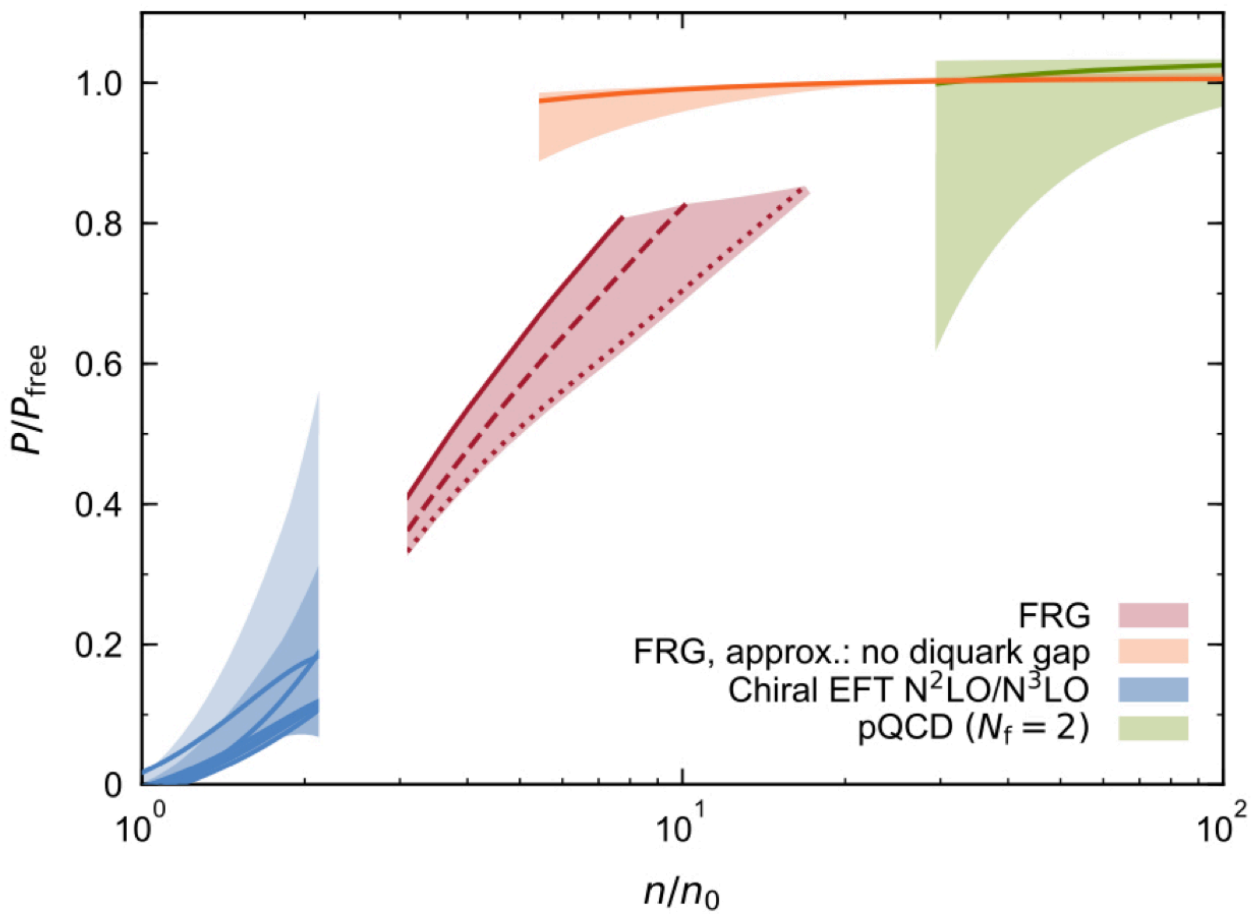
NuSym23 - concluding remarks - 21/09/2023

Kai Hebeler:
EoS: ChEFT should be able to extrapolate (asymptotical input) on the FRenormalisation Group expectation at higher densities.
Causality + NS mass constraints may help extrapolate between 1.5 and 8 n_sat.

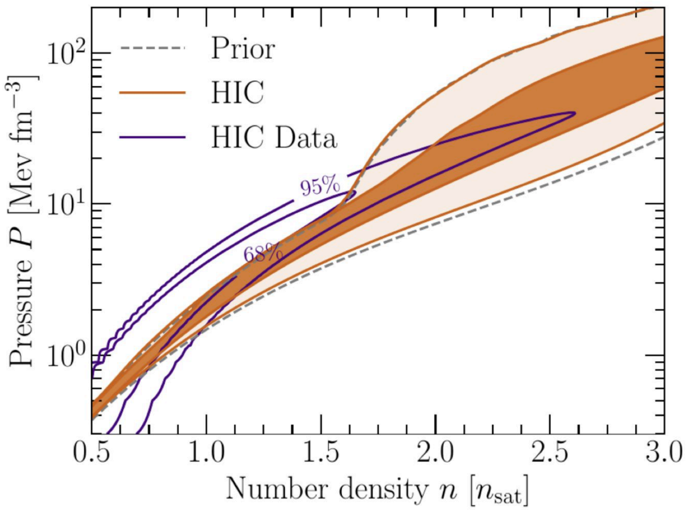


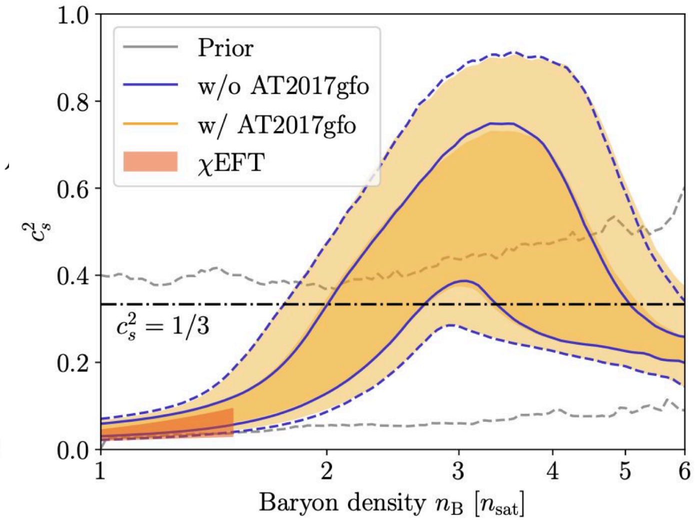
Tim Dietrich:
Improving the design of GW telescopes (triangle arms, 2 L’s, …) for a better accuracy.
More events => improved accuracy, but model dependant.
Combining ChEFT, radio pulsar measurements, X-ray NICER measurements, GW, kilonova observations, HIC: way for large improvements of accuracy.

Peter Pang:
Next step of improvements:
- HIC : higher densities probed for Easy, better accuracy
- astro modelling
- nuclear theory: understand why ChEFT is systematically softer than astro and HIC in the 1-1.5 n_sat density range.

Joint analysis: NMMA (nuclear physics and multi-messenger astrophysics): simultaneous analysis of GW, kilonova, and GRB afterglow.
<u>Open question</u>: is the 1-1.5 n_sat tendency of ChEFT priors to push down the pressure (softer) as regard to HIC and astro expectations correct?
How to to reliably improve the interdisciplinary / multi-messenger study on supra nuclear matter?

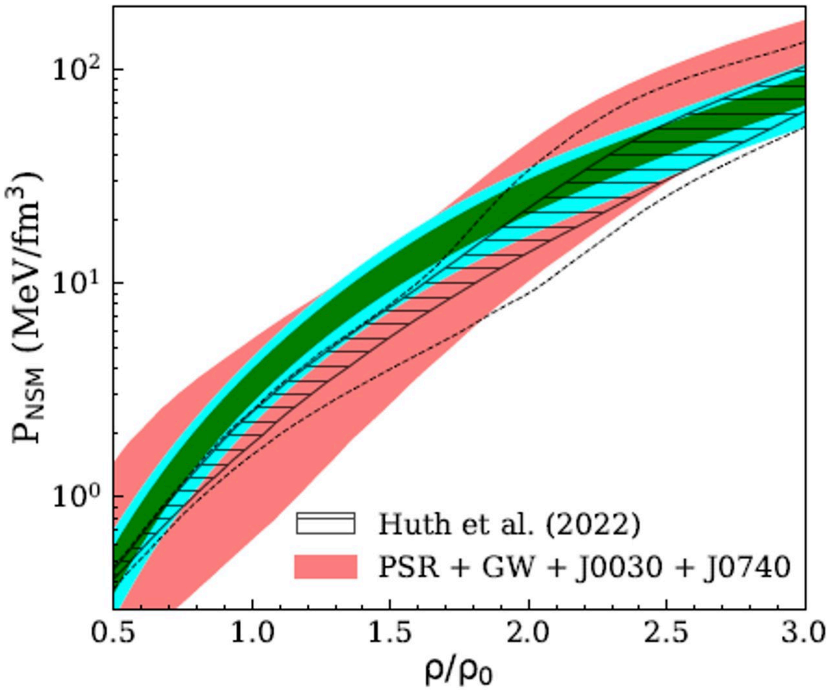
HIC experiments:





Betty Tsang:
Prior : EoS’ from meta modelling (cf. J. Margueron).
Is ChEFT (NLO3) suited for priors?

Removing PREX does not influence much: low densities are not constraining a lot, in the contrary to HIC constrains which affect results of the posterior (up to 3 n_sat).



Easy constraints from HIC: Important to take into account n/p effective mass splitting (m.d.i.) -> reflected in L vs m* expectation. But transport model dependant: must be resolved (TMEP).
Transport model proof can be done on HIC results? => **benchmarking on many relevant observables.**
Promising observable as a constraint: R21 (n/p rich system) vs pt/A for p, d, t, 3He, 4He
Golden age of HIC’s for EoS studies to come with new facilities.

BK Agrawal:

At least 3-4 nuclear matter parameters constraints of the EoS are needed to get decent NS properties description (tidal deformability, radius).

Qsym least important.

For constraining the radius, K0, Q0, J0, L0 are the most relevant.

Most influence on tidal deformability: Ksym,0.

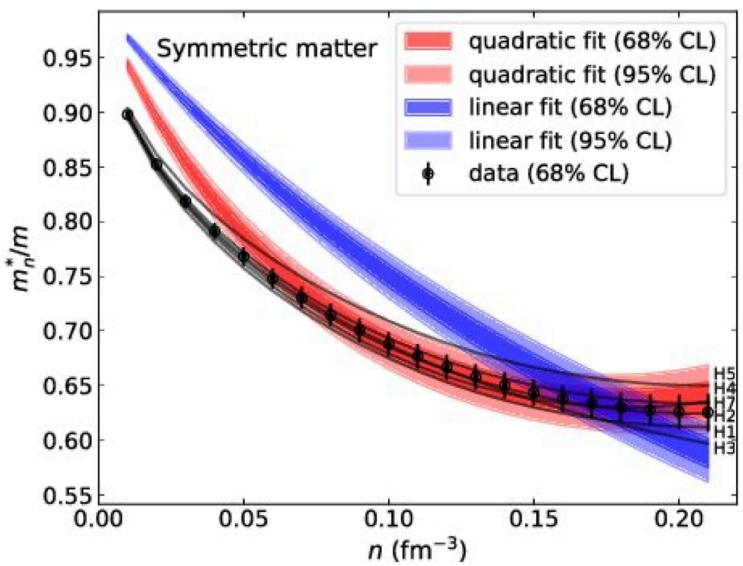
The radius determination requires at least 2 parameters.

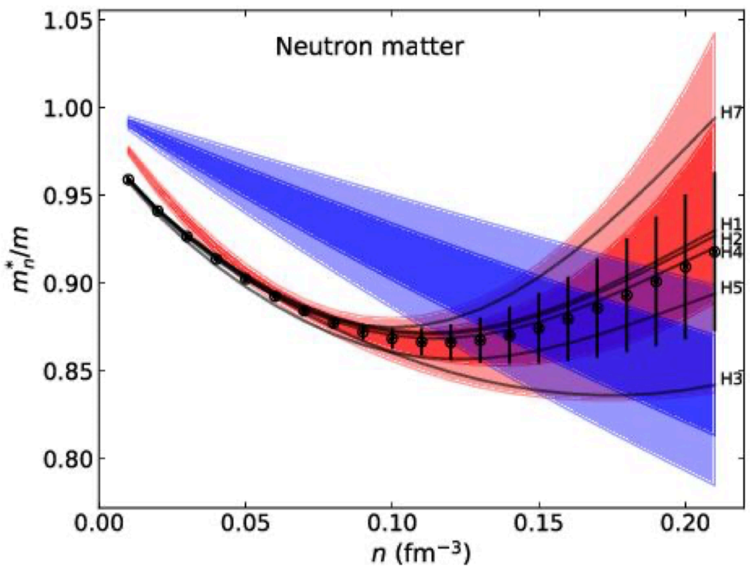
The tidal deformability : 3 or more.

—> sheds light on which parameters are the most important to be accurately constrained by e.g. HIC's

R. Somasundaram:

(m* vs density : quadratic (vs linear) approximation more realistic. Dependance slightly different in neutron matter and symmetric matter.



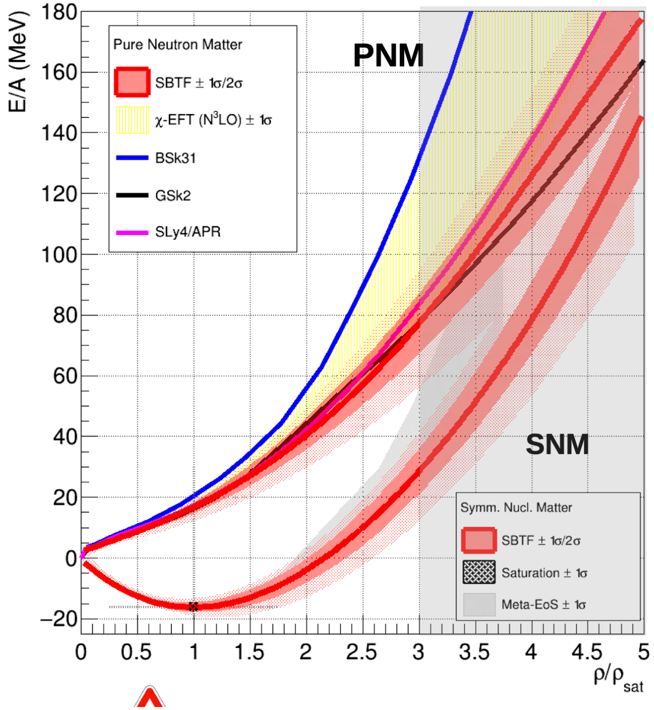


EFT models better than phenomenological models in the inner crust than in the outer crust)

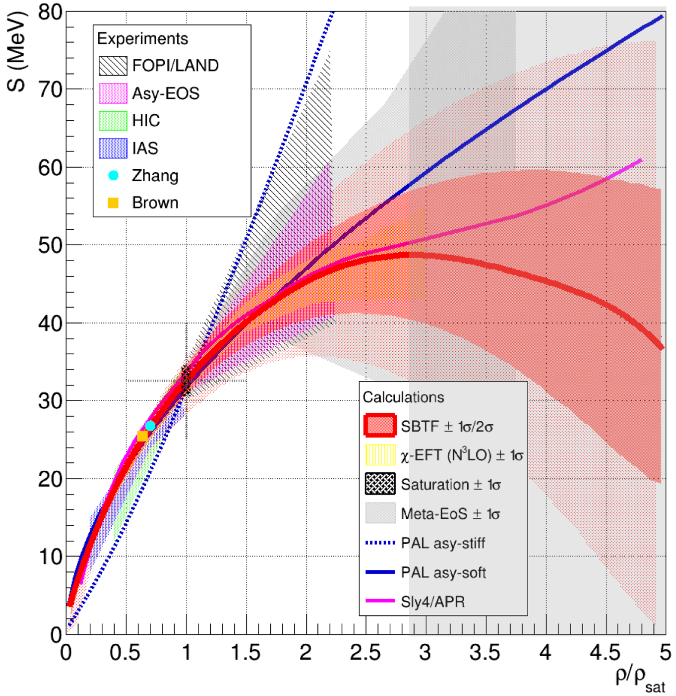
Future developments: uncertainties below 2 n_sat should decrease by a factor of 2.
But what about Easy above?
3rd generation of GW detectors by 2030 : 10 times more sensitive -> 300 detections of NS mergers with signal/noise > 100
-> improvements of nuclear theory needed / implied

Olivier Lopez:
Optimisation of Myers-Swiatecki (SeylerBlanchardThomasFermi) parameters of the binding energy chart of (N,Z) -> accuracy x 10.
-> L = 57+/-10 MeV   Delta r_np = 0.029 fm
-> Delta r_np in tension with PREX-II (L=109 MeV, Delta r_np = 0.282 f)m
From these parameters, on can derive the EoS (PNM, SNM) - slides 16, 20, 26 - S0=32 MeV.

Isoscalar & Neutron



Isovector



Questions : accuracy of PREX/CREX results?
Uncertainties from HIC should be reduced. ASY-EOS etc in order to disentangle
Is this Taylor expansion valid above 2 n_sat
Can we access a possible phase transition at large densities in neutron star mergers ?

Sébastien Guilllot:

The hot spots are geometrically described as combination of circle (circle, crescent).

What matters a lot : suppression of background noise in signal vs time curves : sky, non-X-ray, X-ray atmosphere -> modelling
Still many data sets to (re)analyse, including newly discovered millisecond pulsars;
Hot spots tend to like to be close to each other. Geometry not as trivial as anticipated.
Several arguments favour a hydrogen composition of the pulsar's atmosphere: Results of He or hydrogen partially ionised differ from H atmosphere.
Measurement of a dozen NS radii with few percent accuracy (and eventual phase transition) => next generation of observatories
New-Athena (2035) : sensitivity x 5 % NICER, better time resolution, lower background -> from simulations: 1600k seconds and 10% radius accuracy for NICER, 500k sec and 3% accuracy average for New-Athena. **And will improve disentangling the composition of the atmosphere.**
Can understand better the interior of neutron stars.
<u>Questions:</u>
Can New-Athena distinguish between different surface spot patterns?
How does NEW-Athena compare to other proposed X-ray missions?
Project : repository of observational constraints (radii, masses, tidal deformabilities, etc.) = CompARE

Jocelyn Read:
VIRGO, LIGO, KAGRA -> a few hundreds Mpc around 2028
Questions:

- Is there a limit in the formation of heavy-black holes?
- Do BH prefer a characteristic mass?
- How much NS mergers contribute to formation of heavy elements?
- Is there a mass gap between NS and BH?
- Do GW sources differ from those seen in EM?

Galactic double NS masses are more peaked around 1.4 solar mass than those observed from GW (1.1-2 solar mass).
LIGO/VIRGO: 45 significant alerts in 2023.
Offilne search may find other candidates.

Newer generations: Einstein Telescope, Cosmic Explore, etc -> much higher sensitivity and signal/noise ratio, broader frequency range (1-1000 Hz)

Today's rare events are tomorrow's precision physics.
Question: what are we missing for the next generation of detectors?

Carolyn Raithel:
What additional physics can we learn from post-merger GW : asteroseismology of the remnant NS.
Post-merger Gas probe the EoS at finite temperatures (tens of MeV).
Temperature influences neutrino emissivities
Thermal pressure determines the long term stability.

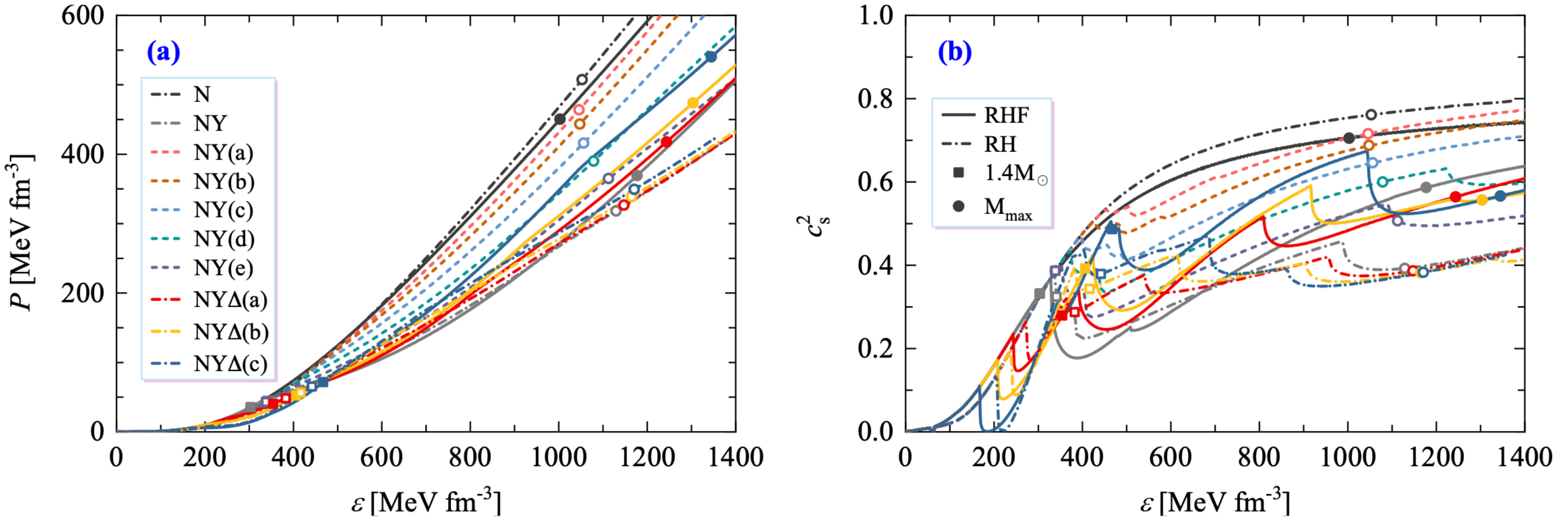
Questions: What information will we be able to extract from the post-merger GWs? And what developments in modelling do we need to be ready to interpret these signals?

Armen Sedrakian:

Hyperons and delta-resonances in cold nuclear matter.
Hyperons (NY interaction) in the medium soften the EoS.

And NYDelta even more. -> NS radii and max. mass decrease.
His model -> the NS max. mass drops to 2.3 solar mass with hyperon+Deltas (2.5 for pure nucleonic NS).

Hot compact stars and BNS mergers.
The implementation of hyperons and Deltas maintain the temperature constant around 30-40 MeV in NS above 2 n_sat at constant entropie, because they open new degrees of freedom on dissipation of temperature. With only neutrons, the temperature would increase at large densities.



Importance of taking into account the influence of hyperons and Delta resonances in the EoS at large densities (above 2 n_sat). Large influence on high order terms of the symmetry energy density dependance.

Open question: can we measure the temperature versus time in coincidence with a GW, not only in the post merger phase? Kilonova event are already very rare…

Micaela Oertl:

Do not neglect the **non-nucleonic composition at high density**: hyperons, Delta resonances, pion/kaon condensates. And eventually superconducting phase transitions (quark-gluon plasma).

First-order phase transition :

- if unstable object: almost no identifiable signal (immediate collapse to BH at once of phase transition)
- if stable hybrid NS, oscillation frequencies (deviations in the f_peak vs tidal deformability curve) can signal a phase transition.

No information a priori about composition in absence of a phase transition -> additional information on symmetric matter needed

Can we detect a phase transition with 3rd generation detectors? (depends on onset density, masses distance of NS mergers)

How to combine all informations (GW with 3rd generation detectors, neutrinos from next galactic supernova with efficient detectors, …) to understand the phase diagram of strongly interacting matter?