Cosmic rays solar modulation exploiting GPU parallelization

Giovanni Cavallotto (INFN MiB), Stefano Della Torre (INFN MiB)

Spoke 3 Technical Workshop, Trieste October 9 / 11, 2023

ICSC Italian Research Center on High-Performance Computing, Big Data and Quantum Computing

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dall'Unione europea
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Scientific Rationale

- **Modulation of galactic cosmic rays in heliosphere (**arXiv:1704.03733**)**

- **The CR propagation is described by Parker equation (**arXiv:1703.06192**) (dominated by magnetic random scattering)**

- **Space weather**

- **Single event effect**

- **CR background in space experiments**

System of stochastic differential equations

- MC backward in time integrated

- Parallelization of the N particle simulated

Heliopause

Injection Points
at Earth Orbit

Sun

Jovian
Mag.

Time
Over
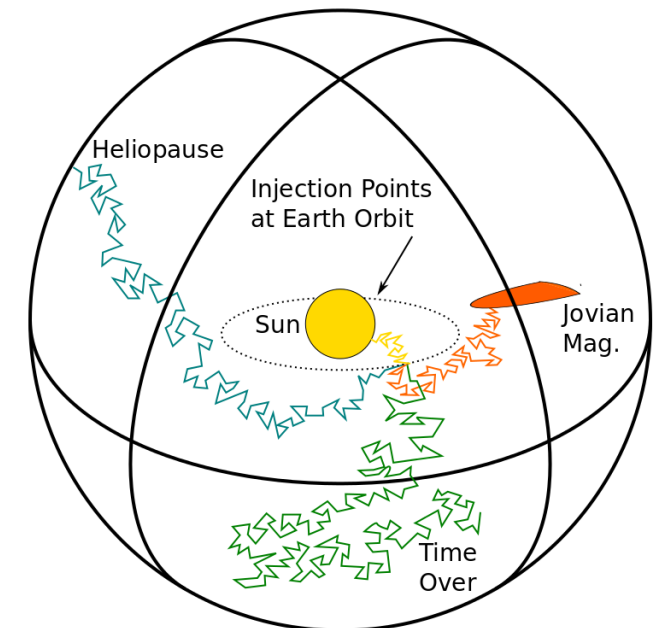
Technical Objectives, Methodologies and Solutions

- **Complete GPU porting of the SDE integration code (cosmica)**
- **Code optimization based on the NVIDIA Ampere architecture**
- **Performances test of other GPUs**
- **Distribute open source code customizable with different physical models**
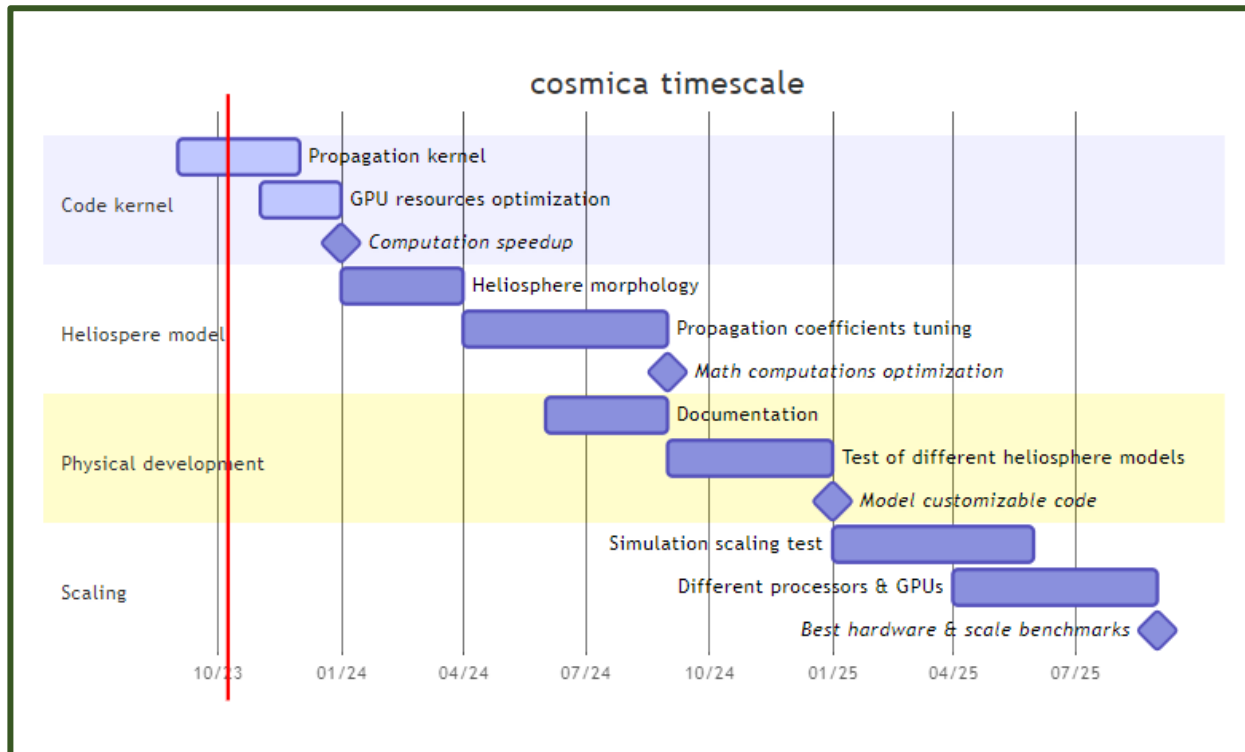
Tools:

- **Cuda C/C++ language**

- **Profiling with NVIDIA Nsight tools**

Algorithms:

- **Backward SDE integration with Eulero-Mayorana method**

- **SIMD parallelization on GPU**

Timescale, Milestones

KPIs

cosmica timescale

- **Keep the execution time under 3 minutes**

- **Produce 5 test run a week**

- **Build a performance benchmark weekly**

- **Release an updated version & documentation every month**

- **Produce 5 high statistics test for model & parameter testing**

Accomplished Work, Results

- Hired of Giovanni Cavallotto since 01/09
- Designed the code GPU algorithm
- Spotted the code bottleneck (cuda profiling)
- Established code performance benchmarks
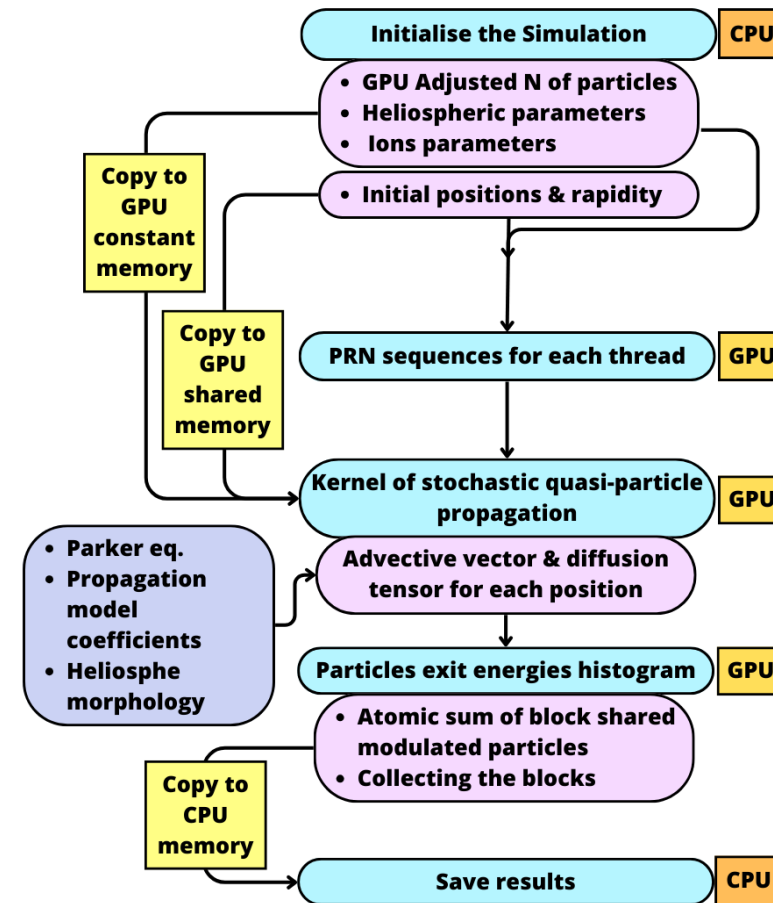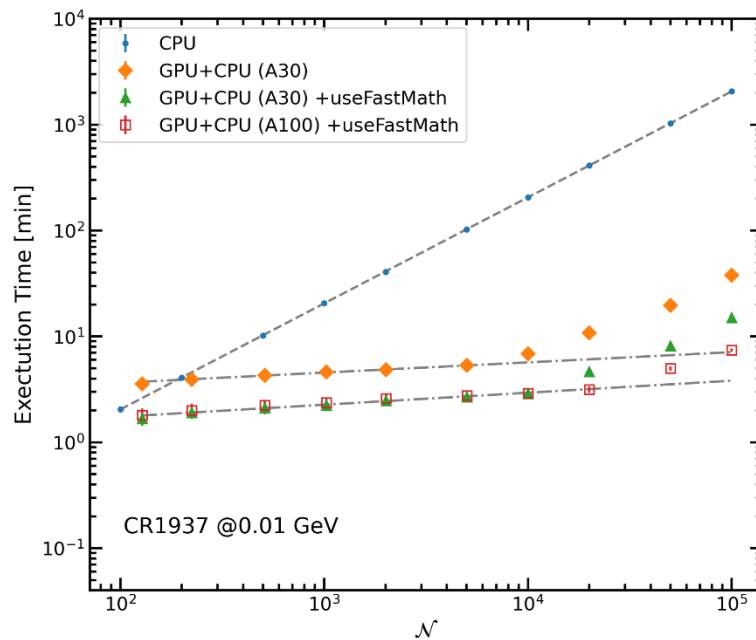
Next Steps and Expected Results (by next checkpoint: April 2024)

Identified optimization points:

- **Passing from particle energy to rigidity (one SDE becomes trivial)**

- **Optimazing the registers and shared memory usage (avoid memory saturation)**

- **Occupancy optimization managing threads and blocks number**

- **Remove the code bottleneck: branch diverging, infinity loops, stucked particle propagation**

- **Configure the heliosphere morphology model**

Expected results:

- **Produce consistent simulations with same CPU precision**

- **Simulation speedup ≥ 50 times CPU code**