Read me first

This is a short note on the use of the relativistic EOS table. Please read through before you use it.

1 EOS updates

We name different versions of the EOS table as follows. The ranges of the temperature T, proton fraction Y_p, and baryon mass density ρ_B are listed in Table 1.

- **EOS1**: 1998-version, with only nucleons.
  The detailed description can be found in the file *guide_EOS1.pdf* and the reference *PTP100(1998)1013*.

- **EOS2**: 2010-version, with only nucleons.
  The framework and contents in EOS2 are the same as in EOS1, so one can refer to the same documents and *guide_EOS2.pdf*. Comparing with EOS1, there are mainly six improvements in EOS2:
  (1) We have increased T grids as shown in Table 1.
  (2) We have used linear mesh for Y_p.
  (3) We have taken regular logarithmic meshes for T and ρ_B.
  (4) We have consistently used the physical constants given by Table 2 in all codes.
  (5) We have deleted column 3 in EOS1 which is $\log_{10}(Y_p)$.
  (6) We have corrected wrong μ_p for the case of $Y_p = 0$ and $T = 0$ in EOS1.

- **EOS3**: 2010-version, with nucleons and Λ hyperons.
  The framework including Λ hyperons is based on *PTP115(2006)325*. The ranges and contents in EOS3 are the same as in EOS2 besides two more columns (columns 17 and 18) are added in EOS3.

Table 1: The ranges of the temperature T, proton fraction Y_p, and baryon mass density ρ_B in these EOSs. In addition, the cases of $T = 0$ and $Y_p = 0$ are also provided.

Version	Parameter	Minimum	Maximum	Mesh	Number
EOS1	$\log_{10}(T)$ [MeV]	-1.00	2.00	∼0.10	31+1
	$\log_{10}(Y_p)$	-2.00	-0.25	0.025	71+1
	$\log_{10}(\rho_B)$ [g/cm^3]	5.10	15.40	∼0.10	104
EOS2	$\log_{10}(T)$ [MeV]	-1.00	2.60	0.04	91+1
	Y_p	0.01	0.65	0.01	65+1
	$\log_{10}(\rho_B)$ [g/cm^3]	5.10	16.00	0.10	110
EOS3	$\log_{10}(T)$ [MeV]	-1.00	2.60	0.04	91+1
	Y_p	0.01	0.65	0.01	65+1
	$\log_{10}(\rho_B)$ [g/cm^3]	5.10	16.00	0.10	110

Table 2: The physical constants used in EOS2 and EOS3 taken from *PLB667(2008)103*.

Quantity	Symbol	Value
conversion constant	$\hbar c$	197.327 [MeVfm]
atomic mass unit	m_u	931.494 [MeV]
circumference ratio	π	3.141592653

1.1 Contents in EOSs

We briefly list the definitions of the quantities tabulated in EOS2 and EOS3. For more detailed description of these quantities, one can refer to *guide_EOS2.pdf*, *guide_EOS3.pdf*, and *PTP100(1998)1013*. The file *eos.tab* is the main table except the cases of $T = 0$ (given by *eos.t00*) and $Y_p = 0$ (given by*eos.yp0*). $\log_{10}(T)$ and T are written at the beginning of each block as "Log10(Temp)" and "Temp" in the table, while we use a string of characters "ccccccccccc" to divide blocks with different T. In each block, the quantities in the columns are

- (C1) logarithm of baryon mass density: $\log_{10}(\rho_B)$ [g/cm^3]
- (C2) baryon number density: n_B [fm^{-3}]
- (C3) proton fraction: Y_p

- (C4) free energy per baryon relative to the free nucleon mass M: F [MeV], $F = \frac{f}{n_B} - M$
- (C5) internal energy per baryon relative to the atomic mass unit m_u: $E_{\rm int}$ [MeV], $E_{\rm int} = \frac{\epsilon}{n_B} - m_u$. Note that we have used $m_u = 931.494$ MeV in EOS2 and EOS3 instead of $m_u = 931.49432$ MeV in EOS1.
- (C6) entropy per baryon: S [k_B]
- (C7) mass number of the heavy nucleus: A
- (C8) charge number of the heavy nucleus: Z
- (C9) effective nucleon mass: M_N^* [MeV]
- (C10) free neutron fraction: X_n
- (C11) free proton fraction: X_p
- (C12) alpha-particle fraction: X_α
- (C13) heavy nucleus fraction: X_A
- (C14) pressure: p [MeV/fm^3]
- (C15) chemical potential of the neutron relative to the free nucleon mass M: μ_n [MeV]. In EOS3, neutrons and Λ hyperons have the same chemical potential, $\mu_n + M = \mu_\Lambda + M_\Lambda$.
- (C16) chemical potential of the proton relative to the free nucleon mass M: μ_p [MeV]
- (C17) effective Λ mass: M_Λ^* [MeV]
- (C18) Λ hyperon fraction: X_Λ, which is defined by $X_\Lambda = n_\Lambda / n_B$.

1.2 EOS checking

We have done the following check for these EOSs:

(1) the consistency of the fractions,

$$X_p + X_n + X_\Lambda + X_\alpha + X_A = 1.$$

(2) the consistency of the relation between F, $E_{\rm int}$, and S,

$$F = E_{\rm int} - TS + m_u - M.$$

(3) the consistency of the thermodynamical quantities,

$$F = \mu_n(1 - Y_p) + \mu_p Y_p - \frac{p}{n_B}.$$

In general, these consistency relations can be satisfied within a few thousandths.

2 Documents

The detailed description on EOS1, EOS2, and EOS3 can be found in the files *guide_EOS1.pdf*, *guide_EOS2.pdf*, and *guide_EOS3.pdf*, respectively. Please refer to the following papers when you publish scientific articles by using these EOSs.

- (1) Relativistic equation of state of nuclear matter for supernova and neutron star, H. Shen, H. Toki, K. Oyamatsu and K. Sumiyoshi, Nuclear Physics A637 (1998) 435-450.
- (2) Relativistic equation of state of nuclear matter for supernova explosion, H. Shen, H. Toki, K. Oyamatsu and K. Sumiyoshi, Progress of Theoretical Physics, 100 (1998) 1013-1031.

We will write another paper on EOS2 and EOS3 in near future.

3 Contact

If you find any error or strange behavior, please contact us. We would appreciate it very much if you could give us suggestions on these EOSs. Please contact one of the following authors

==========

Hong Shen
School of Physics, Nankai University,
Tianjin 300071, China
E-mail: shennankai@gmail.com

==========

==========

Kohsuke Sumiyoshi
Physics Group, Numazu College of Technology (NCT),
Ooka 3600, Numazu, Shizuoka 410-8501, Japan
E-mail: sumi@numazu-ct.ac.jp

==========