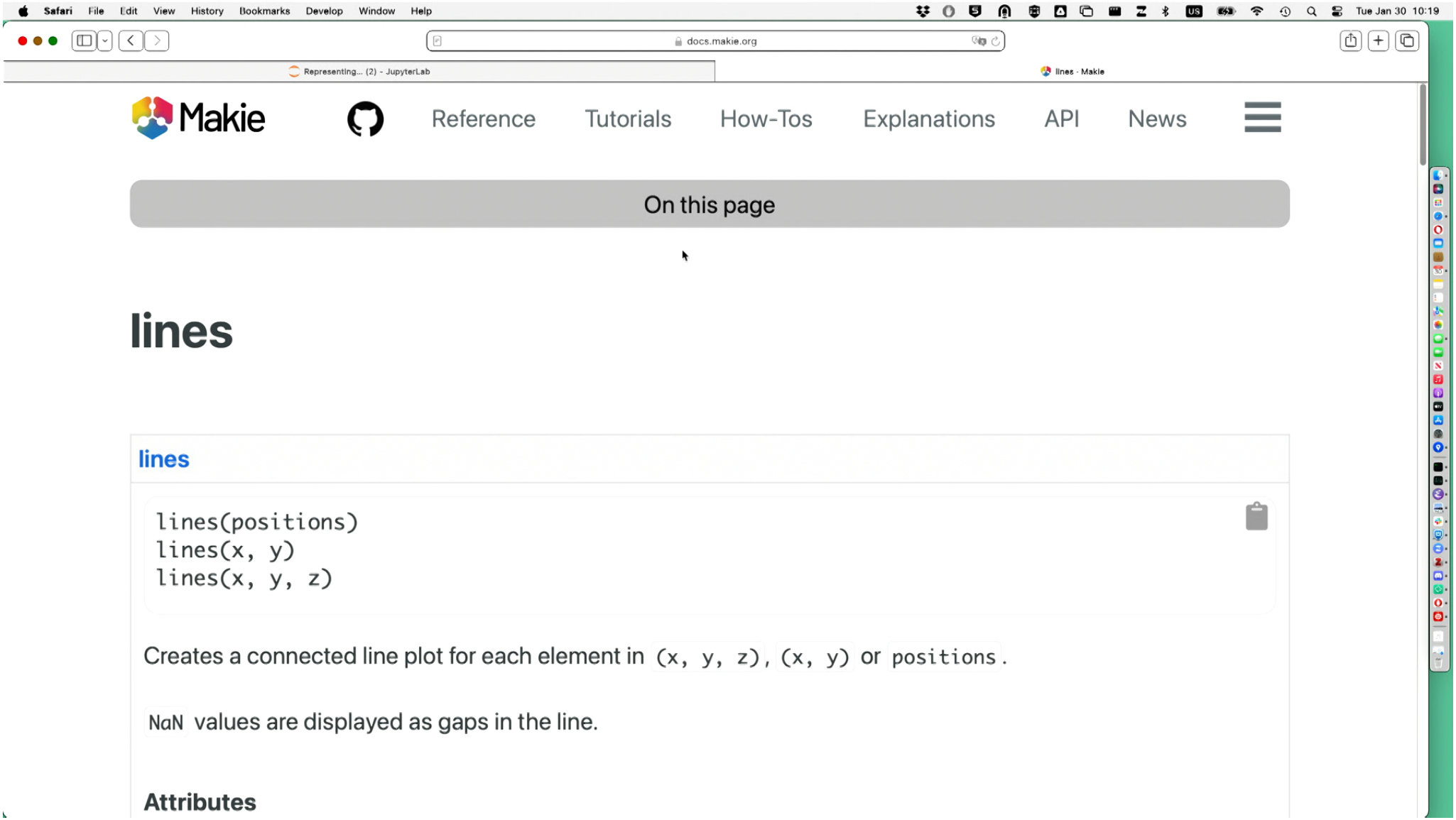
Title: Numerical Methods Lecture

Speakers: Dustin Lang

Collection: Numerical Methods 2023/24

Date: January 30, 2024 - 10:15 AM

URL: https://pirsa.org/24010025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API
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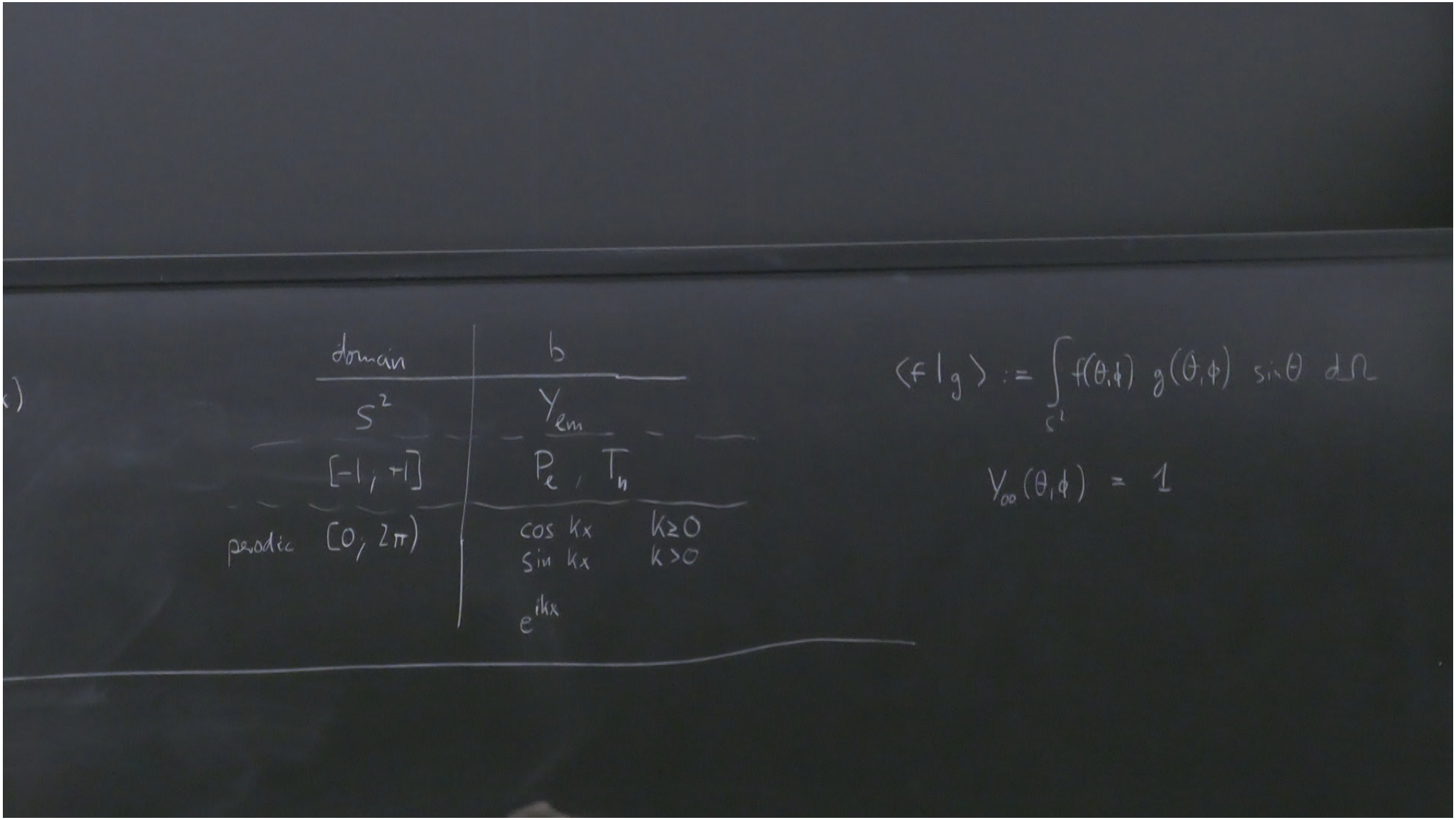
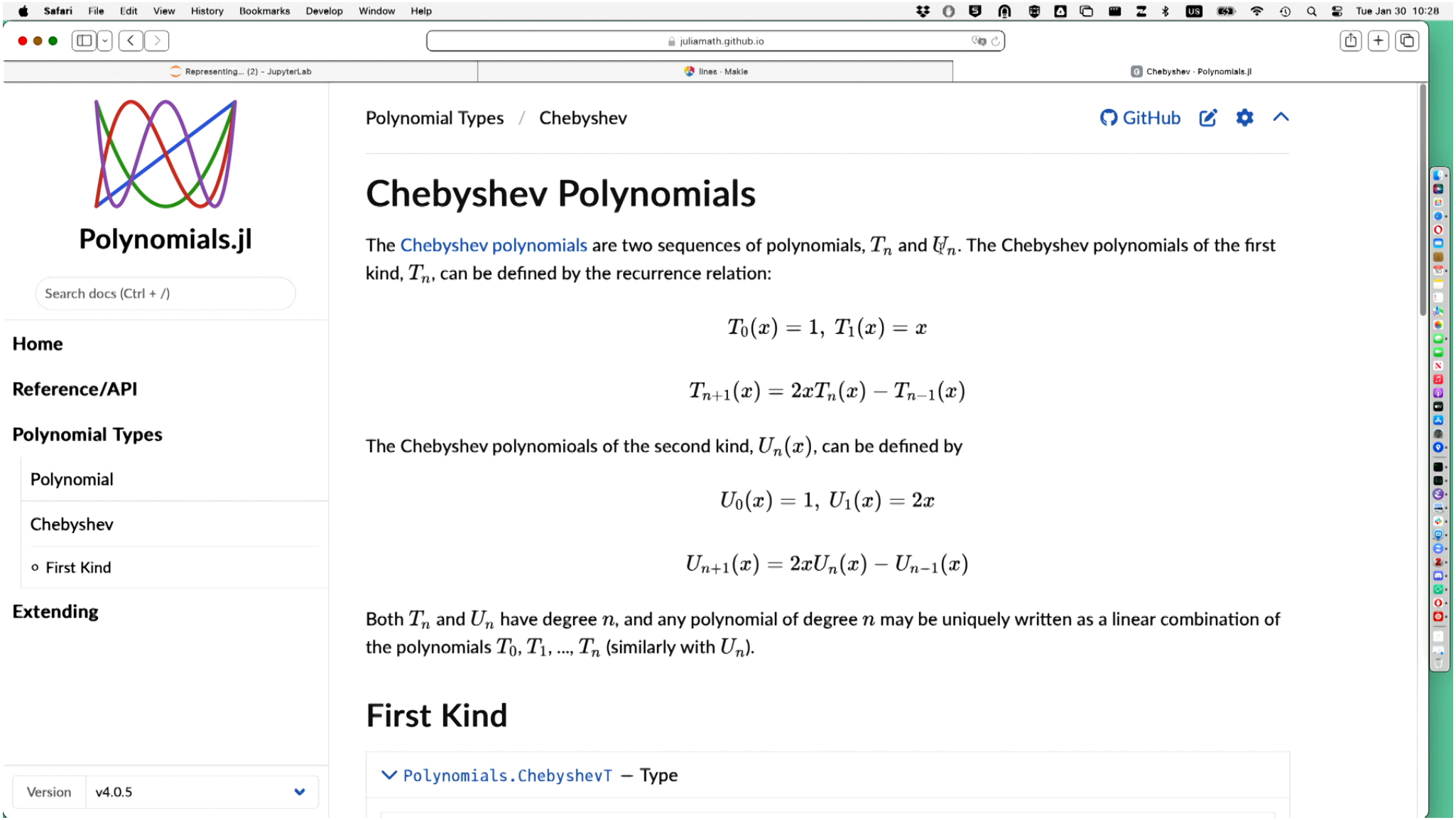
lines
lines
lines(positions)
lines(x, y)
lines(x, y, z)
Creates a connected line plot for each element in (x, y, z), (x, y) or positions.
NaN values are displayed as gaps in the line.
Attributes

$$f^*(x) = \sum_{i=0}^{\infty} c^i b_i(x)$$

$$f(x) = \sum_{i=0}^{n} c^i b_i(x)$$

domain	b	
S^2	$Y_{\ell m}$	
$[-1, +1]$	P_ℓ , T_n	
periodic $[0, 2\pi)$	$\cos kx$	$k \geq 0$
	$\sin kx$	$k > 0$
	e^{ikx}	


domain
b
S^2
$Y_{\ell m}$
$[-1, +1]$
P_ℓ , T_n
periodic $[0, 2\pi)$
$\cos kx$ $k \geq 0$
$\sin kx$ $k > 0$
e^{ikx}
$\langle f | g \rangle := \int_{S^2} f(\theta,\phi)\, g(\theta,\phi)\, \sin\theta\, d\Omega$
$Y_{00}(\theta,\phi) = 1$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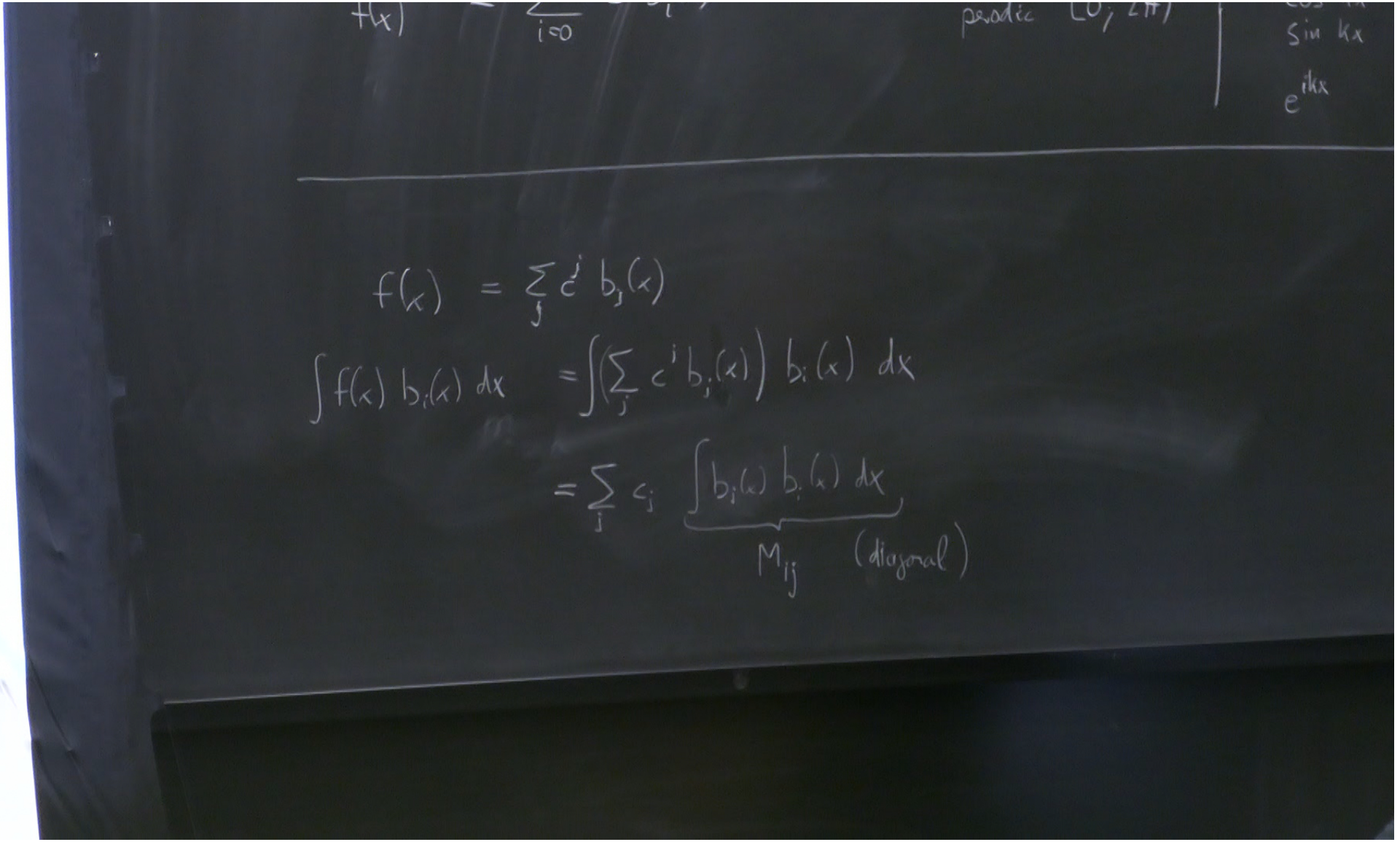
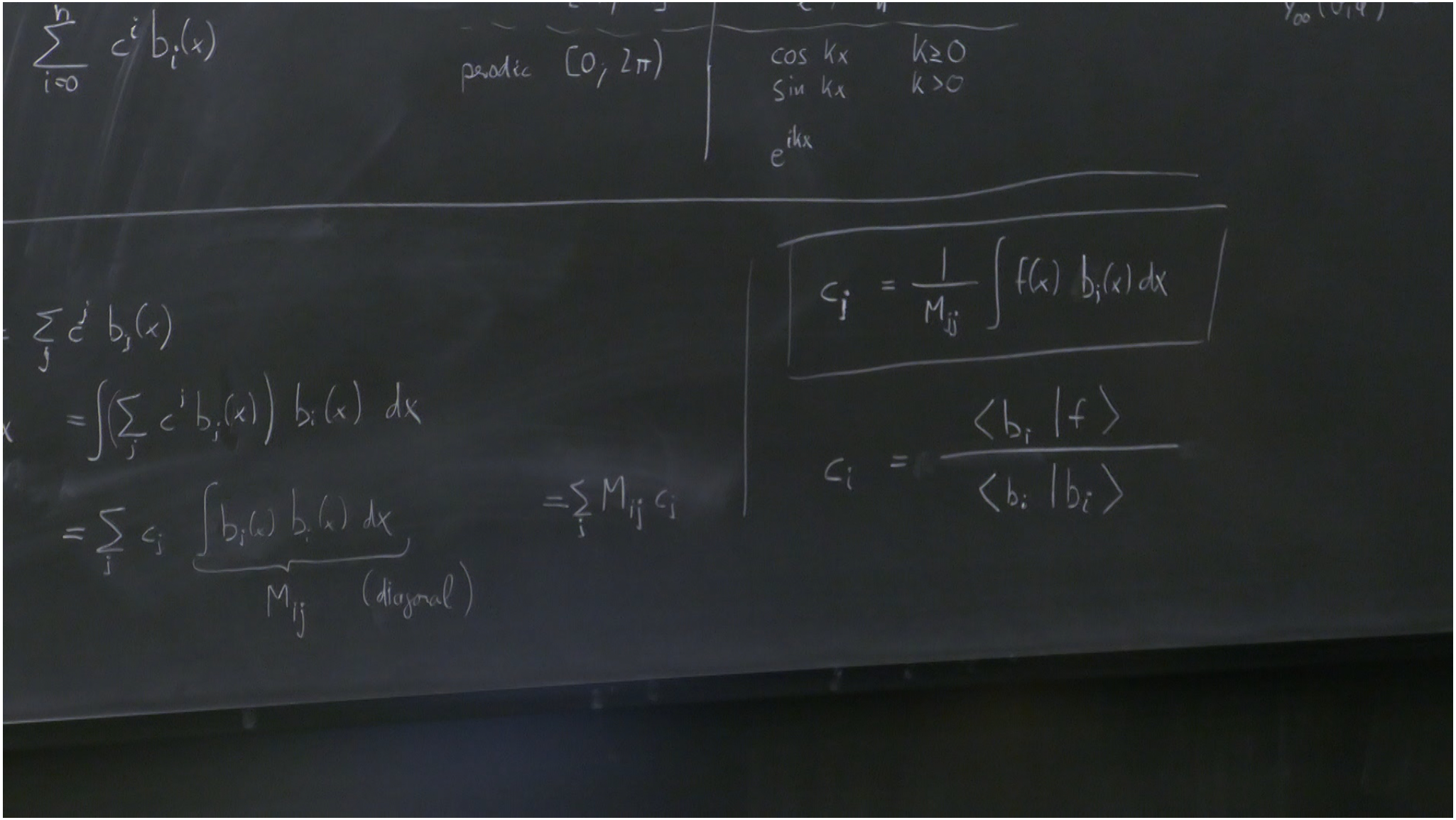
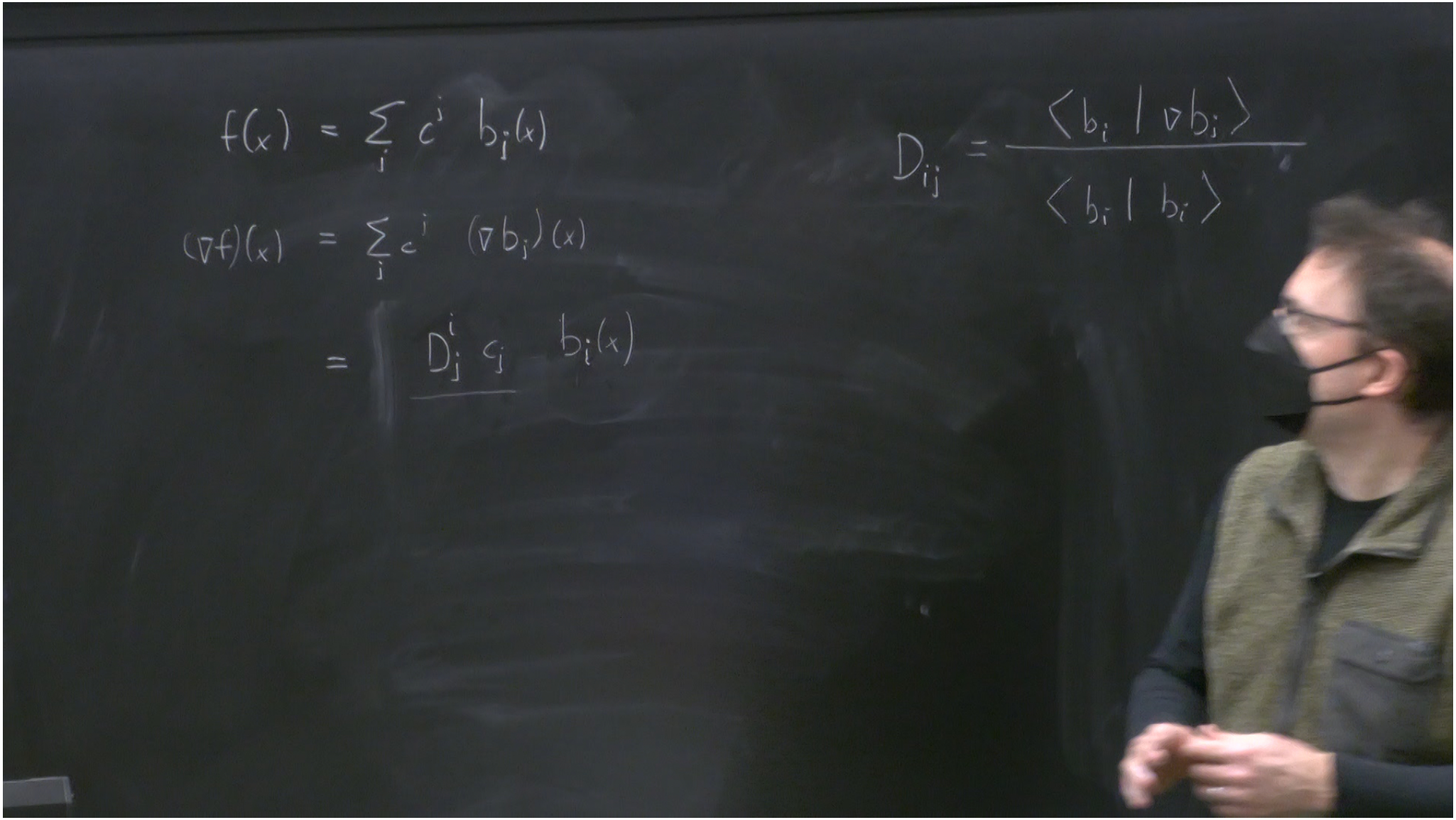
Polynomial
Chebyshev
First Kind
Extending
Version
v4.0.5
Polynomial Types / Chebyshev
GitHub
Chebyshev Polynomials
The Chebyshev polynomials are two sequences of polynomials, T_n and U_n. The Chebyshev polynomials of the first kind, T_n, can be defined by the recurrence relation:
$$T_0(x) = 1,\ T_1(x) = x$$
$$T_{n+1}(x) = 2xT_n(x) - T_{n-1}(x)$$
The Chebyshev polynomioals of the second kind, $U_n(x)$, can be defined by
$$U_0(x) = 1,\ U_1(x) = 2x$$
$$U_{n+1}(x) = 2xU_n(x) - U_{n-1}(x)$$
Both T_n and U_n have degree n, and any polynomial of degree n may be uniquely written as a linear combination of the polynomials T_0, T_1, ..., T_n (similarly with U_n).
First Kind
Polynomials.ChebyshevT — Type


f(x)
i=0
periodic [0, 2π]
sin kx
e^{ikx}
$f(x) = \sum_j c^j b_j(x)$
$\int f(x)\, b_i(x)\, dx = \int \left(\sum_j c^j b_j(x)\right) b_i(x)\, dx$
$= \sum_j c_j \underbrace{\int b_j(x)\, b_i(x)\, dx}_{M_{ij}}$ (diagonal)


$\sum_{i=0}^{n} c^i b_i(x)$
periodic $[0, 2\pi)$
$\cos kx \quad k \geq 0$
$\sin kx \quad k > 0$
e^{ikx}
$c_j = \frac{1}{M_{jj}} \int f(x)\, b_j(x)\, dx$
$= \sum_j c^j b_j(x)$
$= \int \left(\sum_j c^j b_j(x) \right) b_i(x)\, dx$
$= \sum_j c_j \int b_j(x)\, b_i(x)\, dx$
$= \sum_j M_{ij} c_j$
M_{ij} (diagonal)
$c_i = \frac{\langle b_i | f \rangle}{\langle b_i | b_i \rangle}$


$f(x) = \sum_i c^i \, b_i(x)$
$(\nabla f)(x) = \sum_i c^i \, (\nabla b_i)(x)$
$= D^i_j \, c_j \, b_i(x)$
$D_{ij} = \frac{\langle b_i \mid \nabla b_j \rangle}{\langle b_i \mid b_i \rangle}$

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symmetry.pi.local

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Representing Functions.ipy

Code

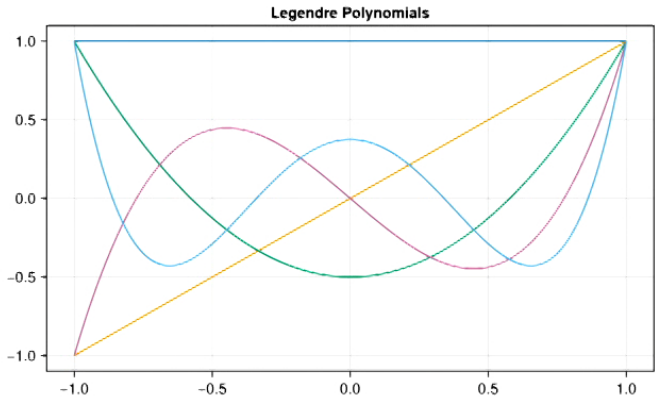
Julia 1.10.0

```
[1]: using LegendrePolynomials

[2]: using WGLMakie

[10]: xs = -1:0.01:+1
      fig = Figure(size=(640, 400))
      axis = Axis(fig[1, 1]; title="Legendre Polynomials")
      for l in 0:4
          lines!(axis, xs, [Pl(x,l) for x in xs])
      end
      fig
```

[10]:



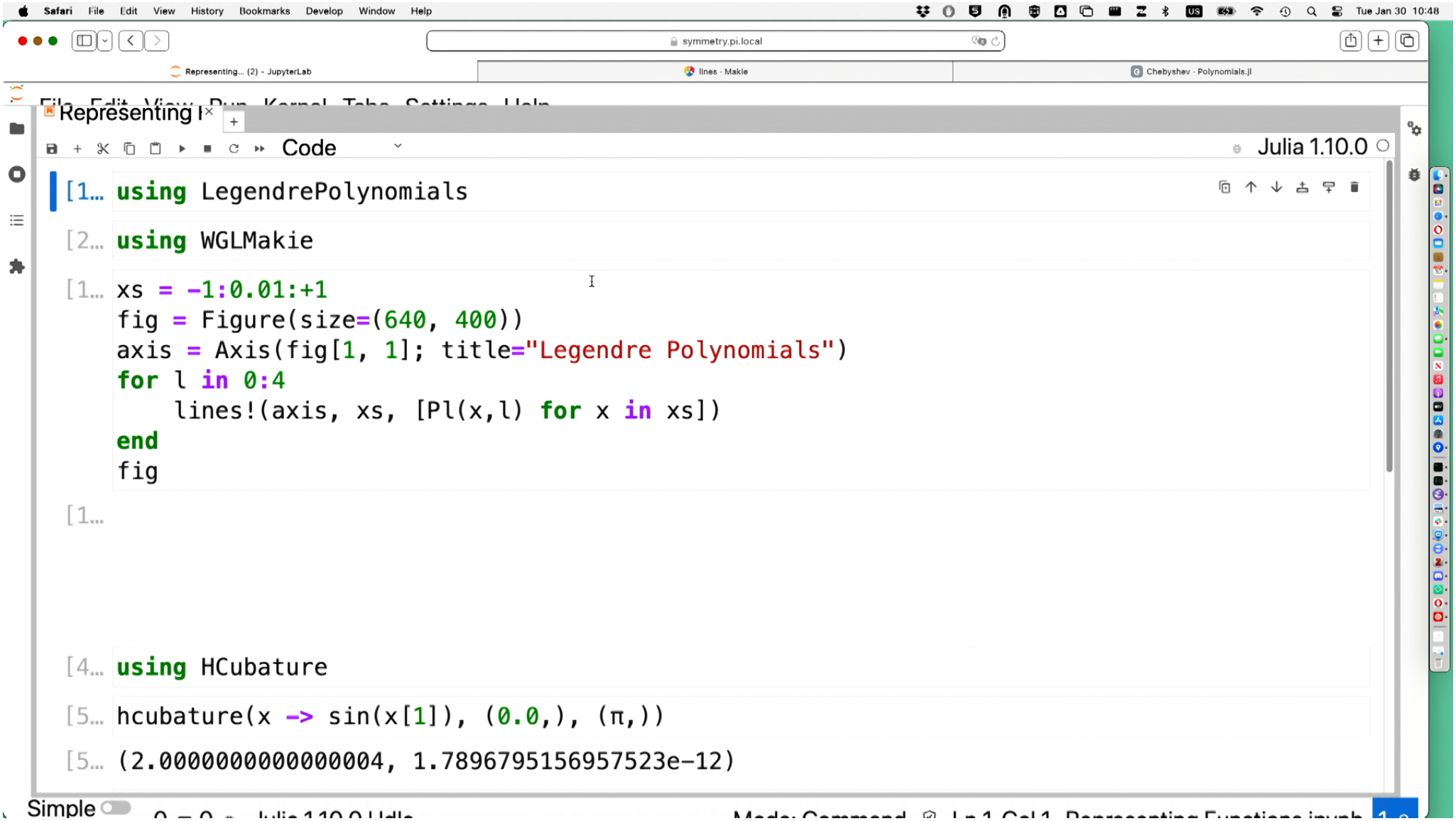

```
[4]: using HCubature

[5]: hcubature(x -> sin(x[1]), (0.0,), (π,))

[5]: (2.0000000000000004, 1.7896795156957523e-12)

[ ]:
```

Simple 0 6 Julia 1.10.0 | Idle Mode: Command Ln 1, Col 1 Representing Functions.ipynb 1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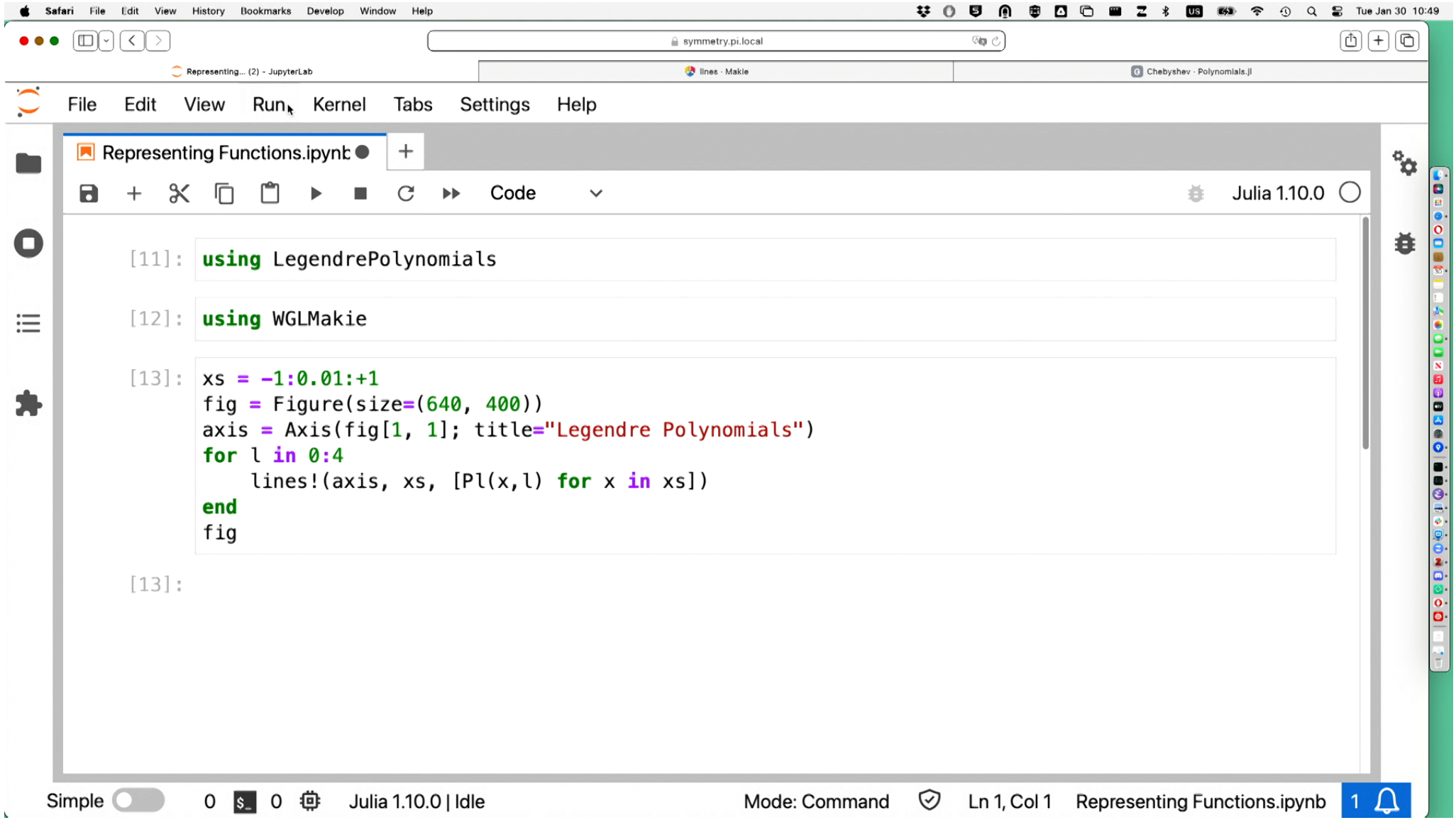
symmetry.pi.local
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
Representing
Code
Julia 1.10.0
[1… using LegendrePolynomials
[2… using WGLMakie
[1… xs = -1:0.01:+1
fig = Figure(size=(640, 400))
axis = Axis(fig[1, 1]; title="Legendre Polynomials")
for l in 0:4
lines!(axis, xs, [Pl(x,l) for x in xs])
end
fig
[1…
[4… using HCubature
[5… hcubature(x -> sin(x[1]), (0.0,), (π,))
[5… (2.0000000000000004, 1.7896795156957523e-12)
Simple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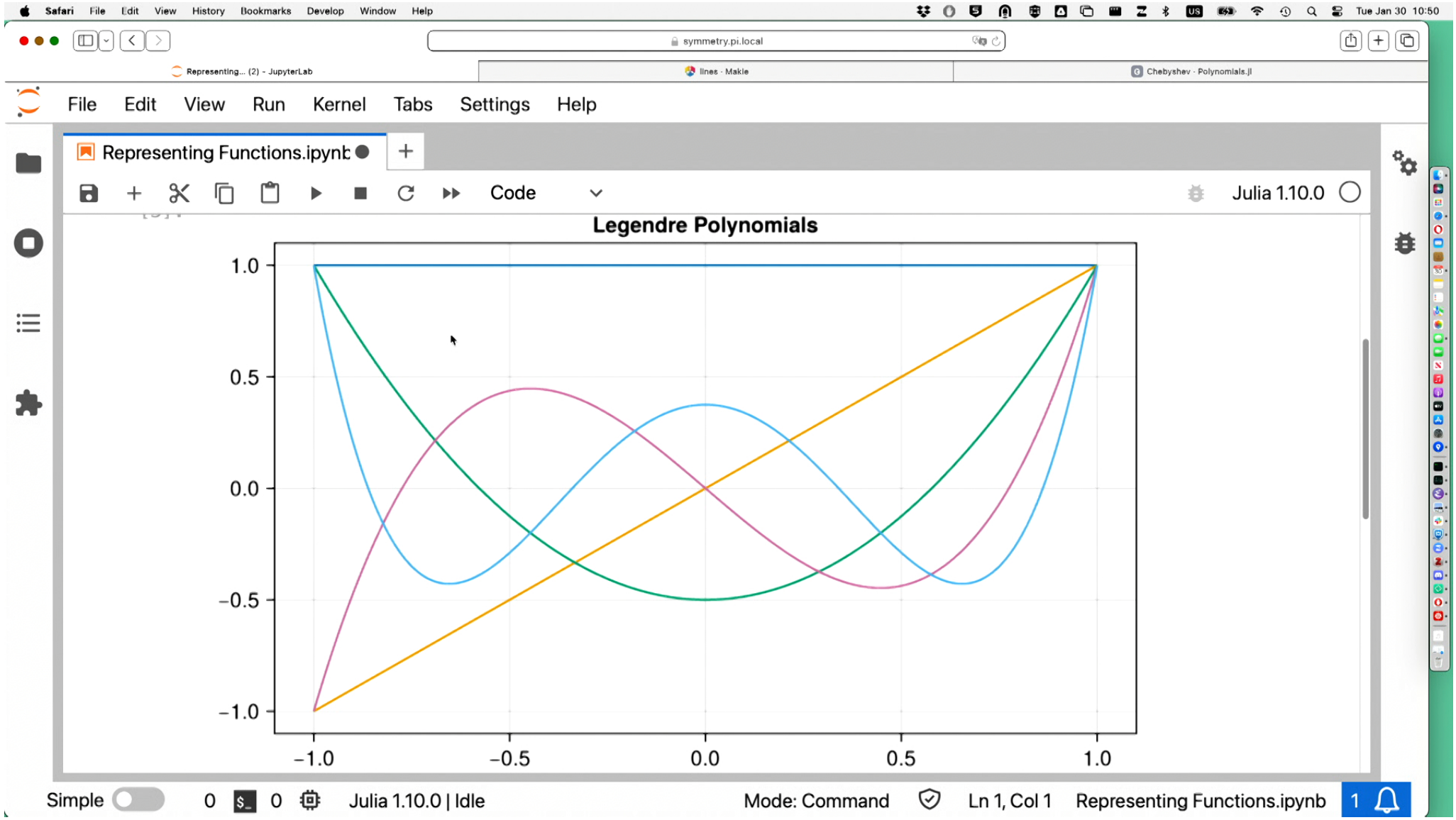
symmetry.pi.local
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
File Edit View Run Kernel Tabs Settings Help
Representing Functions.ipynb
Code
Julia 1.10.0
[11]: using LegendrePolynomials
[12]: using WGLMakie
[13]: xs = -1:0.01:+1
fig = Figure(size=(640, 400))
axis = Axis(fig[1, 1]; title="Legendre Polynomials")
for l in 0:4
lines!(axis, xs, [Pl(x,l) for x in xs])
end
fig
[13]:
Simple
0
0
Julia 1.10.0 | Idle
Mode: Command
Ln 1, Col 1
Representing Functions.ipynb
1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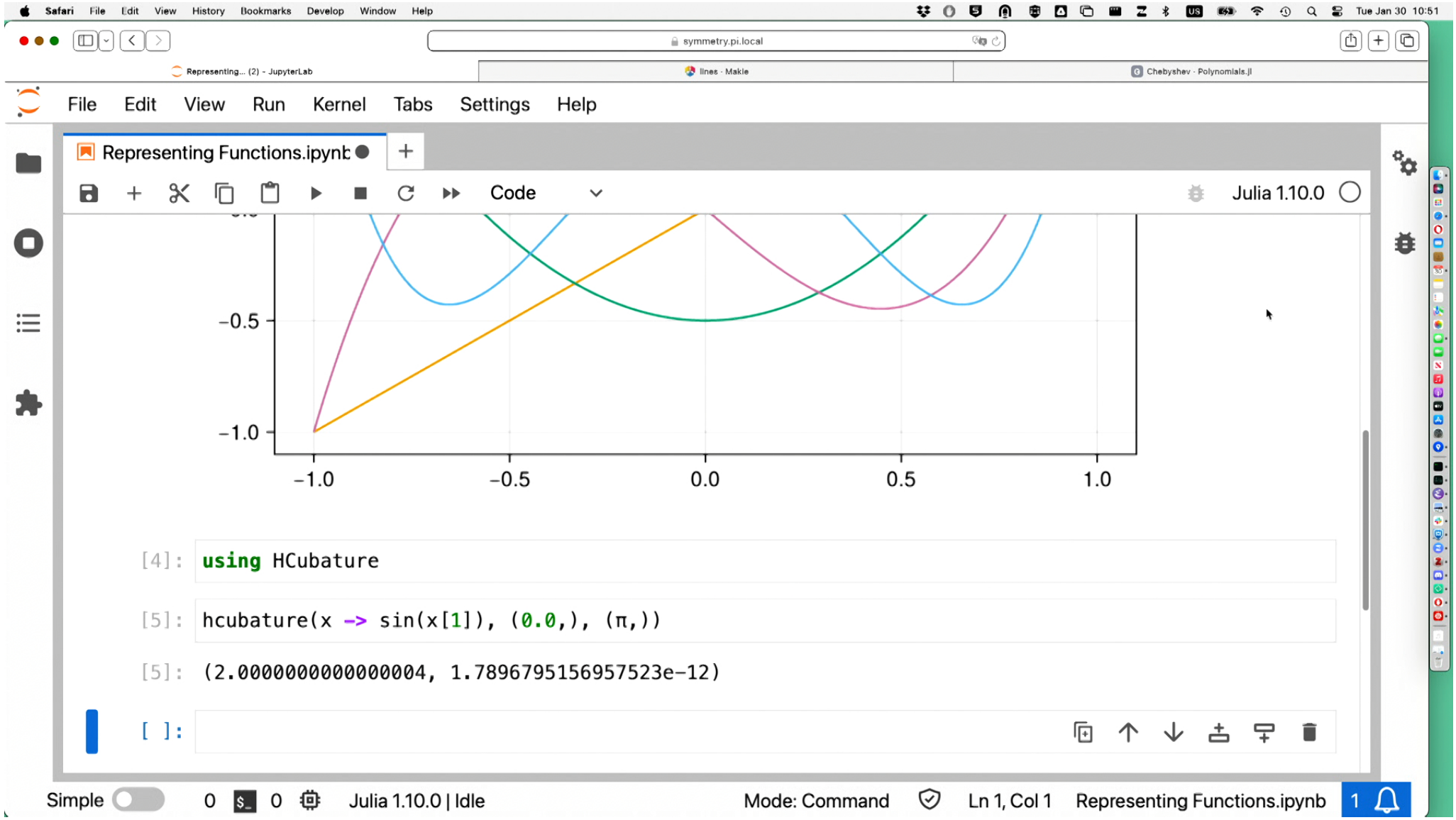
Tue Jan 30 10:50
symmetry.pi.local
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
File Edit View Run Kernel Tabs Settings Help
Representing Functions.ipynb
Code
Julia 1.10.0
Legendre Polynomials
1.0
0.5
0.0
−0.5
−1.0
−1.0
−0.5
0.0
0.5
1.0
Simple
0
0
Julia 1.10.0 | Idle
Mode: Command
Ln 1, Col 1
Representing Functions.ipynb
1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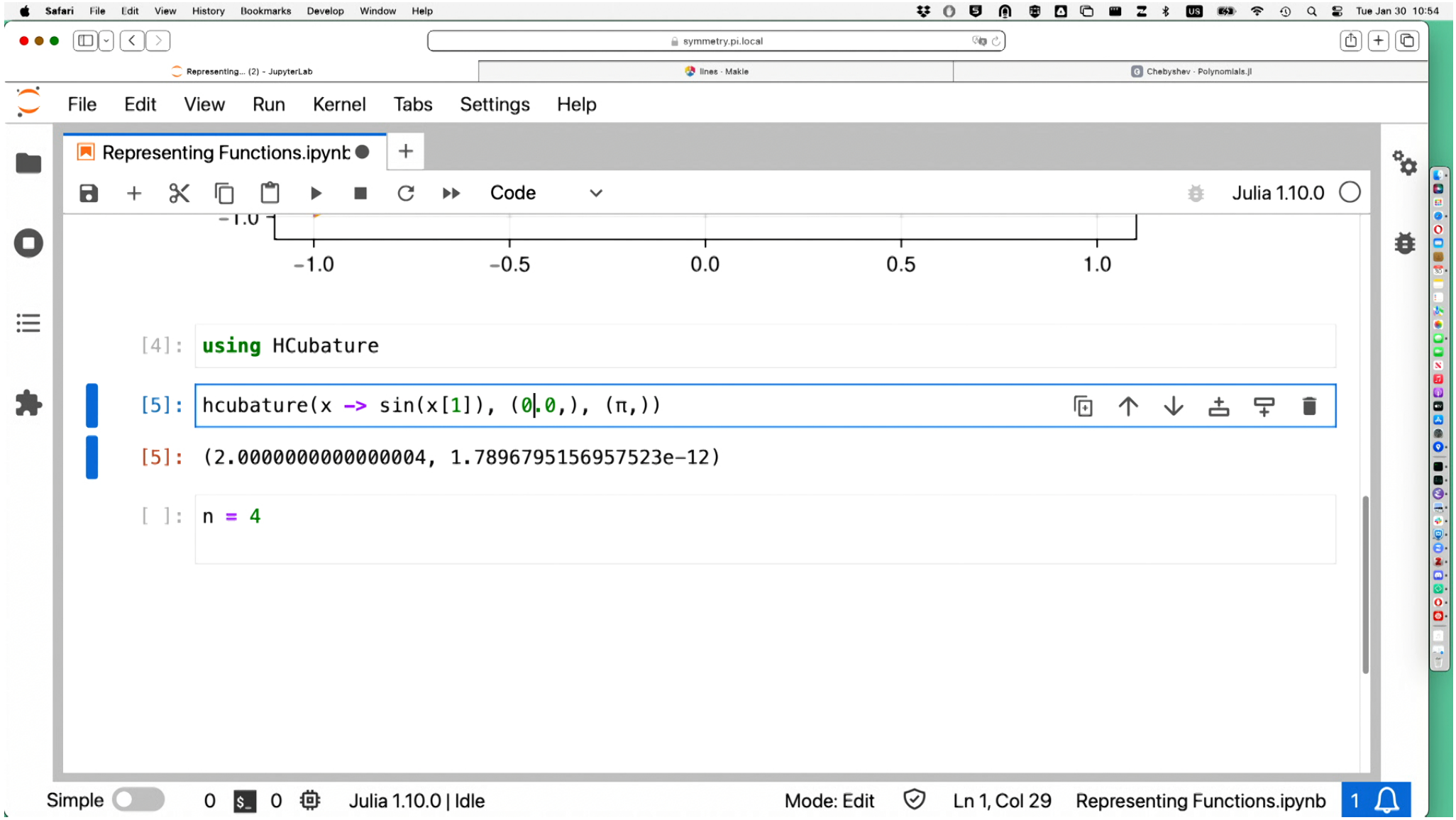
symmetry.pi.local
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
File Edit View Run Kernel Tabs Settings Help
Representing Functions.ipynb
Code
Julia 1.10.0
−0.5
−1.0
−1.0
−0.5
0.0
0.5
1.0
[4]: using HCubature
[5]: hcubature(x -> sin(x[1]), (0.0,), (π,))
[5]: (2.0000000000000004, 1.7896795156957523e-12)
[ ]:
Simple
0
0
Julia 1.10.0 | Idle
Mode: Command
Ln 1, Col 1
Representing Functions.ipynb
1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Tue Jan 30 10:54
symmetry.pi.local
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
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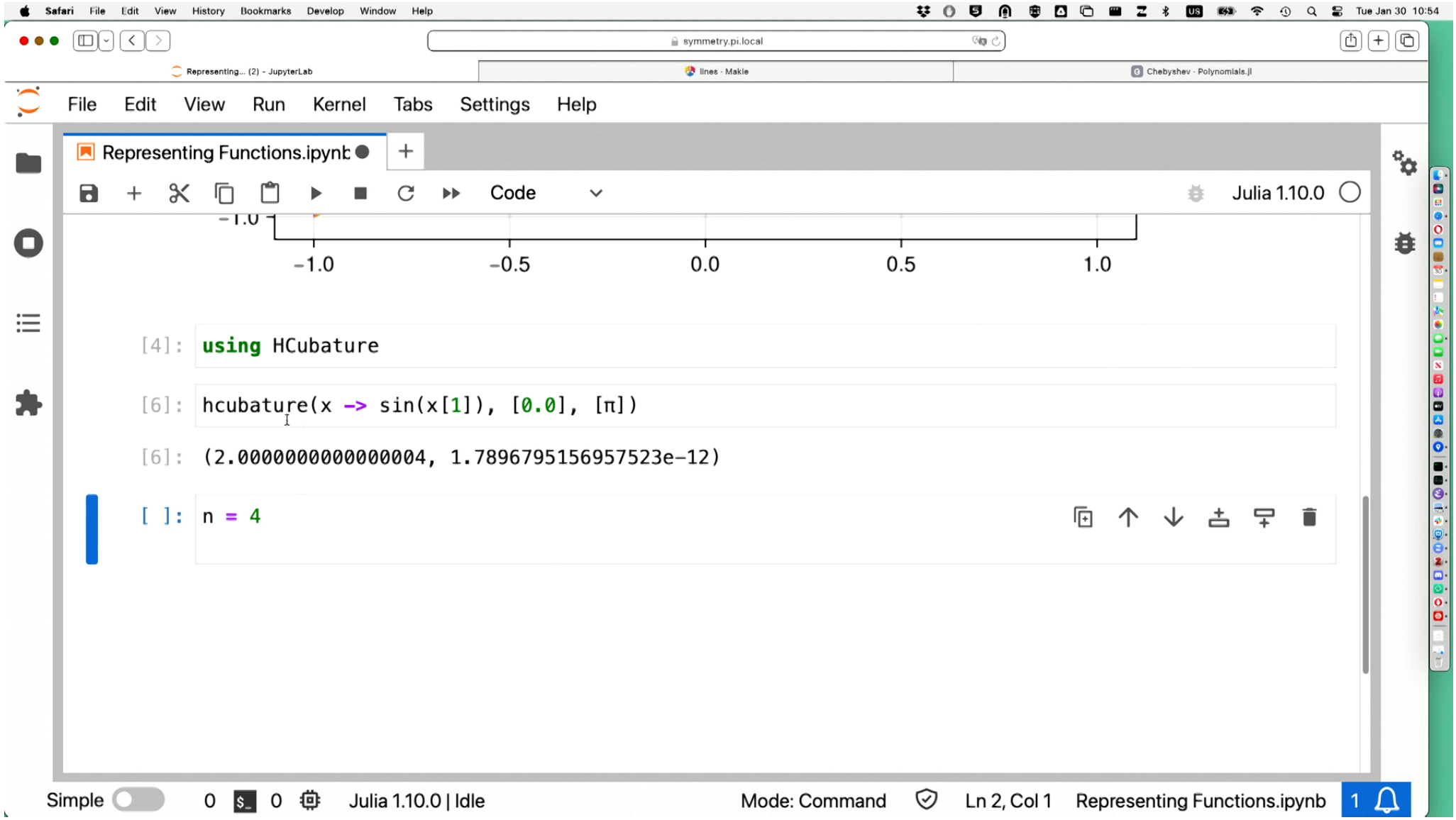
Representing Functions.ipynb
Code
Julia 1.10.0
−1.0
−0.5
0.0
0.5
1.0
[4]: using HCubature
[5]: hcubature(x -> sin(x[1]), (0.0,), (π,))
[5]: (2.0000000000000004, 1.7896795156957523e-12)
[ ]: n = 4
Simple
0
0
Julia 1.10.0 | Idle
Mode: Edit
Ln 1, Col 29
Representing Functions.ipynb
1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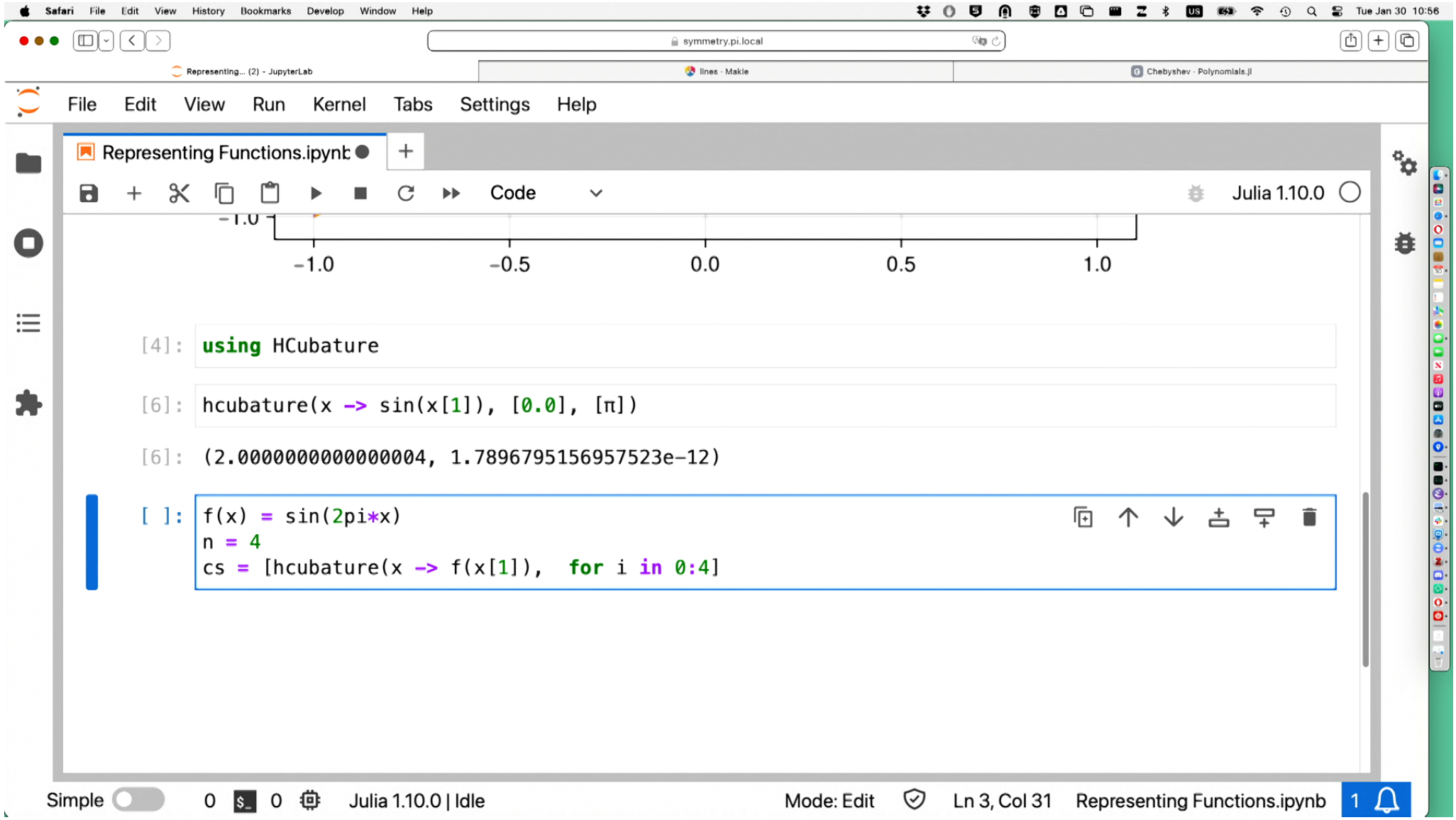
Tue Jan 30 10:54
symmetry.pi.local
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
File Edit View Run Kernel Tabs Settings Help
Representing Functions.ipynb
Code
Julia 1.10.0
−1.0
−0.5
0.0
0.5
1.0
[4]: using HCubature
[6]: hcubature(x -> sin(x[1]), [0.0], [π])
[6]: (2.0000000000000004, 1.7896795156957523e-12)
[ ]: n = 4
Simple
0
0
Julia 1.10.0 | Idle
Mode: Command
Ln 2, Col 1
Representing Functions.ipynb
1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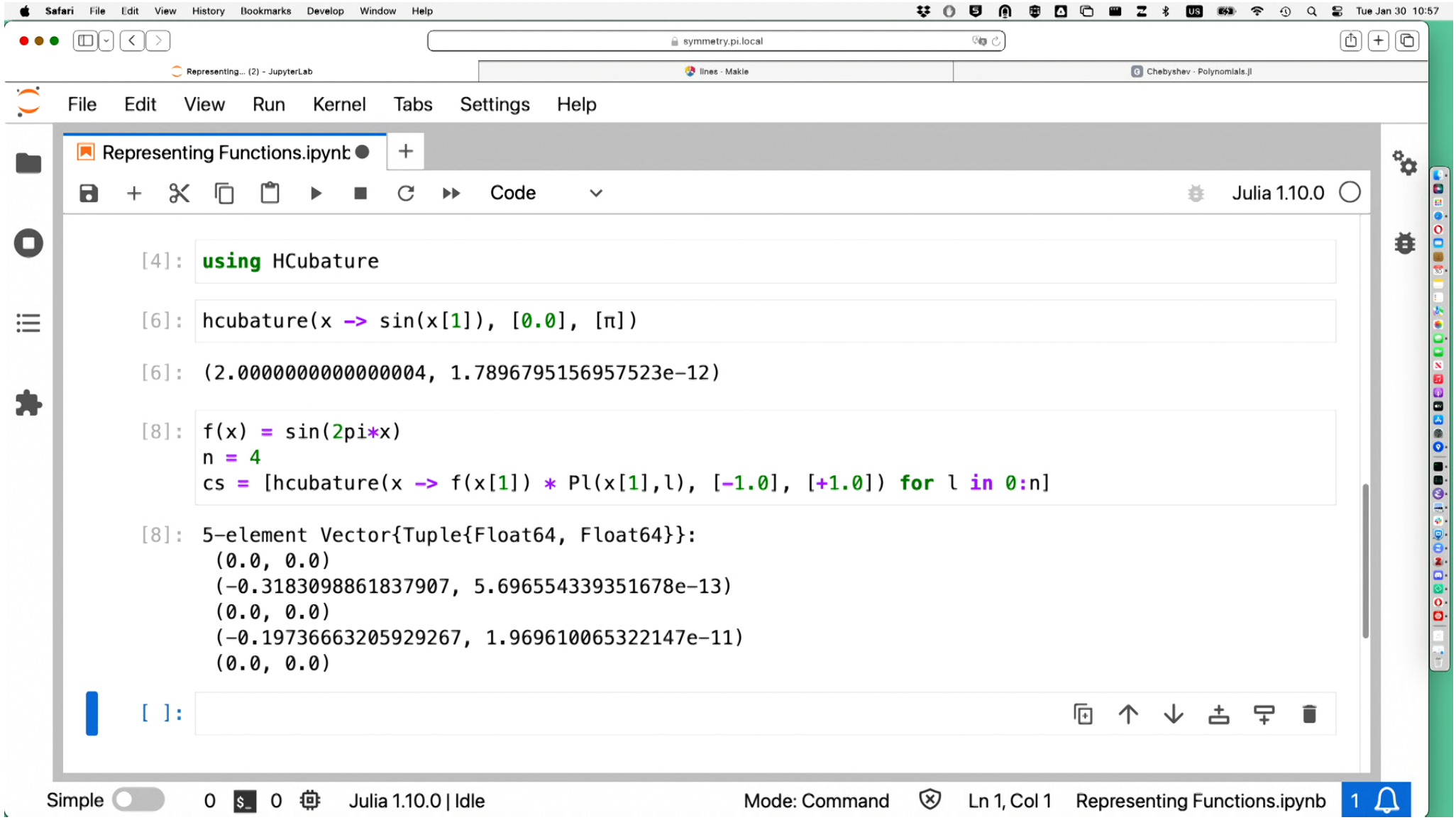
symmetry.pi.local
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
File Edit View Run Kernel Tabs Settings Help
Representing Functions.ipynb
Code
Julia 1.10.0
−1.0
−0.5
0.0
0.5
1.0
[4]:
using HCubature
[6]:
hcubature(x -> sin(x[1]), [0.0], [π])
[6]:
(2.0000000000000004, 1.7896795156957523e-12)
[ ]:
f(x) = sin(2pi*x)
n = 4
cs = [hcubature(x -> f(x[1]), for i in 0:4]
Simple
0
0
Julia 1.10.0 | Idle
Mode: Edit
Ln 3, Col 31
Representing Functions.ipynb
1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symmetry.pi.local
Representing... (2) - JupyterLab
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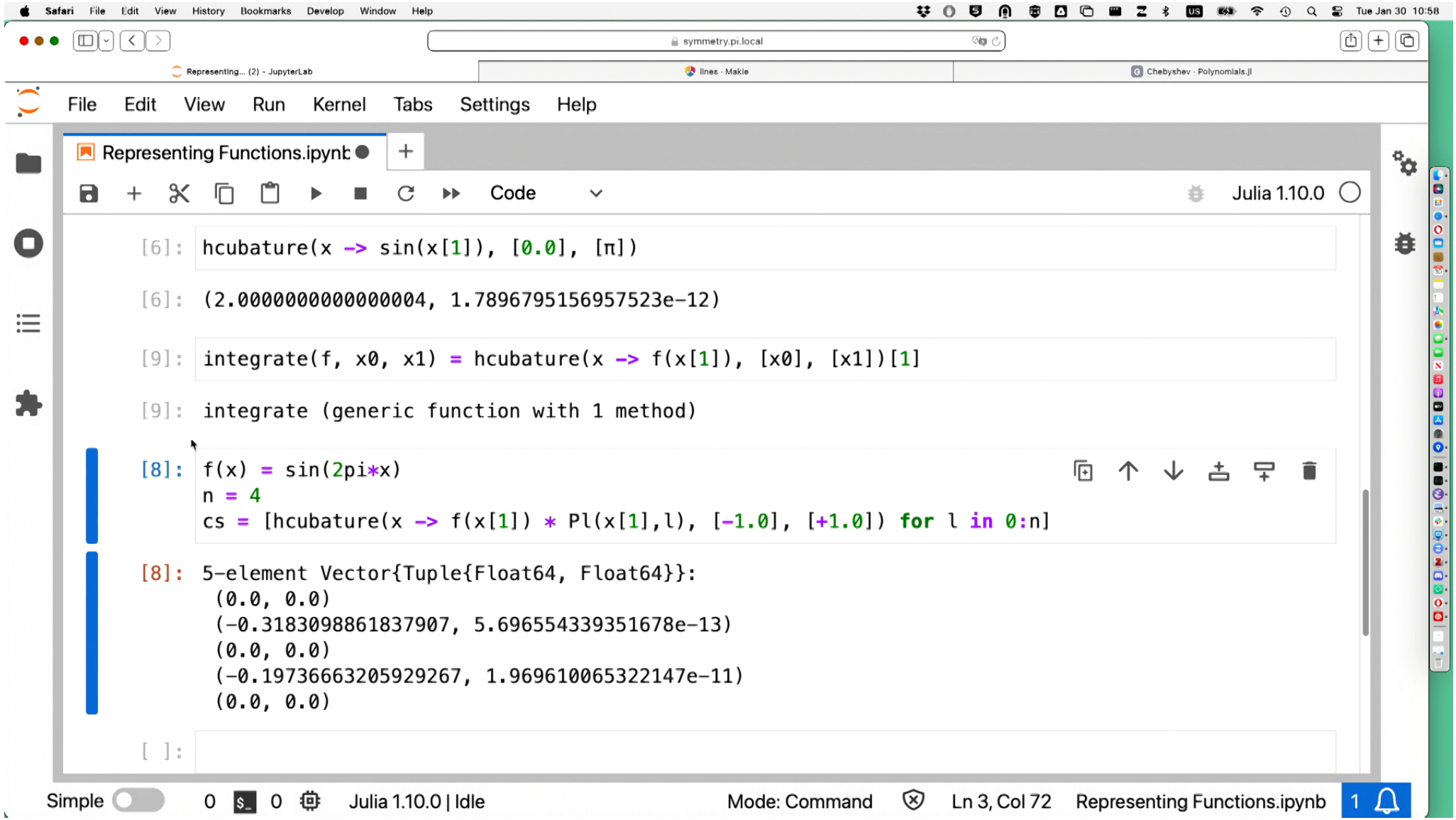
Representing Functions.ipynb
Code
Julia 1.10.0
[4]: using HCubature
[6]: hcubature(x -> sin(x[1]), [0.0], [π])
[6]: (2.0000000000000004, 1.7896795156957523e-12)
[8]: f(x) = sin(2pi*x)
n = 4
cs = [hcubature(x -> f(x[1]) * Pl(x[1],l), [-1.0], [+1.0]) for l in 0:n]
[8]: 5-element Vector{Tuple{Float64, Float64}}:
(0.0, 0.0)
(-0.3183098861837907, 5.696554339351678e-13)
(0.0, 0.0)
(-0.19736663205929267, 1.969610065322147e-11)
(0.0, 0.0)
[ ]:
Simple
0 $_ 0
Julia 1.10.0 | Idle
Mode: Command
Ln 1, Col 1
Representing Functions.ipynb
1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symmetry.pi.local
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Chebyshev · Polynomials.jl
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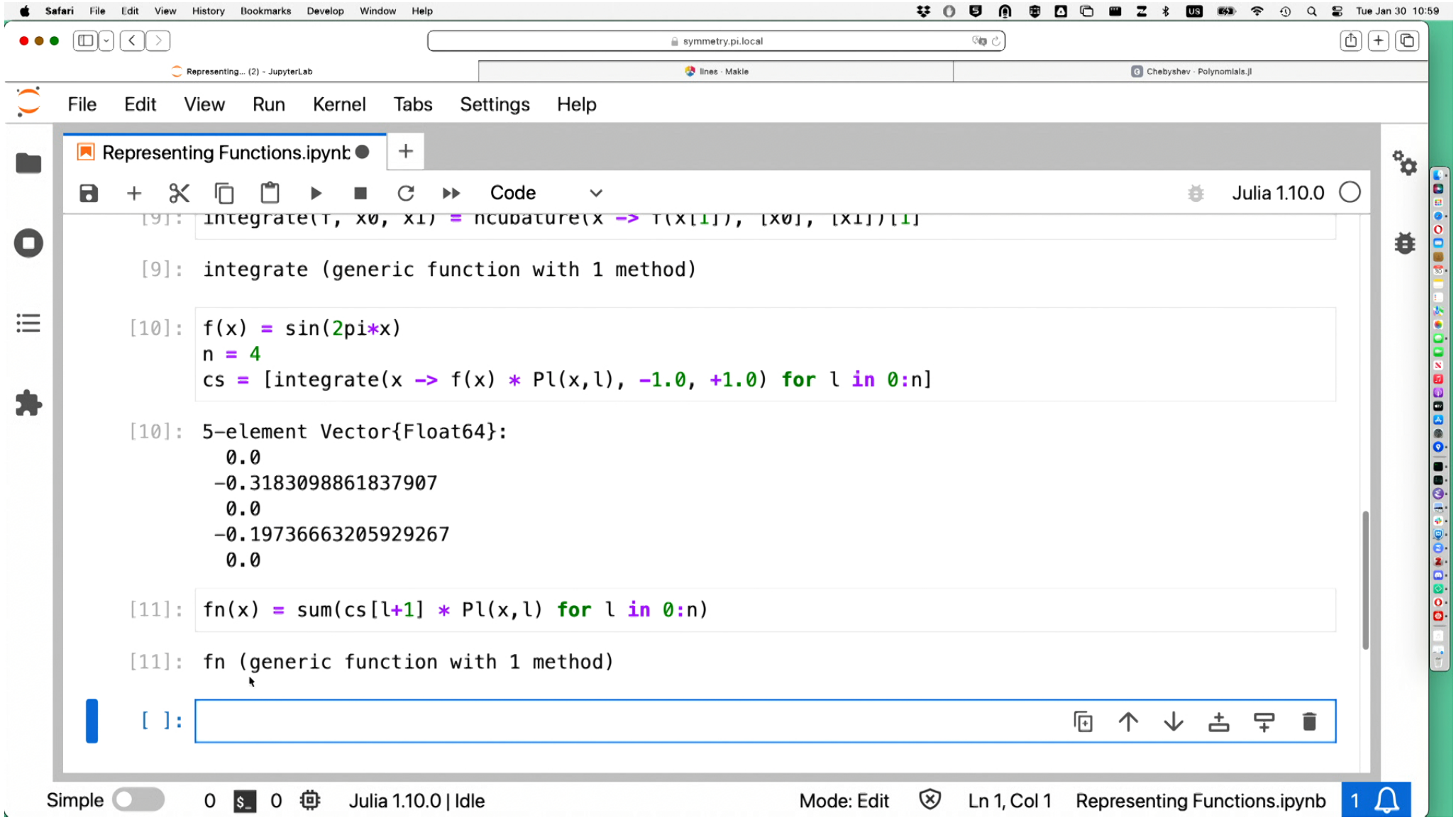
Representing Functions.ipynb
Code
Julia 1.10.0
[6]: hcubature(x -> sin(x[1]), [0.0], [π])
[6]: (2.0000000000000004, 1.7896795156957523e-12)
[9]: integrate(f, x0, x1) = hcubature(x -> f(x[1]), [x0], [x1])[1]
[9]: integrate (generic function with 1 method)
[8]: f(x) = sin(2pi*x)
n = 4
cs = [hcubature(x -> f(x[1]) * Pl(x[1],l), [-1.0], [+1.0]) for l in 0:n]
[8]: 5-element Vector{Tuple{Float64, Float64}}:
(0.0, 0.0)
(-0.3183098861837907, 5.696554339351678e-13)
(0.0, 0.0)
(-0.19736663205929267, 1.969610065322147e-11)
(0.0, 0.0)
[ ]:
Simple 0 $_ 0 Julia 1.10.0 | Idle Mode: Command Ln 3, Col 72 Representing Functions.ipynb 1


Safari File Edit View History Bookmarks Develop Window Help
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symmetry.pi.local
Representing... (2) - JupyterLab
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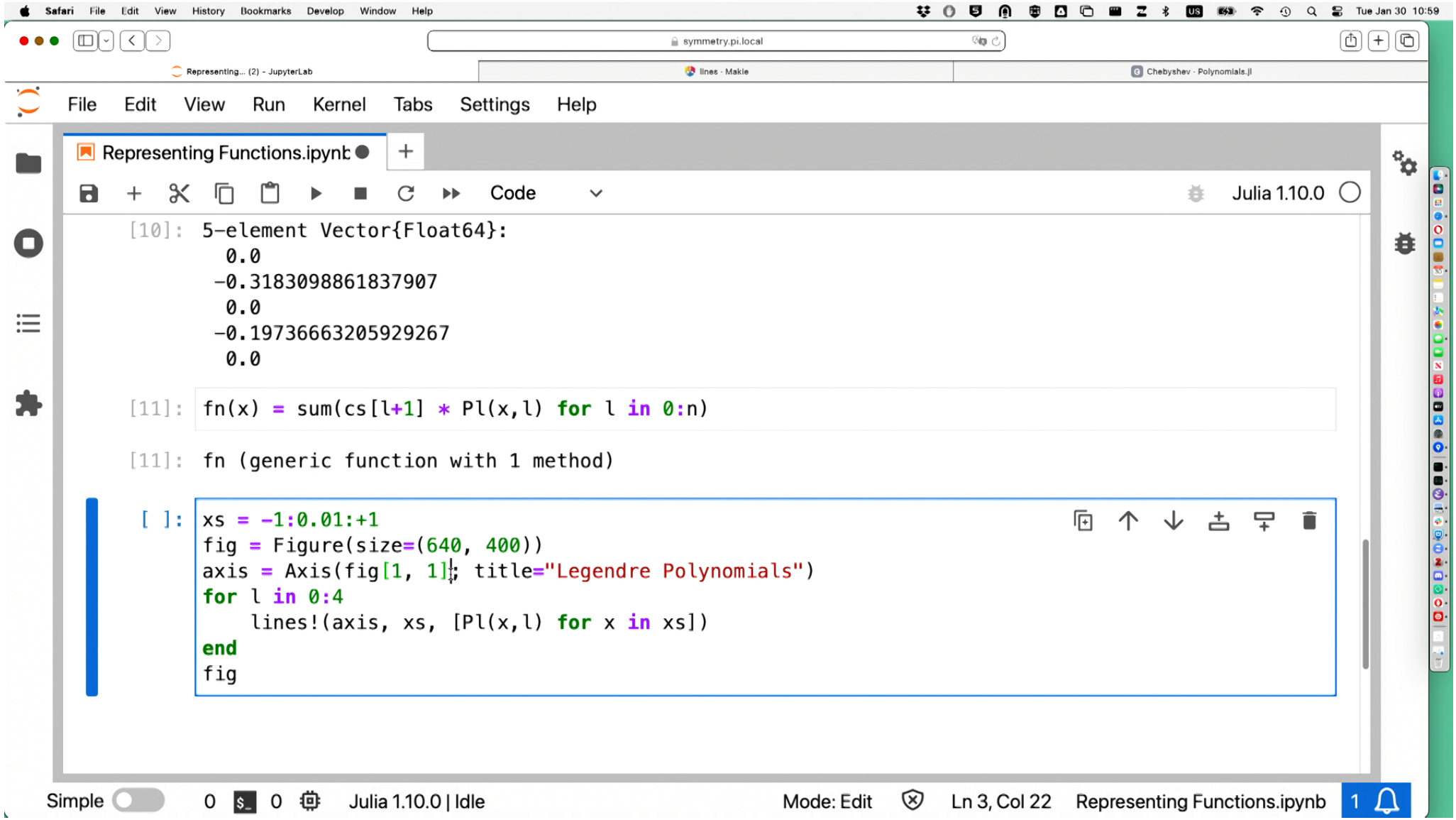
Representing Functions.ipynb
Code
Julia 1.10.0
integrate (generic function with 1 method)
f(x) = sin(2pi*x)
n = 4
cs = [integrate(x -> f(x) * Pl(x,l), -1.0, +1.0) for l in 0:n]
5-element Vector{Float64}:
0.0
-0.3183098861837907
0.0
-0.19736663205929267
0.0
fn(x) = sum(cs[l+1] * Pl(x,l) for l in 0:n)
fn (generic function with 1 method)
Simple
Julia 1.10.0 | Idle
Mode: Edit
Ln 1, Col 1
Representing Functions.ipynb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symmetry.pi.local
Representing... (2) - JupyterLab
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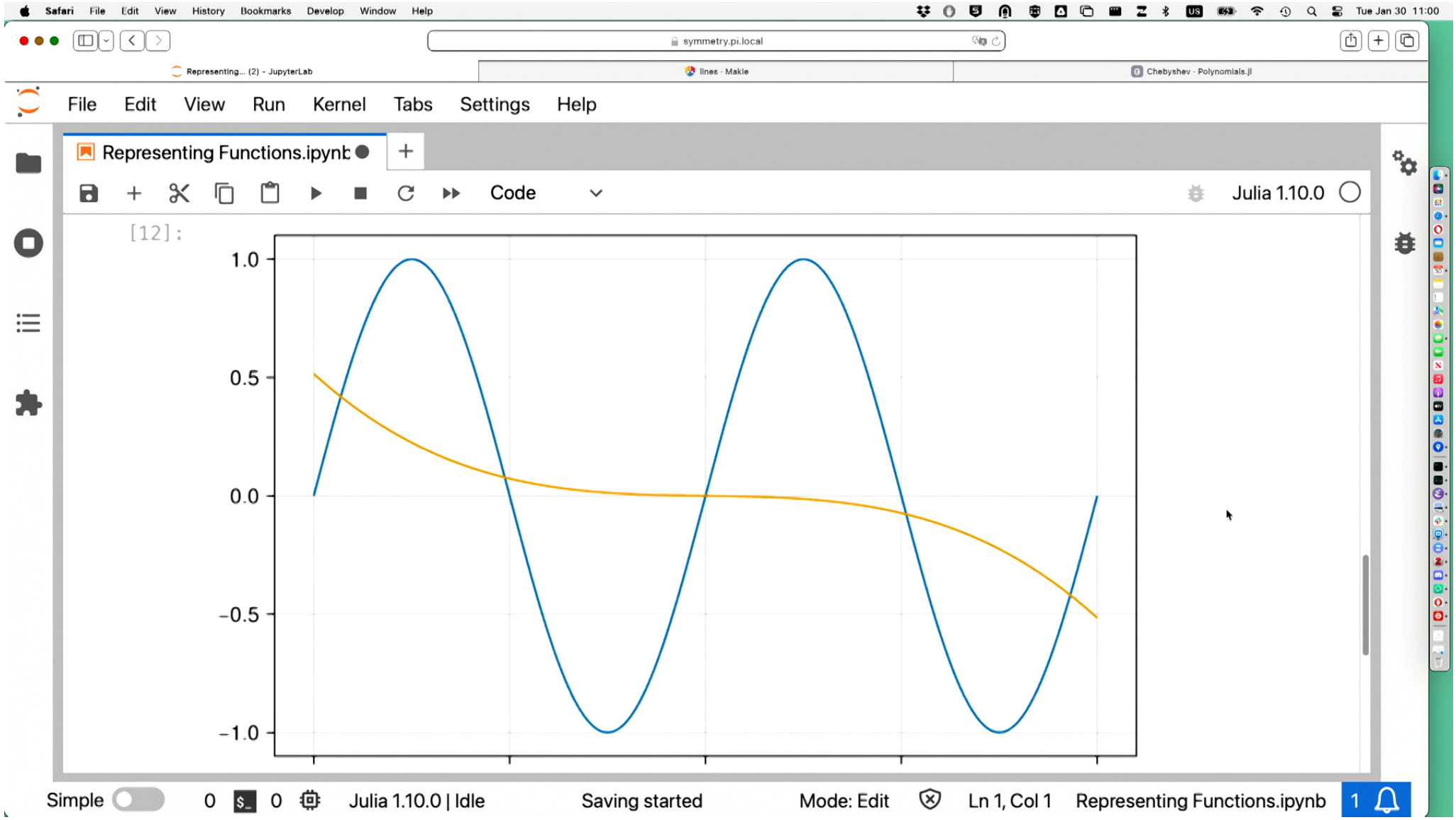
File Edit View Run Kernel Tabs Settings Help
Representing Functions.ipynb
Code
Julia 1.10.0
[10]: 5-element Vector{Float64}:
0.0
-0.3183098861837907
0.0
-0.19736663205929267
0.0
[11]: fn(x) = sum(cs[l+1] * Pl(x,l) for l in 0:n)
[11]: fn (generic function with 1 method)
[ ]:
xs = -1:0.01:+1
fig = Figure(size=(640, 400))
axis = Axis(fig[1, 1]; title="Legendre Polynomials")
for l in 0:4
lines!(axis, xs, [Pl(x,l) for x in xs])
end
fig
Simple
0
0
Julia 1.10.0 | Idle
Mode: Edit
Ln 3, Col 22
Representing Functions.ipynb
1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symmetry.pi.local
Representing... (2) - JupyterLab
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Chebyshev · Polynomials.jl
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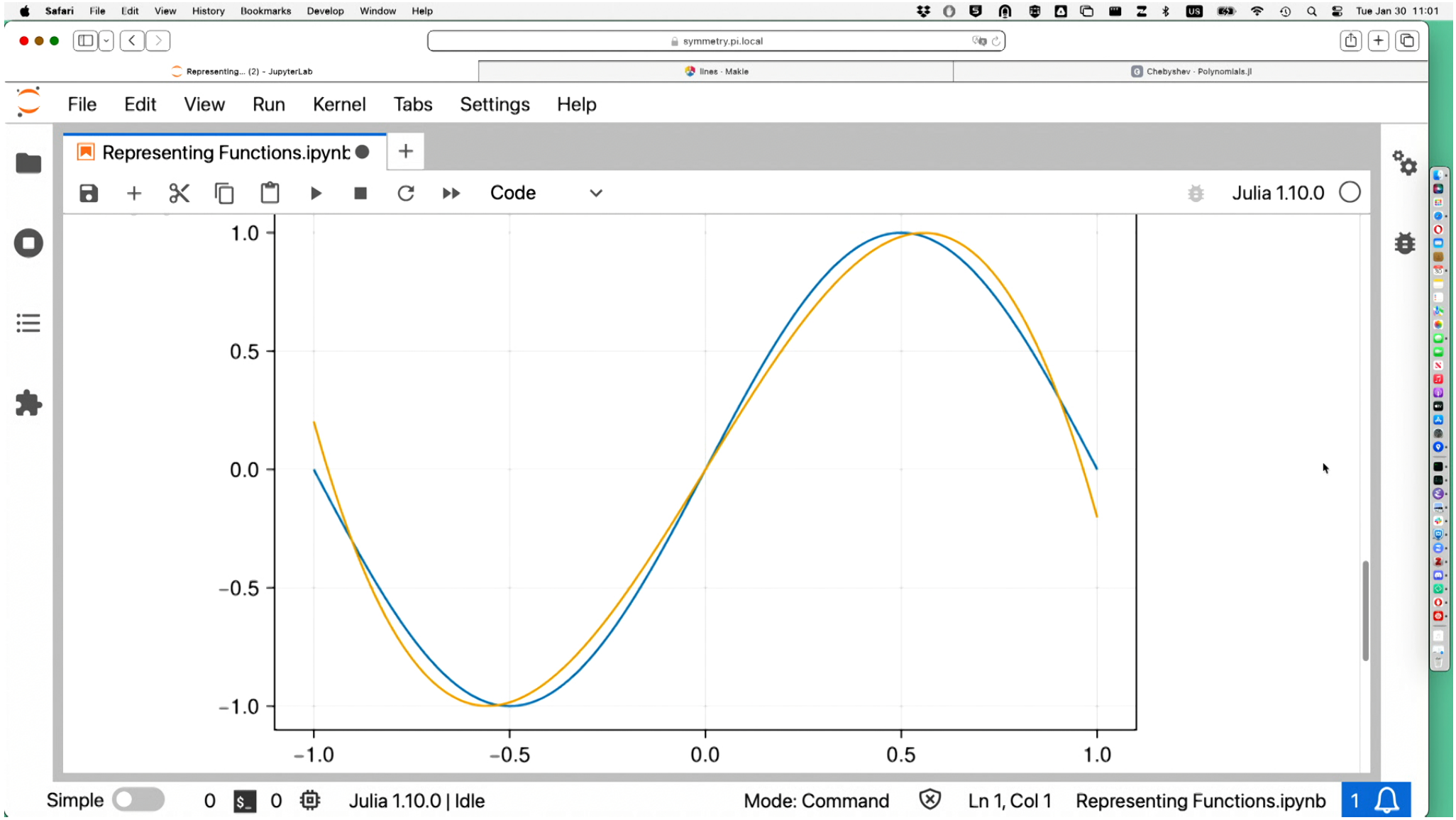
Representing Functions.ipynb
Code
Julia 1.10.0
[12]:
1.0
0.5
0.0
−0.5
−1.0
Simple
0
0
Julia 1.10.0 | Idle
Saving started
Mode: Edit
Ln 1, Col 1
Representing Functions.ipynb
1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symmetry.pi.local
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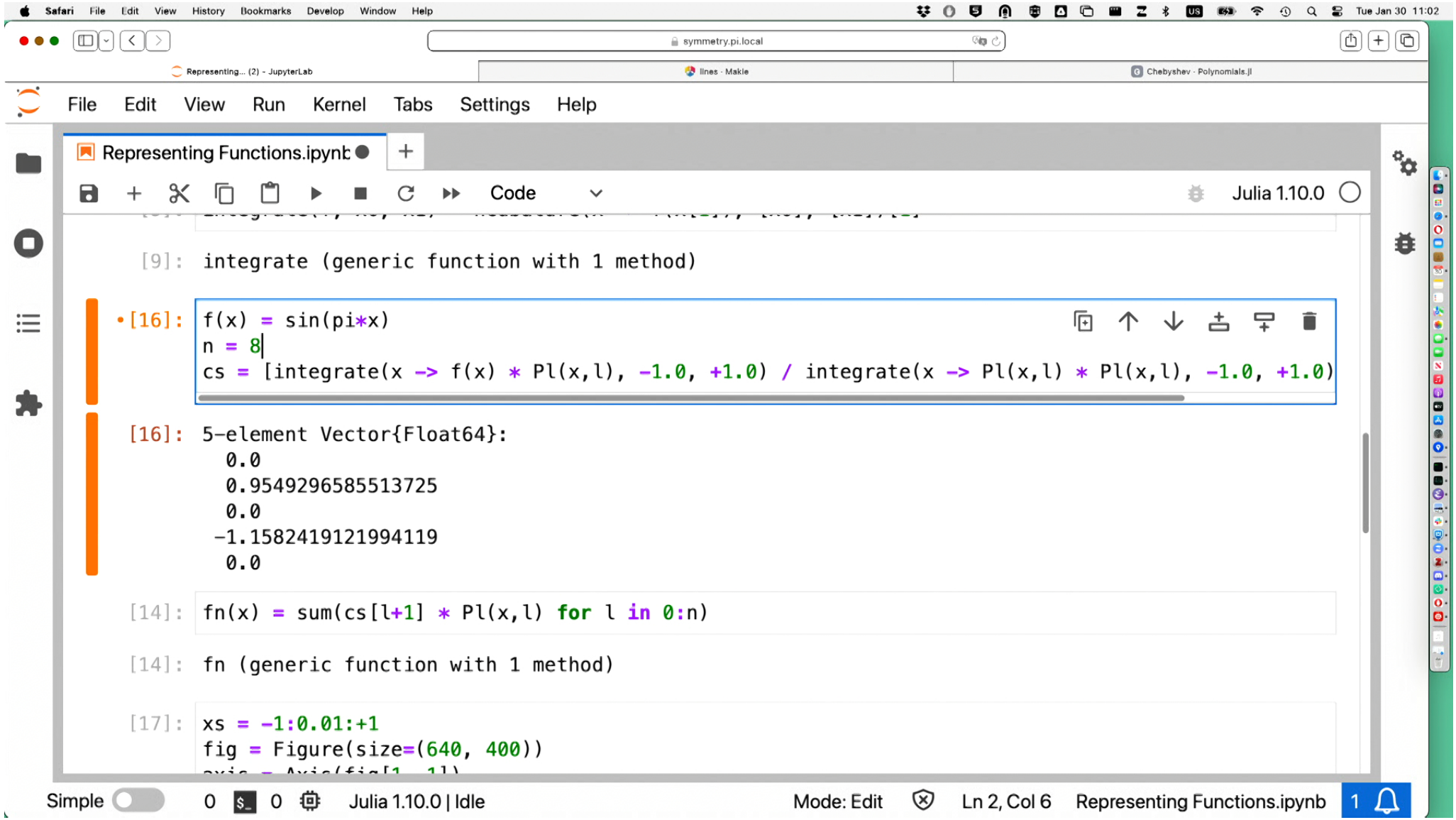
Representing Functions.ipynb
Code
Julia 1.10.0
1.0
0.5
0.0
−0.5
−1.0
−1.0
−0.5
0.0
0.5
1.0
Simple
0
0
Julia 1.10.0 | Idle
Mode: Command
Ln 1, Col 1
Representing Functions.ipynb
1


Safari File Edit View History Bookmarks Develop Window Help
Tue Jan 30 11:02
symmetry.pi.local
Representing... (2) - JupyterLab
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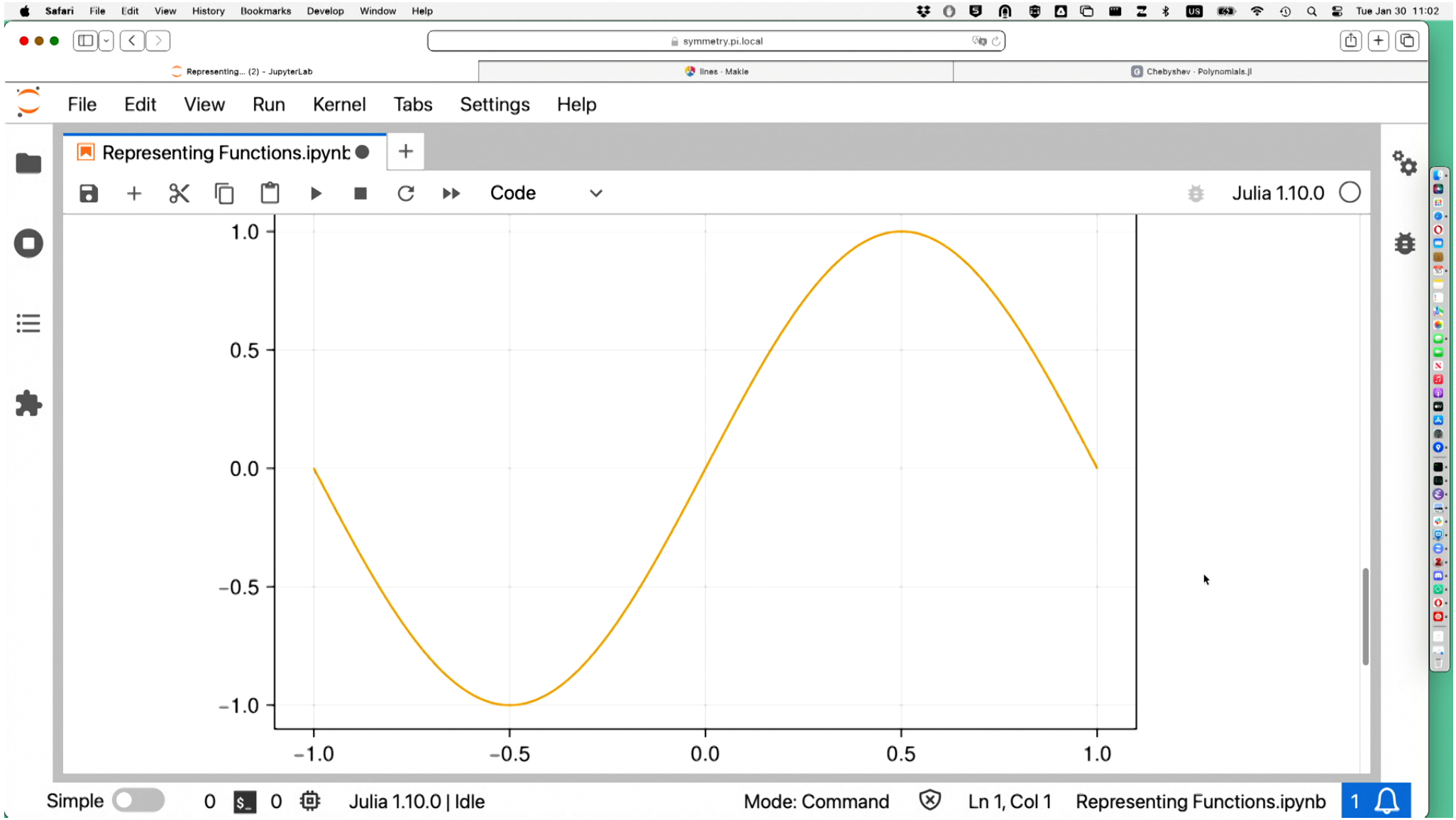
Representing Functions.ipynb
Code
Julia 1.10.0
[9]: integrate (generic function with 1 method)
[16]:
f(x) = sin(pi*x)
n = 8
cs = [integrate(x -> f(x) * Pl(x,l), -1.0, +1.0) / integrate(x -> Pl(x,l) * Pl(x,l), -1.0, +1.0)
[16]: 5-element Vector{Float64}:
0.0
0.9549296585513725
0.0
-1.1582419121994119
0.0
[14]: fn(x) = sum(cs[l+1] * Pl(x,l) for l in 0:n)
[14]: fn (generic function with 1 method)
[17]:
xs = -1:0.01:+1
fig = Figure(size=(640, 400))
Simple
0 0
Julia 1.10.0 | Idle
Mode: Edit
Ln 2, Col 6
Representing Functions.ipynb
1


Safari File Edit View History Bookmarks Develop Window Help
Tue Jan 30 11:02
symmetry.pi.local
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
File Edit View Run Kernel Tabs Settings Help
Representing Functions.ipynb
Code
Julia 1.10.0
1.0
0.5
0.0
−0.5
−1.0
−1.0
−0.5
0.0
0.5
1.0
Simple
0
0
Julia 1.10.0 | Idle
Mode: Command
Ln 1, Col 1
Representing Functions.ipynb
1

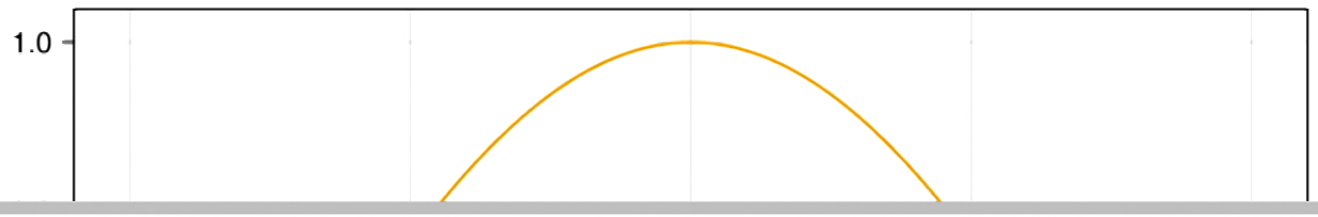
```
 0.0
-0.0011468766264065096
 0.0
 4.099752785713395e-5
```

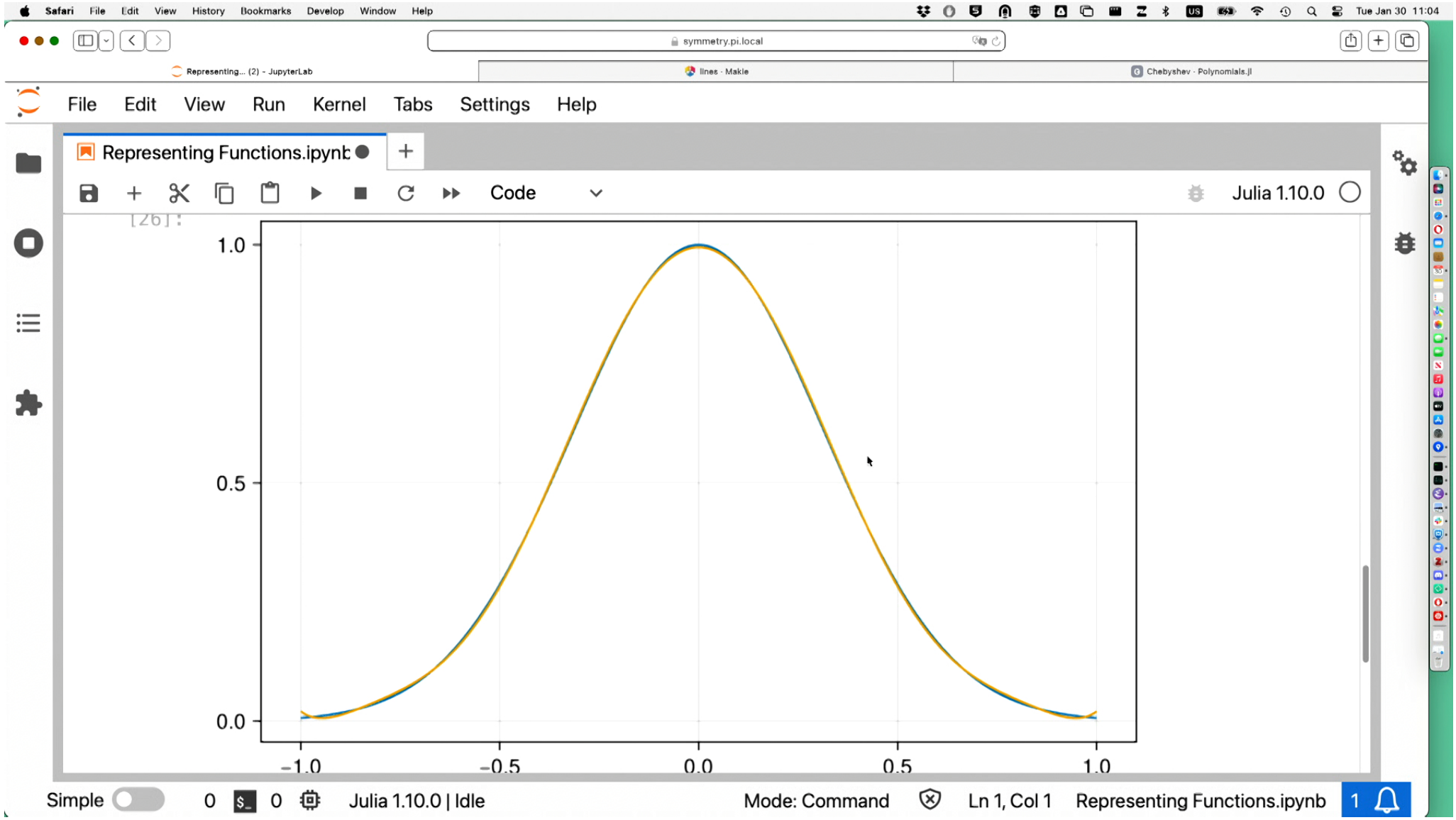
[22]:
```
fn(x) = sum(cs[l+1] * Pl(x,l) for l in 0:n)
```

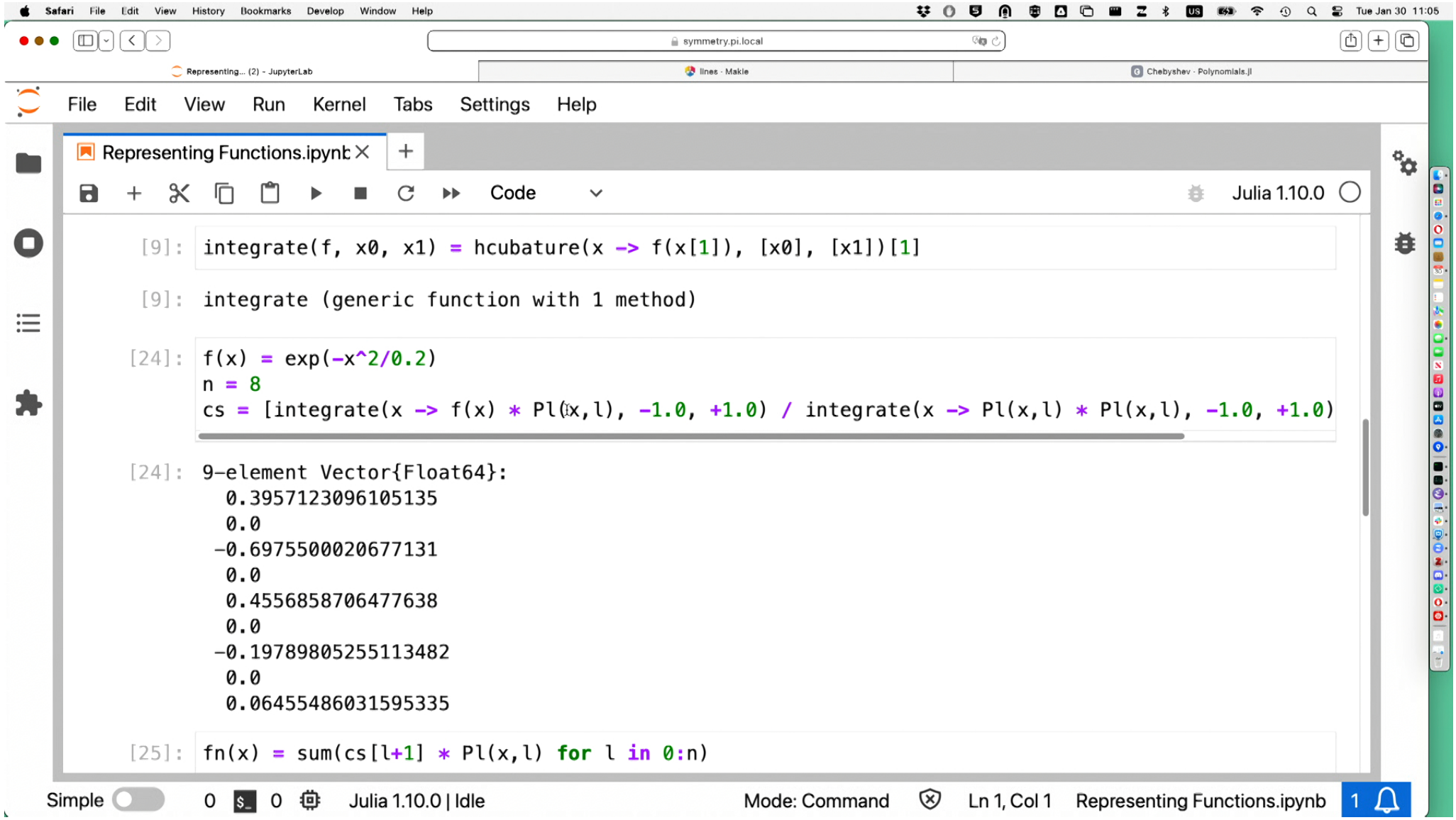
[22]:
```
fn (generic function with 1 method)
```

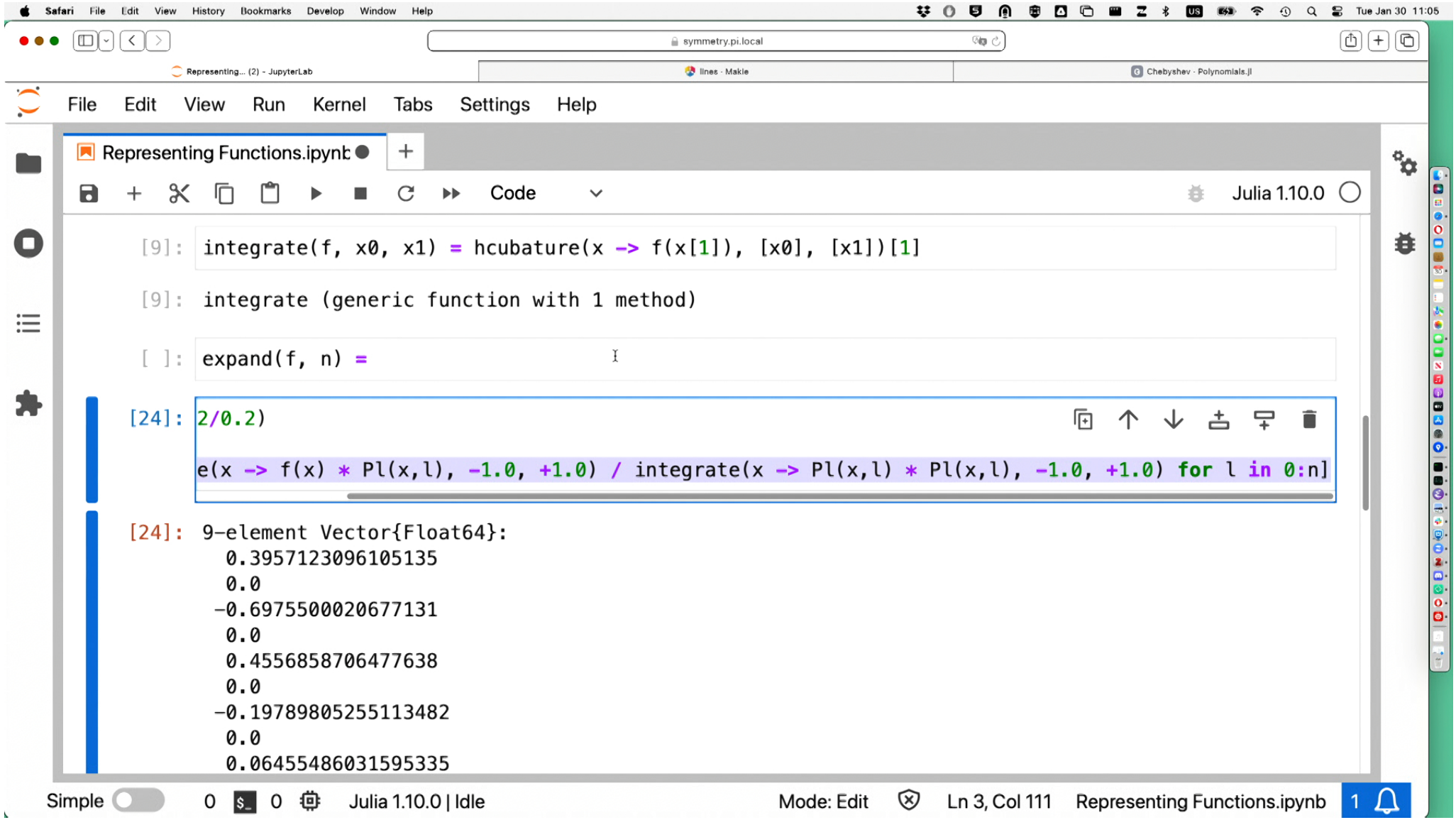
[23]:
```
xs = -1:0.01:+1
fig = Figure(size=(640, 400))
axis = Axis(fig[1, 1])
lines!(axis, xs, f.(xs))
lines!(axis, xs, fn.(xs))
fig
```

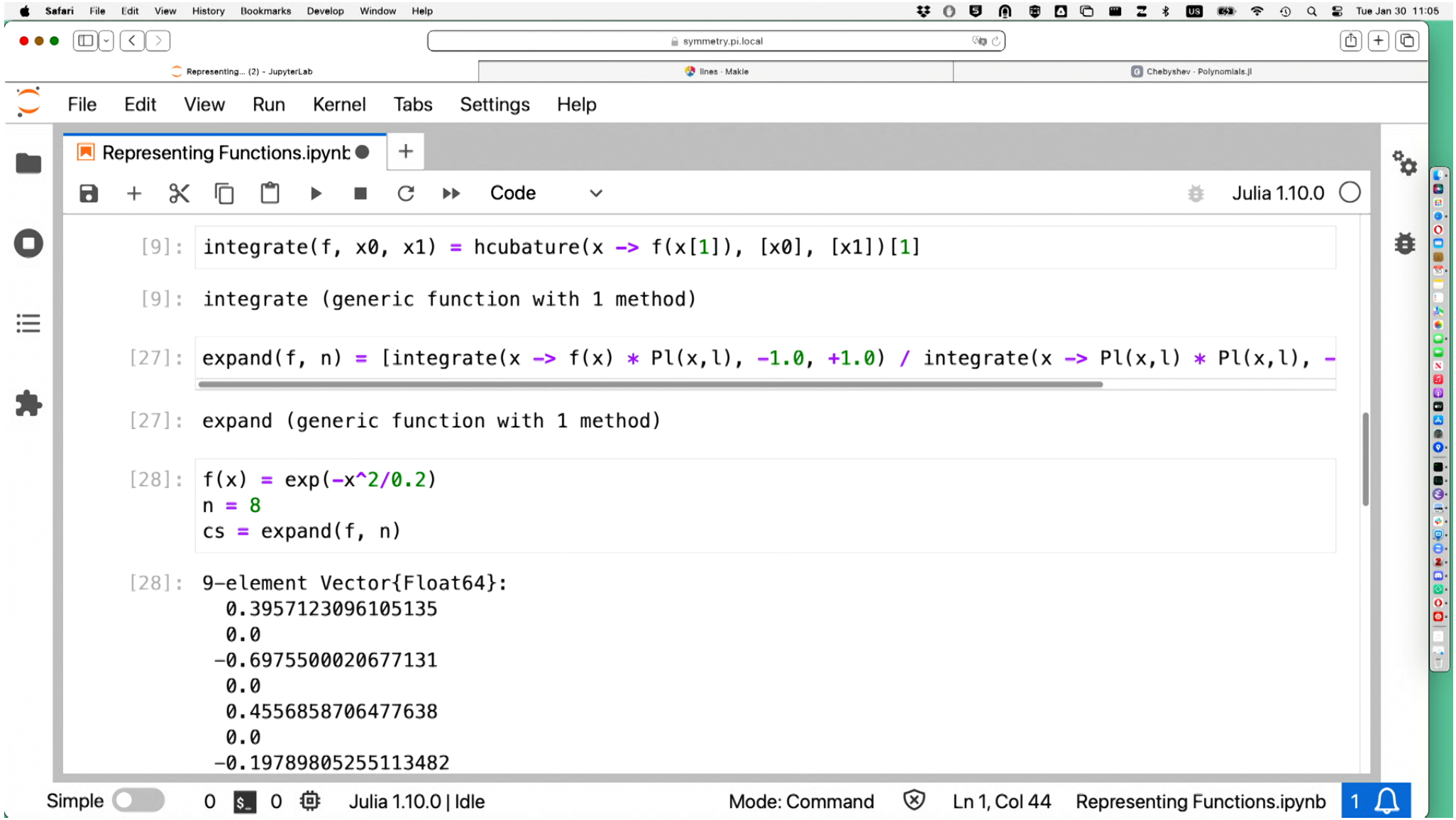
[23]:

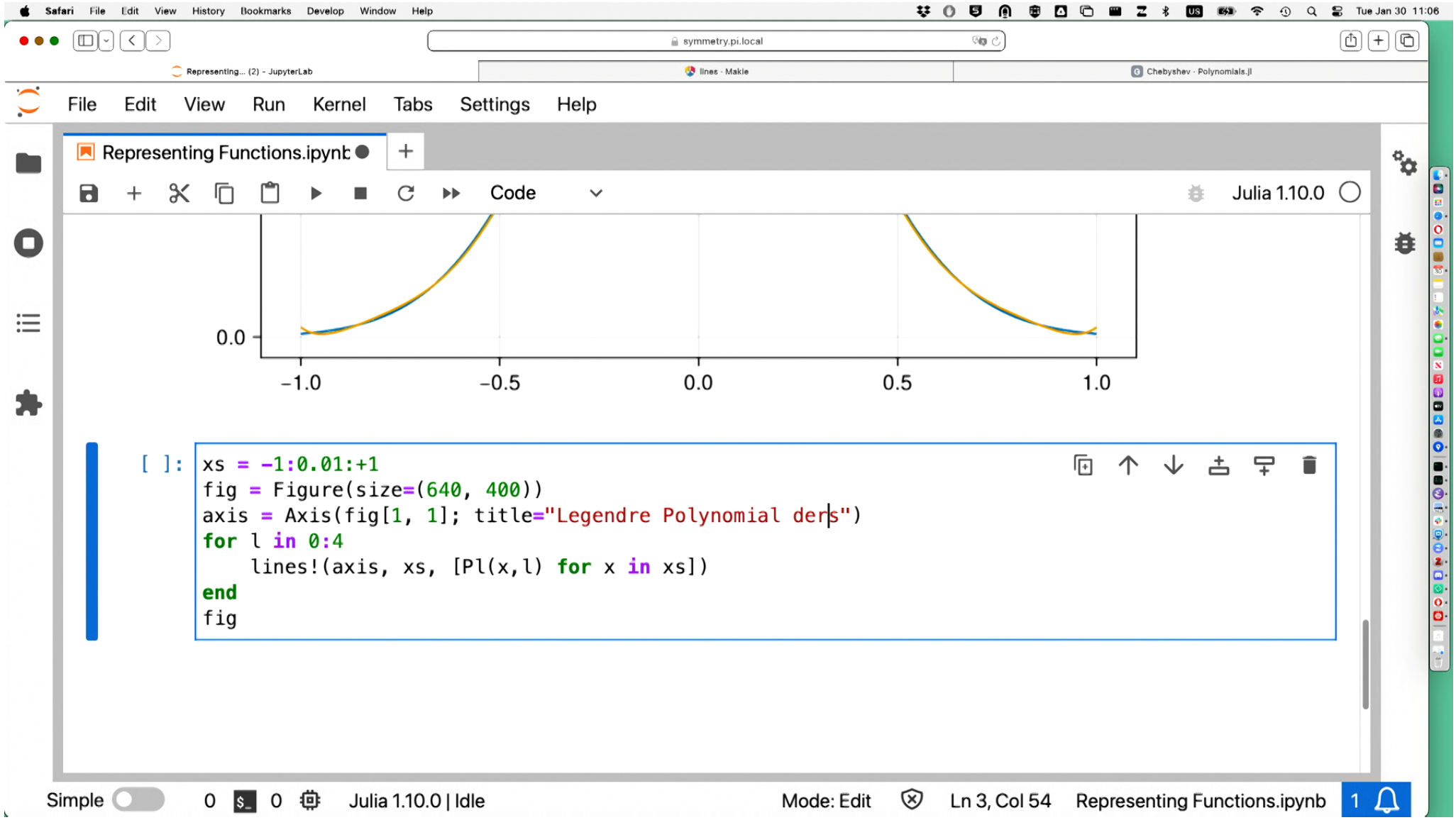


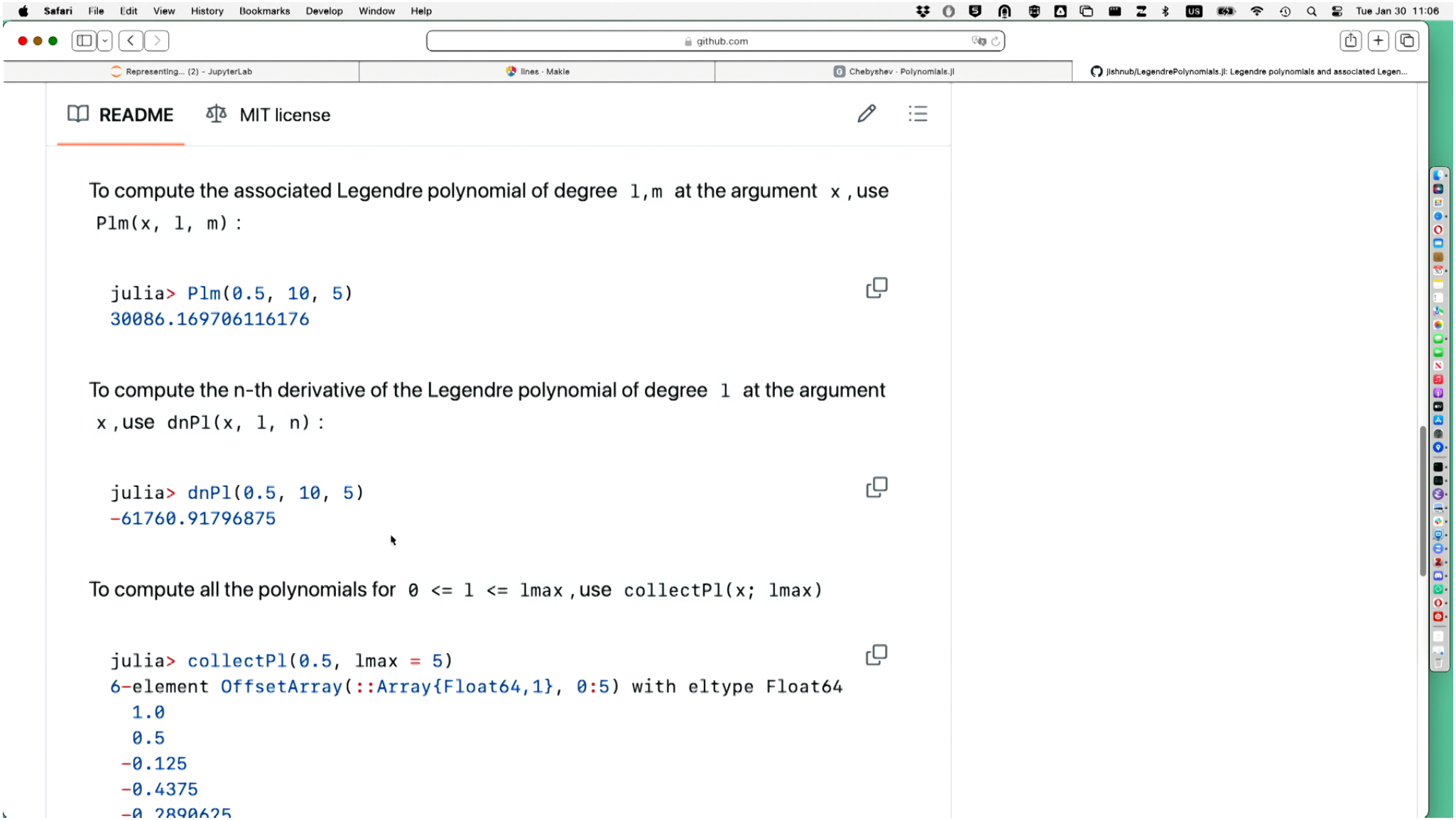

Safari File Edit View History Bookmarks Develop Window Help
Tue Jan 30 11:04
symmetry.pi.local
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
File Edit View Run Kernel Tabs Settings Help
Representing Functions.ipynb
Code
Julia 1.10.0
[26]:
1.0
0.5
0.0
−1.0
−0.5
0.0
0.5
1.0
Simple
0
0
Julia 1.10.0 | Idle
Mode: Command
Ln 1, Col 1
Representing Functions.ipynb
1

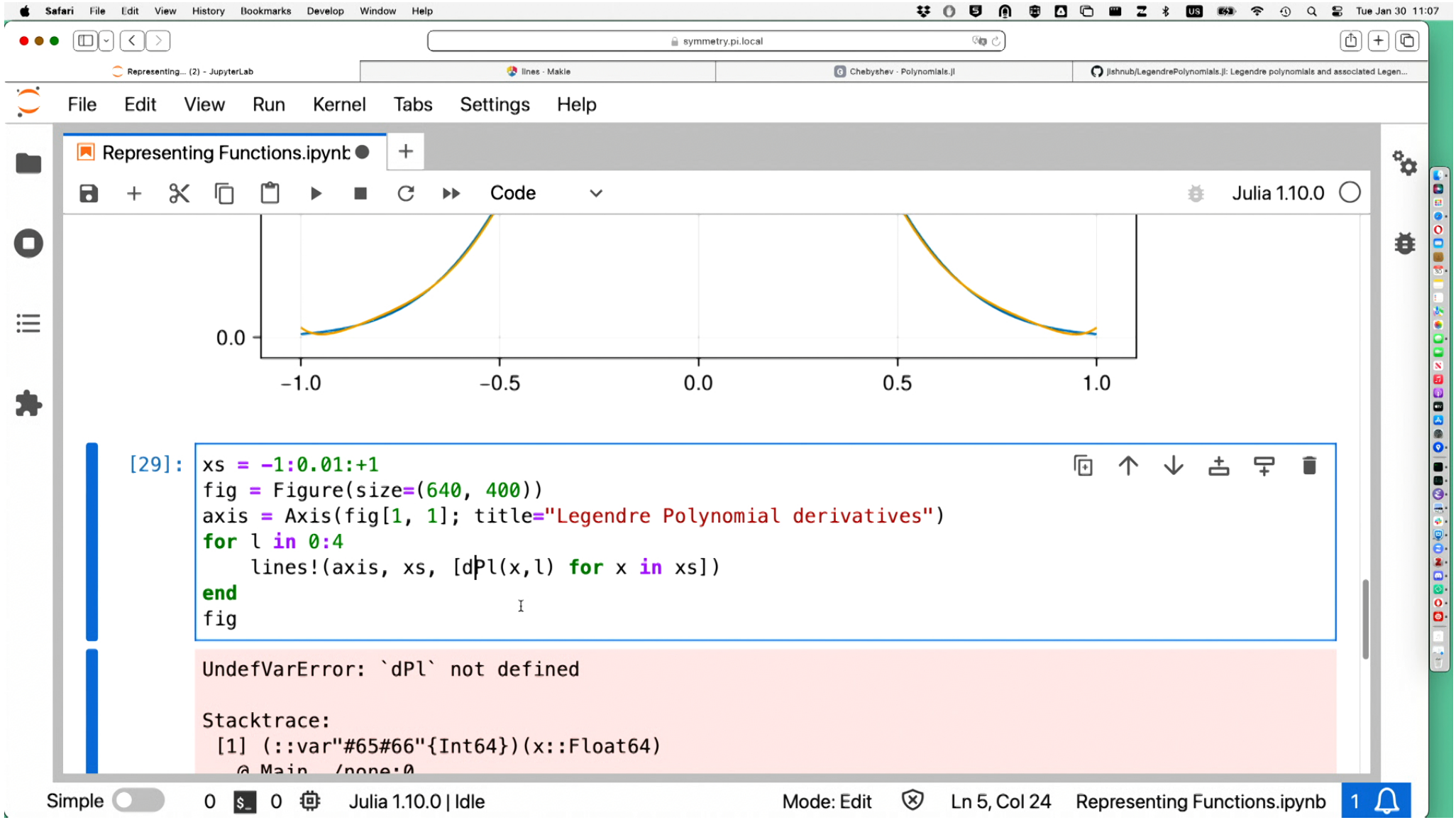

Safari File Edit View History Bookmarks Develop Window Help
Tue Jan 30 11:05
symmetry.pi.local
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
File Edit View Run Kernel Tabs Settings Help
Representing Functions.ipynb
Code
Julia 1.10.0
[9]: integrate(f, x0, x1) = hcubature(x -> f(x[1]), [x0], [x1])[1]
[9]: integrate (generic function with 1 method)
[24]: f(x) = exp(-x^2/0.2)
n = 8
cs = [integrate(x -> f(x) * Pl(x,l), -1.0, +1.0) / integrate(x -> Pl(x,l) * Pl(x,l), -1.0, +1.0)
[24]: 9-element Vector{Float64}:
0.3957123096105135
0.0
-0.6975500020677131
0.0
0.4556858706477638
0.0
-0.19789805255113482
0.0
0.06455486031595335
[25]: fn(x) = sum(cs[l+1] * Pl(x,l) for l in 0:n)
Simple
0 0
Julia 1.10.0 | Idle
Mode: Command
Ln 1, Col 1
Representing Functions.ipynb
1

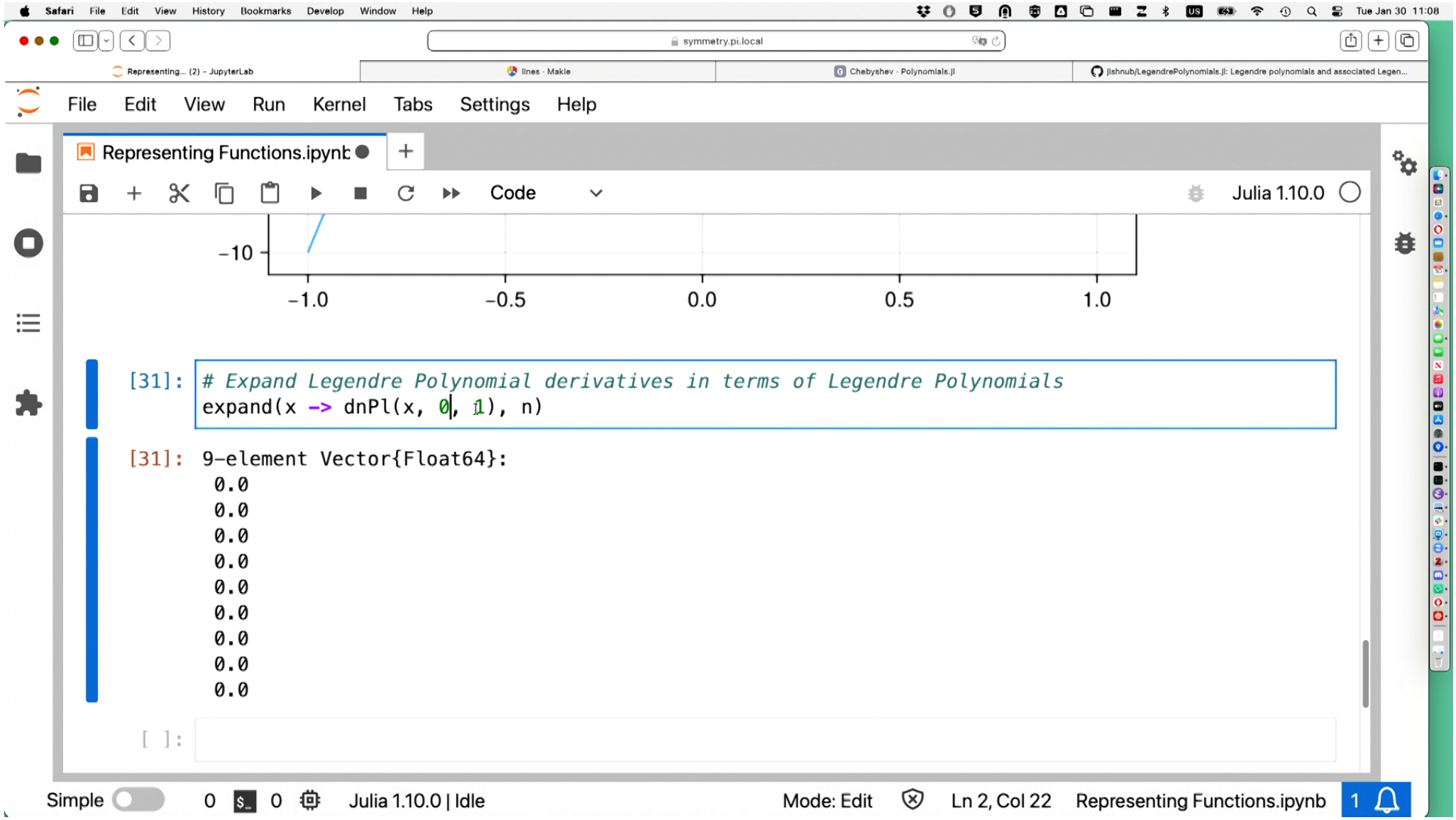

Safari File Edit View History Bookmarks Develop Window Help
Tue Jan 30 11:05
symmetry.pi.local
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
File Edit View Run Kernel Tabs Settings Help
Representing Functions.ipynb
Code
Julia 1.10.0
[9]: integrate(f, x0, x1) = hcubature(x -> f(x[1]), [x0], [x1])[1]
[9]: integrate (generic function with 1 method)
[ ]: expand(f, n) =
[24]: 2/0.2)
e(x -> f(x) * Pl(x,l), -1.0, +1.0) / integrate(x -> Pl(x,l) * Pl(x,l), -1.0, +1.0) for l in 0:n]
[24]: 9-element Vector{Float64}:
0.3957123096105135
0.0
-0.6975500020677131
0.0
0.4556858706477638
0.0
-0.19789805255113482
0.0
0.06455486031595335
Simple
0
0
Julia 1.10.0 | Idle
Mode: Edit
Ln 3, Col 111
Representing Functions.ipynb
1

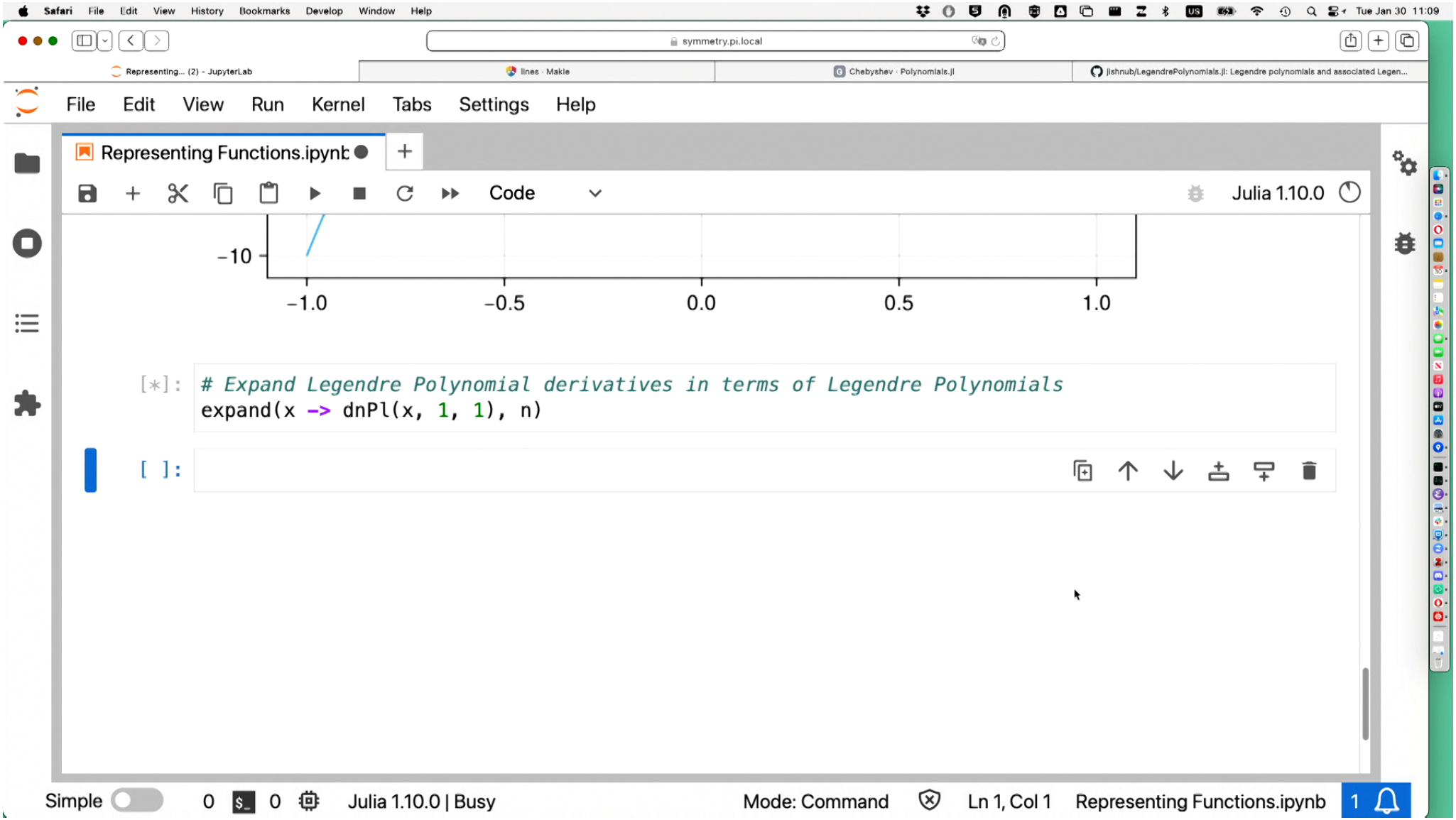

Safari File Edit View History Bookmarks Develop Window Help
Tue Jan 30 11:05
symmetry.pi.local
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
File Edit View Run Kernel Tabs Settings Help
Representing Functions.ipynb
Code
Julia 1.10.0
[9]: integrate(f, x0, x1) = hcubature(x -> f(x[1]), [x0], [x1])[1]
[9]: integrate (generic function with 1 method)
[27]: expand(f, n) = [integrate(x -> f(x) * Pl(x,l), -1.0, +1.0) / integrate(x -> Pl(x,l) * Pl(x,l), -
[27]: expand (generic function with 1 method)
[28]: f(x) = exp(-x^2/0.2)
n = 8
cs = expand(f, n)
[28]: 9-element Vector{Float64}:
0.3957123096105135
0.0
-0.6975500020677131
0.0
0.4556858706477638
0.0
-0.19789805255113482
Simple
0
0
Julia 1.10.0 | Idle
Mode: Command
Ln 1, Col 44
Representing Functions.ipynb
1

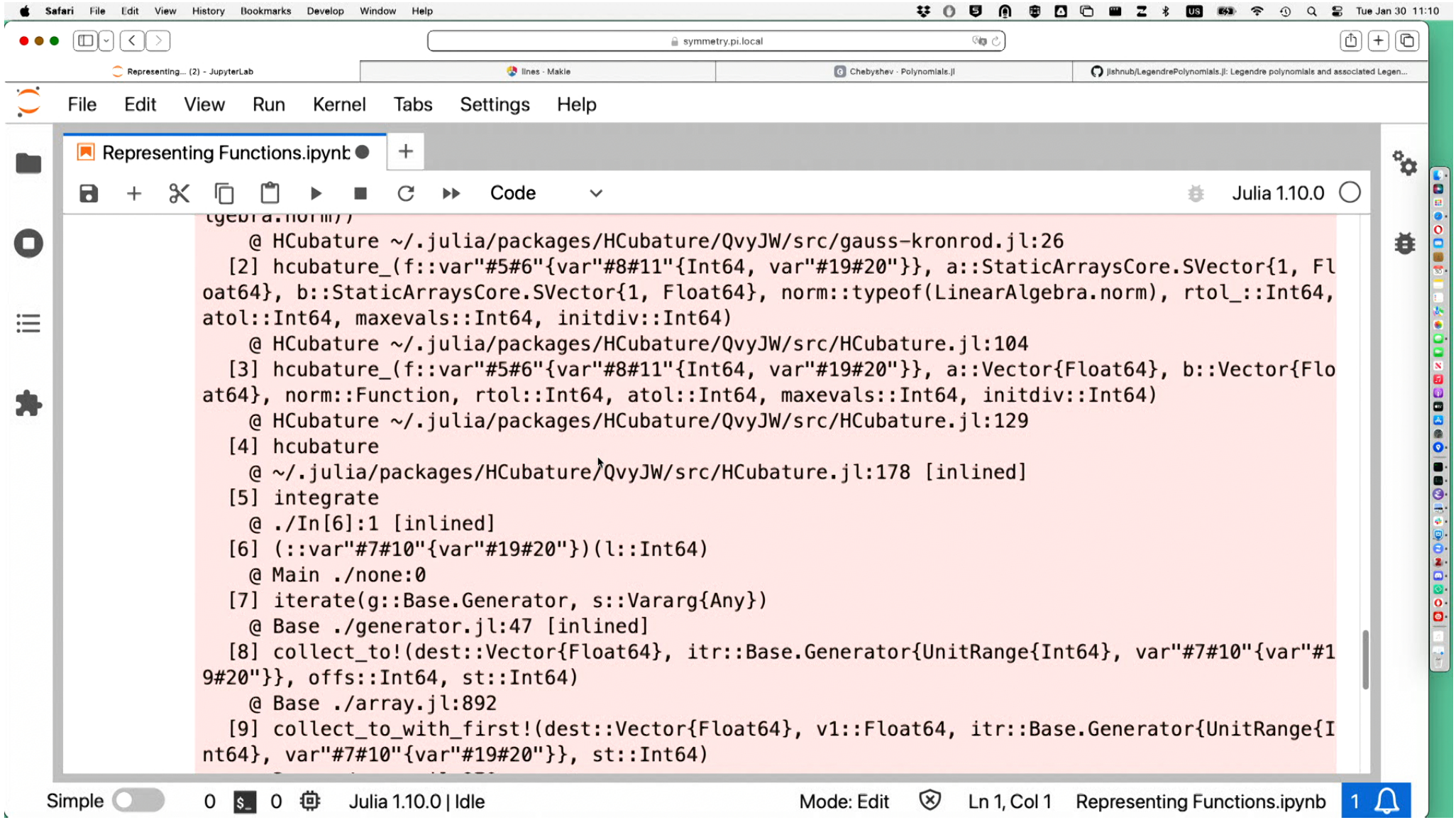

Safari File Edit View History Bookmarks Develop Window Help
Tue Jan 30 11:06
symmetry.pi.local
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
File Edit View Run Kernel Tabs Settings Help
Representing Functions.ipynb
Code
Julia 1.10.0
0.0
−1.0
−0.5
0.0
0.5
1.0
[ ]:
xs = -1:0.01:+1
fig = Figure(size=(640, 400))
axis = Axis(fig[1, 1]; title="Legendre Polynomial ders")
for l in 0:4
lines!(axis, xs, [Pl(x,l) for x in xs])
end
fig
Simple
0
0
Julia 1.10.0 | Idle
Mode: Edit
Ln 3, Col 54
Representing Functions.ipynb
1

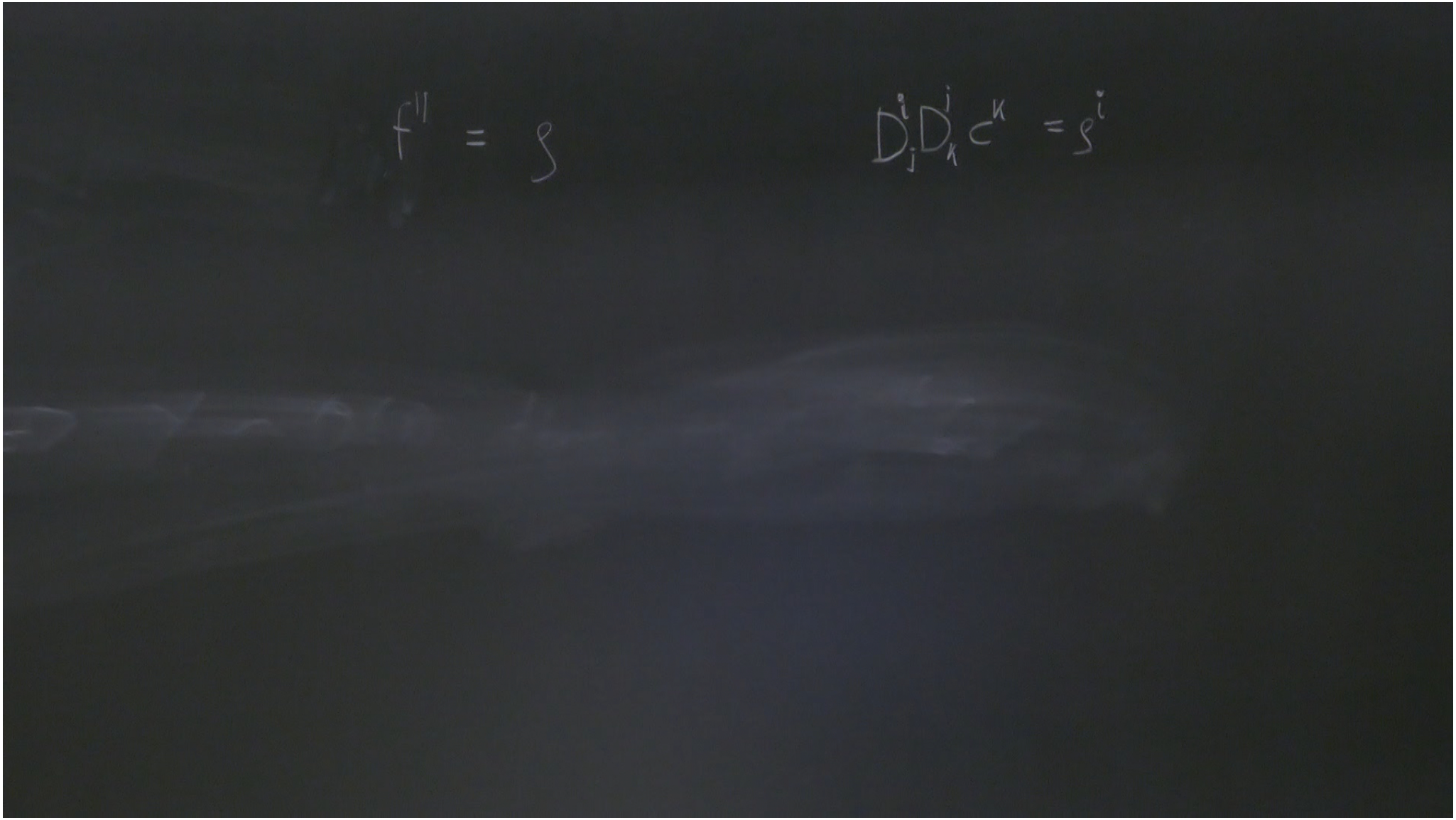

Safari File Edit View History Bookmarks Develop Window Help
Tue Jan 30 11:06
github.com
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
jlshnub/LegendrePolynomials.jl: Legendre polynomials and associated Legen...
README
MIT license
To compute the associated Legendre polynomial of degree l,m at the argument x, use Plm(x, l, m):
julia> Plm(0.5, 10, 5)
30086.169706116176
To compute the n-th derivative of the Legendre polynomial of degree l at the argument x, use dnPl(x, l, n):
julia> dnPl(0.5, 10, 5)
-61760.91796875
To compute all the polynomials for 0 <= l <= lmax, use collectPl(x; lmax)
julia> collectPl(0.5, lmax = 5)
6-element OffsetArray(::Array{Float64,1}, 0:5) with eltype Float64
1.0
0.5
-0.125
-0.4375
-0.2890625


Representing Functions.ipynb
Code
Julia 1.10.0
0.0
−1.0
−0.5
0.0
0.5
1.0
[29]:
xs = -1:0.01:+1
fig = Figure(size=(640, 400))
axis = Axis(fig[1, 1]; title="Legendre Polynomial derivatives")
for l in 0:4
lines!(axis, xs, [dPl(x,l) for x in xs])
end
fig
UndefVarError: `dPl` not defined
Stacktrace:
[1] (::var"#65#66"{Int64})(x::Float64)
Simple
Julia 1.10.0 | Idle
Mode: Edit
Ln 5, Col 24
Representing Functions.ipynb


Safari File Edit View History Bookmarks Develop Window Help
Tue Jan 30 11:08
symmetry.pi.local
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
jlshnub/LegendrePolynomials.jl: Legendre polynomials and associated Legen...
File Edit View Run Kernel Tabs Settings Help
Representing Functions.ipynb
Code
Julia 1.10.0
−10
−1.0
−0.5
0.0
0.5
1.0
[31]:
# Expand Legendre Polynomial derivatives in terms of Legendre Polynomials
expand(x -> dnPl(x, 0, 1), n)
[31]:
9-element Vector{Float64}:
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
[ ]:
Simple
0
0
Julia 1.10.0 | Idle
Mode: Edit
Ln 2, Col 22
Representing Functions.ipynb
1


Safari File Edit View History Bookmarks Develop Window Help
Tue Jan 30 11:09
symmetry.pi.local
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
jlshnub/LegendrePolynomials.jl: Legendre polynomials and associated Legen...
File Edit View Run Kernel Tabs Settings Help
Representing Functions.ipynb
Code
Julia 1.10.0
−10
−1.0
−0.5
0.0
0.5
1.0
[*]:
# Expand Legendre Polynomial derivatives in terms of Legendre Polynomials
expand(x -> dnPl(x, 1, 1), n)
[ ]:
Simple
0
0
Julia 1.10.0 | Busy
Mode: Command
Ln 1, Col 1
Representing Functions.ipynb
1


Safari File Edit View History Bookmarks Develop Window Help
Tue Jan 30 11:10
symmetry.pi.local
Representing... (2) - JupyterLab
lines · Makie
Chebyshev · Polynomials.jl
jishnub/LegendrePolynomials.jl: Legendre polynomials and associated Legen...
File Edit View Run Kernel Tabs Settings Help
Representing Functions.ipynb
Code
Julia 1.10.0
@ HCubature ~/.julia/packages/HCubature/QvyJW/src/gauss-kronrod.jl:26
[2] hcubature_(f::var"#5#6"{var"#8#11"{Int64, var"#19#20"}}, a::StaticArraysCore.SVector{1, Float64}, b::StaticArraysCore.SVector{1, Float64}, norm::typeof(LinearAlgebra.norm), rtol_::Int64, atol::Int64, maxevals::Int64, initdiv::Int64)
@ HCubature ~/.julia/packages/HCubature/QvyJW/src/HCubature.jl:104
[3] hcubature_(f::var"#5#6"{var"#8#11"{Int64, var"#19#20"}}, a::Vector{Float64}, b::Vector{Float64}, norm::Function, rtol::Int64, atol::Int64, maxevals::Int64, initdiv::Int64)
@ HCubature ~/.julia/packages/HCubature/QvyJW/src/HCubature.jl:129
[4] hcubature
@ ~/.julia/packages/HCubature/QvyJW/src/HCubature.jl:178 [inlined]
[5] integrate
@ ./In[6]:1 [inlined]
[6] (::var"#7#10"{var"#19#20"})(l::Int64)
@ Main ./none:0
[7] iterate(g::Base.Generator, s::Vararg{Any})
@ Base ./generator.jl:47 [inlined]
[8] collect_to!(dest::Vector{Float64}, itr::Base.Generator{UnitRange{Int64}, var"#7#10"{var"#19#20"}}, offs::Int64, st::Int64)
@ Base ./array.jl:892
[9] collect_to_with_first!(dest::Vector{Float64}, v1::Float64, itr::Base.Generator{UnitRange{Int64}, var"#7#10"{var"#19#20"}}, st::Int64)
Simple
0
0
Julia 1.10.0 | Idle
Mode: Edit
Ln 1, Col 1
Representing Functions.ipynb
1


$f'' = \rho$
$D^i_j D^j_k c^k = \rho^i$