ALBUS : Anomaly detector for Long duration BUrst Searches

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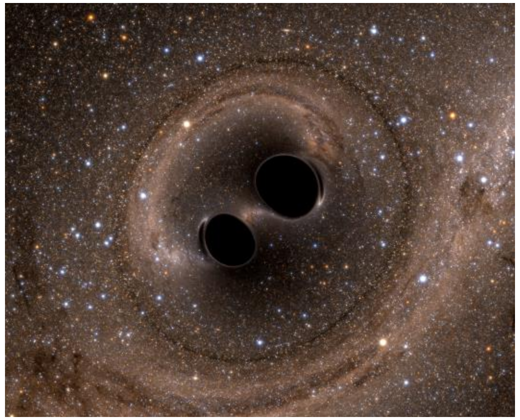
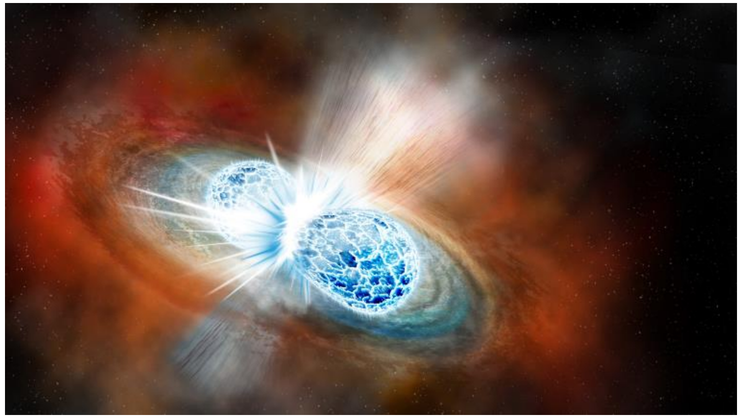
1) What are Bursts ?

- Gravitational waves detected so far : compact binary coalescences (CBC)

- Black Hole-Black Hole
- Neutron star-Neutron star
- Black Hole-Neutron star





- Expected class of events : Bursts

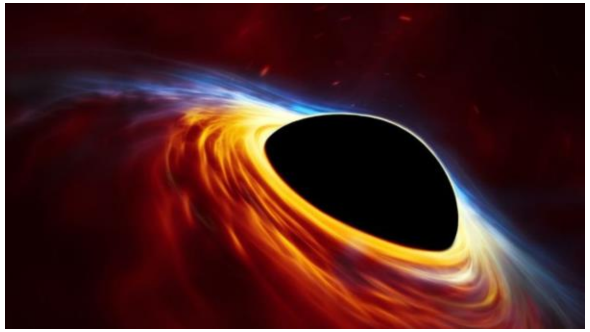
- Anything that is transient and not a CBC
- two families of bursts : short- (< 2 sec) and long duration (> 2 sec)

1) What are Bursts ?

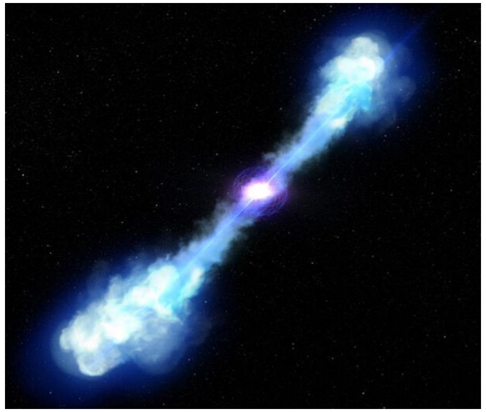
- What are the phenomena generating long-duration bursts ?

Non-axisymmetric deformations in magnetars

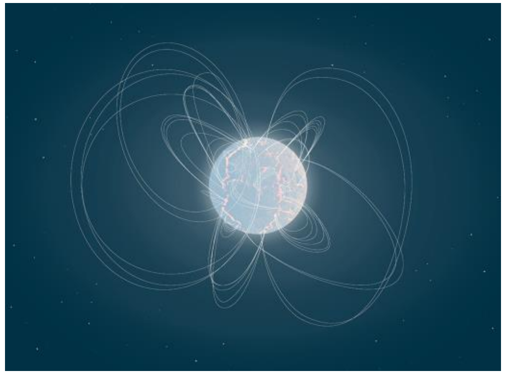
Accretion disk instabilities around black holes



Gamma-ray Bursts



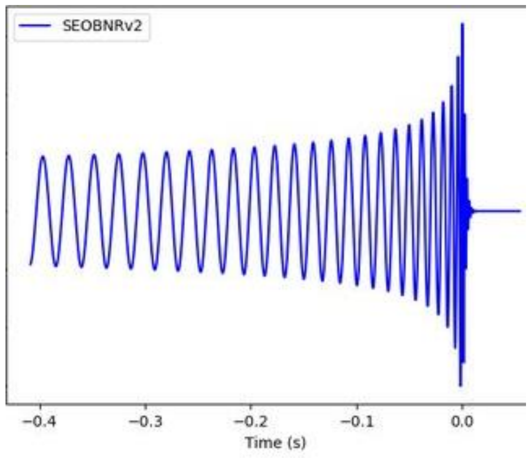
Fallback accretion in newborn neutron stars



2) How do we detect them ?

- CBC detection : general relativity => model of collision = waveform

=> then try to match those models to the data (matched filtering)

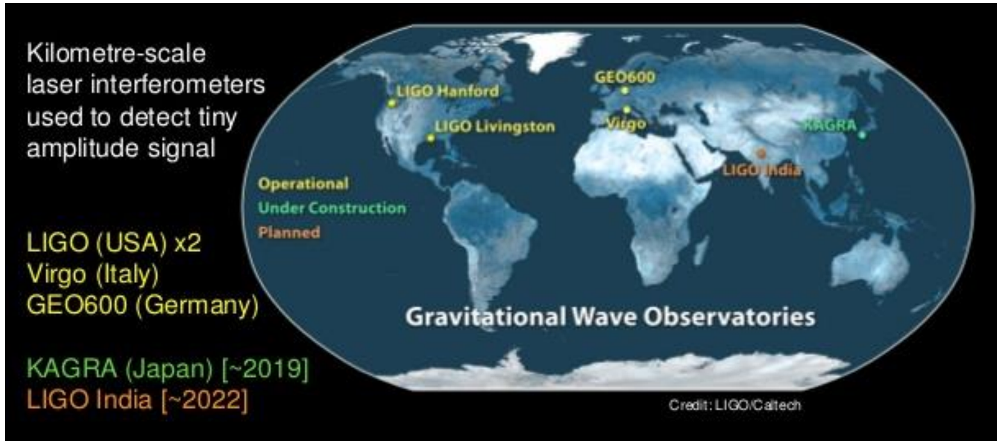


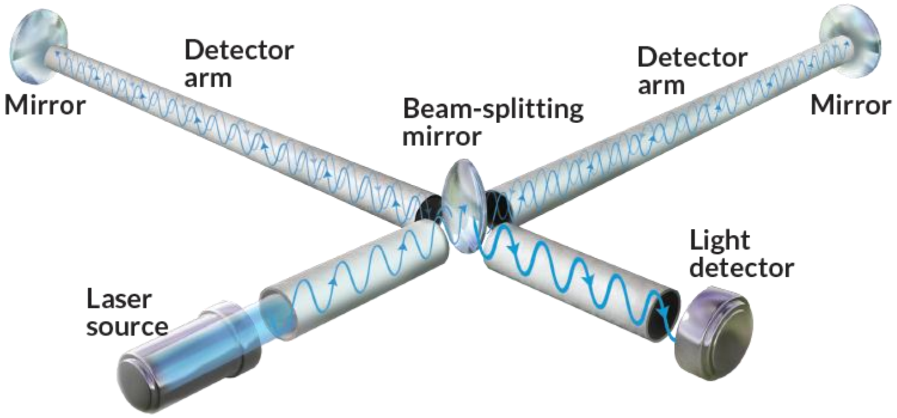
- Many other phenomena can generate GWs !

=> But physics is poorly known...

=> Models not accurate enough to apply match filtering.

Solution : use multiple detectors to find correlation in the data





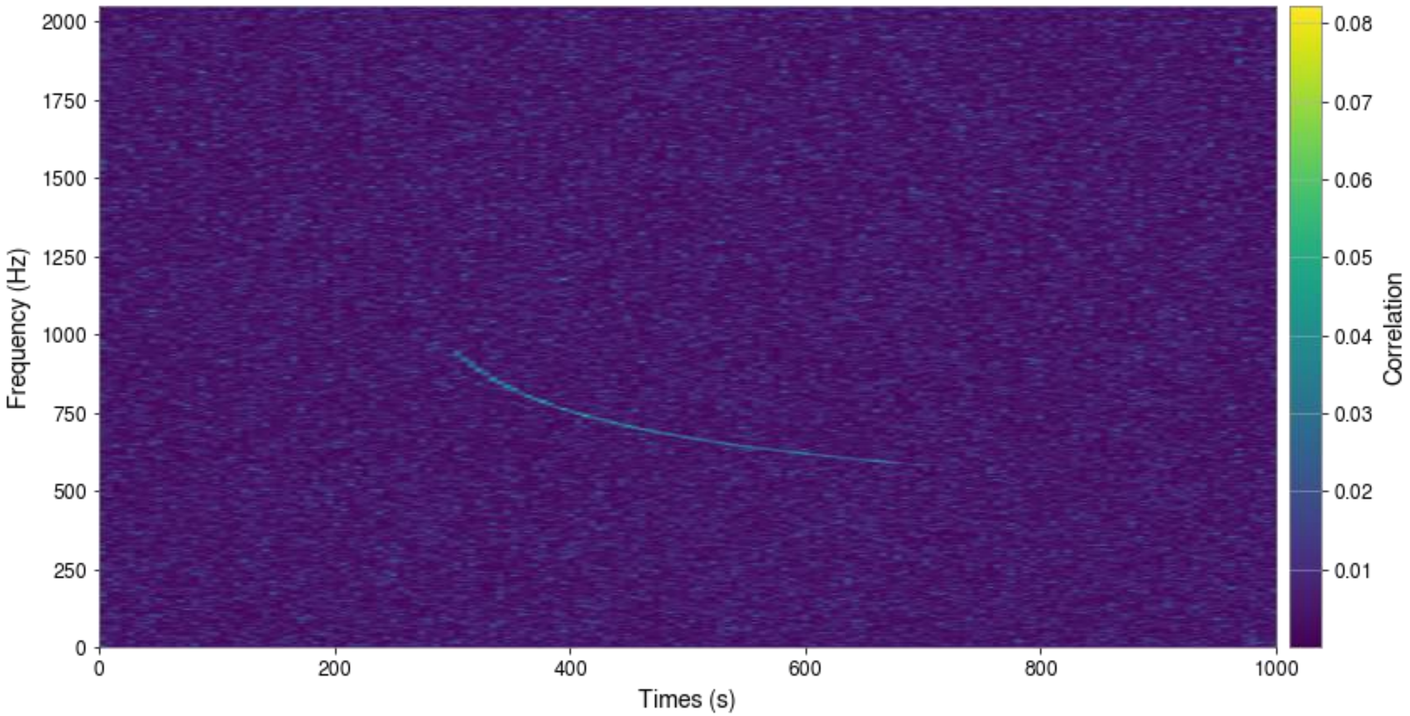
2) How do we detect them ?

- Excess of power method

=> Search in Time-Frequency space => minimal assumption : well represented in that TF space

=> Bursts should be clusters of high-correlation pixels

=> Many sources of noise (seismic, laser noise, suspensions, etc.)

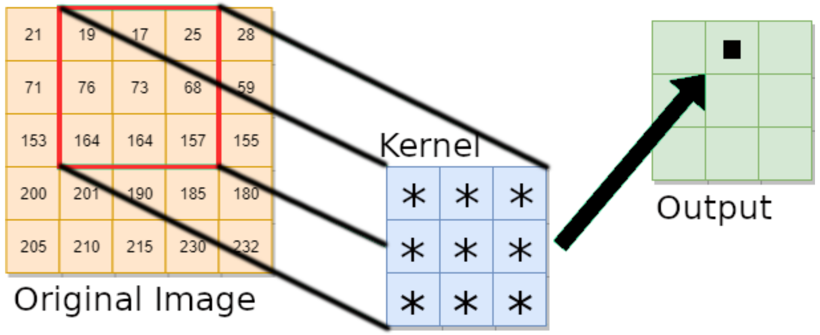


3) Convolutional neural networks

- Class of artificial neural networks employing convolution

=> easy to use and understand

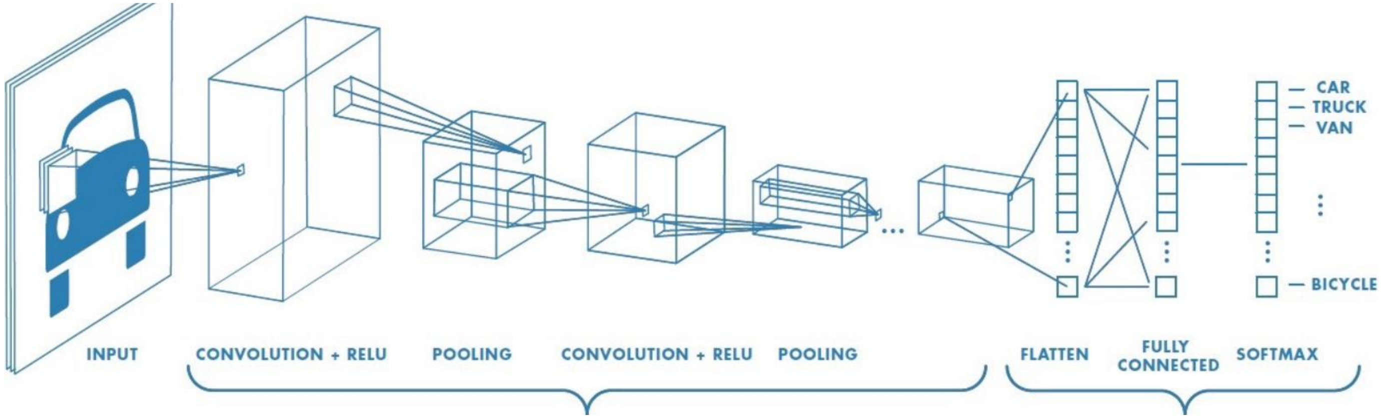
=> allows to downscale the information

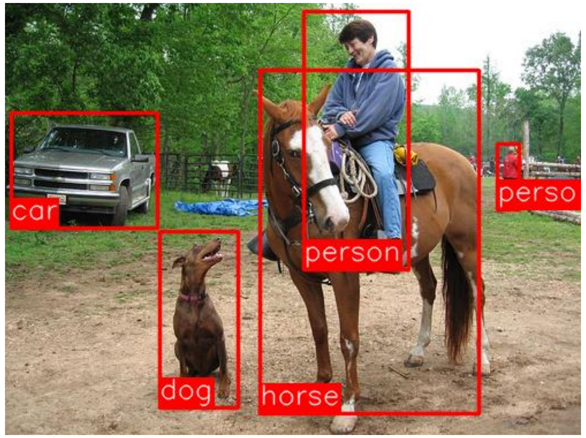


- Image processing applications often require :

=> classification tasks (medical images, galaxy catalogs, ...)

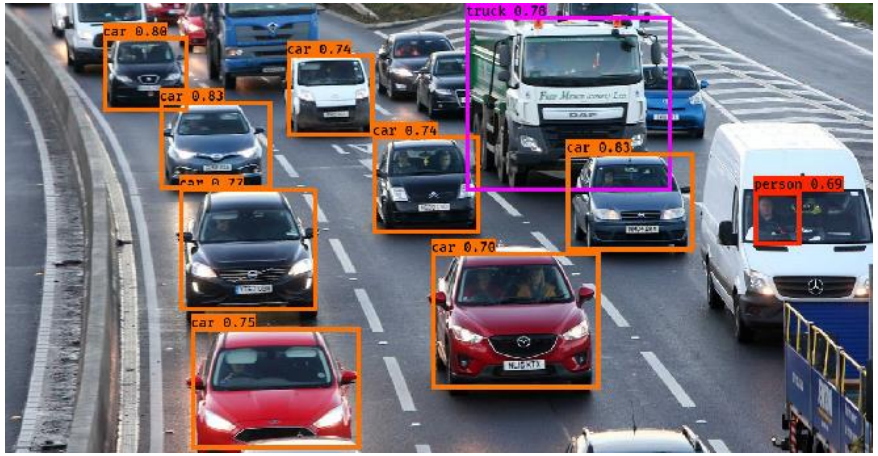
=> bounding box determination (self-driven cars, face recognition, ...)

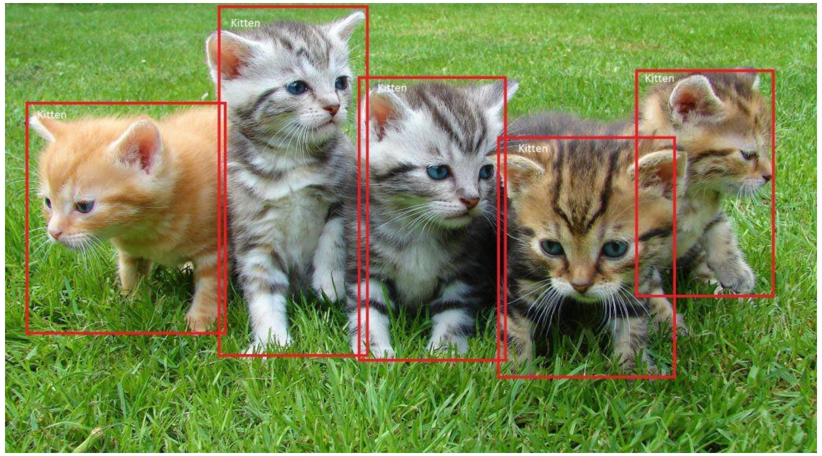




3) Convolutional neural networks

- Efficient at recognizing patterns and shapes :



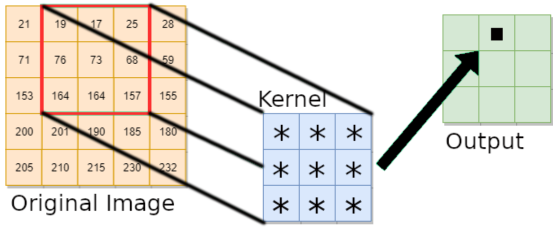


- Note : a neural network is nothing without a well-designed loss function !

=> loss function = what you want to minimize to achieve your goal (classification, prediction, …)

=> loss function gives feedbacks to update the weights (in kernels, …)

=> bad weight updates = badly conditioned training = bad results



4) New approach : mimic long-duration burst signals

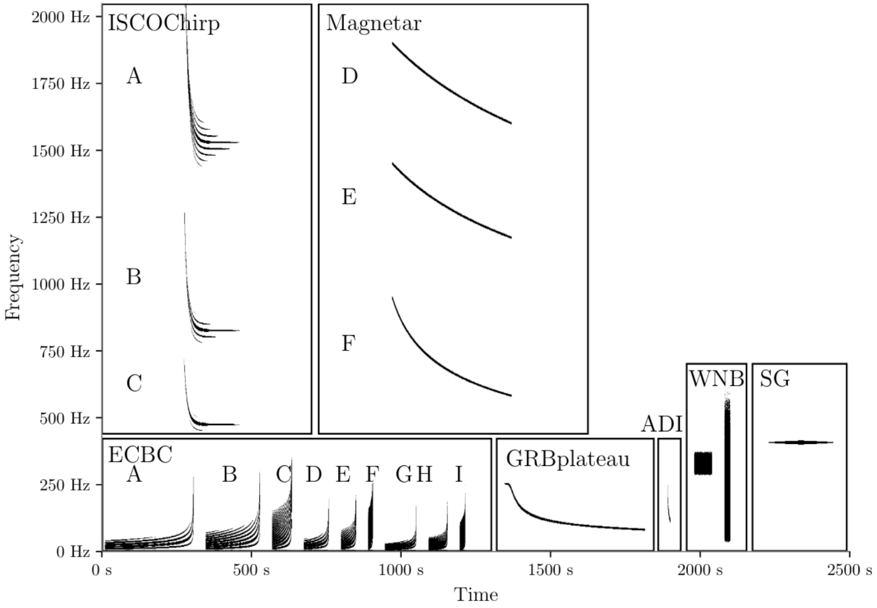
- Problem : can't rely on the long-duration models

- too many uncertainties in the physical phenomena
- models cannot be used as patterns to match for

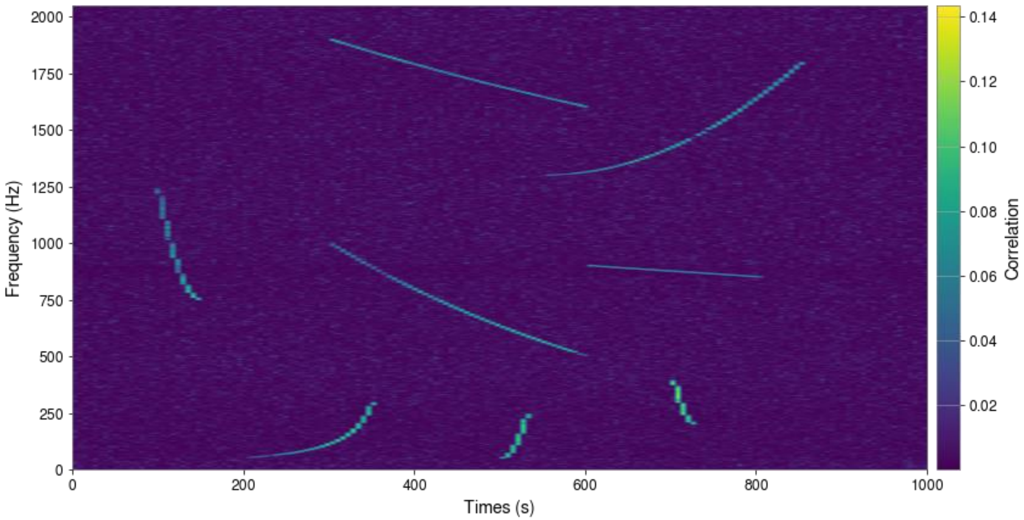
- They all show a "chirp up" or "chirp down" behavior

==> easily mimicked thanks to the *Python Scipy* library !

==> Allow to generate chirps as time series

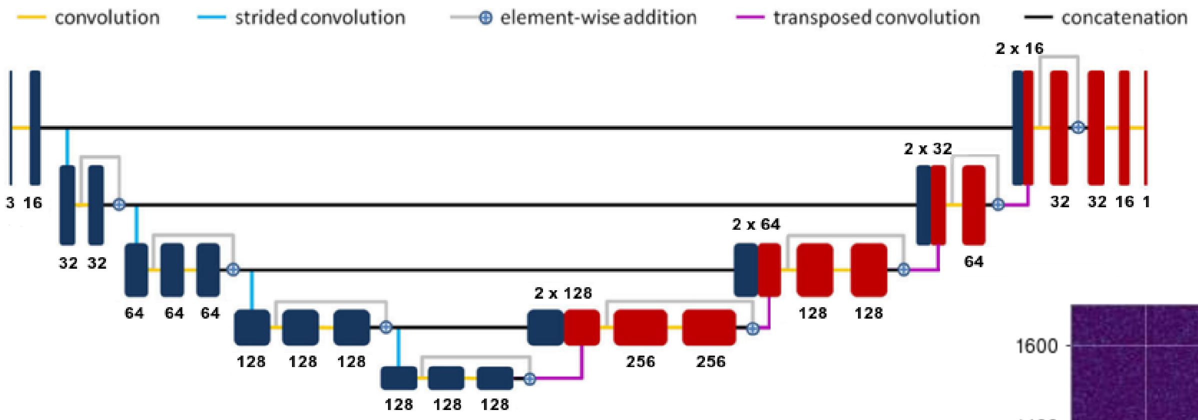


Taken from O3 long-duration paper : https://dcc.ligo.org/public/0174/P2100078/011/o3_long_duration.pdf



4) New approach : mimic long-duration burst signals

- Inspired by ***Xing et al., 2019***. (https://doi.org/10.1186/s12859-019-3037-5), coded with PyTorch
- Downscaling and upscaling network

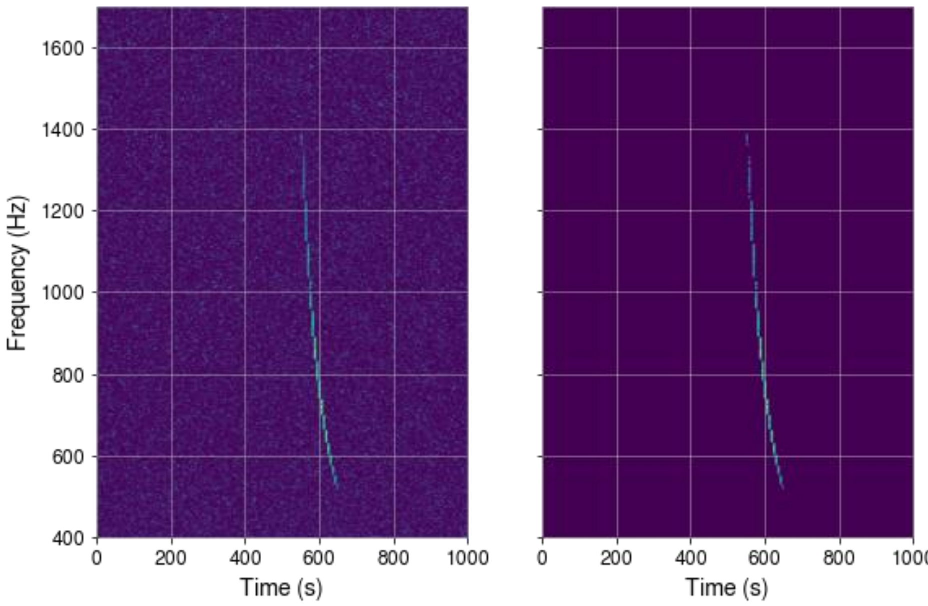


- Method :

- train the network so that : output (O) $\simeq$ target (T)

==> our target will be injection in empty TF map

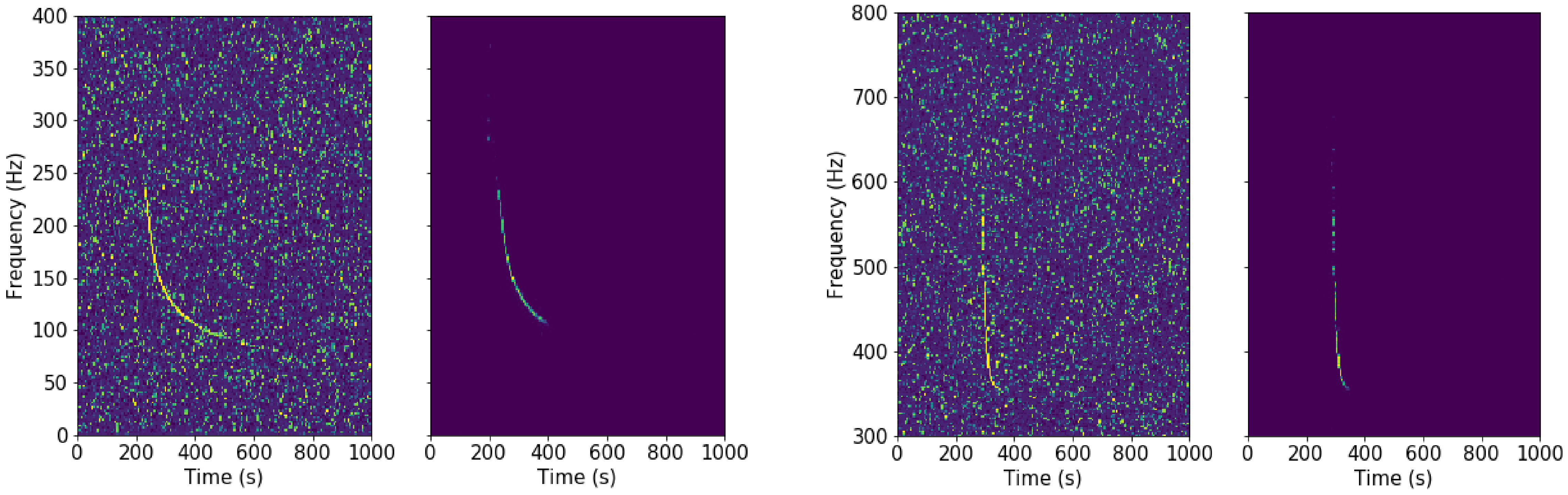
==> Empty map for noise-only images



- Loss that is being minimized : $MSE = \frac{1}{2} \sum_{i,j} (T_{ij} - O_{ij})^2$

5) Early Results

- Localization : Time-Frequency maps with injection

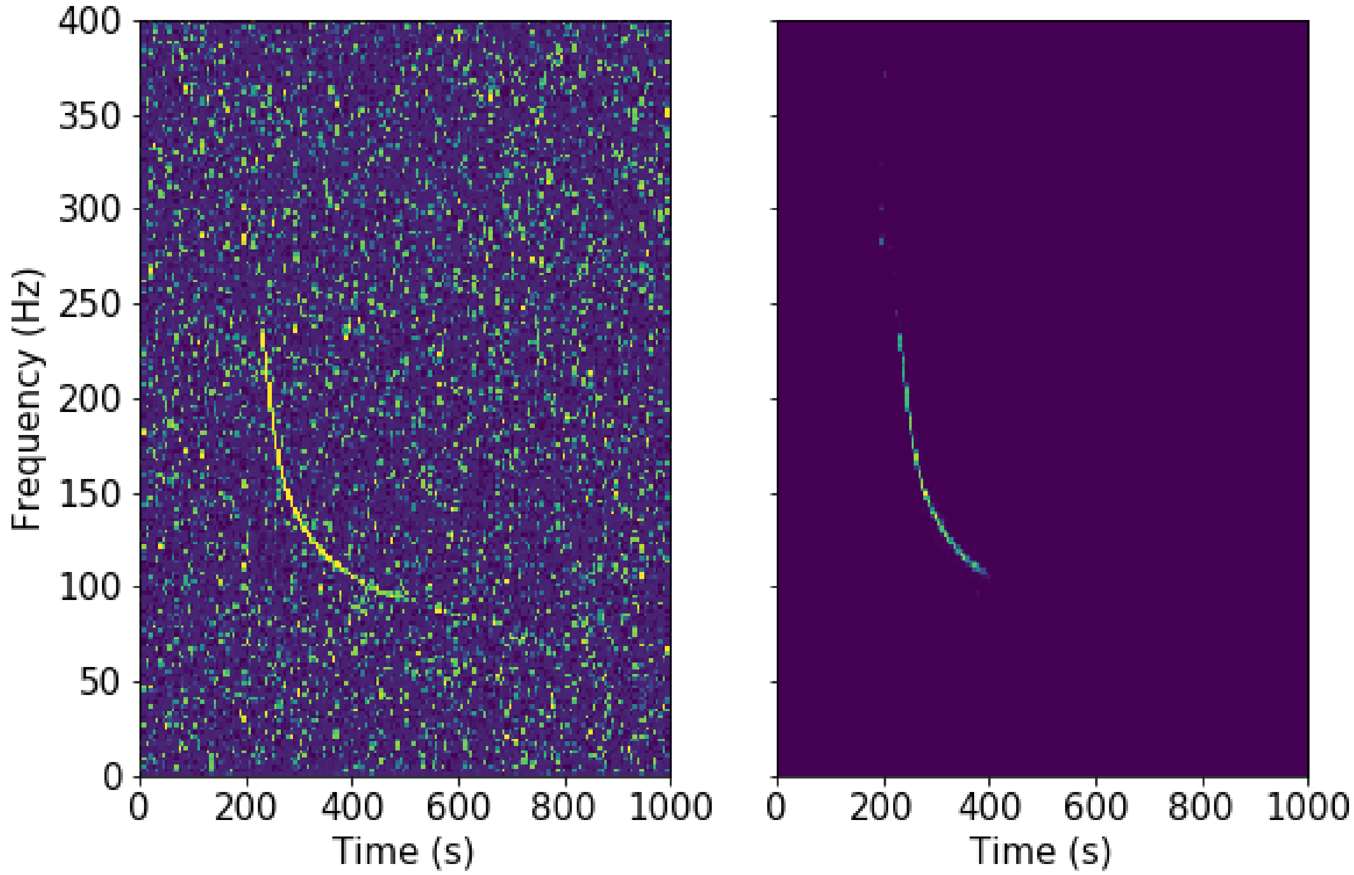


5) Early Results

- Localization : Time-Frequency maps with injection

- next step : learn the connectivity between pixels

==> What about the time-frequency maps with only pure noise ?



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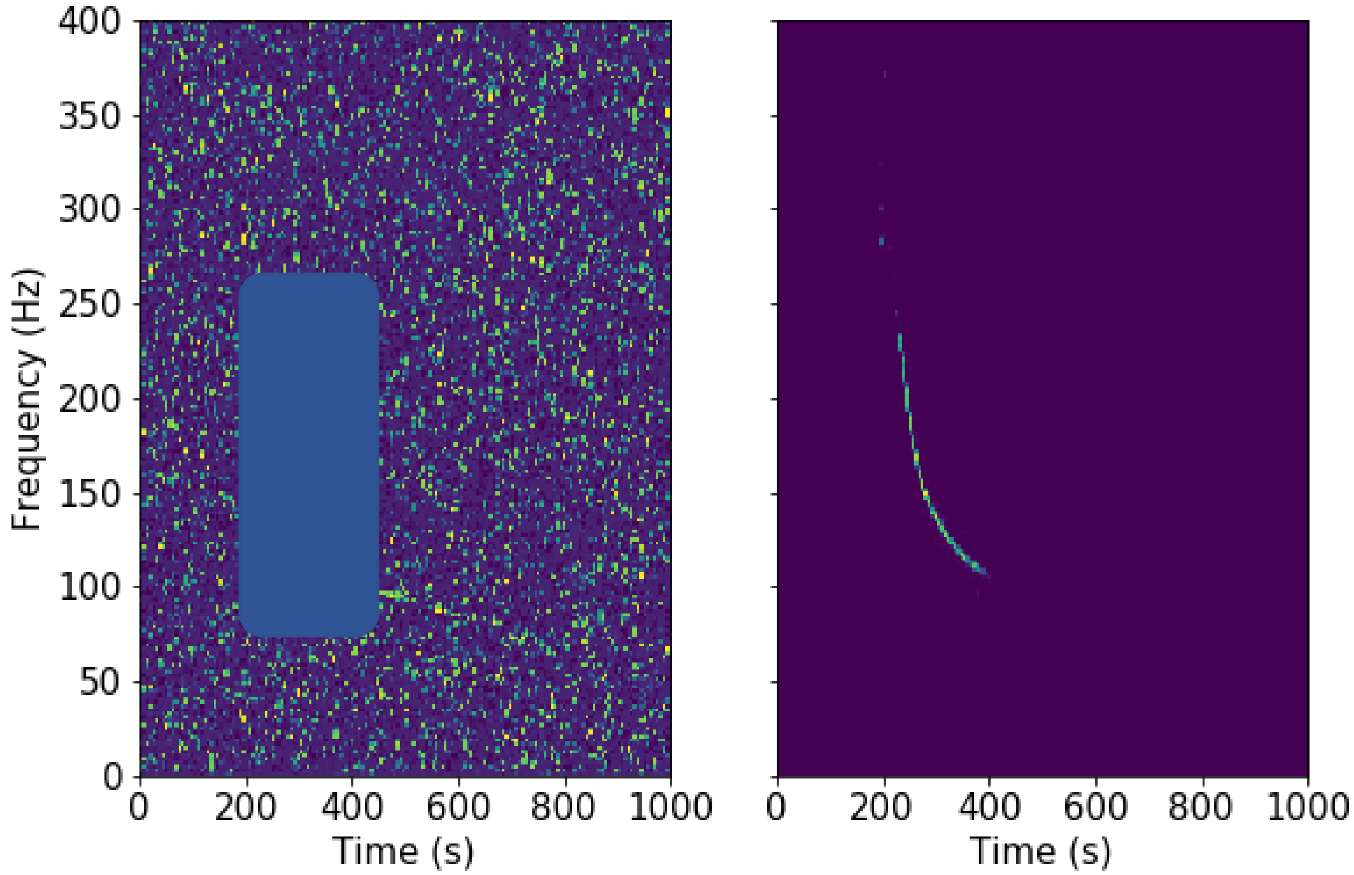
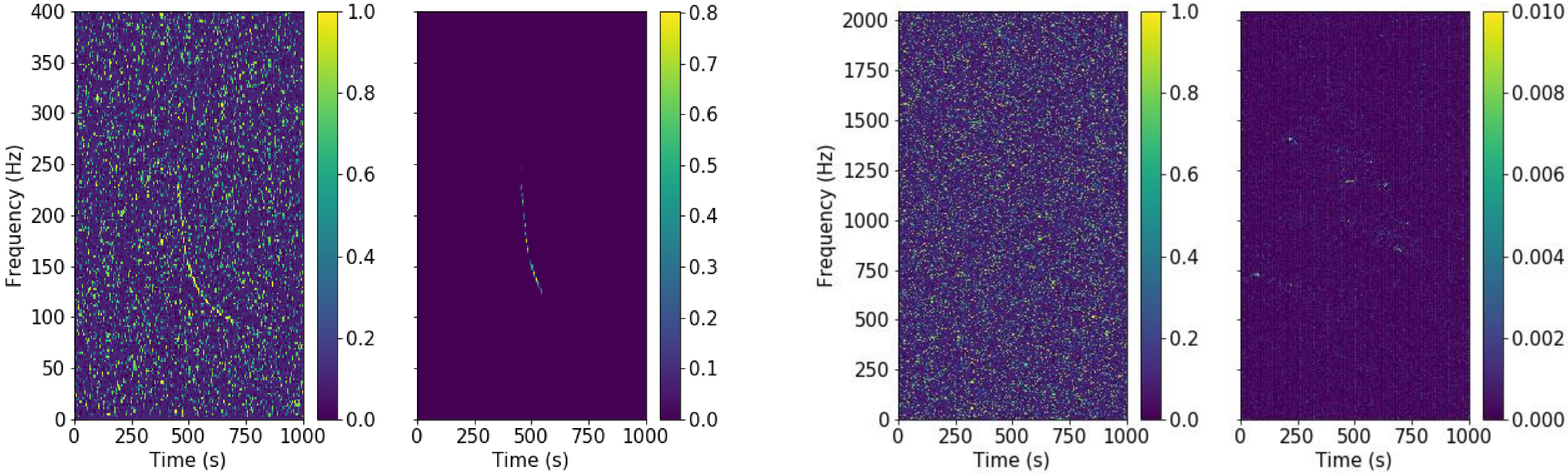


5) Early Results

- Localization : Time-Frequency maps with pure noise

- Values at least 1 order of magnitude lower than injection images

- Sparse and uncorrelated pixels



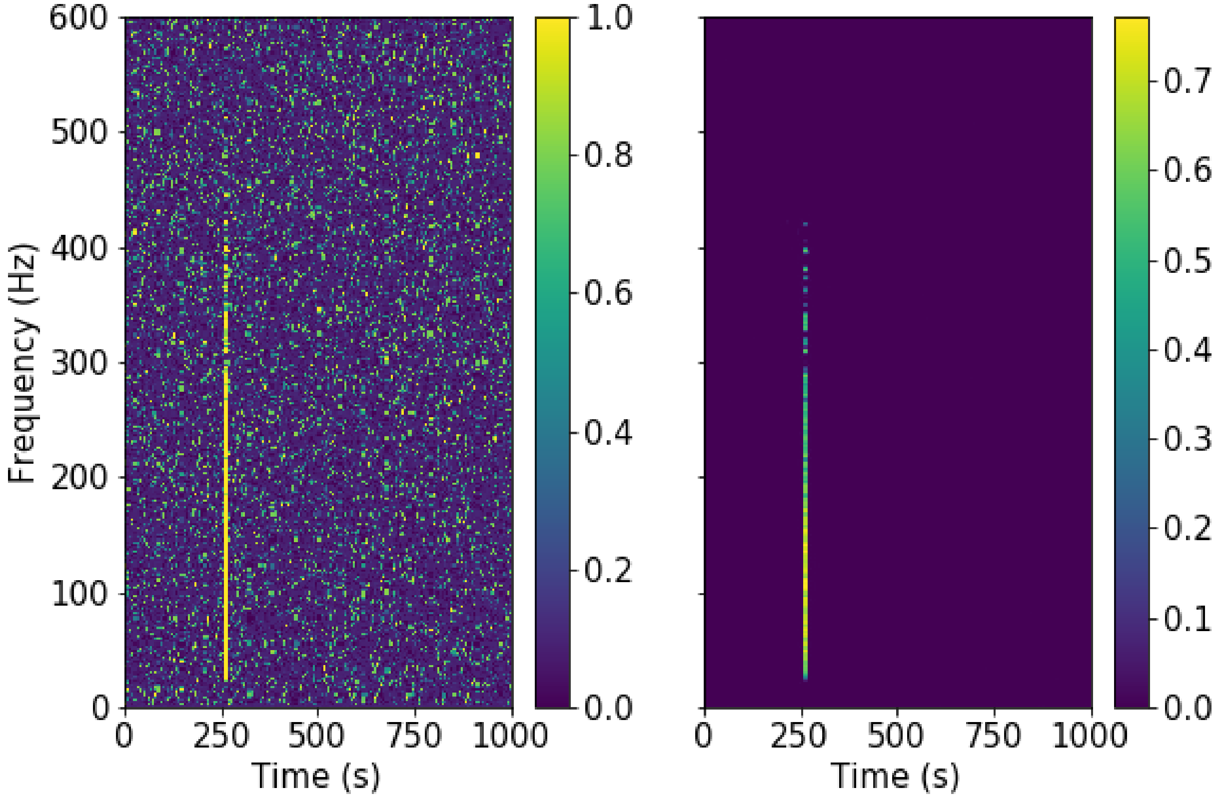
5) Early Results

- Localization : Time-Frequency maps with pure noise

- Instrumental/environmental noise transients (glitches) are detected !

=> limit the sensitivity of our searches

=> need for a tool to remove them



6) Improvements and future plans

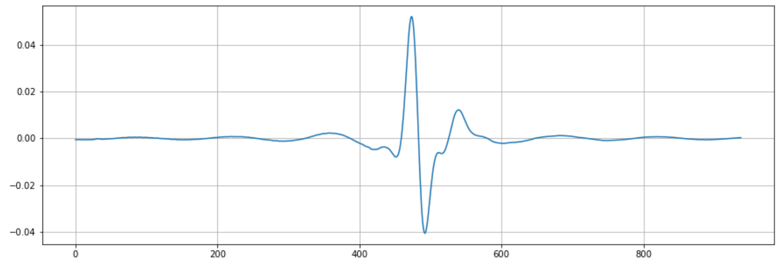
- State of the work : internal LVK review start by the end of November

- Implement new training method : Curriculum Learning (train with the easiest samples at first)

=> should increase the performances for low amplitude injections

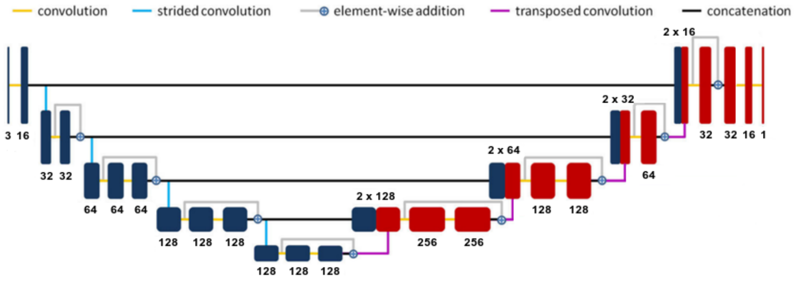
- Add a classifier to remove glitches

=> see the work of Melissa Lopez and myself (paper out soon)



- Test on new problems (can be adapted to any image shape !)

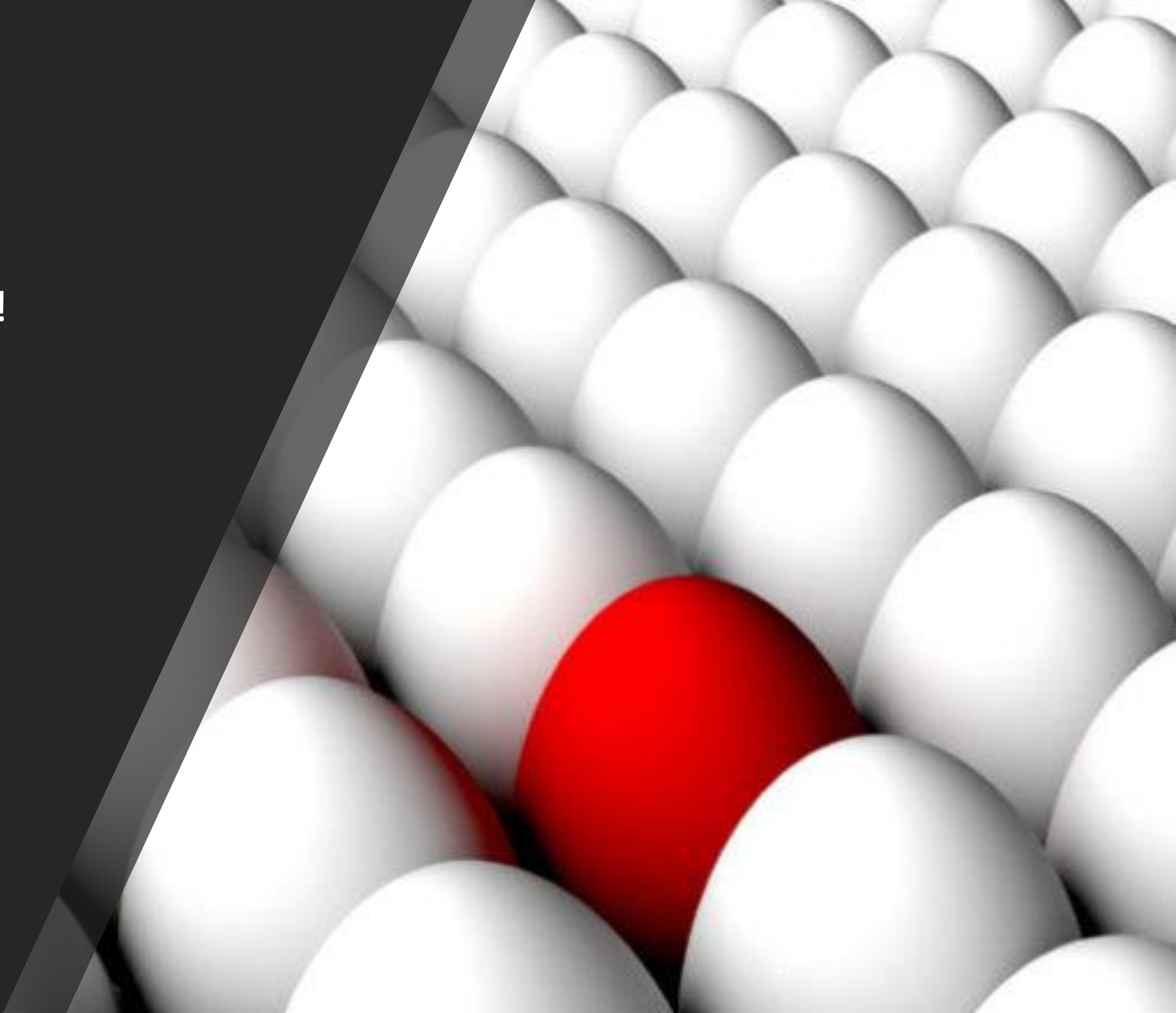
=> GW background search, GW from supernovae, ...



THE END

Thank you for your attention !

Questions ?



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