Interactive Website for Visualizing Habitability in Exoplanetary Systems

Mr. Krit Promsanuwong (Grade 12)
[Thoengwittayakhom School]

Introduction

The habitable zone (HZ) is a general concept in astronomy, yet most modeling tools remain inaccessible to non-specialist users. To address this, I've developed Exoplanet Visualizer (exoplanetvisualizer.com), a browser-based platform that computes HZ boundaries using the Kopparapu et al. (2014) climate model, simulates Keplerian orbital mechanics, and provides stellar context through a Hertzsprung–Russell (HR) diagram. The application sources data via the NASA Exoplanet Archive API and enables exploration of thousands of confirmed exoplanetary systems and interactive investigation of habitability outcomes, lowering technical barriers for both educational and scientific use.

Methodology

Stellar and planetary parameters for thousands of systems were retrieved from Christiansen et al. (2025) NASA Exoplanet Archive via API queries and structured into a unified dataset. Each system includes stellar and planetary parameters such as stellar luminosity, effective temperature, stellar radius, orbital period, and eccentricity. These parameters are processed and rendered client-side using D3.js

Habitable zone limits are computed using polynomial parameterization from Kopparapu et al. (2014) of the effective stellar flux with coefficients provided in Table 1, expressed as

$$S_{eff} = S_{eff\odot} + aT + bT^2 + cT^3 + dT^4$$

Coeff.	Maximum Greenhouse	Runaway Greenhouse 0.1 $M_\oplus$	Runaway Greenhouse 1 $M_\oplus$	Runaway Greenhouse 5 $M_\oplus$
$S_{eff\odot}$	0.356	0.99	1.107	1.188
A	6.171e-5	1.209e-4	1.332e-4	1.433e-4
B	1.698e-9	1.404e-8	1.58e-8	1.707e-8
C	-3.198e-12	-7.418e-12	-8.308e-12	-8.968e-12
D	-5.575e-16	-1.713e-15	-1.931e-15	-2.084e-15

Table 1 Coefficients for Polynomial Fitting

Where $T = T_{eff} - 5780\,K$ denotes the stellar effective temperature offset from solar values and the coefficients are provided by Kopparapu et al. (2014). The corresponding orbital distance for a given HZ boundary is then derived as

$$d = \sqrt{\frac{L_\star/L_\odot}{S_{eff}}}$$

The outer HZ boundary, defined by the maximum greenhouse limit, is treated as effectively mass-independent, while the inner boundary is computed for planetary masses of 0.1, 1.0, and 5.0 Earth masses to reflect differing atmospheric heat retention.

Elliptical orbits are simulated by solving Kepler's equation each frame using the Newton–Raphson iterative method (converging in 2–4 iterations). The eccentric anomaly is used to obtain the true anomaly, followed by the instantaneous orbital radius, with Cartesian coordinates subsequently derived via trigonometric relations.

$$E_{n+1} = E_n - \frac{E_n - e\,sin\,sin\,E_n\; - M}{1 - e\,cos\,cos\,E_n}$$

Newton–Raphson Update for Kepler's Equation

The site is statically deployed via Vercel and can be freely accessed by any modern browser at URL https://exoplanetvisualizer.com

All computations are performed client-side with no backend dependency.

Result

The application generates two-dimensional representations of interactive orbital architectures alongside habitable zones (Fig 1) and a Hertzsprung-Russell Diagram (Fig 2). Computed HZ distances align with established results under identical stellar inputs, confirming validity. Users may also input custom stellar and planetary parameters to visualize hypothetical or newly reported systems under the same framework. All outputs are produced as SVGs

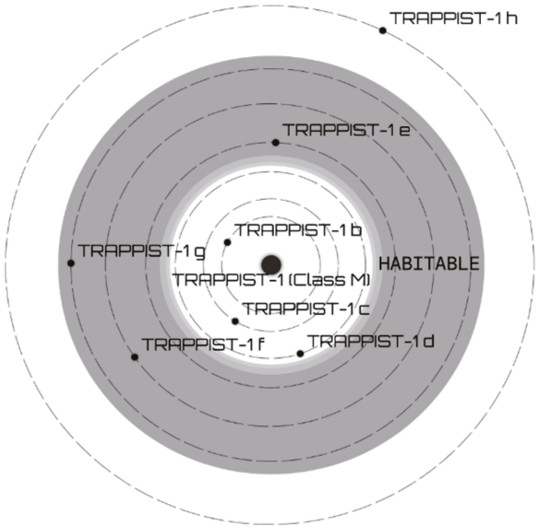

Figure 1 Orbital Diagram of TRAPPIST-1

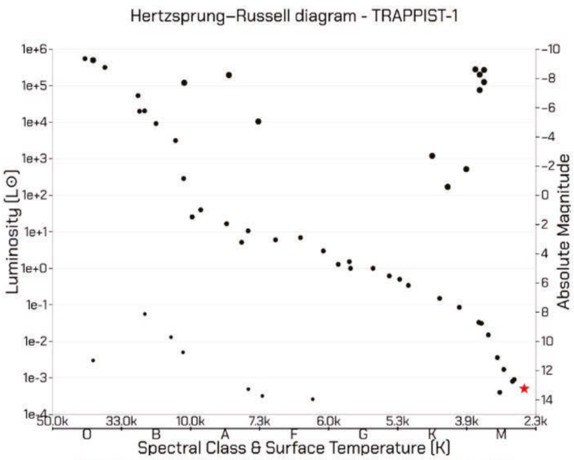

Figure 2 Hertzsprung-Russell Diagram with Target Star

References

Kopparapu, R. K. et al. (2014). *Habitable zones around main-sequence stars*. Astrophysical Journal Letters, 787, L29. https://doi.org/10.1088/2041-8205/787/2/L29

Christiansen, J. L. et al. (2025). *NASA Exoplanet Archive: Data and tools*. Planetary Science Journal, 6, 186. https://doi.org/10.3847/PSJ/ade3c2