African School of Fundamental Physics and Applications

UNIVERSITY OF DSCHANG

FLUCTUATIONS EFFECTS ON PHASE TRANSITIONS USING RENORMALIZED GAUSSIAN APPROACH (RGA)

OPTION: CONDENSED MATTER PHYSICS

BY

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MOTIVATION

PLAN

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I- LANDAU THEORY OF SECOND ORDER PHASE TRANSITIONS

The Landau's theory of phase transitions is built on the existence of the order parameter ϕ whose value characterizes the phase in prevailing in the system considered.

- In the disordered phase of high symmetry, usually at high temperature,

$$\phi = 0 \quad (I.1a)$$

- In the ordered phase of lower symmetry, $\phi \neq 0$ (I.1b)

LANDAU assumes that the free energy of the system can be written as a function of the order parameter:

$$F(T,\phi) = F_0(T) + a(T)\phi^2 + c\phi^4 \qquad (I.2)$$

Where $a(T) = a_0(T - T_C)$ $\qquad (I.3)$ is the quadratic term

By minimizing the free energy $F(T,\phi)$ we obtain:

$$\begin{cases} \phi = 0, & T > T_C \\ \phi = 0 \;\; or \; \phi = \pm\sqrt{a_0(T-T_C)}, & T < T_C \end{cases} \qquad (I.4)$$

➢**BEHAVIOUR OF THE SUSCEPTIBILITY AND THE INVERSE SUSCEPTIBILITY**

$$\chi = \left(\frac{\partial \phi}{\partial h}\right)_T \qquad (I.5)$$

$$G = F(T,\phi) - \phi h \qquad (I.6)$$

$$\frac{\partial G}{\partial \phi} = 2a_0(T-T_C)\phi + 4c\phi^3 - h = 0 \qquad (I.7)$$

$$2a_0(T-T_C)\chi + 12c\phi^2\chi - 1 = 0 \qquad (I.8)$$

$$\chi \propto 1/[a_0(T-T_C)] \qquad (I.9)$$

$$\chi^{-1} \propto a_0(T-T_C) \qquad (I.10)$$

➢ LIMITS OF THE LANDAU MODEL

• The LANDAU model is implecitly a mean field theory

we approach the order parameter by its most probable value equated to the average value by abandoning any fluctuations.

• The LANDAU model is exact in dimension $d \geq 4$

II- RENORMALIZED GAUSSIAN APPROACH (RGA) TO SECOND ORDER PHASE TRANSITIONS

The starting point is the functional of the following LANDAU-GINZBURG-WILSON (LGW) Hamiltonian:

$$H_{LGW} = \int \frac{d^d x}{\varepsilon_0} \left[c\left(\nabla_x \phi(x)\right)^2 + a(T)\phi^2(x) + b_0\phi^4(x) + \cdots \right] \qquad (II.1)$$

Additional term introduced to take into account the spatial inhomogeneities

We account for the geometry, the strongly fluctuating and the corrolated nature of the low-dimensional system following the transformations:

$$a_0(T - T_{C0}) \rightarrow a_0(d,T) = a_0(T - T_{C0}) + \Sigma^*(d,T) \qquad (II.2)$$

Where $\Sigma^*(d,T) = \eta \left[\frac{T}{T_{C0}}\right] \left(\frac{T - T_{C0}}{T_{C0}} + \frac{\Sigma^*(d,T)}{a_0 T_{C0}} \right)^{\frac{d}{2}-1} \qquad (II.3)$

Consequence: All thermodynamic observables are dimension-dependent (including the critical temperature). $d_C = 4$ remains the upper- critical dimension .

Example:

- the new statistic susceptibility is given by:

$$\chi^* \propto 1/a_0(T - T_{C0}) + \Sigma^*(d,T) \qquad (II.4)$$

- And the inverse susceptibility is given by:

$$\chi^{*-1} \propto a_0(T - T_{C0}) + \Sigma^*(d,T) \qquad (II.5)$$

- The real critical temperature [1]:

$$T_C = T_{C0}(1 - v_{dc}) \quad where \begin{cases} v_{1C} \sim 1 \\ v_{2C} = \dfrac{K_{2D}}{1 + K_{2D}} \\ v_{3C} \approx 0 \\ v_{4d} = 0 \end{cases} \qquad (II.6)$$

III

NUMERICAL RESULTS: INTERPRETATION

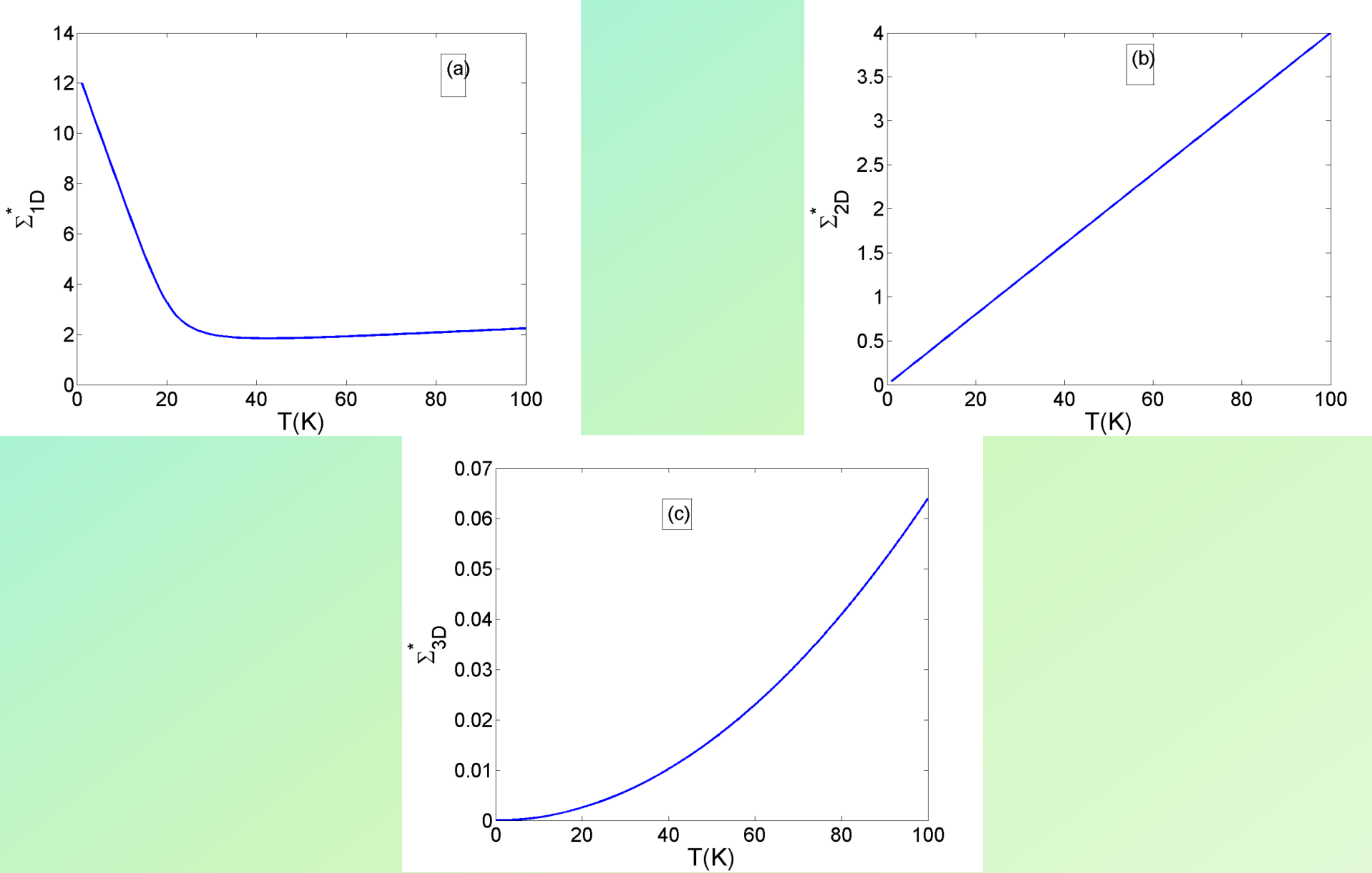

Figure 1: the temperature T dependence of the scaled correction term for one, two, and three dimensional lattice systems. It assumed that T_c=25K, a_0=0.5, K_d=1.

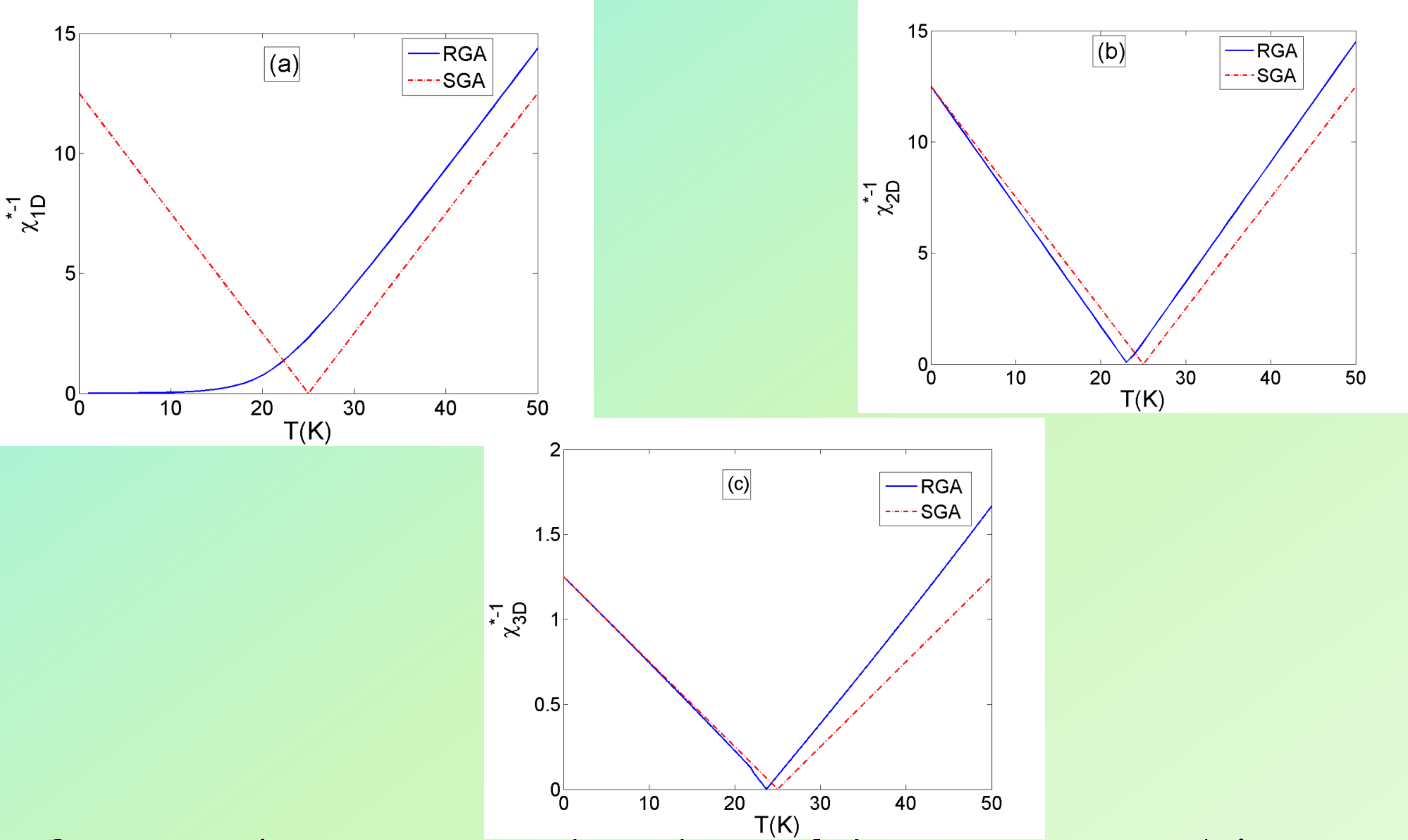

Figure 2: The temperature dependence of the inverse susceptibility and showing the type of behavior it exhibits for a (*a*) 1D lattice system, (*b*) 2D lattice system, and(*c*) 3D lattice system. *Tc*= 25 K, a_o= 0.5, K_d= 1

Conclusion and Perspective

- We etablish that the fluctuations effects play a crucial role in the determination of thermodynamic quantities and also on the phase transitions and critical phenomena.

- We also remark that in the LANDAU theory, thermodynamic quantities are independent to the geometry of space whereas they are dependent to geometry of space for the RGA

- As perspective: determination of other correction terms, application to multiferroic materials

FOR YOUR ATTENTION!