PLANETARY HABITABILITY DURING THE POST-MAIN-SEQUENCE

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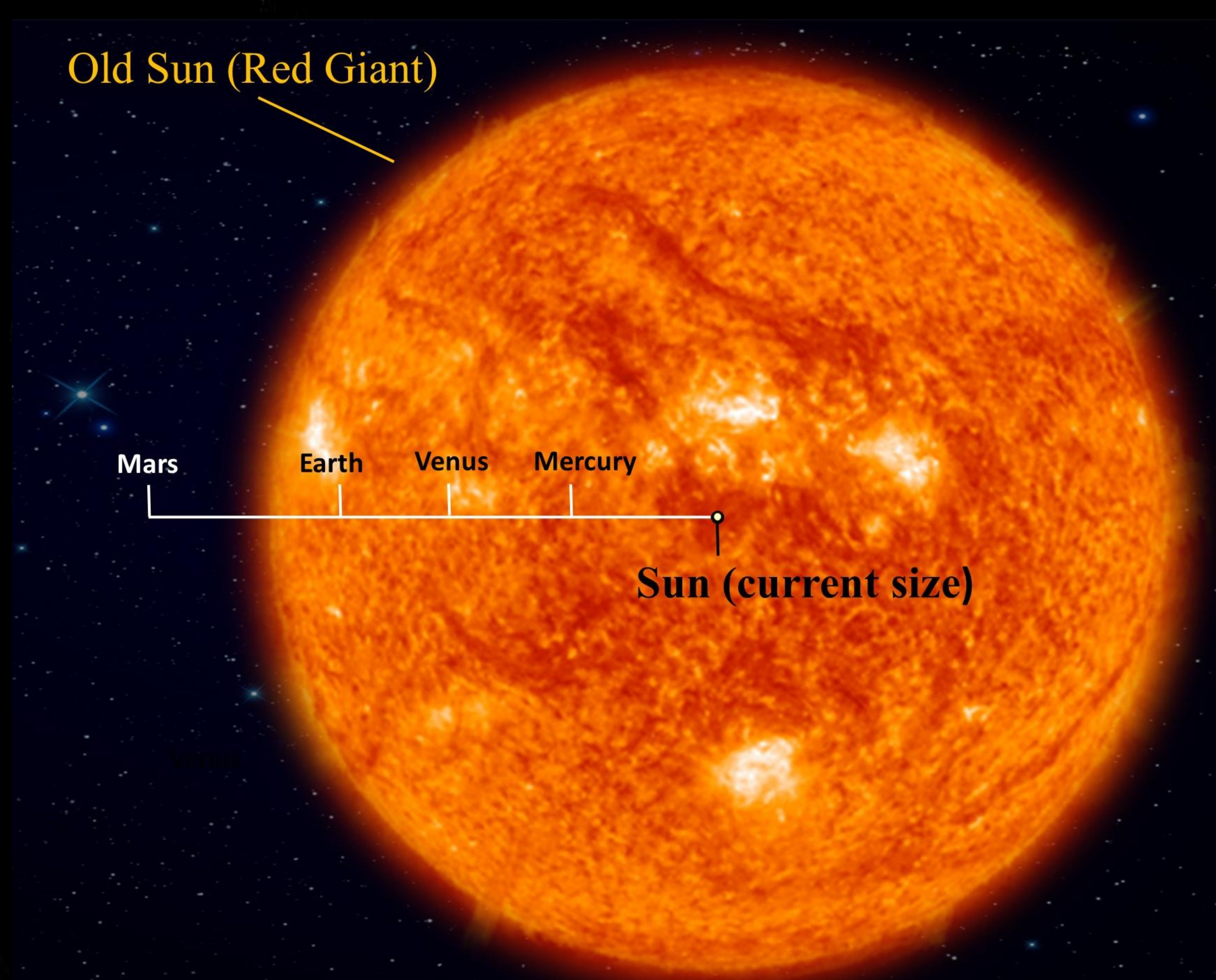
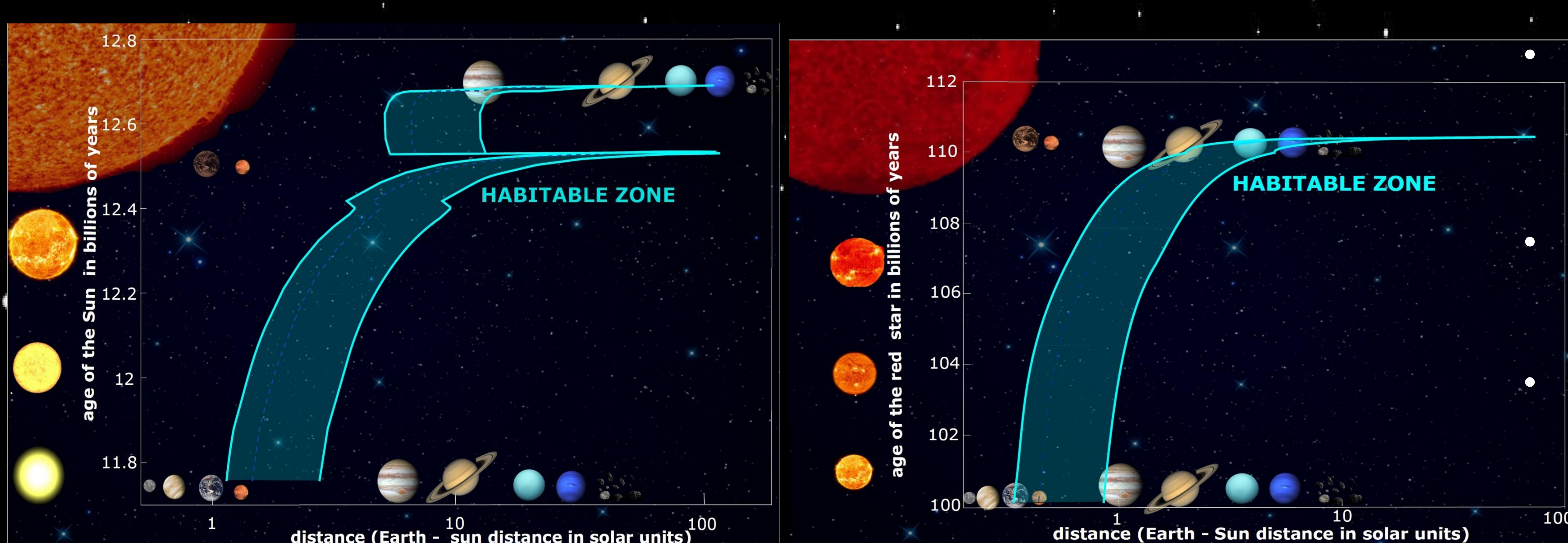


Figure 1: *Size comparison between our current Sun, the orbits of the inner planets, and the future red giant Sun*

- As a star ages, it exhausts the hydrogen in its core
- After this hydrogen is exhausted completely, it becomes a red giant and enters the post-main-sequence (post-MS)
- During the post-MS, red giants get larger, and the habitable zone (HZ), the circular region around a star in which liquid water could exist on a planetary surface, moves outward as well
- In this work, we modeled where the HZ is for red giants and assess the resultant effects on planetary atmospheres and orbits (Ramirez and Kaltenegger, 2016)

EVOLUTION OF HABITABLE ZONE AND ORBITS DURING POST-MAIN-SEQUENCE



-The HZ will eventually move so far outward that frozen worlds in the outer regions of the system melt, potentially unveiling hidden life
- Planets around small stars can reside in this post-MS HZ for up to 9 billion years, enough time for life to start up again
- As the star continues to age, it loses mass and strong stellar winds are ejected, eroding planetary atmospheres and pushing planets out to farther distances

Figure 2: *Shows the evolution of the post-MS HZ as the Sun (left) and red dwarf star (right) age*

DIRECT IMAGING OF PLANETS DISTANT FROM THEIR STARS

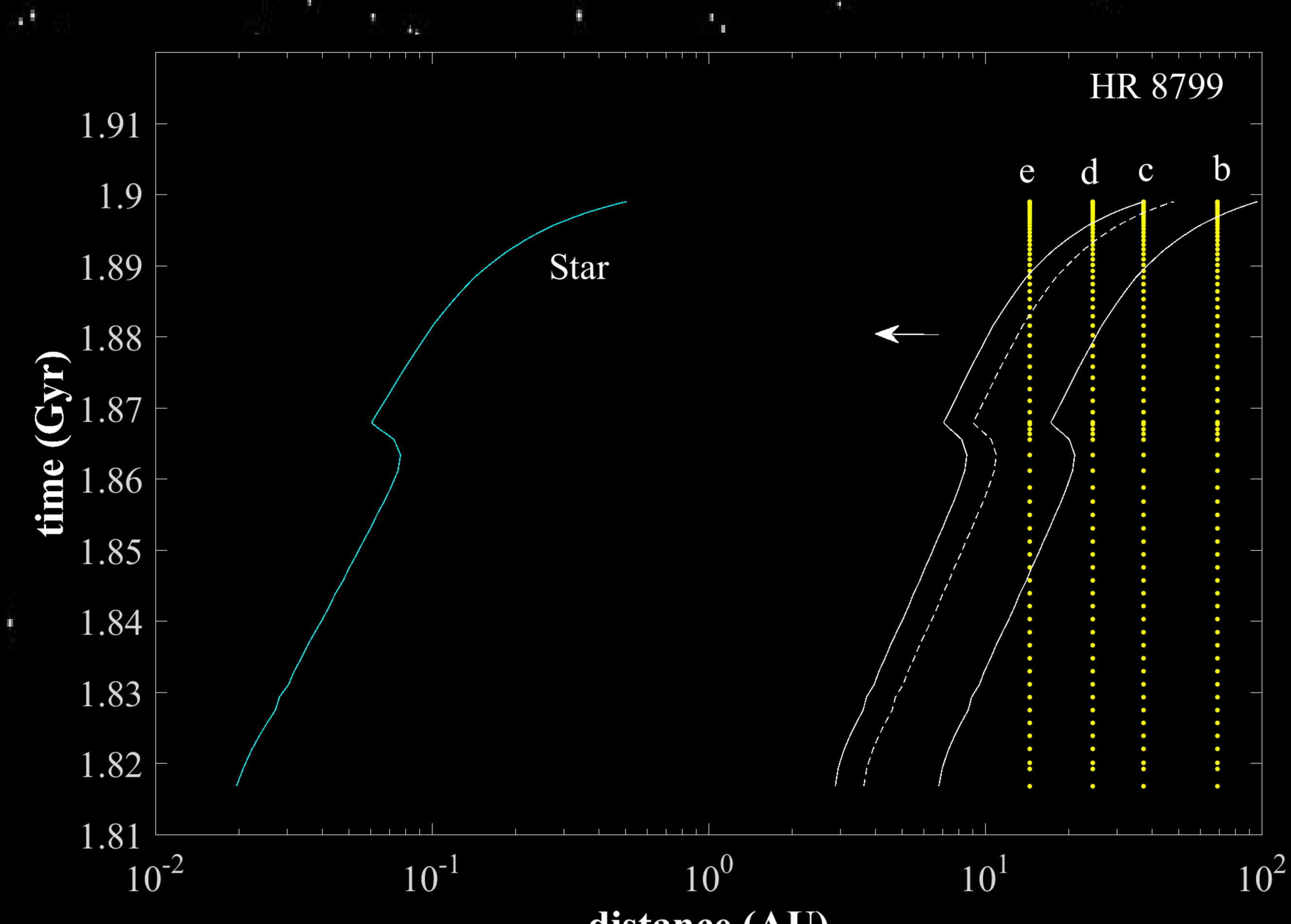


Figure 3: *Comparison of orbits of the directly-imaged exoplanets HR 8799 b-e (yellow dots) with the radius (left green line) and post-MS HZ distance of the host star (white lines). The runaway greenhouse (arrow) is triggered inside the inner edge of the HZ.*

- HR8799 (spectral class: A5) is ~ 30 million years old and is nearly 5 times as bright as our Sun
- The planets (e - b) orbit ~ 14 - 70 AU from their parent star
- Although HR8799 is a young star (not a red giant) it proves that planets do orbit in the farthest reaches of solar systems and can be detected

SIMONS FOUNDATION

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REFERENCES

Ramirez , R. and Kaltenegger, L., (2016). *Habitable zones around post-main-sequence stars*. ApJ, 823, 6, 14 pp