Characterizing social information spreading by using event synchronization and causality measures

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MS Network Perturbations
Dynamics Days Europe
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UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH
Campus d'Excel·lència Internacional

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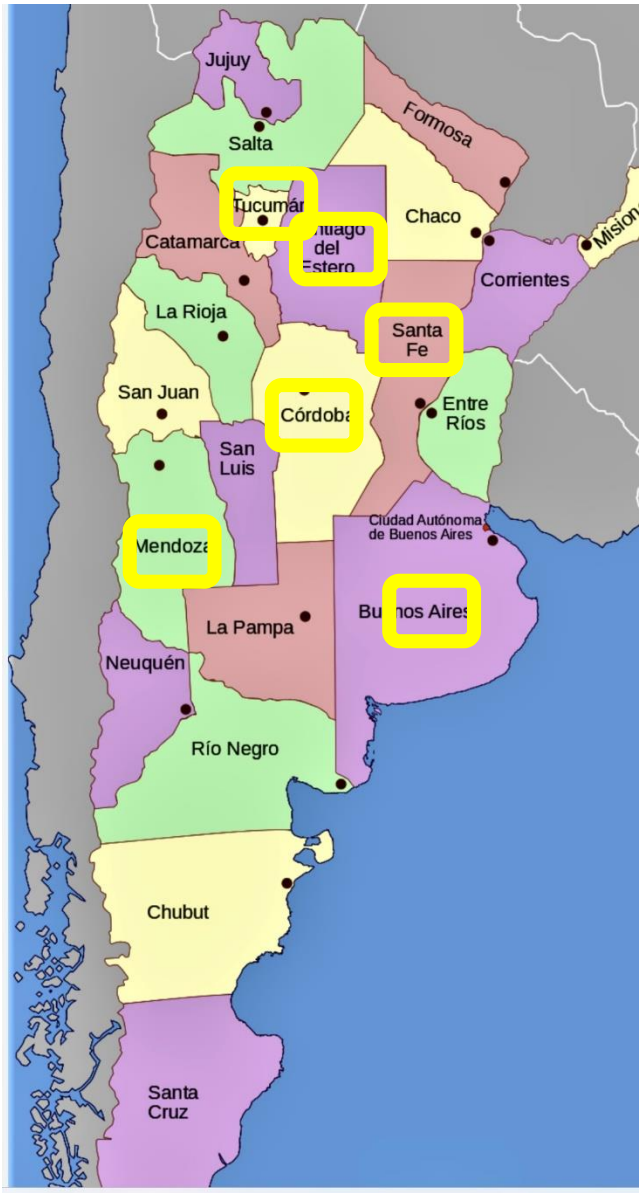
Diffusion of information in Argentina

- Six observed “nodes”:
  - Buenos Aires
  - Cordoba
  - Tucuman
  - Mendoza
  - Santa Fe
  - Santiago del Estero



- “Perturbation output”:
  # of articles in the press
  (20 topics)

Reunión en Tucumán

Gobernadores del norte reclamaron por la falta de gasoil

Fue durante la 10ª reunión del Consejo de la región Norte Grande. Por parte del Gobierno nacional, Juan Manzur amenazó que caerán “con todo el peso de la ley” sobre quienes alteren los valores del combustible.

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Data analyzed

Presentan un proyecto de ley para "garantizar el abastecimiento de combustible líquido"

Política *30 de mayo de 2022* *Por LPTV*

El proyecto impulsado por el legislador Berarducci y acompañado por el bloque del PJS apunta a solucionar una de las crisis que aqueja al sector productivo.

Sergio Berni se cruzó con los transportistas en la autopista La Plata-Buenos Aires y lanzó una advertencia: "Tienen 5 minutos o me llevo los camiones"

"¿Vas a seguir haciendo show?", le preguntó el ministro de Seguridad bonaerense al líder de la protesta, antes de levantar el corte con la Policía; se quejaban por la falta de gasoil

Paro de transportistas: "Una protesta pacífica, a la orilla de la ruta"

Eduardo Reinoso, presidente de la ATCT, dijo que no habrá cortes durante la movilización. El PE pidió actuar preventivamente a la Justicia

- 28000 news articles published in Argentina in the selected six main cities.
- 4 months (26/05/2022 - 26/09/2022).
- We used an unsupervised non-negative matrix factorization algorithm to classify the articles in 20 non-orthogonal topics.

S. Pinto, F. Albanese, C. O. Dorso, and P. Balenzuela. *Quantifying time-dependent media agenda and public opinion by topic modeling*. Physica A, 524:614, 2019

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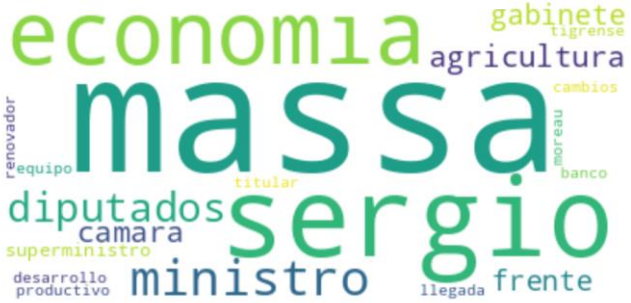
Examples of topics

Alberto Fernandez

Avion Irani

Sergio Massa



Sabag Montiel

Diego Luciani

Silvina Batakis

Cristina Kirchner

Inflacion

Dolar

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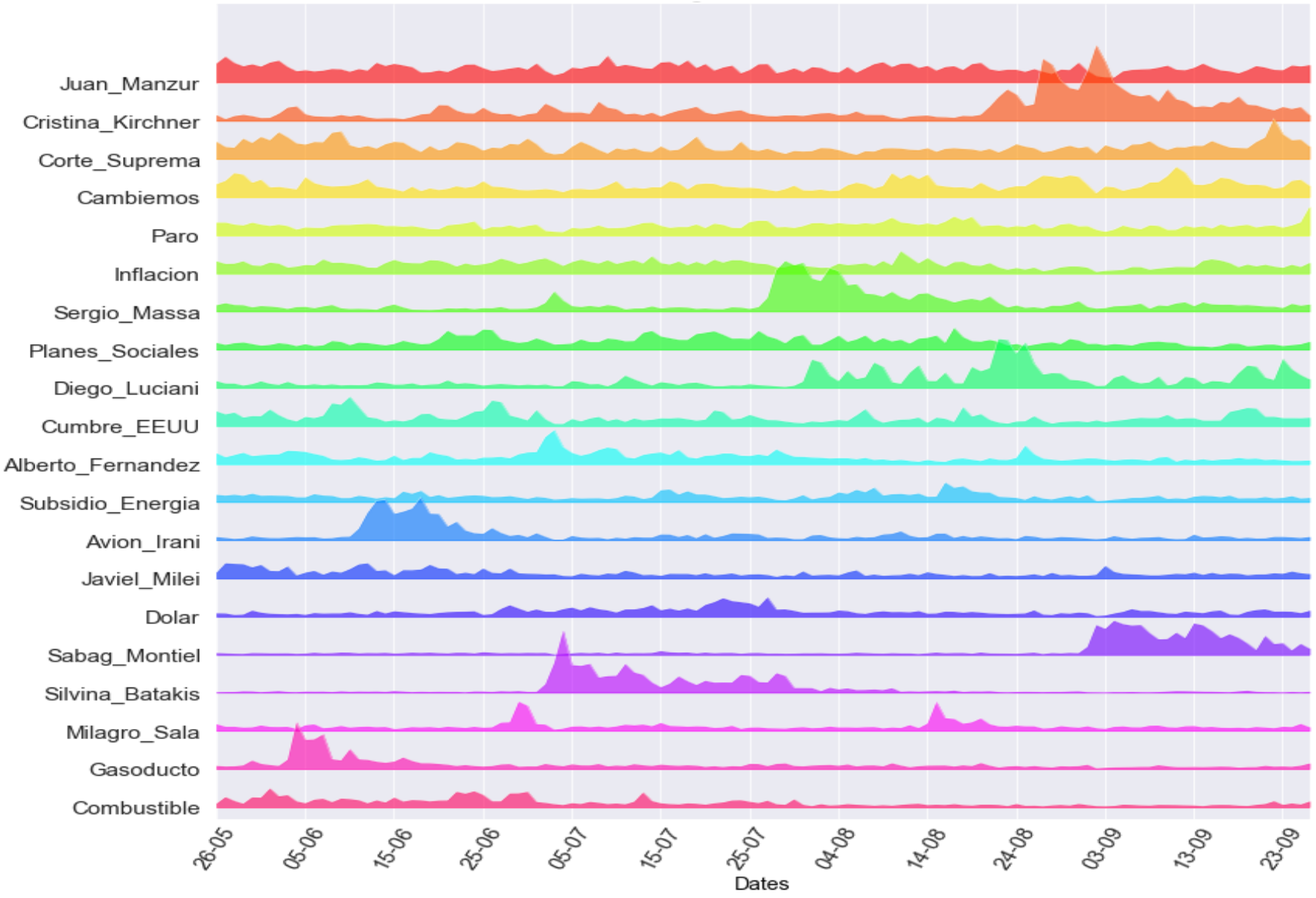
We obtain a time series for each topic, by adding the total number of articles per day.



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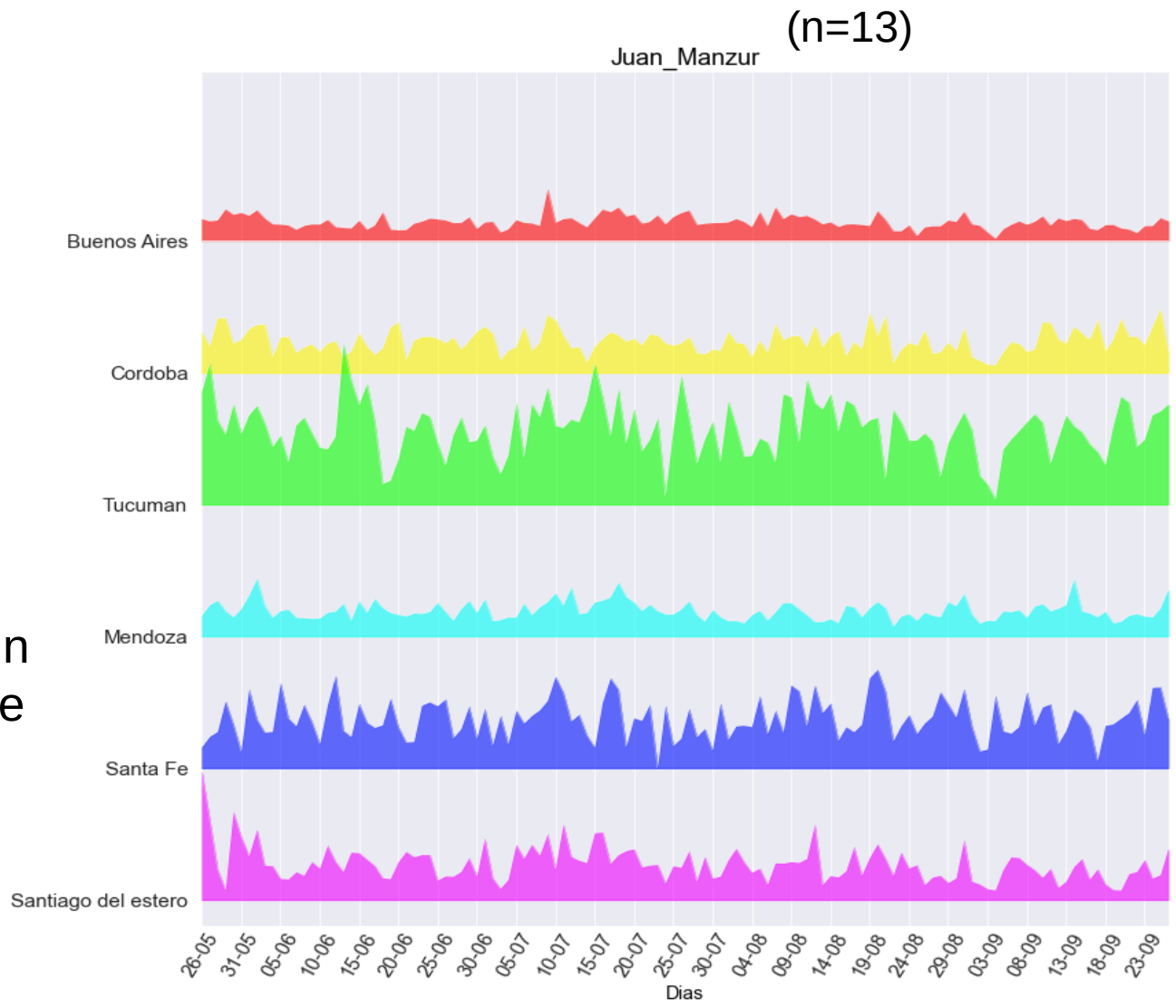
We also obtain a time series for each topic in each city

$x_{n,i}(t)$

n=topic
i = city
t = time

Normalized such that in each city, each day, the total “attention” is 1:

$$\sum_{n} x_{n,i}(t) = 1$$



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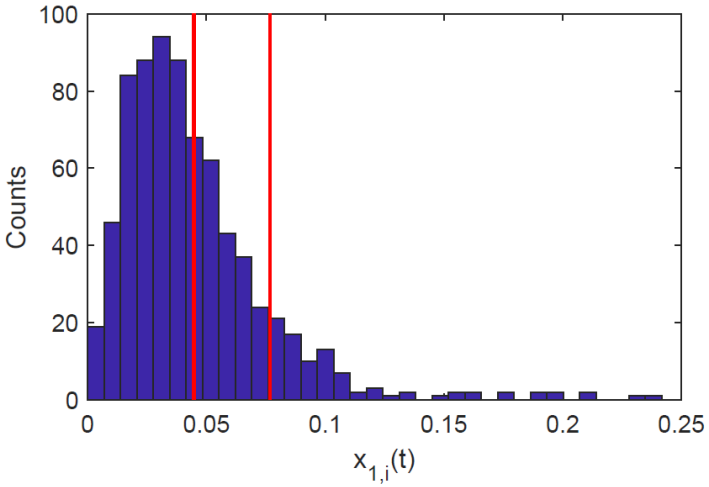
To define "events" in a time series we use two thresholds

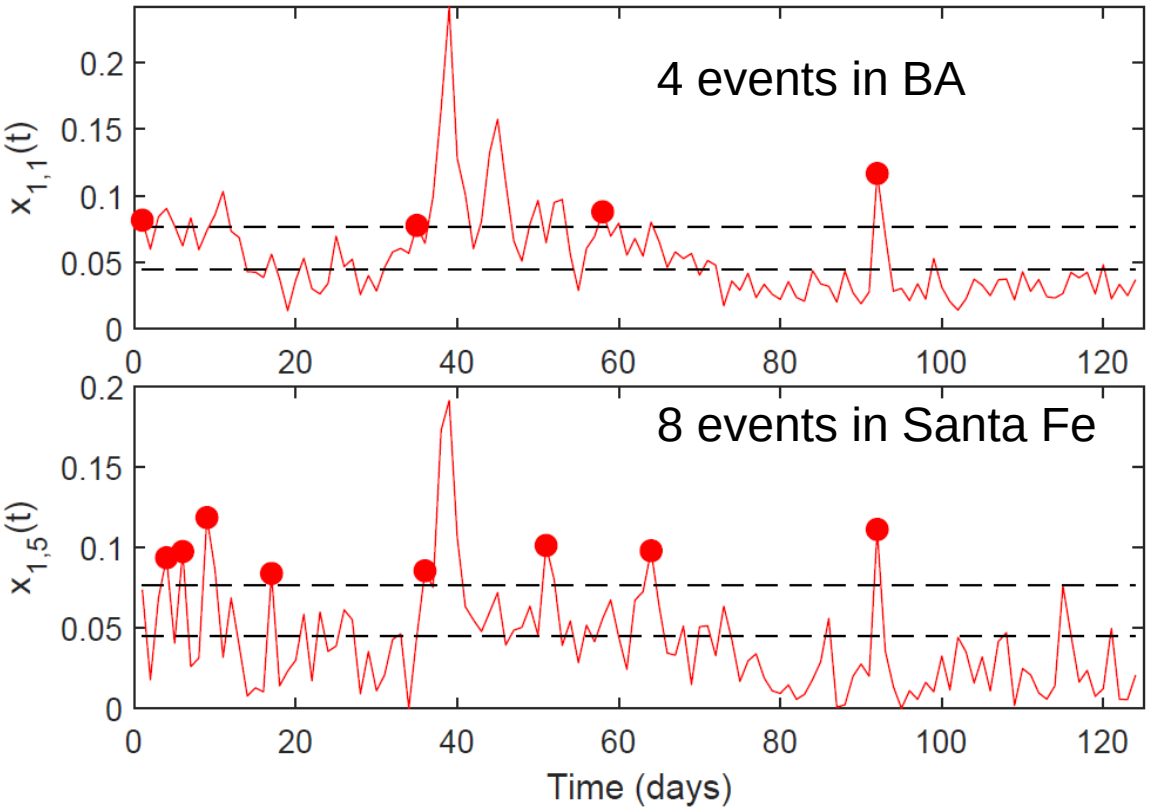
$TH1(n)=\mu(n)=\langle x_{n,i}(t)\rangle_{i,t}$, $TH2(n)=\mu(n)+\sigma(n)$

Example: topic #1 "*Alberto Fernandez*"

Histogram of $x_{1,i}(t)$

All cities, all times





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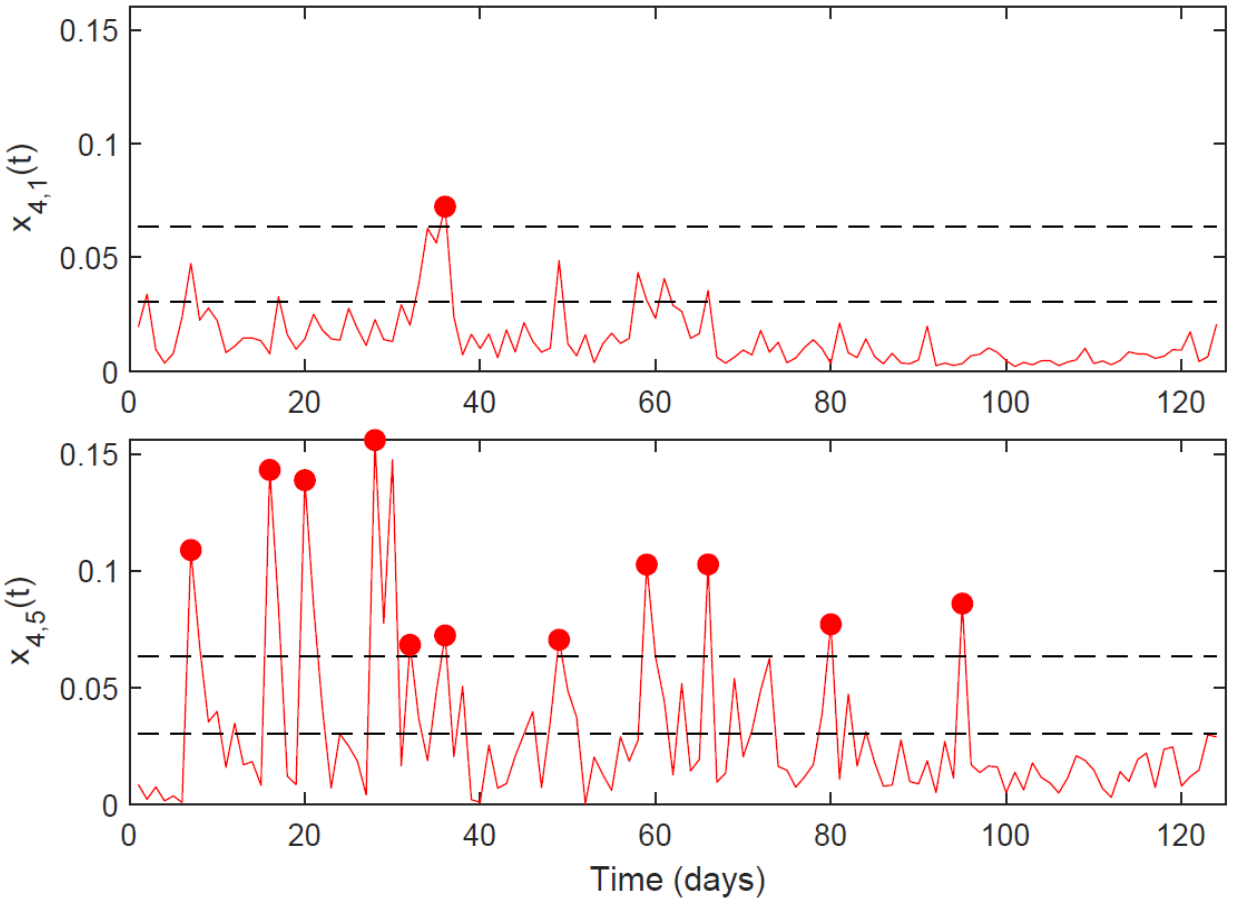
Example: topic *Combustible (n=4)*

1 event in BA

11 events in Santa Fe



- How to find “synchronized events”?
- How to detect when an event (a “perturbation”) in a city propagates and causes events in other cities?

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Event synchronization measures

- Count $c^{\tau}(x|y)$ = number of times an event appears in *x(t)* shortly after (within interval **τ=3 days**) an event appears in *y(t).* Idem for $c^{\tau}(y|x)$. Synchronized events count ½.
- Calculate:

$$Qs = 2[c^{\tau}(x|y) + c^{\tau}(y|x)] / [m_x+m_y]$$

$$Qa = 2[c^{\tau}(x|y) - c^{\tau}(y|x)] / [m_x+m_y]$$

m_x, m_y are the number of events in *x(t)* and *y(t)*.

- Q_s = 1 : the events of the signals are fully synchronized.
- q_a =1 : the events in *x* always occur before those in *y*.
- q_a = -1 : the events in *x* always occur after those in *y*.

No “causal” information

Quian Quiroga et al, PRE 66, 041904 (2002).

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Side note

Chaos ARTICLE pubs.aip.org/aip/cha

Quantifying the synchronization of the spikes emitted by coupled lasers

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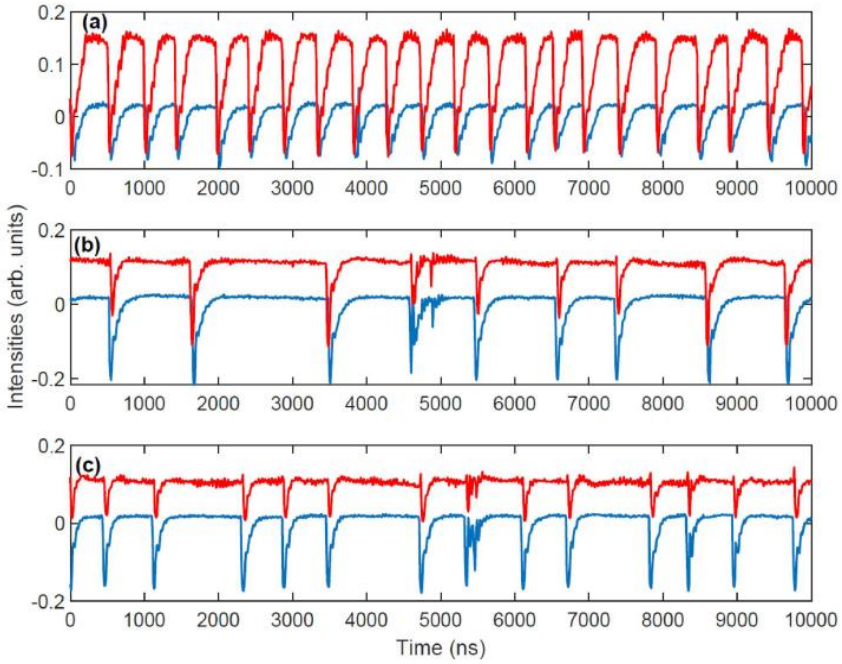

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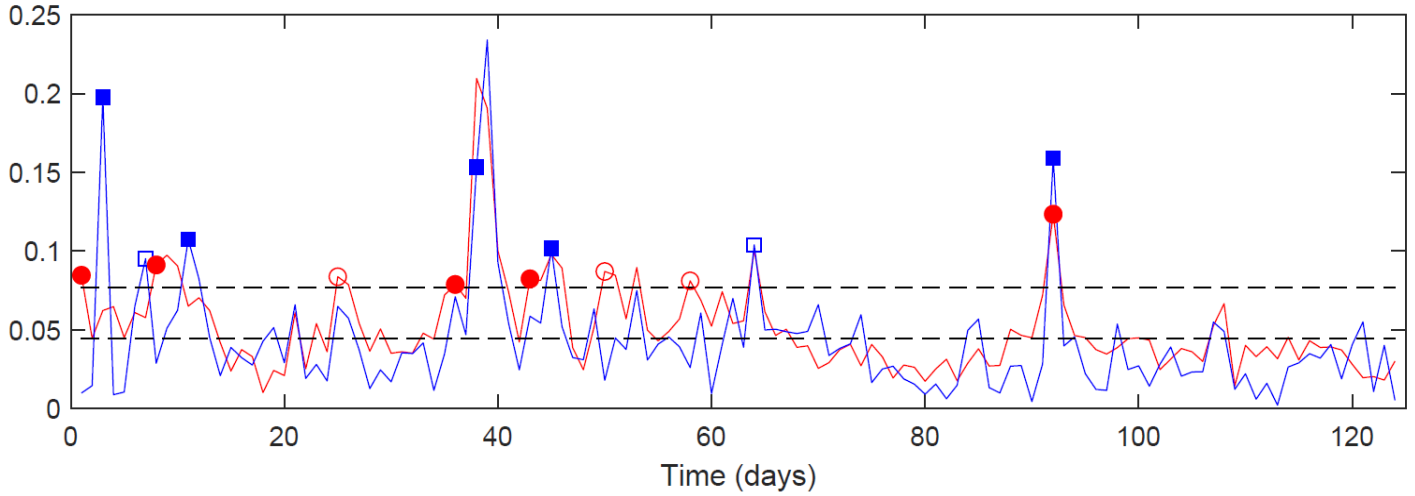
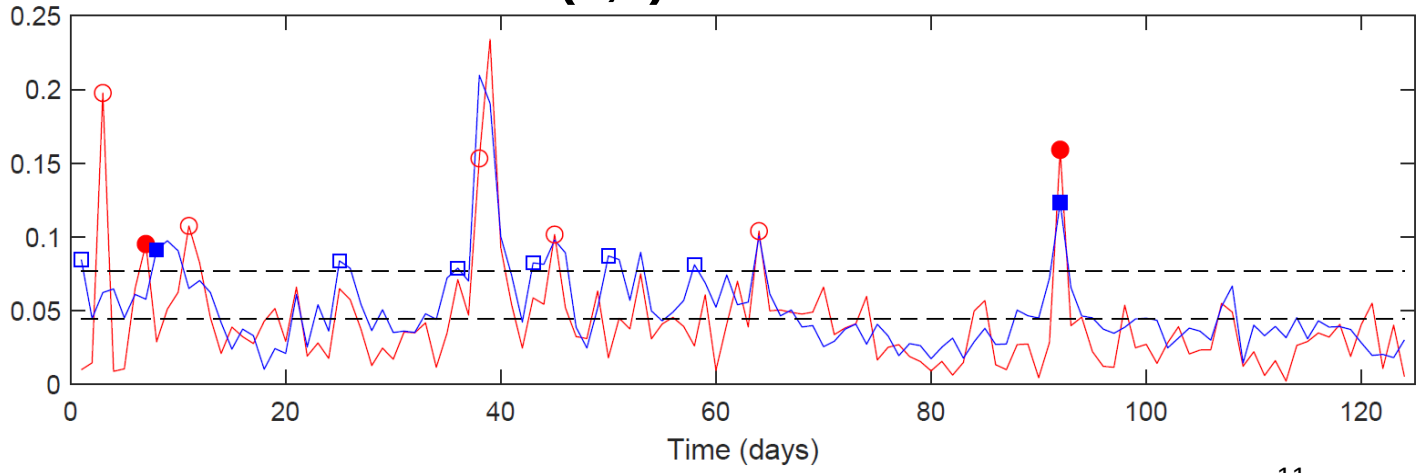
Example: topic "*Alberto Fernandez*" (n=1)

Mendoza → Santiago del Estero C(4,6)=4.5



Santiago del Estero → Mendoza C(6,4)=1.5



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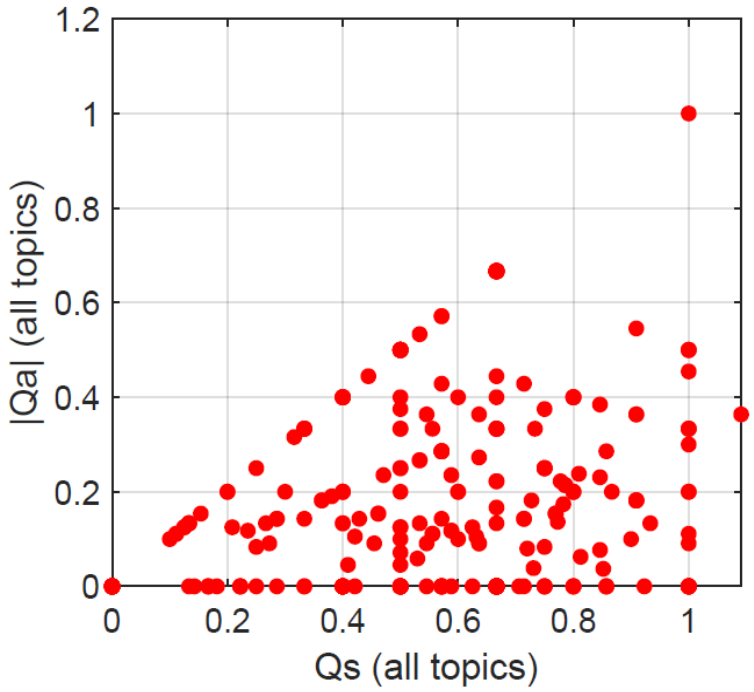
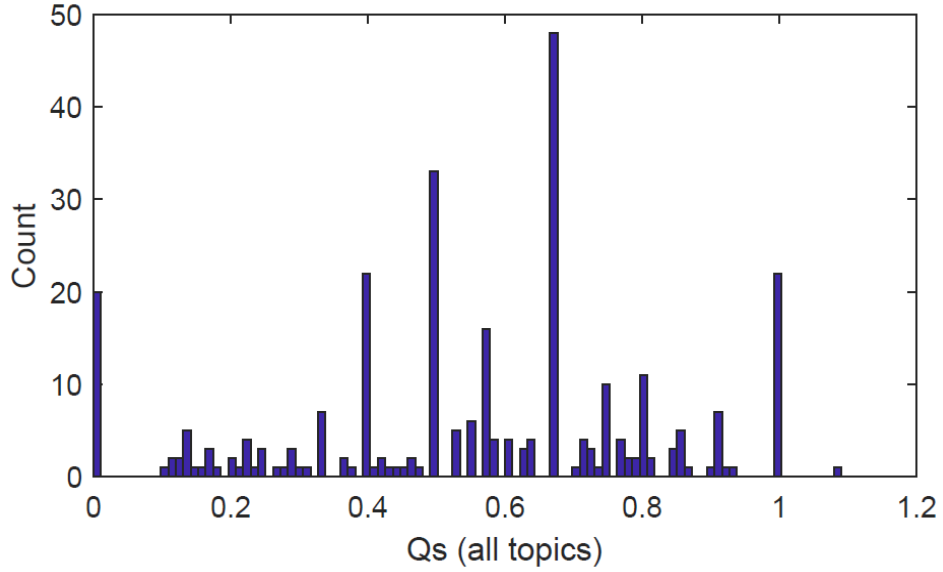
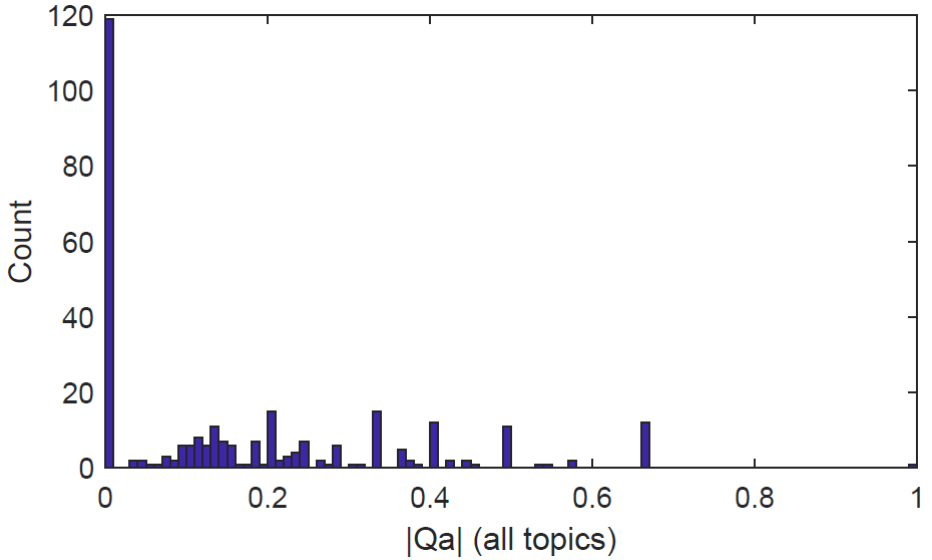
|Qa| and Qs

$Qs = 2[c^{\tau}(x|y) + c^{\tau}(y|x)] / [m_x+m_y]$

$Qa = 2[c^{\tau}(x|y) - c^{\tau}(y|x)] / [m_x+m_y]$







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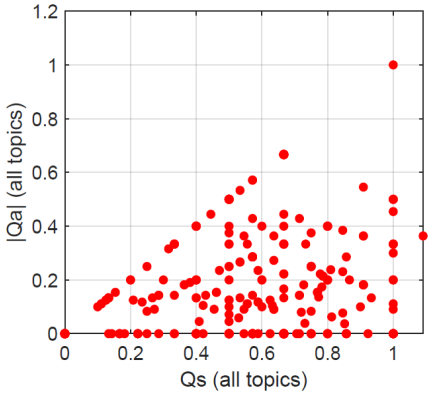
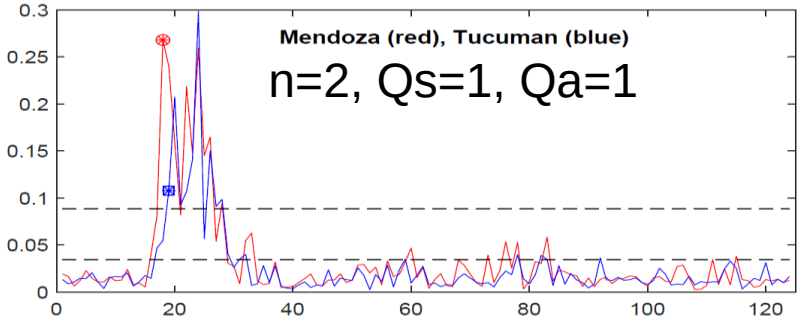
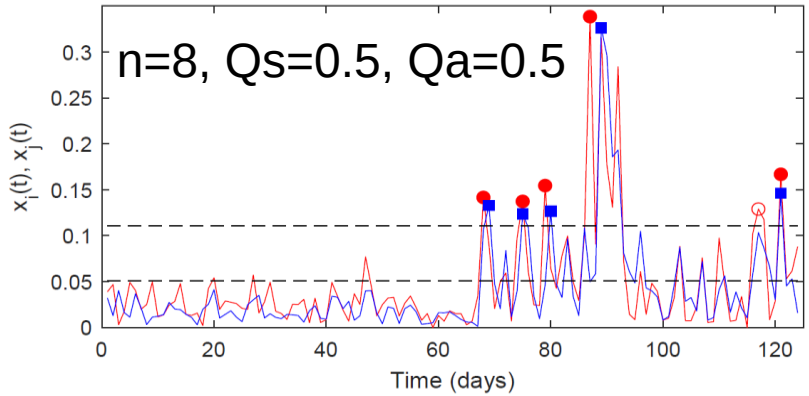
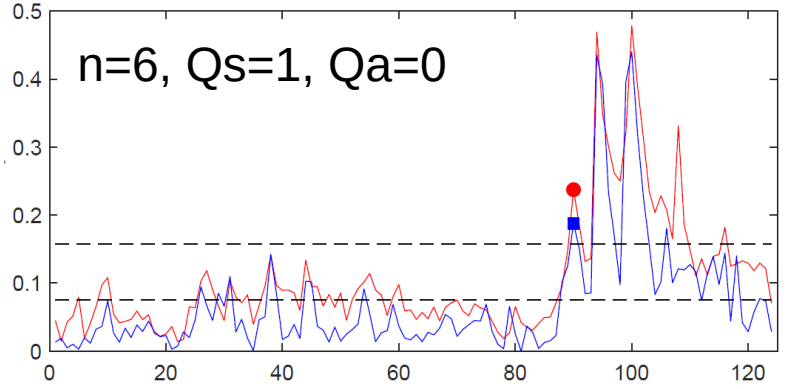
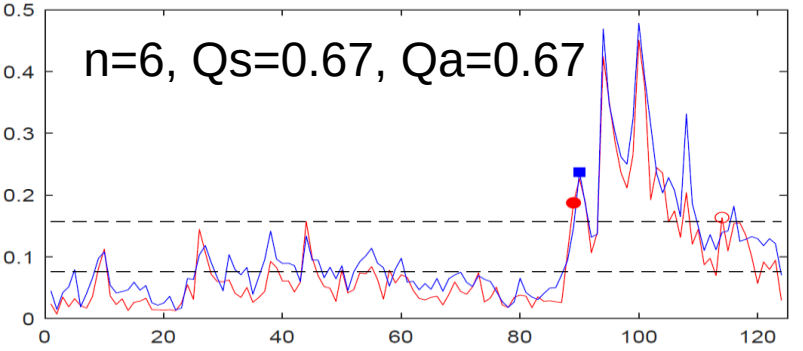
Let's look at some examples

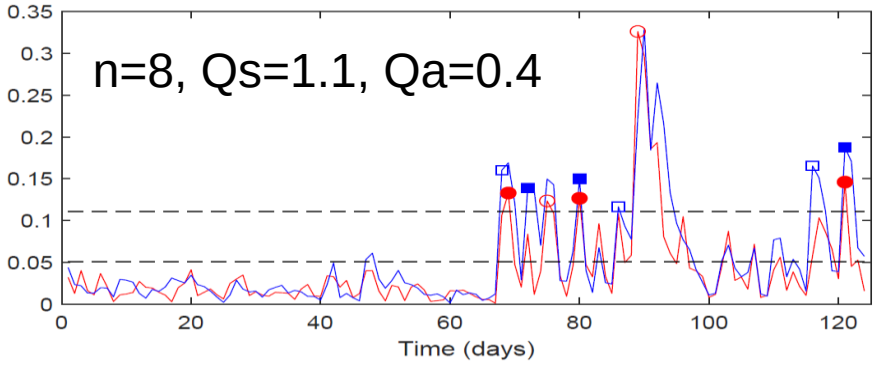


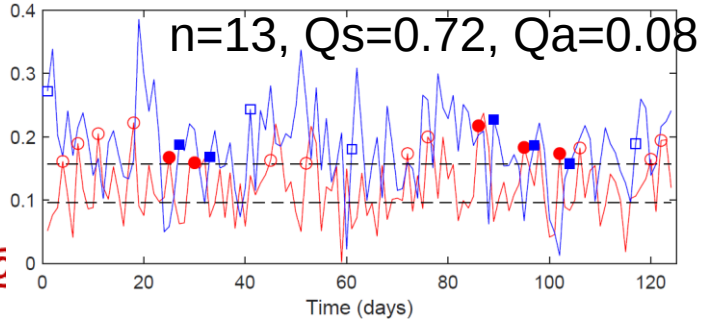












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Granger Causality

Hypothesis: X_1 and X_2 can be described by stationary autoregressive linear models.

$$X_1(t) = \sum_{j=1}^{p} A_{11,j}\ X_1(t-j) + E_1(t)$$

past of X_1 — Residual error

$$X_1(t) = \sum_{j=1}^{p} A_{11,j}\ X_1(t-j) + \sum_{j=1}^{p} A_{12,j} X_2(t-j) + E'_1(t)$$

past of X_1 — past of X_2 — Residual error

If $\langle E'_1(t)\rangle < \langle E_1(t)\rangle$ ⇒ $X_2 \rightarrow X_1$

C. W. J. Granger *Investigating causal relations by econometric models and cross-spectral methods*. *Econometrica* 37, 424–438 (1969) **(> 10000 citations)**

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Transfer Entropy (TE)

- TE: is the *Conditional* Mutual Information, given the "past" of one of the variables.

$$TE\ (x,y) = MI\ (x,\ y|x_{\tau})$$

$$TE\ (y,x) = MI\ (y,\ x|y_{\tau})$$

- MI (x,y) = MI (y,x) but TE (x,y) $\neq$ TE(y,x)

- TE and GC are equivalent for Gaussian processes.

T. Schreiber, Measuring information transfer, Phys. Rev. Lett. 85, 461 (2000).

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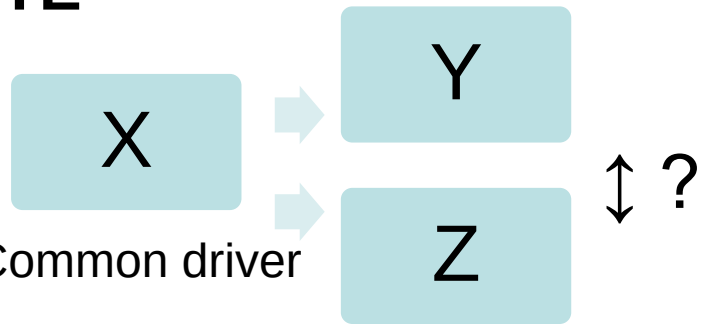
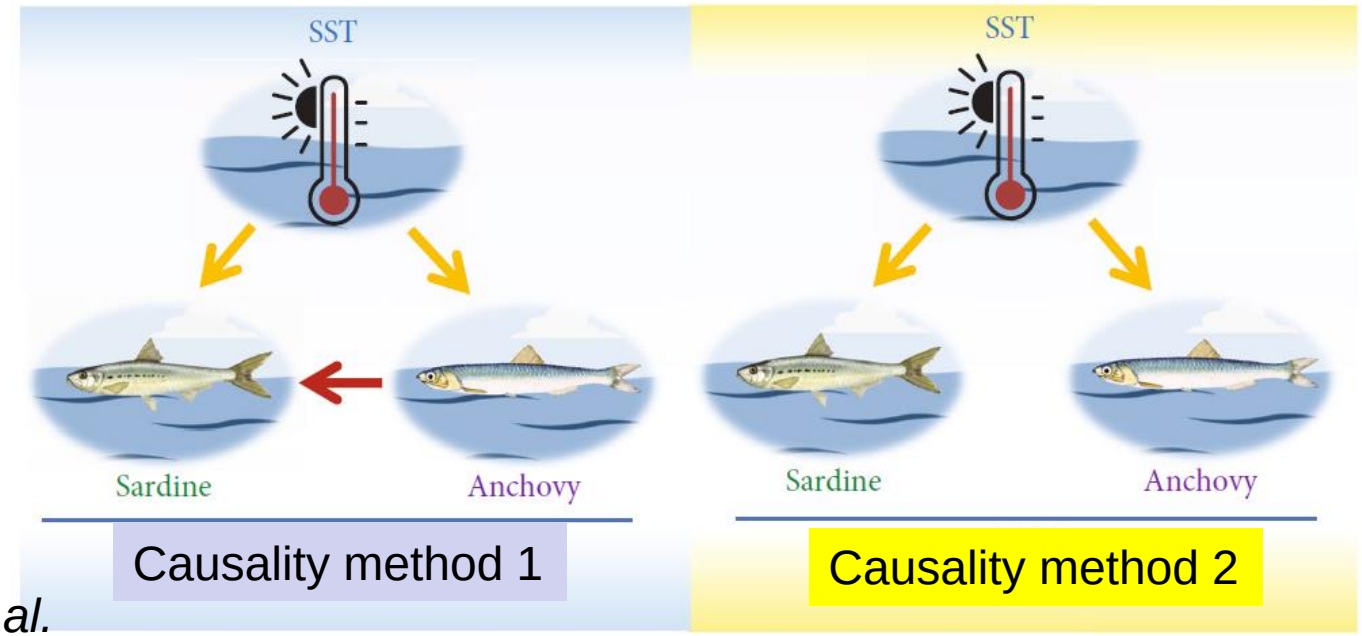
Problems of Grange Causality and TE

Indirect link X→Z?



Common driver



X. Ying et al.
AAAS Research 2022

Many alternative approaches to try to “solve” these problems.

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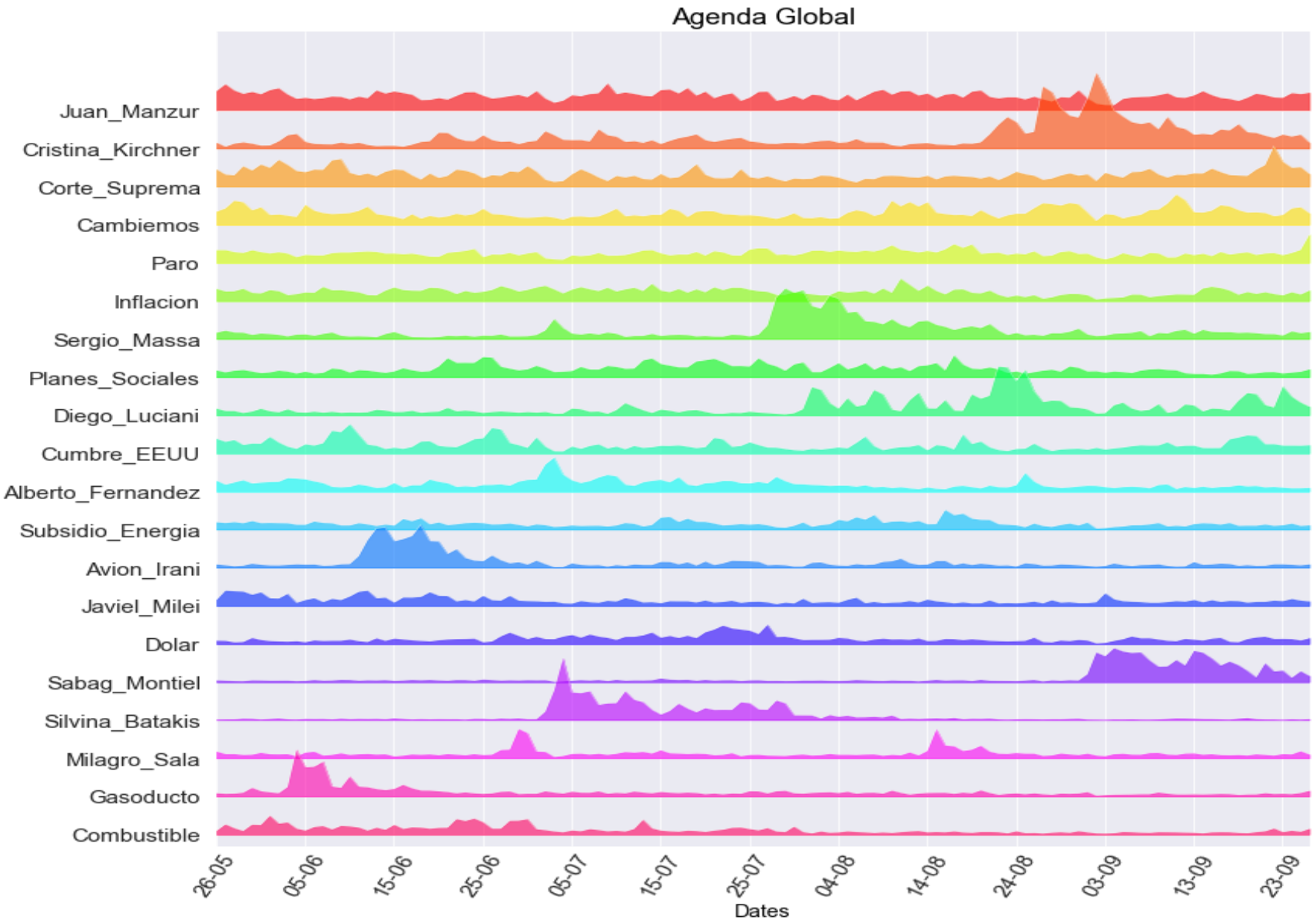
Reminder



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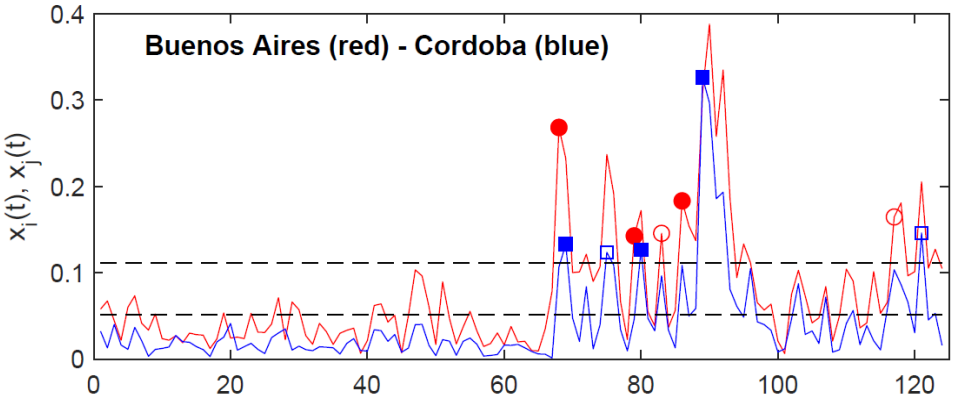
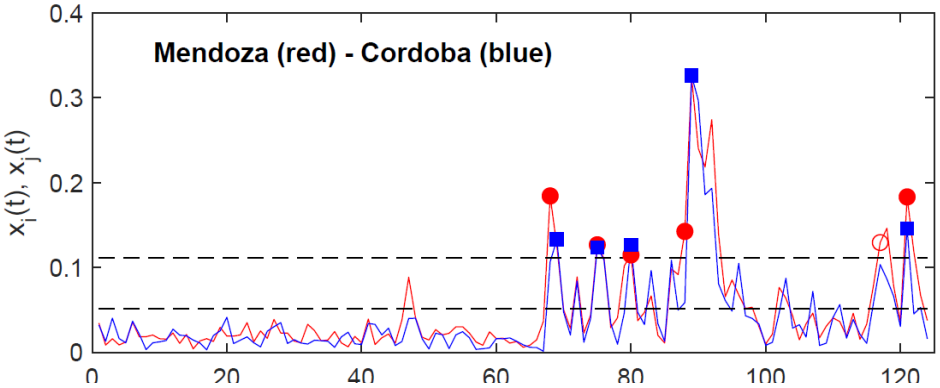
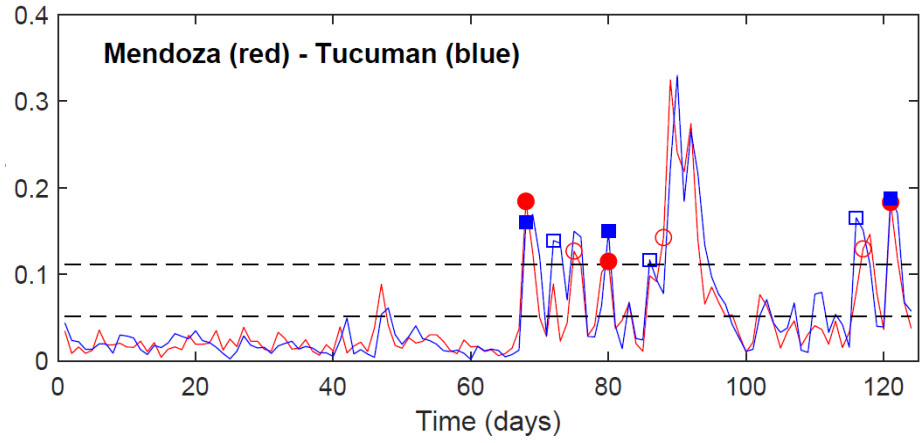
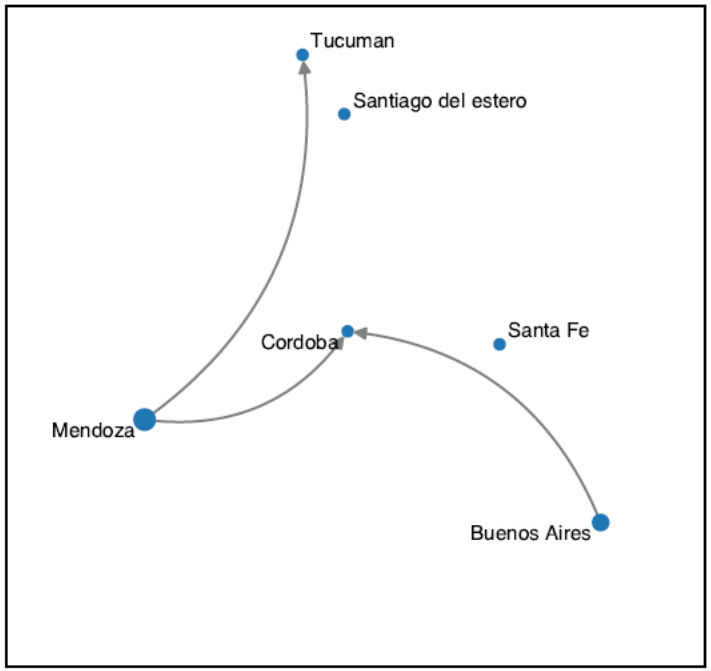
Preliminary results. Example topic "*Diego Luciani*"

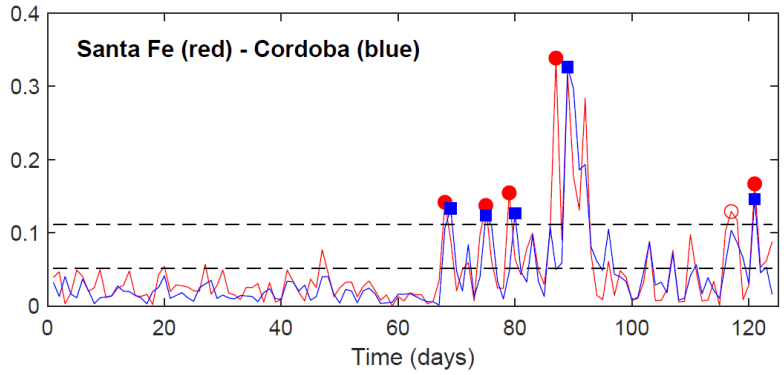






GC and TE "significant"





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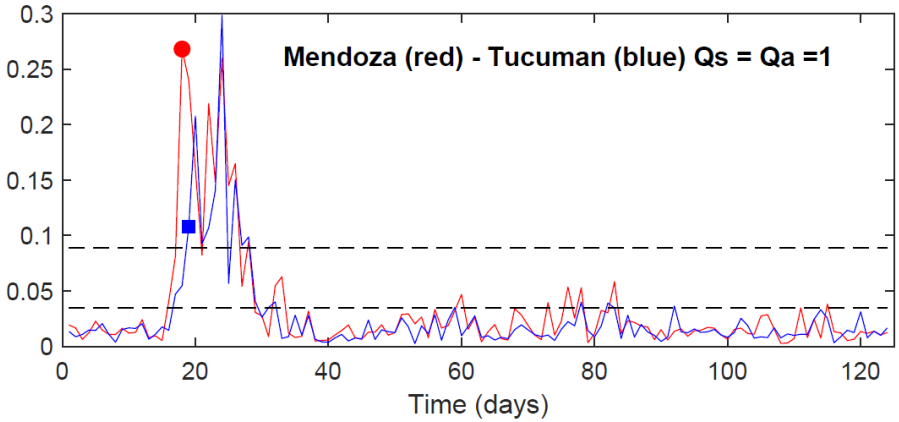
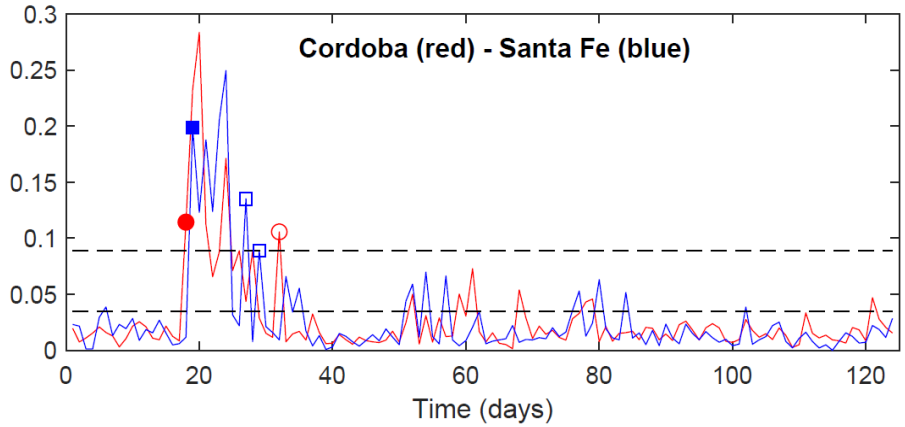
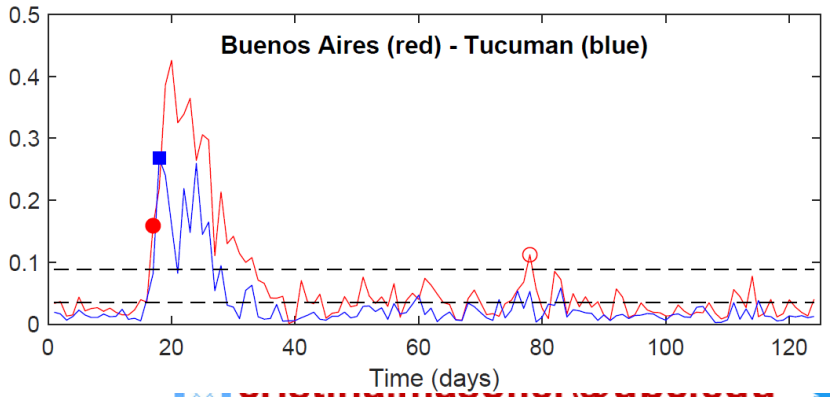
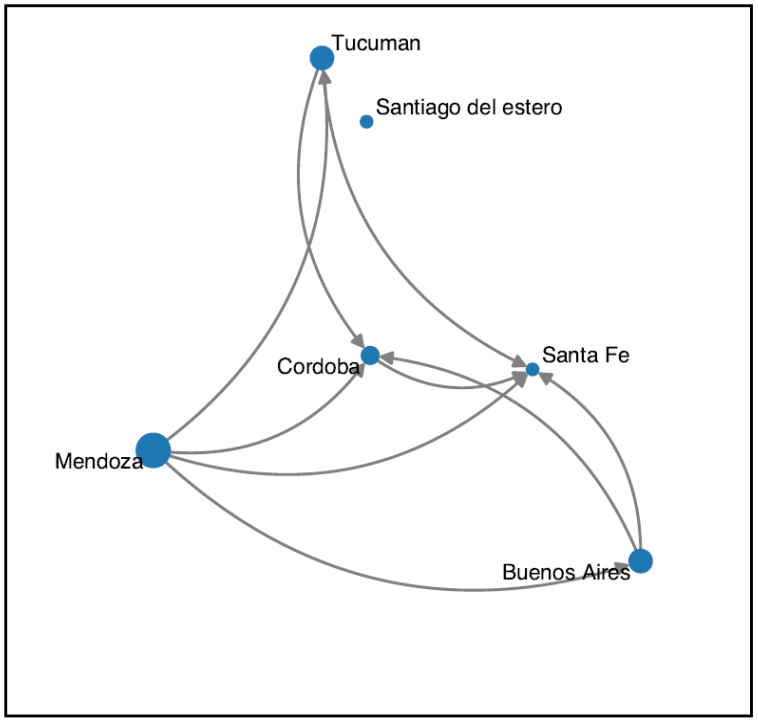
Preliminary results. Example topic "*Avion Irani*" (n=2)

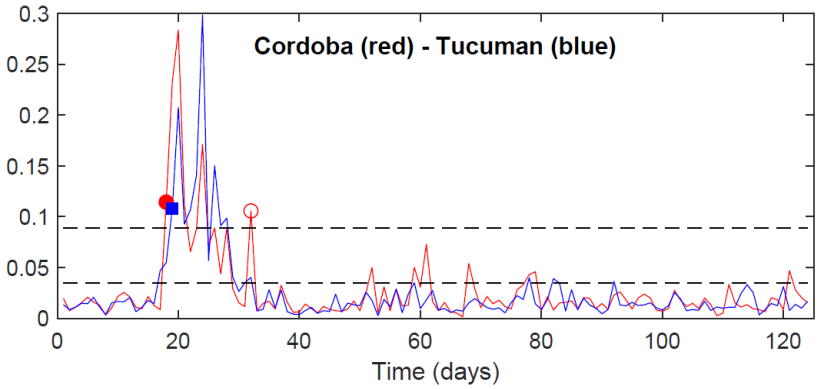






GC and TE "significant"





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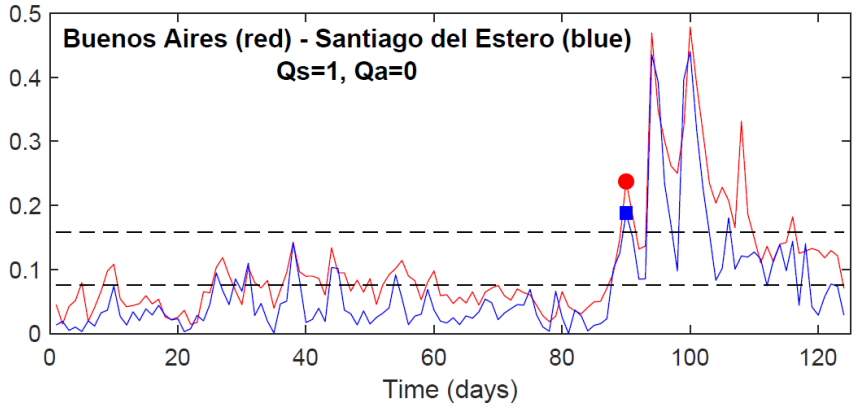
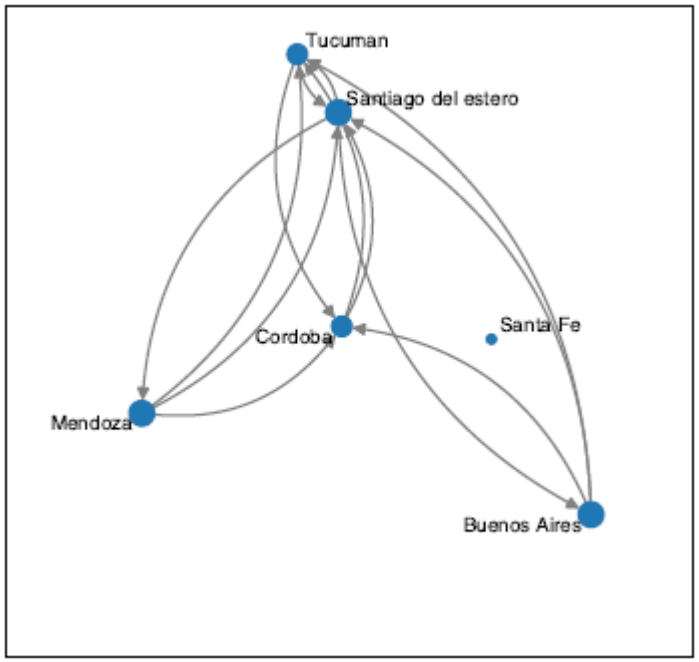
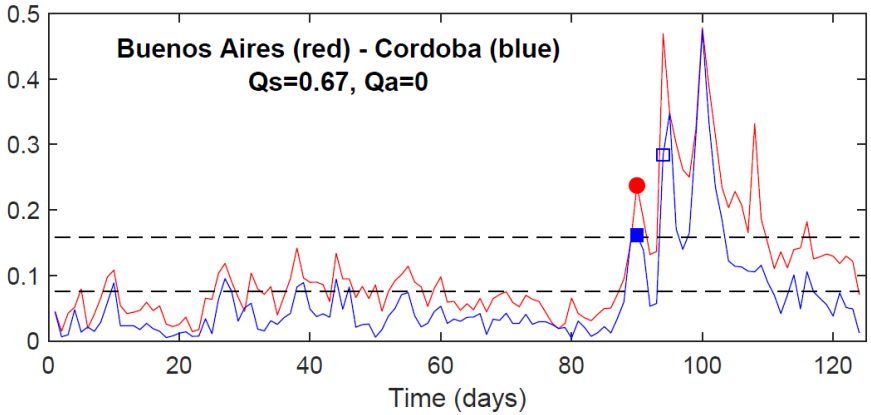
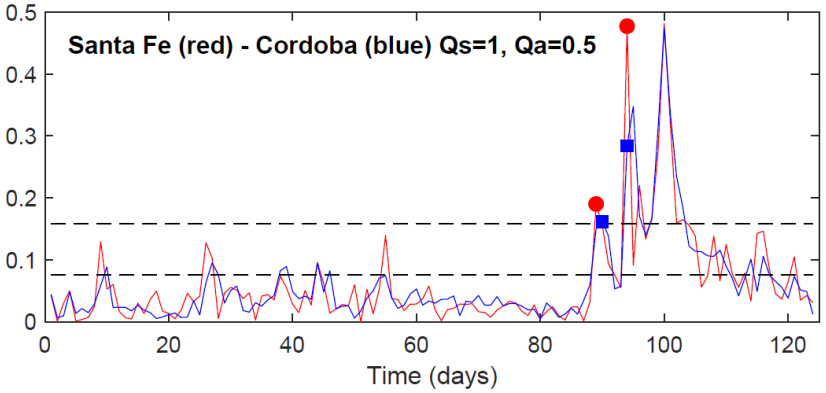
Preliminary results. Example topic "*Cristina Kirchner*" (n=6)

GC and TE "significant"









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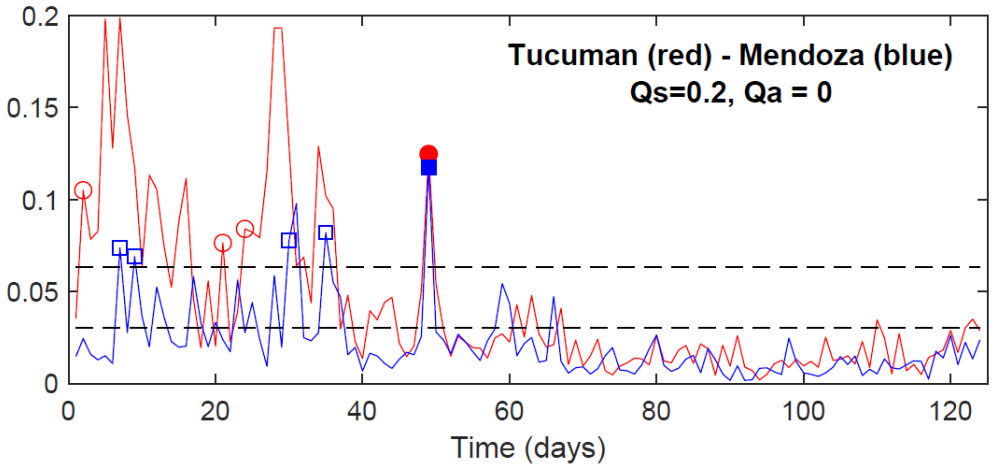
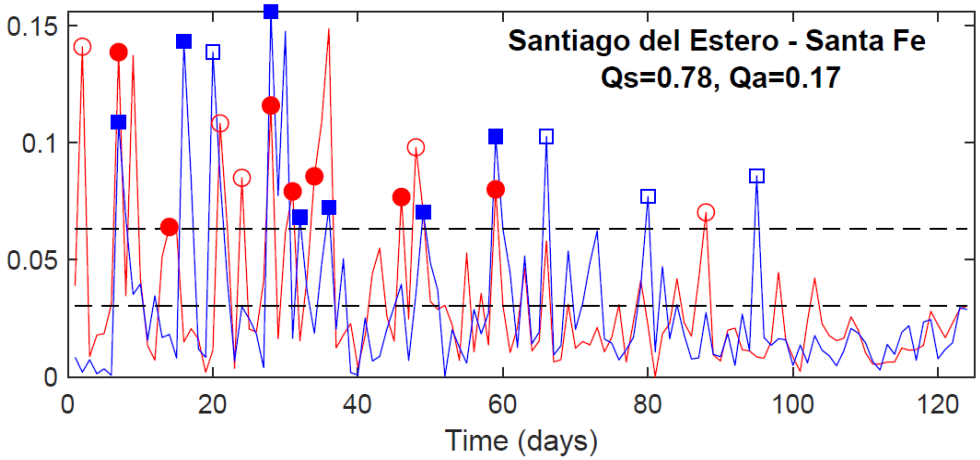
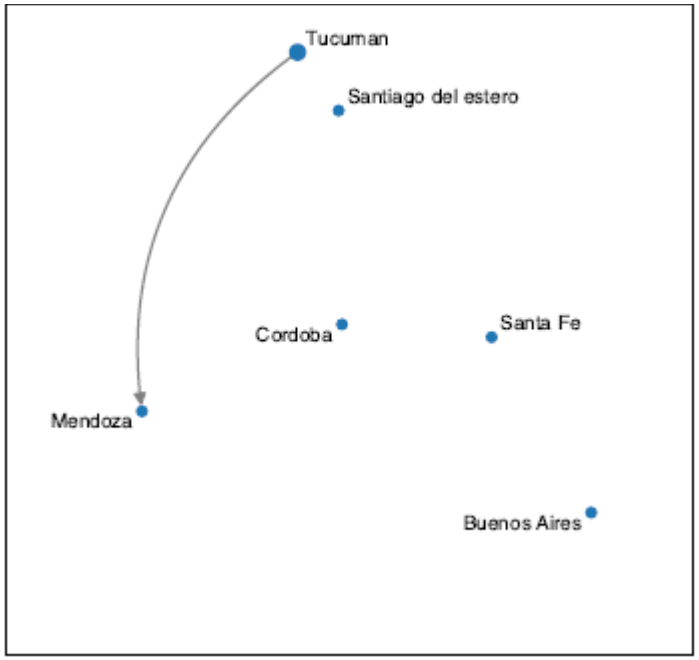
Preliminary results. Example topic "*Combustible*" (n=4)





GC and TE "significant"



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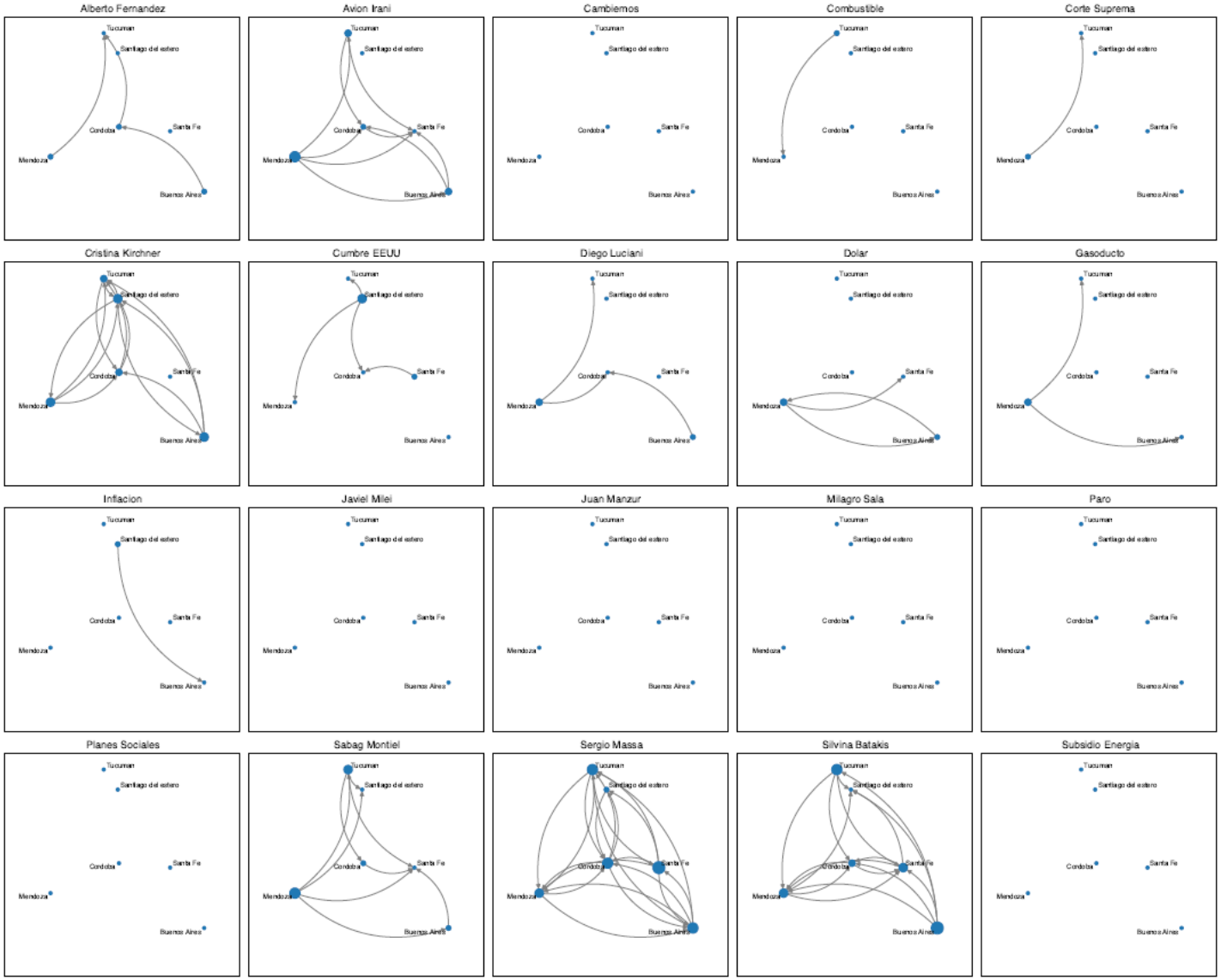
Preliminary results: causal networks for all topics



In topics that have no causal links (GC and/or TE is small), Qs and Qa are also small.

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Preliminary conclusions

- The results obtained with event synchronization are promising but clearly, more study is needed on how to define the events.

- Some coincidences but also differences were found between event-synchronization links and causal links.

- Question: how to “prune” (binarize) to extract meaningful links?

Thanks to my collaborators.
Thank you for your attention!


L. Garcia


G. Tirabassi


P. Balenzuela

Advertisement: 3-year PhD scholarship available in my group, funded by Marie Curie Training Network BE-LIGHT (Machine learning and data analysis for BiomEdical LIGHT-based technologies)

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