The Impact of the Equation of State in Core-Collapse Supernovae

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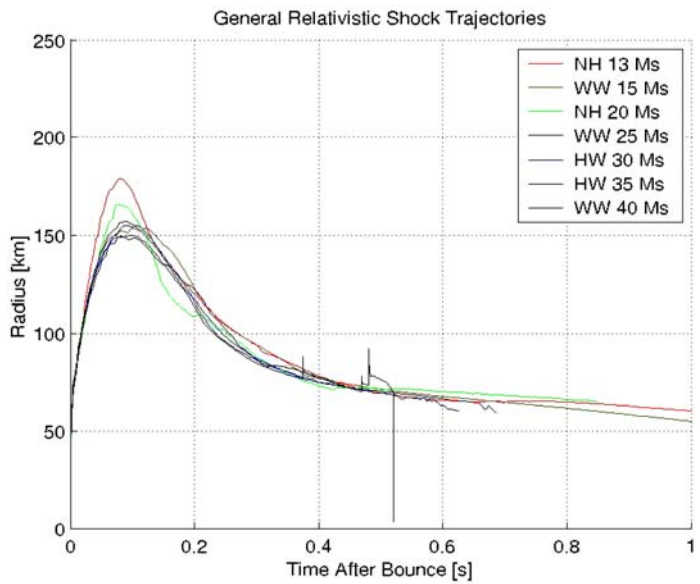
Delineating EoS Effects

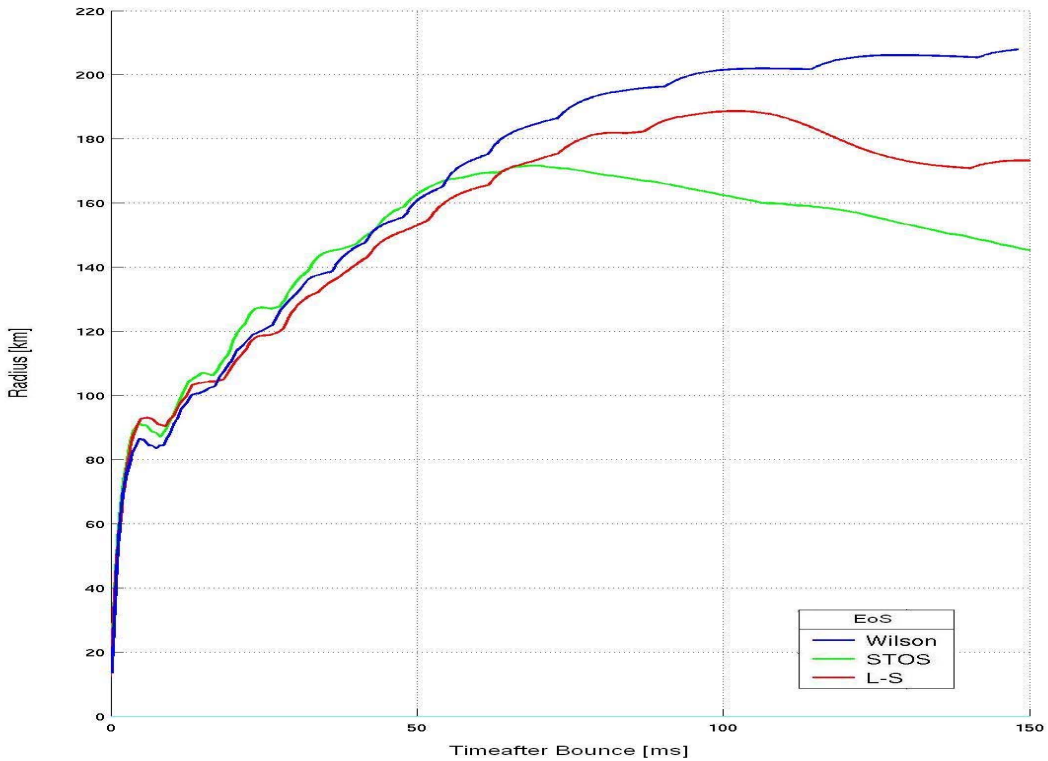
- Spherically symmetric collapse, bounce and shock stall simulations.
- Tool: AGILE-BOLTZTRAN (Mezzacappa & Bruenn 1993 a b c, Messer 2001,Liebendörfer et al. 2001
  - Has fully implicit, multi-group, 4-flavor Boltzmann neutrino transport
    - Most modern neutrino physics included
    - GR simulations use new LMSH electron capture rates (Hix et al. 2004, Langanke et al. 2003) as well as Bruenn 85 electron capture rates (Bruenn S W 1985 ApJS 58 771–841)
  - AGILE – implicit spherically symmetric hydrodynamics with an adaptive mesh.
  - Both general relativistic (including gravitational redshift) and Newtonian gravity.
  - Modular architecture allows use of multiple realistic equations of state.
  - 15 Solar Mass Progenitor



Equations of State

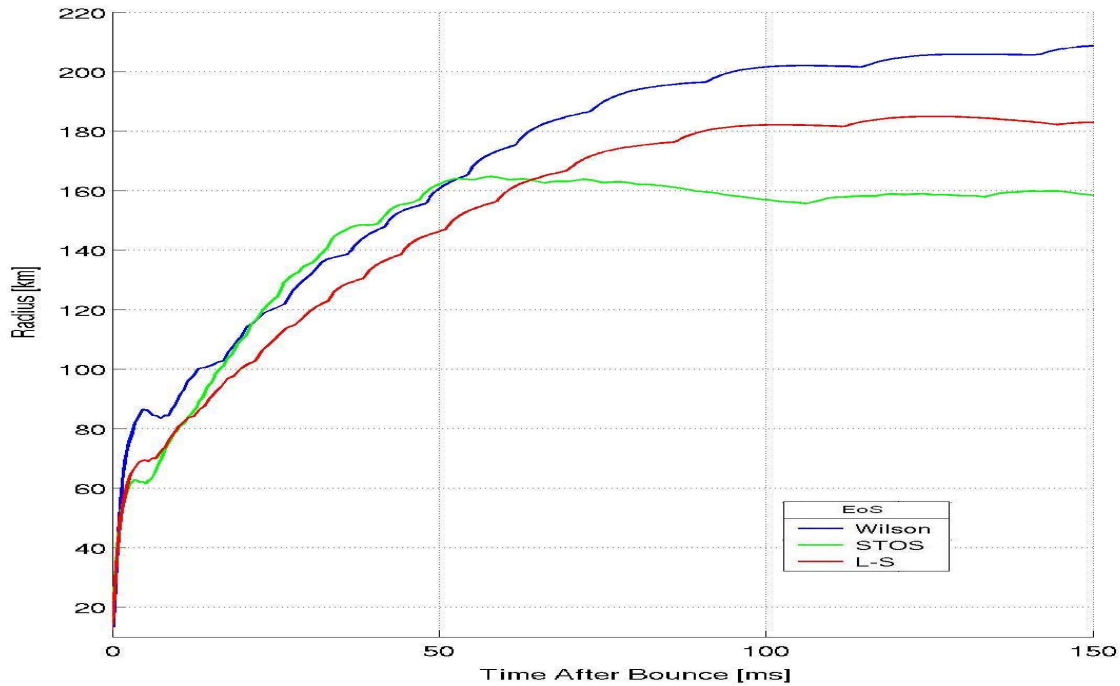
- J. Lattimer and F. D. Swesty 1991, Nucl. Phys. A535, 331. (Lattimer-Swesty Routine, L-S)
- H.Shen, H.Toki, K.Oyamatsu, K.Sumiyoshi 1998 NuPhA 637, 435. (STOS.)
- Richard L. Bowers and James R. Wilson 1982 ApJ. 50, 115 (Wilson)

General Relativistic Shock Trajectory with Bruenn 85 Electron Capture Rates



- "Bumpiness" due to the shock traveling out through successive zones
- Wilson EoS Shock ~10 km further than L-S EoS
- STOS EoS Shock begins to in fall after ~60 ms

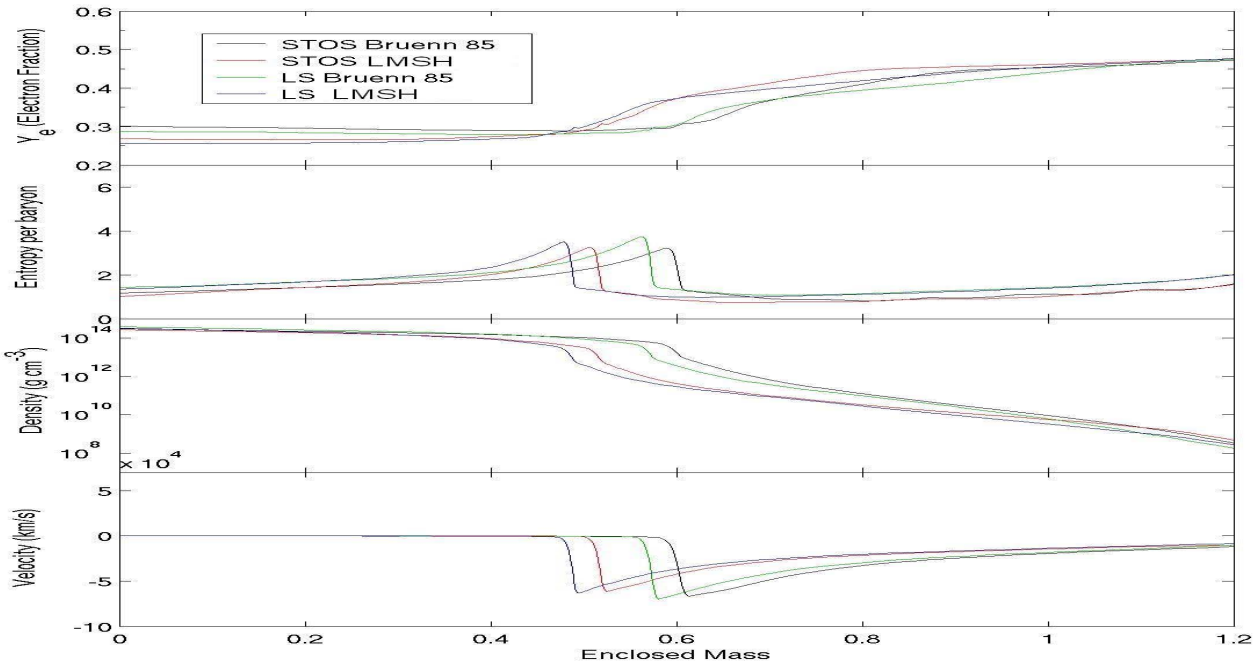
General Relativistic Shock Trajectory with LMSH Electron Capture Rates



- Contrasts Bruenn 85 Electron Capture Rates
- Wilson EoS Shock ~20 km further out than L-S EoS
- STOS EoS Shock begins to in fall after ~55 ms

At Bounce

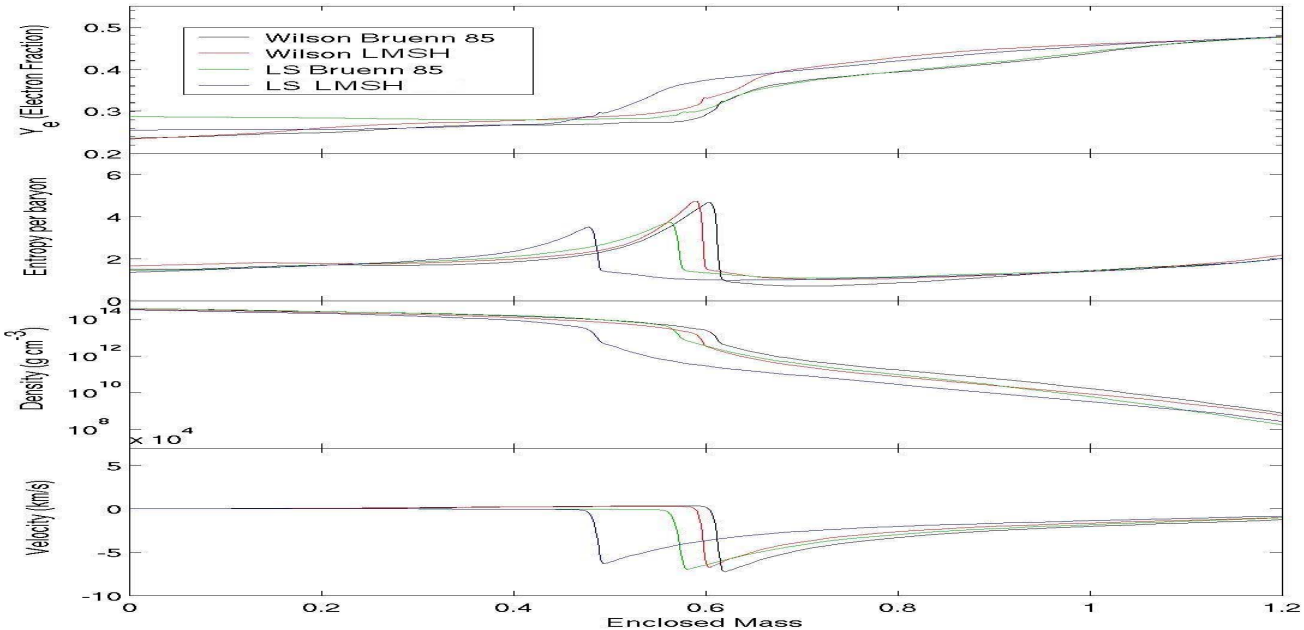
STOS and Lattimer-Swesty EoS



- ~ .03 $M_{\odot}$ inner core difference, 0.0134 Y_e difference between L-S and STOS with LMSH rates
- ~ .04 $M_{\odot}$ inner core difference, 0.0128 Y_e difference between L-S and STOS with Bruenn 85 rates
- The EOS determination of the composition ties it to the neutrino interaction processes for changes in Y_e

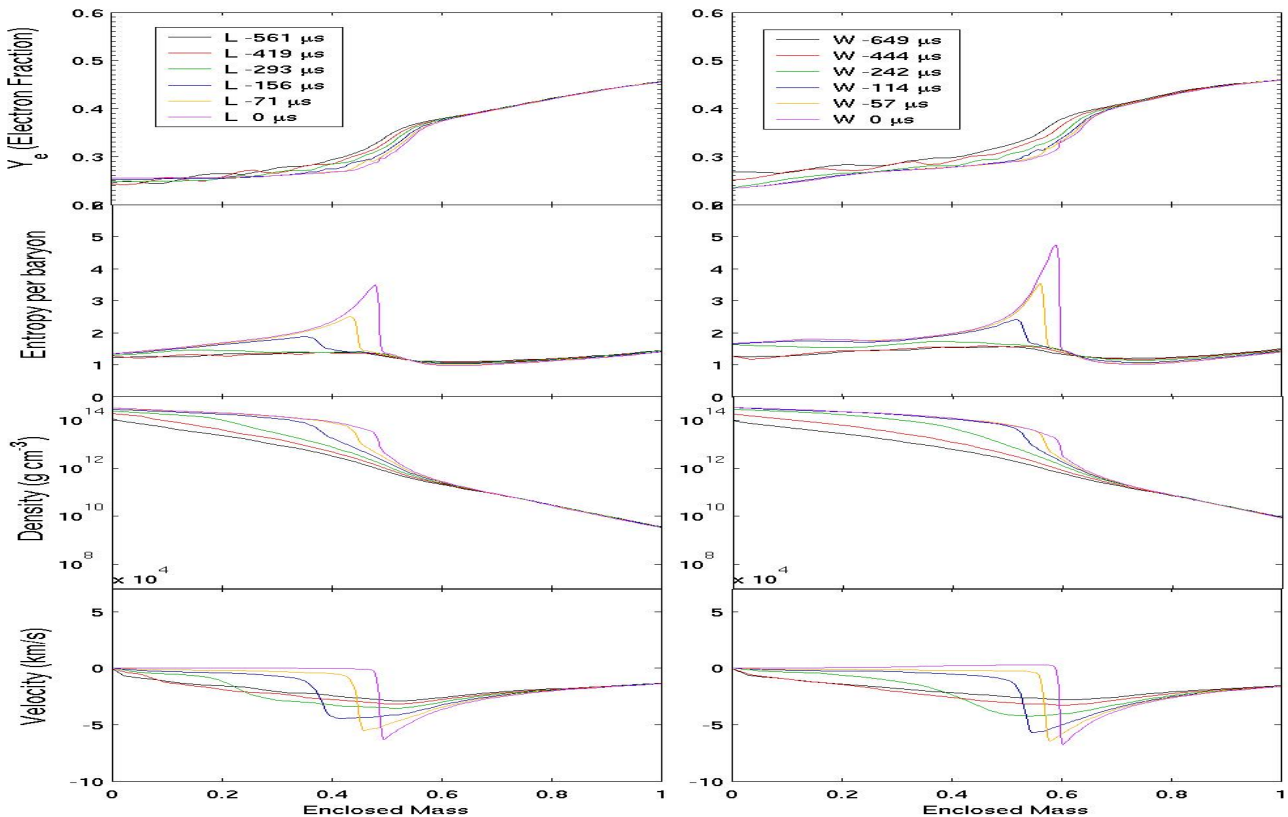
At Bounce

Wilson and Lattimer-Swesty EoS



- Static Ye for L-S increasing Ye for Wilson EoS, requires a closer look
- ~ .10 $M_{\odot}$ inner core difference, .0515 Y_e difference between L-S and Wilson with LMSH electron capture rates
- ~ .05 $M_{\odot}$ inner core difference, .0218 Y_e difference between L-S and Wilson with Bruenn 85 electron capture rates

A Closer look at the Lattimer-Swesty/Wilson EoS Comparison



- Ye decreases rapidly in the central core. Pions!
- Higher Bounce density.
- Other Thermodynamic differences: Entropy, Pressure and Chemical Potential

Discussion and the Future

- AGILE BOLTZTRAN provides a unique laboratory to perform these EoS comparisons
- The difference in shock formation radius seen between L-S and STOS comparable to that seen moving from Bruenn (1985) electron capture physics to modern LMP hybrid rates
- The Future:
  - A look at Instabilities
  - Survey other EoS's
    - Baron, Cooperstein and Kahana
    - ORNL/Oxford Hartree-Fock
    - Your EoS here, Have tester, will travel