Cosmic rays modulation in heliosphere models on GPU

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Parker's transport equation stochastic solution for simulation cosmic rays distribution in the heliosphere is demanding on computing resources. We implemented 1D Forward-in-time and Backward-in-time models for GPU with successful acceleration ranged from 7x to 86x. This acceleration was gained with not a negligible reduction of accuracy, especially with changing the entire simulation from double-precision float-point format to floating-point format. This led to a certain deviation that we called pulsations that showed in results with input time step less than 2.0 s. We also discuss the comparison of our solution with Dunzlaff et al. and the overall accuracy of results gained from GPU implementation of 1D Forward-in-time and Backward-in-time models. Our approach is similar to Dunzlaff et al. in [1]. But instead of defining the injection point on the CPU, we are defining it and calculating additional parameters on GPU.

Parker's transport equation stochastic differential equation (SDE) solution [2] [3] can be demanding on resources. This especially applies to cases in which we want to use simulations with low-time steps. F-p method was accelerated by 7.71x against reference CPU system, acceleration in this case was very similar in various combination of input parameters. B-p method was accelerated by 86.87x to 183.47x against reference CPU system.

In the majority of evaluated cases, the maximal deviation was 10% for energies greater than 1 GeV. For the test with input parameters of solar wind V = 400 km/s, diffusion coefficient K0 = 5 x 1022 cm2/s and time step dt = 5 s we simulated 1 trillion quasiparticles. Accuracy over 1 GeV is acceptable, with maximum deviation of 10%. Under 1GeV we can observe deviations up to 24% at 0.3 GeV. For verification of our GPU implementation of F-p model we compared multiple version of GPU implementations with different accuracy against CPU implementation of F-p model in double precision. Energy spectra for single and double precision are nearly identical with maximal deviation of 13% at low energy, likely due to insufficient statistics of CPU spectra.

References

[1] Computer Physics Communications 192 (2015):156-165

[2] Space Science Reviews 212.1 (2017): 151-192.

[3] J. Geophys. Res. Space Physics, 121,doi:10.1002/2015JA022237