A General Method for Determining the Habitable Zone around a Main Sequence Star
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Two stages of calculations

Stage 1: Estimate the host star’s absolute luminosity based on the star’s apparent visual magnitude (three steps)
First Step (stage 1)– Calculate the absolute visual magnitude of the host star based on the star’s apparent magnitude.

\[ M_v = m_v - 5 \log(d/10) \]

Where:

\( M_v \) = Absolute magnitude of the star
\( m_v \) = apparent magnitude of the star (visual spectrum)
\( d \) = distance from Earth to the star in parsecs

Second Step (stage 1) – Calculate bolometric magnitude of the host star.

\[ M_{bol} = M_v + BC \]

Where:

\( M_{bol} \) = bolometric magnitude of the star
\( M_v \) = the absolute magnitude of the star
BC = bolometric correction constant

Use the following table for general bolometric correction values [generalized from Habets and Heintz (1981)]

<table>
<thead>
<tr>
<th>Spectral class</th>
<th>BC</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>-2.0</td>
</tr>
<tr>
<td>A</td>
<td>-0.3</td>
</tr>
<tr>
<td>F</td>
<td>-0.15</td>
</tr>
<tr>
<td>G</td>
<td>-0.4</td>
</tr>
<tr>
<td>K</td>
<td>-0.8</td>
</tr>
</tbody>
</table>
Third Step (stage 1) – Calculate the absolute luminosity of the host star

\[ \frac{L_{\text{star}}}{L_{\text{sun}}} = 10^{\left[ M_{\text{bol\ star}} - M_{\text{bol\ sun}} \right] / -2.5} \]

Where:

- \( \frac{L_{\text{star}}}{L_{\text{sun}}} \) = the absolute luminosity of the star in terms of the absolute luminosity of the sun
- \( M_{\text{bol\ star}} \) = the bolometric magnitude of the host star
- \( M_{\text{bol\ sun}} \) = the bolometric magnitude of the sun = 4.72
- 2.5 is a constant value used for comparing stellar luminosities -- known as "Pogson's Ratio."

Stage 2: Approximate the radii of the host star’s habitable zone boundaries

One step – Place the value for the host star’s absolute luminosity (that you calculated above) into the expressions below.

\[ r_i = \sqrt{\frac{L_{\text{star}}}{1.1}} \]
\[ r_o = \sqrt{\frac{L_{\text{star}}}{0.53}} \]

Where:

- \( r_i \) = the inner boundary of the habitable zone in astronomical units (AU)
- \( r_o \) = the outer boundary of the habitable zone in astronomical units (AU)
- \( L_{\text{star}} \) is the absolute luminosity of the star
- 1.1 is a constant value representing stellar flux at the inner radius (based on Kasting et al., 1993, cited below; Whitmire et al., 1996, cited below)
- 0.53 is a constant value representing stellar flux at the outer radius (based on Kasting et al., 1993, cited below; Whitmire et al., 1996., cited below)
Example

Star Gl 581

$m_v = 10.55$

Spectral type = M3

$BC = -2.0$ (based on M class star, and approximated using value in above table)

Distance = 6.26 parsecs

1. Calculate absolute visual magnitude

$M_v = 10.55 - 5\log(6.26/10) = 11.57$

2. Calculate bolometric magnitude

$M_{bol} = 11.57 + (-2.0) = 9.57$

3. Calculate absolute luminosity

$L_{Gl 581}/L_{sun} = 10^{\frac{(9.57 - 4.72)}{-2.5}} = 0.011$

4. Approximate the boundaries of the habitable zone for this star

$r_i = \sqrt{\frac{0.011}{1.1}} = 0.1$ AU

$r_o = \sqrt{\frac{0.011}{0.53}} = 0.14$ AU

For more information on the development of this methodology, please consult the references listed below, and see the chapter entitled "Astronomical Circumstances" by Tom Morris, available here at planetarybiology.com.

References


Available for download from this site (with my notes)

**An alternative approach has been proposed by:**


Try the online habitable zone calculator based on this alternative approach at:

[University of Washington Virtual Planetary Laboratory](https://exomars.jpl.nasa.gov/)