

Supplementary Information

Death in Venice: A Digital Reconstruction of a Large Plague Outbreak During 1630-1631

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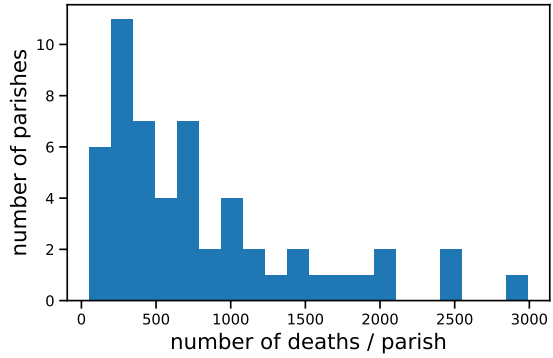
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+ Equal contribution.

*“Sia laudato il signor Iddio non
ci sono stati morti.”*

Bless the Lord, there have been
no deaths [today].

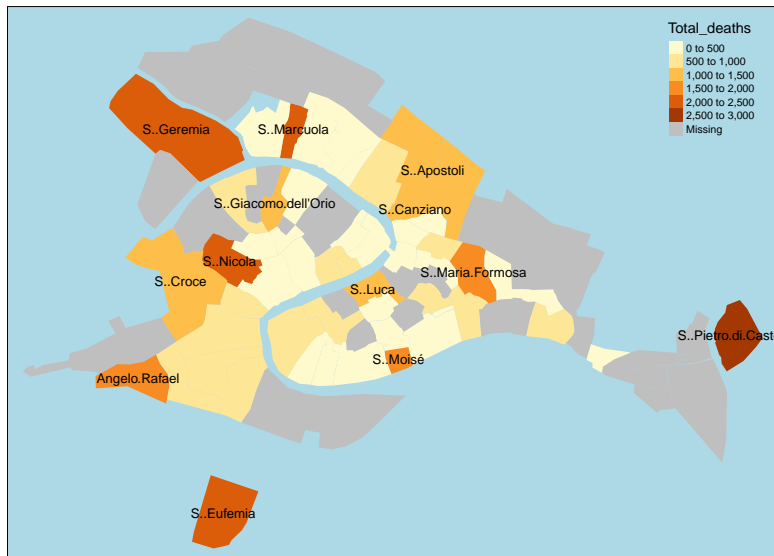
December 24th 1630, in
Sant’Eufemia, Venice.



(a)

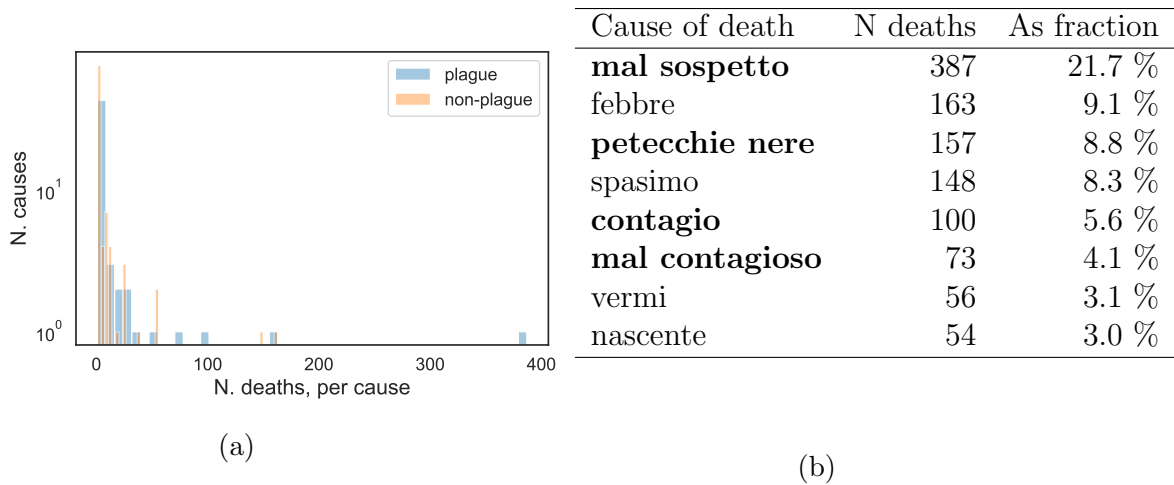
| Parish | N deaths | As fraction of total deaths |
|-----------------------|----------|-----------------------------|
| S. Eufemia | 2089 | 4.8 % |
| S. Nicola | 2097 | 4.9 % |
| S. Geremia | 2405 | 5.6 % |
| S. Marcuola | 2491 | 5.8 % |
| S. Pietro di Castello | 2990 | 6.9 % |

(b)

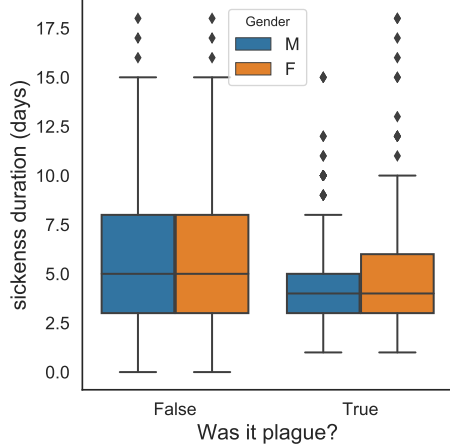


(c)

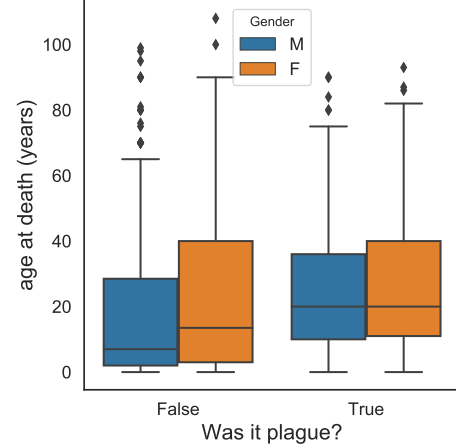
Supplementary Figure SI1: Distribution of number of deaths by parish. (a) One can clearly see the skewed distribution, with the top 24% of parishes accounting for about 55% of the total deaths. (b) For the sake of clarity, only parishes with more than 2000 deaths are listed. (c) Map of Venice parishes, color-coded by total recorded deaths, summed over the entire time-window. For clarity, only the names of parishes with more than 1000 total deaths are shown.



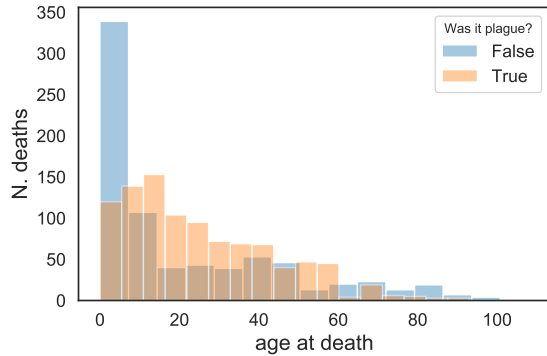
Supplementary Figure SI2: Distribution of number of deaths by cause, for the parish of *Sant'Eufemia*. In the records, 156 unique causes of death are found, of which 56 were attributed to plague. The distribution of attributed causes is skewed, with the top 5% of causes accounting for about 63% of the overall deaths (a). For the sake of clarity, only causes with more than 50 deaths are listed; in bold the ones attributed to plague (b).



(a)



(b)

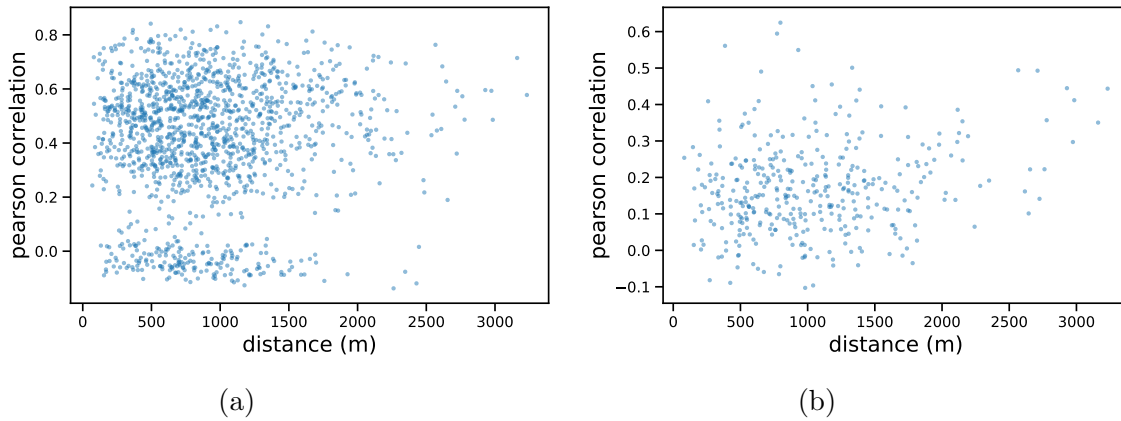


(c)

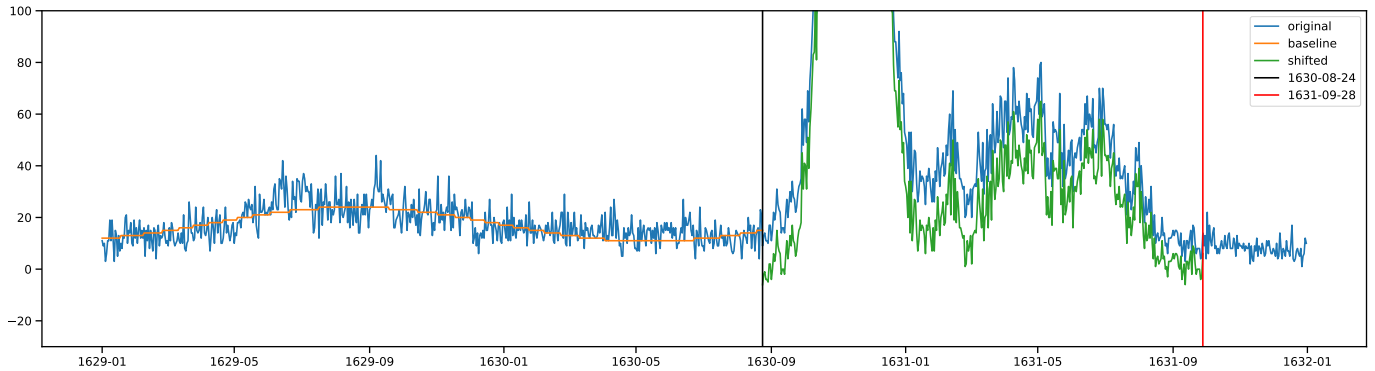
| Age cohort (years old) | Plague | Not plague | Aggregated |
|---------------------------|--------|------------|------------|
| Infant (0-2) | 3.38% | 23.52% | 12.16% |
| Child (3-13) | 32.01% | 29.2% | 30.42% |
| Young (14-23) | 20.95% | 8.74% | 15.63% |
| Adult (24-44) | 29.2% | 16.45% | 23.64% |
| Old (45+) | 17.28% | 19.28% | 18.15% |

(d)

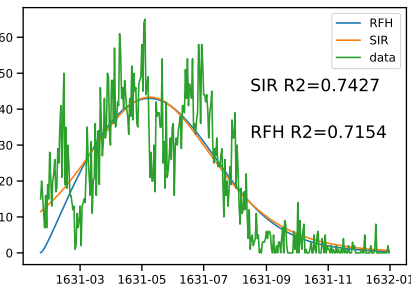
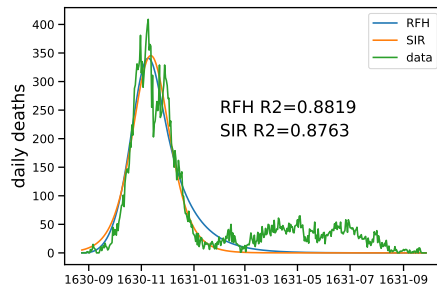
Supplementary Figure SI3: Demographic statistics for the parish of *Sant'Eufemia*, from the 1630-31 records. (a) Distribution of sickness duration, by sex and cause of death for *S. Eufemia* death records – for sake of clarity the boxplots include only cases with a sickness spanning less than 20 days (this still covers about 88% of the total sickness duration distribution). (b,c) Distributions of age at death, divided by cause of death. No significant age difference emerges due to sex ($p > 0.001$ on two samples KS test, for both causes of death) (b), while a significant one appears between the plague VS non-plague deaths, aggregated over sex ($p < 10^{-20}$ on two samples KS test) (c). (d) Table with the same numbers of deaths, divided into age groups. Note that an infant mortality at birth between 20 and 30% was common at the time [1].



Supplementary Figure SI4: Pairwise Pearson correlation between cases time-series of each couple of parishes (y-axis) against the distance between the two parishes (x-axis). The same scatter plot for all parishes ($N_{parishes} = 54$) for the entire time-windows (a) and for the largest parishes, for the 1631 outbreaks only (b). The largest parishes are defined as those reporting more than 500 deaths ($N_{parishes} = 28$).

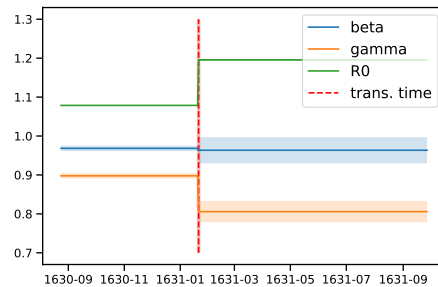


(a)

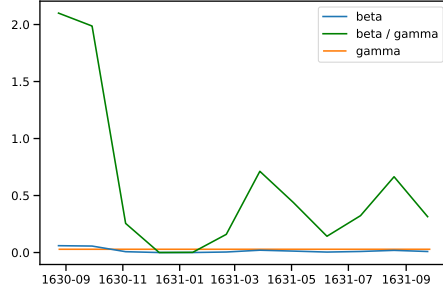


(b)

(c)

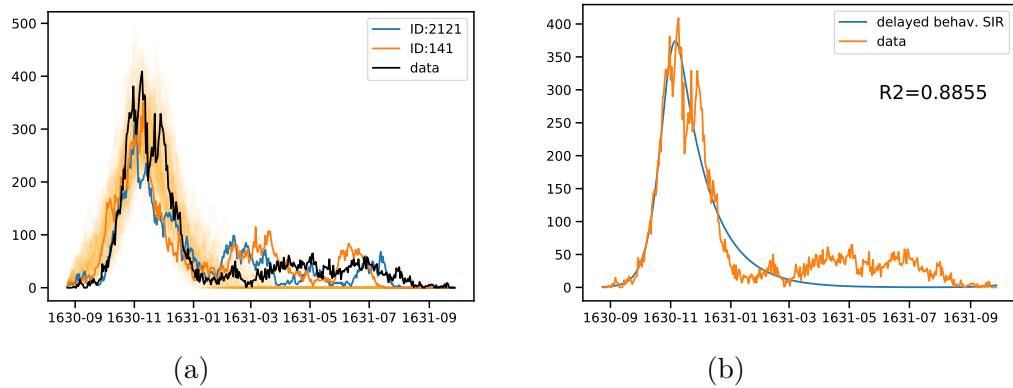


(d)



(e)

Supplementary Figure SI5: (a) Estimation of baseline cases due to other causes: a sinus function (orange line) is fitted from the beginning of the data until the beginning of the fit (black vertical line) to estimate the mortality rate, which is then applied to the original data (blue) to get the data (green line) used for the fit (red vertical line indicates the estimated end of the epidemic). (b-c) Comparison between a simple SIR and the more complex RFH model, in the 400 days window (b) and zoomed on the second part of the epidemic (c). (d) Fitted parameters for the time-dependent SIR model, as in Figure 4b. (e) Evolution of fitted $\beta(I)$ and $\beta(I)/\gamma$ for the delayed behavioral SIR shown in Figure 4c.



Supplementary Figure SI6: (a) Selected stochastic simulations of a simple SIR model on top of a small-word network. Two particular epidemics are highlighted, in order to show the possibility of having a large peak followed by a long tail, as present in the data. In shaded orange we only show, for sake of clarity, the simulated epidemics with lowest deviation from the data ($RMSE < 50 - N = 93$) (b) Best fit of deterministic behavioral delayed SIR. Although the model can fit very well the first part of the epidemic, it does not show a secondary outbreak, in 1631.

| Death causes | Related to plague ? | Death causes | Related to plague ? |
|----------------------------|---------------------|----------------------------------|---------------------|
| | | febbre e doglia di schiena | False |
| annegato | False | febbre e doglie di testa | False |
| apoplessia | False | febbre e ferita | False |
| brusco | False | febbre e flusso | False |
| bubbone pestilenziale | | febbre e gotta | False |
| all'inguine | True | febbre e lepra(?) | False |
| caduta | False | febbre e mazzucco | True |
| caduta | False | febbre e nosella | False |
| caduta apoplettica | False | febbre e petecchie | True |
| caduto da una scala | False | febbre e petecchie nere | True |
| caita nella gola | False | febbre e petecchie rosse | True |
| cancro alla bocca | False | febbre e petecchie rosse | |
| carbone | True | non pestilenziali | False |
| carboni | True | febbre e punta | False |
| carboni e parto | True | febbre e spasimo | False |
| carbonie e petecchie nere | True | febbre e suspetto | True |
| catare nella gamba | False | febbre e un brusco | False |
| catarro | False | febbre e una doglia in un fianco | False |
| contagio | True | febbre e una postima | False |
| contagio e petecchie nere | True | febbre e una scorencia | False |
| convertito etico | False | febbre e variole | False |
| croplasion | False | febbre e vecchiezza | False |
| disperso | False | febbre e vermi | False |
| doglia di testa | False | febbre etica | False |
| doglia di testa e mazzucco | True | febbre etica e catarro | False |
| doglia di testa e vermi | False | febbre ferita e flusso | False |
| doglia e spasimo | False | febbre galica e catarro | False |
| dolor di vita | False | febbre maligna | True |
| febbre | False | febbre maligna e mal sospetto | True |
| febbre | False | febbre maligna e punti | True |
| febbre continua | False | febbre senza sospetto | False |
| febbre continua e | | ferita | False |
| altre indisposizioni | False | ferita | False |
| febbre e catarro | False | ferita dietro l'orecchio | False |
| febbre e doglia | False | ferite | False |
| | | ferite da peste | True |

Supplementary Table SI1: Manual classification of all 156 death causes as reported in necrologies, as associated to plague or not – part 1.

| Death causes | Related to plague ? | Death causes | Related to plague ? |
|----------------------------|---------------------|-------------------------------|---------------------|
| ferito | False | | |
| flusso | False | | |
| fracassato la testa | False | parto e febbre | False |
| illegibile | False | parto e ferita | False |
| incinta da febbre e doglie | False | parto e spasimo | False |
| infermo | False | partorito morto | False |
| ipolesia | False | patimento | False |
| ipoplessia e febbre | False | per non aver avuto latte | False |
| macchie nel petto | | percossia | False |
| giudicate pestilenziali | True | peste | True |
| mal caduco | False | peste e petecchie nere | True |
| mal caduco e vermi | False | peste e strupiata | True |
| mal contagioso | True | petecche paonazze | True |
| mal di febbre | False | petecchi nere | True |
| mal di gotta | False | petecchie | True |
| mal di mare e mal sospetto | True | petecchie | True |
| mal di mazzucco | True | petecchie e febbre maligna | True |
| mal di pietra | False | petecchie e mazzucco | True |
| mal di reni | False | petecchie e spasimo | True |
| mal mazzucco | True | petecchie e un brusco | True |
| mal sospetto | True | petecchie et un brusco | True |
| mal sospetto e petecchie | True | petecchie nere | True |
| mazzucco | True | petecchie nere | True |
| morto improvvisamente | False | petecchie nere contagiose | True |
| n.d. | False | petecchie nere e carbone | True |
| nascente | False | petecchie nere e rosse | True |
| non aver latte | False | petecchie nere pestilenziali | True |
| non si sa il male | False | petecchie pestilenziali | True |
| nosella | False | petecchie rosse | True |
| nosella di mal contagioso | True | petecchie rosse e alcune nere | True |
| nosella nel cuore | False | petecchie rosse e parto | True |
| paralitico senza contagio | False | petecchie rosse verso il nero | True |
| parto | False | | |

Supplementary Table SI2: Manual classification of all 156 death causes as reported in necrologies, as associated to plague or not – part 2.

| Death causes | Related to plague ? |
|--------------------------|---------------------|
| punta | False |
| rogna | False |
| sconosciuta | False |
| sempre infermo | False |
| senza peste esterna | False |
| senza sospetto | False |
| spasimo | False |
| spasimo e infermitá | False |
| spasimo e mazzucco | True |
| spasimo e petecchie nere | True |
| spasimo e sturioli | False |
| spasimo e vecchiezza | False |
| spasimo e vermi | False |
| stroppiata su la palada | False |
| strupiata | False |
| tumore | False |
| tumore alla gola | False |
| un carbon | True |
| variole | False |
| variole e sturioli | False |
| vecchiezza | False |
| vecchiezza e febbre | False |
| vermi | False |
| vermi e petecchie | True |
| vermi e spasimo | False |

Supplementary Table SI3: Manual classification of all 156 death causes as reported in necrologies, as associated to plague or not – part 3.

References

- [1] Weiner Gordon M. The Demographic Effects of the Venetian Plagues of 1575-77 and 1630-31. *Genus*, 26(1/2):41-57, 1970.