july 24, 2024

exoplanet classification

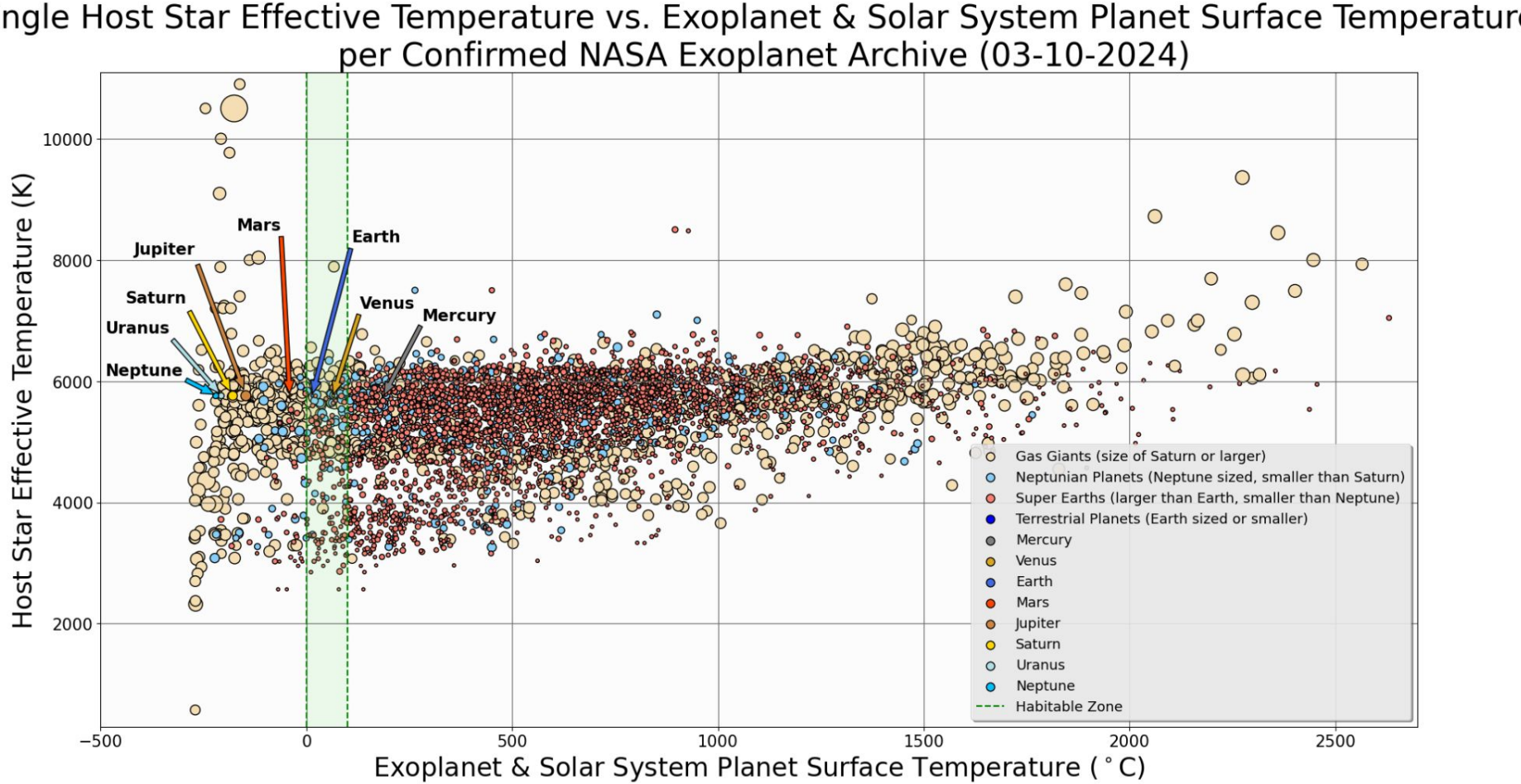
(mostly focused on the figure i’ve produced for the hz exoplanet paper)

- figure (with slight changes)
- issues with venus

figure

new added items:

- earth and other planets of the solar system (with arrow labels for reference)
- resized axis labels (for easier viewing)
- slight scaling tweaking


Single Host Star Effective Temperature vs. Exoplanet & Solar System Planet Surface Temperature per Confirmed NASA Exoplanet Archive (03-10-2024)
Host Star Effective Temperature (K)
Exoplanet & Solar System Planet Surface Temperature (°C)
10000
8000
6000
4000
2000
−500
0
500
1000
1500
2000
2500
Jupiter
Mars
Earth
Saturn
Venus
Mercury
Uranus
Neptune
Gas Giants (size of Saturn or larger)
Neptunian Planets (Neptune sized, smaller than Saturn)
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Jupiter
Saturn
Uranus
Neptune
Habitable Zone

data sources for the planet temperatures

```
# Solar System Temperatures Reference:
#
#
# Sun data source:
#     https://nssdc.gsfc.nasa.gov/planetary/factsheet/sunfact.html
#
# Mercury data source:
#     https://nssdc.gsfc.nasa.gov/planetary/factsheet/mercuryfact.html
#     https://en.wikipedia.org/wiki/Mercury_(planet)
#
# Venus data source:
#     https://nssdc.gsfc.nasa.gov/planetary/factsheet/venusfact.html
#     https://en.wikipedia.org/wiki/Venus
#
# Earth data source:
#     Orbital Eccentricity: https://en.wikipedia.org/wiki/Orbital_eccentricity
#
# Mars data source:
#     https://nssdc.gsfc.nasa.gov/planetary/factsheet/marsfact.html
#     https://en.wikipedia.org/wiki/Orbit_of_Mars
#
# Jupiter data source:
#     https://nssdc.gsfc.nasa.gov/planetary/factsheet/jupiterfact.html
#     https://en.wikipedia.org/wiki/Jupiter
#
# Saturn data source:
#     https://nssdc.gsfc.nasa.gov/planetary/factsheet/saturnfact.html
#     https://en.wikipedia.org/wiki/Saturn
#
# Uranus data source:
#     https://nssdc.gsfc.nasa.gov/planetary/factsheet/uranusfact.html
#     https://en.wikipedia.org/wiki/Uranus
#
# Neptune data source:
#     https://nssdc.gsfc.nasa.gov/planetary/factsheet/neptunefact.html
#     https://en.wikipedia.org/wiki/Neptune
```

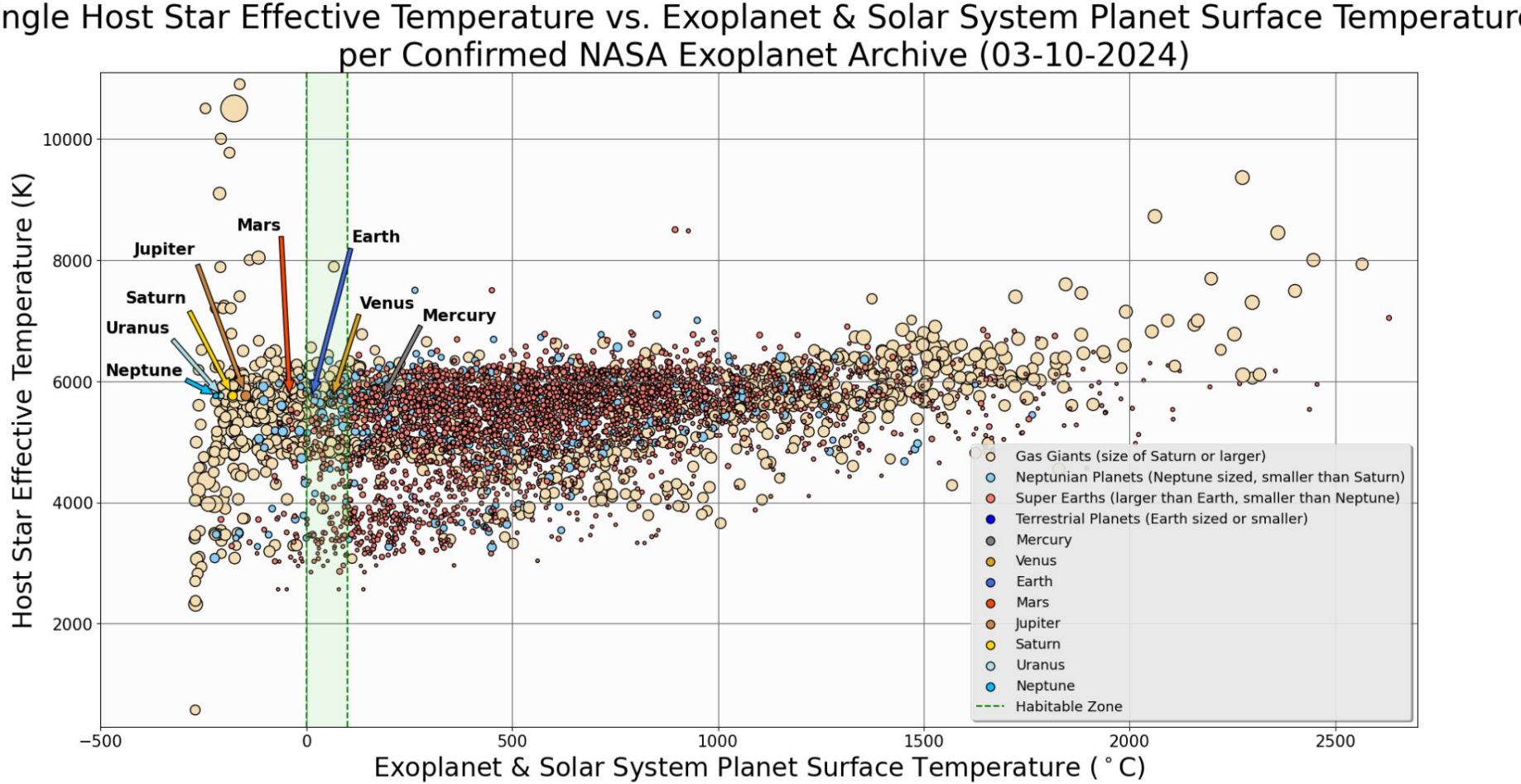
- taken from **nasa** & **wikipedia**
- sample fact sheet from venus on the right

Venus Fact Sheet

Venus/Earth Comparison

Bulk parameters

	Venus	Earth	Ratio (Venus/Earth)
Mass (10^{24} kg)	4.8673	5.9722	0.815
Volume (10^{10} km^3)	92.843	108.321	0.857
Equatorial radius (km)	6051.8	6378.1	0.949
Polar radius (km)	6051.8	6356.8	0.952
Volumetric mean radius (km)	6051.8	6371.0	0.950
Ellipticity (Flattening)	0.000	0.00335	0.0
Mean density (kg/m^3)	5243	5513	0.951
Surface gravity (mean) (m/s^2)	8.87	9.82	0.903
Surface acceleration (eq.) (m/s^2)	8.87	9.78	0.907
Surface acceleration (pole) (m/s^2)	8.87	9.83	0.902
Escape velocity (km/s)	10.36	11.19	0.926
GM (x 10^6 km^3/s^2)	0.32486	0.39860	0.815
Bond albedo	0.77	0.294	2.6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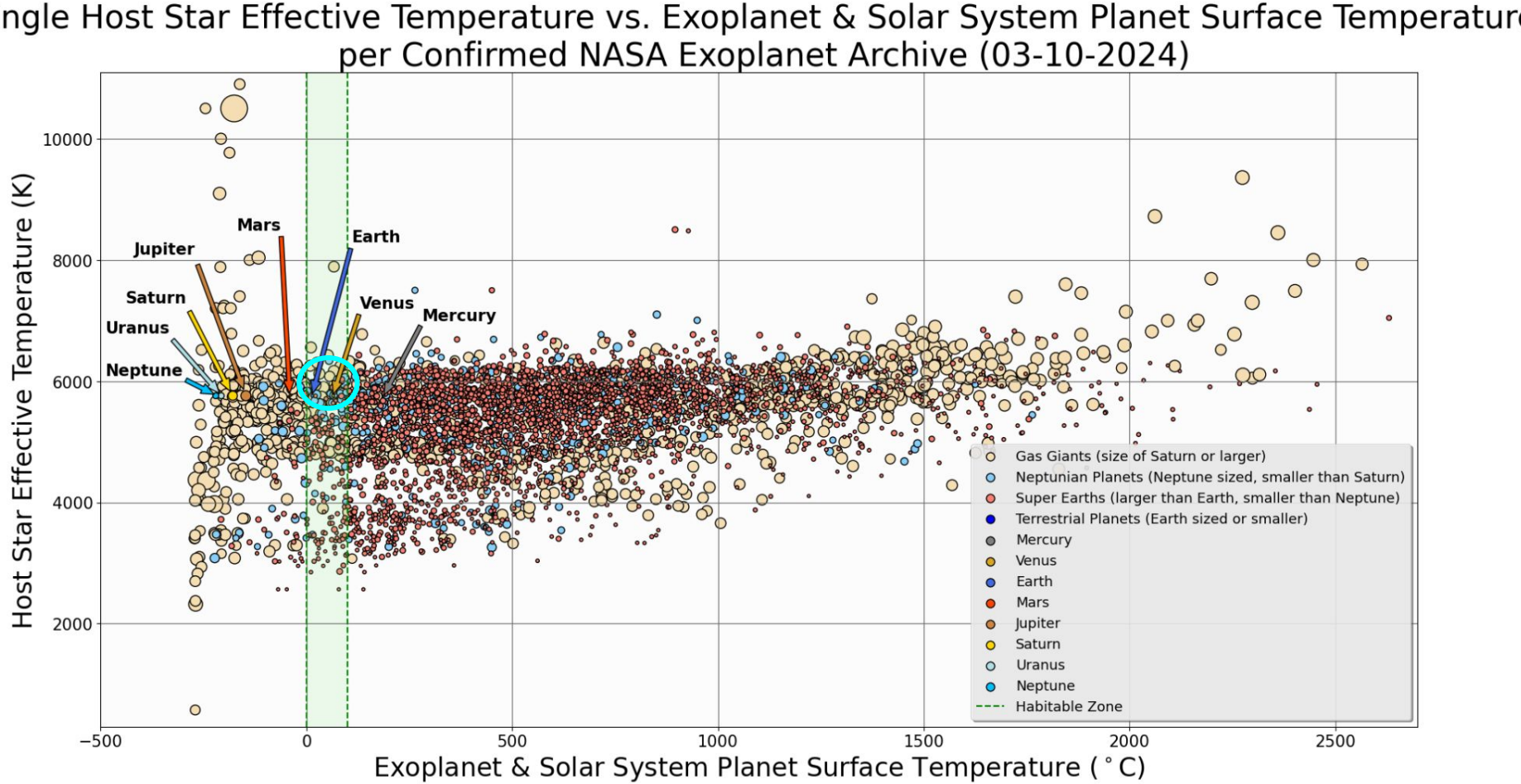
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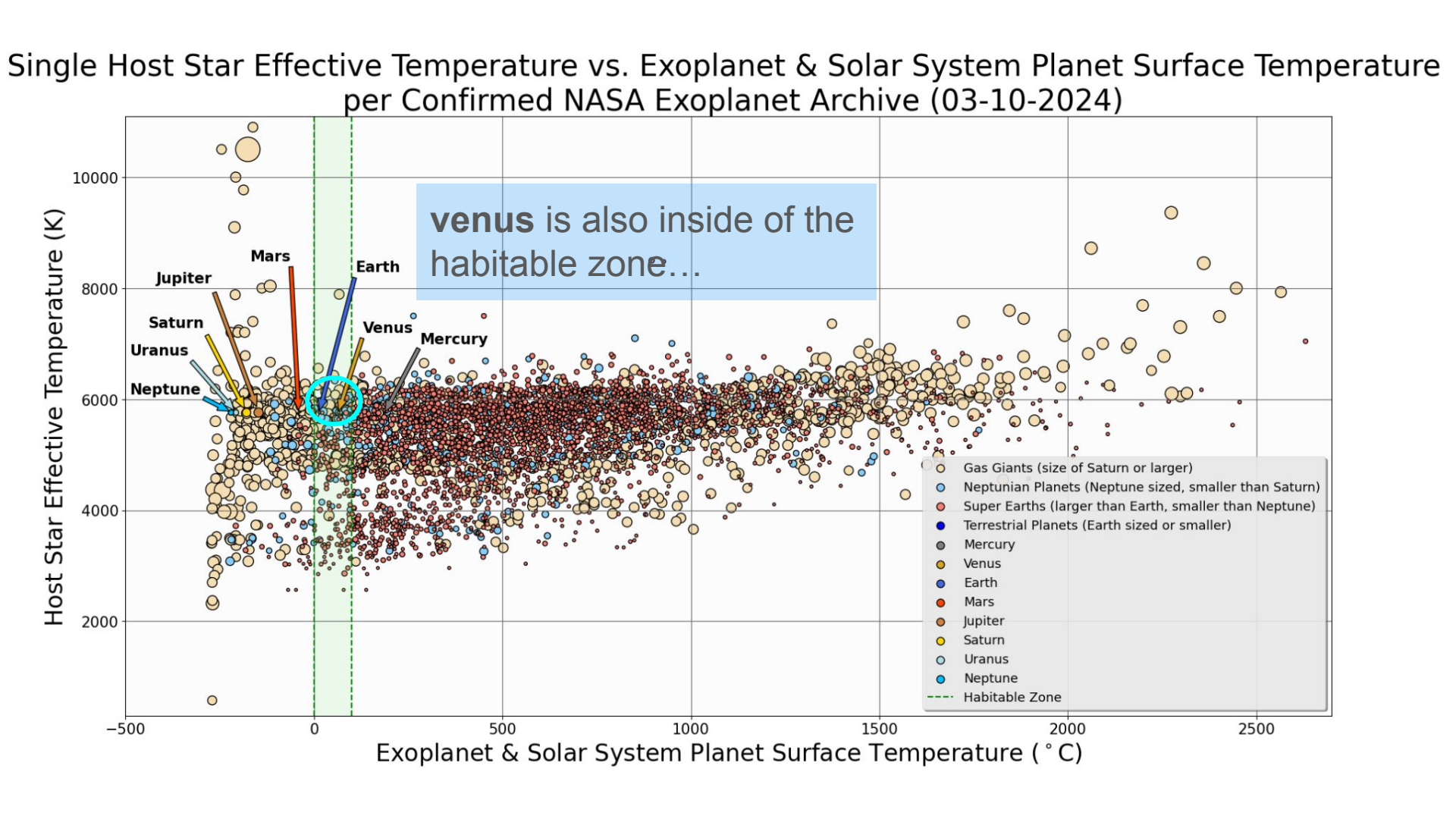
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venus is also inside of the habitable zone…
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Habitable Zone

venus in the habitable zone…

…which doesn’t really make sense. so i went to check the calculations for planet surface temperature.

venus in the habitable zone…

…which doesn't really make sense. so i went to check the calculations for planet surface temperature.

2.2 Habitability Zone Determination

The habitable zone of a given exoplanet was determined based on its calculated average surface temperature, denoted as $T_{surf,ave}$, a critical indicator of potential liquid water presence. We categorized exoplanets as "Too Hot" ($T_{surf,ave}$ >100°C), "Too Cold" ($T_{surf,ave}$ <0°C) or within the habitable zone ("In HZ") for $T_{surf,ave}$ between the benchmark temperature range of 0 to 100°C. This classification was vital to identifying exoplanets that could potentially support life under the assumed necessary precursor of liquid phase H_2O. Utilizing the basic Radiative Equilibrium equation as derived from first principles of radiative heat transfer, the exoplanet average surface temperature calculation considered several characterizing factors. These include the exoplanet's distance from its host star (d), the host's effective surface temperature ($T_\odot$) and radius ($R_\odot$), exoplanet albedo (A) and an additional scaler to account for bulk atmospheric greenhouse gas effect (k):

$$T_{surf,ave} = kT_\odot(1-A)^{0.25}(R_\odot/(2d))^{0.5} \quad (1)$$

Applying equation (1) to each listing in the NASA Exoplanet Archive enabled selective sifting of the database to produce quantified results based on the aforementioned exoplanet HZ status categories. Additionally, where the Archive had no entry for the observable parameters $T_\odot$ and/or $R_\odot$ and/or d, a designation of "N/A" was made for the associated exoplanet to denote insufficient information for determining HZ status in those cases.

venus in the habitable zone…

$$T_{surf,ave} = kT_{\odot}(1 - A)^{0.25}(\frac{R_{\odot}}{2d})^{0.5}$$

venus in the habitable zone…

$$T_{surf,ave} = kT_{\odot}(1 - A)^{0.25}(\frac{R_{\odot}}{2d})^{0.5}$$

- $T_{\odot}$ is the effective temperature of **the sun** (same across all planets)
- $R_{\odot}$ is the radius of **the sun** (same across all planets)
- 2.6 Assumptions and Limitations

  Our analysis was underpinned by several assumptions, notably adopting Earth's albedo (A = 0.306) as a baseline for exoplanets as well as accounting for the atmospheric greenhouse gas effect through the bulk temperature factor (k = 1.13), again using Earth as the standard. Recognizing that our empirical relationships, based on a large but nonetheless limited dataset, might introduce certain biases, we were careful to frame our findings within these constraints. Where assumptions were necessary to complete calculations, rational bracketing conditions were applied accordingly.

A = 0.306 (same across all planets)

k = 1.13 (same across all planets)

so the only thing that's different is d (distance from the sun).

venus in the habitable zone…

- in the case of venus, venus's atmosphere is extremely heavy, which means that its *k* value should have been much higher than the Earth standard we used across the solar system.
- but in general, we weren't too off:

MERCURY	0	188.396908
VENUS	1	64.527543
EARTH	2	13.975212
MARS	3	−40.566530
JUPITER	4	−147.285665
SATURN	5	−180.398576
URANUS	6	−207.607572
NEPTUNE	7	−220.789400

^^ FORMULA RESULTS ^^

- Mercury: 333°F (167°C)
- Venus: 867°F (464°C)
- Earth: 59°F (15°C)
- Mars: Minus 85°F (-65°C)
- Jupiter: Minus 166°F (-110°C)
- Saturn: Minus 220°F (-140°C)
- Uranus: Minus 320°F (-195°C)
- Neptune: Minus 330°F (-200°C)
- Dwarf Planet Pluto: Minus 375°F (-225°C)

^^ NASA DATA ^^