CompOSE
CompStar Online Supernovae Equations of State

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CompOSE meeting

Institut de Physique Nucléaire de Lyon (IPNL)

CompOSE I

- **features**
  - repository of equations of state (data tables and additional information) for applications in astrophysics, nuclear physics and beyond
  - EoS for nuclear/quark matter and stellar matter

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  - EoS for nuclear/quark matter and stellar matter
  - EoS can be one-, two-, or three-dimensional
  - information on thermodynamic quantities, chemical composition and microscopic quantities
  - flexible data format for storage of EoS tables
  - tools for extracting, interpolating and generating EoS tables according to the needs of the user with determination of additional quantities
  - supports ASCII and HDF5 data formats in output
  - subscription for newsletter available

CompOSE II

- **access & up-to-date information**
  - website: `compose.obspm.fr`
    no registration needed any more
  - manual (version 1.00, $\approx$ 70 pages): available from website
    or arXiv:1307.5715 [astro-ph.SR], will be updated soon

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- **objective of today's meeting**
  - extension of CompOSE database
    $\Rightarrow$ contribute your EoS

How to contribute with your EoS

three steps:

- **preparation of EoS tables**
  - three tables with parameters (mandatory):

    temperature T, baryon number density n_b, charge fraction Y_q
  - table with thermodynamic quantities (mandatory)
  - table with composition of matter (optional)
  - table with microscopic quantities (optional)

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- **uploading your EoS to the database**
  - no general rule
  - contact the CompOSE administrators: `develop.compose@obspm.fr`

Preparation of EoS tables I

- **parameter tables (mandatory)**
  - temperature T
    unit: MeV
    name of file: `eos.t`
  - baryon number density n_b
    unit: fm^{-3}
    name of file: `eos.nb`
  - charge fraction Y_q
    unit: $-$ (dimensionless)
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  - general structure of file:

$i_X^{\min}$	(minimum index)
$i_X^{\max}$	(maximum index)
$X(i_X^{\min})$	(value at minimum index)
$X(i_X^{\min}+1)$	
$\vdots$	
$X(i_X^{\max}-1)$	
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  - one entry per row, $X(i_X+1) > X(i_X)$
  - $i_X^{\max} - i_X^{\min} + 3$ rows in total
  - $i_X^{\max} - i_X^{\min} + 1$ values of quantity X

Preparation of EoS tables II

- **table with thermodynamic quantities (mandatory)**
  - name of file: `eos.thermo`
  - general structure of file

$$m_n \quad m_p \quad I_l \qquad \text{(first row)}$$

$$i_T \;\; i_{n_b} \;\; i_{Y_q} \;\; Q_1 \;\; Q_2 \;\; Q_3 \;\; Q_4 \;\; Q_5 \;\; Q_6 \;\; Q_7 \;\; N_{\mathrm{add}} \;\; \underbrace{q_1 \;\; q_2 \;\; \ldots \;\; q_{N_{\mathrm{add}}}}_{N_{\mathrm{add}}\ \mathrm{quantities}} \qquad \text{(subsequent rows)}$$

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  - m_n: neutron mass in MeV, m_p proton mass in MeV
  - I_l: lepton index, $I_l = 0$ no leptons, I_l with leptons (e and/or μ)
  - parameter indices: $i_T \;\; i_{n_b} \;\; i_{Y_q}$
  - $Q_1 = p/n_b$ [MeV], $Q_2 = s/n_b$ [dimensionless], $Q_3 = \mu_b/m_n - 1$ [dimensionless], $Q_4 = \mu_q/m_n$ [dimensionless], $Q_5 = \mu_l/n_b$ [dimensionless], $Q_6 = f/(n_b m_n) - 1$ [dimensionless], $Q_7 = e/(n_b m_n) - 1$ [dimensionless]
  - N_{add} number of additional quanties $q_1, \ldots, q_{N_{\text{add}}}$ (defined by contributor of EoS)
  - order of rows 2, 3, . . . irrelevant

Preparation of EoS tables III

- **table with composition of matter (optional)**
  - name of file: `eos.compo`
  - general structure of file (every row)

$$i_T \;\; i_{n_b} \;\; i_{Y_q} \;\; I_{\mathrm{phase}} \;\; N_{\mathrm{pairs}} \underbrace{I_1 \;\; Y_{I_1} \;\; \ldots \;\; I_{N_{\mathrm{pairs}}} \;\; Y_{I_{N_{\mathrm{pairs}}}}}_{N_{\mathrm{pairs}}\ \mathrm{pairs}}$$

$$N_{\mathrm{quad}} \;\; \underbrace{I_1 \;\; A^{\mathrm{av}}_{I_1} \;\; Z^{\mathrm{av}}_{I_1} \;\; Y_{I_1} \;\; \ldots \;\; I_{N_{\mathrm{quad}}} \;\; A^{\mathrm{av}}_{I_{N_{\mathrm{quad}}}} \;\; Z^{\mathrm{av}}_{I_{N_{\mathrm{quad}}}} \;\; Y_{I_{N_{\mathrm{quad}}}}}_{N_{\mathrm{quad}}\ \mathrm{quadruples}}$$

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  - parameter indices: $i_T \;\; i_{n_b} \;\; i_{Y_q}$, phase index I_{phase} (defined by contributor of EoS)
  - number of pairs (N_{pairs}) and quadruples (N_{quad}), can change from row to row
  - particle (for pairs) or group (for quadruples) indices I_i (see below) and corresponding number fractions $Y_i = n_i/n_b$ [dimensionless]
  - average mass numbers $A^{\mathrm{av}}_{I_i}$ and average charge numbers $Z^{\mathrm{av}}_{I_i}$
  - order of rows irrelevant

Preparation of EoS tables IV

- **table with microscopic quantities (optional)**
  - name of file: `eos.micro`
  - general structure of file (every row)

$$i_T \;\; i_{n_b} \;\; i_{Y_q} \;\; N_{\mathrm{qty}} \;\; \underbrace{K_1 \;\; q_{K_1} \;\; K_2 \;\; q_{K_2} \;\; \ldots \;\; K_{N_{\mathrm{qty}}} \;\; q_{K_{N_{\mathrm{qty}}}}}_{N_{\mathrm{qty}}\ \mathrm{pairs}}$$

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  - name of file: `eos.micro`
  - general structure of file (every row)

$$i_T \;\; i_{n_b} \;\; i_{Y_q} \;\; N_{\mathrm{qty}} \;\; \underbrace{K_1 \;\; q_{K_1} \;\; K_2 \;\; q_{K_2} \;\; \ldots \;\; K_{N_{\mathrm{qty}}} \;\; q_{K_{N_{\mathrm{qty}}}}}_{N_{\mathrm{qty}}\ \mathrm{pairs}}$$

  - parameter indices: $i_T \;\; i_{n_b} \;\; i_{Y_q}$
  - number of quantities (N_{qty}), can change from row to row
  - indices K_i defining quantity and particle (see below)
  - order of rows irrelevant

Preparation of EoS tables V

- **indices for identification of particles** (here the most common in EoS tables)
  - leptons: $I_i = 0$ electrons, $I_i = 1$ muons
  - baryons: $I_i = 10$ neutrons, $I_i = 11$ protons
  - nuclei: $I_i = 1000\, A_i + Z_i$
    e.g. $I_i = 2001$ ^{2}H, $I_i = 3001$ ^{3}H, $I_i = 3002$ ^{3}He, $I_i = 4002$ ^{4}He
  - more in table 3.2 of manual

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- **indices for identification of quantities and particles**
  - $K_i = 1000\, I_i + J_i$ with particles index I_i and quantity index J_i
  - quantity indices

    $J_i = 50$ nonrelativistic single-particle potential U_{I_i} [MeV]
    $J_i = 51$ relativistic vector self-energy V_{I_i} [MeV]
    $J_i = 52$ relativistic scalar self-energy S_{I_i} [MeV]

    more in table 7.3 of manual
  - example: $K_i = 11052$ scalar self-energy of proton

Testing of tables and preparation of data sheet

- **preparation of** FORTRAN **program** `compose.f90`
  - download `code.zip` from CompOSE website
  - unzip `code.zip`
  - change line 26 in `Makefile` to `HDF5 = 0`
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  - run `compose`
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- **preparation of data sheet**
  - download `eosform.zip` from CompOSE website
  - compile C++ program `eosform.cpp` (e.g. with `g++ -o eosform eosform.cpp`)
  - run `eosform` to generate LaTeXfile `datasheet.tex`
  - compile `datasheet.tex` and edit if necessary

Interpolation

- should reproduce values of all quantities at basic grid points
- depends on order I (set in file `eos.parameters`)
  - $I = 1$ interpolation continuous in function values
  - $I = 2$ interpolation continuous in function and first derivatives
  - $I = 3$ interpolation continuous in function, first and second derivatives
- derivatives calculated by finite-difference formula on non-equidistant grids

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- problems:
  - thermodynamic consistency, quantities not independent
  - oscillations depending on grid resolution

  $\Rightarrow$ interpolation errors
- alternatives?