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THE 3-D NUMERICAL SIMULATIONS OF THE DEPENDENCE OF THE DISK STRUCTURE FROM THE WIND CONFIGURATION IN ONE-POINT IN MICROQUASAR CYG X-1. THE CASE OF THE HIGH RESOLUTION GRID IN THE VERTICAL DIRECTION

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ABSTRACT. The present paper is devoted to the investigation how the disk structure is depending from the one-point wind one in microquasar CYG X-1. The results show that when the region in which the wind is absent in the vicinity of one-point has the size less or equal to 0.07 the disk radius is very small, order of 0.08 in units of orbital separation. When this size is increased to 0.115 the disk radius becomes to be of standard size to be equal to 0.22 in units of orbital separation. By the other words these results show that the disk structure is strong depending from many factors including and the donor's wind configuration in the vicinity of one-point. This configuration is inherent to microquasars only. Indeed, since microqausars are the massive close binary systems; the donor in these systems is massive star from which the strong radiation-driving wind is blowing. On the other hand, in microquasars accretion disks are present and it means that one-point stream is also present in microqausars. It in turn means that the matter configuration in the vicinity of one-point is very complicated since the high mass loss rate donor's wind and one-point stream must be existing in the vicinity of one-point simultaneously. This situation maybe resolved when we suppose that the central source in an accretion disk will influence on the donor's atmosphere structure in the vicinity of one-point and in turn will be result in the break of wind in the vicinity of one-point. This finally will be means that one-point stream will be existing in one-point without a wind and it, flowing in the accretor's Roche lobe, will be result in an accretion disk formation. Here one problem is arising: what is the configuration of wind in the extended vicinity of one-point and from what the parameters this configuration is depending and haw this configuration will be results to the disk structure change. We good understand that this situation is arising in the case of microquasars only and we try to resolve this problem in the present paper.

АНОТАЦІЯ. Дана стаття присвячена вивченню питання як структура диску залежить від вітру в точці L1 для мікроквазара CYG X-1. Результати показують, що коли розмір області, в якій вітер відсутній в околиці точки L1 , менше або дорівнює 0,07, радіус диску дуже малий, близько 0,08 в одиницях орбітального розподілу. Коли розмір області збільшується до величини 0,115 то радіус диску стає стандартним та рівним 0,22 в одиницях орбітального розподілу. Іншими словами, результати показують, що структура диску досить сильно залежить від багатьох факторів, включаючи конфігурацію вітру донора в околиці точки L1. Ця конфігурація властива тільки для мікроквазарів. Дійсно, оскільки мікроквазари є масивними тісними подвійними системами, донор в таких системах являєтья масивною зорею, від якої тече сильний радіаційний вітер. З іншого боку, в мікроквазарах акреційні диски присутні і це означає, що потік газу в околиці точки L1 також присутній. Це, в свою чергу, означає, що конфігурація речовини в околиці точки L1 дуже складна, оскільки вітер донора з високою швидкістю втрати маси та потік речовини з точки L1 повинні існувати в околиці точки L1 одночасно. Ця ситуація може бути вирішена, якщо припустити, що центральне джерело в акреційному диску буде впливати на структуру атмосфери донора в околоці точки L1 і це буде, в свою чергу, приводити до руйнування вітру в околиці точки L1. Це остаточно буде означати, що потік речовини в точці L1 буде існувати без вітру та він буде втікати в порожнину Роша акретора, приводячи до формування акреційного диску. Тут виникає одна проблема: яка конфігурація вітру в розширеній околиці точки L1 існує, від яких параметрів вона залежить та як ця конфігурація буде впливати на зміну структури диску. Ми добре розуміємо, що ця ситуація виникає тільки у випадку мікроквазарів,

то ж ми намагались вирішити цю проблему в даній статті.

Keywords: Stars: binaries - stars: jets - methods: numerical - hydrodynamics.

1. Introduction

The present paper is devoted to the numerical calculations of the dependence of the disk radius from the wind configuration in the vicinity of one-point in microquasar CYG X-1. We will to calculate the set of an accretion disk model with the variety of the regions in which the donor's wind is absent in the vicinity of one-point.

The paper have the four section. The first is an introduction. The second is the numerical model description. On the third one we describe our numerical results. The last section is the discuss and conclusions.

2. The numerical algorithm

The description of the numerical algorithm in use in details is given in our previous works (Nazarenko & Nazarenko, 2014, 2015, 2016, 2017; Nazarenko, 2018, 2019, 2020). Shortly, this algorithm is as follows: to resolve the non-stationary Euler's hydrodynamical equations we have used the astrophysical variant of "large-particles" code by Belotserkovskii and Davydov (Belotserkovskii & Davydov, 1982); to simulate one-point-stream we use the donor's atmosphere model that in turn is constructed on the base Kurucz's grid (Kurucz, 1979) with the donor's parameters; we use the free-flow boundary conditions allowing to a gas to flow freely via the calculation area boundaries; to calculate mass flow real temperature we use the radiation cooling explicitly (Cox & Daltabuit, 1971). In the present calculation we use the rectangular coordinate system centred on the donor's centre. We have adopted the donor's mass to be equal to 40 solar mass and the accretor's mass to be equal to 10 solar mass. The precession period in the present simulations is about of 8 orbital periods. Hereafter all the distances will be given in units of the orbital separations; the temperature will be given in units of EV; the density will be given in units of 10^{11} cm^{-3}; the times in the figures (see below) are given in units of the precession period. The initial one-point density is equal to 0.3134. In the present simulations the grid size is equal to 116*190*190. The cell sizes in orbital plane are equal to 0.00955 and this size in the vertical direction is equal to 0.0815. The last means that in our present simulations the jets will be launched on highness of 10000 Schwarzschild radiuses.

Accordingly Wijers and Pringle (Wijers R.A.M.J. & Pringle J.E., 1999) we have choose the mass transfer rate to be equal to $5{\cdot}10^{-8}$ solar mass per year. The donor's wind mass lost rate is order of $5{\cdot}10^{-4}$ solar mass per year.

3. The results

The range of the donor's wind models has two size of the region in which the wind is absent in the vicinity of one-point. These sizes are as 0.07 and 0.115. In the first size the accretion disk radius is very small and is equal to 0.08 (see Fig. 1; here the number 1 is marking the disk; the number 2 is marking the shock that is arising as the result of the interacting of two parts of the donor's wind are flowing upper and below a disk). In the second size the disk radius has the standard one (see Fig. 2; here the number 1 is marking the disk and the number 2 id marking the spiral one-armed shock in the disk) equal to 89 per sent of the accretor's Roche lobe radius i.e. 0.22. Such the two results show that in the case of the very strong and narrow wind in the vicinity of one-point the affection of this wind on a disk results in the strong decreasing of the disk radius (namely this situation is observed in microquasar CYG X-1 – Karitskaja E.A., Bochkarev N. 2006, private communication).

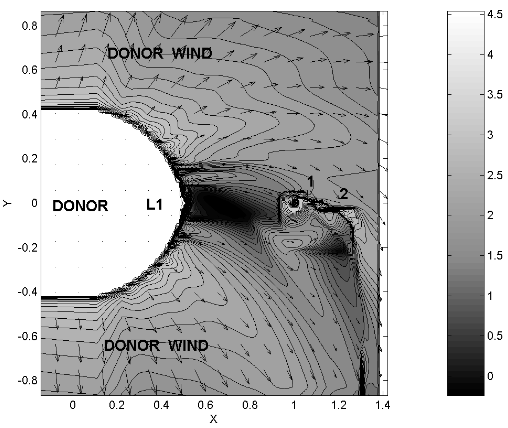

Figure 1: The orbital plane disk structure in the case of the wind in the vicinity of one-point with the size of 0.07.

4. Summary and conclusions

In the present paper we have confirmed numerically by the method of 3-D hydrodynamics that an accretion disk radius in microquasars is strong depending from the wind configuration in the vicinity of one-point. Indeed, when the region of the donor's wind vicinity one-point absence is order of or less 0.07 the our disk model have the small radius order of 0.08 of the orbital sep-

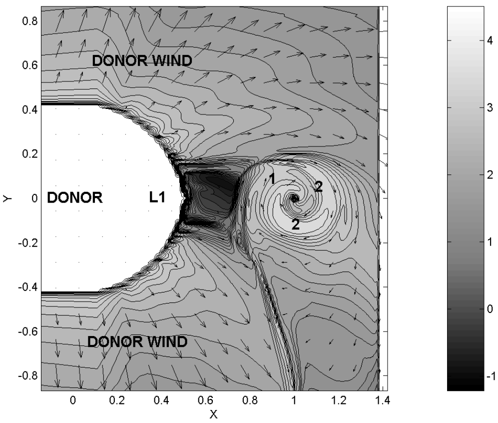

Figure 2: The orbital plane disk structure in the case of the wind in the vicinity of one-point with the size of 0.115.

aration that is about of 30 per sent of the accretor's Roche lobe. When this region size is more or equal to 0.115 the disk radius have the standard magnitude equal to 89 per sent of the accretor's Roche lobe (in the units of orbital separation this radius is equal to $0.22 \div 0.24$).

In the future works we will continue to analyse the influence of the physical parameters (the binary mass transfer rate, the wind configuration, the wind mass lost rate, the disk's viscosity) on the microquasar disk structure variety. In the future works we also will check how the dependence of the disk radius from the donor's wind configuration in the vicinity of one-point will to affect on ON-OFF state productions in precessing mechanism of generation of these states.

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