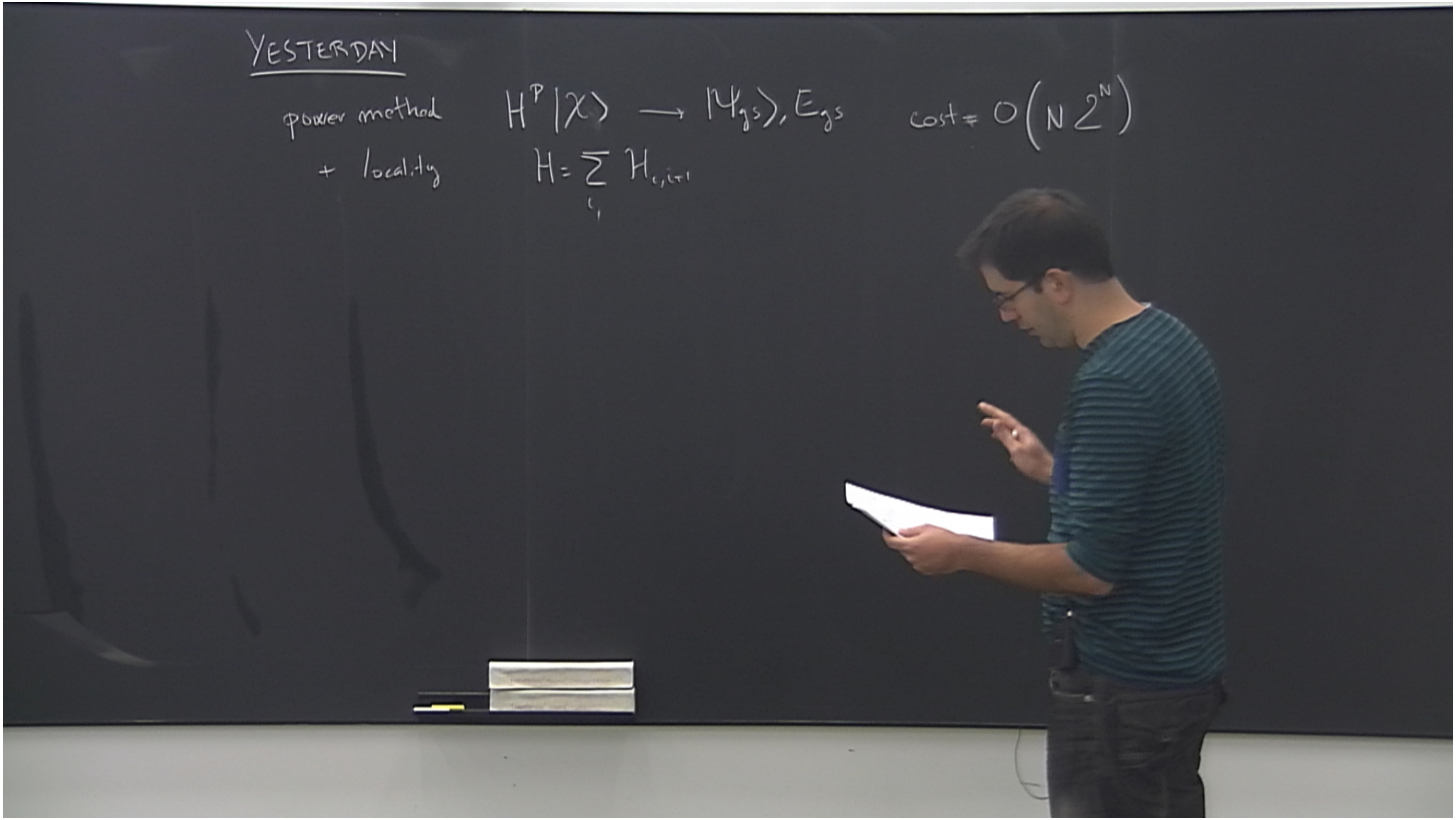
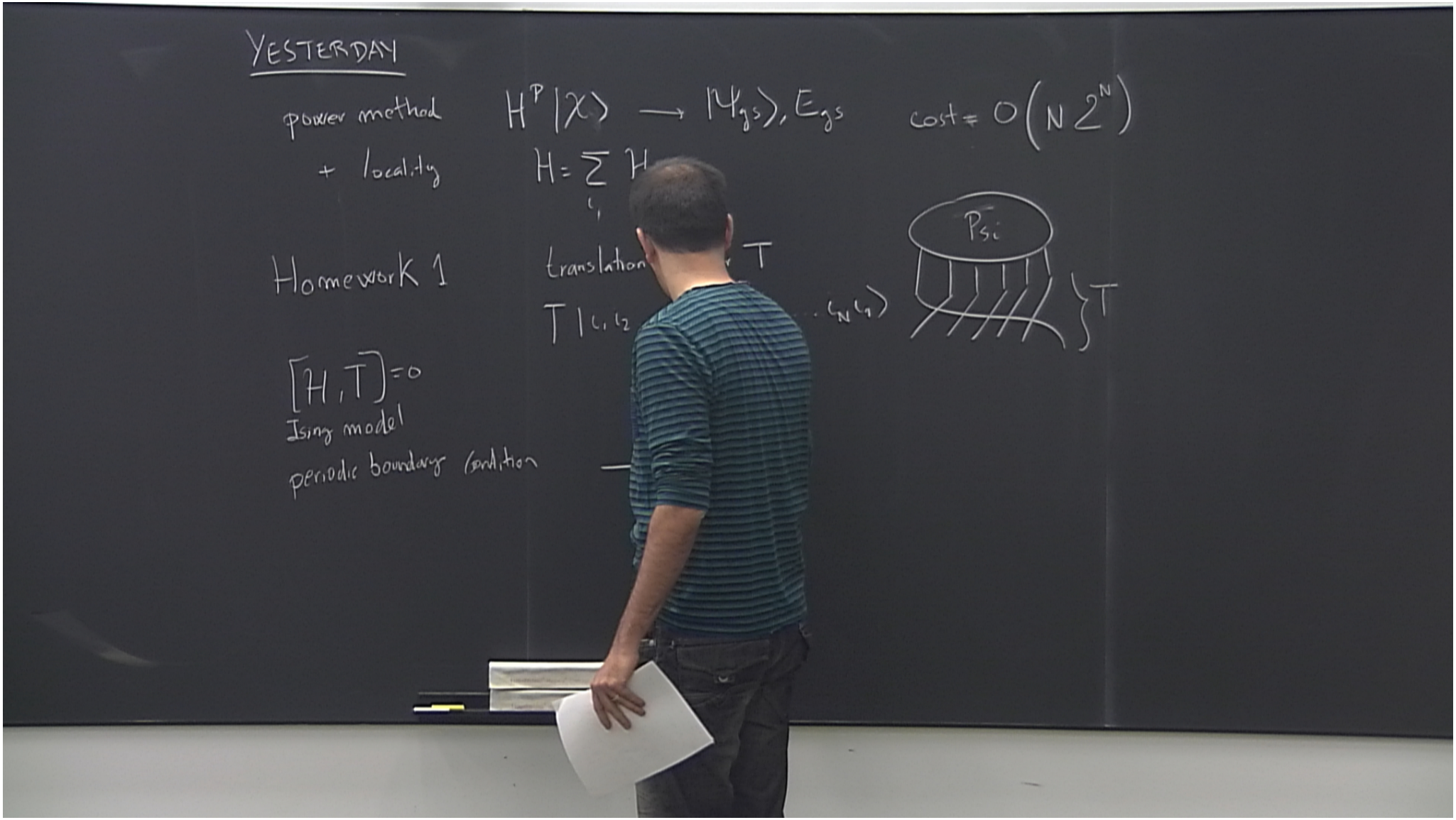
Title: 13/14 PSI - Explorations in Condensed Matter - Lecture 5

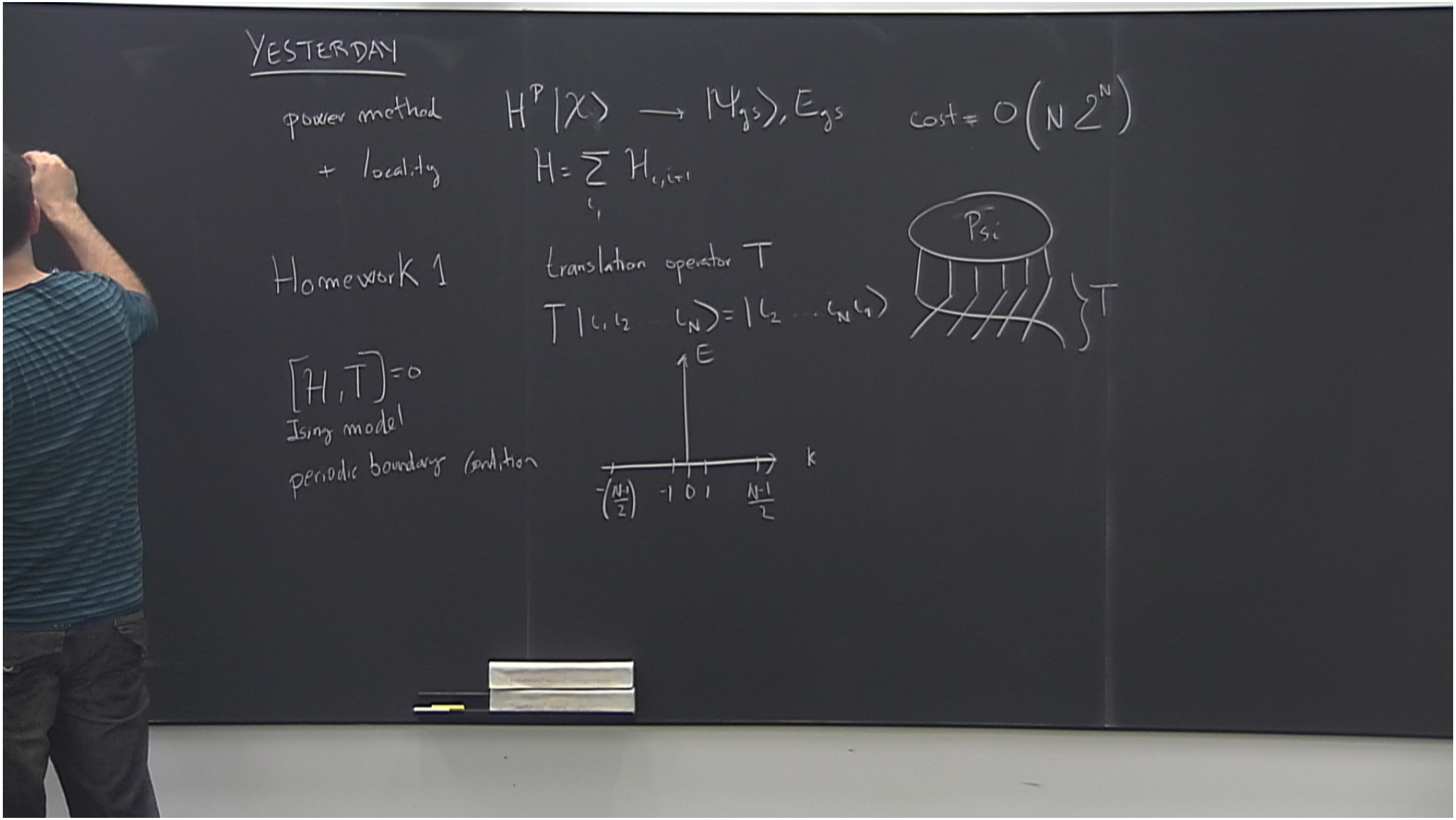
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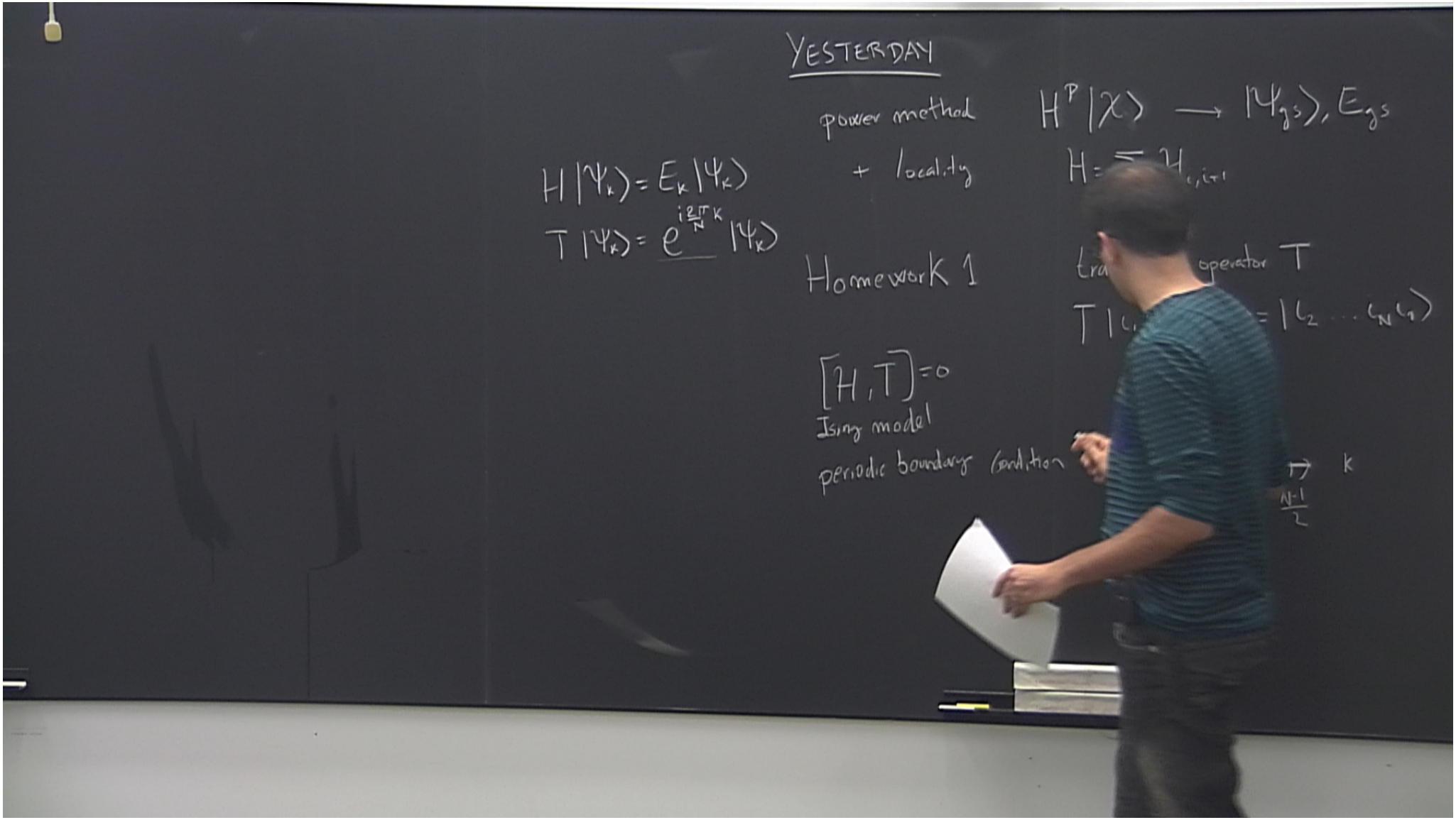
URL: http://pirsa.org/14040026

Abstract:


YESTERDAY
power method
+ locality
$H^p|\chi\rangle \longrightarrow |\psi_{gs}\rangle, E_{gs}$
$H = \sum_i H_{i,i+1}$
cost = $O(N 2^N)$


YESTERDAY
power method
+ locality
$H^P|\chi\rangle \longrightarrow |\psi_{gs}\rangle, E_{gs}$
cost $= O(N 2^N)$
$H = \sum_i H_i$
Homework 1
translation
T
$[H, T] = 0$
Ising model
periodic boundary condition
P_{S_i}
T


YESTERDAY
power method
+ locality
$H^p|\chi\rangle \longrightarrow |\psi_{gs}\rangle, E_{gs}$
cost $= O(N 2^N)$
$H = \sum_i H_{i,i+1}$
Homework 1
translation operator T
$T|i_1 i_2 \ldots i_N\rangle = |i_2 \ldots i_N i_1\rangle$
P_{si}
T
$[H, T] = 0$
Ising model
periodic boundary condition
E
k
$-\left(\frac{N-1}{2}\right)$
-1
0
1
$\frac{N-1}{2}$


YESTERDAY
power method
+ locality
$H^p|\chi\rangle \longrightarrow |\psi_{gs}\rangle, E_{gs}$
$H = \sum H_{i,i+1}$
$H|\psi_k\rangle = E_k|\psi_k\rangle$
$T|\psi_k\rangle = e^{i\frac{2\pi}{N}k}|\psi_k\rangle$
Homework 1
operator T
$T|\sigma_1 \ldots \sigma_N\rangle = |\sigma_2 \ldots \sigma_N \sigma_1\rangle$
$[H, T] = 0$
Ising model
periodic boundary condition
k
$\frac{N-1}{2}$

YESTERDAY

power method $H^P|\chi\rangle \longrightarrow |\psi_{gs}\rangle, E_{gs}$ cost $= O(N 2^N)$

+ locality $H = \sum_i H_{i,i+1}$

$H|\psi_k\rangle = E_k|\psi_k\rangle$

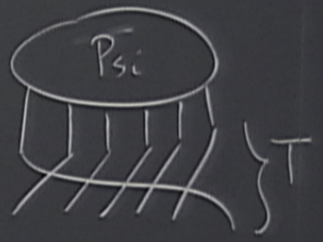
$T|\psi_k\rangle = e^{i\frac{2\pi}{N}k}|\psi_k\rangle$

N odd

Homework 1

translation operator T

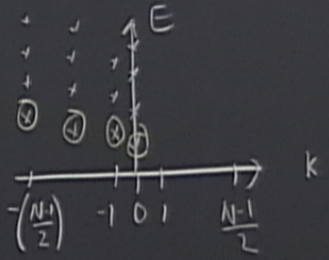
$T|i_1 i_2 \ldots i_N\rangle = |i_2 \ldots i_N i_1\rangle$

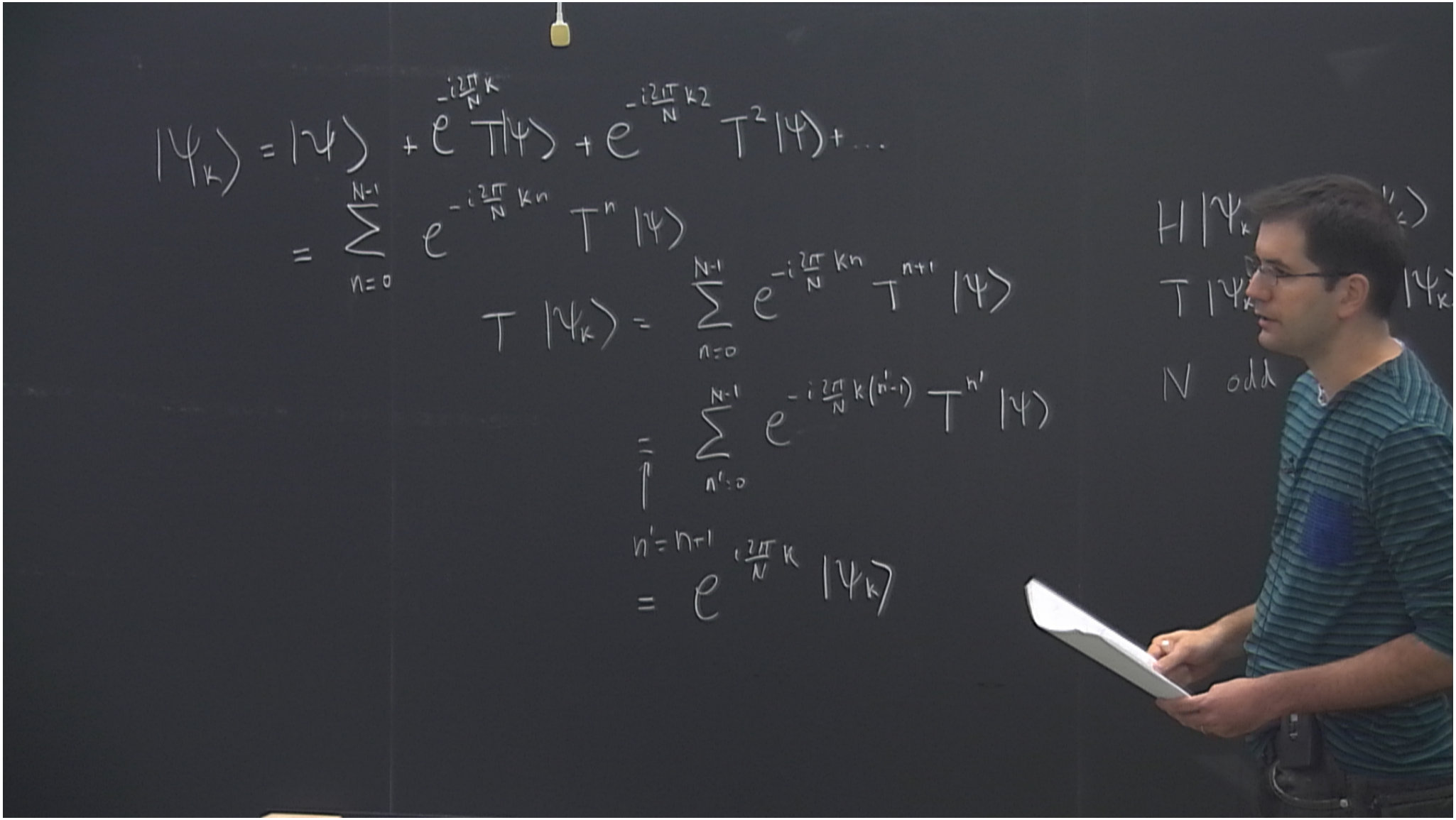


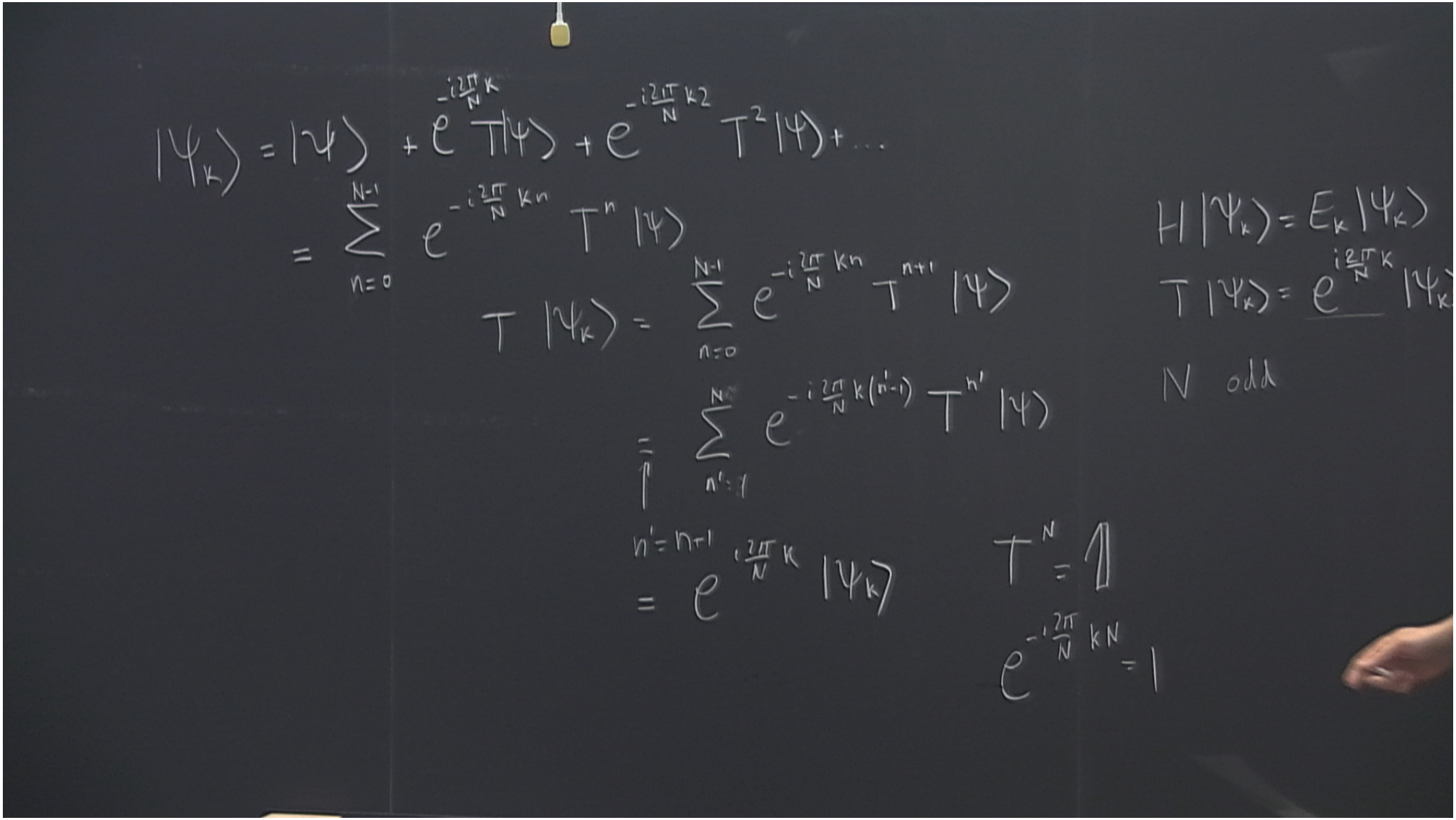
$[H,T]=0$

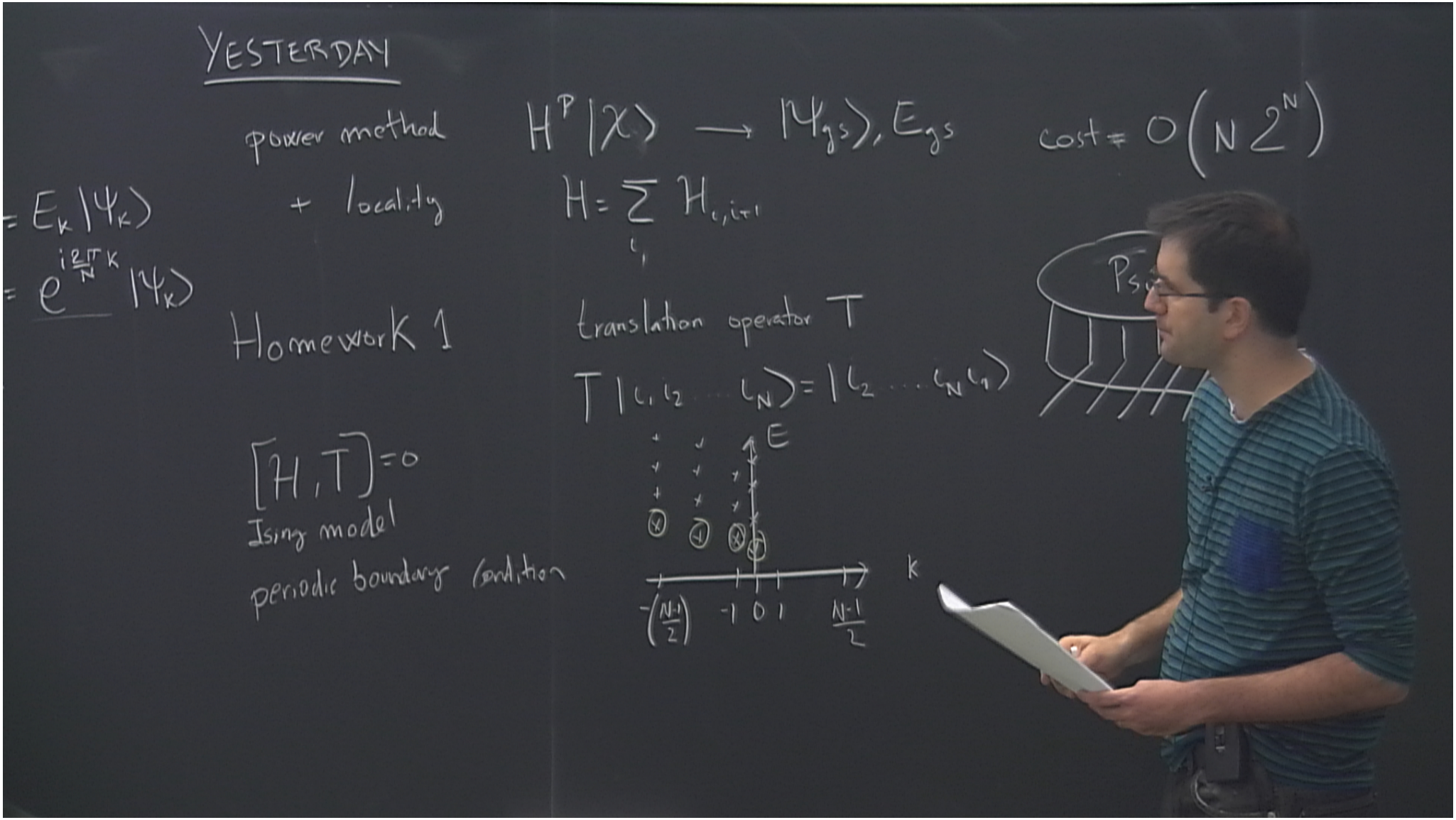
Ising model

periodic boundary condition




$|\psi_k\rangle = |\psi\rangle + e^{-i\frac{2\pi}{N}k} T|\psi\rangle + e^{-i\frac{2\pi}{N}k2} T^2|\psi\rangle + \ldots$
$= \sum_{n=0}^{N-1} e^{-i\frac{2\pi}{N}kn} T^n |\psi\rangle$
$T|\psi_k\rangle = \sum_{n=0}^{N-1} e^{-i\frac{2\pi}{N}kn} T^{n+1}|\psi\rangle$
$= \sum_{n'=0}^{N-1} e^{-i\frac{2\pi}{N}k(n'-1)} T^{n'}|\psi\rangle$
$n' = n+1$
$= e^{i\frac{2\pi}{N}k}|\psi_k\rangle$
$H|\psi_k$
$T|\psi_k$
$|\psi_k$
N odd


$|\psi_k\rangle = |\psi\rangle + e^{-i\frac{2\pi}{N}k} T|\psi\rangle + e^{-i\frac{2\pi}{N}k2} T^2|\psi\rangle + \ldots$
$= \sum_{n=0}^{N-1} e^{-i\frac{2\pi}{N}kn} T^n |\psi\rangle$
$T|\psi_k\rangle = \sum_{n=0}^{N-1} e^{-i\frac{2\pi}{N}kn} T^{n+1}|\psi\rangle$
$= \sum_{n'=1}^{N} e^{-i\frac{2\pi}{N}k(n'-1)} T^{n'}|\psi\rangle$
$n' = n+1$
$= e^{i\frac{2\pi}{N}k}|\psi_k\rangle$
$T^N = 1$
$e^{-i\frac{2\pi}{N}kN} = 1$
$H|\psi_k\rangle = E_k|\psi_k\rangle$
$T|\psi_k\rangle = e^{i\frac{2\pi}{N}k}|\psi_k\rangle$
N odd

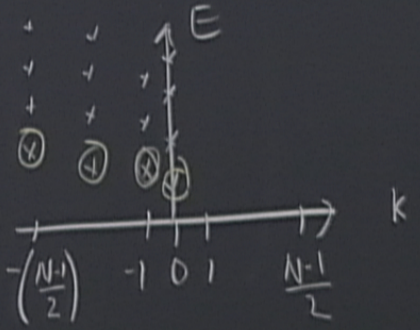

YESTERDAY
power method
+ locality
$H^P|\chi\rangle \longrightarrow |\psi_{gs}\rangle, E_{gs}$
cost $= O(N 2^N)$
$H = \sum_{i} H_{i,i+1}$
$= E_k|\psi_k\rangle$
$= e^{i\frac{2\pi}{N}k}|\psi_k\rangle$
Homework 1
translation operator T
$T|i_1 i_2 \dots i_N\rangle = |i_2 \dots i_N i_1\rangle$
$[H,T]=0$
Ising model
periodic boundary condition
E
k
$-\left(\frac{N-1}{2}\right)$
-1
0
1
$\frac{N-1}{2}$

$H^P|\chi\rangle \longrightarrow |\psi_{gs}\rangle, E_{gs}$ cost $= O(N 2^N)$ $N \sim 20$

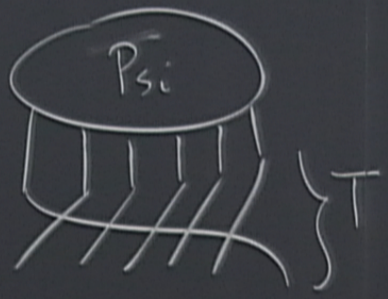
$H = \sum_{i} H_{i,i+1}$

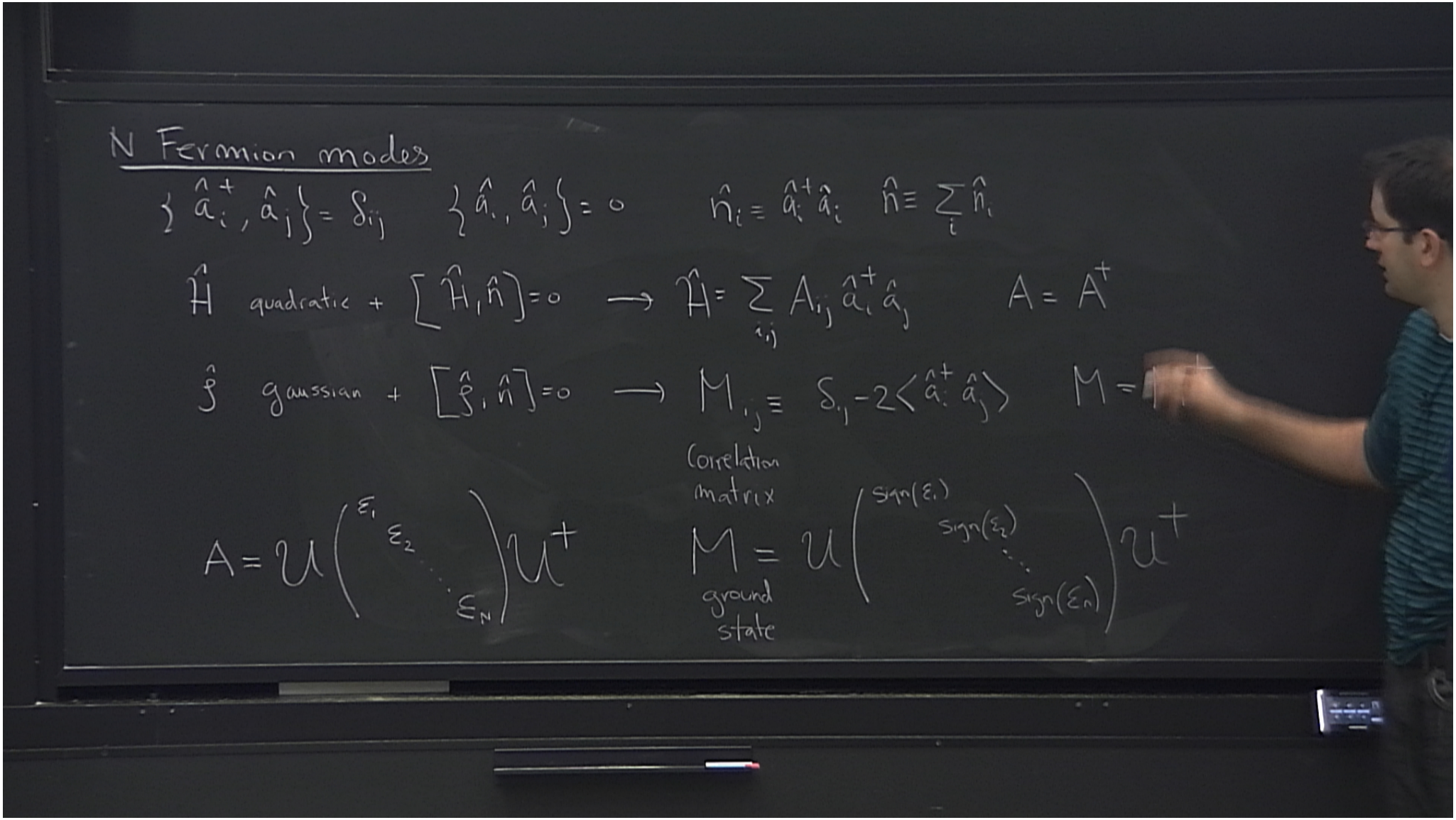
translation operator T

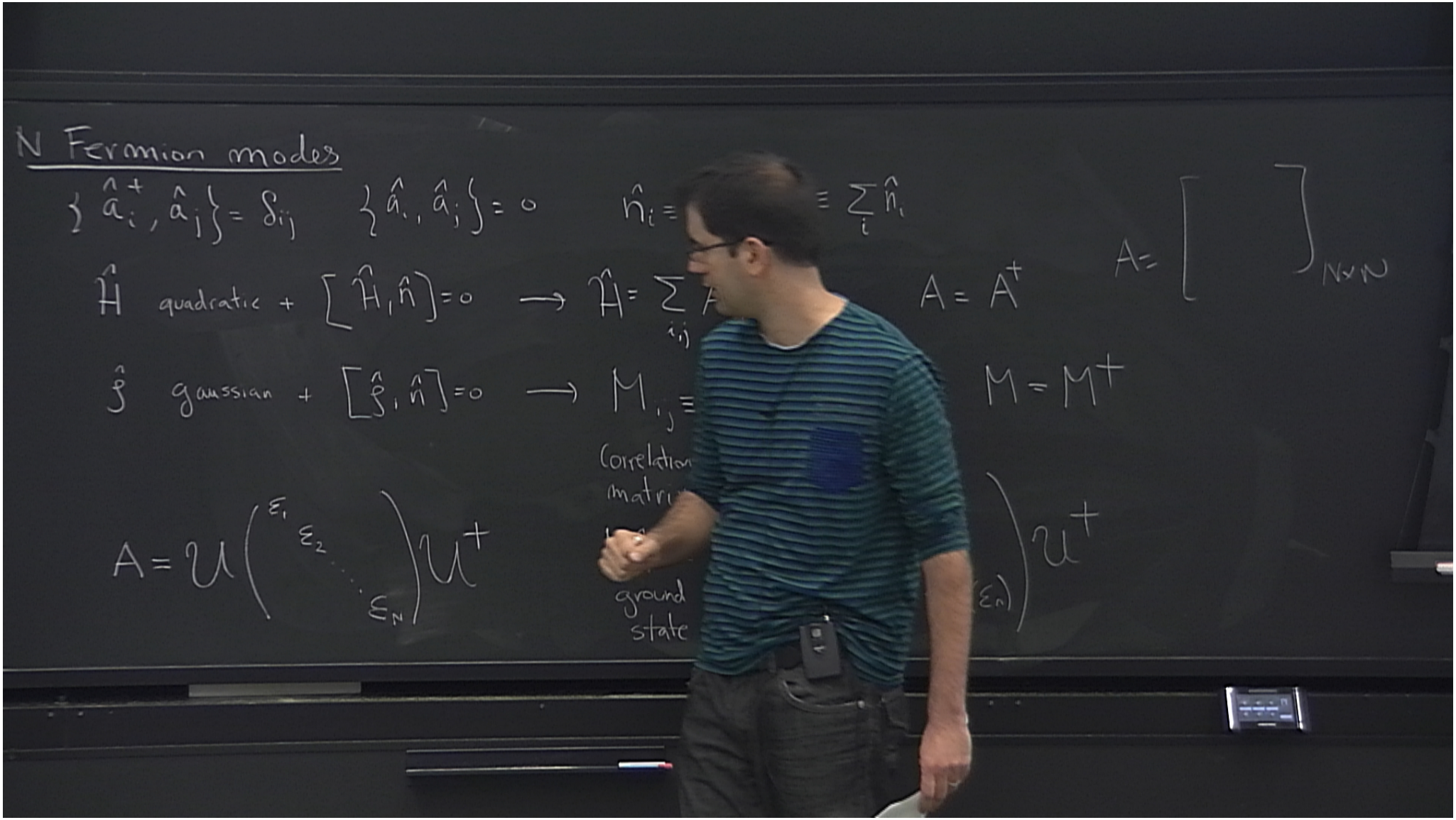
$T|i_1 i_2 \ldots i_N\rangle = |i_2 \ldots i_N i_1\rangle$



condition




N Fermion modes
$\{\hat{a}_i^\dagger, \hat{a}_j\} = \delta_{ij}$ $\{\hat{a}_i, \hat{a}_j\} = 0$ $\hat{n}_i \equiv \hat{a}_i^\dagger \hat{a}_i$ $\hat{n} \equiv \sum_i \hat{n}_i$
$\hat{H}$ quadratic + $[\hat{H}, \hat{n}] = 0 \longrightarrow \hat{H} = \sum_{i,j} A_{ij} \hat{a}_i^\dagger \hat{a}_j$ $A = A^\dagger$
$\hat{\rho}$ gaussian + $[\hat{\rho}, \hat{n}] = 0 \longrightarrow M_{ij} \equiv \delta_{ij} - 2\langle \hat{a}_i^\dagger \hat{a}_j \rangle$ $M =$
Correlation matrix
$A = U \begin{pmatrix} \varepsilon_1 & & \\ & \varepsilon_2 & \\ & & \ddots \\ & & & \varepsilon_N \end{pmatrix} U^\dagger$
$M = U \begin{pmatrix} \mathrm{sign}(\varepsilon_1) & & \\ & \mathrm{sign}(\varepsilon_2) & \\ & & \ddots \\ & & & \mathrm{sign}(\varepsilon_n) \end{pmatrix} U^\dagger$
ground state

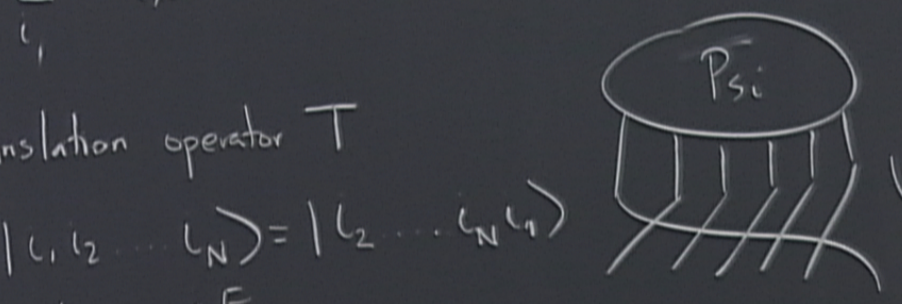

N Fermion modes
$\{\hat{a}_i^\dagger, \hat{a}_j\} = \delta_{ij}$
$\{\hat{a}_i, \hat{a}_j\} = 0$
$\hat{n}_i \equiv$
$\equiv \sum_i \hat{n}_i$
$\hat{H}$ quadratic + $[\hat{H}, \hat{n}] = 0 \longrightarrow \hat{H} = \sum_{i,j}$
$A = A^\dagger$
$A = \begin{bmatrix} \\ \end{bmatrix}_{N \times N}$
$\hat{\rho}$ gaussian + $[\hat{\rho}, \hat{n}] = 0 \longrightarrow M_{ij} =$
$M = M^\dagger$
Correlation matrix
$A = U \begin{pmatrix} \varepsilon_1 & & \\ & \varepsilon_2 & \\ & & \ddots \\ & & & \varepsilon_N \end{pmatrix} U^\dagger$
ε_n
ground state

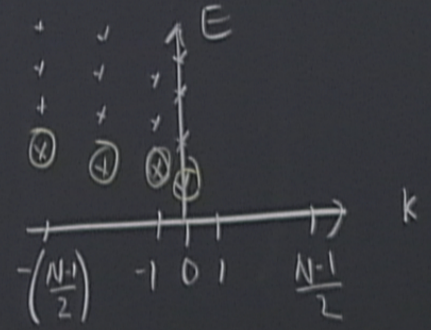
$H^P|\chi\rangle \longrightarrow |\psi_{gs}\rangle, E_{gs}$ cost $= O(N 2^N)$ $N \sim 20$

$H = \sum_i H_{i,i+1}$

translation operator T

$T|i_1 i_2 \ldots i_N\rangle = |i_2 \ldots i_N i_1\rangle$



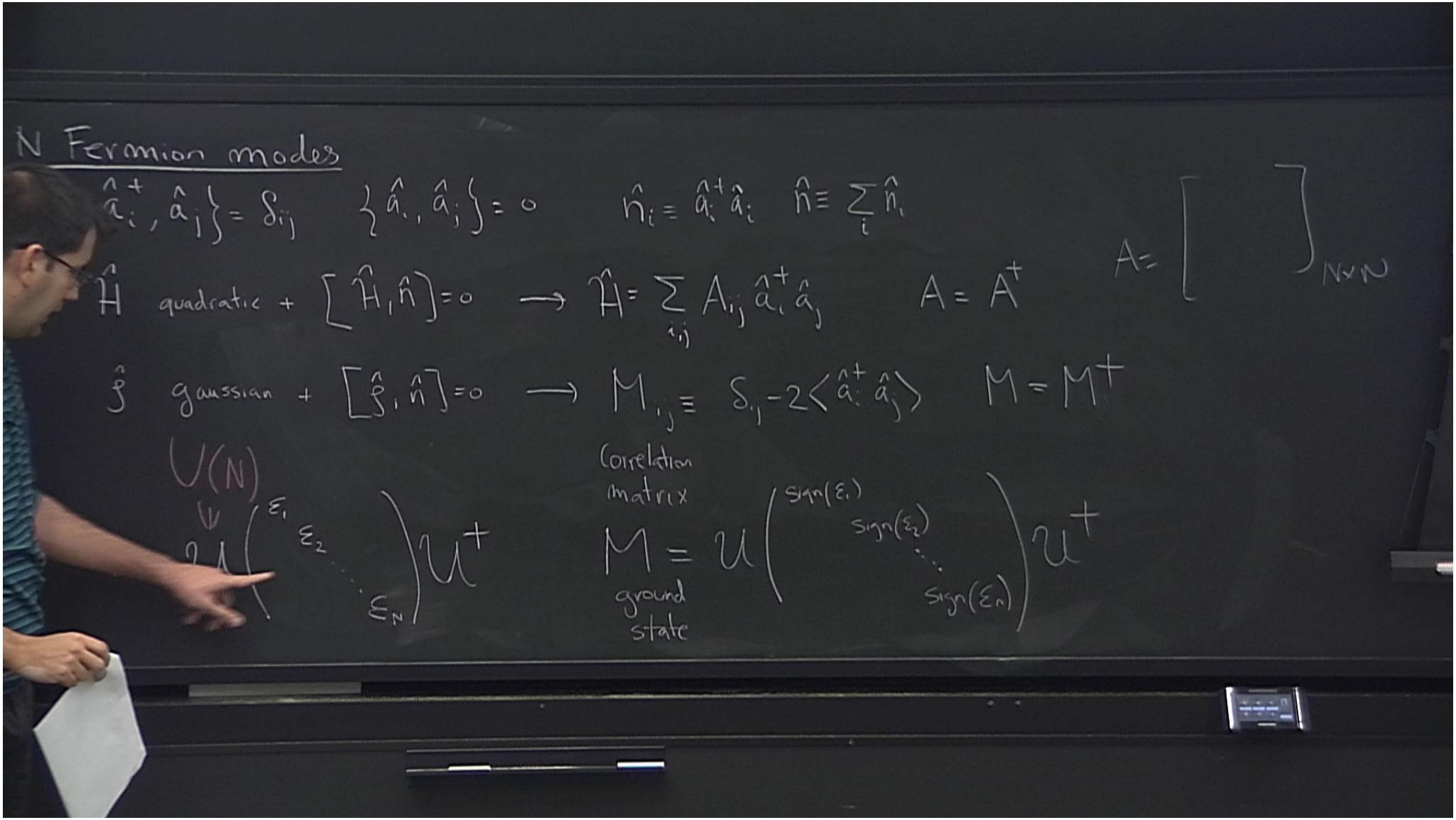


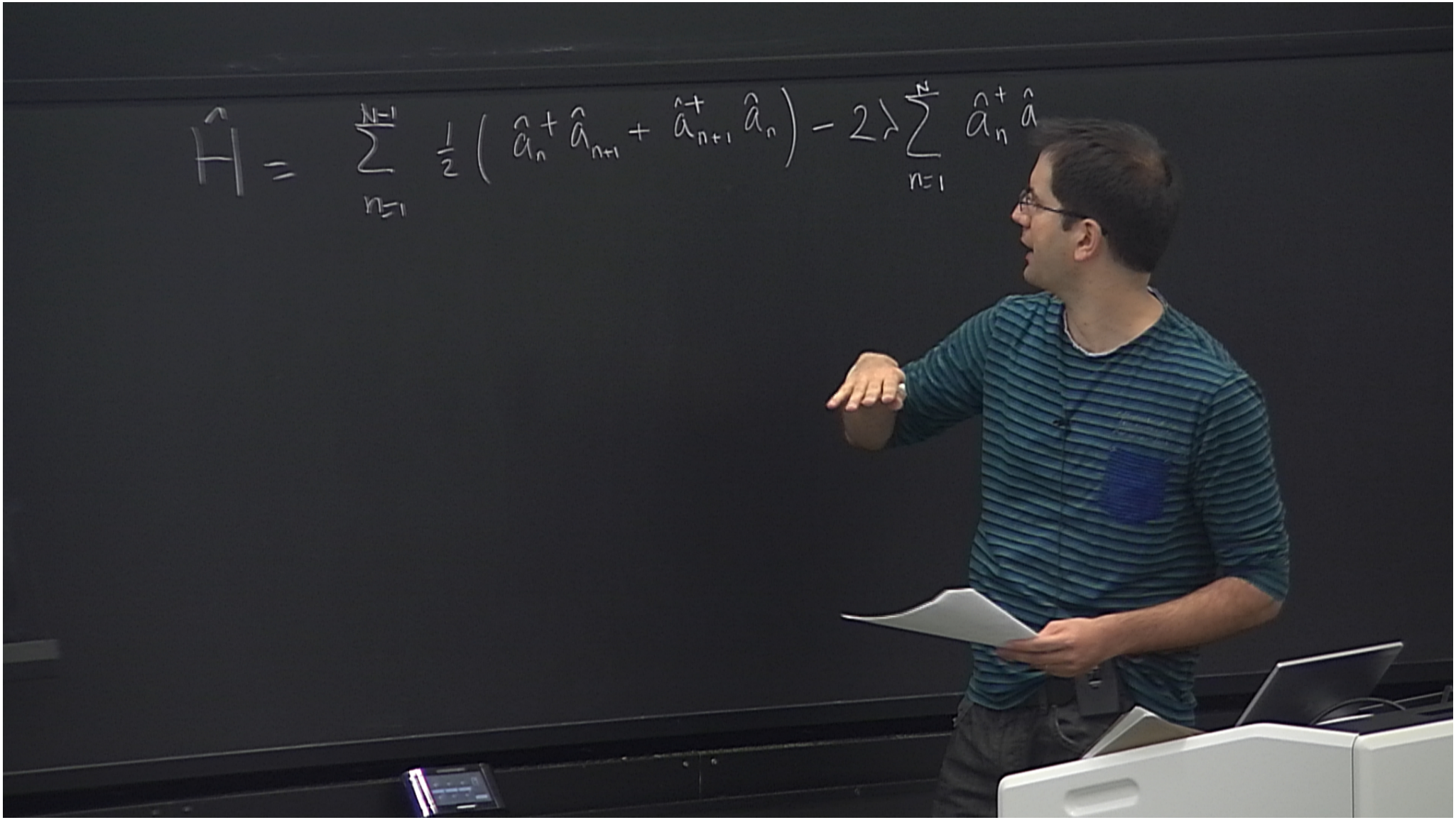
condition

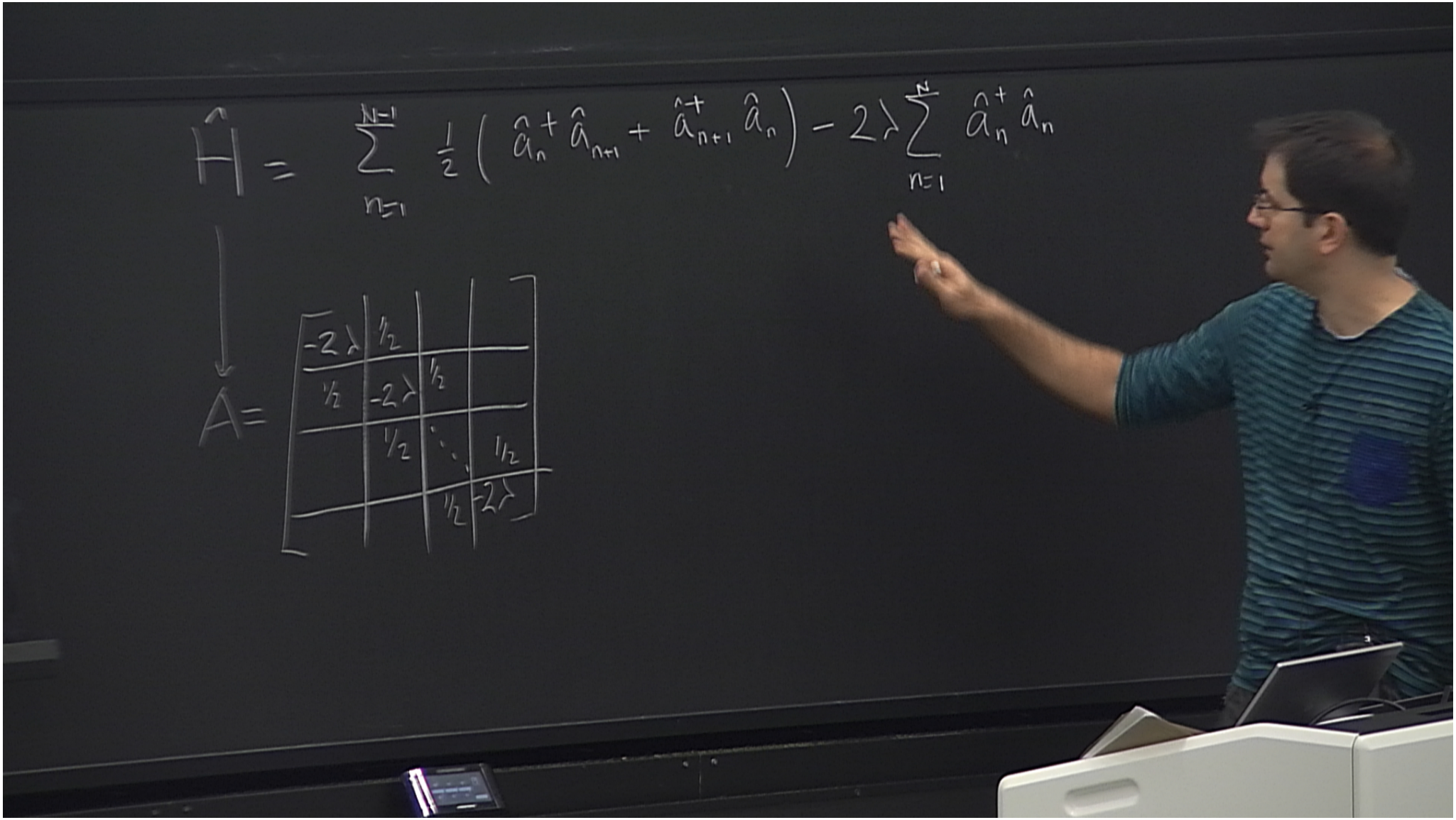
$2^N \times 2^N$ $\hat{H}_1$ $\hat{S}$

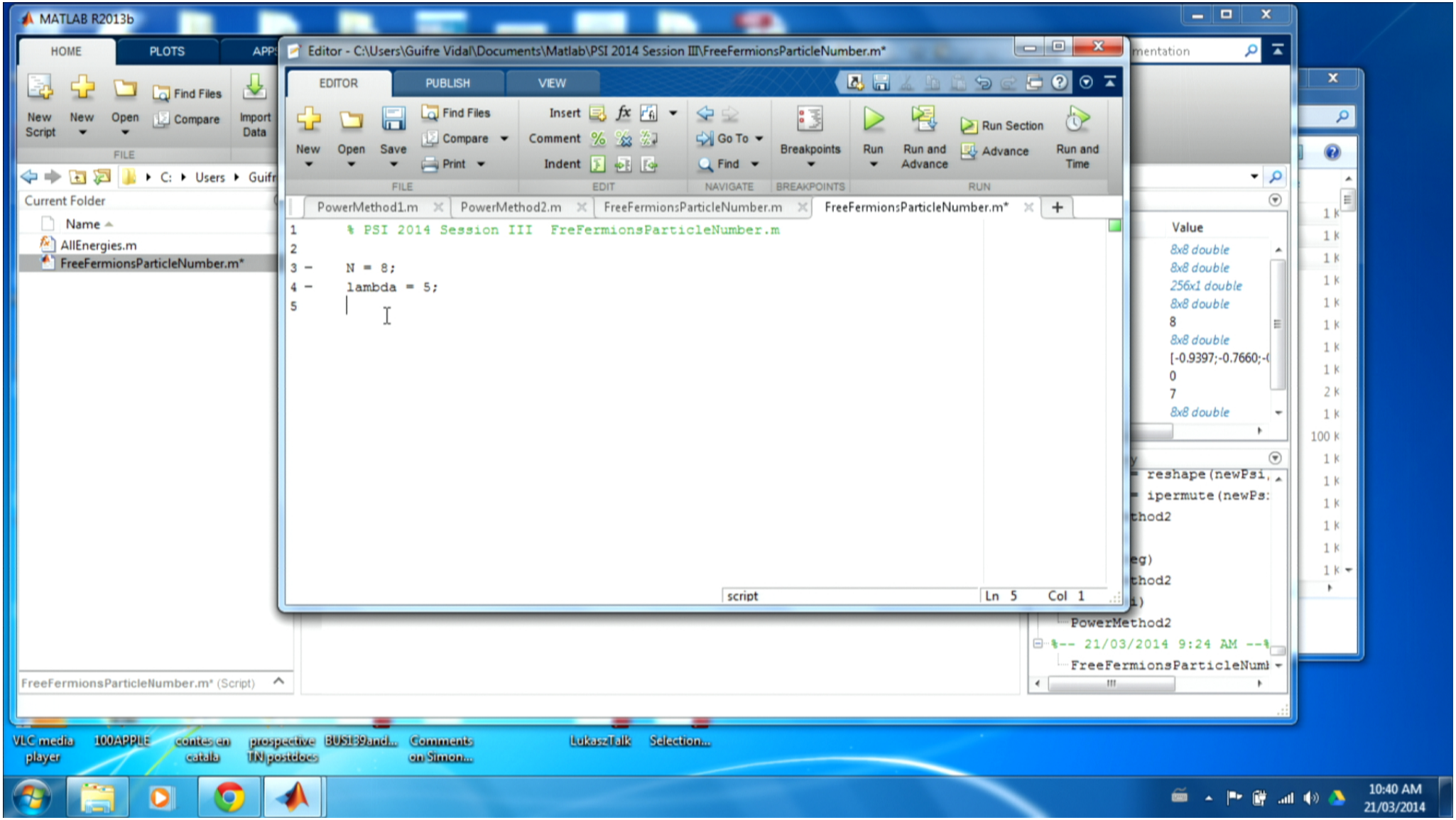
$\downarrow$ $\downarrow$

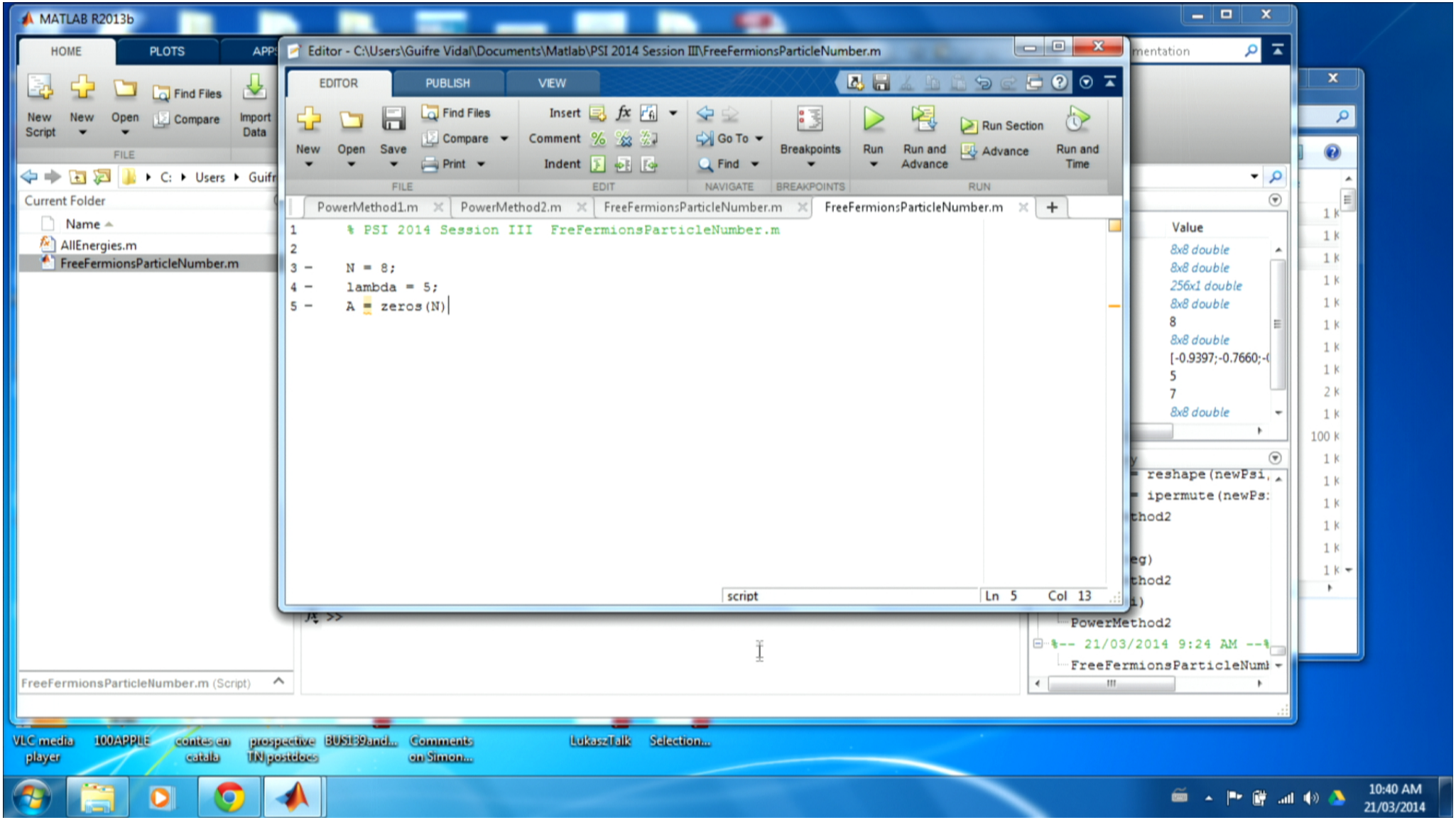
$N \times N$ A M

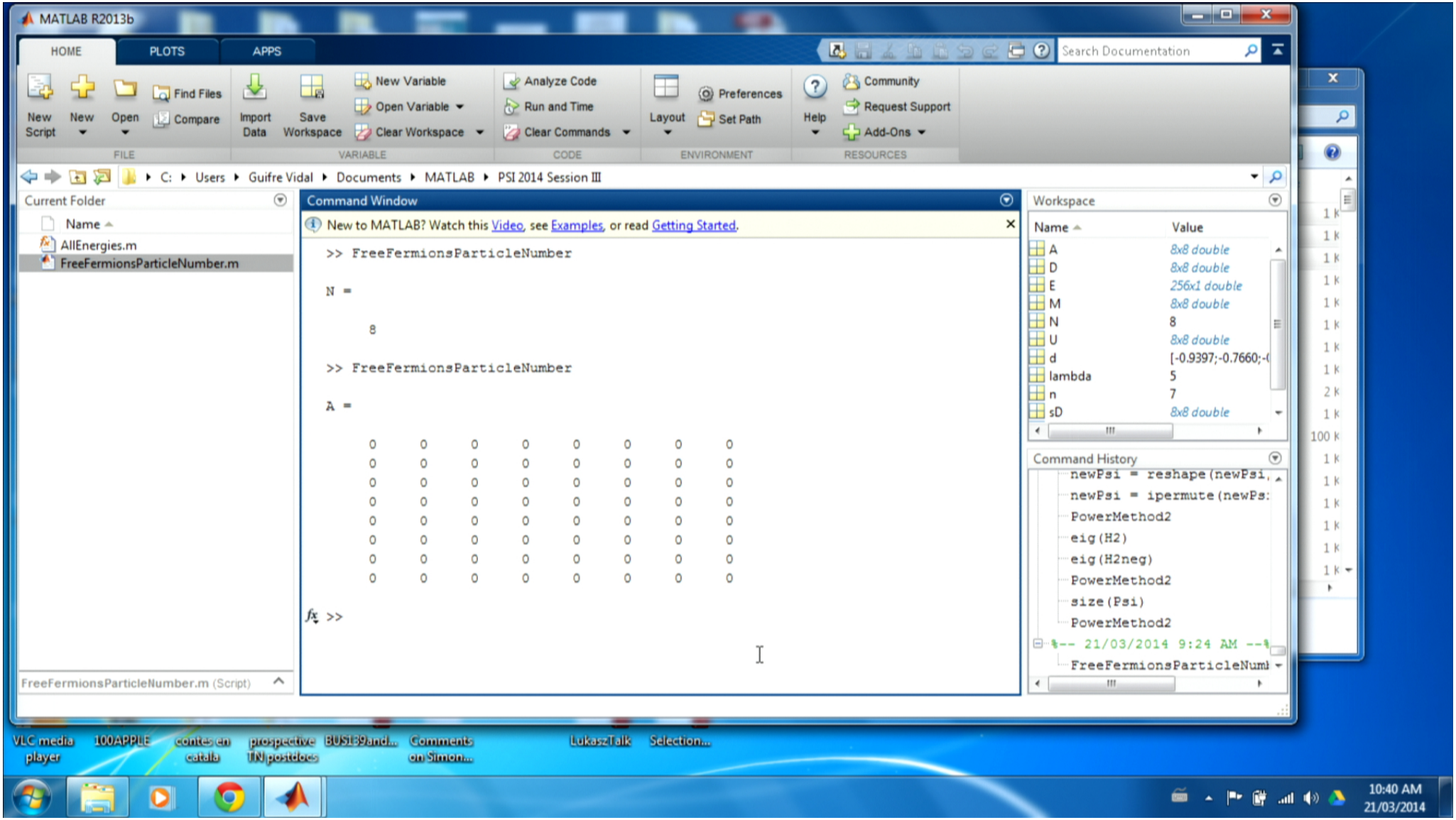

N Fermion modes
$\{\hat{a}_i^\dagger, \hat{a}_j\} = \delta_{ij}$ $\{\hat{a}_i, \hat{a}_j\} = 0$ $\hat{n}_i \equiv \hat{a}_i^\dagger \hat{a}_i$ $\hat{n} \equiv \sum_i \hat{n}_i$
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$\hat{\rho}$ gaussian + $[\hat{\rho}, \hat{n}] = 0 \longrightarrow M_{ij} \equiv \delta_{ij} - 2\langle \hat{a}_i^\dagger \hat{a}_j \rangle$ $M = M^\dagger$
$U(N)$
ε_1 ε_2 ε_N
Correlation matrix
$M = U \begin{pmatrix} \mathrm{sign}(\varepsilon_1) & & \\ & \mathrm{sign}(\varepsilon_2) & \\ & & \mathrm{sign}(\varepsilon_n) \end{pmatrix} U^\dagger$
ground state

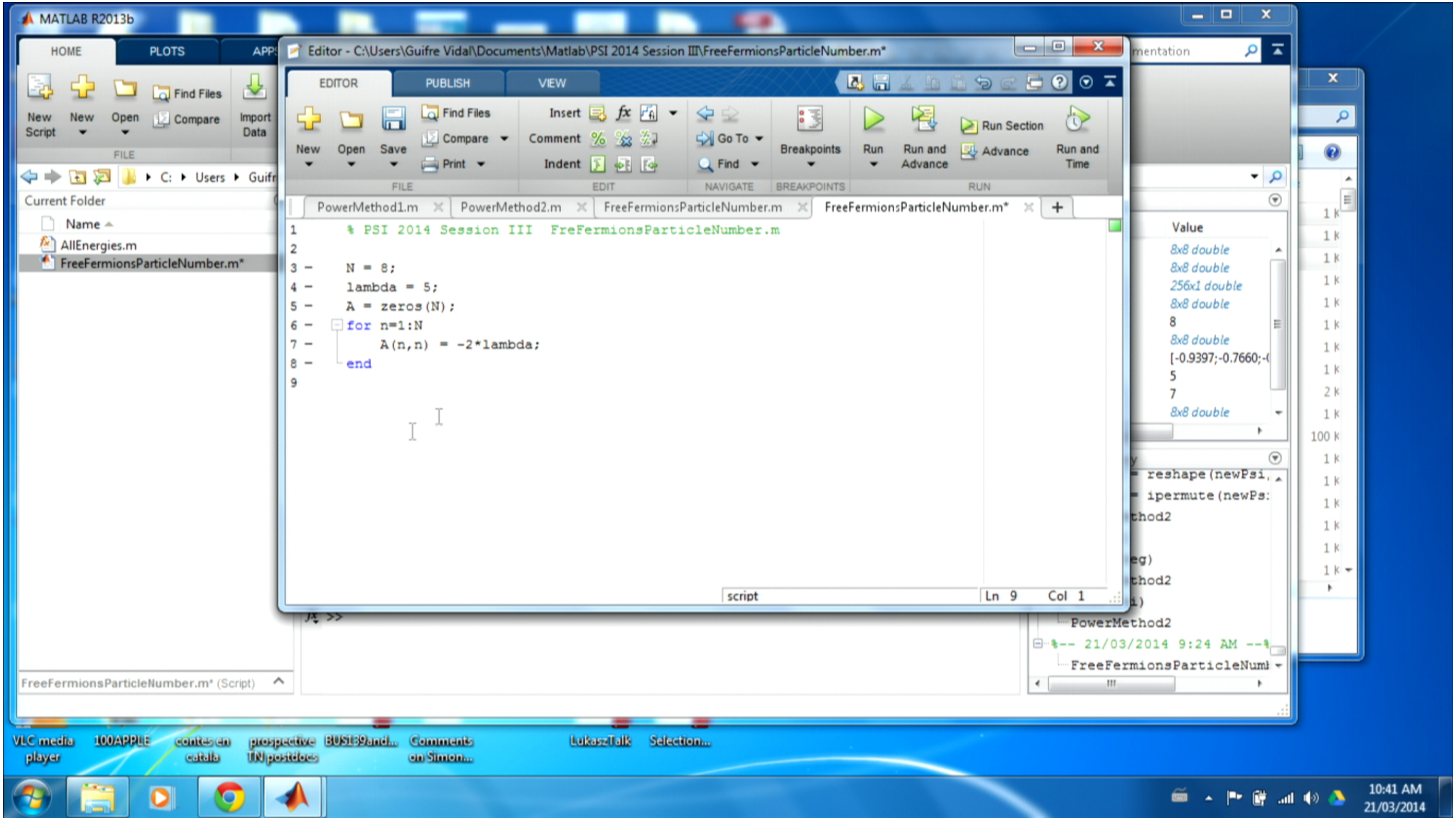

$\hat{H} = \sum_{n=1}^{N-1} \frac{1}{2}\left(\hat{a}_n^\dagger \hat{a}_{n+1} + \hat{a}_{n+1}^\dagger \hat{a}_n\right) - 2\lambda \sum_{n=1}^{N} \hat{a}_n^\dagger \hat{a}$

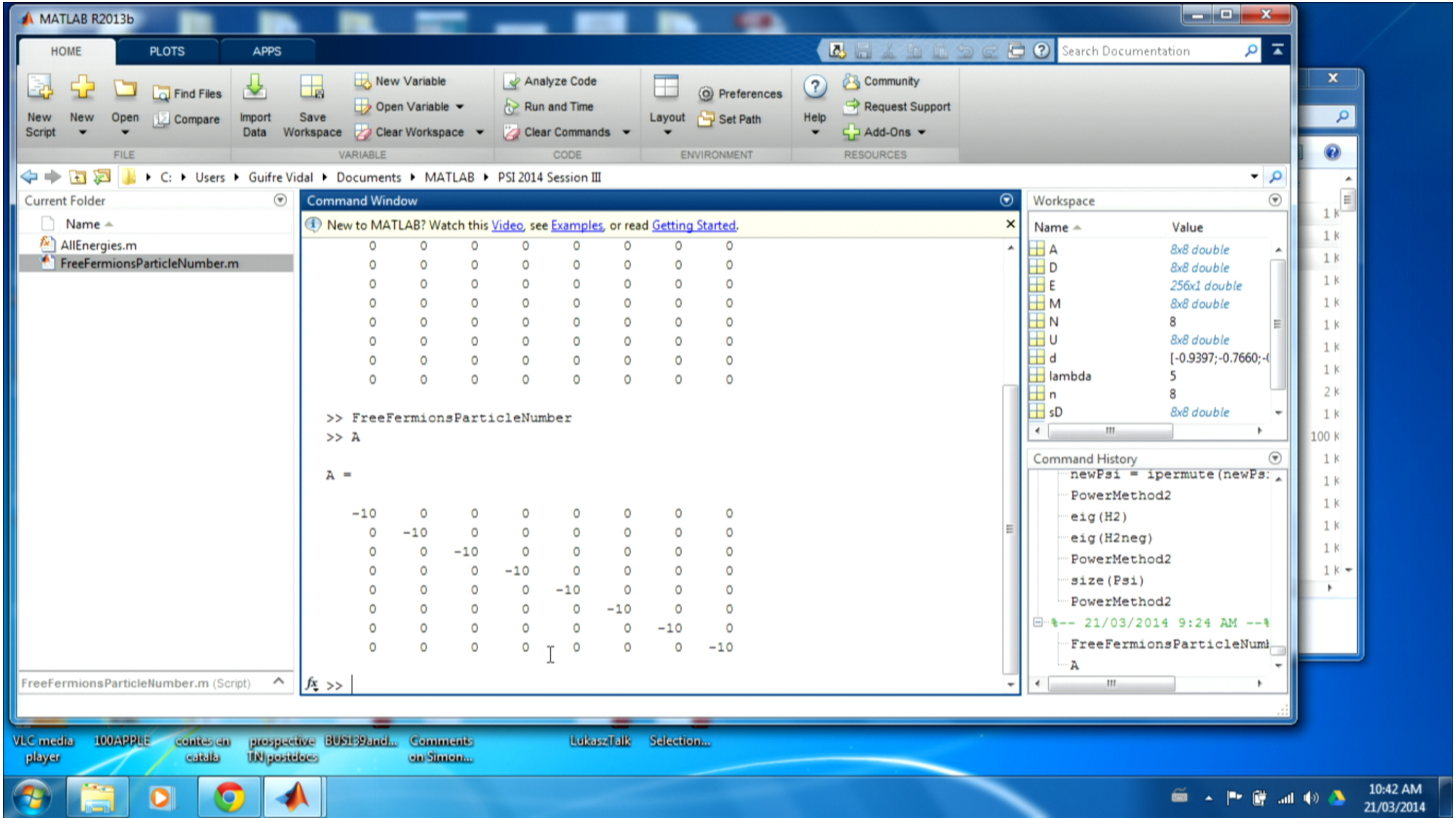

$\hat{H} = \sum_{n=1}^{N-1} \frac{1}{2}\left(\hat{a}_n^+ \hat{a}_{n+1} + \hat{a}_{n+1}^+ \hat{a}_n\right) - 2\lambda \sum_{n=1}^{N} \hat{a}_n^+ \hat{a}_n$
$\hat{A} =$
-2λ $\frac{1}{2}$
$\frac{1}{2}$ -2λ $\frac{1}{2}$
$\frac{1}{2}$ $\ddots$ $\frac{1}{2}$
$\frac{1}{2}$ -2λ

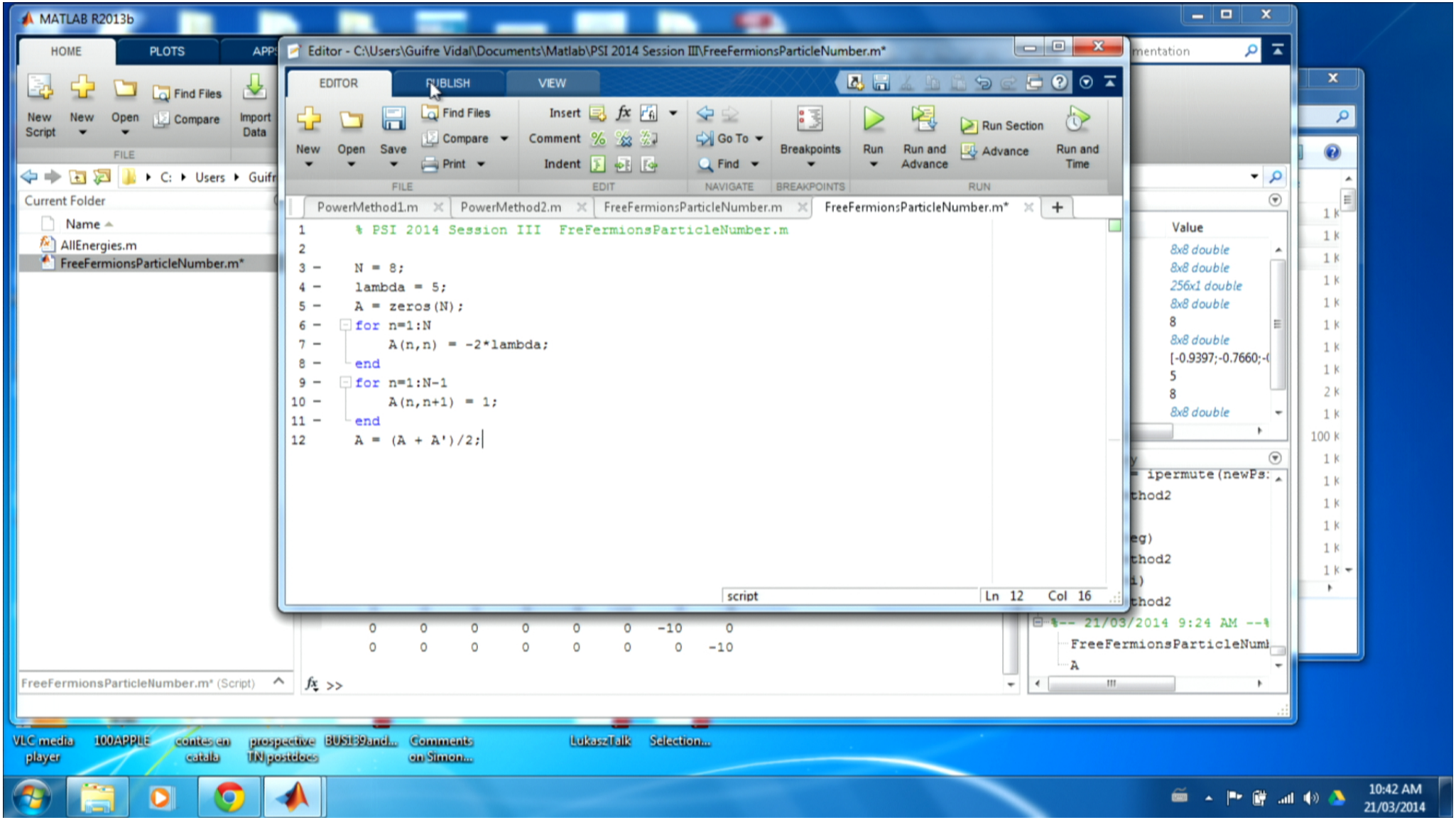

MATLAB R2013b
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EDITOR
PUBLISH
VIEW
PowerMethod1.m
PowerMethod2.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m*
1 % PSI 2014 Session III FreFermionsParticleNumber.m
2
3 - N = 8;
4 - lambda = 5;
5
script
Ln 5 Col 1
Current Folder
Name
AllEnergies.m
FreeFermionsParticleNumber.m*
Value
8x8 double
8x8 double
256x1 double
8x8 double
8
8x8 double
0
7
8x8 double
PowerMethod2
%-- 21/03/2014 9:24 AM --%
10:40 AM
21/03/2014

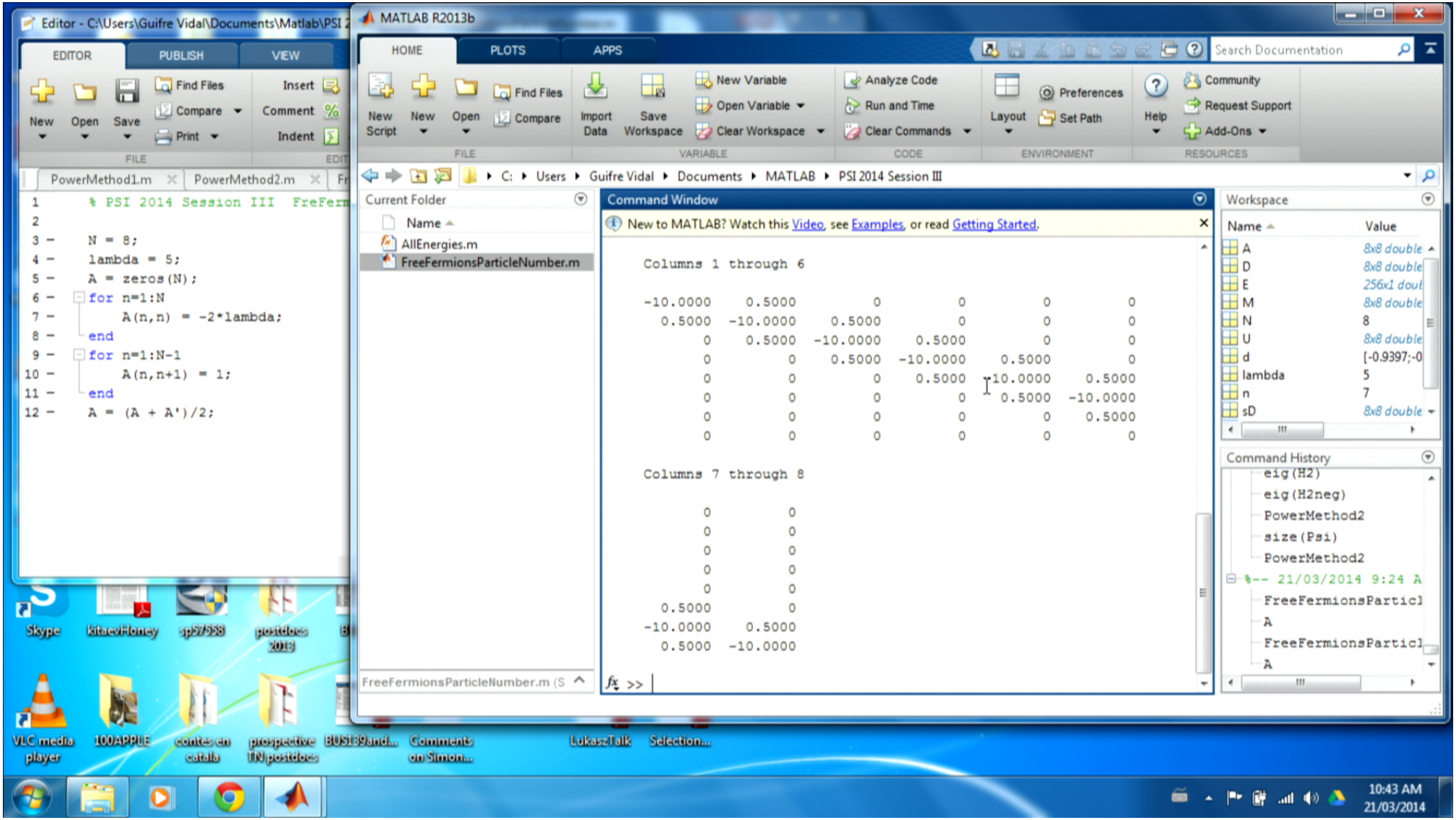

MATLAB R2013b
Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2014 Session III\FreeFermionsParticleNumber.m
EDITOR
PUBLISH
VIEW
PowerMethod1.m
PowerMethod2.m
FreeFermionsParticleNumber.m
% PSI 2014 Session III FreFermionsParticleNumber.m
N = 8;
lambda = 5;
A = zeros(N)
script
Ln 5 Col 13
Current Folder
AllEnergies.m
FreeFermionsParticleNumber.m
Value
PowerMethod2
FreeFermionsParticleNumber.m (Script)
10:40 AM
21/03/2014

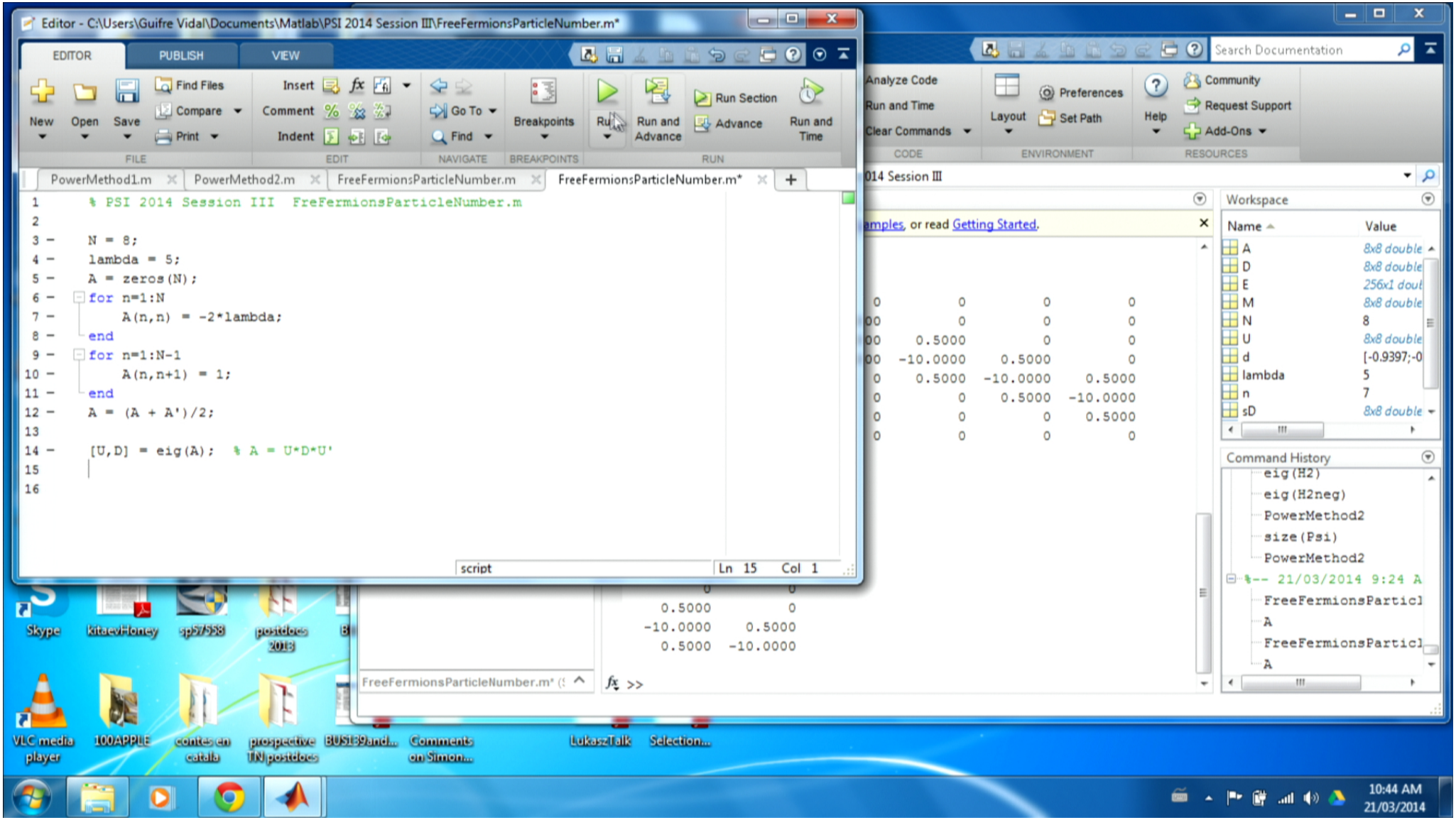

MATLAB R2013b
HOME
PLOTS
APPS
Search Documentation
New Script
New
Open
Find Files
Compare
Import Data
Save Workspace
New Variable
Open Variable
Clear Workspace
Analyze Code
Run and Time
Clear Commands
Layout
Preferences
Set Path
Help
Community
Request Support
Add-Ons
FILE
VARIABLE
CODE
ENVIRONMENT
RESOURCES
C: ▸ Users ▸ Guifre Vidal ▸ Documents ▸ MATLAB ▸ PSI 2014 Session III
Current Folder
Name
AllEnergies.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m (Script)
Command Window
New to MATLAB? Watch this Video, see Examples, or read Getting Started.
>> FreeFermionsParticleNumber
N =
8
>> FreeFermionsParticleNumber
A =
0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
fx >>
Workspace
Name
Value
A 8x8 double
D 8x8 double
E 256x1 double
M 8x8 double
N 8
U 8x8 double
d [-0.9397;-0.7660;-(
lambda 5
n 7
sD 8x8 double
Command History
newPsi = reshape(newPsi,
newPsi = ipermute(newPs:
PowerMethod2
eig(H2)
eig(H2neg)
PowerMethod2
size(Psi)
PowerMethod2
%-- 21/03/2014 9:24 AM --%
FreeFermionsParticleNumb
VLC media player
100APPLE
contes en catala
prospective TN postdocs
BUSI39and...
Comments on Simon...
LukaszTalk
Selection...
10:40 AM
21/03/2014

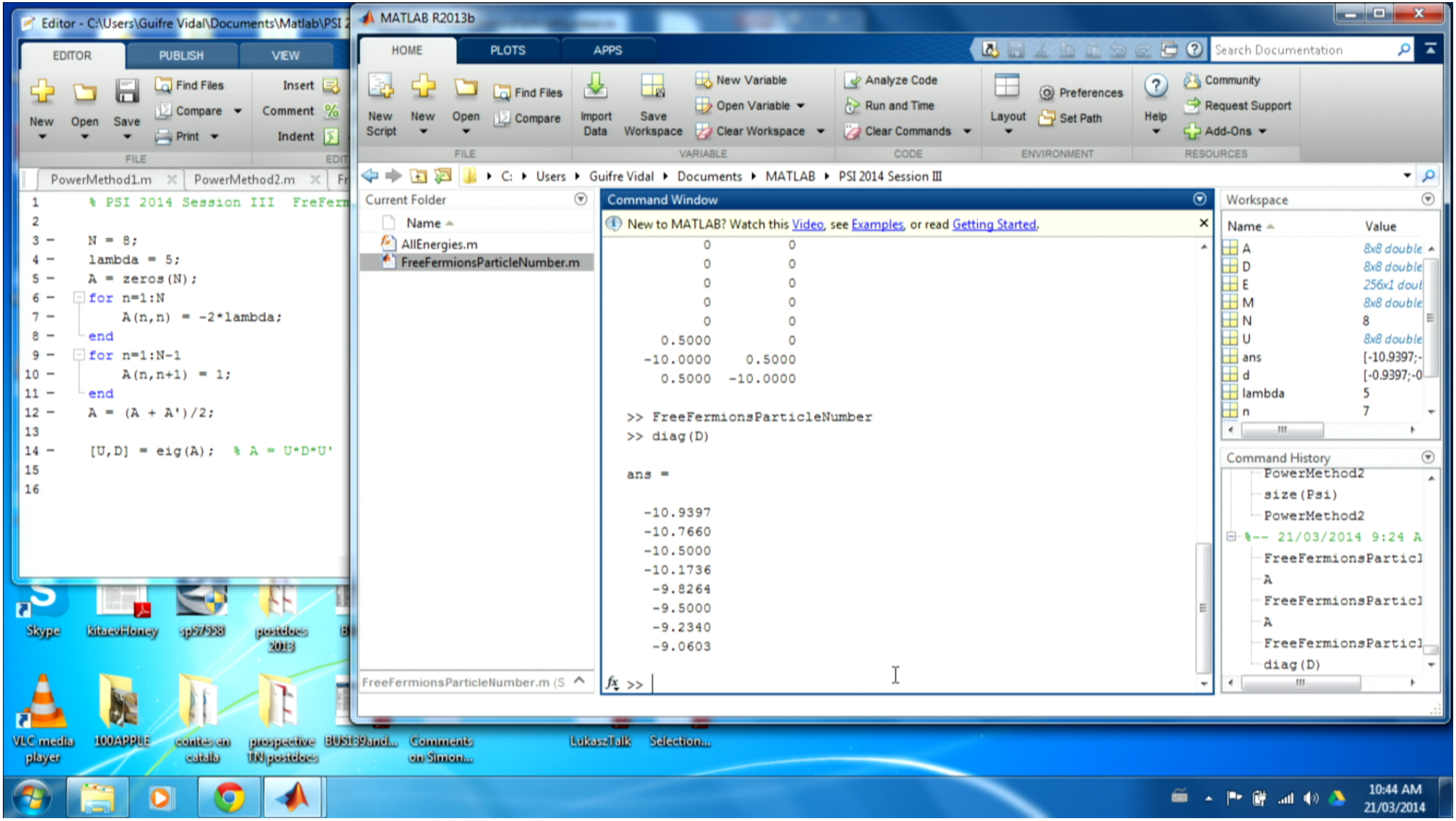

MATLAB R2013b
Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2014 Session III\FreeFermionsParticleNumber.m*
EDITOR
PUBLISH
VIEW
PowerMethod1.m
PowerMethod2.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m*
1 % PSI 2014 Session III FreFermionsParticleNumber.m
2
3 - N = 8;
4 - lambda = 5;
5 - A = zeros(N);
6 - for n=1:N
7 - A(n,n) = -2*lambda;
8 - end
9
script
Ln 9 Col 1
Current Folder
Name
AllEnergies.m
FreeFermionsParticleNumber.m*
Value
8x8 double
8x8 double
256x1 double
8x8 double
8
8x8 double
5
7
8x8 double
PowerMethod2
%-- 21/03/2014 9:24 AM --%
FreeFermionsParticleNumb
10:41 AM
21/03/2014

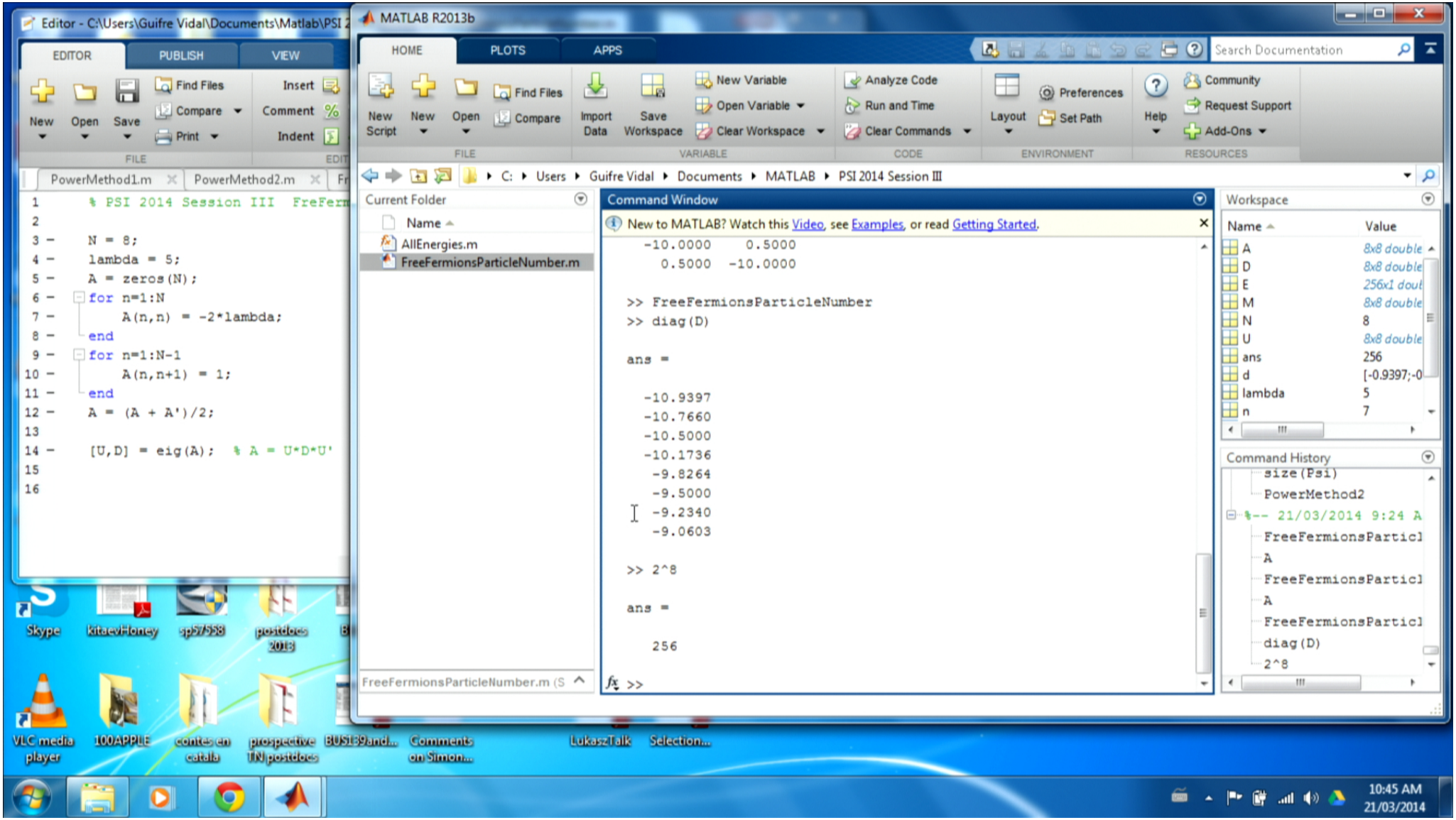

MATLAB R2013b
HOME
PLOTS
APPS
Search Documentation
New Script
New
Open
Find Files
Compare
Import Data
Save Workspace
New Variable
Open Variable
Clear Workspace
Analyze Code
Run and Time
Clear Commands
Layout
Preferences
Set Path
Help
Community
Request Support
Add-Ons
FILE
VARIABLE
CODE
ENVIRONMENT
RESOURCES
C: ▸ Users ▸ Guifre Vidal ▸ Documents ▸ MATLAB ▸ PSI 2014 Session III
Current Folder
Name
AllEnergies.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m (Script)
Command Window
New to MATLAB? Watch this Video, see Examples, or read Getting Started.
>> FreeFermionsParticleNumber
>> A
A =
-10 0 0 0 0 0 0 0
0 -10 0 0 0 0 0 0
0 0 -10 0 0 0 0 0
0 0 0 -10 0 0 0 0
0 0 0 0 -10 0 0 0
0 0 0 0 0 -10 0 0
0 0 0 0 0 0 -10 0
0 0 0 0 0 0 0 -10
>>
Workspace
Name
Value
A 8x8 double
D 8x8 double
E 256x1 double
M 8x8 double
N 8
U 8x8 double
d [-0.9397;-0.7660;-
lambda 5
n 8
sD 8x8 double
Command History
newPsi = ipermute(newPs
PowerMethod2
eig(H2)
eig(H2neg)
PowerMethod2
size(Psi)
PowerMethod2
%-- 21/03/2014 9:24 AM --%
FreeFermionsParticleNum
A
VLC media player
100APPLE
contes en catala
prospective TN postdocs
BUSI39and...
Comments on Simon...
LukaszTalk
Selection...
10:42 AM
21/03/2014

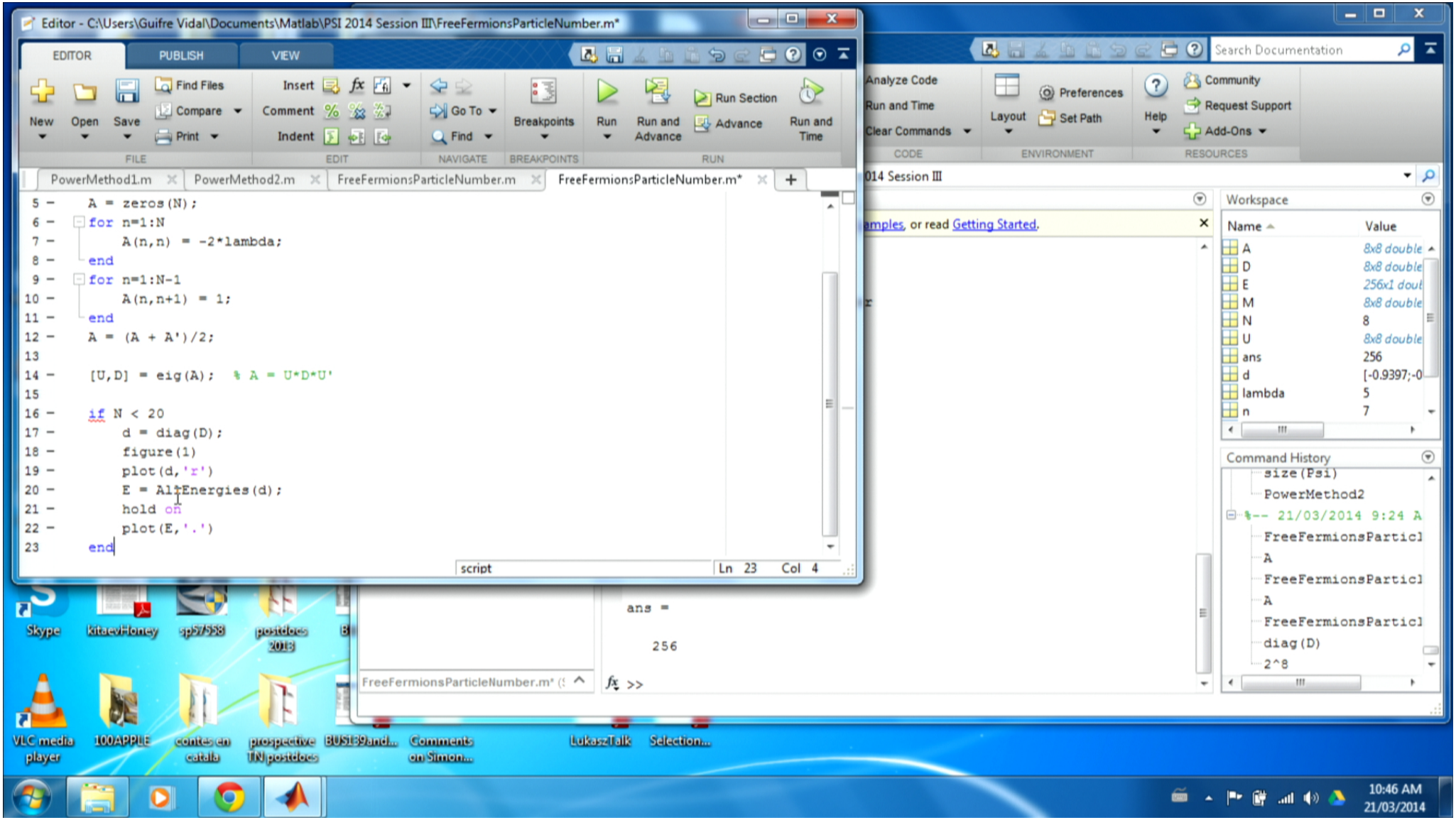

MATLAB R2013b
Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2014 Session III\FreeFermionsParticleNumber.m*
EDITOR
PUBLISH
VIEW
PowerMethod1.m
PowerMethod2.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m*
1 % PSI 2014 Session III FreFermionsParticleNumber.m
2
3 N = 8;
4 lambda = 5;
5 A = zeros(N);
6 for n=1:N
7 A(n,n) = -2*lambda;
8 end
9 for n=1:N-1
10 A(n,n+1) = 1;
11 end
12 A = (A + A')/2;
script
Ln 12 Col 16
Current Folder
Name
AllEnergies.m
FreeFermionsParticleNumber.m*
Value
8x8 double
8x8 double
256x1 double
8x8 double
8
8x8 double
5
8
8x8 double
-- 21/03/2014 9:24 AM --
FreeFermionsParticleNumb
A
FreeFermionsParticleNumber.m* (Script)
>>
10:42 AM
21/03/2014

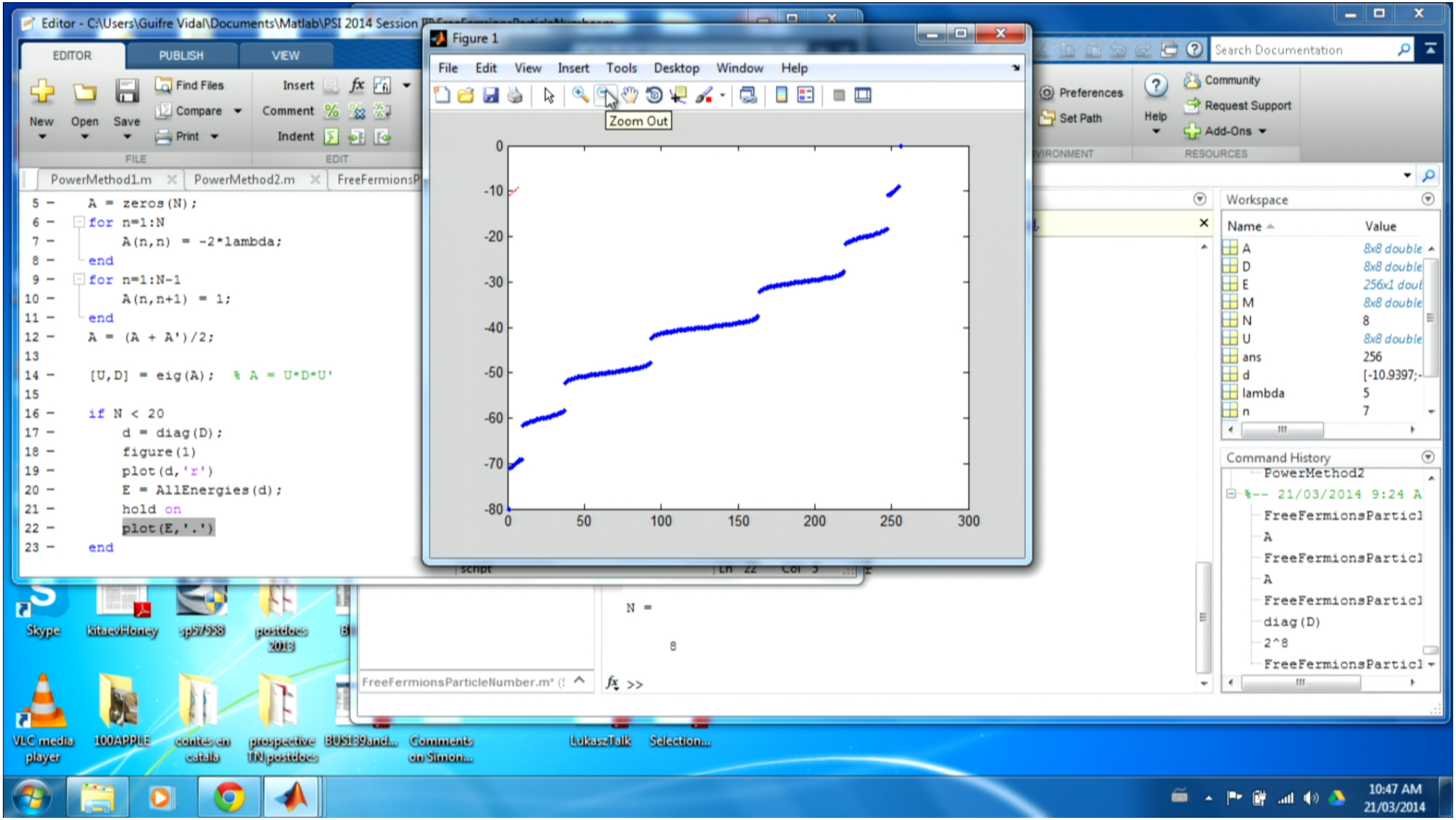

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2
EDITOR
PUBLISH
VIEW
New
Open
Save
Find Files
Compare
Print
Insert
Comment
Indent
FILE
PowerMethod1.m
PowerMethod2.m
1 % PSI 2014 Session III FreeFerm
2
3 N = 8;
4 lambda = 5;
5 A = zeros(N);
6 for n=1:N
7 A(n,n) = -2*lambda;
8 end
9 for n=1:N-1
10 A(n,n+1) = 1;
11 end
12 A = (A + A')/2;
MATLAB R2013b
HOME
PLOTS
APPS
Search Documentation
New Script
New
Open
Find Files
Compare
Import Data
Save Workspace
New Variable
Open Variable
Clear Workspace
Analyze Code
Run and Time
Clear Commands
Layout
Preferences
Set Path
Help
Community
Request Support
Add-Ons
FILE
VARIABLE
CODE
ENVIRONMENT
RESOURCES
C: ▸ Users ▸ Guifre Vidal ▸ Documents ▸ MATLAB ▸ PSI 2014 Session III
Current Folder
Name
AllEnergies.m
FreeFermionsParticleNumber.m
Command Window
New to MATLAB? Watch this Video, see Examples, or read Getting Started.
Columns 1 through 6
-10.0000 0.5000 0 0 0 0
0.5000 -10.0000 0.5000 0 0 0
0 0.5000 -10.0000 0.5000 0 0
0 0 0.5000 -10.0000 0.5000 0
0 0 0 0.5000 -10.0000 0.5000
0 0 0 0 0.5000 -10.0000
0 0 0 0 0 0.5000
0 0 0 0 0 0
Columns 7 through 8
0 0
0 0
0 0
0 0
0 0
0.5000 0
-10.0000 0.5000
0.5000 -10.0000
Workspace
Name
Value
A 8x8 double
D 8x8 double
E 256x1 doul
M 8x8 double
N 8
U 8x8 double
d [-0.9397;-0
lambda 5
n 7
sD 8x8 double
Command History
eig(H2)
eig(H2neg)
PowerMethod2
size(Psi)
PowerMethod2
%-- 21/03/2014 9:24 A
FreeFermionsPartic
A
FreeFermionsPartic
A
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kitaevHoney
sp57558
postdocs 2013
VLC media player
100APPLE
contes en catala
prospective TN postdocs
BUS139and...
Comments on Simon...
LukaszTalk
Selection...
10:43 AM
21/03/2014

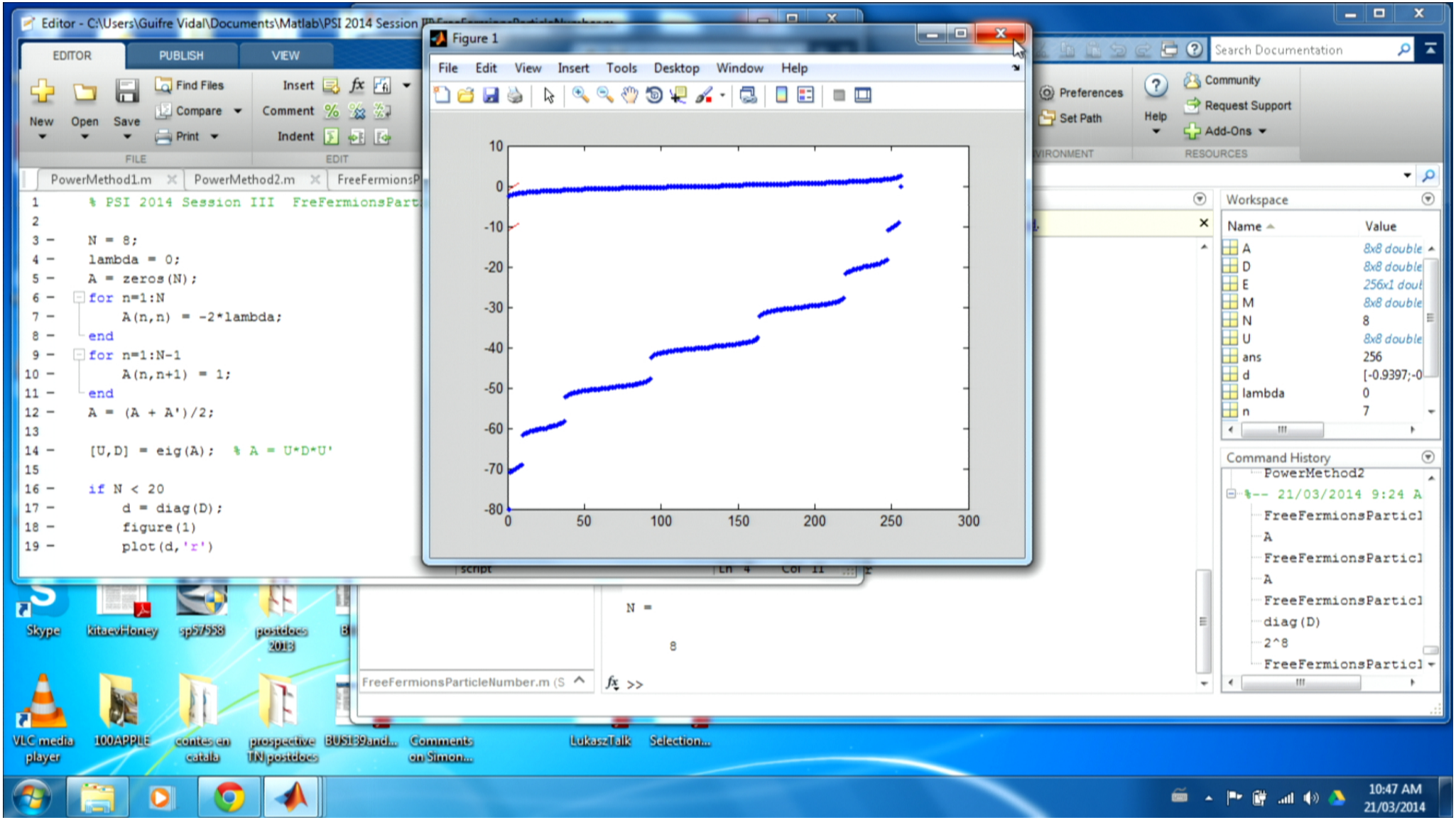

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2014 Session III\FreeFermionsParticleNumber.m*
EDITOR
PUBLISH
VIEW
PowerMethod1.m
PowerMethod2.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m*
1 % PSI 2014 Session III FreFermionsParticleNumber.m
2
3 N = 8;
4 lambda = 5;
5 A = zeros(N);
6 for n=1:N
7 A(n,n) = -2*lambda;
8 end
9 for n=1:N-1
10 A(n,n+1) = 1;
11 end
12 A = (A + A')/2;
13
14 [U,D] = eig(A); % A = U*D*U'
15
16
script
Ln 15 Col 1
Workspace
Name
Value
A 8x8 double
D 8x8 double
E 256x1 doul
M 8x8 double
N 8
U 8x8 double
d [-0.9397;-0
lambda 5
n 7
sD 8x8 double
Command History
eig(H2)
eig(H2neg)
PowerMethod2
size(Psi)
PowerMethod2
%-- 21/03/2014 9:24 A
FreeFermionsPartic
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FreeFermionsPartic
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postdocs 2013
VLC media player
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Comments on Simon...
LukaszTalk
Selection...
10:44 AM
21/03/2014

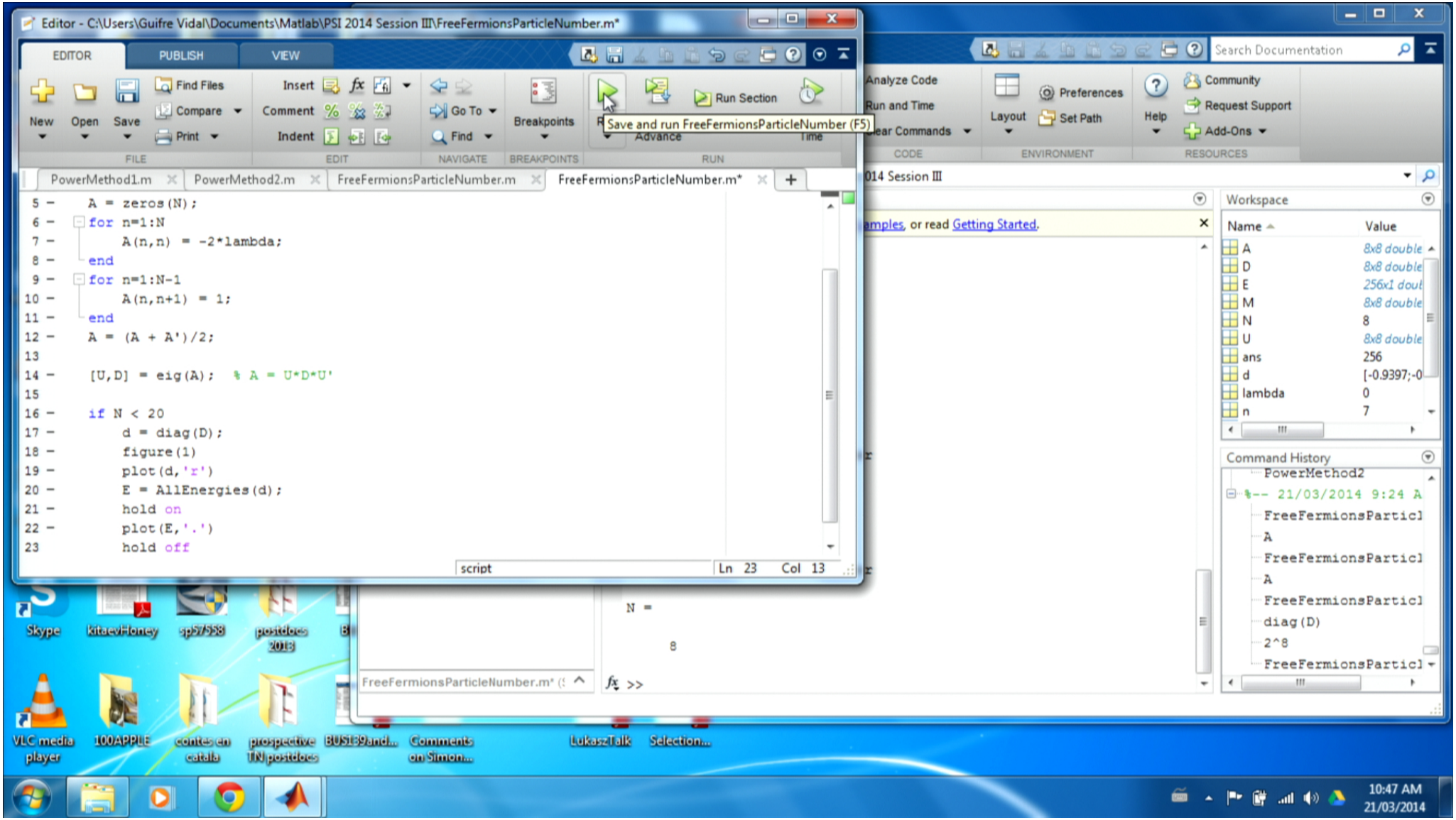

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2
EDITOR
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Find Files
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Print
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Comment
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FILE
PowerMethod1.m
PowerMethod2.m
1 % PSI 2014 Session III FreeFerm
2
3 - N = 8;
4 - lambda = 5;
5 - A = zeros(N);
6 - for n=1:N
7 - A(n,n) = -2*lambda;
8 - end
9 - for n=1:N-1
10 - A(n,n+1) = 1;
11 - end
12 - A = (A + A')/2;
13
14 - [U,D] = eig(A); % A = U*D*U'
15
16
MATLAB R2013b
HOME
PLOTS
APPS
Search Documentation
New Script
New
Open
Find Files
Compare
Import Data
Save Workspace
New Variable
Open Variable
Clear Workspace
Analyze Code
Run and Time
Clear Commands
Layout
Preferences
Set Path
Help
Community
Request Support
Add-Ons
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CODE
ENVIRONMENT
RESOURCES
C: ▸ Users ▸ Guifre Vidal ▸ Documents ▸ MATLAB ▸ PSI 2014 Session III
Current Folder
Name
AllEnergies.m
FreeFermionsParticleNumber.m
Command Window
New to MATLAB? Watch this Video, see Examples, or read Getting Started.
0 0
0 0
0 0
0 0
0 0
0.5000 0
-10.0000 0.5000
0.5000 -10.0000
>> FreeFermionsParticleNumber
>> diag(D)
ans =
-10.9397
-10.7660
-10.5000
-10.1736
-9.8264
-9.5000
-9.2340
-9.0603
>>
Workspace
Name
Value
A 8x8 double
D 8x8 double
E 256x1 doul
M 8x8 double
N 8
U 8x8 double
ans [-10.9397;-
d [-0.9397;-0
lambda 5
n 7
Command History
PowerMethod2
size(Psi)
PowerMethod2
%-- 21/03/2014 9:24 A
FreeFermionsPartic
A
FreeFermionsPartic
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FreeFermionsPartic
diag(D)
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BUS139and...
Comments on Simon...
LukaszTalk
Selection...
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21/03/2014

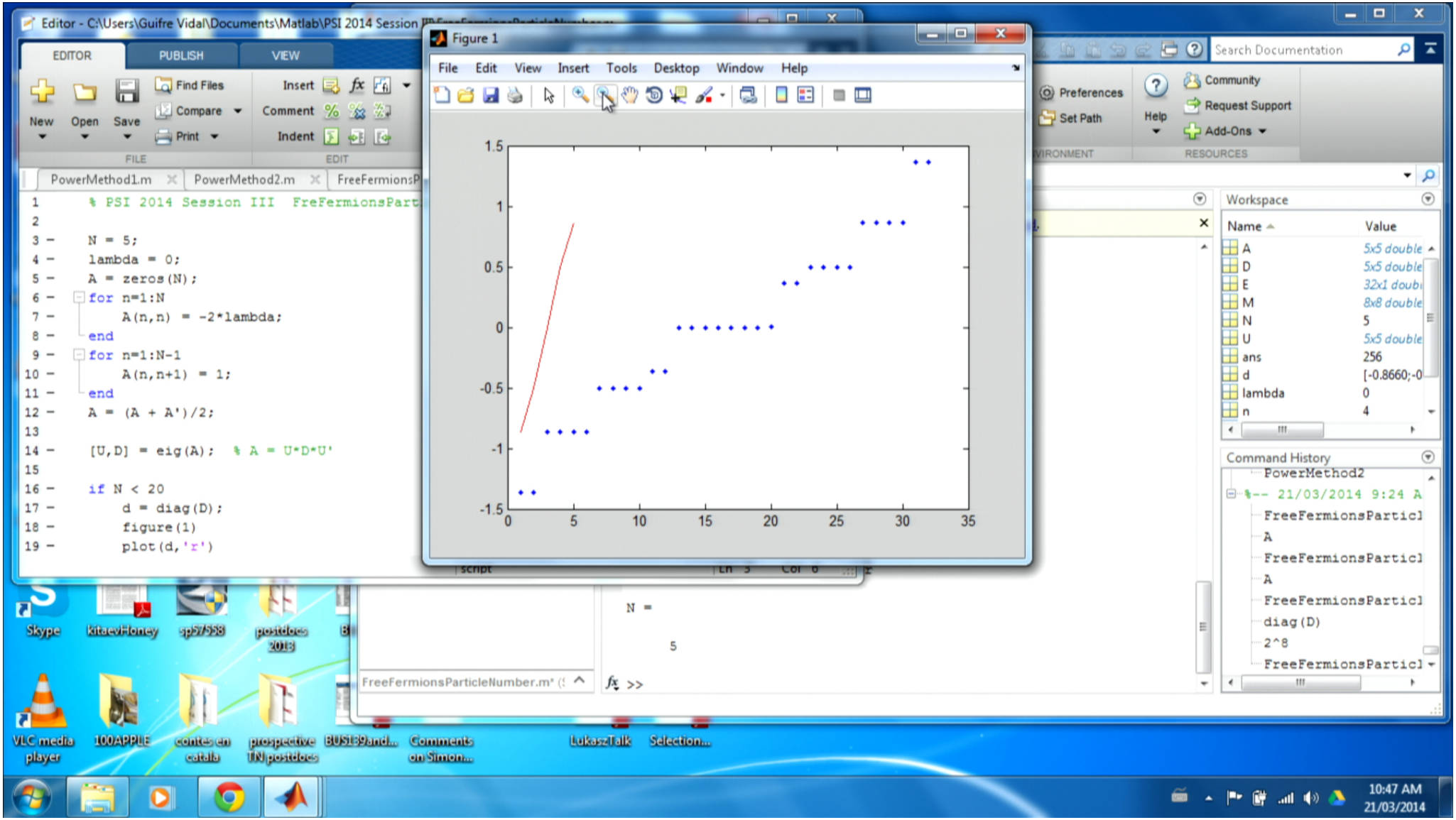

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FILE
PowerMethod1.m
PowerMethod2.m
1 % PSI 2014 Session III FreeFerm
2
3 - N = 8;
4 - lambda = 5;
5 - A = zeros(N);
6 - for n=1:N
7 - A(n,n) = -2*lambda;
8 - end
9 - for n=1:N-1
10 - A(n,n+1) = 1;
11 - end
12 - A = (A + A')/2;
13
14 - [U,D] = eig(A); % A = U*D*U'
15
16
MATLAB R2013b
HOME
PLOTS
APPS
Search Documentation
New Script
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Find Files
Compare
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Save Workspace
New Variable
Open Variable
Clear Workspace
Analyze Code
Run and Time
Clear Commands
Layout
Preferences
Set Path
Help
Community
Request Support
Add-Ons
FILE
VARIABLE
CODE
ENVIRONMENT
RESOURCES
C: ▸ Users ▸ Guifre Vidal ▸ Documents ▸ MATLAB ▸ PSI 2014 Session III
Current Folder
Name
AllEnergies.m
FreeFermionsParticleNumber.m
Command Window
New to MATLAB? Watch this Video, see Examples, or read Getting Started.
-10.0000 0.5000
0.5000 -10.0000
>> FreeFermionsParticleNumber
>> diag(D)
ans =
-10.9397
-10.7660
-10.5000
-10.1736
-9.8264
-9.5000
-9.2340
-9.0603
>> 2^8
ans =
256
>>
Workspace
Name
Value
A 8x8 double
D 8x8 double
E 256x1 doul
M 8x8 double
N 8
U 8x8 double
ans 256
d [-0.9397;-0
lambda 5
n 7
Command History
size(Psi)
PowerMethod2
%-- 21/03/2014 9:24 A
FreeFermionsPartic
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FreeFermionsPartic
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FreeFermionsPartic
diag(D)
2^8
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BUS139and...
Comments on Simon...
LukaszTalk
Selection...
10:45 AM
21/03/2014

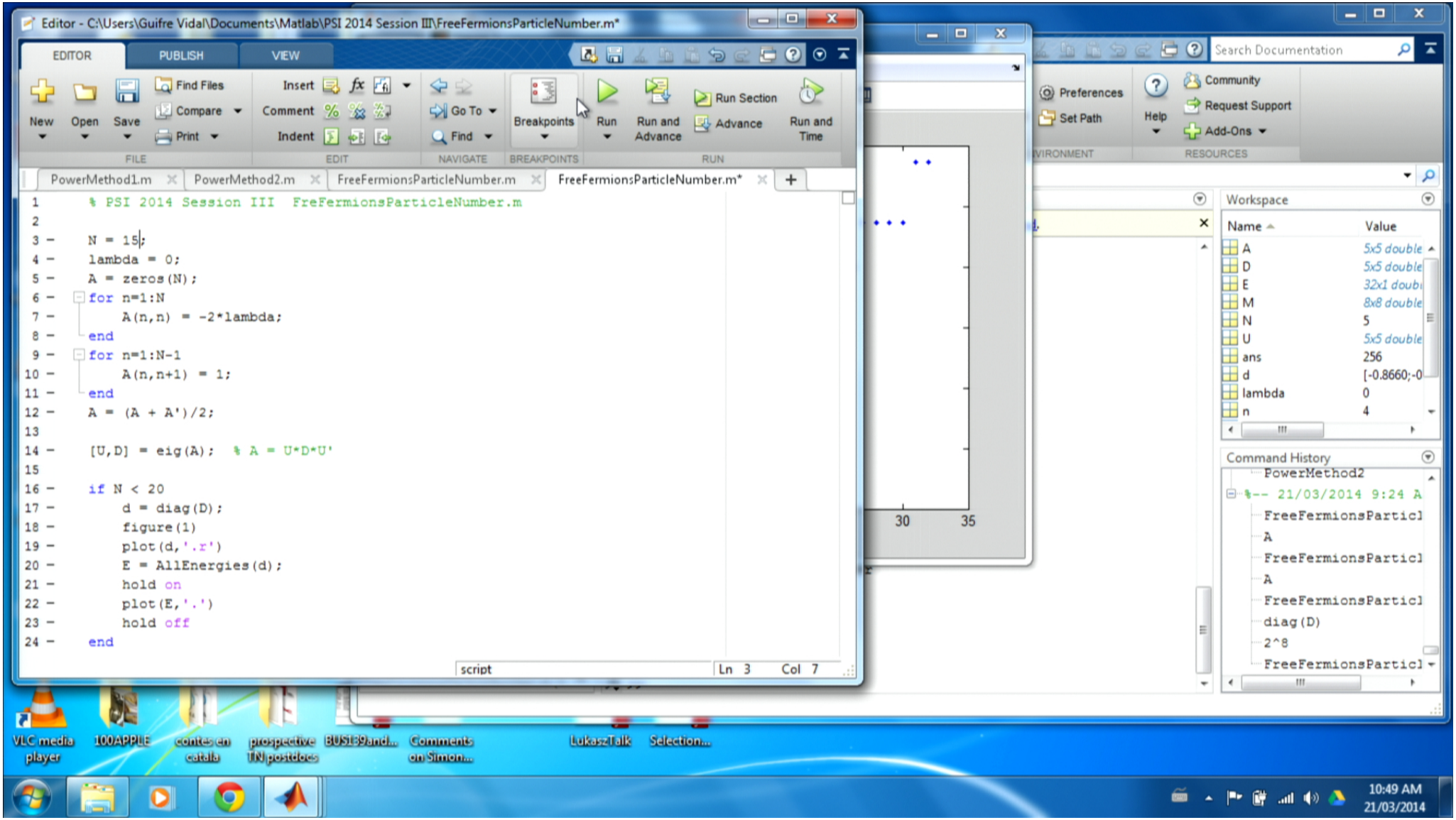

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2014 Session III\FreeFermionsParticleNumber.m*
EDITOR
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Find Files
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Print
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Go To
Find
Breakpoints
Run
Run and Advance
Run Section
Advance
Run and Time
FILE
EDIT
NAVIGATE
BREAKPOINTS
RUN
PowerMethod1.m
PowerMethod2.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m*
A = zeros(N);
for n=1:N
A(n,n) = -2*lambda;
end
for n=1:N-1
A(n,n+1) = 1;
end
A = (A + A')/2;
[U,D] = eig(A); % A = U*D*U'
if N < 20
d = diag(D);
figure(1)
plot(d,'r')
E = AltEnergies(d);
hold on
plot(E,'.')
end
script
Ln 23 Col 4
Search Documentation
Analyze Code
Run and Time
Clear Commands
Layout
Preferences
Set Path
Help
Community
Request Support
Add-Ons
CODE
ENVIRONMENT
RESOURCES
014 Session III
Workspace
Name
Value
A
D
E
M
N
8
U
ans
256
d
lambda
5
n
7
Command History
size(Psi)
PowerMethod2
%-- 21/03/2014 9:24 A
FreeFermionsParticl
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FreeFermionsParticl
A
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diag(D)
2^8
ans =
256
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BUS139and...
Comments on Simon...
LukaszTalk
Selection...
10:46 AM
21/03/2014

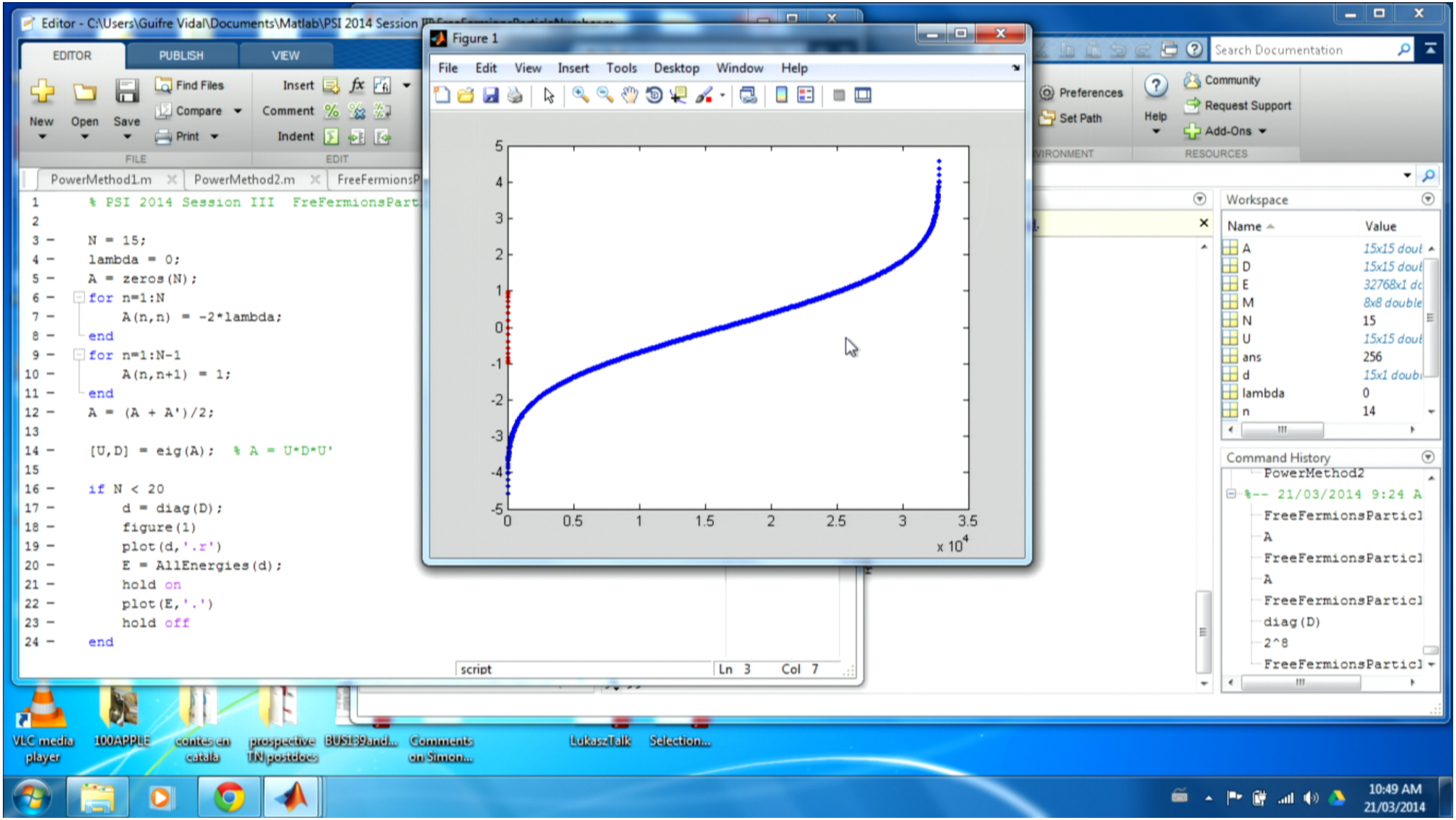

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2014 Session
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FILE
EDIT
PowerMethod1.m
PowerMethod2.m
FreeFermionsP
5 - A = zeros(N);
6 - for n=1:N
7 - A(n,n) = -2*lambda;
8 - end
9 - for n=1:N-1
10 - A(n,n+1) = 1;
11 - end
12 - A = (A + A')/2;
13
14 - [U,D] = eig(A); % A = U*D*U'
15
16 - if N < 20
17 - d = diag(D);
18 - figure(1)
19 - plot(d,'r')
20 - E = AllEnergies(d);
21 - hold on
22 - plot(E,'.')
23 - end
Figure 1
File Edit View Insert Tools Desktop Window Help
Zoom Out
0
-10
-20
-30
-40
-50
-60
-70
-80
0
50
100
150
200
250
300
Search Documentation
Preferences
Set Path
Help
Community
Request Support
Add-Ons
RESOURCES
Workspace
Name
Value
A 8x8 double
D 8x8 double
E 256x1 doul
M 8x8 double
N 8
U 8x8 double
ans 256
d [-10.9397;-
lambda 5
n 7
Command History
PowerMethod2
%-- 21/03/2014 9:24 A
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FreeFermionsPartic
A
FreeFermionsPartic
diag(D)
2^8
FreeFermionsPartic
N =
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FreeFermionsParticleNumber.m*
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Comments on Simon...
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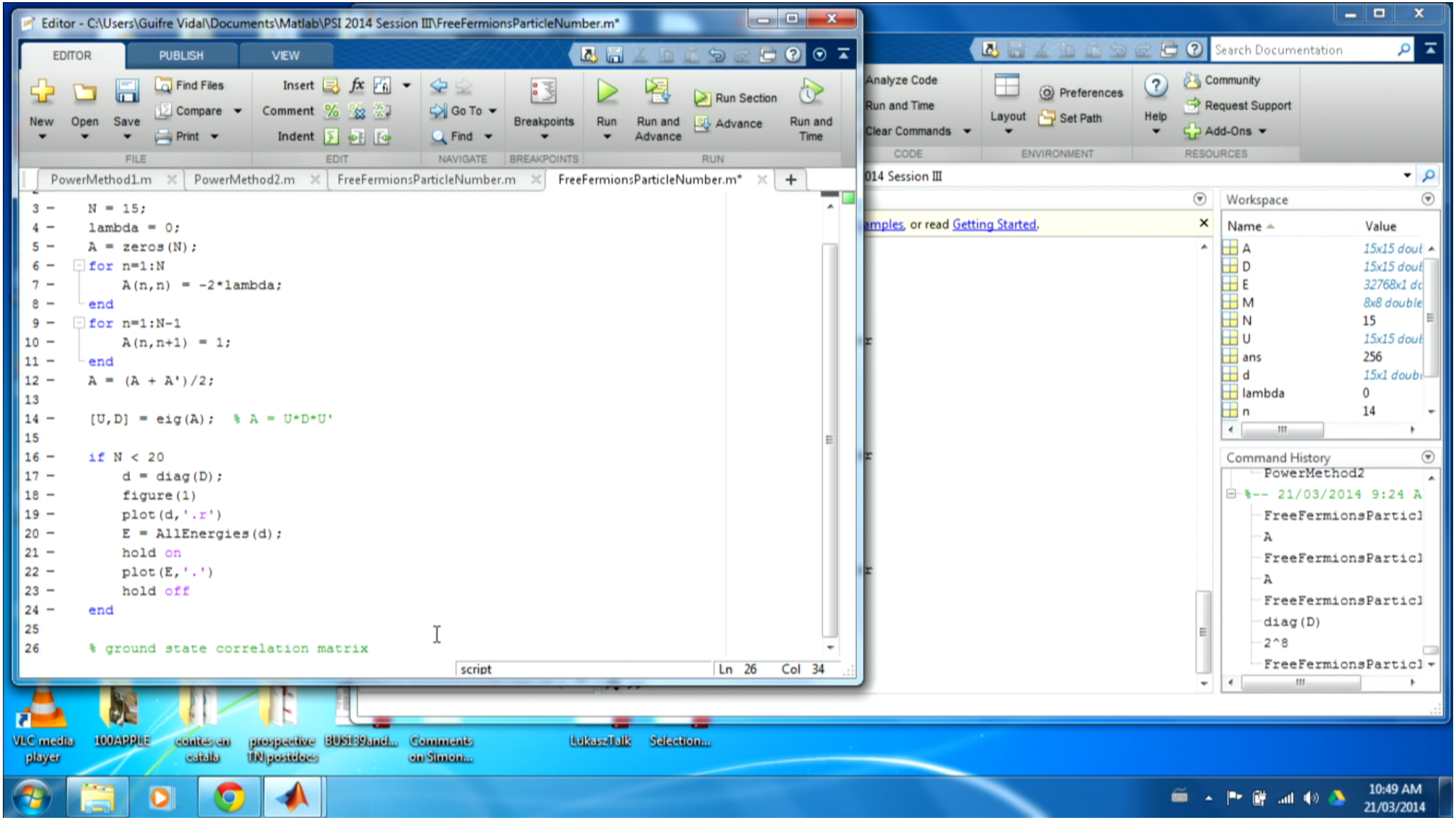

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2014 Session III\FreeFermionsParticleNumber.m
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Compare
Print
Insert
Comment
Indent
FILE
EDIT
PowerMethod1.m
PowerMethod2.m
FreeFermionsP
1 % PSI 2014 Session III FreeFermionsPart
2
3 - N = 8;
4 - lambda = 0;
5 - A = zeros(N);
6 - for n=1:N
7 - A(n,n) = -2*lambda;
8 - end
9 - for n=1:N-1
10 - A(n,n+1) = 1;
11 - end
12 - A = (A + A')/2;
13
14 - [U,D] = eig(A); % A = U*D*U'
15
16 - if N < 20
17 - d = diag(D);
18 - figure(1)
19 - plot(d,'r')
script
Ln 4 Col 11
Figure 1
File Edit View Insert Tools Desktop Window Help
10
0
-10
-20
-30
-40
-50
-60
-70
-80
0 50 100 150 200 250 300
Search Documentation
Preferences
Set Path
Help
Community
Request Support
Add-Ons
RESOURCES
Workspace
Name Value
A 8x8 double
D 8x8 double
E 256x1 doul
M 8x8 double
N 8
U 8x8 double
ans 256
d [-0.9397;-0
lambda 0
n 7
Command History
PowerMethod2
%-- 21/03/2014 9:24 A
FreeFermionsPartic
A
FreeFermionsPartic
A
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diag(D)
2^8
FreeFermionsPartic
N =
8
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Comments on Simon...
LukaszTalk
Selection...
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21/03/2014

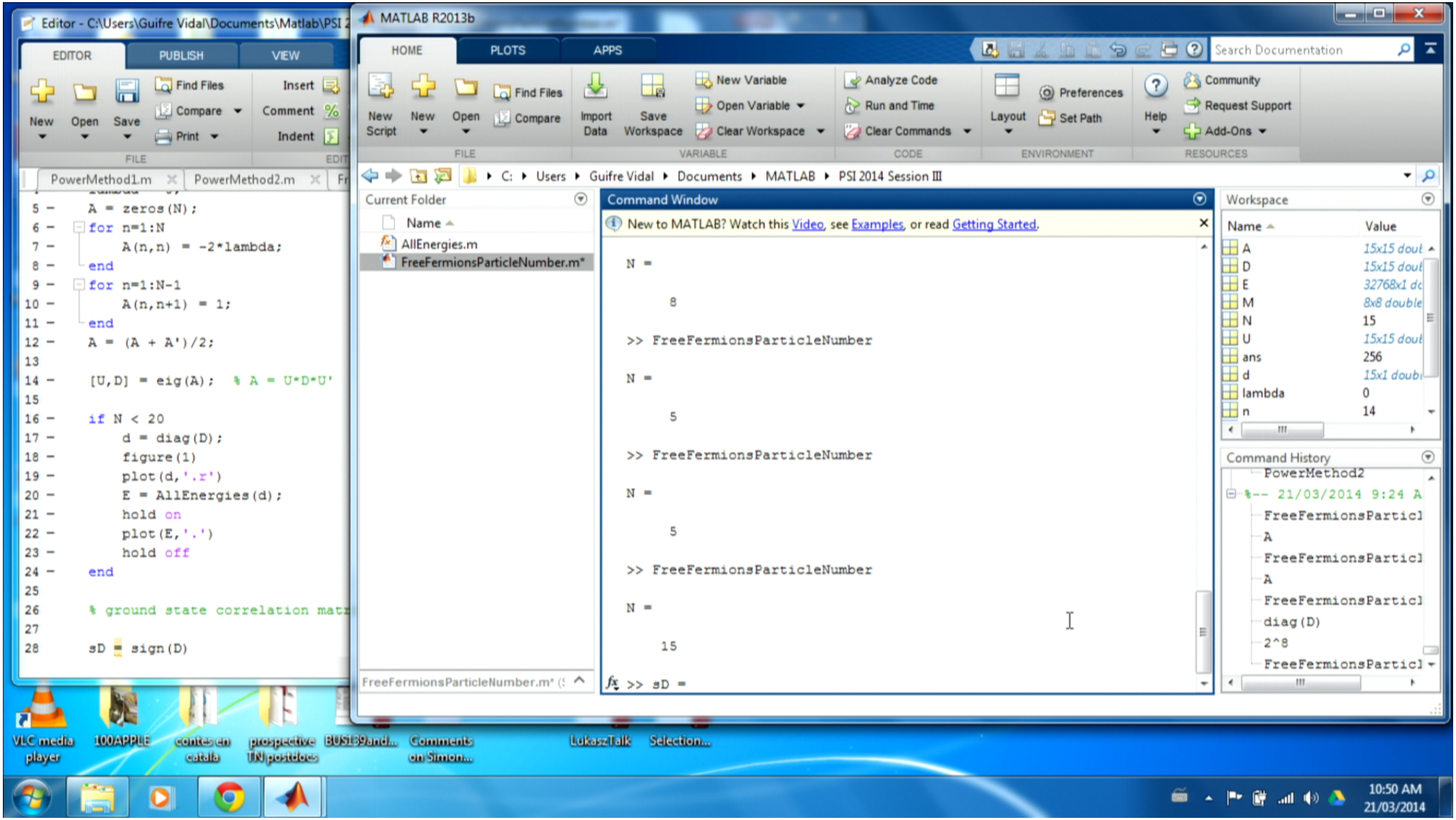

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2014 Session III\FreeFermionsParticleNumber.m*
EDITOR
PUBLISH
VIEW
Save and run FreeFermionsParticleNumber (F5)
PowerMethod1.m
PowerMethod2.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m*
5 - A = zeros(N);
6 - for n=1:N
7 - A(n,n) = -2*lambda;
8 - end
9 - for n=1:N-1
10 - A(n,n+1) = 1;
11 - end
12 - A = (A + A')/2;
13
14 - [U,D] = eig(A); % A = U*D*U'
15
16 - if N < 20
17 - d = diag(D);
18 - figure(1)
19 - plot(d,'r')
20 - E = AllEnergies(d);
21 - hold on
22 - plot(E,'.')
23 hold off
script
Ln 23 Col 13
Workspace
Name
Value
Command History
N =
8
>>

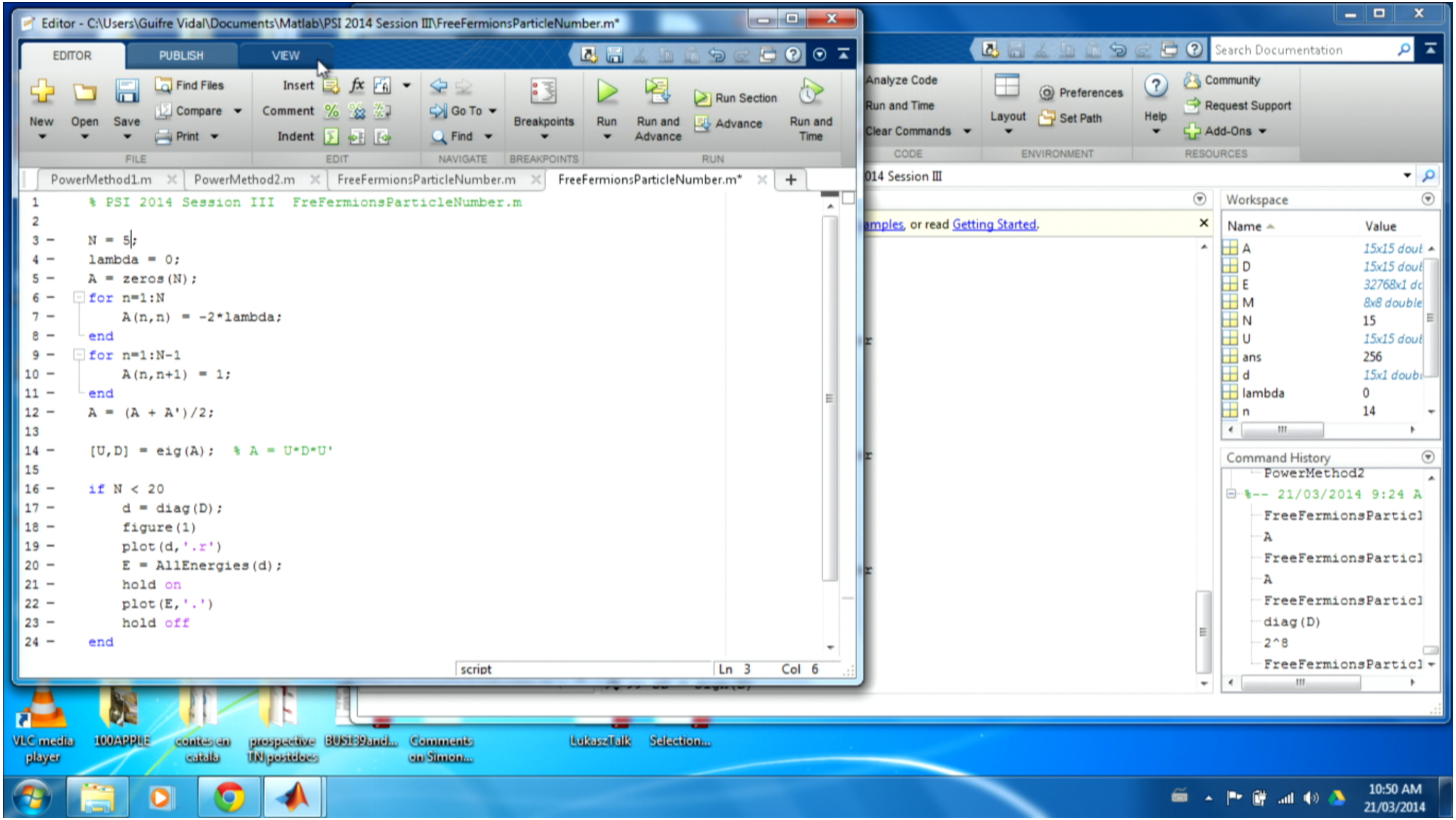

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2014 Session
EDITOR
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New
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Find Files
Compare
Print
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Comment
Indent
PowerMethod1.m
PowerMethod2.m
% PSI 2014 Session III FreeFermionsPart
N = 5;
lambda = 0;
A = zeros(N);
for n=1:N
A(n,n) = -2*lambda;
end
for n=1:N-1
A(n,n+1) = 1;
end
A = (A + A')/2;
[U,D] = eig(A); % A = U*D*U'
if N < 20
d = diag(D);
figure(1)
plot(d,'r')
Figure 1
File Edit View Insert Tools Desktop Window Help
1.5
1
0.5
0
-0.5
-1
-1.5
0 5 10 15 20 25 30 35
Search Documentation
Preferences
Set Path
Help
Community
Request Support
Add-Ons
RESOURCES
Workspace
Name
Value
A 5x5 double
D 5x5 double
E 32x1 doubl
M 8x8 double
N 5
U 5x5 double
ans 256
d [-0.8660;-0
lambda 0
n 4
Command History
PowerMethod2
%-- 21/03/2014 9:24 A
FreeFermionsPartic
A
FreeFermionsPartic
A
FreeFermionsPartic
diag(D)
2^8
FreeFermionsPartic
N =
5
>>
FreeFermionsParticleNumber.m*
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postdocs 2013
VLC media player
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prospective TN postdocs
BUS139and...
Comments on Simon...
LukaszTalk
Selection...
10:47 AM
21/03/2014

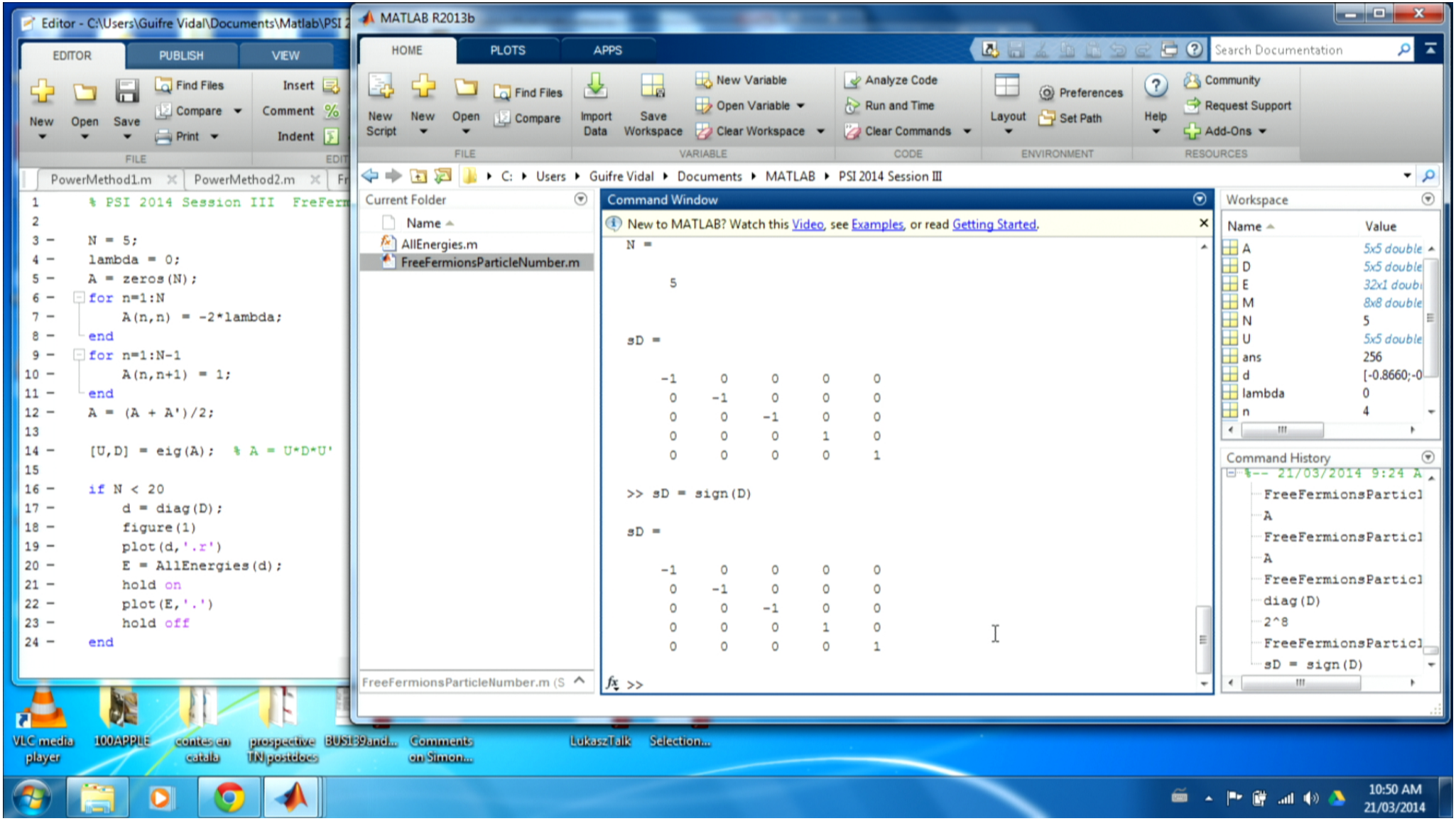

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2014 Session III\FreeFermionsParticleNumber.m*
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Find Files
Compare
Print
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Go To
Find
Breakpoints
Run
Run and Advance
Run Section
Advance
Run and Time
FILE
EDIT
NAVIGATE
BREAKPOINTS
RUN
PowerMethod1.m
PowerMethod2.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m*
% PSI 2014 Session III FreFermionsParticleNumber.m
N = 15;
lambda = 0;
A = zeros(N);
for n=1:N
A(n,n) = -2*lambda;
end
for n=1:N-1
A(n,n+1) = 1;
end
A = (A + A')/2;
[U,D] = eig(A); % A = U*D*U'
if N < 20
d = diag(D);
figure(1)
plot(d,'.r')
E = AllEnergies(d);
hold on
plot(E,'.')
hold off
end
script
Ln 3 Col 7
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Workspace
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Command History
PowerMethod2
%-- 21/03/2014 9:24 A
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FreeFermionsPartic
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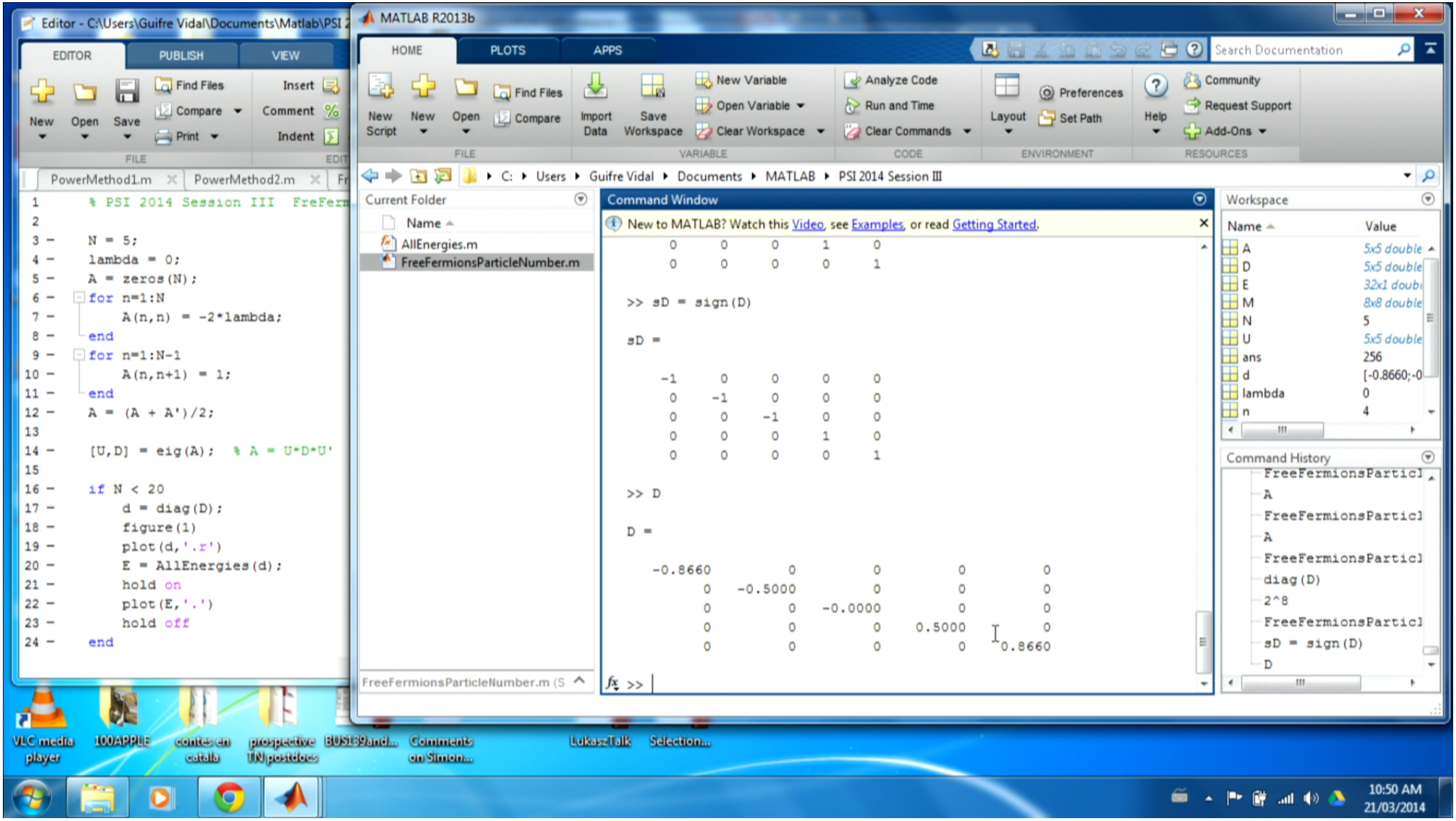

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2014 Session III\FreeFermionsParticleNumbers
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PowerMethod1.m
PowerMethod2.m
FreeFermionsP
1 % PSI 2014 Session III FreFermionsPart
2
3 - N = 15;
4 - lambda = 0;
5 - A = zeros(N);
6 - for n=1:N
7 - A(n,n) = -2*lambda;
8 - end
9 - for n=1:N-1
10 - A(n,n+1) = 1;
11 - end
12 - A = (A + A')/2;
13
14 - [U,D] = eig(A); % A = U*D*U'
15
16 - if N < 20
17 - d = diag(D);
18 - figure(1)
19 - plot(d,'.r')
20 - E = AllEnergies(d);
21 - hold on
22 - plot(E,'.')
23 - hold off
24 - end
script
Ln 3
Col 7
Figure 1
File Edit View Insert Tools Desktop Window Help
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RESOURCES
Workspace
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lambda
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Command History
PowerMethod2
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diag(D)
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FreeFermionsPartic
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Comments on Simon...
LukaszTalk
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21/03/2014

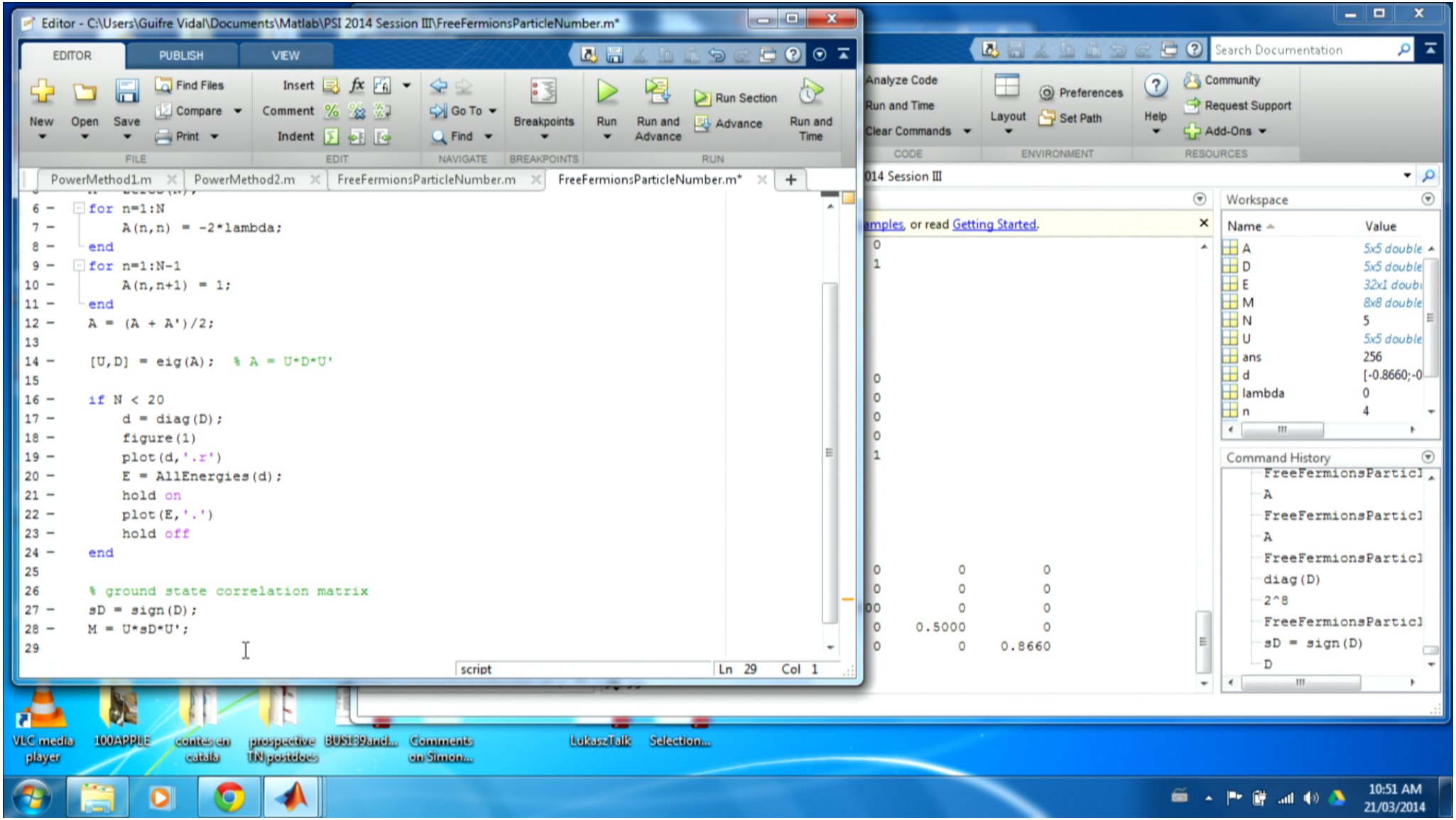

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2014 Session III\FreeFermionsParticleNumber.m*
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PowerMethod1.m
PowerMethod2.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m*
N = 15;
lambda = 0;
A = zeros(N);
for n=1:N
A(n,n) = -2*lambda;
end
for n=1:N-1
A(n,n+1) = 1;
end
A = (A + A')/2;
[U,D] = eig(A); % A = U*D*U'
if N < 20
d = diag(D);
figure(1)
plot(d,'.r')
E = AllEnergies(d);
hold on
plot(E,'.')
hold off
end
% ground state correlation matrix
script
Ln 26 Col 34
Workspace
Name
Value
Command History
Search Documentation
014 Session III
10:49 AM
21/03/2014

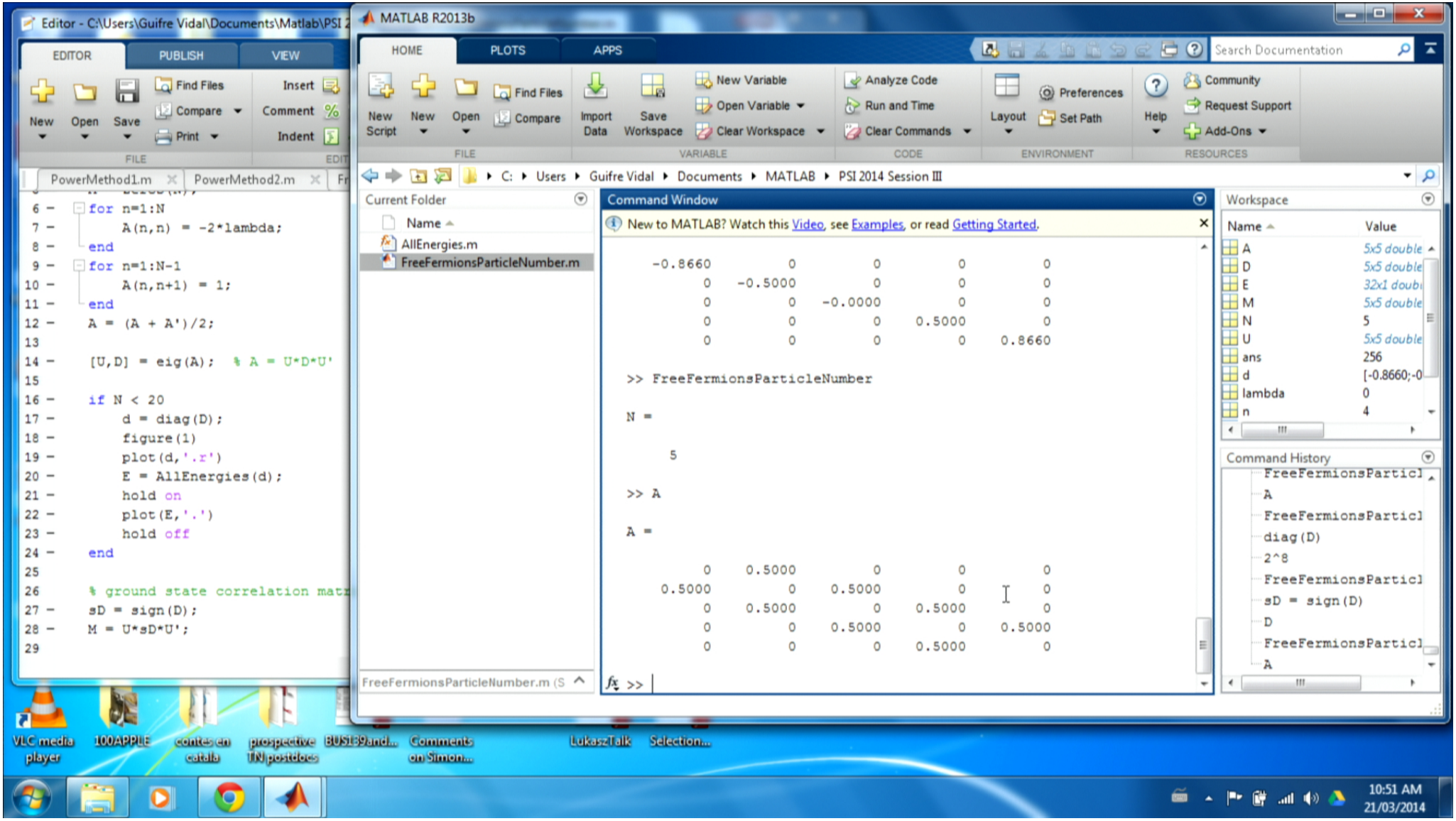

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2
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Find Files
Compare
Print
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Indent
FILE
PowerMethod1.m
PowerMethod2.m
5 - A = zeros(N);
6 - for n=1:N
7 - A(n,n) = -2*lambda;
8 - end
9 - for n=1:N-1
10 - A(n,n+1) = 1;
11 - end
12 - A = (A + A')/2;
13
14 - [U,D] = eig(A); % A = U*D*U'
15
16 - if N < 20
17 - d = diag(D);
18 - figure(1)
19 - plot(d,'.r')
20 - E = AllEnergies(d);
21 - hold on
22 - plot(E,'.')
23 - hold off
24 - end
25
26 % ground state correlation matr
27
28 sD = sign(D)
MATLAB R2013b
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Search Documentation
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New Variable
Open Variable
Clear Workspace
Analyze Code
Run and Time
Clear Commands
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RESOURCES
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Current Folder
Name
AllEnergies.m
FreeFermionsParticleNumber.m*
Command Window
New to MATLAB? Watch this Video, see Examples, or read Getting Started.
N =
8
>> FreeFermionsParticleNumber
N =
5
>> FreeFermionsParticleNumber
N =
5
>> FreeFermionsParticleNumber
N =
15
>> sD =
Workspace
Name
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U
ans
d
lambda
n
Command History
PowerMethod2
%-- 21/03/2014 9:24 A
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diag(D)
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FreeFermionsPartic
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Comments on Simon...
LukaszTalk
Selection...
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21/03/2014

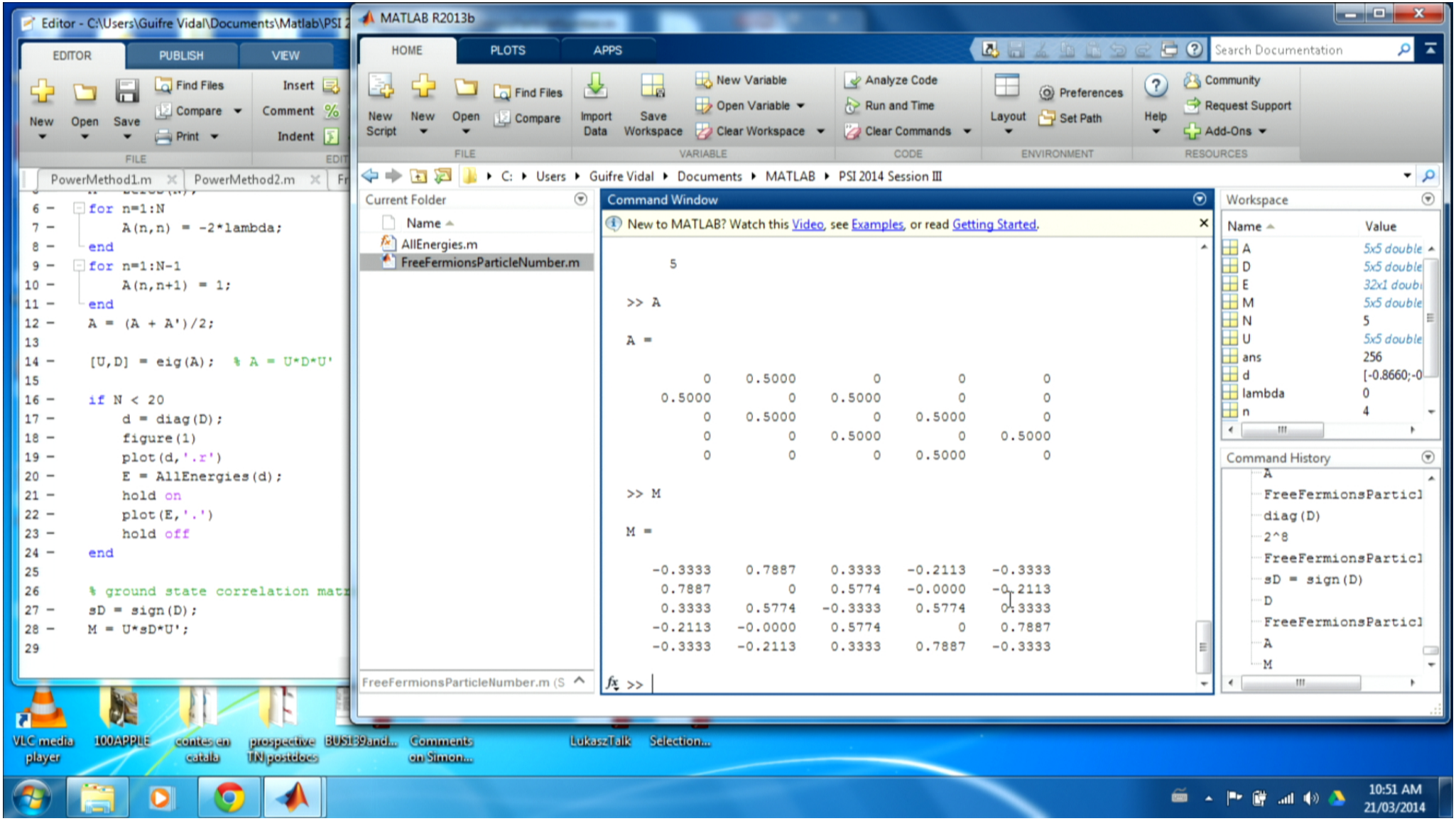

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2014 Session III\FreeFermionsParticleNumber.m*
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VIEW
PowerMethod1.m
PowerMethod2.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m*
% PSI 2014 Session III FreFermionsParticleNumber.m
N = 5;
lambda = 0;
A = zeros(N);
for n=1:N
A(n,n) = -2*lambda;
end
for n=1:N-1
A(n,n+1) = 1;
end
A = (A + A')/2;
[U,D] = eig(A); % A = U*D*U'
if N < 20
d = diag(D);
figure(1)
plot(d,'.r')
E = AllEnergies(d);
hold on
plot(E,'.')
hold off
end
script
Ln 3 Col 6
Workspace
Name
Value
Command History
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BUSI39and...
Comments on Simon...
LukaszTalk
Selection...
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21/03/2014

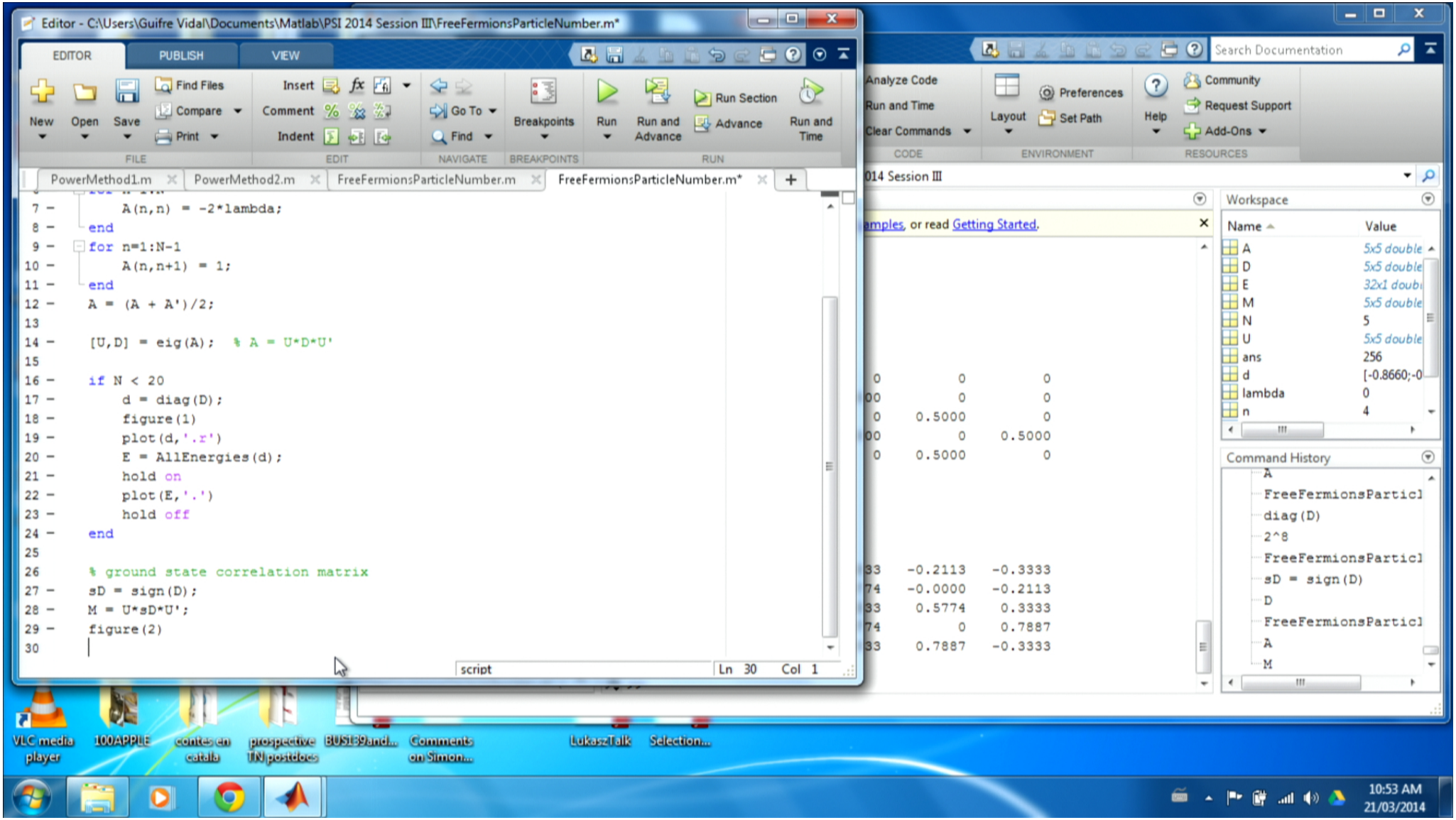

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2
EDITOR
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PowerMethod1.m
PowerMethod2.m
1 % PSI 2014 Session III FreeFerm
2
3 - N = 5;
4 - lambda = 0;
5 - A = zeros(N);
6 - for n=1:N
7 - A(n,n) = -2*lambda;
8 - end
9 - for n=1:N-1
10 - A(n,n+1) = 1;
11 - end
12 - A = (A + A')/2;
13
14 - [U,D] = eig(A); % A = U*D*U'
15
16 - if N < 20
17 - d = diag(D);
18 - figure(1)
19 - plot(d,'.r')
20 - E = AllEnergies(d);
21 - hold on
22 - plot(E,'.')
23 - hold off
24 - end
MATLAB R2013b
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New Variable
Open Variable
Clear Workspace
Analyze Code
Run and Time
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CODE
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RESOURCES
C: ▸ Users ▸ Guifre Vidal ▸ Documents ▸ MATLAB ▸ PSI 2014 Session III
Current Folder
Name
AllEnergies.m
FreeFermionsParticleNumber.m
Command Window
New to MATLAB? Watch this Video, see Examples, or read Getting Started.
N =
5
sD =
-1 0 0 0 0
0 -1 0 0 0
0 0 -1 0 0
0 0 0 1 0
0 0 0 0 1
>> sD = sign(D)
sD =
-1 0 0 0 0
0 -1 0 0 0
0 0 -1 0 0
0 0 0 1 0
0 0 0 0 1
>>
Workspace
Name
Value
A 5x5 double
D 5x5 double
E 32x1 doubl
M 8x8 double
N 5
U 5x5 double
ans 256
d [-0.8660;-0
lambda 0
n 4
Command History
%-- 21/03/2014 9:24 A
FreeFermionsPartic
A
FreeFermionsPartic
A
FreeFermionsPartic
diag(D)
2^8
FreeFermionsPartic
sD = sign(D)
VLC media player
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BUS139and...
Comments on Simon...
LukaszTalk
Selection...
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21/03/2014

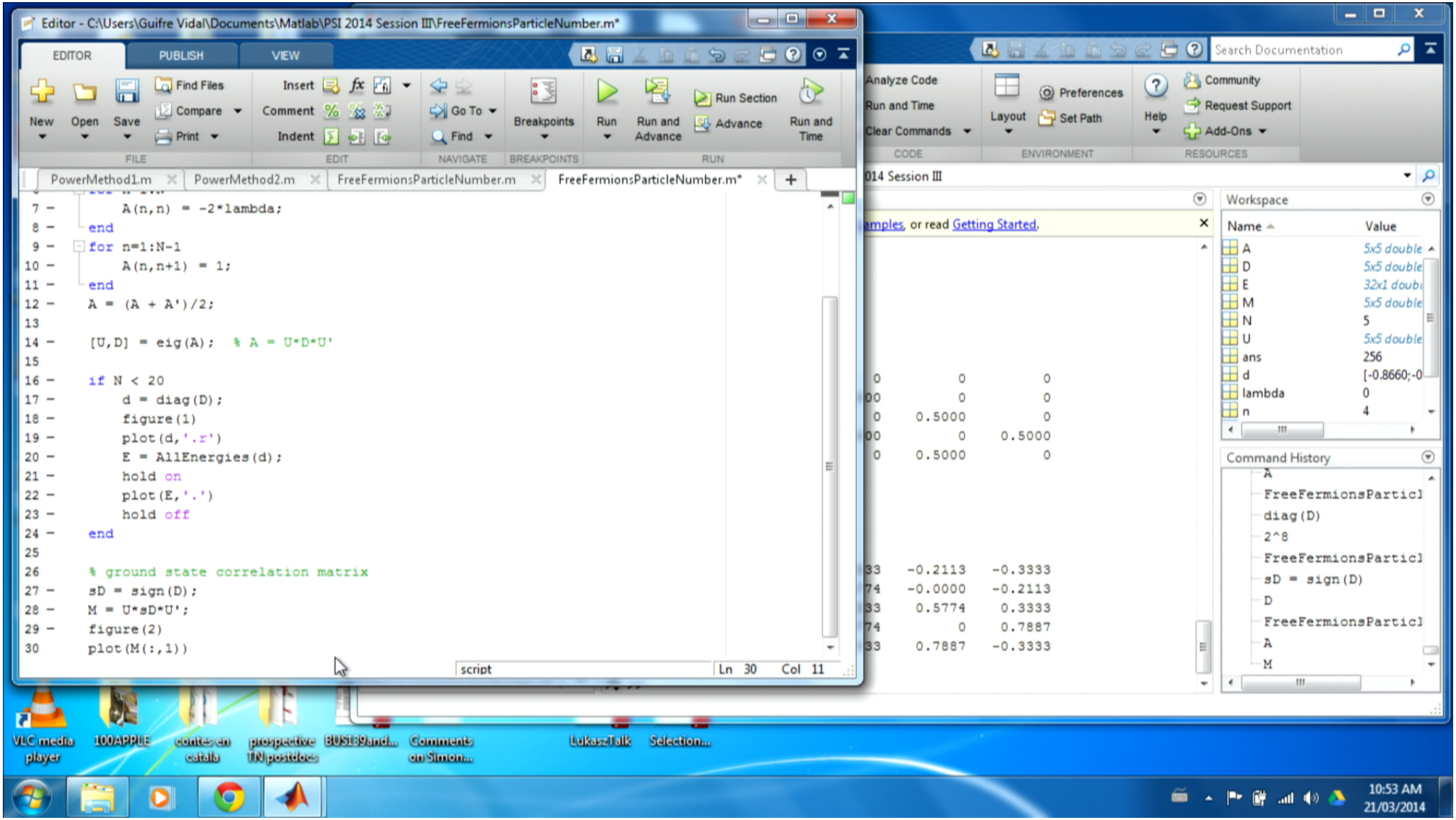

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2
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PowerMethod1.m
PowerMethod2.m
1 % PSI 2014 Session III FreeFerm
2
3 - N = 5;
4 - lambda = 0;
5 - A = zeros(N);
6 - for n=1:N
7 - A(n,n) = -2*lambda;
8 - end
9 - for n=1:N-1
10 - A(n,n+1) = 1;
11 - end
12 - A = (A + A')/2;
13
14 - [U,D] = eig(A); % A = U*D*U'
15
16 - if N < 20
17 - d = diag(D);
18 - figure(1)
19 - plot(d,'.r')
20 - E = AllEnergies(d);
21 - hold on
22 - plot(E,'.')
23 - hold off
24 - end
MATLAB R2013b
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Open Variable
Clear Workspace
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Add-Ons
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CODE
ENVIRONMENT
RESOURCES
C: ▸ Users ▸ Guifre Vidal ▸ Documents ▸ MATLAB ▸ PSI 2014 Session III
Current Folder
Name
AllEnergies.m
FreeFermionsParticleNumber.m
Command Window
New to MATLAB? Watch this Video, see Examples, or read Getting Started.
0 0 0 1 0
0 0 0 0 1
>> sD = sign(D)
sD =
-1 0 0 0 0
0 -1 0 0 0
0 0 -1 0 0
0 0 0 1 0
0 0 0 0 1
>> D
D =
-0.8660 0 0 0 0
0 -0.5000 0 0 0
0 0 -0.0000 0 0
0 0 0 0.5000 0
0 0 0 0 0.8660
>>
Workspace
Name
Value
A 5x5 double
D 5x5 double
E 32x1 doubl
M 8x8 double
N 5
U 5x5 double
ans 256
d [-0.8660;-0
lambda 0
n 4
Command History
FreeFermionsPartic
A
FreeFermionsPartic
A
FreeFermionsPartic
diag(D)
2^8
FreeFermionsPartic
sD = sign(D)
D
VLC media player
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Comments on Simon...
LukaszTalk
Selection...
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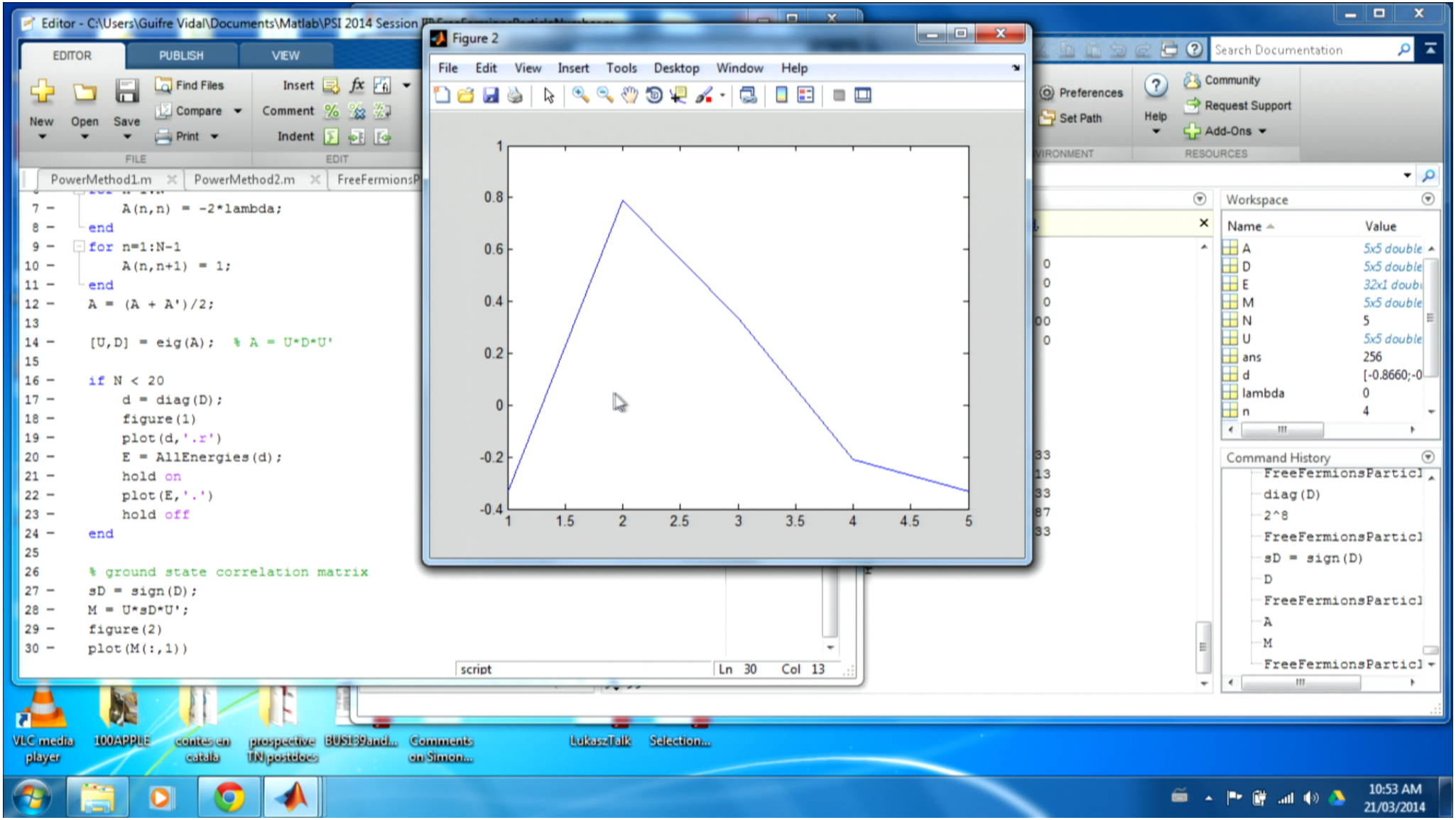

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2014 Session III\FreeFermionsParticleNumber.m*
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PowerMethod1.m
PowerMethod2.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m*
for n=1:N
A(n,n) = -2*lambda;
end
for n=1:N-1
A(n,n+1) = 1;
end
A = (A + A')/2;
[U,D] = eig(A); % A = U*D*U'
if N < 20
d = diag(D);
figure(1)
plot(d,'.r')
E = AllEnergies(d);
hold on
plot(E,'.')
hold off
end
% ground state correlation matrix
sD = sign(D);
M = U*sD*U';
script
Ln 29 Col 1
Workspace
Name
Value
Command History
Search Documentation
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LukaszTalk
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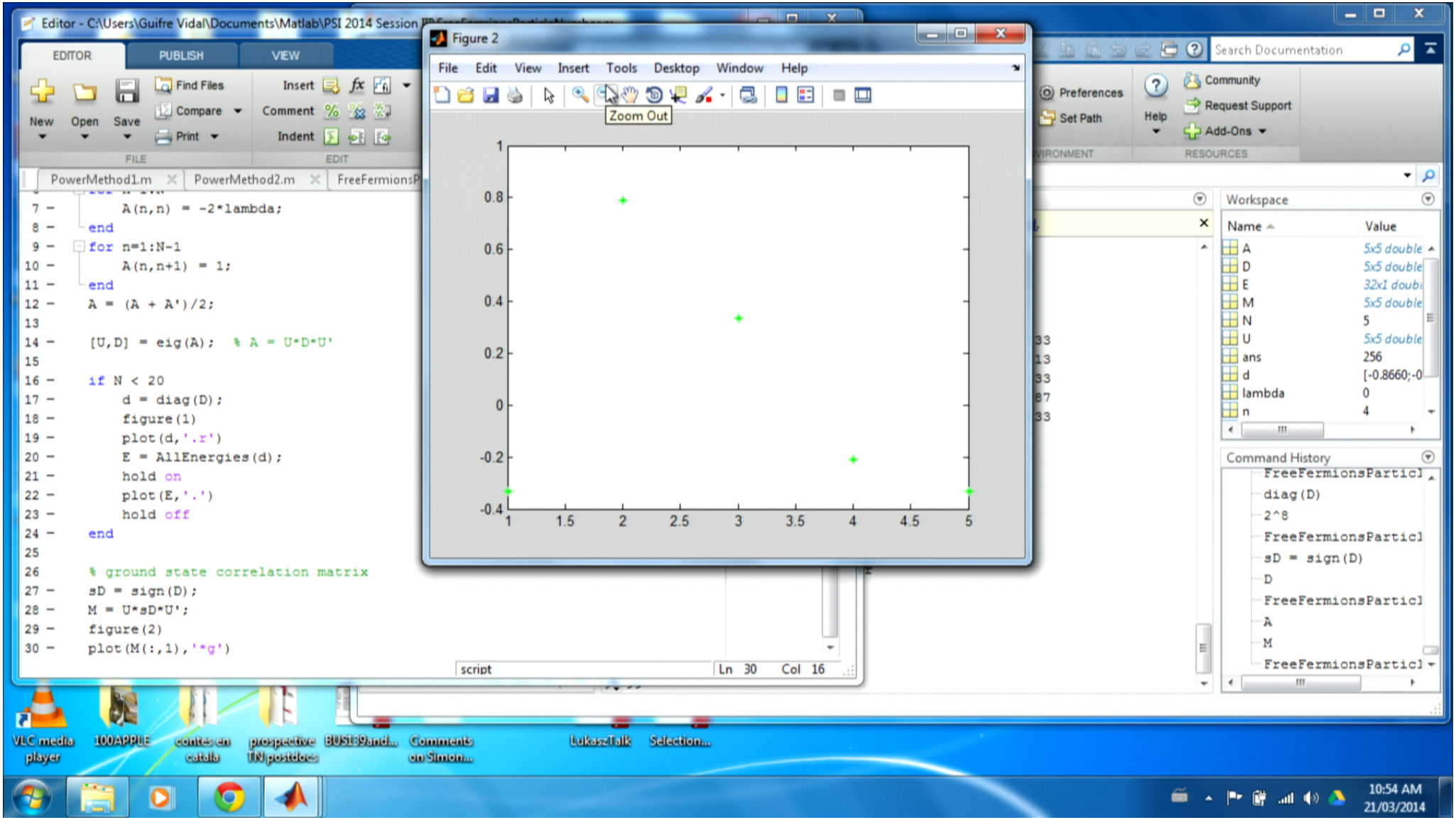

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FILE
PowerMethod1.m
PowerMethod2.m
for n=1:N
A(n,n) = -2*lambda;
end
for n=1:N-1
A(n,n+1) = 1;
end
A = (A + A')/2;
[U,D] = eig(A); % A = U*D*U'
if N < 20
d = diag(D);
figure(1)
plot(d,'.r')
E = AllEnergies(d);
hold on
plot(E,'.')
hold off
end
% ground state correlation matr
sD = sign(D);
M = U*sD*U';
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New Variable
Open Variable
Clear Workspace
Analyze Code
Run and Time
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RESOURCES
C: ▸ Users ▸ Guifre Vidal ▸ Documents ▸ MATLAB ▸ PSI 2014 Session III
Current Folder
Name
AllEnergies.m
FreeFermionsParticleNumber.m
Command Window
New to MATLAB? Watch this Video, see Examples, or read Getting Started.
-0.8660 0 0 0 0
0 -0.5000 0 0 0
0 0 -0.0000 0 0
0 0 0 0.5000 0
0 0 0 0 0.8660
>> FreeFermionsParticleNumber
N =
5
>> A
A =
0 0.5000 0 0 0
0.5000 0 0.5000 0 0
0 0.5000 0 0.5000 0
0 0 0.5000 0 0.5000
0 0 0 0.5000 0
>>
Workspace
Name
Value
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D
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M
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U
ans
d
lambda
n
Command History
FreeFermionsParticl
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diag(D)
2^8
FreeFermionsParticl
sD = sign(D)
D
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Comments on Simon...
LukaszTalk
Selection...
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21/03/2014

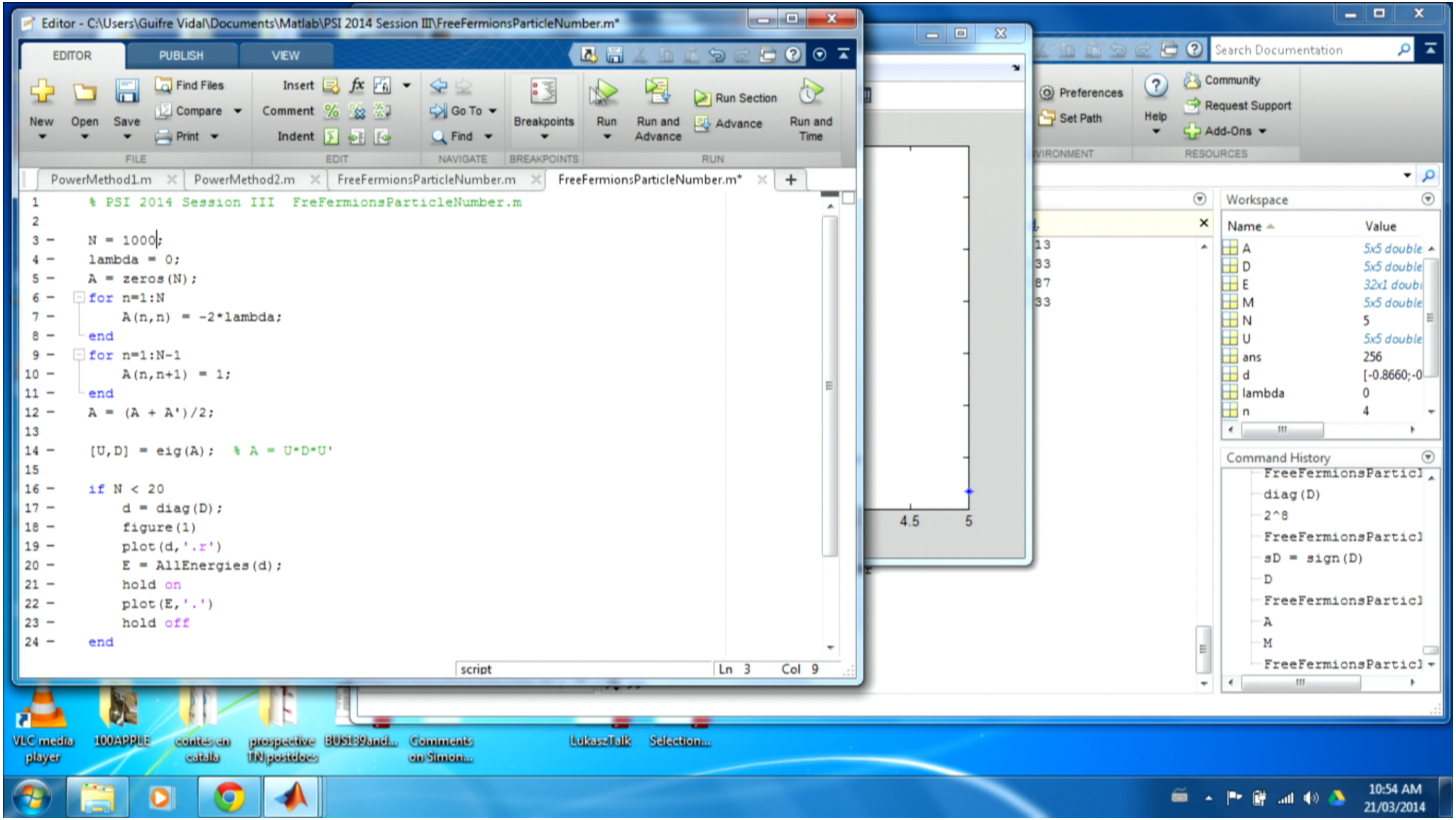

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2
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Find Files
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Comment
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FILE
PowerMethod1.m
PowerMethod2.m
for n=1:N
A(n,n) = -2*lambda;
end
for n=1:N-1
A(n,n+1) = 1;
end
A = (A + A')/2;
[U,D] = eig(A); % A = U*D*U'
if N < 20
d = diag(D);
figure(1)
plot(d,'.r')
E = AllEnergies(d);
hold on
plot(E,'.')
hold off
end
% ground state correlation matr
sD = sign(D);
M = U*sD*U';
MATLAB R2013b
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Save Workspace
New Variable
Open Variable
Clear Workspace
Analyze Code
Run and Time
Clear Commands
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Set Path
Help
Community
Request Support
Add-Ons
FILE
VARIABLE
CODE
ENVIRONMENT
RESOURCES
C: ▸ Users ▸ Guifre Vidal ▸ Documents ▸ MATLAB ▸ PSI 2014 Session III
Current Folder
Name
AllEnergies.m
FreeFermionsParticleNumber.m
Command Window
New to MATLAB? Watch this Video, see Examples, or read Getting Started.
5
>> A
A =
0 0.5000 0 0 0
0.5000 0 0.5000 0 0
0 0.5000 0 0.5000 0
0 0 0.5000 0 0.5000
0 0 0 0.5000 0
>> M
M =
-0.3333 0.7887 0.3333 -0.2113 -0.3333
0.7887 0 0.5774 -0.0000 -0.2113
0.3333 0.5774 -0.3333 0.5774 0.3333
-0.2113 -0.0000 0.5774 0 0.7887
-0.3333 -0.2113 0.3333 0.7887 -0.3333
>>
Workspace
Name
Value
A 5x5 double
D 5x5 double
E 32x1 doubl
M 5x5 double
N 5
U 5x5 double
ans 256
d [-0.8660;-0
lambda 0
n 4
Command History
A
FreeFermionsPartic
diag(D)
2^8
FreeFermionsPartic
sD = sign(D)
D
FreeFermionsPartic
A
M
VLC media player
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BUS139and...
Comments on Simon...
LukaszTalk
Selection...
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21/03/2014

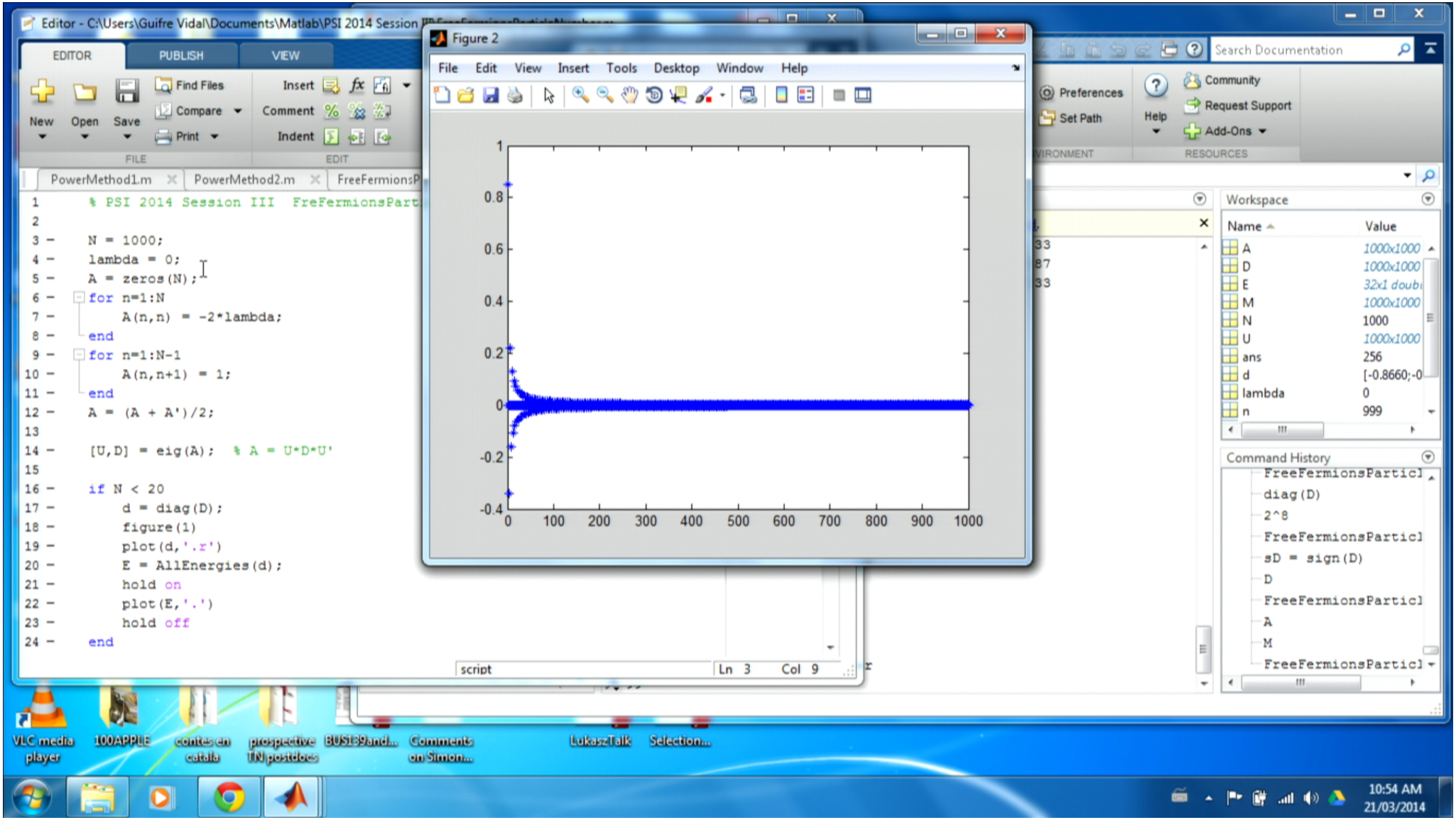

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2014 Session III\FreeFermionsParticleNumber.m*
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Breakpoints
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Run and Advance
Run Section
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Run and Time
FILE
EDIT
NAVIGATE
BREAKPOINTS
RUN
PowerMethod1.m
PowerMethod2.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m*
A(n,n) = -2*lambda;
end
for n=1:N-1
A(n,n+1) = 1;
end
A = (A + A')/2;
[U,D] = eig(A); % A = U*D*U'
if N < 20
d = diag(D);
figure(1)
plot(d,'.r')
E = AllEnergies(d);
hold on
plot(E,'.')
hold off
end
% ground state correlation matrix
sD = sign(D);
M = U*sD*U';
figure(2)
script
Ln 30 Col 1
Search Documentation
Analyze Code
Run and Time
Clear Commands
Layout
Preferences
Set Path
Help
Community
Request Support
Add-Ons
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Workspace
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Command History
FreeFermionsParticl
diag(D)
2^8
sD = sign(D)
D
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BUSI39and...
Comments on Simon...
LukaszTalk
Selection...
10:53 AM
21/03/2014

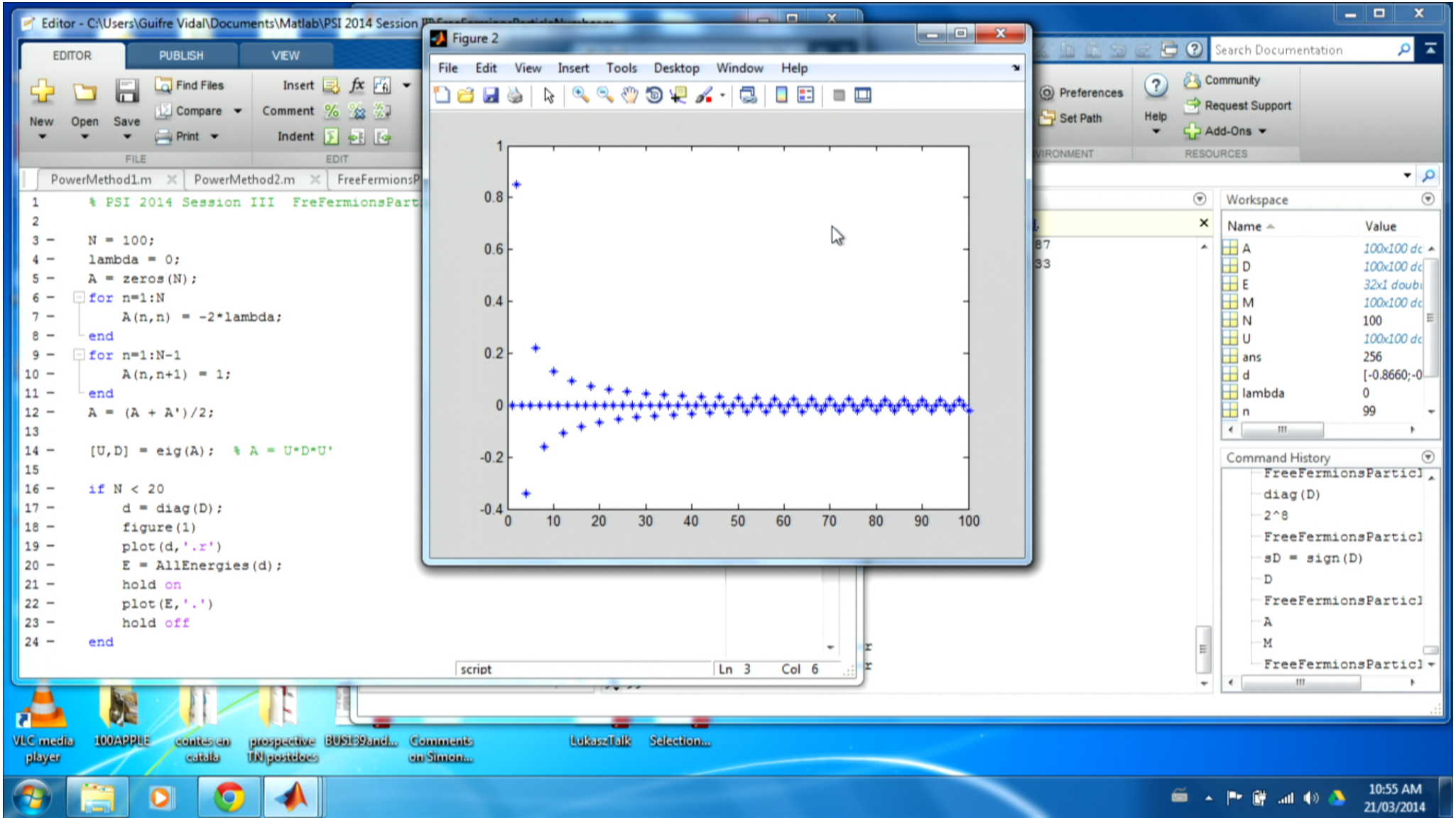

Editor - C:\Users\Guifre Vidal\Documents\Matlab\PSI 2014 Session III\FreeFermionsParticleNumber.m*
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Find
Breakpoints
Run
Run and Advance
Run Section
Advance
Run and Time
FILE
EDIT
NAVIGATE
BREAKPOINTS
RUN
PowerMethod1.m
PowerMethod2.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m*
A(n,n) = -2*lambda;
end
for n=1:N-1
A(n,n+1) = 1;
end
A = (A + A')/2;
[U,D] = eig(A); % A = U*D*U'
if N < 20
d = diag(D);
figure(1)
plot(d,'.r')
E = AllEnergies(d);
hold on
plot(E,'.')
hold off
end
% ground state correlation matrix
sD = sign(D);
M = U*sD*U';
figure(2)
plot(M(:,1))
script
Ln 30
Col 11
Search Documentation
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Workspace
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A
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Command History
FreeFermionsParticl
diag(D)
2^8
sD = sign(D)
D
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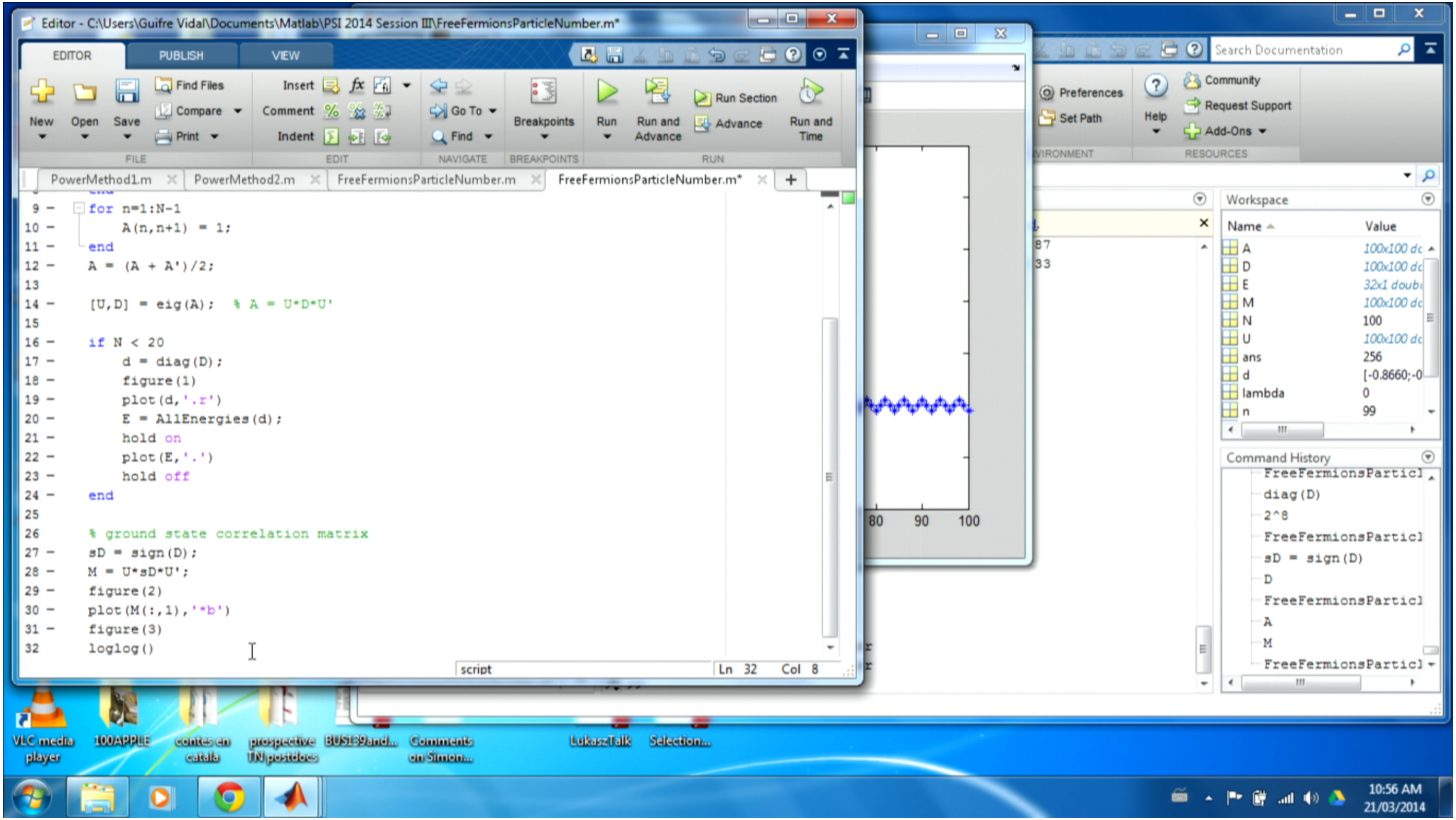

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EDIT
PowerMethod1.m
PowerMethod2.m
FreeFermionsP
A(n,n) = -2*lambda;
end
for n=1:N-1
A(n,n+1) = 1;
end
A = (A + A')/2;
[U,D] = eig(A); % A = U*D*U'
if N < 20
d = diag(D);
figure(1)
plot(d,'.r')
E = AllEnergies(d);
hold on
plot(E,'.')
hold off
end
% ground state correlation matrix
sD = sign(D);
M = U*sD*U';
figure(2)
plot(M(:,1))
script
Ln 30 Col 13
Figure 2
File Edit View Insert Tools Desktop Window Help
1
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-0.2
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1 1.5 2 2.5 3 3.5 4 4.5 5
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Set Path
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Community
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RESOURCES
Workspace
Name
Value
A 5x5 double
D 5x5 double
E 32x1 doubl
M 5x5 double
N 5
U 5x5 double
ans 256
d [-0.8660;-0
lambda 0
n 4
Command History
diag(D)
2^8
sD = sign(D)
D
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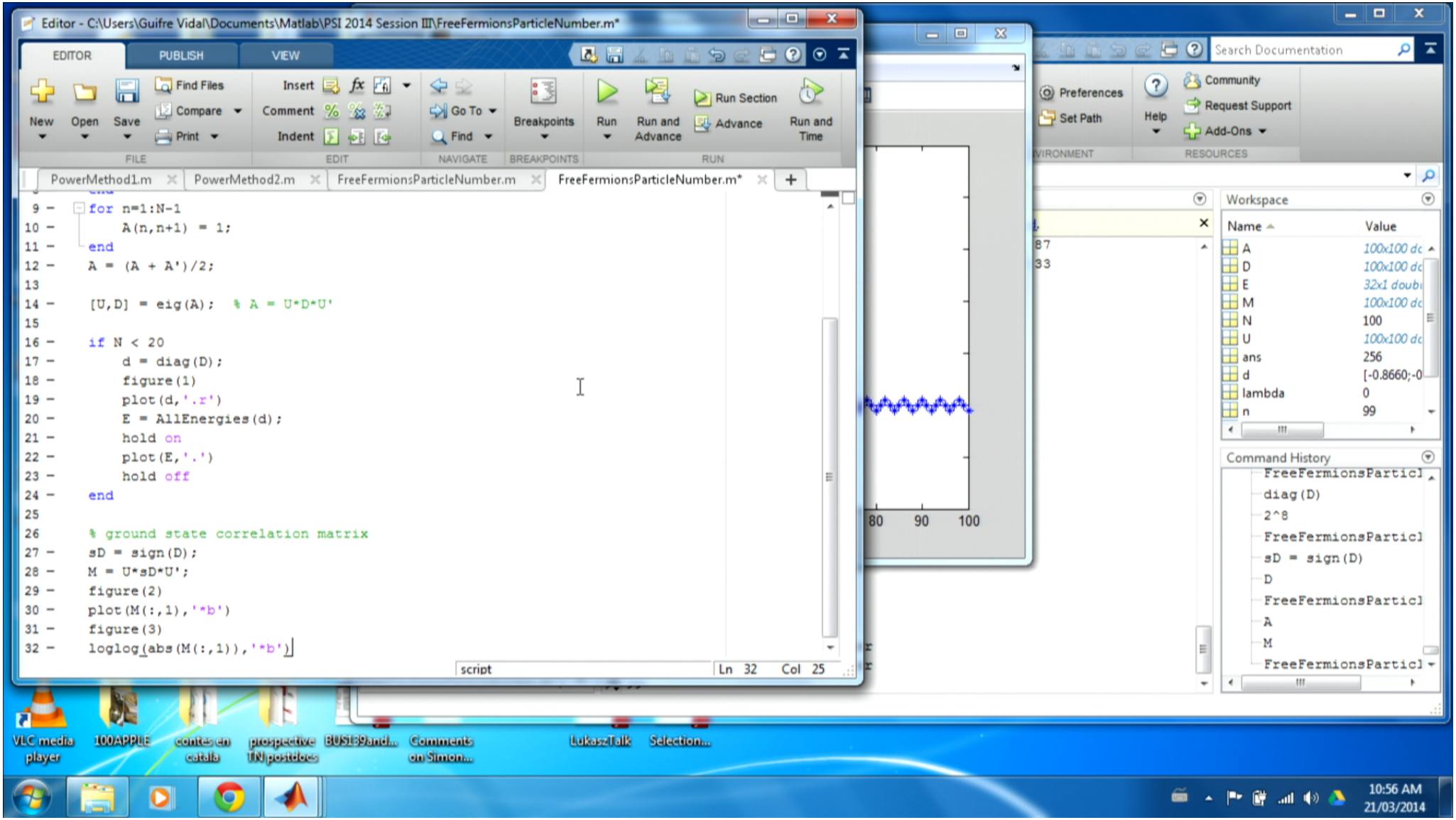

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PowerMethod1.m
PowerMethod2.m
A(n,n) = -2*lambda;
end
for n=1:N-1
A(n,n+1) = 1;
end
A = (A + A')/2;
[U,D] = eig(A); % A = U*D*U'
if N < 20
d = diag(D);
figure(1)
plot(d,'.r')
E = AllEnergies(d);
hold on
plot(E,'.')
hold off
end
% ground state correlation matrix
sD = sign(D);
M = U*sD*U';
figure(2)
plot(M(:,1),'*g')
script
Ln 30 Col 16
Figure 2
File Edit View Insert Tools Desktop Window Help
Zoom Out
1
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-0.4
1 1.5 2 2.5 3 3.5 4 4.5 5
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Workspace
Name
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A 5x5 double
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M 5x5 double
N 5
U 5x5 double
ans 256
d [-0.8660;-0
lambda 0
n 4
Command History
FreeFermionsPartic
diag(D)
2^8
FreeFermionsPartic
sD = sign(D)
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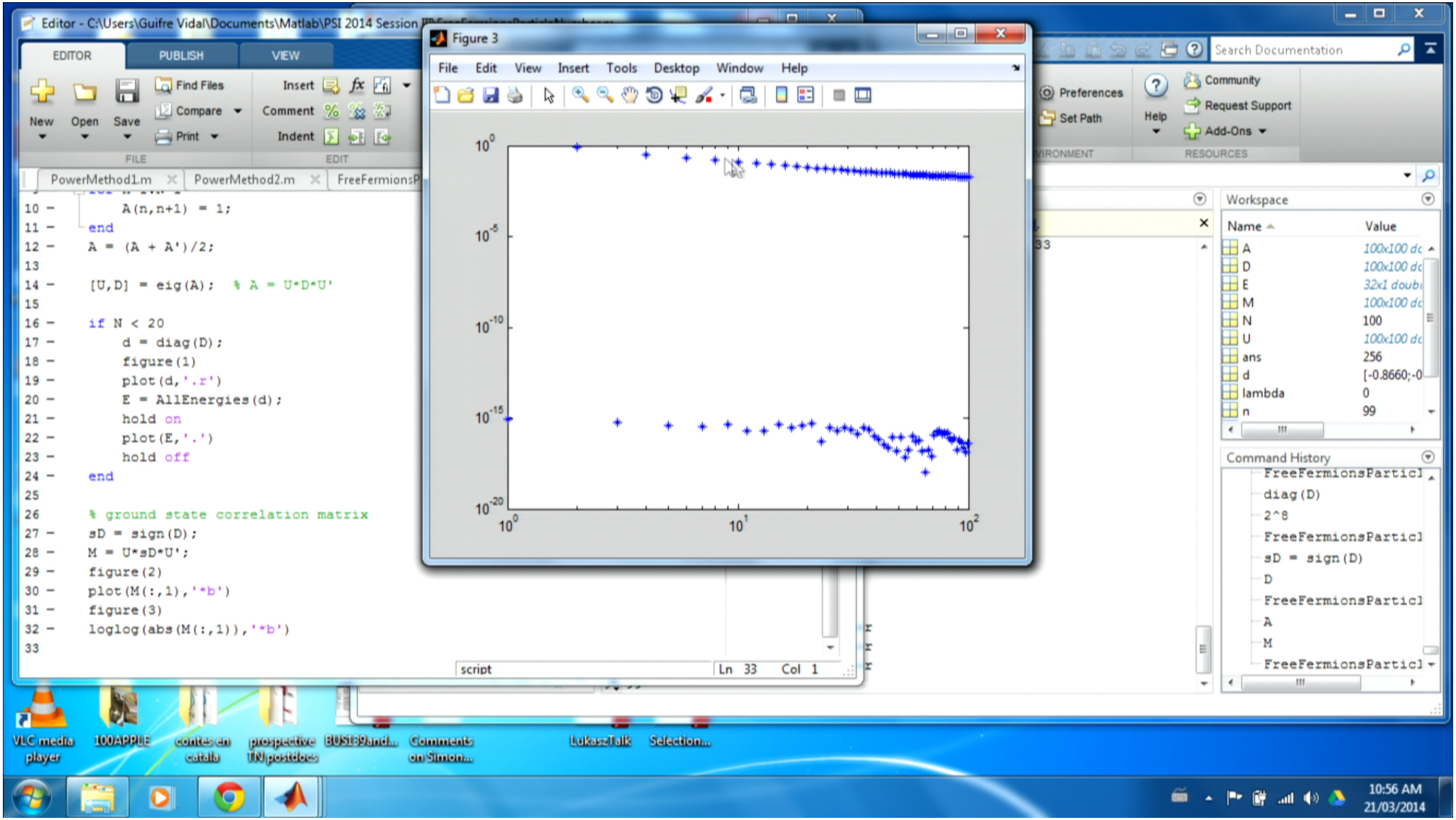

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BREAKPOINTS
RUN
PowerMethod1.m
PowerMethod2.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m*
% PSI 2014 Session III FreFermionsParticleNumber.m
N = 1000;
lambda = 0;
A = zeros(N);
for n=1:N
A(n,n) = -2*lambda;
end
for n=1:N-1
A(n,n+1) = 1;
end
A = (A + A')/2;
[U,D] = eig(A); % A = U*D*U'
if N < 20
d = diag(D);
figure(1)
plot(d,'.r')
E = AllEnergies(d);
hold on
plot(E,'.')
hold off
end
script
Ln 3 Col 9
Search Documentation
Preferences
Set Path
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Community
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RESOURCES
Workspace
Name
Value
A 5x5 double
D 5x5 double
E 32x1 doubl
M 5x5 double
N 5
U 5x5 double
ans 256
d [-0.8660;-0
lambda 0
n 4
Command History
FreeFermionsPartic
diag(D)
2^8
FreeFermionsPartic
sD = sign(D)
D
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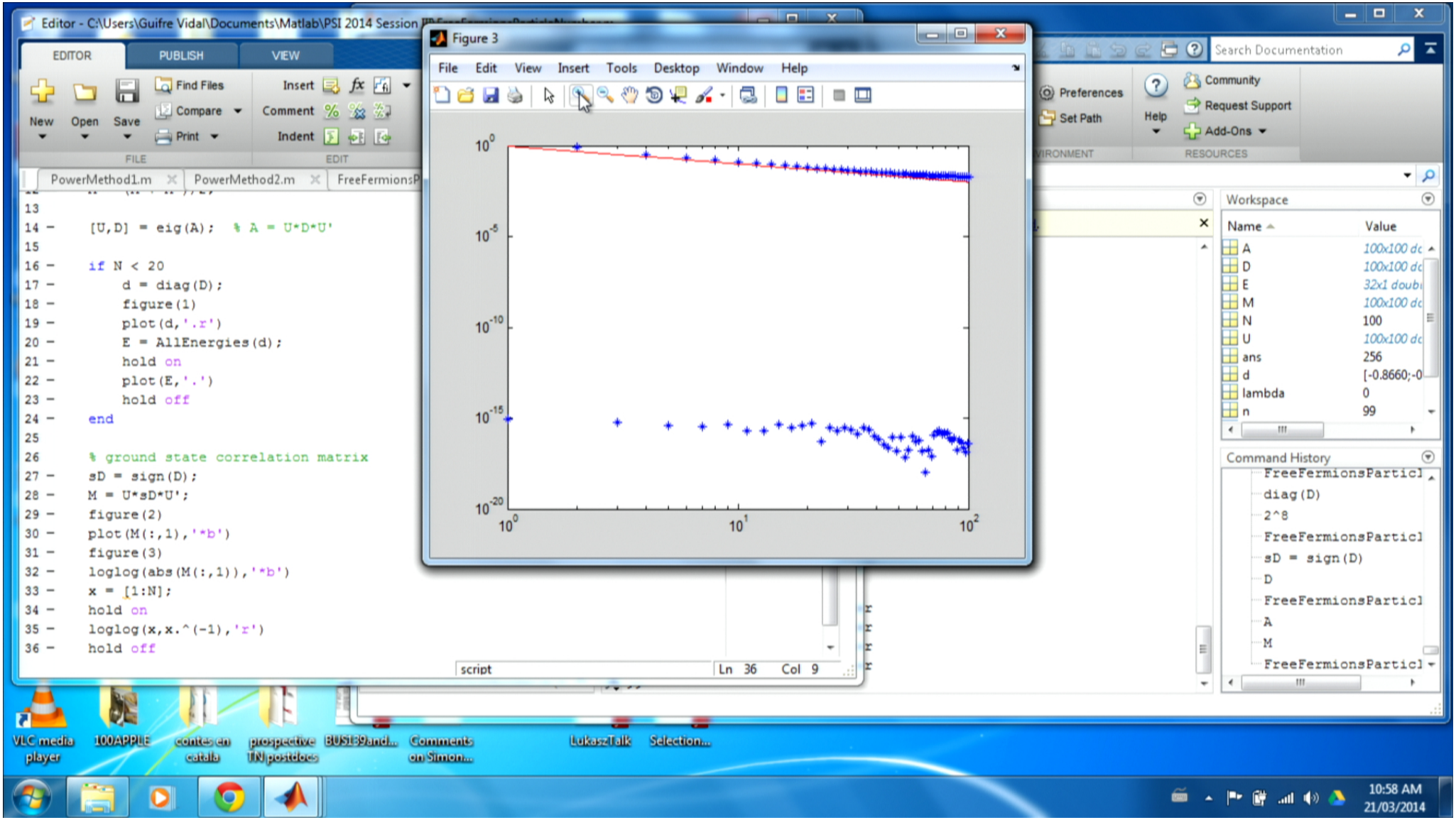

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EDIT
PowerMethod1.m
PowerMethod2.m
FreeFermionsP
1 % PSI 2014 Session III FreFermionsPart
2
3 - N = 1000;
4 - lambda = 0;
5 - A = zeros(N);
6 - for n=1:N
7 - A(n,n) = -2*lambda;
8 - end
9 - for n=1:N-1
10 - A(n,n+1) = 1;
11 - end
12 - A = (A + A')/2;
13
14 - [U,D] = eig(A); % A = U*D*U'
15
16 - if N < 20
17 - d = diag(D);
18 - figure(1)
19 - plot(d,'.r')
20 - E = AllEnergies(d);
21 - hold on
22 - plot(E,'.')
23 - hold off
24 - end
script
Ln 3
Col 9
Figure 2
File
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1
0.8
0.6
0.4
0.2
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-0.2
-0.4
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100
200
300
400
500
600
700
800
900
1000
Search Documentation
Preferences
Set Path
Help
Community
Request Support
Add-Ons
RESOURCES
Workspace
Name
Value
A 1000x1000
D 1000x1000
E 32x1 doubl
M 1000x1000
N 1000
U 1000x1000
ans 256
d [-0.8660;-0
lambda 0
n 999
Command History
FreeFermionsPartic
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2^8
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sD = sign(D)
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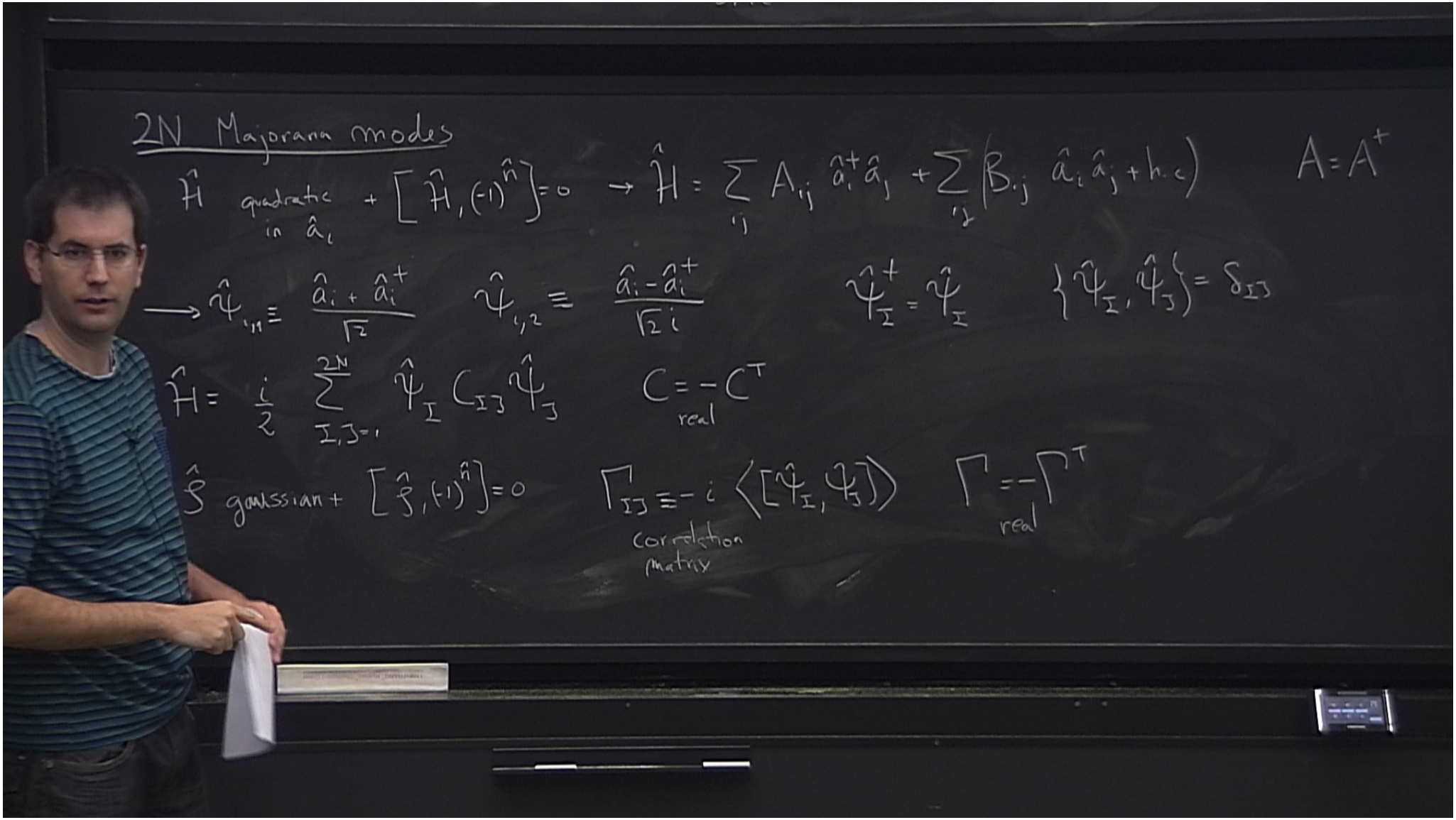

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EDIT
PowerMethod1.m
PowerMethod2.m
FreeFermionsP
1 % PSI 2014 Session III FreFermionsPart
2
3 - N = 100;
4 - lambda = 0;
5 - A = zeros(N);
6 - for n=1:N
7 - A(n,n) = -2*lambda;
8 - end
9 - for n=1:N-1
10 - A(n,n+1) = 1;
11 - end
12 - A = (A + A')/2;
13
14 - [U,D] = eig(A); % A = U*D*U'
15
16 - if N < 20
17 - d = diag(D);
18 - figure(1)
19 - plot(d,'.r')
20 - E = AllEnergies(d);
21 - hold on
22 - plot(E,'.')
23 - hold off
24 - end
script
Ln 3
Col 6
Figure 2
File Edit View Insert Tools Desktop Window Help
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0 10 20 30 40 50 60 70 80 90 100
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Workspace
Name
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A
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d
lambda
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n
99
Command History
diag(D)
2^8
sD = sign(D)
D
A
M
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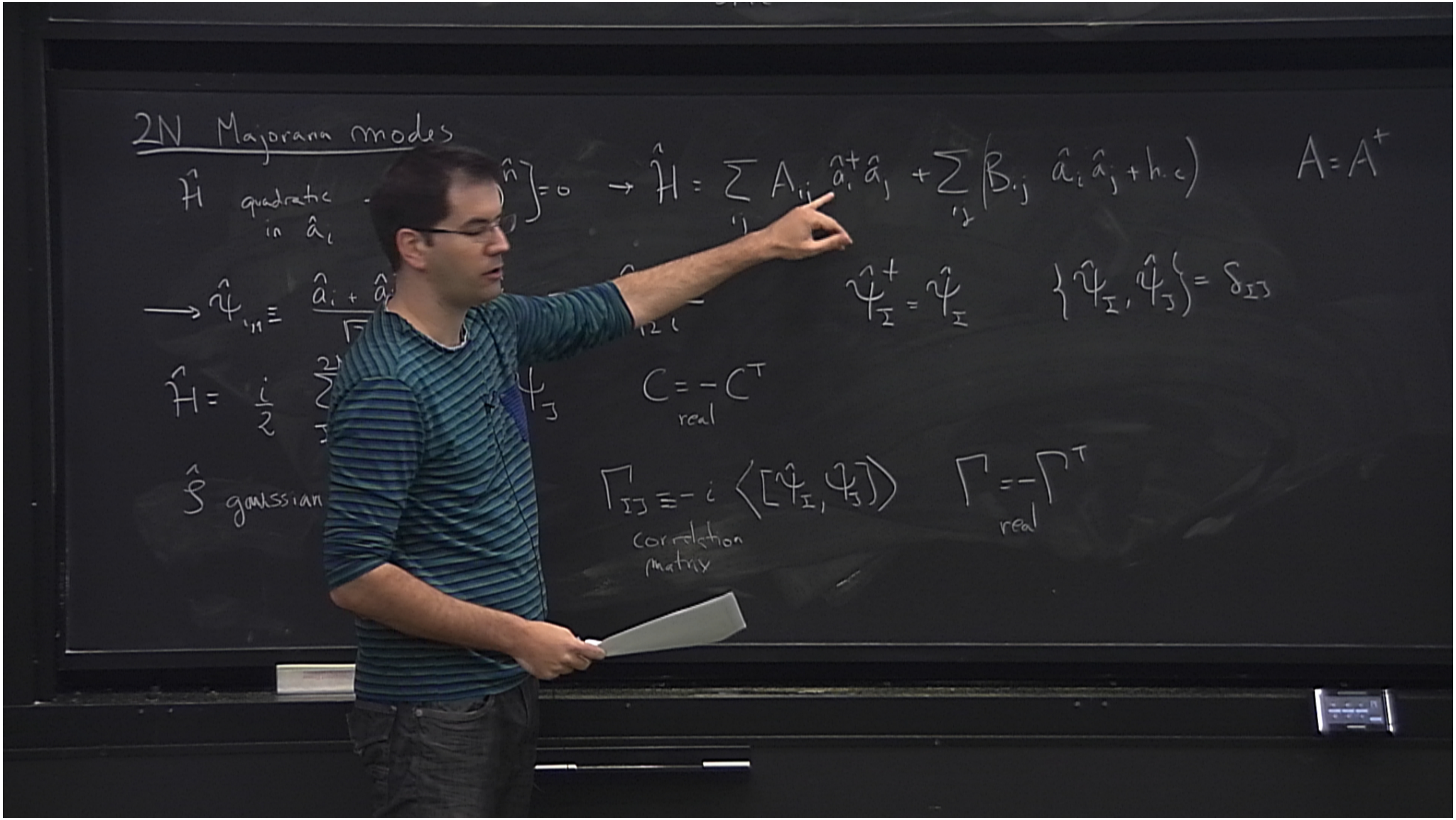

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Run and Time
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BREAKPOINTS
RUN
PowerMethod1.m
PowerMethod2.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m*
for n=1:N-1
A(n,n+1) = 1;
end
A = (A + A')/2;
[U,D] = eig(A); % A = U*D*U'
if N < 20
d = diag(D);
figure(1)
plot(d,'.r')
E = AllEnergies(d);
hold on
plot(E,'.')
hold off
end
% ground state correlation matrix
sD = sign(D);
M = U*sD*U';
figure(2)
plot(M(:,1),'*b')
figure(3)
loglog()
script
Ln 32 Col 8
Search Documentation
Preferences
Set Path
Help
Community
Request Support
Add-Ons
Workspace
Name
Value
A
D
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ans
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d
lambda
0
n
99
Command History
diag(D)
2^8
sD = sign(D)
D
A
M
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100
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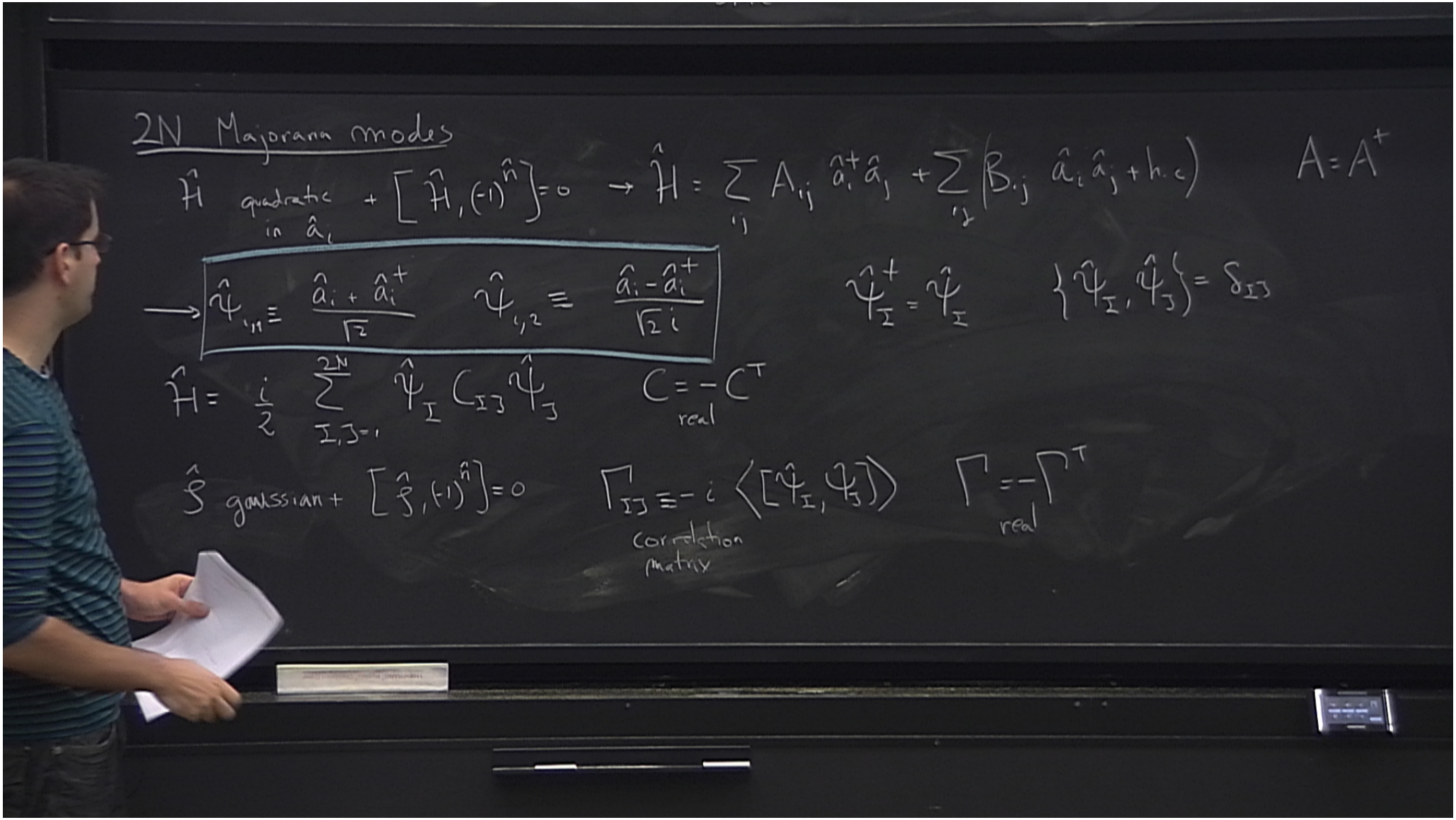

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RUN
PowerMethod1.m
PowerMethod2.m
FreeFermionsParticleNumber.m
FreeFermionsParticleNumber.m*
for n=1:N-1
A(n,n+1) = 1;
end
A = (A + A')/2;
[U,D] = eig(A); % A = U*D*U'
if N < 20
d = diag(D);
figure(1)
plot(d,'.r')
E = AllEnergies(d);
hold on
plot(E,'.')
hold off
end
% ground state correlation matrix
sD = sign(D);
M = U*sD*U';
figure(2)
plot(M(:,1),'*b')
figure(3)
loglog(abs(M(:,1)),'*b')
script
Ln 32 Col 25
Search Documentation
Preferences
Set Path
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Workspace
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Value
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256
d
lambda
0
n
99
Command History
diag(D)
2^8
sD = sign(D)
D
A
M
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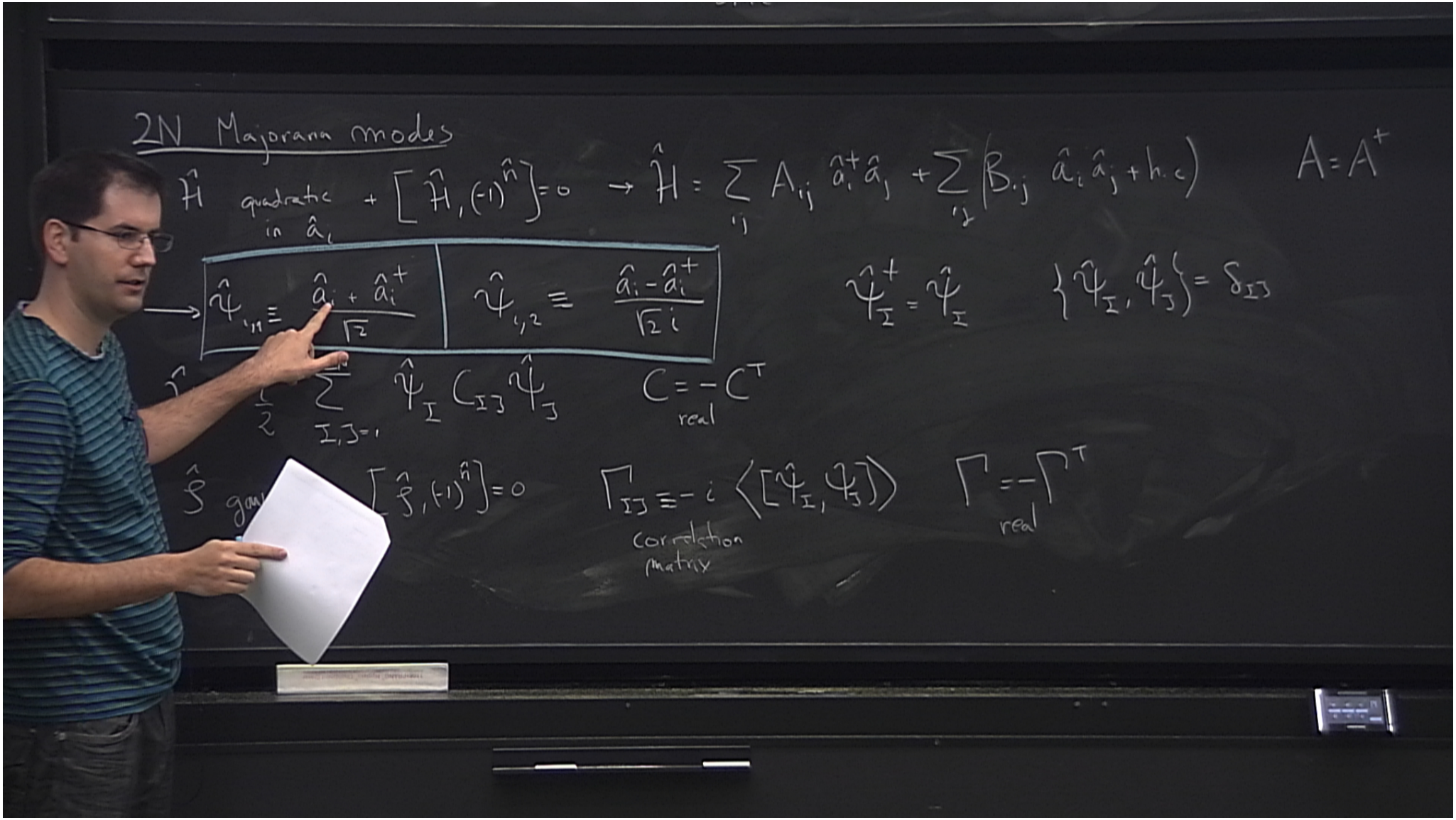

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EDIT
PowerMethod1.m
PowerMethod2.m
FreeFermionsP
10 - A(n,n+1) = 1;
11 - end
12 - A = (A + A')/2;
13
14 - [U,D] = eig(A); % A = U*D*U'
15
16 - if N < 20
17 - d = diag(D);
18 - figure(1)
19 - plot(d,'.r')
20 - E = AllEnergies(d);
21 - hold on
22 - plot(E,'.')
23 - hold off
24 - end
25
26 % ground state correlation matrix
27 - sD = sign(D);
28 - M = U*sD*U';
29 - figure(2)
30 - plot(M(:,1),'*b')
31 - figure(3)
32 - loglog(abs(M(:,1)),'*b')
33
script
Ln 33 Col 1
Figure 3
File Edit View Insert Tools Desktop Window Help
10^{0}
10^{-5}
10^{-10}
10^{-15}
10^{-20}
10^{0}
10^{1}
10^{2}
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Set Path
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Command History
FreeFermionsPartic
diag(D)
2^8
FreeFermionsPartic
sD = sign(D)
D
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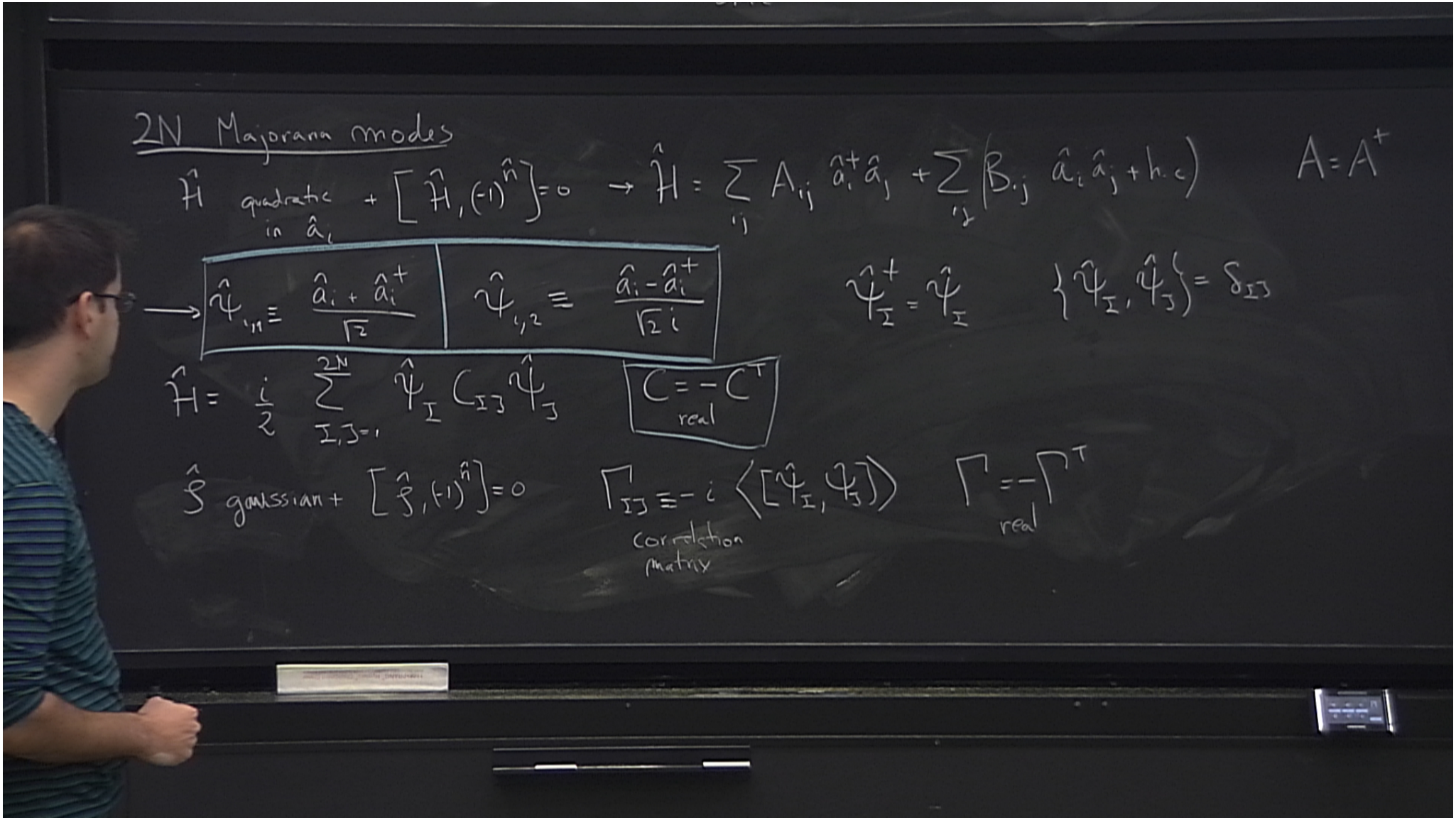

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PowerMethod1.m
PowerMethod2.m
FreeFermionsP
13
14 - [U,D] = eig(A); % A = U*D*U'
15
16 - if N < 20
17 - d = diag(D);
18 - figure(1)
19 - plot(d,'.r')
20 - E = AllEnergies(d);
21 - hold on
22 - plot(E,'.')
23 - hold off
24 - end
25
26 % ground state correlation matrix
27 - sD = sign(D);
28 - M = U*sD*U';
29 - figure(2)
30 - plot(M(:,1),'*b')
31 - figure(3)
32 - loglog(abs(M(:,1)),'*b')
33 - x = [1:N];
34 - hold on
35 - loglog(x,x.^(-1),'r')
36 - hold off
script
Ln 36 Col 9
Figure 3
File Edit View Insert Tools Desktop Window Help
10^{0}
10^{-5}
10^{-10}
10^{-15}
10^{-20}
10^{0}
10^{1}
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RESOURCES
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U
ans
256
d
lambda
0
n
99
Command History
FreeFermionsPartic
diag(D)
2^8
FreeFermionsPartic
sD = sign(D)
D
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FreeFermionsPartic
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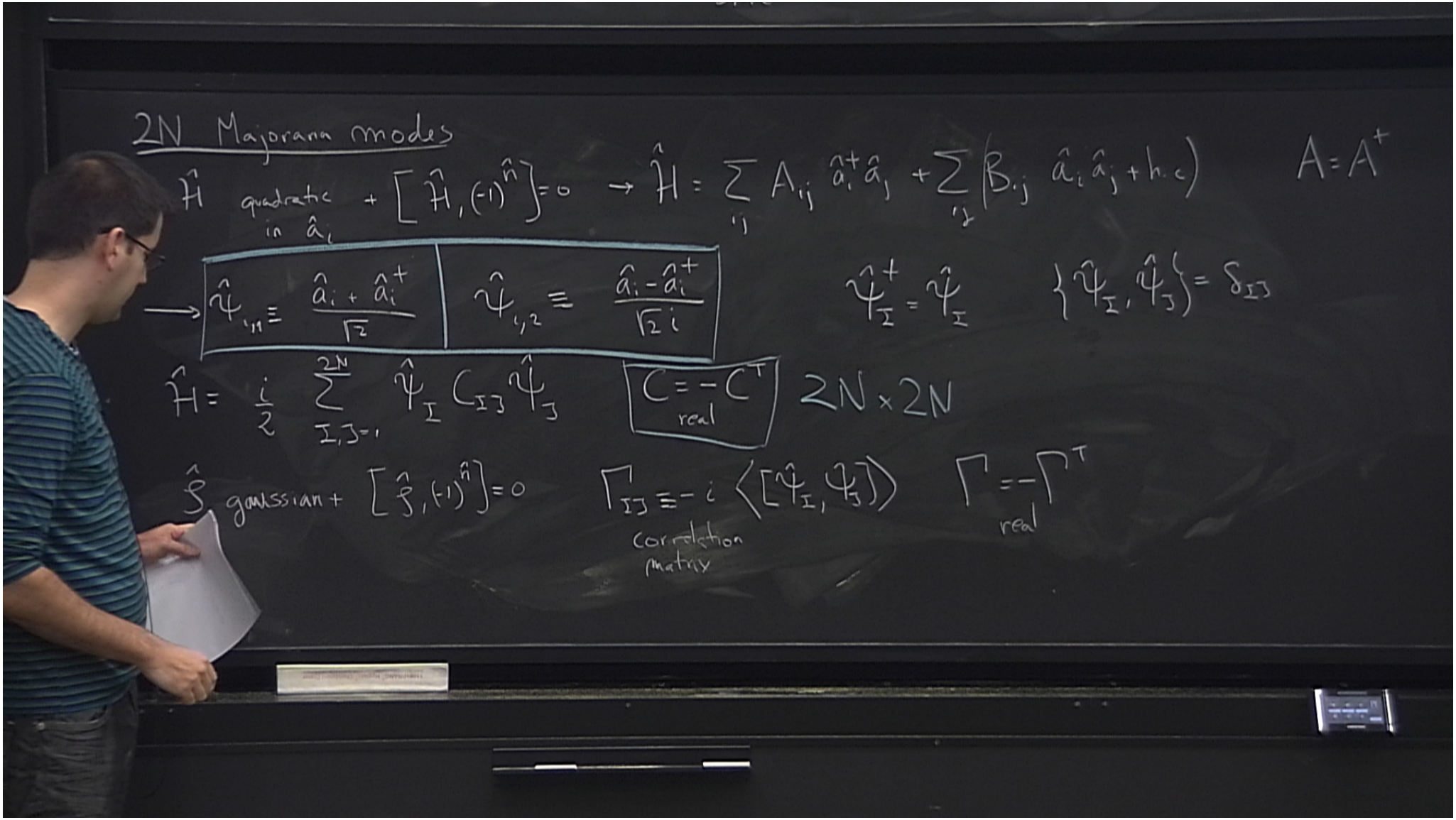

2N Majorana modes
$\hat{H}$ quadratic in $\hat{a}_i$ + $[\hat{H}, (-1)^{\hat{n}}] = 0$ → $\hat{H} = \sum_{ij} A_{ij} \hat{a}_i^\dagger \hat{a}_j + \sum_{ij} (B_{ij} \hat{a}_i \hat{a}_j + h.c)$ $A = A^\dagger$
→ $\hat{\psi}_{i,1} \equiv \frac{\hat{a}_i + \hat{a}_i^\dagger}{\sqrt{2}}$ $\hat{\psi}_{i,2} \equiv \frac{\hat{a}_i - \hat{a}_i^\dagger}{\sqrt{2}i}$ $\hat{\psi}_I^\dagger = \hat{\psi}_I$ $\{\hat{\psi}_I, \hat{\psi}_J\} = \delta_{IJ}$
$\hat{H} = \frac{i}{2} \sum_{I,J=1}^{2N} \hat{\psi}_I C_{IJ} \hat{\psi}_J$ $C = -C^T$ real
$\hat{\rho}$ gaussian + $[\hat{\rho}, (-1)^{\hat{n}}] = 0$ $\Gamma_{IJ} \equiv -i \langle [\hat{\psi}_I, \hat{\psi}_J] \rangle$ $\Gamma = -\Gamma^T$ real
Correlation matrix

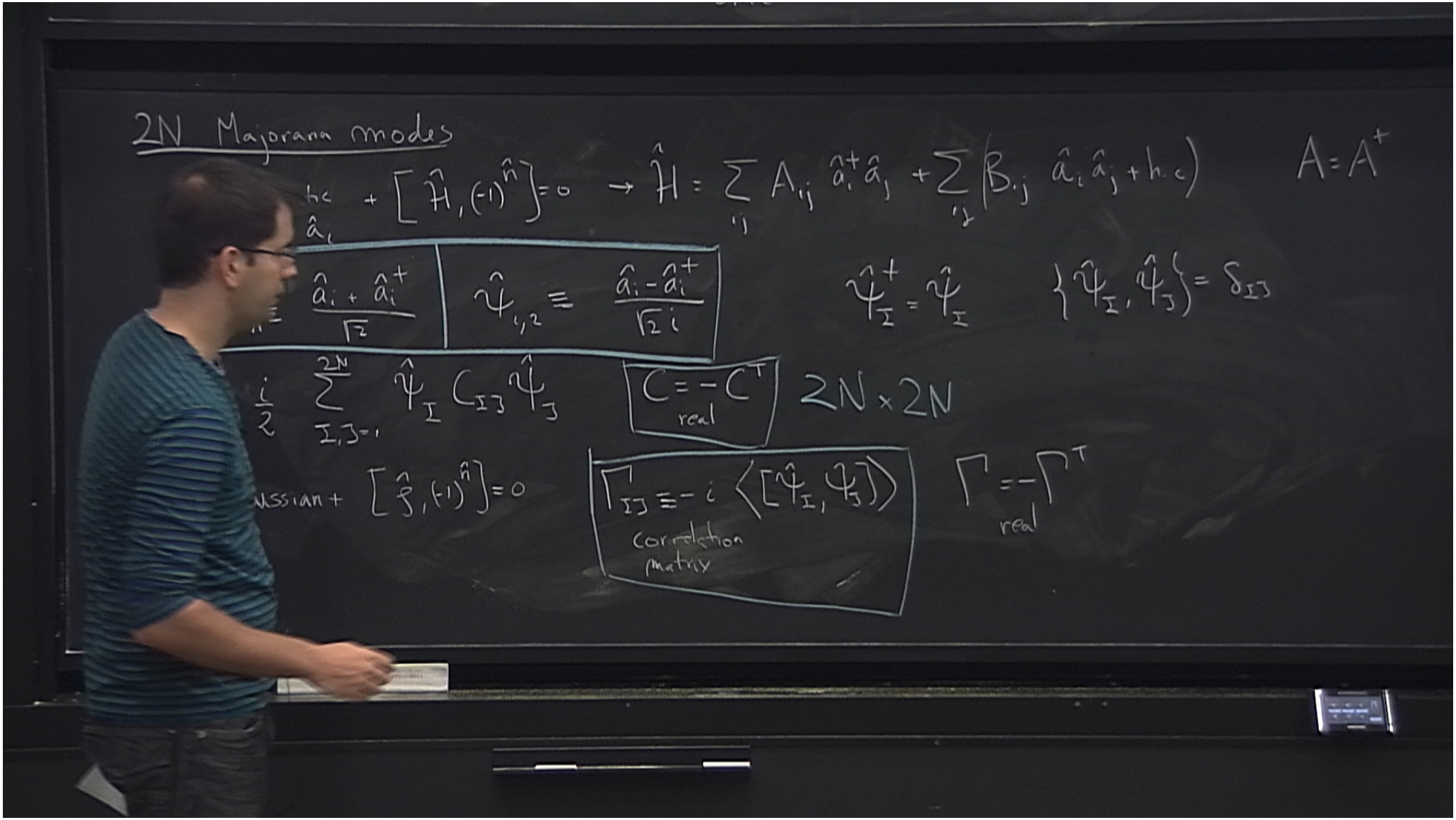

2N Majorana modes
quadratic
in $\hat{a}_i$
$\hat{H} = \sum A_{ij} \hat{a}_i^\dagger \hat{a}_j + \sum_{ij} (B_{ij} \hat{a}_i \hat{a}_j + h.c)$
$A = A^\dagger$
$\hat{\psi}_I^\dagger = \hat{\psi}_I$
$\{\hat{\psi}_I, \hat{\psi}_J\} = \delta_{IJ}$
$C = -C^T$
real
$\hat{\rho}$ gaussian
$\Gamma_{IJ} \equiv -i \langle [\hat{\psi}_I, \hat{\psi}_J] \rangle$
correlation matrix
$\Gamma = -\Gamma^T$
real

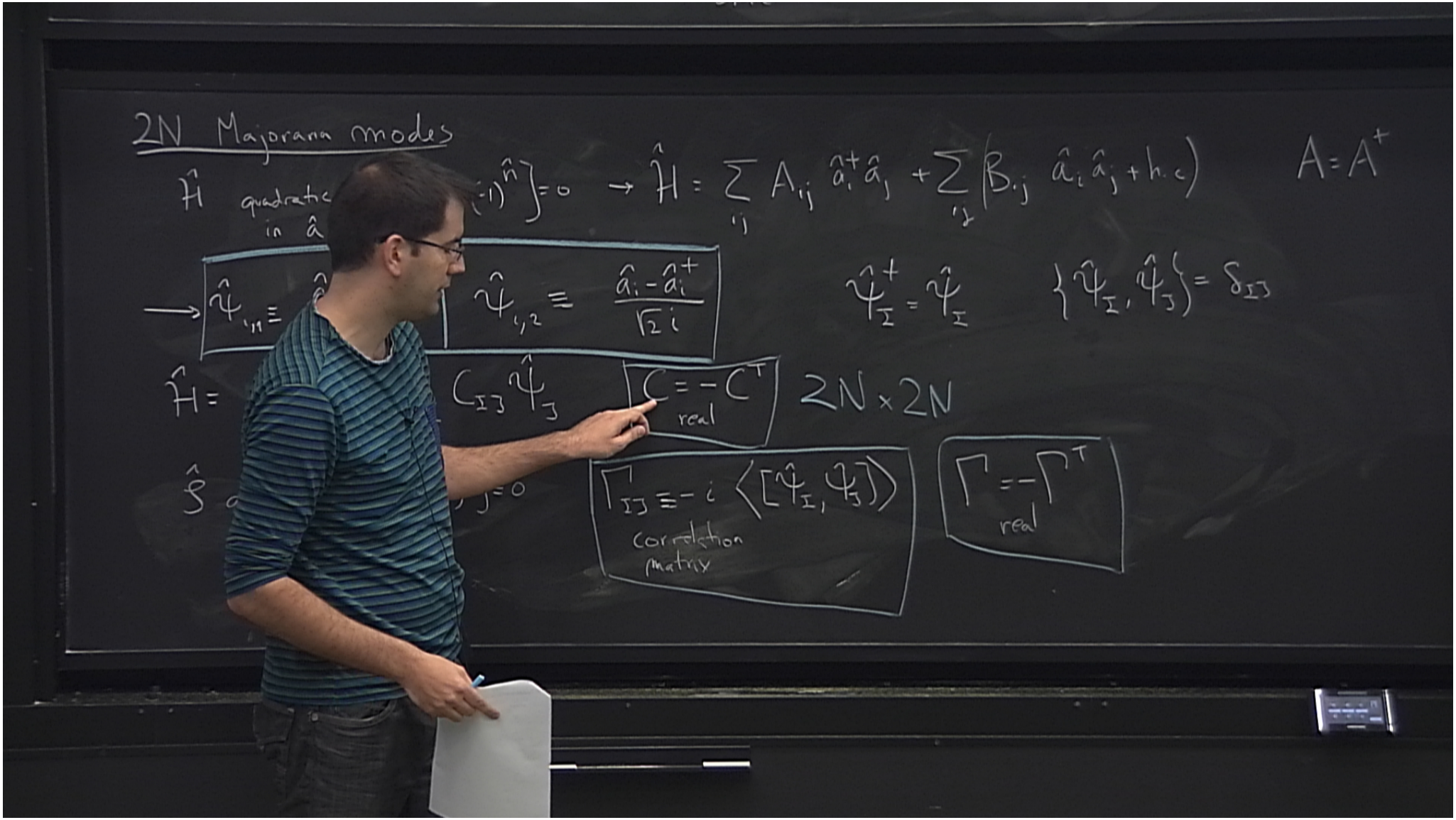

2N Majorana modes
$\hat{H}$ quadratic in $\hat{a}_i$ $+ [\hat{H}, (-1)^{\hat{n}}] = 0 \rightarrow \hat{H} = \sum_{ij} A_{ij} \hat{a}_i^\dagger \hat{a}_j + \sum_{ij} (B_{ij} \hat{a}_i \hat{a}_j + h.c)$ $A = A^\dagger$
$\hat{\psi}_{i,1} \equiv \frac{\hat{a}_i + \hat{a}_i^\dagger}{\sqrt{2}}$ $\hat{\psi}_{i,2} \equiv \frac{\hat{a}_i - \hat{a}_i^\dagger}{\sqrt{2}\, i}$
$\hat{\psi}_I^\dagger = \hat{\psi}_I$ $\{\hat{\psi}_I, \hat{\psi}_J\} = \delta_{IJ}$
$\hat{H} = \frac{i}{2} \sum_{I,J=1}^{2N} \hat{\psi}_I C_{IJ} \hat{\psi}_J$ $C = -C^T$ real
$\hat{\rho}$ gaussian $+ [\hat{\rho}, (-1)^{\hat{n}}] = 0$ $\Gamma_{IJ} \equiv -i \langle [\hat{\psi}_I, \hat{\psi}_J] \rangle$ $\Gamma = -\Gamma^T$ real
correlation matrix

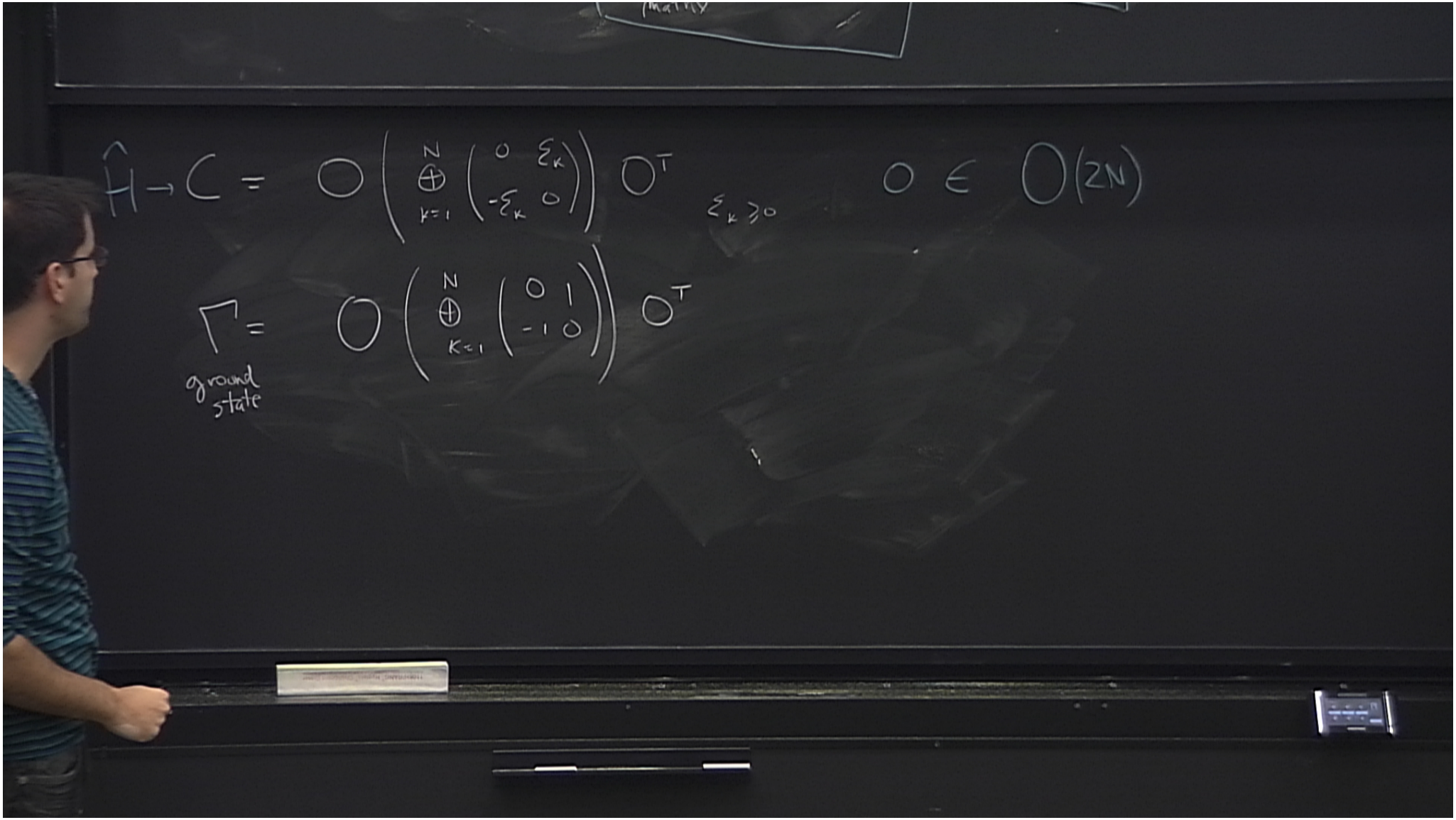

2N Majorana modes
quadratic in $\hat{a}_i$
$\hat{\psi}_{i,1} \equiv \frac{\hat{a}_i + \hat{a}_i^\dagger}{\sqrt{2}}$
$\hat{\psi}_{i,2} \equiv \frac{\hat{a}_i - \hat{a}_i^\dagger}{\sqrt{2}\,i}$
$A = A^\dagger$
$\hat{\psi}_I^\dagger = \hat{\psi}_I$
$\{\hat{\psi}_I, \hat{\psi}_J\} = \delta_{IJ}$
$C = -C^T$
real
$\Gamma_{IJ} \equiv -i \langle [\hat{\psi}_I, \hat{\psi}_J] \rangle$
correlation matrix
$\Gamma = -\Gamma^T$
real

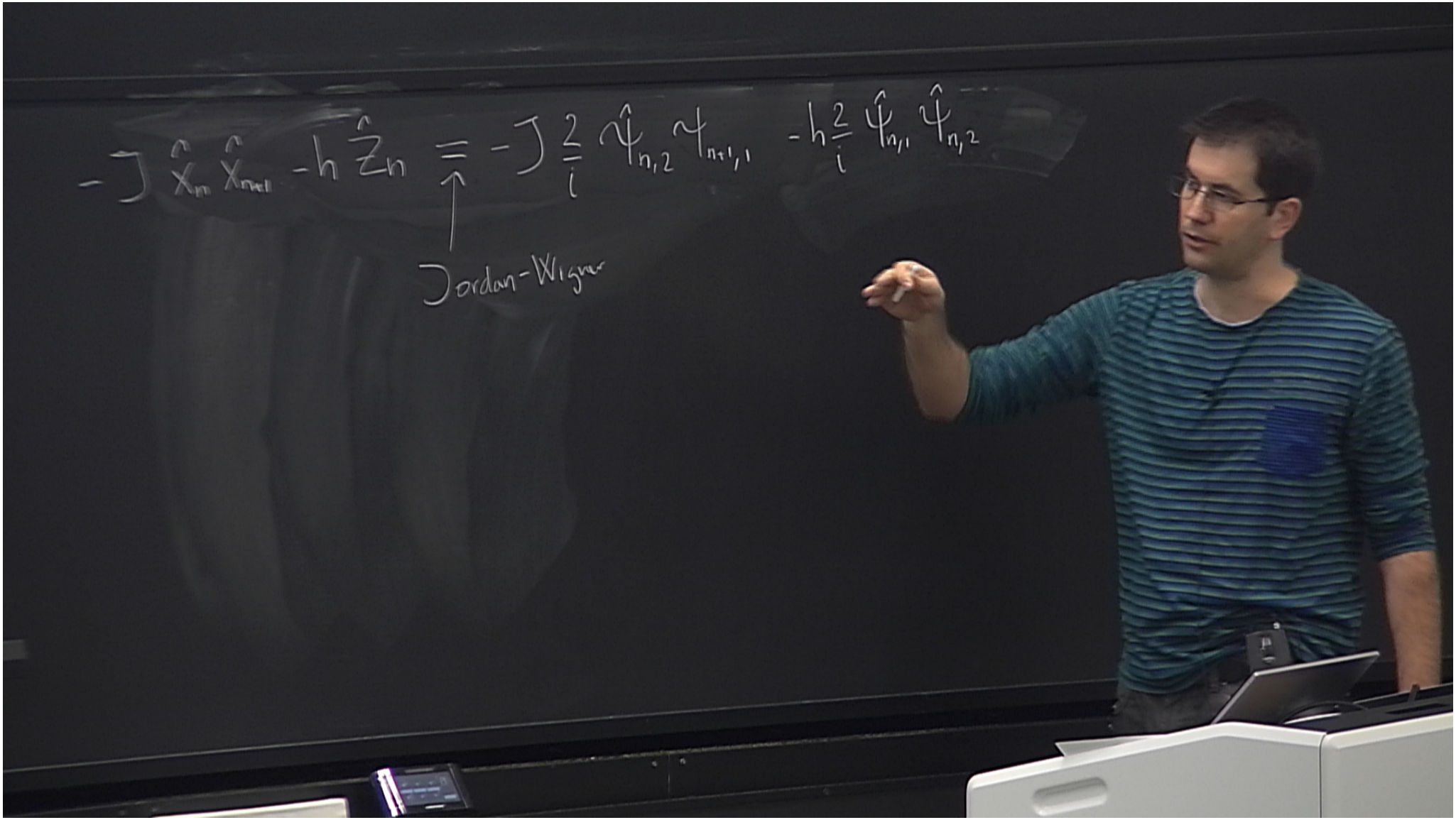

2N Majorana modes
$\hat{H}$ quadratic in $\hat{a}_i$ + $[\hat{H}, (-1)^{\hat{n}}] = 0$ $\rightarrow$ $\hat{H} = \sum_{ij} A_{ij} \hat{a}_i^\dagger \hat{a}_j + \sum_{ij} (B_{ij} \hat{a}_i \hat{a}_j + h.c)$ $A = A^\dagger$
$\hat{\psi}_{i,1} \equiv \frac{\hat{a}_i + \hat{a}_i^\dagger}{\sqrt{2}}$ $\hat{\psi}_{i,2} \equiv \frac{\hat{a}_i - \hat{a}_i^\dagger}{\sqrt{2}i}$
$\hat{\psi}_I^\dagger = \hat{\psi}_I$ $\{\hat{\psi}_I, \hat{\psi}_J\} = \delta_{IJ}$
$\hat{H} = \frac{i}{2} \sum_{I,J=1}^{2N} \hat{\psi}_I C_{IJ} \hat{\psi}_J$ $C = -C^T$ real
$\hat{\rho}$ gaussian + $[\hat{\rho}, (-1)^{\hat{n}}] = 0$ $\Gamma_{IJ} \equiv -i \langle [\hat{\psi}_I, \hat{\psi}_J] \rangle$ $\Gamma = -\Gamma^T$ real
correlation matrix

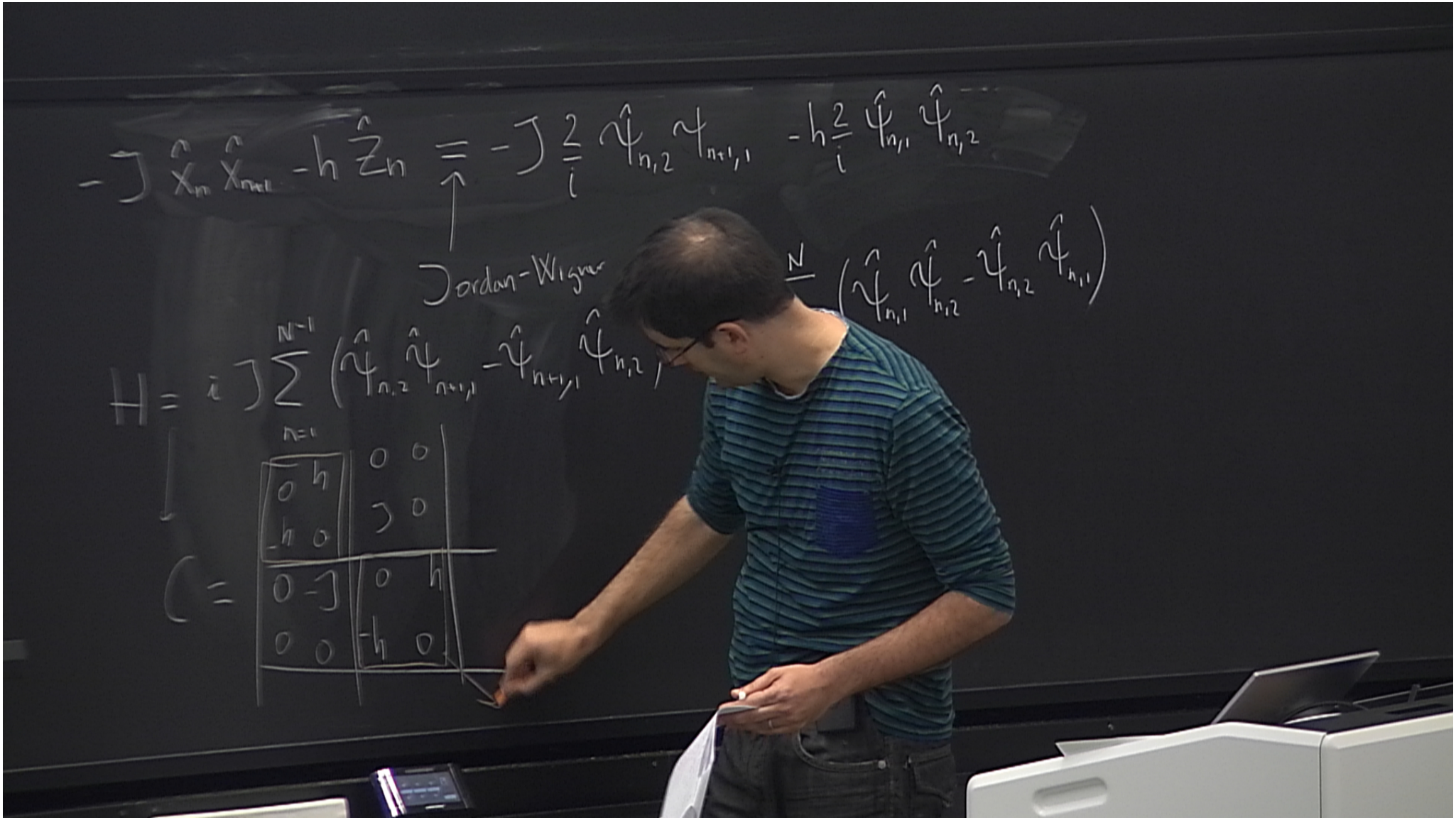

2N Majorana modes
$\hat{H}$ quadratic in $\hat{a}_i$ $+ [\hat{H}, (-1)^{\hat{n}}] = 0 \rightarrow \hat{H} = \sum_{ij} A_{ij} \hat{a}_i^\dagger \hat{a}_j + \sum_{ij} (B_{ij} \hat{a}_i \hat{a}_j + h.c)$ $A = A^\dagger$
$\hat{\psi}_{i,1} \equiv \frac{\hat{a}_i + \hat{a}_i^\dagger}{\sqrt{2}}$ $\hat{\psi}_{i,2} \equiv \frac{\hat{a}_i - \hat{a}_i^\dagger}{\sqrt{2}i}$
$\hat{\psi}_I^\dagger = \hat{\psi}_I$ $\{\hat{\psi}_I, \hat{\psi}_J\} = \delta_{IJ}$
$\hat{H} = \frac{i}{2} \sum_{I,J=1}^{2N} \hat{\psi}_I C_{IJ} \hat{\psi}_J$ $C = -C^T$ real $2N \times 2N$
$\hat{\rho}$ gaussian $+ [\hat{\rho}, (-1)^{\hat{n}}] = 0$ $\Gamma_{IJ} \equiv -i \langle [\hat{\psi}_I, \hat{\psi}_J] \rangle$ correlation matrix $\Gamma = -\Gamma^T$ real

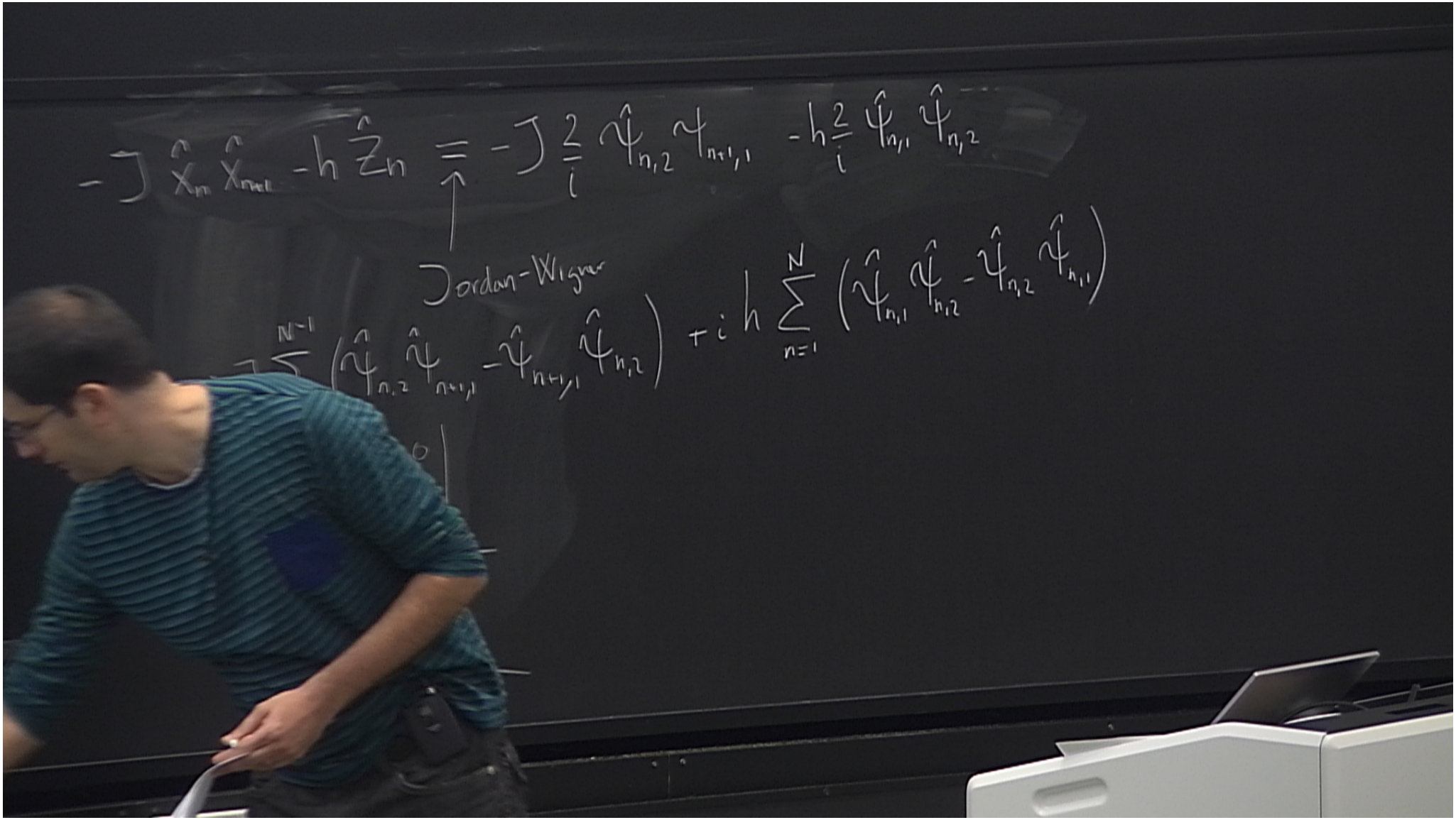

2N Majorana modes
$\hat{a}_i$ h.c $+\left[\hat{\mathcal{H}}, (-1)^{\hat{n}}\right]=0 \rightarrow \hat{\mathcal{H}} = \sum_{ij} A_{ij}\, \hat{a}_i^\dagger \hat{a}_j + \sum_{ij} \left(B_{ij}\, \hat{a}_i \hat{a}_j + h.c\right)$ $A = A^\dagger$
$\frac{\hat{a}_i + \hat{a}_i^\dagger}{\sqrt{2}}$ | $\hat{\psi}_{i,2} \equiv \frac{\hat{a}_i - \hat{a}_i^\dagger}{\sqrt{2}\, i}$
$\hat{\psi}_I^\dagger = \hat{\psi}_I$ $\{\hat{\psi}_I, \hat{\psi}_J\} = \delta_{IJ}$
$\frac{i}{2} \sum_{I,J=1}^{2N} \hat{\psi}_I C_{IJ} \hat{\psi}_J$ $C = -C^T$ real $2N \times 2N$
$\left[\hat{\beta}, (-1)^{\hat{n}}\right]=0$
$\Gamma_{IJ} \equiv -i \langle [\hat{\psi}_I, \hat{\psi}_J] \rangle$ correlation matrix
$\Gamma = -\Gamma^T$ real

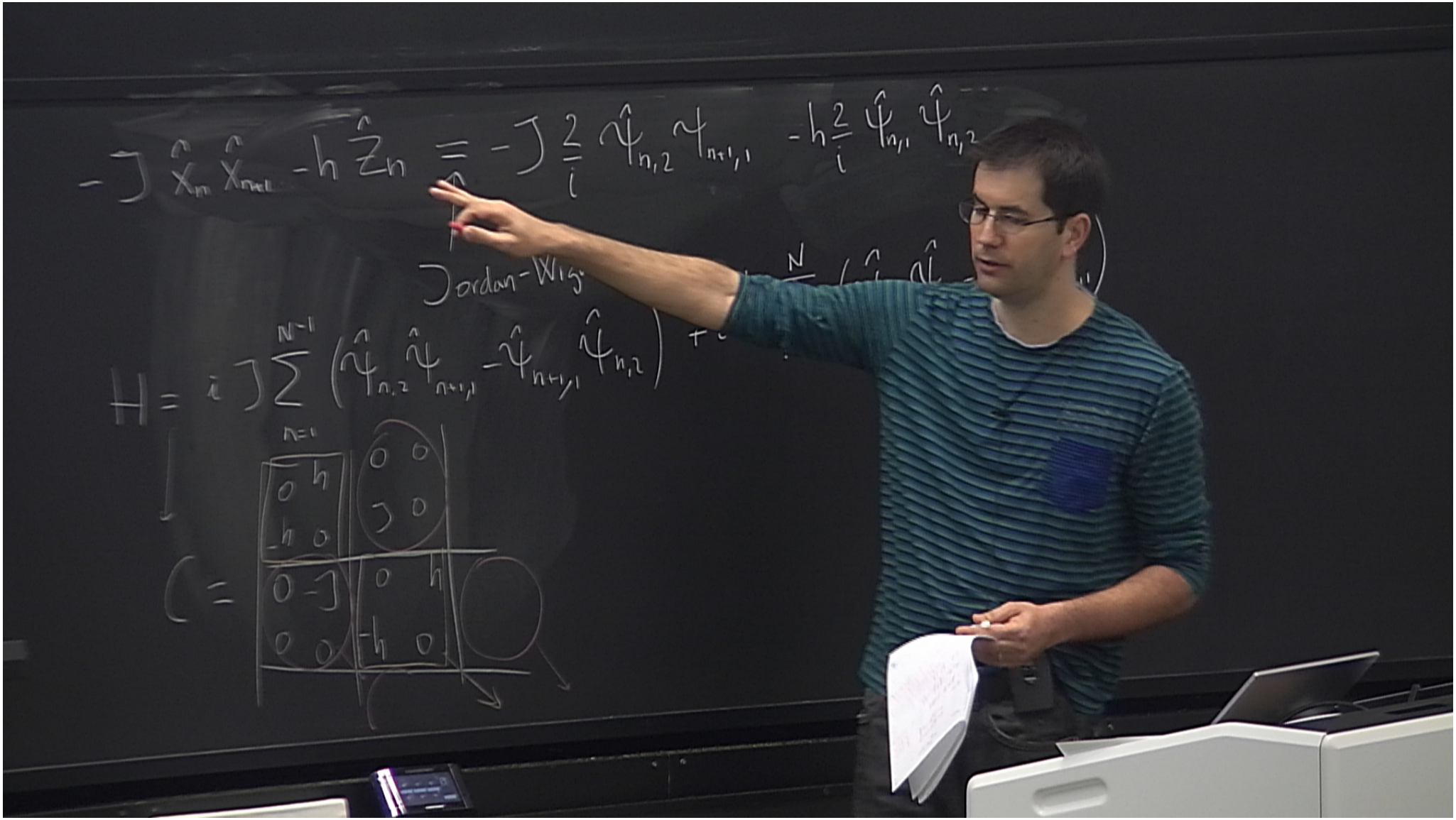

2N Majorana modes
quadratic
in â
$\hat{\psi}_{i,1} \equiv$
$\hat{\psi}_{i,2} \equiv \frac{\hat{a}_i - \hat{a}_i^\dagger}{\sqrt{2}\,i}$
$\hat{\psi}_I^\dagger = \hat{\psi}_I$
$\{\hat{\psi}_I, \hat{\psi}_J\} = \delta_{IJ}$
$C_{IJ}\hat{\psi}_J$
$C = -C^T$
real
$2N \times 2N$
$\Gamma_{IJ} \equiv -i\langle[\hat{\psi}_I, \hat{\psi}_J]\rangle$
correlation matrix
$\Gamma = -\Gamma^T$
real
$A = A^\dagger$

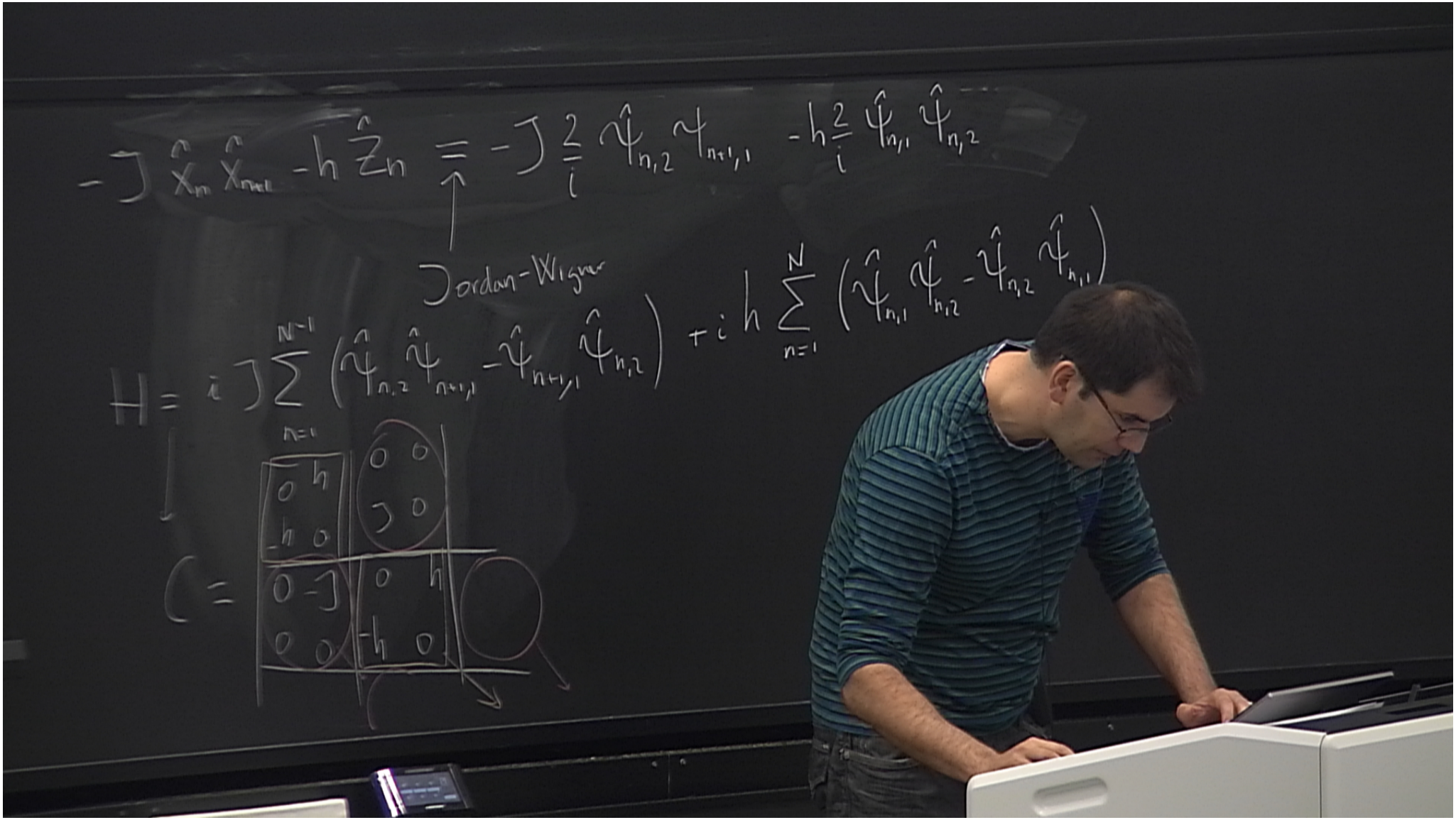

$\hat{H} \to C = O\left(\bigoplus_{k=1}^{N} \begin{pmatrix} 0 & \varepsilon_k \\ -\varepsilon_k & 0 \end{pmatrix}\right) O^T$
$\varepsilon_k \geq 0$
$O \in O(2N)$
$\Gamma = O\left(\bigoplus_{k=1}^{N} \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}\right) O^T$
ground state


$-J\hat{x}_n\hat{x}_{n+1} - h\hat{z}_n = -J\frac{2}{i}\hat{\psi}_{n,2}\hat{\psi}_{n+1,1} - h\frac{2}{i}\hat{\psi}_{n,1}\hat{\psi}_{n,2}$
Jordan-Wigner


Jordan-Wigner


Jordan-Wigner


Jordan-Wig
H = i J Σ
n=1
N-1
C =


Jordan-Wigner