Task #2: Are We Alone? 1/04/26

Objective: Identify which conditions that make a planet capable of supporting life and determine the most promising exoplanet for future exploration.

- The Drake Equation:

1) The last four coefficients because as of right now the only basis we can estimate them from is ourselves.
2) Distance from our planet to potential other planets.
3) We are assuming earth-like conditions needed for all life.
4) The pessimism line is essentially the H_0, its probability is so low (statistically significant) that it can't be true and thus there is other life out there.
5) If civilizations existence is temporary, we can study their downfall to prevent ours.
6) Exoplanets means a possibility of Earth-like life. And if our searches return empty-handed, perhaps the possibility of a hidden factor not yet understood.

$$N = R_* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

- N = Number of civilizations we could possibly communicate with
- R_* = Rate of star formation in our galaxy
  $\approx 1.65 \pm 0.19\ M_\odot$ per year (solar masses/year)
- f_p = fraction of stars with planets
  $\sim 90-100\%$
- n_e = Average number of planets per star that could support life
  $\sim 0.37-0.88$ planets per star
- f_l = fraction of habitable planets that actually develop life: 0-1
- f_i = fraction of those with life that evolve intelligent life: 0.003%-100.2%
- f_c = fraction of intelligent civilizations that develop technology to communicate: 10-20%
- L = length of time such civilizations release detectable signals: Anywhere from 100 - a few thousand

Very rough estimations because our only frame of reference is ourselves

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- Scenarios:

1) Best-case scenario (optimistic):

2 · 100% · 1 · 100% · 100% · 100% · 100,000,000

= 200,000,000 planets with civilizations

2) Worst case scenario (pessimistic)

1 · 40% · 1 · 20% · 0.02% · 10% · 100

= 0 civilizations

3) personal estimate:

1.65 x 95% · 1 · 20% · 3% · 10% · 1000

= 3 civilizations

- Reflection:

1) I am surprised by just the sheer impossibility of life on other planets, even the optimistic view has only 0.0005% of stars having planets with civilizations.
2) Yes, the possibility is just too low
3) Yes because we would understand that we may be a part of a broader something
4) No, there isn't much we could do about either answer within my life span.
5) If life's so rare?! Then why do we exist?

- Habitable Zone:

$$d = \sqrt{\frac{L}{C}}$$

d = distance from in AU

L = star's luminosity in (solar units)

C = constant based on the habitable zone boundary

C Table:

C	Conservative	Optimistic
Inner	1.1	1.78
Outer	0.53	0.32

*only applicable to main-sequence stars (Types G, K, or M)

Factors for Life:

- Star Type: Controls the stability, amount of energy, amount of radiation, and duration of possible life supporting planets.
- Location in the habitable zone: too far to either extreme prevents liquid water, which is key for life.
- Prescence of water: A high abundance of liquid water is needed, too much or too little, or the wrong phase could hurt the chances of life.
- Atmosphere: A proper atmosphere traps some (not too much or too little) heat, protects from radiation, and is not composed of toxic gases.
- Greenhouse effect: Must be kept in middle, too little means it's too cold, and too much means it's too hot.
- Planetary Mass & Size: Too little gravity cannot sustain an atmosphere, and too much may harm potential life.
- Magnetic Field: Proper feild protects against radiation and coronal mass ejections, without this, the atmosphere & possible life can be damaged.
- Geologic Activity: Moderate amounts can recycle carbon & provide heat for liquid water, too much can be deadly.
- Stellar Activity: The star must be moderately calm, too much UV, instability & radiation can damage the planet.
- Day length & Tidal Locking: Day length must be moderate for smooth wind speeds & stable circulated temperatures. Too extreme can cause extreme temperatures on the day & night sides, life could only exist in between.
- Chemical Building Blocks: Quite literally needed in some high quantity for life to form.
- Energy sources: Life needs consistent steady energy, can come in a variety of ways, but it must be consistent.
- Surface Temperature: Needs to be moderate for liquid water, but not extreme enough that the water changes phase or life is damaged

The Habitability Rubric:

	1	2	3	4	5
Location in the habitable zone	Far outside - Too hot/cold	Near either edge	Near either edge but within zone	Solidly in habitable zone	Almost pefectly in the center
Star Type O–M	Types O–A - Short life - High Radiation	Type F - Wider habitable zone - Bad UV	Type M - Long lifespan - May flares - Tight HV	Type G - Stable - Shorter lives	Type K - Long lifespan - Low radiation
Planetary Mass & Size in Earth masses ($M_\oplus$)	< 0.1 $M_\oplus$ - No Atmosphere or $> 5.0 M_\oplus$	$0.1–0.5 M_\oplus$ - Thin atmosphere	- $0.5–0.8$ $M_\oplus$ - Weaker atmosphere	- $0.8–2.0$ $M_\oplus$ - Strong Atmosphere	$2.0–4.0 M_\oplus$ - Strong gravity for very strong atmosphere
Presence of Water - Ideally Liquid	No evidence of water	Possible subsurface or Ice Water	Water Vapor	Strong evidence for atmosphere or surface water	Multiple peices of evidence for stable liquid water
Atmosphere - whether planet has atmosphere that is suitable for life	No atmosphere	Thin atmosphere - can't protect	- Present but Hostile or too Dense	- Thick stable w/ CO_2, N_2, O_2	- Thick, stable, has O_3
Surface Temperature - Needs to be suitable for Liquid H_2O & life	- $< -50°C$ or $> 100°C$ - Extreme hot or cold	$-50°C$ to $-10°C$ or $50°C$ to $100°C$	$-10°C$ to $0°C$ or $35°C$ to $50°C$	$0°C$ to $35°C$	$10°C$ to $29°C$
Chemical building Blocks - C, H, O, N, P, S	No signs of any	Basic elements, - H, He, CO_2	C, H, O	CHNO	CHNOPS

Exo Planets:

- TRAPPIST-1e

- distance$_{x2}$ $= \sqrt{\frac{L}{\ell}} = \sqrt{\frac{0.00052}{\ell}}$

- real $d = 0.029$ AU - inner edge $= \frac{d_{conservative} + d_{optimistic}}{2} = \frac{\sqrt{\frac{0.00052}{1.1}} + \sqrt{\frac{0.00052}{1.78}}}{2}$

$= \cancel{0.02121\ AU} = 0.01709$ AU

- outer $= \frac{d_c + d_o}{2} = \frac{\sqrt{\frac{0.00052}{0.53}} + \sqrt{\frac{0.00052}{0.32}}}{2}$

$= 0.0358$ AU

- Location in habitable zone: 4/5
  - Not perfectly in middle but not in either extreme
- Star Type: 4/5
  - M type would be 3/5, but TRAPPIST-1 is relatively quiet
- Mass & size: 3/5
  - earth like gravity but likely thinner atmosphere
- Water Presence: 2/5
  - Some possibility, not known
- Atmosphere: 2/5
  - Unknown composition & likely thin
- Surface temp: 2/5
  - extreme roughly on the cold side
- Chemical building blocks: 2/5
  - Possible carbons, only 2 points because unknown

Total: 22/35

- Kepler-70b:

$d_{real} = 0.006$ AU

$d_{inner} = 3.44$ AU $= \frac{1}{2}\left(\sqrt{\frac{22}{1.1}} + \sqrt{\frac{22}{1.78}}\right)$

$d_{outer} = 7.367$ AU $= \frac{1}{2}\left(\sqrt{\frac{22}{0.53}} + \sqrt{\frac{22}{0.32}}\right)$

1/5 - Habitable zone:
- Far too close

1/5 - Star Type:
- Still likely too extreme radiation

2/5 - Mass & size:
- Sub earth & thin atmosphere

1/5 - H_2O Presence
- Impossible

1/5 - Atmosphere:
- likely stripped away

1/5 - Surface temp:
- way too extreme

1/5 - Chemical building blocks
- Unknown & unsupported

Total: 8/35

WASP-43B

$d_{real} = 0.0142\ AU$
$d_{inner} = 0.1204\ AU = \frac{1}{2}\left(\sqrt{\frac{0.02}{1.1}} + \sqrt{\frac{0.02}{1.78}}\right)$
$d_{outer} = 0.222\ AU = \frac{1}{2}\left(\sqrt{\frac{0.02}{0.53}} + \sqrt{\frac{0.02}{0.32}}\right)$

1/5 - Habitability zone
- Far too close to star

5/5 - Star Type
- Main sequence star type K

1/5 - Planet size & mass
- Far to large & massive for surface habitability

3/5 - Water Presence
- Vapor in atmosphere

3/5 - Atmosphere:
- Way too dense
- Not proper elements

1/5 - Surface temp
- Far too hot

3/5 - Chemical Building Blocks
- CH_4O

- Total:
16/35

Kepler-442b

- $d_{real} = 0.409\ AU$
- $d_{inner} = 0.6650 = \frac{1}{2}\left(\sqrt{\frac{0.61}{1.1}} + \sqrt{\frac{0.61}{1.78}}\right)$
- $d_{outer} = 1.2267 = \frac{1}{2}\left(\sqrt{\frac{0.61}{0.53}} + \sqrt{\frac{0.61}{0.32}}\right)$

1/5 - Habitability zone
- Too close to star

4/5 - Planet size & mass
- Super Earth
- Strong atmosphere, manageable g

2/5 - Atmosphere
- No data but likely there
- 2/5 placeholder

5/5 - Star Type
- K-type dwarf, stable, little radiation, long life

0/5 - Water Presence
- No data

2/5 - Surface temp
- -40°C

0/5 - Chemical Building Blocks
- Unknown

Total: 14

Kepler-452b

- $d_{real} = 1.046\ AU$
- $d_{inner} = 0.9322\ AU = \frac{1}{2}\left(\sqrt{\frac{1.20}{1.1}} + \sqrt{\frac{1.20}{1.78}}\right)$
- $d_{outer} = 1.72\ AU = \frac{1}{2}\left(\sqrt{\frac{1.20}{0.53}} + \sqrt{\frac{1.2}{0.32}}\right)$

3/5 - HZ: Near edge but in zone
4/5 - Star Type: G-Type Star
5/5 - Planet size & mass: Just big enough without issue
0/5 - Water Presence: Unknown
2/5 - Atmosphere: 2/5 placeholder bc gravity & unknown reality
3/5 - Surface Temp: -8°C
0/5 - Chemical building blocks: Unknown

= 17/35