1 Proposed Research

In the last decade, astrophysical systems with one white dwarf and another body (e.g. a black hole or another white dwarf), referred to collectively as WD binaries, have become increasingly important for several topics in astrophysics. Mergers of WD-WD binaries create a variety of astrophysical systems, the most important of which are type Ia supernovae, the standard candle of observational astronomy. WD-BH (black hole) systems are expected to produce detectable flares that can be observed to yield constraints on currently unknown physics (https://arxiv.org/pdf/1701.08162.pdf).

Tidal interactions, the effect of an uneven gravitational field produced by one body on the other, are the key component in such systems. In WD binaries, tidal interactions are expected to excite internal gravity waves in the WD. These then propagate towards the surface and dissipate by wave breaking, as ocean waves do on a beach, among other mechanisms. Prior work shows that this wave breaking can play a dominant role in determining the internal structure of the WD. Nonetheless, previous treatments of WD binaries adopt incomplete, semi-analytical treatments to estimate the location and strength of wave-breaking induced dissipation. For such fluid systems, numerical simulation is the only way to obtain quantitatively accurate results.

We propose to study nonlinear wave breaking of internal gravity waves in WDs using numerical hydrodynamic codes. There are already a wide assortment of suitable hydrodynamical codes capable of solving the fully nonlinear hydrodynamical equations, we expect to be able to apply such codes with slight modifications to solve the proposed problem. Should existing codes prove inapplicable, the applicant is well equipped to develop suitable software from scratch (§2). We aim to extend our findings to observational signatures for a variety of compositions and uncertain material properties.

The results of our study as GW astronomy continues to improve; inaccuracies are especially important to mitigate with the high sensitivity requirements involved. Conversely, a gravitational wave detection could yield significant information on WD dynamics that, thanks to their ubiquity, could have ramifications throughout astronomy. Equally importantly, our approach would be highly transferable to other problems such as tidal heating during exoplanet formation, another area of crucial and open research.

A tentative timeline for research follows:

- 2–4 months: Set up hydrodynamic code, calibrate against simplified, well-understood fiducial models.
- 4–10 months: Apply hydrodynamic code to systems found in literature.
- 10–14 months: Generate observational counterparts to predicted phenomena.
- 14–24 months: Explore related interesting astrophysical systems, seek analytical descriptions of any discovered phenomena.

2 Plan of Study

Cornell University is the ideal institution to pursue the proposed research. Professor Dong Lai, the applicant's adviser, has authored numerous papers on WD tidal dissipation and is a foremost expert in the subject. Other faculty and researchers at Cornell are equally well-suited for the project. Notably, Professor Saul Teukolsky is a leading researcher in numerical techniques in astrophysics for the past five decades.

The applicant earned two B.S. from the California Institute of Technology in Physics and Computer science and is well equipped for the proposed problem with teaching proficiency in differential equations and completed coursework in computational physics, astrophysical fluid dynamics, GPU programming and others. Future relevant coursework includes astrophysical processes, celestial mechanics and physics of compact objects, all of which are scheduled to be completed within six months of recipt of the fellowship funding. These courses will enable both a complete treatment of relevant physics and accurate, fast programming of numerical codes.

The proposed study is integral to the long-term career goals of the applicant, a professorship in astrophysics at a research institution. Proficiency in numerical techniques and software development is extremely important in modern astrophysical studies. White dwarfs both are important to observational astronomy and involve many astrophysical processes, so such a project would be relevant to many members of the academic community and open avenues for collaboration.