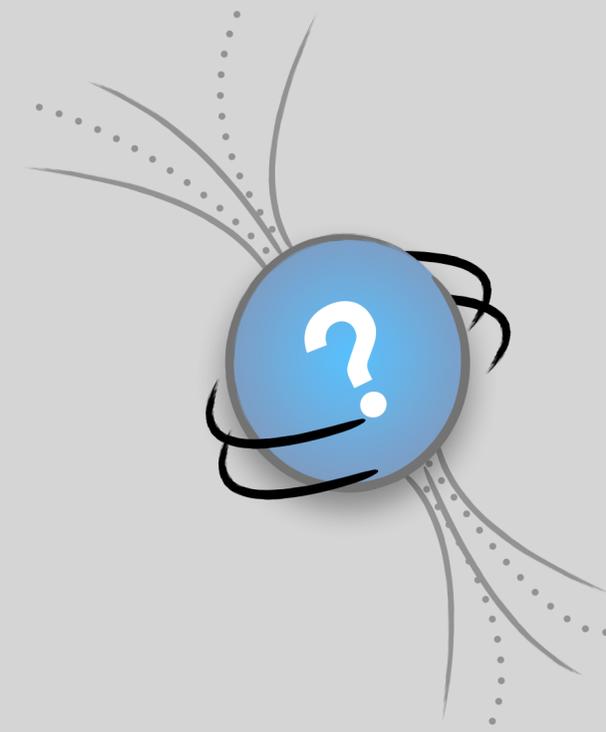




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How can deep learning help us decipher neutron star composition

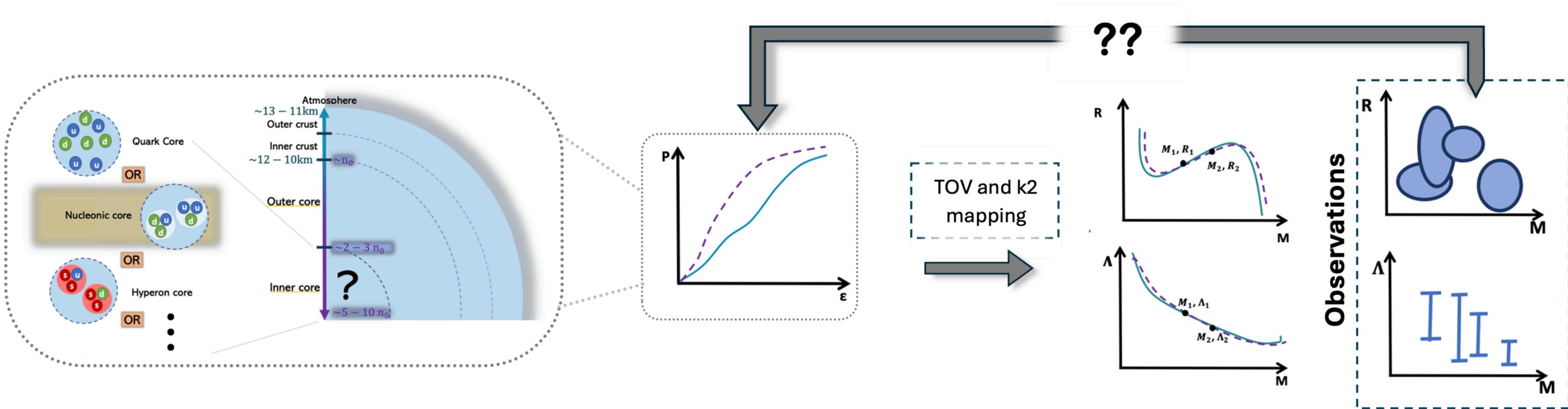


Valéria Carvalho

Michał Bejger, Constança Providência, Márcio Ferreira

5 February 2026

The challenge: A sparse and noisy inverse problem



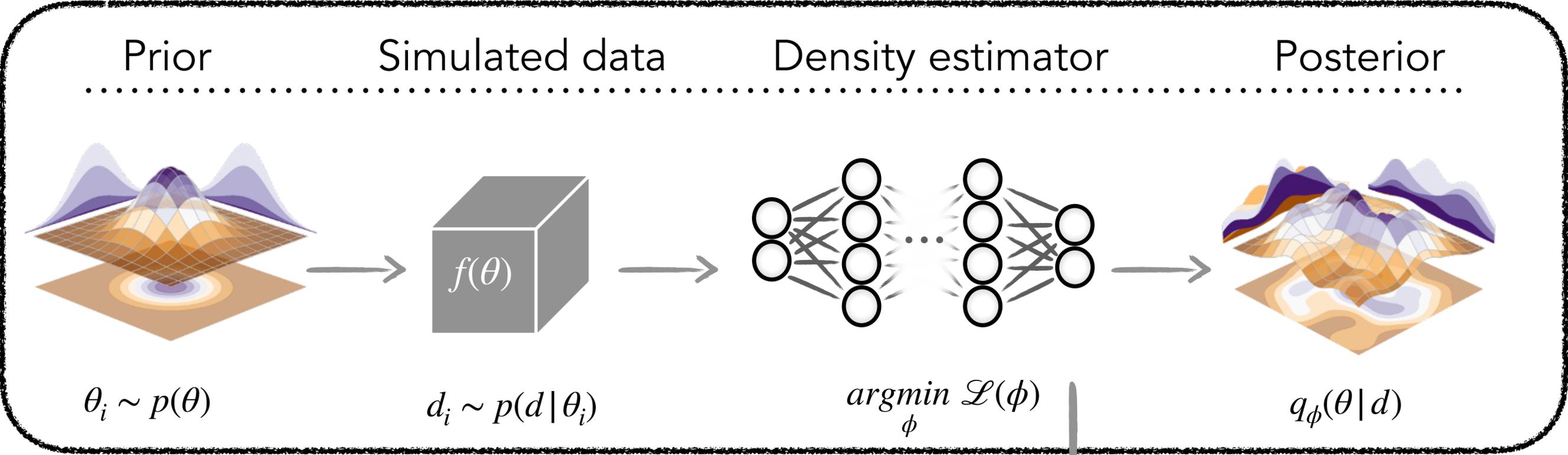
For current observations:

- ▶ Sparse coverage of observables,
- ▶ Uncertainties and degeneracies.

For future observations:

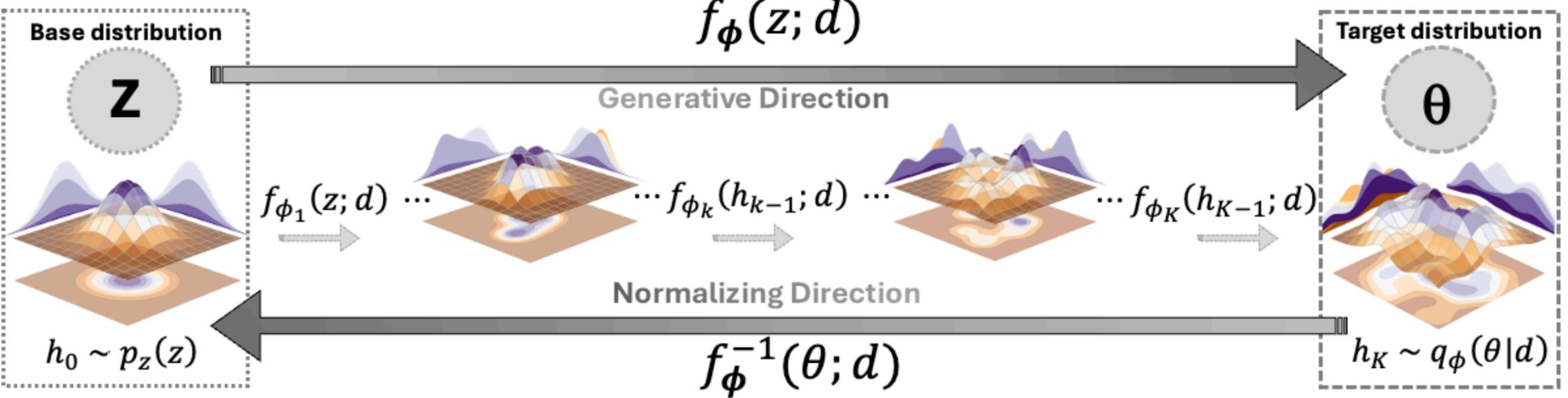
- ▶ Large amount of data,
- ▶ Smaller uncertainties, less degeneracies.

Neural posterior estimation



Conditional Normalizing Flows (CNF)

- Invertible
- Flexible
- Bijective



Quantities we aim to predict : $p(EoS | O)$

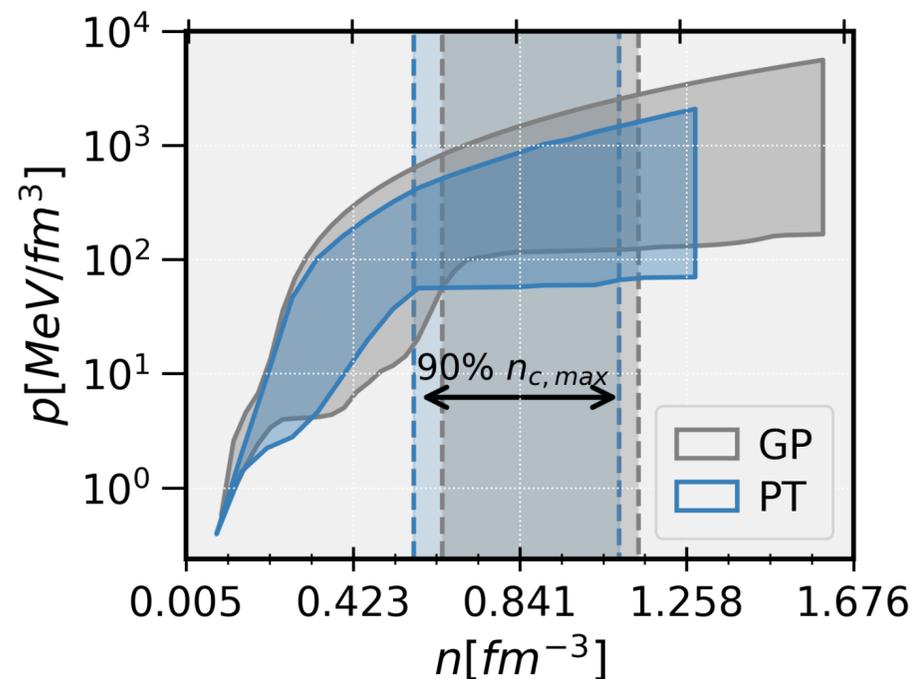
Two agnostic models :

Piecewise Polytopics (PT) PRD **111**,023035 (2025)

Gaussian Processes (GP) *Nat Commun* **14**, 8451 (2023)

The predicted physical quantities :

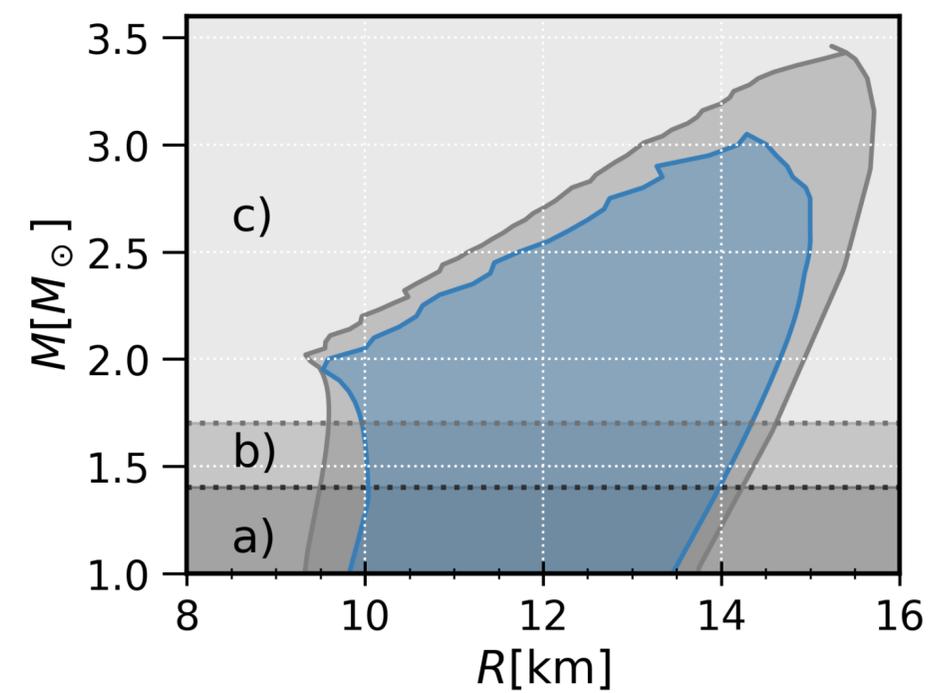
$$\begin{cases} \mathbf{p}(\mathbf{n}) = [p(n_1), \dots, p(n_{20})], \\ \mathbf{c}_s^2(\mathbf{n}) = [c_s^2(n_1), \dots, c_s^2(n_{20})], \\ \mathbf{\Delta}(\mathbf{n}) = [\Delta(n_1), \dots, \Delta(n_{20})], \end{cases}$$



The conditioned quantities :

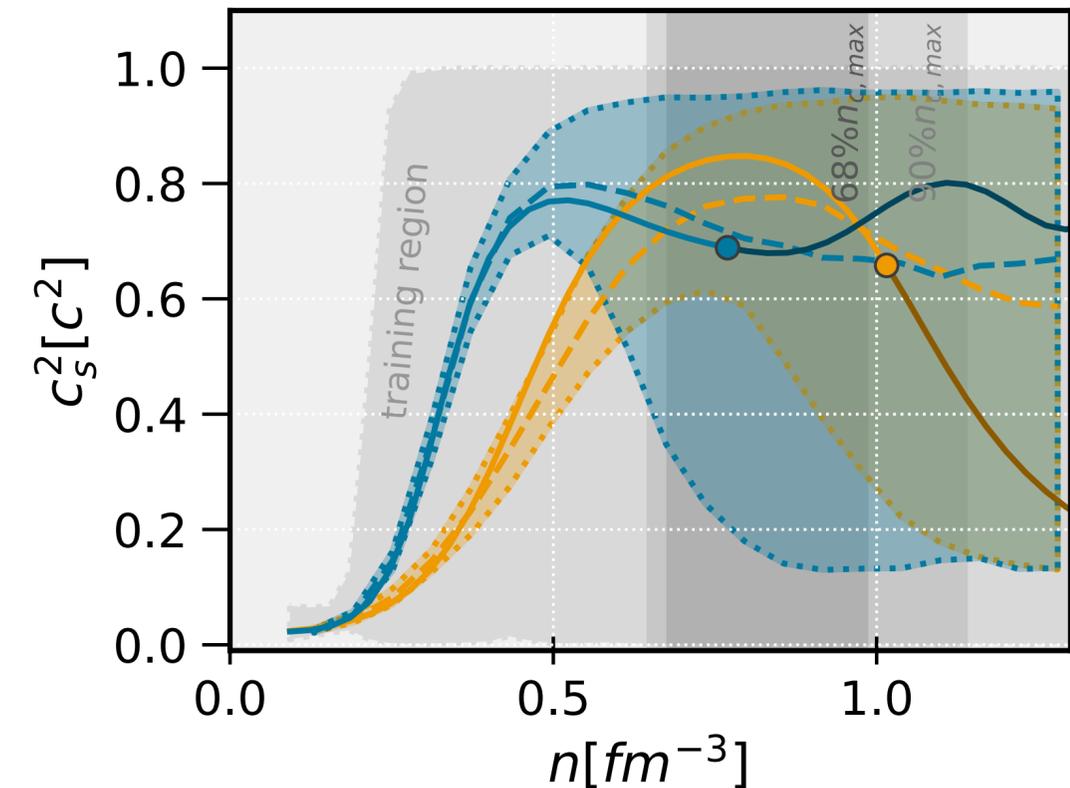
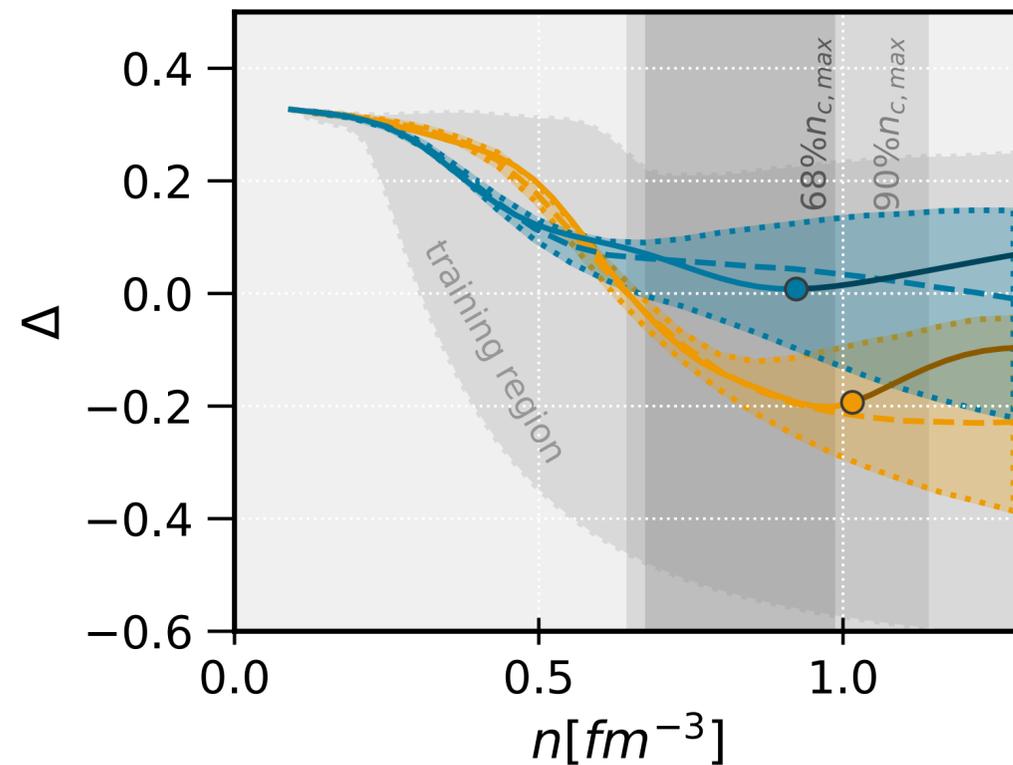
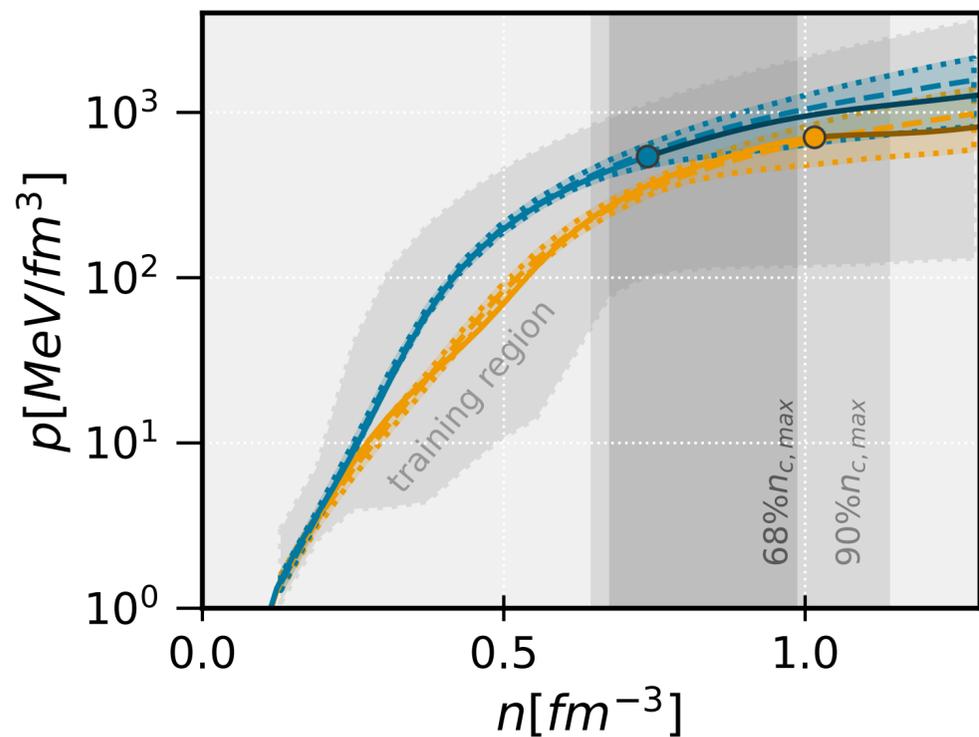
$$\begin{cases} R_x = [M_1, \dots, M_{15}, R_1, \dots, R_{15}], x \in [1,2] \\ R\Lambda_x = [M_1, \dots, M_{15}, R_1, \dots, R_{15}, M_1^*, \dots, M_{15}^*, \Lambda_1, \dots, \Lambda_{15}]. \end{cases}$$

$x = 1$ without noise, $x = 2$ with gaussian noise.

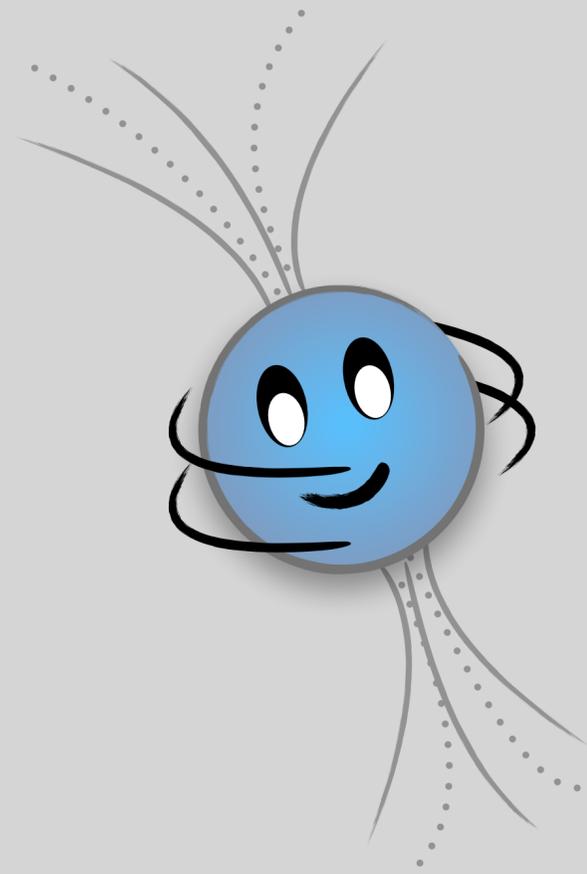


*Key result: Accurate EoS reconstruction

- ▶ Prediction for 2 samples of the test set $R\Lambda_2$ —, with a 90 % CI  and median ,
- ▶ Increase in dispersion near maximum central density, represented by ,
- ▶ Predictions always inside the CI.



Just for GP dataset



**Thank you for
your attention**

More information available at:
val.mar.dinis@gmail.com