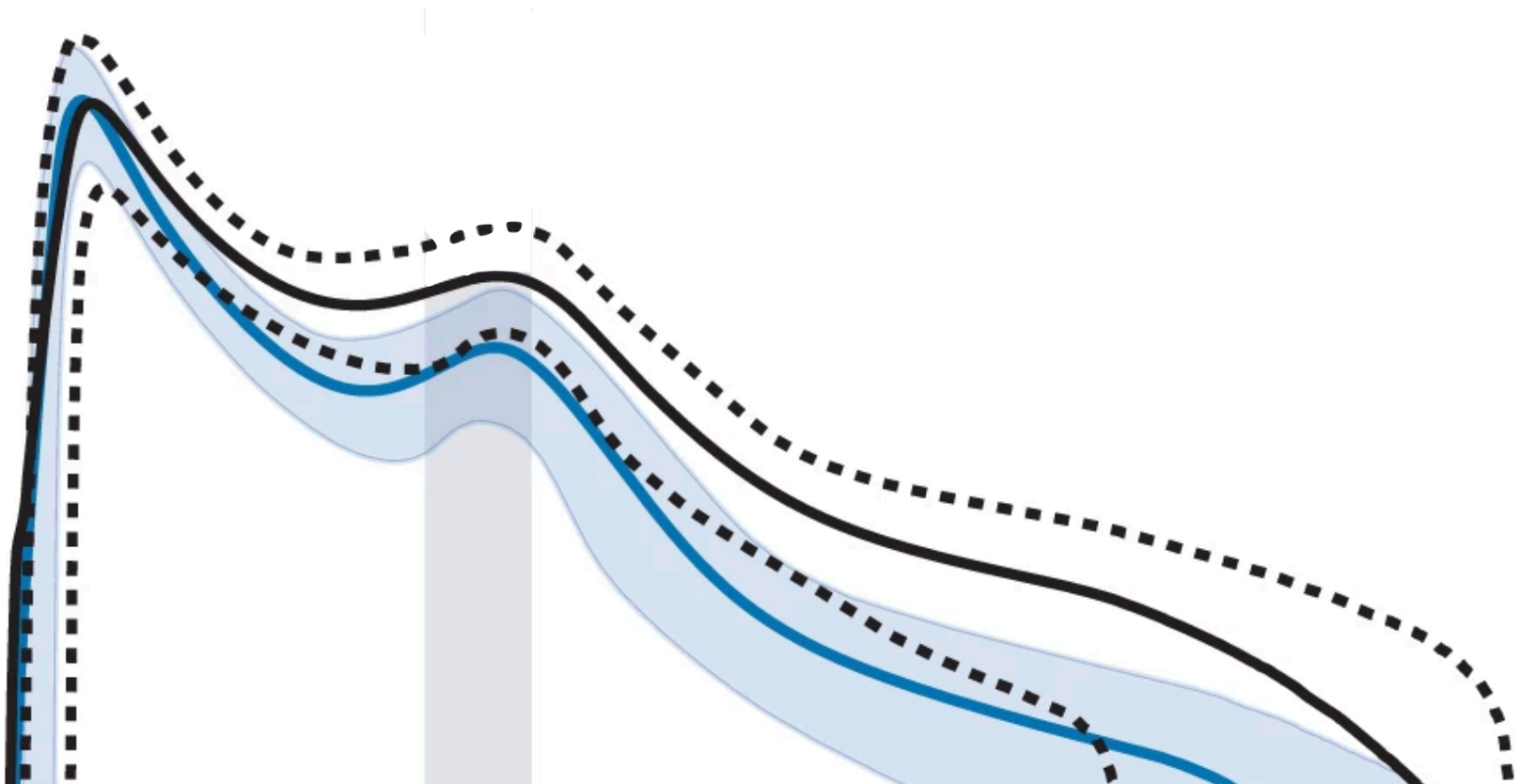
Discussion session:
Machine learning in gravitational-wave population inference

Davide Gerosa
University of Milano-Bicocca

Sylvia Biscoveanu
Northwestern University



Jun 5, 2025
Scientific Machine Learning for Gravitational Wave Astronomy
Providence, RI

Four discussion points

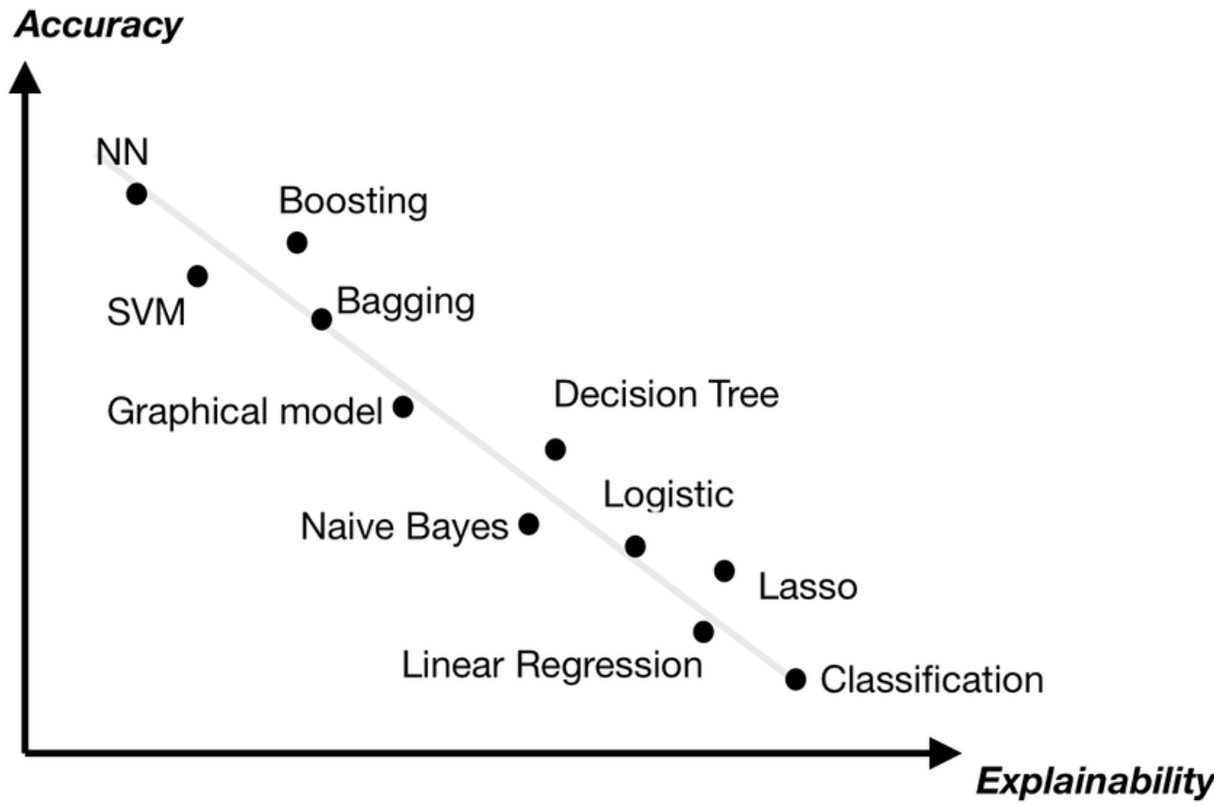
(aka things the two of us think are important in GW pops)

1. Flexibility vs interpretability
2. Large catalogs
3. Models vs data
4. Completeness vs contamination

1. Flexibility vs interpretability

- How much do our results depend on the choice of p_pop?
- (and is this even an issue?)
- Three ways of doing it (more?)
  - Parametric (our beloved power-law+peak)
  - Non-parametric (what does it even mean)
  - Astrophysical (ML emulators to pop synths?)
- Non-parametric is very abstract, astrophysical is model-dependent
- Where's the right balance between flexibility and interpretability?
- Do we care about the model hyperparameters? Or all we want is a reconstruction of the parameters?
- Extrapolation in unseen region (should the variance blow up?)
- Let's not forget we also need a p_det (that is, a model for the detector, while p_pop is a model for the Universe)

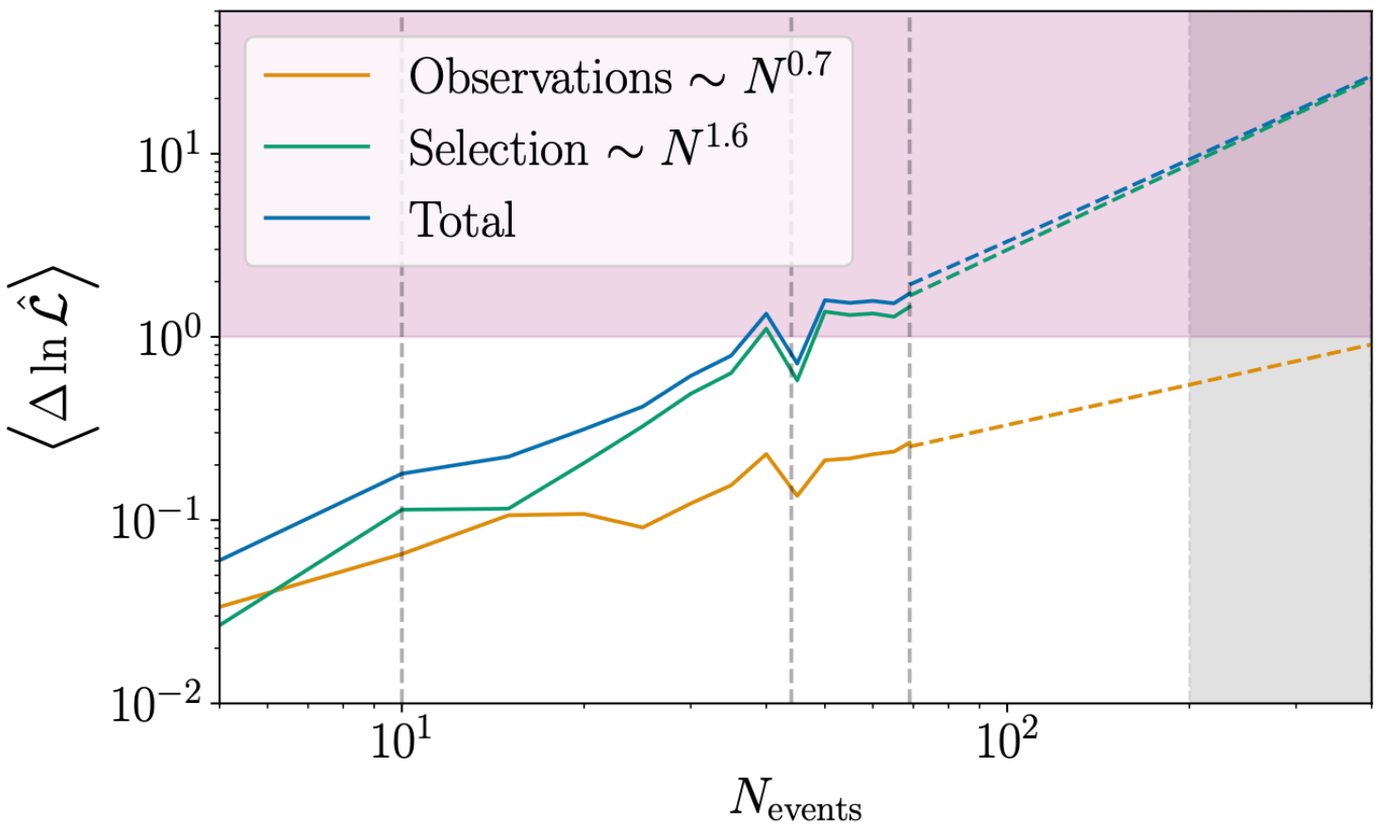
A machine learning plot…



2. Large catalogs

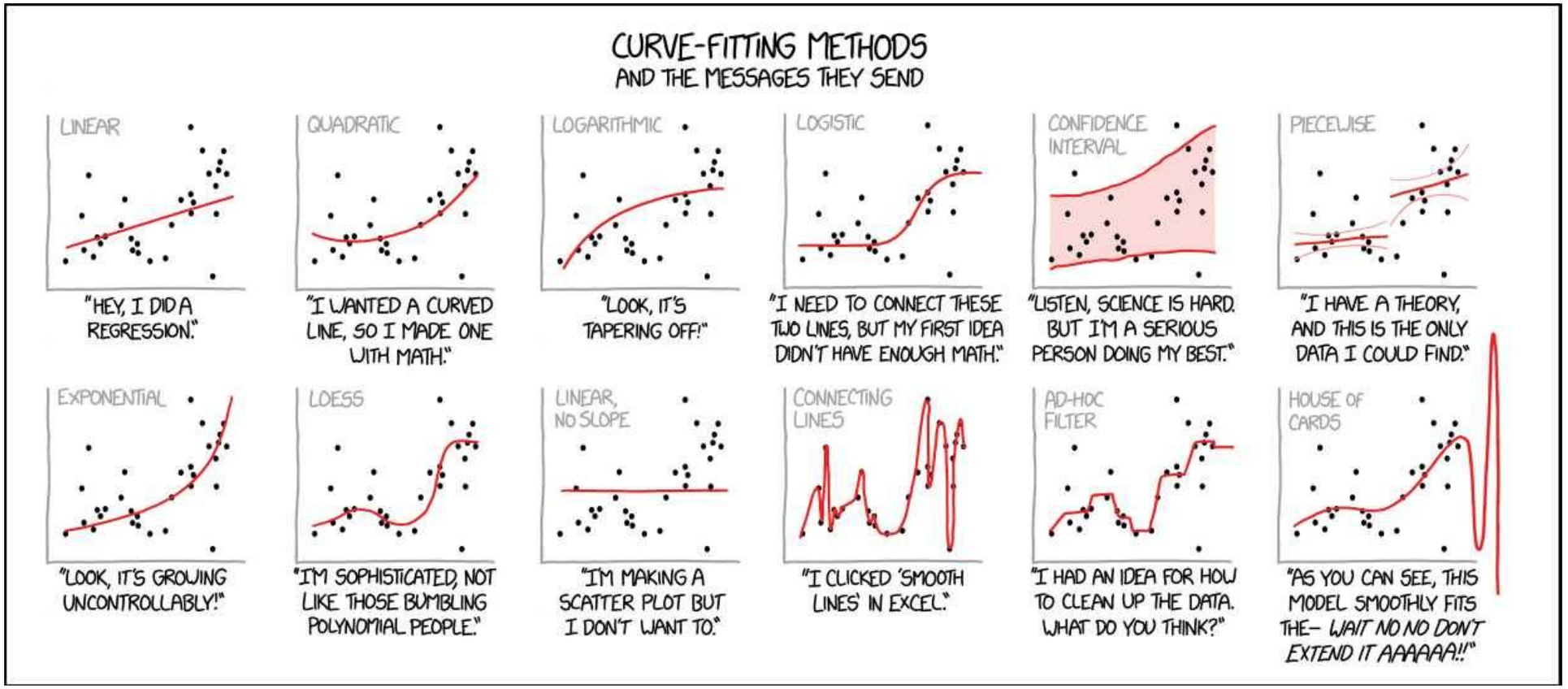
- Monte Carlo integral uncertainty is already affecting results and limiting accessible models
- We cannot keep "recycling" individual-event PE posteriors and sensitivity injections when catalog size reaches O(1000)
- Solutions:
    - Density estimation
    - Simulation-based inference
    - Emulators

- This ties with the “global fit” approach for LISA, where the separation between searches / PE / populations is very blurred.
- Should ground-based folks do the same? Do we need a “global fit” like thing for LVK/CE/ET as well?



3. Models vs data

- In an ideal world, we would sample directly in the astrophysical parameters that shape the resulting compact-object populations
  - Common envelope, critical mass ratio for mass transfer, tidal synchronization timescale, etc.
- But, we cannot run a full pop synth sim at each step of a stochastic sampler!
- Role of posterior predictive checks (dimensionality problem here?)
- Questions:
  - How do we map from data to astrophysical models?
  - How realistic/useful are the model parameters themselves?
  - Can we interpolate between simulations at discrete points in the model parameter space?

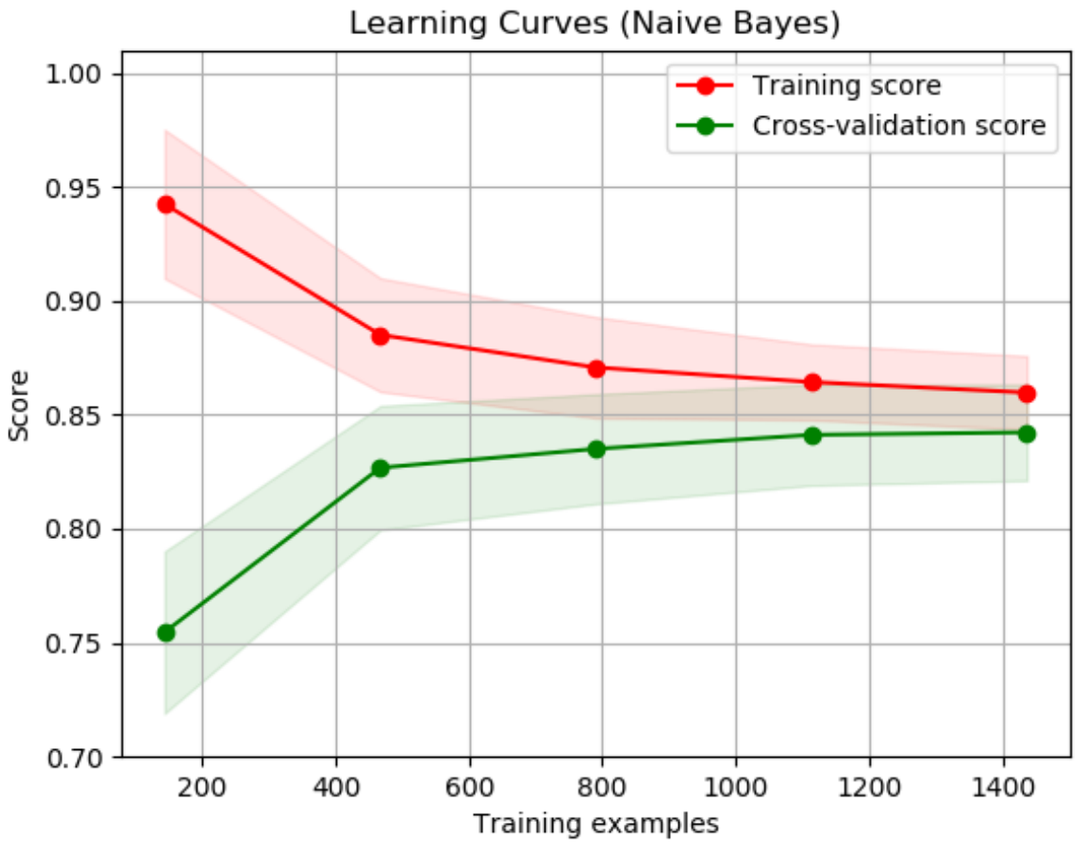


4. Completeness vs contamination

- Do we even want more data? (higher FAR triggers)
- Is that going to help or just make our lives miserable?
- The ML people use “learning curves” to address this question. Useful here?
- Where’s the balance between completeness and contamination? Can we learn from the machine-learning classification literature?
- Do we still want to fit the entire catalog with a single p_pop? Unlikely that a single astro model will explain all the events we’ll see

- Do subpopulations at some point? How to do it consistently? (e.g. tails of posterior extending inside regions of interest)
- Is the (non) detection of the stochastic background going to be useful? When?

Another machine learning plot…



Plan for today

- Work in small groups until the coffee break
- After coffee, summaries from each group (10-ish minutes each)
- Your summary should include a meme
- Ideally flesh out one paper idea?

1. Flexibility vs interpretability
2. Large catalogs
3. Models vs data
4. Completeness vs contamination

SIGN UP HERE

https://128.pl/**teYku**

Please try to split somewhat evenly…

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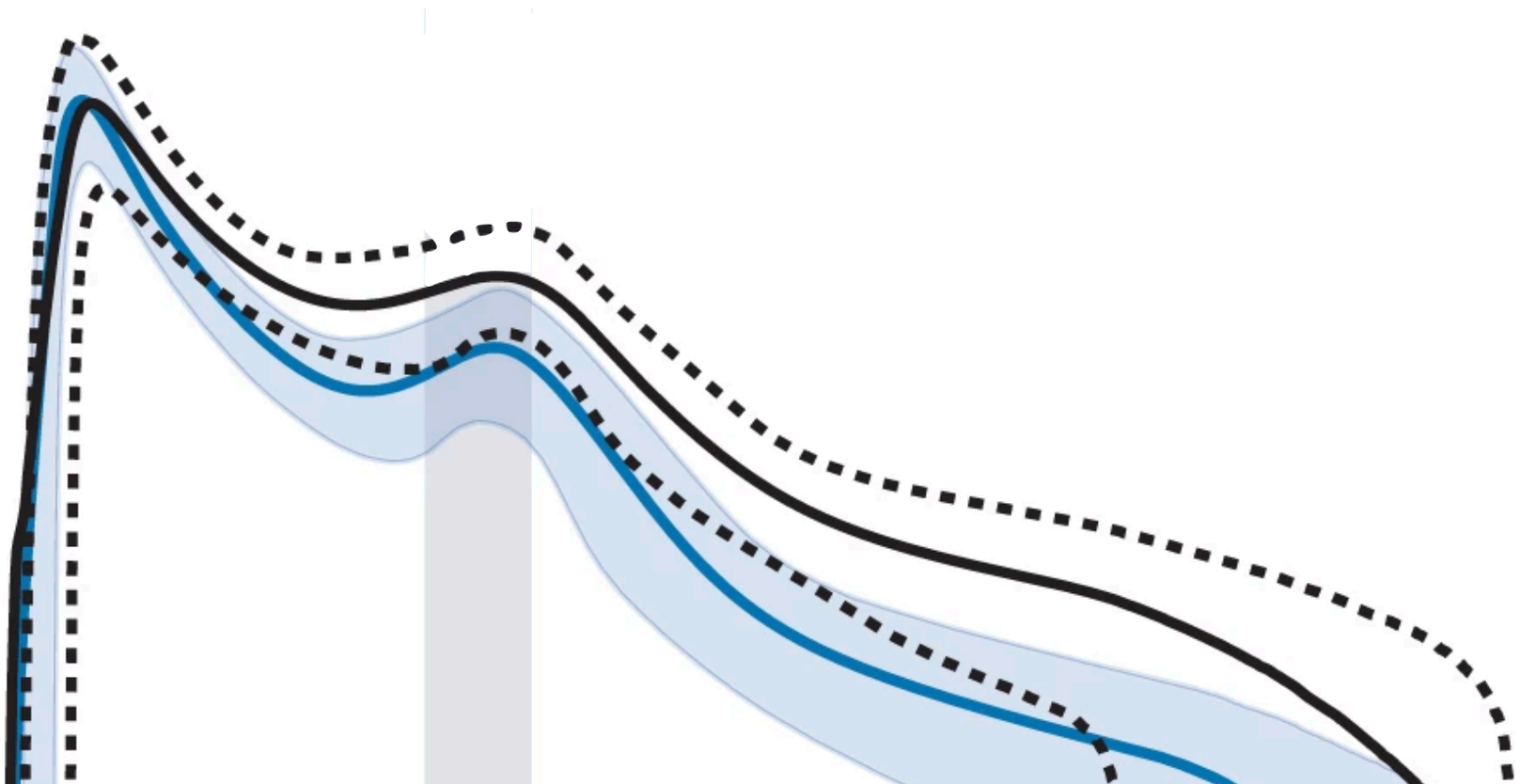

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