CALCULATING THE LUNAR ORBIT ANOMALY. L. M. Riofrio, Sailorstarfightr@yahoo.com

Introduction: Studies of the Moon, corroborated by recent numerical simulation, have confirmed a large anomaly in lunar orbital evolution. The Lunar Laser Ranging Experiment (LLRE) reports the Moon's semimajor axis increasing at *3.82±.07 cm/yr,* anomalously high. Tidal data indicates a recession rate of only *2.9 ± 0.6 cm/yr.* Eclipse observations independently measure a recession rate of *2.82 ± .08 cm/yr.* Detailed numerical simulation predicts *2.91 cm/yr*. A cosmology where speed of light c is related to time t by $GM = tc^3$ has been suggested to predict the redshifts of Type Ia supernovae. By this hypothesis, lunar orbital distance would appear to increase an additional *0.935 cm/yr.* An anomaly in the lunar orbit may be precisely accounted for, shedding light on speculations of ``dark energy."

Lunar Orbit Anomaly: The Moon has long been known to be slowly drifting from Earth due to tidal forces. As the Moon raises tides on Earth, tidal bulges travel ahead of the Moon due to Earth's 24-hour rotation. A tidal bulge pulls the Moon slightly ahead in its orbit, and causes Earth's rotation rate to slow. In this way angular momentum is transferred from Earth's rotation to the Moon, causing the Moon's semimajor axis to increase.

The Lunar Laser Ranging Experiment bounces light off corner reflectors left on the Moon by Apollo astronauts. Previously LLRE has been used to investigate geophysics of the Earth-Moon system and test Relativity. Accuracy is considered fine enough to constrain changes in Newton's gravitational constant *G.* LLRE has measured the Moon's semimajor axis at $a = 384,402 km$. Repeated measurements appear to indicate that distance increasing *3.82 ± 0.7 cm/yr,* anomalously high. [1] If the Moon were gaining angular momentum at this rate, it would have coincided with Earth less than *2 Gyr* ago. Our studies of lunar samples convincingly show that the Moon has existed separately from Earth for over 4.5 Gyr.

Tidal Rhythmites: Geology and paleontology can also tell how the Moon's distance has changed. Tidal rhythmites, in particular, carry a record of lunar-induced tides. Sedimentary layers may be left on a daily and diurnal frequency. Thicknesses of sedimentary layers vary with the height of local tides. Rhythmites can be used to determine lunar distance over hundreds of millions of years.

Starting with today's LLRE measurement, we may compile estimates of lunar orbital distance based on rhythmites. [2]

Sediment Location	Age 10^3 yr	Distance 10^3 km
Present	0	384.4
Mansfield	310±5	375.3±1.9
Elatina	620±100	370.9±0.1

The Mansfield sediment of Indiana, the most recent, places the *Moon 375,300 ± 1,900 km* away 310 Myr ago, a recession rate of *2.9 ± 0.6 cm/yr*. An independent study of the Elatina and Reynella tidal rhythmites also indicates a lower recession rate. [3]

Eclipse Records: Corroborating data may have come from historical astronomers. If the narrow track of total eclipse is recorded over an observatory, it provides an accurate measure of Earth's slowing rotation rate. As Earth and Moon form a closed system, this tells us how much angular momentum has been transferred. A recession rate of *3.82 ± 0.7 cm/yr* corresponds to change in Earth's length of day of *2.30 msec/cyr.* Observations spanning 2700 yr show change in LOD of 1.70 ± *.05 msec/cyr,* corresponding to a lunar recession of *2.82 ± 0.08 cm/yr.* [4]

Numerical Simulation: Transfer of angular momentum between Earth and Moon is subject to many variables. These include depth of oceans, location of ocean basins, and the slow movement of continents over time. Recently a detailed numerical simulation of lunar orbital evolution has been made which accounts for these factors. The simulation has been successfully used to predict the height of today's tides. According to numerical simulation, some quantities previously considered as constants may be treated as variables. [5] The simulation predicts for today a recession rate of *2.91 cm/yr*, in agreement with tidal and eclipse data. LLRE's laser light differs by over *12δ.*

Speed of Light: As with Mercury and the moons of Jupiter, anomalies in orbits may have implications for Physics. One theory suggests that speed of light *c* is related by:

$$GM = tc^3$$

Where t is age of the Universe, GM combines its mass and gravitational constant. [6]

Solving, we would have:

$$c(t) = (GM)^{1/3} t^{-1/3}$$

Time for light to return would increase yearly, making the Moon appear to recede faster as measured by LLRE.

This model has previously been suggested to predict "accelerating" redshifts of Type Ia supernovae. It may also be used to model features seen in the cosmic microwave background, predicting a 4.507034% proportion of baryonic matter.

Apparent anomaly in lunar distance would then be proportional to change in *c:*

$$\frac{\dot{a}}{a} = -\frac{\dot{c}}{c} = \frac{1}{3t}$$

Multiplied by the Moon's semimajor axis, that distance would appear to increase an additional *0.935 cm/yr.* Theory precisely accounts for the *12σ* anomaly.

Discussion: When scholars disagreed whether light traveled instantaneously or had a finite speed. Galileo suggested measuring the velocity of light with lanterns placed on distant hilltops, but lacked an accurate clock. Ole Roemer used observations of Jupiter's moons to first measure the finite speed of light. Today we have laser lanterns and the distant hilltop of the Moon. The Lunar Laser Ranging Experiment, considered highly accurate, may reveal possible variation in *c*.

The *2.9 ± 0.6 cm/yr* recession rate found in Mansfield sedimentary data has been attributed to anomalous tides over many millions of years, an inference that is not independently verified. The lower recession rate is verified by the more precise *2.82 ± 0.08 cm/yr* found from eclipse data. An anomaly in eclipse records just *2700 yr* old is convincingly non-tidal in origin. Corrected for the speed of light, lunar recession rate would be *2.88 ± 0.07 cm/yr*. This value is in agreement with sedimentary data, eclipse records and the Moon's geologic age.

A predicted change in the speed of light may have been seen in redshifts of Type Ia supernovae. Rather than acceleration, redshifts may show signs of *c* slowing. Supernova observations may closely corroborate lunar data.

The speed of light has been a subject of speculation since at least the first Lord Kelvin [7]. More recently by Moffat [8], Albrecht and Maguiejo [9]. More accurate measurements of *c* will soon be possible with the Atomic Clock Ensemble in Space (ACES) aboard ISS. Experiments involving the Sun, Moon and supernovae, when viewed together, may indicate a "*c* change" in physics. In Planck units $GM = tc^3$ may be expressed as $M = R = t$.

This work was assisted by NASA. Great thanks are due to colleagues at the ARES group in Johnson Space Center, Houston.

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