



# **AI/ML in gravitational wave data analysis**

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# Current situation

- LIGO-Virgo-KAGRA (LVK) Collaboration has monthly AI meetings led by postdoc Melissa Lopez
  - These are meetings of interested individuals, no major formal/structural effort
  - Internally reviewed software used in ongoing observing run is almost all “classical”
- No formal effort within the Einstein Telescope Collaboration
- However, considerable R&D effort at Nikhef/UU
  - In-house experts:
    - Anuradha Samajdar (staff)
    - Melissa Lopez (postdoc)
    - Peter Tsun Ho Pang (postdoc)
    - Tom Dooney (PhD student, computer science, Open University, works at UU)
    - Luca Negri (PhD student, UU)
    - Thibaut Wouters (PhD student, UU)
  - Collaboration with computer scientists at RU, Open University
- 4 recent PhD theses (2 already defended, 2 to be defended in 2025), ~10 BSc/MSc theses
- Tools under development and methodologies used:
  - FlowMC, JIM, Jester for parameter estimation: based on Google’s JAX
  - FLEX for parameter estimation: based on DNNs
  - DeepExtractor for instrumental glitch characterization: U-nets

# Mid-term

- Possible developments in LVK in the next 2-4 years:
  - Replacement of parameter estimation software by AI-based tools
  - Replacement of classical glitch characterization tools
  
- Nikhef involvement and impact:
  - Reasonable to say that we are among the leading institutes
    - Complementary efforts: Cambridge, Glasgow, Johns Hopkins
    - Collaborating with us: UC Louvain, Potsdam
  - Research output in the form of methodology papers, publicly available code
  - **However**, conservative attitude within LVK may slow down adoption of AI/ML tools
    - “Black box” concerns
    - Labor-intensive overhaul of parameter estimation infrastructure took place over the past few years
      - Collaboration members being protective of classical tools they put effort in
  
- Hardware needs:
  - GPUs were just acquired as part of a NWO Large grant for GW
  - Resources at Snellius (SURFsara) have been easy to acquire
  
- Missing expertise: currently we are users of techniques that were developed and made public by computer scientists elsewhere
  - Would clearly be beneficial to have in-house AI experts

# Long-term future

- Next 5-10 years: need to develop data analysis tools for Einstein Telescope
  - From scratch! – Methods currently used by LVK would not work
    - Loud signals, long signals, overlapping signals
    - Characterization of underlying noise will be essential for precision science
      - How to do this if every stretch of data contains signal?
- Will in part be done in the context of a recently acquired ENW-XL