FACULTY
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Supervisor's report on Doctoral Thesis

Author: Milan Pešta

Title: Illuminating binary star evolution with observed populations and theoretical modeling

The doctoral thesis of **Milan Pešta** focuses on the interplay of statistical modelling of large datasets using machine learning techniques and open problems in the evolution and fate of binary stars, including systems harboring black holes and neutron stars. Both issues are compelling and timely since they are broadly related to recent advances in gravitational wave astronomy and efforts to make sense of large data volumes coming from time-domain surveys of the sky.

Milan's thesis is divided into five Chapters and a final Conclusion section. The first two Chapters provide broader context to the rest of the thesis. The first Chapter introduces various types of binary stars and their methods of detection with a particular focus on binaries containing one "dark" component, which could be either a neutron star or a black hole. The Chapter is generally very clearly written and logically organized. I only found one inaccuracy in Equation 1.1, where quantity r_3 is likely meant to refer to the distance from the axis of rotation. This equation would also benefit from reformulation using vector notation.

The second Chapter is focused more on methods used to describe properties of binaries and especially their light curves, in particular the light curve synthesis tool PHOEBE, Bayesian statistics, and random forest classifiers. Here, I particularly praise the description of random forest classifiers, which are not part of the usual Astronomy curriculum.

The third Chapter presents results of a work conducted at a summer school, where Milan is one of three equally contributing co-authors. The issue addressed is the effect of parameterization on modelling of eclipsing binary light curves. By performing controlled experiments in relation to previously published work, it was possible to get better insight into the discrepancies in the results.

Institute of Theoretical Physics
V Holešovičkách 747/2, 180 00 Praha 8, Czech Republic
pejcha@utf.mff.cuni.cz
+420 95155 2495

The fourth Chapter is the first core part of the thesis and addresses the mass ratio distribution of contact binary stars, which is sculpted by long-term evolutionary processes and cataclysmic events such as the Darwin instability. This work has two parts: Bayesian modelling of a population of contact binaries utilizing astrophysical information (period-color-luminosity relation) and an inference of a mass-ratio distribution for contact binaries. This project was quite complex with a number of moving parts, but Milan was able to sort these issues out and obtain successful inference of mass-ratio distribution, which I believe is the first one using this method. During this work, Milan made several independent choices on how to model aspects of the problem and interpreted the results in the context of existing astrophysical models. The paper was published in a well-recognized journal Astronomy & Astrophysics and is already collecting citations.

The fifth Chapter is the second core part of the thesis and provides an in-depth look at degeneracies encountered when classifying smooth light curves of binary stars, where very similar light curves can arise from quite different geometric configurations. The analysis considers also the effect of uncorrelated instrumental noise and stellar spots, which are a major culprit in many systems. In this work, Milan proceeded almost completely independently including selecting the statistical methods, formulating appropriate comparisons, and structuring and writing the final manuscript. The paper was submitted to Astronomy & Astrophysics. The doctoral thesis ends with a Conclusion section describing planned future work in this field.

To summarize, during his PhD studies Milan has become familiar with a number of advanced machine learning techniques, the physics and phenomenology of binary star observations, and astrophysical theories explaining binary evolution. In my opinion, Milan's work presented in this thesis and his papers show that he can perform independent creative scientific work. I strongly recommend his thesis for acceptance and awarding him the PhD degree.

doc. Mgr. Ondřej Pejcha, Ph.D.
Associate Professor
Institute of Theoretical Physics
Faculty of Mathematics and Physics
Charles University Prague, Czech Republic
pejcha@utf.mff.cuni.cz