Evryscope & K2 Constraints on TRAPPIST-1 Superflare Occurrence and Planetary Habitability

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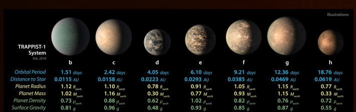


TRAPPIST-1 is a flare star with 3-6 habitable-zone planets[1,2].

Frequent flares[3] could affect planets' potential habitability by:

- Destroying volatiles[4] e.g. O_3
- Providing energy for synthesis of precursor molecules for life[5]

How does TRAPPIST-1's flare rate influence its planets' habitability?

Search Telescope: The Evryscope

Limiting mag: ~16 in *g'*
Cadence: 2 mins
Field of view: 8000 sq. deg.
Number of telescopes: 22
Resolution: 13 arcsec/px
Number of images: ~2,000,000
Sources monitored: 10,000,000
Avg. number of epochs: 33,000

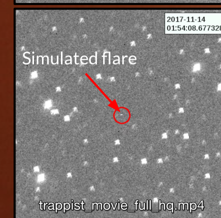
The Evryscope provides long-term coverage, so is less susceptible to bias from stellar activity cycles[6,7] than short-term surveys. We complement continuous observations from K2 by catching rare, high-energy flares.

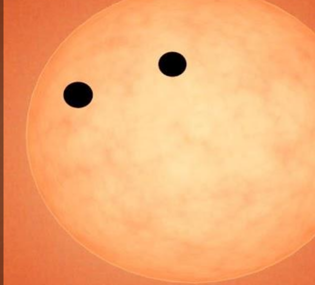
TRAPPIST-1 is dim (*g'* = 19.3), but high-energy flares that could harm atmospheres would be visible to the Evryscope.

We sequence all Evryscope images of TRAPPIST-1's position for playback using Python and FFmpeg.

We search the sequence for flares.

In 9,210 frames over 3 years, no flares were confirmed.





Artist's concept of TRAPPIST-1 with transiting planets.

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We combine flare discoveries from K2[8] with Evryscope non-detection of flares in the sensitivity region E > $10^{32.2}$ erg to place new constraints on the flare frequency distribution (FFD) of TRAPPIST-1.

Rates for superflares ($\nu_{superflares}$) and flares in the sensitivity region ($\nu_{flares \geq 32.2\, log\, erg}$) are lower than previously estimated.

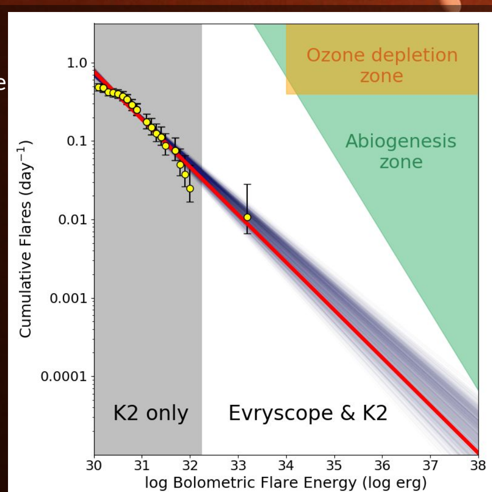
We also revise the FFD slope (α) and intercept (β).

Orange zone: Cumulative flare rate would deplete ozone in planetary atmospheres[4].

TRAPPIST-1's planets currently **do not receive enough high-energy flares to deplete atmospheric ozone.**

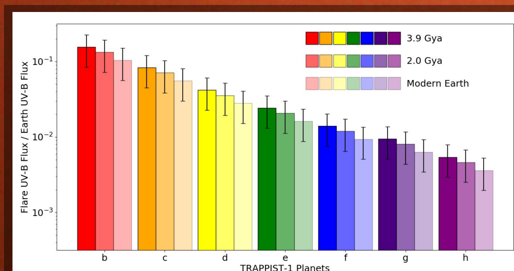
Green zone: Cumulative flare rate would provide enough UV flux to power abiotic synthesis of some RNA precursor molecules[5] (abiogenesis).

TRAPPIST-1's planets currently **do not receive enough high-energy flares to sustain abiogenesis.**

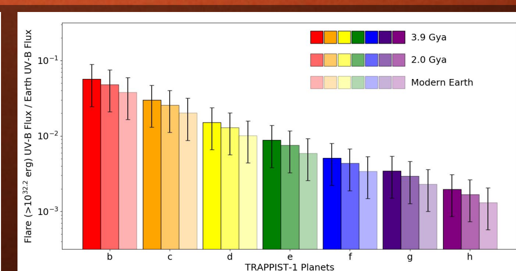


$\nu_{superflares} = 4.2^{+1.9}_{-0.2}$ yr^{-1} ; $\nu_{flares \geq 32.2\, log\, erg} = 12.1^{+3.5}_{-0.3}$ yr^{-1}

$\alpha = -0.61^{+0.01}_{-0.08}\ \frac{day}{erg}$; $\beta = 18.1^{+2.3}_{-0.5}$ day^{-1}



Cumulative annual top-of-atmosphere UV-B flux incident on each planet of TRAPPIST-1, calculated with all flares.



Cumulative annual top-of-atmosphere UV-B flux incident on each planet of TRAPPIST-1, calculated with flares > $10^{32.2}$ erg.

Assuming a 9000 K blackbody for the flares' spectral energy distributions*, we convert cumulative annual flare bolometric flux to UV-B flux.

We calculate the cumulative annual top-of-atmosphere UV-B flux at each planet, as a fraction of the cumulative annual top-of-atmosphere UV-B flux received by Earth[9] for various epochs throughout Earth's history.

* Flares also radiate energy as spectral line emission[6]. ~9000 K blackbodies are widely used[6,10,11, e.g.] because of their ability to describe the white-light continuum emission[11,12] in flares. The white-light model includes empirical fits to the emission lines.
The blackbody assumption enables the estimation of fluxes in relevant bands using conversion relations.

Even including smaller flares (< $10^{32.2}$ erg), UV-B flux for all planets is far less than for Earth.

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