ALIEN EARTHS

Which Nearby Planetary Systems Are Likely to
Host Habitable Planets and Life?

MONTHLY NEWSLETTER

December 2025

Recent Publications

A substellar flyby that shaped the orbits of the giant planets

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TOI-7166 b: a habitable zone mini-Neptune planet around a nearby low-mass star

....

Characterizing Temperatures of Flares on the M Dwarf Wolf 359 from Simultaneous Multiband Optical Observations

Alien Earths is part of NASA's Nexus for Exoplanetary System Science program, which carries out coordinated research toward the goal of searching for and determining the frequency of habitable extrasolar planets with atmospheric biosignatures in the Solar neighborhood.

Our interdisciplinary teams includes astrophysicists, planetary scientists, cosmochemists, material scientists, chemists, biologists, and physicists.

The Principal Investigator of Alien Earths is Daniel Apai (University of Arizona). The projects' lead institutions are The University of Arizona's Steward Observatory and Lunar and Planetary Laboratory.

For a complete list of publications, please visit the AE Library on the SAO/NASA Astrophysics Data System.

Alien Earths All-Hands Meeting 2026

You are invited to attend the **Alien Earths All Hands Meeting**, taking place **February 3-6, 2026** at the **Hacienda del Sol** in Tucson! The meeting will kick off at noon on Tuesday, February 3 and continue through Friday, February 6, wrapping up after lunch. Join us for a week of science highlights, group discussions, and collaboration across the Alien Earths team.

We can't wait to see everyone there!

A substellar flyby that shaped the orbits of the giant planets

Brown, Garett; Malhotra, Renu; Rein, Hanno

The Open Journal of Astrophysics, Volume 8

The modestly eccentric and non-coplanar orbits of the giant planets pose a challenge to solar system formation theories which generally indicate that the giant planets emerged from the protoplanetary disk in nearly perfectly circular and coplanar orbits. We demonstrate that a single encounter with a 2—50 Jupiter-mass object, passing through the solar system at a perihelion distance less than 20 AU and a hyperbolic excess velocity of 1—3 km/s, can excite the giant planets' eccentricities and mutual inclinations to values comparable to those observed. We describe a metric to evaluate how closely a simulated flyby system matches the eccentricity and inclination secular modes of the solar system. We estimate that there is about a 1-in-9000 chance that such a flyby occurs during the solar system's residence in its primordial cluster and produces a dynamical architecture similar to that of the solar system. The scenario of an ancient close encounter with a substellar object offers a plausible explanation for the origin of the moderate eccentricities and inclinations and the secular architecture of the planets. We discuss some broader implications of disruptive flyby encounters on planetary systems in the Galaxy.

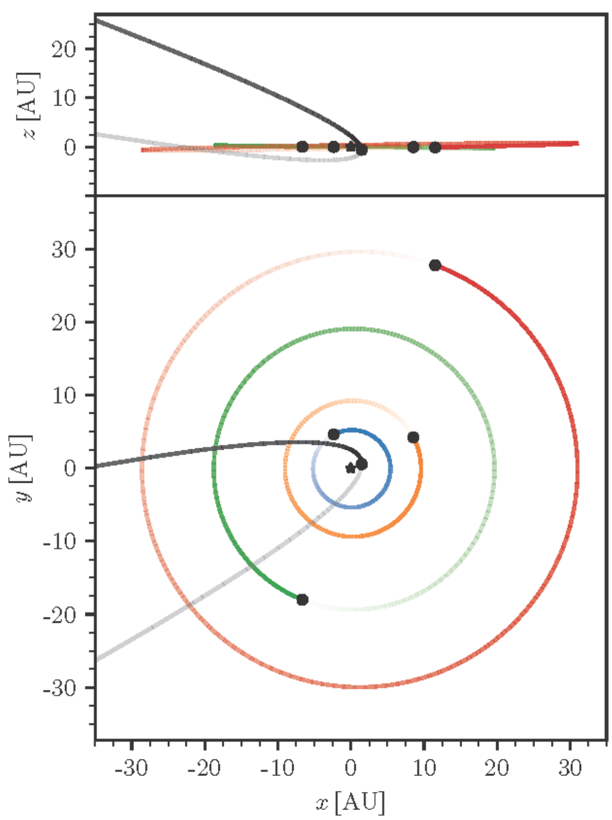

Figure 3. A snapshot of the flyby simulation that produces the best match to the solar system. The flyby parameters for the encounter are $m_\star = 8.27 M_J$, $q_\star = 1.69$ AU, $v_\infty = 2.69$ km s^{-1}, and $i_\star = 131^\circ$.

TOI-7166 b: a habitable zone mini-Neptune planet around a nearby low-mass star

Barkaoui, Khalid; Pozuelos, Francisco J.; Rackham, Benjamin V.; Burgasser, Adam J.; Triaud, Amaury H. M. J.; Serra-Ricart, Miquel ; Timmermans, Mathilde ; Yalçınkaya, Selçuk; Soubkiou, Abderahmane ; Stassun, Keivan G.; Collins, Karen A. ; Amado, Pedro J. ; Baştürk, Özgur ; Burdanov, Artem ; Davis, Yasmin T.; de Wit, Julien ; Demory, Brice-Olivier ; Deveny, Sarah ; Dransfield, Georgina ; Ducrot, Elsa ; Gillon, Michaël; Chew, Yilen Gómez Maqueo ; Hooton, Matthew J.; Horne, Keith ; Howell, Steve B. ; Muñoz, Clàudia Janó ; Jehin, Emmanuel ; Jenkins, John M. ; Littlefield, Colin ; Martín, Eduardo L. ; Niraula, Prajwal ; Pedersen, Peter P. ; Queloz, Dedier ; Scott, Madison G.; Sefako, Ramotholo; Shporer, Avi ; Stockdale, Christopher ; Softich, Emma ; Sota, Alfredo ; Tofflemire, Benjamin ; Şimşir, Özlem ; Varas, Roberto ; Lang, Francis Zong ; Zúñiga-Fernández, Sebastián S.

→ Monthly Notices of the Royal Astronomical Society, Volume 544, Issue 2, pp. 2637-2652, 16 pp.

We present the discovery and validation of TOI-7166 b, a $2.01 \pm 0.05 R_\oplus$ planet orbiting a nearby low-mass star. We validated the planet by combining Transiting Exoplanet Survey Satellite and multicolour high-precision photometric observations from ground-based telescopes, together with spectroscopic data, high-contrast imaging, archival images, and statistical arguments. The host star is an M4-type dwarf at a distance of ~ 35 pc from the Sun. It has a mass and a radius of $M_\star=0.190\pm0.004 M_\odot$ and $R_\star=0.222\pm0.005 R_\odot$, respectively. TOI-7166 b has an orbital period of 12.9 d, which places it close to the inner edge of the Habitable Zone of its host star, receiving an insolation flux of $S_p=1.07 \pm 0.08 S_\oplus$ and an equilibrium temperature of $T_{eq} = 249\pm5$ K (assuming a null Bond albedo). The brightness of the host star makes TOI-7166 a suitable target for radial velocity follow-up to measure the planetary mass and bulk density. Moreover, the physical parameters of the system including the infrared brightness ($K_{mag}=10.6$) of the star and the planet-to-star radius ratio (0.0823 ± 0.0012) make TOI-7166 b an exquisite target for transmission spectroscopic observations with the James Webb Space Telescope, to constrain the exoplanet atmospheric compositions.

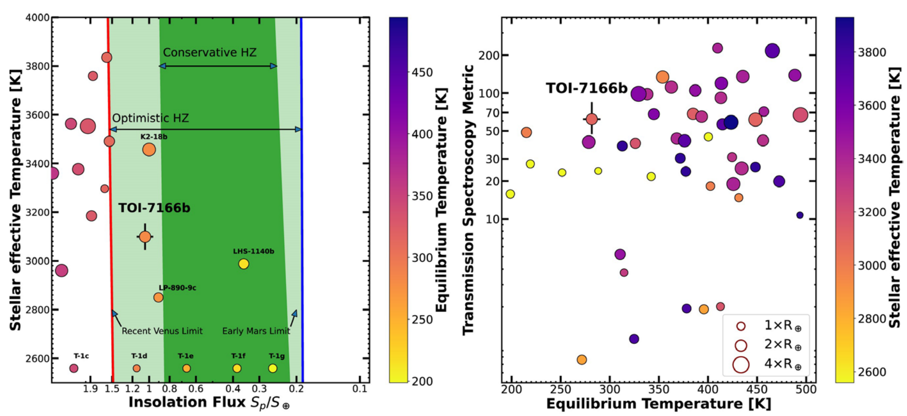

***Figure 11**. Left panel: Stellar effective temperature () as a function of incident stellar flux () of known transiting exoplanets orbiting host stars cooler than 4000 K. The size of each point corresponds to the planet's size, and the colour indicates its equilibrium temperature. The light green region denotes the optimistic habitable zone, bounded by a solid red line (recent Venus limit) and a solid blue line (Early Mars limit). The dark green region indicates the conservative habitable zone as defined by R. K. Kopparapu 2013. Right panel: Transmission spectroscopy metric (E. M. R. Kempton et al. 2018) against the planetary equilibrium temperature for the same sample displayed in the left panel. The points are coloured according to the stellar effective temperature. TOI-7166 b is highlighted by the error bars.*

Characterizing Temperatures of Flares on the M Dwarf Wolf 359 from Simultaneous Multiband Optical Observations

Lin, Chia-Lung; Huang, Li-Ching; Hou, Wei-Jie ; Hsiao, Hsiang-Yao ; Ip, Wing-Huen

The Astronomical Journal, Volume 170, Issue 6, id.297, 18 pp.

We present a flare temperature study of the highly active M dwarf Wolf 359 using simultaneous multiband (u, g, r, i, and z) photometric observations from the Lulin 1 m and 41 cm telescopes. Twelve flares were detected over five nights, with significant brightness increases in the u, g, and r bands; only three were seen in i, and none in z. From broadband spectral energy distribution fitting and g/r color ratio, we derive an average flare temperature of 5500 ± 1600 K, significantly cooler than the canonical 10,000 K. We obtained a power-law relation between FWHM flare temperature and energy in the solar-class flare regime and extrapolated it to higher energies, superflare regime. This power-law is consistent with the trends reported for M dwarf superflares in previous studies, suggesting a common temperature—energy scaling across several orders of magnitude. However, the scatter in the superflare regime increases, indicating that such energetic events may involve more complex physical mechanisms and limiting the applicability of simple blackbody models at the high-energy flares. Using our FWHM flare temperature—TRIPOL g energy relation and the reported flare energy frequency distribution of Wolf 359, we evaluated the potential flare contribution to photosynthetically active radiation (PAR) in the habitable zone. We find that typical solar-class giant flares (Efl,bol ~ 9 × 1031 erg, Tfl,fwhm ~ 6800 K) are not frequent enough to sustain Earth-like net primary productivity. Even under the extreme superflare condition (~1036 erg, ~16,500 K), flare activity remains far from meeting the PAR threshold.

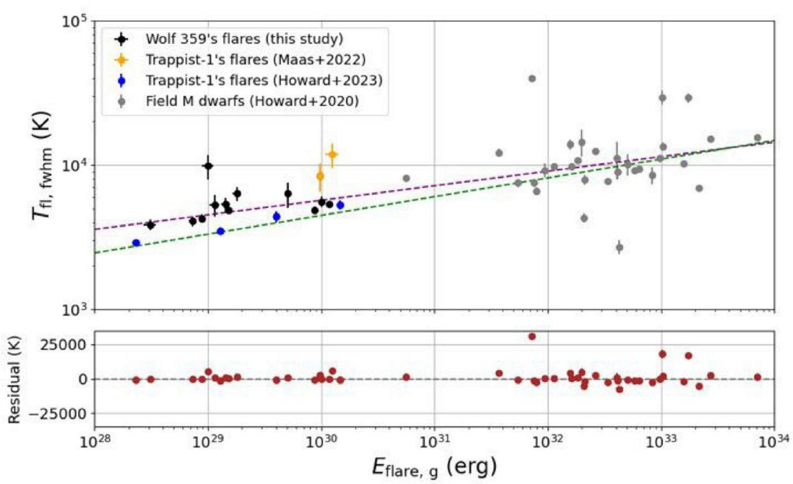

***Figure 7**. Relationship between TRIPOL g-band flare energies and FWHM temperatures for the M dwarfs' flares. Black dots represent flares observed on Wolf 359 in this study. Gray dots are flares from field M dwarfs reported by W. S. Howard et al. (2020). TRAPPIST-1 flares are shown as yellow and blue dots, corresponding to data from A. J. Maas et al. (2022) and W. S. Howard et al. (2023), respectively. The green dashed lines show the power-law correlations derived from M dwarf superflares reported by W. S. Howard et al. (2020). The purple dashed lines represent the power-law correlations derived from low-energy Wolf 359's flares reported in this study and Trappist-1's flares reported in A. J. Maas et al. (2022) and W. S. Howard et al. (2023) (see Equation (8) and the coefficients in Table 7). The subpanels below each panel show the residuals diagrams relative to the solar-class flare power laws, visually demonstrating the goodness of fit for flares across all energy regimes.*