Gradient Mechanism Initiation of Detonations

... in the context of the GCD model

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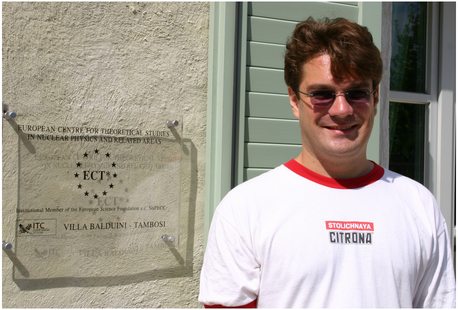
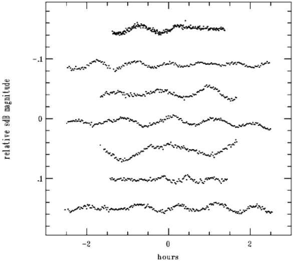
Basics

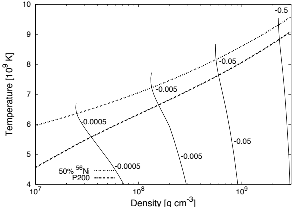


At the ECT* in Trento 2004

- Born and raised in Germany
- 1998-2002 University of Arizona
  B.S. Astronomy/Math/Physics
- 2002-2007 University of Chicago
  Physics Ph.D. candidate
  Advisor Jim Truran
- Generously supported by JINA, but also much interaction and support from the FLASH Center

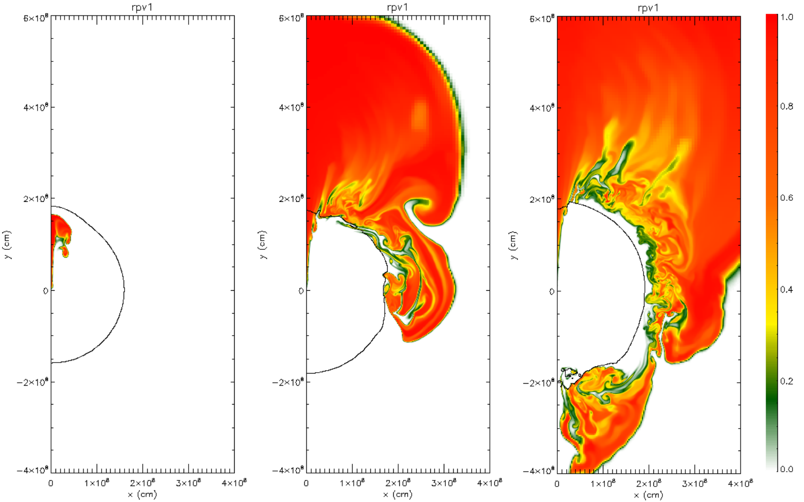
Past and Present Research Interests



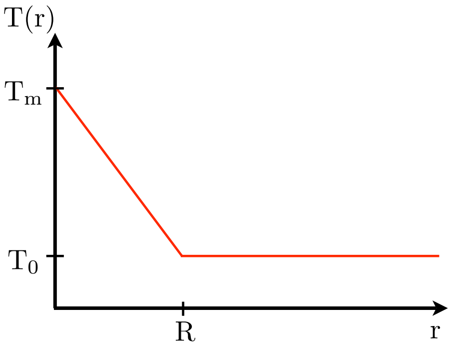


- Comparative photometry observations of sdB stars in binaries for eclipses, reflection effects etc.
  Discovered new class of long period g mode pulsators (class PG 1716+426)
- Interest in r-process nucleosynthesis
- NSE calculations for Type Ia Supernova flame models
- Neutronization in Type Ia Supernovae
- Initiation and structure of detonations

Rising Bubble, Breakout and Gravitationally Confined Flow



Initiation of a detonation from a hot spot

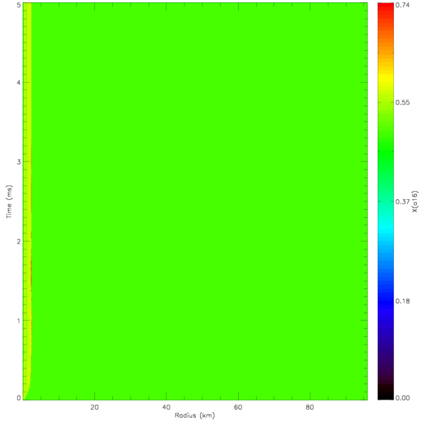


Temperature profile used

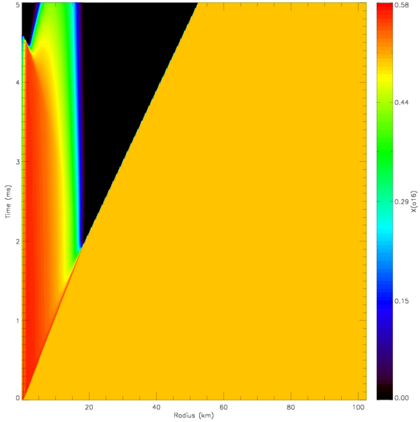
- FLASH3 solves reactive Euler equations (fully compressible, PPM)
- 64 blocks with 16 zones and 7 levels of AMR, blocksize = R
- 13 Species Network
- 1-D Spherical Geometry
- Systematically determined smallest radius for which detonation initiates by bisection
- Varied composition, T_m and T_0

$\rho = 10^7$ g cm^{-3} $\quad T_{max} = 3.2 \cdot 10^9$ K $\quad T_0 = 4 \cdot 10^8$ K $\quad$ Oxygen

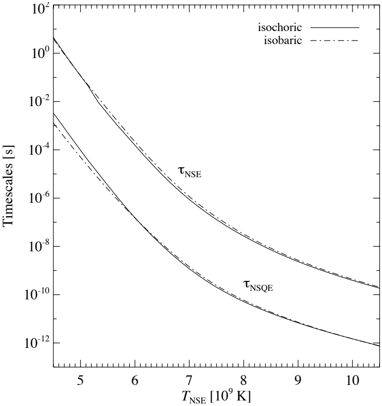
R = 1.5 km



R = 1.6 km



Nuclear Statistical Equilibrium (NSE) I



- Asymptotic state nuclear matter reaches in detailed balance (fusion reactions are balanced by photo-dissociation)
- At a given temperature, density and electron fraction NSE is well defined
- Timescale to reach NSE much longer than timescale to reach NSQE
- Can now calculated state of the art NSE from any initial state under constraints (constant enthalpy, pressure)

Nuclear Statistical Equilibrium (NSE) II

$$\sum_i X_i - 1 = 0 \tag{1}$$

$$\sum_i \frac{m_u}{m_i}\Big[(Y_e - 1)Z_i + Y_e N_i\Big] X_i = 0 \tag{2}$$

$$X_i = \frac{m_i}{\rho} g_i \left(\frac{2\pi m_i kT}{h^2}\right)^{3/2} \Lambda_i \exp\left[\frac{Z_i\mu_p + N_i\mu_n + Q_i}{kT}\right] \tag{3}$$

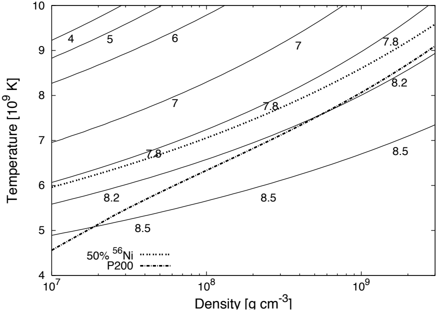
$$\Lambda_i = \exp\left(-f_i\right) \tag{4}$$

$$f_i = A_1\left[\sqrt{\Gamma_i\left(A_2 + \Gamma_i\right)} - A_2 \ln\left(\sqrt{\frac{\Gamma_i}{A_2}} + \sqrt{1 + \frac{\Gamma_i}{A_2}}\right)\right] + 2A_3\left[\sqrt{\Gamma_i} - \arctan\left(\sqrt{\Gamma_i}\right)\right] \tag{5}$$

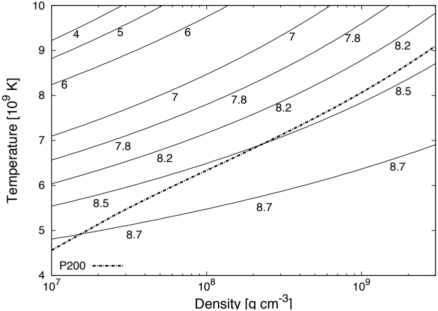
where $A_1 = -0.9052$ and $A_2 = 0.6322$ and $A_3 = -\frac{\sqrt{3}}{2} - \frac{A_1}{\sqrt{A_2}}$.

Effects of Electron Captures

NSE Binding Energies



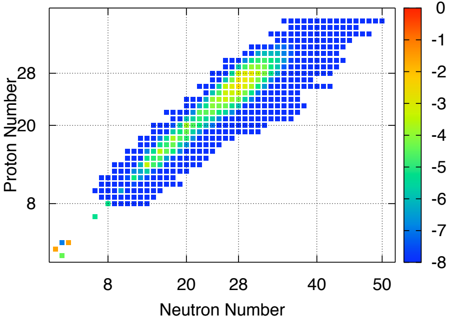
$$Y_e = \frac{N_P}{N_P + N_N} = 0.50$$



$$Y_e = 0.48$$

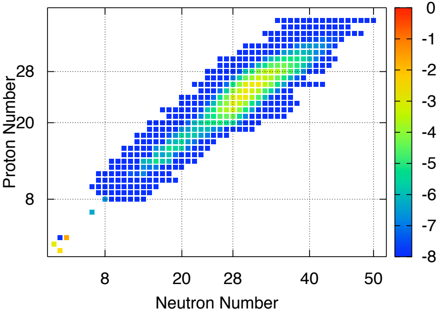
Mass Fractions in NSE along central zone W7 trajectory

$t = 2 \cdot 10^{-6}$ s



$Y_e = 0.50$
$\rho = 2.0 \cdot 10^9$ g cm^{-3}
$T = 8.4 \cdot 10^9$ K

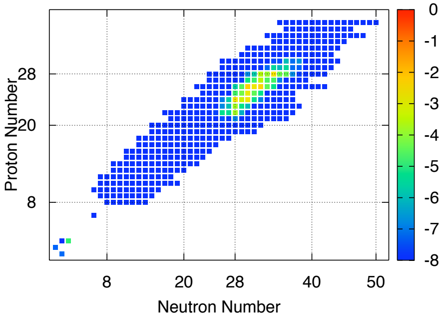
$t = 0.78$ s



$Y_e = 0.455$
$\rho = 8.0 \cdot 10^8$ g cm^{-3}
$T = 8.2 \cdot 10^9$ K

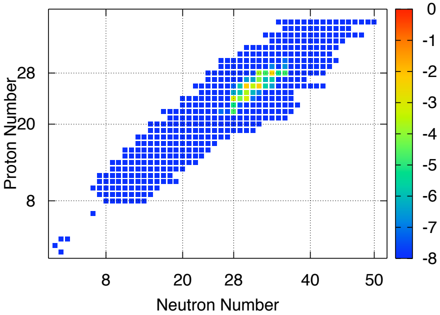
Mass Fractions in NSE along central zone W7 trajectory

$t = 1.2$ s



$Y_e = 0.455$
$\rho = 4.4 \cdot 10^7$ g cm^{-3}
$T = 4.2 \cdot 10^9$ K

$t = 1.5$ s

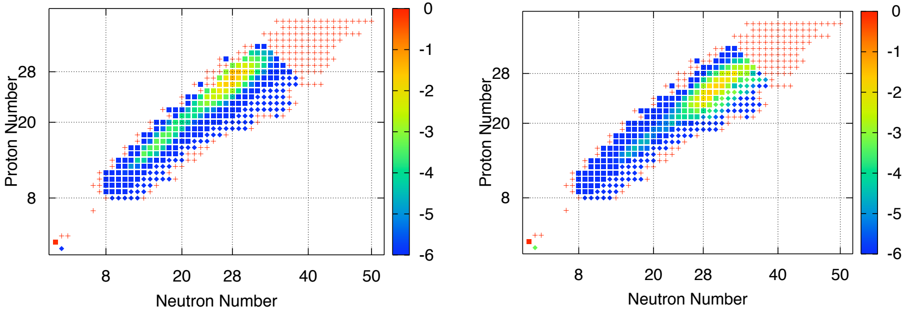


$Y_e = 0.455$
$\rho = 1.3 \cdot 10^7$ g cm^{-3}
$T = 2.8 \cdot 10^9$ K

Fractional Neutronization Rate: $\log_{10}\left(\frac{|\dot{Y}_e^i|}{\dot{Y}_e}\right)$

$t = 2 \cdot 10^{-6}$ s
$\dot{Y}_e = -4.1 \cdot 10^{-1}$ s^{-1}

$t = 2.6 \cdot 10^{-3}$ s
$\dot{Y}_e = -2.6 \cdot 10^{-3}$ s^{-1}



$Y_e = 0.50$
$\rho = 2.0 \cdot 10^9$ g cm^{-3}
$T = 8.4 \cdot 10^9$ K

$Y_e = 0.455$
$\rho = 8.0 \cdot 10^8$ g cm^{-3}
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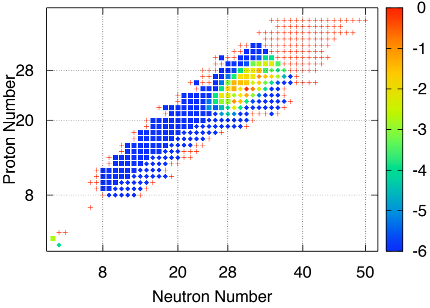
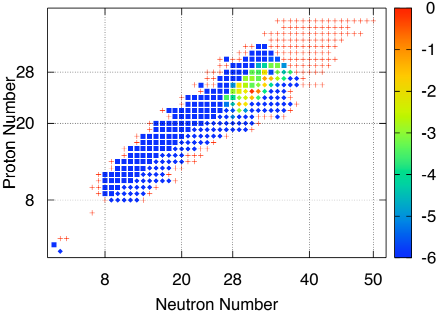
Fractional Neutronization Rate: $\log_{10}(\frac{|\dot{Y}_e^i|}{\dot{Y}_e})$

$t = 1.2$ s
$\dot{Y}_e = -2.0 \cdot 10^{-7}\ s^{-1}$



$Y_e = 0.455$
$\rho = 4.4 \cdot 10^7$ g cm^{-3}
$T = 4.2 \cdot 10^9$ K

$t = 1.5$ s
$\dot{Y}_e = 0\ s^{-1}$



$Y_e = 0.455$
$\rho = 1.3 \cdot 10^7$ g cm^{-3}
$T = 2.8 \cdot 10^9$ K