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

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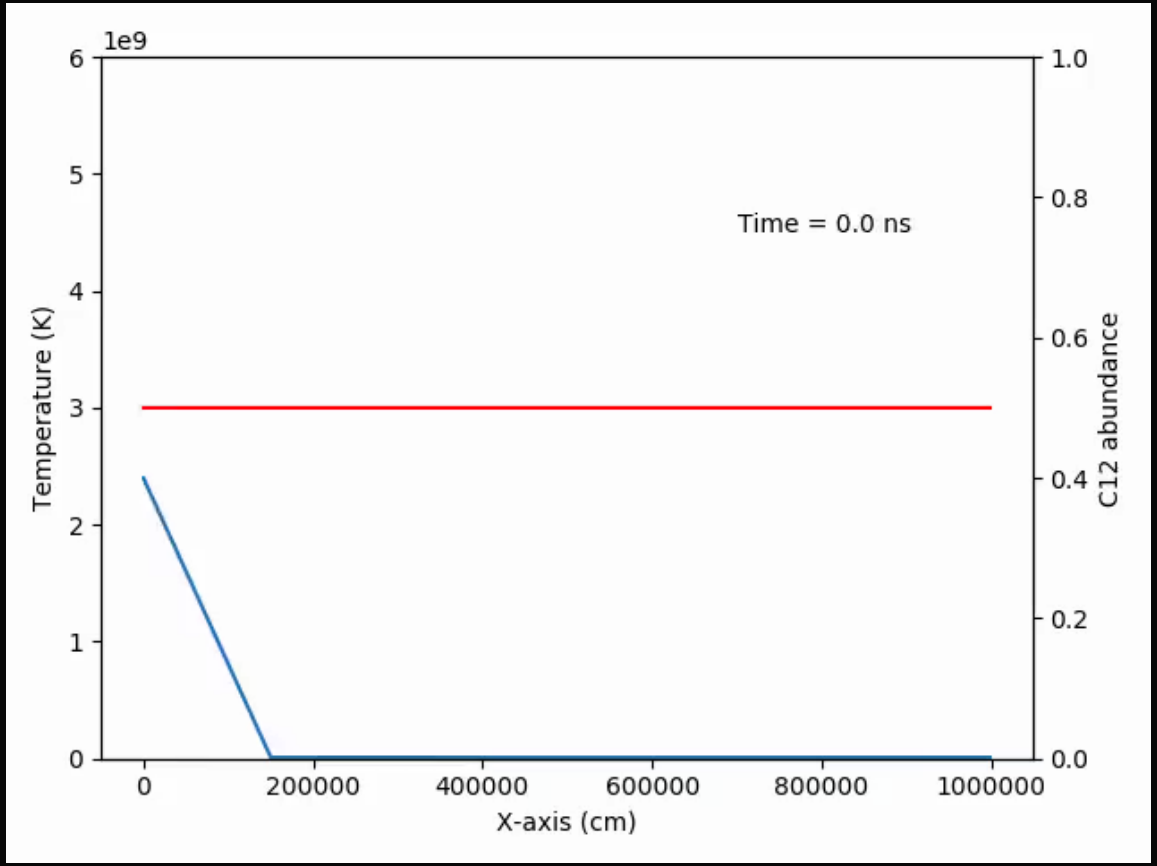
Outline

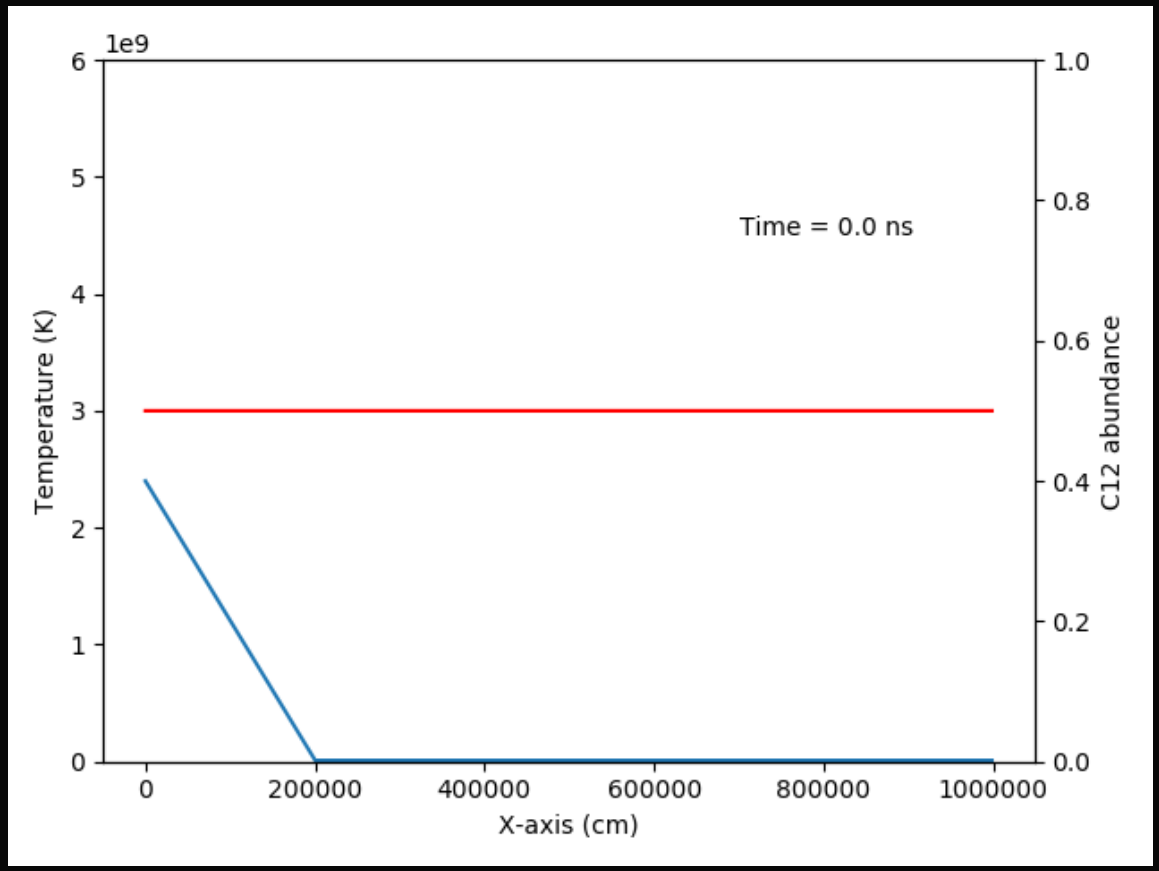
- What is a Type Ia Supernova (SNe Ia)?
- Stellar Lifetime
- White Dwarf
- Deflagration to Detonation Transition
- Zel'dovich Gradient Mechanism
- Carbon Detonation
- Helium Detonation
- Nuclear Physics
- Method
- Results

Zel'dovich Gradient Mechanism



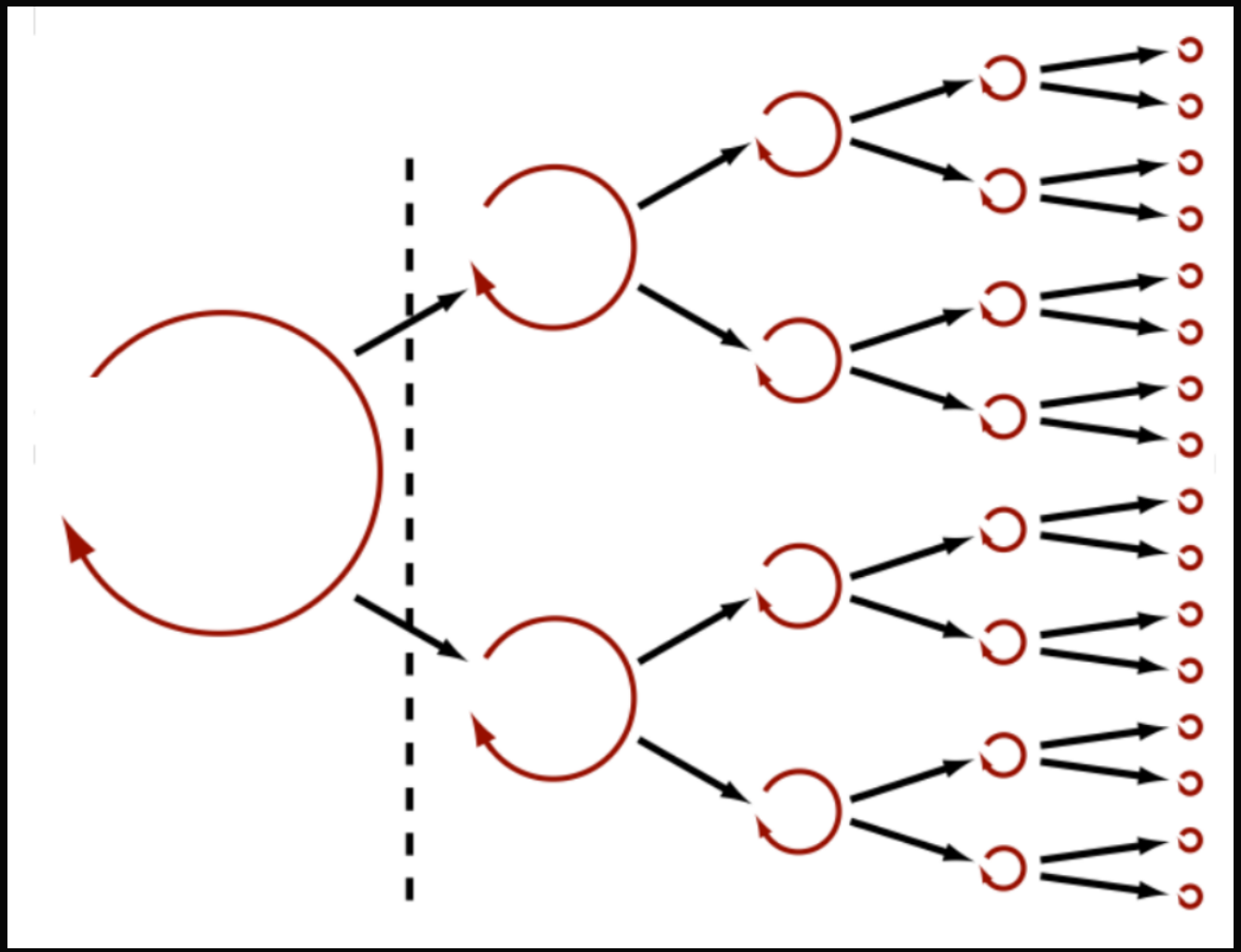
Failed detonation

Zel'dovich Gradient Mechanism



Successful Detonation

Turbulence



Kolmogorov's Theory (1941)

Carbon Detonation

- Highly Turbulent (Re $\simeq 10^{15}$)
- Karlovitz Number
  - Ka = (nuclear time scale/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

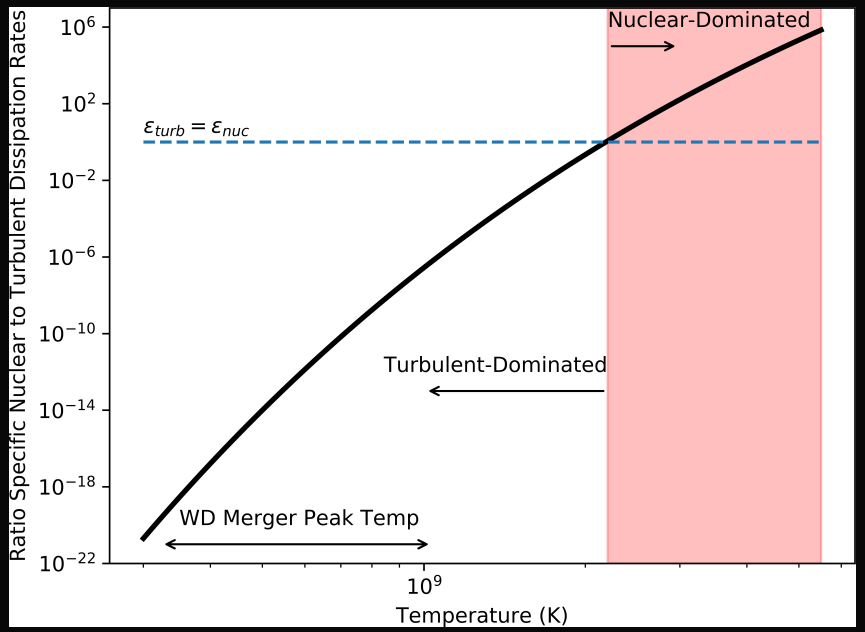


Figure: Analytic Curve for Carbon Detonation

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.

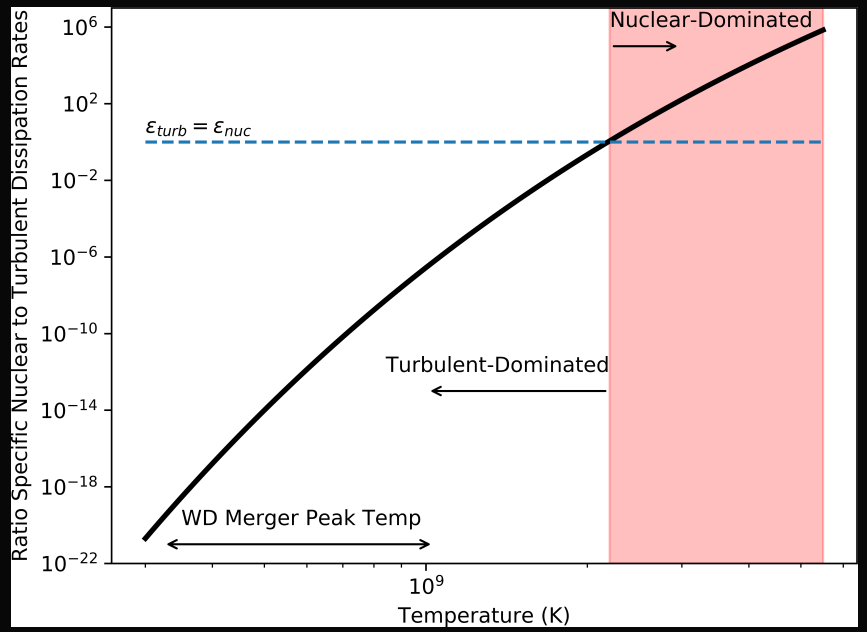
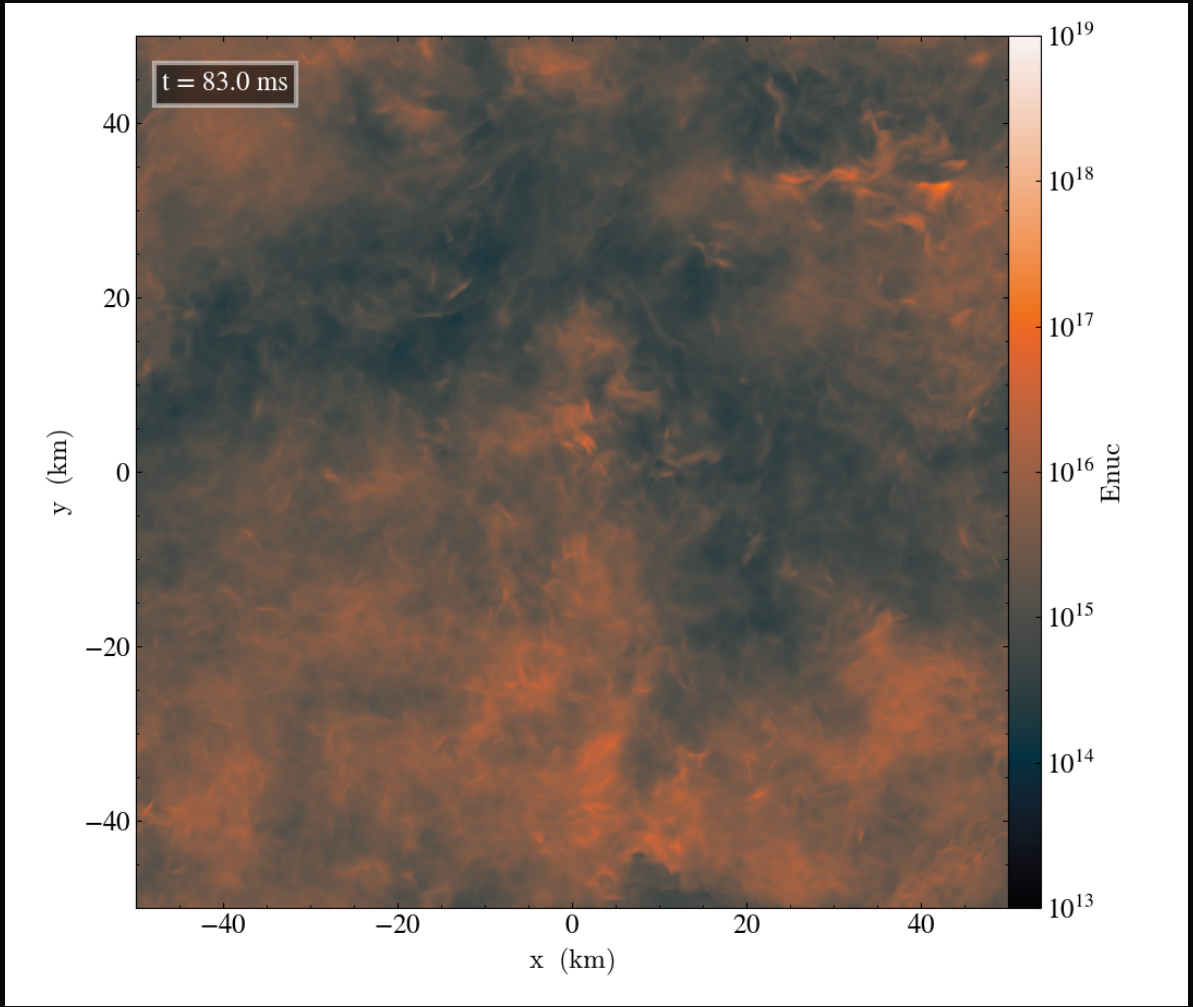
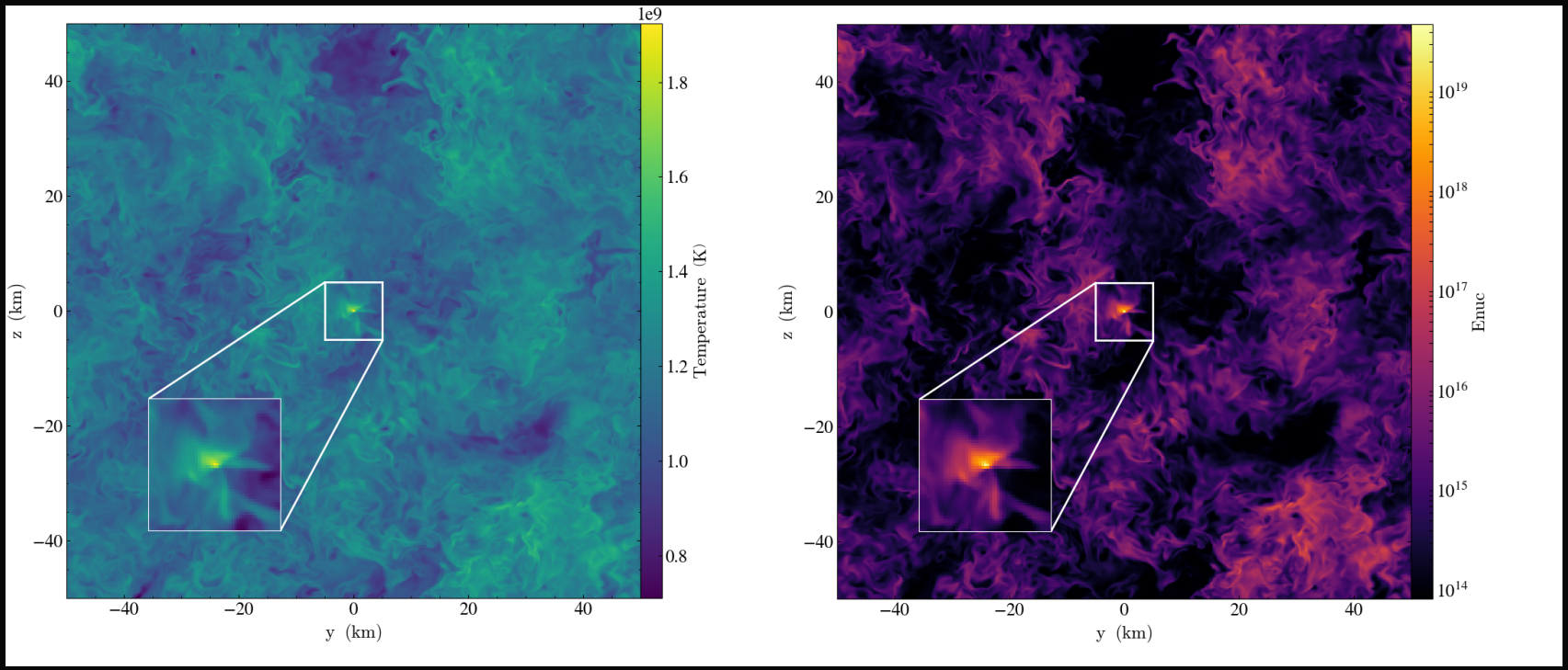


Figure: Analytic Curve for Carbon Detonation

Carbon Detonation

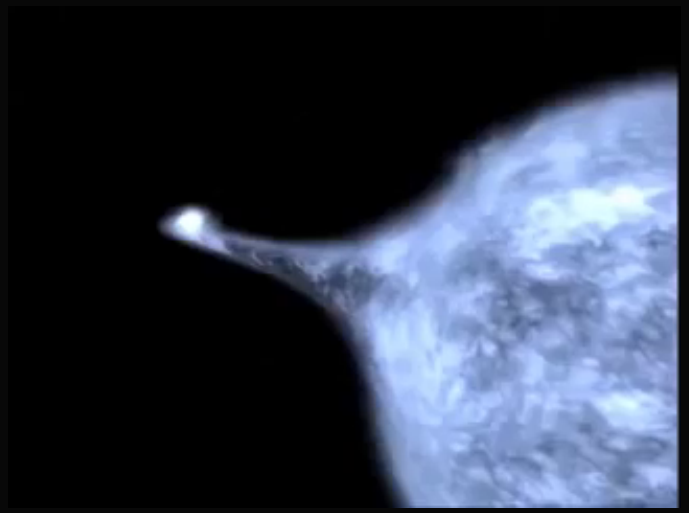


Carbon Detonation



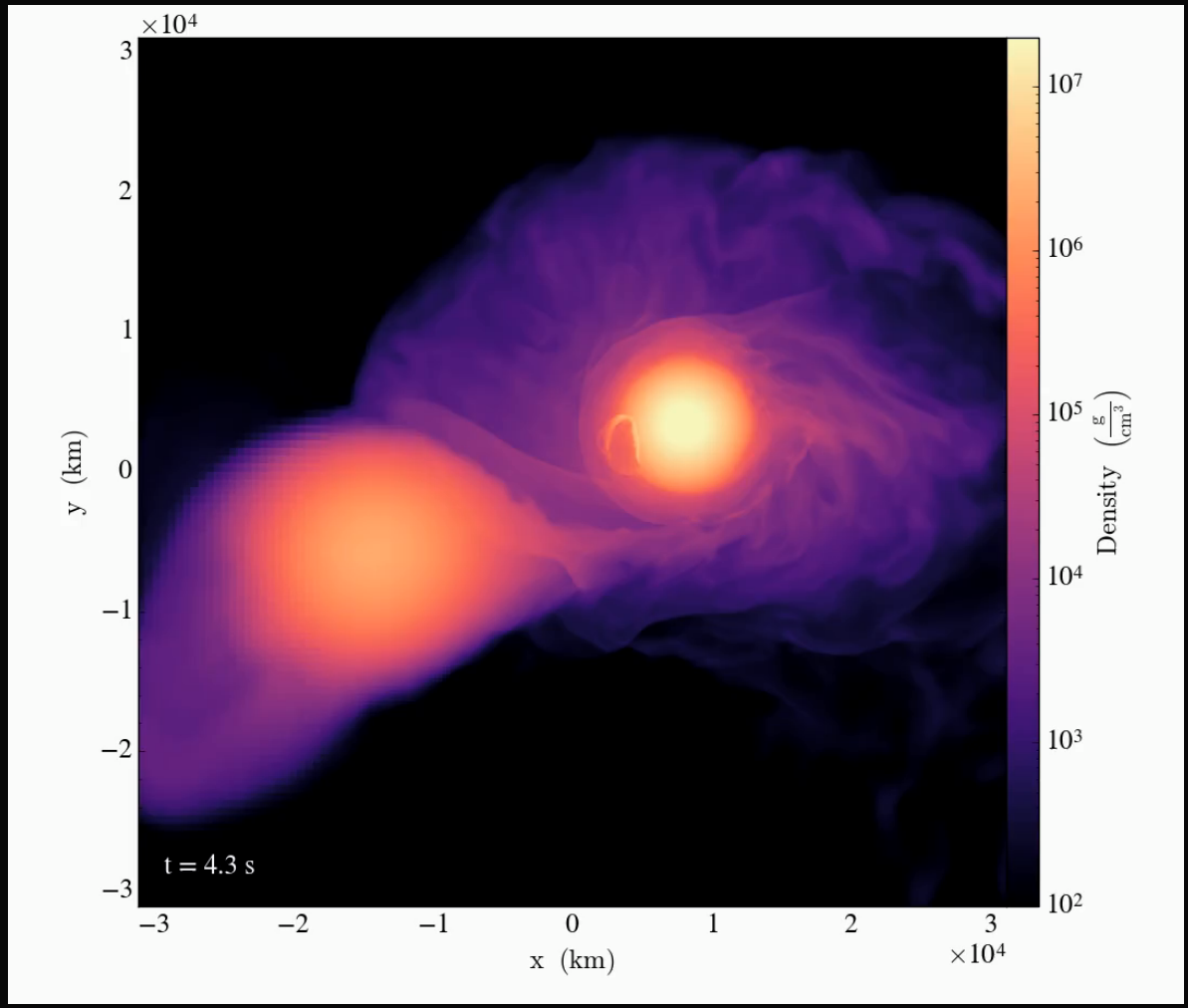
Slice plots at the moment of detonation.

Helium Detonation



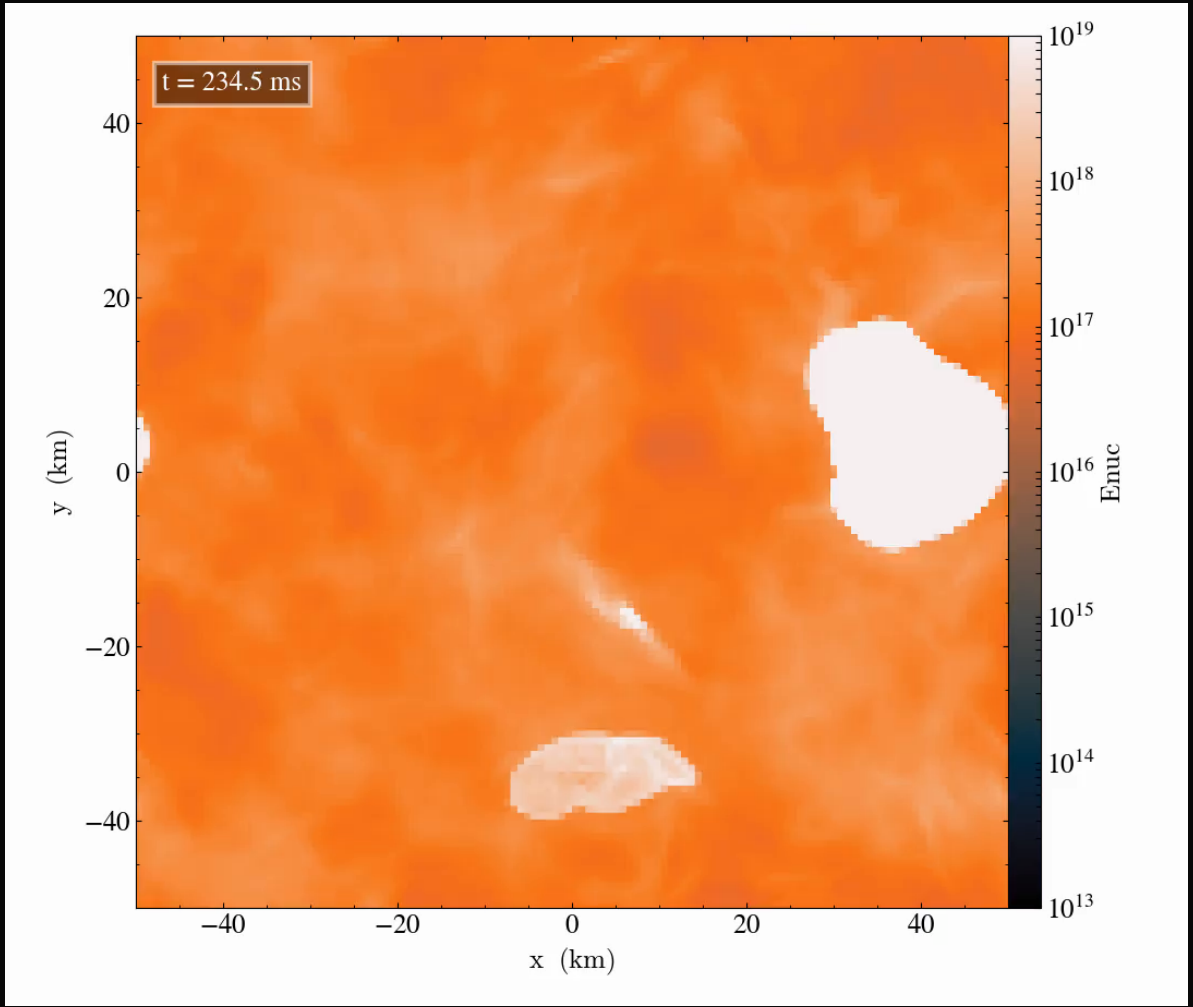
NASA, ESA and P. Ruiz-Lapuente, cut and colored by S. Geier

Helium Detonation



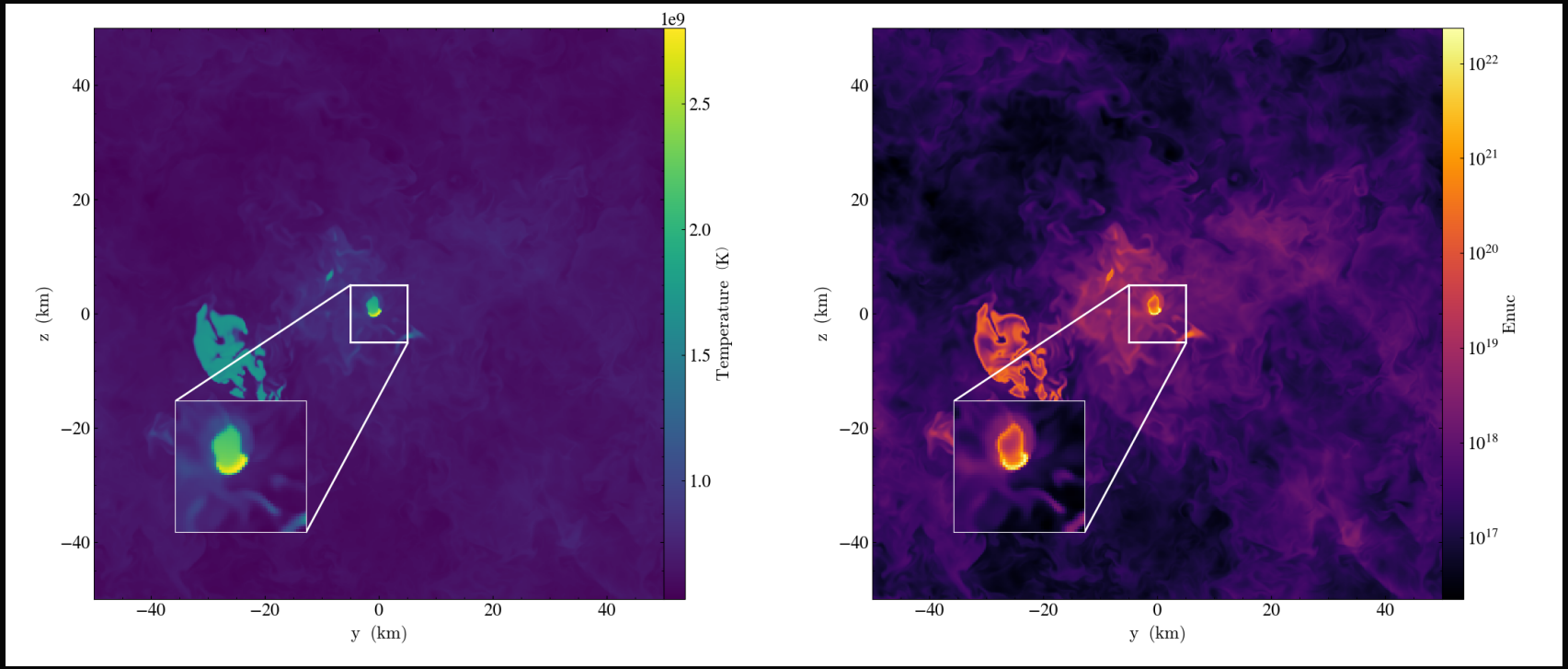
Vishal Tiwari (2019)

Results



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

Results


1e9
2.5
2.0
1.5
1.0
Temperature (K)
40
20
0
−20
−40
z (km)
−40
−20
0
20
40
y (km)
10^{22}
10^{21}
10^{20}
10^{19}
10^{18}
10^{17}
Enuc