HIPification and Profiling Tools

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AMD

Agenda

Porting CUDA codes to HIP

Profiling tools

Objectives

This training:

- Demonstrates how to convert CUDA codes into HIP
- Explains the meaning of the term ‘hipify’
- Provides an idea of the common ‘gotchas’ of porting apps

Getting started with HIP

CUDA VECTOR ADD

```
__global__ void add(int n,
                    double *x,
                    double *y){
  int index = blockIdx.x * blockDim.x
              + threadIdx.x;
  int stride = blockDim.x * gridDim.x;

  for (int i = index; i < n; i +=
stride){
    y[i] = x[i] + y[i];
  }
}
```

HIP VECTOR ADD

```
__global__ void add(int n,
                    double *x,
                    double *y){
  int index = blockIdx.x * blockDim.x
              + threadIdx.x;
  int stride = blockDim.x * gridDim.x;

  for (int i = index; i < n; i += stride){
    y[i] = x[i] + y[i];
  }
}
```

KERNELS ARE SYNTACTICALLY THE SAME

CUDA APIs vs HIP API

CUDA	HIP
cudaMalloc(&d_x, N*sizeof(double));	hipMalloc(&d_x, N*sizeof(double));
cudaMemcpy(d_x, x, N*sizeof(double), cudaMemcpyHostToDevice);	hipMemcpy(d_x, x, N*sizeof(double), hipMemcpyHostToDevice);
cudaDeviceSynchronize();	hipDeviceSynchronize();

Launching a kernel

CUDA KERNEL LAUNCH SYNTAX

```
some_kernel<<<gridsize, blocksize,
              shared_mem_size, stream>>>
              (arg0, arg1, ...);
```

```
some_kernel<T_ARGS><<<gridsize, blocksize,    shared_
mem_size, stream>>>(arg0, arg1, ...);
```

HIP KERNEL LAUNCH SYNTAX

```
hipLaunchKernelGGL(some_kernel,
                   gridsize, blocksize,
                   shared_mem_size, stream,
                   arg0, arg1, ...);
```

```
hipLaunchKernelGGL(
  HIP_KERNEL_NAME(some_kernel<T_ARGS>),
  gridsize, blocksize,    shared_mem_size, stream,
      arg0, arg1, ...);
```


HIPification Tools for faster code porting

- ROCm provides 'HIPification' tools to do the heavy-lifting on porting CUDA codes to ROCm
  - Hipify-perl
  - Hipify-clang

- Good resource to help with porting: https://rocmdocs.amd.com/en/latest/Programming_Guides/HIP-porting-guide.html

- In practice, large portions of many HPC codes have been automatically Hipified:
  - ~90% of CUDA code in CORAL-2 HACC
  - ~80% of CUDA code in CORAL-2 PENNANT
  - ~80% of CUDA code in CORAL-2 QMCPack
  - ~95% of CUDA code in CORAL-2 Laghos

The remaining code requires programmer intervention

HIPify Tools

- Hipify-perl:
  - Easy to use – point at a directory and it will attempt to hipify CUDA code
  - Very simple string replacement technique: may make incorrect translations
    - `sed -e ‘s/cuda/hip/g’` (e.g., cudaMemcpy becomes hipMemcpy)
  - Recommended for quick scans of projects

- Hipify-clang:
  - Requires CLANG compiler
  - More robust translation of the code
  - Uses clang to parse files and perform semantic translation
  - Can generate warnings and assistance for code for additional user analysis
  - High quality translation, particularly for cases where the user is familiar with the make system

Hipify-perl

- Sits in $HIP/bin/ (**export PATH=$PATH:[MYHIP]/bin**)
- Command line tool: **hipify-perl foo.cu > new_foo.cpp**
- Compile: **hipcc new_foo.cpp**
- How does this this work in practice?
  - Hipify source code
  - Check it in to your favorite version control
  - Try to build
  - Manually work on the rest

Hipify-clang

- Available at https://github.com/ROCm-Developer-Tools/HIPIFY
- Build from source
- ‘Hipification’ requires same headers that would be needed to compile it with clang:
- `./hipify-clang foo.cu -I /usr/local/cuda-8.0/samples/common/inc`
- Understands how to translate many CUDA libraries (cuBLAS, cuFFT, cuSPARSE, etc.)
- Will get useful warning messages about unknown conversions

```
[10:59:29][pabauman@fry:~/work/qmcpack/build/hipify]$ /home/pabauman/work/hip-testing/hipify-clang-install/bin/hi
pify-clang /home/pabauman/work/qmcpack/src/src/QMCWaveFunctions/EinsplineSetCuda.cpp -o-dir=. -examine -I/usr/inc
lude/libxml2 -I/usr/include/hdf5/serial -I/home/pabauman/work/qmcpack/src/src -I/home/pabauman/work/qmcpack/build
/src -I/home/pabauman/work/qmcpack/build/include -I/home/pabauman/work/qmcpack/src/external_codes/mpi_wrapper -I/
home/pabauman/work/qmcpack/src/external_codes/boost_multi -I/home/pabauman/work/qmcpack/src/external_codes/catch
-I/usr/lib/x86_64-linux-gnu/openmpi/include
/tmp/EinsplineSetCuda.cpp-9b0c60.hip:135:5: warning: CUDA identifier is unsupported in HIP.
    cudaMemPrefetchAsync(pos, 3 * N * sizeof(float), curr_gpu, spline_streams[devicenr]);
    ^
/tmp/EinsplineSetCuda.cpp-9b0c60.hip:183:5: warning: CUDA identifier is unsupported in HIP.
    cudaMemPrefetchAsync(pos, 3 * N * sizeof(float), curr_gpu, spline_streams[devicenr]);
    ^
/tmp/EinsplineSetCuda.cpp-9b0c60.hip:226:5: warning: CUDA identifier is unsupported in HIP.
    cudaMemPrefetchAsync(pos, 3 * N * sizeof(float), curr_gpu, spline_streams[devicenr]);
    ^
```


Gotchas

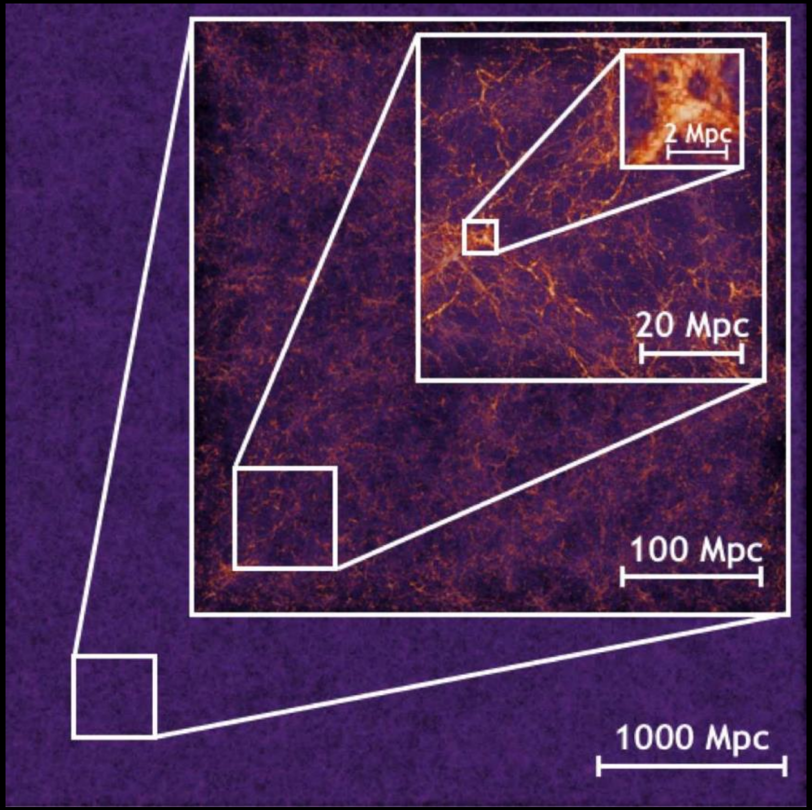
- Hipify tools are not running your application, or checking correctness
- Code relying on specific hardware aspects (e.g., warp size == 32) may need attention after conversion
- Hipifying can't handle inline PTX assembly
  - Can either use inline GCN ISA, or convert it to HIP
- Hipify-perl can't handle library calls, hipify-clang can handle library calls

What to look for when porting:

- Inline PTX assembly
- CUDA Intrinsics
- Hardcoded dependencies on warp size, or shared memory size
  - Grep for "32" *just in case*
  - Do not hardcode the warpsize! Use something like #define WARPSIZE *size*
- Code geared toward limiting size of register file on NVIDIA hardware
- Functions implicitly inlined
- Unified memory

Example: HACC

- Hardware Accelerated Cosmology Code
- Simulates time-evolution of universe
  - Mpc = Megaparsec = 3.09×10^{22} meters
- **Our HIP success story:**
  - **Ported in an afternoon**
- Profiling:
  - 10% of time is spent in the tree walk
  - >80% in the short force kernels
    - **(GPU kernel)**
  - 5% in the 3d Transposes / FFTs



$$f_{SR} = (s + \epsilon)^{-3/2} - f_{grid}(s)$$

where,

$$s = \mathbf{r} \cdot \mathbf{r}$$

and,

$$f_{grid}(s) = POLY_5(s)$$

HACC: What made it a success

- **What was easy?**
  - Simple GPU kernel
  - Few library dependencies (FFTW, not in kernel)
  - No advanced CUDA features
- **What was difficult?**
  - Inline PTX: required translation to AMD GCN
  - Hand-written wave-32 code (for a reduction)

Porting HACC

CUDA	HIP
`cudaMemcpyAsync(d_npos,h_npos,Nposbytes, cudaMemcpyHostToDevice,stream);`	`hipMemcpyAsync(d_npos,h_npos,Nposbytes, hipMemcpyHostToDevice,stream);`
`cudaMemcpyAsync(d_mask,h_mask,NmaskBytes, cudaMemcpyHostToDevice,stream);`	`hipMemcpyAsync(d_mask,h_mask,NmaskBytes, hipMemcpyHostToDevice,stream);`
`calcHHCullenDehnen<<<blocksPerGrid, threadsPerBlock, 0, stream>>> (cnt, SIZE, d_npos, d_mask, rsm);`	`hipLaunchKernelGGL(calcHHCullenDehnen, blocksPerGrid, threadsPerBlock, 0,stream, cnt, SIZE, d_npos, d_mask, rsm);`
`cudaMemcpyAsync(h_pos, d_npos+(SIZE-cnt),cntBytes, cudaMemcpyDeviceToHost,stream);`	`hipMemcpyAsync(h_pos, d_npos+(SIZE-cnt),cntBytes, hipMemcpyDeviceToHost,stream);`
`cudaMemcpyAsync(h_mask,d_mask,NmaskBytes, cudaMemcpyDeviceToHost,stream);`	`hipMemcpyAsync(h_mask,d_mask,NmaskBytes, hipMemcpyDeviceToHost,stream);`

Fortran + CUDA C/C++ -> Fortran + HIP C/C++

- The only difference here is that the CUDA C/C++ code is linked with some Fortran routines
- Assumption is these Fortran routines do not contain CUDA Fortran
- This behaves like you would expect:
  - hipify the CUDA
  - Compile your HIP C/C++ with hipcc
  - Compile your Fortran code
  - Link with hipcc
- Example scenario: your HIP C/C++ code makes calls to Fortran functions (e.g., LAPACK functions) on the host

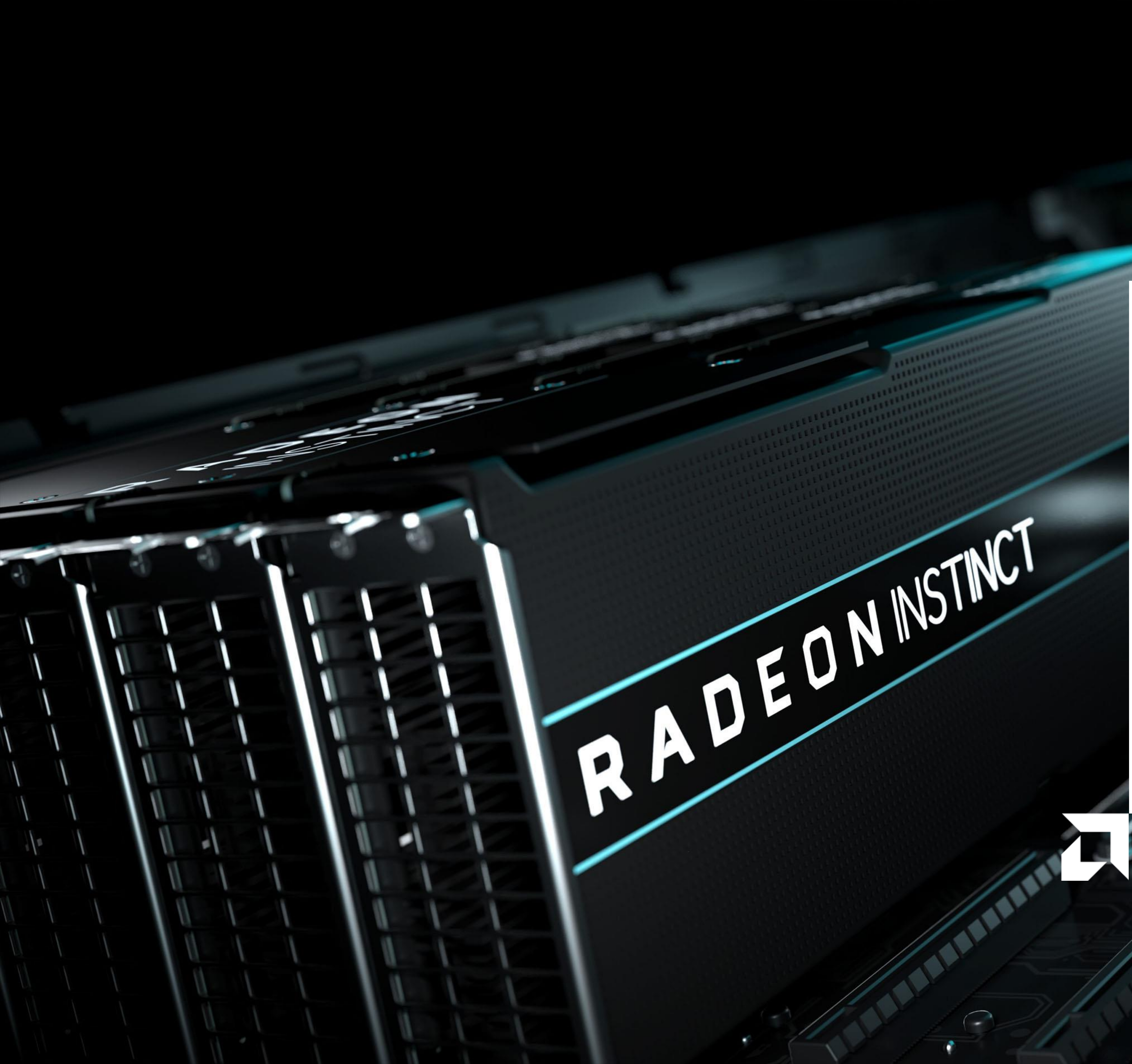
CUDA Fortran -> Fortran + HIP C/C++

- There is no HIP equivalent to CUDA Fortran
- But HIP functions are callable from C, using `extern C`, so they can be called directly from Fortran
- The strategy here is:
  - **Manually port** CUDA Fortran code to HIP kernels in C++
  - Wrap the kernel launch in a C function
  - Call the C function from Fortran through Fortran's ISO_C_binding
- This strategy should be usable by Fortran users since it is standard conforming Fortran
- ROCm has an interface layer, hipFort, which provides the wrapped bindings for use in Fortran
  - https://github.com/ROCmSoftwarePlatform/hipfort

Portability layers using HIP

Several portability layers are already supporting, or implementing, HIP

- RAJA
  - HIP kernel execution policies syntactically identical to CUDA
  - Official PRs under review
- Kokkos
  - HIP kernel execution policies syntactically identical to CUDA
  - Support is in beta and under development by Kokkos and AMD developers
- OCCA
  - OKL kernels can compile for HIP devices
  - Available in OCCA's master branch
- OpenMP 5.0
  - gcc and Cray's C++ compiler support target offload regions



Profiling

AMD GPU Profiling

- ROC-profiler (or simply rocprof) is the command line front-end for AMD's GPU profiling libraries
  - Repo: https://github.com/ROCm-Developer-Tools/rocprofiler
- rocprof contains the central components allowing the collection of application tracing and counter collection
  - Under constant development
- Provided in the ROCm releases
- The output of rocprof can be visualized using the chrome browser with chrome tracing

rocprof: Getting started + useful flags

- To get help:
  - `$ /opt/rocm/bin/rocprof -h`
- Useful housekeeping flags:
  - --timestamp <on|off> : turn on/off gpu kernel timestamps
  - --basenames <on|off>: turn on/off truncating gpu kernel names (i.e., removing template parameters and argument types)
  - -o <output csv file>: Direct counter information to a particular file name
  - -d <data directory>: Send profiling data to a particular directory
  - -t <temporary directory>: Change the directory where data files typically created in /tmp are placed. This allows you to save these temporary files.
- Flags directing rocprofiler activity:
  - -i input<.txt|.xml> - specify an input file (note the output files will now be named input.*)
  - --hsa-trace - to trace GPU Kernels, host HSA events (more later) and HIP memory copies.
  - --hip-trace - to trace HIP API calls
  - --roctx-trace - to trace roctx markers
- Advanced usage
  - -m <metric file>: Allows the user to define and collect custom metrics. See rocprofiler/test/tool/*.xml on GitHub for examples.

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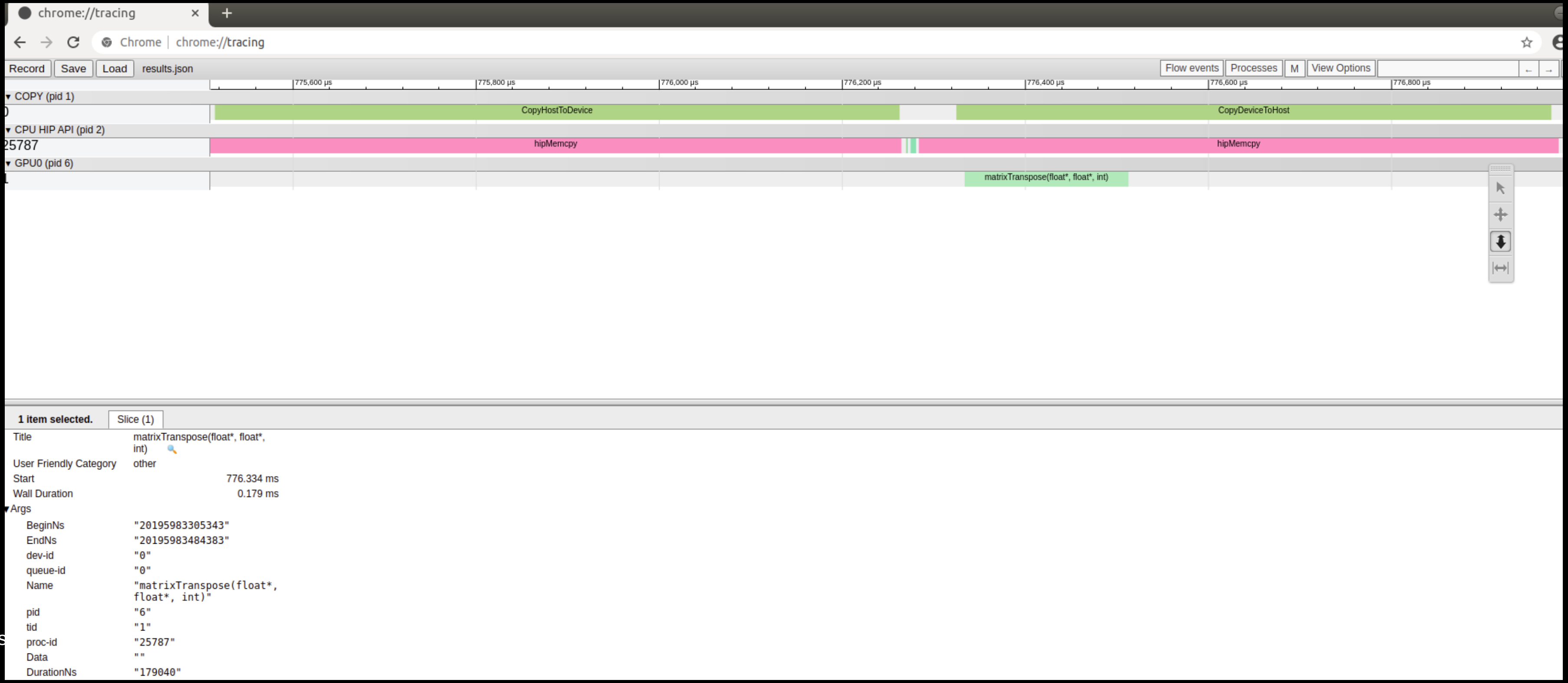
rocprof: Collecting application traces (1)

- rocprof can collect a variety of trace event types and generate timelines in JSON format for use with chrome-tracing, currently:

Trace Event	rocprof Trace Mode
HIP API call	--hip-trace
GPU Kernels	--hip-trace
Host <-> Device Memory copies	--hip-trace
CPU HSA Calls	--hsa-trace
User code markers	--roctx-trace

rocprof: Collecting application traces (2)

- rocprofiler can collect traces
  - `$ /opt/rocm/bin/rocprof --hip-trace <app with arguments>`
  - This will output a .json file that can be visualized using the chrome browser
  - Go to chrome://tracing and then load in the .json file.
    - The trace will display HIP calls, mem copies, kernels.



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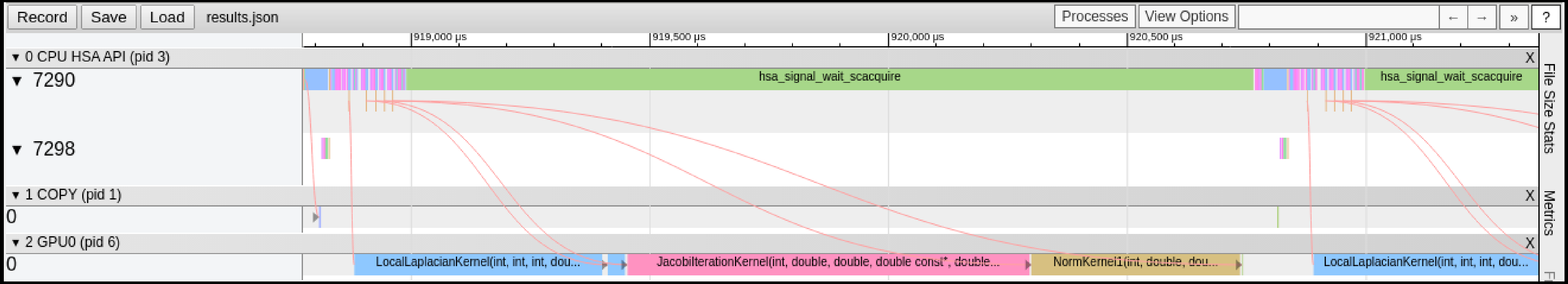
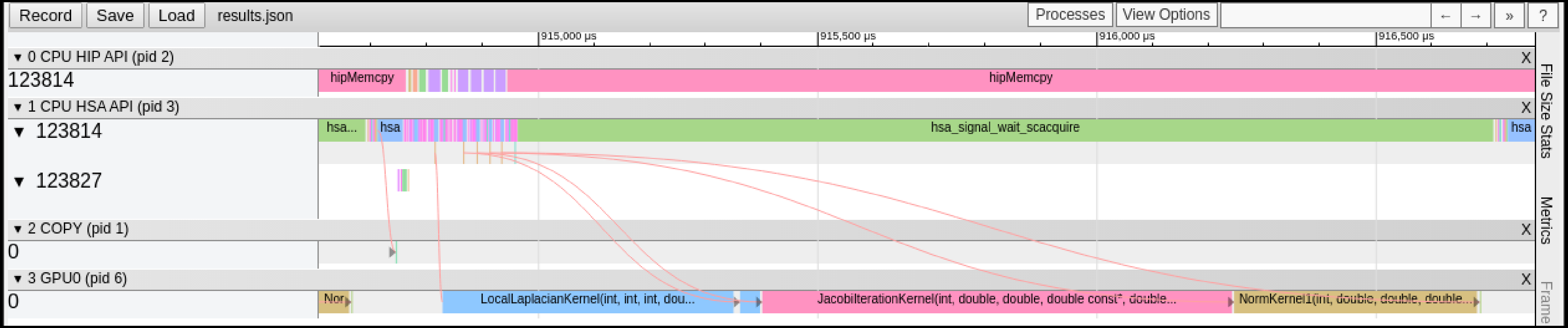
rocprof: Collecting application traces (3)

- rocprofiler can collect traces
  - `$ /opt/rocm/bin/rocprof --hsa-trace <app with arguments>`
  - This will output a .json file that can be visualized using the chrome browser
  - Go to chrome://tracing and then load in the .json file
    - The trace will display copies, hsa signals, and kernel calls
    - Slowest trace mode – Use with caution



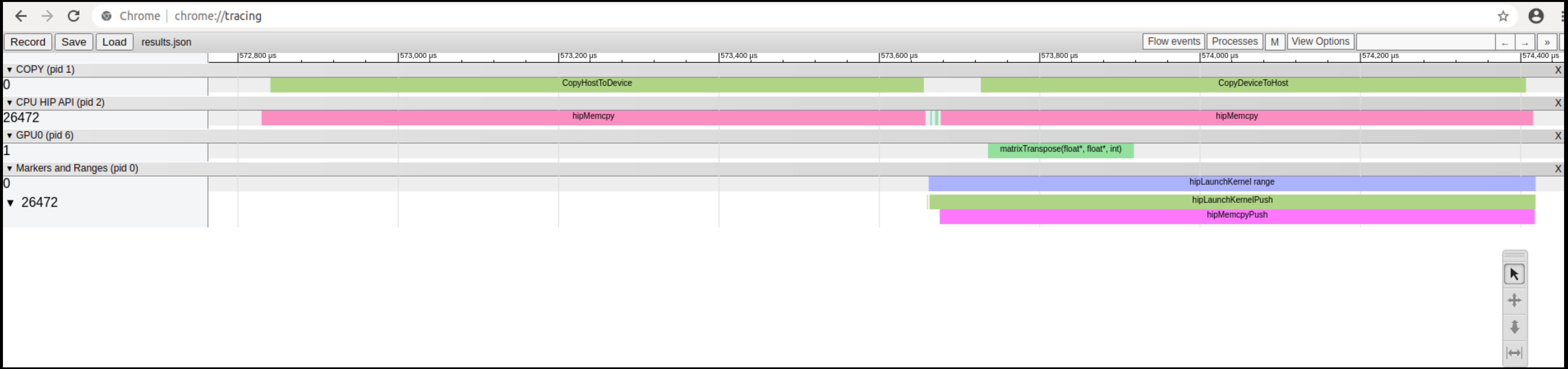
rocprof: Collecting application traces (4)

- rocprofiler can collect multiple trace modes simultaneously
  - `$ /opt/rocm/bin/rocprof --hsa-trace --hip-trace <app with arguments>`
  - This command will additionally add HIP API calls to the trace



rocprof: Collecting application traces (5)

- Rocprof can collect user code-markers using rocTX
  - See MatrixTranspose.cpp example on roctracer GitHub page for sample in-code usage
  - `$ /opt/rocm/bin/rocprof --hip-trace --roctx-trace <app with arguments>`



rocprof: Collecting hardware counters

- rocprofiler can collect a number of hardware counters and derived counters
  - `$ /opt/rocm/bin/rocprof --list-basic`
  - `$ /opt/rocm/bin/rocprof --list-derived`
- Specify counters in a counter file. For example:
  - `$ /opt/rocm/bin/rocprof -i rocprof_counters.txt <app with args>`
  - `$ cat rocprof_counters.txt`

```
pmc : Wavefronts VALUInsts VFetchInsts VWriteInsts VALUUtilization VALUBusy WriteSize
pmc : SALUInsts SFetchInsts LDSInsts FlatLDSInsts GDSInsts SALUBusy FetchSize
pmc : L2CacheHit MemUnitBusy MemUnitStalled WriteUnitStalled ALUStalledByLDS LDSBankConflict
...
```

  - A limited number of counters can be collected during a specific pass of code.
    - Each line in the counter file will be collected in one pass
    - You will receive an error suggesting alternative counter ordering if you have too many / conflicting counters on one line
  - A .csv file will be created by this command containing all of the requested counters

rocprof: Commonly Used Counters

- VALUUtilization: The percentage of ALUs active in a wave. Low VALUUtilization is likely due to high divergence or a poorly sized grid
- VALUBusy: The percentage of GPUTime vector ALU instructions are processed. Can be thought of as something like compute utilization
- FetchSize: The total kilobytes fetched from global memory
- WriteSize: The total kilobytes written to global memory
- L2CacheHit: The percentage of fetch, write, atomic, and other instructions that hit the data in L2 cache
- MemUnitBusy: The percentage of GPUTime the memory unit is active. The result includes the stall time
- MemUnitStalled: The percentage of GPUTime the memory unit is stalled
- WriteUnitStalled: The percentage of GPUTime the write unit is stalled

Full list at: https://github.com/ROCm-Developer-Tools/rocprofiler/blob/amd-master/test/tool/metrics.xml

Performance counters tips and tricks

- GPU Hardware counters are global
  - Kernel dispatches are serialized to ensure that only one dispatch is ever in flight
  - It is recommended that no other applications are running that use the GPU when collecting performance counters
- Use "`--basenames on`" which will report only kernel names, leaving off kernel arguments.
- How do you time a kernel's duration?
  - `$ /opt/rocm/bin/rocprof --timestamps on -i rocprof_counters.txt <app with args>`
  - This produces four times: DispatchNs, BeginNs, EndNs, and CompleteNs
  - Closest thing to a kernel duration: EndNs - BeginNs
  - If you run with "`--stats`" the resultant results file will automatically include a column that calculates kernel duration
    - Note: the duration is aggregated over repeated calls to the same kernel

rocprof: Multiple MPI Ranks

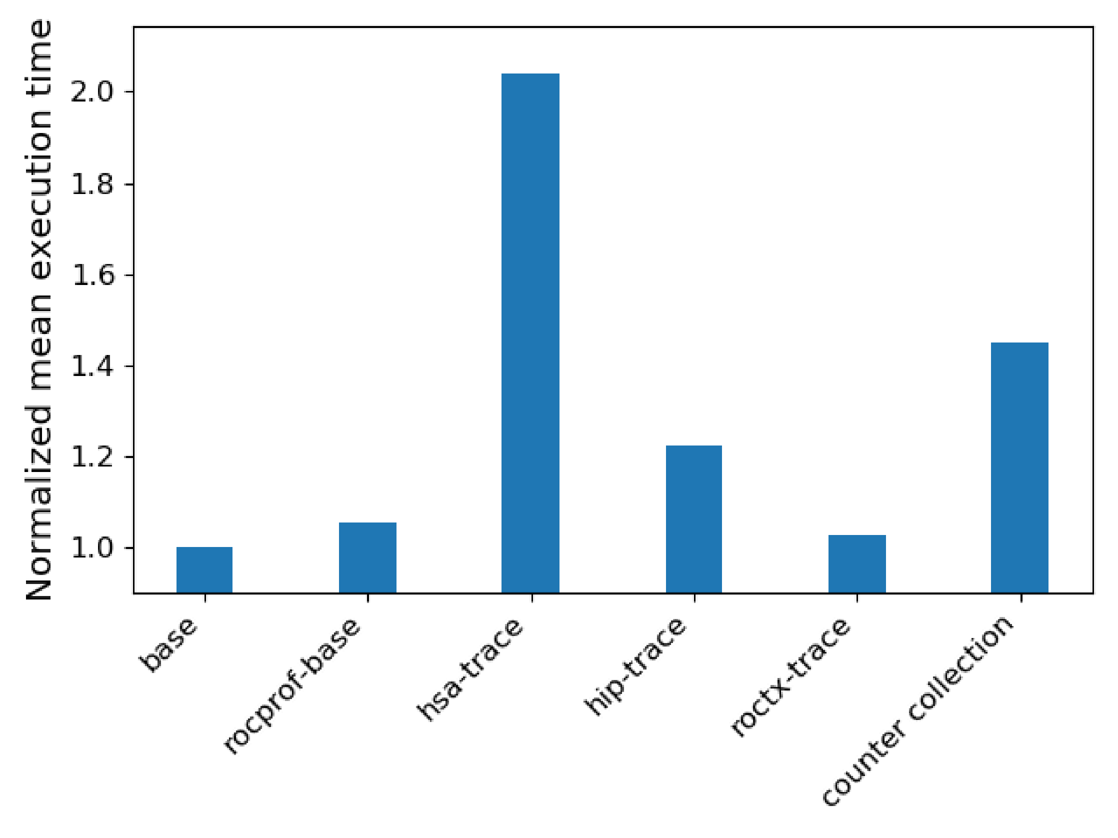
- rocprof can collect counters and traces for multiple MPI ranks.
- Say you want to profile an application usually called like this:
  - `mpiexec –np <n> ./Jacobi_hip –g <x> <y>`
  - Then invoke the profiler by executing:

```
rocprof --hip-trace mpiexec -np <n> ./Jacobi_hip -g <x> <y>
```

- This will produce a single unified CSV file for all ranks
- Multi-node profiling currently isn’t supported

rocprof: Profiling Overhead

Simple estimation of profiling overhead, obtained via wall-clock timing of entire application run via Linux ‘time’ utility:



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