Global HPCC Benchmarks in Chapel

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Chapel in a nutshell

Chapel:

- a new parallel language being developed by Cray Inc.
- part of DARPA’s HPCS* program
- first public release occurred this past weekend

*HPCS = High Productivity Computing Systems

When we last saw you at HPCC…

HPCC 2006: Chapel "elegance only" entry

- **goal:** show where Chapel was headed
- 3 benchmarks: STREAM Triad, Random Access, FFT
- written with elegance and scalability in mind
- compiled and executed correctly, *but:*
  - only supported single-threaded execution
  - leaked memory

  ⇒ no performance

This year's entry

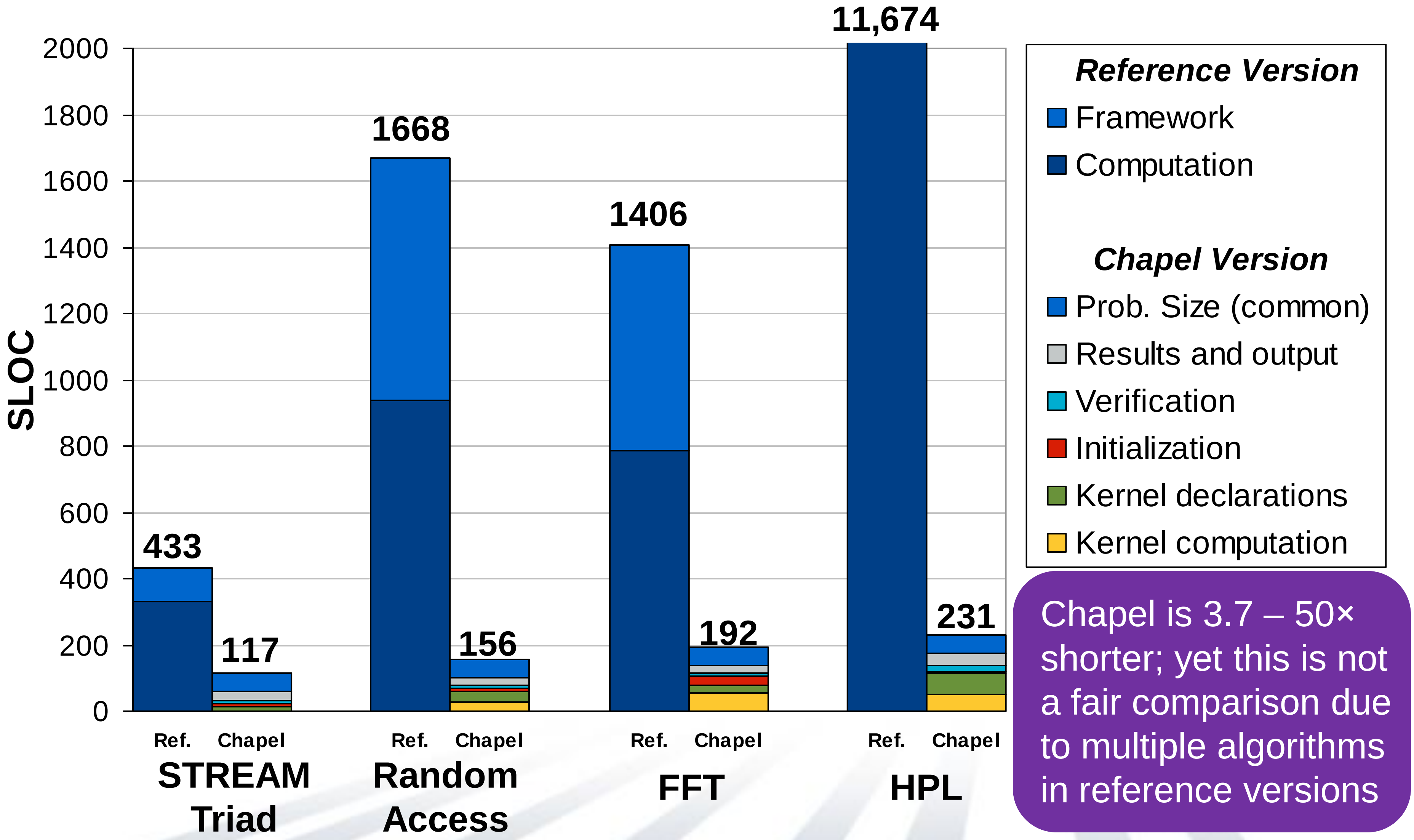
- First public performance numbers for Chapel execution
- First distributed memory execution of our data parallel features
- As intended, our code is quite similar to 2006 entry
- First locality-sensitive implementation of HPL in Chapel

Please set your expectations appropriately:

- This is a snapshot of a work in progress, not the final word
- Our first *distribution* ran for the first time only two months ago

Focus less on our current performance
and more on *how* we got it

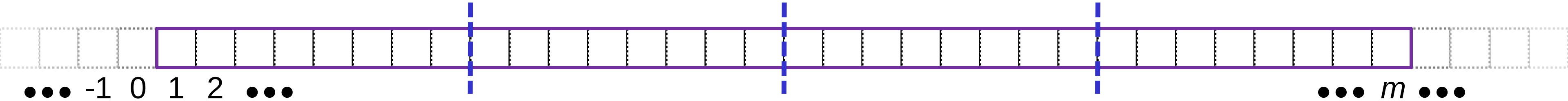
Code Size Summary (SLOC)



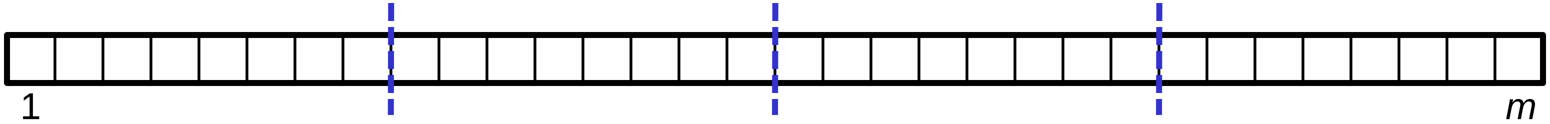
Chapel is 3.7 – 50× shorter; yet this is not a fair comparison due to multiple algorithms in reference versions

STREAM Triad in Chapel

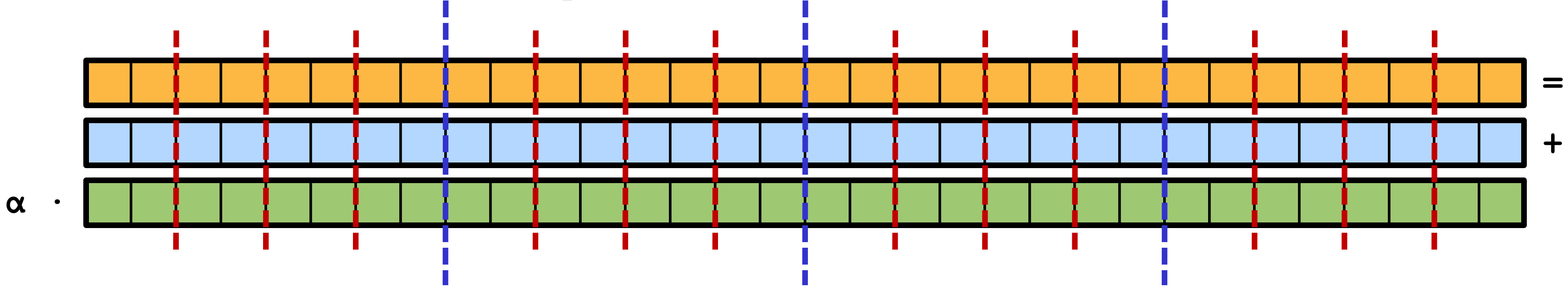
```
const BlockDist = new Block1D(bbox=[1..m], tasksPerLocale=…);
```



```
const ProblemSpace: domain(1, int(64)) distributed BlockDist
                  = [1..m];
```



```
var A, B, C: [ProblemSpace] real;
```

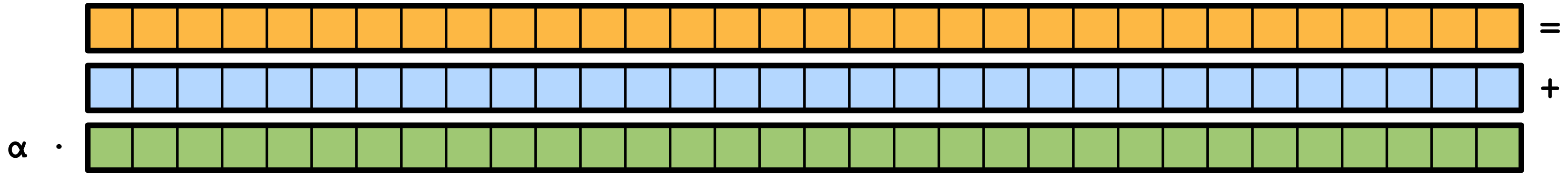


```
forall (a, b, c) in (A, B, C) do
  a = b + alpha * c;
```

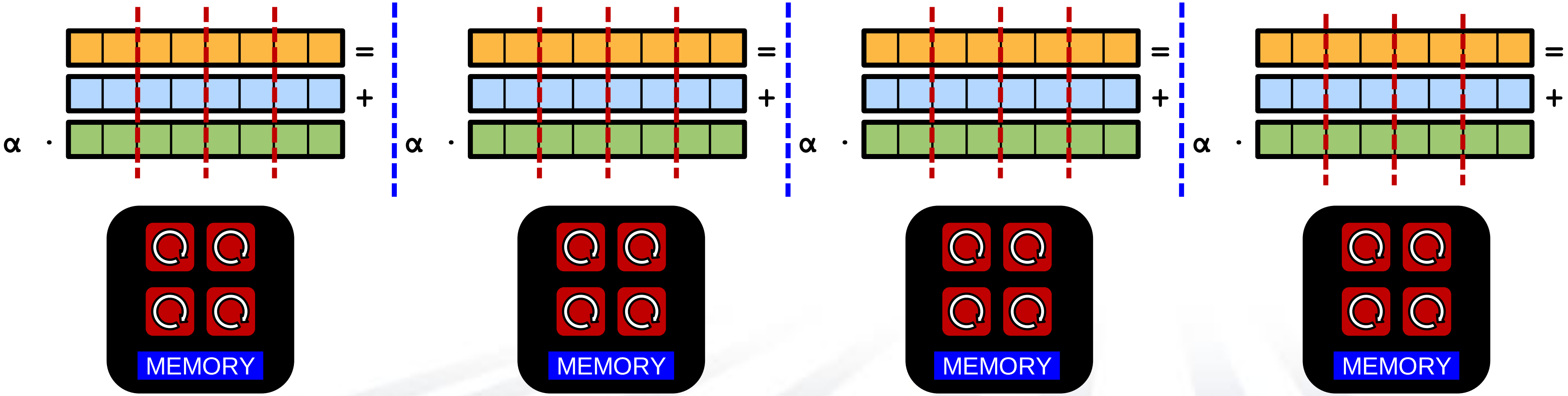
Chapel Distributions

Distributions: "Recipes for parallel, distributed arrays"

- help the compiler map from the computation's global view…



…down to the *fragmented*, per-processor implementation



Chapel Distributions

- (Advanced) Programmers can write distributions in Chapel
- Chapel will support a standard library of distributions
  - *research goal:* using the same mechanism that users would
- Block1D is our first such distribution
  - *our compiler has no semantic knowledge of block distributions*
  - only of a distribution’s interface--how to…

    …create domains and arrays using that distribution

    …map indices to locales

    …access array elements

    …iterate over indices/array elements

    - sequentially
    - in parallel
    - in parallel and zippered with other parallel iteratable types

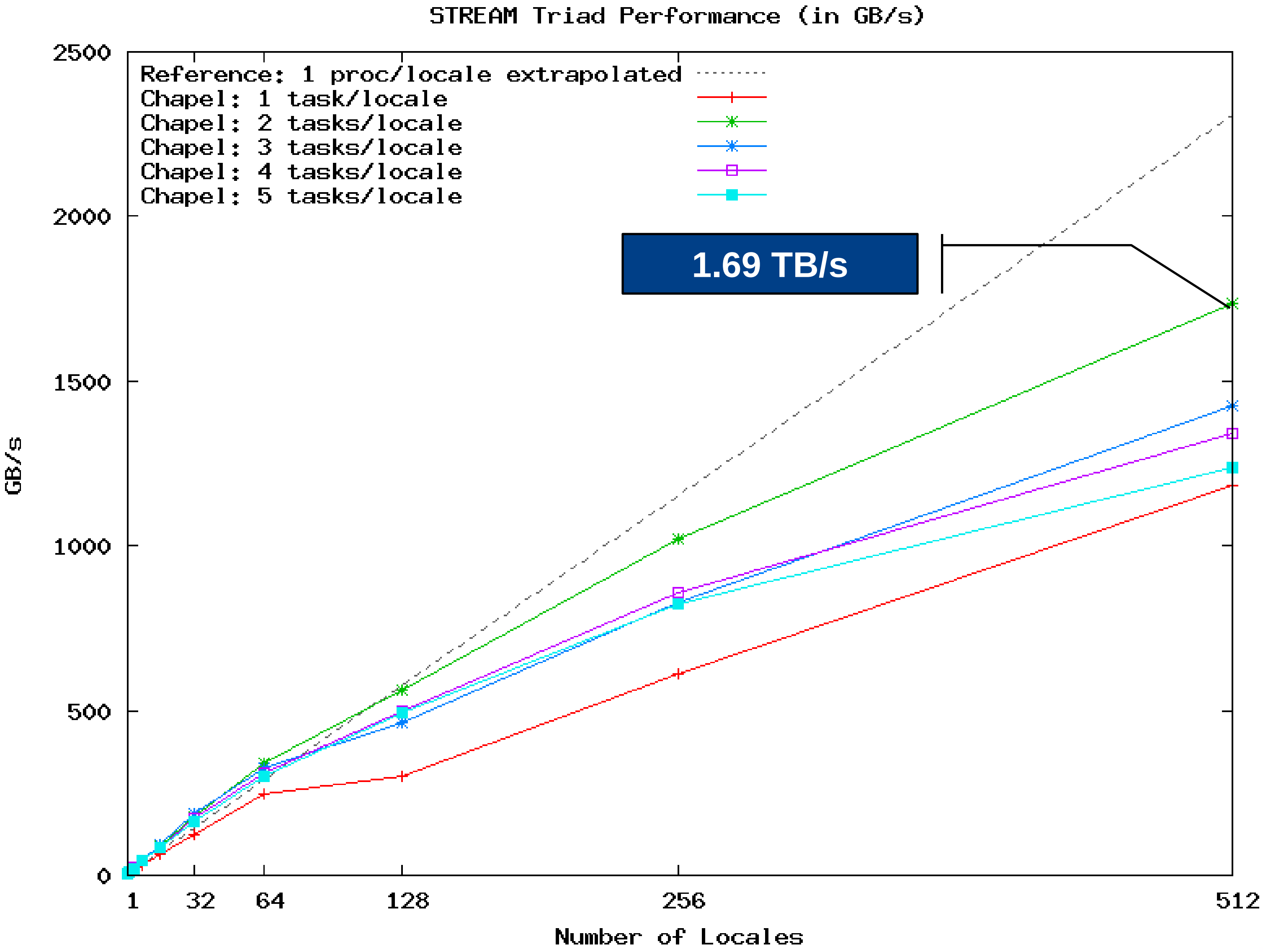
    …and so forth…

Experimental Platform

machine characteristic	*value*
name	jaguar
model	Cray XT4
location	ORNL
# compute nodes	7,832
compute node processor	2.1 GHz AMD Opteron
cores per node	4
total user RAM per node	7.68 GB

STREAM Triad characteristic	*value*
per-node problem size	85,985,408
per-node memory required	1.92 GB
percent of available memory	25.0%

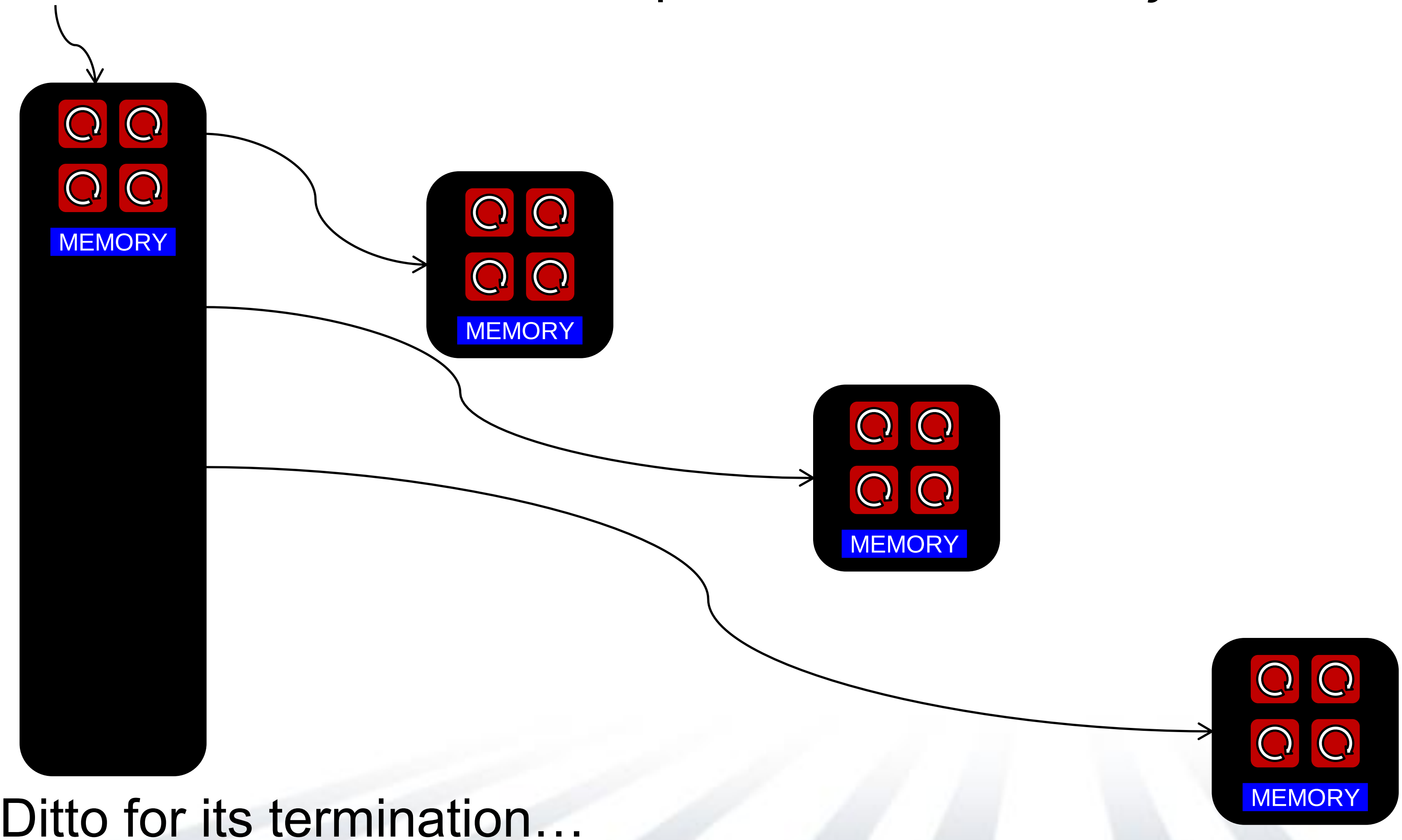
Chapel STREAM Performance



1.69 TB/s

Why doesn't Chapel scale perfectly?

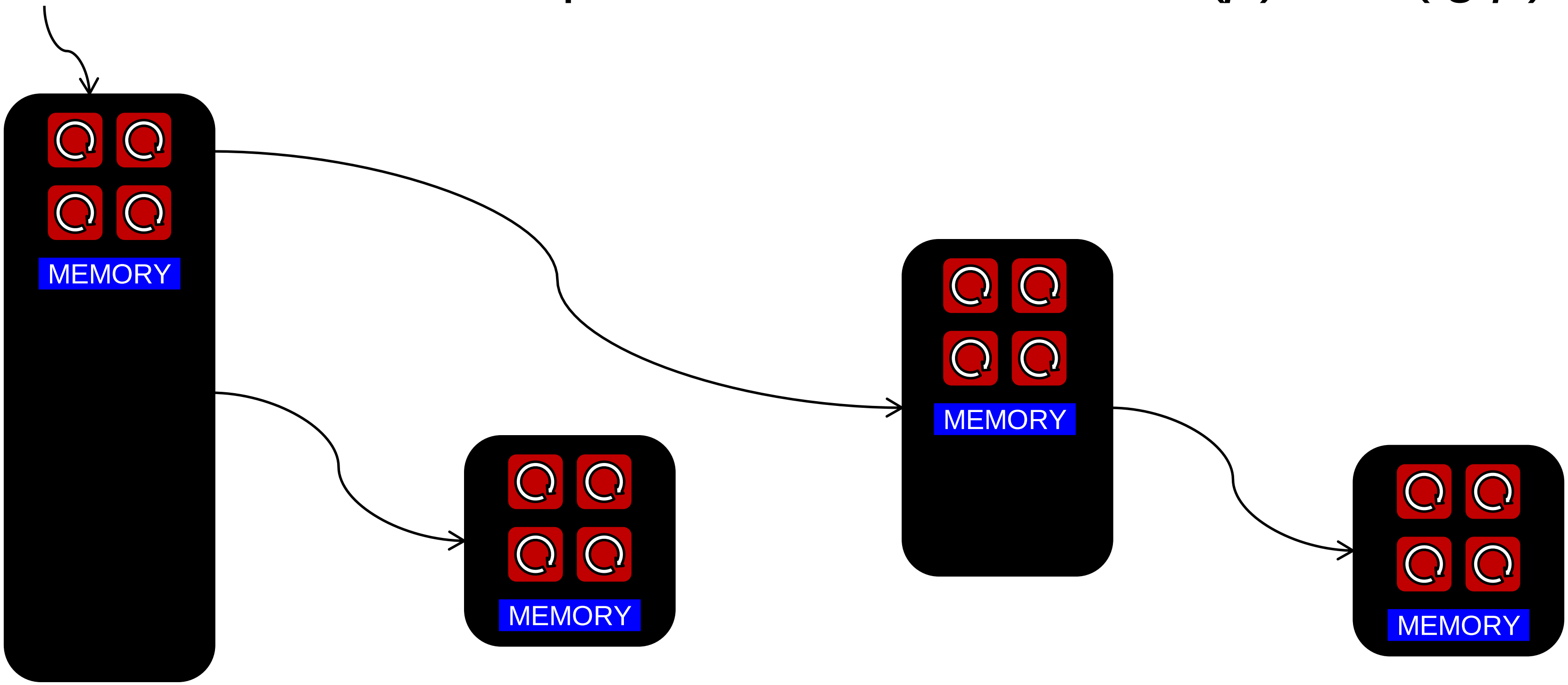
- Because Block1D's current parallel iterator is *very* naive…



- Ditto for its termination…

Strategies for improvement

- Use tree-based startup/teardown to convert O(*p*) to O(lg *p*)



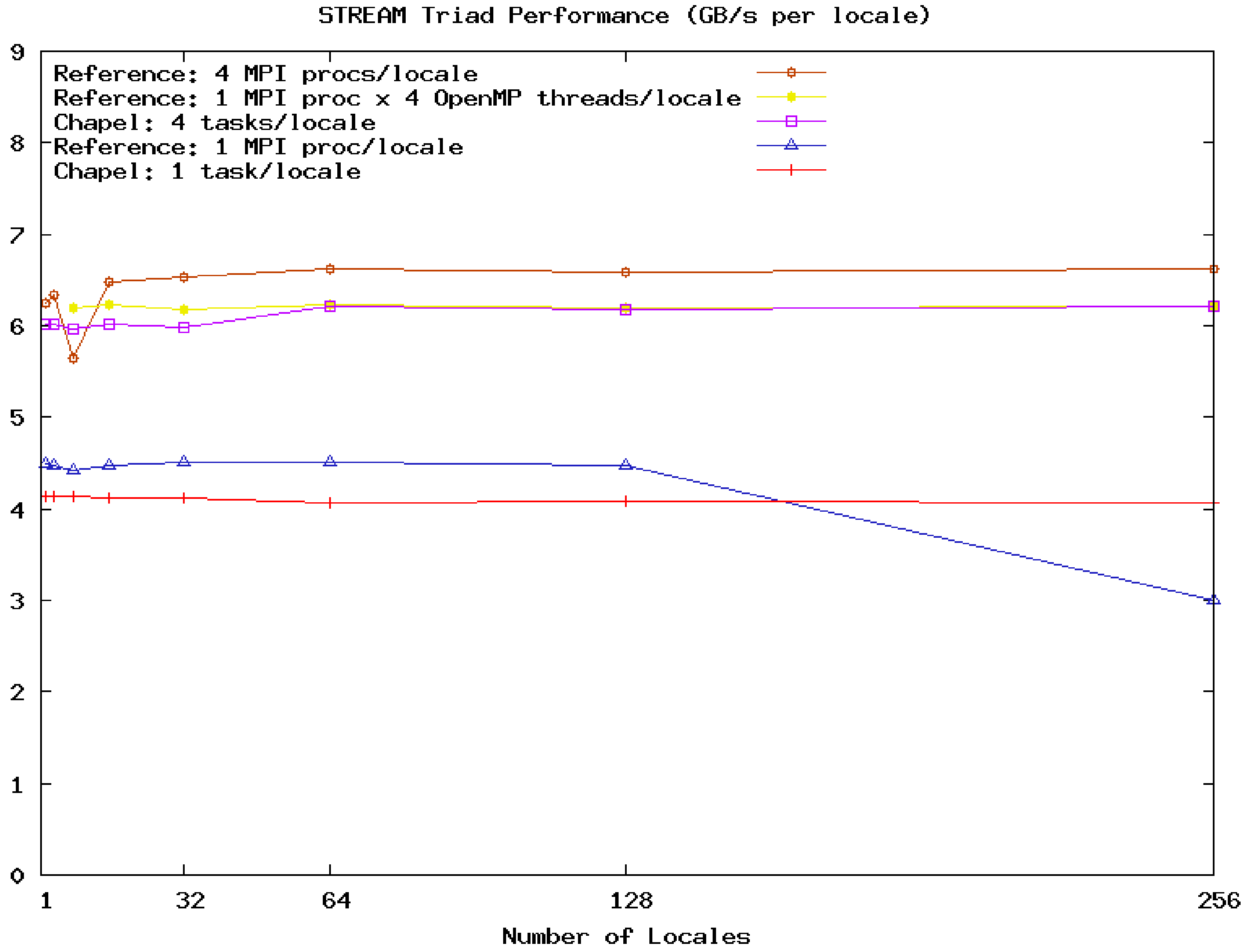
- *Or:* Have compiler optimize code to use SPMD exec. model
  - reduces O(lg *p*) to O(1) by amortizing into program startup/teardown

SPMD-style Chapel

- In the meantime, users can code in SPMD like the MPI version using Chapel’s support for *multiresolution programming*:

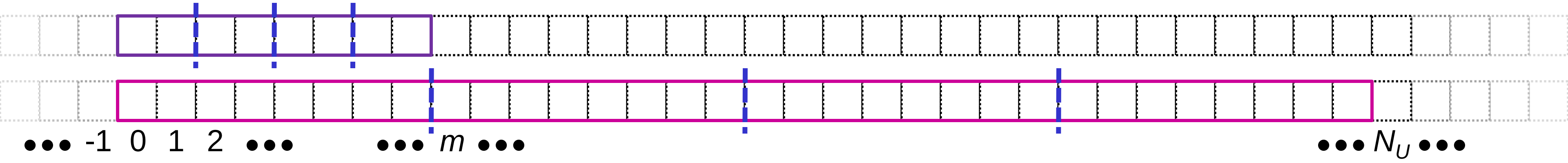
```
var localGBs: [LocaleSpace] real;

coforall loc in Locales do
  on loc {
    const myProblemSpace: domain(1, int(64))
          = BlockPartition(ProblemSpace, here.id, numLocales);
    var myA, myB, myC: [myProblemSpace] real(64);
    const startTime = getCurrentTime();
    local {
      for (a, b, c) in (myA, myB, myC) do
        a = b + alpha * c;
    }
    const exetTime = getCurrentTime() - startTime;
    localGBs(here.id) = timeToGBs(execTime);
  }

const avgGBs = (+ reduce localGBs) / numLocales;
```

SPMD Chapel Performance

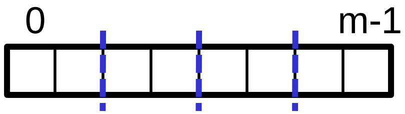


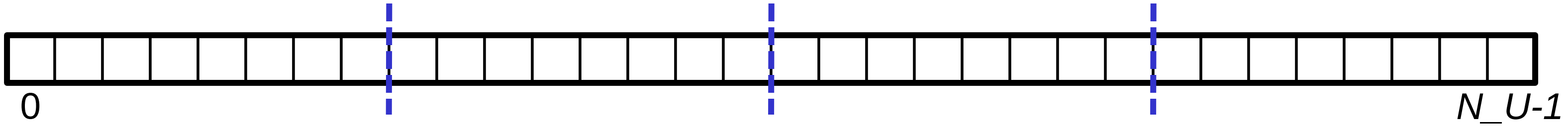
RA Declarations in Chapel

```
const TableDist  = new Block1D(bbox=[0..m-1], tasksPerLocale=…),
      UpdateDist = new Block1D(bbox=[0..N_U-1], tasksPerLocale=…);
```

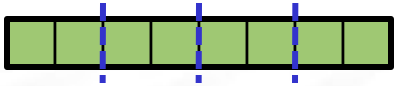


```
const TableSpace: domain(1, uint(64)) distributed TableDist = [0..m-1],
      Updates: domain(1, uint(64)) distributed UpdateDist = [0..N_U-1];
```



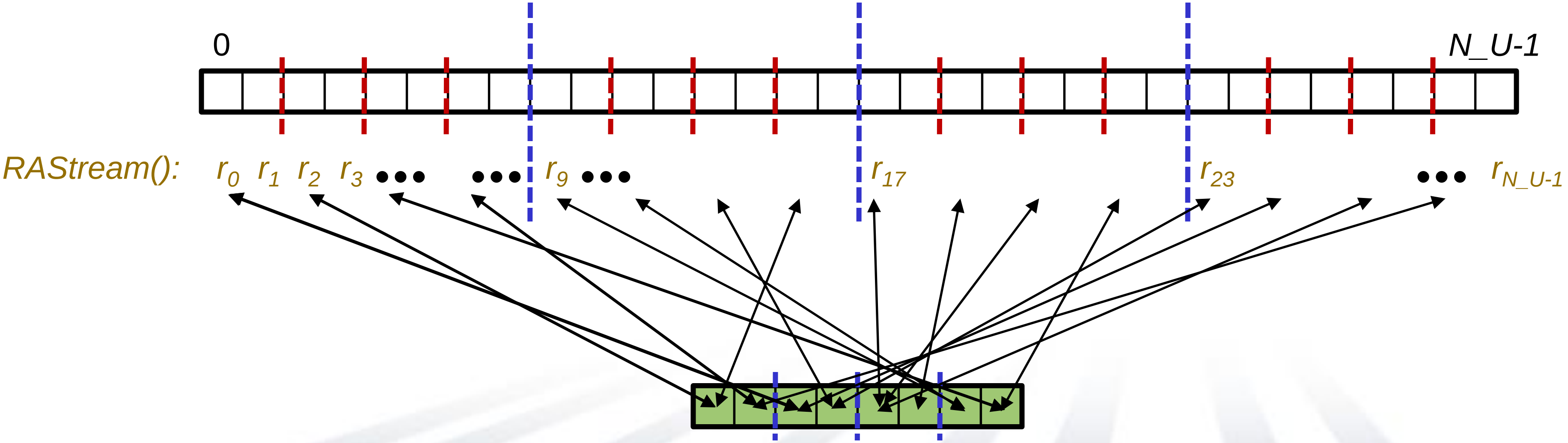


```
var T: [TableSpace] uint(64);
```

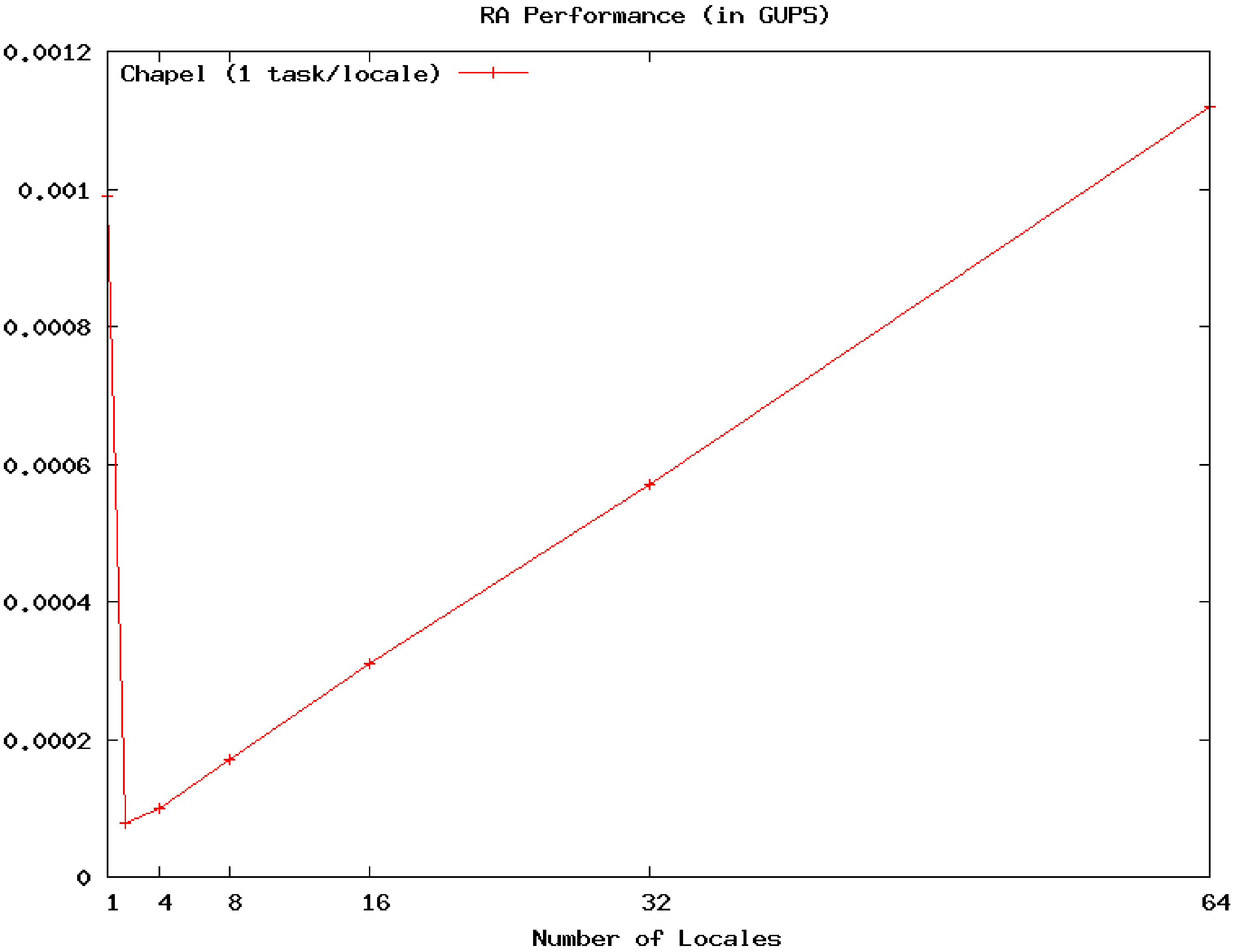


RA Computation in Chapel

```
const TableSpace: domain(1, uint(64)) distributed TableDist = [0..m-1],
      Updates: domain(1, uint(64)) distributed UpdateDist = [0..N_U-1];

var T: [TableSpace] uint(64);


forall (_, r) in (Updates, RAStream()) do
  on T(r&indexMask) do
    T(r&indexMask) ^= r;
```


0
N_U-1
RAStream():
r_0 r_1 r_2 r_3 ••• ••• r_9 ••• r_{17} r_{23} ••• r_{N_U-1}

RA Performance in Chapel



FFT and HPL Status

- FFT :
  - not yet running on distributed memory
    - Block1D not yet rich enough to support slicing, re-indexing
  - have made a big effort to reclaim descriptor memory from slicing
    - can now run full problem size
- HPL:
  - not yet running on distributed memory
    - need to add block-cyclic, dimensional, and replicated distributions
  - current version written to be locality-aware
- All four of these codes are very clean and should serve as great references to others attempting the HPC Challenge

Acknowledgements

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Summary

- Chapel is scaling on dist. memory machines, if not perfectly
  - more importantly, scalability limiters are known and addressable
- Chapel achieved its first Terabyte/sec
- Chapel has started to demonstrate user-defined distributions
  - Recall that these have only been working for two months
  - (and a busy two months at that: first public release, two tutorials, …)
- See you at HPCC 2009!

In the meantime, download Chapel, try it out,
and please give us your feedback:

http://chapel.cs.washington.edu

(our HPCC codes and report are available within the release)