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Force-based Layout of Non-Markovian Temporal Networks

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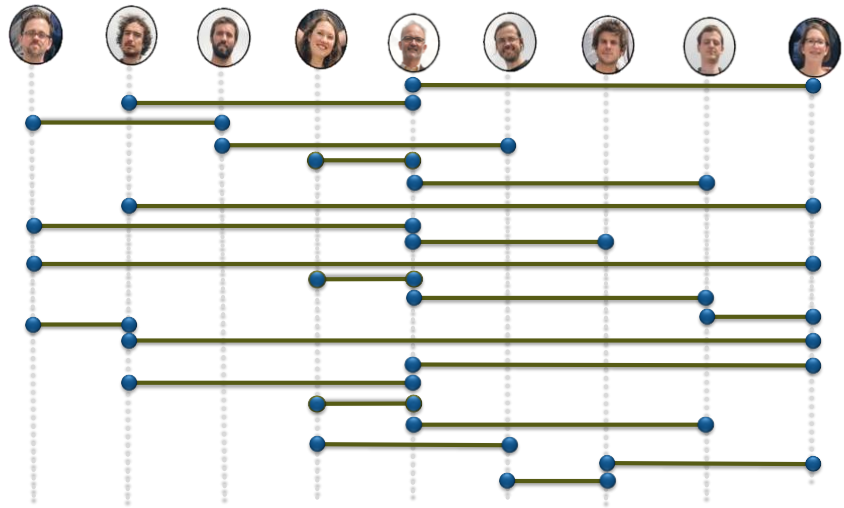

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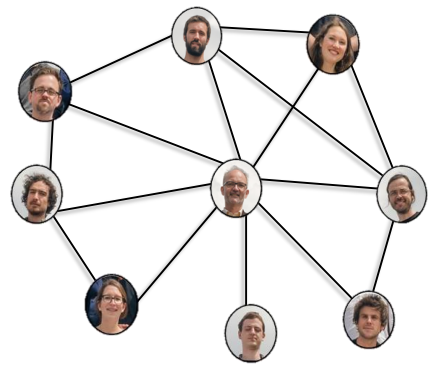
An aggregated perspective



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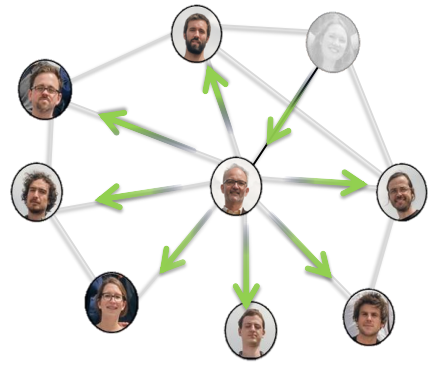
The fallacy of transitivity



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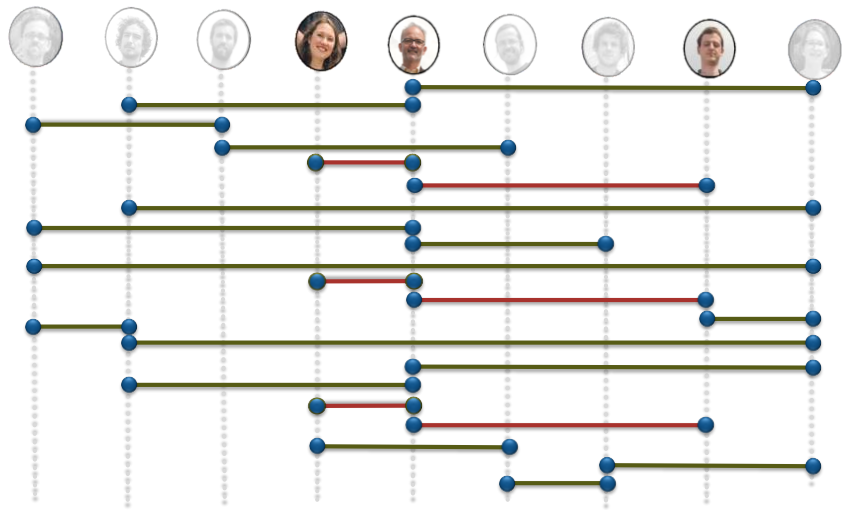
The time dimension



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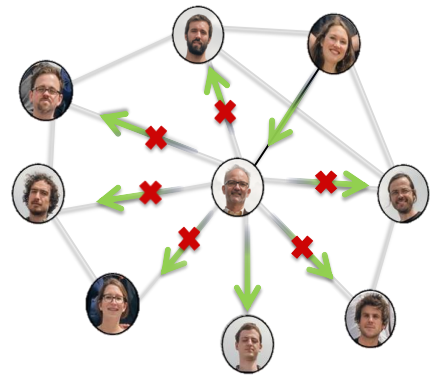
Finding



Real-world temporal networks are not Markovian!

R Pfitzner, I Scholtes, A Garas, CJ Tessone, F Schweitzer: **Betweenness Preference: Quantifying Correlations in the Topological Dynamics of Temporal Networks,** Phys. Rev. Let., Vol. 110, 198701, May 10 2013

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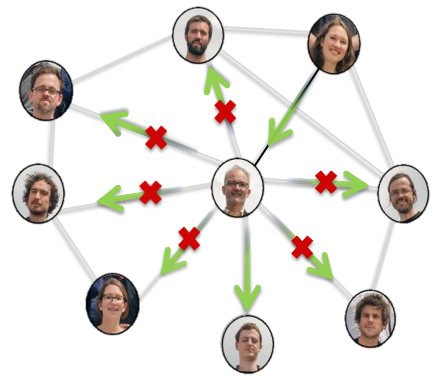
Finding



Aggregate networks are poor representations of dynamic (social) systems!

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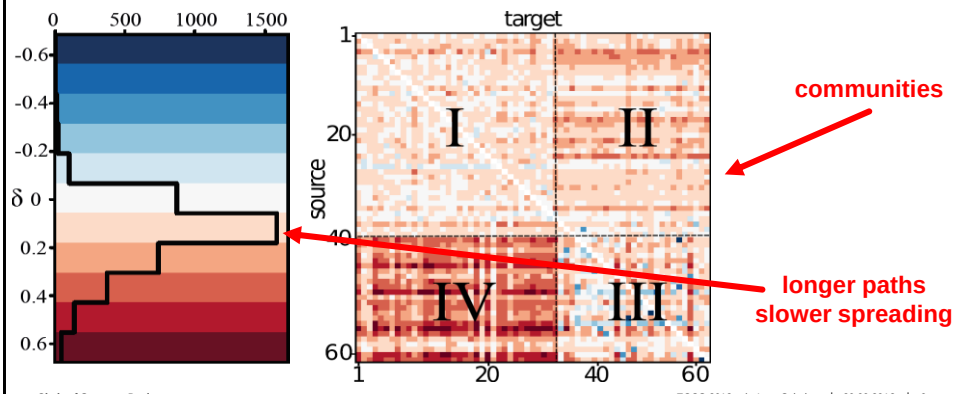
Effects on dynamical processes

Q: How much longer are paths compared to the aggregate network?



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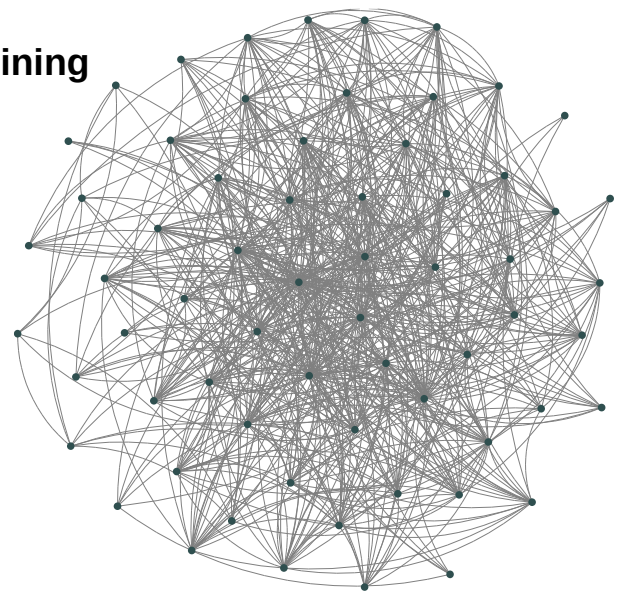
MIT Reality Mining



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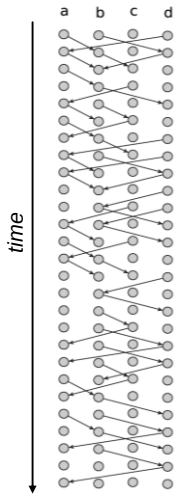
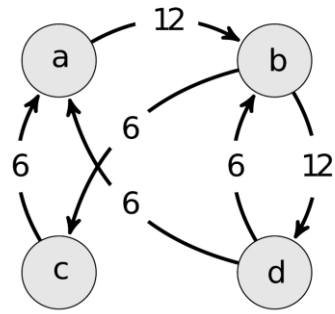
Aggregate networks



$G^{(1)}$



Does not capture non-Markovian dynamics
„False“ transitivity
No reasonable spectral analysis

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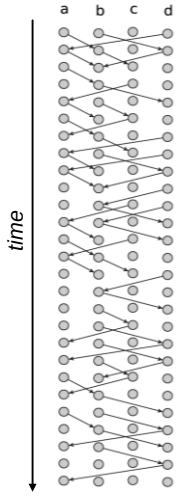
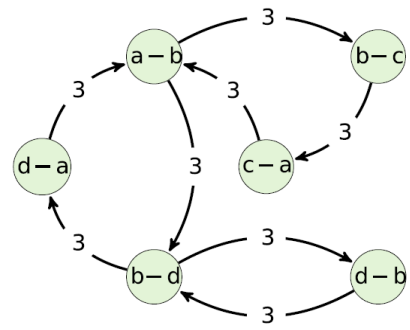
Second-order aggregate networks



$G^{(2)}$



State-space expansion
Transitivity holds!
Spectral analysis of temporal networks

I Scholtes, N Wider, R Pfitzner, A Garas, CJ Tessone, F Schweitzer: **Slow-Down vs. Speed-Up of Information Diffusion in Non-Markovian Temporal Networks,** arXiv:1307.4030, July 15 2013

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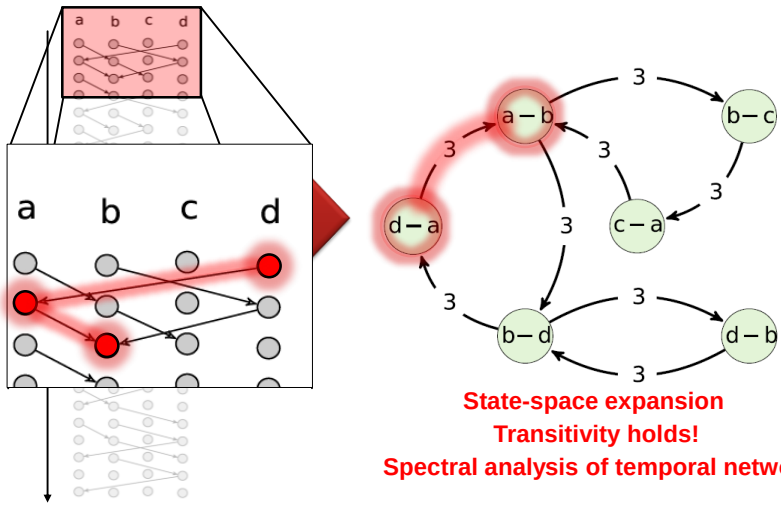
Second-order aggregate networks



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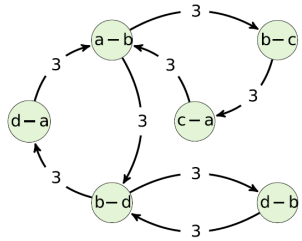
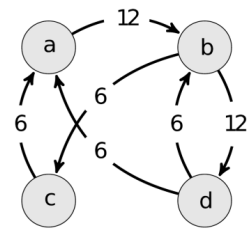
Spectra of dynamic networks



$\lambda_1 = 1$
$\lambda_2 = 0.873$
$\lambda_3 = 0.873$
$\lambda_4 = 0.61$
$\lambda_5 = 0.54$
$\lambda_6 = 0$



$\lambda_1 = 1$
$\lambda_2 = 0.816$
$\lambda_3 = 0.816$
$\lambda_4 = 0$
$\lambda_5 = 0$
$\lambda_6 = 0$

I Scholtes, N Wider, R Pfitzner, A Garas, CJ Tessone, F Schweitzer: **Slow-Down vs. Speed-Up of Information Diffusion in Non-Markovian Temporal Networks,** arXiv:1307.4030, July 15 2013

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Spectra of dynamic networks

$$\begin{pmatrix} 0 & \frac{1}{2} & \frac{1}{2} & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{2} & \frac{1}{2} \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \end{pmatrix} \qquad \begin{pmatrix} 0 & \frac{1}{3} & \frac{2}{3} & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{2} & \frac{1}{2} \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{1}{3} & \frac{2}{3} & 0 & 0 & 0 \end{pmatrix}$$

$\lambda_1 = 1$
$\lambda_2 = 0.873$
$\lambda_3 = 0.873$
$\lambda_4 = 0.61$
$\lambda_5 = 0.54$
$\lambda_6 = 0$

$S^* = 1.44$

Slow-down factor

>1 → slow-down
<1 → speed-up

$\lambda_1 = 1$
$\lambda_2 = 0.816$
$\lambda_3 = 0.816$
$\lambda_4 = 0$
$\lambda_5 = 0$
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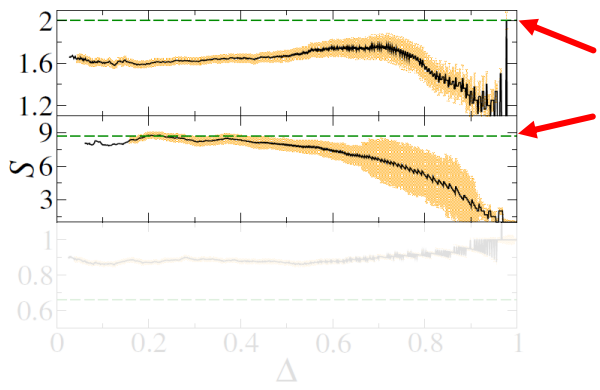
Slow-down of information diffusion



maximum slow-down

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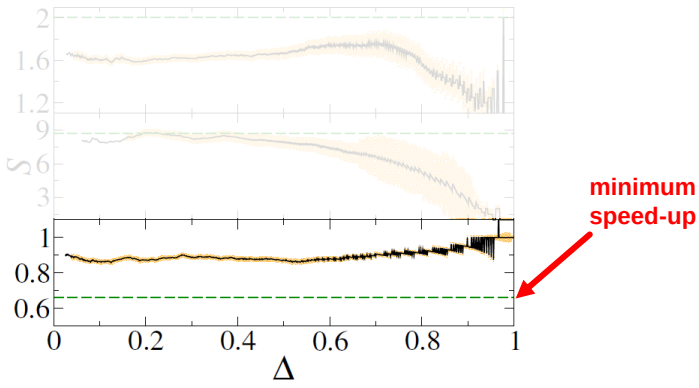
Speed-up of information diffusion



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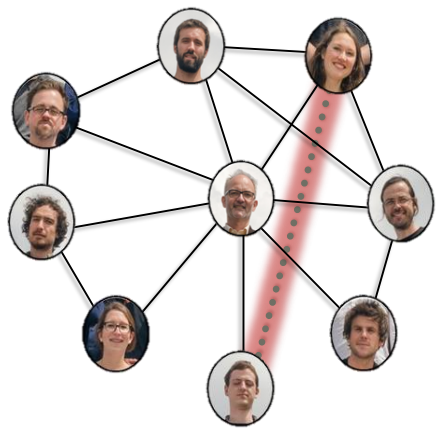
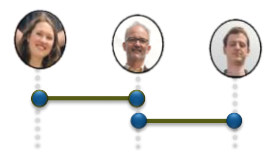
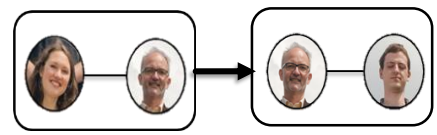
Force-based layout of temporal networks





2nd order aggregate network



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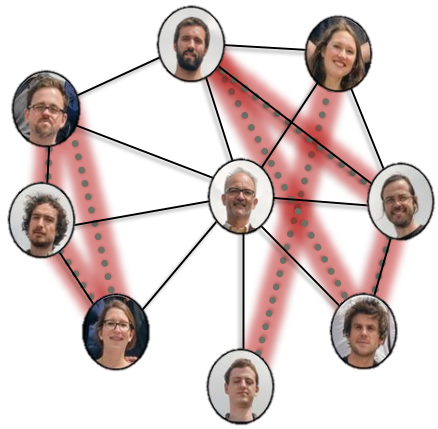
Force-based layout of temporal networks



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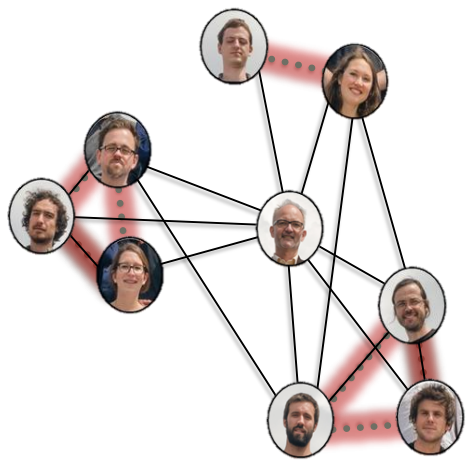
Causality-preserving layout



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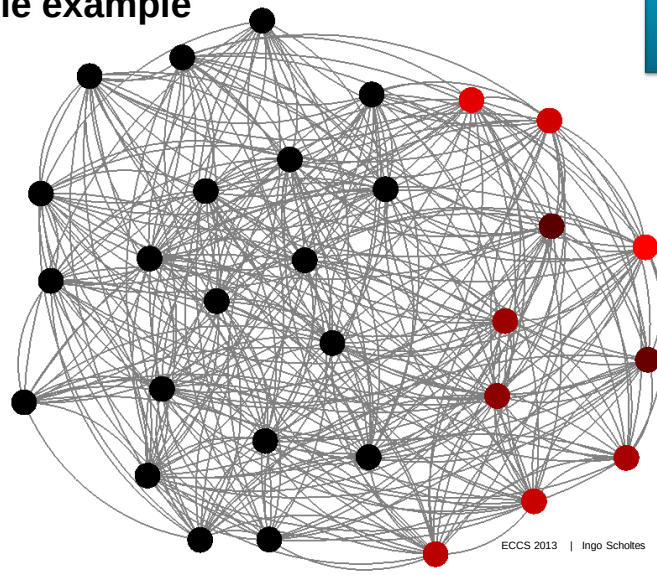
A simple example



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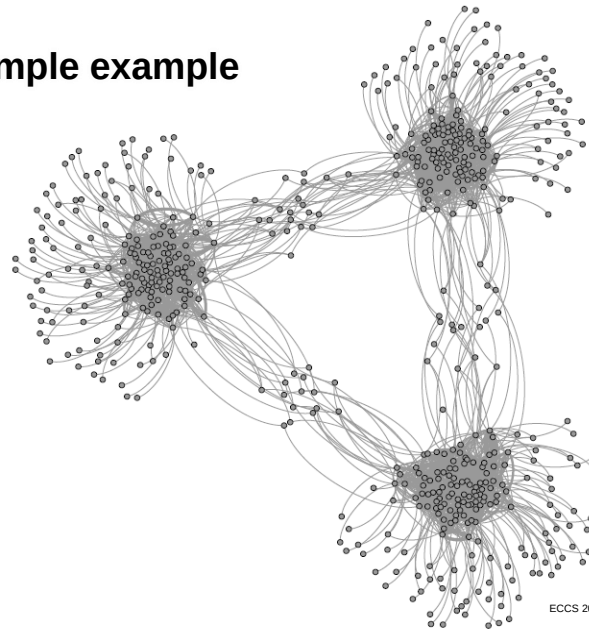
A simple example



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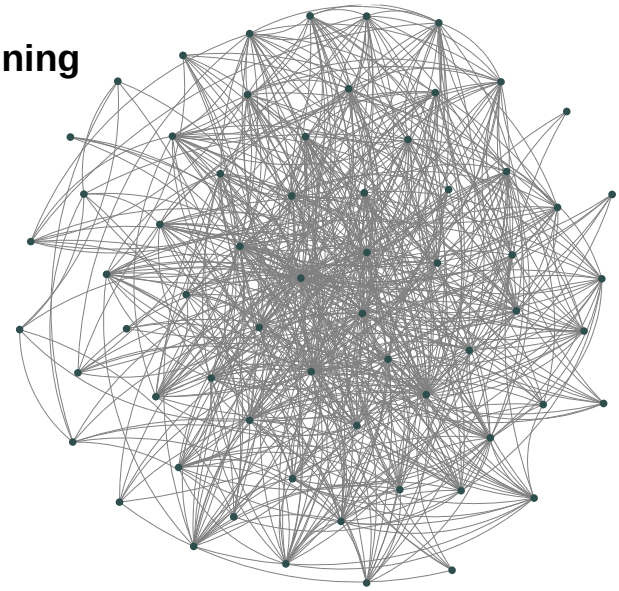
MIT RealityMining



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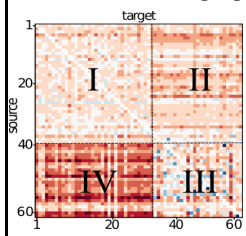
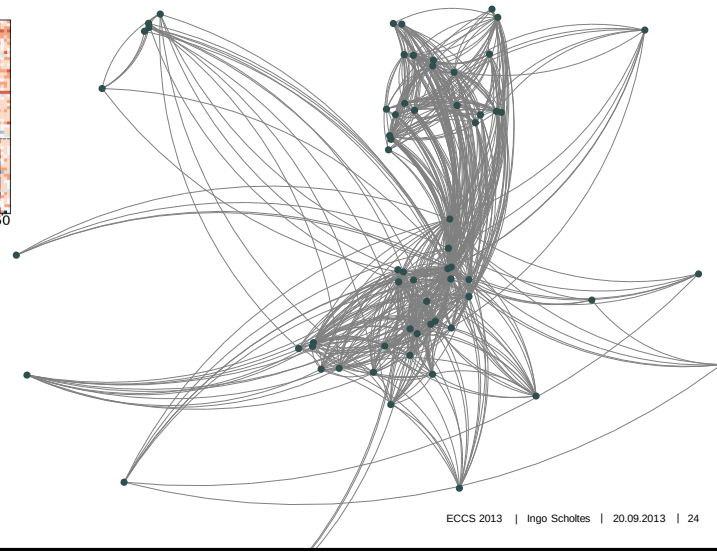
Causality-preserving layout





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Thank you!

R Pfitzner, I Scholtes, A Garas, CJ Tessone, F Schweitzer: **Betweenness Preference: Quantifying Correlations in the Topological Dynamics of Temporal Networks,** Physical Review Letters, Vol. 110, 198701, May 10 2013

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