Ettinger Journals

How Did Earth Receive Its Water?

Learn the Incredible Sudden Means of Delivery from the Outer Solar System

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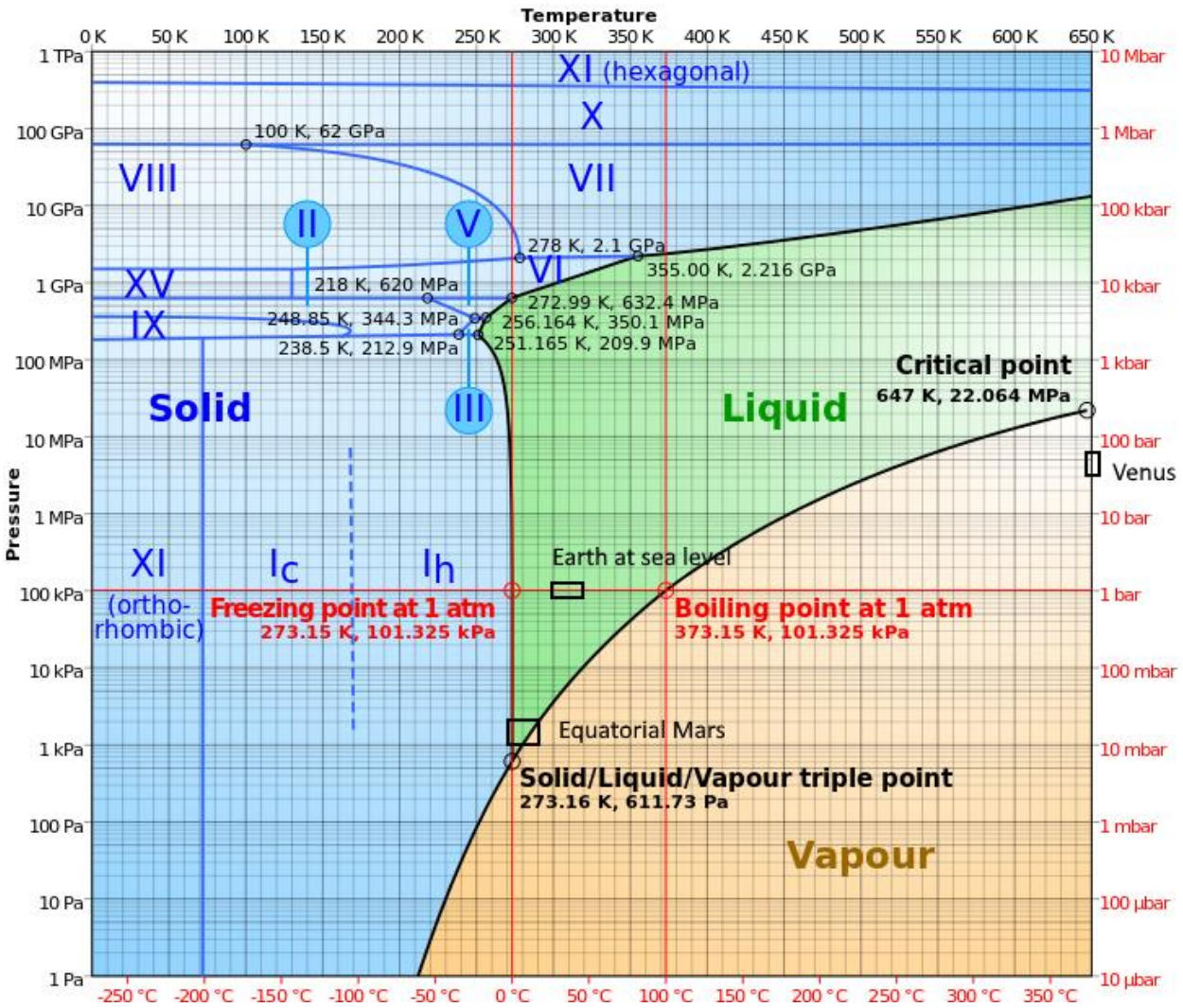
How did Earth receive its water?

How did our planet, Earth, receive its water, critical to giving birth to and sustaining life? No simple answer is forthcoming from our astrophysicists and planetary scientists. If we tour the solar system as NASA has these past 50 years, we discover that the planets, moons, and minor planets between the Sun and the distance to the orbit of Jupiter, our first gas giant located at 5.5 AU, are mostly bone dry. Why was Earth favored with water orbiting at one AU from the Sun? Even our nearest neighbor, the Moon, lacks hydrous qualities which should be expected. The major accepted hypothesis for the formation of the Earth-Moon system is a collision that supposedly mixed the mantles of the two bodies bringing any water that Earth had to the Moon. The predicted amount of Moon's water and any significant hydrated minerals cannot be found from the data analysis of NASA's Apollo Missions.

An important hypothesis is developed that the inner terrestrial planets lost all their gaseous volatiles that outgassed to their molten surfaces by severe solar winds and elevated surrounding temperatures of the forming protostar. A study of extra-solar stars, the size of our Sun, reveals a very hot surrounding corona reaching outward two or more AU called the T-Tauri phase. These high temperatures can easily boil off or strip the lighter volatiles, including water, from nearby planets. Only their heavier rocky materials are left behind to form the terrestrial planets that eventually cool to make hard crustal surfaces with metallic cores. These planets' volatiles were carried away possibly toward the "frost line" near 5 AU to form the giant gaseous planets of Jupiter and Saturn. The stripped materials from the inner solar system formed icy compounds of solids that were more abundant than the metals and silicates of the cores of the terrestrial planets. The abundance of the lighter volatiles allowed the outer planets to grow faster and capture hydrogen and helium being carried away by the solar winds. The "frost line" acted as a barrier to accelerate the accumulation of material about any forming planetary core beyond 5 AU from the Sun.

The following diagram shows the thermodynamic properties of water depicting the conditions at the surface of the terrestrial planets: Mars is near the triple point where liquid water cannot exist due to very low atmospheric pressure; Earth is in the liquid region because it has enough atmospheric pressure and receives enough radiant energy and is massive enough to retain its atmospheric constituents; and Venus is near the critical point where water becomes a very steamy vapor that can easily be lost to outer space. Venus's atmospheric elevated temperature above water's boiling point is not only due to its being closer to the Sun but primarily due to its greenhouse gas of carbon dioxide.



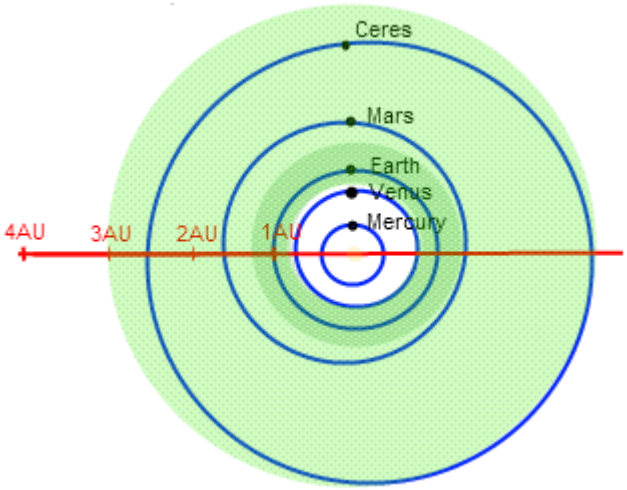
Triple Point Diagram Indicating Planets within Solar System Habitable Zone

Image from Wikipedia.org, Triple point diagram indicating planets with Solar System habitable zone

Mercury at 0.3 AU is too close to the Sun and too hot to possess a reasonable temperature for liquid water. Venus has an appropriate mass to hold water vapor, but unfortunately, most of its volatiles were boiled away during the T-Tauri phase. Venus's CO_2 atmospheric gas is due to continued outgassing as it cooled after the transitional T-Tauri phase. Most of Venus's outgassed lighter gases reached the surface too soon and were swept away by the young protostar's solar winds. Why this outgassing process did not occur similarly with Earth is not yet determined by consensus science. The reason will become self-apparent; Earth was in another location almost 2.7 AU from the Sun and very close to the "frost line" during the T-Tauri phase of the Sun's development. Mars's young forming atmosphere suffered the same fate as Venus's but in a different way. Martian exploration shows evidence of water erosion before 4.0 billion years ago. Ice was likely formed and melted forming river channels due to its initial heat of formation and CO_2 creating a greenhouse gas. But Mars, due to its small size and lack of sufficient atmospheric pressure, eventually lost its lighter volatile gases, including water, to outer space.

Earth's Moon is assumed to reside in a similar orbital position as it currently does. A similar fate of its loss of atmosphere occurred due to its small size, just as Mercury, and experiencing the circumstellar temperatures of the Sun's T-Tauri phase.

In astronomy, the circumstellar habitable zone, or simply the habitable zone (HZ), is the range of orbits around a star within which a planetary surface can support liquid water given sufficient atmospheric pressure. The bounds of the HZ are based on Earth's position in the solar system and the amount of radiant energy it receives from the Sun. The next diagram shows the predicted HZ zone.



Estimated Extent of the Solar System's Habitable Zone
Image from Wikipedia.com Circumstellar habitable zone

The most probable zone includes a small range, the darker green, on either side of the Earth's orbital radius. A possible less likely zone reaches out to the asteroid, Ceres, at about 2.7 AU and includes Mars at 1.5 AU. The difficulty of water existing within any of these ranges is the required pressure and temperature combination produced by the atmosphere, the size or mass of the planetoid for holding onto the atmospheric gases, and the magnetic field surrounding such a body that protects solar winds from washing away the topmost atmospheric particles. Only Earth has these required features. The interesting fact is that Earth's proposed first orbital location within the asteroid Main Belt near Ceres resides within the proposed HZ where liquid water can exist if other conditions are met.

An unanswerable mystery is created by Earth's still possessing its water and other volatiles such as nitrogen and methane and surviving the T-Tauri phase. The same processes of atmospheric stripping of Mercury, Venus, possibly the Moon, and Mars should have occurred with Earth in its orbit between Venus and Mars. Astrophysicists first tried to resolve the mystery by imagining icy watery comets or asteroids colliding and delivering the water from the outer solar system after the hot T-Tauri phase when the Sun became a stable, behaved main-sequence star. Also, a good assumption is that all the planets were formed near the solar system's birth around 4.6 billion years ago. However, after space exploration of asteroids and comets, their discovered compositions were very dry and mostly carbonaceous rocks. Instead of being hopefully "dirty snowballs" with much water, these rogue bodies were looking like the debris from the collisions of hard crustal surfaces. Another discovery, not fully

proven, is that the only difference between comets and asteroids is the more extreme elliptical orbits of the comets that brings them periodically closer to the Sun.

An amazing discovery of the compositions of these comets and asteroids were carbonaceous minerals in which some could only be created by water and/or by extremely hot temperatures exceeding the melting temperature of silicate rock of which they were made. There are no hot melting temperatures in the outer solar system. The theory of "dirty snowballs" for comets got flipped over. These comets and asteroids were created by collisions of bodies that not only had water but also rocky surfaces. Possibly collisions occurred in the outer solar system where water could exist as hardened ice on the surfaces of smaller rogue planetoids and planetary moons. But strangely enough, no outer solar system bodies have rocky crustal surfaces. I can only predict a hypothesis not yet fully explored by consensus science.

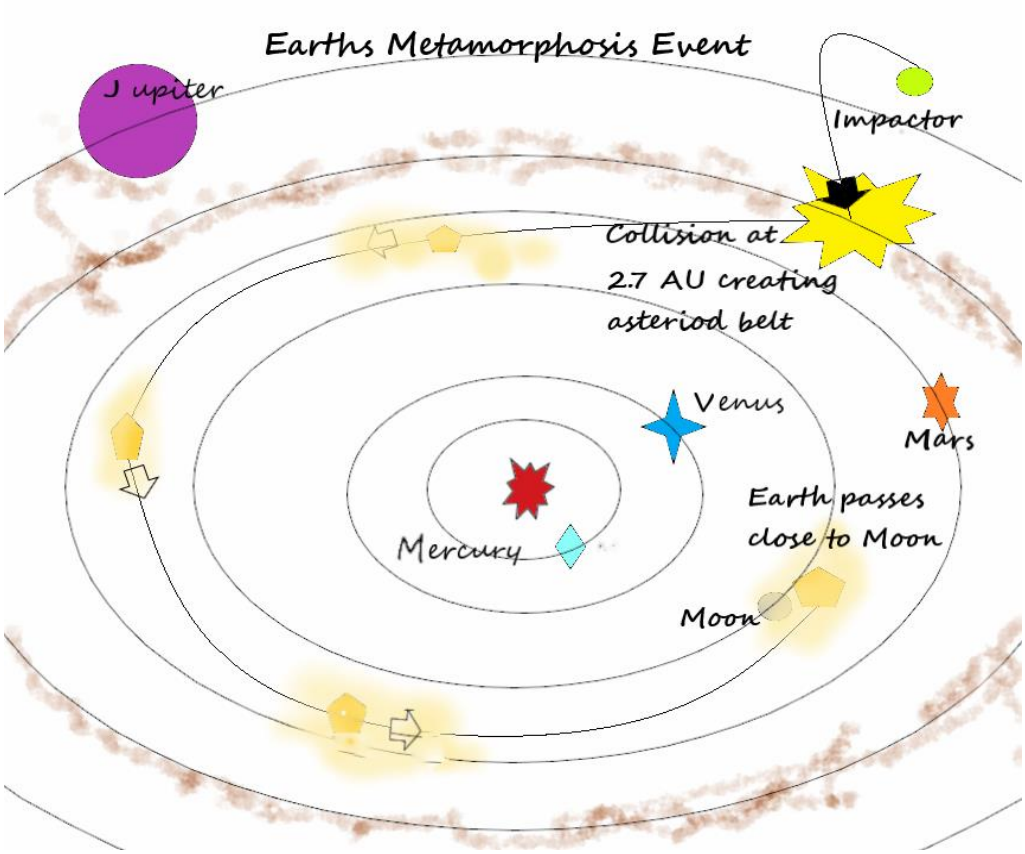
Possibly, a collision occurred near the "frost line" between a frozen icy body and another larger body already outgassing water vapor that condensed into liquid water and cooled the outer molten surface into a hardened crust. This impacted, broken crust possibly became the ejected shards of rock that astrophysicists call asteroids. Coincidentally, the Main Belt of asteroids, the possible result of a major collision, is an orbiting debris field found centered at 2.7 AU adjacent to the beginning of the solar system's frost line. The formation of a very new hypothesis is in the making. If this storyline occurred, we need to solve the whereabouts of these two bodies: call them planet Gaia and the rogue impactor. The debris of their collision, which is less than the mass of a small moon, is the Main Belt of asteroids and likely other asteroids that created the Late Heavy Bombardment (LHB) of the inner solar system predicted to have occurred about 3.9 billion years ago. This scenario, believed to have occurred, will show the solution to the mystery of where Earth's water came from.

The simple proposal is that planet Gaia was a watery planet residing where the Main Belt of asteroids now resides. This planet was another terrestrial planet beyond Mars whose lightest volatiles of hydrogen and helium were stripped away but kept some heavier volatiles such as water, CO_2, and methane because it was both massive enough and far enough away from the heat of the Sun's T-Tauri phase. Enough atmospheric pressure coming probably from CO_2 allowed water to liquefy and rapidly aid in cooling the molten surface to become a thick, rocky crust. This planet became completely covered with an ocean, probably with frozen polar ice caps. About 3.9 billion years ago, a massive icy rogue body impacted Gaia's surface, penetrating and mixing with its mantle. Parts of the impactor and Gaia's crust exploded and ejected debris causing the asteroid belt and numerous other asteroids to find their way into the inner solar system and possibly become Trojan asteroids captured by Jupiter.

This invasion of asteroids into the inner solar system created numerous impact craters on Mercury, Mars, and the Moon which astrophysicists call the Late Heavy Bombardment (LHB) which is difficult to address without having this proposed hypothesis. This scenario can help explain why meteorites are composed of different rocks coming from Gaia's crust, but mostly carbonaceous with some minerals forming from the high temperature of impact and the water in Gaia's Ocean. Meteorites are not the original primordial dust that formed the solar system's proposed dusty nebular disk. Their age reflects the time when Earth's original primordial crust solidified probably remarkably close to the solar system's birth. The ages of the meteorites should vary according to whether they solidified on Gaia's crust or crystallized in open space after the impact. The question remains about where Gaia and the impactor are today.

This proposal is given a name called the Earth's Metamorphosis (EMM) hypothesis. The energy of impact, fortunately, was absorbed by the youthful molten Earth with the frozen impactor like an icy snowball being thrown into a snowman. The energy was expended into penetrating, mixing, and expanding Gaia's mantle and crust, creating the launching of collisional debris, tilting of the spin axis, and displacing planet Gaia toward the Sun. A debris field of asteroids gravitationally accompanied Gaia as it fell toward the Sun. As the planet began to accelerate, its increased spiraling velocity caused its centripetal force to equal the gravitational force from the Sun; at this point, Gaia with its debris begins to orbit the Sun at a much closer distance of one AU. Coincidentally, its new orbital radius matches closely with the existing terrestrial planet that is now called the Moon. This planet of Gaia has now metamorphosed into planet Earth. Each time Earth passes the Moon it slows and moves the Moon outward due to gravitational and angular momentum exchanges until their orbital velocities became matched. This EMM hypothesis easily explains the abnormal size of the Moon compared to Earth, its unusual distance from Earth, the difference in orbital planes, Earth's unusual high density by acquiring the small iron core of an impactor, and the now understood capture mode of the Earth-Moon system that NASA is trying to determine.

This unique manner of capture, completely different from the binary nature of other major satellite formations, is how both the water of planet Gaia and the impregnated water of the icy impactor were brought to their present habitable zone one AU from the Sun after it became a main-sequence star. A diagram of this event is shown below.



Earth's Orbital Displacement from the Outer Solar System by a Rogue Impactor
from Doug Ettinger

The consequences of this chaotic history explain many more of the Earth-Moon system's evolution and its mysteries. This evolution requires water in each step along the way to the having water-based living organisms of today. The incredible amazement of these steps is indeed a miracle that any supreme creator may have difficulty replicating. Let's begin the storyline with planet Gaia, after its birth at about 4.6 billion years ago, when it was covered completely with an ocean and had much outgassing on its sea bottom from differentiation of gaseous volatiles before it suffered a great impact about 3.9 billion years ago.

1. Liquid-water environments have been found to exist in the absence of atmospheric pressure and at temperatures outside the habitable zone, HZ, temperature range. For example, Saturn's moons Titan and Enceladus and Jupiter's moons Europa and Ganymede, all of which are outside the habitable zone, may hold large volumes of liquid water in subsurface oceans.

   Outside the HZ, tidal heating and radioactive decay are two possible heat sources that could contribute to having liquid water. Abbot and Switzer, in 2011, claimed the possibility that subsurface water could exist on rogue planets or moons as a result of radioactive decay-based heating and the insulation by a thick surface layer of ice. The EMM hypothesis is suggesting that the icy impactor may have been an ice-covered moon of another planet that had long-period orbits around the Sun. This displaced icy impactor may have brought life, in the manner described, to Gaia in its subsurface oceans.

2. Life on Gaia may have already started before its great impact. Under its first ocean, stable, subsurface habitats could have been teeming with life. On Earth today, living organisms are found more than 6 kilometers below the ocean's surface. Since the total surface is predicted to have survived with numerous cracks, except for the giant impact crater creating the mega-continent, very primitive life may have survived the critical passage to a safe haven at one AU from the Sun.
3. The collisional debris not only would fall back to Earth but would be swept up by the Moon, as is evidenced by its present craters, when Earth passed each orbit before their orbital velocities matched.
4. The huge impact crater caused an elevated landmass, called the first mega-continent, that covered about 1/5 to ¼ of Earth's surface.
5. The impactor created large-grained intrusive granite not found anywhere else in the solar system and a granitic continental crust differing from the remaining basaltic oceanic crust; the Great Unconformity is geological evidence of the slow rising and crystallization of this intrusive granite about 1.6 billion years ago. Its formation of granite plutons by water can only be answered by the impact of an icy orb penetrating deeply into Earth's mantle with tremendous force and temperature; water cannot be delivered that deeply into the mantle in any other way, not even with plate tectonics. Any captured new primordial water would have quickly risen to the surface due to gravitational compression if it did not chemically combine with other molecular compounds due to the tremendous pressures of a high-energy impact.
6. As previously mentioned, Gaia's great impact caused it to metamorphose into planet Earth. The new Earth gained more volatiles of water and gases such as CO_2, methane, ammonia, and nitrogen, which caused a secondary outgassing and increased greenhouse gases for its first atmosphere. Many differentiated gases trapped under Earth's primal crust spawned the Moho

layer and geological hot spots of randomly located magma chambers with added volatiles that has caused island chains around the world.

7. The Earth, now closer to the Sun, will receive more radiant energy to aid in the photosynthesis process and make oxygen from CO_2. After the newly chemically reactive oxygen with various sinks of iron and silicates aided by water ceased, atmospheric oxygen was then generated.
8. Due to the unbalanced raised, spinning mega-continental surface, unusual dynamical forces were created. After the lithosphere matured into a harder upper mantle located between the outer basaltic/granitic crusts and the slippery Moho layer, plate tectonics and continental drift started. Plate tectonics to this degree of activity is not found anywhere else in the solar system due to the lack of liquid water on other bodies.
9. These processes of continental drift and plate tectonics would keep the continued raising of global plateaus and mountain ranges and their subsequent wasting, erosion, and severe climatic weather via the all-important liquid oceans, rains, and episodic melting of ice sheets.
10. Without liquid water, the rock cycle of sedimentary to metamorphic to igneous rocks would be impossible; the rock cycle continually mixed elements and compounds to form the important minerals that engendered life from simple multi-cellular to complex organisms. However, the rock cycle never involved the primordial intrusive granites that can only be formed by the great impact.

Liquid water is the central item for creating weather, climate, and life on this planet which is not available for the other celestial bodies in our solar system. And the mystery of its arrival from the outer solar system is now corroborated by the following scientific research. Let's examine accepted experimental evidence and current theorizing for this truth. The present, questionable scientific hypotheses by astrophysicists for producing the origin of water are listed and scrutinized.

The Pre-Solar Nebula Theories for Accretion and Binary Processes are Reviewed

The Accretion Process

The Sun is thought to had been a T-Tauri star and observed to have typically a pre-planetary disc with 0.001 to 0.1 Sun masses. The Hubble Space Telescope observed these discs having diameters of 1000 AU and reaching surface temperatures of about 1000 K (1340° F). Of course, the planets have to form from these dusty discs before the dust is driven away by the new star's solar winds. Researchers determined that the terrestrial cores grew to about 0.05 Earth masses and ceased to accumulate matter about 100,000 years after the Sun began to gravitationally fuse and ignite. The theory continues with subsequent collisions and mergers to allow terrestrial planets to grow to their present sizes. Water and other lighter volatiles could not condense under these conditions. Planetesimals could only form from compounds with high melting points such as metals like iron, nickel, and aluminum, and rocky silicates. The lighter volatiles are driven to the cooler edges of the pro-planetary disc beyond the frost line which continually adjusted its orbital distance as the Sun became more stable with its outer envelope receding and cooling, thus ending its T-Tauri high-temperature envelop.

The oldest materials found in the solar system currently are inside meteorites that are thought to trace the first solid materials in the presolar disc. But many of these meteorites have minerals that are only known to form in the presence of water. A dichotomy exists between meteorites with high melting

points condensing along with minerals that need water. How do these planetesimals, proposed to make up the very hot primordial dust, create these hydrous minerals? A clear explanation is not provided by consensus science.

Other Issues arise with this theory that researchers quickly point out. The inner planets' initial orbits inside the protoplanetary disc require high eccentricity to collide, merge, sweep out dust and gas, and grow to their current size. No adequate answer exists for how the orbits then became stable and nearly circular as they exist today. Of course, the delivery of water to only one planet, Earth, by supposed water enriched asteroids or comets (not yet found) after the Sun becomes a main-sequence star and after planet formation is completed is the most vexing problem and presently unanswered.

Several simulations of our young Sun interacting with close-passing stars over the first 100 million years of its life produces anomalous orbits in the outer solar system such as detached objects. These computer simulations also lead to another possibility of captured smaller stars such as is evidenced by the observed prolific binary star systems. Perhaps the Sun captured a brown dwarf star with a dimness that is difficult to detect and that has a long-period orbit around our Sun causing occasionally instability and catastrophism observed by human space exploration and recorded in ancient human traditions. The new thinking is that the Sun has a sister star that periodically travels through the solar system randomly creating various havoc with the Sun's planets.

If astrophysicists completely accept the accretion method for planetary formation, then problems in the outer solar system are created. Over billions of years, there exists no good reason why the millions of asteroids in the main belt do not accrete to form a planet. The asteroids are not the hopeful primordial dust and gasses of the presolar nebula but are the collisional products of two or more hard rocky-icy bodies. An excellent suggestion is that two major bodies collided in this location at 2.7 AU, perhaps both with ice and/or liquid water, and their debris would never have a chance to re-organize into another planet because planetary-formation conditions no longer existed. The two bodies merged causing the orbit of the combined bodies to be displaced inward and develop a new orbit close to an existing terrestrial planet called our Moon. This scenario sets up explanations for why only planet Earth has water; why Earth's satellite is more massive and with more distance than normal satellites; why an asteroid belt exists between Mars and Jupiter; and why a Late Heavy Bombardment of asteroids occurred about 3.9 billion years ago.

The Binary Process

Reaching outside the nebula-hypothesis paradigm is considered. Very possibly, the planets and most major satellites were formed by a binary process in which the parent body, the Sun and the outer planets, emitted other bodies during its formation close to its equatorial plane. The emitting body powered by outside energy from the galaxy is trying to balance electromagnetic forces similar to a Z-pinch created in a plasma laboratory. The emitted bodies would possess a molten globular structure of different sizes and come from the same material as the parent, which is mostly hydrogen and helium with a remaining 2% of the mass consisting of heavier elements created by stellar nucleosynthesis either by the star and/or by earlier generations of stars. In the same fashion as the accretion process, differentiation of lighter volatiles rising to the surface would occur rapidly. This thinking eliminates some problems in the accretion process with astrophysicists dealing with the impossible timescale that is needed to accrete materials for especially the larger orbits of the ice giants of Uranus and Neptune.

The binary mode still aligns with the idea that the T-Tauri phase burns off the hydrogen, helium, and other lighter volatiles for the inner terrestrial planets.

Other specialized research follows that continues to corroborate that Earth's water is due to the planet's existing close to the solar system's frost line at 2.7 AU from the Sun during the T-Tauri transition and retaining its water in liquid form on a crustal surface at that same time.

Isotopic ratios of heavy noble gases

Xenon is useful for showing the loss of water over time. Xenon is inert and is not removed by chemical reactions. Comparisons of abundances of its nine stable isotopes in the current atmosphere reveal Earth lost at least one ocean early in the Hadean and Archean eons. This result aligns with Earth's having a primordial ocean before its major impact and violently losing possibly some liquid through vaporization into space.

Mineralogical evidence in zircon crystals

The ages of zircon crystals establish that liquid water and atmosphere existed 4.404 billion years ago, very soon after the formation of Earth. This measured time presents a paradox of a cool Earth existing during the turmoil of its formation by the accretion of large planetesimals and its location within the high temperatures of the pre-nebular disc of the T-Tauri phase. The paradox goes away if Earth is assumed to have previously formed with much less heat from accretion by a binary mode close to a cooler distance of about 2.7 AU from the Sun.

Delivery of ice-enriched bodies from beyond the frost line

The boundary where water-ice bodies could form in the early solar system is known as the frost line. This frost line is located about 2.7 to 3.1 AU from the Sun. The feasibility of delivering enough of this ice-water from that distance so early in the solar system's formation is in question. Both its timing and method of transportation cannot be easily explained unless both Earth and its water were displaced from the frost line region 500 to 600 million years after its formation due to a large impactor.

Lunar samples from Apollo missions 15 and 17

The chemical compositions from lunar samples indicate that water was already present on Earth before the Moon was formed. This result corroborates that planet Earth was created before the Moon with no need to have them be the same age within millions of years. Also, from previous research, water existed on Earth very early, as long as 4.4 billion years ago near the hypothesized solar system's age.

Isotope differences between Earth's atmosphere and mantle

Noble gas isotope ratios of Earth's oceans and mantle are different, suggesting different sources such as either coming from a Moon-forming impactor or the proposed impact at 2.7 AU. The proposed impactor that embedded itself into the Earth's mantle and mixed its mantle can explain the different sources.

Concluding Summary

In conclusion, I wholeheartedly accept the Earth's Metamorphism (EMM) hypothesis. Planet Earth formed originally near 2.7 AU from the Sun and avoided the extremely warm conditions of the proto-Sun's T-Tauri phase, unlike the other closer terrestrial planets. Still, within the habitable zone (HZ), planet Earth quickly formed a CO_2 atmosphere and liquid ocean on top of a hardened crust. The solar system had matured with the Sun entering the main sequence of stars, with a completed retinue of planets and with the sweeping away of most of its pre-solar dusty disc. The Earth had some time to develop a thick crust and outgas most of its lighter volatiles.

Then at 3.9 billion years ago, an icy impactor struck and penetrated Earth, bringing more lighter volatiles, including water. The first mega-continent on Earth was created from the huge impact crater to later provide the processes of plate tectonics and continental drift. The energy from the impact mixed internally the two mantles, expanding and cracking the existing Earth's crust. The resulting kinetic energy was also expended into tilting the planet's spin axis and displacing its orbit inward toward the Sun.

As the gorged planet with its debris fell, its velocity increased until its centripetal force equaled the Sun's gravitational force. At that point, the Earth followed a new orbit close to the existing orbit of another terrestrial planet, now called the Moon. Earth's orbital velocity was slightly faster and passed the Moon on each orbit thereby exchanging gravitational forces and angular momentum. The resulting unique capture mode slowed Earth to match the Moon's velocity and move the Moon farther away. The shared orbits resulted in the Moon's making a weaving synchronized orbit with Earth. The collisional debris either fell back to Earth or was swept up by the Moon causing the craters we see and the mares of hardened volcanic lava created by a continuing sweeping of minor asteroids spanning 900 million years. The Moon eventually becomes tidally locked to the Earth. This transfigured Earth now receives greater light and radiant heat from the closer Sun and a lessor light and mild tidal acceleration from the Moon.

Now you know how the mysterious origin of Earth's water occurred with some reasonable certainty. The only important water on the Moon or Mars will be brought there by humans.

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