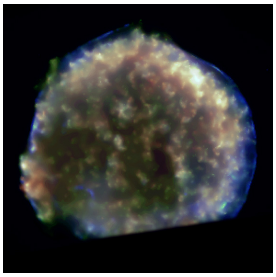
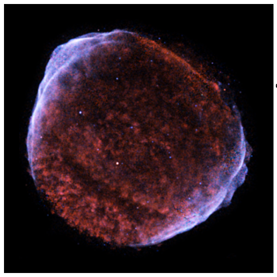
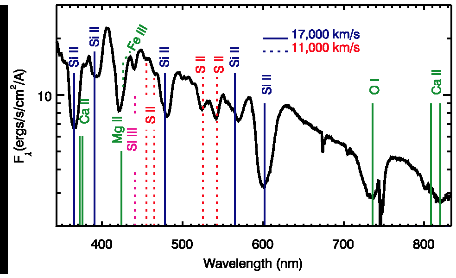
Neutron Enrichment During a Type Ia Supernova



Tycho Supernova [1]



SN 1006[2]



SN 2004dt Spectrum[3]

Near the core of the exploding white dwarf (WD), a nuclear flame burns ^{12}C and ^{16}O to a hot soup made up of elements near ^{56}Ni and some 20% ^{4}He by mass. This material is in an *active* equilibrium state, termed nuclear statistical equilibrium (NSE), in which continuously occurring particle fusion is balanced by photo-disintegration. The energy release of this material must be treated consistently to accomplish accurate hydrodynamical simulations of rising bubbles and plumes of this NSE ash. At high densities where the flame is ignited, a significant number of protons are converted into neutrons, mostly via capture of electrons. This changes the isotopes which are produced in the explosion, which can be observed in the energetic and spectral characteristics of the explosion and in the material which it leaves behind. More than half of the iron in the solar system comes from this type of supernova.

The early deflagration phase of the supernova is when the most neutron-rich elements will be made and will provide important constraints on the several currently proposed mechanisms for the precise scenario for the explosion, including the variation expected within each and among them. We also are investigating the variation possible due to the initial composition, both metallicity and Carbon fraction, and central density at ignition, which might allow the parent stellar population to influence the outcome of the explosion. By carefully simulating the effects of electron captures on the hydrodynamics of the explosion and the resulting nucleosynthesis, we hope to understand what nuclear physics can be usefully improved for this specific but high-profile astrophysical application.

Image credit: [1]NASA/CXC/SAO [2]NASA/CXC/Rutgers/J.Hughes [3]Wang etal 2006, ApJ, 653, 490

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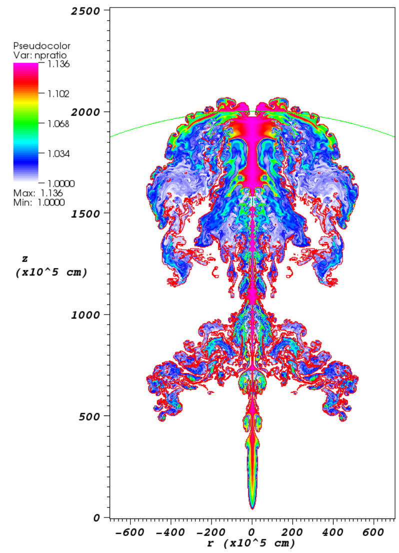
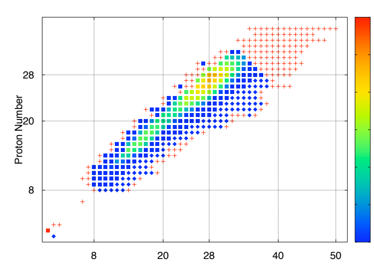


Ratio of neutrons to protons in rising, burning material during a Type Ia supernova. The green line indicates the original surface of the star, and the red outline is the interface between burned material (interior) and unburned carbon and oxygen. This plume has grown for 0.98 seconds from an ignition 40 km from the center of the star.



Fractional contribution to neutron enrichment ($\log_{10}$ of fraction) from each nuclide in initial burning phase. Squares make neutrons from protons and electrons, and diamonds do the reverse. Capture of electrons on free protons (lower left) dominates.

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