



Chapel Comes of Age: Productive Parallelism at Scale

Brad Chamberlain, Chapel Team, Cray Inc.

PNW PLSE Workshop

May 14, 2018



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Chapel: Niche or Quiche?

Brad Chamberlain, Chapel Team, Cray Inc.

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What is Chapel?



Chapel: A productive parallel programming language

- portable & scalable
- open-source & collaborative

Goals:

- Support general parallel programming
 - “any parallel algorithm on any parallel hardware”
- Make parallel programming at scale far more productive



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Chapel and Productivity



Chapel aims to be as...

- ...programmable as Python**
- ...fast as Fortran**
- ...scalable as MPI**
- ...portable as C**
- ...flexible as C++**
- ...fun as [your favorite programming language]**



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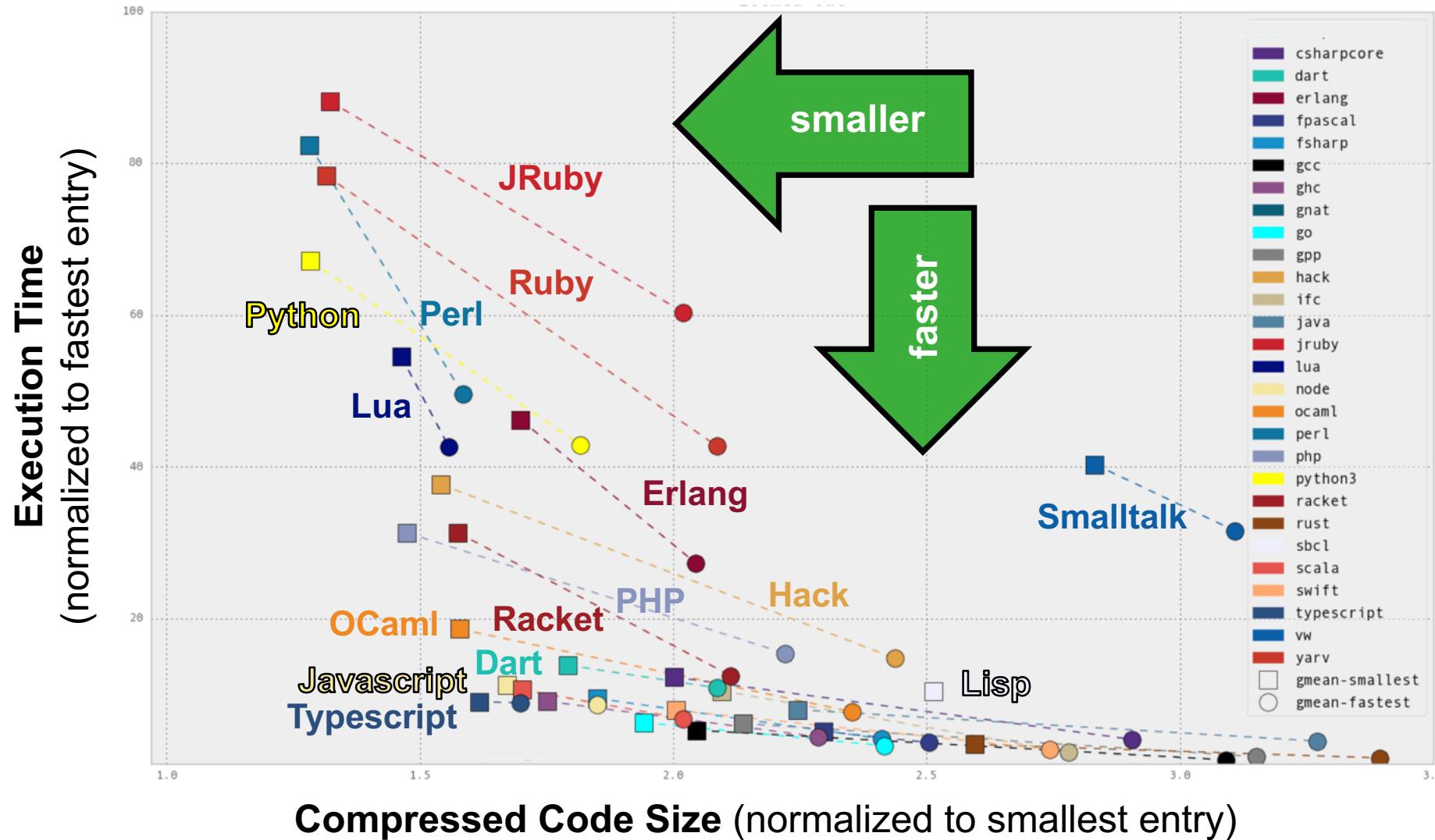
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CLBG Cross-Language Summary

(Oct 2017 standings)



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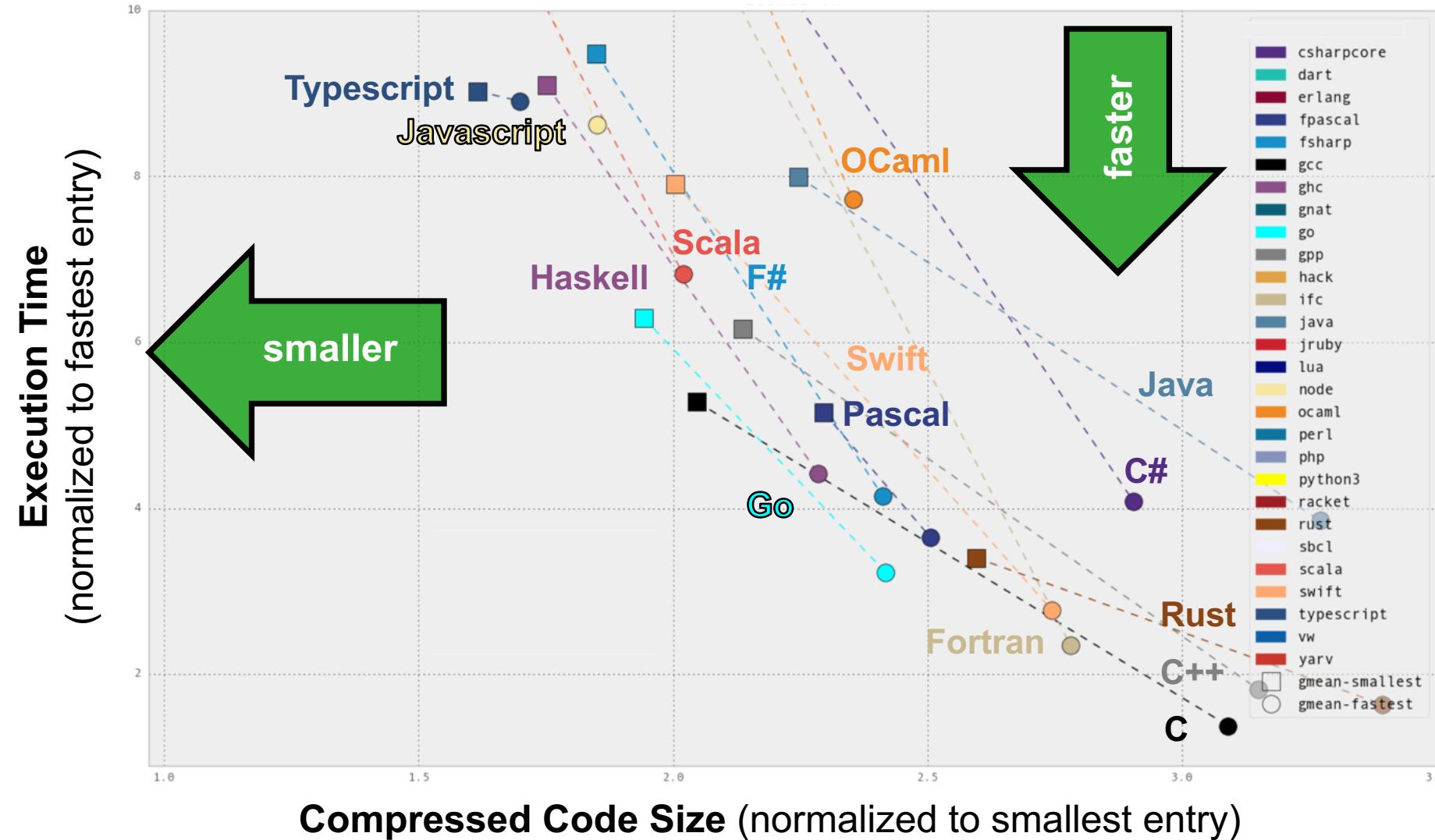
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CLBG Cross-Language Summary

(Oct 2017 standings, zoomed in)



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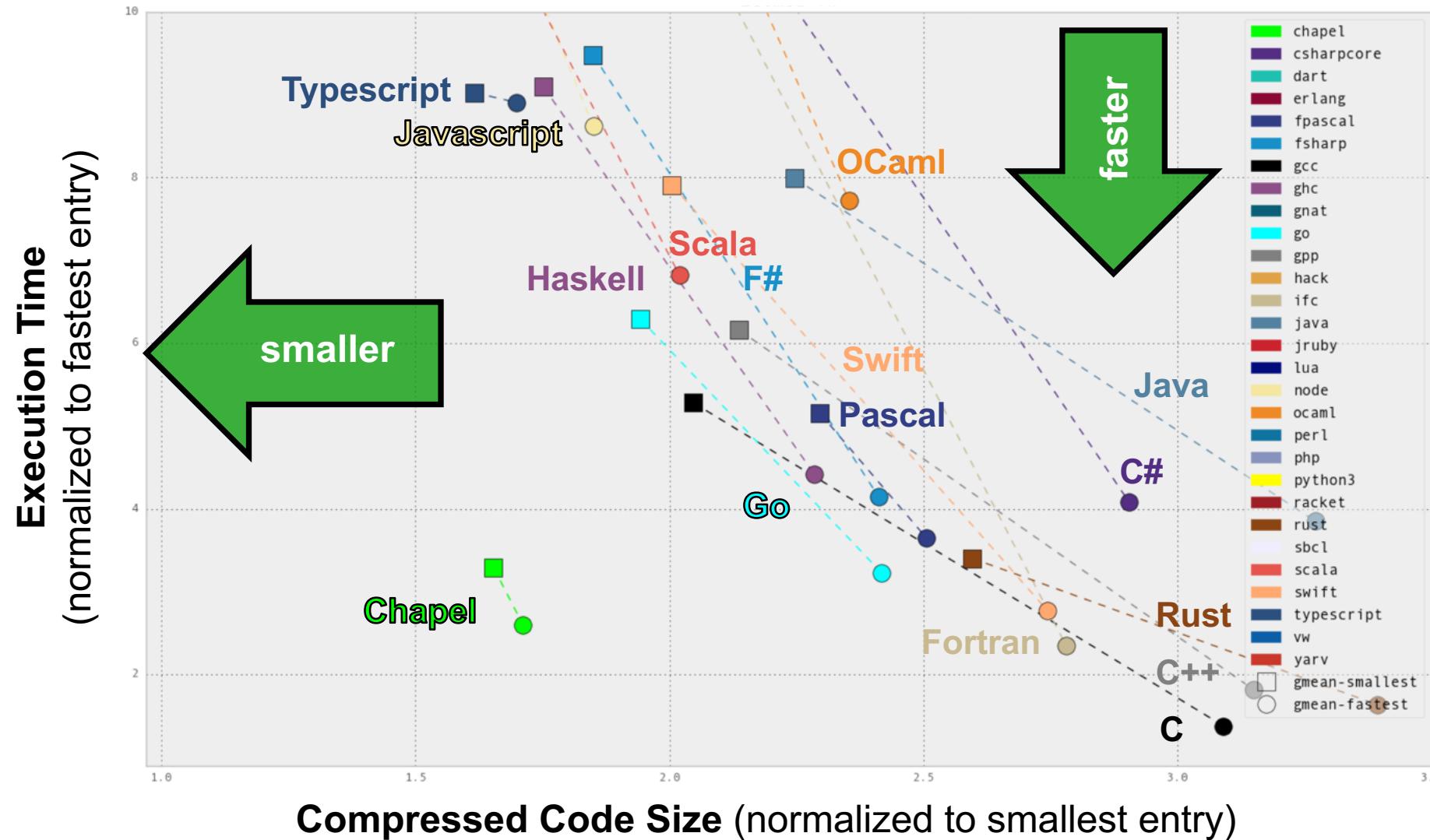
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CLBG Cross-Language Summary

(Oct 2017 standings, zoomed in)



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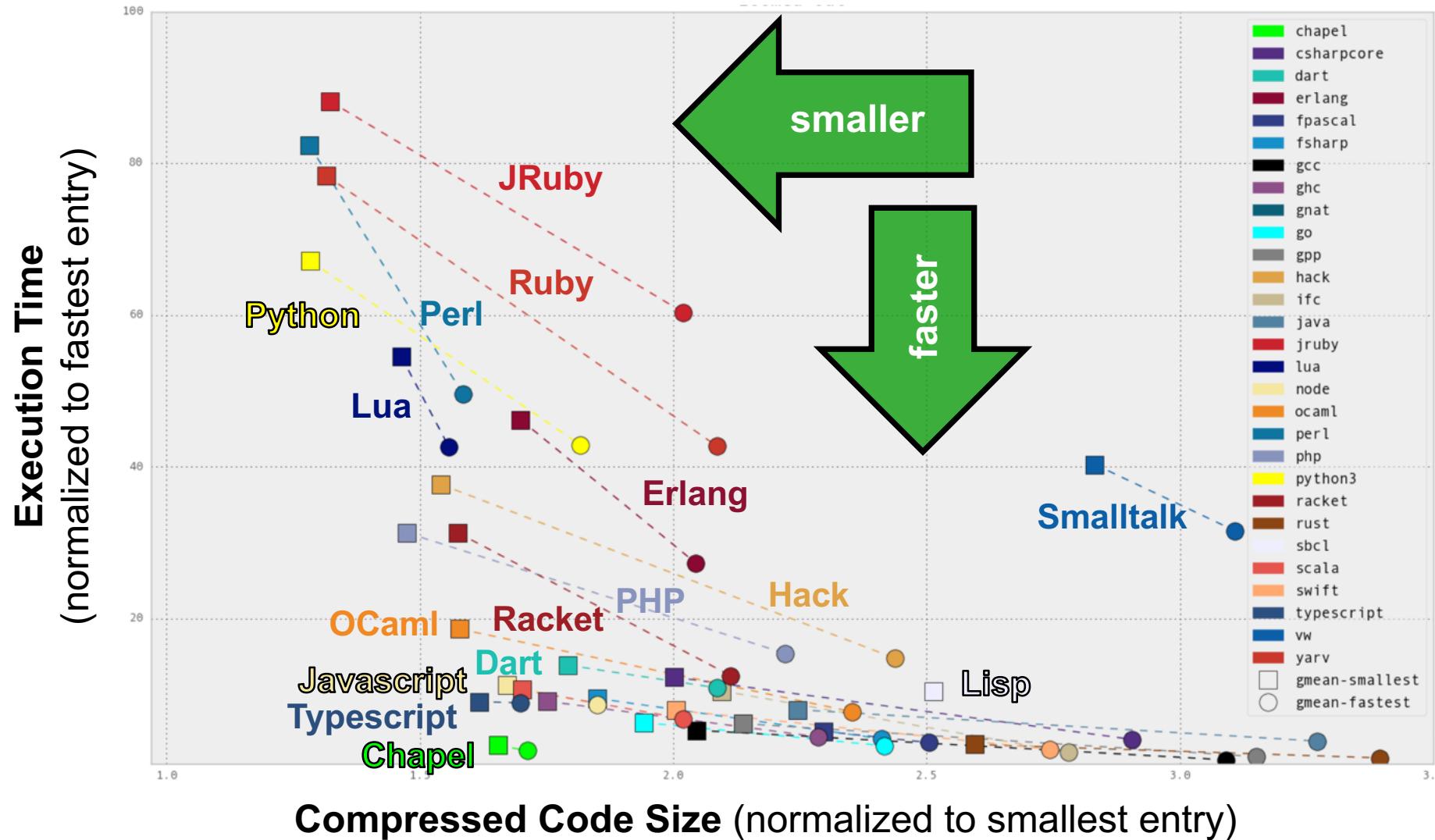
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CLBG Cross-Language Summary

(Oct 2017 standings)



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CLBG: Qualitative Code Comparisons



Can also browse program source code (*but this requires actual thought!*):

```
proc main() {
    printColorEquations();

    const group1 = [i in 1..popSize1] new Chameneos(i, ((i-1)%3):Color);
    const group2 = [i in 1..popSize2] new Chameneos(i, colors10[i]);

    cobegin {
        holdMeetings(group1, n);
        holdMeetings(group2, n);
    }

    print(group1);
    print(group2);

    for c in group1 do delete c;
    for c in group2 do delete c;
}

// Print the results of getNewColor() for all color pairs.
// proc printColorEquations() {
//     for c1 in Color do
//         for c2 in Color do
//             writeln(c1, " + ", c2, " -> ", getNewColor(c1, c2));
//             writeln();
// }

// Hold meetings among the population by creating a shared meeting
// place, and then creating per-chameneos tasks to have meetings.
// proc holdMeetings(population, numMeetings) {
//     const place = new MeetingPlace(numMeetings);

//     coforall c in population do          // create a task per chameneos
//         c.haveMeetings(place, population);

//     delete place;
}
```

excerpt from 1210.gz Chapel entry

```
void get_affinity(int* is_smp, cpu_set_t* affinity1, cpu_set_t* affinity2)
{
    cpu_set_t active_cpus;
    FILE* f;
    char buf[2048];
    pos;
    cpu_idx;
    physical_id;
    core_id;
    cpu_cores;
    apic_id;
    cpu_count;
    i;

    char const* processor_str = "processor";
    processor_str_len = strlen(processor_str);
    physical_id_str = "physical id";
    physical_id_str_len = strlen(physical_id_str);
    core_id_str = "core id";
    core_id_str_len = strlen(core_id_str);
    cpu_cores_str = "cpu cores";
    cpu_cores_str_len = strlen(cpu_cores_str);

    CPU_ZERO(&active_cpus);
    sched_getaffinity(0, sizeof(active_cpus), &active_cpus);
    cpu_count = 0;
    for (i = 0; i != CPU_SETSIZE; i += 1)
    {
        if (CPU_ISSET(i, &active_cpus))
        {
            cpu_count += 1;
        }
    }

    if (cpu_count == 1)
    {
        is_smp[0] = 0;
        return;
    }

    is_smp[0] = 1;
    CPU_ZERO(affinity1);
```

excerpt from 2863.gz C gcc entry



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CLBG: Qualitative Code Comparisons



Can also browse program source code (*but this requires actual thought!*):

```
proc main() {
    printColorEquations();

    const group1 = [i in 1..popSize1] new Chameneos(i, 0);
    const group2 = [i in 1..popSize2] new Chameneos(i, 0);

    cobegin {
        holdMeetings(group1, n);
        holdMeetings(group2, n);
    }

    print(group1);
    print(group2);

    for c in group1 do delete c;
    for c in group2 do delete c;
}

// Print the results of getNewColor() for all colors
// in the population
proc printColorEquations() {
    for c1 in Color do
        for c2 in Color do
            writeln(c1, " + ", c2, " : ", getNewColor(c1, c2));
    writeln();
}

// Hold meetings among the population by creating a shared
// place, and then creating per-chameneos tasks to have
// them meet
proc holdMeetings(population, numMeetings) {
    const place = new MeetingPlace(numMeetings);

    coforall c in population do // create a task
        c.haveMeetings(place, population);

    delete place;
}
```

excerpt from 1210.gz Chapel entry

```
void get_affinity(int* is_smp, cpu_set_t* affinity1, cpu_set_t* affinity2)

cobegin {
    holdMeetings(group1, n);
    holdMeetings(group2, n);
}
```

```
size_t
char const*
size_t
char const*

processor_str      = "processor";
processor_str_len = strlen(processor_str);
physical_id_str   = "physical id";
physical_id_str_len = strlen(physical_id_str);
core_id_str        = "core id";
n(core_id_str);
cores;
n(cpu_cores_str);

active_cpus;
f;
buf [2048];
pos;
cpu_idx;
physical_id;
core_id;
cpu_cores;
apic_id;
cpu_count;
i;

is_smp[0] = 1;
CPU_ZERO(affinity1);
```

excerpt from 2863.gz C gcc entry



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CLBG: Qualitative Code Comparisons



Can also browse program source code (*but this requires actual thought!*):

```
proc main() {  
  
    char const* core_id_str = "core id";  
    size_t core_id_str_len = strlen(core_id_str);  
    char const* cpu_cores_str = "cpu cores";  
    size_t cpu_cores_str_len = strlen(cpu_cores_str);  
  
    CPU_ZERO(&active_cpus);  
    sched_getaffinity(0, sizeof(active_cpus), &active_cpus);  
    cpu_count = 0;  
    for (i = 0; i != CPU_SETSIZE; i += 1)  
    {  
        if (CPU_ISSET(i, &active_cpus))  
        {  
            cpu_count += 1;  
        }  
    }  
  
    if (cpu_count == 1)  
    {  
        is_smp[0] = 0;  
        return;  
    }  
}
```

excerpt from 1210.gz Chapel entry

```
void get_affinity(int* is_smp, cpu_set_t* affinity1, cpu_set_t* affinity2)  
{  
    cpu_set_t active_cpus;  
    FILE* f;  
    char buf[2048];  
    pos;  
    cpu_idx;  
    physical_id;  
    core_id;  
    cpu_cores;  
    apic_id;  
    cpu_count;  
    i;  
  
    char const* processor_str = "processor";  
    size_t processor_str_len = strlen(processor_str);  
    physical_id_str = "physical id";  
    physical_id_str_len = strlen(physical_id_str);  
    core_id_str = "core id";  
    core_id_str_len = strlen(core_id_str);  
    cpu_cores_str = "cpu cores";  
    cpu_cores_str_len = strlen(cpu_cores_str);  
  
    CPU_ZERO(&active_cpus);  
    sched_getaffinity(0, sizeof(active_cpus), &active_cpus);  
    cpu_count = 0;  
    for (i = 0; i != CPU_SETSIZE; i += 1)  
    {  
        if (CPU_ISSET(i, &active_cpus))  
        {  
            cpu_count += 1;  
        }  
    }  
  
    if (cpu_count == 1)  
    {  
        is_smp[0] = 0;  
        return;  
    }  
    is_smp[0] = 1;  
    CPU_ZERO(affinity1);  
}
```

excerpt from 2863.gz C gcc entry



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Excerpt from PNW PLSE Review

*“Chapel has been around for quite a while,
and it still seems like a niche language...”*



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Chapel: “A Niche Language”?

Chapel is arguably niche in that it...
...was originally designed for HPC

Yet, Chapel’s chief concerns aren’t HPC-specific:

- performance
- programmability (cf. Python)
- parallelism (cf. multicore)
- distributed memory (cf. cloud computing)



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Chapel: “A Niche Language”?

Chapel is arguably niche in that it...

...was originally designed for HPC

...has only a modest-sized community (so far)

Yet, we've historically discouraged its use in production...



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Chapel: A Quiche Language!



The outsider's impression:



The reality, for most of Chapel's history:



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Image sources: <https://www.themountaintinkitchen.com>, <https://xkcd.com/>



Chapel: A Quiche Language!

The outsider's impression:



○ Why aren't more people using
this delectable language?

Though recently, it's more like:



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Image sources: <https://www.themountaintinkitchen.com>, <https://xkcd.com/>

Chapel: “Been Around for Quite Awhile”



Chapel’s Infancy: DARPA HPCS (2003–2012)

- Research focus: ~6-7 FTEs
 - distinguish locality from parallelism
 - seamlessly mix data- and task-parallelism
 - support user-defined distributed arrays, parallel iterators

Chapel’s Adolescence: “the five-year push” (2013–2018)

- Development focus: ~13-14 FTEs
 - **performance and scalability**
 - **ecosystem:** documentation, libraries, tools, ...
 - **base language fixes:** OOP features, error-handling, strings, ...



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Chapel: “Been Around for Quite Awhile”



Chapel’s Infancy: DARPA HPCS (2003–2012)

- Research focus: ~6-7 FTEs
 - distinguish locality from parallelism
 - seamlessly mix data- and task-parallelism
 - support user-defined distributed arrays, parallel iterators

Chapel’s Adolescence: “the five-year push”

(2013–2018)

Then Now

- Development focus: ~13-14 FTEs
 - **performance and scalability**
 - **ecosystem:** documentation, libraries, tools, ...
 - **base language fixes:** OOP features, error-handling, strings, ...



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Chapel Ecosystem: Then vs. Now



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Documentation: Then



After HPCS:

- a PDF language specification
- a Quick Reference sheet
- a number of READMEs
- ~22 primer examples

The image shows a terminal window with several tabs open, illustrating the documentation produced after the HPCS event.

- Chapel Language Specification Version 0.93**: A PDF document detailing the language specification, including sections like "How to write a one-line "Hello, world" program", "Operators", "Statements", and "Procedures".
- Chapel Quick Reference**: A quick reference sheet summarizing Chapel syntax, including operators like `+` and `*`, statements like `if` and `while`, and procedures like `proc` and `func`.
- Expression Precedence and Associativity**: A table showing the precedence and associativity of Chapel operators.
- Statements**: A section of the quick reference detailing statements such as `if`, `cond`, `do`, `while`, and `for` loops.
- File Edit Options Buffers Tools chpl Help**: A tab showing a code example of parallel tasks using `begin`, `cobegin`, and `coforall` statements.
- File Edit Options Buffers Tools Help**: A tab showing a code example of the `taskParallel.chpl` primer, which illustrates parallel tasking features.
- Formal Argument Intents**: A section of the quick reference detailing argument intents like `inout`, `in`, and `out`.
- Named Formal Arguments**: A section of the quick reference detailing named formal arguments.
- Default Values for Formal Arguments**: A section of the quick reference detailing default values for formal arguments.



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Documentation: Now



Now: 200+ modern, hyperlinked, web-based documentation pages

The screenshot displays a multi-page documentation site for Chapel. The top navigation bar includes links for "Docs", "Chapel Documentation", "View page source", and a search bar. The main content area shows several sections:

- Compiling and Running Chapel**: Includes links to Quickstart Instructions, Using Chapel, Platform-Specific Notes, Technical Notes, and Tools.
- Writing Chapel Programs**: Includes links to Quick Reference, Hello World Variants, Primers, Language Specification, Built-in Types and Functions, Standard Modules, Package Modules, Standard Layouts and Distributions, and Chapel Users Guide (WIP).
- Language History**: Includes links to Chapel Evolution and Archived Language Specifications.
- Using Chapel**: Shows a detailed table of contents for the Using Chapel section, including sub-sections like Chapel Prerequisites, Setting up Your Environment for Chapel, Building Chapel, Compiling Chapel Programs, Chapel Man Page, Executing Chapel Programs, Multilocale Chapel Execution, Chapel Launchers, Chapel Tasks, Debugging Chapel Programs, and Reporting Chapel Issues.
- Task Parallelism**: Shows code examples for task parallelism, including `config const n = 10; // Used for the forall loop`, `writeln("1: *** The begin statement ***");`, and `begin writeln("1: output from spawned task");`.
- Begin Statements**: Describes the `begin` statement and its execution behavior.
- Cobegin Statements**: Describes the `cobegin` statement and its execution behavior.



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Libraries: Then

After HPCS: ~25 library modules

- documented via source comments, if at all:

```
// Copyright (c) 2004-2013, Cray Inc. (See LICENSE file for more details)

// Random Module
//
// This standard module contains a random number generator based on
// the one used in the NPB benchmarks. Tailoring the NPB comments to
// this code, we can say the following:
//
// This generator returns uniform pseudorandom real values in the
// range (0, 1) by using the linear congruential generator
//
// x_{k+1} = a x_k (mod 2**46)
//
// where 0 < x_k < 2**46 and 0 < a < 2**46. This scheme generates
// 2**44 numbers before repeating. The seed value must be an odd
// 64-bit integer in the range (1, 2**46). The generated values are
// normalized to be between 0 and 1, i.e., 2**(-46) * x_k.
//
// This generator should produce the same results on any computer
// with at least 48 mantissa bits for real(64) data.
//
// Open Issues
//
// 1. We would like to support general serial and parallel iterators
// on the RandomStream class, but this is not possible with our
// current parallel iterator framework.
//
// 2. The random number generation functionality in this module is
// currently restricted to 64-bit real, 64-bit imag, and 128-bit
// complex values. This should be extended to other primitive types
// for which this would make sense. Coercions are insufficient.
//
// 3. Can the multiplier 'arand' be moved into the RandomStream class
// so that it can be changed by a user of this class.
//
// 4. By default, the random stream seed is initialized based on the
// current time in microseconds, allowing for some degree of
// randomness. The intent of the SeedGenerator enumerated type is to
// provide a menu of options for initializing the random stream seed,
// but only one option is implemented to date.
//
// Note on Private
//
// It is the intent that once Chapel supports the notion of 'private',
// everything prefixed with RandomPrivate_ will be made private to
--uu---F1 Random.chpl Top L1 (Chapel/l Abbrev)-----
Mark set
```

```
// Copyright (c) 2004-2013, Cray Inc. (See LICENSE file for more details)

extern type qio_regexp_t;

extern record qio_regexp_options_t {
    var utf8:bool;
    var posix:bool;
    var literal:bool;
    var nocapture:bool;
    // These ones can be set inside the regexp
    var ignorecase:bool; // (?i)
    var multiline:bool; // (?m)
    var dotnl:bool; // (?s)
    var nongready:bool; // (?U)
}

extern proc qio_regexp_null():qio_regexp_t;
extern proc qio_regexp_init_default_options(ref options:qio_regexp_options_t);
extern proc qio_regexp_create_compile(str:string, strlen:int(64), ref options:qio_regexp_options_t, ref compiled:qio_regexp_t);
extern proc qio_regexp_create_compile_flags(str:string, strlen:int(64), flags:s\string, flagslen:int(64), isUtf8:bool, ref compiled:qio_regexp_t);
extern proc qio_regexp_create_compile_flags_2(str:c_ptr, strlen:int(64), flags:c_ptr, flagslen:int(64), isUtf8:bool, ref compiled:qio_regexp_t);
extern proc qio_regexp_retain(ref compiled:qio_regexp_t);
extern proc qio_regexp_release(ref compiled:qio_regexp_t);

extern proc qio_regexp_get_options(ref regexp:qio_regexp_t, ref options: qio_re\gexp_options_t);
extern proc qio_regexp_get_pattern(ref regexp:qio_regexp_t, ref pattern: string\ );
extern proc qio_regexp_get_ncaptures(ref regexp:qio_regexp_t):int(64);
extern proc qio_regexp_ok(ref regexp:qio_regexp_t):bool;
extern proc qio_regexp_error(ref regexp:qio_regexp_t):string;

extern const QIO_REGEXP_ANCHORED:c_int;
extern const QIO_REGEXP_ANCHOR_START:c_int;
extern const QIO_REGEXP_ANCHOR_BOTH:c_int;

extern record qio_regexp_string_piece_t {
    var offset:int(64); // counting from 0, -1 means "NULL"
    var len:int(64);
}

extern proc qio_regexp_string_piece_isnull(ref sp:qio_regexp_string_piece_t):bo\ol;
--uu---F1 Regexp.chpl Top L1 (Chapel/l Abbrev)-----
```



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Libraries: Now

Now: ~60 library modules

- web-documented, many user-contributed

The screenshot shows two pages from the Chapel Documentation 1.16 website:

- Standard Modules**: A list of standard library modules. The visible items include: Assert, Barrier, Barriers, BigInteger, BitOps, Buffers, CommDiagnostics, DateTime, DynamicIterators, FileSystem, GMP, Help, IO, List, Math, Memory, Path, Random, Reflection, Regexp, Spawn, Sys, SysBasic, SysCTypes, SysError, Time, Types, and UtilReplicatedVar.
- Package Modules**: A list of package modules. The visible items include: BLAS, Collection, Crypto, Curl, DistributedBag, DistributedDeque, DistributedIterators, FFTW, FFTW_MT, Futures, HDFS, HDFSIterator, LAPACK, LinearAlgebra, MPI, Norm, OwnedObject, RangeChunk, RecordParser, Search, SharedObject, Sort, VisualDebug, and ZMQ.



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Tools: Then



After HPCS:

- **highlighting modes** for emacs and vim
- **chpldoc**: documentation tool (rough draft)



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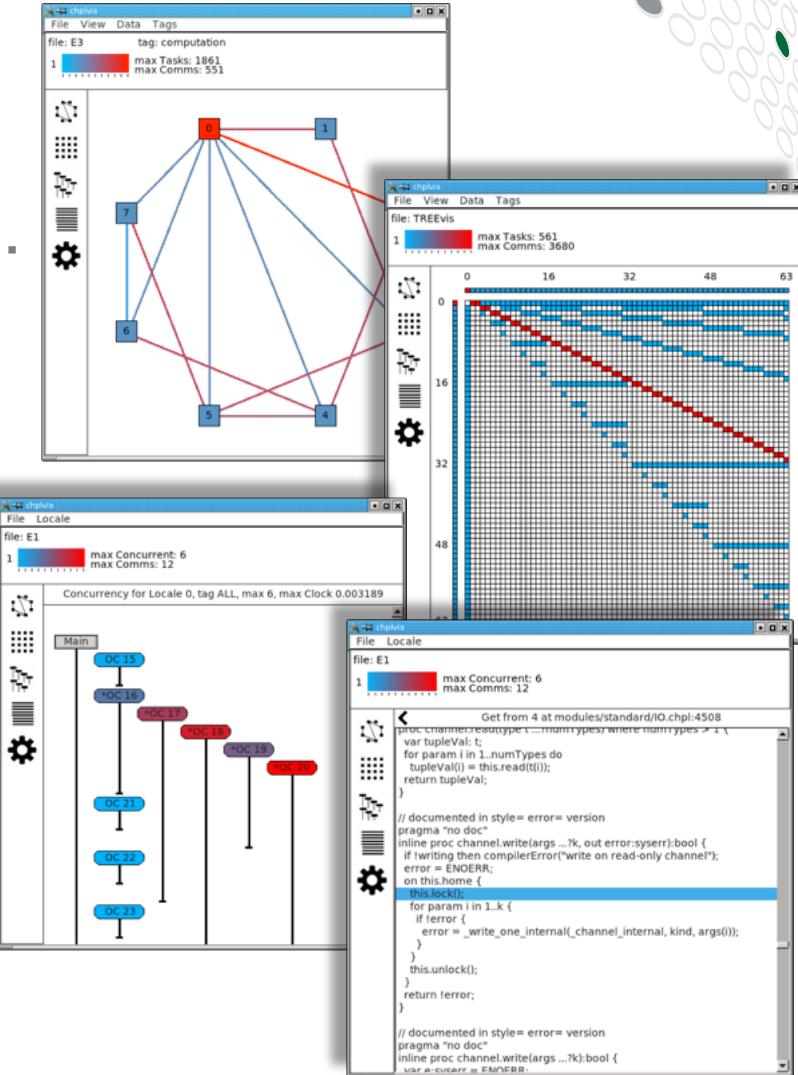
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Tools: Now

Now:

- **highlighting modes** for emacs, vim, atom, ...
- **chpldoc**: documentation tool
- **mason**: package manager
- **c2chapel**: interoperability aid
- **chptags**: helps search Chapel code
- **bash tab completion**: command-line help
- **chplvis**: performance visualizer / debugger



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Chapel Performance: Then vs. Now



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Performance Focus Areas during 5-year push



- Cleaner, simpler generated code
- NUMA sensitivity within multi-socket nodes
- Best-use of RDMA and NIC memory registration
- Reduced overheads in tasks, memory, communication
- Bulk transfer optimizations
- ...and much more...



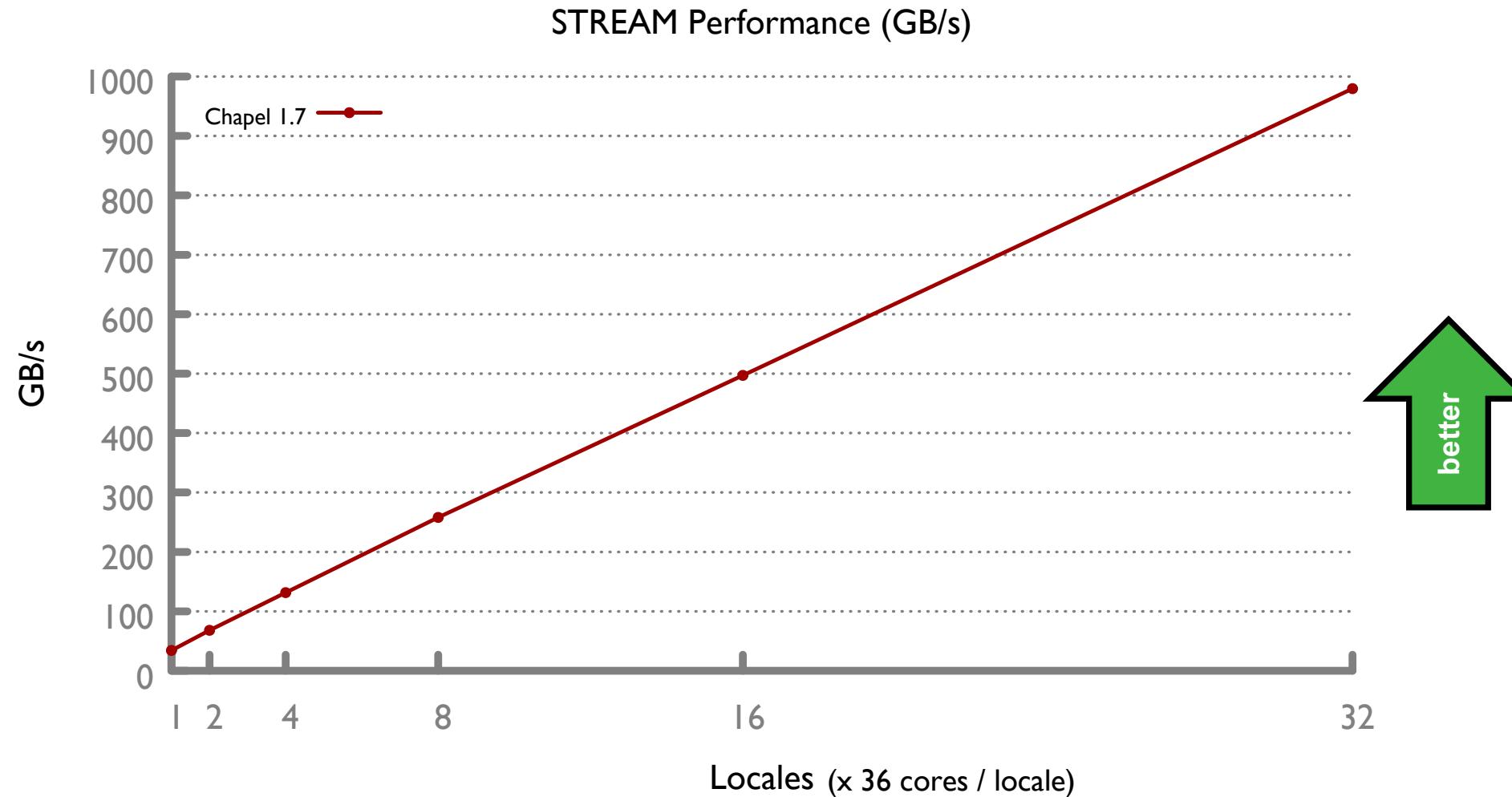
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STREAM Triad Performance: Chapel Then



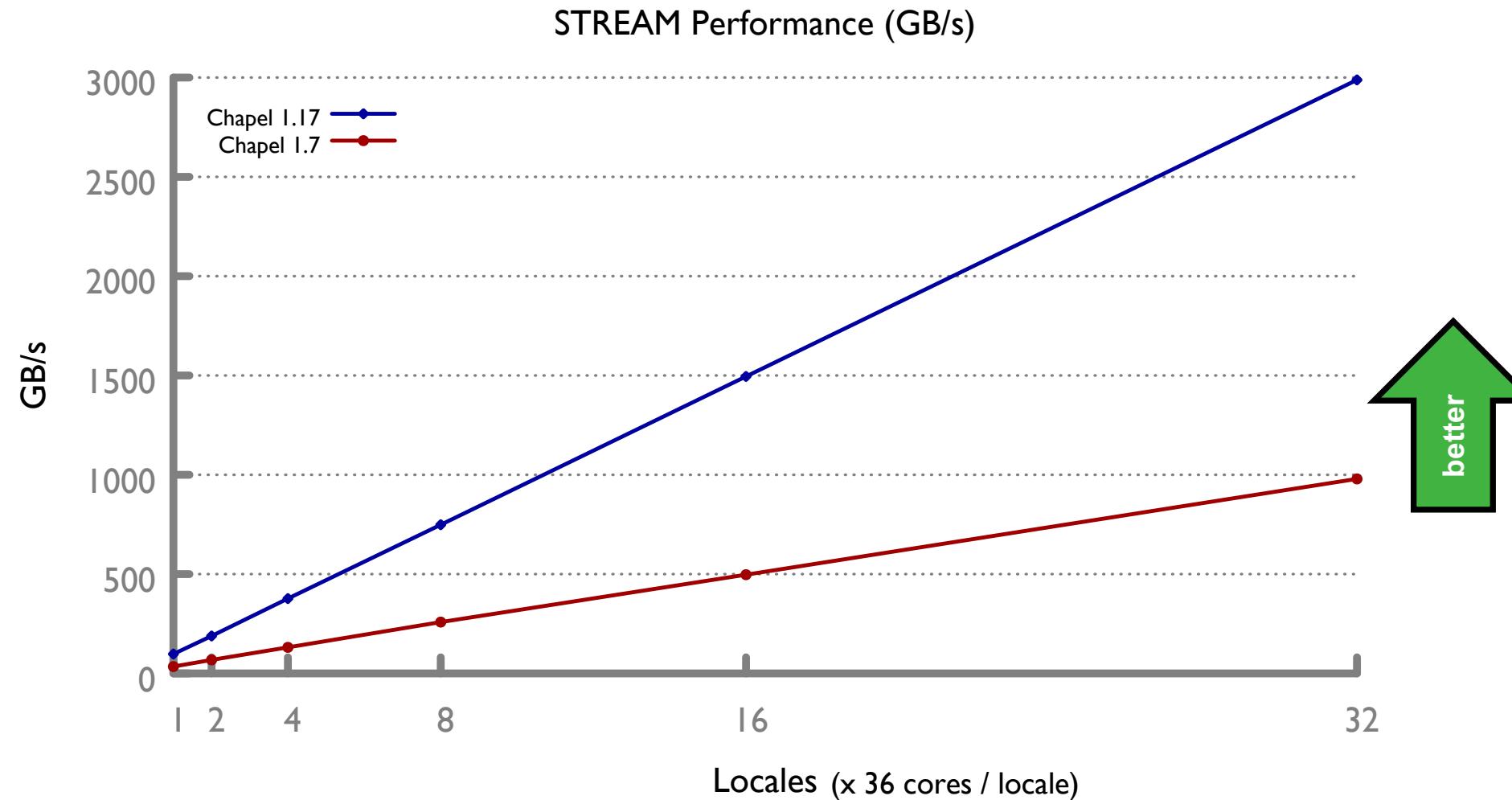
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STREAM Triad Performance: Chapel Then vs. Now



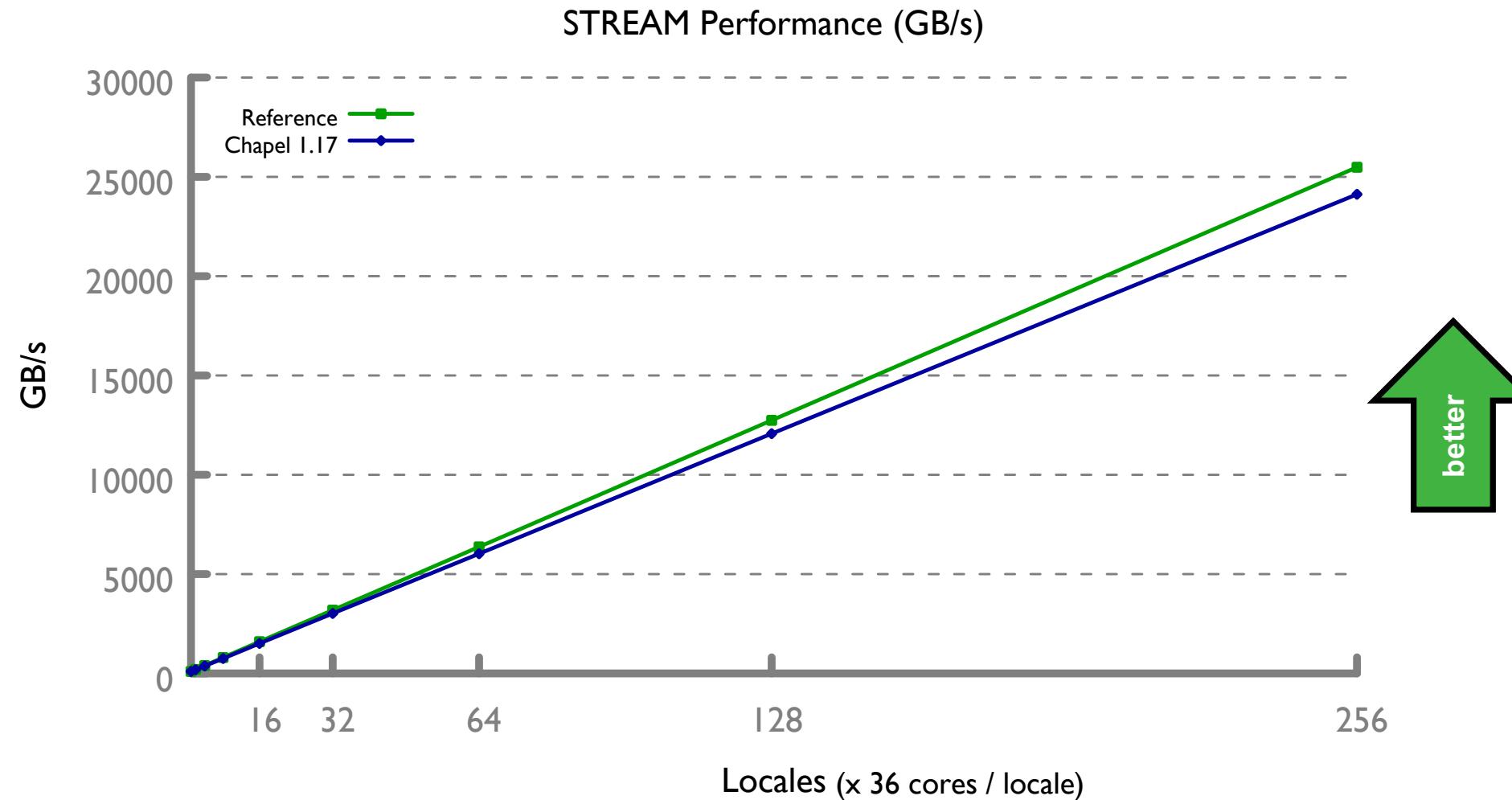
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STREAM Triad Performance: Chapel Now vs. ref



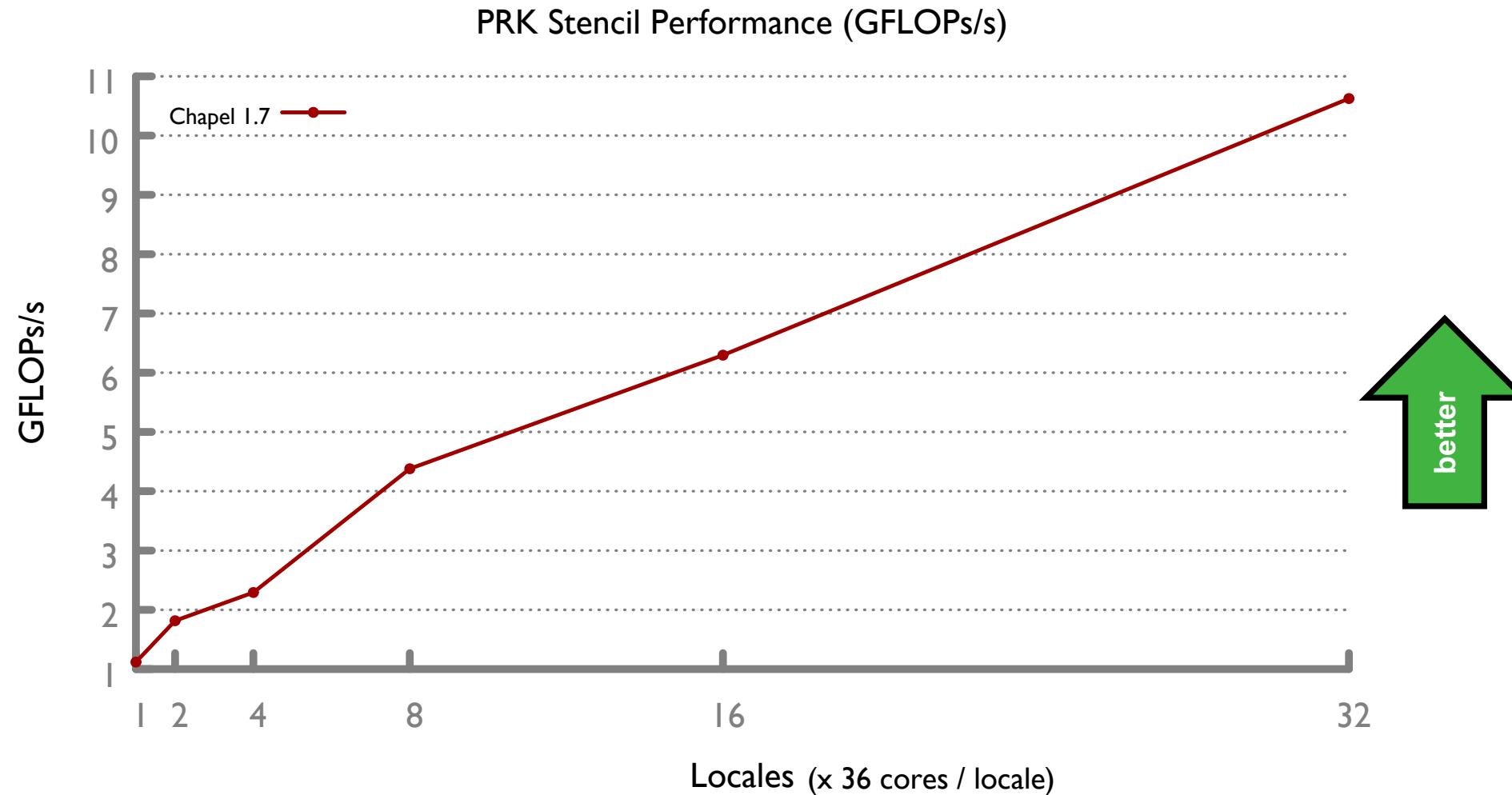
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PRK Stencil Performance: Chapel Then



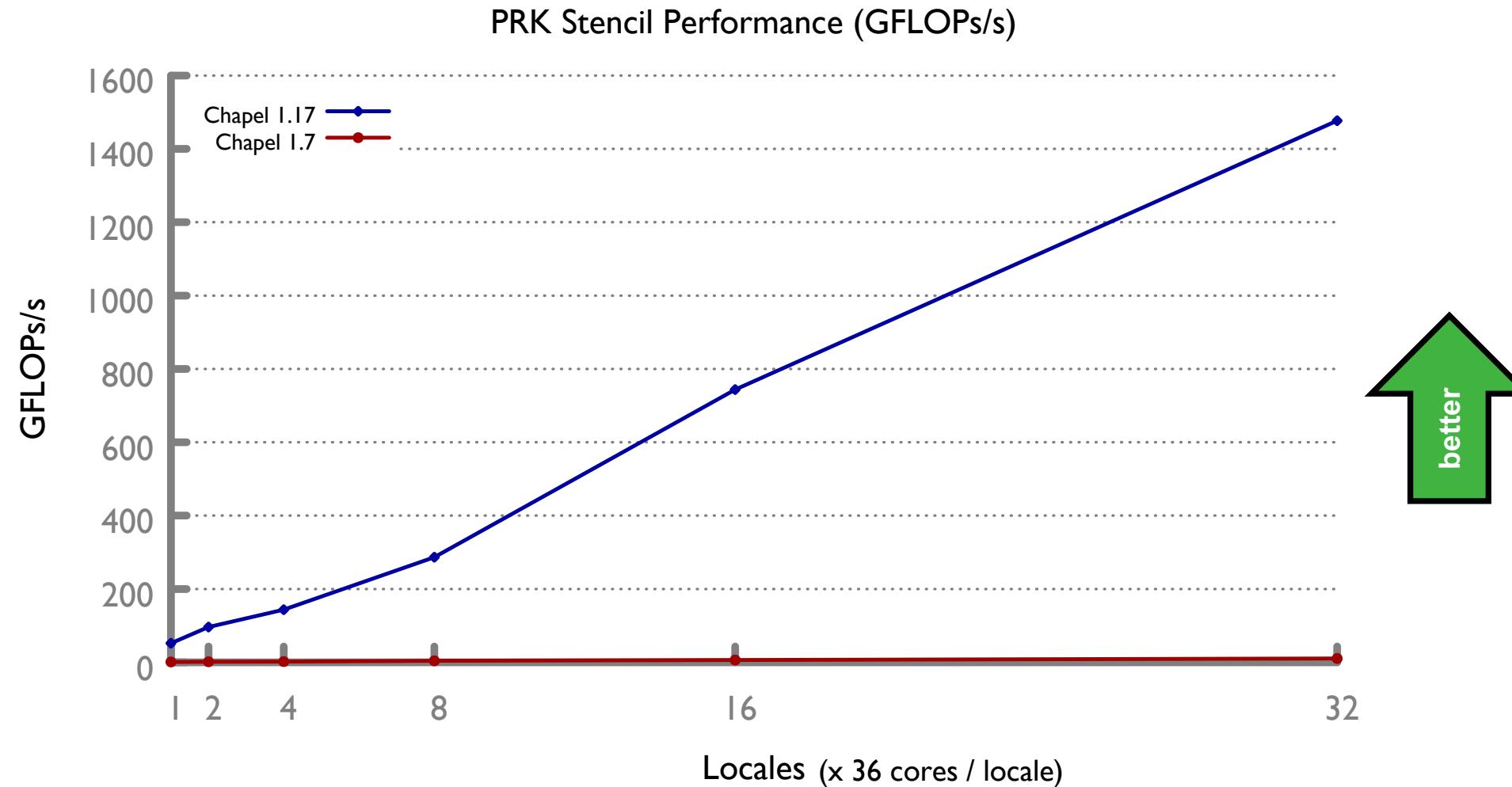
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PRK Stencil Performance: Chapel Then vs. Now



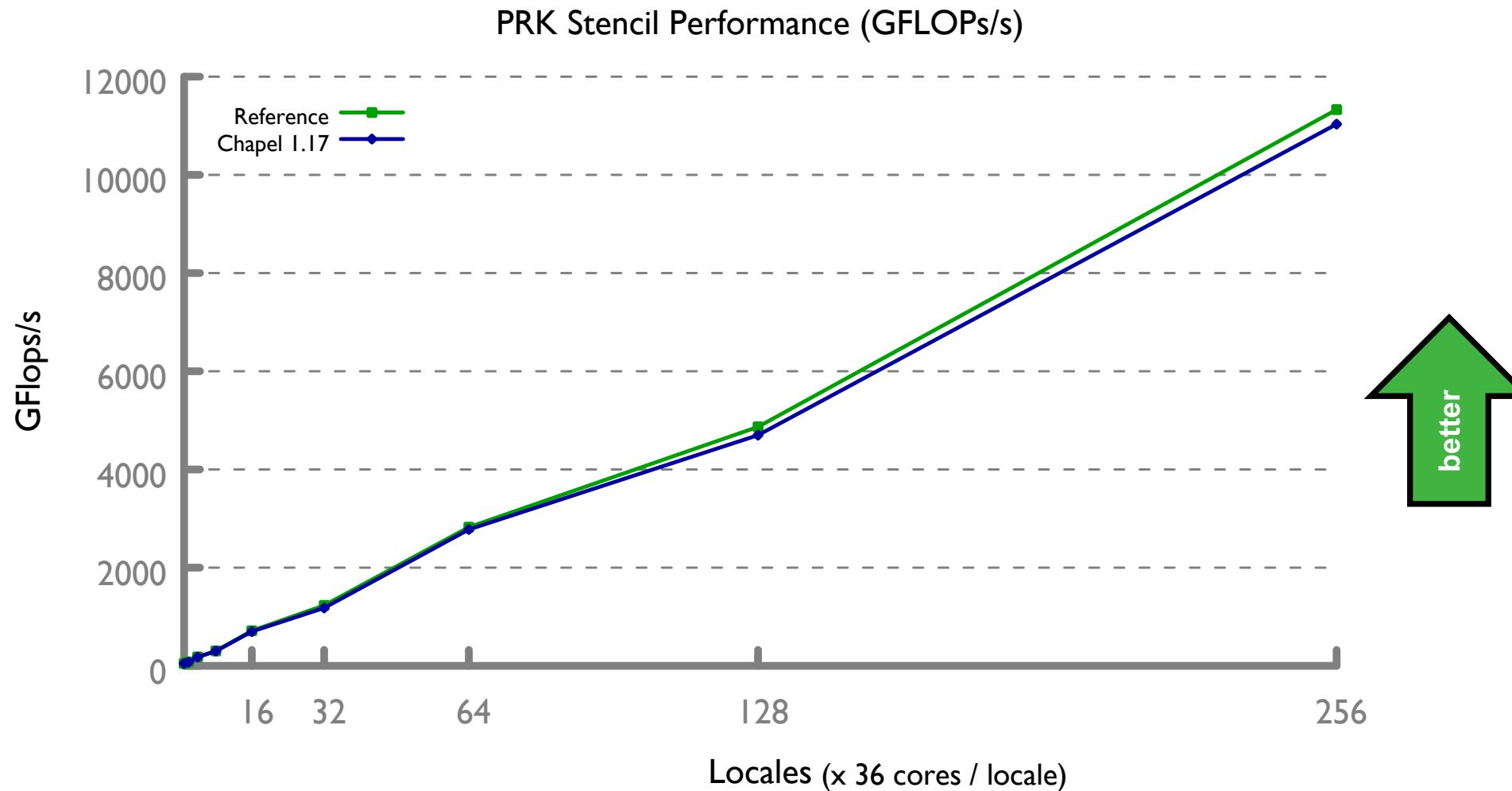
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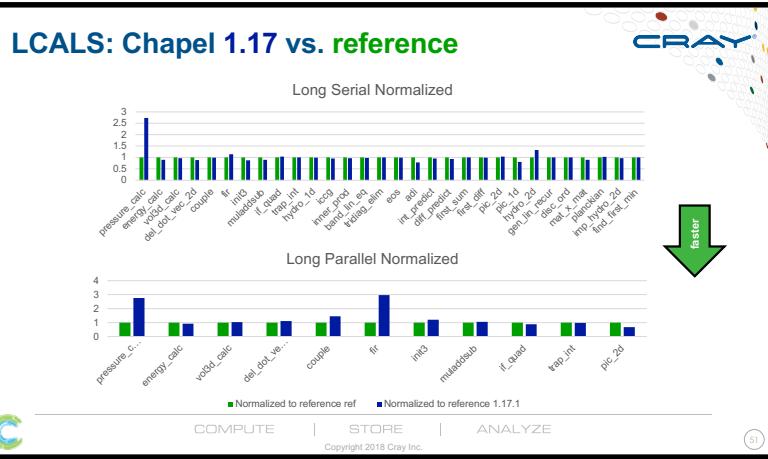
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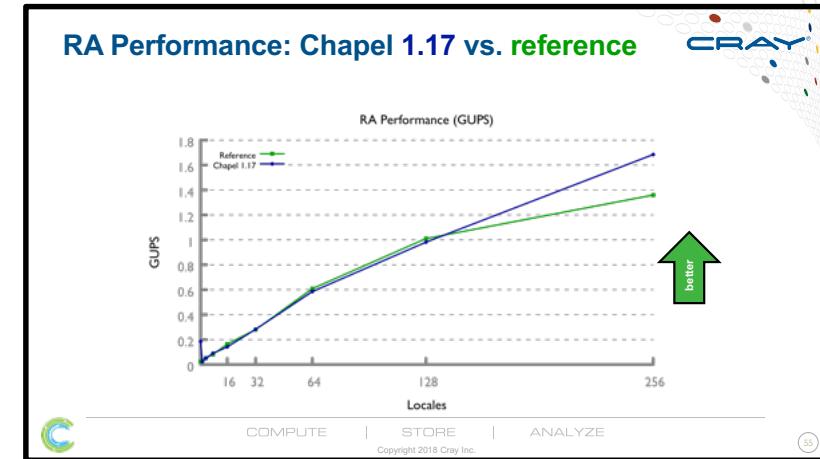
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HPC Patterns: Chapel Now vs. reference



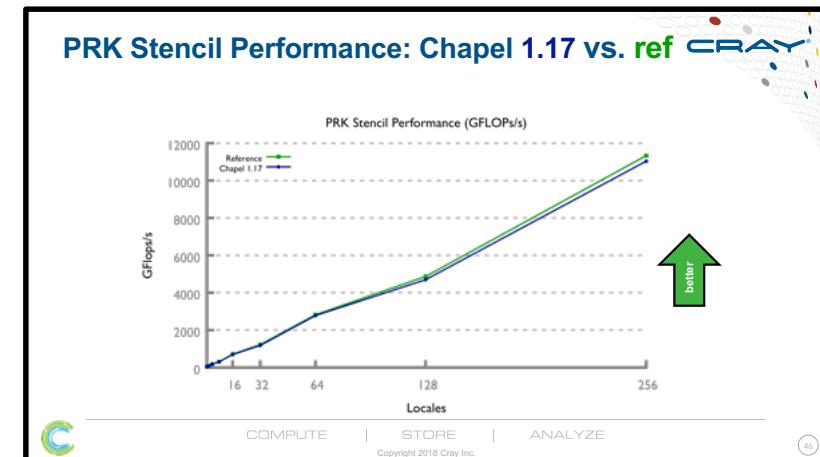
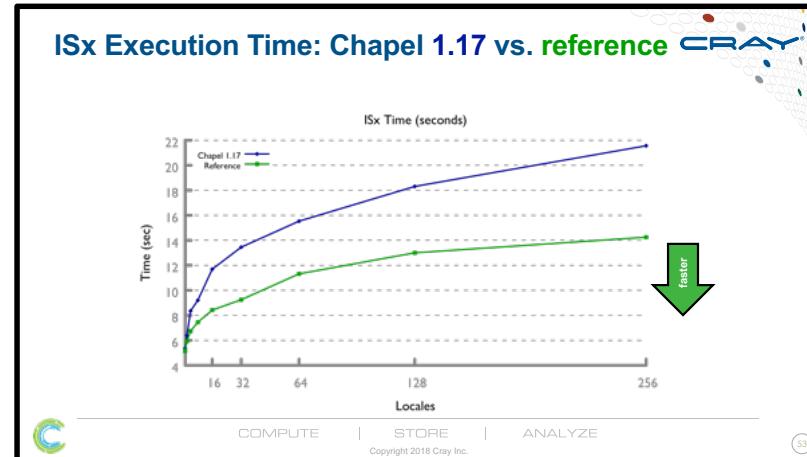
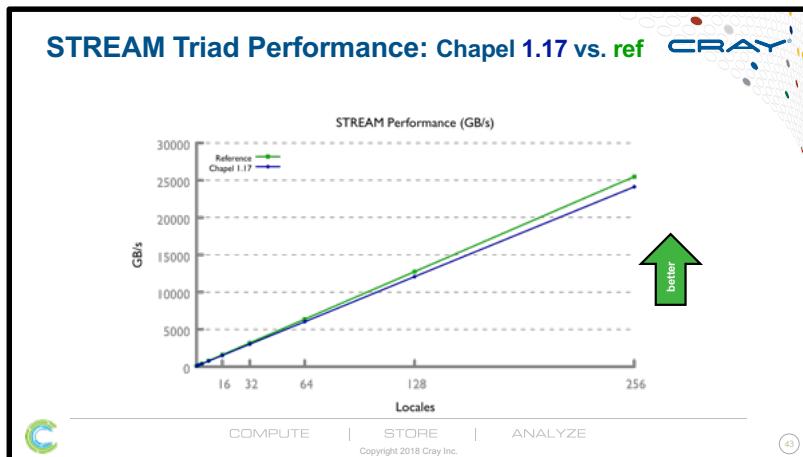
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HPCC RA



STREAM
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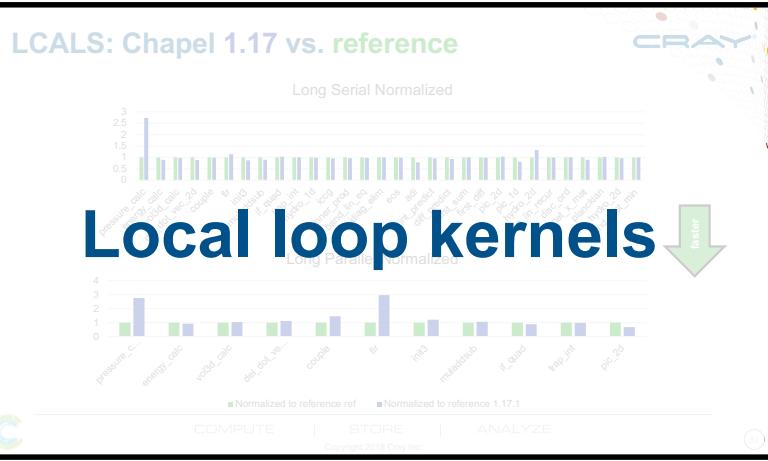
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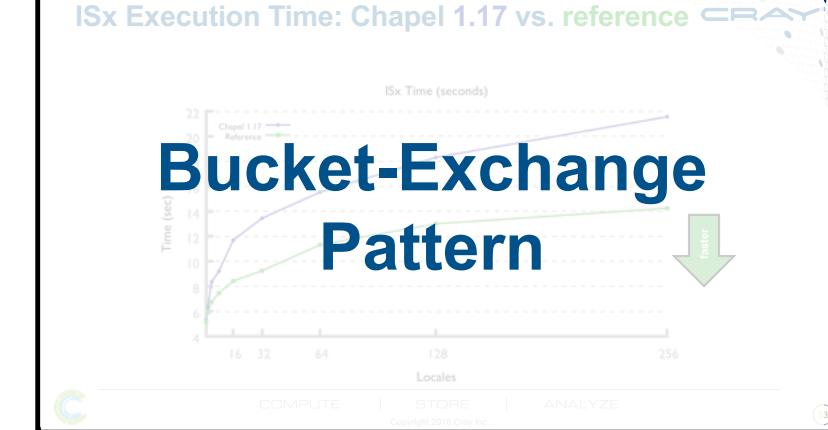
Nightly performance tickers online at:
<https://chapel-lang.org/perf-nightly.html>

HPC Patterns: Chapel Now vs. reference

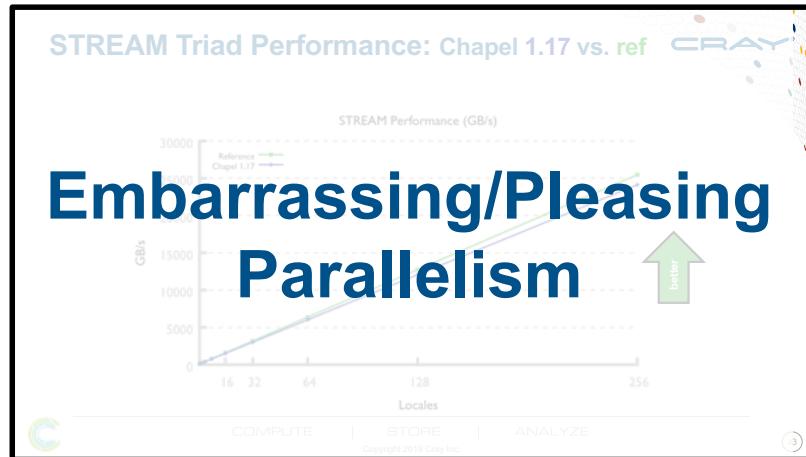
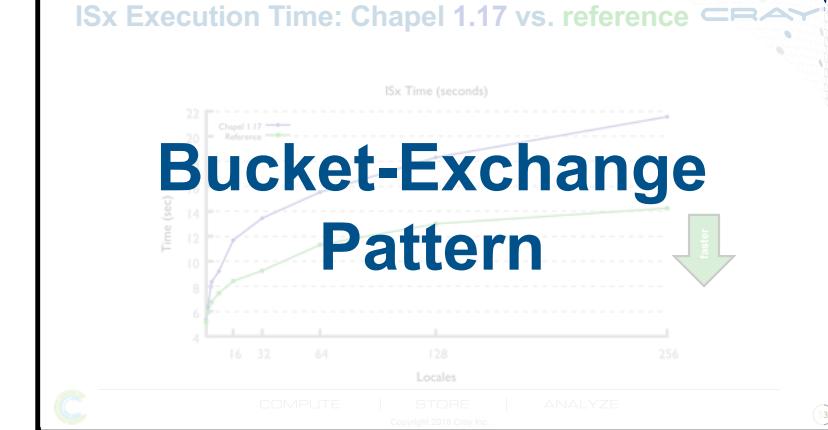


LCALS

STREAM
Triad



HPCC RA



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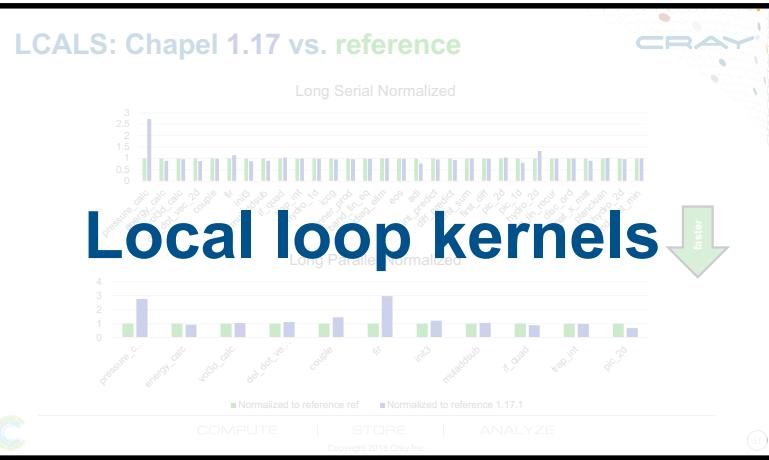
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Nightly performance tickers online at:
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HPC Patterns: Chapel Now vs. reference

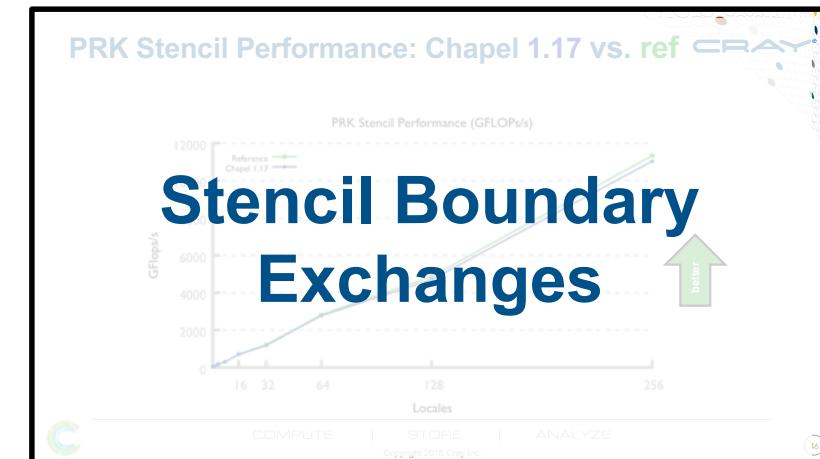
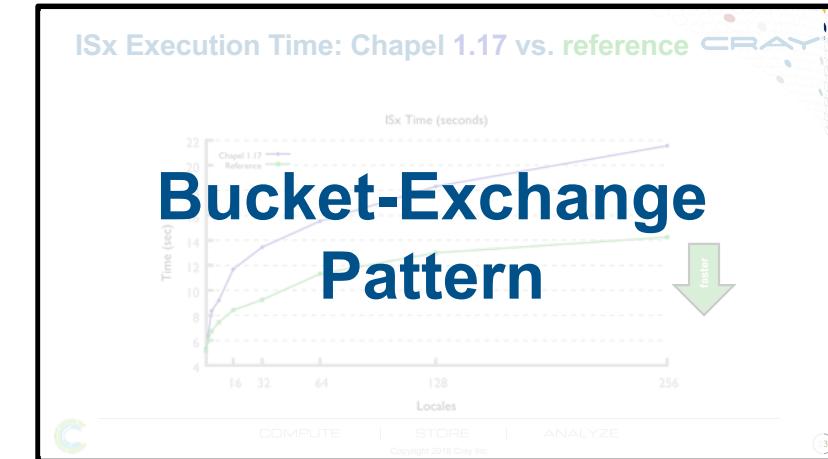
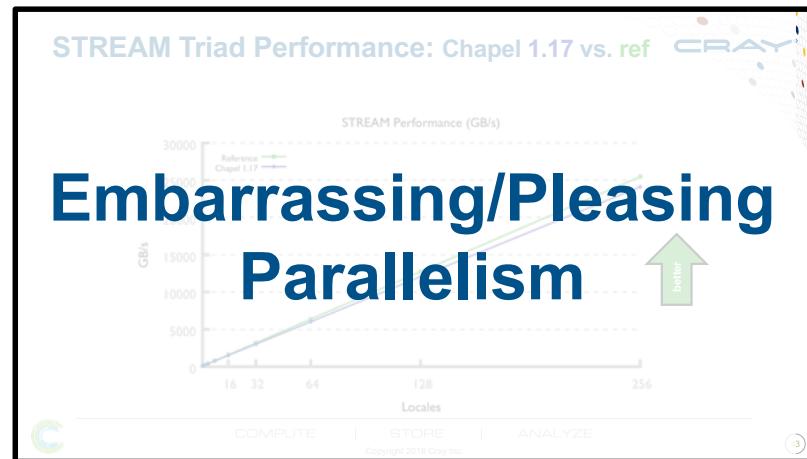


LCALS

HPCC RA

STREAM
Triad

PRK
Stencil



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Nightly performance tickers online at:
<https://chapel-lang.org/perf-nightly.html>

HPCC Random Access Kernel: MPI



```

/* Perform updates to main table. The scalar equivalent is:
 *
 * for (i=0; i<NUPDATE; i++) {
 *   Ran = (Ran << 1) ^ ((s64Int) Ran < 0) ? POLY : 0;
 *   Table[Ran & (TABSIZE-1)] ^= Ran;
 * }
 */

MPI_Irecv(&LocalRecvBuffer, localBufferSize, tparams.dtype64,
          MPI_ANY_SOURCE, MPI_ANY_TAG, MPI_COMM_WORLD, &inreq);
while (i < SendCnt) {
    /* receive messages */
    do {
        MPI_Test(&inreq, &have_done, &status);
        if (have_done) {
            if (status.MPI_TAG == UPDATE_TAG) {
                MPI_Get_count(&status, tparams.dtype64, &recvUpdates);
                bufferBase = 0;
                for (j=0; j < recvUpdates; j++) {
                    inmsg = LocalRecvBuffer[bufferBase+j];
                    LocalOffset = (inmsg & (tparams.TableSize - 1)) -
                                 tparams.GlobalStartMyProc;
                    HPCC_Table[LocalOffset] ^= inmsg;
                }
            } else if (status.MPI_TAG == FINISHED_TAG) {
                NumberReceiving--;
            } else
                MPI_Abort( MPI_COMM_WORLD, -1 );
            MPI_Irecv(&LocalRecvBuffer, localBufferSize, tparams.dtype64,
                      MPI_ANY_SOURCE, MPI_ANY_TAG, MPI_COMM_WORLD, &inreq);
        }
    } while (have_done && NumberReceiving > 0);
    if (pendingUpdates < maxPendingUpdates) {
        Ran = (Ran << 1) ^ ((s64Int) Ran < ZERO64B ? POLY : ZERO64B);
        GlobalOffset = Ran & (tparams.TableSize-1);
        if ( GlobalOffset < tparams.Top)
            WhichPe = ( GlobalOffset / (tparams.MinLocalTableSize + 1) );
        else
            WhichPe = ( (GlobalOffset - tparams.Remainder) /
                        tparams.MinLocalTableSize );
        if (WhichPe == tparams.MyProc) {
            LocalOffset = (Ran & (tparams.TableSize - 1)) -
                         tparams.GlobalStartMyProc;
            HPCC_Table[LocalOffset] ^= Ran;
        }
    }
    else {
        HPCC_InsertUpdate(Ran, WhichPe, Buckets);
        pendingUpdates++;
    }
    i++;
}
else {
    MPI_Test(&outreq, &have_done, MPI_STATUS_IGNORE);
    if (have_done) {
        outreq = MPI_REQUEST_NULL;
        pe = HPCC_GetUpdates(Buckets, LocalSendBuffer, localBufferSize,
                             &peUpdates);
        MPI_Isend(&LocalSendBuffer, peUpdates, tparams.dtype64, (int)pe,
                  UPDATE_TAG, MPI_COMM_WORLD, &outreq);
        pendingUpdates -= peUpdates;
    }
}
/* send remaining updates in buckets */
while (pendingUpdates > 0) {
    /* receive messages */
    do {
        MPI_Test(&inreq, &have_done, &status);
        if (have_done) {
            if (status.MPI_TAG == UPDATE_TAG) {
                MPI_Get_count(&status, tparams.dtype64, &recvUpdates);
                bufferBase = 0;
                for (j=0; j < recvUpdates; j++) {
                    inmsg = LocalRecvBuffer[bufferBase+j];
                    LocalOffset = (inmsg & (tparams.TableSize - 1)) -
                                 tparams.GlobalStartMyProc;
                    HPCC_Table[LocalOffset] ^= inmsg;
                }
            } else if (status.MPI_TAG == FINISHED_TAG) {
                /* we got a done message. Thanks for playing... */
                NumberReceiving--;
            } else
                MPI_Abort( MPI_COMM_WORLD, -1 );
            MPI_Irecv(&LocalRecvBuffer, localBufferSize, tparams.dtype64,
                      MPI_ANY_SOURCE, MPI_ANY_TAG, MPI_COMM_WORLD, &inreq);
        }
    } while (have_done && NumberReceiving > 0);
}

MPI_Test(&outreq, &have_done, MPI_STATUS_IGNORE);
if (have_done) {
    outreq = MPI_REQUEST_NULL;
    pe = HPCC_GetUpdates(Buckets, LocalSendBuffer, localBufferSize,
                         &peUpdates);
    MPI_Isend(&LocalSendBuffer, peUpdates, tparams.dtype64, (int)pe,
              UPDATE_TAG, MPI_COMM_WORLD, &outreq);
    pendingUpdates -= peUpdates;
}
/* send our done messages */
for (proc_count = 0 ; proc_count < tparams.NumProcs ; ++proc_count) {
    if (proc_count == tparams.MyProc) { tparams.finish_req[tparams.MyProc] =
                                         MPI_REQUEST_NULL; continue; }
    /* send garbage - who cares, no one will look at it */
    MPI_Isend(&Ran, 0, tparams.dtype64, proc_count, FINISHED_TAG,
              MPI_COMM_WORLD, tparams.finish_req + proc_count);
}
/* Finish everyone else up... */
while (NumberReceiving > 0) {
    MPI_Wait(&inreq, &status);
    if (status.MPI_TAG == UPDATE_TAG) {
        MPI_Get_count(&status, tparams.dtype64, &recvUpdates);
        bufferBase = 0;
        for (j=0; j < recvUpdates; j++) {
            inmsg = LocalRecvBuffer[bufferBase+j];
            LocalOffset = (inmsg & (tparams.TableSize - 1)) -
                         tparams.GlobalStartMyProc;
            HPCC_Table[LocalOffset] ^= inmsg;
        }
    } else if (status.MPI_TAG == FINISHED_TAG) {
        /* we got a done message. Thanks for playing... */
        NumberReceiving--;
    } else
        MPI_Abort( MPI_COMM_WORLD, -1 );
    MPI_Irecv(&LocalRecvBuffer, localBufferSize, tparams.dtype64,
              MPI_ANY_SOURCE, MPI_ANY_TAG, MPI_COMM_WORLD, &inreq);
}
MPI_Waitall( tparams.NumProcs, tparams.finish_req, tparams.finish_statuses);

```



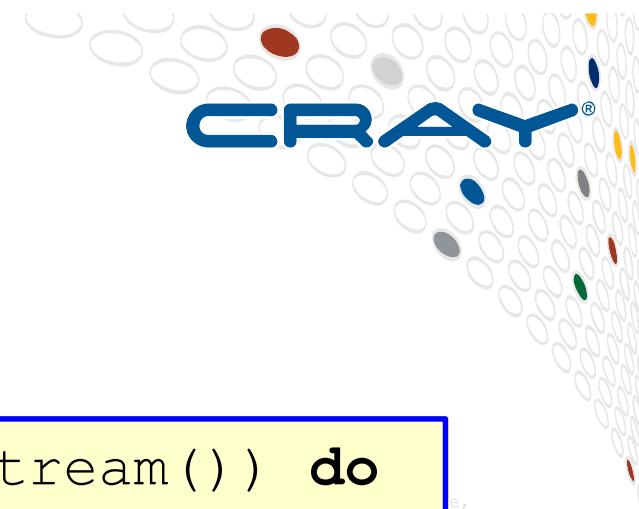
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HPCC Random Access Kernel: MPI



```
/* Perform updates to main table. The scalar equivalent is:  
 *  
 * for (i=0; i<NUPDATE; i++) {  
 *   Ran = (Ran << 1) ^ (((s64Int) Ran < 0) ? POLY : 0);  
 *   Table[Ran & (TABSIZ-1)] ^= Ran;  
 * }  
  
MPI_Irecv(&LocalRecvBuffer, localBufferSize, tparams.dtype,  
          MPI_ANY_SOURCE, MPI_ANY_TAG, MPI_COMM_WORLD,  
          while (i < SendCnt) {  
    /* receive messages */  
    do {  
      MPI_Test(&inreq, &have_done, &status);  
      if (have_done) {  
        if (status.MPI_TAG == UPDATE_TAG) {  
          MPI_Get_count(&status, tparams.dtype64, &recvUpdates);  
          bufferBase = 0;  
        }  
      }  
    }  
  }  
  /* send our done messages */  
  for (proc_count = 0 ; proc_count < tparams.NumProcs ; ++proc_count) {  
    if (proc_count == tparams.MyProc) {  
      tparams.finish_req[tparams.MyProc] = MPI_REQUEST_NULL; continue;  
    }  
    /* send garbage - who cares, no one will look at it */  
    Isend(&Ran, 0, tparams.dtype64, proc_count, FINISHED_TAG,  
          statuses);  
  }
```

Chapel Kernel

```
forall (_, r) in zip(Updates, RASTream()) do  
  T[r & indexMask] ^= r;
```

MPI Comment

```
/* Perform updates to main table. The scalar equivalent is:  
 *  
 * for (i=0; i<NUPDATE; i++) {  
 *   Ran = (Ran << 1) ^ (((s64Int) Ran < 0) ? POLY : 0);  
 *   Table[Ran & (TABSIZ-1)] ^= Ran;  
 * }  
 */
```



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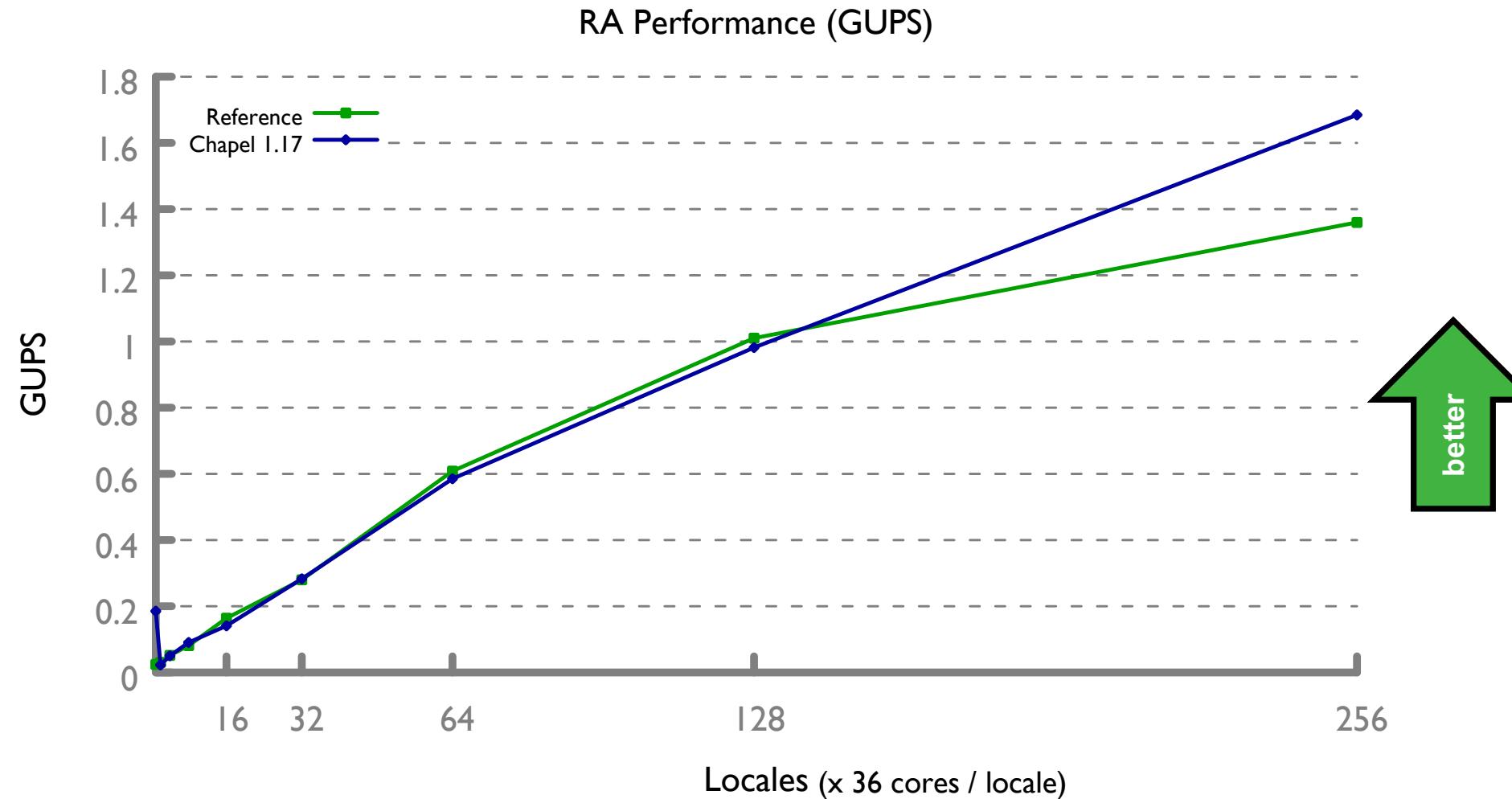
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RA Performance: Chapel Now vs. reference

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What's Next?



CHIUW 2018: The 5th annual Chapel Implementers and Users Workshop

- Vancouver BC, Friday May 25th
- Details: <https://chapel-lang.org/CHIUW2018.html>



Chapel's college years: plans for 2018-2021

- Further Performance and Scalability Improvements
- Libfabric/OFI Support
- GPU Support
- Cloud Support
- Chapel AI



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The Chapel Team at Cray (May 2018)



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Chapel Community Partners



Lawrence Berkeley
National Laboratory



Yale

(and several others...)

<https://chapel-lang.org/collaborations.html>



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Summary



- Chapel's made huge progress over the past five years
- Ready for use in production*
- Open to collaborations
 - Plenty of research questions remain



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Chapel Resources



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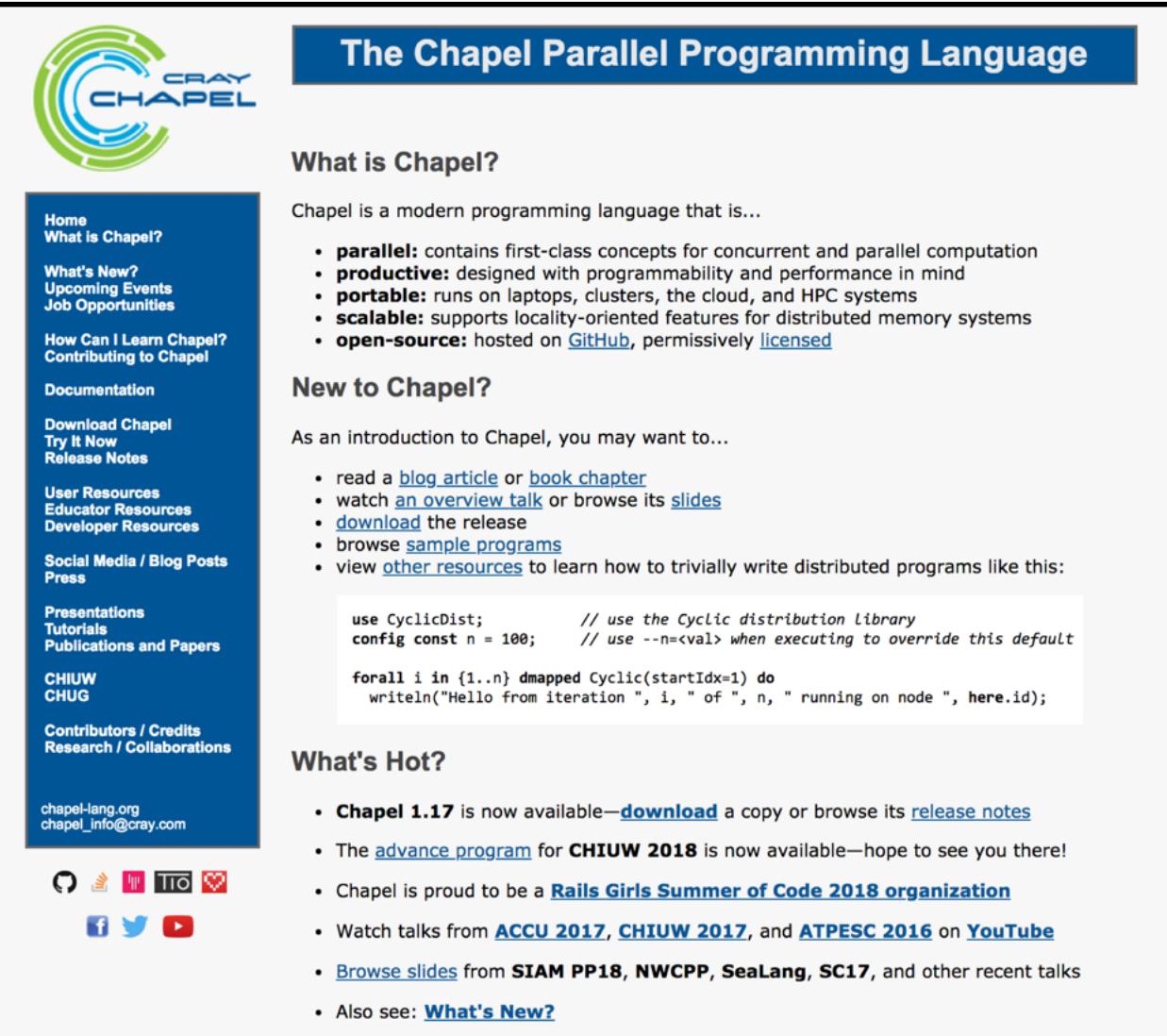
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Chapel Central



<https://chapel-lang.org>

- downloads
- documentation
- resources
- presentations
- papers



The Chapel Parallel Programming Language

What is Chapel?

Chapel is a modern programming language that is...

- **parallel:** contains first-class concepts for concurrent and parallel computation
- **productive:** designed with programmability and performance in mind
- **portable:** runs on laptops, clusters, the cloud, and HPC systems
- **scalable:** supports locality-oriented features for distributed memory systems
- **open-source:** hosted on [GitHub](#), permissively [licensed](#)

New to Chapel?

As an introduction to Chapel, you may want to...

- read a [blog article](#) or [book chapter](#)
- watch [an overview talk](#) or browse its [slides](#)
- [download](#) the release
- browse [sample programs](#)
- view [other resources](#) to learn how to trivially write distributed programs like this:

```
use CyclicDist;           // use the Cyclic distribution library
config const n = 100;      // use --n=<val> when executing to override this default
forall i in {1..n} dmapped Cyclic(startIdx=1) do
    writeln("Hello from iteration ", i, " of ", n, " running on node ", here.id);
```

What's Hot?

- **Chapel 1.17** is now available—[download](#) a copy or browse its [release notes](#)
- The [advance program](#) for **CHIUW 2018** is now available—hope to see you there!
- Chapel is proud to be a [Rails Girls Summer of Code 2018 organization](#)
- Watch talks from [ACCU 2017](#), [CHIUW 2017](#), and [ATPESC 2016](#) on [YouTube](#)
- [Browse slides](#) from **SIAM PP18**, **NWCPP**, **SeaLang**, **SC17**, and other recent talks
- Also see: [What's New?](#)



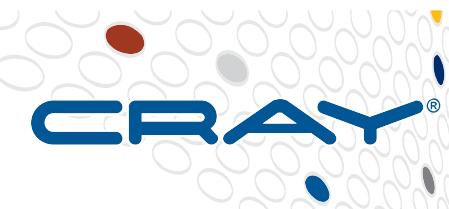
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Chapel Social Media (no account required)



<http://twitter.com/ChapelLanguage>

<http://facebook.com/ChapelLanguage>

<https://www.youtube.com/channel/UCHmm27bYjhknK5mU7ZzPGsQ/>

The image shows three screenshots of social media platforms displaying content related to the Chapel programming language:

- Twitter:** The Chapel Language (@ChapelLanguage) profile page. It features a large green and blue 'C' logo, the text "Chapel Language", and a bio stating "Chapel is a productive parallel programming language designed for large-scale computing whose development is being led by cray_inc". It shows 576 tweets, 48 following, 278 followers, 200 likes, and 1 list.
- Facebook:** The Chapel Programming Language page. It features the same green and blue 'C' logo, the text "Chapel Programming Language", and a bio stating "We're pleased to note that Chapel is currently ranked Computer Language Benchmarks Game's 'fast-fast'. That said, we're even prouder of how clear and concise our programs are relative to other entries that perform similarly". It shows 1 post from April 21 at 5:47pm.
- YouTube:** The Chapel Parallel Programming Language channel page. It features the green and blue 'C' logo, the text "Chapel Parallel Programming Language", and a bio stating "Chapel videos". It shows 72 subscribers and several video thumbnails, including "CHI UW 2017 keynote: Chapel's Home in the New Landscape of Scientific Frameworks, Jonathan Dursi" (53:48), "The Audacity of Chapel: Scalable Parallel Programming Done Right - Brad Chamberlain [ACCU 2017]" (53:54), and "PYCON UK 2017: On Big Computation and Python" (24:47).



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Chapel Community



<https://stackoverflow.com/questions/tagged/chapel>

<https://github.com/chapel-lang/chapel/issues>

<https://gitter.im/chapel-lang/chapel>

chapel-announce@lists.sourceforge.net

The collage consists of four panels:

- Stack Overflow Questions:** Shows a list of tagged questions under the [chapel] tag. Examples include "Tuple Concatenation in Chapel" and "Is there a way to use non-scalar values in functions with what".
- Github Issues:** Shows the GitHub repository for chapel-lang/chapel. It displays a list of open issues, such as "Implement 'bounded-coforall' optimization for remote coforalls" and "make uninstall".
- Gitter Chat:** Shows a Gitter channel for chapel-lang/chapel. A recent conversation discusses array syntax and copy semantics, with code snippets provided.
- Community Stats:** A purple-themed page titled "Where communities thrive" that shows statistics like "JOIN OVER 800K+ PEOPLE" and "CREATE YOUR OWN COMMUNITY".



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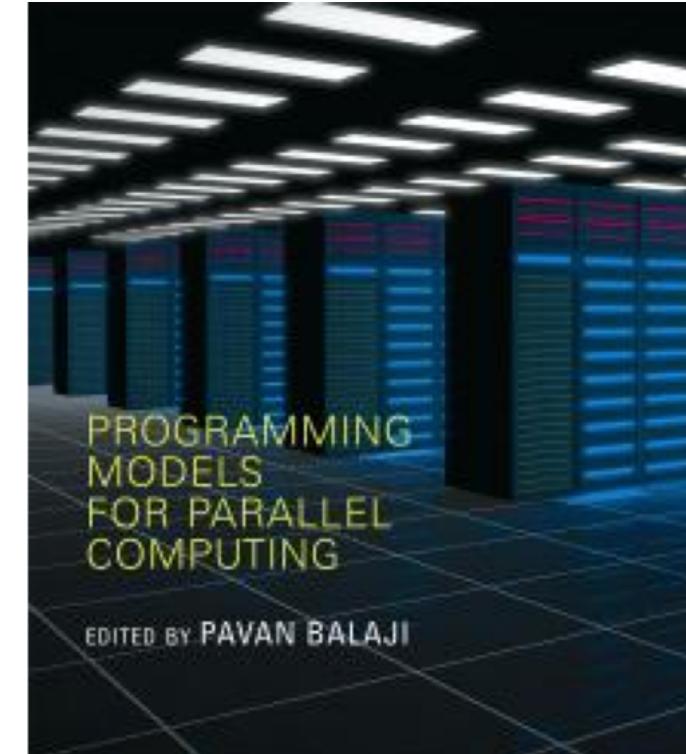
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Suggested Reading (healthy attention spans)



Chapel chapter from *Programming Models for Parallel Computing*

- a detailed overview of Chapel's history, motivating themes, features
- published by MIT Press, November 2015
- edited by Pavan Balaji (Argonne)
- chapter is also available [online](#)



Other Chapel papers/publications available at <https://chapel-lang.org/papers.html>



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Suggested Reading (short attention spans)



CHIUW 2017: Surveying the Chapel Landscape, [Cray Blog](#), July 2017.

- *a run-down of recent events (as of 2017)*

Chapel: Productive Parallel Programming, [Cray Blog](#), May 2013.

- *a short-and-sweet introduction to Chapel*

Six Ways to Say “Hello” in Chapel (parts [1](#), [2](#), [3](#)), [Cray Blog](#), Sep-Oct 2015.

- *a series of articles illustrating the basics of parallelism and locality in Chapel*

Why Chapel? (parts [1](#), [2](#), [3](#)), [Cray Blog](#), Jun-Oct 2014.

- *a series of articles answering common questions about why we are pursuing Chapel in spite of the inherent challenges*

[Ten] Myths About Scalable Programming Languages, [IEEE TCSC Blog](#)

([index available on chapel-lang.org “blog posts” page](#)), Apr-Nov 2012.

- *a series of technical opinion pieces designed to argue against standard reasons given for not developing high-level parallel languages*



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Where to..

Submit bug reports:

[GitHub issues for chapel-lang/chapel](#): public bug forum

chapel_bugs@cray.com: for reporting non-public bugs

Ask User-Oriented Questions:

[StackOverflow](#): when appropriate / other users might care

[Gitter \(chapel-lang/chapel\)](#): community chat with archives

chapel-users@lists.sourceforge.net: user discussions

Discuss Chapel development

chapel-developers@lists.sourceforge.net: developer discussions

[GitHub issues for chapel-lang/chapel](#): for feature requests, design discussions

Discuss Chapel's use in education

chapel-education@lists.sourceforge.net: educator discussions

Directly contact Chapel team at Cray: chapel_info@cray.com



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Questions?



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