Many-Body Localization by DMRG and ED Studies

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KITP workshop

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Preprints: ArXiv1509.06786; 1510.08145

Outline

Introduction: Many-body localization (MBL)
Numerical studies of MBL phase and transition
Different DMRG (MPS) for Ex-states

Our DMRG for Ex: A modified DMRG algorithm for accurately obtaining excited states

Nontrivial Distributions for MBL: for larger systems N=24--72

Address and discuss open issues: intermediate (Griffiths) regime and phase transition-ED/DMRG
Mobility edge (large-N DMRG results and scaling)
—spin ½ Heisenberg model in random fields

MBL phase and numerical studies

Reviews: Nandkishore & Huse (2015); Altman & Vosk (2015)

Many-body localization: an MBL at finite energy density exhibits Anderson localization

MBL cannot thermalize: this violates the interacting system "eigenstate thermalization hypothesis (ETH)"

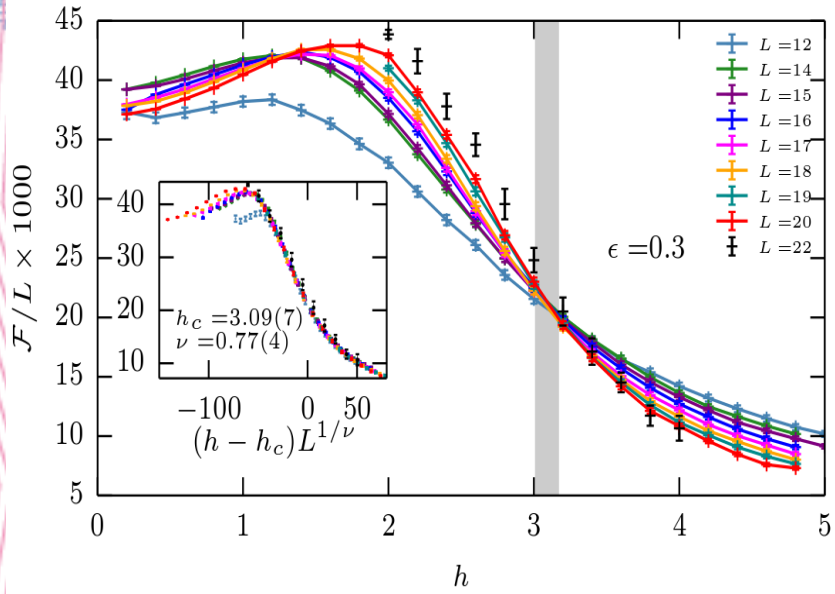
MBL state has low entanglement ---allowing developing DMRG (MPS) related algorithms

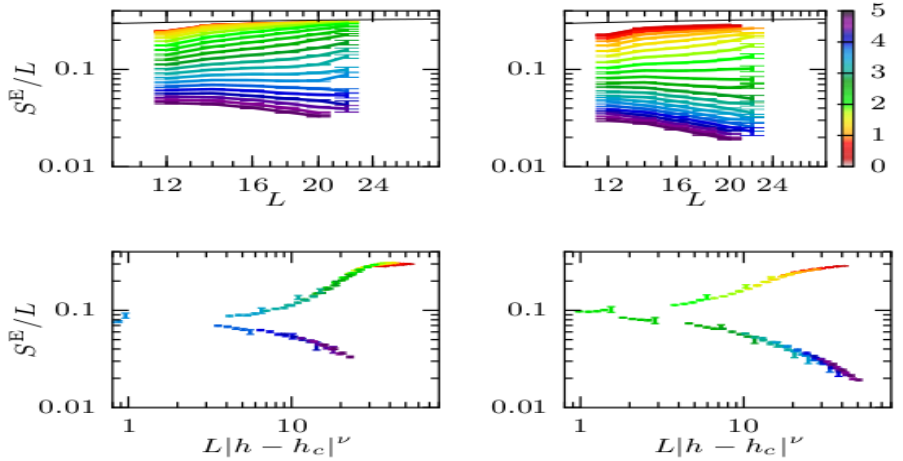
Numerical studies of 1D models, 2-leg ladders---phases and transition. 1D: Luitz et al. (2015), Kjall et al (2014), Oganesyan & Huse (2007), Pal & Huse (2008); Monthus & Garel (2010), Iyer et al. (2013)

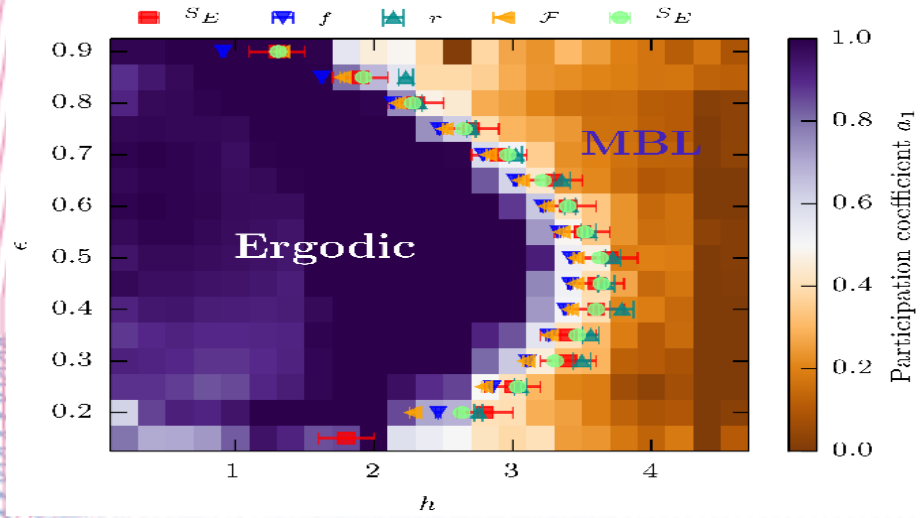
……. Agarwal et al, Gopalakrishnan et al, Vosk et al., Potter et al., Serbyn & Moore .....

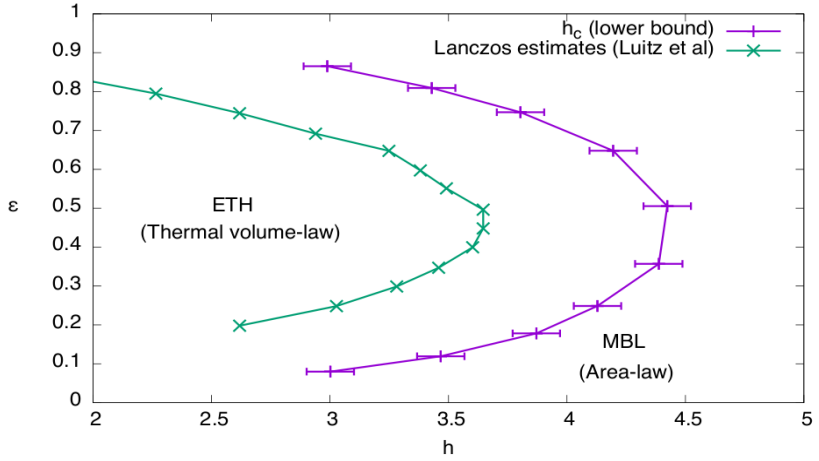
ED studies of 1D s=1/2 model

Luitz et al. 2015: Heisenberg model in random fields N=12--22





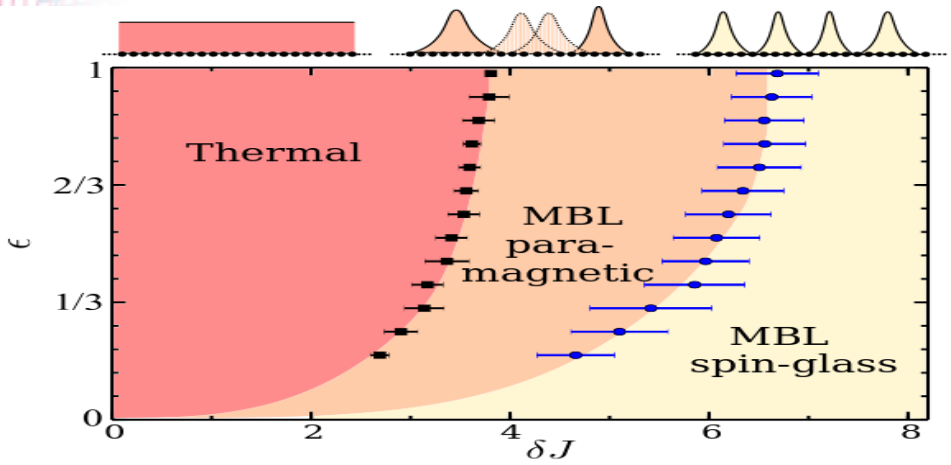


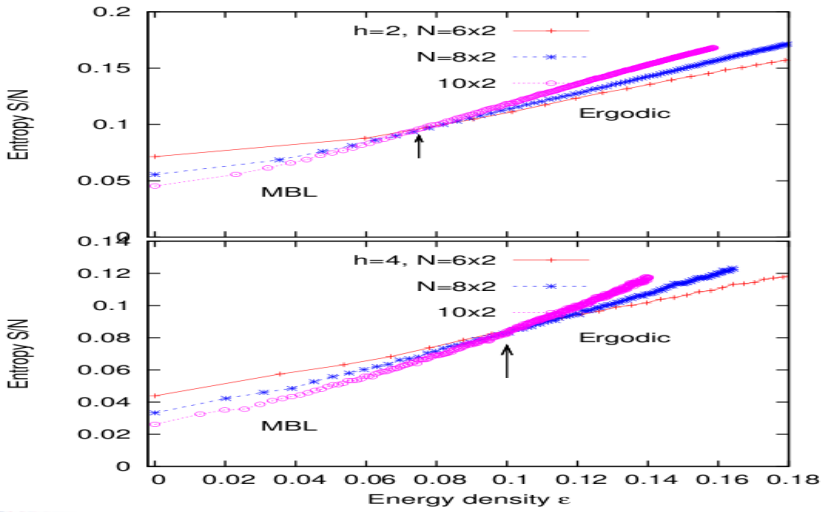


Devakul, Singh 2015: linked cluster expansion

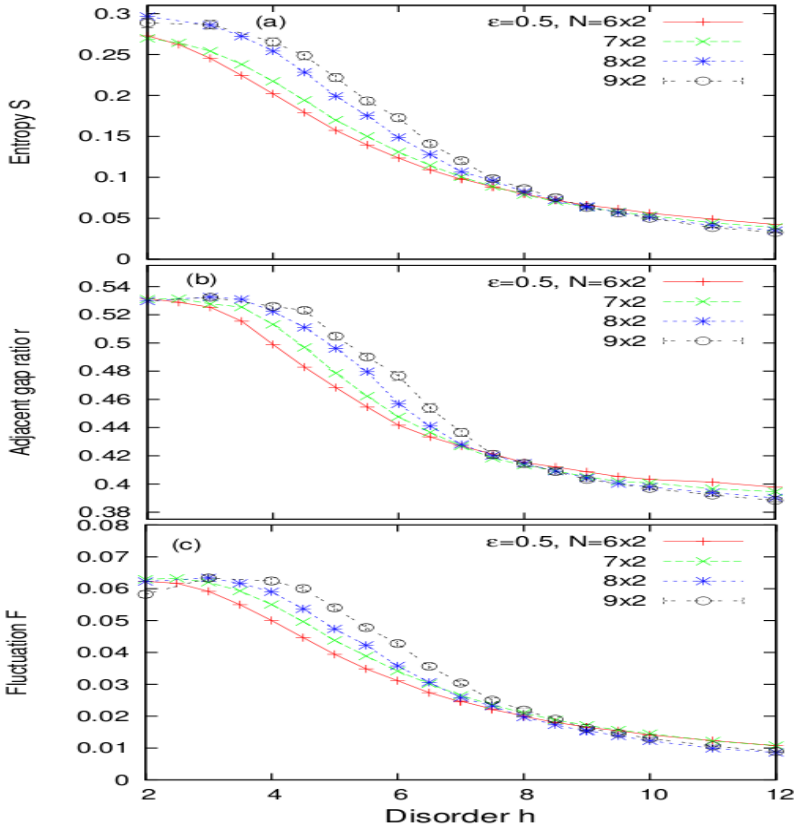
Transitions in different models

Kjall et al (2014)



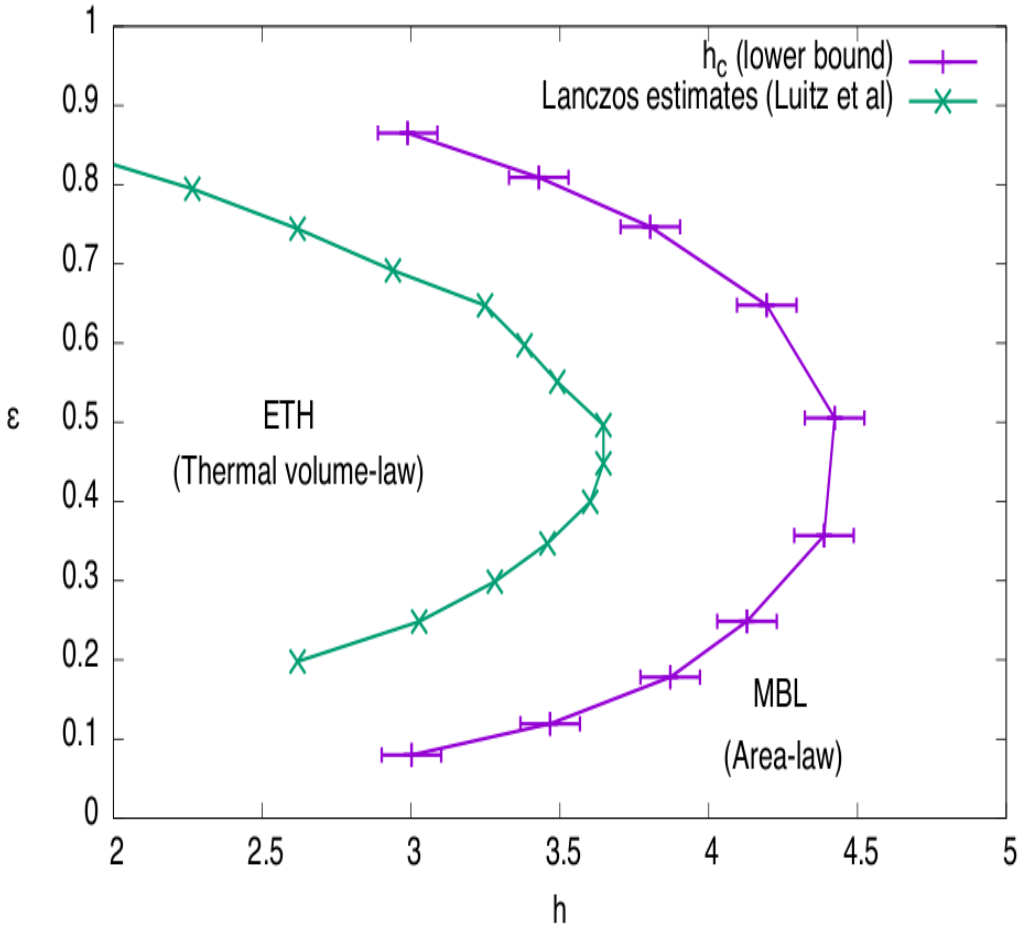


Baygan, Lim, DNS (2015)
N=12--20



Open issues about critical hc and mobility edge may be resolved with larger system studies

Devakul, Singh 2015



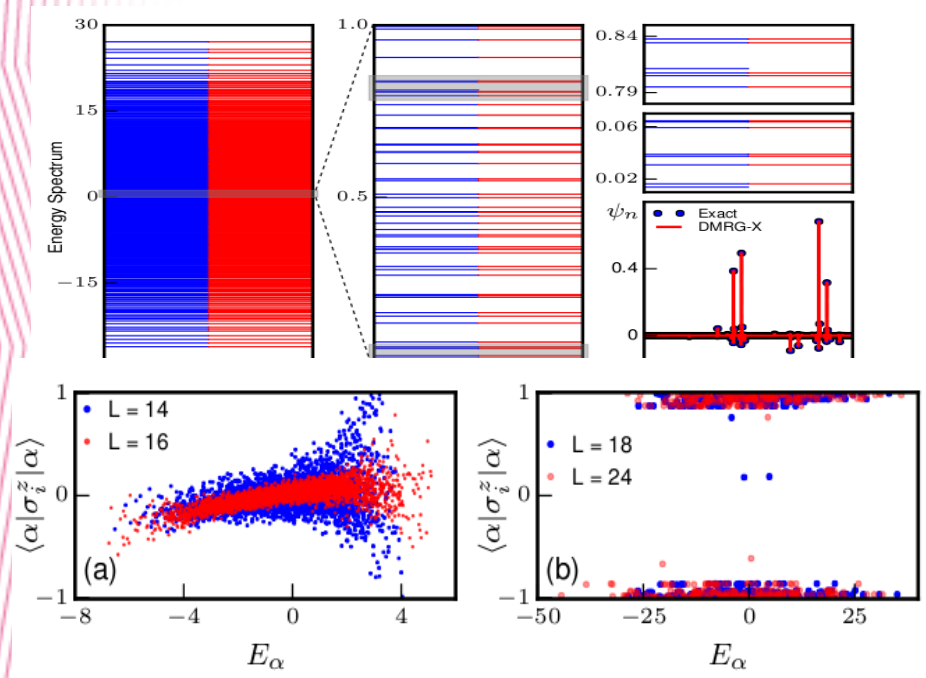
Open issues regarding transition
Agarwal et al, Gopalakrishnan et al,
Vosk et al., Potter et al.,
Serbyn & Moore .....

Mobility edge—role of rare Regions

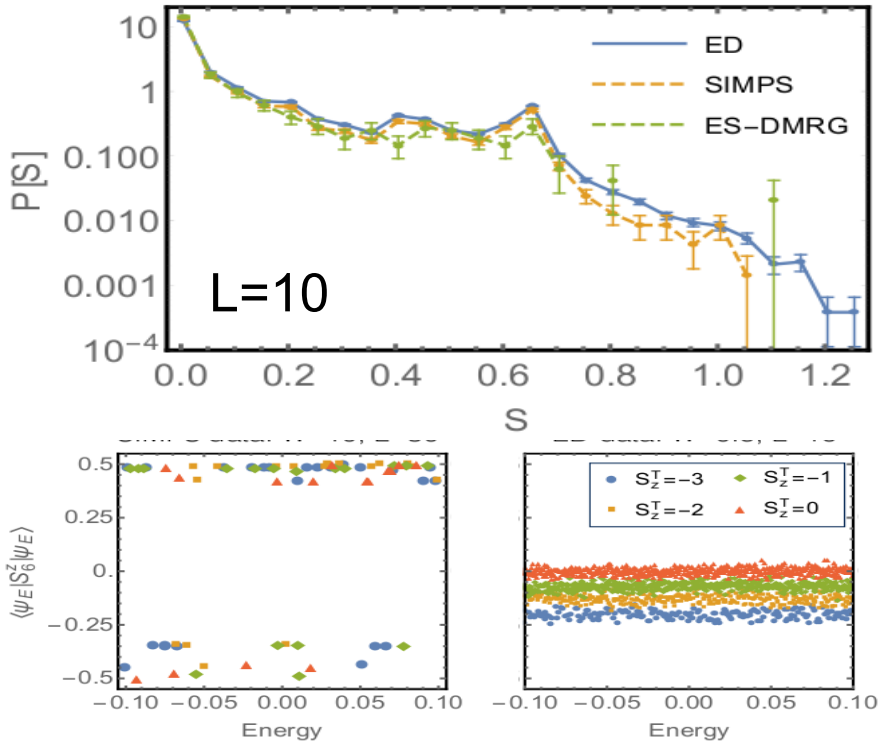
Laumann et al.
Huang
Vosk et al.
de Roeck et al.
Mondragon-Shem et al.
.....

Some DMRG methods for excited states

Khemani, Pollmann, Sondhi,
arXiv1509.00483



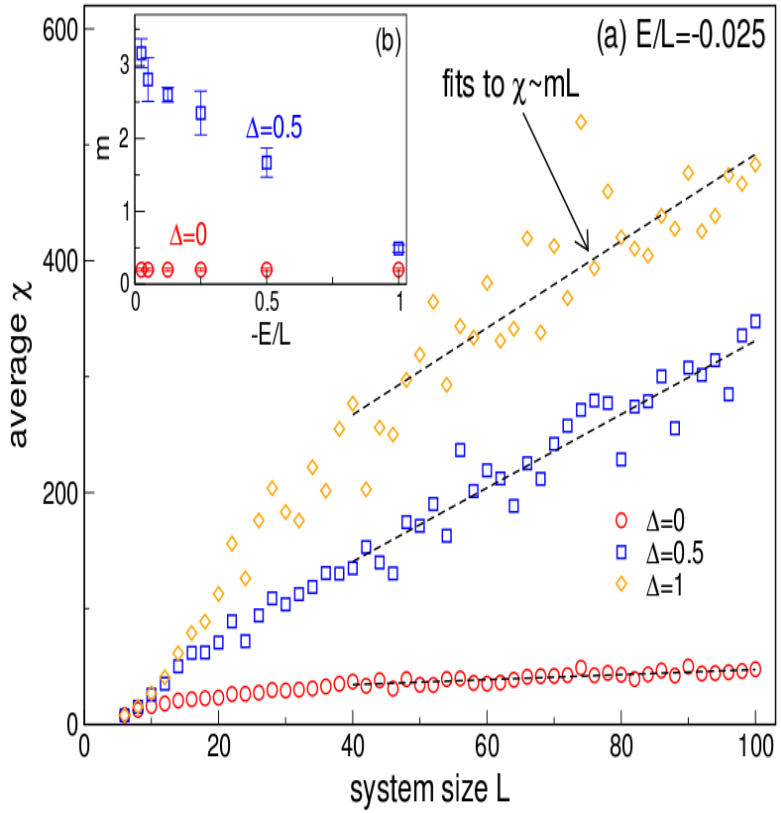
Yu, Pekker, clark
arXiv1509.01244

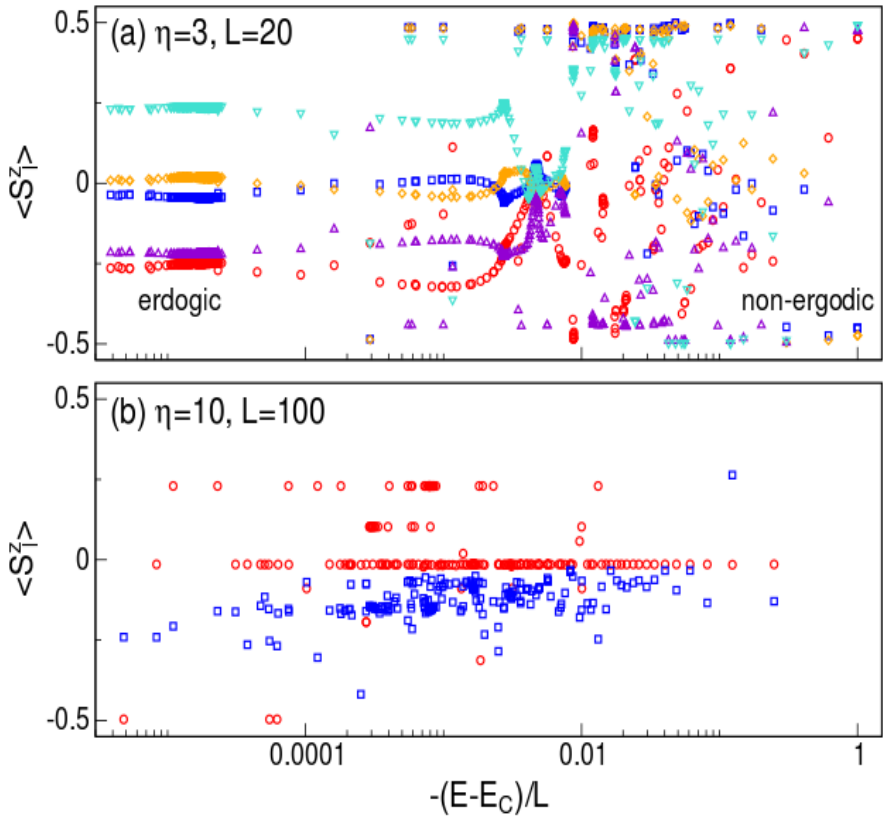


There are also other developments: Pekker & Clark; Friesdorf et al.
Pollmann et al.; Chandran et al.
Kennes & Karrasch

Missing statistics for larger systems—different scope than our work

Kennes & Karrasch ---targeting superposition state





Entanglement DMRG (En-DMRG) for excited states

S. R. White 1992 DMRG

Initialization: larger M-bond dimension

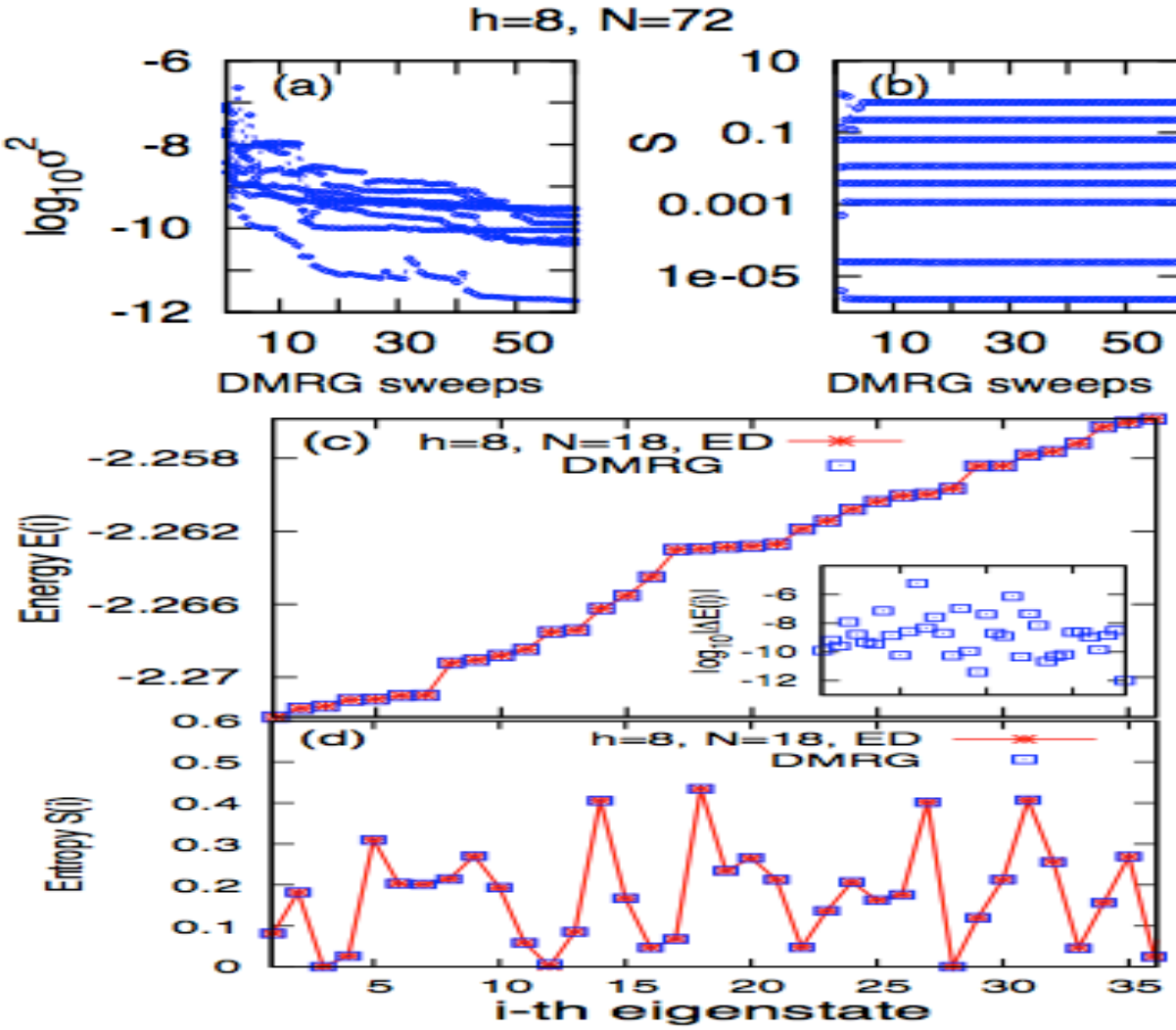
Sweep: growing M to capture entanglement; targeting a couple of states to reduce frustration

Lanczos: H'=(H-Et)^2 & H

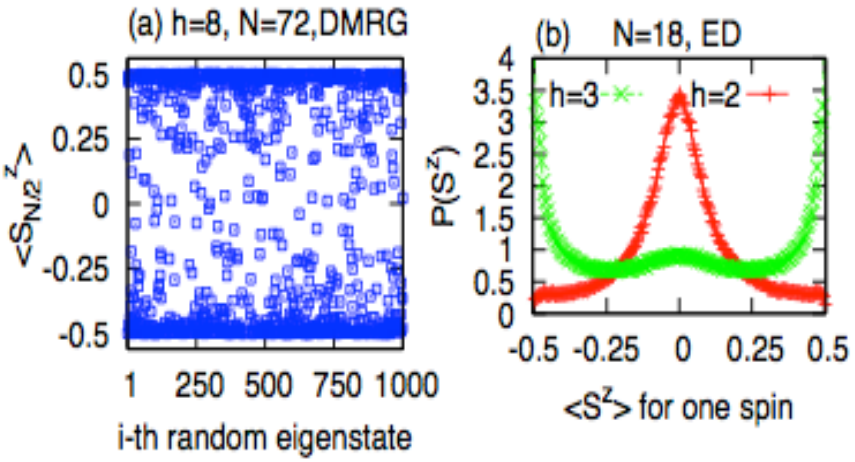
Truncation error (auto)control: <~10^(-8)

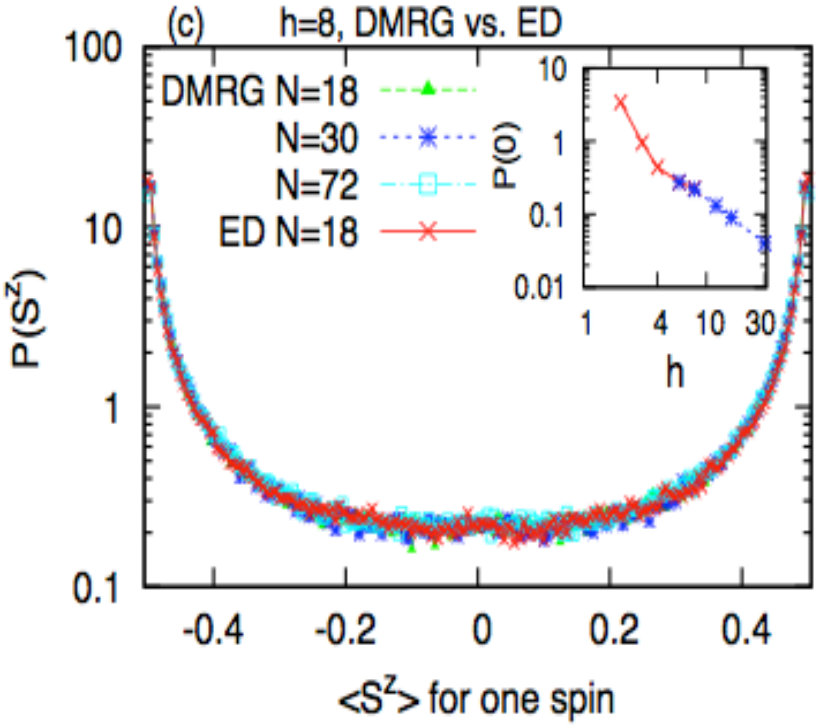
En-DMRG for excited states

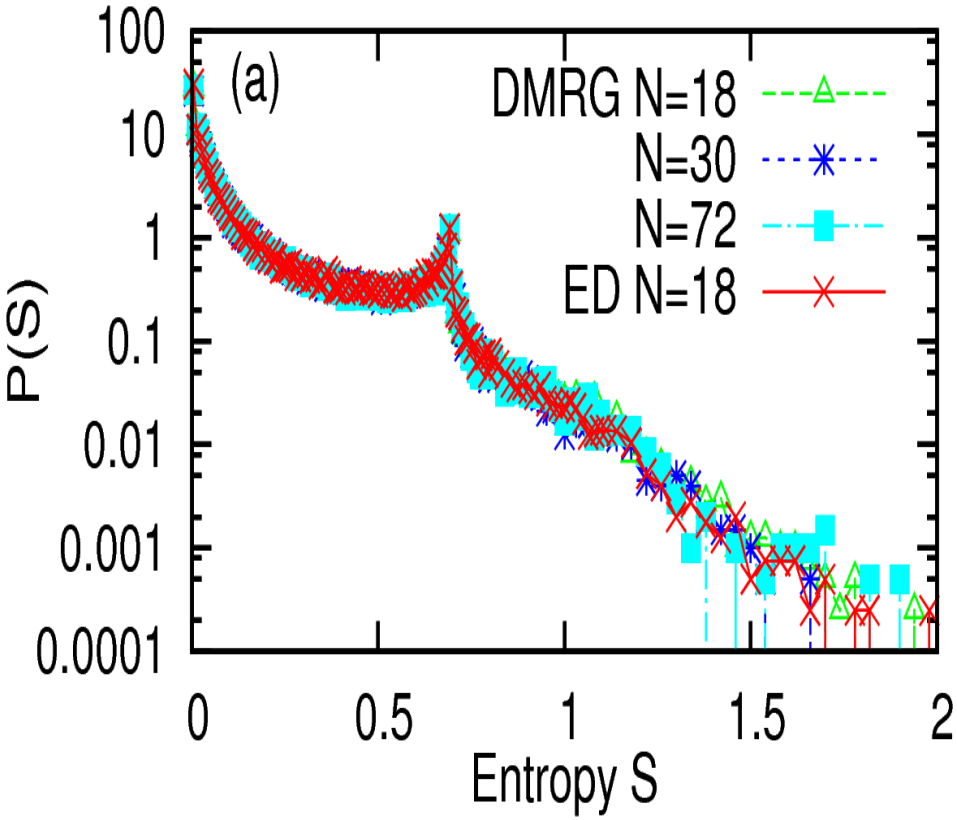
$$H = \sum_{i=1}^{N-1} \vec{S}_i \cdot \vec{S}_{i+1} - \sum_i h_i S_i^z ,$$



En-DMRG distributions functions for MBL





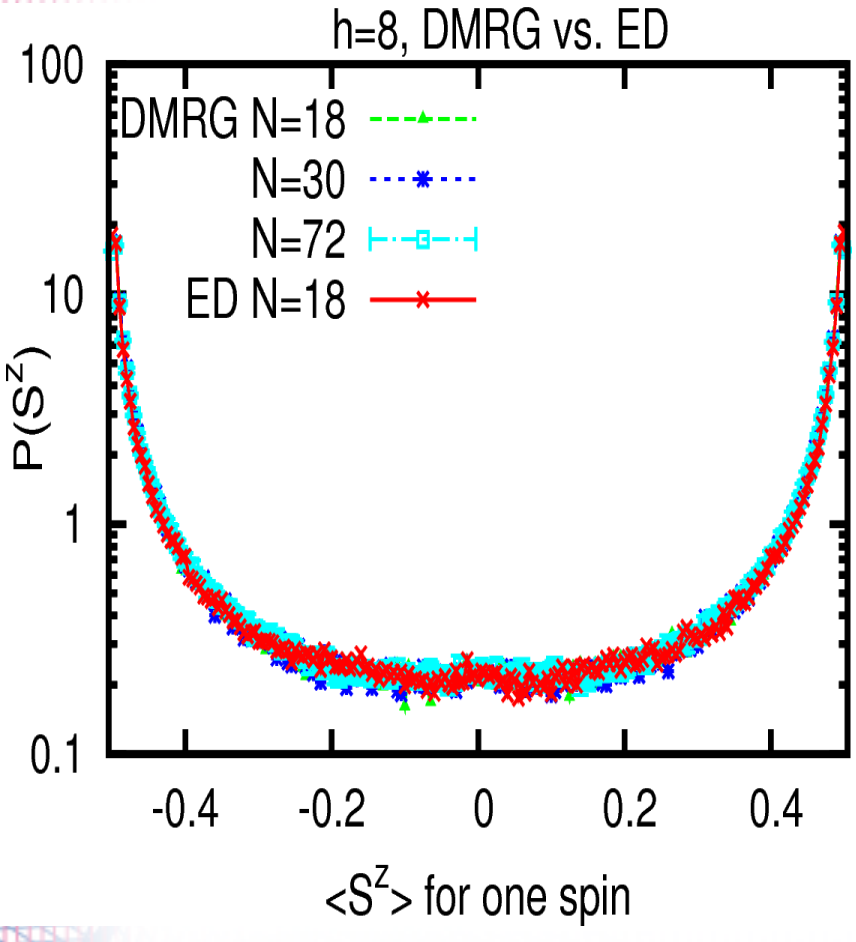


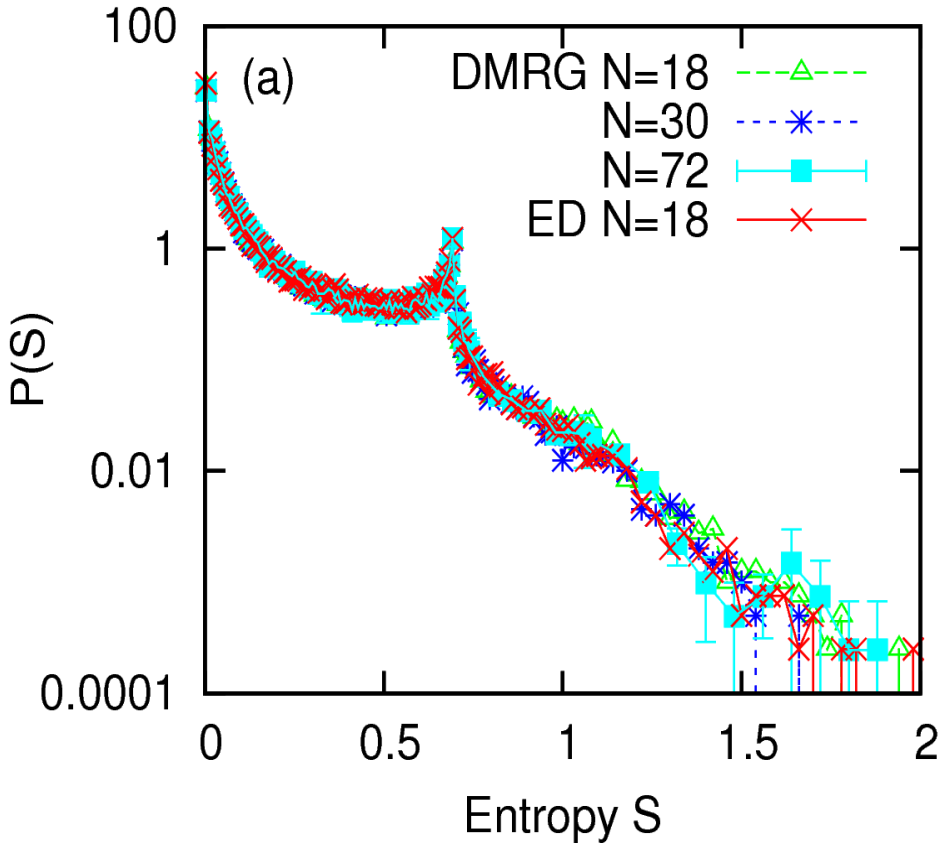
H=8, M~48-72 (bond dim.)

Exponential decay of P(S) on the larger S side

Bauer & Nayak (2013) ED

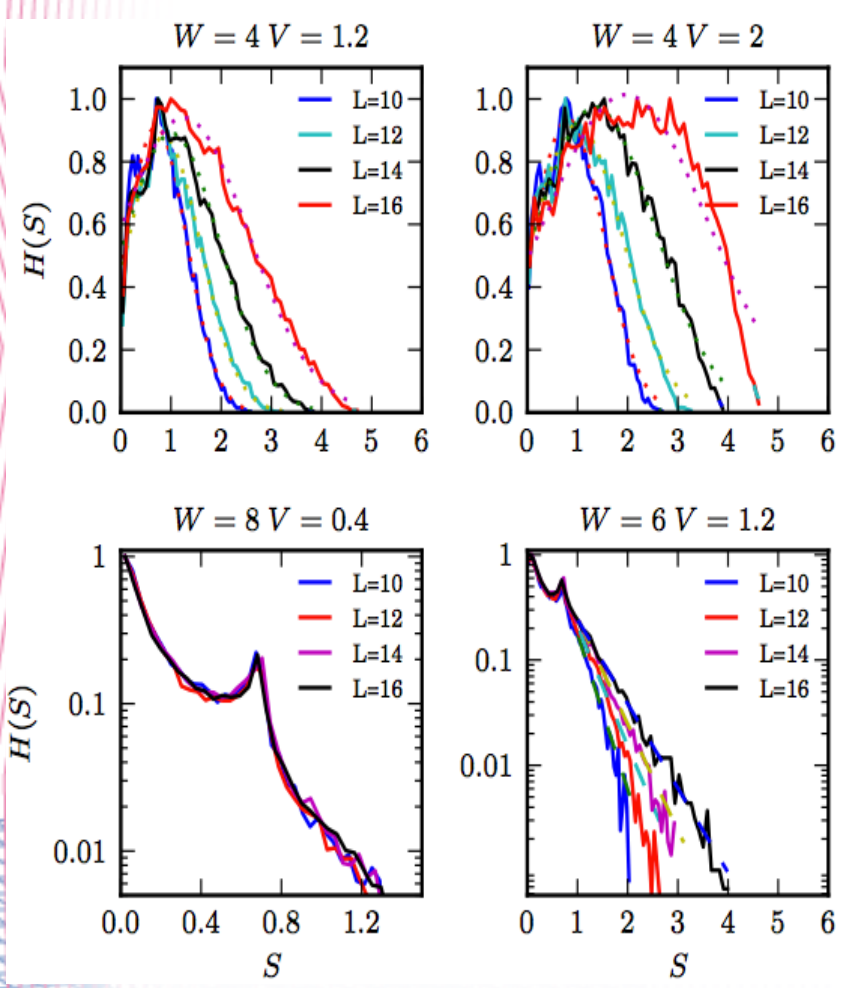
Error bar near the tail of P(S) is large



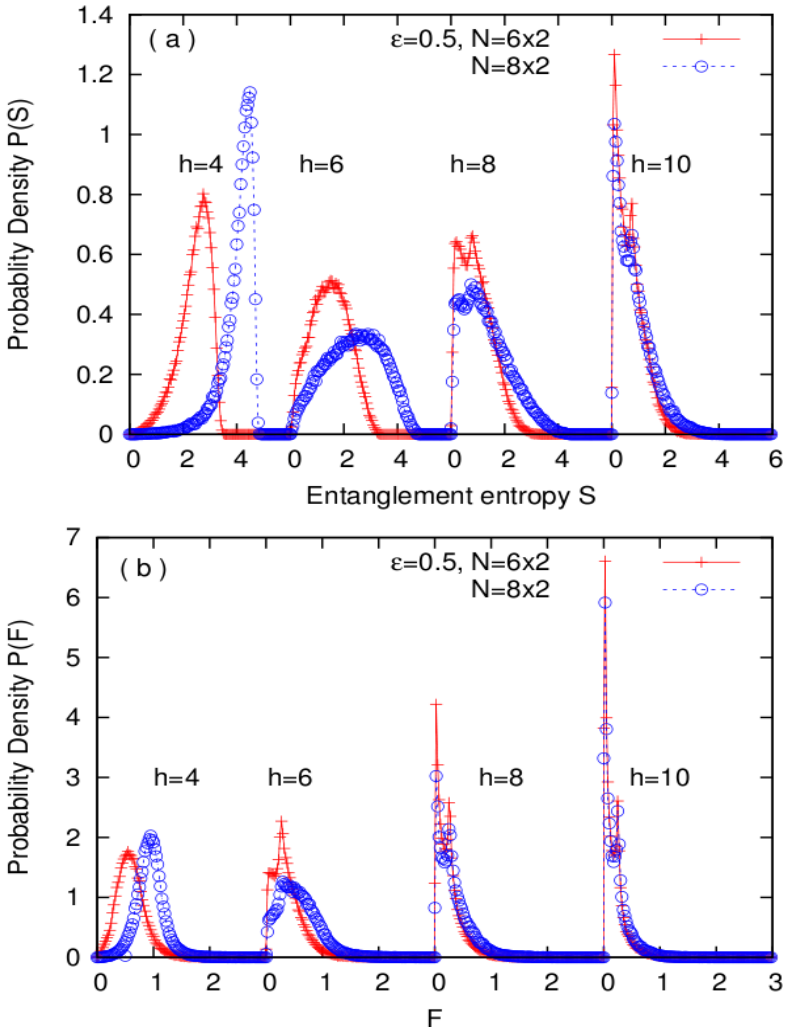


Similar distributions in 2-leg ladders

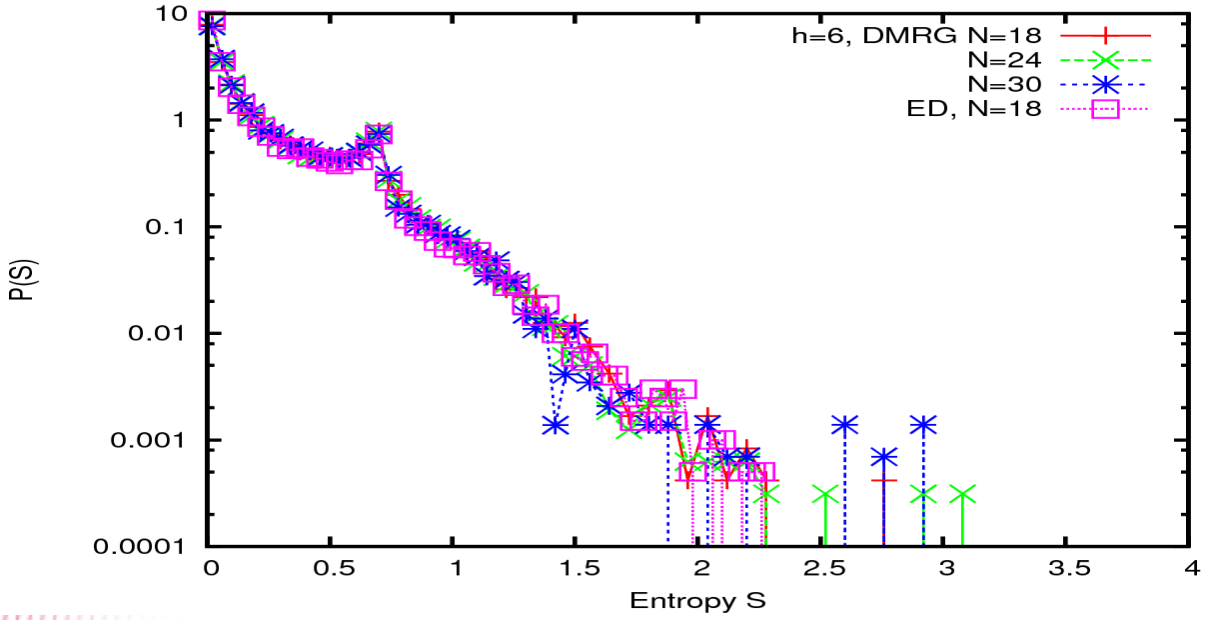
Bauer & Nayak (2013)

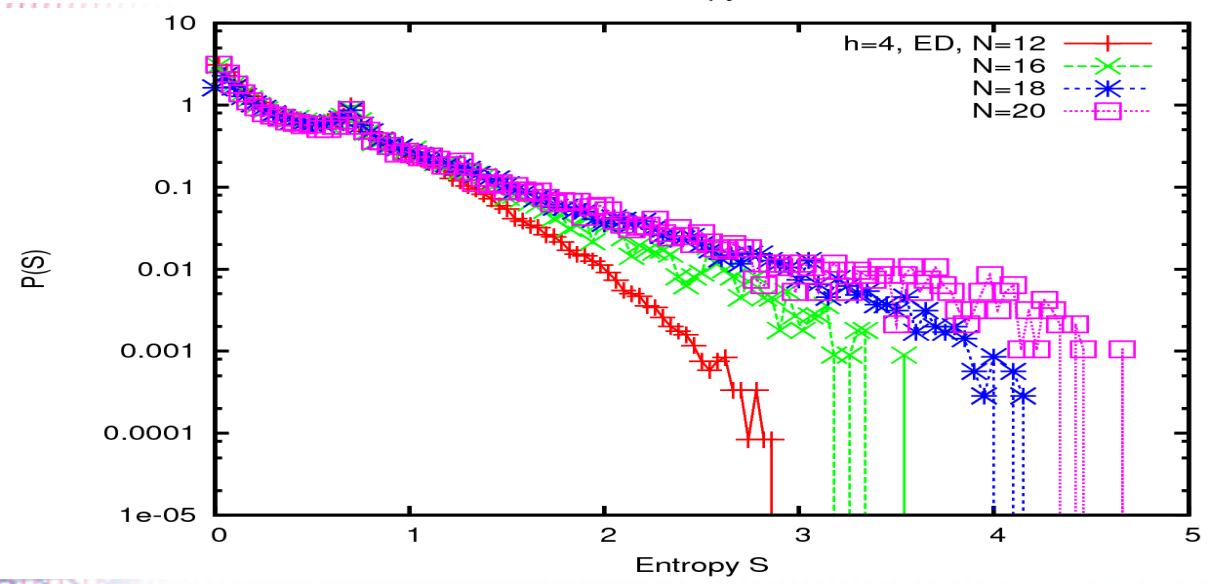


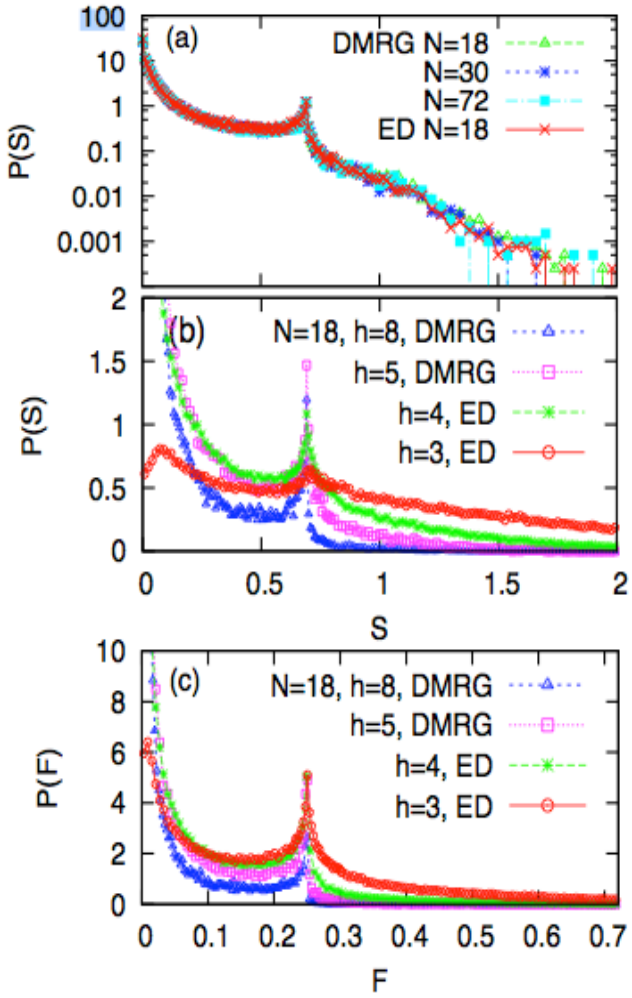
Baygan, Lim, DNS (2015)



Entropy distribution P(S) reveals the evolution from MBL to delocalized phase



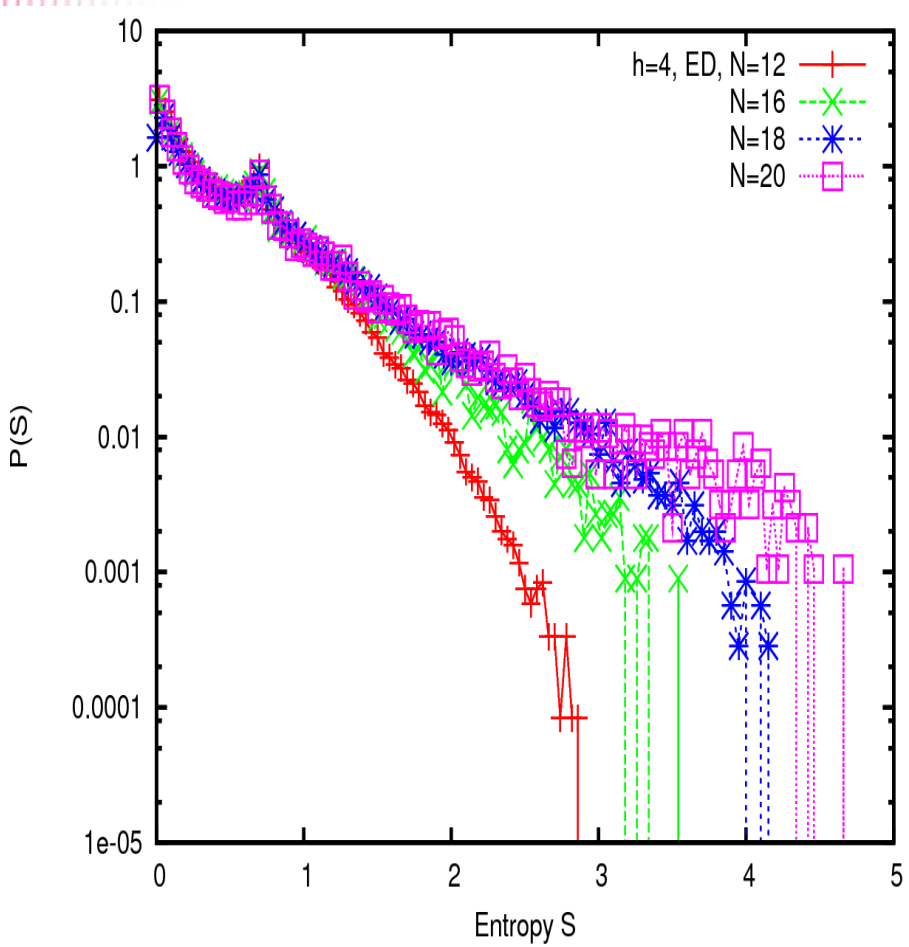




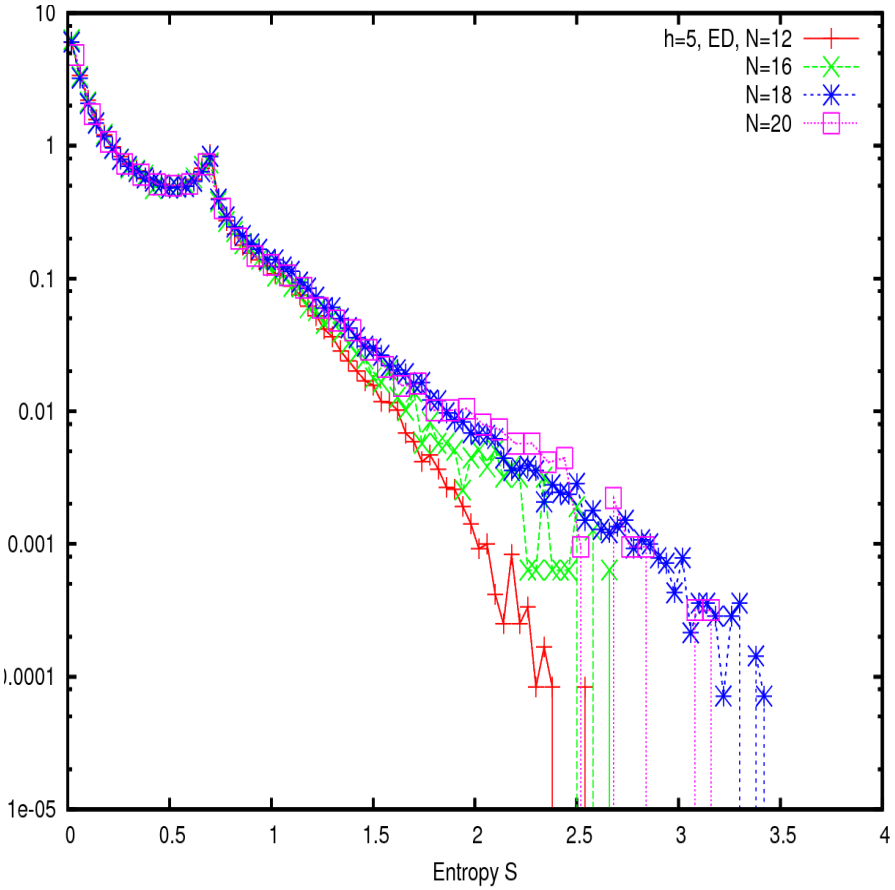
With reduced h, P(S) grows from the tail for h=4 (ED)

Entropy distribution P(S) reveals the evolution from MBL to delocalized phase

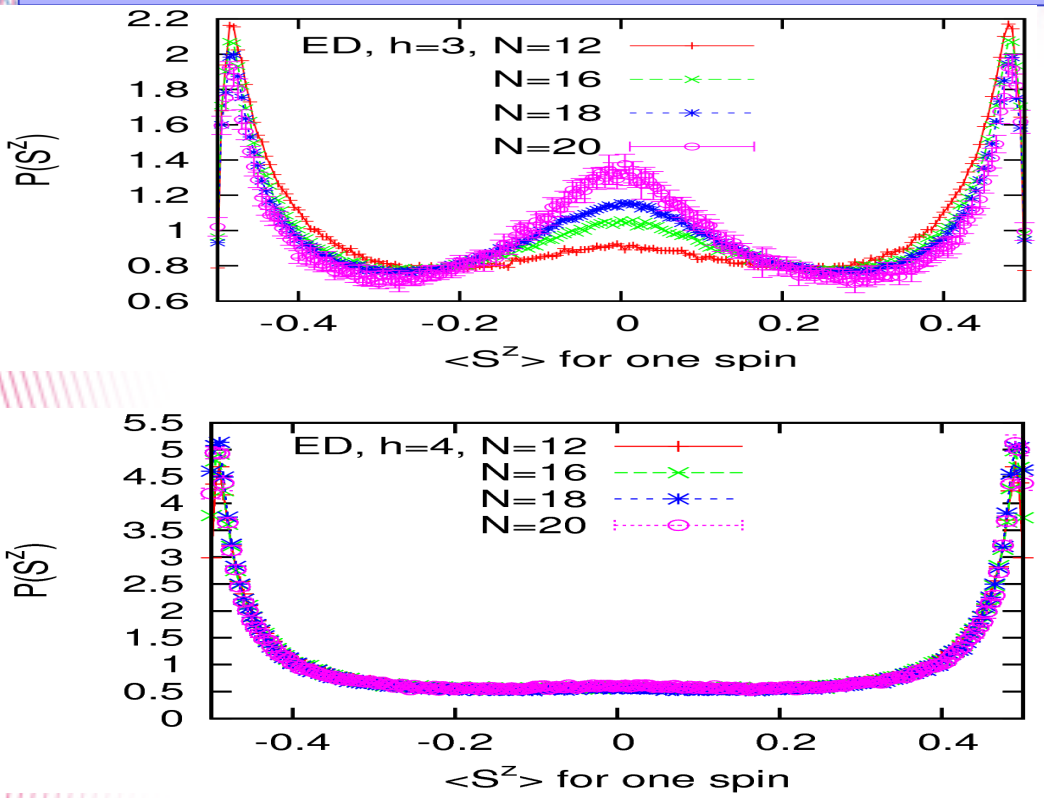
h=4

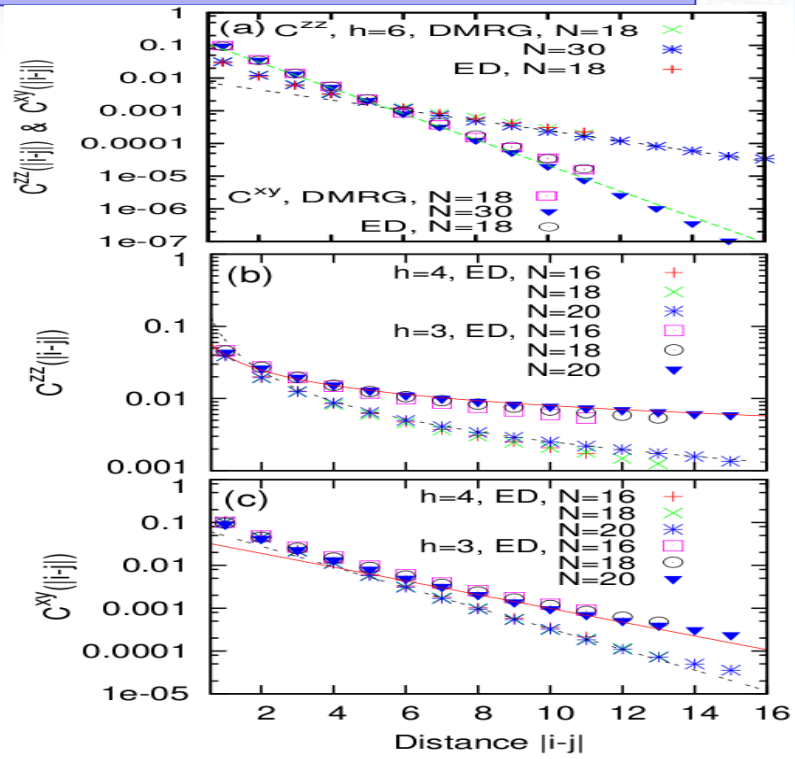


h=5



DMRG-ED to study phase diagram

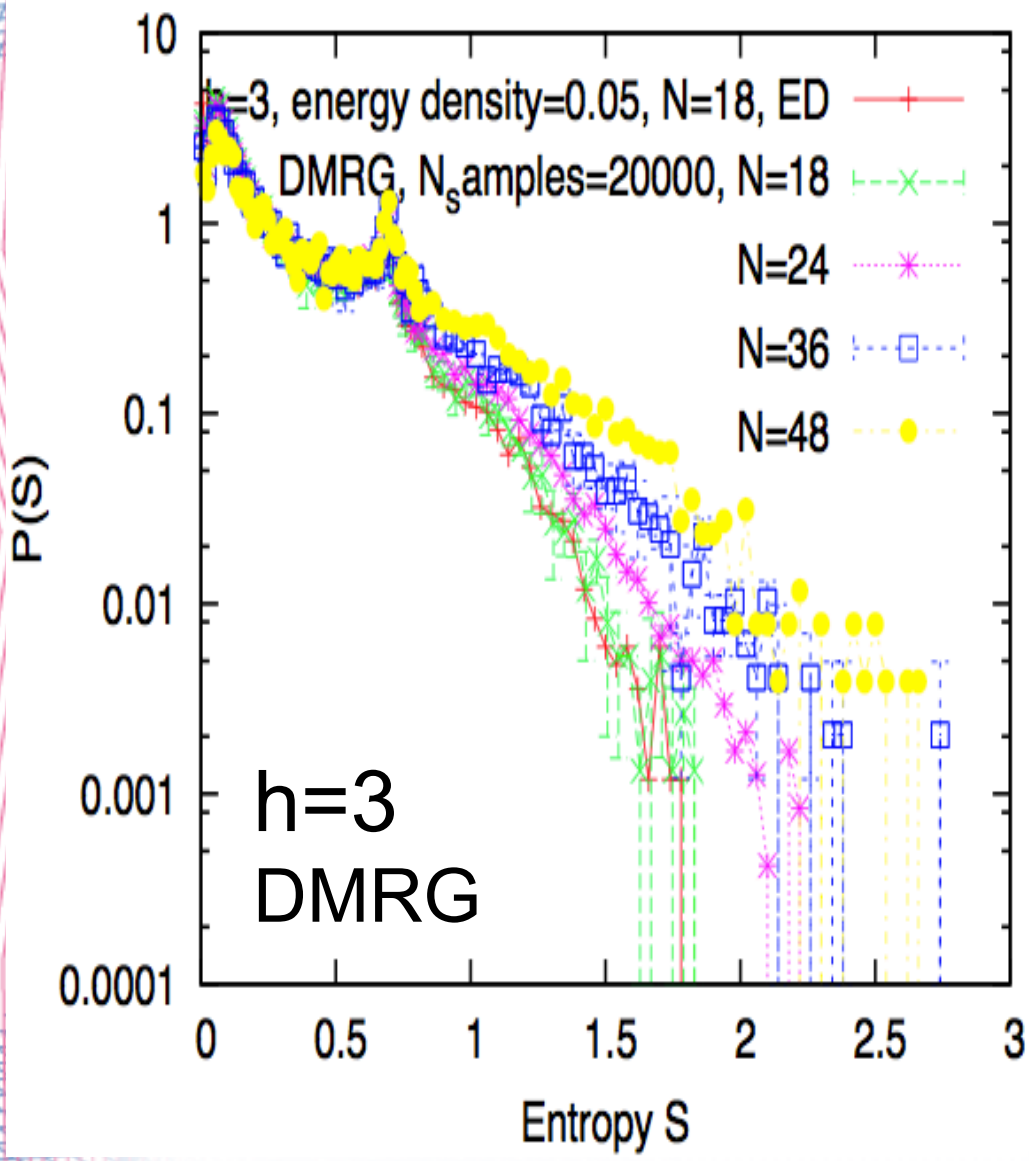


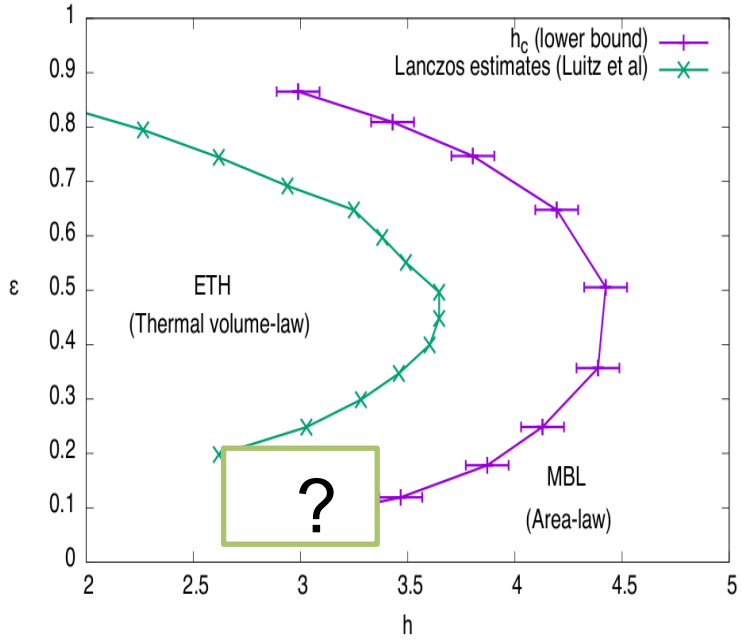


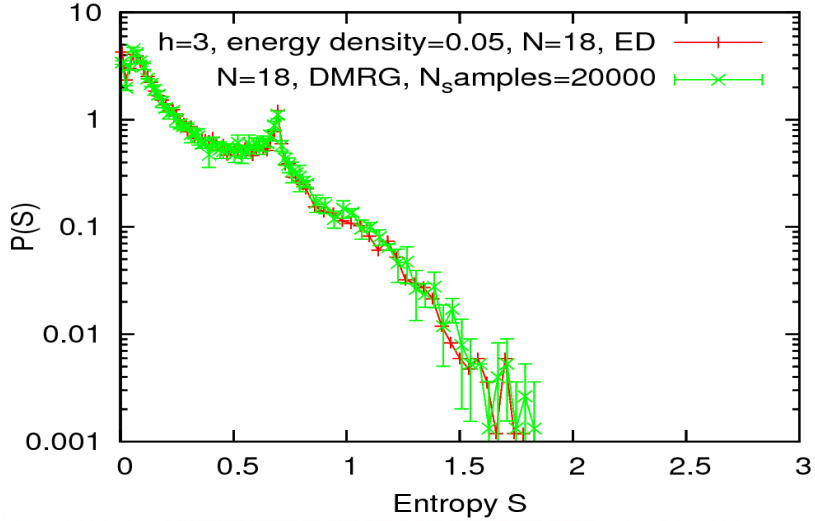
Serbyn & Moore
Agarwal et al, Gopalakrishnan et al,
Vosk et al., Potter et al.,

The critical regime may have strong size effect. Entropy grows with N slowly from the long tail of S (Griffiths regions).

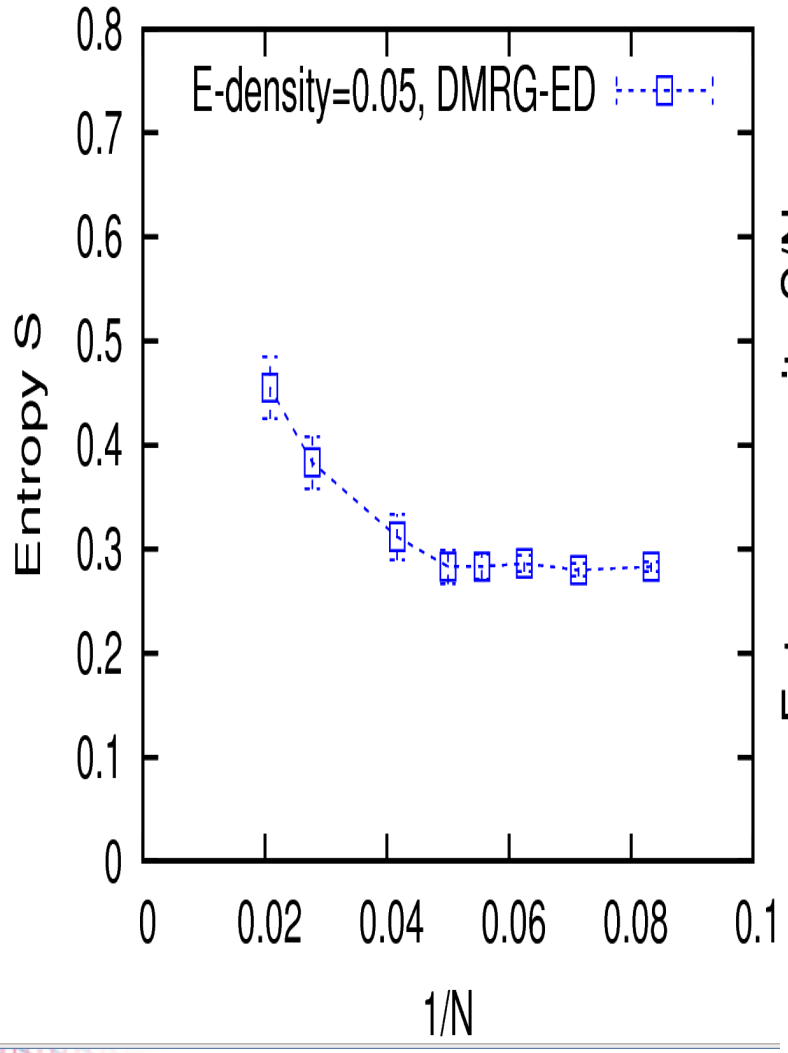
ED identified mobility edge and finite size effect

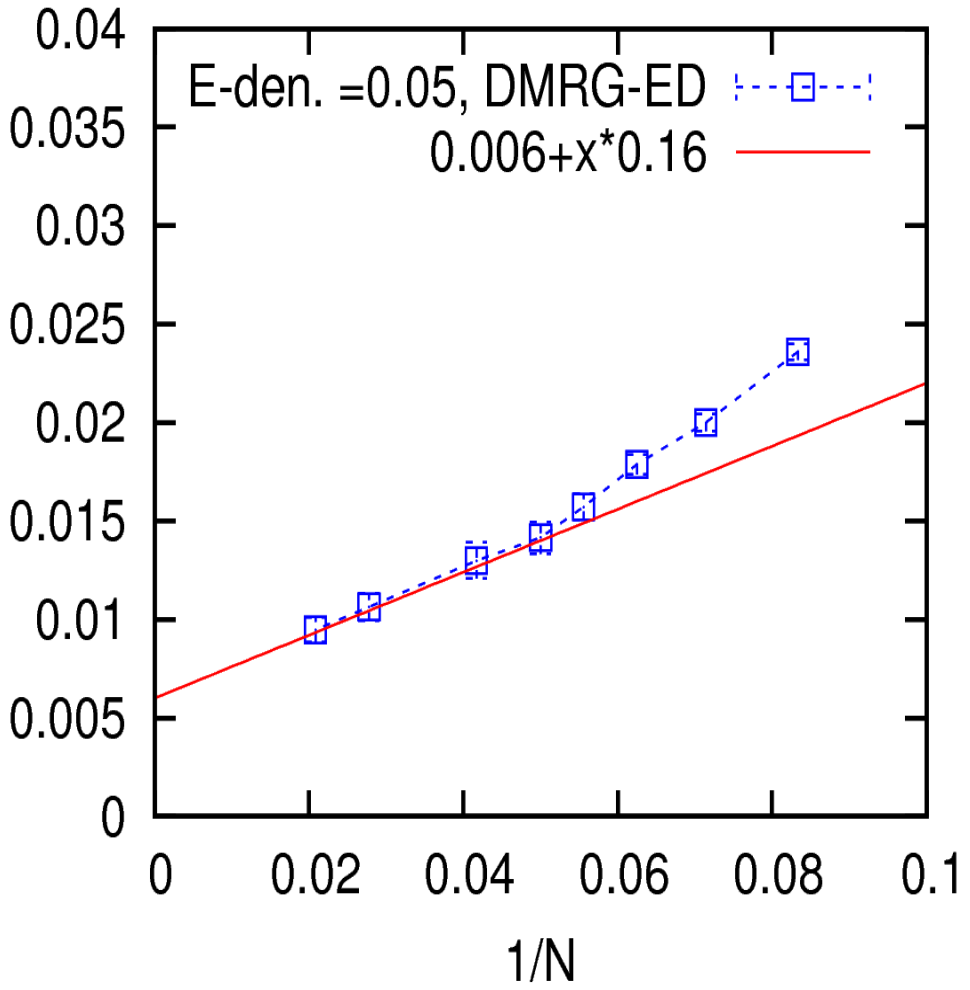




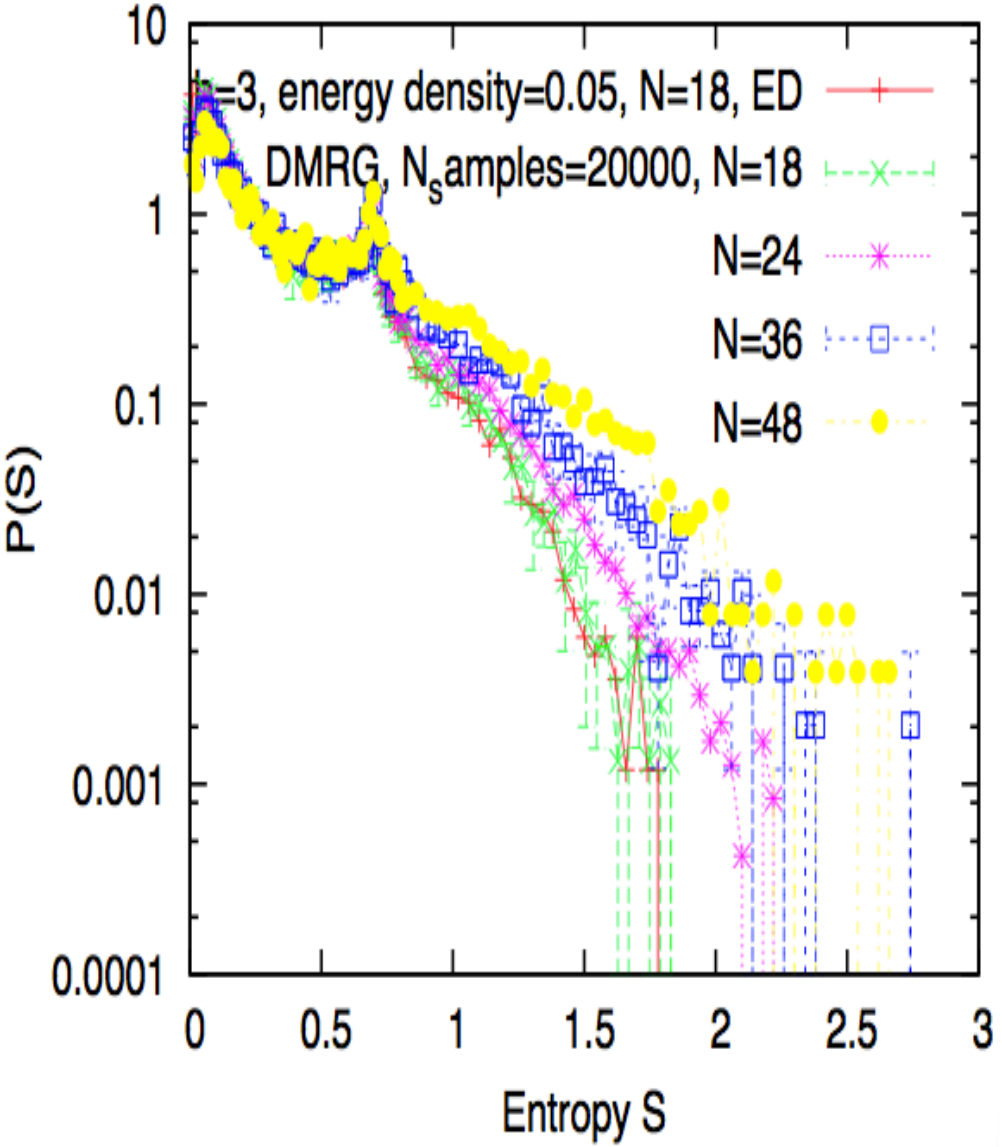


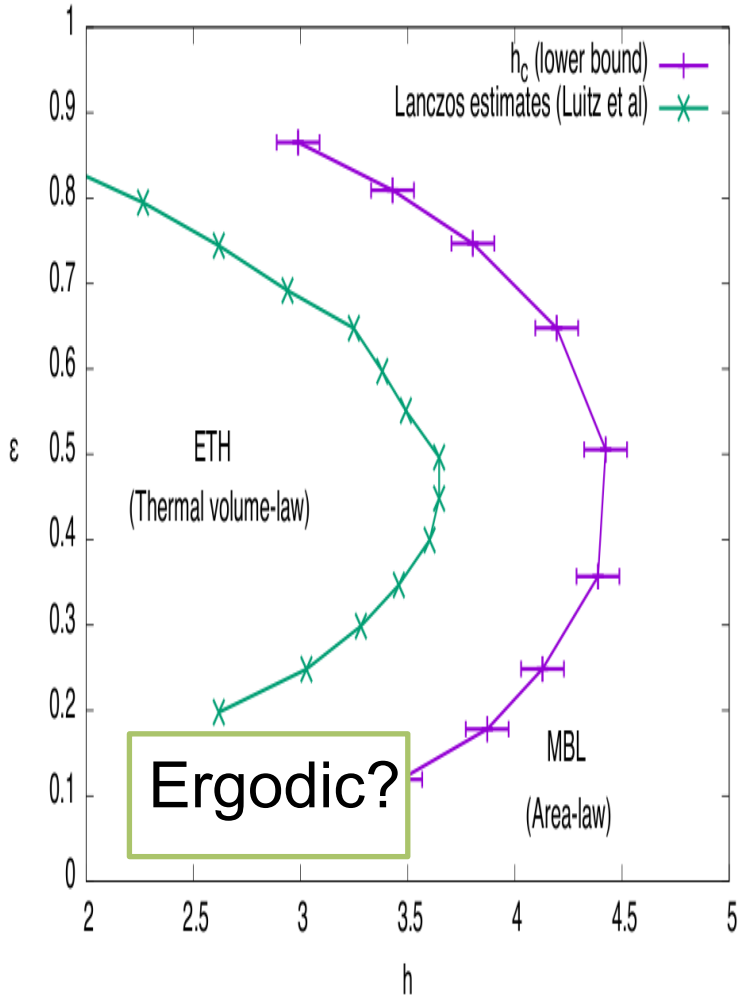
Entropy scaling for “the possible MBL phase below mobility edge”, S/N goes to constant





The lower energy “MBL phase” (ED) may be Ergodic phase





Summary

En-DMRG for excited states in MBL systems is highly accurate in obtaining statistical features of MBL phase.

Following the evolution of distribution functions, and combining DMRG-ED, we propose a phase diagram with an intermediate regime (thermal side) between delocalized ergodic and MBL phases.

Using DMRG to study lower energy excited states, we determine that the mobility edge “determined by ED” may be in Ergodic phase -----on going work.

Thank you