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INTERACTIVE WEBSITE FOR VISUALIZING HABITABILITY IN EXOPLANET SYSTEMS

AUTHOR MR. KRIT PROMSANUWONG
ADVISOR MRS. NUTCHA REUNMOOL
THOENGWITTAYAKHOM SCHOOL

SCAN FOR SITE

ABSTRACT

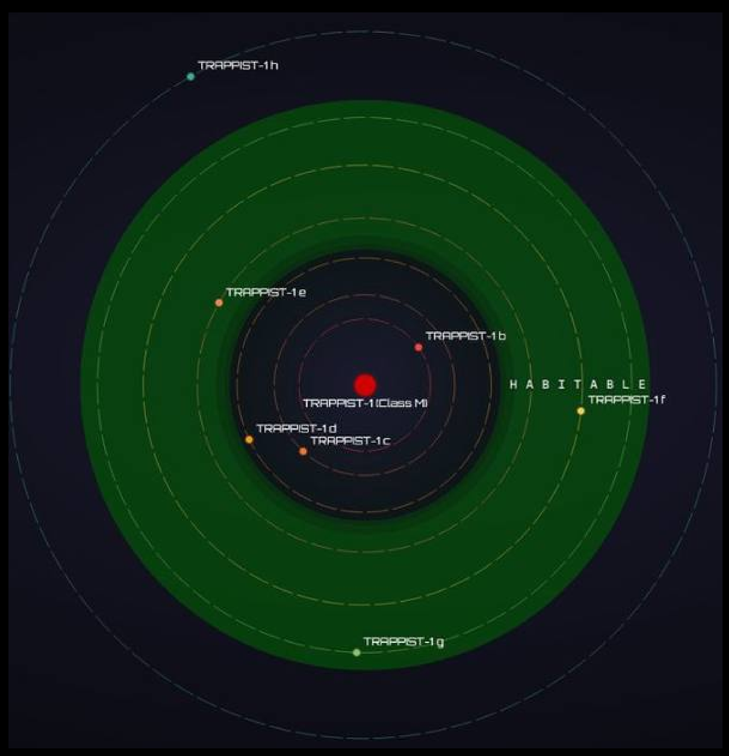
This project introduces a browser-based application for visualizing habitable zones (HZs) and orbital configurations of exoplanetary systems based on stellar parameters of 4,134 systems retrieved from the NASA Exoplanet Archive [2]. Systems hosting planets with high Earth Similarity Index (ESI) scores are highlighted for reference. HZ boundaries are defined as the runaway and maximum greenhouse limits with Kopparapu et al. (2014) model [1]. The inner edge is mass-dependent and plotted for 0.1, 1.0, and 5.0 $M_\oplus$ to reflect differences in atmospheric heat retention; the outer edge is treated as nearly mass independent. Each static diagram includes the orbital layout alongside the HZ, stellar placement on a Hertzsprung–Russell (HR) diagram, and access to system parameters. Users may also define custom systems. The web application is accessible at www.exoplanetvisualizer.com

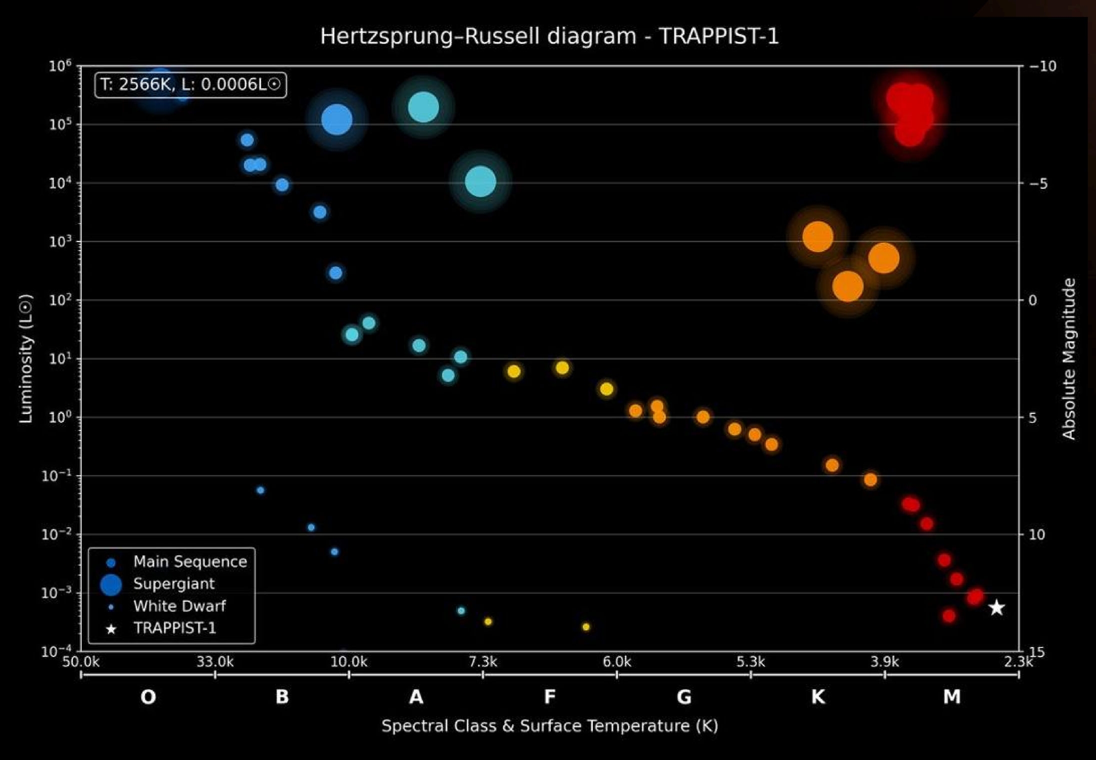
INTRODUCTION

The habitable zone (HZ) is the region around a star where liquid water could exist on a planet's surface under plausible atmospheric conditions. This application computes HZ boundaries using stellar parameters from the NASA Exoplanet Archive and the model by [1]. The outer edge, based on the maximum greenhouse effect, is treated as constant across planetary masses. The inner edge varies with mass and is plotted for 0.1, 1.0, and 5.0 $M_\oplus$. Users can select individual inner boundaries or view all three simultaneously as nested, shaded regions. In combined mode, each additional mass adds a nested HZ boundary, with a zoomed inset improving visual clarity in the inner regions. Each system is rendered as a static diagram showing orbits and HZs, with a corresponding HR diagram. Users can also input custom stellar and planetary parameters.

RESULT

The web app at www.exoplanetvisualizer.com features 4,134 systems from the NASA Exoplanet Archive. Its static graph generator produces accurate 2D plots of planetary orbits and habitable zones. For four sample systems computed HZ values match Kopparapu et al. (2014)'s calculator, ensuring accuracy. The Hertzsprung-Russell diagram places the target star among a set of references stars by temperature and luminosity, and a D3.js orbit simulator renders circular orbits with interactive controls. Together, these tools allow users to visualize and contextualize stellar and planetary system data effectively.





METHODOLOGY

Data Collection

Stellar and planetary parameters for 4,134 systems were retrieved via a TAP query to the NASA Exoplanet Archive [2] and stored as structured JSON. Each entry contains star name, mass ($M_\odot$) luminosity ($L_\odot$), effective temperature (K), radius($R_\odot$), and a list of planets with names, masses ($M_\oplus$), semi-major axes (AU), and orbital periods (earth days).

Interface

Users interact through a browser frontend, choosing presets or entering custom stellar and planetary data. These inputs go to the backend, which returns two base64-encoded SVGs: a static orbital diagram with HZ zones and an HR diagram. Meanwhile, a D3.js orbit simulator updates instantly using local JSON, with tooltips, speed/zoom controls, start/stop, and randomized planet positions.

Calculations

The stellar flux is computed using a fourth-degree polynomial fit with coefficients based on $T = T_{\text{eff}} - 5780\,\text{K}$

$$S_{\text{eff}} = S_{\text{eff}\odot} + aT_* + bT_*^2 + cT_*^3 + dT_*^4$$

The corresponding boundary distance is then derived from this flux.

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

CONCLUSION

This project delivers a static, browser-based platform for visualizing habitable zones and orbital configurations of exoplanetary systems. It combines empirically validated models of HZ boundaries with accurate orbital plots and a proportion-scaled Hertzsprung–Russell diagram for stellar context. All computed HZ distances match calculated values from Kopparapu et al. (2014)'s calculator [4] when provided identical parameters, and stellar placements appear consistent with NASA Models. The result is a browser-based tool that requires no local installation, making it ideal for both educational use and preliminary exoplanet research.

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[1] 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

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