Theories Of The Origin Of The Moon Essay, Research Paper

The Moon is the only natural satellite of Earth. The distance from Earth

is about

384,400km with a diameter of 3476km and a mass of 7.35\*1022kg. Through

history it has had many names: Called Luna by the Romans, Selene and

Artemis

by the Greeks. And of course, has been known through prehistoric times.

It is

the second brightest object in the sky after the Sun. Due to its size and

composition, the Moon is sometimes classified as a terrestrial "planet"

along with

Mercury, Venus, Earth and Mars.

Origin of the Moon

Before the modern age of space exploration, scientists had three major

theories for the origin of the moon: fission from the earth; formation in

earth

orbit; and formation far from earth. Then, in 1975, having studied moon

rocks

and close-up pictures of the moon, scientists proposed what has come to be

regarded as the most probable of the theories of formation, planetesimal

impact

or giant impact theory.

Formation by Fission from the Earth

The modern version of this theory proposes that the moon was spun off from

the earth when the earth was young and rotating rapidly on its axis. This

idea

gained support partly because the density of the moon is the same as that

of

the rocks just below the crust, or upper mantle, of the earth. A major

difficulty

with this theory is that the angular momentum of the earth, in order to

achieve

rotational instability, would have to have been much greater than the

angular

momentum of the present earth-moon system.

Formation in Orbit Near the Earth

This theory proposes that the earth and moon, and all other bodies of the

solar

system, condensed independently out of the huge cloud of cold gases and

solid

particles that constituted the primordial solar nebula. Much of this

material

finally collected at the center to form the sun.

Formation Far from Earth

According to this theory, independent formation of the earth and moon, as

in

the above theory, is assumed; but the moon is supposed to have formed at a

different place in the solar system, far from earth. The orbits of the

earth and

moon then, it is surmised, carried them near each other so that the moon

was

pulled into permanent orbit about the earth.

Planetesimal Impact

First published in 1975, this theory proposes that early in the earth’s

history,

well over 4 billion years ago, the earth was struck by a large body called

a

planetesimal, about the size of Mars. The catastrophic impact blasted

portions

of the earth and the planetesimal into earth orbit, where debris from the

impact

eventually coalesced to form the moon. This theory, after years of research

on

moon rocks in the 1970s and 1980s, has become the most widely accepted

one for the moon’s origin. The major problem with the theory is that it

would

seem to require that the earth melted throughout, following the impact,

whereas

the earth’s geochemistry does not indicate such a radical melting.

Planetesimal Impact Theory (Giant Impact Theory)

As the Apollo project progressed, it became noteworthy that few scientists

working on the project were changing their minds about which of these three

theories they believed was most likely correct, and each of the theories

had its

vocal advocates. In the years immediately following the Apollo project,

this

division of opinion continued to exist. One observer of the scene, a

psychologist,

concluded that the scientists studying the Moon were extremely dogmatic and

largely immune to persuasion by scientific evidence. But the facts were

that the

scientific evidence did not single out any one of these theories. Each one

of them

had several grave difficulties as well as one or more points in its favor.

In the mid-1970s, other ideas began to emerge. William K. Hartmann and D.R.

Davis (Planetary Sciences Institute in Tucson AZ) pointed out that the

Earth, in

the course of its accumulation, would undergo some major collisions with

other

bodies that have a substantial fraction of its mass and that these

collision would

produce large vapor clouds that they believe might play a role in the

formation of

the Moon. A.G.W. Cameron and William R. Ward (Harvard University,

Cambridge MA) pointed out that a collision with a body having at least the

mass

of Mars would be needed to give the Earth the present angular momentum of

the

Earth-Moon system, and they also pointed out that such a collision would

produce a large vapor cloud that would leave a substantial amount of

material in

orbit about the Earth, the dissipation of which could be expected to form

the

Moon. The Giant Impact Theory of the origin of the Moon has emerged from

these suggestions.

These ideas attracted relatively little comment in the scientific community

during

the next few years. However, in 1984, when a scientific conference on the

origin

of the Moon was organized in Kona, Hawaii, a surprising number of papers

were

submitted that discussed various aspects of the giant impact theory. At the

same

meeting, the three classical theories of formation of the Moon were

discussed in

depth, and it was clear that all continued to present grave difficulties.

The giant

impact theory emerged as the "fashionable" theory, but everyone agreed that

it

was relatively untested and that it would be appropriate to reserve

judgement on

it until a lot of testing has been conducted. The next step clearly called

for

numerical simulations on supercomputers.

?The author in collaboration with Willy Benz (Harvard), Wayne L.Slattery at

(Los

Alamos National Laboratory, Los Alamos NM), and H. Jay Melosh (University

of

Arizona, Tucson, AZ) undertook such simulations. They have used an

unconventional technique called smooth particle hydrodynamics to simulate

the

planetary collision in three dimensions. With this technique, we have

followed a

simulated collision (with some set of initial conditions) for many hours of

real

time, determining the amount of mass that would escape from the Earth-Moon

system, the amount of mass that would be left in orbit, as well as the

relative

amounts of rock and iron that would be in each of these different mass

fractions.

We have carried out simulations for a variety of different initial

conditions and

have shown that a "successful" simulation was possible if the impacting

body had

a mass not very different from 1.2 Mars masses, that the collision occurred

with

approximately the present angular momentum of the Earth-Moon system, and

that the impacting body was initially in an orbit not very different from

that of the

Earth.

?The Moon is a compositionally unique body, having not more than 4% of its

mass in the form of an iron core (more likely only 2% of its mass in this

form).

This contrasts with the Earth, a typical terrestrial planet in bulk

composition,

which has about one-third of its mass in the form of the iron core. Thus, a

simulation could not be regarded as ?successful? unless the material left

in orbit

was iron free or nearly so and was substantially in excess of the mass of

the

Moon. This uniqueness highly constrains the conditions that must be imposed

on

the planetary collision scenario. If the Moon had a composition typical of

other

terrestrial planets, it would be far more difficult to determine the

conditions that

led to its formation.

The early part of this work was done using Los Alamos Cray X-MP computers.

This work established that the giant impact theory was indeed promising and

that

a collision of slightly more than a Mars mass with the Earth, with the

Earth-Moon

angular momentum in the collision, would put almost 2 Moon masses of rock

into

orbit, forming a disk of material that is a necessary precursor to the

formation of

the Moon from much of this rock. Further development of the hydrodynamics

code made it possible to do the calculations on fast small computers that

are

dedicated to them.

Subsequent calculations have been done at Harvard. The first set of

calculations

was intended to determine whether the revised hydrodynamics code reproduced

previous results (and it did). Subsequent calculations have been directed

toward

determining whether "successful" outcomes are possible with a wider range

of

initial conditions than were first used. The results indicate that the

impactor must

approach the Earth with a velocity (at large distances) of not more than

about 5

kilometers. This restricts the orbit of the impactor to lie near that of

the Earth. It

has also been found that collisions involving larger impactors with more

than the

Earth-Moon angular momentum can give "successful" outcomes. This initial

condition is reasonable because it is known that the Earth-Moon system has

lost

angular momentum due to solar tides, but the amount is uncertain. These

calculations are still in progress and will probably take 1 or 2 years more

to

complete

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