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Evolution of Truncated Decretion Disks in Be/X-Ray Binaries

A.T. Okazaki

Faculty of Engineering, Hokkai-Gakuen University, Toyohira-ku, Sapporo 062-8605, Japan

M.R. Bate

School of Physics, University of Exeter, Stocker Road, Exeter EX4 4QL, UK

G.I. Ogilvie and J.E. Pringle

Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, UK

Abstract. We investigate the evolution of decretion disks around Be stars in Be/X-ray binaries, using a 3D SPH code. In Be disks in Be/X-ray binaries, the material ejected from the star gains the angular momentum by the viscous torque and loses it by the resonant torque exerted by the neutron star. As a result, the disk is truncated at a radius at which the resonant torque is larger than the viscous torque. Owing to the resonant truncation, the mass ejected from the star accumulates in the outer disk, making the density distribution in the radial direction much flatter than that in disks around isolated Be stars. The resonant truncation is more efficient for systems with a smaller orbital eccentricity.

1. Introduction

The Be/X-ray binaries represent the largest subclass of high mass X-ray binaries. These systems consist of a Be star (i.e., a B star with an equatorial disk) and, generally, a neutron star. The orbit is wide (several tens of days $\lesssim P_{\rm orb} \lesssim$ several hundred days) and eccentric ($0.1 \lesssim e \lesssim 0.9$).

Recently, using a semi-analytical model, Negueruela & Okazaki (2001) and Okazaki & Negueruela (2001) showed that the Be-star disk in Be/X-ray binaries should be truncated at a resonant radius, owing to the resonant torque extered by the neutron star. The purpose of this paper is to study the evolution of the Be disk in Be/X-ray binaries, based on numerical simulations.

2. Numerical Method and Assumptions

Simulations presented here were performed with a three-dimensional, smoothed particle hydrodynamics (SPH) code based on a version originally developed by Benz (1990). The artifificial viscosity was adjusted so as to keep Shakura-Sunyaev's viscosity parameter $\alpha = 0.1$. To model the mass ejection from the

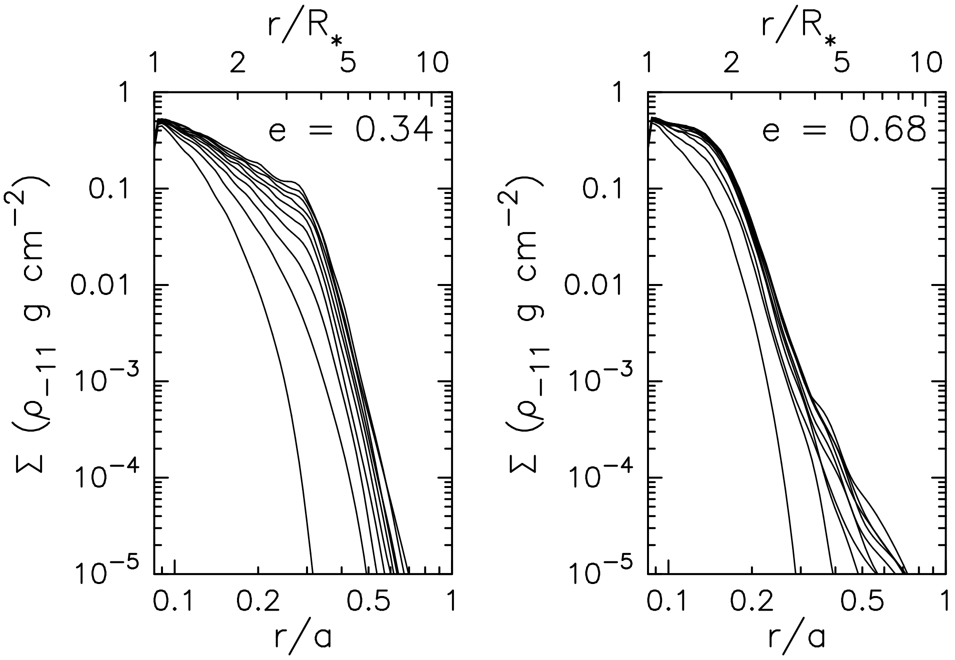

Figure 1. Surface density evolution of the Be decretion disk for $e = 0.34$ (left) and $e = 0.68$ (right). The time interval between adjacent contours is $5P_{\rm orb}$ ($t = 5P_{\rm orb}, \dots, 50P_{\rm orb}$ from bottom to top). $\rho_{-11} = \rho_0/10^{-11}\,{\rm g\,cm^{-3}}$, where ρ_0 is the base density of the disk.

Be star, isothermal particles rotating at the Keplerian angular velocity were injected, at a constant rate, into a radius just outside the stellar surface. We took a system of an $18M_\odot$ Be star and a $1.4M_\odot$ neutron star with an orbital period of 24.3 d (semimajor axis $a \sim 12R_*$, where R_* is the stellar radius).

3. Evolution of Truncated Disks around Be Stars in Be/X-Ray Binaries

Figure 1 shows the surface density evolution of the Be disk in Be/X-ray binaries with two different values of orbital eccentricity e. From Figure 1, we note that the Be disk in Be/X-ray binaries is resonantly truncated at a radius smaller than the periastron distance, but the resonant truncation is less efficient and more mass goes to the neutron star for a higher orbital eccentricity.

References

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