What Type of Technosignatures Can We Detect?

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Abstract

The existence of causal constraints introduces a temporal selection effect in the type of technosignatures that we can detect. I discuss the implications of this fact on the characteristic of detectable technosignatures, and in particular their longevity.

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Causal constraint

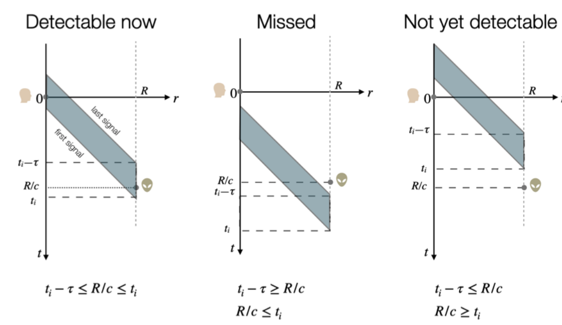
Obvious fact: Any technosignature we can detect must be in our **past light cone**, i.e.:

$$t_i - \tau \leq R/c \leq t_i$$

Appearance of technosignature (t_i)
Duration of technosignature (τ)
Distance of technosignature (R/c)

Balbi (2018); see also Grimaldi (2017), Lares, Funes & Gramajo (2020)

Causal constraint



Implications

- *R/c* is a **small quantity**!
- **Not-so-obvious fact**: The causal constraint acts as a **filter**, imposing a **fine-tuning** of two otherwise uncorrelated timescales:
  - t_i can in principle be anything **between 0 and 10^{10} years**
  - τ is unknown but, a priori, **unrelated to t_i**
  - however, for any detectable technosignature, **$t_i - \tau$ must be < 10^3-10^4 years** (for galactic locations)

What type of technosignatures can we detect?

- A technosignature is only detectable if its lifespan **matches almost exactly** its appearance epoch (this is true **regardless of their abundance, their probability distribution**, etc.)
- If exo-civilizations appear uniformly over the history of the galaxy, we should expect that **the vast majority of technosignatures have $t_i \sim 10^9$ years**
- Therefore, there are essentially two types of technosignatures that we can detect:
  1. **long-duration** technosignatures, with **$t_i \sim \tau \sim 10^9$ years**
  2. **late-appearing** technosignatures, with **$t_i \sim 10^3$ years**

A possible duration-based classification scheme

- **Type A**: $\tau \sim 10^3$ years
- **Type B**: $\tau \sim 10^6$ years
- **Type C**: $\tau \sim 10^9$ years

If we make a detection, **it will most likely be a Type C technosignature** — but this does not mean that Type C are the most likely to exist!

Type A might seem more common, but are only detectable **if they are *coeval* to us**!

Either way, we are probably **looking for outliers**

Enter statistics

$$N = \Gamma \bar{\tau}$$

Number of detectable technosignatures (N)
Average rate of appearance (Γ)
Average duration ($\bar{\tau}$)

If there were a total of N_T technosignatures in a volume around Earth, and they appeared uniformly over $T \sim 10^{10}$ years, then:

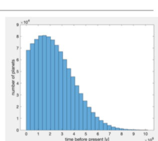
$$N = N_T \frac{\bar{\tau}}{T} \Rightarrow \frac{N}{N_T} = \frac{\bar{\tau}}{T} \ll 1$$

Only a small fraction of technosignatures is detectable, so apparently we would need a large total number to succeed. But is this really so?

Even more statistics

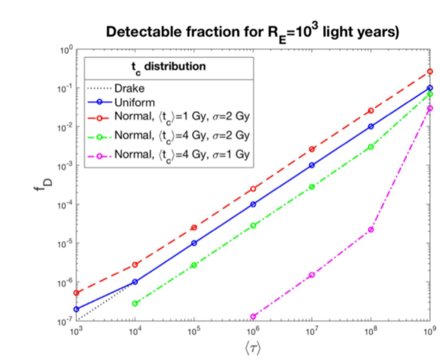
The rate of appearance might vary in time: $\Gamma = \Gamma(t)$

Simulate appearance of technosignatures at random time and locations **in a radius *R*=1kly** and compute the total number needed for at least one detection



	Type A ($\tau = 10^3$ y)	Type B ($\tau = 10^6$ y)	Type C ($\tau = 10^9$ y)
uniform, $0 \leq t_i \leq 10^{10}$	$N_T = 10^7$	$N_T = 10^4$	$N_T = 10$
normal, $\langle t_i \rangle$=1.5 Gy, σ_{t_i}=2.24 Gy	$N_T = 6.7 \times 10^6$	$N_T = 5.6 \times 10^3$	$N_T = 5$

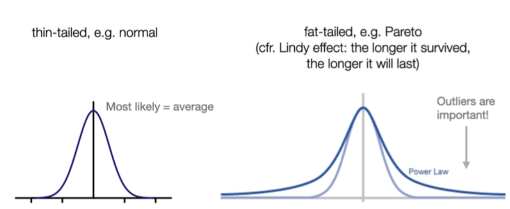
This is comparable to the number of stars in the volume!



Balbi 2018

Longevity

- We should not think in terms of civilization/species longevity, but in terms of **technosignature persistence**
- For example, longevity distributions for organisms and technologies are very different



Work in progress!

The case for optimism

- **Uniformity is probably a wrong assumption**: the epoch of appearance can have a distribution peaked around some epoch, or increasing/decreasing in time, etc.
- We don't really need a large *average* duration: it is enough to have ***a few*** **very long-lived technosignatures** to succeed: things are radically different if the duration of technosignatures is fat-tailed (cfr. Lindy effect, etc)
- The best strategy is to **look for Type C** technosignatures (also: **go extragalactic**)
- **Monte Carlo simulations** (as opposed to standard estimates of *N* that rely on stationary processes) are the way to get an insight on this

References

- Balbi, A. 2018. "The Impact of the Temporal Distribution of Communicating Civilizations on Their Detectability." Astrobiology 18 (1): 54–58. https://doi.org/10.1089/ast.2017.1652.
- Grimaldi, C. 2017. "Signal Coverage Approach to the Detection Probability of Hypothetical Extraterrestrial Emitters in the Milky Way." Scientific Reports 7. https://doi.org/10.1038/srep46273.
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Techno Climes