Fluctuation Induced Conductivity in $YBa_2Cu_3O_{7-\delta}$ + $CoFe_2O_4$ Composites

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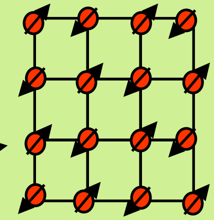
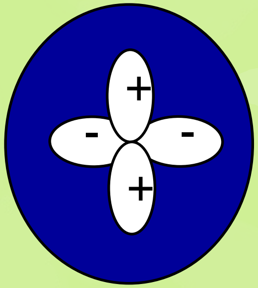
Plan of Presentation

- **INTRODUCTION**
  - **Signature features of cuprate superconductors**
  - **Phase Diagram**
  - **Excess conductivity**
  - **Why study the excess conductivity**
- **EXPERIMENTAL DETAILS**
- **RESULTS AND DISCUSSION**
- **CONCLUSIONS**

Signature features of cuprate superconductivity

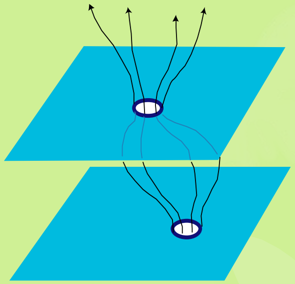
1. Strong Correlation





2. Quasi-2D anisotropy

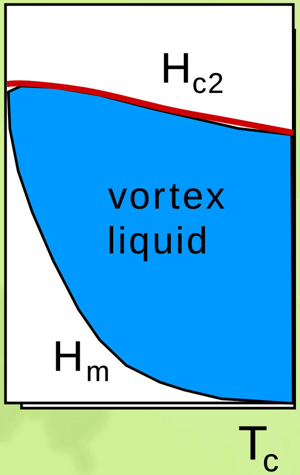
3. *d*-wave pairing, very short ξ



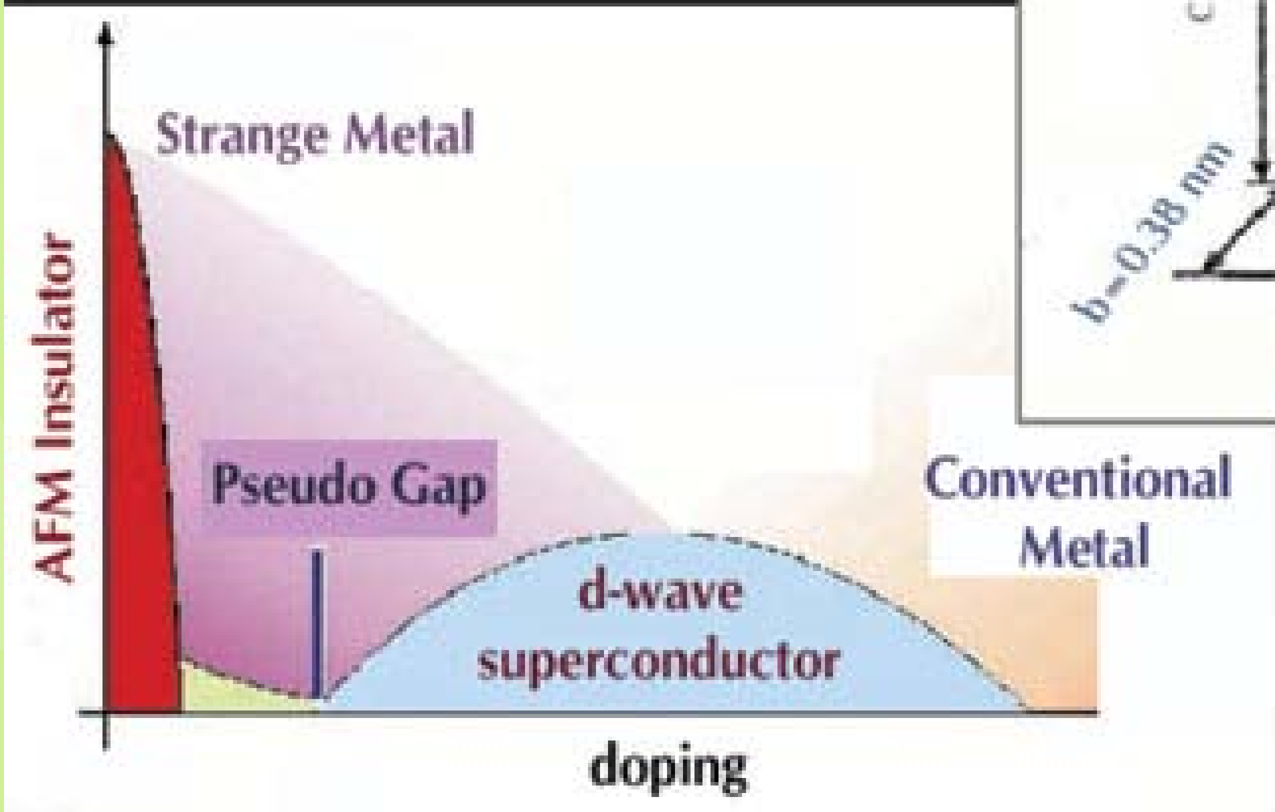
4. Spin gap, spin-pairing at T*

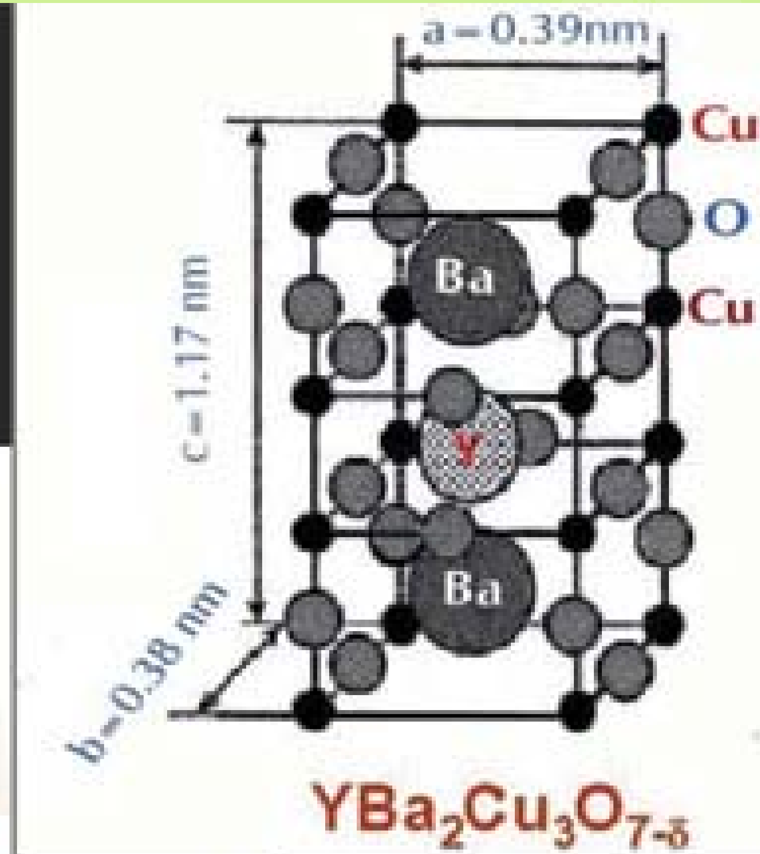
5. Strong fluctuations, vorticity

6. Loss of phase coherence at T_c



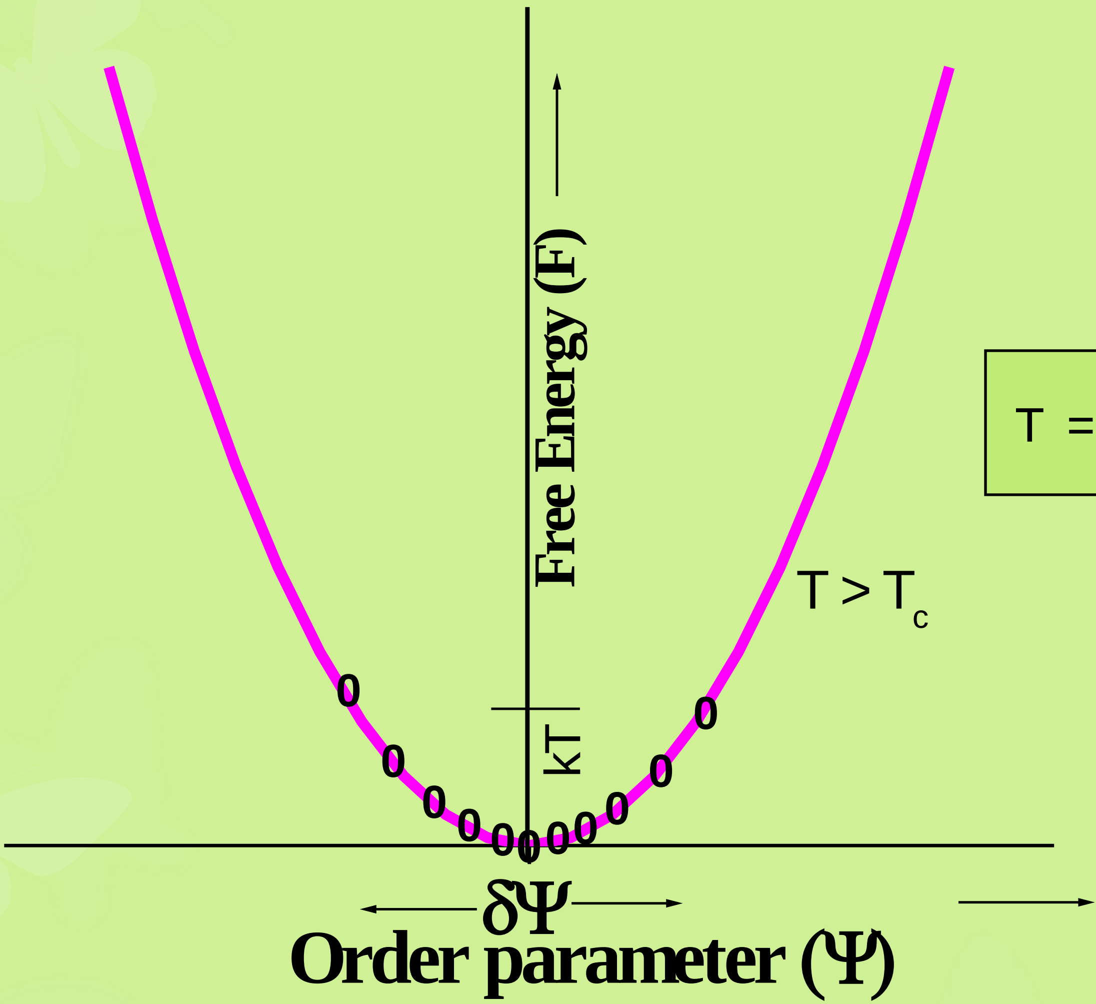
Phase Diagram

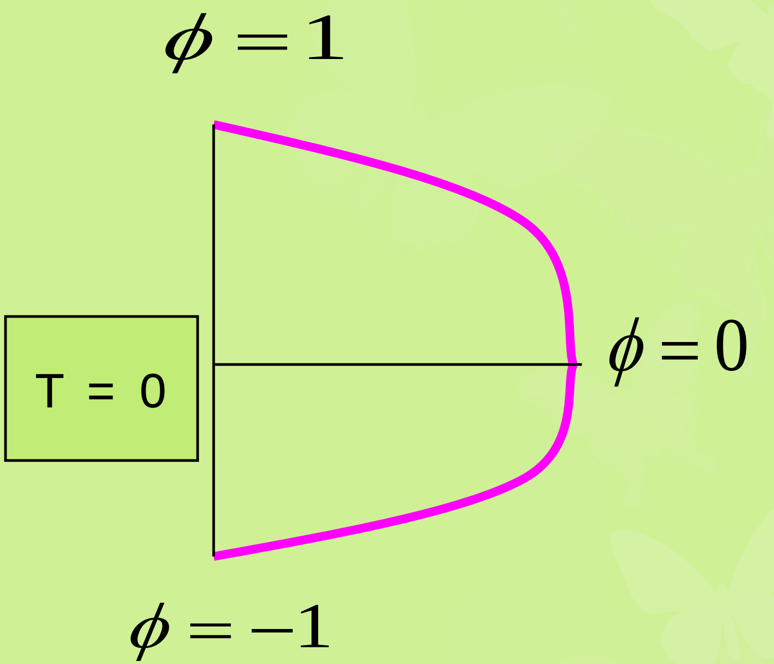




Lattice Structure

SCOPF (Superconducting Order Parameter Fluctuation)

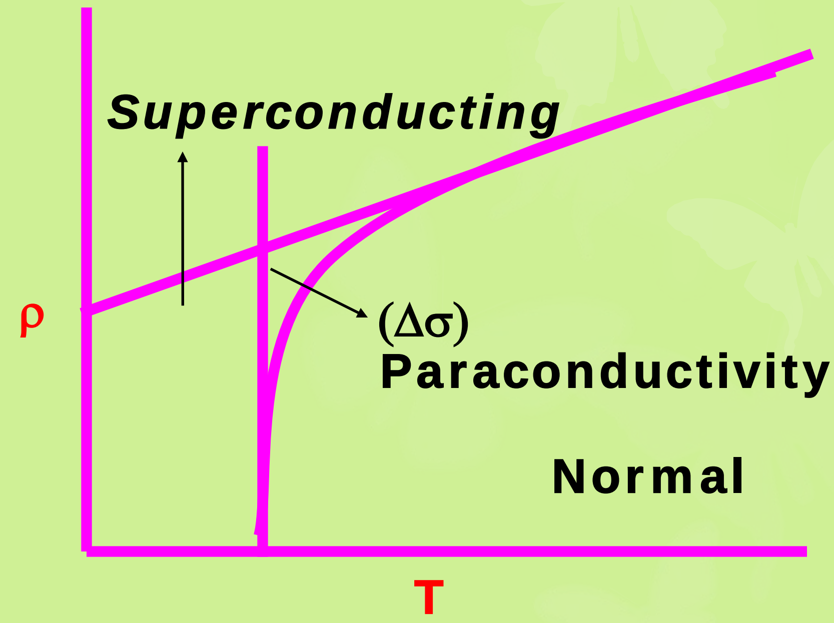




$$\phi = \frac{n_+ - n_-}{n_+ + n_-}$$

n_+ **no of spin up and** n_- **no of spin down**

Paraconductivity region extends over a wide temperature region (±10K) around T_c in HTSC's due to



- * Very short coherence lengths
- * High operating temperatures
- * Layered structure of the conducting CuO_2 planes

$$\Delta\sigma\,(T) = 1/\rho_M - 1/\rho_R$$

ρ_M IS THE MEASURED RESISTIVTY

AND

ρ_R IS THE REGULAR RESISTIVITY

Why study the excess conductivity($\Delta\sigma$)?

- To understand the origin of excess conductivity $\Delta\sigma$
- To obtain superconducting coherence length
- ξ (0 K)
- To obtain effective dimension of the Fluctuations
- Address the very mechanism of superconductivity in HTSC's

Advantages of YBCO over other ceramic superconductors

- **Stable compound with a T_c above 77 K.**
- **Neither toxic elements nor volatile compounds.**
- **Easy to make single-phase YBCO.**
- **High J_c at Higher magnetic Field.**
- **Suitable material for magnetic study**

Focus of our study

To study the dimensionality fluctuation in YBCO/x$CoFe_2O_4$ composite samples.

EXPERIMENTAL

YBCO Preparation

- Y : Ba: Cu= 1:2:3
- Stirred in 2-methylethanol for 12 hours
- Dried and evaporated at 70-80∘C
- Calcined at 900^0C for 12 hours
- YBCO + x $CoFe_2O_4$ (x = 0.0,0.1,0.2,0.3 wt.%) mixed
- Pelletized
- Sintered at 920^0C for 12 hours
- Annealing at 500^0C for 12 hrs in an oxygen supply

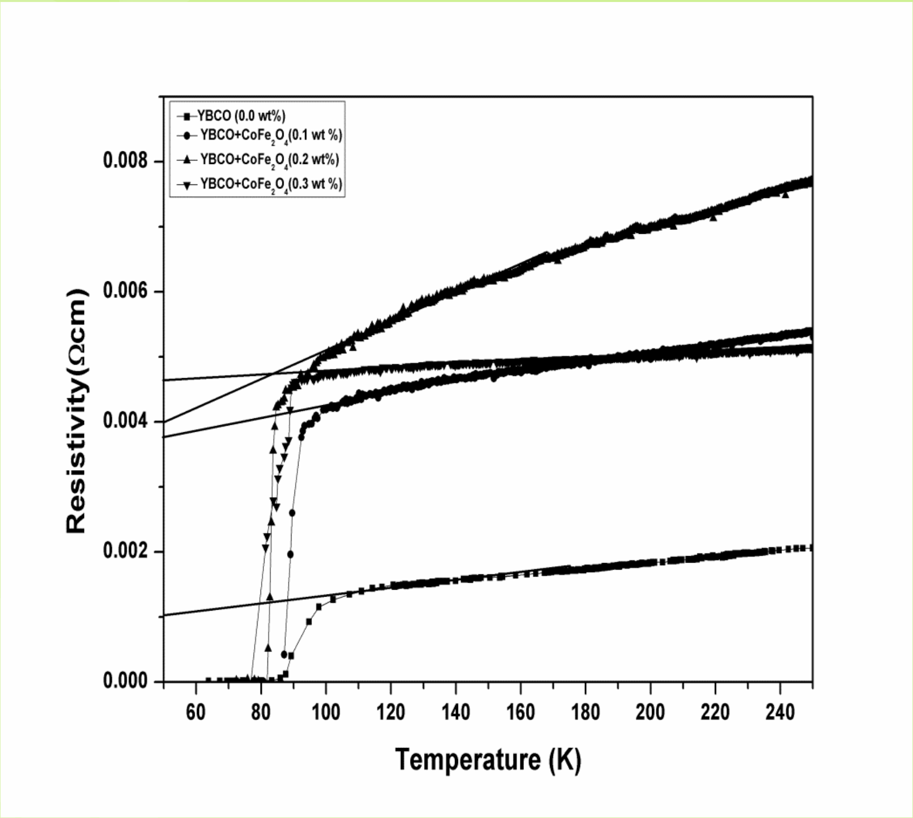
- Both the components are prepared separately. $CoFe_2O_4$ is prepared through solid state route.

Characterization of samples

(a) DC Electrical Resistivity Study

(b) Magnetisation ~Temperature Study

Temperature dependence of the resistivity for YBCO +x$CoFe_2O_4$ composites (x = 0.0,0.1,0.2,0.3 wt. %).

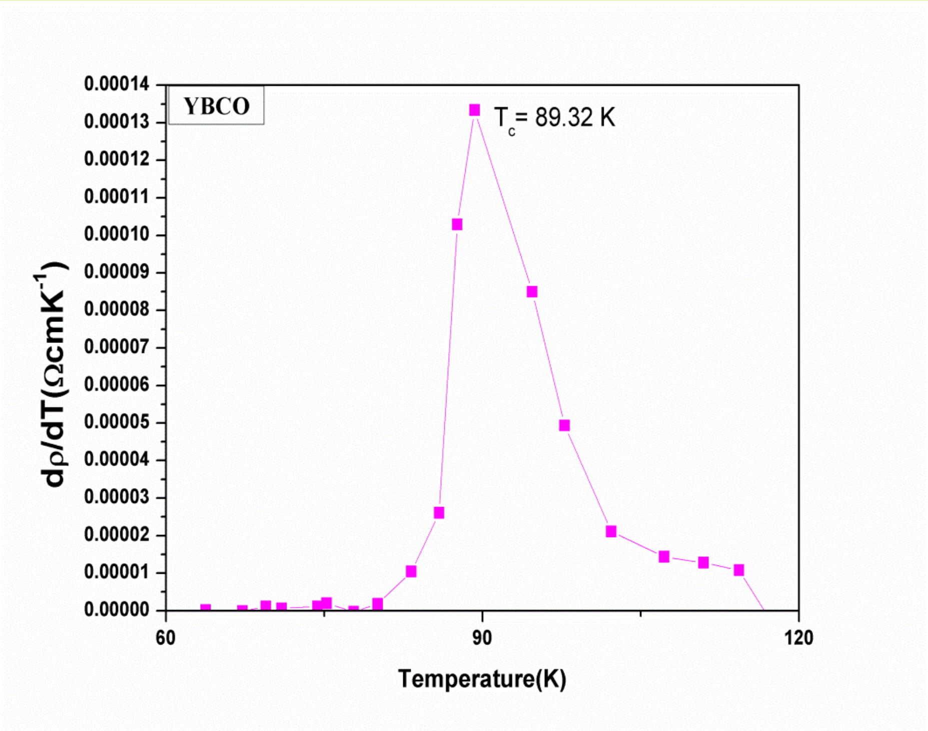


Resistive transition exhibits two different regimes:-

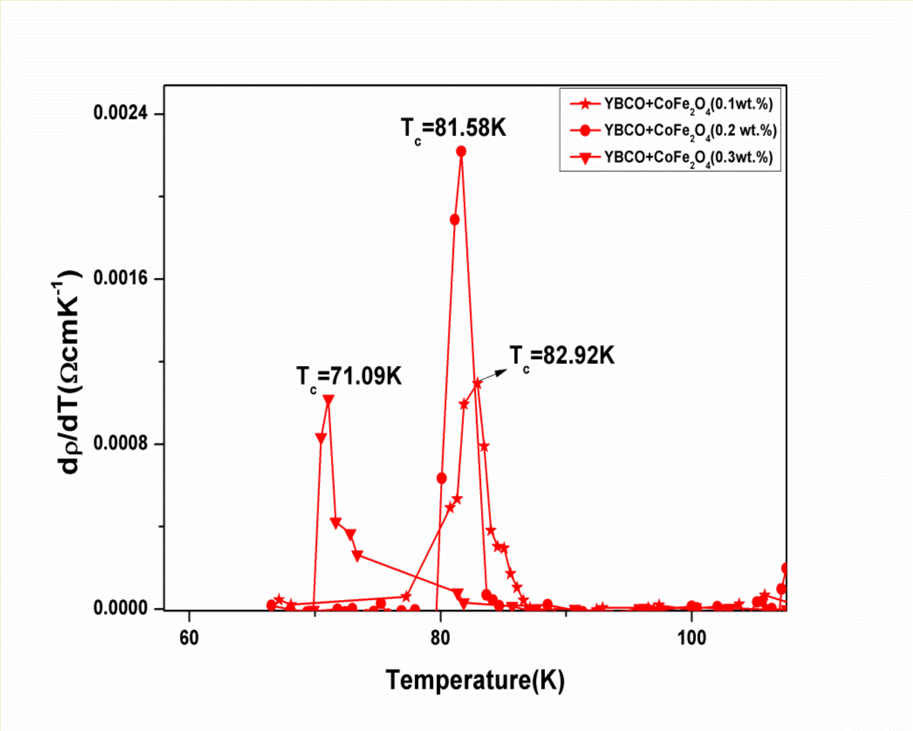
- Normal state that shows a metallic behavior (above 2Tc)
- Deviation from linearity due to cooper pairs give rise to excess conductivity or paraconductivity

Linear fitting of resistivity in the temperature range 150 to 250 K and extrapolated to 0 K gives resistivity slope (dρ/dT) and residual resistivity ρ_0 of YBCO/x$CoFe_2O_4$ composites

Temperature derivative of resistivity of YBCO+ X $CoFe_2O_4$ composites (x = 0.0, 0.1,0.2,0.3 wt.%)



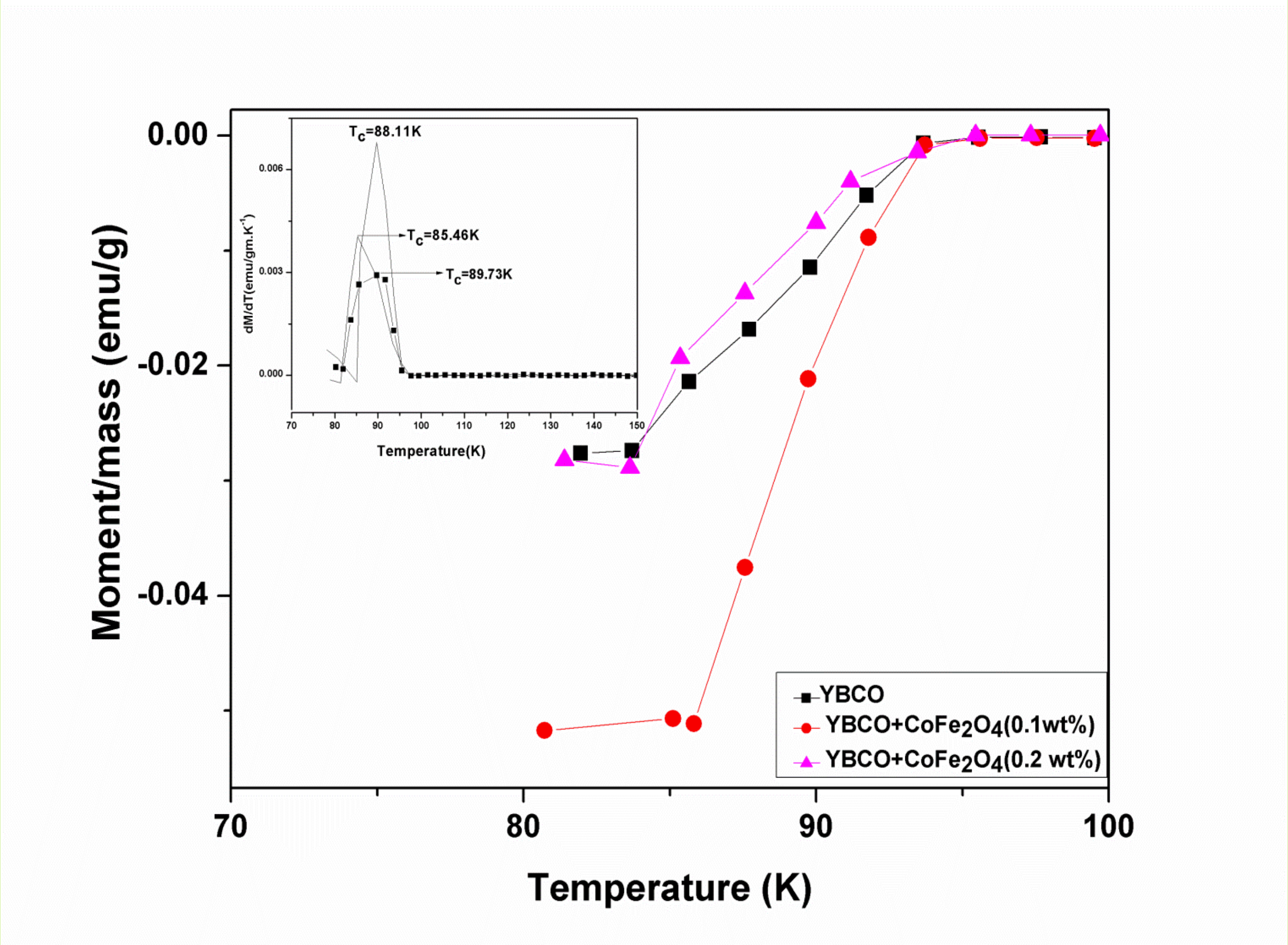
YBCO



YBCO+x $CoFe_2O_4$

- T_c is defined at the peak position.
- T_c is observed to decrease by addition of $CoFe_2O_4$.

Temperature dependence of the Magnetisation for $YBCO+xCoFe_2O_4$ composites (x = 0.0,0.1,0.2,0.3wt.%)



- Composite samples shows completely Diamagnetic property i.e satisfying partial Meissner effect

Excess Conductivity

Excess conductivity ($\Delta\sigma$) diverge as power-law given by AL theory

$$\Delta\sigma = A\varepsilon^{-\lambda}$$

$\varepsilon = (T-T_c)/T_c$ is reduced temperature.

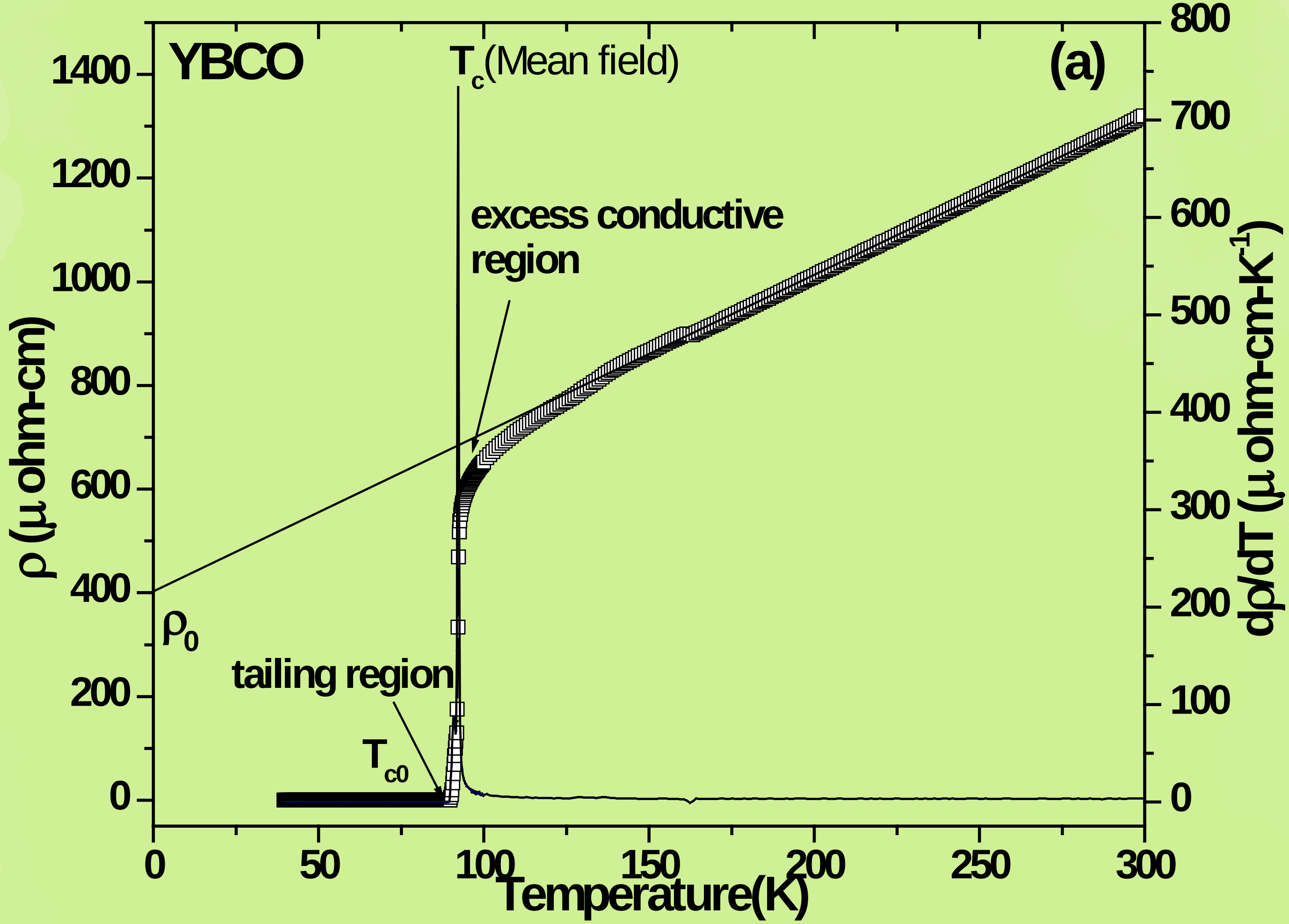
λ=Critical exponent depends on Dimensionality(D)

$$\lambda = 2-D/2$$

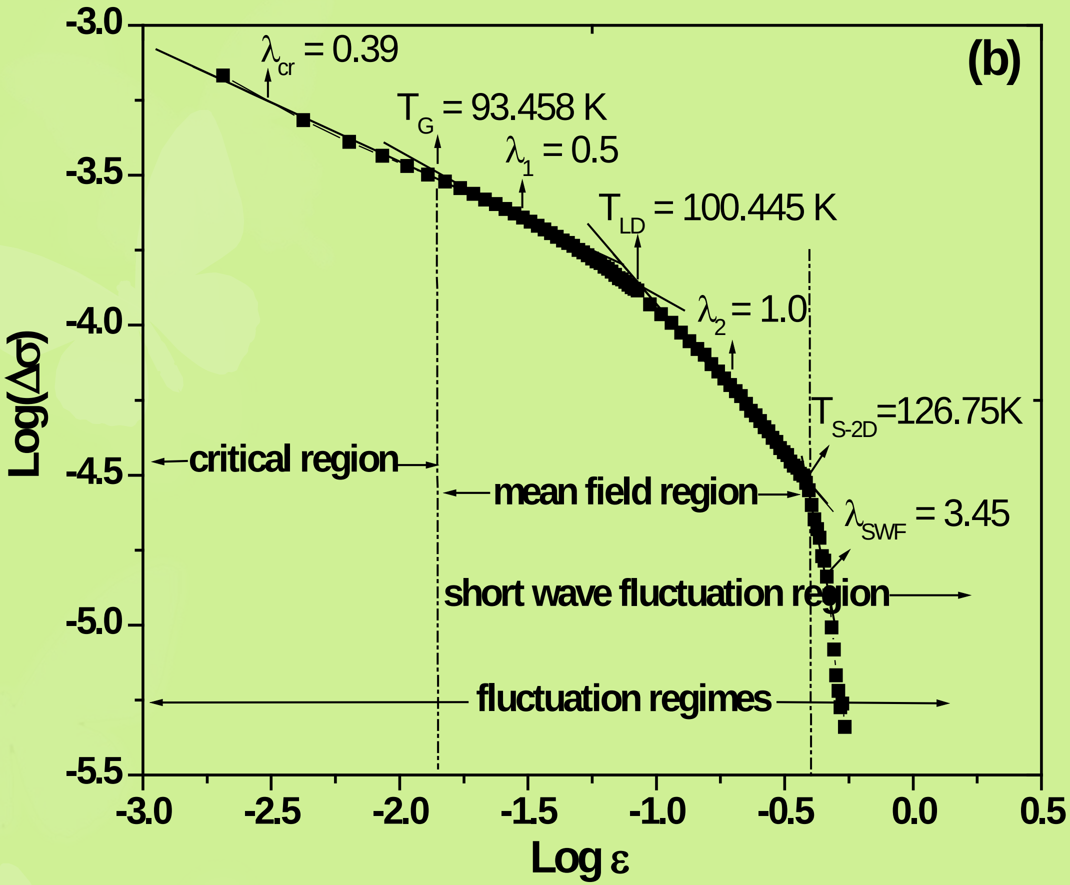
A = Temperature dependent parameter

For 3D $A = e^2/32\hbar\xi(0)$ and $\lambda = 0.5$

For 2D $A = e^2/16\hbar d$ and $\lambda = 1$



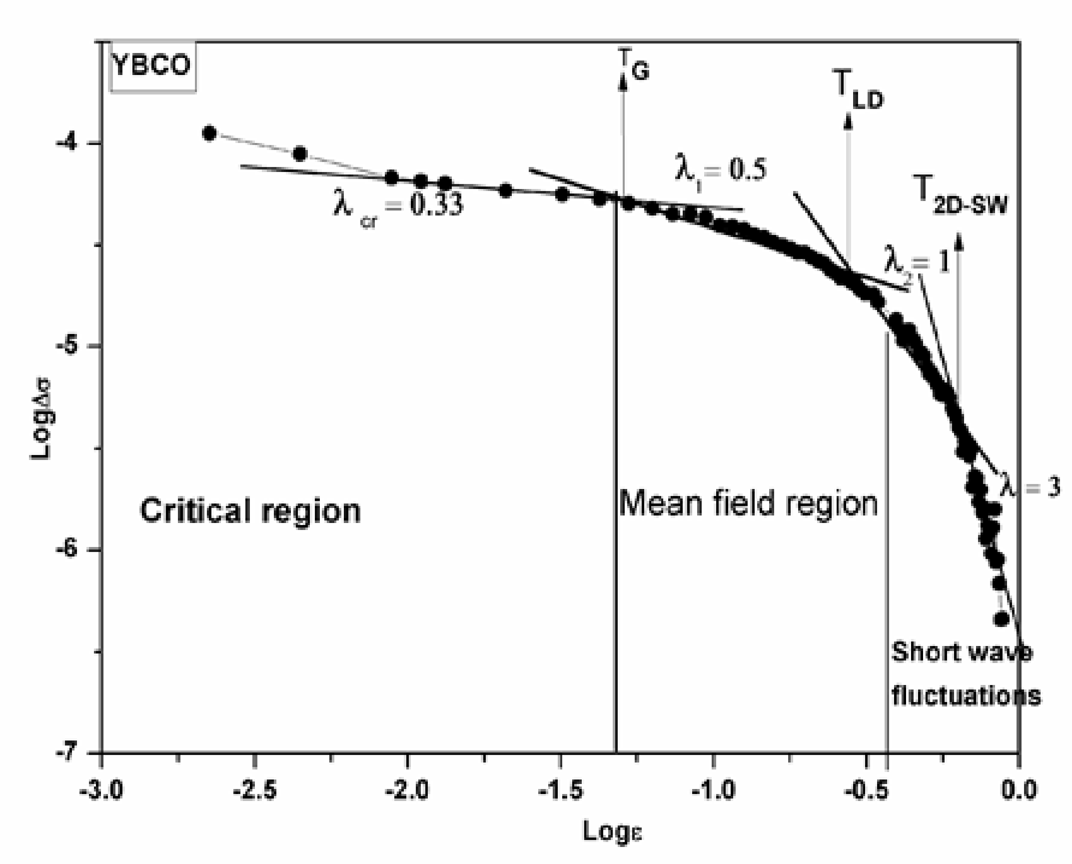
Resistivity and excess conductivity as a function of temperature for YBCO



- 3D-XY-universality class close to T_c
- λ_{cr1} = 0.33 called as the 3D XY-E (model-E dynamics.)
- λ_{cr2} = 0.67 static critical scaling
- λ_{3D} = 0.5 (3D fluctuation)
- λ_{2D} = 1.0 (2D fluctuation)
- λ_{2D-SW}=3 (short-wave fluctuation)

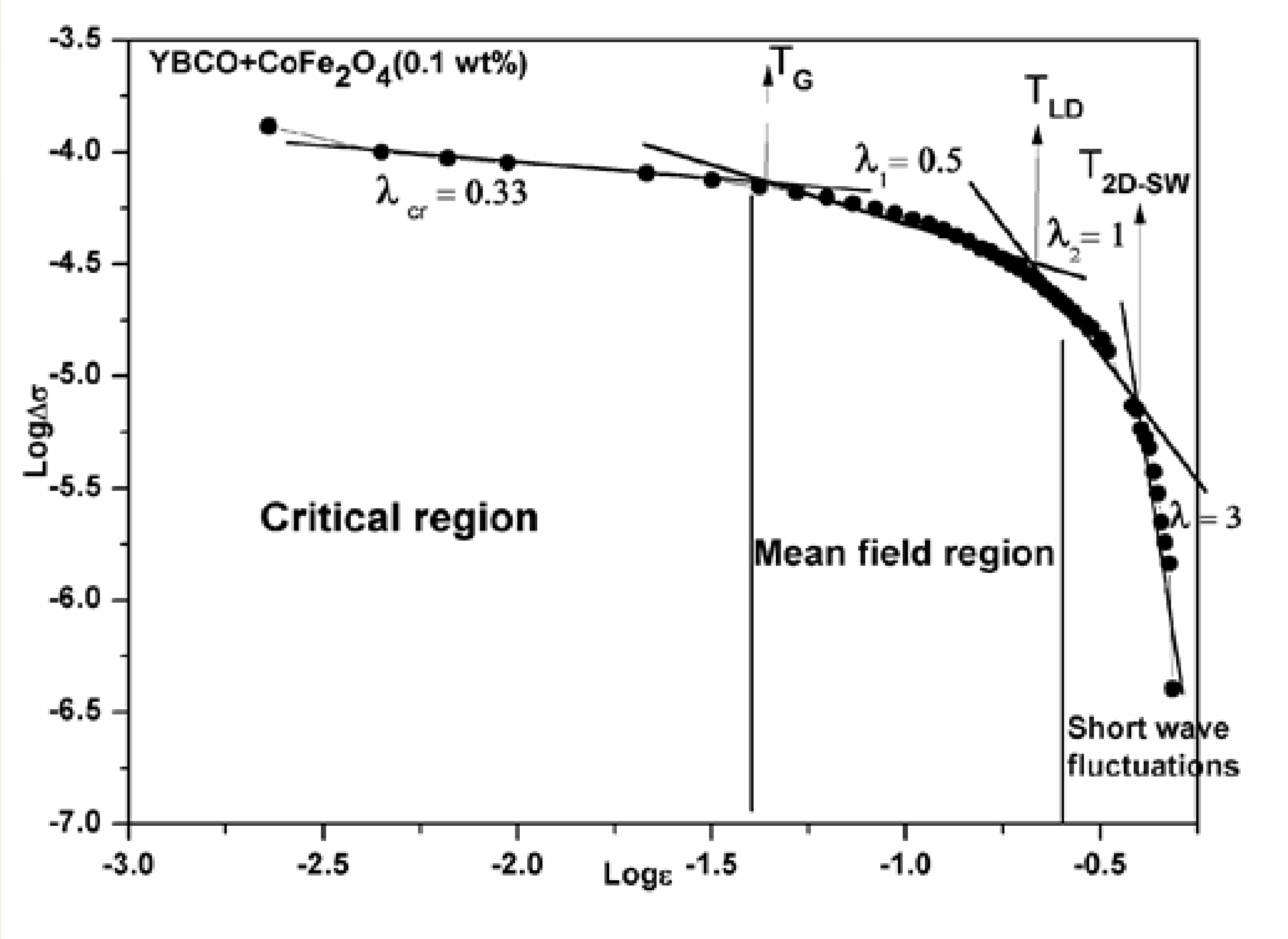
Excess conductivity (Δσ) varies as $\varepsilon^{-\lambda}$

Log – Log plots of excess conductivity as a function of reduced temperature for YBCO

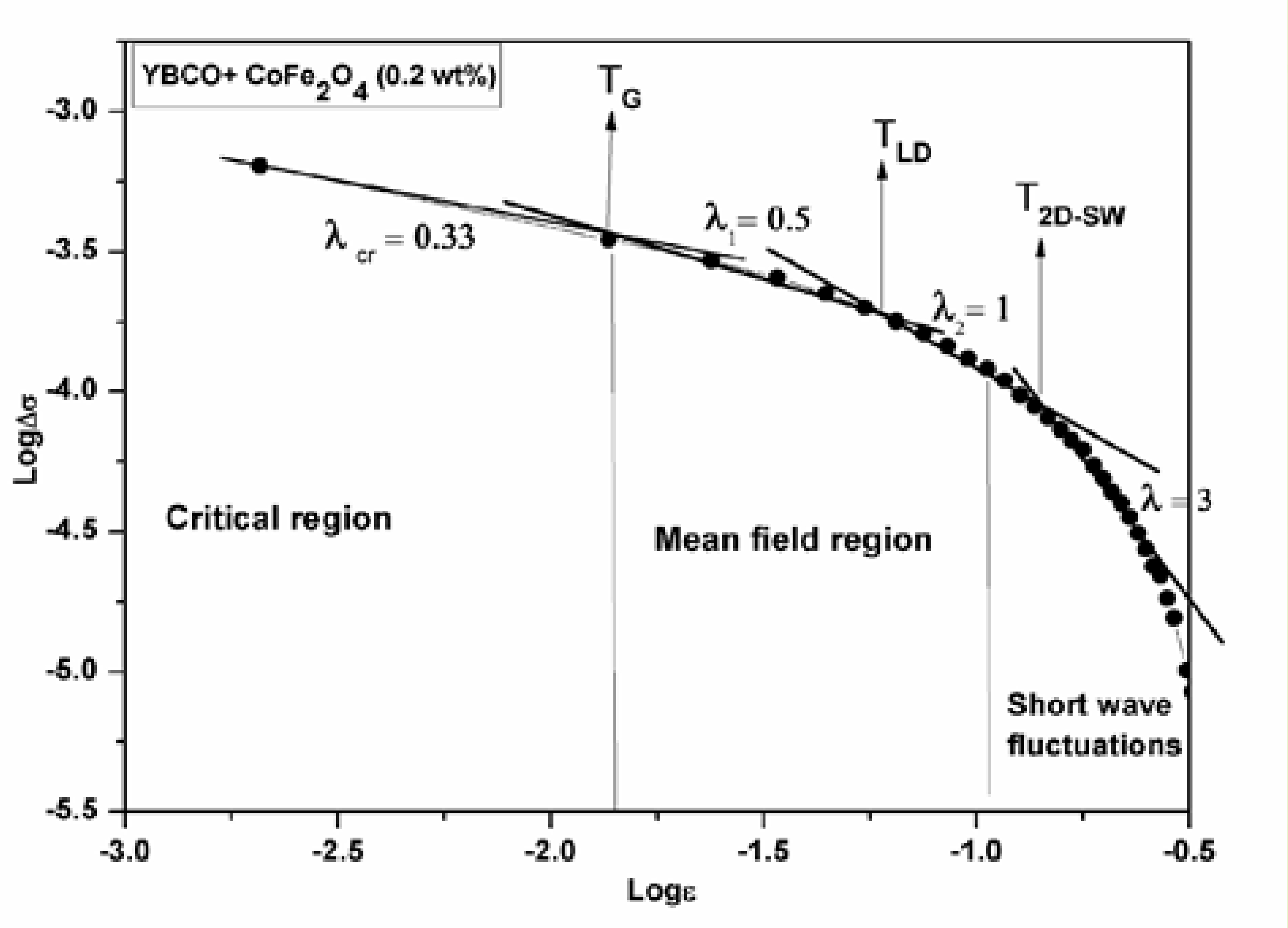


- Fluctuations shows 3 regions
  (a) Mean Field Region
  Exhibiting 2 slopes
  (i) λ= 0.5 (3D fluctuations)
  (ii) λ = 1 (2D fluctuations)
  (b) Critical region (λ = 0.33)
  (c) Short wave fluctuations
  One slope with λ = 3

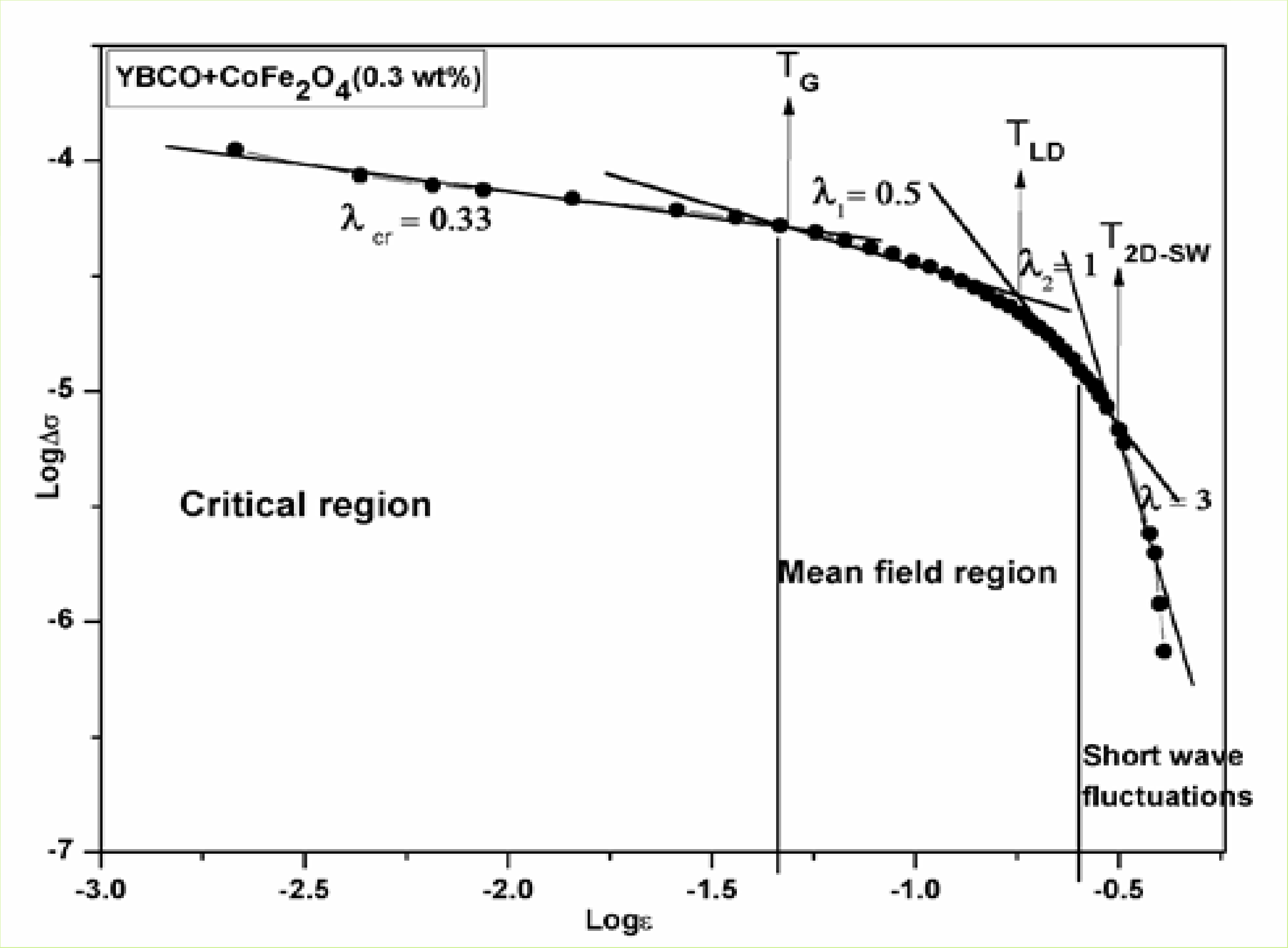
Log–log plot of excess conductivity $1/\rho - 1/\rho_R$
as a function of reduced temperature $\epsilon = (T-T_c)/T_c$



Log–log plot of excess conductivity $1/\rho - 1/\rho_R$ as a function of reduced temperature (ϵ)



Log–log plot of excess conductivity $1/\rho - 1/\rho_R$ as a function of reduced temperature (ϵ)



Log–log plot of excess conductivity $1/\rho - 1/\rho_R$ as a function of reduced temperature (ϵ)

Various Cross over temperatures in YBCO / x $CoFe_2O_4$ Composite with x = 0.0, 0.1, 0.2, 0.3 wt.%.

$CoFe_2O_4$ (wt %)	T_{c0}(K)	T_c(K)	T_G(K)	T_{LD}(K)	$T_{2D\text{-}SW}$(K)
0.0	83.60	89.31	104.14	128.08	148.63
0.1	80.89	82.92	104.01	125.45	138.55
0.2	78.77	81.58	103.24	115.67	127.55
0.3	69.17	71.09	90.14	104.71	113.95

Conclusions

- **With increase in wt.% of $CoFe_2O_4$ in YBCO the critical temperature T_c and T_{c0} decreases gradually .**
- **The different cross-over temperatures T_G, T_{LD}, $T_{2D\text{-}SW}$ also decreases with increase in wt.% .**
- **Decrease in T_{LD} indicates that 3D fluctuation is dominant in the mean field region with increase in wt.% of $CoFe_2O_4$ in the composite.**

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THANK YOU