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Numerical Simulation of an Accretion Disc in a Close Binary System : Angular Momentum Transfer due to Spiral Shocks

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Among various models of accretion disc in a close binary system, the alpha disc model is thought to be the standard one. One of alternative models is the spiral shock model. We perform three-dimensional numerical simulations of Roche lobe overflow in a close binary system using various parameters. We confirm that spiral shocks exist in all cases. The stream from L1 point penetrates into the accretion disc. Disc gas collides with the L1 stream to form a bow shock. Due to this shock, gas accretes more than we expected in 2D calculation.

Recently, spiral structure has been found in the accretion disc of some cataclysmic variables. Observed spiral structure is very similar with one obtained in numerical simulations.

One of the main longstanding problems of accretion discs in a close binary system is a mechanism of angular momentum transport. Among proposed mechanisms, the alpha model (Shakura & Sunyaev 1973) is thought to be the standard one. In this model, viscosity originating from turbulence, magnetism or whatever, is supposed to transport angular momentum. One of alternative models is the spiral shock model. In this model the tidal force due to a companion star excites stationary spiral shock waves in the accretion disc. The gas in the disc loses its angular momentum when it passes through the spiral shocks. This angular momentum is transported to the orbital angular momentum of the binary system via tidal interaction.

The alpha disc model essentially predicts an axi-symmetric structure of the disc except for the stream from the L1 point, while the spiral shock model predicts a bi-symmetric structure except for the stream. This fact is very important in order to distinguish between the two models observationally.

This spiral shock model was proposed by Sawada, Matsuda & Hachisu (1986) in which they carried out 2D calculations and found the spiral shock numerically. Since then, a number of two-dimensional simulations have been performed and they have confirmed that spiral shocks appear in accretion discs. Spruit (1987) obtained self-similar solutions of spiral shocks in a semi-analytic manner.

Latest progress of computor resources enables us to do three-dimensional calculations with sufficient resolution. The existence of spiral shocks has been confirmed even in 3D.

We perform three-dimensional numerical simulations of Roche lobe overflow in a close binary system using finite volume method. We use specific heat ratio of ideal gas, mass ratio of binary system and temperature of secondary star as parameters.

Our results are written below:

1) Spiral shocks exist in all cases.

2) The stream from L1 point penetrates into the accretion disc.
So there is no hot spot.

3) Disc gas collides with the L1 stream to form a bow shock. Due to this shock, gas accretes more than we expected in 2D calculation.

Recently, Steeghs, Harlaftis & Horne (1997) found the first convincing evidence for spiral structure in the accretion disc of the eclipsing dwarf nova binary IP Pegasi using the technique known as Doppler tomography. Dwarf novae are subclass of cataclysmic variables. Since then, spiral structure has been found in the accretion disc of some cataclysmic variables. Observed spiral structure is very similar with one obtained in numerical simulations. However, that disc which agrees well with observed one is rather hot compared with what is ordinarily assumed for dwarf novae. This discrepancy between the simulations and observations is an important problem to solve.