Simulation of protoplanetary disk images with embedded low-mass companions

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1 Introduction

The images of many protoplanetary disks have an asymmetric shape, that is usually explained by the inclination of the disk plane to the picture plane and anisotropic scattering of stellar radiation by circumstellar dust grains ([4]; [5] and others). But some of the asymmetric disk are observed almost face-on. In this report we discuss the models which can explain the asymmetry in that case. This work continues our study of asymmetries of images of the protoplanetary disks, caused by the motion of a low-mass companion, described in the paper [6]. It is also connected with the submitted paper [7].

2 Method

We consider the model of an young star with a protoplanetary disk and a low-mass companion ($q = M_1 : M_2 \leq 0.1$), which is moving on a circular orbit, slightly inclined to the disk plane ($\alpha \leq 10^\circ$). Periodic perturbations in the circumstellar disk caused by the orbital motion of the companion produce streams of matter and density waves ([1] and others). The inner part of the disk is warped because of the inclination of the companion orbit to the disk plane [3]: Fig. 1. For studies of these phenomena we calculated the set of the hydrodynamic models of such a system for the wide range of the parameters with SPH method (see [2] and references) and investigate the influence of gas-dynamic perturbations on the images of circumstellar disks in the IR wavelengths.

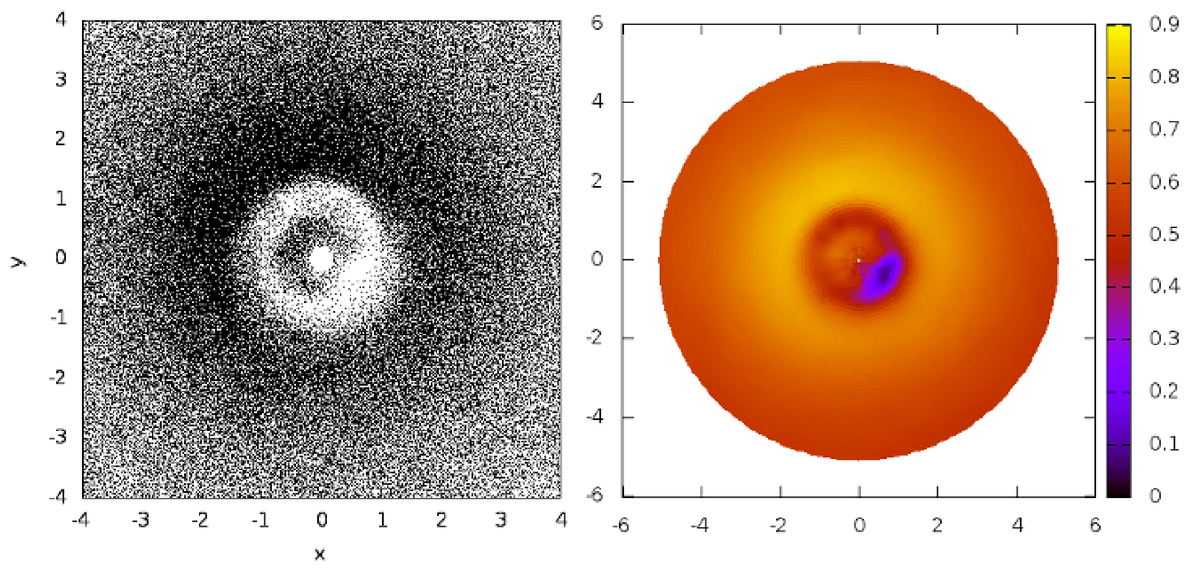

Figure 1: The matter distribution in the inner part of the disk, which sited above disk plane ($z \geq 0$) (left) and the height distribution of the disk matter, where the vertical optical dense equal 1 (model 1) (right). The scale of x, y axis and color one are in units of the semi-major axis a (here and below). The radius of the sublimation zone equal $0.2a$ ($q = 0.01, e = 0, \alpha = 10^\circ$ - model 1).

3 Discussion

If $q = 0.01$ asymmetry of images are connected with the inclination of the circumstellar disk of the main star. The form and amplitude of it depend on the radius of the dust sublimation zone (Fig. 2). In some cases the image of disk can has "horseshoe-like feature", which are very similar to some disk images observed almost face-on (Fig. 3).

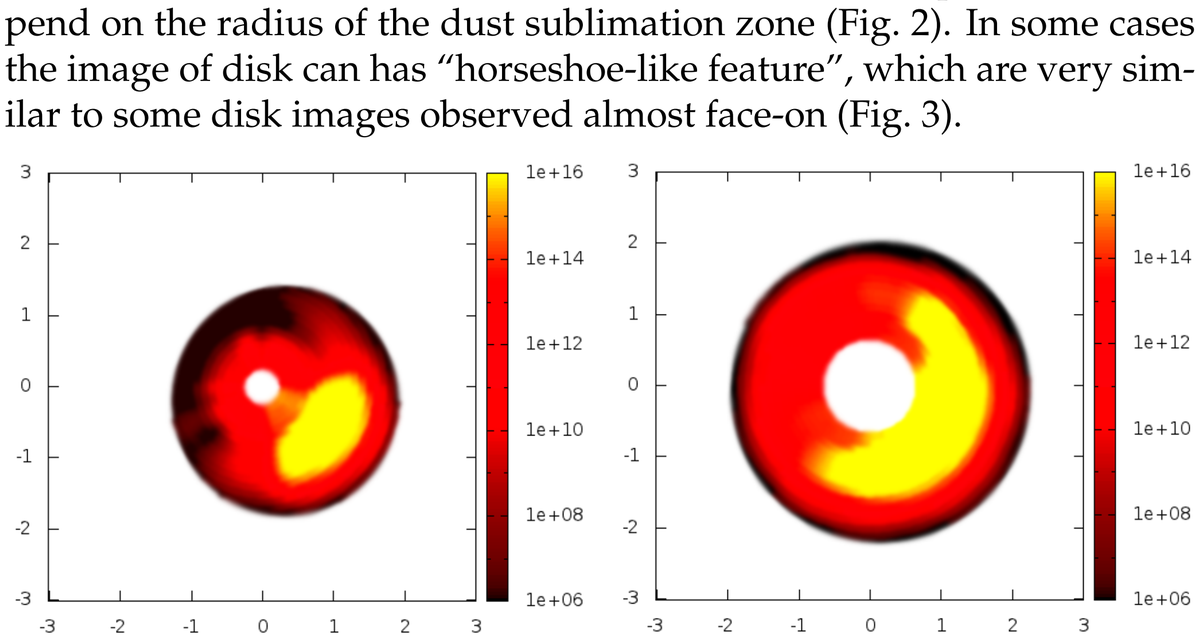

Figure 2: The theoretical images of the protoplanetary disk in model 1 in K-band. The radius of the sublimation zone $0.2a$ (left) and $0.6a$ (right). The color scale is in μJy (here and below).

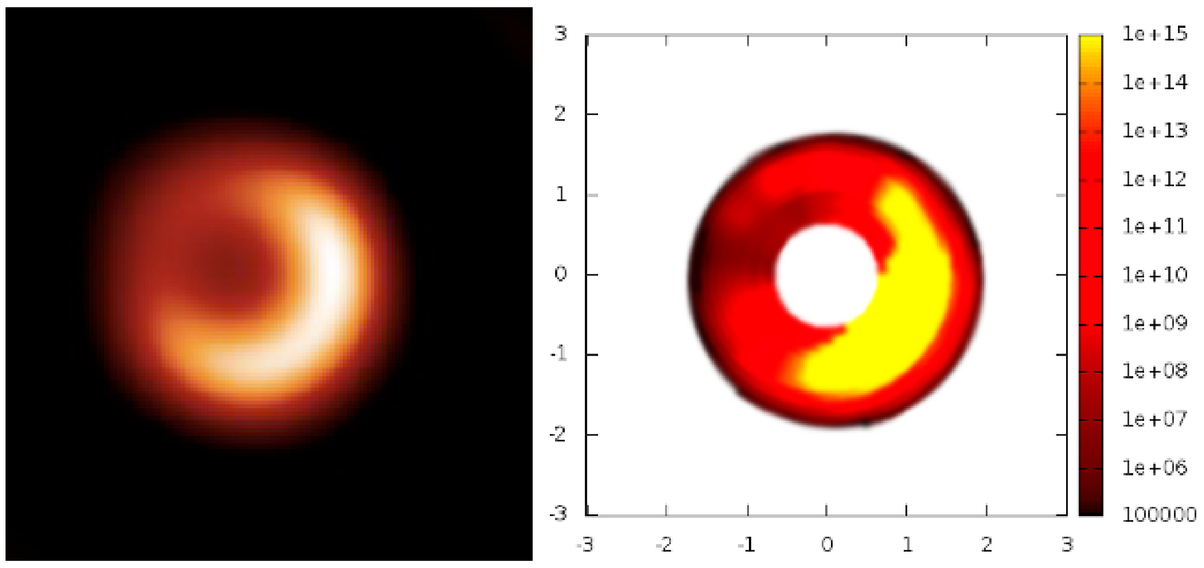

Figure 3: The observed disk image from the paper [4](left) and the theoretical image in K-band ($L_* = 1300 L_\odot, a = 4AU$, model 1).

If the orbit of the companion is eccentric one the asymmetric structures on disk images reflect the streams of matter, which support the accretion activity of the star and companion (Fig. 4).

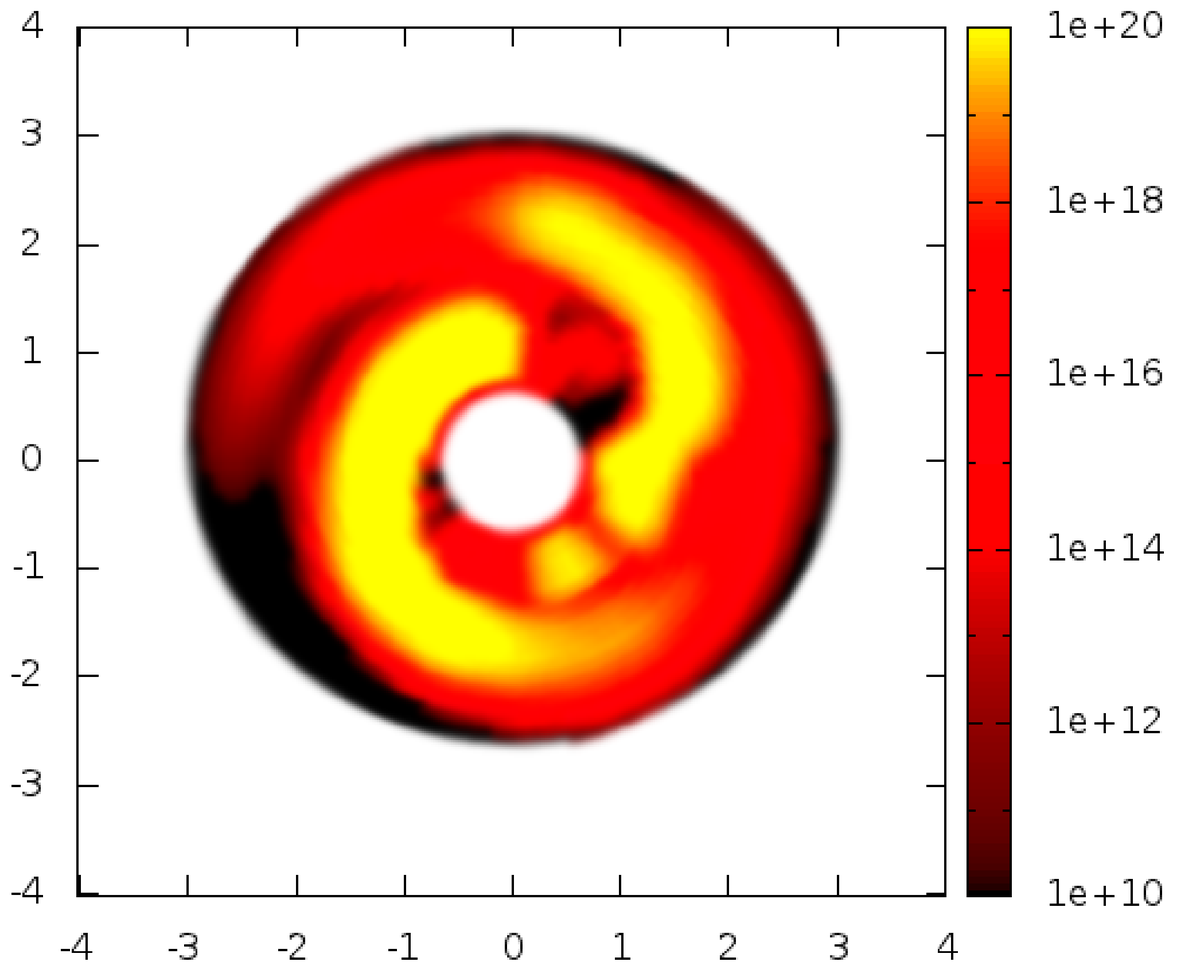

Figure 4: The theoretical images of the protoplanetary disk in model $q = 0.1, e = 0.5, \alpha = 0^\circ$ (model 2) in K-band.

The properties of the described model open new opportunities of searching low-mass companions in the sicrcumatellar disks of young stars. The stars with protoplanetary disks, which are observed face-on or under the small inclination angle α, are the best ones for this purpose.

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References

[1] Artymowicz & S. H. Lubow, Astrophys. J. 467, L77

[2] Sotnikova, Astrofizika 39, 259, 1996

[3] Larwood & J. C. P. Papaloizou, MNRAS 285, 288, 1997

[4] Tuthill et al, Astrophys. J., 577:826, 2002

[5] Marinas et al, Astrophys. J., 737:57 (19pp), 2011

[6] Demidova et al, Astron. Lett. , Vol. 39, pp. 26, 2013

[7] Ruge et al, A&A subm., 2013