A Multicanonical Monte Carlo Study of the 3D $\pm J$ Spin Glass

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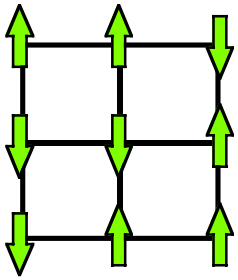
The $\pm J$ Model

$$H = -\sum_{\alpha=1,2} \sum_{\langle i,j \rangle} J_{ij} \sigma_i^{(\alpha)} \sigma_j^{(\alpha)}$$

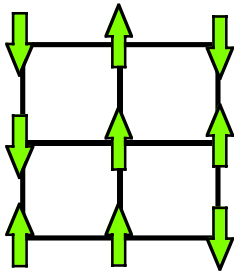
$$J_{ij} = \pm 1 \text{ (quenched)}$$

Overlap Order Parameter

$$q = \frac{1}{N} \sum_{i=1}^{N} \sigma_i^{(1)} \sigma_i^{(2)}$$



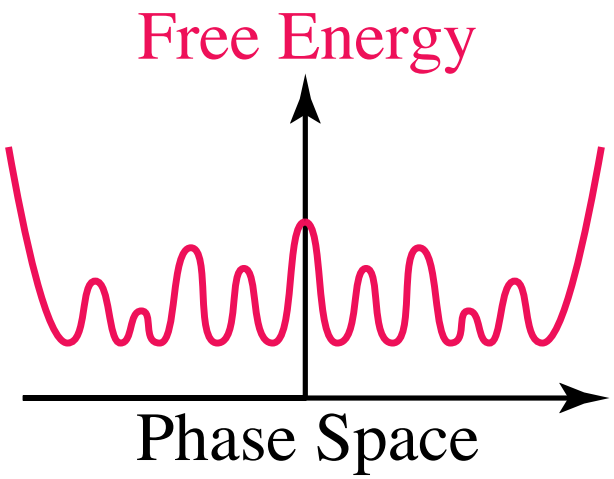
replica 1

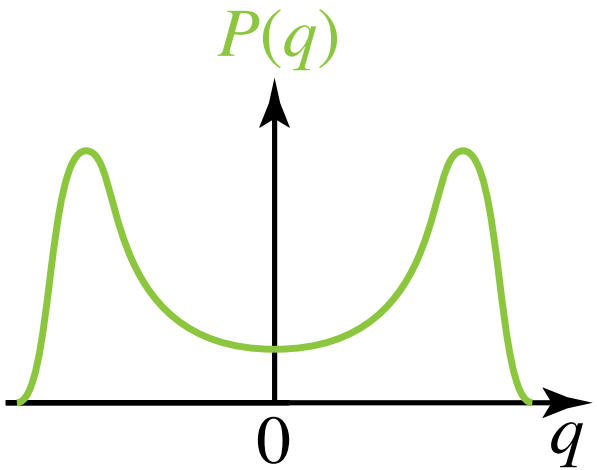


replica 2

Low-Temperature Phase

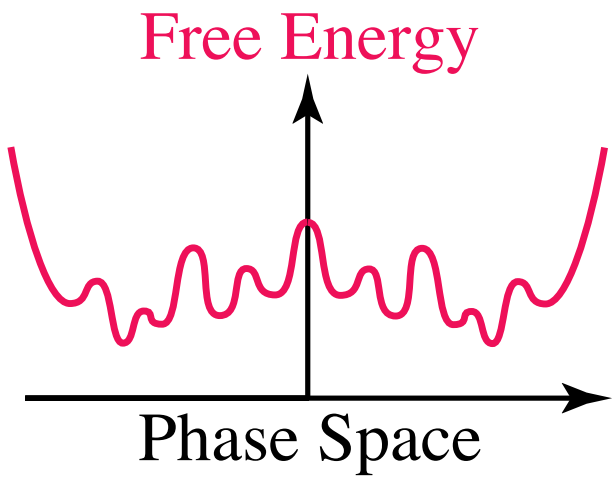
Mean-field picture
(Parisi *et al.*)

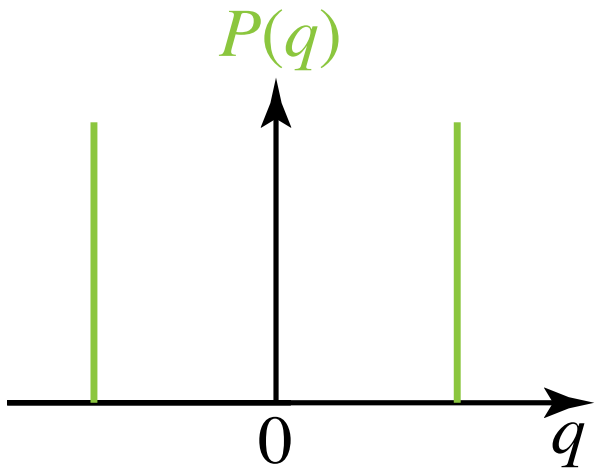




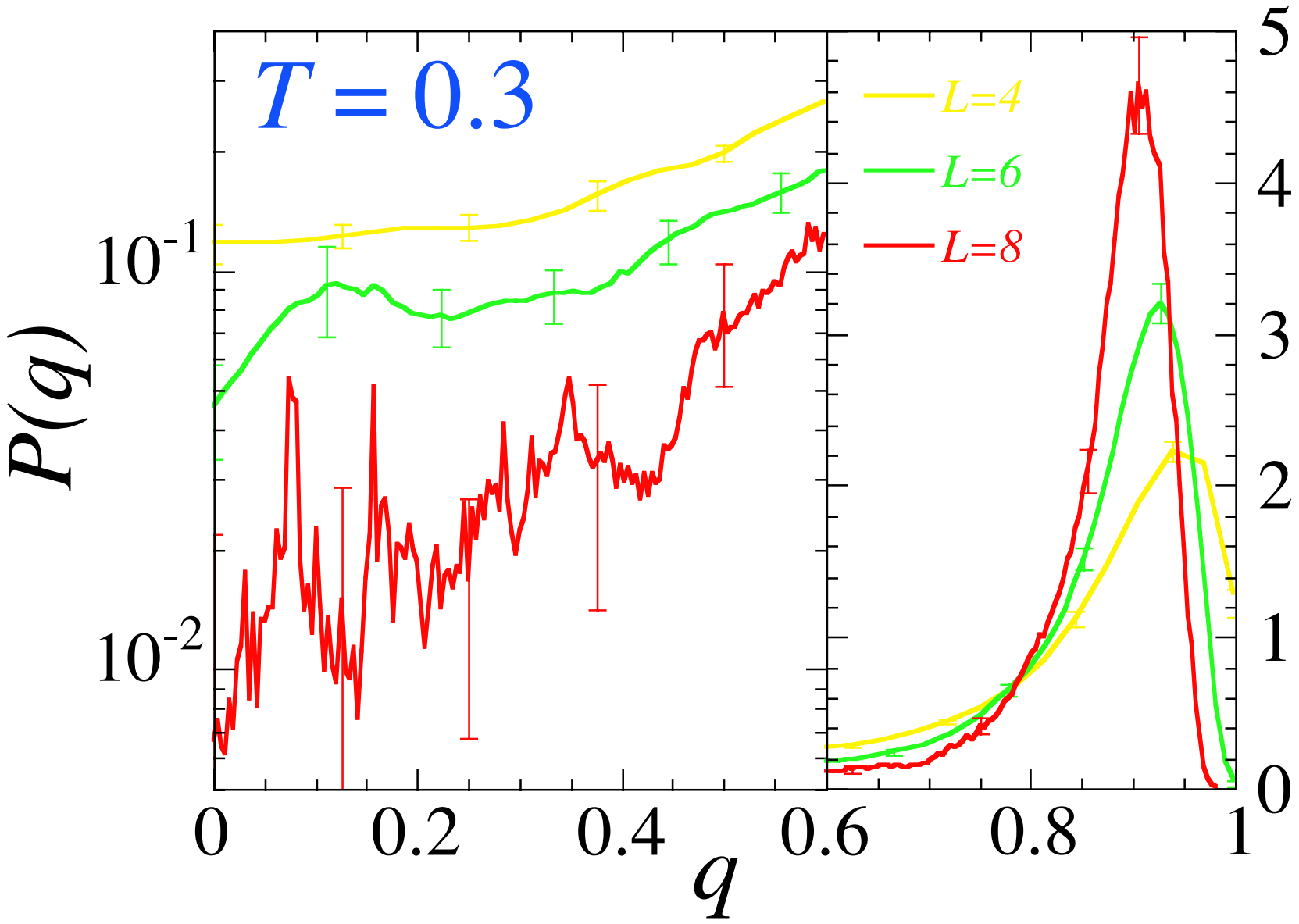
$$L \to \infty$$
$$T \approx 0$$

Droplet picture
(Fisher & Huse)

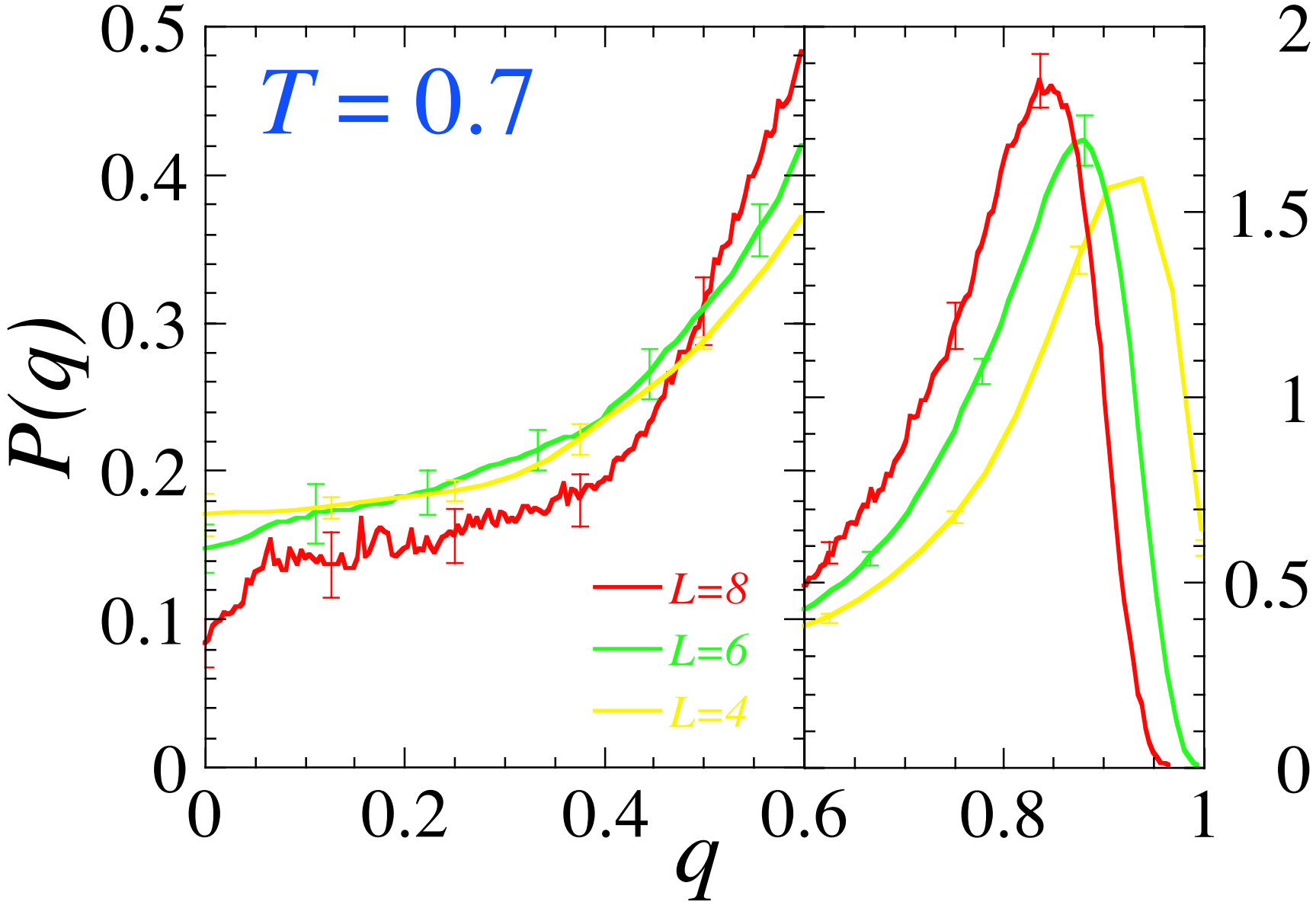




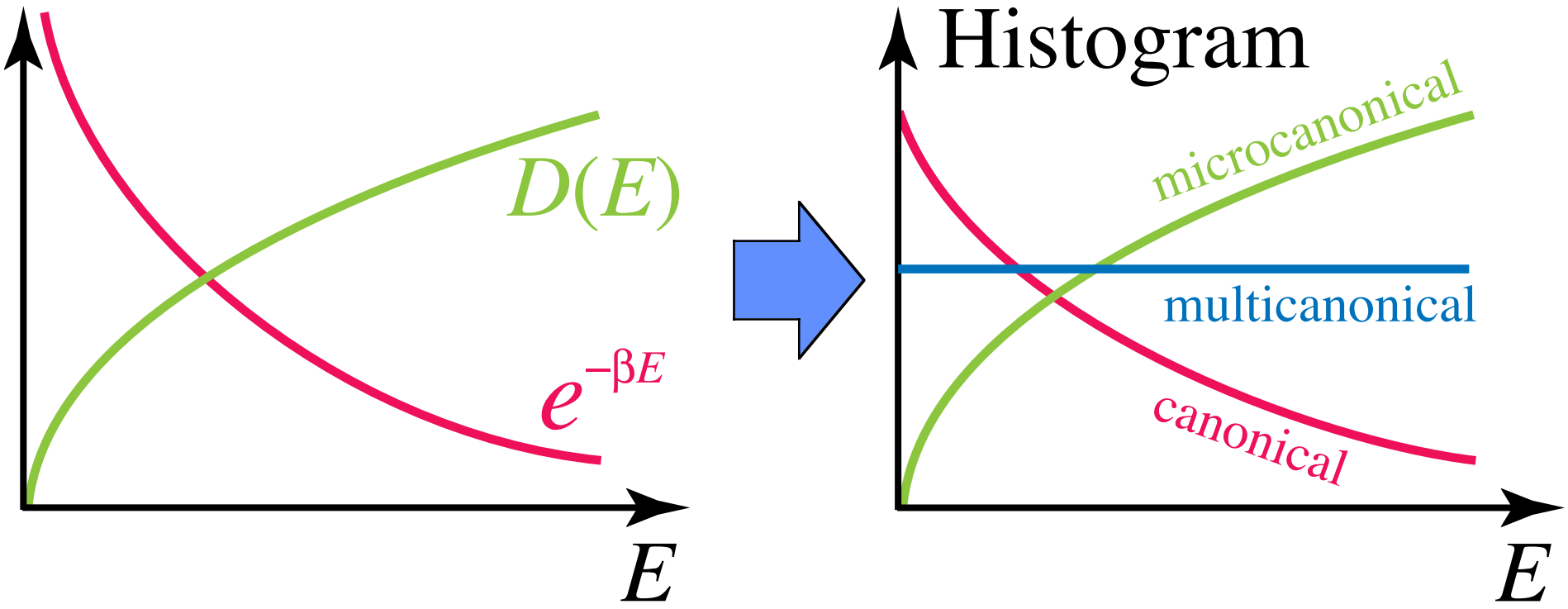
Order-Parameter Distribution



At higher temperatures



Flattening the histogram



Microcanonical: Few low-energy states

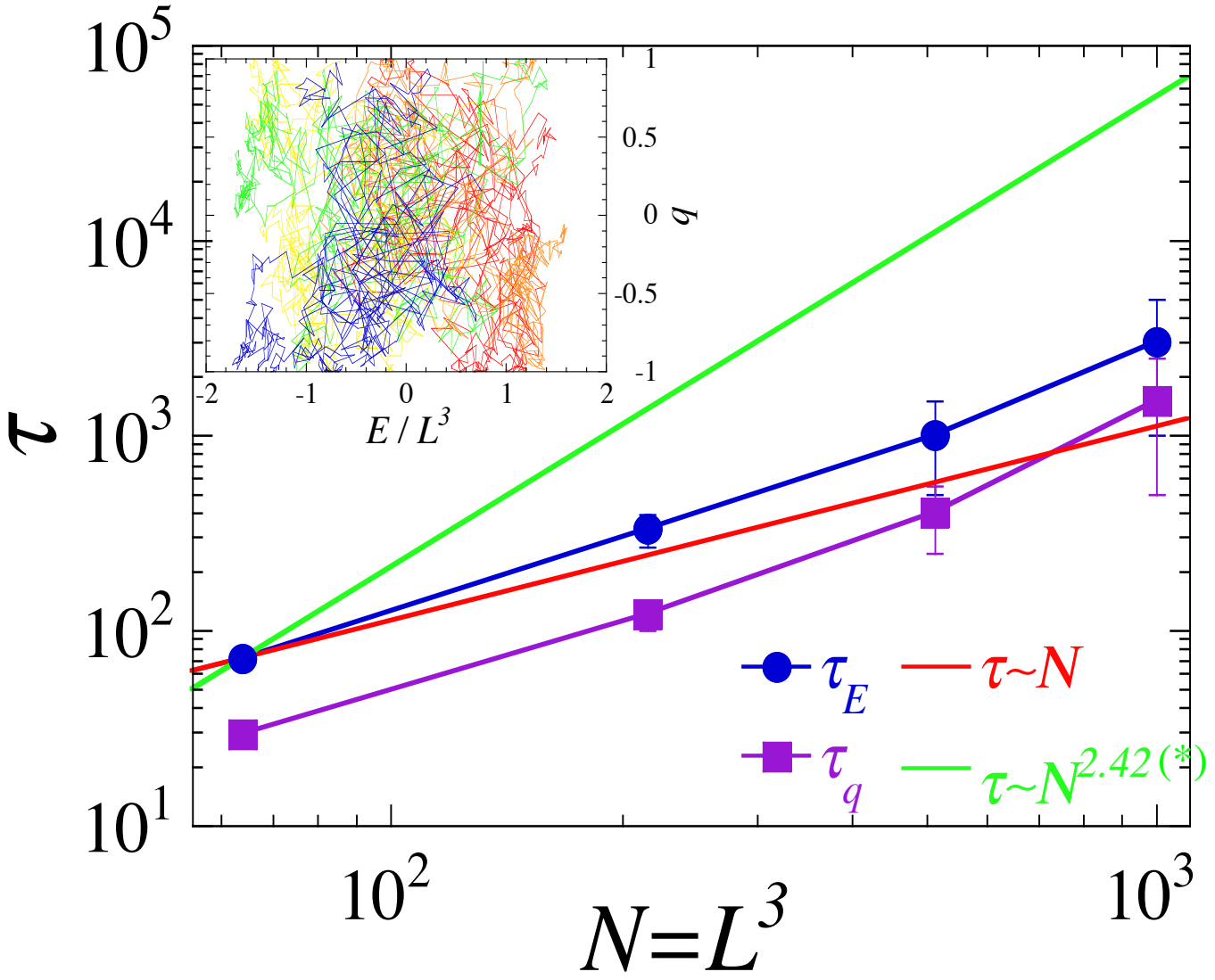
Canonical: Few high-energy states

Trapped by local minima

Multicanonical: Samples uniformly

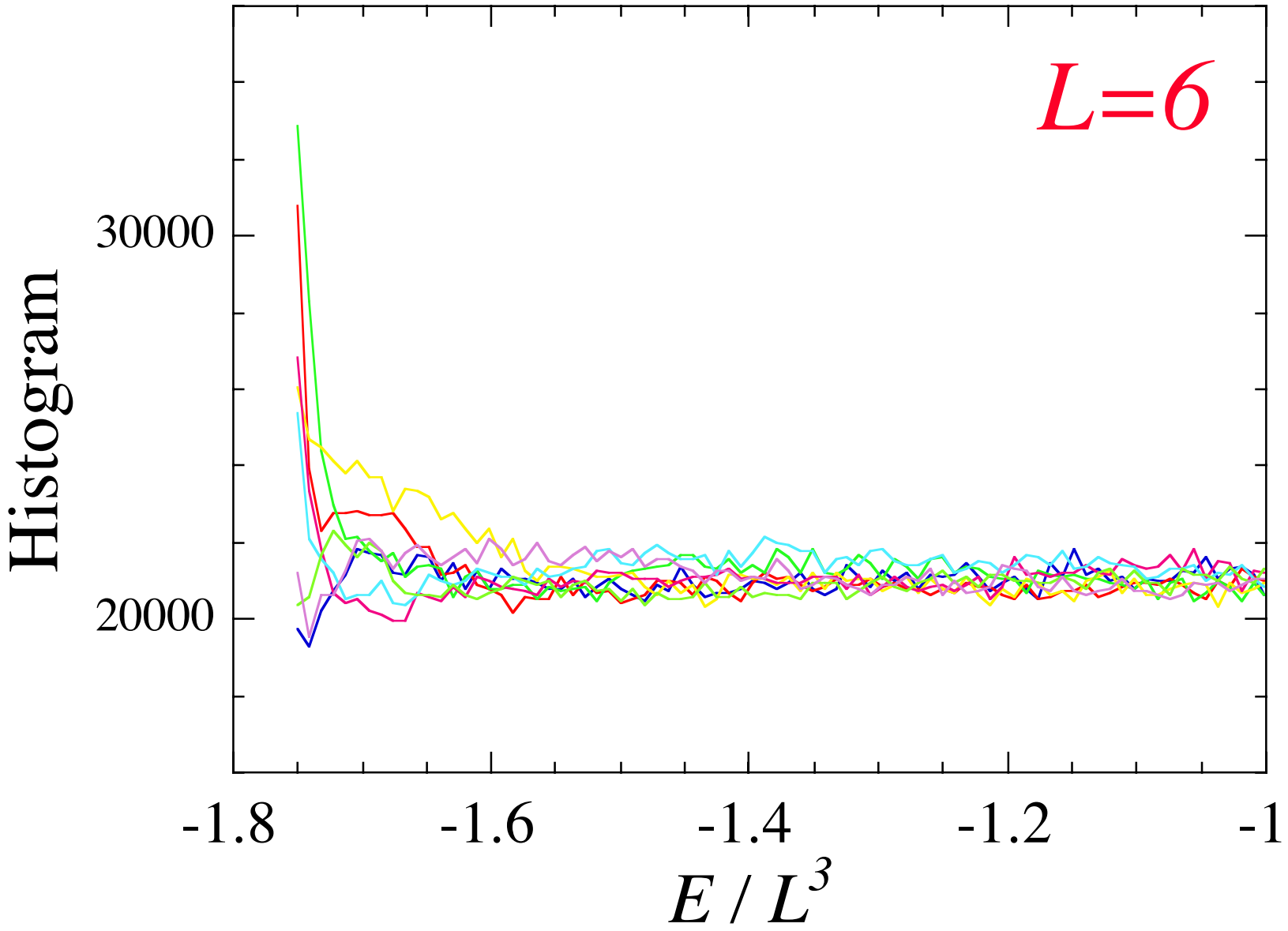
Auto-Correlation Time

Making the bivariate histogram $h(E,q)$ flat

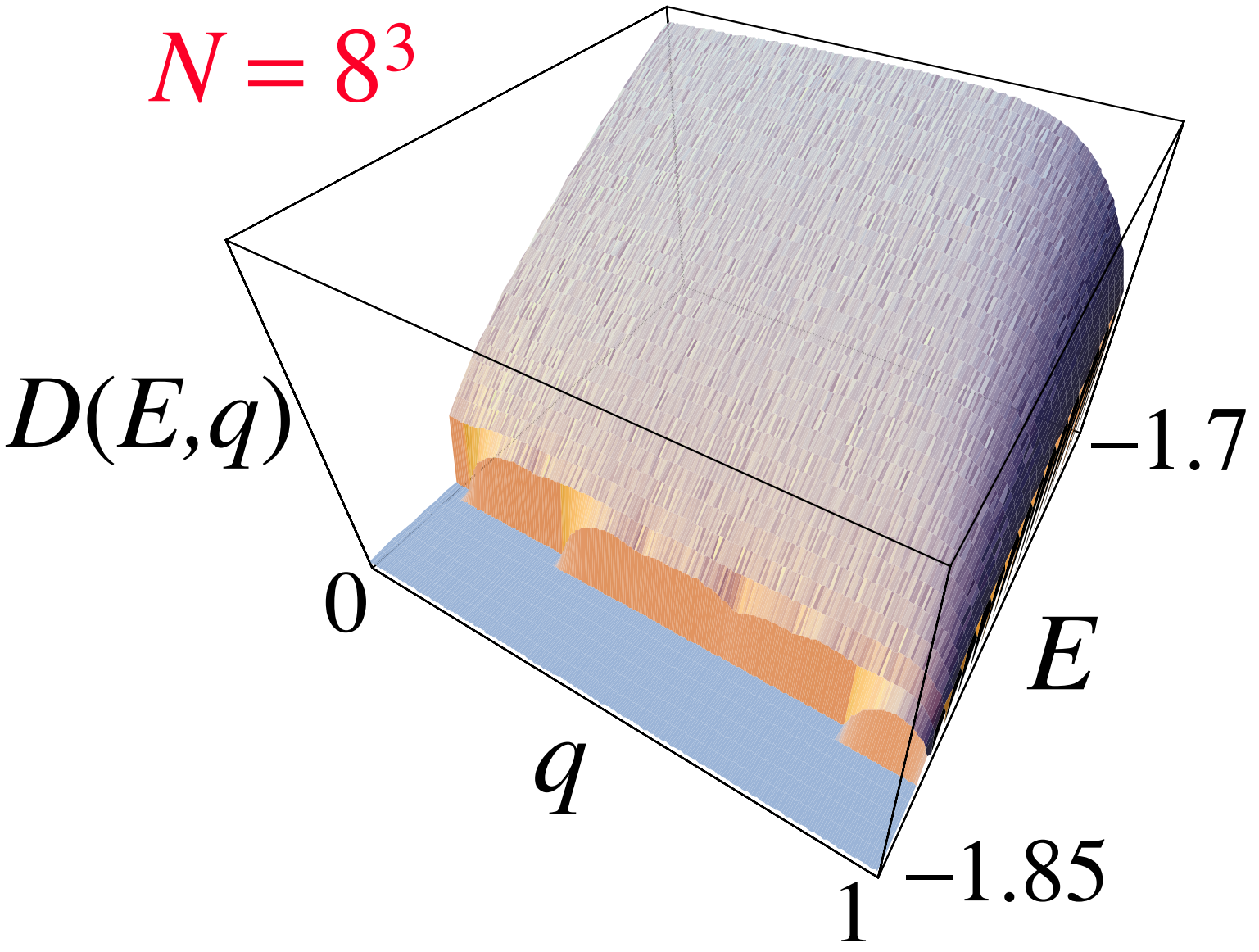


(*) Monovariate multicanonical
Berg & Janke, PRL**80**, 4771 ('98)

Monovariate Multicanonical



Density of States $D(E,q)$



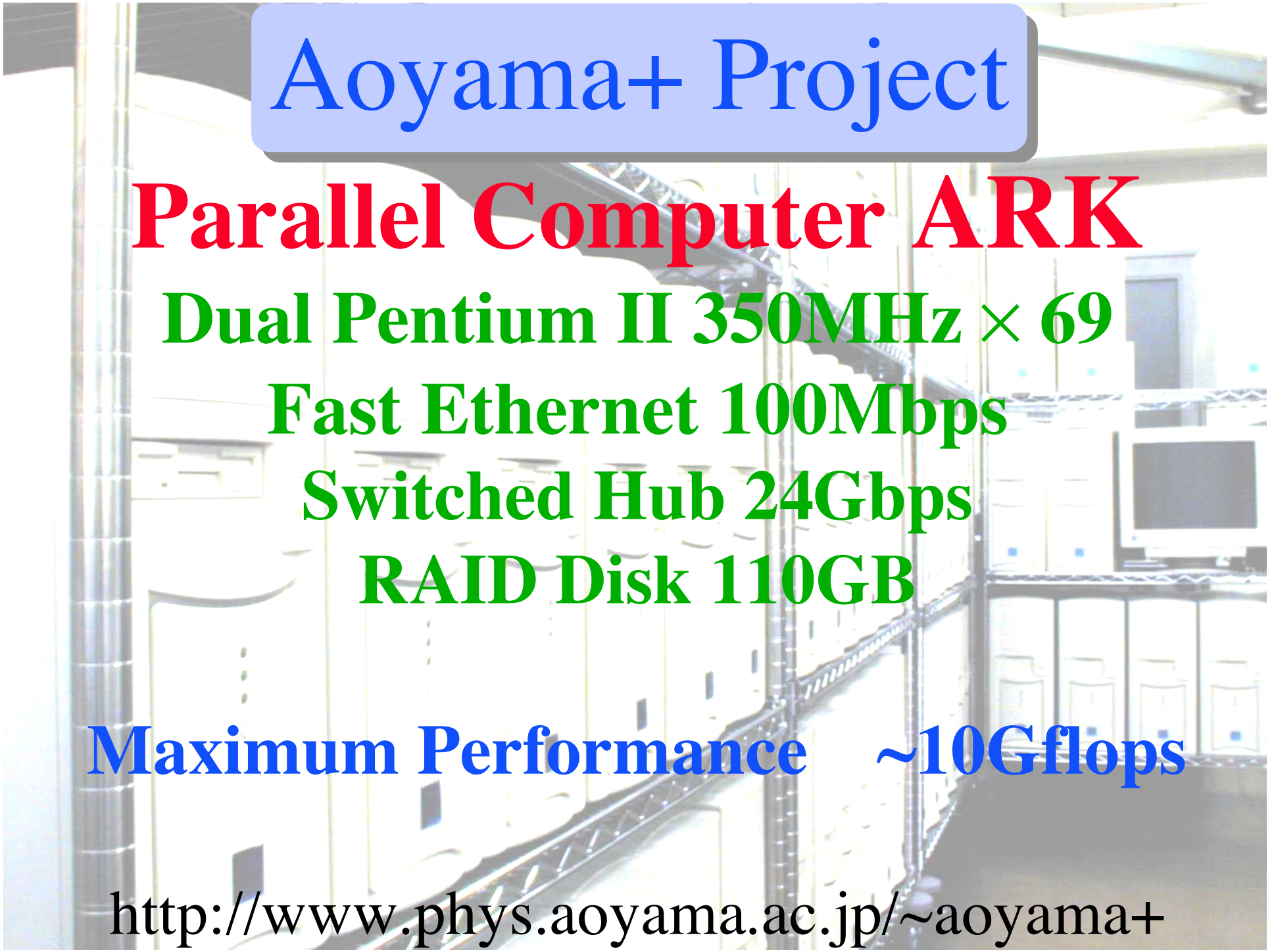
Summary

- Bivariate Multicanonical Monte Carlo Method

  $\rightarrow$ Correlation Time: $\tau \sim N$

- Low-Temperature Phase

  $\rightarrow$ The result of $P(q; T=0.3)$ suggests the droplet picture



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