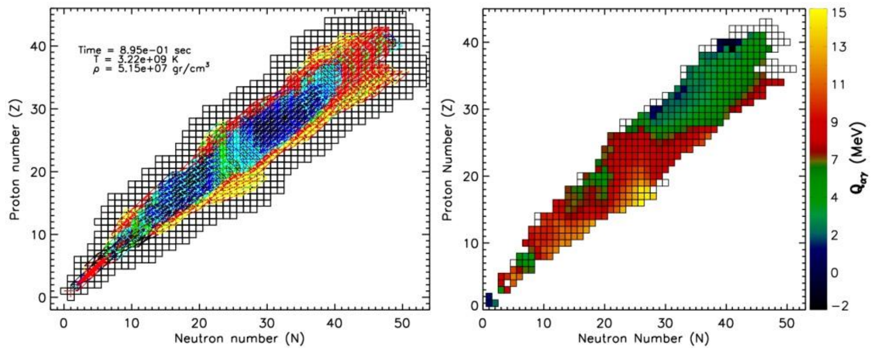
# Trends in $^{44}$Ti and $^{56}$Ni from Core-Collapse Supernovae




Most of the silicon-group and iron-group elements are created during the last two weeks of a massive star's life. Identification and analysis of the key nuclear reactions during this phase of the star's evolution can quantify trends in the way the elements and isotopes are produced. Nuclear structure effects may account for some of the reaction trends and isotopic yields. For example, the drop of alpha cluster binding energies near the closed Z=28 shell (right panel) may lead to the formation of two separate equilibrium clusters of nuclei during the expansion (left panel).

Detection of radioactive nuclides such as $^{56}$Ni and $^{44}$Ti may be used to diagnose the nature of the supernova explosion. The isotope $^{44}$Ti is generally produced in massive star supernovae models, but has only been detected in the Cassiopeia A supernova remnant. Resolution of this paradox could, in part, be due to nuclear physics. $^{44}$Ti is produced or depleted via one of several reaction mechanisms depending on the strength of the explosion (Figure 1). Each region in Figure 1 is characterized by specific reaction sequences, which control the trends of $^{44}$Ti synthesis. We identify these reactions by detailed sensitivity studies on reaction rates (Figure 2). In contrast, radioactive $^{56}$Ni, which powers the supernovae's light curve, tends to be produced by large-scale equilibrium patterns. Even during the non-equilibrium part of the evolution, the largest nuclear flows are localized around $^{56}$Ni. This combination assures a large mass of $^{56}$Ni is created during the explosion [1].

We compare the amounts of $^{44}$Ti and $^{56}$Ni ejected in three different massive star supernova models with those from simplified hydrodynamic profiles in Figure 3. The peak temperatures and densities achieved by different layers in the supernova models span several of the distinct regions we identify in Figure 1. The trends in the $^{44}$Ti and $^{56}$Ni profiles from the simplified hydrodynamic profiles generally explain the tendencies of the yields from supernova models but at a fraction of the computational cost.

[1] Magkotsios G., Timmes F.X., Wiescher M., Fryer C.L., Hungerford, A., Young P., Bennett M., Diehl S., Herwig F., Hirschi R., Pignatari M., Rockefeller, G. 2008, ArXiv e-prints, http://arxiv.org/abs/0811.4651

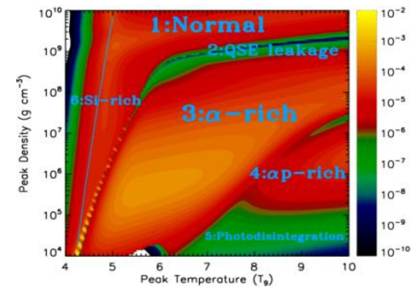



Figure 1: Final mass fraction of $^{44}$Ti in the peak temperature-density plane. Six distinct regions of $^{44}$Ti synthesis are labeled.

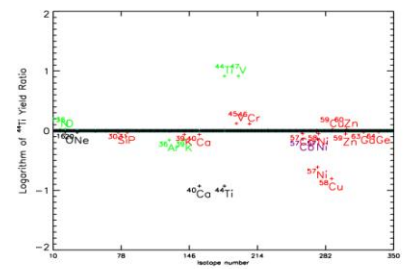


Figure 2: Reactions affecting $^{44}$Ti synthesis are identified by state of the art sensitivity studies on reaction rates.

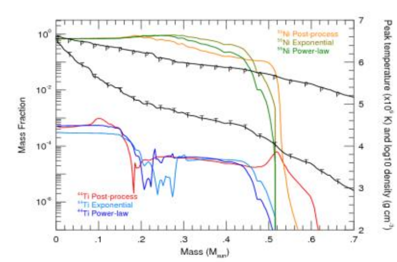



Figure 3: Simplified expansion profiles may adequately describe the trends of $^{44}$Ti and $^{56}$Ni from computationally intensive post-processed models.

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Magkotsios, G., Timmes, F.X., Hungerford, A.L., Fryer, C.L., Young, P.A., Wiescher, M., 2010, ApJS, in preparation

**Movies:**
http://cococubed.asu.edu/research_pages/ti44_ni56.shtml