

OBSERVATIONS OF *PHOEBE*, THE NINTH SATELLITE OF *SATURN*,

By E. E. BARNARD.

In 1898 Professor Wm. H. PICKERING announced the discovery, by photography, of a very faint ninth satellite to *Saturn*, which he named *Phoebe*. I was anxious to observe this object visually and wrote to Professor PICKERING for an ephemeris. He was unable to give me one because the observations were not enough to determine the orbit. Matters lay thus for six years, but as there was no ephemeris it was impossible to look for the satellite visually, especially as it was an extremely faint object and at a very great distance from *Saturn*.

In May, 1904, I learned that Professor PICKERING had secured more photographs of the satellite and was getting out an orbit. I wrote again for an ephemeris. Fortunately, however, Professor PICKERING was himself able to come to the Yerkes Observatory and make a search for the satellite, but, unfortunately, an urgent telegram called him away after but one night's search.

Professor PICKERING left with me some photographs and later sent an ephemeris. This ephemeris he afterward found was somewhat in error because of the unusual motion of the satellite. I was requested to compare one of the photographs with the sky so as to form some idea of the probable visual magnitude of *Phoebe*, as the satellite was as bright as the fainter stars shown on the photograph. Some of these stars were marked 16th, 17th and 17½ magnitude. The position was $\alpha = 17^h 50^m$ $\delta = -22\frac{1}{2}^\circ$. On July 4, with the position an hour west of the meridian, I was able to see all the stars in the region marked out by Professor PICKERING. From this it would appear that *Phoebe* ought to be seen visually with the 40-inch. I had already looked for it on the nights of June 17 and 25. It was also looked for on July 4 and 10, but the ephemeris was not exact enough for one thing and the seeing was not perfect enough for another, and the satellite was not found.

Finally, three ephemeris positions of ten-day intervals were issued in a Bulletin from Harvard College Observatory, but no favorable opportunity occurred to look for the satellite until the ephemeris had expired. The last of these positions was for Aug. 3. I waited for a continuation of the new ephemeris, which did not come until Aug. 18.

In the first of August we had the great pleasure of a visit from Professor TURNER, of Oxford, England, who had just visited Harvard College Observatory. From what he told me of his visit to Cambridge I was further convinced that the existence of the satellite was real, though I had never doubted it from the first announcement of its discovery. The night of Aug. 8 being favorable, Professor TURNER extrapolated a position of the satellite from the

expired ephemeris and we have made a careful search for the satellite. A small star was found exactly at the indicated place, but measures showed no motion. A fainter star was seen about one minute of arc north following, but its distance from the assigned place made it unlikely that it was the satellite. Both Professor TURNER and I estimated this star to be one magnitude fainter than the star just measured, which I had referred by the micrometer to an 11th magnitude star in

$$1904.0 \quad \alpha = 21^h 23^m 0^s.2 \quad \delta = -16^\circ 37' 15''.5$$

(This position was obtained by comparison with *Saturn*).

Measures of the small star with respect to the 11th star gave,

$$\text{Pos. Ang. } 300^\circ.99 \text{ (4)} \quad \text{Dist. } 53''.57 \text{ (2)}$$

$$\text{These give } \Delta\alpha - 0' 46''.4 = -0^m 3^s.22$$

$$\Delta\delta + 0' 26''.8$$

This faint star was, therefore, in

$$1904.0 \quad \alpha = 21^h 22^m 57^s.0 \quad \delta = -16^\circ 36' 48''.7 \quad 15^m \pm$$

The position of the fainter star, which I had sketched on the diagram, can be quite closely determined. By measuring the diagram the object was found to be 4".8 following and 39" north of the above star. This would give it the position,

$$1904.0 \quad \alpha = 21^h 23^m 1^s.8 \quad \delta = -16^\circ 36' 9''$$

with a probable error of about 5"

Later, Prof. E. C. PICKERING informed me that no star existed in any of his photographs at the place of this object, and furthermore, that it nearly occupied very closely the ephemeris position of *Phoebe*. This position was examined several times subsequently, but the seeing was such as to leave one in doubt as to the existence of the object, but on Sept. 5 the conditions were good enough to be certain that it had disappeared. On this date I again searched for the satellite at the ephemeris place but the seeing had become poor and it was not found. On Sept. 12 the conditions were better and the absence of the object was certain. On this night, which was favorable, I again searched for *Phoebe*, and near its position found a faint star which measures soon showed was not the satellite (see star 2 of the list of positions later on). I then applied a higher power, which often brings out fainter stars, and two excessively faint stars were seen nearer its ephemeris place. The following of the two — and which was slightly the brighter — was measured with reference to a 13^m star.

$\Delta\delta$			
$10^h 8^m 16^s$	$0' 45.33''$	(2)	Faint object north.
$10 13 38$	$0 44.62$	(2)	
$10 10 57$	$0 44.97$	(4)	

$\Delta\alpha$			
$10^h 23^m 6^s$	$1' 48.74''$	(3)	Faint object following.
$10 37 41$	$1 45.06$	(3)	
$10 47 46$	$1 43.03$	(3)	
$10 36 11$	$1 45.61$	(9)	$= 0^m 7^s.40$

Though this object was excessively faint and difficult (est. $16^m.7$) the measures in $\Delta\alpha$ clearly showed motion towards the west. The intervals in the $\Delta\delta$ measures were not great enough to make motion certain, but the slight difference would indicate a change towards the south. The theoretical motion of *Phoebe* was southwest.

The $\Delta\alpha$ consistently gave a westward motion of $0''.226$ per minute of time. Using this motion and reducing the two last measures to the epoch of the first one we have

$10^h 23^m 6^s$	$\Delta\alpha$	$1' 48.74''$
$10 37 41$		$1 48.42$
$10 47 46$		$1 48.71$

I have lately determined the position of the 13^m comparison star with reference to Radcliffe 1890 Catalogue, No. 5764, whose place, brought up, is

$$1904.0 \quad \alpha = 21^h 16^m 54^s.05 \quad \delta = -17^\circ 14' 36''.6$$

The observations gave (13^m star — 5764)

$$\Delta\alpha = -4^m 35^s.07 \quad \Delta\delta = -12' 24''.3$$

This gives for the comparison star

$$1904.0 \quad \alpha = 21^h 12^m 18^s.98 \quad \delta = -17^\circ 27' 0''.9$$

Reduction to apparent place $+3^s.11 \quad +19''.8$

The place of the satellite was, therefore,

$$10^h 10^m 57^s \quad \delta \text{ apparent} = -17^\circ 25' 56''.1$$

$$10 36 11 \quad \alpha \text{ apparent} = 21^h 12^m 29^s.49$$

Professor PICKERING informs me that the above position falls almost exactly in the ephemeris place.

I have searched a number of times since with an ephemeris kindly supplied me by Dr. F. E. Ross, of Washington, who is investigating the orbit of the satellite, but the conditions have never been such as would show such a faint object.

When *Saturn* gets further north, however, there will be no trouble in visually observing the satellite, but at the present low altitude the seeing is seldom good enough to see a very faint object like *Phoebe*.

In these observations five other stars were incidentally observed. Following are the positions:

No.	Mag.	α 1904.0	δ 1904.0
1	11	$21^h 12^m 9^s.20$	$-17^\circ 23' 39''.2$
2	16	$21 12 29.74$	$-17 25 46.3$
3	9	$21 14 57.67$	$-17 24 58.2$
4	10	$21 15 5.14$	$-17 23 20.7$
5	11	$21 16 25.89$	$-17 19 1.8$

The third star is S.D. $17^\circ.6239$.

The 13^m star (to which the satellite was referred) was compared also with this star. When the place of 6239 is accurately determined it will give a better position of the 13^m star, because in the comparison with Radcliffe 5764 three intermediate stars had to be used.

The measures are

$$13^m \text{ star} - \text{S.D. } 17^\circ.6239$$

$$\Delta\alpha = -2^m 38^s.69 \quad (12)$$

$$\Delta\delta = -2' 2''.6 \quad (4)$$

At the observation of Aug. 8 (assuming the faint object to have been the satellite) *Phoebe* would not be fainter than 16^m . At the observation of Sept. 12 it would not be brighter than $16\frac{1}{2}^m$. The estimation on this last date made it $16^m.7$.

The observations have not been printed before because I had hoped to get more measures to go with them, but there is now no further chance this season.

NOTE.

Professor E. C. PICKERING has supplied me with the position of the star S.D. $17^\circ.6239$ which has been carefully observed at the Naval Observatory, Washington.

$$1900.0 \quad \alpha = 21^h 14^m 44^s.40 \quad \delta = -17^\circ 25' 59''.2$$

Using this star, the position of the 13^m comparison star of Sept. 12 is

$$1904.0 \quad \alpha = 21^h 12^m 19^s.11 \quad \delta = -17^\circ 27' 1''.6$$

The resulting place of *Phoebe* on Sept. 12 was therefore

$$10^h 10^m 57^s \text{ apparent } \delta = -17^\circ 25' 56''.8$$

$$10^h 36^m 11^s \text{ apparent } \alpha = 21^h 12^m 29^s.60$$

The times are Central Standard time ($6^h 0^m$ slow of G.M.T.).

Yerkes Observatory, 1904 November.

CONTENTS.

THE CONSTANT OF ABERRATION, BY C. L. DOOLITTLE.
OBSERVATIONS OF COMET *d* 1904 (BORRELLY), BY H. C. WILSON.
NEW COMET (GIACOBINI, MARCH 26).
NOTATION OF NEWLY DISCOVERED VARIABLE STARS.
OBSERVATIONS OF MINOR PLANETS, BY W. WALTER DINWIDDIE.
MINIMA OF THE ALGOL-TYPE VARIABLE 7096 SY CYGNI, BY J. A. PARKHURST.
DISCOVERY OF A SIXTH SATELLITE OF JUPITER.
COMET *e* 1904 (BORRELLY).
ORBIT OF COMET *d* 1904 (GIACOBINI).
OBSERVATIONS OF COMET *e* 1904 (BORRELLY), BY J. G. PORTER.
SUNSPOT OBSERVATIONS, BY A. W. QUIMBY.
SUNSPOT OBSERVATIONS, BY ROBERT H. BAKER.
OBSERVATION OF COMET *e* 1904 (BORRELLY), BY E. E. BARNARD.
NOTE ON THE MASSES OF MERCURY, VENUS AND THE EARTH, AND ON THE SOLAR PARALLAX, BY A. HALL.
OBSERVATIONS OF PHOEBE. THE NINTH SATELLITE OF SATURN, BY E. E. BARNARD.

PUBLISHED AT BOSTON, AND CUSHING ROAD, WELLESLEY HILLS, MASS., SEMI-MONTHLY, BY S. C. CHANDLER. ADDRESS, BOX 216, WELLESLEY HILLS, MASS.
Associate Editors, ASAPH HALL and LEWIS BOSS. PRICE, \$5.00 THE VOLUME. PRESS OF THOS. P. NICHOLS, LYNN, MASS. Closed March 27.

Entered February 2, 1903, at Boston, Mass., as second-class matter, under Act of Congress of March 3, 1879.