Fermi Project Update

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March 16, 2021

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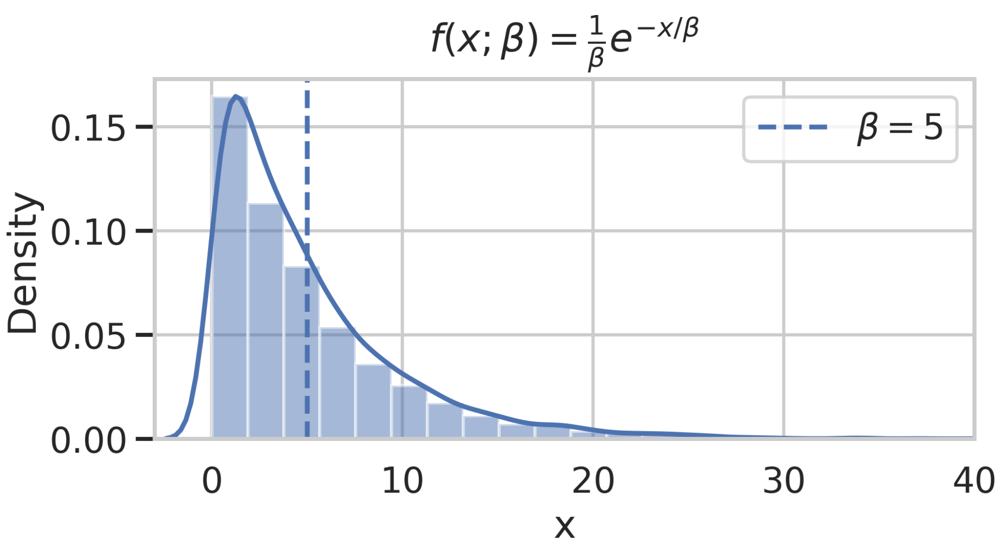
1 March Update

1.1 Introduction

Goal: Add as an input a fixed probability of destruction per timestep.
Method: Since we are considering events which occur continuously and independently at a constant average rate, this type of process is called a **Poisson point process**. Furthermore, the probability distribution describing the time between events in a Poisson point process is the **exponential distribution**, shown below.[1]



[1] The mean (expectation) value is given by β. The median value is $\beta \ln 2$

1.1.1 Collapse Time

Let

$$T_s = Average\ Civilization\ Lifetime$$

Then

$$P(t) = \frac{1}{T_s}e^{-t/T_s} = probability\ of\ a\ civilzation\ having\ a\ lifetime\ equal\ to\ t$$

And

$$\begin{aligned} P(t \leq T_*) &= \int_0^{T_*} P(t)dt \\ &= \frac{1}{T_s}\int_0^{T_*} e^{-t/T_s}dt \\ &= 1 - e^{-T_*/T_s} = probability\ of\ a\ civilization\ having\ a\ lifetime\ less\ than\ or\ equal\ to\ T_* \\ &= probability\ of\ a\ civilization\ experiencing\ spontaneous\ collapse\ within\ some\ time\ T_* \end{aligned}$$

Thus, if $T_* = 10^6\ yrs = 1\ Myr$, then...

$$\boxed{P(t \leq 1\,Myr) = 1 - \exp\left(-\frac{1\,Myr}{T_s}\right) = probability\ of\ civilization\ dying\ per\ Myr \equiv P_{death}}$$

1.1.2 Abiogenesis Time

Similarly, let

$$T_a = Average\ Timescale\ for\ Abiogenesis\ Event$$

Then

$$P(t) = \frac{1}{T_a}e^{-t/T_a} = probability\ of\ an\ abiogenesis\ event\ occuring\ at\ some\ time\ t.$$

And

$$P(t \leq T_*) = \int_0^{T_*} P(t)dt = \frac{1}{T_a}\int_0^{T_*} e^{-t/T_a}dt = 1 - e^{-T_*/T_a} = probability\ of\ an\ abiogenesis\ event\ occuring\ within\ some\ time\ T_*$$

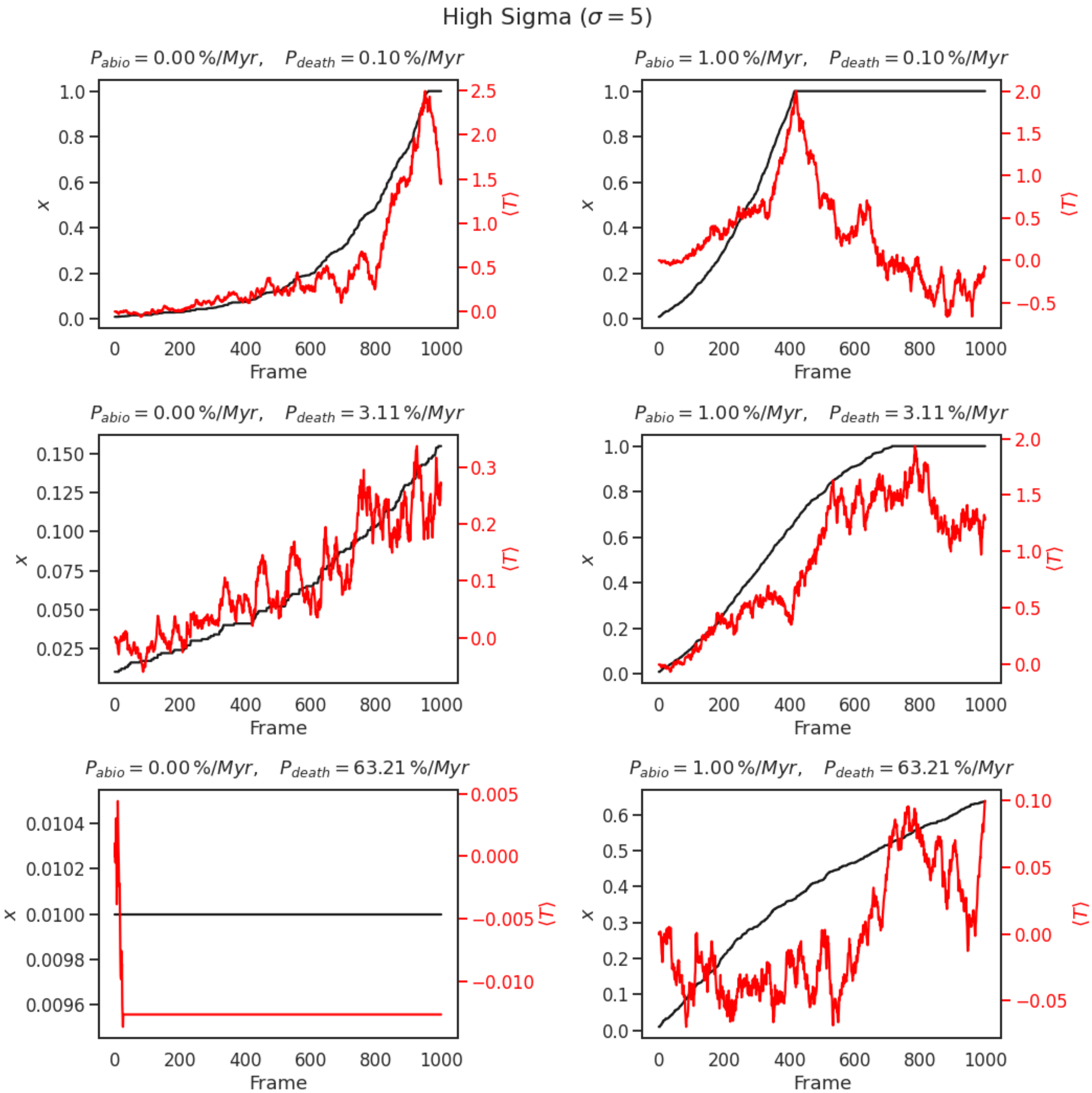
Thus, if $T_* = 10^6\ yrs = 1\ Myr$, then...

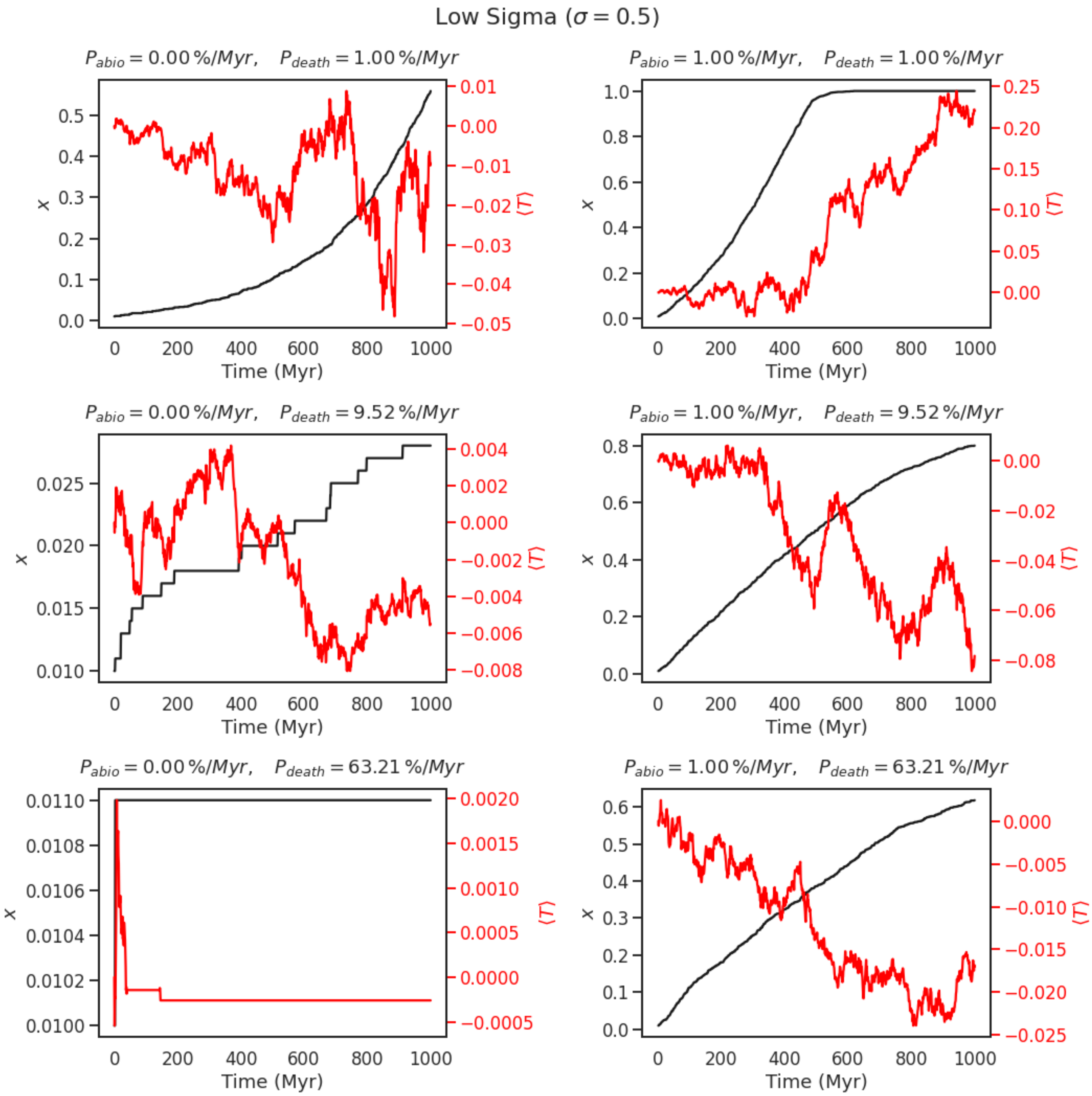
$$\boxed{P(t \leq 1\,Myr) = 1 - \exp\left(-\frac{1\,Myr}{T_a}\right) = probability\ of\ abiogenesis\ event\ per\ Myr \equiv P_{abio}}$$

1.2 Parameter Sweeps

- **Columns**: ($[\log T_s] = \log yrs$)
  - Top: $\log T_s = 9$ (low P_{death})
  - Middle: $\log T_s = 7.6$
  - Bottom: $\log T_s = 6$ (high P_{death})
- **Rows**: Left column has no abiogenesis events, while right column has abiogenesis events occuring with a 1% probability per year for each system. ($[\log T_a] = \log yrs$)
  - Left: $\log T_a = 20$ (no abiogenesis)
  - Right: $\log T_a = 16$ (yes abiogenesis)

Each model was run for 100 Myr. The black line shows x, defined as the number of habited systems over the total number of systems. The red line shows the average technological value of the systems.


High Sigma (σ = 5)
P_abio = 0.00 %/Myr, P_death = 0.10 %/Myr
P_abio = 1.00 %/Myr, P_death = 0.10 %/Myr
P_abio = 0.00 %/Myr, P_death = 3.11 %/Myr
P_abio = 1.00 %/Myr, P_death = 3.11 %/Myr
P_abio = 0.00 %/Myr, P_death = 63.21 %/Myr
P_abio = 1.00 %/Myr, P_death = 63.21 %/Myr
x
⟨T⟩
Frame



Low Sigma ($\sigma = 0.5$)
$P_{abio} = 0.00\,\%/Myr, \quad P_{death} = 1.00\,\%/Myr$
$P_{abio} = 1.00\,\%/Myr, \quad P_{death} = 1.00\,\%/Myr$
$P_{abio} = 0.00\,\%/Myr, \quad P_{death} = 9.52\,\%/Myr$
$P_{abio} = 1.00\,\%/Myr, \quad P_{death} = 9.52\,\%/Myr$
$P_{abio} = 0.00\,\%/Myr, \quad P_{death} = 63.21\,\%/Myr$
$P_{abio} = 1.00\,\%/Myr, \quad P_{death} = 63.21\,\%/Myr$
x
$\langle T \rangle$
Time (Myr)