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Interaction between the Be star and the compact companion in TeV γ-ray binaries

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Abstract. We report on the results from 3-D SPH simulations of TeV binaries with Be stars. Since there is only one TeV binary (B 1259-63) where the nature of the compact companion has been established, we mainly focus on this Be-pulsar system. From simulations of B 1259-63 around periastron, we find that the pulsar wind dominates the Be-star wind and strips off an outer part of the Be-star disk, causing a strongly asymmetric, phase-dependent structure of the circumstellar material around the Be star. Such a large modulation may be detected by optical, IR, and/or UV observations at phases near periastron. We also discuss the results from simulations of another TeV binary LS I+61 303, for which the nature of the compact object is not yet known.

Keywords. gamma rays: theory, stars: emission-line, Be, stars: winds, outflows, stars: individual (B 1259-63, LS I+61 303)

1. Introduction

Recent progress in VHE γ-ray astronomy, driven by ground-based Cherenkov telescopes such as H.E.S.S., MAGIC & VERITAS, has established TeV ($= 10^{12}$ eV) γ-ray binaries as a new class of γ-ray sources. There are only three binaries and one binary candidate that show persistent TeV emission. The nature of the compact object has been established only for one system (B1259−63). Interestingly, three among these four systems have a Be star, which is an early-type star with a polar wind and a dense equatorial disk. Interaction between the Be-star envelope and the compact companion is a key to modeling these systems and understanding physics of high energy emission.

In this paper, we report on the results from 3-D SPH simulations of two TeV binaries, B1259−63 ($P_{\rm orb} = 3.4\,{\rm yr}$, $e = 0.87$) and LS I+61 303 ($P_{\rm orb} = 26.5\,{\rm d}$, $e = 0.537$), both of which have a Be star as the primary. In B1259−63 consisting of a B2Ve star and a

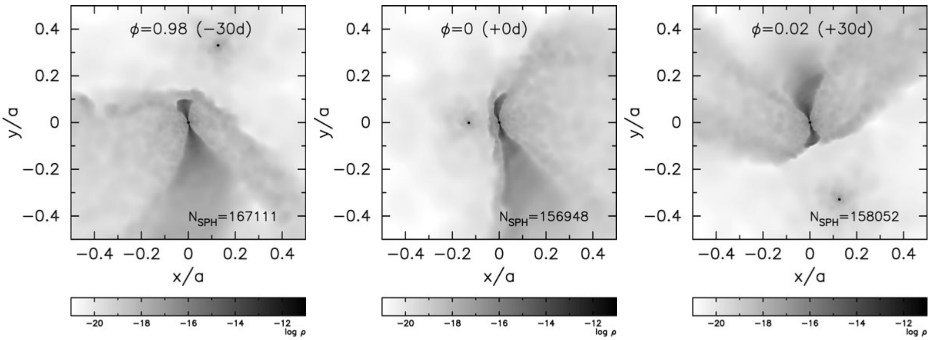

Figure 1. Snapshots of the interaction in B1259−63 around periastron: one month prior to periastron (*left*), periastron (*middle*), and one month after periastron (*right*). The grey-scale plot shows the density on the orbital plane in the logarithmic scale. The Be star has the mass loss rates of $4 \times 10^{-9} M_{\odot}\mathrm{yr}^{-1}$ via the equatorial disk and $10^{-9} M_{\odot}\mathrm{yr}^{-1}$ via the stellar wind, while the pulsar wind has the power of $8.2 \times 10^{35}\,\mathrm{erg\,s}^{-1}$. Annotated in each panel are the orbital phase and the number of SPH particles.

pulsar, the pulsar wind collides with the Be disk and wind, whereas in LS I+61 303, where the nature of the compact object is not yet known, there is a debate on whether it is a colliding wind binary (Dubus 2006) or a microquasar (Romero et al. 2007).

2. Numerical model

Simulations presented here were performed with a 3-D SPH code, in which optically thin radiative cooling is taken into account. In these simulations, relativistic pulsar wind is emulated by a non-relativistic 10^4 km s^{-1} wind with the adjusted mass-loss rate so as to give the same momentum as a relativistic flow with the assumed energy.

3. B1259−63

Figure 1 shows snapshots of the interaction in this proto-typical TeV binary around periastron. From the figure, we note that the pulsar has a huge influence on the circumstellar environment of the Be star. The wind from the pulsar dominates the Be-star wind and strips off an outer part of the Be-star disk on the side of the pulsar. The strongly asymmetric, phase-dependent structure of the circumstellar material around the Be star may be detected by optical, IR, and/or UV observations.

4. LS I+61 303

In order to see whether two competing models, i.e., a colliding wind model and a microquasar model, are distinguished by studying the Be disk structure, we have carried out a simulation based on each model. Our preliminary results show that the effect of the compact object on the Be disk structure is undistinguishable between these models, as long as the power of the pulsar wind $\lesssim 10^{36}\,\mathrm{erg\,s}^{-1}$, but this has to be confirmed by further detailed studies.

References

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