

On the lost minor planet (719) Albert

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Summary. The Amor-type ($q = 1.19$) minor planet (719) Albert was lost, soon after its discovery by J. Palisa in Vienna in 1911. A new investigation of the available data, including a complete re-reduction of the Copenhagen and Heidelberg observations, shows that they are mutually consistent, if the timing uncertainty of the ill-defined end-points of the faint photographic trails is taken into account. A new orbit has been computed, but since the orbital longitude is indeterminate at the present epoch, recovery attempts cannot be based on an ephemeris.

Key words: asteroids – astrometry

1. Introduction

The lost minor planet (719) Albert (1911 MT) – one of the two remaining in this category – was discovered on October 3, 1911 by Johann Palisa as a 12 mag. object with fast prograde motion. The discovery was made visually at the 27-inch refractor of the Imperial Observatory in Vienna. At this time, Palisa collaborated closely with Max Wolf at Königstuhl (Heidelberg), who observed photographically. The cooperation benefitted from the complementary nature of their observational methods; discoveries and star charts were most easily made photographically, while the follow-up and securing of positions for critical objects took advantage of the time-saving visual technique.

The unusual motion of (719) Albert immediately indicated an exceptional object and various efforts were undertaken to follow it, cf. Palisa (1911), Kobold (1911), Wolf (1911), Ebell (1912), Palisa (1912a), and Wolf (1912d), but the minor planet was soon lost and all attempts to recover it were in vain. A summary of these events has been written by Ashbrook (1978).

Since some doubts have been raised about the consistency of the original positions, we give here a critical discussion of all available data. They include remeasurements of the Heidelberg plates obtained by M. Wolf and also a thorough revaluation of the visual observations by C. F. Pechüle, as described in his observing book from the Copenhagen Observatory. Incidentally, the Albert case illustrates the advantages of micrometric measurements of fast moving objects, whose faint photographic trails have ill-defined end-points.

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2. The observations

Five sets of observations are available: micrometer measurements from Vienna and Copenhagen, and photographic plates from Greenwich, Heidelberg and Johannesburg, respectively. We now discuss these observations in some detail; the positional data, in some cases corrected, are given in Table 1 and will be used for the orbital computation.

2.1. Vienna

Palisa secured a total of eight micrometer measures on Oct. 3, and four additional measures on Oct. 4, 1911, all in bright moon-light (Palisa, 1911). Later, Palisa (1912b) revised the first position by the rejection of one comparison. Here we use the (1950.0) positions which are included in the data set on the Minor Planet Center magnetic tape (Marsden, 1986). However, the time of the observation on Oct. 4.07773 is changed to 4.07402, in accordance with the revised time indicated by Palisa (1912b), and the longitude $1^{\text{h}}05^{\text{m}}21^{\text{s}}$ of Vienna, for which the value $1^{\text{h}}00^{\text{m}}00^{\text{s}}$ was apparently used in the MPC data set.

2.2. Copenhagen

C. H. Pechüle secured two positions at the 36 cm refractor at the Copenhagen Observatory. His original observing books are extant at the Institute for the History of the Exact Sciences at the University of Aarhus; the relevant four pages are reproduced in Fig. 1. The comparison star is AGK₃ $-0^{\circ}0091 = \text{SAO } 128972$ and the screw-value ($1^{\text{R}} = 24''.285$) of the micrometer is available from similar notebooks by Prof. E. Strömgren. It is therefore possible to completely re-reduce the observations, although Pechüle's notes are very brief and were obviously only intended for personal use. Because of minor errors and inconsistencies, they can only be fully decoded by comparison with other notes, elsewhere in the books. For easy reference, the letters (A, B, ... I) identify the corresponding sections in Fig. 1. The numbers actually recorded by Pechüle are in *italics*:

(A) "New Pl(anet) MT with direct motion discovered by Palisa Oct. 3".

(B) "hardly 12^m difficult to see in somewhat misty air, moonlight until 14^h and low altitude".

(C) 6 eye and ear comparisons. An M.E.T. clock reckoning from Oct. 3.5 is used.

Table 1. Observations and residuals (unit of weight: 3")

1911 U.T.	R.A.	(1950.0)	Decl.	<i>P</i>	<i>p_x</i>	<i>x</i>	<i>p_y</i>	<i>y</i>	Observatory
Sep. 16.86858	23 ^h 59 ^m 00 ^s .77		12°52'56".3	138°	0.01	+ 6".9	4.00	+3".9	Heidelberg
16.88520	23 59 03.67		12 52 01 7	138	0.01	+ 9.6	4.00	−3.9	Heidelberg
Oct. 4.07402	00 44 01.75		00 28 08.1	90	1.00	+ 2.2	1.00	−2.7	Wien
4.90579	00 45 40.13		−00 00 22.7	90	0.50	+ 5.9	0.50	−2.5	Wien
5.05606	00 45 55.76		−00 05 24.8	90	14.00	− 0.5	3.50	+1.6	Copenhagen
5.09498	00 45 59.90		−00 06 46.6	90	5.3	− 1.5	1.90	−1.9	Copenhagen
11.89340	00 57 33.29		−03 25 14.8	138	1.00	+ 0.9	4.00	+0.9	Greenwich
11.92554	00 57 36.02		−03 26 02.3	138	1.00	+ 0.8	4.00	+1.8	Greenwich
11.94131	00 57 37.38		−03 26 29.4	138	1.00	+ 4.0	4.00	−0.0	Greenwich
17.94125	01 05 51.16		−05 33 54.9	138	0.01	− 8.1	4.00	−0.8	Heidelberg
17.99807	01 05 55.01		−05 34 55.5	138	0.01	− 8.1	4.00	−1.1	Heidelberg
18.81579	01 06 56.21		−05 48 18.6	138	0.10	−24.5	2.00	+0.2	Johannesburg

Pl(anet) S(outh)	★ N(orth)	Planet − ★
13 ^h 59 ^m 30 ^s .1	14 ^h 00 ^m 48 ^s .7	−1 ^m 18 ^s .6
12 ^m 48 ^s .0	14 ^m 05 ^s .8	17 ^s .8
17 ^m 36 ^s .7	18 ^m 54 ^s .0	17 ^s .3
23 ^m 50 ^s .0	25 ^m 06 ^s .8	16 ^s .8
27 ^m 07 ^s .0	28 ^m 23 ^s .4	16 ^s .4
39 ^m 41 ^s .8	40 ^m 57 ^s .5	15 ^s .7

A normal place is formed by equal weights: Mean time of planet observations ($14^h20^m06^s$) + clock correction (+38") − longitude of Copenhagen (9^m41^s) = $14^h11^m03^s$, which is the published local mean time (Pechüle, 1911, 1912). For the R.A. difference is obtained:

$\Delta\alpha$, mean	−1 ^m 17 ^s .10
Correction to sidereal time interval	−0 ^s .21
Differential refraction	−0 ^s .01
Published value	−1 ^m 17 ^s .32

Assuming a uniform hourly motion of +4^s.84, the residuals become:

$$(O - C): \quad -0^s.2 \quad +0^s.1 \quad 0^s.0 \quad 0^s.0 \quad -0^s.1 \quad +0^s.2$$

from which the mean error $\pm 0^s.1$ is estimated for a single timing. The visual observations will not provide a very high accuracy, but the internal consistency of the individual comparisons is an effective check on gross errors. In particular, it was experienced at the Copenhagen Observatory that when the computations were made independently by two persons, then this procedure resulted in very reliable positions, cf. Stömgren (1983).

We note in passing that identifications of minor planets are greatly facilitated when, in addition to positions, daily motions are also available; this was the case with the observational procedure used by Pechüle. Recently, minor planets have been discovered in CCD frames and their motion could be followed in real time on the monitor screen, e.g. 1985 SA (Hansen, 1985; Kristensen, 1986), heralding a "renaissance" of the micrometer method.

(D) Declinations were observed twice with the micrometer:

M.E.T.	Pl. S.	★ <i>N</i>	Diff.
14 ^h 08 ^m 33 ^s	11 ^R .874	22 ^R .814	10 ^R .940 = −265".7
14 ^h 34 ^m 00 ^s	7 ^R .834	20 ^R .238	12 ^R .404 = −301".3
14 ^h 21 ^m 17 ^s	Mean value: = −283".5		
	Correction for motion: +1".7		
	Differential refraction: −0".3		
	Published value: −282".1 = −4'42".1		

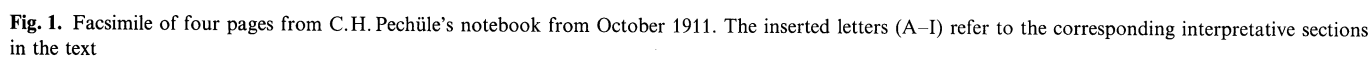
The mean declination is reduced to the clock-time ($14^h20^m06^s$) of the normal point in R.A. by the assumed hourly motion −84"/h.

(E) Parallax factors are computed from M.E.T. ($14^h20^m44^s$) and give the hour angle +34°22'. The 4-figure accuracy indicated is not needed and actually not attained; a table of Bessel's auxiliary angle *N* (Bessel, 1841), here 60°26' must have been used. Curiously enough, it is the complementary angle, to those used in the computations of differential refraction. The parallax factors were standards at the time, but are of no interest today and will not be further discussed.

(F) However, an inspection of the procedure used for computing the differential refraction is necessary in order to distinguish between the two methods used for observations: either the fixed threads are parallel to the true declination circles or the stars follow the moving threads in their apparent motion. The observing books elsewhere contain computations for low-altitude objects according to both methods, but it is never stated explicitly which method was used. In the present case the correction in R.A. was computed by

$$\kappa \cdot (\delta_{pl} - \delta_{\star}) \cdot \tan^2 \zeta \cdot \sin(2\eta) \cdot \sec \delta$$

which shows that the micrometer was adjusted to follow the apparent motion of the stars. An interpretation of the numbers is given below; the angles are in degrees and logarithms are stated for natural numbers:



N (Bessels' aux. angle)	$30^{\circ}.4$	κ	6.440
δ	$-0^{\circ}.3$	$\delta_{p1} - \delta_{\star} = -283''$	2.452_n
		$\tan^2 \zeta$	0.524
$\cotan n$ (Bessels' " n ")	9.480	$\cos^2 \delta$	0
$1/\sin(N + \delta)$	0.300	$\sin(2\eta)$	9.793
$\tan \zeta \sin \eta$	9.780	$\log(-0''.16)$	9.209_n
$(= \cotan n / \sin(N + \delta))$		Corr. in α :	$-0^{\circ}.01$
$\tan \zeta \cos \eta$	0.237		
$(= \cotan(N + \delta))$			
η (parall. angle)	$19^{\circ}.2$	$\kappa \cdot (\delta_{p1} - \delta_{\star})$	8.892_n
		$(= 6.440 + 2.452)$	
$\tan \zeta$	0.262	$1/\sin^2(N + \delta)$	0.600
$(= \cotan(N + \delta) / \cos \eta)$		$\log(-0''.31) =$	9.492_n
ζ (zenith dist.)	$61^{\circ}.3$	Corr. in δ :	$-0''.3$
κ (refraction. const.)	6.440		

The 3-figure computations were further simplified – probably by mental arithmetic and use of nearest entries in auxiliary tables. For instance N should have been $29^{\circ}.4$ and not $30^{\circ}.4$ as stated, and $\log \cotan n$ should be 9.526 instead of 9.480. Such errors make the notes hard to decode and a correct interpretation requires the intercomparison of several similar computation schemes in the books.

(I) Here Pechüle remarks – and underlines – that the second observation has little weight and that between the first and the second observation, the planet, southbound, passed so near west of a somewhat brighter star that it could not be observed; this does not necessarily imply that the star and the planet were indistinguishable in the telescope, but only that they were so near and hence the transits so close in time that the visual timings would be disturbed.

In order to see whether this information might be useful for the present investigation, we looked for the mentioned star on the Palomar Observatory Sky Survey, a glass copy of which is available at the ESO Headquarters in Garching. Indeed, a star of magnitude ~ 13.5 and neutral colour (i.e. of spectral type $\sim A-F$) is seen near the line which connects the two Copenhagen observations on Oct. 5 (Table 1). Its position was measured on a Heidelberg plate from 1911 (B2577, see below), the blue POSS plate from 1954 (O1196) and an ESO R Schmidt plate from 1978 (No. 3029), using SAO stars as standards. Comparing with other stars of the same magnitude in the field, no significant proper motion is detected and the mean position from the three measurements is R.A. = $00^{\text{h}}45^{\text{m}}58^{\text{s}}.89$; Decl. = $-00^{\circ}06'2''.8$ (1950.0). This star is not contained in any catalogue within the SIMBAD data base. From the motion of the planet, we find that the closest passage occurred at a distance of $\sim 14''$ at position angle $\sim 235^{\circ}$, or south-west of the star. This fully confirms Pechüle's note and strengthens our belief in the accuracy of his observations.

Other entries in both Pechüle's and Strömgren's notebooks indicate that the planet was later searched for, but could not be found. On Oct. 15, Pechüle writes: "Comet Beljowsky visible $6^{\text{h}}40^{\text{m}}$ between clouds but too low for observation ... night becomes clear ... search long for planet MT around $1^{\text{h}}06^{\text{m}} - 6^{\circ}34'$ (then an illegible reference, maybe to the star BD $-6^{\circ}22'$ at the said position) without finding it". Oct. 16, says: "searches for 1911 MT without result". Later he wrote some remarks on the preceding pages; there is a reference to the additional observations on Astron. Nachr. 4575 (H) and also the ephemeris in Lick Bull. No. 210 (G). All this confirms the exceptional observational efforts which were undertaken in order to secure the discovery, as

reported by Wolf (1912d) and also by the Central Bureau for Astronomical Telegrams (Kobold, 1911).

In want of the perihel orbit technique for the computation of search ephemerides, Ebell (1912) used parabolic orbits, although they did not fit; the usual circular orbits could not be used, as they will always give a retrograde opposition. The ephemerides based on elliptical elements became available much too late for directing a dedicated search (Franz, 1912; Haynes and Pitman, 1912; Haynes, 1912a–c; Kiess, 1912; von Tolnay, 1912). They lead, however, to the identification of additional, photographic observations from Greenwich, Heidelberg and Johannesburg.

2.3. Greenwich

3 observations were identified on Greenwich plates (Dyson, 1912). Recent attempts to procure these plates for remeasurement were unsuccessful. According to G. E. Taylor (1981), the file states "lent to Prof. Pickering 1912, June 22". The present whereabouts of these plates are unknown.

2.4. Heidelberg

Recent remeasurements of Heidelberg plates have proven useful for the recovery of the lost minor planets (473) Noll (Marsden, 1987) and (1179) Mally (Schmadel and West, 1988). They also contributed to the solution of the long-standing (330) Adalberta problem (West et al., 1982).

Two plates, B2885 and B2886, were obtained on October 17, 1911 at Heidelberg by F. Kaiser, and Wolf (1912a, b) identified a trail of 1911 MT on the first of these. Later, another trail of this object was identified and measured on the best plate of a pair, A6425 and A6426 from Sept. 16 (Wolf, 1912c). In an attempt to improve these data by means of modern methods, Dr. G. Klare kindly searched the old records at the Heidelberg-Königstuhl Observatory and forwarded the available plates (A6425/26 and B2885) to one of the authors (RMW) for remeasurement at ESO. Another plate, B2877 from Oct. 11, 1911, which might also show 1911 MT, was also put at our disposal.

The plates are stored in manilla envelopes and are in good shape; with the exception of B2877, which has a strong yellow hue, they have been well fixed and have little or no plate fog.

The B2885 plate was obtained on Oct. 17 with the 40 cm Bruce telescope. The plate scale is $101''.4/\text{mm}$; it measures $25 \times 30 \text{ cm}^2$ ($7^{\circ} \times 8^{\circ}.5$) and was exposed during 3 hours under mediocre sky conditions. From the trail of minor planet (2185) Guangdong of mag. 15.9, it can be seen that in particular the last third of the exposure must have been affected by bad transparency because of haze or clouds. (1562) Gondolatsch at mag. 16.3, (2040) Chalonge at mag. 17.1 and (2511) Patterson at mag. 16.7 are in the field, and since their trails can not be seen, the limiting magnitude for main-belt objects is ~ 16 .

The trail of (719) Albert can barely be perceived on the original plate and it was therefore decided to make a photographically amplified copy (cf. West et al., 1982) before measurement. This brought out a faint, rather uneven trail of 2 mm length and in position angle $\sim 135^{\circ}$, as shown in Fig. 2. The reality was verified by comparison with the corresponding POSS plate; the trail is situated between a galaxy (indicated by "A" in Fig. 2) and a galactic star ("B"). It starts near another, fainter galactic star ("C") and the southern part is ill-defined, for the reason explained above.

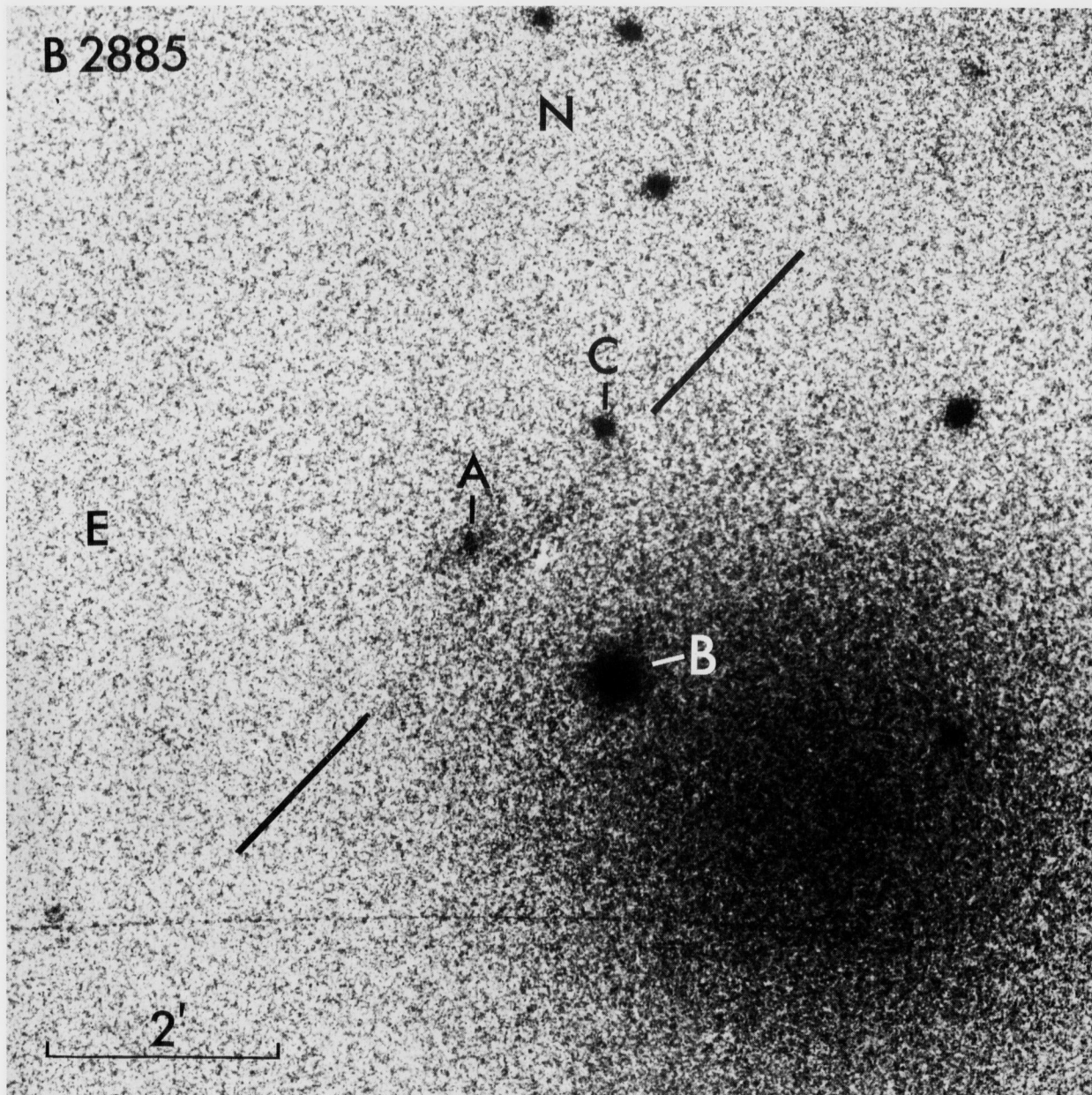


Fig. 2. Enlargement of photographically amplified print from Heidelberg plate no. B2885 of October 17, 1911. The uneven trail of (719) Albert, at position angle $\sim 137^\circ$, is seen between a galaxy (A) and a galactic star (B). The trail begins near another galactic star (C). The large spot in the SW corner is the enhanced and diffuse image of an ink spot on the rear side of the plate, marking the position of the trail for the measurement in 1912. The scale is indicated by a 2' bar

Two reductions were made, following the method described by Walter and West (1986), and by means of 20 Perth-70 and 21 SAO stars, respectively; the rms values in R. A. and Decl. are $\sim 1''.2$. In each case four points on the trail were measured, two of which were subjectively perceived as the trail "ends", and two others at the best-defined parts of the trail. There was good agreement between the settings, but it also became clear that the trail ends are effectively undefined and that the first two points cannot a priori be associated with the epochs of the exposure start and end. Thus, although the direction of the trail is well defined, the timing along the trail is not. For this reason, the resulting positions can be used, but the corresponding epochs must be found during the orbital solution. In other words, the distance from the trail will indicate the goodness of the orbital fit.

Another plate from the same telescope, B2877, was obtained on Oct. 11, 1911. (719) Albert is in the field, rather close to the eastern edge, where the stellar images are affected by severe coma. The visual inspection leaves the impression of an extremely faint trail, but it would in any case be unmeasurable.

The Sept. 16 Heidelberg plate pair (A6425/A6426) was obtained with the Voigtländer lenses; the plate scale is $\sim 250''/\text{mm}$ and the size is $13 \times 18 \text{ cm}^2$ ($9^\circ \times 12^\circ.5$). They were exposed simultaneously during 90 min, and after an interval of $6^{\text{m}}40^{\text{s}}$, the second plate was exposed during further 90 min. The A6425 plate shows a very faint, diffuse and uneven trail near the northern edge of the plate, which was measured by E. Ernst in 1912 (Wolf, 1912c); this is also indicated on the envelope ("MT gemessen, Aug. 1912") and the trail is marked "MT" with an arrow) on the

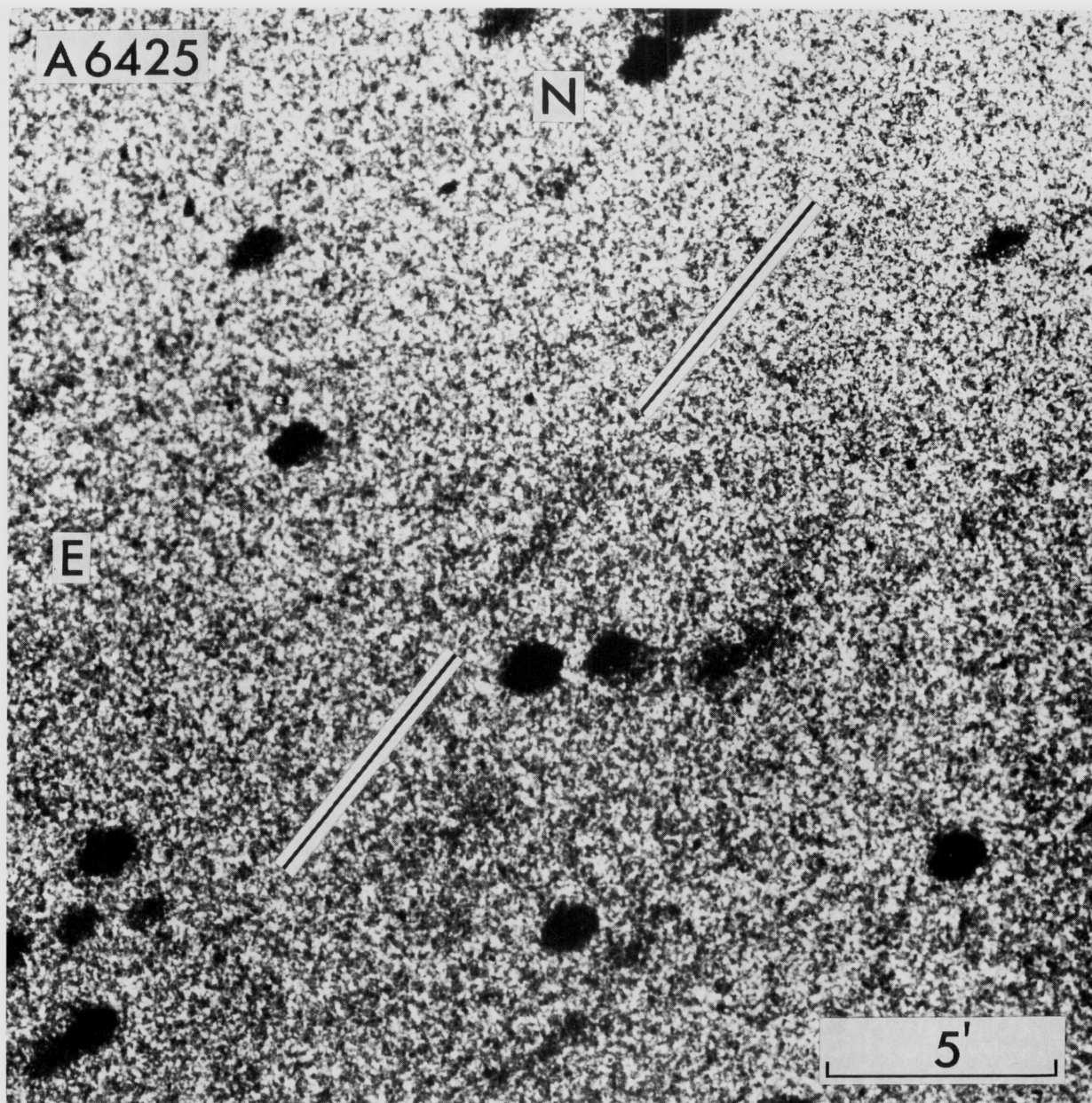


Fig. 3. Enlargement of a photographically amplified print from Heidelberg plate no. A 6425, showing the very faint, predisccovery trail of (719) Albert on September 16, 1911. The scale is indicated by a 5' bar

rear side of the plate. This area of the plate is clearly out of focus and affected by coma. The length of the trail is about 0.6 mm.

Again, photographic amplification was needed, before a remeasurement could be attempted (Fig. 3). Based on 25 SAO stars, rms values of $\sim 1''.5$ were achieved in both directions. As was the case for B2885, three, not quite consistent positions were determined on the trail, and their corresponding times of observation will here be considered quantities to be solved for.

On the A 6426 plate, an exceedingly faint trail of the same direction can barely be discerned. Whereas it therefore confirms the reality of the trail on A 6425, it is not measurable.

2.5. Johannesburg

The Johannesburg observation resulted from a request by J. Palisa (1912a). The weather was moderately good on Oct. 18, and a 4^h

exposure was obtained, but the planet could not be found in the central $15^\circ \times 15^\circ$ field before the ephemerides became available (Innes, 1912). A very faint (14 mag) trail was first rejected, because the ephemerides, based on an interval of only $1^d.03$, indicated a shorter trace. No use will be made here of the information about the end-points of this trail. The accurate position was determined by J. Palisa (1912c).

3. The orbit

The orbit determination is affected by the indeterminateness of objects found almost exactly opposite to the Sun, in which case the motion will be nearly on a great circle. On the other hand this gives the advantage that the areas in which other observations may be found are greatly reduced. Here we start from the unquestionable

observations from Vienna on Oct. 3 and 4, and from Copenhagen on Oct. 4. First, a variety of Väisälä orbits show the authenticity of the Greenwich positions on Oct. 11. Thereafter it can be successfully demonstrated in a similar manner that the Oct. 17 Heidelberg, the Oct. 18 Johannesburg and finally the Sept. 16 Heidelberg positions are also genuine.

The proposed Oct. 26 Mt. Hamilton position (Haynes, 1912c; Kiess, 1912) must be disregarded, because it would imply the existence of visible trails on available plates and this is not the case. With the tentative identification by E.S. Haynes (1912c), there should be other trails within a few arcminutes from the Sept. 16, and Oct. 17, 18 trails, but such trails are not reported. From the orbit which is determined below, the predicted position on Oct. 26 may be just outside the field of the Mt. Hamilton plate; it might be useful to inspect the plate again, if it can be found.

The order of magnitude of the distance to the planet was estimated by Crommelin (1911, 1912), on the basis of parallax effects.

We derive a new set of elements by a standard computer programme for differential orbit improvement, but the equations of condition for $\cos \delta \cdot \Delta \alpha$ and $\Delta \delta$ have been slightly modified to equations for

$$x = +\sin P \cdot \cos \delta \cdot \Delta \alpha + \cos P \cdot \Delta \delta$$

$$y = -\cos P \cdot \cos \delta \cdot \Delta \alpha + \sin P \cdot \Delta \delta,$$

respectively. Ordinary observations then correspond to $P = 90^\circ$, and if the times are uncertain on a trail with position angle P , this is fully accounted for by putting the corresponding weight $p_x = 0$. (O – C) residuals x and y are listed in Table 1 and show that the observations are consistent. The epochs for the positions from Heidelberg plates on Sept. 16 and Oct. 17 were interpolated. The resulting elements are given in Table 2.

The perihel distance (q) is very well determined and there is no doubt that the object is of the Amor type. If the perihel is passed when the longitude of the Sun is $\lambda_\odot = 158^\circ$ (around Sept. 1), then we have the very favourable conditions which occurred at the time of discovery.

At perihel, the longitudinal daily motion in the orbit ($\dot{v}$) is only slightly slower than that of the Earth (k):

$$\dot{v} = k \cdot p^{-3/2} (1 + e \cdot \cos v)^2 \simeq 0.959 k$$

and the opposition will last 2 to 3 months. The velocity exceeds that of the Earth, when

$$r\dot{v} = k \cdot p^{-1/2} \cdot (1 + e \cdot \cos v) \geq k, \quad p = a \cdot (1 - e^2)$$

or $|v| \leq 49^\circ$ or $|M| \leq 13^\circ$. In this case, the motion is *prograde*. If the conditions of visibility are defined as when $B \leq 18^m$ and also when

the elongation from the Sun exceeds 150° , then the planet is visible if the perihel is passed within $\sim 55^d$ of September 1.

4. Conclusions

The critical examination of the case of the lost planet (719) essentially confirms the orbit of Herget (cf. Ashbrook, 1978), published in the Leningrad Ephemerides of Minor Planets. From the uncertainty in the orbital elements, as indicated in Table 2, the number of orbital revolutions after 77 years is: $17^R 8 \pm 0^R 3$, hence the present location in the orbit is quite uncertain and ephemeris-guided searches would appear devoid of any significant chances of success. However, the conditions of visibility are not so restrictive, and it is not entirely impossible that unidentified positions may exist in the present data base, although a serious difficulty for the identification is that such positions are likely to be single only. The present data base lacks information about the daily motion which could disclose an unusual object and for single positions, the photographic technique does not distinguish between pro- or retrograde motions. Preferably, the same region should have been photographed during two consecutive nights, whereby (719) Albert would easily disclose itself by an unusual motion. For an effective identification of single observations, a rather more accurate, initial orbit would be required than the one now available for this lost minor planet.

A possible search method exists (Kristensen, 1981) for the case in which the orbital ellipse is approximately known, whereas the longitude in the orbit is unknown. For each individual observation in the data file to be searched, an eccentric anomaly (E) is computed from α and the corresponding declination δ_e is compared with the observed δ_o . If two nearby positions of the planet are present in the file, then they can be identified by the motion, i.e. as having similar $(\delta_o - \delta_e)$ residuals. In the case of (719) Albert, any belonging positions in the file are likely to have different designations because of the unusual motion. A preliminary search by this method through a subset of the MPC data file (about 230 000 positions, up to 1980) did not reveal any potential candidate (pair or multiplets of) positions, and it may be necessary to invest rather large amounts of computer time in order to perform an exhaustive analysis of all available positions, which have not yet been attributed to known objects.

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Table 2. Orbital elements for (719) Albert

a	2.6453 ± 0.032	
e	0.5501 ± 0.005	
i	$10^\circ 96' \pm 0.07$	Ecliptic and
Ω	$186^\circ 10' \pm 0.07$	equinox (1950.0)
ω	$151^\circ 89' \pm 0.03$	
M	$0^\circ 57'$	Epoch and Osc. 1911 Sept. 1.0
q	1.1901 ± 0.0012	$= a(1 - e)$
P	4.30 ± 0.08	year
$B(1,0)$	$16^m 6$	

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