Predicting the unpredictable in violent political conflict

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large events in political conflict

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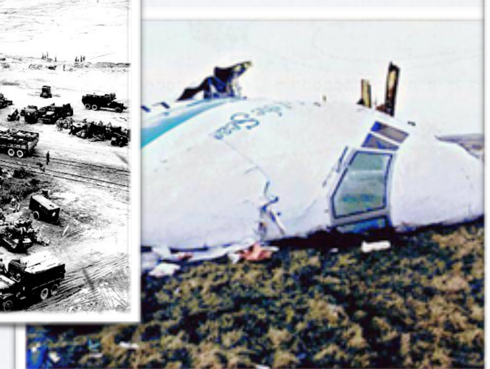
- large **international wars**
  - 7 wars with $x \geq 100{,}000$ battle deaths in 100 years
- large **terrorist attacks**
  - 37 attacks with $x \geq 100$ deaths in 40 years

such events have disproportionate impact

1939: WW2

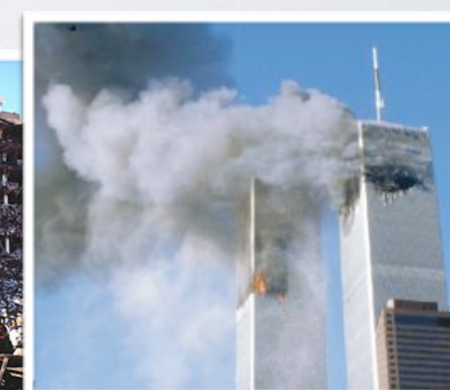
1980: Iran-Iraq War

1950: Korean War



1988: Pan Am Flight 103, Lockerbie

1995: Oklahoma City bombing



2001: World Trade Center

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can such events be predicted with algorithms?

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~~**no.**~~ **it depends...**

large events in political conflict

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❌ *in specific*

who, what, where, why, how, when

large events in political conflict

can such events be predicted with algorithms?

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in specific

who, what, where, why, how, when

why? such events are *rare* (little data), too many *relevant variables*, too much historical *contingency*, human *agency*, *incomplete* information, etc.

over-fit the past & under-fit the future

can't *replace* human expertise & evidence trails

* Machine learning algorithms, being general models, require large amounts of data to learn which possible correlations in the observed data are relevant for accurate predictions, but rare events, by definition, lack the data required for that learning. Worse, for highly specific questions (who, what, when, where, etc.), machines are typically much worse than humans at *thinking like a human would*, and no machine learning algorithm exists that can account for human agency.

large events in political conflict

🔮 **can such events be predicted with algorithms?**

~~no:~~ it depends:

✅ *in aggregate*

statistical forecasts & risk estimates

why? robust *statistical patterns* exist, *in aggregate*, which allow *probabilistic* estimates, over populations (*not* individuals)

➔ **average over contingencies & beyond individual agency**

➔ **reflects fundamental constraints**

* An interesting middle ground exists in long-running conflicts with relatively stable conditions. There, it may be possible to use machine learning to make accurate out-of-sample predictions of future events, but such approaches are brittle, and fail spectacularly when the underlying conflict rules shift because of agency, contingency, or technology. Generally, it is not understood at what *scale* of aggregation, or what circumstances of conflict, such effects assert themselves.

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🤔 **what are some of these patterns?**

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a general pattern in terrorism

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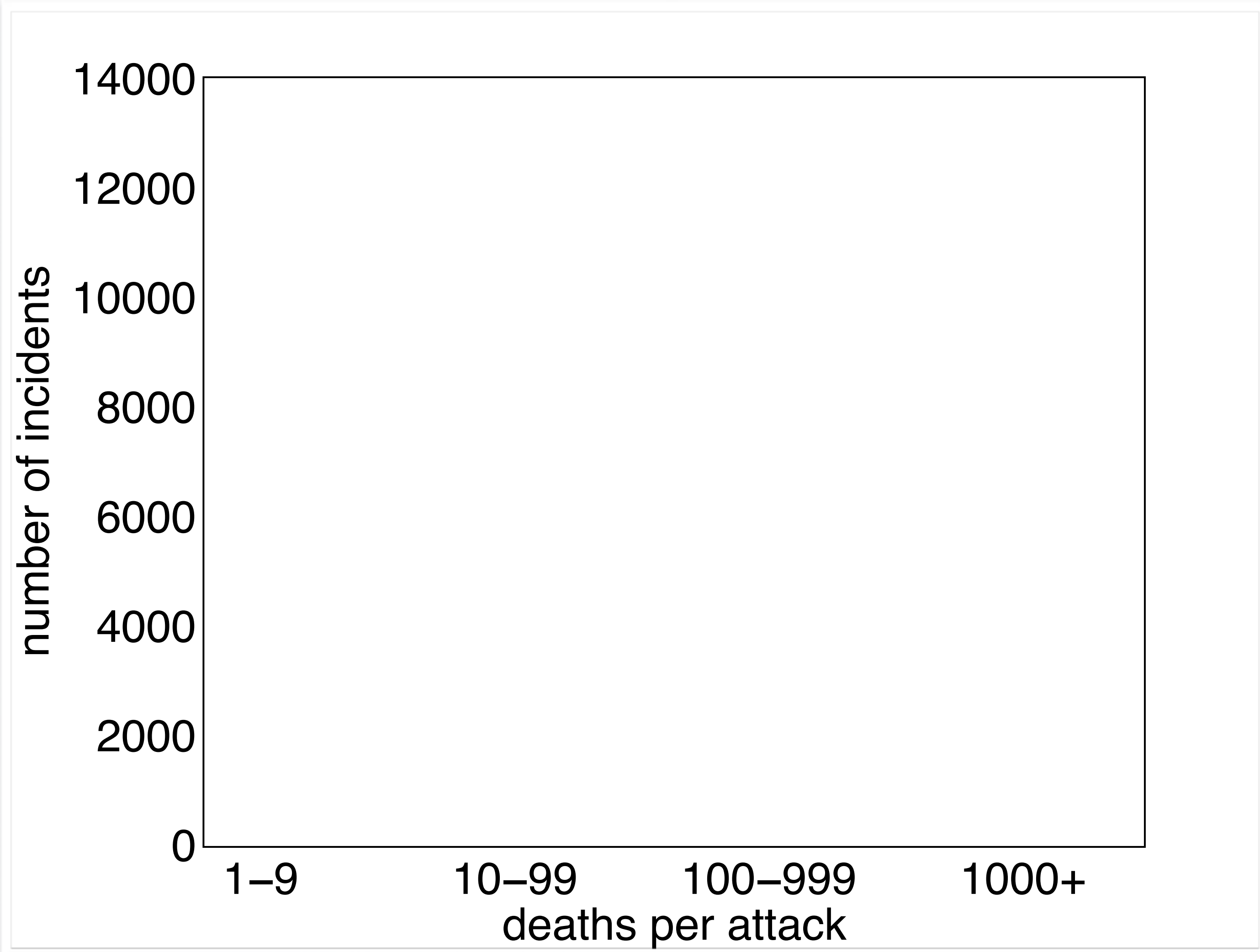
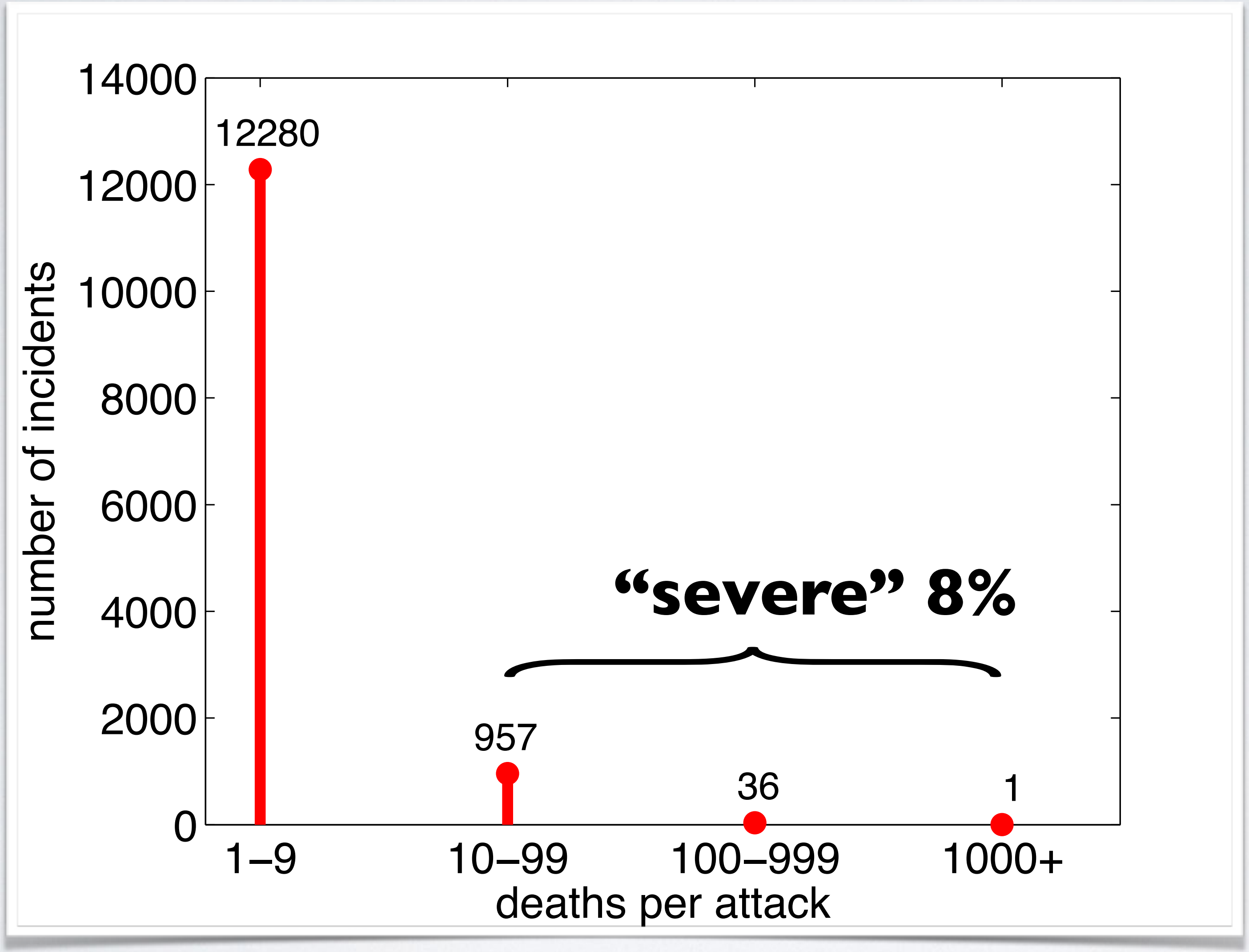


40,000 terrorist events from MIPT-RAND database (1968-2007)

a general pattern in terrorism



13,274 *deadly* events from MIPT-RAND database (1968-2007)

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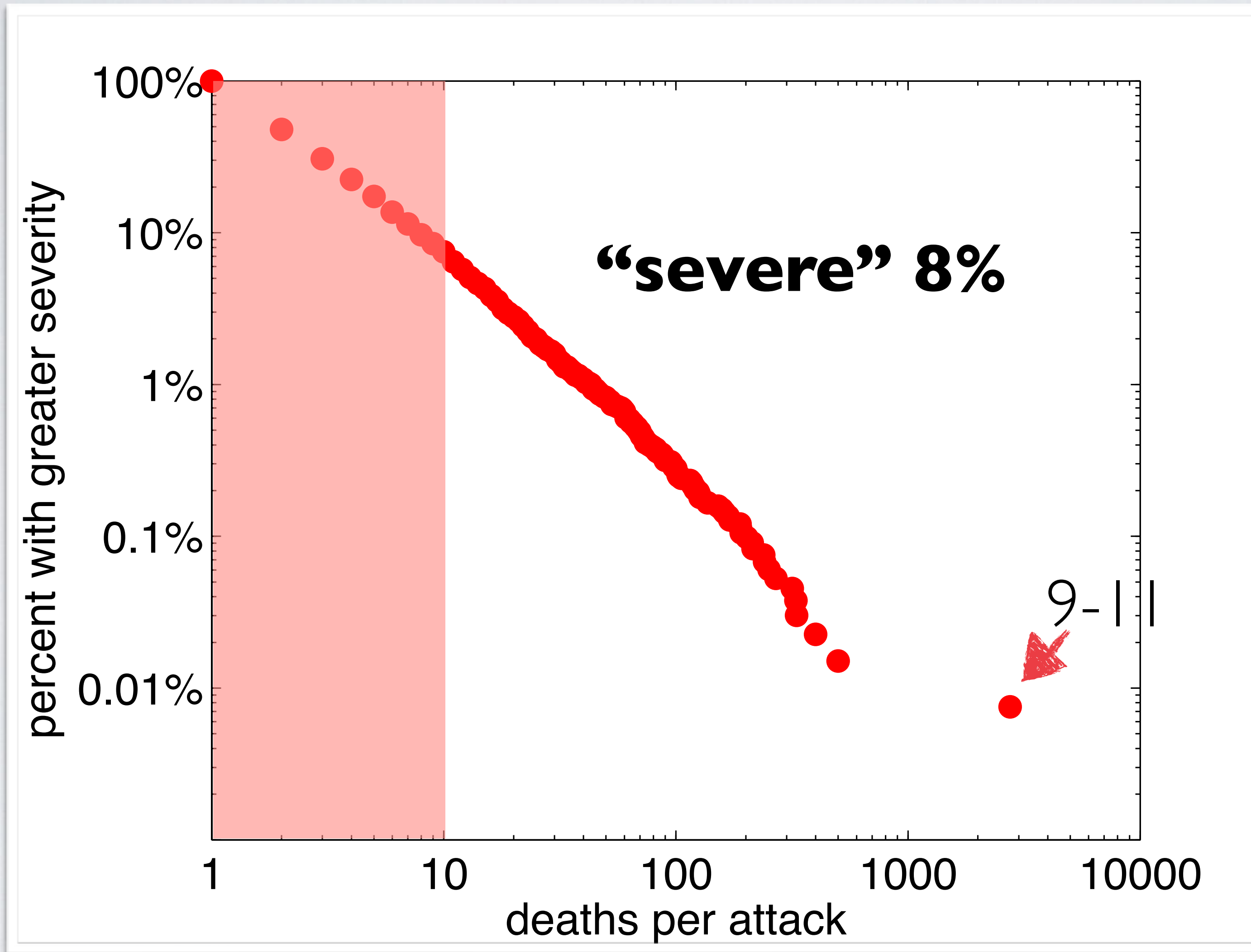

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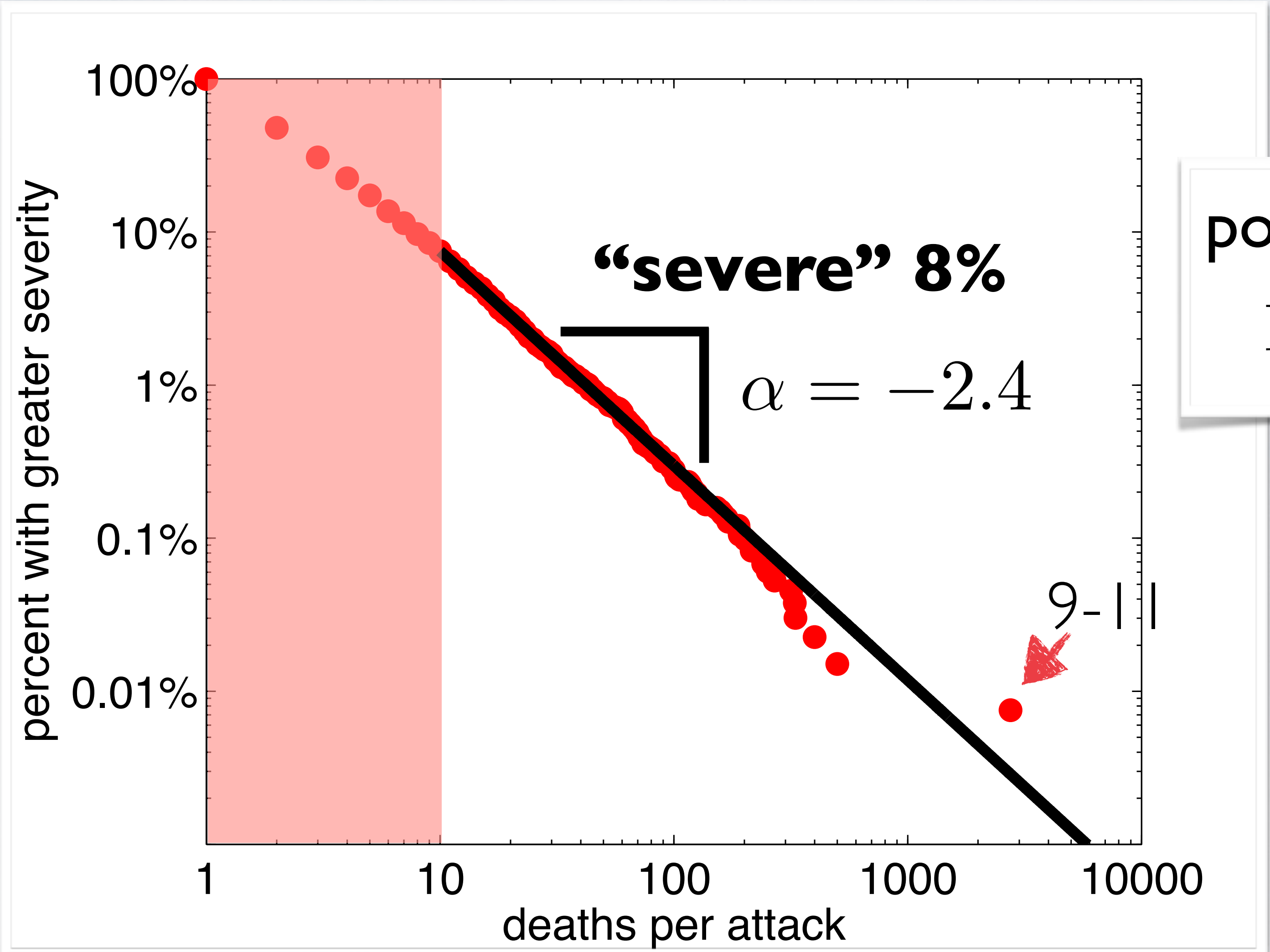

power-law model

$$\Pr(x) \sim x^{-\alpha}$$

Clauset, Young & Gleditsch, Journal of Conflict Resolution (2007)
Clauset, Shalizi & Newman, SIAM Review (2009)

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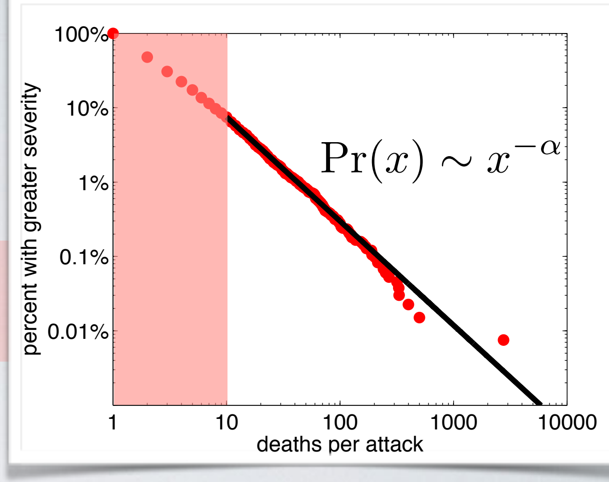

power-law pattern holds across some covariates

- different decades (70s, 80s, 90s, 00s, 10s)
- different types of weapon (guns, fire, bombs, etc.)
- different levels of economic development (OECD)
- but **not** with a universal exponent α
  - its shape varies, making predictions harder

Clauset, Young & Gleditsch, Journal of Conflict Resolution (2007)
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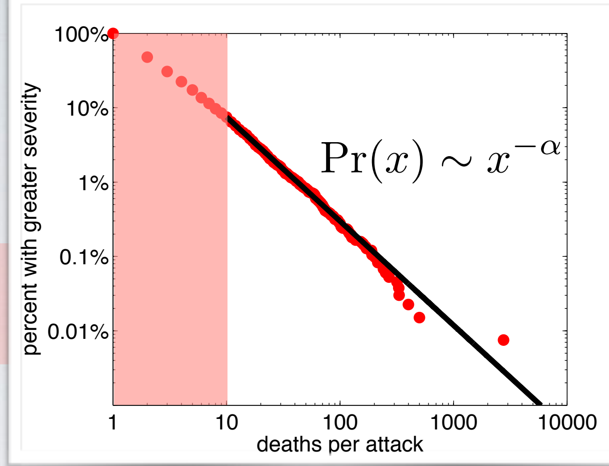

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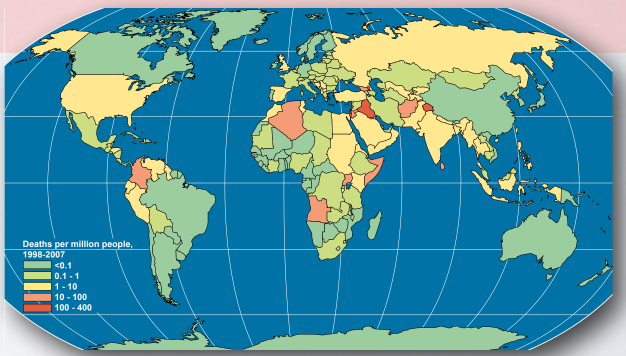
the pattern **fails** for others



- suicide attacks alone
- arbitrary regions (North America, Asia, Europe, etc.)

why? ➜ contingency matters

Clauset, Young & Gleditsch, Journal of Conflict Resolution (2007)
Clauset, Shalizi & Newman, SIAM Review (2009)

patterns across terrorist groups

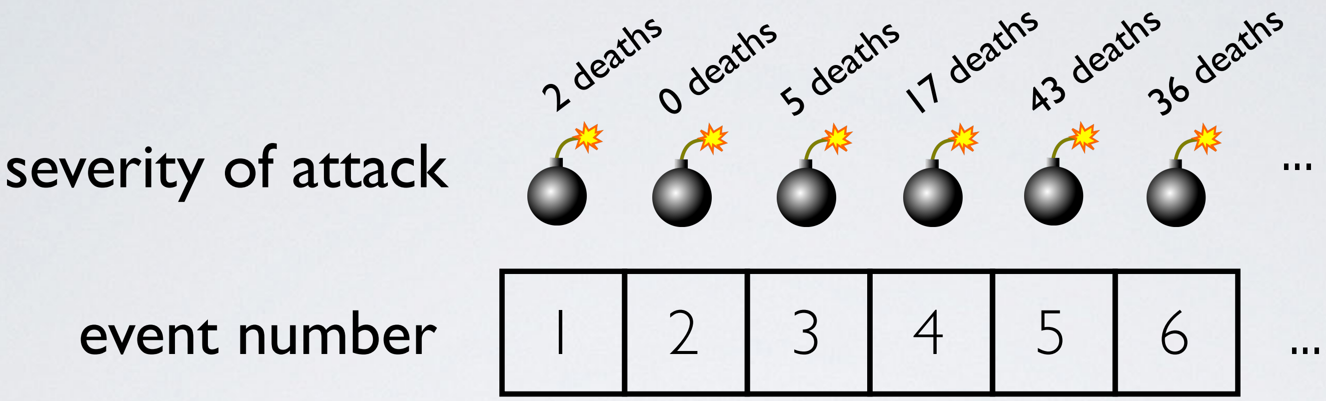
patterns across terrorist groups

800+ known terrorist groups, worldwide, over 40 years

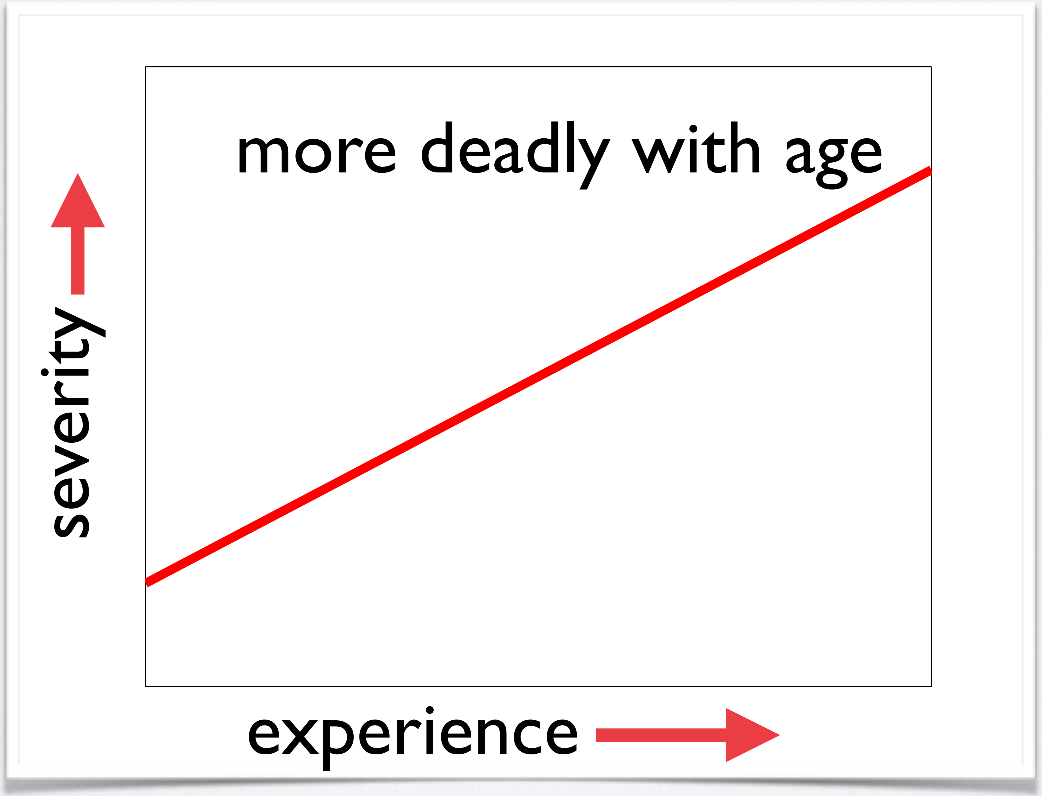
- do older / more experienced groups create *larger* events?
- how often do they launch attacks?

Clauset & Gleditsch, PLoS ONE (2012)

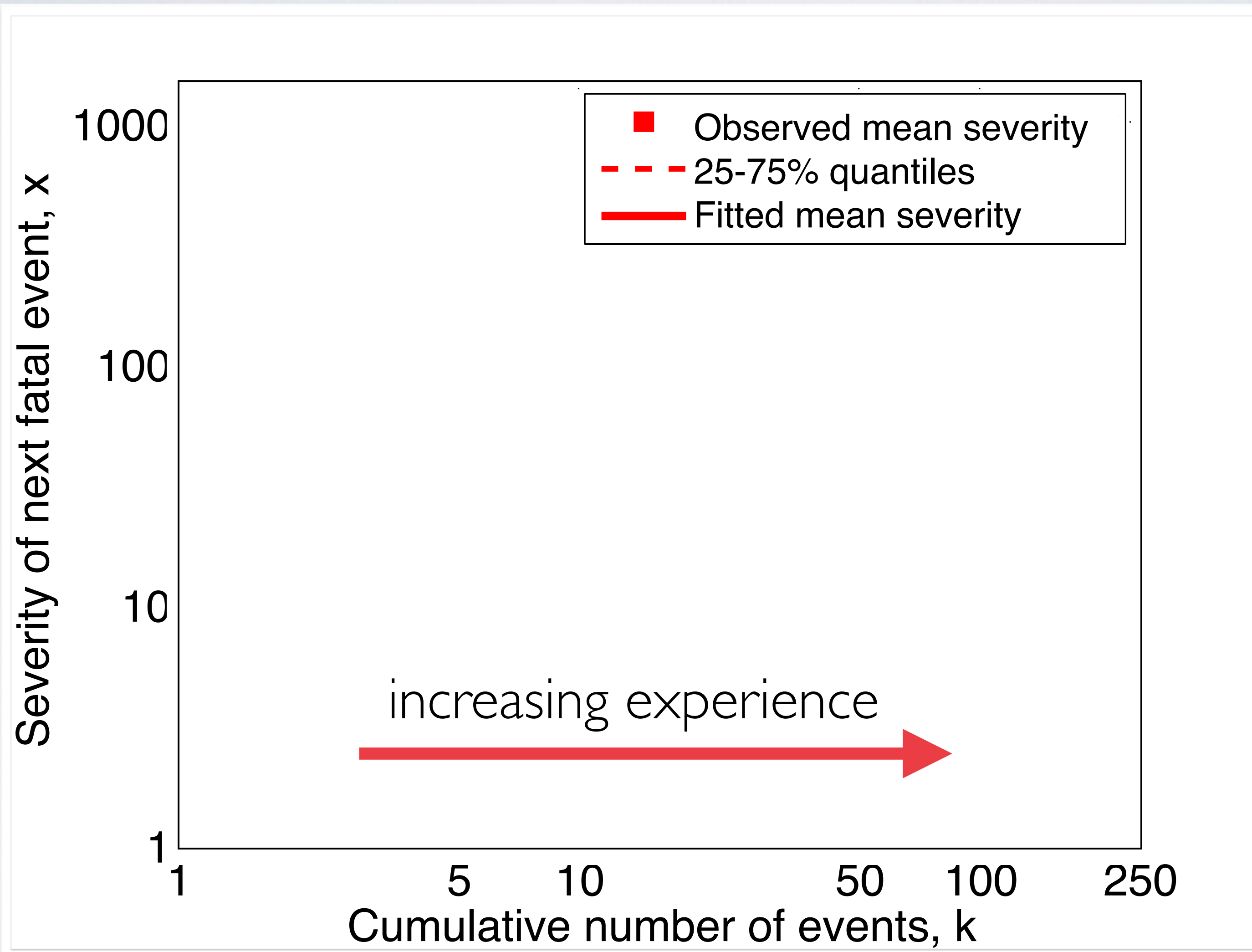
patterns across terrorist groups : severity



example:



patterns across terrorist groups : severity



Clauset & Gleditsch, PLoS ONE (2012)

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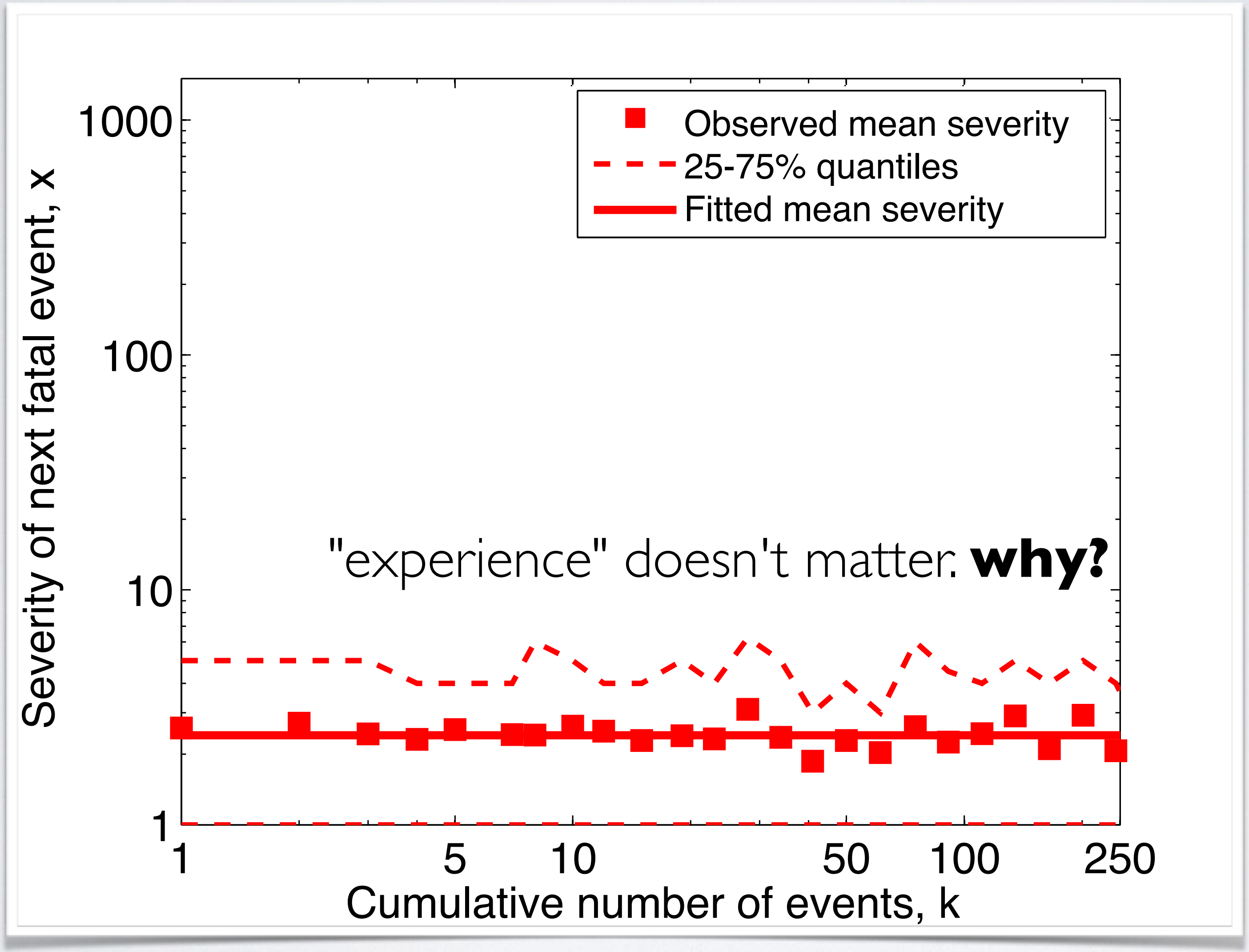

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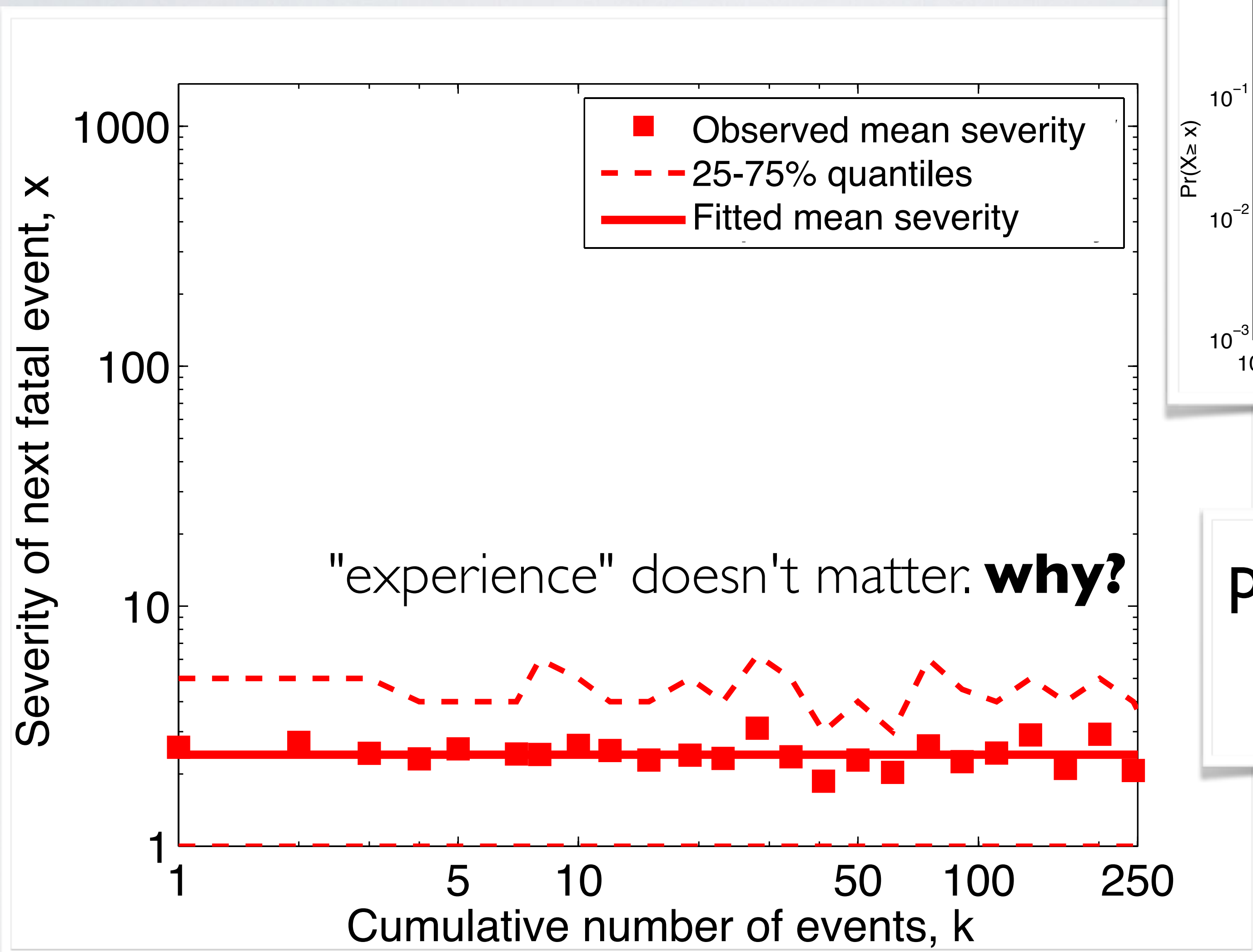

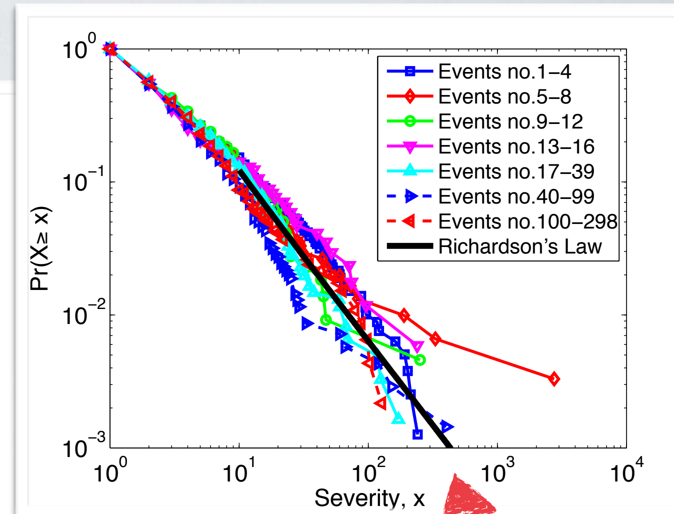

power-law model

$$\Pr(x) \sim x^{-\alpha}$$

The inset shows the marginals, which cluster around the general pattern in terrorism we saw earlier.

Clauset & Gleditsch, PLoS ONE (2012)

patterns across terrorist groups : frequency

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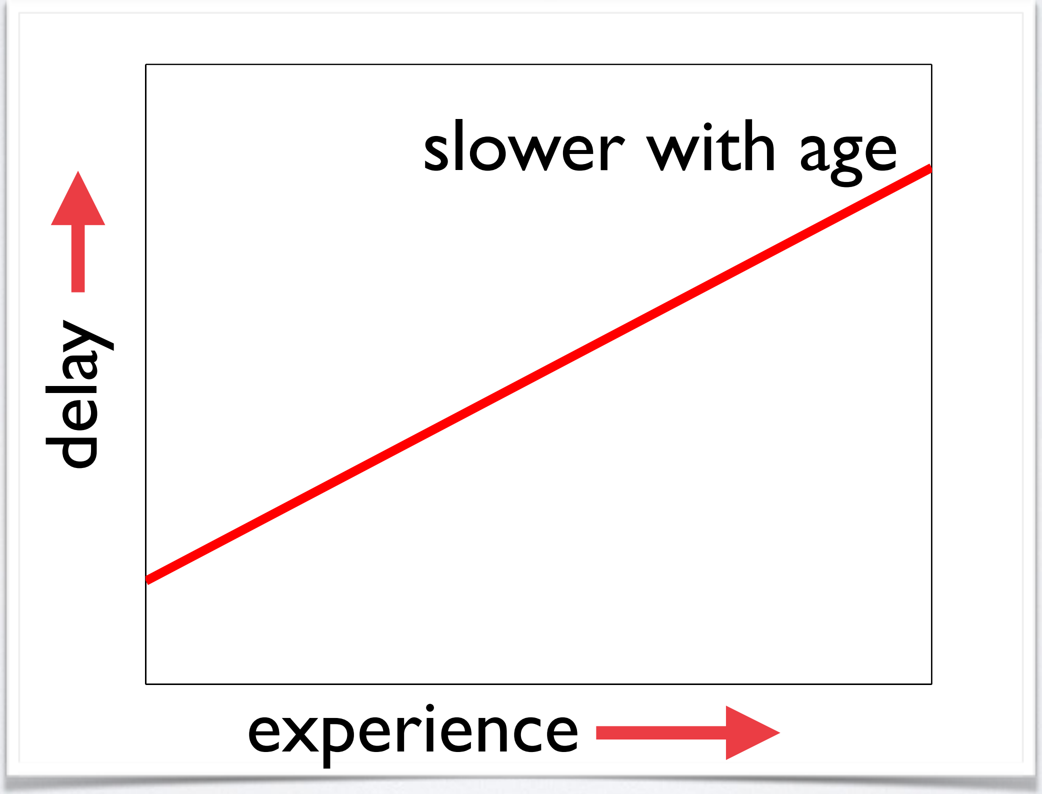
time between attacks	12 days	15 days	14 days	28 days	43 days	38 days	...
event number	1	2	3	4	5	6	...

example:



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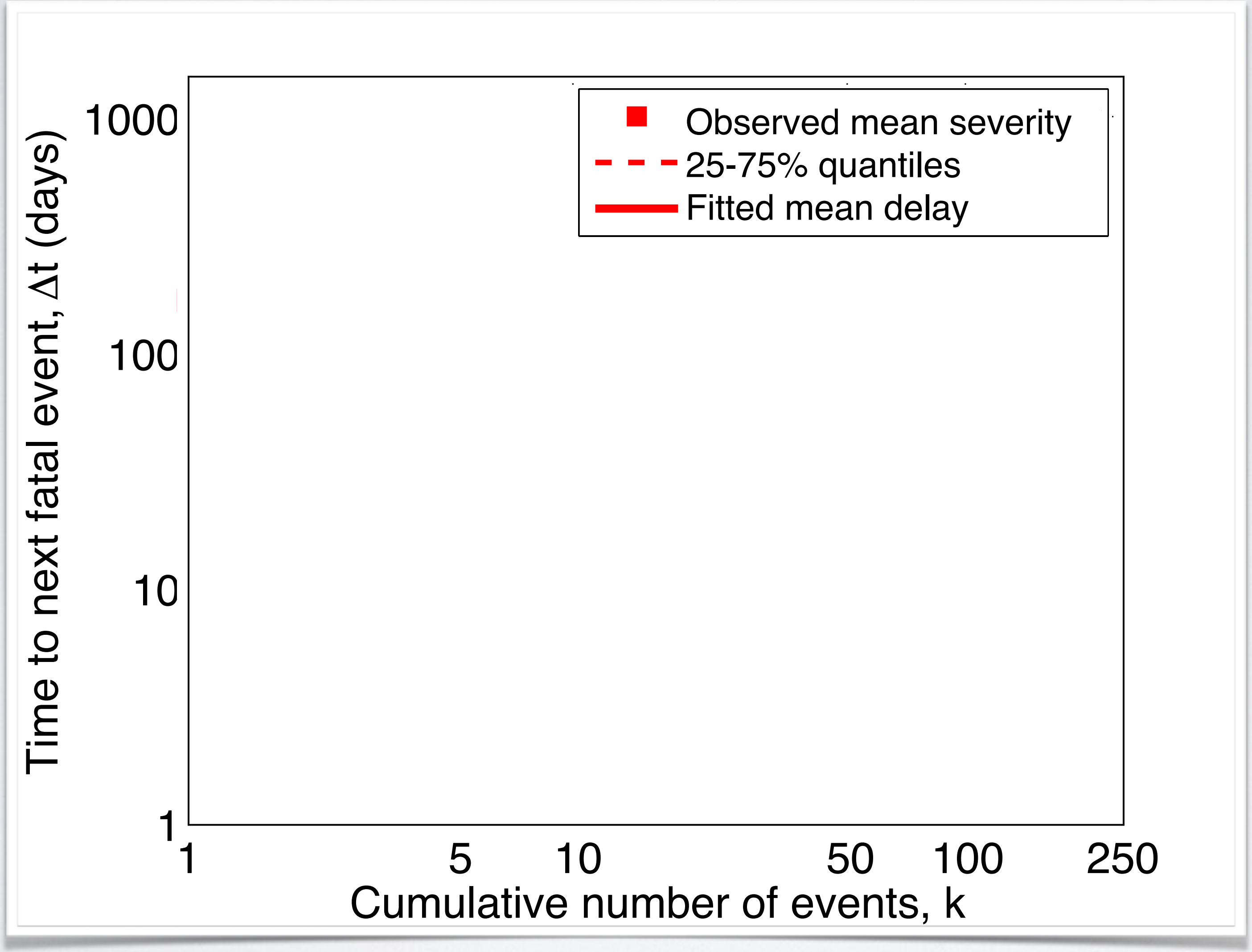

Clauset & Gleditsch, PLoS ONE (2012)

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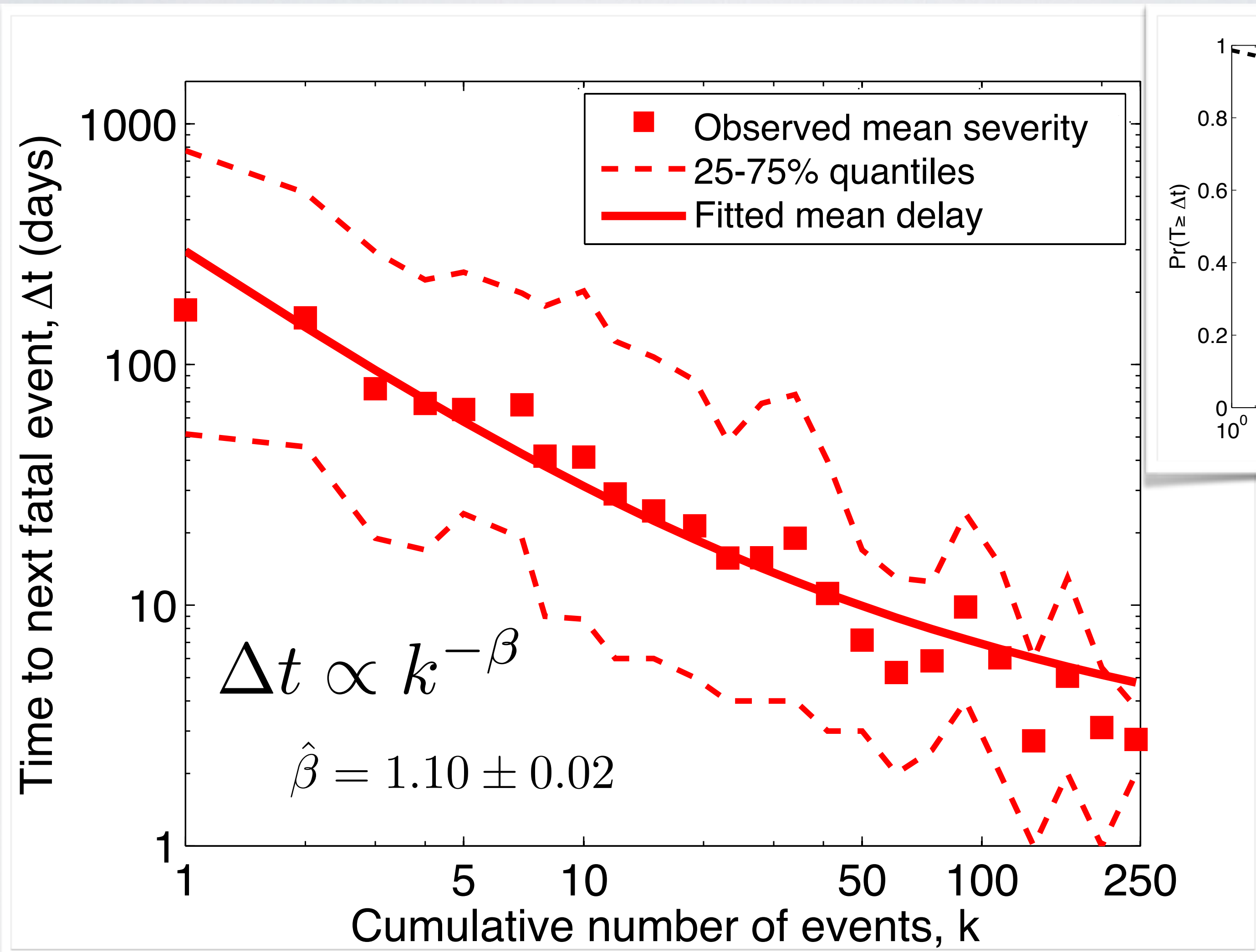
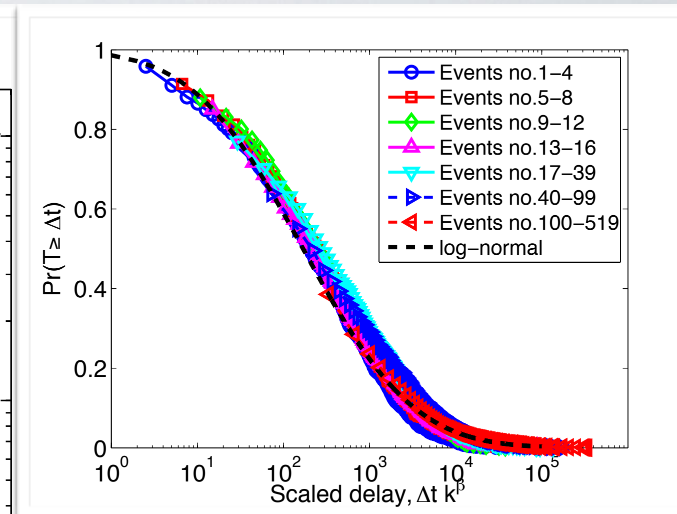


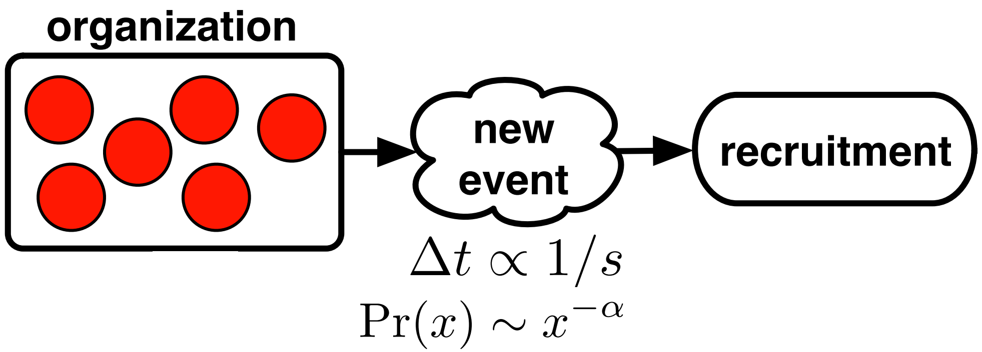


The inset shows a "data collapse" of the marginals, indicating that each follows a lognormal distribution, whose location is determined by *k*

Clauset & Gleditsch, PLoS ONE (2012)

patterns across terrorist groups : frequency

a simple explanation : organizational growth



Δt delay between consecutive events

x severity of events (deaths)

Clauset & Gleditsch, PLoS ONE (2012)

patterns across terrorist groups : frequency

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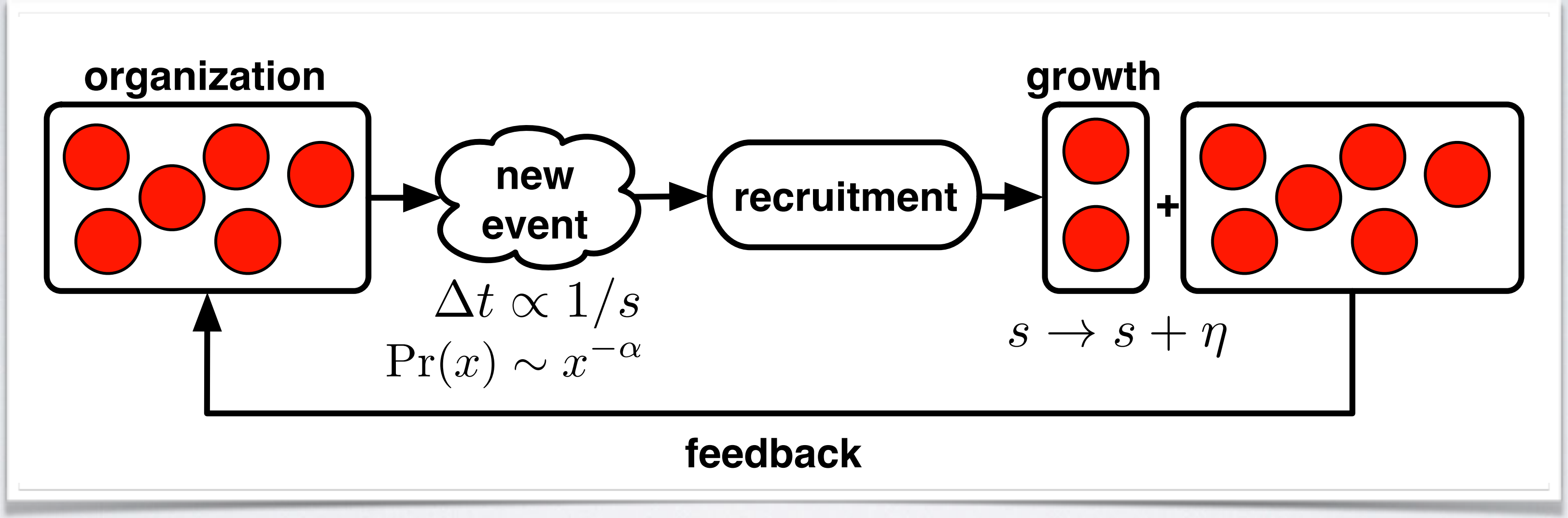

Δt delay between consecutive events

x severity of events (deaths)

simulate this process, plot Δt vs. k →

Clauset & Gleditsch, PLoS ONE (2012)

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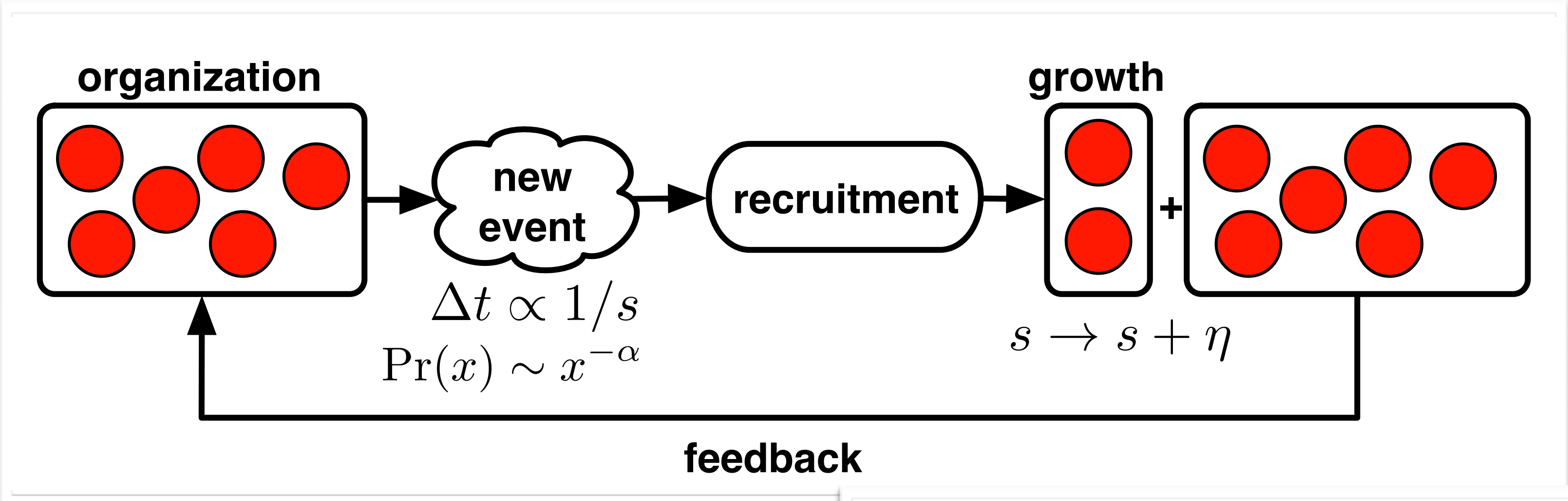

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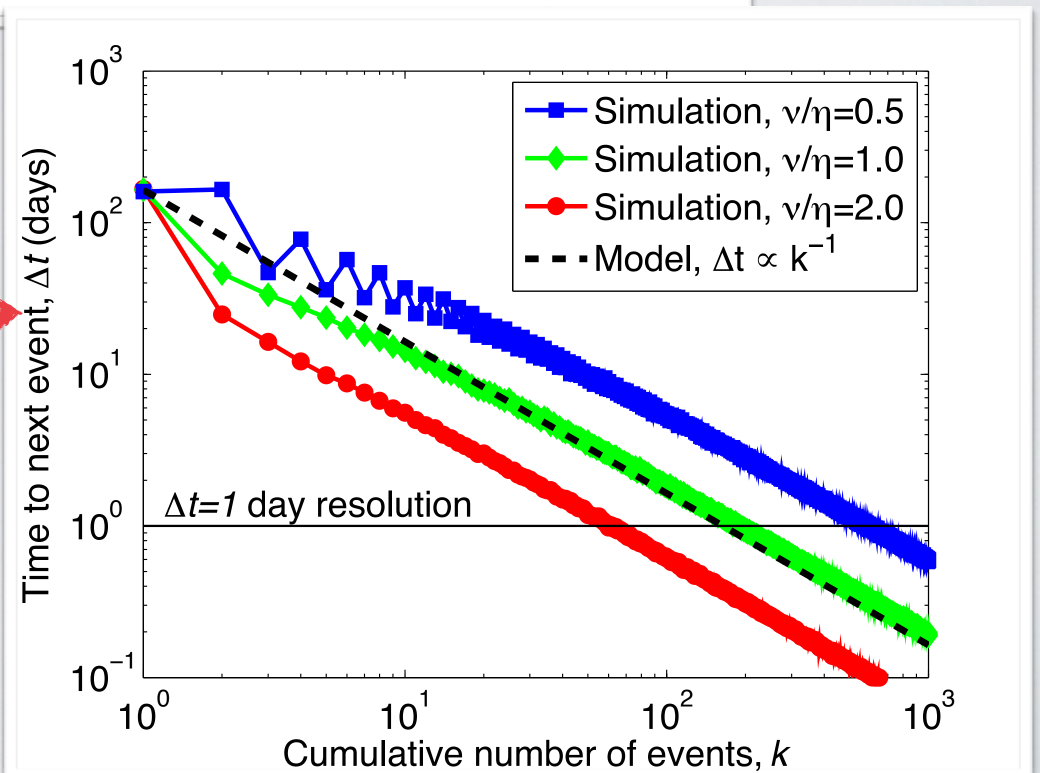
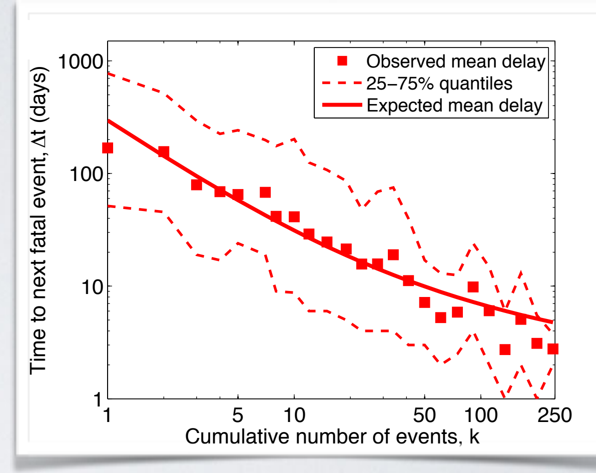


Clauset & Gleditsch, PLoS ONE (2012)

patterns across terrorist groups

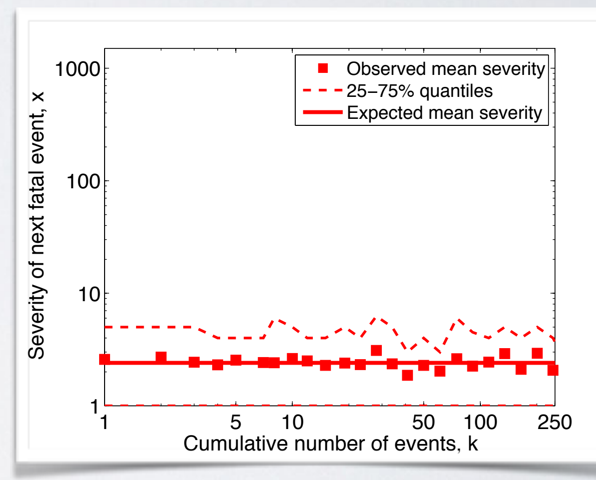
attack production is labor constrained

- bigger groups → more / faster attacks
- attack-recruitment cycle
- acceleration rate varies by group ideology
  [religious groups progress more quickly than secular]



attack severity is independent of labor, experience

- older groups more deadly because faster attacks
- large events just as likely from small groups



prediction: "starve the beast" of recruits → less growth → fewer attacks → lower *risk* of large events

Clauset & Gleditsch, PLoS ONE (2012)

predicting the unpredictable

forecasting ~~predicting~~ the unpredictable

how probable was a 9/11-sized event?

forecasting ~~predicting~~ the unpredictable

how probable was a 9/11-sized event?

requires a probability model $\Pr(x)$

key observations

- care only about large events
  disproportionate consequences
- unknown upper tail structure
  several models fit well
- little data in upper tail
  large statistical uncertainty

forecasting ~~predicting~~ the unpredictable

how probable was a 9/11-sized event?

requires a probability model $\Pr(x)$

key observations

1. care only about large events
   disproportionate consequences
   → separate tail from body

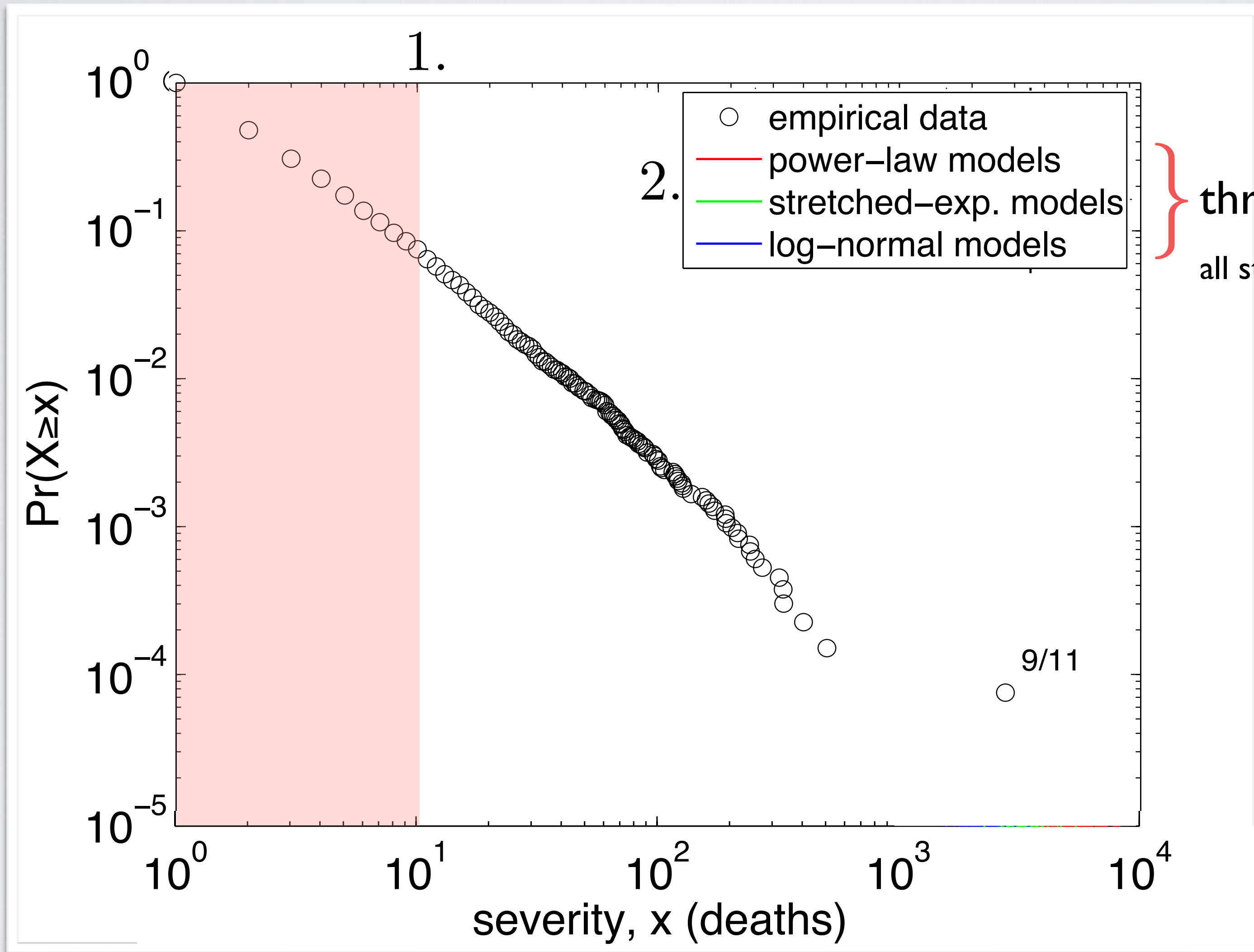
2. unknown upper tail structure
   several models fit well
   → multiple tail models

3. little data in upper tail
   large statistical uncertainty
   → distribution over conclusions

model-based, data-driven forecasts

Clauset & Woodard, Annals of Applied Statistics (2013)

forecasting ~~predicting~~ the unpredictable



three high-variance models

all statistically *consistent* with upper tail

Clauset & Woodard, Annals of Applied Statistics (2013)

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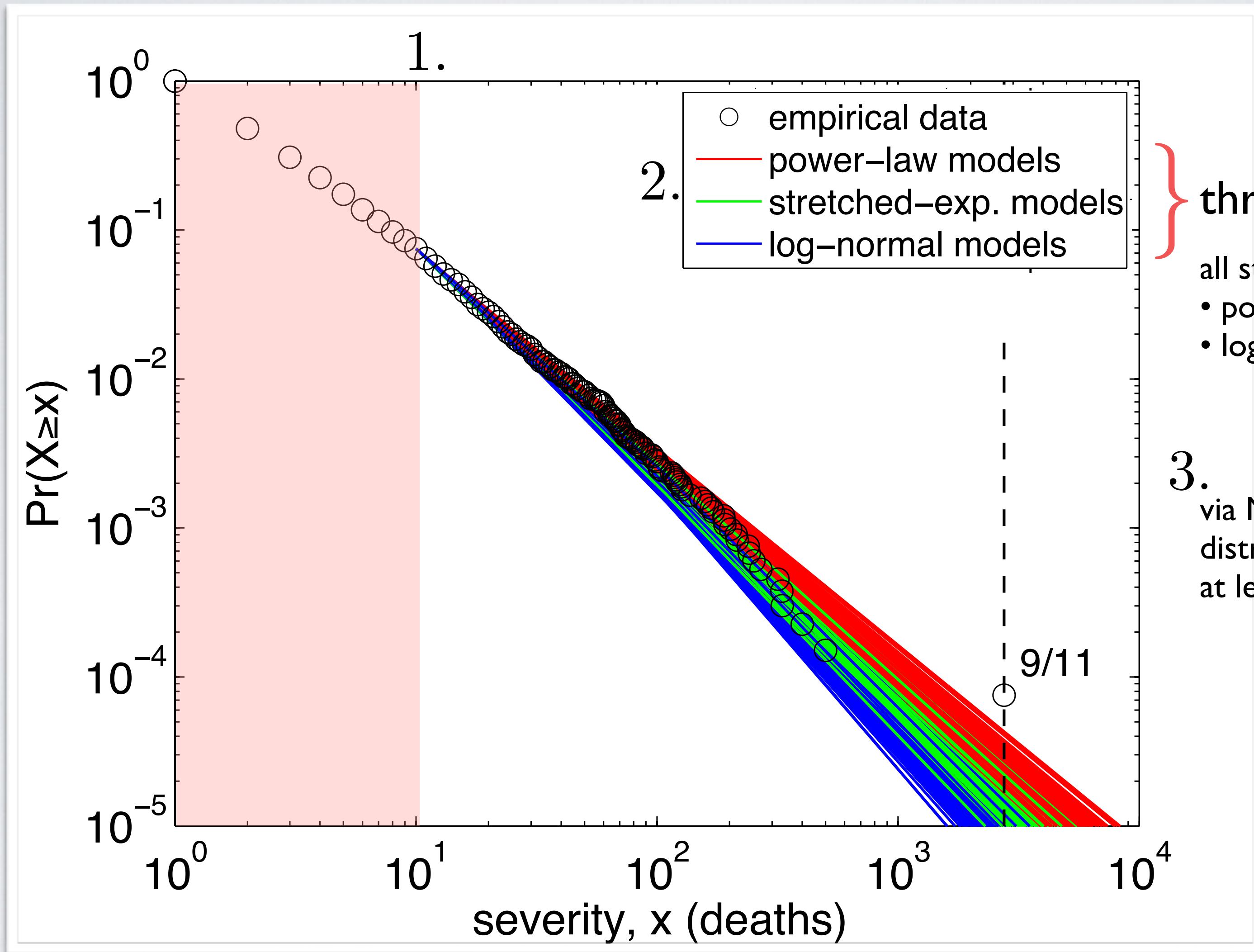


three high-variance models

all statistically *consistent* with upper tail

- power law is most "pessimistic"
- log-normal is most "optimistic"

3.

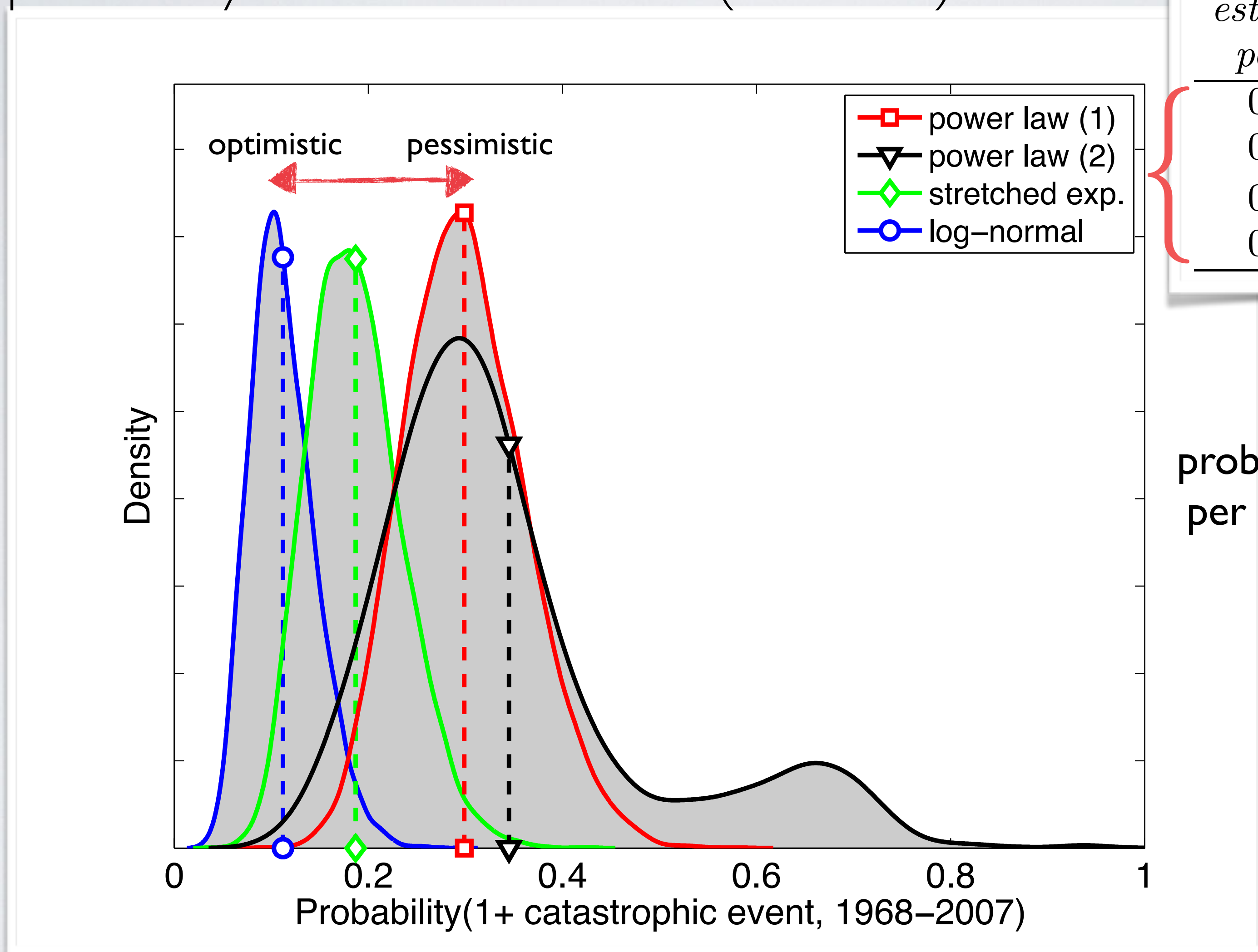
via Monte Carlo, estimate posterior distribution of fraction of histories with at least one 9/11-sized event

$$\rho = 1 - F(x \mid \theta(Y, x_{\min}))^{n_{\text{tail}}}$$

Clauset & Woodard, Annals of Applied Statistics (2013)

forecasting ~~predicting~~ the unpredictable

3. probability of 9/11-sized event (historical)



est. $\Pr(x \geq 2749)$ *per event,* $q(x)$	*est. prob.* p*, 1968–2007*
0.0000270200	0.299
0.0000346345	0.347
0.0000156780	0.187
0.0000090127	0.112

probability per event

40 year probability

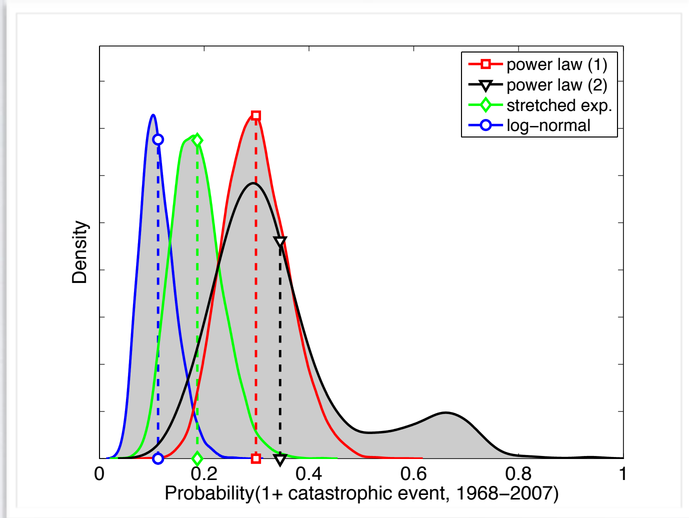
accounting for severity conditioned on weapon type, country's OECD status, and before/after 1998 does not substantially alter conclusions

Clauset & Woodard, Annals of Applied Statistics (2013)

forecasting ~~predicting~~ the unpredictable

recipe for large event forecasts

1. focus on *large events* only
   separate "body" from "tail", then use tail models
2. use *multiple* models
   true tail structure unknown ➔ large model uncertainty
3. compute *distribution* over outcomes
   little data in tail ➔ large statistical uncertainty
4. combine with time series model $n(t)$
   more events per unit time ➔ more risk of a large event



➔ start with population (all terrorism, all wars), in aggregate

➔ add covariates to model, but avoid over-fitting*

➔ greater uncertainty better than false certainty

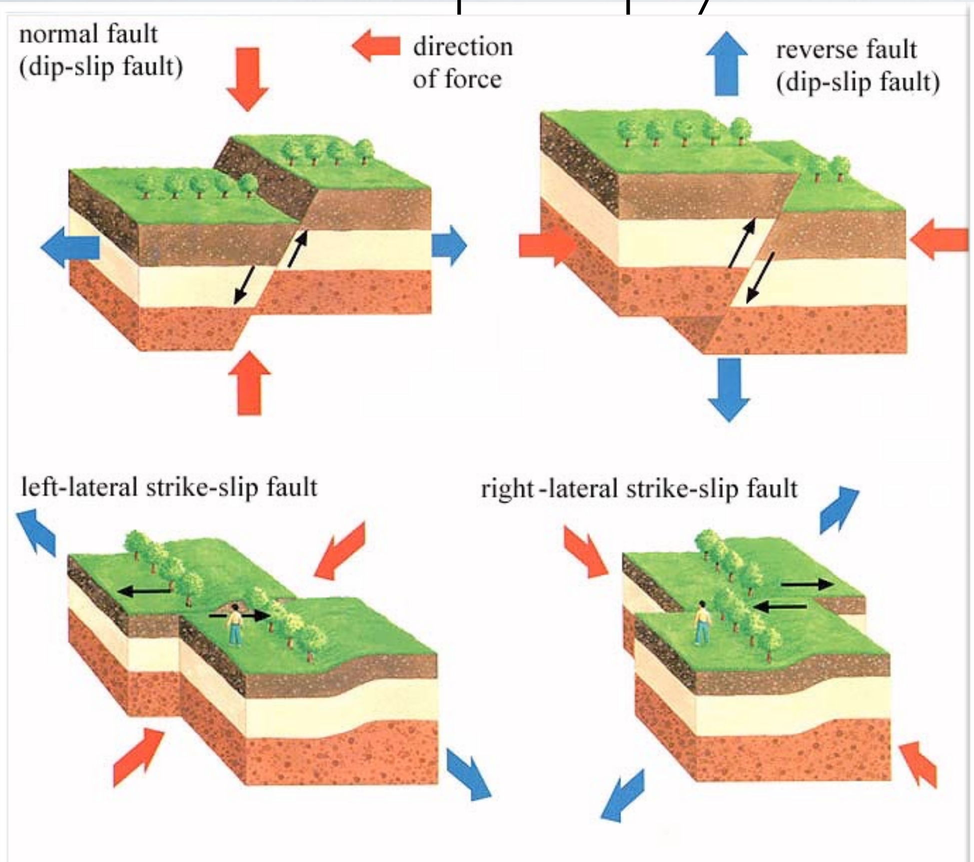
* easier said, than done

Clauset & Woodard, Annals of Applied Statistics (2013)

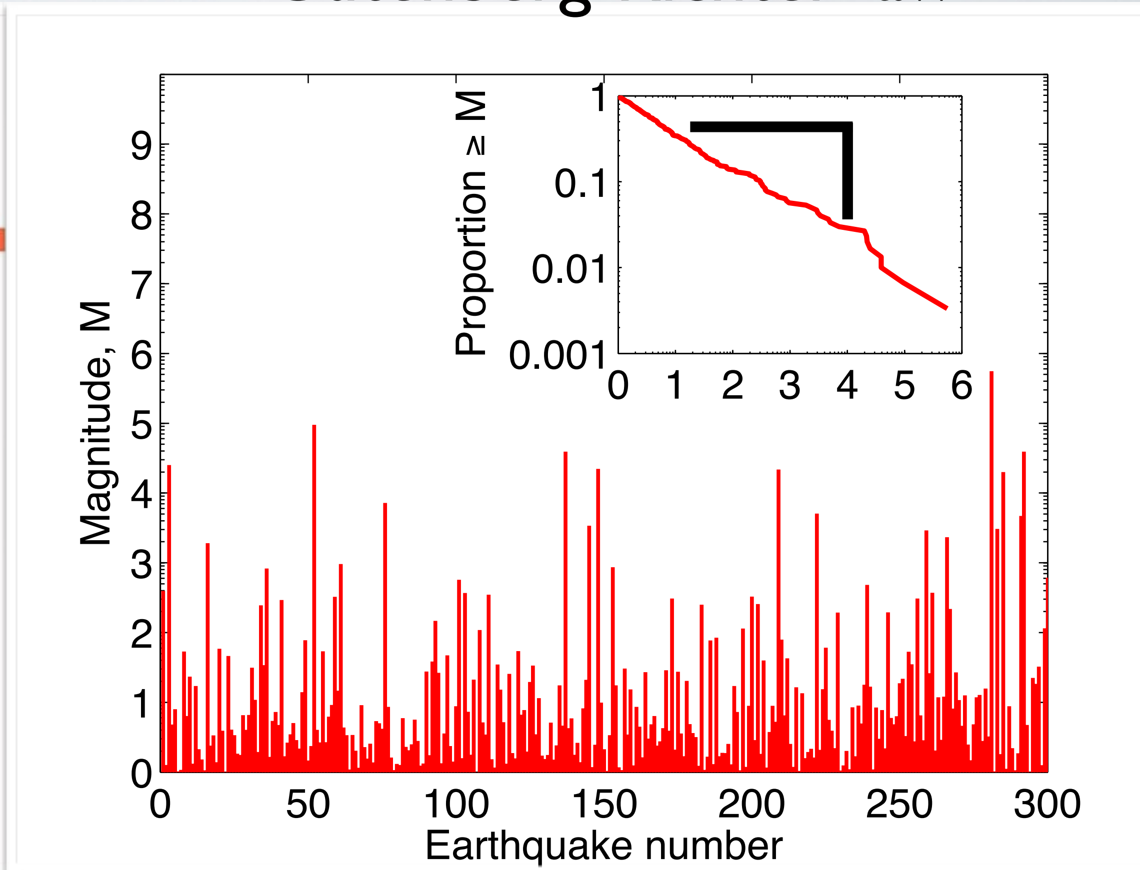
prediction in violent political conflict

prediction in ~~violent political conflict~~ seismology

earthquake physics



Gutenberg-Richter law

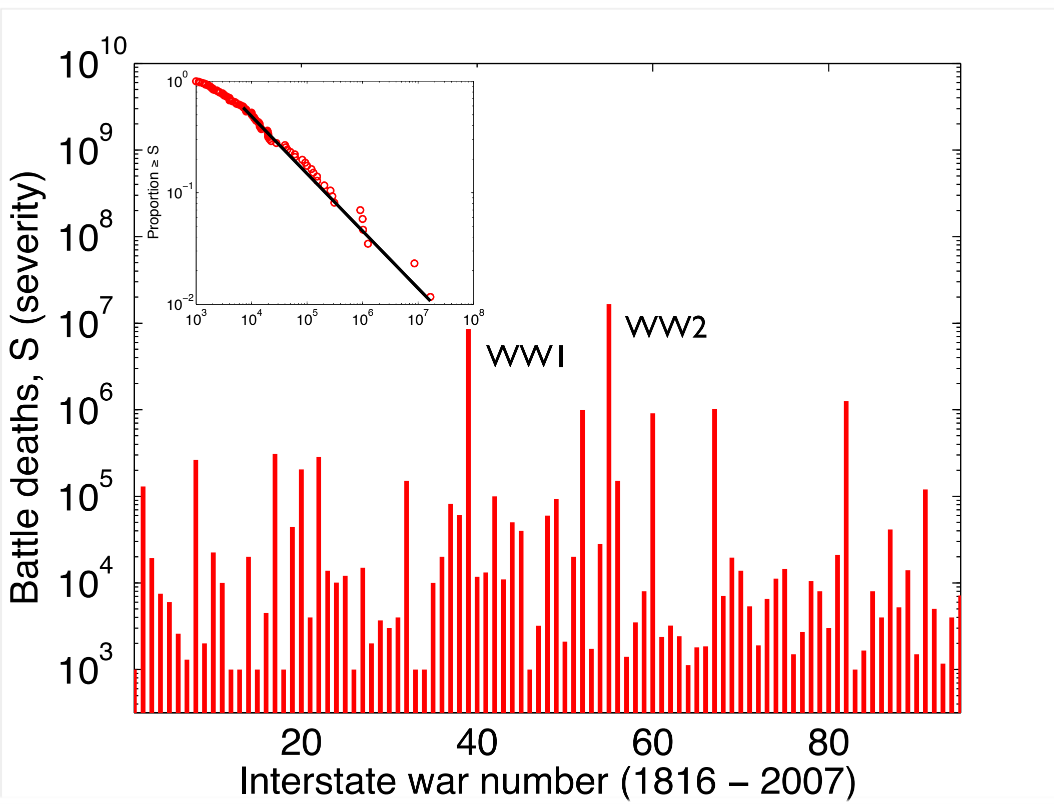


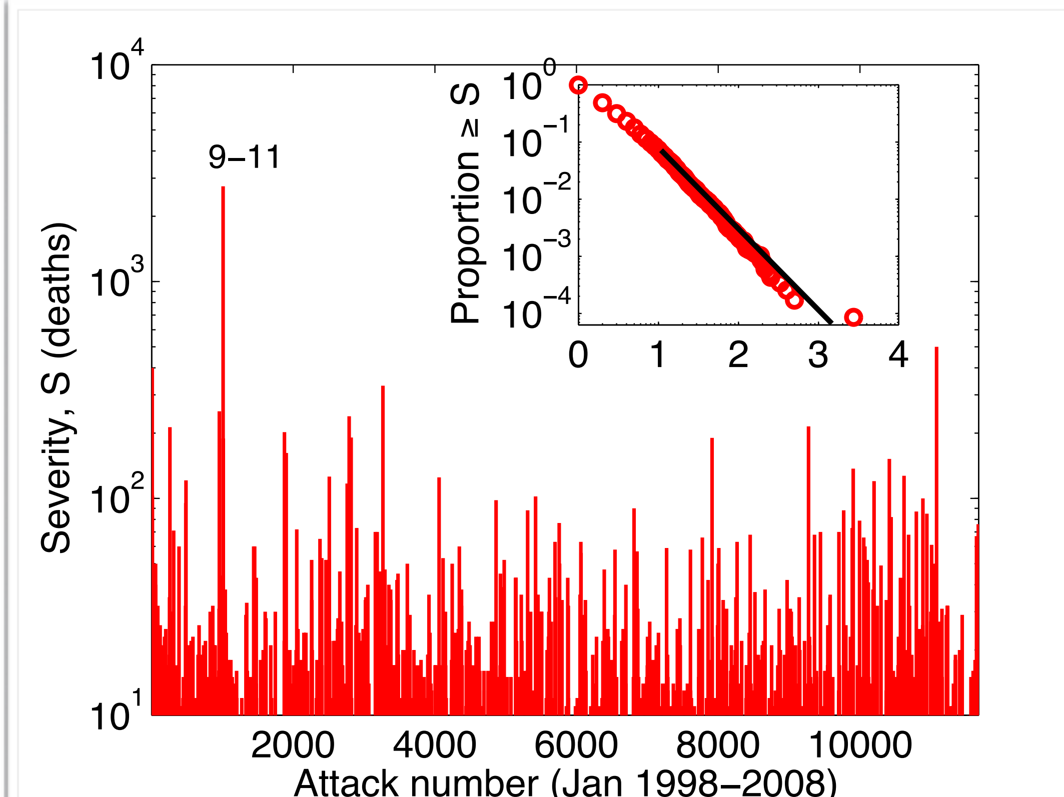
$$(\text{frequency}) \propto (\text{magnitude})^{-\alpha}$$

power-law relation

international wars & global terrorism

international wars also follow power-law statistics





$$(\text{frequency}) \propto (\text{magnitude})^{-\alpha}$$

power-law relation

on wars, see Braumoeller, Only The Dead (2019)

earthquakes	**terrorism & war**
Gutenberg-Richter law $F \propto M^{-\alpha}$	Richardson's law $F \propto S^{-\alpha}$
physics largely *known*	processes largely *unknown*
processes *fixed*	processes *dynamic, adaptive*
forecasting possible (years of successes)	forecasting is possible (over long term)
prediction very hard (years of failures)	prediction very hard (agency & contingency)

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why? robust *statistical patterns* exist, *in aggregate*, which allow *probabilistic* estimates, over populations (*not* individuals)

- **average over contingencies & beyond individual agency**
- **capture fundamental constraints**
- **best predictions made using *multiple* means for controlling *model uncertainty* and *statistical uncertainty***

acknowledgements


Kristian Gleditsch
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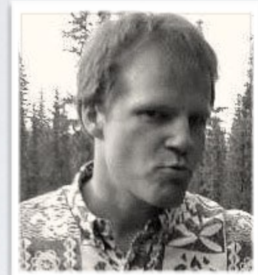
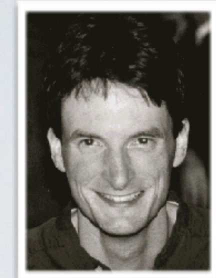
Computer Science, MSU


Ryan Woodard
ETH Zürich


Cosma Shalizi
Statistics, CMU


Mark Newman
Physics, Michigan

and

Lars-Erik Cederman Barbara Walter James McNerney Brian Tivnan Valerie Wilson

references

Trends and fluctuations in the severity of interstate wars
. *Science Advances* (2018)

Estimating the historical and future probabilities of large terrorist events
with R. Woodard *Annals of Applied Statistics* (2013)

Developmental dynamics of terrorist groups
with K.S. Gleditsch *PLoS ONE* (2012)

Power-law distributions in empirical data
with C.R. Shalizi & M.E.J. Newman *SIAM Review* (2009)

On the frequency of severe terrorist attacks
with M. Young & K.S. Gleditsch *Journal of Conflict Resolution* (2007)

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Trends and fluctuations in the severity of interstate wars

Aaron Clauset*