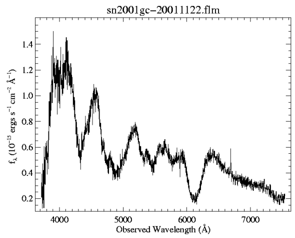
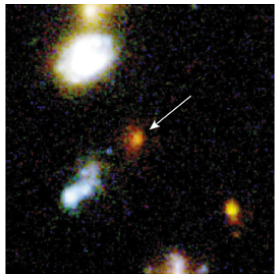
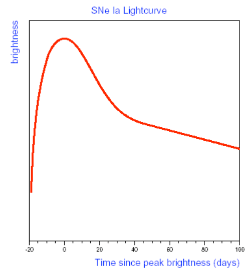
Type Ia Supernova Energetics



sn2001gc spectrum[1]



SN 1997ff[2]



Type Ia lightcurve[3]

Type Ia supernovae, spectroscopically defined by the absence of H and a deep Si II absorption line at 612 nm, are among the most luminous transient events in the universe, with explosion energies $\sim 10^{51}$ ergs frequently outshining their host galaxies (SN 1997ff was detected at a record redshift of z=1.755). The Phillips relation, correlating peak luminosity with lightcurve decay time, allows for the use of type Ia SNe as probes of the Hubble flow, revealing the acceleration of the expansion of the universe. Explaining the empirical Phillips relation with a detailed supernova model is crucial in checking the hypothesis in the arguments for a positive cosmological constant.

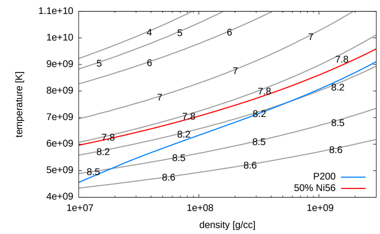
Type Ia SNe are believed to be thermonuclear explosions of accreting C/O white dwarfs near the Chandrasekhar limit, powered by the energy released in burning the initial composition to Nuclear Statistical Equilibrium (NSE). Numerical simulations of the explosion should take into account that the NSE state is not static, but rather shifts from a NSE rich in ^{4}He to a NSE completely dominated by Fe-peak elements as the initially hot ashes cool on a hydrodynamic timescale. The nuclear binding energy released during this process is $\sim$ 20% of the total energy released. The amount of ^{56}Ni produced, which is believed to power the optical lightcurve via the decay chain

$$^{56}\mathrm{Ni} \xrightarrow{T_{1/2}=\,6.08d} {}^{56}\mathrm{Co} \xrightarrow{T_{1/2}=\,77.2d} {}^{56}\mathrm{Fe}$$

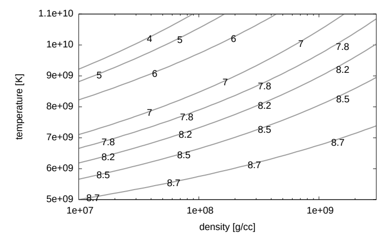
depends sensitively on the trajectories of the hydrodynamical evolution of the explosion, which are affected by electron captures: A lower Y_e reduces the contribution of degenerate electrons to the total pressure, and neutrinos carry away energy. Furthermore, as Y_e decreases, the most abundant nucleus in NSE shifts from ^{56}Ni to more neutron rich Fe-peak nuclei. This could result in an additional release in binding energy, since the trinity of the most tightly bound nuclei ^{62}Ni, ^{58}Fe and ^{56}Fe have significantly higher binding energies than ^{56}Ni ($\sim$ 0.15 MeV/nucleon), and a smaller heat capacity of the ion gas, since the mean nucleon number per nucleus increases for a neutron rich NSE.

Image credit: [1]CfA, [2]HST, [3]CfCP.

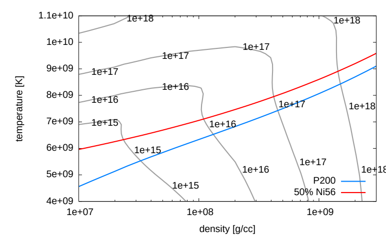
This work is supported by the Joint Institute for Nuclear Astrophysics under NSF Grant PHY0216783 and by the U.S. Department of Energy under grant No. B523820 to the ASC/Alliance Center for Astrophysical Thermonuclear Flashes at the University of Chicago.



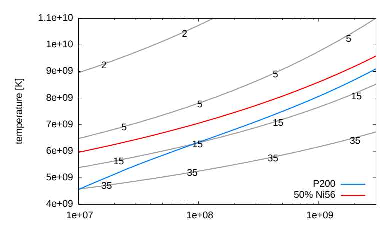
Y_e = 0.5 contours of binding energy per nucleon in NSE.



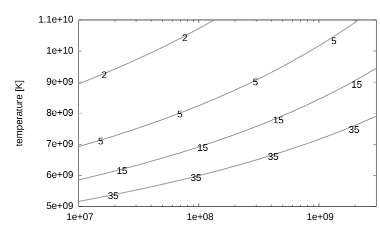
Y_e = 0.475 contours of binding energy per nucleon in NSE.



Y_e = 0.5 contours of ν energy loss rates [ergs/g/s] in NSE.



Y_e = 0.5 contours of mean nucleon number in NSE.



Y_e = 0.475 contours of mean nucleon number in NSE.

Researchers:
I. R. Seitenzahl[1], D.M. Townsley[1],
F. Peng[1], A. C. Calder[1,2],
J. Truran[1,2], D. Q. Lamb[1,2]

[1] U. Chicago
[2] ASC Flash Center