The modeling of high energy activity in binaries containing a pulsar

Key words

binary stars, gamma radiation, radiation modelling

Abstract

The observational data collected by the LAT detector placed on-board the Fermi space observatory caused an enormous growth in the number of registered gamma-ray sources. The previously unknown type of binaries, composed of a massive star and a compact object, emitting high energy gamma-ray radiation ($> 100\,\mathrm{MeV}$), was revealed. These gamma-ray binaries constitute a small and not well known group. Despite intensive observational effort, the nature of the compact object in most of these systems remains unknown. The spectral characteristics of the gamma-ray binaries are similar to the emissions from the gamma pulsars.This feature was the reason the model of high energy emission from gamma-ray binaries was created based on the assumption, that a pulsar is the compact object in such systems. A high energy flux modulation with a period consistent with the orbital period indicates an additional process responsible for the high energy emissions.

A deep study of gamma-ray binaries allows to gain and broaden the current knowledge about the physical processes occurring in extreme conditions. Neither the mechanism of particle acceleration nor the production of high energy radiation is yet well understood. A lack of a full understanding of these phenomena is reflected in simplifications used in models of gamma-ray binaries. Among works, in which pulsar is assumed to be a compact object in gamma-ray binaries, one can list Dubus et al. (2008); Sierpowska-Bartosik & Torres (2008); Bednarek (2011); Dubus et al. (2015).

In this thesis, a model of a high energy emission from gamma-ray binaries is presented. It is based on the inverse Compton scattering process of stellar photons in the unshocked pulsar wind region. The model was applied to the best known member of a mentioned group of binaries – binary LS 5039. The main goal of this thesis is to investigate the impact of the shape of the electron energy distribution on the validity of the model results when confronted with observations, i.e. spectra and light curves. Furthermore, the impact of including the shock, formed as a result of a collision of the magneto-hydrodynamic pulsar wind with the stellar wind, was established. Additionally, a hypothetical region was considered, in which the pulsar wind particles are accelerated.

The thesis is organized in sections, where the first is an introduction to the high energy astrophysics. The prime discoveries are described, which led to starting the observations in the high energy band and their development in time. The second section is dedicated to the theoretical knowledge and the observations of pulsars. In the next section the observations of known gamma-ray binaries are described. The

fourth section contains specifications on a selection of models of LS 5039 binary, in which a pulsar is considered as the compact object. The model created by the author of this thesis is introduced in the fifth section. The next section is dedicated to the detailed analysis of the significance of the parameters of the model and their impact on the results. In the seventh section the results of the model for the binary LS 5039 are presented for different assumptions. This section also contains several parameter values selected for the best compatibility between the observations and the model result. The summary of this work is presented in the eight section. Additionally, one appendix is included containing used notation with a short description.

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