THE EARTH-MOON SYSTEM

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ABSTRACT

The origin of the moon continues to be a lively area of discussion. A collision between a young, molten earth and a large planetesimal has become a popular explanation. After reviewing the traditional origin theories, the likelihood of lunar origin by collision will be examined. An upper limit on the age of the dynamical earth-moon system is also calculated. The result reveals a fundamental time conflict with secular views of the moon's history.

INTRODUCTION

The moon is earth's nearest neighbor in space. As a consequence, its age and history are connected closely with that of the earth. Theories for the moon's origin have proliferated over the years, especially since the Apollo moon landings. However, none of the origin theories have been very convincing, either to secular or creation scientists. Table I summarizes the four most popular lunar origin theories, together with their major problems. The problems fall into three major categories: **dynamical** - usually a conflict with the observed angular momentum of the earth-moon system; **chemical** - both differences and similarities between the compositions of the earth and moon; **probability** - an extremely low chance of occurrence. These three constraints on lunar formation have doomed every attempt to fit the moon into a self-generating, evolutionary history (1).

Origin Theory	Description	Major Problems
Fission	Moon tore loose from a rapidly spinning earth.	c, d
Capture	Moon formed elsewhere in the solar system, and later entered earth orbit.	c, d, p
Nebula Accretion	Moon formed close to the earth, from dust and rocky material.	c, d
Collision	A large object collided with the earth; fragments formed the moon.	p

Table I. Summary of four lunar origin theories. Major problems fall into three categories: chemical differences (c), dynamical conflicts (d), low probability (p).

Recently the collision theory of lunar origin has received wide publicity (2-5). Computer modeling has been used to describe an impact of a large object, called a

planetesimal, with a molten proto-earth. Further speculation results in the reformation of the earth with its present tilt, and subsequent moon formation from orbiting collision debris. The collision concept has not become popular because of any inherent ability to solve all of the basic lunar origin problems. Instead, the failure of other theories simply has caused lunar collision to fill the gap as an ad hoc idea, at least until a better origin scenario is developed. Two technical problems with the collision theory will be discussed here. Each problem in itself is sufficient to cast serious doubt on the collision theory.

MEAN FREE PATH AND TIME

The concept of mean free path is usually applied to gas molecules. However, it equally well can describe macroscopic planetary objects. The mean free path of a group of objects is the average distance traveled between individual collisions. This length (ℓ) is given by

$$\ell = \frac{1}{n\sigma} \qquad (1)$$

where n is the density of objects (number per cubic kilometer), and σ is the collision cross section (km^2). The mean free time between collisions, τ , is expressed by

$$\tau = \frac{\ell}{v} \qquad (2)$$

where v is the average speed of the objects. Parameter values can be chosen to estimate the likelihood of moon formation by a collision. A reasonable density n is based on 100 Mars-size objects moving randomly in a spherical region three billion miles in radius, the size of Neptune's orbit. In the evolutionary assumption of a chaotic, early solar system, a planar mass distribution has not yet developed. Ignoring gravitational effects, σ is just twice the cross sectional area of Mars, $2\pi r^2$, where r is the planet's radius. The speed v is taken from the orbital motion of Jupiter, a good average value for the solar system. The results follow:

$n = 2.63 \times 10^{-28}$ km^{-3}

$\sigma = 7.26 \times 10^{7}$ km^2

$v = 13.1$ km/sec

$\ell = 5.24 \times 10^{19}$ km

$\tau = 4 \times 10^{18}$ sec = 127 billion years

With one hundred planetary objects in random motion, one would thus expect **less** than a **single** collision per billion years. However, the lunar collision origin theory requires a violent interaction within the first few million years of solar system history, a one-in-a thousand chance. Clearly, the collision explanation for the moon's formation is no more credible than the previous failed theories. The improbability is compounded greatly by similar collision explanations for many other moons and planets in the solar system. The high density of Mercury, the backspin of Venus, the severe tilt of Uranus - all conveniently are explained by catastrophic collisions of early solar system objects.

MOON - EARTH SEPARATION

The gravity attraction between the earth and moon at their present separation distance is a stupendous force, 7×10^{19} pounds. There is also a large force differential between the earth's near and far sides from the moon, resulting in the daily tides. The earth's tidal distortion is illustrated in Figure 1.
Note that earth's tidal bulges actually occur somewhat East of the moon's location, since the land and seas do not respond instantly to the gravity force. The result of this delay is a continuous, slight forward pull on the moon. Consequently the moon slowly spirals outward from the earth, increasing its

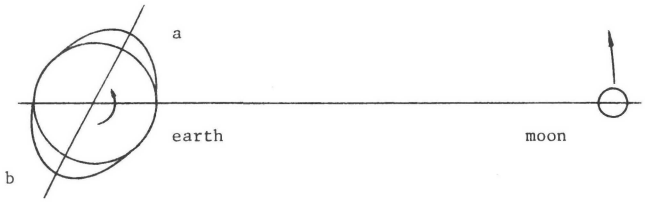

Figure 1. The moon's gravitational attraction results in tidal bulges a, b on the earth. The angle between the tidal bulges and the moon, actually 3°, is exaggerated for clarity. Arrows indicate earth's rotation and the moon's revolution.

distance at a present measured rate of about 4 centimeters per year. However this separation rate, dr/dt, is strongly dependent on the total earth-moon distance r,

$$\frac{dr}{dt} = \frac{k}{r^6} \qquad (3)$$

where k is a constant (6). The effect of this differential equation is shown in Figure 2.

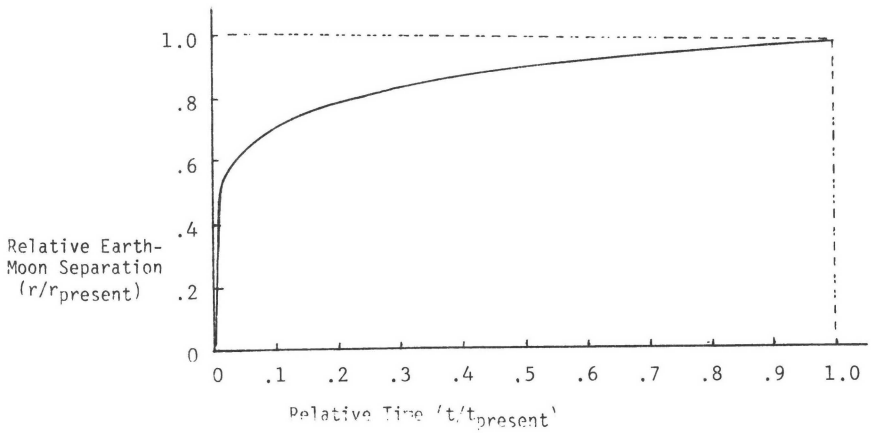

Figure 2. The relative earth-moon separation as a function of time. The steep curve in the past results from an r^{-6} dependency of the moon separation rate. Extrapolation shows that the moon would have physically contacted the earth about 1.4 billion years ago.

Assuming an original earth-moon contact by either collision or fission. There is a very rapid initial separation of the earth and moon. Such a close encounter, with resultant strong tidal heating, should have caused large-scale melting of

the earth and moon (7). Early lunar craters would also have been permanently distorted by the large lunar tide effects, since the largest impact basins on the moon are thought to have formed 4 billion years ago. However, evidence for such a close encounter is totally lacking. The earth and moon appear to have been widely separated from the beginning, in agreement with the creation view.

Solution of Equation (3) gives the backward extrapolated time t at which the moon would be in physical contact with the earth,

$$t = \frac{r_{e-m}}{7\frac{dr}{dt}} \qquad (4)$$

where r_{e-m} is the present earth-moon distance. Substitution gives

$$t = 1.37 \times 10^9 \text{ years}$$

This apparent time of moon origin is 70% less than the moon's assumed age of 4.6 billion years! Clearly, a large scale time problem exists for all secular moon origin theories. In contrast, Figure 1 shows that the earth-moon distance has not changed significantly over the past 10,000 years, only about one-half mile. On a recent creation time scale the earth-moon system shows great stability, and the close-approach problems are avoided.

FURTHER STUDY

If the moon was once close to us, angular momentum considerations require an initial rapidly spinning earth. Data which allegedly supports a shorter rotation period for the early earth need to be critically analyzed (8). Other solar system moons should also be moving outward from their planets due to tidal effects. If future measurements show this motion, especially for the Pluto-Chiron pair, then evolutionary time-scale problems abound throughout the solar system. If moons have indeed spiraled slowly outward from their planets, all intervening matter should have been gravitationally "swept up" and deposited on the moon surfaces. In particular, the observed rings of four planets (Saturn, Jupiter, Uranus, and Neptune) should not exist, since they all have orbiting moons well beyond their rings. Accretion of collision fragments into objects like the moon is an assumption that also needs critical study. For example, the asteroid belt is outside the sun's Roche Limit, yet has not coalesced into a planet. Our own moon and other planetary satellites within the solar system have much to tell us about solar system history.

CONCLUSION

Having given up on traditional lunar origin theories, many scientists now are promoting a collision between the early earth and a Mars-size object. However, fundamental problems remain, including the small probability of collision and also the short upper-limit on earth-moon history, approximately 1.4 billion years. The origin of our beautiful natural satellite, the moon, remains unexplained by contemporary science.

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DISCUSSION

Dr. DeYoung focuses upon two continuing problems with lunar formation theories. The first applies only to the relatively recent collision theory -- the probability of such a collision is too low. Unfortunately, his mean-free-path treatment is not convincing for three reasons. He ignores gravity, which would increase the impact parameter and make a better case for collisions, his assumption of 100 Mars-sized objects with in Neptune's orbit seems somewhat arbitrary, and the assumption of chaotic motion is not in accord with current solar system formation theories. When such an analysis still allows a one in a thousand chance of collision, we cannot say that the collision theory has been falsified. The second problem facing evolutionary theories is the lack of evidence for lunar recession over the last 4.5 billion years, a criticism not yet satisfactorily answered by astronomers.

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CLOSURE

I thank Mr. Paul Steidl for his interaction. Gravity has not been fully ignored in the discussion: the planetesimals are gravitationally bound within a Neptune-sized orbit. Gravity between particles is neglected, and is justified in view of the speeds involved. The 100 Mars-sized objects are certainly arbitrary. However, it is a generous concession, since planets are already assumed to have formed. Any refinements will surely lower the probability of lunar origin by collision. Early chaotic motion is a part of current solar system views. This arises from the many extreme dynamical properties of the planets.

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