CompOSE(db)

CompStar Online Supernovæ Equations of State (data base)

a short status report

T.Klähn, S.Typel, M.Oertel
... and more!
The ‘original’ idea of a CompStar EoS

*Roughly one year ago...*

Development of state of the art EoS for applications in astrophysics.
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Modelers have their favorite EoS, phase space domains, data formats.

*CompStar as research network provides a perfect frame for this kind of project:*

Manpower + Expertise
Regular Meetings + Funding
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And still ... not much seems to have happened over the last year despite a large initial interest of many colleagues from CompStar
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Of course, this is the wrong impression. EoS developers developed EoS. SN and NS modelers modeled NS and SN.

And this is, what they are supposed to do.
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Of course, this is the wrong impression. EoS developers developed EoS. SN and NS modelers modeled NS and SN.

And this is, what they are supposed to do.

CompStar as a funded research community *can* will provide a long lasting contribution by supporting both communities, and establish a tool for fast communication of recent results.

Make new EoS available:
• accessible from the same source
• following given data standard(s)
• accounting for observational constraints

This is the idea behind CompOSE(db).
CompOSE

Website:

Currently: http://klahn.ift.uni.wroc.pl/
Domain name is temporary. Server hosts CompOSE, only. Backups by IFT, Uni Wroclaw.
Registration is required for data access, only.
Manual is publicly available.

Manual:

At the present stage, the manual is both, documentation and guideline for future features.

Latest published version is v1.1.
Last version is v1.2, 65 pages.
About CompOSE

The online service CompOSE provides data tables for different state of the art equations of state (EoS) ready for further usage in astrophysical applications, nuclear physics and beyond.

If you decide to publish work using one or more of the here provided EoS we ask you to cite the given references and would be happy if you acknowledge CompOSE.
A. Fantina, M. Oertel (and of course the original authors!)

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<thead>
<tr>
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<th>Hits</th>
</tr>
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F. Sandin, T. Fischer, R. Lastowiecki
(and of course the original authors!)
CompOSE

CompStar Online
Supernovae Equations of State

BECAUSE MATTER MATTERS

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- EoS
  - EoS Overview
  - EoS Details
  - EoS Interpolation
- Links
- My Profile
- Contact us!

Development
- Recent Changes
- FAQ and known BUGS

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</table>

THIS COULD BE YOURS!
S. Typel, M. Hempel (don’t miss his talk!), I. Sagert, D. Blaschke, F. Sandin, R. Lastowiecki, D. Zablocki, T.K.
We explicitly invite colleagues from in AND outside CompStar to use CompOSE(db) and to contribute their EoS!

Can’t stress enough: Original authorship is acknowledged. References are provided. Users are pointed to them and asked to cite.
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A lot of this work has been done by Stefan Typel.

For all of the following holds: This is work in progress.
Your ideas and comments are welcome.
You, too.
## CompOSE

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What CompOSE can do and what not

*We cannot offer an online service in form of a tool box, i.e., choosing the parameters as you want and run the codes online. ... However, we try to provide the tables in a large parameter space.*

But: If runs for new parameter sets have been performed, the data will be available!

*If you make use of the tables provided, you will be guided to the scientific publications where the particular EoS models have been described in detail. Please cite them when using the tables for scientific purposes.*

*Compose is designed in a modular way, thus allowing to extend the service over time. More and more models and parameter sets will be provided in time and might be freely connected with the help of the phase transition tool described in appendix C.*

Latter will hold for ‘classical’ phase transition constructions a la Maxwell and Gibbs (quark-hadron phase transition) as far as the initial EoS allow for it.
How to prepare EoS tables

EoS are tabulated as function of:

Temperature \( T \) \([\text{MeV}]\)

Baryon number density \( n_b = \sum_i B_i n_i \) \([\text{fm}^{-3}]\)

Hadronic charge fraction \( Y_q = \frac{n_q}{n_b} \) \([\text{dimensionless}]\)

(explicitely decided to not tabulate electron fraction; does not exist for a pure nuclear EoS)

Each quantity is tabulated in a separate file...
How to prepare EoS tables

t{XYZ}.dat

1
101
0.10000000000000002
0.10680004325145757
0.11406249238513211
0.12181879120101156
0.13010252169108319
0.13894954943731380
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0.15848931924611140
0.16926666150378764
0.18077686769634349
0.19306977288832508
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0.22022019499873760
0.23519526350709594
0.25118864315095812
0.26826957952797270
0.28651202696637817
.
.
.

Indexing: Allows to split/add/skip data blocks. Might not appear to be so necessary, but our approach is modular.

Index Nr of first entry
Total Nr of entries
First entry (here connected to index 1)

EoS B

‘Transition’

EoS A

Further advantage: Error Fixing!

Same format for rho{XYZ}.dat and yq{XYZ}.dat
# How to prepare EoS tables

**Thermodynamics:** thermoXYZ.dat

<table>
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<tr>
<th>iT</th>
<th>iTb</th>
<th>IQ</th>
<th>IQ2</th>
<th>IQ3</th>
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<th>IQ5</th>
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<td>-2.6377197270295810E-002</td>
<td>5.0813663262906535E-004</td>
</tr>
</tbody>
</table>

1. **pressure divided by the baryon number density** $Q_1 = \frac{p}{n_b}$ [MeV],
2. **entropy per baryon** $Q_2 = \frac{s}{n_b}$ [dimensionless],
3. **scaled and shifted baryon chemical potential** $Q_3 = \frac{\mu_b}{m_n} - 1$ [dimensionless],
4. **scaled hadronic charge chemical potential** $Q_4 = \frac{\mu_q}{m_n}$ [dimensionless],
5. **scaled lepton chemical potential** $Q_5 = \frac{\mu_l}{m_n}$ [dimensionless].
How to prepare EoS tables

Why these five quantities?

Basic thermodynamical potential is free energy:

\[ f(T, n_b, Y_q) = -p + \mu_b n_b + \mu_q n_q + \mu_l n_l = -p + [\mu_b + Y_q (\mu_q + \mu_l)] n_b \]

1st derivatives:

\[ s = -\left. \frac{\partial f}{\partial T} \right|_{n_b, Y_q} \]

\[ p = n_b^2 \left. \frac{\partial (f/n_b)}{\partial n_b} \right|_{T, Y_q} \]

\[ \mu_b + (\mu_q + \mu_l) Y_q = \left. \frac{\partial f}{\partial n_b} \right|_{T, Y_q} \]

\[ \mu_q + \mu_l = \frac{1}{n_b} \left. \frac{\partial f}{\partial Y_q} \right|_{T, n_b} \]
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\[ f(T, n_b, Y_q) = -p + \mu_b n_b + \mu_q n_q + \mu_l n_l = -p + [\mu_b + Y_q (\mu_q + \mu_l)] n_b \]

2nd derivatives are determined numerically:

Specific heat capacity:
\[ c_V = \frac{N_b}{T} \left( \frac{dS}{dT} \right)_{V,N_b} = -T \left( \frac{\partial^2 F}{\partial T^2} \right)_{n_b} \]

Isothermal compressibility:
\[ \kappa_T = -\left( \frac{1}{V} \frac{dV}{dp} \right)_{T,N_b} = \left( 2p + n_b^3 \left( \frac{\partial^2 F}{\partial n_b^2} \right)_T \right)^{-1} \]

... and so on
How to use EoS tables

For the user: Given ‘dense’ input data and/or good interpolation user can define table with grid of his choice.

CompOSE(db) stage 2: Online Service; automatic generation of full (or partial) table for given set of \((T, n_b, Y_q)\) in single or separate files.
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CompOSE(db) stage 2: Online Service; automatic generation of full (or partial) table for given set of \( (T, n_b, Y_q) \) in single or separate files.

Further options: \( \beta \)-equilibrated EoS T=0 EoS
How to prepare EoS tables

Next relevant information is the *composition*: compositionXYZ.dat

15 entries:

\[ i_T \quad i_n_b \quad i_Y_q \quad I_{\text{phase}} \quad A_{\text{heavy}} \quad Z_{\text{heavy}} \quad X_{\text{heavy}} \quad X_n \quad X_p \quad X_e \quad X_\mu \quad X_d \quad X_t \quad X_h \quad X_\alpha \]

Future format (not yet supported):

\[ i_T \quad i_n_b \quad i_Y_q \quad I_{\text{phase}} \quad A_{\text{heavy}} \quad Z_{\text{heavy}} \quad X_{\text{heavy}} \quad I_1 \quad X_1 \quad \ldots \quad I_i \quad X_i \quad \ldots \quad I_{N_{\text{part}}} \quad X_{N_{\text{part}}} \]

A similar format could be considered for the thermodynamics table.
How to use EoS tables

Table 11.2.: Quantities containing information on the composition which are stored in the data tables with their units and the identifier for the ASCII files. The symbol $\#$ stands for the particle index $I_i$ as defined in table 3.2.

<table>
<thead>
<tr>
<th>identifier $Q$ of quantity</th>
<th>quantity/expression</th>
<th>unit</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>phase</td>
<td>$I_{\text{phase}}$</td>
<td>dimensionless</td>
<td>phase index</td>
</tr>
<tr>
<td>xheavy</td>
<td>$X_{\text{heavy}}$</td>
<td>dimensionless</td>
<td>fraction of representative heavy nucleus</td>
</tr>
<tr>
<td>aheavy</td>
<td>$A_{\text{heavy}}$</td>
<td>dimensionless</td>
<td>mass number of representative heavy nucleus</td>
</tr>
<tr>
<td>zheavy</td>
<td>$Z_{\text{heavy}}$</td>
<td>dimensionless</td>
<td>charge number of representative heavy nucleus</td>
</tr>
<tr>
<td>x#$$</td>
<td>$X_i$</td>
<td>dimensionless</td>
<td>fraction of particle $i$</td>
</tr>
</tbody>
</table>
How to use EoS tables

Table 3.2: Baryon $B_i$, strangeness $S_i$, and charge $Q_i$ numbers and indices $I_i$ of the most relevant particles $i$ in dense matter.

<table>
<thead>
<tr>
<th>particle class</th>
<th>symbol of particle $i$</th>
<th>$B_i$</th>
<th>$S_i$</th>
<th>$Q_i$</th>
<th>particle index $I_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>nuclei ($A &gt; 1$)</td>
<td>$ZA$</td>
<td>$A$</td>
<td>$Z$</td>
<td>$1000 - A + Z$</td>
<td></td>
</tr>
<tr>
<td>baryons</td>
<td>$n$</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>10</td>
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<tr>
<td></td>
<td>$p$</td>
<td>1</td>
<td>0</td>
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<td>11</td>
</tr>
<tr>
<td></td>
<td>$\Delta^-$</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>20</td>
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<td></td>
<td>$\Delta^0$</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>$\Delta^+$</td>
<td>1</td>
<td>0</td>
<td>+1</td>
<td>22</td>
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<td></td>
<td>$\Delta^{++}$</td>
<td>1</td>
<td>0</td>
<td>+2</td>
<td>23</td>
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<tr>
<td></td>
<td>$\Lambda$</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>$\Sigma^-$</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>110</td>
</tr>
<tr>
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<td>$\Sigma^0$</td>
<td>1</td>
<td>-1</td>
<td>0</td>
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<tr>
<td></td>
<td>$\Sigma^+$</td>
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<td>0</td>
<td>0</td>
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<td>400</td>
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<td>-1</td>
<td>1</td>
</tr>
</tbody>
</table>
Things we work on and think about...

- Semi-automatic phase transitions

- output in HDF5-format

- Provide information regarding basic properties of EoS in Astrophysics/HIC. (maximum NS mass; maybe M-R, M-n; DURca threshold; elliptic flow)

- Complementary tables (e.g. pairing gaps, effective masses)

- adopt output format of established EoS tables (Lattimer-Swesty, Shen, others?) ... might be useful for users which want to ‘just see what this EoS does’
We need your input!

The easiest way to make sure CompOSE(db) will be what you want it to be ...
We need your input!

The easiest way to make sure CompOSE(db) will be what you want it to be ... 

... is to work on it.

Thank you