Is a sub 2 hour marathon in the near future? Modeling rare events in sports.

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Outline

- Baseball Rare Events (if needed only)
- Background
- Marathon Data
- Simple Model
- Self-Exciting Model
- Further Research

Background

Are we living in a time of records?

- Include NY Times article screenshot of headline.
- Brief summary of article's premise.

How can we address this question?

What would randomness look like?

Pictures of Rod and Nick running

Marathon World Record Data

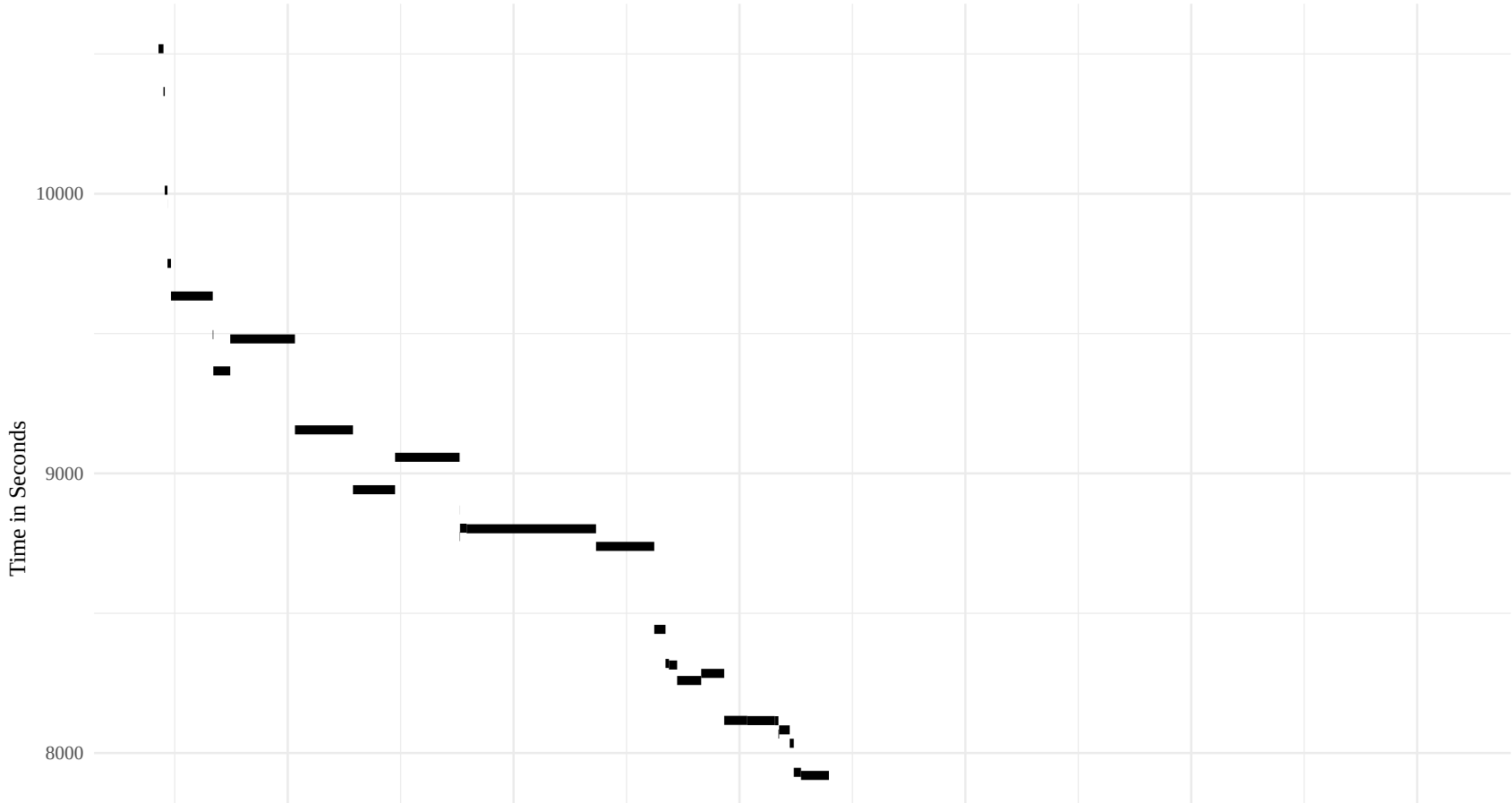
Men's Marathon world records since 1908

NEED TO CLEAN UP - NICER TABLE WITH JUST TIME NAME NATIONALITY DATE MAYBE INCLUDE A COUPLE OF PICTURES OF PEOPLE

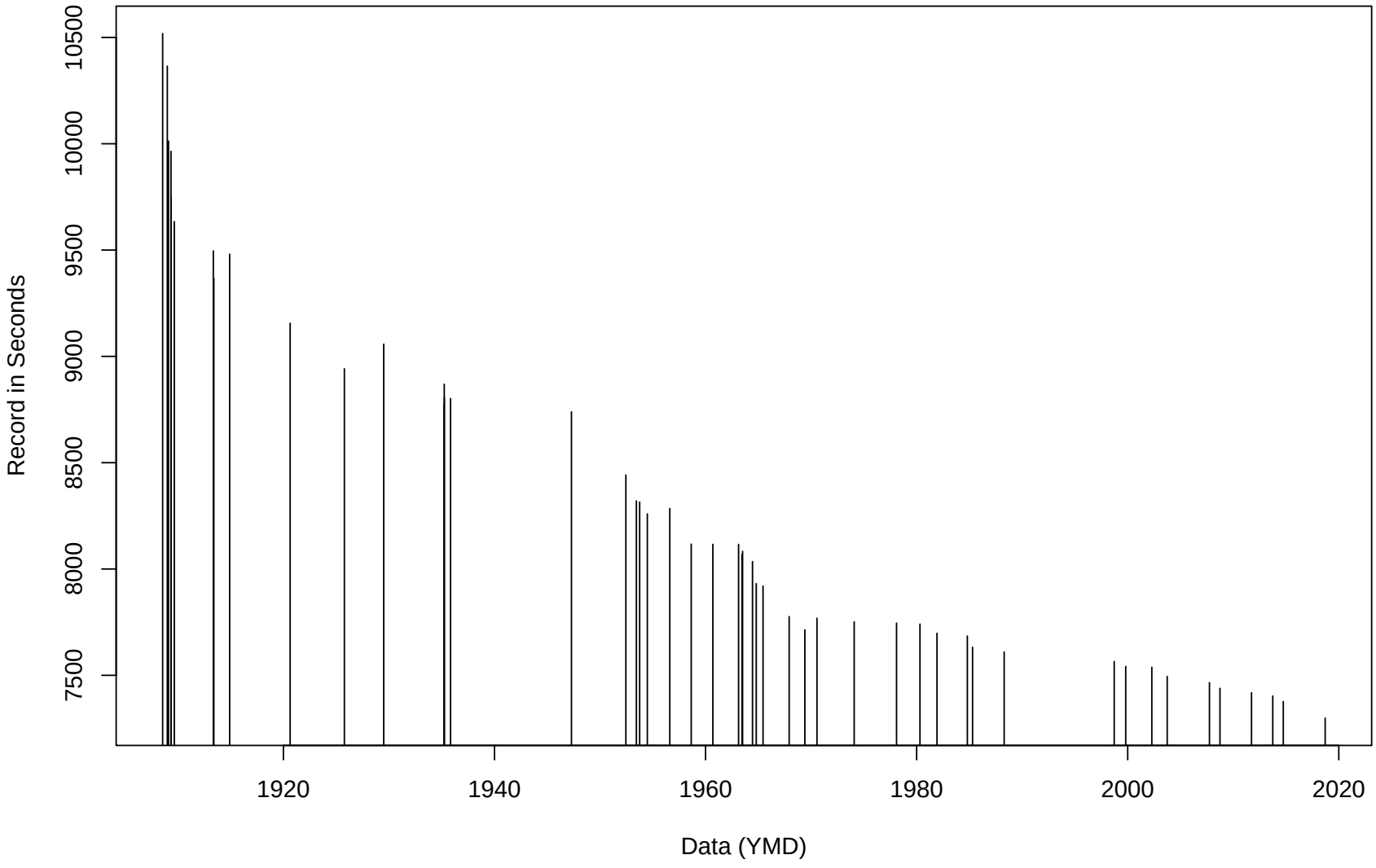
```
## # A tibble: 6 x 11
##   Time  Name  Natio~1 Date  Event~2 Source Notes Time_t
##   <chr> <chr> <chr>   <chr> <chr>   <chr>  <chr> <Perioc
## 1 2:55~ John~ United~ July~ London~ IAAF[~ Time~ 2H 55M
## 2 2:52~ Robe~ United~ Janu~ Yonker~ IAAF[~ Note~ 2H 52M
## 3 2:46~ Jame~ United~ Febr~ New Yo~ IAAF[~ Note~ 2H 46M
## 4 2:46~ Albe~ United~ May ~ New Yo~ IAAF[~ Note~ 2H 46M
## 5 2:42~ Henr~ United~ May ~ Polyte~ IAAF[~ Note~ 2H 42M
## 6 2:40~ Thur~ Sweden  Augu~ Stockh~ IAAF[~ Note~ 2H 40M
## # ... with 1 more variable: end <date>, and abbreviated
## #   1: Nationality, 2: `Event/Place`, 3: Time_sec
## # i Use `colnames()` to see all variable names
```

Visualizing the data

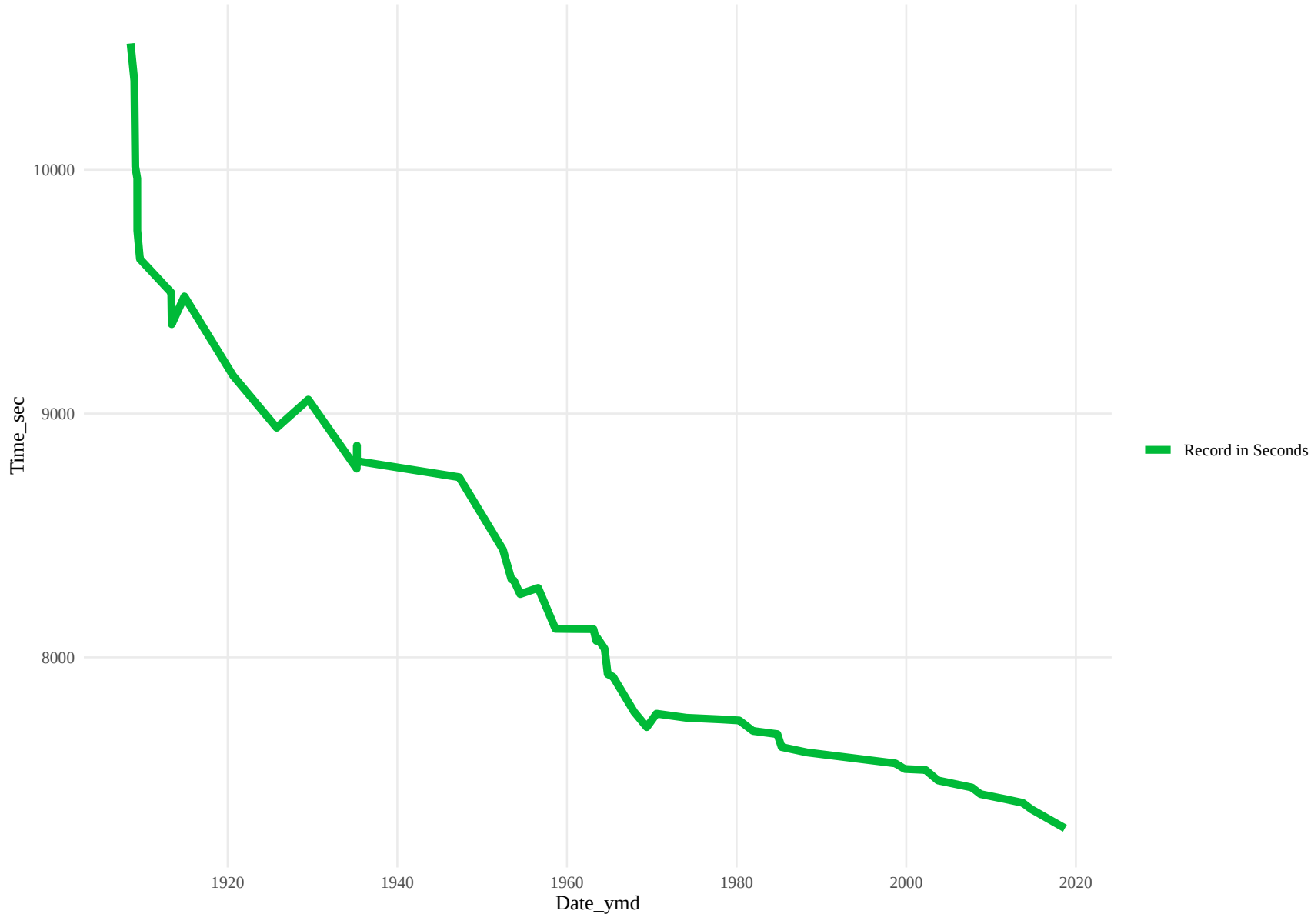
AGAIN NEED CLEANING UP - NEED TIMES IN SOMETHING OTHER THAN SECONDS MAYBE INCLUDE 2 HOUR HORIZONTAL BAR MAYBE HAVE A SLIDE WHERE ADD PICTURES OF PEOPLE WHO LOWERED RECORD BY A LOT WHICH PLOT(S) TO USE? MAYBE TWO OF THEM BUT ON ONE SLIDE?



Visualize B


Record in Seconds
7500
8000
8500
9000
9500
10000
10500
1920
1940
1960
1980
2000
2020
Data (YMD)

Visualize C


10000
9000
8000
Time_sec
1920
1940
1960
1980
2000
2020
Date_ymd
Record in Seconds

SIMPLE MODEL

POISSON PROCESS (NEED TO SHORTEN, OR PUT ON TWO SLIDES)

A model for a series of discrete events where the average time between events is known, but the exact timing of events is "random" meeting the following criteria:

- Events are independent of each other. The occurrence of one event does not affect the probability another event will occur.
- The average rate (events per time period) is constant.
- Two events cannot occur at the same time.

The time between events (known as the interarrival times) follow an exponential distribution defined as:

$$P(T > t) = e^{-\lambda t}$$

Where T is the random variable of the time until the next event, t is a specific time for the next event, and λ is the rate: the average number of events per unit of time. Note the possible values of T are greater than 0 (positive only).

Reasonableness of Exponential Interarrivals

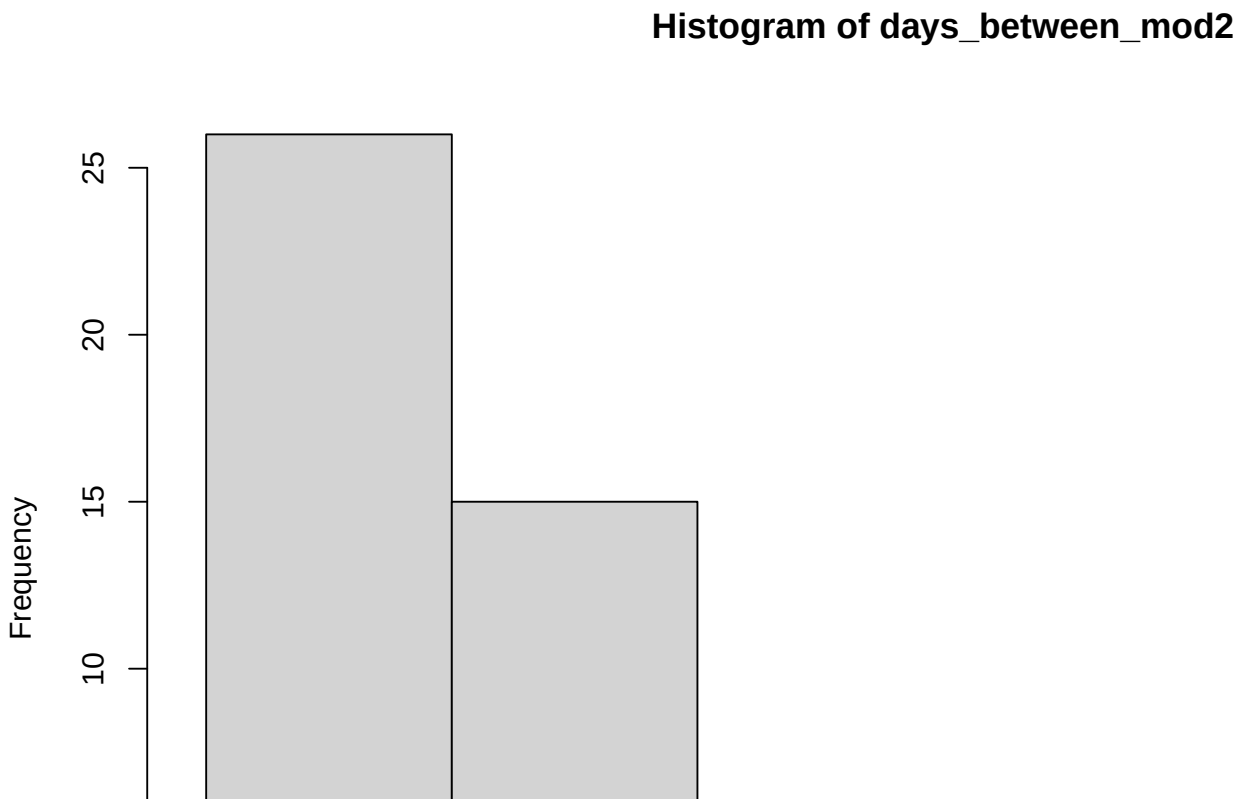
The exponential distribution has certain attributes, for example:

$E(T) = 1/\lambda$ $SD(T) = 1/\lambda$

The mean and standard deviation of the years between records:

```
## [1] 2.249427
```

```
## [1] 2.428191
```

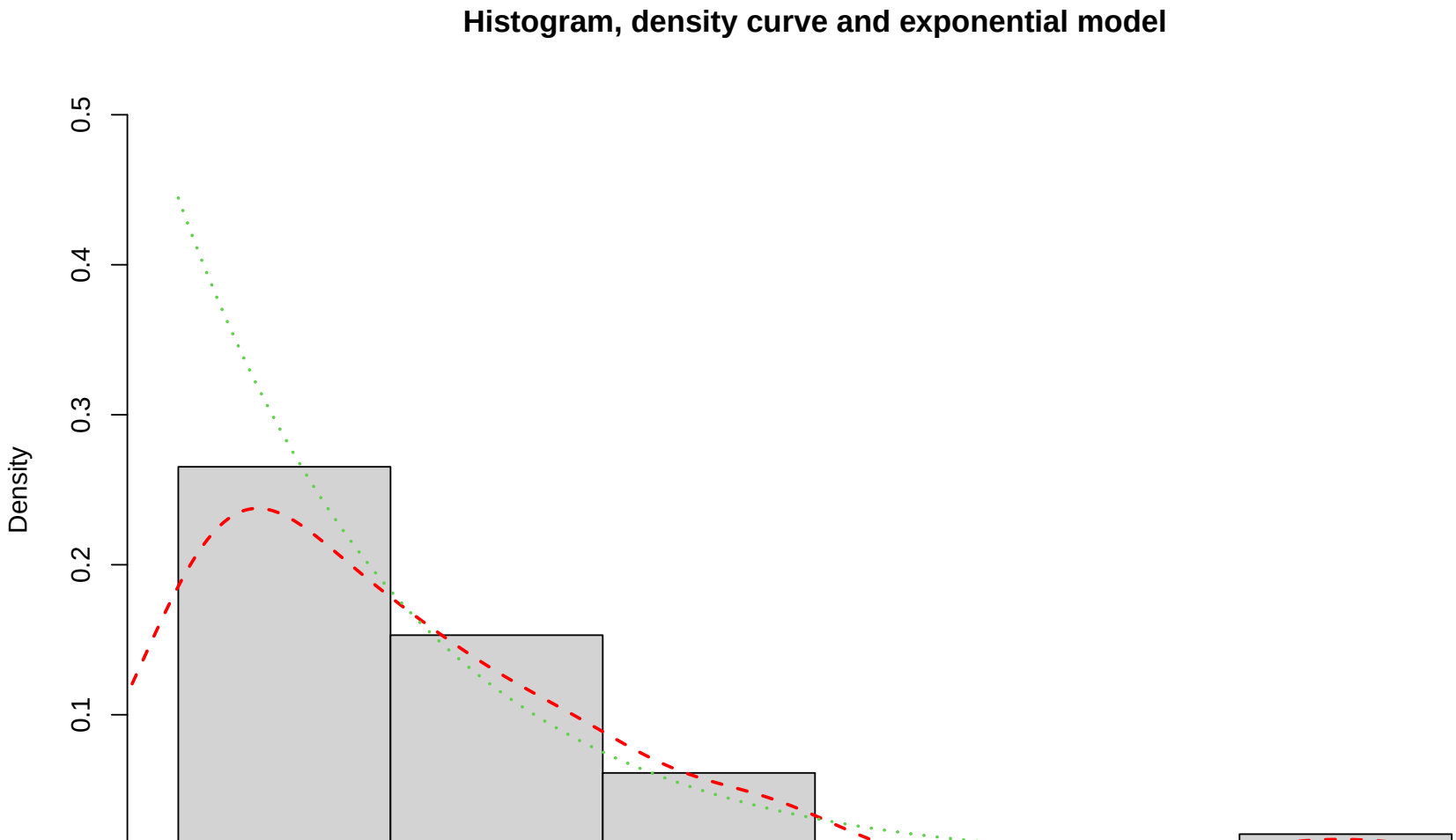


MORE ON THE SIMPLE MODEL

We estimate (MLE) $\lambda = 1/E(T)$

```
##      rate
## 0.4445577
```

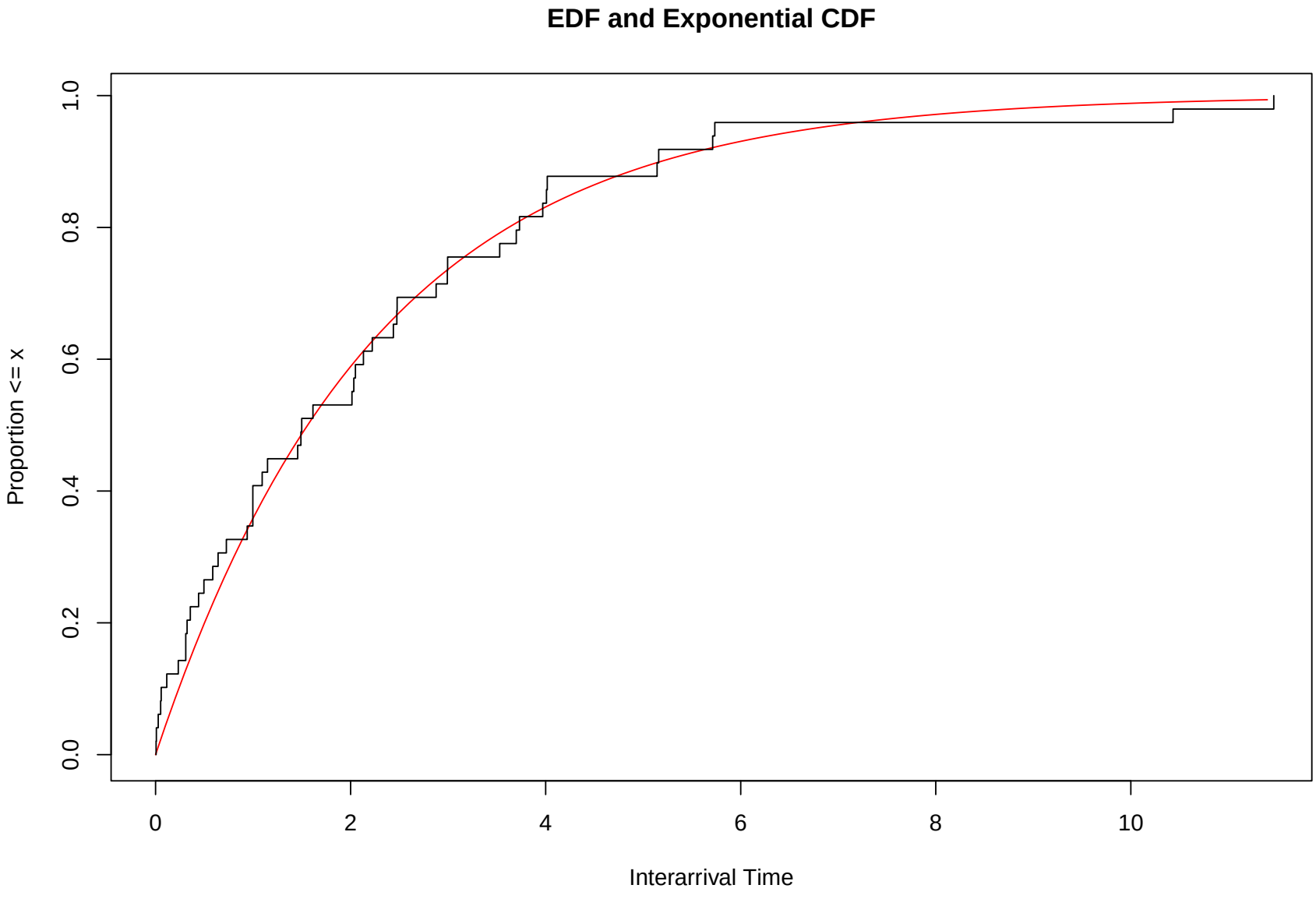
Model fit



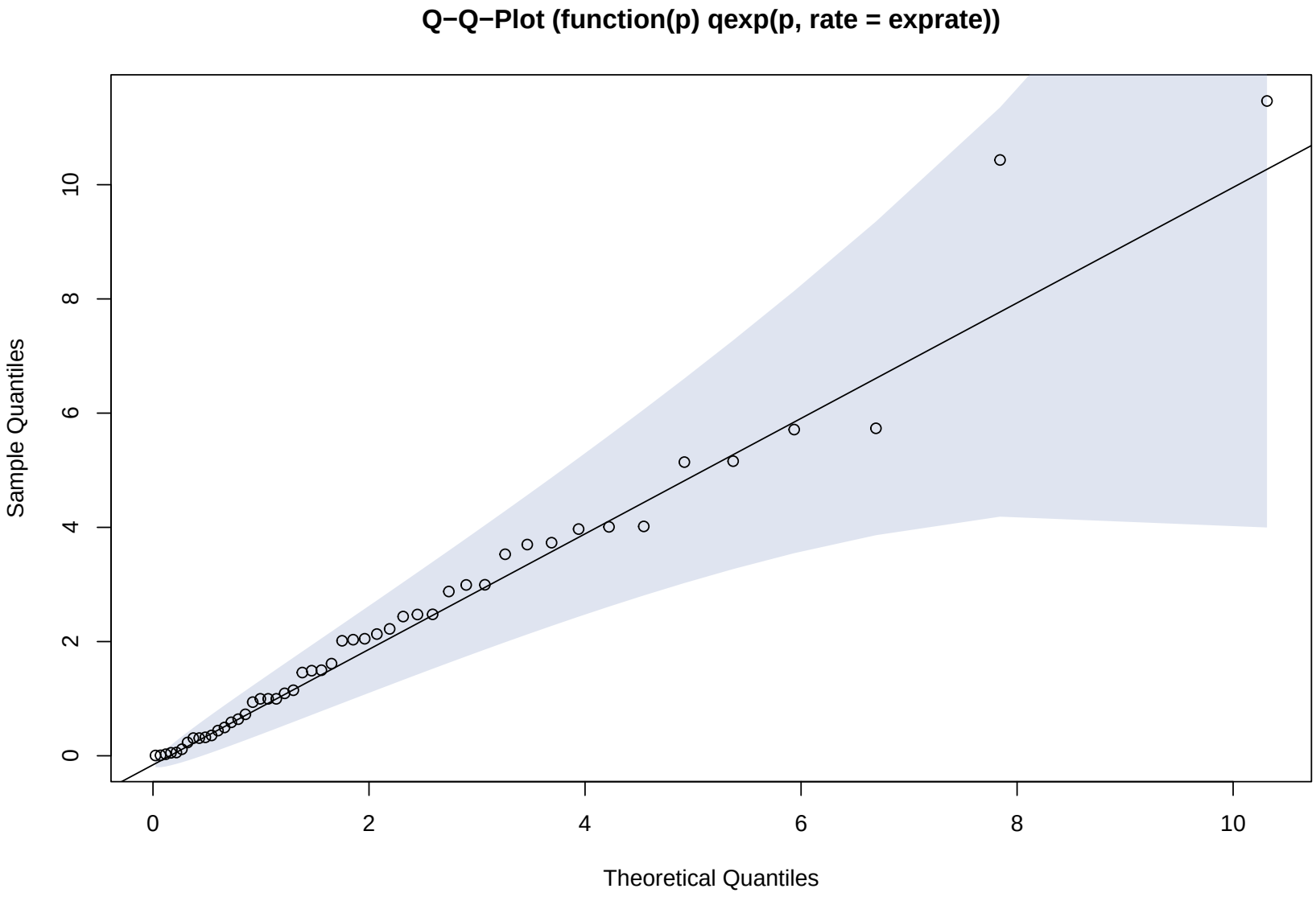
Fit of simple model

```
##
##  One-sample Kolmogorov-Smirnov test
##
## data:  days_between_mod2
## D = 0.078053, p-value = 0.9264
## alternative hypothesis: two-sided

##
##  Cramer-von Mises test of goodness-of-fit
##  Braun's adjustment using 7 groups
##  Null hypothesis: exponential distribution
##  with parameter rate = 0.444557679401457
##  Parameters assumed to have been estimated from data
##
## data:  days_between_mod2
## omega2max = 0.35315, p-value = 0.5002

##
##  Anderson-Darling test of goodness-of-fit
```

Fit of simple model B



Are records then random?



What are the poorly fit points?

LOOK BACK AT THE ORIGINAL DATA HERE...LONGEST TIMES BETWEEN EVENTS (I THINK - NEED TO LOOK MORE CLOSELY)...ONE IS WW2 PRETTY SURE...THE OTHER NEED TO LOOK AGAIN - MAYBE AN UNUSUALLY LARGE LOWERING OF THE RECORD OR SOMETHING?

A "Self-Exciting" Model

Hawkes Processes

- Let H_t be the history of events up to time t. The Hawkes (1971) model of the conditional intensity is:

$$\lambda(t|H_t) = \nu + \sum_{i:t_i<t} g(t - t_i)$$

where ν is the background rate of events and g is the "triggering function".

- The "triggering" function can be further decomposed:

$$g = \mu g^*$$

where g^* is a density function known as the "reproduction kernel" and μ is known as the "reproduction" mean.

- A common choice for the "reproduction kernel" is the exponential density given by:

$$g^*(s) = \alpha e^{-\beta t}$$

Fitting the model

Parameter estimates for marathon data (exponential) Hawkes process, using MLE:

- baseline intensity 0.396
- reproduction mean 0.121
- exponential reproduction function rate 3.91

Note the baseline intensity is slightly lower than the constant model rate estimate of 0.445

The estimated reproduction function is then:

$$g(t) = \mu g^*(t) = \mu\beta e^{-\beta t}$$
$$= 0.12 * 3.91 e^{-3.91 t}$$

Model implications

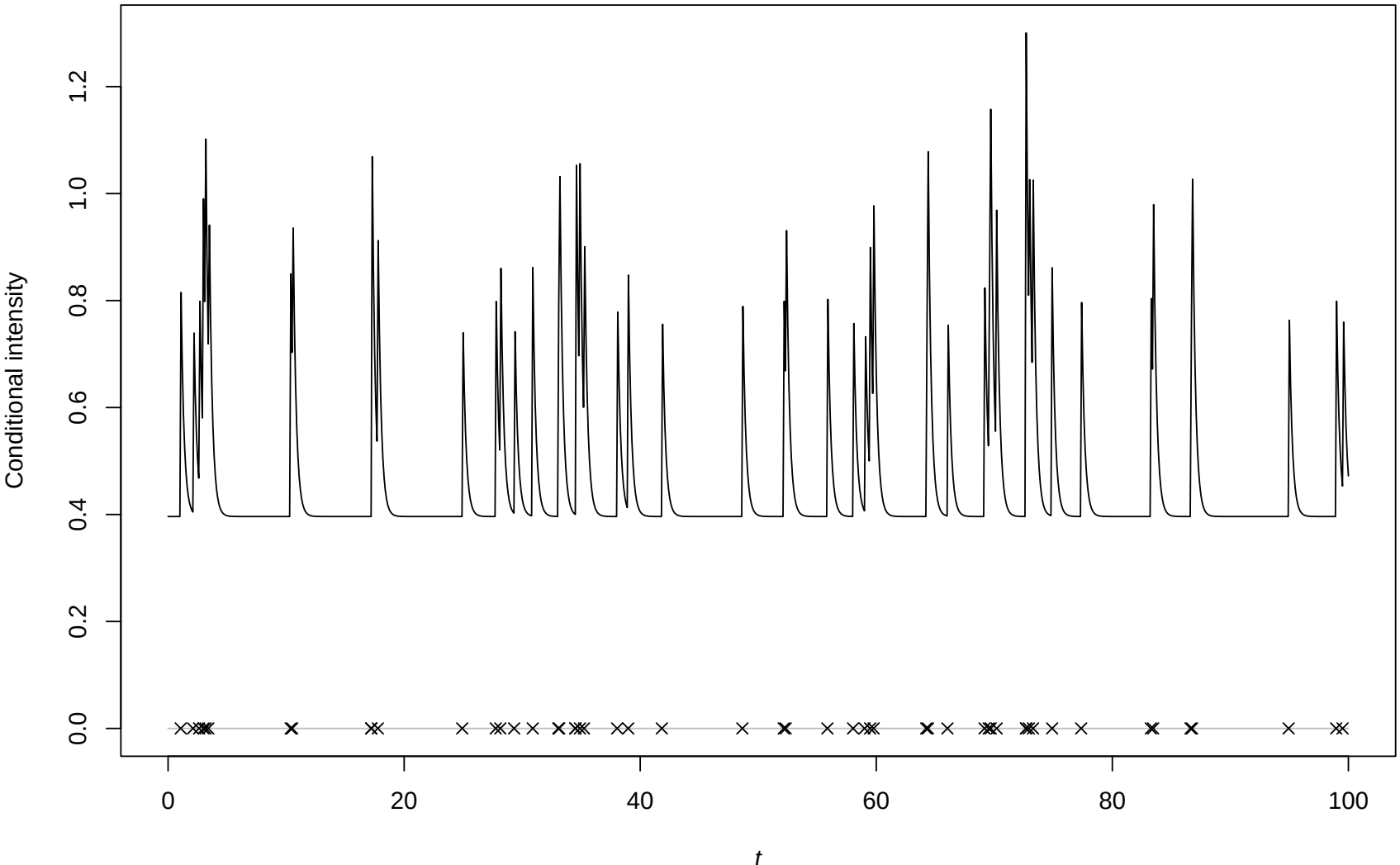
At the instant of the first event (world record), $t = t_1$ so $g(t - t_1 = 0)$ and the reproduction rate is:

$$g(0) = 0.12 * 3.91e^{-3.910} = 0.12 * 3.91 = 0.471$$

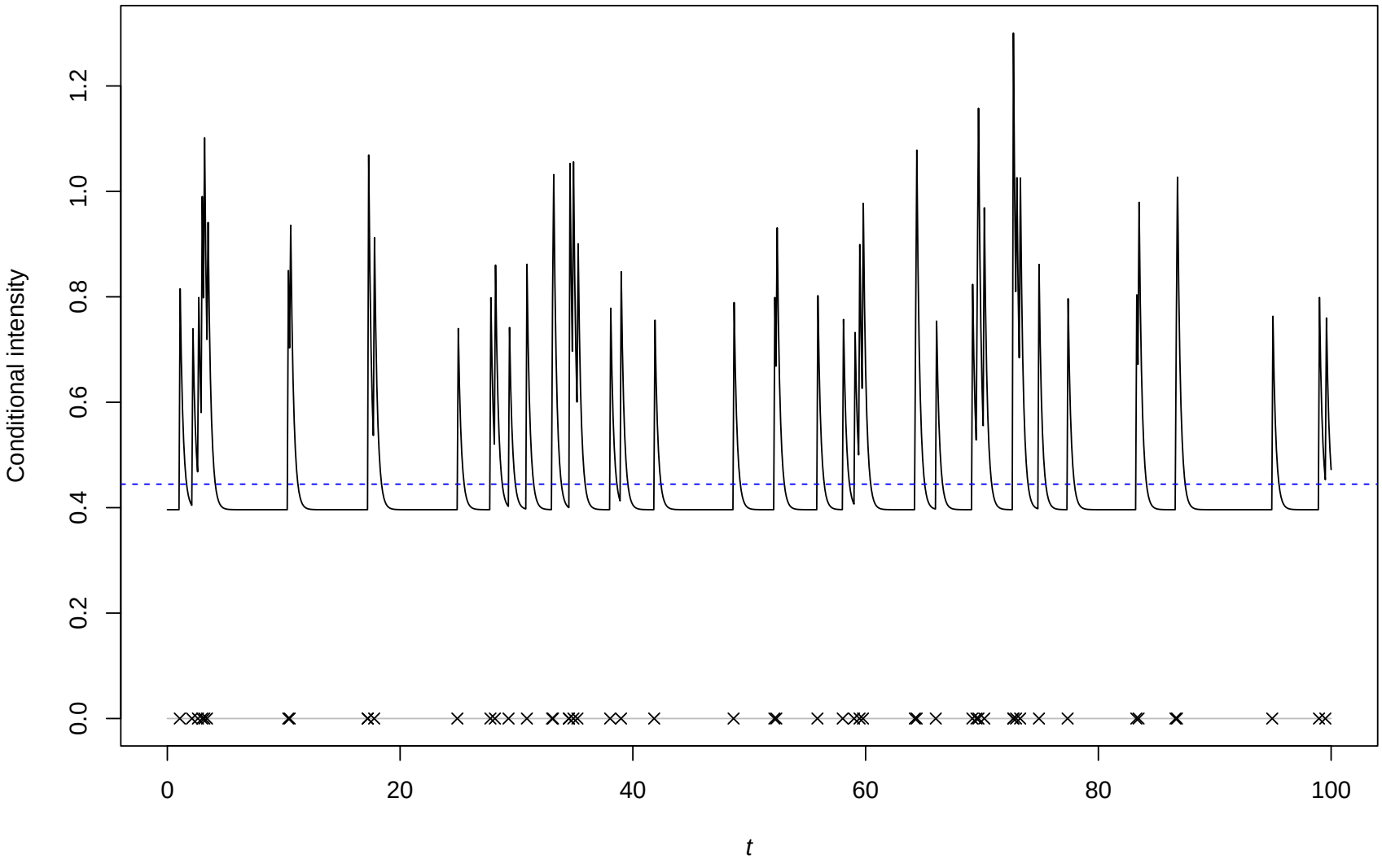
- The rate increases from the baseline rate of 0.396 by this amount at the moment of this occurrence
- The rate then decays back to baseline over time (unless a new event occurs).
- Each new event "excites" the rate to increase and then decay

The Intensity Function over Time

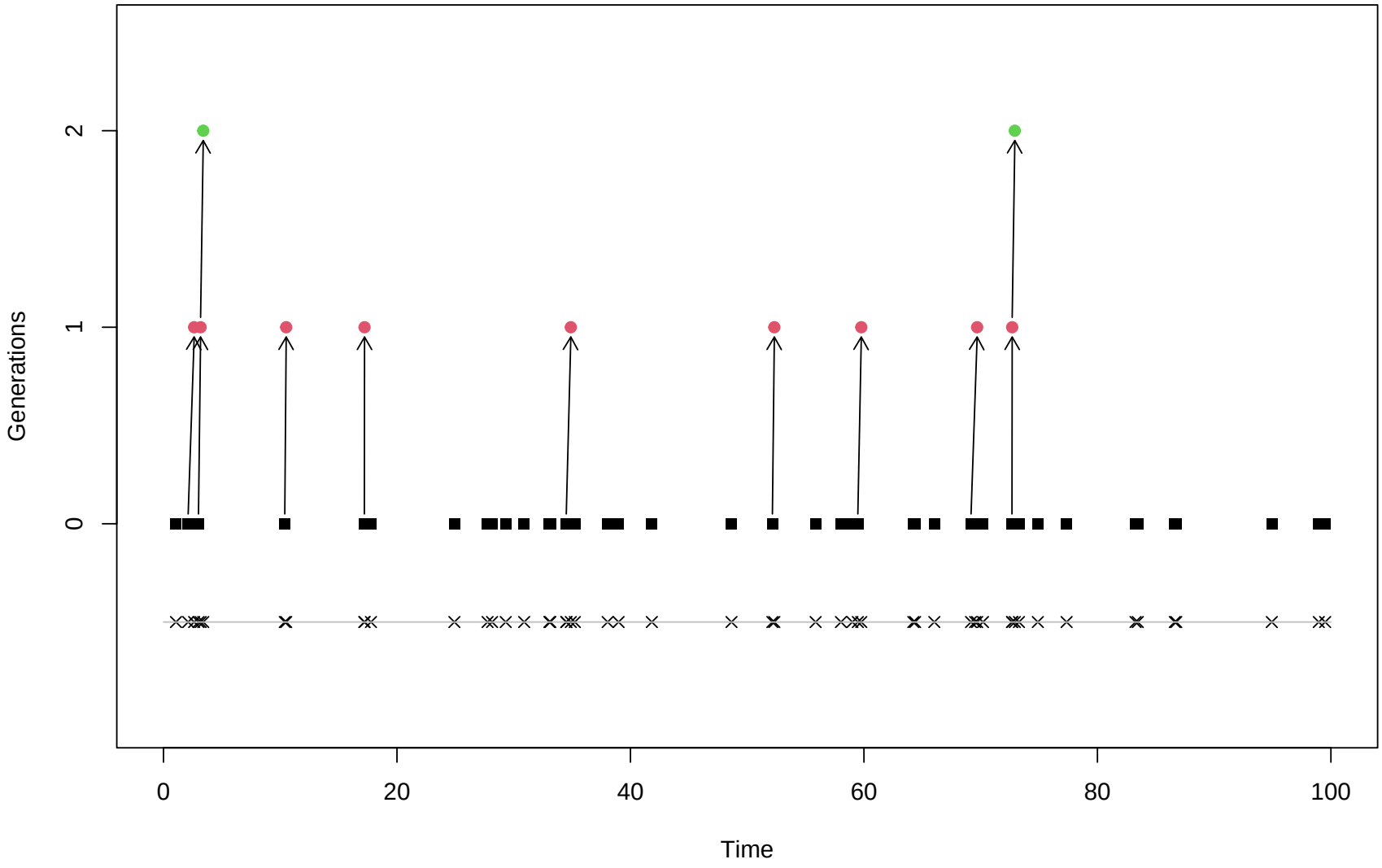
Below is based on a simulation of the intensity function over a 100 year period. NOTE: HERE WOULD BE NICE TO SHOW FOR OUR DATA ALTHOUGH MIGHT NOT GIVE THE FULL PICTURE ANYWAY



Intensity compared to the constant rate model

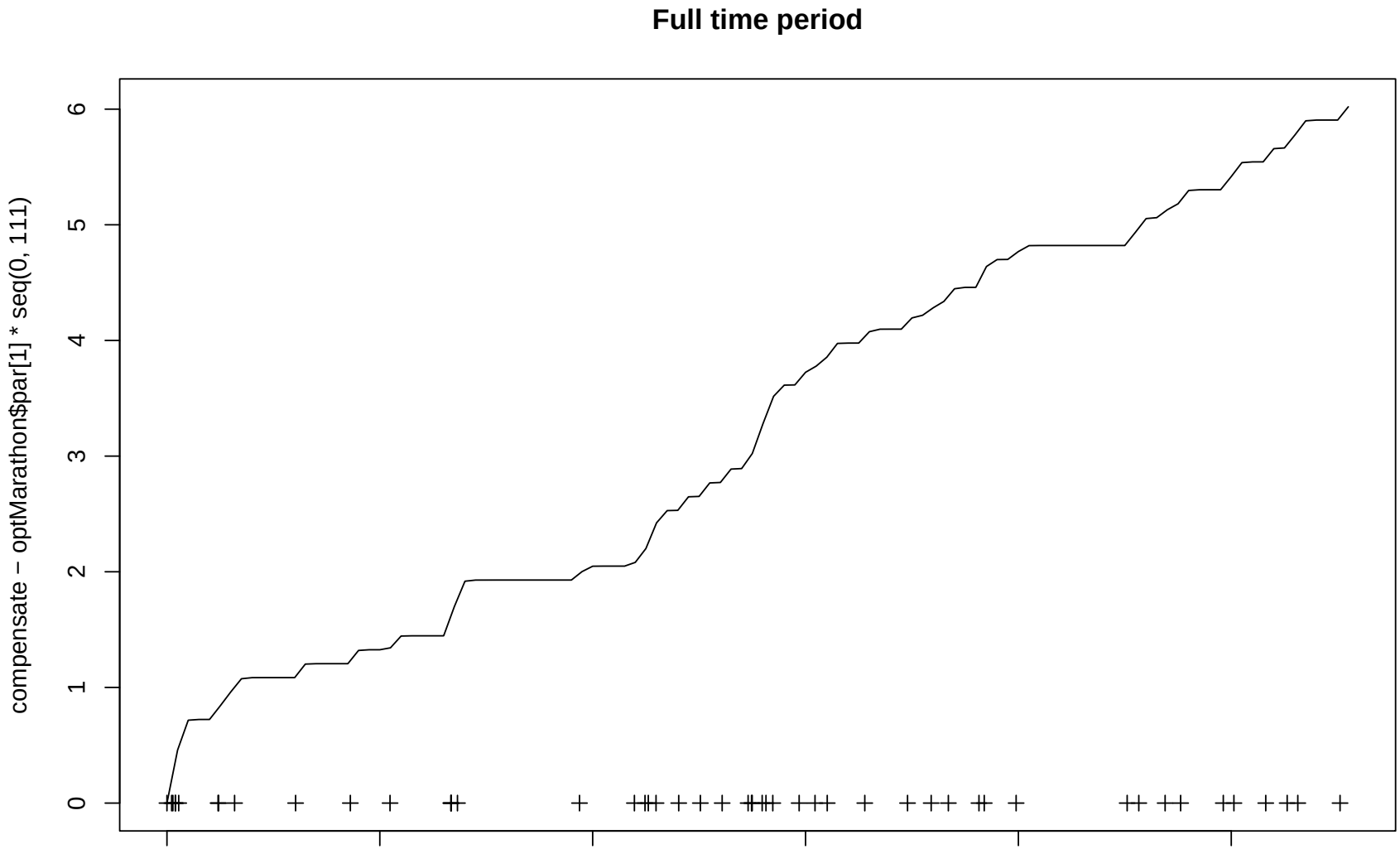


Process as "Generations"



The Compensator Function

NEED TO WORK ON EXPLAINING - BELOW IS THE VERSION TAKING OUT BASELINE. . . MAYBE START WITH CONSTANT (CAN DO Poisson MODEL AND THEN THE BASELINE RATE HERE)



Residuals

References

Data source: Wikipedia (https://en.wikipedia.org/wiki/Marathon_world_record_progression) scraped August 12, 2022

Poisson process: https://towardsdatascience.com/the-poisson-distribution-and-poisson-process-explained-4e2cb17d459

Hawkes, Alan G. 1971. "Spectra of Some Self-Exciting and Mutually Exciting Point Processes." Biometrika 58 (1): 83–90. https://doi.org/10.2307/2334319.

"Hawkesbow" package...