

Project Title: Fast moving pulsars**Name: Maxim Vladimirovich Barkov****Laboratory at RIKEN: Astrophysical Big Bang Laboratory**

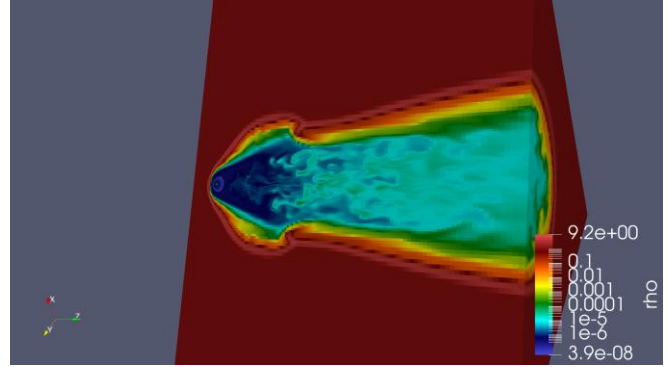
1. In our previous project we solve the following problem:

Bow shocks generated by pulsars moving through weakly ionized interstellar medium (ISM) produce emission dominated by non-equilibrium atomic transitions. These bow shocks are primarily observed as Ha nebulae. We perform self-consistent 2D relativistic hydrodynamic calculations of the bow shock structure and generate non-LTE emissivity maps, combining global dynamics of relativistic flows, and detailed calculations of the non-equilibrium ionization states. We find that though typically Ha emission is dominant, spectral fluxes in [O III], [S II] and [N II] may become comparable for relatively slowly moving pulsars. Overall, morphology of non-LTE emission, especially of the ionic species, is a sensitive probe of the density structures of the ISM.

In previous research we made wide general parameter study, but in the present project we performing simulation dedicated specific PWN PSR J2030+4415, which was observed on 6m telescope in [O III].

2. We used public PLUTO code in 3D RHD regimes. The Taube EOS was adopted for work with Multi-Ion Non-Equilibrium Cooling (MINEq) module. MINEq module was extended to work with larger number ions and spectral lines.
3. We started 3D RHD simulation of PSR J2030+4415 with proper ISM density and pulsar velocity. The setup is very computationally heavy and requires long run.

Bellow we show preliminary results. We hope to finalize our run before FY2026.



At the plot the ISM concentration is shown.

4. The project now is performing well and should be successfully finished. The initial parameters and setup are done. The model is performing stably.
5. The project was applied in the September 2025 and access to the cluster was granted close to the middle of the February 2026. We expect to reach the proper solution after 500 000 CPUhours. During the next FY we plan to publish and present results of the project. Moreover, the project planned to be continued in the next FY, there we plan to implement 3D RHD simulation with nonuniform ISM as boundary condition, which we will get from dedicated simulation. So, we will have system of equation, initial and boundary condition as realistic as possible at the moment.