Neural network-based emulation of interstellar medium models

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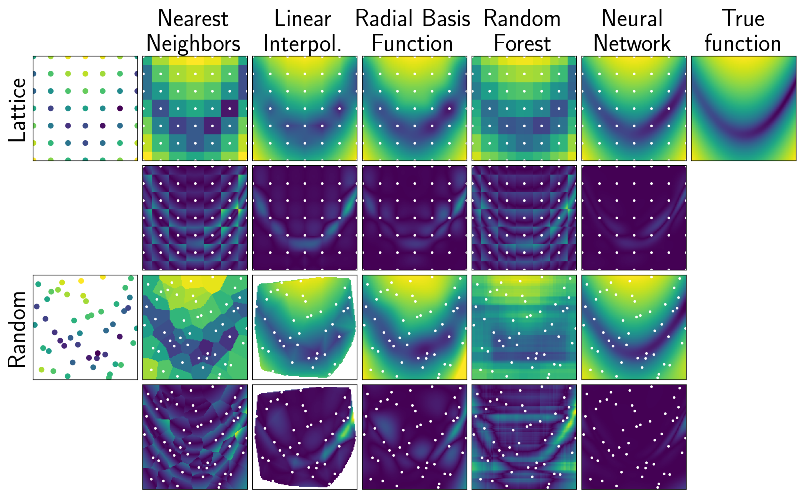
The interpretation of line observations from the interstellar medium (ISM) requires comparisons with astrophysical numerical models to infer physical conditions such as thermal pressure, kinetic temperature or visual extinction. Usually, ISM models are too time-consuming, in particular for Bayesian inference procedures that require thousands of calls. As a result, they are often replaced by interpolation of a grid of precomputed models, the accuracy of which is rarely assessed.

We propose a new general method to derive faster (from more than ten hours to a few milliseconds for a calculation), lighter and typically two to three times more accurate approximations of the model. These emulators are defined with artificial neural networks. The specificities inherent to ISM models are addressed to design and train adequate neural networks. For example, the problem of anomalies in model outputs is handled by automatically detecting and then ignoring them during training, in order to achieve a more robust version of the model. Other properties such as the important number of outputs or their redundancy are also taken into account, for instance by dividing them into clusters according to their similarity, then jointly training dedicated, simpler networks for each cluster.

We compare the proposed neural networks with standard interpolation methods, such as nearest neighbors, linear, spline, or radial basis function to emulate a representative ISM numerical model, the Meudon PDR code. This work will enable efficient inferences on million-pixel images of multiline observations.



Comparison between some interpolation and regression methods on a mathematical function for two different types of training sets (grid and random).

References

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