cluster motions, star streaming, galactic rotation, space distribution, and so on. The subject is to be reviewed in this POPULAR ASTRONOMY series. Statistical and dynamical students are continually asking for more motions and for more accurate motions. This has encouraged mass production of less accurate motions by repetition of photographic plates at short intervals, with insufficient elimination of systematic and accidental errors. And we must caution that it has taken a century to build our basic motions accurately and it may well take another century to define accurately the basic cosmic motions.

The stars have a human interest also. The broadcasting of accurate standard time regulates the industries and commerce of the nations. Yesterday the stars and their signals guided merchant ships across the Atlantic and clipper planes over the Pacific. Today the same stars and their signals guide the Allied fleets around and over darkened Europe, and over the lone islands of the Pacific.

I like a sentence by Dr. Kopff, "We must continue to study the motions in the universe, both near and distant, more exactly and more in detail; and we are glad that we can go back to our star catalogs—often a little despised—as the foundation of our science."

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The Periodic Comet Holmes (1892 III)

By N. T. BOBROVNIKOFF

The recent unexpected increase in the brightness[1] of Comet 1942 *g* (Whipple) brings to mind another remarkable comet, designated 1892 III. It was so exceptional in its physical behavior that an hypothesis of the comet itself being the result of a collision of two unknown asteroids was seriously discussed.[2] Its orbit was also remarkable, being wholly included between the orbits of Mars and Jupiter, with the perihelion distance 2.12 and the aphelion distance 5.10 astronomical units. The eccentricity of its orbit, 0.38, made that altogether like an orbit of an asteroid rather than that of a comet.

The comet was discovered on November 6, 1892, by E. Holmes in London less than three degrees from the Andromeda Nebula which it exceeded in brightness. It was established later that the discovery occurred 145 days after perihelion. The comet until its discovery had been receding from the earth for several weeks and was projected in approximately the same point in the sky, but remained unnoticed.

The orbital history of the comet is very instructive showing how easy it is to lose a faint periodic comet. In 1892-93 the variations in its brightness drew attention of many astronomers, and more than 600 observations of its position are in existence. H. J. Zwiers devoted many years to the computation of its orbit.[3] For the apparition of 1899, he computed the perturbations not only by Jupiter and Saturn but also by the Earth. The comet was re-discovered as Comet 1899 II. It was very faint (the maximum apparent brightness 13^m) and consequently was observed only with the largest telescopes. Zwiers' computations were so exact that the predicted time of perihelion passage required a correction of only $0^d.43$ to reconcile the theory with observations. The comet was observed only 21 times, and Zwiers computed for the apparition of 1906 only the perturbations by Jupiter. The comet (1906 III) was observed by Max Wolf photographically only four times, and the last observation was very uncertain.

For the apparition of 1912, Zwiers published an ephemeris which was based on elements without any allowance for the perturbations. As was subsequently shown by Polak[4] the perturbations by Jupiter for this apparition were very large. The period increased by 0.47 years and the eccentricity diminished from 0.412 to 0.379. The increase in the period of revolution was the main cause that this comet was not found in 1912.

For the apparition of 1928, an ephemeris was furnished by the computing section of the British Astronomical Association. The comet was due at perihelion on March 22, 1928, but it was not favorably situated for the observers in the northern hemisphere. It was not found then, and there is little chance that it will ever be found again.

Three circumstance make this comet unique in the annals of astronomy. Some comets displayed one or two of these characteristics, but none possessed all three. They are: large variations in the apparent brightness at a heliocentric distance of almost three astronomical units; the character of its spectrum; and the formation of spherical envelopes around the nucleus.

The comet was not well observed in December, 1892, and in the first part of January, 1893. On January 16 Palisa,[5] in Vienna, found with the 27-inch refractor, instead of a diffuse comet of 10th or 12th magnitude as expected, a yellow star of 8th magnitude with an envelope 20″ in diameter. The comet increased in brightness by the next day and could be seen with the naked eye. After January 18 it began to decline in brightness, and by the beginning of April it became very faint.

Holetschek[6] found that the comet suddenly increased in brightness on January 16 by $9^m.1$. This remarkable result cannot be accepted. The collation of all available photometric observations based on actual estimates of the brightness in comparison with the stars is given in Table 1. All observations have been reduced to a uniform Harvard system and aperture 2.67 inches, as explained in my previous papers.[7] The corrections (ΔH) are given in the sixth column of Table 1. The fifth column gives the observed magnitude, and the last column, the corrected magnitude. Observations are those of Backhouse,[8] Barnard,[9] Bigourdan,[10] Coit,[11] Gruss,[12] Holetschek,[13] and Kammermann.[14] It is seen that the total increase in brightness (Figure 1) amounted to only $2^m.8$ and, furthermore, that the increase in brightness was by no means sudden, as is seen from the observations by Backhouse on December 24 and January 10. Holetschek did not use Backhouse's observations and was apparently misled by a statement by Kobold (made after the increase in brightness) that on January 12 the comet was hardly visible in the neighborhood of a 10^m star. Holetschek assumed the comet's magnitude to be about 15, whereas considering the large negative correction for the 18-inch telescope used by Kobold, it was probably about 11^m, which agrees well enough with the description.

TABLE 1

BRIGHTNESS OF COMET HOLMES

No.	Observer	G.M.T.	Instr.	H′ (m)	ΔH (m)	H (m)
1	Barnard	Nov. 9.59	n.e.	5.4	+0.4	5.8
2	"	" 9.69	n.e.	4.5	+0.4	4.9
3	Backhouse	" 12.41	4″5	4.8	—0.3	4.5
4	Barnard	" 12.84	n.e.	4.9	+0.4	5.3
5	Backhouse	" 13.25	n.e.	5.0	+0.4	5.4
6	"	" 13.25	bin.	5.0	+0.3	5.3
7	Bigourdan	" 13.44	n.e.	5.0	+0.4	5.4
8	Coit	" 13.54	n.e.	5.0	+0.4	5.4
9	Barnard	" 13.71	n.e.	5.1	+0.4	5.5
10	Backhouse	" 14.27	n.e.	5.1	+0.4	5.5
11	"	" 14.27	bin.	5.1	+0.3	5.4
12	"	" 14.58	n.e.	5.5	+0.4	5.9
13	Barnard	" 14.71	n.e.	5.3	+0.4	5.7
14	Backhouse	" 16.29	n.e.	5.5	+0.4	5.9
15	"	" 16.29	bin.	5.6	+0.3	5.9
16	Barnard	" 16.64	n.e.	5.0	+0.4	5.4
17	"	" 21.64	n.e.	6.0	+0.4	6.4
18	Backhouse	" 24.44	n.e.	6.1	+0.4	6.5
19	"	Dec. 11.35	n.e.	7.0	+0.4	7.4
20	"	" 11.35	bin.	7.0	+0.3	7.3
21	"	" 24.44	bin.	9.3	+0.3	9.6
22	"	Jan. 10.49	bin.	8.9	+0.3	9.2
23	Barnard	" 16.75	3″	8.0	—0.1	7.9
24	"	" 16.79	3″	7.9	—0.1	7.8
25	Kammermann	" 17.33	10″	7.8	—1.2	6.6
26	Backhouse	" 17.44	bin.	7.6	+0.3	7.9
27	Barnard	" 17.67	3″	7.9	—0.1	7.8
28	Gruss	" 18.25	8″	7.4	—1.0	6.4
29	Holetschek	" 20.33	1″5	7.0	+0.2	7.2
30	Kammermann	" 20.33	10″	8.1	—1.2	6.9
31	Backhouse	" 20.40	bin.	6.9	+0.3	7.2
32	"	" 21.33	bin.	7.0	+0.3	7.3
33	"	" 21.49	bin.	7.0	+0.3	7.3
34	"	" 22.41	bin.	7.1	+0.3	7.4
35	Holetschek	" 23.33	1″5	6.8	+0.2	7.0
36	Backhouse	" 23.40	bin.	7.3	+0.3	7.6
37	"	Feb. 4.33	bin.	7.9	+0.3	8.2
38	Holetschek	" 10.27	1″5	8.4	+0.2	8.6
39	Backhouse	" 10.33	bin.	7.7	+0.3	8.0
40	"	Mar. 16.33	4″5	11.5	—0.3	11.2

Figure 1 gives also the light curve of the nucleus based on Wendell's observations at Harvard.[15] Both curves show a nearly parallel run, but the increase in the brightness of the nucleus was apparently more abrupt and amounted to five magnitudes. This is in agreement with the statement of all observers that on January 16 practically the whole light of the comet was concentrated in the nucleus. Wendell's observations have not been reduced to the same system as the observations for the total brightness. The correction due to the aperture of his instrument is uncertain owing to the fact that he used a special photometer. However, the curves at January 16 give a consistent result, and, therefore, the correction could not have been large.

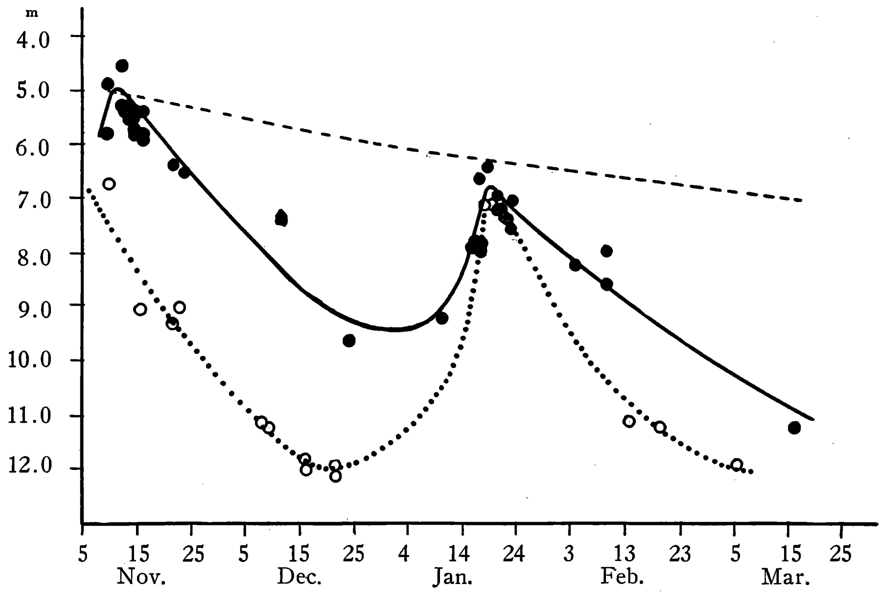

FIGURE 1

The variation in brightness of Comet Holmes November 9, 1892 to March 16, 1893. Filled circles represent total brightness, open circles represent the brightness of the nucleus. The general variation in total brightness is indicated by the solid line, that of the nucleus by the dotted line. The upper nearly straight line indicates the expected variation in total brighness due to the reflected light of the sun.

Finally, the upper, nearly straight line gives the variation in the brightness of the comet due to the reflected sunlight. It is adjusted to correspond to the brightness of the comet in early November.

It would seem that the variation in brightness was roughly periodic with maxima early in November and in the middle of January. The next maximum, however, would have fallen at the beginning of April, and it certainly did not occur. The comet was observed at Northfield[16] on April 2, and at Strassburg[17] on April 6, and it was exceedingly faint.

The apparent disagreement of observations for the same date may be due to the uncertainty in the estimates as well as to the actual variation in brightness within a short period mentioned by Barnard and others.

It is impossible to find any law of variation in the brightness of this comet that would satisfy all observations. It is safe to assume that the comet was very faint prior to its discovery in November, 1892. According to Berberich the maximum theoretical brightness was attained on September 27, and on August 18 the comet should have been as bright as at discovery. An object a few degrees from the Andromeda Nebula and brighter than the nebula could not have remained unnoticed for three months. The discovery of the comet was undoubtedly due to its sudden increase in brightness comparable to that of the middle of January.

If we draw a line on Figure 1 parallel to the curve of the theoretical brightness through the observations of December 24 and March 16, we might consider it as representing the normal brightness of the comet. In that case the absolute brightness, H_0, of the comet (reduced to $\Delta = 1$, $r = 1$, on the basis of its light proportional to Δ^{-2} r^{-2}) was $6^m.6$. This, however, cannot be reconciled with the observations of the beginning of April when the comet was very faint even in the large telescopes. If we assume that in April $H = 15^m.5$, the lowest value possible, we still get for H_0 in April $10^m.4$.

In 1899, however, the absolute brightness was $11^m.7$. In 1906 the photographic brightness results in $H_0 = 11^m.9$, but the visual brightness was undoubtedly much lower, as comets usually have a negative color index. The comet could not be seen at all in the Lick telescope.

We cannot escape the conclusion that the outbursts in 1892-3 so exhausted the cometary matter that the comet grew steadily fainter with each subsequent apparition. In other words the comet exists now probably in the form of a body indistinguishable from the faintest asteroids.

The spectrum of the comet was observed by Campbell,[18] Keeler,[19] v. Konkoly,[20] Vogel,[21] Ferrari,[22] and Lockyer[23] in November with the same result. The spectrum was practically wholly continuous with perhaps only the slightest suggestion of the carbon bands. The spectrum, therefore, was very different from that of most comets. At the outburst in January 16, the spectrum was observed by Wendell[15] on January 16 and by Kammermann[14] on January 17. The spectrum remained unchanged. Many observers emphasized the yellow or reddish color of the nucleus at the outburst.

The increase in brightness and the formation of a spherical envelope on January 16 under the eye of the observer is described in detail by Barnard:[9]

> "Between 6^h and 7^h I set for Holmes' comet with the 12-inch telescope, with little expectation to see it again on account of its faintness. A small, bright hazy star presented itself in the field . . . Thinking this could not be the comet, a second setting was made with the same result. Still uncertain, a series of measures was made to see if the object was in motion. The results showed that it was really the comet. At 9:55

. . . in the finder of the 12-inch telescope it was 7.9 magnitude, and appeared like a small bright star—wholly indistinguishable from a star. At $10^h 10^m$ it was certainly increasing in brightness. The nucleus could then be easily made out (in the 12-inch telescope) and was distinct though at first it was only suggested. . . At $10^h 20^m$ there was no question that the nucleus was brightening; it had become very easy and seemed to have formed during the observations. . .

"With the 36-inch telescope the appearance of the comet was the same as that on November 8 with the 12-inch. Its outline was quite definite, and the nucleus was pretty bright, central, hazy, and yellow, while the nebulosity was bluish. At $11^h 0^m$ with the 12-inch telescope it was certainly brighter and the nucleus better seen."

It is evident that, although the comet was gradually growing brighter for several days, the most violent disturbance occurred on January 16. At about that time a mass of material was thrown off the nucleus in every direction, producing a uniform spherical envelope. This material was presumably dust, as it gave a wholly continuous spectrum. Since the ejection was in all directions, no disturbance of the orbital motion of the comet could be expected. L. Boss[24] found no evidence of any disturbance in the residuals of the position observations for this and following dates. It is interesting to note that the intersection of the radius-vector of the comet with the surface of the sun was very far from any sunspots recorded for January 16 and preceding dates, and the connection of the outburst with the sun-spot activity is therefore unlikely.[25] The same conclusion is indicated by the list of magnetic storms[26] on the earth. The nearest storm before the outburst, and at that a very weak one, was recorded on January 5.

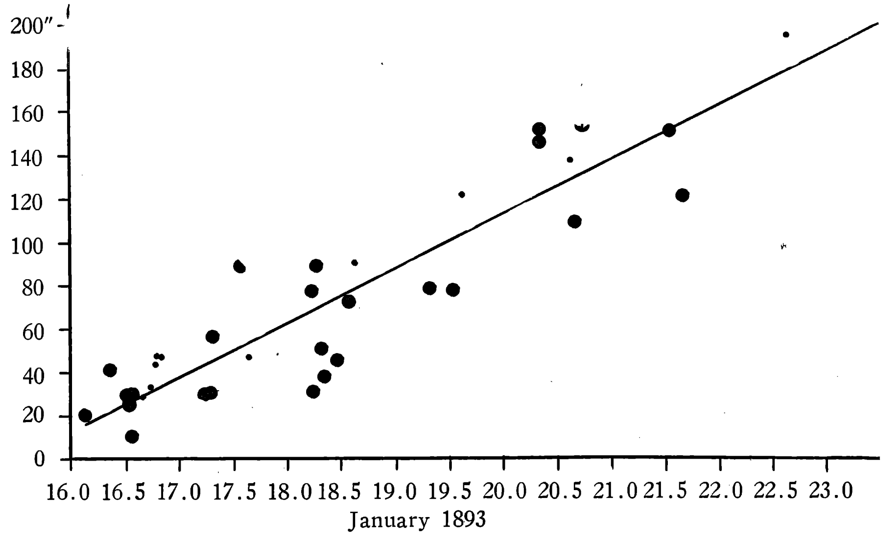

FIGURE 2

The expansion of the spherical envelope of Comet Holmes, January 16 to January 23, 1893. Dots represent the measures of the diameter by Barnard, filled circles by others.

The spherical envelope was expanding rather rapidly as was noticed by Barnard.[9] Besides his measures, those of Palisa,[5] Kobold,[27] Lovett,[28] Pechüle,[29] Wilson,[30] Hough,[31] Lamp,[32] Wendell,[15] Deichmüller,[33] Schorr,[34] Roberts,[35] and Ristenpart[36] are available for the period of January 16 to January 22. After the latter date the outlines of the envelope became too indefinite for any reliable measures.

TABLE 2

MOTION OF MATTER NEAR NUCLEUS JANUARY 16-22, 1893

No.	G.M.T. Jan.	Diameter	Observer	Place
1	16.184	20″	Palisa	Vienna
2	16.369	41	Kobold	Strassburg
3	16.551	25	Lovett	Charlottesville
4	16.558	30	Pechüle	Copenhagen
5	16.572	30	Wilson	Northfield
6	16.585	10	Hough	Evanston
7	16.677	29	Barnard	Mt. Hamilton
8	16.743	32	"	"
9	16.771	44	"	"
10	16.780	47	"	"
11	16.819	47	"	"
12	17.258	30	Lamp	Kiel
13	17.291	30	Pechüle	Copenhagen
14	17.305	56	Kobold	Strassburg
15	17.578	90	Wendell	Cambridge, Mass.
16	17.631	46	Barnard	Mt. Hamilton
17	18.210	30	Deichmüller	Bonn
18	18.235	78	Palisa	Vienna
19	18.259	87	Schorr	Hamburg
20	18.322	50	Kobold	Strassburg
21	18.333	39	Roberts	London, photo, reflector
22	18.483	45	Ristenpart	Karlsruhe
23	18.567	71	Hough	Evanston
24	18.622	90	Barnard	Mt. Hamilton
25	19.316	78	Kobold	Strassburg
26	19.519	76	Hough	Evanston
27	19.618	121	Barnard	Mt. Hamilton
28	20.333	145	Roberts	London, photo, reflector
29	20.347	150	Palisa	Vienna
30	20.615	136	Barnard	Mt. Hamilton
31	20.662	108	Wendell	Cambridge, Mass.
32	21.551	120	Wilson	Northfield
33	21.631	150	Wendell	Cambridge, Mass.
34	22.646	195	Barnard	Mt. Hamilton

These data are given in Table 2. They are plotted in Figure 2. Although there is considerable scattering of values of the diameter, it is seen that the increase was uniform over the period of six and a half days. The variation in the geocentric distance between January 16 and 22 was not enough to distort the curve. There is no appreciable systematic difference in the estimates of the diameter made with different telescopes. It is seen from Figure 2 that Barnard's measures (denoted by dots) are the most consistent as might be expected, since Barnard made a special effort in measuring the diameter of the comet.

Table 3 gives the thirty-four observations of Table 2 organized into ten normal places. The columns marked D and p.e. give the observed diameter with its probable error; column Δ the geocentric distance of the comet,[37] and columns D_Δ and p.e. give the diameter reduced to the distance $\Delta = 1$ with the corresponding probable error.

TABLE 3

EXPANSION OF ENVELOPE

January 16-22, 1893

Normal Places

N.p.	No.	G.M.T.	$t-t_0$	D	p.e.	Δ	D_Δ	p.e.	o—c
I	6	16.470	0.470	26″	2″.9	2.380	61″.9	6″.9	+ 6″.1
II	5	16.758	0.758	40	2.6	2.384	95.4	6.2	+21.6
III	3	17.285	1.285	39	5.9	2.393	93.3	14.1	—13.4
IV	2	17.604	1.604	68	14.9	2.398	163.1	35.8	+36.5
V	5	18.272	2.272	57	7.3	2.408	137.3	17.5	—31.1
VI	3	18.557	2.557	69	8.8	2.413	166.5	21.2	—19.7
VII	3	19.484	3.484	92	9.9	2.427	223.3	24.0	—20.8
VIII	4	20.489	4.489	135	6.3	2.442	329.7	15.4	+22.8
IX	2	21.591	5.591	135	10.2	2.459	332.0	25.1	—43.7
X	1	22.646	6.646	195	....	2.476	482.8	....	+41.2

We can represent the uniform increase, V, in the diameter by a formula:

$$D = D_0 + V\,(t - t_0)$$

where t_0 is arbitrary. Assuming t_0 to be January 16.000, we have for $t - t_0$ the values given in the fourth column of Table 3.

Solving for V and D_0 by the method of least squares, we find

$$V = 62''.5 \pm 3''.4$$

which represents the increase in the diameter of the comet per day reduced to the distance $\Delta = 1$. Converted into km/sec, we have

$$V = 0.54 \pm 0.03 \text{ km/sec.}$$

The radial velocity of expansion, v, is therefore:

$$v = 0.27 \pm 0.01 \text{ km/sec.}$$

The date of the beginning of expansion is obviously when D is equal to zero, or $D_0 = V\,(t_0 - t)$. Since from the least squares solution $D_0 = 26''.37$, the expansion started 0.894 days before the chosen origin of time, or on January 15.106 G.M.T.

The velocity of expansion probably was not uniform over small intervals of time. The scattering of measures after January 16 is of no particular significance as the envelope was getting diffuse. However, on January 16 Barnard described it as sharply defined, and yet from his five measures on this date, the following radial velocities of expansion can be derived:

TABLE 4

VELOCITY OF EXPANSION FROM BARNARD'S MEASURES

January 16

Time between		v	
8:15	9:50	0.45 km/sec	expansion
9:50	10:30	3.60 km/sec	expansion
10:30	10:43	7.16 km/sec	expansion
10:43	11:14	0.23 km/sec	contraction

The expansion therefore may have proceeded in a series of pulsations rather than in a strictly uniform manner.

From the last column of Table 3, which gives the residuals o — c of the diameter of the comet reduced to $\Delta = 1$, it is seen that the general character of the velocity over the whole period of observation was uniform. The residuals are of the size of probable errors of the normal places, and there is no evidence of a systematic departure from the straight line. The average probable error of the normal places computed from the combination of individual observations is 18″.5. From the least squares solution the probable error of one normal place of weight unity is 21″.1. The agreement is so good that we are justified in assuming that the straight line represents perfectly the increase in the diameter of the comet.

The analogous phenomenon of the expansion of a spherical envelope occurred also early in November, but the data are not available for the determination of the velocity of expansion. If we accept Barnard's measures of the diameter of the envelope on November 8, which give for November 8, 8:00 P.S.T. 260″, and for 9:40 P.S.T. 286″, the velocity of radial expansion is

$$v = 1.52 \text{ km/sec},$$

that is, some five times as large as found for January. The envelope was not very sharply defined, and this figure would indicate only the order of magnitude of the velocity.

On the other hand, Hough gives the diameter of the nucleus for the period January 19 to January 30 indicating slow but continuous expansion. From his data the average velocity of radial expansion was 2″.2 per day, that is, 0.05 km/sec, about one-fifth of the velocity found for the envelope in January.

The formation of spherical halos around cometary nuclei is a rare phenomenon observed only in a few comets. Their explanation involves many difficulties from the theoretical point of view as was discussed by me in detail in a previous paper.[38] The most remarkable result is that the radial velocity of expansion comes out very much the same for different comets.

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