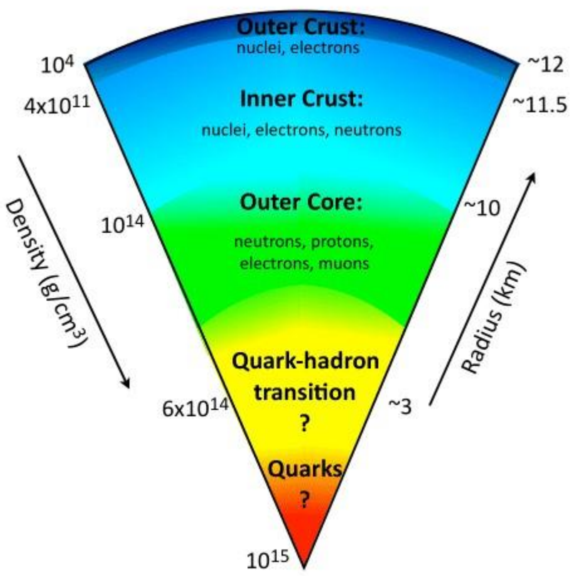
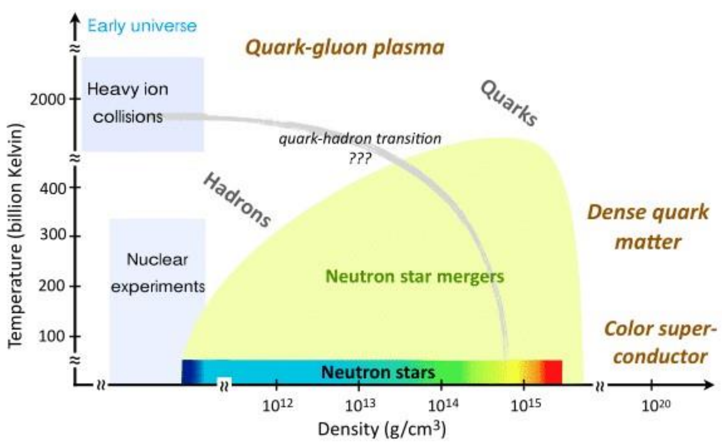
Contributions of gravitational-wave observations to heavy-ion physics

Edit Fenyvesi
Institute for Nuclear Research (Atomki), Debrecen, Hungary; Wigner Research Centre for Physics, Budapest, Hungary

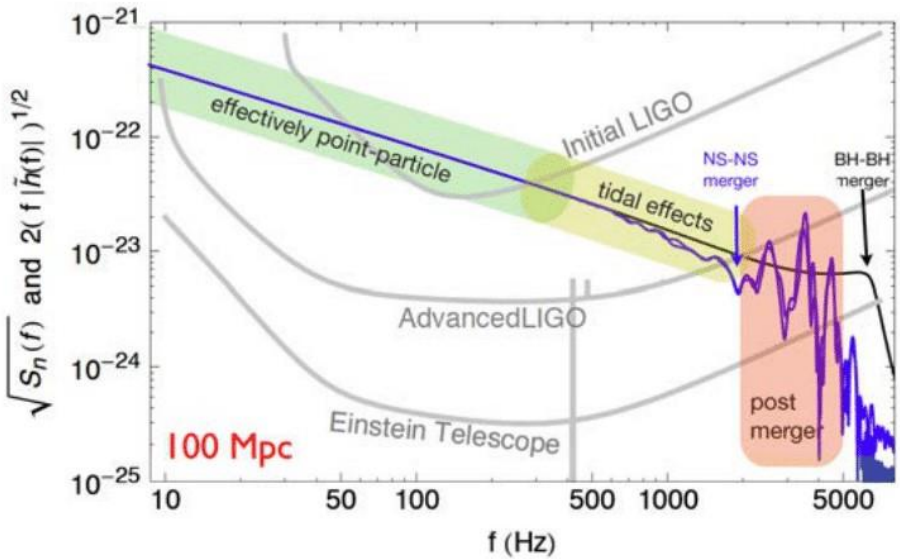




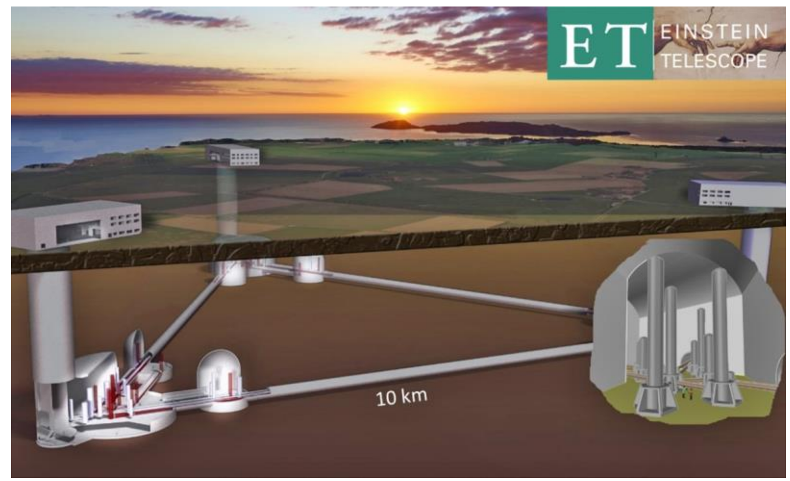
Left: Conjectured interior structure of a **neutron star** [1].

Right: Matter encountered in neutron stars and binary mergers explores a large part of the QCD phase diagram in regimes that are inaccessible to terrestrial collider experiments [1].

Gravitational-wave detectors



Gravitational-wave signal from a NS-NS merger at a distance 100 Mpc, as it sweeps across the detector-accessible frequency range [1].



Einstein Telescope

Merging nuclear theory, multi-messenger astrophysics and data from HIC experiments

- According to a recently published study, new constraints on the EOS above 1 n_{sat} was given by merging theoretical computations, results of heavy-ion collision (HIC) experiments and GW signals together with other multi-messenger astronomy observations of neutron stars [3].
- At first, 15000 different EOS were created in a way that they span the theoretical uncertainty range of the chiral effective field theory calculations.
- The GW170817 signal was compared to theoretical GW models depending on the features of NSs. This way, constraint on maximum mass of NSs could be made, which resulted in greater accuracy of the EOS.
- The Einstein Telescope is expected to detect GW signals of 7×10^4 neutron star mergers per year, therefore different parameters of NSs could be examined with increased accuracy.
- This way, improved EOS could be determined in the n_{sat} range where theoretical calculations become less reliable.
- Moreover, EOS of the matter arises after the coalescence of NSs could be known better by being able to detect the GW signal of the post-merger phase.

References:
[1] ET Steering Committee Editorial Team,Design Report Update 2020 for the Einstein Telescope., https://gwic.ligo.org/3Gsubcomm/docs/ET-0007B-20_ETDesignReportUpdate2020.pdf
[2] LIGO-Virgo Compact Binary Catalogue., https://catalog.cardiffgravity.org/
[3] S. Huth, P.T.H. Pang, I. Tews, et al., Constraining neutron-star matter with microscopic and macroscopic collisions., Nature 606, 276–280 (2022). doi:10.1038/s41586-022-04750-w. https://doi.org/10.1038/s41586-022-04750-w