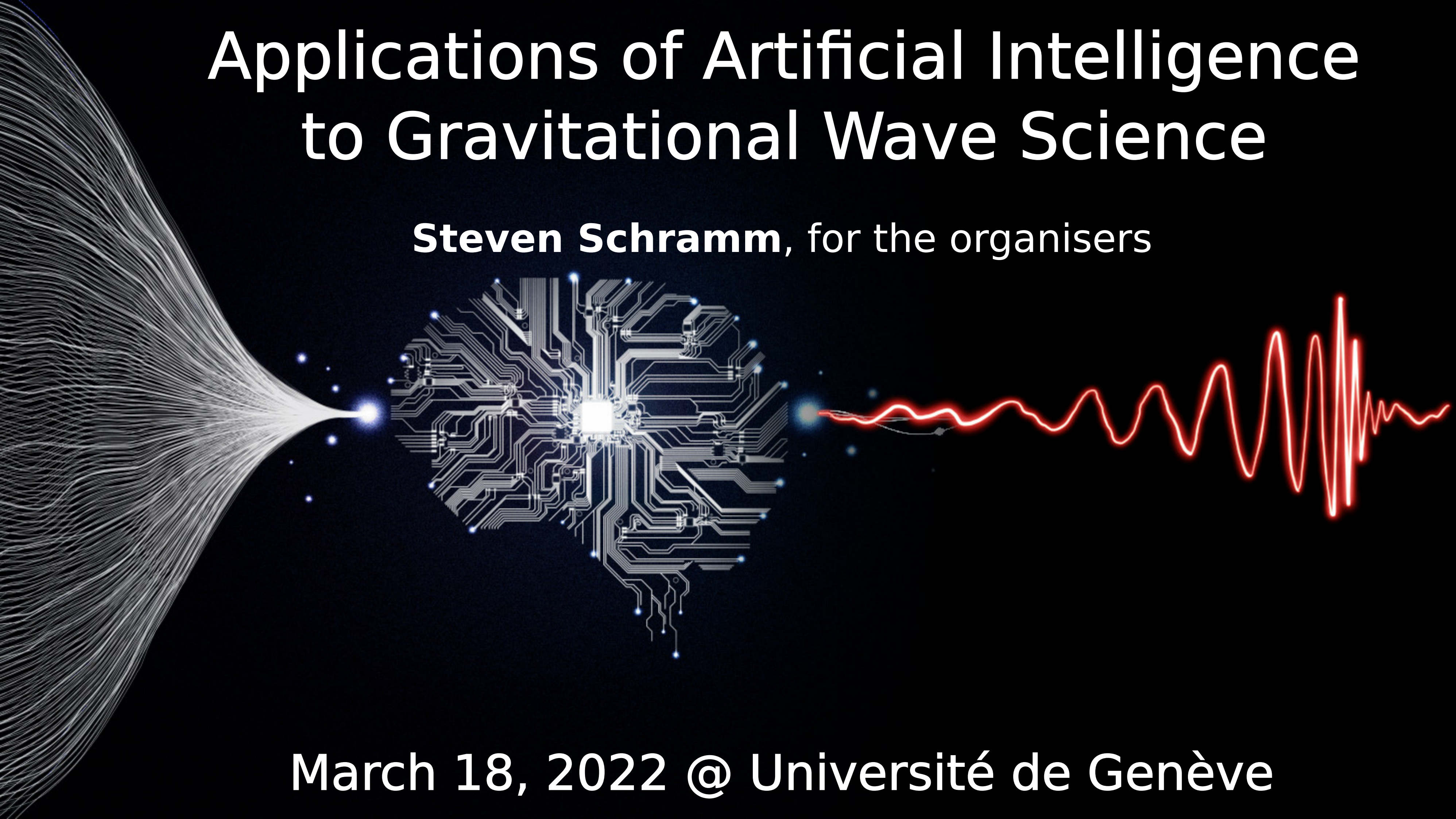


Applications of Artificial Intelligence to Gravitational Wave Science

Steven Schramm, for the organisers



March 18, 2022 @ Université de Genève

Welcome to the event

At UniGe, we have people interested in both:

- Artificial Intelligence (AI) / Machine Learning (ML)
- Gravitational Wave (GW) science

Today, our main objectives are to:

- Help AI experts to understand GW challenges
- Help GW experts to understand AI opportunities
- Foster collaboration between AI and GW communities
- Kick-start cross-departmental activities at UniGe

There are more than 50 people registered to the event

- We are very happy to see such broad interest!

The organisers

- Cross-departmental: astronomy, particle physics, theory
- Includes people with a background in **GW science** and **artificial intelligence / machine learning**
- Frequently in **Einstein Telescope** (future GW observatory)



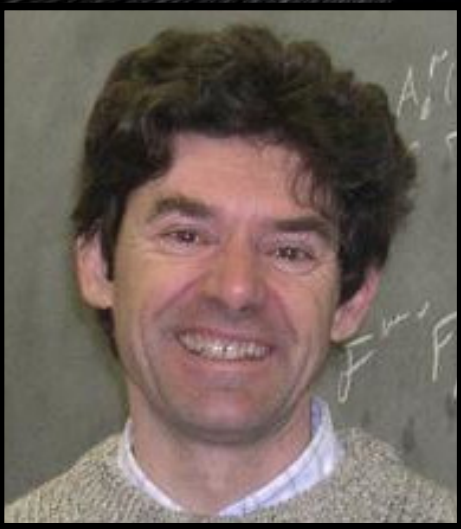
Federico Sanchez, full professor
Department of particle & nuclear physics

- T2k international spokesperson
- **Considering Einstein Telescope activity**
- **Machine Learning for sample generation**
- Director of the UniGe DPNC



Georges Meynet, full professor
Department of astronomy

- **Stellar computational astrophysics**
- **Modelling of massive star evolution**
- **Head of UniGe Stellar Evolution group**
- **Considering Einstein Telescope activity**



Michele Maggiore, full professor
Department of theoretical physics

- **Gravitational wave physics**
- **Chair of the Einstein Telescope Observational Science Board (OSB)**
- **Einstein Telescope Steering Committee**



Steven Schramm, assistant professor
Department of particle & nuclear physics

- **Member of Einstein Telescope (OSB, eIB)**
- Member of the ATLAS Collaboration
- **Background in Machine Learning for data analysis and signal identification**



Tobias Golling, associate professor
Department of particle & nuclear physics

- Member of the ATLAS Collaboration
- **Machine Learning in various contexts**
- **Recipient of a Sinergia grant on AI as applied to physical sciences**



Anastasios Fragkos, assistant professor
Department of astronomy

- **Member of Einstein Telescope (OSB, eIB)**
- **ET Board of Scientific Representatives**
- **Stellar & gravitational wave astrophysics**
- **Machine Learning for model simulation**



Antonio Riotto, full professor
Department of theoretical physics

- **Cosmology and astroparticle physics**
- **Convener of Einstein Telescope OSB Division 3: Population Studies**
- Director of the UniGe DPT

Overview of the event

- We are very happy to welcome four external experts to our event
- They will present three dedicated talks, with time for questions
 - There will then be a panel discussion, with all of the experts
 - You are very much encouraged to ask questions to the panel!

Talks are oriented around key subjects of AI as applied to GW science:

- **AI for GW data analysis**

Elena Cuoco; EGO and Scuola Normale Superiore di Pisa

- **AI for GW simulation/emulation and parameter estimation**

Jonathan Gair; Max Planck Institute for Gravitational Physics

- **AI for GW inference**

Otto Hannuksela; Chinese University of Hong Kong

Kyungmin Kim; International Center for Astrophysics, KASI

Our invited experts (speakers)



Elena Cuoco



Jonathan Gair



Kyungmin Kim

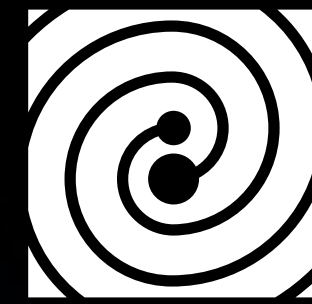


Otto Hannuksela

Gravitational Wave Science Centre

A new "centre facultaire" at UniGe

- This event is part of the kickoff activities



GWSC

GRAVITATIONAL
WAVE
SCIENCE
CENTER

Founding members from three departments at UniGe:

- Department of Astronomy
- Department of Particle and Nuclear Physics
- Department of Theoretical Physics

Anyone interested in GW science is welcome to join the mailing list

- Follow-up events will be announced here: gwsc-events@listes.unige.ch

We will add those who indicated interest in follow-ups when registering

- Others who want to join can contact gwsc-info@unige.ch

For more details, and other involvement types, please see the website:

<http://gwsc.unige.ch/>

GW science and UniGe

We are entering a new era of GW science

- **2015**: first detection of a GW signal
- **2017**: first multi-messenger detection involving a GW signal
- **Present**: detections of dozens of GW events per year
- **2030s**: next generation GW observatories planned to come online; expect continuous signals, transient sources every second

UniGe is well-positioned to make world-leading contributions

- Already a leader in multi-messenger (MM) astronomy
 - Participation in EM, cosmic ray, and neutrino MM activities
- Leading role in supporting next generation GW observatories
 - In particular, critical and growing role in Einstein Telescope
- Active in many areas related to GW modelling and interpretation

AI/ML research and UniGe

We are similarly in a new era of AI/ML

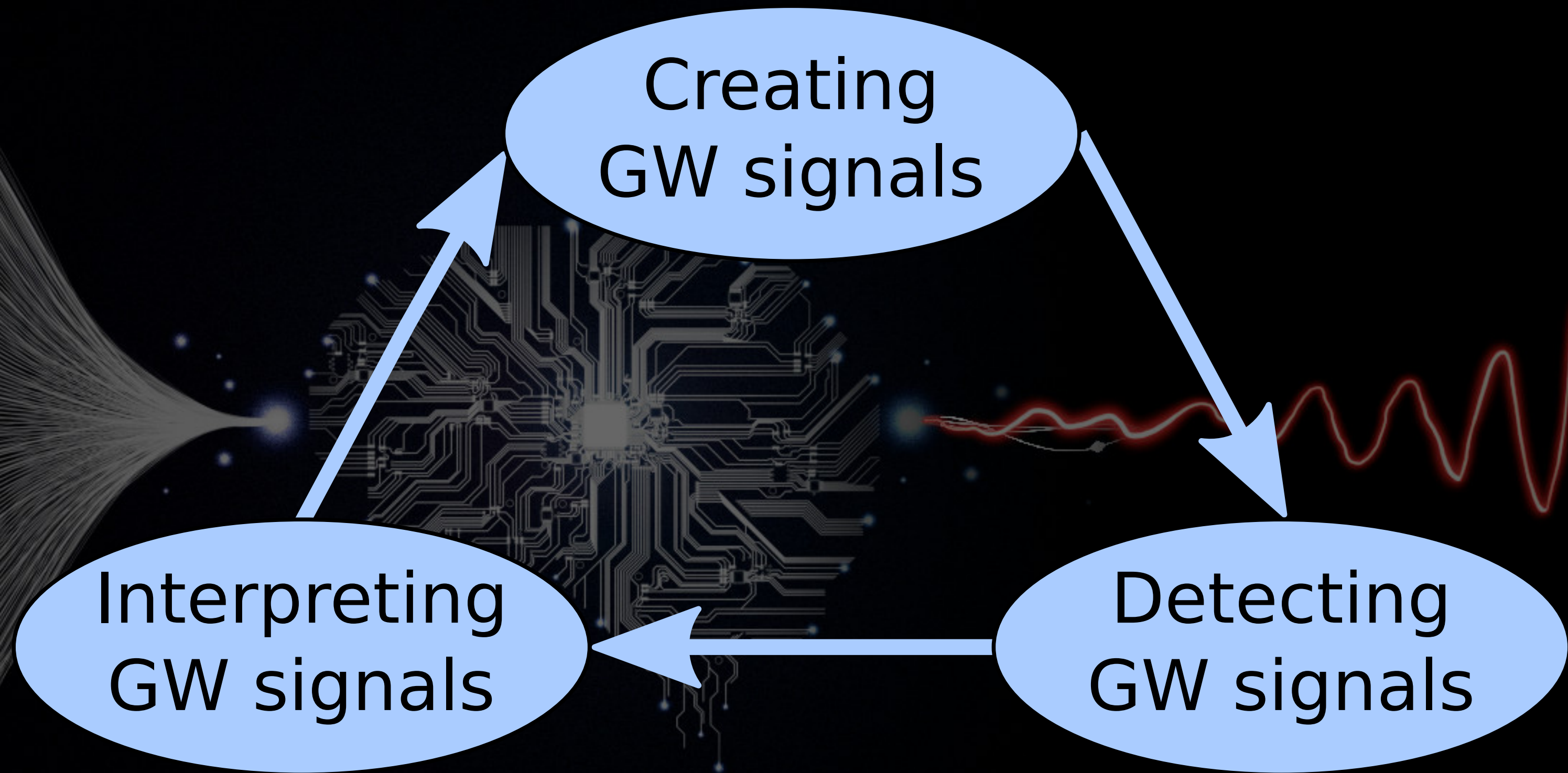
- Enormous computational power (including dedicated hardware)
- Algorithmic developments that can exploit this power
- Advances in the understanding of how to exploit large datasets

UniGe is actively involved in unifying AI/ML and astro/physics

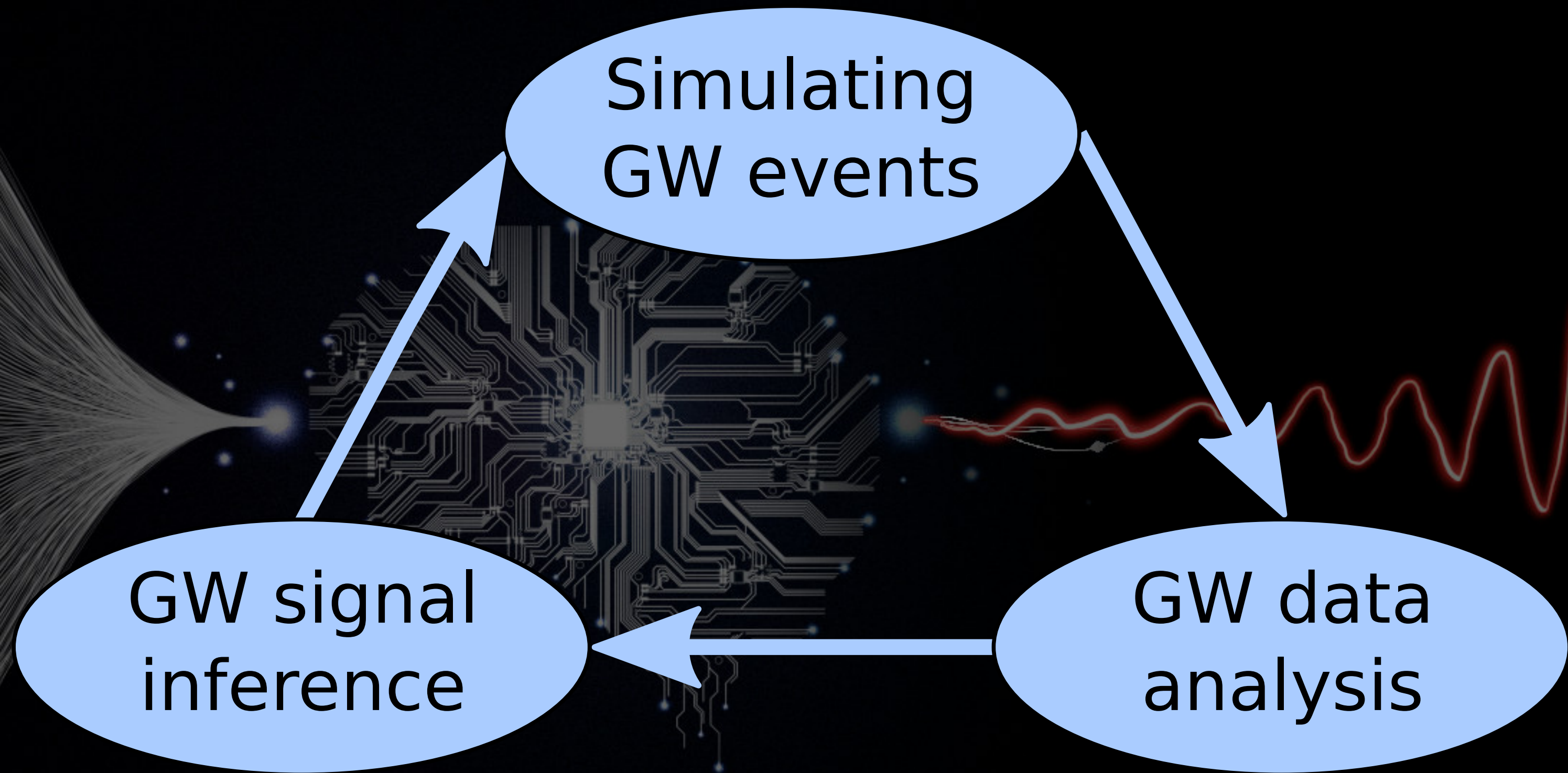
- SNSF Sinergia; Robust Deep Density Models for High-Energy Particle Physics and Solar Flare Analysis (RODEM)
[Co-Is: Francois Fleuret, Tobias Golling, Slava Voloshynovskiy]
- SNSF Sinergia; AstroSignals: A New Window on the Universe, with the New Generation of Large Radio-Astronomy Facilities
[Co-I: Daniel Schaerer; partners: Miroslava Dessauges-Zavadsky, Slava Voloshynovskiy]

UniGe is well-positioned to discuss applying AI to GW research

A very brief intro to GW science



A very brief intro to GW science



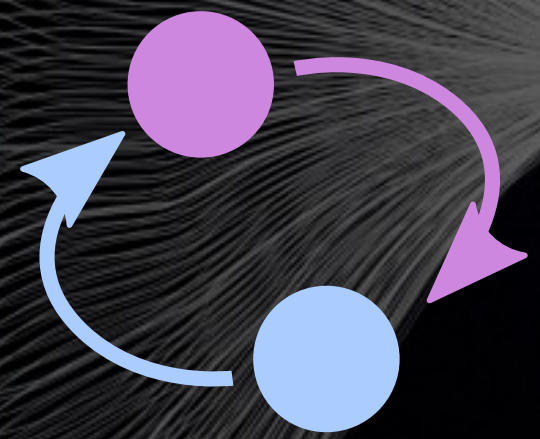
Following slides are indicative, not exhaustive

Simulating GW events

Do initial conditions lead to a merger?

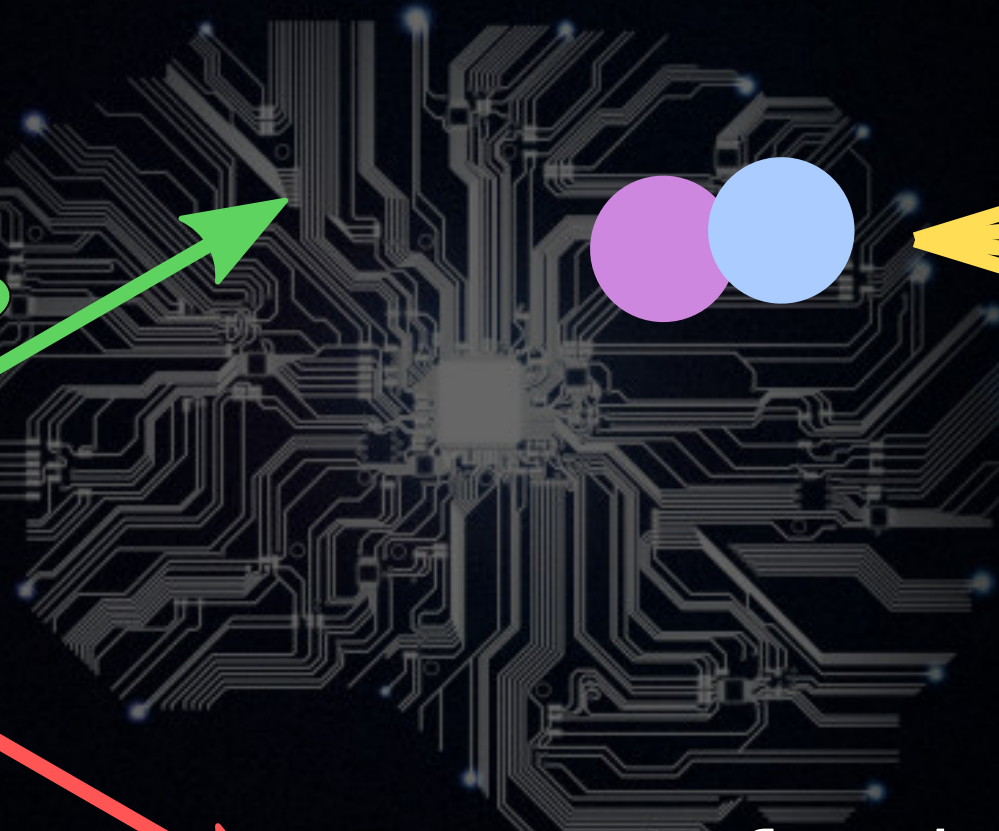
What are the parameters of interest?

How do these propagate to the observer?

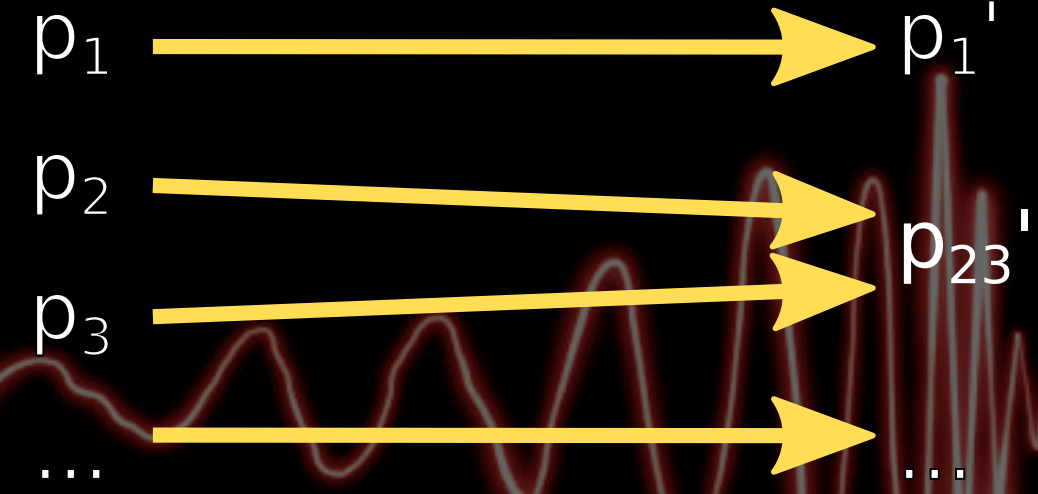


Yes

No



Do not further simulate system



Classification

Regression

Regression

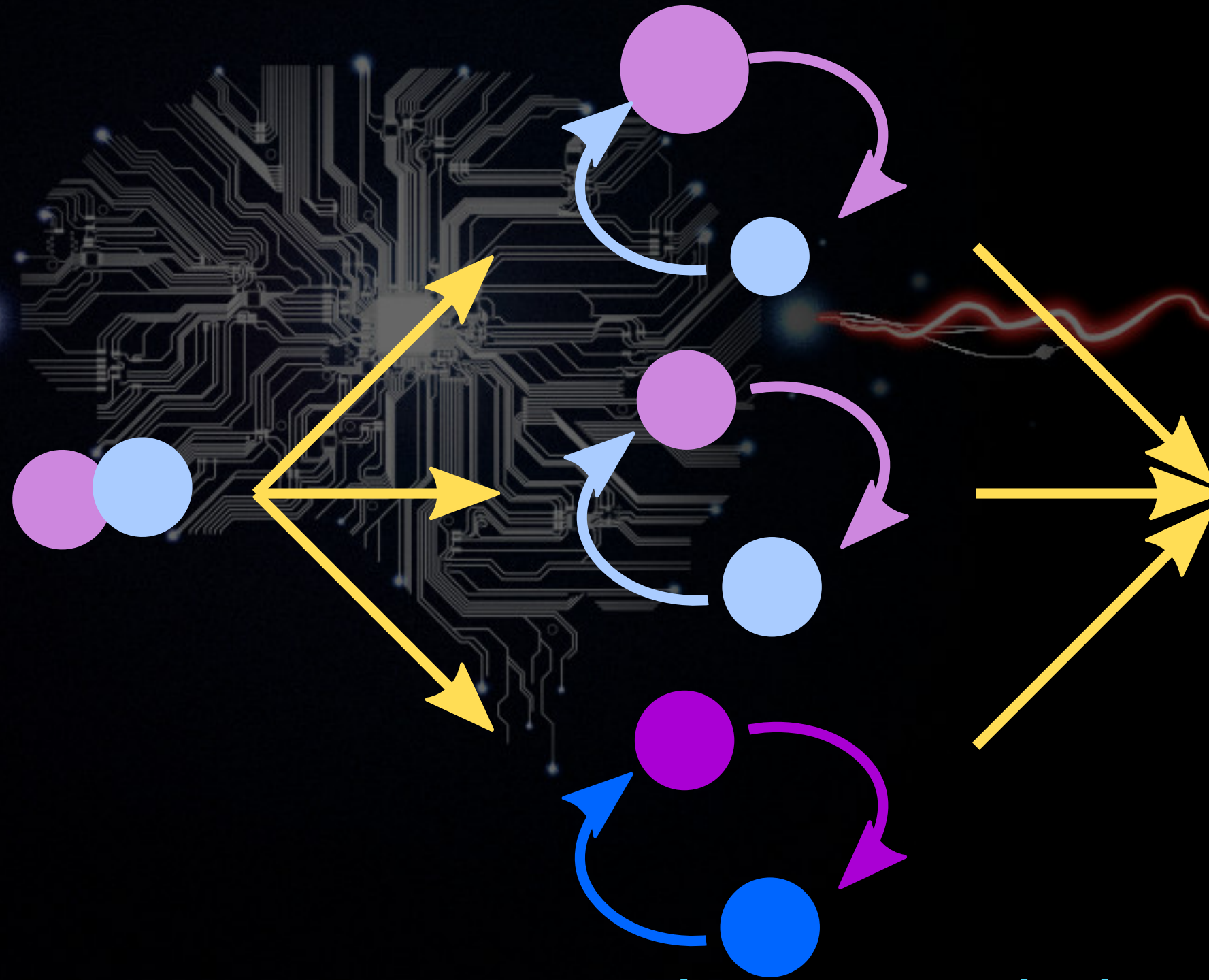
GW signal inference

Given observed parameters, what was the source?

What is the likely origin of the source system?

What does this imply about different astrophysical models?

p_1
 p_2
 p_3
...



Population studies:
Model A vs B

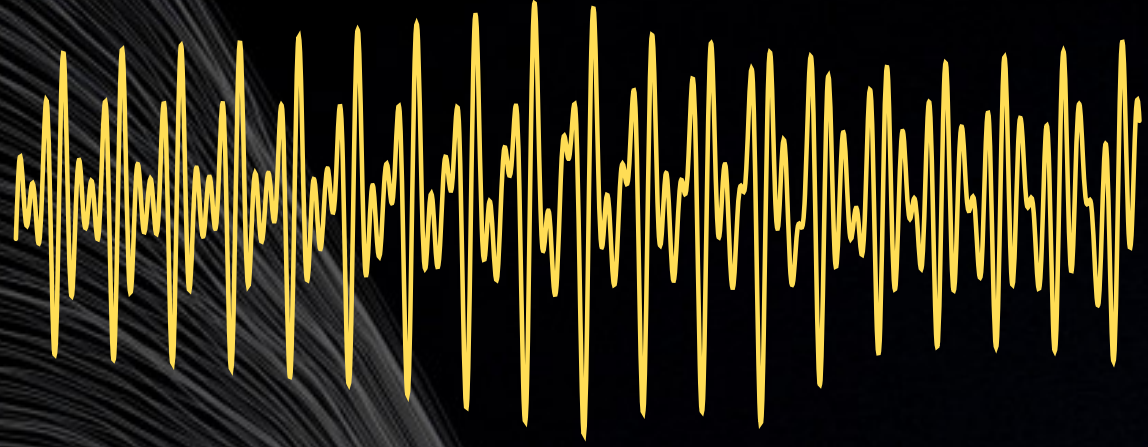
Regression

Generative models

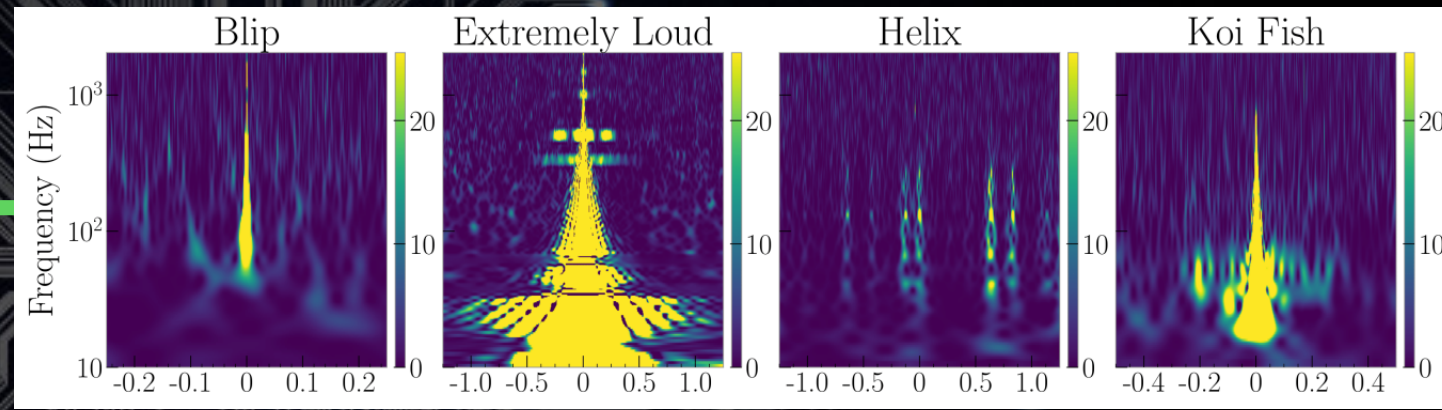
Generative models

GW data analysis

Observed time-series



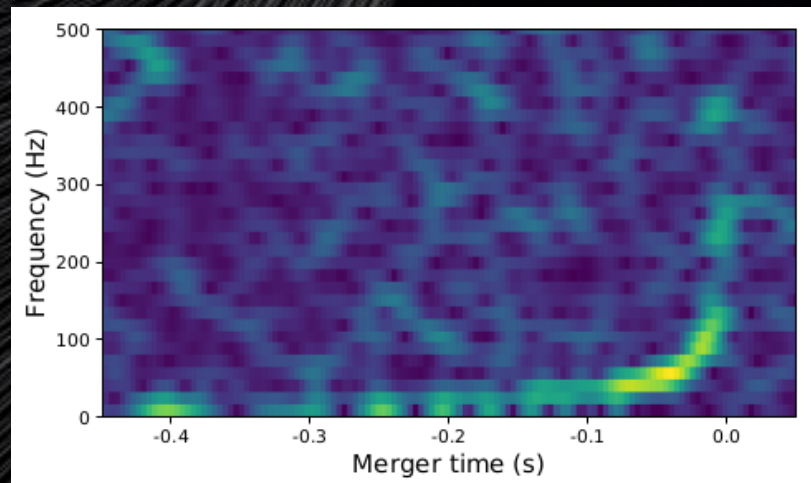
Is there a glitch?



No



Noise suppression



Various signal probes

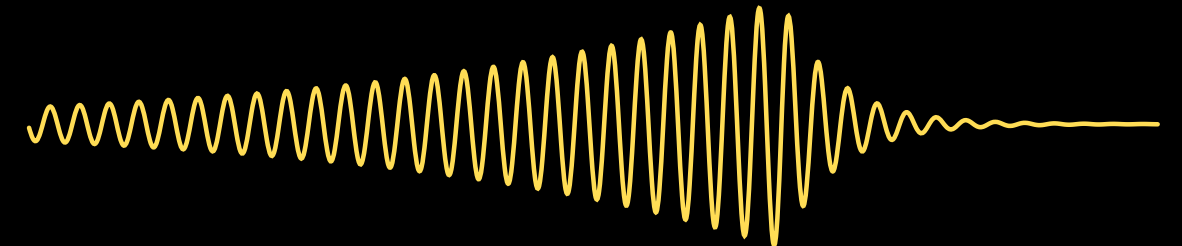


Is there a signal?

Yes



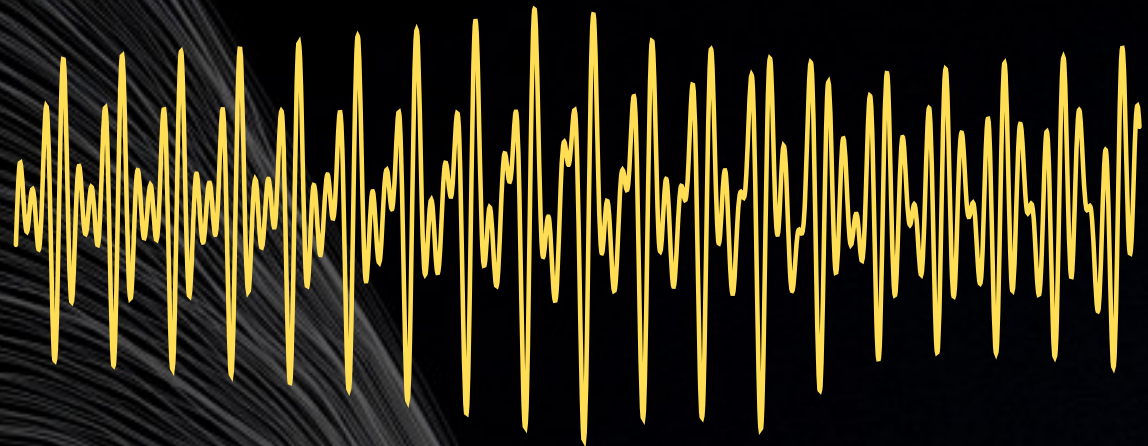
Extracted GW signal



Waveform banks, etc

GW data analysis

Observed time-series



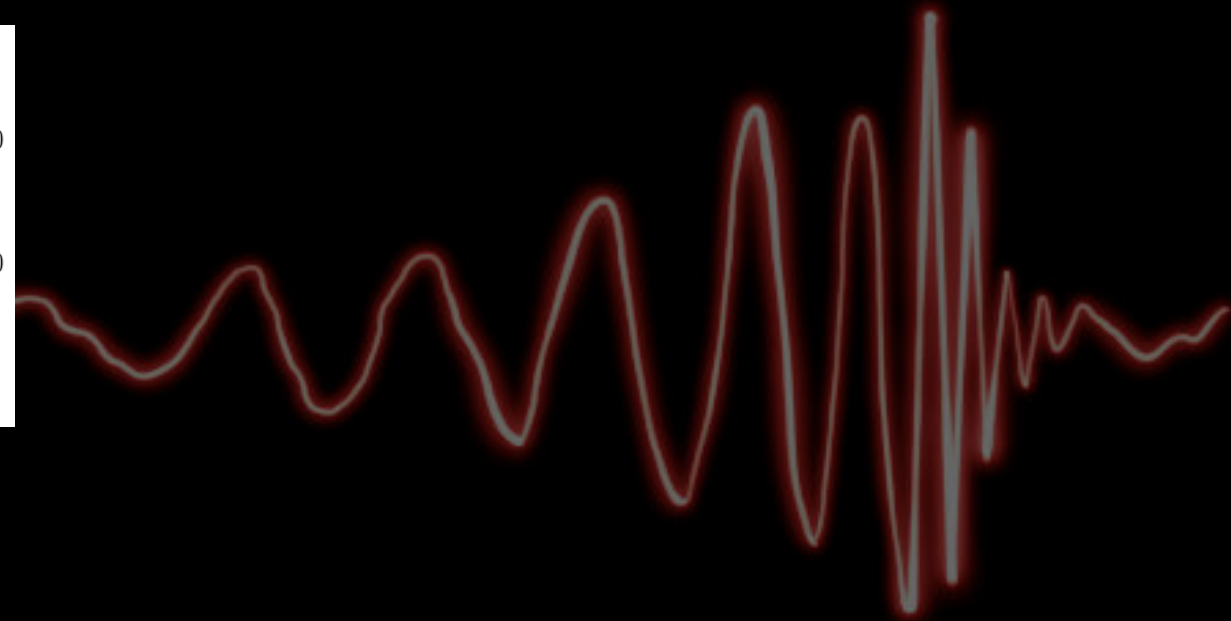
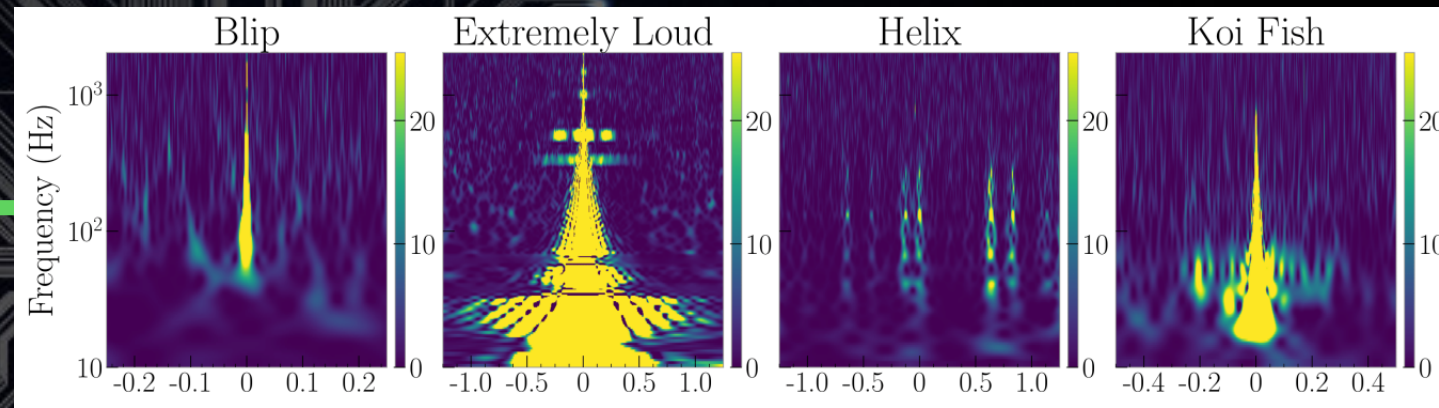
Is there a glitch?

Classification, clustering

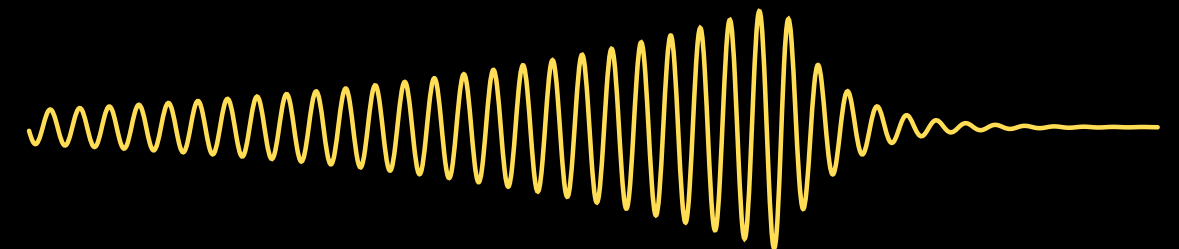
No

Noise suppression

De-noising



Extracted GW signal



Regression

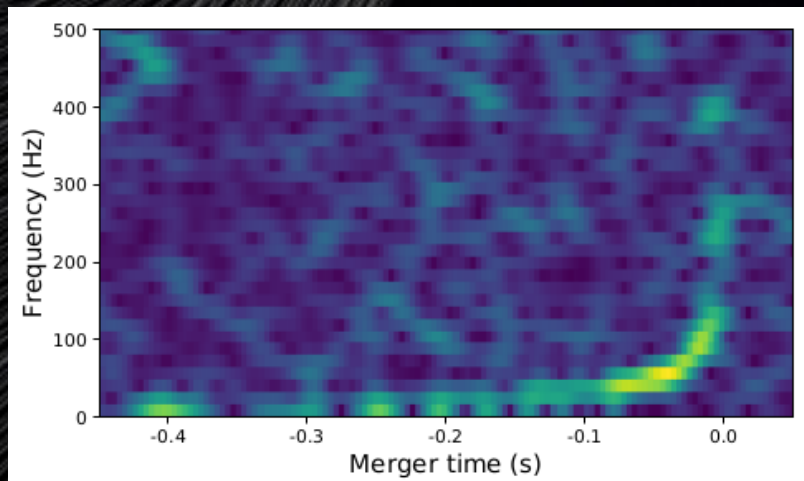
Various signal probes

Is there a signal?

Yes

Waveform banks, etc

Classification, anomalies



We hope that you enjoy the event!

