ELIAS AND FRANCIS LOOMIS ON VARIABLE STARS, 1866-69

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Abstract

The conclusions regarding variable stars (including Algol, Mira, η Carinae, and T Coronae Borealis) reached by both Elias and Francis Loomis are summarized and compared with now current knowledge.

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1. Introduction

Elias Loomis (1811-1889), Professor of Natural Philosophy and Astronomy at Yale from 1860 until his death, was a most prolific writer of text books - 23 - of which 15 were on mathematics, 5 1/2 on astronomy, 1 1/2 on meteorology, and one on natural philosophy (physics). Their entire circulation amounted to over 600,000 copies sold. In addition, his bibliography lists some 150 articles, the majority of which are on meteorology. Only some 50 are on astronomy, of which just two are related to variable stars, one on Algol, the other on "η Argus" (which constellation had already been renamed Carina when a century before Lacaille subdivided the cumbersomely large constellation Argo). In his 1856 treatise, *The Recent Progress of Astronomy*, Loomis devoted a chapter of five pages to "Observations of New and Variable Stars," mentioning in particular Mira and Algol and noting, "More than forty such cases have been noticed, although in many of them the change of brightness is not very remarkable." He describes η Carinae as "a case of a few stars whose remarkable changes of brightness have not been reduced to any law of periodicity even though observations spread over centuries." He also discussed several known novae and indicated that Hind in London had discovered 15 new variables during his search for planets.

Francis E. Loomis (1842-1918), one of the sons of Elias Loomis, was also interested in variable stars, perhaps even stimulating his father's interest. Young Loomis wrote a thesis on variable stars for which he earned a Ph.D. degree at Yale in 1866; he then went to Goettingen University where he enlarged his thesis, *Periodic Stars*, published by the Goettingen University Press, and for which he was awarded a Ph.D. from Goettingen in 1869. In this dissertation he discussed four variables in detail, Algol, Mira, η Carinae, and T Coronae Borealis, and tabulated a summary of 100 stars for which periods had ostensibly been determined.

2. The Loomis' Discussions of Variable Stars

a) Algol

For his analysis of the period of Algol, Francis Loomis compiled all the known published observations at minimum, tabulating the 229 observed between October 3, 1853, and December 14, 1868. This list included seven observations by Maria Mitchell while she was on Nantucket in 1855-6, but remarkably none by either himself or the elder Loomis. Elias Loomis in his 1866 paper on Algol had reported that he had observed a few minima of Algol from New Haven, quoting one as on October 21, 1865, and in his *Treatise on Astronomy* of 1866 he gave another date, November 11, 1864, neither of which is included in Francis Loomis' table of the observed minima of Algol.

The observations of Algol spanned from 1784 to 1866. From these data he concluded that "the inequalities in the rate of variation of Algol are real and are not wholly due to the influence of the atmosphere, or to errors of observation." He found 84 minima before 1830, also 84 between 1830 and 1854, and over 170 between 1854 and 1868. From these, like Argelander (1855) before him, he noted that the period changes, having diminished by 8 1/2 seconds from 1784 to 1859, had subsequently increased again. Dividing the material into 16 groups (the first ten, through 1851, copied from Argelander) he found that the longest period corresponded to May 27, 1784, namely $2^d\ 20^h\ 48^m\ 59^s.416 \pm 0.316$, the shortest, January 3, 1859, $2^d\ 20^h\ 48^m\ 50^s.901 \pm 0.680$. Elias Loomis in the paper delivered at the Buffalo meeting of the AAAS in 1866 reached similar conclusions but had subdivided the material somewhat differently, indicating the minimum period in 1855 rather than 1859. The most recent results from the _Second Supplement_ to the _General Catalogue of Variable Stars_ (GCVS) (Kukarkin _et al_. 1974) are given as an array of discrete periods (see Table I) as well as a complicated formula to represent the observations from 1782 to 1949 more smoothly. In Figure 1 these periods are compared with those given by Francis Loomis in his thesis, converted to decimals of a day. The periods published by Argelander and Loomis are given to 0.001 second (10^{-8}d) but the published errors run from 0.039 to 0.857 second. The reasons for the apparently abrupt changes in period were not understood by Loomis and are still unsolved.

Later in his dissertation the younger Loomis lumps Algol with the other types of periodic variables in attempting to account for the variation. Neither Elias nor Francis Loomis seems to have favored the now accepted binary star explanation which had first been advocated by Goodricke in 1783 (see Shapley and Howarth 1929), who gave two alternatives, "If it were not perhaps too early to hazard even a conjecture on the cause of this variation, I should imagine it could hardly be accounted for otherwise than either by the interposition of a large body revolving around Algol, or some kind of motion of its own, by which part of its body, covered with spots or such like matter, is periodically turned toward the earth." The elder Loomis rejected both of these suggestions, arguing, "We cannot ascribe these variations of brightness to the flattened form of Algol, or to dark spots upon its surface, for in such a case the duration of greatest brightness could not exceed one half of the entire period." In regard to the eclipsing binary hypothesis he argued that if Algol had the mass of the sun and the eclipse were central, the dark companion would have twice the diameter of Algol. But as the eclipse appears to be only partial the companion would have to be even larger, "which would make its volume more than ten times that of Algol. Algol thus becomes an important satellite to an obscure central body of enormous magnitude; a supposition so improbable that it is presumed no one will be disposed to accept it." He would have been amazed by the present range of stellar diameter-determinations, a few of which even exceed 1000 solar diameters.

Elias Loomis favored another hypothesis, namely that "all the observed phenomena may be explained by supposing a nebulous body of irregular form, with a length of nearly two million miles, or a group of small solid bodies of the same extent, revolving about Algol as centre." The changes in period would then be explained "by supposing, _not_ a change in the absolute time of revolution of the nebulous body, but simply a change of position of the major axis of the orbit with reference to a line from the earth to Algol." It was not until 1889 that the binary theory was verified by H. C. Vogel's spectroscopic discovery of Doppler shifts that could best be explained by orbital motion (Vogel 1890; Shapley and Howarth 1929).

b) Mira

Mira, discovered in 1596, was fairly steadily observed from 1660 on, and was already announced in 1667 as having a mean period of 333 days. Although the cycle lengths and shape of the light curve varied significantly from cycle to cycle, the mean period has been remarkably sustained. Francis Loomis, who tabulated the maxima and minima from October 5, 1839, to November 10, 1868, found that the intervals between successive maxima ranged from 228 to 369 days, and between minima from 251 to 381 days, with a mean of 331 1/2 days. This value may be compared with the overall mean of 331.57 days to 1966 given in the First Supplement to the GCVS (Kukarkin et al. 1971), the tabulated value of 331.65 days for 1964 and 1969, and Proust's (1983) period of 333.81 days for 1950 to 1982. Loomis pointed out that the brightness at maximum light varied between the fantastic limits of fainter than 6 to first magnitude. Although no definitive period had been found for the fluctuations at maximum, he inferred periods of 40 and 160 years. Much later, Guthnick (1901), analyzing observations to 1900, found four periodic corrections to the 331.7 day period, indicating secondary periods of 36, 72, 85, and 234 years (Mueller and Hartwig 1918).

Proust tabulated the magnitudes at maximum and at minimum, reduced to a uniform system, for all the observed cycles from 1596 to 1981, and gave an O-C diagram starting with 1639 and based on a constant period of 332 days. To this diagram I have added the three early points for 1596 and 1609 and the recent maxima provided by the AAVSO. See Figure 2. This O-C curve shows that the period from 1596 until about 1680 was shorter, 330.2 days. It then increased abruptly to 333 days, and from then until about 1970 the period oscillated around 331.5 days, confirming Loomis' period which had been derived for 1839-1868. The period has subsequently increased sharply to about 336 days. The oscillation amplitudes of the cycles in the O-C curve are successively approximately 80, 80, 40, 40, and 50 days, in surprising agreement with the cycles Loomis had attributed to supermaxima. Proust's reduced magnitudes at maximum light range from 2.1 to 5.0. Those brighter than magnitude 2.5 occur at successive intervals of 63, 32, 15, and 21 years, not in agreement with Loomis.

In an attempt to interpret the variations of Mira, Loomis quotes Bouilland in 1667 as having supposed Mira to have one bright side, one dark, and that the observed variations in magnitude could be explained by the rotation of the star.

c) η Carinae

Strangely, the paper by Elias Loomis on η Argus, dated April 9, 1869, contains the same data and reaches the same conclusions as does Francis Loomis' thesis of the same year. Neither mentions or gives credit to the other. Both conclude that the star is probably periodic, "whose changes of brightness vary from the first to the sixth magnitude(s), and whose period is about seventy years." (They use identical wording except that one used the singular, the other the plural of the word "magnitude.") From the well-observed hump lasting from 1811 to 1869, with maximum in 1843, they derived a period of 67 years which also fit the early observations by Halley in 1677 (4th magnitude) and by Lacaille in 1751 (2nd magnitude). See Figure 3. Earlier, Wolf (1863) had indicated a period of 46 years, which the Loomises considered too short.

Mueller and Hartwig, in the Geschichte und Literatur des Lichtweschels (1918), give some early references evidently not available to the Loomises. η Carinae was not included in Friedrich von Houtmann's 1603 catalogue which showed stars of 4th and 5th magnitude observed in India in the last decade of the 16th century. Therefore, the variable must have been fainter than 5th magnitude. This satisfies the Loomis 67-year period perfectly. η is reported by Mueller and Hartwig to occur as one of the stars marked d on the Bayer Atlas (edition not specified). Bayer stars marked d are of the 3rd or 4th magnitude. It is not known whether the epoch of Bayer's observations is earlier or later than those by Houtmann. However, in view of the distortions of the configuration "Argo" on the Bayer chart, the identification with the star we now call η is dubious at best. The only edition of Bayer's Uranometria to which I have had access is that of 1655. There, no star in Argo is actually labelled η. Mueller and Hartwig's comments about a star marked d agree completely with this 1655 edition. Since the Greek letter designations originated with Bayer, the letter η probably did appear in the first 1603 edition.

Still earlier observations of η Carinae in Babylonian times have also been suspected (Allen 1963). Another observation not cited by the Loomises was one by Father Noel (as pointed out by von Winnecke in 1859) who observed η Carinae at about 2nd magnitude sometime between 1685 and 1689. This observation, too, fits the Loomis period. Figure 3 shows the observations available by 1869 as large dots, with the primary cycle traced at 67-year intervals.

In 1974 Feinstein and Marraco, who reported a secondary variation with an amplitude of 0.2**V** in a period of 1110 days, published the major light curve up to 1973. At primary minimum between 1900 and 1940 the star reached approximately 8th visual magnitude. Curiously, there had been an increase of about one magnitude in 1889 (from 7.6 to 6.7) which seemed like the beginning of an ascending branch, a vestigial confirmation of the Loomis period, but which failed to materialize, decreasing to low minimum within ten years in contrast to the over twenty years of duration of the bright primary maximum of 1843. The star receded to its lowest recorded brightness by 1940 when it began a slow steady increase from 8th to 6th magnitude by 1973. See Figure 4. After 1960 Figure 4 shows two sets of magnitudes. The upper set is photoelectric **V** magnitudes by Feinstein and Marraco; the lower set is visual mean annual magnitudes from the AAVSO and the Variable Star Section of the Royal Astronomical Society of New Zealand. There is an approximately 0.2 magnitude systematic difference between the **V** and the visual. This difference may in part be attributed to the presence of bright nebulosity in which the variable is embedded. Maximum brightness appears to have been reached in 1981/2, with possibly a slight (0.1 magnitude) decline to 1984.

As the inferred minima depicted in Figure 3 appear to be more sharply defined than the maxima, the larger tick marks at the bottom of Figures 3 and 4 indicate the predicted times of minimum reckoned from 1800 on the basis of the 67-year period. This seems to suggest that the maxima of η Carinae may not be as peculiar or significant as its sudden decline, after 1850, to a possibly previously unprecedented low minimum. This nova-like variable seems to remain a perpetual enigma. Observations over the next two decades should prove important for the interpretation of the behavior and evolution of this star. Loomis' forgotten period may possibly play a crucial role.

d) T Coronae Borealis

The variation of T Coronae Borealis, now known to be a recurrent nova, was described by F. Loomis as "of the same kind as those of Mira and η Argus, but the period is probably a very long one, perhaps several centuries." In 1866 the star rose from 9th to 2nd magnitude, decreased to 6th in a week, and back to 9th in less than a month. Loomis tabulated all the available observations, arranged by observer. John Birmingham has always been credited with having been the first to discover the nova, on May 12, 1866. Yet Loomis lists a few observations made earlier that same month by W. Barker - observations that had already been discredited as fraudulent by Hind in August, and by Stone in December of 1866.

Loomis also noted that William Herschel had observed T CrB at ninth magnitude in 1782, and John Herschel at sixth magnitude, on June 9, 1842. William Herschel on July 18, 1782, had recorded a binary (separation 41".2) about one degree south following ε CrB. This star seems to be the same (BD +26° 2765) as a star dubiously described as a close double (0".2) by Jeffers in 1946, included in the IDS but not there identified as T CrB. John Herschel (1867) after the announcement of the 1866 discovery of T CrB published for the first time a segment of a chart of naked-eye stars he had observed on June 9, 1842, (in a project he had abandoned when he learned that Argelander was engaged in similar work, namely the preparation of the Bonner Durchmusterung). Herschel's chart shows a naked-eye star in the same position as T CrB. If Loomis really did give credence to John Herschel's discovery, only 24 years before the primary outburst, one wonders why he expected the star to have a period possibly as long as centuries. (The reason appears toward the end of his thesis.) Herschel's observation, unless it was simply forgotten, must subsequently have been discredited, as it is not mentioned either under T CrB or as an independent suspected nova in the GCVS, the Geschichte und Literatur des Lichtweschels (1920), or the New General Catalogue of Suspected Variables (NSV) (Kholopov et al. 1982). T CrB, however, did flare up again in 1946, just 80 years after its previous maximum. Interestingly, Huggins observed its spectrum in 1866. It was described as a composite, showing a solar-type absorption spectrum combined with an emission spectrum.

e) 100 "Periodic" Stars

Besides the four selected stars that Loomis discussed in some detail, he tabulated the 100 (out of the over 120 then known to be variable) for which periods had previously been published. It is of interest to compare these periods with the corresponding ones in the most recently available GCVS. In 89 cases the agreement is as good as can be expected from the relatively small numbers of epochs generally involved in the early determinations. The periods of most of the Mira stars differ by less than 60 days, smaller than the differences in successive cycle lengths that Loomis listed for Mira itself. Table II lists the remaining eleven discordant results. Most of them pertain to irregular or semi-regular stars. For R Lib the old period is spurious, related to the new through the annual gaps in the observations. μ Cephei has three modern periods (730 days, 904 days, and 13.5 years) uniquely related to the 5-6 year period that Loomis quoted from Chandler (1864), the inferred period computed from the three modern periods being 5.9 years.

The 315-year period given for Tycho's Nova was taken from Huggins and Klinkerfues (1868) who pointed out that there had been novae with poorly determined positions in Cassiopeia in the years 945 and 1264. If these were indeed the same as that of 1572, the period of 315 years would imply that Tycho's star would have been bright at the time of the birth of Christ, hence the Christmas Star. As Tycho's star is now confirmed as a supernova (as well as for other reasons), this hypothesis is, of course, untenable.

3. Historic Interpretations

Having concluded his compilation of data and periods, Francis Loomis speculated on possible causes for the variations. He discussed four hypotheses, all of which were wanting in one respect or another, especially as he was searching for a common cause for all, including Algol, the genuinely periodic stars, and the "temporary" stars:

1. Stellar rotation of a thin, disc-shaped star, alternately presenting flat-face and edge-on appearances to the observer, could not explain

the light curve of Algol or "the seemingly capricious" irregularities of Mira or η Carinae. "This hypothesis should then be absolutely rejected."

2. An annular eclipse of Algol by a companion adequately explains the major variations of that star, but is not compatible with the variations of Mira or η Carinae.

3. "It has been supposed that a cluster of dark bodies, or a nebulous body of great extent may revolve about the variable star so as at times to intercept a portion of its light." This hypothesis seemed to him to have some merit. However, he concluded, "The remarkable fluctuations in the light of Mira, of η Argus and T Coronae, seem to indicate changes in the condition of the star itself: so that although this third hypothesis may be to some extent true, it does not seem sufficient to explain all the phenomena."

4. "It has been supposed that the variable star may not be uniformly luminous upon every part of its surface, but by rotation upon an axis may occasionally present to the earth a disc partially covered with dark spots, and shining therefore with a dimmer light." Again this would not account for all the observed phenomena, even when it was additionally stipulated that the star-spots themselves were variable.

Already in his 1866 edition of his Treatise on Astronomy the elder Loomis had enunciated these four hypotheses, and concluded that temporary stars were probably also periodic stars but of longer period. In the 1869 edition of the Elements of Astronomy, Elias Loomis concluded, "If we suppose that the spots are periodically developed upon the surface of the variable star, similar to those which are observed upon our sun, but of vastly greater extent, the phenomena of most of the variable stars may be explained." Later he seemed to vacillate. In the 1871 and 1874 editions of the Treatise on Astronomy he favored the hypothesis of the interception of light by a nebulous body, but once more in 1888, his last edition, he reverted to the star-spot theory: "It seems most philosophical to conclude that the changes in the periodic stars are due to causes analogous to those which exist in our own system," adding that it should not be surprising that a few stars should be found for which the changes are far greater than in the sun.

In text books it is not always necessary to state specific sources. Hence it is not clear from the elder Loomis' treatises who had originated the various hypotheses. Obviously, however, father and son must have shared thoughts and discussions. The analogy between some light curves and the sunspot cycle was evidently not original with either Loomis. R. Wolf (see Clerke 1902) had been credited with this suggestion as early as 1852, while the same suggestion by Goodricke in 1783 as an alternative for the binary hypothesis seemed to have been entirely forgotten.

In connection with his fourth hypothesis, Francis Loomis looked into the variations of sunspots, speculating whether disturbing effects of the planet Jupiter could be responsible, Jupiter having nearly the same period of revolution as the sunspot period. He suggested that differences might be due to magnetic effects, noting how the magnetic pole of the earth changes progressively. If indeed Jupiter were responsible for the sunspots, the other planets should likewise, but to a lesser extent, affect the sunspot cycle. He seemed actually to find evidence for secondary periodicities related to Saturn, Venus, and the Earth. Therefore, he reasoned that unseen planetary companions might similarly be responsible for stellar variations. His reasoning reflects his father's interest in terrestrial magnetism and its relation to sunspots and aurorae. In fact, the apparent relationships between sunspots and planetary configurations were more fully discussed by Elias Loomis in 1870 and presumably had originated with him. The younger Loomis did not estimate the amplitude of the total light variation of the sun during a sunspot cycle (only a few hundredths of a magnitude), which is far smaller than the variations of the mainly Mira-type stars he was trying to explain.

Regarding temporary stars like T CrB, Francis Loomis recalls that their outbursts had generally been ascribed to direct collison of some foreign body like a comet. If the star observed by John Herschel in 1842 was really the same as that of 1866 (T CrB), then he strongly favored the hypothesis that T CrB was influenced by a large planet in a highly eccentric orbit approaching close to the surface of the star.

In conclusion, Francis Loomis favored star-spots caused by planetary disturbances as the major cause of stellar variability. While the sunspot theory is untenable for the relatively high amplitude stars he studied, it is of interest to note that modern photoelectric photometry is detecting for other stars of low amplitude the star-spots that the Loomises advocated more than a hundred years before, but now without implicating planets. Pulsation theory, now taken for granted, did not come into vogue until nearly 1920. It had been first suggested by A. Ritter in 1878-9, but seems to have been virtually ignored until Shapley in 1914 revived it in his refutation of the then prevalent hypothesis that Cepheid variables were binary systems with ellipsoidal components, and Eddington in 1918-19 put the pulsation theory on firm ground by his mathematical development. Evidently Elias Loomis was not aware of Ritter's work when he revised the latest editions of his treatises.

Tremendous advances in the understanding of these variables have been accomplished since the time of the Loomises. While older generations of astronomers struggled to interpret their observations they came upon ideas that future generations could not support. Yet often those very hypotheses that ultimately failed to account for the observations in hand independently recurred later to account for new data on other types of stars. The elder Loomis in particular did much to stimulate the progress of astronomy through his teaching and his text books, whether right or wrong from our present standpoint. Francis Loomis, after a brilliantly promising early career, was less fortunate. Although he lived to age 76, he spent most of his life as an incurable invalid. In 1871 he was appointed Professor of Physics and Industrial Mechanics at Cornell University, but within eight months he resigned after illness and losing one lung. He moved to Switzerland, hoping against hope that the climate there would be beneficial to his health. His Goettingen thesis was his only published contribution to astronomy.

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TABLE I

Consecutive Periods of Algol

Years	Period
1784-1835	2^{d}.8673 442
1835-1854	3 012
1854-1901	2 775
1901-1913	2 967
1913-1915	2 506
1915-1944	3 0807
1944-1952	3 4862
1952 ff	3 2442

TABLE II

Discordant Results

Var	Loomis Period	GCVS Period	GCVS Type	Remarks
S Mon	3.45d	-	Ia	
R Sct	71.7d	140.05d	RV	
T Psc	146.5d	260d	SR	
R Mon	204d	-	Ina	
V Sgr	316d	-	Cst	Misnamed U Sgr
R Lib	723d	241.76d	M	Spurious: 1/241.76 - 1/365 = 1/723
μ Cep	5-6 yrs	904d	SRc	Misnamed U Cep
		730d		1/730 - 1/904 = 1/3788d = 1/10.4 yrs
		13.5 yrs		1/10.4 + 1/13.5 = 1/5.9 yrs
P Cyg	18 yrs	-	N1	
η Car	67 yrs	-	SN?	
R Cep	73 yrs	-	Cst	
B Cas	315? yrs	-	SN	Misnamed β Cas. Tycho's Nova 1572

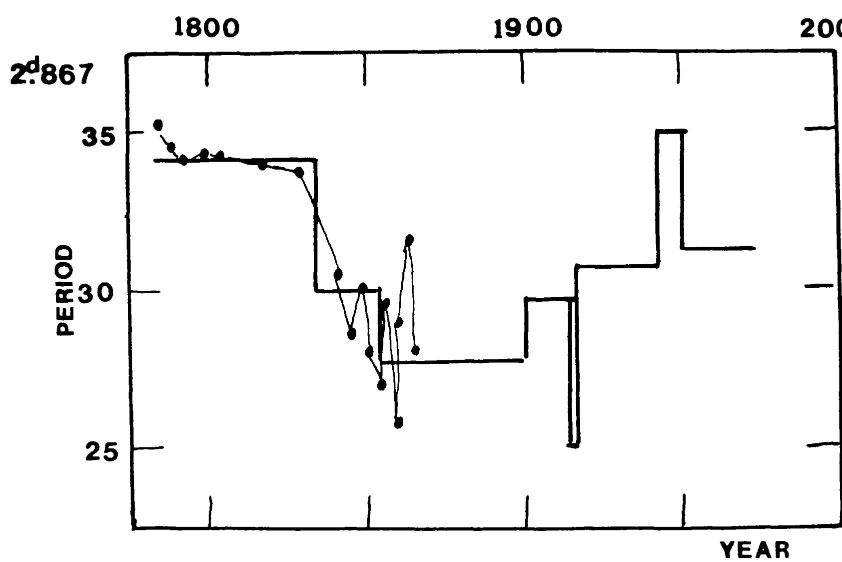

Figure 1. The changing period of Algol. Dots from the Loomis dissertation; horizontal segments from the GCVS.

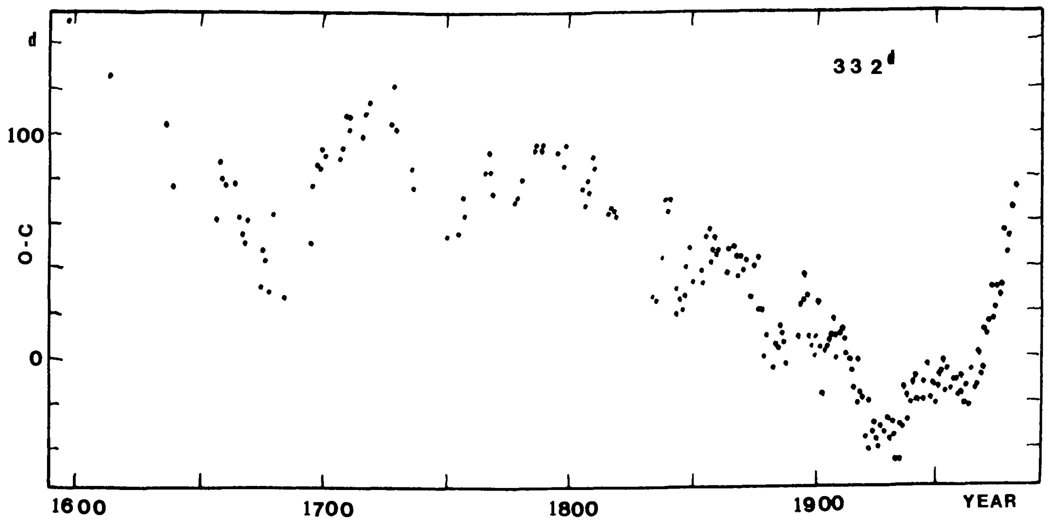

Figure 2. O-C diagram for Mira for 332-day period (after Proust).

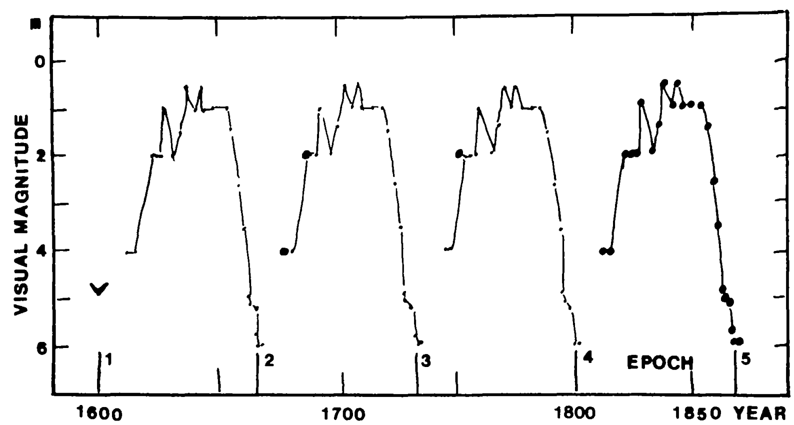

Figure 3. Observations of η Carinae fitted to the 67-year period determined by the Loomises in 1869. Large dots are actual observations. The final cycle is retraced (small dots) at 67-year intervals back to 1600. Predicted minima are numbered 1 - 5.

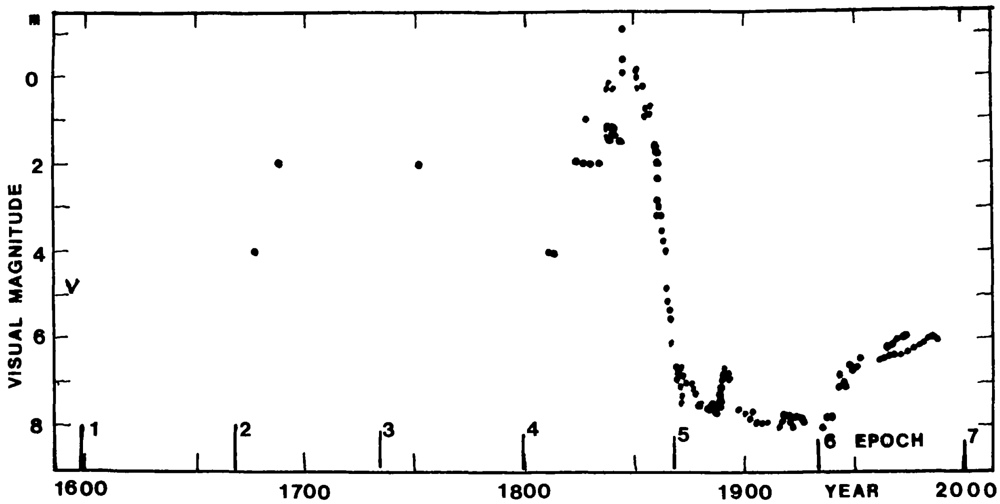

Figure 4. Complete light curve of η Carinae from 1600 to 1984. Predicted minima are numbered 1 - 7. After 1950 the lower set of points are visual observations, the upper, photoelectric **V**-magnitudes.