New nuclear equation of state for core-collapse supernovae with realistic nuclear forces

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We have constructed a new nuclear equation of state (EOS) for core-collapse supernova (SN) simulations based on the variational many-body theory.

Our Plan to Construct the SN-EOS

Uniform Nuclear Matter : Cluster variational method (AV18 + UIX)

Non-uniform Nuclear Matter : Thomas-Fermi calculation

Low-density region

High-density region

Completion of a Nuclear EOS table for SN simulations

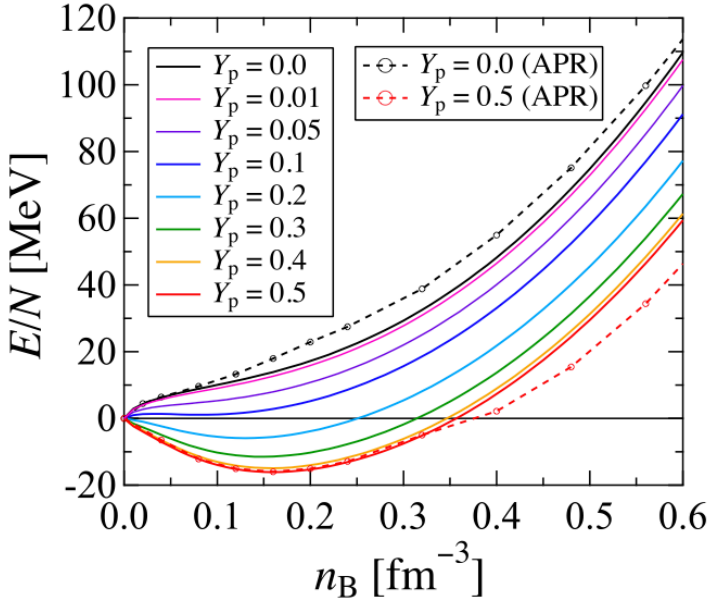
NPCSM 2016 @ YITP, November 1st, 2016

Uniform Nuclear Matter

Potential: AV18+UIX
Wave function: Jastrow wave function

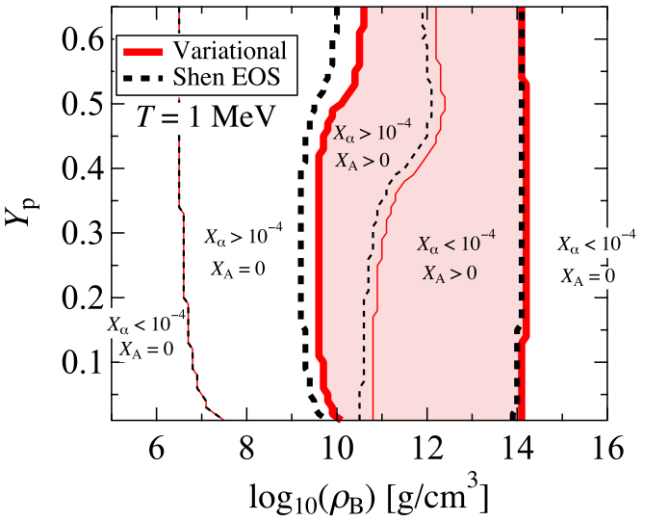
n_0[fm^{-3}]	E_0[MeV]	K [MeV]	S [MeV]
0.16	−16.1	245	30.0

Our EOS : NPA902 (2013) 53 APR : PRC58 (1998) 1804

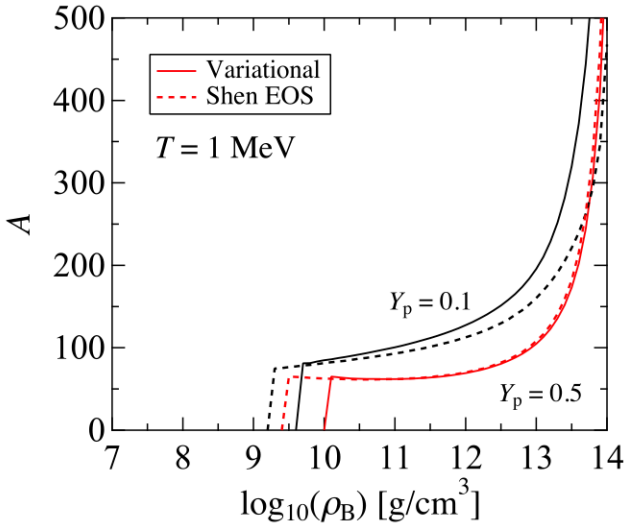


Energy per nucleon at 0 MeV

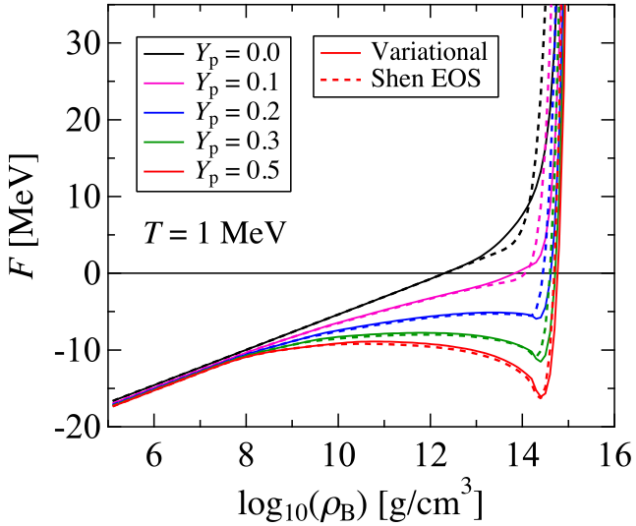
Non-uniform Nuclear Matter



Phase diagram of nuclear matter



Mass number A

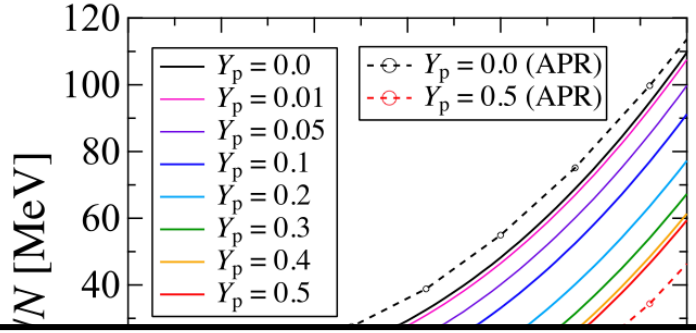


Free energy per nucleon

Variational EOS : H. Togashi et al., in preparation. Shen EOS : APJS 197 (2011) 20

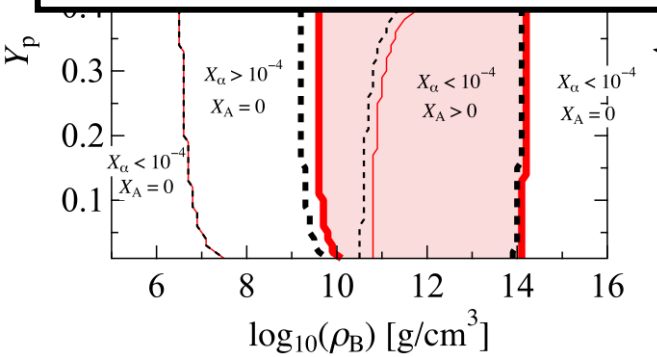
Uniform Nuclear Matter

Potential: AV18+UIX
Wave function: Jastrow wave function

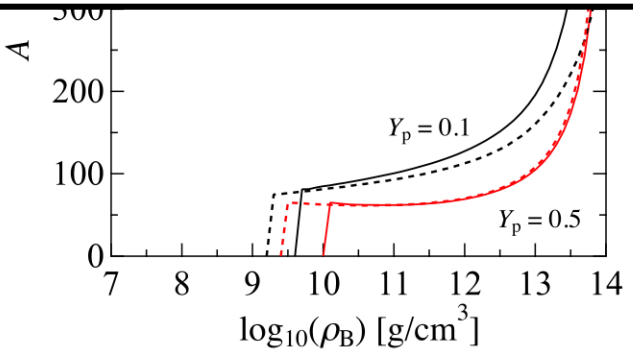


Ranges and grids of T, Y_p, and ρ_B (same as in the case of the Shen EOS)

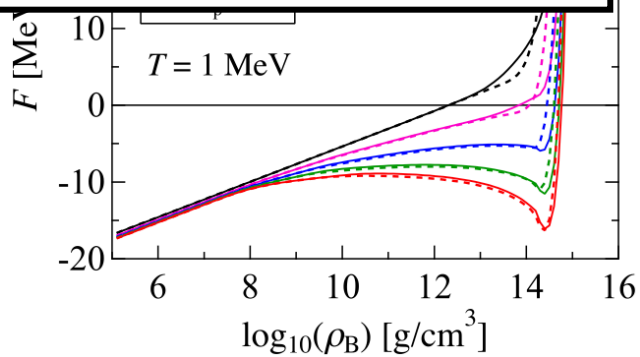
Parameter	Minimum	Maximum	Mesh	Number
$\log_{10}(T)$ [MeV]	-1.00	2.60	0.04	$91+1$
Y_p	0	0.65	0.01	66
$\log_{10}(\rho_B)$ [g/cm^3]	5.1	16.0	0.10	110



Phase diagram of nuclear matter



Mass number A



Free energy per nucleon

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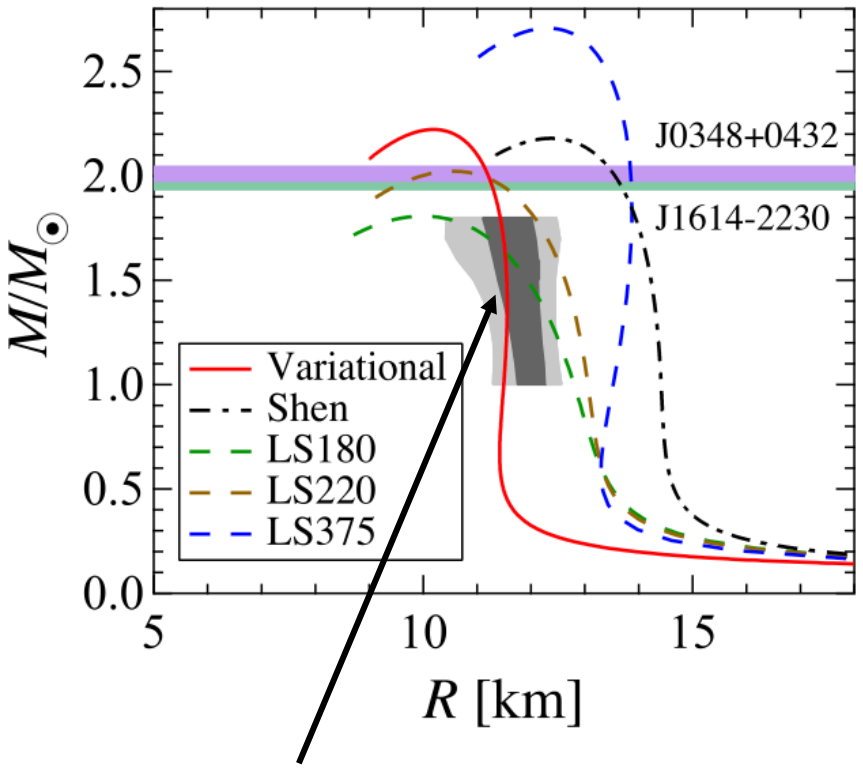
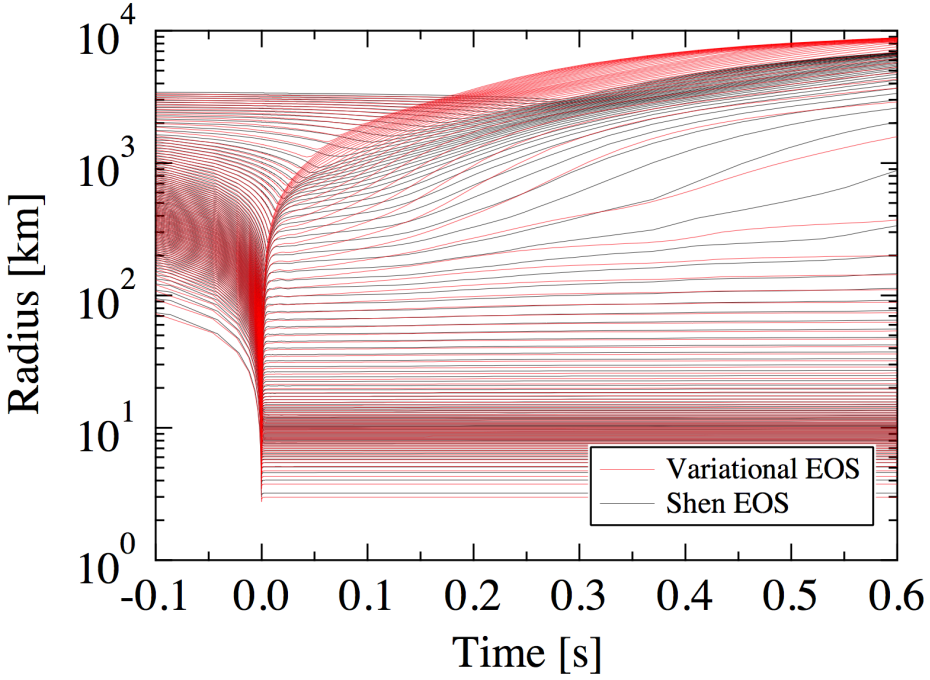
Application to astrophysics

Neutron Stars with our EOS



Radius of a 1.4 $M_\odot$ neutron star:
$R_{1.4}$ = 11.56 km

Core-Collapse SN Simulation



- 1D full GR simulation
- Adiabatic collapse
- Progenitor: Woosley & Weaver 1995, 15$M_\odot$
  (Astrophys. J. Suppl. 101 (1995) 181)

Our new SN-EOS table will be available soon!