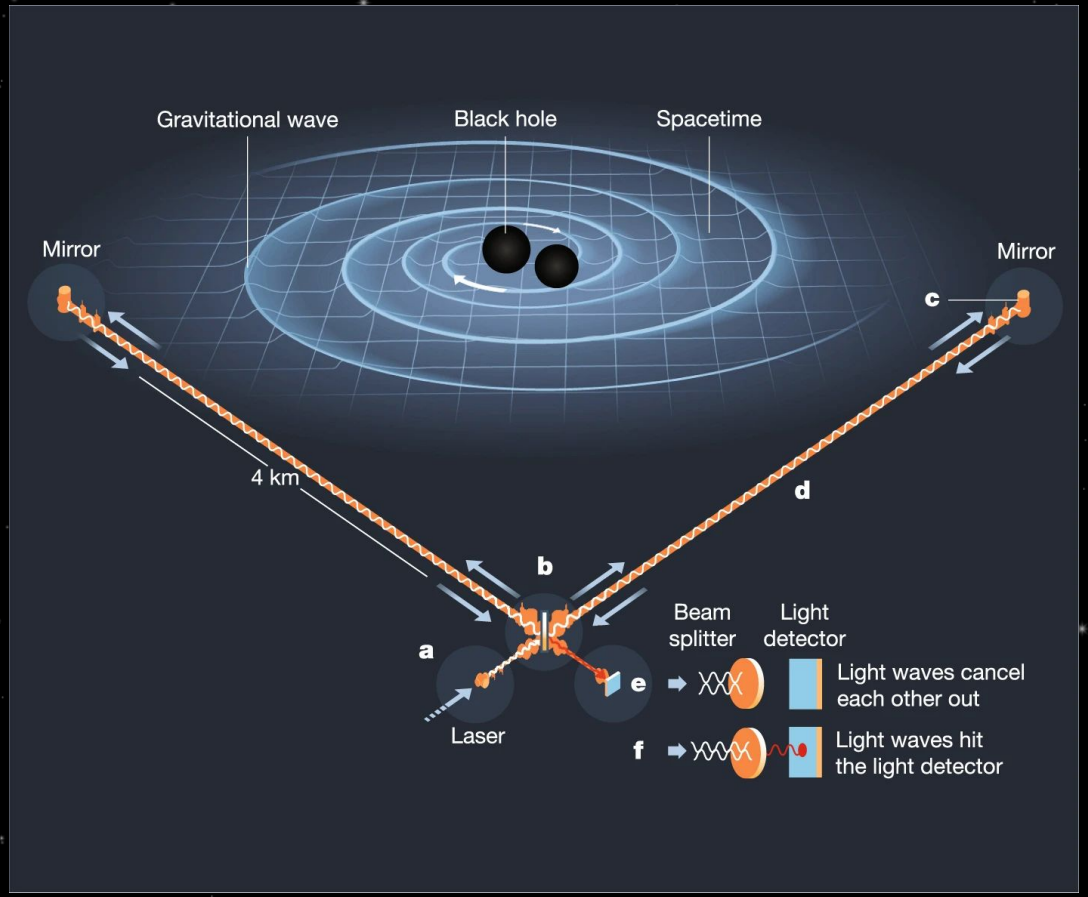
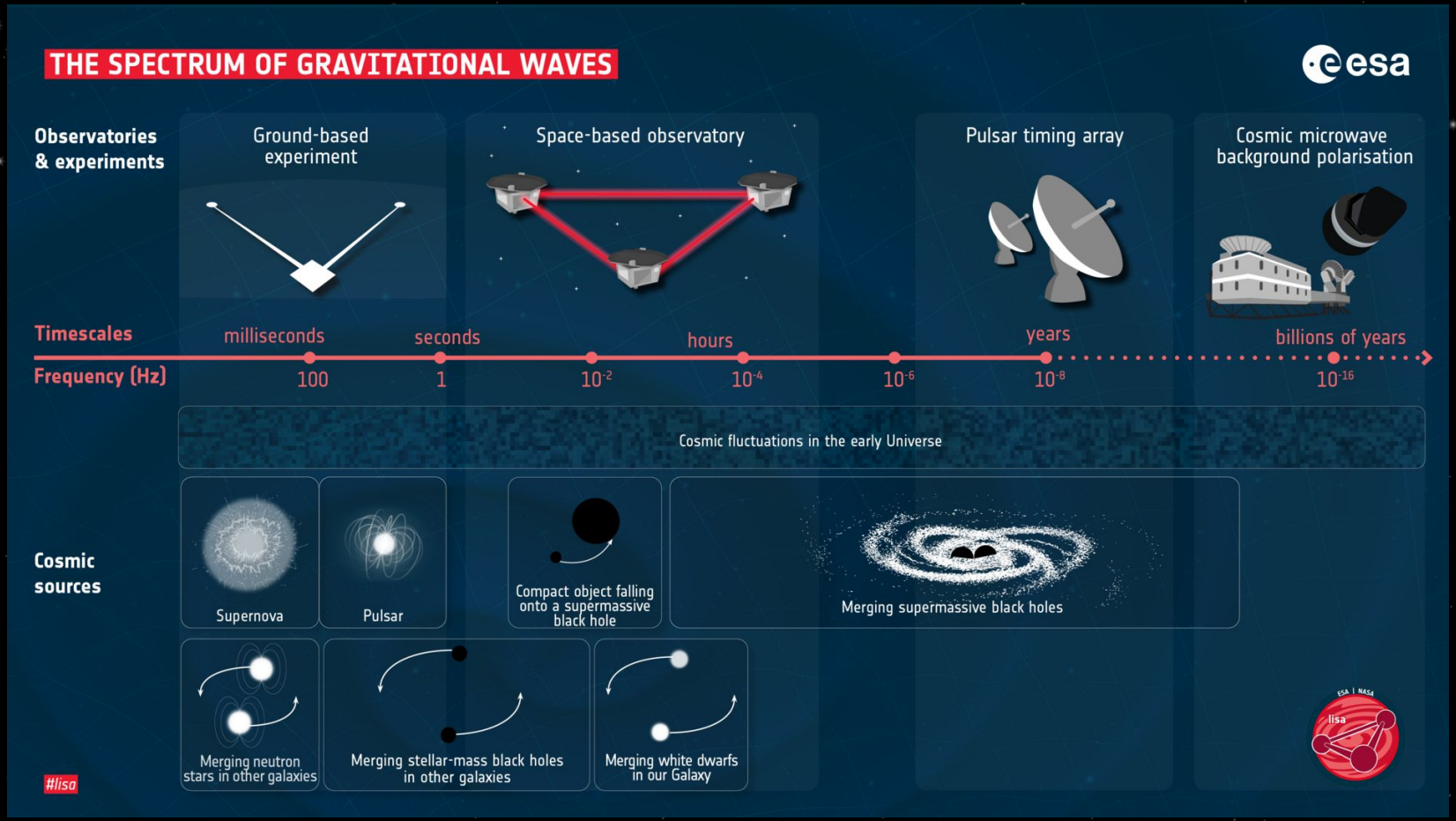
Analysis of Gravitational Waves

Characterizing the Origins of GW with Machine Learning Techniques



https://www.nature.com/articles/s41586-019-1129-z/figures/1

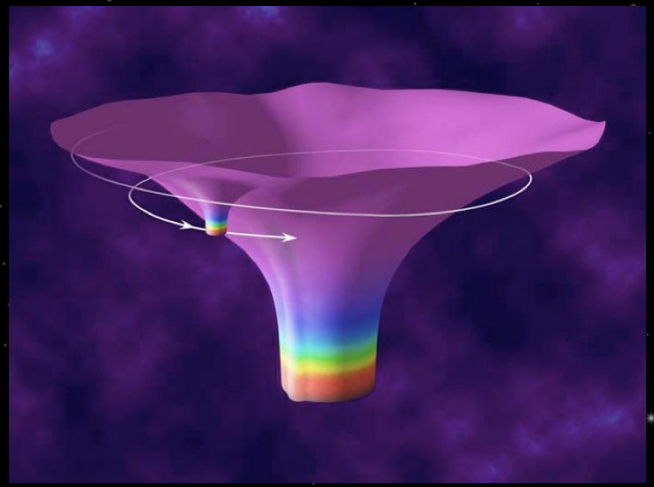


https://www.esa.int/ESA_Multimedia/Images/2021/09/The_spectrum_of_gravitational_waves

EMRI -
Extreme Mass Ratio Inspiral

$$\mu/M = 10^{-4} - 10^{-7}$$

$$f = 10^{-4} - 10^{-1}\ \mathrm{Hz}$$



Extreme mass ratio inspiral. (2023, June 5). In *Wikipedia*. https://en.wikipedia.org/wiki/Extreme_mass_ratio_inspiral

Goal: Extraction of the Parameters from the Signal

Simulation of Data - Preprocessing - NN Training - NN Evaluation

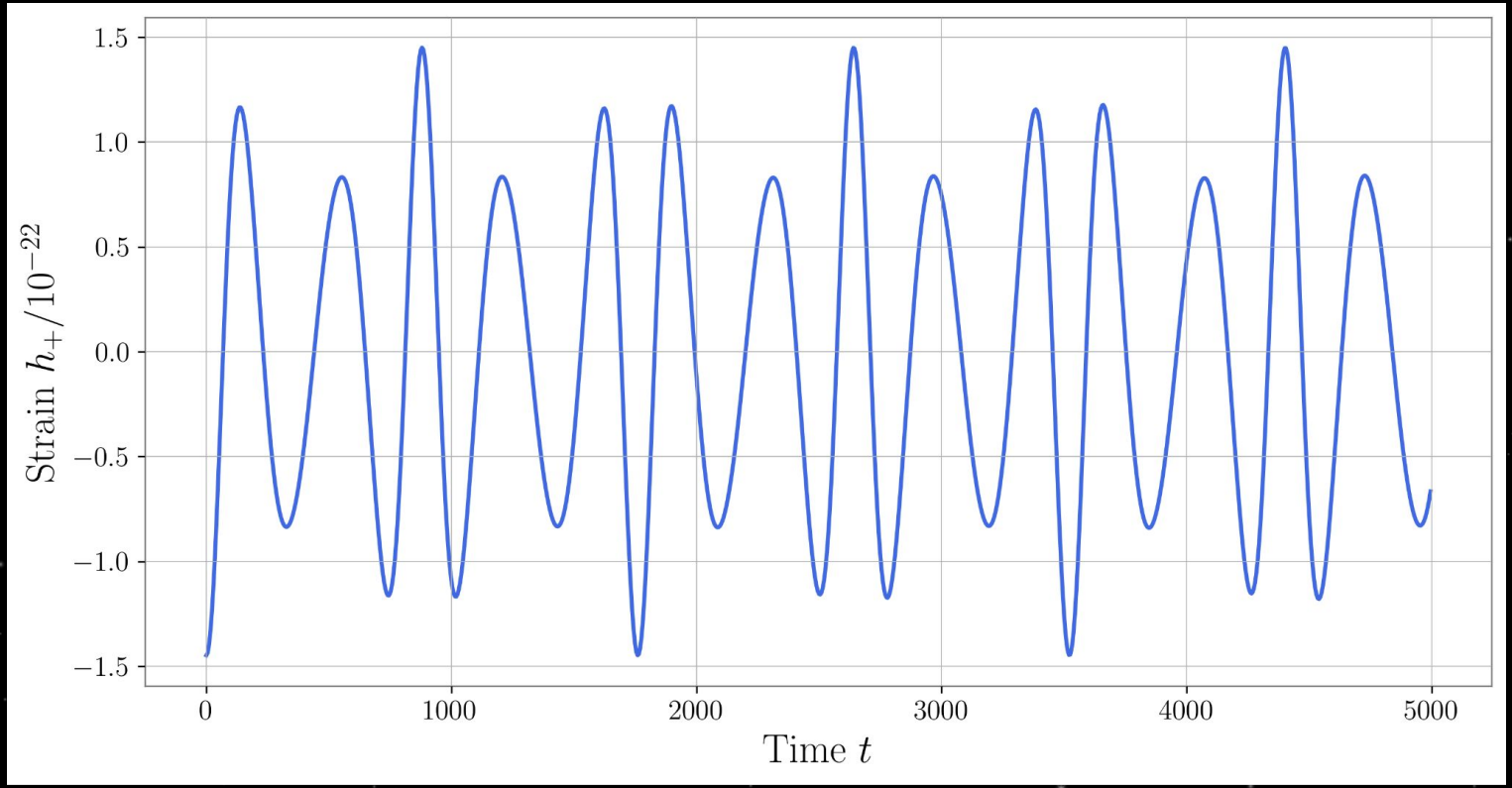
Strain $h(t) = h_+ - ih_\times$

$$h = \frac{\mu}{d_L} \sum_{lmkn} A_{lmkn}(t) S_{lmkn}(t) e^{im\phi} e^{-i\Phi_{mkn}(t)}$$

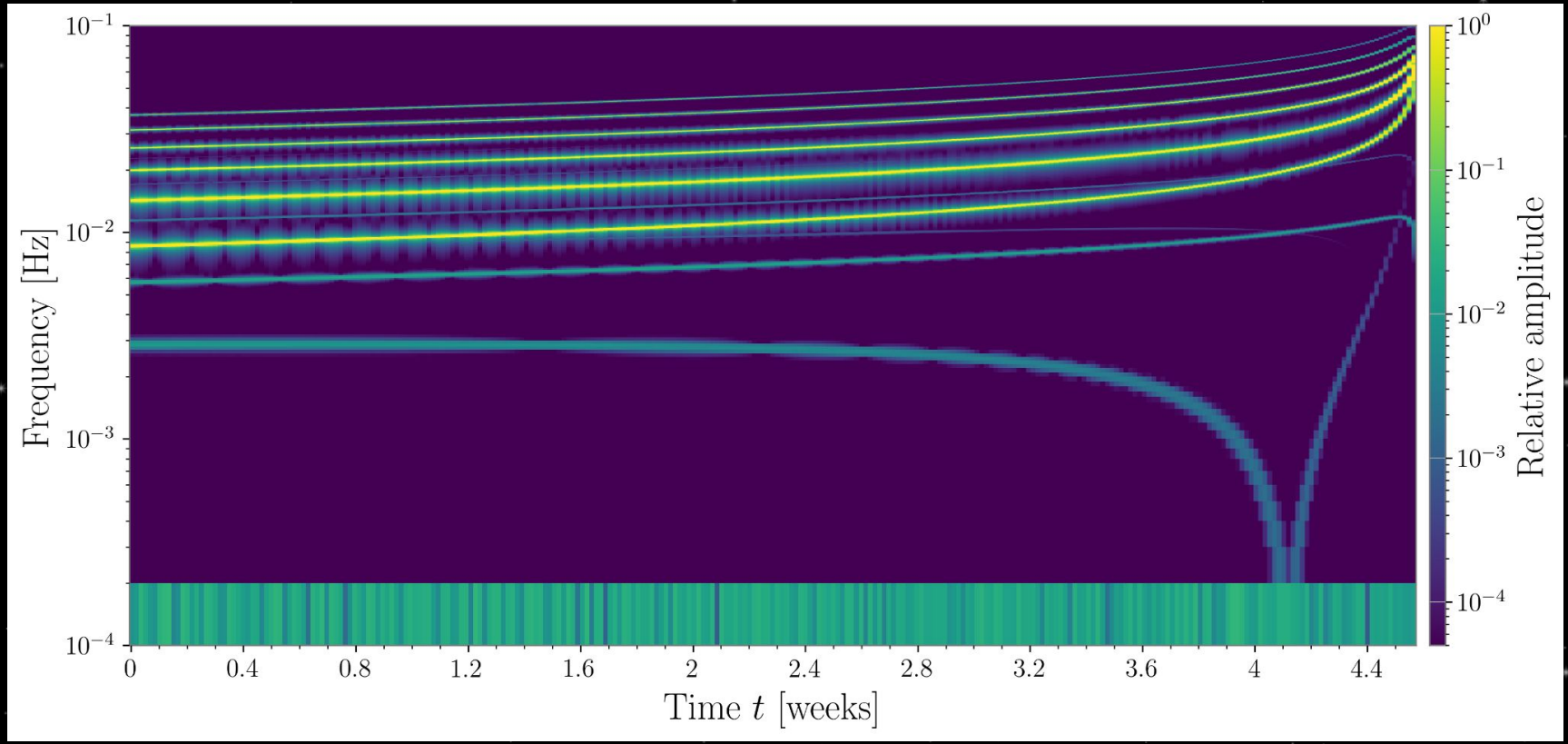
The full EMRI parameter space is 17 dimensional

Orbit	$\{M, \mu, d_L, a, p_0, e_0\}$
Directions	$\{x_I, \theta_S, \phi_S, \theta_K, \phi_K\}$
Initial Phases	$\{\Phi_r, \Phi_\theta, \Phi_\phi\}$

Strain h_+

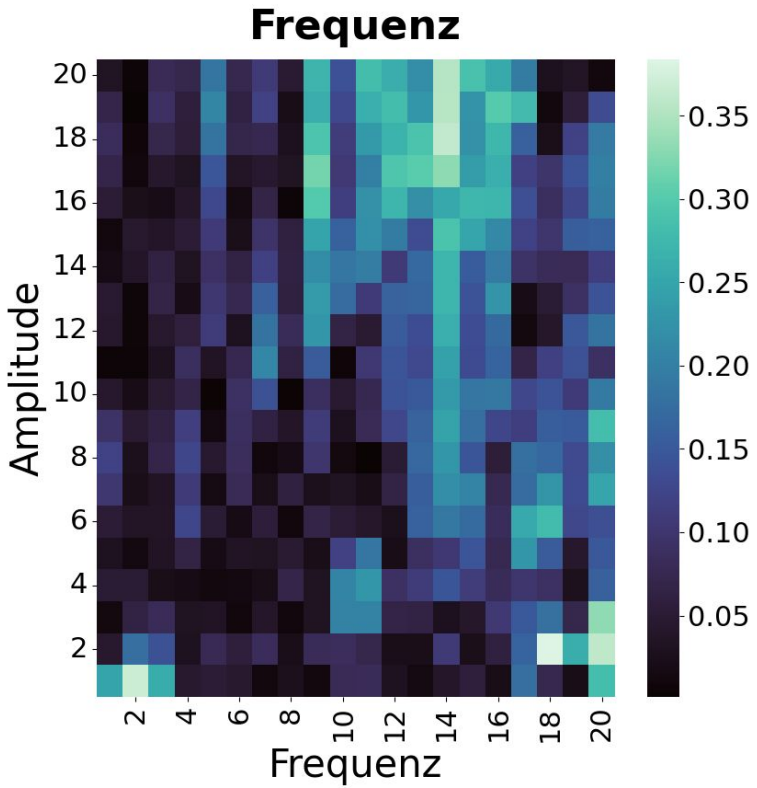

1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
Strain $h_+/10^{-22}$
0
1000
2000
3000
4000
5000
Time t

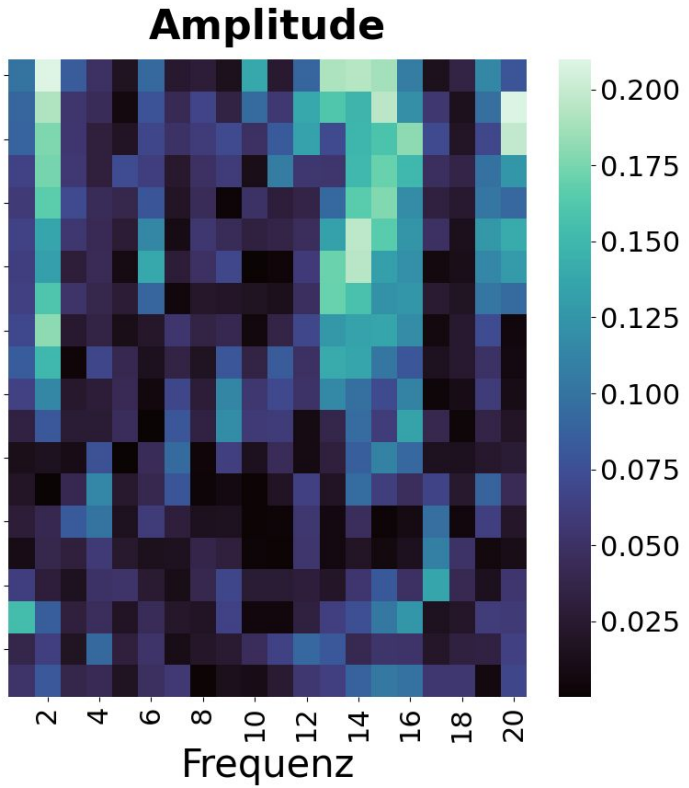
Spectrogram

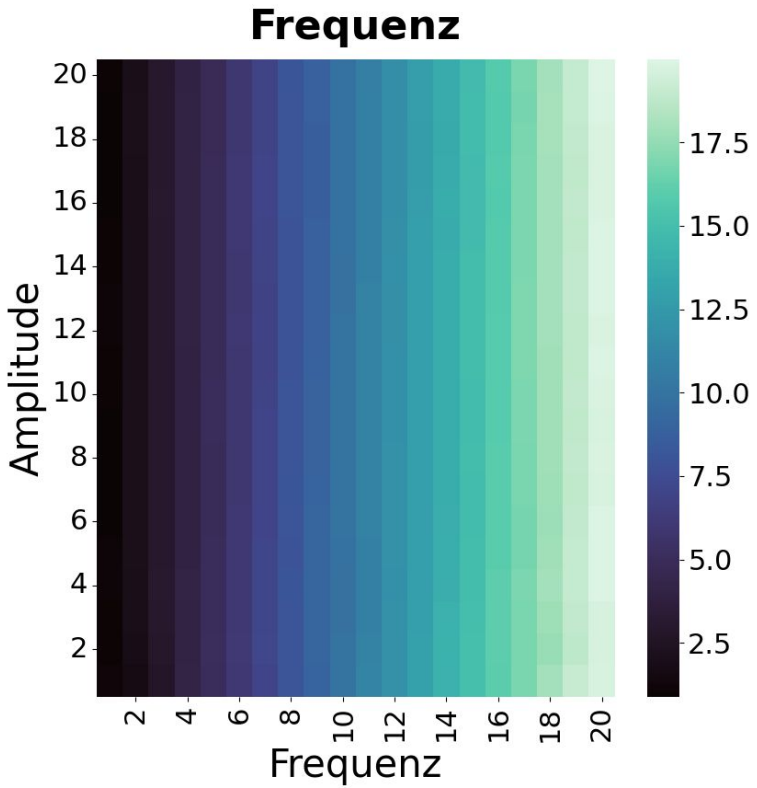


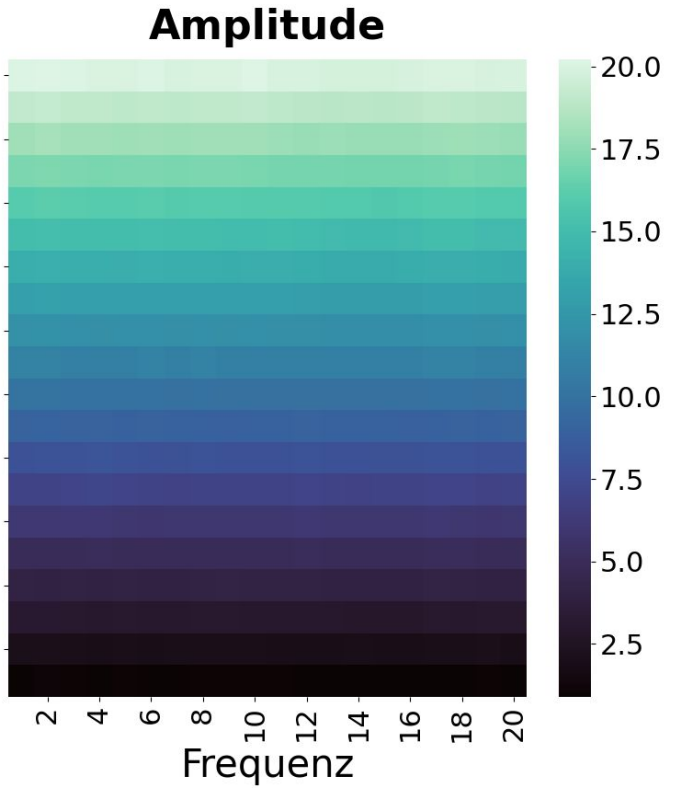
Test: Parameter Extraction

$$y(t) = A \cdot \sin(f \cdot t)$$


Frequenz
Amplitude
20
18
16
14
12
10
8
6
4
2
0.35
0.30
0.25
0.20
0.15
0.10
0.05
2
4
6
8
10
12
14
16
18
20
Frequenz


Amplitude
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
2
4
6
8
10
12
14
16
18
20
Frequenz


Frequenz
Amplitude
20
18
16
14
12
10
8
6
4
2
2
4
6
8
10
12
14
16
18
20
Frequenz
17.5
15.0
12.5
10.0
7.5
5.0
2.5


Amplitude
2
4
6
8
10
12
14
16
18
20
Frequenz
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5