Carl Edward Fields, Jr. - Proposed Plan of Graduate Study and Research

Stars explode. Supernovae (SNe), or stellar explosions, can occur through the ignition of a degenerate white dwarf star, a star that is supported by quantum electron degeneracy pressure, or by the core collapse of a massive star. Recent transient surveys, such as The *Dark Energy Survey* have discovered and imaged thousands of supernovae since 2013 including the anomalous SNe DES13S2cmm. However, even with this wealth of observational data, many aspects of the evolution and subsequent explosion of massive stars remain unknown.

I propose to investigate the stellar structure and evolution of massive stars and core collapse supernovae (CCSNe) explosion mechanisms. I wish to join the TAPIR group at the California Institute of Technology where I will conduct this research while pursuing my Ph.D in Astronomy. The computational resources available at my proposed graduate institution, will make these efforts feasible while the expertise of the group I wish to join will provide the necessary support to successfully address these scientific questions. Additionally, courses required for the Astronomy Ph.D at Caltech include topics such as: *Relativistic Astrophysics*, *Physics of Stars*, and *Structure and Evolution of Stars*, all of which will be strong proponents in the advancement of my knowledge of these topics.

Getting the progenitor right. The star that will eventually explode as a CCSNe is referred to as the progenitor. Computational modeling of the progenitor can lead to insight of how a star will end its life, or allow one to infer the initial progenitor of an observed supernova. Recent 3D hydrodynamic simulations of radiation dominated envelopes in massive stars and internal magnetic field strengths of order $\sim 10^5$ Gauss, suggest the need for further investigation [2]. I will investigate the uncertainties associated with the structure and evolutionary properties of massive stars.

Using the stellar evolution code, Modules for Experiments in Stellar Astrophysics, I will focus on uncertainties due to the nuclear reaction rates, compositional mixing, and the effects of rotation and induced magnetic dynamos. Specific steps include the sampling of new Monte Carlo nuclear reaction rate distributions for key reaction rates using the recently constructed rate library, STARLIB [3], and performing a quantitative assessment of the effect of varying strengths of compositional mixing and rotational values. The utilization of new measurements of nuclear reaction rates at astrophysically relevant energies forthcoming from the *Facility for Rare Isotopes Beams* will also be paramount in this effort.

Supernova explosion mechanisms. Collapse of the iron core within a massive star initiates the CCSNe explosion. The inner core is then halted once densities exceed that of nuclear matter, resulting in core bounce launching a shock towards the still collapsing outer core. However, the shock is not strong enough to blow up the star and is usually halted. This stalled shock has led to the so-called 'failed supernovae' problem and has left many scientist trying to determine the mechanism which allows for the efficient explosion of CCSNe observed. Recent studies suggest a correlation between the local neutrino heating rate and successful explosion [1]. I propose to continue this effort by investigating various explosion mechanisms of CCSNe and addressing uncertainties therein. My primary numerical instrument will be the 3D adaptive mesh hydrodynamic code, FLASH.

The focused efforts presented here would result in the advancement of our understanding of the evolution and subsequent explosion of massive stars, leading to advancements in the fields of cosmology, astronomy, and theoretical physics. Namely, the next step towards understanding the cosmic chemical evolution of our Universe is to move towards a deeper understanding of the nucleosynthetic yields of CCSNe. Furthermore, with the recent upgrade of The Laser Interferometer Gravitational-Wave Observatory complete, direct detection of gravitational waves is imminent. A new field of astrophysics is upon us and requires necessary interplay between astronomy and theoretical physics.

These are immense, broad questions that require expertise in multiple backgrounds as well as interdisciplinary collaborative efforts. I wish to complete my Ph.D. in Astronomy at Caltech followed by pursuit of postdoctoral research and an academic position. Along my journey, I wish to play an important role in science communication, public outreach, as well as an advocate for educational equality and the advancement of equal representation amongst minorities in science. Being supported by the FORD Foundation through the Predoctoral Fellowship Program would accelerate my goals by allowing me to begin research my first year and be invaluable in preparing me for a successful career.

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[1] Couch, S. M., & Ott, C. D. 2015, The Astrophysical Journal, 799, 5

[2] Fuller, J., Cantiello, M., Stello, D., Garcia, R. A., & Bildsten, L. 2015, Science, 350, 423

[3] Sallaska, A. L., Iliadis, C., Champange, A. E., et al. 2013, ApJS, 207, 18