
Model with NNN couplings and a small defect on site 1

Anisotropic, open boundaries

$$\sum_{n=1}^{L-1} \frac{J}{4} (\sigma_n^x \sigma_{n+1}^x + \sigma_n^y \sigma_{n+1}^y + 0.48 \sigma_n^z \sigma_{n+1}^z) + 1 \cdot \sum_{n=1}^{L-2} \frac{J}{4} (\sigma_n^x \sigma_{n+2}^x + \sigma_n^y \sigma_{n+2}^y + 0.48 \sigma_n^z \sigma_{n+2}^z) + 0.1 \frac{J}{2} \sigma_1^z$$

Directory

Eigenvalues

Histogram of the EIGENVALUES

```
In[ ]:= te = Import["Eig_L12u06Jz0.48dF0.00lF1.00hF0.00bF0.10AveR0001.dat", "Table"];  
ta = Table[te[[k, 1]], {k, 1, Length[te]}];  
dim = Length[ta];
```

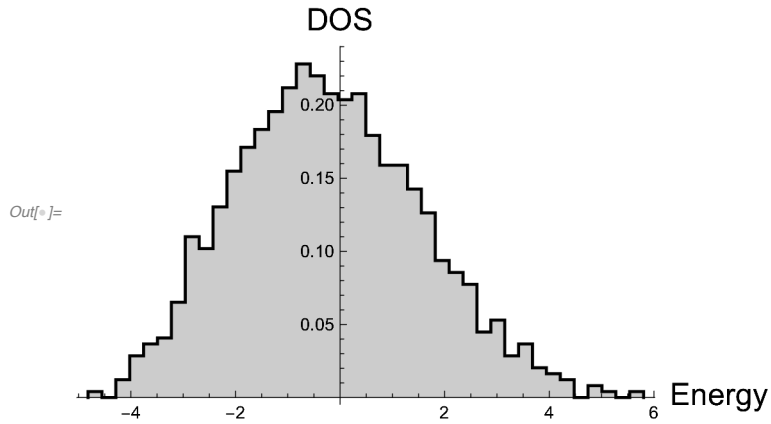
```
Print["NORMALIZED Histogram. It has a Gaussian shape, but not symmetric."]  
Histogram[ta, Automatic, "Probability"]
```

NORMALIZED Histogram. It has a Gaussian shape, but not symmetric.



DOS

```
In[ ]:= te = Import["DOS_L12u06Jz0.48dF0.00lF1.00hF0.00bF0.10AveR0001.dat", "Table"];  
dim = 1000.;  
ListPlot[te, Joined → True, PlotStyle → Black,  
  Filling → Axis, AxesLabel → {"Energy", "DOS"}]
```



Level spacing distribution: P(s)

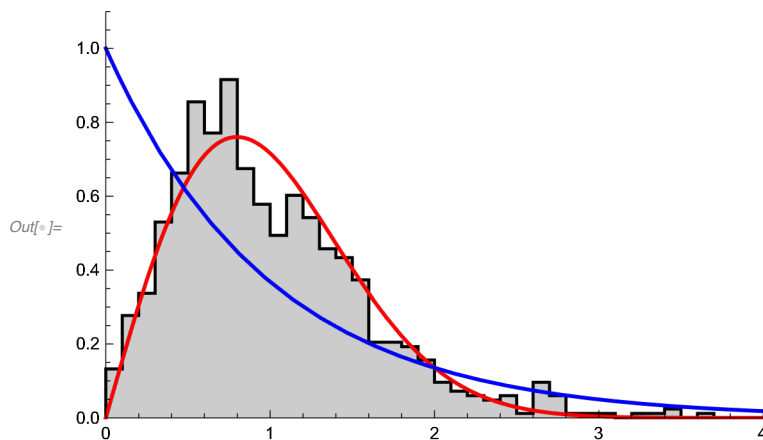
```

In[ ]:= (* Theoretical curves *)
Clear[WignerDyson, Poisson];
WignerDyson = Plot[Pi s / 2. Exp[-Pi s^2 / 4.],
  {s, 0, 8}, PlotRange -> {0, 1}, PlotStyle -> {Red, Thick},
  LabelStyle -> Directive[Black, Bold, Medium], AxesLabel -> {"s", "P"}];
Poisson = Plot[Exp[-s], {s, 0, 8}, PlotRange -> {0, 1}, PlotStyle -> {Blue, Thick},
  LabelStyle -> Directive[Black, Bold, Medium], AxesLabel -> {"s", "P"}];

(* Numerical results *)
te = Import["Ps_L12u06Jz0.48dF0.00lF1.00hF0.00bF0.10AveR0001.dat", "Table"];
dim = 1000.;
aa = ListPlot[te, Joined -> True,
  PlotStyle -> Black, Filling -> Axis, PlotRange -> {{0, 4}, {0, 1.1}}];

Show[{aa, WignerDyson, Poisson}]

```



Average of the ratio of consecutive levels: \tilde{r}

```

In[ ]:=
te = Import["rTilde_L12u06Jz0.48dF0.00lF1.00hF0.00bF0.10AveR0001.dat", "Table"];
Print["The numerical result  $\tilde{r}$ =", te[[1, 1]], " is close to theoretical  $\tilde{r}=0.54$ "]

```

The numerical result $\tilde{r}=0.502333$ is close to theoretical $\tilde{r}=0.54$

Eigenstates

PR and Shannon

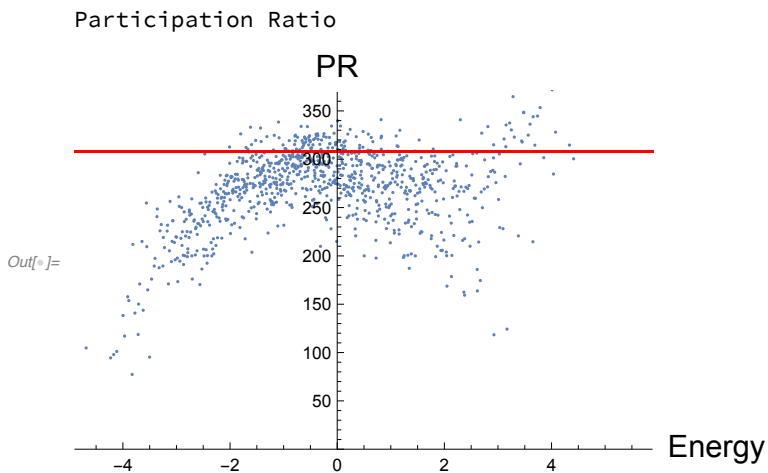
```

In[ ]:= te = Import["PRSh_L12u06Jz0.48dF0.00lF1.00hF0.00bF0.10AveR0001.dat", "Table"];
pr = Table[{te[[k, 1]], te[[k, 2]]}, {k, 1, Length[te]};
sh = Table[{te[[k, 1]], te[[k, 3]]}, {k, 1, Length[te]};

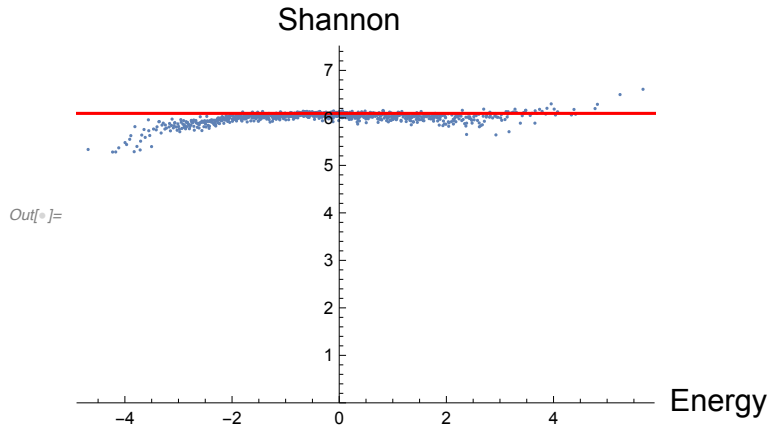
dim = Length[te];
prplot = ListPlot[pr, PlotRange -> {0, dim / 2.5}, AxesLabel -> {"Energy", "PR"}];
shplot =
  ListPlot[sh, PlotRange -> {0, Log[2 dim]}, AxesLabel -> {"Energy", "Shannon"}];
prgoe = Plot[dim / 3., {x, -100, 100}, PlotStyle -> Red];
shgoe = Plot[Log[0.48 dim], {x, -100, 100}, PlotStyle -> Red];

Print[];
Print["Participation Ratio"];
Show[{prplot, prgoe}]
Print[];
Print["Shannon Entropy"];
Show[{shplot, shgoe}]

```



Shannon Entropy



ETH: NNN (chaos) vs clean XXZ (integrable)

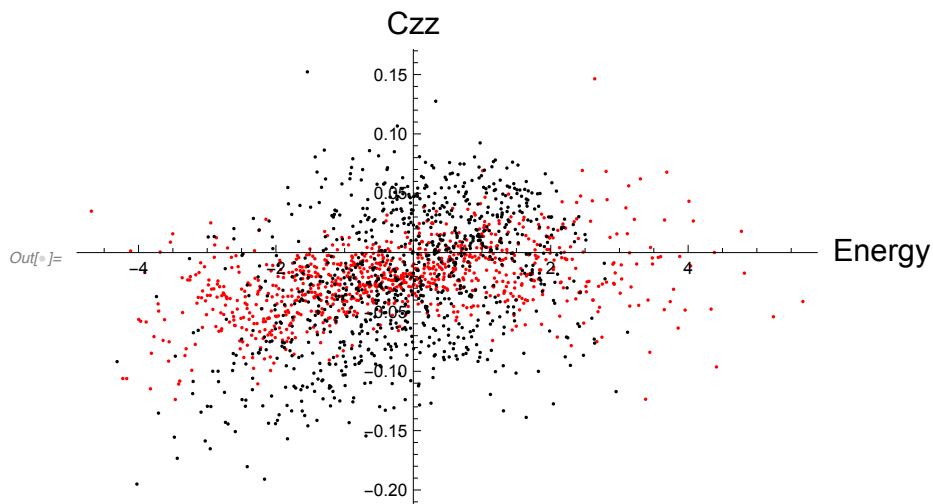
EEV: diagonal-ETH

$$C_{zz} = \langle \alpha | S_{L/2}^z S_{L/2+1}^z | \alpha \rangle$$

```

In[ ]:= te = Import["EEV_L12u06Jz0.48dF0.001F1.00hF0.00bF0.10AveR0001.dat", "Table"];
ta = Import["EEV_L12u06Jz0.48dF0.001F0.00hF0.00bF0.10AveR0001.dat", "Table"];
ListPlot[{te, ta}, PlotStyle -> {Red, Black}, AxesLabel -> {"Energy", "Czz"}]

```



OFF-diagonal-ETH: 200 eigenstates in the middle of the spectrum

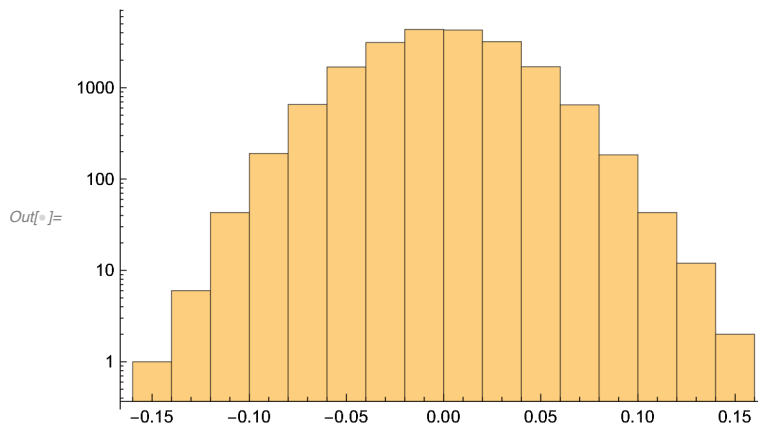
$$O_{ab} = \langle \beta | S_{L/2}^z | \alpha \rangle$$

```

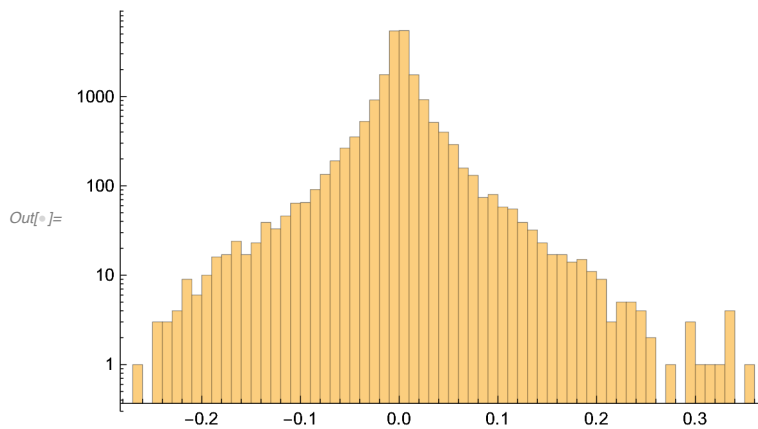
In[6]:= te = Import["Oab_L12u06Jz0.48dF0.00lF1.00hF0.00bF0.10AveR0001.dat", "Table"];
teF = Flatten[te];
ta = Import["Oab_L12u06Jz0.48dF0.00lF0.00hF0.00bF0.10AveR0001.dat", "Table"];
taF = Flatten[ta];
Print["Oab for the chaotic model"];
Histogram[teF, ScalingFunctions -> {"Linear", "Log"}, PlotRange -> All]
Print[];
Print["Oab for the integrable model"];
Histogram[taF, ScalingFunctions -> {"Linear", "Log"}, PlotRange -> All]

```

Oab for the chaotic model



Oab for the integrable model



Dynamics

LDOS

```

In[ ]:= ena = Import["Calpha_L12u06Jz0.48dF0.00lF1.00hF0.00bF0.10AveR0001AveI0100.dat"];
dim = Length[ena];
Energies = Table[ena[[k, 1]], {k, 1, dim}];
Calpha = Table[ena[[k, 2]], {k, 1, dim}];

ta = Import[
  "InfoIni_L12u06Jz0.48dF0.00lF1.00hF0.00bF0.10AveR0001AveI0100.dat", "Table"];
gamSq = ta[[11, 1]];
Emid = ta[[5, 1]];

Clear[lbin, tot, minE, maxE, Eint, Em];
lbin = 0.2;
Min[Energies];
Max[Energies];
minE = Min[Energies] - 2 lbin;
maxE = Max[Energies] + 2 lbin;
tot = (maxE - minE) / lbin + 1;
Eint = Table[(minE - lbin / 2.) + lbin (k - 1), {k, 1, tot + 1}];
Em = Table[minE + lbin (k - 1), {k, 1, tot}];

Clear[ldos];
Do[
  ldos[k] = 0.;
  , {k, 1, tot + 10}];

Do[
  Do[
    If[Eint[[k]] ≤ Energies[[j]] < Eint[[k + 1]], ldos[k] = ldos[k] + Calpha[[j]] ^ 2 ];
    , {k, 1, tot}];
  , {j, 1, dim}];

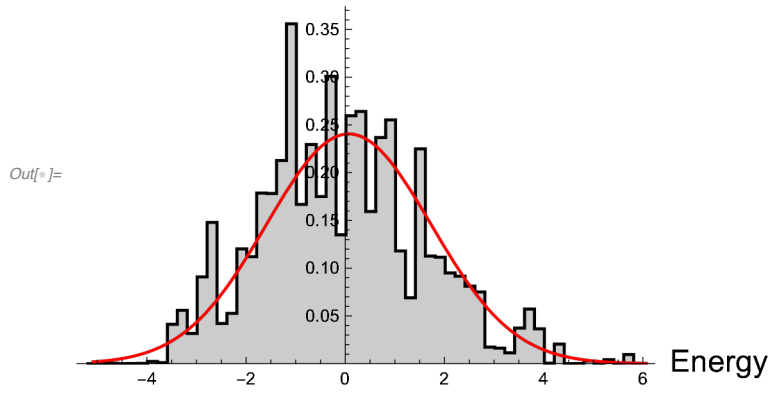
ldosLista = Flatten[Table[
  {{Eint[[k]], ldos[k] / (lbin)}, {Eint[[k + 1]], ldos[k] / (lbin)}}, {k, 1, tot}], 1];

ldosPlot = ListPlot[ldosLista, Joined → True, PlotStyle → Black, Filling → Axis,
  AxesLabel → {"Energy", "LDOS=|Calpha|^2"}, PlotRange → {All, {0, All}}];
bb = Plot[(1. / Sqrt[2. Pi gamSq]) Exp[-0.5 ((x - Emid) ^ 2) / gamSq],
  {x, minE, maxE}, PlotRange → All, PlotStyle → Red];
Print[]
Print[]
Print["The LDOS is naturally"]
Show[{ldosPlot, bb}]

```


The LDOS is naturally

$$\text{LDOS} = |\alpha|^2$$



SP

```

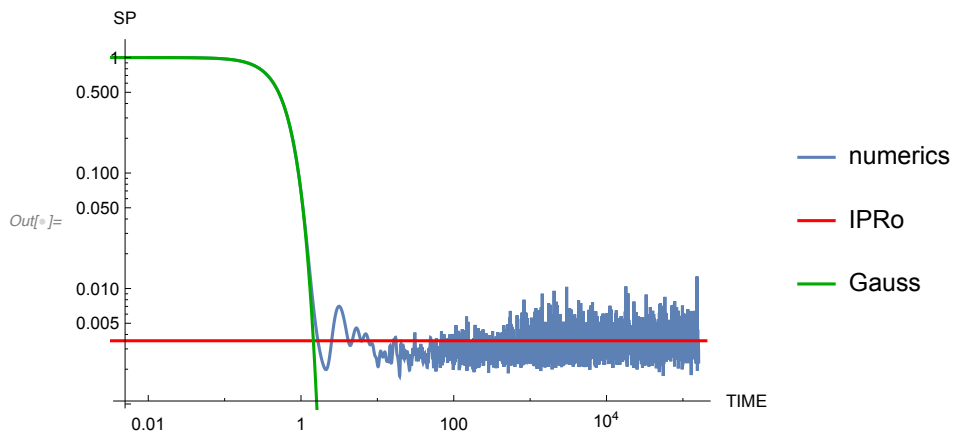
In[ ]:= totIni = 100;
ta =
  Import["SP_L12u06Jz0.48dF0.00lF1.00hF0.00bF0.10AveR0001AveI0100.dat", "Table"];
splot = ListLogLogPlot[ta, Joined → True, PlotRange → All,
  AxesLabel → {"TIME", "SP"}, PlotLegends → {"numerics"}];
te = Import["InfoIni_L12u06Jz0.48dF0.00lF1.00hF0.00bF0.10AveR0001AveI0100.dat",
  "Table"];

ipr0 = Sum[te[[14 + 18 (k - 1), 1]], {k, 1, totIni}] / totIni;
ipr0plot =
  LogLogPlot[ipr0, {x, 0.001, 200000}, PlotStyle → Red, PlotLegends → {"IPRo"}];

gauSq = Sum[te[[11 + 18 (k - 1), 1]], {k, 1, totIni}] / totIni;
gaus = LogLogPlot[Exp[-gauSq x^2], {x, 0.001, 20},
  PlotStyle → Darker[Green], PlotLegends → {"Gauss"}];

Show[{splot, ipr0plot, gaus}]

```



IPR(t) averaged over 100 initial states

```

In[198]:= totIni = 100;
ta = Import[
  "IPRt_L12u06Jz0.48dF0.00lF1.00hF0.00bF0.10AveR0001AveI0100.dat", "Table"];
splot = ListLogLogPlot[ta, Joined → True, PlotRange → All,
  AxesLabel → {"TIME", "IPR"}, PlotLegends → {"numerics"}];
te = Import["InfoIni_L12u06Jz0.48dF0.00lF1.00hF0.00bF0.10AveR0001AveI0100.dat",
  "Table"];

ipr = Sum[te[[17 + 18 (k - 1), 1]], {k, 1, totIni}] / totIni;
iprplot = LogLogPlot[ipr, {x, 0.001, 200 000},
  PlotStyle → Red, PlotLegends → {"IPR_sat"}];

gauSq = Sum[te[[11 + 18 (k - 1), 1]], {k, 1, totIni}] / totIni;
gaus = LogLogPlot[Exp[-gauSq x^2]^2, {x, 0.001, 20},
  PlotStyle → Darker[Green], PlotLegends → {"Gauss^2"}];

```

```
Show[{splot, iprplot, gaus}]
```

