

First machine learning gravitational-wave search mock data challenge and Space for Humankind

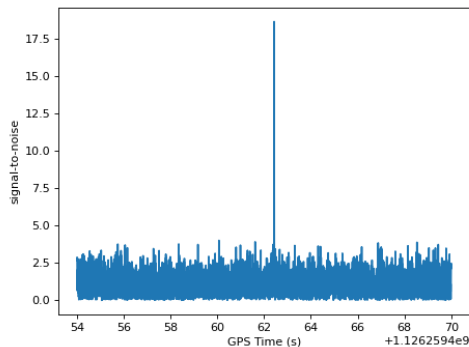
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Gravitational wave searches

- ▶ binary black holes
- ▶ standard: matched filtering
 - ▶ dense template bank
 - ▶ slide templates over signal
 - ▶ non-optimal
 - ▶ computationally demanding
- ▶ complicated noise characteristic, glitches



source: PyCBC

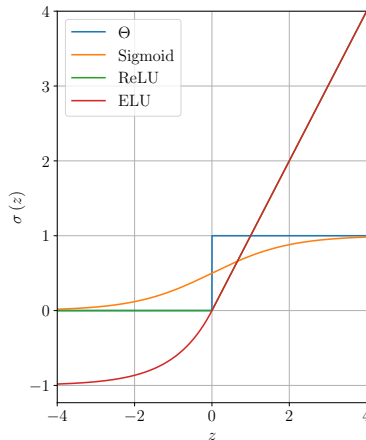
Neural Networks

artificial neurons

$$f(\mathbf{x}) = \sigma \left(\sum_j w_j x_j + b \right)$$

activation function

$$\text{ELU}(z) = \begin{cases} \exp(z) - 1 & \text{if } z < 0 \\ z & \text{if } z \geq 0 \end{cases}$$



Neural Networks

organized in layers:

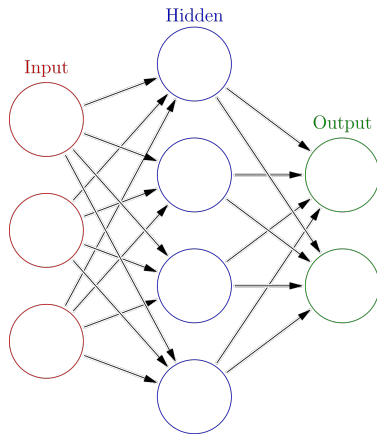
- ▶ matrix multiplication
- ▶ element-wise non-linear functions

training:

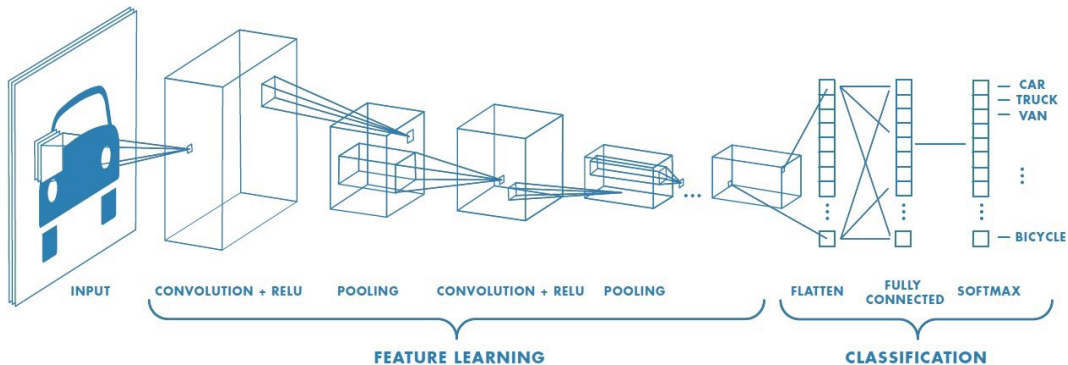
- ▶ dataset
- ▶ loss function (BCE)

$$\text{BCE}(\bar{\mathbf{Y}}, \mathbf{Y}) = -\frac{1}{m} \sum_{i=1}^m \sum_{j=1}^2 \log(\bar{Y}_{ij}) Y_{ij}$$

- ▶ GD-based optimizer



Convolutional Neural Networks



source: MathWorks

MLGWSC-1

- ▶ mock data challenge [SZN⁺23, SZ21]
- ▶ BBH signals in long segments from 2 detectors
- ▶ 4 test datasets, progressive complexity
- ▶ 4 ML + 2 traditional contributions

Test data

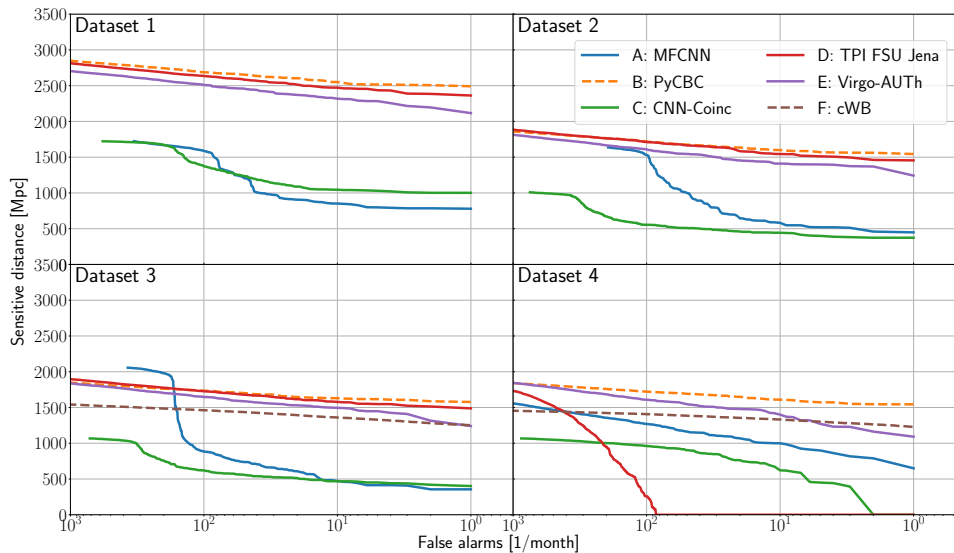
- ▶ 1-month strain in H1 and L1
- ▶ IMRPhenomXPHM injections

DS	injections			noise	
	spins	modes	masses	noise	PSD
1	zero	$l = 2, m = \pm 2$	$10 - 50 M_{\odot}$	Gaussian	fixed
2	aligned	$l = 2, m = \pm 2$	$7 - 50 M_{\odot}$	Gaussian	O3a
3	generic	all implemented ¹	$7 - 50 M_{\odot}$	Gaussian	O3a
4	generic	all implemented	$7 - 50 M_{\odot}$	real O3a noise	

Submissions: produce list of triggers and ranking statistics

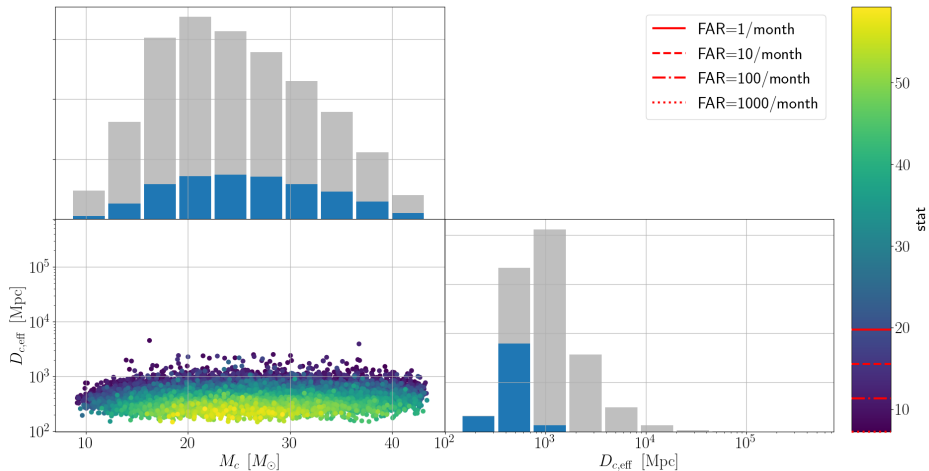
¹(2, 2), (2, -2), (2, 1), (2, -1), (3, 3), (3, -3), (3, 2), (3, -2), (4, 4), (4, -4)

MLGWSC-1 results

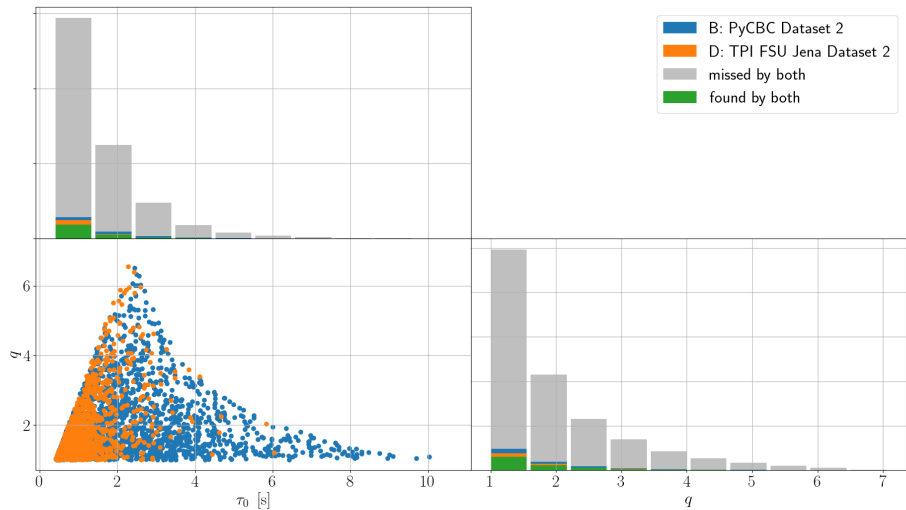


MLGWSC-1 results

D: TPI FSU Jena Dataset 1



MLGWSC-1 results



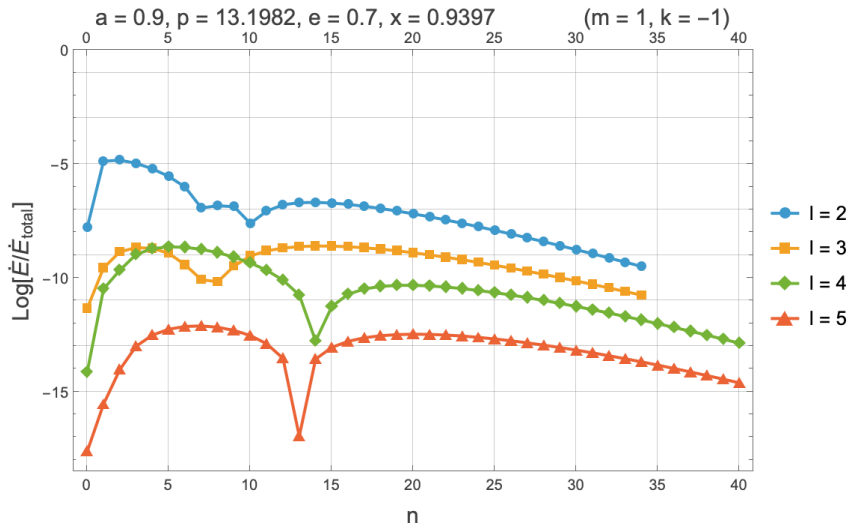
Conclusions

- ▶ precession & higher modes: irrelevant so far
- ▶ artefacts of test data distribution
- ▶ signal length

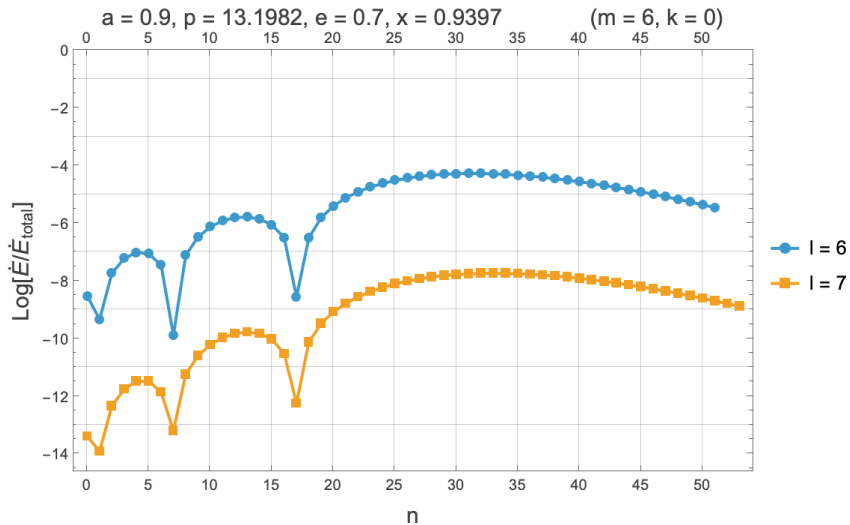
Outlook

- ▶ longer signals
- ▶ LISA data

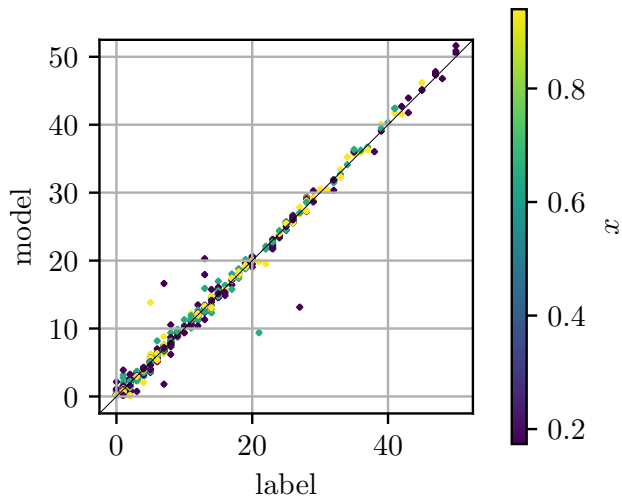
Dominant mode estimator



Dominant mode estimator



Dominant mode estimator



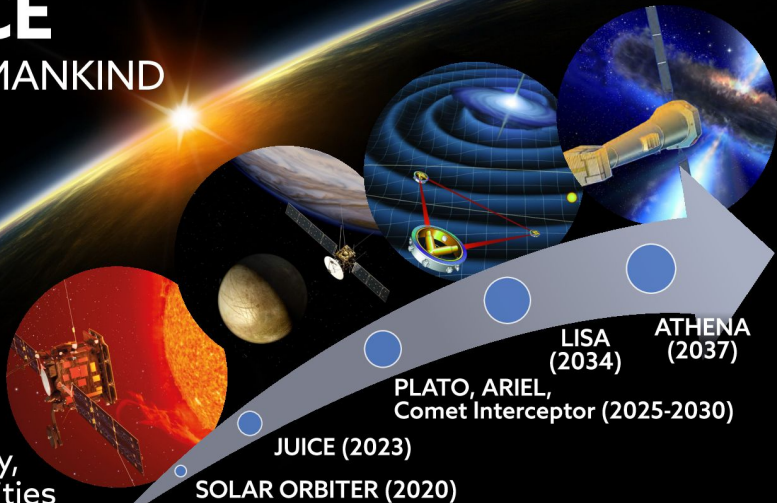


SPACE FOR HUMANKIND

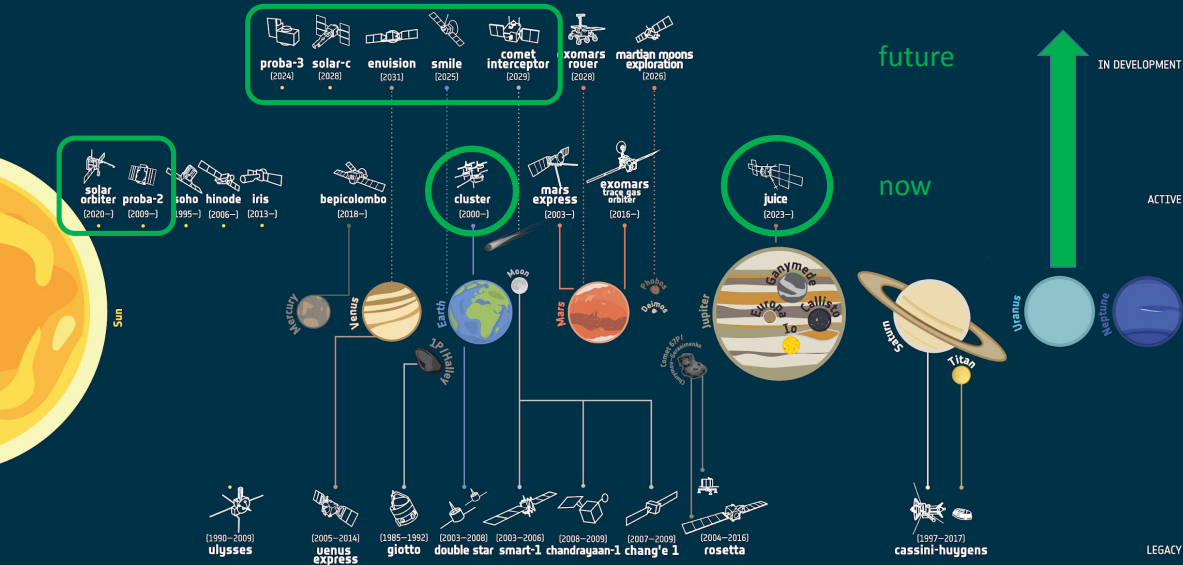
21 research topics
12 institutes of CAS
14 partners

international scientific
space projects

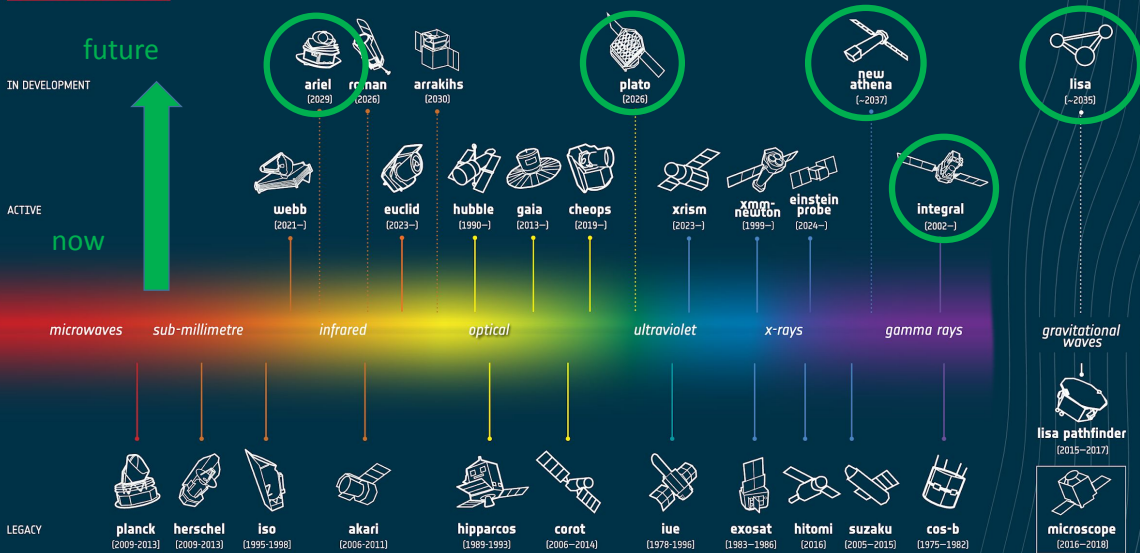
collaboration with industry,
government and universities



SOLAR SYSTEM EXPLORERS



COSMIC OBSERVERS

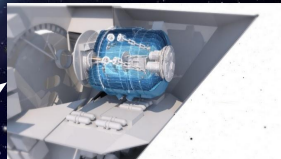


newATHENA

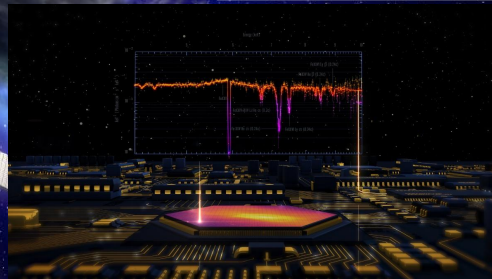
(Advanced Telescope for High Energy Astronomy)

ESA planned large X-ray Observatory
to study **Hot and Energetic Universe**

*2037



Instrument **X-ray Integral Field Unit (X-IFU)** for high-resolution X-ray spectroscopy



Czech contribution to read-out electronics

References I



Marlin Schäfer and Ondřej Zelenka.
MLGWSC-1 Github repository, 2021.



Marlin B. Schäfer, Ondřej Zelenka, Alexander H. Nitz, He Wang, Shichao Wu, et al.
First machine learning gravitational-wave search mock data challenge.
Phys. Rev. D, 107:023021, January 2023.