Abstracts of MMA2018, May 29 – June 1, 2018, Sigulda, Latvia

ON NUMERICAL SIMULATION OF SPIRAL–VORTICAL STRUCTURES IN ROTATING GASEOUS DISKS

ALEXANDER ZLOTNIK

Department of Mathematics, National Research University Higher School of Economics

Myasnitskaya str., 20, 101000, Moscow, Russia

E-mail: `azlotnik@hse.ru`

The study is devoted to several aspects concerning numerical simulation of spiral-vortical structures in rotating gaseous disks using a rather simple model exploiting 2D non-stationary barotropic Euler equations with a body force. The numerical results suggest the possibility of a purely hydrodynamical basis for the formation and evolution of such structures well-known in astrophysical observations and theory.

New axially symmetric stationary solutions of the equations are derived that modify approximate solutions known previously. These solutions with added small perturbations are applied as initial data in the non-stationary problem whose solutions then demonstrate the formation of density arms with bifurcation. Also numerical simulations confirm the correctness of laboratory shallow water experiments to describe the formation of large-scale vortical structures in thin gaseous disks; see [1] for more details.

The computations are based on a special quasi-gas-dynamical (QGD) regularization of the Euler equations in polar coordinates. The QGD regularization of the Euler and compressible Navier-Stokes systems of equations can be considered a kinetically motivated Petrowsky parabolic regularization [2] involving additional 2nd order in space terms with a regularizing parameter $\tau > 0$. The energy equality in polar coordinates is proved ensuring that the total energy is non-increasing in time; this is the crucial physical property.

The construction of special symmetric spatial discretization on a non-uniform radial-angled mesh in a ring is accomplished [3]; the discretization preserves the mentioned energy property. The unknown density and velocity are defined on the same mesh whereas the mass flux and the viscous stress tensor are defined on the staggered meshes. Additional difficulties in comparison with the Cartesian coordinates are overcome, and a number of novel elements are implemented in the discretization to this end, in particular, a self-adjoint and positive definite discretization for the Navier-Stokes viscous stress tensor, special discretizations of the pressure gradient and regularizing terms using enthalpy, non-standard mesh averages for various products of functions, etc. The discretization is also well-balanced. The main results are valid for $\tau = 0$ as well, i.e. for the barotropic compressible Navier-Stokes system in polar coordinates that is of independent interest.

This study was supported by the RFBR, project no. 16-01-00048.

REFERENCES

[1] T.G. Elizarova, A.A. Zlotnik and M.A. Istomina. Hydrodynamical aspects of the formation of spiral-vortical structures in rotating gaseous disks. *Astron. Reports*, **62** (1):9-18, 2018.

[2] A.A. Zlotnik. Energy equalities and estimates for barotropic quasi-gasdynamic and quasi-hydrodynamic systems of equations. *Comput. Math. Math. Phys.*, **50** (2):310-321, 2010.

[3] A.A. Zlotnik. On the energy dissipative spatial discretization of the barotropic quasi-gasdynamic and compressible Navier-Stokes systems of equations in polar coordinates. *Russ. J. Numer. Anal. Math. Model.*, **33** (4), 2018.