MOON TIDE AND THE ORIGIN OF LIFE

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ABSTRACT: A system containing three or more objects (such as the solar system) always has chaotic behavior and uncertainty, which play an important role in its evolution history. Possible influence of the Moon and its ocean tide effect on the creation and evolution of life on Earth is investigated in the in-determistic approach. Assuming that at time of the origin of life, the Moon was much closer to the Earth, so the tides raised by Moon was much large than nowadays. Big amplitude of tides allows more efficiency for creation and evolution of life via stronger wetting/drying cycles and mixing the pre-biotic soup in primordial sea. A model of tidal pools in frame work of restricted problem is investigated.

Keywords: tide, source of life

THỦY TRIỀU VÀ NGUỒN GỐC CỦA SỰ SỐNG

TÓM TẮT: Một hệ thống chứa 3 vật thể trở lên (ví dụ hệ Mặt Trời) luôn có sự tương tác hỗn loạn và quĩ đạo không hoàn toàn xác định. Điều này đóng vai trò quan trọng trong lịch sử tiến hóa của hệ thống đó. Ảnh hưởng có thể có của Mặt Trăng và tác động thủy triều của Mặt Trăng đối với sự hình thành và tiến hóa của sự sống trên Trái Đất được nghiên cứu theo phương pháp tiếp cận xác định. Giả sử vào thời điểm hình thành sự sống, Mặt Trăng ở gần Trái Đất hơn rất nhiều nên thủy triều do Mặt Trăng gây lên lớn hơn rất nhiều so với hiện nay. Biên độ thủy triều lớn có hiệu quả cao hơn tới việc hình thành và tiến hóa sự sống thông qua các chu kì nước dâng cao, hạ thấp mạnh mẽ, trộn lẫn hỗn hợp tiền sinh học trong biển nguyên thủy. Bài báo này nghiên cứu mô hình bể thủy triều trong khuôn khổ bài toán ba vật thể.

Từ khóa: Thủy triều, nguồn gốc sự sống.

1. Research history

The question of the origin of life on Earth has long puzzled scientists. To date, no one has come up with a totally convincing origin story and there are even suggestions that life may have originated elsewhere, and been delivered to Earth on the comets and asteroids that bombard our planet. This theory, panspermia, is attractive, since it removes the burden of life having had to form on our planet, giving us an infinitely greater range of origins, mechanisms, and times. It is certainly the case that biologically-viable bacteria can be transferred between the planets according to reference number [1, 2, 3, 5, 7, 8]. But for now, let's just consider those theories that suggest life originated here, rather than being brought from elsewhere. For theories that suggest life originated on Earth, it has often been proposed that the moon may have played in important role in its origin. The youthful Earth was a vastly different place to the planet we observe today, but current thinking holds that our early oceans contained a plethora of organic molecules of varying complexity. Many mechanisms have been proposed for the origin of those molecules, ranging from delivery by cemetery and asteroidal impactors to a huge variety of chemical processes, or even production through radioactive decay! The question of how those molecules went on to become life is another thing entirely. Again, a number of different theories have been put forth, but one particularly relevant to our story relies on the presence of the moon driving vast tides, which created huge tidal areas, in which complex chemistry would occur.

We know that, shortly after its formation, the moon was very, very close to Earth, and that therefore the tides it would raise on the oceans would be far, far greater than those we see today. Since the days were far shorter, tides washed in and out again with great frequency, creating vast tidal areas on the boundaries of any continents that existed at the time. Some authors have suggested these tidal regions helped to concentrate radioactive materials near the high-tide line, which would in turn have helped to make the building blocks of life.

Although it is far from certain, it's definitely feasible that the moon may have played a role in the origin of life according to reference number [4, 6].

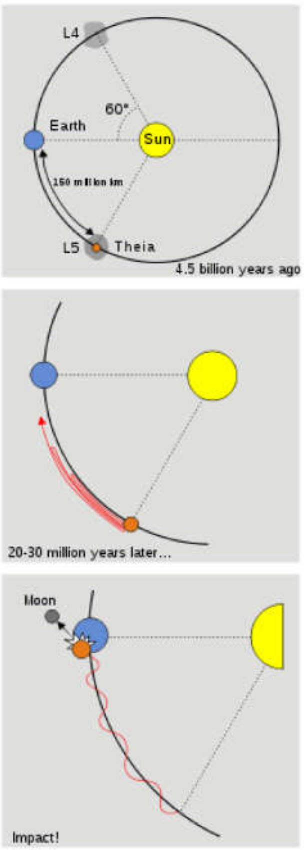
In this work, we investigate the hypothesis of Moon origin of life on Earth. Although it is far from certain, it's definitely feasible that the moon may have played a role in the origin of life. We analyze the role of chaotic behavior and uncertainty, show that they play an important role in its evolution history. In concept of in-determistic, we investigate some possible influence of the Moon and its ocean tide effect on the creation and evolution of life. We propose a simple model of tidal pools in frame work of restricted problem of Sun-

Earth-Moon system according to reference number [5, 8].

2. Giant impact hypothesis

The most widely accepted explanation for the origin of the Moon involves a collision of two protoplanetary bodies during the early accretion period of Solar System evolution. This “giant impact hypothesis”, which became popular in 1984, satisfies the orbital conditions of the Earth and Moon and can account for the relatively small metallic core of the Moon.

According to the giant impact hypothesis, there was once a Mars-sized body referred to as Theia orbiting in our solar system. Theia would have formed in about the same orbit as Earth, but about 60^0 ahead or behind.



When the protoplanet had grown to be about the size of Mars, its size made it too heavy for its orbit to remain stable. As a result, its angular distance from Earth varied increasingly, until it finally it crashed into the Earth. The energy involved in this collision is impressive: trillions of tons of material would have been vaporized and melted. In parts of the Earth the temperature would have risen to 10000 °C.

The collision would have occurred 4.533 billion years ago when Theia would have hit the Earth at an oblique angle, and destroyed itself in the process. Theia’s mantle and a significant portion of the Earth’s silicate mantle were thrust into space. The left over materials from Theia mixed with the materials from the Earth and eventually formed the Moon.

Earlier research validating this hypothesis, was conducted by scientists from Oxford University, University of California, and Swiss Federal Institute of Technology, who compared silicon isotopes from Earth rocks, as well as other materials from our solar system such as rocky materials from meteorites showing that the Earth’s core and the Moon’s core contain the same silicon isotopic material, which would support that the two were once a single body until a large impact separated them.

3. Chaotic of the Sun-Earth-Moon system

The Sun-Earth-Moon system is a 3 body problem always has chaotic behavior. Moon plays an important role on stabilization of Earth rotation and favorite life creation and evolution on Earth [9].

Among many other arguments, the moon played a central role in their "Rare Earth" hypothesis and the presence of an over-sized moon, such as ours, is most likely a key component to making a planet habitable. Beyond this, they argued a key component of Earth's habitability has been its remarkably stable axial tilt by the presence of the moon.

Without the moon, they argue, the Earth's axis would vary hugely, and chaotically, on timescales of millions of years ranging from almost no tilt at all, through the planet's current tilt (just over 23 degrees), to our planet being tipped over on its side, like Uranus, causing all locations on the planet to experience six months of daytime, followed by six months of night, every single year.

While such an idea sounds somewhat outlandish, it is based on observations of the planet Mars. At the current epoch, the axial tilt of Mars is almost identical to that of Earth 25 degrees against our 23 and a half. However, while Earth's axial tilt varies by only a degree or so in either direction, that of Mars is far more chaotic. In fact, it is thought that Mars' axial tilt varies between 0 degrees and around 60 degrees, over a few million years, as a result of perturbations from the other planets [10].

Thus, this would render the planet hugely inhospitable for complex life.

This hypothesis (that the moon is required to stabilize Earth's axis) has unfortunately not stood up to scientific scrutiny, revealed something far more interesting. The Earth's axial tilt is actually remarkably stable for a wide range of Earth-moon configurations (even for scenarios without the moon). But, were the moon just slightly larger (by around ten kilometers, just a third of 1% of its diameter), it would force Earth's axis to become unstable, driving a hugely chaotic motion. More recently, other researchers have reached the same conclusion a giant moon is not needed for Earth's axial tilt to be stable. In other words, had the "big splash" that formed the Earth-moon system created a satellite just slightly larger, Earth would likely be a far less pleasant place for life to develop and thrive. And perhaps "Earths" aren't quite as rare as we might otherwise have thought [9,10].

4. Role of moon tide in the origin and evolution of life

By driving the tides, lunar companion may have jump-started biology or at least accelerated its progression It all started some 4.5 billion years ago when, as theory has it, our nascent Earth was blindsided by a Mars-size planetary embryo, believed to have spun Earth into its initial fast rotation of roughly 12 hours per day. The molten mantle thrown into orbit after the catastrophic lunar-forming impact quickly coalesced into our moon. Within a few thousand years, Earth cooled to an object with a molten surface and a steam atmosphere. Life emerged some 700 million years later, or about 3.8 billion years ago. But four billion years ago a cooling Earth already had an ocean, but remained barren. The moon was perhaps half as distant as it is now, and as a result, the ocean tides were much more extreme.

The oceans' tidal flow helps transport heat from the equator to the poles. Without the lunar tides, it's conceivable that climate oscillations from the ice age to the interglacial would be less extreme than they are. Such glaciations caused migrations of animal and plant species that probably helped speed up speciation.

Tidal heat transfer could have also mitigated climate fluctuations. The problem in determining which "tidal forcing" scenario is correct is that climate researchers currently lack data spanning extremely long timescales. Tools of evolution are also driven by the tides' influence on these intertidal regions. In a rocky intertidal area, it's very clear there are strong evolutionary pressures brought on by a changing environment over a short spatial scale. Without our moon, our marine environment would be much less rich in terms of species diversity.

A lot of origin-of-life reactions involve getting rid of water. Some 3.9 billion years ago, fast tidal cycling caused by the influence of our moon enabled the formation of precursor nucleic acids. A 12-hour Earth day would have produced high tides, these lunar tides would have moved many miles inland, beyond the crashing waves driven by the sun or surface winds, and onto a vast, flat landscape. In the early Earth environment, that such fast lunar tidal oscillations would result in the highly saline low-tide environment that protonucleic acid fragments would have needed to associate and assemble complementary molecular strands. Having bonded in pairs at low tide, these newly formed molecular strands would then dissociate at high tide, when salt concentrations were reduced, providing a self-replicating system, so DNA would ultimately have arisen from such protonucleic acids.

5. Simple model of role of moon tide in the origin and evolution of life

Suppose Earth-Moon distance in the unit of R_1 = 384,400 *km* (its present value) is

$$r = C\,[1 - \exp(-t)], \quad (1)$$

where t is the time accounted from giant impact moment in the unit of Gy (1Gy = 1 billion years), C is a constant defined by the conditions: at giant impact moment: $t = t_0 = 0$, $r = r_0 = 0$; and at present time: $t = t_1 = 4.53$, $r = r_1 = R/R_1 = 1$. Substitute the value of t into the equation (1), we have

$r(t = t_0 = 0) = r_0 = 0$ at $t = t_0 = 0$

$r(t = t_1) = r_1 = R/R_1 = 1 = C[1 - \exp(-t_1)]$ at $t = t_1$

$1 = C[1 - \exp(-4.53)]$

Then finally, we get

$$C = 1/[1 - \exp(-4.53)] = 1.0109 \quad (2)$$

In the figure 1 we plotted calculated values of Earth-Moon distance from equation (2).

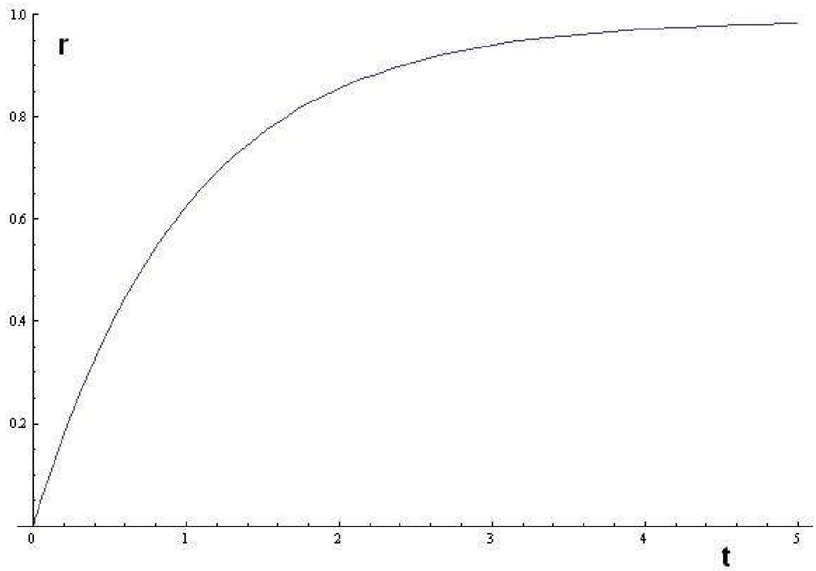


Figure 1. Calculated values of Earth-Moon distance n.

Calculated values of *r* at some time ago *τ* and those corresponding values r_d taken from data base were shown in Table 1, and have a quite good agreement. We note here the comparison indicates that the Moon wasnt close to Earth 1.5 Gy ago, where life was emerged.

Table 1. Calculated values of *r* at some time ago *τ* and corresponding values r_d taken from data base

τ (Gy ago)	0	0.62	1.5	2.45	3.9
r from equation (2) (×384,000 km)	1	0.969	0.941	0.866	0.462
r_d from data base (×384,000 km)	1	0.965±0.05		0.862±0.05	

The height of the ocean tide raised on the Earth surface by Moon is

$$H = \frac{3}{4\pi}\frac{m_M R_E{}^4}{M_E R^3}, \ (3)$$

where $m_M = 7.349\times10^{22} kg$ is Moon mass, $M_E = 5.974\times10^{24}\ kg$ is the Earth mass, $R_E = 6.378\times10^{6}\ m$ is Earth equatorial radius. Taking present tide height $H_1 = \frac{3}{4\pi}\frac{m_M R_E{}^4}{M_E R_1{}^3}$ as the unit of length, the tide height h is

$$h = H/H_1 = 1/r^3, \ (4)$$

The value of h as a function of time is plotted in the figure 2. We can see that 3.9 Gy ago, where life forms came into existence tides were huge and tides flooded able extended coastal arrears several hundred kilometers inland. Define the relative lunar efficiency η_{mix} of mixing processes

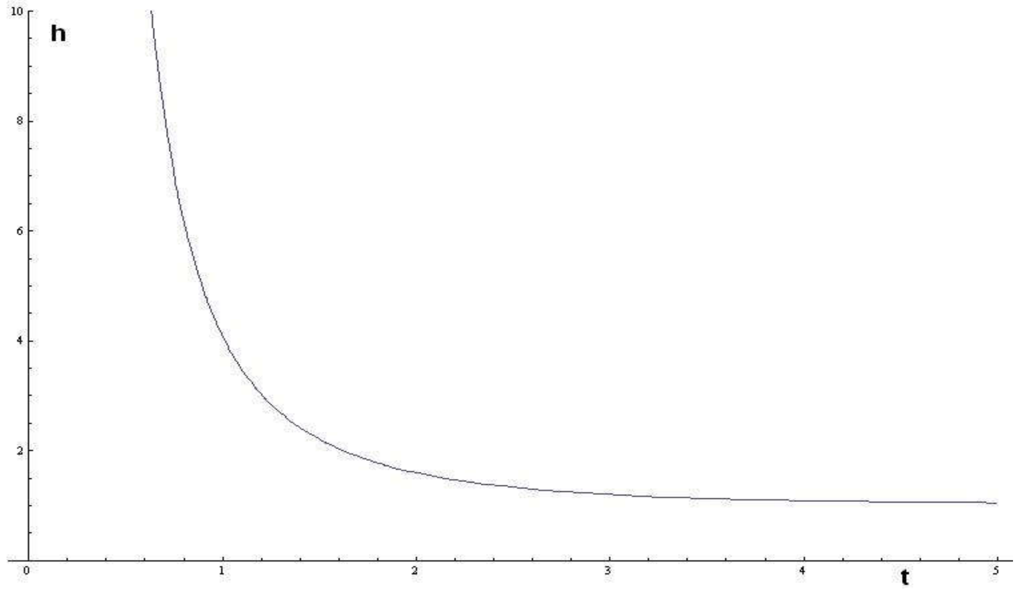


Figure 2. The value of tide height h as a function of time.

in ancient oceans compare those in present and assuming $\eta_{mix} \sim h$, we got

$$\eta_{mix} = 1/r^3, \ (5)$$

The lunar efficiency η_{wd} of wetting/drying cycles is proportional to Ω the mean rotation frequency of Moon around Earth. From angular momentum converse law, we have $\Omega \sim 1/R$. Using $\Omega = 29.5h$ the present lunar orbital day as the frequency unit, we define the relative lunar efficiency η_{wd} of wetting/drying cycles as

$$\eta_{wd} = 1/r, \ (6)$$

We estimate the length of day LOD is 20.6 h at 2.5 Gy ago, and 11 h at 3.9 Gy ago. The total relative lunar efficiency in origin and evolution of life on Erath η is defined

$\eta = \eta mix \eta wd = 1/r4$, (7)

Table 2 shown the values of relative tide height *h* and relative total lunar efficiency *η* in several moment of time ago. The Moon influence was not so much in 2.45 Gy ago, but was very strong at 3.9 Gy ago.

Table 2 the values of relative tide height *h* and relative total lunar efficiency *η* in several moment of time ago *τ*

τ (Gy ago)	0	0.62	1.5	2.45	3.9
h from equation (4)	1	1.099	1.200	1.54	10.14
η from equation (7)	1	1.134	1.275	1.778	21.95

and expressed in Figure 3.

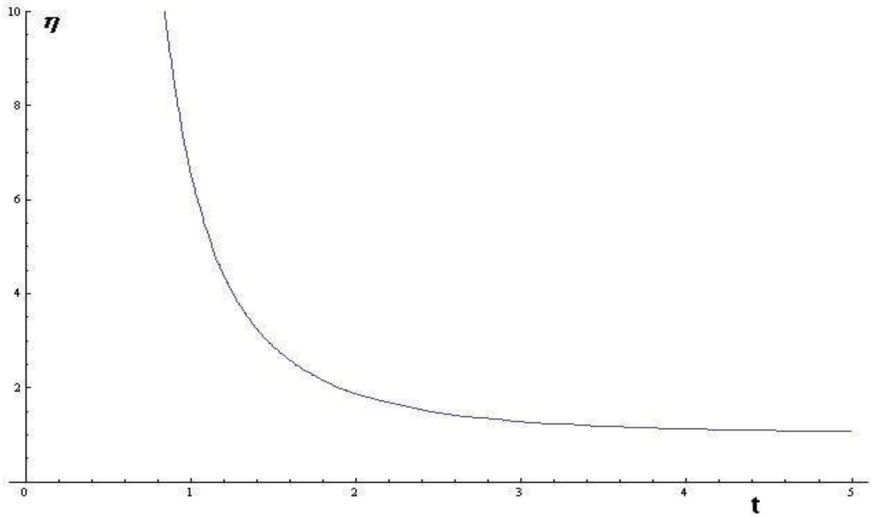


Figure 3. total relative lunar efficiency in origin and evolution of life on Erath.

6. Conclusions

In this work based on the concept of in-determistic, we investigated some possible influence of the Moon and its ocean tide effect on the creation and evolution of life. For this, we propose a simple model of tidal pools in frame work of restricted problem of Sun-Earth-Moon system. This model has a good agreement with the Earth data base.

Using our proposed simple model, we have shown that Moon plays important role in emergence and evolution life on Earth. Main supporting lunar contributions are: amplification and stabilization creation and development life from earlier moment and to day. Moon stabilizes rotation of Earth so and weather condition favorite for life.

Beside Earth surface temperature condition, Moon tide is significant argument for life. Fast and huge tide cycling in beginning of life provide an important mechanism for the amplification, and thereby Darwinian selection, of DNA-like molecules. This tide mechanism requires rapid planetary rotation, and exploits tidal flooding, both being consequences of the early collision that produced the Moon according giant impact hypothesis.

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