Constraining Supernova Physics through Gravitational-Wave Observations with BayesWave

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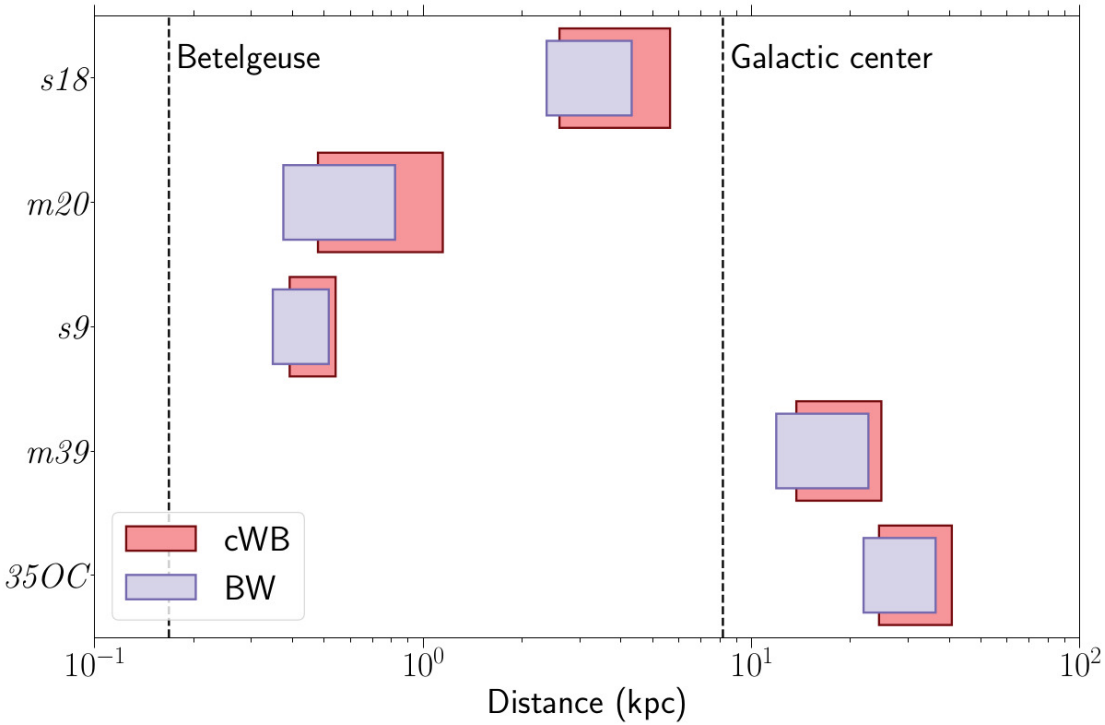
CCSNe and BayesWave

- We have to rely on model-independent burst search algorithms
- We have already used BW in the O3 short-duration all-sky search



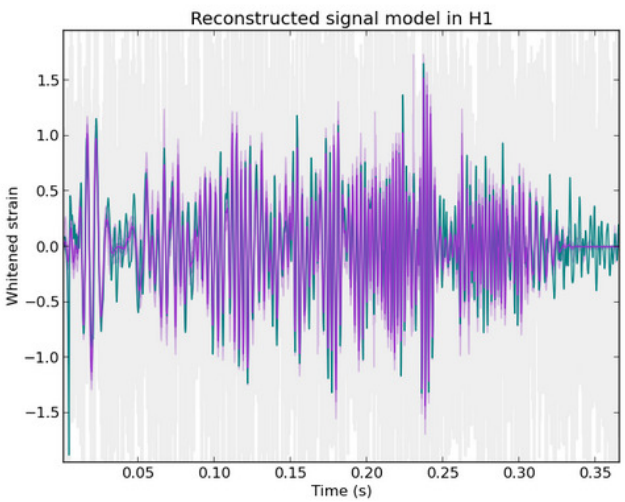
- Raza, McIver, Dálya, Raffai: more detailed study + optimization of BW for SNe: `https://arxiv.org/abs/2203.08960`

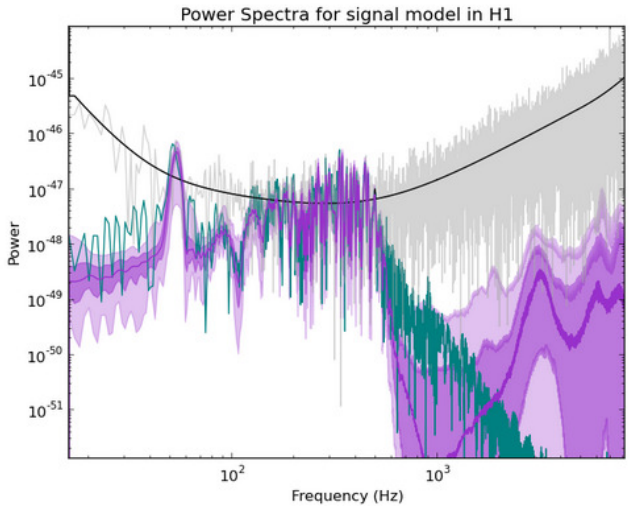
Scope of this project

- How accurately can we classify the explosion mechanism?
- What features of the waveform can we reliably reconstruct?
- What constraints can we give on the physical properties, e.g. mass or angular momentum?

Methods

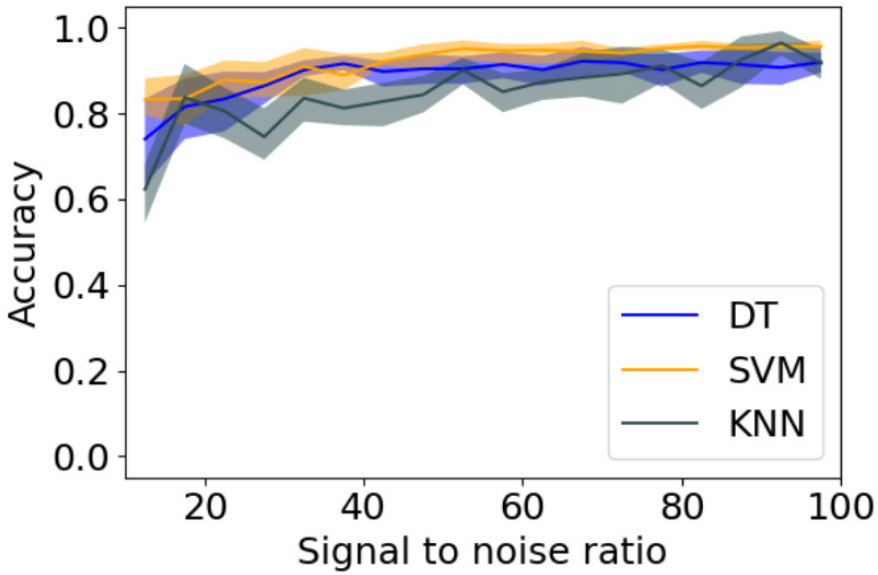
- Chose 14 different 3D CCSN models, 1000 waveforms from each
- SNRs uniform between $10 - 100$
- Using a HLVK network with O5 sensitivities
- Reconstructing them with the SN-optimized BW
- Dimensionality reduction (PCA, UMAP)
  + classifier (SVM, kNN, DT) / regression (LR, LASSO)



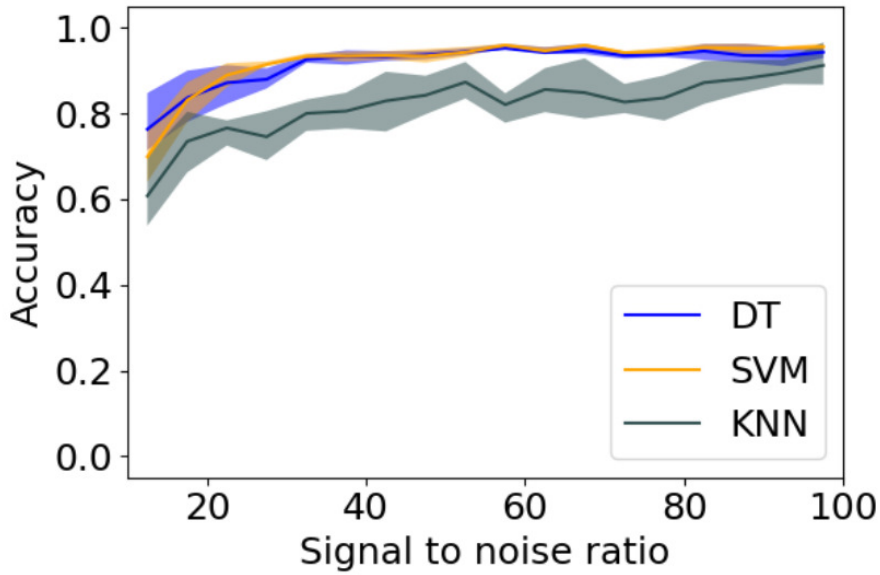


Results: Explosion mechanism

Magneto-rotational vs. neutrino-driven

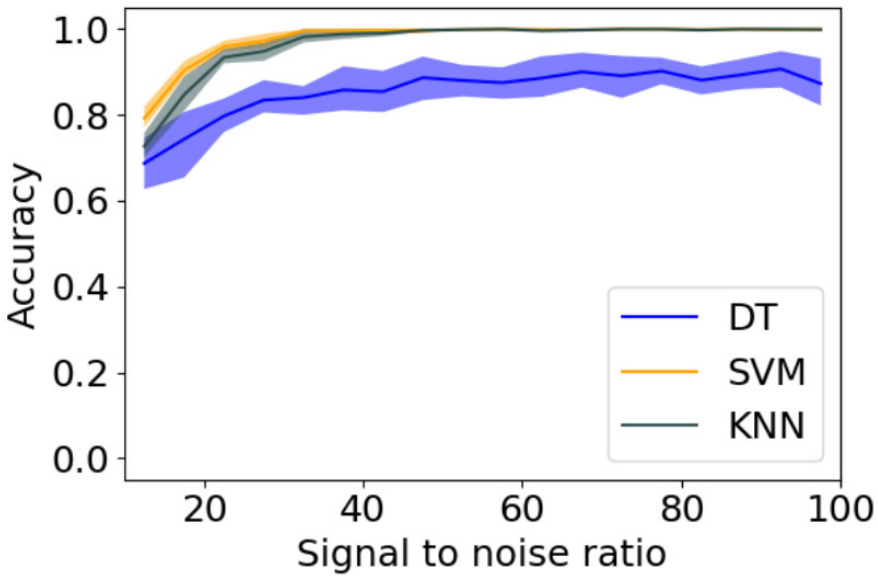


(a) PCA

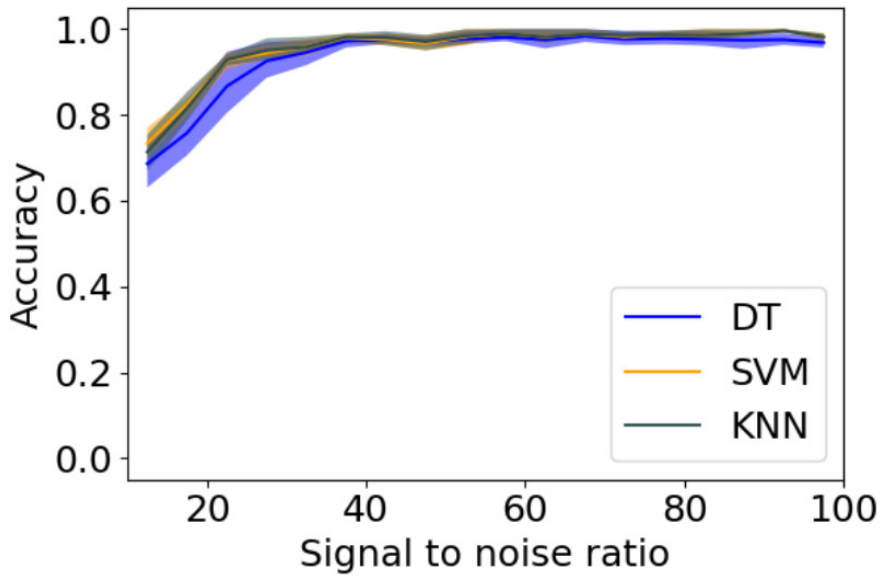


(b) UMAP

Results: Presence of rotation

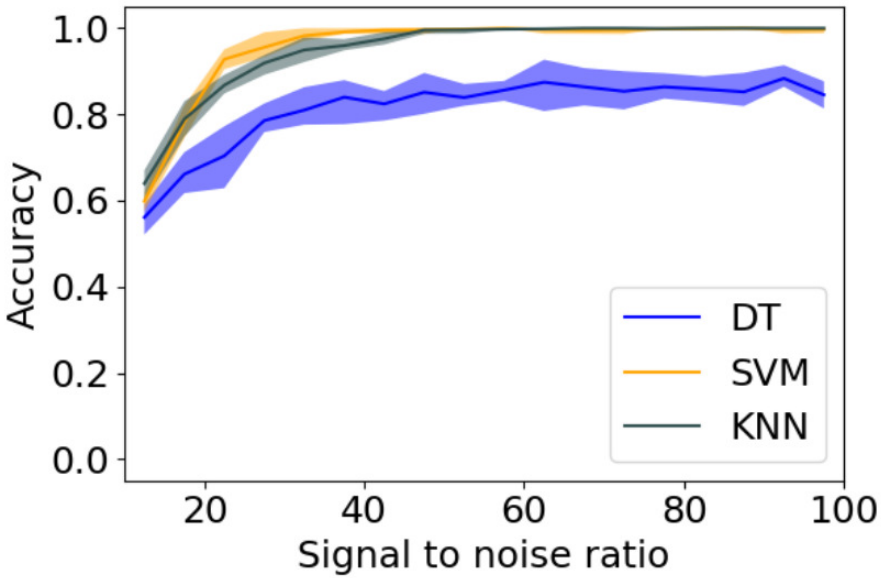


(a) PCA

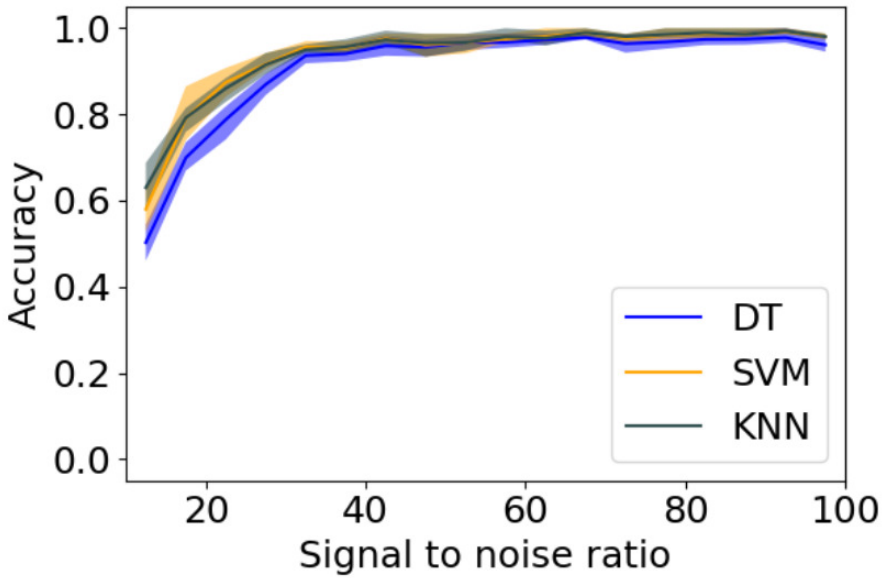


(b) UMAP

Results: Presence of prompt convection

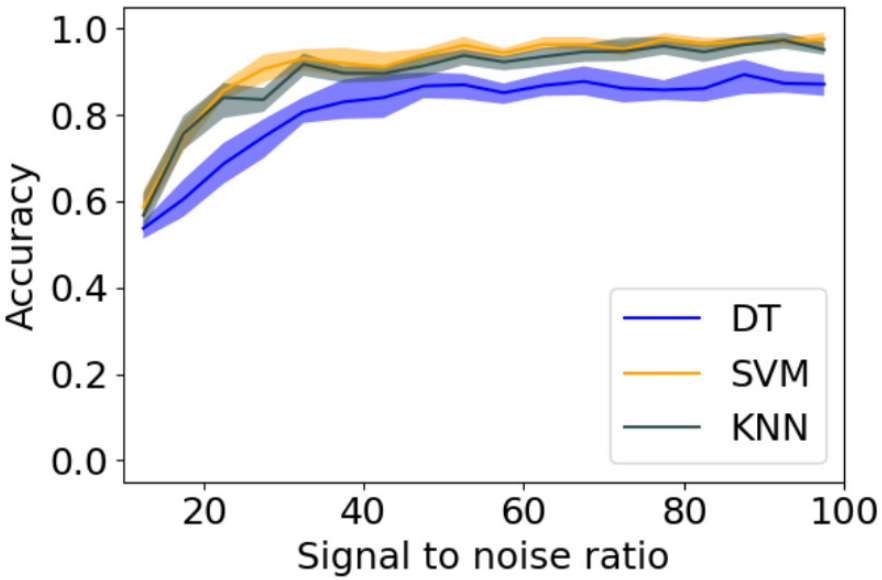


(a) PCA

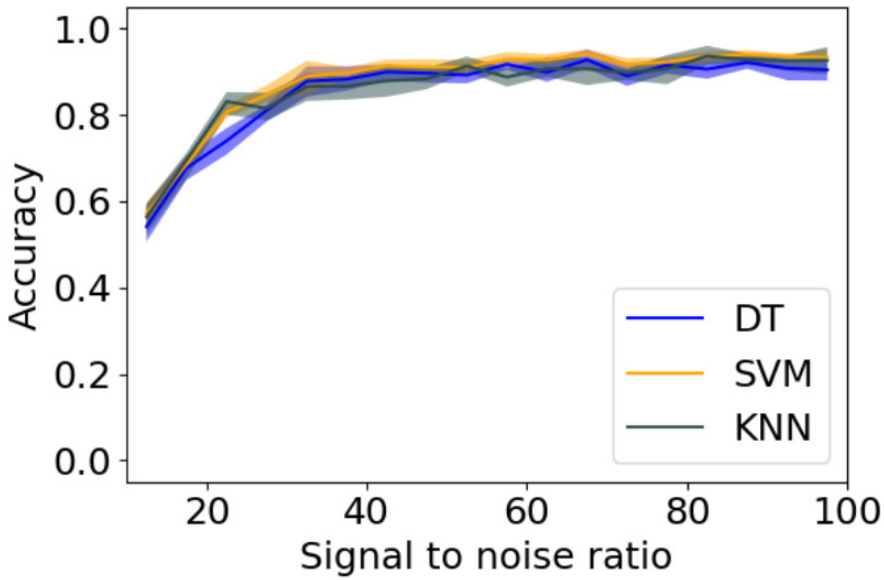


(b) UMAP

Results: Presence of SASI

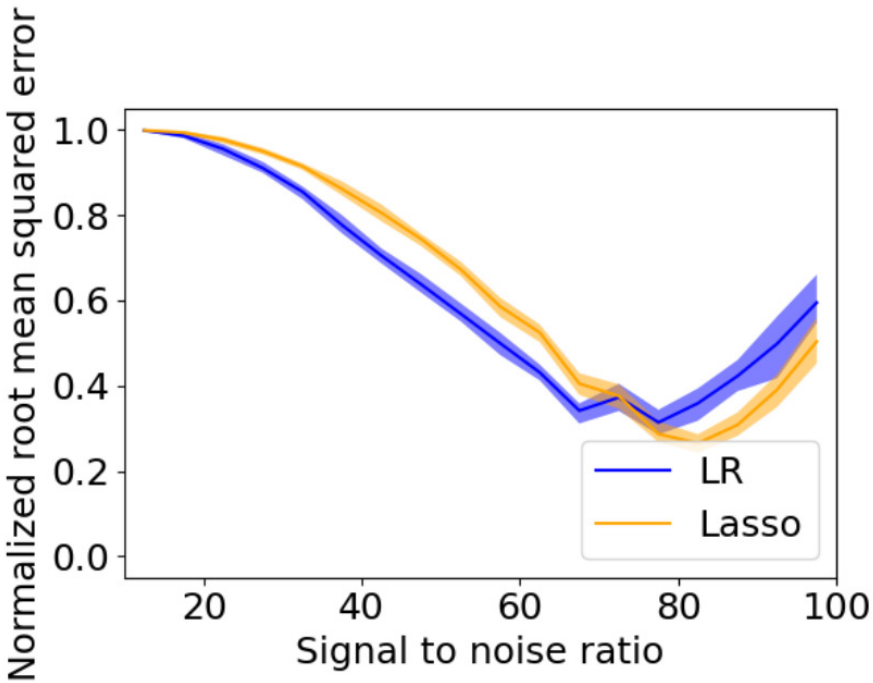


(a) PCA

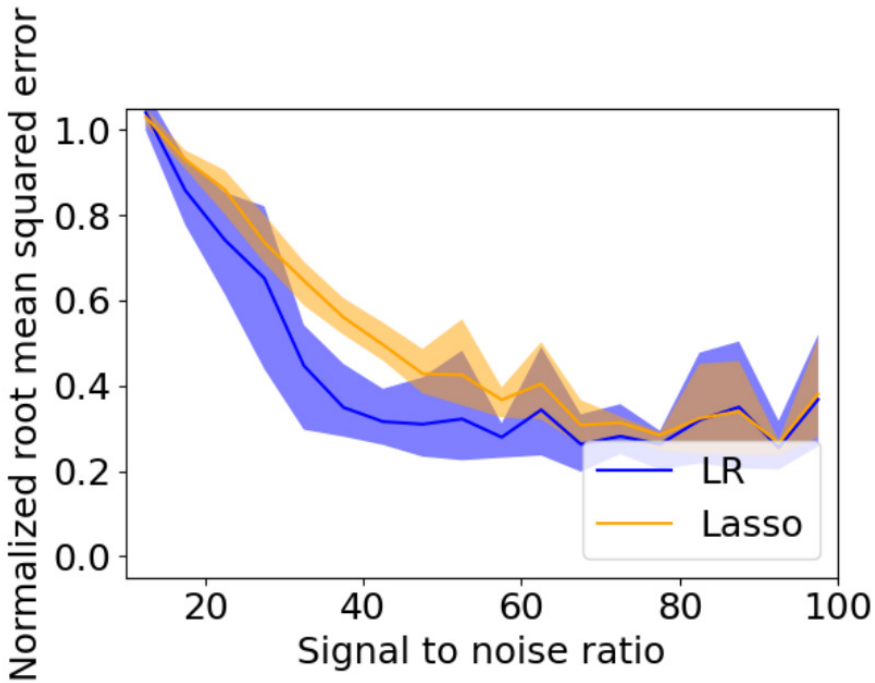


(b) UMAP

Results: Progenitor mass

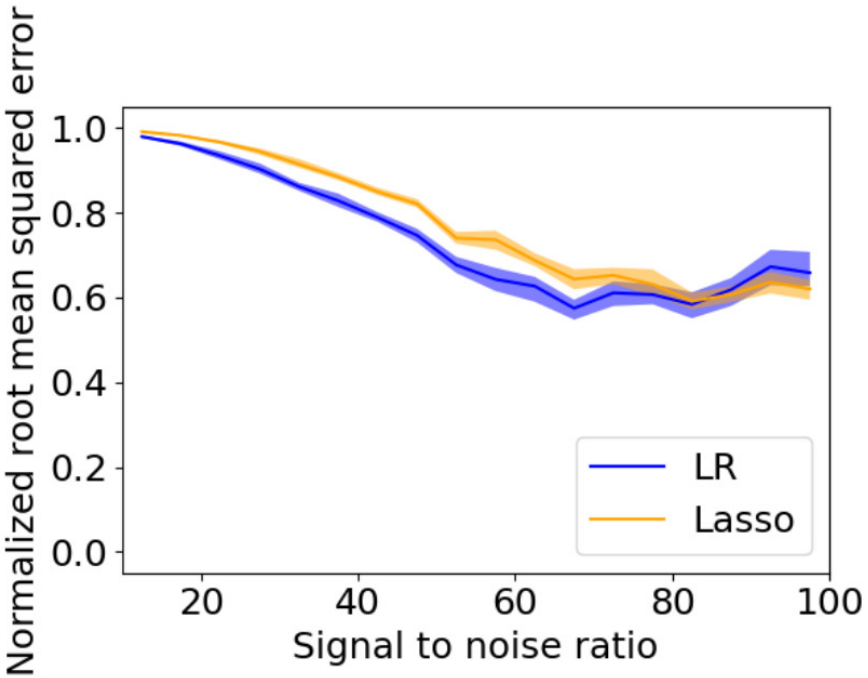


(a) PCA

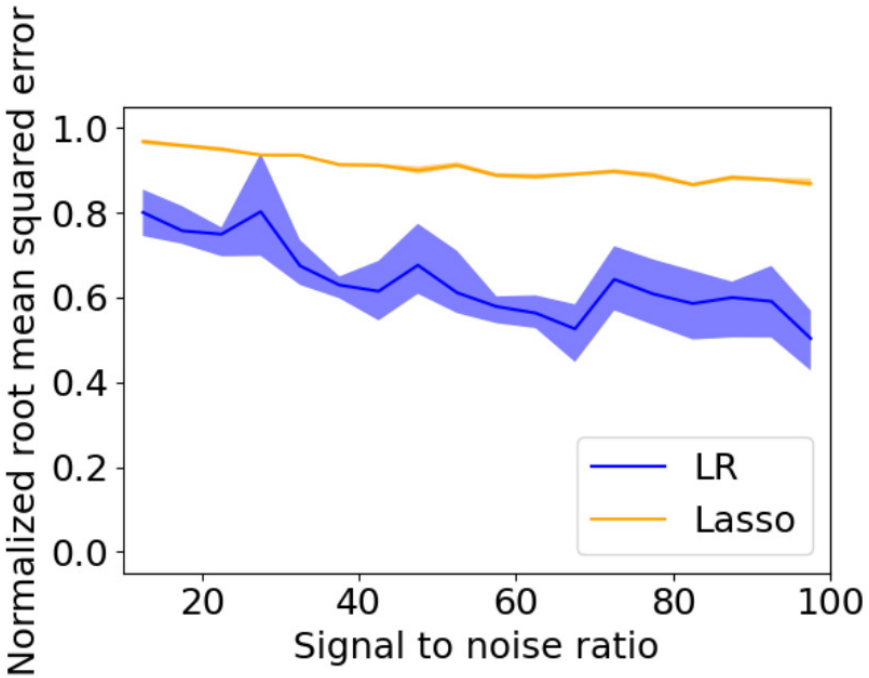


(b) UMAP

Results: Rotational velocity

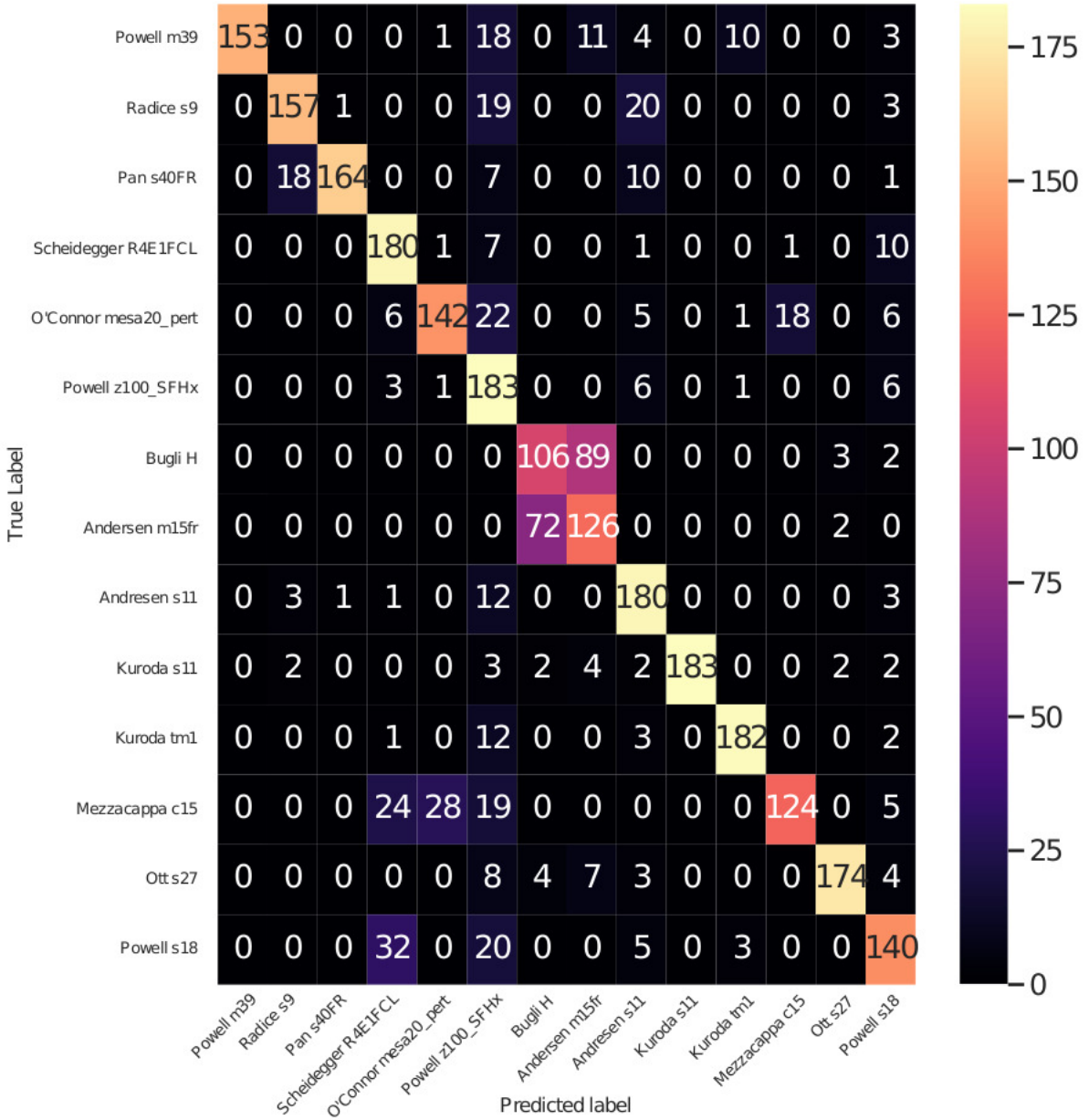


(a) PCA



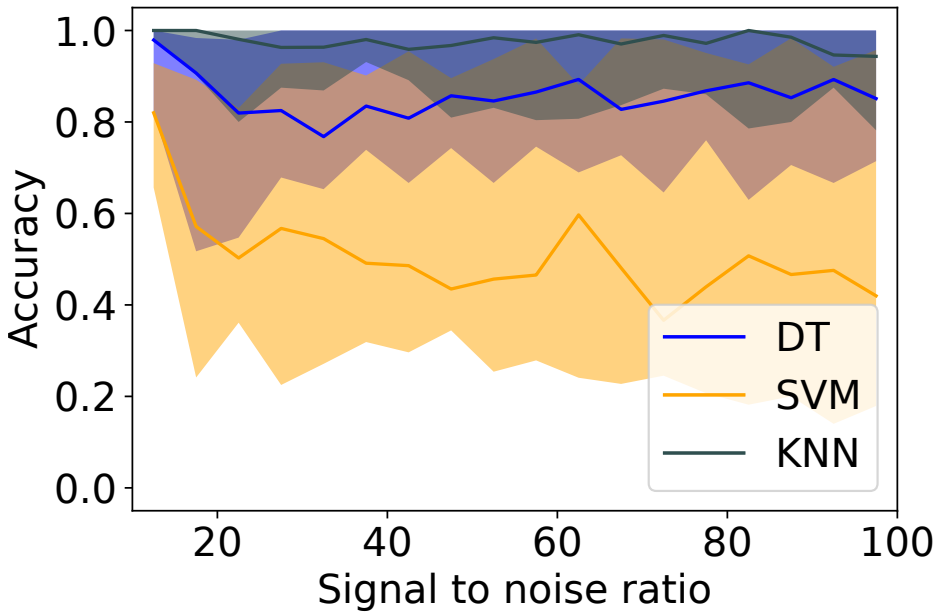
(b) UMAP

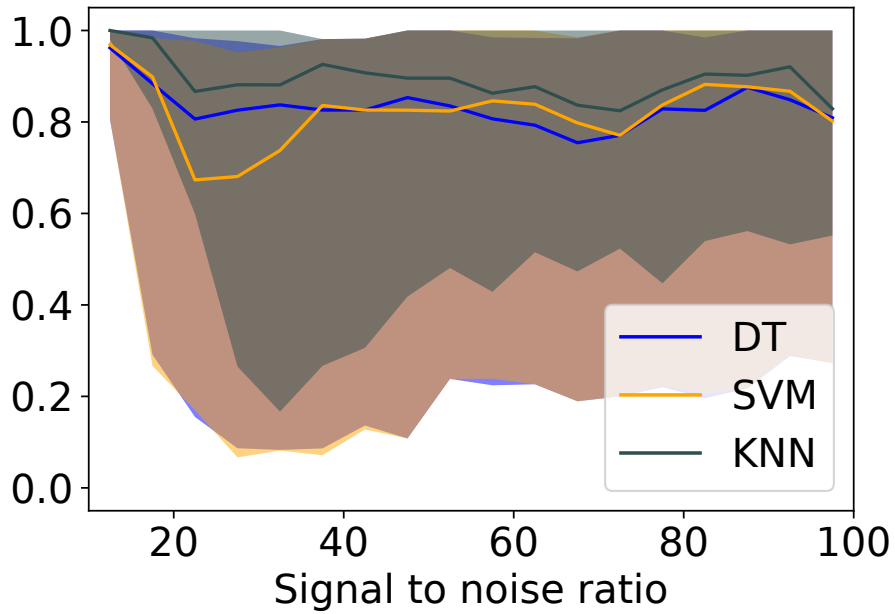
Confusion matrix



Testing on unused model

Predicted shock revival mechanism for neutrino-driven models





Summary

- 14 different 3D CCSN models, 1000 waveforms from each
- Reconstructing them with the SN-optimized BW
- Generally PCA/UMAP+SVM seems to be the most accurate, but all methods work quite well for $\mathrm{SNR}_{\mathrm{net}} \gtrsim 25$
- Paper on P&P review: https://pnp.ligo.org/P2300045/