ASTROPHYSICS FOR A WARM, WET EARLY MARTIAN ATMOSPHERE

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Introduction:
The “Faint Young Sun” has posed a problem for Mars atmosphere models. Models of the Sun’s evolution predict that at about 4.5 Gyr ago Mars was too cold for liquid water. Today’s observations indicate the presence on early Mars of extensive water flows and possibly oceans. Meteorite data indicates conditions suitable for life. Geological and paleontological history of Earth also conflicts with solar models. A solution may be in the speed of light. The paradox and theoretical solution combine astrophysics, Relativity and planetary science.

Faint Young Sun:
The standard solar model predicts that about 4.5 Gyr ago the Sun shone with about 70 percent of its present power. Because power, *P,* is related to temperature, *T,* by the Stefan-Boltzmann law, $P \propto \sigma T^4$, planetary temperatures would have been about 91 percent of present value. Mars average temperature today is about 218K, so temperature in the past would have been only 199K. Any surface water on Mars or Earth would have been frozen solid.

Spacecraft like the Mars Reconnaissance Orbiter (MRO) have mapped Mars’ surface in detail. Mapping shows many features characteristic of water flow, such as alluvial fans and riverbeds. Other features have been interpreted as the shoreline of an ancient ocean nearly 3.5 Gyr old[i]. These multiple indicators show a “warm, wet” early Mars.

Martian meteorites examined at Johnson Space Center show evidence that early Mars had conditions suitable for life. The oldest, ALH84001, is over 4 Gyr old. This meteorite has shown several indicators of microbial life[ii]. Carbonates, which have also been found by the Spirit Rover, are another sign of warmer conditions[iii]. Biomarkers are indicators that early Mars was not completely frozen.

Geology of Earth shows evidence of extensive sedimentation before 4 Gyr ago, indicating the presence of rivers and seas. The earliest Earth organisms are at least 3.4 Gyr and possibly over 4 Gyr old. Liquid water and life both existed when models predict Earth and Mars were frozen solid. This conflict of model with observations is the Faint Young Sun paradox.[ivvvivii]

A much higher concentration of carbon dioxide has been suggested [viiiix] to create higher temperatures, but there is no direct geological evidence for this. Studies of iron carbonates[x] show that Earth had at most 20 percent of the required amount of CO_2. On Mars, such a dense CO2 layer would be unstable, quickly leaking into Space. A hypothesis of CO2 heating has presented a significant challenge for Mars atmosphere modelers[xi].

Hot Young Solution:
Relativity and new physics may help save the standard solar model. The Sun converts fuel to energy according to $E = mc^2$. One Theory predicts that *c* is related to *t* by:

$$GM = tc^3$$

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

Solving for *c*, we would have:

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

Billions of years ago, solar output and temperature therefore may have been higher than once thought.

Mars and Earth are estimated to be 4.6 Gyr and the Universe 13.7 Gyr old, 1.5 times its age at Solar System formation. Energy mc^2 is adjusted by: $(1.5)^{2/3} = 1.31$. From an initial estimate of 70 percent, the Sun’s actual output was 0.92 of the present luminosity. Planetary temperatures were then $(0.92)^{1/4} = 98$ percent of today’s temperature. If we start with an estimate of 76 percent, solar luminosity was exactly the present value. The “solar constant” may indeed be nearly constant. If *c* had not changed in precisely the amounts predicted, life might not have appeared on Earth’s surface.

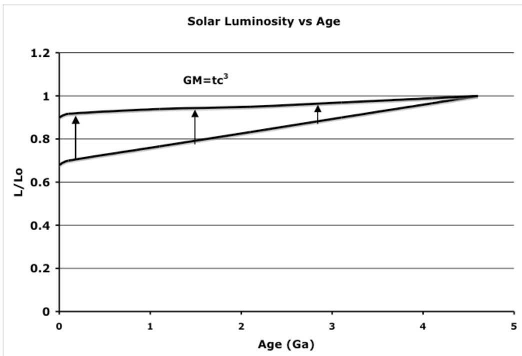

Fig. 1: Solar luminosity vs. solar system age. L/L_0 is luminosity as a fraction of present value. Lower line is standard solar model. Upper line indicates luminosity when *c* change is a factor. If speed of light *c* is precisely related to Universe age *t* by $GM = tc^3$, luminosity remains nearly constant.

Supernovae:
The speed of light may play a part in a puzzle of distant exploding stars. Since the time of Edwin Hubble, we have known the Universe to be expand-

ing because redshifts of objects increase linearly with distance. When observations are extended to distant Type Ia supernovae, higher redshifts mysteriously curve upward. This has led to speculation about acceleration and repulsive energies. Redshifts are roughly proportional to an object's velocity v divided by c. Redshifts would curve upward if the universe does not accelerate, but c slows down. Theory's prediction curve matches supernova data precisely. Low redshifts increase linearly with distance, but starting near redshift of 0.1 they increase non-linearly. Applied to our solar system, supernova data may also indicate that billions of years ago stellar luminosity was higher than once thought.

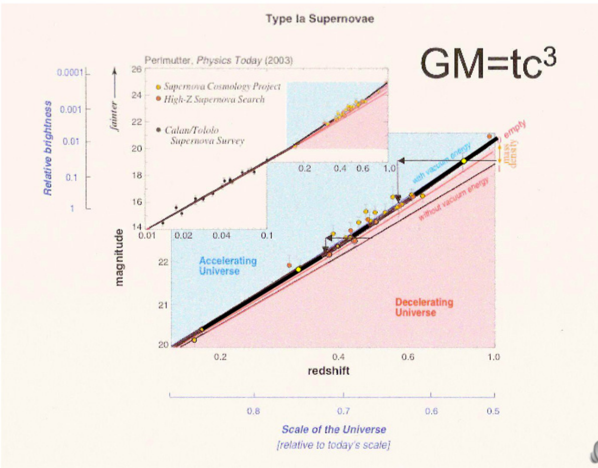

Fig. 2: Courtesy Supernova Cosmology Project. Magnitude vs. redshift for Type Ia supernovae. Apparent magnitude is proportional to log10 of distance. Low redshifts increase linearly with magnitude, indicating Hubble expansion. Object of redshift 1.0 recedes at 60 percent of today's speed of light, which is 42 percent of c at time light was emitted. Measured redshift is 0.57 *(horizontal arrow).* Supernova energy output is doubled, for a magnitude change of -.75 *(vertical arrow).* Black prediction curve precisely fits supernova data, both low redshifts that increase linearly and high redshifts that increase non-linearly.

Lunar Orbit Anomaly:

Another line of evidence comes from Apollo journeys to the Moon. Our Lunar Laser Ranging Experiment (LLRE) has reported the Moon's semimajor axis increasing at *3.82 ±.07 cm/yr,* anomalously high. The Moon is known to be receding due to tidal forces transferring angular momentum from Earth. If the Moon were gaining momentum at this rate, it would have coincided with Earth less than 2 Gyr ago. Earth's sedimentation record indicates that the Moon's average recession rate over the past 310 million years is much less. Eclipse records corroborate a slower recession rate.

Starting with today's LLRE measurement, Bills and Ray[xiii] have compiled estimates of lunar orbital distance from sedimentary data:

Sediment Location	Age 10^6 yr	Distance 10^3km
Present	0	384.4
Mansfield	310±5	375.3±1.9
Elatina	650±100	357.1±0.1
Cottonwood	900±100	350.9±4.6

Table 1: Estimates of lunar orbital distance from sedimentary data. Adapted from Bills, Ray (1999.)

Mansfield, the most recent and accurate datum, indicates that the Moon has been receding at only *2.9 ± 0.6 cm/yr.* As with planet Mercury, discrepancies in orbits can be very significant.

Corroborating evidence may come from historical eclipse records. If the narrow track of total eclipse has been reported over an observatory, it provides an accurate measure of rotation rate. Since Earth and Moon form a closed system, this tells how much angular momentum has been transferred. Eclipse records[xiv] correspond to a lunar recession rate of 2.82 ± .08 cm/yr, matching the Mansfield datum. LLRE differs from two independent data sets by over 10σ.

If the speed of light slows, time for light to return would increase each year, making the Moon appear to recede faster as measured by LLRE. Predicted change in c today is 1 in 41.1 Gyr. Multiplied by the Moon's distance of 384,402 km, that distance will appear to increase an additional *0.935 cm* per year. An anomaly in the Moon's orbit is precisely accounted for, indicating that c slows to this day.

Conclusion:

The solution to a Mars mystery may be seen in the light of the Sun. Images from spacecraft indicate that early Mars had flowing water. Martian meteorites indicate conditions suitable for life. If the speed of light c, and in turn solar luminosity, were greater the problem of Mars' temperature would be greatly simplified.

The speed of light has been subject of speculation since at least the time of Thomson (Lord Kelvin)[xv]. More recently changing c has been independently promoted by Moffatt[xvi], Albrecht and Maguiejo[xvii] Some experiments suggest that the fine-structure constant α may also change, though in these calculations α is considered constant. The Sun, Moon and planets provide additional data points to supplement supernova data from a more distant past. In conclusion, the "Faint Young Sun" does not pose a problem but provides a window from planetary science to astrophysics and cosmology. The speed of light may greatly simplify problems of Mars' early atmosphere. In Planck units, $GM = tc^3$ may be combined with scale $R = ct$ as: $M = R = t$

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