Introduction to the Julia Programming Language

NSF ACES

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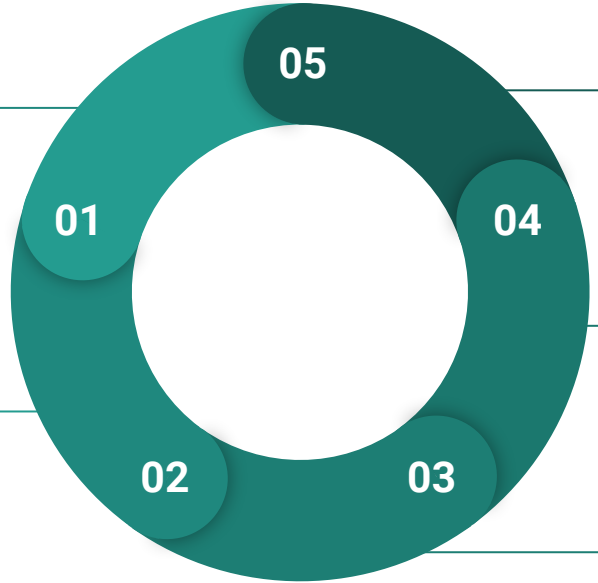
Introduction to Julia: Outline



Part I. A brief overview of Julia (~10 mins)

Part II. Getting Started with Julia on ACES (~10 mins)

Part III. Mathematical Operations in Julia (~10 mins)

Part IV. Variables, Data Types and Structures, Functions and Flow Control (~35 mins)

Part V. Plotting with Julia (~10 mins)

Part I: A brief overview of Julia

Julia is a high-level general-purpose dynamic programming language primarily designed for **high-performance numerical analysis and computational science**.

- Born in MIT's Computer Science and Artificial Intelligence Lab in 2009
- Combined the best features of Ruby, MatLab, C, Python, R, and others
- First release in 2012
- Latest stable release v1.10.2 as of Mar 31, 2024
- https://julialang.org/
- customized for "greedy, unreasonable, demanding programmers".
- Julia Computing established in 2015 to provide commercial support.

Major features of **Julia:**

- **Fast**: designed for high performance
- **General**: supporting different programming patterns
- **Dynamic**: dynamically-typed with good support for interactive use
- **Technical**: efficient numerical computing with a math-friendly syntax
- **Optionally typed**: a rich language of descriptive data types
- **Composable**: Julia's packages naturally work well together

*"Julia is as programmable as Python while it is as fast as Fortran for number crunching. It is like **Python on steroids**."*

--an anonymous Julia user on the first impression of Julia.

Where to Run Julia

- Juno IDE - developed for the Julia language (no longer under development)
- VSCode - extensions for Julia are actively being managed
- Jupyter Notebook
- Julia REPL
  - Run, Evaluate, Print, Loop
  - Interactive
  - Searchable history, tab-completion, keybindings, dedicated help and shell modes

Part II: Getting started with Julia on ACES

ACES

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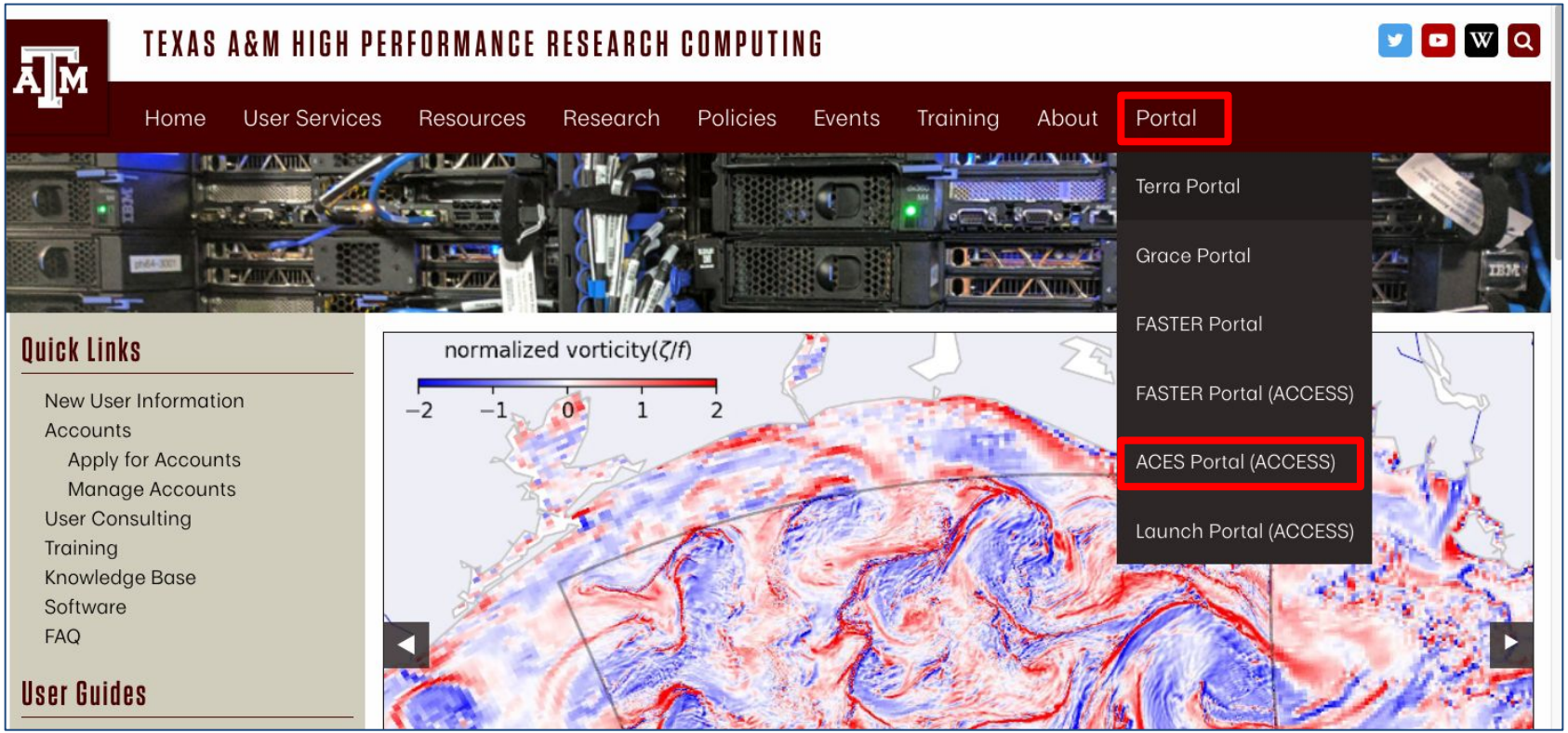
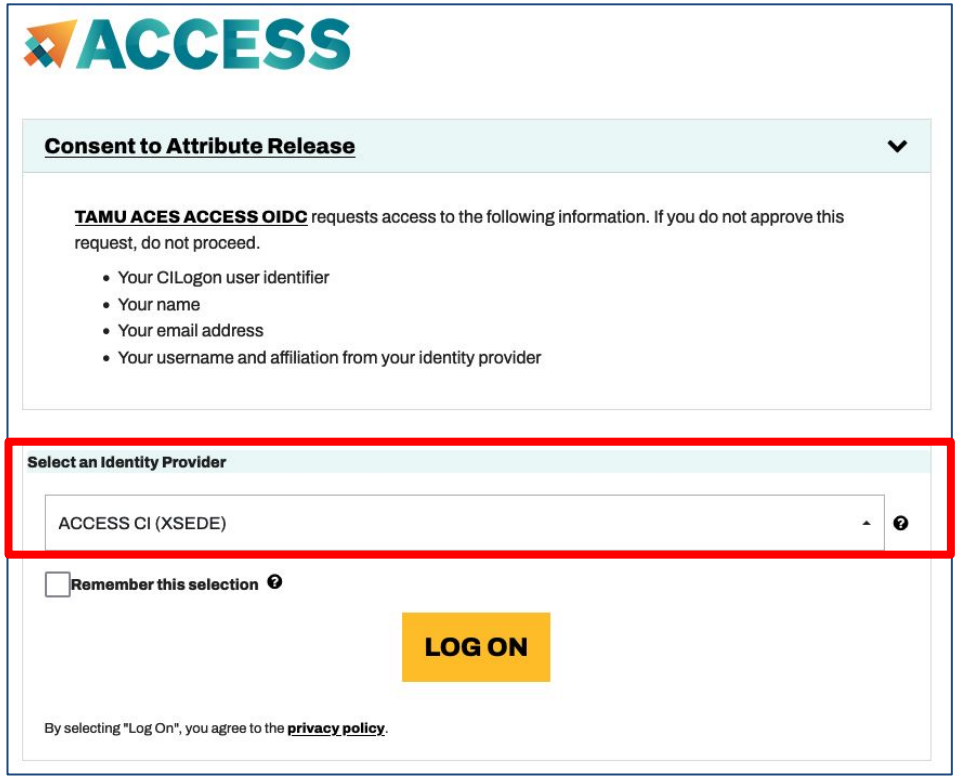
julia

Accessing the HPRC ACES Portal

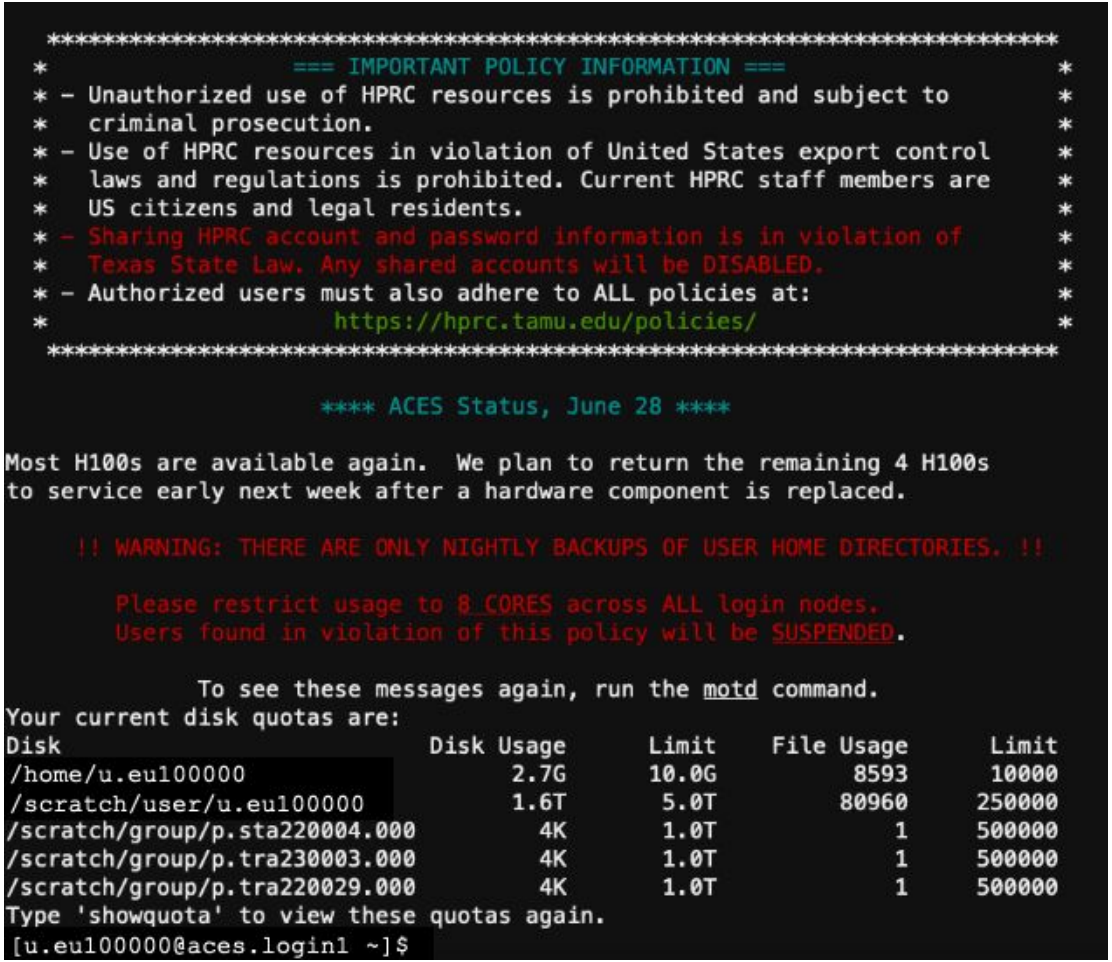


Accessing the HPRC ACES Portal

Select the Identity Provider appropriate for your account



Accessing the ACES Shell


****
* === IMPORTANT POLICY INFORMATION === *
* - Unauthorized use of HPRC resources is prohibited and subject to *
* criminal prosecution. *
* - Use of HPRC resources in violation of United States export control *
* laws and regulations is prohibited. Current HPRC staff members are *
* US citizens and legal residents. *
* - Sharing HPRC account and password information is in violation of *
* Texas State Law. Any shared accounts will be DISABLED. *
* - Authorized users must also adhere to ALL policies at: *
* https://hprc.tamu.edu/policies/ *
****
**** ACES Status, June 28 ****
Most H100s are available again. We plan to return the remaining 4 H100s
to service early next week after a hardware component is replaced.
!! WARNING: THERE ARE ONLY NIGHTLY BACKUPS OF USER HOME DIRECTORIES. !!
Please restrict usage to 8 CORES across ALL login nodes.
Users found in violation of this policy will be SUSPENDED.
To see these messages again, run the motd command.
Your current disk quotas are:
Disk Disk Usage Limit File Usage Limit
/home/u.eu100000 2.7G 10.0G 8593 10000
/scratch/user/u.eu100000 1.6T 5.0T 80960 250000
/scratch/group/p.sta220004.000 4K 1.0T 1 500000
/scratch/group/p.tra230003.000 4K 1.0T 1 500000
/scratch/group/p.tra220029.000 4K 1.0T 1 500000
Type 'showquota' to view these quotas again.
[u.eu100000@aces.login1 ~]$

Using Pre-installed Julia Modules

Step 1. Find the module to be loaded

$ module spider julia
...
Description:
Julia is a high-level, high-performance dynamic programming language for numerical computing

Versions:
Julia/1.8.5-linux-x86_64
Julia/1.9.3-linux-x86_64
Julia/1.10.0-musl-x86_64
Julia/1.10.2-linux-x86_64

...

Step 2. Load the module

$ module load Julia/1.10.2-linux-x86_64

Step 3. Start Julia REPL

$ julia

You can also use the web-based interface to find software modules available on HPRC systems.

Installing Your Own Copy of Julia

Step 1. Find the version to be installed at Download Julia

Current stable release: v1.10.4 (June 4, 2024)

Checksums for this release are available in both SHA256 and MD5 formats.

Platform	64-bit	32-bit
Windows [help]	installer, portable	installer, portable
macOS x86 (Intel or Rosetta) [help]	.dmg, .tar.gz	
macOS (Apple Silicon) [help]	.dmg, .tar.gz	
Generic Linux on x86 [help]	glibc (GPG), musl[1] (GPG)	glibc (GPG)
Generic Linux on ARM [help]	AArch64 (GPG)	
Generic Linux on PowerPC [help]	little endian (GPG)	
Generic FreeBSD on x86 [help]	.tar.gz (GPG)	

* You can install the latest Julia version (v1.10.4 June 4, 2024) directly by running this in your terminal:

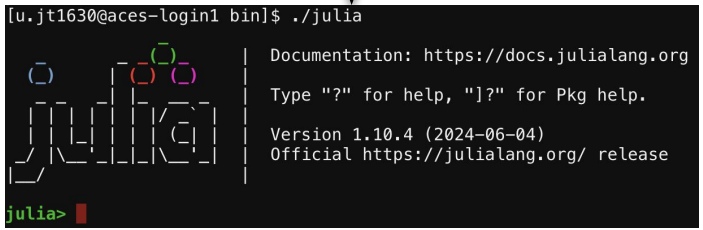
$curl -fsSL https://install.julialang.org | sh

Step 2. Download & Unzip

```
$ cd $SCRATCH
$ wget https://.../julia-1.10.4-linux-x86_64.tar.gz
$ tar -zxvf julia-1.10.4-linux-x86_64.tar.gz
```

Step 3. Start Julia REPL

```
$ module purge
$ cd $SCRATCH/julia-1.10.4/bin; ./julia
```



Installing Julia Packages

```
# export Julia Depot path (default to ~/.julia)
$export JULIA_DEPOT_PATH=$SCRATCH/.julia

# start Julia
$julia

# type ']' to open Pkg REPL
# press backspace or ^C to quit Pkg REPL.
julia>]
(@v1.9) pkg> add Plots UnicodePlots Plotly
```

Copying Course Examples

- Navigate to your personal scratch directory

```
$ cd $SCRATCH
```

- Files for this course are located at

  `/scratch/training/julia_examples.tgz`

  Make a copy in your personal scratch directory

```
$ cp /scratch/training/julia/julia_examples.tgz $SCRATCH/
```

- Extract the files

```
$ tar -zxvf julia_examples.tgz
```

- Enter this directory (your local copy)

```
$ cd julia_examples
```

```
$ julia helloworld.jl
```

Julia - Quickstart

- The julia program starts the interactive **REPL**.
- You can switch to the **shell mode** if you type a **semicolon**.
- A **question mark** will switch you to the **help mode**.
- The **<TAB>** key can help with autocompletion.
- To get version information:

```
julia> versioninfo()
```

- Special symbols can be typed with a backslash **and** **<TAB>**, but they might not show properly on the web-based terminal.

```
julia> \sqrt <TAB>
julia> for i ∈ 1:10 println(i) end  #\in <TAB>
```

Julia REPL Keybindings

Keybinding	Descrition
^d	Exit (when buffer is empty)
^c	Interrupt or cancel
^l	Clear console screen
Return/Enter, ^J	New line, executing if it is complete
? or ;	Enter help or shell mode (when at start of a line)
^R, ^S	Incremental history search
]	Enter Pkg REPL
Backspace or ^c	Quit Pkg REPL

Part III: Mathematical Operations in Julia

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Arithmetic Operators

Expression	Name	Description
+x	unary plus	the identity operation
-x	unary minus	maps values to their additive inverses
x + y	binary plus	performs addition
x - y	binary minus	performs subtraction
x * y	times	performs multiplication
x / y	divide	performs division
x ÷ y	integer divide	x / y, truncated to an integer
x ^ y	power	raises x to the yth power
x % y	remainder	equivalent to rem(x,y)

More about Arithmetic Operators

- The **order of operations** follows the math rules.
- The **updating version** of the operators is formed by placing a "**=**" immediately after the operator. For instance, **x+=3** is equivalent to **x=x+3**.
- **Unicode** could be defined as operator.
- **A "dot" operation** is automatically defined to perform the operation element-by-element on arrays in every binary operation.
- **Numeric Literal Coefficients**: Julia allows variables to be immediately preceded by a numeric literal, implying multiplication.

Arithmetic Expressions

Some examples:

```
julia> 10/5*2
julia> 5*2^3+4\2
julia> -2^4
julia> 8^1/3
julia> pi*ℯ #\euler <TAB>
julia> x=1; x+=3.1
julia> x=[1,2]; x = x.^(-2)
```

Relational Operators

==	True, if it is equal
!=,≠	True, if not equal to #\ne <TAB>
<	less than
>	greater than
<=,≤	less than or equal to #\le <TAB>
>=,≥	greater than or equal to #\ge <TAB>

** try ≠(4,5), what does this mean? How about !=(4,5)*

Boolean and Bitwise Operators

&&	Logical and
||	Logical or
!	Not
xor()	Exclusive OR
|	Bitwise OR
~	Negate
&	Bitwise And
>>	Right shift
<<	Left shift

NaN and Inf

NaN is a not-a-number value of type Float64.

Inf is positive infinity of type Float64.

-Inf is negative infinity of type Float64.

- **Inf** is equal to itself and greater than everything else except **NaN**.
- **-Inf** is equal to itself and less then everything else except **NaN**.
- **NaN** is not equal to, not less than, and not greater than anything, including itself.

```
julia> NaN == NaN
false

julia> NaN != NaN
true

julia> NaN < NaN
false

julia> NaN > NaN
false

julia> isequal(NaN, NaN)
true

julia> isnan(1/0)
false
```

Part IV: Variables, Data Types and Structures, Functions and Flow Control

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Variables

Examples:

```
julia> b = true; typeof(b)
julia> x = "Hi"
julia> y = 10
julia> z = complex(1, y)
julia> println(b, x, y, z)
julia> b = nothing; show(b)
julia> 🏈=2; 🏃=1     # \:football: <TAB> \:runner: <TAB>
```

Naming Rules for Variables

- Variable names must begin with a letter or underscore

  julia> 4c = 12

- Names can include any combinations of letters, numbers, underscores, and exclamation symbol. Some unicode characters could be used as well

  julia> c_4 = 12; δ = 2

- Maximum length for a variable name is not limited
- Julia is case sensitive. The variable name **A** is different than the variable name **a**.

Displaying Variables

- We can display a variable (i.e., show its value) by simply typing the name of the variable at the command prompt (leaving off the semicolon).

- We can also use **print** or **println** (print plus a new line) to display variables.

```
julia> print("The value of x is:"); print(x)
julia> println("The value of x is:"); print(x)
```

Exercise

Create two variables: **a = 4** and **b = 17.2**

Now use Julia to perform the following set of calculations:

$(b+5.4)^{1/3}$

$b^2-4b+5a$

```
a>b && a>1.0
```

```
a!=b
```

Data Types

- Data types in Julia are polymorphic, they can be
  - dynamic: determined at runtime (e.g. Python, R)
  - static: defined explicitly (e.g. Java, C++)

*more information on declaring types here: https://docs.julialang.org/en/v1/manual/types/

- Data types include:
  - char
  - string
  - float
  - int
  - bool

Chars and Strings

Char: represent a single character

- Denoted with single quotations ‘ ‘

String: can represent an object of one or more characters

- Denoted with double quotations “ “

```
julia> a = 'H'  #a is a character object
julia> b = "H"  #a is a string with length 1
```

Strings can be easily manipulated with built-in functions:

```
julia> c = string('s') * string('d')
julia> length(c); d = c^10*"4"; split(d,"s")
```

Working with Strings

1. The built-in type used for strings in Julia is **String**. This supports the full range of Unicode characters via the UTF-8 encoding.
2. Strings are **immutable.**
3. One can do comparisons and a limited amount of arithmetic with Char.
4. All indexing in Julia is **1-based**: the first element of any integer-indexed object is found at index 1.

```
julia> str = "Hello, world!"
julia> c = str[1]       #c = 'H'
julia> c = str[end]     #c = '!'
julia> c = str[2:8]     #c = "ello, w"
```

Working with Strings

Interpolation: Julia allows interpolation into string literals using **$**, as in Perl. To include a literal **$** in a string literal, escape it with a backslash:

```
julia> "1 + 2 = $(1 + 2)"  #"1 + 2 = 3"
julia> print("\$100 dollars!\n")
```

Working with Strings

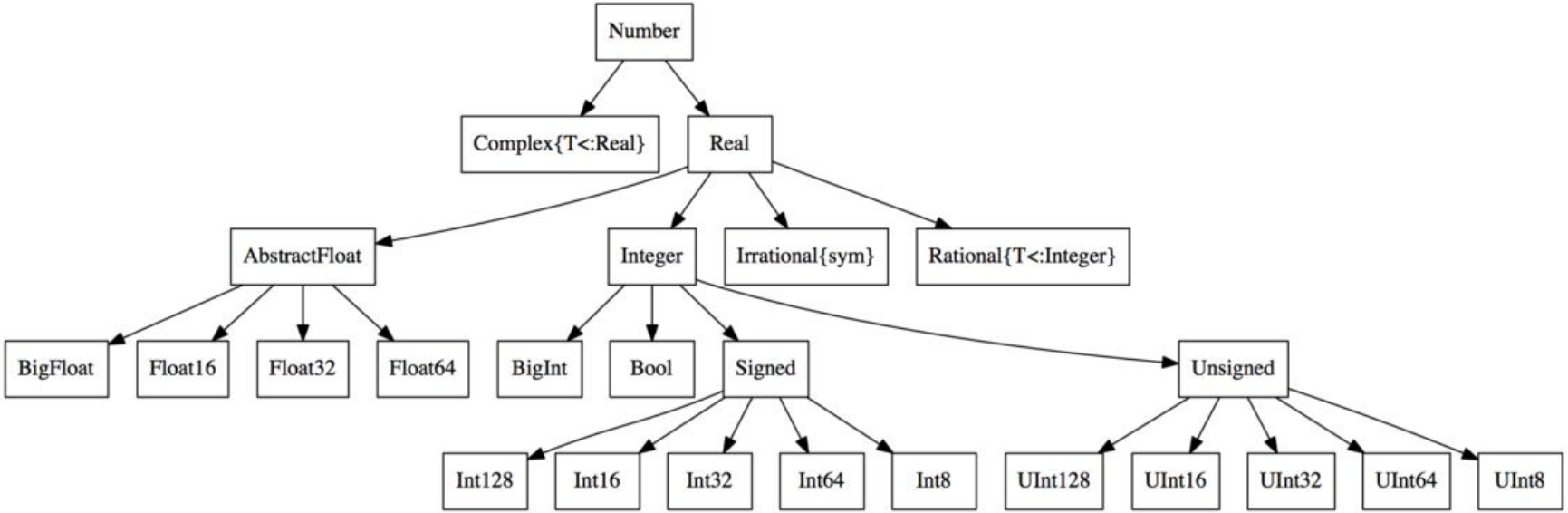
Julia comes with a collection of tools to handle strings.

```
julia> str="Julia"
julia> occursin("lia", str)
julia> z = repeat(str, 10)
julia> firstindex(str)
julia> lastindex(str)
julia> length(str)
```

Julia also supports Perl-compatible regular expressions.

```
julia> occursin(r"^\s*(?:#|$)", "# a comment")
```

Numerical Data Types



Integer Data Types

Type	Signed?	Number of bits	Smallest value	Largest value
Int8	✓	8	-2^7	2^7 - 1
UInt8		8	0	2^8 - 1
Int16	✓	16	-2^15	2^15 - 1
UInt16		16	0	2^16 - 1
Int32	✓	32	-2^31	2^31 - 1
UInt32		32	0	2^32 - 1
Int64	✓	64	-2^63	2^63 - 1
UInt64		64	0	2^64 - 1
Int128	✓	128	-2^127	2^127 - 1
UInt128		128	0	2^128 - 1
Bool	N/A	8	false (0)	true (1)

Handling Big Integers

An overflow happens when a number goes beyond the representable range of a given type. Julia provides **BigInt** type to handle big integers.

```
julia> x = typemax(Int64)
julia> x + 1
julia> x + 1 == typemin(Int64)
julia> x = big(typemax(Int64))^100
```

Floating Point Data Types

Type	Precision	Number of bits	Range
Float16	half	16	-65504 to -6.1035e-05 6.1035e-05 to 65504
Float32	single	32	−3.402823E38 to −1.401298E-45 1.401298E-45 to 3.402823E38
Float64	double	64	-1.79769313486232E308 to -4.94065645841247E-324 4.94065645841247E-324 to 1.79769313486232E308

- Additionally, full support for **Complex** and **Rational Numbers** is built on top of these primitive numeric types.
- All numeric types interoperate naturally without explicit casting thanks to a user-extensible **type promotion system**.

Working with Floating Points

Perform each of the following calculations in your head.

```
julia> a = 4/3
julia> b = a - 1
julia> c = 3*b
julia> e = 1 - c
```

What does Julia get?

Working with Floating Points

What does Julia get?

```
julia> a = 4/3   #1.3333333333333333

julia> b = a - 1 #0.3333333333333326

julia> c = 3*b   #0.9999999999999998

julia> e = 1 - c #2.220446049250313e-16
```

It is impossible to perfectly represent all real numbers using a finite string of 1's and 0's.

Working with Floating Points

Now try the following with BigFloat

```
julia> a = big(4)/3

julia> b = a - 1

julia> c = 3*b

julia> e = 1 - c #-1.7272337110188...e-77
```

Next, set the precision and repeat the above

```
julia> setprecision(4096)
```

BigFloat variables can store floating point data with arbitrary precision with a performance cost.

Complex and Rational Numbers

The global constant **im** is bound to the complex number **i**, representing the principal square root of **-1**.

```
julia> 2(1 - 1im)

julia> sqrt(complex(-1, 0))
```

Note that **3/4im == 3/(4*im) == -(3/4*im)**, since a literal coefficient binds more tightly than division. **3/(4*im)!=(3/4*im)**

Julia has a **rational number** type to represent exact ratios of integers.
Rationals are constructed using the **//** operator, e.g., **9//27**

Some Useful Math Functions

Rounding and division functions

Function	Description
round(x)	round x to the nearest integer
floor(x)	round x towards -Inf
ceil(x)	round x towards +Inf
trunc(x)	round x towards zero
div(x,y)	truncated division; quotient rounded towards zero
fld(x,y)	floored division; quotient rounded towards -Inf
cld(x,y)	ceiling division; quotient rounded towards +Inf
rem(x,y)	remainder; satisfies x == div(x,y)*y + rem(x,y); sign matches x
gcd(x,y...)	greatest positive common divisor of x, y,...
lcm(x,y...)	least positive common multiple of x, y,...

Sign and absolute value functions

Function	Description
abs(x)	a positive value with the magnitude of x
abs2(x)	the squared magnitude of x
sign(x)	indicates the sign of x, returning -1, 0, or +1
signbit(x)	indicates whether the sign bit is on (true) or off (false)
copysign(x,y)	a value with the magnitude of x and the sign of y
flipsign(x,y)	a value with the magnitude of x and the sign of x*y

** The built-in math functions in Julia are implemented in C(openlibm).*

Getting Help with Functions

- For help on a specific function or macro, type **?** followed by its name, and press enter. This only works if you know the name of the function you want help with. With **^S** and **^R** you can also do historical search.

```
Julia> ?cos
```

- Type **?help** to get more information about help

```
Julia> ?help
```

Code Elements and Syntax

- Comments start with '#'
- Compound expressions
  - Can be created with ";" chains

```
julia>z = (x = 1, y = 2, x + y)
```

  - or with blocks: start with "begin" and finish with "end"

```
julia> z = begin
           x = 1
           y = 2
           x + y
       end
```

Data Structures

Tuples: ordered sequence of elements.

- Good for small fixed-length collections
- Immutable

```
julia> t = (1, 2, 3)
julia> t = ((1, 2), (3, 4))
julia> t[1][2]
```

Data Structures

Arrays: ordered collection of elements.

- In Julia, **arrays** are used for lists, vectors, tables, and matrices
- Mutable

```
julia> a = [1, 2, 3]          # column vector
julia> b = [1 2 3]            # row vector
julia> c = [1 2 3; 4 5 6]     # 2x3 vector
julia> d = [n^2 for n in 1:5]
julia> f = zeros(2,3); g = rand(2,3)
julia> h = ones(2,3); j = fill("A",9)
julia> k = reshape(rand(5,6),10,3)
julia> [a a]                          # hcat
julia> [b;b]                          # vcat
```

Array and Matrix Operations

Many Julia operators and functions can be used preceded with a dot. These versions are the same as their non-dotted versions, and work on the arrays element by element.

```
julia> b = [1 2 3; 4 5 7; 7 8 9]
julia> b .+ 10          # each element + 10
julia> sin.(b)          # sin function
julia> b'               # transpose (transpose(b))
julia> inv(b)           # inverse
julia> b * b            # matrix multiplication
julia> b .* b           # element-wise multiplication
julia> b .^ 2           # element-wise square
```

Data Structures

Sets: mainly used to eliminate repeated numbers in a sequence/list and are also used to perform some standard set operations.

```
julia> months=Set(["Nov","Dec","Dec"])
julia> typeof(months)
julia> push!(months,"Sept")
julia> pop!(months,"Sept")
julia> in("Dec", months)
julia> m=Set(["Dec","Mar","Feb"])
julia> union(m,months)
julia> intersect(m,months)
julia> setdiff(m,months)
```

Data Structures

Dictionaries: mappings between keys and items stored in the dictionaries.

- To define a dictionary, use **`Dict()`**

```
julia> m=Dict("Oct"=>"October",
              "Nov"=>"November",
              "Dec"=>"December")
julia> m["Oct"]
julia> get(m, "Jan", "N/A")
julia> haskey(m, "Jan")
julia> m["Jan"]="January"
julia> delete!(m, "Jan")
julia> keys(m)
julia> values(m)
julia> map(uppercase, collect(keys(m)))
```

Flow Control

Julia has the following controlling constructs:

- **ternary** expressions
- **boolean switching** expressions
- **if elseif else end** - conditional evaluation
- **for end** - iterative evaluation
- **while end** - iterative conditional evaluation
- **try catch error throw** exception handling

Conditional Statements

- Execute statements if condition is true.
- There is no "**switch"** and "**case"** statement in Julia.
- There is an "**ifelse"** statement.

```
julia> a = 8
julia> if a>10
           println("a > 10")
       elseif a<10
           println("a < 10")
       else
           println("a = 10")
       end
```

Loop Control Statements - *for*

for statements help repeatedly execute a block of code for a certain number of iterations. Loop variables are local.

```
julia> for i in 0:1:10
           if i % 3 == 0
               continue
           end
           println(i)
       end
julia> for l in "julia"
           print(l, "-^-")
       end
```

Loop Control Statements - *while*

while statements repeatedly execute a block of code as long as a condition is satisfied.

```
julia> n = 1
julia> s = 0
julia> while n <= 100
           s = s + n
           n = n + 1
       end
julia> println(s)
```

Exception Handling Blocks

try … catch construction checks for errors and handles them gracefully

```
julia> s = "test"
julia> try
           s[1] = "p"
       catch err
           println("caught an error: $err")
           println("continue with execution!")
       end
```

Functions: Building Blocks of Julia

Two equivalent ways to define a function

```
julia> function func(x,y)
           return x + y, x
       end

julia> Σ(x,y) = x + y, x
```

Operators are functions

```
julia> +(1,2); plusfunc=+
Julia> plusfunc(2,3)
```

Recommended style for function definition: **append ! to names of functions that modify their arguments**

Functions with Optional Arguments

You can define functions with optional arguments with default values.

```
julia> function point(x, y, z=0)
         println("$x, $y, $z")
       end
julia> point(1,2); point(1,2,3)
```

Keywords and Positional Arguments

Keywords can be used to label arguments. Use a **semicolon** after the function's unlabelled arguments, and follow it with one or more **keyword=value** pairs

```
julia> function func(a, b, c="one"; d="two")
         println("$a, $b, $c, $d")
       end
julia> func(1,2); func(d="four", 1, 2, "three")
```

Dotted Functions

Dot syntax can be used to vectorize functions, i.e., applying functions **elementwise** to arrays.

```
julia> func(a, b) = a * b
julia> func(1, 2)
julia> func.([1,2], 3)
julia> sin.(func.([1,2],[3,4]))
```

Part V: Plotting with Julia

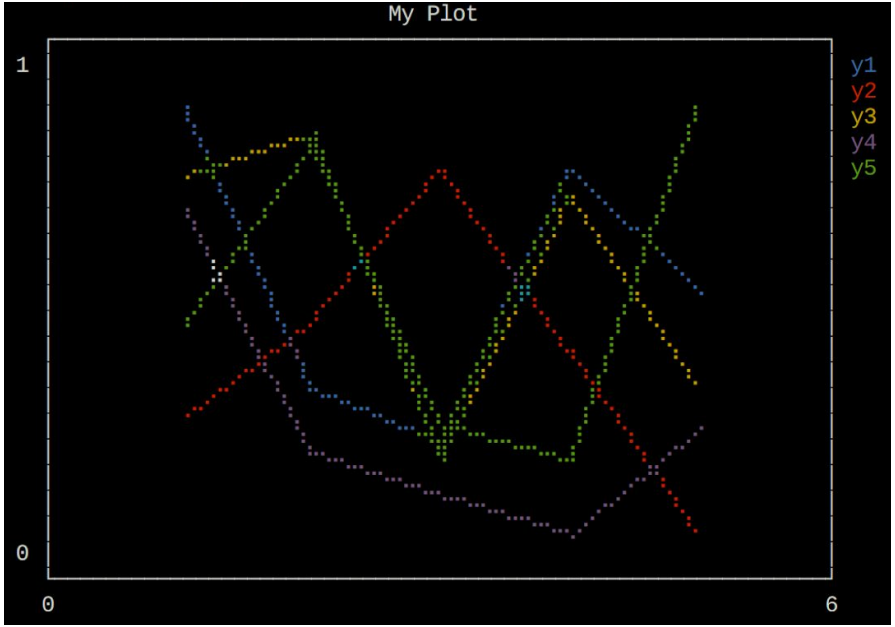
ACES

ACCELERATING COMPUTING
FOR EMERGING SCIENCES

UnicodePlots

UnicodePlots is simple and lightweight and it plots directly in your terminal (*might not work with web-based shell*).

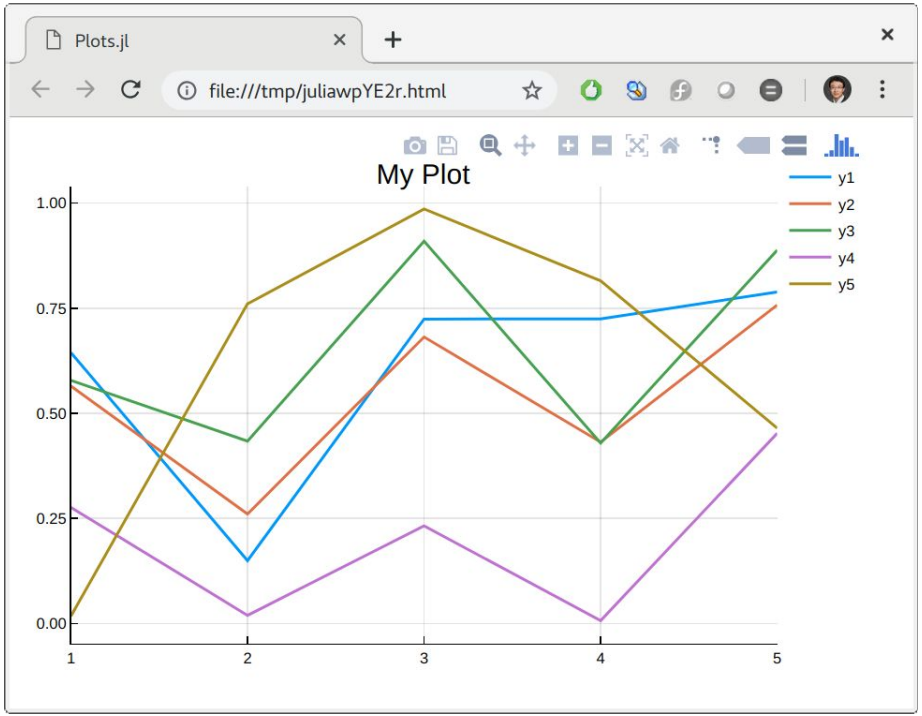
```
julia> using Plots
julia> unicodeplots()
julia> plot(rand(5,5), linewidth=2, title="My Plot")
```



Plotly Julia Library

Plotly creates leading open source software for Web-based data visualization and analytical apps. Plotly Julia Library makes interactive, publication-quality graphs online (not working with web-based shell).

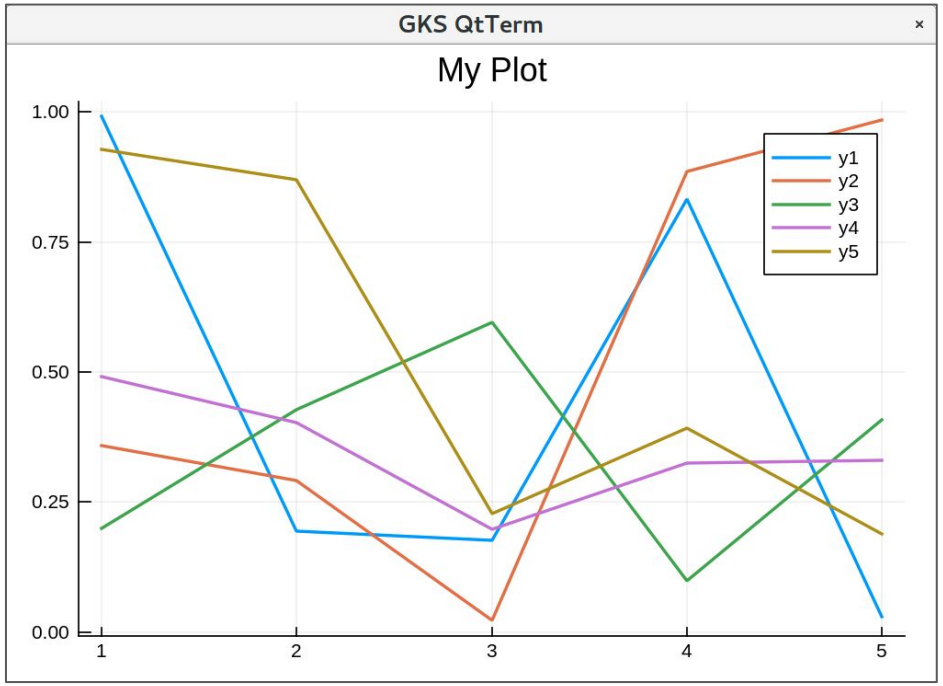
```
julia> using Plots
julia> plotly()
julia> plot(rand(5,5), linewidth=2, title="My Plot")
```



GR Framework

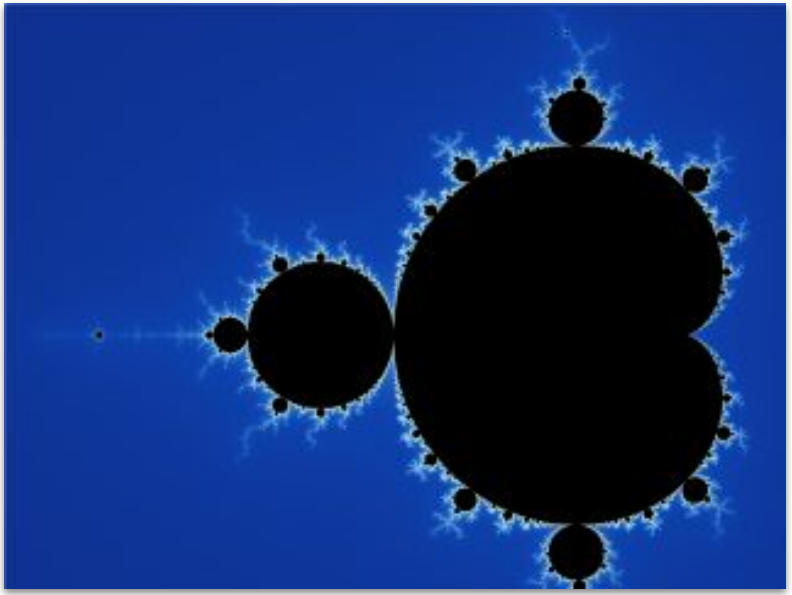
GR framework is a universal framework for cross-platform visualization applications (not working with web-based shell).

```
julia> using Plots
julia> gr()
julia> plot(rand(5,5), linewidth=4, title="My Plot", size=(1024,1024))
```



Fractals

- Fractals refer to geometric shapes containing detailed structures at arbitrarily small scales
- Fractals appear similar at various scales



Credit: Fractal - Wikipedia

Benoit Mandelbrot Set

$$z_{n+1} = z_n^2 + c$$

- z and c are complex numbers.
- Starting with z_0=0.
- Mandelbrot set is the set of values of c when z_n remains bounded for a relatively large n.

Mandelbrot - Julia Version

```
function mandelbrot(a)
  z = 0
  for i=1:50
      z = z^2 + a
  end
  return z
end

for y=1.0:-0.05:-1.0
  for x=-2.0:0.0315:0.5
      abs(mandelbrot(complex(x, y))) < 2
? print("*") : print(" ") # in one line
  end
  println()
end
```

The first published picture of the Mandelbrot set, by Robert W. Brooks and Peter Matelski in 1978, reproduced with the code to the left.

Online Resources

Official Julia Document

https://docs.julialang.org/en/v1/

Julia Online Tutorials

https://julialang.org/learning/

Introducing Julia (Wikibooks.org)

https://en.wikibooks.org/wiki/Introducing_Julia

MATLAB–Python–Julia cheatsheet

https://cheatsheets.quantecon.org/

The Fast Track to Julia

https://juliadocs.github.io/Julia-Cheat-Sheet/

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Texas A&M at PEARC24

Talk/Event	Date/Time	Room
Tutorial: Hands-on exercises on the Intel Data Center GPU Max 1100 (PVC-GPU) for AI/ML and Molecular Dynamics Workflows on the ACES Testbed	Mon, July 22, 2024 9:00 AM-12:30 PM ET	Room 553B
Seventh Workshop on Strategies for Enhancing HPC Education and Training (SEHET24)	Mon, July 22, 2024 9:00 AM-12:30 PM ET	Room 557
Workshop: Providing cutting-edge computing testbeds to the science and engineering community	Mon, July 22, 2024 1:30 PM-5:00 PM ET	Room 554A
Workshop: Engaging Secondary Students in Computing: K12 Outreach	Mon, July 22, 2024 1:30 PM-5:00 PM ET	Room 553A
Cultivating Cyberinfrastructure Careers through Student Engagement at Texas A&M University High Performance Research Computing	Tue, July 23, 2024 11:00 AM-11:25 AM ET	Junior Ballroom
Insight Gained from Migrating a Machine Learning Model to Intelligence Processing Units	Tue, July 23, 2024 11:00 AM-11:25 AM ET	Room 551 A&B
BOF 4: What's in it for me? How can we truly democratize the research computing and data community?	Tue, July 23, 2024 1:30 PM-2:30 PM ET	Room 551 A&B

Texas A&M at PEARC24

Talk/Event	Date/Time	Room
BRICCs: Building Pathways to Research Cyberinfrastructure at Under Resourced Institutions	Tue, July 23, 2024 3:25 PM-3:50 PM ET	Junior Ballroom
Memory Bandwidth Performance across Accelerators	Tue, July 23, 2024 3:25 PM-3:50 PM ET	Ballroom B
Container Adoption in Campus High Performance Computing	Wed, July 24, 2024 11:00 AM-11:25 AM ET	Ballroom B
Engaging Secondary Students in Computing and Cybersecurity	Wed, July 24, 2024 3:15 PM-3:30 PM ET	Room 557
Exploring the Viability of Composable Architectures to Overcome Memory Limitations in High Performance Computing Workflows	Wed, July 24, 2024 3:45 PM-4:00 PM ET	Room 553 A&B
Performance of Molecular Dynamics Acceleration Strategies on Composable Cyberinfrastructure	Wed, July 24, 2024 4:15 PM-4:30 PM ET	Room 551 A&B
BOF 17: Fantastic ACCESS Cyberinfrastructure Resources and Where to Find Them	Wed, July 24, 2024 4:45 PM-5:45 PM ET	Room 553 A&B
BOF 18: Recipes to build successful cross-institutional collaborative computing	Wed, July 24, 2024 4:45 PM-5:45 PM ET	Junior Ballroom

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