The Proceedings of the International Conference on Creationism

Volume 2
Print Reference: Volume 2:II, Pages 47-52

Article 40

1990

A Study of Roemer's Method for Determining the Velocity of Light

Eugene F. Chaffin
Bluefield College

A STUDY OF ROEMER'S METHOD FOR DETERMINING THE VELOCITY OF LIGHT

EUGENE F. CHAFFIN
BLUEFIELD COLLEGE
BLUEFIELD, VA 24605

ABSTRACT

Data taken by the author during August to December 1988 on eclipses of the first major satellite of Jupiter are compared with data taken by Roemer and Picard 300 years ago. Both sets of data are analyzed by the same method, or as nearly the same as possible, to determine whether the speed of light has changed. The conclusion depends on, and is rather sensitive to, whether or not Io's mean daily motion has changed in the 300 years.

INTRODUCTION

In the late 1600's Cassini, Roemer, Picard and other astronomers at the Paris observatory accurately recorded times of ingresses and egresses of Io (the first major satellite of Jupiter) into and out of Jupiter's shadow. Since Cassini and other prominent European scientists held that the speed of light was infinite, Roemer's use of these eclipse data to find the time required for light to cross an astronomical unit caused great controversy. In Roemer's day the astronomical unit was not known accurately, hence Roemer avoided giving a value for the speed of light, instead announcing a value of 11 minutes for the time for light to cross an astronomical unit. By today's standards, this value is too large, mainly because Roemer did not have an accurate value for the mean daily motion, n_1, of Io, and because Newton's Principia was not yet published and an accurate theory of the perturbations of Io caused by Europa (the second major Jovian moon) did not yet exist.

Study has shown that Io's mean daily motion differs from twice the mean daily motion of Europa by a value of only 0.8 degrees per day (Greenberg, Goldstein, and Jacobs, 1986). Europa forces Io to have different speeds at different points in its nearly circular orbit. The equatorial bulge of Io nods back and forth due to competition between Jupiter's gravitational pull and this resonance with Europa. Tremendous tidal friction and heating are produced inside Io. The Voyager spacecraft discovered active volcanoes on Io. The Io-Europa resonance also involves Ganymede (the third major Jovian moon), but the effect of Ganymede on Io is smaller than that of Europa. A perturbation of Io's longitude is produced by Europa, whose amplitude is approximately half a degree and whose angular frequency is approximately twice the difference between the mean daily motions of Io and Europa (Goldstein 1975).

There are two major reasons why a creationist might extract useful information from a study of Roemer's data. One is the possibility that the speed of light has changed. Setterfield 1987 and Troitskii 1987 discuss this possibility. Another is the fact that the data could reveal a value for the change in Io's orbital period for the last 300 years, and that coupled with theory can be used to estimate the amount of energy loss caused by tidal heating inside Io. If the tidal heating is significantly less than the measured infrared heat flux (which seems to be the case according to studies by Lieske 1987), then that would speak in favor of a young solar system which has not had time to cool.

MODERN DATA COMPARED TO ROEMER'S DATA

To provide a group of control data, the author personally observed ingresses and egresses of Io into Jupiter's shadow from August 1988 to the present. A six inch Newtonian reflector telescope was used to observe Jupiter, and the audible tones from National Bureau of Standards radio station WWV were used (counted) as a clock. The WWV tones have an accuracy of better than one second over the years it has operated, broadcasting universal coordinated time (UTC). For ingresses of Io into Jupiter's shadow, Io was watched until it disappeared (and also the area was observed for a half minute or so afterwards, to be certain that it was really gone). For egresses, observation was made from a few minutes before the expected egress until well after Io appeared. The WWV tones were simultaneously noted in order to determine the exact time of these events. My data are given in Table I.

TABLE I. 1988 DATA ON ECLIPSES OF IO

Coordinated Universal Time of Event (UTC)		Ingress (i) or Egress (e)
August 12	9:46:06	i
September 20	8:14:40	i
September 27	10:08:33	i
September 29	4:37:21	i
October 6	6:31:40	i
October 13	8:25:25	i
October 15	2:54:30	i
October 29	6:43:33	i
December 7	7:23:35	e
December 25	0:11:19	e

A computer program was written to evaluate the parameters L_0, L_2, and L_3 of the perturbation in longitude of Io caused by Europa. These are essentially the same parameters as defined by Goldstein 1975. The results of the program for both the 1988 data (ten points) and the Roemer-Picard data (using 19 of the best points recorded in Goldstein et al. 1973) are presented in Table II. The mean daily motion parameter L_1 was held constant at the value reported by Goldstein 1975 by slightly adjusting the perturbation frequency ω. Following Goldstein 1975, I took into account the 48.6 degrees/year precession of Io's orbit (which is inclined by only 2 arc minutes to Jupiter's equator) by slightly adjusting the inclination angle i of Io's orbit to the plane of Jupiter's orbit. The Roemer-Picard data were relatively insensitive to this inclination angle i, hence I adopted Goldstein's value of 3.06752 degrees. The 1988 data were more sensitive to this parameter, since they are only spread over some five months, and Jupiter's equator was inclined during this period by the maximum amount possible relative to Earth. The value of 3.12 degrees gave the best fit for the 1988 data.

TABLE II. PARAMETERS FOR THE PERTURBATION IN IO'S LONGITUDE CAUSED BY EUROPA

Data	L_0(deg.)	L_1(deg./day)	L_2(deg.)	L_3(deg.)	(rad/day)
Roemer-Picard	-.11934	203.488959	-.11263	.47268	3.56462
1988	.25698	203.488959	-.24090	.43715	3.56410

The data for the longitude and distances of Jupiter were taken from the Astronomical Almanac for 1988 (Washington, W.S. Government Printing Office). Figure 1 illustrates the angular relations between Io's orbit and Jupiter's orbit. Figure 2 illustrates the spherical triangle formed by w = the true anomaly of the Jupiter, i = the inclination of Io's orbit to the plane of Jupiter's orbit, l = longitude of Io from its ascending node, and λ = the latitude of the antisolar point. The following equation follows from the spherical trigonometry:

$$l = \tan^{-1}\left[\frac{\tan(w - w_0)}{\cos(i)}\right] \quad (1)$$

Having determined L_0, L_2, and L_3, a second computer program was written to accept as input the speed of light and use it to calculate the time of ten successive eclipses. Then the program calculated the sum of the squares of the differences between theoretical and observed times, in seconds. Then I ran the program for several values of the speed of light. The results are in Table II. As can be seen from the values in the table, the 1988 data are consistent with the modern value of the speed of light, 2.99792458×10^8 meters/second, the sum of the squares of the residuals being smallest in that case. This provides a control, indicating that the methodology is most consistent with a value of 3.2×10^8 meters/second, which is 6.7% larger than the modern value. For various reasons, I expected this work to prove that the speed of light was the same in the 1670's as today, but this is apparently not the outcome.

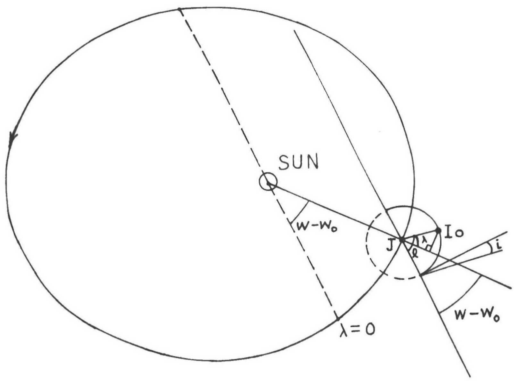

Figure 1. The orbits of Jupiter and Io, showing the angles involved. W is the true anomaly of Jupiter, while W_0 is the true anomaly of the position in jupiter's orbit where the latitude λ, of the antisolar point is zero. l is the longitude of Io in its orbit, measured from its ascending node. i is the inclination of Io's orbit to the plane of Jupiter's orbit.

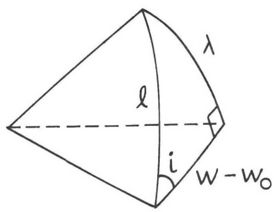

Figure 2. The spherical triangle formed by the angles defined in Figure 1.

TABLE III. RESULTS SHOWING THE SUM OF THE SQUARES OF THE RESIDUALS IN SECONDS VERSUS THE ASSUMED SPEED OF LIGHT

Speed of Light (m/sec)	Data	Sum of the Squares of the Residuals
2.8×10^8	1988	10001.050
2.9979×10^8	1988	1603.279
3.05×10^8	1988	1974.113
3.1×10^8	1988	3154.281
3.2×10^8	1988	7633.448
2.8×10^8	Roemer-Picard	32736.34
2.9979×10^8	Roemer-Picard	27680.10
3.05×10^8	Roemer-Picard	27020.43
3.1×10^8	Roemer-Picard	26603.55
3.2×10^8	Roemer-Picard	26330.78
3.3×10^8	Roemer-Picard	26698.16
3.5×10^8	Roemer-Picard	28932.33

IS IO'S PERIOD CONSTANT?

It should be noted that Goldstein 1975 and Jacobs 1986 concluded that Io's mean daily motion increased from 203.48892 degrees/day in the 1670's to 203.488959 degrees/day in the twentieth century. However, this is controversial since Lieske 1987, on the basis of extensive modelling of Voyager data, Lunar Ranging Laser Data, as well as modern and medieval eclipse data of Jovian satellites concluded that Io's mean daily motion decreased rather than increased. The result is strongly dependent on the theory adopted for the correction between universal time and ephemeris time. Universal time essentially uses the Earth's rotation rate as a clock, whereas it is known that the Earth's rotation rate is variable. Ephemeris time is based on planetary orbital motion, and is expected to give a uniform rate. These differences are not so important in comparing time changes over, say, the 10 or so years of the Roemer-Picard observations, but they are important over the 300 year gap between then and now. In particular, they effect the value of the mean daily motion that emerges from the Roemer-Picard data.

Because of the above mentioned controversy, I felt free to adopt the present value, n_1, of the mean daily motion of Io, rather than Goldstein's value for the 1670 epoch, which is 1.9×10^{-5} per cent smaller. This would seem to be proper methodology, since differences in the data ascribed by Goldstein et al. to changes in the period of Io might really be due to changes in the speed of light. However, when Goldstein's value n_1 = 203.48892 degrees per day is used, the situation actually got worse, the data giving the best results for a speed of light equal to 3.5 x 10^8 meters per second.

One might adopt the viewpoint that Lieske is right, and the value of n_1 in the past was larger rather than smaller. However, Lieske 1987 gave $\dot{n}_1/n_1 = -0.74 \pm .87 \times 10^{11}$ per year, and although the sign is now correct, the amount is now too small. The 1670's data still support a value for the speed of light larger than at present, about 3.2 x 10^8 meters/sec.

But suppose that Lieske was too conservative, and the value of $\dot{n}_1/n_1$ was larger in absolute value than he concluded. Then it would be possible to conclude that the speed of light 300 years ago was the same as today. The model must then allow tides raised on Jupiter by Io to be significant, in order to provide the torque, (Jupiter's reaction back on Io) necessary for this change. The long term average tidal dissipation rate inside Io must then be relatively small, too small to account for the measured high heat flux coming from Io. The conventional literature could not accept this situation without an abnormally high amount of radioactive material inside Io, to generate the extra decay heat needed to balance the energy equation. But young Earth creationism could readily accept this situation, since in a 6000 year old solar system there would not have been much time for crustal heat loss rates on Io to have dropped. This alternative thus also seems to support the young Earth position, as does the variable speed of light alternative.

CONCLUSION

The possibility of the speed of light changing with time has interesting implications with regard to the age of the universe. Goldstein, Trasco, and Ogburn 1973 analyzed data taken by Roemer and Picard in the late 1600's and concluded that the speed of light had not changed by more than 0.5% if at all. But later work--Goldstein 1975--increased the margin of error to 2.6% The purpose of this work was to analyze the sources of error to understand and present the results from a creationist's standpoint. For this purpose, the author personally took data on the times of ingress and egress of Io (the first major satellite of Jupiter) into the shadow of Jupiter. The data were taken during August to December 1988, using National Bureau of Standards radio station WWV as a clock, and were analyzed for comparison with the data of 300 years ago. The analysis included important geometric effects such as the change in the length of the part of the shadow that Io traverses. The results show that if the period and other parameters of Io's orbit have been constant, then the speed of light must have been greater in the past. However, there are tidal forces operating on Io which could well have changed Io's mean daily motion over 300 years. The future analysis of these tidal actions may well lead to the conclusion that Roemer's data do not support the idea of a variable speed of light.

REFERENCES

Goldstein, S.J., Trasco, J.D., and Ogburn, T.J. III 1973, On the velocity of light three centuries ago, The Astronomical Journal 78(1):122-125.

Goldstein, S.J. 1975, On the secular change in the period of Io, The Astronomical Journal 80(1):532-539.

Goldstein, S.J. and Jacobs, K.C. 1986, The contraction of Io's orbit, The Astronomical Journal 92(1):199-202.

Greenberg, R., Goldstein, S.J., and Jacobs, K.C. 1986, Orbital accelerations and the energy budget in the galilean satellite system. Nature 320:789-790.

Lieske, J.H. 1987, Galilean satellite evolution: observational evidence for secular changes in mean motions, Astronomy and Astrophysics 176:146-158.

Setterfield, B. and Norman, T. 1987, The Atomic Constants, Light, and Time, available from Lambert T. Dolphin, 2111 Grenola Drive, Cupertino, CA 95014, 90 pages.

Troitskii, V.S. 1987, Physical constants and the age of the universe, Astrophysics and Space Science 139(2):389-411.

DISCUSSION

Dr. Chaffin has done a good job of helping to clarify the numerous complexities which surround attempts to measure the speed of light with high precision using Roemer's method. It is very refreshing to see some modern experimental input into the question of the constancy of the speed of light by a creationist.

Why are the sum of the squares of the residuals so much larger for the Roemer-Picard data in Table III than for the 1988 data?

The main conclusion I draw from this paper is that it is probably hopeless to try to disentangle hypothesized changing speed of light effects from other plausible yet unrelated phenomena affecting Roemer type measurements of the speed of light over the past 300 years at the required precision. Does Dr. Chaffin agree with this conclusion?

Gerald E. Aardsma, Ph.D.
San Diego, California

The measurements by Roemer give us some of our best early data on the velocity of light. The author has carefully repeated Roemer's method in our time in order to better understand his data and associated error factors. Dr. Chaffin also considers possible changes in the motion of Jupiter's moon Io which could account for Roemer's value for "c" being significantly higher than the present value. This is an outstanding and careful paper. It is clear, very well written and appropriate for the current discussion that the velocity of light might not be a true constant of nature. I recommend this paper without hesitation, it is excellent.

Lambert T. Dolphin, Ph.D.
California

I like Dr. Chaffin's approach of doing both observation and analysis for himself in this study; it is a refreshing change from the secondhand science which unfortunately has obscured some previous creationist studies of the speed of light. In addition, the paper is valuable because it reveals the complexities involved in the analysis of Roemer's data. It appears that Roemer's choice of Io as the Jovian satellite to observe was unfortunate, since Io interacts so strongly with Europa and Jupiter. I had not known that astronomers do not agree on whether Io is accelerating or decelerating in its orbit at present. Until that basic question is settled, it looks like we cannot say from Roemer's data whether or not the speed of light was different in the seventeenth century. Another important contribution of the paper is its clarification of the young solar system implications of the observed high heat flow from Io.

D. Russell Humphreys, Ph.D.
Albuquerque, New Mexico

The exact procedure followed by Roemer, and by Dr. Chaffin could be made more clear. Dr. Chaffin's general conclusion is that Roemer's data, which had great influence on Setterfield's "c-decay" theory, may not be used to support it. More important to this reviewer is the fact that this entire debate on "c-decay" for the past 10 years has failed to address the fundamental question, "What does one exactly mean by the speed of light?", and it was hoped that Dr. Chaffin would be the one to do so. Let me illustrate. If one assumes that light is a stream of particles called, photons, like water droplets from a nozzle, then the "speed of light" (as usually measured) is simply the statistical average of the various photon speeds, including those that suffer an absorption and re-emission along their path. Hence one must carefully distinguish between the speed of uncollided photons (which we define in vacuo) and remainder whose speed is really (distance travelled divided by transit time plus residence time during each absorption by a nucleon in its path. Nor may one assume that the path used by Roemer (from the earth to the moon of Jupiter) is anything close to a perfect vacuum now that we know how much "trash" fills outer space, most is invisible. If on the other hand, one assumes that light is a wave phenomenon, in harmony with the divine pattern used elasticity, sound and water waves, then we have the problem expressed in the old quatrain: "If sound waves wave air, and water waves wave water, what is it that waves when a lightwave waves?"

Robert L. Whitelaw, M.S.
Blacksburg, Virginia

CLOSURE

I appreciate the positive comments of Drs. Aardsma, Dolphin, Humphreys, and Mr. Whitelaw. In answer to Dr. Aardsma's questions, Goldstein 1975 gave the standard deviation as 31.5 seconds for the fifty points included in his final solution. However, that was after the period of Io had been adjusted to give the best fit. Before the adjustment the residuals are larger. These residuals are larger than for the 1988 data since Roemer did not have radio station WWV or atomic clocks. Time zones did not exist in Roemer's day. Roemer evidently recorded his eclipses in apparent solar time, which must be corrected to a "true" time scale. The equation of time corrections are discussed in the Goldstein 1975 reference.

Can hypothesized changing speed of light effects be disentangled from other plausible yet unrelated phenomena? I think that independent study of tidal friction on Io and Jupiter may eventually provide an answer to the question of how much energy is being removed from Io's orbit via these dissipative effects. Parameters of tidal friction, including the constants called the Love numbers by geophysicists, are poorly defined for Jupiter at present. Analysis of space probe data may soon define the parameters more accurately, however.

Since the conference I have found that the results of my computer programs depend more on which points are analyzed than I thought at the time. The 6.7% faster value for the speed of light reported here thus should not be taken as a precise prediction resulting from a body of theory but merely as an indicator of the realm of possibility that is consistent with the data. The fact that Goldstein and Lieske did not agree on whether Io's period increased or decreased appears to be linked to this variability of the results with the choice of data set.

I thank Professor Whitelaw for his questions. I found that there were others at the conference who had similar questions which they expressed verbally. In my opinion, experiments have shown that the speed of light does not depend on the velocity of the source. Also, the velocity of the Earth in its orbit is 30 kilometers per second, while that of Jupiter is 13 kilometers per second. Hence, the relative velocity of Earth and Jupiter is negligible compared to the speed of light. Even if one were to assume some sort of dependence of the speed of light on the speed of the source, the results of my computer programs would not be significantly changed. With regard to extinction of the light due to dust, cosmic rays, protons, electrons, hydrogen atoms, etc. in interplanetary space, the densities of these types of matter can be found in various sources. At the distance of the Earth from the sun, there are about 8 electrons per cubic centimeter of space, and the extinction length can be calculated to be about 400 to 500 astronomical units. The theory behind these calculations can be found in the following:

Brecher, K. 1977. "Is the speed of light independent of the velocity of its source?" Physical Review Letters 39(17):1051-1054.

Filippas, T.A. and J.G. Fox 1964. "Velocity of Gamma Rays from a Moving Source." Physical Review 135(4b):1071-1075.

Hamilton, J. 1959. The Theory of Elementary Particles Clarendon Press: Oxford, pages 16-19.

As to Prof. Whitelaw's final question about what the medium for light waves is, I will say that this question seems to be an important one, and that the final form for the answer will be very important for our understanding of physics, but that it will not affect the operational questions addressed in this paper.

Eugene F. Chaffin, Ph.D.