Title: Lecture - Numerical Methods, PHYS 777

Speakers: Erik Schnetter, Dustin Lang

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Subject: Other

Date: January 06, 2025 - 2:00 PM

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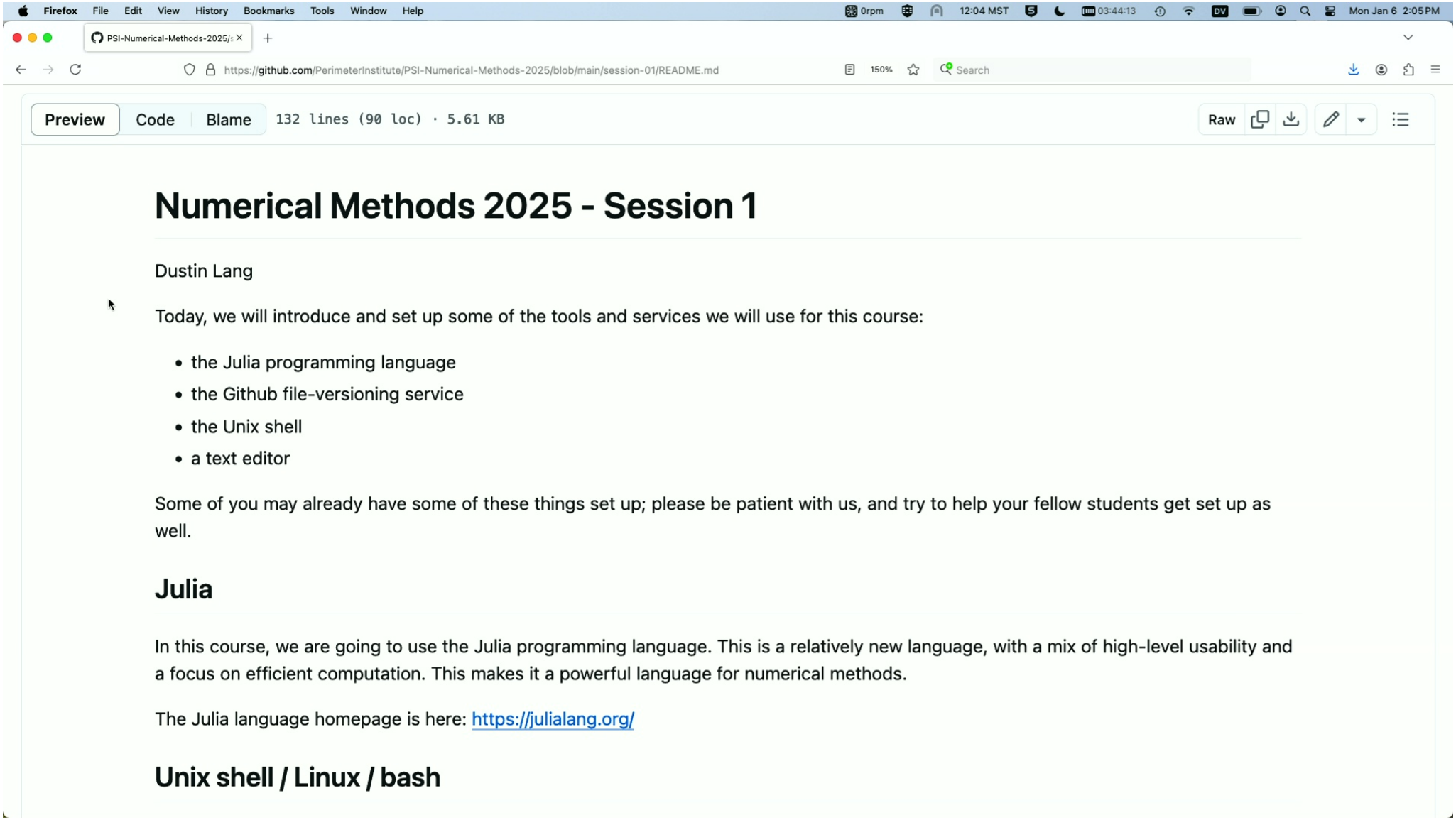


Numerical Methods 2025 - Session 1

Dustin Lang

Today, we will introduce and set up some of the tools and services we will use for this course:

- the Julia programming language
- the Github file-versioning service
- the Unix shell
- a text editor

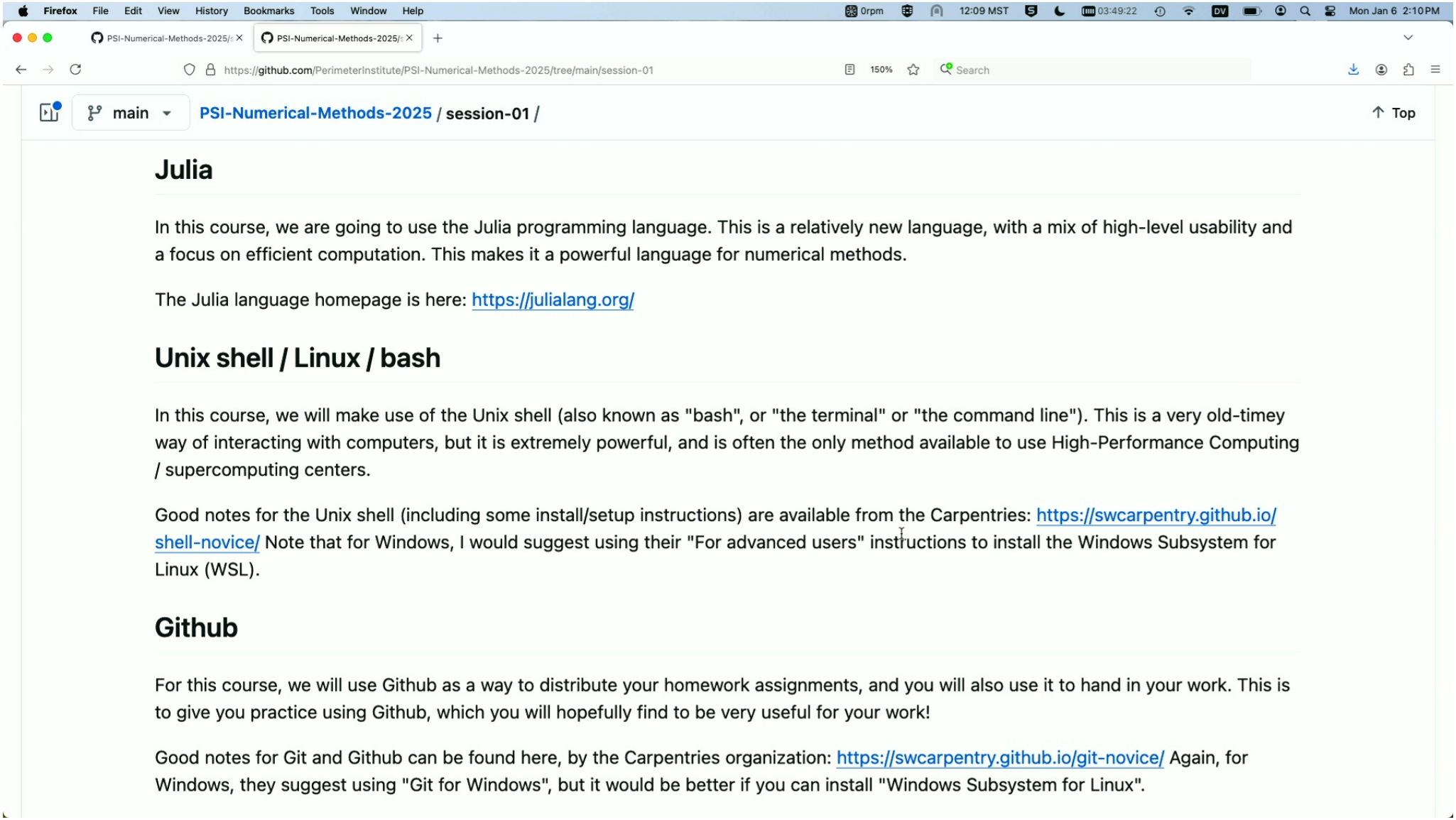
Some of you may already have some of these things set up; please be patient with us, and try to help your fellow students get set up as well.

Julia

In this course, we are going to use the Julia programming language. This is a relatively new language, with a mix of high-level usability and a focus on efficient computation. This makes it a powerful language for numerical methods.

The Julia language homepage is here: https://julialang.org/

Unix shell / Linux / bash



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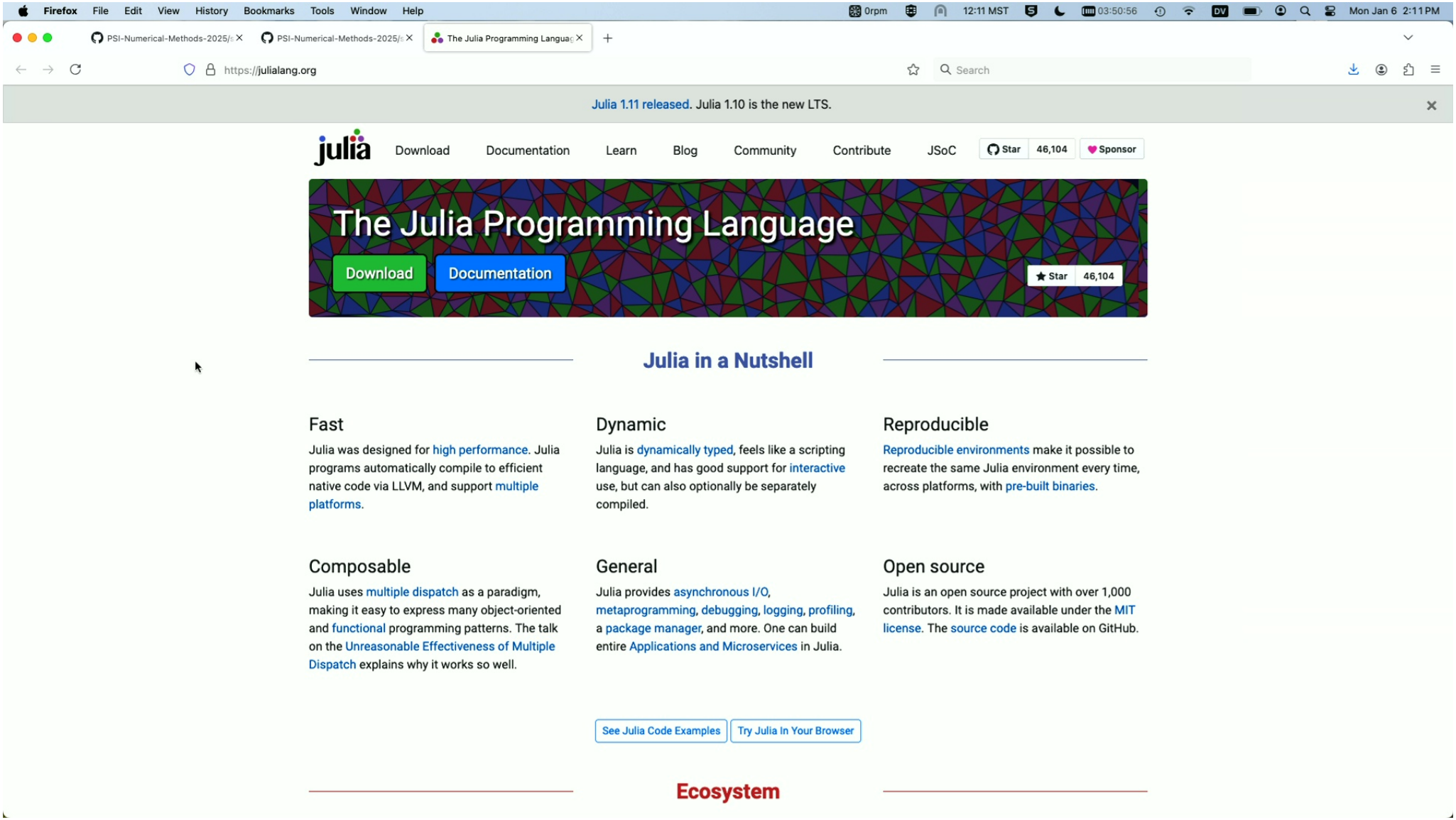
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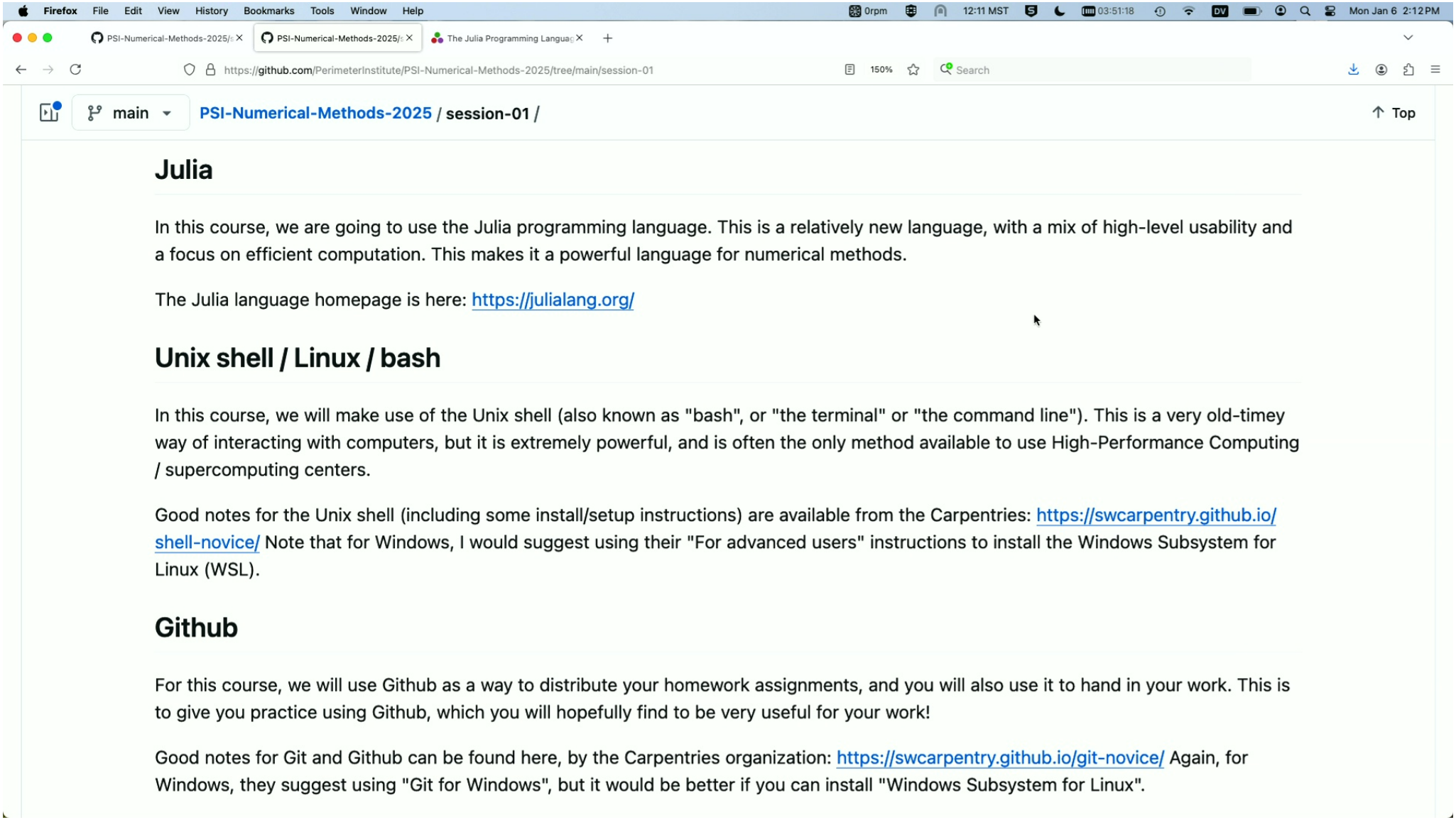
PSI-Numerical-Methods-2025/
The Julia Programming Langua
https://julialang.org
Search
Julia 1.11 released. Julia 1.10 is the new LTS.
julia
Download
Documentation
Learn
Blog
Community
Contribute
JSoC
Star 46,104
Sponsor
The Julia Programming Language
Download
Documentation
Star 46,104
Julia in a Nutshell
Fast
Julia was designed for high performance. Julia programs automatically compile to efficient native code via LLVM, and support multiple platforms.
Dynamic
Julia is dynamically typed, feels like a scripting language, and has good support for interactive use, but can also optionally be separately compiled.
Reproducible
Reproducible environments make it possible to recreate the same Julia environment every time, across platforms, with pre-built binaries.
Composable
Julia uses multiple dispatch as a paradigm, making it easy to express many object-oriented and functional programming patterns. The talk on the Unreasonable Effectiveness of Multiple Dispatch explains why it works so well.
General
Julia provides asynchronous I/O, metaprogramming, debugging, logging, profiling, a package manager, and more. One can build entire Applications and Microservices in Julia.
Open source
Julia is an open source project with over 1,000 contributors. It is made available under the MIT license. The source code is available on GitHub.
See Julia Code Examples
Try Julia In Your Browser
Ecosystem



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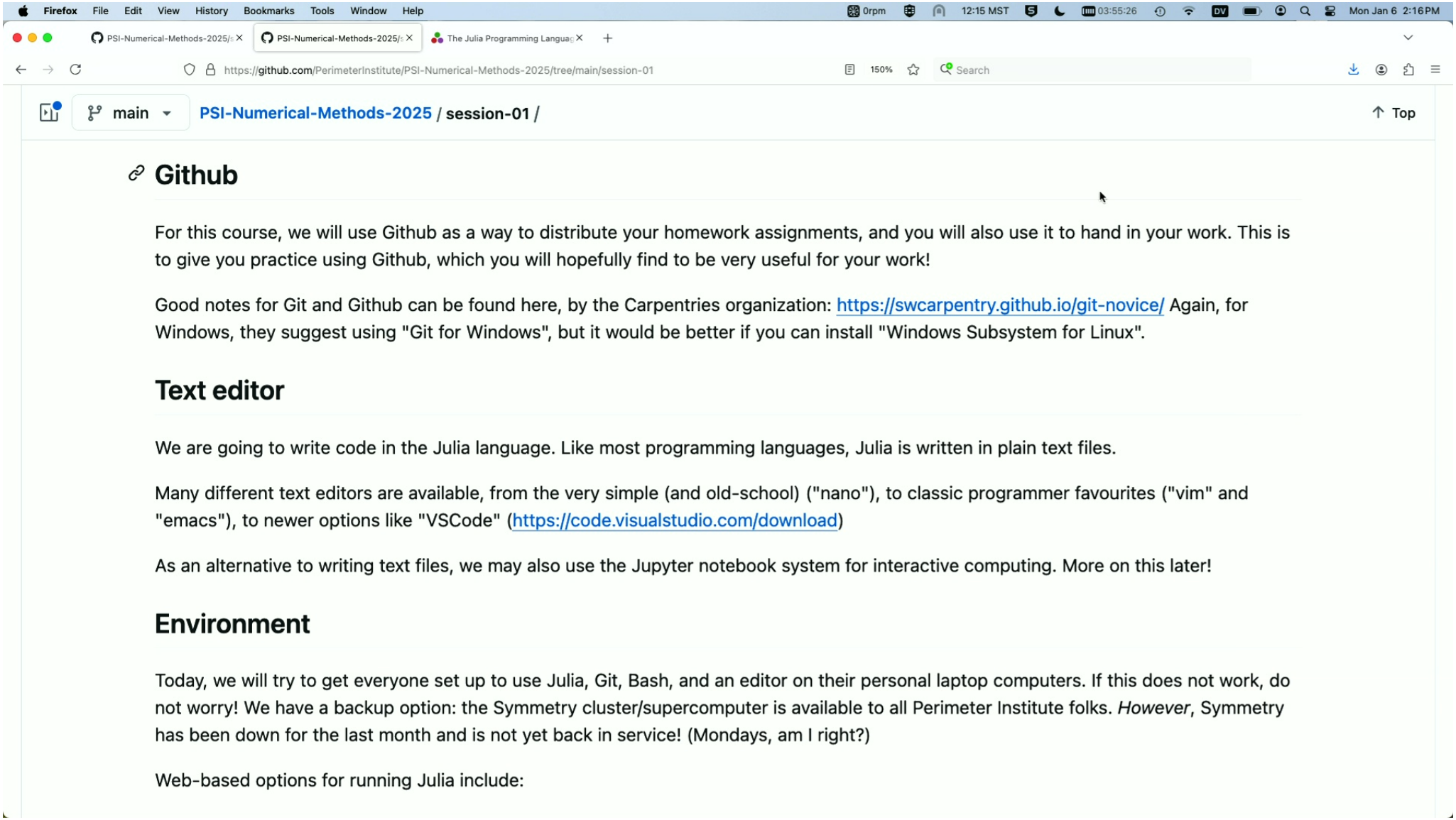

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Text editor

We are going to write code in the Julia language. Like most programming languages, Julia is written in plain text files.

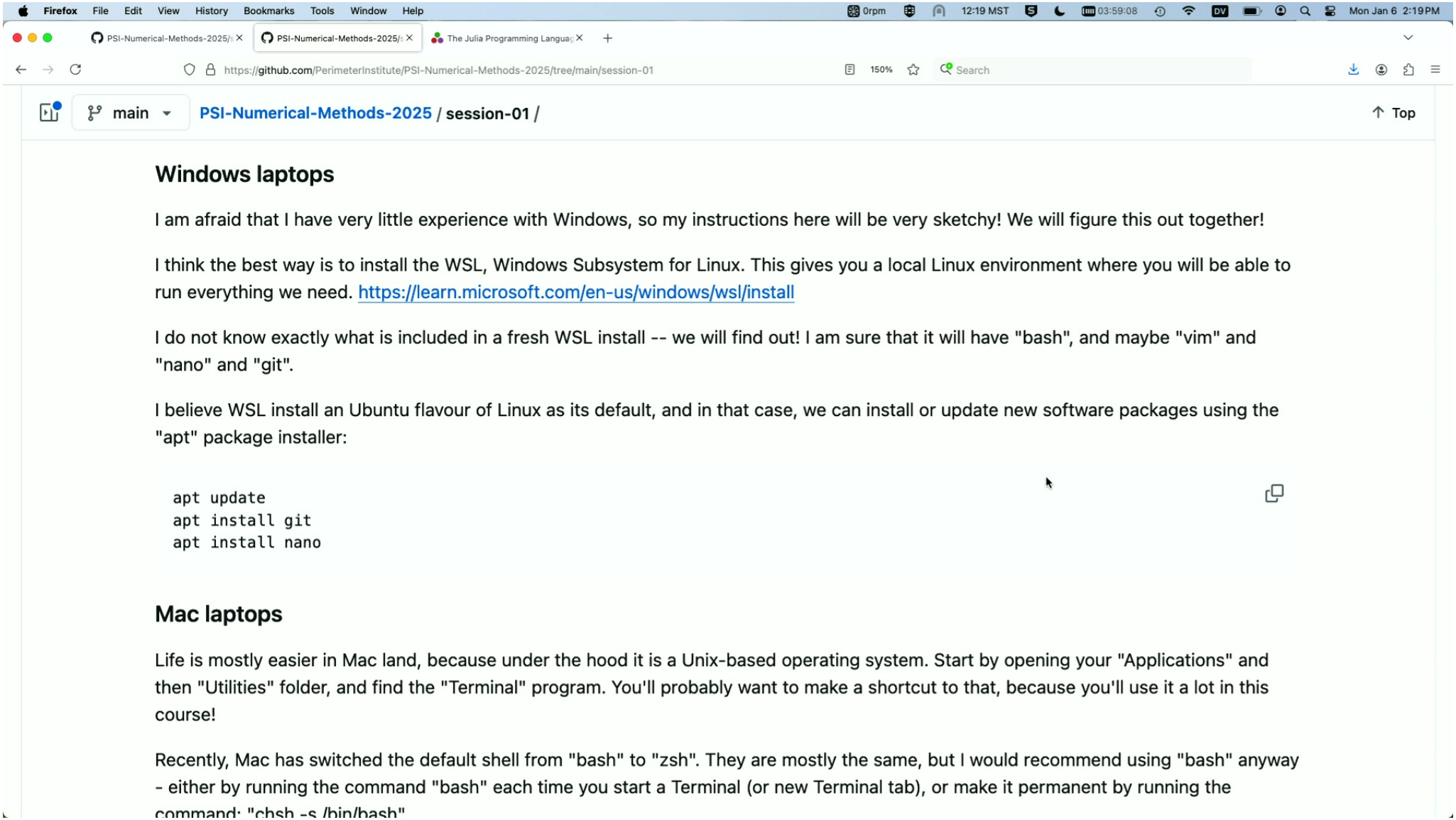
Many different text editors are available, from the very simple (and old-school) ("nano"), to classic programmer favourites ("vim" and "emacs"), to newer options like "VSCode" (https://code.visualstudio.com/download)

As an alternative to writing text files, we may also use the Jupyter notebook system for interactive computing. More on this later!

Environment

Today, we will try to get everyone set up to use Julia, Git, Bash, and an editor on their personal laptop computers. If this does not work, do not worry! We have a backup option: the Symmetry cluster/supercomputer is available to all Perimeter Institute folks. *However*, Symmetry has been down for the last month and is not yet back in service! (Mondays, am I right?)

Web-based options for running Julia include:



Windows laptops

I am afraid that I have very little experience with Windows, so my instructions here will be very sketchy! We will figure this out together!

I think the best way is to install the WSL, Windows Subsystem for Linux. This gives you a local Linux environment where you will be able to run everything we need. https://learn.microsoft.com/en-us/windows/wsl/install

I do not know exactly what is included in a fresh WSL install -- we will find out! I am sure that it will have "bash", and maybe "vim" and "nano" and "git".

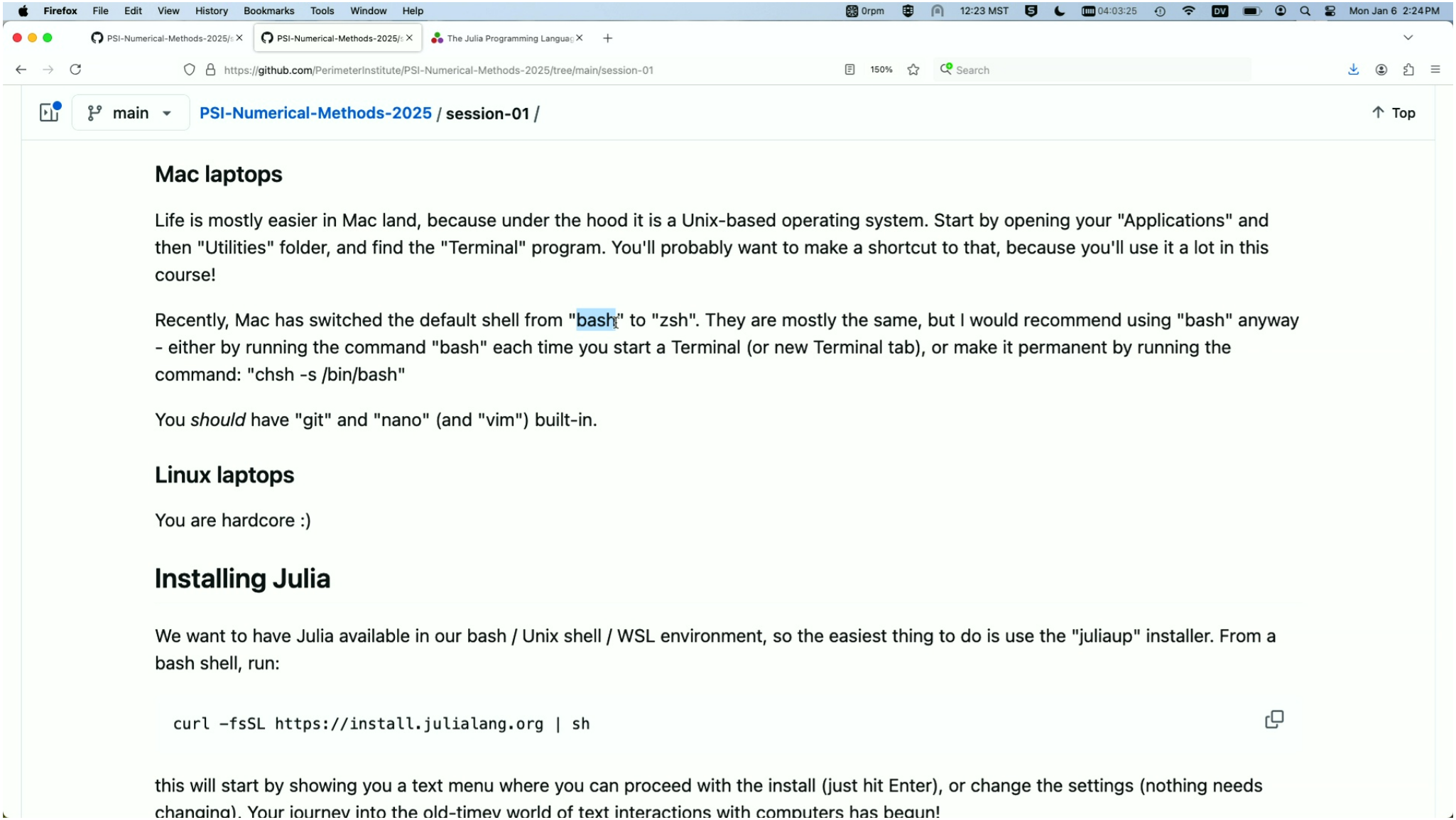
I believe WSL install an Ubuntu flavour of Linux as its default, and in that case, we can install or update new software packages using the "apt" package installer:

```
apt update
apt install git
apt install nano
```

Mac laptops

Life is mostly easier in Mac land, because under the hood it is a Unix-based operating system. Start by opening your "Applications" and then "Utilities" folder, and find the "Terminal" program. You'll probably want to make a shortcut to that, because you'll use it a lot in this course!

Recently, Mac has switched the default shell from "bash" to "zsh". They are mostly the same, but I would recommend using "bash" anyway - either by running the command "bash" each time you start a Terminal (or new Terminal tab), or make it permanent by running the command: "chsh -s /bin/bash"


Firefox File Edit View History Bookmarks Tools Window Help
Mon Jan 6 2:24 PM
https://github.com/PerimeterInstitute/PSI-Numerical-Methods-2025/tree/main/session-01
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You should have "git" and "nano" (and "vim") built-in.
Linux laptops
You are hardcore :)
Installing Julia
We want to have Julia available in our bash / Unix shell / WSL environment, so the easiest thing to do is use the "juliaup" installer. From a bash shell, run:
curl -fsSL https://install.julialang.org | sh
this will start by showing you a text menu where you can proceed with the install (just hit Enter), or change the settings (nothing needs changing). Your journey into the old-timey world of text interactions with computers has begun!


Terminal Shell Edit View Window Help
Mon Jan 6 2:25 PM
dstn — bash — 80×24
Last login: Mon Jan 6 12:05:02 on ttys023
The default interactive shell is now zsh.
To update your account to use zsh, please run `chsh -s /bin/zsh`.
For more details, please visit https://support.apple.com/kb/HT208050.
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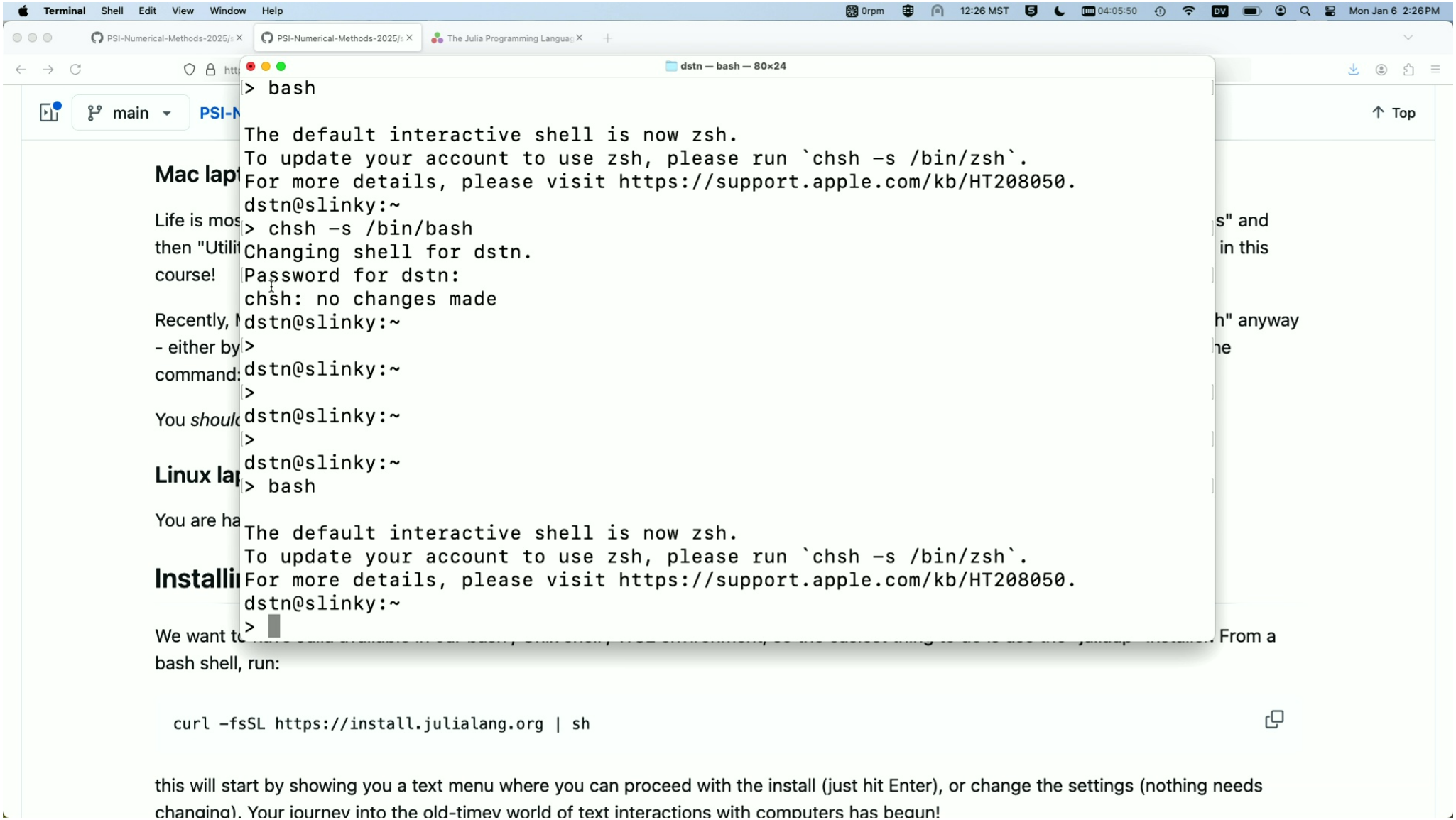
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For more details, please visit https://support.apple.com/kb/HT208050.
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> chsh -s /bin/bash
Changing shell for dstn.
Password for dstn:
chsh: no changes made
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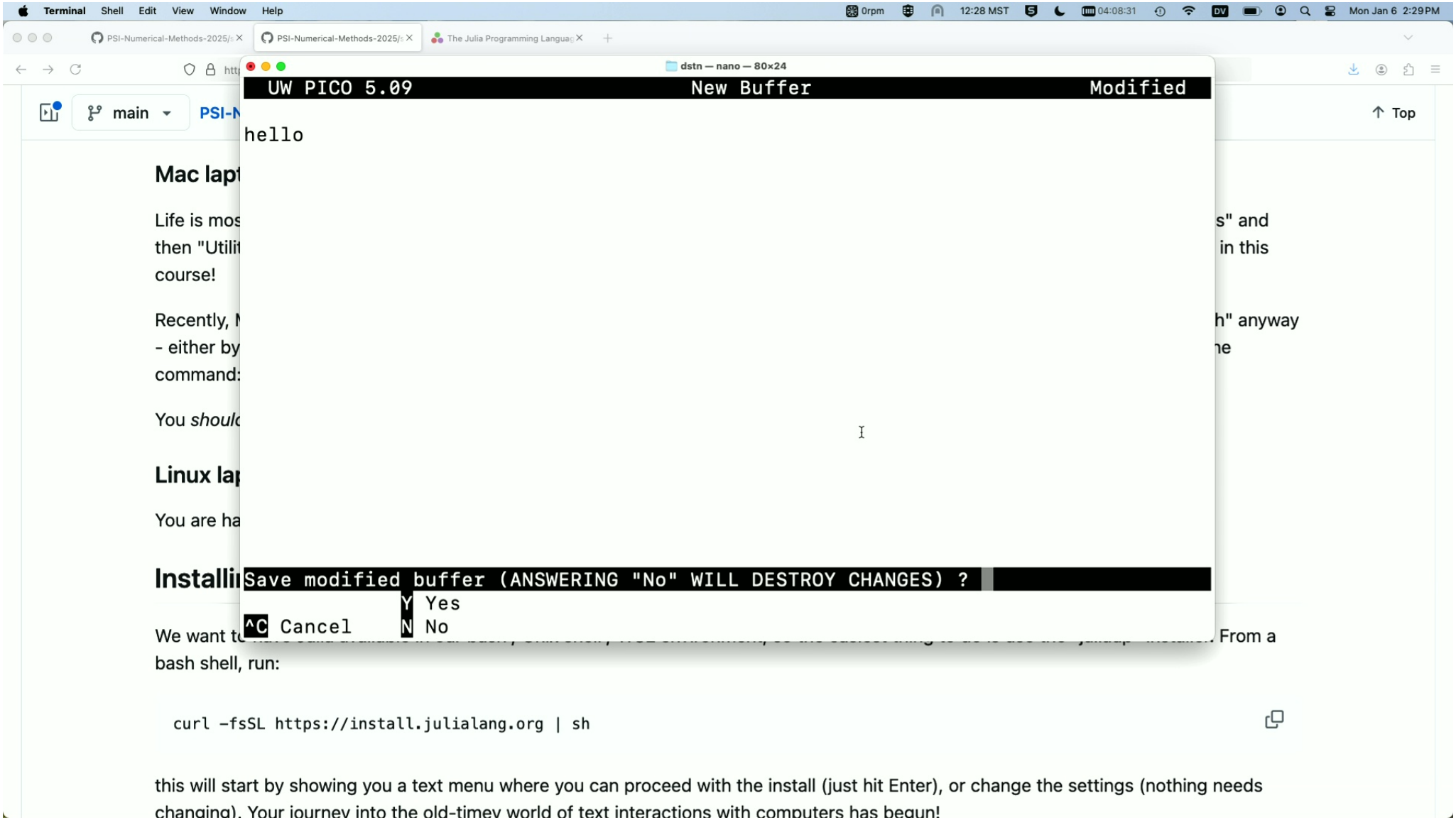
Terminal Shell Edit View Window Help
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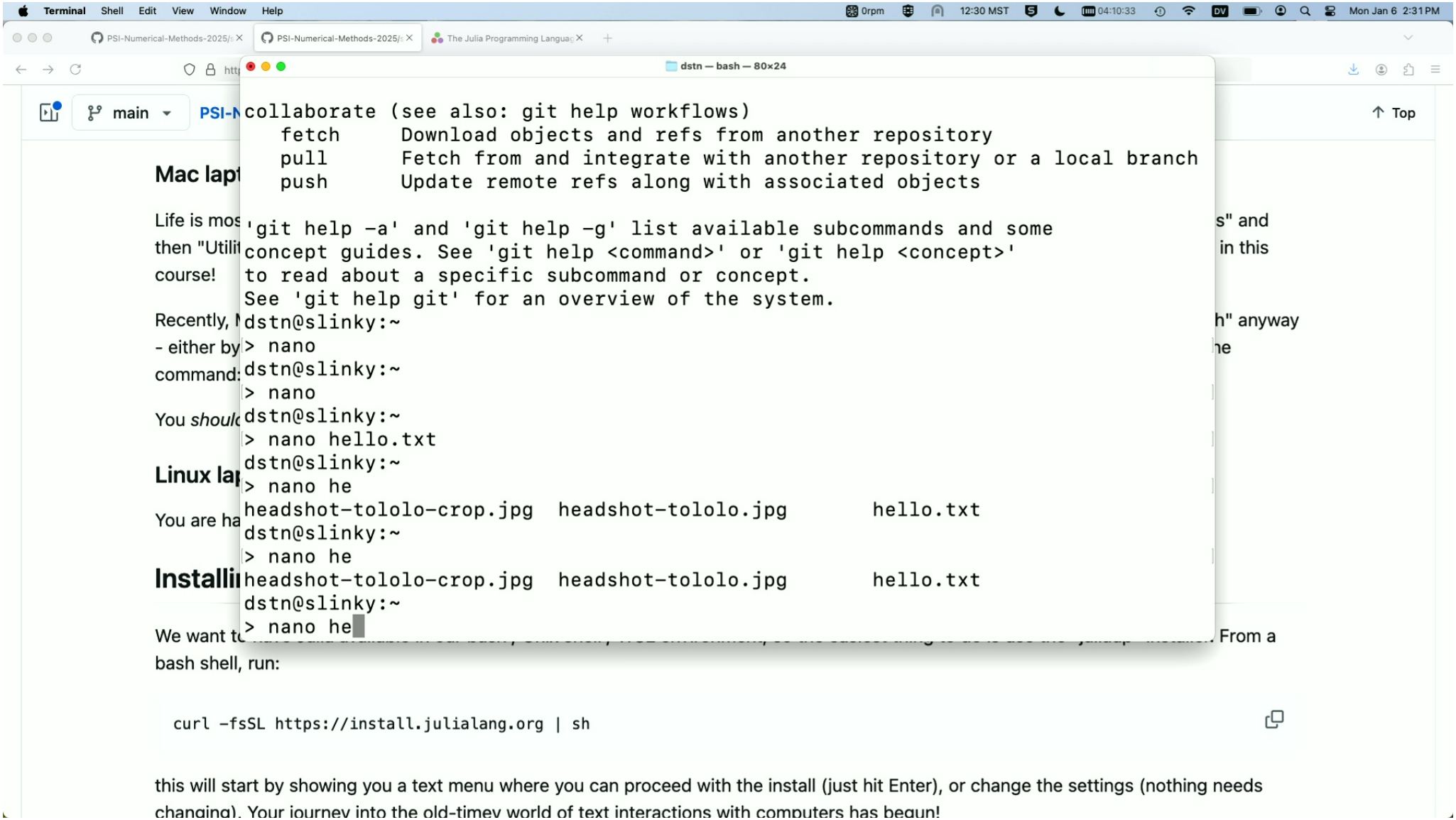
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The Julia Programming Langua
dstn — bash — 80×24
collaborate (see also: git help workflows)
fetch Download objects and refs from another repository
pull Fetch from and integrate with another repository or a local branch
push Update remote refs along with associated objects
'git help -a' and 'git help -g' list available subcommands and some
concept guides. See 'git help <command>' or 'git help <concept>'
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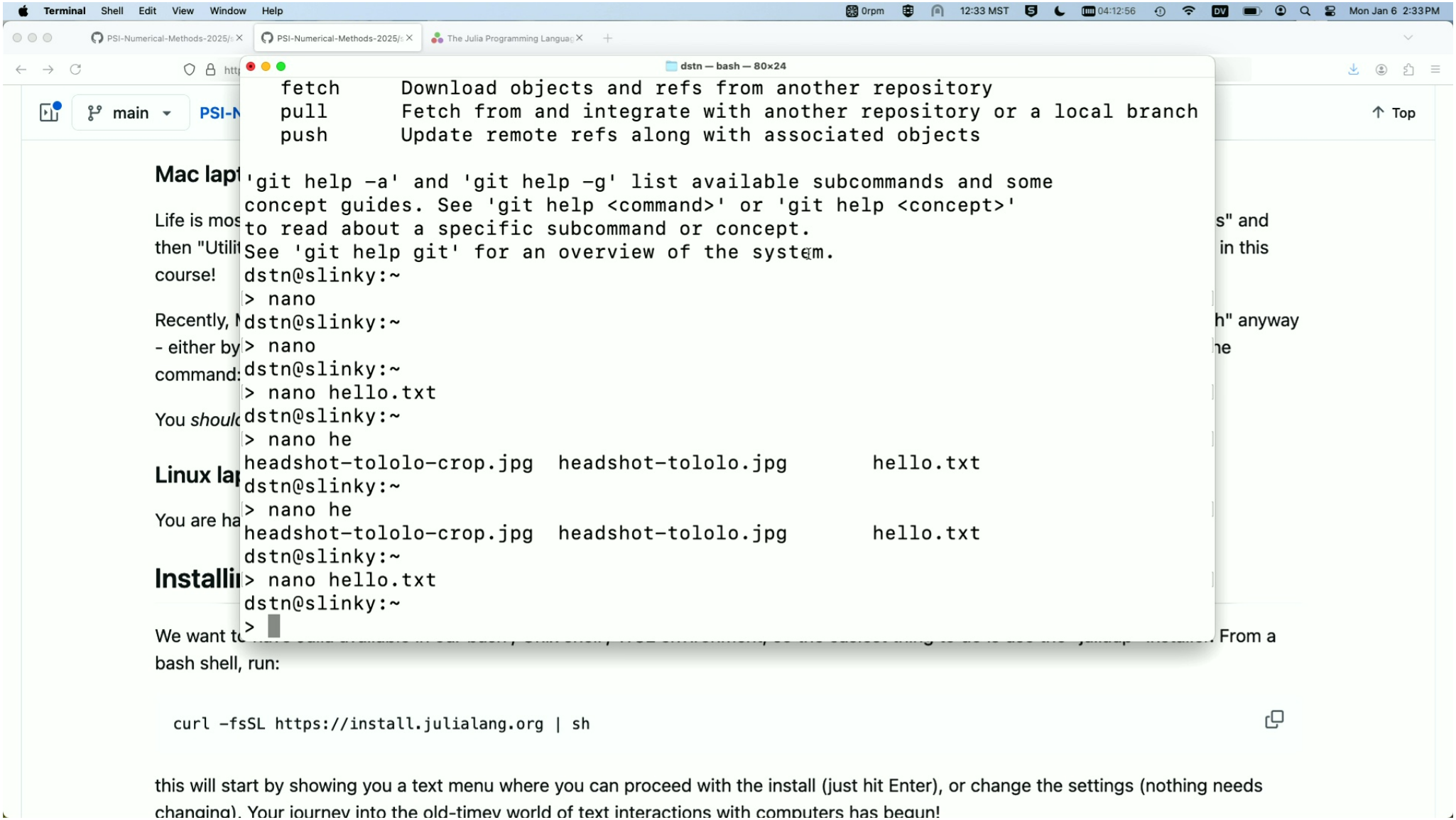
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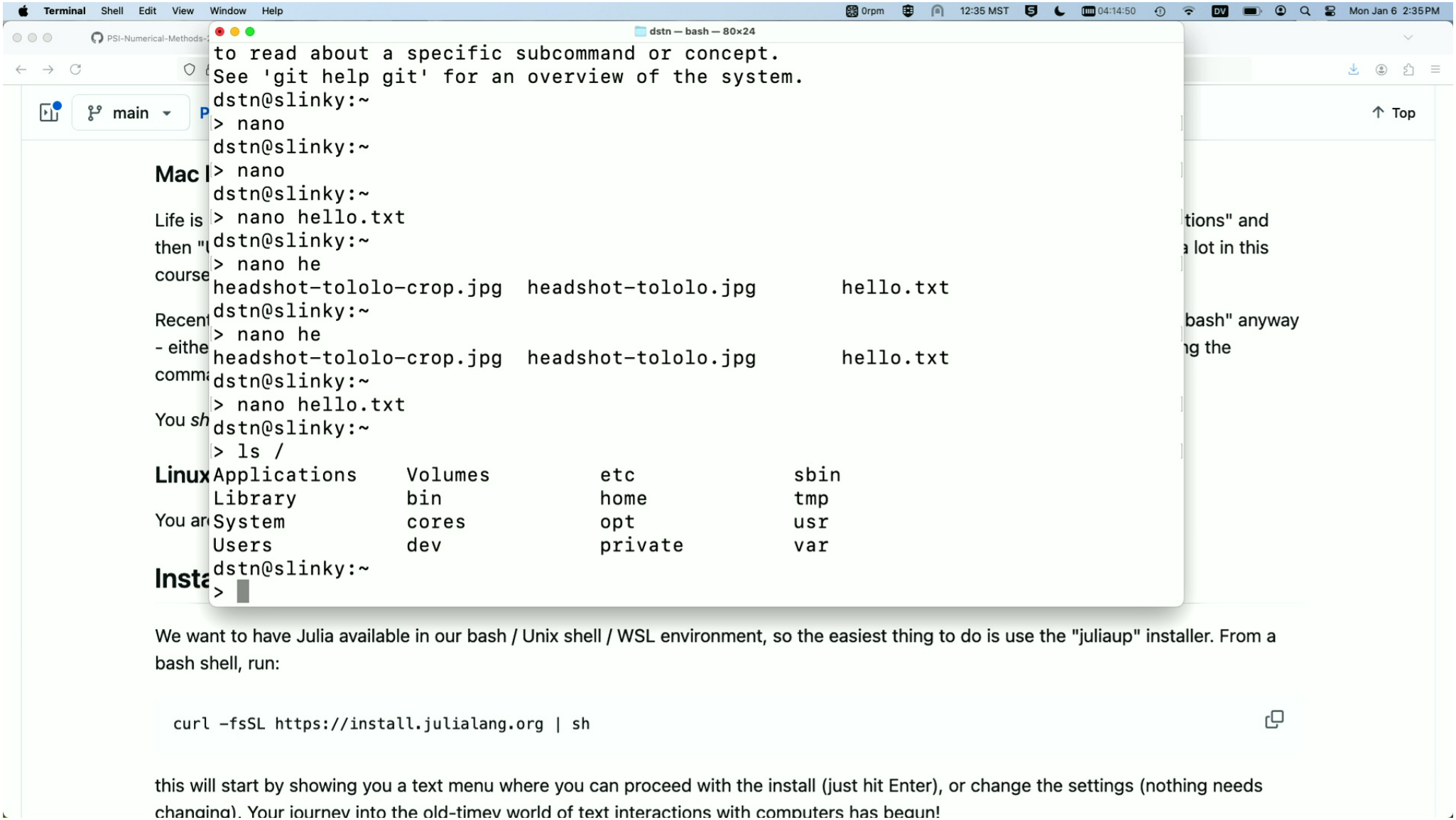
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dstn@slinky:~
> nano hello.txt
dstn@slinky:~
> ls /
Applications Volumes etc sbin
Library bin home tmp
System cores opt usr
Users dev private var
dstn@slinky:~
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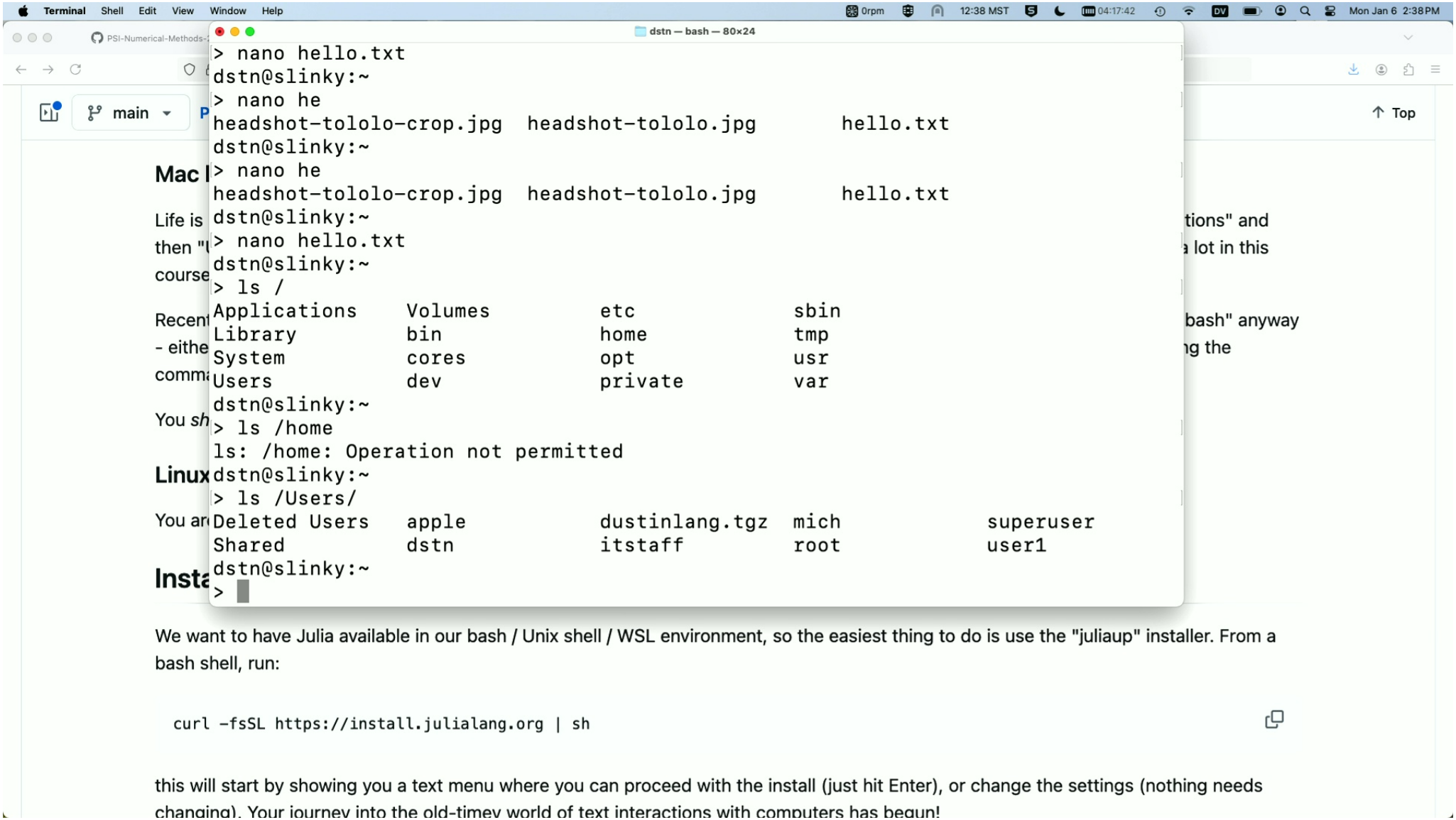
Terminal Shell Edit View Window Help
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> nano hello.txt
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> ls /
Applications Volumes etc sbin
Library bin home tmp
System cores opt usr
Users dev private var
dstn@slinky:~
> ls /home
ls: /home: Operation not permitted
dstn@slinky:~
> ls /Users/
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dstn@slinky:~
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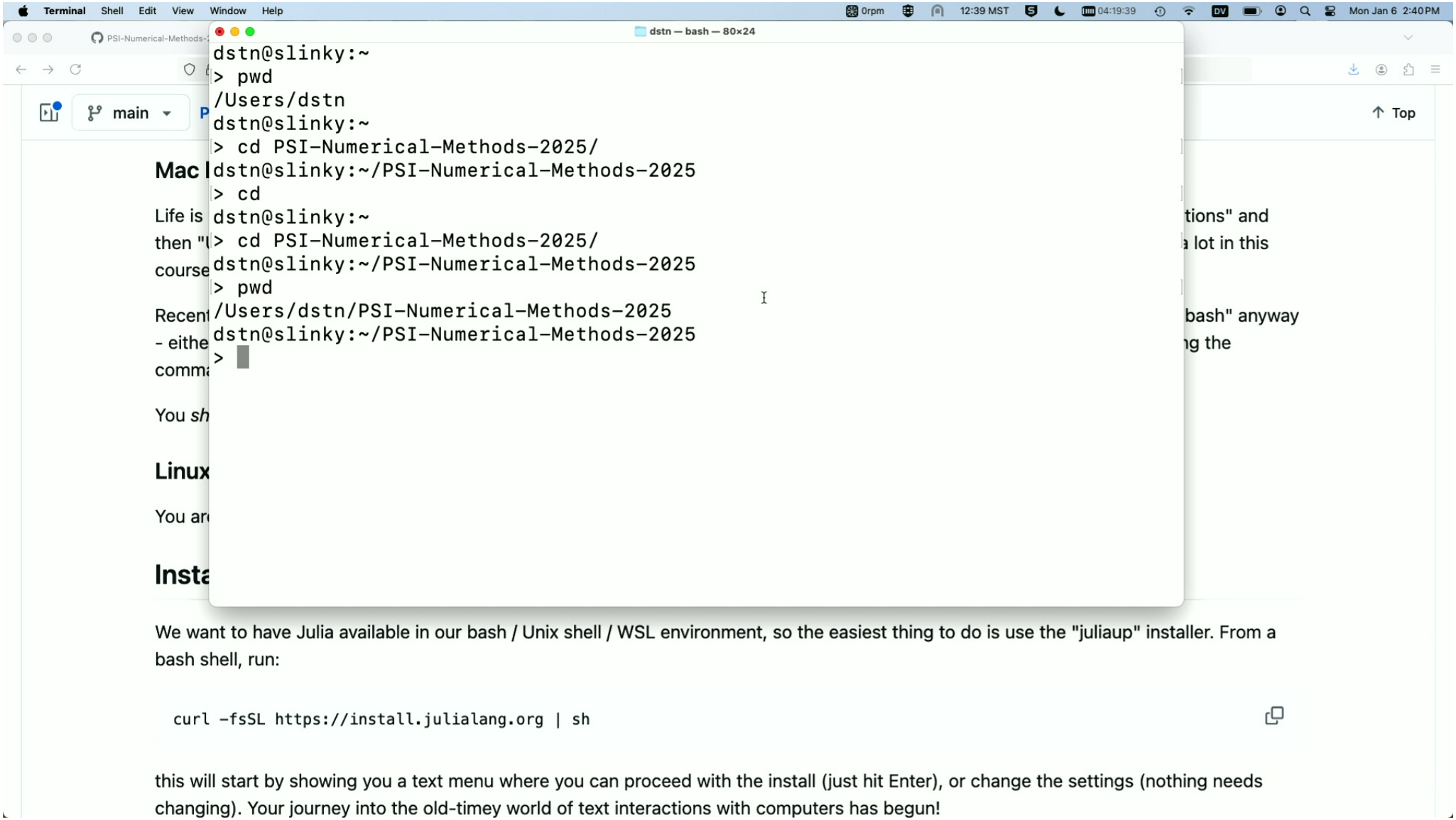
Terminal Shell Edit View Window Help
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dstn — bash — 80×24
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> pwd
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> cd
dstn@slinky:~
> cd PSI-Numerical-Methods-2025/
dstn@slinky:~/PSI-Numerical-Methods-2025
> pwd
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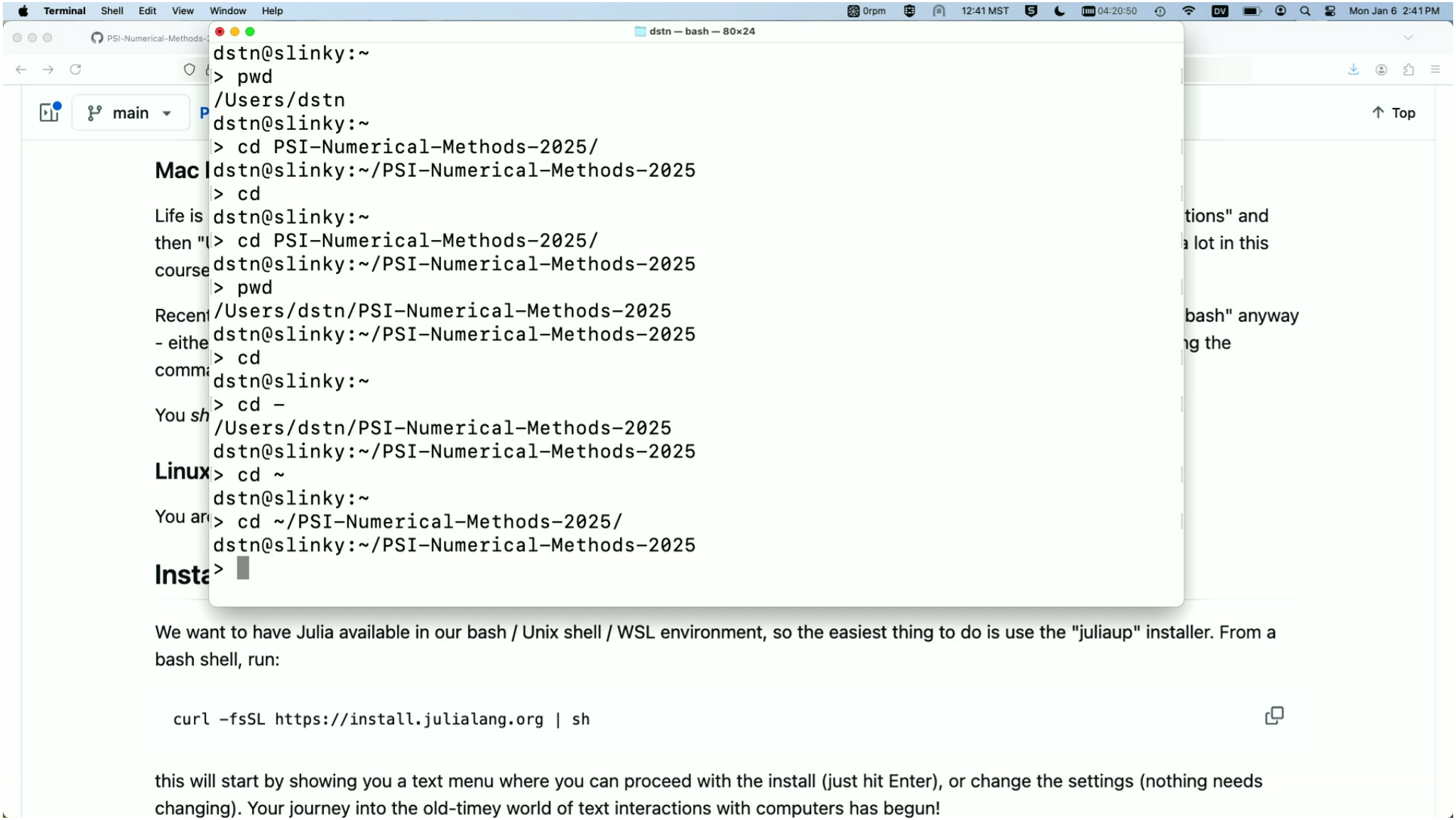
Terminal Shell Edit View Window Help
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> cd PSI-Numerical-Methods-2025/
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> cd
dstn@slinky:~
> cd PSI-Numerical-Methods-2025/
dstn@slinky:~/PSI-Numerical-Methods-2025
> pwd
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dstn@slinky:~/PSI-Numerical-Methods-2025
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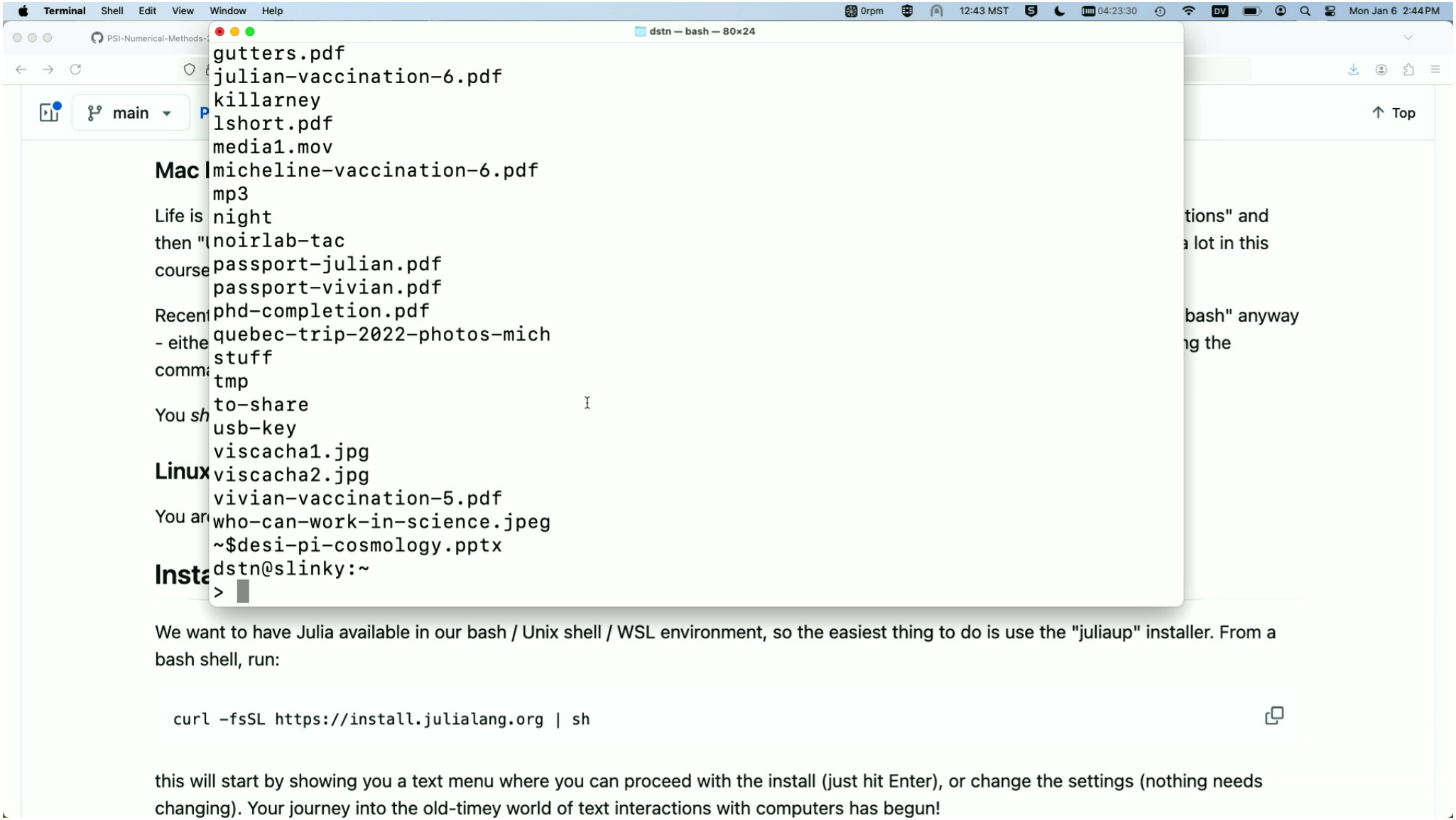
Terminal Shell Edit View Window Help
12:43 MST
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dstn — bash — 80×24
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curl -fsSL https://install.julialang.org | sh
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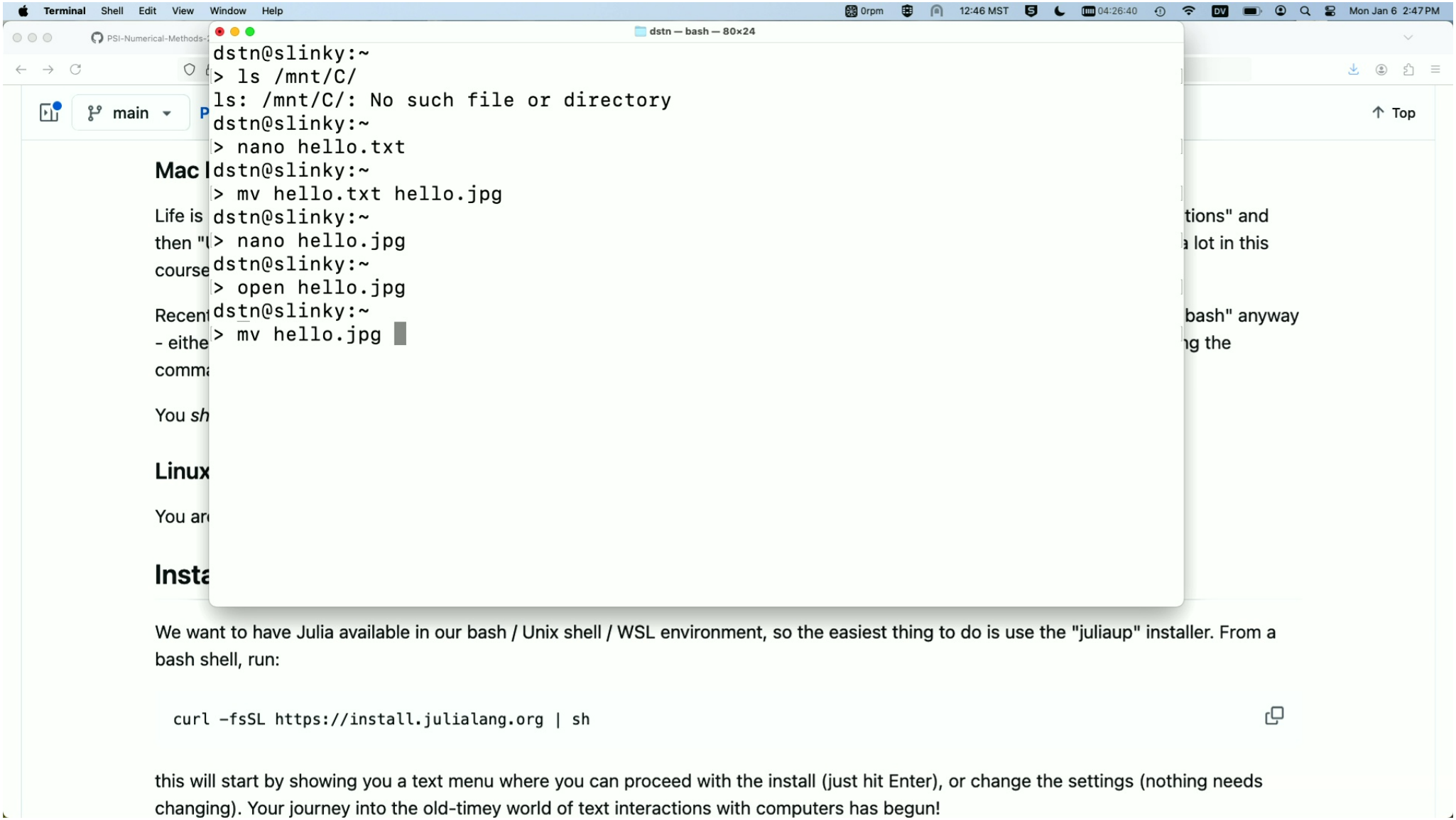
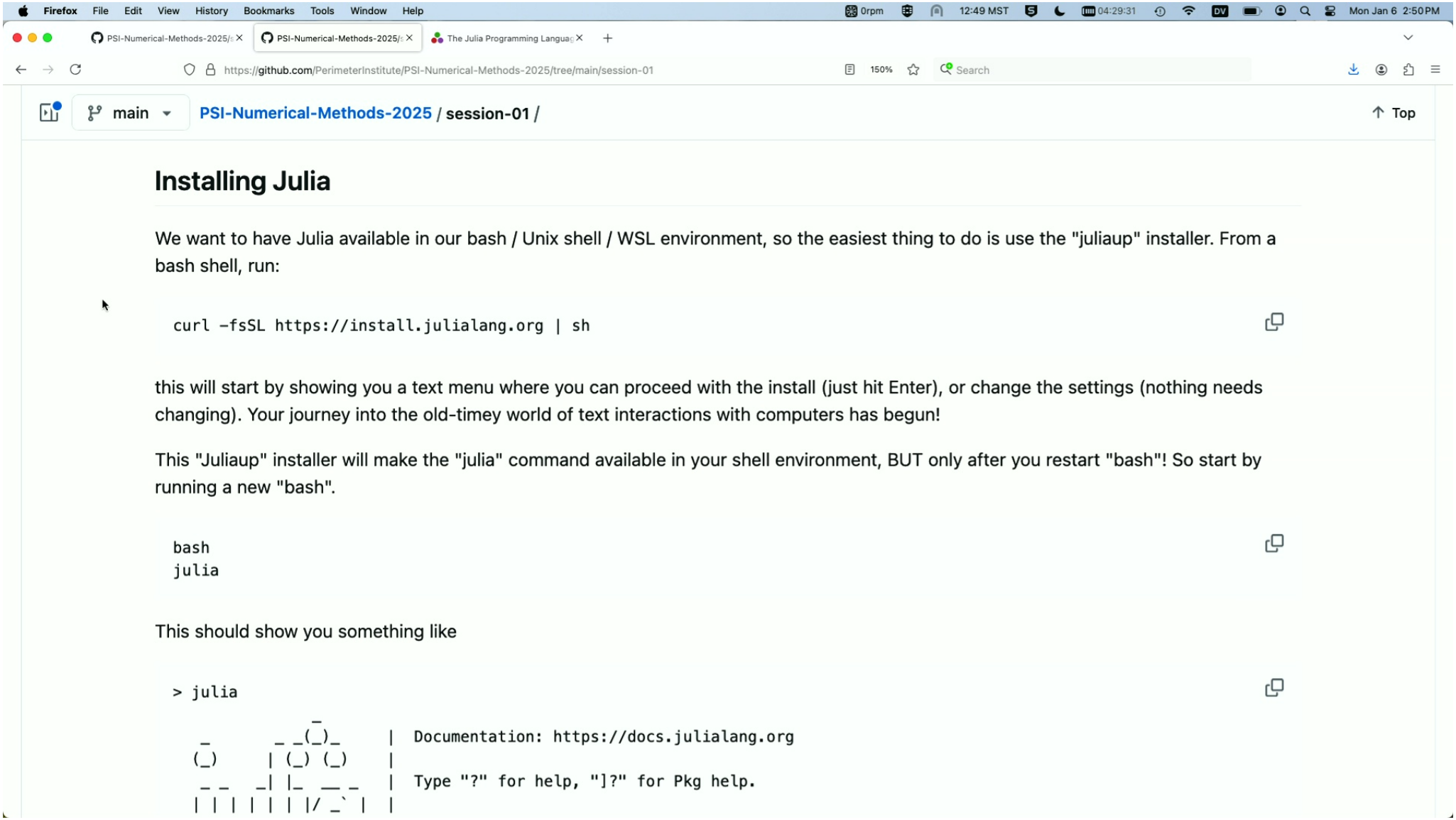
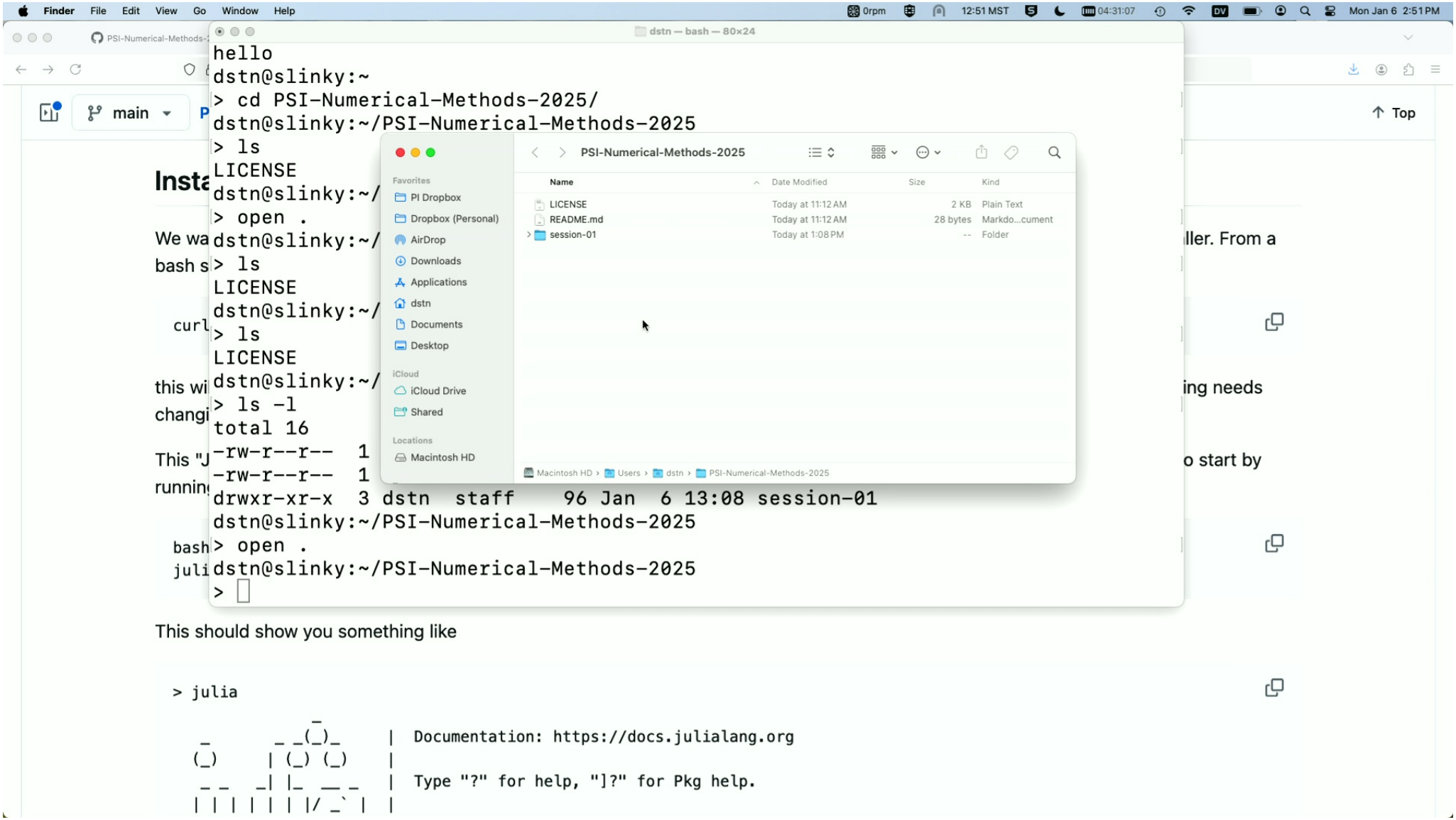
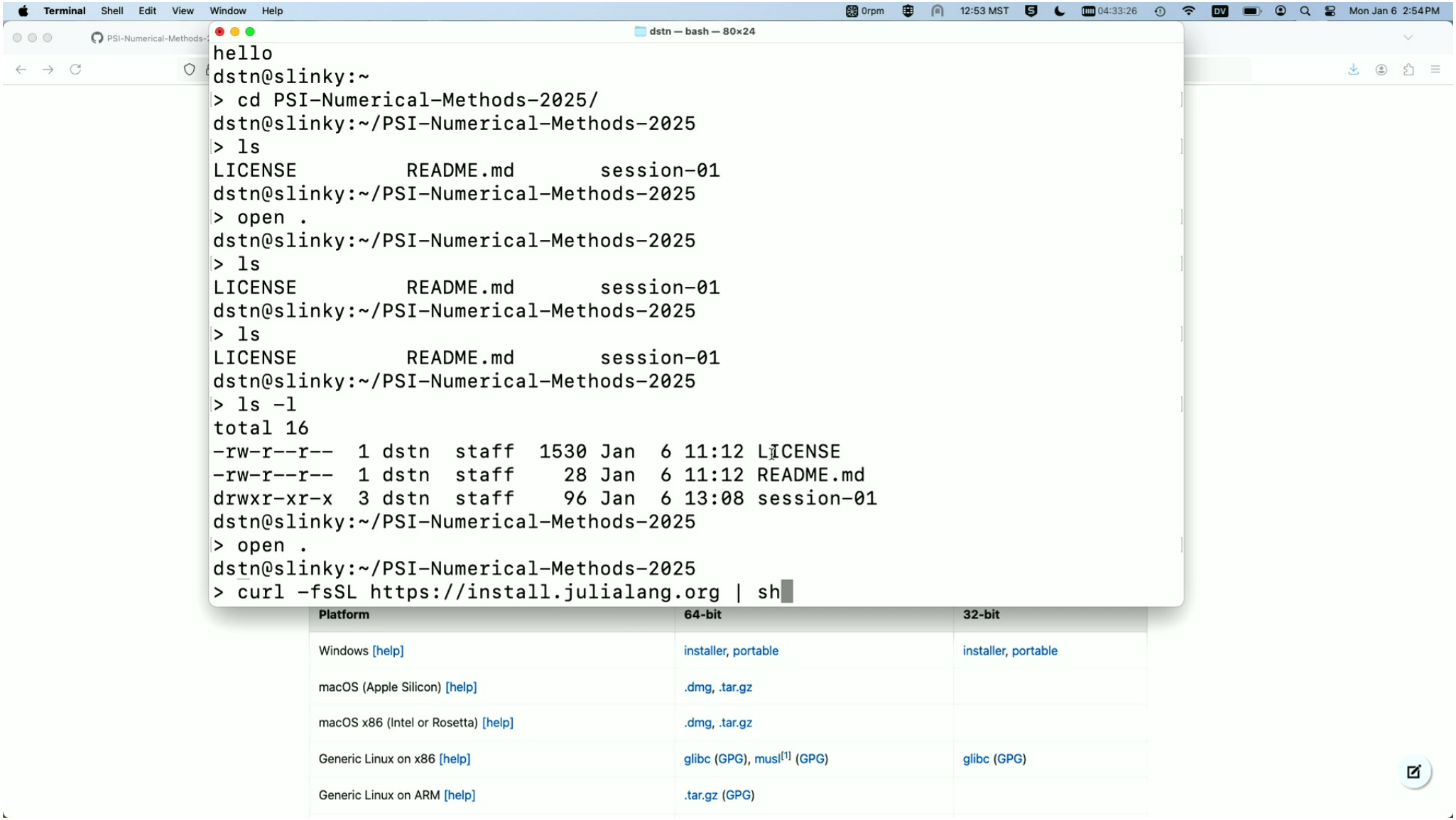
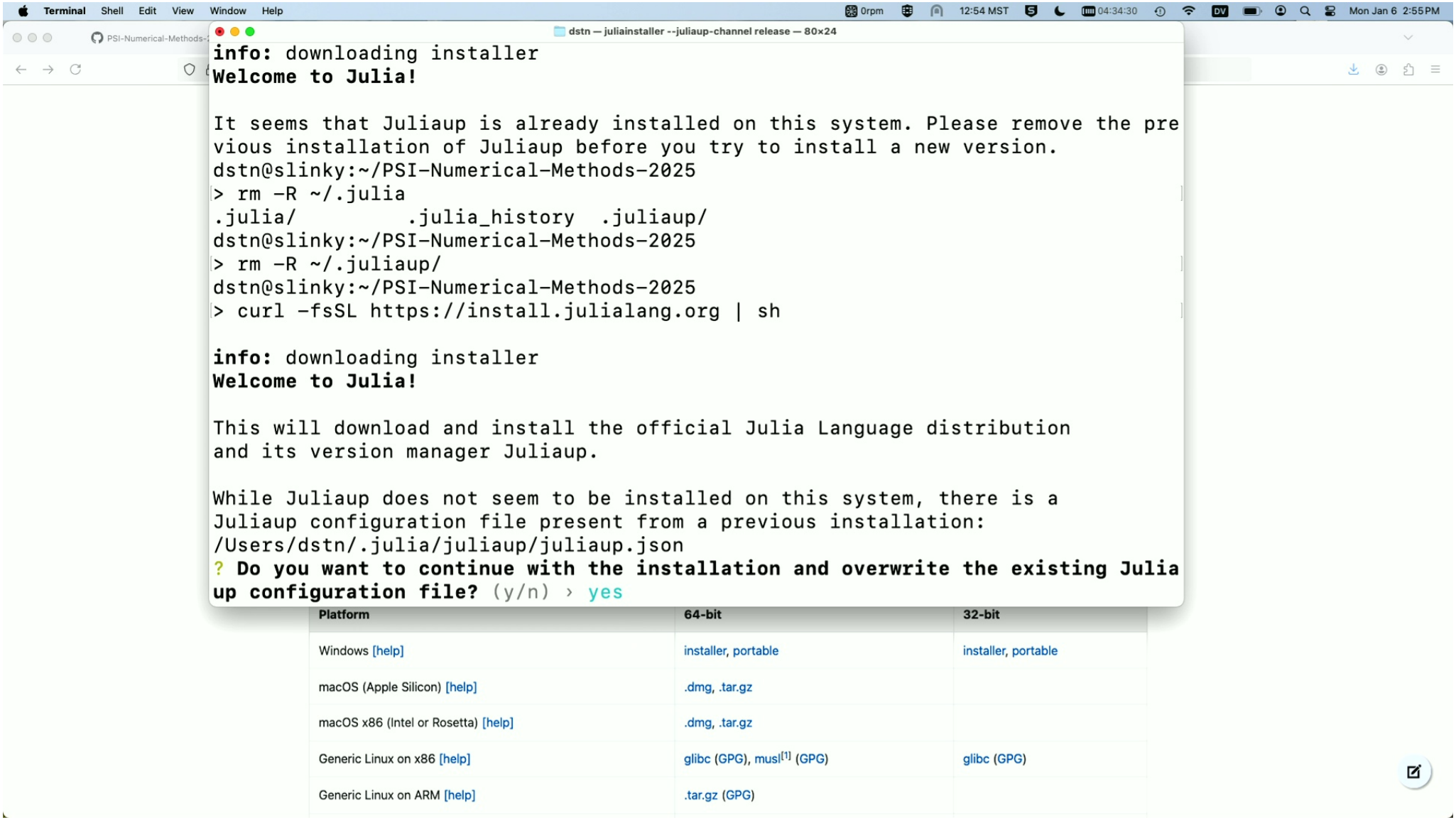
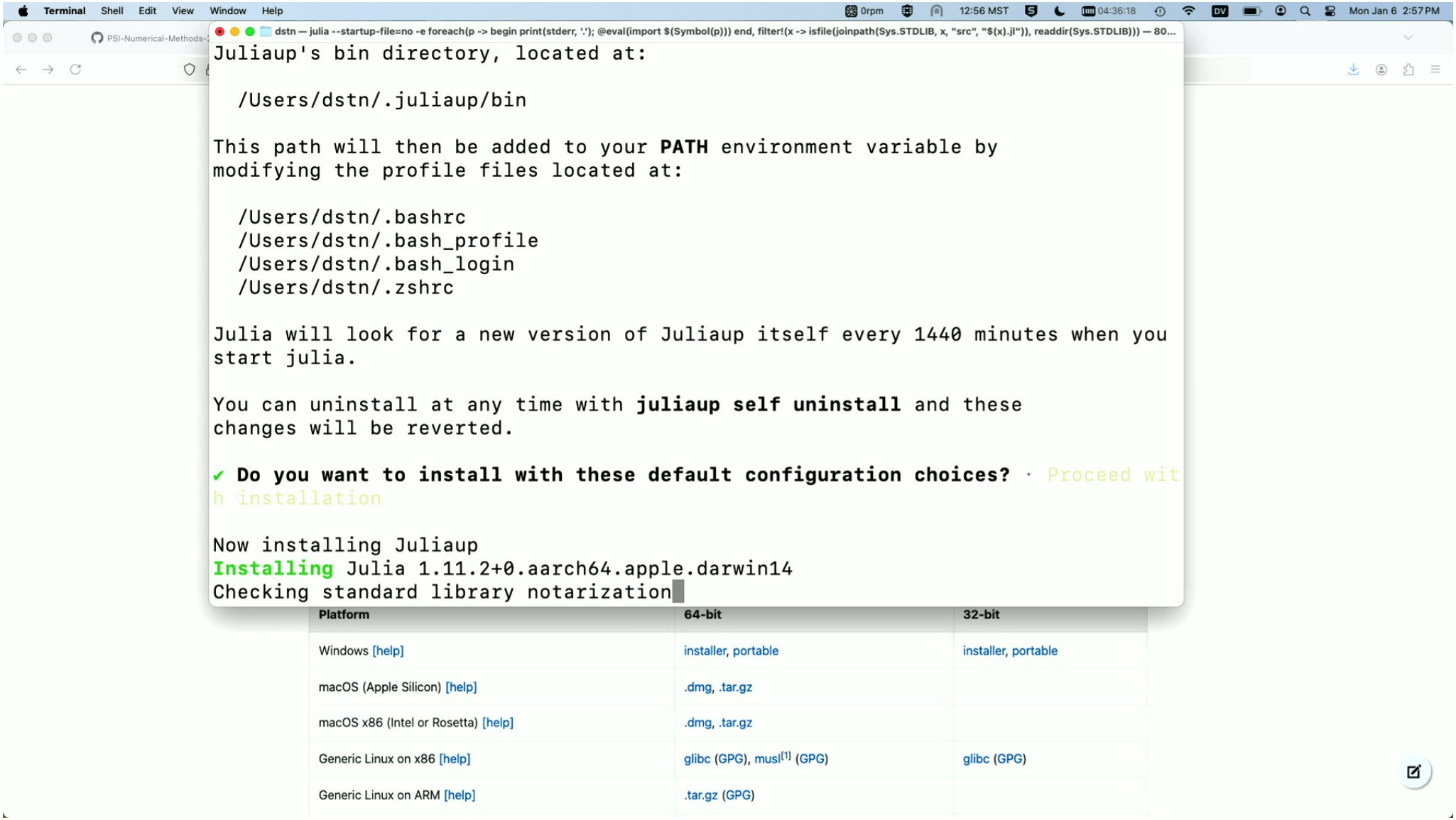

Terminal Shell Edit View Window Help
Mon Jan 6 2:47 PM
dstn — bash — 80×24
dstn@slinky:~
> ls /mnt/C/
ls: /mnt/C/: No such file or directory
dstn@slinky:~
> nano hello.txt
dstn@slinky:~
> mv hello.txt hello.jpg
dstn@slinky:~
> nano hello.jpg
dstn@slinky:~
> open hello.jpg
dstn@slinky:~
> mv hello.jpg
main
Top
Mac I
Life is
tions" and
then "
a lot in this
course
Recent
bash" anyway
- eithe
ng the
comma
You sh
Linux
You ar
Insta
We want to have Julia available in our bash / Unix shell / WSL environment, so the easiest thing to do is use the "juliaup" installer. From a bash shell, run:
curl -fsSL https://install.julialang.org | sh
this will start by showing you a text menu where you can proceed with the install (just hit Enter), or change the settings (nothing needs changing). Your journey into the old-timey world of text interactions with computers has begun!

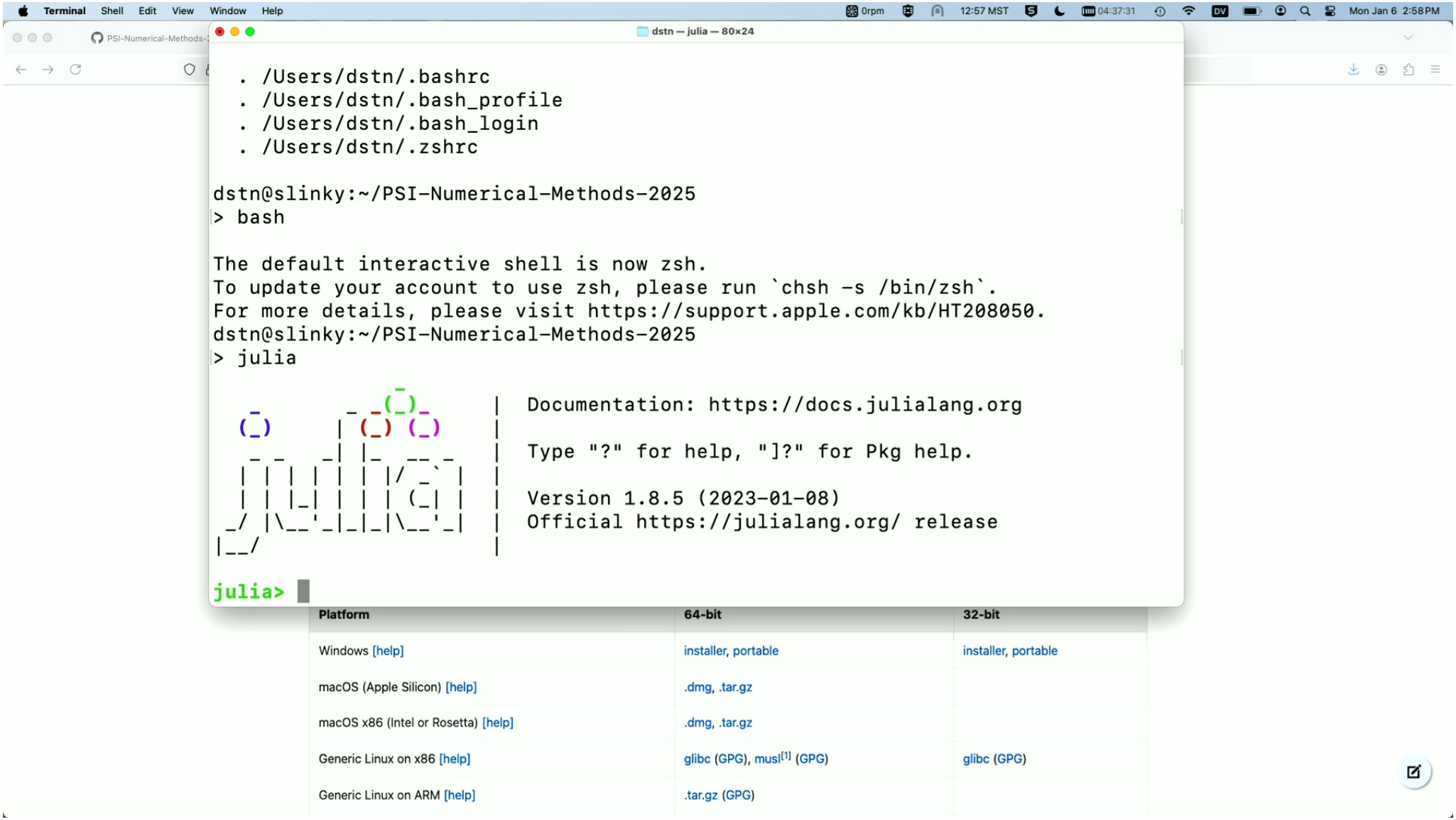

Firefox File Edit View History Bookmarks Tools Window Help
12:49 MST
Mon Jan 6 2:50 PM
PSI-Numerical-Methods-2025/
PSI-Numerical-Methods-2025/
The Julia Programming Langua
https://github.com/PerimeterInstitute/PSI-Numerical-Methods-2025/tree/main/session-01
150%
Search
main
PSI-Numerical-Methods-2025 / session-01 /
Top
Installing Julia
We want to have Julia available in our bash / Unix shell / WSL environment, so the easiest thing to do is use the "juliaup" installer. From a bash shell, run:
curl -fsSL https://install.julialang.org | sh
this will start by showing you a text menu where you can proceed with the install (just hit Enter), or change the settings (nothing needs changing). Your journey into the old-timey world of text interactions with computers has begun!
This "Juliaup" installer will make the "julia" command available in your shell environment, BUT only after you restart "bash"! So start by running a new "bash".
bash
julia
This should show you something like
> julia
Documentation: https://docs.julialang.org
Type "?" for help, "]?" for Pkg help.

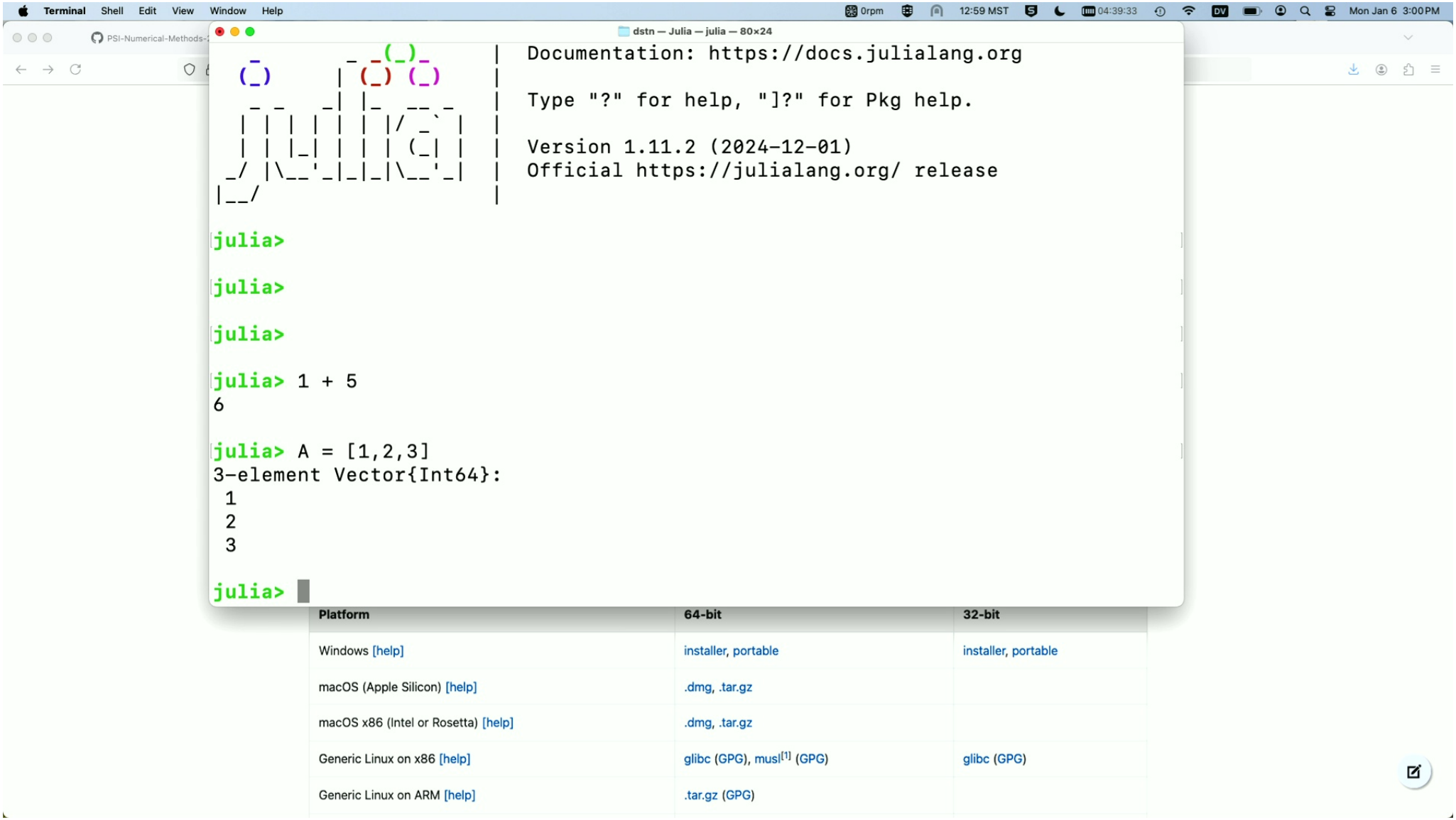

Finder File Edit View Go Window Help
dstn — bash — 80×24
hello
dstn@slinky:~
> cd PSI-Numerical-Methods-2025/
dstn@slinky:~/PSI-Numerical-Methods-2025
> ls
LICENSE
> open .
> ls
LICENSE
> ls
LICENSE
> ls -l
total 16
-rw-r--r-- 1
-rw-r--r-- 1
drwxr-xr-x 3 dstn staff   96 Jan 6 13:08 session-01
dstn@slinky:~/PSI-Numerical-Methods-2025
> open .
dstn@slinky:~/PSI-Numerical-Methods-2025
>
PSI-Numerical-Methods-2025
Favorites
PI Dropbox
Dropbox (Personal)
AirDrop
Downloads
Applications
dstn
Documents
Desktop
iCloud
iCloud Drive
Shared
Locations
Macintosh HD
Name
Date Modified
Size
Kind
LICENSE
Today at 11:12 AM
2 KB
Plain Text
README.md
Today at 11:12 AM
28 bytes
session-01
Today at 1:08 PM
Folder
Macintosh HD › Users › dstn › PSI-Numerical-Methods-2025
main
Top
This should show you something like
> julia
Documentation: https://docs.julialang.org
Type "?" for help, "]?" for Pkg help.

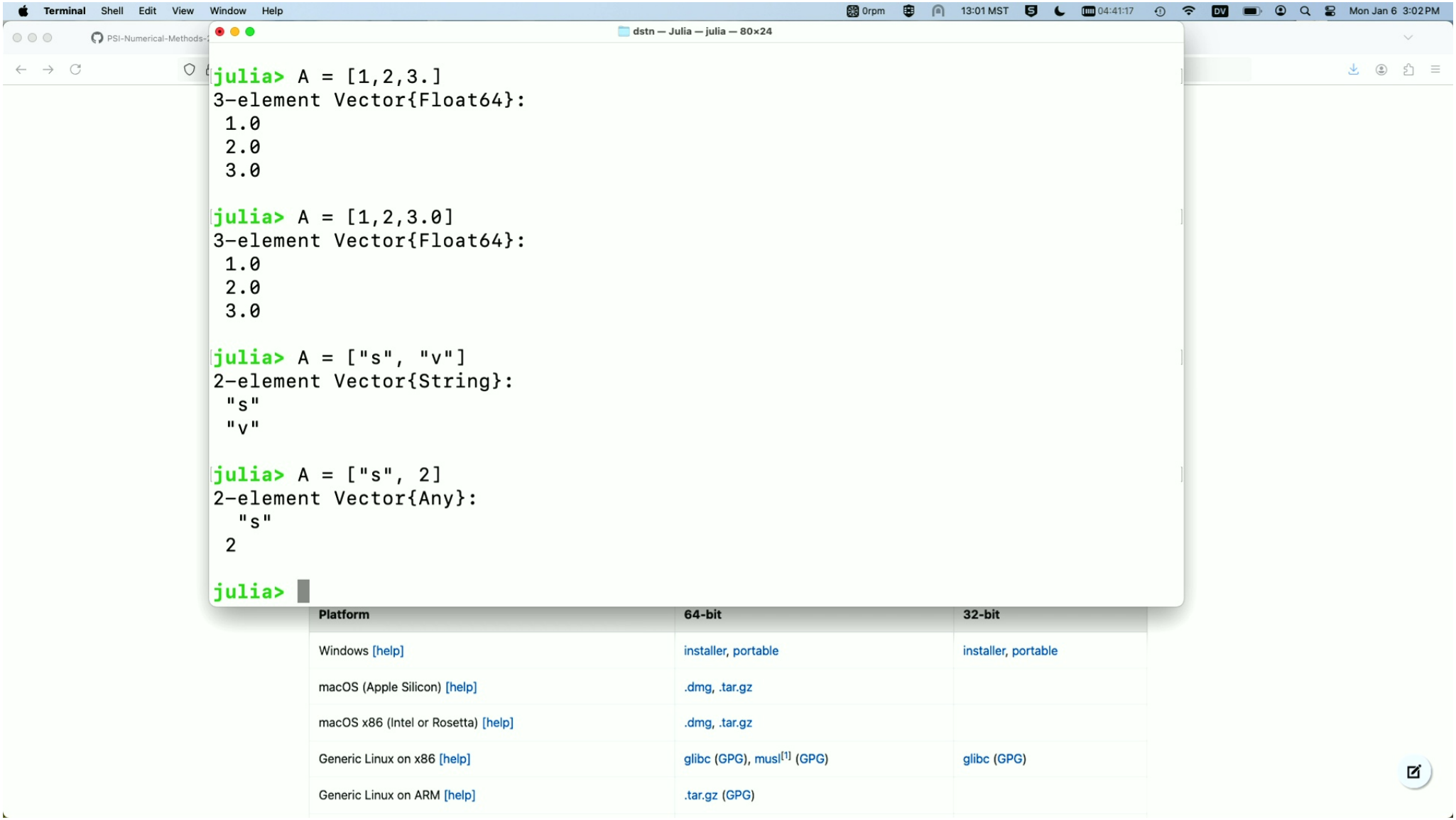

Terminal Shell Edit View Window Help
12:53 MST
Mon Jan 6 2:54 PM
dstn — bash — 80×24
hello
dstn@slinky:~
> cd PSI-Numerical-Methods-2025/
dstn@slinky:~/PSI-Numerical-Methods-2025
> ls
LICENSE README.md session-01
dstn@slinky:~/PSI-Numerical-Methods-2025
> open .
dstn@slinky:~/PSI-Numerical-Methods-2025
> ls
LICENSE README.md session-01
dstn@slinky:~/PSI-Numerical-Methods-2025
> ls
LICENSE README.md session-01
dstn@slinky:~/PSI-Numerical-Methods-2025
> ls -l
total 16
-rw-r--r-- 1 dstn staff 1530 Jan 6 11:12 LICENSE
-rw-r--r-- 1 dstn staff 28 Jan 6 11:12 README.md
drwxr-xr-x 3 dstn staff 96 Jan 6 13:08 session-01
dstn@slinky:~/PSI-Numerical-Methods-2025
> open .
dstn@slinky:~/PSI-Numerical-Methods-2025
> curl -fsSL https://install.julialang.org | sh
Platform
64-bit
32-bit
Windows [help]
installer, portable
installer, portable
macOS (Apple Silicon) [help]
.dmg, .tar.gz
macOS x86 (Intel or Rosetta) [help]
.dmg, .tar.gz
Generic Linux on x86 [help]
glibc (GPG), musl[1] (GPG)
glibc (GPG)
Generic Linux on ARM [help]
.tar.gz (GPG)

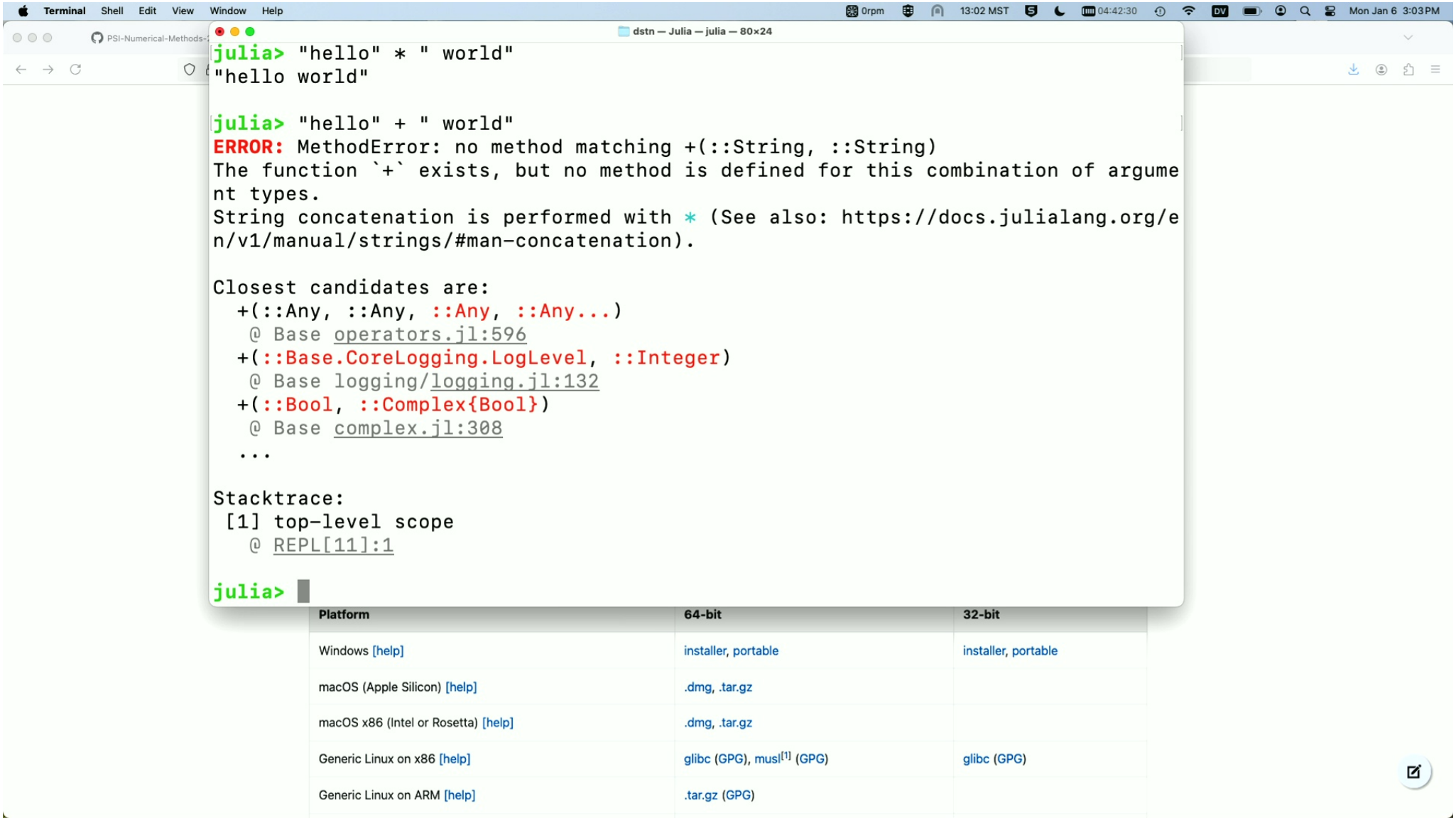

Terminal Shell Edit View Window Help
12:54 MST
Mon Jan 6 2:55 PM
dstn — juliainstaller --juliaup-channel release — 80×24
info: downloading installer
Welcome to Julia!
It seems that Juliaup is already installed on this system. Please remove the pre
vious installation of Juliaup before you try to install a new version.
dstn@slinky:~/PSI-Numerical-Methods-2025
> rm -R ~/.julia
.julia/ .julia_history .juliaup/
dstn@slinky:~/PSI-Numerical-Methods-2025
> rm -R ~/.juliaup/
dstn@slinky:~/PSI-Numerical-Methods-2025
> curl -fsSL https://install.julialang.org | sh
info: downloading installer
Welcome to Julia!
This will download and install the official Julia Language distribution
and its version manager Juliaup.
While Juliaup does not seem to be installed on this system, there is a
Juliaup configuration file present from a previous installation:
/Users/dstn/.julia/juliaup/juliaup.json
? Do you want to continue with the installation and overwrite the existing Julia
up configuration file? (y/n) › yes
Platform
64-bit
32-bit
Windows [help]
installer, portable
installer, portable
macOS (Apple Silicon) [help]
.dmg, .tar.gz
macOS x86 (Intel or Rosetta) [help]
.dmg, .tar.gz
Generic Linux on x86 [help]
glibc (GPG), musl[1] (GPG)
glibc (GPG)
Generic Linux on ARM [help]
.tar.gz (GPG)


Terminal Shell Edit View Window Help
12:56 MST
Mon Jan 6 2:57 PM
dstn — julia --startup-file=no -e foreach(p -> begin print(stderr, '.'); @eval(import $(Symbol(p))) end, filter!(x -> isfile(joinpath(Sys.STDLIB, x, "src", "$(x).jl")), readdir(Sys.STDLIB))) — 80...
Juliaup's bin directory, located at:
/Users/dstn/.juliaup/bin
This path will then be added to your PATH environment variable by modifying the profile files located at:
/Users/dstn/.bashrc
/Users/dstn/.bash_profile
/Users/dstn/.bash_login
/Users/dstn/.zshrc
Julia will look for a new version of Juliaup itself every 1440 minutes when you start julia.
You can uninstall at any time with juliaup self uninstall and these changes will be reverted.
✔ Do you want to install with these default configuration choices? · Proceed with installation
Now installing Juliaup
Installing Julia 1.11.2+0.aarch64.apple.darwin14
Checking standard library notarization
Platform
64-bit
32-bit
Windows [help]
installer, portable
installer, portable
macOS (Apple Silicon) [help]
.dmg, .tar.gz
macOS x86 (Intel or Rosetta) [help]
.dmg, .tar.gz
Generic Linux on x86 [help]
glibc (GPG), musl[1] (GPG)
glibc (GPG)
Generic Linux on ARM [help]
.tar.gz (GPG)


Terminal Shell Edit View Window Help
Mon Jan 6 2:58 PM
dstn — julia — 80×24
. /Users/dstn/.bashrc
. /Users/dstn/.bash_profile
. /Users/dstn/.bash_login
. /Users/dstn/.zshrc
dstn@slinky:~/PSI-Numerical-Methods-2025
> bash
The default interactive shell is now zsh.
To update your account to use zsh, please run `chsh -s /bin/zsh`.
For more details, please visit https://support.apple.com/kb/HT208050.
dstn@slinky:~/PSI-Numerical-Methods-2025
> julia
Documentation: https://docs.julialang.org
Type "?" for help, "]?" for Pkg help.
Version 1.8.5 (2023-01-08)
Official https://julialang.org/ release
julia>
Platform
64-bit
32-bit
Windows [help]
installer, portable
installer, portable
macOS (Apple Silicon) [help]
.dmg, .tar.gz
macOS x86 (Intel or Rosetta) [help]
.dmg, .tar.gz
Generic Linux on x86 [help]
glibc (GPG), musl[1] (GPG)
glibc (GPG)
Generic Linux on ARM [help]
.tar.gz (GPG)


Terminal Shell Edit View Window Help
Mon Jan 6 3:00 PM
dstn — Julia — julia — 80×24
Documentation: https://docs.julialang.org
Type "?" for help, "]?" for Pkg help.
Version 1.11.2 (2024-12-01)
Official https://julialang.org/ release
julia>
julia>
julia>
julia> 1 + 5
6
julia> A = [1,2,3]
3-element Vector{Int64}:
1
2
3
julia>
Platform
64-bit
32-bit
Windows [help]
installer, portable
installer, portable
macOS (Apple Silicon) [help]
.dmg, .tar.gz
macOS x86 (Intel or Rosetta) [help]
.dmg, .tar.gz
Generic Linux on x86 [help]
glibc (GPG), musl[1] (GPG)
glibc (GPG)
Generic Linux on ARM [help]
.tar.gz (GPG)


Terminal Shell Edit View Window Help
0rpm 13:01 MST 04:41:17 Mon Jan 6 3:02 PM
dstn — Julia — julia — 80×24
julia> A = [1,2,3.]
3-element Vector{Float64}:
1.0
2.0
3.0
julia> A = [1,2,3.0]
3-element Vector{Float64}:
1.0
2.0
3.0
julia> A = ["s", "v"]
2-element Vector{String}:
"s"
"v"
julia> A = ["s", 2]
2-element Vector{Any}:
"s"
2
julia>
Platform
64-bit
32-bit
Windows [help]
installer, portable
installer, portable
macOS (Apple Silicon) [help]
.dmg, .tar.gz
macOS x86 (Intel or Rosetta) [help]
.dmg, .tar.gz
Generic Linux on x86 [help]
glibc (GPG), musl[1] (GPG)
glibc (GPG)
Generic Linux on ARM [help]
.tar.gz (GPG)


Terminal Shell Edit View Window Help
13:02 MST
Mon Jan 6 3:03 PM
dstn — Julia — julia — 80×24
julia> "hello" * " world"
"hello world"
julia> "hello" + " world"
ERROR: MethodError: no method matching +(::String, ::String)
The function `+` exists, but no method is defined for this combination of argument types.
String concatenation is performed with * (See also: https://docs.julialang.org/en/v1/manual/strings/#man-concatenation).
Closest candidates are:
+(::Any, ::Any, ::Any, ::Any...)
@ Base operators.jl:596
+(::Base.CoreLogging.LogLevel, ::Integer)
@ Base logging/logging.jl:132
+(::Bool, ::Complex{Bool})
@ Base complex.jl:308
...
Stacktrace:
[1] top-level scope
@ REPL[11]:1
julia>
Platform
64-bit
32-bit
Windows [help]
installer, portable
installer, portable
macOS (Apple Silicon) [help]
.dmg, .tar.gz
macOS x86 (Intel or Rosetta) [help]
.dmg, .tar.gz
Generic Linux on x86 [help]
glibc (GPG), musl[1] (GPG)
glibc (GPG)
Generic Linux on ARM [help]
.tar.gz (GPG)