2D AND 3D MASS TRANSFER SIMULATIONS IN β LYRAE SYSTEM

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ABSTRACT. 2D and 3D mass transfer simulations of the mass transfer in β Lyrae binary system. We have received that from a point L_3 40 per cent of mass transfer from L_1-point is lost.The structure of a gas envelope, around system is calculated.3-D mass transfer simulations has shown presence the spiral shock in the disk around primary star's and a jet-like structures (a mass flow in vertical direction) over a stream.

Key words: Stars:interect binary systems; simulation.

The second brightest star of summer constellation βLyra, β Lyrae, has been studying astronomers for the past 200 years. β Lyrae (10 Lyr, HR 7106, HD 174638, BD+33 3223, ADS 11745A) is the brightest member (component A) of an optical system of six star and 13.086d spectroscopic and eclipsing binary with the ample evidence of circumstellar matter within and around the system. Now, it is existing two models of the envelope in β Lyrae: that of Wilson (1974) who argued that disk around the mass accreting star (the primary) is massive (of the order of a solar mass), modelled it as a very flattened ellipsoid.

Hubeny,Plaves (1991) presented a different quantitative model of disk, assuming explicitly that the disk is an accreting disk and treating its vertical structure as to be self-consistently. This disk model has e negligibly small mass and is in the form of a normal Keplerian disk bounded from outside by a half-torus. Its 'height' (i.e.thickness in the direction perpendicular to the orbital plane) grows with the distance from the primary. Comparing their model with the various data and using the geometrical constrains, Hubeny and Plavec concluded that the disk have the radius of about 25 $R_\odot$ and height of about 6 $R_\odot$

Here we present 2d and 3d simulations of the mass transfer in the β Lyrae binary system.

Our approach to the mass transfer is based on two points: i. to obtain the initial stream structure (the one in L_1) we will simulate the stream formation process instead to use Lubow and Shu model (Lubow and Shu, 1975 hereafter LS). ii. to set up the secondary internal structure in the vicinity of L_1 point we will use the

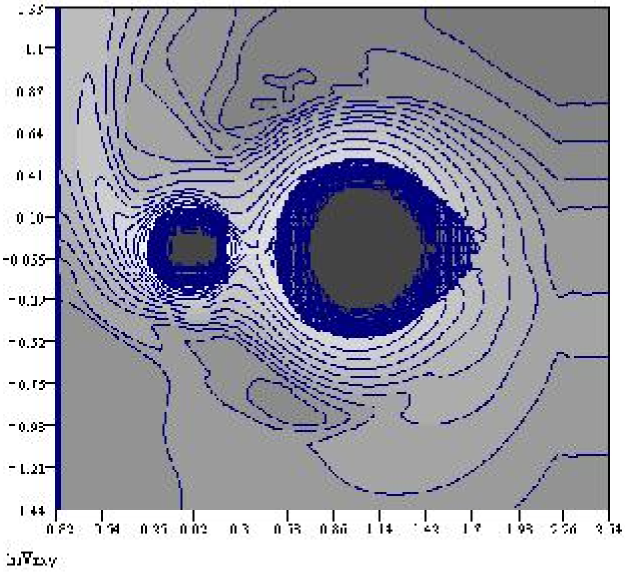

Figure 1: The density contours for the primary's radius equal to 0.5, fV=0.1.

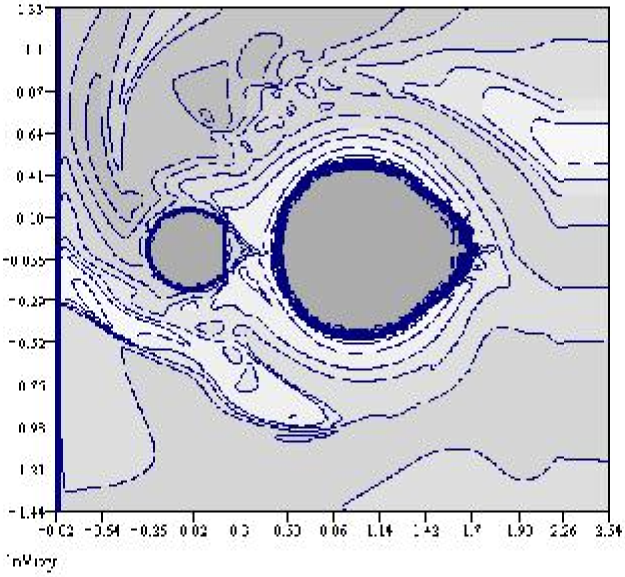

Figure 2: The temperature contours for the primary's radius equal to 0.5, fV=0.1.

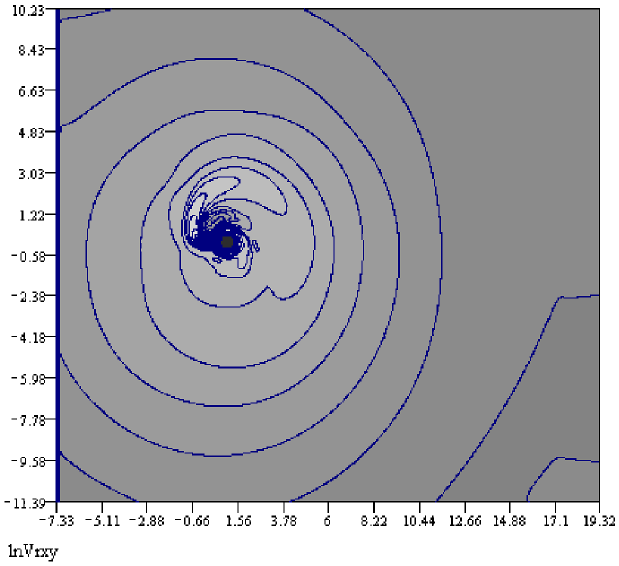

Figure 3: The density contours for the very large grid the 2d-model of the outer envelope.

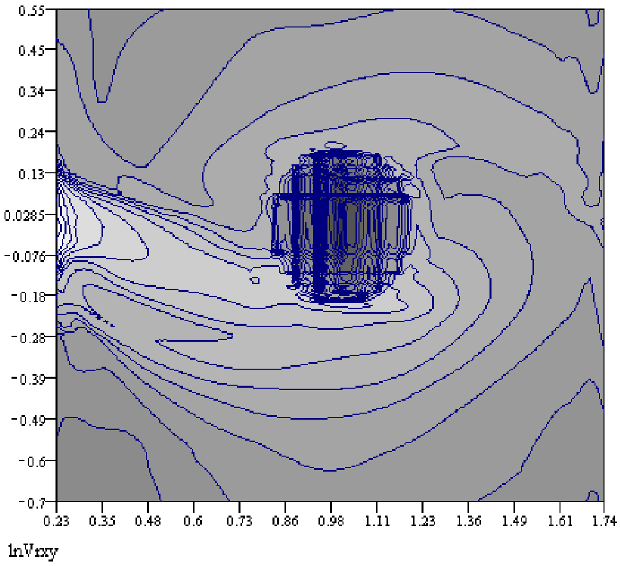

Figure 4: The density contours in orbital plane for 3d-simulations, Rprim=0.2, fV=0.5.

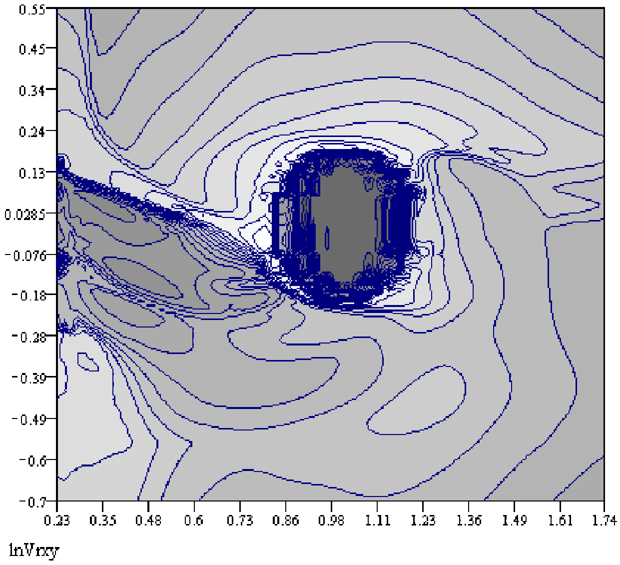

Figure 5: The temperature contours in orbital plane for 3d-simulations, Rprim=0.2, fV=0.5.

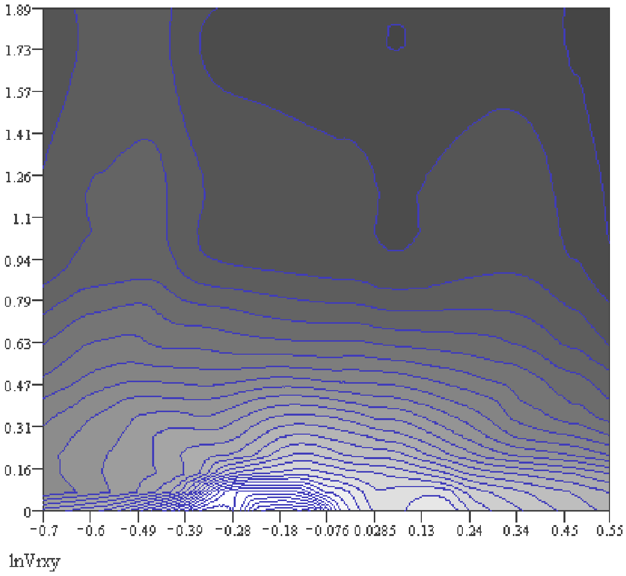

Figure 6: The density contours in zy-plane, lying on the spiral shock I.

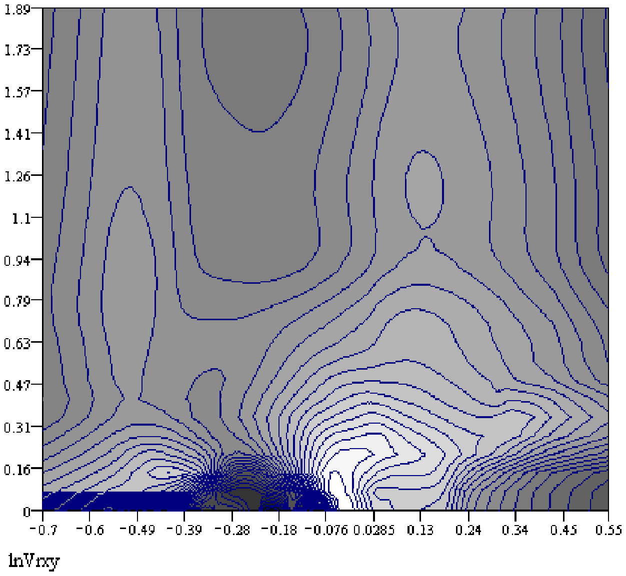

Figure 7: The temperature contours in zy-plane, lying on the spiral shock I.

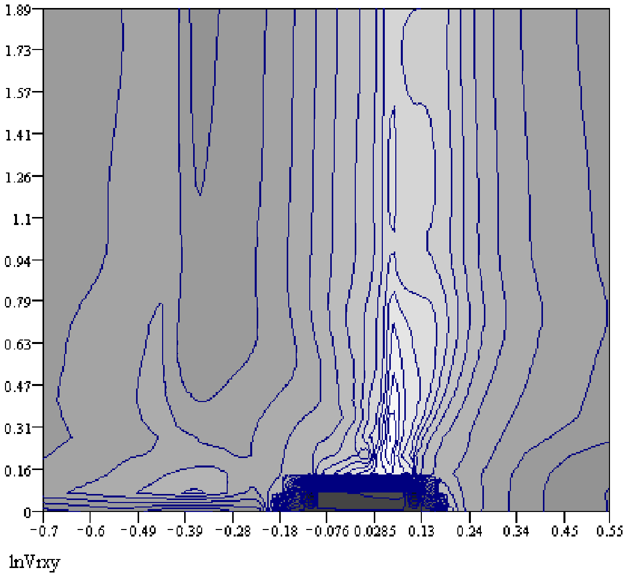

Figure 9: The temperature contours in zy-plane, lying on the mass accreting star.

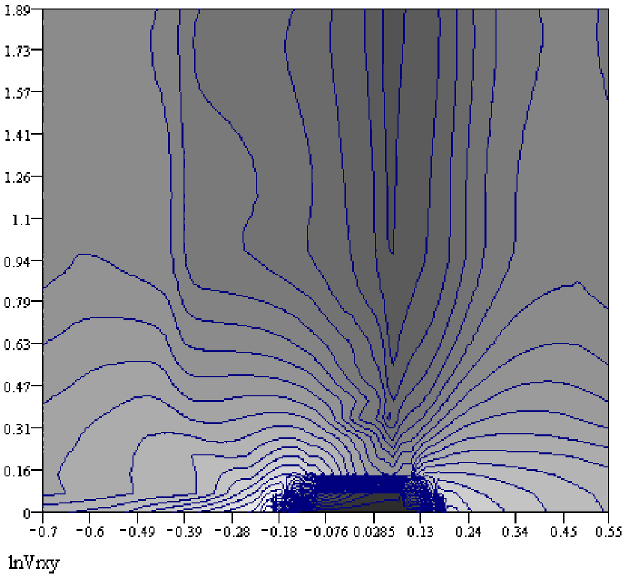

Figure 8: The density contours in zy-plane, lying on the mass accreting star.

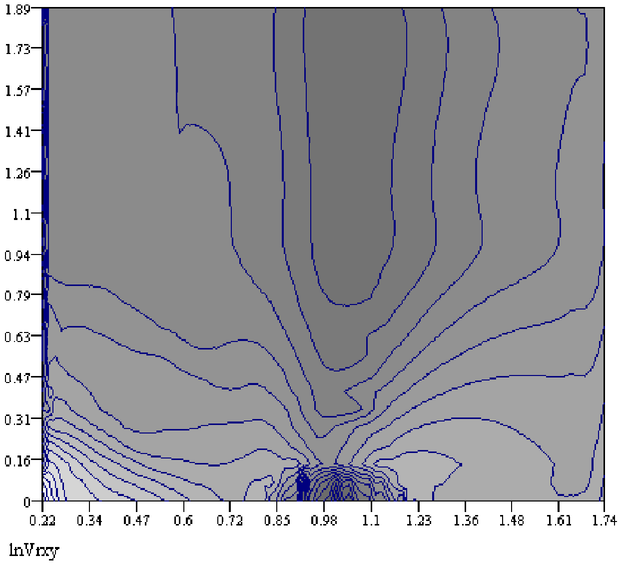

Figure 10: The density contours in zx-plane, lying on line of centres.

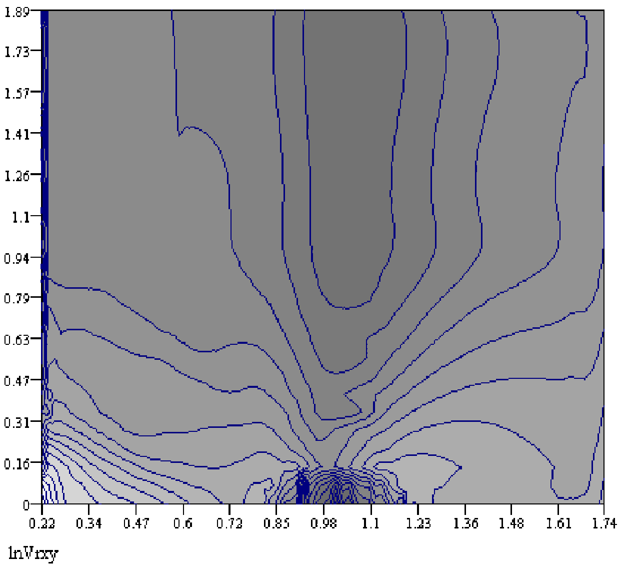

Figure 11: The temperature contours in zx-plane, lying on line of centres.

Kurucz's grid (Kurucz, 1979)

To calculate the mass flow We use non-stationary Euler-hydrodynamics equations which are resolved by 'big-particles' code developed by Belotserkovskii and Davydov (Belotserkovskii and Davydov, 1982) at the computer center of Akademy of Science of SU. We use such the code version where the artificial viscosity is implemented at the first time substep and which is two order accuracy in time and space. The simplicity of algorithm organization and high stability in calculation allow to use PC to calculate the mass transfer in CBS. WE have used in simulations PS-Pentiuum 3 of Odessa Astronomical Observatory of Odessa State University. On practice the CPU time of every time step take about 2.6-3.5 sec. and total required number of the time step to obtain the steady state in the solution is order of 300,000 -500,000.

Our treatment of binary model is standard since We consider: the synchronization rotation of the spin rotation of the binary components with them orbital motion when we shall simulate the stream formation near L_1-point and its motion further in a calculation area; We use the Roche lobe model of the binary component gravitation and all the effects of the orbital rotation in the binary (the centrifugal and Coriolis forces); circular orbits of the binary components. We account a gas as perfect one consisting from hydrogen for the simplicity.

We drop the specific heats ratio to 1.3-1.4 to take into account the possible radiative cooling effect in mass flow. This is usual way to take in account this radiative effects (see for example Molteni et, al 1991; Bisikalo et.al. 1999). We adopt the binary parameters to be: mass of the mass losing star (the secondary) equal to 2 $M_{\odot}$, mass of mass accreting star is 12 $M_{\odot}$, orbital period of 13.086 days. The peculiarity of mass transfer in binaries with the binary components - normal stars is the problem to discribe stream-the primary star interaction. We decide this problem introducing the special coefficient on the primary surface, Fv, which decreases the gas velocity here relatively velocity in surrounding cells. By such the way if the velocity in cells surrounding the primary's surface is V than the velocity on the primary's surface is Fv*V where Fv$\leq$1. The case Fv=1 discribes the entirely free flow of gas via the primary, maximum of accretion process; the case Fv$\leq$1 discribes partially reflecting and partially absorbting boundary conditions; the case of Fv=0 shows the absent accretion process on the primary, the entirely reflecting boundary conditions.

Taking into account the inevitable indefinite in the binary parameters (We have in mind in the first turn the primary radius) We calculate 2d- and 3d-models for the various primary radius:- 0.5 for 2d-simulations and 0.2 for 3d simulations (hereafter all the distance will be given in units of the orbital separations). We choose the Fv-coefficient to be equal to 0.1 for 2d-model and to be 0.5 for 3d-model.

The 2d-model we show in Fig.1a and Fig.1b where the density and temperature contours are plotted. As one can see from this Figure the mass flow with large primary radius and strong reflection of a stream from the primary produces the contact envelope around the binary components. The peculiarity of this mass transfer variant is that a gas of a stream reflecting from the primary is going back to L_1-point and interacts with a gas placed here. As result of this the mass transfer rate in L_1-point decrease on the appreciable value in 5-7 time. The another peculiarity of this model is the mass outflow from another side of the secondary in the vicinity of L_3-point. This take place due to considerable size of the secondary's atmosphere which penetrates beyond L_3-point. The mass transfer in L_3-stream is 40 per cent of mass transfer from L_1-point. In order to show how L_3-stream moves out of the system We calculate the mass transfer in the system on the very larger grid, where x-coordinates range in the interval $-8 \div +19$ and y-coordinate range in the interval $-8 \div +9$. Such outer envelope produced by L_3-stream is shown in Fig.2 where the density contours are plotted. It is clear seen how the L_3 stream is moving under Coriolis forces and regularly transform in the outer envelope. Thus, L_3-stream originates the binary system wind blowing from the system with the velocity 50-350 km. $sek^{-}1$ and density less than 10^9 $cm^{-}3$ on the distance more than 2-3 from center mass of the system. We also think that z-thickness of this wind is increased with increasing of the distance from center mass of the system.

We present 3d-model of the mass transfer in β Lyrae in Fig.3-6. In Fig.3 the density and temperature contours are plotted in the orbital plane of the system.

We clear see the place where a stream interacts with the primary, the spiral shock I when a gas orbiting the primary strikes a stream moving from L_1-point, a thin ring of high temperature in internal parts of accreting disk close to the primary's surface. We also see the spiral shock II (these notations of spirals shocks are given in that of Bisikalo's paper, 1999) that is placed upper and right of the primary star. Thus a mass flow in 3d-simulations produces the spiral shocks I and II, accreting disk, the place of star-stream interaction (PS-SI) and outer envelope. The cross-sections of a stream and spiral I in the z-y plane near PS-SI in the directions perpendicular to the stream motion are shown in Fig.4 a and b where density and temperature contours are plotted. As one can see from this Figure y-size of a stream is about 0.2 and z-size is almost 0.08 that show that y-z cross section of a stream is elliptical. The Fig.4b show that spiral I reflects from a stream and have the complicated form of the standing wave. The Fig.4b also show that a stream is very cool in respect to surrounding a gas in a disk and envelope. The Fig.4c show the velocity field in y-z cross section stated above. This velocity fields has a jet-like structures (a mass flow in vertical direction) over a stream. It confirms the suggestion of Harmanec et al. (1996) and numerical simulations of Bisikalo et al. (2000) about jet-like structures in β Lyrae.

The Fig. 5 and 6 show the y-z cross-section lying on the center of the primary and x-z cross-section lying on line of center respectively. These Figures show that upper the primary a pillar of a gas exists with a small density and high temperature. This pillar is a result from an accreting of a gas on the primary. It structure also originates jet-like structure (upper the primary).

It show that jet-like structure in β Lyrae is more complicated than was supposed and was calculated in Harmanec et al.(1996) and Bisikalo et al.(2000) papers. As one can see from Figures 5 and 6 circumstellar envelope consists of two parts: accreting disk that have the form of torus and outer envelope in which z-thickness of a gas is increased with a increasing of distance from the primary. The essential part of outer envelope has the size of 12 $R_\odot$ although to define exactly 'size' of the envelope is hard problem (it is necessary to define optical thickness in 3d-medium).

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