

# 'Sulfur world' lava planets?

Potential family of worlds, hidden inside JWST data, revealed by interior-atmosphere evolution model

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Read The Paper

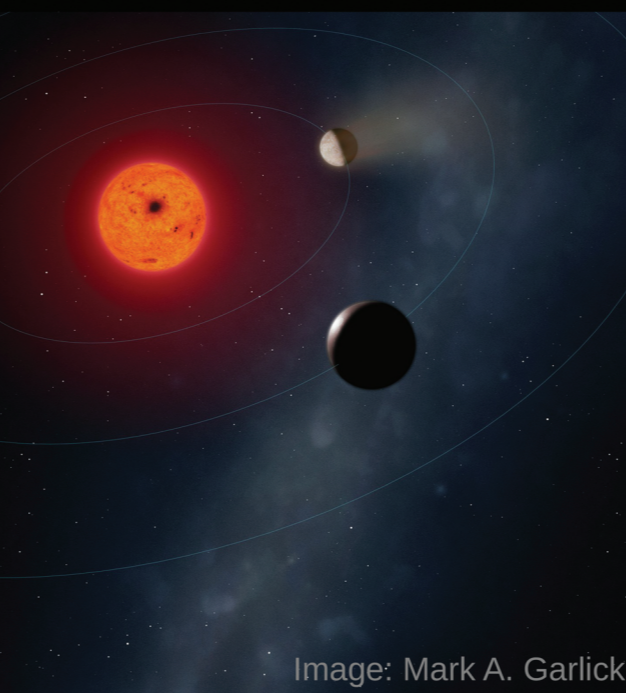
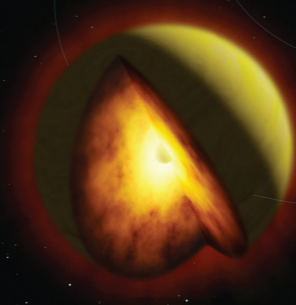


Image: Mark A. Garlick

L 98-59: bright ~5 Gyr M3V star with three transiting exoplanets

L 98-59 b = rocky sub-Venus with SO<sub>2</sub>

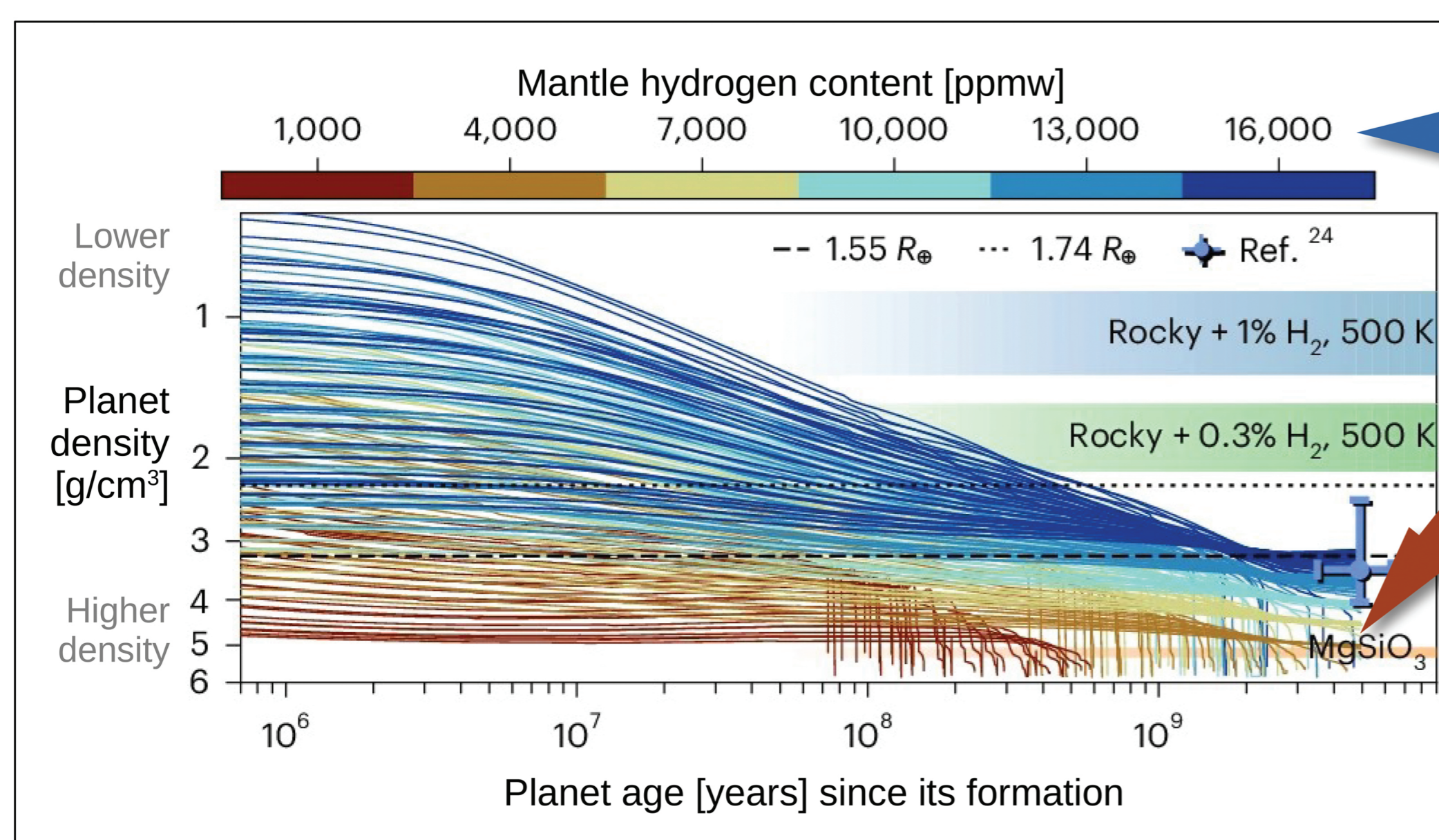
L 98-59 c = tidally-heated super-Earth

**L 98-59 d = confirmed H<sub>2</sub>S + H<sub>2</sub>**

L 98-59 d's low bulk density robustly confirms its atmosphere. Transmission spectra have found H<sub>2</sub>S >10%. It straddles the 'cosmic shoreline' and sits on the 'radius valley'. *How did it form & evolve? What is it made of?*

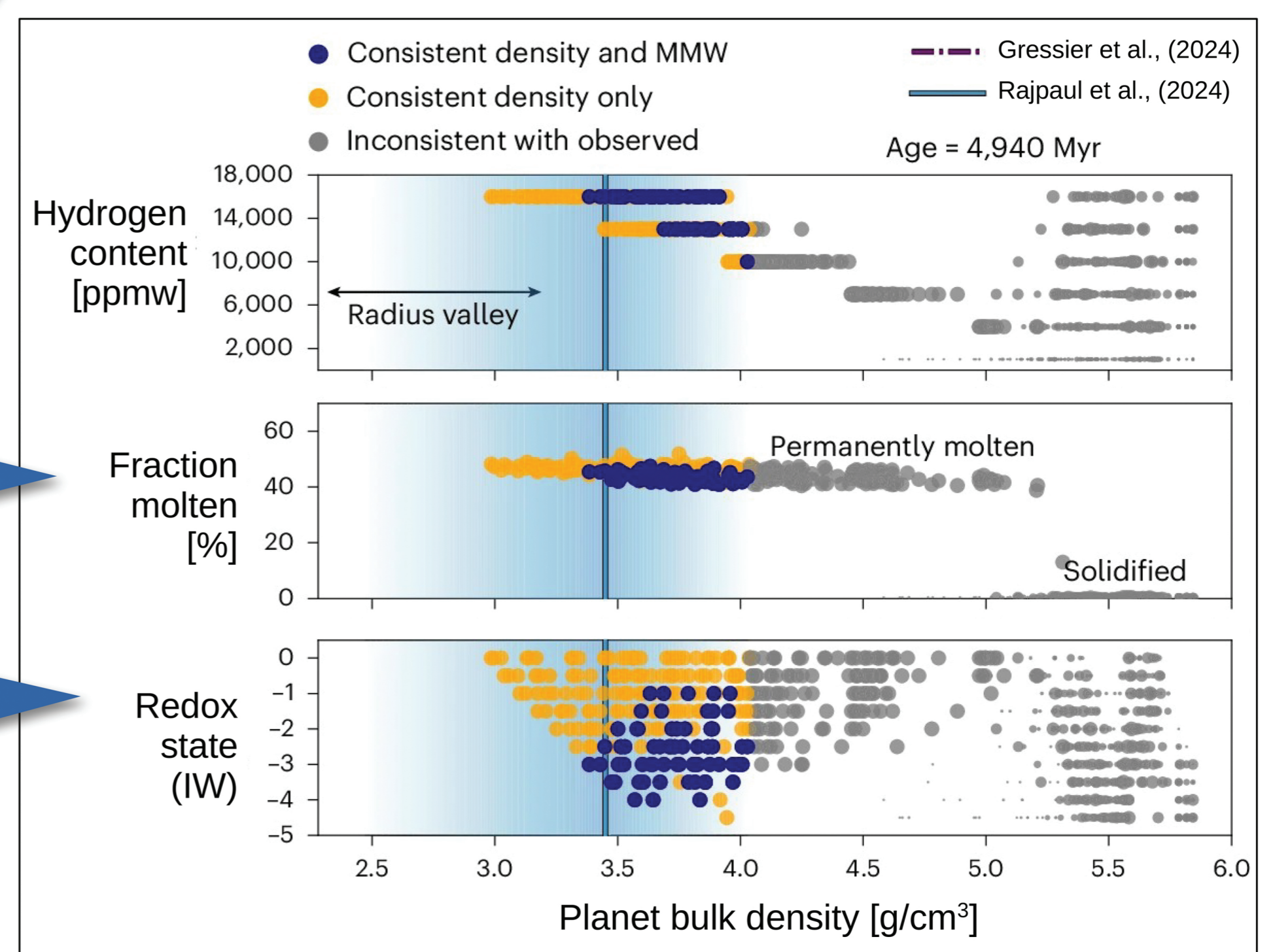
**Methods:** Simulated the complete evolution of this super-Earth using **PROTEUS**: a model which self consistently simulates geodynamics, outgassing, climate processes, escape, and stellar evolution. From diverse initial conditions, we replayed L 98-59 d's lifetime to resolve constraints on its chemistry and density.

**Results:** Simulations reveal cooling, contraction, and photoevaporation across radius valley. Despite a modest irradiation, its massive greenhouse atmosphere sustains the primordial magma ocean. Molten and reducing conditions efficiently dissolve volatiles (esp. sulfur), shielding them against hydrodynamic escape.



Planet formed 'volatile-rich' with >100x Earth's early hydrogen budget. Also enhanced with sulfur since its formation.

Smaller volatile inventories would be lost.



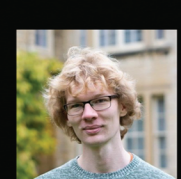
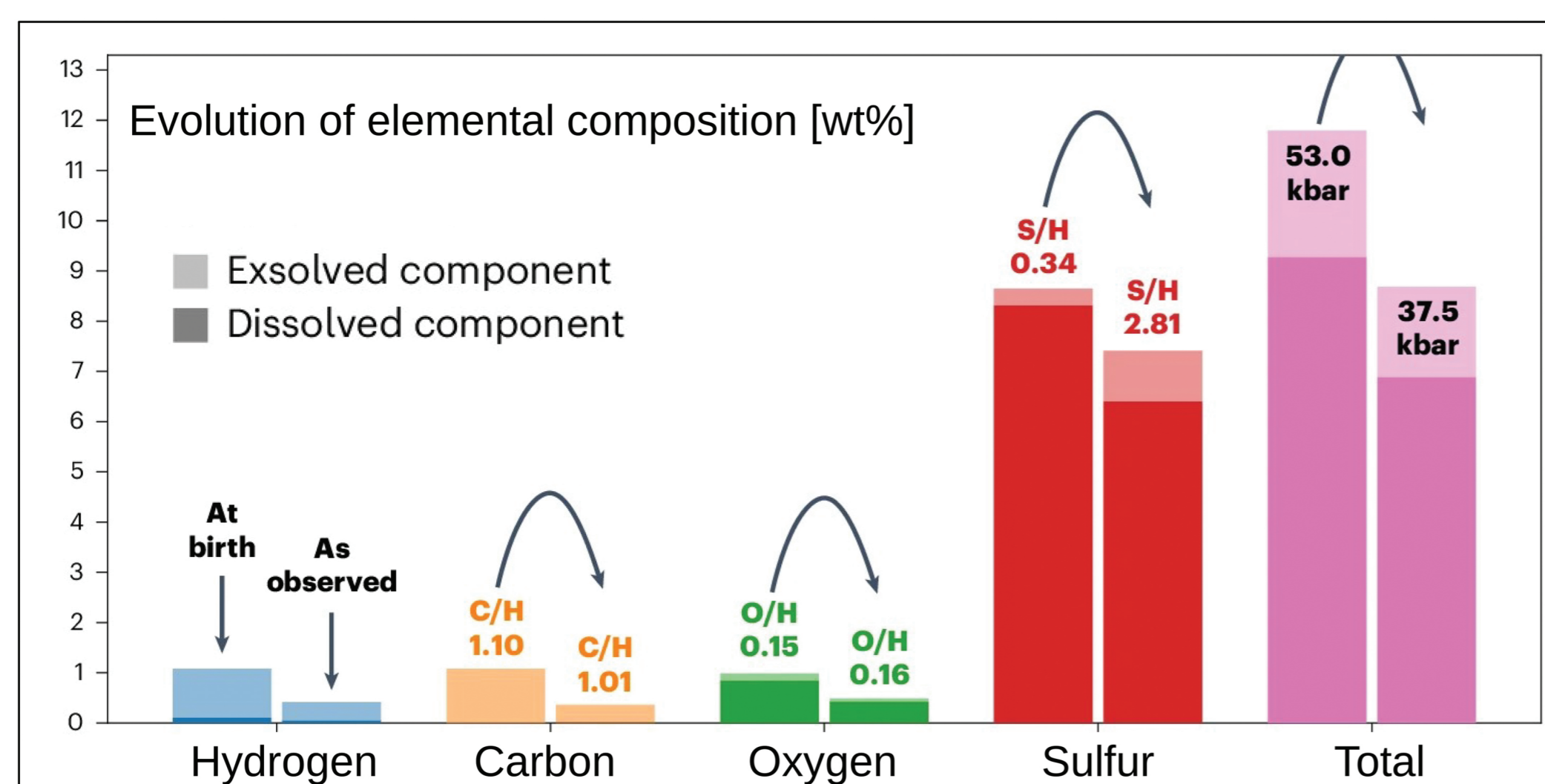
This planet does not fit into existing categories.

Similar targets will be observed with PLATO, Ariel, and ELT. Planetary evolution models are necessary.

PROTEUS can interpret these data, providing insight into exoplanets' interiors and their lifetime histories.

Atmospheric greenhouse effect sustains the 'mushy' magma ocean on this super-Earth.

Reduced interior dissolves S<sup>2-</sup> ions; protected from escape. Disfavours water-world scenario.



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Paper > [nature.com/articles/s41550-026-02815-8](https://nature.com/articles/s41550-026-02815-8)  
Code > [proteus-framework.org](https://proteus-framework.org) (open source)