CA17137 G2Net WG1 meeting, April 11, 2022,
Faculty of Mathematics of the University of Valencia

Complex systems in the G2Net research

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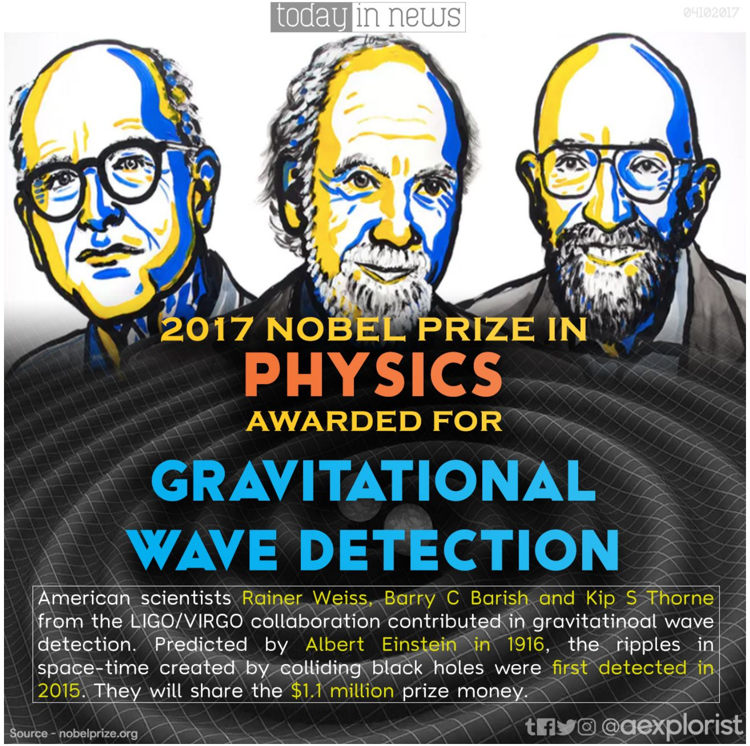
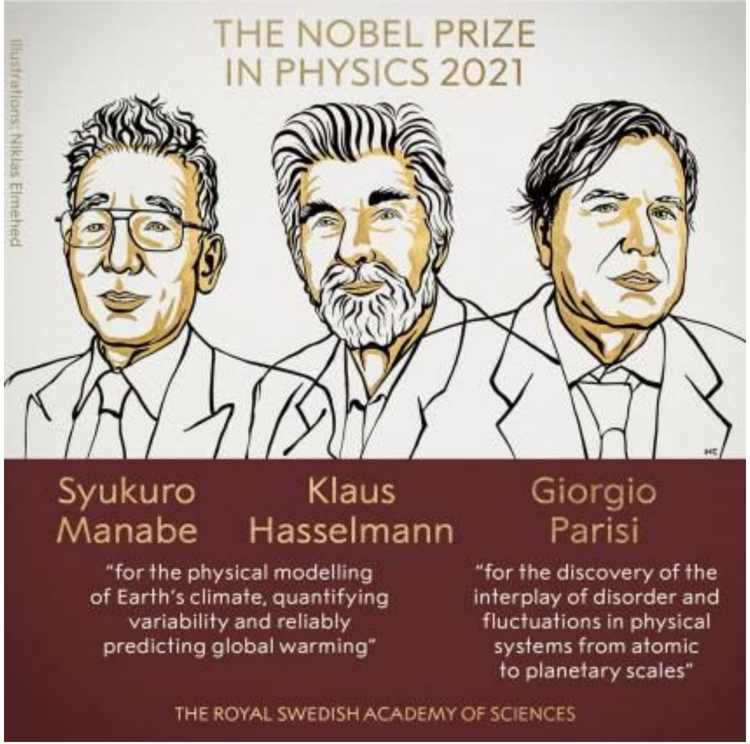
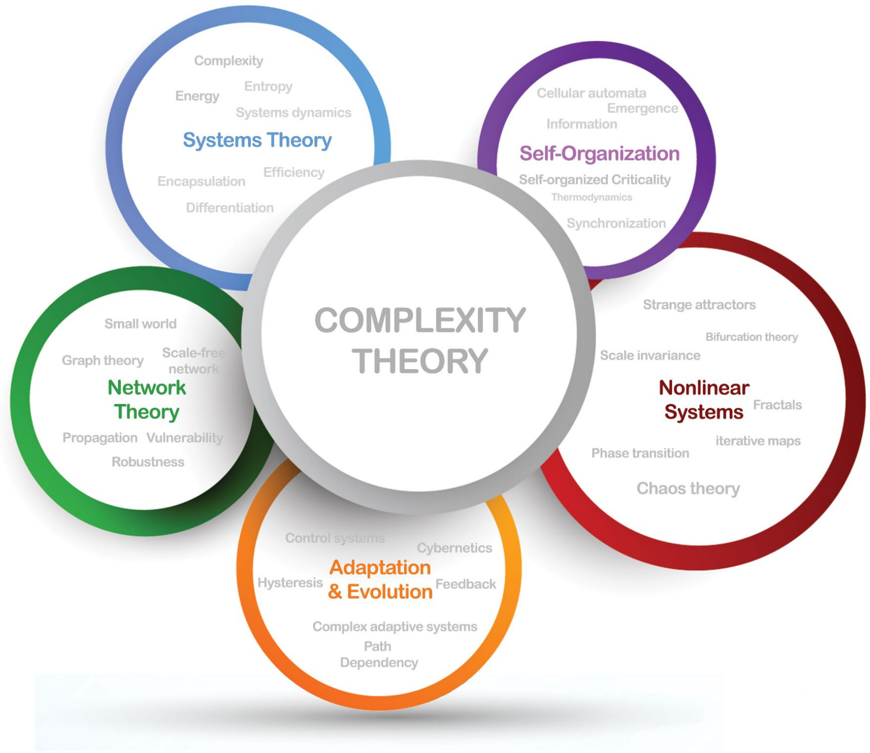
Nobel prices on CA17137 topics



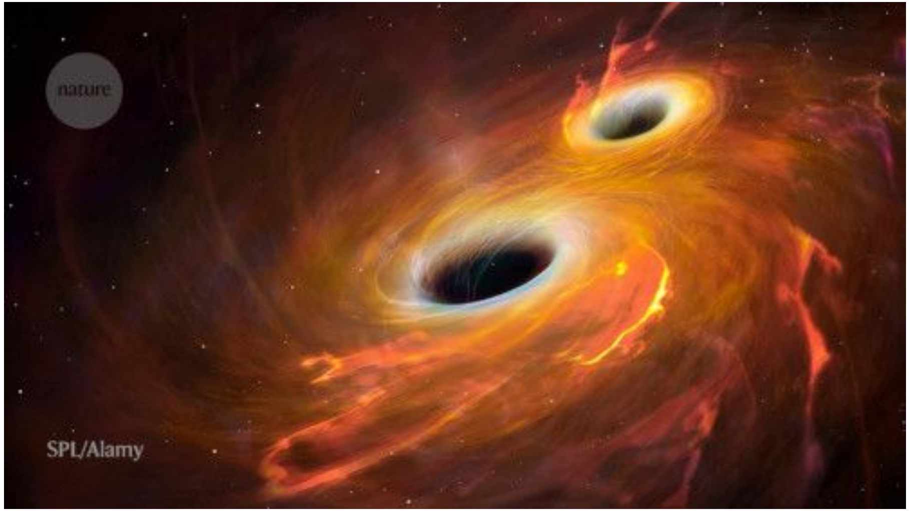


Gurnam’s overview



- *Gurnam Singh, "Gurnam's Grapevine - Embracing Chaos And Complexity In Your Research",* [*https://hls-pgr-newsletter.github.io/_columns/18-05-01-gurnam-02-chaos.html*](https://hls-pgr-newsletter.github.io/_columns/18-05-01-gurnam-02-chaos.html)

GW detector and its environment as a complex system



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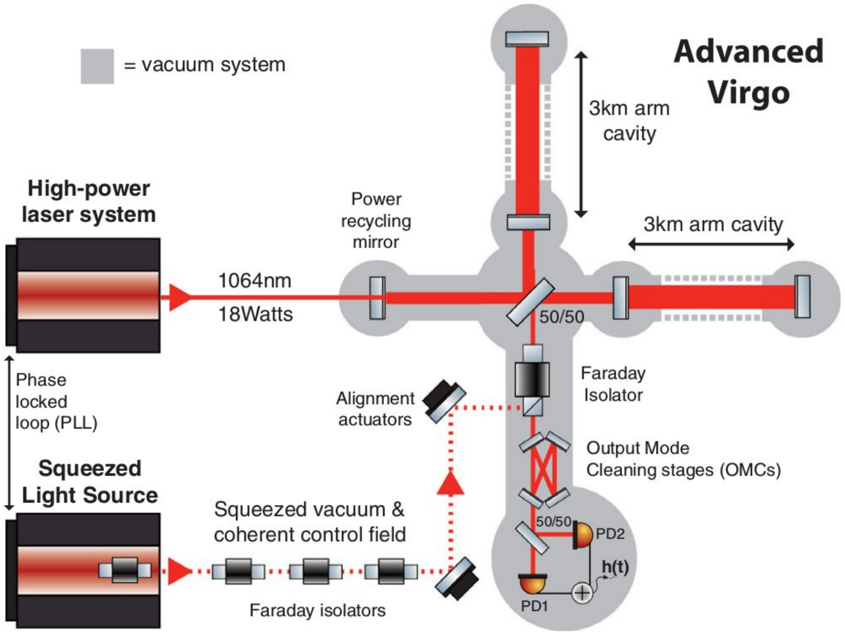
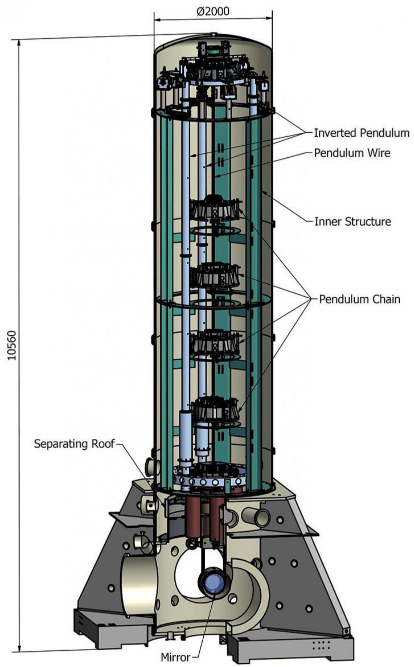


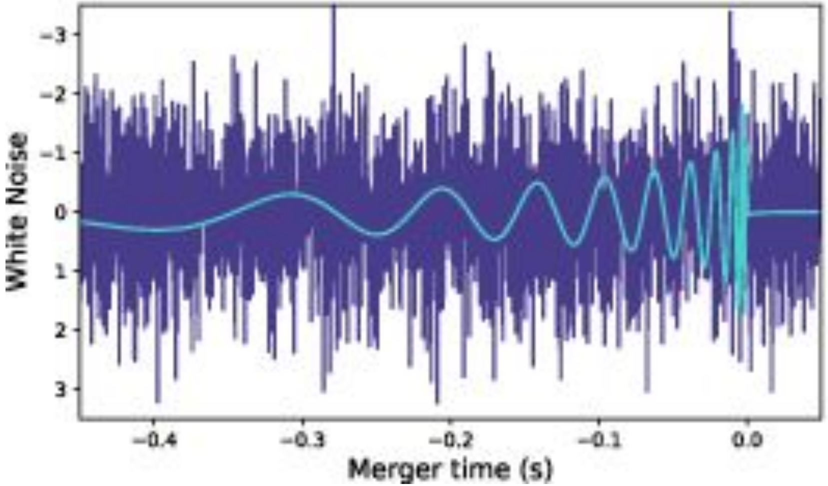
Quantum enhanced Advanced Virgo gravitational-wave detector

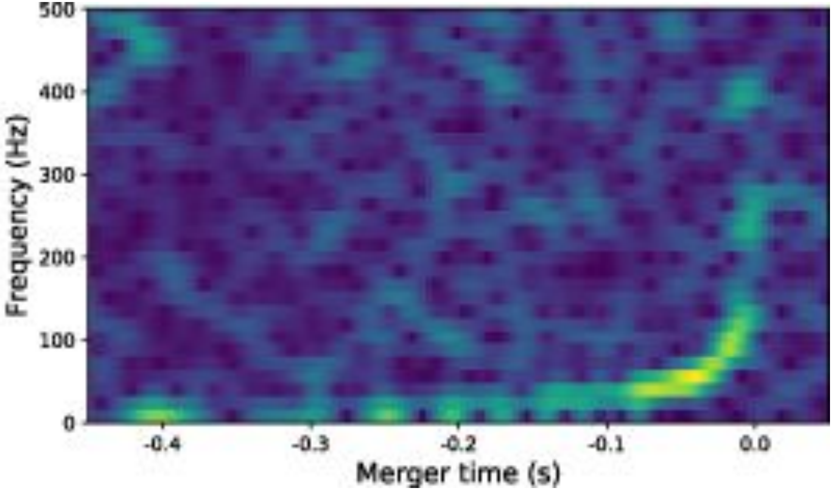


The VIRGO Superattenuator

- *Acernese, Fausto, et al. Physical review letters 123.23 (2019): 231108.*
- *Sequino, Valeria, and Mateusz Bawaj. Nature (2020): 583(7814): 31-32.*
- *Accadia, Thimothée, et al. Journal of Instrumentation 7.03 (2012): P03012.*

GW detector and its environment as a complex system



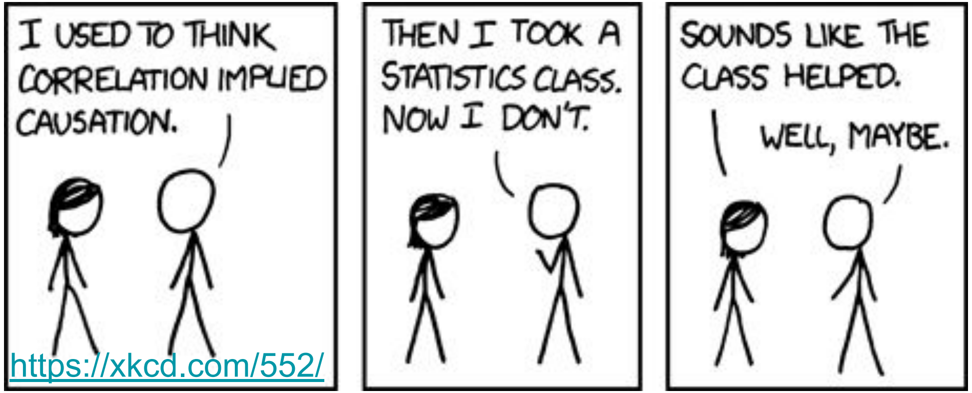


- *Cuoco, Elena, et al. "Enhancing gravitational-wave science with machine learning." Machine Learning: Science and Technology 2.1 (2020): 011002.*

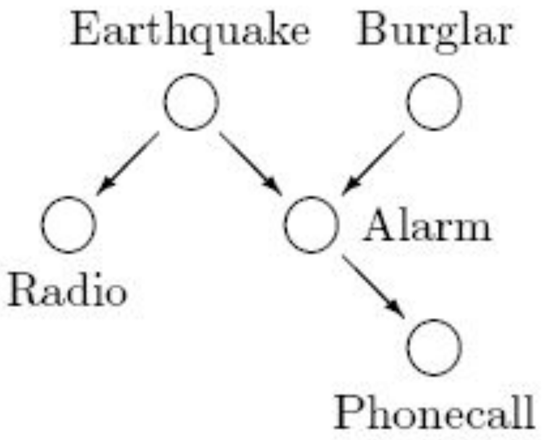
Fractals

- *Cavaglia, Marco. "Characterization of gravitational-wave detector noise with fractals." arXiv preprint:2201.09984 (2022)*

Causality and causal networks



https://xkcd.com/552/



Fred lives in Los Angeles and commutes 60 miles to work. Whilst at work, he receives a phone-call from his neighbour saying that Fred's burglar alarm is ringing. What is the probability that there was a burglar in his house today? While driving home to investigate, Fred hears on the radio that there was a small earthquake that day near his home. `Oh', he says, feeling relieved, `it was probably the earthquake that set of the alarm'. What is the probability that there was a burglar in his house?

- *Pearl, Judea. Causality. Cambridge university press, 2009.*
- *MacKay, David. J. C.Information theory, inference and learning algorithms. Cambridge University Press, 2003*

CA17137 MoU - WG1’s main tasks

1. To investigate ML classification schemes for GW glitches

2. To design ML pattern-recognition techniques to identify non-stationary spectral lines and non-stationary noise sources.

3. To evaluate possible HPC solutions for DL pipelines for online glitch classification.

4. To investigate how to classify candidates derived from the search of GW signals emitted by pulsars.

CA17137 MoU - WG2’s main tasks

1. To assess the influence of seismic signals on GW records.
2. To learn current approaches to the issue of seismic noise and adapt appropriate methods from the wide spectrum of seismological tools.
3. To participate in creating ML procedures to automate data processing.
4. To design a solution for the application of robots and seismic sensors to monitor seismic noise around GW detectors and help in the Newtonian Noise suppression.
5. To investigate possible ML methods in seismological problems.

Noise fluctuations in devices and complex signals

Challenges in seismology [CA17137, MoU]:

- Long-range correlated seismic signals modeling.
- Self-organization in complex seismic time series.
- Physical interpretation of seismic component of the signal from GW detector.
- Nonlinear Fokker-Planck equation: Drift and diffusion term affects the fluctuation of seismic time series

$$\frac{\partial}{\partial t}p(x,t) = \underbrace{-\frac{\partial}{\partial x}F(x)p(x,t)}_{\text{drift term}} + \underbrace{\frac{\partial^2}{\partial x^2}G\left(p(x,t)\right)p(x,t)}_{\text{nonlinear diffusion term}}$$

CA17137 MoU - WG3's task

1. To explore possible applications of reinforcement learning in the control of scientific experiments, and specifically in GW detectors. While most of the initial work will be done in simulated environments, control algorithms will later be tested on dedicated experiments such as the position and orientation of a test mass with single-stage suspension, or the correction of optics profiles by adaptive technology and wave-front sensing.

2. Once tested in these experiment, to find applications in detector prototypes to prepare for an implementation in GW detectors.

Open research: information, learning and thermodynamics

- Black hole thermodynamics (experimental confirmation - ML methods still an open question).
- Statistical physics of non equilibrium processes (modeling of Earth and the equipment).
- Advanced information theoretic and learning methods for the equipment control (latter talk).
- Physics of phase transitions and emergency (latter talk).

Let us continue at coffee breaks

and discussion sessions!

Thank you for your attention!