

Robin Delabays

robin.delabays@hevs.ch

www.DelabaysRobin.site

Hes·so VALAIS
WALLIS



School of Engineering

Locating the Source of Forced Oscillations in Transmission Power Grids

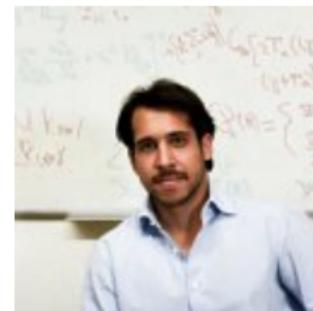
DOI: [10.1103/PRXEnergy.2.023009](https://doi.org/10.1103/PRXEnergy.2.023009)



People



Andrey Lokhov (LANL)



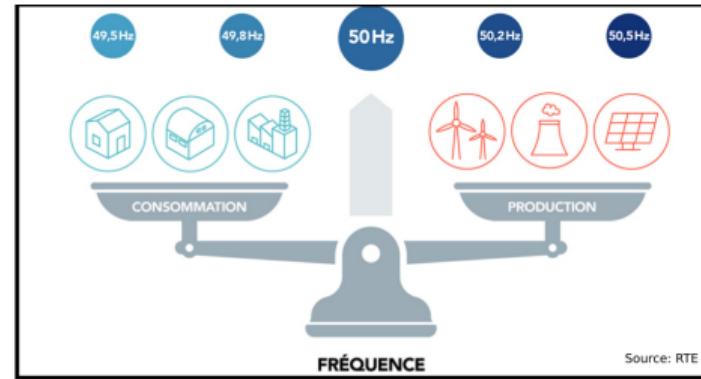
Melvyn Tyloo (LANL)



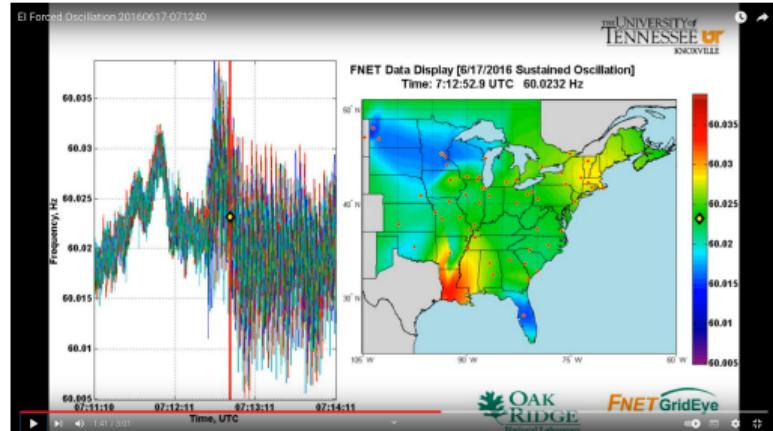
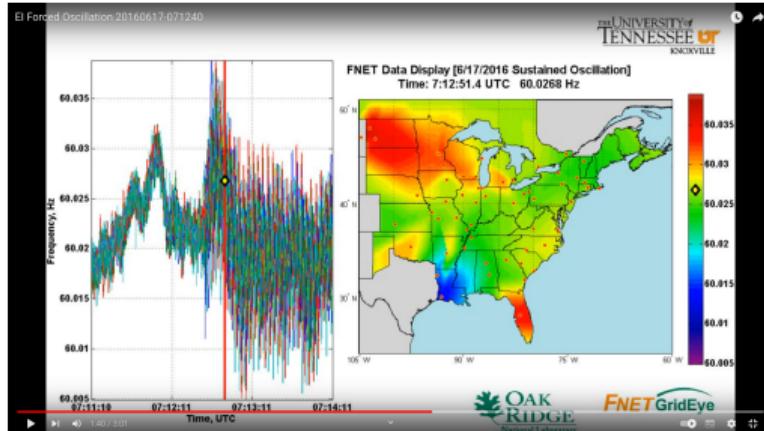
Marc Vuffray (LANL)

Power grid dynamics

$$m_j \ddot{\theta}_j + d_j \dot{\theta}_j = P_{\text{m},j} - P_{\text{e},j} = P_j - \sum_k B_{jk} \sin(\theta_j - \theta_k)$$

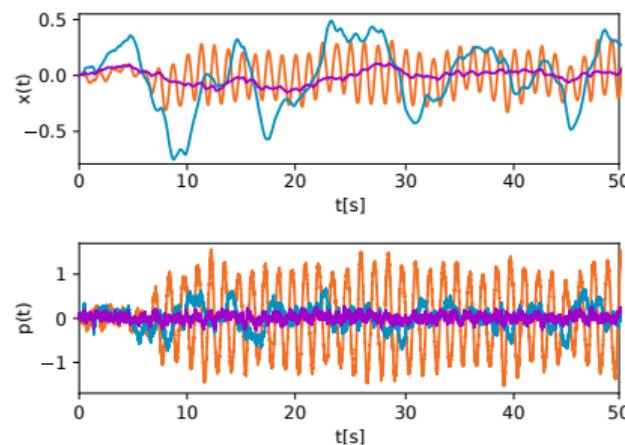
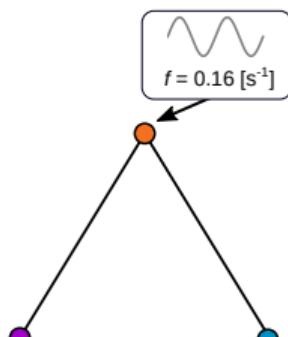


Forced oscillations

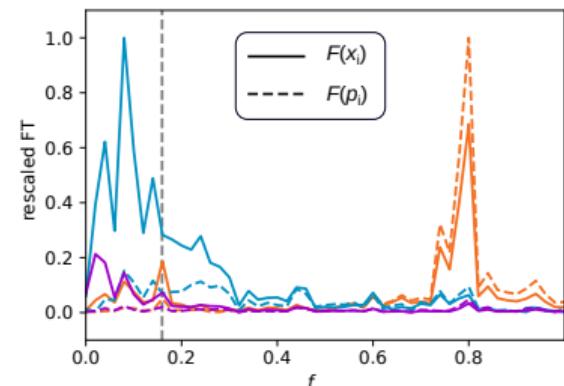
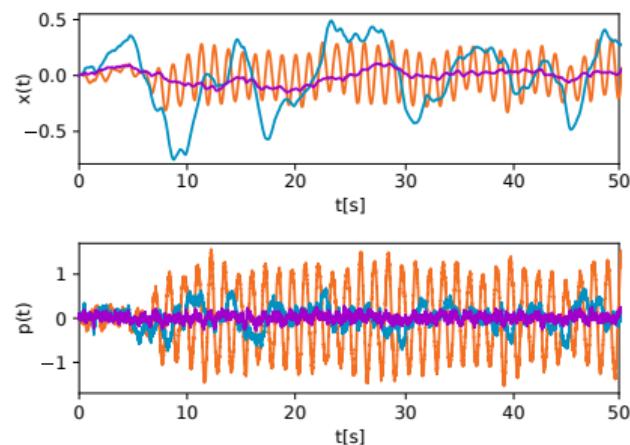
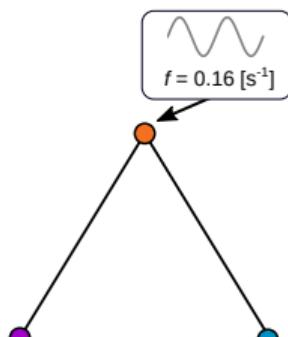


<https://www.youtube.com/watch?v=1vuxZJitEJg>

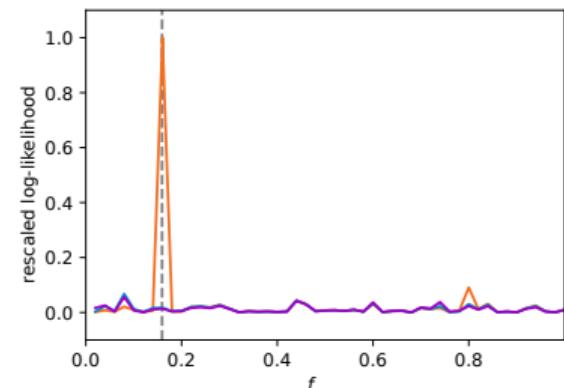
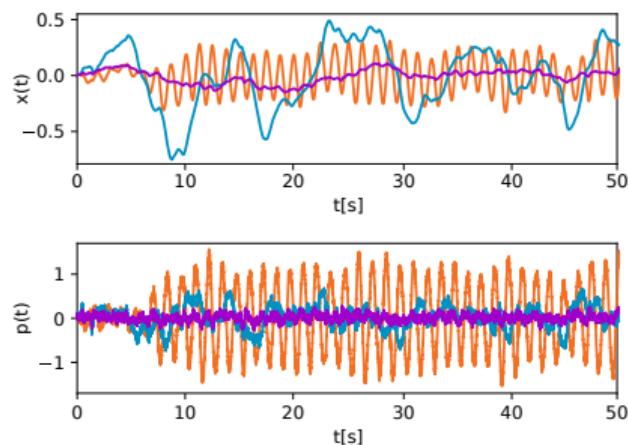
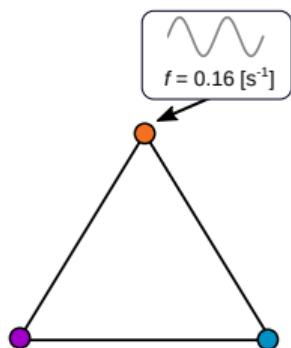
Intuitive (but a bit naive) approach: ...



Intuitive (but a bit naive) approach: the Fourier Transform



Using the SALO algorithm



SALO: System-Agnostic Location of Oscillations

Dynamics: $M\dot{\mathbf{p}} = D\mathbf{p} + B\mathbf{x} + \gamma\mathbf{e}_\ell \cos(2\pi ft + \phi) + \xi$.

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Dynamics: $M\dot{\mathbf{p}} = D\mathbf{p} + B\mathbf{x} + \gamma\mathbf{e}_\ell \cos(2\pi ft + \phi) + \xi$.

Discretized: $\Delta_{t_j} = A\mathbf{X}_{t_j} + \gamma\mathbf{e}_\ell \cos(2\pi kt_j/T + \phi) + \xi_j$.

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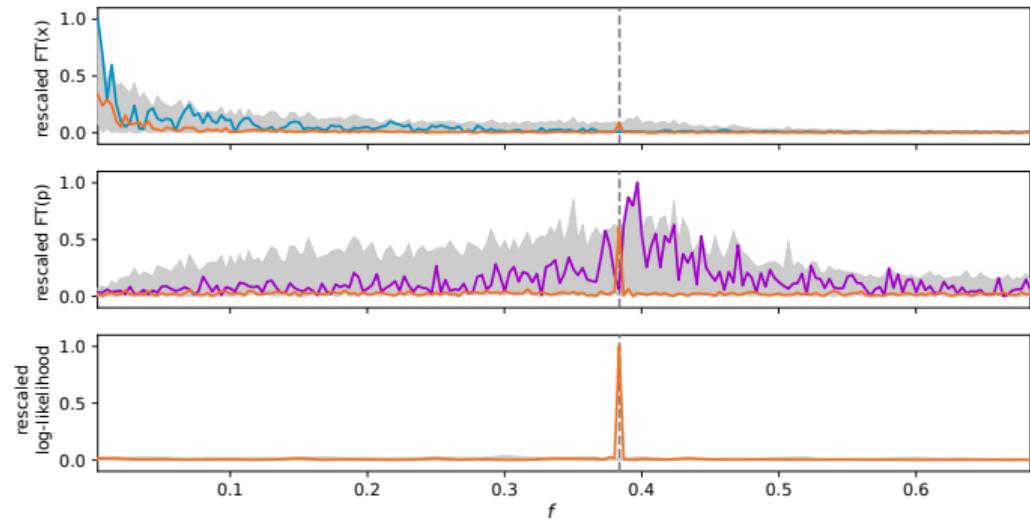
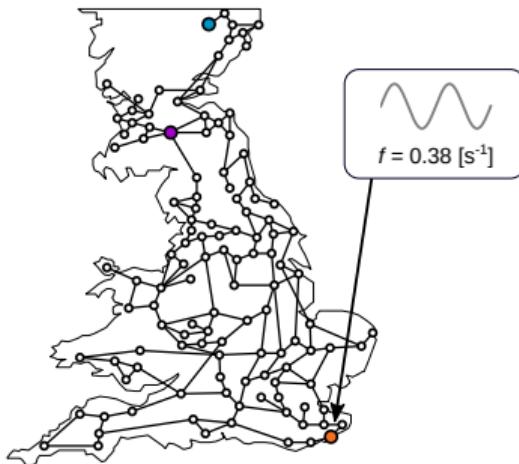
Discretized: $\Delta_{t_j} = A\mathbf{X}_{t_j} + \gamma\mathbf{e}_\ell \cos(2\pi kt_j/T + \phi) + \xi_j$.

Least square error:

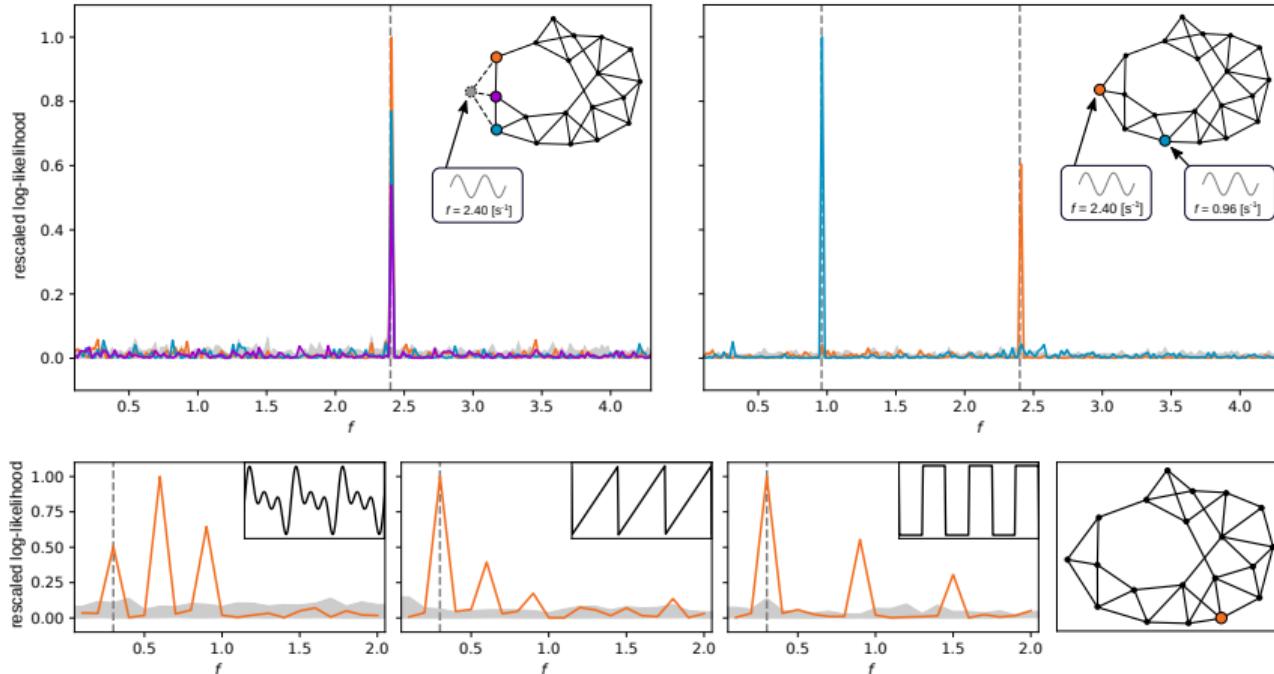
$$\text{SALO: } \arg \min_{A, \gamma, k, \ell, \phi} \sum_{j=0}^{T-1} \|\Delta_{t_j} - A\mathbf{X}_{t_j} - \gamma\mathbf{e}_\ell \cos(2\pi kt_j/T + \phi)\|^2.$$

... and a bit of work.

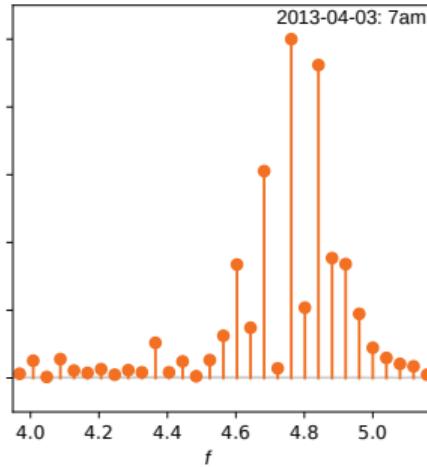
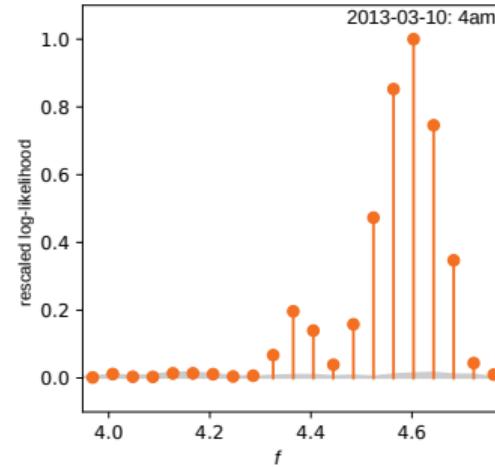
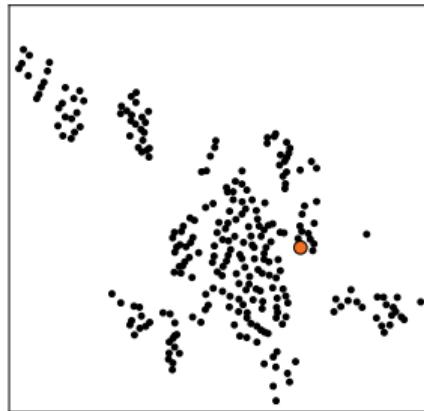
Synthetic data



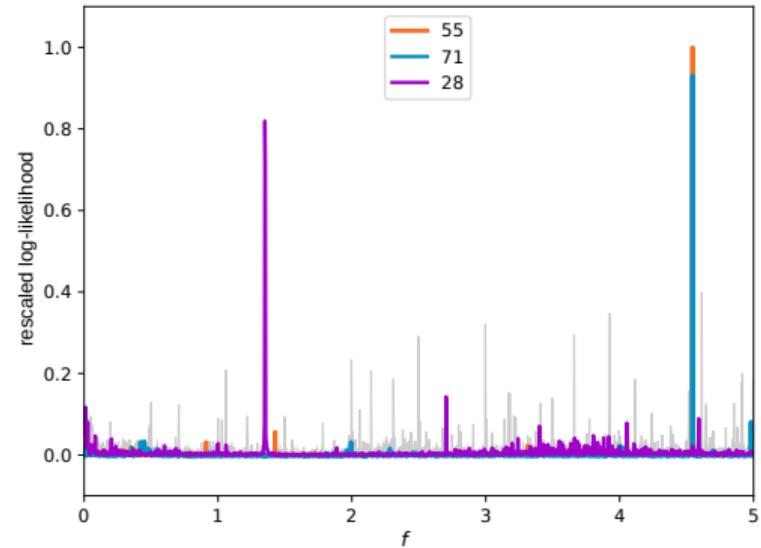
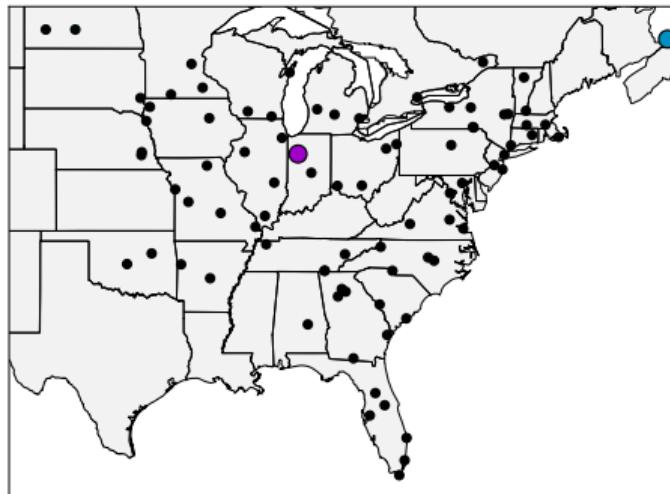
Multiple or hidden sources



Measurement data



Measurement data (bis)



Refinements to SALO

- Relaxation of the amplitude vector:

$$\text{SALO-relax: } \arg \min_{A, \gamma, k, \phi} \sum_{j=0}^{T-1} \|\Delta_{t_j} - A\mathbf{x}_{t_j} - \gamma \cos(2\pi kt_j/T + \phi)\|^2.$$

- Use of prior information.

Refinements to SALO

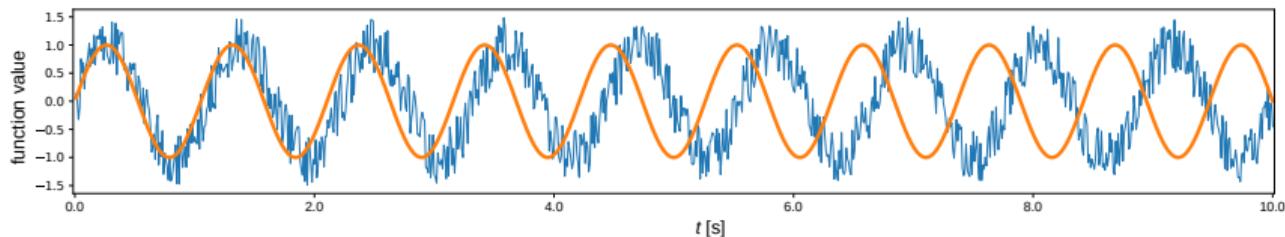
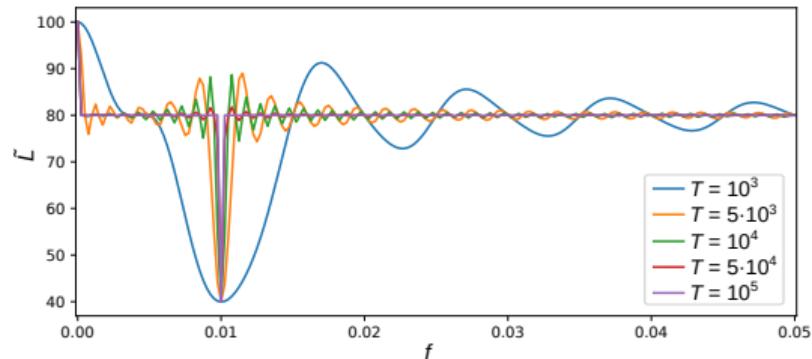
- Relaxation of the amplitude vector:

$$\text{SALO-relax: } \arg \min_{A, \gamma, k, \phi} \sum_{j=0}^{T-1} \|\Delta_{t_j} - A\mathbf{X}_{t_j} - \gamma \cos(2\pi kt_j/T + \phi)\|^2.$$

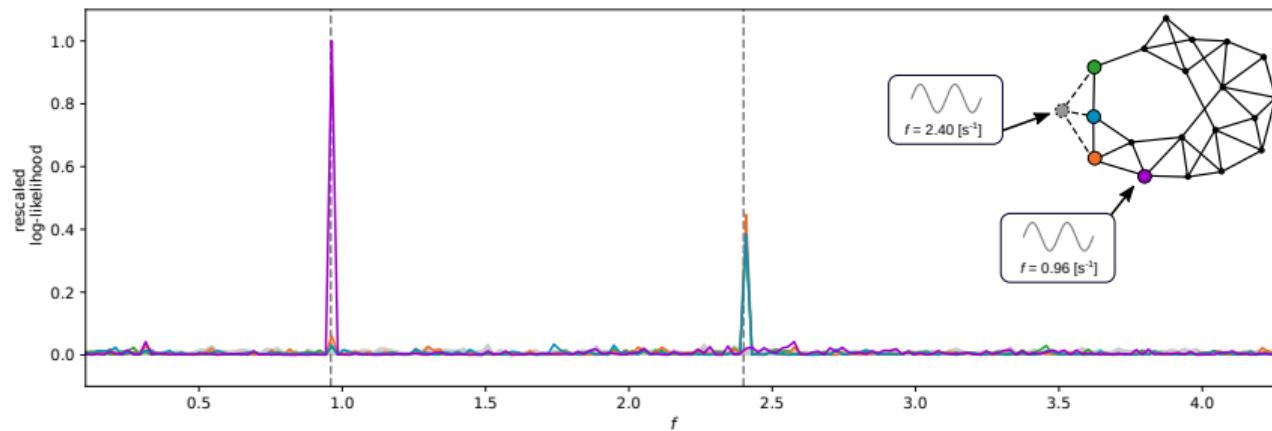
- Use of prior information.

Thank you!

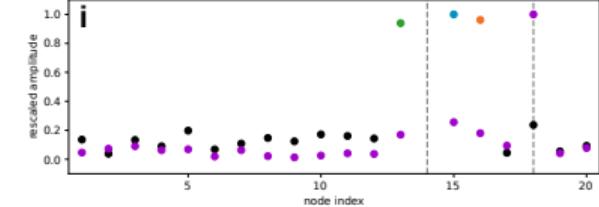
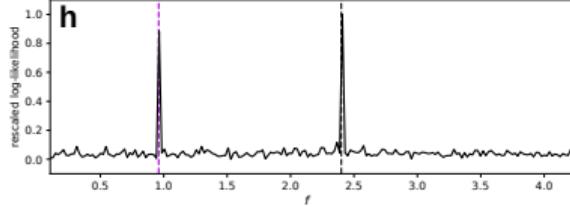
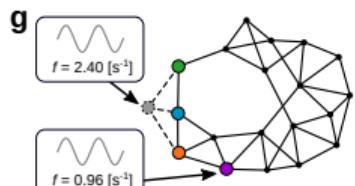
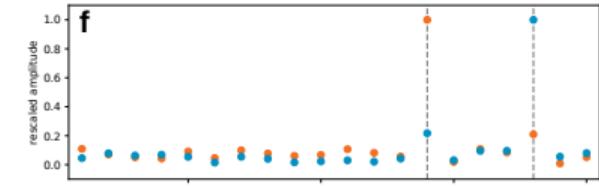
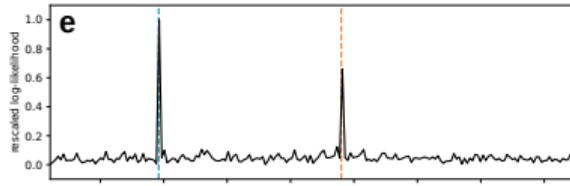
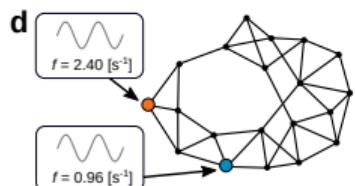
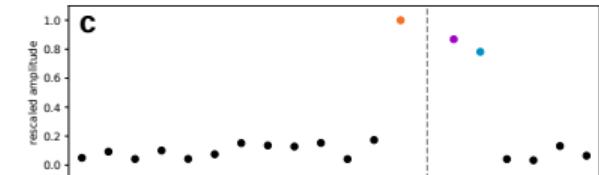
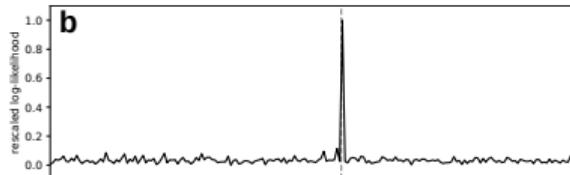
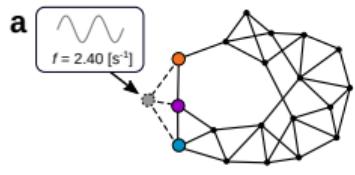
Optimization landscape



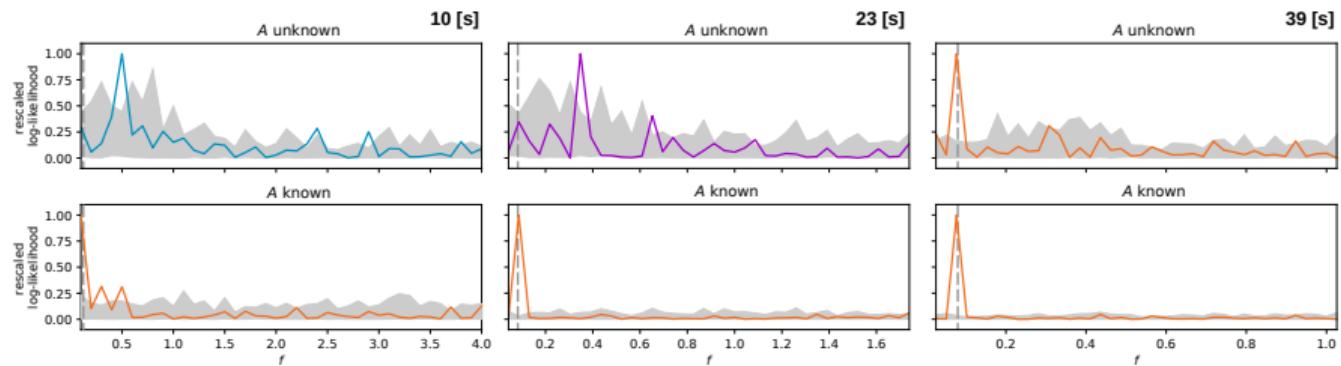
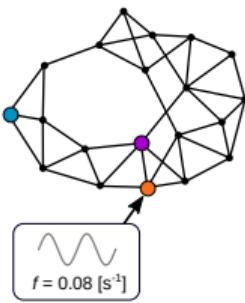
Complex cases



Complex cases



Informed SALO



Informed SALO-relax

