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CF-UM-UP

Universidade do Minho
Escola de Ciências

Introduction to the julia programming language

Bruno Amorim

Quantum Agora, 25th March 2021

Disclaimer:

I am a bad programmer (in python,C and Fortran)
I am slightly better with Julia

Why do we need another programming language?

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- Python
- Mathematica
- Matlab
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Compromise:
1) Prototype in easy language
2) When performance becomes critical, rewrite parts/whole code in fast language

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- Duplication of effort
- Need to learn two languages or fast parts become a blackbox!

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☺ **Fast** languages:

Two language problem!

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Enter Julia

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From https://julialang.org/blog/2012/02/why-we-created-julia/

“ **Why We Created Julia**

14 February 2012 | **Jeff Bezanson Stefan Karpinski Viral B. Shah Alan Edelman**

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So what is Julia?

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New language: 1st public realease in 2012, stable 1.0 version in 2018
Current version: 1.6.0 (released yesterday!)
Initially development at MIT:

- *Julia: A Fast Dynamic Language for Technical Computing,* ***arXiv:1209.5145***
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- Open source
- Solves the two language problem
- Interactive
- High performance
- Simple syntax
- Aimed at scientific computing

Open source

source code hosted on github

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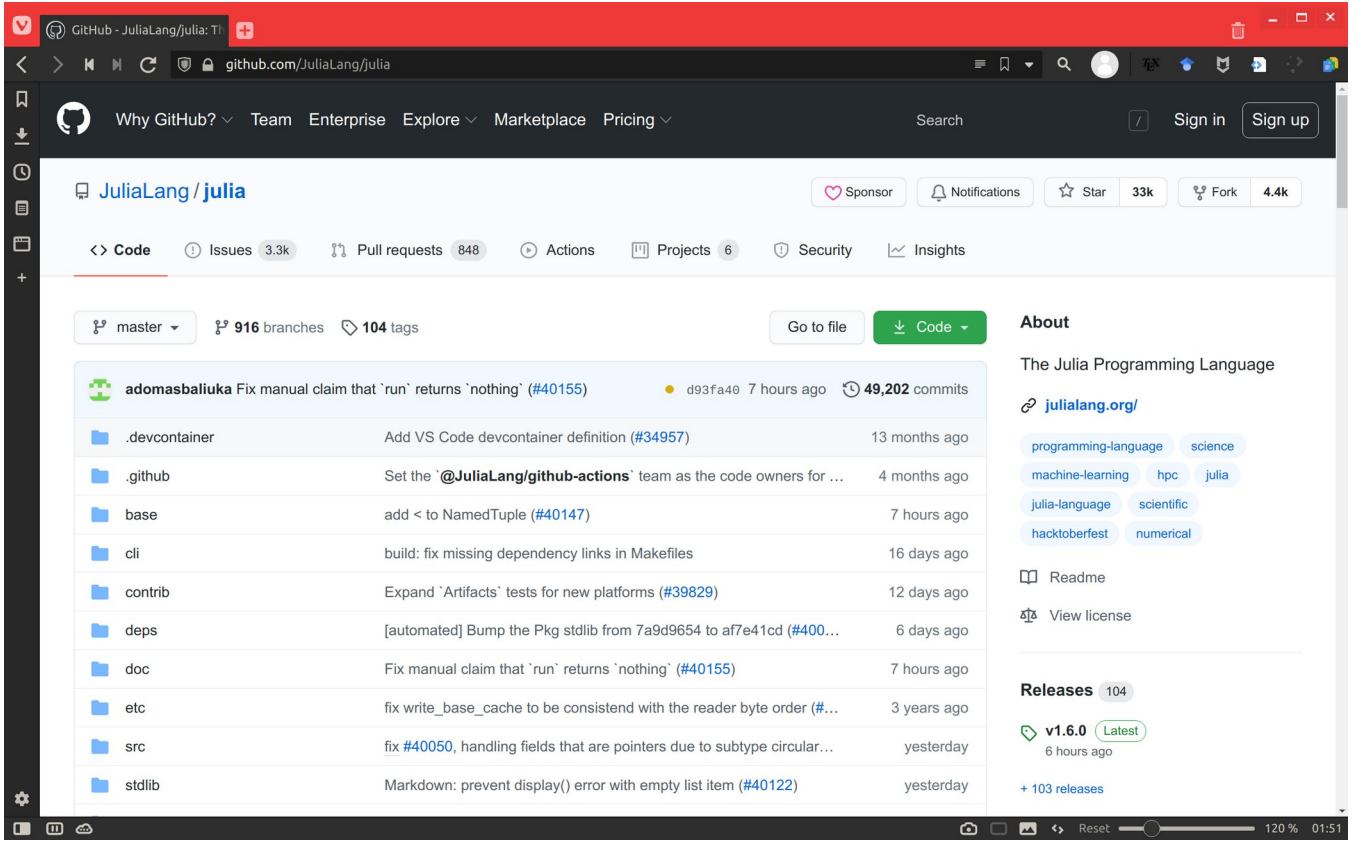

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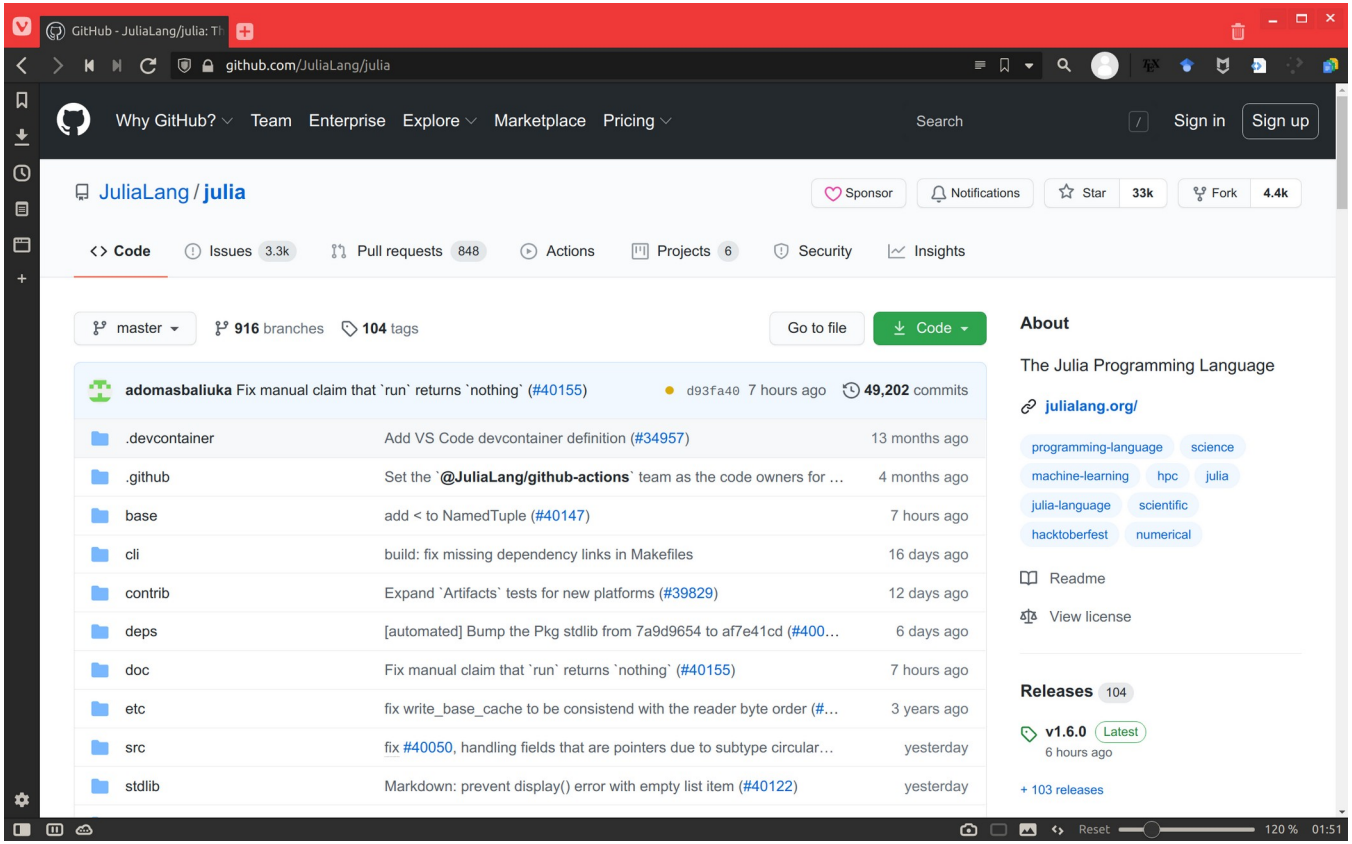
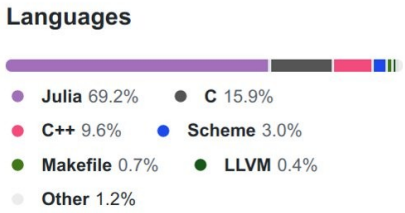


Many contributers



Julia is mostly written in Julia

This is true for most packages!

Solving the two language problem

Julia packages are mostly written in Julia

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JuliaLinearAlgebra / **IterativeSolvers.jl**

Code | Issues 40 | Pull requests 5 | Actions | Projects | Security | Insights

Languages

Julia 100.0%

SciML / **DifferentialEquations.jl**

Code | Issues 110 | Pull requests | Actions | Projects | Security | Insights

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Julia 96.4% **TeX** 3.6%

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Julia 96.4% **TeX** 3.6%

contrast with

numpy / **numpy**

Code | Issues 2k | Pull requests 235 | Actions | Projects 8 | Wiki | Security | Insights

Languages

Python 63.5% **C** 35.2%
C++ 1.0% **JavaScript** 0.1%
Fortran 0.1% **Shell** 0.1%

scipy / **scipy**

Code | Issues 1.3k | Pull requests 319 | Actions | Projects | Wiki | Security | Insights

Languages

Python 51.8% **Fortran** 19.2%
C 17.3% **C++** 11.4%
TeX 0.2% **CMake** 0.1%

Julia is an interactive language

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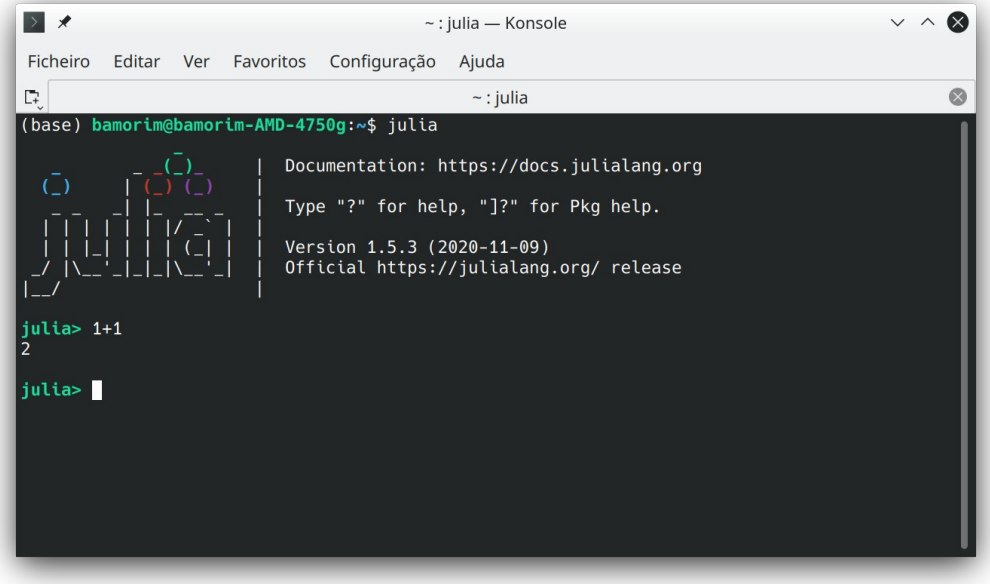
REPL (Read Eval Print Loop shell)



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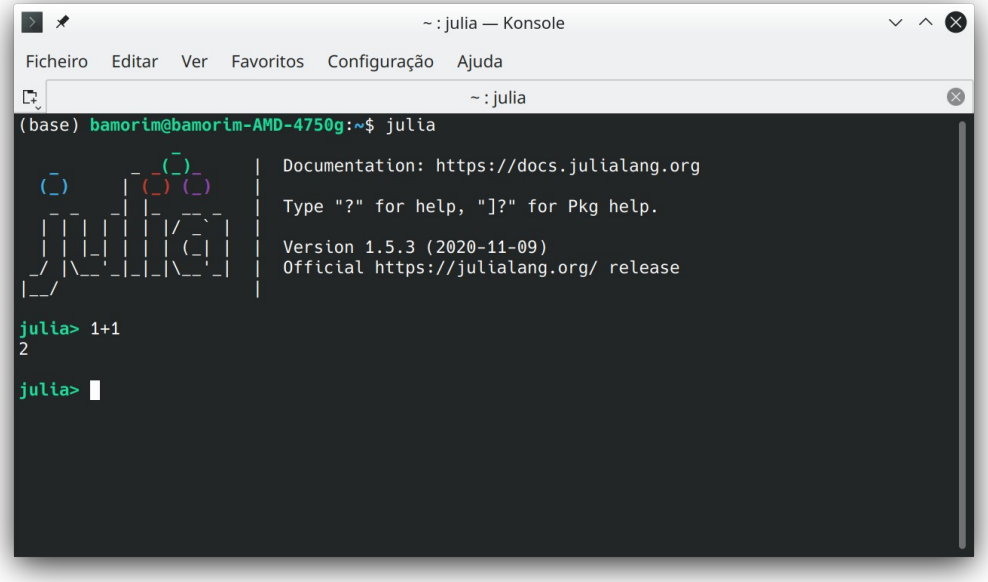
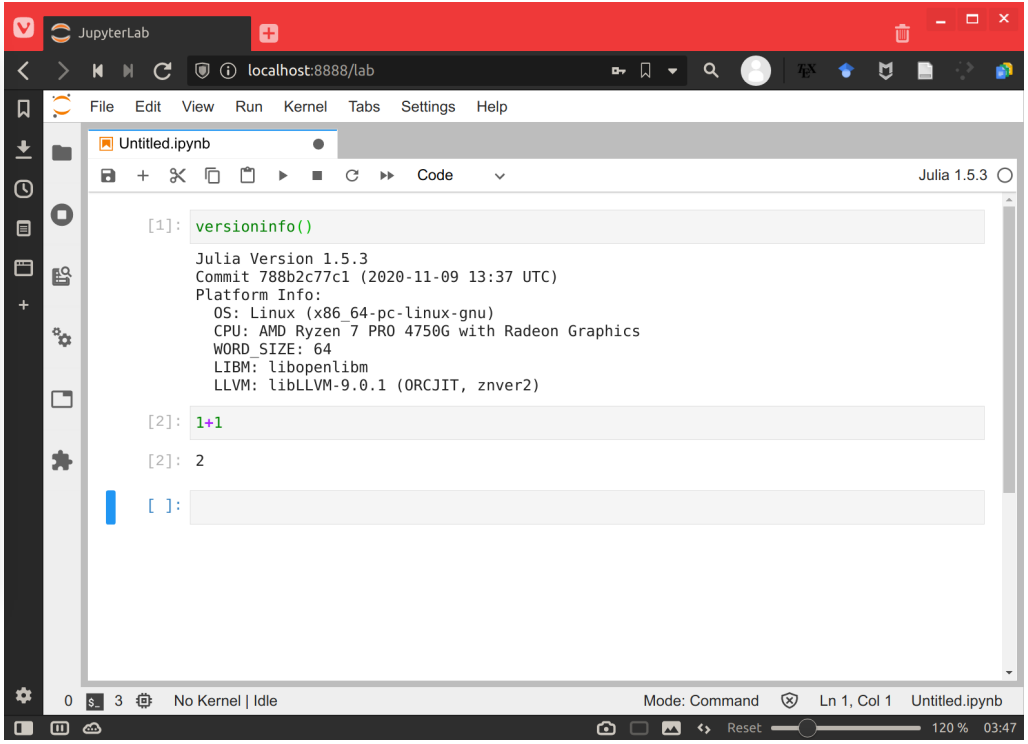
jupyter notebooks





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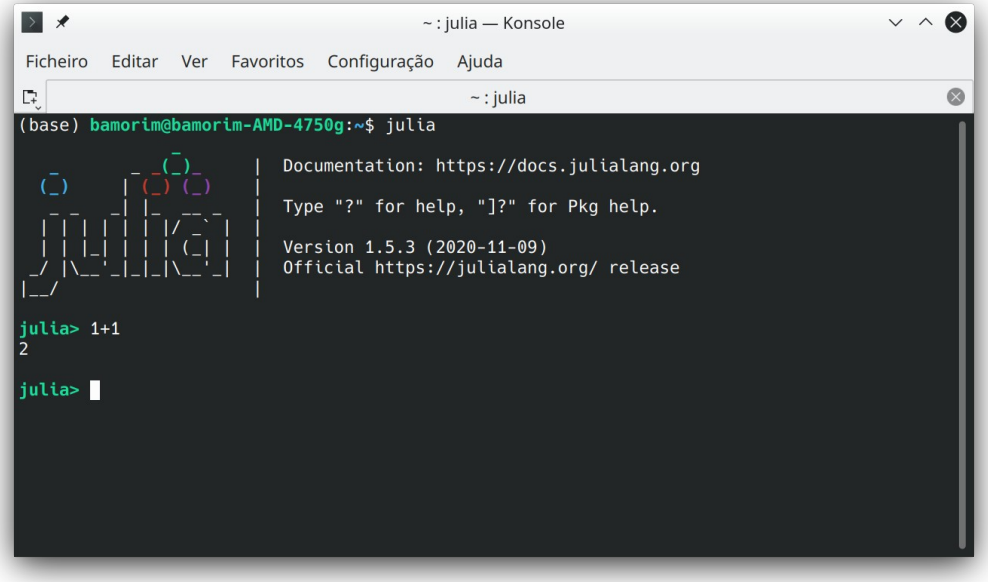
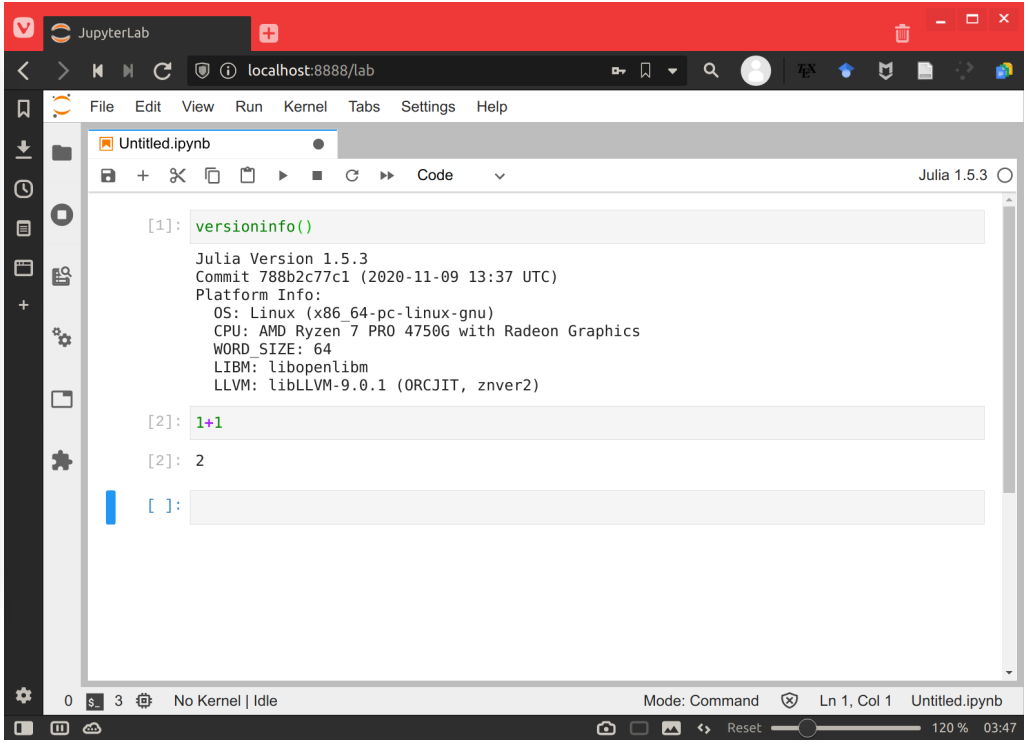
Julia





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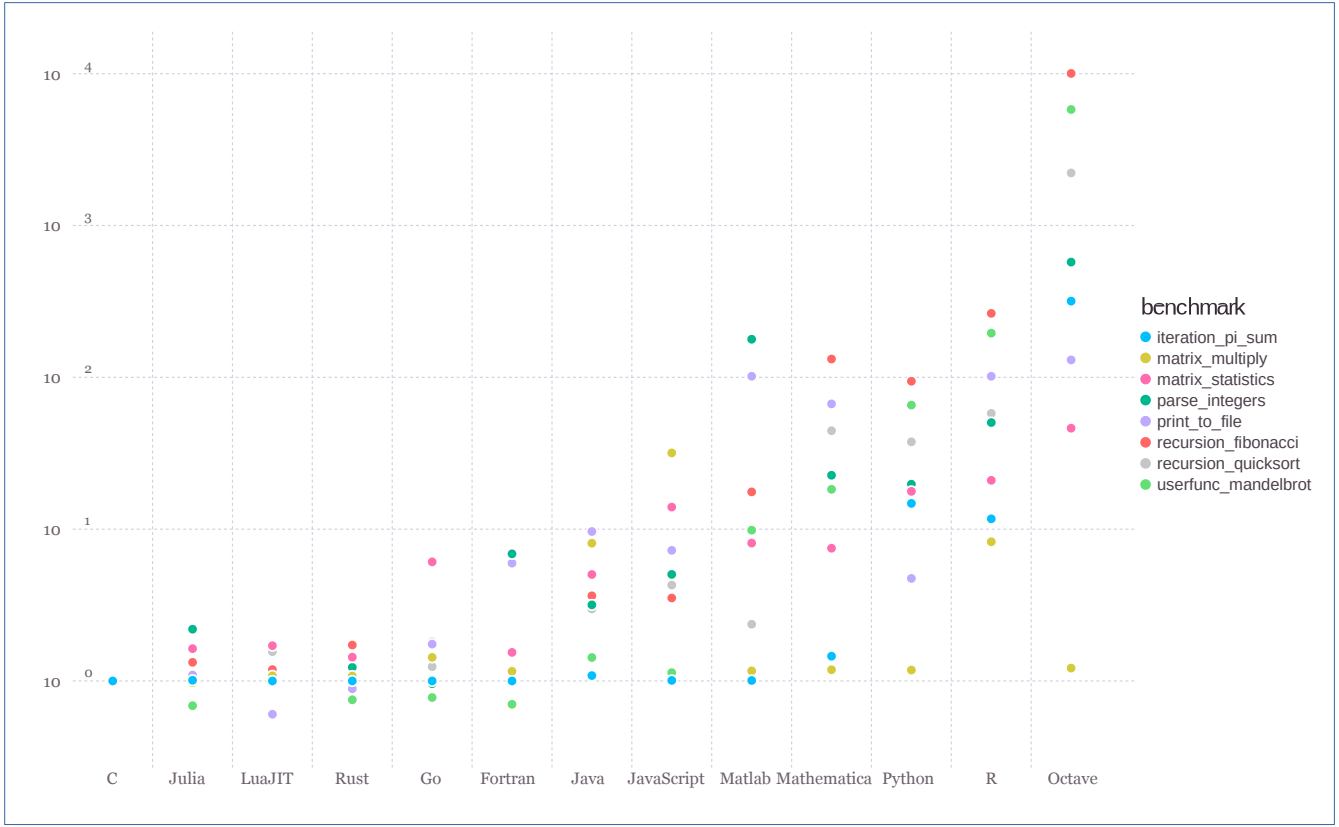
Julia microbenchmarks from https://julialang.org/benchmarks/



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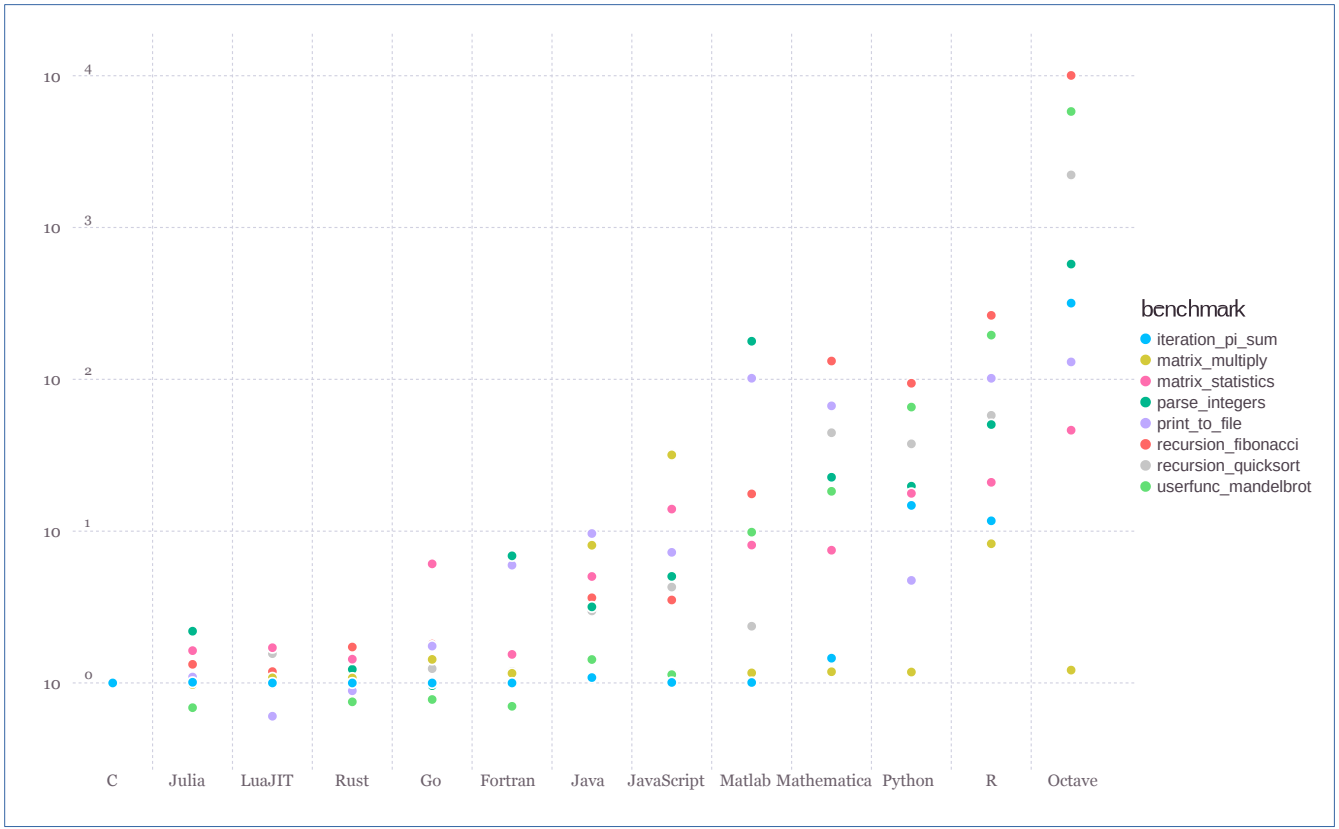

Julia is actually a compiled language!

It uses LLVM (same backend as the Clang C compiler)

Julia has nice syntax

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Let us define a function that returns a rotation by an angle that is a multiple of 2pi/6:

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Python code:

```
import numpy as np

def c6rotation(n):

    return np.array([
        [np.cos(2*np.pi*n/6), -np.sin(2*np.pi*n/6)],
        [np.sin(2*np.pi*n/6), np.cos(2*np.pi*n/6)]
    ])
```

Julia has nice syntax

Let us define a function that returns a rotation by an angle that is a multiple of 2pi/6:

Julia code:

```julia
c6rotation(n) = [
    cos(2π*n/6) -sin(2π*n/6);
    sin(2π*n/6) cos(2π*n/6)
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Maybe this sparked your interest

But you might be asking:

“Is anyone using Julia?”

Julia adoption

Julia adoption

Julia adoption evolution between 1st Jan 2020 and 1st Jan 2021:

	Total Cumulative as of Jan 1, 2020	Total Cumulative as of Jan 1, 2021	Change
Number of Julia Downloads (JuliaLang + Docker + JuliaPro)	12,950,630	24,205,141	+87%
Number of Julia Packages	2,787	4,809	+73%
GitHub stars (Julia language repo + registered packages)	99,830	161,774	+62%
YouTube views (Julia language channel)	1,562,223	3,320,915	+113%
Published citations of Julia: A Fast Dynamic Language for Technical Computing (2012) + Julia: A Fresh Approach to Numerical Computing (2017)	1,680	2,531	+51%
Discourse posts	137,399	211,888	+54%
TIOBE Index Rank	#47	#23	+24

from: https://juliacomputing.com/blog/2021/01/newsletter-january/

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Companies using Julia

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From https://juliacomputing.com:

JULIA USERS AND JULIA COMPUTING CUSTOMERS

intel
Disney
BNDES
O BANCO DO DESENVOLVIMENTO DE TODOS OS BRASILEIROS
amazon
Capital One
KPMG
Google
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Microsoft
IBM
BLACKROCK
NASA
Ford
OAK RIDGE
National Laboratory
AstraZeneca
FEDERAL AVIATION ADMINISTRATION
AVIVA
WESTERN ASSET
abbvie
Chevron
ExxonMobil
FEDERAL RESERVE BANK OF NEW YORK
INCORPORATED MAY 18, 1914
gsk
JPMORGAN CHASE & CO.
Pfizer
moderna
messenger therapeutics
SANOFI
STATE STREET
Takeda
EY
Building a better working world

Companies using Julia

From https://juliacomputing.com:

JULIA USERS AND JULIA COMPUTING CUSTOMERS

Science Labs

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Tech

intel
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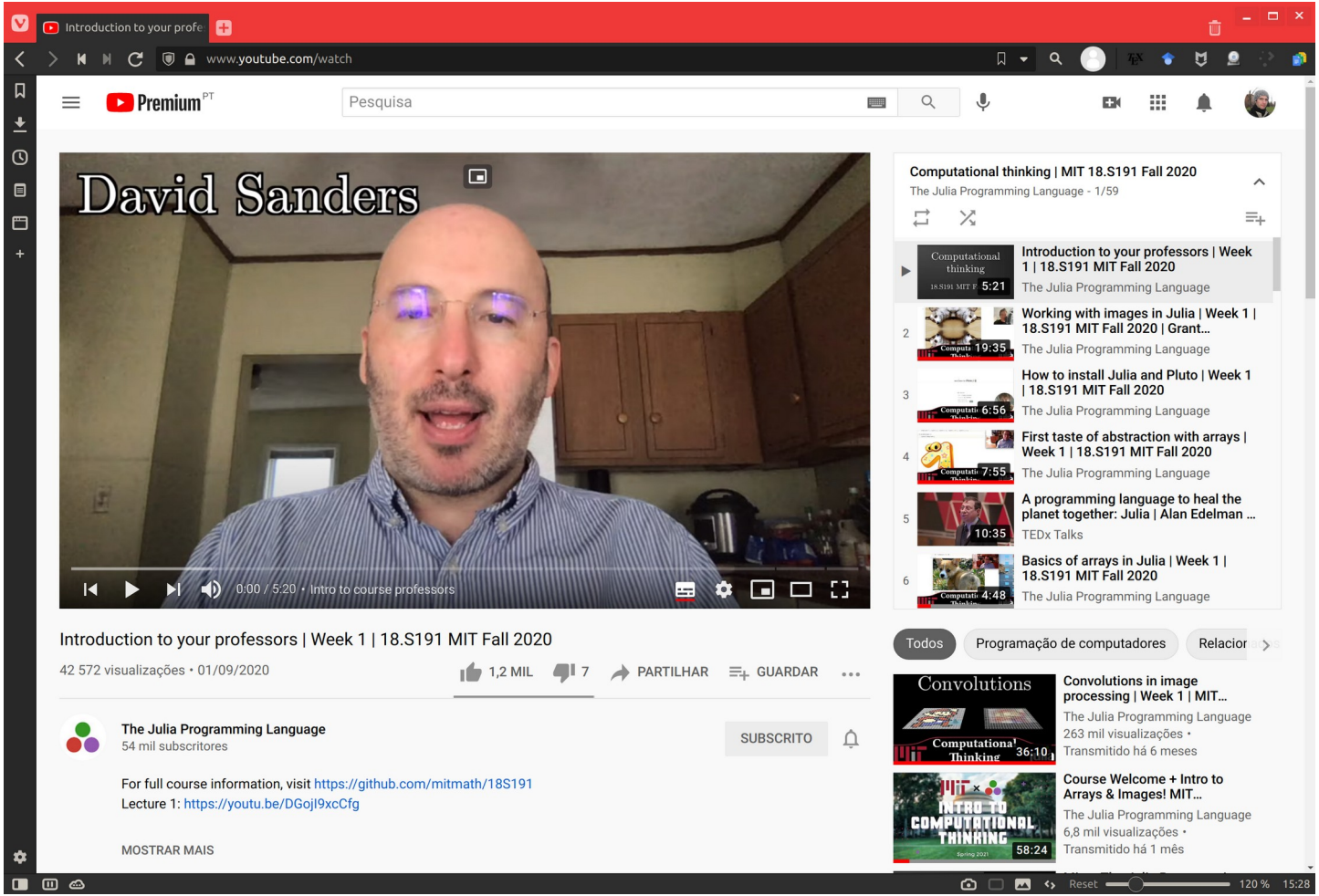
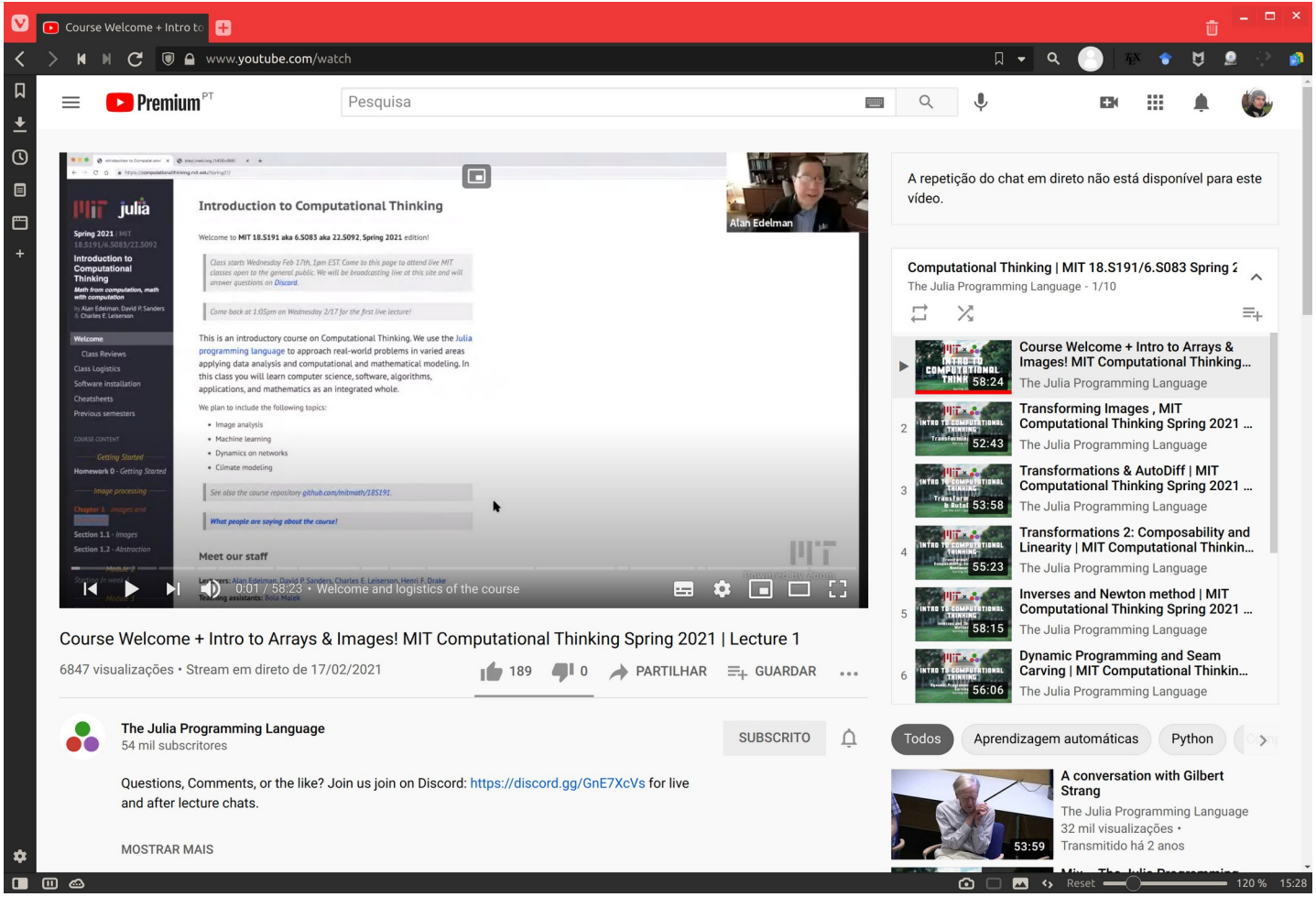
Most importantly:

Julia is being taugh at universities!

Julia course at MIT



Julia course at MIT



Julia course at MIT

It is being taught for some time:

- Massachusetts Institute of Technology (MIT)
  - 6.251 / 15.081, Introduction to Mathematical Programming (Prof. Dimitris J. Bertsimas), Fall 2015
  - 18.06, Linear Algebra: Fall 2015, Dr. Alex Townsend; Fall 2014, Prof. Alexander Postnikov; Fall 2013, Prof. Alan Edelman
  - 18.303, Linear Partial Differential Equations: Analysis and Numerics (Prof. Steven G. Johnson), Fall 2013–2016.
  - 18.337 / 6.338, Numerical Computing with Julia (Prof. Alan Edelman). Fall 2015 (IJulia notebooks). Fall 2013–
  - 18.085 / 0851, Computational Science And Engineering I (Prof. Pedro J. Sáenz)
  - 18.330, Introduction to Numerical Analysis (Dr. Homer Reid), Spring 2013–2015
  - 18.335, Introduction to Numerical Methods (Prof. Steven G. Johnson), Fall 2013, Spring 2015
  - 18.338, Eigenvalues Of Random Matrices (Prof. Alan Edelman), Spring 2015
  - 18.S096, Performance Computing in a High Level Language (Steven G. Johnson, Alan Edelman, David Sanders, Jeff Bezanson), January 2017.
  - 15.093 / 6.255, Optimization Methods (Prof. Dimitris Bertsimas and Dr. Phebe Vayanos), Fall 2014
  - 15.S60, Software Tools for Operations Research (Iain Dunning), Spring 2014
  - 15.083, Integer Programming and Combinatorial Optimization (Prof. Juan Pablo Vielma), Spring 2014

From: https://julialang.org/learning/classes/

Julia in other universities:

From: https://julialang.org/learning/

For a more detailed list: https://julialang.org/learning/classes/

Projects using Julia: Celeste project

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Project to catalog Sloan Digital Sky Survey

- processed ~ 178 terabytes of data in 14.6 minutes
- peak performance: 1.54 **petaflops**
- used **1.3 million threads** running on **9 300 nodes** at NERSC (National Energy Research Scientific Computing Center)
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For more info:
- https://juliacomputing.com/case-studies/celeste/
- https://youtu.be/uecdcADM3hY
- https://github.com/jeff-regier/Celeste.jl

Projects using Julia: Clima project

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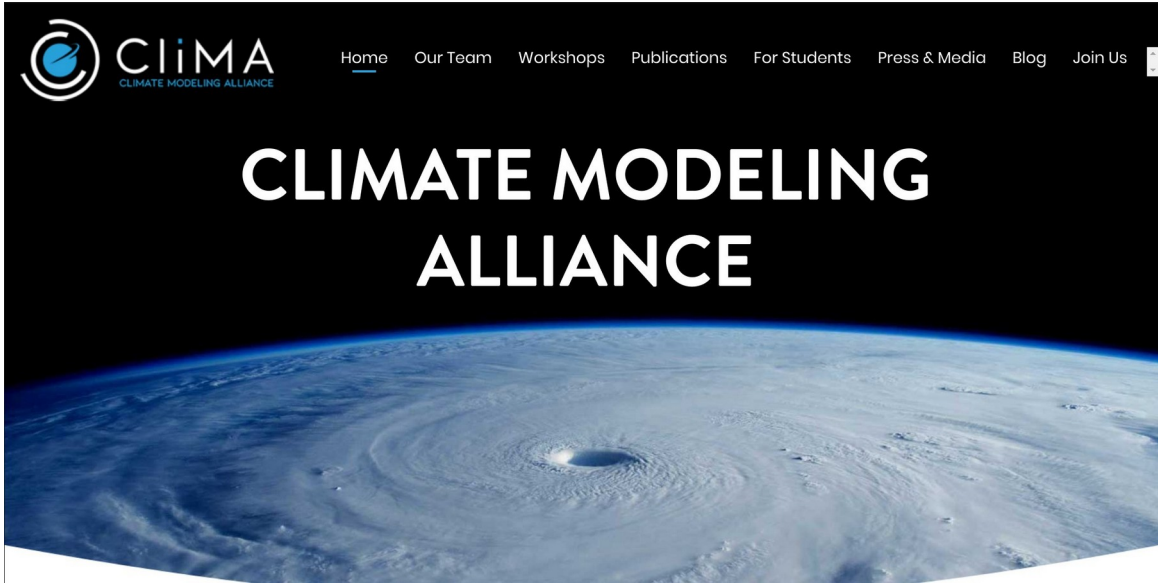
https://clima.caltech.edu

New climate model built from the ground up in Julia
Research consurtium:
- Caltech
- MIT
- Naval Postgraduate School
- Jet Propulsion Laboratory



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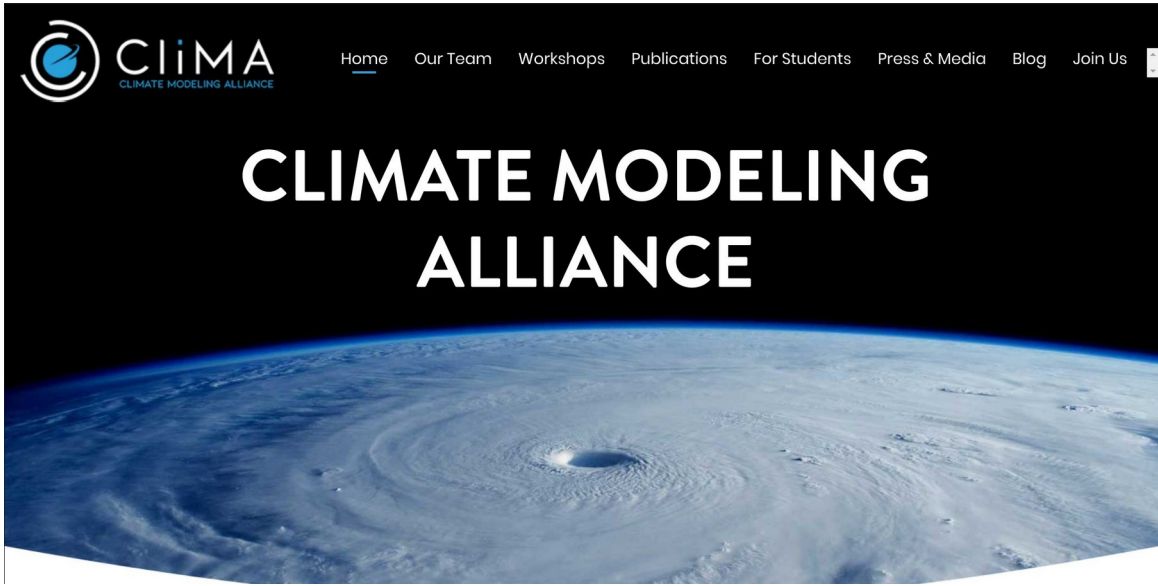

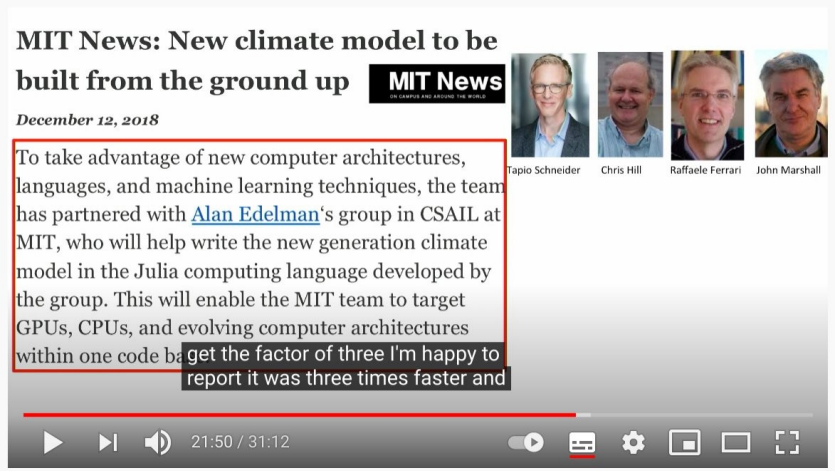

Where OK with a 3x slowdown.
Ended up being 3x faster!

https://youtu.be/nwdGsz4rc3Q?t=1238

https://www.hpcwire.com/2020/01/14/julia-programmings-dramatic-rise-in-hpc-and-elsewhere/

Rich package ecosystem

Rich package ecosystem

- **Iterative Linear Solvers:** IterativeSolvers.jl, KrylovKit.jl
- **Eigensolvers:** ArnoldiMethod.jl, KrylovKit.jl
- **Differential equations:** DifferentialEquations.jl
- **Integration:** QuadGK.jl, FastGaussQuadrature.jl, Quadrature.jl
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Physics related packages:

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- **Quantum Computing:** Yao.jl
- **Quantum optics:** QuantumOptics.jl
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You can search for more using:
- juliahub.com/ui/Packages
- juliaobserver.com/packages
- just use google

More resources to learn about julia

- **Julia page:** julialang.org
- **Julia documentation:** docs.julialang.org
- **Julia forum:** discourse.julialang.org
- **Julia youtube channel:** www.youtube.com/user/JuliaLanguage/playlists

More tutorials and books are listed in julialang.org/learning