

**On the recent origin of the Moon:
a four-five body scenario for a capture event
and its mathematical modeling
via nonlinear optimization**

Emilio Spedicato

**University of Bergamo
Department of Mathematics
emilio@unibg.it**

October 2009

Abstract

The problem of Moon's origin appears in ancient writers not to say in even more ancient traditions or religions. It has been studied since the development of modern mathematics as a celestial mechanics problem. Before space missions permitted to analyze lunar rocks, it was commonly accepted that Moon formed with Earth from a cloud of gas and dust whose condensation, via complex processes, is thought to explain the formation of planets. However analysis of the rocks showed a different isotopic structure than terrestrial rocks, a fact invalidating the common origin theories. Among new theories, the preferred one is that Moon formed from material ejected in space after a giant tangential impact with a body of size similar to Mars. We give arguments from ancient traditions that Moon's origin may be quite recent, as proposed by Alfred De Grazia, albeit in a different scenario. We date its origin as our satellite at the end of last Ice Age, whose cause we attribute to a large body passing near Earth and whose satellite was captured becoming our Moon. Finally we argue that Mars was probably an Earth

satellite before Moon's capture, revolving on a more distant orbit. The event that led to capture of Moon also led to the removal of Mars. The proposed scenario may be investigated mathematically within a 4 or 5 body scenario, as a multiparametric nonlinear optimization problem.

1. Some literature theories on the origin of the Moon

The origin of the Moon is still one of the open problems in astronomy. Indeed up to the first collection of lunar rocks, while several theories existed in the literature, it was widely believed that the Moon originated coevally with Earth from the giant gas and dust cloud, consisting of material emitted by the explosion of an earlier star (our Sun is a second generation star). The condensation of such cloud led to the formation of Sun, of terrestrial type planets, and of the gaseous planets. When the Kuiper belt existence from a hypothesis became a fact, it too was considered as having formed in this process, while the more distant and spherically distributed Oort cloud, whose existence is doubted by some, is considered, see e.g. Clube and Napier (1982), to consist to a large extent by material captured in different parts of the galaxy when the solar system crosses a molecular cloud (an event where part of the Oort cloud is also lost). The above scenario was due to a large extent to Whetherill (1979), who concluded that terrestrial type planets could form only in the vicinity of Sun, say within half a billion km, while the large gas planets could form only beyond. This main point of Whetherill scenario failed with the discovery in the last several years of many (more than 200 presently) planetary systems around other stars. Here some large gas planets were found orbiting very close to their star, at about 1 million km. Even considering that the observed systems are biased towards those with large planets since only a handful of small planets have been found, it is clear that Whetherill model uses simplifications and hypotheses not true generally. The mechanism explaining why large planets can be so close to a star is due to Del Popolo (2001, 2002). Moreover additional mathematical computations by Meyer et al (2002) have provided a result almost unbelievable, namely that large gas planets do not form in the previously estimated time of order 10 million years, but just in a few centuries! And quite strong arguments by Ackerman (1999 a,b), including the analysis of the Shoemaker-Levy impact on Jupiter, even indicate that the so called gas planets may have a solid inner part, consisting of clathrates and other materials.

The problem of satellite formation is similar but possibly more rich of solutions. Indeed satellites could form coevally with the planet, but they could

also arise from later impacts or capture of bodies being originally on their own orbit or gravitationally tied to another body. As said above, the coeval formation of the Moon has now been dropped due to the isotopic composition of lunar rocks being different than in Earth rocks. A mechanism that would separate particles by their isotopic constitution seems not to be available. Hence one has looked at other possible origins, in particular the three body capture and a large impact with debris coalescing around Earth. The last mechanism is now preferred by most astronomers, see for instance Boss (1986) or Palme (2004). It assumes that a body of Mars type mass impacted Earth tangentially billion of years ago. The body essentially vaporized with part of Earth material. Part of it fell over Earth, part escaped to space, part condensed around Earth forming the Moon. Notice that multiple Moon systems might arise under such conditions, see Canup et al (1987), but simulation shows that after some time they would usually coalesce into just one. The impact process has been simulated mathematically with different parameters and suitable impactor composition in order to explain the mineral composition of the Moon.

Another theory that can explain a Moon differing in material composition is capture. The simplest form of capture assumes that the Moon, originating from somewhere else in solar system or outside it, passes close to Earth and, on entering the so called Hill sphere, where Earth gravity dominates Sun's, is captured. However this event is generally impossible due to the laws of the three body problem. This fact was learned from Tom Van Flandern, who visited this author twice in Bergamo, as a lecturer at the 1999 Conference on New Scenarios on the Evolution of Solar System and at the 2001 Conference on Fifty Years since publication of Velikovsky's book *Worlds in Collision*. Such a capture is possible under special conditions, like a sudden decrease in the mass of the Sun, see Szebehely and Evans (1980), or if Earth was enveloped by a sufficiently thick atmosphere, see the study by Nakazawa et al (1980), where the authors obtain the remarkable result that Moon's orbit would circularize in less than a century.

Capture is possible, under *fine tuning*, as Van Flandern again told this author in an email of 5-11-07, sadly not long before he died by cancer, in a 4-body scenario, like the one that we propose below, apparently never considered before. It should be possible also in a 5-body scenario, that we will additionally discuss, since it seems necessary to justify certain properties that Earth obtains from the presence of a satellite.

Our scenario sets Moon's capture within uman memory. We set it in the framework of the great catastrophic event that in our opinion led to fast ending of last Ice Age, to the demise of an advanced civilization, the one

referred to by Plato as the Atlantis civilization, see Spedicato (2007 a, b), to the destruction of many animal species and a large part of mankind. Here we recall that also prof De Grazia proposed a relatively recent origin of the Moon. His view was that Moon was expelled from the region of Earth where is now the Pacific Ocean, that he sees as a scar left by lunar departure. He additionally uses this event to explain several geologic features of Earth. While the last word is not said about his theory, it seems to face unresolvable difficulties, say:

- which mechanism can produce the event, expelling part of Earth with enough kinetic energy to settle into orbit
- how could life survive such an immense catastrophic event
- why there is no significant difference in the geology of the bottom of Pacific and other oceans, an observation made to me by geologist Walter Alvarez of Berkeley University, one of the discoverers of the K-T event.

In the following section we give our scenario for the capture of the Moon within a 4-bodies gravitational system, then we extend it to a 5-bodies scenario. Our idea was born from consideration of religious and mythological traditions. Then we discuss a possible validation of such a scenario formulated as a nonlinear optimization problem.

2. Recent origin of the Moon in a 4-body capture event?

Velikovsky in an unpublished book, named *In the beginning* in the website for his unpublished papers produced by Jan Sammer, briefly considered the possibility that the Moon was recently captured, in view of certain statements in the Bible and other sources. Here we quote some of his references (V) and others found by (S) us in reading books dealing with ancient traditions.

- (S) The Chimu were a people of the coastal civilization in Peru, predating the Incas civilization, which took over only around the 14th century AD. For the Chimu the Moon appeared at a certain time in the sky and had a father, the god Pachamacac. This god was also god of the Incas, who were monotheist. The name Pachamacac means *He who creates, animates* (macac) *all, the universe* (Pacha), see Miccinelli et al (1988).

- (S) The Malekula are a tribe of the New Guinea mountains (where about 700 languages are spoken and there is a great genetic variation among tribes). They claim that *there was a time when air was full of vapors and it was almost impossible to see even at short distance. When the sky cleared they saw that the sea level had arisen and many lands had disappeared. Moreover in the sky the Moon had appeared.*
- (S) The Hindu claim that the Moon appeared after the sea had boiled, see Daniélou (2002).
- (V) In Bible Job addresses God as the Lord of when there was the Moon and when there was not; see *Psalm 72-5* and *Job 25-5*
- (S) Censorinus in *De die natali* writes that *Arcadians claim, but I do not believe it, that before Moon existed the year had not 12 but 3 months*
- Velikovsky in the above quoted book cites several Greek and Roman writers for whom Moon appeared within human memory, among them Democritus, Anaxagoras, Aristoteles, Apollonius, Plutarch, Ovidius, Hippolitus, Lucian. He also observes that another claim was that the Moon was more luminous in the past. Unfortunately I am writing this article without having checked the exact content of the statements by the above authors
- (S) An important symbol in Islamic world, whose origin is not Arabic but Turkish (the Turkish area has some of the oldest traditions in the world, only partly explored, as the *Epic of Manas* of the Kirghisians consisting of some 6 million verses) is the well known *large half Moon having inside a small five pointed star*. This symbol appears on the flag of Turkey.

Human memory may go back several thousand years, possibly even over nine thousand years as the memory of the great catastrophe that destroyed Atlantis shows, if it is correct that such an event corresponds to the end of the last Ice Age, as argued by Muck (1956), Barbiero (1974), Collins (2000), Spedicato (1991, 2007 a,b) and others. In fact even older memories seem to have survived, if we can associate the most ancient catastrophe in the Mayan record, the one due to fire followed by a time of strong winds, with the impact over the Laurentide region that has been recently identified by several geologist, as having taken place around 10.900 BC, at the end of the Clovis period. Such impact led indeed to widespread fires, that left some 3 million square km layer of partially burned material, called the *black mat* (I saw such

a layer in the Escalante desert, Utah, when I was guest of the remarkable non academic scholar who was Evan Hansen). And the period following the event is now believed to have been a time affected by unusually strong storms, even in Europe, where whole forests were often flattened. And such strong winds may explain the Atlantis story of Plato, where he claims the city of Atlantis was located in a place *protected from winds*, a statement never commented upon as far as I know and in fact quite unusual. Even older memories, circa 19.000 and 27.000 BC, may have been preserved by the first two Indian yugas, if the yugas chronology, like the one given by other great numbers in ancient traditions, can be obtained by the decrypting technique given by Spedicato (2009 a).

In a recent monograph in Italian language, planned for a translation into English, Spedicato (2009 b), we have developed the idea presented at the Milos conference of 2005 on Atlantis, that the most likely cause of the end of the last Ice Age, and of the rapid melting of ices and increase of world temperature now proposed by several authors, see e.g. Pedersen (2007), was the close passage near Earth of a large body. The tidal effects of such passage slightly deformed our planet, broke the thin crust of the oceans bottom, let huge amount of magma pour out producing immense warm rains. The vapours coming from the oceans where hot magma was pouring out let people who could survive the turmoil and see the event from high mountains near ocean shores think the sea was boiling, therefore explaining the Hindu statement on lunar origin. Tsunamis raged, rain and vapours affected much of the planet, visibility decreased, ices melted, sea water level increased, details perfectly recorded by the Malekula. Notice that for a wide range of latitudes-altitudes the increase of temperature and the humidity due to the strong warm rains must have led to intolerable level of temperature, hence to the death of many living being. Large mammals died in the low lying plains of the Americas, but survived in Africa, where many of them were living on high plateaus, 2000 m or more. So humans survived preferably on high latitudes or on high mountain ranges (Caucasus, New Guinea, Ethiopia, Asian mountain....) a fact that easily explains why there we find the highest amount of different languages and genetic mutations.

The appearance in the sky of the new satellite, the Moon, after these events can be explained if the passing body had a satellite that was lost to Earth, a fact possible in a 4-bodies context. *Then there was a time with the Moon and a time without*, as Job and the Psalm declare. And the Moon had a father, as the Chimu stated, to be identified with the large body passing near Earth. Incidentally the fate of this body is a very interesting question. Here we just recall two possibilities. One is that it continued on a previous very elliptic orbit, so that one could think of it as the mysterious Sumerian planet called

Nibiru, of which however there is now no evidence. The other possibility is that it should be identified, as John Ackerman proposes, with the object that impacted on Jupiter, forming an immense crater whose remain is present Red Spot; from such a crater immense amount of material was ejected, leading to the formation, to the birth, of Venus. So Ackerman proposes a mechanism for Venus recent birth that was not provided by Velikovsky. As observed by Spedicato (2009 a) the time of the event can be estimated quite precisely from a Toltec statement that Venus was born circa 3800 years before the beginning of their *long year*, i.d. before circa 3100 BC (notice that precise dating of Mayan-Toltec years is *impossible* since the numbers are given in days and the number of days in a year cannot be considered constant for several reasons). Thus we would have for Venus birth circa 6900 BC (the material beginning to condense probably about 6500 BC, fifth “day” of “creation” according to Talmudic scholars). This date is essentially the one found by the Tollmanns (1993) for Earth being impacted sevenfold in different points, impacts easily explainable in terms of material ejected in space by the event proposed by Ackerman.

The acquisition of the Moon can be considered as a relatively minor event compared with the gravitational effects of the passing body, the main cause of the greatest catastrophe in Plato’s list. However we are faced with the existence of geological structures called *varves* that are due to tidal effects of our satellite and extend in time well before the end of the last Ice Age. This problem can be solved if the capture of the Moon meant also the loss of a previous satellite, that could also produce varves, and there are some arguments that such a satellite was.... Mars. Such a loss would moreover lessen the effects of Moon’s capture, especially if Moon would set in a resonant orbit that favours stabilization of Earth axis, as is indeed the case. Suggestions of existence of a previous satellite that was quite probably Mars are found in the following items:

- The quoted statement in Censorinus can be interpreted as the existence, previous to the Moon, of another satellite having about 3 cycles per year, hence providing 3 months per year. By Kepler’s third law we can estimate that such a satellite orbited farther away than Moon, about 1 million km from us. Finding such passage of Censorinus, which as far as I know escaped even the attention of Velikovsky, was quite a surprise for me, because I believed impossible to get an estimate of the distance of the previous satellite!
- The Turkish symbol can be interpreted as the new Moon appearing larger in the sky and with well defined phases. The star inside, having 5 points, suggests that it refers to Mars, the 5th body from the Sun. Its being smaller suggests that it loomed in the sky smaller than the Moon. Thus we suspect that the 5-

pointed star used often in human traditions refers originally as a symbol to Mars, with its related features of war and violence..... notice that Solomon, man of peace and tolerance, adopted a 6-pointed star.

Several features of Mars suggest a previous close relation with Earth, as the similar rotation period and similar axis angle on the ecliptic. Moreover the evidence from Martian missions of water recently lost catastrophically by Mars, some probably still surviving in the soil, is quite compatible with the removal that we prospect here. Notice that Mars would have been in the habitable zone, hence life probably existed on it. And possibly not only low level life. Hence the many geometric features in Mars that suggest artificiality, see several papers in *Metares Bulletin* edited by Tom Van Flandern, or the recent book by Piccaluga (2006), get one extra argument in favour of their artificiality.

Now Mars has a diameter about twice that of Moon. Since its distance is estimated from Censorinus at about 2.5 times the present Moon distance, we estimate a reduction of its light a factor over 6 by distance, but an increase a factor 4 by surface size. Hence, albedo being similar, its observed luminosity should have been less than present luminosity of the Moon; angular diameter was also less. But we have also to consider the statements in Greek and Latin authors that Moon was initially more brilliant. This quite mysterious statement took suddenly a meaning for me when, at the September 2009 Italian Archaeoastronomy Society conference in Firenze, I knew from scholar Giuseppe Brunod that many petroglyphs found in Val Camonica (over 100.000 discovered till now), show by their monthly signs that the year in the fourth millennium BC consisted of 13 months. If this finding is correct, then it means:

- Moon was closer, hence looming larger and more luminous, from Kepler's third law
- its superiority over the previous satellite was even more remarkable
- we obtain a strong reason why number 13 was so sacrally important among Toltec, Mayas and Aztecs, appearing in their various calendars, architectonic features and even rituals as the killing of their king by the Aztec if he had been in power 13 years. Just recall that the sacred Maya year, the *tzolkin*, consisted of 260 days, i.e. 13 by 20. What the reason for 20, another "sacred number", we leave to another paper....

The year got 12 months most likely after the second great catastrophe quoted by Plato. Albeit almost no one discusses such a second catastrophe, it is almost

certainly the Biblical Flood, corresponding to the Sumerian-Akkadian Flood of Ziusudra-Utnapishtim, that for reasons not to be detailed here I set at 3161 BC (again I thank Toltec for allowing me to solve the enigma: 3161 or 3171?). The cause of the Flood was most probably a close passage of Mars, that after having been removed from its position as Earth main satellite, in the following millennia repeatedly approached Earth with catastrophic effects, albeit not comparable with those of the event that ended Ice Age, see Patten and Windsor (1996) . The 3161 BC was more catastrophic, a fact foreseen by Noah and others. We believe that during this close passage Mars had the final loss of its waters, part of which reached Earth, being the biblical *fountains of the high*. We tend to accept Ackerman genial and bold proposal, that sees in this passage the final loss of Mars core, that became Hermes-Mercury. Thus we understand the well known statement of Plutarch that *Hermes stole one seventieth of the light of the Moon passing it to the year whose number of days increased by 5....*

Therefore the year length in days passed from 360 to about 365, the extra five days being about one seventieth of 360 and being generally considered in ancient civilization as special days, devoted to festivals (by Mayas...) or with prohibition for traveling, marrying, making contract (by Egyptians)...

For analysis of the final interactions of Mars and Earth, see the recent monograph of De Grazia (2009), written with material partly obtained while visiting Bergamo and exploring in particular the area of Bolsena lake. For a mathematical study that the final rounding up of the orbits of Mars and Venus does not violate conservation laws, see Dixon (2002).

We conclude our scenario for the Moon observing that it was a bonus for mankind after the terrible events that ended Ice Age, of which mankind recovered after some 4000 years, at the time of the Eden events soon followed by what we call the neolithic age.

Moon was seen as a gift sent by gods to provide light in the night, at a level not available when the satellite was Mars. Its name is clearly related to light in the sky, see e.g.:

- in Chinese, *hue lean*, “lamp in the sky”
- in Latin, and many post latin *languages*, *luna*, by metathesis and trivially acceptable vowel changes *lu*→*ul*→*el*, “light”, *na*→*an*, “sky”, light of the sky

There are, to my knowledge, no instances of the Moon having a bad qualification in ancient records.

3. Mathematical modeling Moon's capture

Our scenario can be validated to some extent by mathematical simulation. We can set it as a multiparametric problem, to be solved via nonlinear optimization. Of course we make a number of simplifications, to reduce the dimensionality of the problem, being satisfied just to have a first order solution to the problem. We define here the problem features, letting to the future the actual calculations, that require many man-months of work.

As simplifying hypotheses, for the problem not considering Mars, we will assume that:

- **the orbits of the considered bodies lie on the ecliptic plane**
- **the Earth orbit is circular, as well as the orbit of the satellite S of the object P (whose passage near Earth ends the Ice Age and gives us the Moon)**
- **all bodies mass are concentrated in one point, thereby disregarding tidal deformations and their specific rotation**
- **only gravitational effects are considered originated by P, S, Earth and Sun**
- **only gravitational forces are considered.**

The following parameters cannot be provided by the above study. They must be inserted at a number of discrete values, hereby solving the problem for several cases:

- **the mass μ of the body P**
- **the radius ϑ of the orbit of S**
- **the distance Δ of closest passage of P to Earth**
- **the point ω wherefrom we start the approach of P to Earth; it should be set at a value much greater than the radius of Earth orbit**
- **the time τ needed for P to come "close" to Earth orbit.**

We can formulate our problem as a multistage heuristic parametric nonlinear unconstrained optimization problem in two variables. Let v_1, v_2 be the velocity components of P in ω , they being our variables in the optimization. We want to select them so that P passes as close as possible to the selected distance Δ of a certain point on Earth orbit. We can do this by minimizing over v_1, v_2 the square of the difference between Δ and the position $\rho(v_1, v_2, \tau)$ at time τ of P computed by solving the Newtonian equations of motion. Accurate solution of such equations is important and to this purpose the new

algorithms of Trigiante and Brugnano may be used. At this moment we have just solved a 2-bodies problem, the orbit of P being expected to be elliptic.

Once values of v_1 , v_2 are obtained by the minimization process we repeat the computations adding S in the computations with a ∂ greater than Δ . We try different initial positions of S in its orbit till, at the time of closest distance to Earth orbit, S will lie inside Earth orbit. At this moment we have solved a 3-bodies problem. It would be useful to follow the trajectories by a graphic representation of the system.

Then we add Earth to the scenario, trying for it different positions along to initially circular orbit (it will undergo of course a perturbation), till it gets in a position at a distance from P about Δ , with S expected to be inside the orbit, hence closer to Earth than to P. Here we have solved a 4-bodies problem.

Finally the distances of S from P and Earth will be monitored by further application of the dynamical equations, to verify if S remains in the vicinity of Earth.

As formulated above, the problem is multiparametric in only two dimensions as an optimization problem. It might be possible to include some parameters in the optimization procedure.

Once the above model provides numerical evidence that capture is possible under some parameter range, one could study of the behaviour of Mars assumed as being initially our satellite, in order to derive the parameters of its orbit after it is lost by Earth. Notice that in principle Earth could have resulted in having two satellites!

Acknowledgements

The idea that Earth could have acquired Moon recently was suggested by Velikovsky's information in the book *In the beginning* and by the quoted statements of the Chimu, Malekula, Hindu and Censorinus. The idea that Mars was a previous satellite emerged during a discussion with Marco Fagone, author of a website on Mars. Stimulating discussions and important documentary material has been provided by prof Alfred De Grazia and his wife and collaborator Amy de Grazia.

References

- 1 – J. Ackerman, *Firmament*, website
- 2 – J. Ackerman, *Chaos*, website
- 3 – F. Barbiero, *Civiltà sotto ghiaccio*, Nord Editrice, Milano, 1974
- 4 – A.P. Boss, *Moon's birth shocked Earth?*, Nature 324, 110-111, 1986
- 5 – R.M. Canup, H.F. Levison and G.R Stewart, *Evolution of a terrestrial multiple Moon system*, Preprint, Southwest Research Institute, 1999
- 6 – V. Clube and B. Napier, *The cosmic serpent*, Faber and Faber, 1982
- 7 – A. Collins, *Gateway to Atlantis*, Carroll and Graf, 2000
- 8 – A. Daniélou, *Miti e dei dell' India*, BUR, 2002
- 9 – A. Del Popolo, N. Ercan and Gambera M., *Migration of giant planets in planetesimals disks*, MINRAS 325, 1402, 2001
- 10 – A. Del Popolo, *Extra solar planets, detection and theoretical problems*, Proceedings of the Conference *Fifty years after worlds in Collision by Velikovsky: classical and new scenarios on the evolution of the solar system*, E. Spedicato and A. Agriesti editors, University of Bergamo, 151-180, 2002
- 11 – A. De Grazia, *The iron age of Mars*, Metron, 2009
- 12 – L. Dixon, *On Velikovsky's orbits, a mathematically possible concept*, Proceedings of the Conference *Fifty years after worlds in Collision by Velikovsky: classical and new scenarios on the evolution of the solar system*, E. Spedicato and A. Agriesti editors, University of Bergamo, 73-77, 2002
- 13 – L. Meyer, T. Quinn, J. Wadsley and J. Stadel, *Formation of great planets by fragmentation of protoplanetary disks*, Science 298, 1756-1759, 2002
- 14 – C. Miccinelli and C. Animato, *Quipu, il nodo parlante dei misteriosi Incas*, Ecig, 1988
- 15 – O. Muck, *Atlantis, die Welt der Sinflut*, Olter, 1956

- 16 – K. Nakazawa, T. Komuro and C. Hayashi, *Origin of the Moon. Capture by gas drag of the Earth's primordial atmosphere*, Earth, Moon and Planets, Springer, 28, 3, 1983
- 17 – H. Palme, *The giant impact formation of the Moon*, Science 304, 2004
- 18 – D. Patten and S. Windsor, *The Mars Earth wars*, Pacific Meridian, 1996
- 19 – E. Piccaluga, *Ossimoro Marte, vita intelligente sul pianeta rosso*, Hera Books, 2006
- 20 – E. Spedicato, *Apollo objects, Atlantis and Deluge*, NEARA Journal 26, 1-16, 1991
- 21 – E. Spedicato, *Atlantis in Quisqueya 1. The Atlantis destruction, part I: catastrophic end of the last Ice Age by extraterrestrial agents*, Proceedings of the International Conference on *The Atlantis Hypothesis: Searching for a Lost Land*, Milos island, July 2005, S. Papamarinopoulos ed., Heliotopos, 389-404, 2007
- 22 – E. Spedicato, *Atlantis in Quisqueya 2. The Atlantis destruction, part II: interpretation of the Platonic story and Atlantis in Hispaniola*, Proceedings of the International Conference on *The Atlantis Hypothesis: Searching for a Lost Land*, Milos island, July 2005, S. Papamarinopoulos ed., Heliotopos, 405-416, 2007
- 23 – E. Spedicato, *Ancient large chronological numbers decrypted*, preprint, submitted to Journal of Scientific exploration, 2009
- 24 – C. Szebehely and R. T. Evans, *On the capture of the Moon*, Springer, 21, 3, 1980
- 25 – A. and E. Tollman, *Unt die Sintflut gab es doch. Vom Mythos zur historischen Wahrheit*, Dröner Knaur, 1993
- 26 – G. Whetherill, *Apollo objects*, Scientific American, 240, 38, 1979

Appendix: Some theories on Lunar formation

In the following we consider some theories that have appeared in relatively recent literature. Our survey is certainly non complete, but is based upon a lengthy search of the literature via internet. We refer to articles, papers and conference presentations.

1 - Szebehely and R. T. Evans, The University of Texas, Austin, Tex., USA

***On the capture of the Moon*, Springer, 21, 3, 1980**

This paper studies the possibility of lunar capture depending on variations of the solar mass under certain well specified conditions regarding the behavior of the three-body dynamical system formed by the Sun, Earth and Moon. It is found that a large amount of decrease in the solar mass (approximately 37%) is required to allow capture if the model of the planar restricted problem of three bodies is assumed, if masses of Earth and Moon did not change and if the angular momentum of the Sun-Earth system did not change. Such large mass-changes of the Sun can not be associated with radiation mass losses but only with catastrophic events, such as stellar close approaches.

2 - S. Fred Singer - University of Virginia, Charlottesville, Virginia, USA,

***Origin of the moon by tidal capture and some geophysical consequences*, Earth, Moon, and Planets, Springer, 5, 1-2, 1972**

Of the many proposed modes of origin of the Moon, some violate physical laws; many are in conflict with observations; all are improbable. Perhaps the least improbable - based on recent tidal theory calculations and on the interpretation of lunar rock data - is capture of the Moon as it passed near the Earth in a direct (prograde) orbit, shortly after the formation of Moon and Earth, about 4.5 billion years ago. (Capture of the Moon from an initially retrograde orbit as proposed some years ago, leads to physically unacceptable consequences.) The effects of capture on the Earth would have been cataclysmic, leading to intensive heating of its interior, to volcanism, and to the immediate formation of an atmosphere and hydrosphere. Thus capture of a Moon may have given rise to the unique properties of the Earth (in the Solar System) and to the early evolution of life, about 3.5 billion years ago.

3 - Gary Peterson, Ph.D. dissertation, San Diego State University,

Capture of the Moon, 2006

We were taught in introductory geology courses that the Moon was made of material that was ejected from the proto-earth some 4+ billion years ago, while Gary Peterson, the "Independent Planetologist", is proposing a different, perhaps controversial mechanism. To wit, he will set forth the hypothesis that the Moon is a planetesimal body that was gravitationally captured early in Earth history.

4 - Kiyoshi Nakazawa, Teruyoshi Komuro and Chushiro Hayashi,

Origin of the Moon. Capture by gas drag of the Earth's primordial atmosphere, Earth, Moon and Planets, Springer, 28, 3, 1983

We propose a new scenario of the lunar origin, which is a natural extension of planetary formation processes studied by us in Kyoto. According to these studies, the Earth grew up in a gaseous solar nebula and, consequently, the sphere of its gravitational influence (i.e., the Hill sphere of the Earth) was filled by a gas forming a dense primordial atmosphere of the Earth. In the later stages, this atmosphere as well as the solar nebula was dissipated gradually, owing to strong activities of the early-Sun in a T Tauristage. In the present and the subsequent papers, we study a series of dynamical processes where a low energy (i.e., slightly unbound) planetesimal is trapped within the terrestrial Hill sphere, under the above-mentioned circumstances that the gas density of the primordial atmosphere is gradually decreasing. It is clear that two conditions must be satisfied for the lunar origin: first, an unbound planetesimal entering the Hill sphere have to dissipate its kinetic energy and come into a bound orbit before it escapes from the Hill sphere and, second, the bound planetesimal never falls onto the surface of the Earth. In this paper we study the first condition by calculating the orbital motion of a planetesimal in the Hill sphere, which is affected both by solar gravity and by atmospheric gas drag. The results show that a low energy planetesimal with lunar mass or less can be trapped in the Hill sphere with a high probability, if it enters the Hill sphere at stages before the atmospheric density is decreased to about 1/50 of the initial value.

In the subsequent paper, the second condition will be studied and it will be shown that a tidal force, among other forces, is very important for a trapped planetesimal to avoid collision with the Earth and stay eternally in the Hill sphere as a satellite.

**5 - Antonio F B. de A Prado, Instituto Nacional de Pesquisas Espaciais
São José dos Campos, SP. Brazil**

Analytical and Numerical Approaches to Study the Gravitational Capture in the Four-Body Problem, Report July-September 2006, Vol. XXVIII, No. 3

The objective of this paper is to study the problem of gravitational capture in the bicircular restricted four-body problem. A gravitational capture occurs when a massless particle changes its two-body energy around one celestial body from positive to negative without the use of non-gravitational forces. We mainly study the effect of the fourth-body included in the dynamics. The Earth-Moon system with the inclusion of the Sun is used for the numerical simulations. The results show the savings obtained in this more realistic model when compared with the more traditional restricted three-body problem model. It is clear that large savings are obtained thanks to the effect of the Sun, if a proper geometry is used for the maneuver.

**6 - James K. Miller, Jet Propulsion Laboratory Report, CALTECH,
Pasadena, CA**

Lunar transfer trajectory design and the four-body problem, 1991

The existence of a ballistic trajectory from the Earth to orbit about the Moon was long considered to be impossible based on analysis of the three-body problem. In 1990 a ballistic trajectory from the Earth to lunar orbit was discovered while analyzing a plan to salvage the Muses A (Hiten) spacecraft. This trajectory utilized the Sun's gravity in conjunction with the Earth and Moon's gravity and was thus the first example of a practical four-body trajectory design. This paper presents a review of lunar transfer trajectories that go beyond three-body theory and the Jacobi integral. These include Hiten, Lunar A and the Genesis return trajectory from the vicinity of the Moon to Earth. It is shown that these trajectories may be analyzed by piecing together segments where three-body motion dominates.

**7 - Antonio Fernando Bertachini de Almeida Prado
Ernesto Vieira Neto, Instituto Nacional de Pesquisas Espaciais
São José dos Campos - SP - 12227-010 - Brazil**

The objective of this paper is to study the problem of gravitational capture in the regularized restricted three-body problem. A gravitational capture occurs

when a massless particle changes its two-body energy around one celestial body from positive to negative without the use of non-gravitational forces. We studied the importance of several of the parameters involved for a capture in the Earth-Moon system, including the time required for the capture and the effects of the periaapse distance. Then, we generalize those results for other binary systems, like the Sun -Earth, Sun -Mars and Sun - Jupiter systems. Next, we cover the whole interval of the mass parameter m (the mass ratio of the two primaries) and we study the gravitational capture in the interval $0.0 < m < 0.5$. The elliptical restricted problem is also considered as an option for the model.

8 - Jerry K. Cline

Satellite aided capture, Celestial Mechanics and Dynamical Astronomy, Springer, 19, 4, 1979

A two body, patched conic analysis is presented for a planetary capture mode in which a gravity assisted by an existing natural satellite of the planet aids in the capture. An analytical condition sufficient for capture is developed and applied to some planet/satellite systems: Earth/Moon, Jupiter/Ganymede, Jupiter/Callisto, Saturn/Titan and Neptune/Triton. Co-planar, circular planetary orbits are assumed. Three sources of bodies to be captured are considered: spacecraft launched from Earth, bodies entering the solar system from interstellar space, and bodies already in orbit around the Sun. Results show that the Neptune/Triton system has the most capability for satellite aided capture of those studied. It can easily capture bodies entering the Solar System from interstellar space. Its ability to capture spacecraft launched from Earth is marginal and can only be decided with better definition of physical properties. None of the other systems can capture bodies from these two sources, but all can capture bodies already in orbit around the Sun under appropriate conditions.

9 - R. R. Winters and R. J. Malcuit

The lunar capture hypothesis revisited, Earth, Moon, and Planets, Springer, 17, 4, 1977

Recent work on planetary formation processes has suggested that ancient planetary bodies could have been warmer and, therefore, more easily deformable soon after formation than at present. By use of the estimates for

the elastic parameters believed to be appropriate for a warm ancient Moon and Earth, it is shown that the energy of deformation of the planetary bodies during a close gravitational encounter was sufficient to effect capture.

10 - Adrian Brunini

Capture of planetesimals by the giant planets, Earth, Moon, and Planets, Springer, 71, 3, 1995

We investigate the possibility of gravitational capture of planetesimals as temporary or permanent satellites of Uranus and Neptune during the process of planetary growth. The capture mechanism is based on the enhancement of the Hill's sphere of action not only due to the mass acquired by the planet, but also by variation of the planet-Sun distance as a consequence of the scattering of planetesimals by the planets of the outer solar system. Our calculations indicate that satellite capture was very important, especially during the first stages of the accretion process, contributing in a significant way to the planetary growth.

11 - Adrian Brunini

On the satellite capture problem, Celestial Mechanics and Dynamical Astronomy, Springer, 64, 1-2, 1996

The stability and capture regions in phase space for retrograde and direct planetary satellites are investigated in the frame of the Circular Restricted Three-Body Problem. We show that a second integral of motion furnishes an accurate description for the stability limit of retrograde satellites. The distribution of heliocentric orbital elements is studied, and possible candidates to be temporary Jovian satellites are investigated. Previous results, limited to orbits satisfying the Mirror Theorem, are extended to give a complete set of capture conditions in phase-space.

12 - F. Szenkovits and Z. Makò, Astron. Dept. of the Eotvos Univ. Report, 2005

Pulsating zero velocity surfaces and capture in the elliptic restricted

three-body problem

Zero velocity surfaces are deduced in the gravitational restricted three-body problem by using the Jacobi integral. These surfaces are the boundaries of the Hill's regions: regions where the motion of the third, massless particle around the two primaries is possible. V. Szebehely generalized this result for the planar elliptic restricted three body problem. In a recent paper (Mak'ó and Szenkovits (2004)) the authors presented a generalization of this result for the spatial elliptic restricted three-body problem, where the existence of an invariant relation was proved. From this invariant relation the equation of the zero velocity surfaces can be deduced. In this paper we discuss the pulsation and the change of the type of these zero velocity surfaces and we present applications to the phenomenon of the gravitational capture. In the model of the spatial elliptic restricted three-body problem criteria of the capture are deduced by using the pulsating Hill's regions.

13 - O. C. Winter and E. Vieira Neto, Grupo de Dinâmica Orbital & Planetologia, UNESP, Guaratinguetá, CEP 12500-000, SP, Brazil, 2001

Time analysis for temporary gravitational capture

In a previous work, Vieira Neto & Winter (2001) numerically explored the capture times of particles as temporary satellites of Uranus. The study was made in the framework of the spatial, circular, restricted three-body problem. Regions of the initial condition space whose trajectories are apparently stable were determined. The criterion adopted was that the trajectories do not escape from the planet during an integration of 105 years. These regions occur for a wide range of orbital initial inclinations. In the present work we study the reason for the existence of such stable regions. The stability of the planar retrograde trajectories is due to a family of simple periodic orbits and the associated quasi-periodic orbits that oscillate around them. These planar stable orbits had already been studied (Hénon 1970; Huang & Innanen 1983). Their results are reviewed using Poincaré surface of sections. The stable non-planar retrograde trajectories, are found to be tridimensional quasi-periodic orbits around the same family of periodic orbits found for the planar case. It was not found any periodic orbit out of the plane associated to such quasi-periodic orbits. The largest region of stable prograde trajectories occurs at . Trajectories in such region are found to behave as quasi-periodic orbits evolving similarly to the stable retrograde trajectories that occurs at .

Neptune's capture of its moon Triton in a binary-planet gravitational encounter
Nature, 411, 192-194, 2006

Triton is Neptune's principal satellite and is by far the largest retrograde satellite in the Solar system (its mass is »40 per cent greater than that of Pluto). Its inclined and circular orbit lies between a group of small inner prograde satellites and a number of exterior irregular satellites with both prograde and retrograde orbits. This unusual configuration has led to the belief that Triton originally orbited the Sun before being captured in orbit around Neptune^{1–3}. Existing models for its capture^{4–6} however, all have significant bottlenecks that make their effectiveness doubtful. Here we report that a three-body gravitational encounter between a binary (of » 103-kilometre-sized bodies) and Neptune is a far more likely explanation for Triton's capture. Our model predicts that Triton was once a member of a binary with a range of plausible characteristics, including ones similar to the Pluto/Charon pair.

Acknowledgements

Thanks are due to Tom Van Flandern for discussion on this topic and to Marco fagone for first proposing to this author the idea of Mars as a former satellite of Earth.

Correspondence address:

Prof. Emilio Spedicato
emiliospedicato@gmail.com