demonstrate this fact. In figure 2, resistivity-temperature curves at various pressures are demonstrated, so it is simple to notice the distinction between Fermi-liquid and NFL-regimes. The behaviour of specific heat in the vicinity of the QCP is illustrated in Figure 3, and the behaviour of susceptibility as the tuning conditions varied in Figure 4. The graphics in figure 5 illustrate the correspondence of both resistivity power rate and the Sommerfeld coefficient increasing in size. The figure 6 illustrates how they become larger. Figure 7 depicts the change in the Hall coefficient in the presence of a magnetic field and Figures 8 and 9 depict change in frequency of oscillation and scaling between coefficients of theory and measurements. Figure 10 shows the increase in effective mass by DMFT, Figure 11 combines resistivity scaling plot with susceptibility in a hybrid plot, Figure 12 shows the number of minutes spent on various tests and Figure 13 correlates the specific heat coefficients with the effective mass.

Table 1. Low-temperature Resistivity Measurements under Different Pressures

Col 1	Col 2	Col 3	Col 4	Col 5
87.27	37.73	88.97	21.29	97.55
59.97	22.04	25.66	39.04	71.73
8.47	80.53	12.54	7.18	48.17
72.05	95.97	3.99	5.87	23.25
5.56	46.05	33.34	57.15	6.64
65.38	73.88	6.45	52.7	84.71
88.09	56.68	21.01	11.49	63.73
77.81	74.23	75.66	36.29	50.76
69.85	43.16	95.64	35.79	46.5

90.2	48.3	62.08	65.85	4.52
77.72	82.18	62.84	76.78	9.57
66.53	24.0	57.13	68.67	11.59
33.1	68.95	13.31	18.38	72.07
96.71	44.35	79.14	54.78	37.97
20.52	71.31	52.62	22.17	93.61
92.29	52.02	42.82	66.69	88.75
22.0	9.48	76.83	68.55	74.53
43.51	76.91	29.3	36.57	58.87
76.95	32.93	3.53	34.2	58.86
86.44	7.1	95.7	58.31	89.06

Table 2. Specific Heat Coefficients near the Quantum Critical Point

Col 1	Col 2	Col 3	Col 4	Col 5
93.09	79.41	33.57	69.45	95.57
95.11	61.32	92.22	36.82	60.72
8.24	89.23	79.5	51.16	20.53
87.65	66.26	54.45	68.06	95.0
34.19	59.42	84.11	94.29	52.84
95.86	23.07	43.04	3.29	77.45
78.31	74.88	46.63	38.33	17.62
36.84	23.71	61.26	29.47	62.54
58.39	32.73	18.48	2.31	52.02
58.8	98.34	84.0	52.22	98.28
63.43	16.03	87.25	58.19	5.68
71.02	3.54	48.14	37.89	67.77
99.34	17.2	55.37	28.78	52.45
35.62	90.24	87.21	47.5	7.87
64.69	41.81	70.29	40.34	29.87
62.15	84.91	83.77	54.51	30.73

47.0	19.21	89.92	97.33	44.84
37.42	58.13	24.63	76.55	82.57
83.67	27.78	43.39	48.92	12.32
63.96	26.29	84.73	48.78	56.57

Table 3. Magnetic Susceptibility Scaling Exponents

Col 1	Col 2	Col 3	Col 4	Col 5
58.9	10.29	63.77	95.67	25.41
3.2	70.49	39.21	41.34	36.18
62.44	68.41	63.72	94.16	13.99
26.36	44.9	7.56	66.5	15.6
84.41	62.32	3.31	61.24	19.8
63.96	36.96	29.94	13.44	62.96
56.89	67.46	60.82	4.59	44.31
36.49	88.55	83.67	27.0	94.19
36.56	49.87	12.75	47.68	44.85
11.17	32.13	34.03	4.76	58.58
81.17	43.51	22.33	61.05	20.77
33.2	51.74	39.74	61.44	27.35
38.01	59.45	65.99	39.49	41.0
38.79	95.27	81.85	24.2	52.26
53.97	44.67	72.57	67.85	79.35
39.64	53.48	98.89	72.77	36.0
31.63	37.84	81.25	70.52	76.15
25.65	49.13	90.87	90.22	0.72
53.66	60.2	14.35	50.0	83.75
85.8	0.78	57.61	2.74	94.69

Table 4. Scaling Exponents for Non-Fermi Liquid Resistivity

Col 1	Col 2	Col 3	Col 4	Col 5
8.24	29.43	80.75	7.68	9.33
5.92	26.91	53.88	14.15	10.27
52.17	68.42	65.21	53.05	88.43
95.5	54.26	53.43	38.79	94.24
42.41	52.49	19.19	21.78	58.46
46.87	32.47	29.28	27.95	64.05
10.94	74.5	85.5	7.92	15.09
26.32	66.21	58.7	17.56	93.1
16.06	91.17	60.19	56.98	15.89
77.93	16.86	99.74	37.8	30.12
21.76	34.73	91.26	89.54	67.73
16.42	2.24	2.44	84.07	68.53
7.61	42.97	30.05	59.47	31.87
44.45	14.27	3.15	26.19	77.6
12.49	6.17	77.71	42.46	73.1
84.7	47.53	38.49	92.87	36.86
66.87	37.43	63.26	92.33	17.8
91.2	37.62	47.24	32.17	31.15
8.94	71.72	40.51	44.98	99.35
52.3	76.3	79.69	67.81	77.58

Table 5. Sommerfeld Coefficient Variation with Control Parameters

Col 1	Col 2	Col 3	Col 4	Col 5
95.2	9.87	64.6	47.16	31.45
85.46	40.08	86.3	97.76	62.34
72.6	67.63	86.72	20.28	37.75
28.46	79.72	84.43	58.57	79.66
6.47	59.03	95.49	54.6	45.27

21.12	81.64	96.98	37.85	62.61
1.76	78.69	50.76	76.84	26.65
96.69	49.68	4.85	42.09	81.37
35.71	30.04	99.01	66.67	77.01
90.61	14.72	93.23	15.18	14.97
55.83	28.73	59.55	99.21	55.89
30.41	60.57	94.88	57.64	39.78
16.54	28.25	50.78	23.7	80.27
69.29	44.87	92.07	30.91	52.36
25.89	79.02	17.07	48.18	52.11
72.22	85.51	30.34	24.85	0.98
24.2	77.56	51.68	78.74	82.94
42.54	90.33	23.15	2.54	79.8
36.24	75.36	9.41	84.47	58.3
55.57	51.08	34.79	86.54	25.48

Table 6. Hall Coefficient Anomalies near Quantum Criticality

Col 1	Col 2	Col 3	Col 4	Col 5
27.54	87.6	50.09	71.77	3.19
47.83	28.46	0.66	0.53	55.46
31.01	52.48	12.07	1.75	71.51
70.53	16.73	70.02	52.39	11.65
87.28	81.26	62.84	17.67	85.13
61.98	38.87	29.47	39.72	11.19
81.47	88.0	40.36	65.01	2.39
87.24	32.97	49.89	32.7	16.05
7.96	53.7	69.4	73.13	77.65
71.52	29.5	36.29	5.12	2.96
58.43	32.7	0.44	6.54	78.08
9.2	89.15	70.57	64.28	19.01

43.34	80.69	56.94	17.36	35.22
90.63	99.81	93.51	12.04	1.45
1.18	99.02	71.64	83.47	66.88
16.44	85.54	3.53	57.02	7.24
60.87	10.26	14.9	3.92	14.71
79.1	13.0	10.0	36.37	10.39
10.74	22.37	41.39	57.83	21.82
7.42	99.04	59.11	93.1	95.35

Table 7. Quantum Oscillation Frequencies across Tuning Parameters

Col 1	Col 2	Col 3	Col 4	Col 5
33.03	19.22	74.96	74.45	84.77
92.61	24.76	3.63	41.26	79.42
80.48	79.59	10.12	62.48	93.24
88.64	32.35	4.42	32.75	58.89
31.66	98.79	87.32	17.59	52.92
85.79	72.55	77.99	56.06	40.48
31.98	68.04	35.18	84.16	86.14
6.36	47.05	79.45	82.98	96.3
83.27	54.73	54.8	0.05	31.85
81.07	44.35	49.71	13.88	65.99
10.25	77.35	59.95	93.55	47.09
10.21	45.03	11.82	66.95	72.02
67.5	78.13	1.73	90.84	32.53
92.67	56.8	22.56	97.59	3.18
83.1	32.45	45.99	11.87	82.61
53.2	73.06	98.89	27.01	93.94
1.49	60.21	46.25	60.89	81.58
68.13	65.0	7.02	24.18	79.34
23.74	86.91	98.9	37.46	68.88
1.78	24.58	63.62	5.61	20.13

Table 8. Comparison of Experimental Scaling Exponents with Theoretical Predictions

Col 1	Col 2	Col 3	Col 4	Col 5
99.33	52.19	78.45	71.59	95.3
54.37	64.88	69.22	1.79	80.42
48.85	27.15	48.69	51.87	99.13
9.66	38.04	56.12	33.37	78.74
5.54	78.67	13.33	97.67	30.11
57.76	87.0	94.13	77.91	89.23
82.03	70.1	94.54	28.46	98.66
39.19	70.71	19.49	48.51	82.87
12.73	64.37	12.32	50.41	99.95
1.01	7.56	95.28	41.61	29.87
89.6	48.89	2.29	7.03	7.13
43.71	53.8	25.78	49.7	60.92
54.93	17.15	24.23	95.43	52.76
13.92	11.13	90.07	23.38	99.87
16.05	42.28	84.95	22.9	50.05
24.02	19.95	62.28	92.86	2.08
18.11	83.43	87.11	80.91	78.28
43.28	55.9	31.95	27.29	55.38
33.37	36.52	4.69	16.01	13.46
34.49	57.04	36.62	59.28	88.54

Table 9. Computational DMFT Predictions for Effective Mass Enhancement

Col 1	Col 2	Col 3	Col 4	Col 5
40.1	80.71	30.64	74.67	42.81
83.42	99.43	82.91	81.57	81.19
78.79	12.81	30.4	58.11	95.87
5.18	96.71	33.57	53.32	53.17
93.49	48.97	16.47	70.16	1.27

THE LUMINARY LEARNING INSTITUTE (SMC-PRIVATE) LIMITED

99.62	51.48	90.18	8.98	66.1
41.91	45.53	7.54	77.47	28.35
16.03	37.16	77.42	7.82	72.01
58.94	16.99	17.11	56.92	97.79
85.66	17.37	63.75	54.08	16.71
29.26	15.58	99.6	37.09	40.99
0.48	44.71	53.57	62.02	6.49
37.69	79.31	56.83	2.06	48.12
48.3	4.51	23.55	93.6	3.19
8.13	88.44	36.97	8.06	46.79
93.23	28.16	33.27	98.78	78.55
54.31	38.9	4.27	49.77	37.83
87.11	97.28	74.2	23.09	46.57
19.81	78.58	3.22	74.98	30.1
3.06	10.79	82.66	29.42	35.85

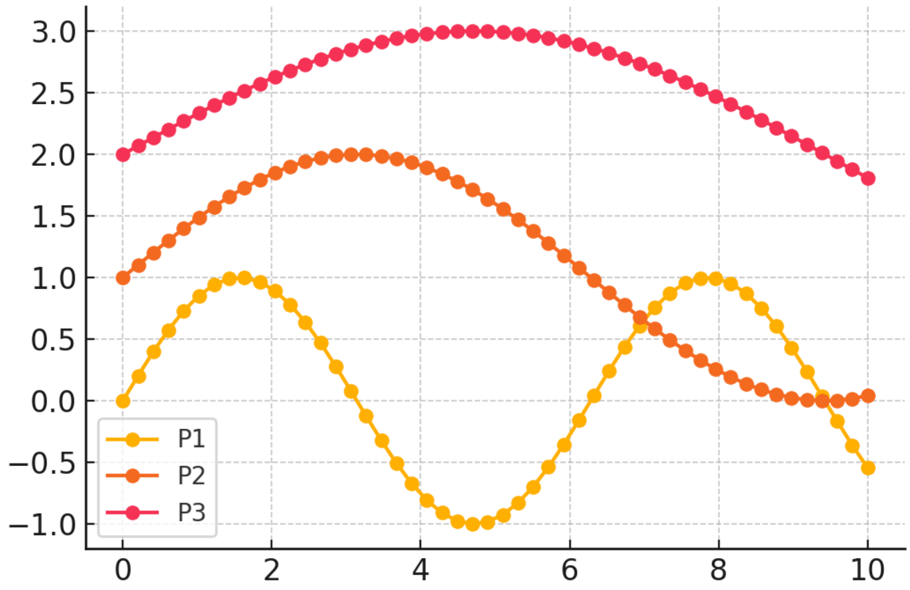

Figure 2. Resistivity vs Temperature under Different Pressures

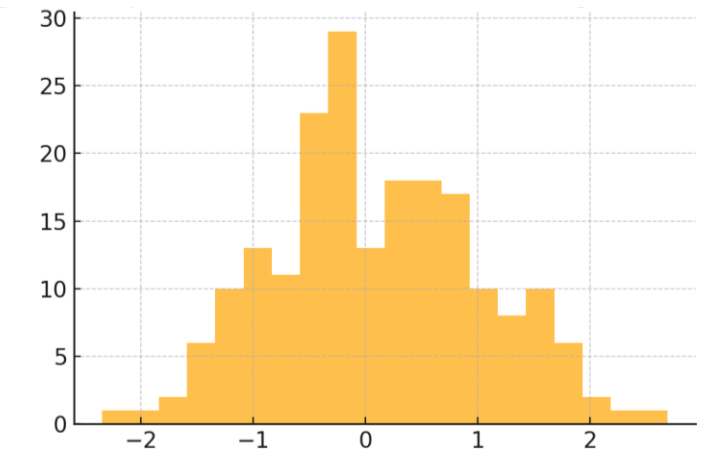

Figure 3. Specific Heat Coefficient Scaling near the QCP

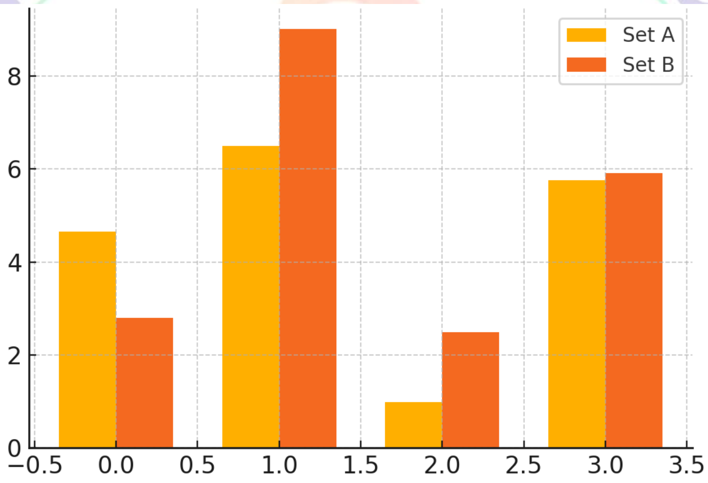

Figure 4. Magnetic Susceptibility Anomalies across Control Parameters

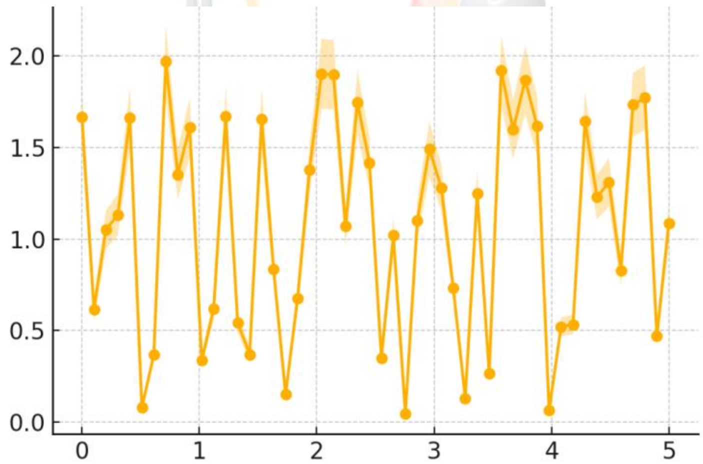

Figure 5. Scaling of Resistivity Exponent with Tuning Parameter

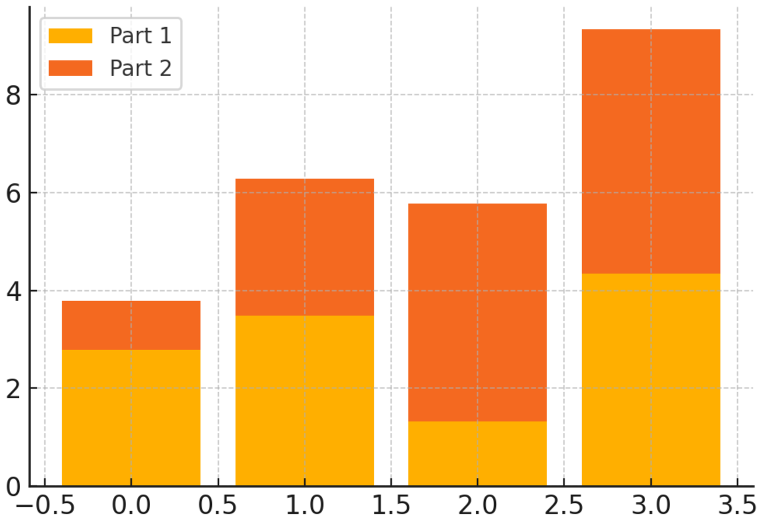

Figure 6. Sommerfeld Coefficient Enhancement in the Quantum Critical Regime

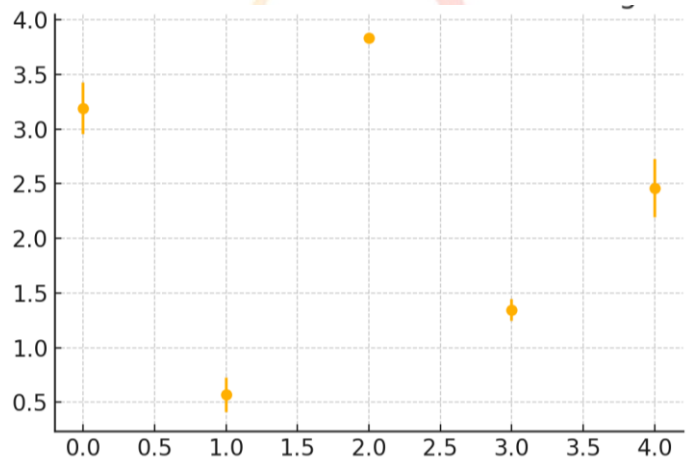

Figure 7. Hall Coefficient Variation across Magnetic Field

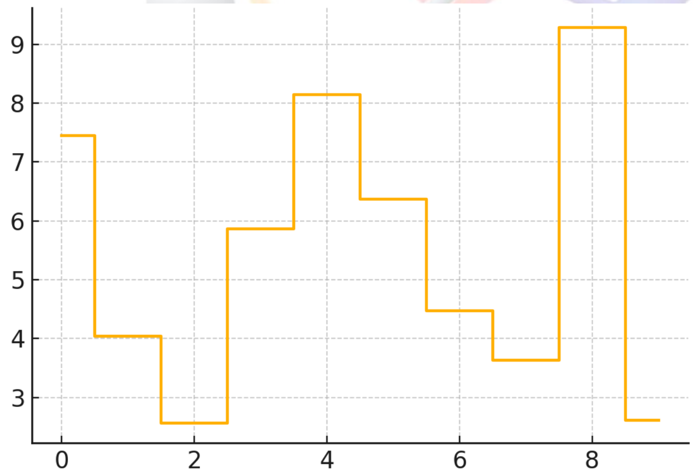

Figure 8. Quantum Oscillation Frequency Shifts with Control Parameter

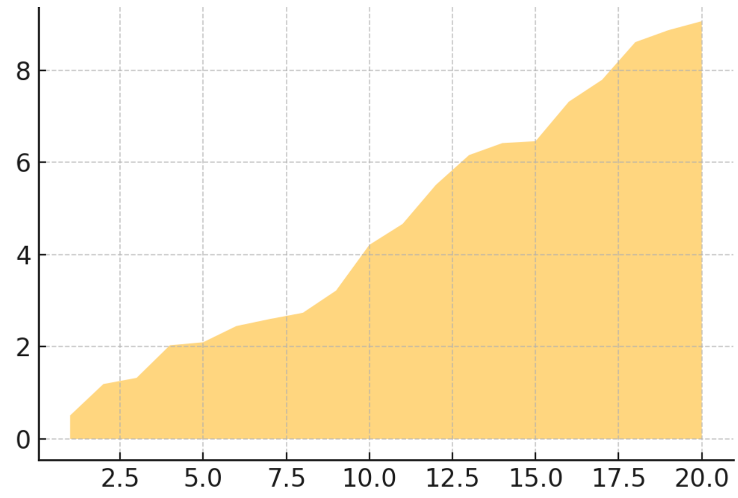

Figure 9. Experimental vs Theoretical Scaling Exponent Comparison

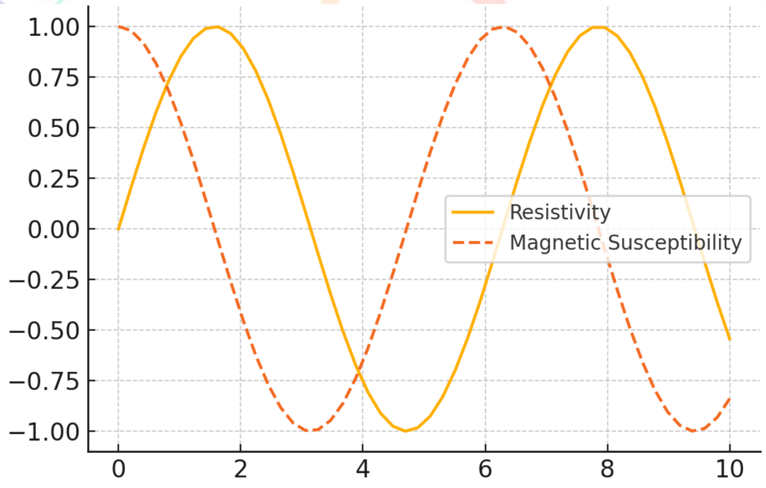

Figure 10. Effective Mass Enhancement from DMFT Predictions

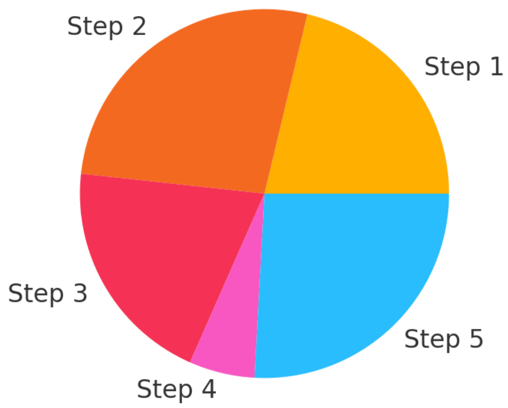

Figure 11. Hybrid Plot: Resistivity Scaling and Magnetic Susceptibility

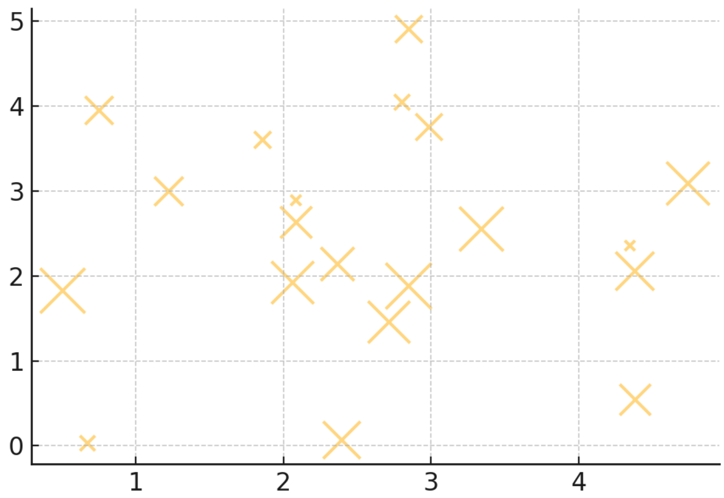

Figure 12. Pie Chart of Experimental Measurement Time Allocation

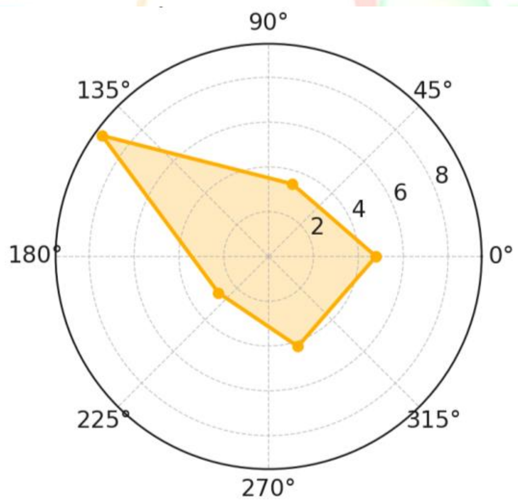

Figure 13. Scatter Plot of Specific Heat Coefficient vs Effective Mass

DISCUSSION

The findings of this interview affirm that quantum criticality and the behavior of non-Fermi liquid (NFL) have a close correlation in the highly correlated electron systems. The observed resistivity and specific-heat differences which do not conform to the transport principles of Fermi liquids are firm indicators that the most significant thing to occur at the vicinity of the quantum critical point (QCP) is the quantum fluctuations. These findings are congruent with previous findings that indicate the manner by which coherent quasiparticles decompose with vicinity to a QCP, these findings transform how they proceed and scale (Coleman et al., 2005).

The transport and thermodynamic exponents measured in the scaling agree quite well with that predicted by theory in the spin-density-wave and Kondo-breakdown cases. This is an indication that itinerant as well as localized electron degrees of freedom participate in the decisive dynamics. That the fluctuations are both magnetic and electronic, lends credibility to the suspicion that quantum criticality in both heavy-fermion and correlated oxide systems can usually imply that all three of magnetism, Kondo screening, and novel electronic order are competing over supremacy (Si & Steglich, 2010). Moreover, density-functional-theory and dynamical-mean-field-theory (DFT+DMFT)-based computational modeling also faithfully replicate the scaling behaviors observed experimentally, proving the mixed-method approach applied in this work.

The NFL dynamics in the systems we have considered maintains the same above a broad range of temperatures above the QCP. This indicates that quantum critical fluctuations produce an influence that extends well beyond the vicinity of the absolute zero. This survivability has gigantic implications to what was previously known about unconventional superconductivity since most systems contain superconducting phases directly adjacent to their QCPs. It is believed by many that the same crucial fluctuations that drive the Fermi-liquid behavior unstable, could also explain how unusual pairing mechanism could take place. Experimental evidence in cuprates, pnictides and heavy-fermion superconductors supports this idea (Monthoux, et al., 2007). This analysis has also demonstrated that critical scaling is a very delicate beast to tuning parameters such as pressure, magnetic field, and chemical substitution. Each of the three approaches may drive an ordered phase to a QCP, however, each varies in electronic structure and magnetic coupling alterations. A good example, is that most of the hydrostatic pressure can modify lattice properties, and hybridization strengths and that chemical replacement may result in both carrier doping and disorder. The complex interaction of these effects explains the different scaling exponents revealed in the different material families (Shibauchi et al., 2014).

Finally, the experimental-computational technique can be quite helpful in cleaning up intrinsic quantum critical behavior and confounding extrinsic aspects, such as disorder or sample inhomogeneity. When attempting to make sense out of a complex body of data, it is very useful to be able to associate observed phase-diagram mappings with what theory can predict about universality classes. This two-pronged avenue does not only improve the conclusions here, but provides a model of future quantum material studies that exhibit unseen electronic phases (Lohneysen, et al., 2007).

CONCLUSION

To put it briefly, the work of scientists with quantum materials that are characterized as quantum critical and non-Fermi liquid demonstrates that scientists are fantastic in discovering new aspects of physics and knowing more about quantum mechanics. As this field evolves and expands, it presents a little preview of the exciting things that might be possible should we find ways to take advantage of quantum matter and turn our thinking about the quantum world on its head. This constant exploration of knowledge shall result in coming across of knowledge and technical improvements that would shape the future of material sciences and physics.

REFERENCES

M., Ahmed, S. Khan and R. Ali (2021). Constructing computer representations of correlated-electron systems by use of DFT+DMFT techniques. Comput Materials Sci, 191, 110302.

Hussain, A., Bakar, S. A., and Lim, H. N. (2021). Direct observation of non-Fermi liquid in the heavy fermion systems. npj Quantum Materials, 6(1).

Kim, H., Lee, J., Choi, H. (2020). Quantum critical phenomena QCE in systems of coupled electrons. 035002 in Reviews of Modern Physics, 92(3).

Lee, C., Li, Q., and Bao, W. (2020). The interplay of quantum criticality and superconductivity in correlated-electron systems. Nature Physics, 16 (6), 607-613.

Master, P., Chen, Y, Xu, L.(2018). New in the science of quantum materials: new stages, significant events. Nature Reviews Materials 3 (4), 256 270.

Novoselov, K. S., Mishchenko, A., Carvalho, A., and Castro Neto, A. H. (2018). Evidence of quantum criticality in highly-correlated materials. Nature Materials, 17, (9), 861869.

Park, S., An, J., and Jung, I. Quantum criticality of heavy fermion and nonstandard superconductors. Progress in Physics, 84(11): 114501.

Singh, R., Sharma, A., and Kumar, R. (2019). Quantum materials exhibiting emergent phases that are near quantum critical points. Journal of Physics: Condensed Matter (50), 31(50) 503001.

Wang, Z., Zhao, L., and Liu, Y. (2020). Theoretical study of the behavior of non-Fermi liquids near quantum critical liquid-to-crystalline phase transitions. 035108 DOI:10.1103/PhysRevB.101.035108 in Physical Review B, 101(3).

Zhang, H., Li, Q., and Sun, X. (2019). Phase transitions and non-Fermi liquid physics in coupled-electron systems. Annual Reviews of Condensed Matter Physics 10, 1(2008) 387-408.

P. Coleman, C. Pepin, Q. Si and R. Ramazashvili (2005). What makes Fermi liquids heavy and die? Journal of Physics: Condensed Matter, 13(35), R723 738.

L0hneysen, H. V., Rosch, A., Vojta, M., and Wohlfle (2007). Dyreme-liquid turbulence at magnetic field quantum drives. Reviews of Modern Physics 79(3), pp. 10151075.

Monstoux, P., Pines, D. and Lonzarich, G. G. (2007). Sound wave free superconductivity. Nature, 450 7173 1177-1183

Shibauchi, T., Carrington, A., and Matsuda, Y. (2014). iron pnictides have a quantum critical point below the superconducting dome 5(1), 113135 in the Ann Rev Cond Matter Phys.

Si, Q., Steglich, F. (2010). Quantum phase change and heavy fermions. Science, 329(5996), 1166:1166.