THE UNIVERSITY OF ARIZONA

Department of Astronomy
Steward Observatory

Dr. Kaitlin M. Kratter
Associate Professor
933 North Cherry Avenue
Tucson, AZ 85721
(520) 621-0260
kkratter@email.arizona.edu

Dec. 2nd, 2021

To the Evaluation Committee:

I am writing to provide a very favorable external review of the Habilitation Thesis of Dr. Ondrej Pejcha. Dr. Pejcha's contributions to our theoretical understanding of core collapse supernovae and common envelope evolution have had broad impacts on the field of stellar astrophysics.

The document begins in Chapter 1 with a brilliantly written overview of the key problems in the explosion mechanism for core collapse supernovae, highlighting his foundational work on the neutrino mechanism. Figure 1.1 highlights one of his valuable contributions to the field, illustrating the lack of a one-to-one correspondence between progenitor mass and explosion outcome. The chapter concludes with a stated plan to pursue the most unique, rare supernovae in an era of rapidly increasing data acquisition. This focus will be vital to progress in the field.

In addition to the numerous important discoveries and predictions that derive from Dr. Pejcha's work, I believe it is particularly noteworthy the manner in which he demonstrates mastery of various forms of scientific inquiry. Not only does Dr. Pejcha carry out complex semi-analytic calculations to understand neutrino transport and nucleosynthesis, he also utilizes state-of-the-art non-linear hydrodynamic calculations to test hypotheses and make observational predictions. Dr. Pejcha has used this work to generate useful semi-empirical or parameterized models that can be easily employed by observational astronomers to reliably test his predictions.

The ability to seamlessly interface the world of observational astronomy with the most technical theoretical calculations is a rare and valuable skill. The set of papers with co-author Prieto in 2015 are an excellent example, demonstrating how to successfully translate real observations into the necessary measured quantities for understanding explosion mechanisms (while also illustrating the common pitfalls and degeneracies between parameters). More recently, in Kurfurst et al 2020, Pejcha and collaborators have gone a step further, and worked to turn increasingly complex calculations (2D simulations) into observables via post processing into predicted lightcurves. This work is also noteworthy for how the authors have taken a problem with an incredible number of free parameters, and tried to isolate the most important model features necessary to generate meaningful observational predictions.

In Chapter 2, Pejcha turns to another long-standing problem in astrophysics: the phase of common envelope evolution wherein binary stars evolve off the main sequence in such close proximity that their atmospheres interact. As emphasized by Pejcha, binary evolution is vital to our understanding of core collapse supernovae given the overwhelming frequency of interacting companions. Indeed, binary evolution should be the default model.

The background on common envelope evolution is adeptly summarized in the beginning of the chapter. His work on this subject also illustrates his skill and flexibility as a researcher. To test classic work on the division between bound and unbound outflows from binaries undergoing common envelope evolution, Pejcha developed his own radiation hydrodynamics code purpose-built for the task. In addition to validating the work of others, he made novel discoveries regarding the importance of shocks in unbound outflows, which explain previously mysterious optical counterparts to these events. This novel code has enabled other breakthroughs as well related, to a separate class of objects known as Luminous Red Novae. Pejcha has convincingly demonstrated through post-processing of these simulations that gradually increasing mass loss through the second Lagrange point can explain the transition from double to single peaked light curves.

Chapter 2 also explains how Pejcha has combined complex secular dynamical models with common envelope evolution to explain how triple star systems may uniquely sculpt planetary nebulae. This work once again highlights his ability to leverage substantial theoretical knowledge to directly explain observations.

The future work laid out at the end of the chapter sounds incredibly promising, in particular the planned development and use of a moving mesh radiation hydrodynamics code. One of the long-standing problems in common envelope evolution is the inability of existing codes to adequately eliminate systematics caused by artificial numerical viscosity in SPH codes. This novel hydrodynamic technique will alleviate this hinderance.

In summary, the body of work presented by Pejcha is demonstrates mastery of multiple areas of stellar astrophysics using a range of techniques. His work has already had dramatic impacts on the field, and his planned research directions are bold, yet achievable by such a talented scientist. He will no doubt continue to drive the direction of his field.

As a final note, the overlap in content noted by “TurnItIn” is not a cause for concern in any fashion. Dr. Pejcha has included in this thesis an entire third Chapter comprising his own first and co-authored published research in the top journals in the field. This work complements the broad background overview and summaries provided in Chapters 1 and 2. Any duplication identified is simply because these papers are already part of the scientific literature.

Sincerely,

[redacted]

Dr. Kaitlin M. Kratter