Earth-like exoplanets might be in short supply for the Habitable Worlds Observatory

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Credit: NASA

How common are Earth-like exoplanets—also called exo-Earths—and which exoplanetary systems should we target to find them?

This is what a study hopes to address as a team of researchers investigated potential targets for the planned Habitable Worlds Observatory (HWO), which was recommended during the Decadal

Survey on Astronomy and Astrophysics 2020 (Astro2020) and is slated to launch in the 2040s.

The study is published on the *arXiv* preprint server.

Most notably, HWO will use the direct imaging method to identify exo-Earths, and this study holds the potential to create a more scientifically cost-effective approach for identifying and studying exoplanets.

Here, Universe Today discusses this incredible research with Dr. Stephen Kane, who is a Professor of Planetary Astrophysics at UC Riverside and lead author of the study, regarding the motivation behind the study, significant results, potential system candidates for identifying exo-Earths, the significance of using the direct imaging method, and how this research could influence the 2030 decadal survey. Therefore, what was the motivation behind the study?

"The Habitable Worlds Observatory (HWO) is a direct imaging mission that was the top-ranked priority from the last Astrophysics decadal survey," Dr. Kane tells Universe Today.

"Part of the current effort is to select the most suitable stars that will be the target of HWO observations. There is presently a list of 164 stars on the HWO target list that the community is working with. Since some of the HWO targets are known to already have planets, I conducted a dynamical analysis of those systems to determine if a terrestrial planet in the Habitable Zone (HZ) could maintain a stable orbit."

Out of those 164 stars in the study, 30 host a total of 70 known planets: 11 systems with one planet, seven systems with two planets, six systems with three planets, four systems with four planets, one system with five planets, and one system with six planets.

The system with five planets is HD 75732, more commonly known as 55 Cancri, and is located approximately 41 light-years from Earth. The five planets range in size between eight Earth masses (planet e) and approximately three Jupiter masses (planet d), with the orbit of planet f at least partially traversing the HZ throughout its approximate 260-day orbit.

The system with six planets is HD 219134, also called Gliese 892, and is located approximately 21 light-years from Earth. The six planets range in size between approximately 4.37 Earth masses (planet c) to more than 98 Earth masses (planet h), with the orbit of planet g hypothesized to partially traverse the HZ during its orbit based on a 2015 study and 2021 study.

For the study, the researchers used a series of computer models to calculate the plausible size of each star's habitable zone, referred to as a dynamically viable habitable zone (DVHZ).

The team then inserted a terrestrial planet into the habitable zone to ascertain if it could maintain a stable orbit for the 10,000,000-year duration of the computer model based on the current planetary population in each system, also known as system architecture. Therefore, what were the most significant results from the study and what follow-up studies are in the works?

"We investigated 30 stars on the HWO target list and found that 11 of those have a HZ that is severely impacted by the presence of a giant planet in the system," Dr. Kane tells Universe Today.

"This shows that there needs to be a much more thorough analysis of the remaining HWO target stars to determine if they might have similar dynamical problems. We are already planning a detailed radial velocity study of those stars to search for additional planets."

Regarding which exoplanetary systems are the most promising candidates for identifying exo-Earths, Dr. Kane tells Universe Today, "Actually, what we do in our study is identify the LEAST promising targets by ruling out the presence of Earth mass planets in the HZ of those systems. Among those systems is the bright star pi Mensae, which hosts a giant planet whose orbit sends it regularly crashing through the HZ, ensuring that no habitable planets can exist there."

Identifying and studying exoplanets is conducted through a variety of detection methods, including transit, radial velocity, gravitational microlensing, timing, and direct imaging. For the transit method, astronomers collect data on the dip in starlight that occurs when an exoplanet passes in front of it.

For the radial velocity method, astronomers detect tiny wobbles that a star exhibits as it tugs on an exoplanet orbiting it. For the gravitational microlensing method, astronomers use a star's gravitational field as a lens when it is almost exactly in alignment with a distant star, magnifying the distant star within the front star's gravitational field. When this happens, the gravitational field of a present exoplanet in the front star influences the front star's gravitational field.

For the timing method, also called the transit-timing variation method, astronomers used data from an exoplanet that was detected using the transit method to try and find other planets within the system by detecting changes in the timing of the first planet caused by another planet.

For the direct imaging method, astronomers used a coronagraph to block the brightness of a star, revealing exoplanets that would have otherwise been lost in the star's glare.

Of the 5,743 exoplanets confirmed by NASA, 74.5% are from the transit method, 19% are from the radial velocity method, 3.9% are from microlensing, 1.4% are from the direct imaging method, 0.52% are from the transit-timing variation method, with the remaining from other methods, including eclipse timing variations, orbital brightness modulation, pulsar timing, astrometry, pulsating timing variations, and disk kinematics.

With the planned Habitable Worlds Observatory, astronomers plan to use the direct imaging method, despite it achieving one of the lowest numbers of detected exoplanets. Therefore, why was the direct imaging method chosen for the HWO mission, and is the direct imaging the most viable method for identifying exo-Earths? If not, what method(s) would work best?

"We currently primarily use indirect methods to detect and characterize exoplanets," Dr. Kane tells Universe Today.

"Though these methods can be used to infer planetary properties such as mass, radius, and some atmospheric composition, this can only be achieved for a very limited number of planets. Direct imaging provides much more additional information, such as detailed atmospheric composition, and may even be used to infer surface topography and rotation rate."

As noted, HWO was recommended during the Decadal Survey on Astronomy and Astrophysics 2020 (Astro2020), the latter of which is sponsored by the National Research Council of the National Academy of Sciences and is a report conducted approximately every 10 years to ascertain the current state of the field of astronomy and astrophysics and the direction of research for the following 10 years.

Along with pursuing further research on black holes, neutron stars, and galaxy evolution, Astro2020 also emphasized the search for habitable exoplanets and extraterrestrial life, and HWO was born from previous proposed missions known as the Habitable Exoplanet Observatory (HabEx) and Large Ultraviolet Optical Infrared Surveyor (LUVOIR).

Therefore, with HWO being recommended by the 2020 decadal survey, how could the results from this study influence HWO being discussed in the 2030 decadal survey?

"Our results refine the HWO target list and so strengthen the science output of the mission," Dr. Kane tells Universe Today.

"The elimination of nearby bright targets may mean that HWO will need to shift to fainter, further targets which, in turn, may require a larger telescope to achieve the same goals. HWO is an exciting mission and will provide incredible insights into the prevalence of habitable planets. As we learn more about the nearest planetary systems, we will greatly increase the odds of the success for HWO."

More information: Stephen R. Kane et al, Dynamical Viability Assessment for Habitable Worlds Observatory Targets, *arXiv* (2024). [DOI: 10.48550/arxiv.2408.00263](https://dx.doi.org/10.48550/arxiv.2408.00263)

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