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

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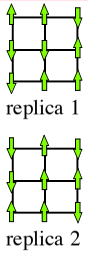
## The $\pm J$ Model

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

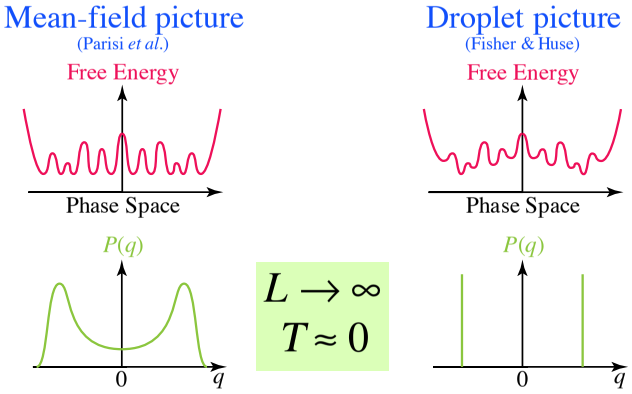
$J_{ij} = \pm 1$ (quenched)

Overlap Order Parameter

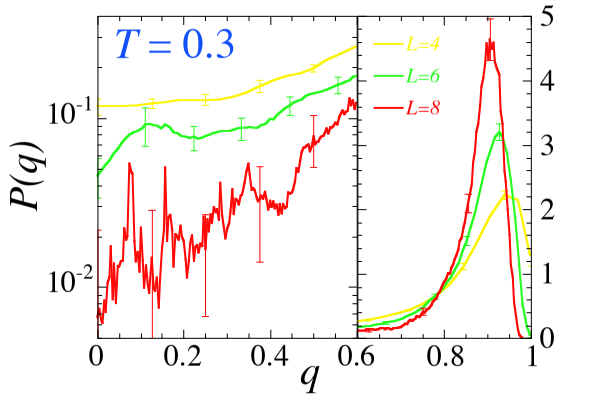
$$q = \frac{1}{N} \sum_{i=1}^{N} \sigma_i^{(1)} \sigma_i^{(2)}$$



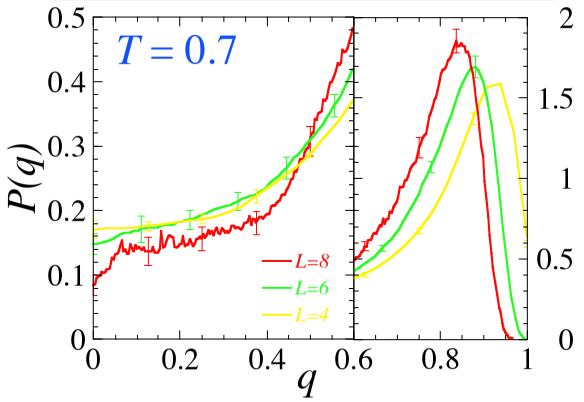

## Low-Temperature Phase



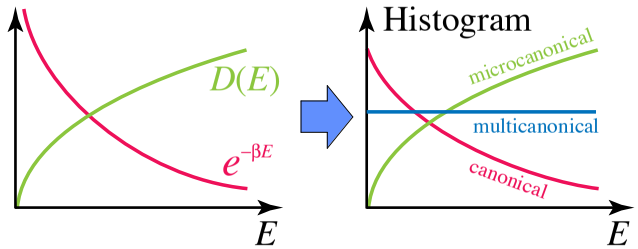

## Order-Parameter Distribution




## At higher temperatures



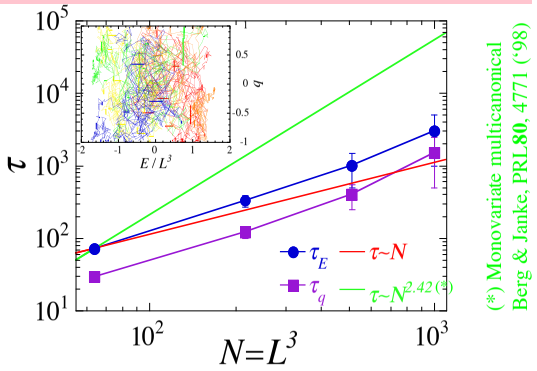

## Flattening the histogram



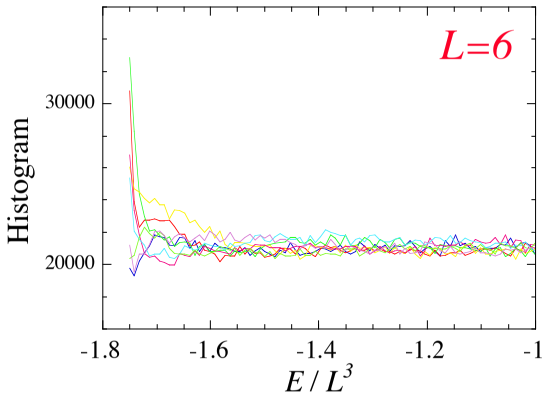

Microcanonical: Few low-energy states
Canonical: Few high-energy states
Trapped by local minima
Multicanonical: Samples uniformly

## Auto-Correlation Time

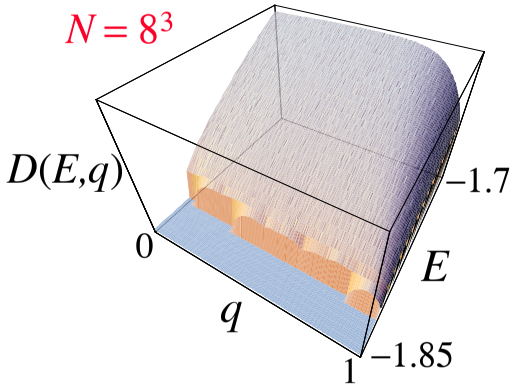
Making the bivariate histogram $h(E,q)$ flat




## Monovariate Multicanonical




## Density of States $D(E,q)$




## Summary

- Bivariate Multicanonical Monte Carlo Method
  → Correlation Time: $\tau \sim N$
- Low-Temperature Phase
  → The result of $P(q; T=0.3)$ suggests the droplet picture

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