HEIBRiDS
Helmholtz Einstein International
Berlin Research School in Data Science

Admission Round 2019

Project Title	**Solving the simulation problem of ground-based gamma-ray astronomy**
Project leads / supervisors	Prof. Dr. David Berge (DESY, Helmholtz) Prof. Dr. Alexander Reinefeld (HU Berlin, ECDF)
Project description	The H.E.S.S. telescopes make use of the atmosphere to measure cosmic photons above 100 GeV. Such gamma rays initiate air showers when they smash into the atmosphere. This technique is limited by the fact that 1 in 10^7 cosmic-ray protons produces an air shower that perfectly mimics a gamma ray. This constitutes an irreducible background, which we usually subtract by measuring it, sacrificing half of the field of view of H.E.S.S. Ultimately, this approach severely limits the sensitivity of such telescopes: gamma-ray sources larger than the background control region are completely missed. Air shower simulations are one possible solution of this problem. If they could be used to produce background predictions, the entire field of view of H.E.S.S. could be used for gamma-ray measurements. Currently, this is not possible, because 10^7 protons have to be simulated for a single gamma-ray-like proton air shower. This is unaffordable with our current (very sizable) computing resources. Within HEIBRiDS, via a PhD project supervised jointly by DESY and ZIB scientists, we propose to solve this problem by developing techniques to speed up the simulations by factors of at least 10^4. To achieve the speedup, we plan to combine (at least) two approaches: (1) parallelization/optimization of the software for manycore CPUs or GPUs and (2) implementing smarter simulation schemes which allows us to only fully simulate interesting gamma-ray-like showers, or implement fast approximations to safe CPU time. According to our quick calculation, a speed up of $O(10^4)$ can be achieved by combining these methods. This PhD project aims to explore new aspects of existing data by developing smarter simulation algorithms or alternatively new highly parallelized simulation algorithms. This project is therefore a showcase for interdisciplinary Data Science – the cooperation of DESY and ZIB scientists shall result in new algorithms and methods to extract knowledge from a large (gamma-ray) dataset. We do this by combining the know-how of the DESY PIs, who know all about the data and the measurement technique (atmospheric air showers), with the computer-science expertise of the ZIB PIs, who have experience in the development of smart and fast simulation algorithms on massively parallel manycore processors for physics applications

References	[1] S.Funk, Space- and Ground-Based Gamma-Ray Astrophysics, Annual Review of Nuclear and Particle Science, Vol. 65:245-277, https://arxiv.org/abs/1508.05190 . [2] D.Berge, S.Funk, J.Hinton, Background Modelling in Very-High-Energy Gamma-Ray Astronomy, Astronomy & Astrophysics, Vol. 466:1219-1229, https://arxiv.org/abs/astro-ph/0610959. [3] G.Maier and J.Knapp, Cosmic-Ray Events as Background in Imaging Atmospheric Cherenkov Telescopes, Astropart.Phys., Vol 28, 2007, http://arxiv.org/abs/0704.3567. [4] T. Ablyazimov, A. Abuhoza, R. P. Adak, A. Reinefeld, et al. Challenges in QCD matter physics - The scientific programme of the Compressed Baryonic Matter experiment at FAIR, Euro Phys J A 53:60 (2017) [5] T. Kramer, M. Noack, Prevailing Dust-transport Directions on Comet 67P/Churyumov–Gerasimenko, ApJL, **2015**, vol. *813*, L33 [6] C. Kreisbeck, T. Kramer, M. Rodriguez, B. Hein, High-performance solution of hierarchical equations of motion for studying energy transfer in light-harvesting complexes, Journal of chemical theory and computation, **2011**, vol. *7*, pp 2166–2174 [7] F. Wende, Th. Steinke, M. Klemm, A. Reinefeld. Concurrent Kernel Offloading. In: James Reinders, Jim Jeffers (eds.), High Performance Parallelism Pearls: Multicore and Many-core Programming Approaches, Morgan Kaufman, 2014.