Hot and Dense Matter Equation of State Probability Distributions for Astrophysical Simulations

Andrew W. Steiner

UTK/ORNL

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Collaborators: **Xingfu Du**, Jeremy Holt

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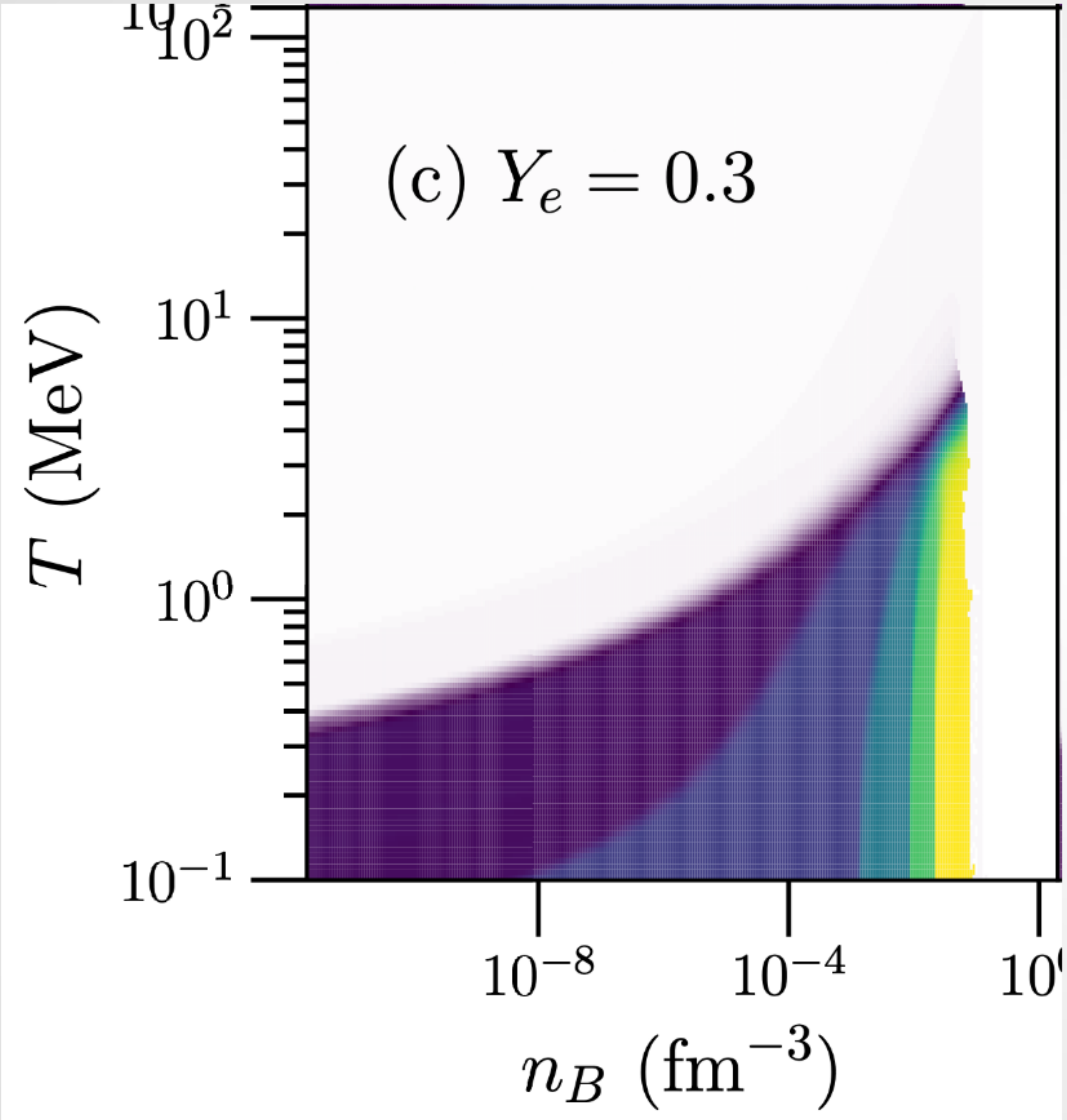
    - Symmetric nuclear matter near saturation density: Skyrme model fit to nuclear masses and other experimental data
    - Hot matter near the saturation density: finite temperature corrections based on a Skyrme model fit to results obtained from the Luttinger-Ward expansion

Adding Nuclei - Part I

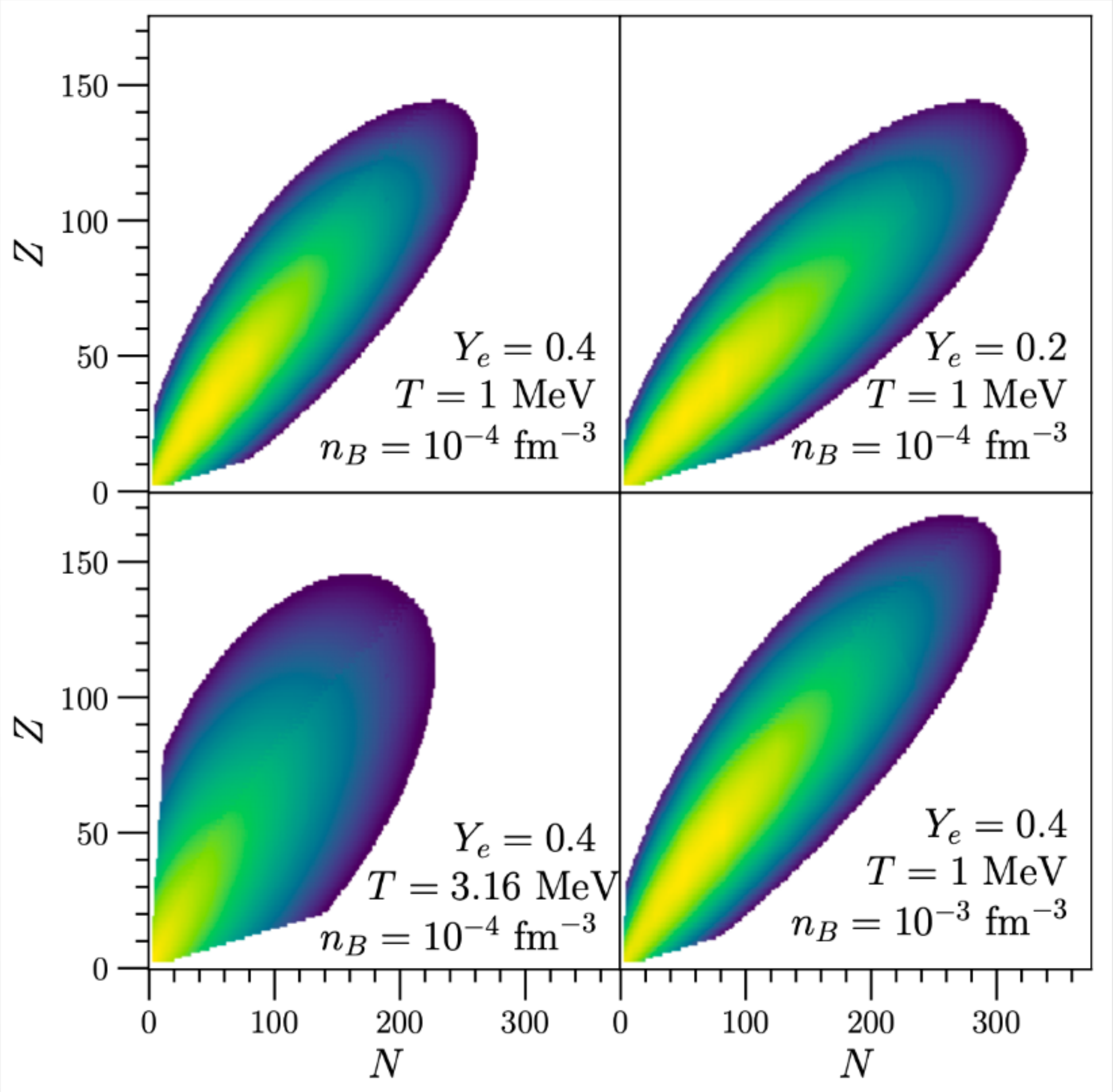
- Nuclear masses from 2020 AME or Moller et al. (2016) masses
- Phenomenological partition functions based on Shen et al. (2010) to describe hot nuclei
- No nuclei beyond the driplines yet
- No pasta yet
- Full nuclear distribution at every (n_B, Y_e, T) point
- Nuclear part of the free energy based on SFH (developed earlier by Hempel and Schaffner-Bielich)
- Excluded volume correction
- Coulomb energy for spherical nuclei in a Wigner-Seitz cell

Adding Nuclei - Part II

- No modification of surface energy for the medium
- Nucleon chemical potentials are the same inside and outside nuclei



The mean $< A >$ at fixed $Y_e = 0.3$



The nuclear distribution at four selected points

Tables

- Baryon density, 2×10^{-12} to $2\ \mathrm{fm}^{-3}$
- Electron fraction, 0.01 to 0.7
- Temperature, 0.1 to $120\ \mathrm{MeV}$
- Fully open source, https://github.com/awsteiner/eos
- Only 8 tables for now, but thousands of tables could easily be generated from the same code

Table of Contents

Quick search

Go

UTK EOSs for Astrophysical Simulations

This C++ code constructs the equation of state of homogeneous nucleonic matter for use in simulations of core-collapse supernovae and neutron star mergers. This code was originally described in a paper on arxiv.org. The source code is available on github. The installation of Boost, GSL (versions 1.16 and later), HDF5 (versions 1.8.14 and later), and the most current version of O2scl is required in order to compile the code to generate and analyze EOS tables. (You do not necessarily need to compile the code to use the EOS tables.)

You will need to manually edit the makefile to work with your system and then compile `eos_nuclei` in order to generate an EOS. The homogeneous matter EOS from Du et al. (2019) has a separate executable `eos`, which can also be compiled.

More documentation will be added as time permits.

EOS Web Page Tour II

Table of Contents

Quick search

Go

Tables to Download

- Fiducial
- Large Mmax
- Large SL
- Large R
- Small SL
- Small R
- Smaller R
- Fiducial L414

Table of Contents

Quick search

Go

Table Format

The table is an HDF5 file and the datasets are given below. Several quantities are stored in tensor_grid objects, which are stored as HDF5 groups with the name of the group given below. The contents of the rank 3 tensor are stored in the dataset named data in each group.

Grid

- `n_nB`: number of points in baryon density grid
- `n_Ye`: number of points in electron fraction grid
- `n_T`: number of points in temperature grid
- `nB_grid`: array containing baryon density grid (in fm^{-3})
- `Ye_grid`: array containing electron fraction grid
- `T_grid`: array containing temperature grid (in MeV)

Physical quantities

These are stored as double-precision numbers.

- `hc`: $\hbar c$ (in MeV fm)
- `alpha_em`: α_{EM}, the fine structure constant
- `m_neut`: the mass of the neutron (in MeV)
- `m_prot`: the mass of the proton in MeV (in MeV)

Back to EOS tables

- Will submit to PRC this week
- I want them to be useful!
- Developing consistent neutrino opacities (Zidu Lin)
- I'm taking requests!
- E.g. Adam requested some second derivatives of F and densities going down to $10^{-14}~\mathrm{fm}^{-3}$, both of which are easily do-able.

EOS Future

- Muons

  Some coding work, since muons coincide with nuclei at high T

- Pions a la Reddy and Fore

  At least some coding work required

- Model in-medium corrections to the surface energy

  I'd prefer to do this by calibrating with HF calculations rather than TF (as in LS-based tables), but this is quite a bit of work

- Pasta

  Some coding work required

- Hyperons and quarks

  Not too difficult, if one presumes, e.g. $\mu_d = \mu_s$

- Momentum-dependent interactions

  Not difficult to code, but poorly calibrated to nuclear structure (except maybe for Gogny)