Title: PSI 2019/2020 - Computational Physics - Lecture 8

Speakers: Erik Schnetter

Collection: PSI 2019/2020 - Computational Physics

Date: February 12, 2020 - 12:30 PM

URL: http://pirsa.org/20020015

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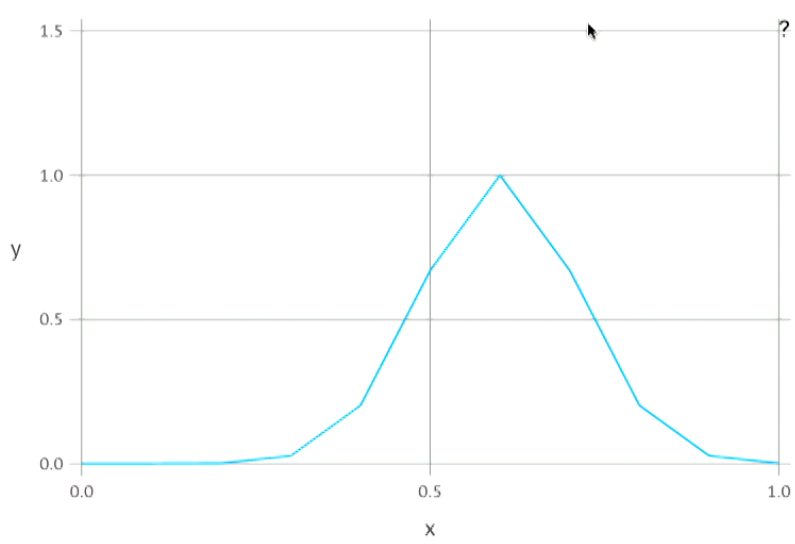
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FiniteDifferences.ipynb

Code | git | Julia 1.3.1

[16]:
```
plot(x=xs, y=[g11(x) for x in xs], Geom.line)
```

[16]:



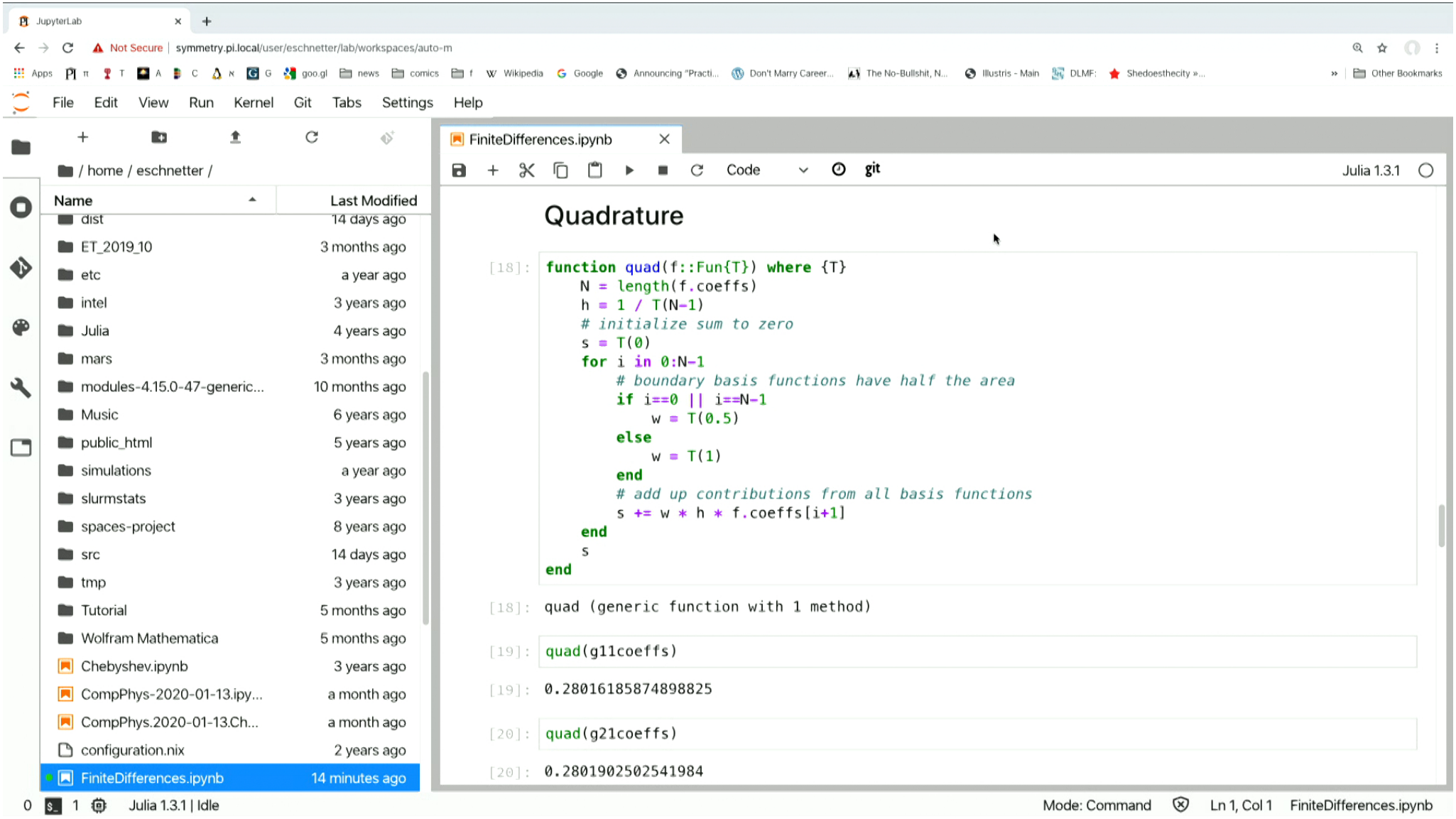
[17]:
```
g21coeffs = sample(g, 21)
g21(x) = evaluate(g21coeffs, x)
plot(x=xs, y=[g21(x) for x in xs], Geom.line)
```

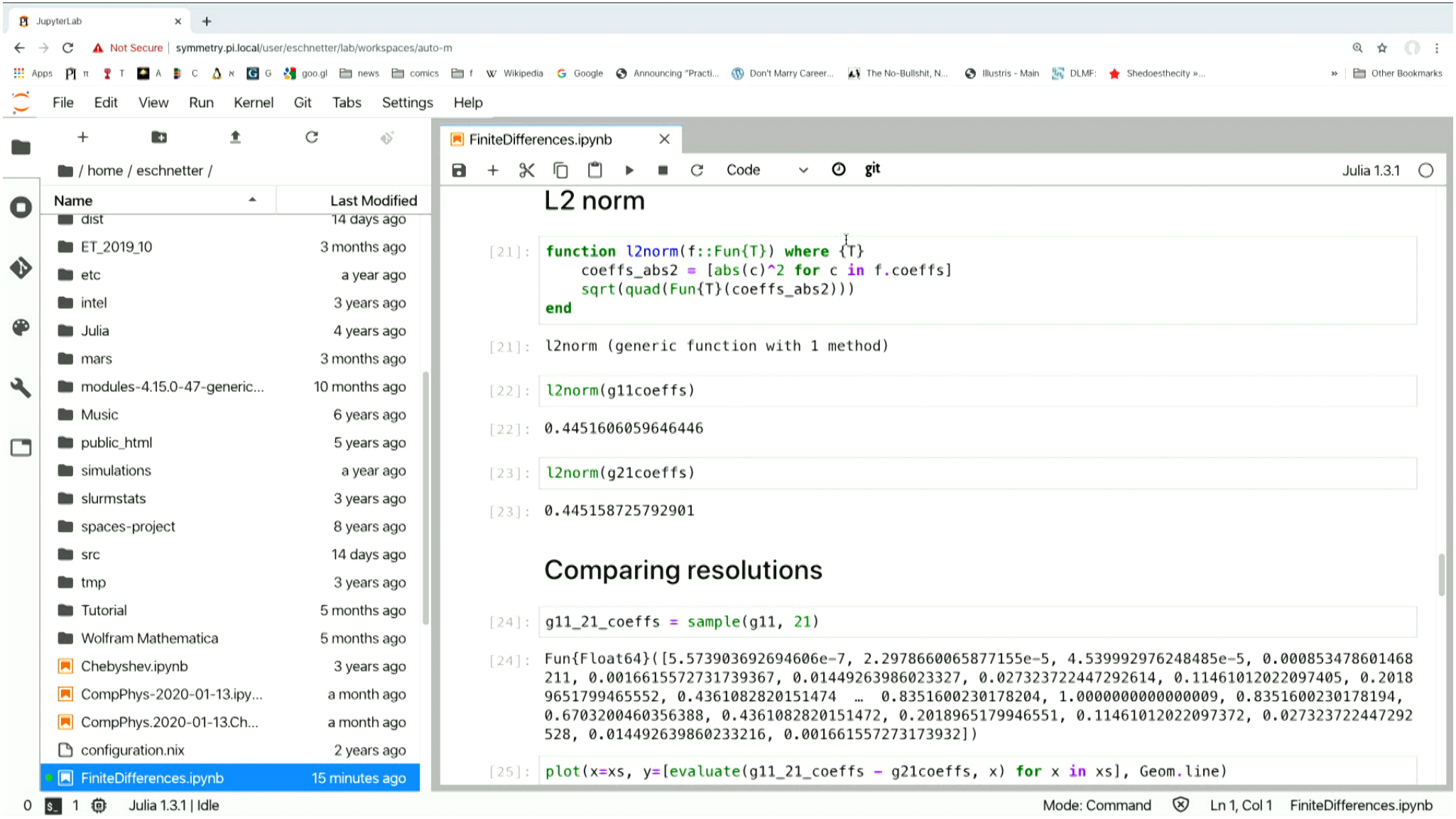
[17]:



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FiniteDifferences.ipynb
Code
git
Julia 1.3.1
Quadrature
[18]:
function quad(f::Fun{T}) where {T}
N = length(f.coeffs)
h = 1 / T(N-1)
# initialize sum to zero
s = T(0)
for i in 0:N-1
boundary basis functions have half the area
if i==0 || i==N-1
w = T(0.5)
else
w = T(1)
end
add up contributions from all basis functions
s += w * h * f.coeffs[i+1]
end
s
end
[18]: quad (generic function with 1 method)
[19]: quad(g11coeffs)
[19]: 0.28016185874898825
[20]: quad(g21coeffs)
[20]: 0.2801902502541984
0 1 Julia 1.3.1 | Idle
Mode: Command
Ln 1, Col 1
FiniteDifferences.ipynb


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configuration.nix 2 years ago
FiniteDifferences.ipynb 15 minutes ago
FiniteDifferences.ipynb
Code
git
Julia 1.3.1
L2 norm
[21]:
function l2norm(f::Fun{T}) where {T}
coeffs_abs2 = [abs(c)^2 for c in f.coeffs]
sqrt(quad(Fun{T}(coeffs_abs2)))
end
[21]: l2norm (generic function with 1 method)
[22]: l2norm(g11coeffs)
[22]: 0.4451606059646446
[23]: l2norm(g21coeffs)
[23]: 0.445158725792901
Comparing resolutions
[24]: g11_21_coeffs = sample(g11, 21)
[24]: Fun{Float64}([5.573903692694606e-7, 2.2978660065877155e-5, 4.539992976248485e-5, 0.000853478601468211, 0.0016615572731739367, 0.01449263986023327, 0.027323722447292614, 0.11461012022097405, 0.20189651799465552, 0.4361082820151474 … 0.8351600230178204, 1.0000000000000009, 0.8351600230178194, 0.6703200460356388, 0.4361082820151472, 0.2018965179946551, 0.11461012022097372, 0.027323722447292528, 0.014492639860233216, 0.0016615572731739 32])
[25]: plot(x=xs, y=[evaluate(g11_21_coeffs - g21coeffs, x) for x in xs], Geom.line)
0 1 Julia 1.3.1 | Idle
Mode: Command
Ln 1, Col 1
FiniteDifferences.ipynb

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FiniteDifferences.ipynb	15 minutes ago

FiniteDifferences.ipynb

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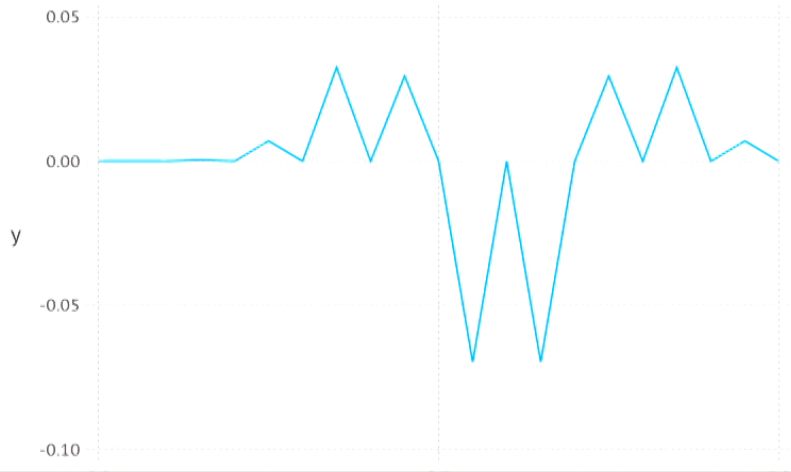
Comparing resolutions

[24]:
```
g11_21_coeffs = sample(g11, 21)
```

[24]:
```
Fun{Float64}([5.573903692694606e-7, 2.2978660065877155e-5, 4.539992976248485e-5, 0.000853478601468211, 0.0016615572731739367, 0.01449263986023327, 0.027323722447292614, 0.11461012022097405, 0.2018965179946551, 0.4361082820151474  …  0.8351600230178204, 1.0000000000000009, 0.8351600230178194, 0.6703200460356388, 0.4361082820151472, 0.2018965179946551, 0.11461012022097372, 0.027323722447292528, 0.014492639860233216, 0.0016615572731739332])
```

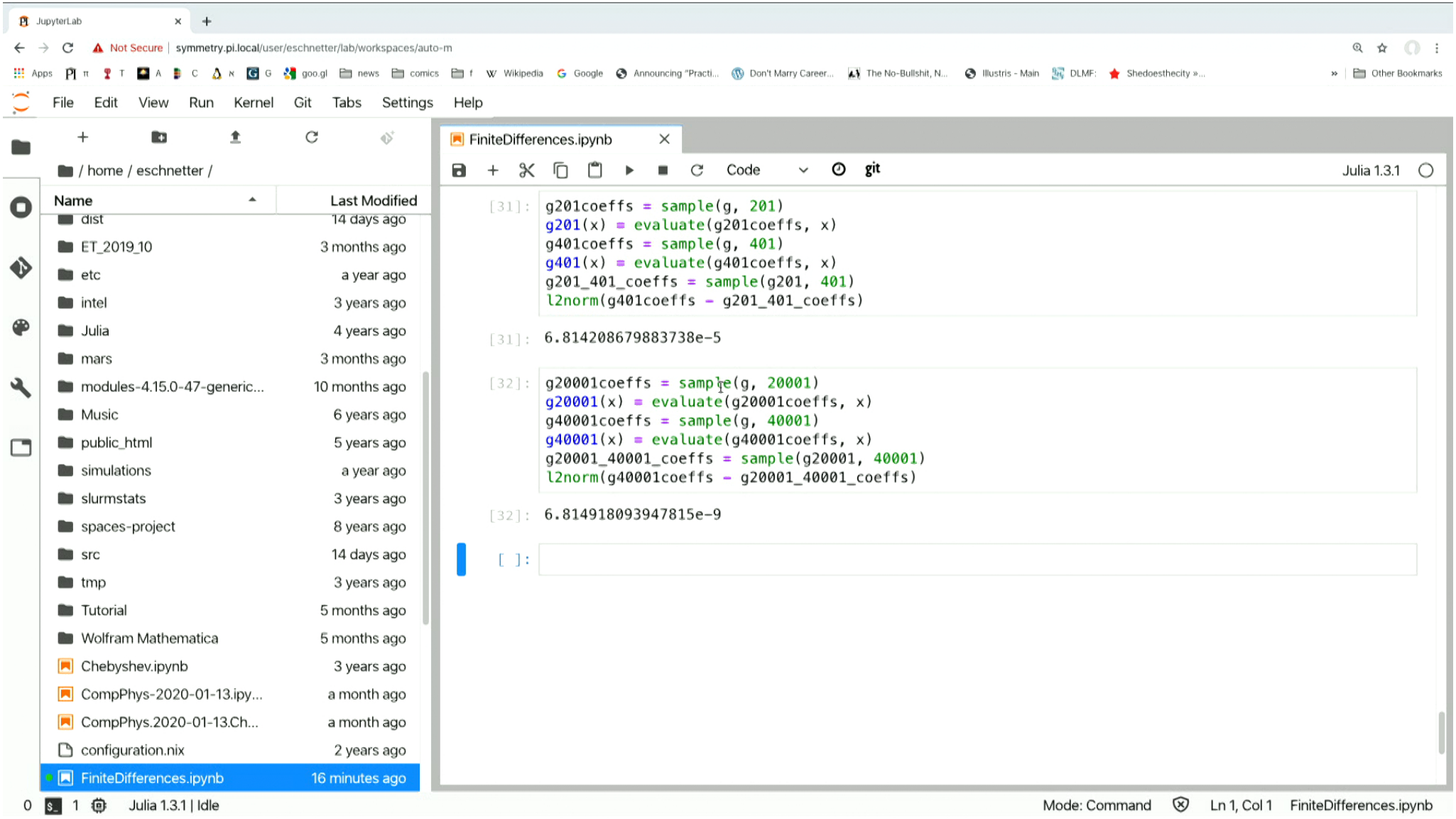
[25]:
```
plot(x=xs, y=[evaluate(g11_21_coeffs - g21coeffs, x) for x in xs], Geom.line)
```

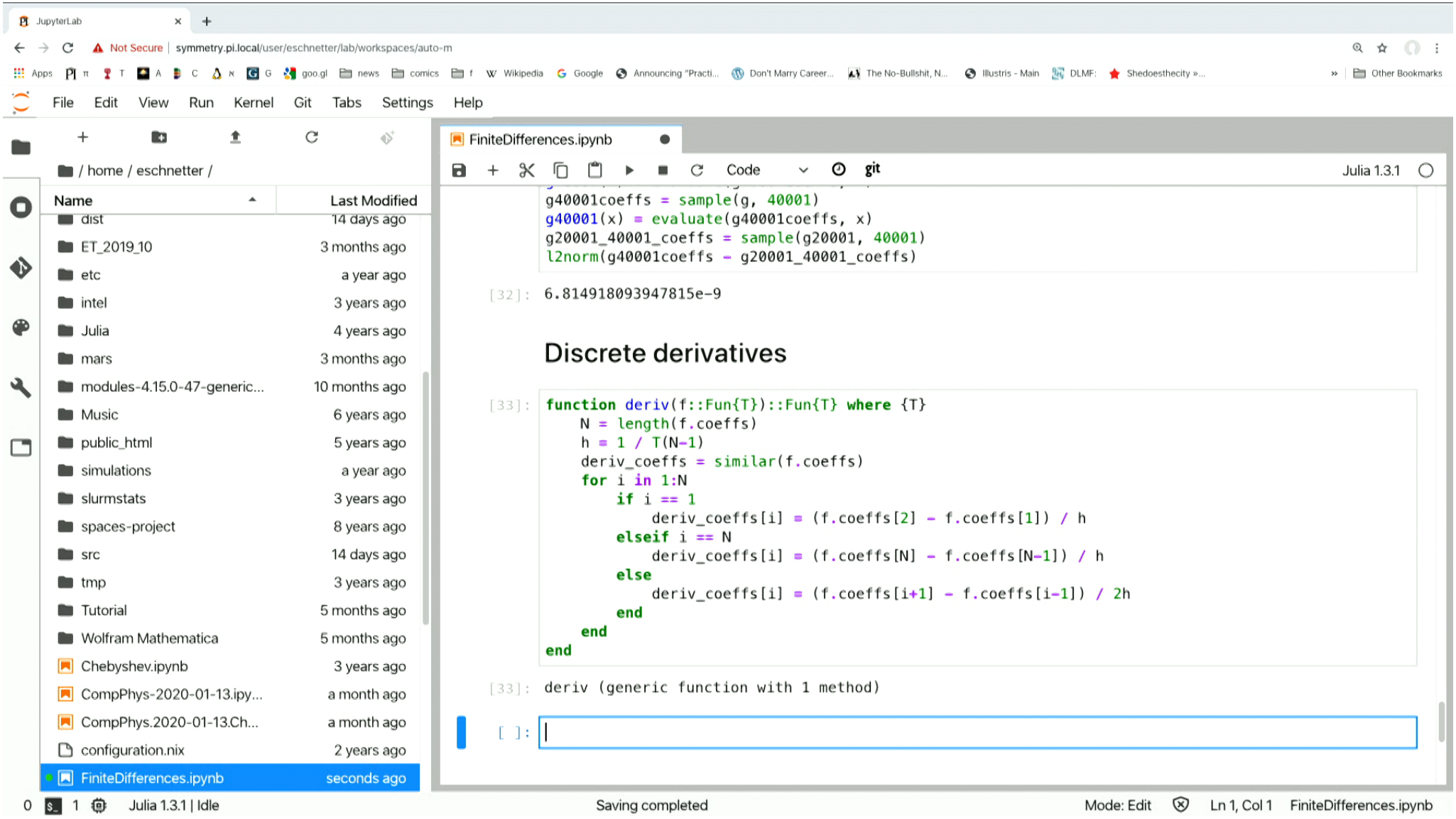
[25]:

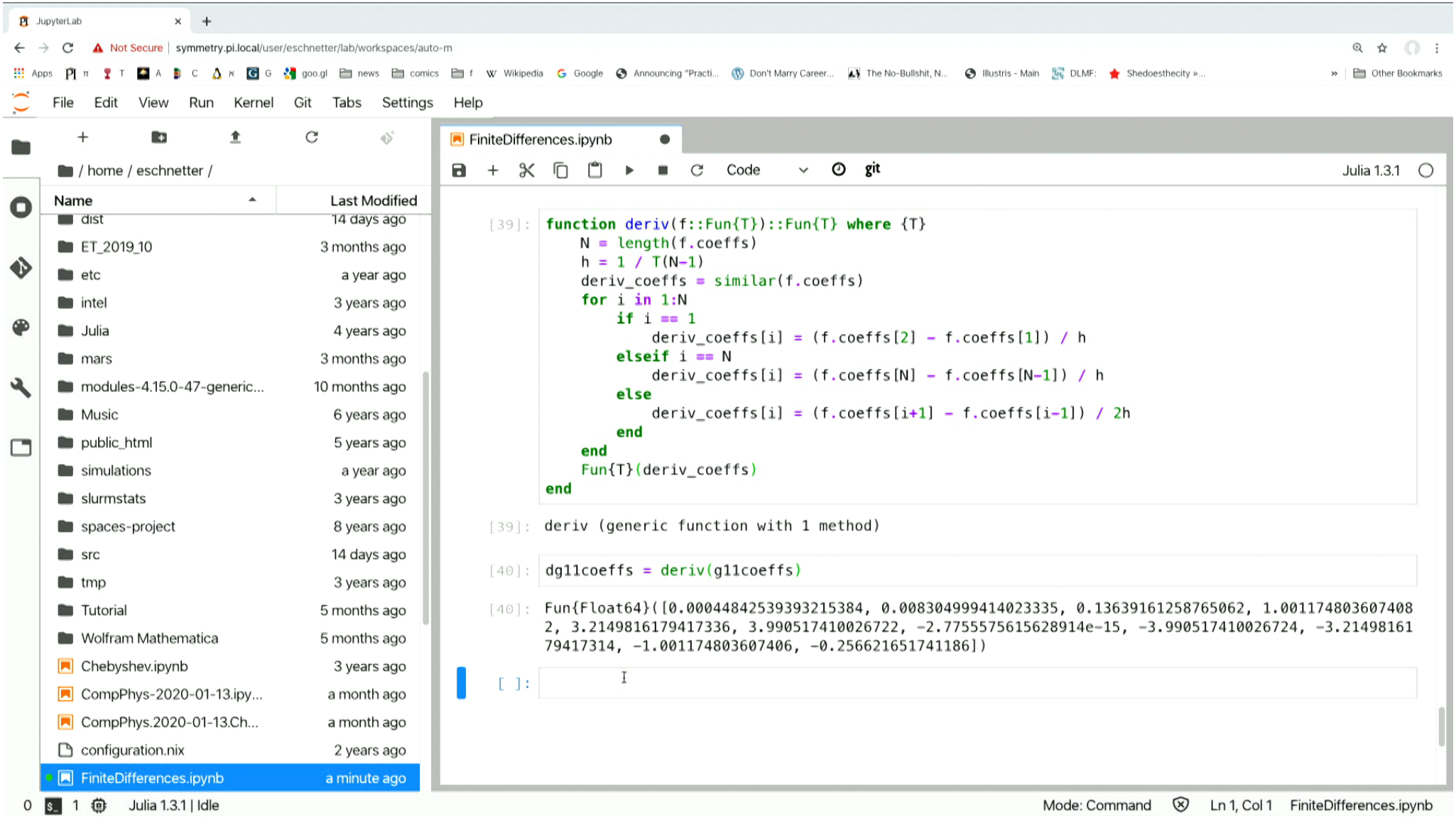


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CompPhys.2020-01-13.Ch... a month ago
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FiniteDifferences.ipynb 16 minutes ago
FiniteDifferences.ipynb
Code
Julia 1.3.1
[31]:
g201coeffs = sample(g, 201)
g201(x) = evaluate(g201coeffs, x)
g401coeffs = sample(g, 401)
g401(x) = evaluate(g401coeffs, x)
g201_401_coeffs = sample(g201, 401)
l2norm(g401coeffs - g201_401_coeffs)
[31]:
6.814208679883738e-5
[32]:
g20001coeffs = sample(g, 20001)
g20001(x) = evaluate(g20001coeffs, x)
g40001coeffs = sample(g, 40001)
g40001(x) = evaluate(g40001coeffs, x)
g20001_40001_coeffs = sample(g20001, 40001)
l2norm(g40001coeffs - g20001_40001_coeffs)
[32]:
6.814918093947815e-9
[ ]:
0 1 Julia 1.3.1 | Idle
Mode: Command
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FiniteDifferences.ipynb seconds ago
FiniteDifferences.ipynb
Code
Julia 1.3.1
g40001coeffs = sample(g, 40001)
g40001(x) = evaluate(g40001coeffs, x)
g20001_40001_coeffs = sample(g20001, 40001)
l2norm(g40001coeffs - g20001_40001_coeffs)
[32]: 6.814918093947815e-9
Discrete derivatives
[33]:
function deriv(f::Fun{T})::Fun{T} where {T}
N = length(f.coeffs)
h = 1 / T(N-1)
deriv_coeffs = similar(f.coeffs)
for i in 1:N
if i == 1
deriv_coeffs[i] = (f.coeffs[2] - f.coeffs[1]) / h
elseif i == N
deriv_coeffs[i] = (f.coeffs[N] - f.coeffs[N-1]) / h
else
deriv_coeffs[i] = (f.coeffs[i+1] - f.coeffs[i-1]) / 2h
end
end
end
[33]: deriv (generic function with 1 method)
[ ]:
0 1 Julia 1.3.1 | Idle
Saving completed
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CompPhys.2020-01-13.Ch... a month ago
configuration.nix 2 years ago
FiniteDifferences.ipynb a minute ago
FiniteDifferences.ipynb
Code
Julia 1.3.1
[39]:
function deriv(f::Fun{T})::Fun{T} where {T}
N = length(f.coeffs)
h = 1 / T(N-1)
deriv_coeffs = similar(f.coeffs)
for i in 1:N
if i == 1
deriv_coeffs[i] = (f.coeffs[2] - f.coeffs[1]) / h
elseif i == N
deriv_coeffs[i] = (f.coeffs[N] - f.coeffs[N-1]) / h
else
deriv_coeffs[i] = (f.coeffs[i+1] - f.coeffs[i-1]) / 2h
end
end
Fun{T}(deriv_coeffs)
end
[39]:
deriv (generic function with 1 method)
[40]:
dg11coeffs = deriv(g11coeffs)
[40]:
Fun{Float64}([0.00044842539393215384, 0.008304999414023335, 0.13639161258765062, 1.001174803607408
2, 3.2149816179417336, 3.990517410026722, -2.7755575615628914e-15, -3.990517410026724, -3.21498161
79417314, -1.001174803607406, -0.256621651741186])
[ ]:
0 1 Julia 1.3.1 | Idle
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FiniteDifferences.ipynb

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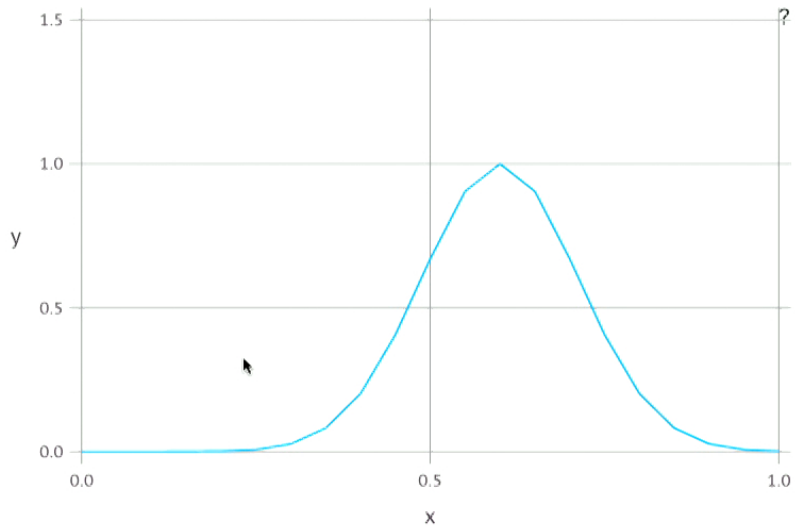
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Wolfram Mathematica	5 months ago
Chebyshev.ipynb	3 years ago
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CompPhys.2020-01-13.Ch...	a month ago
configuration.nix	2 years ago
FiniteDifferences.ipynb	2 minutes ago

FiniteDifferences.ipynb

Code | git | Julia 1.3.1

[17]:
```
g21coeffs = sample(g, 21)
g21(x) = evaluate(g21coeffs, x)
plot(x=xs, y=[g21(x) for x in xs], Geom.line)
```

[17]:



Quadrature

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CompPhys-2020-01-13.ipy...	a month ago
CompPhys.2020-01-13.Ch...	a month ago
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FiniteDifferences.ipynb

Code | git | Julia 1.3.1

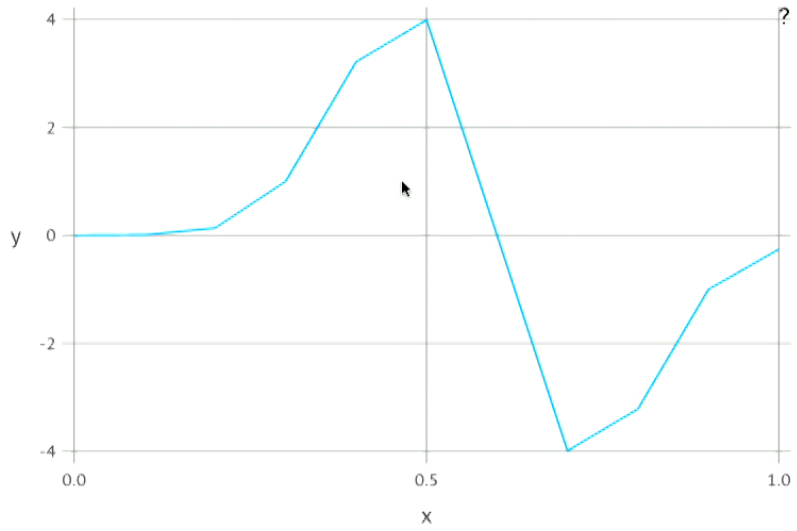
```
79417314, -1.001174803607406, -0.256621651741186])
```

[41]:
```
dg11(x) = evaluate(dg11coeffs, x)
```

[41]:
```
dg11 (generic function with 1 method)
```

[43]:
```
plot(x=xs, y=[dg11(x) for x in xs], Geom.line)
```

[43]:



0 | 1 | Julia 1.3.1 | Idle

Mode: Command | Ln 1, Col 1 | FiniteDifferences.ipynb

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Wolfram Mathematica	5 months ago
Chebyshev.ipynb	3 years ago
CompPhys-2020-01-13.ipy...	a month ago
CompPhys.2020-01-13.Ch...	a month ago
configuration.nix	2 years ago
FiniteDifferences.ipynb	2 minutes ago

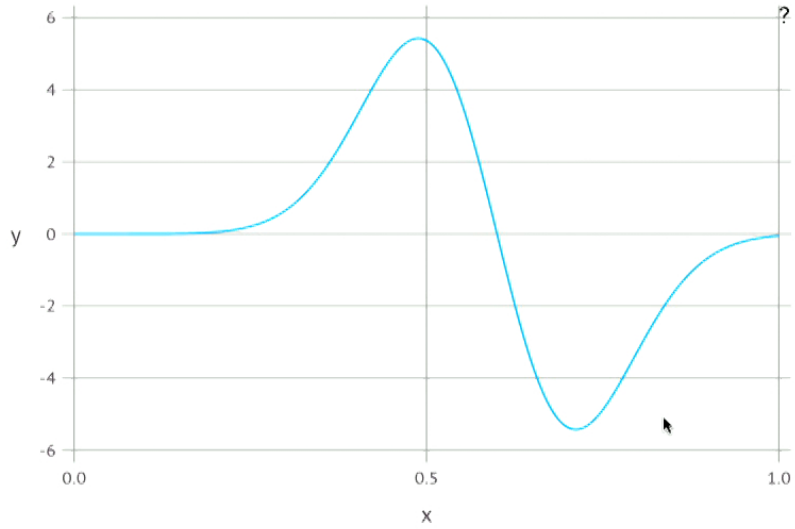
FiniteDifferences.ipynb

Code | git | Julia 1.3.1

```
[47]: dg (generic function with 1 method)

[48]: plot(x=xs, y=[dg(x) for x in xs], Geom.line)
```

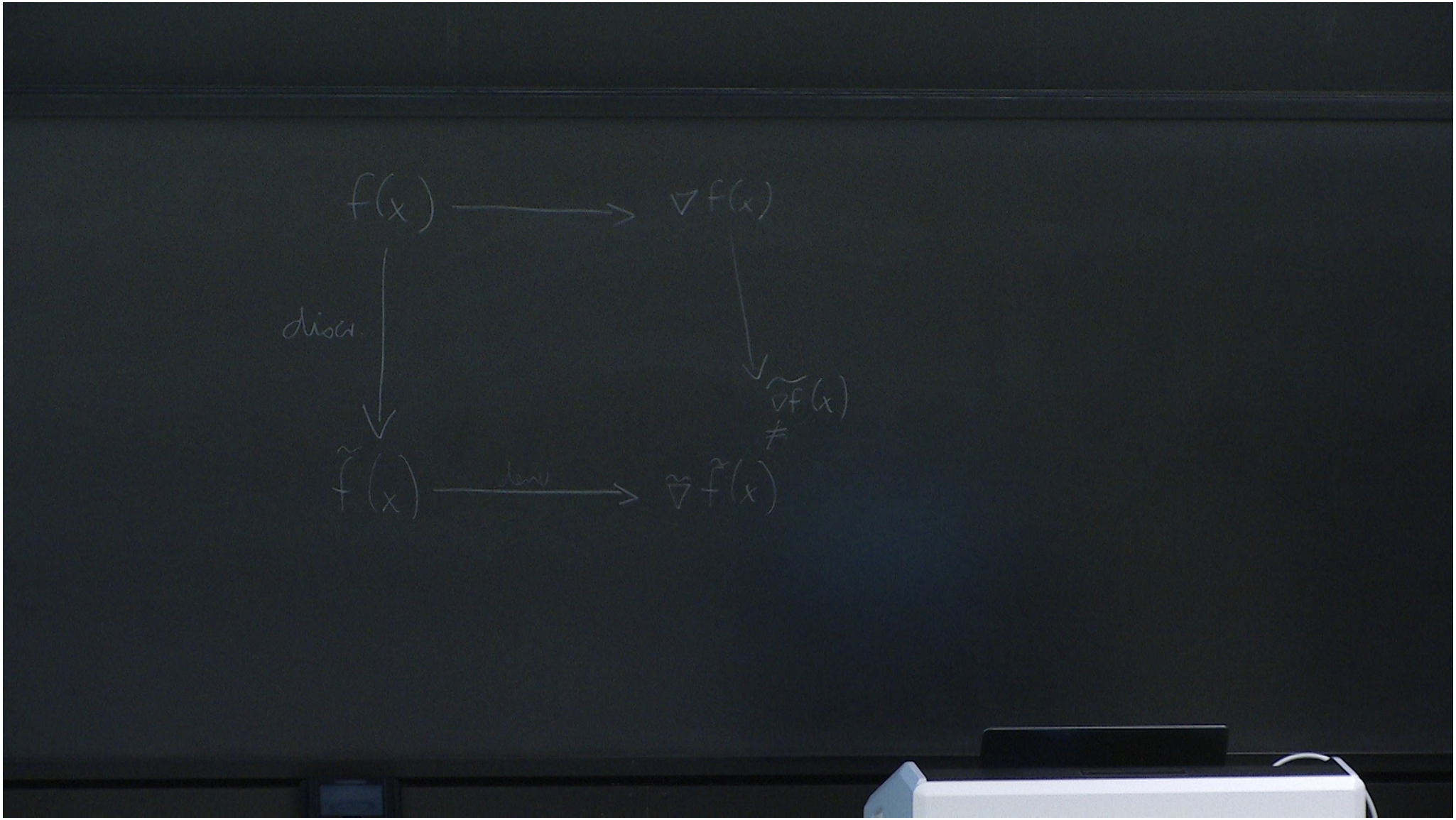
[48]:

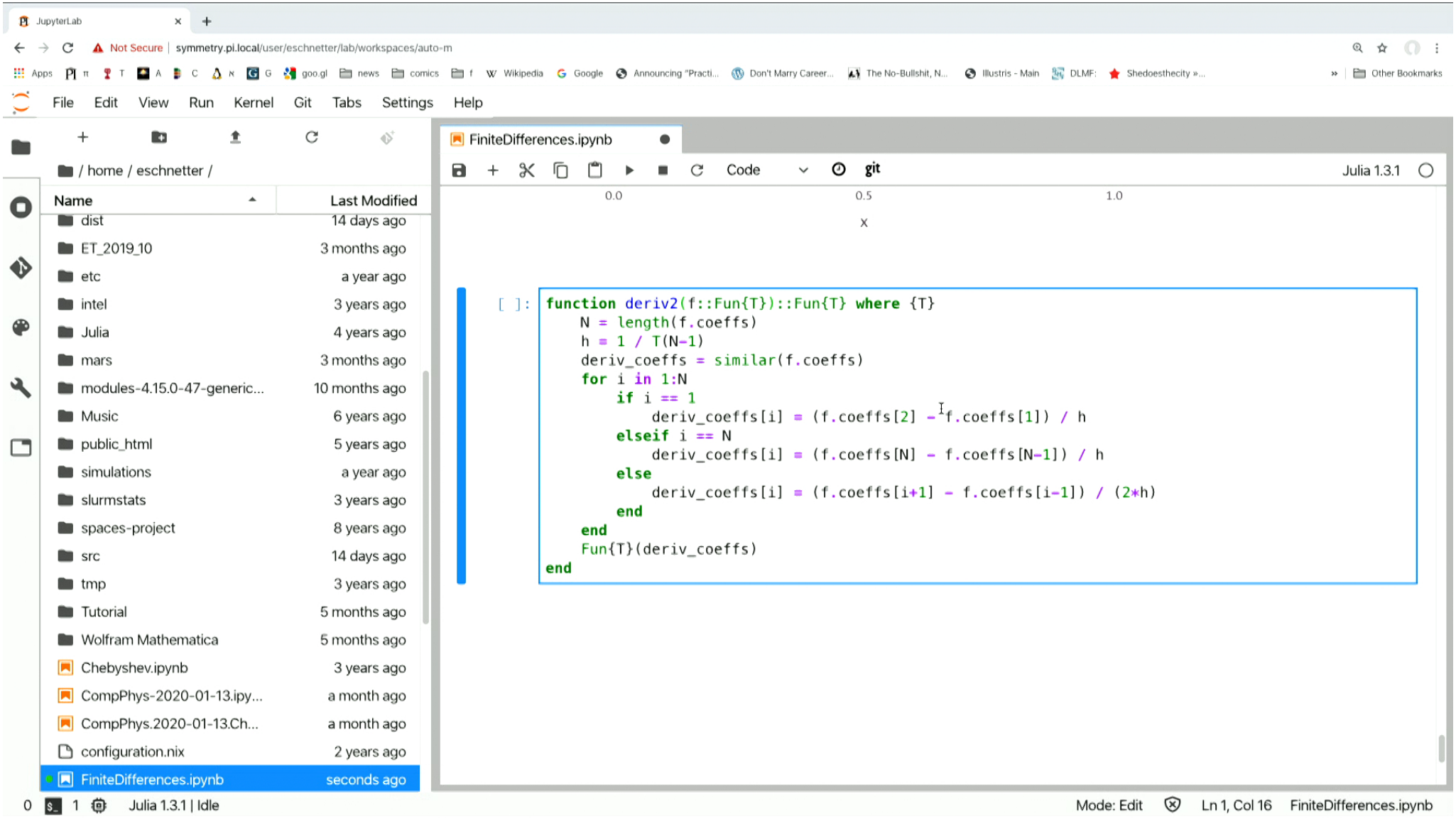


[ ]:

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f(x)
∇f(x)
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$\widetilde{\nabla f}(x)$
≠
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Not Secure
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configuration.nix 2 years ago
FiniteDifferences.ipynb seconds ago
FiniteDifferences.ipynb
Code
Julia 1.3.1
0.0
0.5
1.0
x
[ ]:
function deriv2(f::Fun{T})::Fun{T} where {T}
N = length(f.coeffs)
h = 1 / T(N-1)
deriv_coeffs = similar(f.coeffs)
for i in 1:N
if i == 1
deriv_coeffs[i] = (f.coeffs[2] - f.coeffs[1]) / h
elseif i == N
deriv_coeffs[i] = (f.coeffs[N] - f.coeffs[N-1]) / h
else
deriv_coeffs[i] = (f.coeffs[i+1] - f.coeffs[i-1]) / (2*h)
end
end
Fun{T}(deriv_coeffs)
end
0 1 Julia 1.3.1 | Idle
Mode: Edit
Ln 1, Col 16
FiniteDifferences.ipynb

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FiniteDifferences.ipynb

Code | git | Julia 1.3.1

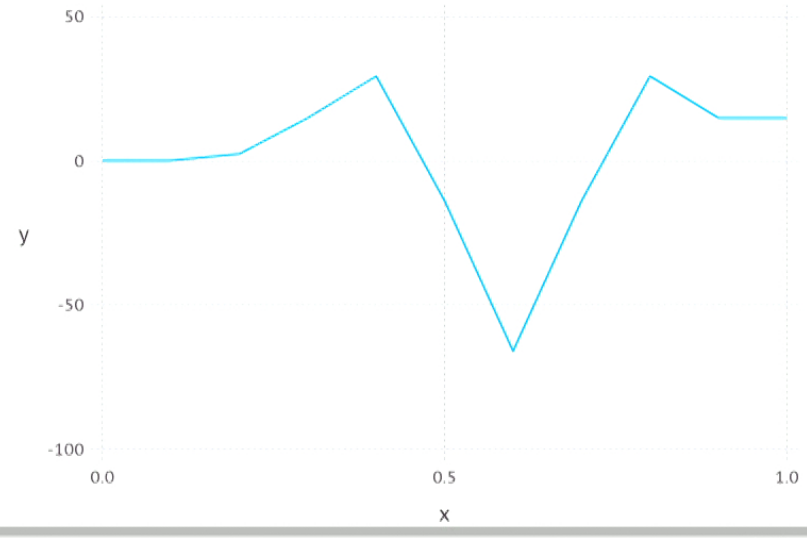
[47]:
```
Fun{Float64}([0.15713148040182362, 0.15713148040182362, 2.4046007830707214, 14.891063037324425, 29.38507324936208, -13.874357407662327, -65.93599079287216, -13.874357407662249, 29.385073249362105, 14.8910630373244, 14.8910630373244])
```

[48]:
```
ddg11(x) = evaluate(ddg11coeffs, x)
```

[48]:
```
ddg11 (generic function with 1 method)
```

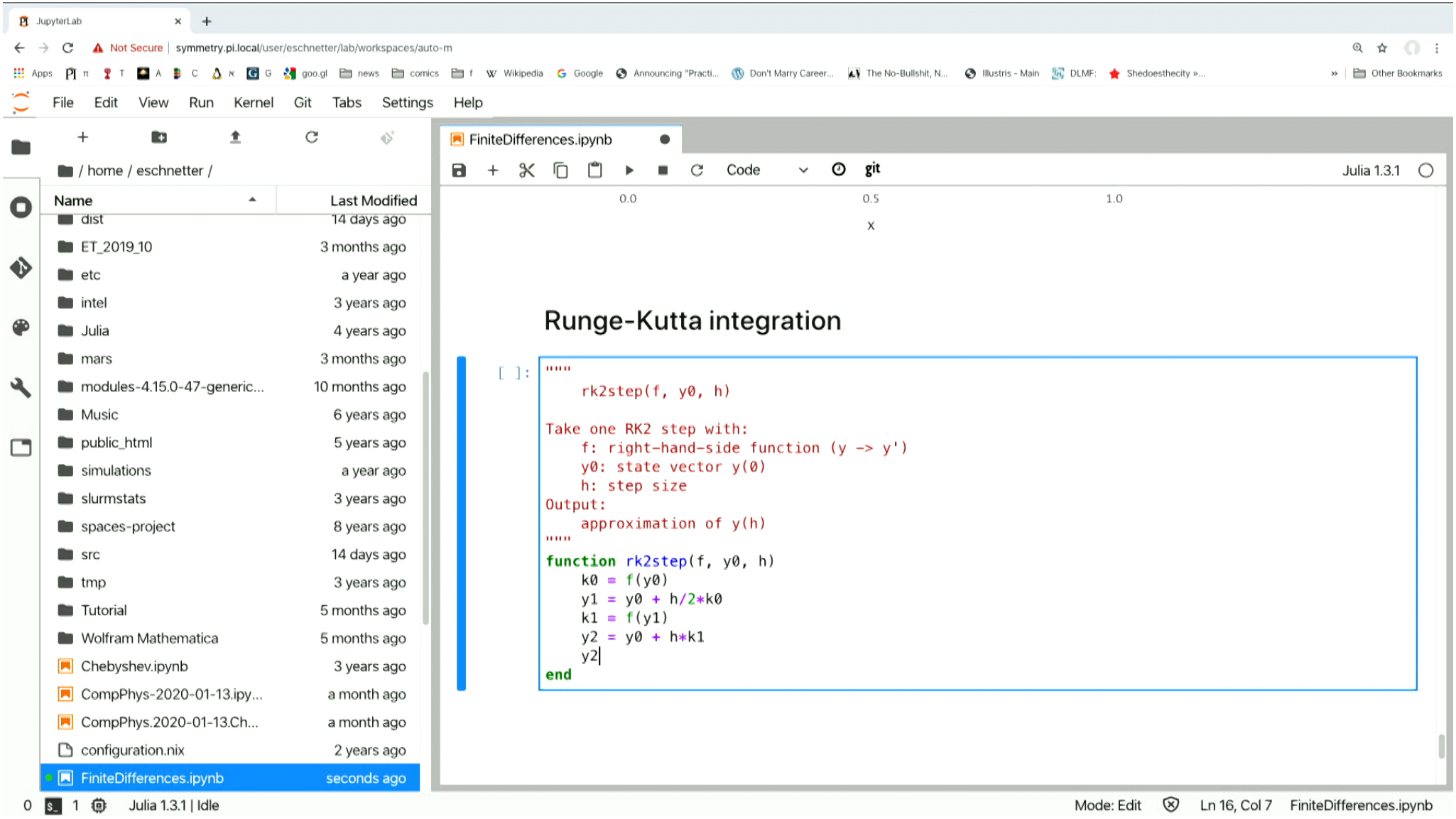
[49]:
```
plot(x=xs, y=[ddg11(x) for x in xs], Geom.line)
```

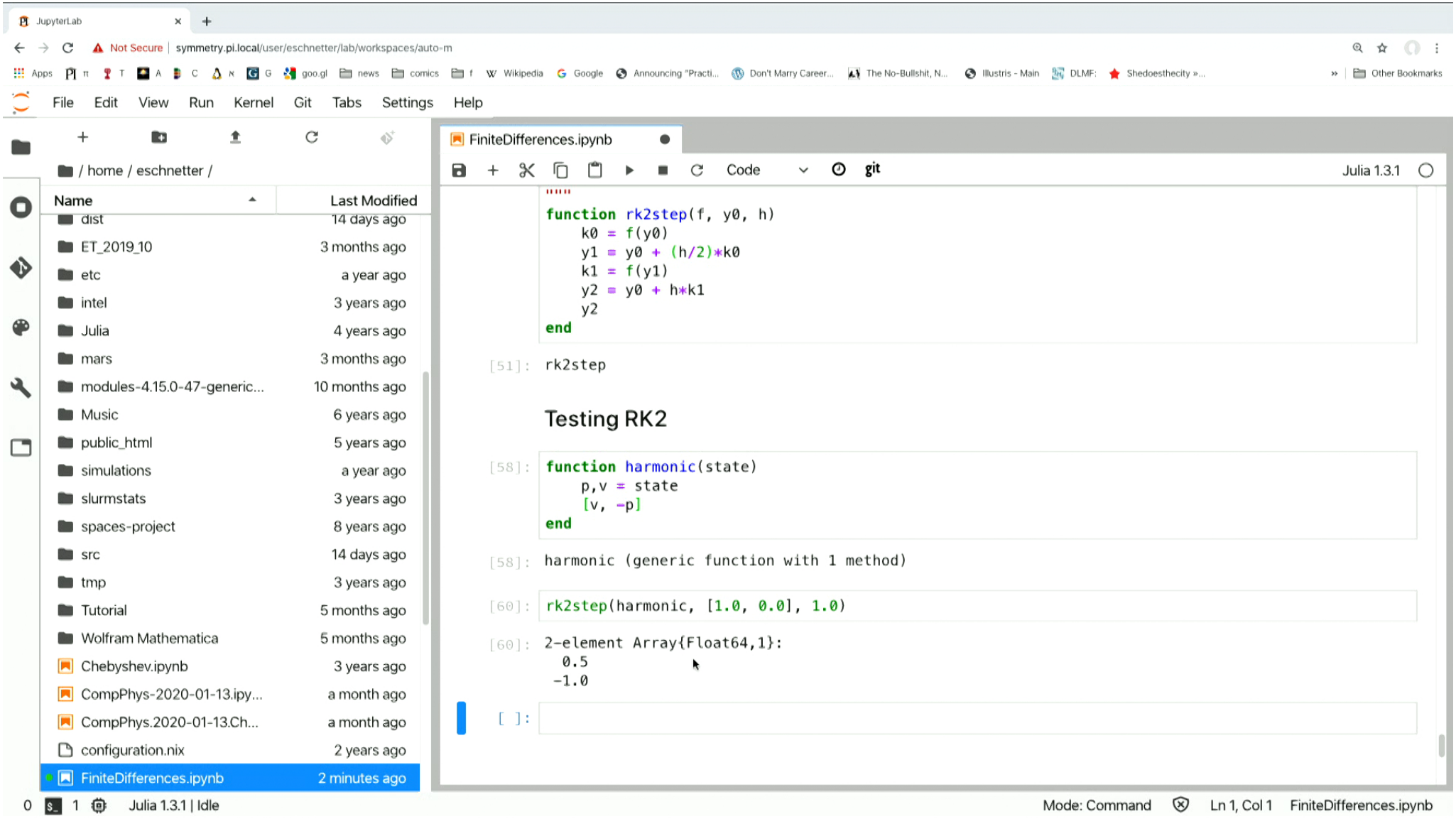
[49]:

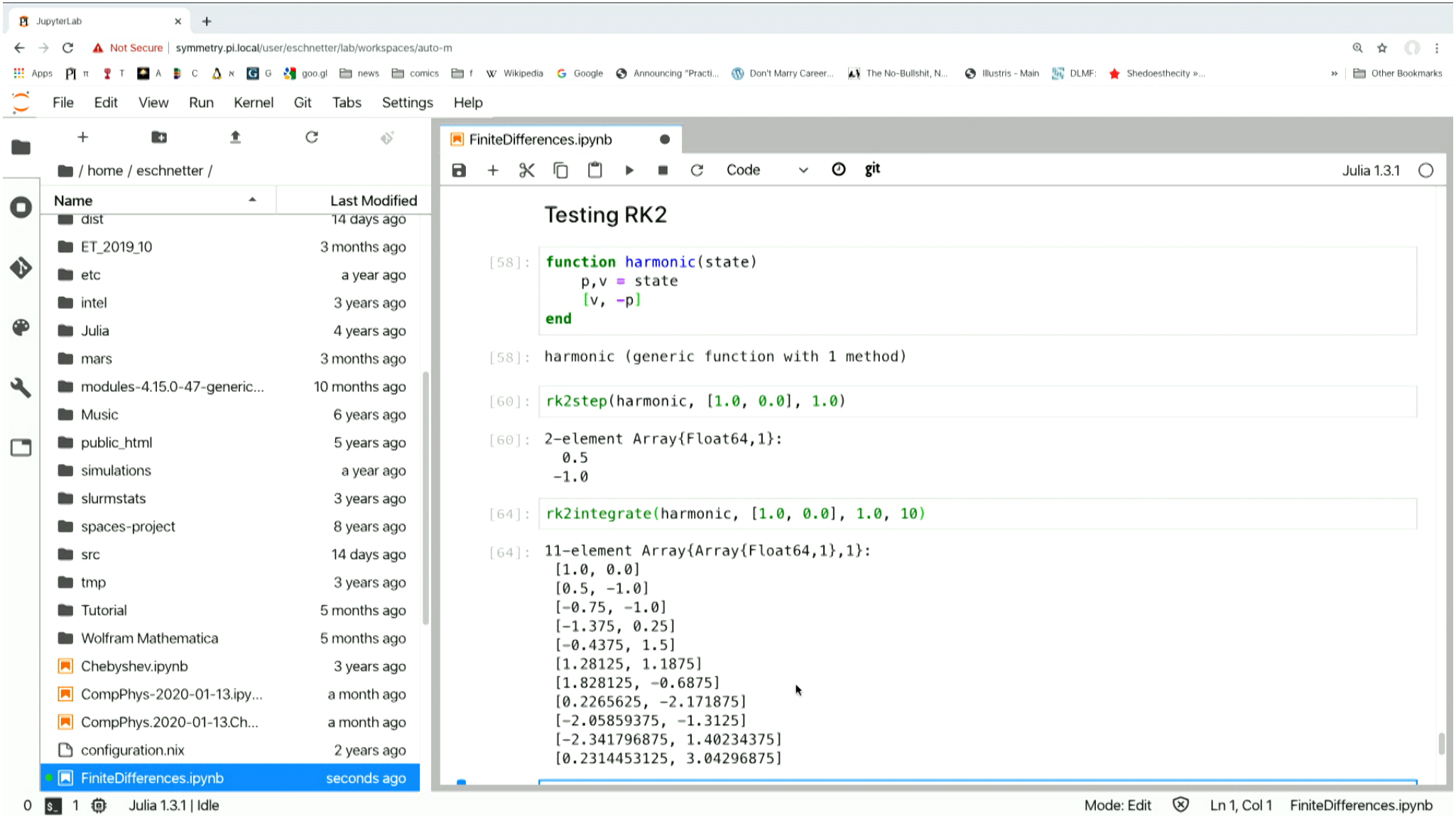


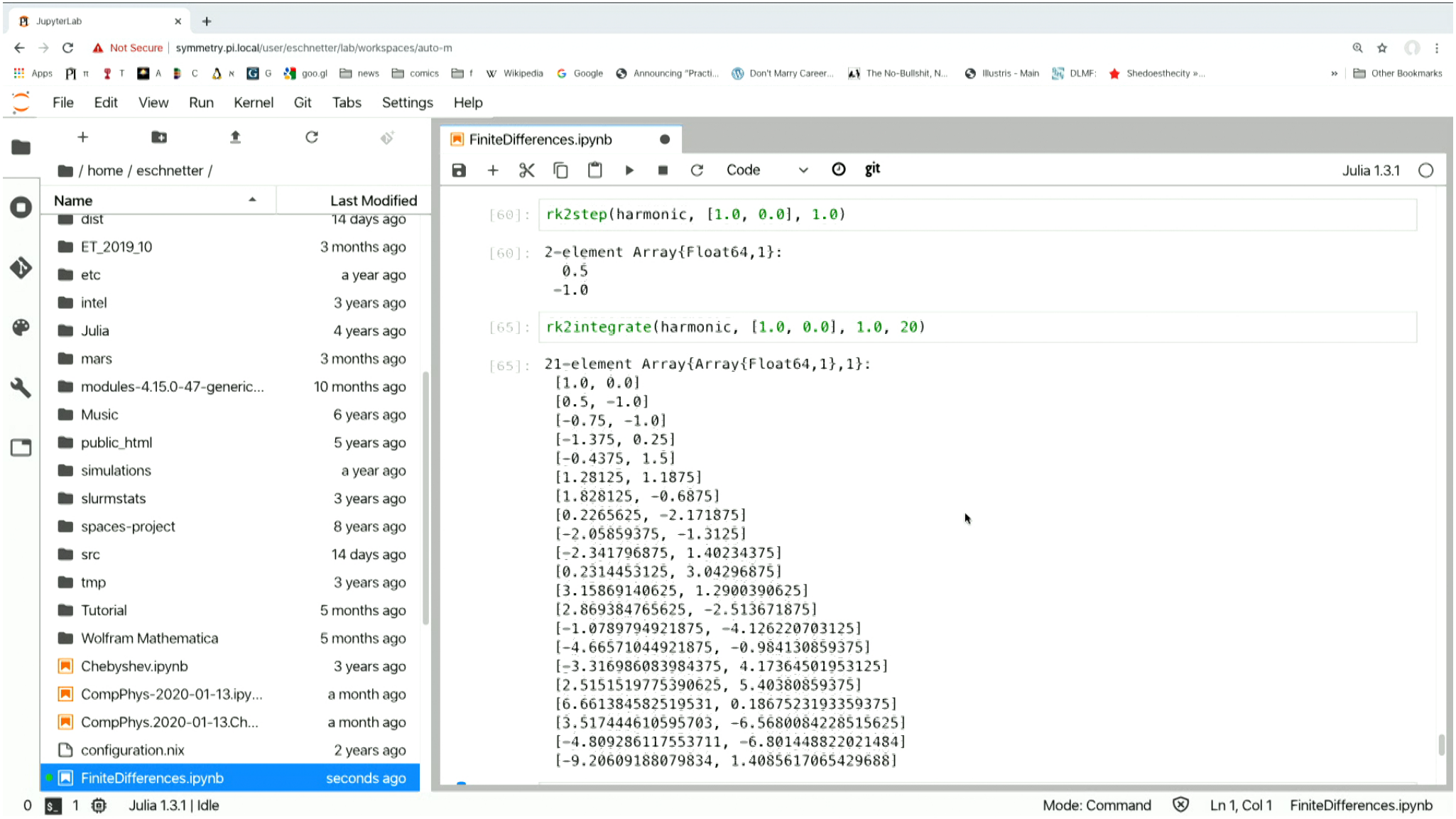
0 | 1 | Julia 1.3.1 | Idle

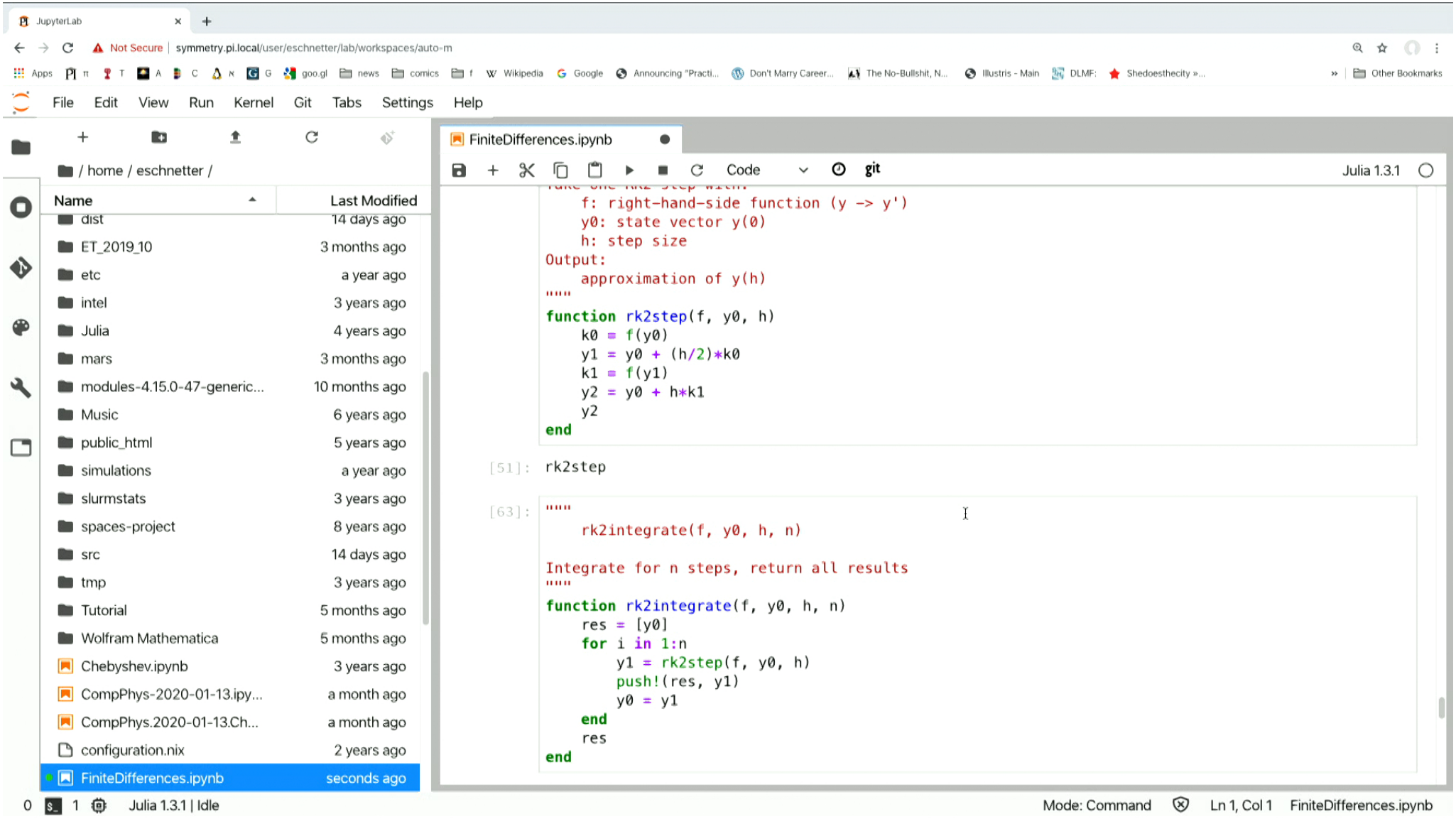
Mode: Edit | Ln 1, Col 1 | FiniteDifferences.ipynb

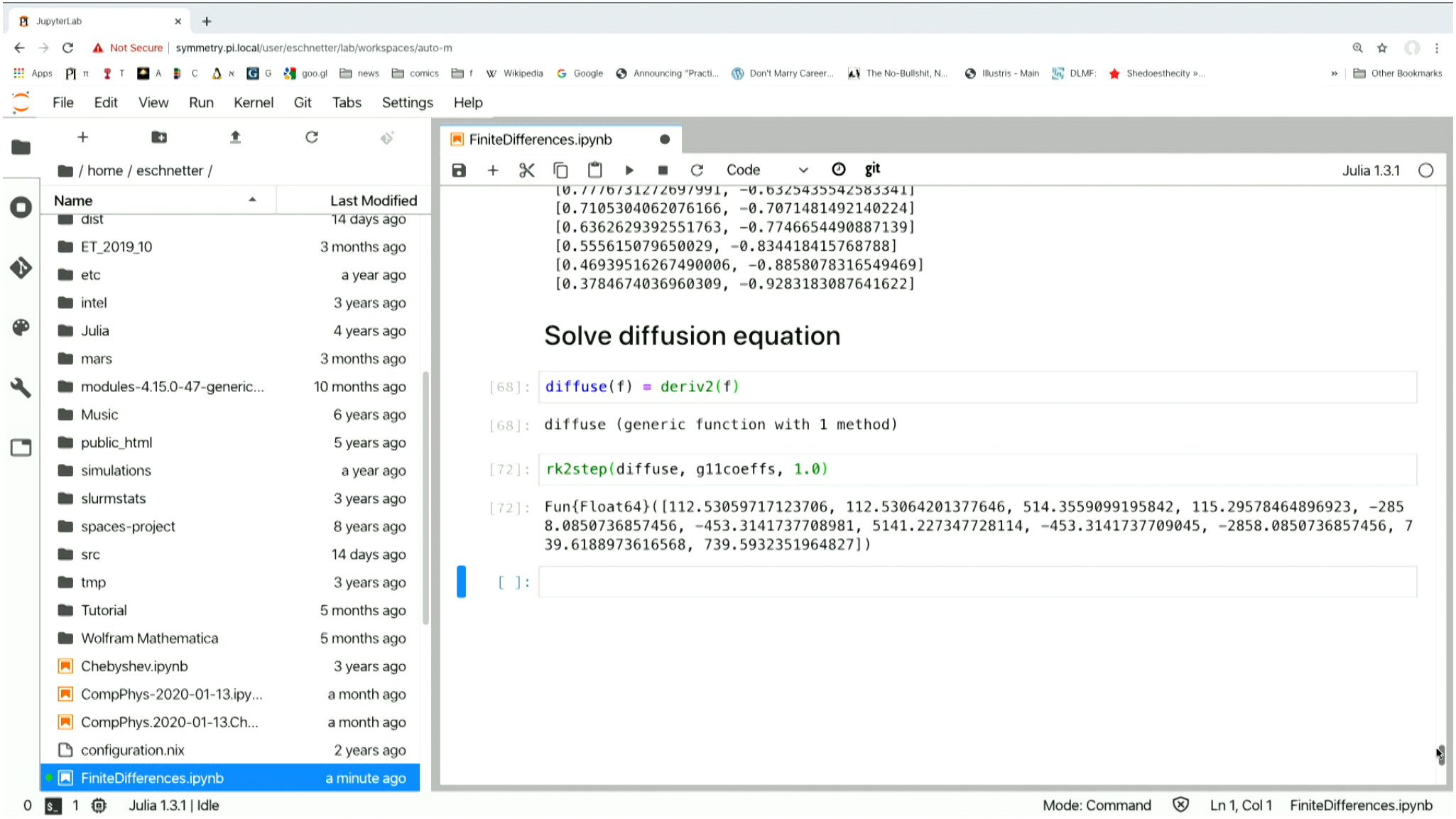

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configuration.nix 2 years ago
FiniteDifferences.ipynb seconds ago
FiniteDifferences.ipynb
Code
git
Julia 1.3.1
0.0
0.5
1.0
x
Runge-Kutta integration
[ ]:
"""
rk2step(f, y0, h)
Take one RK2 step with:
f: right-hand-side function (y -> y')
y0: state vector y(0)
h: step size
Output:
approximation of y(h)
"""
function rk2step(f, y0, h)
k0 = f(y0)
y1 = y0 + h/2*k0
k1 = f(y1)
y2 = y0 + h*k1
y2
end
0 1 Julia 1.3.1 | Idle
Mode: Edit
Ln 16, Col 7
FiniteDifferences.ipynb

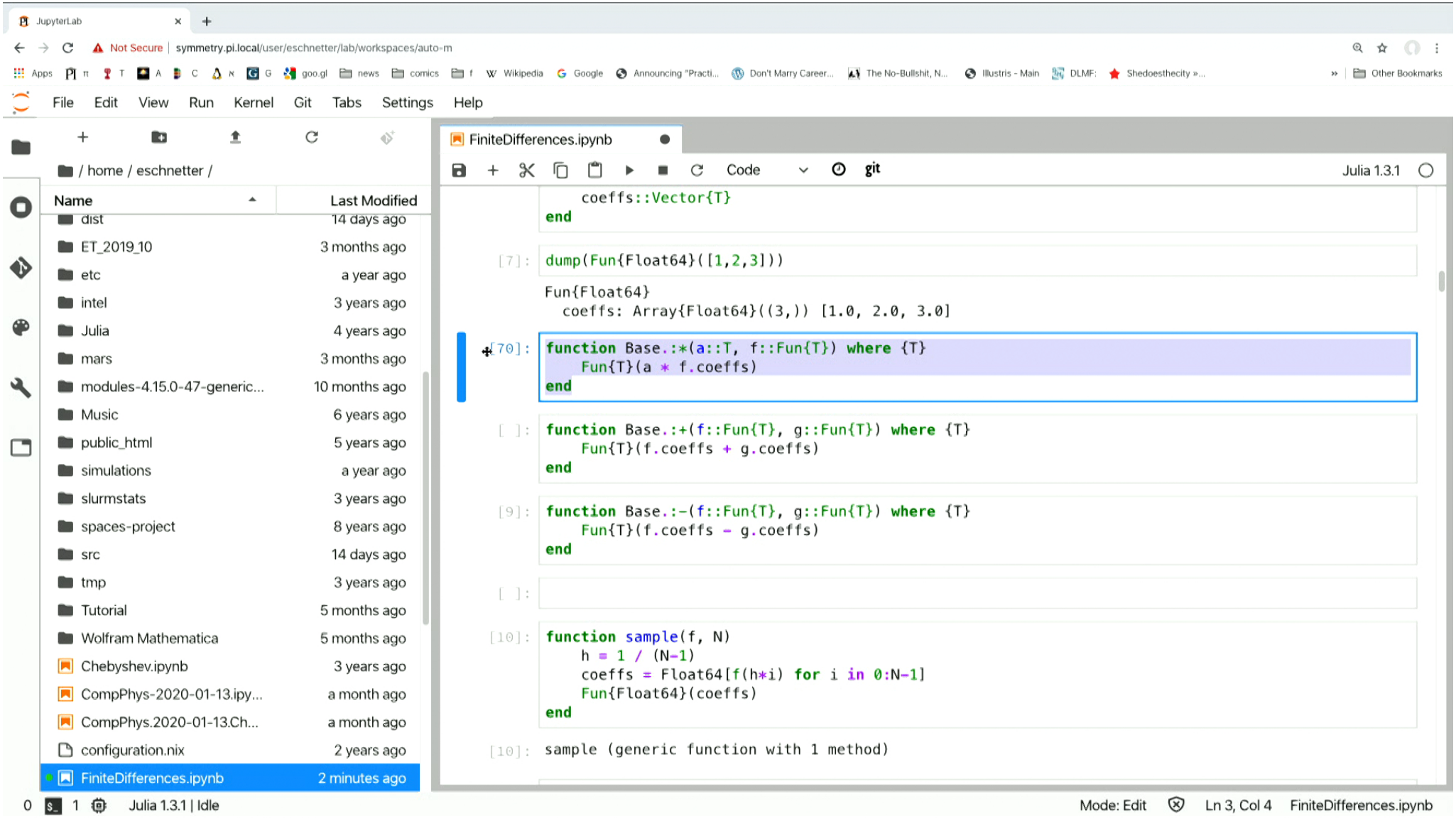

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Code
git
Julia 1.3.1
"""
function rk2step(f, y0, h)
k0 = f(y0)
y1 = y0 + (h/2)*k0
k1 = f(y1)
y2 = y0 + h*k1
y2
end
[51]: rk2step
Testing RK2
[58]: function harmonic(state)
p,v = state
[v, -p]
end
[58]: harmonic (generic function with 1 method)
[60]: rk2step(harmonic, [1.0, 0.0], 1.0)
[60]: 2-element Array{Float64,1}:
0.5
-1.0
[ ]:
0 1 Julia 1.3.1 | Idle
Mode: Command
Ln 1, Col 1
FiniteDifferences.ipynb

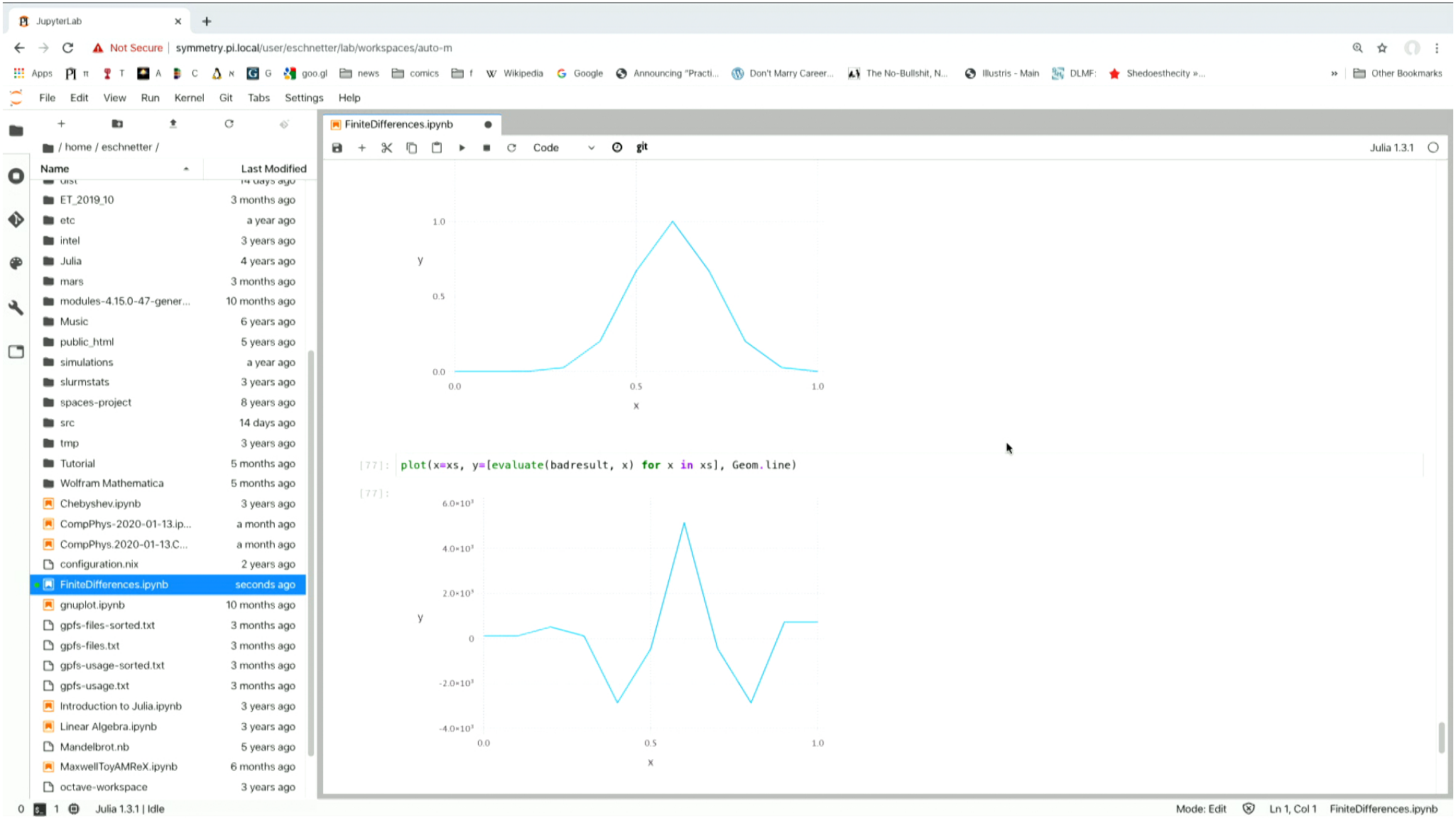

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configuration.nix 2 years ago
FiniteDifferences.ipynb seconds ago
FiniteDifferences.ipynb
Code
Julia 1.3.1
Testing RK2
[58]:
function harmonic(state)
p,v = state
[v, -p]
end
[58]: harmonic (generic function with 1 method)
[60]: rk2step(harmonic, [1.0, 0.0], 1.0)
[60]: 2-element Array{Float64,1}:
0.5
-1.0
[64]: rk2integrate(harmonic, [1.0, 0.0], 1.0, 10)
[64]: 11-element Array{Array{Float64,1},1}:
[1.0, 0.0]
[0.5, -1.0]
[-0.75, -1.0]
[-1.375, 0.25]
[-0.4375, 1.5]
[1.28125, 1.1875]
[1.828125, -0.6875]
[0.2265625, -2.171875]
[-2.05859375, -1.3125]
[-2.341796875, 1.40234375]
[0.2314453125, 3.04296875]
0 1 Julia 1.3.1 | Idle
Mode: Edit
Ln 1, Col 1
FiniteDifferences.ipynb

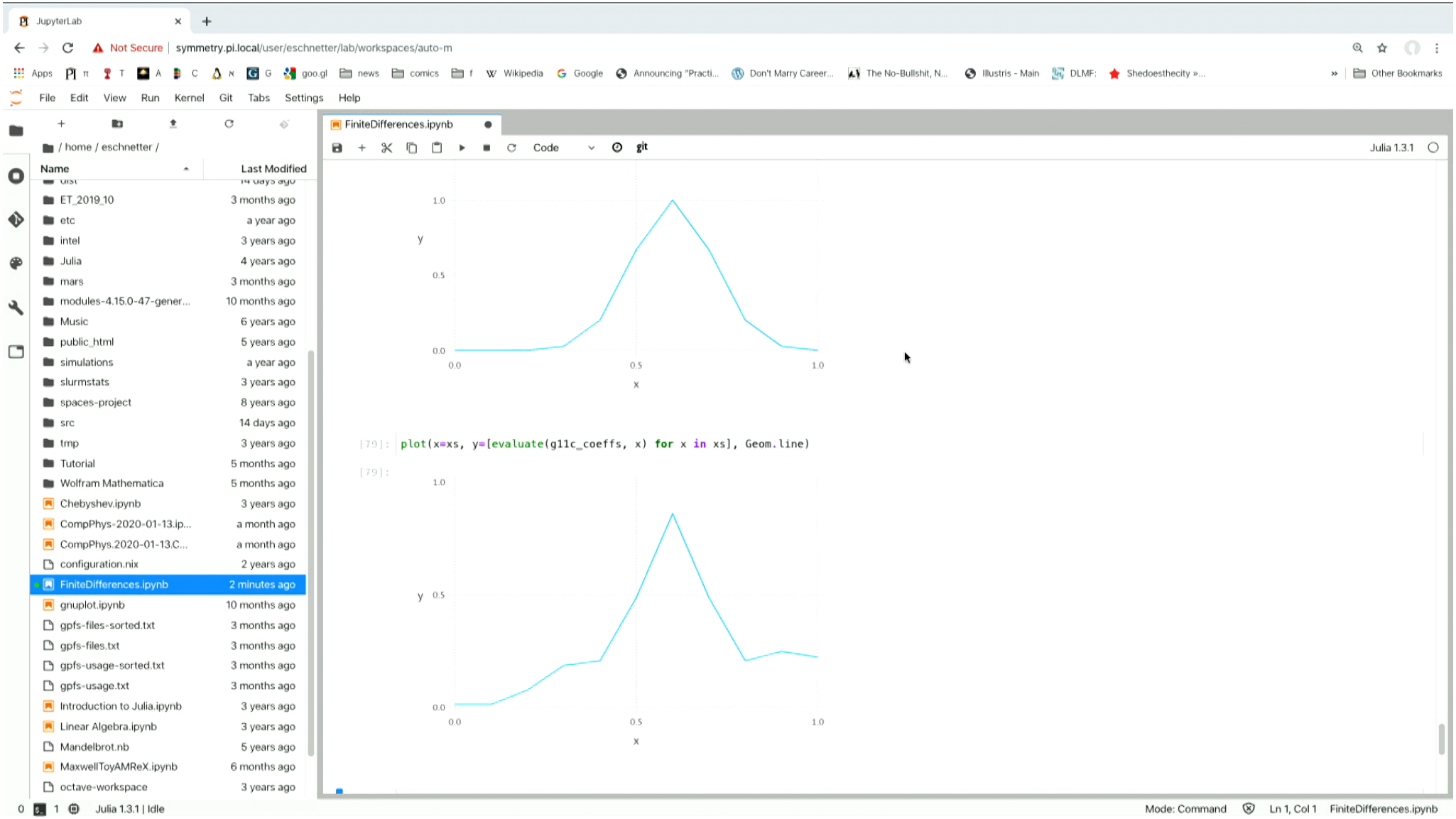

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FiniteDifferences.ipynb
Code
git
Julia 1.3.1
[60]: rk2step(harmonic, [1.0, 0.0], 1.0)
[60]: 2-element Array{Float64,1}:
0.5
-1.0
[65]: rk2integrate(harmonic, [1.0, 0.0], 1.0, 20)
[65]: 21-element Array{Array{Float64,1},1}:
[1.0, 0.0]
[0.5, -1.0]
[-0.75, -1.0]
[-1.375, 0.25]
[-0.4375, 1.5]
[1.28125, 1.1875]
[1.828125, -0.6875]
[0.2265625, -2.171875]
[-2.05859375, -1.3125]
[-2.341796875, 1.40234375]
[0.2314453125, 3.04296875]
[3.15869140625, 1.2900390625]
[2.869384765625, -2.513671875]
[-1.0789794921875, -4.126220703125]
[-4.66571044921875, -0.984130859375]
[-3.316986083984375, 4.173645019531 25]
[2.5151519775390625, 5.40380859375]
[6.661384582519531, 0.1867523193359375]
[3.517444610595703, -6.568008422851 5625]
[-4.809286117553711, -6.801448822021484]
[-9.20609188079834, 1.4085617065429688]
0 1 Julia 1.3.1 | Idle
Mode: Command
Ln 1, Col 1
FiniteDifferences.ipynb

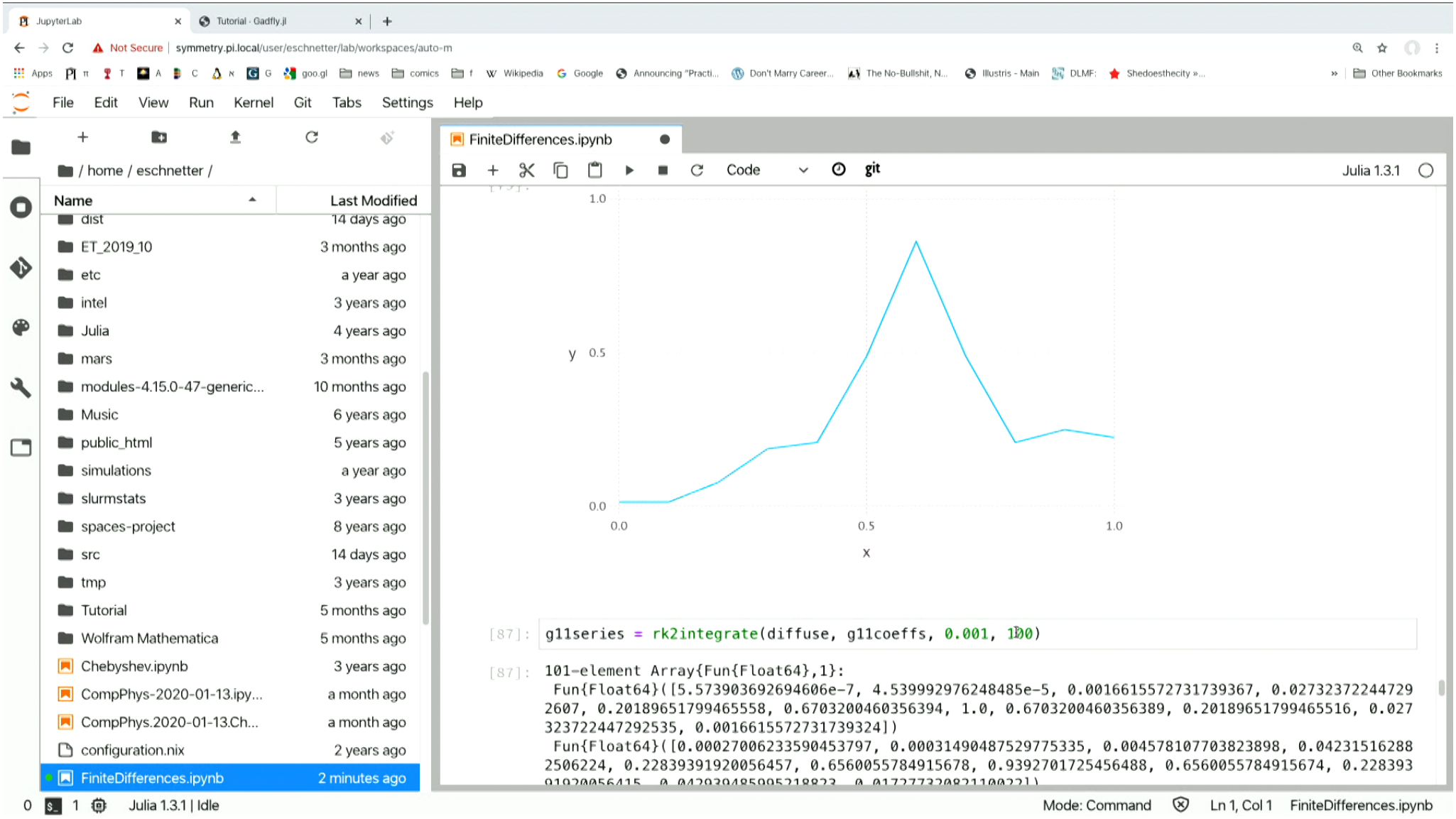

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FiniteDifferences.ipynb
Code
Julia 1.3.1
f: right-hand-side function (y -> y')
y0: state vector y(0)
h: step size
Output:
approximation of y(h)
"""
function rk2step(f, y0, h)
k0 = f(y0)
y1 = y0 + (h/2)*k0
k1 = f(y1)
y2 = y0 + h*k1
y2
end
[51]: rk2step
[63]: """
rk2integrate(f, y0, h, n)
Integrate for n steps, return all results
"""
function rk2integrate(f, y0, h, n)
res = [y0]
for i in 1:n
y1 = rk2step(f, y0, h)
push!(res, y1)
y0 = y1
end
res
end
0 1 Julia 1.3.1 | Idle
Mode: Command
Ln 1, Col 1
FiniteDifferences.ipynb


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CompPhys.2020-01-13.Ch... a month ago
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FiniteDifferences.ipynb
Code
Julia 1.3.1
[0.7776731272697991, -0.6325435542583341]
[0.7105304062076166, -0.7071481492140224]
[0.6362629392551763, -0.7746654490887139]
[0.555615079650029, -0.834418415768788]
[0.46939516267490006, -0.8858078316549469]
[0.3784674036960309, -0.9283183087641622]
Solve diffusion equation
[68]: diffuse(f) = deriv2(f)
[68]: diffuse (generic function with 1 method)
[72]: rk2step(diffuse, g11coeffs, 1.0)
[72]: Fun{Float64}([112.53059717123706, 112.53064201377646, 514.3559099195842, 115.29578464896923, -2858.0850736857456, -453.3141737708981, 5141.227347728114, -453.3141737709045, -2858.0850736857456, 739.6188973616568, 739.5932351964827])
[ ]:
0 1 Julia 1.3.1 | Idle
Mode: Command
Ln 1, Col 1
FiniteDifferences.ipynb


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CompPhys.2020-01-13.Ch... a month ago
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FiniteDifferences.ipynb
Code
Julia 1.3.1
coeffs::Vector{T}
end
[7]: dump(Fun{Float64}([1,2,3]))
Fun{Float64}
coeffs: Array{Float64}((3,)) [1.0, 2.0, 3.0]
[70]: function Base.:*(a::T, f::Fun{T}) where {T}
Fun{T}(a * f.coeffs)
end
[ ]: function Base.:+(f::Fun{T}, g::Fun{T}) where {T}
Fun{T}(f.coeffs + g.coeffs)
end
[9]: function Base.:-(f::Fun{T}, g::Fun{T}) where {T}
Fun{T}(f.coeffs - g.coeffs)
end
[ ]:
[10]: function sample(f, N)
h = 1 / (N-1)
coeffs = Float64[f(h*i) for i in 0:N-1]
Fun{Float64}(coeffs)
end
[10]: sample (generic function with 1 method)
0 1 Julia 1.3.1 | Idle
Mode: Edit
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gpfs-files.txt 3 months ago
gpfs-usage-sorted.txt 3 months ago
gpfs-usage.txt 3 months ago
Introduction to Julia.ipynb 3 years ago
Linear Algebra.ipynb 3 years ago
Mandelbrot.nb 5 years ago
MaxwellToyAMReX.ipynb 6 months ago
octave-workspace 3 years ago
FiniteDifferences.ipynb
Code
Julia 1.3.1
y
x
[77]: plot(x=xs, y=[evaluate(badresult, x) for x in xs], Geom.line)
[77]:
Julia 1.3.1 | Idle
Mode: Edit
Ln 1, Col 1
FiniteDifferences.ipynb


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Linear Algebra.ipynb 3 years ago
Mandelbrot.nb 5 years ago
MaxwellToyAMReX.ipynb 6 months ago
octave-workspace 3 years ago
FiniteDifferences.ipynb
Code
Julia 1.3.1
y
x
[79]: plot(x=xs, y=[evaluate(g11c_coeffs, x) for x in xs], Geom.line)
[79]:
Julia 1.3.1 | Idle
Mode: Command
Ln 1, Col 1
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FiniteDifferences.ipynb
Code
Julia 1.3.1
1.0
y 0.5
0.0
0.0
0.5
1.0
x
[87]: g11series = rk2integrate(diffuse, g11coeffs, 0.001, 100)
[87]: 101-element Array{Fun{Float64},1}:
Fun{Float64}([5.573903692694606e-7, 4.539992976248485e-5, 0.0016615572731739367, 0.02732372244729
2607, 0.20189651799465558, 0.6703200460356394, 1.0, 0.6703200460356389, 0.20189651799465516, 0.027
323722447292535, 0.0016615572731739324])
Fun{Float64}([0.00027006233590453797, 0.00031490487529775335, 0.004578107703823898, 0.04231516288
2506224, 0.22839391920056457, 0.6560055784915678, 0.9392701725456488, 0.6560055784915674, 0.228393
Julia 1.3.1 | Idle
Mode: Command
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CompPhys-2020-01-13.ipy...	a month ago
CompPhys.2020-01-13.Ch...	a month ago
configuration.nix	2 years ago
FiniteDifferences.ipynb	a minute ago

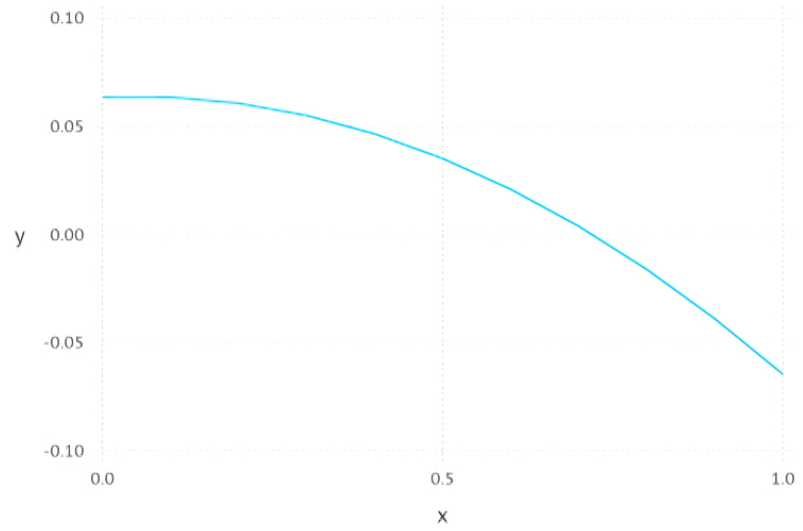
FiniteDifferences.ipynb

Code | git | Julia 1.3.1

```
8, 0.04675194987417582, 0.035371942809998, 0.02113560155542994 5, 0.004042867352028385, -0.01590631
1471514514, -0.038711973267048824, -0.06437413844116771])
 Fun{Float64}([0.06342405269915523, 0.06346889523854847, 0.0606575707473932, 0.054990059063745475,
0.04646632229554545, 0.03508630939095898, 0.020849962295982273, 0.003757222956611539 7, -0.01619195
9678987372, -0.038997623502874314, -0.06465978867699321])
```

[91]:
```
plot(x=xs, y=[evaluate(g11series[1001], x) for x in xs], Geom.line)
```

[91]:



0 | 1 | Julia 1.3.1 | Idle

Mode: Command | Ln 1, Col 1 | FiniteDifferences.ipynb