The Lifetimes of Civilizations
N Recap

\[ N = N_0 \cdot f_s \cdot f_{GHZ} \cdot f_p \cdot n_H \cdot f_\ell \cdot f_J \cdot f_\zeta \cdot f_{Eu} \cdot f_m \cdot f_i \cdot f_c \]

- \( N_0 = 4 \times 10^{11} \)
- \( f_s = 0.2 \)
- \( f_{GHZ} = 0.1 \)
- \( f_p = 0.8 \)
- \( n_H = 2 \)
- \( f_\ell = 1.0 \)
- \( f_J = 0.5 \)
- \( f_\zeta = 0.01 \)
- \( f_{Eu} = 0.1 \)
- \( f_m = 0.1 \)
- \( f_i = 0.1 \)
- \( f_c = 0.3 \)

\[ N = 19,000 \]
Uncertainties on Astrophysical Parameters

\[ N = N_\ast f_s f_{\text{GHZ}} f_p n_H f_\ell f_J f_\zeta f_{\text{Eu}} f_m f_i f_c \]

- \( N_\ast = 4 \times 10^{11} \pm 25\% \)
- \( f_s = 0.2 \pm 0.1 \)
- \( f_{\text{GHZ}} = 0.1 +0.2, -0.05 \)
- \( f_p = 0.8 \pm 0.2 \)
- \( n_H = 2 \)
- \( f_\ell = 1.0 \)
- \( f_J = 0.5 \)
- \( f_\zeta = 0.01 \)
- \( f_{\text{Eu}} = 0.1 \)
- \( f_m = 0.1 \)
- \( f_i = 0.1 \)
- \( f_c = 0.3 \)
Uncertainties on $N_H$

$$N = N_\ast f_s f_{\text{GHZ}} f_p n_H f_\ell f_J f_\zeta f_{\text{Eu}} f_m f_c$$

- $N_\ast = 4 \times 10^{11} \pm 25\%$
- $f_s = 0.2 \pm 0.1$
- $f_{\text{GHZ}} = 0.1 \pm 0.2, -0.05$
- $f_p = 0.8 \pm 0.2$
- $n_H = 2 \pm 1$
- $f_\ell = 1.0$
- $f_J = 0.5$
- $f_\zeta = 0.01$
- $f_{\text{Eu}} = 0.1$
- $f_m = 0.1$
- $f_i = 0.1$
- $f_c = 0.3$
Uncertainties on Sociological Parameters

\[ N = N_\star f_s f_{\text{GHZ}} f_p n_H f_{J} f_{\text{C}} f_{\text{Eu}} f_m f_i f_c \]

- \( N_\star = 4 \times 10^{11} \pm 25\% \)
- \( f_s = 0.2 \pm 0.1 \)
- \( f_{\text{GHZ}} = 0.1 +0.2, -0.05 \)
- \( f_p = 0.8 \pm 0.2 \)
- \( n_H = 2 \pm 1 \)
- \( f_{J} = 1.0 +0, -0.99 \)
- \( f_{\text{C}} = 0.5 +0.3, -0.5 \)
- \( f_{\text{C}} = 0.01 +0.1, -0.01 \)
- \( f_{\text{Eu}} = 0.1 +0.9, -0.1 \)
- \( f_m = 0.1+0.9, -0.1 \)
- \( f_i=0.1 +0.9, -0.1 \)
- \( f_c=0.3 +0.7, -0.3 \)
The Range of N

\[ N = N_\star f_s f_{\text{GHZ}} f_p n_H f_\ell f_J f_{\text{Eu}} f_m f_c \]

• \( N_\star = 4 \times 10^{11} \pm 25\% \)
• \( f_s = 0.2 \pm 0.1 \)
• \( f_{\text{GHZ}} = 0.1 \pm 0.2, -0.05 \)
• \( f_p = 0.8 \pm 0.2 \)
• \( n_H = 2 \pm 1 \)
• \( f_\ell = 1.0 \pm 0, -0.99 \)
• \( f_J = 0.5 \pm 0.3, -0.5 \)
• \( f_{\text{Eu}} = 0.01 \pm 0.1, -0.01 \)
• \( f_m = 0.1 \pm 0.9, -0.1 \)
• \( f_i = 0.1 \pm 0.9, -0.1 \)
• \( f_c = 0.3 \pm 0.7, -0.3 \)

\[ N = 19,000 \text{ (from } 1 \text{ (us) to } 1.1 \times 10^{11} \)
The Last Term

\[ N = N_0 f_s f_{\text{GHZ}} f_p n_H f_j f_e f_{\text{Eu}} f_{m_1} f_{c} L/T \]

\( L \) is the typical lifetime of a communicative civilization

\( T \) is the age of the Galaxy

\( L/T \) is the fraction of the age of the Galaxy that the civilization is able to communicate.
\[ T \]

\[ T \] is known. \( T \sim 10^{10} \) years.

The age of the universe is 13.7 Gyr.

The oldest stars in our Galaxy are about 13 Gyr old (but are meta-poor).

The stars that make up the disk of the galaxy are younger than about 10 Gyr.

The Sun is 4.5 Gyr old.
L

L is not known.

L for humanity is about 100 years.

A typical species survives $10^6$ years.

The Earth becomes uninhabitable in $10^9$ years.

How long will we (or our successors) last?
What are the sociological issues?
\[ N = N^* f_s f_{\text{GHZ}} f_p n_H f_{\ell} f_J f_c f_{\text{Eu}} f_m f_c L/T \]

- \( N^* = 4 \times 10^{11} \pm 25\% \)
- \( f_s = 0.2 \pm 0.1 \)
- \( f_{\text{GHZ}} = 0.1 \pm 0.2, -0.05 \)
- \( f_p = 0.8 \pm 0.2 \)
- \( n_H = 2 \pm 1 \)
- \( f_{\ell} = 1.0 +0, -0.99 \)
- \( f_J = 0.5 +0.3, -0.5 \)
- \( f_c = 0.01 +0.1, -0.01 \)
- \( f_{\text{Eu}} = 0.1 +0.9, -0.1 \)
- \( f_m = 0.1+0.9, -0.1 \)
- \( f_i = 0.1 +0.9, -0.1 \)
- \( f_c = 0.3 +0.7, -0.3 \)
- \( L/T = 10^{-3} -5, +2 \)
- \( N = 19 \) (from 1 (us) to 1.1\times10^{11})
The Distance Between Neighbors

The shape of the Galaxy is approximately cylindrical, with

- Radius = 50,000 ly
- Height = 1000 ly

The volume of the Galaxy is \( \sim \pi r^2 h \), or

\[ V_G = 7.5 \times 10^{12} \text{ ly}^3 \]

The density \( \rho \) of communicating civilizations is

\[ \rho_c = \frac{N}{V_G} \]

The mean distance \( d_c \) between civilizations is

\[ d_c \sim (\rho_c)^{-1/3} \]
The Nearest Civilization

With $N=20$

$$\rho_c \sim 3 \times 10^{-12} \text{ ly}^{-3}$$

$$d_c = 7200 \text{ ly}$$

$$d_c \sim N^{-1/3}, \text{ so}$$

$$d_c = 7200/(N/20)^{1/3}$$

For $d_c = 100 \text{ ly}$, we need $N \sim 7,500,000$