Deepclean: Denoising using PEM and Auxiliary Channels

- \( w(t) \): witness channels that record the data from the auxiliary sensors and PEM.
- \( p(t) \): predicted noise in strain.
- Both \( w(t) \) and \( p(t) \) are 8-second long timeseries with the same sampling rate.
- Ref: 2005.06534, 2108.12430
Deepclean: Training and Inferencing

- $h(t)$: raw strain data.
- $r(t) = h(t) - p(t)$: residual.
- Loss function: $L = \omega_{asd}J_{asd} + \omega_{mse}J_{mse}$, $J_{asd} = \frac{1}{M} \sum_{i=0}^{M-1} \sqrt{\frac{S[r,r][i]}{S[h,h][i]}}$, $J_{mse} = \frac{1}{N} \sum_{i=0}^{N-1} r[i]^2$. 

![Diagram of Deepclean model]

- Encoder (down-sampler)
- Decoder (up-sampler)
Offline Test

- Data used: LIGO Hanford and Livingston data from 2019/04/01 ~ 2019/06/01.
- Target noise:
  - power-line noise at 60Hz and its side-bands (55 ~ 65 Hz, 8th-order Butterworth filter),
  - low-frequency band (8~22Hz).
- Strain channel: GDS-CALIB_STRAIN.
- Sample rate: 16384Hz downsampled to 4096Hz.
- Loss function: ASD loss function only.
Metric of Performance: Improvements in Detection Range

- BNS merger in 20~1024Hz band,
- IMBBH merger in 20~80Hz band.
- Improvements of IMBBH range should be seen in cleaned strain.
- Evaluation of detection range?
- Other metric: SNR, GstLAL?
Safety Check: PE on Injected CBC Events

- 128 events are injected in a 4096-second segment, one injection in every 32-second segments in this 4096-second segment.
- Estimated parameter: chirp mass, mass ratio, luminosity distance.
- PE should be done on both cleaned and uncleared data to show that noise subtraction does not destroy the astrophysical signals.
Online Deployment

- Cleaning 1-second long strain written in frame files.
- Edge effect: Quality Degrading of the noise prediction happens at the edge of the 8s-kernels (around 0.5s from the edge). It’s caused by the windowing the data.
- Edge effect becomes serious when cleaning 1s data.
By taking 6s before and 1s after the target 1s to form a 8s kernel, we can avoid the edge effects.

Only the green segment will be extracted after cleaning.
Training Optimizations

- There are Hyper Parameters of Neural Network to be tuned for better performance.
- In this work, the following parameters are focused:
  a. the duration of the data,
  b. selection of segments and the frequency of training (the cadence for re-training),
  c. choice of loss function weighting
- Further Hyper Parameter Tuning can be done with the help of the Inference as a Service (IaaS) model.
- For the online test, we need pre-trained models.
Performance Evaluation and Safety check for Online Test

- PE for CBC events
- Stochastic signals