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ON THE ORBIT OF (132) *AETHRA*,

By A. ESTELLE GLANCY.

In 1913, interest in this lost planet was revived through the announcement (*M. N.*, 75, 310) by CROMMELIN of a suspected identity between *Aethra* and an asteroid between the eighth and ninth magnitude photographed at the Lowell Observatory with the forty-inch reflector on June 10, 1913. This announcement led to search ephemerides for July 19 to Sept. 13, 1914 by LUTHER (*A. N.*, 4751, 4754); for Oct. 1, 1915 to Mar. 1, 1916 by ALTER (*L. O. B.*, No. 275), and Dec. 1, to Aug. 1, 1917 by ALTER (*L. O. B.*, No. 285) — all based on this identity.

The identity seemed so probable to the writer that a photographic search was begun on Dec. 1, 1916, using a photographic telescope of 64 cm. focal length and an aperture stopped down to 10 cm. Owing to various interruptions, most of the plates were taken during the lunations of February and March, 1917. They cover a wide area around 16^h R. A. and -44° Dec., Duplicate fields, one or more days apart, were compared in the stereo-comparator. By chance *Eros* was found on several of these plates. It was then about 10.2 magnitude. The image was strong and very striking in the stereo-comparator. There were no other moving objects found on these plates. It is probably safe to say that no asteroid brighter than eleventh magnitude was in this region.

About this time I had occasion to refer to the original Lowell observation. It was noticed that the observed position falls within the Cordoba astrographic zone. Search among the Cordoba plates revealed unexpectedly a plate taken on June 9, 1913 with center

$$\text{R. A.} = 15^{\text{h}} 27^{\text{m}} 0^{\text{s}} \quad \text{Dec.} = -28^{\circ} 0'$$

The Lowell observation is (*Lowell Obs. Bull.*, No. 61):

$$\text{Gr. M. T.} \quad 1913, \text{ June } 10.835$$

$$\text{R. A.} = 15^{\text{h}} 27^{\text{m}} 13^{\text{s}} \quad \text{Dec.} = -28^{\circ} 25'.6$$

According to ALTER's elements (*L. O. B.*, No. 285), the daily motion of *Aethra* would be

$$-32^{\circ}.3 \quad +17'.1$$

The interval between the two photographs is 1.2 days. Hence on June 9 the Lowell object, if identical with *Aethra*, should have been in the position

$$\text{R. A.} = 15^{\text{h}} 27^{\text{m}} 52^{\text{s}} \quad \text{Dec.} = -28^{\circ} 46'$$

a position well situated on the Cordoba plate. This plate was set in the stereo-comparator and its entire area was examined with the aid of four additional plates covering it in quarter sections. No moving object was found.

There seems only one conclusion to draw: that *Aethra* is not identical with the Lowell object. In fact, the absence of any asteroid on the Cordoba plate suggests that the Lowell object may be one of those spurious images which are often found.

Here is a good opportunity to emphasize the caution necessary in the identification of asteroids. The images of *Eros* mentioned above were at first mistaken for the object of search. Curiously enough a good representation was obtained using the general elements, Table X, *L. O. B.*, No. 275, assuming $\mu = 882''.525$. A micrometer observation on March 29 left the residuals

$$\Delta\alpha \cos \delta = -10'' \quad \Delta\delta = +39'$$

This value of μ is only 0''.9 less than the value adopted for the representation of the Lowell object; the representation is closer than that for the Lowell object. It would have seemed conclusive had the geocentric motion not been known. An observation on the following day left the unexpected residuals +50'' and -42'. It so happened that the theoretical and the observed motion were just turning from the direct to retrograde direction; the ephemeris motion was north, the observed motion south.

(17)

Considering that there are over eight hundred planets there must often be two in neighboring directions, and it is a very easy matter to alter the elements of one to fit the neighboring position. A rigid identification would require a satisfactory representation in position, velocity and acceleration; in general, it should be sufficient to satisfy the first two conditions, preferably by two observations, or, in the case of a single photographic image, the direction of the trail should be published with an estimate of the magnitude of the daily motion, and in the latter case the investigator should be very cautious in drawing conclusions, no matter how real the image may appear.

In *L. O. Publ.*, Vol. 7, p. 462, the statement is made that the planet *Aethra* was lost owing to the neglect of the perturbations by *Mars* during the period of observation. Some recent investigations by me have led to a different conclusion.

Through an error in making a model of the orbit, I thought there was a close approach to *Mars* during the interval 1873, June 13 to July 5, although I did not recall at the time the statement referred to above. From a study of *L. O. B.*, Nos. 275, 285, it seemed to me that an orbit based on LEUSCHNER'S method for the *Direct Solution of Orbits of Disturbed Bodies*, (*L. O. Publ.* 7, Part 9)*, might give elements so different that they would prove an identity between *Aethra* and some other known asteroid.

So this method as developed for satellite orbits was adapted to the case of a minor planet disturbed by *Mars*.

Then calculations were begun, based on the three normal places given in *L. O. B.*, No. 275†. It was seen at once that the model of the orbit was in error, and when correctly constructed the planet and *Mars* were much further apart, and the disturbing influence was so much diminished that it could be neglected. At the time of the middle observation the relative positions were

June 25.5, 1873	geocentric distance	1.5
	heliocentric distance	2.5
	distance from <i>Mars</i>	1.1

Nor was *Jupiter* near.

What later perturbations *Aethra* may have suffered we cannot say, for the elements are too uncertain to establish its position in following years.

Some calculations have been made to form an idea

*The following errors in the text were noted:
p. 471, line 15, for $a'' (\tan \delta)''$, read $a' (\tan \delta)''$
p. 476, line 23, for that " m would appear in the place of γ ," read " m multiplication by m throughout."
†For the date of the first normal place, June 18.5 read June 19.5.

of the probability that *Aethra* was subject to the disturbing influence of another asteroid.

Taking the orbit of *Aethra* as the fundamental plane, the distance of *Aethra* from the *Sun* and the corresponding distances of the first 131 planets have been computed for each node. The elements of *Aethra* are *AI*, (*L. O. B.*, No. 275); those of the other planets were taken from *B. J.* 1918. No account has been taken of the difference in equinox since the calculations are only approximate. In the cases of thirteen planets the radii vectores differ less than 0.1 astr. units at the ascending node; there are twenty-two planets within the same limit at the descending node. And, more generally speaking, accepting the elements given by BARTON*, (*A. J.*, 702), the average asteroid passes above the plane of *Aethra* at a distance 1.0 units further from the *Sun* than *Aethra*, and passes below the orbit 0.3 closer.

With these geometrical relations a close approach depends only upon the relative positions in the orbits. If a planet's mean motion were exactly equal to that of *Aethra* a passage at the node would never occur except in the one possible case that it always occurs. On the other hand, those planets which can make a close approach must have nearly the same semi-major axis, except as relative eccentricity widens the range. It so happens that a close approach is more likely at the descending node, owing to the smaller eccentricity and larger semi-major axis of the average planet. Most of the thirty-five planets mentioned above have mean motions differing 100'' or less from that of *Aethra*. Suppose the mean motions differ 50'' and the planets are 180° apart when one passes a node. Neglecting the eccentricity, only thirty years would elapse before there would occur a passage at the node.

The planets discovered earlier than *Aethra* were used in the calculations as representative of all and relatively most important, since, in general, the earlier planets have the greater size. Among the thirty-five planets there are twenty-four having a smaller value of g than *Aethra*, (g = magnitude at opposition when reduced to $\rho = r = 1$). Taking g as a measure of size, it is probable that these planets are larger than *Aethra*. In this connection an estimate of the probable diameter of *Aethra* has been made.

Assuming the geocentric albedo, p , to be equal to the mean of the values so far known, using the magnitude at mean opposition given in *B. J.*, and the semi-major axis by ALTER,

$$p = 0.24 \quad m_0 = 10.9 \quad \log a = 0.410 \quad \text{diameter} = 70 \text{ km.}$$

*The value of π seems to be in error by about 180°; it was not used.

The relation between albedo and diameter is found in *Ap. J.* 43, 173. This value has a large probable error, for the albedos of individual planets are known to vary widely, (0.05 to 0.48). Using $p = 0.40$ the diameter would be 110 km.

Of the density of the asteroids little can be said, except that it is probably comparable with that of the denser planets or the meteors. If we assume the density of *Mars*, (3.9), an asteroid of diameter 208 km. at a distance of 0.005 astr. units would have approximately the same influence as *Mars* itself at a distance 0.2.

It seems reasonable to conclude that *Aethra* is larger than the average asteroid, but smaller than many of those discovered earlier and that a sufficiently close approach to any of the above mentioned twenty-four, (they are 3, 7, 8, 9, 14, 19, 20, 23, 26, 27, 30, 32, 37, 57, 59, 61, 70, 78, 79, 88, 100, 103, 114, 119), would change the orbit considerably. There should be included in this list a few others discovered later, for which the calculations have not been made.

Take for example the asteroid (3) *Juno*, whose diameter and albedo have been measured. The diameter is 203 km. (BELL, *Ap. J.* 45, 11). On the basis of ALTER's elements of *Aethra* and the elements of *Juno* found in *B. J.* 1875, *Juno* would have passed its descending node upon the plane of *Aethra* about Jan. 5, 1878, just following *Aethra*. By applying a small negative correction to the position of this node and a small negative correction to *Aethra's* mean motion a hypothetical collision could be made.

More approximate calculations show that a correction $\Delta\mu = -15''$ to $-20''$ to *Aethra* would give a close approach at the descending node of (8) *Flora* in 1880.7.

There is another possibility. Certain asteroids, notably *Eros*, have shown considerable variability in brightness. An extreme case is (77) *Frigga*. This planet was discovered in 1863, lost in 1865, re-discovered in 1879. In *A. N.* 97, 147, PETERS has established that, in order to account for the failures to find it in 1865, 66, 70, 71, 73, the brightness must have diminished greatly, passing from the eleventh to fainter than thirteenth magnitude. In this connection it should be recalled that the brightness of *Aethra* depends solely on a statement by LUTHER in 1892 that *Aethra* was of the 11th magnitude in 1873.

Summarizing the preceding as well as some facts brought out by LUTHER and ALTER:

The orbit of *Aethra* is very uncertain. It is based on an arc of only twenty-two days. Various attempts to improve the elements by slight corrections to the

observations or by selection of the observations show how sensitive this orbit is to small errors of observation. The mean motions differ from $844''$ to $980''$. In fact, the circle and the parabola are just outside the range of solution. One of these orbits suggests the possibility that the mean motion was almost exactly three times that of *Jupiter*, in which case it may have been lost through perturbations.

During the period of observation neither *Jupiter* nor *Mars* was close to the planet.

Aethra is not identical with the 1913 Lowell object.

There is a possibility that *Aethra* has been perturbed by some other asteroid larger than itself.

Aethra is only one of numerous planets which have not been seen since the year of discovery. One lost planet, (77) *Frigga*, when found again, was proved to have so diminished in brightness as to have escaped searches two magnitudes fainter than predicted. It is noticeable that lost planets in general show high inclinations and eccentricities, thereby causing large differences in magnitude at various oppositions and apparent paths outside the usual field of search.

Of all the possibilities, the most probable seems to be that *Aethra* has only chanced to elude observers, partly because of its high inclination and eccentricity and possibly through a large unknown variability in brightness. As pointed out by ALTER, the favorable oppositions occur when the planet is far south of the equator. There would be the greatest probability of success if a search were made at some southern observatory during the spring of one or more years, covering the apparent path on the assumption of a wide range in orbital position.

Extending the same suggestion further, asteroid searches outside the equator and ecliptic might result in some very interesting discoveries for this is where we should look for planets very close to the *Earth*. The one objection to this plan is perhaps the large area of sky which would have to be examined for the reward of a single unusual planet.

Observatorio Nacional, Cordoba,
June 22, 1917.

NOTE

Some time ago a letter was sent to the Lowell Observatory stating the reasons for questioning the genuineness of the asteroid image on the Lowell plate of June 10, 1913, and inquiring about the character of the trail, its direction and the approximate daily motion and possible confirmation on a duplicate field. The above paper has been withheld from publication awaiting a reply.

A letter has just been received from Astronomer C. O. LAMP- LAND, who has courteously detailed the evidence upon which the reality of the image rests. Summing up briefly: the plate is a fifteen-minute exposure with the forty-inch reflector, of inferior

quality owing to haze and clouds; the elongated image has all the appearance of a bright asteroid; duplication of the field is lacking owing to a long period of unfavorable weather; the direction of elongation and the daily motion are very uncertain, but, as nearly as can be determined, the motion is about parallel to the equator and from 10' to 12' per day.

Concerning the possible identification with *Aethra*, the daily motion of *Aethra*, according to the elements by ALTER, would produce a trail inclined about sixty degrees to the observed motion.

Concerning the reality of the image, the asteroid, assuming retrograde motion, ought to be on the Cordoba Astrographic plate of June 9, 1913 in the neighborhood of

$$15^{\text{h}} 28^{\text{m}}.1 \quad -28^{\circ} 26'$$

Assuming direct motion, it should be in the neighborhood of

$$15^{\text{h}} 26^{\text{m}}.3 \quad -28^{\circ} 26'$$

August 21, 1917.

NOTE BY DR. LEUSCHNER.

DR. A. O. LEUSCHNER has added the following footnote to Dr. GLANCY's paper. Dr. GLANCY has asked me to verify certain errata which she has picked up in addition to those already published. I have verified her errata for *Publ. L. O.*, Vol. VII, pages 471 (found here but not published) and 476.

With reference to the erratum *L. O. B.*, page 275, I am quite sure that Dr. GLANCY is correct since the mean of the dates of observation as printed is June 19.5 and not 18.5. Since Dr. ALTER is now a lieutenant in the Coast Artillery and Adjutant to the Commander at Ft. Scott, and since his papers are all packed, reference to his computations cannot be made at this time.

With reference to the statement *L. O. Publ.*, Vol. VII, page 462, it may be pointed out that the hypothesis of perturbations by *Mars* was abandoned, as is pointed out in *L. O. Bulletin*, page 275, in the following words: "Any effect due to perturbation would be very much smaller than the uncertainty due to range."

The original statement in Vol. VII was made entirely on the basis of the previously known orbits before any computation was undertaken here. While the uncertainty of the orbit was recognized at that time, the enormous possible range of the elements became known only in the course of Dr. ALTER's computations. A condition of fairly close approach of *Aethra* to *Mars* within a comparatively short time after the original series of observation in 1873 might be produced by a proper choice of the mean motion and eccentricity within the range of solution. Thus perturbation by *Mars* may yet be a factor in this problem, although the possibility is remote. Of course, on the basis of the orbits involving identity with the Lowell object, no such approach can have occurred. But the large range of possible solutions would entirely obscure the effects of perturbation even if *Aethra* had been close to *Mars* while under observation instead of possibly approaching soon after, which is within the range of probability. The original statement in Vol. VII should therefore not be considered as erroneous, but as one worthy of consideration before the seemingly large range of practical solutions was found by Dr. ALTER's investigation.

If *Aethra* has not been subject to perturbations, the indeterminateness of the elements is sufficient to account for its loss, but it may also be subject to light variation. Furthermore the object may after all have been a comet moving in a highly elliptic orbit. Other cases are on record in which comets have been mistaken for asteroids on account of their star like appearance.

ON THE PREPARATION OF OBSERVATIONS FOR THE DETERMINATION OF A PRELIMINARY ORBIT BY THE METHOD OF LEUSCHNER,

By A. ESTELLE GLANCY.

The calculation of an orbit is simplified if the times of observation are Greenwich mean noon or midnight, and if the intervals are equal. If a graph of all the available observations were drawn on a large scale and a smooth curve passed through them, we could read off $a_1, \delta_1, a_2, \delta_2, a_3, \delta_3$, for any chosen dates. In practice the accuracy of such positions is less than that of the original observations.

I have just completed such a curve preliminary to the determination of an elliptic orbit for the planet 1903 NF, and have used a simple way to improve these positions.

The only available observations for this planet are 1903, Dec. 11, 15, 17, 18. From the Curve I read off the positions for the three dates, Dec. 12.0, 15.5, 19.0. To test the accuracy of these places the interpolations for the dates of observation were made. The comparison was not satisfactory so the following method of correction was used.

For simplicity take this particular case of three geocentric positions read from a smooth curve. It is necessary to assume the second difference constant. Suppose the comparison between the interpolated value for Dec. 11 and the observed value leaves a residual v in the sense $O - C$. Let f, f^I, f^{II} , represent those particular values of the function, the first difference and the second difference which were used in the interpolation. Then the residual is made up as follows:

$$\text{corr. to } f + n \text{ corr. to } f^I + \frac{n(n-1)}{2} \text{ corr. to } f^{II} = v$$

There will be as many equations as there are observations. The differences can always be simply expressed in terms of the functions themselves. Hence we shall have equations of the form:

$$\begin{array}{cccc} a_1 \text{ corr. to } f(a) + b_1 \text{ corr. to } f(a+w) + c_1 \text{ corr. to } f(a+2w) = v_1 & & & \\ a_2 & b_2 & c_2 & v_2 \\ a_3 & b_3 & c_3 & v_3 \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{array}$$