Universal conductance of nanowires near the superconductor-metal quantum transition

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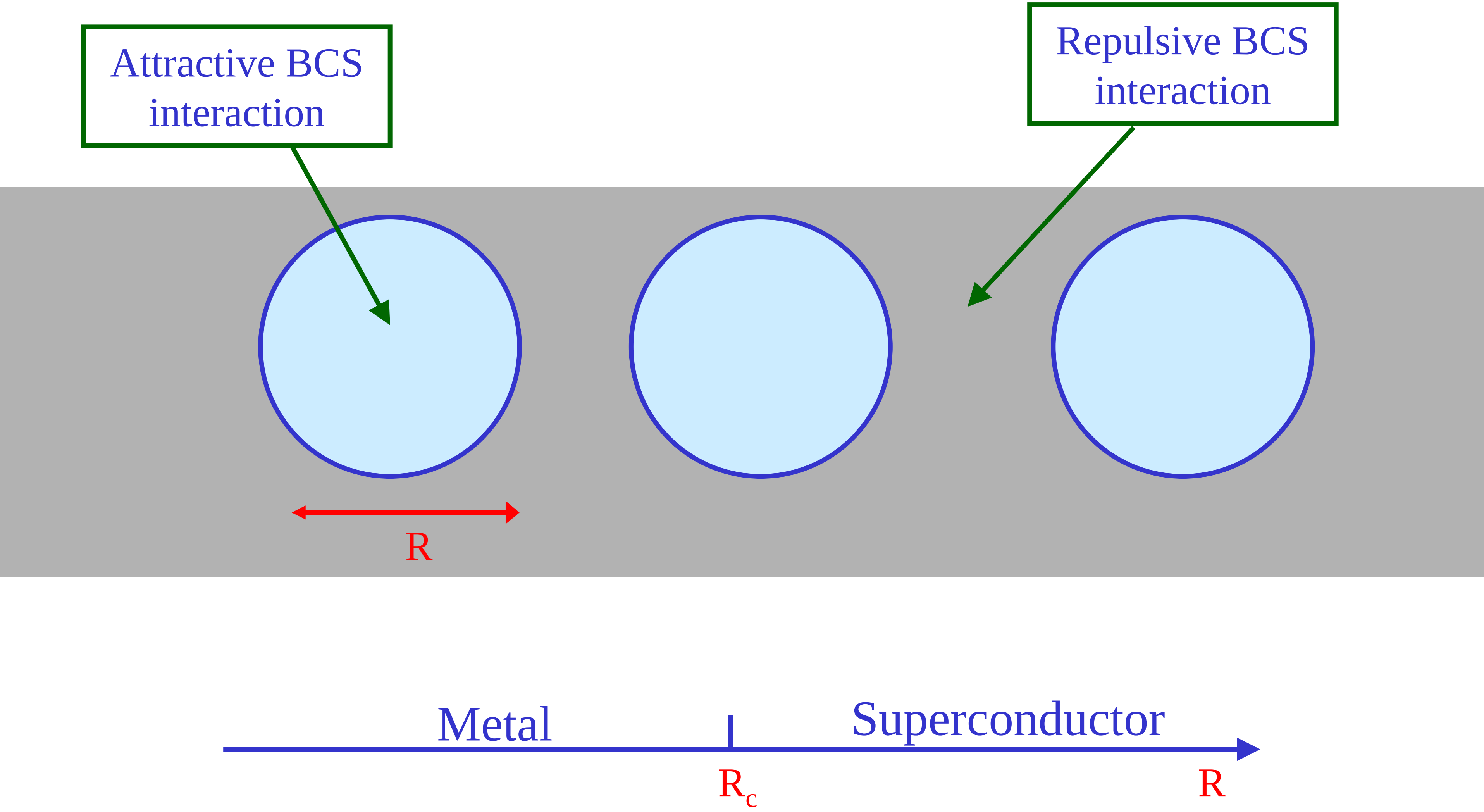
cond-mat/0402431

Talk online:
Google Sachdev

T=0 Superconductor-metal transition



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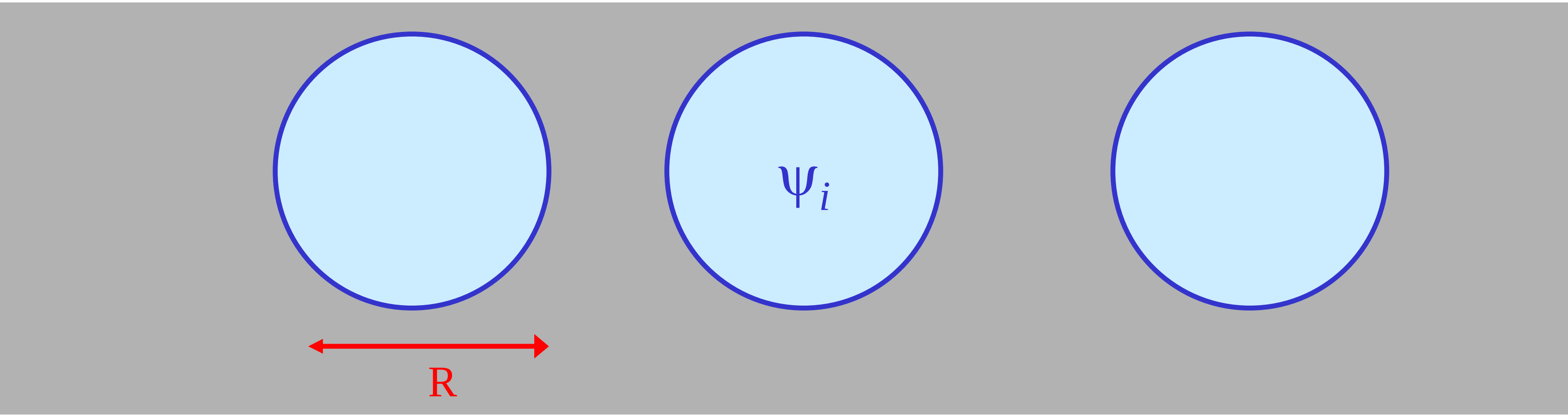
$T=0$ Superconductor-metal transition



$$\mathcal{S} = -\int d\tau \sum_{i,j} J_{ij}\psi_i^*(\tau)\psi_j(\tau) - \int d\tau d\tau' \sum_i \frac{\psi_i^*(\tau)\psi_i(\tau')}{(\tau-\tau')^2}$$

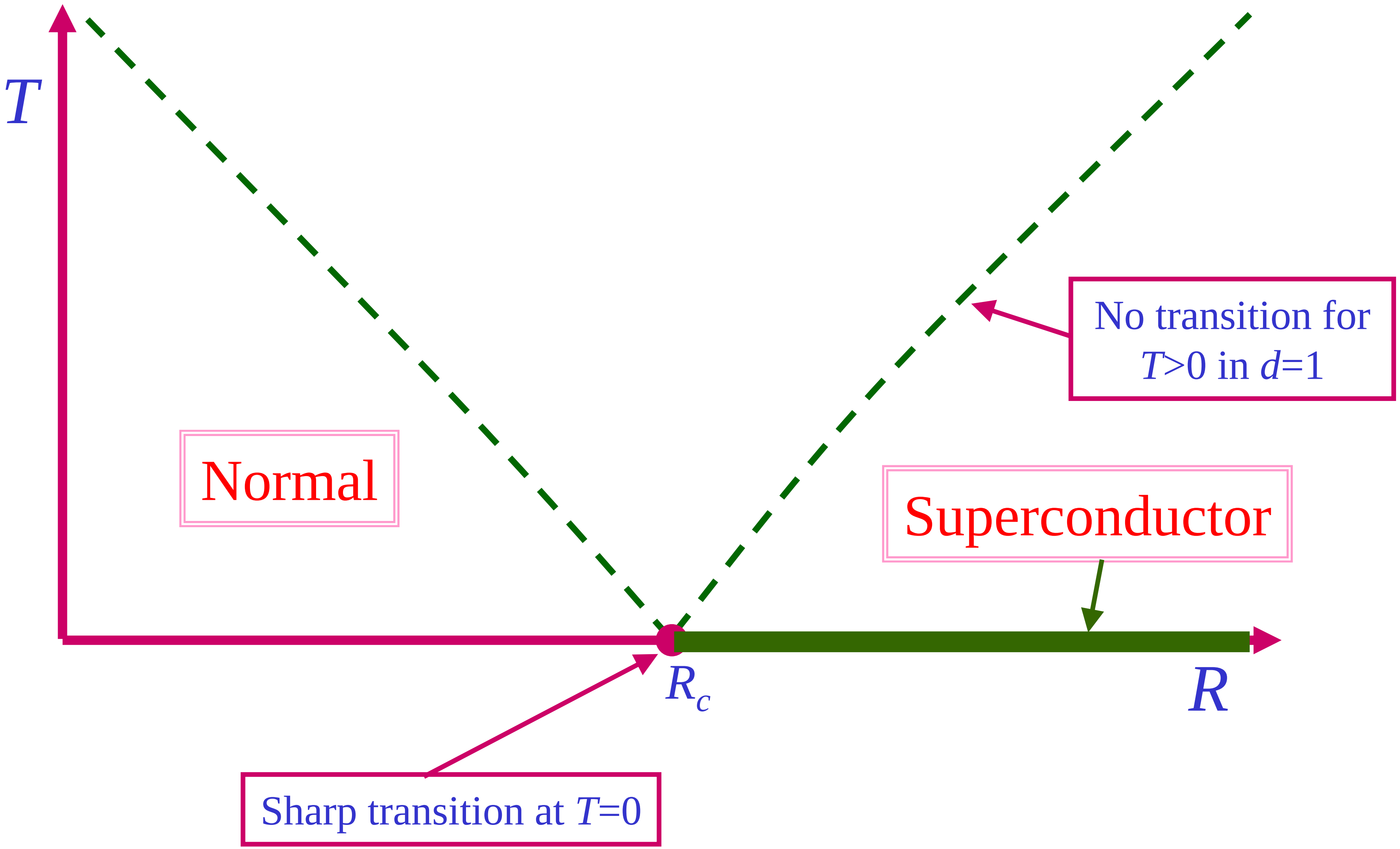
Continuum theory for quantum critical point

$$\mathcal{S}_{\text{bulk}} = \frac{A}{\hbar}\int_0^L dx \left[\int_0^\beta d\tau \left(\delta|\partial_x\psi|^2 + a|\psi|^2 + \frac{b}{2}|\psi|^4\right) + \frac{\hbar\gamma}{\beta}\sum_{\omega_n}|\omega_n||\psi(x,\omega_n)|^2\right],$$

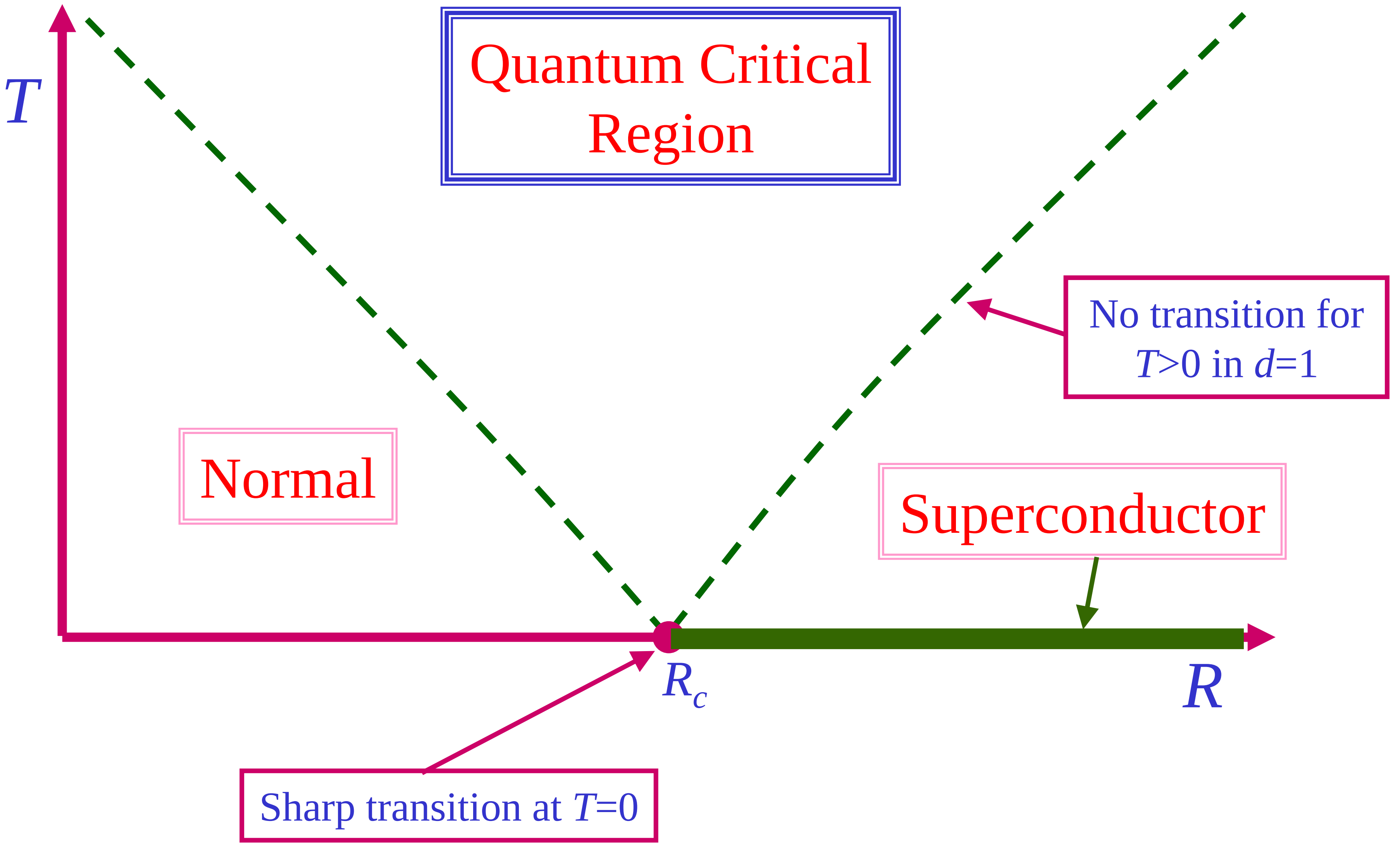
Obeys strong hyperscaling properties in spatial dimensions $d < 2$.
Critical properties can be determined by an expansion in $\epsilon = 2 - d$ in a theory with n-component fields ($n = 2$ here).

$$\begin{aligned} z &= 2 - \eta \\ \eta &= \frac{(n+2)(12-\pi^2)}{4(n+8)^2}\epsilon^2 \\ \nu &= \frac{1}{2} + \frac{(n+2)}{4(n+8)}\epsilon + \frac{(n+2)(n^2 + (38 - 7\pi^2/6)n + 132 - 19\pi^2/3)}{8(n+8)^3}\epsilon^2 \end{aligned}$$

Consequences of hyperscaling



Consequences of hyperscaling



Consequences of hyperscaling

Quantum Critical Region

The conductance g obeys

$$g = \frac{4e^2}{h}\Phi\left(c_1 T L^z, \frac{\hbar\omega}{k_B T}\right)$$

where Φ is a universal function and only constant c_1 is non-universal.

For $L > (c_1 T)^{-1/z}$, we have hydrodynamic, "incoherent" transport and $g = \sigma/L$, where σ is the conductivity which is *independent of the leads* and obeys

$$\sigma = \frac{4e^2}{h}\frac{1}{(c_1 T)^{1/z}}\Phi_1\left(\frac{\hbar\omega}{k_B T}\right)$$

Consequences of hyperscaling

Quantum Critical Region

The conductance g obeys

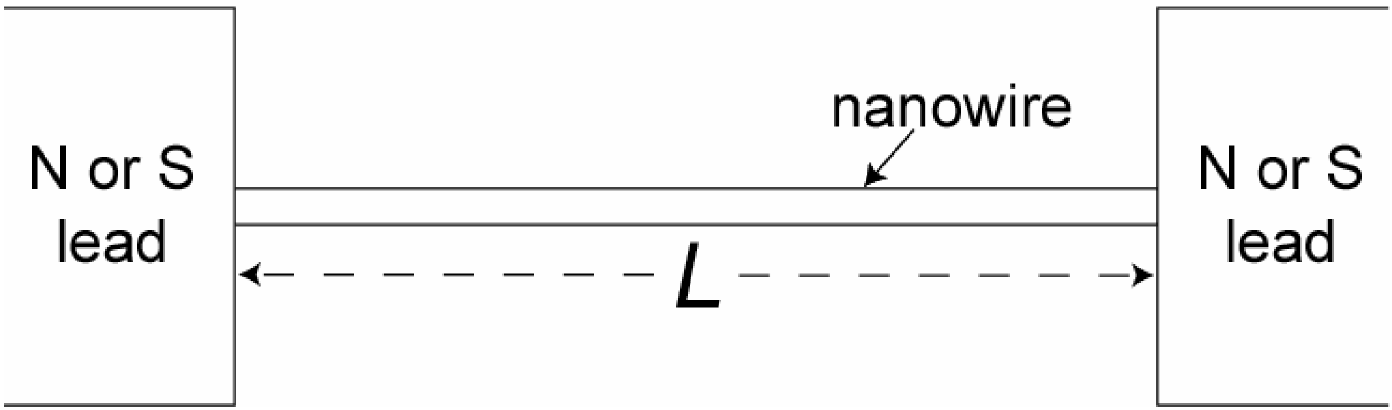
$$g = \frac{4e^2}{h}\Phi\left(c_1 T L^z, \frac{\hbar\omega}{k_B T}\right)$$

where Φ is a universal function and only constant c_1 is non-universal.

For $L < (c_1 T)^{-1/z}$, we have "coherent" transport, and the d.c. conductance is independent of L, but sensitive to the nature of the leads.

$$g = \frac{4e^2}{h}F\left(c_1 \omega L^z\right)$$

Effect of the leads



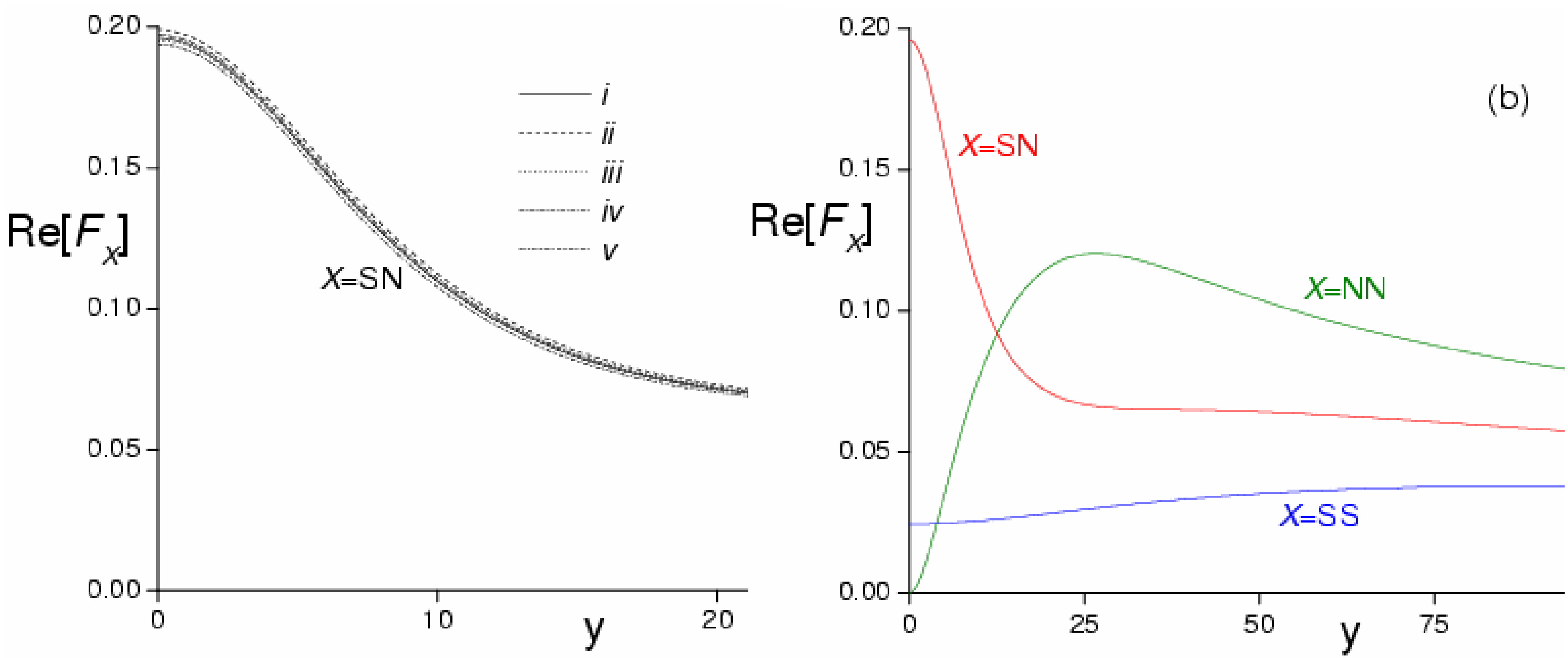
$$\mathcal{S}_{\text{lead}} = \int d\tau \left[-H^* \psi(0,\tau) - H \psi^*(0,\tau) + C |\Psi(0,\tau)|^2 \right]$$

where $H \neq 0$ for a superconducting lead.

Both H and C scale to strong-coupling, and therefore we have Dirichlet boundary conditions ($\Psi = 0$) for a N lead, and Fixed boundary conditions for a S lead

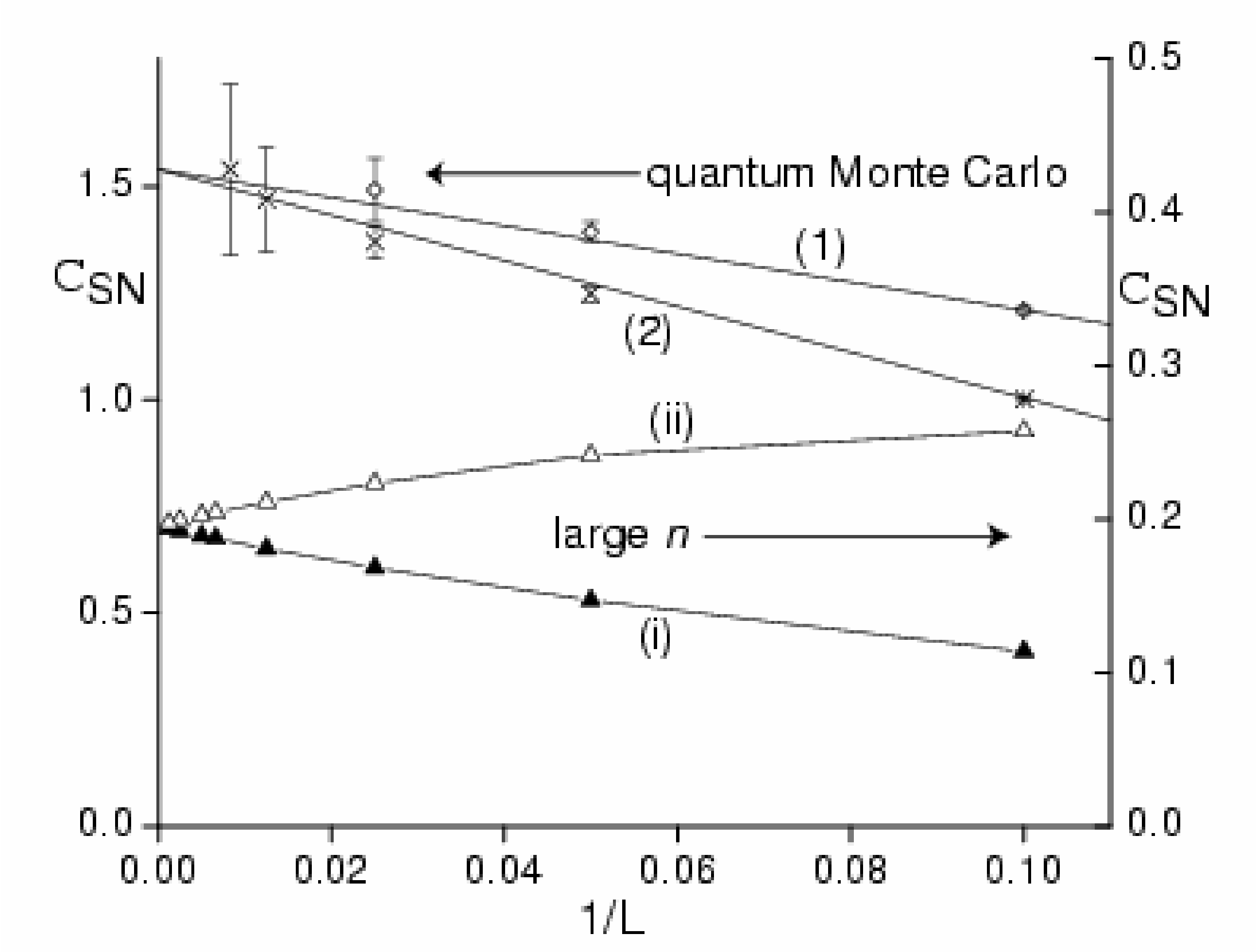
Conductance is *independent* of the specific bare values of H and C.

Large n computation of conductance



$$g = \frac{4e^2}{h} F_X(y) \quad ; \quad y = c_1 \omega L^z$$

Quantum Monte Carlo and large *n* computation of d.c. conductance



$$g = \frac{4e^2}{h} C_{SN}$$

Conclusions

- Universal transport in wires near the superconductor-metal transition
- Theory includes contributions from thermal and quantum phase slips ---- reduces to the classical LAMH theory at high temperatures
- Sensitivity to leads should be a generic feature of the ``coherent’’ transport regime of quantum critical points.