The Origin of the Most Part of Water on the Earth, and the Reason why there is More Water on the Earth than on the other Terrestrial Planets

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The origin of water on the Earth, and the reason why there is more liquid water on the Earth than on the other terrestrial planets of the Solar System is not completely understood. Here we show that these facts are related to a water vapor cloud formed by the vaporization of part of an ice belt that was formed in the beginning of the Solar System.

Key words: Gravitational Interaction, Solar Nebula, Origin of Water, Water in the Atmospheres.

1. Introduction

The origin of water on the Earth, and the reason why there is more liquid water on the Earth than on the other terrestrial planets of the Solar System, is not completely understood. There exist numerous hypotheses as to how water may have accumulated on the earth's surface over the past 4.6 billion years in sufficient quantity to form oceans [1 - 5].

Here, we show that the origin of water on the Earth, and the reason why there is more liquid water on the Earth than on the other terrestrial planets of the Solar System are related to a water vapor cloud formed by the vaporization of part of an ice belt that was formed in the beginning of the Solar System.

2. Theory

The quantization of gravity shows that the *gravitational mass* m_g and *inertial mass* m_i are not equivalents, but correlated by means of a factor χ, which, under certain circumstances can be negative. The correlation equation is [6]

$$m_g = \chi \ m_{i0} \tag{1}$$

where m_{i0} is the *rest* inertial mass of the particle.

The expression of χ can be put in the following forms [6]:

$$\chi = \frac{m_g}{m_{i0}} = \left\{1 - 2\left[\sqrt{1+\left(\frac{W}{\rho \ c^2} n_r\right)^2} - 1\right]\right\} \tag{2}$$

$$\chi = \frac{m_g}{m_{i0}} = \left\{1 - 2\left[\sqrt{1+\left(\frac{D \ n_r^2}{\rho c^3}\right)^2} - 1\right]\right\} \tag{3}$$

where W is the density of electromagnetic energy on the particle (J/kg); D is the radiation power density; ρ is the matter density of the particle (kg/m^3); n_r is the index of refraction, and c is the speed of light.

Equations (2) and (3) show that *only* for $W = 0$ or $D = 0$ *the gravitational mass is equivalent to the inertial mass* $(\chi = 1)$. Also, these equations show that the gravitational mass of a particle can be significtively reduced or made strongly *negative* when the particle is subjected to high-densities of electromagnetic energy.

In the case of *Thermal radiation*, we can relate the energy density to *temperature*, *T*, through the relation,

$$D = \sigma_B T^4 \tag{4}$$

where $\sigma_B = 5.67\times10^{-8} watts/m^2 {}^\circ K^4$ is the *Stefan-Boltzmann's constant*. Thus, for $n_r \cong 1$, we can rewrite (3) in the following form

$$m_g = \left\{1 - 2\left[\sqrt{1+\left(\frac{\sigma_B T^4}{\rho \ c^3}\right)^2} - 1\right]\right\} m_{i0} =$$

$$= \left\{1 - 2\left[\sqrt{1+\left(\frac{2.1\times10^{-33} T^4}{\rho}\right)^2} - 1\right]\right\} m_{i0} \tag{5}$$

The Solar system was formed about 4.6 billion years ago by the gravitational contraction of the called *solar nebula*. The gravitational collapse was much more efficient along the spin axis, so the rotating ball collapsed into a *thin disk* with a diameter of about 200AU, with most of the mass concentrated at its center. As the cloud has contracted, its gravitational potential energy was transformed into kinetic energy. Collisions between particles have transformed this energy into heat. The solar nebula became hottest at its center (called *protosun*). When the temperature of the protosun reached about 10 million K the nuclear reactions have begun. Then the protosun became a star called Sun. Along the time, the temperature of disk around the Sun dropped and the heaviest molecules began to form tiny solid or liquid droplets, a process called *condensation*. By means of this process have emerged: Metals (that condense at ~ 1,600 K), Rocks (condense at 500-1,300 K), *Ices* (that condense at T~150 K), etc. In the *periphery of the solar disk* the temperature was low enough that hydrogen-rich molecules condensed into lighter ices, including *water ice*. Thus, in this region was formed an *ice belt*, extended for millions of kilometers, starting from inner border.

The first solid particles were microscopic in size, orbiting the Sun in nearly circular orbits right next to each other. Then, they began to collide among themselves, making larger particles which, in turn, attracted more solid particles. This process is called *accretion*. The objects formed by accretion are called *planetesimals*.

The collisions among them have increased the temperature at the region of the planetesimals* up to a average value of ~1950°C (~2,300 K) [7] (above the fusion temperature of rocks). Then, Earth, the planets and also an *inner part* of the *ice belt* at the periphery of the solar system would have experienced this temperature.

When the temperature *at the region of the planetesimals* reached the average value close to 2,300K, an inner part of the *ice belt* was vaporized up to a distance ΔR, where the temperature decreased down to a value equal to the ebullition temperature of the water (373.35K). This generated a *big ring of water vapor* at the periphery of the solar system (See Fig. 1), with average density equal to the *initial density of the ice belt*, ρ_i, multiplied by the factor $(T_i/1{,}336.7K)$, i.e., $\rho = \rho_i (T_i/1{,}336.7K)$ †, where T_i is the initial temperature of the ice belt and $1{,}336.7K = (2{,}300K + 373.35K)/2$ is the average temperature at the inner part of the ice belt (ΔR), after the heating.

Data from infrared and radioastronomy state that the average temperature of *interstellar space* is very close to 3K, and the average density is $1\,protons\ .cm^{-3}$ [8]. If water molecules (ice) are added to a region of the interstellar space, then the average density of this region increases and can be calculated based on the following: If the initial density $\rho_{ism} = 1 protons.cm^{-3}$ corresponds to the atomic mass of two protons $(A_{1p} \cong 1)$ then the density due to the water (ice) ρ_{H_2O} corresponds to the atomic mass of the water $(A_{H_2O} = 18)$. Therefore, $\rho_{H_2O} = (A_{H_2O}/A_{1p})\rho_i$ ‡. The arithmetic mean between ρ_{ism} and ρ_{H_2O} will express with some precision *the local average density*, $\bar{\rho}$, i.e.,

$$\bar{\rho} = \frac{\rho_{ism} + \rho_{H_2O}}{2} = \frac{\rho_{ism} + (A_{H_2O}/A_{1p})\rho_{ism}}{2} = \frac{1}{2}\left(\frac{A_{H_2O} + A_{1p}}{A_{1p}}\right)\rho_{ism} \cong 10\ protons.cm^{-3}$$

Assuming that, this was the initial density of the *ice belt* ,i.e.,

$$\rho_i = 10\,protons.cm^{-3} \cong 1.6 \times 10^{-20}\,kg.m^{-3}$$

and that, the initial temperature of the ice belt was $T_i = 3K$, then we can say that the average density of the water vapor cloud, ρ, had the following value

$$\rho = \rho_i (T_i/1{,}336.7K) \cong 3.6 \times 10^{-23} kg.m^{-3}$$

Substitution of the value of ρ into Eq. (5), gives

$$m_{g(cloud)} = \left\{1 - 2\left[\sqrt{1 + \left(5.8 \times 10^{-11} T^4\right)^2} - 1\right]\right\} m_{i0(cloud)} \qquad (7)$$

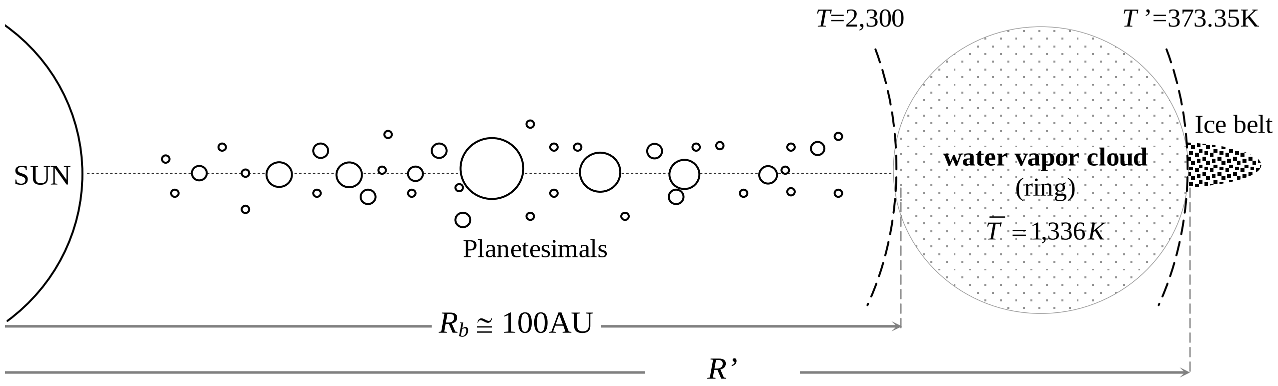
This equation shows that for $T > 373K$ the gravitational mass of the cloud becomes *negative*.

This means that the gravitational mass of the water vapor cloud was initially *negative* because it was subjected to an average temperature greater than 373K. Then, *it was repelled by the positive gravitational mass of the rest of the ice belt,* which the temperature did not get make negative. Similarly, the cloud was also repelled by the Sun. However, since the cloud was near from the positive gravitational mass of ice belt, it was more intensely repelled than by the Sun. Thus, the cloud has been propelled in the direction to the Sun. The extent to which approached the Sun, the density of the cloud was *increasing* because its volume was decreasing. Soon the local temperature was no longer sufficient to become negative the gravitational mass of the cloud. From this point, the gravitational mass of the cloud became *positive* and consequently, the gravitational

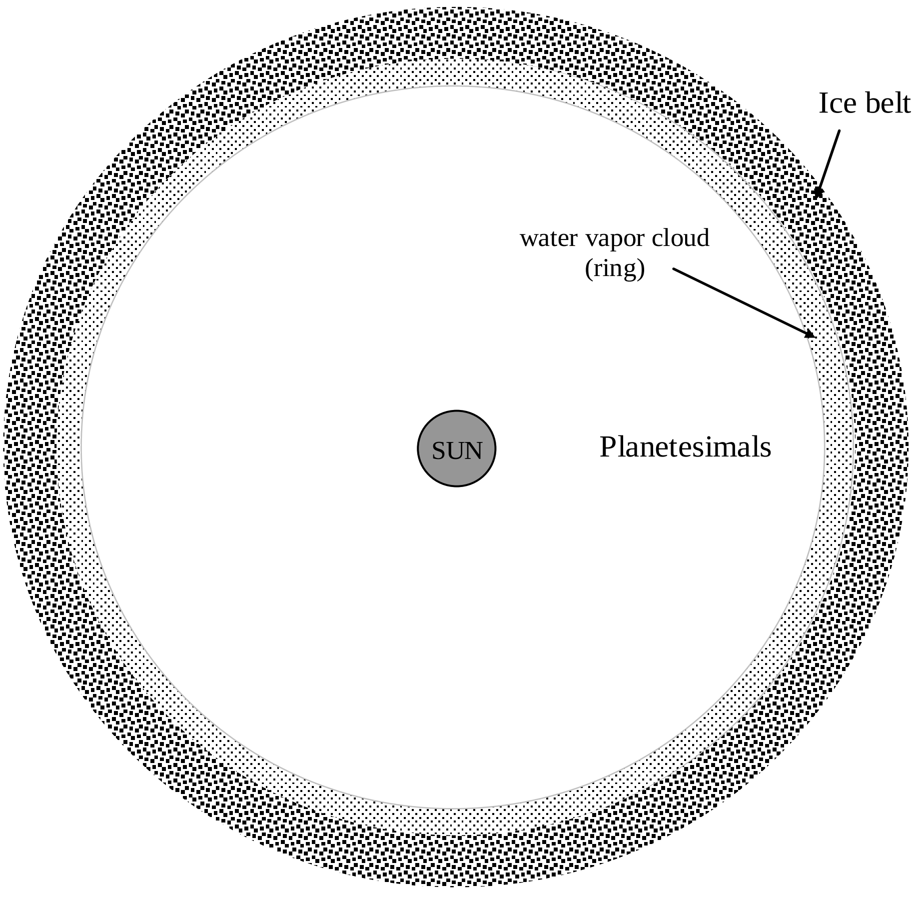
* Up to the ice belt.

† Since the energy density is conserved, we have $W = W_i \rightarrow E/V = E_i/V_i \rightarrow kT/V = kT_i/V_i \rightarrow \rho = \rho_i (T_i/T)$.

‡ Since $\rho_{1p} = A_{1p}(1amu)/V$ and $\rho_{H_2O} = A_{H_2O}(1amu)/V$, we get, $\rho_{H_2O} = \rho_{1p}(A_{H_2O}/A_{1p})$.



(a)



(b)

Fig.1 – *Origin of the Water Vapor Cloud.* Collisions among large planetesimals released a lot of heat, Earth, the planets and also part of the periphery of the disk around the Sun would have experienced temperatures close to 2,300 K (the fusion temperature of rocks). This means that, all the water ice existent in the *inner region of the ice belt* can have vaporized, forming a big ring of water vapor at the periphery of the solar system.

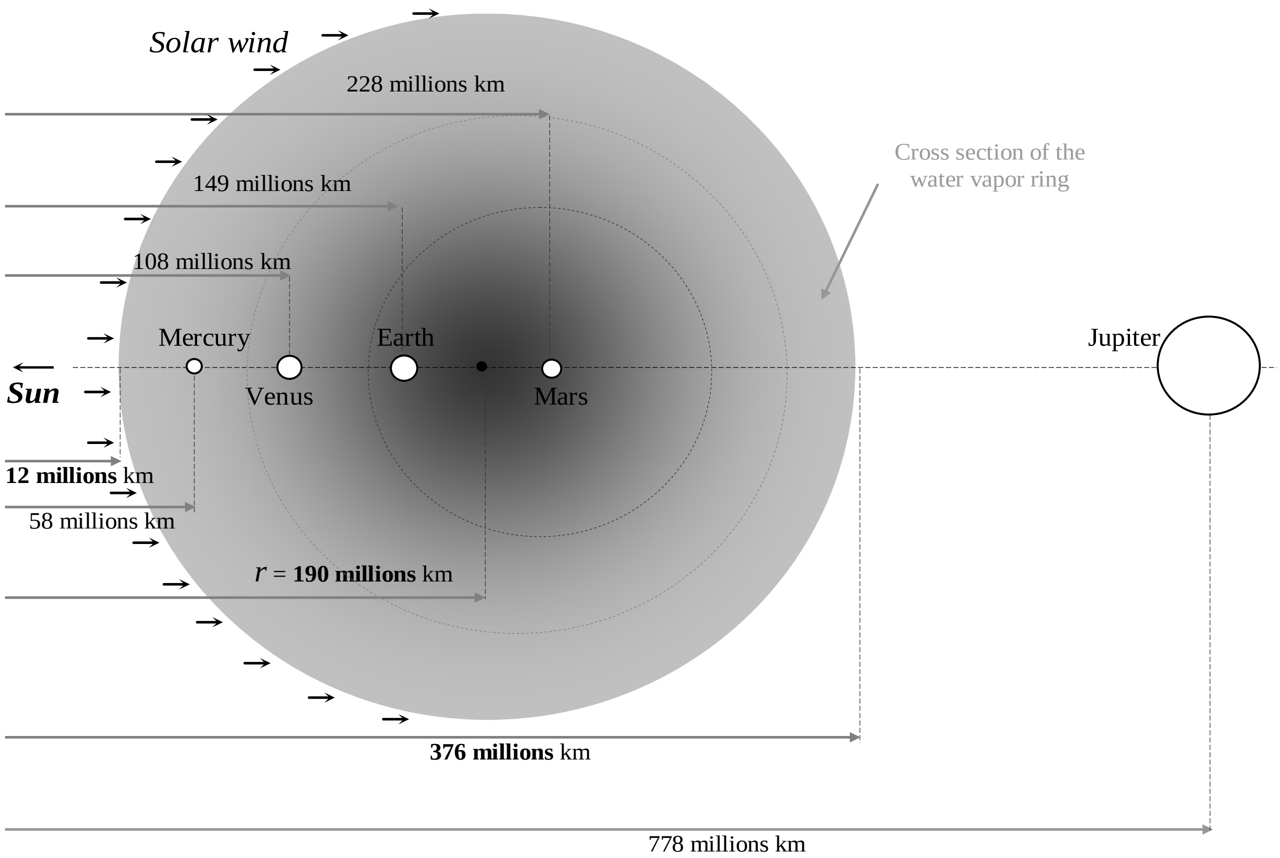


Fig.2 – *Schematic diagram of the cross-section of water vapor ring (cloud) inside the Solar System.* At a distance $r = 376 \ \ millions \ \ km$, between the center of the cloud and the center of the Sun, the pressure of the solar wind became sufficiently strong to stop the cloud. Thus, the cloud crossed Pluto, Neptune, Uranus, Jupiter, Mars, Earth, Venus, Mercury and stopped (its inner surface) between Mercury and the Sun, involving Mars, Earth, Venus and Mercury. The dotted circles show the progressive decreasing of the cross-section of the cloud along the time, due to the absorption of the water vapor by the gravitational fields of the planets, and also the displacement of the cloud, produced by the decreasing of the radius of the cloud (according to Eq.(19)). Based on the position of these planets inside the water vapor cloud, it is easy to conclude that, Earth and Mars have attracted more water vapor then the other planets.

forces between the cloud and the Sun became *attractive*. Thus, the cloud continued its motion to the Sun.

In its route to the Sun the water vapor cloud crossed the region of the planets. Then, a part of the cloud was attracted by the gravitational fields of the planets[§].

At a distance r, between the center of the cloud and the center of the Sun, the pressure of the solar wind became sufficiently strong to stop the cloud, i.e., the force exerted by the solar wind upon the cloud $\left(p_{wind} S_{cloud}\right)$ becomes *equal to* the gravitational force between the Sun and the cloud $\left(GM_{sun} m_{cloud} / r^2\right)$. Since we can write

$$p_{wind} = p_{wind(sun)} \left(\frac{r_{sun}}{r}\right)^2$$

then

$$p_{wind(sun)} \left(\frac{r_{sun}}{r}\right)^2 S_{cloud} = \frac{GM_{sun} m_{cloud}}{r^2} \qquad (8)$$

Since $S_{cloud} = \frac{2\pi \ r_{cloud}}{2}\left(2\pi \ r\right) = 2\pi^2 r_{cloud} \ r$ and

$$\frac{r_{cloud}}{r} = \frac{r_{cloud(i)}}{\left(100AU + r_{cloud(i)}\right)} \qquad (9)$$

then Eq. (8) gives

$$r = \sqrt{\frac{GM_{sun} m_{cloud} \left(100AU + r_{cloud(i)}\right)}{p_{wind(sun)} \ r_{sun}^2 \left(2\pi^2\right) \ r_{cloud(i)}}} \qquad (10)$$

where $r_{cloud(i)}$ is the initial "radius" of the cloud; $r_{sun} = 6.96 \times 10^8 m$ is the equatorial radius of the Sun; m_{cloud} is the mass of the cloud; $M_{sun} = 1.97 \times 10^{30} kg$ is sun's mass; $p_{wind(sun)}$ is the pressure of solar wind at the border of sun, which is given by

$$p_{wind(sun)} = \frac{4D_{sun}}{c} = 0.844 N.m^{-2} \qquad (11)$$

where $D_{sun} = 6.329 \times 10^7 W.m^{-2}$ [9] is the sun's surface emission and c is the light speed.

According to the *Stefan-Boltzmann's law* (Eq. (4)), we can write that

$$R' = R_b \left(\frac{T}{T'}\right)^2 \qquad (12)$$

where $R_b = 100AU$ is the distance from the center of the sun up to the inner border of the ice belt $1AU \cong 1.49 \times 10^{11} m$, and $R' = R_b + \Delta R$. Thus,

$$\Delta R = R' - R_b = \left[\left(\frac{T}{T'}\right)^2 - 1\right] R_b \qquad (13)$$

For $T = 2{,}300K$ and $T' = 373.35K$, we get

$$\Delta R = 36.95 R_b = 3{,}695 AU \qquad (14)$$

This is approximately the "diameter" of the water vapor cloud $\left(r_{cloud(i)} = \Delta R/2 \cong 1{,}847AU\right)$.The diameter of the solar system is about 100,000AU (outer border of the Oort-cloud).

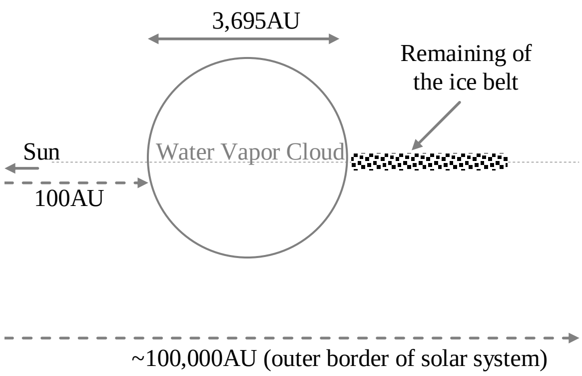


Fig. 3 – Cross-section of the initial water vapor cloud.

The inertial mass of the water vapor cloud, m_{cloud}, can be now calculated by means of the following equation:

$$m_{cloud} = \rho V_{ice \ disk} = 2\pi\rho H_{ice \ disk} \Delta R\left(R_b + r_{cloud(i)}\right) \qquad (15)$$

where $\rho \cong 3.6 \times 10^{-23} kg.m^{-3}$; $H_{ice \ disk}$ can be estimated by means of the expression of the thickness of the disk: $H = 0.033R\left(R/1AU\right)^{\frac{1}{4}}$ [10]. The result for $R = 100 \ AU + r_{cloud(i)}$ is

$$H_{ice \ disk} \cong 6.3 \times 10^{13} m \qquad (16)$$

Thus, Eq. (15) gives

$$m_{cloud} = 2.2 \times 10^{21} kg.m^{-3} \qquad (17)$$

this is about 1.5 times the mass of the Earth's oceans $\left(m_{oceans} = 1.384 \times 10^{21} kg.m^{-3}\right)$.

[§] A planet moving on its trajectory around the Sun, and inside the water vapor cloud (ring), has been progressively capturing water vapor from the water vapor cloud.

By substitution of the values of m_{cloud} and $r_{cloud(i)} = \Delta R/2 \cong 1{,}847 AU$ into Eq. (10), we obtain

$$r = 1.94 \times 10^{11} m = 194 \times 10^{6} km$$

This is the *distance from the center of the cloud to the center of the Sun*.

By means of Eq. (9), we can obtain the value of r_{cloud}. The result is

$$r_{cloud} = r_{cloud(i)}\left(\frac{r}{100AU + r_{cloud(i)}}\right) = $$
$$= (1847AU)\left(\frac{r}{100AU + 1847AU}\right) = $$
$$= \left(\frac{1847AU}{1947AU}\right) r = 0.94\ r \cong 182 \times 10^{6} km \qquad (18)$$

Then, starting from the "radius" of the cloud r_{cloud} at distance r, we can obtain the distances from the center of the Sun up to the extremes of the cloud. They are respectively, $12 \times 10^{6} km$ and $376 \times 10^{6} km$ (See Fig.2).

Remembering that the distance of Mercury, Venus, Earth and Mars to the center of the Sun are respectively: $58 \times 10^{6} km, 108 \times 10^{6} km$, $149 \times 10^{6} km$, $228 \times 10^{6} km$, then we can conclude that the cloud crossed Pluto, Neptune, Uranus, Jupiter, Mars, Earth, Venus, Mercury and stopped (its inner surface) between Mercury and the Sun, involving Mars, Earth, Venus and Mercury.

Substitution of Eq. (9) into Eq. (10) gives

$$r = \frac{GM_{sun} m_{cloud}}{p_{wind\,(sun)}\, r_{sun}^{2} \left(2\pi^{2}\right) r_{cloud}} \qquad (19)$$

This equation shows that the distance r *increases* if r_{cloud} decreases. This is what has occurred, the extent to which the water vapor was attracted by the gravitational fields of the planets involved by the cloud.

The dotted circles in Fig.2 show the progressive decreasing of the cross-section of the cloud along the time, due to the absorption of the water vapor by the gravitational fields of the planets, and also the displacement of the cloud, produced by the decreasing of the radius of the cloud (according to Eq.(19)).

Based on the position of these planets inside the water vapor cloud, it is easy to conclude that, Earth and Mars have attracted more water vapor then the other planets.

The water vapor absorbed by Mercury and Venus it was progressively ejected from it atmosphere, due to the high temperature of these planets. Consequently, only the atmospheres of Earth and Mars** must have retained the most part of the water vapor of the cloud.

The above considerations can explain why the Earth has more water than the others planets of the Solar System. Also can explain why around 4 billion years ago, the percentage of water vapor in the Earth's atmosphere reaches about 70% of atmosphere [11].

The percentage of water vapor in the Earth's atmosphere decreased as it started condensing in liquid form. Then, a continuous rainfall for millions of years led to the buildup of the oceans.

** In order to explain how the water disappeared of the Mars, see ref. [12].

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