Modeling of particle acceleration in star clusters with 3D-MHD simulations

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Young compact clusters of massive stars contain dozens of O-, B- and WR-type stars with fast powerful winds in a small $\sim$ pc radius. The acceleration of particles by ensembles of shocks and waves of compression and rarefaction in the turbulent environment of young massive star clusters (YMSCs) is an alternative to the standard paradigm of Galactic cosmic rays acceleration on supernova shocks. In recent years, the topic is of great interest due to the fact that modern gamma- and X-ray observatories are detecting the radiation from YMSCs (e.g. Westerlund 1, 2), which indicates on particle acceleration processes in these objects. We study propagation and acceleration of particles in a YMSC with the help of 3D magnetohydrodynamic (MHD) modeling using PLUTO, an open source code based on the numerical solution of MHD equations with the Godunov scheme [1]. The code allows modeling of the turbulent environment of YMSCs and obtaining crucial for particle acceleration values of velocity, density and magnetic field inside the cluster core [2]. The particle module implemented in PLUTO allows solving the equations of motion for test charged particles together with MHD equations for the medium. We obtained that protons acceleration up to hundreds of TeV takes place in the cluster core near the termination shocks of O-stars, which are surrounded by shocks of their neighbour stars. The particle spectra and spatial distribution are discussed.

[1] Mignone A, Bodo G, Massaglia S, Matsakos T, Tesileanu O, Zanni C and Ferrari A 2007 *ApJS* **170** 228–242 (*Preprint* `astro-ph/0701854`)

[2] Badmaev D V, Bykov A M and Kalyashova M E 2022 *MNRAS* **517** 2818–2830 (*Preprint* `2209.11465`)