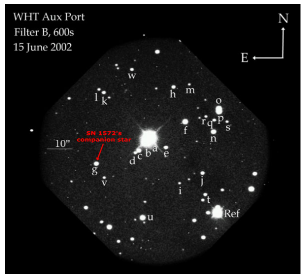
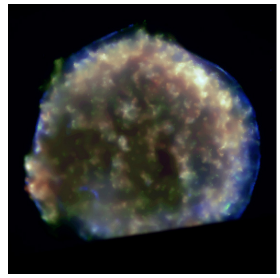
Type Ia Supernova Flame Models

Supernova 1994D[1]



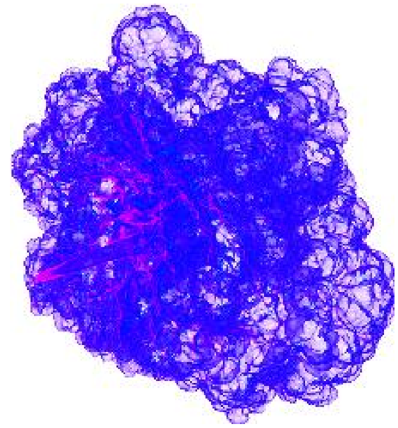
Tycho Supernova companion[2]



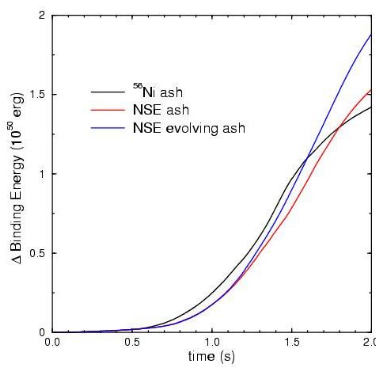
Tycho Supernova (X-ray)[3]

Type Ia supernova explosions are thought to result from a thermonuclear runaway occurring in a C/O white dwarf that has gained mass by accretion from a main sequence companion star. The nature of the explosion is subject to debate, but most models begin with a deflagration born near the center of the white dwarf. The evolution of the thermonuclear flame critically depends on the details of the nuclear burning, particularly on the amount of energy released by the flame. The evolution of the flame during this subsonic deflagration phase of the explosion sets the stage for a possible subsequent transition to a detonation that will incinerate the remainder of the star.

JINA scientists in collaboration with scientists at the ASC Flash Center at the University of Chicago are studying the details of nuclear burning under supernova conditions with the goal of better quantifying the energy release and ash composition of thermonuclear flames. By investigating the energetics and time scales of nuclear burning and the evolving state of the ash in Nuclear Statistical Equilibrium (NSE) at a range of densities, this group is improving and calibrating the sub-grid-scale flame models used in simulations of the deflagration phase of Type Ia supernovae. The figure to the right illustrates the differences in binding energy released during the deflagration found in simulations from an off-center ignition point with different treatments of the nuclear ash. As expected, the evolving NSE case releases the most binding energy. The explanation for this result appears in another contribution, "Type Ia Supernova Energetics".



Volume rendering of the rising Rayleigh-Taylor unstable fireball as it approaches the surface of the star during the deflagration phase of a Type Ia supernova simulation. (From Calder et al. 2004).



Plot of change in nuclear binding energy of the star from a simulation of a rising fireball with ^{56}Ni ash, NSE ash, and NSE ash that subequently evolves.

I. R. Seitenzahl, et al. "On the Effects of Using Approximate Masses in Nuclear Statistical Equilibrium", 2006, in prep.

A. C. Calder, at al. "Flame Energetics for Type Ia Supernova Simulations", 2006, in prep.

A. C. Calder, et al. "Deflagrating white dwarfs: a Type Ia supernova model", 2004 BAAS, 35, 1278

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Image credit: [1]HST, [2]Herschel, [3]Chandra. This work is supported by the Joint Institute for Nuclear Astrophysics under NSF Grant PHY0216783 and by the U.S. Department of Energy under grant No. B523820 to the ASC/Alliance Center for Astrophysical Thermonuclear Flashes at the University of Chicago.