OAK RIDGE National Laboratory

Machine Learning for Nuclear Astrophysics

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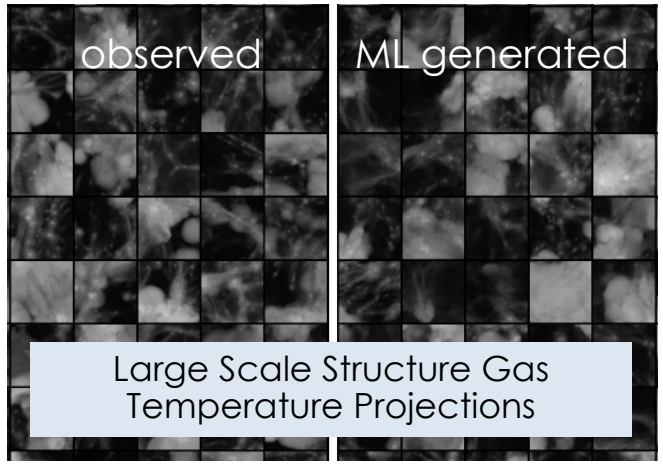

Villaescusa-Navarro Ap J 2021

REVIEWS OF MODERN PHYSICS

Colloquium: Machine learning in nuclear physics

Amber Boehnlein, Markus Diefenthaler, Nobuo Sato, Malachi Schram, Veronique Ziegler, Cristiano Fanelli, Morten Hjorth-Jensen, Tanja Horn, Michelle P. Kuchera, Dean Lee, Witold Nazarewicz, Peter Ostroumov, Kostas Orginos, Alan Poon, Xin-Nian Wang, Alexander Scheinker, Michael S. Smith, and Long-Gang Pang

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- Machine learning (ML) widely used in Astrophysics, beginning to be used in nuclear physics
- tremendous untapped potential for *nuclear astrophysics*
- recommend that
  - the potential of ML to advance nuclear astrophysics be discussed in NSAC LRP
  - ML be a part of future relevant Funding Opportunity Announcements
  - ML toolkits for non-experts be developed for nuclear physics & nuclear astrophysics

Machine Learning in Nuclear Astrophysics - Possibilities

- *Experimental Planning, Design, Execution*
  - **speed** sensitivity studies with emulators, feature selection (DT, RF, SVM)…
  - ***design*** *detectors with BO, GP …*
  - ***tune*** *separators and systems with BO, GP …*
  - ***choose*** *energies with NN, DT, RF, SVM …*
- *Data Analysis*
  - ***identify / classify*** *events with KM, KNN …*
  - ***removing hidden fitting variables*** *with DT, FA, RF …*
- *Computational / Theoretical*
  - ***identify outliers*** *in inputs (e.g., rates) & in outputs (e.g., abundances) of nucleosynthesis simulations using RF, SVM, LR, KM, IF …*
  - ***find patterns*** *in nucleosynthesis flows with NN, CNN, SVM, KM …*
  - ***interpret*** *nucleosynthesis tracer particle results with KM, KNN, RF, PCA …*
  - ***determine uncertainties*** *in models with BNN, emulators …*
  - ***speed up*** *full hydro + nuclear simulations with emulators*
  - ***find functional forms*** *using NN + SR*
  - ***reduce dimensionality*** *(remove non-observable params) with PCA, VAE, GDA…*

GLOSSARY

DT Decision Tree
RF Random Forests
SVM Supp. Vector Mach.
BO Bayesian Optimization
GP Gaussian Process
NN Neural Network
KM K means
KNN K Nearest Neighbors
FA Factor Analysis
RF Random Forests
LR Logistic Regression
IF Isolation Forest
CNN Convolutional NN
BNN Bayesian NN
SR Symbolic Regression
PCA Principal Comp/ Analy.
VAE Var. AutoEncoders
GDA Gen. Discrim. Analy.