"On the Orbit of the Part of the Leonid Stream which the Earth encountered on the Morning of 1898, November 15."

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For an accurate prediction of the return of the Great Leonid swarm of meteors, it is of the highest importance to determine as accurately as possible the orbit in which each part of the swarm is moving.

As has been pointed out by Drs. Stoney and Downing,* the denser part of the stream, with which we are chiefly concerned, being now drawn out to such a length that it takes more than two years to pass any point of the orbit, it results that the perturbing effect of the several planets will not be the same on different parts of the stream.

Hence it follows that the orbit deduced from the observations made during the great shower of 1866, however reliable they may have been, must not be assumed to represent accurately the track of the meteors which we shall meet when we pass through the node of the orbit next November, even when allowance is made for the perturbations which that part of the stream has suffered in the meanwhile.

But although the determinations of the radiant point of the shower made in 1866 are entitled to a high degree of confidence, owing to the large number of meteors upon which they depend, yet the discrepancies existing between the results of different observers, and the fact that the varying effect of the earth's attraction upon the position of the radiant at different zenith-distances was generally overlooked by the observers at the time, introduce an element of uncertainty into the orbit.

The extent of these discrepancies may be estimated from the "List of Observed Places of the Radiant Point in 1866," as given by Professor A. S. Herschel in the 'Monthly Notices of the Royal Astronomical Society,' vol. 27, p. 19, and the effect of this uncertainty on the resulting orbit may be illustrated by comparing the two sets of elements deduced by Adams and Schiaparelli, respectively, from English observations of the radiant point on that occasion. These are—

		Adams.†	Schiaparelli.‡
Period (assumed)	$P =$	33·25 years.	33·25 years.
Mean distance	$a =$	10·340	10·340
Eccentricity	$e =$	0·9047	0·9046
Inclination	$i =$	16° 46′	17° 44′·5
Longitude of node.........	$\nu =$	51° 28′	51° 28′
Longitude of perihelion...	$\pi =$	58° 19′	56° 26′

* 'Roy. Soc. Proc.,' No. 410.

† 'Monthly Notices,' vol. 27; 'The Scientific Papers of John Couch Adams, vol. 1, p. 269.

‡ 'Entwurf einer Astronomischen Theorie der Sternschnuppen,' von J. V. Schiaparelli, p. 57.

The part of the stream through which the earth will pass this year lies between the position of those meteors which the earth encountered last year and that of the meteors of 1866. It is, therefore, of importance to investigate how far the orbit of the meteors observed in November, 1898, agrees with that deduced from the observations of 1866.

Unfortunately the observations obtained in 1898 are fewer than could be desired. Unfavourable weather prevailed almost universally in England. On the Continent meteors were observed at a few stations, but they appear to have been outlying members of the stream, and the denser portion was not encountered until about 19 hrs. G.M.T., on the morning of November 15 (civil time). For observations at the time that the earth was passing through the densest part of the stream, we are wholly dependent upon the American observers. The time of maximum display is, owing to the paucity of meteors, somewhat indefinite, and seems to have differed by several hours at different stations. The most reliable accounts, however, agree in placing it between 19 hrs. 30 min. and 22 hrs. G.M.T. on the morning of the 15th, and from a discussion of all the separate determinations, I have been led to adopt 20 hrs. 45 min. as the most probable time of maximum. This agrees exactly with Professor Young's result, who writes, "The maximum was about 3 hrs. 45 min. (Eastern Standard Time) when for about 20 minutes the meteors averaged two or three a minute."*

In Table I are given—the name of the observer, his observatory or station, its longitude and latitude, the Greenwich time, and the R.A. and declination of the radiant point.

In this connection I may remark that in order to contribute to an accurate determination of the orbit, the G.M.T. corresponding to the observation, and the approximate position of the observer are just as essential as the co-ordinates of the radiant itself. In several of the accounts before us I have had to assume that the position of the radiant corresponds to the time given as that of maximum display, or to the middle of the time over which the watch extended.

The longitudes and latitudes of the observers' positions may also in some cases be in error to the extent of several minutes, but they are sufficiently exact to enable me to compute the "zenith-attraction."

In Table I, I have included only those observations which seem to relate to meteors belonging to the dense, or central, part of the stream. They are all contained in the interval between 18 hrs. 58 min. and 23 hrs. 2 min. G.M.T.

Each of these separate results has to be corrected for the influence of the earth's attraction on the paths of the meteors during their approach, and for the influence of the earth's motion on the apparent position of the radiant.

* 'The Observatory,' December, 1898, p. 459.

Table I.

No.	Name.	Station.	Long.	Lat.	G.M.T.	Radiant. R.A.	Radiant. Decl.	Reference.
			h. m.		h. m.			
1	Sawyer	Brighton, Mass.	4 44	+42° 22′	18 58	148° 45′	+22° 15′	'Astro. Journ.,' No. 451.
2	Pickering	Harvard	4 45	+42 23	19 45	151 40	+22 17	'Astro. Nach.,' 3538.
3	Myers	Urbana	5 53	+40 6	22 45	150 30	+21 30	'Astroph. Journ.,' Jan., 1899.
4	Barnard	Yerkes	5 54	+42 34	21 33	149 0	+24 0	'Astroph. Journ.,' Mar., 1899.
5	Young	Princeton	4 59	+40 21	20 45	151 0	+22 30	'The Observatory,' Dec., 1898.
6	Davis	Columbia	6 9	+38 57	19 15	151 0	+22 0	'Popular Astronomy,' Dec., 1898.
7	Smith	Philadelphia	5 1	+39 57	19 25	150 0	+20 0	,, ,,
8	Culbertson	Hanover	4 49	+43 42	20 30	149 36	+22 12	,, ,,
9	Payne	Northfield, Minn.	..	..	19 7	148 0	+20 30	,, ,,
10	,,	,,	6 13	+44 28	20 52	149 36	+20 54	,, ,,
11	Wilson	,,	..	..	23 2	149 36	+21 30	,, ,,
12	Bracket	Claremont, Cal.	7 51	+34 5	21 17	150 53	+22 20	,, Jan., 1899.
13	Wilson	Northfield	6 13	+44 28	22 0	151 30	+22 18	,, Dec., 1898.

The radiants Nos. 2 and 13 were determined by the aid of photography.

The former varies with the zenith-distance of the radiant and its elongation from the "apex," or the point of the heavens towards which the earth is moving at the time. It has always the effect of displacing the radiant towards the observer's zenith, and hence has been called by Schiaparelli the "zenith-attraction." The amount of this displacement (η) is given by the expression,

$$\tan \tfrac{1}{2}\eta = \frac{w-u}{w+u} \tan \tfrac{1}{2}z,$$

in which z is the apparent zenith-distance of the radiant, u is the velocity of the meteors relatively to the earth before the influence of the earth's attraction has become sensible, while w is the accelerated velocity with which the meteor encounters the earth.

This displacement, which has been too frequently overlooked by meteor observers, may, as pointed out by Schiaparelli, amount in extreme cases to as much as 25° 38′. In the case of the Leonids, however, it happens that the elongation of the radiant from the "apex" is so small (in the case before us not exceeding 11° at any time) that the effect of the zenith-attraction never amounts to half a degree, its greatest value being 29′.

For computing the value of w we have the expression

$$w^2 = u^2 + 2gr,$$

r being the earth's radius, and g the acceleration of gravity at the surface, or, expressing the velocities, as is convenient, in terms of the mean velocity of the earth in its orbit,

$$w^2 = u^2 + 0{\cdot}141587.$$

In computing the value of $2gr$ in the above expression the Sun's parallax has been taken to be 8″·80, and the ratio of the earth's mass to that of the Sun equal to 1/331,100.

We thus have for computing w

$$w = u + [8{\cdot}84999] \times \frac{1}{u} - [7{\cdot}39895] \times \frac{1}{u^3},$$

the figures in brackets being the logarithms of the coefficients.

For determining u we may with quite sufficient precision adopt Adams's orbit of 1866. Also if U denotes the velocity of the earth at any time expressed in terms of its mean velocity, and R its distance from the Sun, then,

$$\mathrm{U} = \sqrt{\frac{2}{\mathrm{R}} - 1},$$

or, neglecting the second power of the eccentricity we may, without loss of accuracy, write $U = 1/R$.

In Table II are given the values of the Sun's longitude (☉), the longitude (l), the right ascension (a) and the declination (d) of the apex, and the orbital velocity of the meteors (v), all of which can be

Table II.

Time.	☉	Log R.	l.	a.	d.	v.
1898, Nov., 14·0	232° 9′·8	9·99514	142° 52′·8	145° 13′·7	+13° 53′·8	1·3877
14·5	232 40·0	·99510	143 22·7	145 42·7	44·0	·3878
15·0	233 10·3	·99505	143 52·7	146 11·9	34·1	·3879

computed from the 'Nautical Almanac' or from Adams's orbit of the meteor stream. These are given for three epochs, viz.:—November 14·0d., 14·5d., and 15·0d., from which their values at the time of each observation may be obtained by interpolation. All of these quantities are needed in the subsequent reduction of the observations, or for deducing the elements of the orbit.

We next compute the quantities u, w, and η, exhibited in Table III.

Table III.

No.	u.	w.	η.
1	2·3779	2·4075	22′
2	·3718	·4014	19
3	·3782	·4078	10
4	·3680	·3977	15
5	·3725	·4021	15
6	·3748	·4044	29
7	·3845	·4140	22
8	·3767	·4063	15
9	·3857	·4152	29
10	·3821	·4116	20
11	·3799	·4094	11
12	·3736	·4032	27
13	·3724	·4020	15

Applying the corrections for the earth's attraction, $d\alpha$ and $d\delta$, to the R.A. and declination from the formulæ

$$d\alpha = \eta \sin p \sec \delta\,; \ d\delta = -\eta \cos p,$$

p being the parallactic angle, we find the corrected R.A. and declination of the radiant, as given in the second and third columns of Table IV. In the next two columns of the same table are found the longitude (L′) and latitude (B′) of the same points, and in the sixth and seventh

Table IV.

No.	α′.	δ′.	L′.	B′.	L.	B.	Wt.
1	149° 4′	+22° 2′	143° 35′	+ 8° 54′	143° 31′	+15° 22′	0·5
2	151 56	22 6	146 5	9 53	147 54	17 3	1·0
3	150 37	21 22	145 11	8 46	146 12	15 6	0·5
4	149 12	23 51	143 4	10 38	142 31	18 22	0·5
5	151 13	22 21	145 22	9 53	146 36	17 4	0·4
6	151 26	21 43	145 47	9 21	147 23	16 9	0·3
7	150 19	19 47	145 29	7 11	146 50	12 24	0·2
8	149 48	22 2	144 14	9 8	144 37	15 47	0·6
9	148 23	20 11	143 38	6 56	143 36	11 59	0·1
10	149 52	20 41	144 46	7 53	145 32	13 37	0·3
11	149 43	21 21	144 24	8 28	144 50	14 38	0·3
12	151 8	22 7	145 23	9 38	146 37	16 38	0·2
13	151 42	22 7	145 52	9 50	147 26	16 53	0·5

columns are given the longitude (L) and latitude (B), of the true radiant corrected for the effect of the earth's orbital motion.

The quantities L and B define the direction of the tangent to the orbit of the meteors at the point where the earth intersects it, and from the mean of these separate determinations, the position of the earth in its orbit at the time, and an assumption with regard to the period of the meteor stream, the orbit is to be determined.*

The only difficulty lies in deciding on the best mode of combining the various observations, or in laying down a rule for determining the weights. In this part of the work a certain amount of arbitrariness is, I think, unavoidable. From a careful consideration of all the circumstances of each case, as far as they are recorded, the experience or inexperience of the observer in this class of work as far as it is stated, the number of meteors observed, and the size of the area from which the meteors appeared to radiate, I have been led to adopt the weights given in the last column of Table IV, which represents, I think very fairly, the relative value of the individual observations. It will be noticed that I have given the two photographic results (Nos. 2 and 13) an importance out of all proportion to the number of trails photographed, viz., four trails in the case of No. 2, and two trails in the case of No. 13. This is, I think, justified by the superior accuracy of photographic results in this class of observations.

I thus find as the definitive position of the radiant of the Leonid meteors of 1898,

$$145^\circ\ 49' \pm 20'{\cdot}5\ ;\quad +16^\circ\ 2' \pm 19'{\cdot}9,$$

corresponding to the epoch November 14·864 (astronomical time).

* See 'Handwörterbuch der Astronomie,' herausgegeben von Dr. W. Valentiner, vol. 2, Breslau, 1898.

From the researches of the late Professor H. A. Newton, and the results of the investigations of Drs. Stoney and Downing on the perturbations of Adams's orbit, the most probable value of the period of revolution would appear to be at present about 33·49 years, corresponding to mean distance of 10·39.

Any admissible variation in the length of the period, however, makes but a small change in the other elements of the orbit, as is evident from Table V, in which the elements in each column have been computed with the value of the mean distance which is contained in it.

Table V.

		I.	II.	III.
(Assumed) period	P =	33·25 yrs.	33·49 yrs.	33·73 yrs.
Mean distance.............	a =	10·34	10·39	10·44
Angle of eccentricity	ϕ =	64° 46′	64° 50′	64° 54′
Inclination	i =	16 3	16 3	16 3
Longitude of descending node	ν =	53 2	53 2	53 2
Longitude of perihelion......	π =	58 40	58 40	58 40

If we adopt the value 10·39 for the mean distance, as being on the whole the most probable, we have the orbit in column II representing the result of the observations of 1898, as far as they have been published.

"A Comparison of Platinum and Gas Thermometers, including a Determination of the Boiling Point of Sulphur on the Nitrogen Scale: an Account of Experiments made in the Laboratory of the Bureau International des Poids et Mesures, at Sèvres." By Drs. J. A. HARKER and P. CHAPPUIS. Communicated by the KEW OBSERVATORY COMMITTEE. Received June 8,—Read June 15, 1899.

(Abstract.)

In 1886, Professor Callendar drew attention to the method of measuring temperature, based on the determination of the electrical resistance of a platinum wire. He showed that the method was capable of a very general application, and that the platinum resistance thermometer was an instrument giving consistent and accurate results over a very wide temperature range.

Callendar pointed out that if R_0 denote the resistance of the spiral of a particular platinum thermometer at 0°, and R_1 its resistance at 100°, we may establish for the particular wire a temperature scale,