COMPUTER SIMULATIONS OF GAS FLOW
AROUND CLOSE BINARY SYSTEMS

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Abstract. A gas-dynamical model of gas streams around close binary systems is given. The velocity field and the density distribution are determined for different parameter ranges. The results succeed in explaining the formation of a ring and a disk around the accreting component. The models furthermore reveal the existence of a tongue of matter extending from the inner Lagrangian point and a jet perpendicular to the system axis.

1. Introduction

It is well known that most close binary systems have envelopes in the form of gas streams. The density in these streams is of the order of $10^{15}$ particles cm$^{-3}$, and the mean free path of the particles is small compared to the typical length of the systems. Thus the application of a hydrodynamical model is crucial.

Early treatments used a stationary pressure-free model of a rarefied gaseous stream (Prendergast, 1960). A different approach was based on the energy and angular momentum balance (Huang, 1965, 1966). Despite the fact that these models include unrealistic assumptions, the results agree well with observations in showing circular motion along the equipotential surfaces. Also the existence of a ring around the accreting component is indicated. A more recent model (Biermann, 1971) treats the case of supersonic outflow and discusses the appearance of shock waves in the stream.

Although the above mentioned results are interesting, they cover only the extreme cases of mass flow, and the intermediate range has not been studied. Moreover, a realistic model of the density distribution does not exist as far as we know.

In what follows we shall apply a time-dependent Fluid-in-Cell type method to study the above problems for the intermediate range of parameters. All models evolved to a stationary state after a certain lapse of time, except for minor regions of turbulence. The results agree well with observations; our models predict the existence of disk and ring structures. Furthermore, they show a tongue of matter extending from the inner Lagrangian point towards the accreting component preceding the eclipse of this component by the mass-losing star, and explain the appearance of a jet perpendicular to the system axis.

2. The Model

Let us consider a semidetached close binary system in which one component has evolved to fill its Roche-lobe, and the other is taken as an accreting mass particle.
Taking into account the observed small eccentricities of such systems, we assume that the components revolve in circular orbits with constant angular velocity.

The known close binary systems are almost all eclipsing binaries, where valuable information is obtained from the area close to the orbital plane. Furthermore, the importance of the inner Lagrangian point (L1) and of the Coriolis force tend to confine the gaseous motion in the orbital plane. Corresponding to this circumstance, and assuming a disk flow of constant thickness, we restrict ourselves to a two-dimensional treatment.

Because the mass-losing star, which has evolved to fill its Roche-lobe, is expected to be a giant, the mass is strongly concentrated in this component. Thus the tidal effect diminishes, and a pure Roche potential can be applied.

The effect of the magnetic field was roughly examined by the use of a ‘harder’ gas, i.e., a gas with a higher ratio of the specific heats ($\gamma$). As no significant change in the results was found, however, the influence of a magnetic field will be disregarded. The gas is assumed to be adiabatic.

Fig. 1. Roche potential; equipotential lines for mass-ratio $\eta = 1$ [top] and $\eta = \frac{1}{3}$ [bottom].