Referee report of the PhD thesis of Jakub Cehula „Theory of stellar mass loss: from binary stars to magnetars"

The PhD thesis studies particular types of stellar mass loss. The thesis is structured into six chapters. Apart from the first introductory chapter and the last concluding chapter, the thesis is based on papers by Jakub Cehula, which were either published in or submitted to the refereed journals.

The second chapter of the thesis contains a paper published in the refereed journal Monthly Notices of the Royal Astronomical Society. Jakub Cehula is the first author of the paper. The paper describes a novel method to calculate the mass-loss rate in semi-detached binaries. The method describes the mass transfer in an analogy with the nozzle flow.

The third chapter builds on the previous work of the applicant and generalizes the mass-transfer theory for stars in the proximity of the Eddington limit. The chapter describes the effect of the radiative force on the mass transfer in binary stars. This chapter is taken from a paper submitted to Monthly Notices of the Royal Astronomical Society. Jakub Cehula is the first author of this paper.

The fourth chapter describes a completely different problem: the dynamics of baryon ejection in magnetar giant flares. This chapter contains a paper published in the journal Monthly Notices of the Royal Astronomical Society. Jakub Cehula is again the first author of this paper. The paper describes a possible model for the magnetar giant flares based on the mass ejection from the surface of the neutron star. The radiation hydrodynamic calculations presented in the paper are able to explain the basic properties of the giant flares.

The fifth chapter summarizes the results of two papers co-authored by Jakub Cehula, which appeared in The Astrophysical Journal and which further develop ideas from Cehula's previous paper. These papers provide additional tests of the giant flare model and show that magnetars could be major sites of r-process nucleosynthesis.

I consider the method for the calculation of the mass transfer rate in binaries as a very original one. The model builds on the nozzle-flow solution of the hydrodynamical equations, which seem to provide a more physically-motivated approach to the solution of hydrodynamical equations than the approaches available in the literature so far. Moreover, the model unifies the previously available prescriptions. I consider the provided solution as a textbook example of the usage of hydrodynamical equations.

On the other hand, I consider the described inclusion of radiation in the mass transfer problem in binaries to be just a first step in this problem. The problem of the mass transfer in stars in proximity to the Eddington limit is a very interesting one and the approach to the solution of this problem provided by the author is also a novel one. However, I think that the radiative transfer in such environment is at least a 2D problem, and I do not think that it can be easily reduced to a 1D problem. In my view, the radiation avoids the region with high opacity, and, consequently, its influence on the flow between binaries could be limited.

The work on the magnetar giant flares provides new and very interesting results. The model reproduces basic observational properties of these flares and could be a major reference for the study of nucleosynthesis. However, the absence of the magnetic field is the obvious shortcoming of the model.

I have several minor comments on the thesis. The accretion flow in high-mass X-ray binaries does not necessarily form a disk (page 11), and the accretion does not typically occur via wind, but via Be-star disk. I would suggest adding some citations to the first

two paragraphs of page 24. It is unclear how the photosphere is defined in Eq. (2.7). Isothermal approximation is typically not valid even in the case of optically thin flow (Sect. 2.2.2). Could not the solution with decreasing velocity in Fig. 2.6 describe an accretion?

It would be relevant to cite the results of the Leuven group (e.g., Debnath et al. 2024) related to the super-Eddington layers in the introduction to Sect. 3. It is confusing to state that super-Eddington layers appear due to iron ionization (page 99) or „massive stars can exceed the continuum Eddington limit" (page 72), because so-called iron opacity bump appears due to iron lines. The algebraic solutions in Sect. 3.4.3 are valid only for constant $\Gamma_{\rm edd}$, what is typically not true in the surface layers of massive stars. Therefore, it is also confusing to mention „a surface Eddington factor $\Gamma_{\rm edd} = 0.78$" (page 85) without mentioning the exact location. The photon tiring limit of Owocki et al. (2004) was devised for gray electron-scattering opacity and its applicability to non-gray opacities might not be straightforward. Also the related sentence on page 97 „super-Eddington ... subsurface layers ...should not develop super-Eddington outflows, because the implied mass-loss rates exceed the photon tiring limit" is also confusing due to a limited extent of such layers.

I have a few questions concerning the thesis:

- The model of mass transfer in Sect. 2 assumes just radial flow, while the model of Kolb & Ritter assumes flow along equipotentials. Is it not possible that, in reality, the flow direction is general, that is, both in radial and tangential directions? Are there any numerical simulations describing such flow available?

- How do the consequences of the von Zeipel theorem affect the mass transfer?

- How the provided model of mass ejection during the magnetar giant flares compares to the MHD model of Thompson & ud-Doula (2018)?

In my view, the thesis brings outstanding results. It is very rare to see analytical solutions of hydrodynamical equations, which still bear strong astrophysical sense. Both the work on mass transfer in binaries and magnetar giant flares could become a major reference for future models. The work done by Jakub Cehula shows that he is a very promising scientist. I think that the thesis fulfills the requirements of the PhD thesis and I recommend Jakub Cehula to be awarded a PhD degree.

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In Brno August 28, 2025