Available online at www.sciencedirect.com
ScienceDirect
Advances in Space Research 46 (2010) 493–499
ADVANCES IN SPACE RESEARCH (a COSPAR publication)
www.elsevier.com/locate/asr

Wolf–Rayet optically thick winds with Alfvén waves

G.R. Keller, V. Jatenco-Pereira *

Instituto de Astronomia, Geofísica e Ciências Atmosféricas, Universidade de São Paulo, Rua do Matão, 1226, Cidade Universitária, São Paulo/SP CEP 05508-900, Brazil

Received 31 January 2008; received in revised form 1 September 2009; accepted 8 October 2009

Abstract

The Wolf–Rayet (WR) stars are hot luminous objects which are suffering an extreme mass loss via a continuous stellar wind. The high values of mass loss rates and high terminal velocities of the WR stellar winds constitute a challenge to the theories of radiation driven winds. Several authors incorporated magnetic forces to the line driven mechanism in order to explain these characteristics of the wind. Observations indicate that the WR stellar winds may reach, at the photosphere, velocities of the order of the terminal values, which means that an important part of the wind acceleration occurs at the optically thick region. The aim of this study is to analyze a model in which the wind in a WR star begins to be accelerated in the optically thick part of the wind. We used as initial conditions stellar parameters taken from the literature and solved the energy, mass and momentum equations. We demonstrate that the acceleration only by radiative forces is prevented by the general behavior of the opacities. Combining radiative forces plus a flux of Alfvén waves, we found in the simulations a fast drop in the wind density profile which strongly reduces the extension of the optically thick region and the wind becomes optically thin too close its base. The understanding how the WR wind initiate is still an open issue.
© 2010 COSPAR. Published by Elsevier Ltd. All rights reserved.

Keywords: Alfvén waves; Wolf–Rayet stars; Stellar winds; Acceleration mechanism

1. Introduction

The stellar wind is the loss of material from the star's external layers. In this process, the material is accelerated outward from an almost static base until it reaches a hight terminal velocity far from the star. Many mechanisms have been suggested in attempting to explain the several different types of winds from distinct objects, such as the radiation pressure on atoms and free electrons (Castor et al., 1975), and on dust particles (Netzer and Elitzur, 1993); gas pressure due to high temperature coronal regions (Parker, 1958) pulsation in AGB stars; sound waves (Pijpers and Hearn, 1989); mechanisms involving magnetic fields, such as Alfvén waves (Parker, 1965) and magnetic rotators (Weber and Davis, 1967), among others.

In the case of massive stars, which are characterized by surface temperatures much higher than the Sun's, the strong radiative fields are thought to be responsible for starting the wind through the radiation pressure. Here, the stellar photons interact with particles in the wind material, such as free electrons and ions of abundant elements, and transfer them their outward directed moment, which is shared with the rest of the wind by Coulomb coupling.

In this work, we make use of the acceleration mechanisms of radiation pressure in the optically thick regime and the one due to a flux of Alfvén waves in the presence of a magnetic field to try explaining how the exceptional winds of Wolf–Rayet (WR) stars are initiated.

1.1. WR stars and their stellar wind

The WR are a peculiar class of stars that, unlike most, present spectra dominated by large emission lines that constitute evidence of strong mass loss. The WR stars are,

* Corresponding author.
E-mail address: jatenco@astro.iag.usp.br (V. Jatenco-Pereira).

0273-1177/$36.00 © 2010 COSPAR. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.asr.2010.03.008

indeed, hot and luminous objects undergoing intense mass loss by means of the denser stellar winds observed among any class of stars. The mass loss observed in these objects are extreme and typically exceeds $10^{-5}\ M_{\odot}$ year^{-1}. Their terminal velocities are also very high and are found in the interval between 700 and 6000 km s^{-1} (Nugis et al., 1998; Nugis and Lamers, 2000). WR stars are thought to be a more evolved stage in the life of stars once very massive, which lost most of their hydrogen rich outer layers, letting exposed in their surface, elements such as carbon, nitrogen, and oxygen, synthesized by nuclear processes inside the star.

These stars present hydrostatic radii of only a few solar radii and their extremely high mass loss rates cause the inner part of the wind to be optically thick so that the star is obscured by it, and only the optically thin part of the atmosphere is seen by the observer (Crowther, 2007). Fig. 1 shows a scheme of the WR wind structure. Above the stellar hydrostatic core (in black), we have the optically thick part of the wind (dark grey area) followed by the optically thin part (light grey area) which continues indefinitely. The photosphere is placed in between the optically thick and thin parts of the wind. Observations indicate that the WR stellar winds can reach very high velocities already at the photospheric radius (Marchenko and Moffat, 1999; Cherepashchuk et al., 1984), which means that an important part of the wind acceleration occurs below the photosphere, at the optically thick part of the wind (Kato and Iben, 1992; Nugis and Lamers, 2002).

Although the WR stars are among the most luminous stellar objects, even their basic properties, such as radii and luminosities are not well established. This happens because their dense winds obscure the stars. Schaerer and Maeder (1992) built up a series of theoretical relations among parameters of the hydrostatic core and its mass. These relations provided us with estimates for the physical parameters of the stellar hydrostatic core and for the initial conditions necessary to our model.

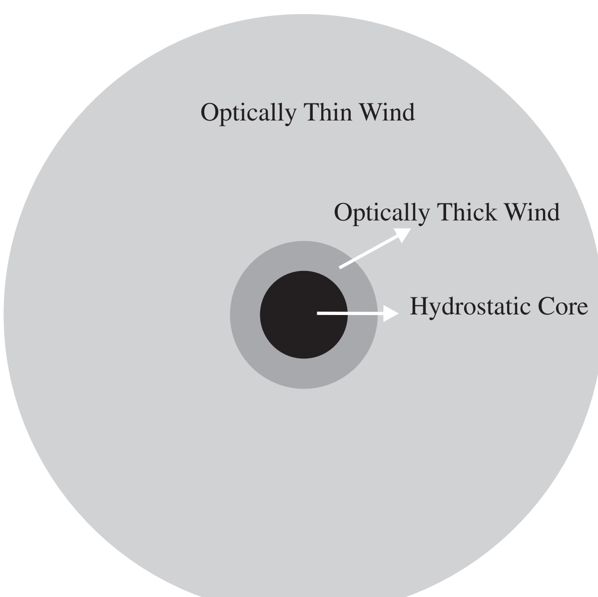

Fig. 1. WR structure scheme with the hydrostatic core appearing in black, the optically thick part of the wind appearing in dark grey, and the optically thin wind, in light grey. The photosphere is placed in between the optically thick and thin parts of the wind (Crowther, 2007).

1.2. The WR momentum problem

The high values of mass loss rates and high terminal velocities of the WR stellar winds challenge the theories of radiation driven winds usually applied to other hot stars such as OB-type stars. This happens because, despite the fact that WR stars have both luminosities and terminal wind velocities comparable to those of the O-stars, their mass loss rates are about an order of magnitude higher than those of O-type stars of similar luminosities. The question that follows then is whether or not the radiative luminosity can generate enough force to drive the WR denser winds. A positive answer requires the momentum transfer, from the radiation to the gas, in the WR winds, to be more efficient than that occurring in the winds of O-type stars by a factor ten. In this context, it is usual to define the efficiency for the transfer of radiative momentum into wind momentum, η, as the ratio between the scalar momentum of the wind in the radial direction and the momentum of the radiation field of the star. In principle η should have values between zero and one, as is indeed observed in OB-type stars. In the particular case in which $\eta = 1$, we have the so-called ‘single scattering upper limit’, in which all photons leaving the star are absorbed or scattered in the wind. This limit is based on the assumption that only the first scattering of a photon contributes to the radiation pressure. For the WR stars, however, η is often found to be higher than one and values in the range $1 < \eta < 20$ have been obtained using clumping-corrected mass loss rates (Nugis and Lamers, 2000), meaning that the momentum of the wind is higher than the momentum of the radiation field that should to move it. This difficulty in applying the line driven wind models to the WR stars became known as the ‘momentum problem’.

To solve the momentum problem, one first effort would be to improve the radiation driven wind theory to obtain the missing momentum from the radiation field. A second one consists simply in the search for other forces capable of driving a stellar wind (e.g. dos Santos et al., 1993a,b).

Gräfener and Hamann (2005) applied their non-LTE atmosphere models for WR stars that incorporate a self-consistent solution of the hydrodynamic equations to different Wolf–Rayet (WR) subtypes (Gräfener and Hamann, 2005, 2006, 2008). The basic result from these computations is that the enhanced WR-type mass loss is primarily triggered by the proximity to the Eddington limit. Also, the triggering of the wind depends of the location of the iron opacity peak, what requires extremely high stellar temperatures. For intermediate spectral subtypes their models predict no mass loss, despite the fact that such objects are commonly observed. They thus conclude that other pro-

Download English Version:

https://daneshyari.com/en/article/1765342

Download Persian Version:

https://daneshyari.com/article/1765342

Daneshyari.com