Hewlett Packard Enterprise

ChapelCon 2024: State of the Chapel Project

Brad Chamberlain

June 7, 2024

What is Chapel?

Chapel: A modern parallel programming language

- Portable & scalable
- Open-source & collaborative

Goals:

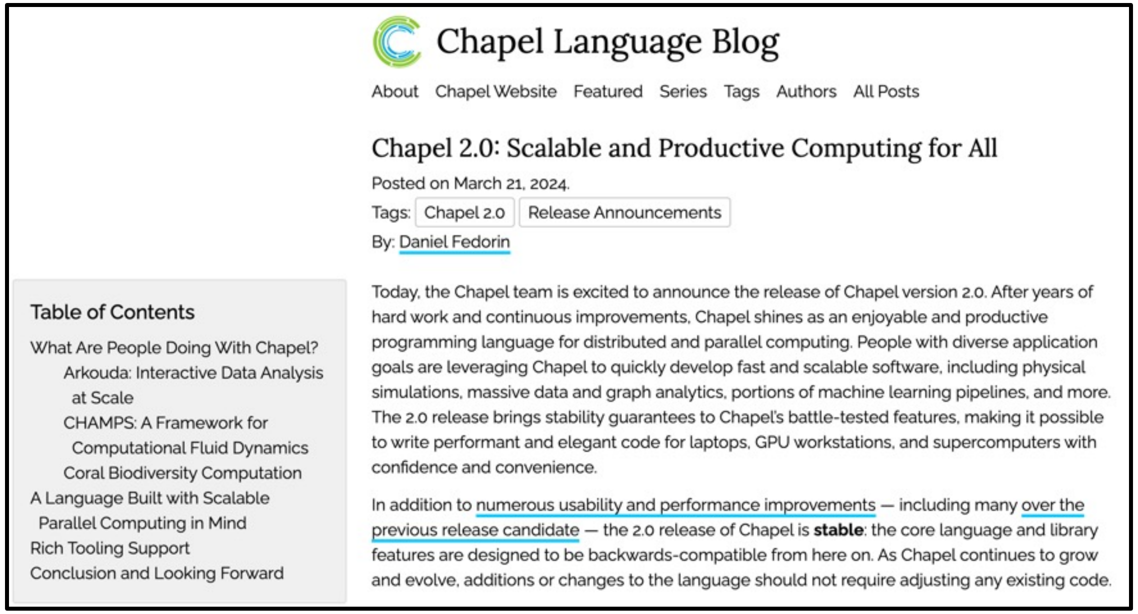
- Support general parallel programming
- Make parallel programming at scale far more productive

Chapel 2.0

Chapel 2.0 has been released!

What is Chapel 2.0?

- A milestone release!
- Stabilizes core language and library features
  - these features should not have breaking changes in the future
- **Released:** March 21, 2024
- Chapel 1.32/1.33 served as release candidates



Chapel Language Blog

About Chapel Website Featured Series Tags Authors All Posts

Chapel 2.0: Scalable and Productive Computing for All

Posted on March 21, 2024.

Tags: Chapel 2.0 Release Announcements

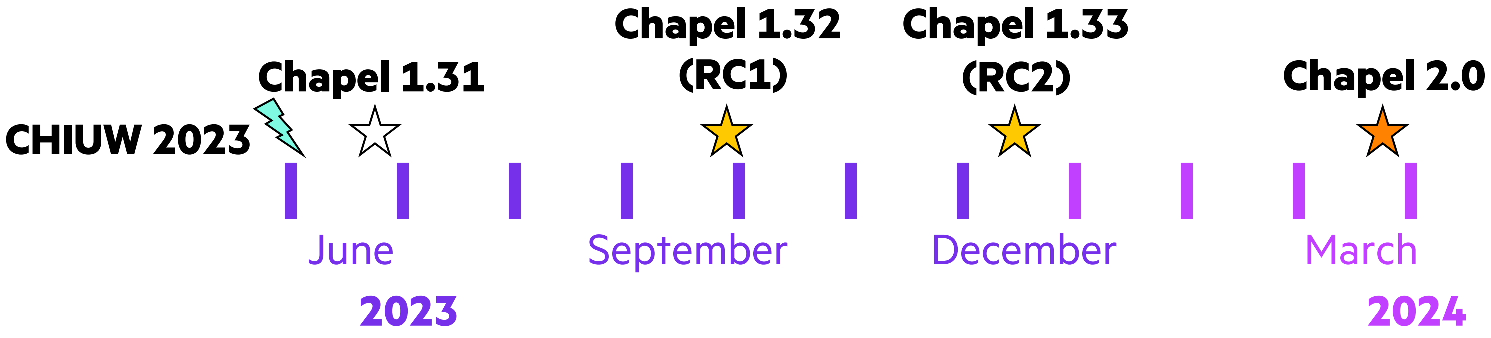
By: Daniel Fedorin

Table of Contents

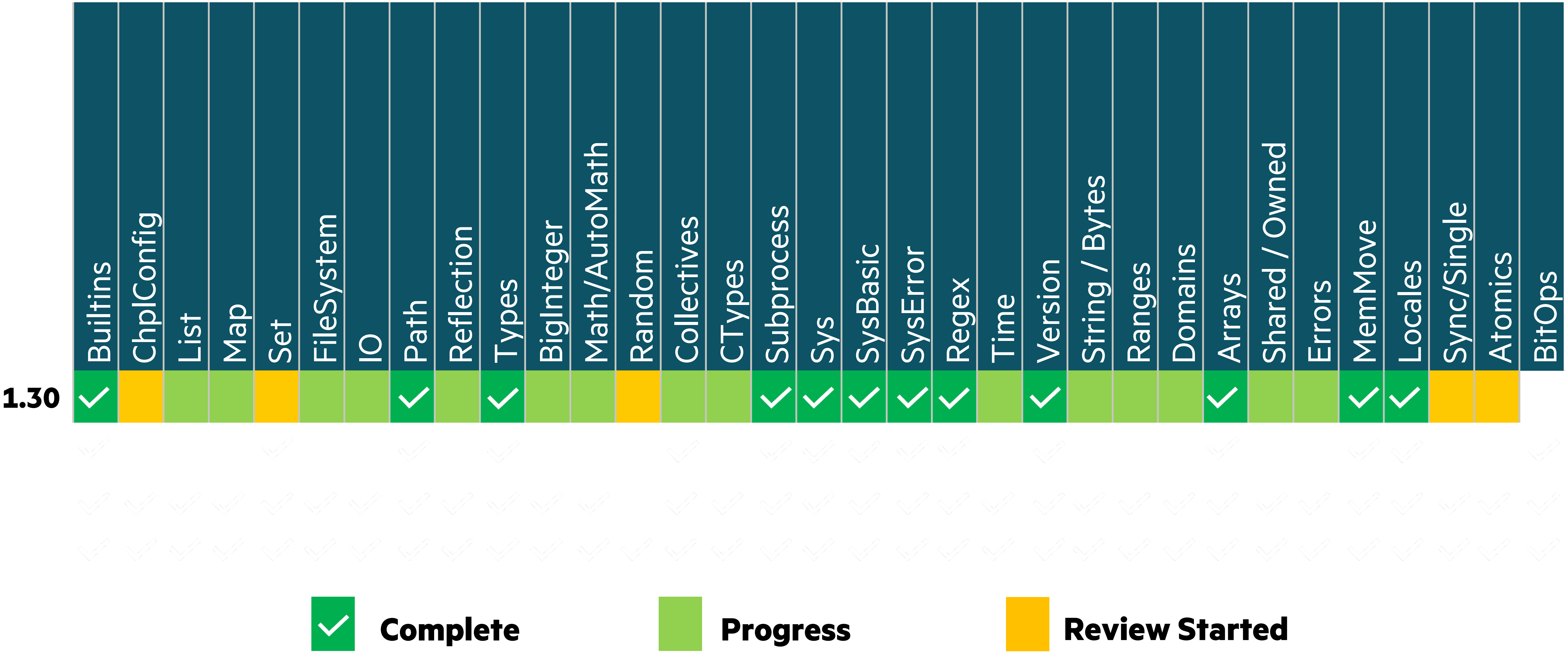
Today, the Chapel team is excited to announce the release of Chapel version 2.0. After years of hard work and continuous improvements, Chapel shines as an enjoyable and productive programming language for distributed and parallel computing. People with diverse application goals are leveraging Chapel to quickly develop fast and scalable software, including physical simulations, massive data and graph analytics, portions of machine learning pipelines, and more. The 2.0 release brings stability guarantees to Chapel's battle-tested features, making it possible to write performant and elegant code for laptops, GPU workstations, and supercomputers with confidence and convenience.

In addition to numerous usability and performance improvements — including many over the previous release candidate — the 2.0 release of Chapel is **stable**: the core language and library features are designed to be backwards-compatible from here on. As Chapel continues to grow and evolve, additions or changes to the language should not require adjusting any existing code.

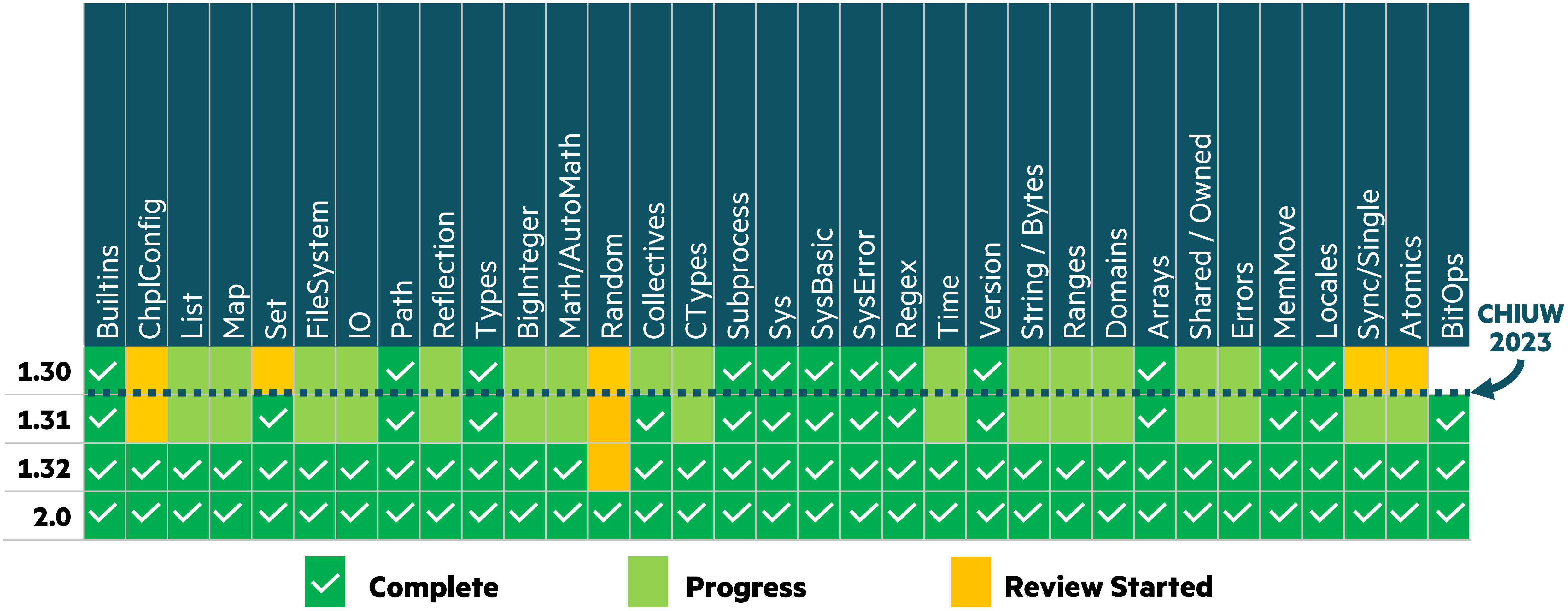
https://chapel-lang.org/blog/posts/announcing-chapel-2.0/



Chapel 2.0 Library Stabilization: Status as of CHIUW 2023



Chapel 2.0 Library Stabilization: Progress since CHIUW 2023



Chapel 2.0 Language Stabilization: Highlights Since CHIUW 2023

Language:

- Visibility of generic types
- Handling of numeric types, including generics
- ‘range’/ ‘domain’/array/distribution improvements
- ‘string’/‘bytes’/‘c_string’ stabilization
- ‘sync’/‘single’ stabilization
- Intents: defaults for arrays, return/yield intents, …
- Protection of special method names
- Lifetimes of temporaries
- Classes: casting, lifetime management, …
- Implicit ‘param’ to ‘const ref’ conversions
- Made ‘serial’ statements unstable
- Marked ‘local’ statements unstable
- …

Chapel 2.0: What's Next?

- **Chapel 2.1:** scheduled for June 27

- **Continue stabilizing features**
  - Prioritize those identified by users / developers
    - e.g., 'Sort' module, 'dmapped' keyword, …
    - use '--warn-unstable' to identify unstable features

- **Establish means of making future changes**
  - e.g., create a Chapel language advisory board?

Community Focus

Focus on the Chapel Community

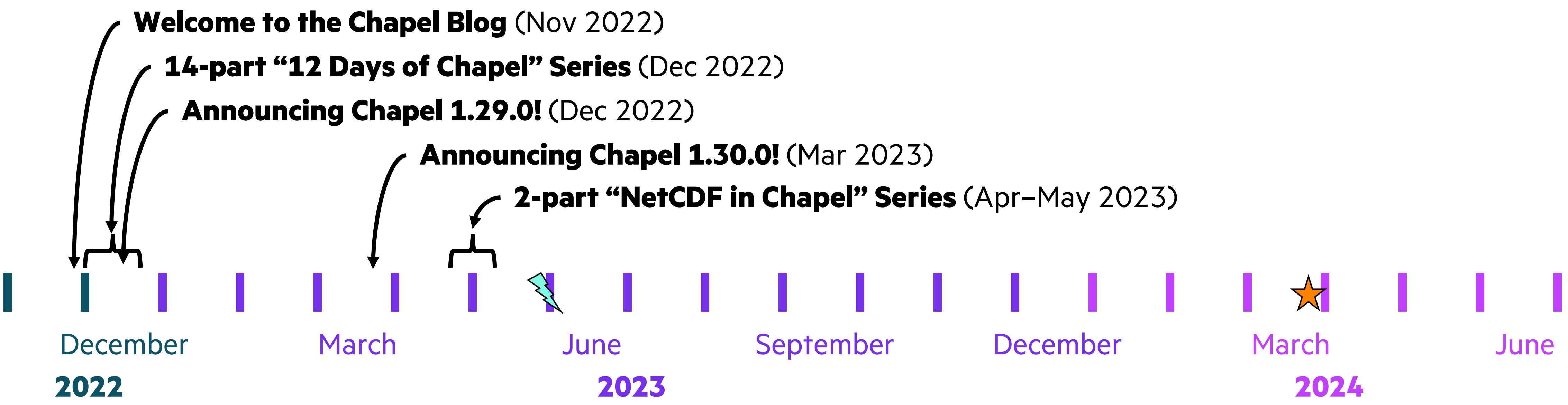
- With 2.0 wrapped up, we have shifted focus toward nurturing the Chapel community
  - Supporting existing users
  - Seeking out new use-cases and users
  - Amplifying our message about Chapel

- This has become our new “all-hands” activity

- Since CHIUW 2023, we have hired our first-ever community manager, Sarah Coghlan

- We’ve also kicked off several initiatives with this community focus in mind:
  - Rebranding CHIUW to **ChapelCon**, expanding its scope and format
  - Renewed focus on resolving **user GitHub issues**
    - 140 closed since CHIUW 2023
    - 88 closed the year prior to that
  - Plus…

Chapel Blog: Articles prior to CHIUW 2023



Chapel Blog: Articles since CHIUW 2023

Generic Linear Multistep Method Evaluator using Chapel (May)

Doing Science in Python? Wishing for more speed or scalability? (Apr)

Chapel's High-Level Support for CPU-GPU Data Transfers and Multi-GPU Programming (Apr)

Navier-Stokes in Chapel — Introduction (Apr)

Supercharged Chapel Editor Support (Apr)

Introducing ChapelCon '24: The Chapel Event of the Year (Apr)

Chapel 2.0: Scalable and Productive Computing for All (Mar)

Changes to Chapel 2.0 Since its First Release Candidate (Feb)

Comparing Standard Library Sorts: The Impact of Parallelism (Jan)

Introduction to GPU Programming in Chapel (Jan)

Announcing Chapel 1.33! (Dec)

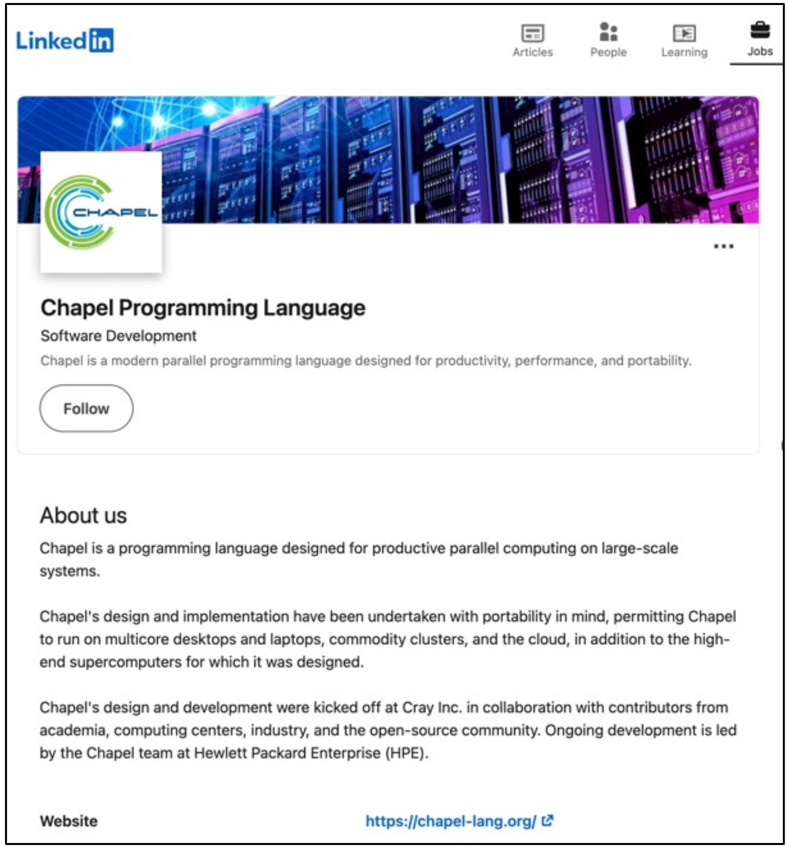
SC23 from the Chapel Language Perspective (Dec)

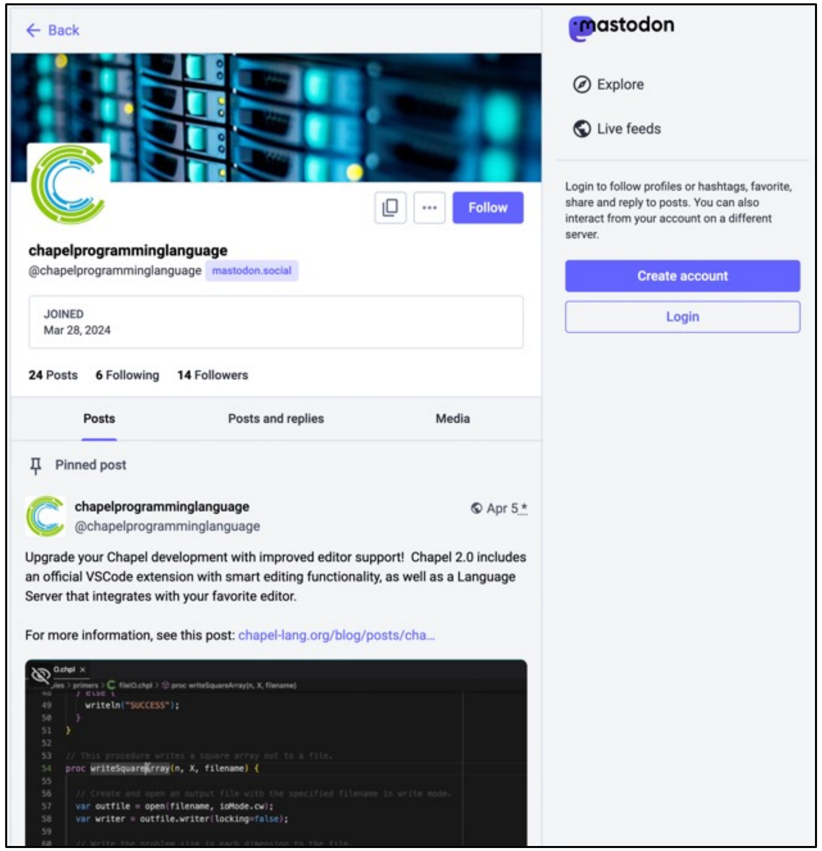
Announcing Chapel 1.32! (Sept)

Announcing Chapel 1.31! (June)

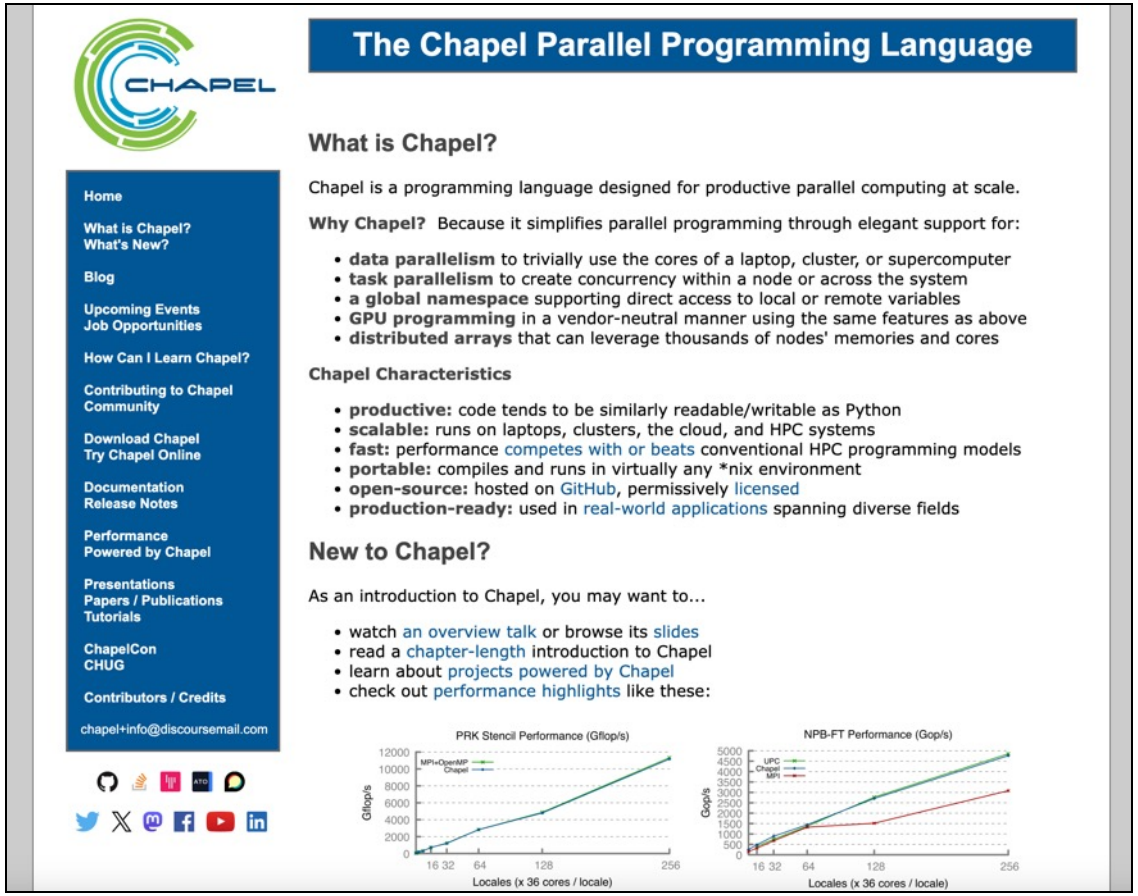
Chapel Social Media

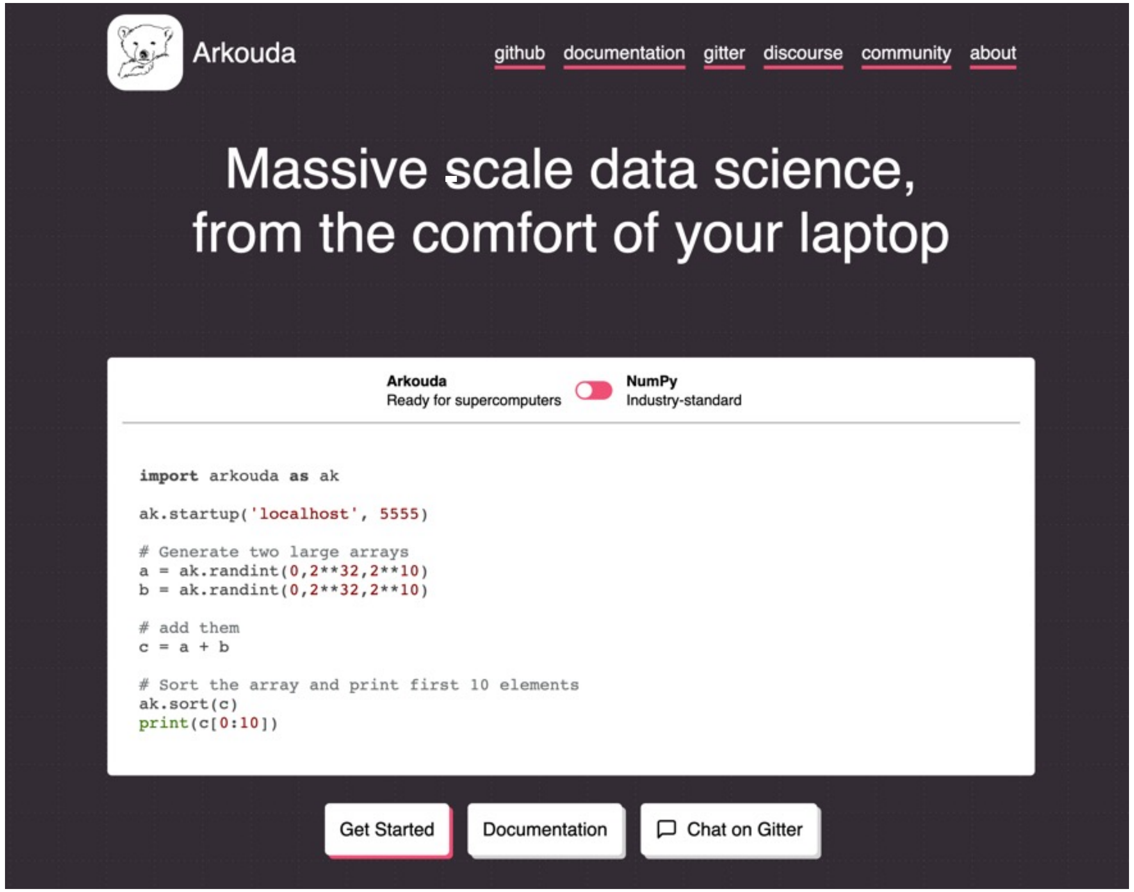
- As with the blog, we're striving to improve the frequency of our social media posts
  - Goal: a tweet every day or two during the work-week
- Recently launched LinkedIn and Mastadon project accounts—follow us there!





Website Redesign





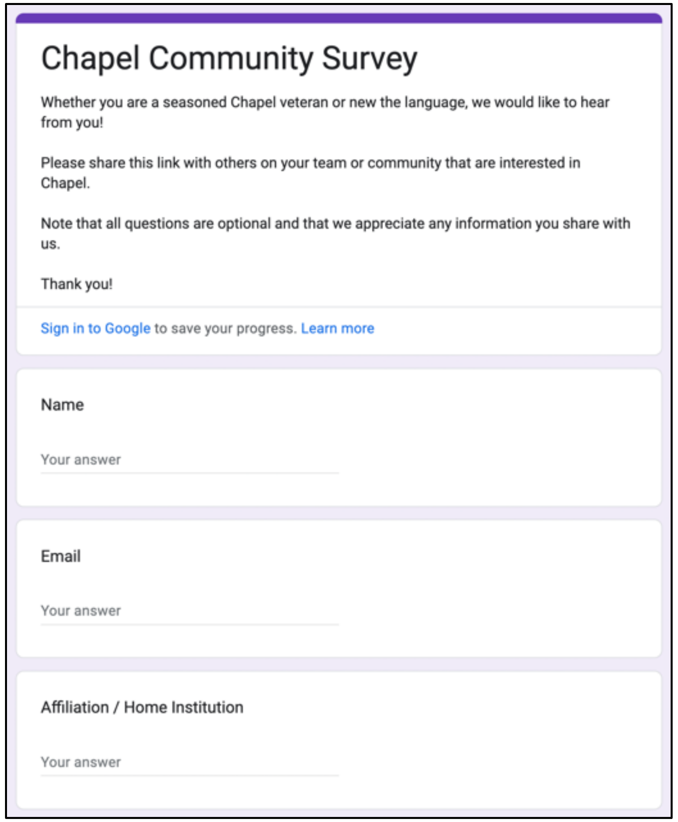
Other Community-Oriented Things That Are Cooking

- Uptick in **talks**, **tutorials**, outreach
- Diversifying **modes of obtaining Chapel**
  - GitHub **Codespaces** (already available)
  - **Ubuntu** and **Enterprise 9** packages (already available)
  - **deb/rpm** packages
  - **Spack** package
  - **AWS AMIs** (Amazon Machine Images)?
- Applying to **HPSF** (High Performance Software Foundation)
- "How-to" **YouTube videos**
- Chapel **educators' forum**
- Quarterly **newsletter**?
- Community **office hours**?
- [...**Your ideas here**...]
  - And your help in growing awareness of Chapel is always appreciated!

Luca speaking today @ 12:00 PT

Chapel Community Survey

- **We launched our first-ever Chapel Community Survey**
  - We would appreciate if everyone attending ChapelCon were to fill it out
  - (Note that there is also a survey about ChapelCon itself—both would be ideal)



Chapel Community Survey

Whether you are a seasoned Chapel veteran or new the language, we would like to hear from you!

Please share this link with others on your team or community that are interested in Chapel.

Note that all questions are optional and that we appreciate any information you share with us.

Thank you!

Sign in to Google to save your progress. Learn more

Name

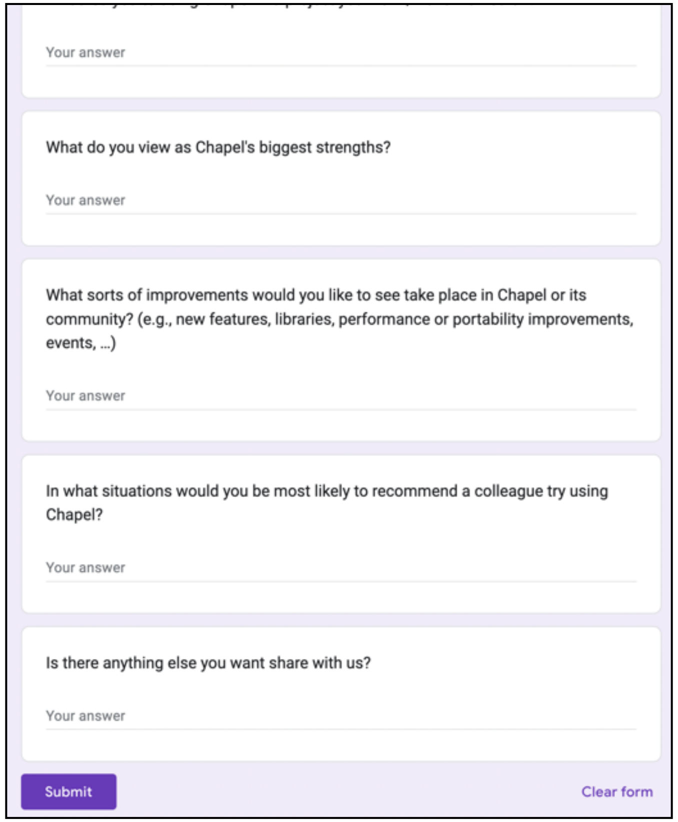
Your answer

Email

Your answer

Affiliation / Home Institution

Your answer



Your answer

What do you view as Chapel's biggest strengths?

Your answer

What sorts of improvements would you like to see take place in Chapel or its community? (e.g., new features, libraries, performance or portability improvements, events, ...)

Your answer

In what situations would you be most likely to recommend a colleague try using Chapel?

Your answer

Is there anything else you want share with us?

Your answer

Submit

Clear form

GPUs

GPU Highlights Since CHIUW 2023

- **Improved AMD support**
  - multi-locale + multi-GPU runs now supported
  - features are in parity with NVIDIA

- **CPU-as-device mode**
  - develop CPU+GPU computations without access to a GPU

- **Improved integration with Chapel language**
  - ‘reduce’ expressions and intents
  - ‘foreach’ intents
  - greater use of ‘@attribute’ syntax

- **Plus, performance, scaling, and significant increases in community usage…**

GPU Performance Improvements Since CHIUW 2023

Performance in previous release was lacking

Significantly improved CPU array initialization

```
var CpuArr: [1..n] int;

on here.gpus[0] {
  var GpuArr: [1..n] int;


  GpuArr = CpuArr;
  CpuArr = GpuArr;
}
```

Time (s)

(RTX A2000)

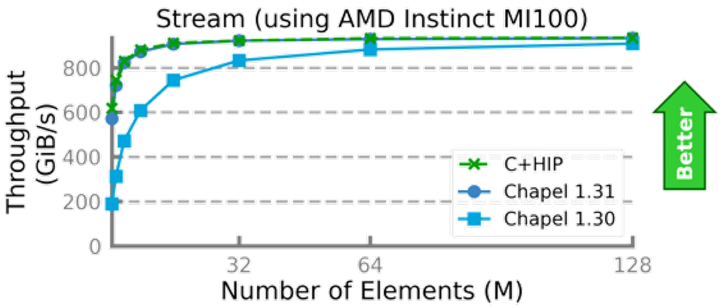
Unified Memory	Array on Device
0.12	0.18
0.038	0.018

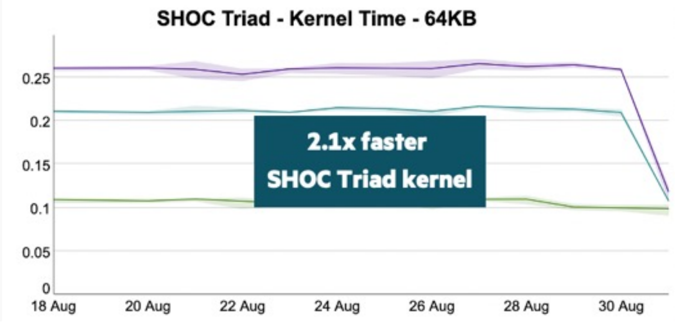
Unified Memory	Array on Device
0.25	0.033
0.14	0.034

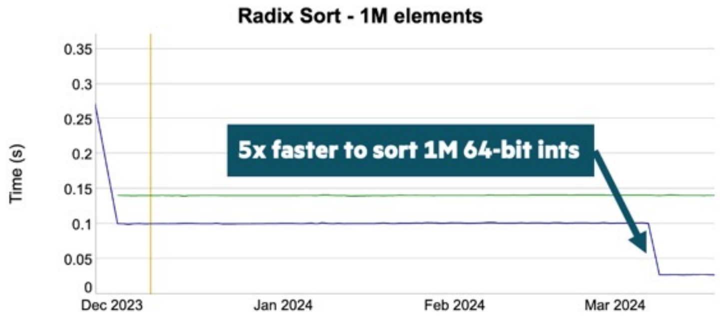
Throughput (GiB/s)

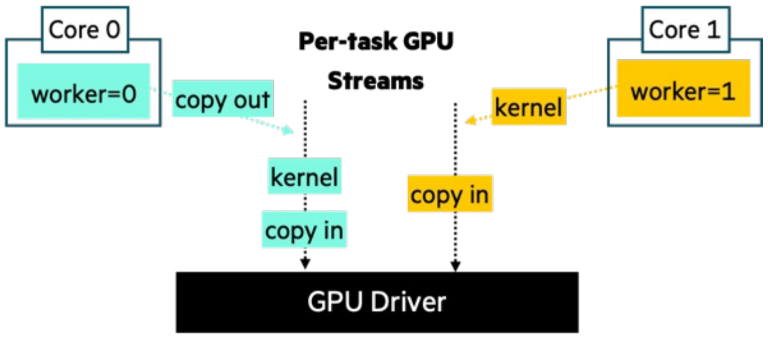
enableGpuP2P=true

	0	1	2	3
0		86.2	86.3	86.3
1	86.1		86.4	86.3
2	86.6	86.5		86.1
3	86.6	86.5	86.5	





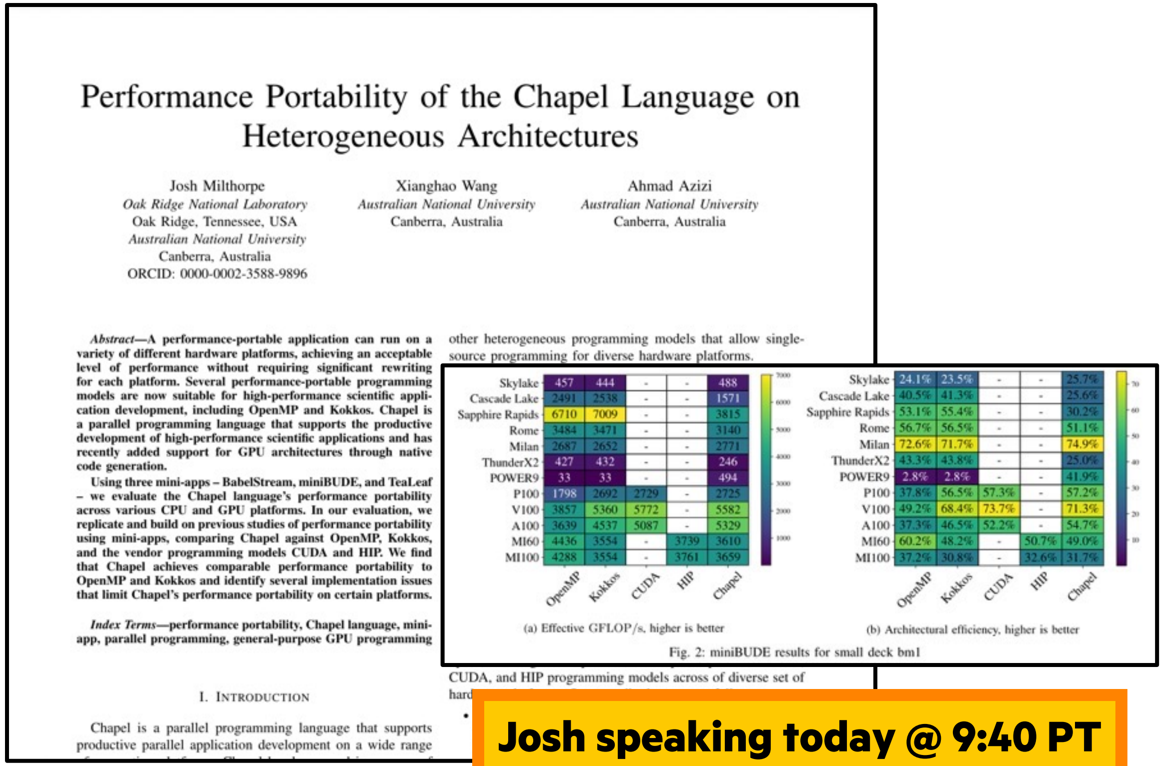




	Speedup	
	NVIDIA A100	**AMD MI250X**
coral	1.80x	1.25x
miniBUDE*	1.82x	1.92x

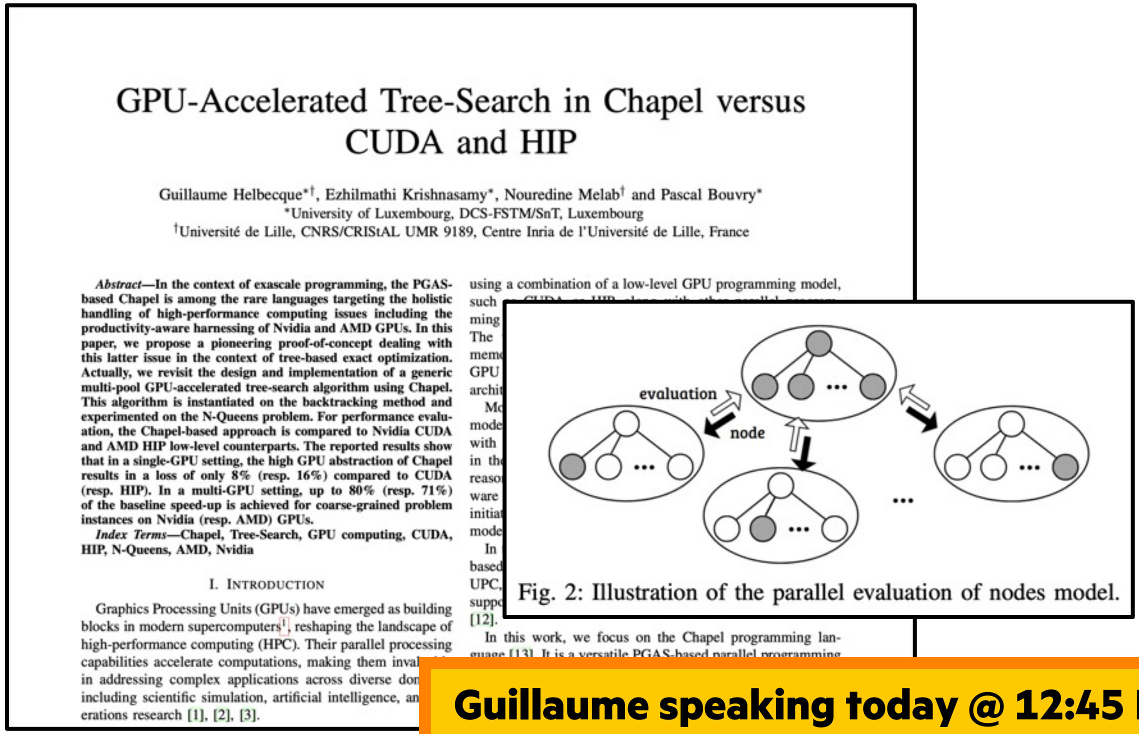
GPU Highlights Since CHIUW 2023: Community Papers at IPDPS Workshops

Performance Portability of the Chapel Language on Heterogeneous Architectures,
Josh Milthorpe, Xianghao Wang, Ahmad Azizi (ORNL / ANU),
HCW 2024



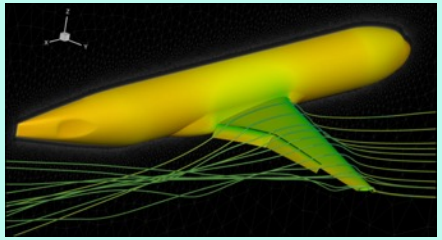
Josh speaking today @ 9:40 PT

GPU-Accelerated Tree-Search in Chapel: Comparing Against CUDA and HIP on Nvidia and AMD GPUs,
Guillaume Helbecque, Ezhilmathi Krishnasamy, Nouredine Melab, Pascal Bouvry (U. Luxembourg / U. Lille),
PDCO 2024

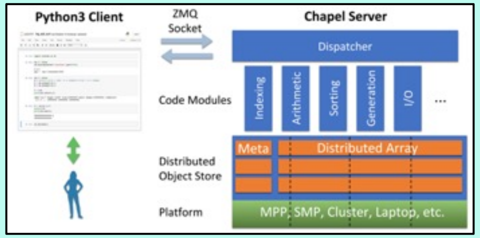


Guillaume speaking today @ 12:45 PT

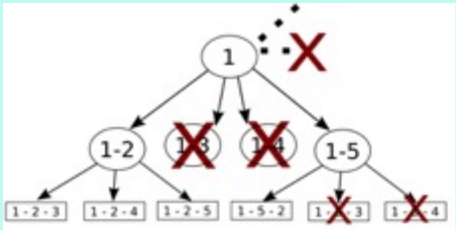
GPU Highlights Since CHIUW 2023: GPUs and User Codes



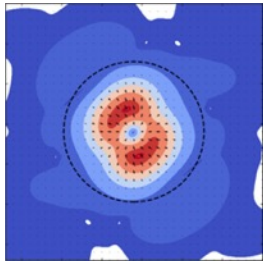
CHAMPS: 3D Unstructured CFD
Laurendeau, Bourgault-Côté, Parenteau, Plante, et al.
École Polytechnique Montréal



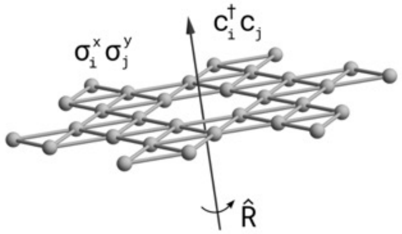
Arkouda: Interactive Data Science at Massive Scale
Mike Merrill, Bill Reus, et al.
U.S. DoD



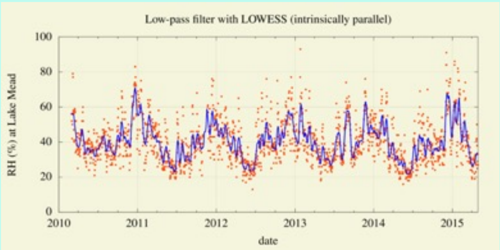
ChOp: Chapel-based Optimization
T. Carneiro, G. Helbecque, N. Melab, et al.
INRIA, IMEC, et al.



ChplUltra: Simulating Ultralight Dark Matter
Nikhil Padmanabhan, J. Luna Zagorac, et al.
Yale University et al.

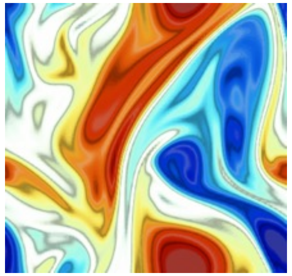


Lattice-Symmetries: a Quantum Many-Body Toolbox
Tom Westerhout
Radboud University

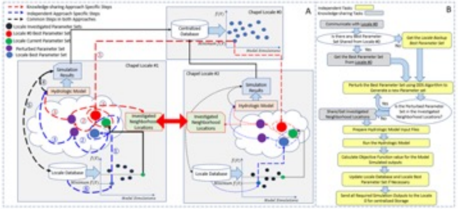


Desk dot chpl: Utilities for Environmental Eng.
Nelson Luis Dias
The Federal University of Paraná, Brazil

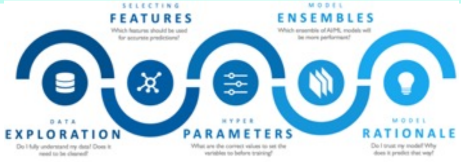
RapidQ: Mapping Coral Biodiversity
Rebecca Green, Helen Fox, Scott Bachman, et al.
The Coral Reef Alliance



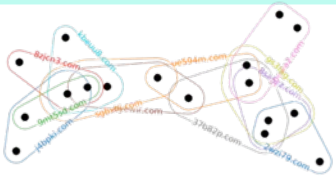
ChapQG: Layered Quasigeostrophic CFD
Ian Grooms and Scott Bachman
University of Colorado, Boulder et al.



Chapel-based Hydrological Model Calibration
Marjan Asgari et al.
University of Guelph



CrayAI HyperParameter Optimization (HPO)
Ben Albrecht et al.
Cray Inc. / HPE



CHGL: Chapel Hypergraph Library
Louis Jenkins, Cliff Joslyn, Jesun Firoz, et al.
PNNL

?

Your Application Here?

(images provided by their respective teams and used with permission)

Active GPU efforts

GPU Highlights Since CHIUW 2023: Scaling on DOE Systems

Investigating Portability in Chapel for Tree-based Optimization on GPU-powered Clusters,
Tiago Carneiro, Engin Kayraklioglu, Guillaume Helbecque, Nouredine Melab (IMEC / HPE / U. Luxembourg, U. Lille),
Euro-Par 2024


Investigating Portability in Chapel for Tree-based Optimization on GPU-powered Clusters

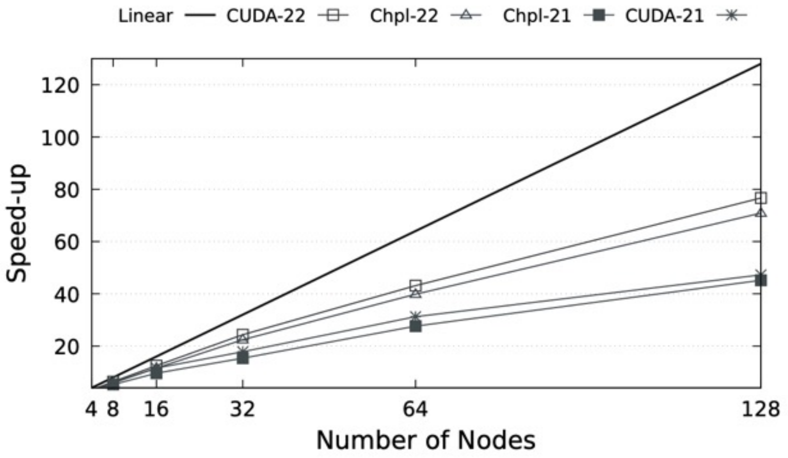
Tiago Carneiro[1[0000−0002−6145−8352]], Engin Kayraklioglu[2[0000−0002−4966−3812]], Guillaume Helbecque[3,4[0000−0002−8697−3721]], and Nouredine Melab[4]

[1] Interuniversity Microelectronics Centre (IMEC), Belgium
tiago.carneiropessoa@imec.be
[2] Hewlett Packard Enterprise, USA
engin@hpe.com
[3] University of Luxembourg, Luxembourg
guillaume.helbecque@uni.lu
[4] Université de Lille, CNRS, Centrale Lille, Inria, UMR 9189 - CRIStAL - Centre de Recherche en Informatique Signal et Automatique de Lille, France
nouredine.melab@univ-lille.fr

Abstract. The Top500 list features supercomputers powered by accelerators from different vendors. This variety brings, along with the heterogeneity challenge, both the code and performance portability challenges. In this context, Chapel's native GPU support comes as a solution for code portability between different vendors. In this paper, we investigate the viability of using the Chapel high-productivity language as a tool to achieve both code and performance portability in large-scale tree-based search. As a case study, we implemented a distributed backtracking for solving permutation combinatorial problems. Extensive experiments conducted on big N-Queens problem instances, using up to 512 NVIDIA GPUs and 1024 AMD GPUs on Top500 supercomputers, reveal that it is possible to scale on the two different systems using the same tree-based search written in Chapel. This trade-off results in a performance decrease of less than 10% for the biggest problem instances.

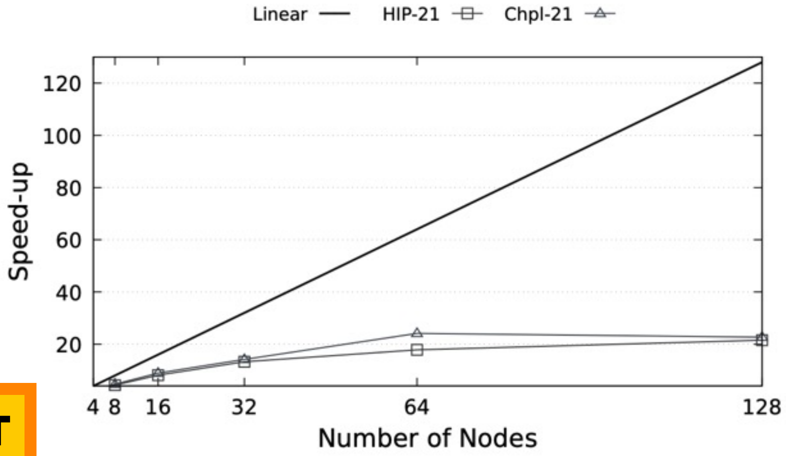
Frontier (ORNL)

128 nodes x 8 GPUs = 1024 GPUs
GPUs: AMD Instinct MI250X



Perlmutter (NERSC)

128 nodes x 4 GPUs = 512 GPUs
GPUs: NVIDIA A100

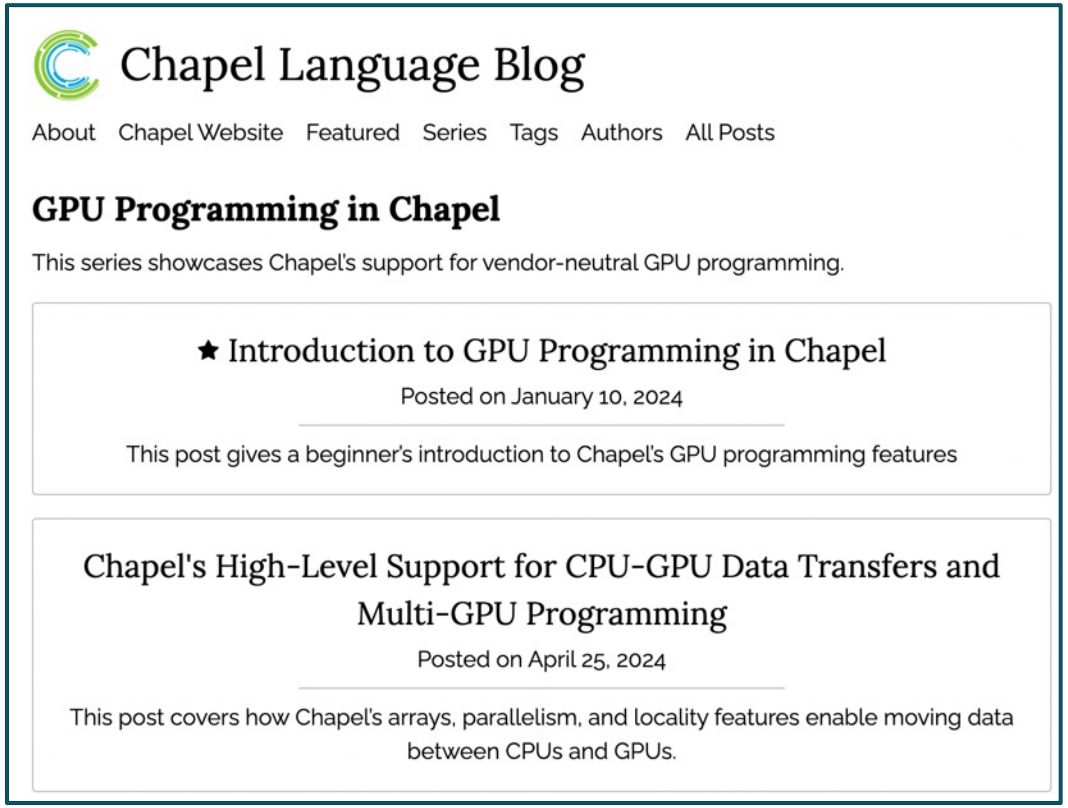


Tiago speaking today @ 10:00 PT

also see Brett's talk @ 10:10 PT

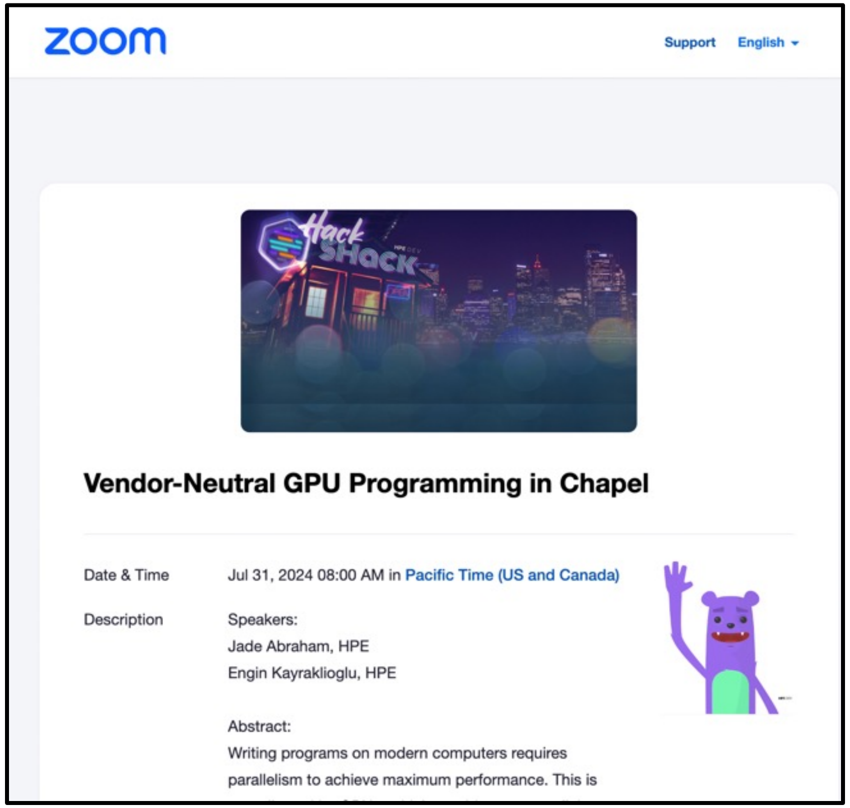
Additional GPU Resources

GPU Programming in Chapel blog series



HPE Developer Meetup:

- Vendor-Neutral GPU Programming in Chapel
- July 31, Free and online



GPU Highlights: ChapelCon 2024 Keynote

A Case for Parallel-First Languages in a Post-Serial, Accelerated World

Paul speaking today @ 10:45 PT

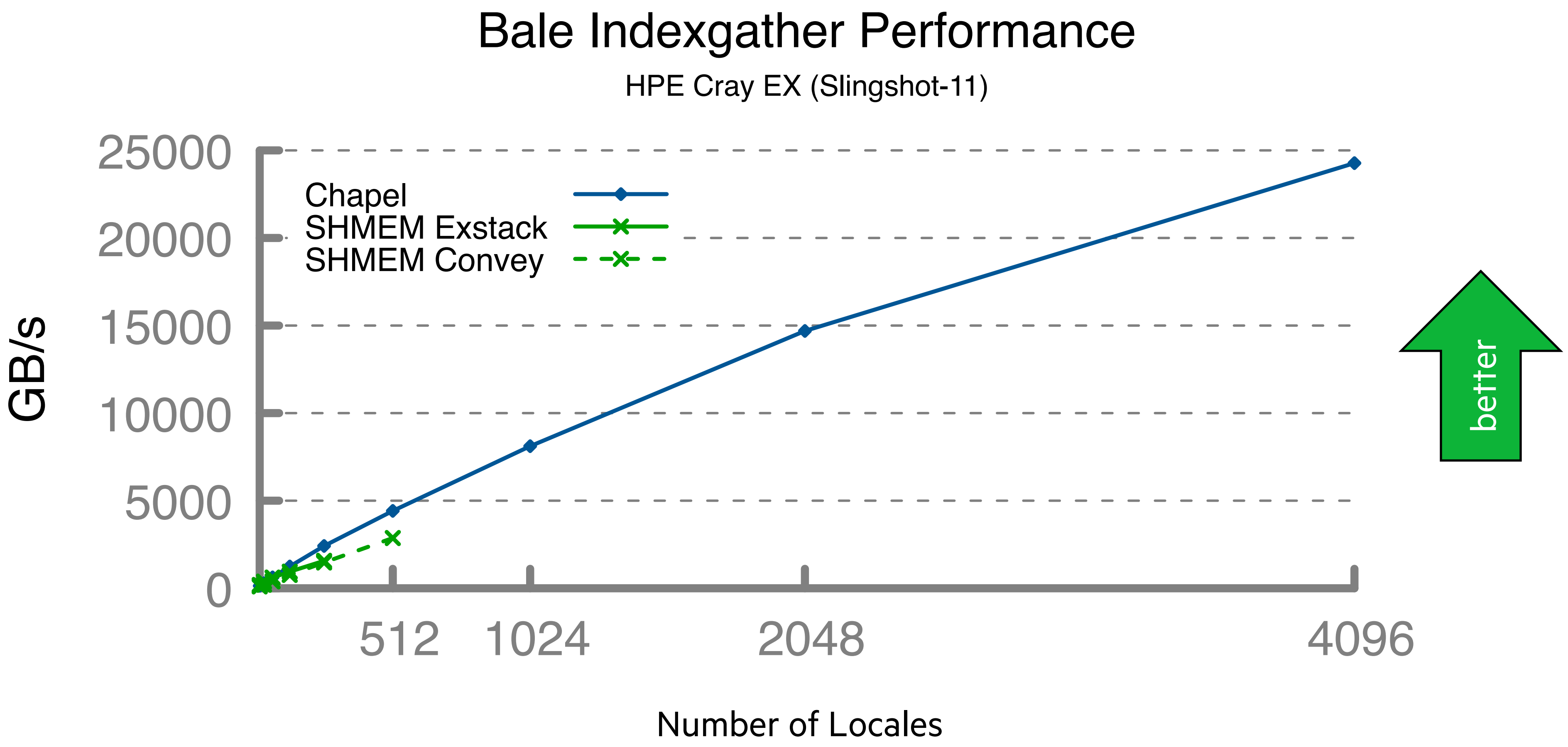
Paul Sathre (Virginia Tech)

Abstract: Parallel processors have finally dominated all scales of computing hardware, from the personal and portable to the ivory tower datacenters of yore. However, dominant programming models and pedagogy haven't kept pace, and languish in a post-serial mix of libraries and language extensions. Further, heterogeneity in the form of GPUs has dominated the performance landscape of the last decade, penetrating casual user markets thanks to data science, crypto and AI booms. Unfortunately GPUs' performance remains largely constrained to expert users by the lack of more productive and portable programming abstractions. **This talk will probe questions about how to rethink and democratize parallel programming for the masses.** By reflecting on lessons learned from a decade and a half of accelerated computing, **I'll show where Chapel 2.0 fits into the lineage of GPU computing, can capitalize on GPU momentum, and lead a path forward**.

Bio: Paul Sathre is a Research Software Engineer in the Synergy Lab and NSF Center for Space, High-performance, and Resilient Computing (SHREC) at Virginia Tech. His research interests encompass systems software and tools and programming systems, particularly with respect to democratizing access to high-performance computing. More recently, his work has focused on the intersection of computational co-design with portable and productive languages, tools, and libraries for heterogeneous computing.

Scalability and Performance

Bale IndexGather in Chapel vs. SHMEM on HPE Cray EX

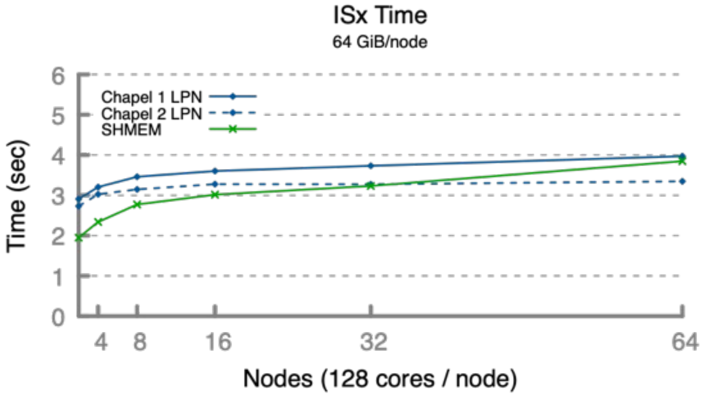


Network Performance Evaluation

Since CHIUW 2023, we have evaluated performance of various communication patterns x networks

- For example, ISx on Slingshot-11, InfiniBand, and AWS:

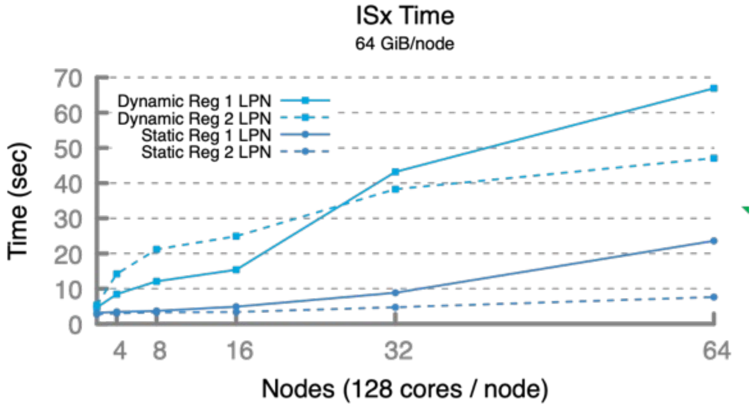
HPE Cray EX



Network: Slingshot-11 (single NIC)

Processor: Dual-socket AMD Milan

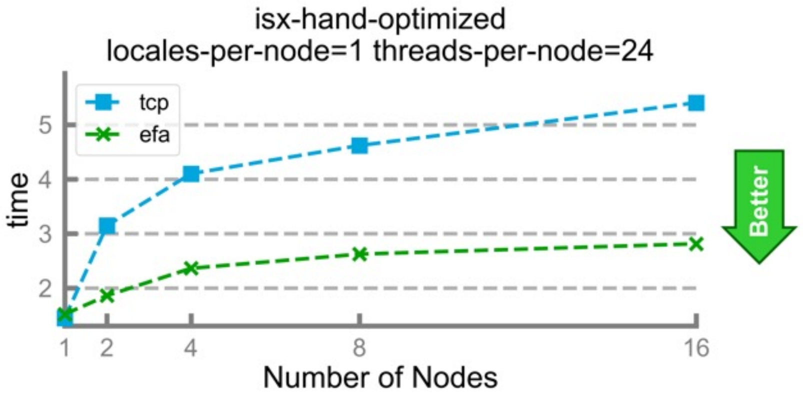
HPE Apollo



Network: InfiniBand HDR-200 (single NIC)

Processor: Dual-socket AMD Milan

AWS



Network: AWS (Ethernet and EFA)

Processor: AWS Graviton3

Notes:

- These AWS results should be considered preliminary and have almost certainly improved since this study
- We also looked briefly at RDMA-enabled Ethernet (not shown here)

Chapel Co-Locales

- A ***locale*** in Chapel is a part of the target system that can run tasks and store variables
  - Traditionally, each compute node has been a locale

- We've recently added support for multiple ***co-locales*** per compute node:
  - Command-line interface: `$ ./myChplProg -nl 8x2    # use 8 nodes w/ 2 locales each…`
  - Typical cases:
    - locale per NIC
    - locale per socket
    - locale per NUMA domain
    - locale per L3 cache

- Co-locales can improve performance via:
  - better network utilization
  - better memory locality and affinity

Stream TRIAD on dual-socket node, Milan CPUs, 64 cores/CPU

Configuration	GB/s	Improvement	Feature
-nl 2	357	N/A	N/A
-nl 2x2	460	28.9%	Socket
-nl 2x8	466	30.5%	NUMA
-nl 2x16	470	31.7%	L3 cache
"first touch"	470	31.7%	N/A

We’ve also improved serial/vector performance this year

- In 2023, our fastest CLBG n-body lagged the baseline by 1.4x
  - Rust, Julia, Fortran, and C++ versions all outperformed it

The Computer Language
23.03 Benchmarks Game

n-body

description

First a few simple programs.
Then optimisations, multicore parallelism, [pdf] vector parallelism.
Last hand-written vector instructions and "unsafe" programs.

source	secs	mem	gz
Chapel #3	5.60	10,940	960
C clang	5.98	11,392	1173
Java	7.76	40,724	1430

×	source	secs	mem	gz	cpu secs	cpu load
1.0	**Rust** #6	**3.92**	11,068	1790	3.92	0% 0% 0% 100%
1.0	**Julia** #8	**4.11**	226,264	1111	4.38	2% 2% 2% 100%
1.1	Classic **Fortran** #6	**4.20**	10,960	1524	4.20	0% 0% 100% 0%
1.2	**C++** g++ #9	**4.88**	10,960	1530	4.88	0% 0% 0% 100%
1.4	Classic Fortran #2	5.37	10,960	1500	5.36	100% 0% 0% 0%
1.4	Classic Fortran	5.48	10,960	1393	5.48	0% 0% 0% 99%
1.4	**Chapel** #3	**5.60**	10,940	960	5.61	99% 0% 0% 0%

- This year, we became the baseline after the 2.0 release
  - With no source changes!

The Computer Language
24.04 Benchmarks Game

n-body

description

First a few simple programs.
Then optimisations, multicore parallelism, [pdf] vector parallelism.
Last hand-written vector instructions and "unsafe" programs.

source	secs	mem	gz
Chapel #3	3.89	19,648	967
C clang	5.65	19,684	1179
Java	7.85	41,512	1437

×	source	secs	mem	gz	cpu secs	cpu load
1.0	**Chapel** #3	**3.89**	19,648	967	3.90	100% 0% 0% 0%
1.0	**Rust** #2	**3.92**	19,660	1809	3.92	0% 100% 0% 1%
1.0	Rust #6	3.95	19,788	1796		
1.1	**Julia** #8	**4.16**	272,512	1129		
1.1	Classic **Fortran** #6	**4.21**	19,856	1530		
1.2	Rust #8	4.51	19,788	1774	4.50	100% 0% 0% 1%
1.3	**C** gcc #6	**4.96**	19,520	1186	4.96	0% 0% 100% 0%

I’ll speak briefly on the CLBG today @ 9:30 PT

Tool Improvements

Chapel Tools: Background

- Tools have been a classic chicken-and-egg problem for Chapel
  - Users don't want to use a new language without tools
  - Tools teams don't want to support a new language until it has users
  - Meanwhile, our team has traditionally had trouble prioritizing tools work

Happily, this has started to change through our Dyno compiler re-work effort

- What tools we have typically come from the open-source community

see Henry, Drake, and Cole's talk @ 8:35 PT

Three New Tools Since CHIUW 2023

chpl-language-server (CLS):

- Enables features within editors that support the Language Server Protocol (LSP) — VSCode, vim, emacs, …
- Provides real-time features to navigate, query, and refactor Chapel code

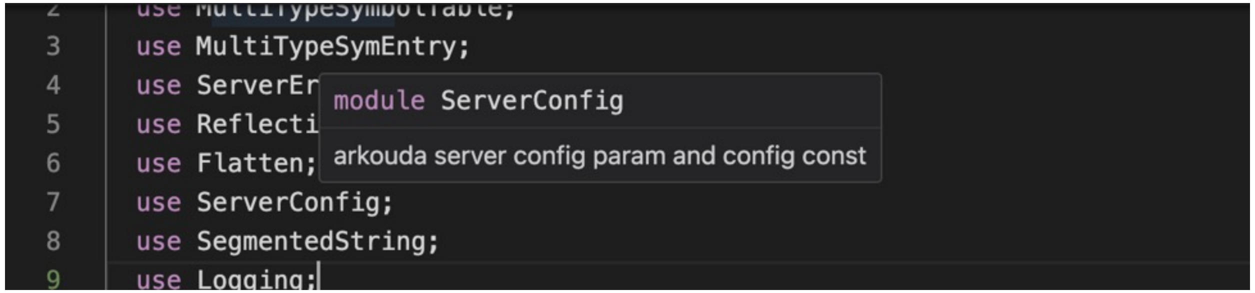
chplcheck:

- A Chapel linter that provides style checks and helps prevent common errors
- Can be run from the command-line or an editor (via LSP)

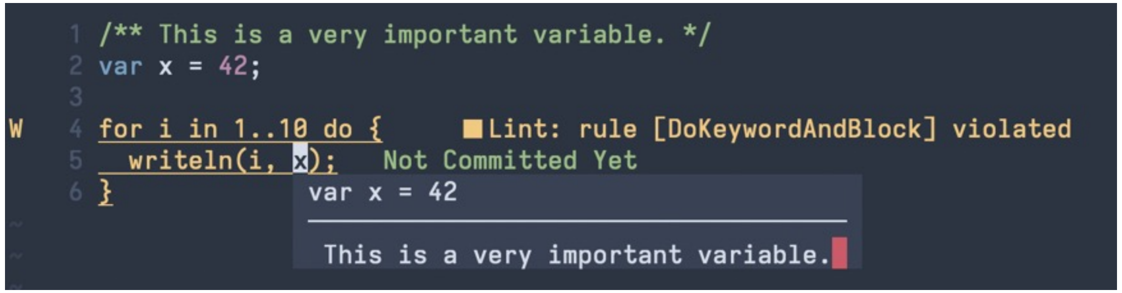
see Daniel and Jade's talk @ 8:55 PT

VSCode extension for Chapel:

- Supports the two tools above, along with syntax highlighting, autofill, GUI breakpoints, …



CLS in VSCode



CLS in Neovim

Time’s running short...
Yet there’s so much I could cover!

There Are Many Other Exciting Talks Today (that I couldn't weave into this talk)

12:20–12:30 **Exploring Machine Learning Capabilities in Chapel: An Internship Journey**
Iain Moncrief (*Oregon State University*)
Abstract: This talk recounts a ...
... from a performance and langua...
experience with learning Chape...

Iain speaking today @ 12:20 PT

12:55–1:15 **Arrays as Arguments in First-Class Functions: the Levenberg-Marquardt Algorithm in Chapel**
Nelson Dias, Débora Roberti and Vanessa Arruda Dias (*Federal University of Paraná, Federal University of Santa Maria*)

Nelson speaking today @ 12:55 PT

1:15–1:35 **On the Design of Graph Analytical Software in Chapel**
Oliver Alvarado Rodriguez, David A. Bader and Zhihui Du (*New Jersey Institute of Technology*)

Oliver speaking today @ 1:15 PT

1:35–1:45 **Implementing Imaginary Elementary Mathematical Functions**
Damian McGuckin, Peter Harding (*Pacific ESI*)
Abstract: Chapel is one of those extremely rare HPC languages in which the imaginary ...
... utines in the complex domain captures how the ...

Damian speaking today @ 1:35 PT

2:00–2:10 **Chapel in a Petabyte-Scale GPU Database Engine with Voltron Data's Theseus**
Trent Nelson and Fernanda Foertter (*Voltron Data*)
... as a first-class citizen. Specifically, ...

Trent speaking today @ 2:00 PT

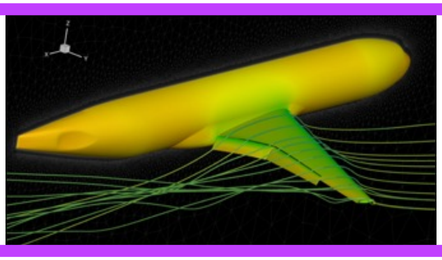
2:10–2:20 **Chplx: an HPX Foundation for Chapel**
Shreyas Atre, Chris Taylor, Patrick Diehl and Hartmut Kaiser (*Louisiana State University, Tactical Computing Labs, LLC*)
... e performance vs code complexity of a 1 ...
... paper investigates the performance and code

Chris speaking today @ 2:10 PT

2:20–2:40 **Follow-Up on Chapel-Powered HPC Workflows for Python**
John Byrne, Harumi Kuno, Chinmay Ghosh, Porno Shome, Amitha C, Sharad Singhal, Clarete Riana Crasta, David Emberson and Abhishek Dwaraki (*Hewlett Packard Enterprise*)

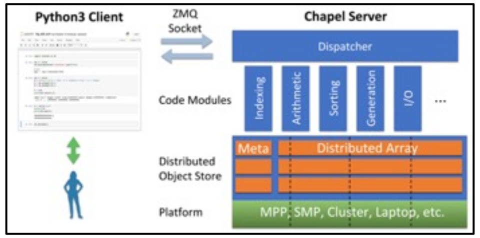
Harumi speaking today @ 2:20 PT

Updates from other CHIUW Alumni



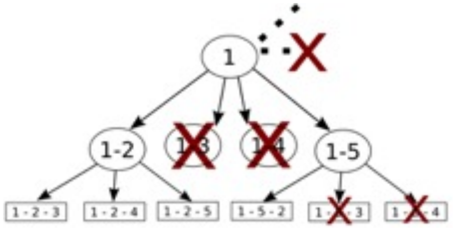
CHAMPS: 3D Unstructured CFD

CHIUW 2021 CHIUW 2022



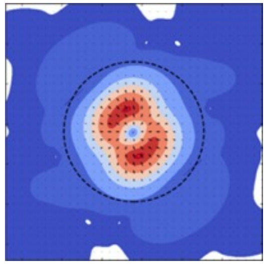
Arkouda: Interactive Data Science at Massive Scale

CHIUW 2020 CHIUW 2023



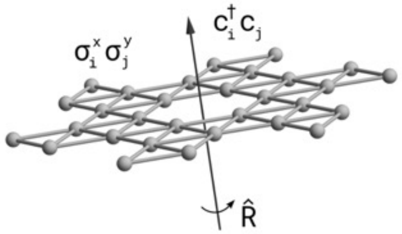
ChOp: Chapel-based Optimization

CHIUW 2021 CHIUW 2023



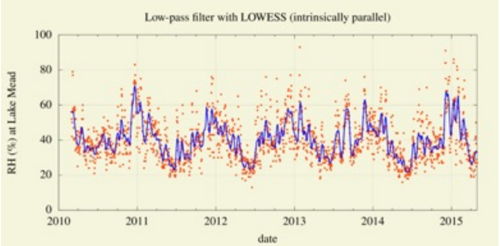
ChplUltra: Simulating Ultralight Dark Matter

CHIUW 2020 CHIUW 2022



Lattice-Symmetries: a Quantum Many-Body Toolbox

CHIUW 2022

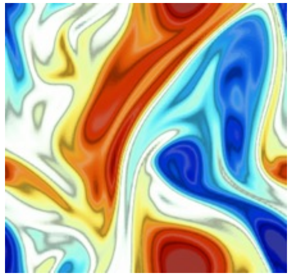


Desk dot chpl: Utilities for Environmental Eng.

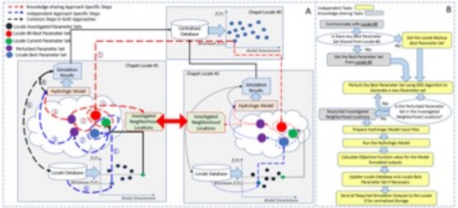
CHIUW 2022

RapidQ: Mapping Coral Biodiversity

CHIUW 2023



ChapQG: Layered Quasigeostrophic CFD



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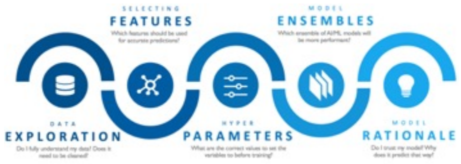
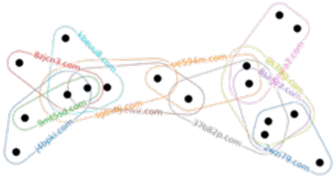
CHIUW 2023



CrayAI HyperParameter Optimization (HPO)

CHIUW 2021



CHGL: Chapel Hypergraph Library

CHIUW 2020

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Your Application Here?

(images provided by their respective teams and used with permission)

Update from the CHAMPS Team

CHAMPS status update

- CHAMPS has seen very rapid development progress since its initiation, in many ways due to the efficiency of Chapel. Alongside the technical developments of our Computational Fluid Dynamics (CFD) capabilities, scientific progress has been very fruitful.

- **The research group is now into more holistic research**, slowing down production quantity to examine more fundamental, high-impact research of similar high quality but **with computational breath that is one-order of magnitude more complex.**
  For instance:
  - **problem size has now reached 2 Billion unknowns**
  - Reynolds-Averaged Navier-Stokes has moved from steady to unsteady flow analysis, **requiring 1000x more calculations/solutions.**

- This is due to the industrial pull, which requires very advanced computational workflows to examine **novel aircraft configurations to attain environmental targets** such as Bombardier Eco-Jet or NASA/Boeing Truss-Braced Wing concepts.

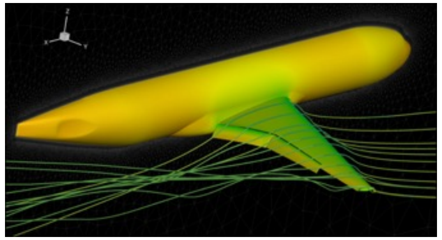
- **Important advances will be presented at the American Institute of Aeronautics and Astronautics AVIATION conference in late July 2024.** Stay tuned!

Bombardier Eco-jet
Blended Wing Body

NASA/Boeing
Truss-Braced Wing

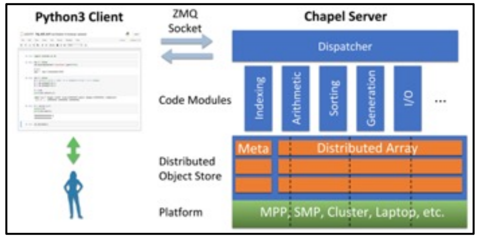
(slide provided by Eric Laurendeau and used with permission)

Updates from other CHIUW Alumni



CHAMPS: 3D Unstructured CFD

CHIUW 2021   CHIUW 2022



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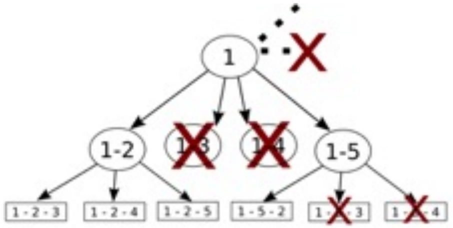

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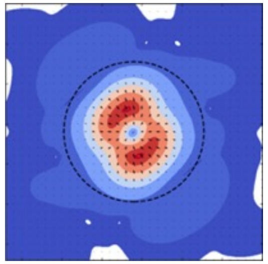

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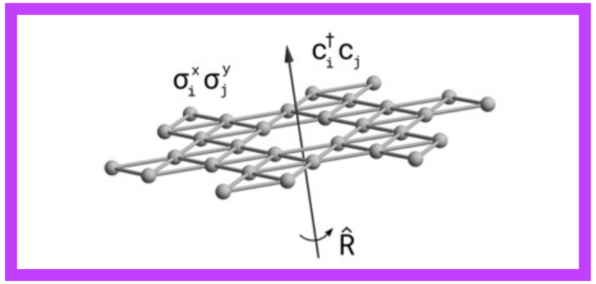

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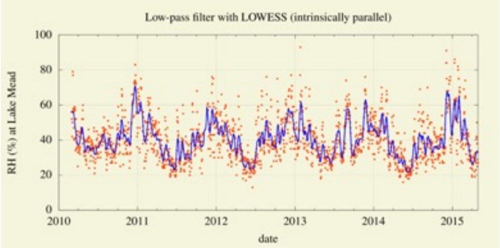

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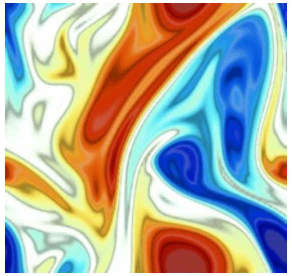

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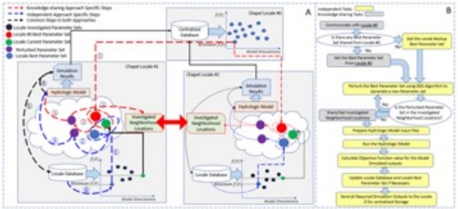

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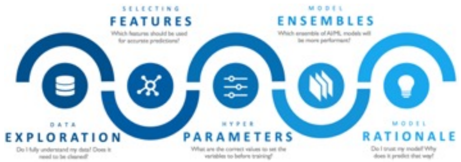
CHIUW 2023



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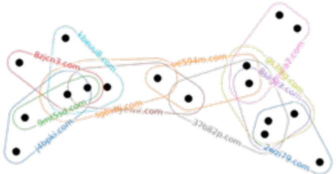

CHGL: Chapel Hypergraph Library

CHIUW 2020

?

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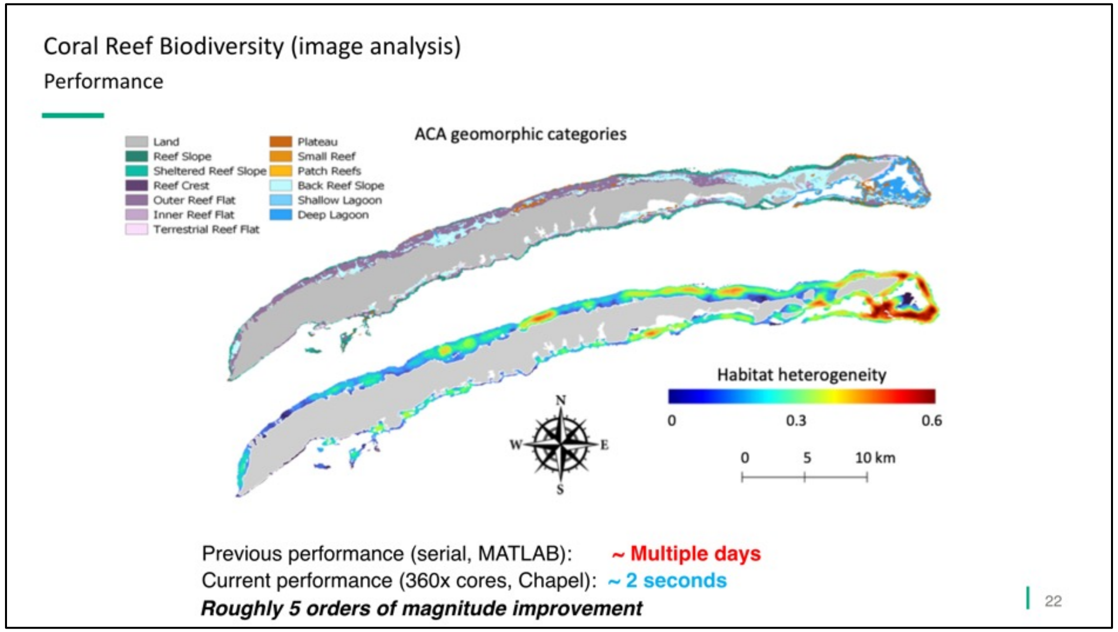
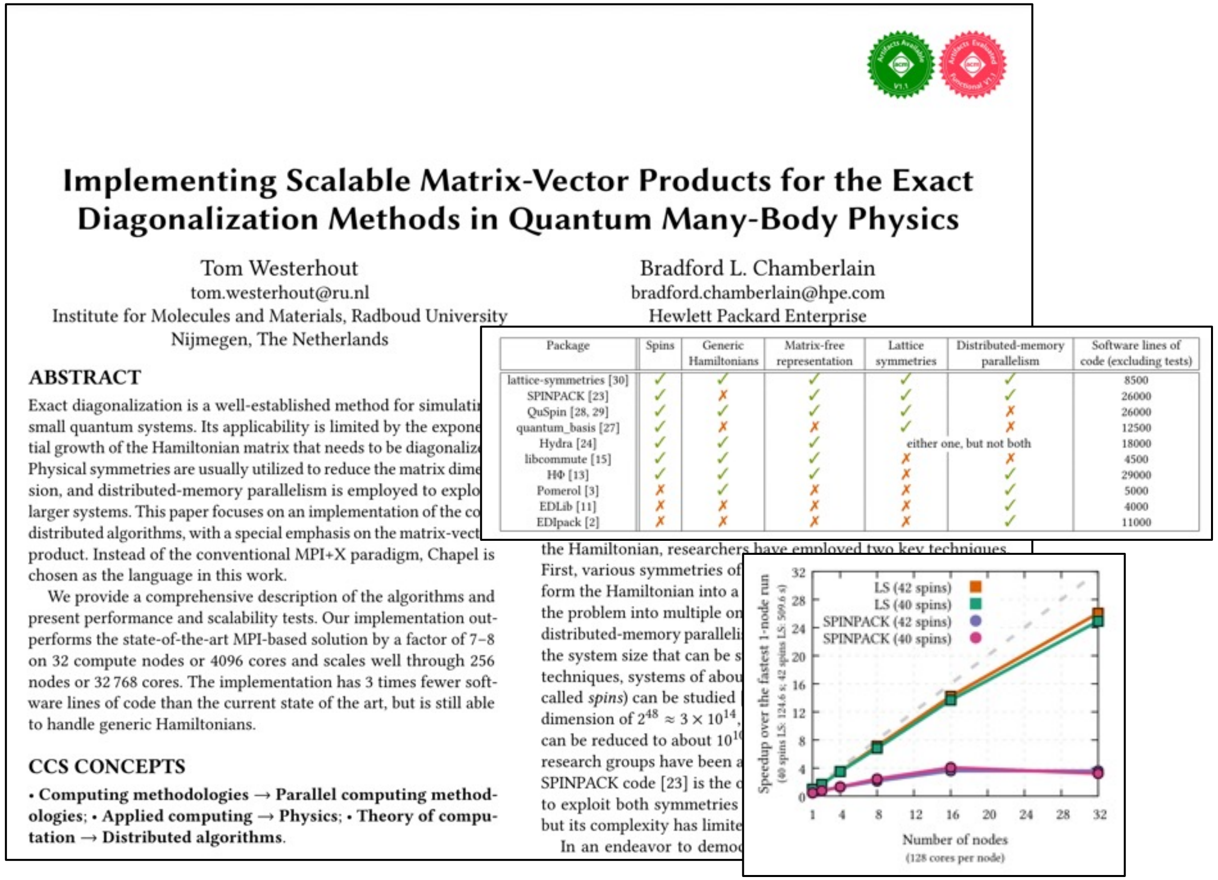
(images provided by their respective teams and used with permission)

Publications at PAW-ATM 2023 (an SC23 workshop)

[High-Performance Programming and Execution of a Coral Biodiversity Mapping Algorithm Using Chapel](#), Scott Bachman (NCAR) et al.



[Implementing Scalable Matrix-Vector Products for the Exact Diagonalization Methods in Quantum Many-Body Physics](#), Tom Westerhout (Radboud University) et al.



Implementing Scalable Matrix-Vector Products for the Exact Diagonalization Methods in Quantum Many-Body Physics

Tom Westerhout
tom.westerhout@ru.nl
Institute for Molecules and Materials, Radboud University
Nijmegen, The Netherlands

Bradford L. Chamberlain
bradford.chamberlain@hpe.com
Hewlett Packard Enterprise

Package	Spins	Generic Hamiltonians	Matrix-free representation	Lattice symmetries	Distributed-memory parallelism	Software lines of code (excluding tests)
lattice-symmetries [30]	✓	✓	✓	✓	✓	8500
SPINPACK [23]	✓	✗	✓	✓	✓	26000
QuSpin [28, 29]	✓	✓	✓	✓	✗	26000
quantum_basis [27]	✓	✗	✗	✓	✗	12500
Hydra [24]	✓	✓	✓	either one, but not both		18000
libcommute [15]	✓	✓	✓	✗	✗	4500
HΦ [13]	✓	✓	✓	✗	✓	29000
Pomerol [3]	✗	✓	✗	✗	✓	5000
EDLib [11]	✗	✗	✗	✗	✓	4000
EDIpack [2]	✗	✗	✗	✗	✓	11000

ABSTRACT

Exact diagonalization is a well-established method for simulati[...] small quantum systems. Its applicability is limited by the expone[...] tial growth of the Hamiltonian matrix that needs to be diagonaliz[...] Physical symmetries are usually utilized to reduce the matrix dime[...] sion, and distributed-memory parallelism is employed to explo[...] larger systems. This paper focuses on an implementation of the co[...] distributed algorithms, with a special emphasis on the matrix-vect[...] product. Instead of the conventional MPI+X paradigm, Chapel is chosen as the language in this work.

We provide a comprehensive description of the algorithms and present performance and scalability tests. Our implementation outperforms the state-of-the-art MPI-based solution by a factor of 7–8 on 32 compute nodes or 4096 cores and scales well through 256 nodes or 32 768 cores. The implementation has 3 times fewer software lines of code than the current state of the art, but is still able to handle generic Hamiltonians.

CCS CONCEPTS

• **Computing methodologies → Parallel computing methodologies**; • **Applied computing → Physics**; • **Theory of computation → Distributed algorithms.**

the Hamiltonian, researchers have employed two key techniques. First, various symmetries of[...] form the Hamiltonian into a[...] the problem into multiple o[...] distributed-memory paralleli[...] the system size that can be s[...] techniques, systems of abou[...] called *spins*) can be studied[...] dimension of $2^{48} \approx 3 \times 10^{14}$[...] can be reduced to about 10^{1}[...] research groups have been a[...] SPINPACK code [23] is the c[...] to exploit both symmetries[...] but its complexity has limite[...]

In an endeavor to demo[...]

Consider submitting work on applications in Chapel to:

PAW-ATM

The 7th Annual
Parallel Applications Workshop, Alternatives To MPI+X

November 17 | 18, 2024

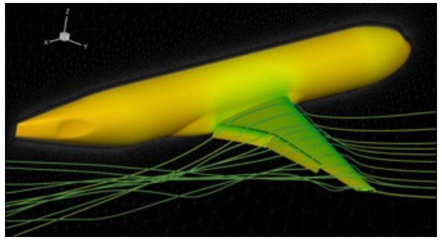
Held in conjunction with SC24

SC24 Atlanta, GA | hpc creates.

Deadline: July 24, 2024

Submission Styles: Papers / Talks

Updates from other CHIUW Alumni



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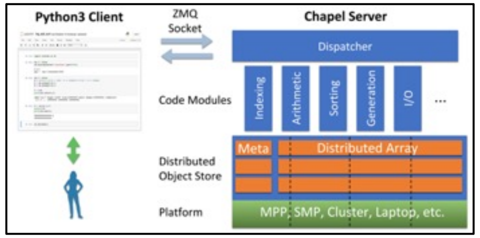

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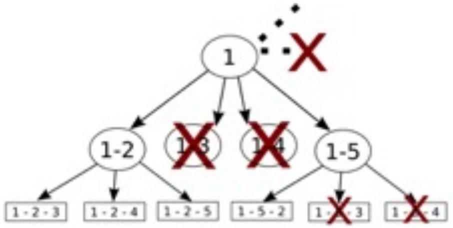

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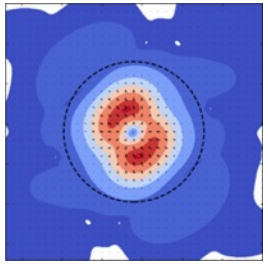

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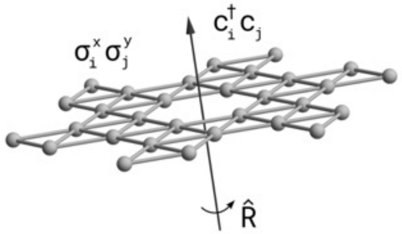

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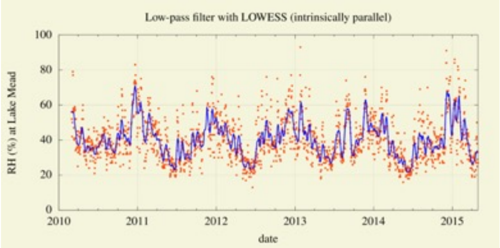

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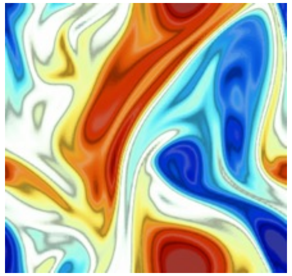

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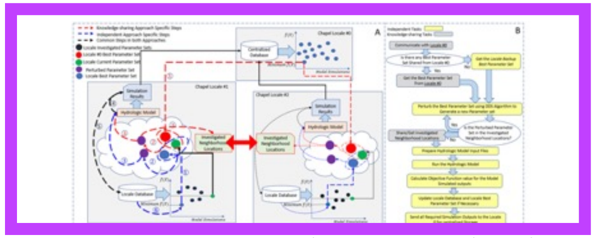

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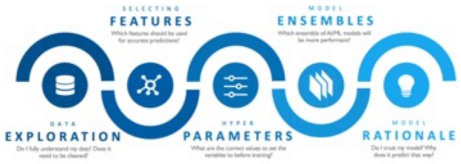

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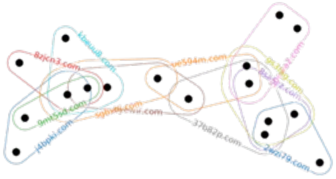

CHGL: Chapel Hypergraph Library

CHIUW 2020

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(images provided by their respective teams and used with permission)

Newly Minted PhDs

- Since her CHIUW 2023 talk, **Marjan Asgari**…
  - Defended her Ph.D. on parallel computing for calibrating hydrological models
    - Her software is still in use by her former research group at University of Guelph
  - Now works for **Natural Resources Canada** focused on parallel computing

- Since his CHIUW 2023 talk, **Thomas Rolinger**…
  - Defended his Ph.D. on compiler optimizations for irregular memory access patterns in PGAS languages
    - Published a paper on his work at IPDPS 2024
  - Now works on **NVIDIA**'s back-end compiler team

Congratulations, Marjan and Thomas!!!

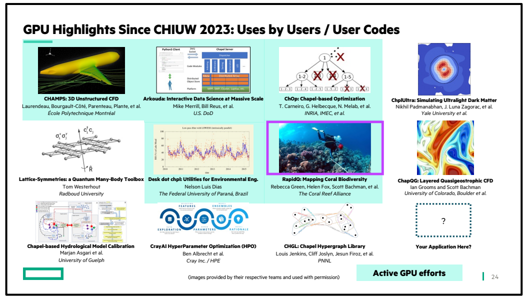
Wrapping Up

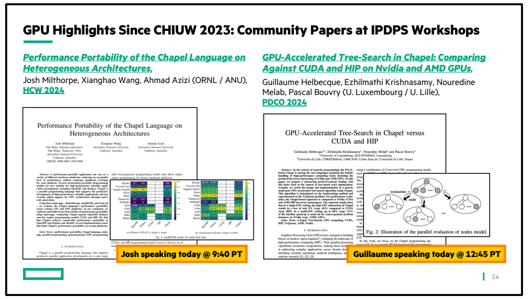
The Chapel Team at HPE

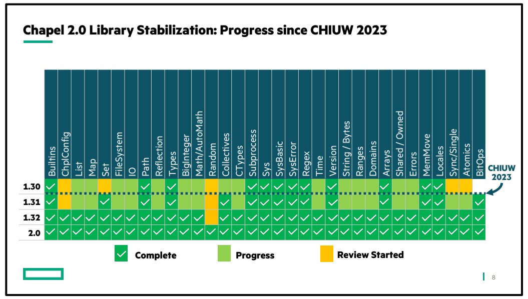
State of the Chapel Project: Summary

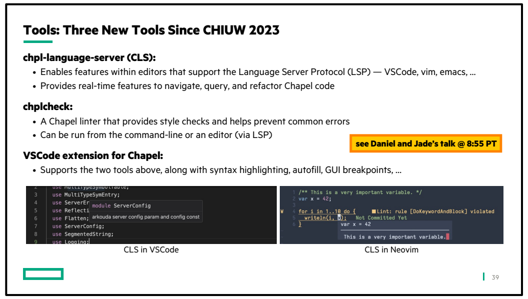
As a team and community, we have accomplished a <u>ton</u> since CHIUW 2023

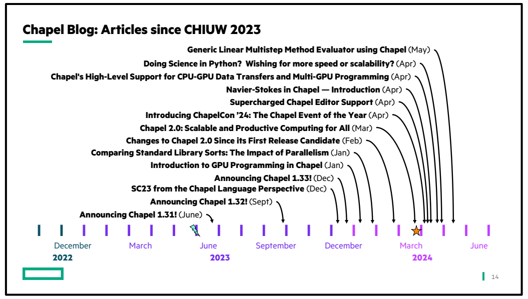
- Released Chapel 2.0 and made ongoing improvements
- Accomplished and published great scientific results
- Improved GPU, tool, and performance features
- Got a great start on renewed focus on community

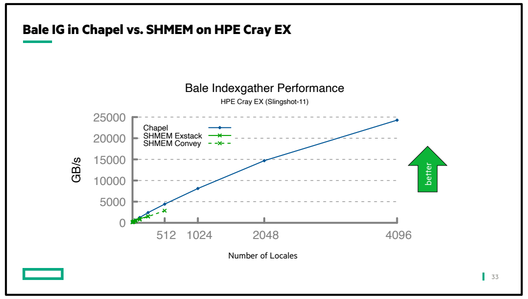


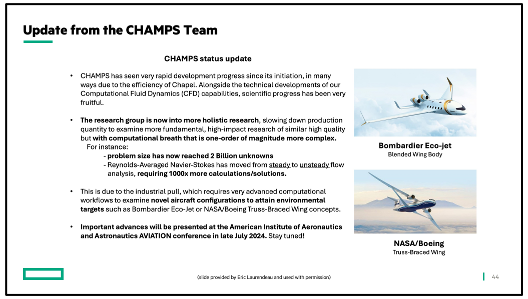












Stay tuned to today's talks to hear more detail about many of these efforts!

We look forward to working with you all in the year to come!

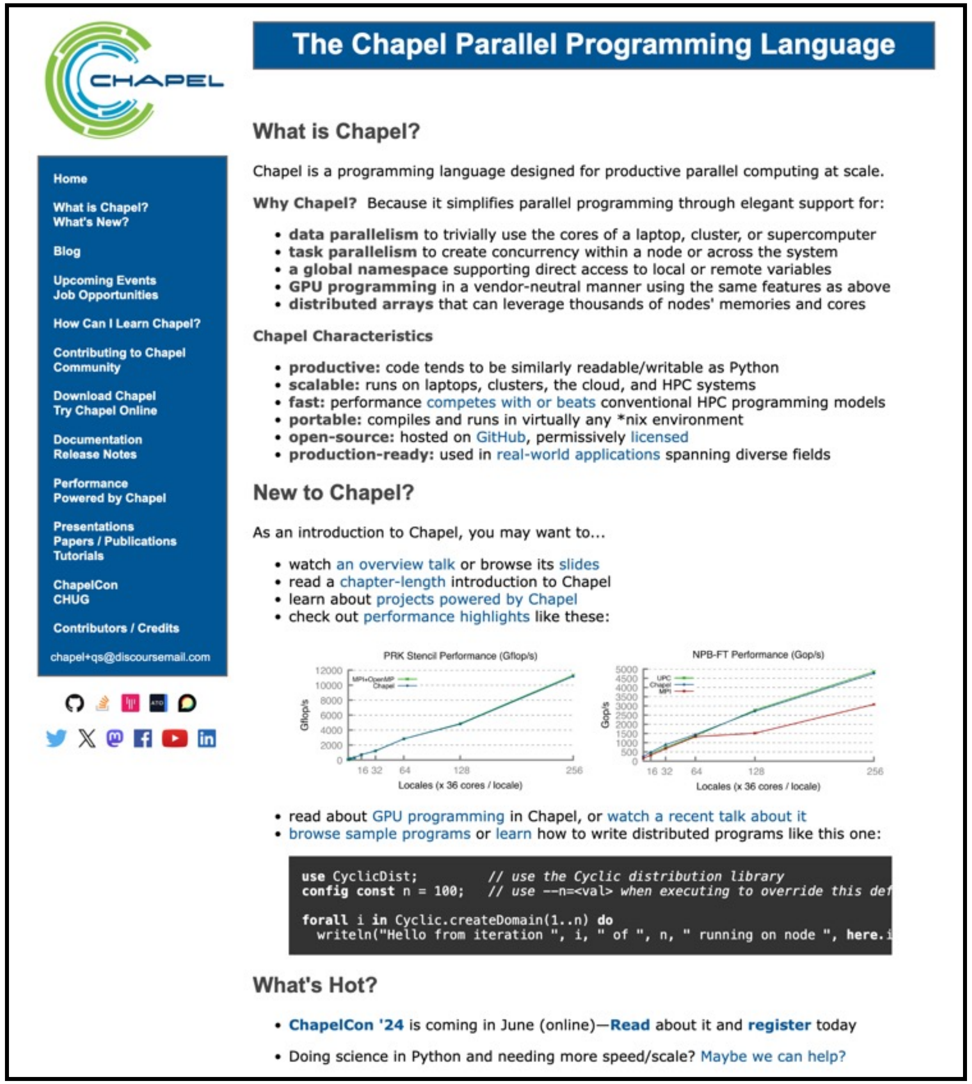
Chapel Resources

Chapel homepage: https://chapel-lang.org
- (points to all other resources)

Blog: https://chapel-lang.org/blog/

Social Media:
- Facebook: @ChapelLanguage
- LinkedIn: @chapel-programming-language
- Mastadon: @ChapelProgrammingLanguage
- X / Twitter: @ChapelLanguage
- YouTube: @ChapelLanguage

Community Discussion / Support:
- Discourse: https://chapel.discourse.group/
- Gitter: https://gitter.im/chapel-lang/chapel
- Stack Overflow: https://stackoverflow.com/questions/tagged/chapel
- GitHub Issues: https://github.com/chapel-lang/chapel/issues



Consider submitting work on applications in Chapel to:

The 7th Annual Parallel Applications Workshop, Alternatives To MPI+X

November 17 | 18, 2024

Held in conjunction with SC24

Deadline: July 24, 2024
Submission Styles: Papers / Talks

Thank you

https://chapel-lang.org
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