The Numerical Hydrodynamic Modeling of Interacting Galaxies by means Hybrid Supercomputer on base Intel Xeon Phi accelerators

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The collisions of galaxies play a important role into a formation of a variety of galaxies, because over the course of a Hubble time, an ordinary galaxy may suffer up to ten collisions with the other galaxies in its cluster [1]. Numerical simulation is main approach for research of these processes. The need to reproduction of various details of flow e.g. some instability processes, forces us to employ the most powerful supercomputers available.

The main ingredients of galaxies are gaseous component and collisionless component for describe of stars and dark matter. Traditionally, a collisionless component is described using N-body models. Nevertheless, this model has disadvantages because of spurious generation of entropy, thermodynamically non self-consistency of star formation and supernovae feedback, increased communication overhead and poor load balancing [2]. The “collisionless stellar hydrodynamics” approach is based on the equations for first moments of the collisionless Boltzmann equation and is adequate for the movement of particles at high kinetic energy in a cluster. In addition, for a description of “collisionless stellar hydrodynamics” and hydrodynamic models an unified numerical methods and parallel algorithms was used [2].

For the system of hyperbolic equations the combination of operator splitting approach (Fluid-in-Cells technique), Godunov method and piecewise-parabolic method on local stencil for high order solver was used. The dual energy formalism for guarantee of non-decrease entropy [3] was used. The subgrid-physics model : a star formation, a supernovae feedback, molecular hydrogen formation, cooling and heating functions, was included. By means numerical simulation on RSC PetaStream was modeled one scenario of interacting galaxies : regions of active star formation/supernovae feedback, and regions with molecular hydrogen formation.

Using of an unified approach for construction of parallel numerical method [4, 5] allowed obtaining on RSC PetaStream supercomputer speed-up factors of 134 for Intel Xeon Phi accelerator and maximum efficiency of 92% is demonstrated using 64 Intel Xeon Phi in native mode on the cluster RSC PetaStream of the Joint Supercomputer Center of the Russian Academy of Sciences.

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[1] Tutukov A.V., Lazareva G.G., Kulikov I.M. Gas dynamics of a central collision of two galaxies: Merger, disruption, passage, and the formation of a new galaxy // Astronomy Reports. – 2011. – V. 55, I. 9. – P. 770-783
[2] Kulikov I. GPUPEGAS: A New GPU-accelerated Hydrodynamic Code for Numerical Simulations of Interacting Galaxies // The Astrophysical Journal Supplements Series. – 2014. – V. 214, 12. – P. 1-12
[3] Godunov S.K., Kulikov I.M. Computation of discontinuous solutions of fluid dynamics equations with entropy nondecrease guarantee // Computational Mathematics and Mathematical Physics. – 2014. – V. 54, № 6. – P. 1012-1024
[4] Kulikov I.M., Chernykh I.G., Snytnikov A.V., Glinskiy B.M., Tutukov A.V. AstroPhi: A code for complex simulation of dynamics of astrophysical objects using hybrid supercomputers // Computer Physics Communications. – 2015. – V. 186. – P. 71-80
[5] Kulikov I., Chernykh I., Glinsky B., Weins D., Shmelev A. Astrophysics Simulation on RSC Massively Parallel Architecture // Cluster, Cloud and Grid Computing (CCGrid), 2015 15th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing. – 2015. – P. 1131-1134