

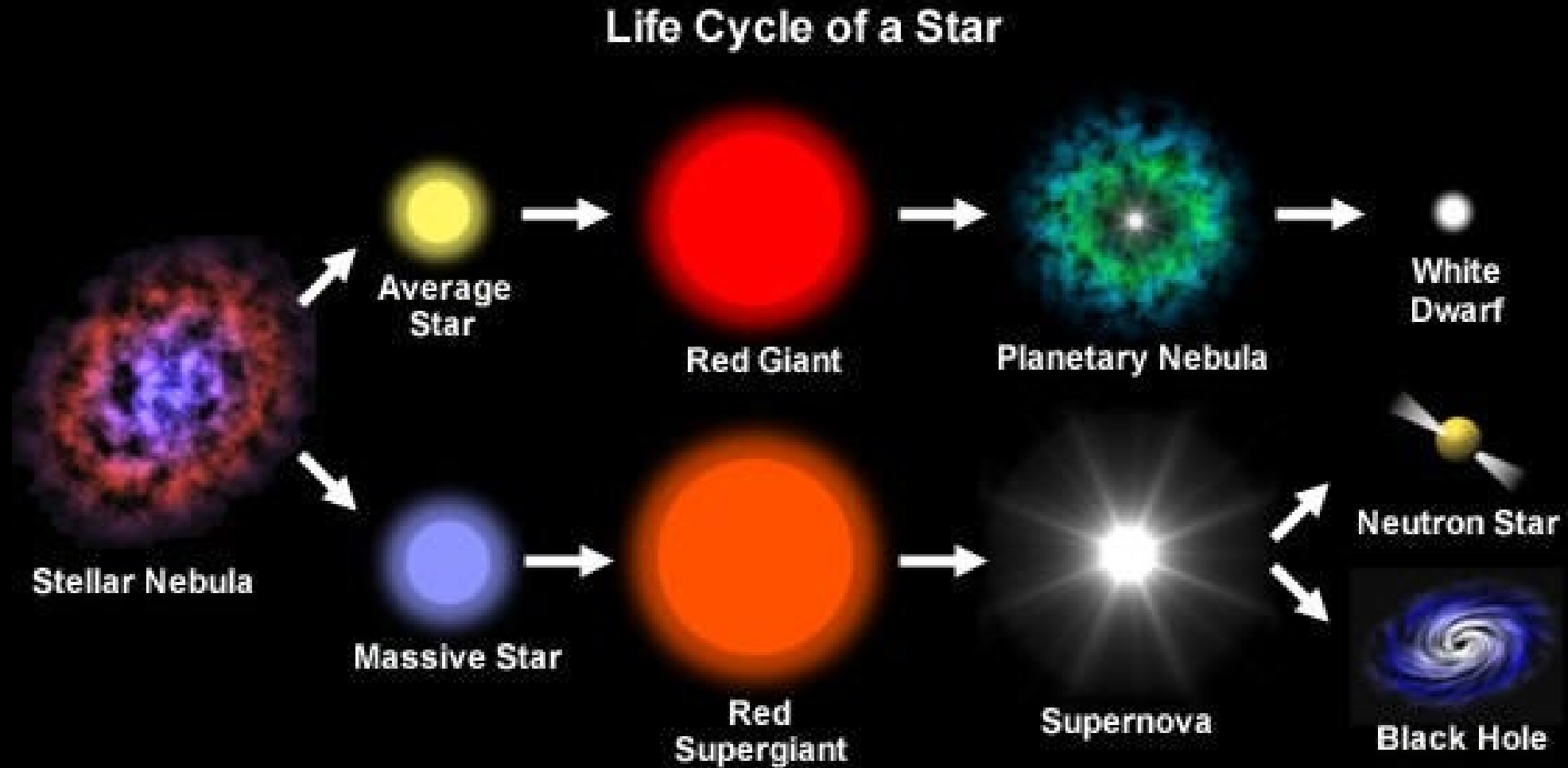
Numerical Frontier in Binary Compact Object Mergers

Gabriel Casabona
DOE CSGF

Northwestern



Stellar Evolution 101

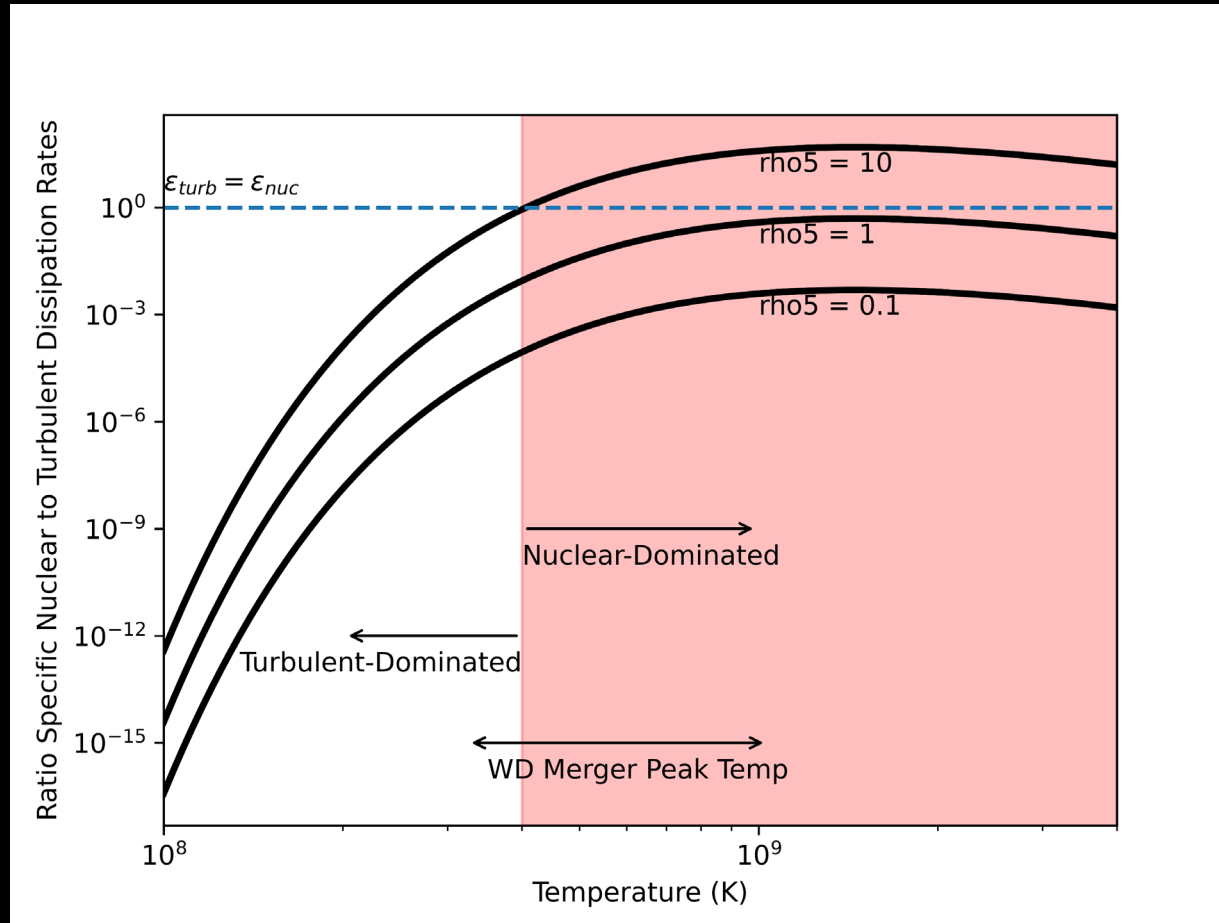


Type Ia Supernova



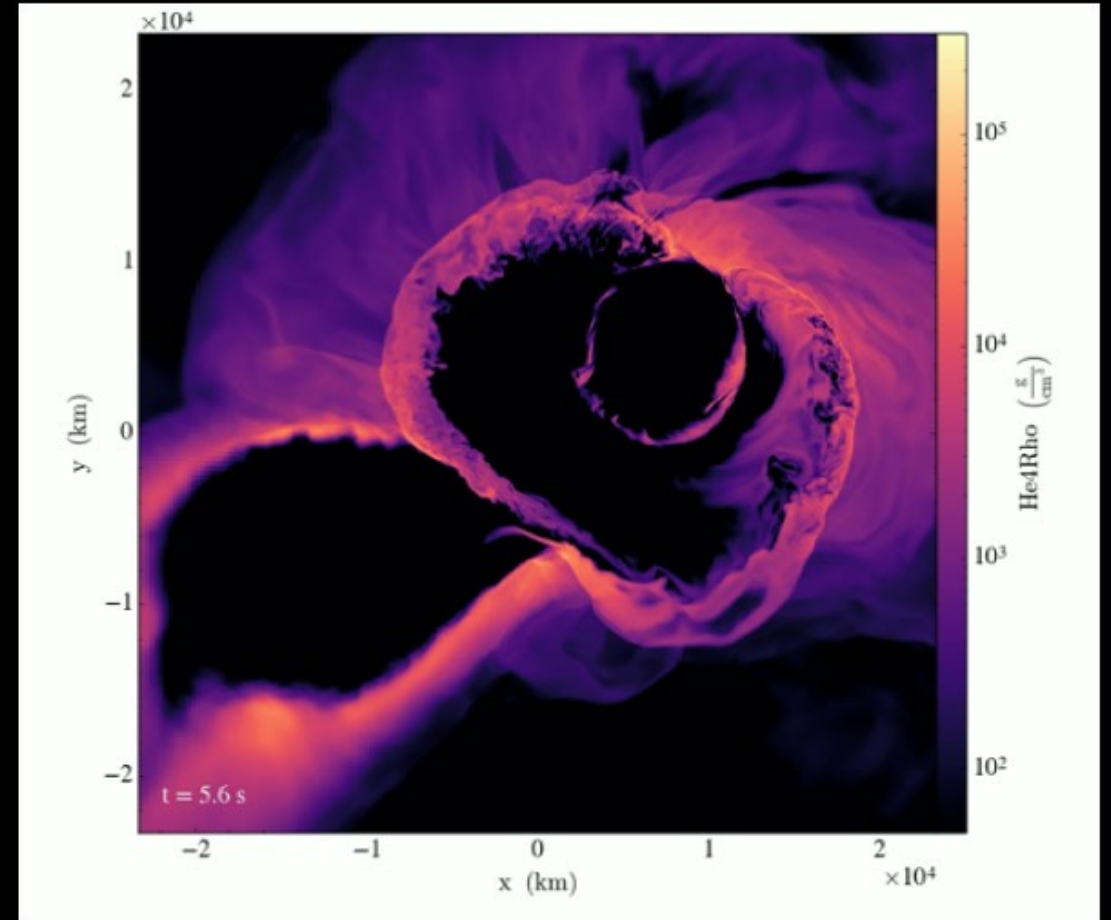
Adriana Manrique Gutierrez (NASA Scientific Visualization Studio)

Type Ia Supernova



Type Ia Supernova

- FLASH4
 - High-energy density physics
 - 3D grid with 512^3 cells
 - Helmholtz EOS
 - 19-isotope network
 - 100 km box
 - Large-scale turbulence
 - ^{12}C , ^4He , and ^{16}O
- Stampede2
 - 4096 cores (OpenMP + MPI)
 - ~ 7 days

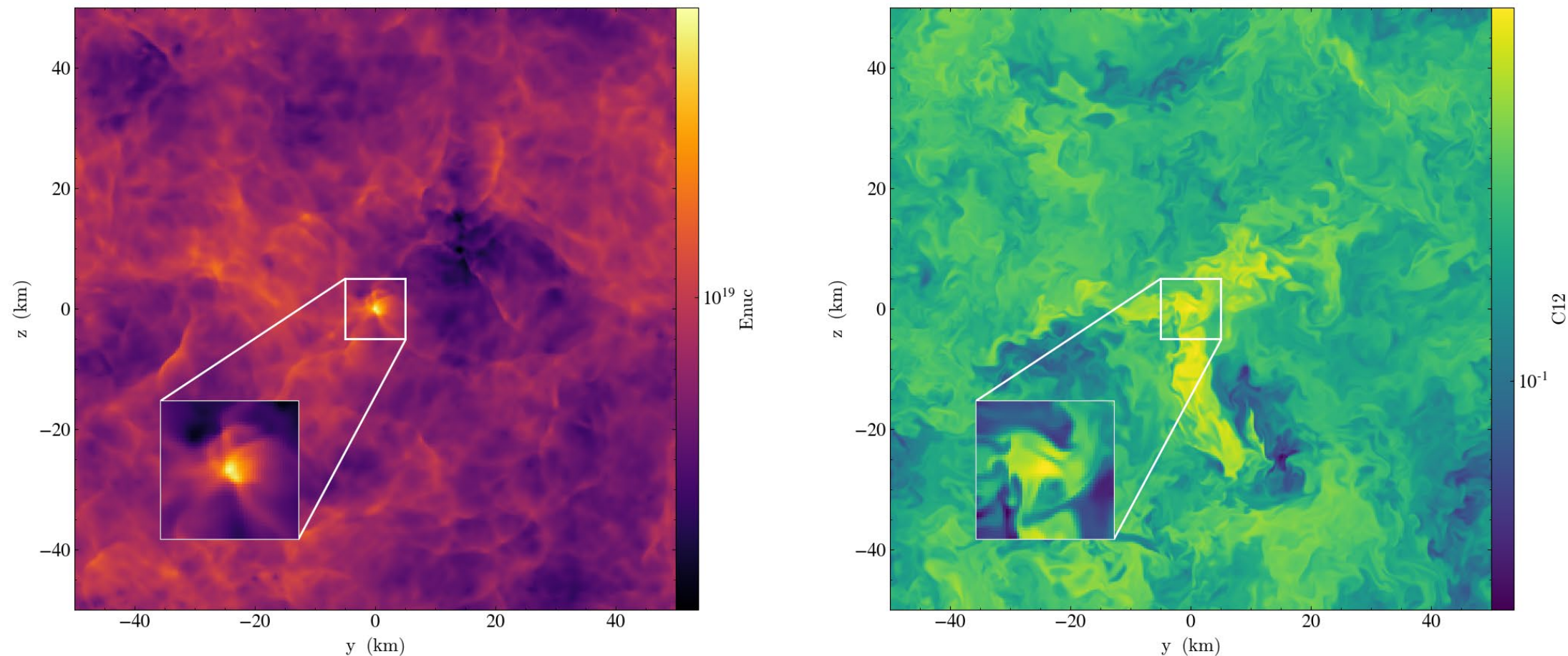


Type Ia Supernova: Results

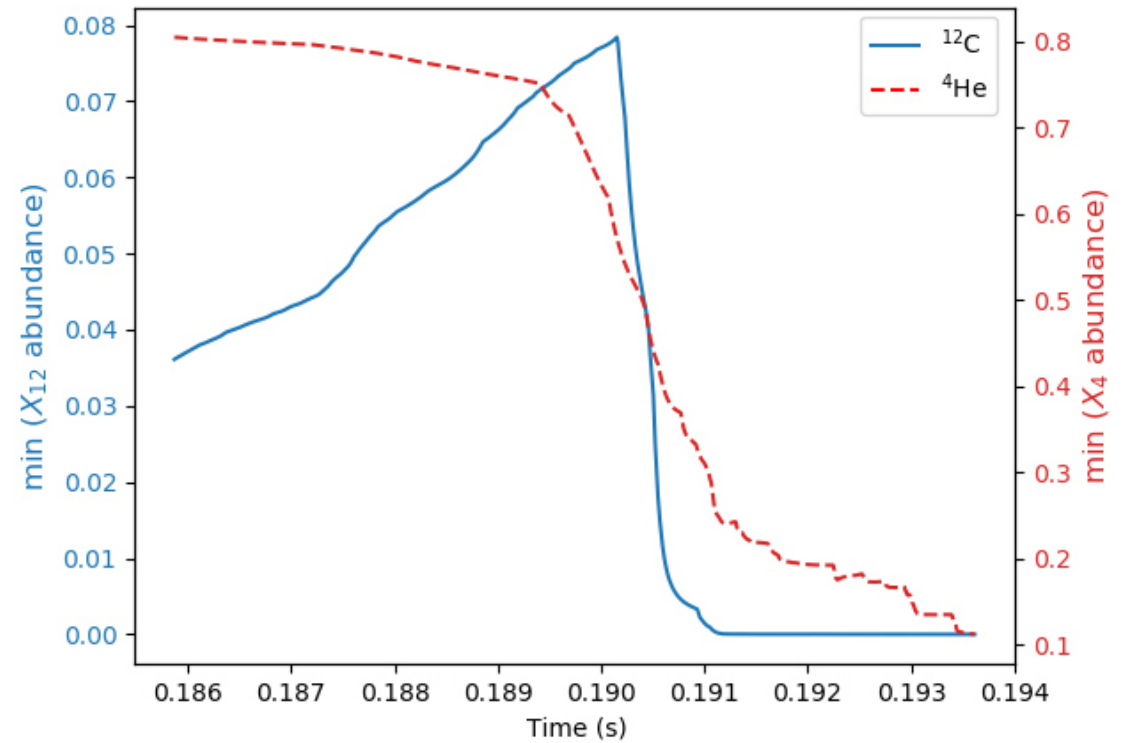
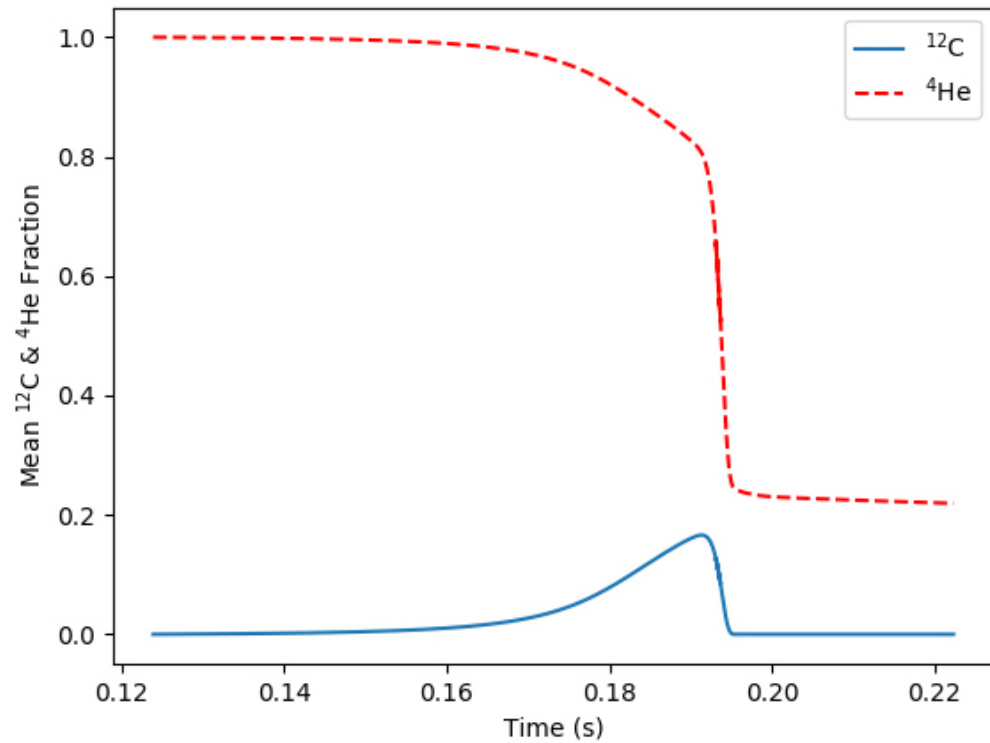
Density (g cm ⁻³)	He Abundance	T_{mean} (K)
10 ⁵	0.1	8.28×10^8
10 ⁵	0.25	8.75×10^8
10 ⁵	1.0	None
10 ⁶	0.1	7.80×10^8
10 ⁶	0.25	6.30×10^8
10 ⁶	1.0	1.06×10^9

Isotope	Mass (g)
⁴ He	8.02×10^{-1}
¹² C	1.69×10^{-1}
¹⁶ O	1.96×10^{-4}
²⁰ Ne	1.42×10^{-4}
²⁴ Mg	4.99×10^{-4}
²⁸ Si	1.94×10^{-2}
³² S	6.62×10^{-3}
³⁶ Ar	6.95×10^{-4}
⁴⁰ Ca	5.02×10^{-6}
⁴⁴ Ti	1.67×10^{-9}

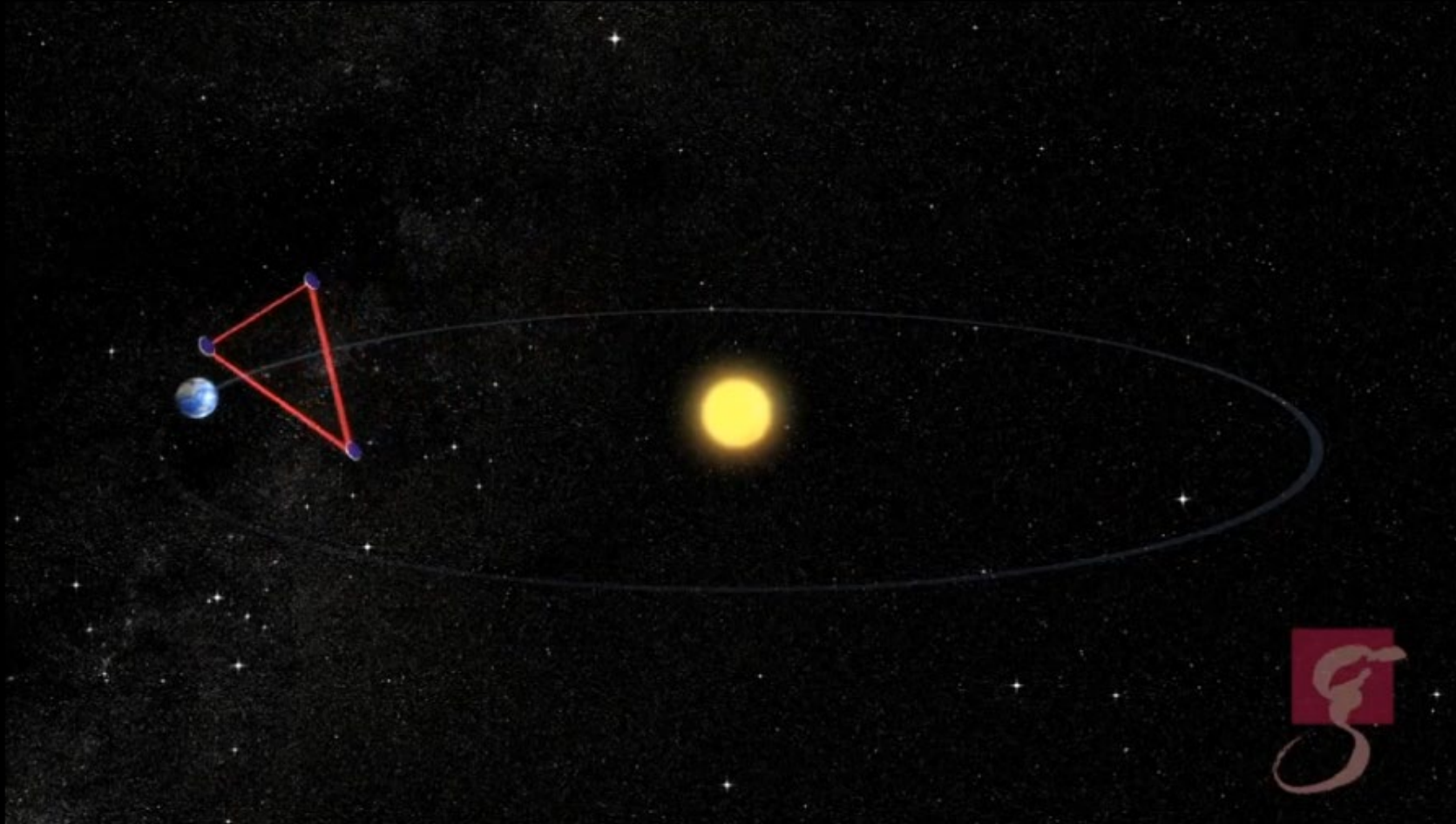
Type Ia Supernova: Results



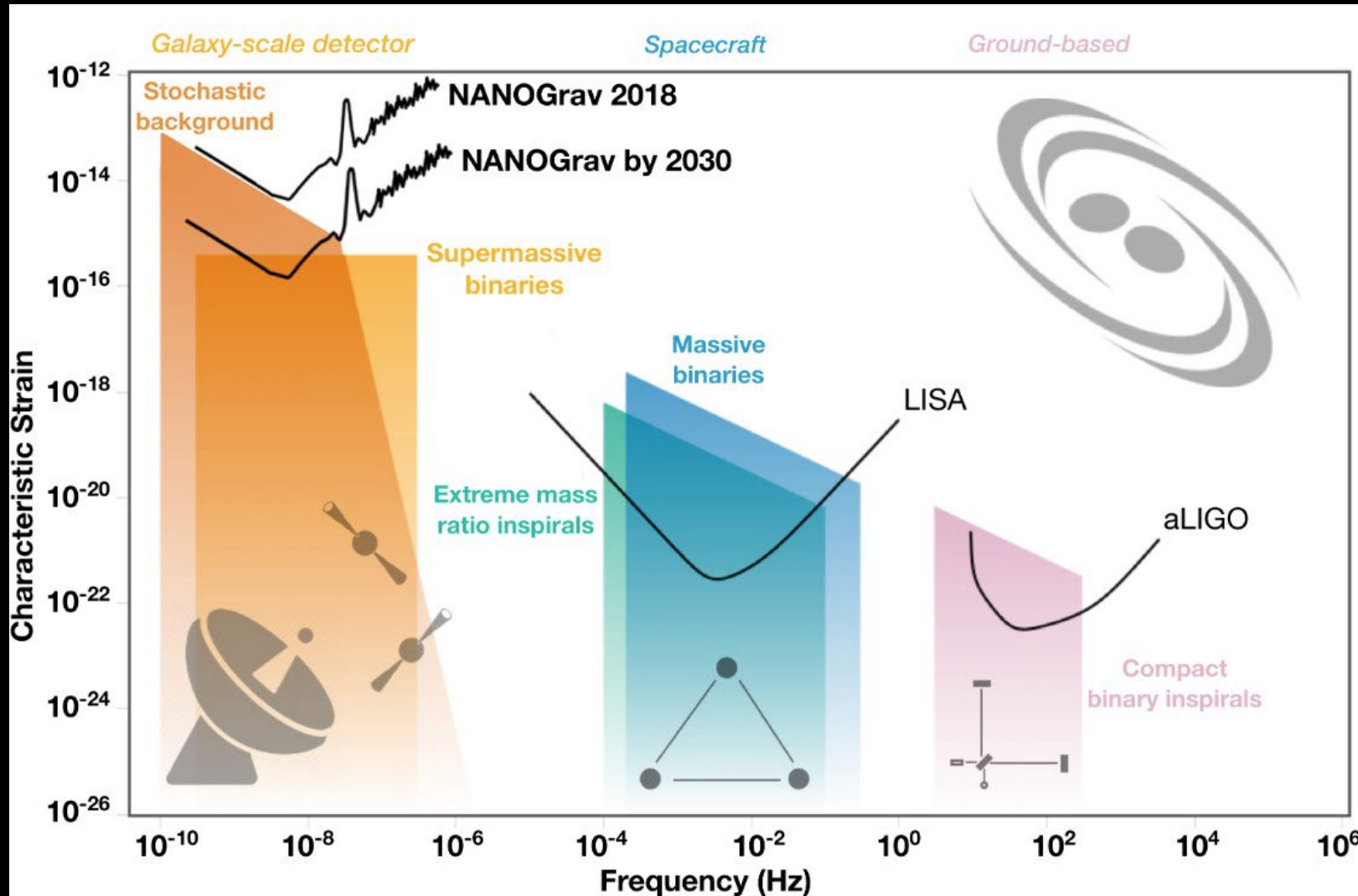
Type Ia Supernova: Results



Laser Interferometer Space Antenna (LISA)



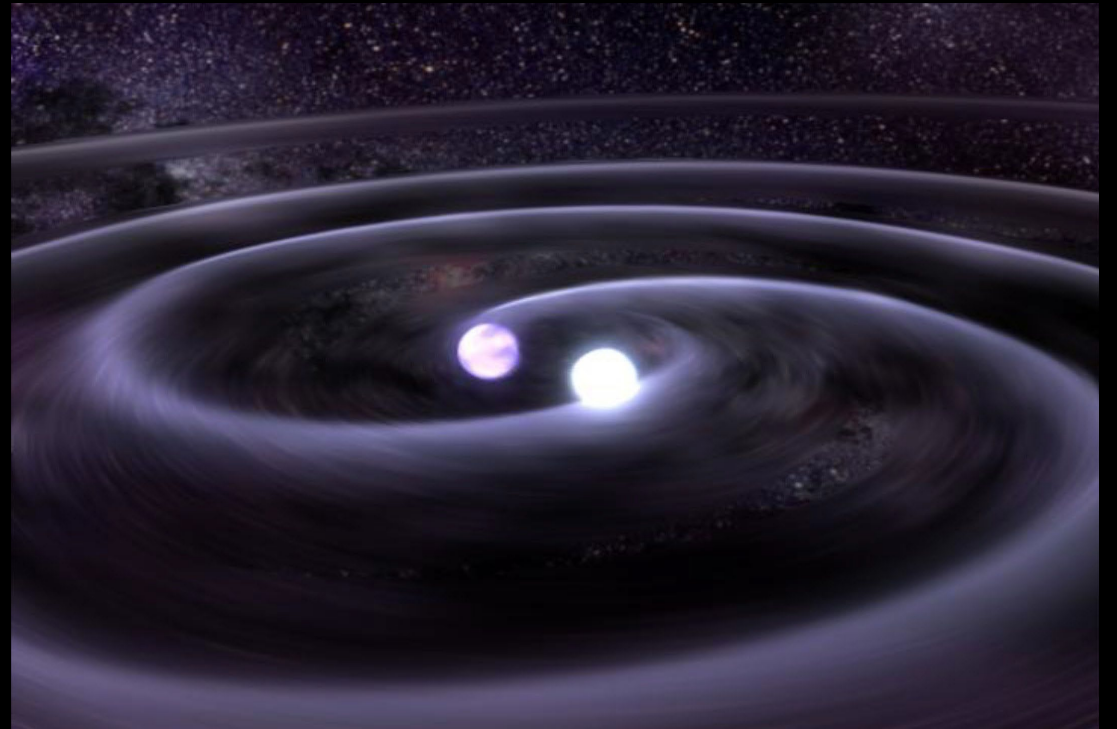
Gravitational Wave Spectrum



S. Taylor, C. Mingarelli, adapted from gwplotter.org (Moore, Cole, Berry 2014)

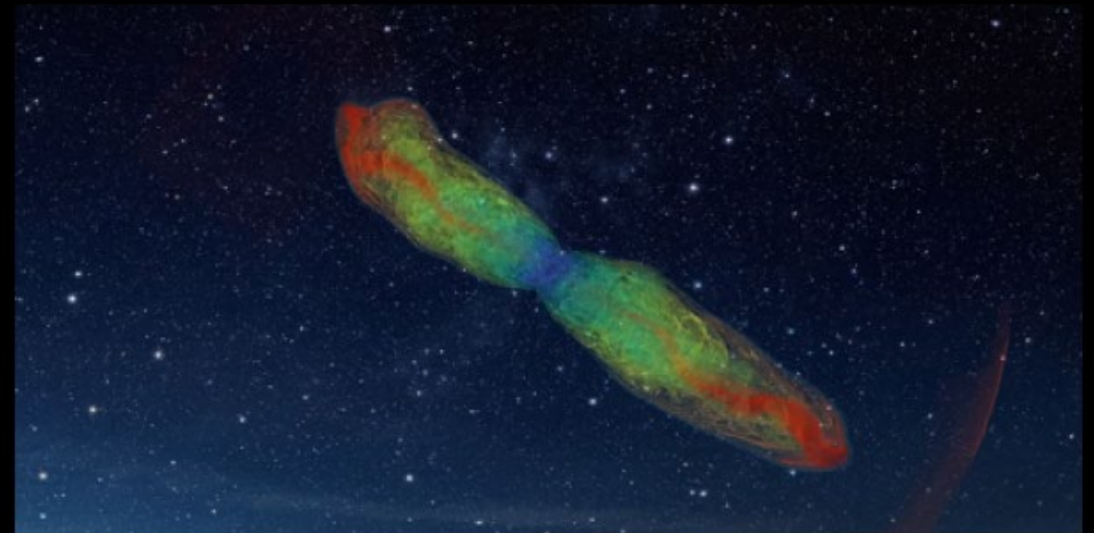
Binary White Dwarf Populations

- Gravitational Waves
 - Galactic sources (10,000 systems)
 - Resonance
- COSMIC
 - Compact Object Synthesis and Monte Carlo Investigation Code
 - Population Synthesis



Collapsars

- Black Holes
 - Trapped gas
 - Jets
 - MS star companion
- Gamma-Ray Bursts
 - Potential Short GRB source
- Questions
 - Population synthesis (COSMIC)
 - Relativity



Gottlieb, *et al.* (2022) CIERA

Neutron Stars

- Neutron-degenerate matter
 - Densest known object
 - Solid outer crust, fluid core
 - Magnetic field $10^8 - 10^{15}$ G
- GW170817
 - Birth of multi-messenger astronomy
- Questions
 - How did it break?
 - What was left behind?



Summary

- Type Ia Supernova
 - *Turbulently-Driven* Detonation mechanism
 - ^{12}C nucleosynthesis from ^4He
- Binary WD Population
 - Gravitational wave detection through LISA
 - Resonance
- Neutron Stars
 - Fully GR treatment of fluid core and solid crust
 - Resonance
- Collapsars
 - Short GRBs
 - Population synthesis

Acknowledgments

- APS Bridge Program
- Dr. Robert Fisher (UMassD)
- Dr. Shane Larson (NU)
- Dr. Oleg Korobkin (LANL)
- Dr. Roseanne Cheng (LANL)
- Dr. Nicole Lloyd-Ronning (LANL)
- DOE CSGF Fellows and Alumni
- Krell Staff!