Wolf-Rayet Phenomena in Massive Stars and Starburst Galaxies
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Colliding stellar winds: magnetic field structure in the interaction region

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Abstract. The geometry structure of the magnetic field in colliding stellar winds is studied. It is shown that the magnetic field influence in the interaction region depends mainly on the ratio of the wind ram pressures of the components, the ratio of the stellar linear rotational velocity to the wind velocity of the magnetized star, and the stellar separation. For the radiative colliding winds the magnetic field influence increases with the importance of the radiative losses. An asymmetric magnetic field structure appears for a given set of binary parameters and the interaction region might be an asymmetric source of non-thermal radio emission.

1. Introduction

The theoretical studies of colliding stellar winds (CSW) in binary systems have been actively carried out in the last decade. Many aspects of the CSW hydrodynamics have been considered up to now (see Myasnikov, Zhekov & Belov 1998 (MZhB) and references therein). On the other hand, an aspect of CSW physics, namely, the non-thermal phenomena, has not been considered properly yet in CSW numerical modelling.

It is well known that a consideranle number of the luminous OB stars and Wolf-Rayet stars are non-thermal, often variable, radio sources (Abbott *et al.* 1986; Bieging *et al.* 1989; van der Hucht *et al.* 1992; van der Hucht 1992; Leitherer *et al.* 1995, 1997). It has to be mentioned, that apart from the non-thermal radio emission, there is no other indication of magnetic fields existence in luminous OB and WR stars. Nevertheless, it is our belief that studying the magnetic field role in the CSW physics is an important issue which has to be considered in the numerical modelling.

2. Model

For the description of the stellar magnetic field we use the simplified Parker (1958) model. This model assumes that the gas outflow (the wind) is radially symmetric and its velocity is considerably larger than the stellar linear rotational velocity. Moreover, the gas flow structure is not influenced by the magnetic field.

Thus we calculate the magnetic field distribution using the so-called *kinematic* approximation (valid for large values of the Alfvén Mach number). It enables us to split the whole complicated MHD problems into two parts. Firstly, the calculation of the hydrodynamical structure is performed, and then, on the basis of the known velocity distribution, the magnetic field is calculated as well. As a result the validity of the kinematic approach may be estimated.

If the magnetic field is normalized by its value at some distance, its distribution depends on the following parameters: *(i)* the ratio of the wind ram pressures of the components in the binary; *(ii)* the ratio of the linear rotational velocity to the wind velocity of the magnetized star; and *(iii)* the stellar separation. Additionally, it also depends on the energy losses in the case of radiative colliding winds. To account for the cooling processes we consider only the free-free emission from a optically thin plasma. The reason for that is related to the problems due to a singularity presence in the stagnation point, which the radiative steady-state colliding winds models face (see, MZhB for details).

3. Discussion

For brevity we will use the following notations. Λ: the ratio of the ram pressures of the stars; ω: a coefficient proportional to the ratio of the stellar linear rotational velocity to the stellar wind velocity; Γ_{ff}: the ratio between the dynamic time-scale for the problem to the characteristic cooling timescale. Thus, the main results and conclusions can be summarized as follows.
(i) The influence of the magnetic field in the interaction region gradually increases with the increase of ω. The same is true for the parameter Γ_{ff}. For binaries with small ω parameter, if the magnetized star is the one with the weaker wind (smaller ram pressure), the influence of the magnetic field will increase with the increase of Λ. The opposite is valid for the case when the magnetized star is the one with the stronger wind. For binaries with large ω parameter the magnetic field influence does not depend on Λ.
(ii) For binaries with intermediate ω parameter an asymmetric magnetic field structure appears in the interaction region. Thus, such binaries are expected to be asymmetric sources of non-thermal radio emission. Observations with good enough spatial resolution may give some information about the stellar magnetic field axis orientation. A detailed description of the model and the results will be be given elsewhere.

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