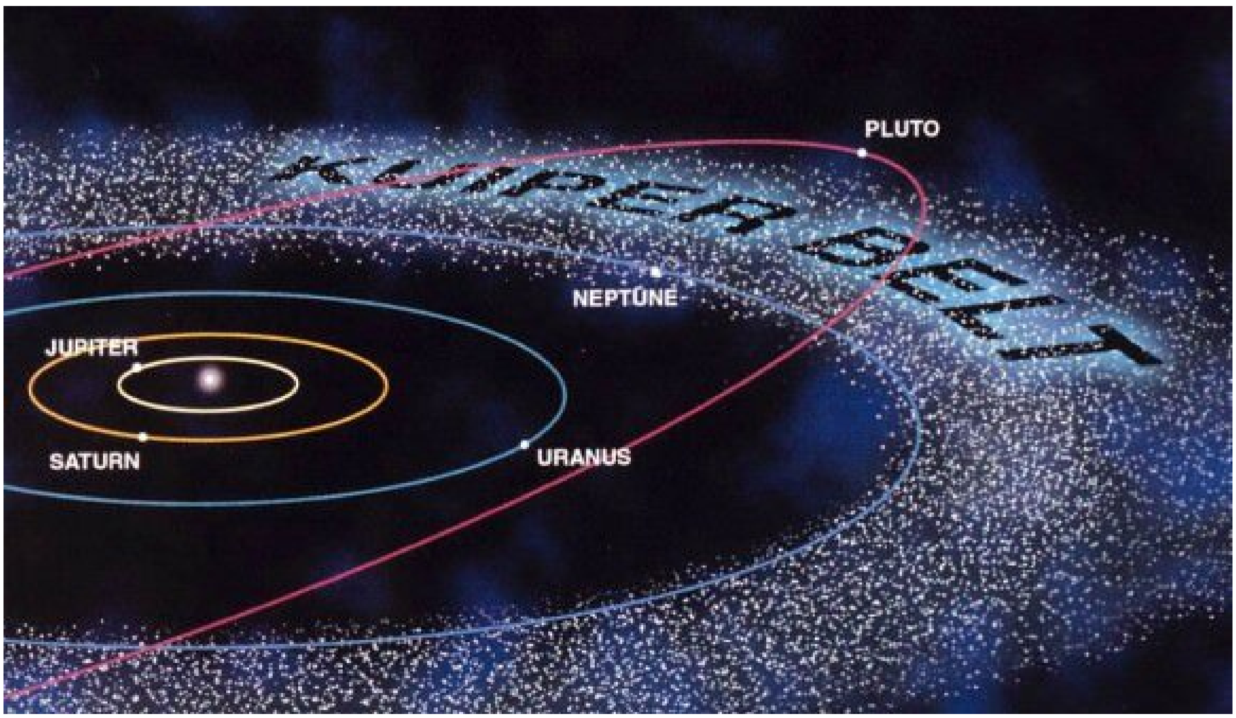
# How did the TRAPPIST-1 planets get their water?

April 10 2020, by Matt Williams




Pluto and its cohorts in the icy-asteroid-rich Kuiper Belt beyond the orbit of Neptune. Credit: NASA

In 2017, an international team of astronomers announced a momentous discovery. Based on years of observations, they found that the TRAPPIST-1 system (an M-type red dwarf located 40 light-years from Earth) contained no less than seven rocky planets. Equally exciting was the fact that three of these planets were found within the star's habitable zone (HZ), and that the system itself has had 8 billion years to develop the chemistry for life.

At the same time, the fact that these planets orbit tightly around a red dwarf star has given rise to doubts that these three planets could maintain an atmosphere or liquid water for very long. According to new research by an international team of astronomers, it all comes down to the composition of the debris disk that the planets formed from and whether or not comets were around to distribute water afterward.

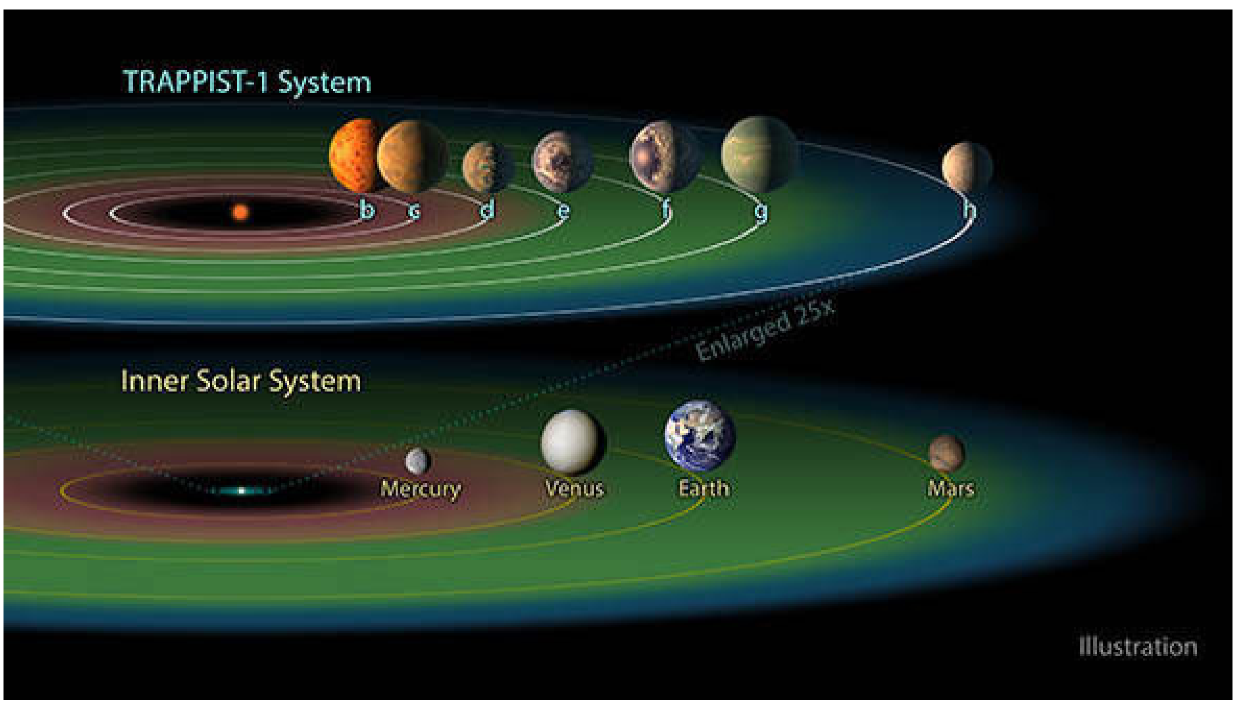
The team responsible for this research was led by Sebastian Marino of the Max Planck Institute for Astronomy (MPIA) and included members from the University of Cambridge, the University of Warwick, the University of Birmingham, the Harvard-Smithsonian Center for Astrophysics (CfA) and the MPIA. The study that describes their findings recently appeared in the *Monthly Notices of the Royal Astronomical Society*.

In terms of how the solar system came to be, astronomers are of the general consensus that it formed over 4.6 billion years ago from a nebula of gas, dust and volatiles (AKA the Nebular Hypothesis). This theory has it that these elements coalesced in the center first, undergoing gravitational collapse to create the sun. Over time, the rest of the material formed a disk around the sun that eventually accreted to form the planets.

Within the outer reaches of the solar system, objects left over from the formation settled into a large belt containing vast amounts of iceteroids—otherwise known as the Kuiper Belt. In accordance with the Late Bombardment Theory, water was distributed to Earth and throughout the solar system by countless comets and icy objects that were knocked out of this belt and sent hurdling inwards.

If the TRAPPIST-1 system has a Kuiper Belt of its own, then it stands to reason that a similar process was involved. In this case, gravitational perturbations would have caused objects to be kicked out of the belt that then traveled toward the seven planets to deposit water on their surfaces. Combined with the right atmospheric conditions, the three planets in the star's HZ might have been sufficient quantities of water on their surfaces.

As Dr. Marino explained to Universe Today via email: "The presence of a belt indicates that a system has a big reservoir of volatiles and water. This reservoir is typically located further out in the cold regions of a system, however, there are different processes that could bring a fraction of that water-rich material near HZ planets and deliver their content. Finding a belt of comets is an indication that the reservoir existed in the first place."



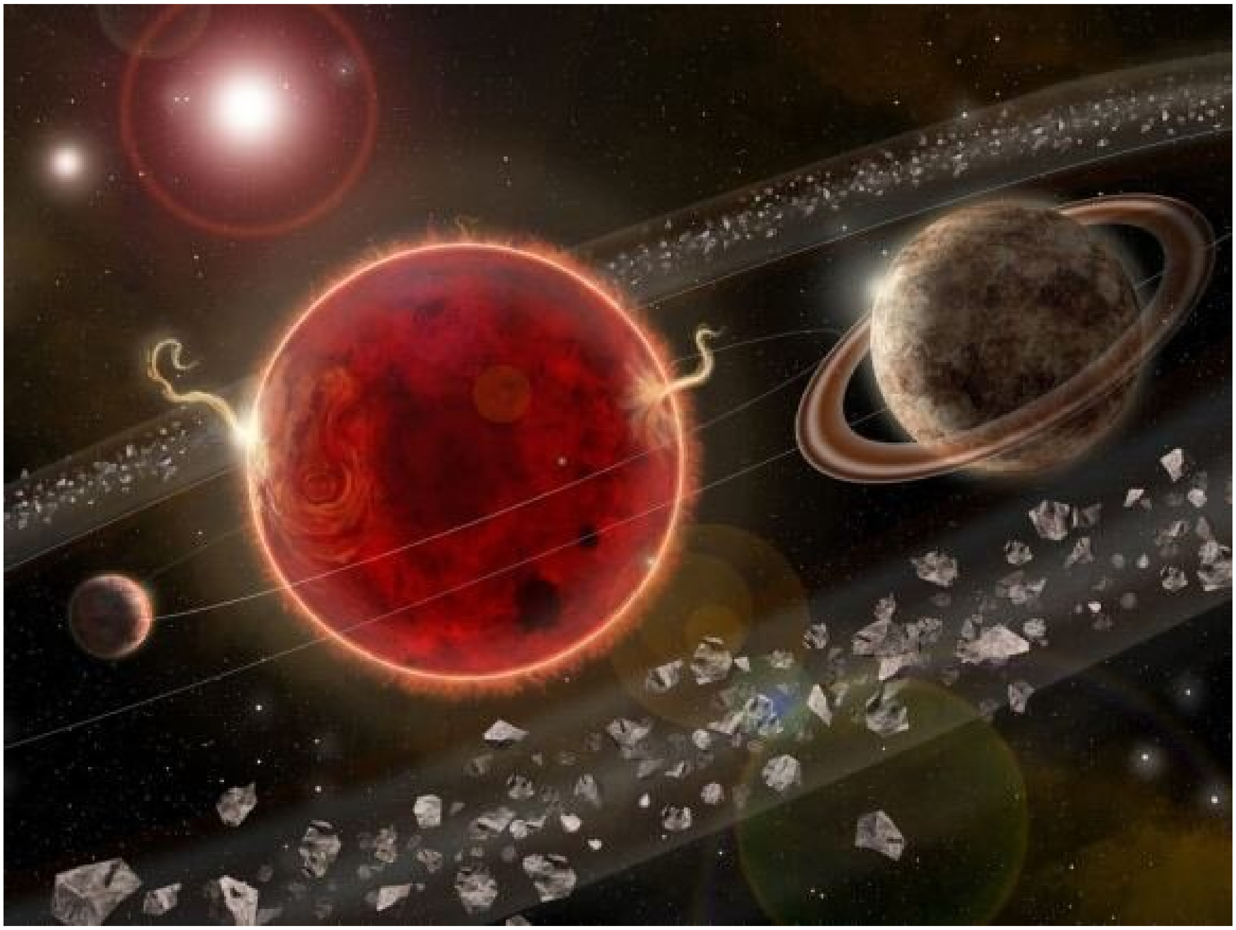

Three of the TRAPPIST-1 planets – TRAPPIST-1e, f and g – dwell in their star’s so-called “habitable zone. CreditL NASA/JPL

However, Dr. Marino also included the caveat that the absence of such a belt around stars today is not proof that a system would not have an adequate supply of water to support life. It is entirely possible that systems that had such a belt initially lost them after billions of years of evolution due to dynamical events. It is also possible that they could become too faint to detect since belts naturally become less massive and bright over time.

To search for a sign of an exo-Kuiper Belt around the TRAPPIST-1 system, the team relied on data collected by the Atacama Large Millimeter/submillimeter Array (ALMA). This array is renowned for its ability to detect objects that emit electromagnetic radiation between the infrared and radio wavelengths with a high degree of sensitivity.

This allows ALMA to visualize dust grains and volatile elements (like carbon monoxide) that characterize debris belts. These are generally too faint to see in visible light, but emit thermal radiation because of the heat they absorb from their respective star. Despite ALMA's sensitivity, the team found no evidence of a exo-Kuiper Belt around TRAPPIST-1.

"Unfortunately, we did not detect this around TRAPPIST-1, but our upper limits allowed us to rule out that the system initially had a massive belt of large comets at a distance similar to the Kuiper Belt," said Dr. Marino. "It is possible, though, that the system did indeed form with such a belt, but it got completely disrupted by a dynamical instability in the system."



An artist's illustration of the Proxima Centauri system. Proxima b in on the left, while Proxima C is on the right. Credit: Lorenzo Santinelli

They further conclude that the TRAPPIST-1 system could have been born with a planetary disk that was smaller than 40 AU in radius and had less than 20 Earth masses worth of materials. Moreover, they theorize that most of the dust grains in the disk were likely to have transported inward and used to form the seven planets that make up the planetary system.

Dr. Marino and his colleagues also used their modeling code to examine archival ALMA data on Proxima Centauri and its system of exoplanets, which include the rocky and potentially habitable Proxima b and the newly found super-Earth Proxima c. In 2017, ALMA data was used to confirm the existence of a cold dust and debris belt there, which was seen as a possible indication that the star had more exoplanets.

Here too, their results showed only upper limits to the gas and dust emission, which would imply that Proxima Centauri's young disk is around one-tenth as massive as the one that formed our solar system. As Dr. Marino explained, this study raises several questions about low-mass star systems:

"If we kept finding that this type of system does not have massive cometary belts, it could mean that all the material used to formed these comets was used instead to form and grow planets closer in. It is very uncertain what that means for the composition of those planets, since it really depends on where and how those planets formed. Just to point out, this type of belt is found around ~20% of nearby stars that are like the sun or massive/brighter. Around low mass stars, this has been much more challenging, and we only know of a few belts around M stars."

This could be due to certain biases that make it easier to detect warmer belts around brighter stars than cold belts around M-type stars, Dr. Marino adds. It could also be the result of some intrinsic difference between the architecture of planetary systems around sun-like stars (G-type or brighter) and those that orbit around red dwarfs.

In short, these results leave the question of how early water was transported throughout M-type star systems a mystery. At the same time, they have encouraged Dr. Marino and his colleagues to apply their techniques to younger and closer star systems in order to refine their models and increase the likelihood of detections.

These efforts will also benefit from new space-based and ground-based telescopes that will be coming online in the coming years. "Some next-generation telescopes are expected to be more sensitive, and thus detect these belts if they are indeed there, but not bright enough to detect them with the current telescopes," said Dr. Marino.

As with other discoveries, these results show how exoplanet studies have made the transition from the process of discovery to the process of characterization. With improvements in instrumentation and methodology, we are beginning to see just how diverse and differentiated other types of star systems can be from our own.

**More information:** S Marino et al. Searching for a dusty cometary belt around TRAPPIST-1 with ALMA, *Monthly Notices of the Royal Astronomical Society* (2020). DOI: 10.1093/mnras/staa266

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