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3D NUMERICAL SIMULATION OF ACCRETION FLOW - INITIAL AND BOUNDARY CONDITIONS AND SPACE RESOLUTION

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Abstract

In this paper we introduce first steps in building of 3D numerical model of accretion flow. We discuss the influence of initial and boundary conditions choice as well as the choice of space resolution grid. The correct choice of space resolution is very important in order to find detailed picture of the flow and, in the same time, to find optimal calculation time.

Choosing incorrect initial or boundary conditions, we can’t receive correct results and louse the purpose of the model.

Introduction

The accretion flow in close binary system is nearly fully ionized plasma, that moves from the surface of one of the binary components toward the surface of another one. The flow travels thru the gravitational and magnetic field of both stars and interacts with the luminosity.

To solve full equation system, describing the dynamics of accretion is impossible. So to find structure and its dynamics, we make either analytical descriptions with many restrictions, or numerical parametrical models.

The physics of accretion flow is not yet fully described. At the time there exists for example different explanations for angular momentum exchange. In our mind it is important creating a numerical model, to be able to vary many parameters and this way to explain the role of each of them for accretion flow behavior.

Space resolution

For astrophysical investigations it is interesting to find detailed flow structure and its dynamics in whole area between first Lagrangian point and compact object surface. The physical conditions (such as magnetic forces, flow density and speed, luminosity and other) are very different from point to point.

In a binary system with distance between the components equal to 10^{15} cm contained neutron star with diameter equal to 10^{6} cm, inner boundary is practically a point for calculations.

To find satisfactory results, we need either to divide the investigated space to rings (fig. 1) or to use different cell dimensions in different radii (the side of the sell need to decries with decreasing of the radii) as it is shown in (fig. 2).

First chouse gives us possibility to work with equal sides of cells everywhere in the investigated space. The second one is easier for programming, but takes much more computational time.

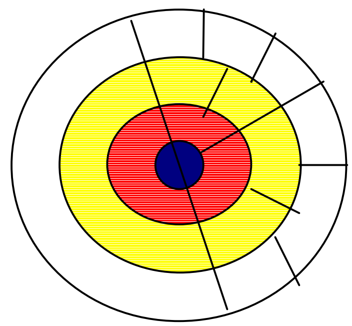

Fig. 1
Grid with equal cell sides – schematic view

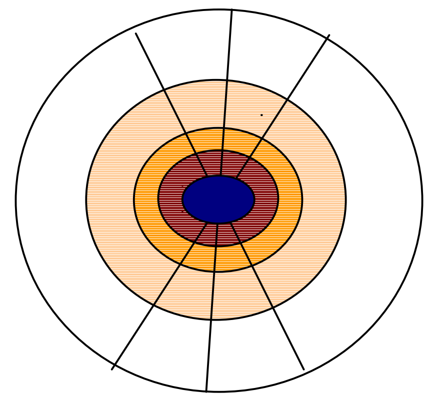

Fig. 2
Grid with different cell sides – schematic view

We decided for 3D model to follow first scenario. It is because we used the same scheme in our previous 2D calculations. At the same time, it gives us possibility to use more or less detailed resolution in some part of the flow according to concrete aim of the simulation.

In this case, using cylindrical reference frame (r, φ, z) with 20 cells between outer and inner boundary in r direction, the attitude R_{out}/R_{in} must not exceed 100.

In z direction the problem in most cases arises because the flow is geometrically thin. If nevertheless we want to investigate vertical distribution of physical parameters, we need at least 5 $\div$ 10 cells in this direction. But, choosing bigger step in r direction and trying to make cells with equal sides in all directions, we can receive practically empty cells and no parametric distributions on z lines.

So, for binary system with $M_1 = 3 \div 4.M_o$, $M_2 = M_o$, $R_{12} = 10^{15}$ cm and $R_1 = 10^6$ cm, we need no less then 4 rings each one with 20 cells in r direction, 5 in z and different numbers on φ lines, choused to confirm circumstance for equal cell sides.

Deciding to follow this way we need to calculate boundary conditions for second other rings from the results of calculations for the inner boundary of the first ring. The outer boundary for the third we find from inner boundary of the second and so on.

Initial conditions

This chouse affects on the calculated results too. The most of authors take uniformly distributed gas in the space around the central object (Meglicki et.al 1993, Bisicalo et.al. 1998, Lanzafame & Belvedere 1997, 1998, Yakawa et.al 1997).

In all our works we starts from empty space.

The reason for this chouse is that every initial distribution affects on the calculation results. We have not reason to take uniformly gas because we know that forces acted on the flow (gravitational and magnetic from both stars) varies strongly from point to point, so we can't obtain such a uniformly gas at this region.

If we want to be really correct and describe accretion flow evolution from it's start point, we need to start at the moment when companion star fill its Roche lobe and starts to loose gas. But each star loose some amount of gas as a stellar wind all it's live.

Boundary conditions

The boundary condition chouse affect on the calculated results because of the nature of used equations.

As we show in our previous works (Dimitrova 1997a, b and 2001a, b) inflow gas velocity, temperature, density and their variations in time, effects strongly on the structure and dynamics of the accretion flow as a hole.

The chouse of inflow gas temperature and its dynamics depend on the spectral class of the companion star. The density and its variation in time we take from the model we permit for the star activity behavior. From this chouse we can obtain or not realistic solution for the accretion luminosity (as we show in (Dimitrova 1997a and 2001b)).

The chouse of the inner boundary conditions depend on investigated space. If inner boundary is the compact object's surface – we take one kind, if this is a ring outside of central object – we take another kind of boundary. In first case we decide that gas fall on the star surface and all its inner energy irradiates as X-ray luminosity. In the second case – we accumulate this part of gas that leave cells as the inflow gas stream for inner investigated region.

As we shown (Dimitrova 2001a), variations in inflow gas density cause wave propagation along spiral fronts and affect on luminosity produced at the central object surface. To chouse realistic long-time behavior of this value is sufficient for explanation of quick variations in X-ray luminosity from the binary system.

To chouse and test such a model for inflow stream variations and caused X-Ray luminosity behavior is one of the most important aims of our numerical simulations.

References:

1. Dimitrowa M.M., 1997, Aerospace Research in Bulgaria, 13, 19, (1997a)
2. Dimitrova M.M., 1997, Aerospace Research in Bulgaria 13, 27, (1997b)
3. Dimitrova M.M., 2001, Aerospace Research in Bulgaria, 16, 144, (2001a)
4. Dimitrova M.M., 2001, Aerospace Research in Bulgaria, 16, 148, (2001b)
5. Meglicki D., Wickramasinghe D., Bicknell G., 1993, MNRAS, 264, 691
6. Bisicalo D.V., Boyarchuk A.A., Chechetkin V.M., Kuznetsov O.A., Molteni D., 1998, MNRAS, 300, 39
7. Lanzafame G., Belvedere G., 1997, MNRAS, 284, 957
8. Lanzafame G., Belvedere G., 1998, MNRAS, 295, 618
9. Yakawa H., Boffin H.M.J., Matsuda T., 1997, MNRAS, 292, 321