Habitable Zone Calculator

1 Setup

1.1 Constants

$$\begin{aligned} T_\odot &= \text{The Sun's effective temperature} \\ &= 5780\,\text{K} \\ L_\odot &= \text{The Sun's luminosity} \\ &= 3.828 \times 10^{26}\,\text{W} \end{aligned}$$

1.2 Input Variables

$$\begin{aligned} T &= \text{The star's effective temperature (in units of K)} \\ L &= \text{The star's luminosity (in units of } L_\odot) \end{aligned}$$

1.3 Output Variables

The constants a_0, a_1, a_2, a_3, a_4 will be defined below for each scenario. Assuming they have been defined, then

$$\begin{aligned} f &= \text{The observed stellar flux (in units of the Sun's stellar flux on Earth)} \\ &= \sum_{n=0}^{4} a_n \cdot (T - T_\odot)^n \end{aligned}$$

$$\begin{aligned} d &= \text{The habitable zone distance (in AU) from the star} \\ &= \sqrt{\frac{L}{f}} \end{aligned}$$

2 Conservative Habitable Zone Limits (1 Earth Mass)

2.1 Inner Habitable Zone — Runaway Greenhouse Limit

$$\begin{aligned} a_0 &= 1.107 \\ a_1 &= 1.332 \times 10^{-4} \\ a_2 &= 1.58 \times 10^{-8} \\ a_3 &= -8.308 \times 10^{-12} \\ a_4 &= -1.931 \times 10^{-15} \end{aligned}$$

2.2 Outer Habitable Zone — Maximum Greenhouse Limit

$$
\begin{aligned}
a_0 &= 0.356 \\
a_1 &= 6.171 \times 10^{-5} \\
a_2 &= 1.698 \times 10^{-9} \\
a_3 &= -3.198 \times 10^{-12} \\
a_4 &= -5.575 \times 10^{-16}
\end{aligned}
$$

3 Optimistic Habitable Zone Limits (1 Earth Mass)

3.1 Inner Habitable Zone — Recent Venus Limit

$$
\begin{aligned}
a_0 &= 1.776 \\
a_1 &= 2.136 \times 10^{-4} \\
a_2 &= 2.533 \times 10^{-8} \\
a_3 &= -1.332 \times 10^{-11} \\
a_4 &= -3.097 \times 10^{-15}
\end{aligned}
$$

3.2 Outer Habitable Zone — Early Mars Limit

$$
\begin{aligned}
a_0 &= 0.3207 \\
a_1 &= 5.5471 \times 10^{-5} \\
a_2 &= 1.5265 \times 10^{-9} \\
a_3 &= -2.874 \times 10^{-12} \\
a_4 &= -5.011 \times 10^{-16}
\end{aligned}
$$

4 Conservative Habitable Zone Limits (5 Earth Masses)

4.1 Inner Habitable Zone — Runaway Greenhouse Limit

$$
\begin{aligned}
a_0 &= 1.188 \\
a_1 &= 1.433 \times 10^{-4} \\
a_2 &= 1.707 \times 10^{-8} \\
a_3 &= -8.968 \times 10^{-12} \\
a_4 &= -2.084 \times 10^{-15}
\end{aligned}
$$

5 Conservative Habitable Zone Limits (0.1 Earth Masses)

5.1 Inner Habitable Zone — Runaway Greenhouse Limit

$$
\begin{aligned}
a_0 &= 0.99 \\
a_1 &= 1.209 \times 10^{-4} \\
a_2 &= 1.404 \times 10^{-8} \\
a_3 &= -7.418 \times 10^{-12} \\
a_4 &= -1.713 \times 10^{-15}
\end{aligned}
$$