

The Search for Habitable Worlds



- Why finding habitable worlds matters for science and society



- What 'habitable' means and how the definition has evolved



- The interdisciplinary nature of the search: astronomy, planetary science, biology, and climate science



- A roadmap of this training: habitability, detection, characterization, candidates, and future missions



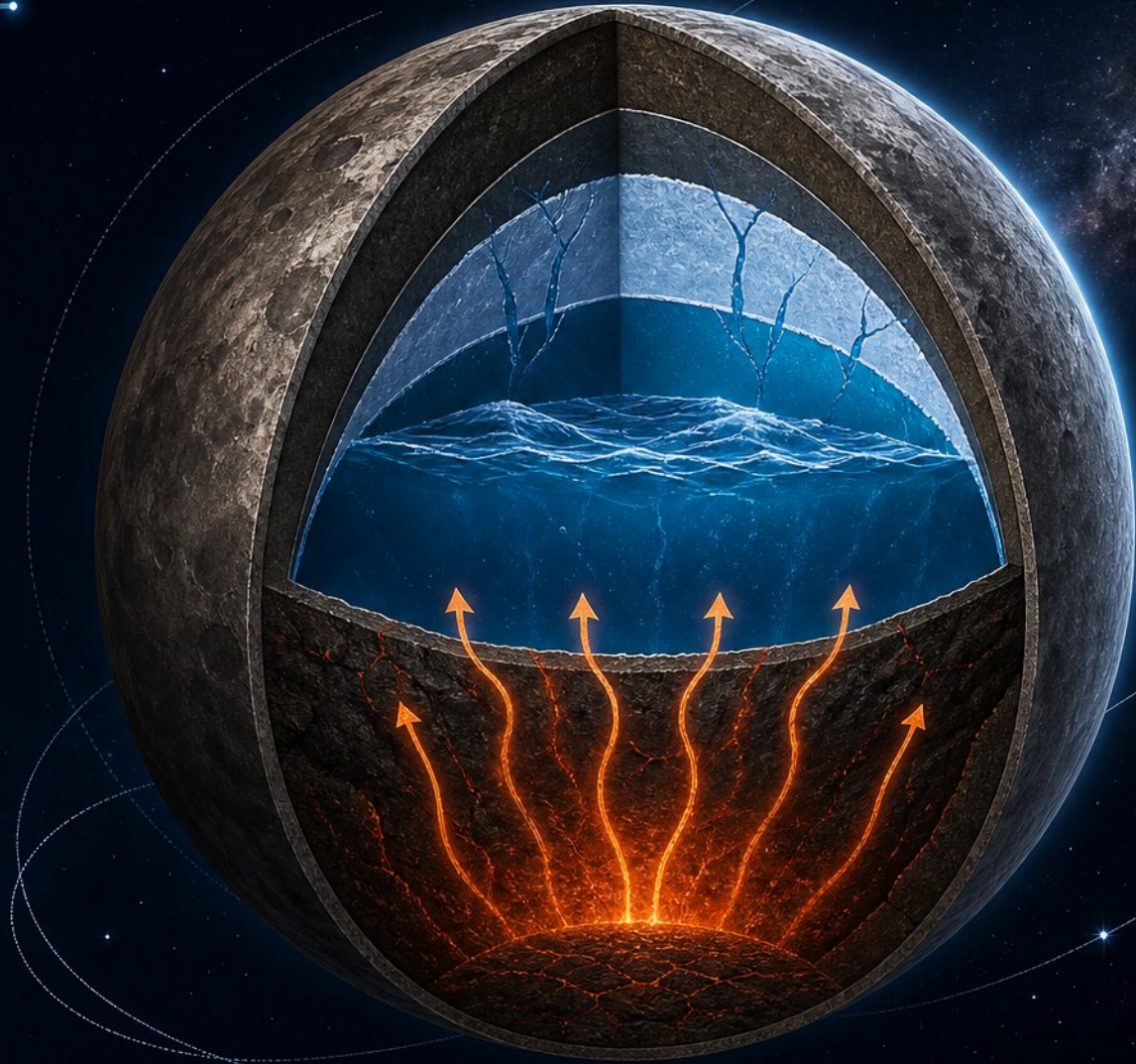
What Does 'Habitable' Actually Mean?

-  Habitable $\neq$ inhabited: conditions support life, but life is absent
-  Earth-like describes similarity, not a confirmed living world
-  The classic habitable zone defines where surface liquid water is possible
-  Subsurface oceans and tidal heating expand habitability beyond the HZ
-  Habitability is time-dependent; it can be lost or gained



Beyond 'Follow the Water'

- Classic habitable zone is a first filter, not proof of life
- 'Euhabitable': stricter, life-centric criteria beyond surface water
- Needs energy, nutrients, and suitable geophysical conditions
- Chemical Goldilocks zone: bioessential elements like P and N
- Habitability is assessed, not assumed from location alone

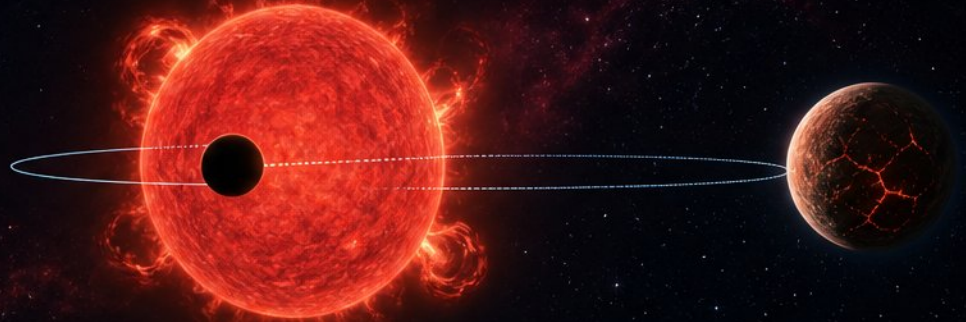


Just-Right Stars and Stable Systems

- Stellar type, age, and activity shape a planet's habitability
- M-dwarfs: common hosts, but flares, tidal locking, and atmospheric erosion challenge retention
- K-dwarfs: "Goldilocks stars" with long lifetimes and milder activity
- System architecture determines whether habitable orbits stay stable long-term

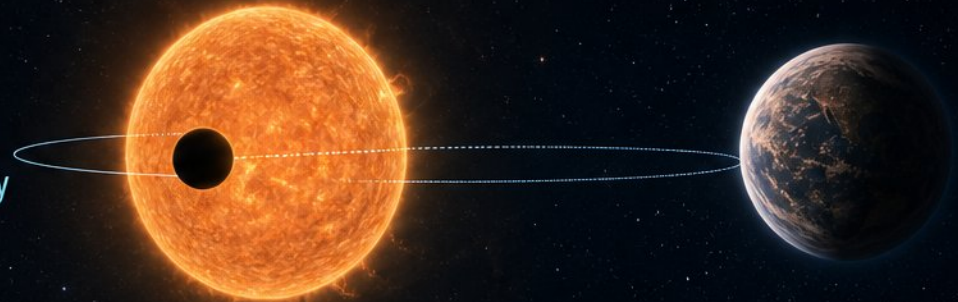
M-dwarf

High activity



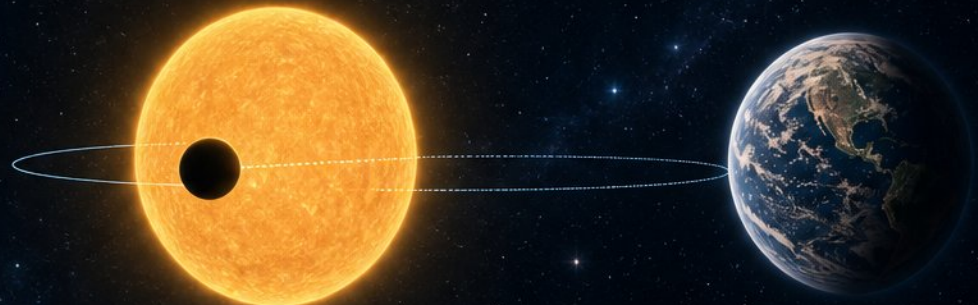
K-dwarf

Moderate activity



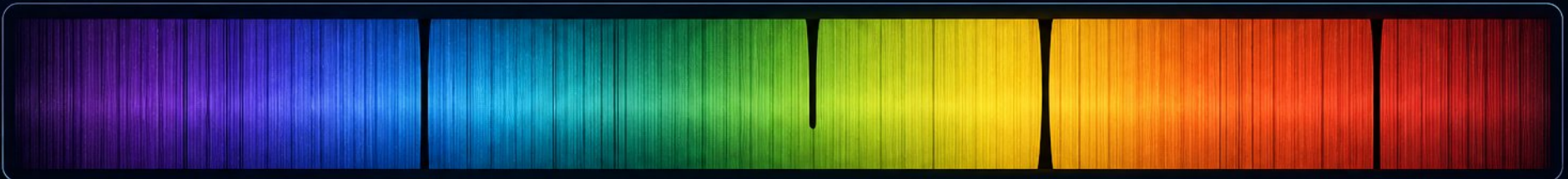
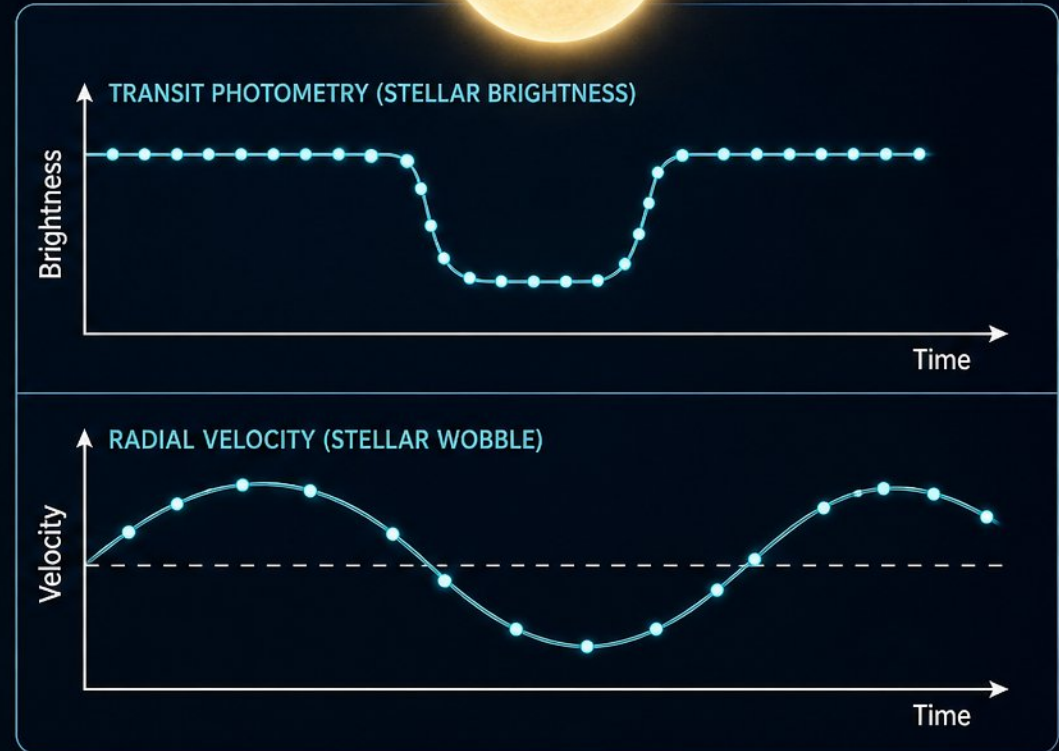
G-dwarf

Low activity



Finding Planets Around Other Stars

- - Transit photometry detects periodic stellar dimming from a planet crossing the star
- - Radial velocity measures stellar wobble to determine minimum planet mass
- - Direct imaging observes young, luminous giants using coronagraphs or starshades
- - Microlensing briefly magnifies distant stars, revealing planets in wide orbits
- - Detection biases favor close-in, large planets; current catalogs reflect this



From Detection to Characterization



1. Detection

Raw observational data reveals a candidate planet



2. Physical Characterization

Mass, radius, and density reveal planet composition



3. Transmission Spectroscopy

Starlight filtering through atmospheres



4. Emission Spectroscopy

Measuring planetary thermal glow



5. Biosignatures & Technosignatures

Interpreting signals for potential signs of life or technology

- Detection is not the same as confirming habitability
- Mass, radius, and density reveal planet composition
- Transmission spectroscopy: starlight filtering through atmospheres
- Emission spectroscopy: measuring planetary thermal glow
- Biosignature and technosignature research is growing rapidly

What JWST Is Teaching Us About Rocky Worlds



- Most precise rocky planet spectra and first thermal emission detections achieved



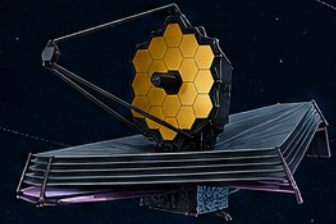
- Stellar contamination remains a major obstacle for M-dwarf transmission spectroscopy



- L 98-59 d: tentative evidence of secondary atmosphere and possible sulfur species

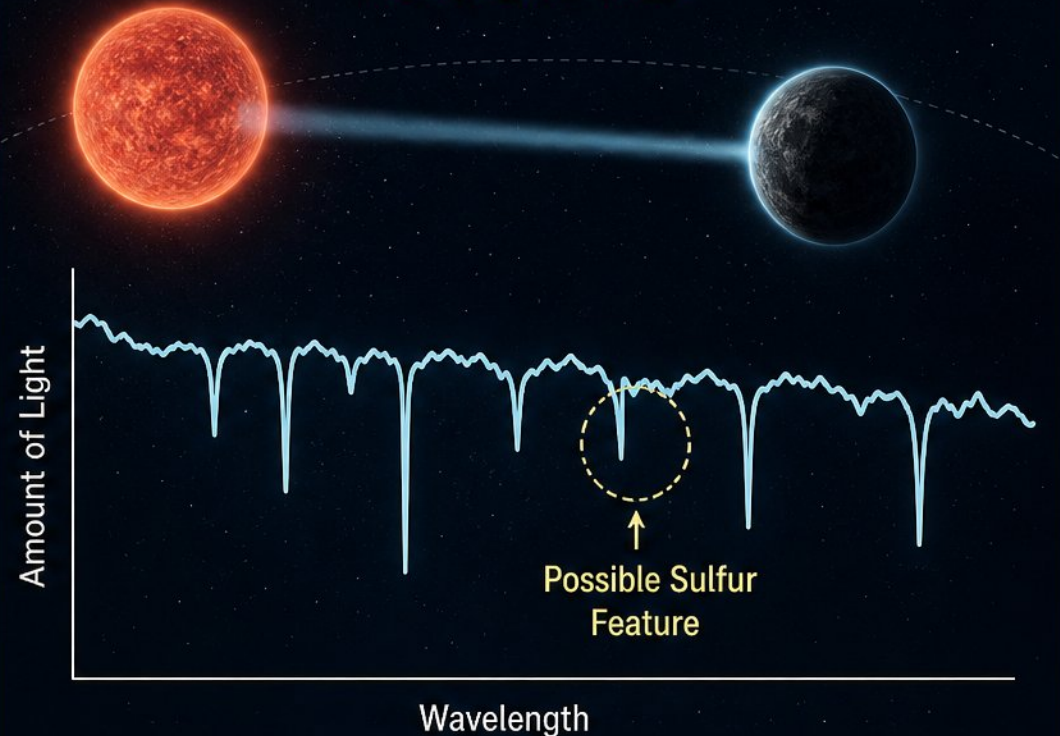


- "Five scale height challenge" set for detecting CO_2 in nitrogen-rich atmospheres



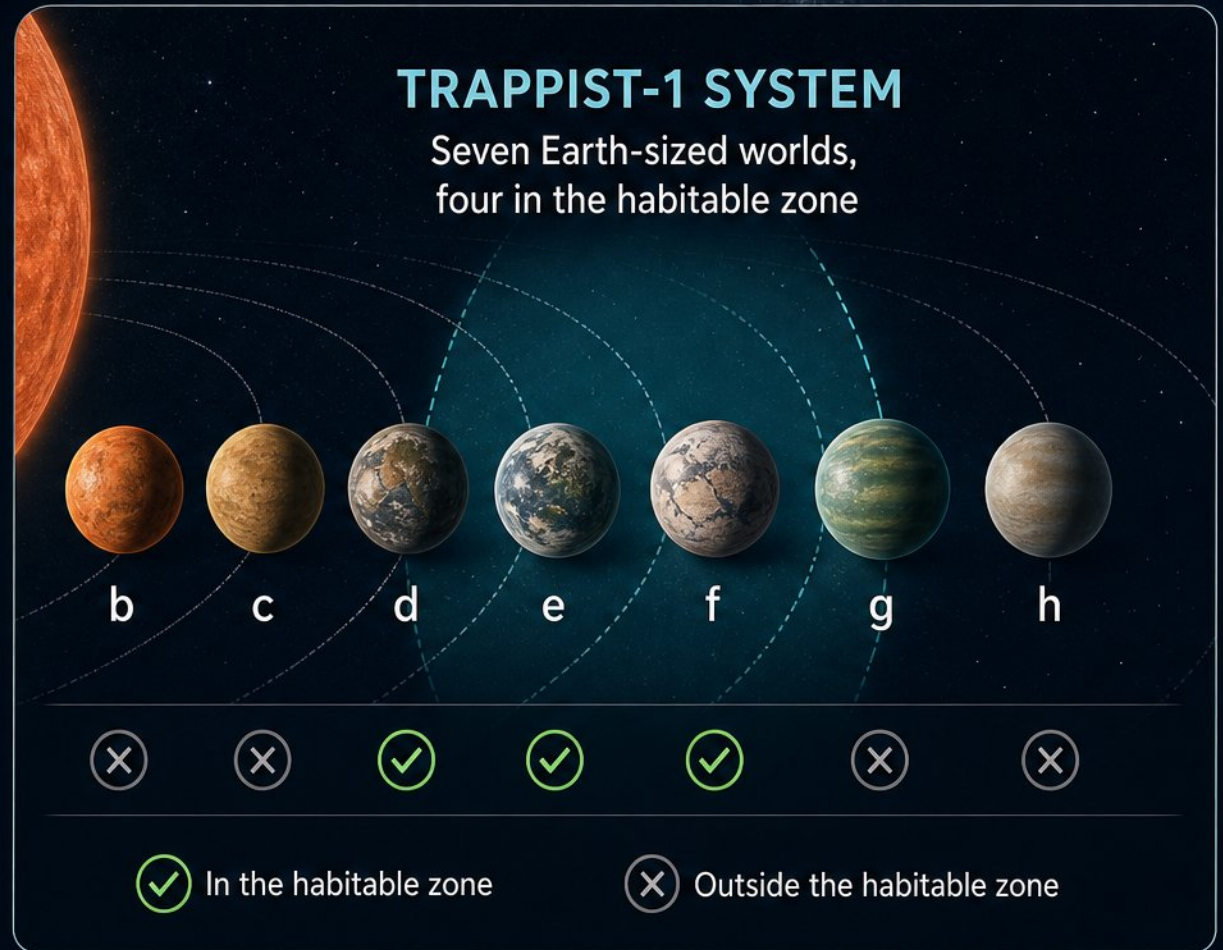
JWST Transmission Spectrum of L 98-59 d

Possible Sulfur Feature



Candidate Habitable Worlds

- 2026 'Project Hail Mary' catalog: 45 rocky exoplanets in habitable zones
- TRAPPIST-1 system: seven Earth-sized worlds, four in the habitable zone
- LHS 1140 b: possible hycean water world and prime JWST target
- Proxima Centauri b: closest candidate, but challenged by M-dwarf flares



The Limits of Habitability: Probing the Edges

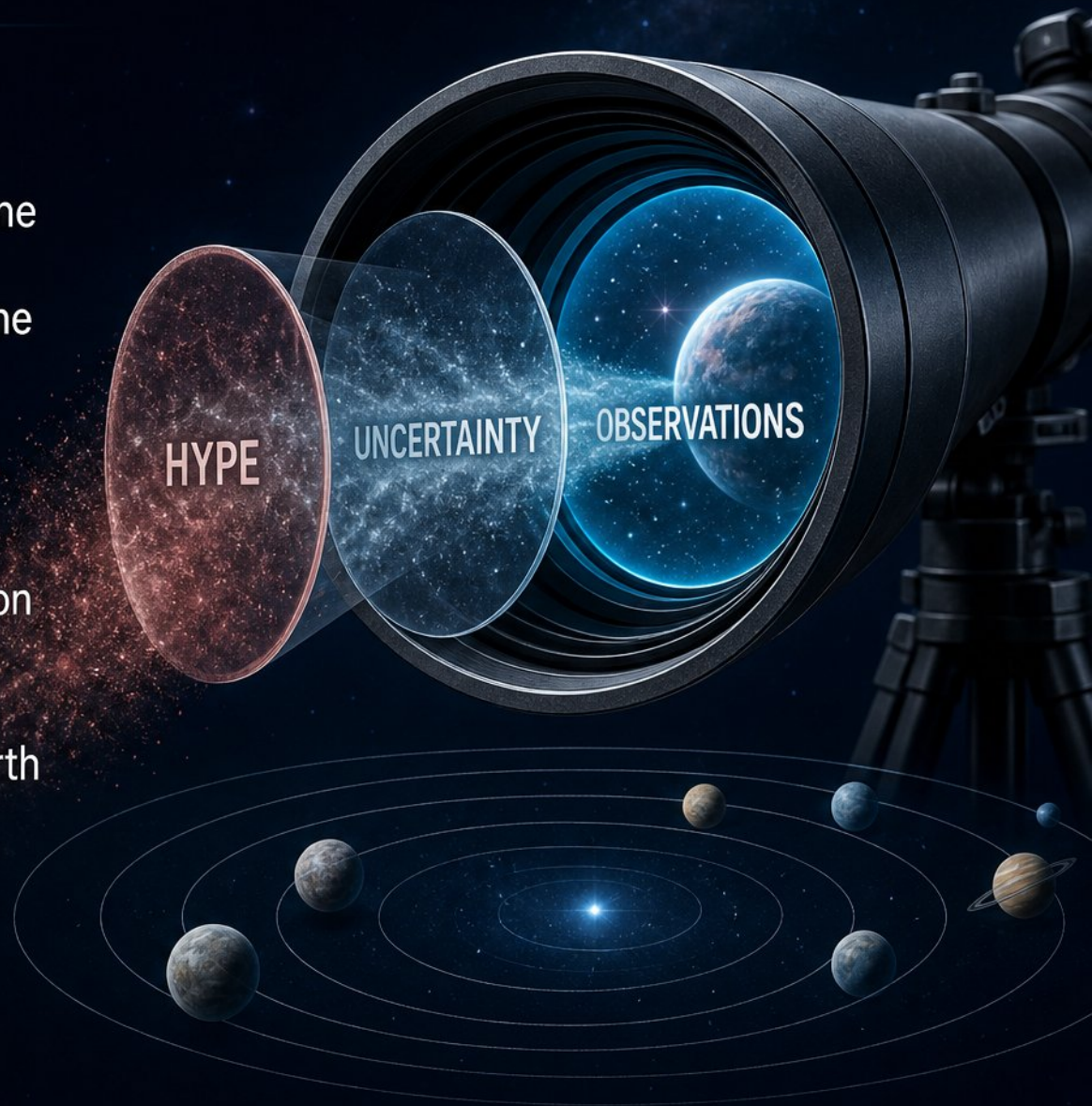


Goldilocks Zone
The Habitable Zone

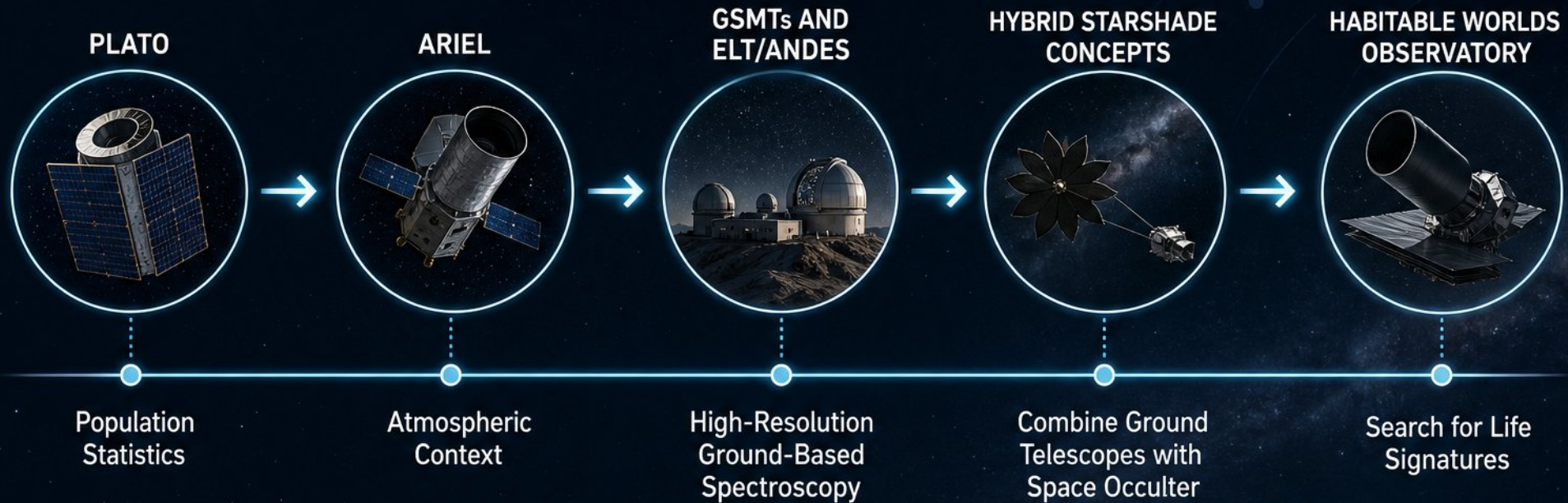
- Venus, Earth, and Mars set our reference boundaries
- 2026 'Project Hail Mary' catalog: 45 rocky HZ exoplanets
- Inner-edge probes: TOI-700 e and K2-3 d may be desiccated
- Outer-edge probes: TRAPPIST-1 g and Kepler-441 b test cold limits

Communicating the Search

- - Avoid labeling any exoplanet as 'Earth 2.0' based on size and orbit alone
- - Emphasize that size and Habitable Zone do not guarantee Earth-like surface conditions
- - Frame uncertainty explicitly: 'potentially habitable' is not confirmation
- - Use models and simulations to illustrate planetary diversity beyond Earth
- - Highlight observational limits before discussing possible surface oceans



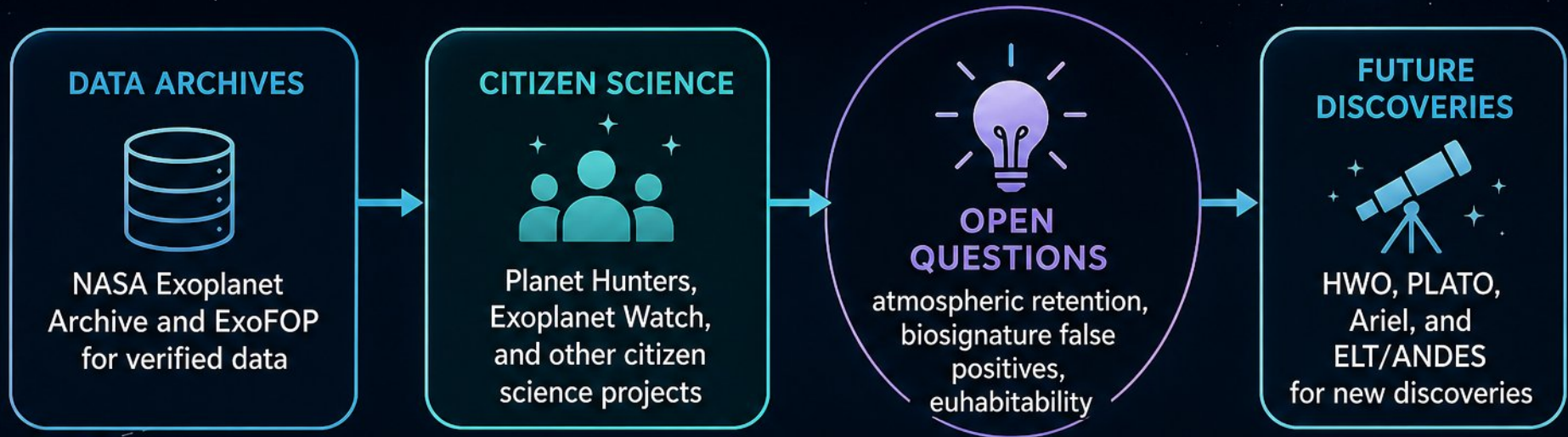
The Future of the Search



- - HWO: first telescope designed to search for life signatures
- - PLATO and Ariel: population statistics and atmospheric context
- - GSMTs and ELT/ANDES: high-resolution ground-based spectroscopy
- - Hybrid starshade concepts combine ground telescopes with space occulter
- - Long-term goal: measure how common truly habitable planets are



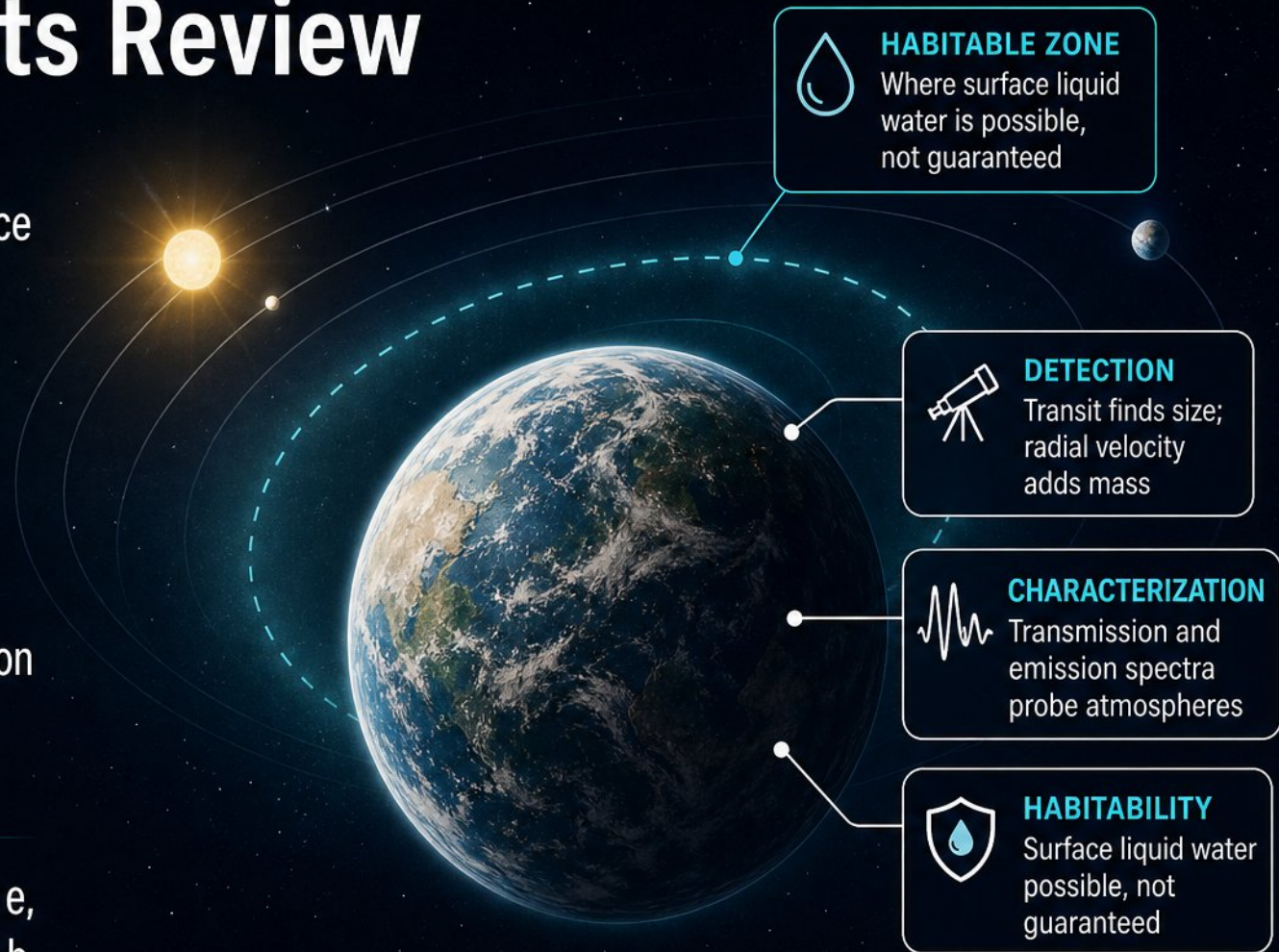
Staying Current and Getting Involved



-  - Use NASA Exoplanet Archive and ExoFOP for verified data
-  - Join Planet Hunters, Exoplanet Watch, and other citizen science projects
-  - Teach "potentially habitable" is not "Earth 2.0"
-  - Track open questions: atmospheric retention, biosignature false positives, euhabitability
-  - Follow HWO, PLATO, Ariel, and ELT/ANDES for new discoveries

Core Concepts Review

- **Habitable zone:** where surface liquid water is possible, not guaranteed
- **Detection:** transit finds size; radial velocity adds mass
- **Characterization:** transmission and emission spectra probe atmospheres
- **Key candidates:** TRAPPIST-1 e, LHS 1140 b, Proxima Centauri b
- **Next steps:** HWO, PLATO, and ELT-class telescopes



WATER IN THREE STATES



SOLID



LIQUID



GAS

PersonWise.

PersonWise • AI digital-human course platform



Scan the code or click anywhere to watch this course live, with voice Q&A

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