A General Method for Determining the Habitable Zone around a Main Sequence Star

by Tom E. Morris
Division of Natural Sciences
Fullerton College, Fullerton, CA, USA
http://planetarybiology.com
tmorris@fullcoll.edu

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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 – 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 – Calculate bolometric magnitude of the host star.

$M_{bol} = M_v + BC$

Where:

M_{bol} = bolometric magnitude of the star
BC = bolometric correction constant

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

Spectral class	BC
B	-2.0
A	-0.3
F	-0.15
G	-0.4
K	-0.8
M	-2.0

Third Step – Calculate the absolute luminosity of the host star

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

Where:

L_{star}/L_{sun} = the absolute luminosity of the star in terms of the absolute luminosity of the sun

$M_{bol\ star}$ = the bolometric magnitude of the host star

$M_{bol\ sun}$ = 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: Estimate 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.

$$r_i = \sqrt{\frac{L_{star}}{1.1}}$$

$$r_o = \sqrt{\frac{L_{star}}{0.53}}$$

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_{star} is the absolute luminosity of the star

Example

Star Gl 581

m_v = 10.55

Spectral type = M3

Distance = 6.21 parsecs

Calculate absolute visual magnitude

M_v = 10.55 – 5log(6.21/10) = 11.58

Calculate bolometric magnitude

M_{bol} = 11.58 + (-2.0) = 9.58

Calculate absolute luminosity

$L_{Gl\ 581}/L_{sun} = 10^{\left[\frac{9.58-4.72}{-2.5}\right]} = 0.011$

Estimate 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

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