NEXT GENERATION WORK

BlueTides is a **path-finder** for developing methods and calculations for future cosmological hydrodynamic simulations of galaxy formation with volumes and resolutions suitable for creating models for next-generation surveys. Our simulations are important as they blaze a trail for future calculations in the future Track 1 systems. Currently, we are evolving models forward in time for only one billion years, rather than the 14 billion years necessary to cover the history of the universe to the present day that next generation systems, assuming they have enough memory capacity, would enable.

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CORE-COLLAPSE SUPERNOVAE THROUGH COSMIC TIME

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EXECUTIVE SUMMARY

Explosions of massive stars (core-collapse supernovae; CCSNe) have a significant impact on the development of galaxies and their heavy element content. We compute 3D simulations of CCSNe that include the complex range of CCSN physics, across the range of input conditions representing the history of massive stars in the universe to obtain the variety of outcomes seen in nature. Our computations account for the appropriate nuclear processes needed to generate and eject heavy elements that are needed to form planets. We have discovered a **previously unseen** nuclear burning behavior that can only be observed through the completeness of our simulations and the included nuclear physics.

INTRODUCTION

Massive stars (mass greater than eight solar masses) are relatively rare, yet they play a significant role in the evolution of galaxies, particularly through their explosive finales as CCSNe. Energy from CCSNe triggers new star formation and elements synthesized in massive stars and CCSNe are the ingredients for terrestrial planets in those star systems. The conversion of gravitational potential energy from the collapse of the stellar core into an expulsion of the stellar envelope is a complex physical process. This physical process combines gravitation, nuclear physics, neutrino physics (neutrinos transport the needed energy to drive the explosion from the collapsed core), and turbulent fluid dynamics with a rich phenomenology.

METHODS & RESULTS

To compute CCSN models in the necessary 3D, we have developed *Chimera*, a program that accounts for neutrino transport and opacities, nuclear equations of state and reaction networks, compressible fluid dynamics, and self-gravity [1, 2]. This project addresses the wide range of pre-supernova stellar configurations from the range of initial masses and the build-up of heavy elements (mostly from previous CCSNe) through cosmic history by sampling in both dimensions. From these models we will address the nature of the CCSN mechanism and the production of elements in the explosions.

In the low-mass, primordial composition simulation in our grid, we have identified a previously unseen burning mode in stellar collapse. During collapse, compression of the silicon shell intensifies the burning of the remaining oxygen at the bottom of the layer until it triggers a silicon flash. The silicon flash burns much of the silicon shell to iron-peak elements and some of the overlying oxygen-neon shell to silicon. The deposited energy alters the collapse dynamics and helps intensify the explosion driven by neutrino heating from the collapsed iron core interior. Silicon flashes have been observed in pre-supernova stellar evolution models for similar progenitors [3], but were not seen in previous work with the same progenitor [4] as nuclear burning was not adequately included.

WHY BLUE WATERS

Computing stellar explosions in 3D requires large and long computations. Blue Waters provides the capacity needed to accommodate our simulation requirements.

NEXT GENERATION WORK

More powerful and capable machines will permit improvements in the computationally expensive portions of CCSN simulations (neutrino transport, nuclear networks, resolution). This will help to better realize the nature of the explosions and increased simulation counts to better account for the variety of inputs and outcomes.