CMF hybrid with crust (2)

EoS Submission Details

EoS name	CMF hybrid with crust (2)
category	Hybrid
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Abstract

The relativistic SU(3) Chiral Mean Field (CMF) model was the first model developed with the intent of describing several systems, among which are the interior of neutron and proto-neutron stars. More specifically it is a non-linear realization of the sigma model which includes pseudo-scalar mesons as the angular parameters for the chiral transformation. Depending on the choice of degrees of freedom, it can include nucleons, hyperons, spin 3/2 (Delta) baryons, light quarks, free leptons and mesons. The model reproduces standard nuclear physical constraints, as well as astrophysical ones, such as massive neutron stars. The quark sector of the model was fitted to reproduce lattice QCD results at zero and small densities.

The model results were found to be in agreement with perturbative QCD for the relevant astrophysical regime. Within the model, baryons and quarks are mediated by vector-isoscalar, vector- isovector, scalar-isoscalar, and scalar-isovector mesons (including strange quark- antiquark states). At low densities and/or temperatures, the nuclear liquid-gas first-order phase transition is reproduced. At high densities and/or temperatures, chiral symmetry is restored, which can be seen in a reduction of the effective baryon masses, and, if the quarks are included in the model, deconfinement takes place. Here, we present two different kinds of EoS. The first one is for cold chemically-equilibrated neutron stars. The second one is for matter out of equilibrium, such as the one created in particle collisions, supernova explosions and neutron star mergers, in which case we vary not only the density, but also the temperature and electric charge fraction.

The versions of the EoS for cold chemically-equilibrated neutron stars are also available connected to crusts, which were chosen for having similar symmetry energy slopes. They are both zero temperature and beta equilibrium unified EoS's by Gulminelli and Raduta (arXiv:1504.04493) available in CompOSE. They considered the effective interactions Rs proposed by Friedrich and Reinhard (for EoS's 1 and 2) and SkM proposed by L. Bennour et al. (for EoS's 3 to 8), both with cluster energy functionals from Danielewicz and Lee. The masses they use for neutrons and protons are 939.5653 MeV and 938.2720 MeV, respectively.

EoS	particles (+N,lep)	interac. (+stand.)	L (MeV)	M_{max} ($M_\odot$)	$R_{M_{max}}$ (km)	$R_{M_{1.4}}$ (km)	$\tilde{\Lambda}_{M_{1.4}}$	$n_{B,Urca}$ (fm^{-3})
1	Hyp+Q		88	1.96	11.11	13.55	889	0.31
2	Q		88	1.96	11.11	13.67	904	N/A*
3	Hyp+Q	$\omega\rho$	75	1.99	11.20	13.15	702	0.45
4	Q	$\omega\rho$	75	1.98	11.21	13.24	739	0.49
5	Hyp+Q	$\omega\rho+\omega^4$	75	2.02	11.89	13.18	723	0.46
6	Q	$\omega\rho+\omega^4$	75	2.01	11.94	13.27	754	0.49
7	Hyp+Δ+Q	$\omega\rho+\omega^4$	75	2.02	11.90	13.18	723	0.46
8	Δ+Q	$\omega\rho+\omega^4$	75	2.01	11.94	13.27	754	0.46

*The Urca process threshold is not reached before the phase transition takes place.

Note: EoS's that have hyperons, also contain strange quarks and muons.

References to the original work

1. V. Dexheimer and S. Schramm, Proto-Neutron and Neutron Stars in a Chiral SU(3) Model, Astrophys. J. 683 (2008) 943.

2. V. Dexheimer and S. Schramm, A Novel Approach to Model Hybrid Stars, Phys. Rev. C 81 (2010) 045201.

3. V. Dexheimer, Tabulated Neutron Star Equations of State Modelled within the Chiral Mean Field Model, Publications of the Astronomical Society of Australia 34 (2017).

4. V. Dexheimer, R. O. Gomes, S. Schramm, H. Pais, What do we learn about vector interactions from GW170817?, J. Phys. G 46 (2019) 3, 034002.

5. V. Dexheimer, R.O. Gomes, T. Klähn, S. Han, M. Salinas, GW190814 as a massive rapidly rotating neutron star with exotic degrees of freedom, Phys.Rev.C 103 (2021) 2.

6. A. Clevinger, J. Corkish, K. Aryal and V. Dexheimer, Hybrid Equations of State for Neutron Stars with Hyperons and Deltas, Eur.Phys.J.A 58 (2022) 5, 96.

Nuclear Matter Properties[1]

	Quantity	Unit	
n_S	saturation density in symmetric matter	fm^{-3}	0.15
E_0	binding energy per baryon at saturation	MeV	-16
K	incompressibility	MeV	300
K'	skewness	MeV	0
J	symmetry energy	MeV	30
L	symmetry energy slope parameter	MeV	88
K_{sym}	symmetry incompressibility	MeV	0
U_Λ	Λ-potential at saturation	MeV	-28
U_Σ	Σ-potential at saturation	MeV	5
U_Ξ	Ξ-potential at saturation	MeV	-18

Neutron Star Properties[1]

	Quantity	Unit	
M_{max}	maximum mass	M_{sun}	1.96
$M_{DU,e}$	mass at DUrca threshold (1/9) w/o μ^-	M_{sun}	N/A
$R_{M_{max}}$	radius at maximum NS mass	km	11.11
$R_{1.4}$	radius at 1.4 M_{sun} NS mass	km	13.67
$\tilde{\Lambda}$	tidal deformability for GW170817 at a mass ratio of $q = 0.8$		904

eos.thermo

eos.thermo and the three grid defining files are CompOSE standard data files and by definition available. The 3 extra columns contain the scaled enthalpy per baryon (e+P)/(n_B m_B)-1, the strangeness number density, which is the particle sum over ($S_i n_i$) in fm^{-3}, and the sum over the number density of baryons and quarks in fm^{-3}.

table dimension	1
table type	2
total number of grid points	1051

[1] 0-values indicate, that the corresponding data is not provided.

Range and density (#) of the grid parameters:

	Quantity	Unit	min	max	#
T	Temperature	MeV	0	0	1
n_b	Baryon Nr Density	fm^{-3}	1.00 x 10^{-7}	1.63	1051
Y_q	Charge Fraction		0	0	1

T, n_b, and Y_q are stored in eos.t, eos.nb, and eos.yq, respectively.

Further Available Data Files

Files and quantities listed in the following are provided beyond CompOSE's core requirements as outlined in Sec. 4.2. of the CompOSE manual.
eos.compo : available

table dimension	1
table type	2
total number of grid points	1051

Phase index is 1 (hadronic matter), 2 (quark matter) or 4 (heavy nuclei present). We provide 17 particle pairs and one quadruple for a unique heavy nucleus

eos.mr : available

table dimension	1
total number of lines	161

The 2 columns contain stellar radii (in km) and stellar masses (in units of solar mass) of a family of stars.