From chiral EFT to perturbative QCD: a Bayesian model mixing approach to symmetric nuclear matter

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Intense experimental, observational, and theoretical effort is focused on constraining the equation of state (EOS) of strongly interacting, dense matter.

While **chiral EFT** can describe the EOS between the typical densities of nuclei and those in the outer cores of neutron stars, **perturbative QCD (pQCD)** can be applied to properties of deconfined quark matter.

However, describing the complete range of densities between nuclear saturation and an almost-free quark gas with a **single EOS with well-quantified uncertainties is a challenging problem**.

We developed a **Gaussian process-based Bayesian model mixing (BMM) method** that combines multiple predictive models in different regions into one overall predictive composite model.

This Bayesian method was applied to chiral EFT (low densities) and pQCD calculations (high densities) of the pressure and speed of sound in symmetric matter as a function of the density.

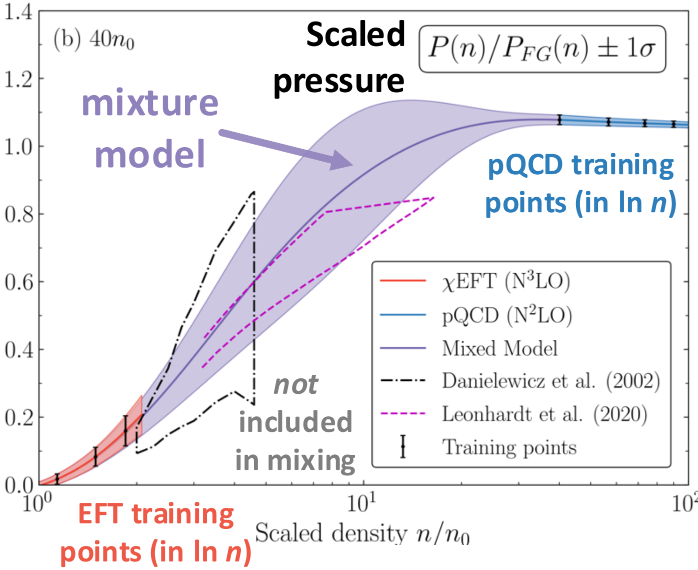
The developed **method is promising for constructing globally predictive, QCD-based EOSs with rigorous UQ to study the structure and evolution of neutron stars**.

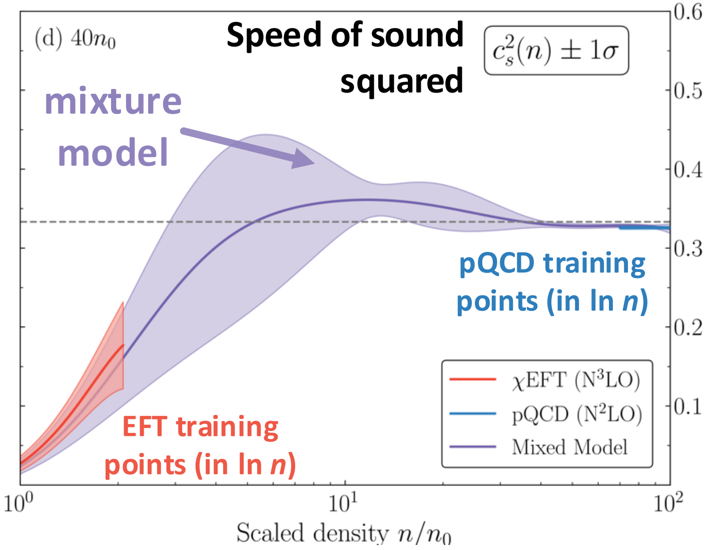
Inferred **long correlation lengths** without hyperpriors render uncertainty on the mixed EOS very small due, even smaller than each model (not shown)

This would lead to an unrealistic, large impact of pQCD on the chiral EFT region.

We placed a *hyperprior* on the correlation length to **enforce small covariances between EFT & pQCD** (shown below).

Smaller length scales result in larger uncertainty bands.





Work in progress: **extensions and applications to neutron star matter** guided by recent EOS constraints from nuclear theory, nuclear experiment, and multi-messenger astronomy

Christian Drischler (Ohio U/FRIB) | drischler@ohio.edu

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Semposki, CD, Furnstahl, Melendez, and Phillips, arXiv:2404.06323