Application of SYK models to strange metals

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Jerusalem Winter School,
January 3, 2019

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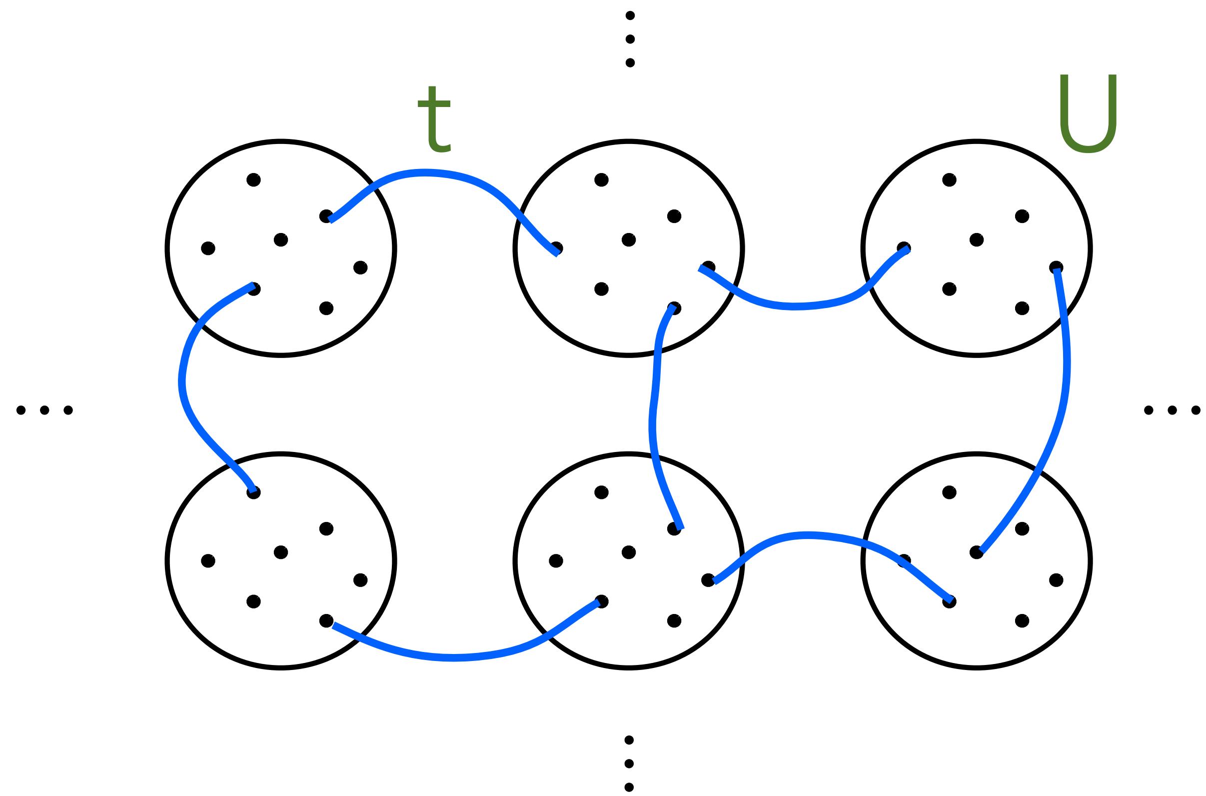
arXiv:1705.00117

See also A. Georges and O. Parcollet PRB **59**, 5341 (1999)

Title: A strongly correlated metal built from Sachdev-Ye-Kitaev models

Authors: Xue-Yang Song, Chao-Ming Jian, Leon Balents



$$H = \sum_{x} \sum_{i<j,k<l} U_{ijkl,x} c^{\dagger}_{ix} c^{\dagger}_{jx} c_{kx} c_{lx} + \sum_{\langle xx' \rangle} \sum_{i,j} t_{ij,xx'} c^{\dagger}_{i,x} c_{j,x'}$$

$$\overline{|U_{ijkl}|^2} = \frac{2U^2}{N^3} \qquad \overline{|t_{ij,x,x'}|^2} = t_0^2/N$$

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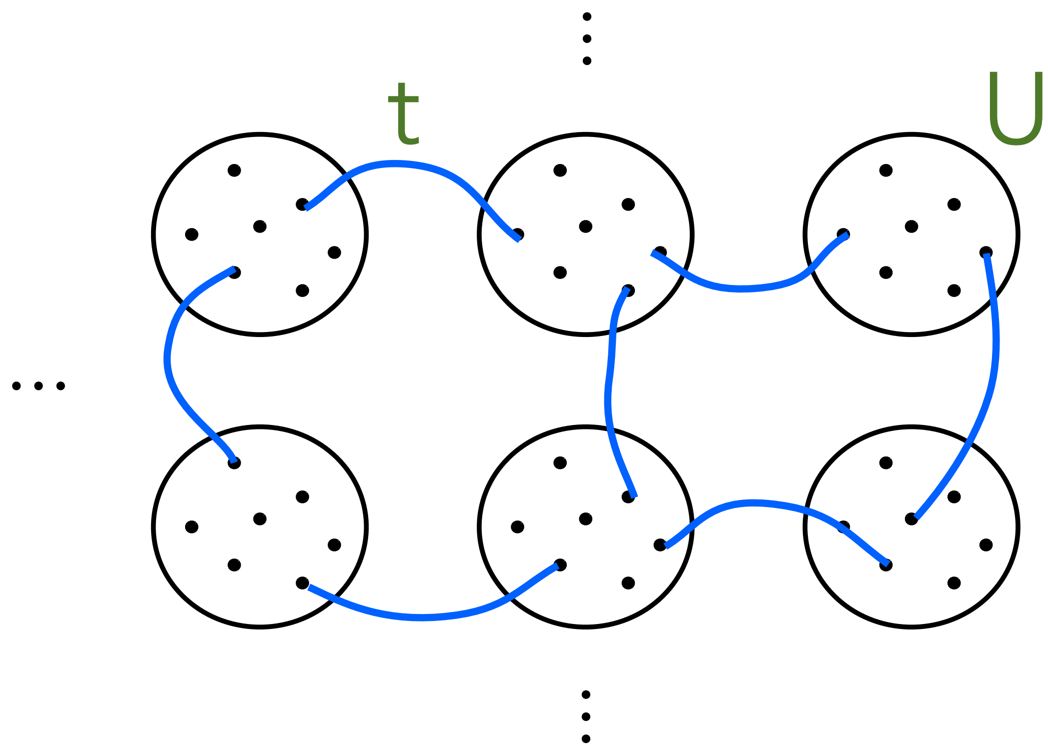
Self-consistent equations



$$G(i\omega_n)^{-1} = i\omega_n + \mu - \Sigma_4(i\omega_n) - zt_0^2 G(i\omega_n),$$
$$\Sigma_4(\tau) = -U_0^2 G(\tau)^2 G(-\tau),$$

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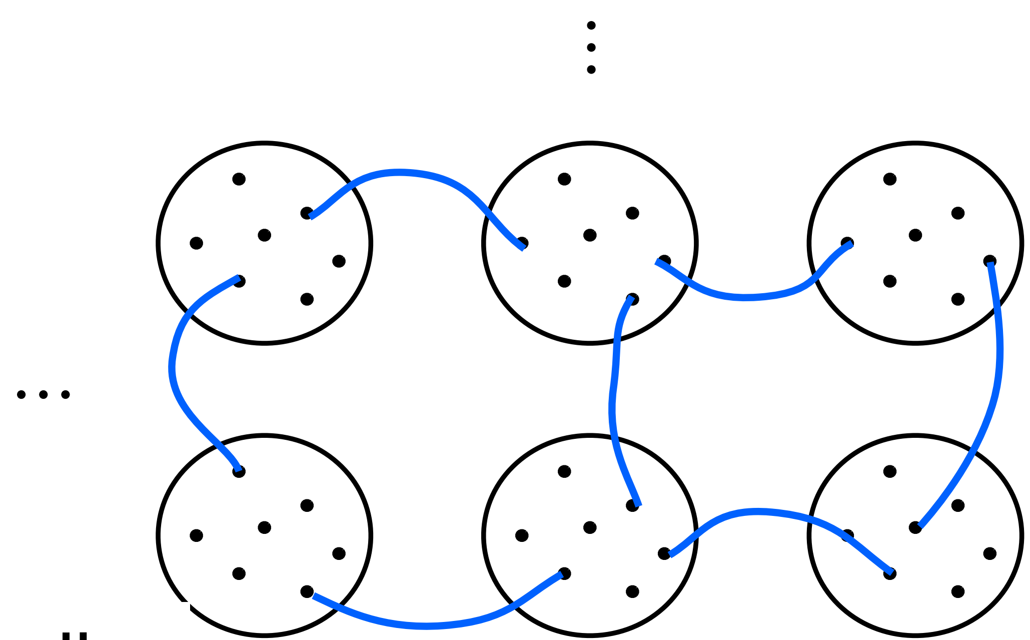
Coherence scale



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$$\Sigma_4(\tau) = -U_0^2 G(\tau)^2 G(-\tau),$$

$$\bar{G}(i\bar{\omega}) = \tilde{t} G(i\omega)$$

Rescaling

$$\bar{\omega} = \frac{\omega}{\tilde{E}_c}, \quad \bar{\tau} = \tau \tilde{E}_c, \quad \bar{G}(i\bar{\omega}) = \tilde{t} G(i\omega) \quad \bar{\Sigma}(i\bar{\omega}) = \Sigma(i\omega)/\tilde{t} \quad \tilde{t} = \left(\frac{z}{2}\right)^{\frac{1}{2}} t$$

$$\bar{G}(i\bar{\omega}) = \frac{\tilde{t}}{U} i\bar{\omega} - \bar{\Sigma}(i\bar{\omega}) \qquad \bar{\Sigma}(\bar{\tau}) = -\bar{G}(\bar{\tau})^2 \bar{G}(-\bar{\tau}) + 2\bar{G}(\bar{\tau}),$$

For t≪U, a single universal coherence scale appears $\tilde{E}_c = \frac{\tilde{t}^2}{U}$

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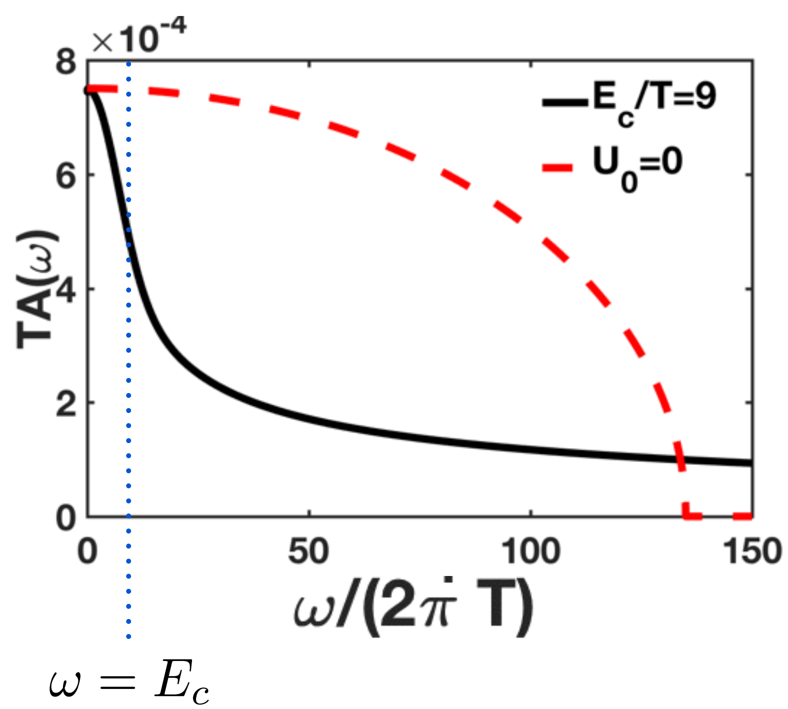
We solve these equations in a real time Keldysh formulation numerically and determine asymptotics analytically.



Narrow "coherence peak" appears in spectral function: heavy quasiparticles form for $T \ll E_c$

Quasiparticle weight $Z \sim t/U$

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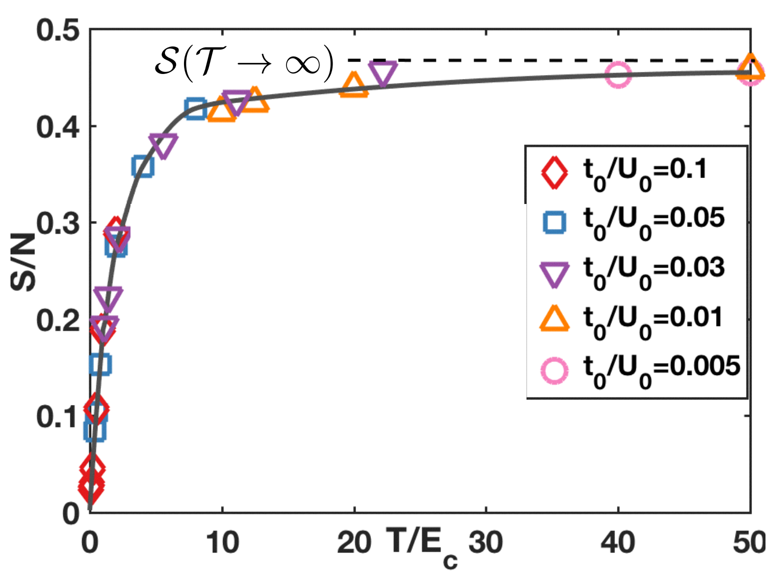
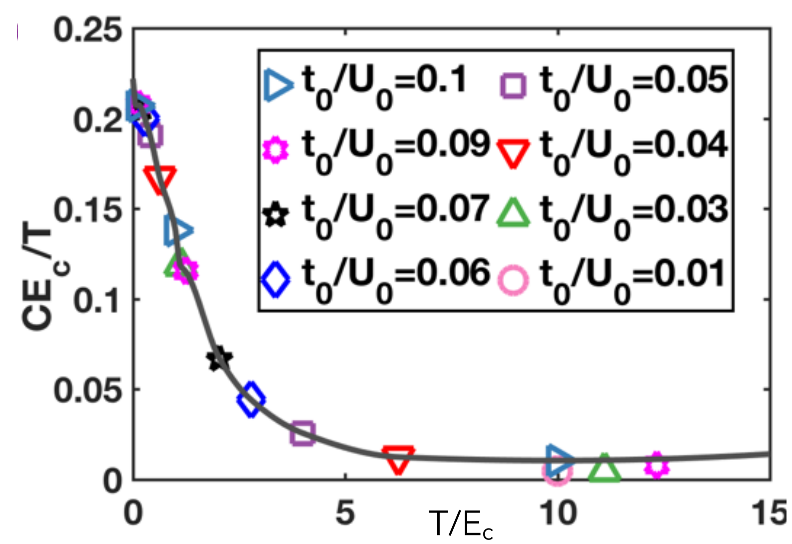
Entropy

Level repulsion: entropy is released for $T<E_c$!





Universal scaling forms

$$S/N = \mathcal{S}(T/E_c)$$

$$C/N = T/E_c \mathcal{S}'(T/E_c)$$

$$\gamma \equiv \lim_{T\to 0} \frac{C}{T} = \frac{\mathcal{S}'(0)}{E_c}$$

Sommerfeld enhancement

$$m^*/m \sim U/t$$

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Conductivity

From the Kubo formula, we have the conductivity

$$\mathrm{Re}[\sigma(\omega)] \propto t_0^2 \int d\Omega \frac{f(\omega+\Omega) - f(\Omega)}{\omega} A(\Omega) A(\omega+\Omega)$$

where $A(\omega) = \mathrm{Im}[G^R(\omega)]$.
At $T > E_c$ this yields

$$\sigma \sim \frac{e^2}{h} \frac{t_0^2}{U} \frac{1}{T}$$

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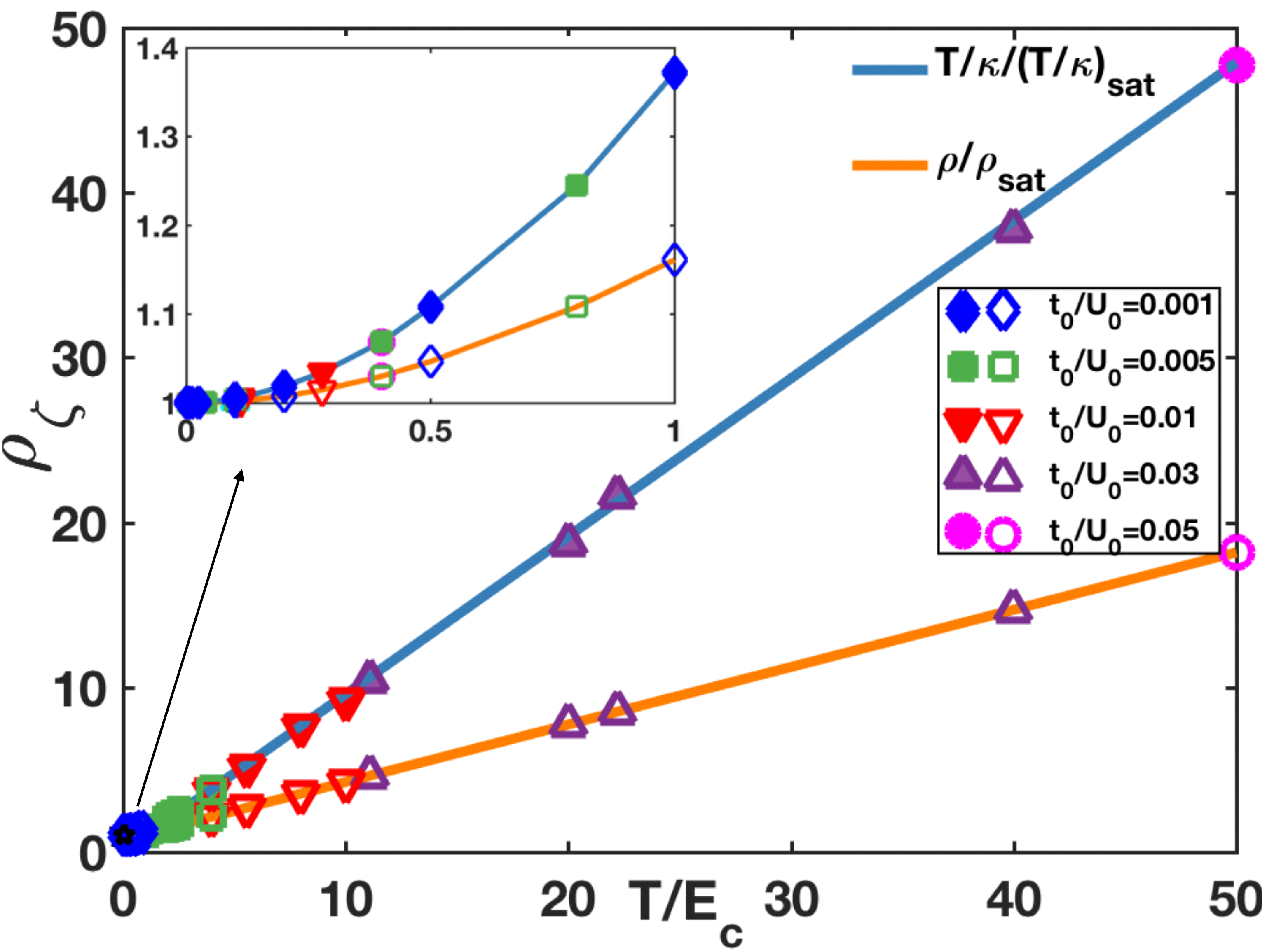
Low 'coherence' scale



$$E_c \sim \frac{t_0^2}{U}$$

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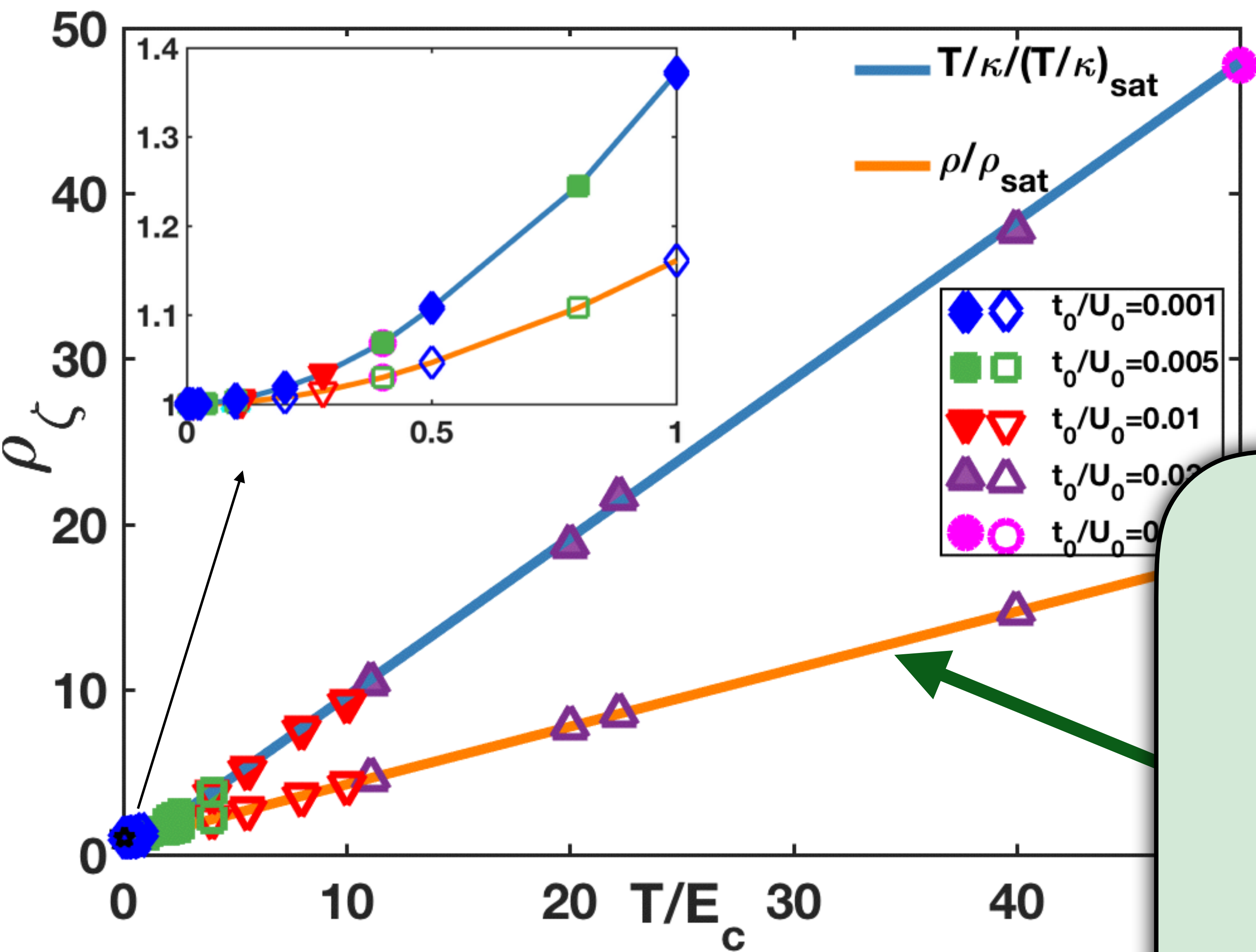

For $E_c < T < U$, the resistivity, ρ, and entropy density, s, are

$$\rho \sim \frac{h}{e^2}\left(\frac{T}{E_c}\right), \quad s = s_0$$

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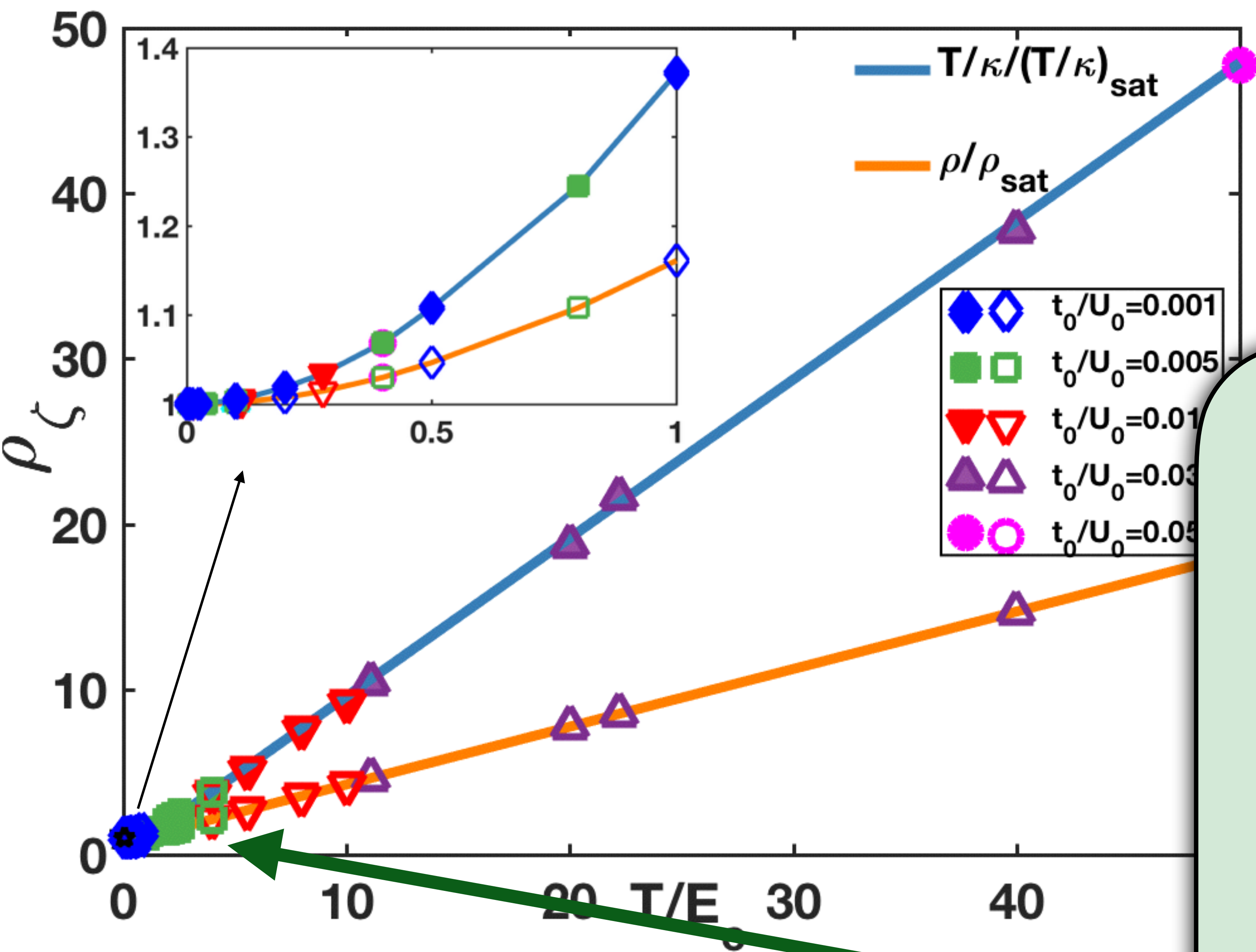

For $T < E_c$, the resistivity, ρ, and entropy density, s, are

$$\rho = \frac{h}{e^2}\left[c_1 + c_2\left(\frac{T}{E_c}\right)^2\right]$$

$$s \sim s_0\left(\frac{T}{E_c}\right)$$