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Performance Portability of an SpMV Kernel Across Scientific Computing and Data Science Applications

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Microapp Design, Coding, and Data

Computation and baseline code

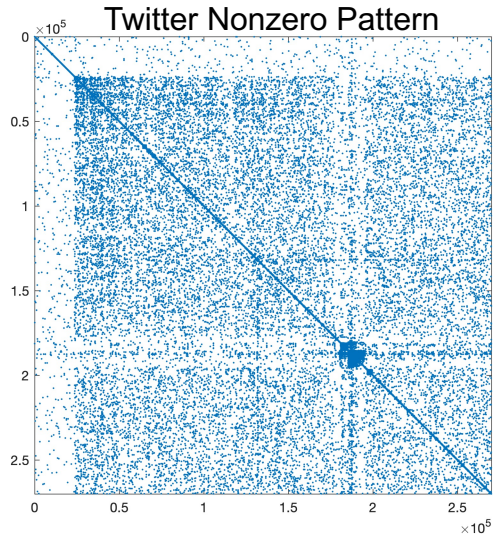
- Sparse matrix-vector product, repeated 100x
- Nested loops (outer loop over rows, inner loop over nonzeros)
- Supports variable number of nonzeros per row
- OpenMP `parallel for` enables CPU multithreading

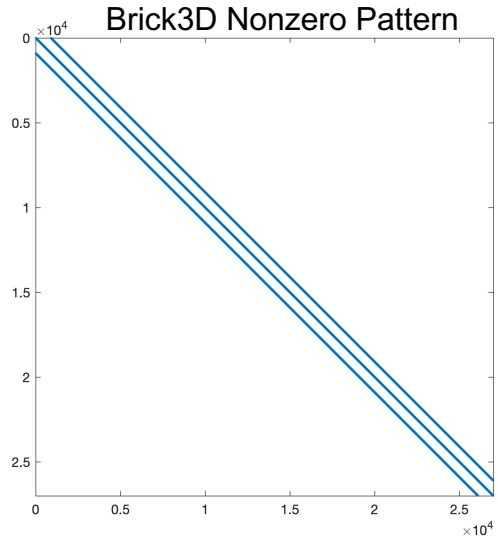
Performance portable code

- OpenMP GPU offload: ~5 lines added or changed
- Kokkos `range`: ~20 lines added or changed
- Kokkos `team`: ~50 lines added or changed
- Includes special data structures used by Kokkos

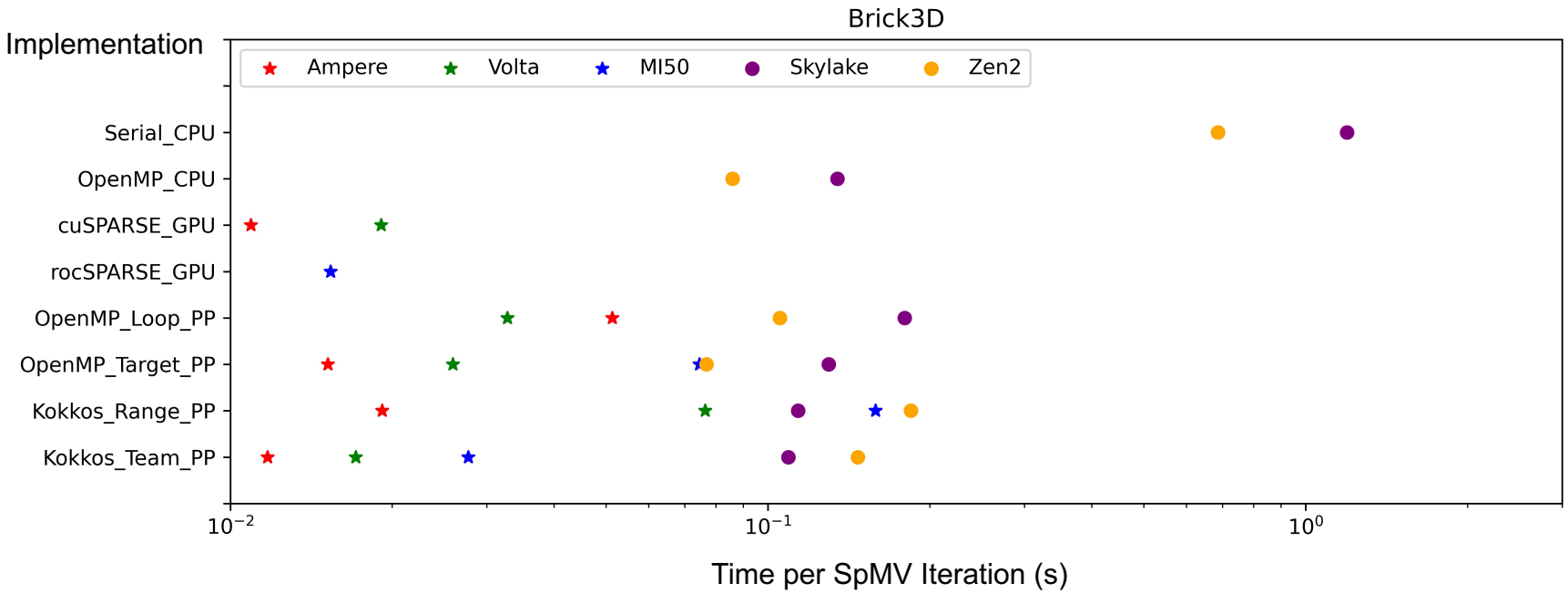
Input Data

- **Twitter:** Twitter-2010 followers network (~265M edges) *[top plot]*
- **Brick3D:** 27-point stencil for the Laplace operator on 3D hex mesh (320^3 mesh points) *[bottom plot]*





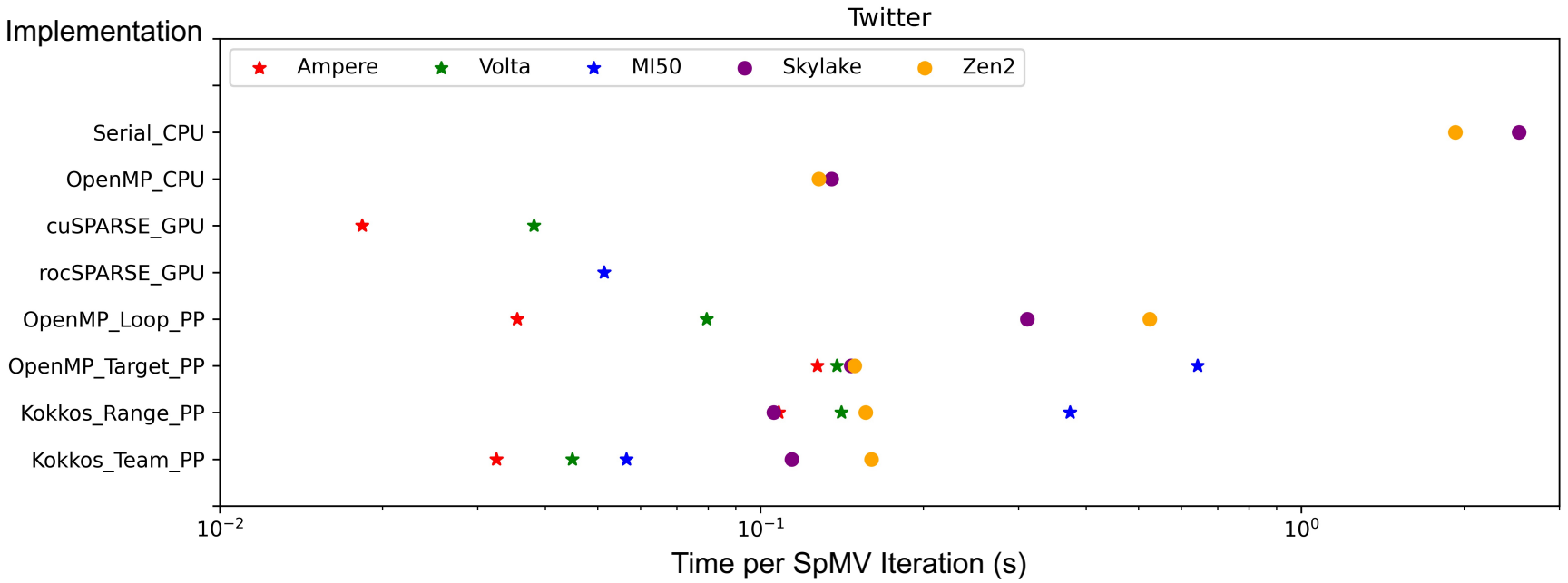
Results: 3D Hex Mesh Stencil



Some success for performance portable [PP] methods

- None significantly underperform CPU-only “classic” OpenMP
- Several perform at or near the level of vendor math libraries on GPU

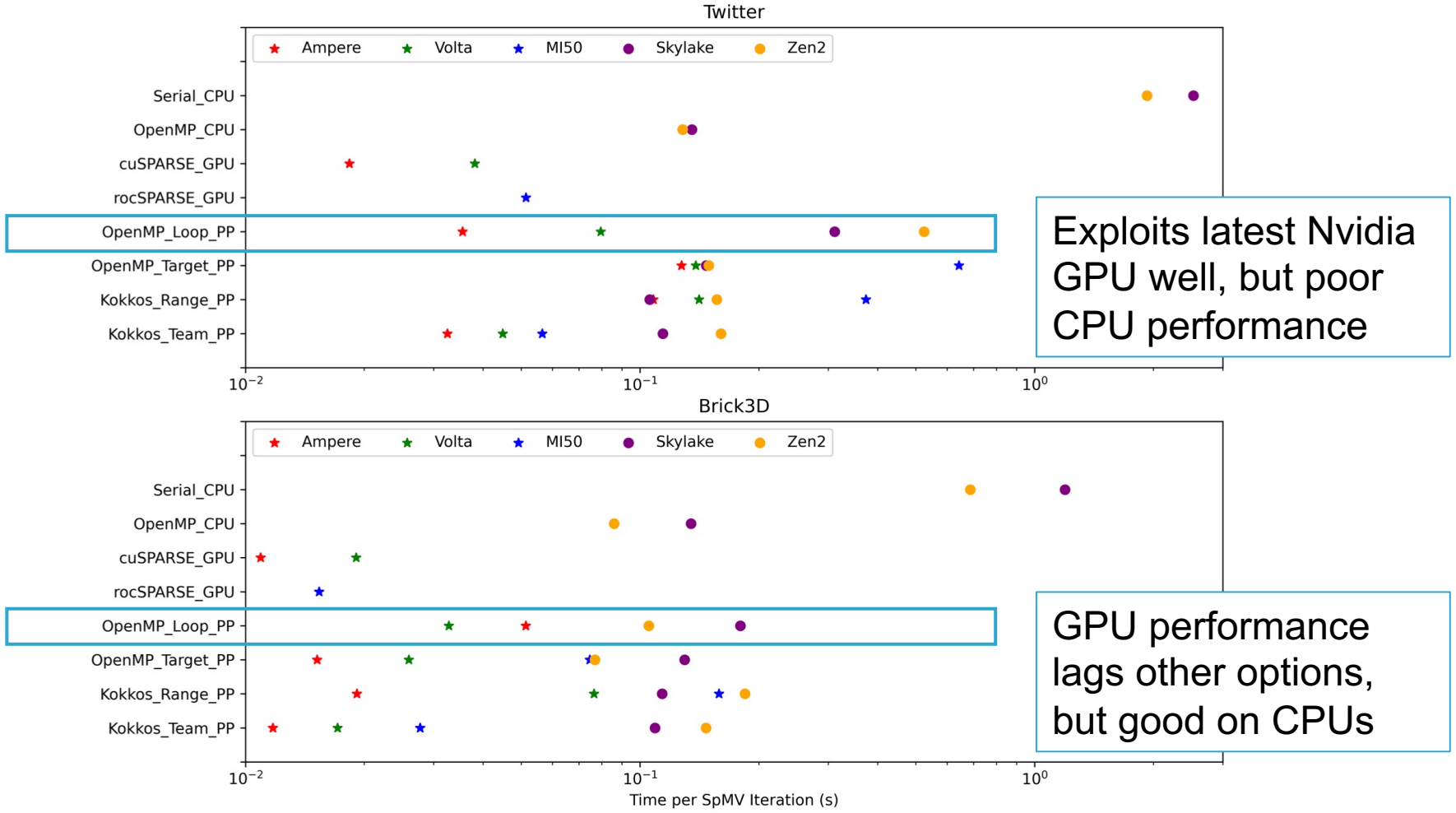
Results: Twitter Followers Network



Less success for performance portable [PP] methods

- Several significantly underperform CPU-only “classic” OpenMP
- Only the most complex (Kokkos `team`) is near the performance of both vendor math libraries on GPU and “classic” OpenMP on CPU

Descriptive OpenMP: `loop` Construct

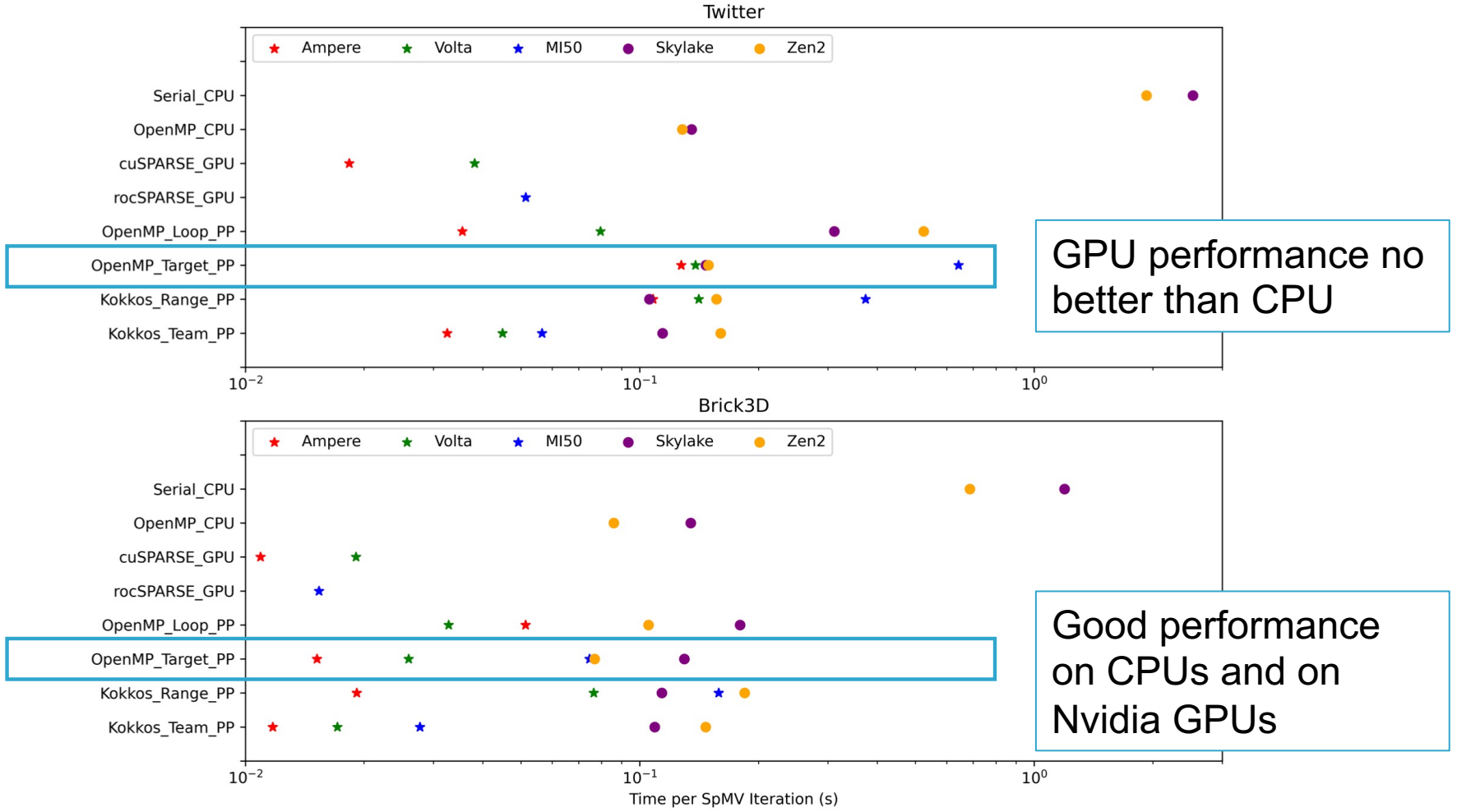


Exploits latest Nvidia GPU well, but poor CPU performance

GPU performance lags other options, but good on CPUs

Not maximizing performance portability

Prescriptive OpenMP: `target teams distribute parallel for`

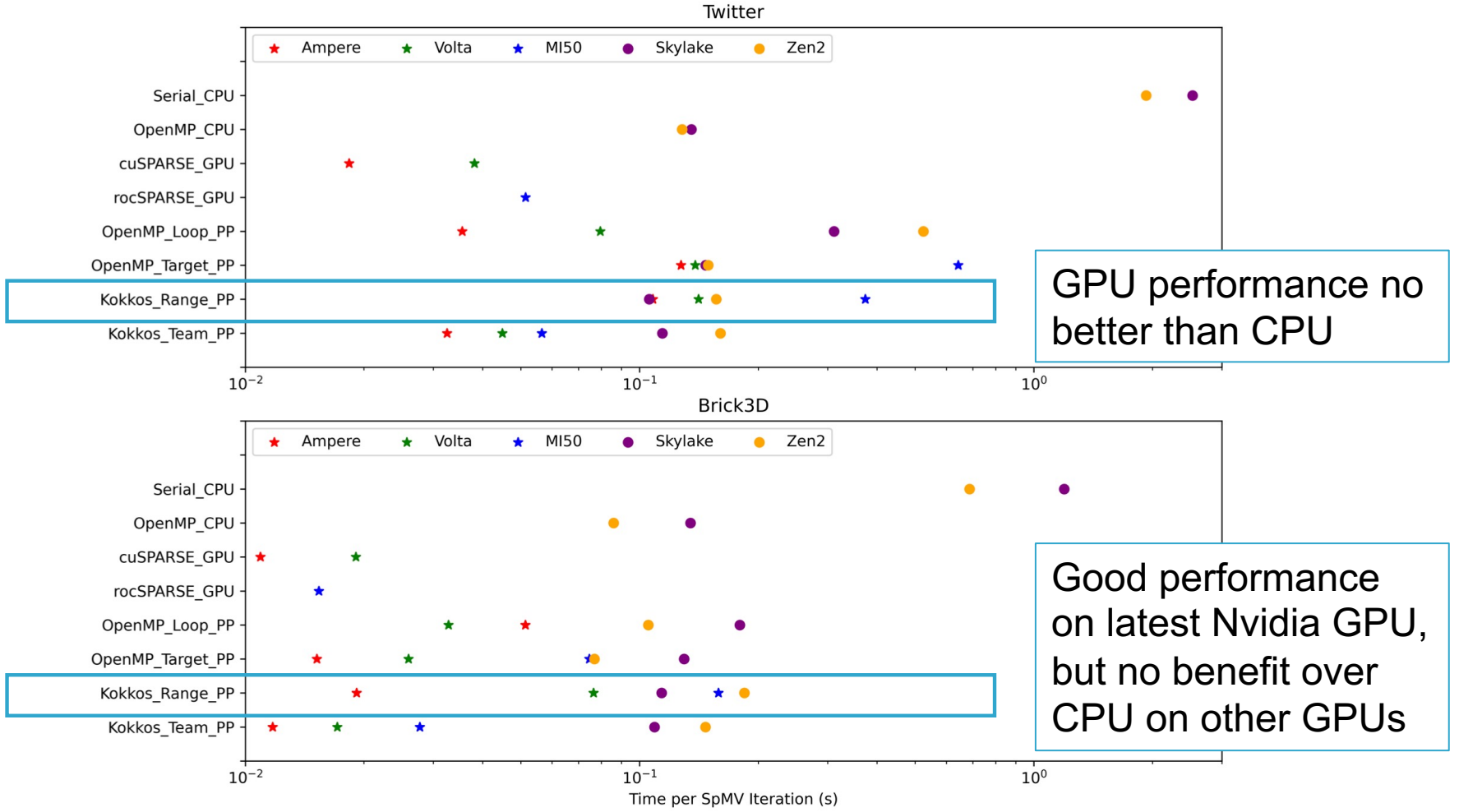


GPU performance no better than CPU

Good performance on CPUs and on Nvidia GPUs

Not maximizing performance portability

Basic Kokkos: `range` Policy (Single-Level Parallelization)



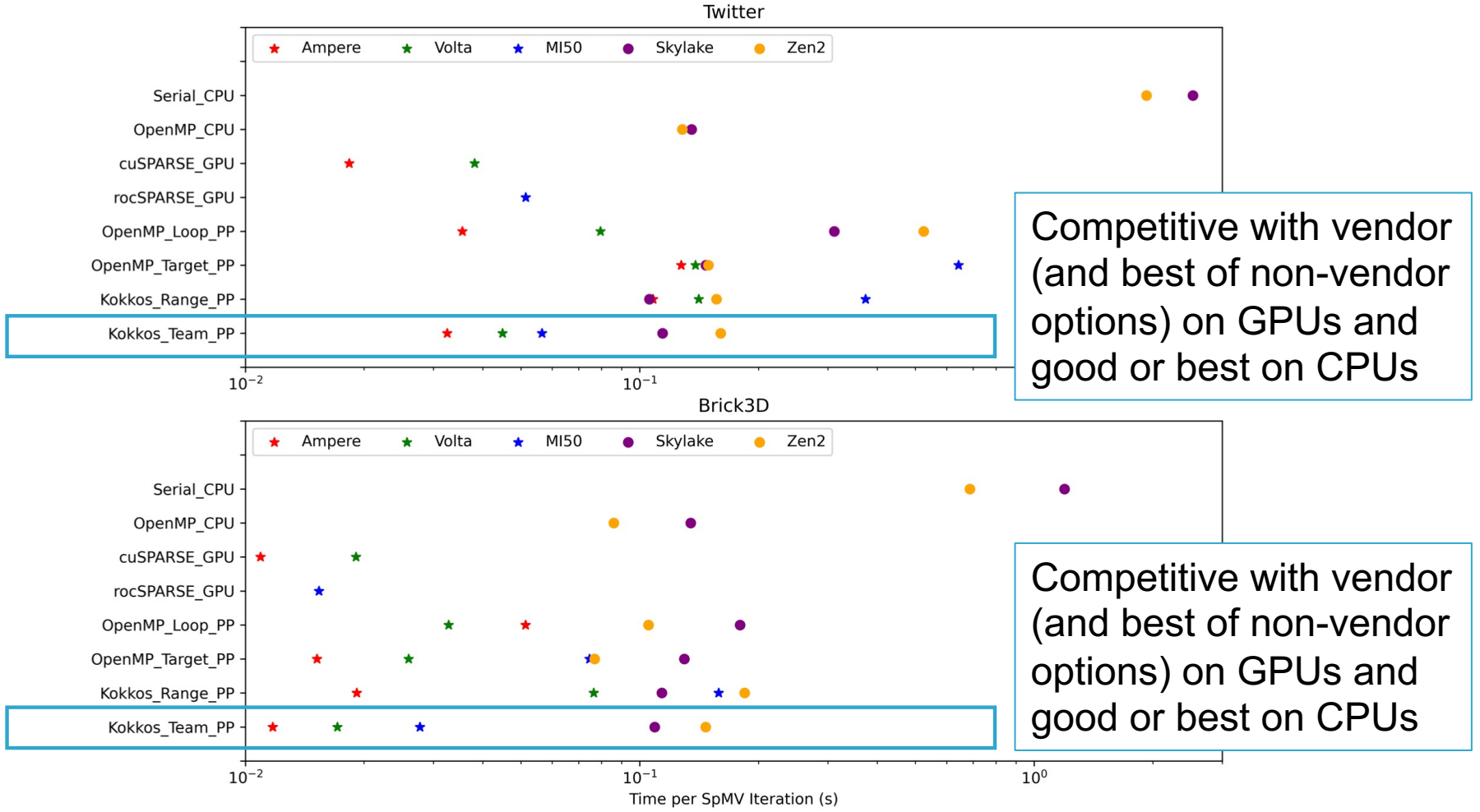
GPU performance no better than CPU

Good performance on latest Nvidia GPU, but no benefit over CPU on other GPUs

Not maximizing performance portability

More Complex* Kokkos: `team` Policy

* Explicitly parallelizing both levels of loops in code AND tuning runtime parameters



Competitive with vendor (and best of non-vendor options) on GPUs and good or best on CPUs

Competitive with vendor (and best of non-vendor options) on GPUs and good or best on CPUs

Maximizes performance portability on this kernel

Takeaways and Future Work

Performance portability is challenging

- Some programming models that were originally designed primarily for scientific computing struggle with our graph analytics input.
- Low-effort code often performs no better on GPU than multicore CPU, especially for the graph analytics input.
- Only more complex code with execution time tuning of key parameters demonstrated performance consistently at or approaching the level of nonportable GPU vendor libraries.

Key considerations for programmers

- Is my specific kernel available in a vendor library?
- Am I willing to work for performance portability?

Many possibilities for future work

- Try newer AMD hardware (MI100) and software (continually improving ROCm stack).
- Test other OpenMP compilers for GPU offload (GCC, Cray).
- Implement new versions in other programming models, e.g., OpenACC.