Deep learning to detect CBC before the merger

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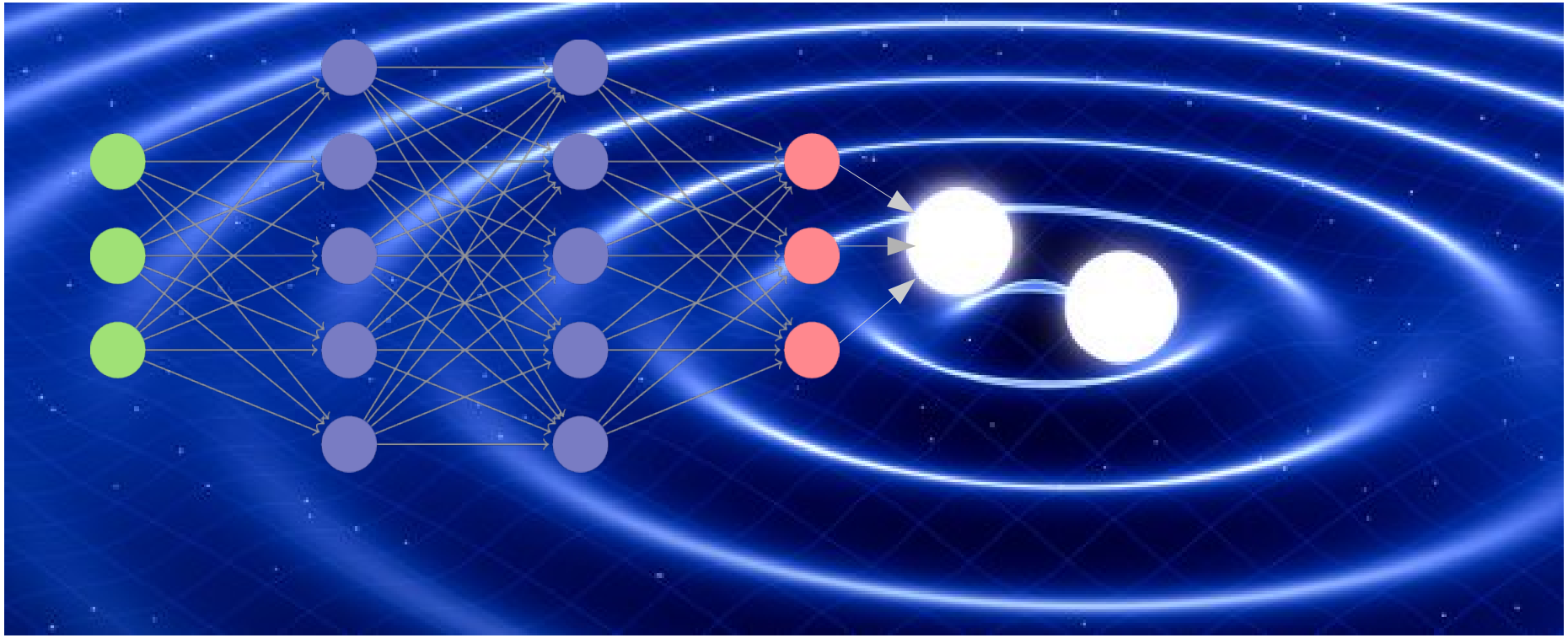


Goals and motivations

Detection of CBC before
the merger using deep learning algorithm

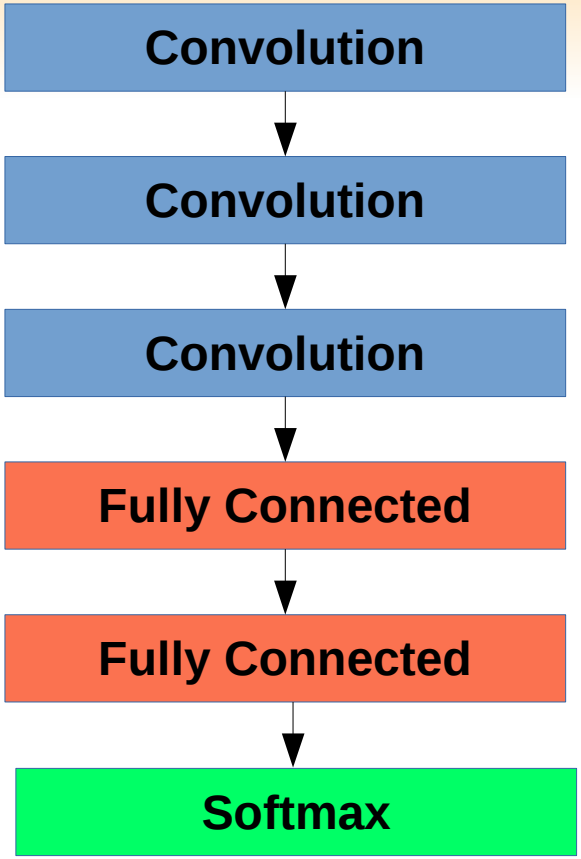
- **Useful for multi-messenger astronomy**
- **Einstein telescope**

Why deep learning ?

- Faster than matched filtering
- SNR from matched filtering is low for seconds of inspiral
- Computationally cheap (after training)

Neural network

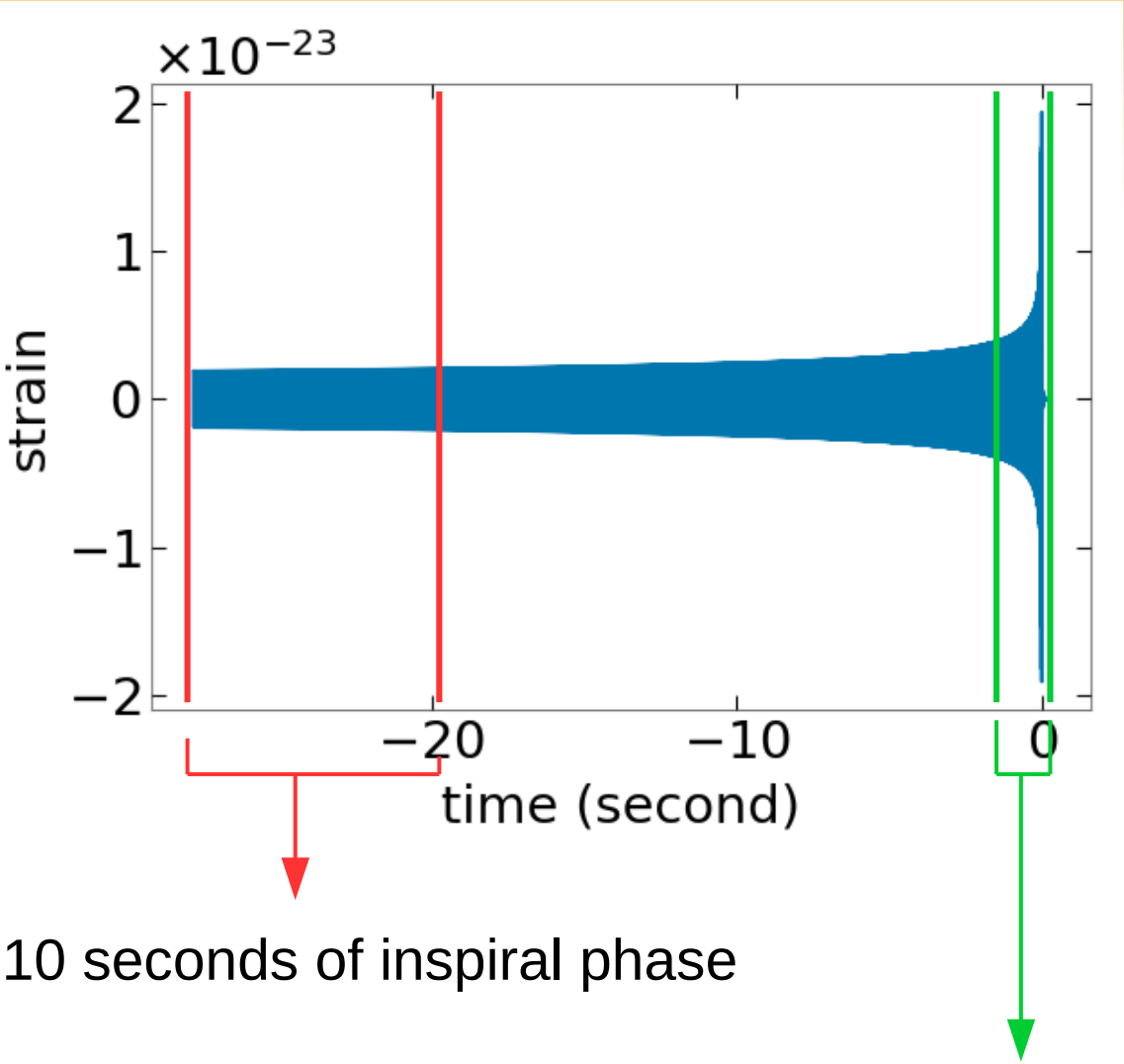
Based on *PHYSICAL REVIEW D 97, 044039 (2018)* by E. A. Huerta and D. George



- 3 layers of convolution (with pool layers)
- 2 layers of fully-connected
- Softmax layer
- Input vector of size 40960 (10 seconds of inspiral)
- Output size : 1 (between 0 and 1)

Output is [0.9, 1.0] => if GW : success
Output is [0.0, 0.1] => if no GW : success
Output]0.1, 0.9[=> failure

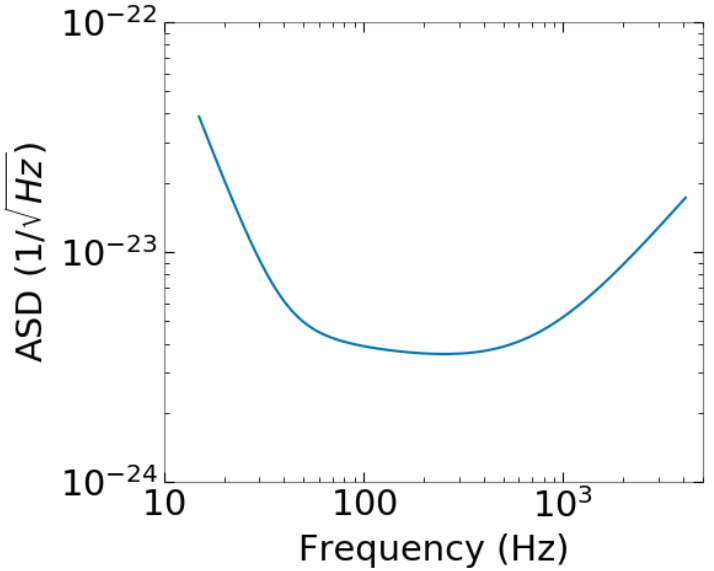
Generation of waveforms and Gaussian noise



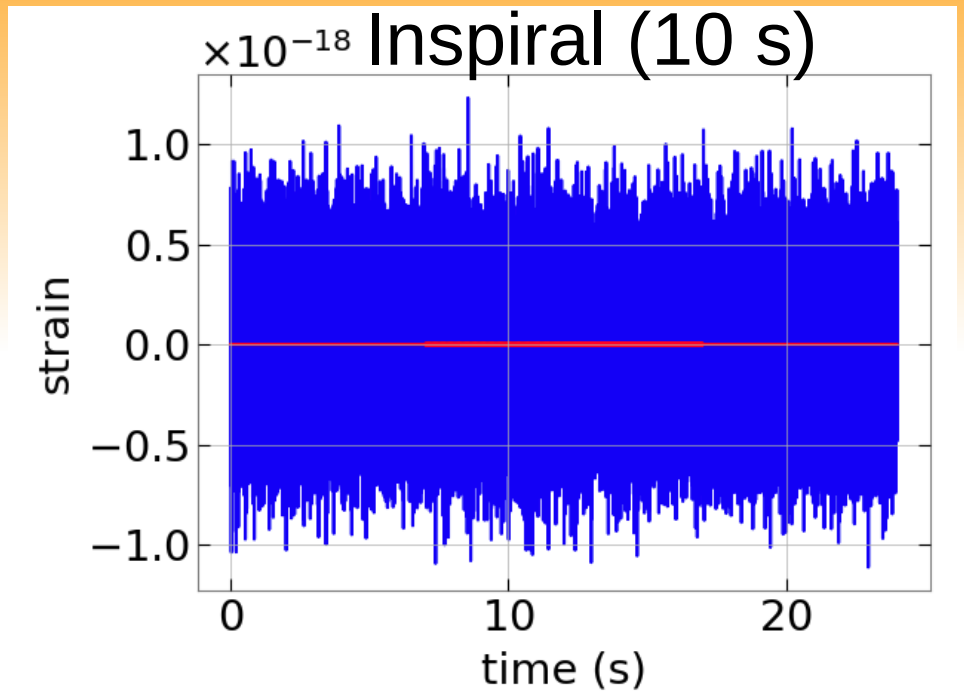
10 seconds of inspiral phase

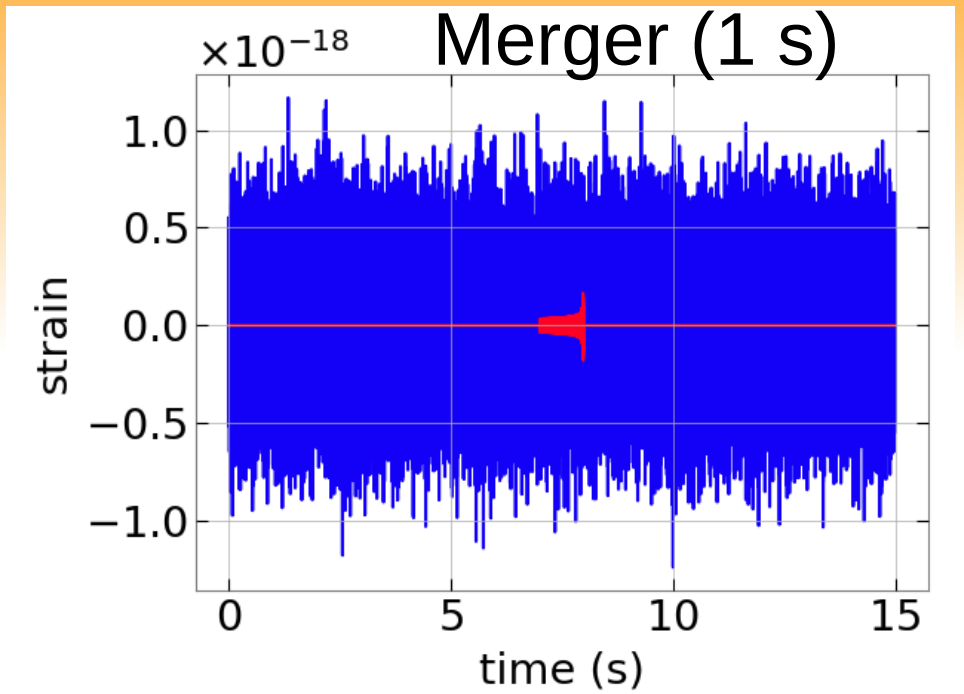
1 second of merger phase

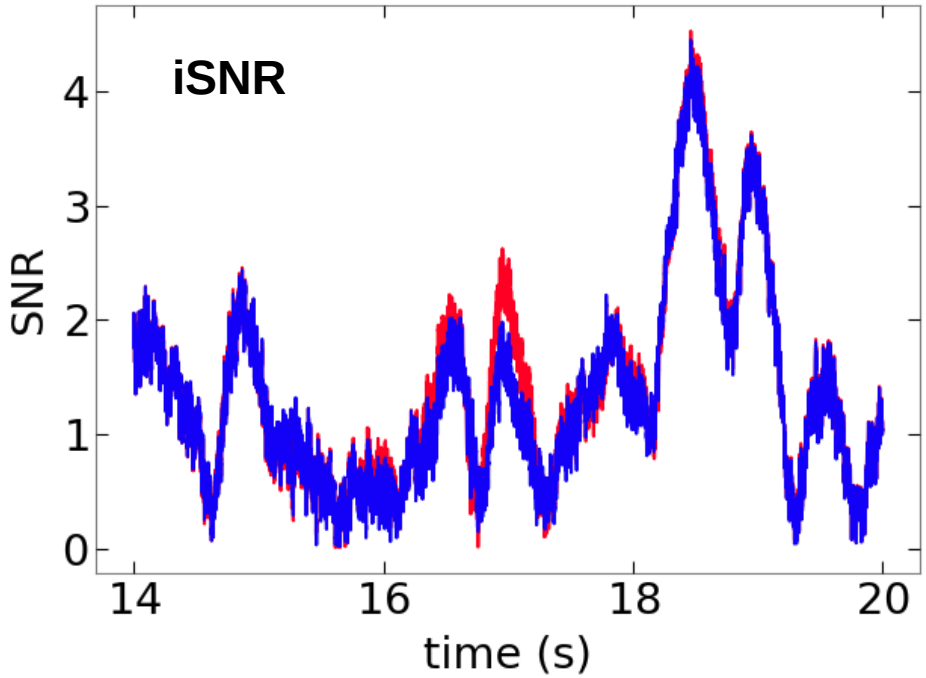
- Generate waveform using pyCBC
- Select 10 seconds of the inspiral
- Select 1 second of the merger (calculate the SNR)
- Generate colored Gaussian noise

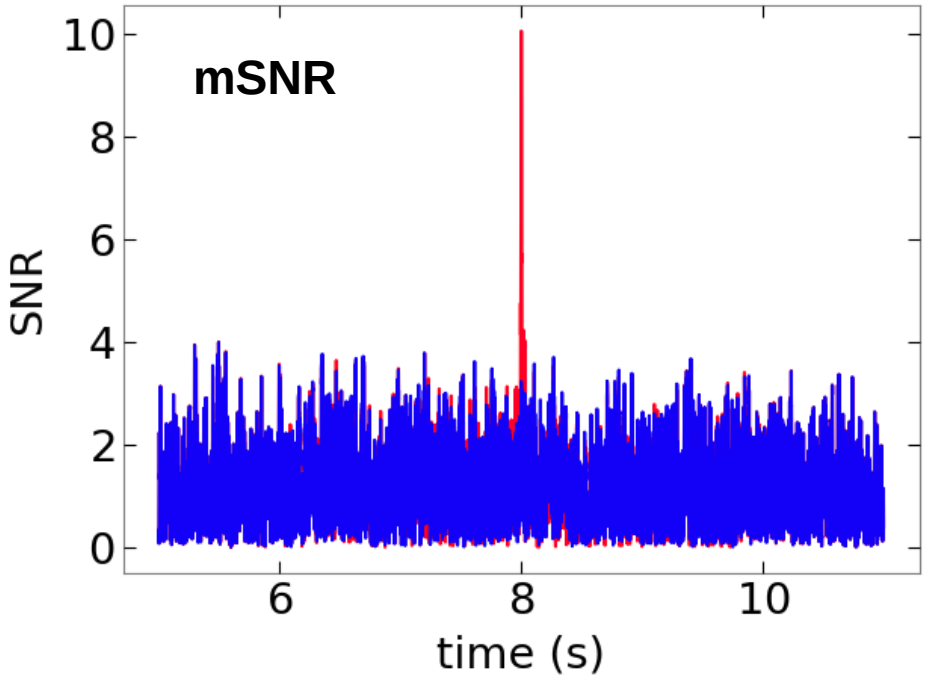


Calculation of the SNR



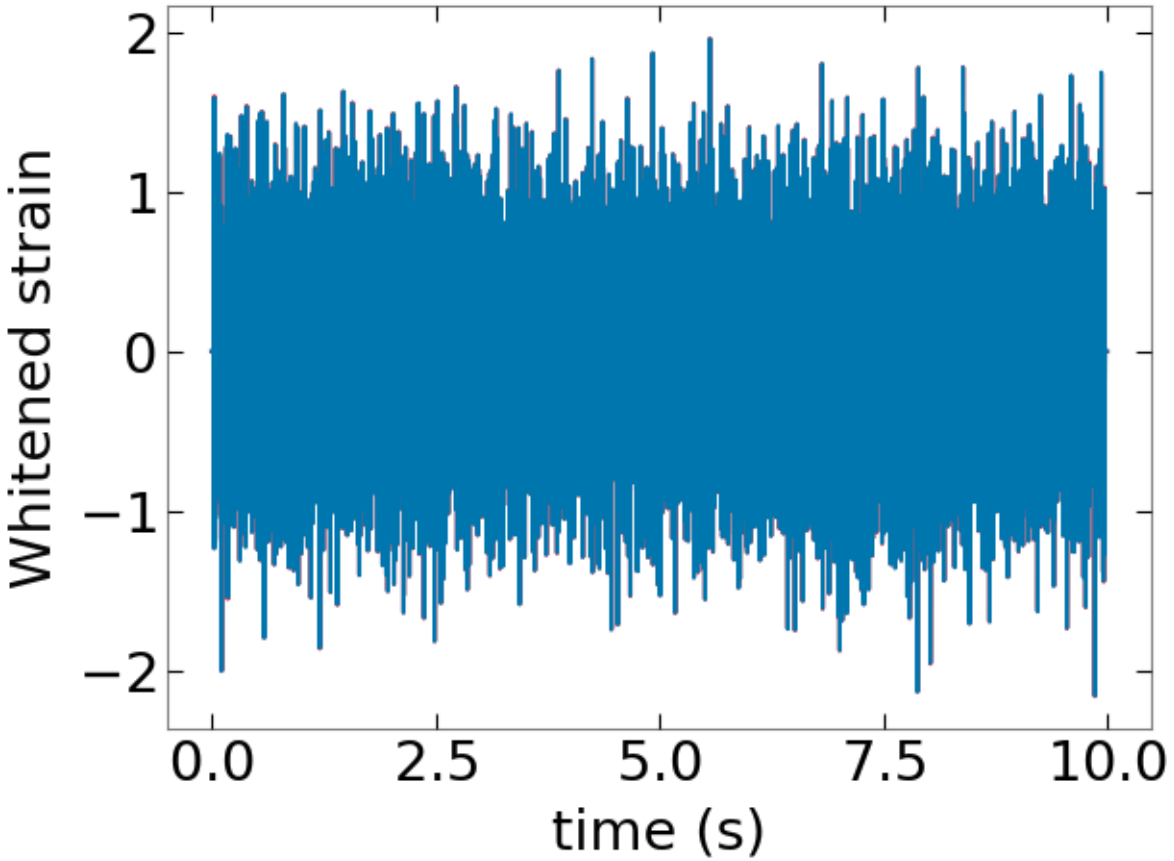






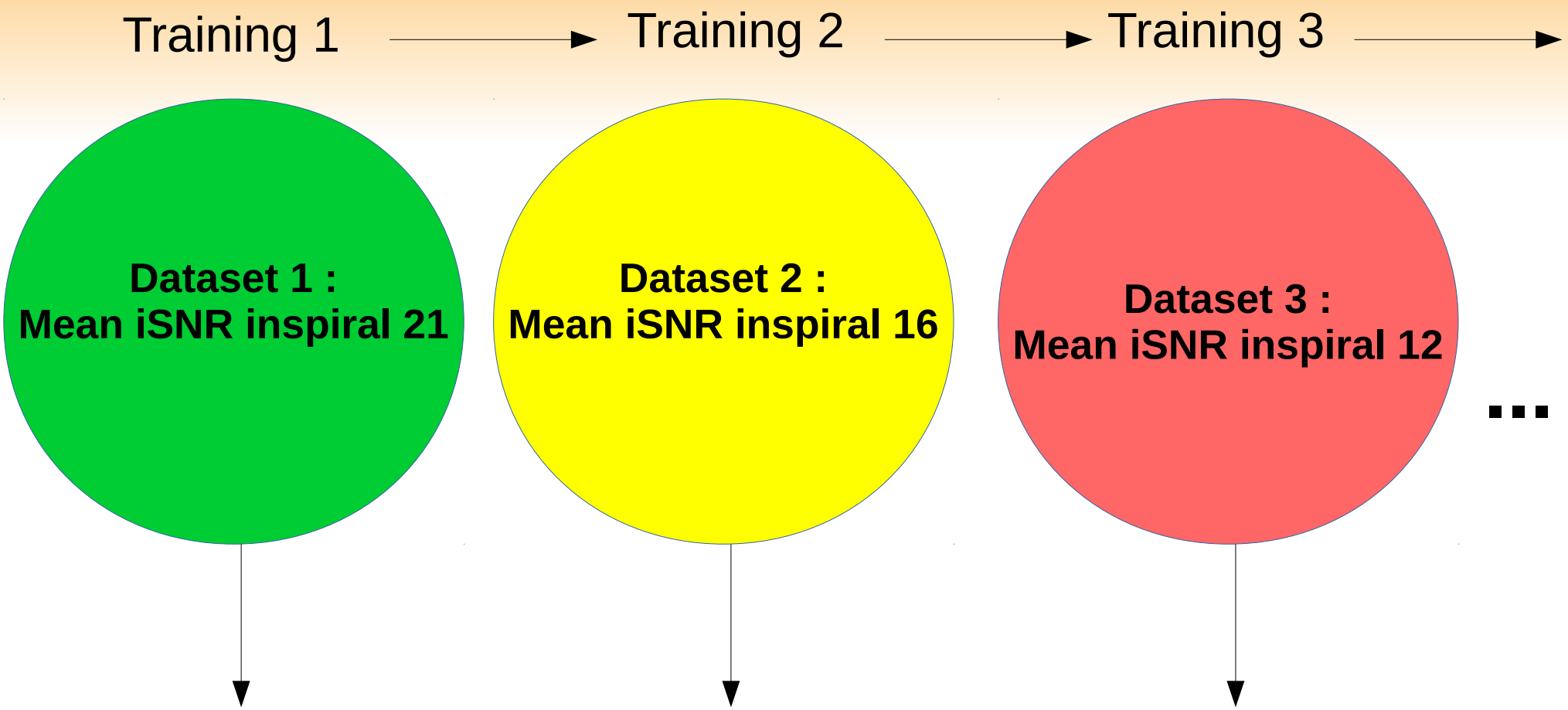
Training on different datasets

Whitened strain : INPUT for neural network



- Generate different datasets focused on small ranges of SNR
- ~ 3000 whitened curves in each dataset
- Half with a GW
- Half only pure noise

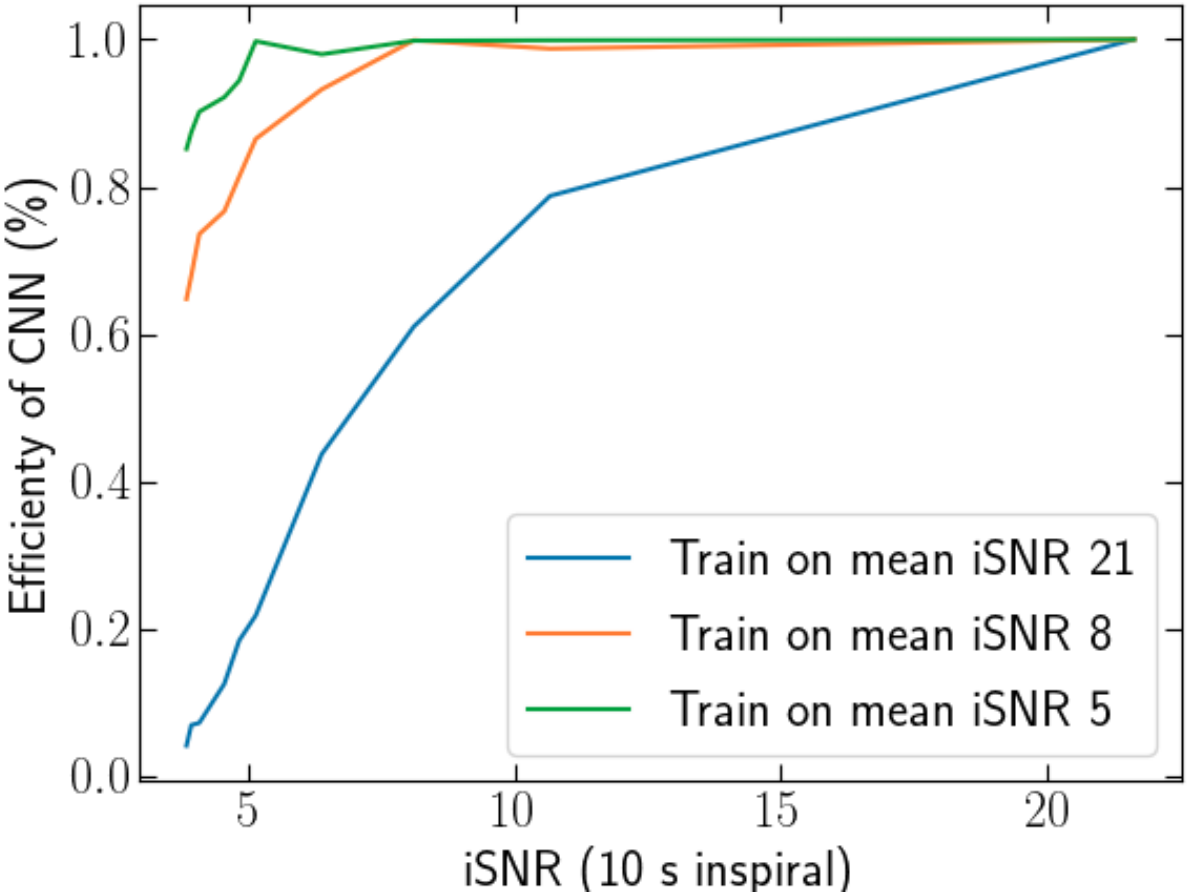
Training on different datasets



Mass 1 and 2 vary from 1 $M_\odot$ to 5 $M_\odot$ with a step of 0.1 $M_\odot$

Results 1 : inspiral

Efficiency of the neural network as a function of the SNR



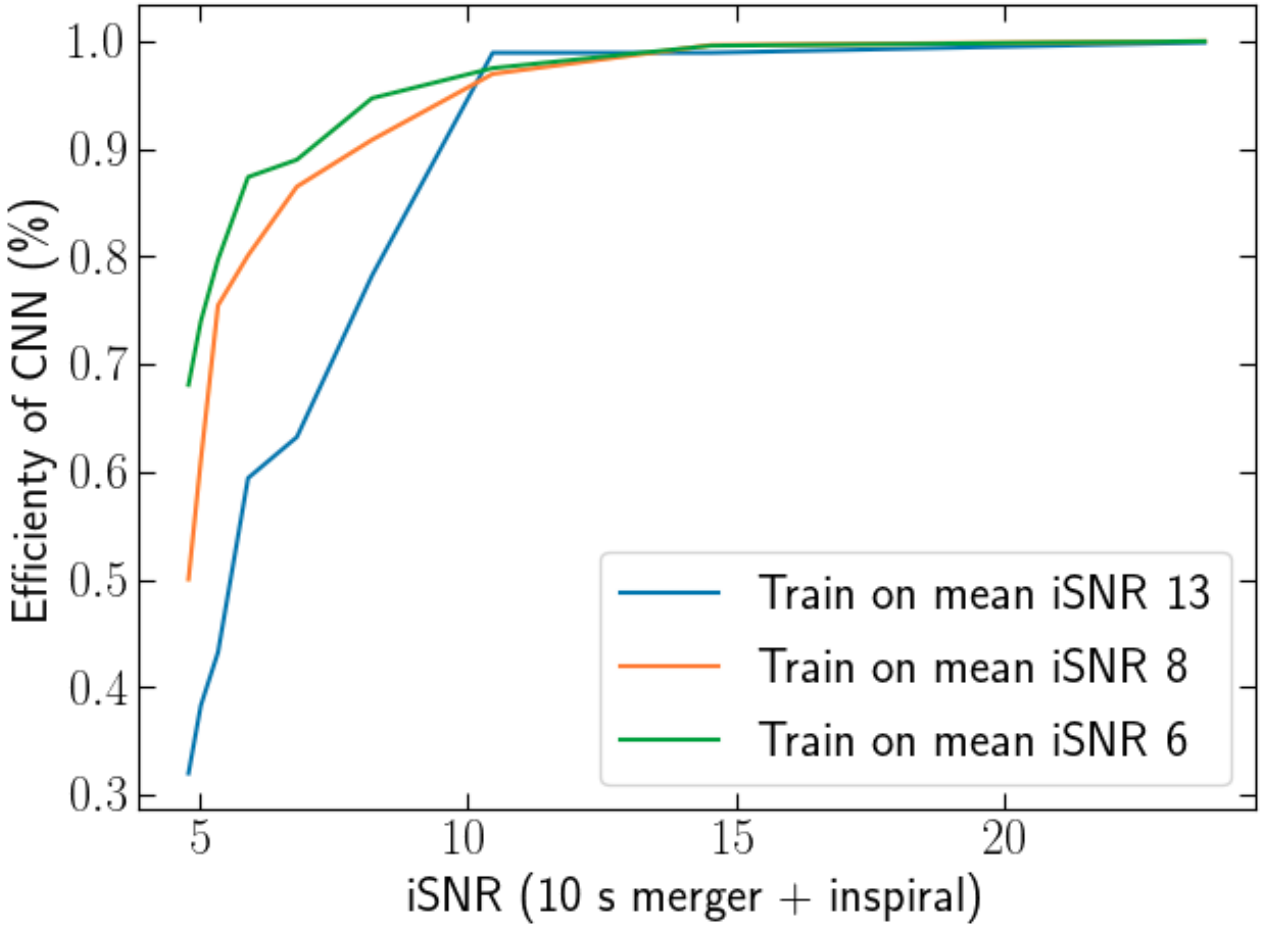
True positive 85.12%	**False positive 0.24%**
True negative 99.76%	**False negative 14.88%**

Mean iSNR (inspiral) : 4

Mean mSNR (merger) : 14

Results 2 : merger + inspiral

Efficiency of the neural network as a function of the SNR

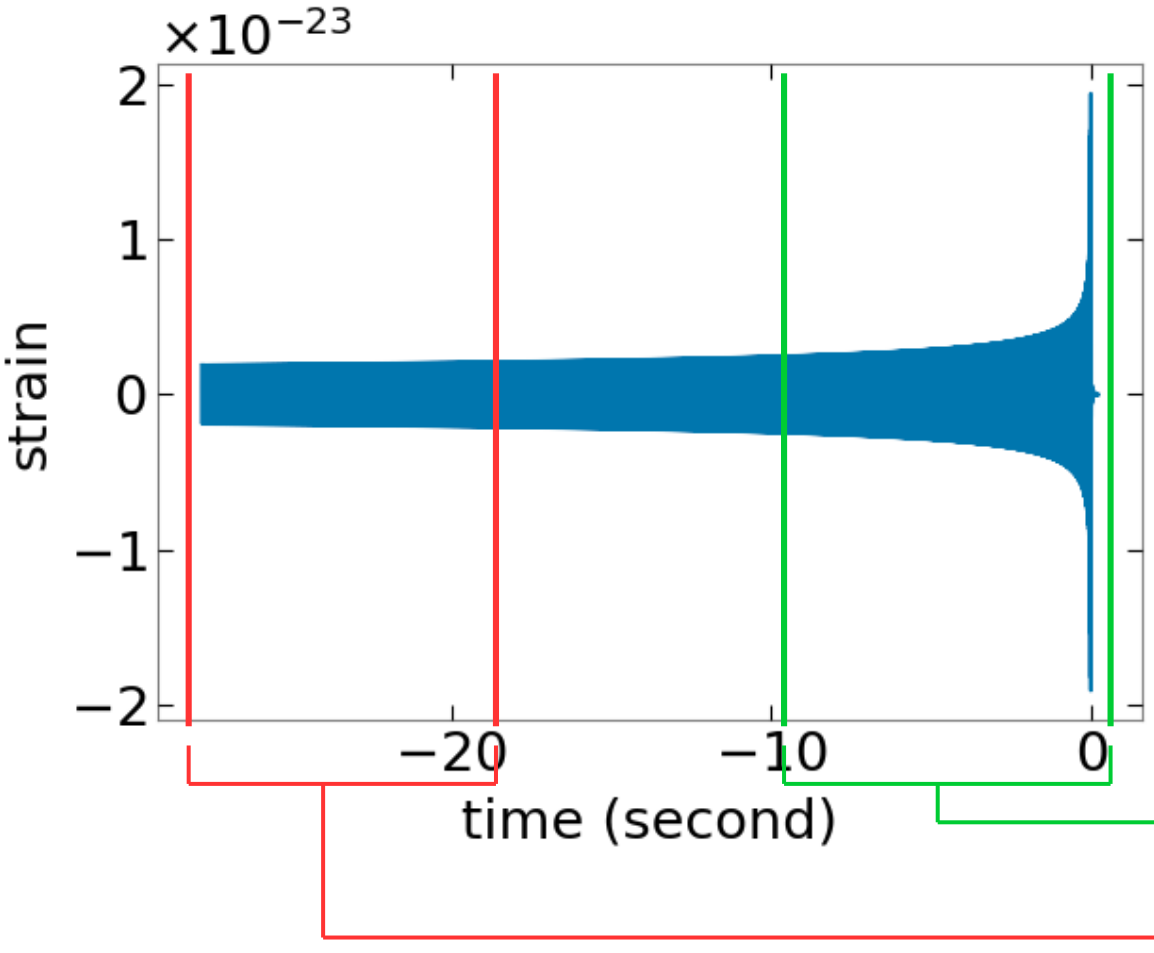


True positive 79.71%	**False positive 14.69%**
True negative 85.31%	**False negative 20.29%**

Mean iSNR (merger/inspiral) : 5

Inspire/merger vs pure inspiral

Why neural network are better with pure inspiral than whith inspiral/merger at the same SNR ?



You need a template with a higher amplitude if you want a 10 seconds inspiral with the same iSNR than a 10 seconds inspiral/merger.

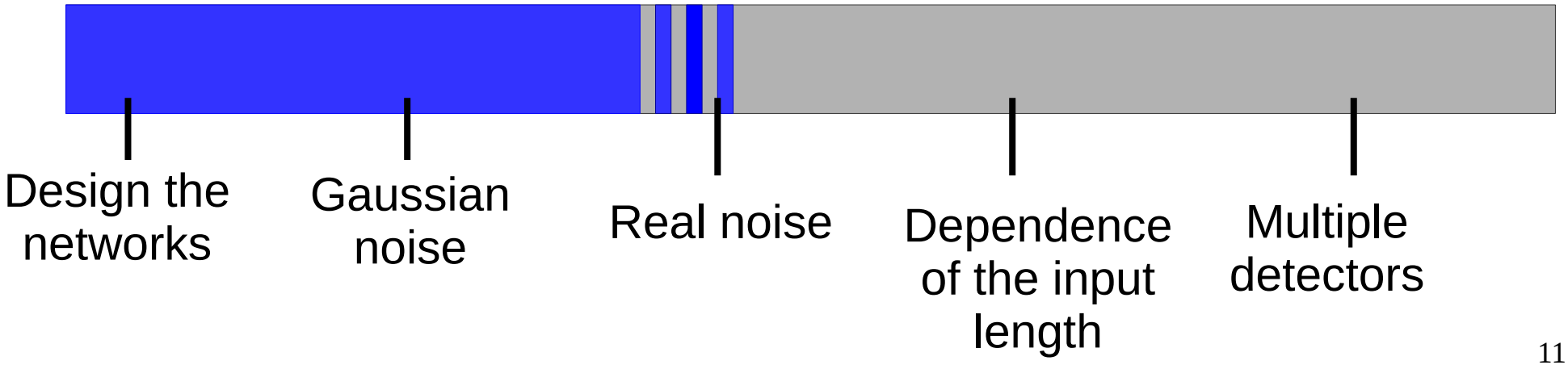
If iSNR ~ 10

Then iSNR << 10

Conclusion

Convolutional networks are able to detect 10 seconds of inspiral into Gaussian noise, even if the iSNR is very low.

Work in progress



Thanks for your attention