Learning Hawkes Processes Under Synchronization Noise

William Trouleau Jalal Etesami Negar Kiyavash
Matthias Grossglauser Patrick Thiran

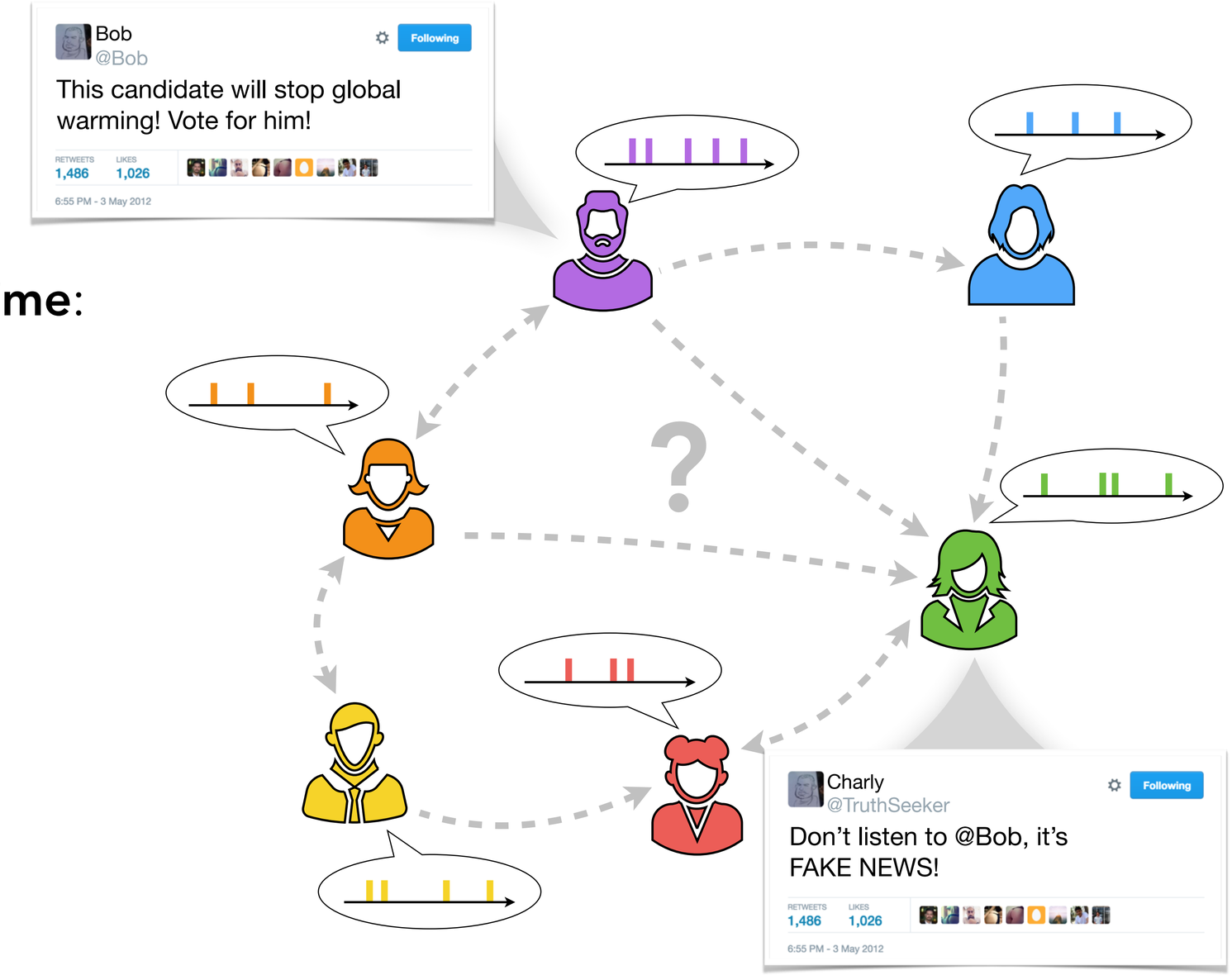
Presented at ICML'19
on Tue Jun 11th 2019

Question of interest

Learning the **causal structure** of **networks** of **multivariate time series** in continuous time

Example1: Information Diffusion

- Consider a **network of users**
- We observe a a **sequence** of **discrete events** in **continuous time**: tweets, Facebook posts…

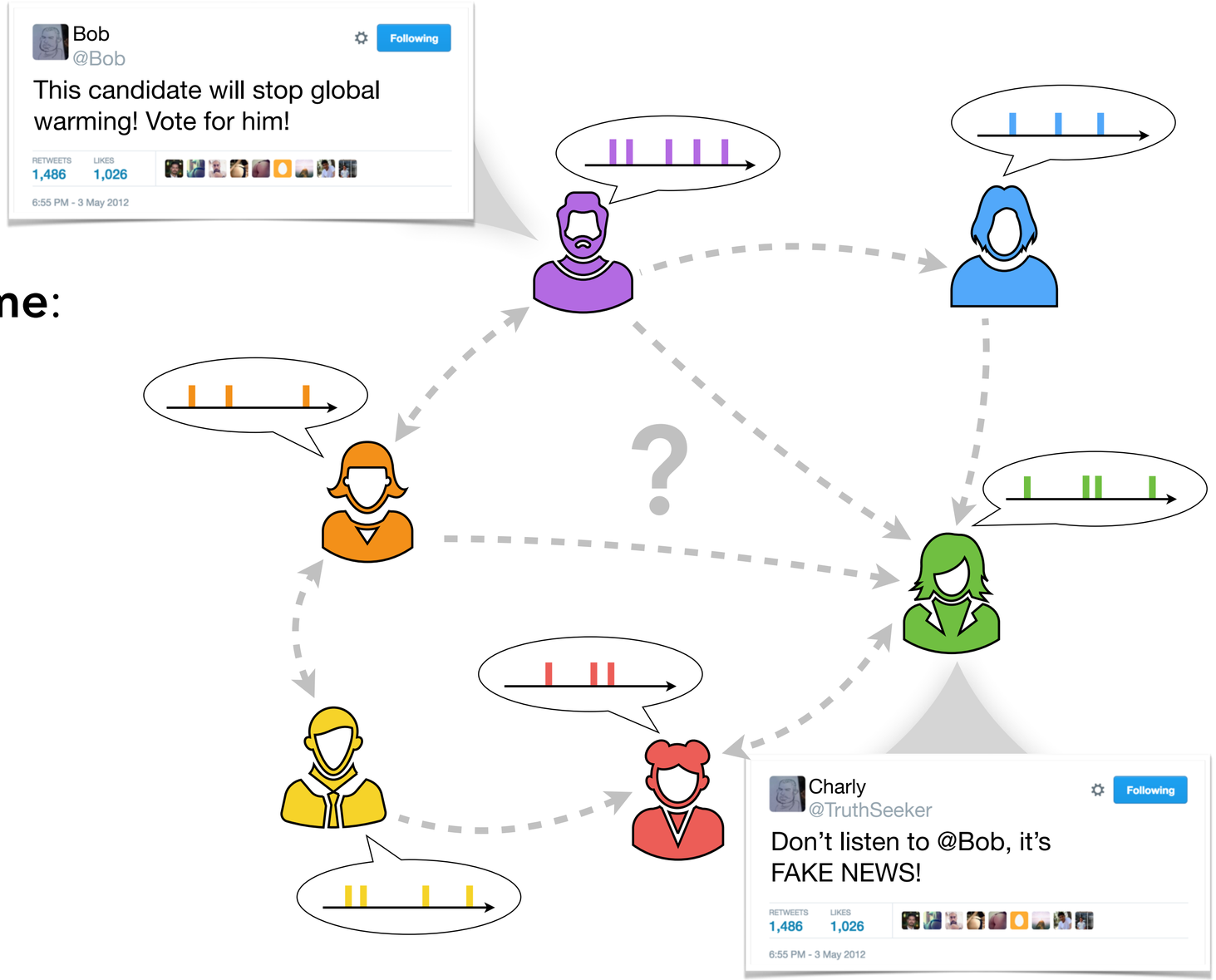


Example1: Information Diffusion

- Consider a **network of users**
- We observe a a **sequence** of **discrete events** in **continuous time**: **tweets**, **Facebook posts**…
- Questions of interest:

  Who **influences** whom?

  How does **fake news spread**?



Example1: Information Diffusion

- Consider a **network of users**
- We observe a a **sequence** of **discrete events** in **continuous time**: **tweets**, **Facebook posts**…
- Questions of interest:

  Who **influences** whom?

  How does **fake news spread**?

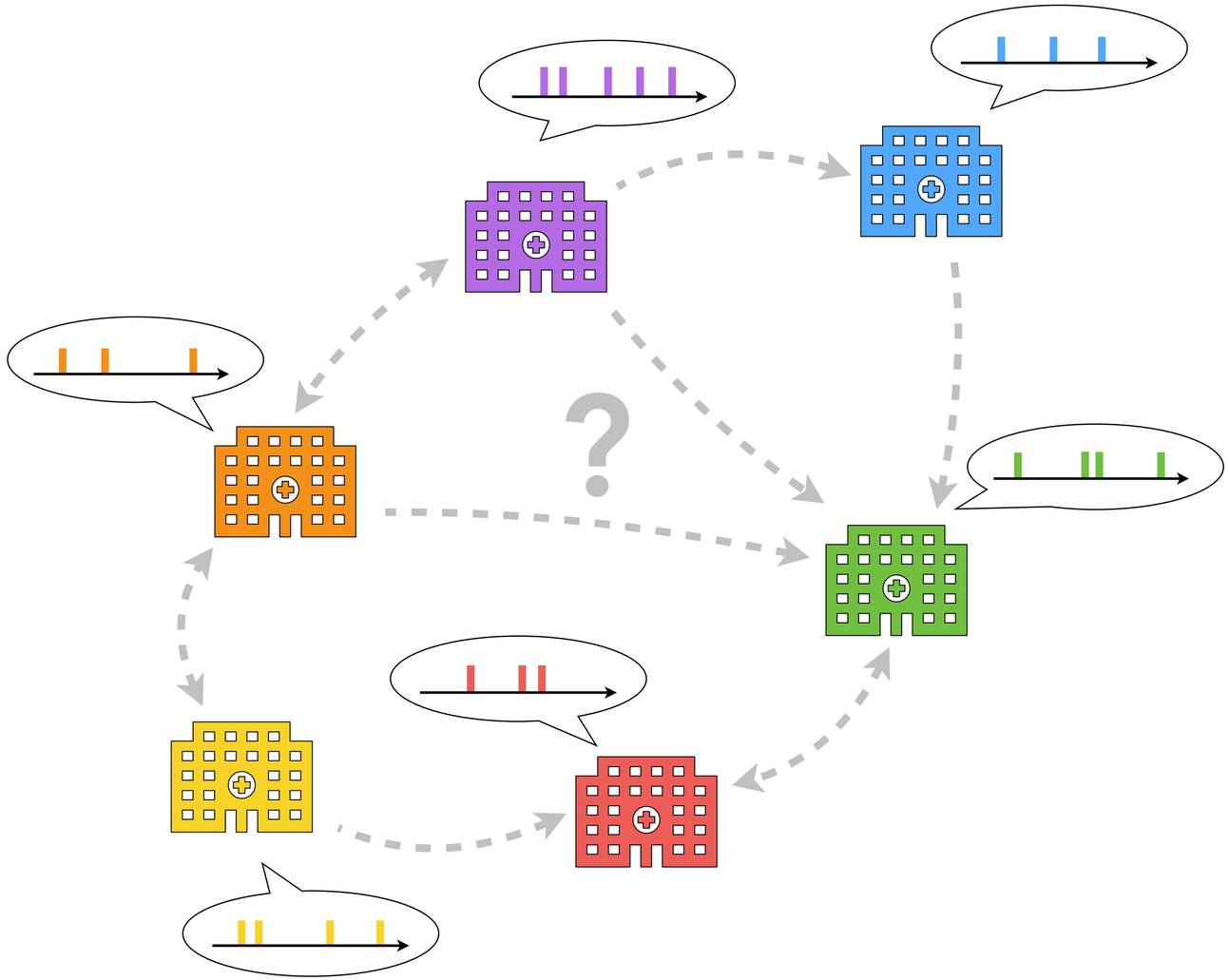
Example 2: Disease Dynamics

- Consider a **network of hospitals**
- We observe a a **sequence** of **discrete events** in **continuous time**: **interactions**, **infections**, **recoveries**…
- Questions of interest:

  Who **infected** whom?

  How does the **disease spread**?

  How to **control** it?



Example 2: Disease Dynamics

- Consider a **network of hospitals**
- We observe a a **sequence** of **discrete events** in **continuous time**: **interactions**, **infections**, **recoveries**…
- Questions of interest:

  Who **infected** whom?

  How does the **disease spread**?

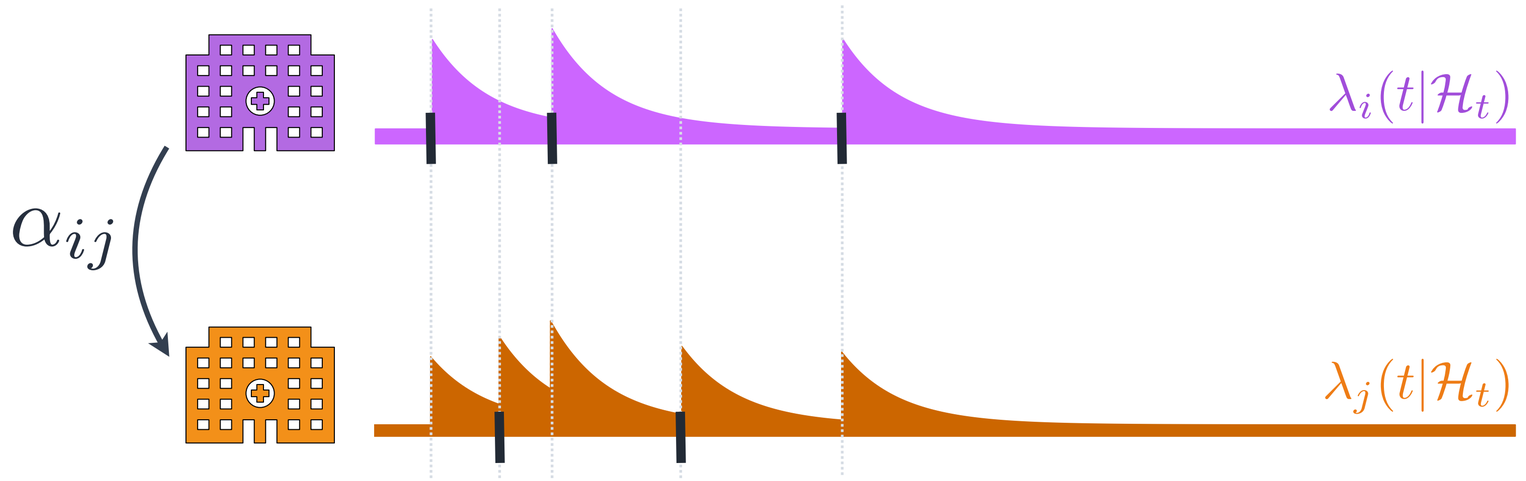
  How to **control** it?

How do we usually solve it?

Method: Multivariate Hawkes Process (MHP)

- **Temporal Point Process**
- Widely used model to learn **causal structure between time series**
- Captures **mutually exciting** patterns of influence between dimensions

$$\lambda_i(t|\mathcal{H}_t) = \mu_i + \sum_{j=1}^{d} \sum_{\tau \in \mathcal{H}_t^j} \kappa_{ij}(t-\tau)$$



Method: Multivariate Hawkes Process (MHP)

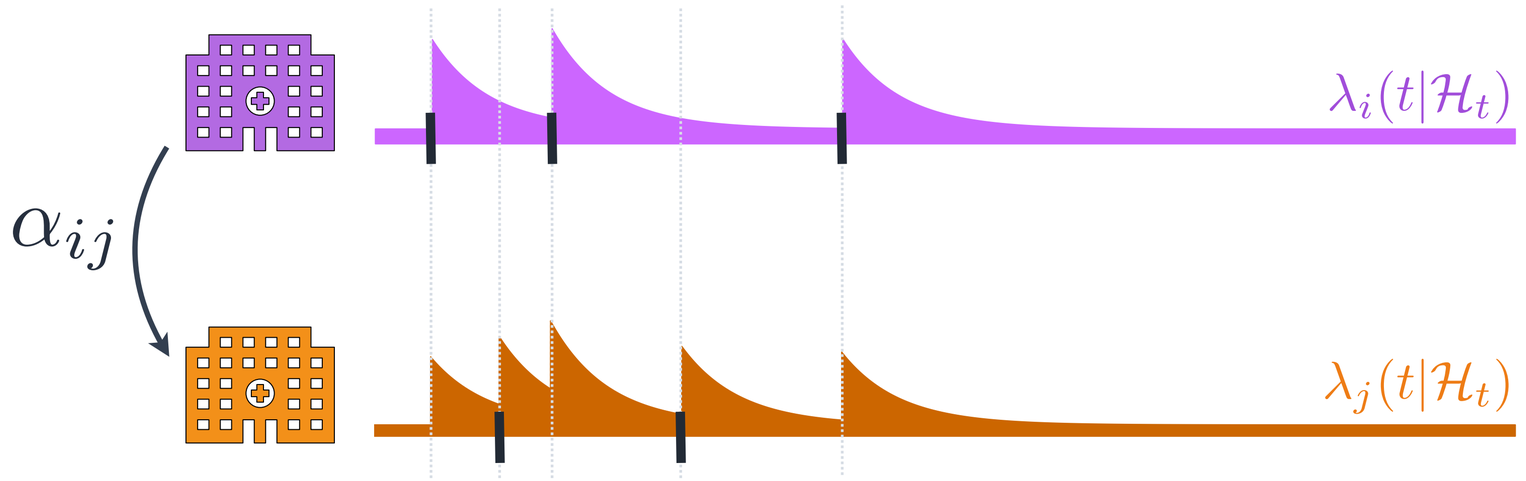
- **Temporal Point Process**
- Widely used model to learn **causal structure between time series**
- Captures **mutually exciting** patterns of influence between dimensions

$$\lambda_i(t|\mathcal{H}_t) = \mu_i + \sum_{j=1}^{d} \sum_{\tau \in \mathcal{H}_t^j} \kappa_{ij}(t-\tau)$$

Exogenous intensity:
constant, independent of the past

Endogenous intensity:
due to excitation from past events, with excitation kernel

$$\kappa_{ij}(t) = \alpha_{ij} e^{-\beta t} \mathbb{1}\{t > 0\}$$



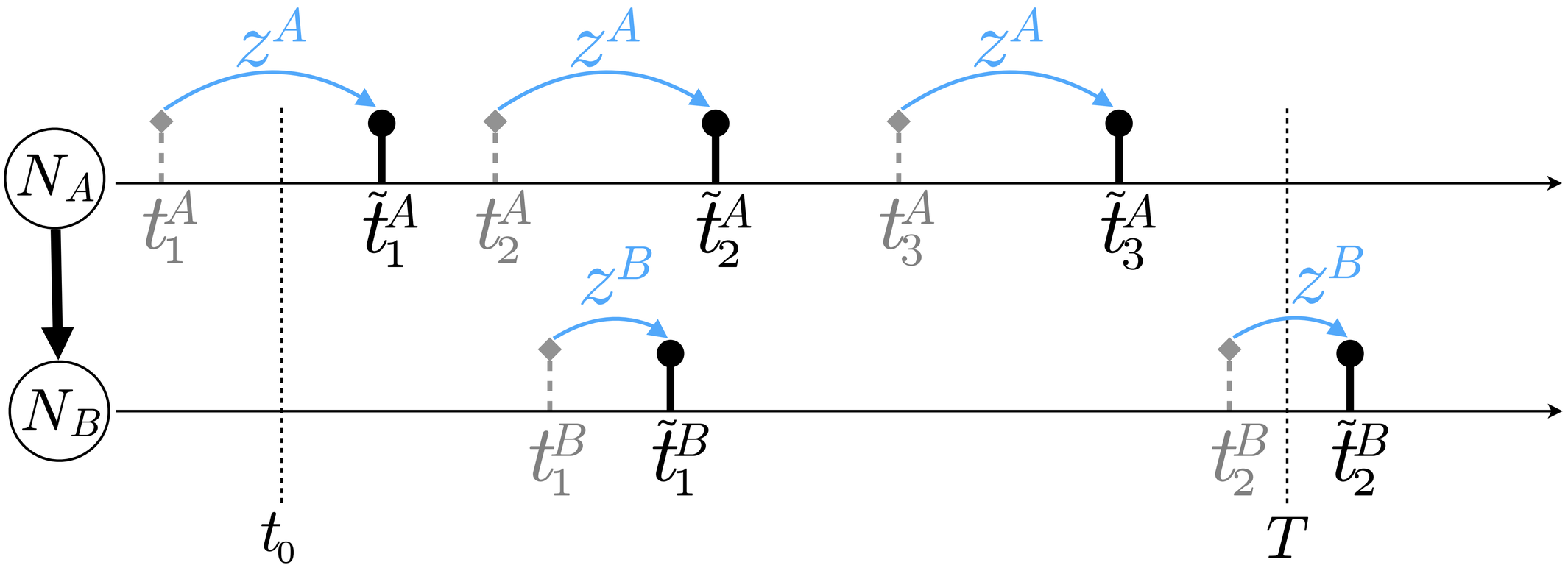
Method: Multivariate Hawkes Process (MHP)

- Prior work assume **perfect traces without noise**
- What if the observed stream of events is subject to a **random** and **unknown time shift**?

How to learn MHPs under noisy observations?

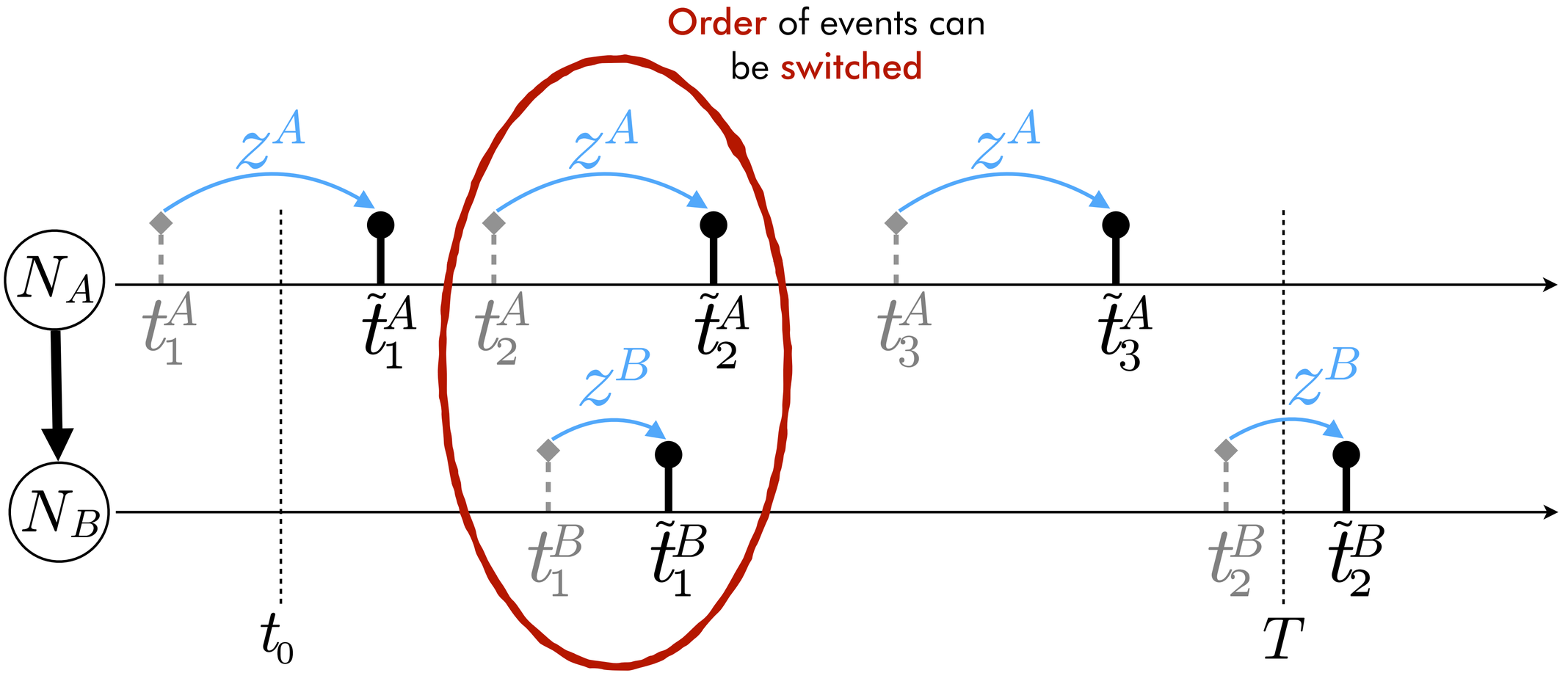
Multivariate Hawkes Process under Synchronization Noise

- What it events have **systematic measurement errors**?



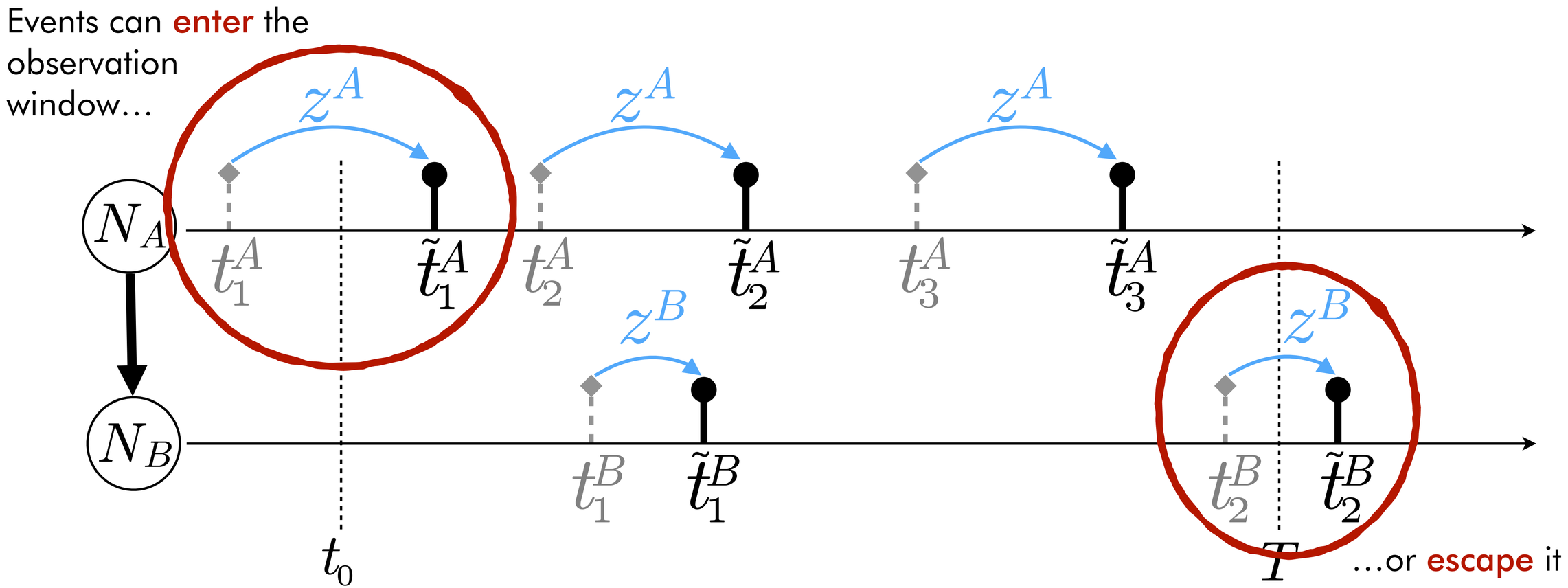
Multivariate Hawkes Process under Synchronization Noise

- What it events have **systematic measurement errors**?



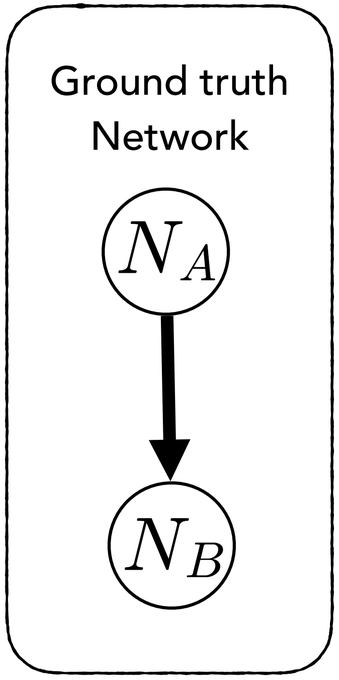
Multivariate Hawkes Process under Synchronization Noise

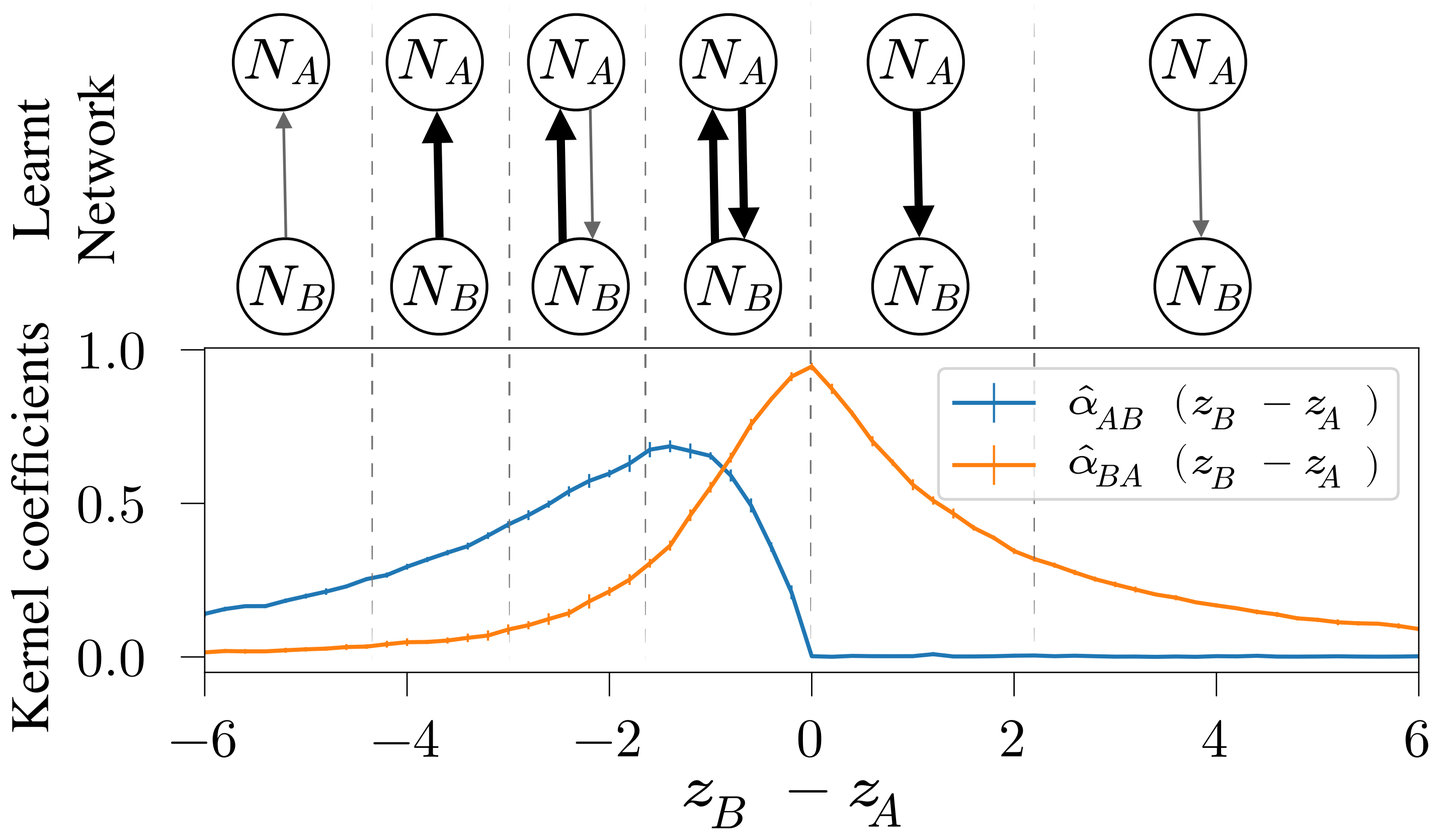
- What it events have **systematic measurement errors**?



Multivariate Hawkes Process under Synchronization Noise

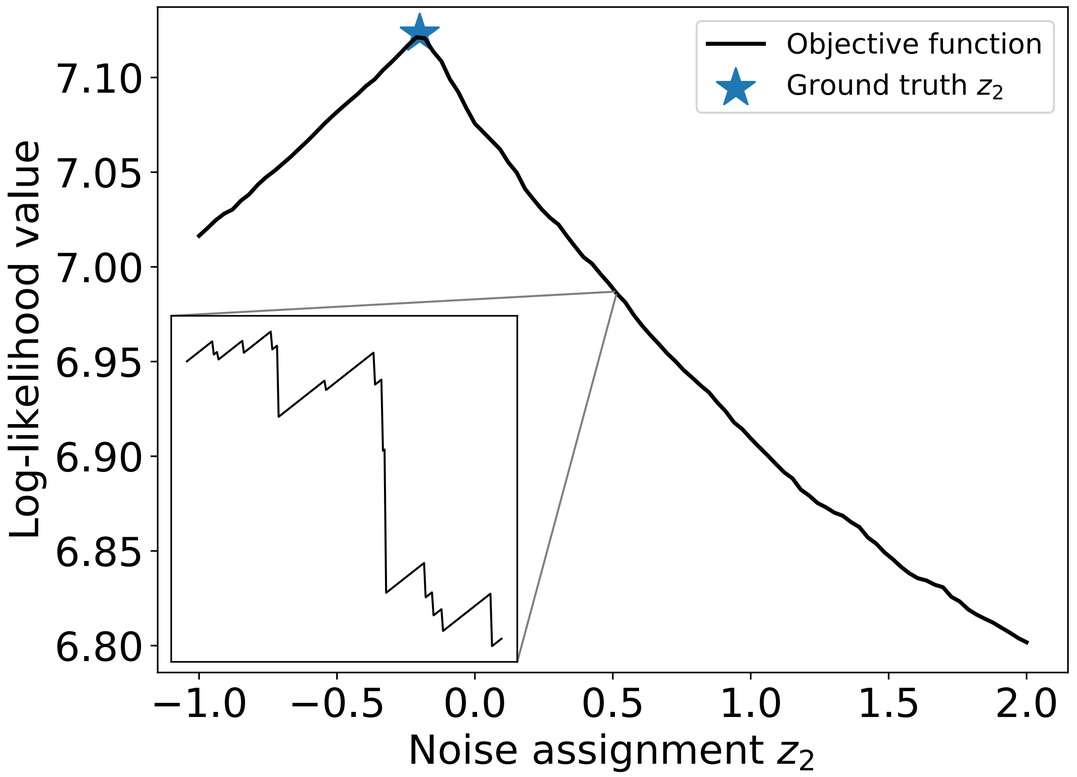
- What it events have **systematic measurement errors**?
- Edges learnt by maximum likelihood estimation can be significantly affected by even small delays





New approach DESYNC-MHP

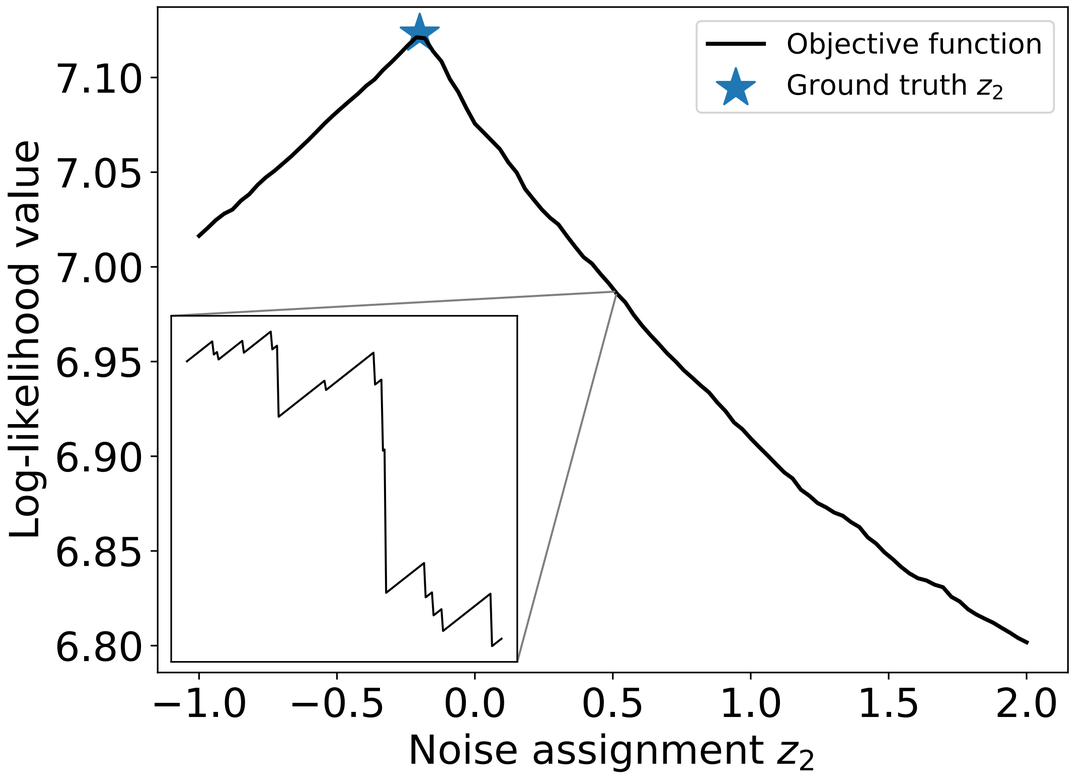
- **Idea:**
  - Consider the noise as parameters
  - Maximize the joint log-likelihood over both MHP parameters and noise



New approach DESYNC-MHP

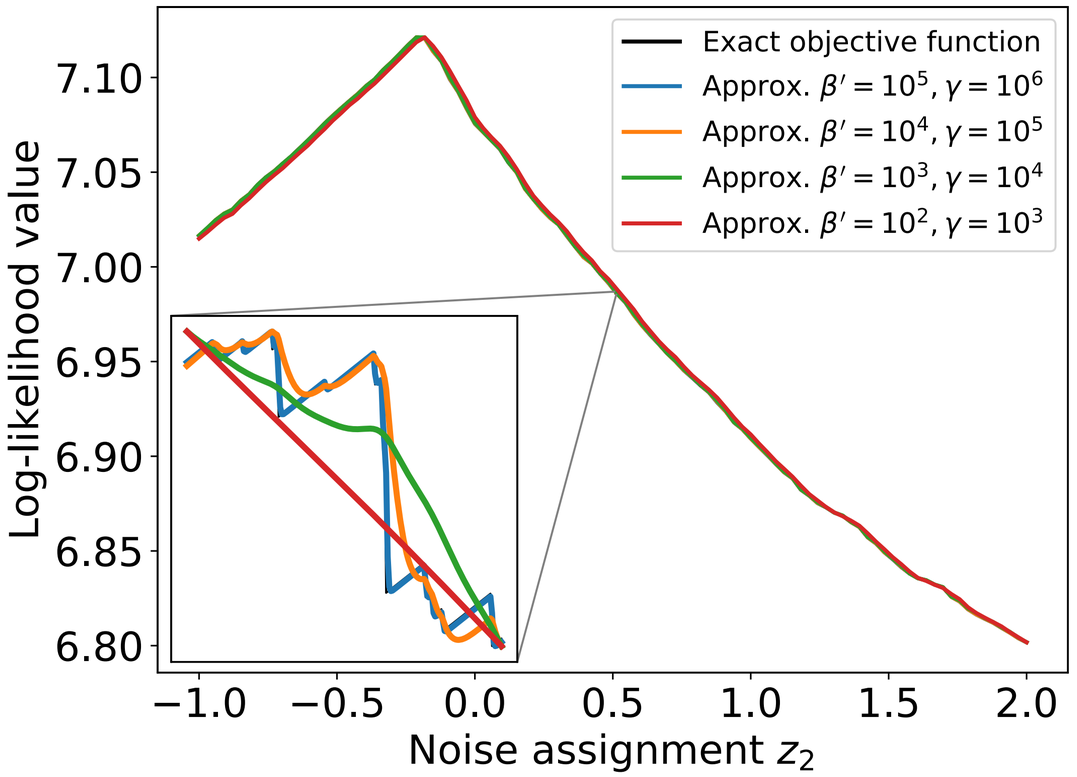
- **Idea:**
  - Consider the noise as parameters
  - Maximize the joint log-likelihood over both MHP parameters and noise

- **Challenges:** resulting objective is
  - Non-smooth
  - Non-convex

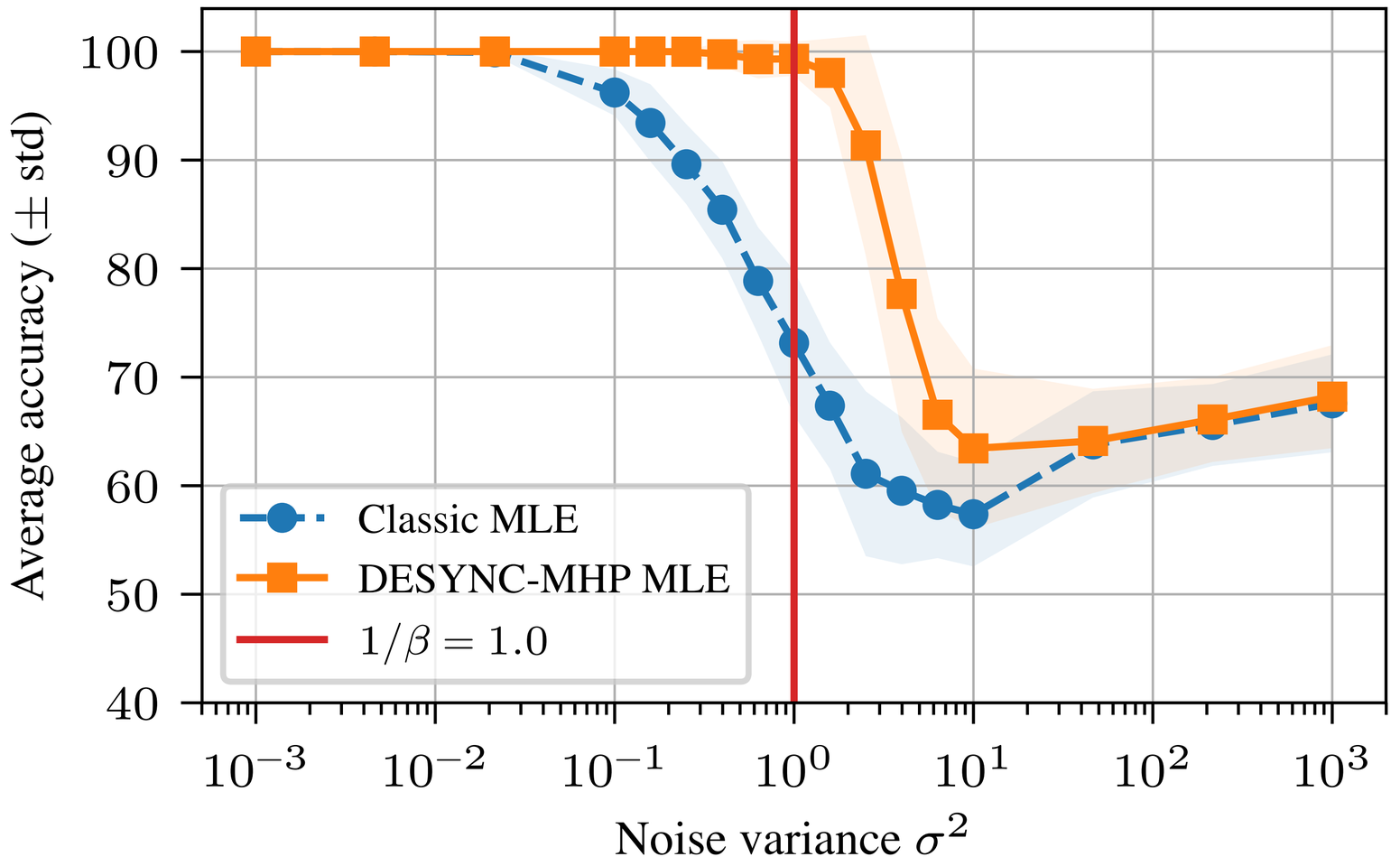


New approach DESYNC-MHP

- **Idea:**
  - Consider the noise as parameters
  - Maximize the joint log-likelihood over both MHP parameters and noise
- **Challenges:** resulting objective is
  - Non-smooth
  - Non-convex
- **Solution:**
  - Approximate the objective with a smooth approximation
  - Use SGD to escape local minima



Experimental Results



Learning Hawkes Processes Under Synchronization Noise

William Trouleau Jalal Etesami Negar Kiyavash
Matthias Grossglauser Patrick Thiran

Come check out our poster tonight !