

Turbulently-Driven Detonation Initiation in Electron-Degenerate Matter with Helium

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MS Thesis Defense

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Type Ia Supernova

- Strong Silicon lines in the absence of Hydrogen
- Used as standardizable candles
- Led to the discovery of the accelerated expansion of the universe
- Cosmic Rays

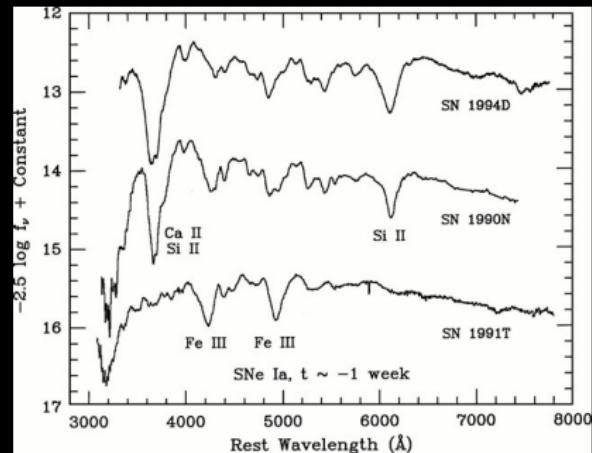


Figure: Filippenko

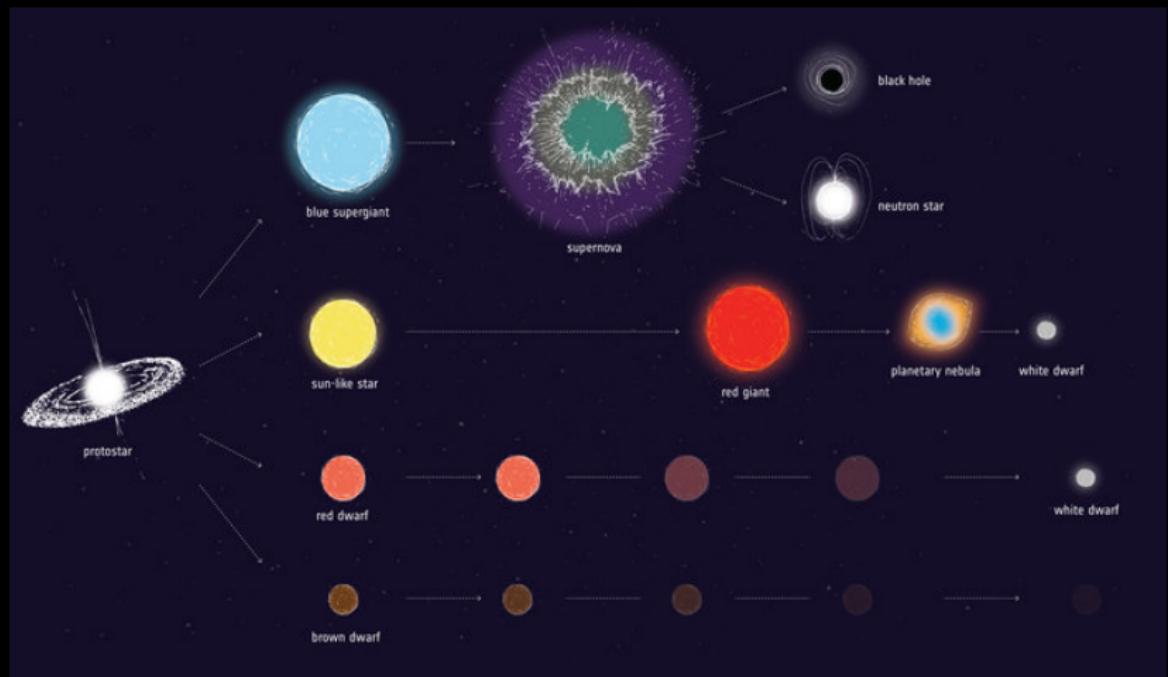
Type Ia Supernova

- SN 2011fe confirmed that a compact object must be the progenitor of a SNe Ia



Figure: 2011fe as seen by the Palomar Transient Factory

Stellar Lifetime



White Dwarf

- Degeneracy Pressure
- Causes volume to decrease as mass increases
- Chandrasekhar Mass Limit $\simeq 1.4 M_{solar}$

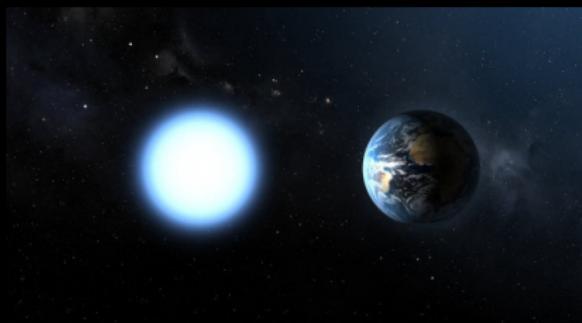
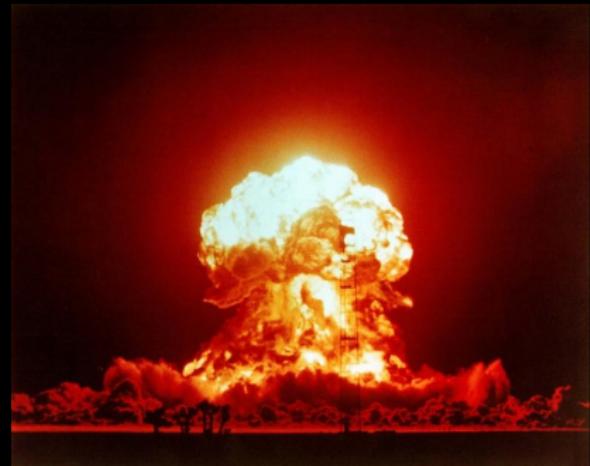
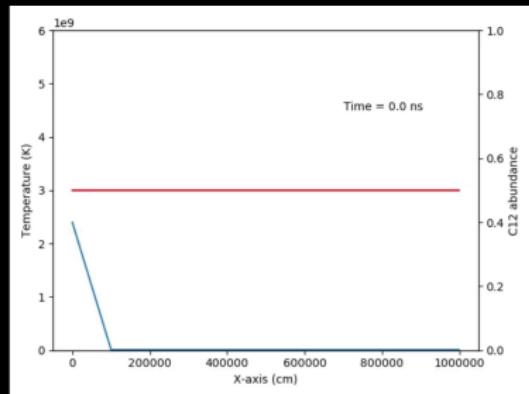


Figure: Sirius B compared to Earth
(European Space Agency)

Detonation

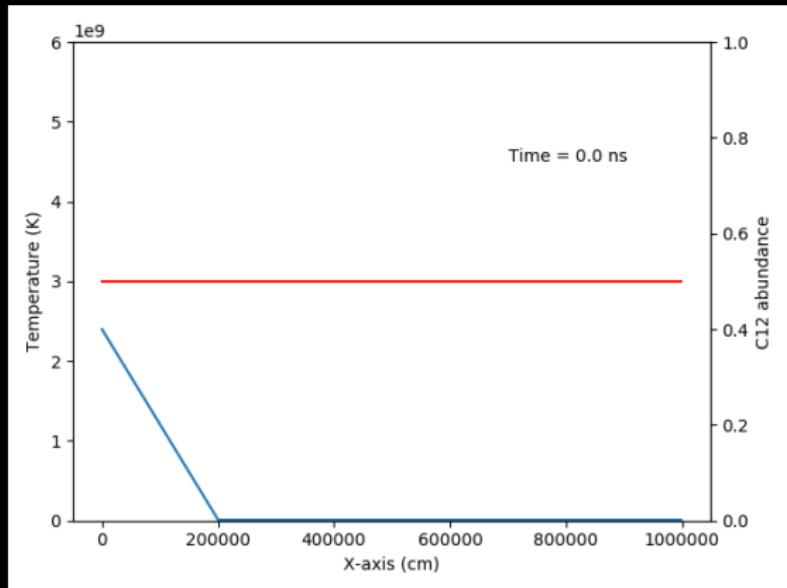


Zel'dovich Gradient Mechanism



Failed detonation

Zel'dovich Gradient Mechanism



Successful Detonation

Carbon Detonation

- Highly Turbulent ($Re \simeq 10^{15}$)
- Karlovitz Number
 - ▶ $Ka = (\text{nuclear time scale}/\text{smallest turbulent time scale}) \simeq 8000$
 - ▶ Distributed Burning Regime
- Turbulent dissipation of energy dominates nuclear burning prior to detonation by up to 20 orders of magnitude

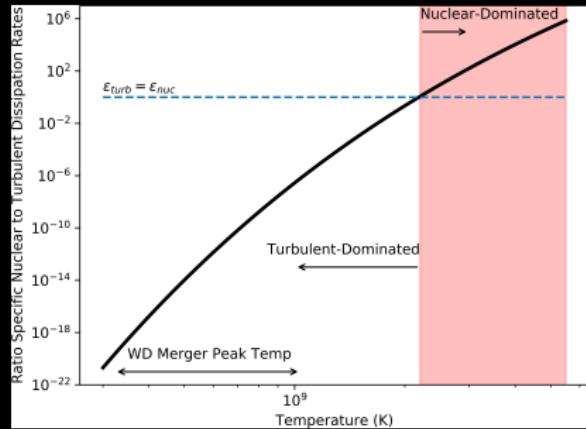


Figure: Sirius B compared to Earth
(European Space Agency)

Carbon Detonation

- Turbulently-Driven Detonation Mechanism of Carbon
- Fisher RT, Mozumdar P, Casabona G. 2019. Carbon Detonation Initiation in Turbulent Electron-Degenerate Matter. The Astrophysical Journal.

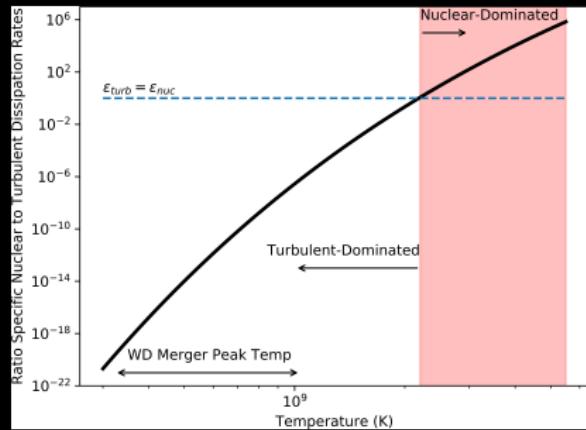
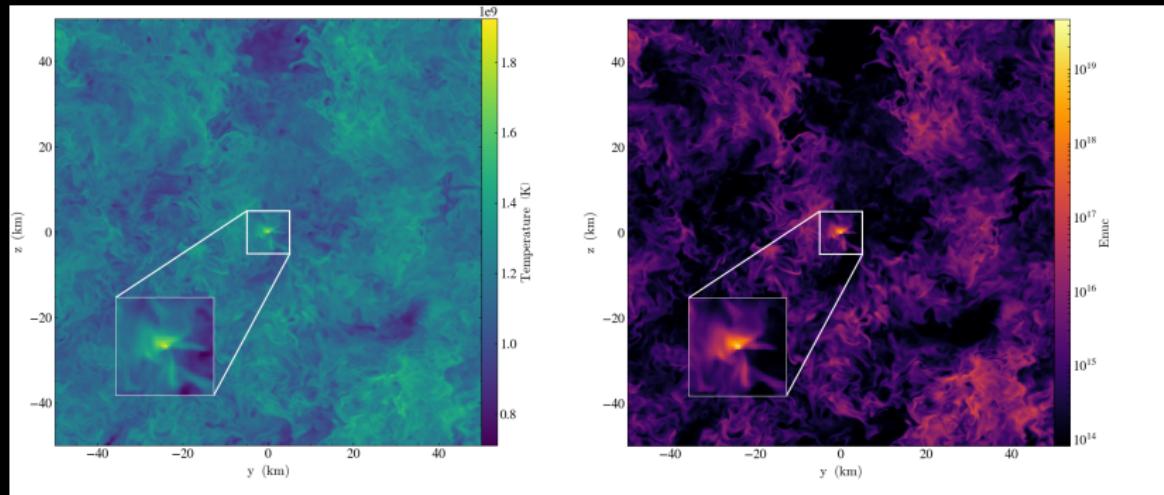


Figure: Sirius B compared to Earth (European Space Agency)

Carbon Detonation

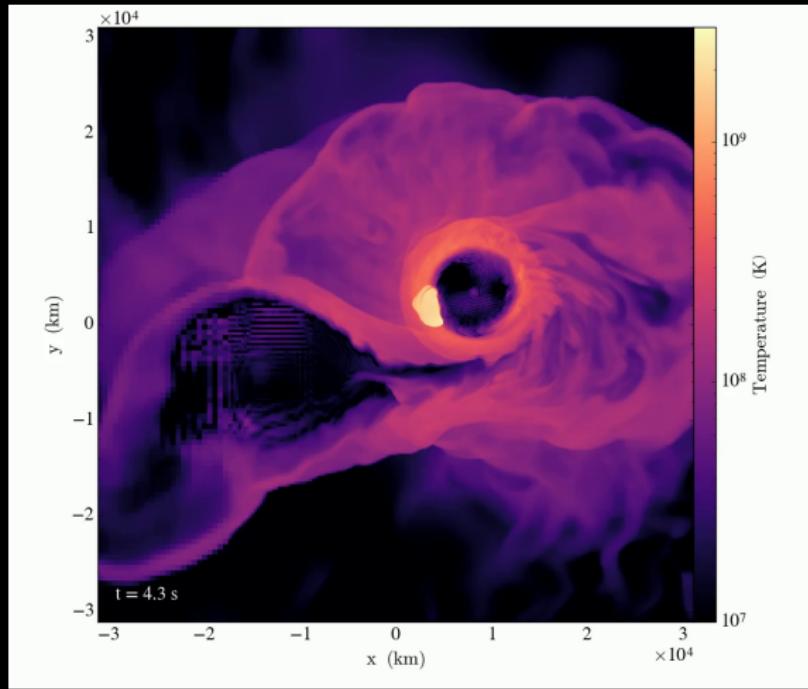
slices.png

Carbon Detonation



Slice plots at the moment of detonation.

Helium Detonation



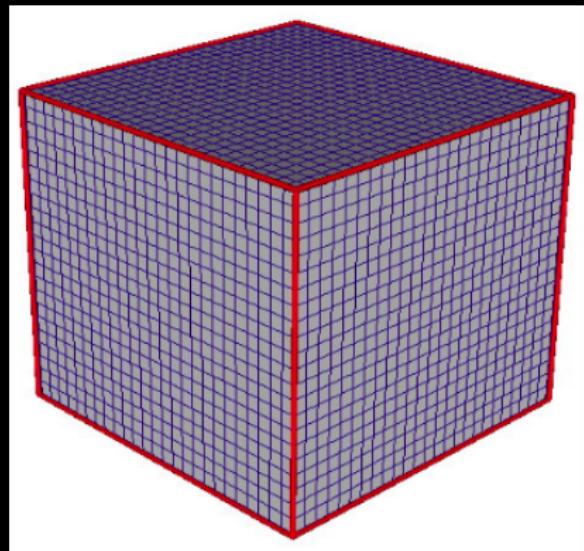
Vishal Tiwari (2019)

Helium Detonation

NASA, ESA and P. Ruiz-Lapuente, cut and colored by S. Geier

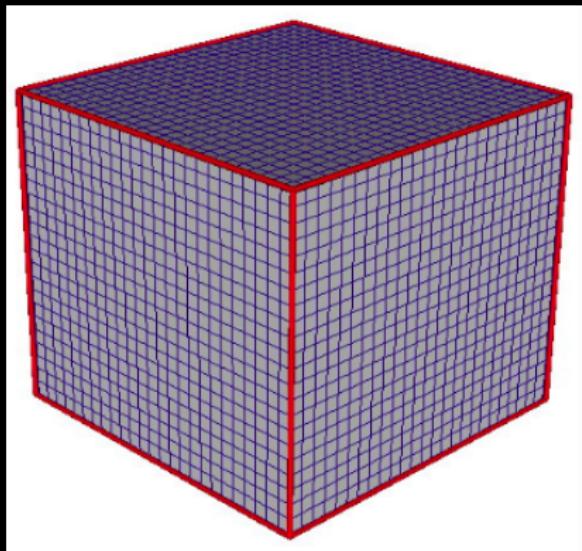
Method

- 3D Models
- 100km periodic box
- Uniform Grid
- Driving force for turbulence on a large scale
- Helmholtz Equation of State
- 19-isotope network

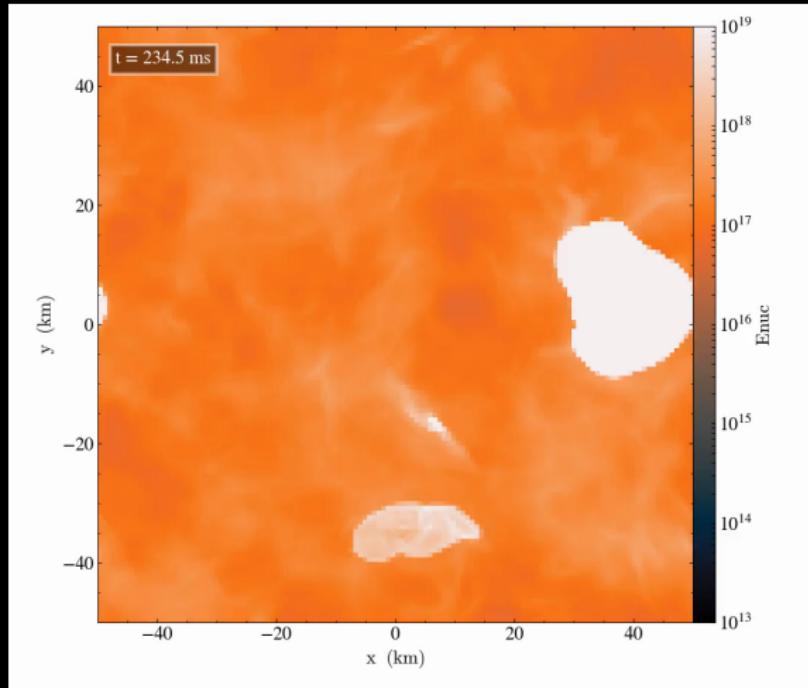


Method

- Resolution set to $128^3, 256^3, 512^3, 1024^3$
- Mass density set to $10^5, 10^6 (\frac{g}{cm^3})$
- Helium fraction set to 1.0, 0.25, 0.1
- Used FLASH4 code on Stampede2



Results



Detonation of 128^3 run with $\rho = 10^6 \frac{gm}{cm^3}$ and He fraction = 0.25.